HUMAN SKELETAL REMAINS
AN INTRODUCTION TO FORENSIC ANTHROPOLOGY

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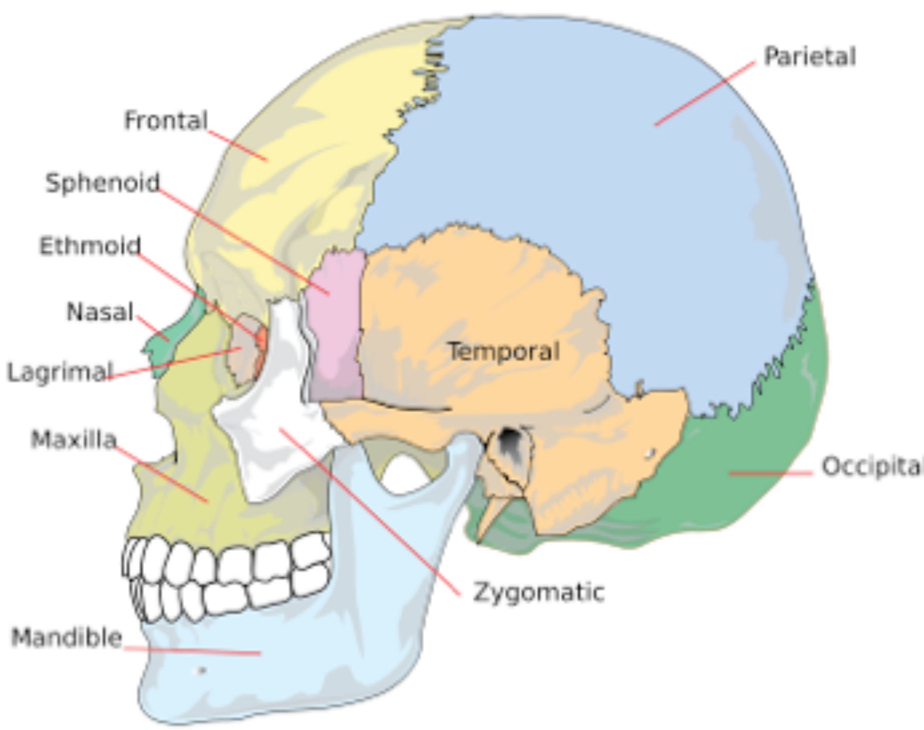
When skeletalized remains are found, whether complete or incomplete, there examination should proceed in a scientific stepwise fashion, the purpose of which is to address a number of key points. These key points are as follows: Are the remains human? What are the sex, race, and age at the time of death, and stature? Are there any distinguishing characteristics either of an anatomic anomaly or pathology, giving rise to unique anatomic features? Is there evidence of a cause of death?

ARE THE REMAINS HUMAN

It goes without saying that all pathologists should be able to identify a human skull. However, with this exception, identification of other bones of the skeleton as to whether they are human or of a species of animal can be quite difficult. This is especially true when the remains consist of a few fragments of long bone, which is due to the fact that the tubular portions of long bones are very similar in mammals. Consequently, unless one is absolutely certain of their identification, it is best to



leave the identification of fragments as well as incomplete skeletal remains to the anthropologist.

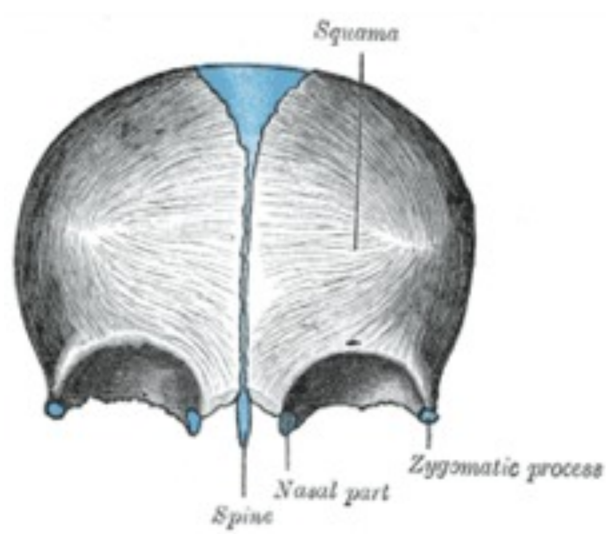
The ability to properly identify skeletal remains is greatly facilitated if you have a reasonable knowledge of the anatomy of the human skeleton. To that end I am going to review some of the fundamental points of human anatomy.

THE SKULL

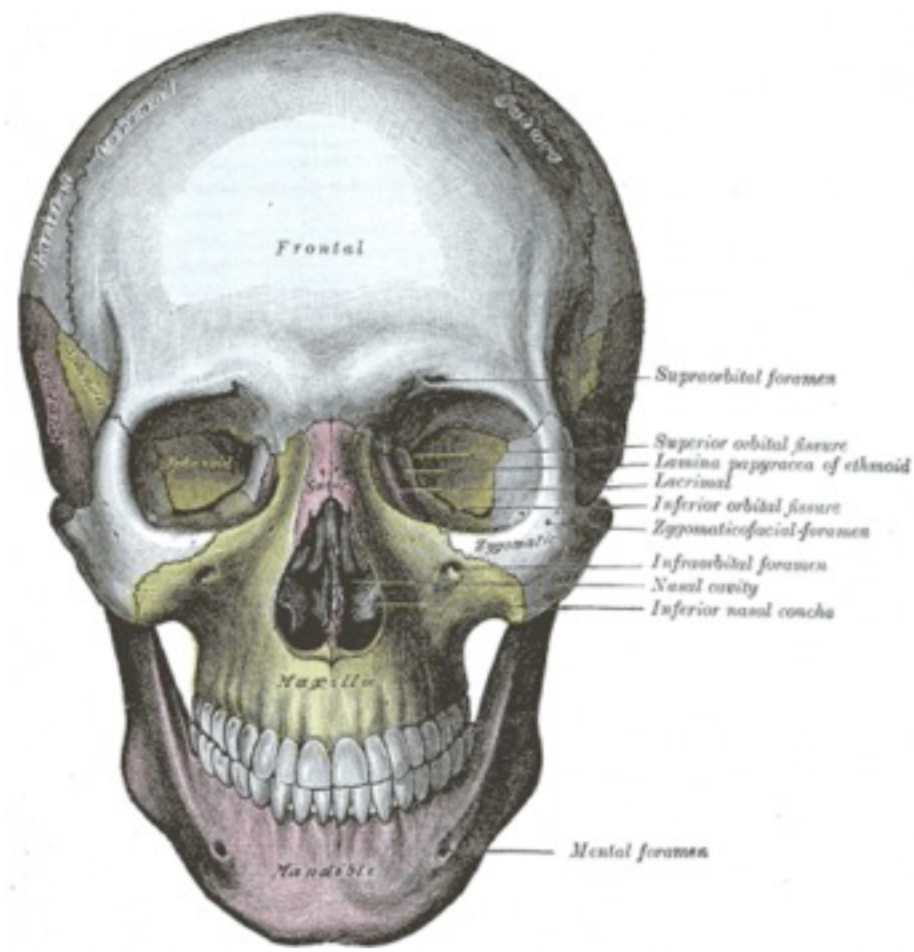
The skull technically includes the mandible. If you leave out the mandible, the resulting anatomic structure is referred to as the cranium; however, these two terms are used interchangeably.

The skull is formed by the fusion of plates of bone with some of these plates containing cavities. The fusion of these plates of bone creates a large cavity, the cranial cavity otherwise referred to as the cranial vault. The cranial cavity is bounded superiorly by the calvarium and inferiorly by the base of the skull.

The calvarium (top of your head covered by scalp) is formed by the fusion of the frontal bones of which there are two, parietal bones of which there are two, temporal bones of which there are two, and the squamosal portion of the occipital bone.

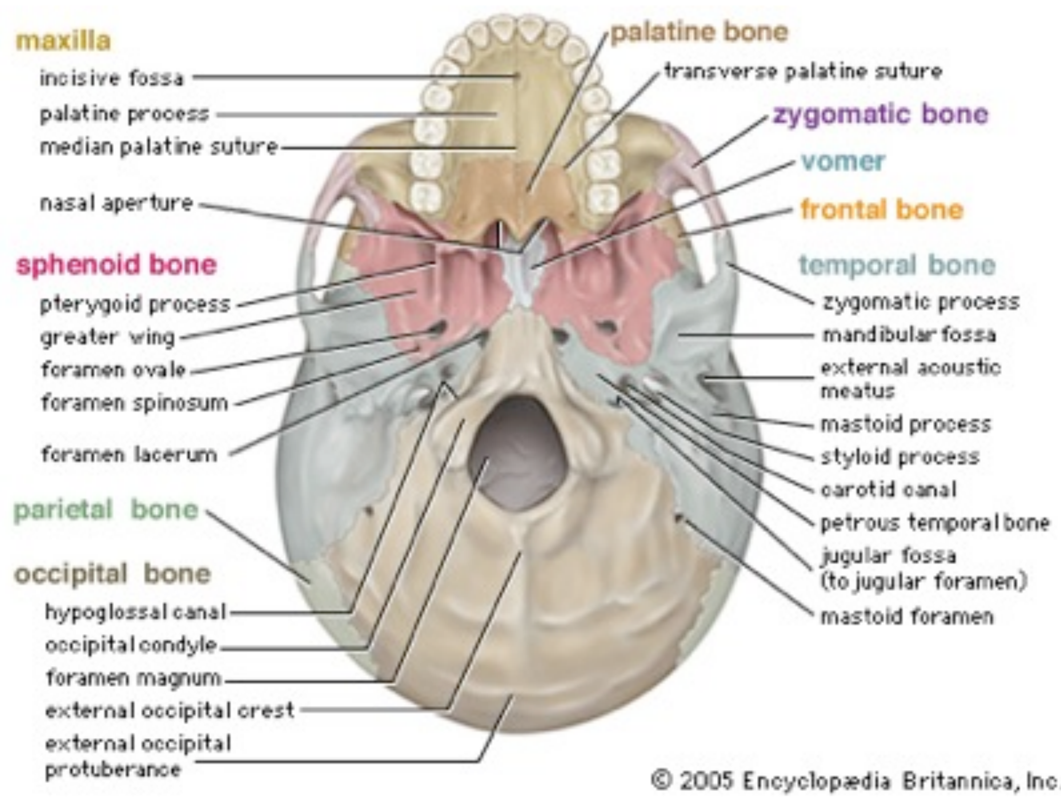


Early in development the frontal bone consists of two plates separated by the metopic suture, which fuses between 3 and 9 months of age. The fusion of the ethmoid bone, sphenoid bone, and portions of the occipital, frontal, parietal and temporal bones form the base of the skull. The points of fusion of these plates of bone are called sutures. As an example, the suture between the frontal and parietal bones is referred to as the coronal suture; that between the parietal bones and the occipital bone is referred to as the lambdoid suture, etc.

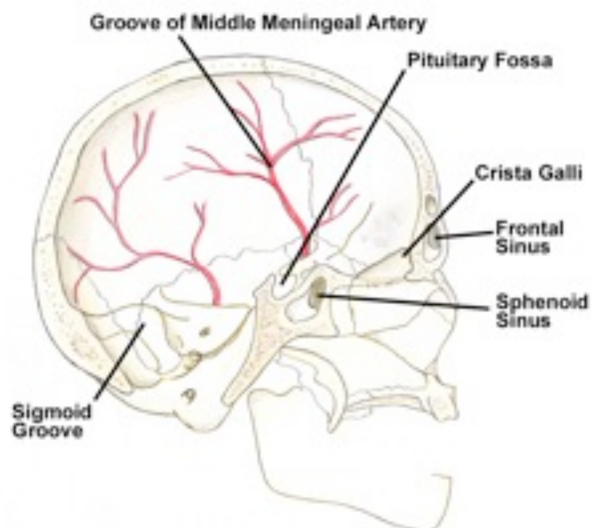


When you look at the skull from the front it shows a number of cavities: two orbits, which contain the eyes and eye muscles, the nasal passages, which begin externally with the external nasal apertures and the mouth, which is formed by the palate, the mandible, and the muscles, in the living, that enclose the mandible. On each side of the skull are two openings within the temporal bones called the external auditory meatus (ear holes).

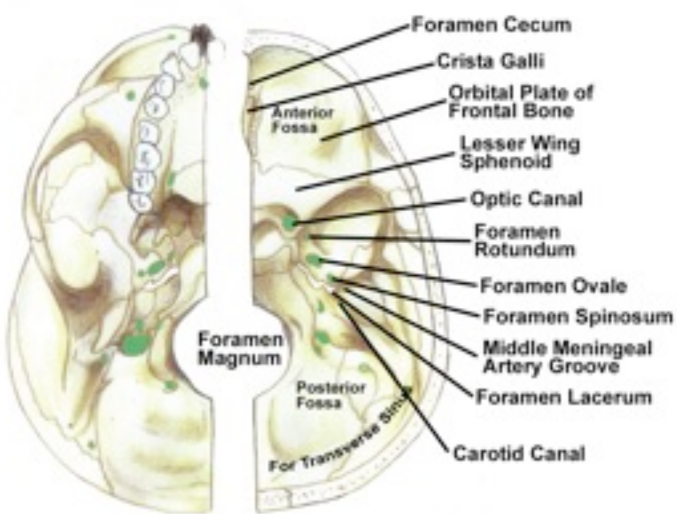
The skull rests on top of the vertebral column, specifically the first cervical vertebra (the atlas), rotating on the atlas by means of two facets, the occipital condyles. The occipital condyles are located on the under surface of the borders of the foramen magnum. The movement of the skull relative to the vertebral column is not only facilitated by the articular surfaces of the occipital condyles but also the neck musculature. Part of the neck musculature is formed by the nuchal muscles that lie at the back of the neck, inserting onto the back of the skull, specifically the superior nuchal line, the midpoint of which is called the inion. Another external anatomic landmark of the skull is a downward projection of bone behind the ear holes (external auditory meatus) called the mastoid processes.



When you remove the calvarium and the brain and look onto the base of the skull you will note it is irregular and has many openings, which are referred to as foramen. These foramen, of which there are 10, are for the passage of nerves and blood vessels. The largest of these foramina is the foramen magnum, which provides for communication between the contents of the posterior cranial fossa and the vertebral canal. The foramen magnum allows for the passage of a portion of the brainstem, the medulla oblongata, to exit the cranial vault and join the cervical portion of the spinal cord. In addition to the passage of the medulla it also allows passage of the spinal accessory nerves, vertebral arteries, the anterior and posterior spinal arteries, the membrana tectoria and the alar ligaments. In contradistinction to the base of the skull, the calvarium has two foramen, the parietal foramen, one on each side, which allows passage of the parietal emissary vein, which anatomoses with the superior sagittal sinus and sometimes a small branch of the occipital artery. This foramen is located in the posterior part of each parietal bone close to the sagittal suture.



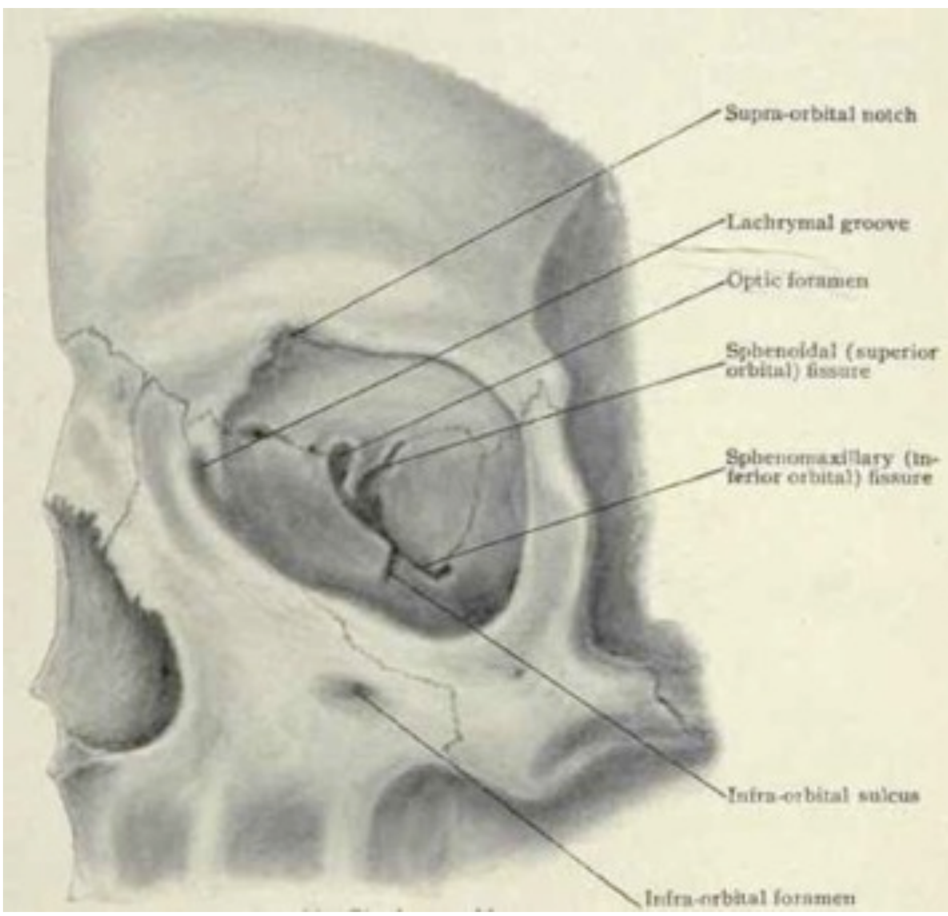
Internal anatomy of the skull, lateral view.



Base of skull.

The base of the skull is divided into pairs of concave depressions called fossae, the anterior and middle fossae and a large deep concavity forming the posterior aspect of the base of the skull. This large deep concavity, which lies to either side of the foramen magnum and behind it, is the posterior cranial fossa, which holds the cerebellum and brainstem. The roof of the posterior fossa is formed by the tentorium cerebelli. Anterior to this are paired fossae, one on either side called the middle cranial fossae, in, which the temporal lobes rest. Anterior to the middle cranial fossae are the anterior cranial fossae, the floor of which is formed by the orbital plates of the frontal bone, which form the roofs of the orbits. Resting on the surface of the orbital plates are the frontal lobes. Immediately between the orbital plates is a bone perforated by many small holes, called the cribiform plate. Passing through these holes are branches of the olfactory nerve, which arises from olfactory receptor neurons, located in the olfactory mucosa of the upper parts of the nasal cavity.

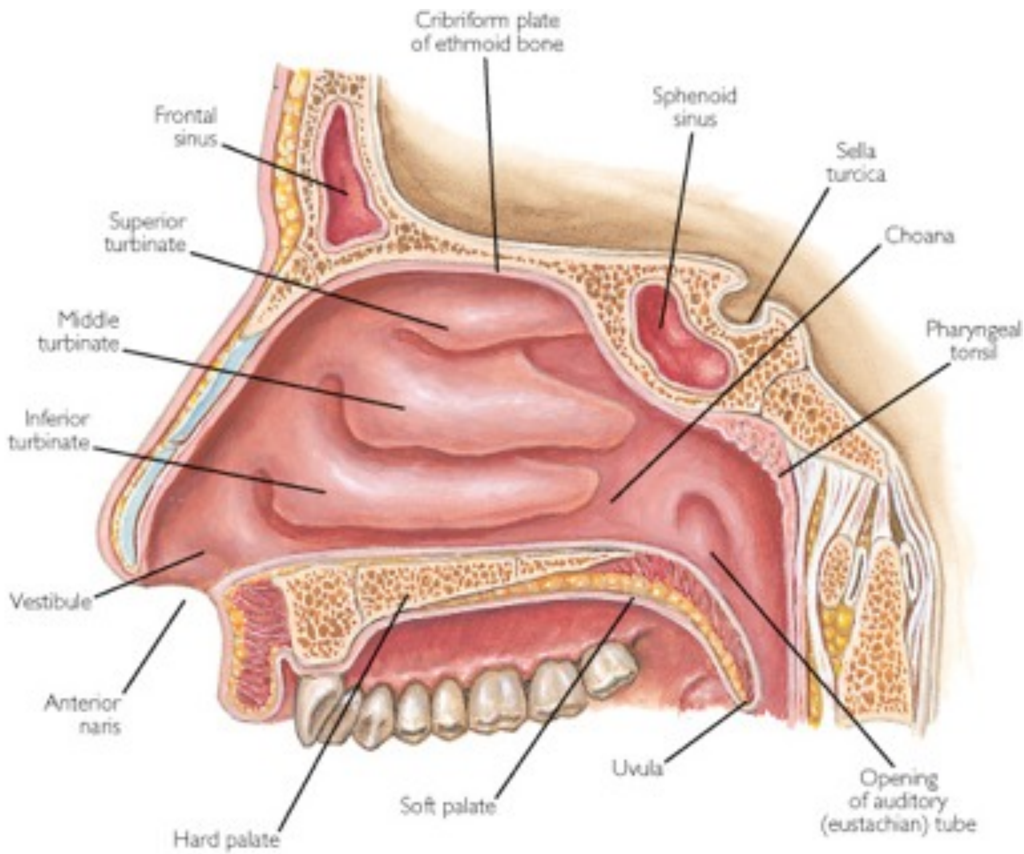
The



Orbits

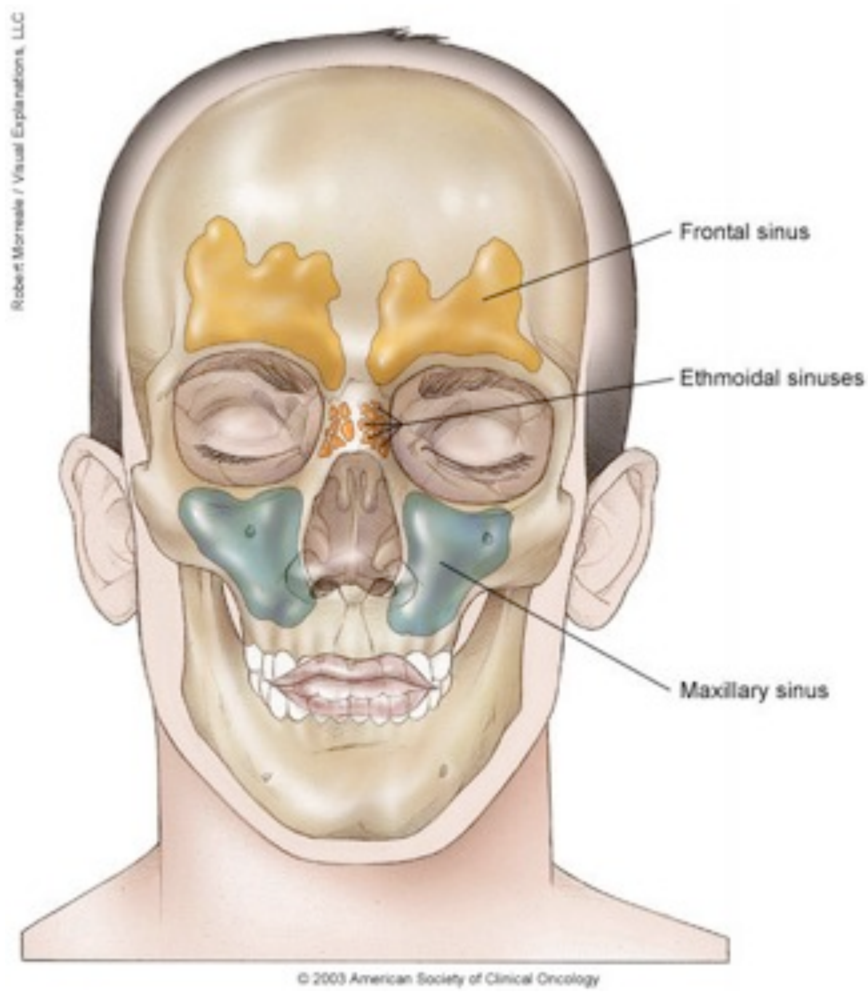
The two orbits contain not only the eyeballs, but also the muscles to move the eyeball and a considerable amount of fat, which in actuality forms a smooth surface for the eyeball to turn on. There is an opening on the medial surface of each orbit (that surface adjacent to the nasal passages) to allow for passage of the lacrimal duct, which drains the normal flow of tears from the anterior surface of the eye down to the floor of the nasal passages.

The Nasal Passages



The palatine process of the maxilla forms the floor of the nasal passages in its anterior three-fourths and by the horizontal portion of the palatine bone in its posterior one-fourth. The medial wall of the nasal cavity, the septum is partly bony and partly cartilaginous. The upper part of the bony septum is formed chiefly by the perpendicular plate of the ethmoid and slightly by the crest of the sphenoid behind. The vomer and the nasal crests of the maxilla and palatine bones compose the lower part. The septal cartilage lies antero-inferiorly and fits into the gap between the diverging borders of the bones (nasal bones anteriorly, ethmoid posteriorly, and the vomer and the palatine processes of the maxilla inferiorly).

The lateral wall of the nasal cavity consists of three projections, the superior, middle, and inferior conchae. The superior and middle are processes of the ethmoid bone, whereas the inferior concha is a separate bone of the skull. Some however, believe the inferior concha arise from the maxillary bone, projecting horizontally into the nasal cavity. The conchae, almost reaching the nasal septum, subdivide each cavity into a series of groove-like passageways, the meatuses. The meatuses are designated by the conchae above them; thus, the superior meatus is inferior to the superior concha, and the middle and inferior meatuses are below the middle and inferior conchae.

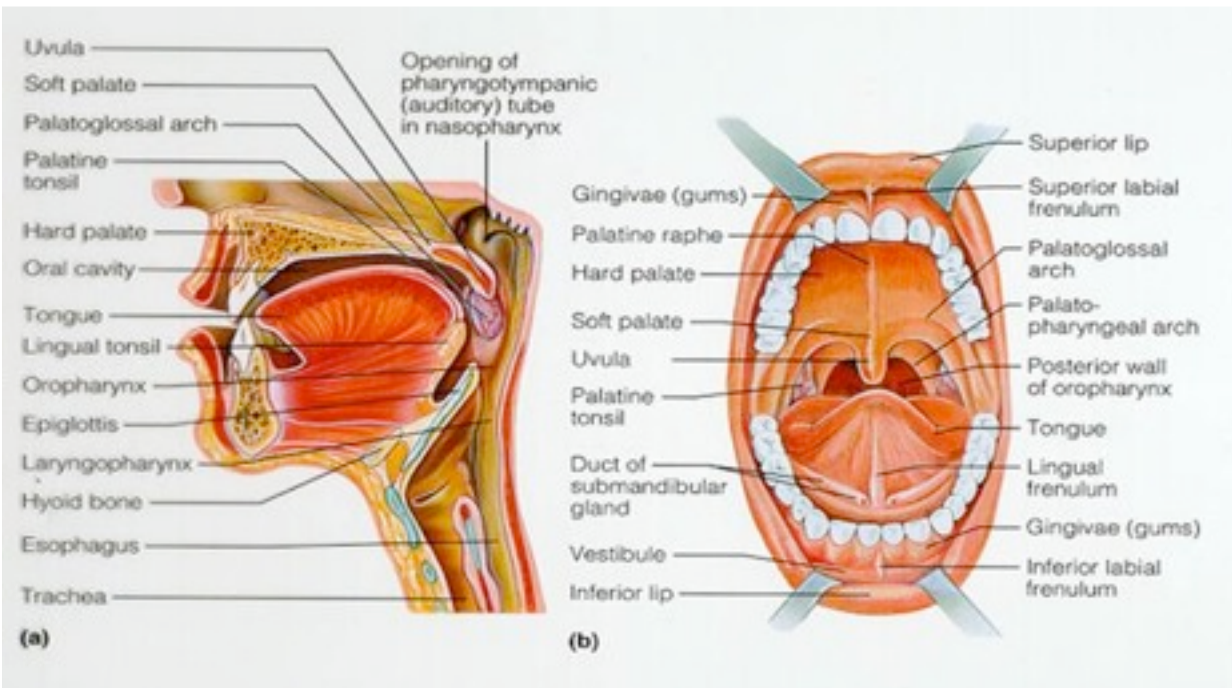


The Sinuses

On either side of the nasal passages, and below the orbits and above the upper molar teeth are thin-walled air-filled spaces, the maxillary sinuses; these communicate with the nasal passages. There are two air-filled spaces adjacent to the nasal passages, the ethmoid and frontal sinuses.

The ethmoid sinuses lie between the upper parts of the nasal cavities and the orbits. They consist of three parts anterior, middle, and posterior all of which drain into the nose.

The frontal sinuses are located behind the superciliary arches (level of eyebrows), are absent at birth, fairly well developed between the seventh and eighth years, reaching full size after puberty. Approximately 5% of people do not have a frontal sinus. The frontal sinuses drain into the nose.

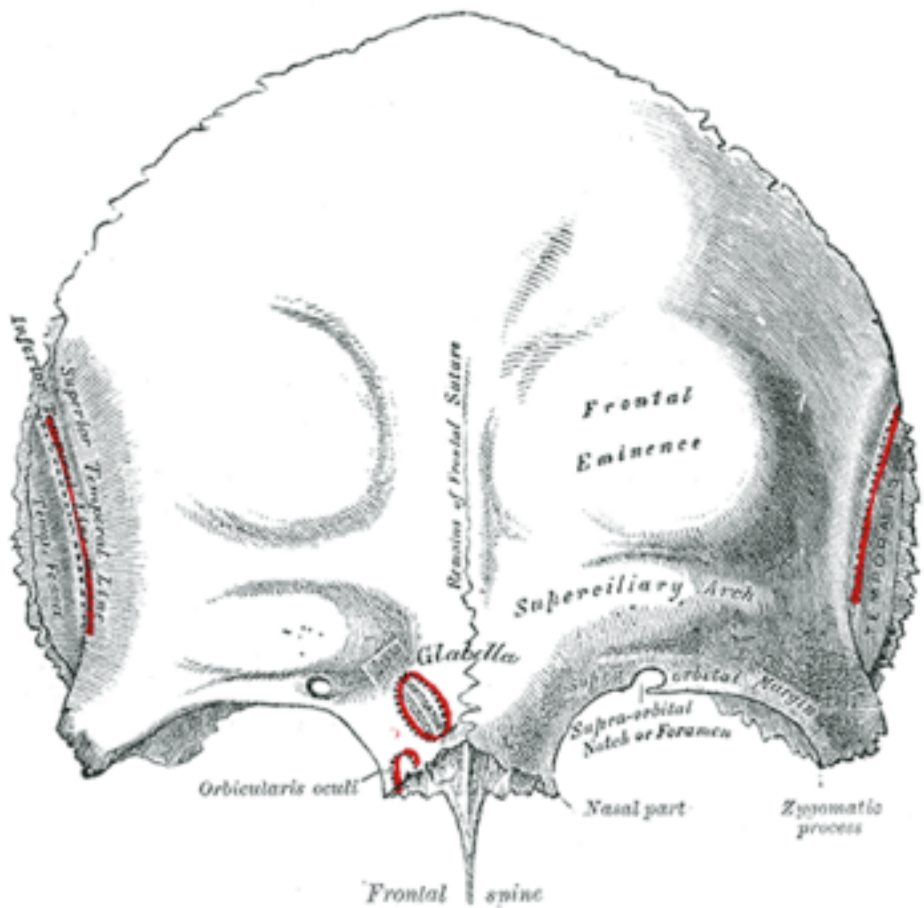


The Mouth Cavity

The basal portion is nearly filled by the tongue. The hard and soft palate forms its roof. The palatine process of the maxilla and the horizontal plate of the palatine bone form the hard palate. The pharynx forms the posterior aspect with the posterior-inferior aspect formed by the epiglottis. The mandible forms the outer inferior margin. The condyles of the mandible articulate in the glenoid fossa of the temporal bone, which is immediately anterior to the external auditory meatus.

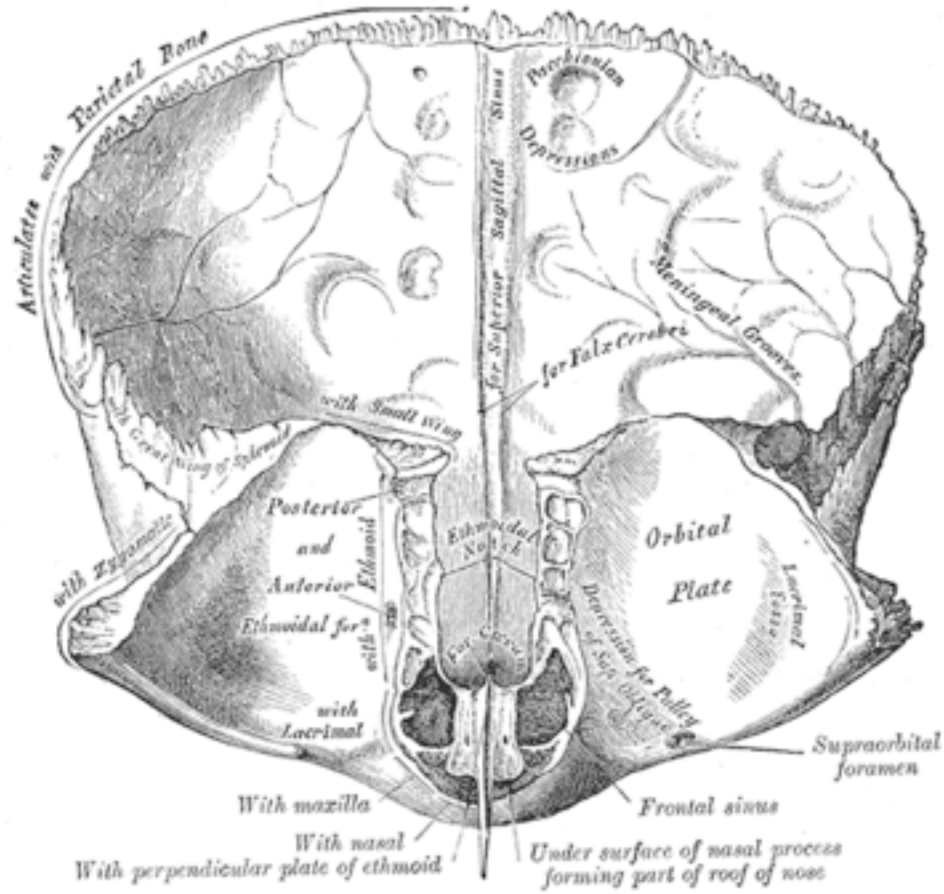
The individual variation in the mandible is so great that it is virtually impossible to fit any but the proper mandible to a skull and have the teeth occlude. Just behind the last upper molar teeth are two thin laminae of bone, the pterygoid plates, which form a strut-like function reinforcing the connection between the face and the cranial vault. The syloid process is a thin spike-like segment of bone just below the external auditory meatus, which gives origin to several muscles and ligaments concerned with the function of the tongue, and swallowing; it varies in length from a few millimeters to a few centimeters.

The



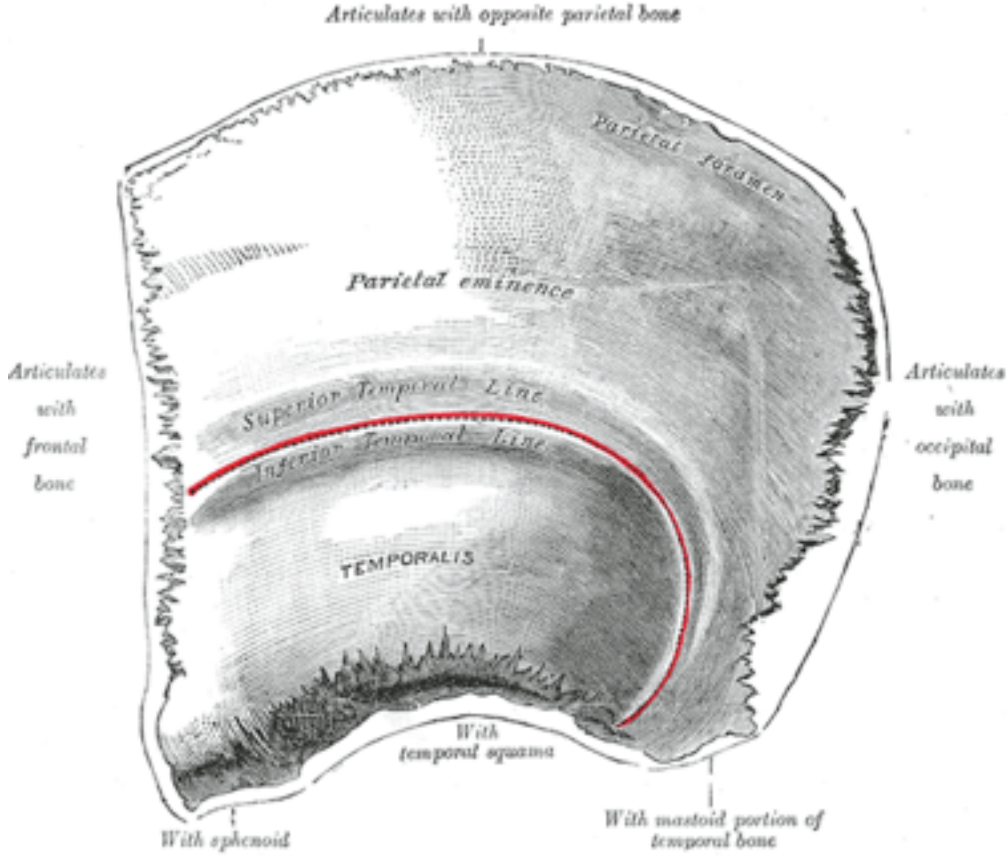
Separate Bones of the Skull

Viewed from above the contour of the cranial vault varies greatly, but is usually a modified oval with its greatest width lying nearer the occipital pole. Four bones constitute this view and articulate through three well-defined sutures. The coronal suture runs in a transverse direction and divides the frontal from the parietal bones.

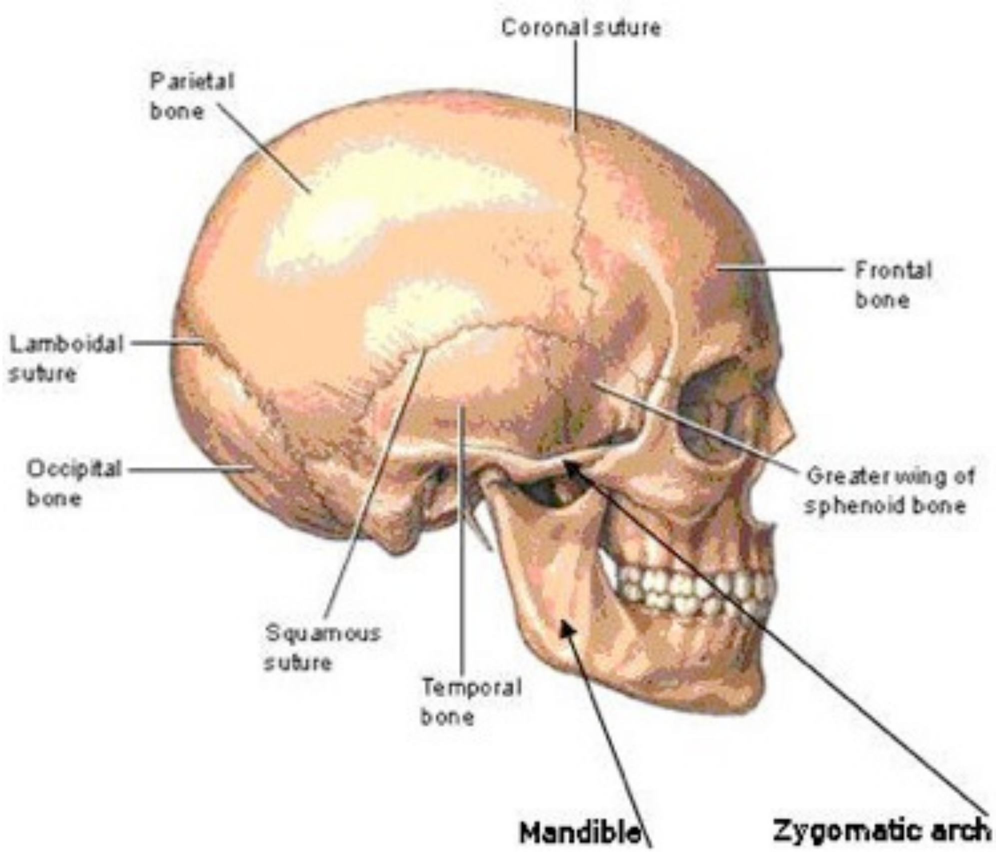


Inferiorly the coronal sutures meet at the junction between the greater wing of the sphenoid bone and the squamosal portion of the temporal bone at a point called the pterion. The frontal bones typically consist of a single plate of bone, the squamosal portion of the frontal bone, although in some adults it is divided into two halves by the metopic suture, which usually closes by six years of age, i.e. it is obliterated or it cannot be seen. The parietal bones are separated by the sagittal suture, which ends in the lambdoid suture, which separates the parietal bones from the occipital bone. These three sutures form two landmarks. Bregma is the point of juncture of the coronal and sagittal sutures and lambda is the point of juncture of the sagittal and lambdoid suture. In the infant, the anterior fontanels occupies the space that well become bregma, typically closing around 18 months after birth. The posterior fontanel occupies the space that will become lambda, typically closing around 2 to 3 months of age.

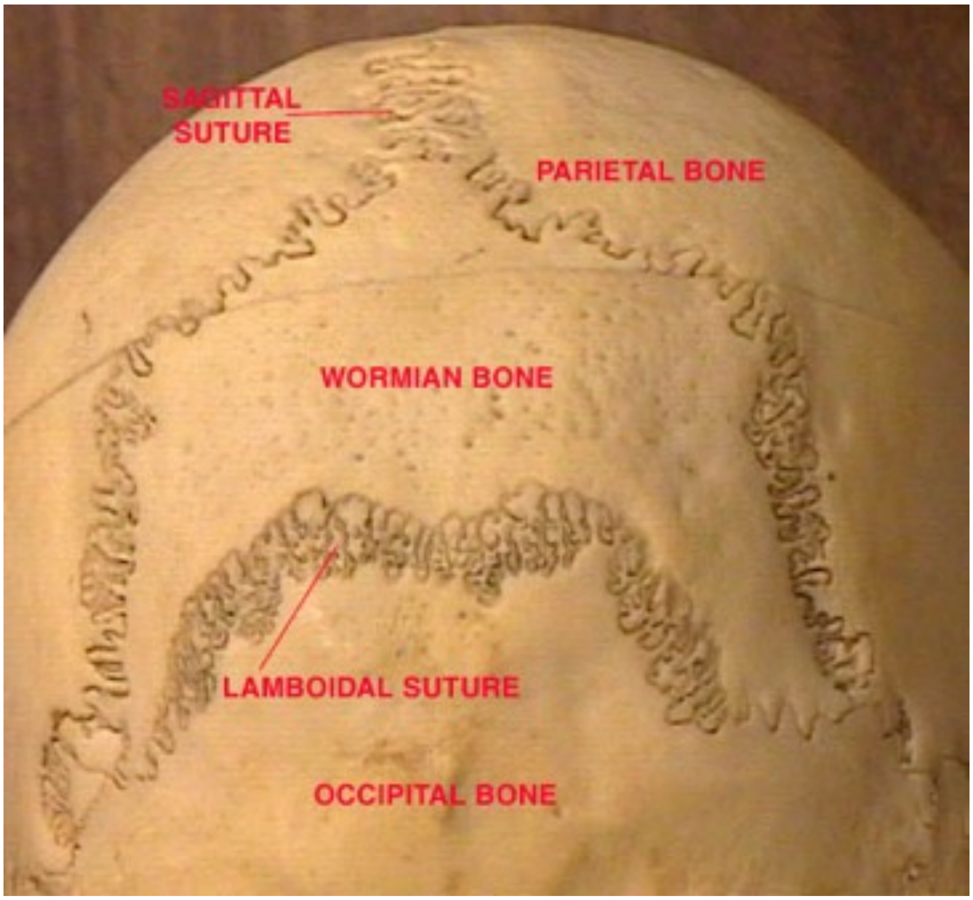
The parietal bones are the only bones of the calvarium that do not turn under to form part of the base of the skull. Also, the parietal bones typically will have a foramen that perforates the parietal bone near the sagittal suture about 3.5 cm



anterior to lambda. It transmits a small emissary vein from the superior sagittal sinus. You will also note that the suture line between the parietal and temporal bones is higher on the outside than inside, indicating an overlap of the two bones. This suture is called the squamosal suture.

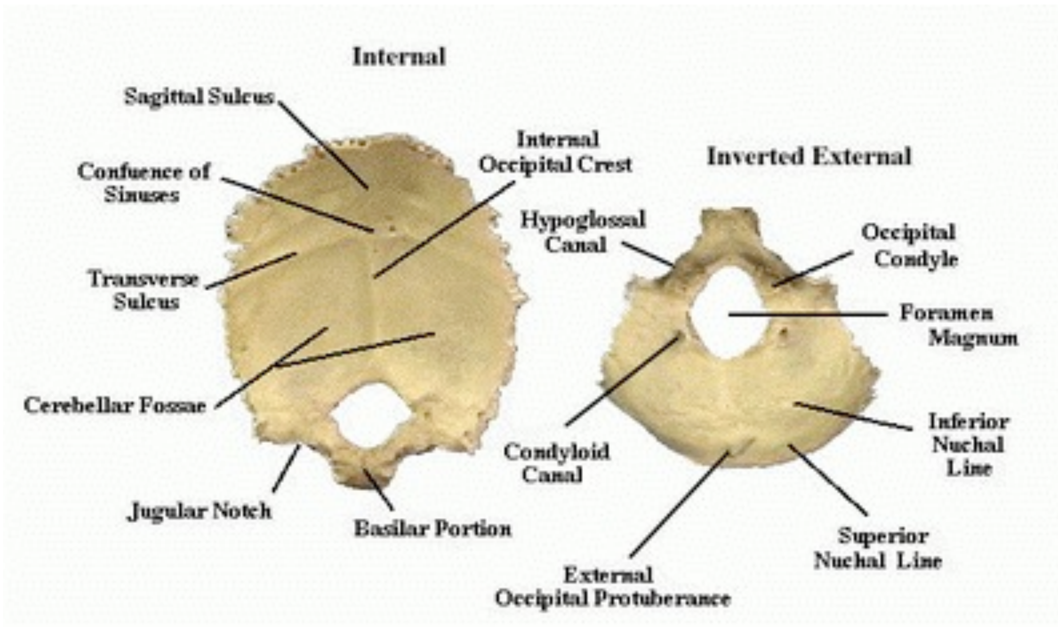


Examining the base of the skull you will note approximately one inch forward of the foramen magnum, the occipital bone joins the center portion of the sphenoid, forming the basi-occipital suture (spheno-occipital synchondrosis). This suture begins to close, fuse, at about nineteen years of age and is obliterated by twenty-five.



When you examine the major sutures such as the lambdoidal, sagittal, etc, you will often find small islands of bone completely surrounded by suture. These are termed Wormian bones, and are highly variable. Sometimes lambda will contain a large Wormian bone referred to as the Inca bone, due to its relatively high frequency of occurrence in Peruvian mummies.

In general the sutures that separate two bones of the skull receive their name from each of the bones. For example, the suture between the sphenoid and temporal bones is called the spheno-temporal (spheno-squamosal, with the squamosal portion of the name referring to the squamosal portion of the temporal bone). The squamosal suture, which separates the parietal and squamosal portion of the temporal bone, does show two modifications in this naming scheme. At the point where the squamosal suture is located above the mastoid it runs virtually straight back forming the parieto-mastoid suture. Following this it turns and runs straight



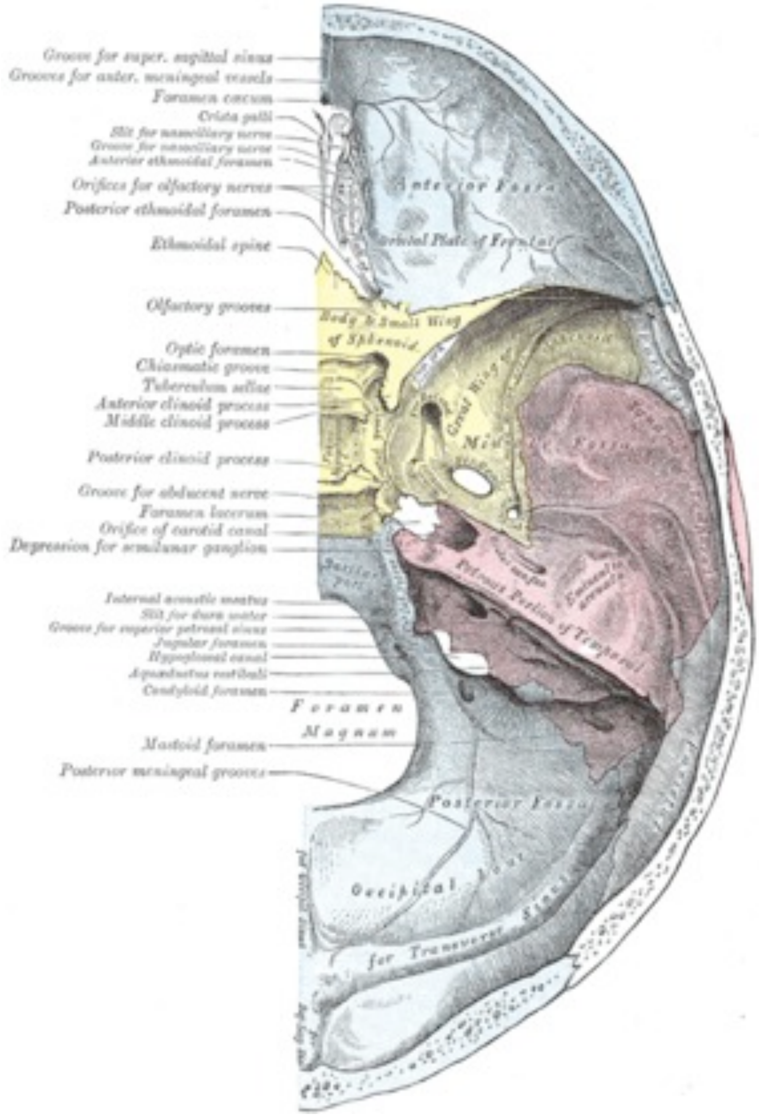
downward forming the occipito-mastoid suture.

At this point we have discussed three bones, which form the base of the skull, the occipital, temporal and sphenoid bones. These bones collectively form the middle and posterior cranial fossae. Examination of the sphenoid bone shows it to be like a butterfly with the large wings traceable on the outside of the skull as it forms part of the cranial vault. In the base of the skull, at the center of the sphenoid, is a deep hollow, which resembles the cantle of a saddle, called the sella turcica (Turkish saddle), which holds the pituitary gland.

Within the anterior portion of the base of the skull, are the anterior cranial fossae. The orbital parts of the frontal bones, ethmoid and sphenoid bones form this portion of the base of the skull.

Bones of the Face

The primary bones of the face are the mandible, maxilla, frontal bones, nasal bones, and zygoma.

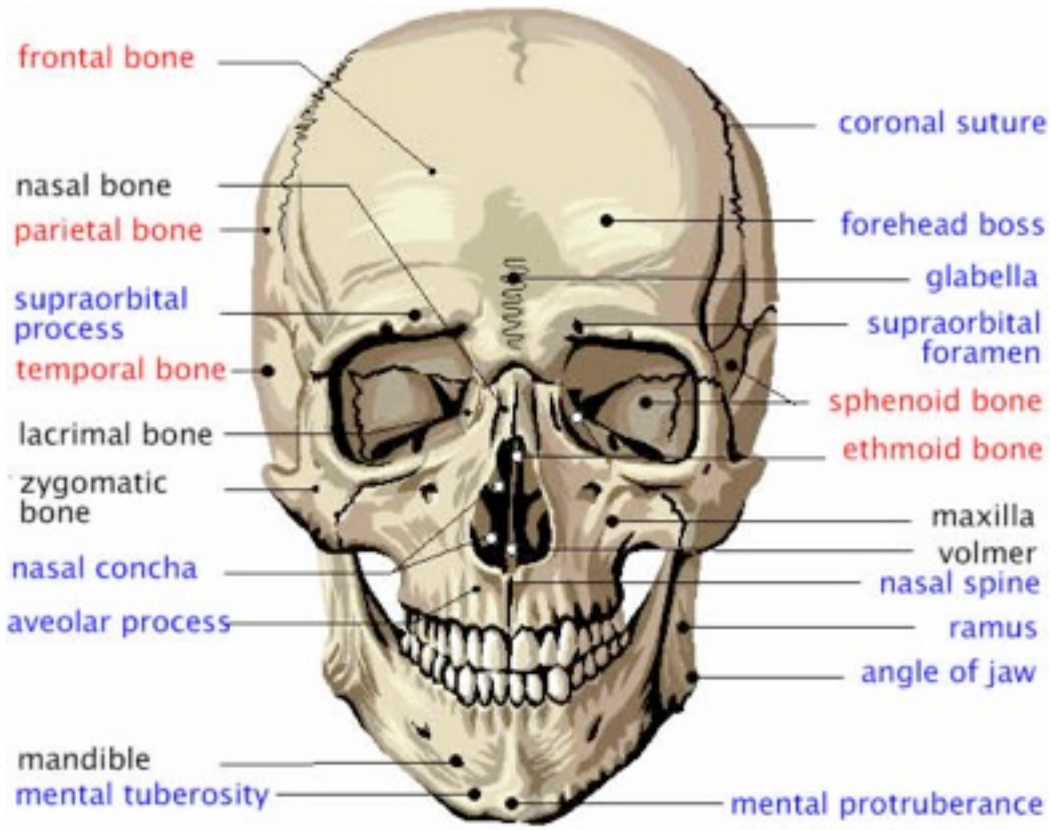


Bones of the Face

The primary bones of the face are the mandible, maxilla, frontal bones, nasal bones, and zygoma.

The zygoma forms the prominence of the cheeks and extends from the temporal bones laterally, where it forms the temporozygomatic suture, to the maxilla. It also forms the sides and floor of the orbits.

Anteriorly it forms the zygomatic arch from which the masseter muscle is attached. The masseter muscle is responsible for closing the mandible for mastication and speech. On its lateral surface, the zygomatic bone has three processes. Inferiorly, a concave process projects medially to articulate with the zygomatic process of the maxilla, forming the lateral portion of the infraorbital rim. This concavity projects superiorly to form the frontal process that articulates with the frontal bone. Posteriorly, a temporal process articulates with the zygomatic of the temporal bone to form the zygomatic arch. On the medial surface of the zygoma is a smooth orbital plate that forms the lateral floor and lateral wall of the orbit. It articulates posteriorly with the greater wing of the sphenoid bone.



The frontal bone forms the anterior portion of the cranium, contains the frontal sinuses, and forms the roof of the ethmoid sinuses, nose, and orbit.
Anteriorly, the external surface is convex superiorly, and it articulates with the parietal bones posteriorly and the greater wing of the sphenoid posteroinferiorly. The anterior convex surface thickens inferiorly to form the supraorbital rims. Just above the supraorbital rims are thickened arches termed the superciliary arches. Their midline unions form a depression called the glabella. Inferolaterally, the supraorbital ridge forms the zygomatic process that articulates with the frontal process of the zygomatic bone. The inferior surface of the frontal bone forms the concave surface of the orbital roof and the anterionasal roof.
The orbital surface articulates posteriorly with the greater and lesser wings of the sphenoid bone, and laterally with the zygoma. On the anterolateral orbital surface is

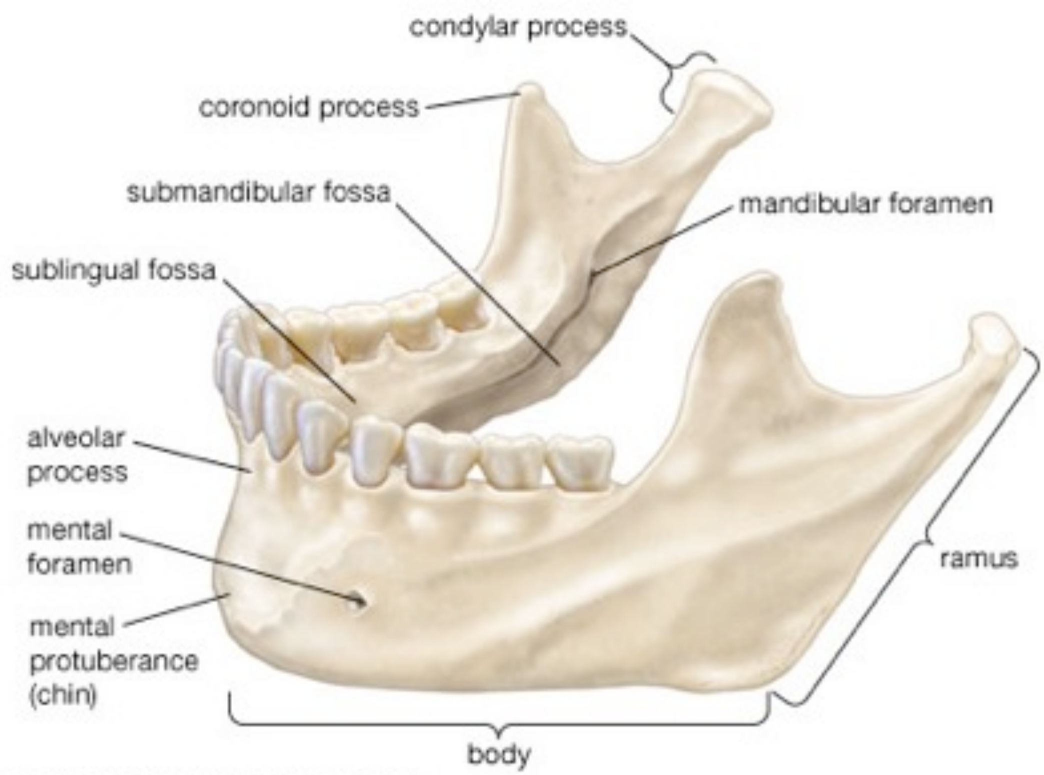
a poorly developed depression for the lacrimal gland. On the medial orbital surface is a small mound where the cartilaginous trochlea of the superior oblique muscle attaches. Anteriorly, between the orbital surfaces, the frontal bone articulates with the anterior portions of the nasal bones and frontal processes of the maxilla. A small vertical midline plate, termed the nasal spine of the frontal bone, contributes to the nasal septum.

The floor of the internal surface forms the floor of the anterior cranial fossa. It has a midline dehiscence termed the ethmoid notch that articulates with the ethmoid bone. Anterior to the ethmoid notch is an upward sloping ridge called the frontal crest, which forms a groove for the superior sagittal siums. At the anterior articulation between the frontal crest and the cribriform plate of the ethmoid bone is a small foramen called the foramen caecum, which usually transmits an emissary vein from the roof of the nasal cavity to the superior sagittal sinus.

The frontal sinus begins to form after the age of 3.5 years. It is located in the anterior midline between the supraorbital rims. In adults, the average dimensions reach 2.4 mm high, 2.9 cm to either side from the midline, and 2 cm in the anteroposterior dimension.

The mandible is a U-shaped bone. It is the only mobile bone of the facial skeleton, and, since it houses the lower teeth, its motion is essential for mastication. At birth the mandible consist of two halves that are united by a fibrous symphysis menti. This two halves typically fuse during the years one through three, although, most show fusion by the end of the first year. There may be separation near the alveolar margin into the second year. It is the largest, strongest and lowest bone in the face. It consists of a horizontal curved body that is convex forward with two broad rami that ascend in a posterosuperior direction posterior to the body on each hemimandible. The mandibular angle is formed by the intersection of the inferior rim of the body and the posterior rim of the ascending ramus. The superior portion of the ramus bifurcates into an anterior coronoid process and a posterior condylar process. The concavity between the 2 processes is called the mandibular notch. The coronoid is the site of attachment of the temporalis muscle. Inferiorly, the condylar process has a narrow neck that widens to a globular head that articulates with the glenoid fossa of the temporal bone forming the temporomandibular joint.

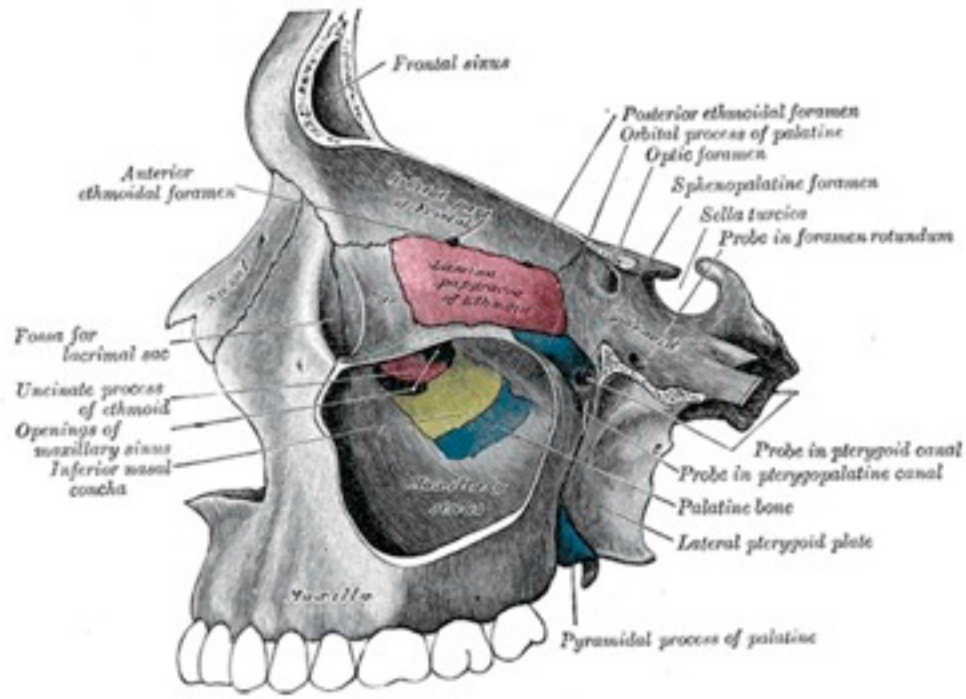
On the medial surface of the ramus, just above the angle is the mandibular foramen, where the nerve supply to the lower teeth enters the mandible to run forward below the nerve roots. The trigeminal nerve (fifth cranial nerve) supplies both the upper and lower dentition. Toward the front of the mandible, below the position of the canine and its first premolar is the mental foramen, which allows for entrance of blood vessels.



The mandible houses the lower dentition, which in adults consists of 2 central and 2 lateral incisors, 2 canines, 2 first and 2 second premolars, and 3 sets of molars.

The point of the chin is called the mental protuberance.

The maxilla contains the upper dentition, forms the roof of the oral cavity, forms the floor of and contributes to the lateral wall and roof of the nasal cavity, houses the maxillary sinus, and contributes to the inferior rim and floor of the orbit. Two maxillary bones are joined in the midline to form the middle third of the face.

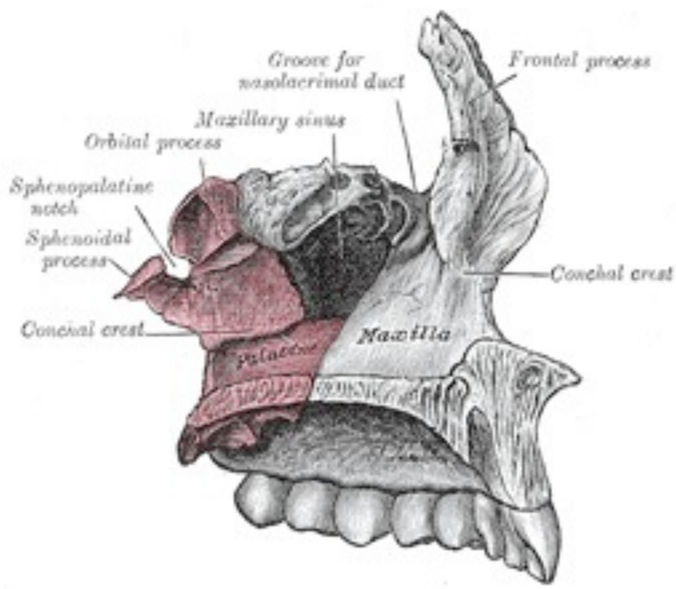


In the midline of the anterior surface of the maxilla is found a prominence called the anterior nasal spine with a lateral concave rim, called the nasal notch that forms the floor of the piriform aperture. Inferiorly, the alveolar process of the maxilla houses the teeth, including 2 central incisors, 2 lateral incisors, canines, 2 premolars, and 3 sets of molars in adults. The tooth roots form vertical wavelike eminences in the anterior face of the maxilla; the canine root is the most prominent, forming the canine eminence, in the anterior face of the maxilla.

Superiorly, the maxillary bone is thickened in an inferior concavity that forms the infraorbital rim. Approximately 5 to 7 mm inferior to the rim lays the infraorbital foramen, which transmits the infraorbital nerve and vessels. The infraorbital rim extends medially and upward to form the frontal process of the maxilla. The frontal process articulates superiorly with the frontal bone, medially with the nasal bone, and posteriorly with the lacrimal bone

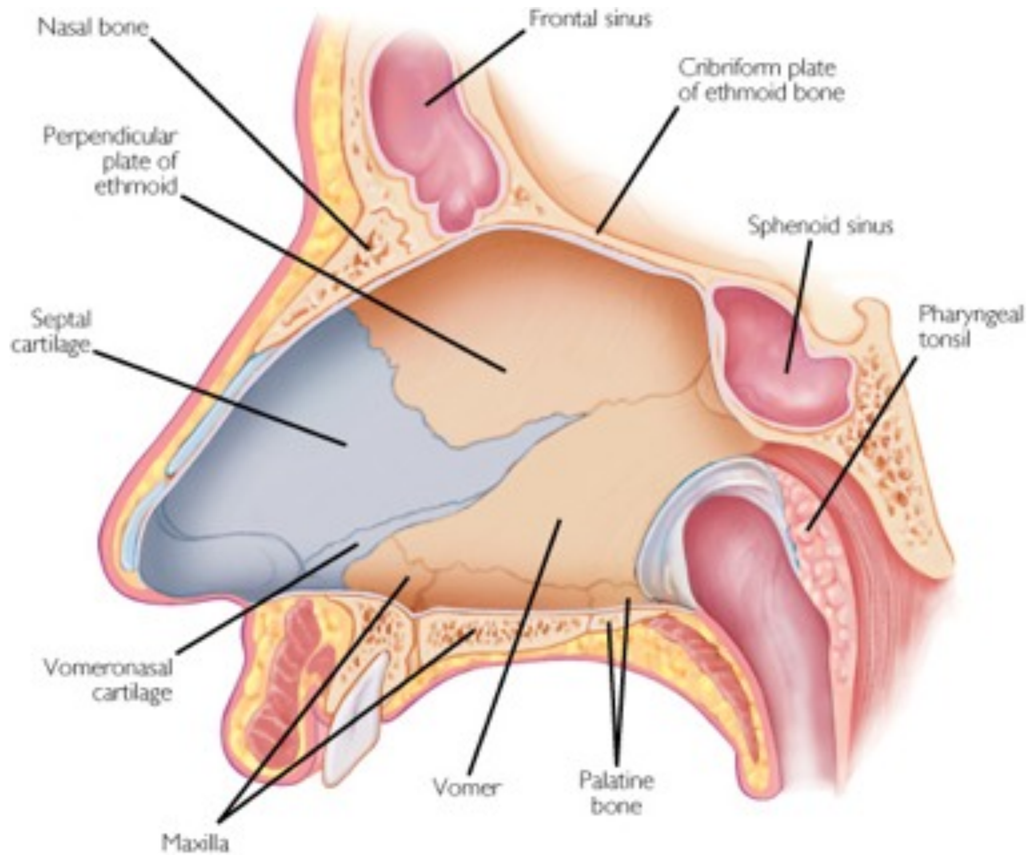
Laterally the maxilla forms the zygomatic process, which articulates with the zygoma to form the lateral portion of the inferior orbital rim. Posteriorly the maxilla articulates with the palatine bone, and medially with the ethmoid, lacrimal, and the inferior concha.

The superior surface of the maxilla forms the medial floor of the orbit. Posteriorly, the free edge forms the anterior border of the inferior orbital fissure. Medially, the orbital surface articulates with the ethmoid bone and lacrimal bone. Behind the frontal process of the maxilla and its anterior lacrimal crest is the nasolacrimal groove. Laterally, the orbital surface articulates with the orbital surface of the



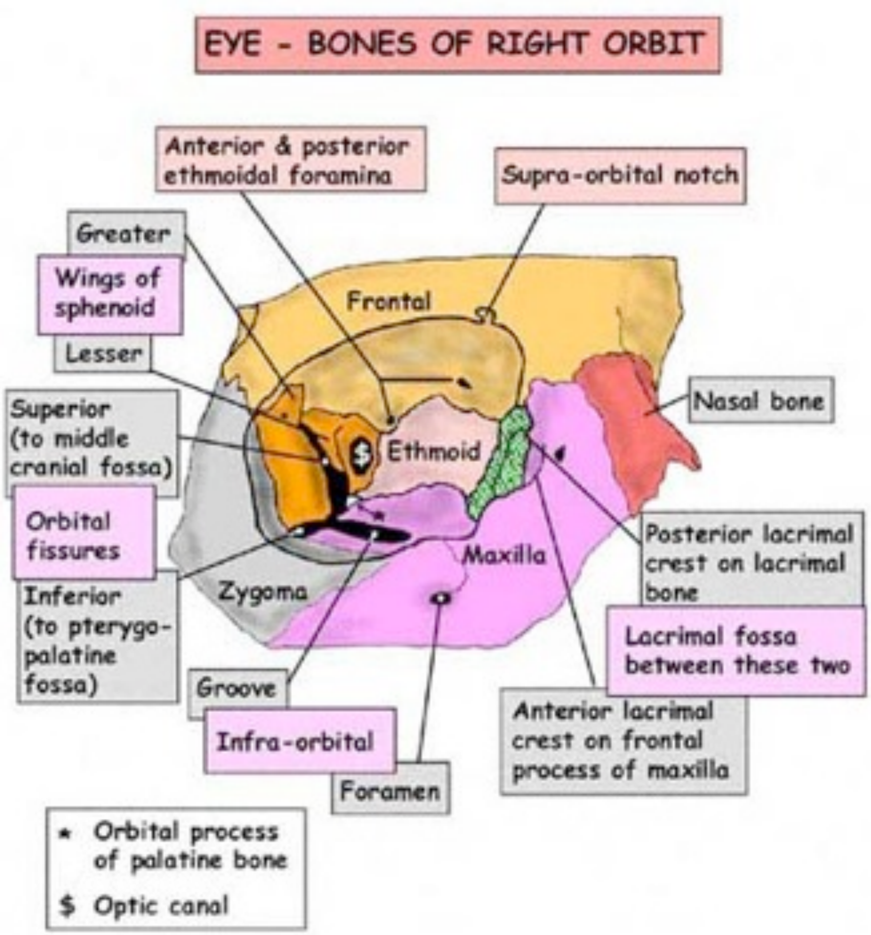
zygoma. On its inferior surface, the maxilla has a horizontal palatine process that forms the bulk of the hard palate. The palatine processes of both maxillae articulate with each other in the midline and with the horizontal plate of the palatine bone posteriorly. Anteriorly in the midline articulation of both palatine processes is the incisive canal, which transmits the nasopalatine nerve and branches of the greater palatine vessels.

The paired nasal bones form the anterosuperior bony roof of the nasal cavity. They articulate with the nasal process of the frontal bone superiorly, the frontal process of the maxillary bone laterally and with one another medially. The inferior border is free and forms the superior margin of the piriform aperture.



Nasal bone
Frontal sinus
Cribriform plate of ethmoid bone
Perpendicular plate of ethmoid
Sphenoid sinus
Pharyngeal tonsil
Septal cartilage
Vomeronasal cartilage
Maxilla
Vomer
Palatine bone

The Orbits

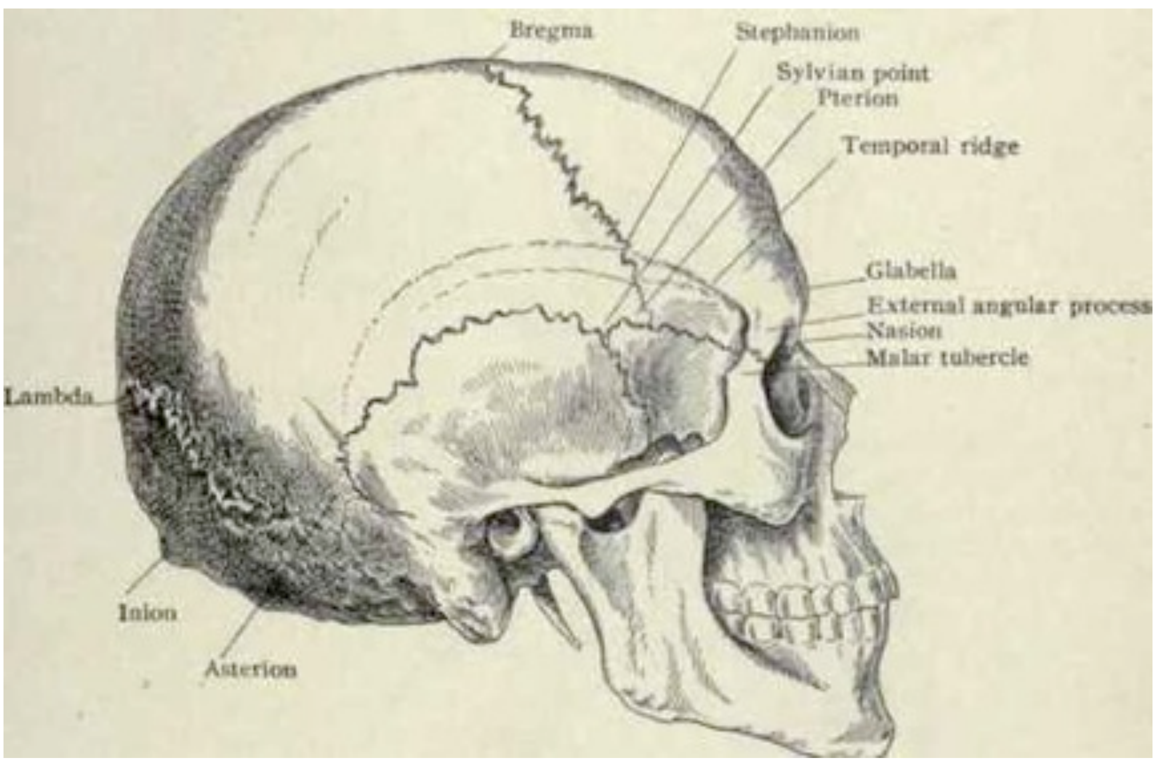


EYE - BONES OF RIGHT ORBIT
Anterior & posterior ethmoidal foramina
Supra-orbital notch
Greater
Wings of sphenoid
Lesser
Frontal
Nasal bone
Superior (to middle cranial fossa)
Ethmoid
Orbital fissures
Inferior (to pterygo-palatine fossa)
Zygoma
Maxilla
Posterior lacrimal crest on lacrimal bone
Lacrimal fossa between these two
Groove
Infra-orbital
Foramen
Anterior lacrimal crest on frontal process of maxilla
* Orbital process of palatine bone
$ Optic canal

The bones forming the roof are mainly the orbital plate of the frontal bone, with the lesser wing of the sphenoid forming the most posterior part. The bones forming the lateral wall are the orbital surfaces of the greater wing of the sphenoid bone and the zygomatic bone. The floor of the orbit is formed by the orbital surfaces of the maxilla and zygomatic bone, with the orbital process of the palatine bone in the most posterior part. The medial wall of the orbit is formed by the lacrimal bone, the orbital plate of the maxilla, with a small part of the body of the sphenoid forming the most posterior part.

Landmarks on the Skull

We have already mentioned some landmarks of the skull, Bregma and Inion. There are many more you will be using when assessing a human skull. The following is a partial list of these landmarks.

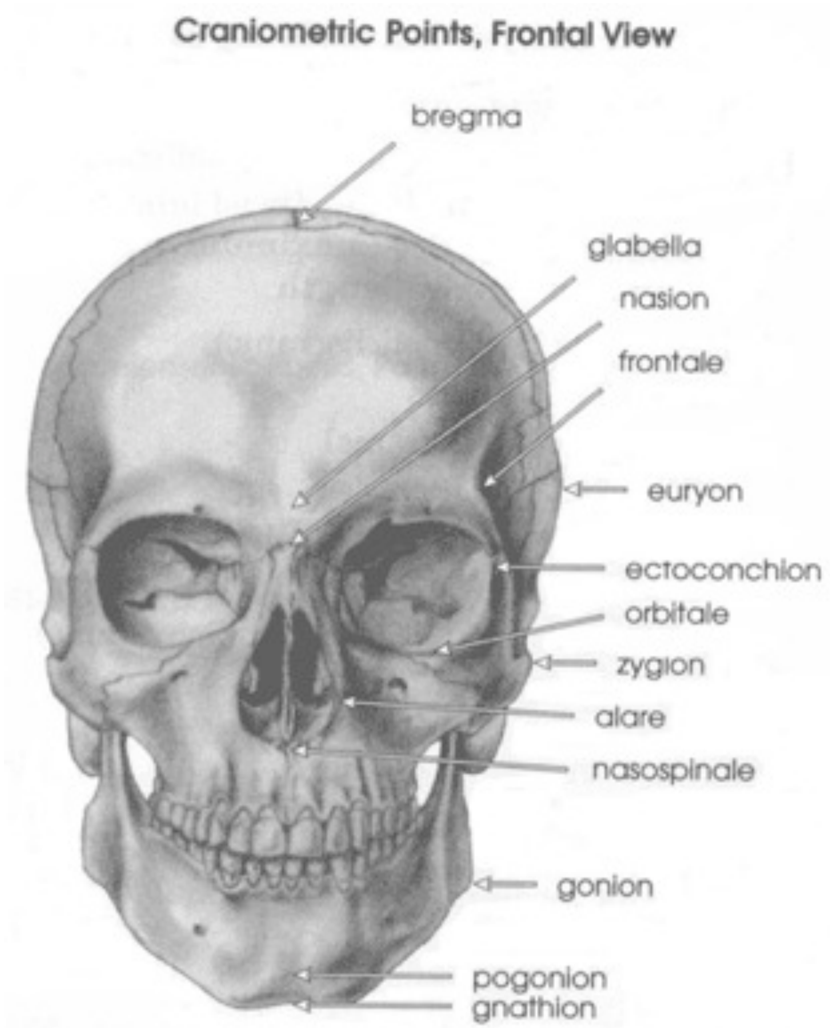


On the Mandible

Gnathion: midpoint on the lower border of the mandible.

Gonion: most lateral point on the angle made by the Body and Ascending Ramus

Infradentale: point on mandibular alveolar margin between the medial incisors.



Pogonion: most anterior point on chin in midline (not to be confused with Gnathion)

Upper Facial Skeleton

Prosthion: most anterior point on the upper alveolar process.

Nasospinale: a point in MSP (mid sagittal plane) on a line between both nariale; usually at base of the nasal spine.

Nasion: midpoint of the sutures of the frontal and nasal bones.

Dacryon: meeting point of the frontal, maxillary and lacrimal bones.

The Vault of the Skull

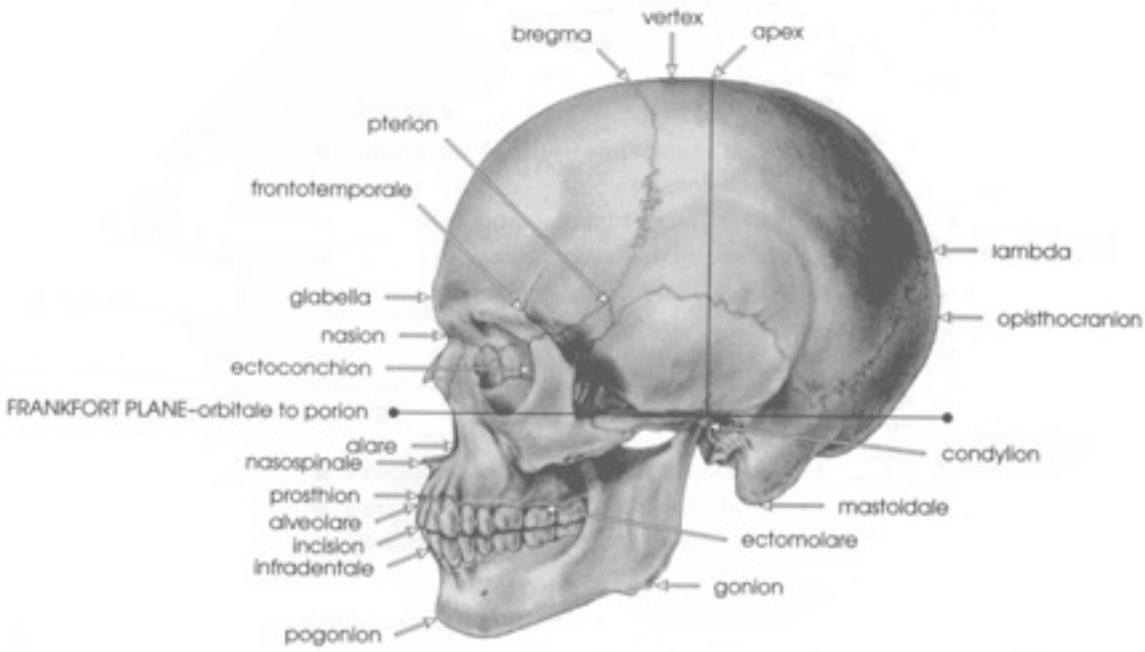
Glabella: most prominent point in MSP between the browridges.

Bregma: meeting place of the coronal and sagittal sutures.

Vertex: highest point on the skull when placed in Frankfort Plane.

Lambda: point where sagittal and lambdoidal sutures meet.

Craniometric Points, Lateral View



Inion: point in MSP of the superior nuchal line.

Opisthocranion: rearmost point on skull wherever found.

Porion: point on upper border of the external auditory meatus.

Asterion: point where the temporal, parietal and occipital bones meet.

Base of Skull

Opisthion: midpoint of posterior margin of the foramen magnum.

Basion: midpoint on the anterior margin of the foramen magnum.

Staphylion: point on a line tangential to the posterior border of the palate where it crosses the interpalatine suture.

Orale: midpoint of a line tangential to the posterior margins of the sockets of the upper medial incisors.

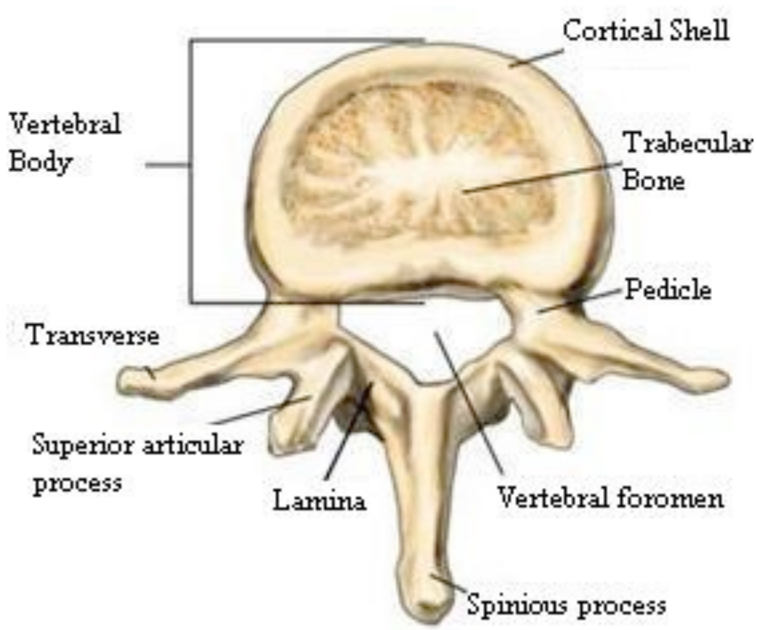
Endomolare: most medial point on inner margin of socket of second upper molar.

Bones of the Vertebral Column, Ribs, Sternum and Sacrum

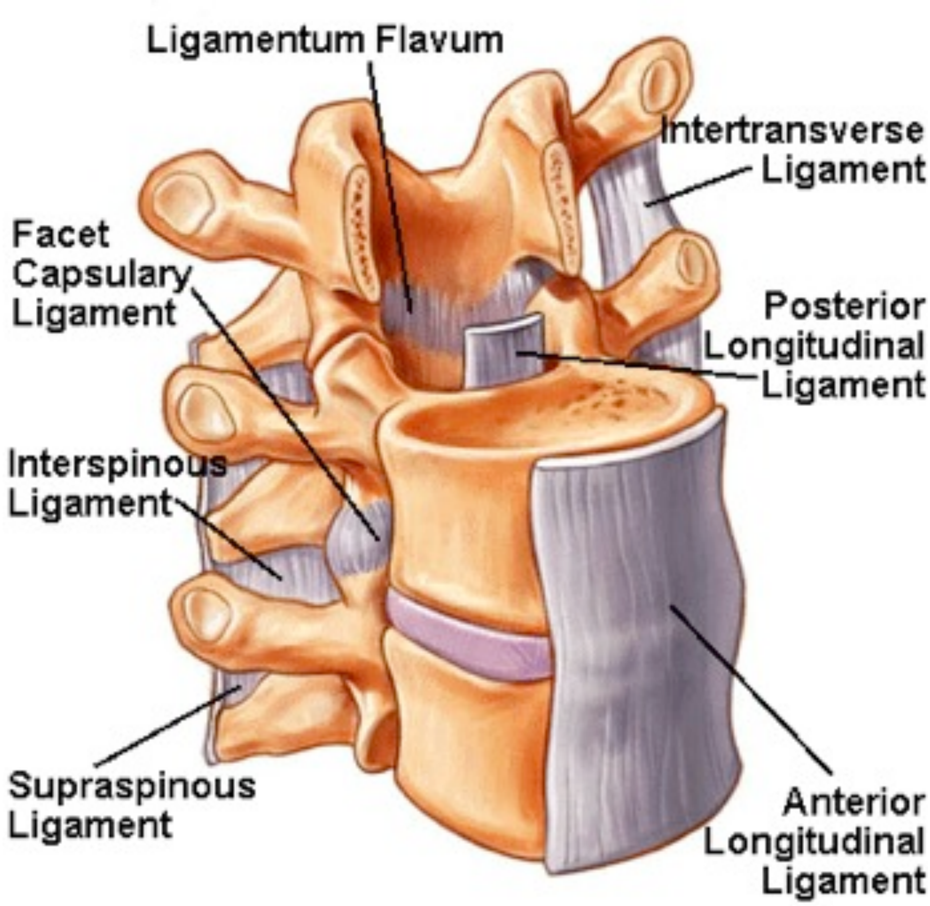
The vertebral column is composed of 33 bones arranged in 5 sections: cervical (7 bones), thoracic (twelve bones), lumbar (5 bones), sacrum (usually a fusion of 5 bones), and coccyx (usually a fusion of four bones).

When looking at the complete vertebral column you will note it forms several curvatures: a concavity in the neck region, a convexity in the thoracic region, a concavity in the lumber region and a convex curve formed by the sacrum and coccyx.

The typical vertebra is composed of two parts, the anteriorly placed body and the



posterior vertebral arch, which encloses the vertebral foramen. The posterior vertebral arch is formed of two pedicles and two lamina, from which arise four articular processes, two transverse processes, and one spinous process.
The cylindroid vertebral body varies in size, shape and proportions in different regions of the vertebral column, with the vertebral body of each vertebrae increasing in size as you go down the vertebral column. Between each of the vertebrae, beginning with C2 and extending to the sacrum are disc-like structures, which allow for articulation between the vertebrae, referred to as intervertebral discs. The vertebrae and intervertebral discs are held in place by two ligaments,



anterior and posterior longitudinal ligaments. The anterior longitudinal ligament runs down the anterior surface of the spine, traversing all of the vertebral bodies and intervertebral discs. The posterior longitudinal ligament is located within they vertebral canal, extending along the posterior surfaces of the bodies of the vertebrae, from the body of the axis (C2) where it is continuous with the membrana tectoria, to the sacrum.

Anteriorly the vertebral bodies show a cephalocaudal increase in their width from the axis to the third lumbar vertebra. This increase in width is due to the increase in load-bearing function. Although, there is some variation in the width of L 4 & 5 vertebral bodies, from that point to the coccygeal apex there is a prominent decrease in width of the vertebra.

Extending posterior-laterally from the posterior-lateral surface of the vertebral body are the pedicles, which are short, thick rounded projections, which form a portion of the intervertebral foramen. They connect the body of the vertebra to the arch by fusing with the lamina. Concavities above and below the pedicles form the intervertebral foramina when the vertebrae articulate with one another. The intervertebral foramen allow for passage of the spinal nerve root, dorsal root ganglion, the spinal artery, communicating veins between the internal and external plexuses, recurrent meningeal nerves, and transforaminal ligaments. The cervical vertebrae have two different vertebral foramena; the paired transverse foramena and the vertebral foramen, while the thoracic and lumbar have only one, the vertebral foramen. The transverse foramena allow for passage of the vertebral artery and vein and the vertebral nerve plexus.

At the point of juncture of the pedicles and lamina are articular processes, two of which are superior and two inferior. These articular processes serve as points of articulation between adjacent vertebrae and thus allow for movement between the adjoining vertebrae. They also contribute to the posterior boundaries of the intervertebral foramena.

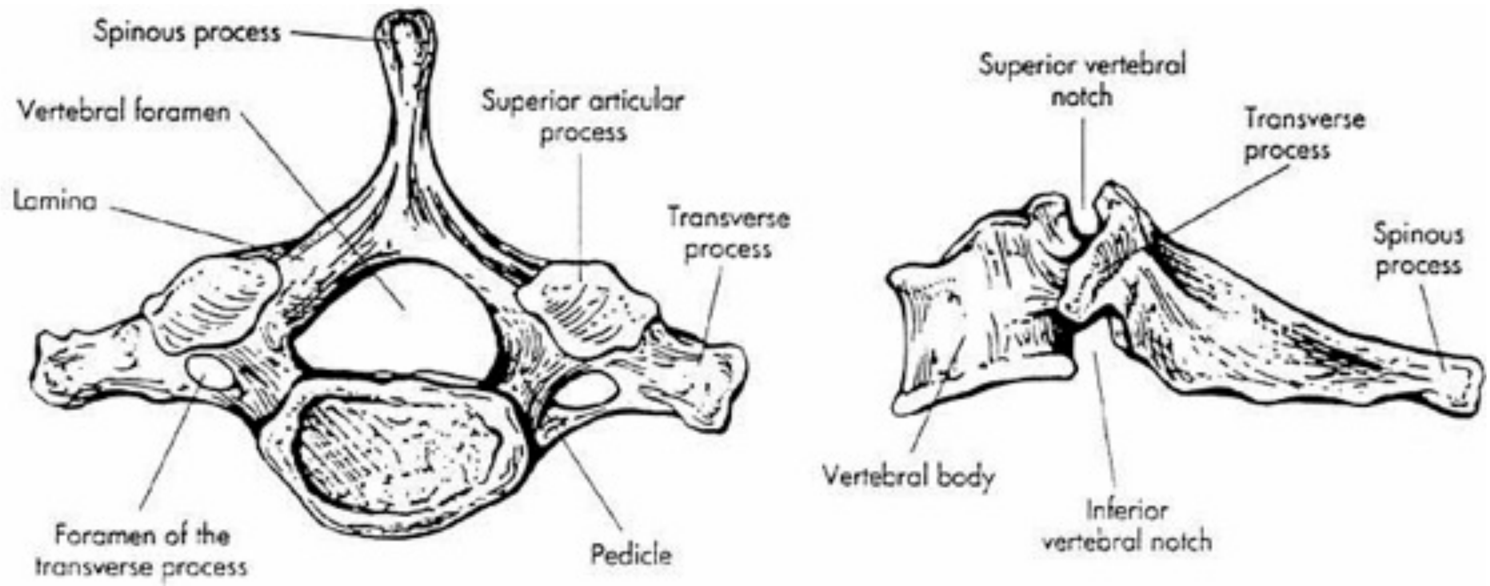
Projecting laterally from the pediculolaminar junctions are segments of bone, the transverse processes, which serve as points of attachment for muscles and ligaments, especially those concerned with rotation and lateral flexion. There is considerable anatomic regional variation in the structure and length of the transverse processes. In the cervical region, the transverse process of the atlas is long and broad, which allows the rotator muscles of the head and neck maximum mechanical leverage. The breadth varies little from the second through the sixth cervical vertebrae, but increases in the seventh. In the thoracic vertebrae, the first is widest; thereafter the breadth decreases to the 12th. The transverse processes become broader in the upper three lumbar vertebrae, and diminish in the 4th and 5th. The transverse process of the 5th lumbar vertebra is the most massive for it allows for force transmission to the pelvis through the ilolumbar ligaments. The thoracic transverse processes articulate with the ribs.

The laminae extend posterior medially where they fuse in the midline to form the dorsal spine. This fusion also forms the posterior component of the vertebral foramen (canal). These spinous processes (dorsal spine) project posteriorly as well as inferiorly. They vary considerably in size, shape and direction. The dorsal spine serves as points of attachment for muscles, which control posture and active movements (flexion/extension, lateral flexion and rotation) of the vertebral column. There is some sexual dimorphism in the vertebrae, with female vertebral bodies having a lower ratio of width to depth.

The vertebral foramen (canal) extends from the foramen magnum to the sacral hiatus (the laminae of the 5th sacral vertebra, and sometimes those of the fourth, fail to meet behind, thus forming the sacral hiatus in the posterior wall of the sacral canal). In the cervical and lumbar regions, which allow for substantive mobility, the vertebral canal is large and triangular. However, in the thoracic region, which does not have the degree of mobility of the cervical and lumbar regions, it is small and circular. The differences in size of the canal coincide with the size of the spinal cord, which is widest in the cervical and lumbar regions. The vertebral canal decreases in size gradually between L1 & L5 with greater relative width in females.

The Cervical Vertebrae

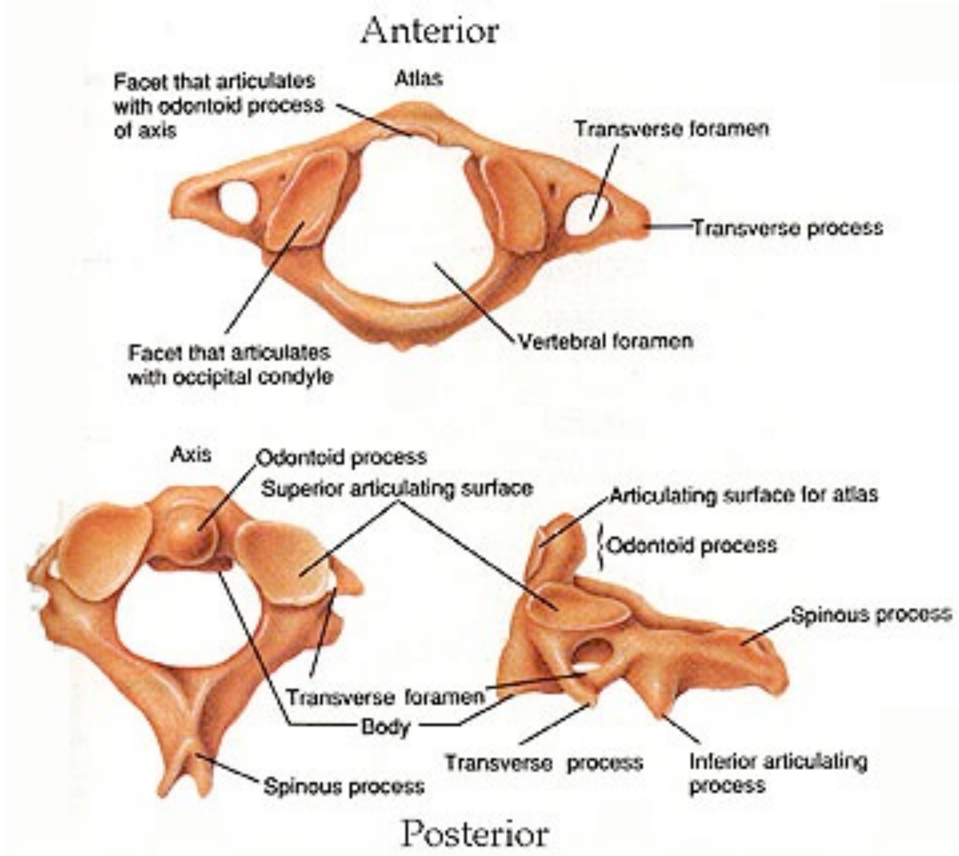
The typical cervical vertebrae have a small relatively broad vertebral body. The short pedicles project posterolateral, whereas the longer laminae project posteromedially, thus forming a triangular vertebral foramen, which is large enough to accommodate the cervical enlargement of the spinal cord. The dorsal spine is short and bifid. Within the transverse process is the foramen transversum (transverse foramen), which as has been previously discussed, allows for passage of the vertebral artery and vein as well as the plexus of sympathetic nerves in each of



the cervical vertebrae with the exception of the seventh, which lacks the vertebral artery.

The vertebral body has a convex anterior surface. He disc margin gives attachment to the anterior longitudinal ligament. The posterior surface is flat or minimally concave with its disc margin giving attachment to the posterior longitudinal ligament. What is important to keep in mind is the discal surfaces of the cervical vertebrae are so shaped in order to restrict both lateral and anteroposterior gliding movements during articulation. The central area of the vertebral body has several vascular foramina, two of which are quite large. These are the basivertebral foramina, which transmits basivertebral veins to the anterior internal vertebral veins.

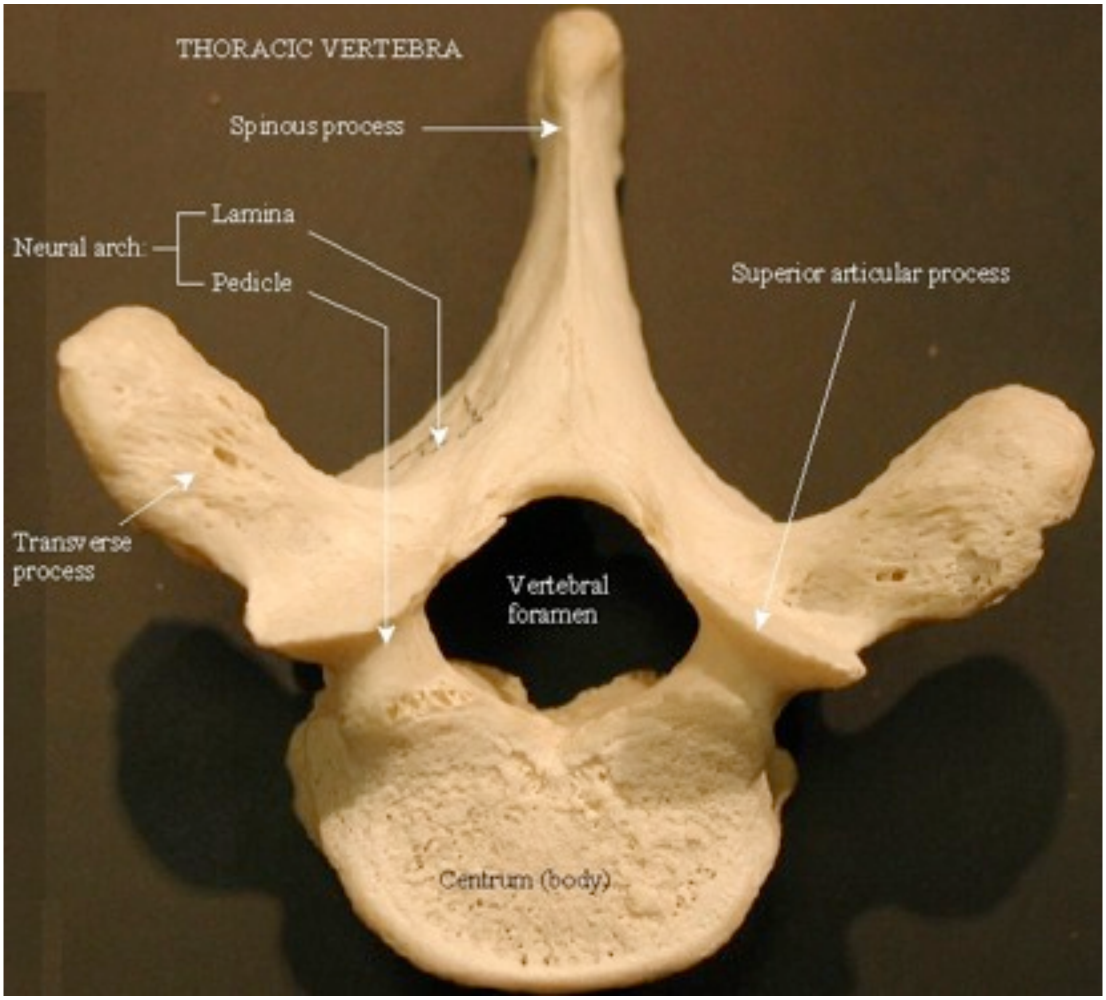
The first and second cervical vertebrae are quite unique. The first is referred to as the atlas and what is unique about this is that it has no vertebral body. In actuality, what would have been its vertebral body became a part of the second cervical vertebra, the axis, to form the odontoid process or dens (tooth). This arrangement allows for greater freedom in rotating the head from side to side, and up and down. Also, the articulating surfaces, or facets, on the superior and inferior surfaces of the atlas are kidney-shaped, permitting the rocking motion of the skull.



The Thoracic Vertebra

These are the most typical vertebrae and most easily recognized. They are also the rib-bearing vertebrae, which manifest by all of the thoracic vertebral bodies displaying lateral costal facets and all but the lowest two or three transverse processes also have facets. The facets articulate with the head of the rib (costocapitular facet/transverse costal facet) and its tubercle (costotubercular facet/superior costal facet) respectively. Keep in mind that the facets of T1 are similar to those of the cervical vertebrae. The first and ninth to 12th vertebrae have atypical features.

The body is typically a wasted cylinder except where the vertebral foramen encroaches,; the transverse and anteroposterior dimensions are almost equal. The articulating surfaces for joining vertebra to vertebra are flat and vertical; the superior facet faces posteriorly, the inferior facets face anteriorly. The lateral margins of the body have facets for articulating with the head of a rib. Some are demi-facets, half on one body and half on the body below. The last thoracic vertebra (12th) is recognized by a change in the inferior articulating facet, which instead of being flat is curved as are the facet of the lumbar vertebrae.

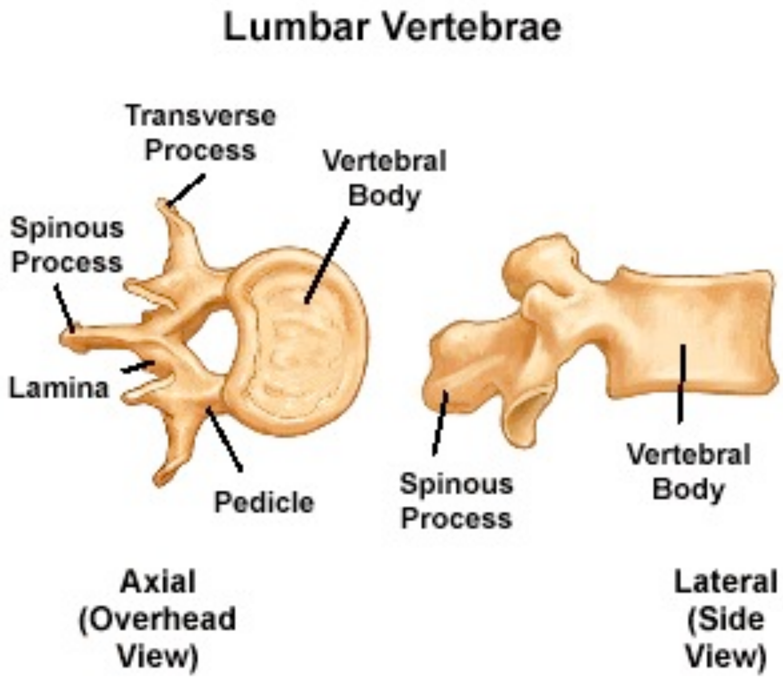


The Lumbar Vertebrae

The lumbar vertebrae are noted for their large size and absence of costal facets and transverse foramina. Their large size is in keeping with the amount of weight they must support. The vertebral body is wider transversely. The vertebral foramen is triangular, larger than the thoracic, but smaller than the cervical.

The vertebral canal extends from the foramen magnum to the sacral hiatus, and follows the vertebral curves. In the cervical and lumbar regions, which exhibit free mobility, it is large and triangular as has been pointed out, but in the thoracic region, where movement is less, it is small and circular. These differences are matched by variations in the diameter of the spinal cord and its enlargements. In the lumbar region, the vertebral canal decreases gradually in size between L1 and L5, with a greater relative width in the female.

The spinous processes are large, flattened from side-to-side, and extend straight back. The superior and inferior articulating facets are curved to form a stronger union with their counterparts of the vertebrae above and below. The transverse processes are thin and long, except on the more substantial fifth pair.

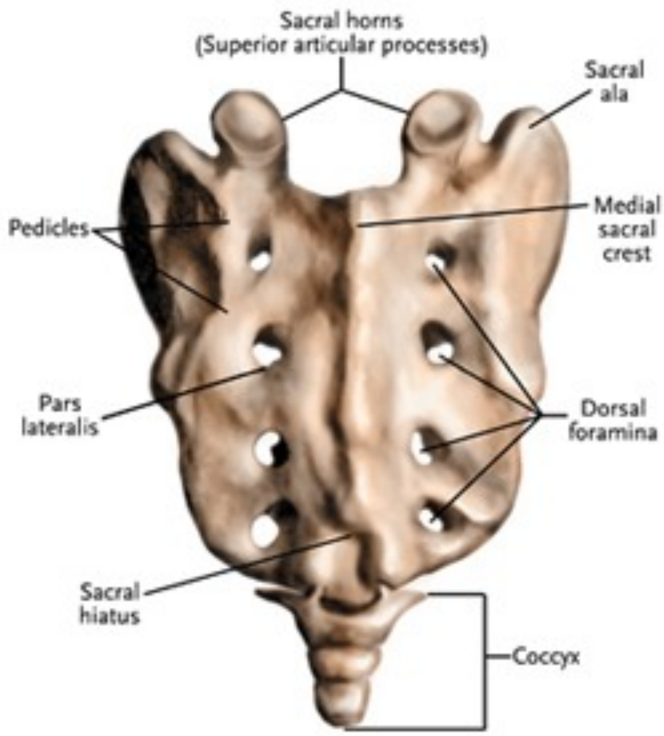


The fifth lumbar vertebra has a massive transverse process, which is continuous with the whole of the pedicle and encroaching on the body. The body is usually the largest and markedly deeper anteriorly, so contributing to the lumbosacral angle.

The Sacrum

The sacrum is a large, triangular fusion usually of five vertebrae, sometimes six, forming the posterior-superior wall of the pelvic cavity, wedged between the two hip bones (innominates). It is blunted at the caudal end (most inferior end), where it articulates with the coccyx and at its superior end it articulates with the wide base of the fifth lumbar vertebra forming the lumbosacral angle. The sacrum is curved longitudinally, the dorsal surface is convex, and the pelvic surface is concave, thus increasing the pelvic capacity. The curvature is greater in males, being more straight in females.

Laterally, there are two auricular (ear-shaped) surfaces for articulation with the innominates. The number of paired foramina tells you how many vertebrae have fused to form the sacrum; if four pairs, than five vertebrae have fused to form the sacrum; if five foramina, then six vertebrae were involved in its formation. At times, the 5th lumbar will fuse either completely or incompletely with the superior sacral segment.



Inferiorly, the coccygeal bones of four to five segments will, at times, also fuse with the sacrum.

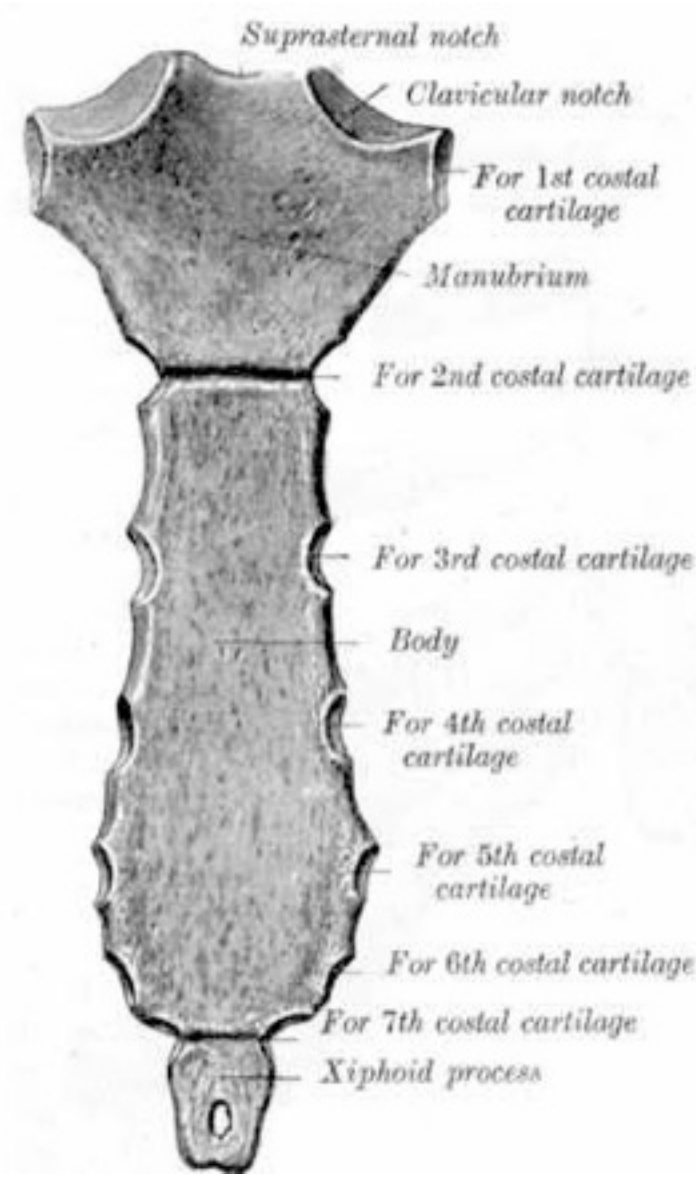
Functionally, the weight of the vertebral column is transmitted down to the last lumbar vertebra, then on to the sacrum, then the innominates and finally to the femurs.

Coccyx

The coccyx is a small triangular bone, usually consisting of four fused rudimentary vertebrae, although the number varies from three to five with the first sometimes being separate. The bone is directed downwards and ventrally from the sacral apex. It is attached to the sacrum by a fibrocartilagenous joint, the sacrococcygeal symphysis.

The coccyx is the remnant of a vestigial tail. Functionally it serves for the attachment of various muscles, tendons and ligaments as well as serving as part of the weight-bearing tripod structure, which acts as a support for the sitting person. When a person sits leaning forward, the ischial tuberosities and inferior rami of the ischium take most of the weight, but as the sitting person leans backward, more weight is transferred to the coccyx.

The Sternum



The sternum is composed of three segments: superiorly the manubrium, the intermediate body and inferiorly the cartilaginous tab, the xiphoid process. At birth the sternum is composed of five separate bones, the uppermost of which is called the manubrium, the lower four of which from the body. Segments three and four of the body fuse between 4 and 8 years, segments one and two fuse between 8 and 25 years, by which time the body is one piece. The manubrium fuses with the body "in old age."

The total length of the sternum is approximately 17 cm in males and less in females. The ratio between the lengths of the manubrium to the length of the body differs between the sexes. In males the manubrium:body length ratio is 49:100 (49 or below) and in females it is 52:100 (52 or above). The sternum may continue to grow beyond the third decade and possibly throughout life.

Its anatomic position is such that it slopes down and slightly forwards, being convex in front and concave behind. There are notches, laterally placed, that act as articulating facets for the clavicle (on the manubrium) and the first seven ribs (on the manubrium and the body). The manubrium is located at the level with the third and fourth thoracic vertebrae. The body is at the level of the fifth to ninth thoracic vertebrae. The xyphoid process anatomically is located in the epigastrium.

There are two common anatomic variations of the sternum, Pectus excavatum and carinatum. Pectus excavatum occurs in about 1 in 500 live births. It shows a depression of the sternum and adjacent costal cartilages giving the chest a funnel-shaped chest. This is often associated with dorsal lordosis. Some also develop scoliosis. The majority of affected individuals show signs of the abnormality in the first 12 months of life. Although, its etiology is unknown, it can be associated with Marfan's syndrome.

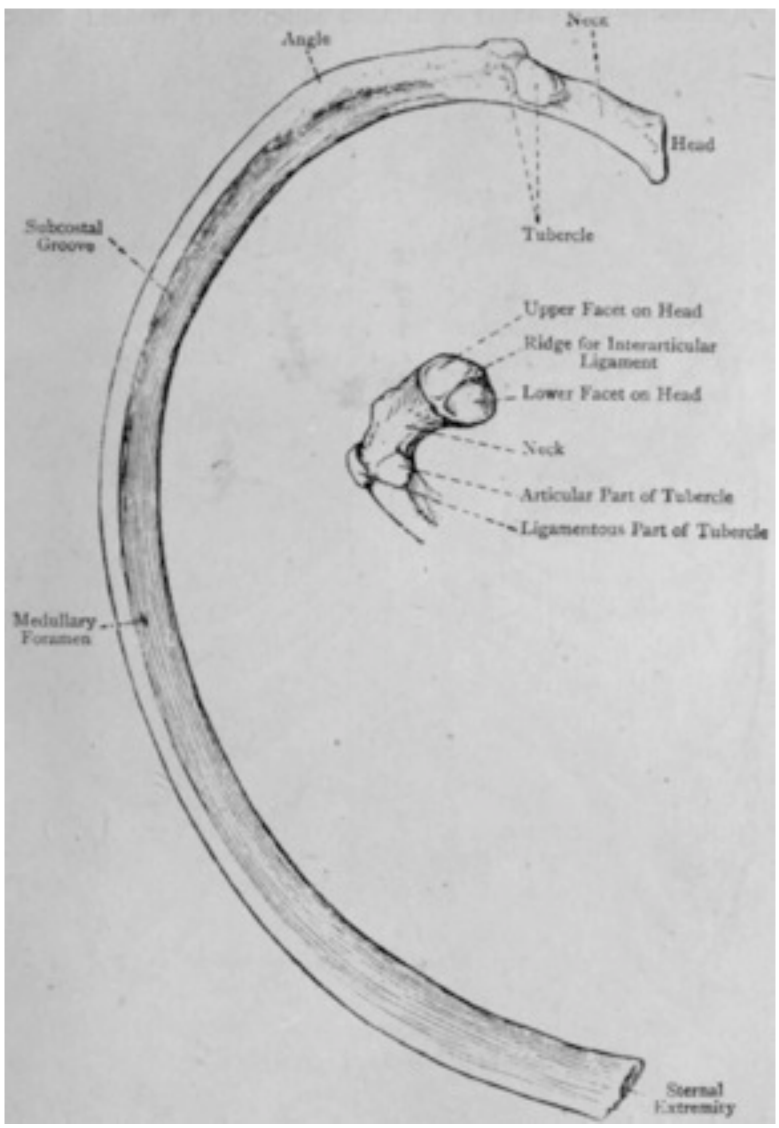
Pectus carniatum is an anterior projection of the sternum, often referred to as pigeon breast (chest). It typically is present in early childhood, progresses during adolescence and then remains the same from age 18 throughout adulthood.

The Ribs

There are 12 pairs of ribs, seven pairs of which articulate directly to the sternum through their cartilages, hence they are referred to as 'true' ribs. The other five pairs are referred to as 'false' ribs in that they either do not articulate with the sternum directly or not at all. Ribs 8, 9 and 10 articulate with the sternum through the cartilage of the seventh rib. Ribs 11 and 12 do not articulate with the sternum or any other bone. Their ends remain free covered by cartilage; hence they are termed 'floating ribs'.

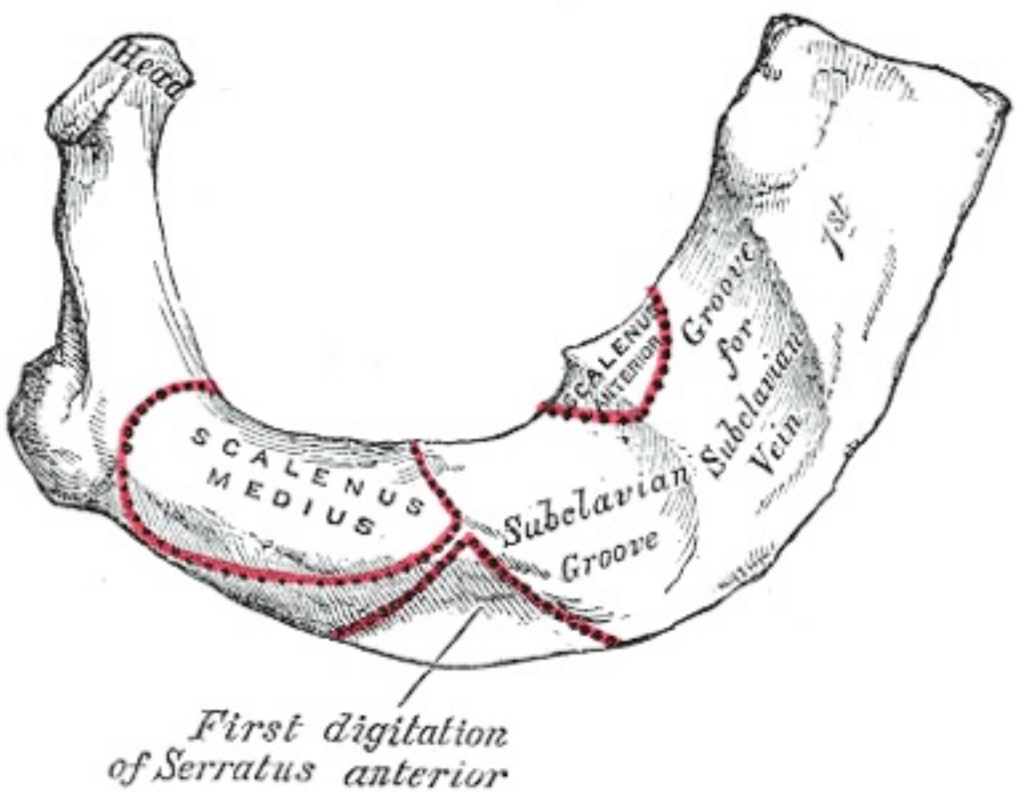
All ribs are attached in the back to the thoracic vertebrae. The spaces between the ribs are known as intercostal spaces; they contain the intercostal muscles, nerves, and arteries.

At the posterior end of each rib is a swelling called the head. The head is separated from another swelling the tuberosity, by a short neck. Some of the heads will show two facets for articulating with the demi-facets on the bodies of the thoracic vertebrae. The lower and larger facet articulates with the body of the corresponding vertebra, its crests attaching to the intervertebral disc above it. The tuberosity has a facet for articulating with the facet at the end of the transverse process on the vertebrae.



The human rib consists of 6 parts: The head, as indicated above, is at the posterior end of the rib, which means it is closest to the vertebral column; the costovertebral joints are the articulations that connect the heads of the ribs to the thoracic vertebrae; the neck is the flattened portion which extends lateralward from the head; the tubercle is an eminence on the posterior surface; the angle is the bending part and the costal groove is a groove between the ridge of the internal surface of the rib and the inferior border.

There are four pairs of atypical ribs: The first rib is a wide shaft that is nearly horizontal and has the sharpest curve of the seven true ribs. Its head has a single facet to articulate with the first thoracic vertebra. It also has two grooves for the subclavian vessels(artery and vein); the second rib is thinner, less curved, and longer than the first rib. It has two facets to articulate with T2 and T1, and a tubercle for muscles to attach to; the 11th and 12th ribs have only one facet on their



head; they are short with no necks or tubercles. Their pointed anterior ends terminate with cartilage in the abdominal wall. The 12th rib serves for the attachment of numerous muscles and ligaments. The anterior surface serves for the attachment of the internal intercostal muscle, costotransverse ligament, diaphragm, pleural reflection and the quadratus lumborium. The posterior surface serves for the attachment of the latissimus dorsi, external oblique, serratus posterior inferior, external intercostal muscle levator costae and erector spinae.

Variations in the number of ribs do occur. About 1 in 200 people have an additional cervical rib with a female predominance. Intrathoracic supernumerary ribs are extremely rare.

Distinguishing the right ribs from the left can be accomplished by noting a number of anatomic features. The first rib is broad and flat, which distinguishes it from the other ribs. The superior surface has two grooves, one carries the subclavian artery and the other, the subclavian vein. With the head to rear, and the top surface readily identifiable, the right and left 1^{st} ribs are easily determined.

The remaining ribs are also easily identified. Hold the rib with the head to the rear; remembering the ribs curve outward and downward. You will also note the superior border is rounded, while the inferior border is sharp.

The Bones of the Upper Limb, Scapula, and Clavicle

Scapula

The scapula is part of the upper limb bones rather than the torso. Its connection with the trunk is indirect. This connection is through the acromion process, which articulates with the lateral end of the clavicle, the medial end of which articulates with the sternum. Laterally it connects with the humerus (arm bone).

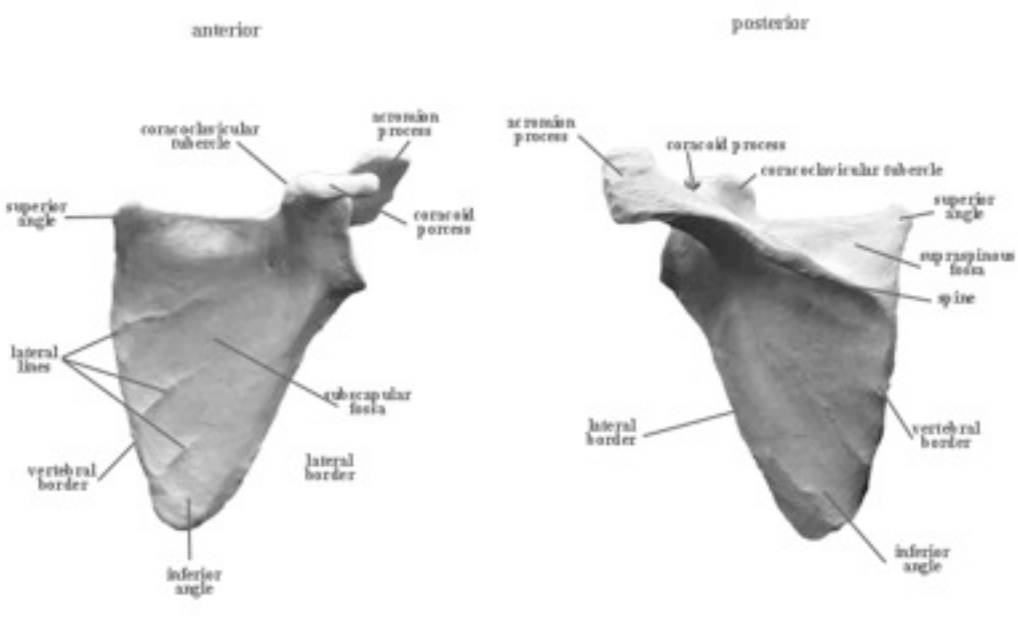
It is a large, flat triangular bone, which lies on the posterolateral aspect of the chest wall, covering parts of the second to seventh ribs. At the top of the posterior surface of the scapula is a shelf-like bone called the spine. The spine increases in mass as it goes from medial to lateral. At is most lateral point is the acromion process. The spine divides the posterior surface into two unequal parts; the portion above the spine is called the supraspinous fossa, which serves for the attachment of the supraspinatus muscle, and that below the infraspinous fossa, which serves for the attachment of the infraspinatus muscle. The upper part of the fossa contains a transverse depression, where the bone appears to be bent on itself along a line that is at right angles to and passing through the center of the glenoid cavity, which articulates with the humerus, forming an angle, called the subscapular angle. Due to the arch formation of the subscapular angle it gives added strength to the body, while the summit of the arch supports the spine and acromian.

The head of the scapula contains the slightly concave, shallow glenoid fossa for articulation with the head of the humerus. Extending upward and forward from the fossa is the coracoid process. Functionally the coracoid and acromion form a protective arch over the head of the humerus preventing upward dislocation.

The anterior surface has a broad concavity called the subscapular fossa, which serves for the attachment of the subscapularis.

Due to the triangular shape of the scapula it forms three angles. The apex at the base is termed, the inferior angle, the upper medial corner the medial or interior angle, the lateral angle is just under the glenoid fossa.

The scapula has three borders: the superior border is the shortest and thinnest; it is concave, extending from the medial angle to the base of the coracoid process, you



Sawchuk and Padiak (c) 2003 **the scapula** will note a notch in the superior border, which is generally deeper in males than females; the axillary border (lateral) is the thickest of the three. It begins above the lower margin of the glenoid cavity, and inclines obliquely downward and backward to the inferior angle; the vertebral border (medial) is the longest of the three, and extends from the medial to the inferior angle.

The Clavicle

Although the clavicle is a short bone, it is actually classified as a long bone that is horizontally positioned toward the top of the shoulder/root of the neck, located directly above the first rib. Even though it is classified as a long bone, the clavicle has no medullary (bone marrow) cavity, like the other long bones. It is composed of spongy (cancellous) bone with a shell of compact bone. In actuality it is a dermal bone derived from elements originally attached to the skull.

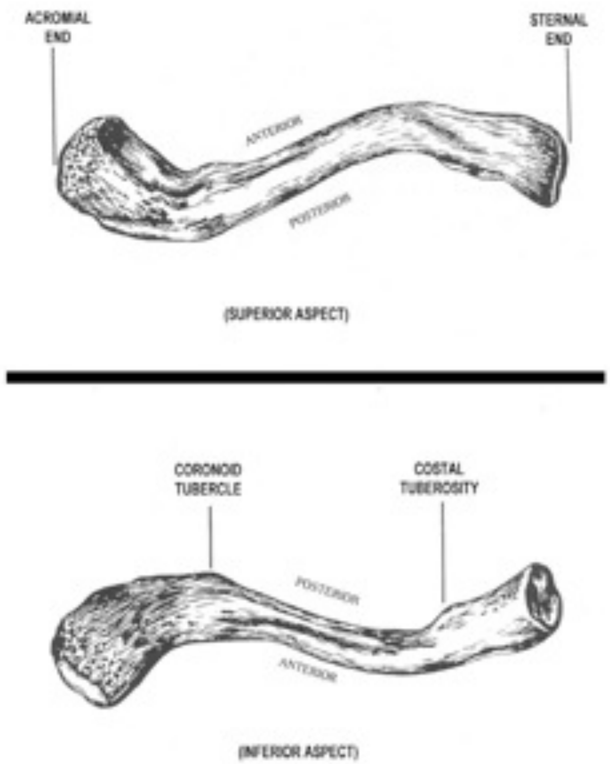
Dermal bone is a bone derived from intramembranous ossification; other examples of bone derived from intramembranous ossification are the bones of the calvarium and jaw.

The clavicle makes up part of the shoulder girdle. The name "clavicle," which means "Little Key" comes from the fact that when the shoulder is abducted, the clavicle rotates along its axis, just as a key rotates along its axis when turned. Medially it articulates with the clavicular notch of the manubrium sterni and the first costal cartilage (first rib). The lateral end is referred to as the acromial end, which articulates with the medial side of the acromian at the acromioclavicular joint.

The clavicle forms a slight S-curve, with its medial end being rounded and its lateral end being flattened.

The female clavicle is shorter, thinner, less curved and smoother, and its acromial end is carried lower than the sternal end in comparison with the male. In males the acromial end is on level with, or slightly higher than, the sternal end when the arm is hanging down. Midshaft circumference is the most reliable single indication of sex, although a combination of this measurement with weight and length yields a better result. In those who do manual labor, the clavicle is thicker, and its ridges for muscular attachment are prominent.

The clavicle has three fundamental functions: It serves as a rigid support from which the scapula and the upper extremity are suspended. This allows for the upper



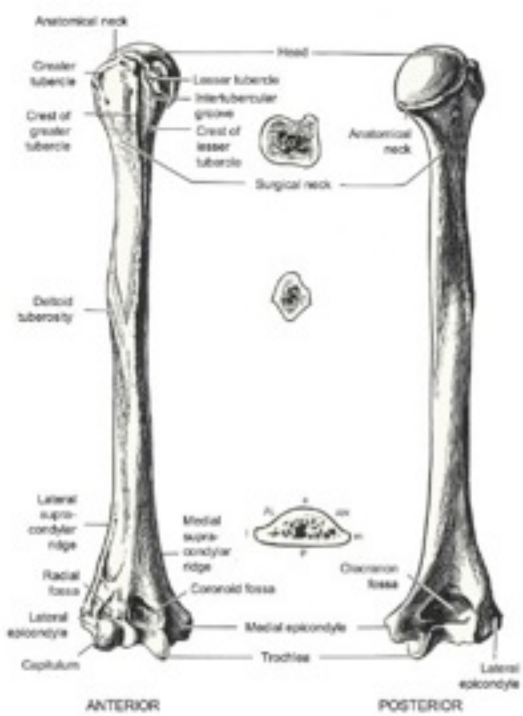
extremity to stay clear of the lateral wall of the thorax giving the upper extremity a maximum range of motion; it covers the cervicoaxillary canal (passageway between the neck and arm), through which several important structures pass; it transmits physical impacts from the upper limb to the axial skeleton.

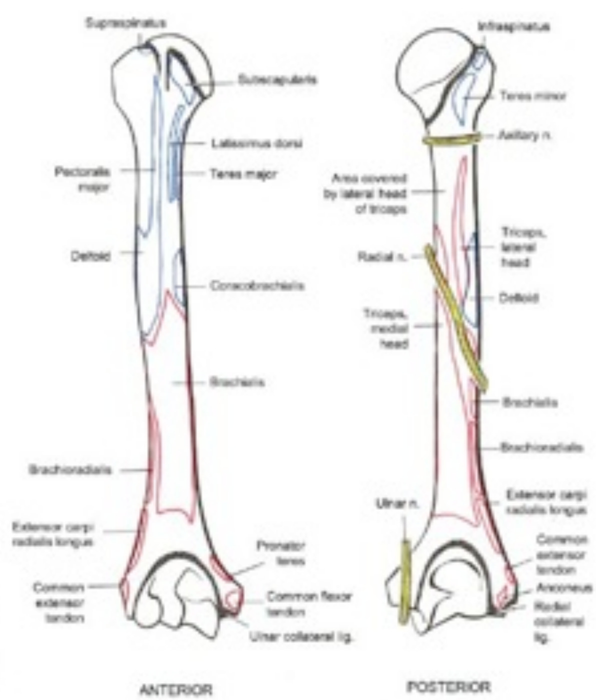
There are some interesting points to remember concerning the clavicle. It is the first bone to begin the process of ossification, which is the deposition of minerals onto a preformed matrix during the development of the embryo, during the 5th and 6th weeks of gestation. It is also one of the last bones to finish ossification, doing so around 21 to 25 years of age. The clavicle can also be useful for aging young adults

based on epiphyseal union of the medial and lateral ends. Although it is said that the clavicle forms by intramembranous ossification, it is not exclusive.
It is relatively simple to tell the right from the left clavicles. The medial end articulates with the sternum and first rib and is shaped somewhat like the head of a club. The lateral end is flattened, superiorly inferiorly, and articulates with the acromian process of the scapula. Note that where the clavicle passes over the coracoid process of the scapula there is a roughened area, which is called a tubercle, on its inferior surface. This coracoid tubercle (which is its name) is also posteriorly placed on the inferior surface. Hold the clavicle so that the coracoid tubercle is down and to the rear. Now place it in your body, remembering that the lateral aspect points away from the body.

The Humerus

The humerus is the longest and largest bone in the upper limb and is typical for a long bone in that it has an expanded proximal and distal end as compared to the shaft.





The rounded head occupies the proximal and medial part of the upper end of the bone and is the humerus's most conspicuous feature. It articulates with the glenoid fossa of the scapula as a ball-and-socket joint, but unlike that of the femur and acetabulum, a very free joint permitting extremely free movment of the arm and shoulder, consequently it is easily dislocated.

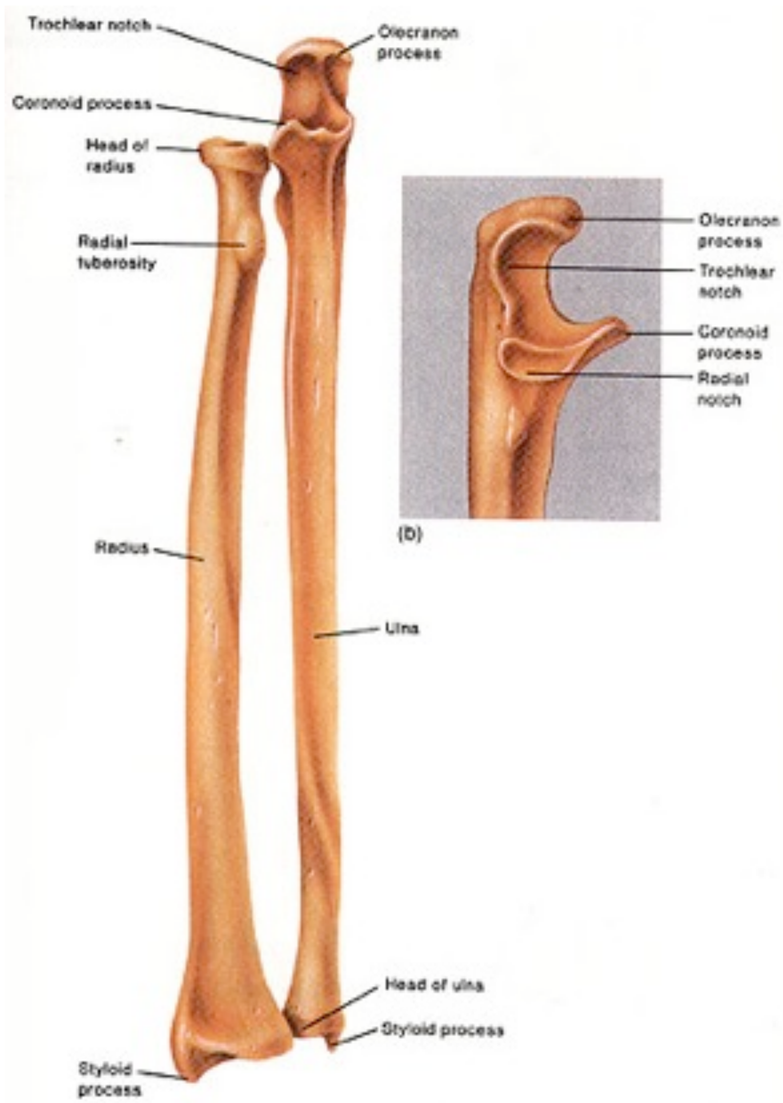
More laterally on the proximal end are the lesser tuberosity, facing forward, and the greater tuberosity on the lateral side. These two tuberosities are located on the anterior aspect of the humerus. The lesser tuberosity serves for the attachment of the subscapularis and the greater for attachments of the supraspinatus (upper most), infraspinatus (middle) and teres minor (lowest, located on the posterior surface). There is a deep groove between the two called the bicipital groove (intertubercular sulcus), which contains the long tendon of the biceps.

Approximately halfway down the shaft is a raised rugosity called the deltoid tuberosity, which is for the insertion of the deltoid muscle.

The distal end of the humerus has two important joint surfaces, the condyles, which are actually continuous. The medial part of the combined surface is the trochlea, or medial condyle, with which the ulna articulates. The ulna moves on the trochlea in a hinged fashion. The lateral condyle, or capitulum, facilitates rotation of the radius regardless of how much or little the elbow is bent. There are two fossae just above the condyles. The coronoid fossa on the anterior aspect accepts the coronoid process of the ulna, and the radial fossa the proximal end of the radius. The posterior aspect of the condyles of the humerus shows a deep fossa, the olecranon fossa, which accommodates the olecranon process of the proximal end of the ulna. On occasion you may see holes in the fossa, which can be due to hyperextension of the elbow. These holes are more often seen in females. Both condyles will have epicondyles, the medial being the larger. This feature should help you in orienting the humerus as to right or left.

The lower anterior surface of the medial epicondyle serves as an attachment for the flexor muscles. The ulna nerve passes across the posterior surface of the medial epicondyle. The lateral and anterior surfaces of the lateral epicondyle serve as a point for attachment of the superficial extensor muscles of the forearm. A small area on its posterior surface gives origin to the anconeus muscle, which is believed to be a continuation of the triceps brachii muscle. This muscle assist in extension of the elbow, it also prevents the elbow joint being pinched in the olecranon fossa during extension of the elbow.

The Ulna and Radius



The ulna is medial to the radius in the supinated forearm. At its proximal end it is shaped like a hook with the concavity of the hook directed forward. On the lateral surface is a sharp interosseous crest, which serves for the attachment of the interosseous membrane. The interosseious membrane serves as a source of muscle attachment. The bone diminishes progressively in mass as it proceeds distally. At its distal end it expands into a small rounded head and styloid process. Note the articulating surface of the lateral aspect of the head of the ulna. This surface permits the proximal end of the radius to rotate. The ulna in actuality takes no direct part in the wrist joint.

The radius is the lateral bone of the forearm. It has expanded proximal and distal ends. The proximal end consists of the head, neck and tuberosity. The tuberosity is located about an inch down and is a raised oval, referred to as the biceps tuberosity, which serves as the point of attachment of the biceps muscle. This tuberosity is on the anterior surface of the radius and is slightly medial. Along its medial border is a sharp crest, which serves as the attachment for the interosseous membrane. Distally the radius is more massive than the ulna, ending in a large concave articular surface, which articulates with the proximal row of carpal (wrist) bones. Its most distal projection is the styloid process.

The Hand

The hand consists of the carpus, metacarpus and the phalanges. There are a total of eight small carpal bones arranged in two parallel rows, which form the wrist, four in the proximal and four in the distal. Looking at the wrist from the palmar surface and proceeding from the radial (lateral) side to the ulna (medial) side is the proximal row, which is composed of the scaphoid, lunate, triquetrum and pisiform. Proceeding in the same fashion, the distal row is composed of the trapezium, trapezoid, capitate and hamate. The scaphoid, lunate and triquetrum form an arch, with the proximal surface being convex, articulating with the radius and the articular disc of the distal radio-ulnar joint. The concavity of the arch articulates with the capitate and hamate. The pisiform articulates with the palmar surface of the triquetrum and not with the distal end of the radius.

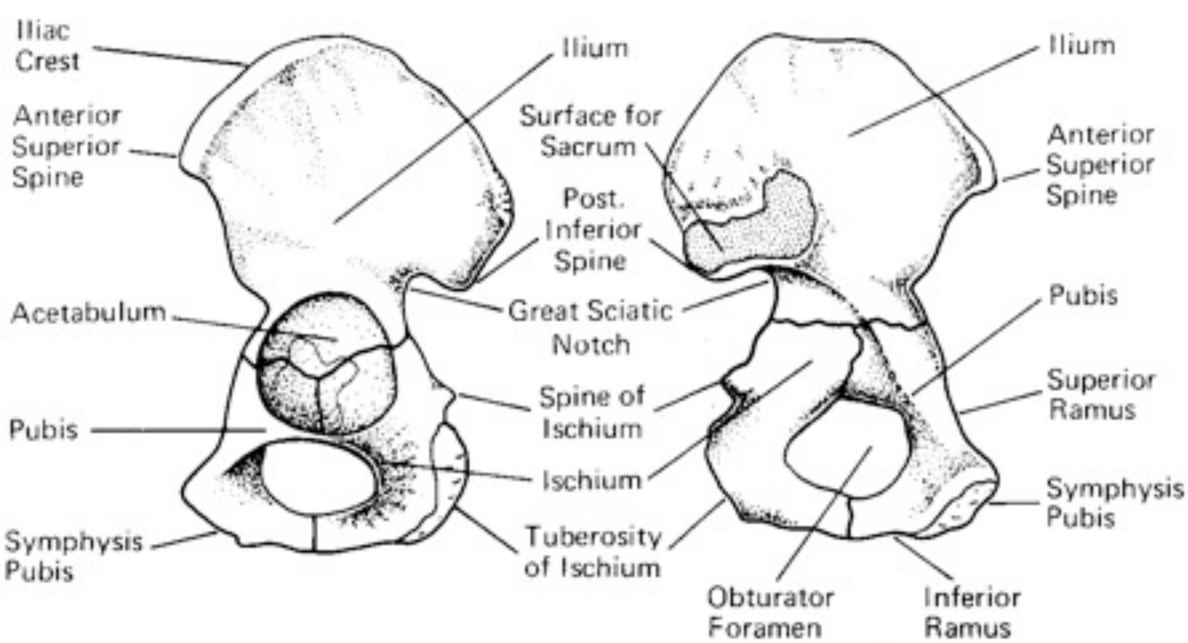
Looking at the palmer (anterior) surface of the wrist you will note the tendons of the muscles, which lie in the forearm and are responsible for flexion of the fingers. The extensor tendons lie on the back of the wrist. The majority of the movements of the hand with the exception for opposition of the thumb are brought about by muscles, which lie in the forearm, some originating as high as the epicondyles of the humerus. There are five metacarpal bones, which are miniature long bones in that they consist of a distal head, shaft and expanded bone. The rounded head articulates with the proximal phalanges. The metacarpal heads produces the knuckles. The metacarpal bases articulate with the distal carpal row and with each other, except the 1st and second. The metacarpals increase in thickness from V to I (little finger to thumb). The length of the metacarpals increases from V to II, with I (the thumb) being the shortest. In contrasts to the metatarsals of the foot, the posterior surface of the metacarpals are broad in diameter, those of the metatarsals are narrower (but for that of the big toe, I)

There are 14 phalanges, three in each finger and two in the thumb. Each has a head, shaft and proximal base. The shaft tapers distally, its dorsal surface being transversely convex. The palmar surface is transversely flat, but gently concave anteriorly in its long axis. The bases of the proximal phalanges carry concave, oval facets, adapted to the metacarpal heads. The bases of the middle phalanges have two concave facets separated by a smooth ridge, conforming to the heads of the proximal phalanges. The bases of the distal phalanges are adapted to the heads of the middle phalanges. The heads of the distal phalanges are non-articular and have a rough, crescentric palmar tuberosity to which the pulps of the fingertips are attached. In contrast to the phalanges of the foot those of the hand are flat on the palmar surface, and rounded on the posterior (dorsal) surface.

Bones of the Lower Limb, Innominate, and Patella

The innominate (hip bone) is a large, flattened, irregularly shaped bone constricted in the center and expanded above and below. In actuality there are two hipbones, right and left with each composed of three separate bones, the ilium, ischium and pubic bone. The hipbones are connected to each other anteriorly at the pubic symphysis, and posteriorly to the sacrum at the sacroiliac joints to form the pelvic ring. The pelvic ring is a basin-shaped ring of bones, which connect the vertebral column to the femurs.

The lateral surface of the innominate has a deep, cup-shaped acetabulum, which articulates with the femoral head. Anterior and inferior to the acetabulum is a large, oval to triangular space formed by the ischium and pubis called the obturator



The left innominate bone. External (*left*) and internal surfaces.

foramen. Above the acetabulium is the ilium, which widens as it goes superior, forming a broad plate with the configuration of a wing, which superiorly terminates in a curveal crest.

These three bones all meet in the acetabulum forming roughly a Y shaped line. The largest of these three bones is the ilium, which is superior to the acetabulum. The next largest is the ischium, which is posteriorly placed. The last is the pubis, which is anteriorly placed and articulates with its identical twin at the symphysis. Up until late childhood these bones are joined together by cartilage, fusing in adults.

The primary function of the bones of the pelvis is to support the weight of the upper body when sitting or standing. It is also designed to transfer the weight from the axial skeleton to the lower appendicular skeleton when standing or walking. Lastly, it provides for the attachment of muscles involved in movement and posture.

The bones of the pelvis also serve to protect the pelvic and abdominopelvic viscera, the urinary bladder and internal reproductive organs as well as providing for the attachment for the external reproductive organs and associated muscles.

The term pelvis refers to the above-discussed bony pelvis, the sacrum and coccyx, the latter two of which have already been discussed. Anatomically, the pelvis is that part of the trunk, which is inferior posterior (below and behind) to the abdomen and serves as the transition area between the trunk and the lower limbs.

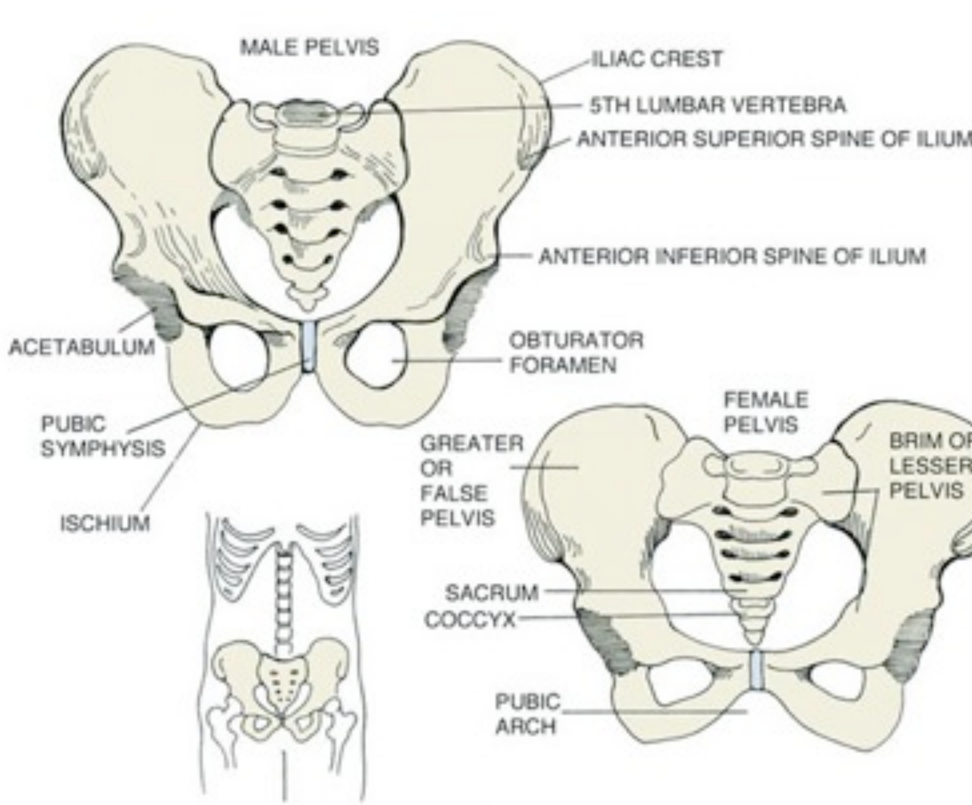
You will also see reference made to the term "pelvic cavity." The pelvic cavity is the space enclosed by the bony pelvis, which is subdivided into the "false" and "true" pelvis. The "false" pelvis consists of the inferior part of the abdominal cavity. It is separated from the "true" pelvis by the ileo-pectineal line. The ileo-pectineal line comprises a line extending from the anterior border of the first sacral segment, across the internal surface of the ilium (where it is known as the arcuate line), immediately inferior to the iliac fossa and iliacus muscle, and then on to a ridge on the superior ramus of the pubic bone where it is referred to as the pectineal line. That which is above this line forms a very incomplete floor to the abdominal cavity. The line itself constitutes the entrance to the "true" pelvis. The "true" pelvis is bordered between the sub pubic angle or pubic arch, the Ischia tuberosities and the coccyx.

The principle differences between the male and female true and false pelvis are as follows:

1. The female pelvis is larger and broader than the male pelvis, which is taller, narrower, and more compact.
2. The female inlet is larger and oval in shape, while the male sacral promontory projects further (i.e. the male inlet is more heart-shaped).
3. The sides of the male pelvis converge from the inlet to the outlet, whereas the sides of the female pelvis are wider apart.
4. The angle between the inferior pubic rami is acute (70°) in the male, but wide (90 – 100°) in the female. Thus, the angle is called the subpubic angle in men and pubic arch in women. Also, the bones forming the angle/arch are more concave in females but straight in males.
5. The distance between the Ischial bones is small in males, making the outlet narrow, but large in females, who have a relatively large outlet. The ischial spines and tuberosities are heavier and project farther into the pelvic cavity in males. The greater sciatic notch is wider in females.
6. The iliac crests are higher and more pronounced in males, making the male false pelvis deeper and narrower than in females.
7. The male sacrum is long, narrow, straighter, and has a pronounced sacral promontory. The female sacrum is shorter, wider; more curved posteriorly, and has a less pronounced promontory.
8. The acetabula are wider apart in females than in males. In males, the acetabulum faces more laterally, while it faces more anteriorly in females. What this means pragmatically is that when men walk the leg can move forwards and backwards in a single plane. In women, the leg must swing forward and inward, from where the pivoting head of the femur moves the leg back in another plane. This change in the angle of the femoral head gives the female gait characteristic swinging of the hips.

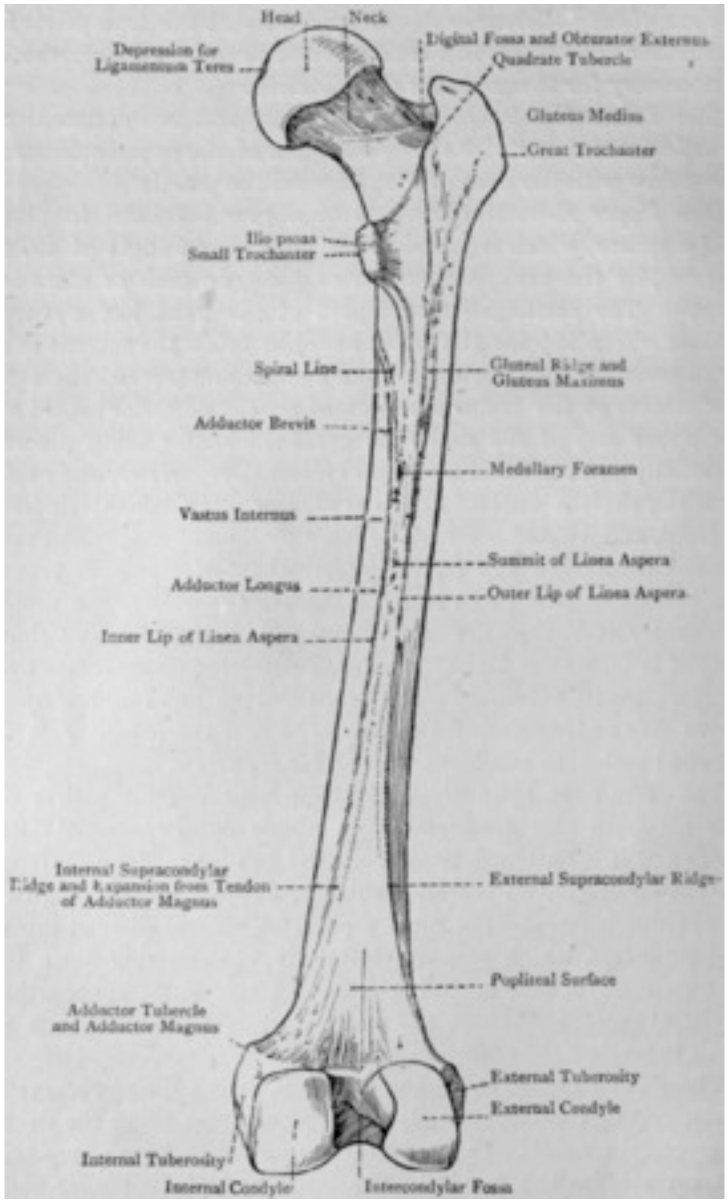
There are a few anatomic landmarks, which need to be noted. These landmarks are helpful in distinguishing the front of the pelvic bones from the rear. Examination of the ilium posteriorly shows the auricular surface for articulation with the sacrum.

Just below is a deep incurve, the greater sciatic notch. Continuing along on the posterior rim of the innominate you will note the ischial spine, which overlook another, more gentle incurve, the lesser sciatic notch. Continuing on the posterior border you then come to the massive ischial tuberosity. The ischial tuberosity carries you to the inferior border of the innominate. The lower border is composed of the rami of the ischium and the pubis. The rami of the ischium and pubis meet and fuse midway. Above this fusion point is a large space called the obturator foramen, most of which is closed by a membrane. The obturator foramen is large and oval in males, but smaller and nearly triangular in females. Continuing medially we are now at the pubic symphysis. We continue across the pubic symphysis to the superior pubic ramus and then onto the opposite ilium.



The Femur

The femur is the longest and strongest bone in the body. Its length is associated with a striding gait, its strength with the weight and muscular forces it is required to withstand. The head faces anterosuperomedially and has an articular surface that is



slightly more than half of a sphere and fits deeply into the acetabulum, which permits for transfer of weight from bone to bone without undue strain on the ligaments. Beneath the femoral head is the femoral neck, which connects the head to the femoral shaft at an angle of approximately 135°. This angle helps facilitate movement at the hip joint, enabling the limb to swing clear. The neck is also laterally rotated with respect to the shaft (angle of anteversion) some 10 to 15°. Not only does the angle at which the shaft and neck meet vary, but so too does the angle which the neck of the femur forms with the horizontal. This is the angle of torsion, which shows some racial differences. The neck-shaft angle is widest at birth and diminishes gradually until adolescence; it is smaller in females.

The femoral neck is approximately 5 cm long, narrowest in its mid-part and widest laterally. The neck also provides a lever for the action of the muscles acting about the hip joint.

At the junction of the neck with the shaft, posterosuperior region is a large, quadrangular projection, which projects superomedially, referred to as the greater trochanter. A little lower down and somewhat medial is another projection called the lesser trochanter. Also, at the point or juncture of the anterior surfaces of the neck with the shaft is a prominent ridge, called the intertrochanteric line. This line extends from a tubercle on the upper part of the anterior aspect of the greater trochanter to a point on the lower border of the neck, anterior to the lesser trochanter. This line is the lateral limit of the hip joint capsule anteriorly. At the junction of the posterior surface of the neck with the shaft is a smooth and prominent ridge called the intertrochanteric crest. It extends from the posterosuperior angle of the greater trochanter to the lesser trochanter.

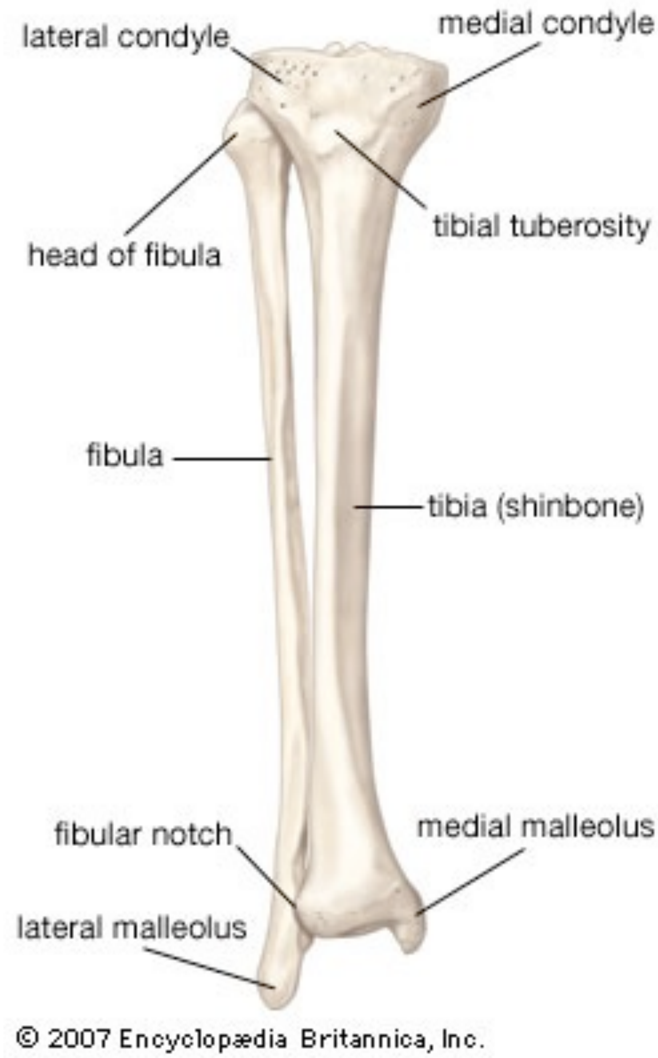
The shaft of the femur has a smooth anterior curvature and posteriorly, a ridge, the linea aspera. The linea aspera gives attachments to the adductor longus, intermuscular septa and the short head of the biceps femoris.

The distal end of the femur has a single rather complex joint surface. From behind and below, the surface appears as two condyles separated by a deep intercondyler fossa. It is these condyles, which glide on the superior surfaces of the tibia as the knee is flexed. From the front you can see the centrally placed patellar surface for articulation with the patella.

You will also note that the two condyles appear to diverge; one is almost in line with the shaft and the other angles away. If you remember that the divergent condyle is always medial, then you will always be able to tell the right from the left femur. Another interesting point to remember is for the paired bones of the body, any diverging masses of bone do so medially.

The Tibia

The tibia lies medial to the fibula and is the next longest bone in the body after the femur. Its shaft is triangular with expanded ends; a strong medial malleolus projects distally from the smaller distal end. The anterior border of the shaft is sharp and



curves medially towards the medial malleolus. Together with the medial and lateral borders it defines the three surfaces of the bone. The exact shape and orientation of these surfaces show individual and racial variations.

The proximal end has medial and lateral condyles, which articulates with the two condyles of the femur. In addition to the condyles, the proximal end also has an intercondylar area and the tibial tuberosity. The tibial tuberosity is located on the tibia's anterior surface, distal to the medial condyle. It is identified as a bony prominence just below the patella. It serves as an attachment point for the patellar ligament.

On the underside of the lateral condyle you will find a flat almost round articulating surface, which articulates with the head of the fibula. The fibula is located lateral to the tibia. The angle of inclination of the superior tibia-fibular joint varies between individuals, and may be horizontal or oblique.

On the lateral aspect of the proximal end of the tibia, just below the knee joint, is Gerdy's tubercle, which is the insertion point for the iliotibial band. The iliotibial band runs down the outside part of the thigh. The peroneal nerve also runs close to Gerdy's tubercle.

The other tubercles of the tibia include the medial and lateral intercondylar tubercles. These tubercles constitute protrusions on the medial and lateral condyles respectively.

The shaft of the tibia has three (crests) borders, which have been previously noted. The anterior crest is the most prominent, beginning above the tuberosity and ending below at the anterior margin of the medial malleolus. It is prominent in the superior two-thirds, but smooth and rounded in its inferior third, serving as a site of attachment of the deep fascia of the leg. The medial crest begins on the posterior aspect of the medial condyle and ends at the posterior border of the medial malleolus. Its superior portion serves for the attachment of the tibial collateral ligament of the knee-joint and insertion to some fibers of the popliteus muscle; from its middle third some fibers of the soleus and flexordigitorum longus take origin. The interosseous crest is thin and prominent commencing above in front of the fibular articular facet, and bifurcates below, to form the boundaries of a triangular region, which serves for the attachment of the interosseous ligament connecting the tibia and fibula.

The distal end of the tibia, when compared to the proximal end, is laterally rotated, which is referred to as tibial torsion. This torsion begins to develop in utero and progresses throughout childhood and adolescence till skeletal maturity is attained. Tibial torsion is approximately 30° in whites and Asian population, but is significantly greater in people of African origin. Some of the femoral neck anteversion seen in the newborn may persist in adult females: this causes the femoral shaft and knee to be internally rotated giving rise to the tibia developing a compensatory external rotation to counteract the tendency of the feet to turn inwards.

On the medial side of the distal end is a downward projection called the medial malleolus. The inferior surface of the tibia is a concave articular surface, which articulates with the talus.

The Fibula

The fibula is the slenderest long bone of the body; it is not a weight bearing bone, as is the tibia. At a point in time it was a large bone of the same size as the tibia, as in the amphibians. However, it has become progressively smaller as the evolutionary process proceeded on to the reptiles and the mammals. It is composed of a proximal head, a narrow neck, a long shaft and a distal lateral malleolus.

The head has a facet, which faces medially, forming an articulation with the tibia, and a styloid process, which projects lateral to the facet. To determine whether you are dealing with the left or right fibula simply hold the bone so the facet faces medially and towards you, the styloid process will be on the side it is in the body.

The distal end is very distinctive. The entire distal end is the lateral malleolus, which is the other hinge of the ankle joint (opposite to the hinge formed by the medial malleolus). The lateral malleolus sits more in line with the shaft of the bone. You will see a smooth articulating surface that takes up from one-half to two-thirds of the medial surface of the distal end. The posterior surface has a broad groove with a prominent lateral border. The medial surface has a triangular articular facet, which articulates with the lateral talar surface. Behind this facet is the malleolar fossa in which the posterior tibio-fibular ligament and the posterior talofibular ligament are attached.

To orient the bone, after determining the proximal from the distal end, hold the bone so that the articulating surface is to the front with the groove behind.

The Patella

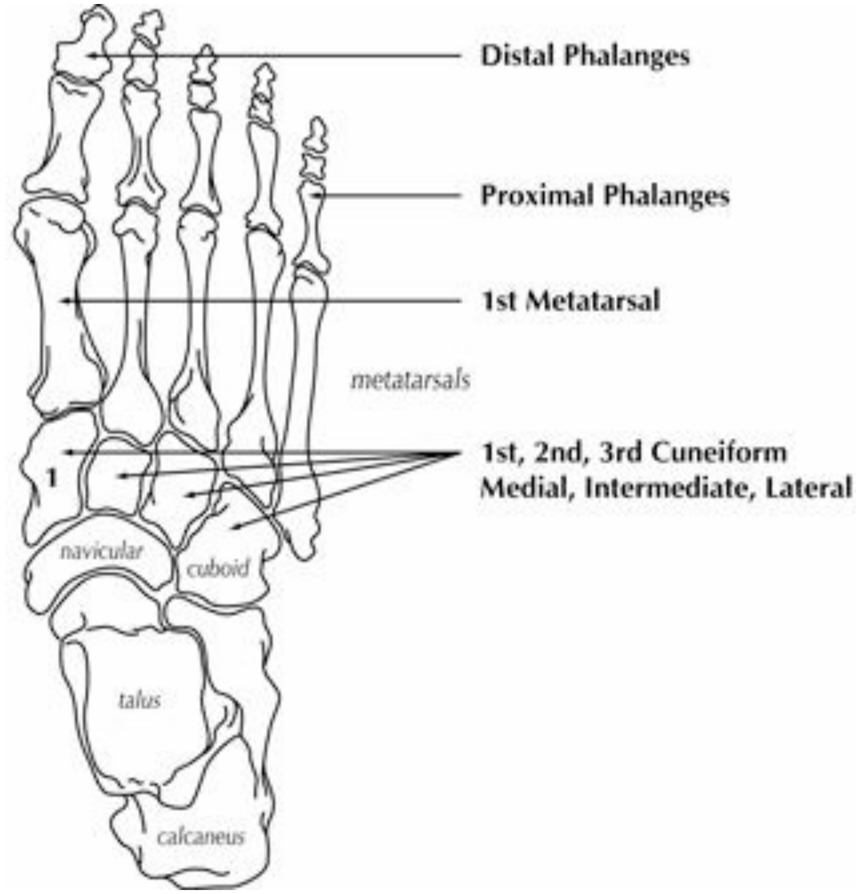
The patella is the largest sesamoid bone and is embedded in the tendon of the quadriceps femoris, anterior to the distal femur (femoral condyles). It is flat, distally tapered, proximally curved, and has an anterior (image on the left) and posterior surface (image on the right), three borders and an apex, which is the distal end of the bone.

A sesamoid bone is a bone embedded in a tendon. Sesamoid bones are found in locations where a tendon passes over a joint, such as the hand, knee or foot. Functionally, they act to protect the tendon and to increase its mechanical effect. The presence of the sesamoid bone holds the tendon slightly farther away from the center of the joint and thus increases its moment arm (torque). Sesamoid bones also prevent the tendon from flattening into the joint as tension increases and therefore also maintain a more consistent moment arm through a variety of possible tendon loads. This differs from menisci, which are made of cartilage and rather act to disperse the weight of the body on joints and reduce friction during movement. Sesamod bones are found throughout the body in addition to the patella including: Two sesamoid bones in the distal portions of the first metacarpal bone. The pisiform of the wrist is also a sesamoid bone. In the foot, the first metatarsal bone has two sesamoid bones at its connection to the big toe.

As stated, the patella is triangular in shape with the apex pointing down. The anterior surface is marked by striations running longitudinally. The posterior surface is the one that articulates with the condyles of the tibia. A strongly marked ridge that is skewed to the medial side separates the two facets, medial and lateral. Thus, you have large lateral articulating facet and a smaller medial facet. To tell right from left, hold the patella in your hand, apex down, and posterior surface towards you. The larger articulating surface is lateral, hence the side it takes in the body.

The Foot

The foot is composed of seven tarsal bones, five metatarsal bones, fourteen phalanges and two sesamoid bones. The tarsal bones are much larger than the carpal, together with the metatarsals, form an anatomic structure, which although has limited flexibility, has great rigidity and resultant strength.



The tarsals form a hinge joint with the distal end of the tibia and fibula, with only the talus actually making contact. The tarsals occupy the proximal half of the foot. Although, the tarsals and carpals are homologous, the tarsals are larger, reflecting their role in supporting and distributing body weight. As is true with the carpal bones, the tarsal bones are arranged in proximal and distal rows, but medially there is an additional single intermediate tarsal element, the navicular, which is interposed between the two rows. The proximal row is made up of the talus and calcaneous, with the talus being medial to the calcaneous. The distal row contains, from medial to lateral, the medial, intermediate and lateral cuneiforms and the cuboid. Collectively these bones display an arched transverse alignment that is dorsally convex.

Looking at the sole of the foot there is a considerable concavity between the tuberosity of the calcaneous behind and the distal ends of the metatarsals in front. In life, this concavity is filled with muscles. Thus, if the above dorsal arch is weakened, this will cause the weight of the body to come to rest on the muscles within the concavity, giving rise to discomfort.

The articulation between the tarsal's and metatarsals is very firm. The metatarsals are bound together by strong ligaments.

The five metatarsals lie in the distal half of the foot and connect the tarsals and phalanges. Like the metacarpals, they are miniature long bones, and have a shaft, proximal base and distal head. Except for the first and fifth, the shafts are long and slender, longitudinally convex dorsally, and concave on their plantar aspects. There bases articulate with the distal tarsal row and with adjacent metatarsal bases. The heads articulate with the proximal phalanges, each by a convex surface that passes farther on to its plantar aspect, where it ends on the summits of two eminences.

On occasion, an os intermetatarseum is encountered between the medial cuneiform and the bases of the first and second metatarsal bones and represents a rare accessory bone in this region.

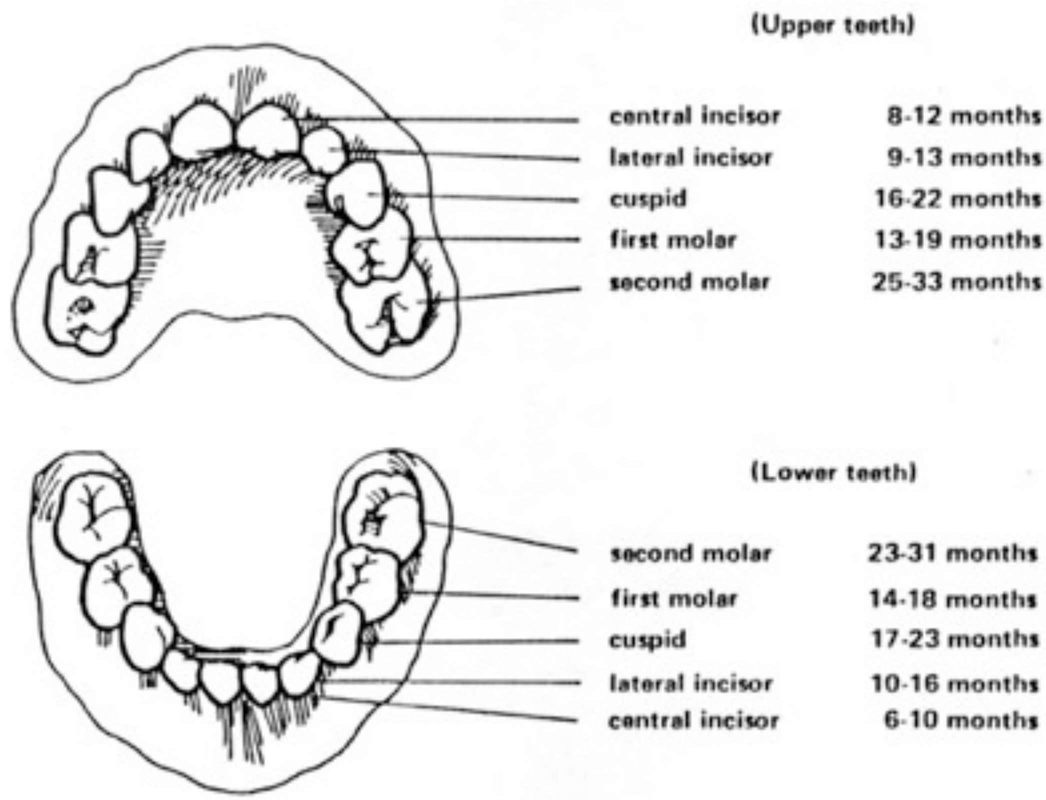
The first metatarsal or big toe has the shortest, thickest and most massive bone of the five. The metatarsals increase in length going from V to II.

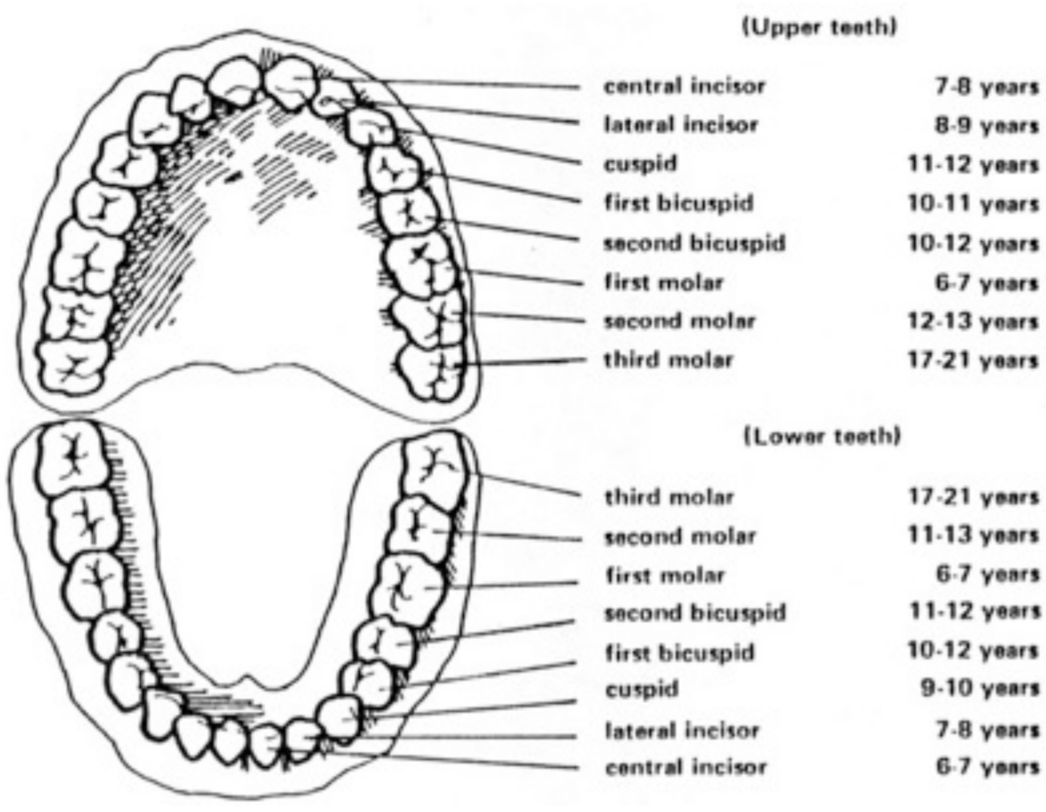
As in the hand, all but the big toe, have three phalanges, the big toe has two. On occasion there are only two phalanges in the little toe and, rarely, this is the case with the other lesser toes. The phalanges in the toes are shorter than those in the hand with their shafts, especially those of the proximal set, being compressed from side to side, thus on cross-section they have a rounded appearance in contrast to the phalanges of the fingers. The distal phalanges resemble those of the fingers, but are smaller and flatter. Each has a broad base for articulation with a middle phalanx and an expanded distal end. A rough tuberosity on the planter surface supports the pulp of the toe, and provides a weight-bearing area.

The Teeth

Tooth development/eruption is one of the most relied upon methods for age determination of juvenile skeletal remains.

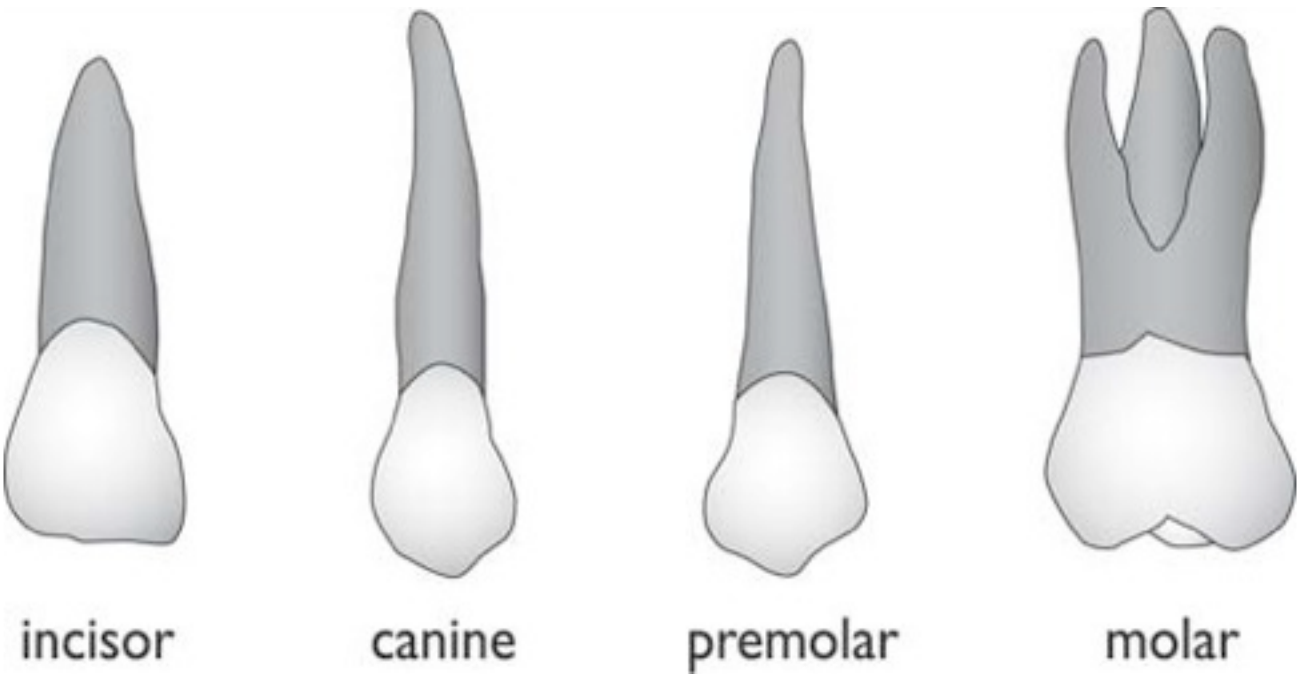
We have two generations of teeth: the deciduous (primary) dentition and the permanent (secondary) dentition. The first deciduous teeth erupt into the mouth at about 6 months after birth and all of the deciduous teeth are erupted by 3 years of age. The first permanent molar erupts at or around 6 years, and then the deciduous teeth are exfoliated one by one to be replaced by their permanent successors. A





complete permanent dentition is present when the third molars erupt at or around the age of 18 to 21 years. In the complete deciduous dentition there are 20 teeth, five in each jaw quadrant (two upper and two lower each with a right and left). In the complete permanent dentition there are 32 teeth, eight in each jaw quadrant. This assumes that there are 6 molars in the upper and lower jaws, however, in some there are only 4 molars and thus there would be 28 teeth.

There are three basic tooth forms in both deciduous and permanent dentition:



incisors, canines and premolars and molars (molariform). The incisors are cutting teeth and have thin, blade-like crowns. The canines are piercing or tearing teeth, and have a single, stout, pointed, cone-shaped crown. The premolars and molars are grinding teeth and posses a number of cusps on an otherwise flattened biting surface. Premolars are bicuspid teeth that are restricted to the permanent dentition and replace the deciduous molars.

As indicated above the teeth are divided into those in the upper jaw (maxillary) and those in the lower (mandibular). They are also further divided into four quadrants, right & left maxillary quadrants and right and left mandibular quadrants. The teeth in each quadrant are further specified as incisors (2), premolars (2) and molars (3). As to what incisor, premolar or molar we are referring to is based on its relationship to the midline. As an example, the incisor immediately adjacent to the midline is called the central incisor, and that which is lateral to the central incisor is called the lateral incisor. The tooth immediately posterolateral to the lateral incisor is the canine. The premolars and molars are also described based on their relationship to the midline. Thus, the first premolar is that which is closes to the midline and is also adjacent to the canine. The second premolar is immediately adjacent to the first premolar. Likewise, the molar, which is closes to the midline and adjacent to the second premolar is the first molar. The molar immediately behind this is the second molar and that which is behind the second is the third molar.

To simplify the examination process the dentition is represented by a numerical system, putting the upper 2 quadrants and lower 2 quadrants in two lines, as:

2:1:2:3
2:1:2:3

or more commonly as 2:1:2:3. This is the pattern of man and the higher apes and the Old World Monkeys. In the New World Monkeys it is: 2:1:3:3 due to the fact they have three premolars.

The above pattern for man is the adult one. The pattern for a baby set (deciduous) is 2:1:2. This is because there are no premolars and always two molars.

The Design and Function of the Teeth

The Incisors: These are generally chisel-shaped and designed for cutting. In some races, notably American Indians and Asians, the lateral margins are built up making them "shovel-shaped," especially the upper incisors. The upper incisors are in general wider than the lower.

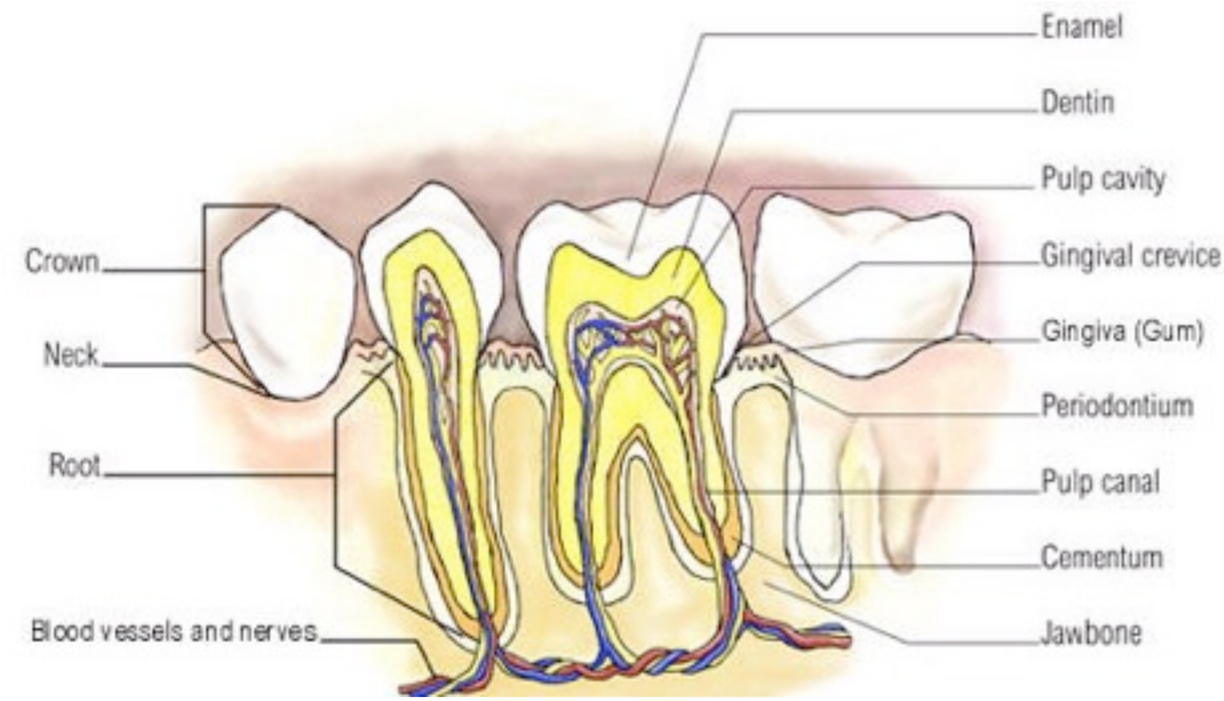
The Canines: These are shaped as a pointed cusp, designed for tearing. If the incisors are "shovel-shaped," the canines will also be "shovel-shaped." The roots of these teeth are typically long and tapering, being the longest of all the roots, however, this is not necessarily always the case.

The Premolars: These are often referred to as bicuspids due to the fact their crown has two cusps. As with the molars, these multiple cusps are designed for grinding of food material as an aid in digestion.

The Molars: These teeth have flattened cusps, which are used for grinding. The upper molars are generally smaller than the lower and generally have three or four cusps; if three, then two are on the buccal (cheek) side and on the lingual (tongue) side.

Anatomic Structure of Teeth

All human teeth display three well-defined structures:



1. The crown, the part of the tooth above the gum line.
2. The neck, a slightly constricted portion of the tooth below the crown.
3. The root, the rest of the tooth below the neck and enclosed in the tooth socket.

From an anthropological and paleontological (paleontology is the study of prehistoric life including organisms' evolution and interactions with each other and their environments) standpoint teeth are of enormous importance for they resist decay the longest due to their chemical composition.

The teeth are composed of:

1. Enamel, hard shinny material, which covers the crown composed of hydroxyapatite, which is a crystalline calcium phosphate.
2. Cementum, a layer of tough, yellowish, bone-like tissue that covers the root of a tooth. It helps hold the tooth in the socket.

3. Dentin, the intermediate tooth layer, which surrounds the pulp cavity and is immediately internal to the enamel. Structurally it is harder than bone.
4. Pulp cavity, this is the soft center of the tooth. It contains blood vessels and nerves.

The roots of the incisors and canines are single, rounded, and tapering, often curved at the ends. As previously noted the root of the canine is typically considerably longer and stouter than those of the incisors. This is a leftover from our evolutionary past when the canine was longer and needed to be.

The roots of the premolars are wider and tend to be grooved in a way, which suggest a tendency to be divided into a lingual and buccal root.

The roots of the molars are quite distinct as between upper and lower. The roots of the lower molars are double, having an anterior and posterior component, each generally grooved like the root of a premolar. The 3rd molar generally has a fused root, which is slightly curved. The roots of the upper molars are three: two on the buccal side and one on the labial side (side toward the lips). The roots of the 2nd molar are generally less spread than the 1st, and the 3rd molar often has a single, massive fused root. There are individual variations on that scheme; single loose molars can be difficult to identify.

Although I have made reference to some of the descriptive terms to describe the surfaces of the tooth I would like to delineate all of them:

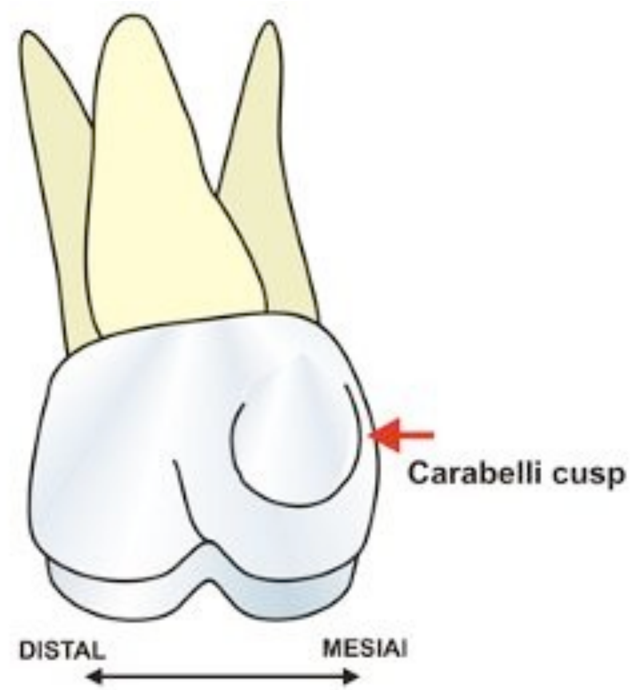
1. Buccal: side of the tooth towards the cheek. This is used with the premolars and molars.
2. Labial: side of the tooth toward the lips. This is used with the incisors and canines.
3. Lingual: side of the tooth toward the tongue.
4. Occlusal: biting surface of a tooth.
5. Mesial: surface of a tooth that lies against an adjoining tooth facing the medial line
6. Distal: surface of a tooth that lies against an adjoining tooth facing away from the midline or if you will, facing posterior.

The identification of loose, single teeth as to upper or lower, right or left side is best left to the anthropologist or dentist. A point that needs to be remembered is that multi rooted teeth are more likely to remain in the alveolar process of skeletonized remains where as single rooted teeth are prone to falling out postmortem as the periodontal ligaments decompose.

Variations in Tooth Morphology

Cusp patterns can vary, especially on the molars. Five cusps are generally seen on the lower (mandibular) molars.

Carabelli's cusp is a tubercle located on the anterior portion of the lingual surface of the upper (maxillary) molars. It is typically seen at the mesopalatal line angle of the maxillary first molars; it becomes progressively less likely on the second, and third molars. This cusp is entirely absent in some individuals and present in others in a



variety of forms. Georg Carabelli, the court dentist of the Austrian Emperor Franz, first described this cusp in 1842. Carabelli's cusp is more common among Europeans (75 to 85% of individuals), and rare among those of the Pacific Islands (35 to 40%). This cusp is also seen in dogs and cats.

A protostylid is an extra cusp that occurs on the anterior aspect of the buccal surface of the lower (mandibular) molars. Dahlberg first proposed this term in a series of publications in 1945, 1949, and 1950. Although it is not commonly seen in modern

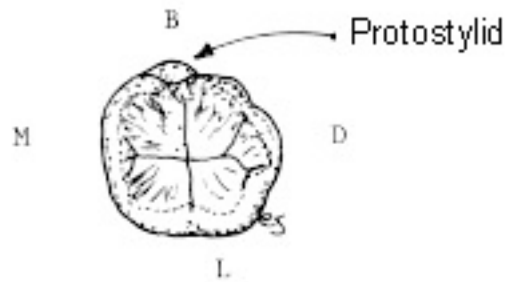


Figure five. Protostylid on the lower first permanent molar

populations, Dahlberg reported it to have a high frequency in Pima Indians. Suzuki and Sakai (1954) also found it to occur fairly frequently in the mandibular molars of the Japanese.

Taurodontism is a condition found in molars where the pulp cavity and body of the tooth are enlarged and the roots reduced to a single root. This was commonly seen in early man (Neanderthals) and is seen occasionally in modern populations, such as those with Klinefelter's syndrome (XXY syndrome, thus it is a condition in which males have an extra X sex chromosome). This condition can involve either a single molar or multiple molars.

Peg-shaped teeth are those teeth whose sides converge or taper together incisally. These occur most commonly at the 3rd molar and lateral incisor site, where congenital absence of these teeth is more common. Note in the picture below the right lateral incisor's peg-shaped appearance.

Abnormally shaped teeth occur as the result of a number of conditions some of which are: Congenital syphilis, Cerebral palsy, Ectodermal dysplasia, anhidrotic, Incontinentia pigmenti achromians, Cleidocranial dysostosis, Ehlers-Danlos syndrome and Ellis-van Creveid syndrome.
Extra roots, persistent deciduous teeth, supernumerary teeth, absent roots, also occur.