Human Osteology & Skeletal Radiology

An Atlas and Guide

Evan Matshes
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Illustrations by Carrie Allen

CRC PRESS

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To
Family, friends, teachers and the likes, whose influence, trust and support made this production possible.

To
Lisa Rudolph, Talina Cyr and Carrie Allen, whose tireless efforts in the production of this book will not be forgotten.

Preface

The study of bones, osteology, is a fundamental part of any serious voyage into the world of human anatomy. Our bony elements serve multiple complex purposes, including support, protection, a framework for movement, and the production of blood cells, just to name a few. Courses such as physiology or histology may adequately cover the function of bone cells (osteocytes) and their supporting cells. However, to properly relate to the macroscopic structures of the body, an understanding of osteologic morphology is key.

We believe that academic ventures into bony anatomy can be simple; hence, the production of this manual. We begin by exploring individual bones, or collections of bones, from a distant perspective – keeping the overall image of the bone(s) in mind. Higher power photographs then help draw out further detail. It is our hope that this process, coupled with the use of fewer terms, will make this atlas "user friendly."

No book can adequately substitute for long hours of study in the gross anatomy lab. Make zealous use of the human skeletal specimens made available to you by your center of higher learning. Be aware, however, that such material can be extremely difficult and expensive to obtain. Always treat your specimen with the utmost respect, not only because of its financial value, but because of the rare opportunity you are afforded by studying the remains of an individual who will remain eternally unknown to you.

Please enjoy this atlas and the studies to which it contributes. Human skeletal anatomy is a fascinating and integral part of our everyday lives.

This book was a major undertaking that spanned several years and involved many people (above and beyond those already recognized as contributors, editors and reviewers). I must recognize the significant influence several people have had in shaping my career in human anatomy, anatomical and forensic pathology. These include Drs. Emma Lew, Valerie Rao, Ranjit Waghray, Bernhard Juurlink, David Dolinak, Graeme Dowling and Bernard Bannach. I must also thank Dr. Joseph H. Davis, Retired Director of the Miami-Dade County Medical Examiner Department. Over the course of forty-plus years, Dr. Davis helped to shape modern death investigation not only in Miami-Dade County, but throughout North America and the world. His work and teachings have had a major influence on countless individuals, including myself. For this, I owe him a debt of gratitude.

This project could not have been possible without the thoughtful review and critique provided by Drs. Warren and Walsh-Haney, our contributing editors. Furthermore, the many reviewers at the Central Identification Laboratory, Hickam Air Force Base in Hawaii including Drs. Holland and Mann who must be thanked for reviewing and critiquing this book. The student body of the University of Saskatchewan Forensic Osteology Work Group must also be commended for their many hours of volunteer time reading and rereading later versions of the manuscript.

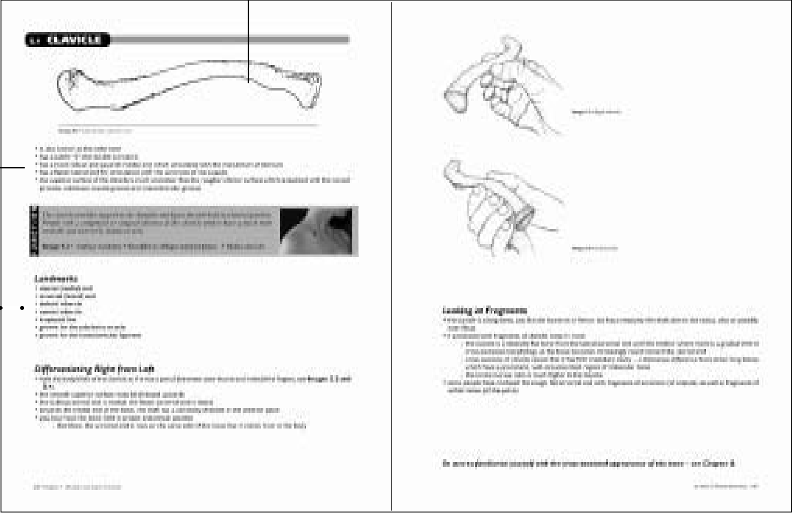
Finally, such a project would not be possible without the support of one's own department and administrators. For this, I must thank our department head Dr. Bernhard Juurlink for his ongoing participation in our osteology work.

Evan Matshes M.D.

How to use this book

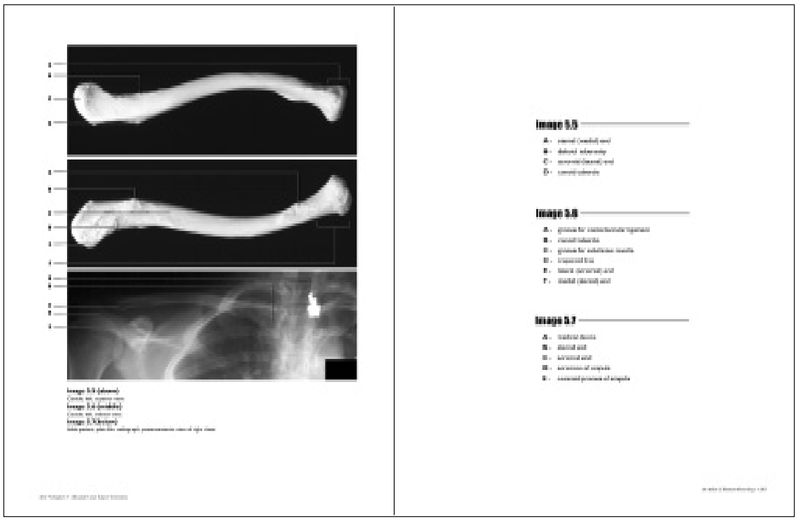
Our goal is to produce a clear and useable photographic atlas, and an accompanying laboratory manual that would be of use to students at all levels of study. As a result, we may provide more information on each bone than you need to know.

Students new to skeletal anatomy should use the initial graphic of each unit to *give them a sense* of what the bone looks like. This allows you to more easily grab the bone out of your teaching set.



Regardless of your focus or level of study, every student learning osteology needs to know basic facts about each bone. Therefore, the first paragraph should be studied.

The **landmarks** provided in this section are limited to the key anatomical features you <u>must know</u> before examinations. When studying, read this list and visualize where you expect to find the items – then confirm your thoughts with the atlas.



Students of the health sciences generally only need information on **whole bones**. As such, the sections regarding **'Differentiating Right from Left'** and **'Looking at Fragments'** can generally be ignored. These sections have been written with anthropology and forensically motivated students in mind.

If you are taking a human osteology course where side-to-side differentiation and fragment identification are requirements, keep in mind that we have only listed a few of the possible techniques to side bones, and only scraped the surface in the discussion of fragmentary osteology. Use our notes as a guide, and take the time to develop your own systems of identification.

Use the atlas photographs and radiologic images (plain film X-rays, CT scans, and MR images) to learn the fine detail of bony anatomy. When available, use natural bone skeletal teaching specimens while reading this book. This will help to confirm what you are reading.

We wish you the best of luck with your studies.

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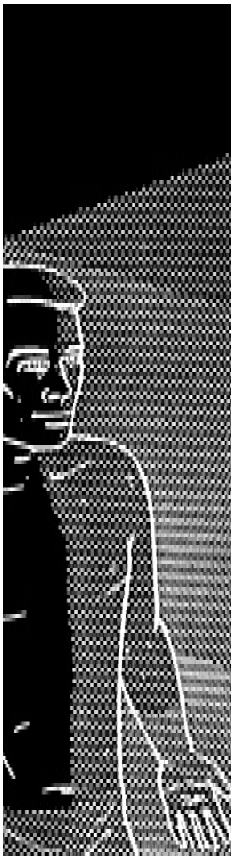
UNIT ONE – The Axial Skeleton

UNIT TWO – The Appendicular Skeleton

UNIT THREE – Wrapping It Up



Chapter One

Anatomical Terms of Direction & Osteologic Terminology

Can you imagine trying to follow directions to a new friend's house without understanding the words *right, left, up, down,* and so forth? One would quickly give up on such a fruitless endeavor. The same can be said of studying human anatomy and osteology without a command of the essential anatomical terminology.

Take the time to master this very abbreviated chapter. It would be terrible for one to become an expert at the human skeleton only to fail a lab exam because of an inability to understand the directions of the professor.

Anatomical Terms of Direction

Students may be frightened (or downright devastated) when they realize that they cannot follow the terminology of their instructors, often because it appears as if they switch between two separate patterns of vocabulary in an entirely random pattern. These two patterns are those used for embryos and quadrupeds, and those for bipedal animals. Note that the terms cranial, rostral, dorsal and ventral have the same meaning in the two terminologies.

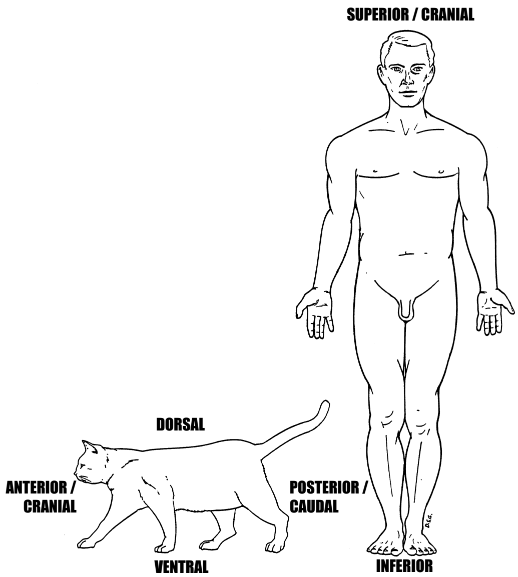


Image 1.1
Illustration of the terms of direction in a quadruped and a biped.

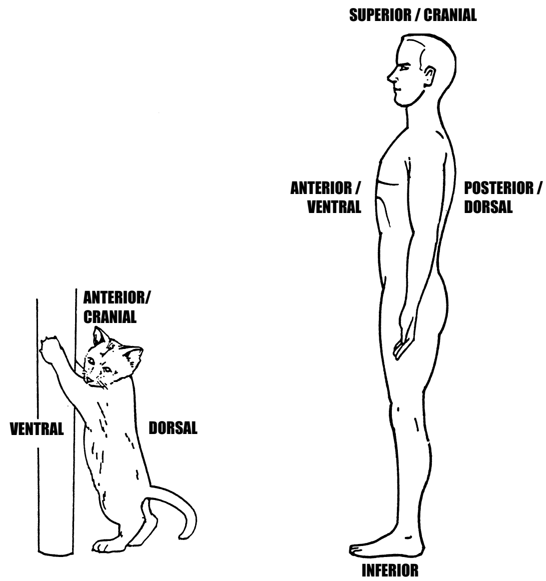


Image 1.2
Illustration of the terms of direction that are synonymous with the quadrupedal and bipedal terminologies.

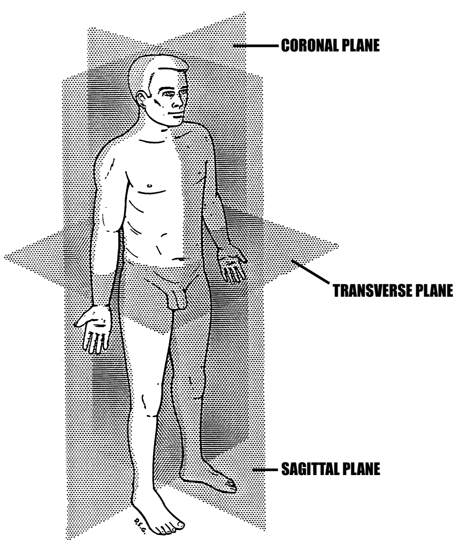


Image 1.3
Illustration of the planes of the human body.

Anterior
The head region of a quadruped or the front side of an upright human.
Cranial, cephalic or rostral
The head region of a quadruped or upright human.
Posterior
The rear end of a quadruped or the back side of an upright human.
Ventral
The belly side of a quadruped or upright human.
Dorsal
The back side of a quadruped or upright human.

These terms are all relative: for instance, in the quadruped, we can say that the shoulder is posterior (or caudal) to the head, and that the shoulder is anterior (or cranial) to the rump. You may even say to yourself, that when a cat is standing it is easy to see that the toes are ventral to the shoulder, but, what about when it is swatting a fly? Even though the foreleg is raised up in the air, the toes continue to be considered ventral to the shoulder. The above terms refer to the relative positions of the various body parts at a time when the creature assumes the anatomical stance. The anatomical stance in adult humans can be considered to be a position in which the body is standing upright with both feet together, arms by the side, and both palms and face directed forward. Therefore, in this stance, the face-side of the body is the anterior side, while the other side is posterior. The head-end can still be referred to as cephalic or cranial, but is more commonly referred to as the **superior** end of the body. Opposingly, the feet are referred to as being **inferior**.

Consider the human – note that the anterior aspect of the human is also his belly; we can therefore substitute this for the term ventral. Similarly, we interchangeably make use of the words posterior and dorsal. Once again note that superior is a perfectly acceptable postembryonic synonym for the terms cranial or cephalic. However, this is not the case for caudal and inferior. Refer to **Image 1.2** and make note that no matter the position of the cat's hindlimb, the foot can never be caudal to the hip since the tail emerges from the rump area. We must make use of another term – inferior. Look at the human in **Image 1.2**; it is apparent that although the rump is caudal to the shoulder, the foot is inferior and *not* caudal to the hip.

Image 1.3 represents the three coordinate planes of the body. The **sagittal** plane runs superiorly-inferiorly along the dorso-ventral axis. The middle of this plane is referred to as the mid-sagittal or median plane. The median plane serves as a reference point for two other terms – these are the **medial** and **lateral**. Any structure that lies closer to the median plane than the other is said to be *medial* to it, while the other is said to be *lateral*. The **transverse** or **horizontal** plane needs no description. The **coronal** or **frontal** plane runs the length of the body and passes through it from side to side, thereby dividing it into anterior and posterior portions.

The terms **superficial** and **deep** describe the positions of structures relative to the surface of the body. The terms **proximal** and **distal** are usually used in relationship to the limbs but may be used with certain other body structures as well. Any structure that is closest to the trunk is said to be proximal to the structure that is farthest away or distal. For example, *the elbow is proximal to the wrist*; or *the wrist is distal to the elbow*.

The palm side of the hand is the **palmar** or **volar** surface while the opposite side is the **dorsal** surface. The sole of the foot is called the **plantar** surface while the other side is referred to as the **dorsal** surface.

Osteologic Terminology

Before considering more details of the human skeleton, it is important to consider the following terms:

1. Terms involving shapes or locations of bones.

Pneumatic bones
These are bones that contain air-filled cavities lined by mucous membranes. From a commercial point of view, the most popular of these bones are those which contain the paranasal air sinuses – these, of course, are the sinuses, which are involved in the sinus headache.
Sesamoid bones
These bones are formed within tendons and get their name from their supposed resemblance to a sesame seed. The largest sesamoid bone in the human body is the patella, popularly known as the knee cap.
Tabular bones
These are simply bones with a flat shape such as the shoulder blade or the bones forming the roof or sides of the skull.
Tubular bones
These are bones sometimes referred to as long bones. These bones are characterized by having an epiphysis at one or both ends plus a centrally located shaft containing a hollow marrow cavity.

2. Terms involving raised areas on the surface of bones.

Caput or head
This usually refers to a rounded articular process, generally marked off by a narrower part, the ***neck****. The word* ***capitulum*** *is used to denote a smaller articular swelling.*
Condyle
Is employed to describe a bony enlargement bearing an articular surface.
Crest or crista
Indicates either a prominent ridge-like border of a bone or a distinct linear elevation or ridge on a bone.
Eminence
A rounded bulge on a bone.
Line
This usually refers to a slight ridge that runs a considerable distance along the surface of a bone.
Process or processus
A marked projection coming off the surface of a bone.
Spine or spina
A slender or pointed projection coming off a bone.
Trochanter
A large tubercle.
Tubercle
Refers to a blunt eminence.
Tuberosity
Refers to a broad blunt elevation.

3. **Terms involving depressions and cavities on or in bones.**

Antrum or sinus
Denotes air spaces within certain cranial bones.
Aperture
This is sometimes used to distinguish the surface opening of a space within a bone.
Canal or canalis
A perforation continued some distance to form a passage.
Cavity or cavum
Applies to a closed space within a bone. For example, the marrow cavity.
Fissure or fissura
A narrow, slit-like aperture.
Fossa
A deep open depression, whether formed by a single bone or by several bones.
Fovea
A shallow pit on a bone.
Hiatus
Sometimes used for a slit-like aperture.
Meatus
A term used for certain passageways in the temporal bone and the passageways from the nasal cavity into the paranasal sinuses.

Unit One:
The Axial Skeleton

The human skeleton can be imagined, in a simplistic manner, to consist of two basic parts: a core of supporting, partially rotating, protecting bones which compose the axial skeleton; and a plethora of distally located bones, the appendicular skeleton, which form the structural basis of the appendages.

The axial skeleton is composed of the skull, vertebrae, ribs, hyoid bone, sacrum and coccyx. Each of these elements has a detailed structure which may require dedicated study to fully appreciate.

Chapter Two

The Skull

The human skull is a complex collection of twenty-eight bones with a detailed embryological history. A thorough understanding of its anatomy, and the unique morphology of its individual elements, is a fundamental component of any osteological pursuit.

The most basic division of the skull is a distinction between the facial skeleton and the cranial skeleton. Obviously, the facial bones make up the face, while the cranial bones make up the "brain box." As you progress through this chapter, it is important to make distinctions between the bones of these two categories as there may be important anatomical and pathological ramifications associated with injuries or disease of these structures. Be aware that the terminology is tricky here: although the frontal bone is a large part of the facial skeleton, it is not developmentally part of the facial skeleton.

2.0 SKULL

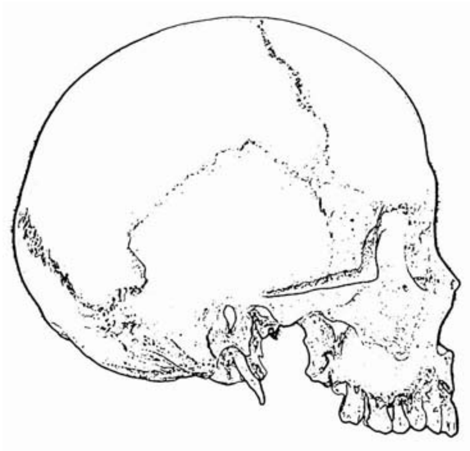


Image 2.1 • *Human cranium, right lateral view.*

- the skull has many important roles, including housing and protecting delicate neurologic tissues of the brain, inner ear and eyes, providing a site of origin for the muscles of mastication, bearing the teeth, and so forth
- the skull can be divided in several ways:
  - <u>skull</u> - all of the bones of the head including mandible
  - <u>cranium</u> - skull without the mandible
  - <u>calvaria</u> - the cranium without the face (commonly incorrectly used to describe the "skull cap")
- the most complex bony structure in the body is the skull – it contains twenty-two separate bones, plus the six ear bones (two of each of the malleus, incus and stapes)
- many of the cranial bones unite at points of contact called sutures
- sutures often have an irregular shape – the bony interdigitations of the suture lines allow for opposing bones to make firm contact with one another
- at the sutures (in childhood, adolescence, and early adulthood), the bones are bound together via intrasutural ligaments
  - over time, these ligaments ossify and the sutures close – eventually leading to sutural obliteration
- many of the sutures get their names because of the names of the two bones they unite, e.g. nasofrontal suture
- exceptions to this include:
  - **coronal** (between the frontal and the two parietal bones)
  - **sagittal** (between the two parietal bones)
  - **lambdoid** (between the two parietal and occipital bones)
  - **squamosal** (between the temporal and parietal bones)

FUNCTION

The skull has many important functions including housing and protecting the brain, eyes and organs of hearing, providing a support for the muscles of mastication, and of course, because of our unique cranial morphology, giving each of us distinctive faces.

Image 2.2 • Surface Anatomy • Adult head with neck in lateral flexion.

Landmarks

There are far too many individual landmarks and sutures in this chapter to list them here. Ensure that you are able to identify those anatomical landmarks demonstrated in our examples of complete and disarticulated skulls.

Skull Variation

Although variation in skeletal morphology is not limited to the bones of the head, skull variants are perhaps the most plentiful, and easily recognizable. Commercially prepared plastic skulls are often very useful in the study of idealized normal anatomy. Use such study tools to become accustomed to "normal" skull osteology, and then be sure to study as many natural bone specimens as possible. This way, you should become accustomed to seeing the broad spectrum of normal anatomy throughout the many different stages of life.

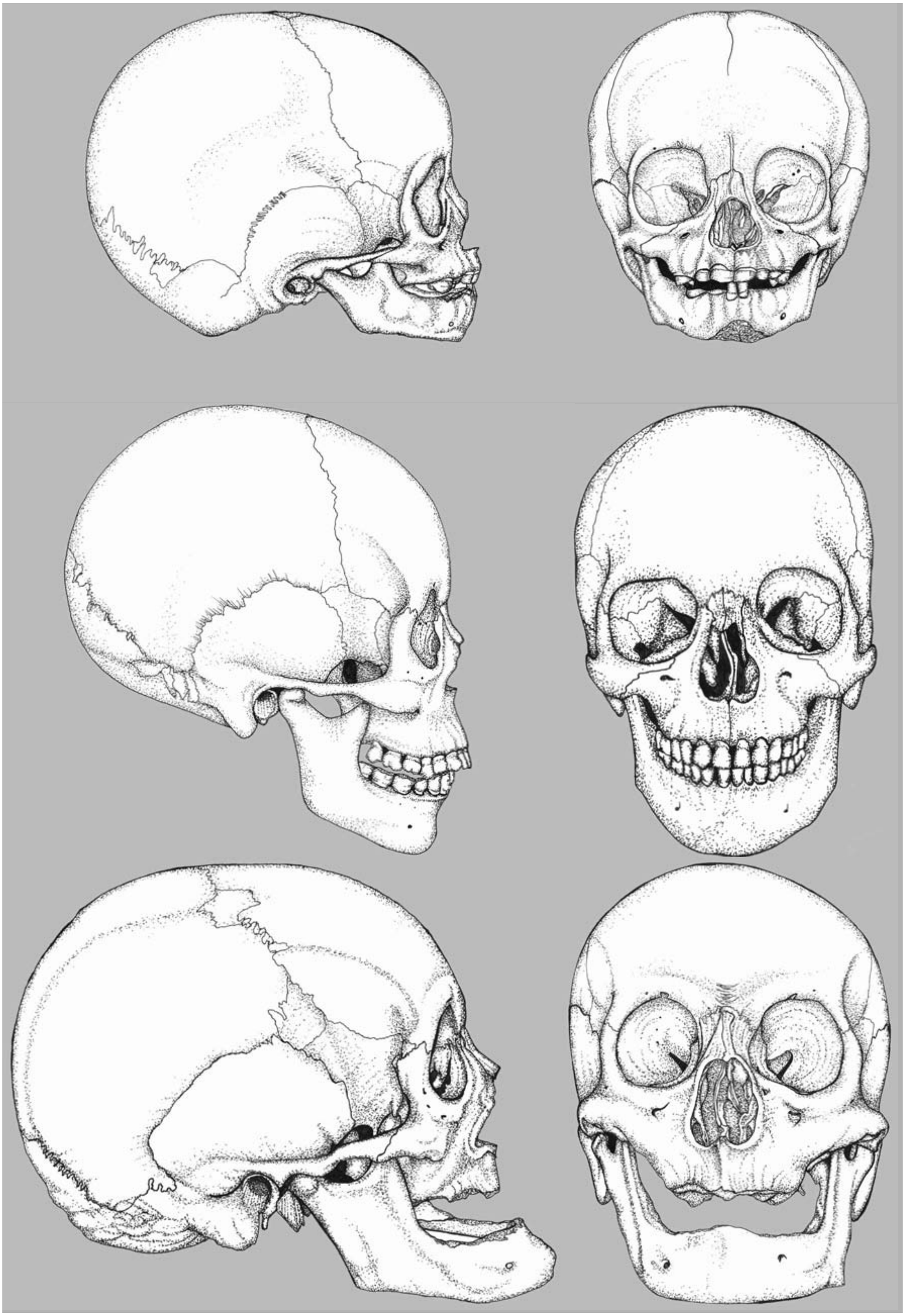


Image 2.3

Human skulls in lateral and anterior planes: young child, adult and elderly (*top to bottom*) .

Image 2.4
Adult skull, anterior view.

Image 2.4

- **A** - frontal bone
- **B** - parietal bone
- **C** - supraorbital foramen
- **D**- nasal bones
- **E** - temporal bone
- **F** - zygomatic bone
- **G** - infraorbital foramen
- **H** - anterior nasal spine
- **I** - maxilla
- **J** - mandible
- **K** - mental foramen

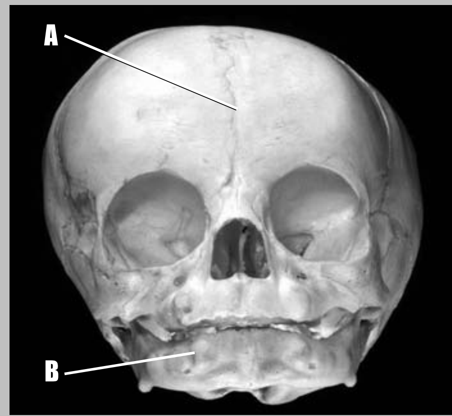


Image 2.5
Examine this fetal skull photograph (developmental age of approximately thirty-four weeks), comparing the overall morphology to that demonstrated in **Image 2.4**. In comparison to the rest of the head, the orbits look greatly enlarged. Also, the parietal bones are prominent. A complete lack of erupted dentition in both mandibular and maxillary dental arcades can also be observed.

A and **B** indicate structures not normally seen in adults. **A** is a *metopic* or *frontal* suture. **B** is an elevation of jaw seen over a deciduous tooth.

Image 2.6
Skull, close-up of anterior view.

Image 2.6

- **A** - supraorbital torus
- **B** - supraorbital foramen
- **C** - supraorbital margin
- **D** - zygomaticofrontal suture
- **E** - nasomaxillary suture
- **F** - nasal suture
- **G** - zygomaticomaxillary suture
- **H** - infraorbital foramen

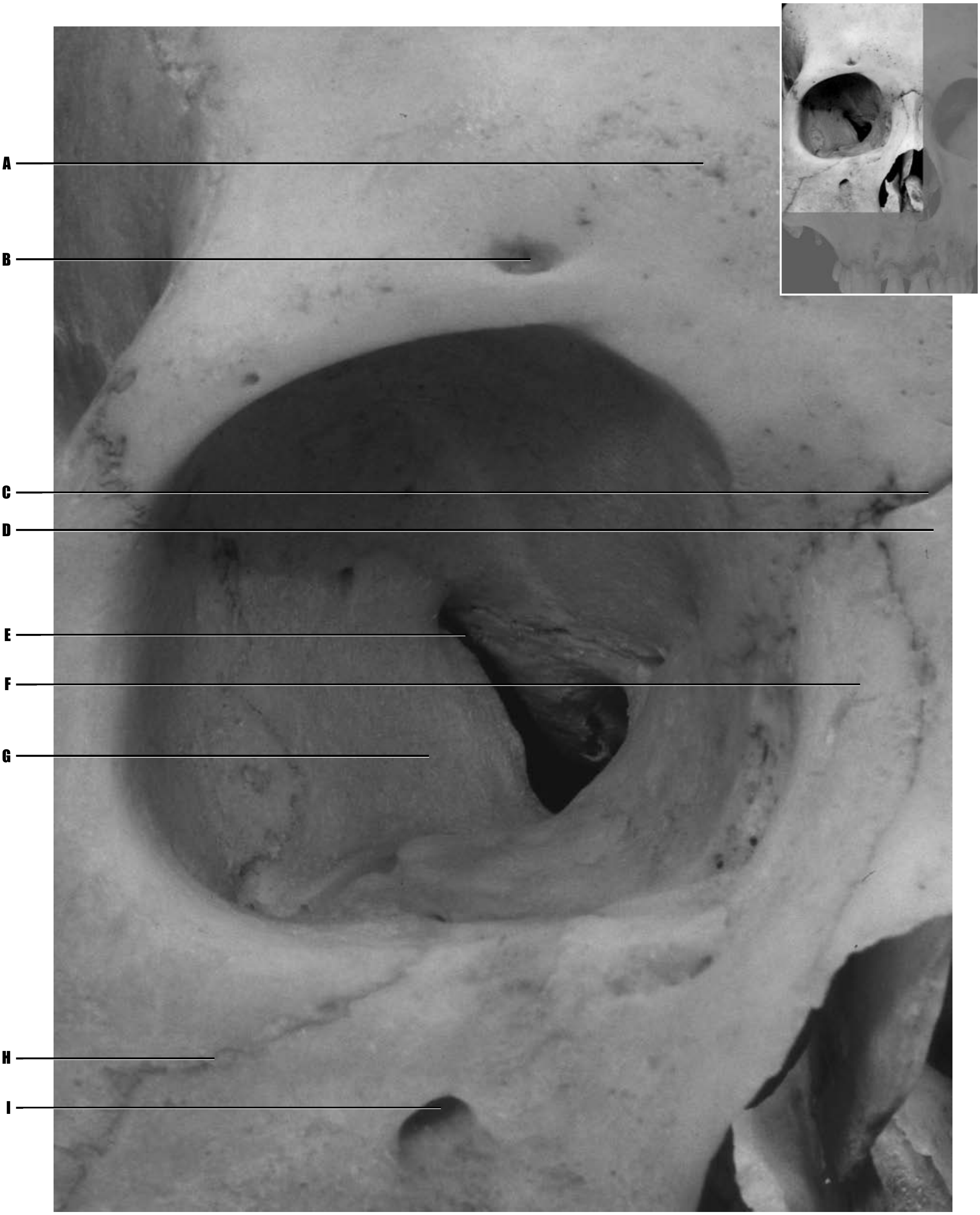


Image 2.7

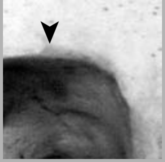
Skull, anterior view, close-up of right orbit. Use the inset photograph for orientation.

Image 2.7

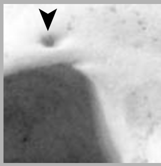
A - supraorbital torus
B - supraorbital foramen
C - nasofrontal suture
D - right nasal bone
E - superior orbital fissure
F - frontal process of maxilla
G - orbital surface of greater wing of sphenoid bone
H - zygomaticomaxillary suture
I - infraorbital foramen

Please note...

Every skull has either a notch or foramen along the supraorbital margin. Both the supraorbital foramen and notch serve the same function: to transport veins, arteries and nerves to and from the face, forehead and orbit.



Supraorbital notch



Supraorbital foramen

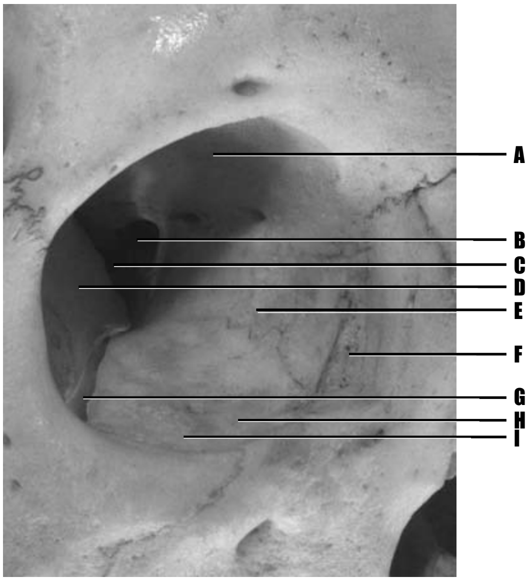


Image 2.8
Right orbit, close-up of right oblique view.

Image 2.8

A - orbital surface of frontal bone
B - optic canal
C - superior orbital fissure
D - orbital surface of greater wing of sphenoid bone
E - orbital surface of ethmoid bone
F - lacrimal bone (with fossa for lacrimal sac)
G - inferior orbital fissure
H - orbital surface of maxillary bone
I - orbital surface of zygomatic bone

Image 2.9

Skull, anterior view, close-up of anterior nasal aperture. Use the inset photograph for orientation.

Image 2.9

A - right nasal bone
B - nasomaxillary suture
C - frontal process of maxilla
D - fossa for lacrimal sac *(indicated by arrow)*
E - superior orbital fissure
F - middle nasal concha
G - perpendicular plate of ethmoid bone
H - inferior nasal concha
I - perpendicular process of vomer
J - anterior nasal spine
K - site of fusion of the two maxillae during development

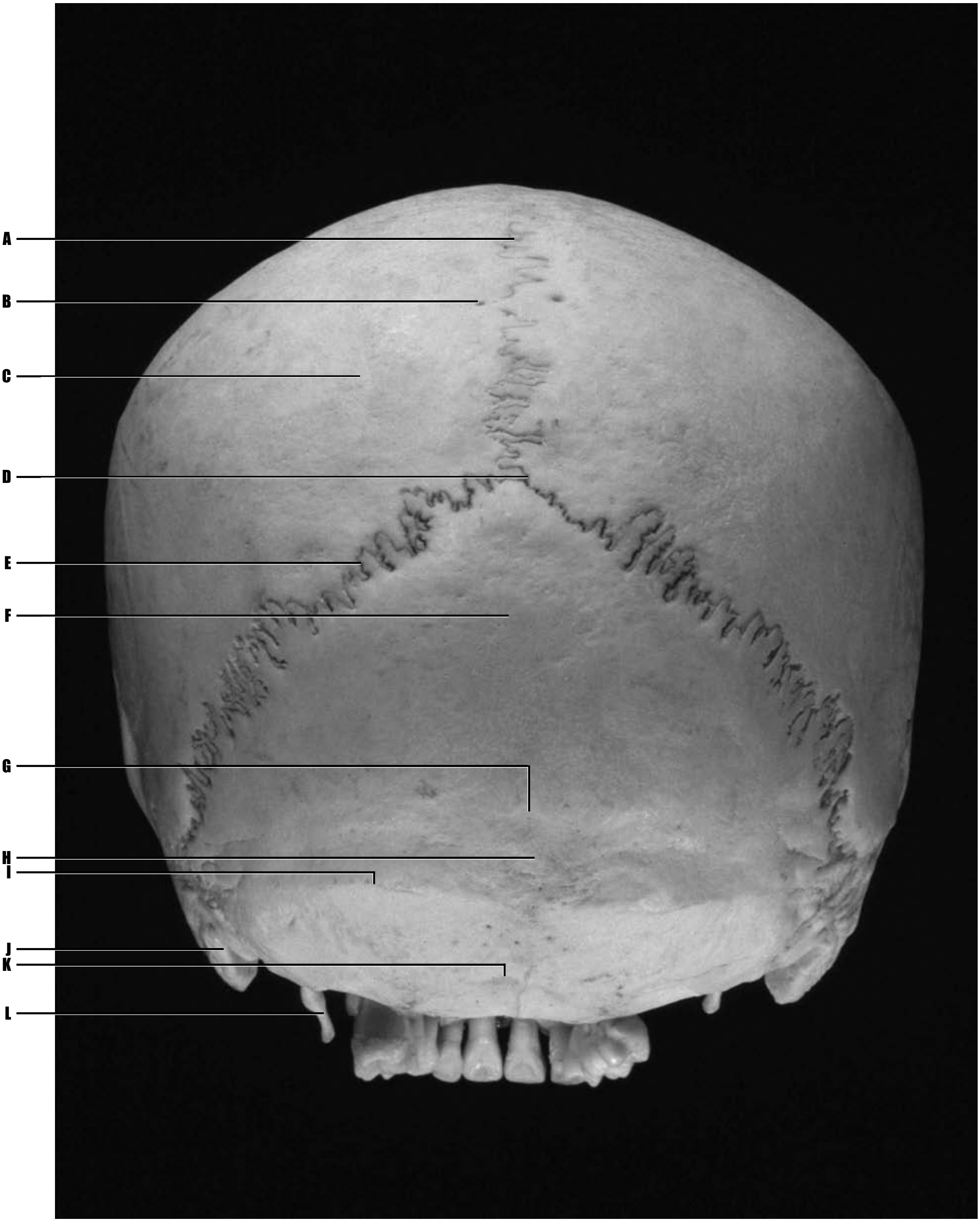


Image 2.10
Cranium, posterior view.

Image 2.10

A - sagittal suture
B - parietal foramen
C - parietal bone
D - lambda (junction of lambdoid and sagittal sutures)
E - lambdoid suture
F - occipital bone
G - highest nuchal line
H - external occipital protuberance
I - superior nuchal line
J - mastoid process
K - inferior nuchal line
L - styloid process

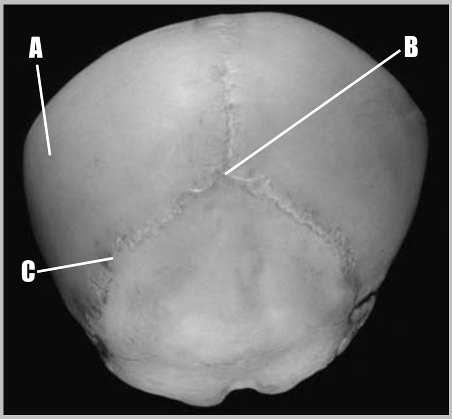
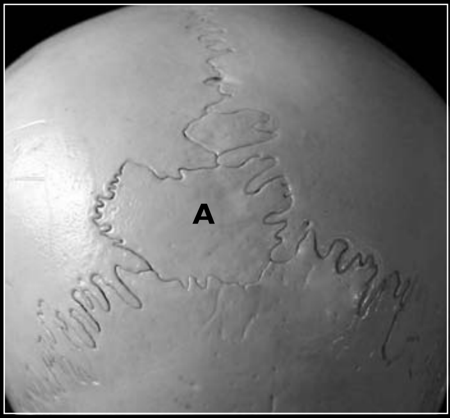
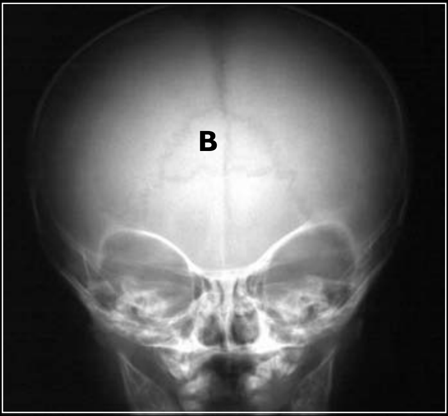


Image 2.11

Examine the fetal skull from the same approach as **Image 2.10**. Notice similar configurations of the sutures and overall skull shape. However, there are important differences in the fetus and neonate. For example, the musculature is poorly developed. As a result of immature musculature, those bony prominences and other structures to which muscles attach and pull against are not yet obviously enlarged. Note this in the aforementioned nuchal lines, mastoid and styloid processes.

A and **B** indicate structures not normally seen in adults. **A** is a *parietal tuberosity*. **B**, at the location termed lambda, is a barely perceivable *posterior fontanelle.* By now, you are able to recognize **C** as the ever popular lambdoid suture.





Images 2.12 and 2.13

Skull, close-up of intrasutural bones.

Supernumerary bones of varying sizes may be seen along the suture lines, with particular frequency along the lambdoid suture. These have been given multiple names including *Wormian ossicles* or *sutural bones* ***(A)***. It is important to recognize such findings as normal variants whether it be in medical imaging, at autopsy, or when examining isolated cranial remains as they might be misinterpreted as fractures.

Image 2.13 is from a young child being investigated for possible hydrocephalus – increased head size because of excessive cerebrospinal fluid. Note the large lambdic ossicle at **B**.

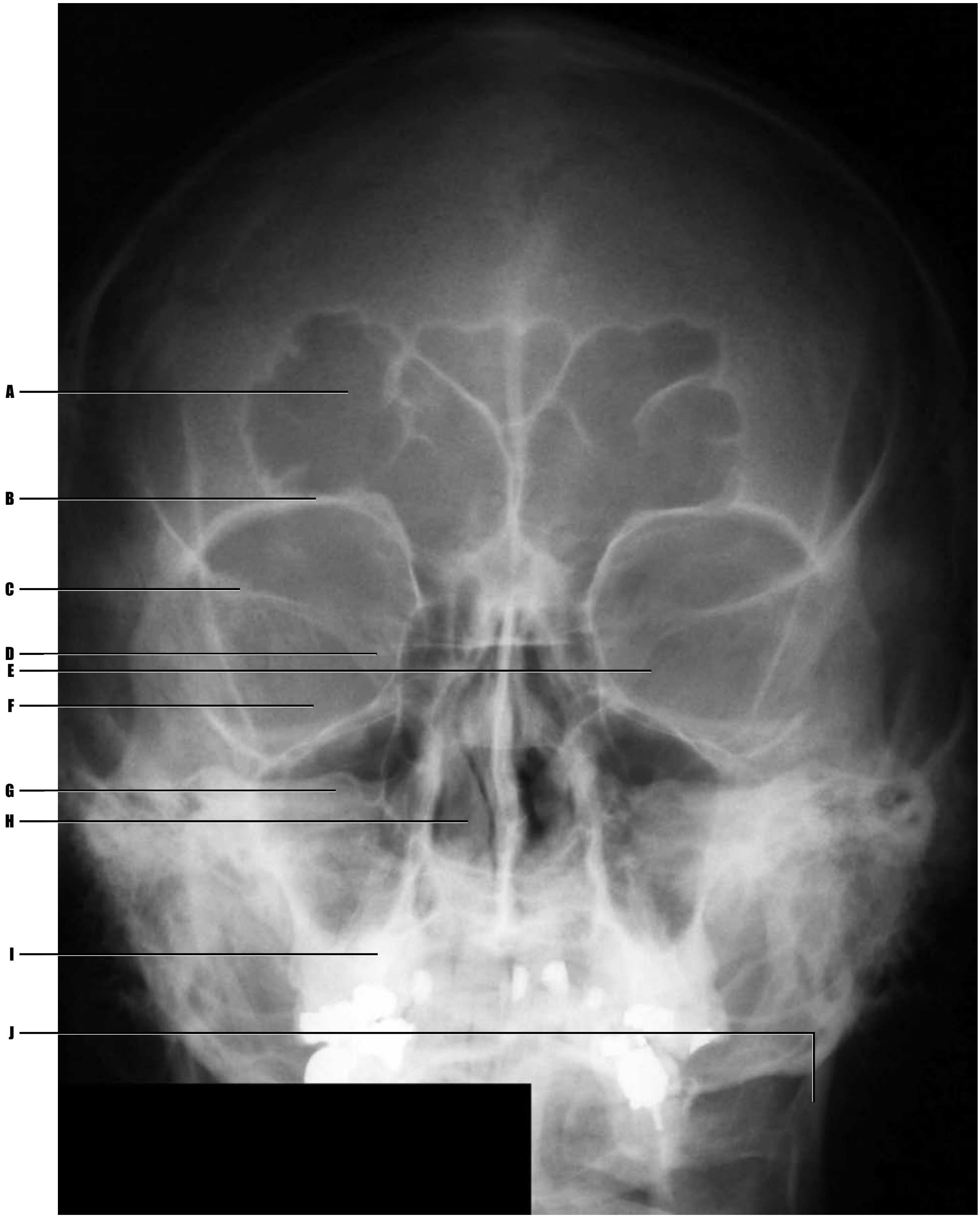


Image 2.14

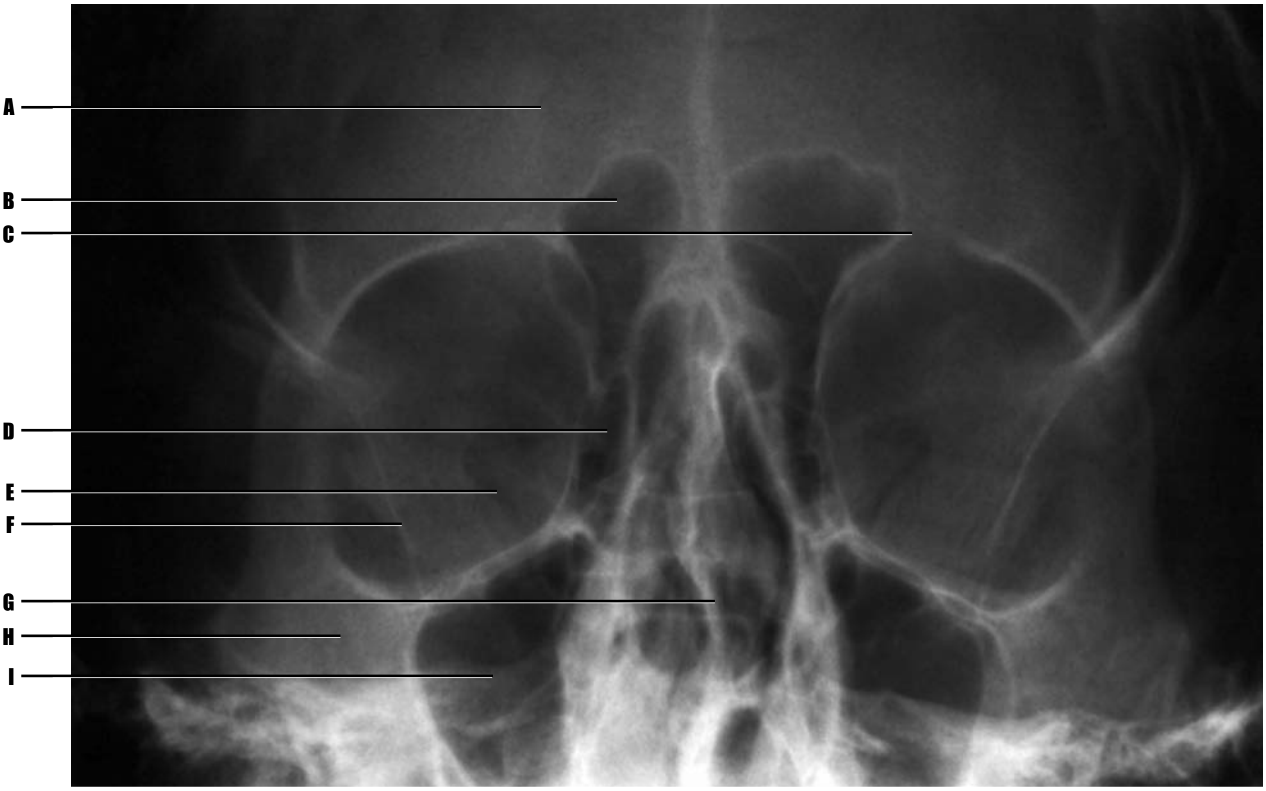
Adult patient, plain film radiograph, "Caldwell view."

The Caldwell view is a radiographic projection used to permit examination of orbital structures, without obstruction of view by the petrous portions of the temporal bones.

Image 2.14

A - frontal sinus*
B - supraorbital margin
C - sphenoid ridge
D - lesser wing of sphenoid
E - superior orbital fissure
F - greater wing of sphenoid
G - petrous ridge
H - inferior nasal concha
I - maxilla
J - angle of mandible

*for a discussion of the sinuses, please see pages 24 and 25.



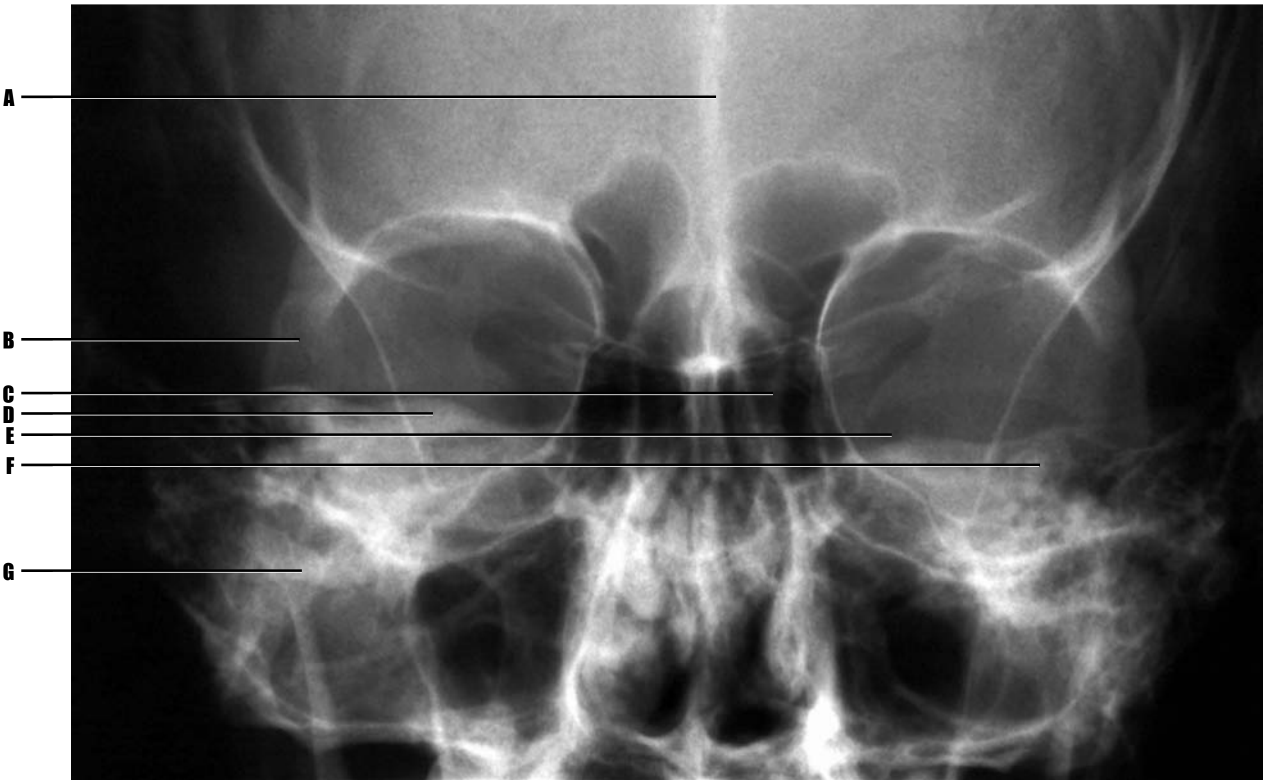


Image 2.15
Adult patient, plain film radiograph, “Caldwell view” of sinuses.
Image 2.16
Adult patient, plain film radiograph, posteroanterior view of sinuses.

Image 2.15

A - frontal bone
B - frontal sinus
C - supraorbital notch
D - ethmoid sinus
E - superior orbital fissure
F - lateral wall of orbit
G - nasal septum (in life, composed of the vomer, perpendicular plate of ethmoid, cartilage)
H - zygomatic bone
I - maxillary sinus

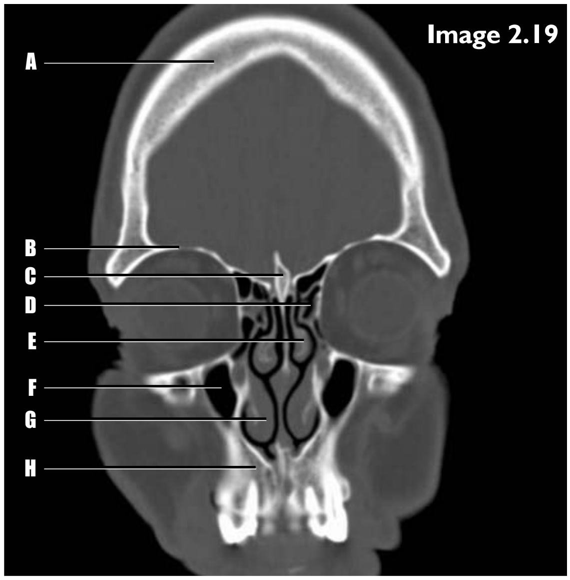
Image 2.16

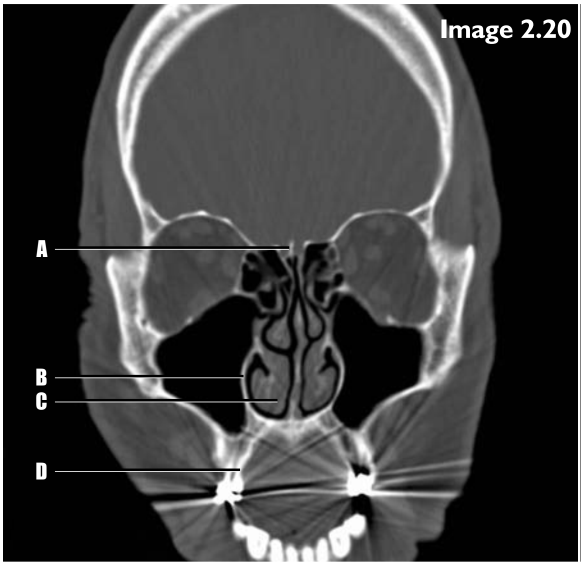
A - crista galli
B - zygomatic process of frontal bone
C - nasal bone
D - petrous ridge
E - foramen rotundum
F - cochlea
G - condyle of mandible

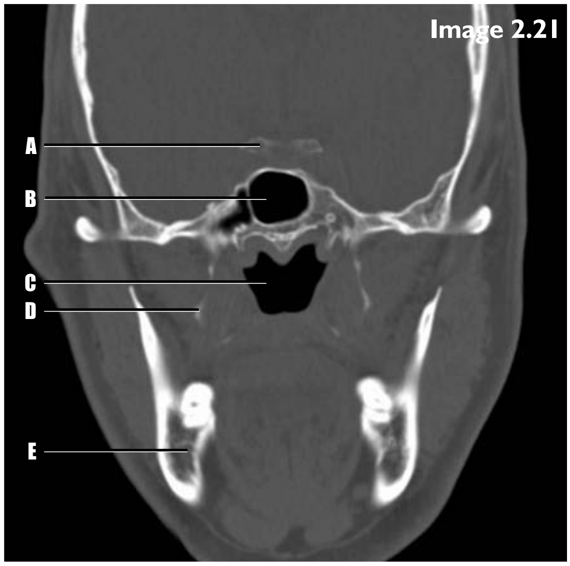
Image 2.17
Adult patient, plain film radiograph, "Waters' view."
The Waters' view is a radiographic projection used to permit examination of orbital structures and the maxillary sinuses.

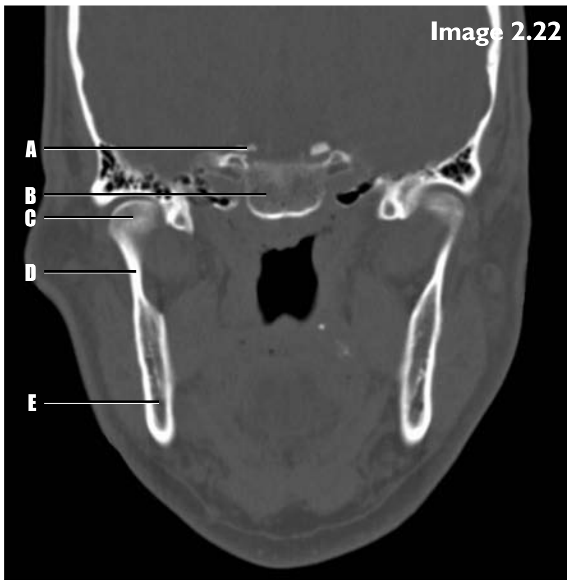
Image 2.17

A - frontal sinus
B - ethmoid sinus
C - lateral wall of orbit
D - nasal bone
E - zygomatic bone
F - inferior nasal concha
G - maxillary sinus
H - lateral wall of maxillary sinus
I - zygomatic arch
J - oral cavity
K - sphenoid sinus
L - mastoid air cells









Paranasal Sinuses

Within the substance of several cranial bones (frontal, maxillae, ethmoid, sphenoid), are paired mucous membrane-lined cavities. These open areas vary markedly in their size, shape, and even in their occurrence. In fact, their morphology is sufficiently random as to make them unique markers of individualization, and therefore a tool for forensic scientists trying to identify unknown human remains by comparing antemortem and postmortem records.

When you have a cold and are producing copious amounts of mucous, you can feel comfortable in blaming the lining of these sinuses for your ample nasal discharge. Beyond that function, though, the sinuses play important roles in warming cool air as it enters your body, and in the modulation of sound in speaking, singing, etc.

NOTE: **Images 2.18** through **2.22** are successive (anterior to posterior) CT scans taken in the coronal plane.

Image 2.18

Adult patient, CT scan of head. Coronal slice through frontal sinus.
A - frontal bone, B - frontal sinus, C - nasal bone, D - nasal septum, E - nasal cavity.

Image 2.19

Adult patient, CT scan of head. Coronal slice through ethmoidal sinuses and anteriormost tip of maxillary sinuses.
A - diploic space of frontal bone, B - orbital shelf of frontal bone, C - crista galli, D - ethmoidal air space, E - middle nasal concha, F - maxillary sinus, G - nasal conchae (turbinates), H - maxilla.

Image 2.20

Adult patient, CT scan of head. Coronal slice through the ethmoidal and maxillary sinuses.
A - cribriform plate, B - medial wall of maxillary sinus, C - nasal conchae (turbinates), D - alveolar region of maxilla.

Image 2.21

Adult patient, CT scan of head. Coronal slice through the sphenoid sinus.
A - anterior clinoid process, B - sphenoid sinus, C - nasopharynx, D - lateral pterygoid plate, E - angle of mandible.

Image 2.22

Adult patient, CT scan of head. Coronal slice through midline of head. Sinuses are not visible in this section.
A - posterior clinoid process, B - basiocciput, C - condyle of mandible, D - neck of mandible, E - ramus of mandible.

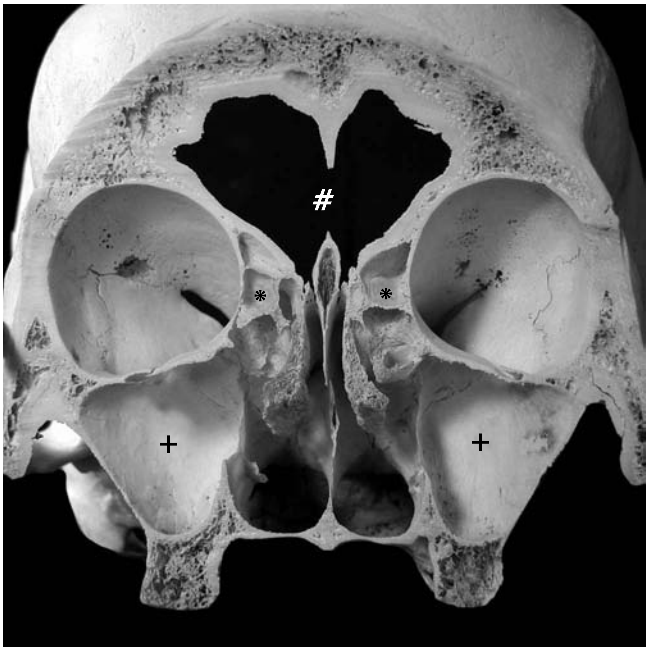


Image 2.23

Skull. Coronal section through maxillary (+), ethmoidal (*), and frontal (#) sinuses (posteriormost segment) .

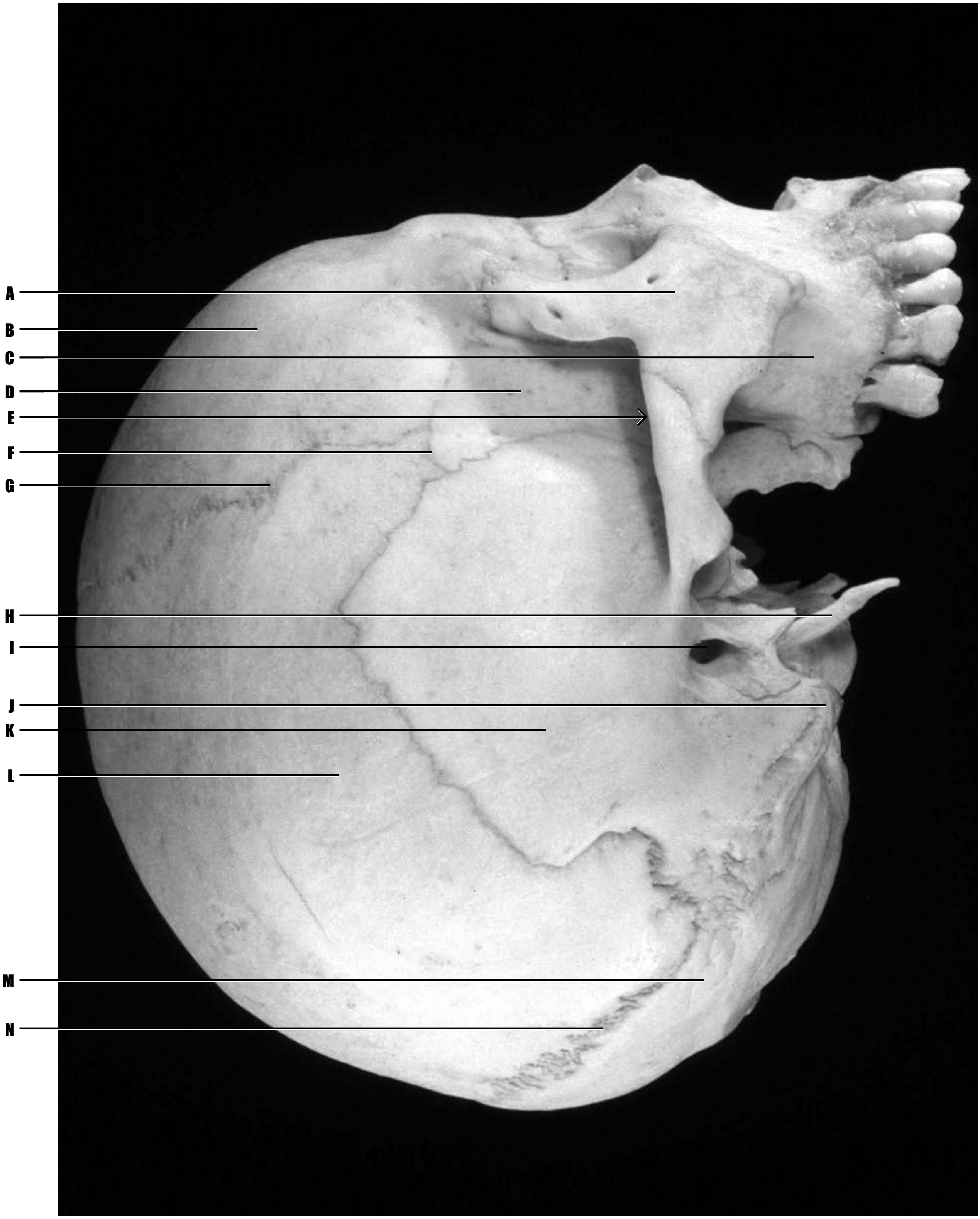


Image 2.24
Cranium, right lateral view.

Image 2.24

A - zygomatic bone
B - frontal bone
C - maxilla
D - greater wing of sphenoid bone
E - temporal fossa *(indicated by arrow)*
F - pterion
G - coronal suture
H - styloid process
I - external acoustic/auditory meatus
J - mastoid process of temporal bone
K - temporal bone
L - parietal bone
M - occipital bone
N - lambdoid suture

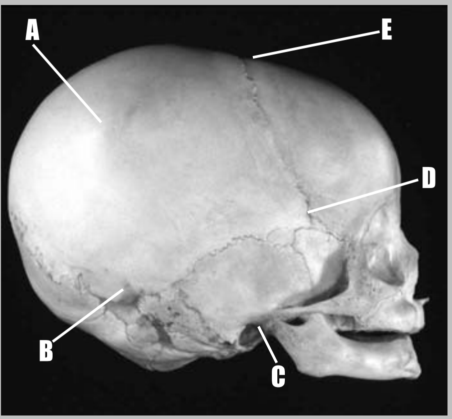


Image 2.25
Examine the fetal skull from the same orientation as that of **Image 2.24**. Notice similar configurations of the sutures and overall skull shape in this particular specimen.

All five letters (A-E) indicate structures not normally present in adult crania. **A** indicates the previously mentioned parietal tuberosity. **B** indicates the posterolateral or mastoid fontanelle. **C** demarcates the tympanic ring, the developmental precursor to the tympanic part of the temporal bone. **D** identifies the position of the pterion, but also indicates the location of the anterolateral or sphenoid fontanelles as would be seen in younger specimens. **E** indicates a barely perceptible lateral extension of the anterior fontanelle.

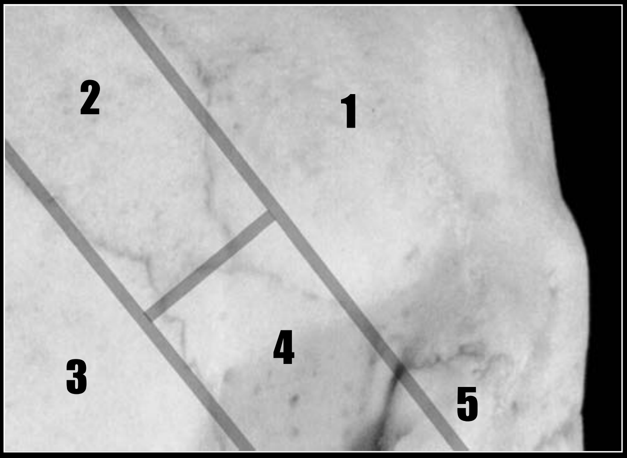


Image 2.26
Skull, right lateral view, close-up of pterion.

Helping you visualize the *PTERION*

Orientation: This is a lateral photograph. The face is directly to the right and the back of the head is directly to the left. The vertex of the skull would be found toward the top of this picture.

This is a close-up of the region just superior to the temporal fossa. It possesses the osteologic landmark known as the pterion. The pterion is the junction of the frontal (1), parietal (2), temporal (3), and sphenoid (4) bones. The zygomatic bone (5) is included to help orient you to the photo. The arrangement of the sutures for bones 1-4 have been said to resemble an 'H', at the center of which the pterion is located. An idealized 'H' has been superimposed in gray to help you visualize this landmark.

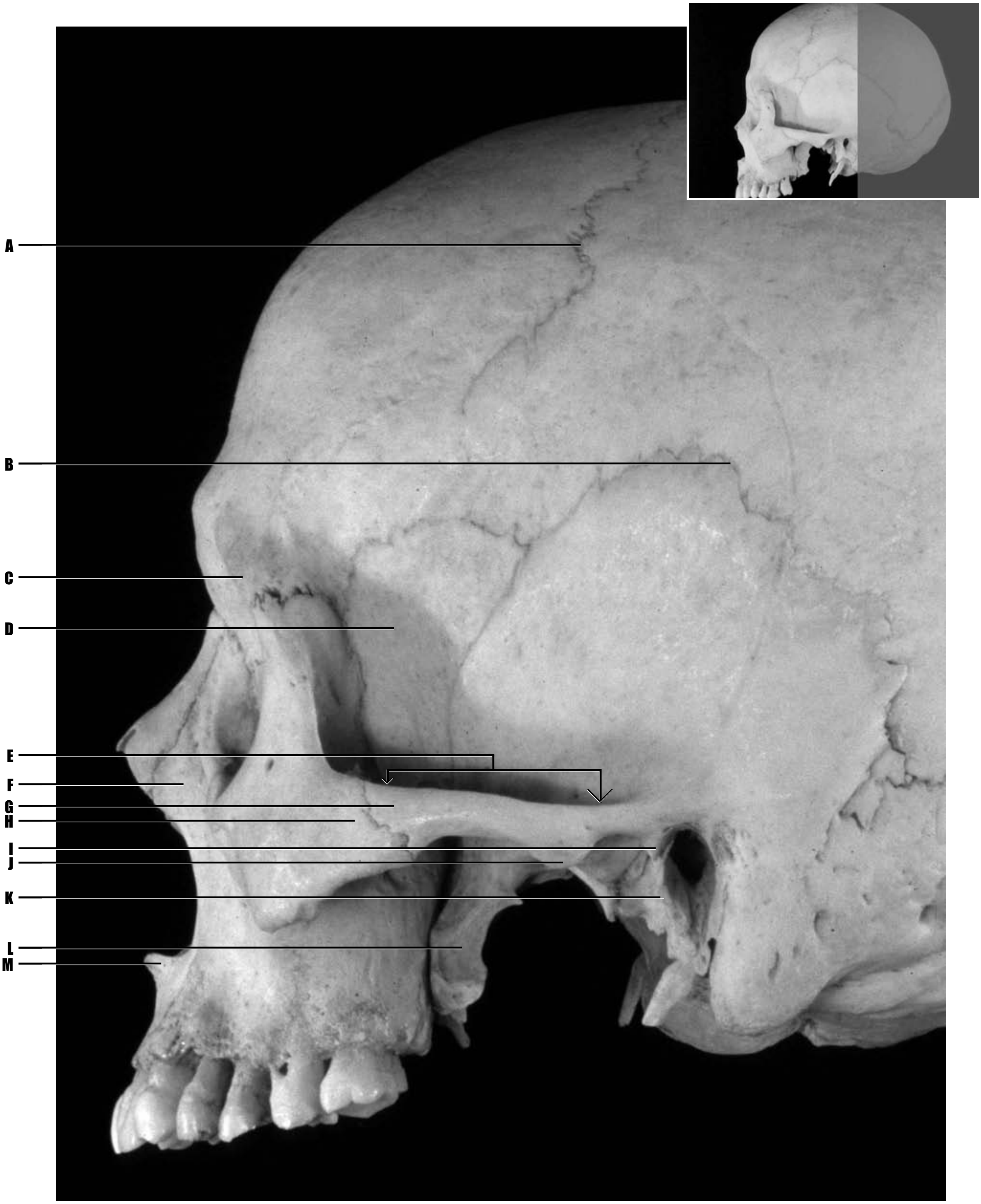


Image 2.27

Cranium, left lateral view, close-up of anterior half. Use the inset photograph for orientation.

Image 2.27

- **A** - coronal suture
- **B** - squamous suture
- **C** - zygomatic process of frontal bone
- **D** - greater wing of sphenoid bone
- **E** - temporal fossa
- **F** - frontal process of maxilla
- **G** - zygomatic process of temporal bone
- **H** - temporal process of zygomatic bone
- **I** - postglenoid tubercle
- **J** - articular tubercle
- **K** - tympanic plate
- **L** - pterygoid process of sphenoid bone
- **M** - anterior nasal spine

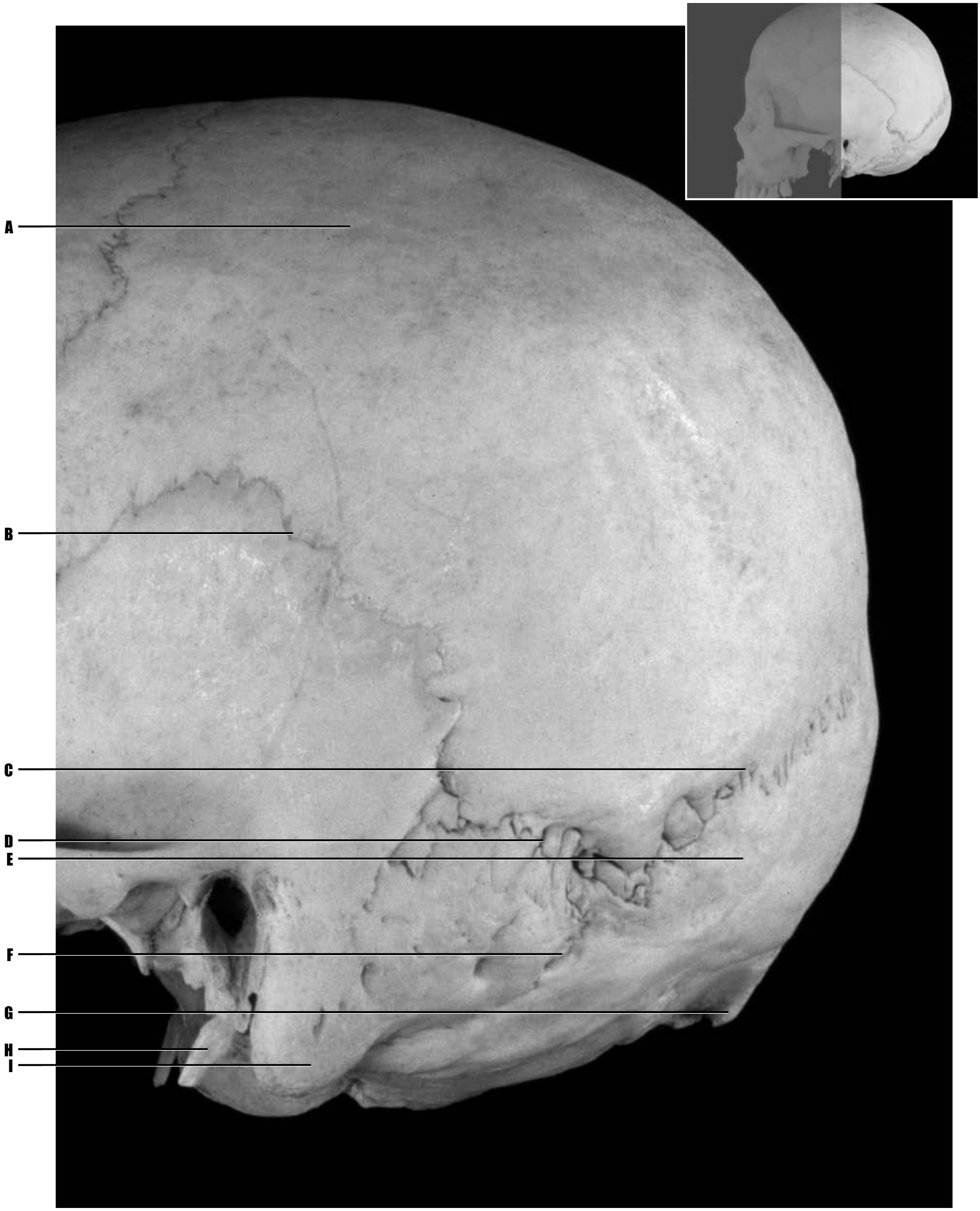


Image 2.28
Cranium, left lateral view, close-up of posterior half. Use the inset photograph for orientation.

Image 2.28

A - parietal bone
B - squamosal suture
C - lambdoid suture
D - parietomastoid suture
E - occipital bone
F - occipitomastoid suture
G - external occipital protuberance
H - styloid process
I - mastoid process of temporal bone

Image 2.29
Skull, right lateral view, close-up of right lateral.

Variation in Landmark Prominence

Orientation: This is a lateral photograph. The face is directly to the right and the back of the head is directly to the left. The vertex of the skull would be found toward the top of this picture.

As you examine different natural bone skulls, you will notice widely varying prominence and appearance of the various anatomical landmarks. One of the most basic and important factors influencing this is muscle mass, and muscle use. With increased muscle bulk, and prolonged use (over years of life), the tugging action of muscle against bony sites of attachment may lead to enhancement of that landmark. In this example, the temporal lines, which course in an arc-like fashion from anterior to posterior, are prominent enough to allow easy visualization.

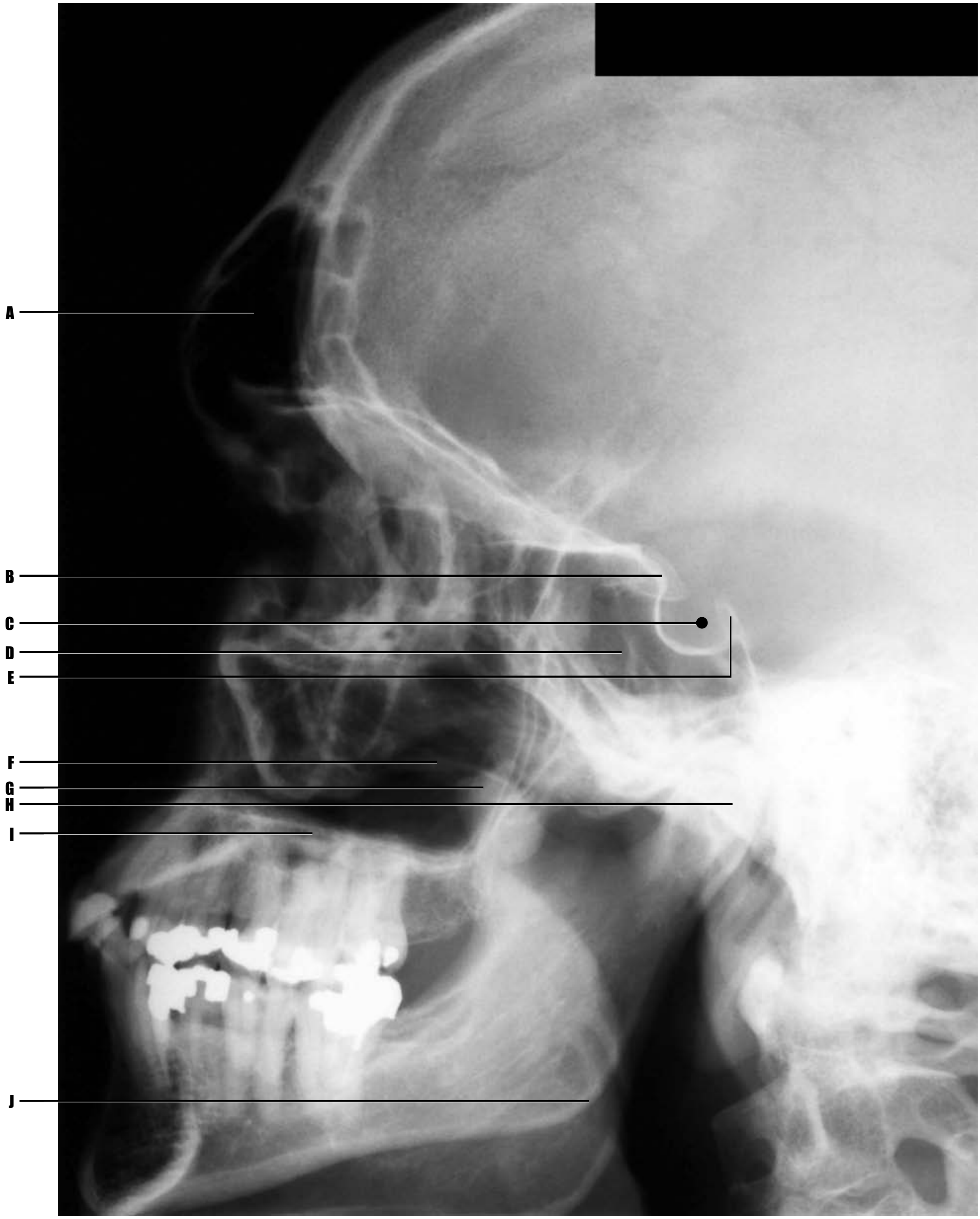


Image 2.30
Adult patient, plain film radiograph, lateral view.

Image 2.30

A - frontal sinus
B - anterior clinoid process
C - hypophyseal (pituitary) fossa
D - sphenoid sinus
E - posterior clinoid process (on dorsum sellae)
F - maxillary sinus
G - coronoid process of mandible
H - head (condyle) of mandible
I - hard palate
J - angle of mandible

Image 2.31
Adult patient, magnetic resonance (MR) imaging of sagittal section through midline of head.

Within this image, one can easily visualize the calvarium, the frontal (+) and sphenoid sinuses (#), the superiormost cervical vertebrae (*), and the complexity of the human intracranial contents.

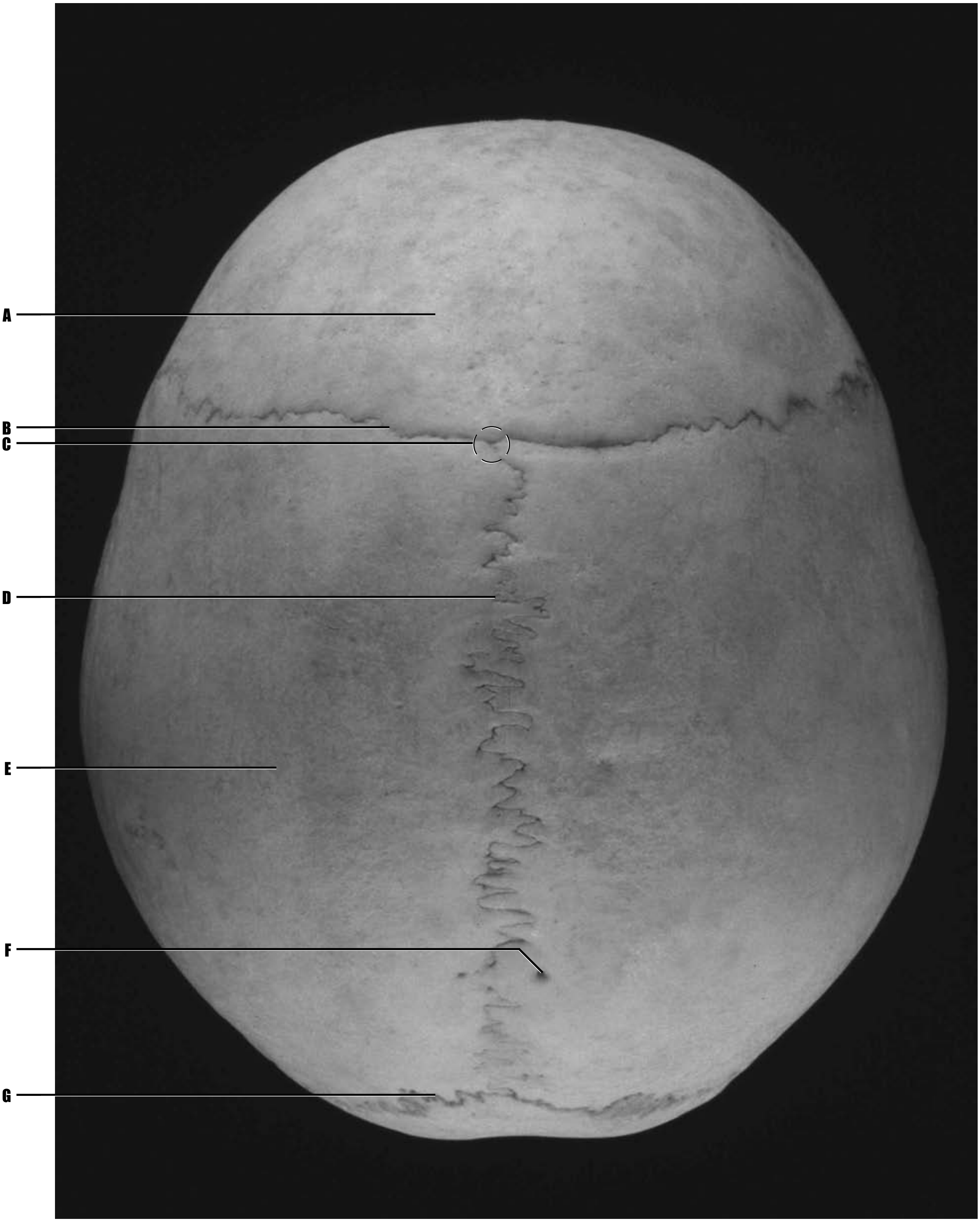


Image 2.32
Skull, vertex view (superior ectocranial surface).

Image 2.32

A - frontal bone
B - coronal suture
C - bregma (site of union of coronal and sagittal sutures)
D - sagittal suture
E - parietal bone
F - parietal foramen (for emissary vein)
G - lambdoid suture

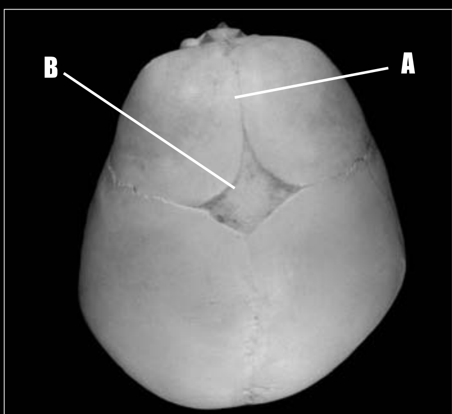


Image 2.33
Fetal skull, superior view.

A quick look at the fontanelles

As you have seen in previous pages, many of the bones of the fetus and neonate have yet to unite. For example, the frontal bone consists of two bones separated by the metopic suture **(A)**. The flat bones of the skull are united not by the bony interdigitations typical of adult sutures, but by lax ligaments which expand to form sheets. We call these the *fontanelles*. The superior view of the fetal skull, as shown here, allows us to see the *anterior fontanelle* **(B)**, the largest of the six fontanelles. It is located at the junction of the sagittal, coronal and metopic (frontal) sutures. The small posterior fontanelle, at the junction of the sagittal and lambdoid sutures, is triangular. The pair of anterolateral or sphenoidal fontanelles are in the temporal fossae while the pair of posterolateral or mastoid fontanelles are just above the mastoid regions.

The anterolateral and posterior fontanelles ossify (close) within two to three months of birth; the posterolateral fontanelles are closed by twelve months; and the anterior fontanelle is closed by eighteen to twenty-four months.

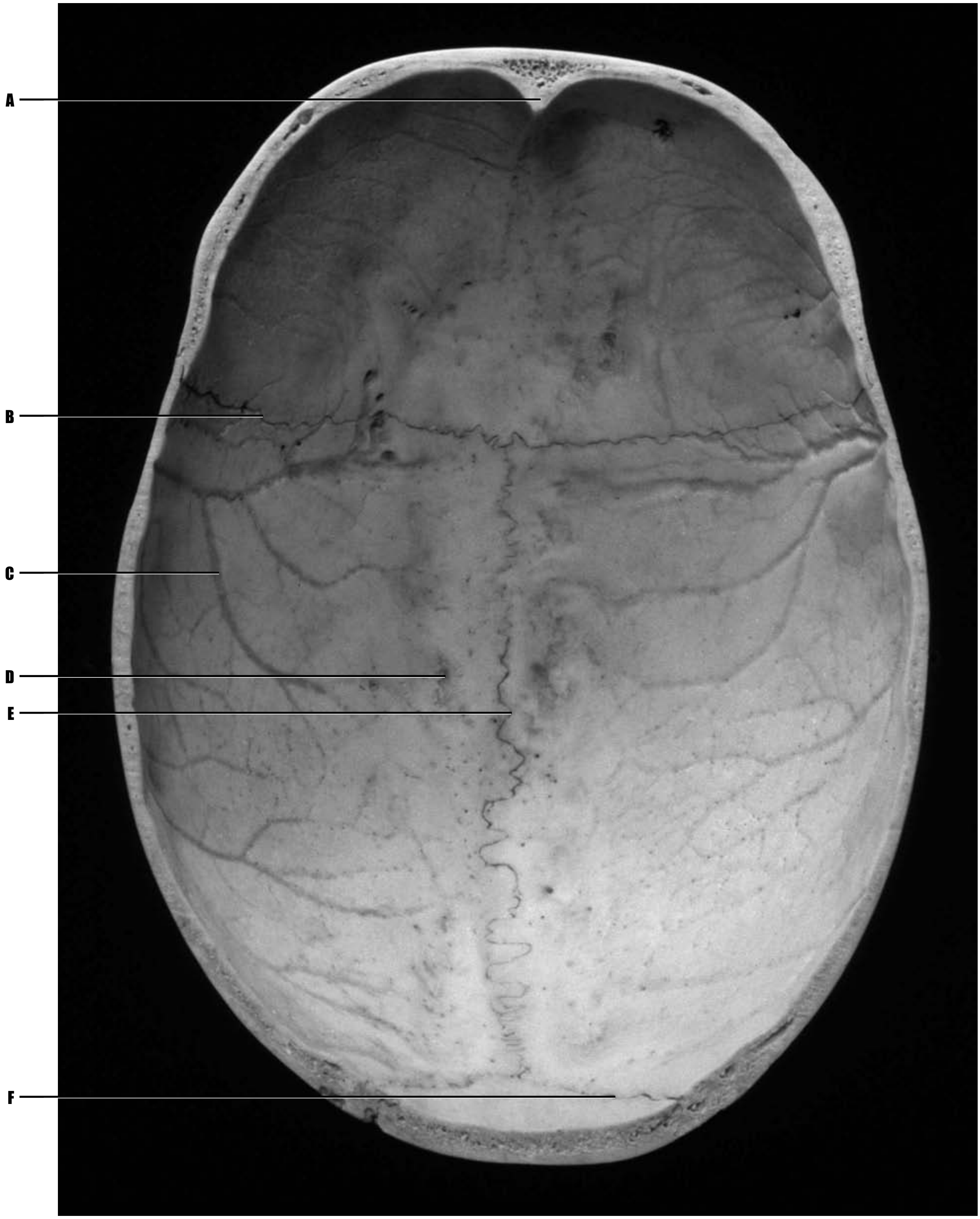


Image 2.34
Skull cap, intracranial view.

Image 2.34

A - frontal crest
B - coronal suture
C - groove for branch of middle meningeal artery
D - granular foveola
E - sagittal suture
F - lambdoid suture

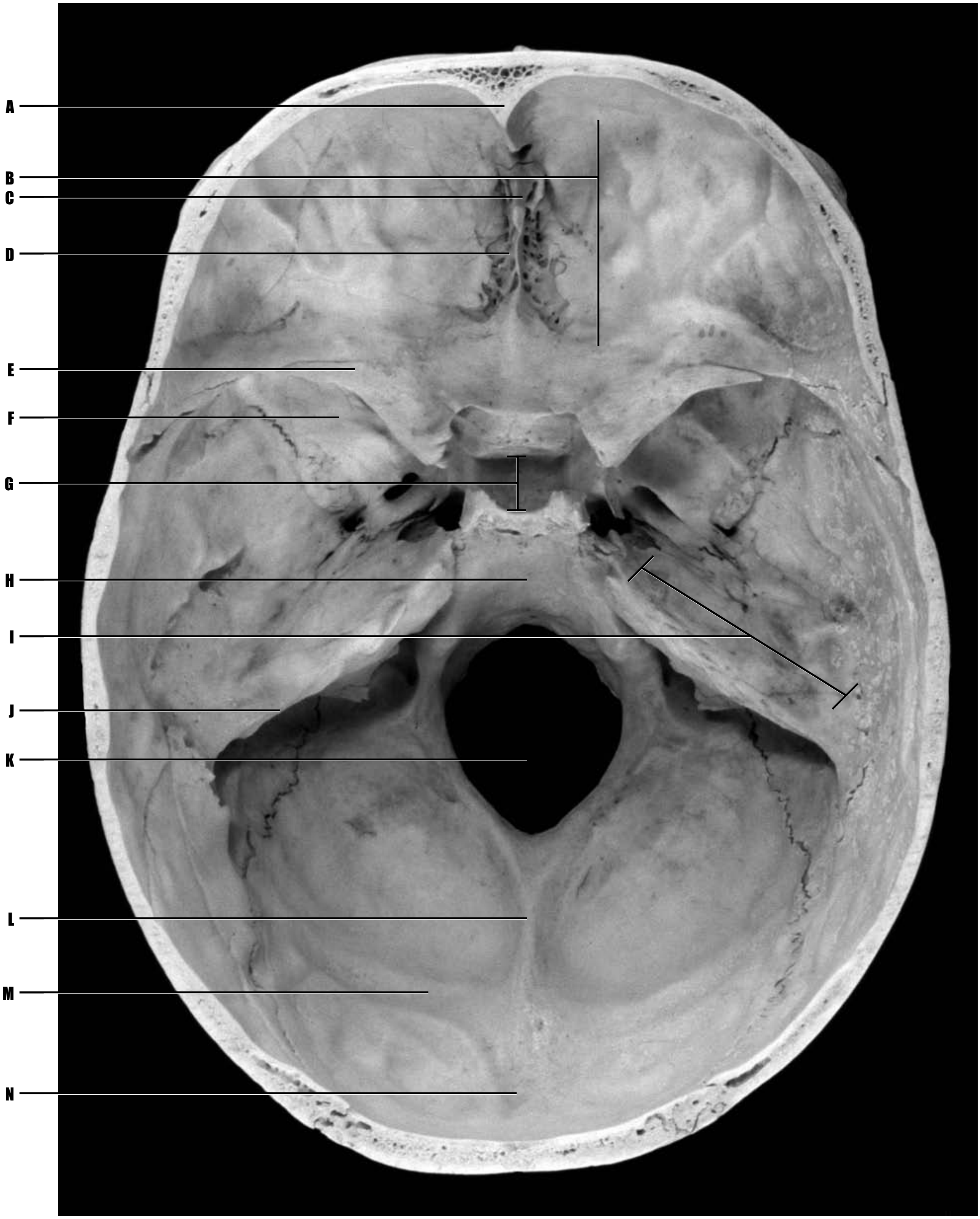


Image 2.35
Skull, intracranial view of skull base.

Image 2.35

A - frontal crest
B - orbital shelf
C - crista galli
D - cribriform plate
E - lesser wing of sphenoid
F - greater wing of sphenoid
G - pituitary (hypophyseal) fossa
H - clivus
I - petrous portion of temporal bone
J - petrous ridge
K - foramen magnum
L - internal occipital crest
M - groove for transverse sinus
N - groove for sagittal sinus

Image 2.36
The three cranial fossae:

The basal component of the intracranium can be divided into three separate units – the anterior (frontal), middle (temporal), and posterior cranial fossae. In life, corresponding regions of brain rest up against the floor of the braincase, and are protected by the dense, bony framework of the skull. In this example, the middle fossa has been shaded *dark gray*, the anterior fossa is above this, posterior is below.

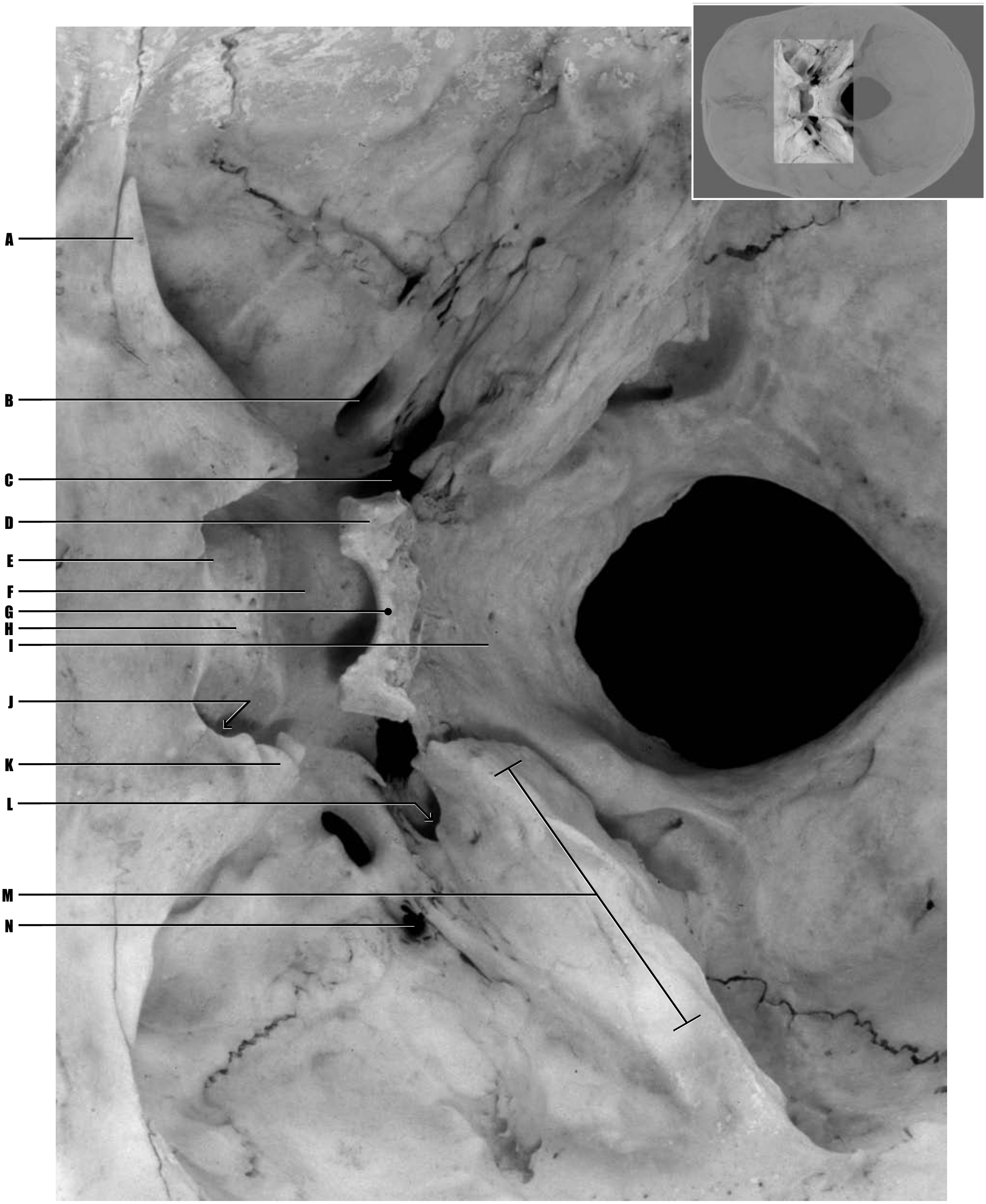


Image 2.37

Skull, important foramina of middle cranial fossa. Use the inset photograph for orientation.

Image 2.37

A - lesser wing of sphenoid
B - foramen ovale
C - foramen lacerum
D - posterior clinoid process
E - chiasmatic groove
F - pituitary fossa
G - dorsum sellae
H - tuberculum sellae
I - clivus
J - optic canal *(indicated by arrow)*
K - anterior clinoid process
L - carotid canal *(indicated by arrow)*
M - petrous portion of temporal bone
N - foramen spinosum

Image 2.38
Cranium, inferior view.

Image 2.38

A - palatine process of maxilla
B - zygomatic bone
C - temporal fossa
D - posterior nasal fossa
E - pterygoid process of sphenoid bone
F - petrous portion of temporal bone
G - occipital condyle
H - foramen magnum
I - occipital bone

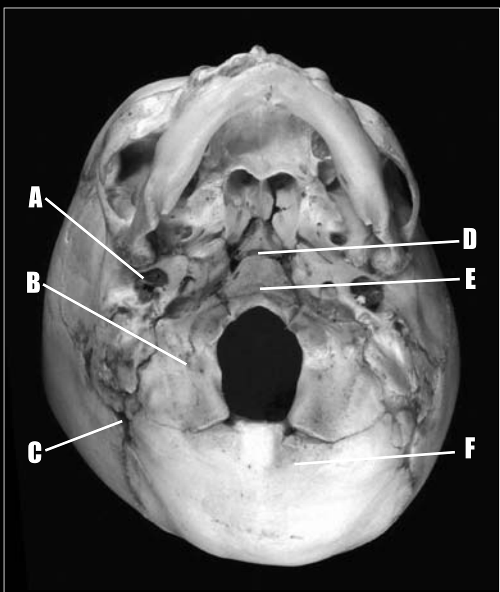


Image 2.39
Fetal skull, inferior view.

Examine the inferior aspect of this fetal skull. The overall morphology is similar to that of an adult cranium. There are, however, several important differences between this and mature skulls.

A indicates the tympanic ring, the previously mentioned developmental precursor to the tympanic part of the temporal bone. **B**, **E** and **F** are the three parts of the developing occipital bone, the condylar, basilar and squamous parts, respectively.

C is the *mastoid* or posterolateral fontanelle.

D is an important landmark, the spheno-occipital synchondrosis. In early life, this space is filled with a cartilaginous growth plate. Growth in this region is responsible for development in length of the skull's base. It is known to typically ossify between eighteen and twenty-five years of age; a detail important to consider when attempting to determine the age at death of an unknown cranial specimen.

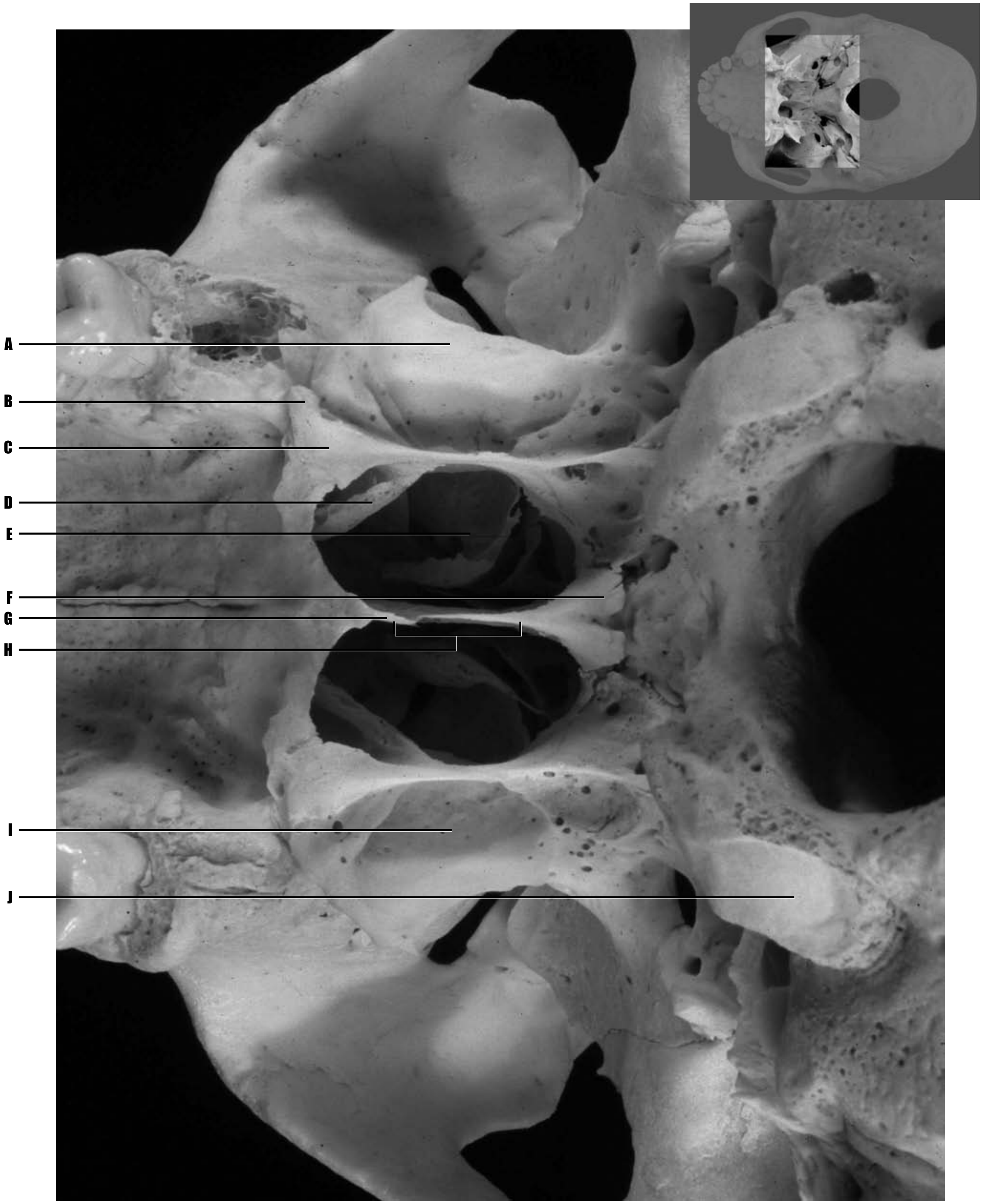


Image 2.40
Cranium, inferior view (posterior nasal aperture).

Image 2.40

A - lateral plate of pterygoid process of sphenoid bone
B - pterygoid hamulus
C - medial plate of pterygoid process of sphenoid bone
D - inferior nasal concha
E - middle nasal concha
F - ala of vomer
G - posterior nasal spine
H - perpendicular plate of vomer
I - pterygoid fossa (between medial and lateral pterygoid plates)
J - occipital condyle

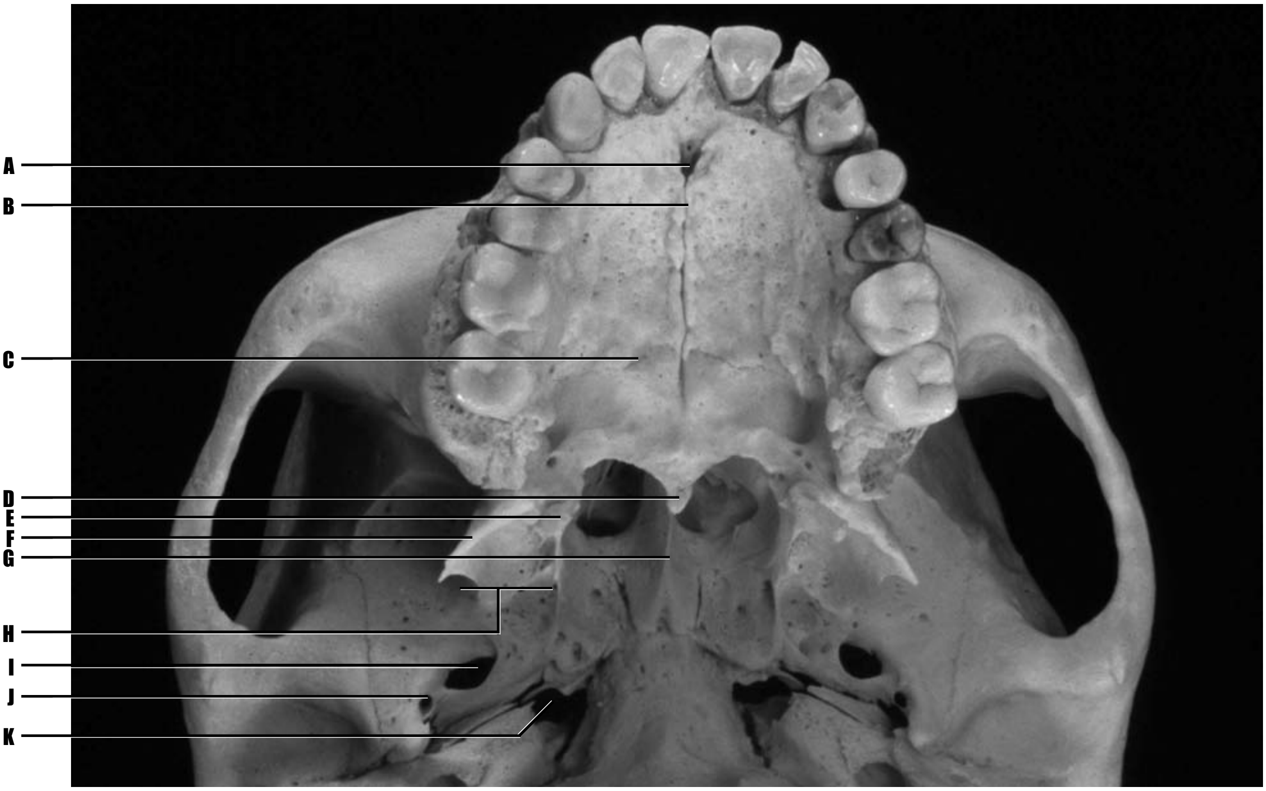


Image 2.41
Cranium, inferior view, close-up of anterior half.

A - incisive foramen

B- median palatine suture

C - transverse palatine suture

D - posterior nasal spine

E - pterygoid hamulus

F - lateral plate of pterygoid process of sphenoid bone

G - vomer

H - pterygoid fossa

I - foramen ovale

J - foramen spinosum

K - foramen lacerum

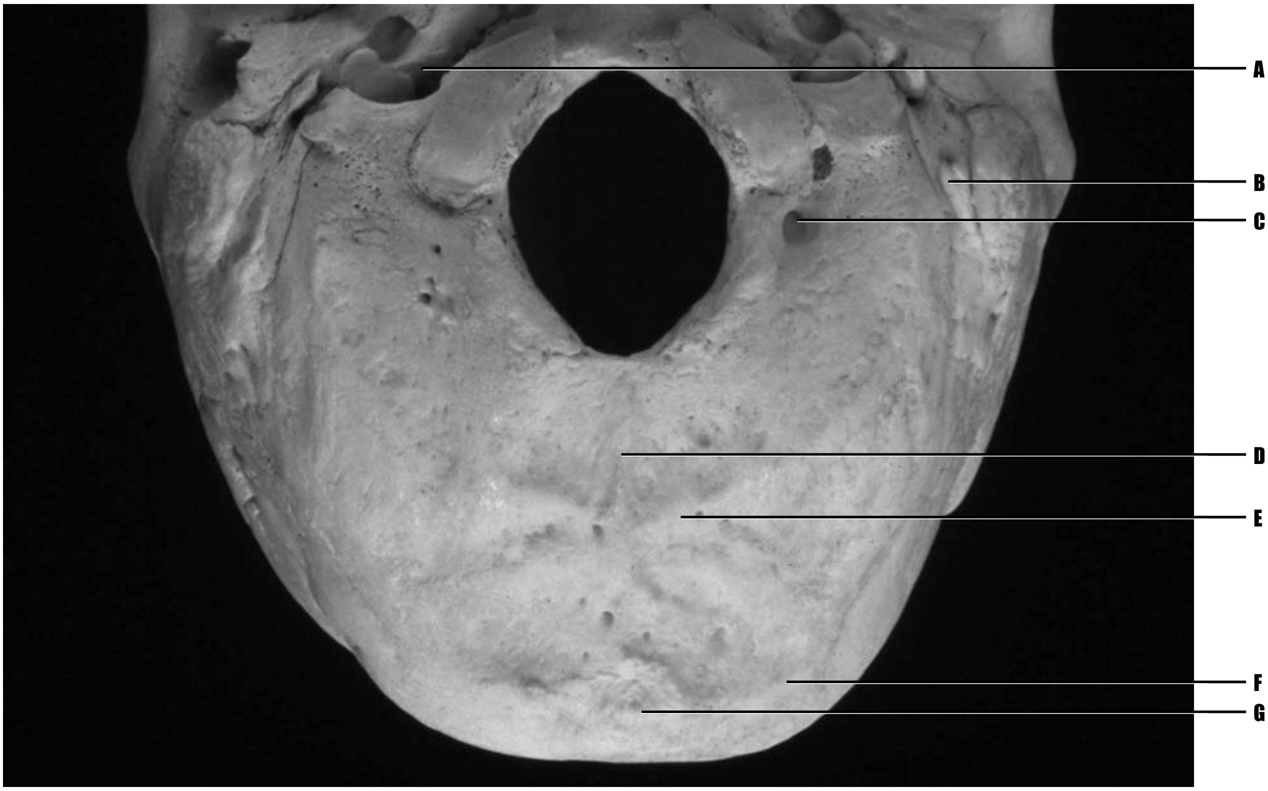


Image 2.42
Skull, inferior view, close-up of posterior half.

A - jugular foramen
B - groove for occipital artery
C - hypoglossal canal *(inconstant)*
D - external occipital crest
E - inferior nuchal line
F - superior nuchal line
G - external occipital protuberance

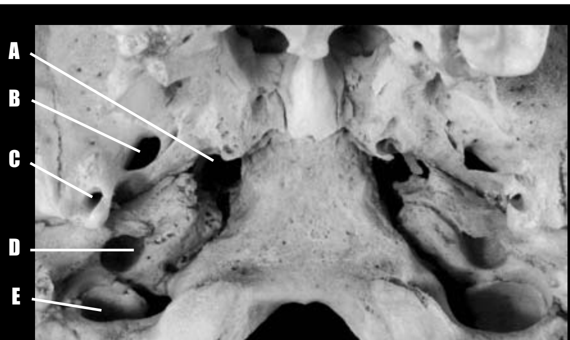


Image 2.43
Close-up of major foramina of the inferior skull.

A relatively large number of important foramina are found within a small region of the basicranium. These make beautiful questions for lab exams. Be sure that you can identify these passageways and learn what anatomical structures pass through each.

A - foramen lacerum; **B** - foramen ovale; **C** - foramen spinosum; **D** - carotid canal; **E** - jugular fossa.

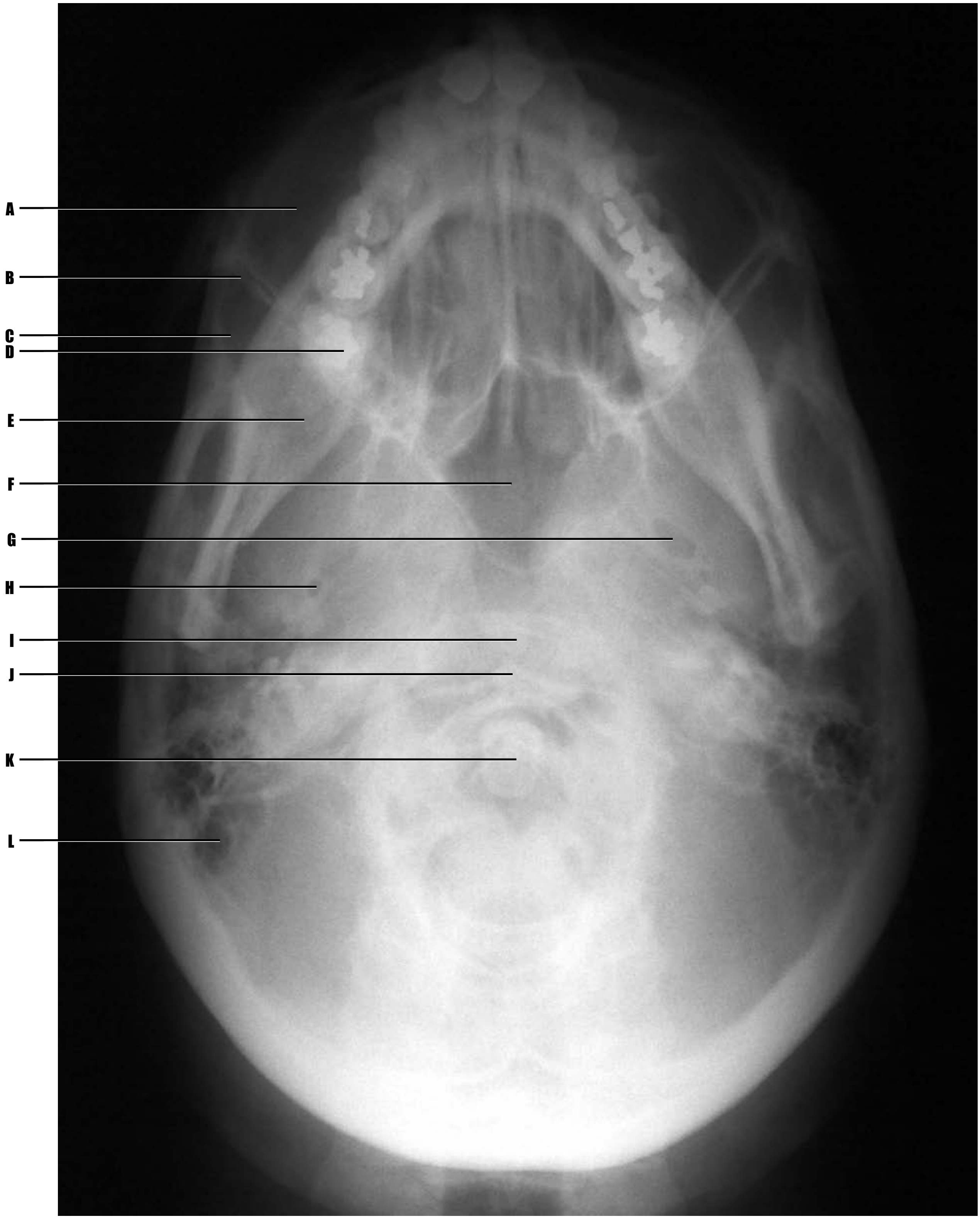


Image 2.44
Adult patient, plain film radiograph, basal view of skull.

Image 2.44

A - maxillary sinus
B - lateral wall of maxillary sinus
C - zygomatic bone
D - dental amalgam on right second molar
E - angle of mandible
F - sphenoid sinus
G - foramen ovale
H - foramen spinosum
I - clivus
J - anterior tubercle of C1 vertebra
K - dens (odontoid process) of C2 vertebra
L - mastoid air cell

Image 2.45
Adult patient, plain film radiograph, basal view of edentulous skull.

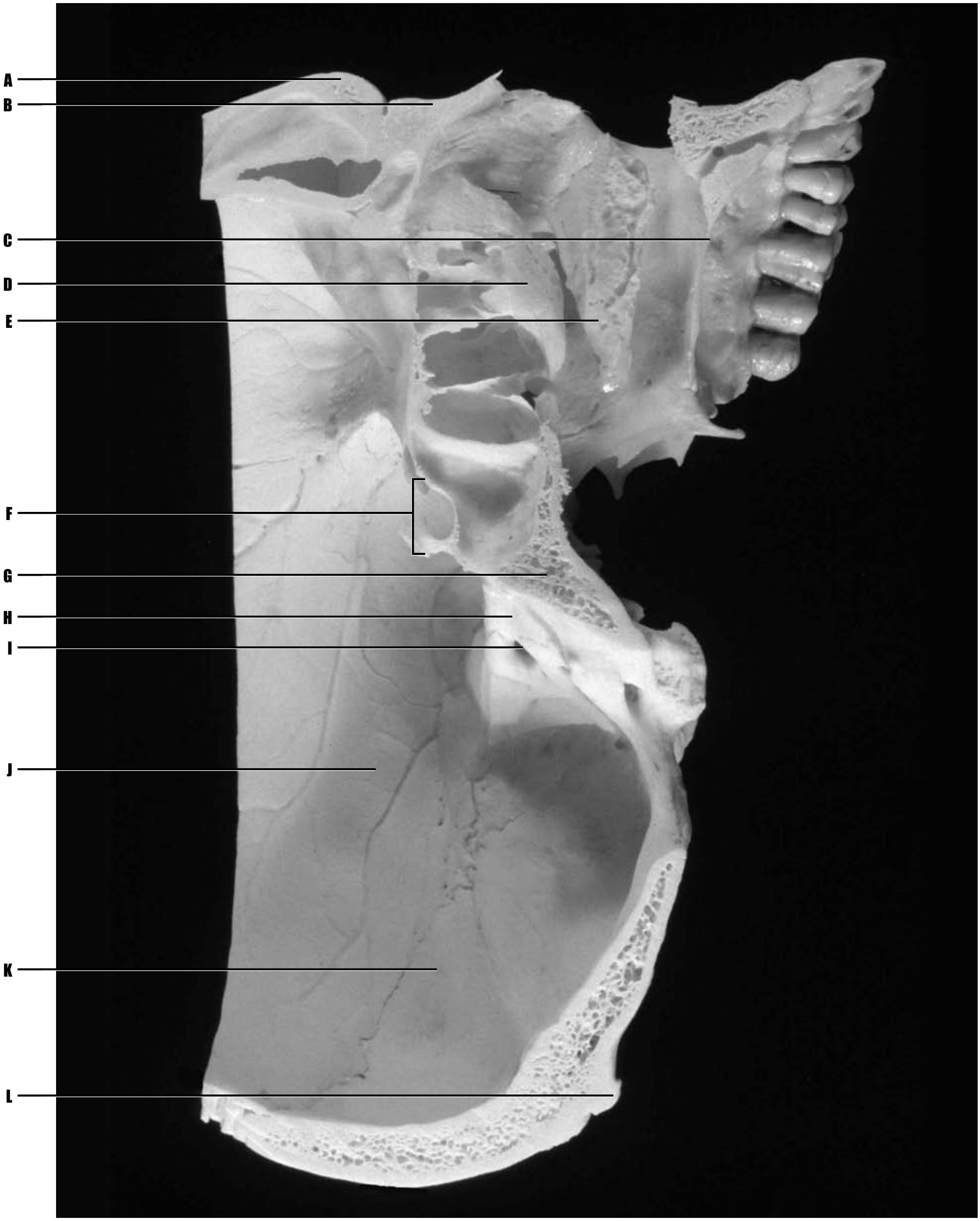


Image 2.46
Cranium, paramedian sagittal section.

Image 2.46

A - frontal bone
B - nasal bone
C - palatine process of maxilla
D- middle nasal concha
E - inferior nasal concha
F - sella turcica
G - basiocciput
H - petrous part of temporal bone
I - internal auditory meatus
J - parietal bone
K - occipital bone
L - external occipital protuberance

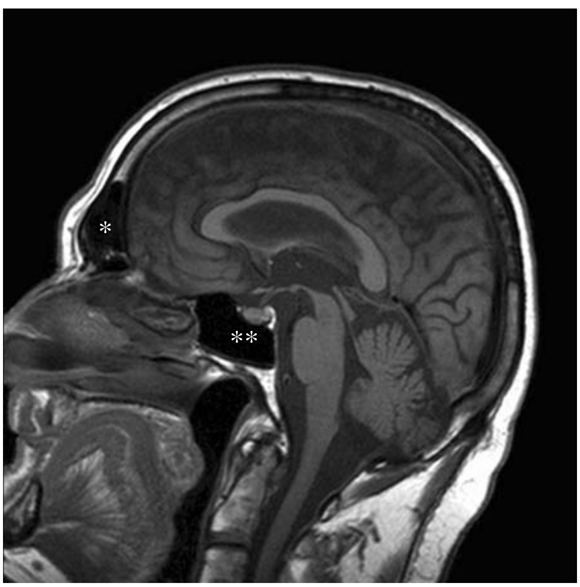
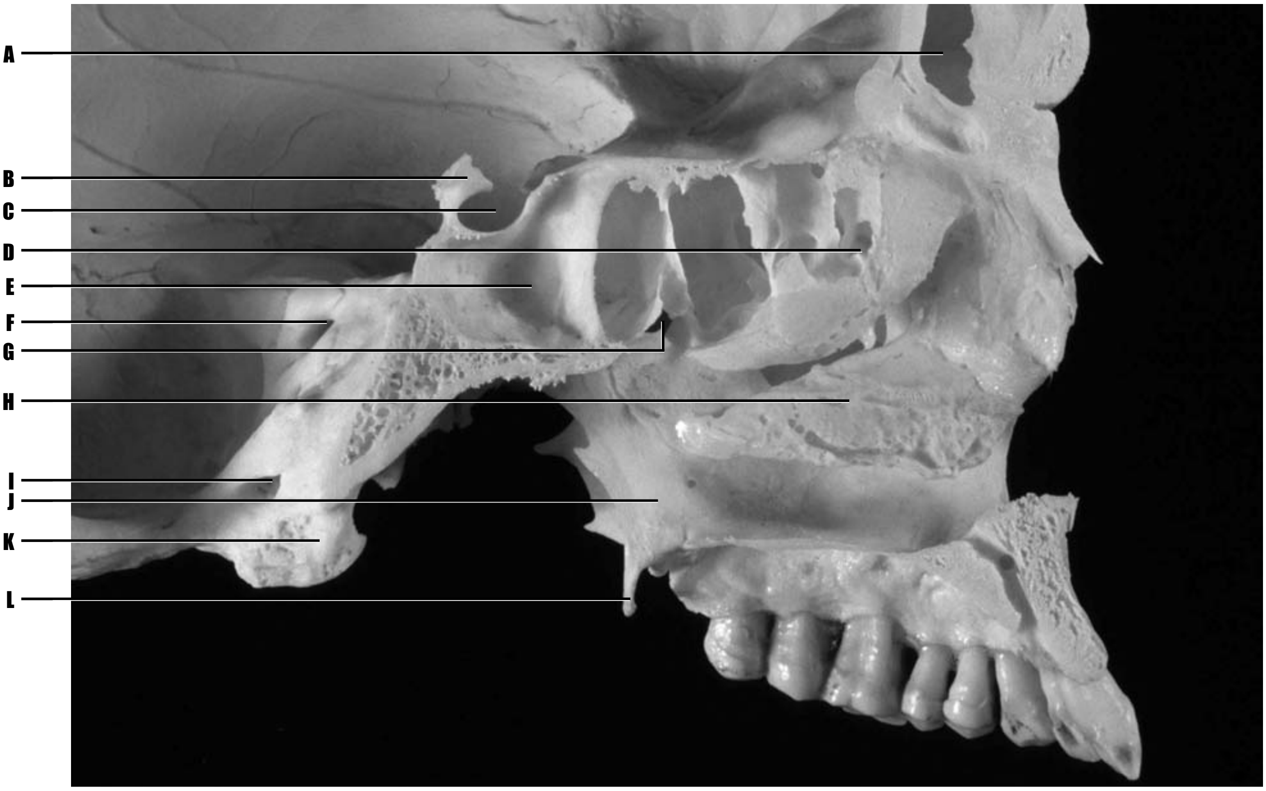


Image 2.47
Adult patient, MR sagittal section through midline of head.

We once again visit this sagittal section to provide contrast with **Image 2.46**. In this image, we can visualize the outline of the brain case (frontal, parietal and occipital bones), the framework of the sphenoid bone, including the sella turcica (resting just to the right and superior of this is the pituitary gland), and the complex anatomy of the nasal region. The frontal (*) and sphenoid (**) sinuses are indicated.



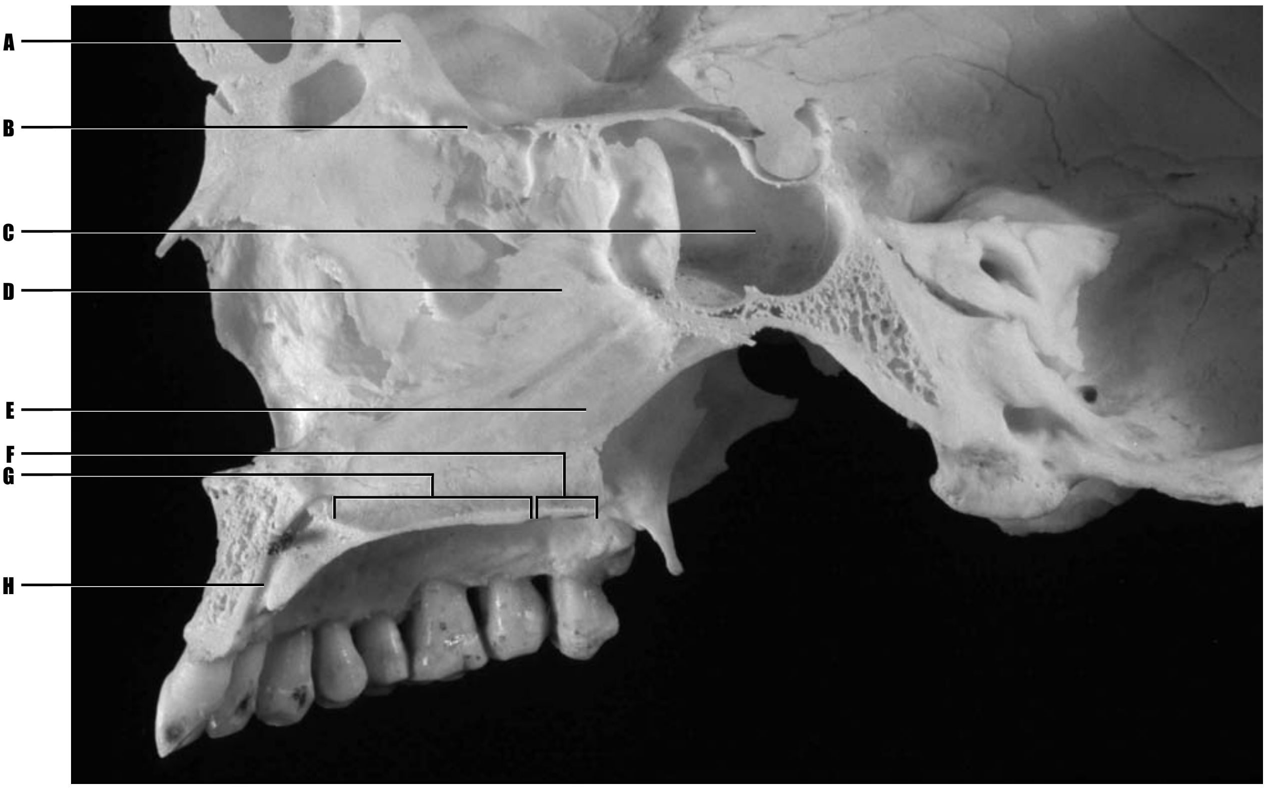


Image 2.48
Cranium, left paramedian section, close-up of nasal region.
Image 2.49
Cranium, right paramedian sagittal section with intact vomer, close-up of nasal region.

Image 2.48

A - frontal air sinus
B - dorsum sellae
C - pituitary fossa
D - ethmoidal air cells
E - sphenoid sinus
F - internal auditory meatus
G - sphenopalatine foramen
H - inferior nasal concha
I - condylar canal
J - medial pterygoid plate of sphenoid bone
K - occipital condyle
L - pterygoid hamulus

Image 2.49

A - crista galli
B - cribriform plate
C - sphenoid sinus
D - perpendicular plate of ethmoid bone
E - vomer
F - horizontal process of palatine bone
G - palatine process of maxilla
H - incisive canal

2.1a FRONTAL BONE

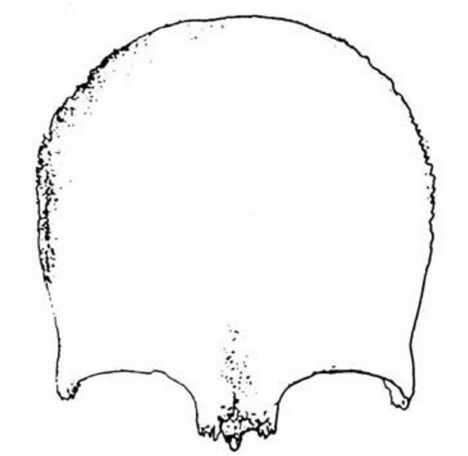


Image 2.50 • *Frontal bone, anterior (facial) view.*

- unpaired bone
- forms the forehead, upper part of the orbits (eye sockets), and much of the anterior cranial fossa (for the anteriormost part of the brain)
- it may be divided in two (down the midline) by a persistent metopic suture
- most adult specimens contain a large sinus cavity
  - note that large sinuses are found only in the frontal, maxilla, and sphenoid bones
- articulates with the parietal, zygomatic, sphenoid, maxilla, ethmoid, nasal and lacrimal bones

Landmarks

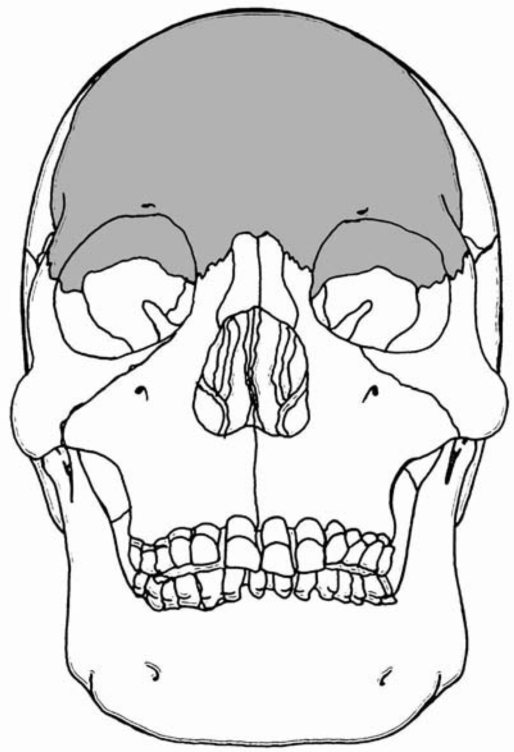
- articular surface for parietal bones (along coronal suture)
- articular surface for sphenoid bone (along frontosphenoidal suture)
- articular surface for zygomatic bone (along zygomaticofrontal suture)
- articular surface for ethmoid bone (along fronto-ethmoidal suture)
- articular surface for nasal bones (along nasofrontal suture)
- frontal eminence
- superciliary arch
- glabella
- supraorbital notch/foramen
- fossa for lacrimal gland
- orbital surface of frontal bone
- nasal spine
- groove for superior sagittal sinus
- frontal crest
- ethmoidal notch

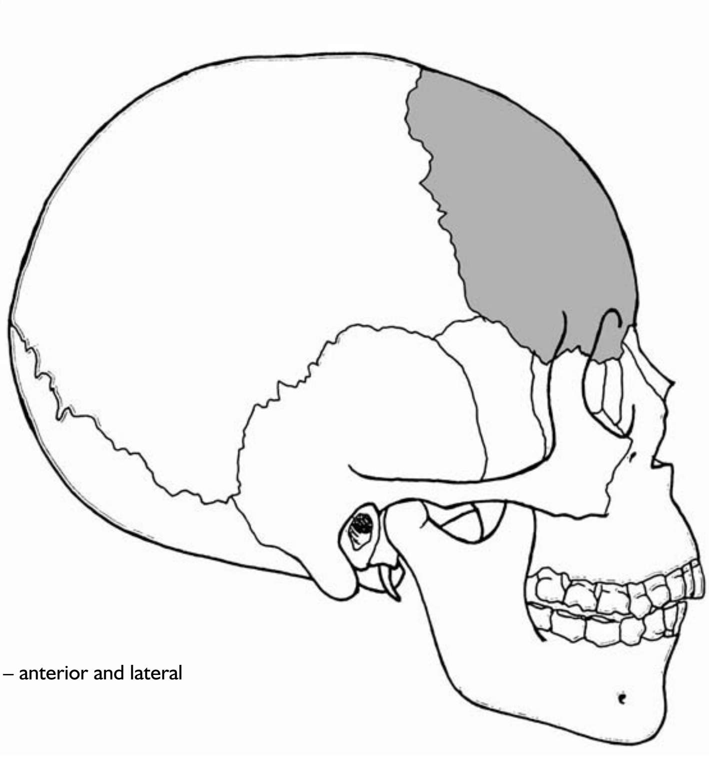
Looking at Fragments

- the coronal suture is at the posterior margin of this bone, and it runs toward the face (anterolaterally)
  - pay attention to the orientation of the bony interdigitations of the coronal suture as they seem to project from the inner table along the length of this suture, except for within one or two centimeters of bregma, where they project from the outer table
- temporal lines are on the outer (ectocranial) surface of the skull
  - these lines run on the lateral cranial surface toward the face, cross the coronal suture, and blend into the zygomatic process of the frontal bone
- many of the cranial bones could be confused with fragmented frontal bone, but:
  - undulations of the orbital shelf are characteristic of the frontal bone
  - vascular grooves are more prominent in the temporal, parietal and occipital bones
  - fragments of a large sinus cavity limit your range of possibilities to frontal, maxilla and sphenoid bones

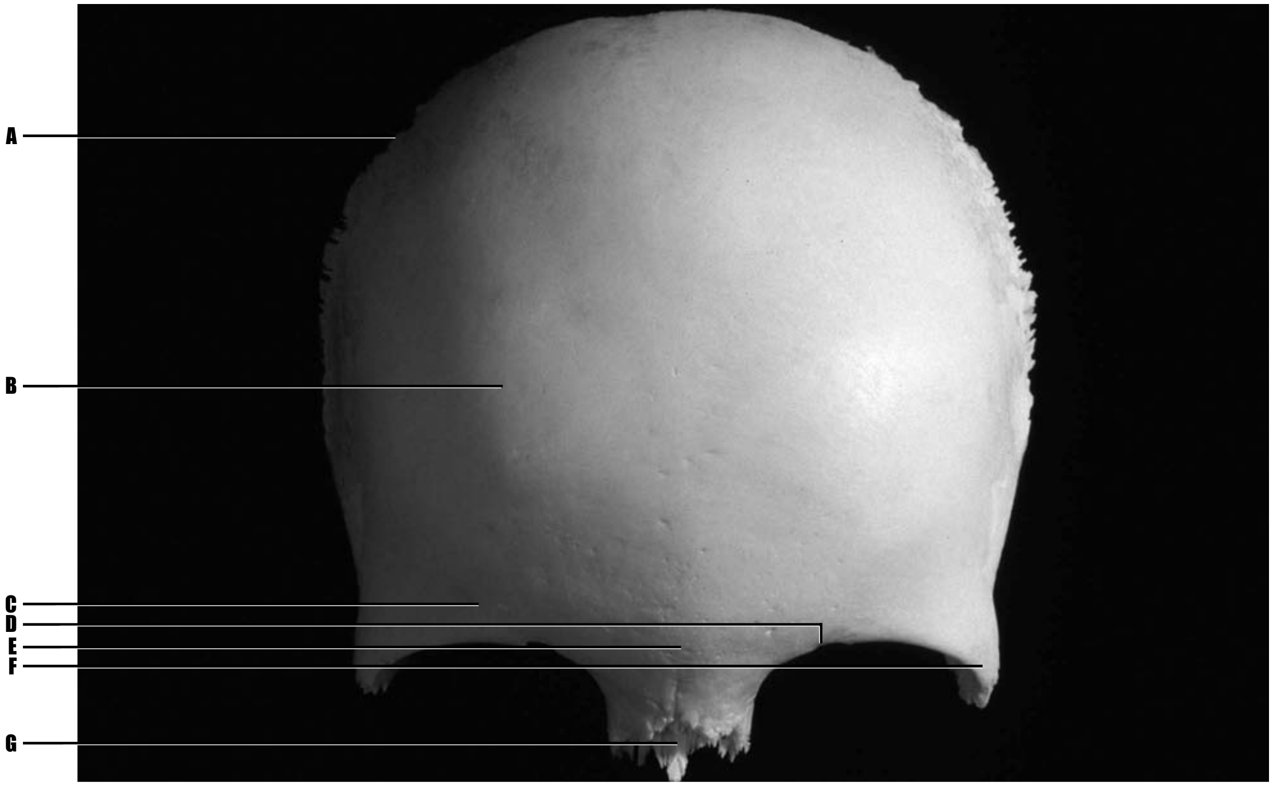
Looking at Fragments continued

- in the postcranial skeleton, fragmented scapula and innominate (thin portions of iliac wing) may also be confused with the frontal bone, as they both have broad, flat surfaces; fragmented acetabulum may resemble the superior orbit, however, the acetabulum is generally far more robust





Images 2.51 (left) and 2.52 (right)
Illustrations demonstrating the **frontal bone** *in situ* – anterior and lateral views respectively.



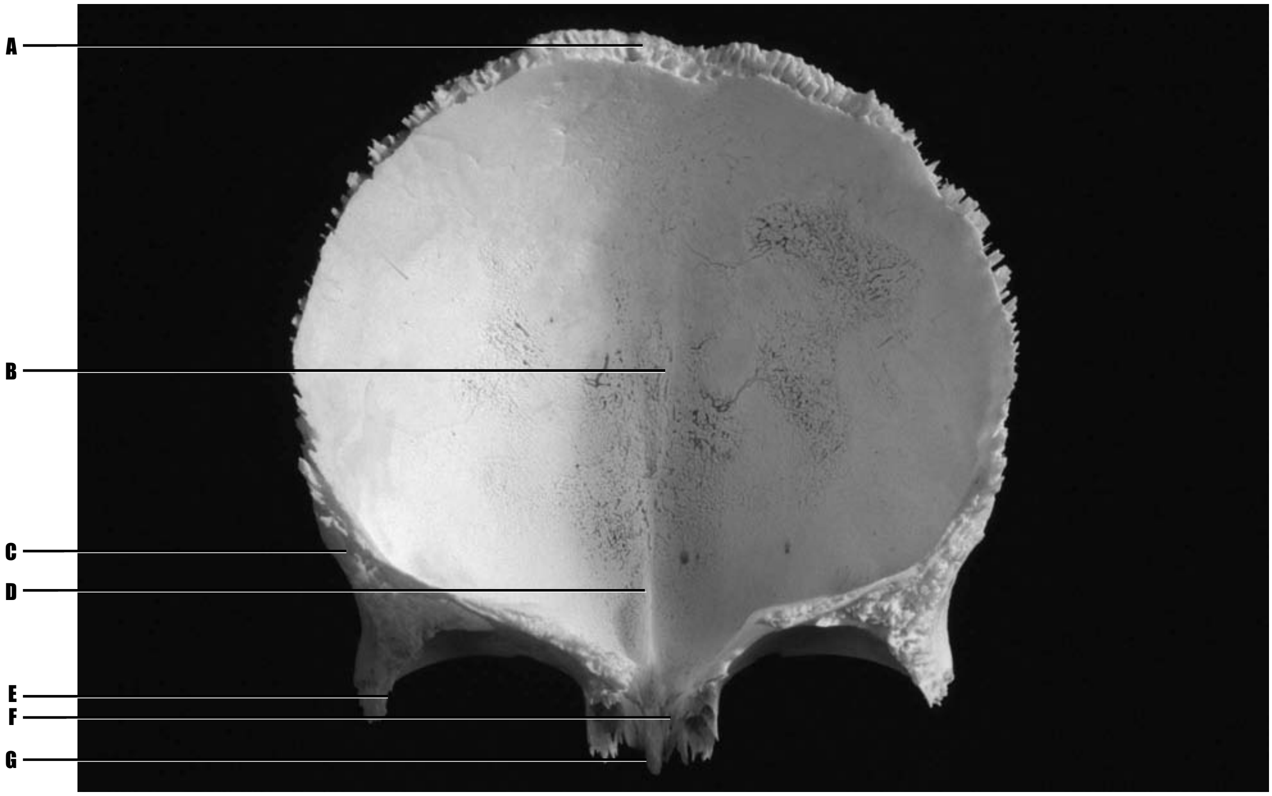


Image 2.53 (above)

Disarticulated juvenile frontal bone, anterior view.

Image 2.54 (below)

Disarticulated juvenile frontal bone, posterior view.

Image 2.53

A - articular surface for parietal bone
(along coronal suture)

B - frontal eminence

C - superciliary arch

D - supraorbital notch

E - glabella

F - zygomatic process of frontal bone

G - articular surface for nasal bones

Image 2.54

A - articular surface for parietal bones

B - groove for superior sagittal sinus

C- articular surface for sphenoid bone
(along frontosphenoidal suture)

D - frontal crest

E - articular surface for zygomatic bone
(along zygomaticofrontal suture)

F - articular surface for ethmoid bone
(along fronto-ethmoidal suture)

G - articular surface for nasal bones

Image 2.55

A - supraorbital notch

B - fossa for lacrimal gland (very shallow in most specimens)

C - orbital surface of frontal bone

D - ethmoidal notch

E - articular surface for sphenoid bone

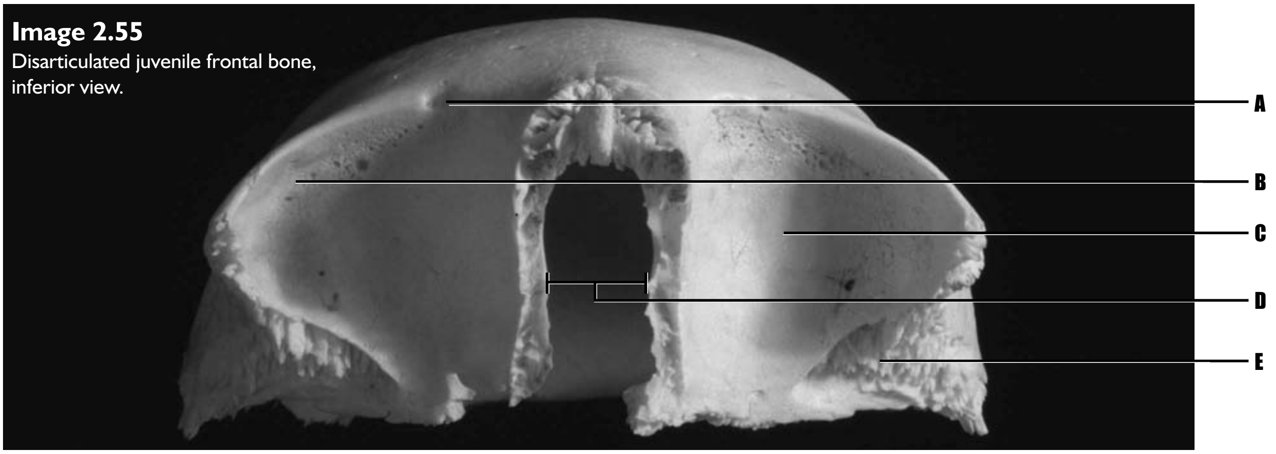


Image 2.55
Disarticulated juvenile frontal bone, inferior view.

2.1b PARIETAL BONE

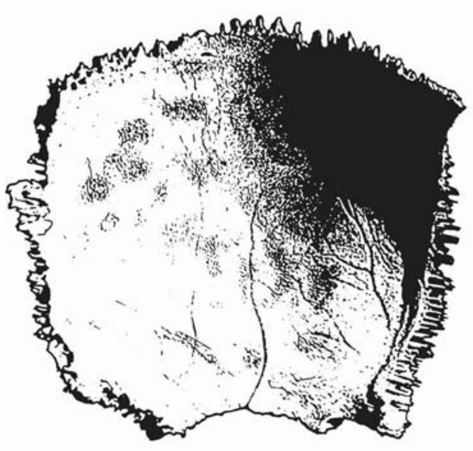


Image 2.56 • *Parietal bone, left, intracranial view.*

- paired bone
- forms most of the lateral and superior brain case
- the intracranial surface may be lined with grooves for branches of meningeal blood vessels (middle meningeal artery), as well as small, rounded pits (granular foveolae) which house outpouchings (arachnoid granulations) from the protective covering of the brain (the meninges)
- one or more parietal foramina may be found toward the posteromedial ectocranial aspect of the parietal bones (located just lateral to the sagittal suture)
- each articulates with the frontal, occipital, temporal and sphenoid bones, and the opposing parietal bone

Landmarks

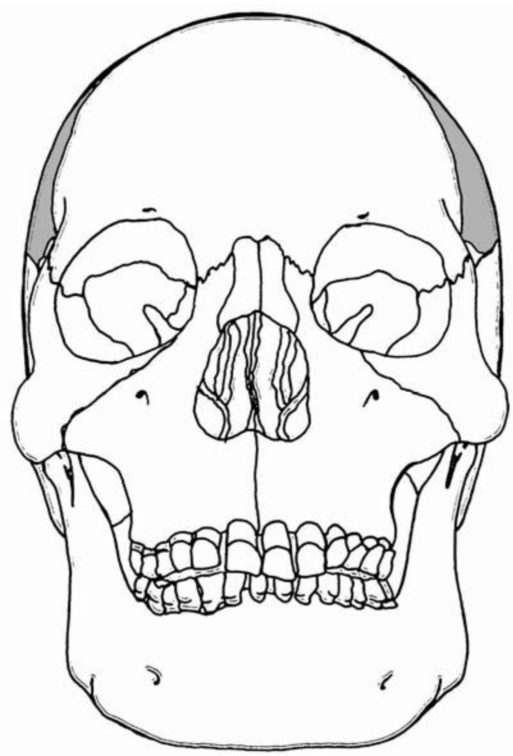
- articular surface for right parietal bone (along sagittal suture)
- articular surface for frontal bone (along coronal suture)
- articular surface for occipital bone (along lambdoidal suture)
- articular surface for temporal bone (along squamosal suture)
- articular surface for sphenoid bone (along sphenoparietal suture)
- parietal eminence
- parietal notch
- groove for superior sagittal sinus
- groove for branch of middle meningeal artery

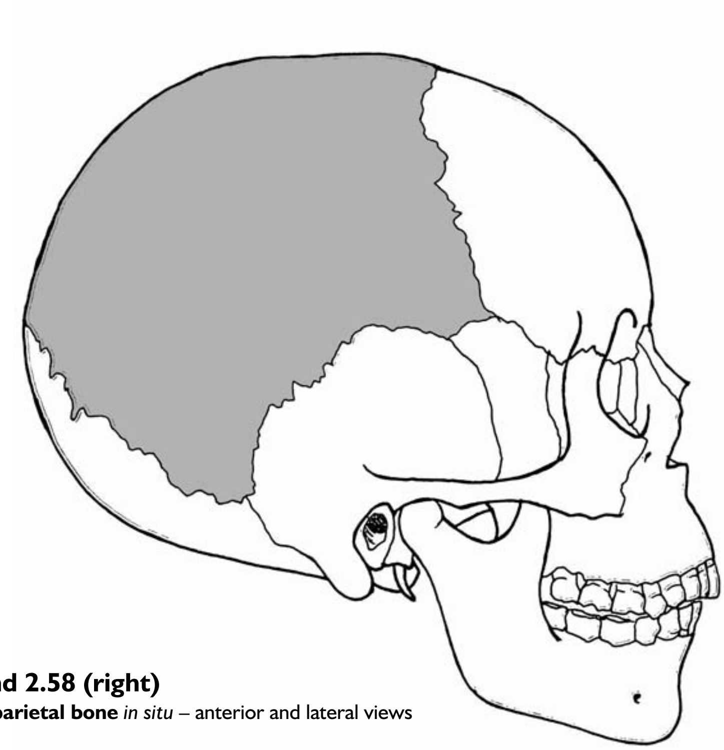
Differentiating Right from Left

- place the subtly concave frontal margin away from you and the convex posterior margin toward you
- now, the ectocranial surface of the bone points toward the side on which the bone belongs

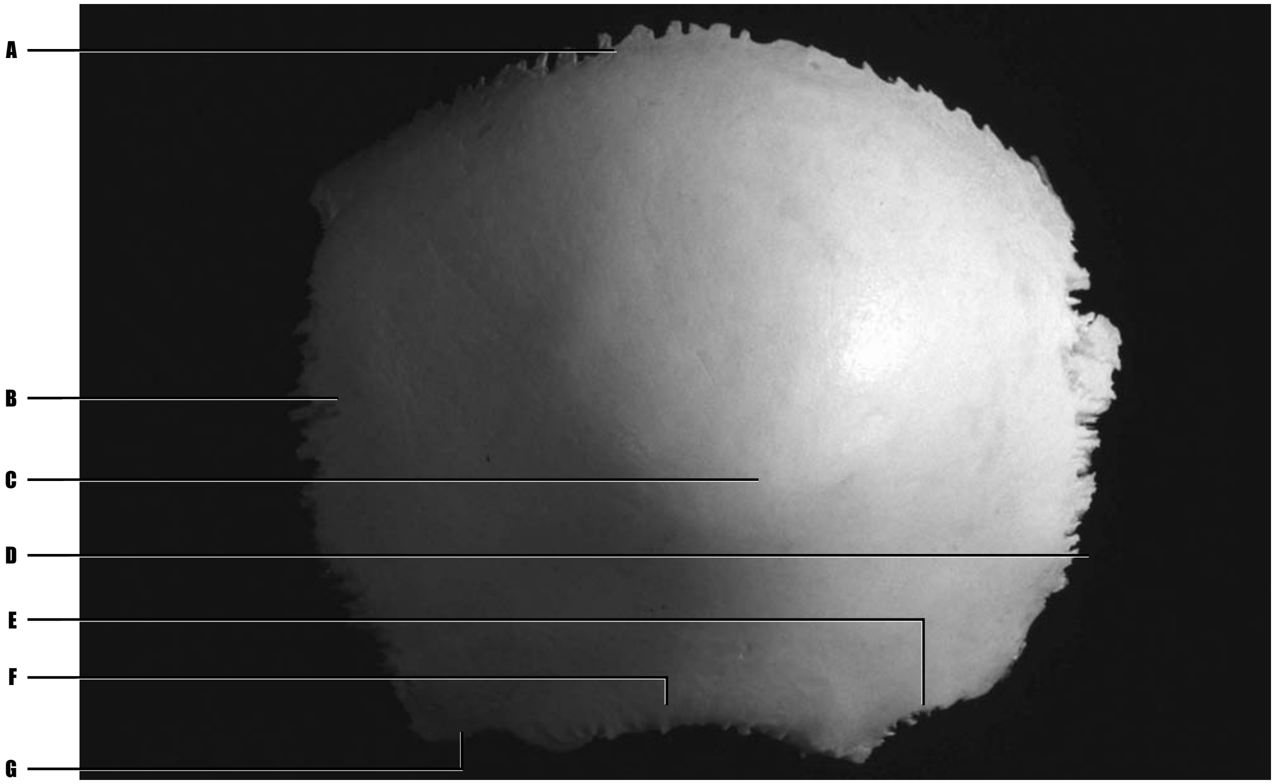
Looking at Fragments

- fragments of flat cranial bones, iliac wing or scapula might be misinterpreted as parietal bone
- one should look for features typical of the parietal bones such as granular foveolae, prominent vascular grooves, and striae radiating from the externally bevelled squamosal suture
  - the vascular grooves run somewhat obliquely toward the posterior aspect of this bone; they are progressively less prominent further away from the coronal suture
  - the ectocranial portion of the squamosal suture (along the inferior margin of the parietal bone) is externally bevelled, and bears fine grooves or striations that point posterosuperiorly
- temporal lines course across the length of the parietal bones in an arc-like fashion; they vary quite markedly in prominence *(see page 31)*





Images 2.57 (left) and 2.58 (right)
Illustrations demonstrating **parietal bone** *in situ* – anterior and lateral views respectively.



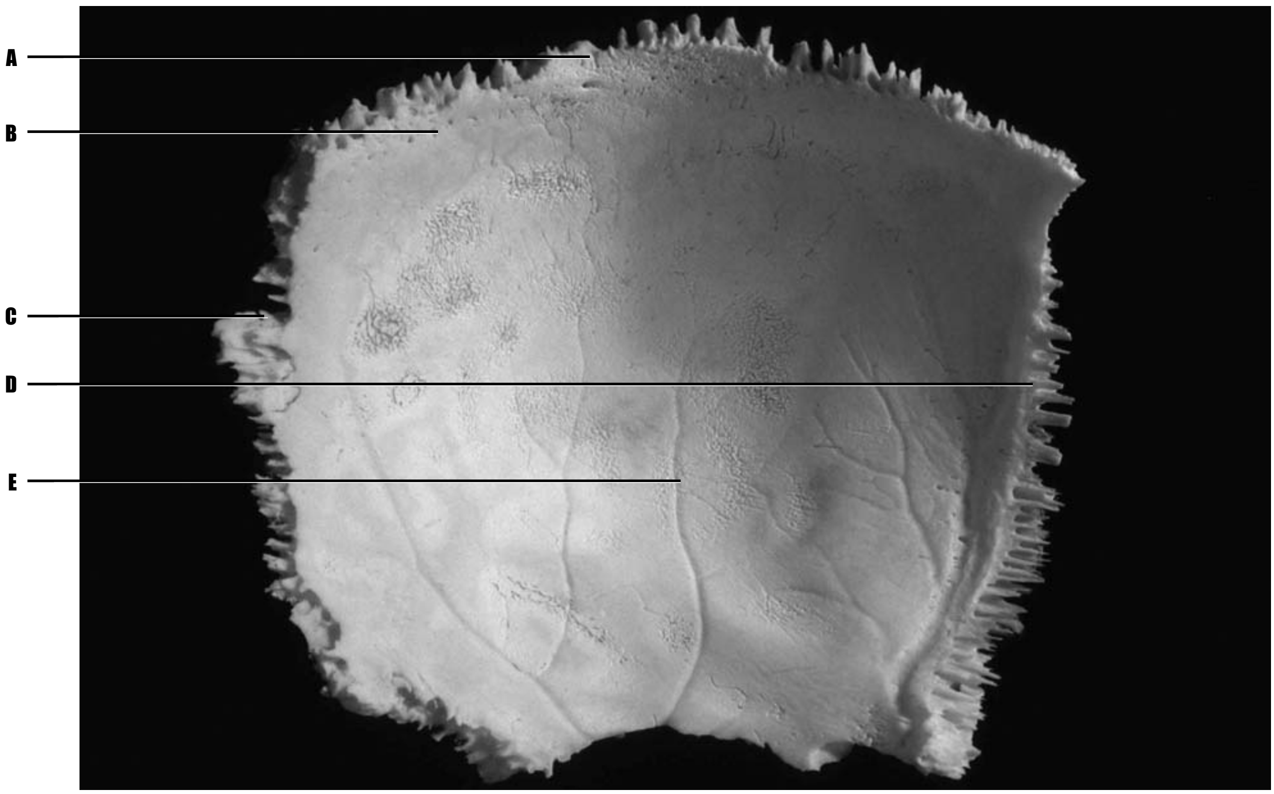


Image 2.59 (above)

Disarticulated juvenile parietal bone, left, external (ectocranial) view.

Image 2.60 (below)

Disarticulated juvenile parietal bone, left, internal (intracranial) view.

Image 2.59

A - articular surface for right parietal bone
(along sagittal suture)

B - articular surface for frontal bone
(along coronal suture)

C - parietal eminence

D - articular surface for occipital bone
(along lambdoidal suture)

E - parietal notch

F - articular surface for temporal bone
(along squamosal suture)

G - articular surface for sphenoid bone
(along sphenotemporal suture)

Image 2.60

A - articular surface for right parietal bone

B - groove for superior sagittal sinus

C - articular surface for occipital bone

D - articular surface for frontal bone

E - groove for branch of middle meningeal artery

2.1c TEMPORAL BONE

Image 2.61 • *Temporal bone, left, ectocranial view.*

- paired bone
- forms part of the lateral and basilar skull
- contains the very small bones of the inner ear, and other complex bony structures of hearing and equilibrium
- has three main parts – squamous (thin), mastoid process, and petrous (dense) part
  - the squamous part is vertically oriented, and forms part of the inferolateral skull; the zygomatic process of the temporal bone is part of the squamous temporal
  - the mastoid process is a robust antero-inferiorly projecting landmark that serves as an attachment for the sternocleidomastoid muscles of the neck
  - the petrous portion is actually part of the brain case – it divides the middle and posterior cranial fossae
  - the petrous portion also contains the inner ear
- each temporal bone articulates with zygomatic, sphenoid, parietal, and occipital bones, along with the mandible

Landmarks

- articular surface for parietal bone (along squamosal suture)
- articular surface for zygomatic bone (along zygomaticotemporal suture)
- articular surface for sphenoid bone (along sphenotemporal suture)
- articular surface for occipital bone (along occipitomastoid suture)
- squamous part of temporal bone
- postglenoid tubercle
- zygomatic process
- articular tubercle
- mandibular fossa
- tympanic part of temporal bone
- suprameatal triangle
- styloid process
- mastoid process
- arcuate eminence
- groove for sigmoid sinus
- apex of petrous temporal bone
- internal auditory meatus
- petrous part of temporal bone
- carotid canal
- occipital groove
- tegmen tympani

Differentiating Right from Left

- with an intact specimen, point the zygomatic process away from you, and the mastoid process toward the ground
- now, the ectocranial surface of the bone points toward the same side as that to which the bone belongs

Looking at Fragments

- squamous temporal bone is the thinnest portion of the brain case (excluding orbital shelf)
- the portion of the squamous temporal that articulates with its opposing parietal bone has a bevelled edge along its medial surface
  - along this bevelled edge are multiple thin grooves or striations which run postero-inferiorly
- the intracranial surface of the squamous temporal bone has vascular grooves that run superiorly and posteriorly
- fragments of zygomatic arch may be confused with fragments of hyoid bone, vertebral laminae, mandibular coronoid process, etc.
  - zygomatic arch fragments will be thin, the superior edge will be sharper than the dull inferior edge, and proximal fragments of the temporal part of the zygomatic process are typically more robust, and progressively widened toward the articular tubercle
- the mastoid process is a distinctive structure
  - fragmented mastoid process will show a honeycomb appearance due to the presence of hundreds of mastoid air cells
  - the longest free edge of a mastoid fragment will be the lateral surface

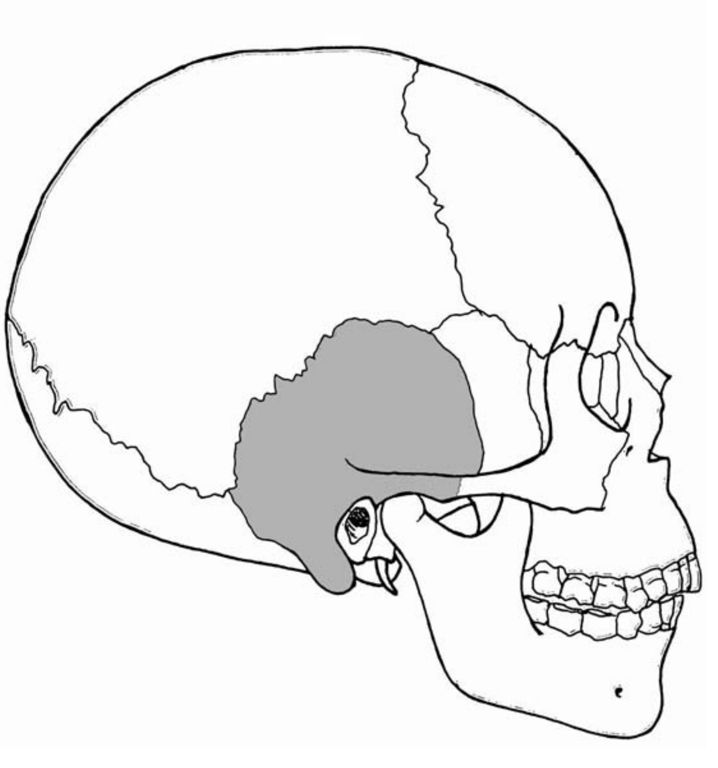
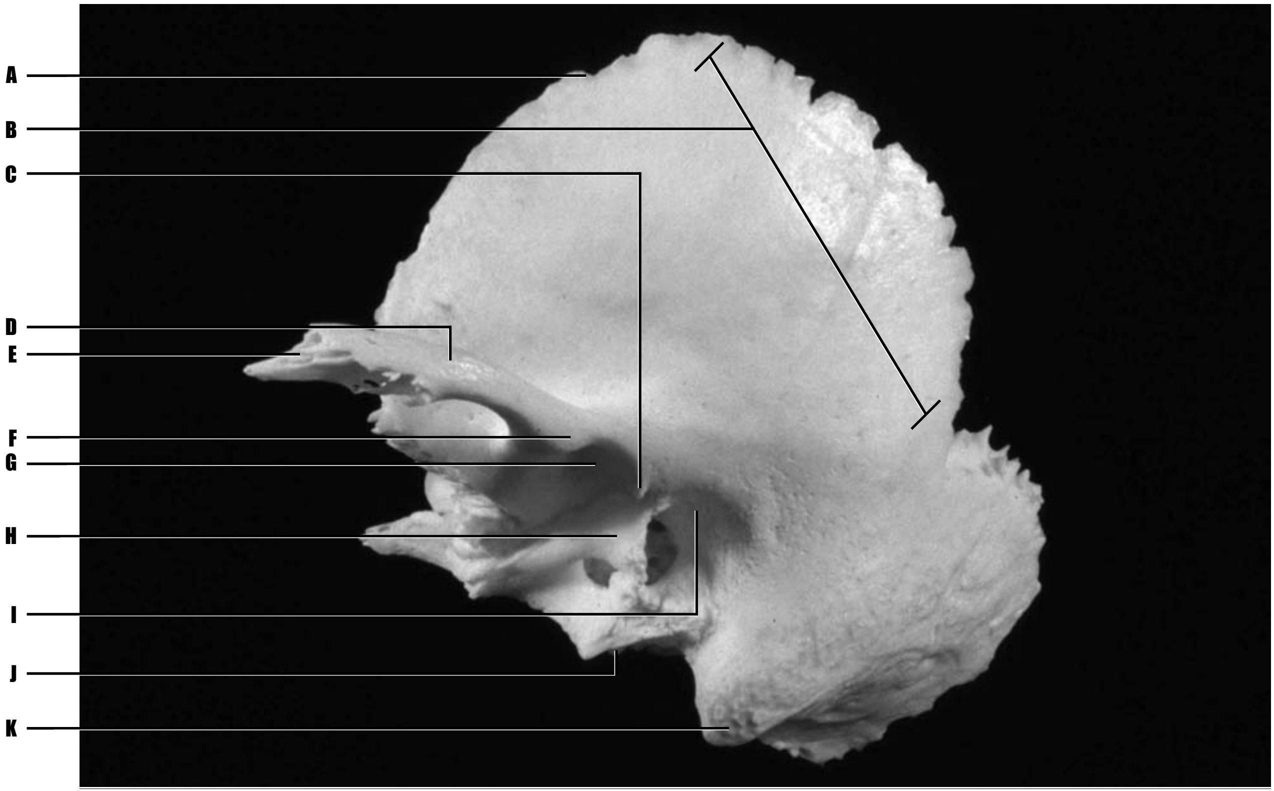


Image 2.62
Illustration demonstrating **temporal bone** in situ – lateral view.



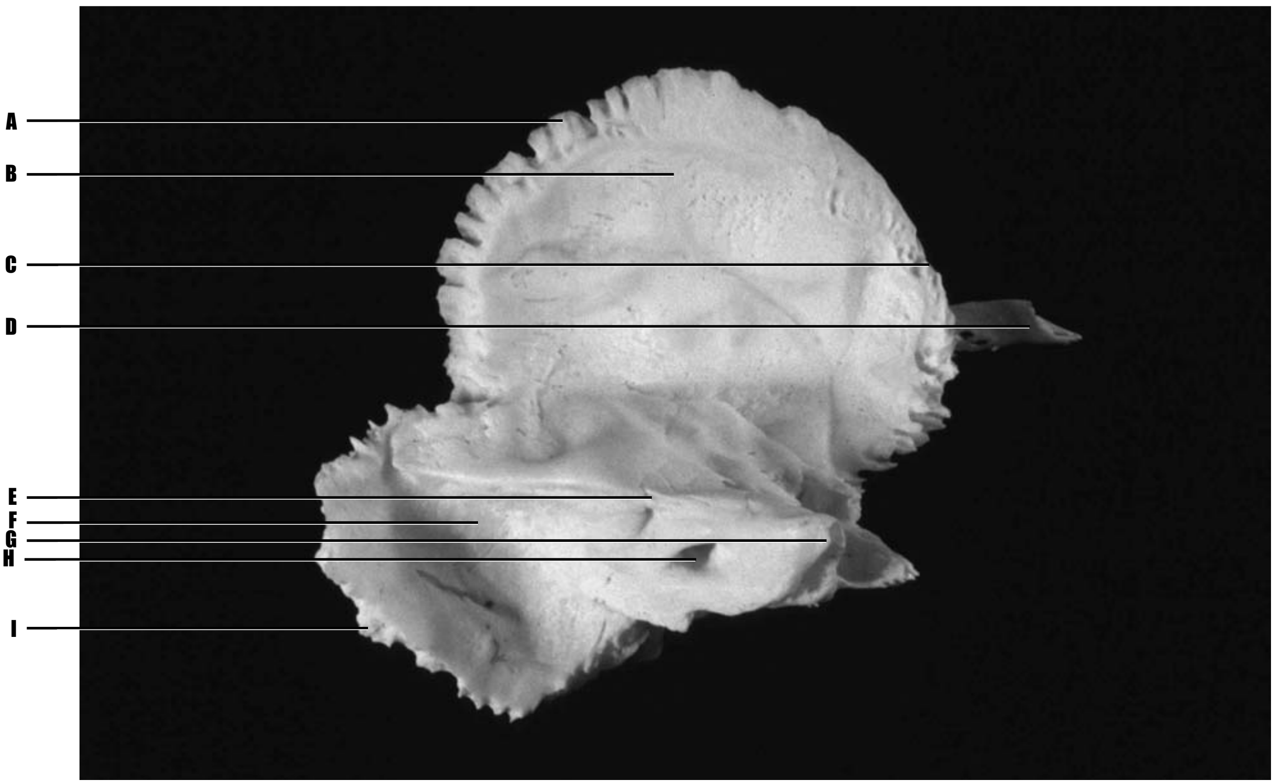


Image 2.63 (above)

Disarticulated juvenile temporal bone, left, external view.

Image 2.64 (below)

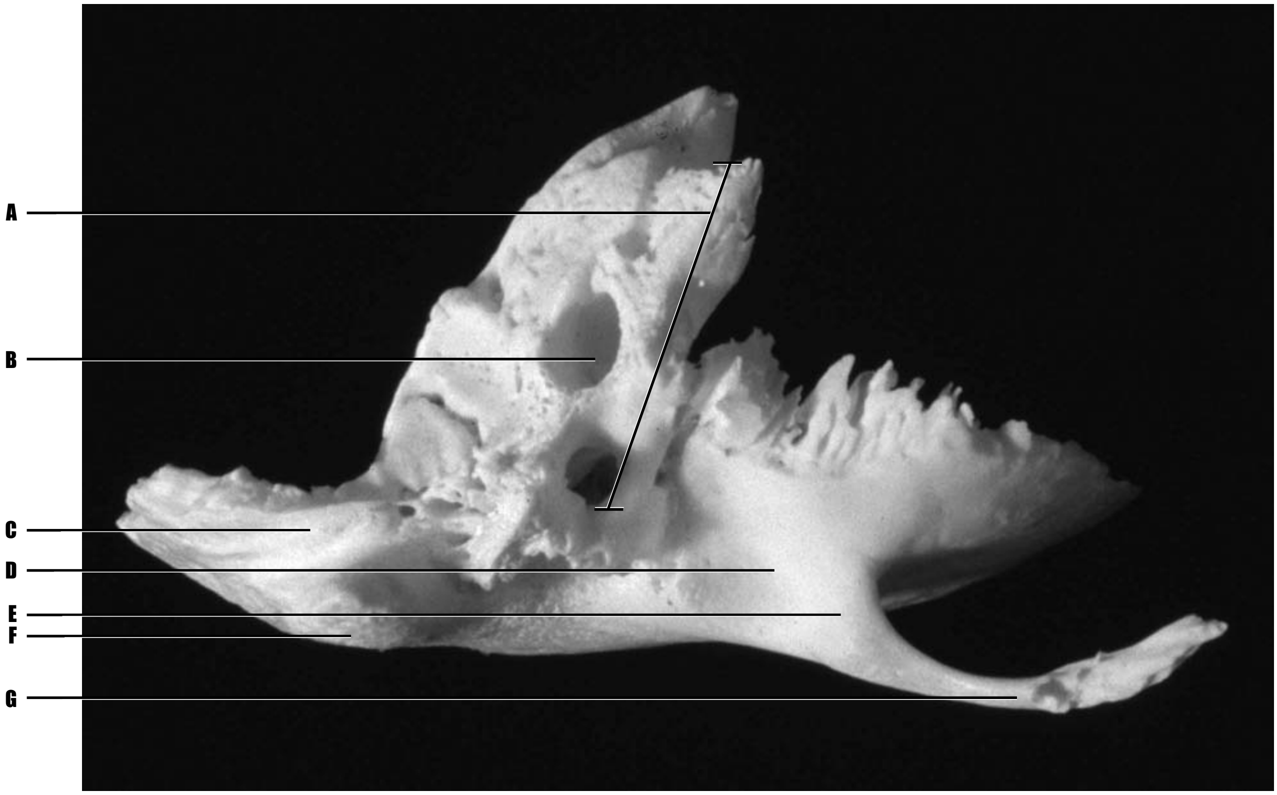
Disarticulated juvenile temporal bone, left, internal view.

Image 2.63

A - articular surface for left parietal bone
(along squamosal suture)
B - squamous part of temporal bone
C - postglenoid tubercle
D - zygomatic process of temporal bone
E - articular surface for zygomatic bone
(along the zygomaticotemporal suture)
F - articular tubercle
G - mandibular fossa
H - tympanic part of temporal bone
I - suprameatal triangle
J - styloid process (very small, and almost hidden in this specimen)
K - mastoid process

Image 2.64

A - articular surface for left parietal bone
B - squamous part of temporal bone
C - articular surface for sphenoid bone
(along sphenotemporal suture)
D - zygomatic part of temporal bone
E - arcuate eminence
F - groove for sigmoid sinus
G - apex of petrous temporal bone
H - internal auditory meatus
I - articular surface for occipital bone
(along occipitomastoid suture)



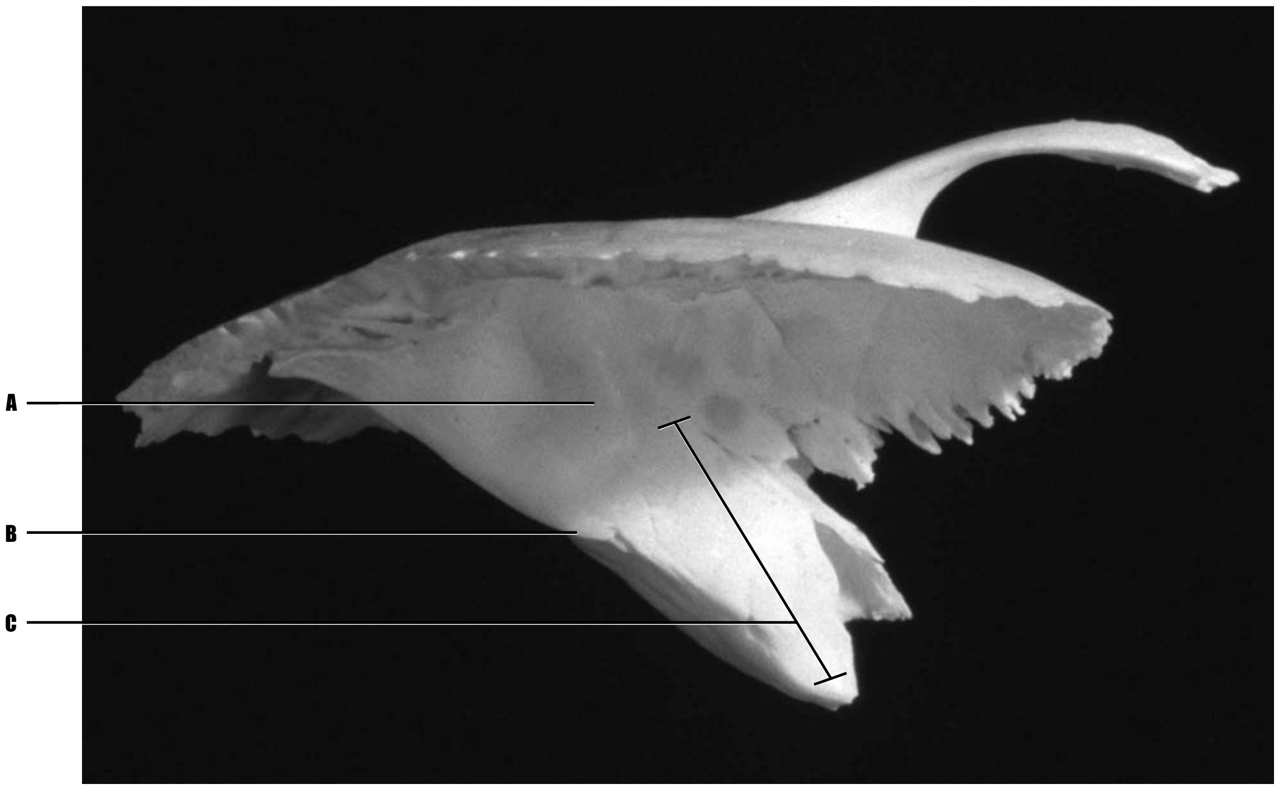


Image 2.65 (above)

Disarticulated juvenile temporal bone, left, inferior view.

Image 2.66 (below)

Disarticulated juvenile temporal bone, left, superior view.

Image 2.65

A - petrous portion
B - carotid canal
C - occipital groove
D - mandibular fossa
E - articular tubercle
F - mastoid process
G - zygomatic process

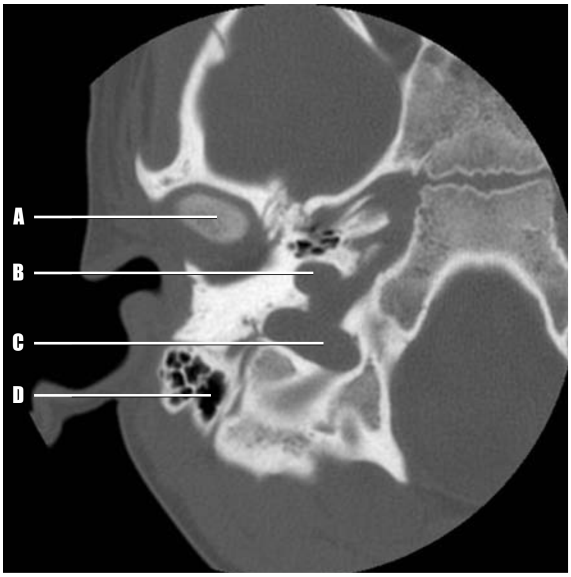
Image 2.66

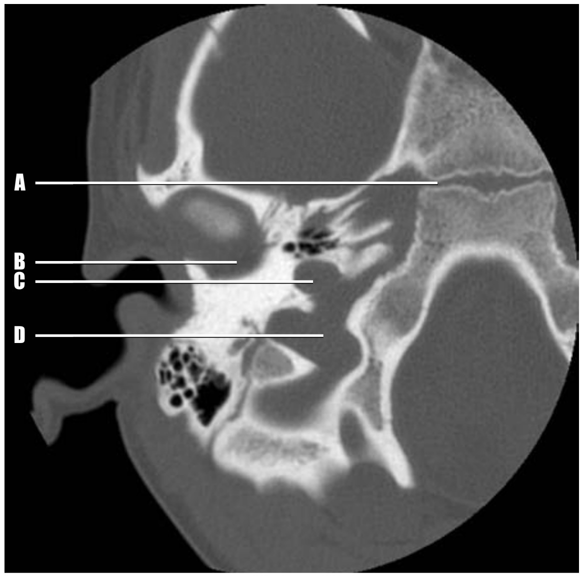
A - tegmen tympani
B - arcuate eminence
C - petrous portion

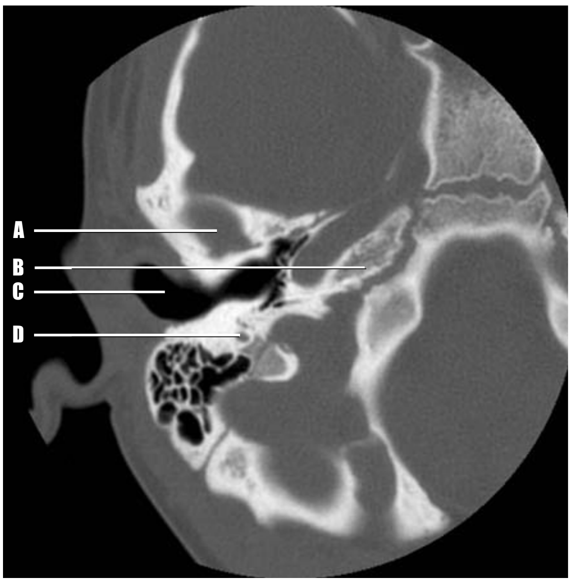
Image 2.67

Auditory ossicles, left.

Previous pages have demonstrated the bony structures associated with the external ear. Although we will not cover other ear structures, such as the semicircular canals, we believe that it is important to briefly display the morphology of the auditory ossicles, the *malleus* (A), *incus* (B) and *stapes* (C), as they may be present individually when non-intact cranial remains are located. Each of these bones play an important role in transferring sound in the form of vibrations from the environment into the inner ear.







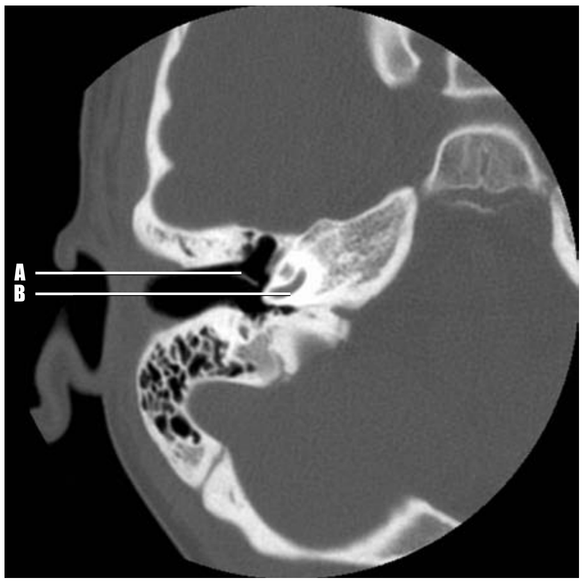


Image 2.68 (above)
Adult patient, horizontal CT scan of temporal bone.

Image 2.70 (below)
Adult patient, horizontal CT scan of temporal bone. Note, this image is immediately superior to the preceding image.

Image 2.69 (above)
Adult patient, horizontal CT scan of temporal bone. Note, this image is immediately superior to the preceding image.

Image 2.71 (below)
Adult patient, horizontal CT scan of temporal bone. Note, this image is immediately superior to the preceding image.

Image 2.68

A - head of mandible
B - carotid canal
C - jugular canal
D - mastoid air cells

Image 2.69

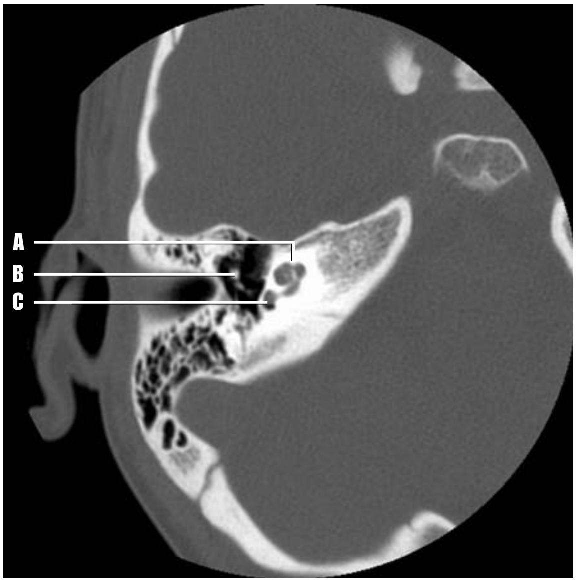
A - spheno-occipital synchondrosis
B - temporomandibular fossa
C - carotid canal
D - jugular canal

Image 2.70

A - temporomandibular fossa
B - apex of petrous temporal bone
C - external auditory/acoustic meatus
D - facial nerve canal

Image 2.71

A - long process of malleus
B - cochlear elements



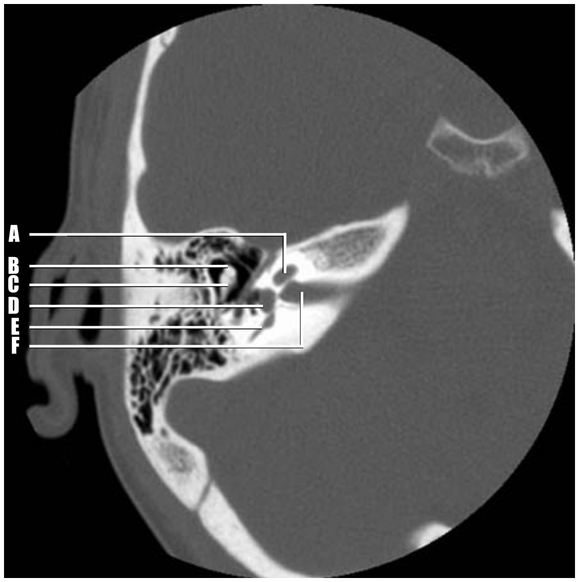


Image 2.72 (above)

Adult patient, horizontal CT scan of temporal bone.

Image 2.73 (above right)

Adult patient, horizontal CT scan of temporal bone. Note, this image is immediately superior to the preceding image.

Image 2.74 (right)

Adult patient, horizontal CT scan of temporal bone. Note, this image is immediately superior to the preceding image.

Image 2.72

A - cochlear elements
B - malleus
C - vestibule of cochlea

Image 2.73

A - cochlea
B - malleus
C - incus
D - posterior semicircular canal
E - vestibule of cochlea
F - internal auditory canal

Image 2.74

A - epitympanum
B - lateral semicircular canal
C - superior semicircular canal
D - posterior semicircular canal

2.1d OCCIPITAL BONE

Image 2.75 • *Occipital bone, oblique right lateral view.*

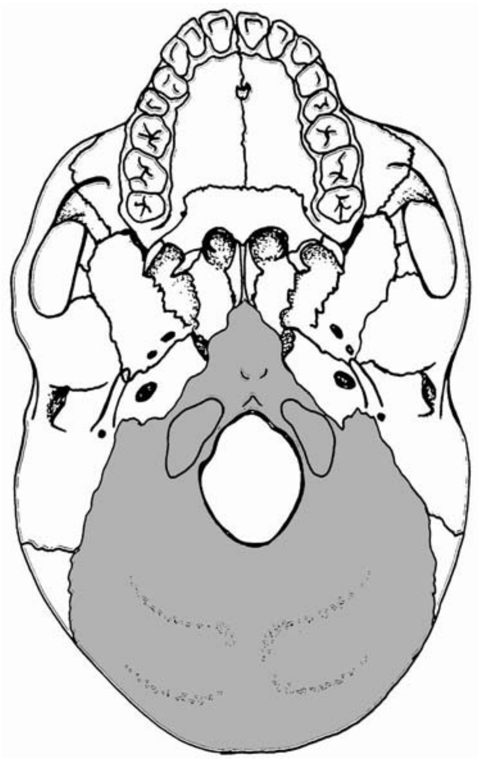
- unpaired bone
- forms much of the postero-inferior cranium
- the ectocranial surface has multiple nuchal lines which run horizontally across the posterior and inferior surfaces
- the intracranial surface has an irregular appearance due to the presence of multiple deep vascular grooves
  - these are for the large dural venous sinuses which drain de-oxygenated blood from the brain
- the flat inferior portion bears the foramen magnum (literally means *big hole*)
- lateral to the foramen magnum are the occipital condyles
  - these condyles confer a unique role to the occipital bone – that of articulation with the postcranial skeleton
- between the basilar part of the young adult occipital and sphenoid bones is a cartilaginous disc; this is referred to as the spheno-occipital synchondrosis
  - with age, the cartilage is converted to bone – a synostosis forms and the synchondrosis disappears
  - this usually occurs between eighteen and twenty-five years of age
- articulates with the parietals, temporal, and sphenoid bones, as well as the C1 vertebra

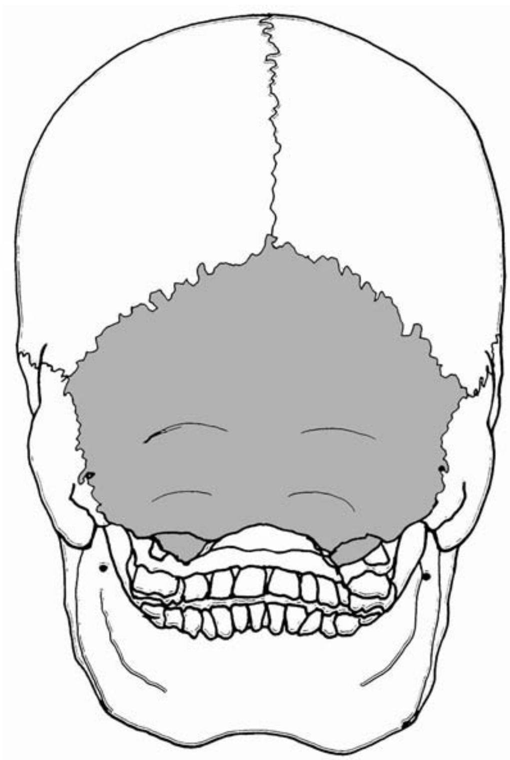
Landmarks

- superior nuchal line (very subtle in most specimens)
- inferior nuchal line
- highest nuchal line
- median nuchal line
- external occipital protuberance
- foramen magnum
- occipital condyle
- basiocciput
- jugular process
- pharyngeal tubercle
- sagittal sulcus
- internal occipital protuberance
- groove for the transverse sinus
- internal occipital crest

Looking at Fragments

- when fragmented, use the lambdoid suture as a landmark
    - thick cranial bone fragments with a deeply serrated suture are considered occipital bone until proven otherwise
    - a distinctive feature of the occipital bone is its marked variation in cross-sectional thickness
- look for flat, irregular nuchal lines coursing over the surface of fragments
    - if such a line is associated with a noticeable bony prominence, this is likely the external occipital protuberance – a structure unique to the occipital bone
- the occipital condyles may look like articular facets from vertebrae, particularly those of the C1 vertebra
    - however, the elliptical or kidney-shaped occipital condyles are generally subtly convex (versus the concave superior articular facets of C1 vertebrae), and are associated with the dense bony framework of the basi-occiput
    - when attempting to side fragments of occipital condyle, keep in mind that their medial border is flush with the foramen magnum
- note that thick linear grooves for the dural venous sinuses are unique to the occipital bone
    - dural venous sinus grooves are distinctive from the vascular grooves made by meningeal vessels (which are much narrower)
- sutural bones might cause interpretive grief, but, all edges of these bones are sutural (i.e., would have bony interdigitations along their edges for articulation with opposing bones), thereby differentiating them from fractured pieces of occipital bone





Images 2.76 (left) and 2.77 (right)
Illustrations demonstrating **occipital bone** *in situ* – inferior and posterior views respectively.

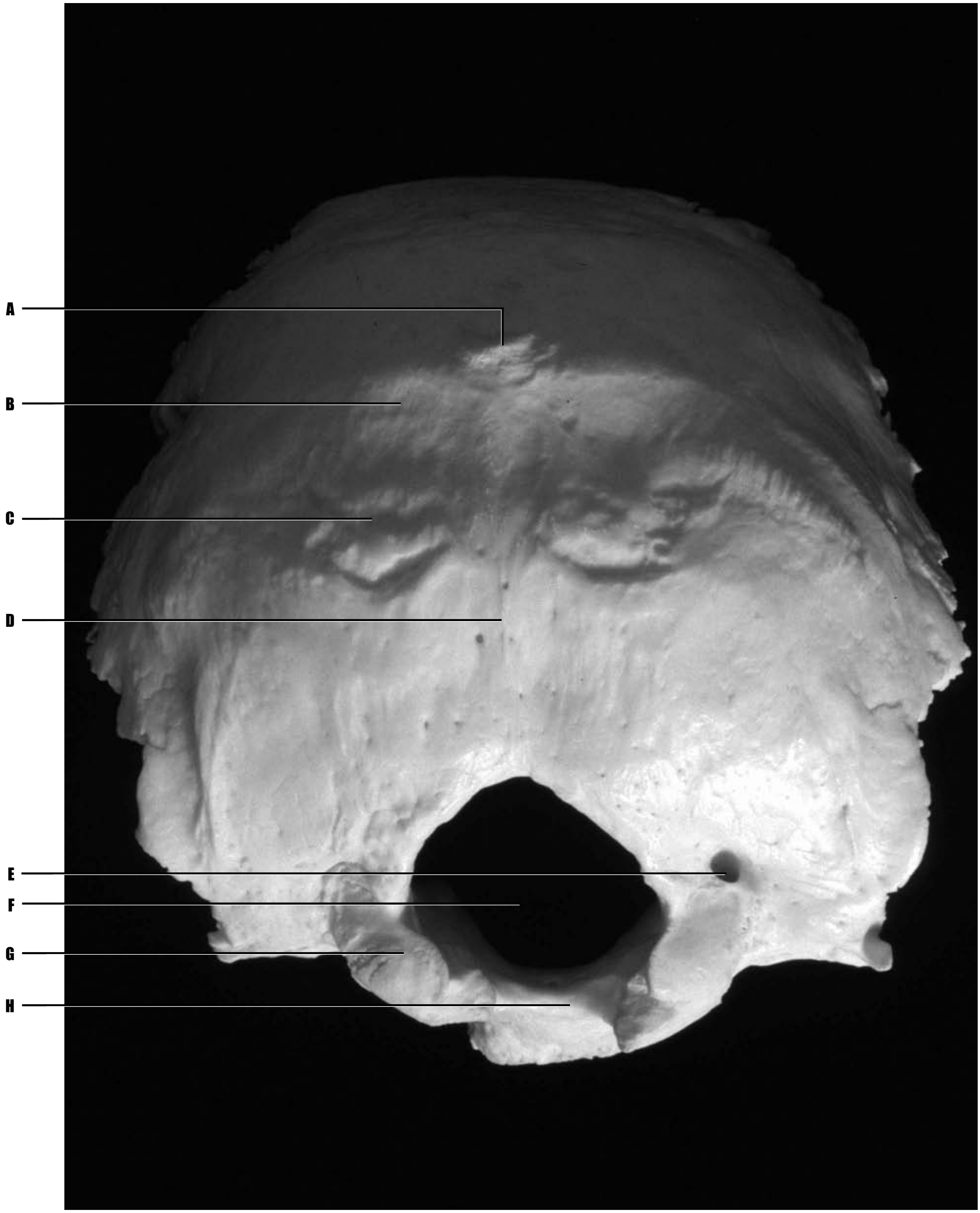


Image 2.78
Disarticulated juvenile occipital bone, postero-inferior view.

Image 2.78

A - external occipital protuberance
B - superior nuchal line
C - inferior nuchal line
D - median nuchal line
E - condylar fossa *(inconstant)*
F - foramen magnum
G - occipital condyle
H - basiocciput

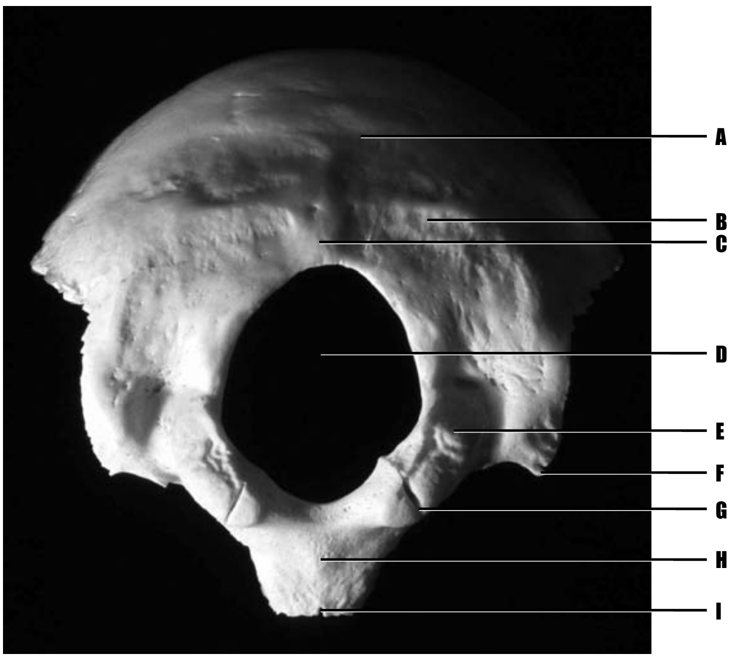


Image 2.79
Disarticulated juvenile occipital bone, inferior view.

Image 2.79

A - superior nuchal line
B - inferior nuchal line
C - median nuchal line
D - foramen magnum
E - occipital condyle
F - jugular process
G - intra-occipital suture (present in young specimens only)
H - pharyngeal tubercle
I - basiocciput

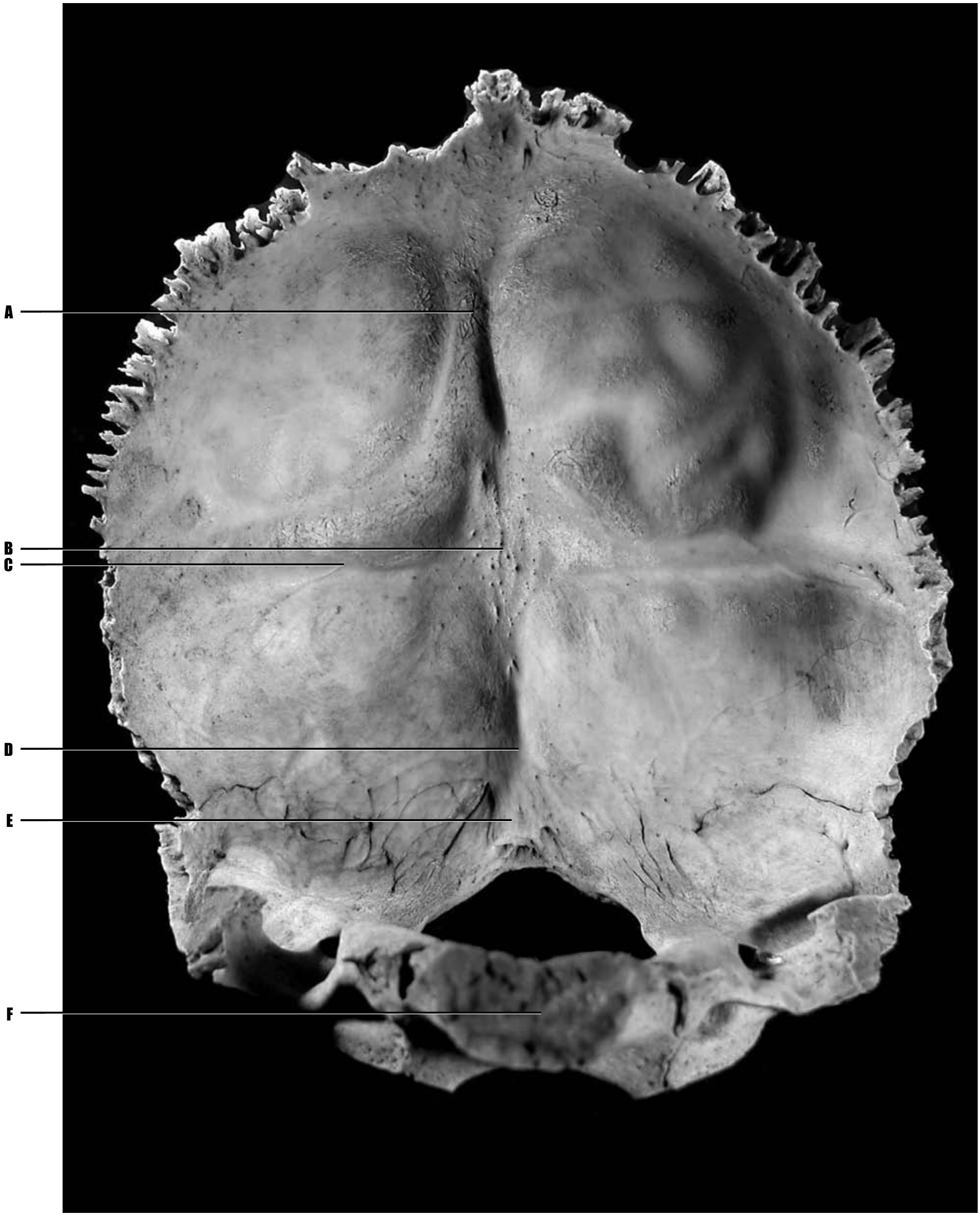


Image 2.80
Disarticulated occipital bone, internal view.

Image 2.80

A - sagittal sulcus
B - internal occipital protuberance
C - groove for the transverse sinus
D - internal occipital crest
E - vermian fossa
F - articular surface for sphenoid bone (site of spheno-occipital synchondrosis)

2.1e MAXILLA

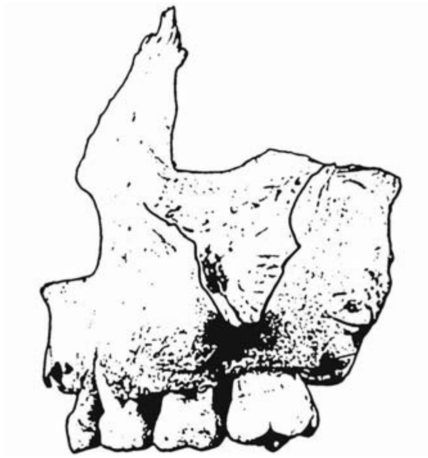


Image 2.81 • *Maxilla, left, lateral view.*

- paired bone
- forms the upper jaw, roof of mouth, part of the nasal cavity floor, and much of the face
- depending on the age of the specimen, the two maxillae may loosely articulate at the intermaxillary suture, or they may be firmly adherent to one another (if the suture has ossified)
- the maxillae house the teeth of the upper jaw in bony tooth sockets (gomphoses)
- the maxilla contains a large sinus cavity – the maxillary sinus
  - note that large sinuses are found only in the frontal, maxilla and sphenoid bones
- articulates with the opposing maxilla, nasal, frontal, ethmoid, lacrimal, inferior nasal concha, palatine, vomer, and zygomatic bones, and occasionally the sphenoid bone

Landmarks

- frontal process
- nasal aperture
- zygomatic process
- infraorbital foramen
- alveolar process
- orbital surface
- infratemporal process
- anterior nasal spine
- canine eminence
- infraorbital groove
- palatine process
- lacrimal groove
- frontal groove
- posterior surface
- ethmoidal crest
- conchal crest
- maxillary air sinus
- nasal crest

Differentiating Right from Left

- orient the specimen so that the anterior nasal aperture is facing you, and the teeth are pointing downwards
  - the anterior nasal spine is now on the same side of the maxilla as that to which the bone belongs

Looking at Fragments

- fragmented portions of jaw (upper or lower) typically contain teeth, or empty tooth sockets
  - this is helpful as it limits your choices to either mandible or maxilla
  - in general, the alveolar processes (plate of bone that overlies teeth) are more prominent in the maxilla
- typically, mandibular fragments are far more robust than those from the maxilla
- much of the maxilla is very thin bone (especially the portion that overlies the large maxillary sinus)
  - small fragments of any thin and flat bone could therefore be confused with fragments of maxilla (ethmoid, sphenoid, flat calvarial bones, scapular body, etc.)
- dense portions of maxilla, such as the frontal and zygomatic processes, tend to remain relatively intact
  - they are therefore useful for identification purposes
  - look for identifiable landmarks such as the infraorbital foramen
- use other more prominent maxillary landmarks to aid in fragment identification
  - infraorbital groove, anterior nasal spine, incisive foramen, etc., have a unique morphology

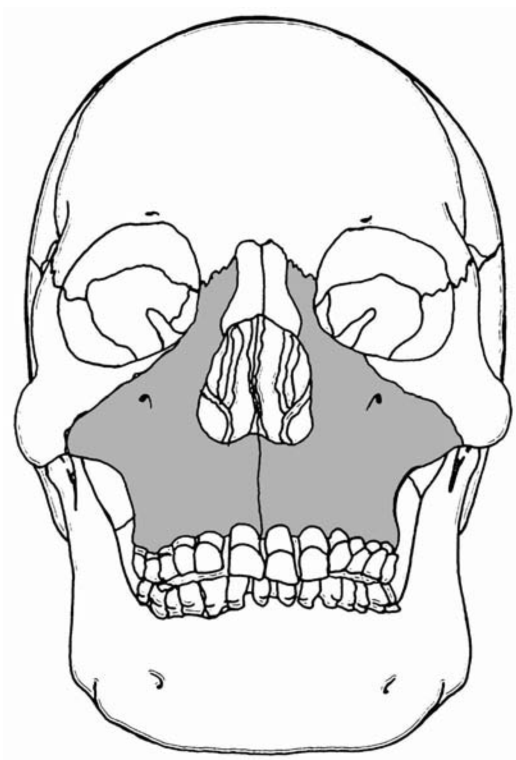
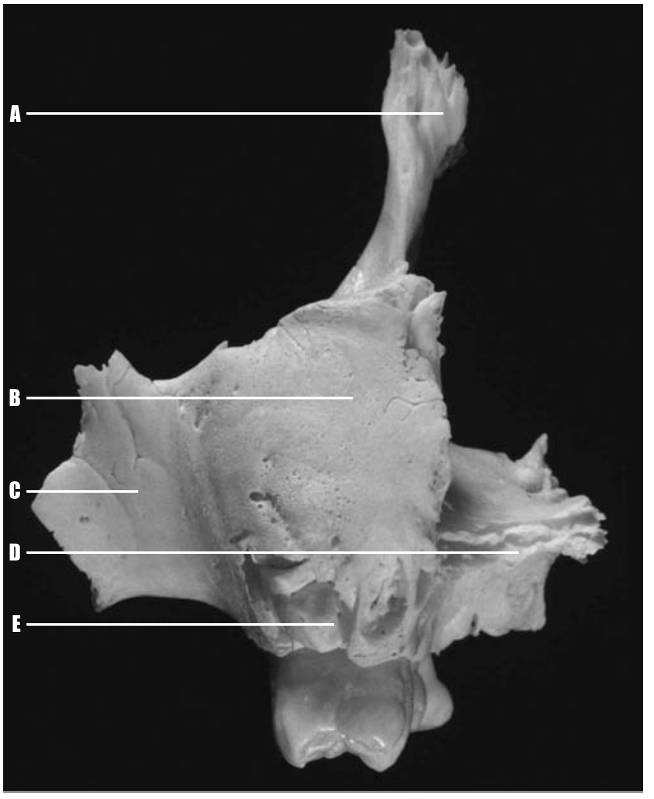
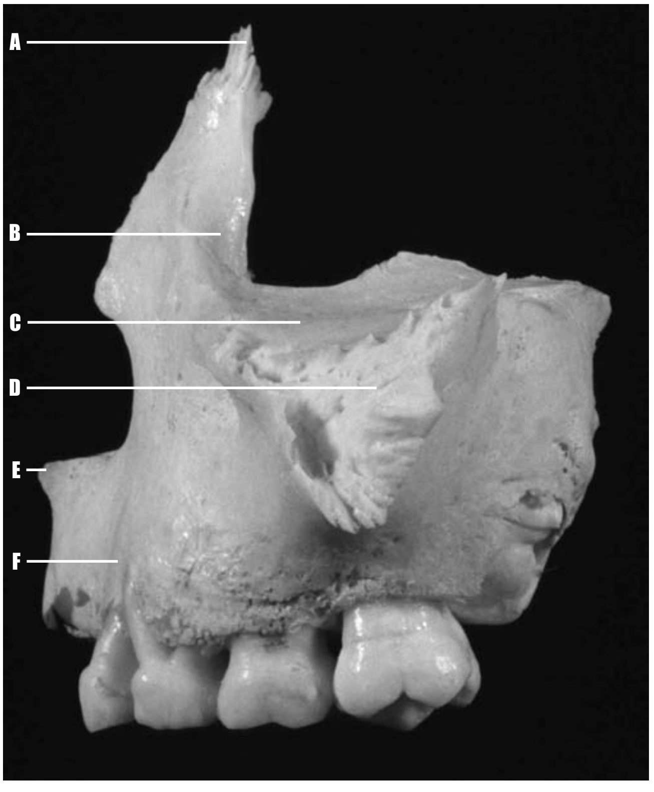


Image 2.82
Illustration demonstrating **maxillae** *in situ* – anterior view.





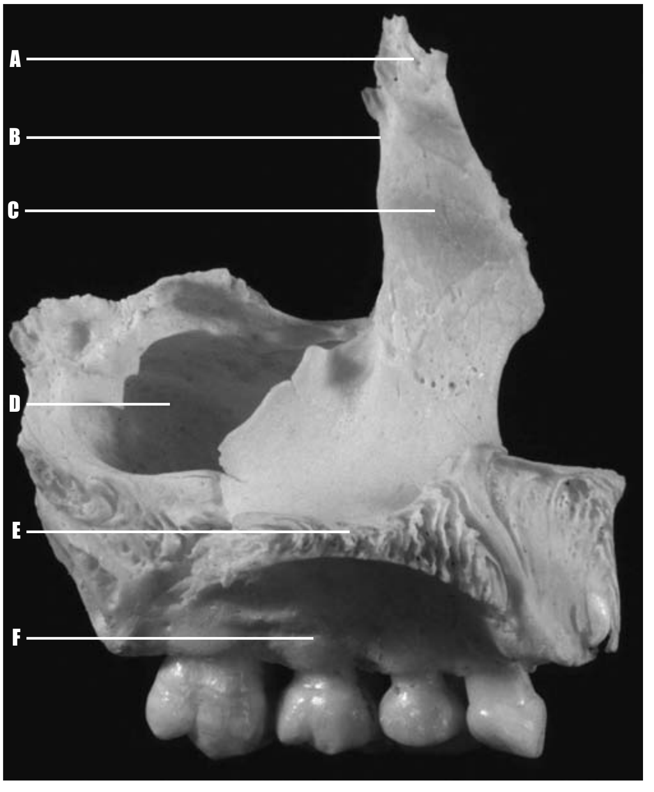


Image 2.83 (above)

Disarticulated juvenile maxilla, left, anterior view.

Image 2.85 (below)

Disarticulated juvenile maxilla, left, lateral view.

Image 2.84 (above)

Disarticulated juvenile maxilla, left, posterior view.

Image 2.86 (below)

Disarticulated juvenile maxilla, left, medial view.

Image 2.83

A - frontal process of maxilla
B - nasal aperture
C - zygomatic process
D - infraorbital foramen
E - alveolar process
F - unerupted first permanent incisor

Image 2.84

A - frontal process of maxilla
B - posterior surface
C - zygomatic process
D - palatine process
E - unerupted first permanent molar

Image 2.85

A - frontal process of maxilla
B - lacrimal groove
C - orbital surface
D - zygomatic process
E - anterior nasal spine
F - canine eminence

Image 2.86

A - frontal process of maxilla
B - ethmoidal crest
C - conchal crest
D - maxillary air sinus
E - palatine process
F - alveolar process of first deciduous molar

Image 2.87

A - infraorbital groove
B - orbital surface
C - zygomatic process
D - palatine process
E - lacrimal groove
F - frontal groove
G - anterior nasal spine

Image 2.88

A - unerupted first permanent molar
B - zygomatic process
C - palatine process

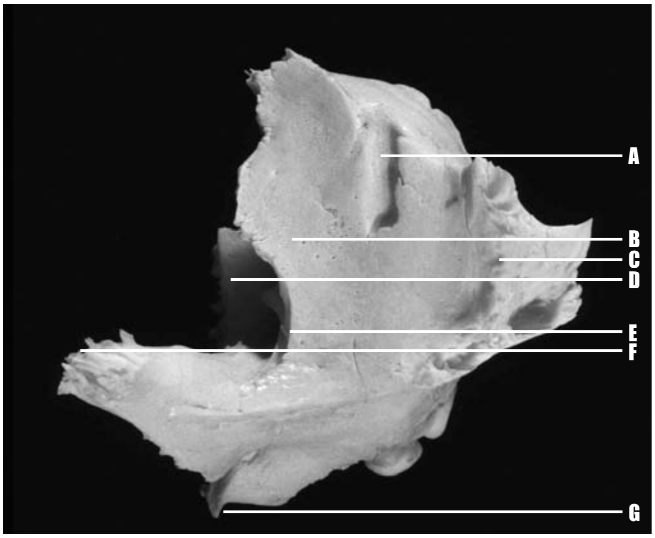


Image 2.87
Disarticulated juvenile maxilla, left, superior view.

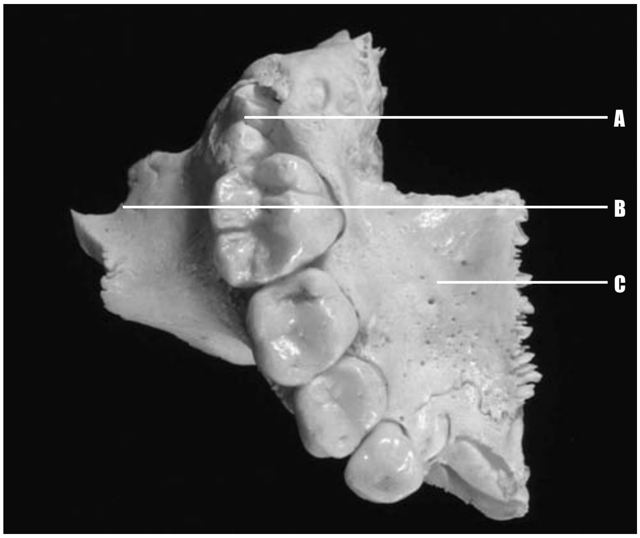


Image 2.88
Disarticulated juvenile maxilla, left, inferior view.

2.1f PALATINE BONE

Image 2.89 • *Palatine bone, inferior view.*

- paired bone
- very small and fragile "L-shaped" bones that contribute to the posterior hard palate, as well as the lateral walls of the nasal fossa
- generally, these bones are firmly adherent to the maxillae
- articulates with the opposing palatine, maxilla, ethmoid, vomer, inferior nasal concha and sphenoid bones

Landmarks

- articular surface for maxilla
- articular surface for opposing palatine bone
- articular surface for sphenoid
- horizontal plate
- greater palatine foramen
- lesser palatine foramen
- pyramidal process
- orbital surface of palatine bone
- orbital process
- sphenopalatine notch
- ethmoidal crest
- conchal crest
- middle meatus
- inferior meatus
- maxillary surface
- sphenoidal process
- palatine surface

Differentiating Right from Left

- hold the pyramidal process of the palatine bone with the posterior nasal spine directed toward you and the horizontal plate directed upward toward the ceiling (i.e., the intraoral portion of the horizontal plate)
- now, the articular surface for the opposing palatine bone is directed toward the same side as that to which this bone belongs

Looking at Fragments

- fragmented portions of palatine bone could look like fragments of maxillary hard palate, or possibly sphenoid, vomer or inferior nasal concha
  - maxillary fragments tend to have a rougher texture, and somewhat more of a concavity on their intraoral surface
  - maxilla and other fragments will lack prominent landmarks such as the greater and lesser foramina
  - the vomer is comparatively smoother than the palatine bone
  - the highly textured appearance of the inferior nasal concha should allow for easy distinction between these two bones
- the articular portion of the body, when highly fragmented, could be confused with orbital shelf
  - one must be clear that although the orbital shelf is corrugated, it is smooth in texture, and not rough like the palatine bones

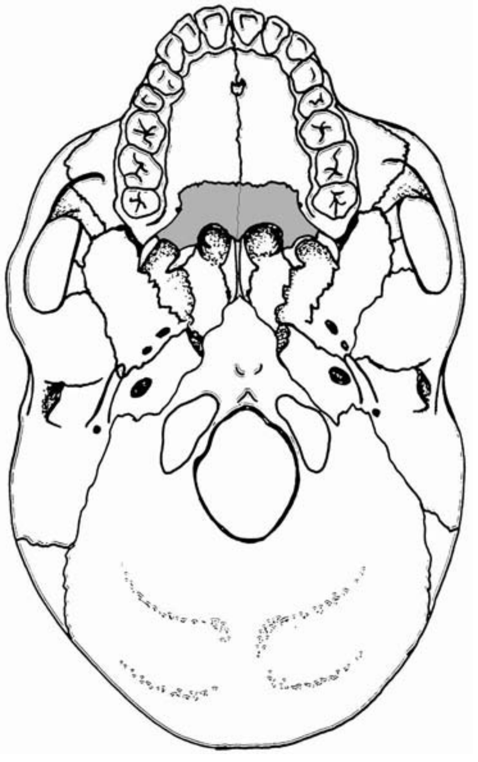
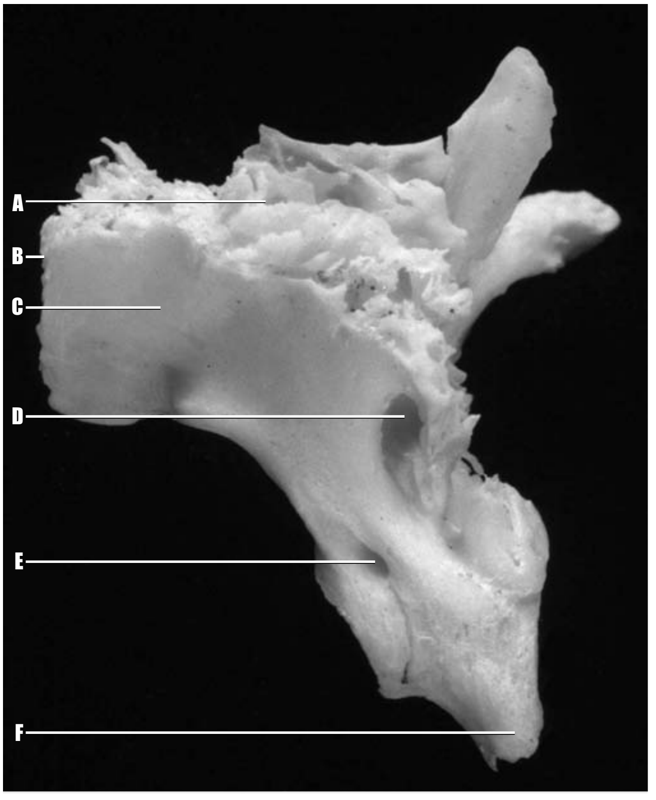
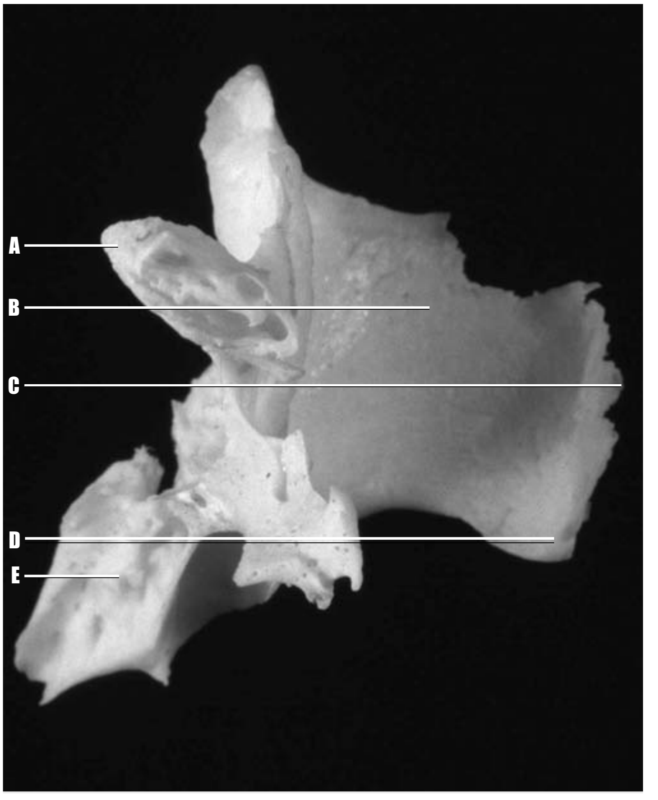
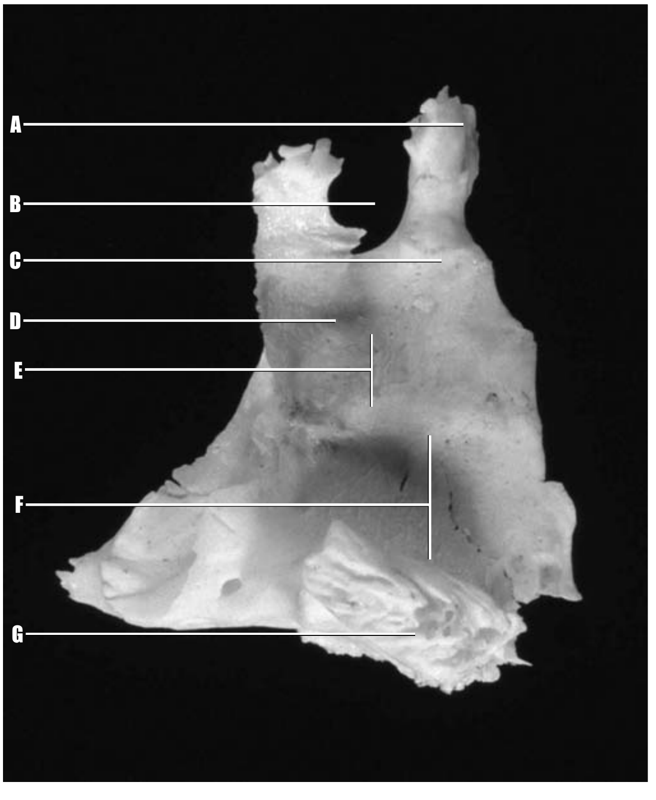


Image 2.90
Illustration demonstrating **palatine bones** *in situ* – inferior view.







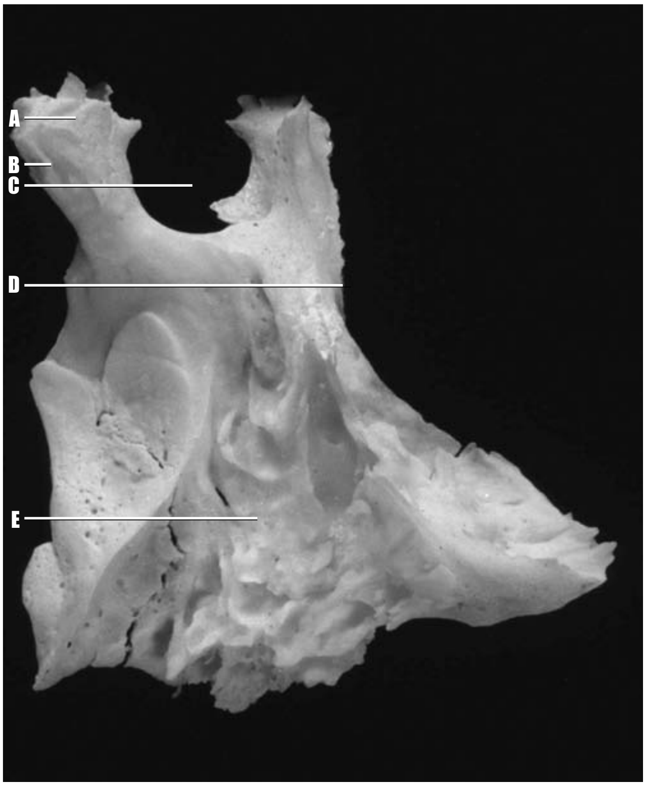


Image 2.91 (above)

Disarticulated juvenile palatine bone, left, inferior view.

Image 2.93 (below)

Disarticulated juvenile palatine bone, left, medial view.

Image 2.92 (above)

Disarticulated juvenile palatine bone, left, superior view.

Image 2.94 (below)

Disarticulated juvenile palatine bone, left, lateral view.

Image 2.91

A - articular surface for maxilla
B - articular surface for right palatine bone
C - horizontal plate of palatine bone
D - greater palatine foramen
E - lesser palatine foramen
F - pyramidal process

Image 2.92

A - orbital surface of palatine bone
B - horizontal plate of palatine bone
C - articular surface for right palatine bone
D - posterior nasal spine
E - pyramidal process

Image 2.93

A - orbital process
B - sphenopalatine notch
C - ethmoidal crest
D - conchal crest
E - middle meatus
F - inferior meatus
G - articular surface for right palatine bone

Image 2.94

A - orbital process
B - maxillary surface
C - sphenopalatine notch
D - articular surface for sphenoid
E - articular surface for maxilla

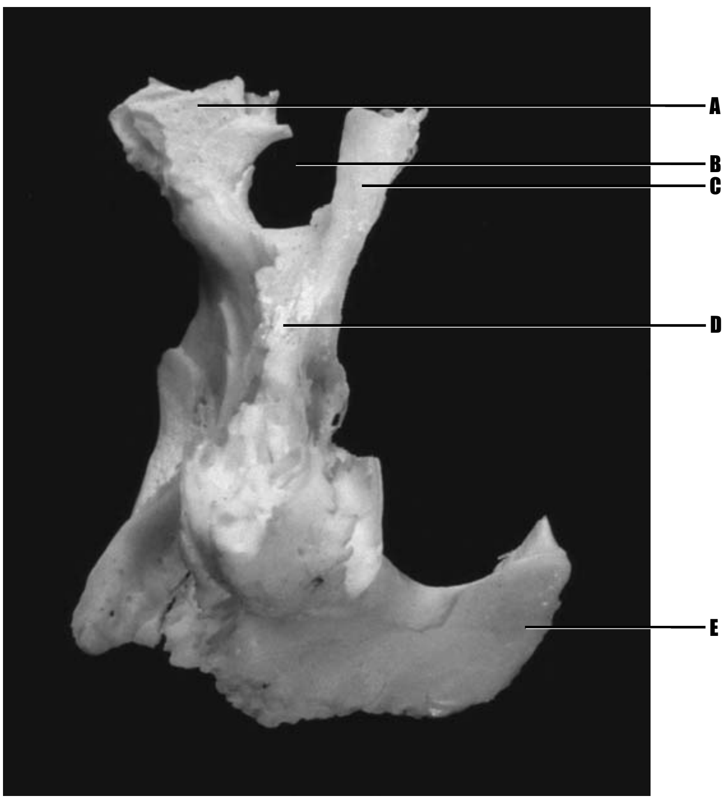


Image 2.95
Disarticulated juvenile palatine bone, left, posterior view.

Image 2.95

A - orbital process
B - sphenopalatine notch
C - sphenoidal process
D - perpendicular plate
E - horizontal process

2.1g VOMER

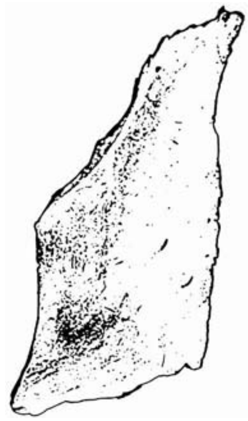


Image 2.96 • *Vomer, lateral view.*

- unpaired bone
- very thin midline structure that is part of the nasal septum, which in life comprises the vomer, perpendicular plate of ethmoid, as well as nasal cartilage and soft tissue
  - this septum divides the nasal cavity into two halves
- articulates with maxilla, palatine, ethmoid and sphenoid bones

Landmarks

- articular surface for maxilla and palatine bone
- articular surface for perpendicular plate of ethmoid bone
- nasopalatine groove
- (posterior) free margin
- ala of vomer

Looking at Fragments

- the superior border is the thickest part of the bone and is recognized by its two small wings, the alae
- fragments of sphenoid, ethmoid, and sometimes very thin nasal bones might be mistaken for the vomer
- fragments of scapular body and thin iliac wing might also be confused with vomer
- if you are unsure whether or not your fragment is the vomer, it may be helpful to look for layering of bone as the anterior margin is frequently multilayered (bi- or multilaminar)

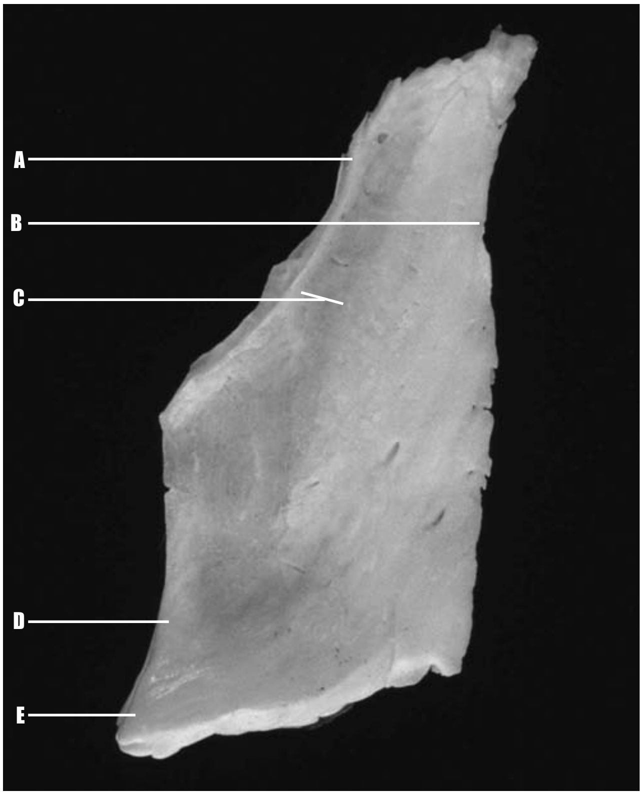


Image 2.97 (above)
Disarticulated juvenile vomer, left lateral view.

Image 2.98 (above)
Disarticulated juvenile vomer, posterior view.

Images 2.97 and 2.98

A - articular surface for maxillae and palatine bones
B - articular surface for perpendicular plate of ethmoid bone
C - nasopalatine groove
D - (posterior) free margin
E - ala of vomer

2.1h INFERIOR NASAL CONCHA

Image 2.99 • *Inferior nasal concha, medial view.*

- paired bone
- also known as the turbinates
- are found within the nasal cavity
- have a characteristically roughened or finely corrugated appearance
- they are extremely light weight and easily fractured
- articulate with the maxilla, palatine, ethmoid and lacrimal bones

Landmarks

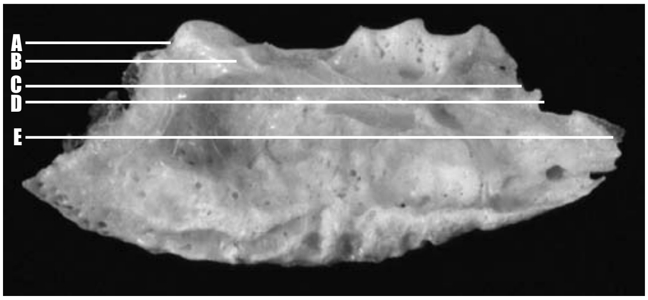
- articular surface for ethmoid bone
- articular surface for palatine bone
- articular surface for maxilla
- lacrimal process
- maxillary process
- ethmoidal process
- lamina

Differentiating Right from Left

- place the convex portion of the bone on the table surface
- now you will notice a bony lip (maxillary process) which partially covers the exposed concave aspect of this bone; this lip should be on the side furthest from you
  - the broadest portion of this lip is now on the opposite side of the inferior nasal concha as that to which the bone belongs

Looking at Fragments

- fragments of inferior nasal concha might be confused with orbital (frontal) shelf, sphenoid, ethmoid or lacrimal bones
  - but, the roughened/corrugated texture is unique to this bony element



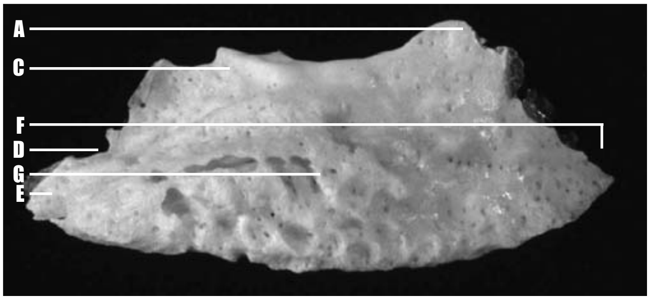


Image 2.100 (above)
Disarticulated juvenile left inferior nasal concha, lateral view. Left is anterior.

Image 2.101 (above)
Disarticulated juvenile left inferior nasal concha, medial view. Right is anterior.

Images 2.100 and 2.101

A - lacrimal process
B - maxillary process (lip of concha)
C - ethmoidal process
D - articular surface for ethmoid bone
E - articular surface for palatine bone
F - articular surface for maxilla
G - lamina

2.1i ETHMOID BONE

Image 2.102 • *Ethmoid bone, oblique superior view.*

- unpaired bone
- midline, extremely fragile, roughly rectangular structure that is made up of multiple vertically oriented sheets of very thin bone
- it forms a small segment of the floor of the anterior cranial fossa, nasal fossa, as well as part of the medial wall of the orbits
- both the superior and middle nasal conchae (the other turbinates) are part of the ethmoidal complex
  - the superior nasal concha is a very modest elevation of the superomedial wall of the body of the ethmoid; it may not be visible in your teaching specimens
- articulates with thirteen bones, which for the sake of sanity, will not be listed

Landmarks

- orbital surface for ethmoid bone
- articular surface for palatine bone
- articular surface for maxilla
- lacrimal process
- maxillary process
- ethmoidal process
- lamina
- superior nasal concha
- middle nasal concha

Looking at Fragments

- the perpendicular plate of ethmoid might be confused with vomer, scapular body, or small fragments of thin iliac wing
  - however, the vomer is much longer, and at its posterior border, it has prominent wings (alae)
  - also, fragments of ethmoid are typically much thinner than those of scapula or ilium

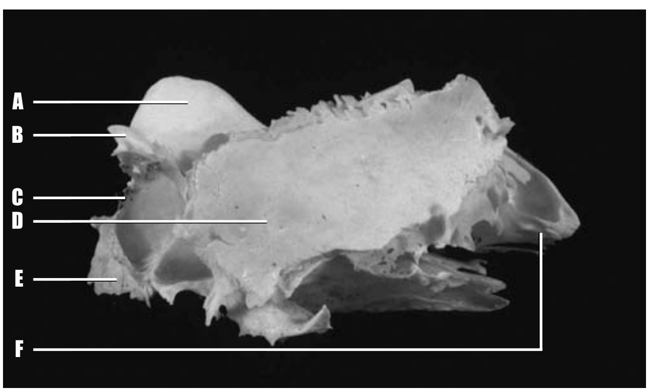


Image 2.103 (above)

Disarticulated juvenile ethmoid, lateral view. Anterior is to the left.

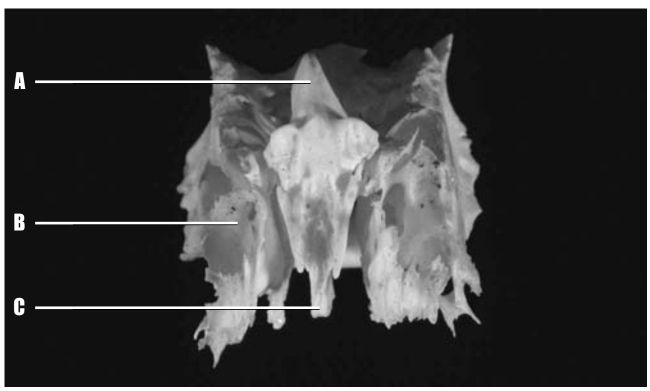
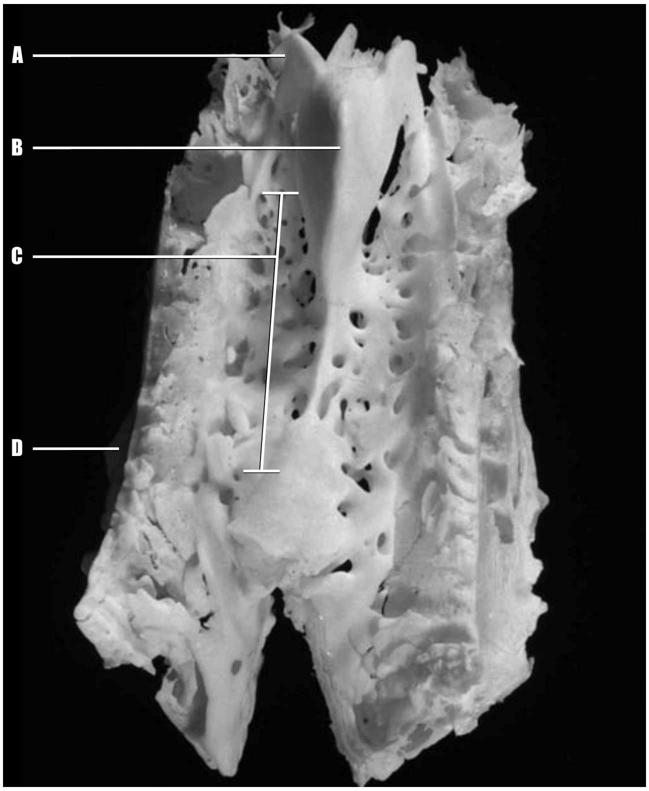


Image 2.104 (above)

Disarticulated juvenile ethmoid, anterior view. Superior is up.



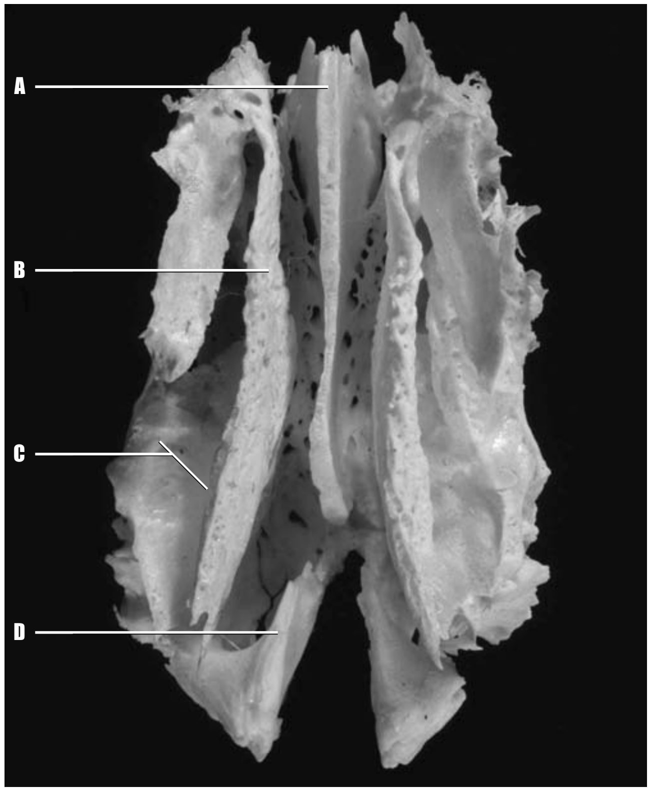


Image 2.105 (above)
Disarticulated juvenile ethmoid, superior view. Anterior is to the top.

Image 2.106 (above)
Disarticulated juvenile ethmoid, inferior view. Anterior is to the top.

Image 2.103

A - crista galli
B - ala
C - articular surface for frontal bone
D - orbital surface
E - articular surface for nasal bone
F- articular surface for vomer

Image 2.104

A - crista galli
B - ethmoidal air cells
C - perpendicular plate

Image 2.105

A - ala
B - crista galli
C - cribriform plate
D - orbital surface of ethmoid

Image 2.106

A - perpendicular plate
B - middle nasal concha
C - middle meatus
D - uncinate process

2.1j SPHENOID BONE

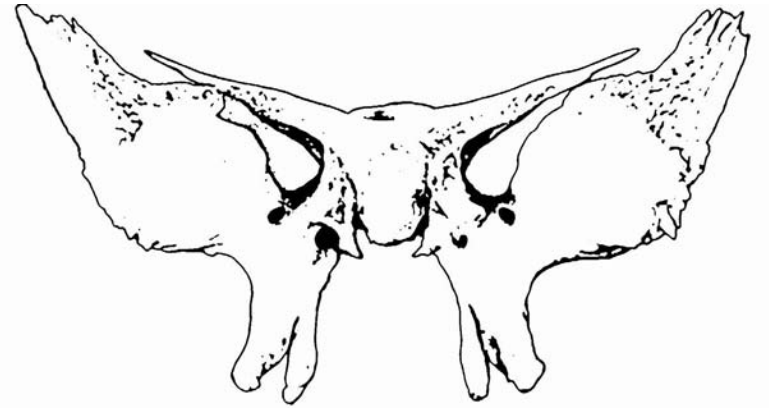


Image 2.107 • *Sphenoid bone, anterior view.*

- unpaired bone
- is a complex structure with both intra- and ectocranial portions
- has a somewhat birdlike appearance
- found between the facial bones and those of the brain case
- can be divided into four parts: body, greater wings, lesser wings, and pterygoid plates (see **Image 2.108**)
- the body bears a large depression – the pituitary fossa (or sella turcica)
    - in life, this contains the pituitary gland
- in most adult specimens, the body contains a large sinus
    - the sinus is actually composed of two or more individual compartments which are separated by bony septae
- the greater wings are large plates of bone that extend laterally to form that portion of the skull between the temporal and frontal bones – they are both intra- and ectocranial
    - the intracranial portion forms much of the middle cranial fossa
- the lesser wings are entirely intracranial
    - they form the posteriormost margin of the anterior cranial fossa
- the pterygoid processes project from the base of the skull as flat plates of bone
- articulates with thirteen other bones, which will not be listed here

Landmarks

- articular surface for frontal bone
- articular surface for temporal bone
- greater wing
- lesser wing
- superior orbital fissure
- optic canal
- crest
- orbital surface of greater wing
- concha
- foramen rotundum
- pterygoid canal
- vaginal process
- pterygoid process
- medial pterygoid plate

Landmarks continued

- lateral pterygoid plate
- pterygoid fossa
- pterygoid hamulus
- dorsum sellae
- body
- spine
- groove for carotid canal
- chiasmatic groove
- jugum
- tuberculum sellae
- anterior clinoid process
- posterior clinoid process
- foramen ovale
- foramen spinosum

Looking at Fragments

- knowledge of the detailed anatomical landmarks is important to properly identify fragments of this bone
  - the sella turcica and its surrounding area are commonly tested on exams of intact and fragmentary osteology
- fortunately, the fragile nature of this bone means that when it does fracture, it tends to remain attached to other, more easily identified bones
- the greater wing is typically easily identifiable as it bears both smooth orbital and ectocranial surfaces
  - be aware, though, that accessory bones near the pterion (see page 27), called epipteric bones, can cause the ectocranial portion of the greater wing to appear smaller
  - epipteric bones, like other sutural bones (such as those along the lambdoid suture), can cause grief during the fragment identification process
  - in the case of epipteric bones, the edges of the bone will be irregular (not clean as in fractures), but not heavily serrated like those found in other sutures

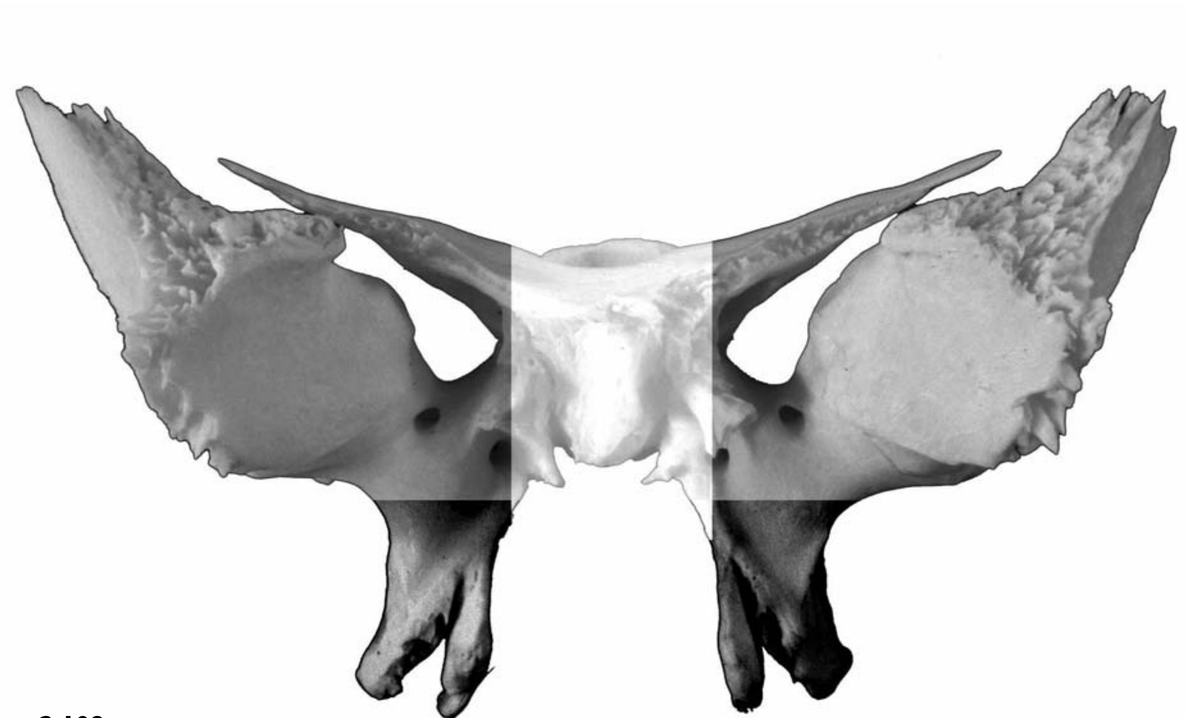
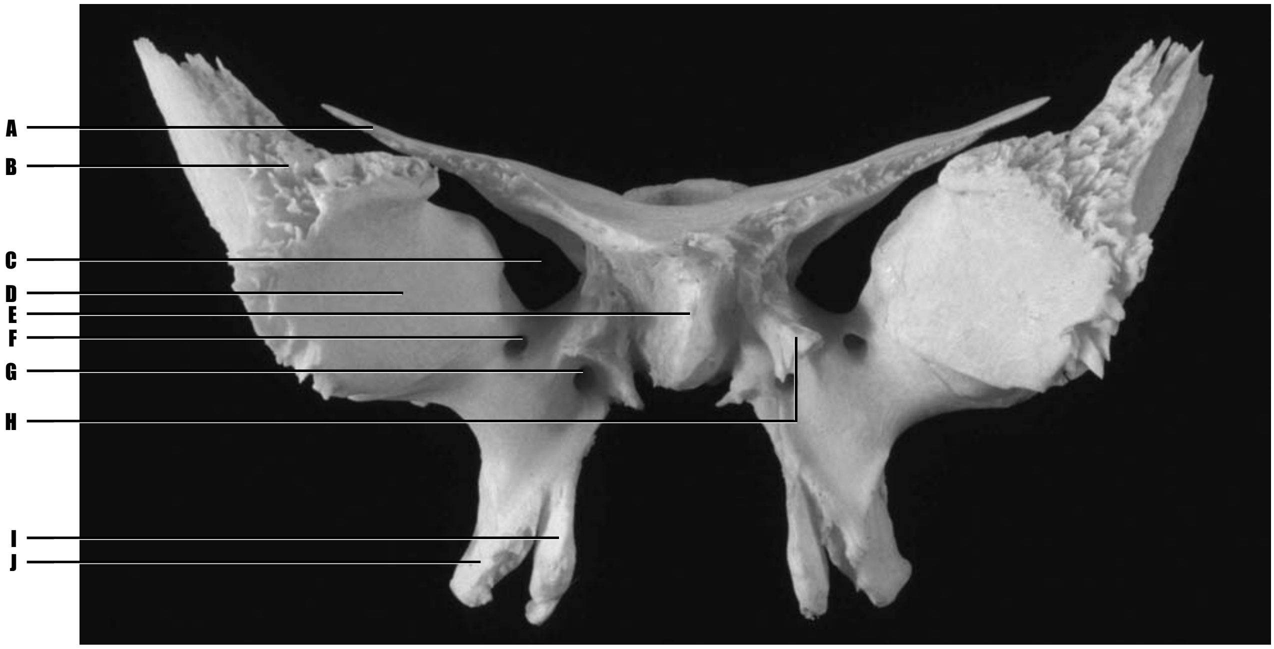


Image 2.108
The above graphic represents the four subdivisions of the sphenoid bone. The central light area is the *body*, the inferior darker areas are the *pterygoid plates*, and the remaining **wings** are easily identified as the *greater* (largest and most lateral) and *lesser* (smaller and most midline) *wings* of the sphenoid bone.



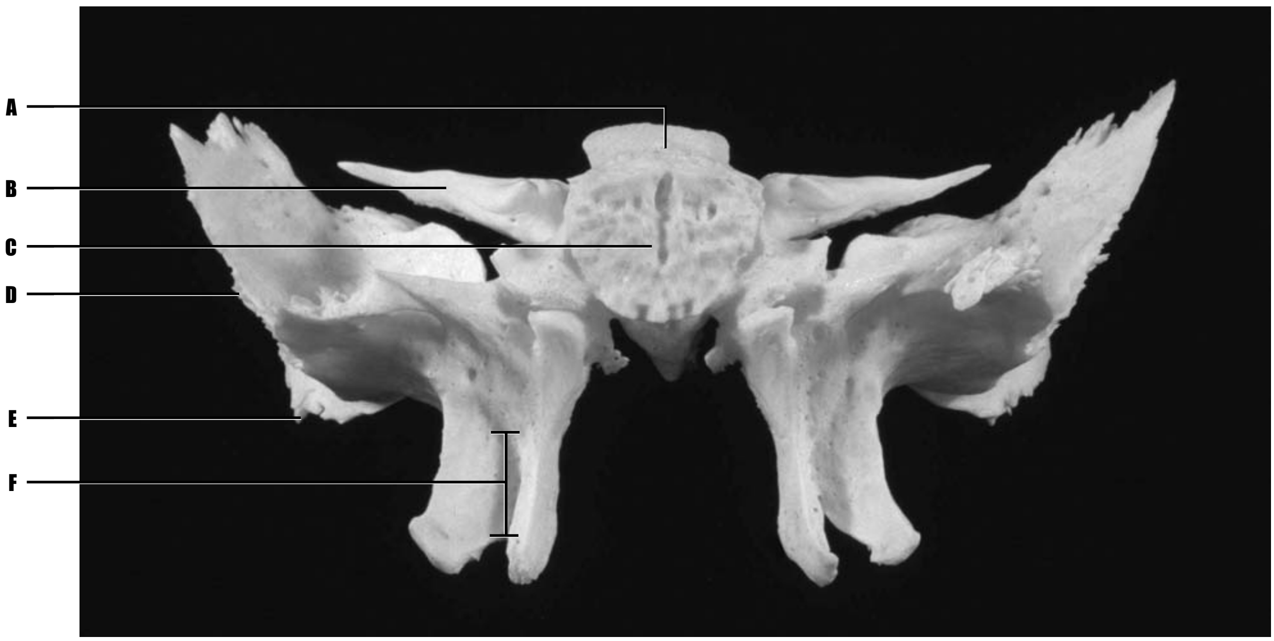


Image 2.109 (above)

Disarticulated juvenile sphenoid bone, anterior view.

Image 2.110 (below)

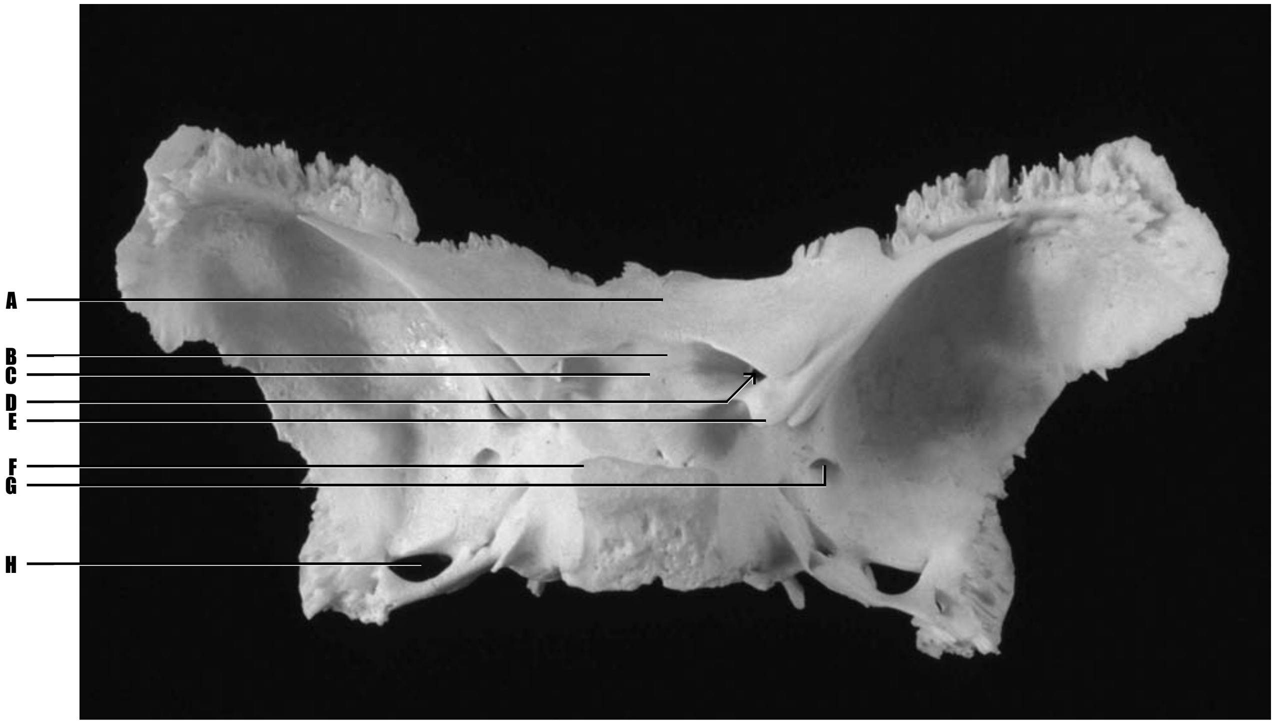
Disarticulated juvenile sphenoid bone, posterior view.

Image 2.109

A - lesser wing
B - articular surface for frontal bone
(along the frontosphenoidal suture)
C - superior orbital fissure
D - orbital surface of greater wing
E - crest
F - foramen rotundum
G - pterygoid canal
H - concha
I - medial pterygoid plate
J - lateral pterygoid plate

Image 2.110

A - dorsum sellae
B - lesser wing
C - body of sphenoid
D - articular surface for squamous temporal bone
(along sphenotemporal suture)
E - spine
F - pterygoid fossa (between the medial and lateral pterygoid plates)



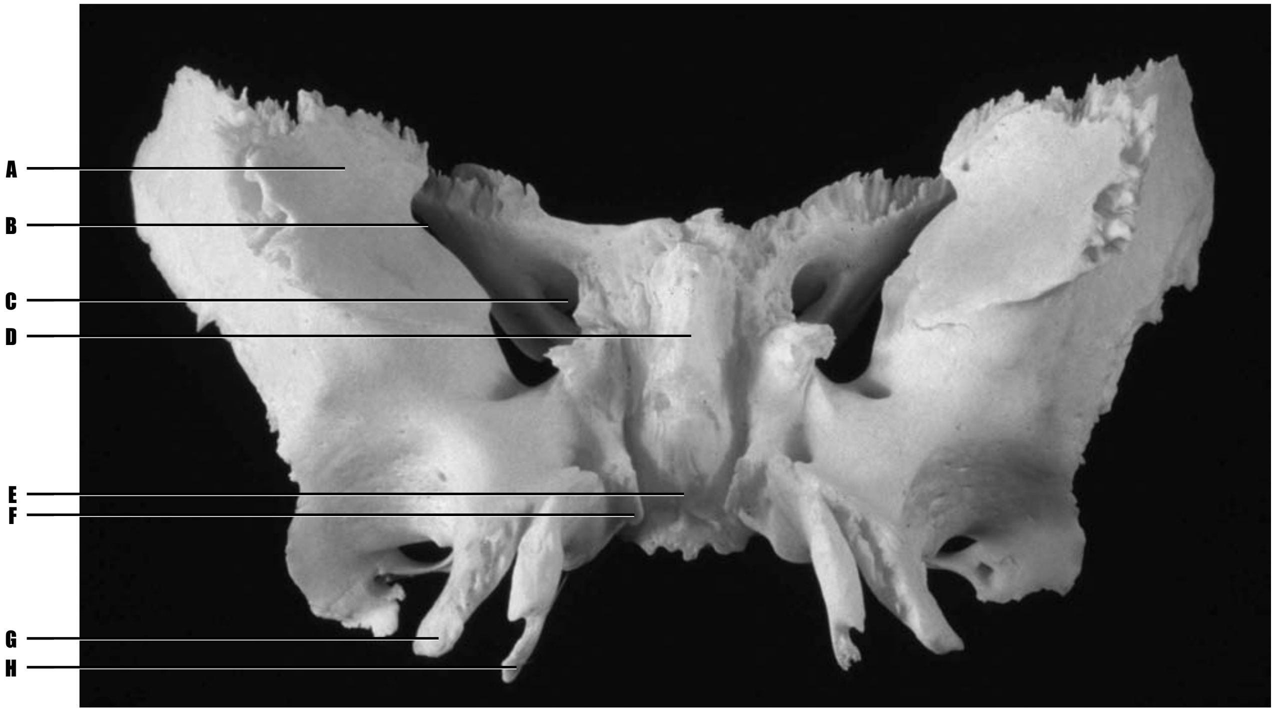


Image 2.111 (above)
Disarticulated juvenile sphenoid bone, superior view. Anterior is up.

Image 2.112 (below)
Disarticulated juvenile sphenoid bone, antero-inferior view. Anterior is up.

Image 2.111

A - jugum
B - chiasmatic groove
C - tuberculum sellae
D - optic canal
E - anterior clinoid process
F - posterior clinoid process
G - foramen rotundum
H - foramen ovale

Image 2.112

A - orbital surface of greater wing
B - superior orbital fissure
C - optic canal
D - crest
E - rostrum
F - vaginal process
G - lateral pterygoid process
H - medial pterygoid plate

2.1k ZYGOMATIC BONE

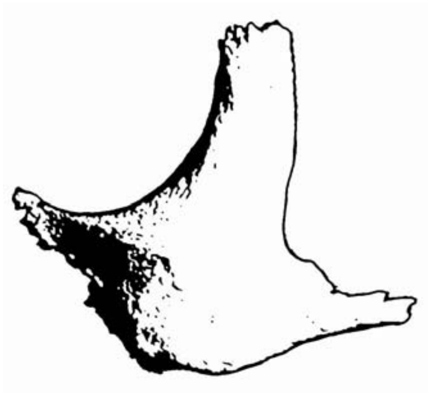


Image 2.113 • *Zygomatic bone, lateral (facial) view.*

- paired bone
- also referred to as the *malar* or *cheek* bones
- forms the lateral wall of the orbit and makes up the bulk of the bony cheek
- the temporal process of the zygomatic bone constitutes the anteriormost aspect of the zygomatic arch by articulating with the zygomatic process of the temporal bone
- each articulates with the maxillary, temporal, frontal, and sphenoid bones

Landmarks

- articular surface for frontal bone
- articular surface for maxilla
- articular surface for temporal bone
- frontal process
- orbital margin
- zygomaticofacial foramen
- zygomatico-orbital foramen
- body
- temporal process

Differentiating Right from Left

- hold the zygomatic bone by its temporal process between your thumb and forefinger
- the frontal process should be up, the inferior margin should be down, and the anterior (facial) surface should be toward you
- the orbital surface of the zygomatic bone (as well as the articular surface for the maxilla) now points in the same direction as that to which the bone belongs

Looking at Fragments

- fragments of frontal process may resemble the zygomatic process of the frontal bone
  - frontal process of the zygomatic bone is generally wider that the zygomatic process of the frontal bone
  - also, the frontal process tends to have a medial (orbital) margin which is more blunt than that of the frontal bone
- the temporal process of the zygomatic bone may be confused with zygomatic process of the temporal bone
  - however, proximal fragments of the temporal part of the zygomatic process are typically more robust than zygomatic fragments of the zygomatic arch
  - the arch progressively widens toward the articular tubercle of the temporal bone
- from time to time, beginners have difficulty differentiating fragments from the zygomatic part of the orbit from those of acetabulum of the pelvis
  - however, the acetabulum is generally much more dense

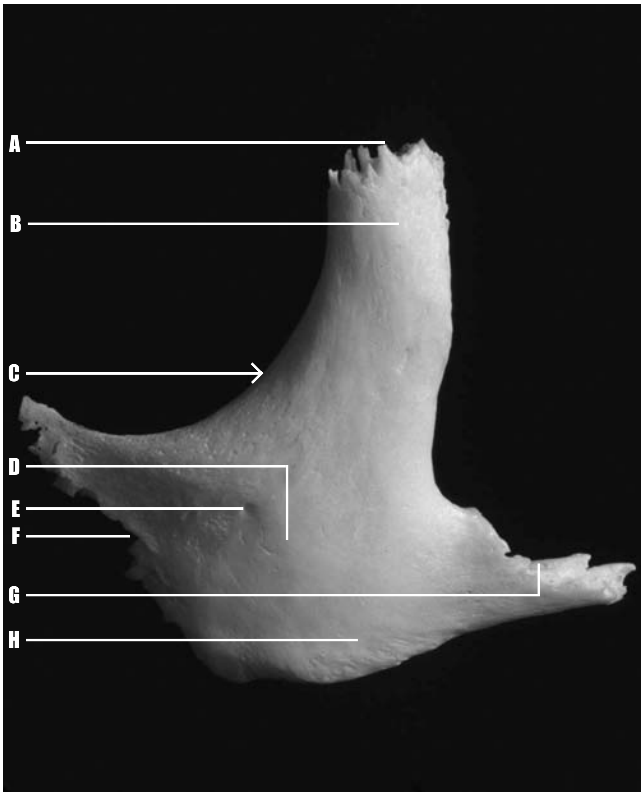


Image 2.114 (above)
Disarticulated juvenile zygomatic, left, anterior surface. Medial is left.

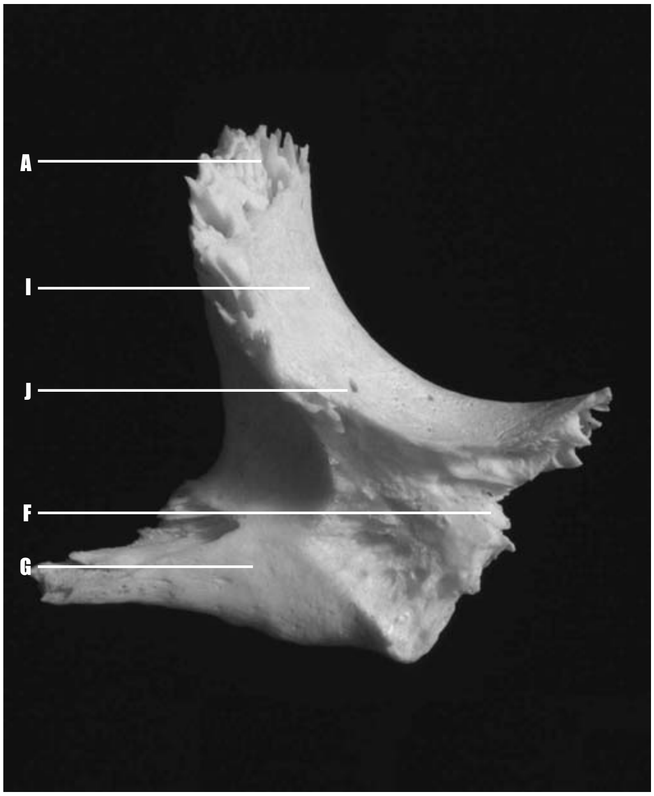


Image 2.115 (above)
Disarticulated juvenile zygomatic, left, posterior surface. Medial is right.

Image 2.114 and 2.115

A - articular surface for frontal bone
(along zygomaticofrontal suture)
B - frontal process
C - orbital margin
D - malar tubercle
E - zygomaticofacial foramen
F - articular surface for maxilla
(along zygomaticomaxillary suture)
G - temporal process of zygomatic bone
H - body
I - orbital surface
J - zygomatico-orbital foramen

2.1/ NASAL BONE

Image 2.116 • *Nasal bone, lateral (facial) view.*

- paired bone
- makes up the paramidline bony aspect of the nose
- found below the glabella and originates at the anthropometric landmark known as the nasion
- a small foramen, the nasal foramen, can be seen on the facial surface of this bone
  - serves to transmit small blood vessels
- articulates with the opposing nasal bone, frontal, maxillary, and ethmoid bones

Landmarks

- articular surface for frontal bone
- articular surface for maxilla
- articular surface for opposing nasal bone
- nutrient foramen
- free margin
- groove for ethmoidal nerve

Differentiating Right from Left

- the free edge is the inferior aspect of the bone
- the superior edge is a serrated, irregular surface that articulates with the frontal bone via the nasofrontal suture
- the thickest articular edge is medial and is for articulating with the opposing nasal bone
- therefore, hold the nasal bone with the superior end upwards, the free (inferior, thinnest) edge down, and the anterior (facial) surface toward you
  - the flat nasal suture (articular surface for the opposing nasal bone) is now on the same side as that to which the bone belongs

Looking at Fragments

- students have mistaken nasal bone fragments for those of ethmoid, sphenoid, and palatine
- it can be helpful to look for the nutrient foramen which is commonly prominent in both nasal bones
- also, it is important to notice that the nasal bone tapers markedly in thickness, with the proximal portion being thicker than the distal

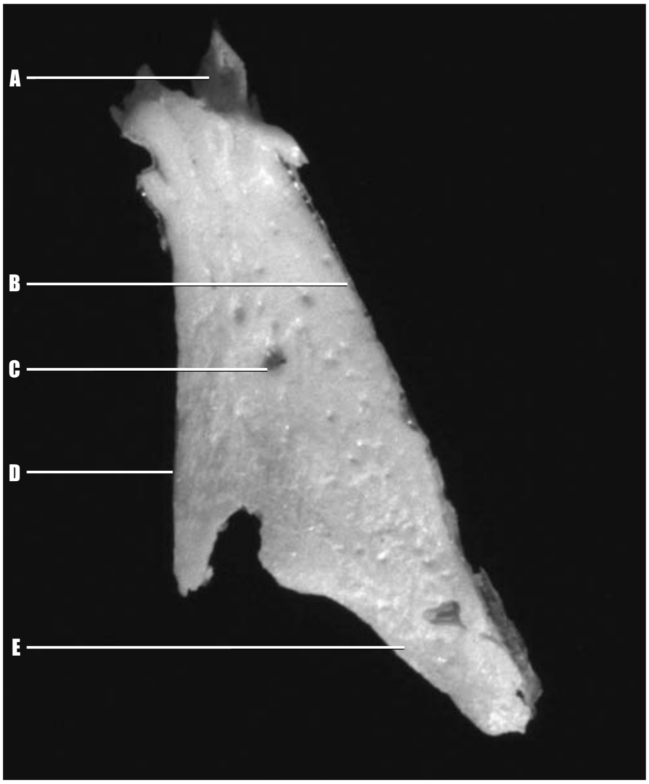


Image 2.117 (above)
Disarticulated juvenile nasal bone, left, anterior surface. Medial is left.

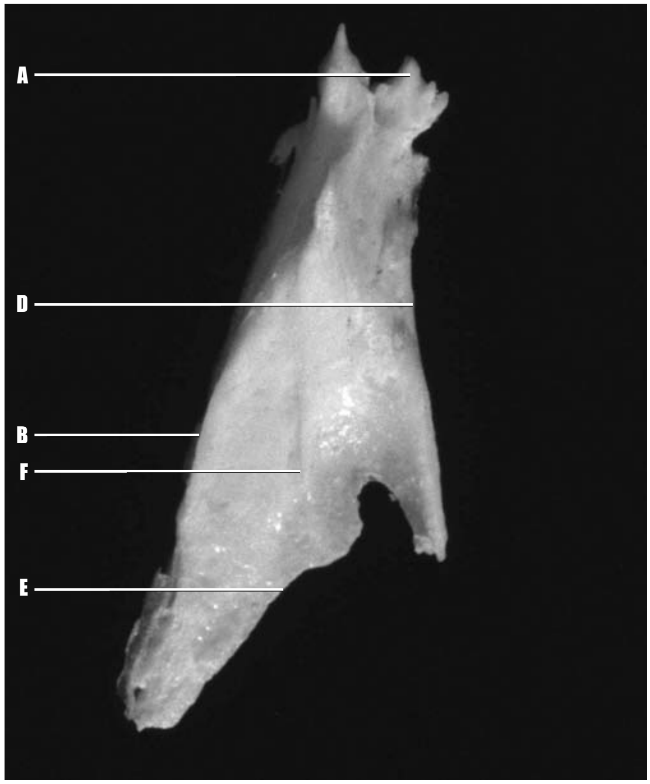


Image 2.118 (above)
Disarticulated juvenile nasal bone, left, posterior surface. Medial is right.

Images 2.117 and 2.118

A - articular surface for frontal bone
B - articular surface for maxilla
C - nutrient foramen
D - articular surface for right nasal bone
E - free margin
F - groove for anterior ethmoidal nerve

2.1m LACRIMAL BONE

Image 2.119 • *Lacrimal bone, lateral (orbital) view.*

- paired bone
- extremely thin and fragile bones of the anteromedial orbit
- in articulation with the maxilla, a lacrimal groove is formed which contains the lacrimal sac and duct
- articulates with the ethmoid, maxillary, and frontal bones, as well as the inferior nasal concha

Landmarks

- articular surface for frontal bone
- articular surface for nasal process of maxilla
- articular surface for orbital surface of maxilla
- articular surface for ethmoid bone
- posterior lacrimal crest
- lacrimal sulcus
- lacrimal hamulus
- nasal surface

Differentiating Right from Left

- keep in mind that the orbital surface is directed laterally, and is at a steep downward slope
- orient the lacrimal bone so that the articular surface for the frontal bone is upwards, the lacrimal hamulus is down, and the orbital surface is toward you
  - the lacrimal groove is now on the same as that to which the bone belongs
  - alternatively, the orbital surface of the lacrimal bone appears to *sweep* toward the same side as that to which the bone belongs

Looking at Fragments

- fragments of lacrimal bone might look like fragments of ethmoid, orbital shelf, scapular body, or other very thin regions of the skeleton which also lack diploë (see page 245)

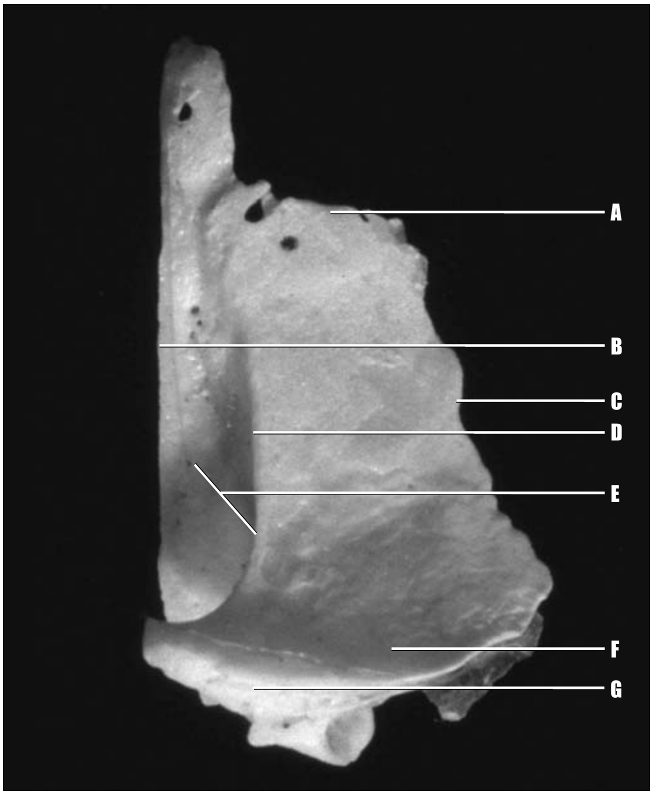


Image 2.120
Disarticulated juvenile lacrimal bone, left, lateral view. Medial is left.

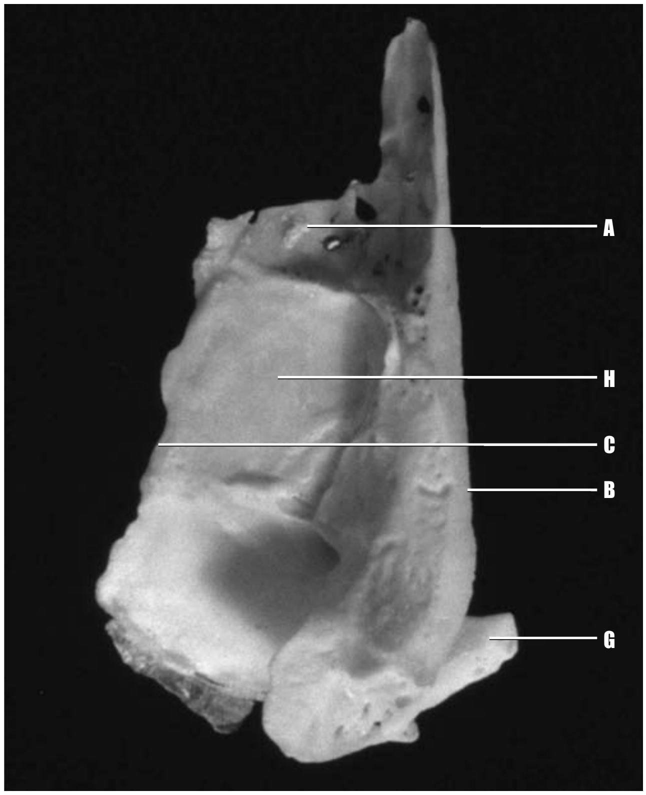


Image 2.121
Disarticulated juvenile lacrimal bone, left, medial view. Medial is right.

Images 2.120 and 2.121

A - articular surface for frontal bone
B - articular surface for frontal process of maxilla
C - articular surface for ethmoid bone
D - posterior lacrimal crest
E - lacrimal sulcus
F - orbital surface of maxilla
G - lacrimal hamulus
H - nasal surface

2.1n MANDIBLE

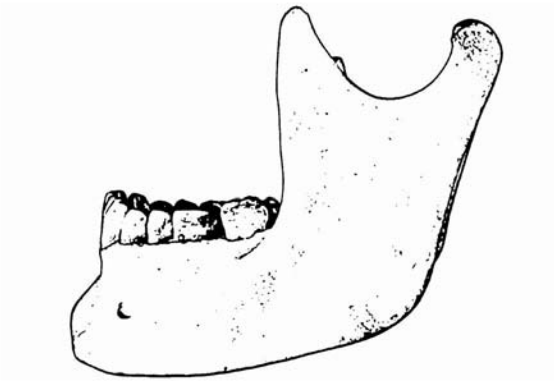


Image 2.122 • *Mandible, lateral view.*

- unpaired bone, but:
  - just prior to birth, the mandible exists as two halves united at the midline (symphysis menti) by a cartilaginous disc
- in the adult stage, it is a singular structure that is the largest, strongest bone of the face
- the mandible houses the teeth of the lower jaw in bony tooth sockets (gomphoses)
- it articulates via its condyles with the temporal bones at the mandibular fossa

Landmarks

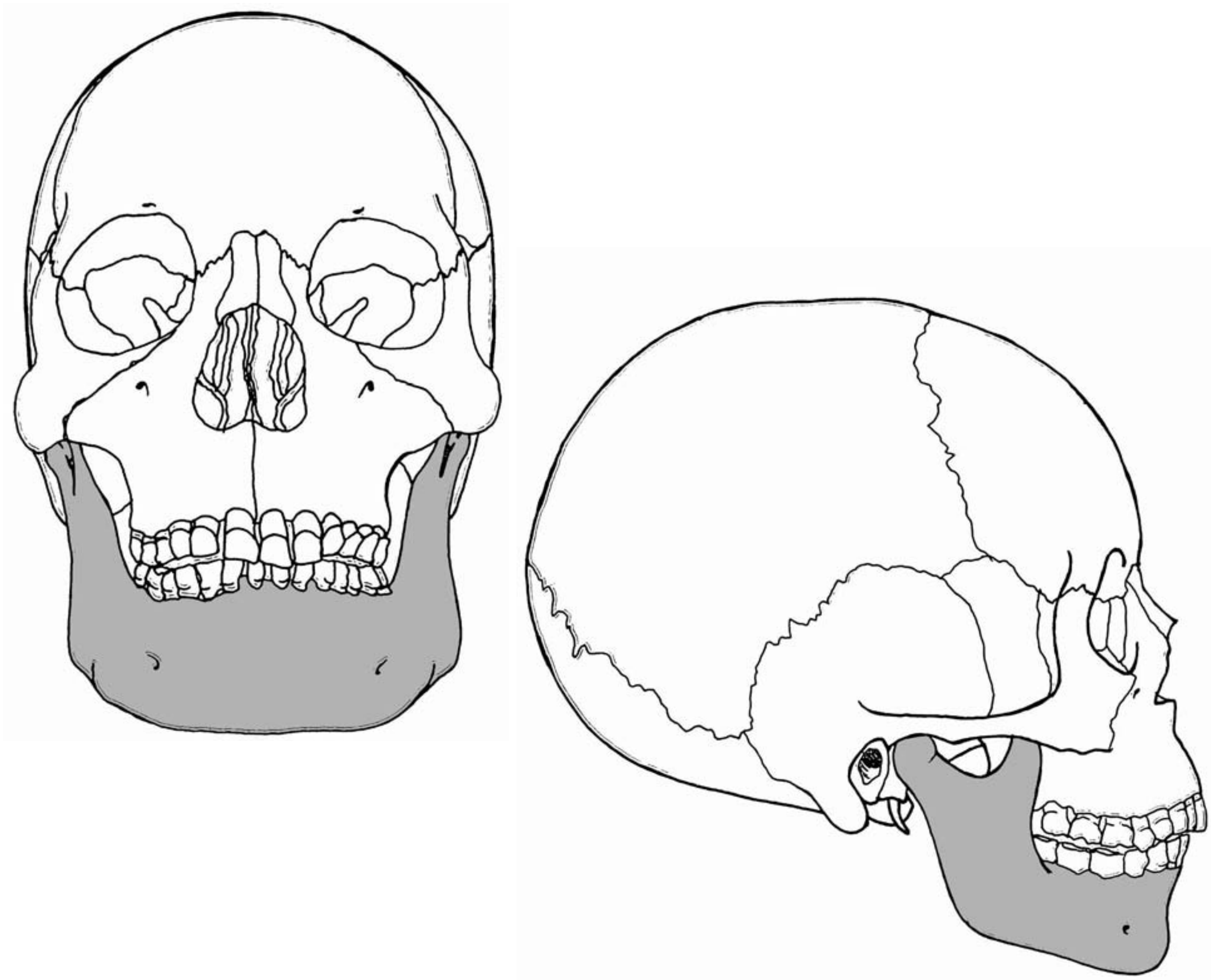
- condyle
- coronoid process
- ramus
- alveolar border
- angle
- masseteric tuberosity
- mental eminence
- mental foramen
- mental protuberance
- body
- mandibular foramen
- lingula
- sublingual fossa
- mylohyoid line
- mylohyoid groove
- mental spine
- digastric fossa
- submandibular fossa

Looking at Fragments

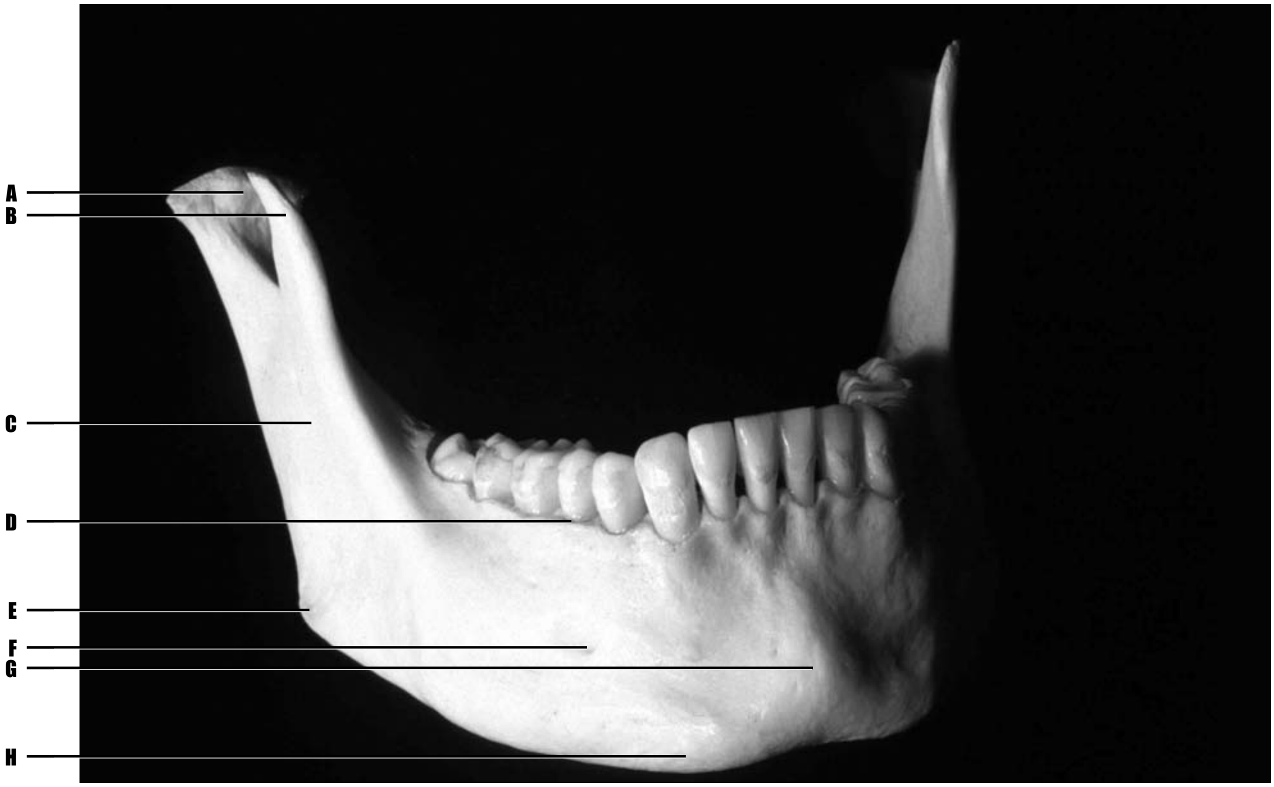
- pay attention to the buccal (cheek side) and lingual (tongue side) surfaces as the lingual surface is smoother when compared to the bumpy alveolar ridges of the buccal side
- pay attention to the types of teeth present within your fragment, or the size of the gomphosis, and remember your mnemonic for the order of teeth (ICPM; see *page 120-121*)
- if you are unlucky enough to have a fragment with only one tooth, it is essential to know the anatomy of that tooth so that you can recognize its orientation within that fragment of jaw
- if you have isolated tooth sockets, you might confuse the mandible and maxilla
  - keep in mind that directly above the maxillary tooth sockets (premolars and molars), one will find the cavernous maxillary sinus

Looking at Fragments continued

- if you have an isolated condyle, keep in mind that the mandibular notch and ramus are continuous only with the lateral side of the condyle (i.e. the majority of the condyle is actually medial)
- if you have an isolated coronoid process, note that this process has a somewhat roughened medial surface
- isolated coronoid processes could be mistakenly identified as fragments of cranial or intrasutural bones
    - however, the smooth edges of the coronoid process are easily distinguished from cranial bones
- similarly, an isolated coronoid process is probably too thick to be confused with the fragile bones of the sphenoid, ethmoid, vomer, etc.



Images 2.123 (left) and 2.124 (right)
Illustrations demonstrating **mandible** *in situ* – anterior and lateral views respectively.



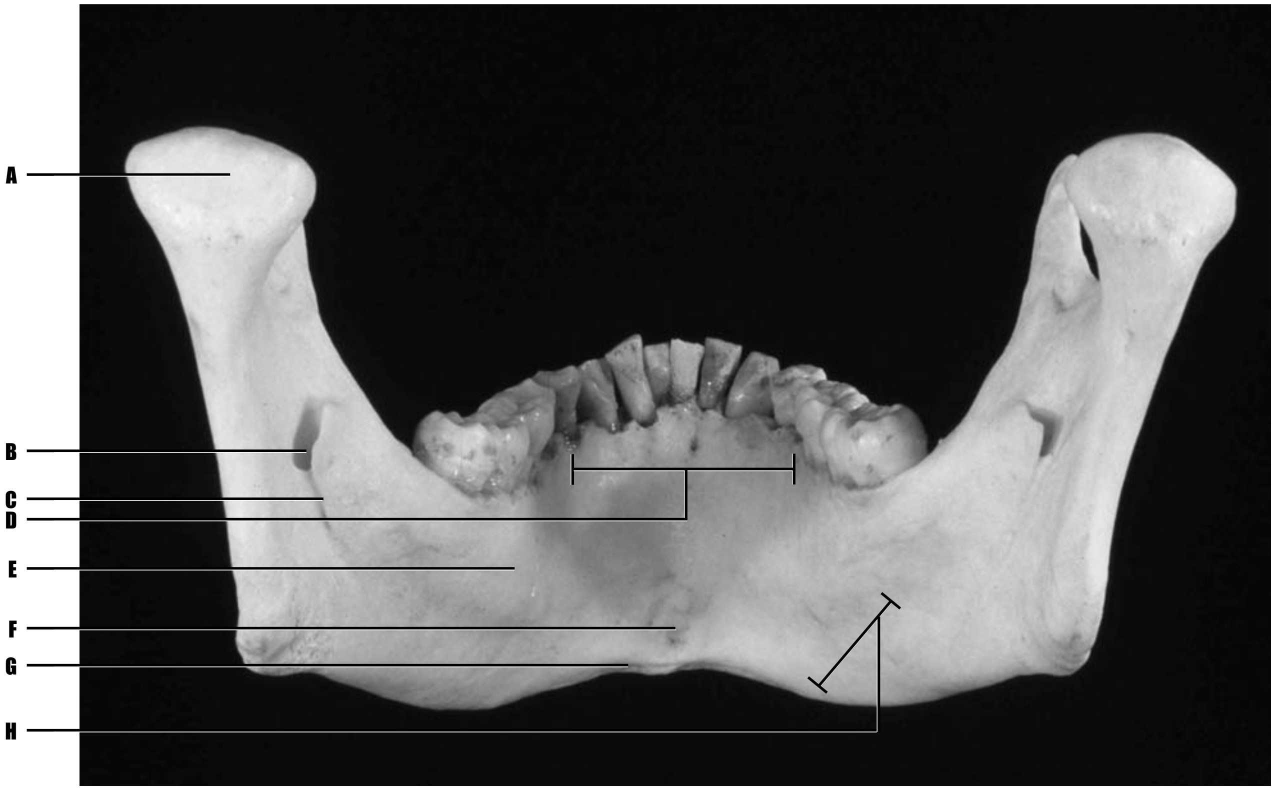


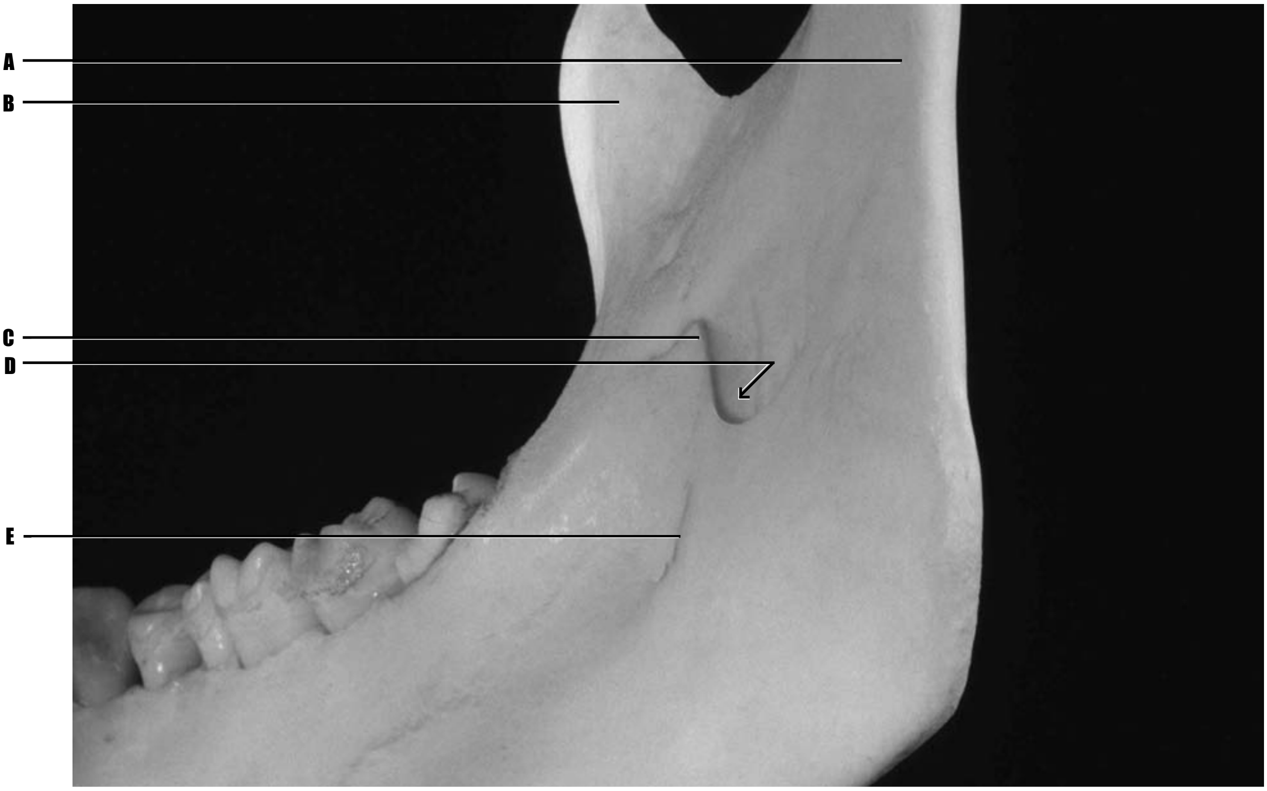
Image 2.125 (above)
Mandible, oblique anterior view.
Image 2.126 (below)
Mandible, posterior view.

Image 2.125

A - condyle (head)
B - coronoid process
C - ramus
D - alveolar border
E - angle
F - mental foramen
G - mental eminence
H - mental protuberance

Image 2.126

A - condyle (head)
B - mandibular foramen
C - opening of the mandibular (inferior alveolar) canal
D - sublingual fossa
E - mylohyoid ridge
F - mental spine
G - digastric fossa
H - submandibular fossa



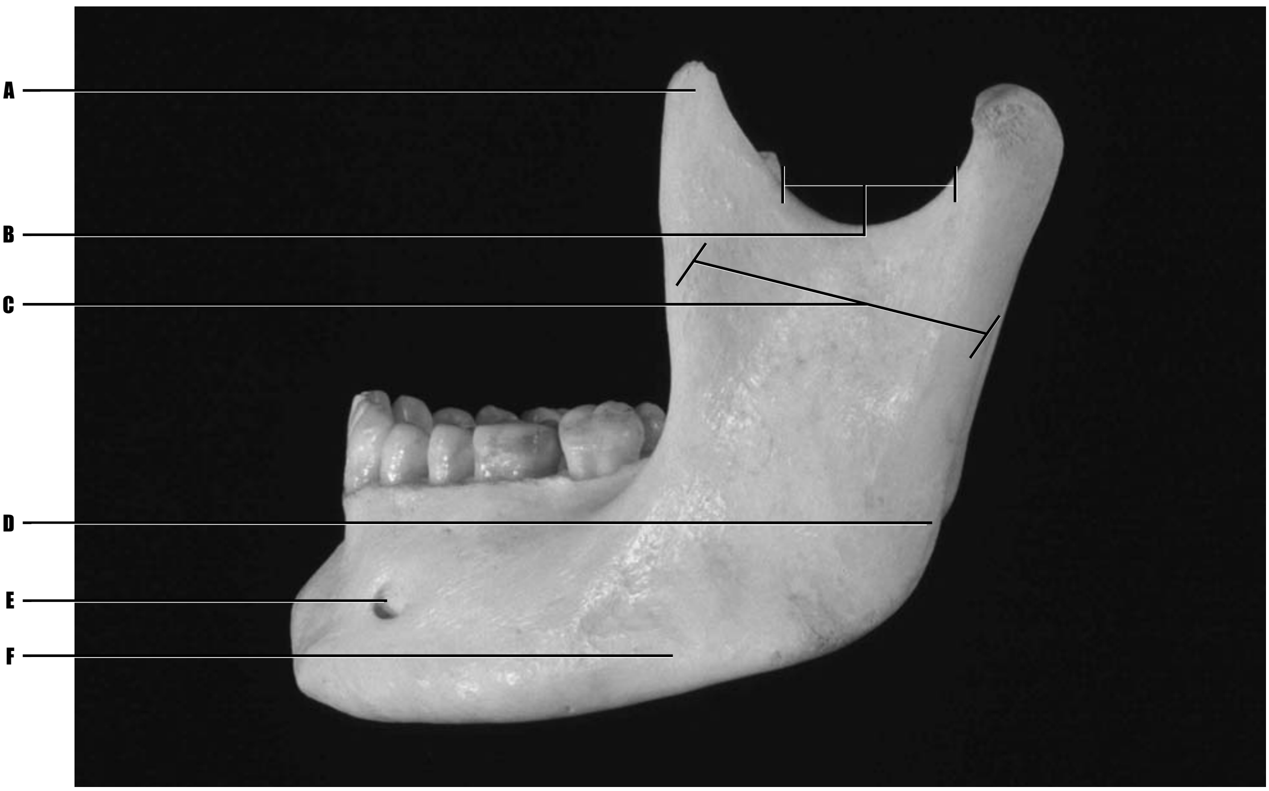


Image 2.127 (above)
Mandible, posteromedial view of right ramus.
Image 2.128 (below)
Mandible, lateral view.

Image 2.127

A - mandibular neck
B - coronoid process
C - lingula
D - mandibular foramen
E - mylohyoid groove

Image 2.128

A - coronoid process
B - mandibular notch
C - ramus
D - angle, also, location of masseteric tuberosity
E - mental foramen
F - body of mandible

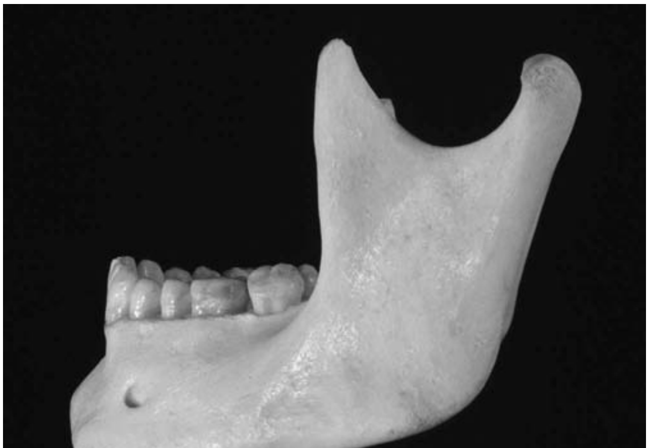


Image 2.129
Young adult mandible, left lateral view.

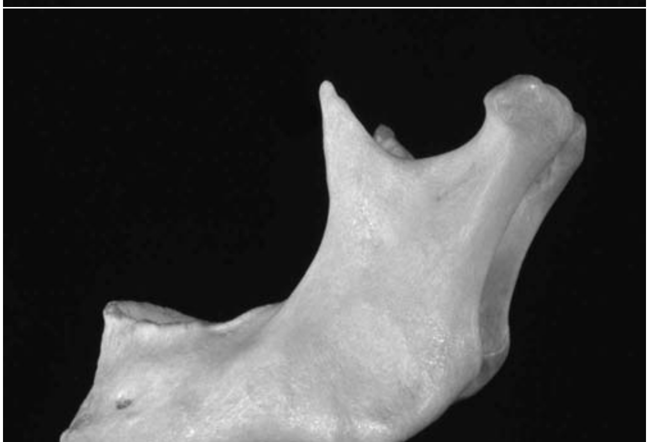


Image 2.130
Edentulous elderly mandible, left lateral view.

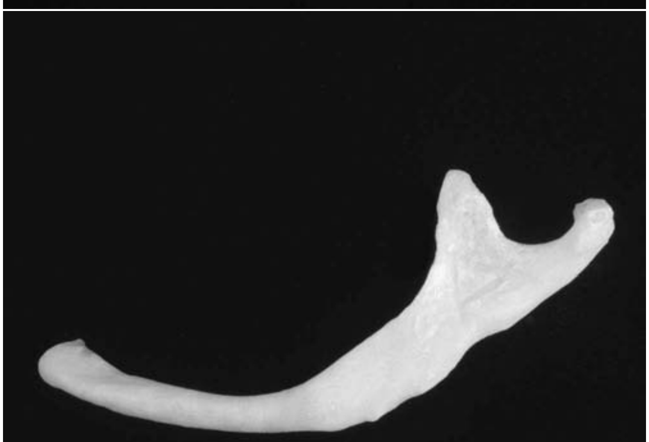


Image 2.131
Edentulous elderly mandible with marked atrophy, left lateral view.

We have previously mentioned that there is great individual variation in skeletal morphology. This is amply demonstrated with comparisons between **Images 2.129** to **2.131** which provide examples of the possible range of mandibular anatomy throughout adult life.

Notice that as the mandible ages, the angle present between the body and ramus becomes less perpendicular, and the mental protuberance is more anteriorly directed. When tooth loss occurs earlier in life, as it has in both **Images 2.130** and **2.131**, there is complete resorption and thinning of the alveolar margin. There is no way to confuse this finding with postmortem tooth loss.

As the individual ages, there is generalized bone loss as degradation exceeds formation. In some disease states, this may be further accentuated, as could be the case in **Image 2.131**. When presented with an isolated bony element such as the half mandible in **Image 2.131**, it is important first to recognize elemental aspects of the anatomy such as the coronoid process, condyle and ramus since landmarks like the mental protuberance, mandibular foramen or robust masseteric tuberosities may no longer be present.

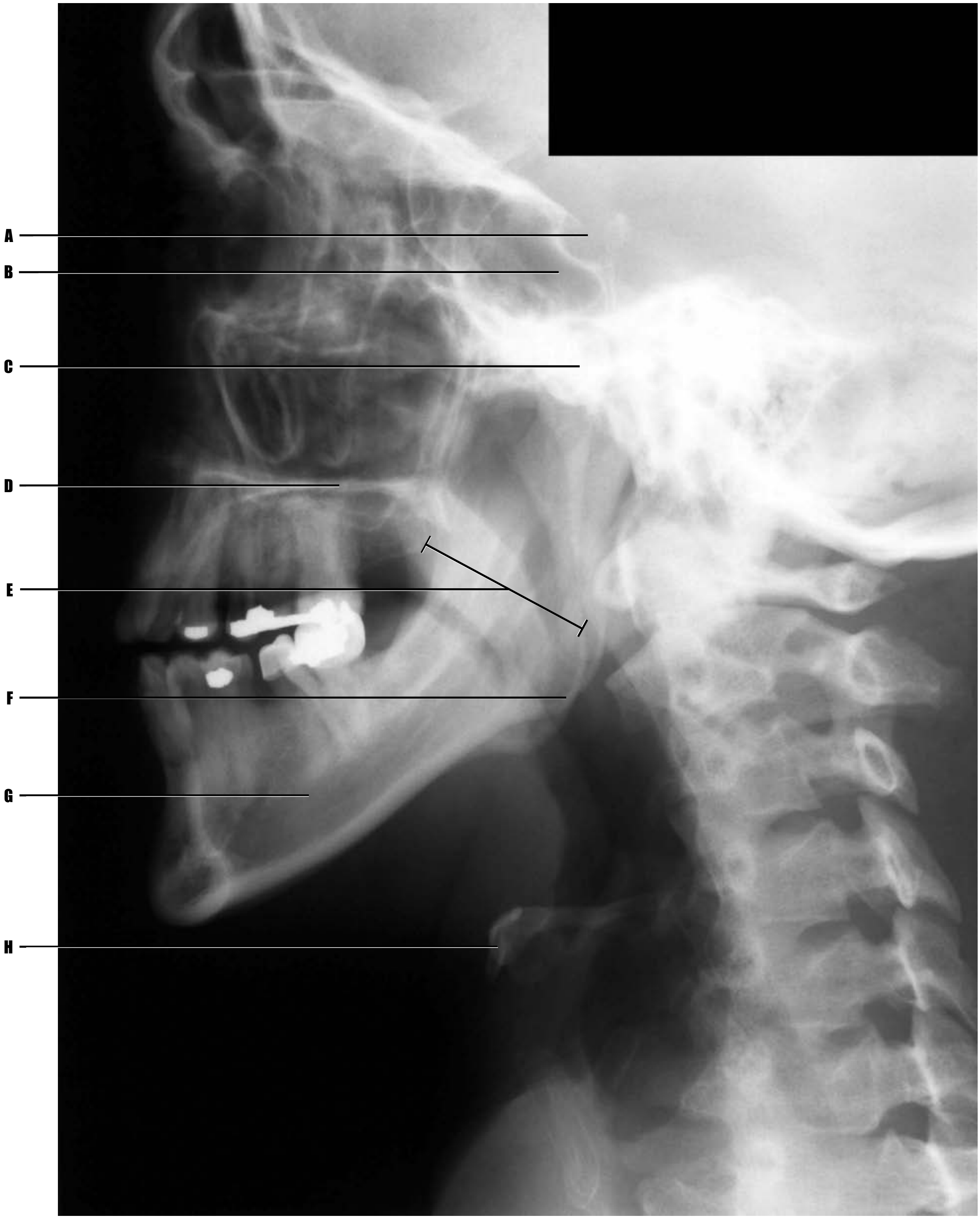


Image 2.132 (above)
Adult patient, plain film radiograph, lateral mandible.

Image 2.132

A - sella turcica

B - sphenoid sinus

C - head of mandible in temporomandibular joint

D - hard palate

E - ramus of mandible

F - angle of mandible

G - body of mandible

H - hyoid bone

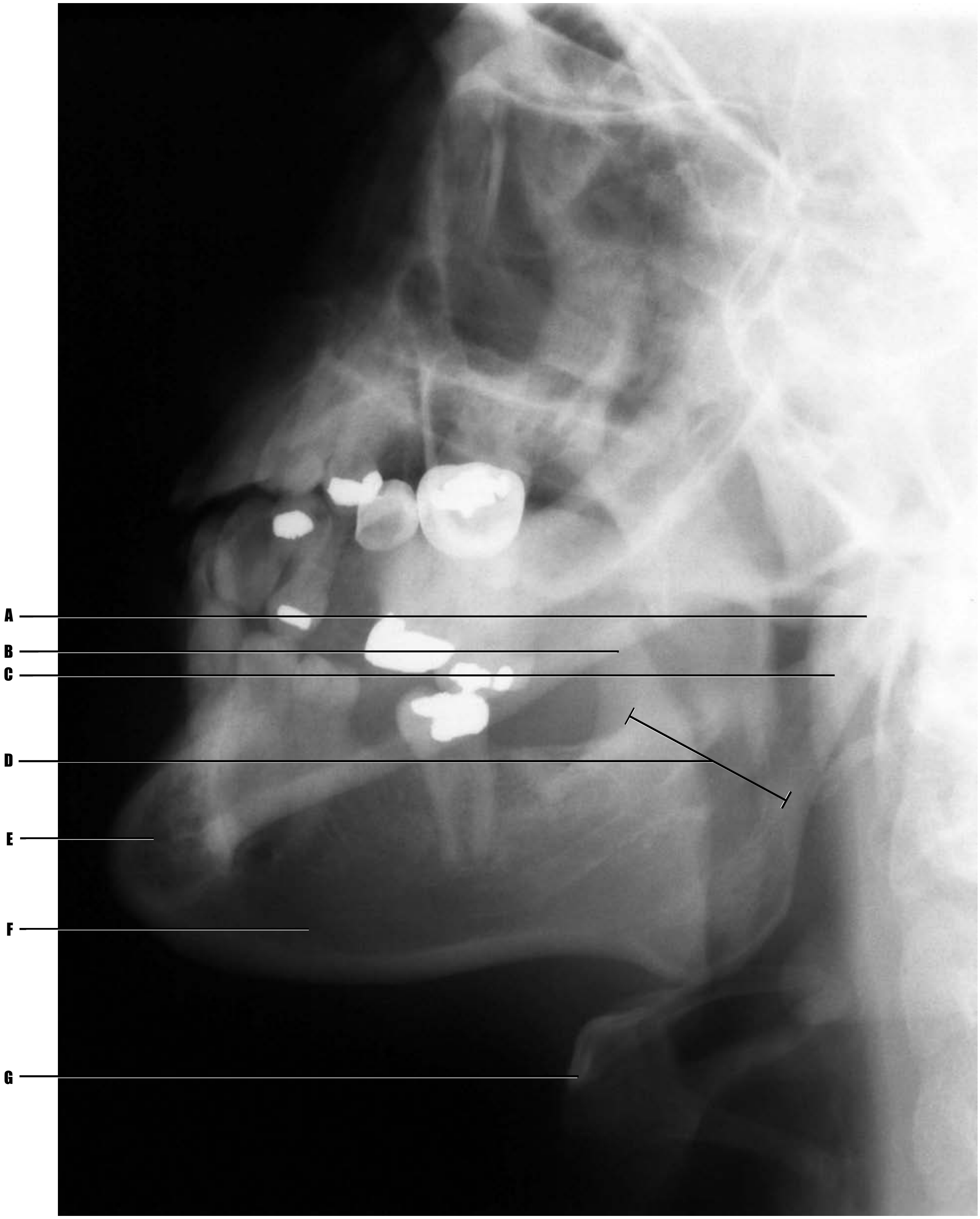


Image 2.133 (above)
Adult patient, plain film radiograph of oblique mandible.

Image 2.133

A - head of mandible
B - coronoid process
C - neck of mandible
D - ramus of mandible
E - symphysis of mandible
F - body of mandible
G - hyoid bone

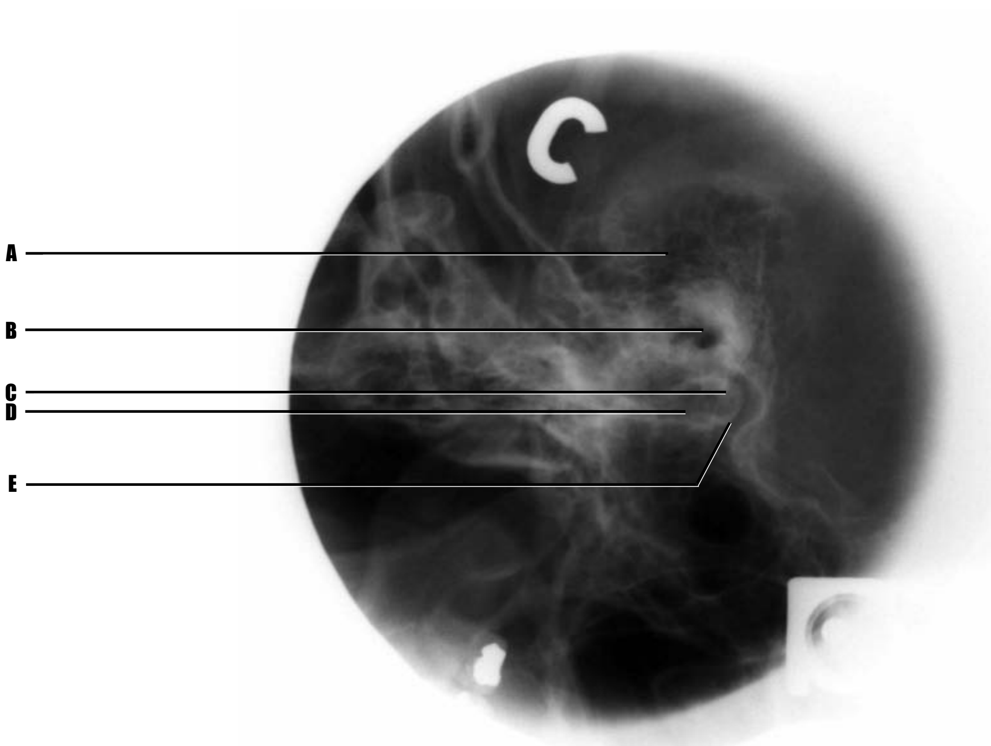
Image 2.134 (above)

Adult patient, plain film radiograph, "Towne's projection" of mandible.

A Towne's projection is a radiographic projection used to permit examination of the bony components of the temporomandibular joint.

Image 2.134

A - occipital bone
B - internal occipital crest
C - petrous ridge of temporal bone
D - mastoid air cells
E - temporomandibular joint
F - neck of mandible
G - nasal septum
H - maxillary sinus
I - mandibular ramus
J - spinous process of first thoracic vertebra (T1)



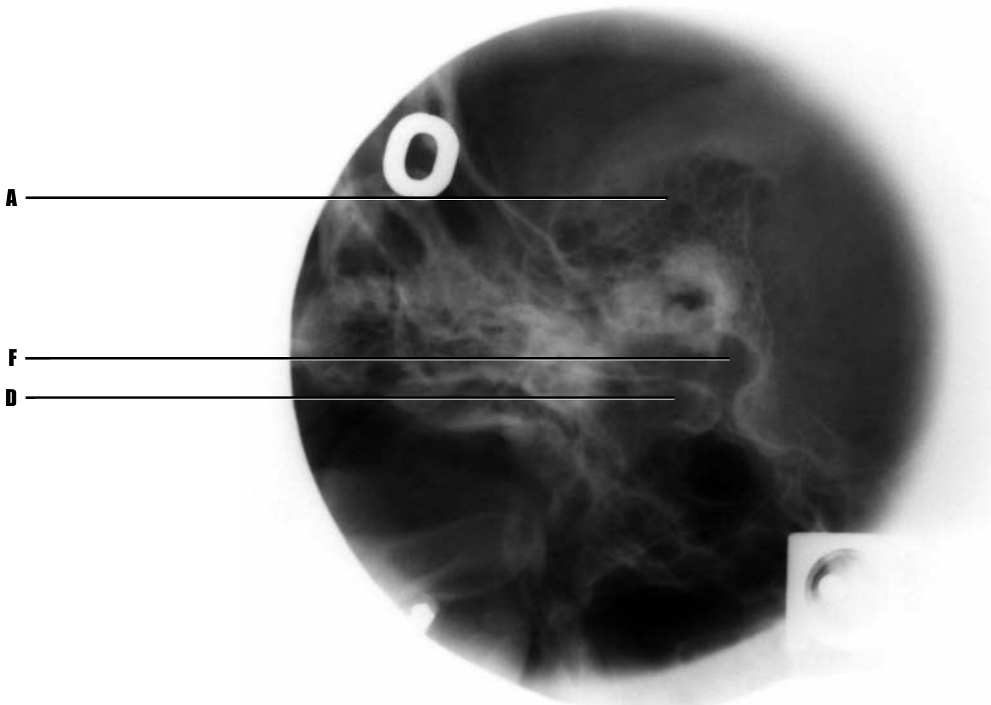


Image 2.135 (above)

Adult patient, fluoroscopic view of temporomandibular joint (TMJ), mouth closed.

Image 2.136 (below)

Adult patient, fluoroscopic view of temporomandibular joint (TMJ), mouth open.

A fluoroscope is a special type of diagnostic imaging that uses X-rays to visualize radio-opaque objects in 'real time'. As such, the movement of the mandible at the temporomandibular joint could be observed with this technique.

Images 2.135 and 2.136

A - mastoid air cells
B - internal acoustic meatus
C - articular surface of mandibular head
D - neck of mandible
E - mandibular fossa
F - temporomandibular space

2.2 DENTITION

- the typical adult skull has thirty-two teeth which are equally divided between the upper and lower jaws
- each jaw can be divided into right and left halves, each of which contains eight teeth:
  - there are **two** incisors, **one** canine, **two** premolars and **three** molars in each quadrant, a relationship that can be conveniently represented with the formula 2.1.2.3 / 2.1.2.3
  - the numerator represents onehalf of the maxilla, while the denominator represents one half of the mandible
  - to aid in the recall of tooth order, students often remember the convenient acronym **ICPM**
- since each tooth has a different morphology which can be categorized into one of the above four types, humans are referred to as being *heterodonts*
- this is in contrast to species like sharks, whose teeth are of only one configuration – they are therefore classified as *homodonts*

Let's consider a few basic, yet important points about teeth:
- *Incisors* are so named because their chisel-like crowns have sharp cutting edges. They are therefore biting teeth. They have a single root.
- *Canines*, or *eyeteeth*, are longer than incisors and their conical crowns may be quite pointed when they first erupt. However, with continued wear, their tips become flattened. They have a single root which is much longer and thicker than that of the incisor.
- *Premolars* are smaller and shorter than canines. They bear two pyramidal cusps on their crowns, an outer buccal (toward the cheek) cusp and an inner lingual (toward the tongue) cusp. It is for this reason that we refer to premolars as being bicuspid. The root of the premolar is flattened and deeply grooved with a tendency to be bifurcated.
- *Molars* are the largest teeth and have broad crowns adapted for the grinding of food. The upper molars have three roots whereas the lowers have only two. Both upper and lower third molars, the *wisdom teeth*, are the smallest molars and frequently erupt late or not at all. Non-eruption may represent complete agenesis of this particular tooth.

Landmarks
- crown
- root
- occlusal surface
- lingual surface
- buccal surface

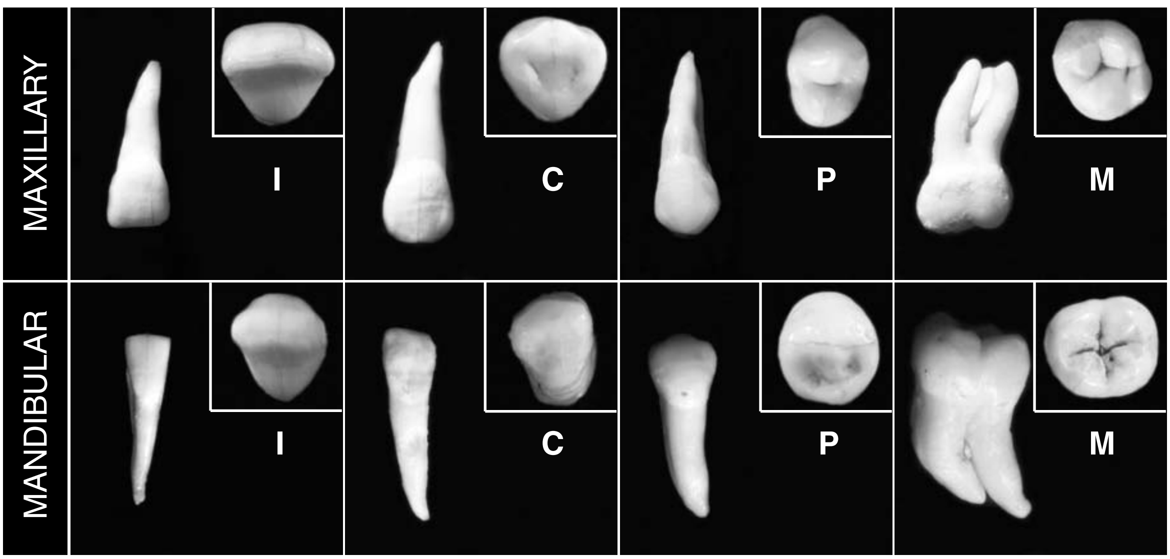


Image 2.137
Examples of adult dentition, one of each of the left maxillary and mandibular central incisors (I), canines (C), second premolars (P) and second molars (M). *Please note that the images are not printed to scale.*

There are several items that should be noted about human dentition:

(1) The dental arches of both the maxillary and mandibular arcades are smooth arches.

(2) The teeth are small and show relatively little difference in size. This can be important to consider when separating human from nonhuman remains.

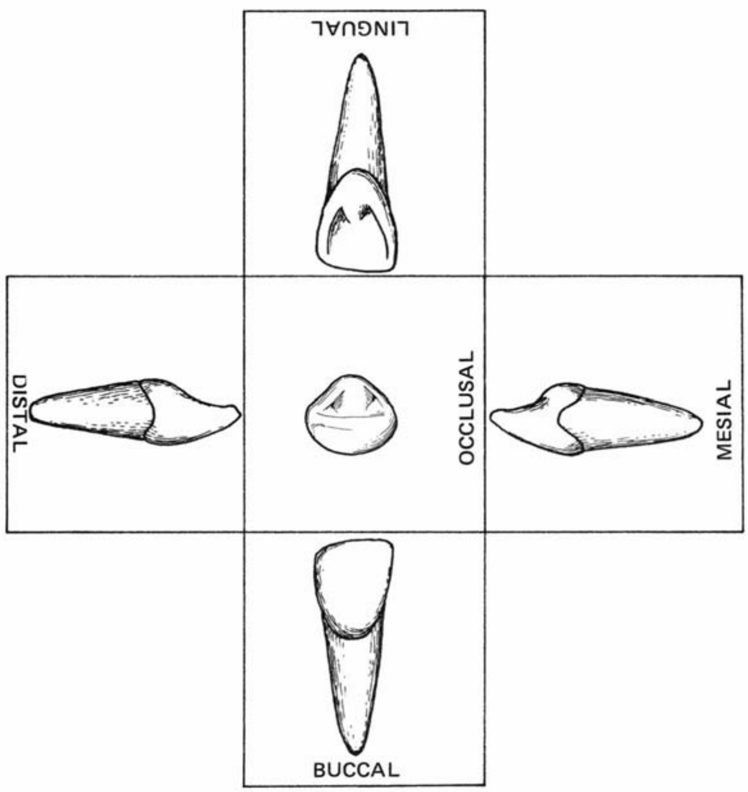
(3) The biting surfaces of the teeth lie in the same plane and the crowns become flat with wear.

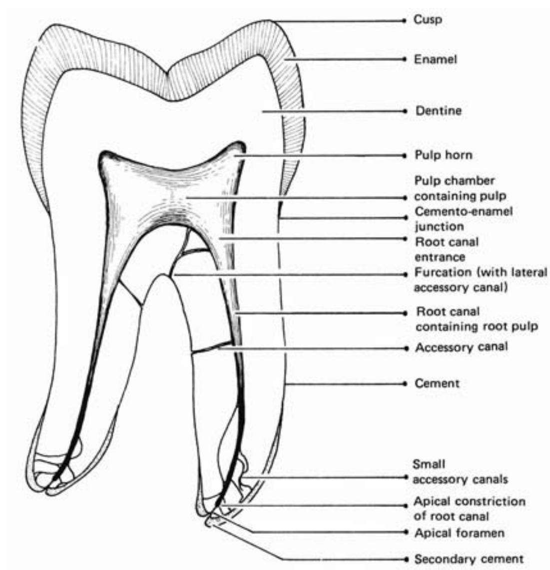
(4) The canines are incisiform (resemble incisors), do not normally project beyond the occlusal plane of the teeth and do not show sexually dimorphic traits which are easily seen in some other primates.

(5) The teeth of both jaws are usually set in a regular row with no gaps (diastema).

The deciduous or primary dentition

- there are twenty primary teeth in the growing child; half of a mandibular or maxillary arcade consists of two incisors, one canine, no premolars and two molars
- this can therefore be represented by the formula 2.1.0.2 / 2.1.0.2
- tooth eruption can be used as a convenient marker for determining the approximate age of young individuals
  - for example, the central deciduous incisors erupt at about six to eight months; the second primary molars at around two years; the permanent first molars at about six years, and so forth.

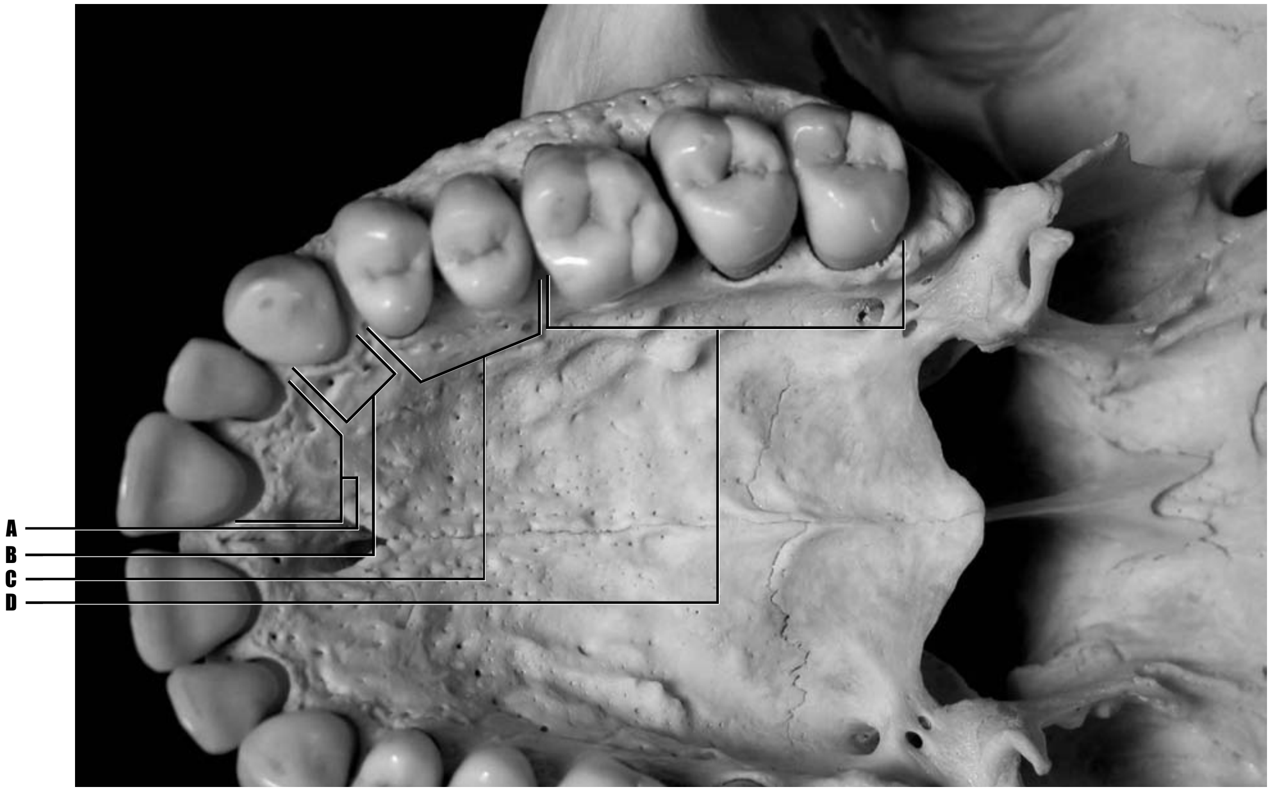




Images 2.138 (left) and 2.139 (right)

Dental terms of direction can be confusing as the terminology may vary depending on whether the tooth is located anteriorly (incisor or canine) or posteriorly (premolar or molar) in the mouth. **Image 2.138** is of an upper left central incisor. This example serves to illustrate the various dental terms of direction. The **buccal** surface is the outer or *cheek*-side of the tooth. The **lingual** surface is on the *tongue*-side of the tooth. The **mesial** surface is toward the midline, and the **distal** surface is away from the midline. The **occlusal** surface refers to the biting surface of the tooth.

Image 2.139 demonstrates the essential anatomy of a stereotypical tooth.



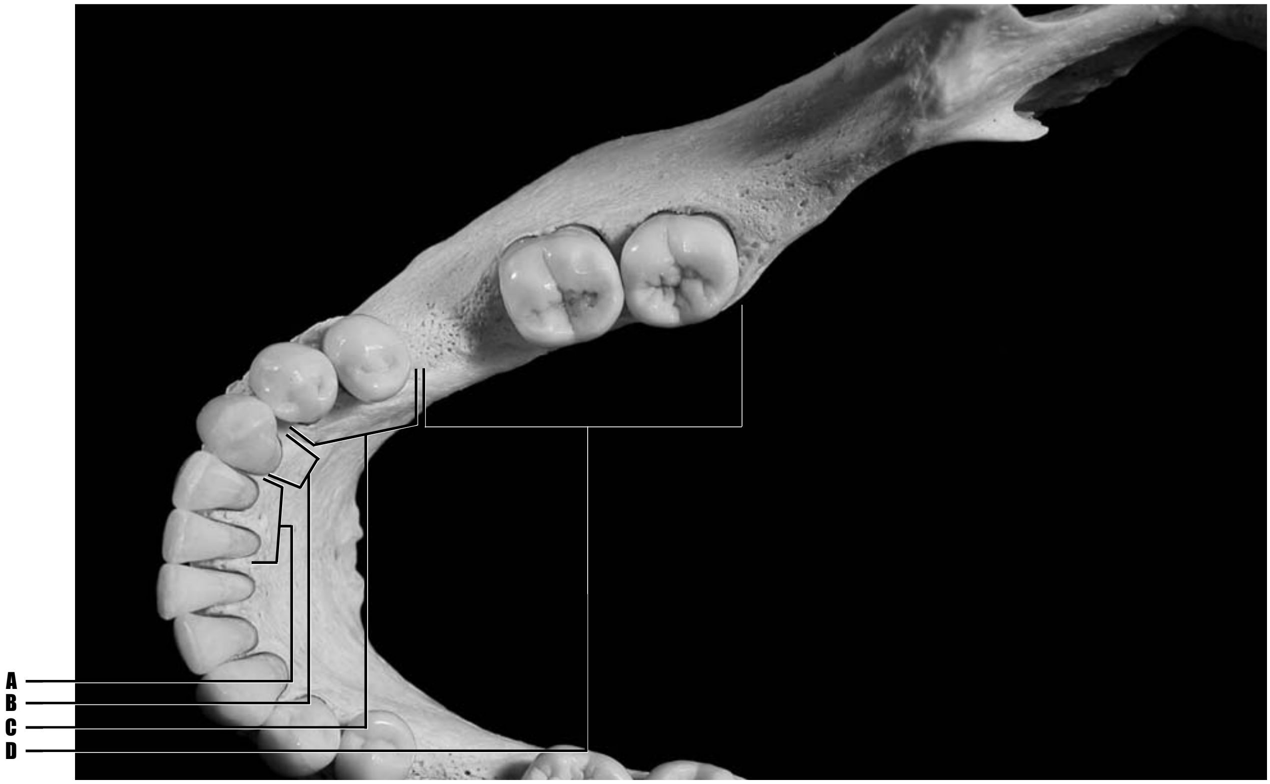


Image 2.140 (above)
Maxilla, dentition of left quadrant.

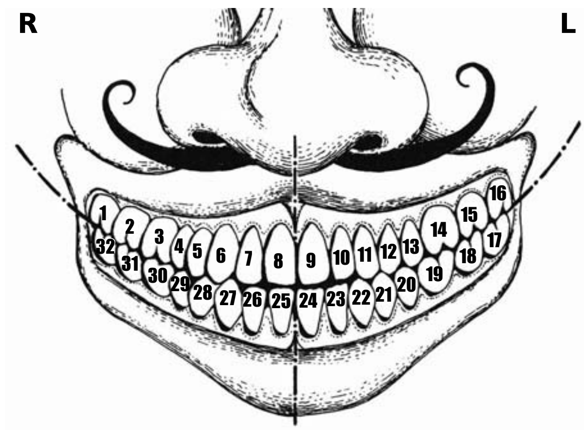
Image 2.141 (below)
Mandible, dentition of right quadrant. Note that the first molars are missing in both the right and left halves of this mandible.

Image 2.140

A - incisors
B - canine
C - premolars
D - molars

Image 2.141

A - incisors
B - canine
C - premolars
D - molars



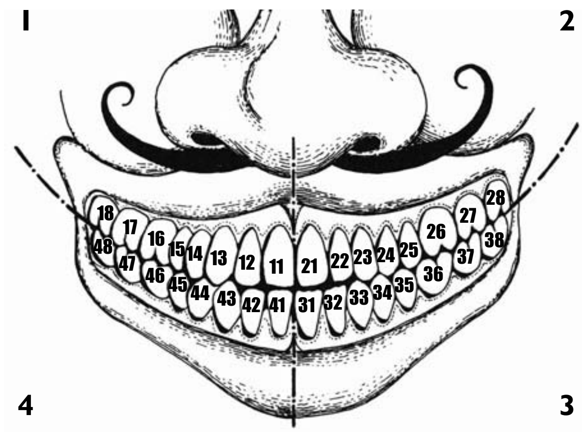
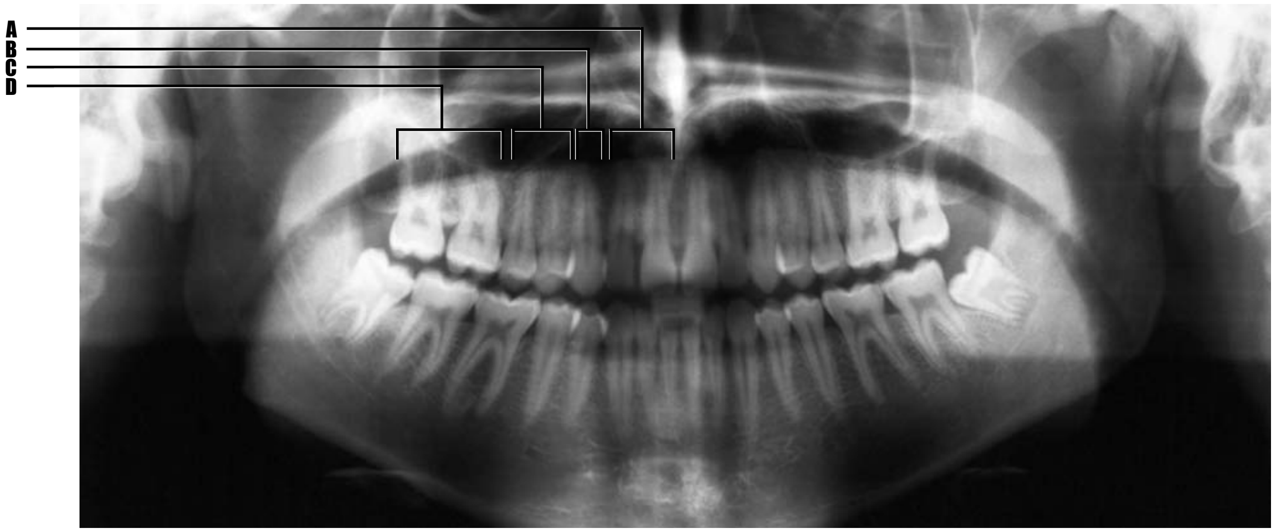
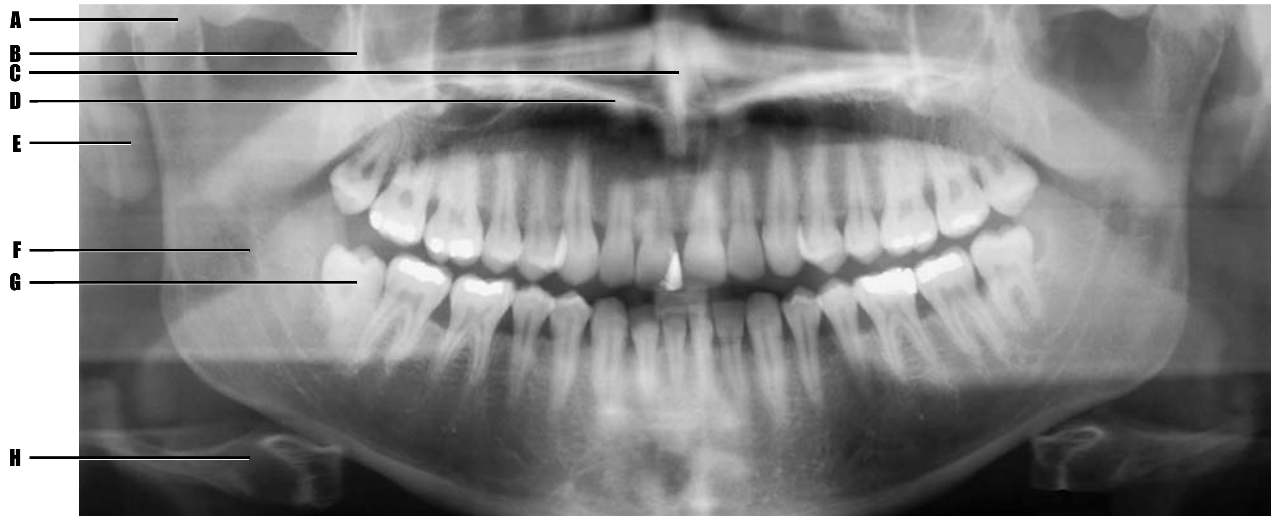


Image 2.142
ABOVE – **Universal Numbering System.**
BELOW – **FDI Numbering System**.
In the FDI system, the first number of any number combination (e.g,. 1 in 18 [may also be written 1.8 or 1-8]) depicts the quadrant in which the tooth resides (i.e., in our example of 18, 1 is the right maxillary quadrant). The second number indicates the tooth position in the arch (i.e., in 18, the tooth is in the eighth position).





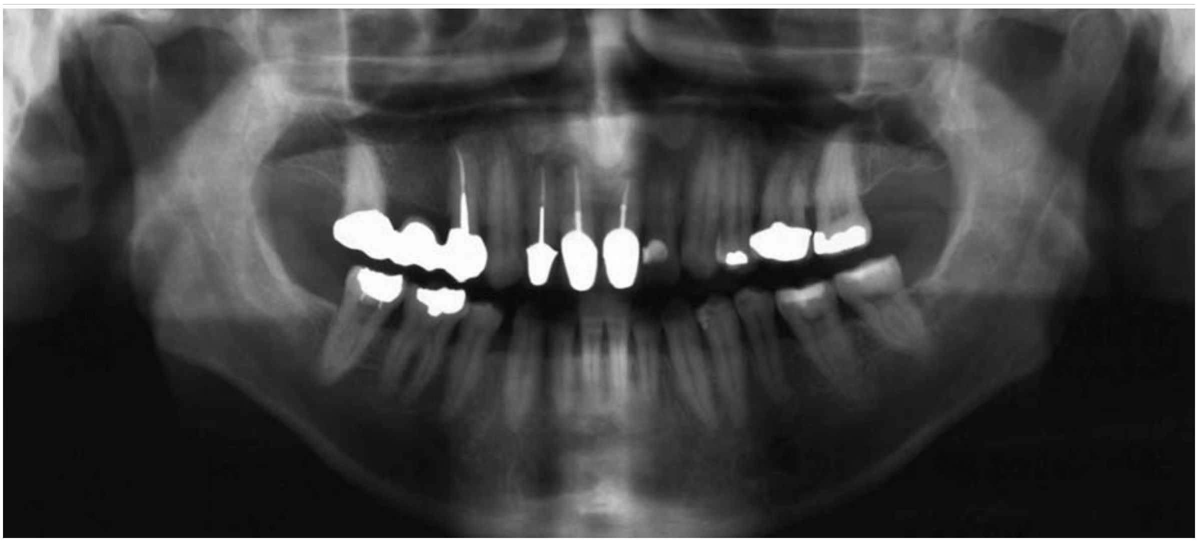


Image 2.143 (top)
Adult patient, plain film radiograph of dental arcades, panoramic view.

Image 2.144 (middle)
Adult patient, plain film radiograph of dental arcades, panoramic view.

Image 2.145 (bottom)
Adult patient, plain film radiograph of dental arcades, panoramic view.
This example serves only to illustrate some of the dental work which may be visible on radiographs of the jaw – here, amalgams, and endodontic procedures are visible. This patient has 24 teeth, and is missing 1, 2, 4, 13, 16, 17, 28 and 32 (Universal numbering system).

Image 2.143

A - incisors
B - canine
C - premolars
D - molars

Image 2.144

A - condyle of mandible
B - lateral border of maxillary sinus
C - nasal septum
D - hard palate
E - soft tissue shadow of earlobe
F - mandibular canal
G - right third molar (wisdom tooth)
H - hyoid bone

Image 2.145

Endodontic work

- root canals on maxillary right first premolar, right lateral and central incisors, and maxillary left central incisor

Fixed prosthodontic work

- three-unit bridge from maxillary right first molar to first premolar
- posts in canals of maxillary right first premolar, lateral and central incisors, and left central incisor
- crowns on maxillary right lateral and central incisors, left central incisor, and left first molar

Restorative work

- amalgam (silver filling) restorations on maxillary left premolar and second molar, and mandibular right first molar
- pinned amalgam restoration of mandibular right second molar
- composite (tooth color) restorations on maxillary left lateral incisor, and mandibular left first and second molars

2.2a INCISORS

- there are eight incisors – two central and two lateral in each quadrant
- their function is in biting and cutting of food, phonetics and esthetics (by supporting the lip)
- incisors are flat, blade-like teeth
- maxillary incisors are wider than they are thick; mandibular incisors are thicker than they are wide
- each incisor has only one root

Tooth Numbering Systems:

	Maxillary centrals	Maxillary laterals	Mandibular centrals	Mandibular laterals
Universal (right and left, respectively)	8, 9	7, 10	25, 24	26, 23
FDI (right and left, respectively)	11, 21	12, 22	41, 31	42, 32

Landmarks

- be able to differentiate between the five surfaces of the crown:
  - incisal (occlusal)
  - facial (labial)
  - lingual (palatal)
  - mesial
  - distal

Occlusal anatomy

- both mandibular and maxillary incisors have a simple blade-like biting surface

How to distinguish between maxillary and mandibular incisors

- compared to maxillary incisors, mandibular incisors:
  - are thicker than they are wide (i.e. wider buccolingually than mesiodistally)
    - this is in comparison to maxillary incisors which are much wider than they are thick (i.e., wider mesiodistally than buccolingually)
  - have a more symmetrical crown with incisal angles that are more square
  - have smooth lingual surfaces with less prominent anatomy
- it can be difficult to distinguish between maxillary and mandibular lateral incisors
  - note that the crowns of mandibular lateral incisors are thinner/sharper toward the incisal surface
  - this differs from the thicker and somewhat rounded crowns of the maxillary lateral incisors

How to distinguish maxillary central from lateral incisors

- maxillary central incisor crowns are longer than they are wide
- the crowns of the lateral incisors are narrower, and they are less symmetrical
- the roots of the lateral incisors are longer, and they curve distally

How to distinguish between maxillary left and right incisors

- hold the tooth with the lingual surface toward you with the incisal edge downwards, and the root upwards – the roots will curve slightly toward the same side to which the tooth belongs

How to distinguish mandibular central from lateral incisors

- the central incisors are more symmetrical
- if you compare central and lateral mandibular incisors from the same mouth, the central incisors will be smaller (narrower)

How to distinguish between mandibular left and right incisors

- for all mandibular incisors, hold the tooth with the crown directed upwards, the root downwards, and the buccal surface toward you – with this orientation, the root will point toward the same side as that to which the tooth belongs
- the roots of mandibular central incisors may only be curved minimally – careful examination may be necessary

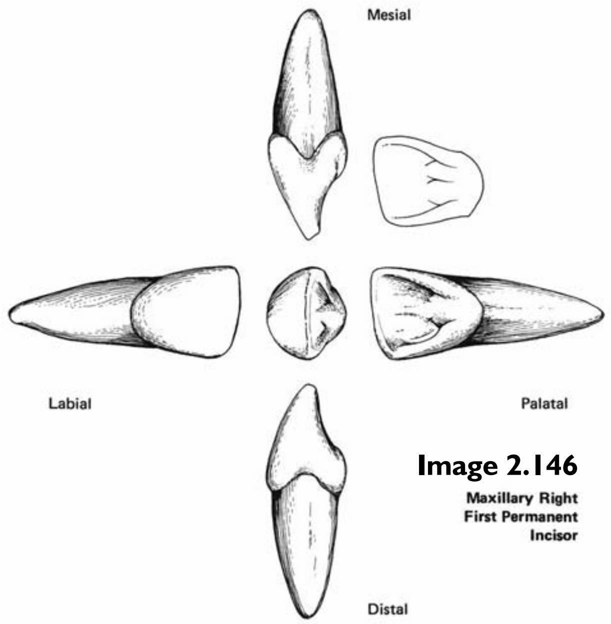


Image 2.146
Maxillary Right
First Permanent
Incisor

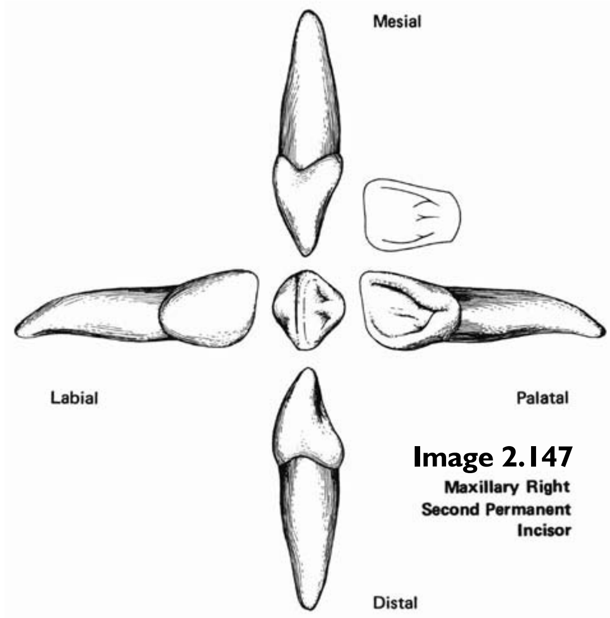


Image 2.147
Maxillary Right
Second Permanent
Incisor

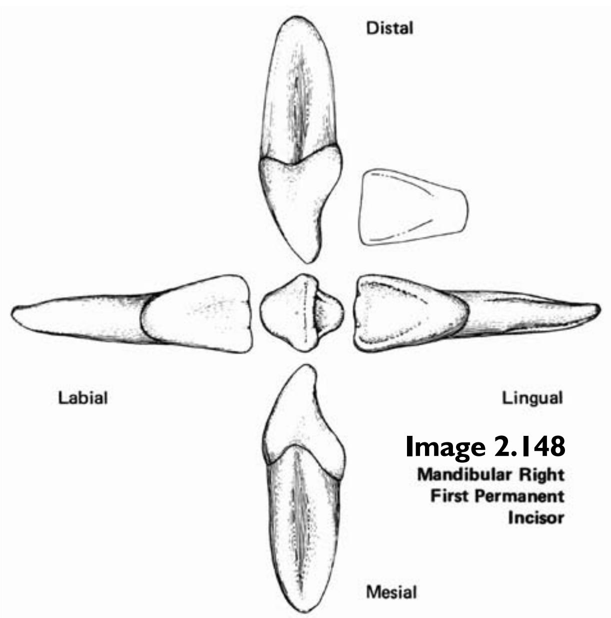


Image 2.148
Mandibular Right
First Permanent
Incisor

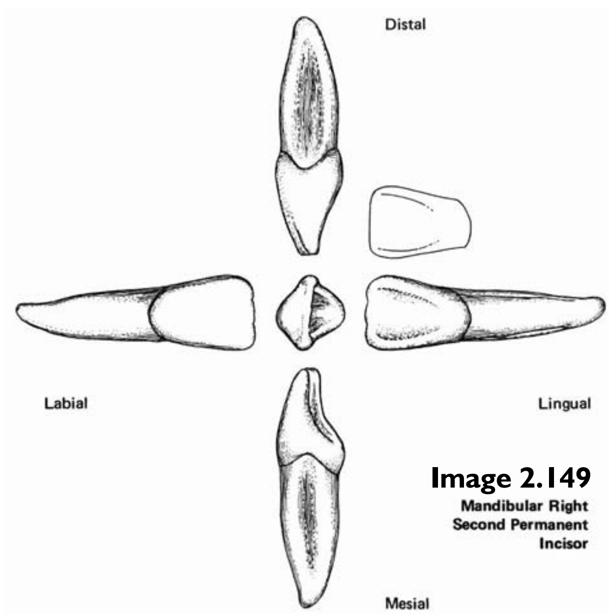


Image 2.149
Mandibular Right
Second Permanent
Incisor

2.2b CANINES

- there are four canines – one in each quadrant
- they function in tearing and chewing food, esthetics and speech
- they are the longest permanent teeth in the mouth
- their crowns are intermediate in appearance between incisors and premolars
- each canine has only one root

Tooth Numbering Systems:

	Maxillary canines	Mandibular canines
Universal (right and left, respectively)	6, 11	27, 22
FDI (right and left, respectively)	13, 23	43, 33

Landmarks

- be able to differentiate between the five surfaces of the crown:
  - incisal
  - facial
  - lingual
  - mesial
  - distal

Occlusal anatomy

- canines are much thicker than the incisors
- like incisors, they have an *incisal* or *biting* edge, which often wears with age
- on the lingual surface of the canine is a small pseudo-cusp or *cingulum*

How to distinguish between maxillary and mandibular canines

- maxillary canines are sharper, and their crowns are wider
- often, the mandibular root is shorter than the maxillary, but the mandibular crown is longer (i.e., crown:root ratio differs between the two dental arcades)

How to distinguish between maxillary left and right canines

- hold the tooth so that the lingual surface is toward you, the crown is downward, and the root is up – the root tip will bend slightly toward the same side as that to which the tooth belongs

How to distinguish between mandibular left and right canines

- hold the tooth so that the lingual surface is toward you, the crown is upwards, and the root is down– the root tip will bend slightly toward the same side as that to which the tooth belongs

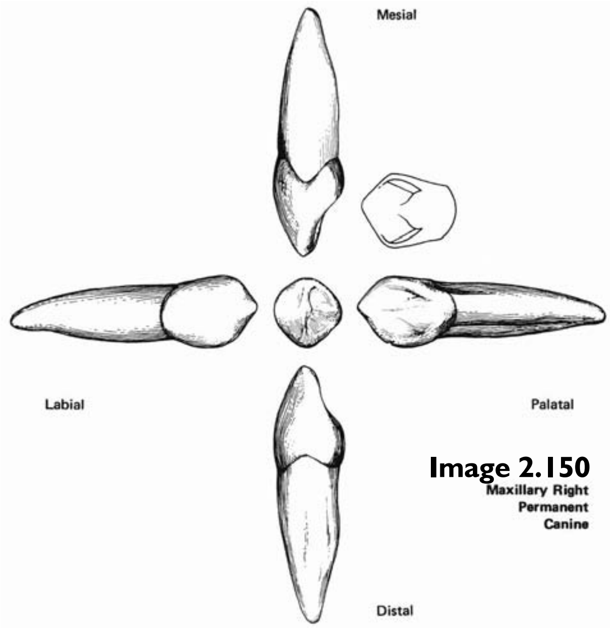


Image 2.150
Maxillary Right
Permanent
Canine

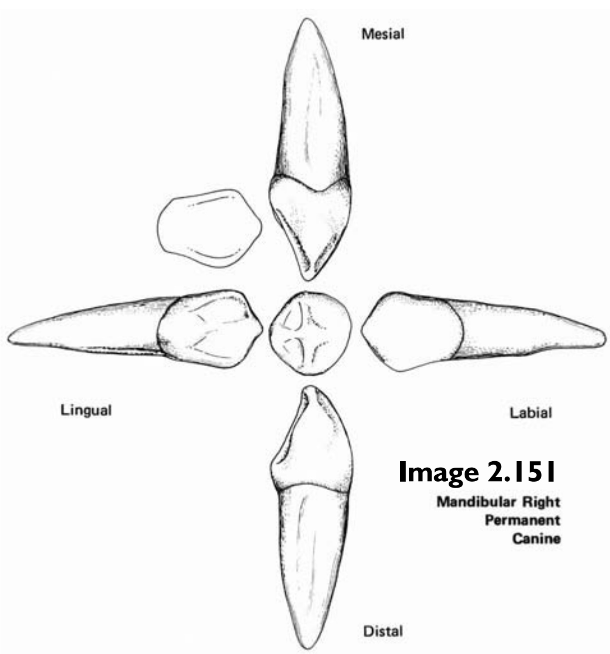


Image 2.151
Mandibular Right
Permanent
Canine

From Dental Morphology: An Illustrated Guide by Geoffrey C. Van Beek. Reprinted by permission of Elsevier Limited.

2.2c PREMOLARS

- there are eight premolars (PM) – two in each quadrant
- they are transitional between canines and molars in function, form and arch position
- function:
  - maxillary first PM – grinding (along with the molars), tearing and piercing (similar to canines), esthetics and phonetics
  - mandibular first PM – only the buccal cusp is functional, so it resembles canine in function
  - mandibular second PM – grinding, along with the molars (has a functional lingual cusp)
- easily visible cusps are on the occlusal surfaces of the PM; there are typically two on each PM, although mandibular PM may have three
- each PM has only one root, although the upper first premolar may have two slender roots instead

Tooth Numbering Systems:

	Maxillary firsts	Maxillary seconds	Mandibular firsts	Mandibular seconds
Universal (right and left, respectively)	5, 12	4, 13	21, 28	29, 20
FDI (right and left, respectively)	14, 24	15, 25	44, 34	45, 35

Landmarks

- be able to differentiate between the five surfaces of the crown:
  - occlusal
  - facial
  - lingual
  - mesial
  - distal

Occlusal anatomy

- cusps are readily visible on the PM (two per tooth, although mandibular PM may have three)
- mesial and distal marginal ridges can always be seen
- there is always one larger buccal cusp, and one or two lingual cusps

How to distinguish between maxillary and mandibular premolars

- crowns of maxillary PM are wider (buccolingually) than they are thick (mesiodistally); mandibular PM are roughly as wide as they are deep
- maxillary PM have two cusps of relatively equal size; mandibular PM typically have two cusps of differing size (the lingual cusp is less prominent)
- a buccal ridge is more prominent on maxillary PM

How to distinguish between maxillary first and second premolars

- first PM crown is larger than the second
- only the first PM may have two root branches (the second premolar usually has a single root)
- buccal and lingual cusps of the second PM are equal in height; first PM have shorter lingual cusps
- the first PM usually has a *mesial concavity*, that is, a linear groove/depression on the mesial side of the tooth, which encroaches upon the crown – there is no such concavity on the second PM

How to distinguish between mandibular first and second premolars

- first PM is smaller than the second
- first PM resembles the mandibular canine in that it has a nonfunctional (small) lingual cusp – that is much like the canine's cingulum
- second PM resembles a molar because it has a functional lingual cusp
- first mandibular PM may have two prominent pits (adjacent a central ridge that runs between the buccal and lingual cusps)
- second mandibular PM typically have a single linear groove running along the midline occlusal surface

How to distinguish between maxillary left and right premolars

- hold the tooth so that the lingual surface is toward you, the crown is downwards, and the root is up – the root tip will bend toward the same side as that to which the tooth belongs

How to distinguish between mandibular left and right premolars

- hold the tooth so that the lingual surface is toward you, the crown is upwards, and the root is down – the root tip will bend slightly toward the same side as that to which the tooth belongs

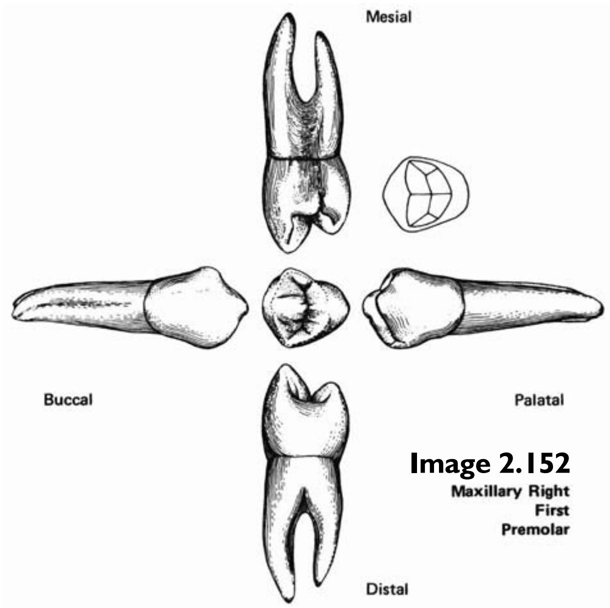


Image 2.152
Maxillary Right First Premolar

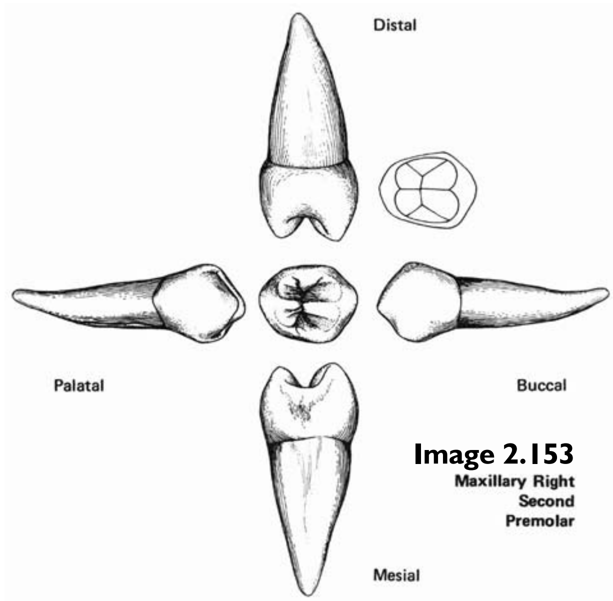


Image 2.153
Maxillary Right Second Premolar

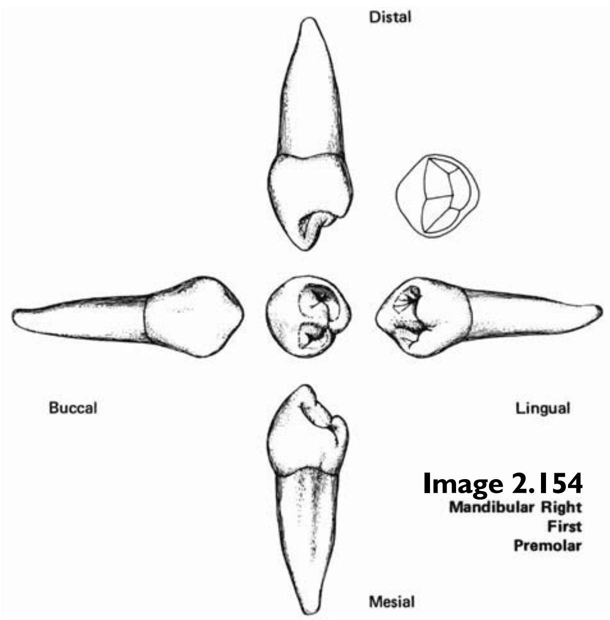


Image 2.154
Mandibular Right First Premolar

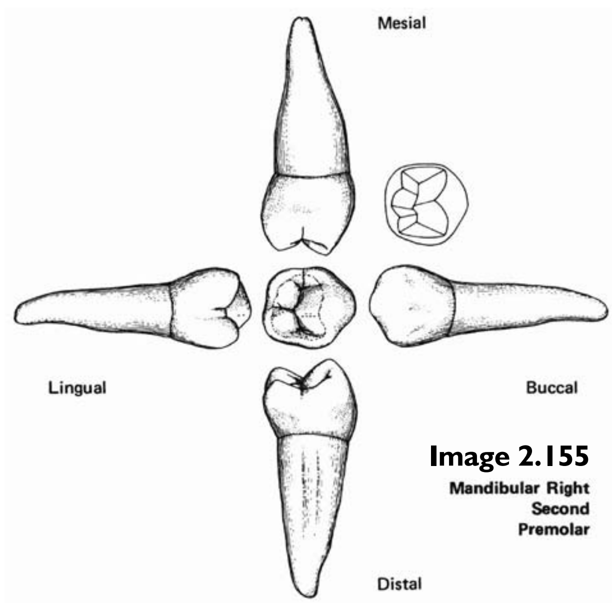


Image 2.155
Mandibular Right Second Premolar

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2.2d MOLARS

- there are eight to twelve molars in the mouth – two or three in each quadrant
- the third molars are congenitally missing in 20% or more of the population
- the first molars are the largest and strongest teeth in each arcade
- their function is in the grinding of food, maintaining the mouth's vertical dimension, and in esthetics (keeping the chin the proper distance from the nose)
- maxillary molars have four cusps, mandibular first molars have five cusps and all other mandibular molars have four
- maxillary molars have three roots, mandibular molars have two
- the third molars can have variable shapes and configurations – for that reason, their discussion here is kept to a minimum

Tooth Numbering Systems:

	Maxillary firsts	Maxillary seconds	Maxillary thirds
Universal (right and left, respectively)	1, 14	2, 15	3, 16
FDI (right and left, respectively)	16, 26	17, 27	18, 28

	Mandibular firsts	Mandibular seconds	Mandibular thirds
Universal (right and left, respectively)	17, 30	18, 31	19, 32
FDI (right and left, respectively)	46, 36	47, 37	48, 38

Landmarks

- be able to differentiate between the five surfaces of the crown:
  - incisal
  - facial
  - lingual
  - mesial
  - distal

Occlusal Anatomy & How to distinguish between maxillary and mandibular molars

- maxillary molars (first and second) have an oblique ridge running distobuccally to mesiolingually, and a transverse ridge running mesiobuccally to mesiolingually
- mandibular molars do not have these ridges, instead, they have a central fossa which runs mesiodistally, a lingual groove, and a buccal groove
  - the first molar has two buccal grooves, and the second molar has one
- the two lingual cusps on maxillary molars are of different size (mesial cusp is usually larger than the distal cusp)
- the two lingual cusps on the mandibular molars are the same size

How to distinguish between maxillary first and second molars

- the first molar has roots that are more 'spread out' than those on the second molar
- the buccal cusps on the first molar are nearly the same size, while the mesiobuccal cusp on the second molar is quite a bit larger than the distobuccal
- the distolingual cusp on the first molar is smaller than the mesiolingual cusp
  - on the second molar, the distolingual cusp is much smaller or absent

How to distinguish between mandibular first and second molars

- the first molars (five cusps) have larger crowns than the second molars (four cusps)
- there are three buccal cusps and two buccal grooves on the first molars, while there are two buccal cusps and only one buccal groove on the second molars
- the buccal and lingual grooves of the first molars are not in line with each other; this differs from the second molars where the buccal and lingual grooves align and intersect at the central groove
- the central groove of the first molars *zigzags* mesiodistally, while the central groove of the second molars is relatively more straight

How to distinguish between maxillary left and right molars

- using the above anatomical features, hold the molar so that the root is upwards, the crown is down, and the distal surface is toward you (the roots will be flaring toward you)
  - the root tips should be pointing toward the same side as that to which the tooth belongs

How to distinguish between mandibular left and right molars

- using the above anatomical features, hold the molar so that the root is downwards, the crown is up, and the distal surface is toward you (the roots will be flaring toward you)
  - the root tips should be pointing toward the same side as that to which the tooth belongs

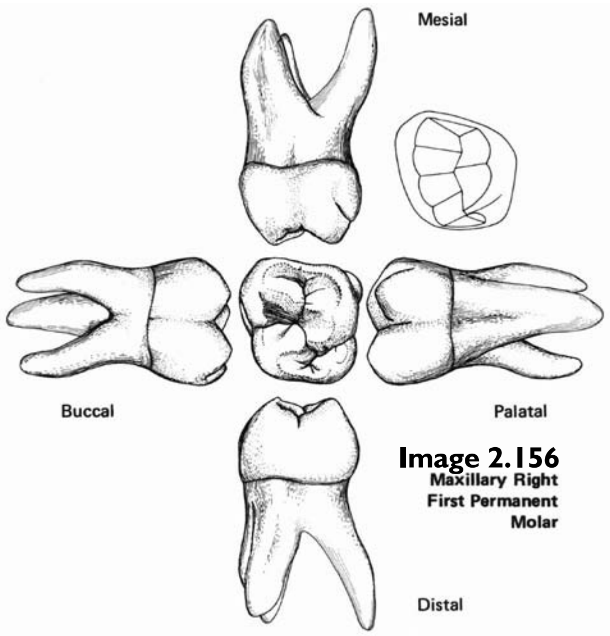

Image 2.156
Maxillary Right First Permanent Molar

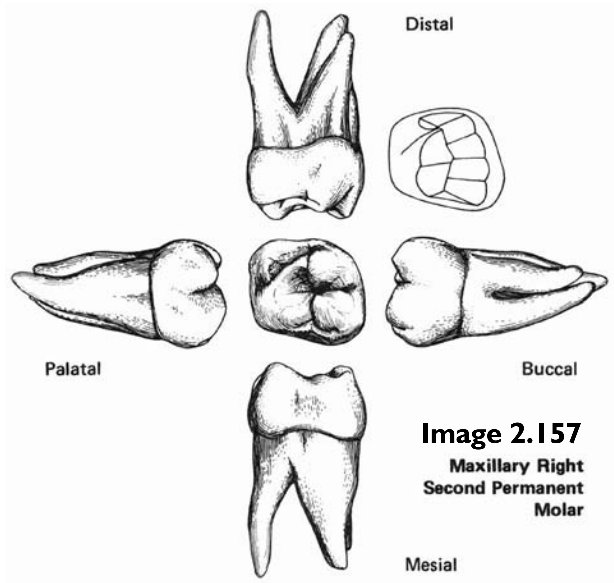

Image 2.157
Maxillary Right Second Permanent Molar

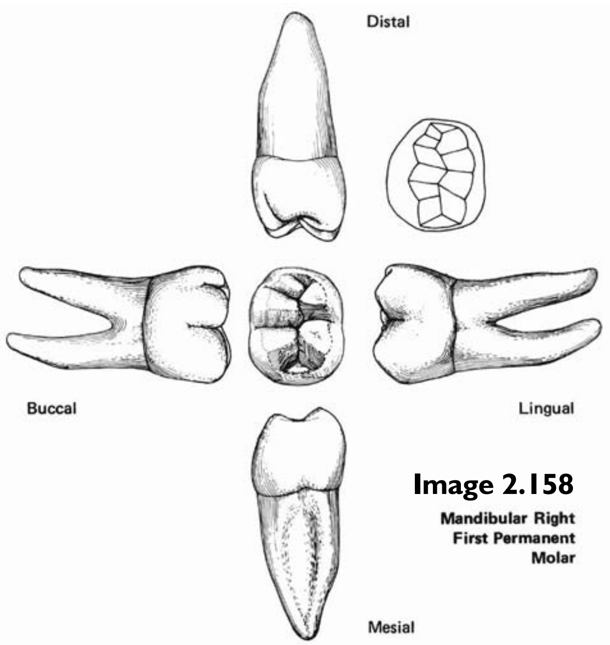

Image 2.158
Mandibular Right First Permanent Molar

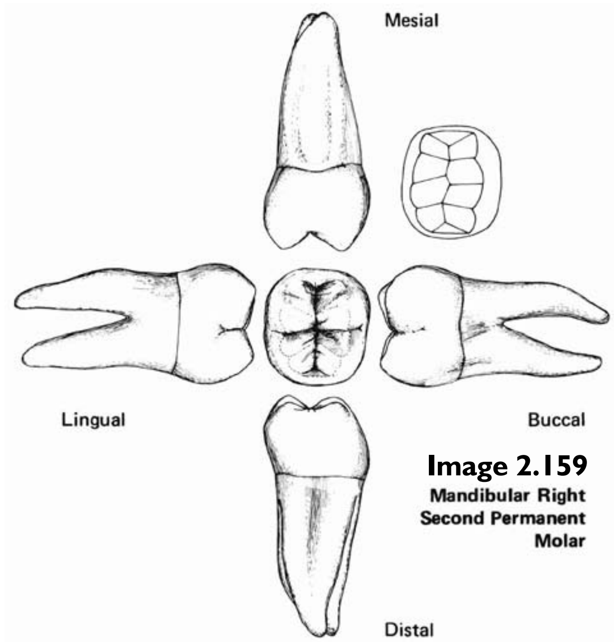

Image 2.159
Mandibular Right Second Permanent Molar

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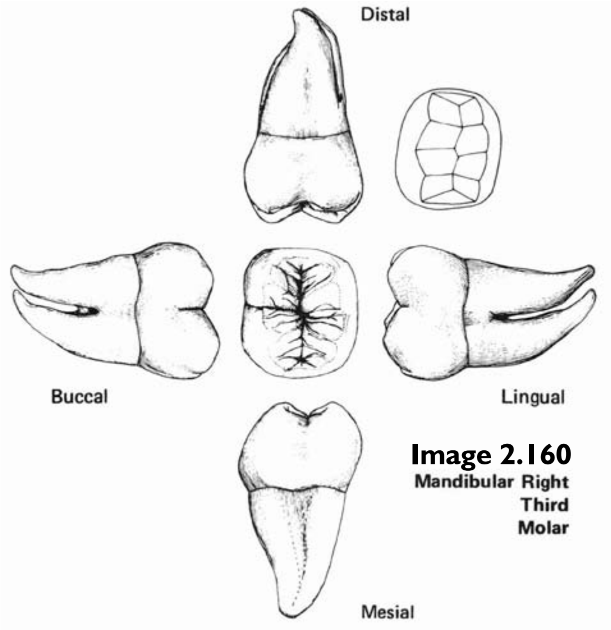
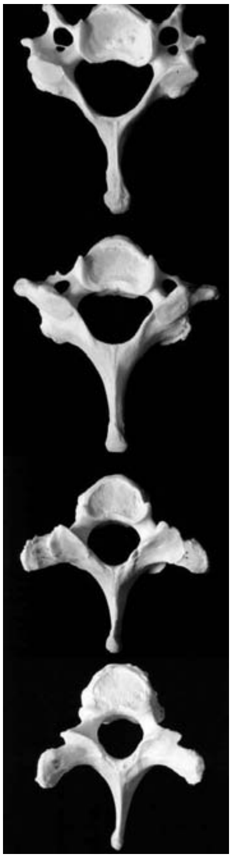


Image 2.160
Mandibular Right Third Molar

- the morphology of the third molar is quite variable
- they tend to be the smallest molars in the mouth
- the distolingual cusp is often small or absent
- they are often wider buccolingually than mesiodistally
- the appearance of the roots is variable



Chapter Three

The Hyoid and Spine

The postcranial elements of the axial skeleton are an interesting variety of bones with a plentitude of functions. Although not strictly part of the axial skeleton, the hyoid bone is a small structure in the neck involved in swallowing, speech, and overall neck form. The vertebrae are bony elements which make up the human backbone or spine. They provide an axis upon which we have limited rotation; protect the spinal cord; protect the vertebral arteries and veins in the cervical region; and articulate with the ribs throughout the thoracic segment. Although there are numerous vertebral structures, students are blessed because they have a relatively uniform appearance with fewer unique landmarks than those observed in the skull.

There are three general types of presacral vertebrae: cervical (in the neck), thoracic (in the chest and upper abdomen) and lumbar (lower abdomen). There are seven cervical vertebrae; four which can be considered "typical" (C3 - C6), and three that are considered to be 'special' (C1, C2 and C7). There are twelve thoracic vertebrae; eight of which are typical (T2-T9) and four which are special (T1 and T10-T12). All five lumbar vertebrae have fairly uniform structures and are not further subdivided.

There are multiple vertebrae which fuse together to form the sacrum, and several rudimentary coccygeal vertebrae which together form the inferiormost part of the vertebral column. Each of these has a distinctive appearance.

3.1 HYOID BONE

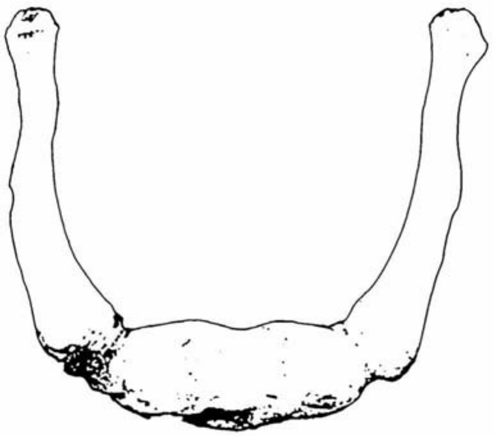


Image 3.1 • *Hyoid bone, superior view.*

- is a U-shaped bone located in the anterosuperior neck above the thyroid cartilage, at a level which approximates the base of the mandible
- it serves as an attachment site for muscles in the neck and floor or the mouth, and plays important roles in speech and in maintaining a patent airway
- it does not articulate with any other bone
  - ligaments from the styloid processes (of the temporal bones) and muscles of the neck support and suspend the hyoid bone
- it has three main parts:
  - the body (is found in the midline and in young adults articulates with the greater horns; in older age, it fuses with them)
  - the greater horns (the large arms of the hyoid)
  - the lesser horns (which are small projections of bone found at the junction of the body and greater horns)
- this bone is of great importance in the forensic pathologic examination of fresh, decomposed, and skeletonized bodies where strangulation is a possibility
  - this is because hyoid bone fractures may indicate that great force was applied to the neck

Landmarks

- body
- greater horns
- lesser horns

Looking at Fragments

- fragments of hyoid bone could resemble portions of lesser wing of sphenoid, or portions of other bones in immature states (particularly vertebrae)
- when identifying hyoid fragments, keep in mind that the lesser horns are superior and that the greater horns taper as they progress posteriorly away from the hyoid body

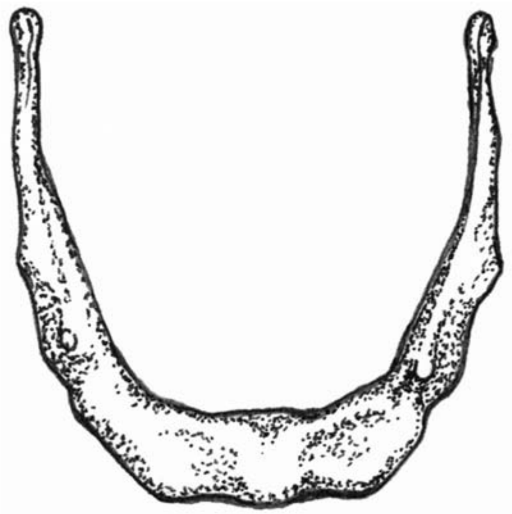


Image 3.2 • Hyoid bone, superior view.
The middle (horizontal) portion of the hyoid bone is the relatively flat body. Projecting upwards are the long and tapering greater horns (cornu). The lesser horns are generally exceedingly small, and as such, are barely visible in this example, as two small projections near the junctions of the body to the two horns.

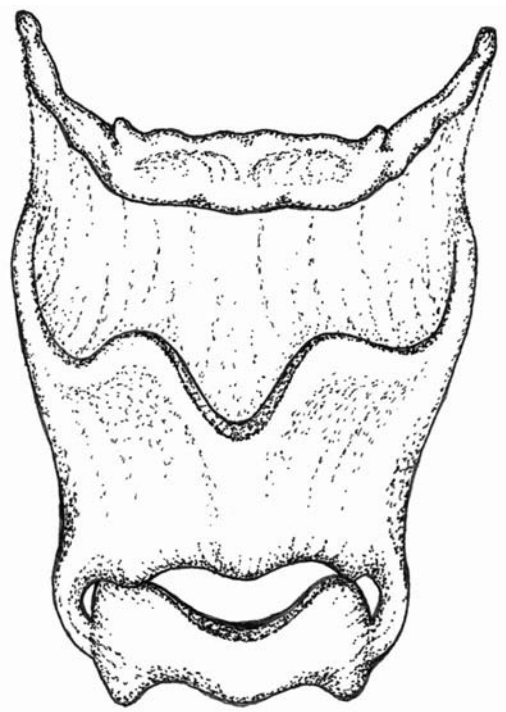


Image 3.3 • Laryngohyoid complex, anterior view.
The anterior neck has a complex bony and cartilaginous framework composed of the hyoid bone, laryngeal cartilages, cricoid cartilage, tracheal rings, and other small cartilaginous elements. This illustration demonstrates the relationship between the major neck structures including the hyoid bone (most superior), thyroid cartilage (middle), and cricoid cartilage (most inferior). Note that the hyoid bone is bound to the larynx via the thyrohyoid membrane, and the cricoid cartilage to the thyroid cartilage via the cricothyroid ligaments.

With increasing age, the neck cartilages become progressively calcified. In a skeletonized state, they may be found as partially or completely ossified elements. They may also be visible on X-rays of the head and neck.

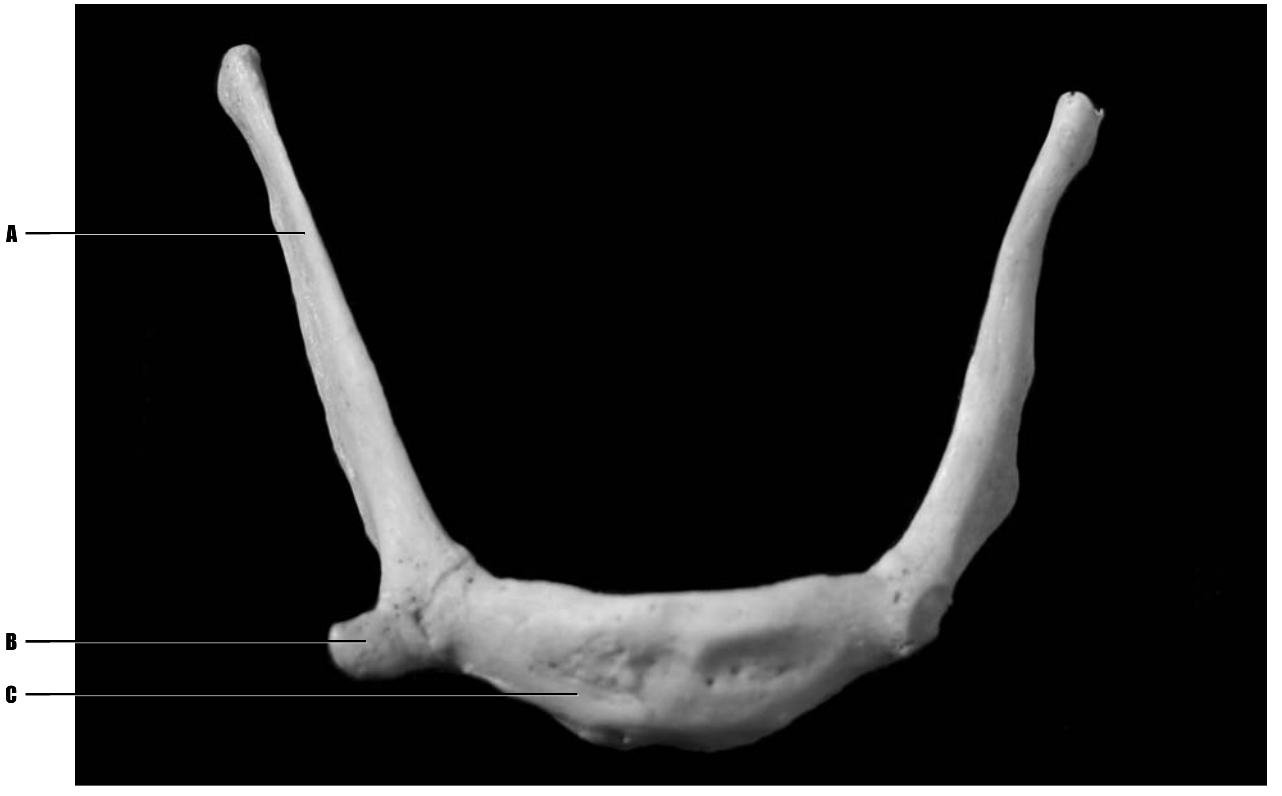


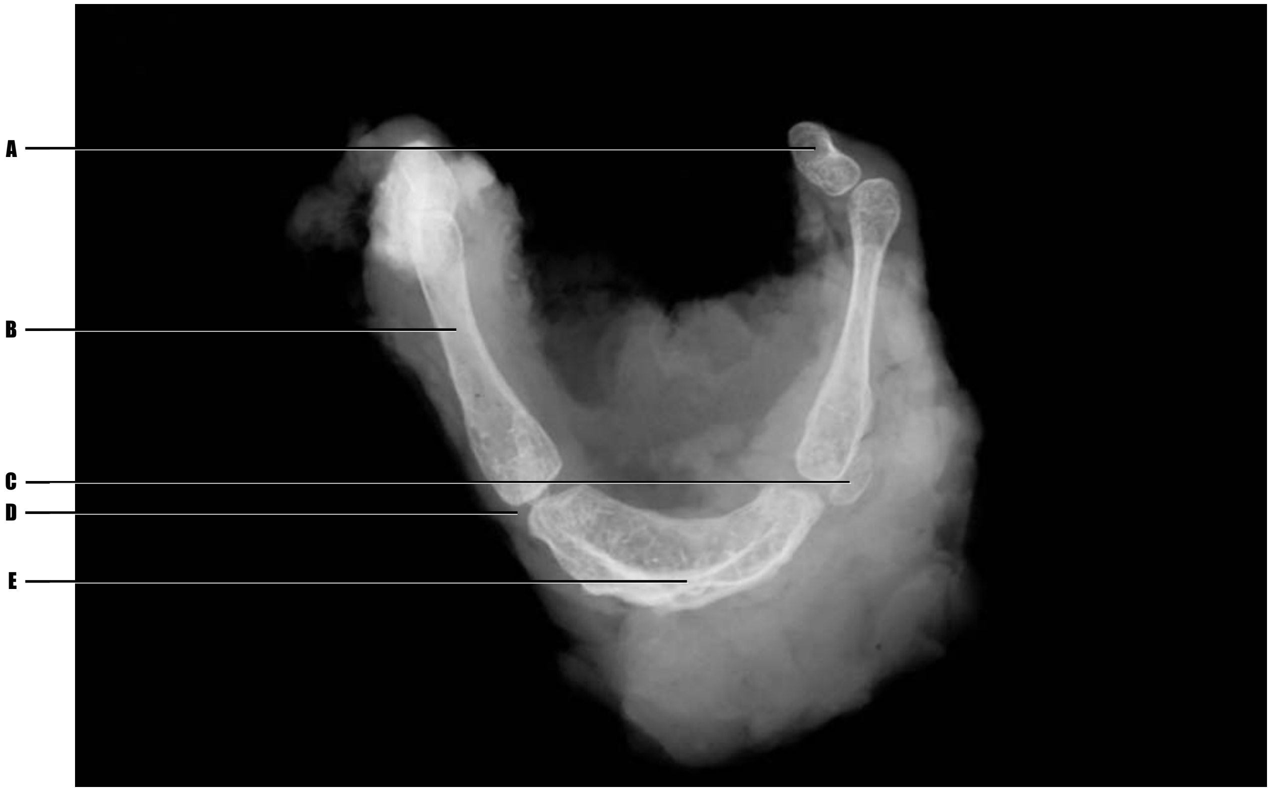
Image 3.4 (above)
Hyoid bone, superior view.
Image 3.5 (below)
Hyoid bone, inferior view.

Images 3.4 and 3.5

A - greater horn (cornu)

B - lesser horn (cornu)

C - body



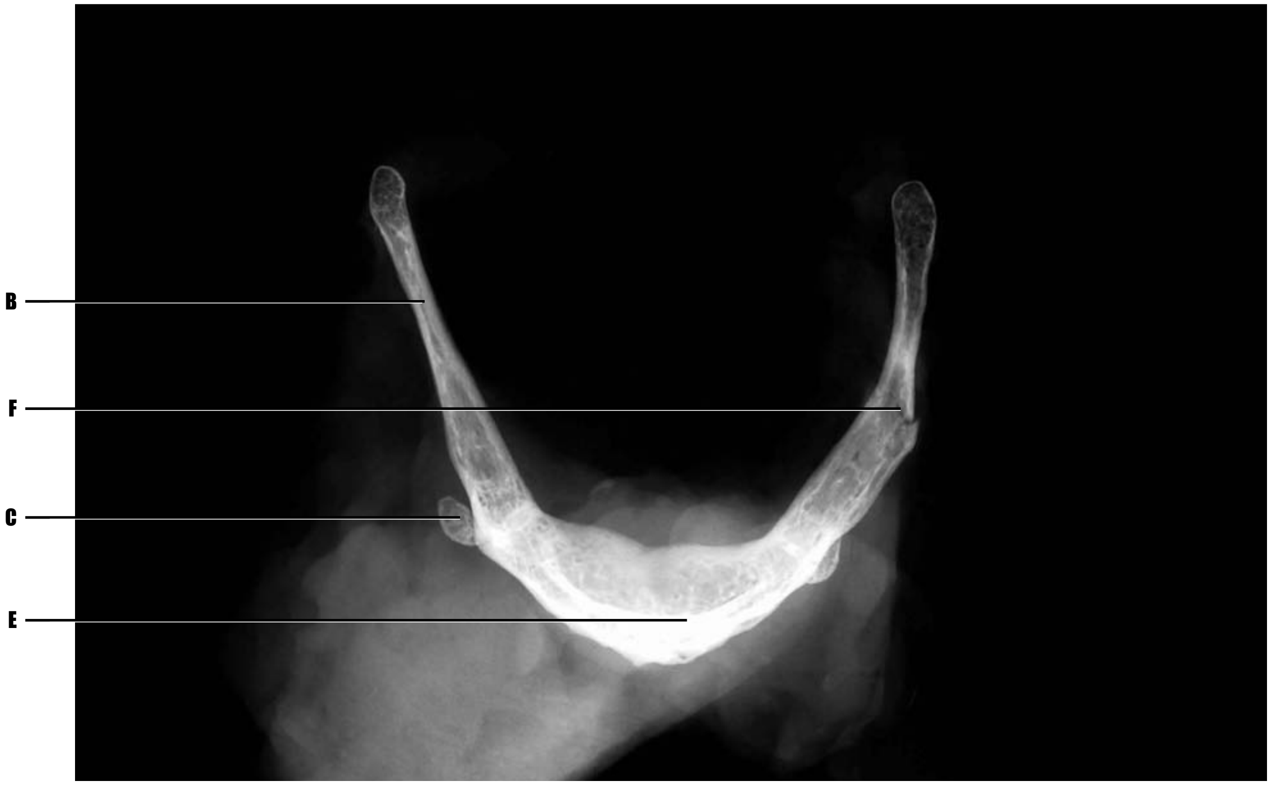


Image 3.6 (above)
Adult patient, plain film radiograph of hyoid bone removed at autopsy. Notice that in this example, the greater horns have not yet fused to the body.

Image 3.7 (above)
Adult patient, plain film radiograph of hyoid bone removed at autopsy. Notice that in this example, the greater horns have fused to the body. Notice the small fracture found at point 'F' in this strangulation victim.

Images 3.6 and 3.7

A - triticeous cartilage (of thyroid cartilage)

B - greater horn

C - lesser horn

D - unfused junction of greater horn to hyoid body

E - body

F - fracture of greater horn

3.2 TYPICAL CERVICAL VERTEBRAE

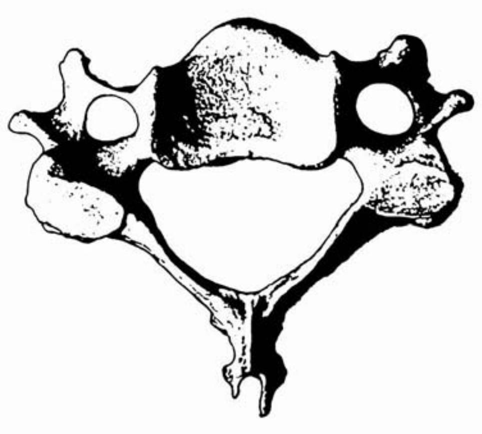


Image 3.8 • *Fifth cervical vertebra (C5), superior view.*

- the typical cervical vertebrae are numbers three through six
- each has a body, a spinous process (which may be bifid [split]), a vertebral arch (for protection of the enclosed spinal cord), superior and inferior articulating facets (for articulation with the preceding and following vertebrae), transverse processes (with transverse foramina to enclose and protect the vertebral arteries); and prominent anterior and posterior tubercles on the transverse processes
- the shape of the vertebral bodies progressively changes from C3 (rectangular) to C7 (increasingly round)
- if the bodies are viewed anteriorly, one can see that the anterosuperior margin is deeply excavated, and the antero-inferior margin appears to subtly project toward the observer (see **Image 3.10**)
  - these traits are unique to cervical vertebrae, and are due to the presence of prominent uncinate (hook) processes at the superolateral boundary of the vertebral bodies

Landmarks

- body
- anterior tubercle
- posterior tubercle
- transverse foramen
- pedicle
- superior articular facet
- inferior articular process
- spinal foramen
- lamina
- spinous process
- uncinate processes
- transverse processes
- vertebral (spinal) foramen

Looking at Fragments

- fragmented vertebrae can be challenging to sort, however, a few pieces of anatomical knowledge can be of immense use in separating the typical cervical vertebrae from other bones of the spine
- the vertebral bodies vary in shape, with lower cervical vertebrae having more rounded bodies
    - the uncinate processes of the anterior vertebral bodies are found only on C3 through C7
    - the antero-inferior margin of the cervical bodies project away from the vertebrae (anteriorly)
    - the exception to this is the body of C7, which has a flat antero-inferior margin
- the typical cervical vertebrae usually have bifid spines
    - the shortest and most robust spine tends to belong to C2; C7 is typically not bifid
    - the cervical spinous processes are typically oriented in the horizontal plane
    - in contrast, thoracic vertebrae have progressively inferiorly projecting spines, as well as thicker and progressively more massive bodies
- C3 through C6 have anterior and posterior tubercles on their transverse processes
- transverse foramina are unique to the cervical vertebrae – be wary, though, that certain variants and disease processes are associated with large, thin walled, septated, or even obliterated foramina
- C7 looks very much like a thoracic vertebra, except for bearing transverse foramina
- unlike thoracic vertebrae, cervical vertebrae do not have articular facets for ribs on the lateral body, or on their transverse processes

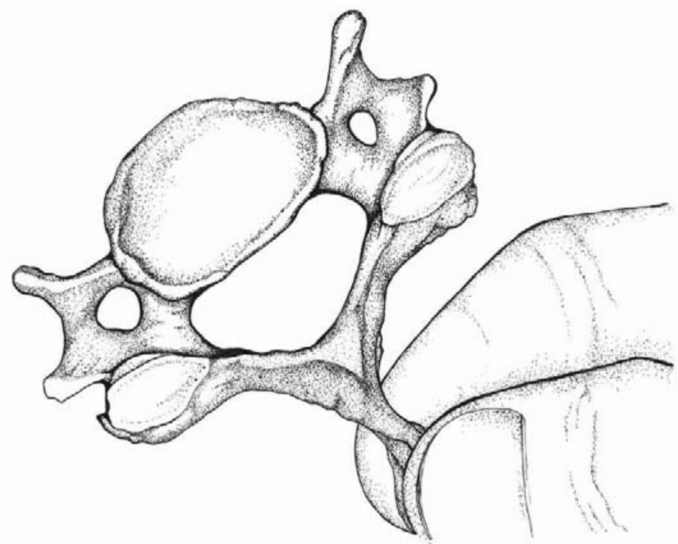


Image 3.9 • C5, superior view.
In this image, the spinous process of the seventh cervical vertebra is grasped between the fingers of the examiner. The body of the vertebra and the superior articular facets are directed toward the top left-hand corner of the page. The superior articular facets (for C4) are directed toward the reader. Notice the prominent anterior and posterior tubercles on the transverse processes – a characteristic feature of the "typical" cervical vertebrae.

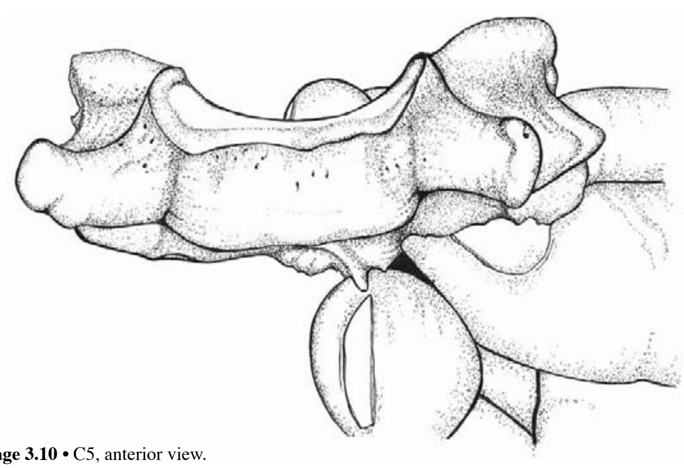
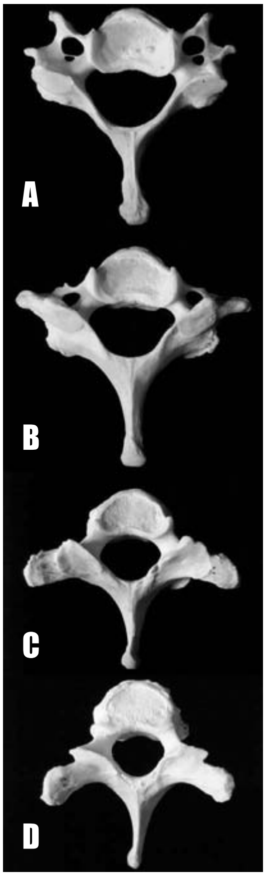


Image 3.10 • C5, anterior view.
In this image, the spinous process of the fifth cervical vertebra is grasped between the fingers of the examiner. The body of the vertebra is toward the reader. The inferior margin of the anterior vertebral body of the typical cervical vertebrae is flat (compare with **Image 3.31**). This is to allow for articulation with the uncinate processes of the vertebra found immediately subjacent (at the uncovertebral joints).

Essential information about vertebrae

It is necessary to have a firm understanding of vertebral structure as one must be able to relate vertebral anatomy to other regions of the skeleton (e.g. C1 to the skull, T1-T12 to the ribs, L5 to the sacrum). A brief discussion is therefore in order.



The first and second cervical vertebrae, the atlas and axis respectively, have the most unusual morphologies of all vertebrae. In embryonic stages, the developing body of C1 fails to fuse with the growing anterior (neural) arches and instead fuses with the body of C2, forming the dens. The superior articular facets of C1 articulate with the occipital condyles (see **Image 2.38**) forming the atlanto-occipital joint. The anatomy of this joint, and the dens, is such that both structures have important relationships to vital brain areas which can be injured if these bony elements are disrupted. The second cervical vertebra forms a pivot on which the head, via C1 can partially rotate. The anterior articular facet of the dens articulates with the articular facet for the dens on the inner surface of the anterior arch of C1. It is this relationship that forms the structural basis for the aforementioned cranial pivot.

C5 (featured on pages 142 and 143) serves as an excellent example of a typical cervical vertebra as its features are common to C3-C6. It has a small body, triangular-shaped vertebral foramen, large round transverse foramen, thin lamina and a bifid spine. The presence of transverse foramina and bifid spines are features of cervical vertebrae in normally developed individuals (note that C7 may often lack a bifid spine). Therefore, they are important landmarks to recognize when trying to identify and categorize isolated vertebral remains. The third through sixth cervical vertebrae also have an additional characteristic of great importance: the presence of anterior and posterior tubercles on the transverse processes. The common carotid arteries run just in front of the anterior tubercles of C6. With only a few pounds of pressure, these vessels can be compressed against the tubercles resulting in rapid unconsciousness and death, should the pressure be maintained over several minutes. This is the anatomical basis of the *choke hold* maneuver.

The seventh cervical vertebra is commonly referred to as *special* because it has an appearance that is transitional between that of a *typical* cervical vertebra and a *typical* thoracic vertebra. Its body, the largest of the cervical segment, has a long, posteriorly directed spinous process, and lacks the large anterior and posterior tubercles that are prominently displayed on C3-C6. Examine the morphology of C6 (**A**), C7 (**B**), T1 (**C**) and T2 (**D**) on the image to the left to view the transition from cervical to thoracic vertebrae.

The thoracic vertebrae are easily distinguished from the cervical and lumbar vertebrae. Their bodies are slightly larger than those in the cervical region, but smaller than the lumbar; they lack transverse foramina; have smaller, rounder vertebral foramina; long, thin, non-bifid spines; and transverse processes which progressively change from being horizontally directed to posteriorly directed. Since they articulate with the ribs, they have special articular surfaces (facets) at specific locations to accomplish this goal. These facets are important when attempting to elucidate the identity of a particular thoracic vertebra or vertebral fragment.

Notice on **Image 3.42** that typical thoracic vertebrae have both superolateral and inferolateral demifacets (half facets) on their bodies, in addition to complete facets on their transverse processes. T1 (**Image 3.46**) differs in that instead of demifacets located both superolaterally and inferolaterally on its body, it has complete facets superolaterally, and demifacets inferolaterally. The other *special* thoracic vertebrae, T10-T12 also differ: T10 has complete facets of the superior body and transverse processes, but lacks facets on the inferior surface of the body. T11 and T12 have complete superolateral facets on their bodies, but lack inferolateral facets, as well as articular surfaces on the transverse processes.

Consider why the facets are arranged as described above. Recall that the typical thoracic vertebra has superolateral, inferolateral and transverse process facets. The facet of the transverse process articulates with the tubercle of its associated rib (see **Image 4.9**) to form a synovial joint. The head of the rib forms a synovial joint with the bodies of two vertebrae through the inferolateral facets of its own vertebra, and through the superolateral facets of the vertebra superior to it. There are differences, remember, in the configuration of the facets. The first rib articulates only with the body of the first thoracic vertebrae. As a result, we see a complete superolateral facet on the body, in addition to a demifacet for the head of the second rib. Additionally, since T10-T12 lack facets on their transverse processes, we have ribs articulating directly with the facets of their own vertebra's body.

By examining the overall shape of the twelve thoracic vertebrae, we notice that there is a gradual enlargement in the size of the body, that the transverse processes become shorter and more posteriorly directed, and that the spinous processes become shorter and angled inferiorly in the mid-thoracic region. By the level of T9 or T10, the spinous process is markedly shortened, posteriorly directed, and broadened in the supero-inferior plane like the lumbar vertebrae (see **Images 3.11** and **3.12**).

Lumbar vertebrae, are broader, robust structures which lack the transverse foramina seen in cervical vertebrae, and the articular facets found in the thoracic region. Like the thoracic vertebrae, they increase in size as one proceeds down the spine. Their spinous processes are quadrangular in shape, posteriorly directed and thickened along their postero-inferior borders. The first four vertebrae have flattened transverse processes projecting directly outwards whereas L5 is characterized by its massive transverse processes. An additional feature which can be useful in categorizing a vertebra as lumbar are the mammillary bodies present on the transverse processes. The lumbar bodies have a shape roughly similar to a kidney.

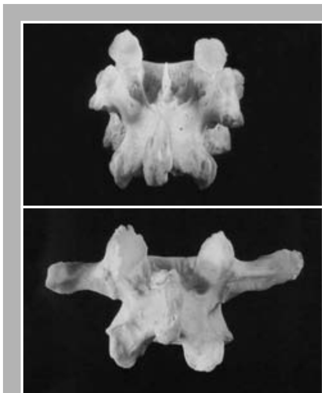
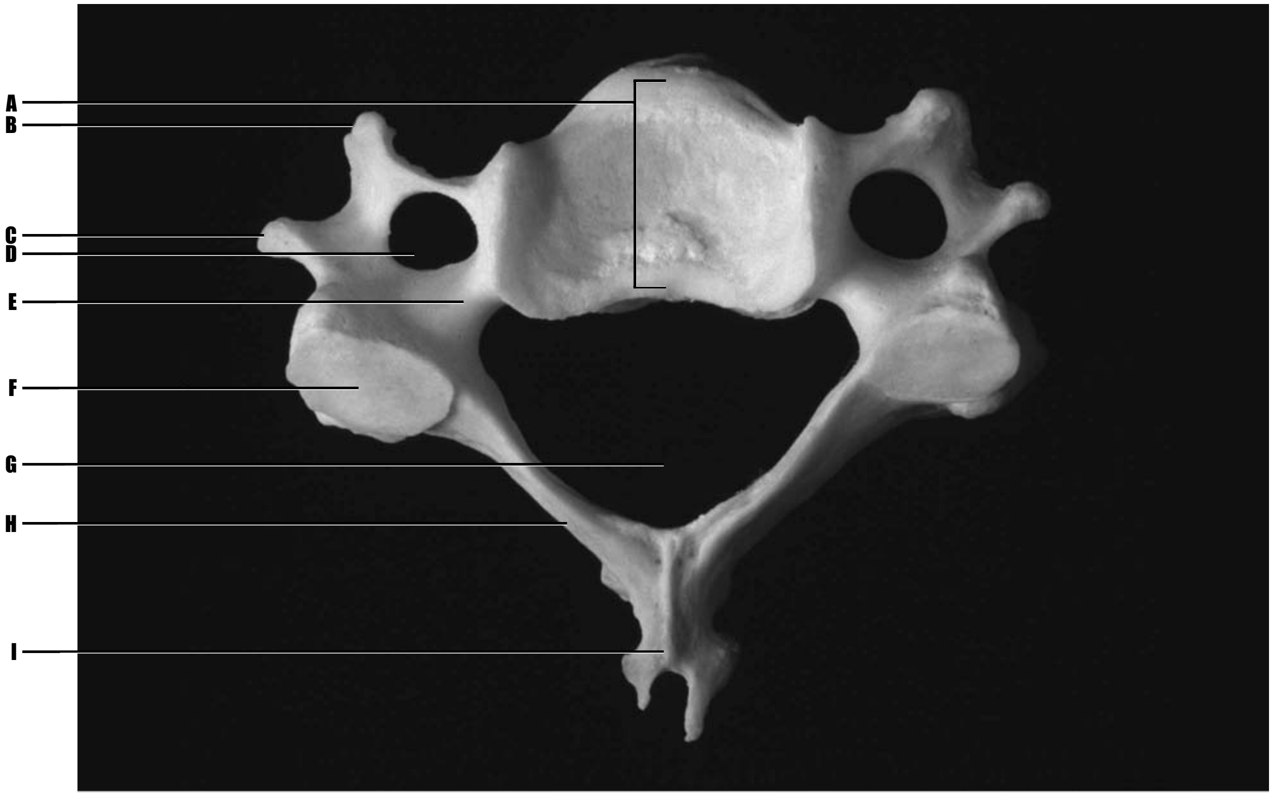


Image 3.11 (above)
Adult T12 vertebra, posterior view.
Image 3.12 (below)
Adult L3 vertebra, posterior view.



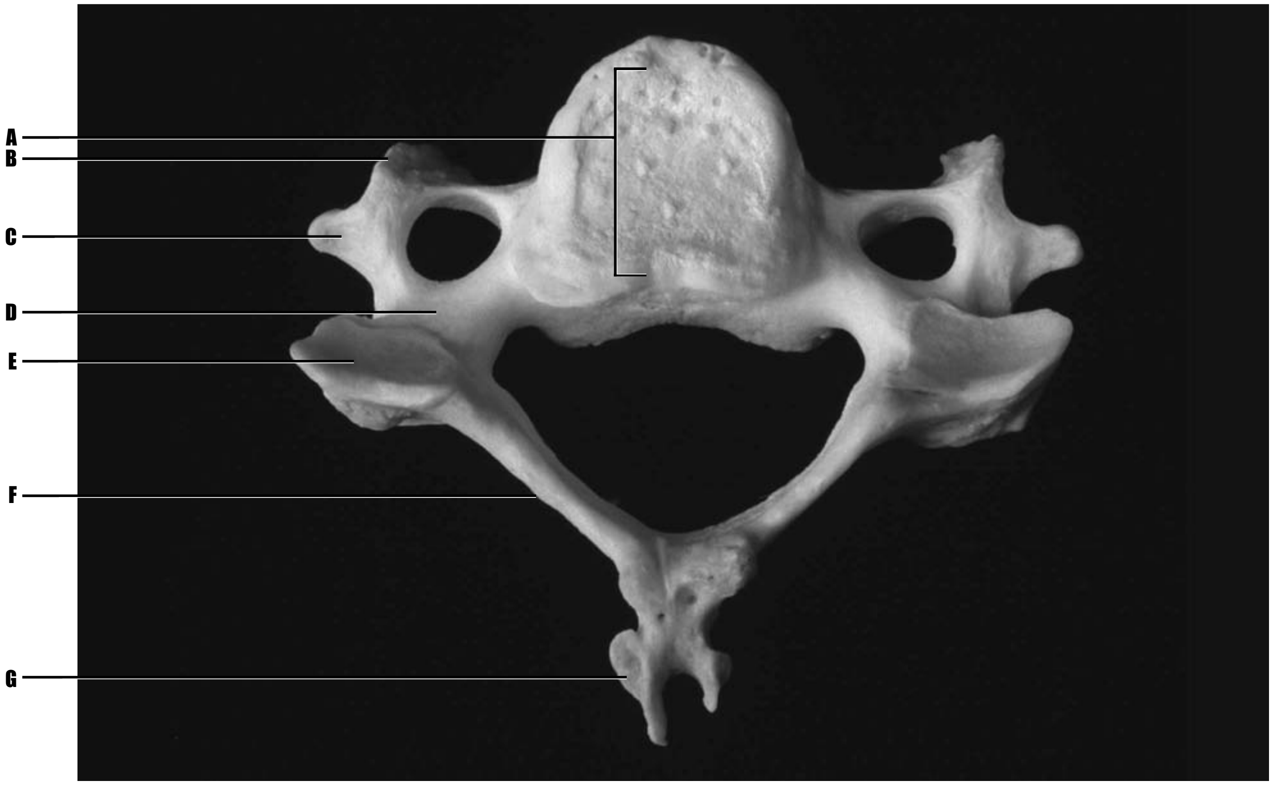


Image 3.13 (above)
C5, superior view.
Image 3.14 (below)
C5, inferior view.

Image 3.13

A - body
B - anterior tubercle
C - posterior tubercle
D - transverse foramen
E - pedicle
F - superior articular facet
G - vertebral or spinal foramen
H - lamina (posterior arch)
I - spinous process

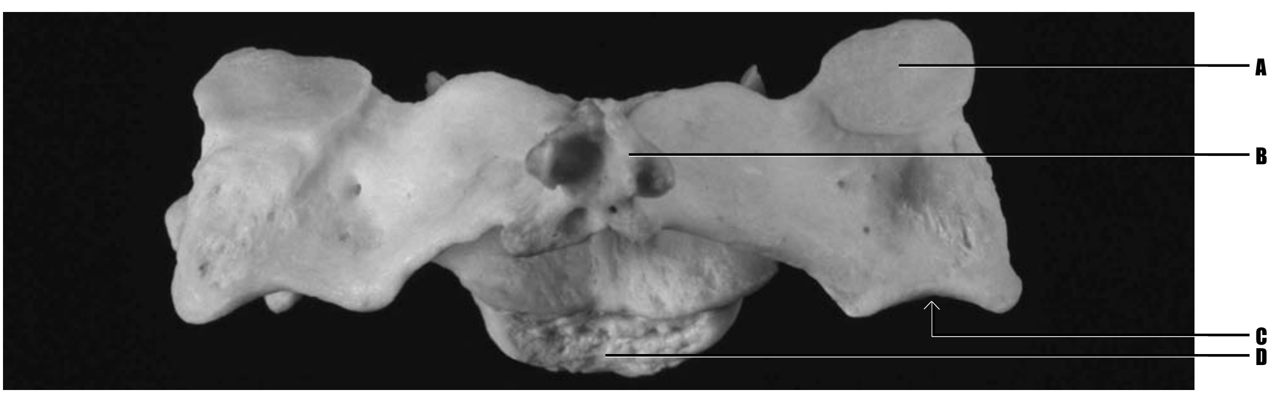
Image 3.14

A - body
B - anterior tubercle
C - posterior tubercle
D - pedicle
E - inferior articular facet
F - lamina (posterior arch)
G - spinous process

Image 3.15

A - superior articular facet
B - spinous process
C - inferior articular process
D - body

Image 3.15
C5, posterior view.



3.3 C1 (ATLAS)

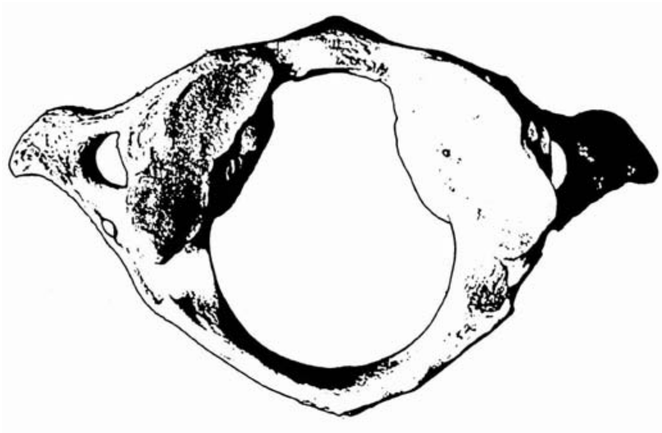


Image 3.16 • *First cervical vertebra (C1), superior view.*

- articulates directly with the base of the skull at the occipital condyles
- is the only vertebra without a body (in early development the body of C1 forms the odontoid process of C2 – a quaint embryologic quirk)
- has no spinous process
- unlike all other vertebrae which have cartilaginous articular discs above and below them, C1 and C2 do not
- on the internal surface of the anterior (neural) arch, one finds an articular facet for the anterior surface of the dens (of C2)
- C1 articulates superiorly with the occipital bone at the base of the skull via synovial joints, and inferiorly with C2
  - the articulation with the skull is called the atlanto-occipital joint – the major movement that occurs here is the simple nodding movement we make when indicating “yes” in conversation

Landmarks

- anterior tubercle
- anterior arch
- articular facet for dens
- superior articular facet
- transverse process
- lateral mass
- transverse foramen
- groove for vertebral artery
- spinal canal
- posterior arch
- posterior tubercle
- inferior articular facet

Looking at Fragments

- some individuals have difficulty differentiating between the superior from inferior surfaces of C1– it is actually quite easy (see **Images 3.17** and **3.18**)
- for starters, examine the articulating facets: those on the superior surface are somewhat concave and shaped more like kidneys, while those on the inferior surface are more oval and flat
- also, the groove for the vertebral artery is found only on the superior surface of C1
  - as the vertebral arteries leave the transverse foramina, they course along these grooves, and enter the skull through the foramen magnum along with the spinal cord
- fragments of anterior (neural) arch bear the anterior tubercle
  - this tubercle is located more so on the inferior than superior aspect of the arch
- fragments of posterior arch are flatter on the inferior than superior surface
  - also, the posterior tubercle is on the inferior margin of the posterior arch

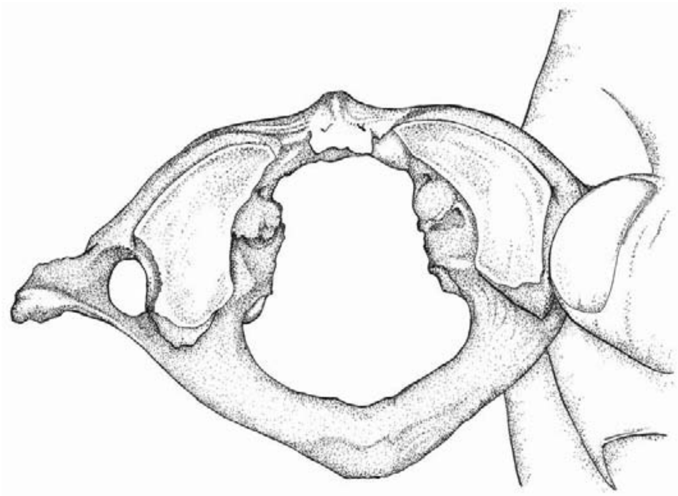


Image 3.17 • *C1*, superior view.
In this image, the transverse process of the first cervical vertebra is grasped between the fingers of the examiner. The anterior tubercle is directed toward the top of the page. The superior articular facets (for the occipital condyles at the base of the skull) are directed toward the reader. The superior articular facets are easily differentiated from the inferior articular facets because of their concave, kidney-shaped appearance. Immediately posterior to the superior articular facets, one will notice grooves for the vertebral arteries. Occasionally, these grooves will be partly or completely encircled with bone and will be canals rather than grooves. Unlike C3 through C6, C1-2 and C7 lack anterior and posterior tubercles on their transverse processes.

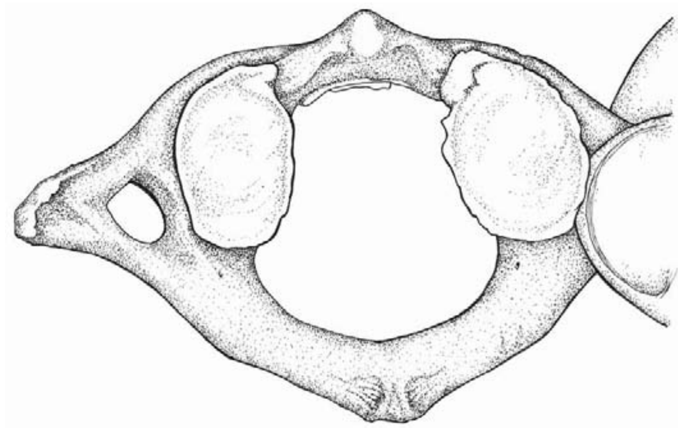
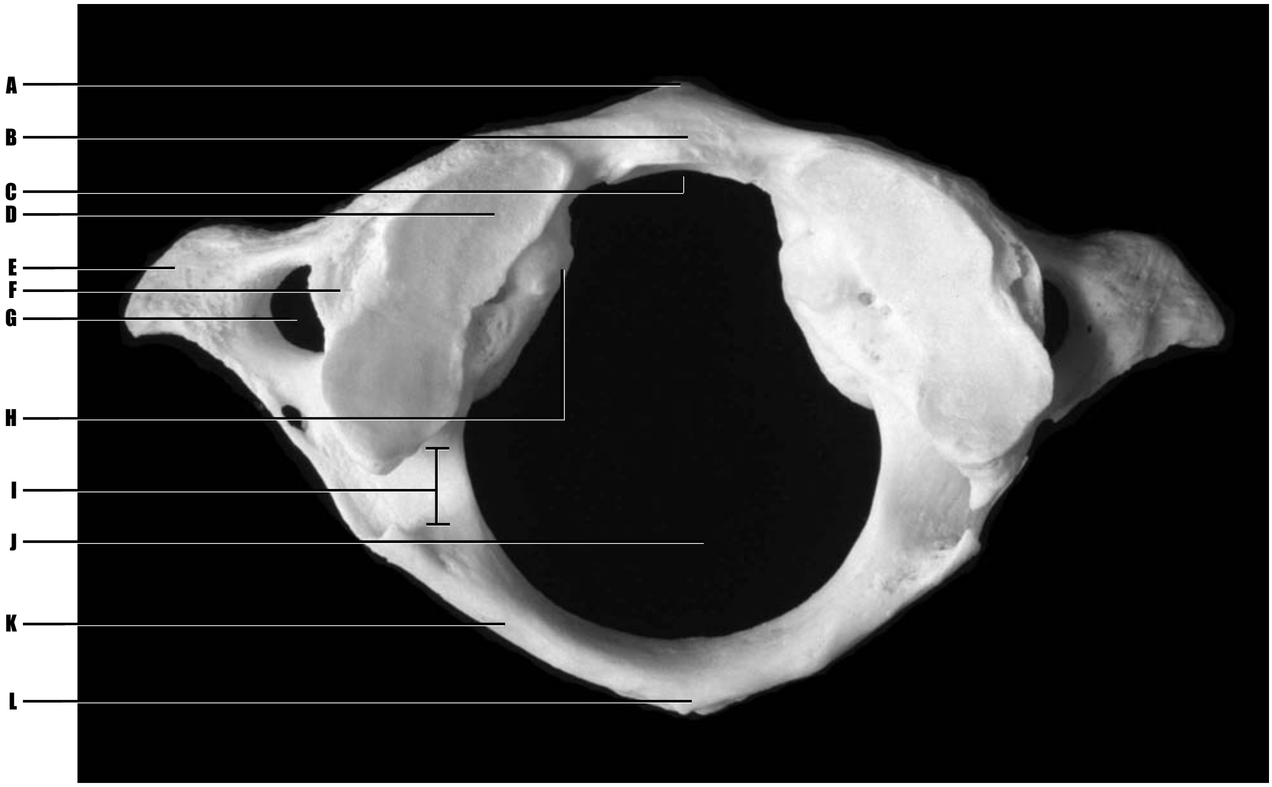


Image 3.18 • C1, inferior view.
In this image, the transverse process of the first cervical vertebra is grasped between the fingers of the examiner. The anterior tubercle is directed toward the top of the page. The inferior articular facets (for C2) are directed toward the reader. The inferior articular facets are easily differentiated from the superior articular facets because of their flat, oval appearance. There are no prominent arterial grooves on the inferior surface of this bone. The articular facet for dens is along the anterior arch of the spinal canal. If one looks into the spinal canal, this facet is located closer to the inferior edge of the arch than the superior edge.



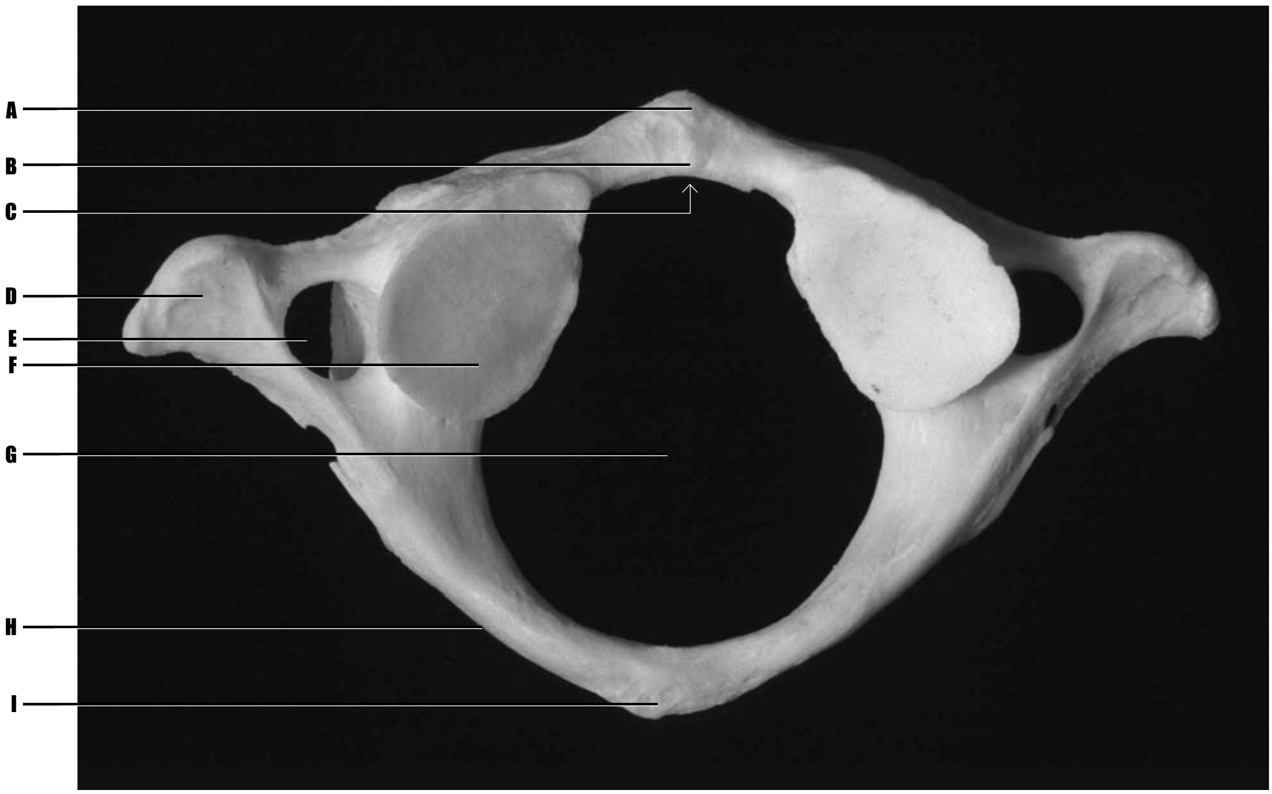


Image 3.19 (above)
C1, superior view.
Image 3.20 (below)
C1, inferior view.

Image 3.19

A - anterior tubercle
B - anterior arch
C - articular facet for dens
D - superior articular facet
E - transverse process
F - lateral mass
G - transverse foramen
H - tubercle for transverse ligament of atlas
I - groove for vertebral artery
J - spinal canal (vertebral foramen)
K - posterior (neural) arch
L - posterior tubercle

Image 3.20

A - anterior tubercle
B - anterior arch
C - articular facet for dens
D - transverse process
E - transverse foramen
F - inferior articular facet
G - spinal canal or vertebral foramen
H - posterior (neural) arch
I - posterior tubercle

Image 3.21

A - superior articular facet
B - anterior tubercle
C - transverse process
D - inferior articular process

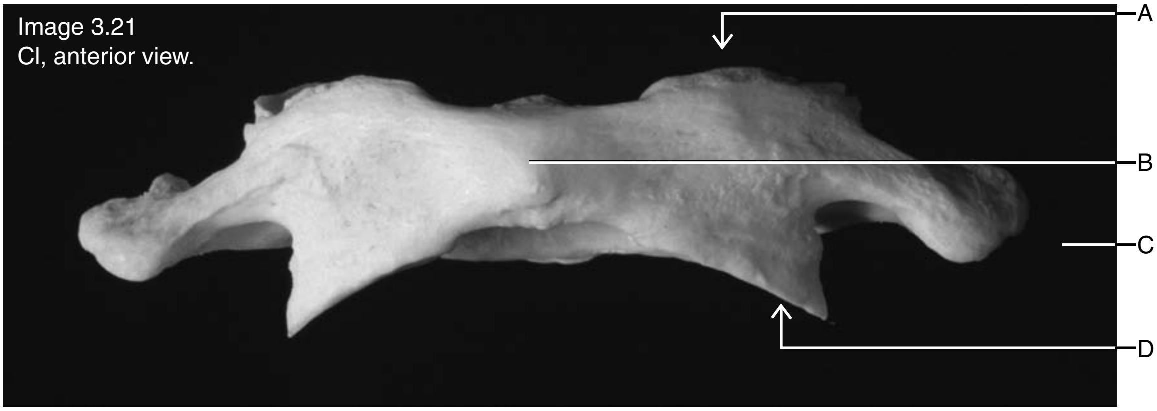


Image 3.21
CI, anterior view.

3.4 C2 (AXIS)

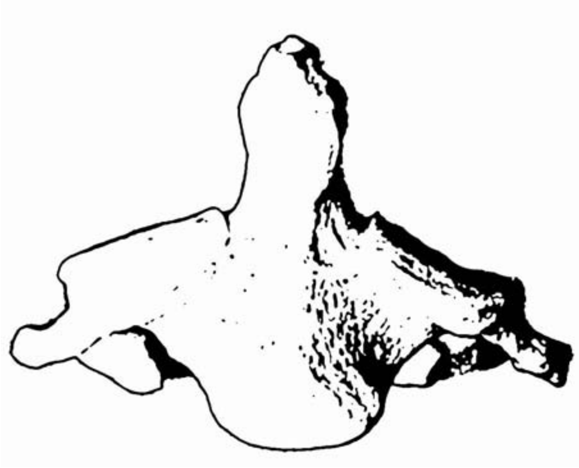


Image 3.22 • *Second cervical vertebra (C2), anterior view.*

- lacks a typical body, but as previously mentioned, has a superiorly projecting process called the dens (also known as the odontoid process) which articulates with C1
- when the head is rotated from side to side (as if indicating "no" in conversation), the atlas pivots around the dens
- unlike the typical cervical vertebrae, C2 does not have anterior and posterior tubercles on its transverse processes
  - a single tubercle on the transverse process (a serial homologue of the posterior tubercle) is seen
- C2 articulates with C1 via superior articulating facets, as well as via an articulating facet for dens
- it also articulates with C3 via inferior articulating facets

Landmarks

- body
- dens
- superior articular facet
- transverse process
- lateral mass
- vertebral foramen
- inferior articular facet
- spinous process
- pedicle

Looking at Fragments

- in theory, a completely fractured and disarticulated odontoid process could be confused with one of the carpals of the wrist, e.g. pisiform bone
  - keep in mind, though, that the single articular facet on pisiform (for triquetral) is subtly concave or scalloped in appearance whereas the articular facet on dens for C1 is more convex and raised from the plane of the remaining bone
- C2 has a massive, wide and short spinous process, surrounded by proportionally thick laminae
- unlike the typical cervical vertebrae which have obliquely oriented superior articular facets, those on C2 are relatively flat

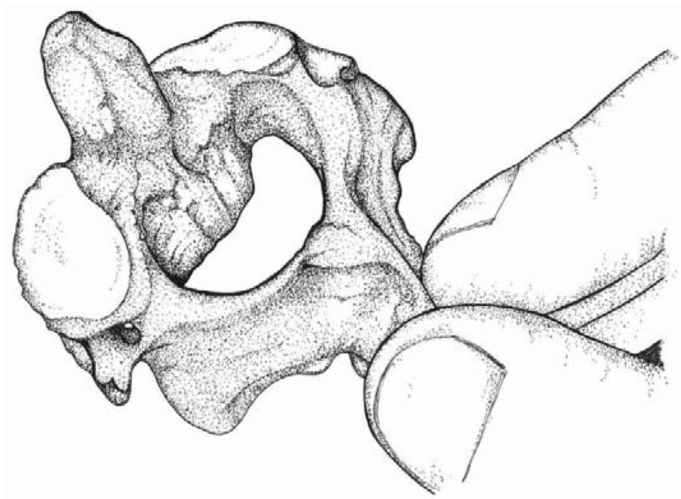


Image 3.23 • C2, oblique posterior view.
In this image, the spinous process of the second cervical vertebra is grasped between the fingers of the examiner. The dens and the superior articular facets (for C1) are directed toward the top left-hand corner of the page. The spinous process and laminae are thicker than the other cervical vertebrae. Unlike C3 through C6, C1-2 and C7 lack anterior and posterior tubercles on their transverse processes (not visible in this example – see pages 154 and 155).

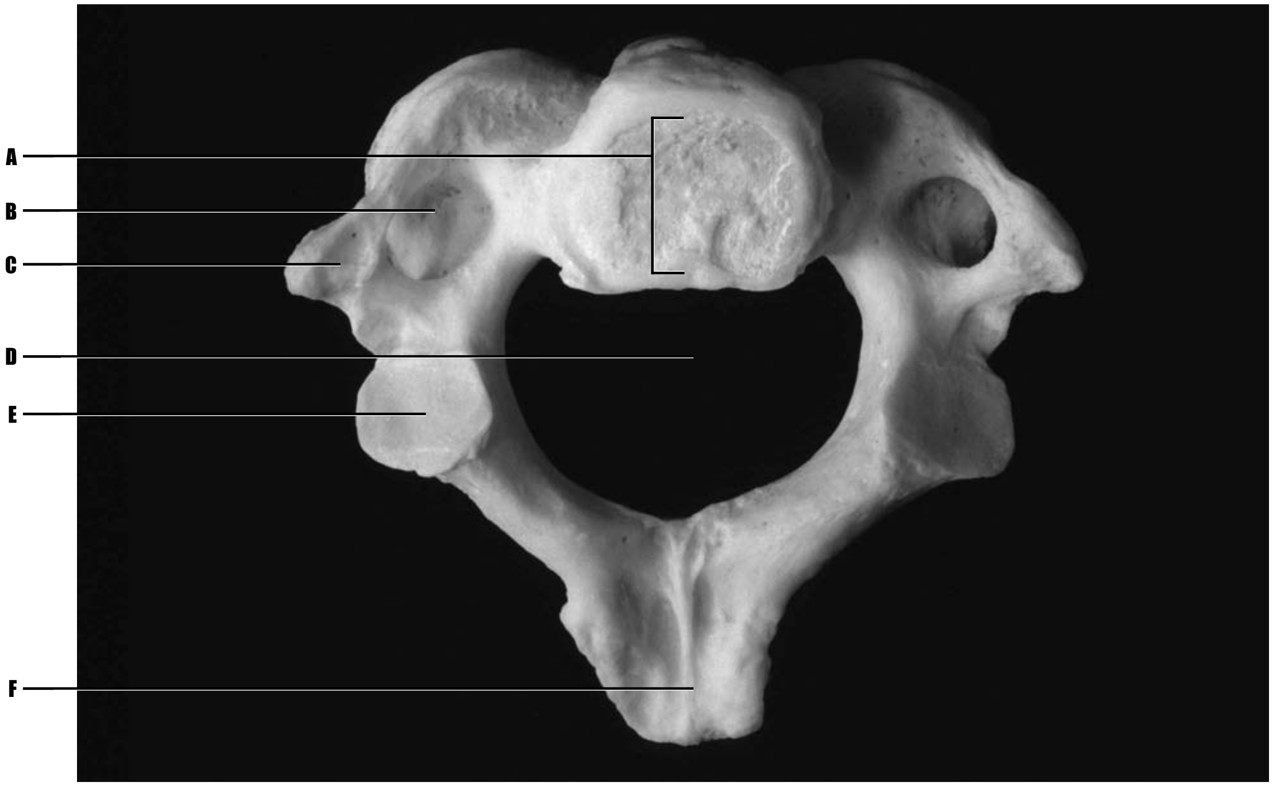


Image 3.24 (above)
C2, superior view.
Image 3.25 (below)
C2, inferior view.

Image 3.24

A - body
B - dens
C - superior articular facet
D - transverse process
E - posterior articular facet of dens
F - lateral mass
G - vertebral foramen
H - spinous process

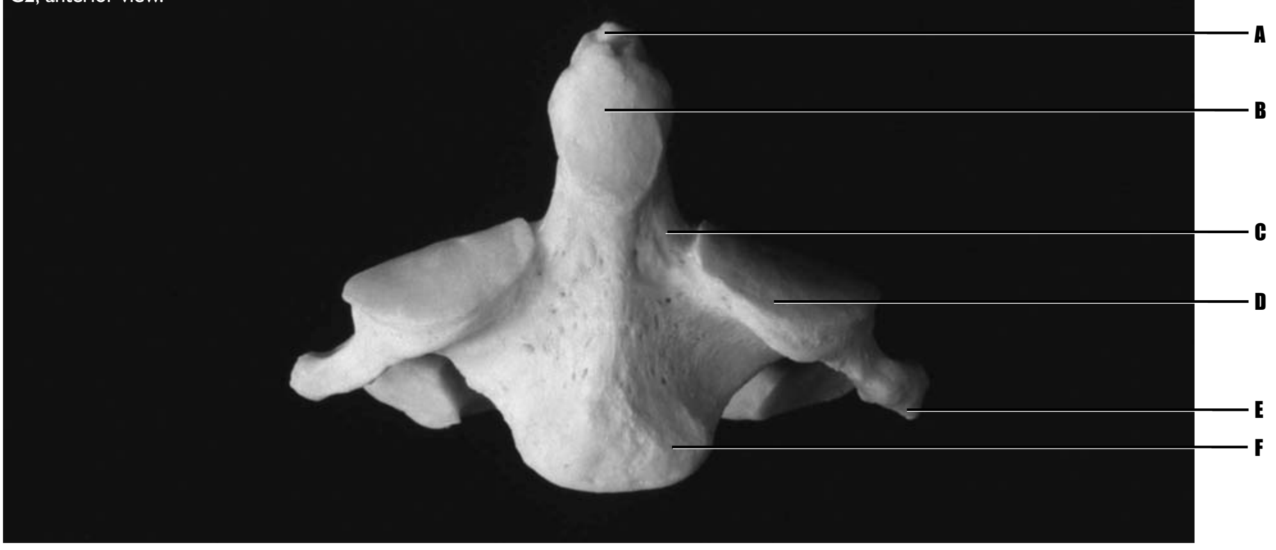
Image 3.25

A - body
B - transverse foramen
C - transverse process
D - vertebral foramen
E - inferior articular facet
F - spinous process

Image 3.26

A - dens
B - anterior articular facet of dens
C - pedicle
D - superior articular facet
E - transverse process
F - body

Image 3.26
C2, anterior view.



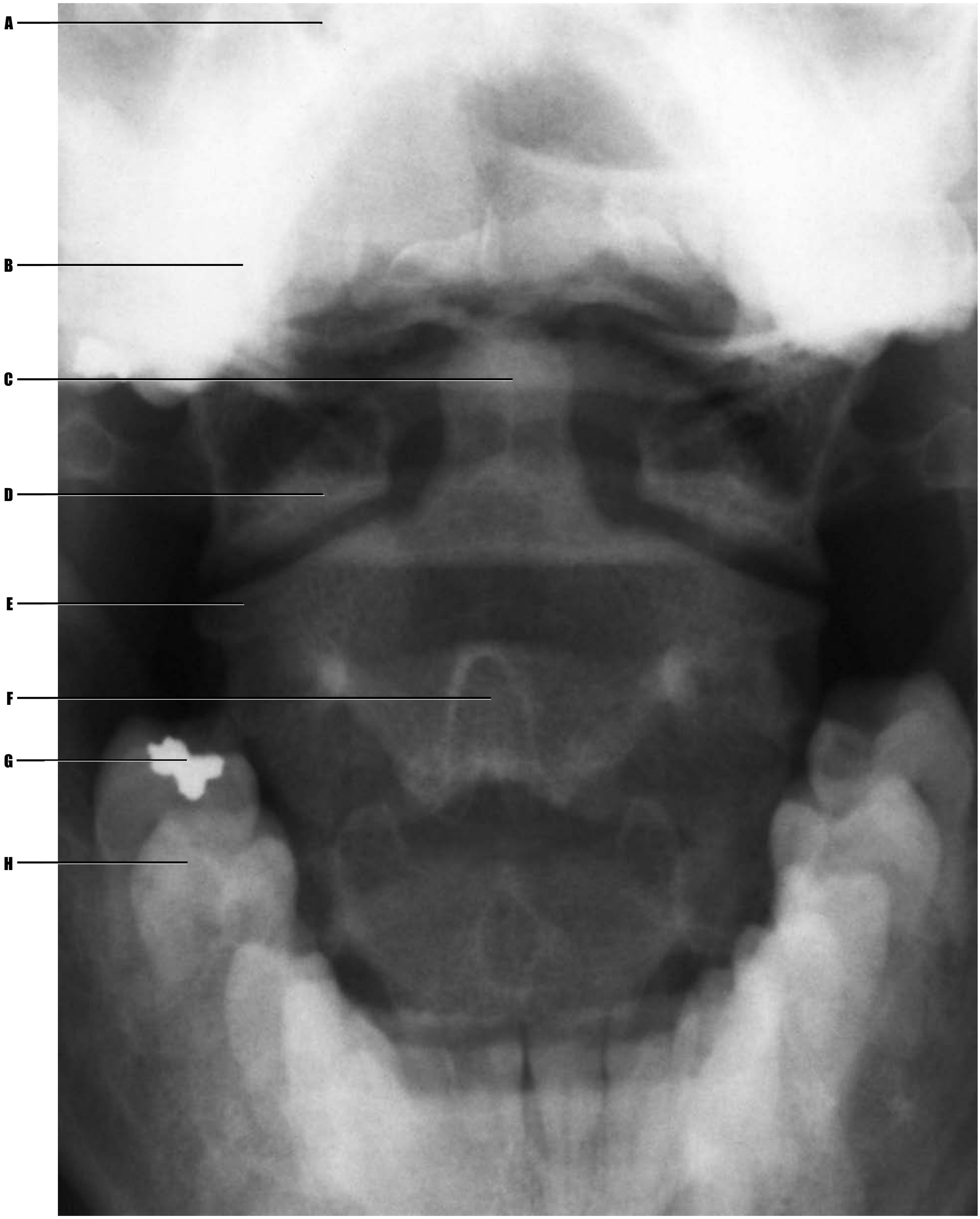


Image 3.27
Adult patient, plain film radiograph, "odontoid view" through open mouth.

Image 3.27

A - maxillary antrum

B - maxilla

C - dens

D - inferior articular process of C1

E - superior articular process of C2

F - spinous process of C2

G - dental amalgam of right second molar

H - right first molar

3.5 C7

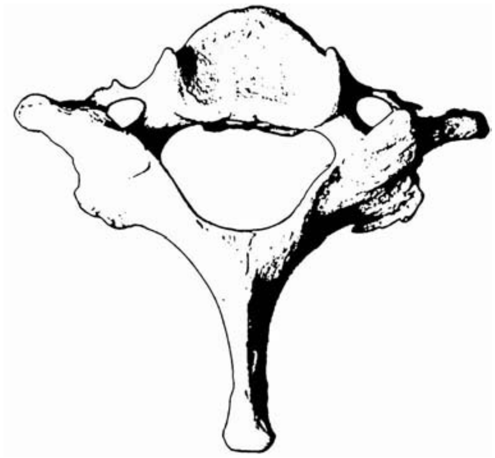


Image 3.28 • *Seventh cervical vertebra (C7), superior view.*

- has features typical of both cervical and thoracic vertebrae:
  - cervical – uncinate processes on the vertebral body, and transverse foramina of the transverse processes
  - thoracic – no anterior or posterior tubercles, flat antero-inferior margin of the vertebral body, relatively horizontal and non-bifid spine
- this vertebra is the most palpable bone of the cervical spine, and has therefore been nicknamed the *vertebra prominens*
  - flex your head forward as if to touch your chin to your chest, and run your hand along your posterior neck – the most prominent bump you feel is the spinous process of C7

Image 3.29 • Adult neck in flexion, posterior view.
In this example, the most prominent bump on the neck is the spinous process of the C7 vertebra – the vertebra prominens.

Landmarks

- body
- superior articular facet
- transverse process
- vertebral foramen
- inferior articular facet
- inferior articular process
- spinous process
- pedicle
- uncinate process

Looking at Fragments

- sort vertebral fragments by looking for unique features which could differentiate between cervical, thoracic and lumbar vertebrae, and then further subcategorize findings to more specific vertebrae
- recall that C7 has: uncinate processes, transverse foramina, and a roughly rounded or rectangular body
- do not forget that C7 lacks anterior and posterior tubercles, and has a non-bifid spine
- unlike the thoracic vertebrae (of which C7 most closely resembles T1), C7 has no costal facets for rib articulation (for these look on the lateral body, and anterior transverse processes)

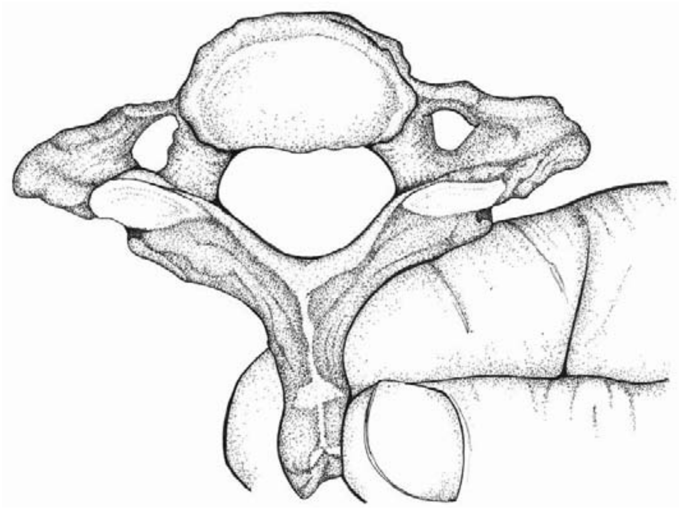


Image 3.30 • C7, superior view.
In this image, the spinous process of the seventh cervical vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the top of the page. The superior articular facets (for C6) are directed toward the reader. Unlike C3 through C6, C1-2 and C7 lack anterior and posterior tubercles on their transverse processes.

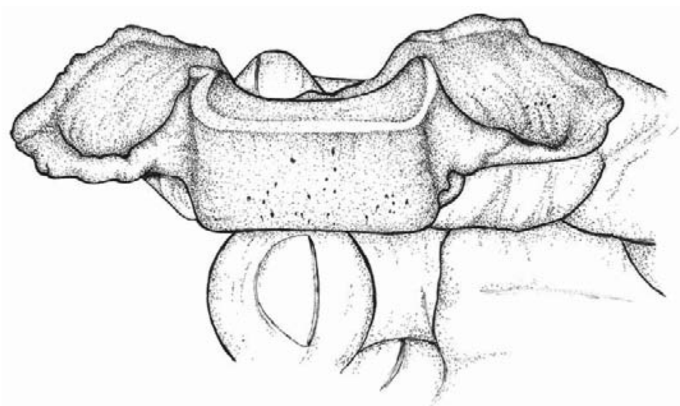


Image 3.31 • C7, anterior view.
In this image, the spinous process of the seventh cervical vertebra is grasped between the fingers of the examiner. The body of the vertebra is toward the reader. The transverse processes resemble "wings." Unlike the typical cervical vertebrae, the inferior margin of the anterior vertebral body of C7 is flat (compare with **Image 3.10**). In the typical cervical vertebrae, this margin is curved at the lateral edges to allow for articulation with the uncinate processes of the vertebra found immediately subjacent (at the uncovertebral joints). As C7 articulates with T1 and the superior margin of the T1 vertebral body lacks uncinate processes, the lateral edges of the inferior C7 body do not need to be curved.

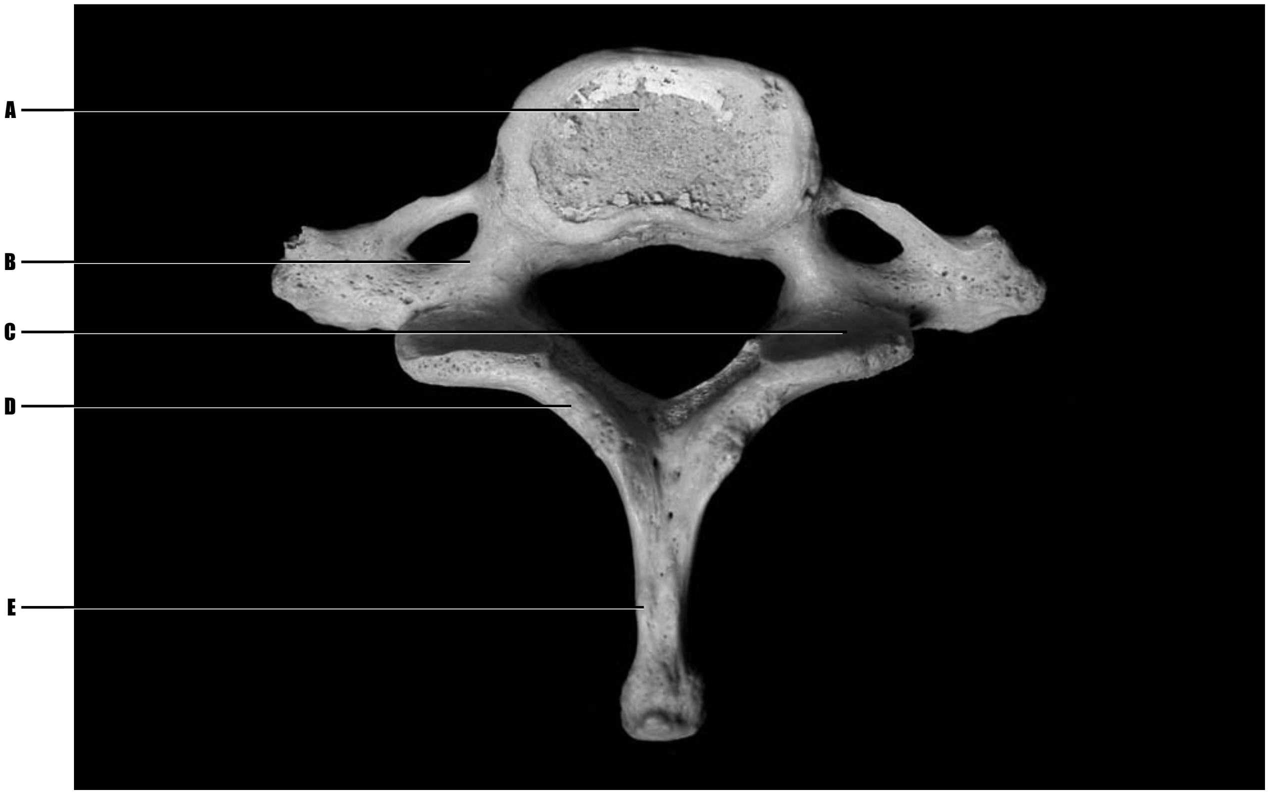


Image 3.32 (above)
Adult seventh cervical vertebra, C7, superior view.
Image 3.33 (below)
Adult seventh cervical vertebra, C7, lateral view.

Image 3.32

A - body
B - transverse foramen
C - pedicle
D - superior articular process
E - vertebral foramen
F - lamina
G - spinous process

Image 3.33

A - body
B - pedicle
C - inferior articular facet
D - lamina (posterior arch)
E - spinous process

Image 3.34
Adult patient, plain film radiograph, anteroposterior (AP) cervical spine.

Image 3.34

A - angle of mandible
B - uncovertebral joint
C - uncinate process of cervical vertebra
D - intervertebral joint space
E - spinous process of C6
F - transverse process of T1
G - medial end of clavicle

Image 3.35
Adult patient, plain film radiograph, lateral cervical spine.

Image 3.35

A - temporomandibular joint
B - posterior wall of maxillary sinus
C - mastoid air sinuses
D - occipital bone
E - anterior tubercle of C2
F - dens
G - C2
H - spinous process of C2
I - vertebral body
J - intervertebral disc
K - inferior articular process
L - superior articular process
M - tracheal air column

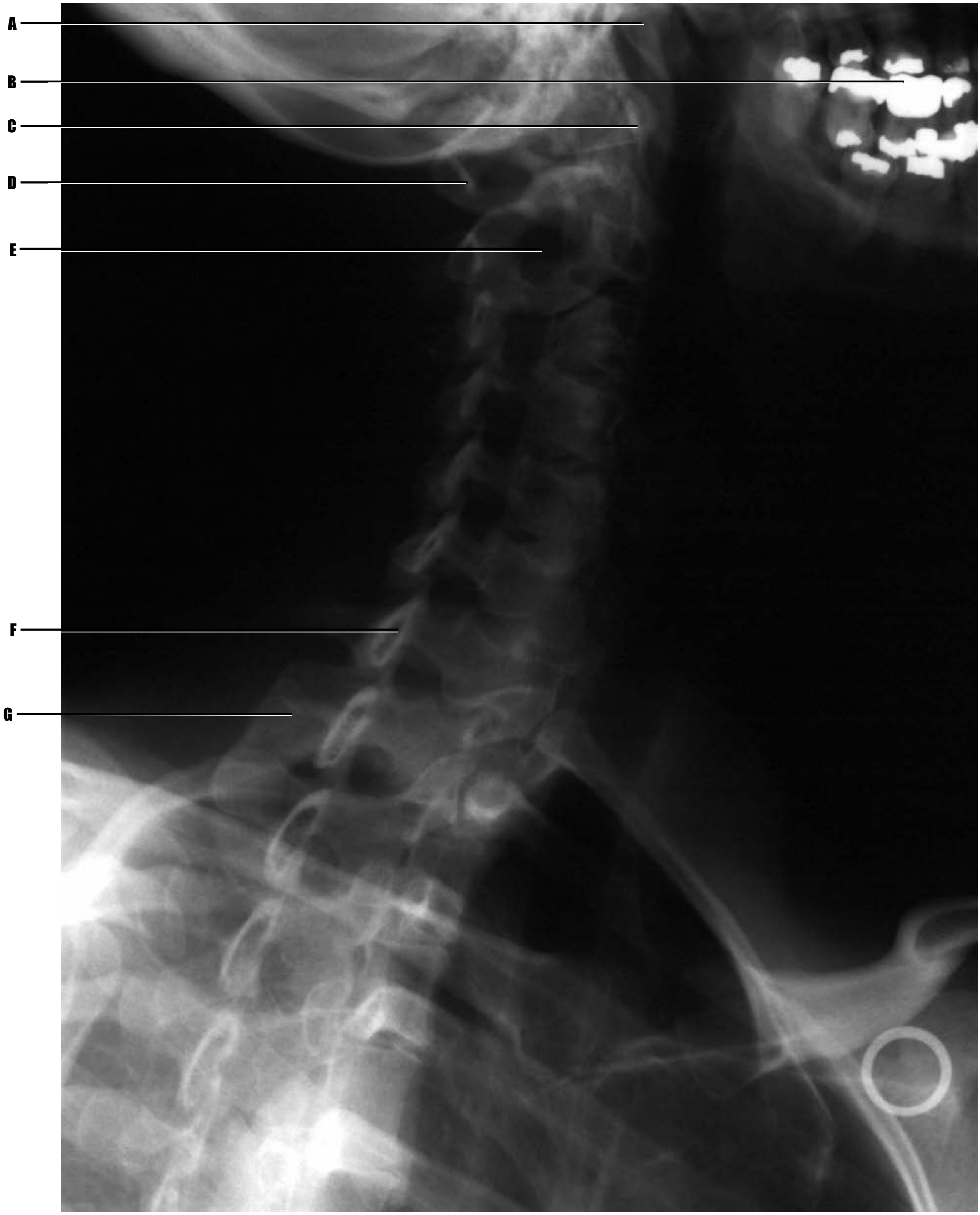


Image 3.36

Adult patient, plain film radiograph, oblique view of cervical spine.

Image 3.36

A - head of mandible

B - dental amalgam of first molar

C - anterior tubercle of C1

D - posterior tubercle of C1

E - vertebral foramen

F - lamina

G - medial portion of first rib

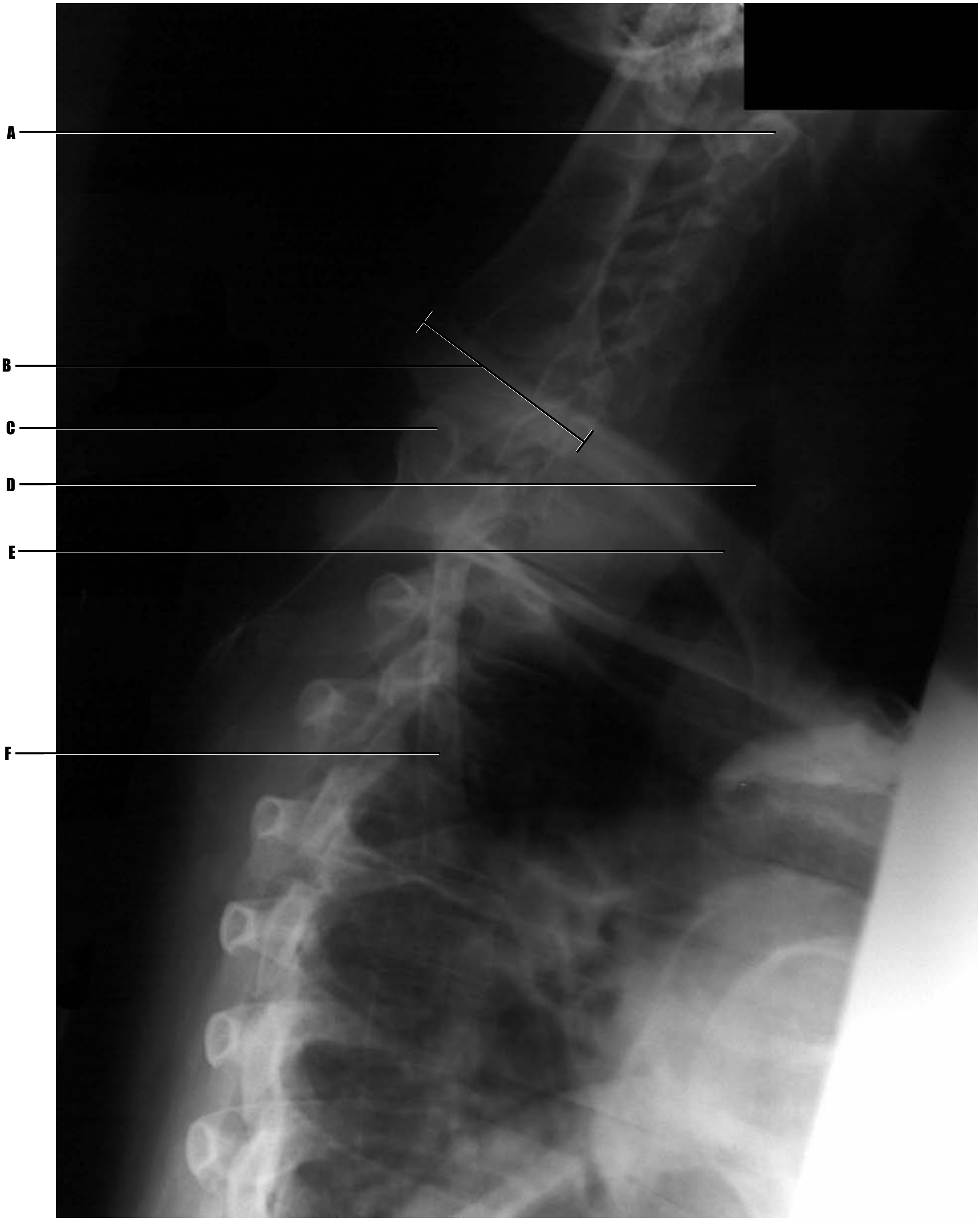


Image 3.37

Adult patient, plain film radiograph, "swimmer's view" of cervical and upper thoracic spine.
A "swimmer's view" is a radiographic projection used to more adequately visualize C7-T2 vertebrae.

Image 3.37

A - odontoid process

B - head of humerus

C - coracoid process

D - tracheal air column

E - clavicle

F - body of scapula

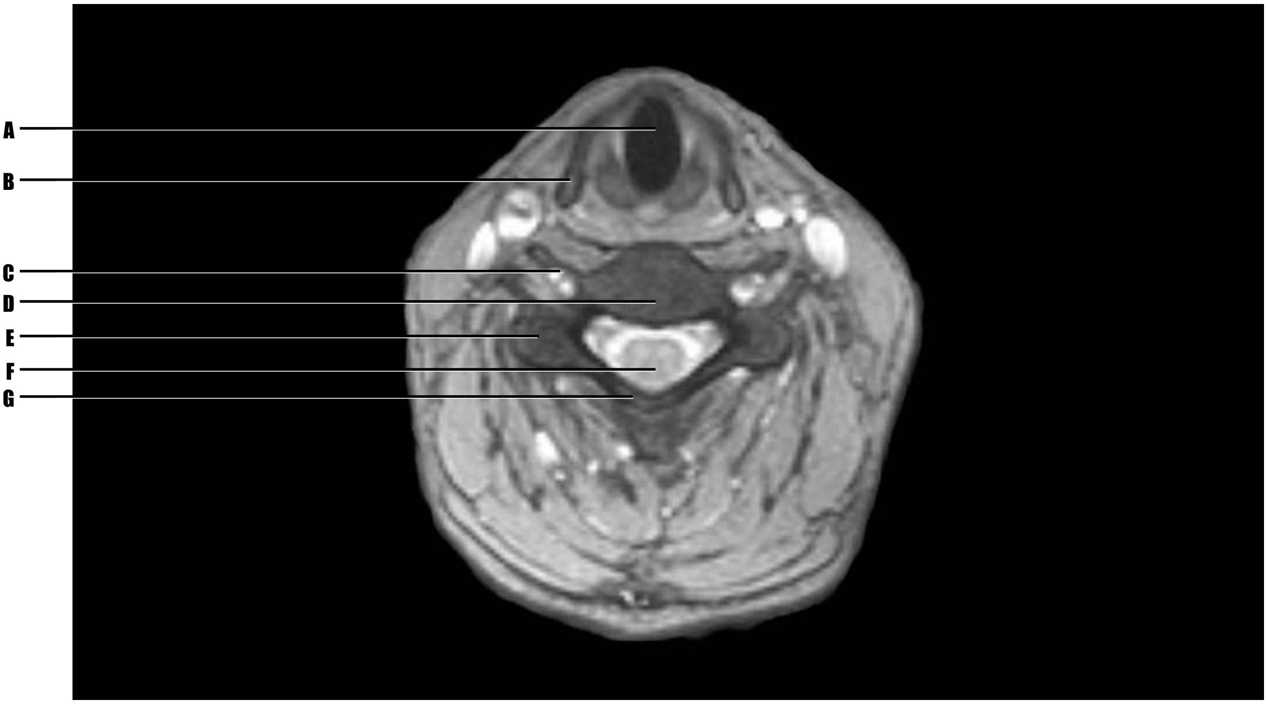


Image 3.38

Adult patient, MR, axial cut through typical cervical vertebra.

Image 3.39

Adult patient, MR, sagittal cut through cervical and high thoracic spine.

Image 3.38

A - trachea
B - thyroid cartilage
C - transverse foramen
D - body of vertebra
E - transverse process of vertebra
F - spinal cord in vertebral canal
G - lamina

Image 3.39

A - dens
B - mandibular symphysis
C - spinal cord
D - manubrium of sternum

3.6 TYPICAL THORACIC VERTEBRAE

Image 3.40 • *Seventh thoracic vertebra (T7), lateral view.*

- the typical thoracic vertebrae are numbers two through nine
- each has a large body, a spinous process (which is not bifid), a vertebral arch (for protection of the enclosed spinal cord), superior and inferior articulating facets (for articulation with the preceding and following vertebrae), transverse processes (without transverse foramina), and articular (costal) facets for ribs on the lateral aspects of their bodies and on the transverse processes
- when viewing the twelve thoracic vertebrae superiorly, one notices that the shape of the body changes from an elongated rectangle to somewhat of a half-circle (~T4-T6) to a larger and more pronounced oval structure toward T12
- the angle of the spinous process changes along the spine:
  - T1 - T3: horizontal
  - T4 - T6: more vertical
  - T7 - T9: increasingly vertical
  - T10 - T12: lumbar-like
- the transverse processes are initially directed somewhat horizontally (T2)
  - however, they become directed progressively posterior toward the lumbar spine
- the typical vertebrae have superior and inferior demi-(half) facets for articulation with two separate ribs
  - i.e. T4's left superior demifacet articulates with the head of the left third rib; T4's left inferior demifacet articulates with the head of the left fourth rib
- all typical thoracic vertebrae have an articular facet on their transverse processes to articulate with the tubercle of their corresponding rib (i.e. the T6 transverse process articular facet articulates with the tubercle of the sixth rib)
- facets on the transverse processes vary in shape as follows:
  - T1 - T6: cuplike facet
  - T7 - T10: flat facet
  - T11 - T12: recall that there are no transverse process facets on these vertebrae

Image 3.41 • Adult back in flexion.
The spinous processes of the thoracic vertebrae become prominently displayed upon flexion.

Landmarks

- body
- pedicle
- superior articular facet

Landmarks continued

- inferior articular facet
- lamina
- costal facet on transverse process
- transverse process
- spinous process
- superior costal demifacet
- inferior costal demifacet
- inferior vertebral notch

Looking at Fragments

- one must first make a distinction between cervical, thoracic and lumbar vertebrae
  - this is done by looking for anatomical features unique to each vertebral category
- e.g., cervical vertebrae have transverse foramina; thoracic vertebrae have costal facets on their bodies, and with few exceptions, on their transverse processes as well; and lumbar vertebrae have mammillary bodies, long thin transverse processes, and massive vertebral bodies
- when looking at isolated thoracic vertebrae, one should be able to easily differentiate between T1, the typical thoracic vertebrae, and T10 through 12
- you should be able to roughly differentiate between upper, middle and lower thoracic based simply on the degree of downward angulation of the spine – recall that the spinous processes become increasingly inferiorly directed toward the lower spine until T9/T10, where they are directed more posteriorly and appear lumbar-like
- the transverse processes become progressively less prominent toward the lower thoracic spine, and increasingly directed in the posterior plane
- with the exception of T11 and T12, articular facets for the ribs can be found on the transverse process
- both the superior and inferior body will have articular facets for the ribs – the exception to this is T10 through T12 where only superior articular facets are found
- keep in mind that degenerative processes like arthritis can alter the appearance of all articular facets, and even obscure them
- use the aforementioned descriptions of transverse facet shape, as well as vertebral body shape to help you identify fragments of vertebrae

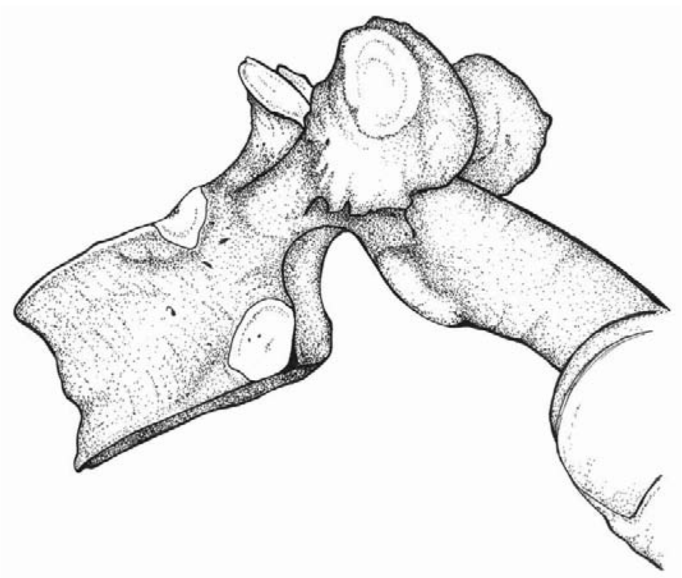
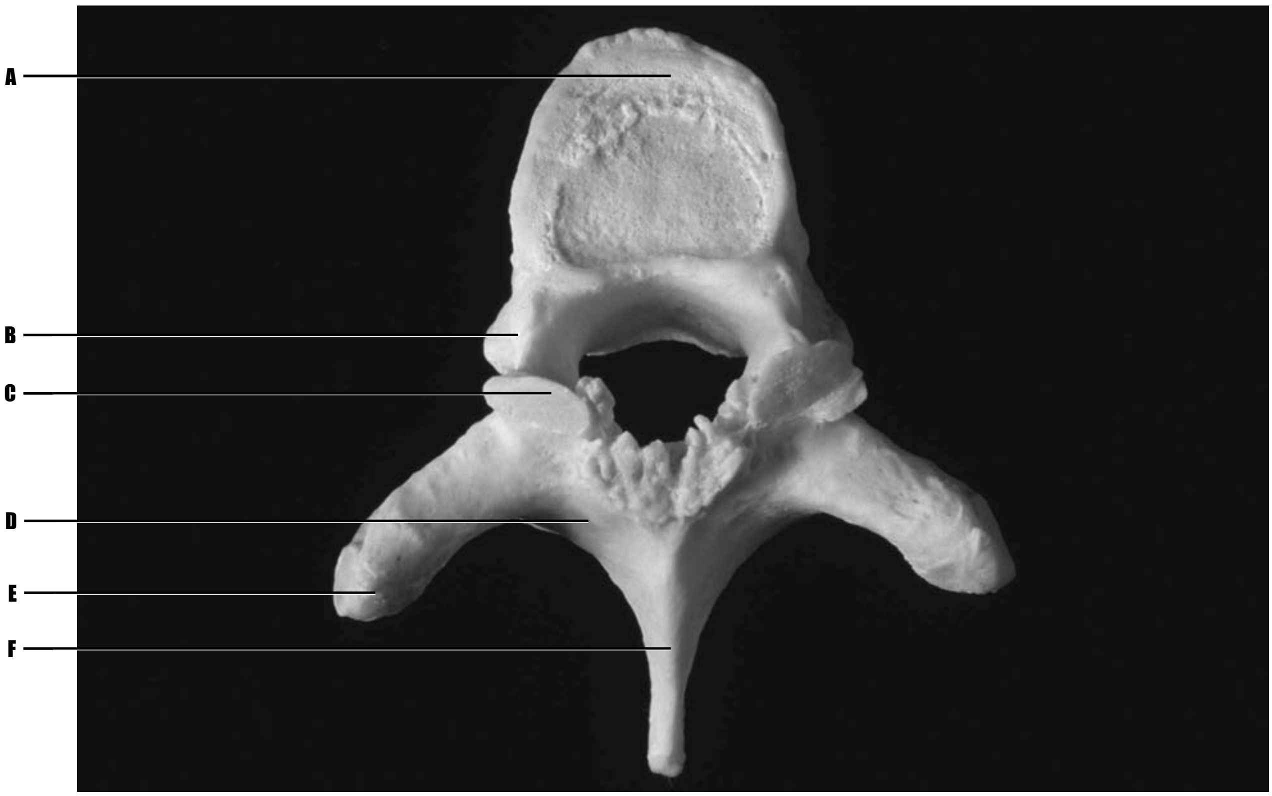


Image 3.42 • T7, lateral view.
In this image, the spinous process of the seventh thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left. In this example, make note of the prominent features of a typical thoracic vertebra, including an inferiorly projecting spine, the presence of superior and inferior demifacets on the body, and a whole facet on the transverse process for articulation with the tubercle of a corresponding rib.



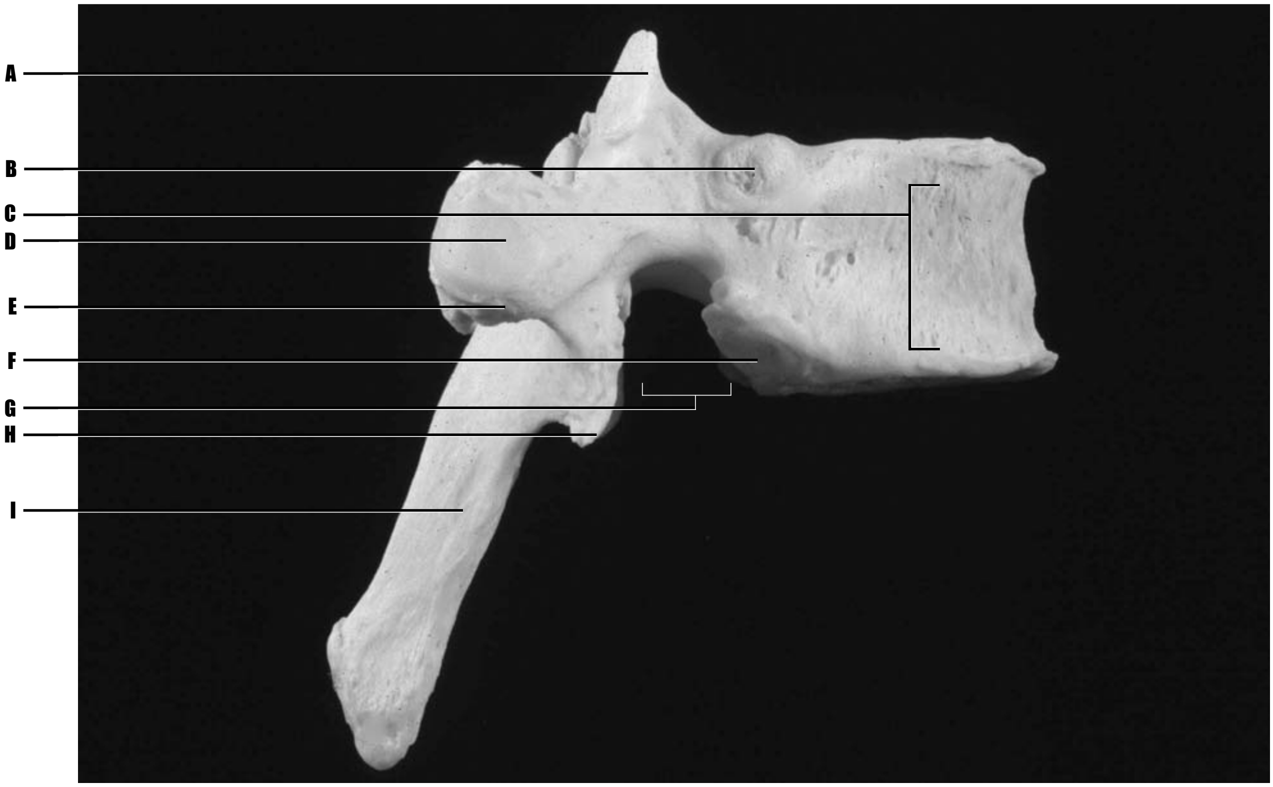


Image 3.43 (above)
T7, superior view.
Image 3.44 (below)
T7, right lateral view.

Image 3.43

A - body
B - pedicle
C - superior articular facet
D - lamina
E - transverse process
F - spinous process

Image 3.44

A - superior articular process
B - superior costal demifacet
C - body
D - costal facet on transverse process
E - transverse process
F - inferior costal demifacet
G - inferior vertebral notch
H - inferior articular process
I - spinous process

3.7 T1

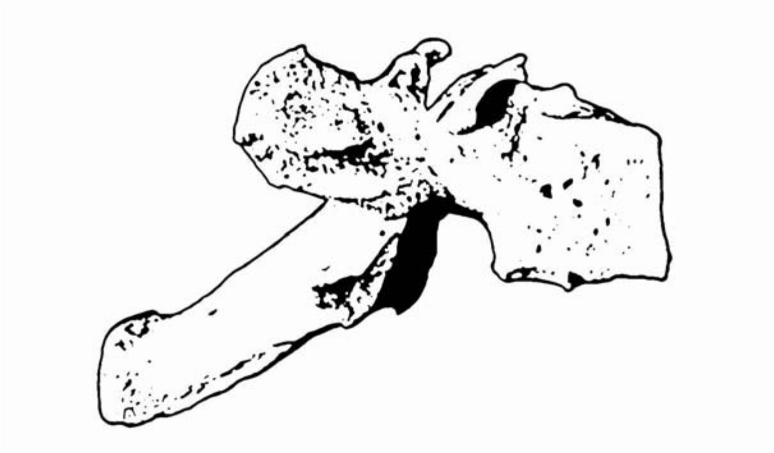


Image 3.45 • *First thoracic vertebra (T1), lateral view.*

- differs from all other thoracic vertebrae in that its spinous process projects somewhat more horizontally (resembling C7), and instead of a superior articulating demifacet, it has a complete (whole) facet for the head of the first rib
- an inferior demifacet is present on the body

Landmarks

- be able to differentiate this vertebra from a typical thoracic vertebra (e.g., T2 - T9)
- body
- pedicle
- superior articular facet
- inferior articular facet
- lamina
- costal facet on transverse process
- transverse process
- spinous process
- superior costal facet
- inferior costal demifacet
- inferior vertebral notch

Looking at Fragments

- T1 has a blunted, somewhat robust spinous process that, like C7, is oriented in the horizontal plane
- unlike C7, there are no transverse foramina, and no uncinate processes on the body
- careful attention to the shape of articular facets on the body will confirm the presence of an inferior half facet, and a superior whole facet – a feature key to the identification process
  - don't forget, there is also a whole articular facet on each transverse process
- note also that the T1 body tends to be flatter and somewhat more compressed in appearance than other thoracic vertebrae

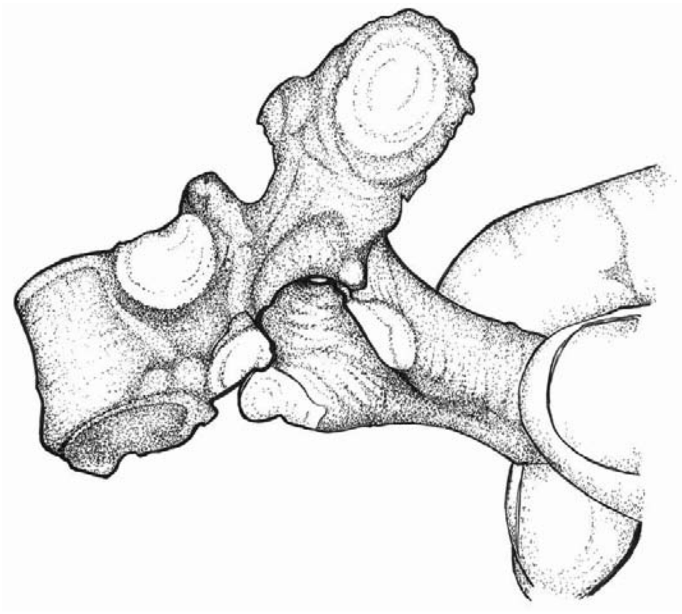


Image 3.46 • T1, left lateral view.
In this image, the spinous process of the first thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left. In this example, note features of a typical thoracic vertebra including the presence of inferior demifacets on the body, and a whole facet on the transverse process for articulation with the tubercle of a corresponding rib. However, this vertebra differs in that it has a complete whole facet on the superolateral margin of the body.

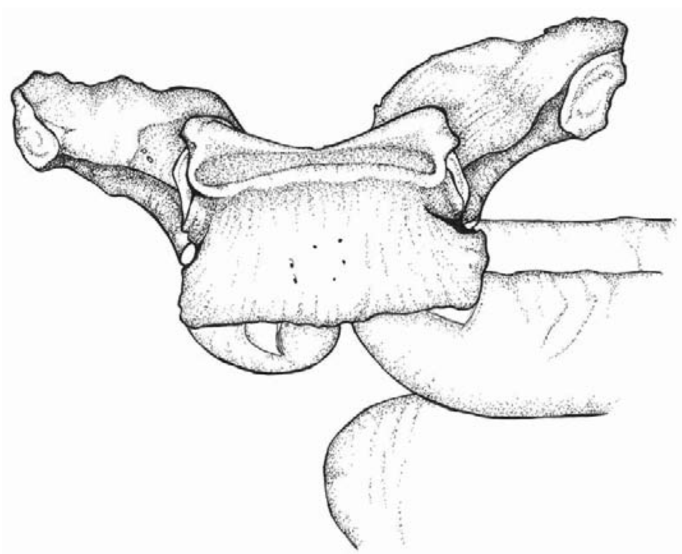
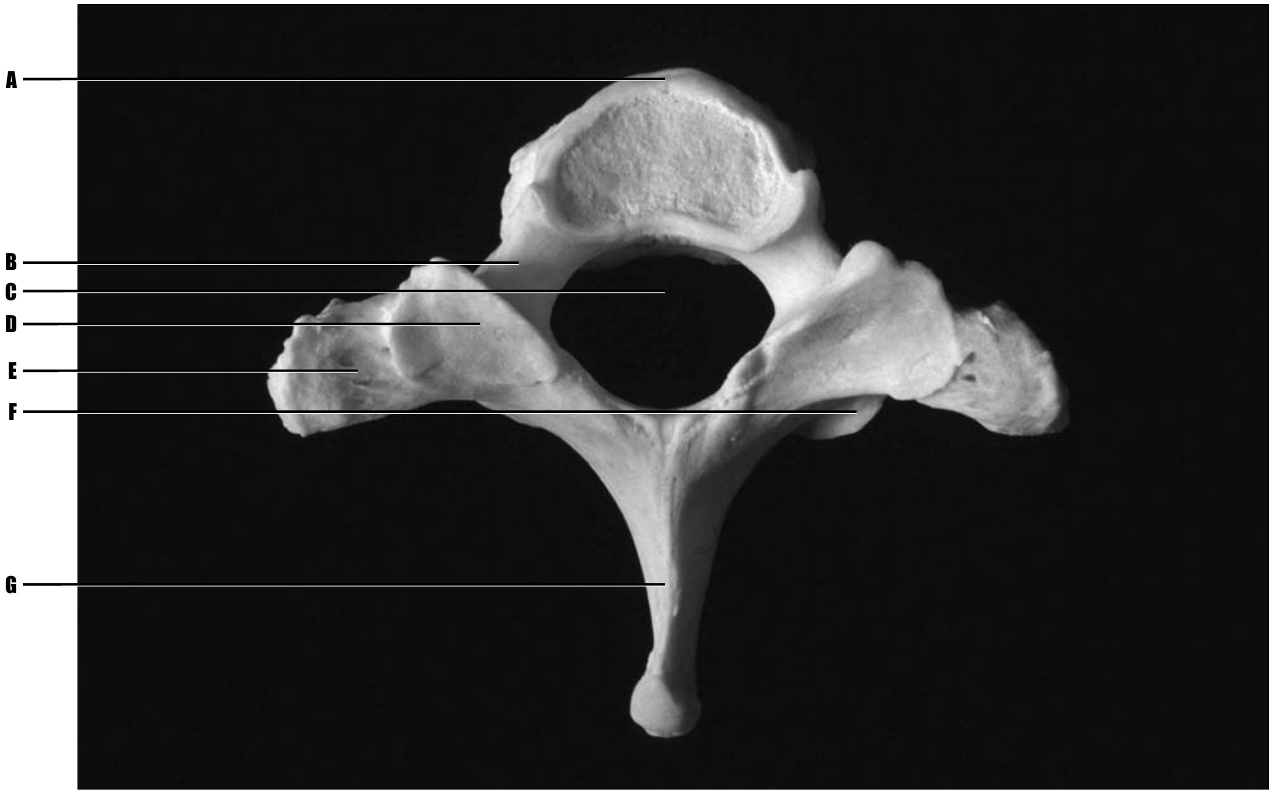


Image 3.47 • T1, anterior view.
In this image, the spinous process of the first thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is toward the reader. The transverse processes resemble "wings." Unlike the cervical vertebrae, the superior and inferior margins of the anterior vertebral body of T1 are flat (compare with **Image 3.10**). In the typical cervical vertebrae, this margin is curved at the lateral edges to allow for articulation with the uncinate processes of the vertebrae located above and below at the uncovertebral joints.



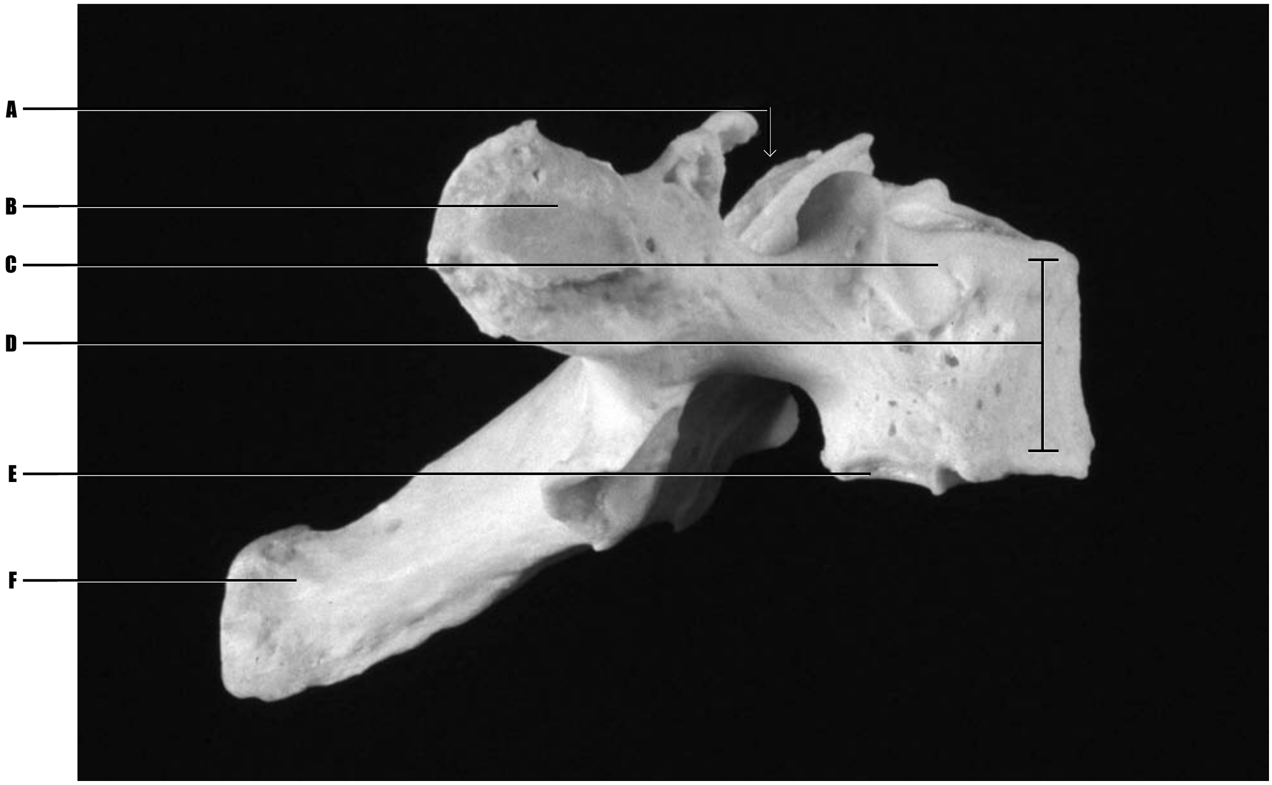


Image 3.48 (above)
T1, superior view.
Image 3.49 (below)
T1, lateral view.

Image 3.48

A - body
B - pedicle
C - vertebral (spinal) foramen
D - superior articular process
E - transverse process
F - inferior articular process
G - spinous process

Image 3.49

A - superior vertebral notch
B - costal facet on transverse process
C - superior costal facet of body
D - body
E - inferior costal demifacet of body
F - spinous process

3.8 T10

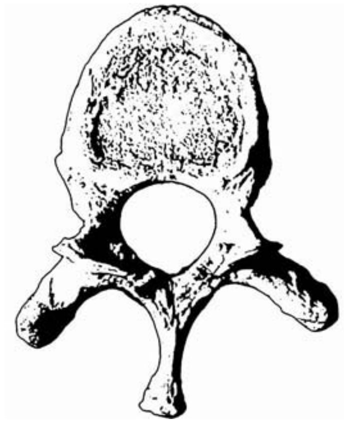


Image 3.50 • *Tenth thoracic vertebra (T10), superior view.*

- has the same basic anatomy as the typical thoracic vertebrae, except:
  - it has no inferior articular demifacet, and it has a complete (whole) superior articular facet
  - it has whole articular facets on its transverse processes
  - the spinous process has become more horizontally oriented again, and is now shorter and robust
- an examination of the lateral profile of T1 through T11 reveals that the inferior articular facets are transversely oriented
  - this differs from T12 and all of the lumbar vertebrae which have laterally (obliquely) oriented inferior articular facets (see **Images 3.56** and **3.61**)
  - T10, therefore, is indistinguishable from T11 by its inferior articular processes alone
  - differentiation of T10 from T11 must be made by the presence of a costal facet on its transverse process (which is lacking on T11 and T12)

Landmarks

- be able to differentiate this vertebra from a typical thoracic vertebra
- body
- pedicle
- superior articular facet
- inferior articular facet
- lamina
- costal facet on transverse process
- transverse process
- spinous process
- superior costal facet
- inferior vertebral notch

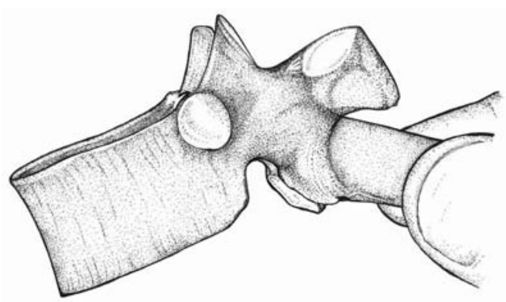


Image 3.51 • T10, left lateral view.
In this image, the spinous process of the tenth thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left. Make note of the features typical of the tenth thoracic vertebra including complete superior facets on its body, no inferior demifacets, and complete facets on its transverse processes. Like T11, the inferior articular processes are oriented parallel to each other, thereby allowing differentiation of T12 from the lumbar vertebrae.

Image 3.52 (above)
T10, superior view.

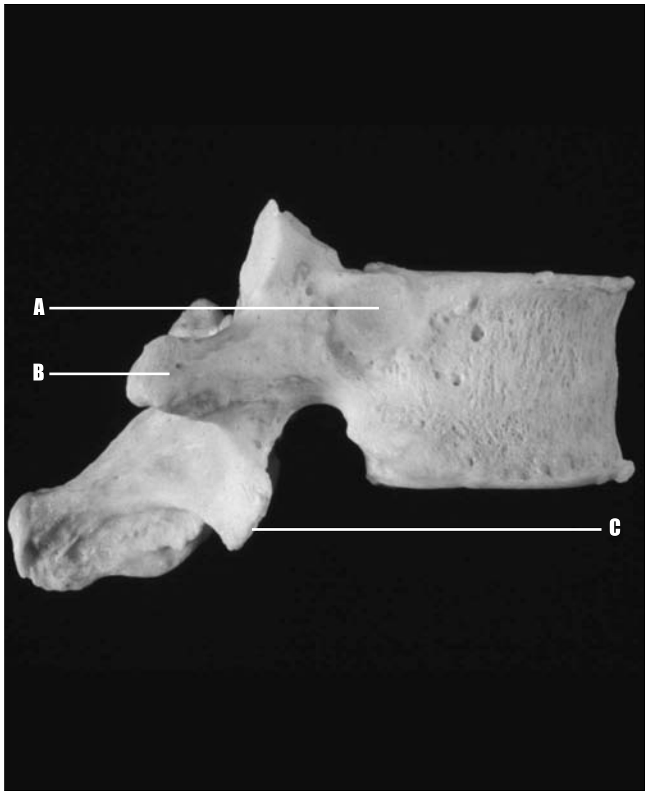


Image 3.53 (above)
T10, lateral view.

Images 3.52 and 3.53

A - superior costal facet for rib

B- transverse process (with articular facet for rib)

C - inferior articular process

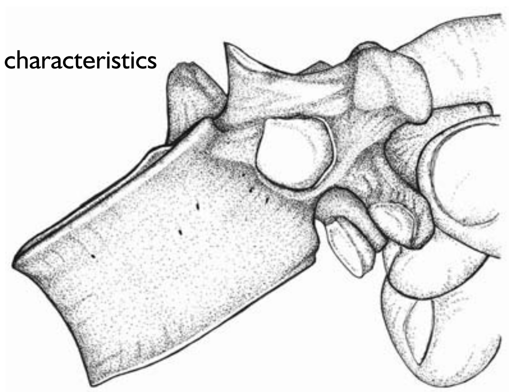
3.9 T11

Image 3.54 • *Eleventh thoracic vertebra (T11), superior view.*

- has the same basic structural anatomy of the typical thoracic vertebrae, except:
  - it has no inferior articular demifacet, and a complete (whole) superior articular facet
  - it does NOT have articular facets on its transverse processes
  - the short and robust spinous process has become more horizontally oriented than those vertebrae preceding it
- an examination of the lateral profile of T1 through T11 reveals that the inferior articular facets are transversely oriented
  - this differs from T12 and all of the lumbar vertebrae which have laterally (obliquely) oriented inferior articular facets
  - T11 is therefore distinguishable from T12 by examining the orientation of the inferior articular processes (see **Image 3.61**)
  - they are transversely oriented in T11, and obliquely oriented in T12

Landmarks

- be able to identify this specific vertebra based on the above special characteristics
- body
- pedicle
- superior articular facet
- inferior articular facet
- lamina
- transverse process
- spinous process
- superior costal facet
- inferior vertebral notch



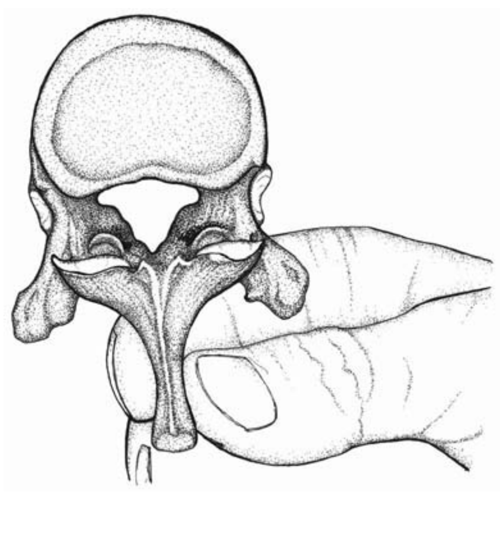


Image 3.55 (above) • T11, left lateral view.
In this image, the spinous process of the eleventh thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left. Make note of the prominent whole costal facet on the body, the lack of an inferior demifacet, as well as the lack of a facet on the transverse process.

Image 3.56 (below) • T11, inferior view.
In this image, the spinous process of the eleventh thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed upward. The transverse orientation of the inferior articular facets/processes is clearly visible in this image. Compare with that of T12 (**Image 3.61** on page 184).

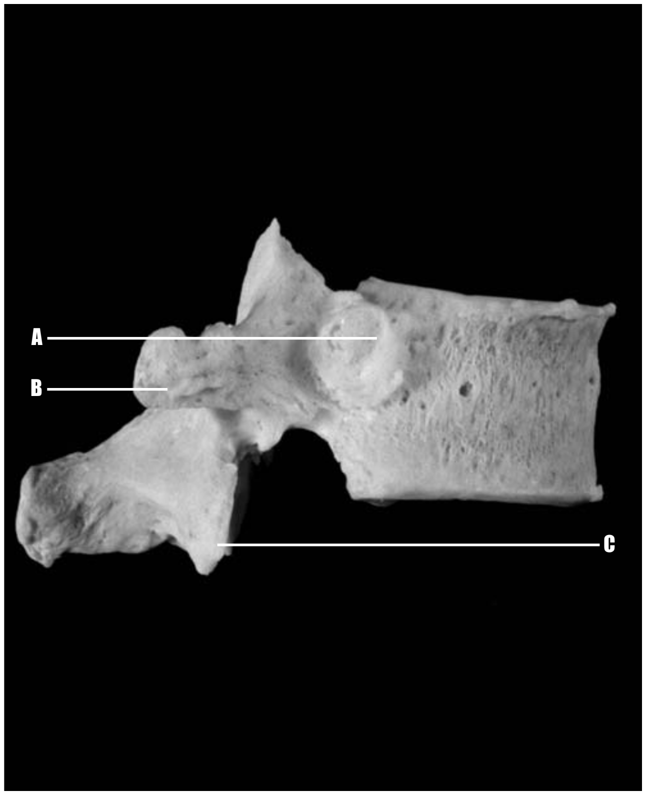


Image 3.57 (above)
T11, superior view.

Image 3.58 (above)
T11, lateral view.

Images 3.57 and 3.58

A - superior costal facet for rib
B - transverse process (without facet for rib)
C - inferior articular process

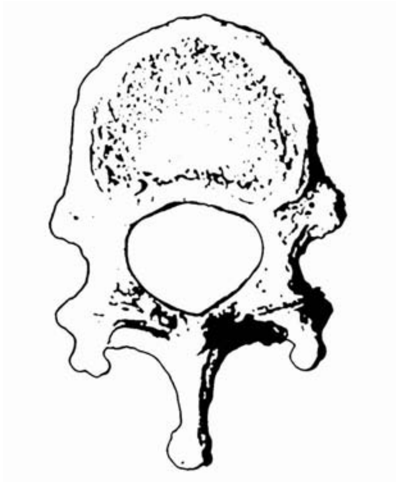
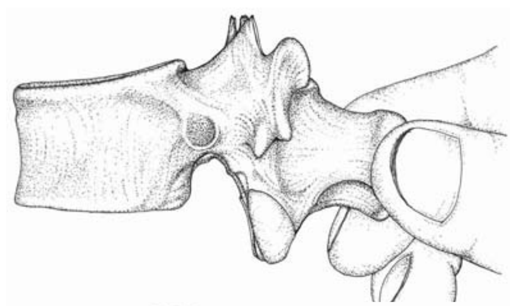


Image 3.59 • *Twelfth thoracic vertebra (T12), superior view.*

- has the same basic structural anatomy of the typical thoracic vertebrae, except:
  - it has no inferior articular demifacet, and a complete (whole) superior articular facet
  - it does NOT have articular facets on its transverse processes
  - the short and robust spinous process has become more horizontally oriented than those vertebrae preceding it, and it has an appearance more like a lumbar than thoracic vertebra
- therefore, it closely resembles the morphology of T11
  - however, as previously stated, rather than being transversely positioned, the inferior articular facets are obliquely oriented, and therefore resemble lumbar vertebral morphology

Landmarks

- be able to identify this specific vertebra based on the above special characteristics
- body
- pedicle
- superior articular facet
- inferior articular facet
- lamina
- transverse process
- spinous process
- superior costal facet
- inferior vertebral notch



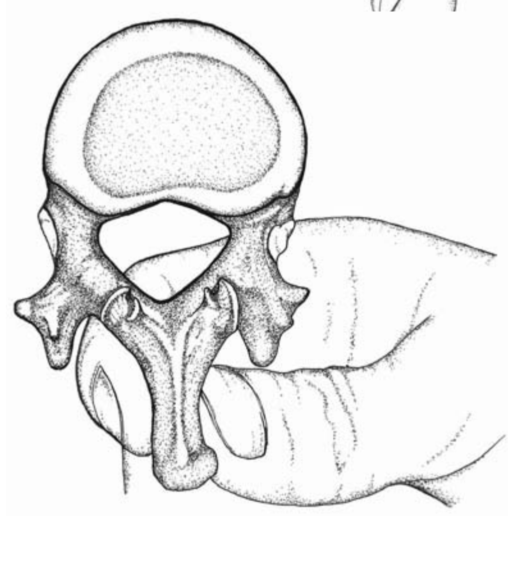


Image 3.60 (above) • T12, left lateral view.
In this image, the spinous process of the twelfth thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left. Make note of the prominent whole costal facet on the body, the lack of an inferior demifacet, as well as the lack of a facet on the transverse process. Note that this configuration does NOT differ from that of T11.

Image 3.61 (below) • T12, inferior view.
In this image, the spinous process of the eleventh thoracic vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed upward. The lack of transverse orientation of the inferior articular facets/processes is clearly visible in this image. Compare with that of T11 (**Image 3.56** on page 182).

Image 3.62
T12, superior view.

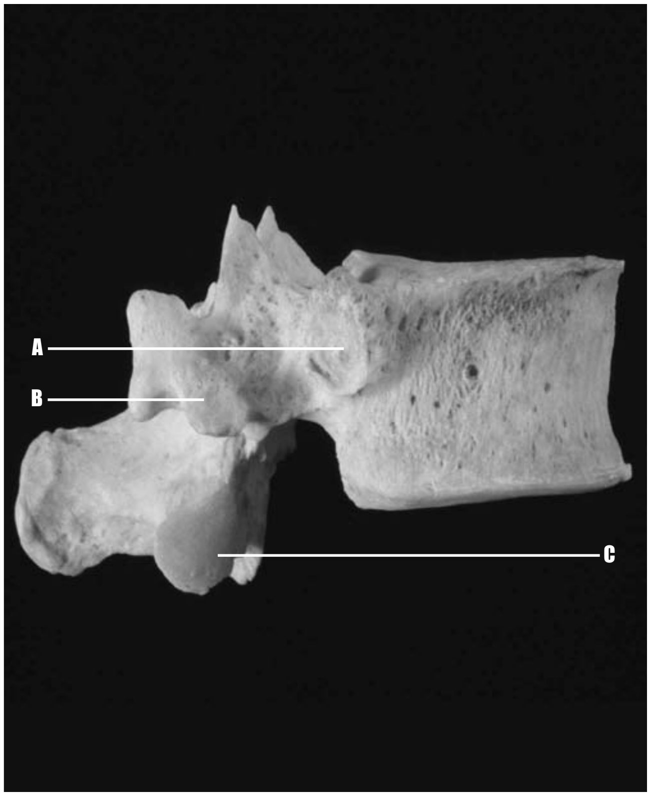


Image 3.63
T12, lateral view.

Images 3.62 and 3.63

A - superior costal facet for rib
B - transverse process (without facet for rib)
C - inferior articular process

Image 3.64
Adult patient, MR, sagittal section through skull, cervical, and thoracic spine.

Image 3.64

A - cerebellum

B - upper cervical spinal cord

C - mandibular symphysis

D - vertebral body

E - spinous process

F - intervertebral disc

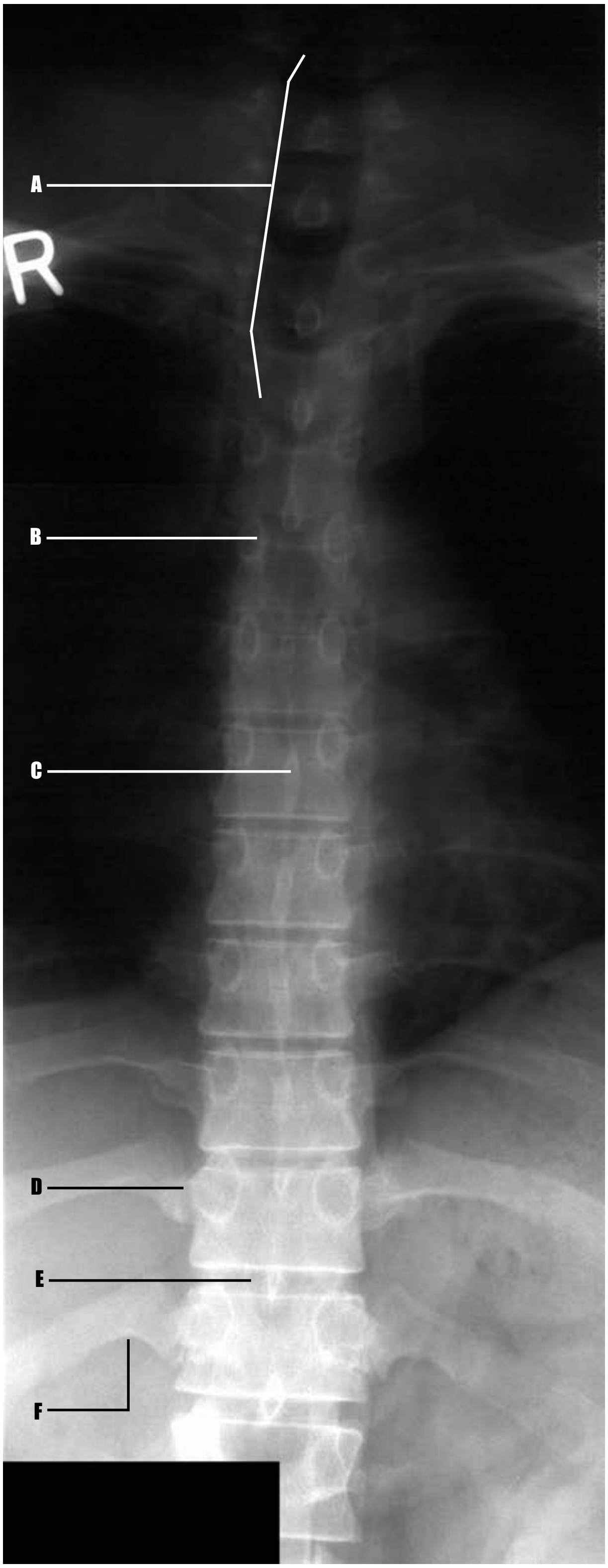


Image 3.65
Adult patient, plain film radiograph, anteroposterior (AP) view of thoracic spine.

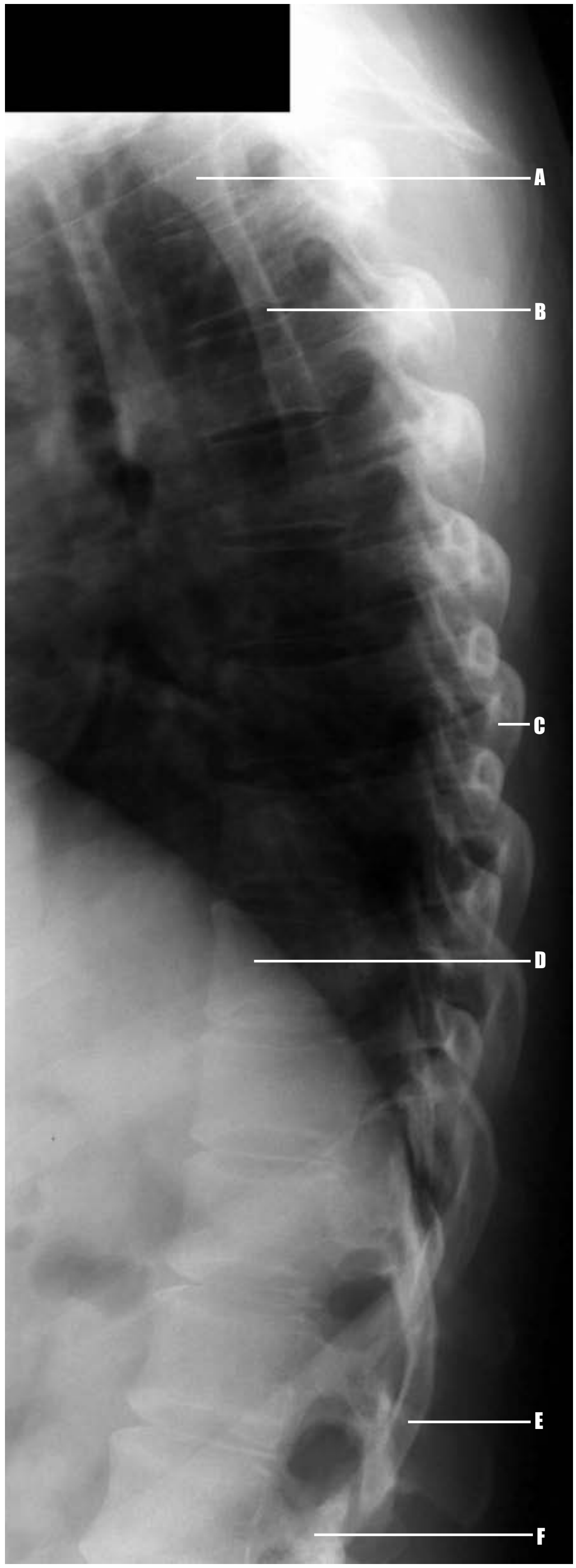


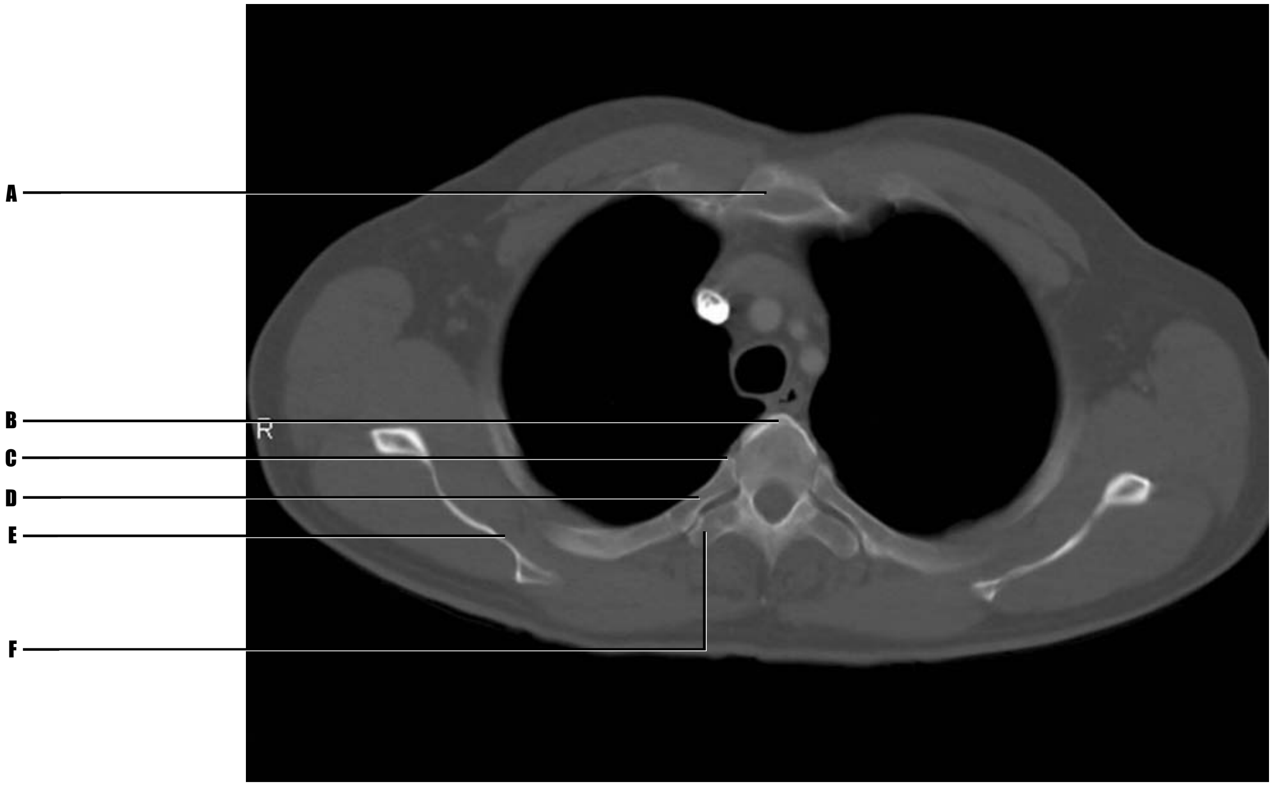
Image 3.66
Adult patient, plain film radiograph, lateral view of thoracic spine, anterior (ventral) is to the left.

Image 3.65

A - tracheal air column
B - pedicle
C - spinous process
D - articular surface of rib head
E - intervertebral disc space
F - neck of rib

Image 3.66

A - neck of scapula
B - body of scapula
C - angle of rib
D - body of vertebra
E - twelfth rib
F - superior articular process



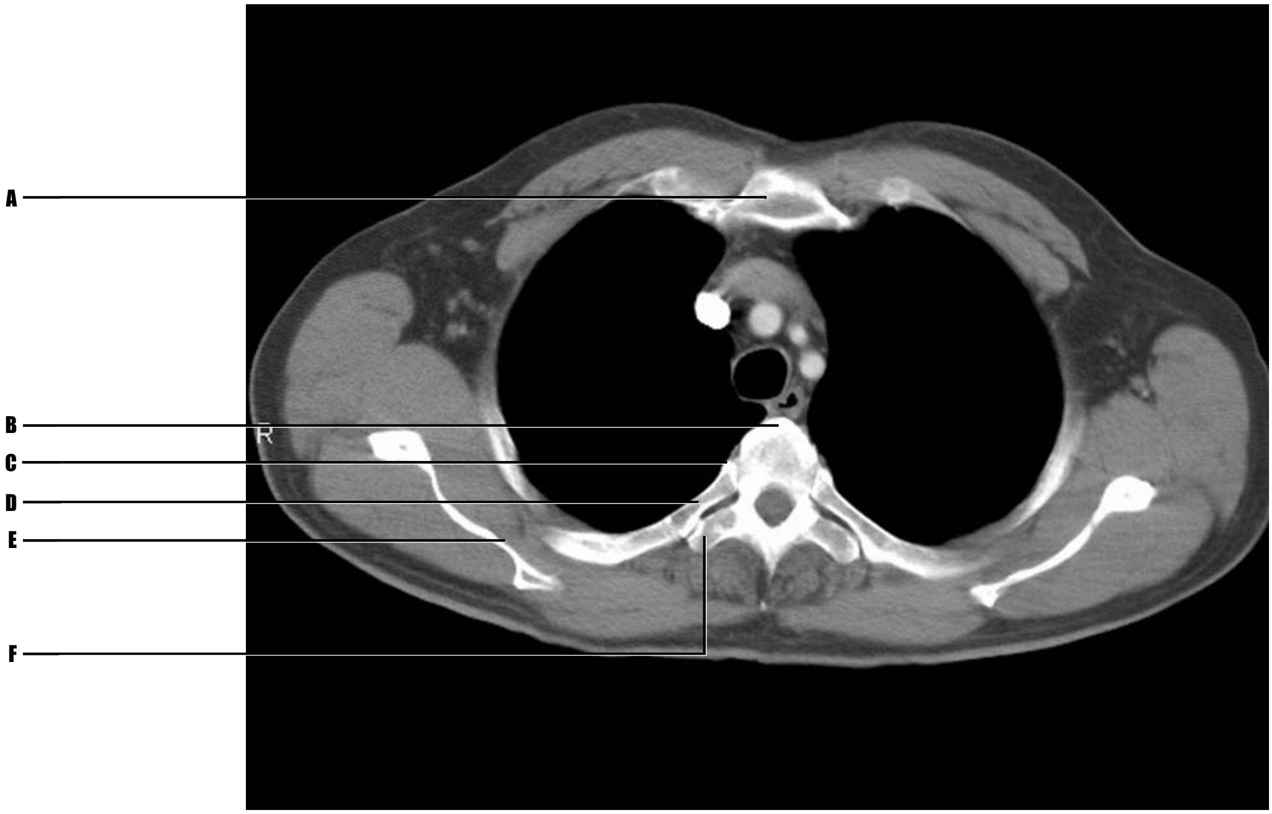


Image 3.67
Adult patient, computed tomography (CT) scan of upper thoracic spine, “bone window”.

Image 3.68
Adult patient, computed tomography (CT) scan of upper thoracic spine, “soft tissue window”.

Images 3.67 and 3.68

A - sternum

B - body of vertebra

C - costovertebral joint

D - neck of rib

E - body of scapula

F - transverse process of vertebra

3.11 LUMBAR SPINE

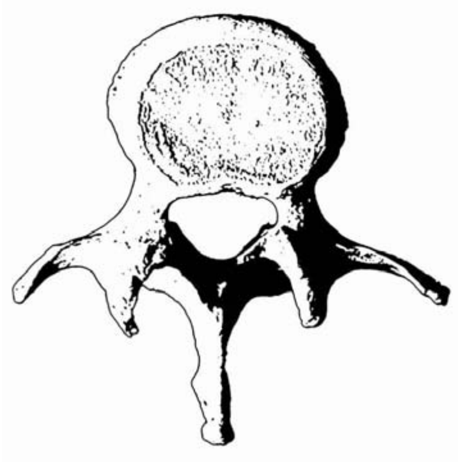


Image 3.69 • *Third lumbar vertebra (L3), superior view.*

- largest presacral vertebrae in the human body
- supports the weight of the body above the pelvis
- have the same general vertebral morphology as the typical thoracic vertebrae, except for:
  - markedly enlarged vertebral body that is wider anteriorly than it is posteriorly, and when viewed from above, has a kidney-like shape
  - sharp, horizontally projecting transverse processes: the first four lumbar vertebrae have flattened transverse processes which project directly sideways; the fifth lumbar vertebra is characterized by its massive transverse process
  - spinous processes that are almost horizontal, quadrangular and thickened along their posterior and inferior borders
  - mammillary bodies are posterior to the transverse processes
- since they do not articulate with the ribs, there are no articular facets on the bodies or transverse processes
- the superior articulating facets are excavated to allow for strong articulation with the convex inferior articulating facets of the preceding lumbar vertebrae, therefore allowing for greater support in the lumbar spine
- the fifth lumbar vertebra is sometimes fused to the sacrum (*sacralization of lumbar vertebra*)

Landmarks

- body
- pedicle
- spinal foramen
- transverse process
- superior articular process
- mammillary process
- lamina
- spinous process
- superior articular facet
- inferior articular process
- inferior articular facet

Looking at Fragments

- lumbar vertebrae can be differentiated from thoracic vertebrae based on the previously mentioned features of a markedly enlarged vertebral body, sharp and horizontally projecting transverse processes, mammillary bodies, thick and blade-like posteriorly projecting spinous process, and the lack of any costal articular facets
- the lumbar vertebrae become progressively more massive as they progress inferiorly toward the sacrum and the posterior aspect of these vertebrae is widened toward L5

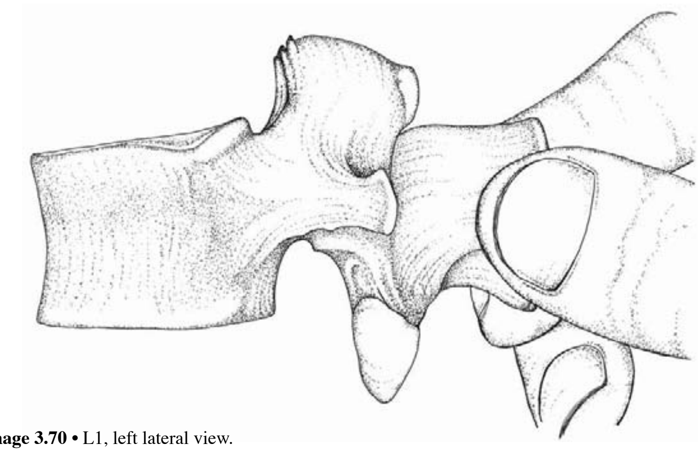


Image 3.70 • L1, left lateral view.
In this image, the spinous process of the first lumbar vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed toward the left.

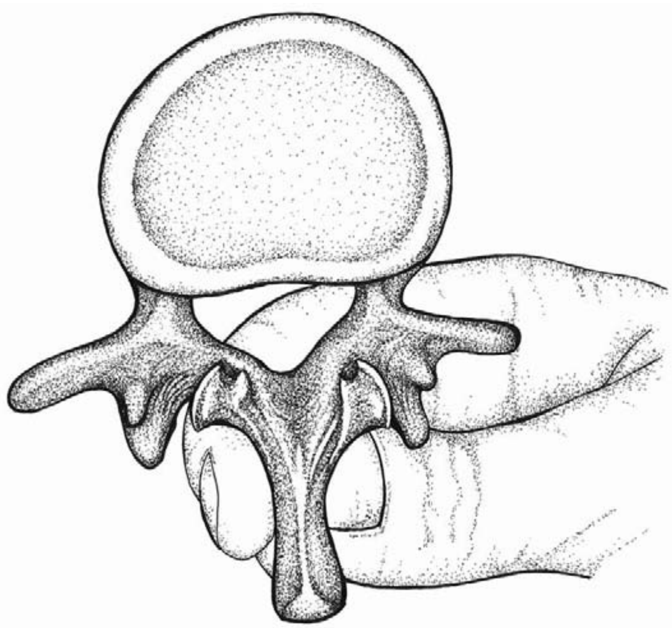


Image 3.71 • L1, inferior view.
In this image, the spinous process of the first lumbar vertebra is grasped between the fingers of the examiner. The body of the vertebra is directed upward. Observe the obliquely oriented, non transverse nature of the inferior articular processes – as discussed with the lower thoracic vertebrae, this can be useful in distinguishing T10 and T11 from T12 through L5.

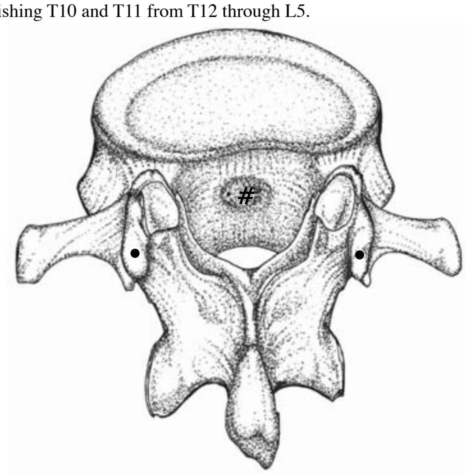


Image 3.72 • L1, posterosuperior view.
The mamillary bodies are indicated by (•) in this image. These are important distinguishing features found only on lumbar vertebrae. Along the anterior wall of the spinal foramen is a small, rounded depression(#). This normal anatomical finding is actually for the spinal venous plexus which runs along the protective coverings of the spinal cord.

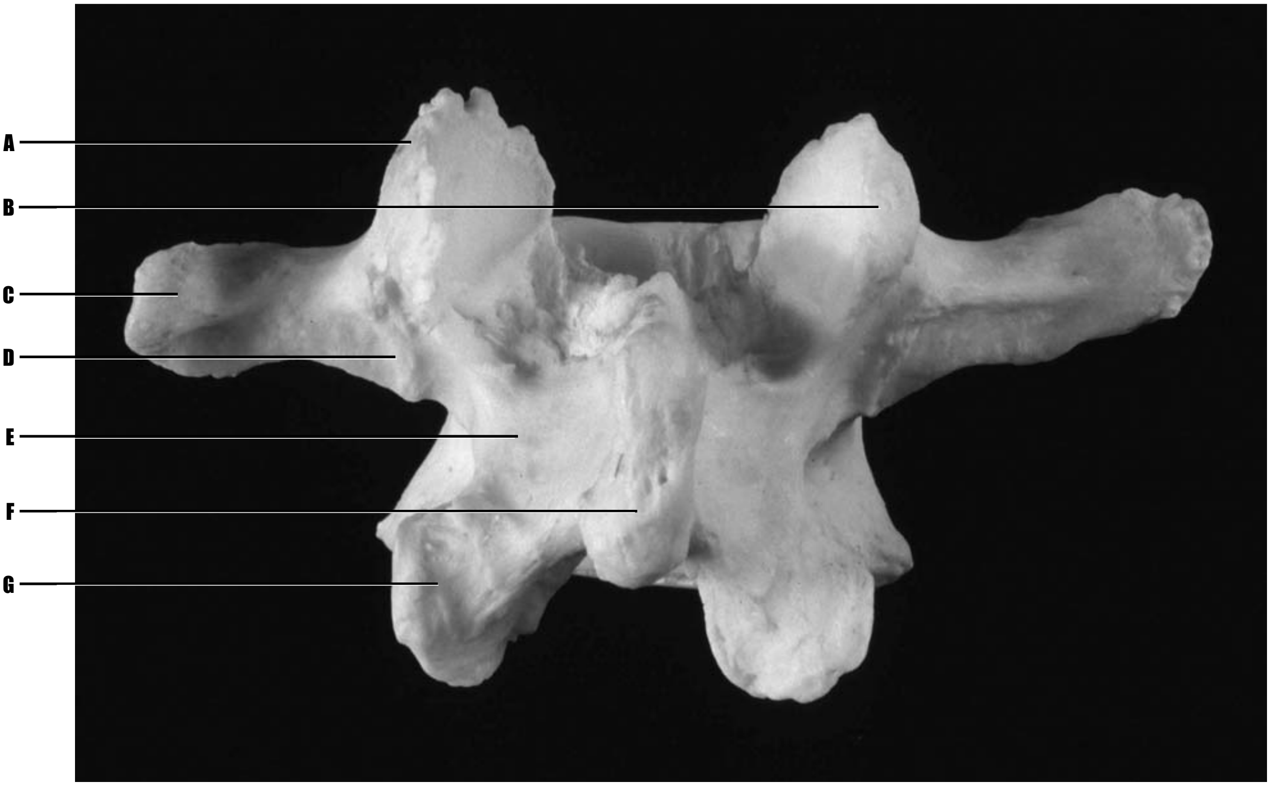


Image 3.73 (above)
L1, superior view.
Image 3.74 (below)
L3, posterior view.

Image 3.73

A - body
B - pedicle
C - spinal foramen
D - superior articular process
E - transverse process
F - mammillary body
G - lamina
H - spinous process

Image 3.74

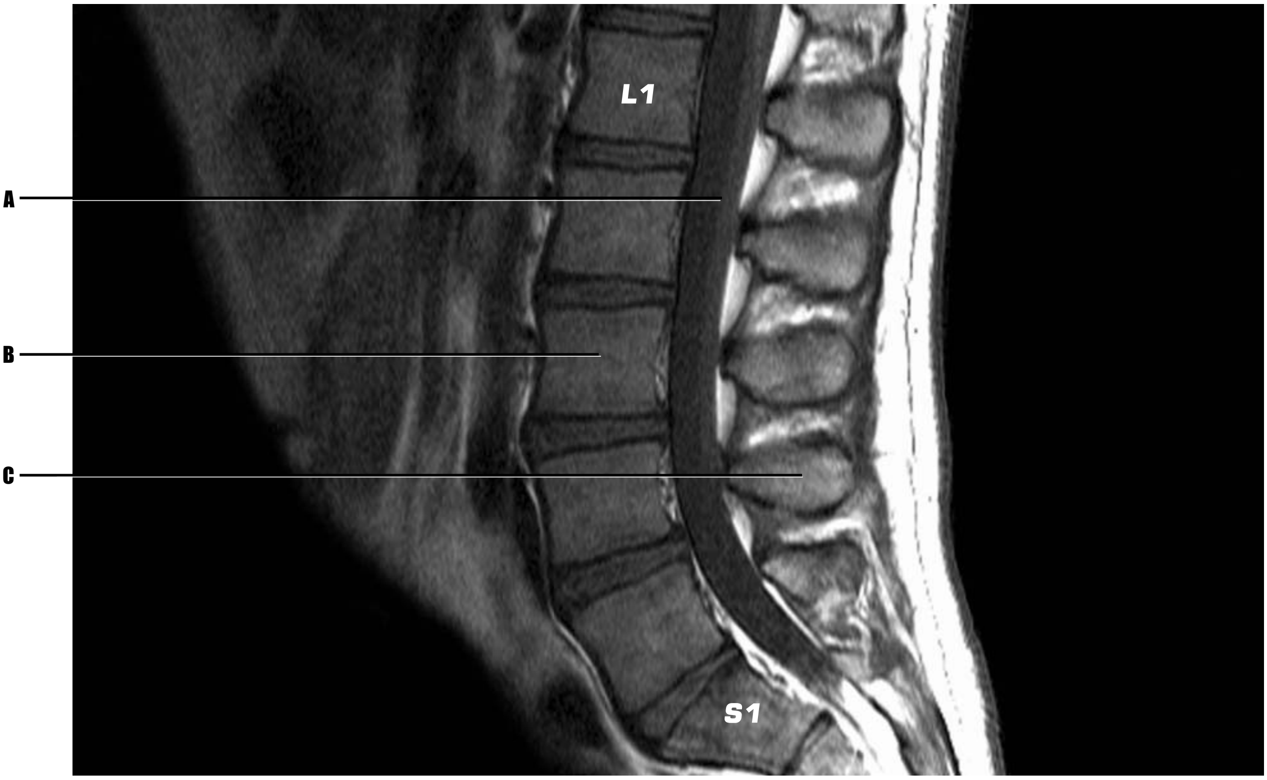
A - superior articular process
B - mammillary body
C - transverse process
D - accessory process
E - lamina
F - spinous process
G - inferior articular process

Image 3.75 (above)
L1, superior view.
Image 3.77 (below)
L3, superior view.
Please note that this image is not to scale.

Image 3.76 (above)
L2, superior view.
Image 3.78 (below)
L4, superior view.

Image 3.79 (above)
L5, superior view.

Use these five images to gain an appreciation of how lumbar vertebral morphology changes from superior to inferior lumbar spine.



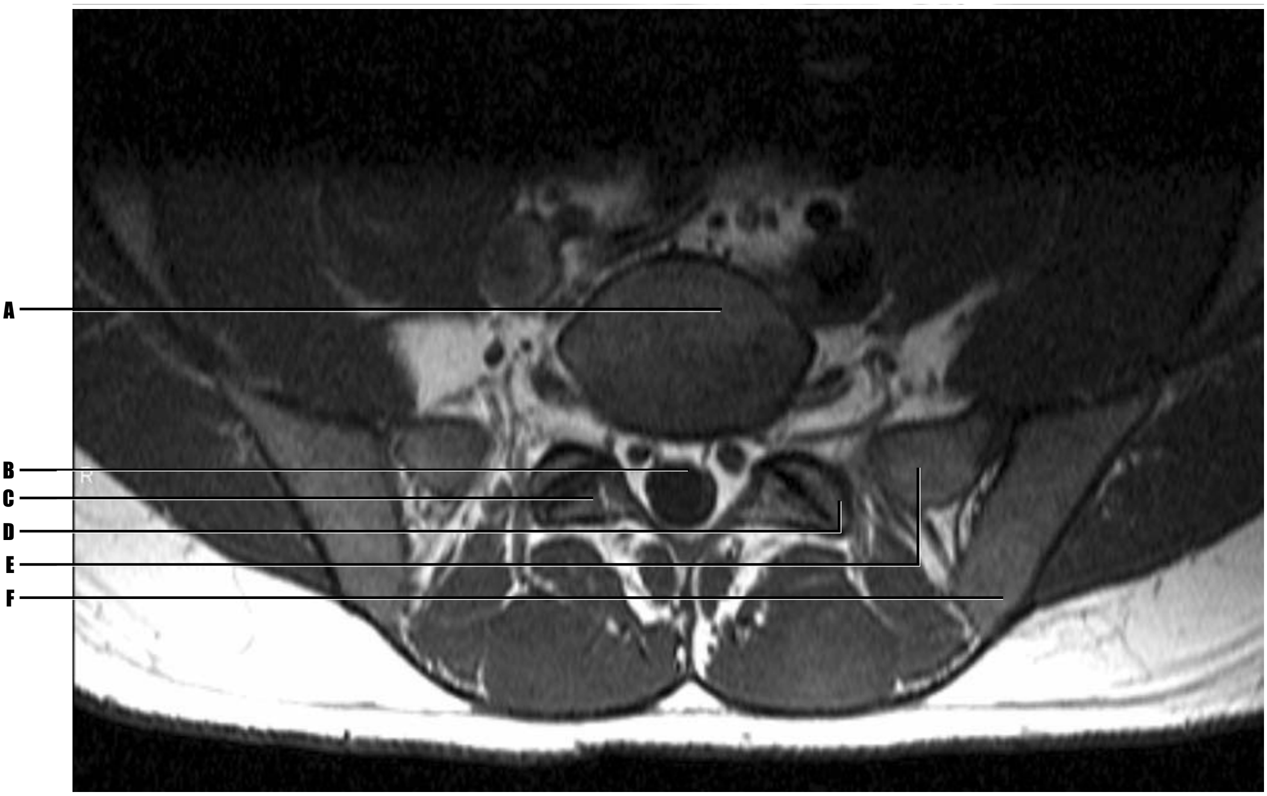


Image 3.80

Adult patient, MR (T1 weighted) of lumbosacral spine (sagittal section). Anterior is to the left.

Image 3.81

Adult patient, MR (T1 weighted) of L5/S1 disc space (horizontal section).

The designation of "T1 weighted" signifies a particular type of MR imaging. It refers to a specific "relaxation time" required by atoms to regain their equilibrium after being perturbed by a radio signal while lying in the strong magnetic field used to obtain MR images.

Image 3.80

A - conus medullaris
B - body of vertebra
C - spinous process of vertebra

Image 3.81

A - body of vertebra
B - spinal cord
C - inferior articular process of L5
D - superior articular process of S1
E - sacral ala
F - ilium

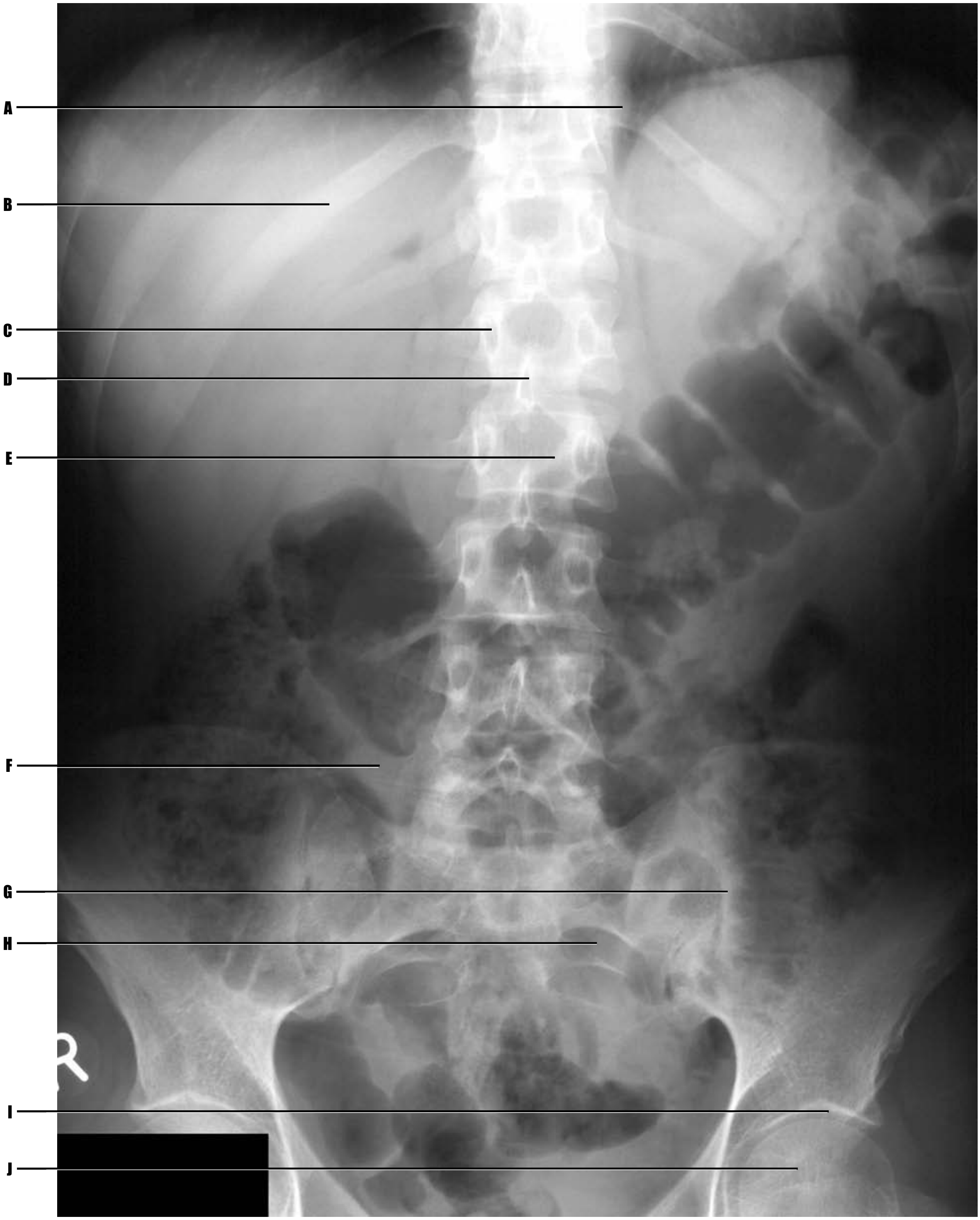


Image 3.82
Adult patient, plain film radiograph, anteroposterior view of abdomen.

Image 3.82

A - head of eleventh rib
B - body of eleventh rib
C - pedicle of L1
D - spinous process of L1
E - lamina of L2
F - transverse process of L5
G - sacroiliac joint
H - sacral neural foramen
I - acetabulum
J - head of femur

Image 3.83
Adult patient, plain film radiograph, lateral lumbar spine.

Image 3.83

A - rib
B - intervertebral disc space
C - superior articular process
D - body of vertebra
E - spinous process
F - inferior articular process
G - interfacetal joint
H - pedicle
I - sacrum

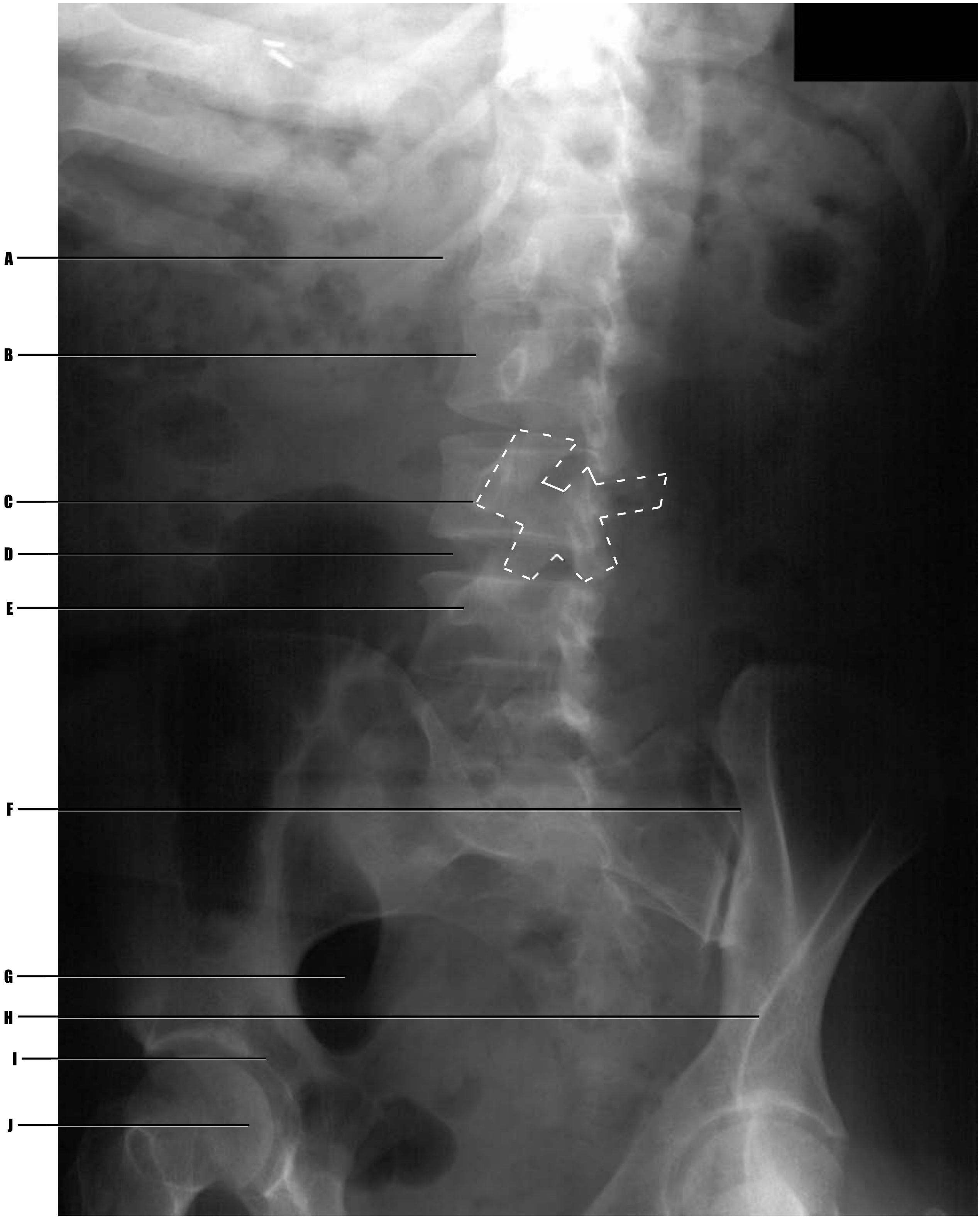
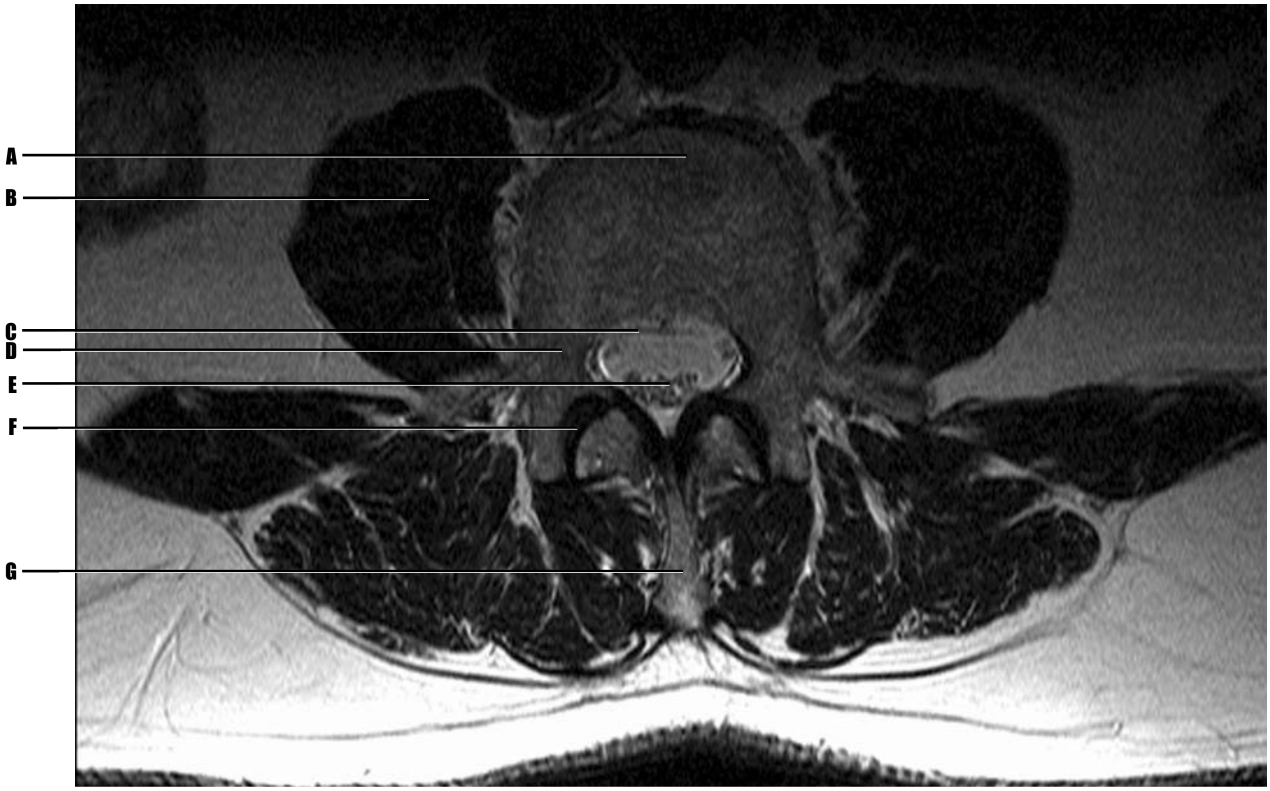


Image 3.84
Adult patient, plain film radiograph, oblique view of lumbar spine.

Image 3.84

A - twelfth rib
B - body of vertebra
C - Scotty dog*
D - intervertebral joint space
E - pedicle
F - sacroiliac joint
G - sciatic notch
H - pectineal line
I - acetabulum
J - femoral head

**A "Scotty dog" is an oblique X-ray of a lumbar vertebra that demonstrates a composite image related to the anatomy of the transverse process, the pedicle, the articular processes, and the pars interarticularis (interarticular part) that simulates the appearance of a Scottish terrier in profile.*



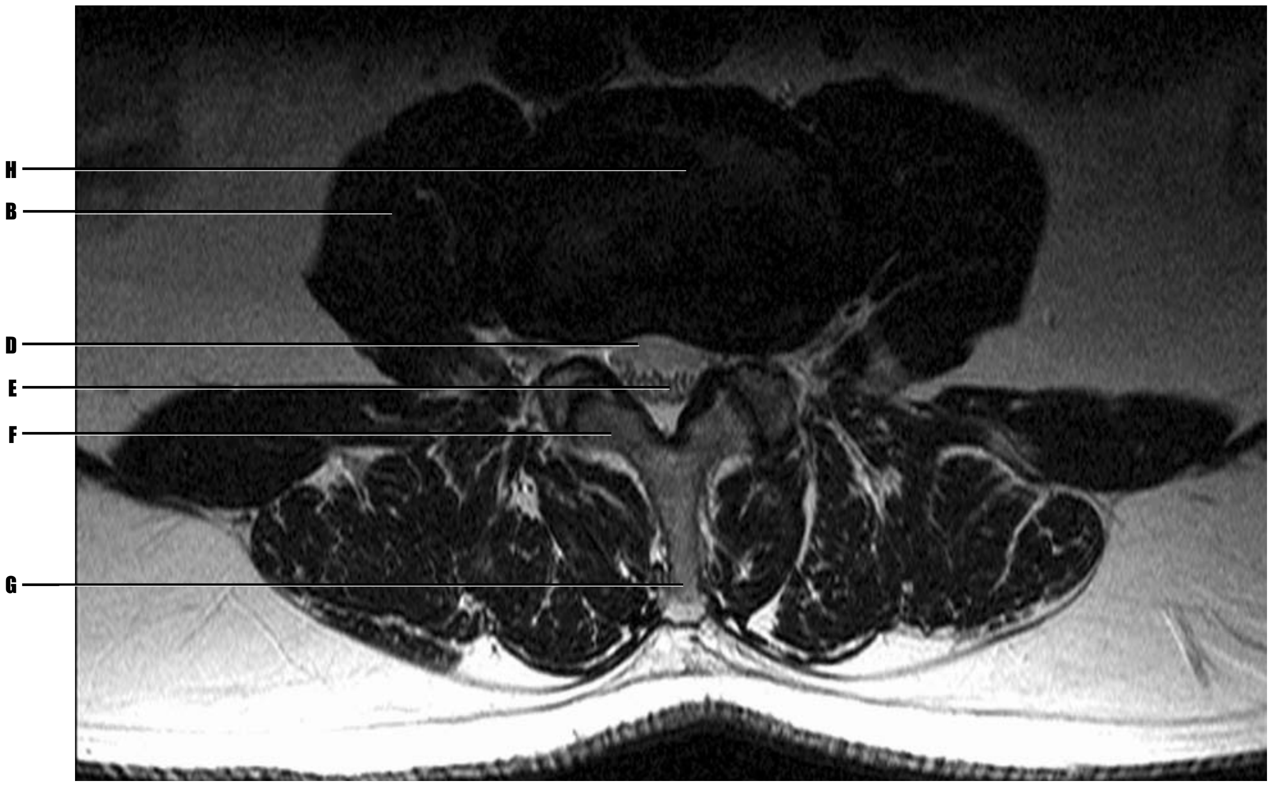


Image 3.85

Adult patient, MR of L2 vertebra, T2 weighted axial section.

Image 3.86

Adult patient, MR of L3/4 disc space, T2 weighted axial section.

The designation of "T2 weighted" signifies a particular type of MR imaging. It refers to a specific "relaxation time" required by atoms to regain their equilibrium after being perturbed by a radio signal while lying in the strong magnetic field used to obtain MR images.

Images 3.85 and 3.86

A - body of vertebra

B - psoas muscle

C - thecal sac

D - pedicle

E - cauda equina

F - facet joint

G - spinous process

H - intervertebral disc

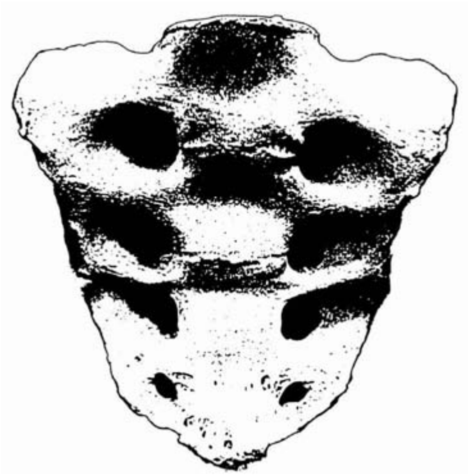


Image 3.87 • *Sacrum, anterior view.*

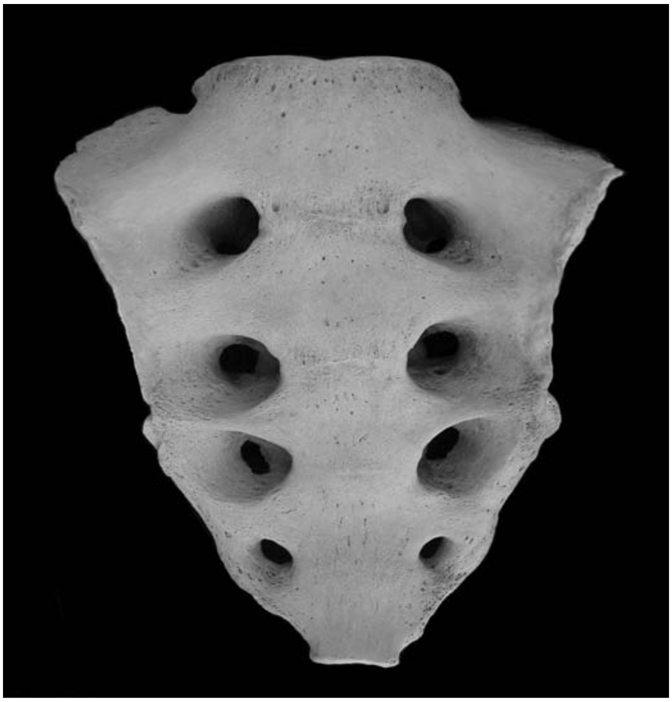
- is composed of five (varies between four to six) sacral vertebrae
  - these fuse into one triangle-shaped bone by adulthood
- the first sacral vertebra is sometimes an independent vertebra (lumbarization of the sacral vertebra)
- the first (superiormost) sacral vertebra is the largest; the size of each following sacral vertebra decreases quite noticeably until the final sacral vertebra, which is small
- articulates with L5 superiorly, the coccyx inferiorly, and the innominates laterally at the sacroiliac joints to form the posterior wall of the pelvic girdle

Landmarks

- articular surface for L5
- auricular surface (articular surface for innominate)
- sacral promontory
- ala
- transverse ridges
- anterior sacral foramina
- articular surface for coccyx
- vertebral canal
- superior articular facet
- mammillary process
- dorsal sacral foramina
- median sacral crest
- intermediate sacral crest
- sacral hiatus

Looking at Fragments

- fragmented sacrum could be confused with lower thoracic or lumbar vertebrae, or with innominate (i.e., the auricular portion)
- keep in mind that:
  - lumbar vertebrae do not have alae and lack the broad articular surfaces for the innominate bones that are seen on the sacrum
  - the concave anterior sacral surface is rather smooth; subtle transverse lines are visible along the midline
  - the convex posterior sacral surface is rather rough and irregular and has a prominent median sacral crest
  - the presence of large sacral foramina is a key identifying feature of sacral fragments – keep in mind that no other bone in the human body has such large foramina arranged throughout its substance



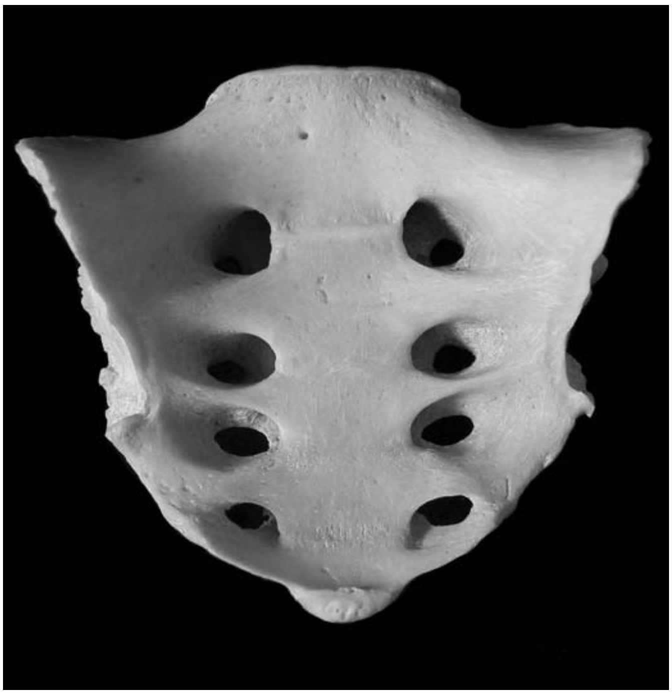


Image 3.88 • Sacrum, male, anterior view (above).
Image 3.89 • Sacrum, female, anterior view (below).
The sacrum, like many other bones in the body, shows a great degree of sexual dimorphism. That is, it has characteristics that differ between males and females. When viewed anteriorly (as in the above examples), the male sacrum tends to be taller, narrower, and flatter (in the anteroposterior plane). Female sacra are generally shorter, wider and more bowl-shaped (in the anteroposterior plane). This is another adaptation conducive to vaginal childbirth.

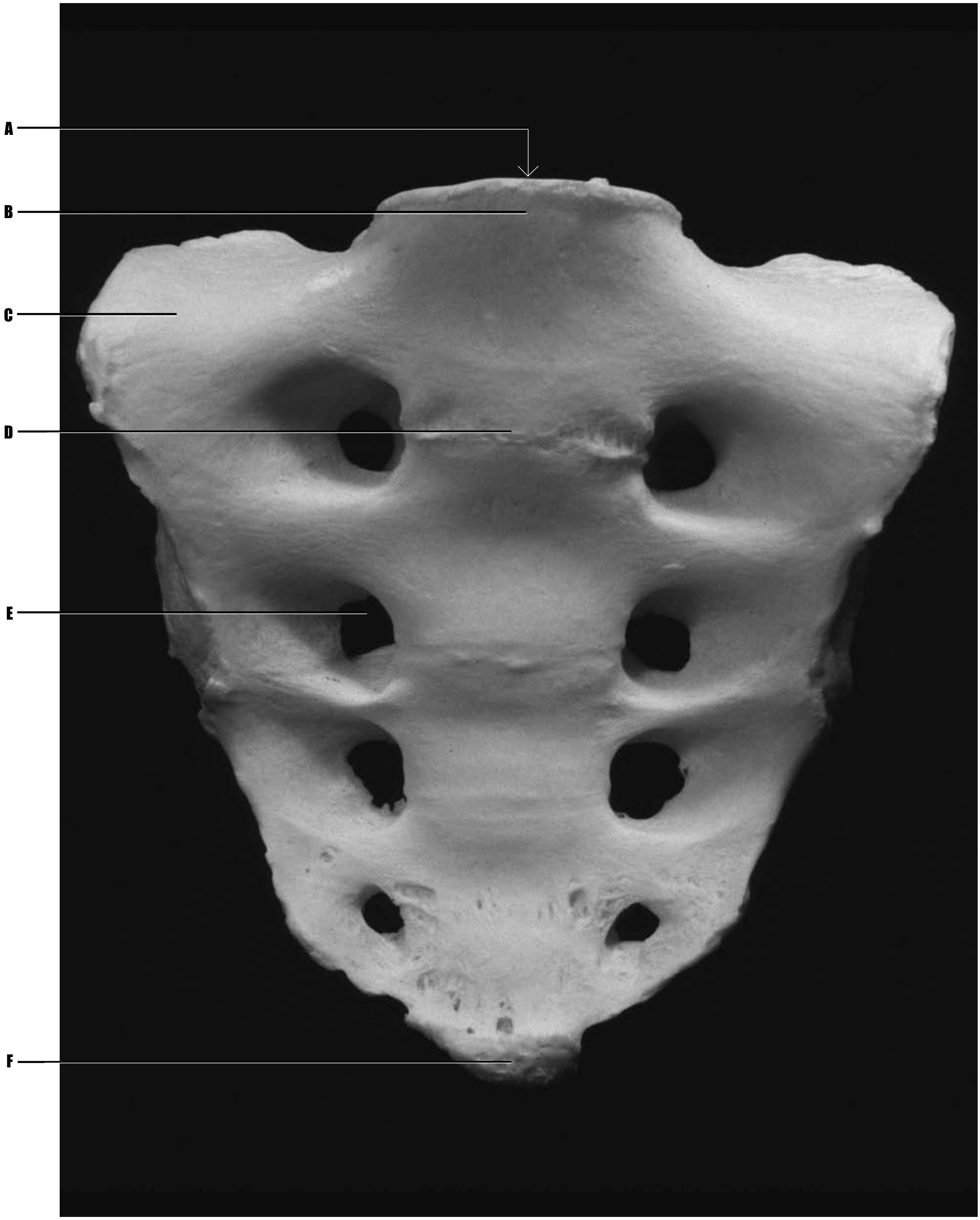


Image 3.90
Sacrum, anterior view.

Image 3.90

A - articular surface for L5

B - promontory

C - ala or wing

D - transverse ridge

E - ventral sacral foramen

F - articular surface for coccyx

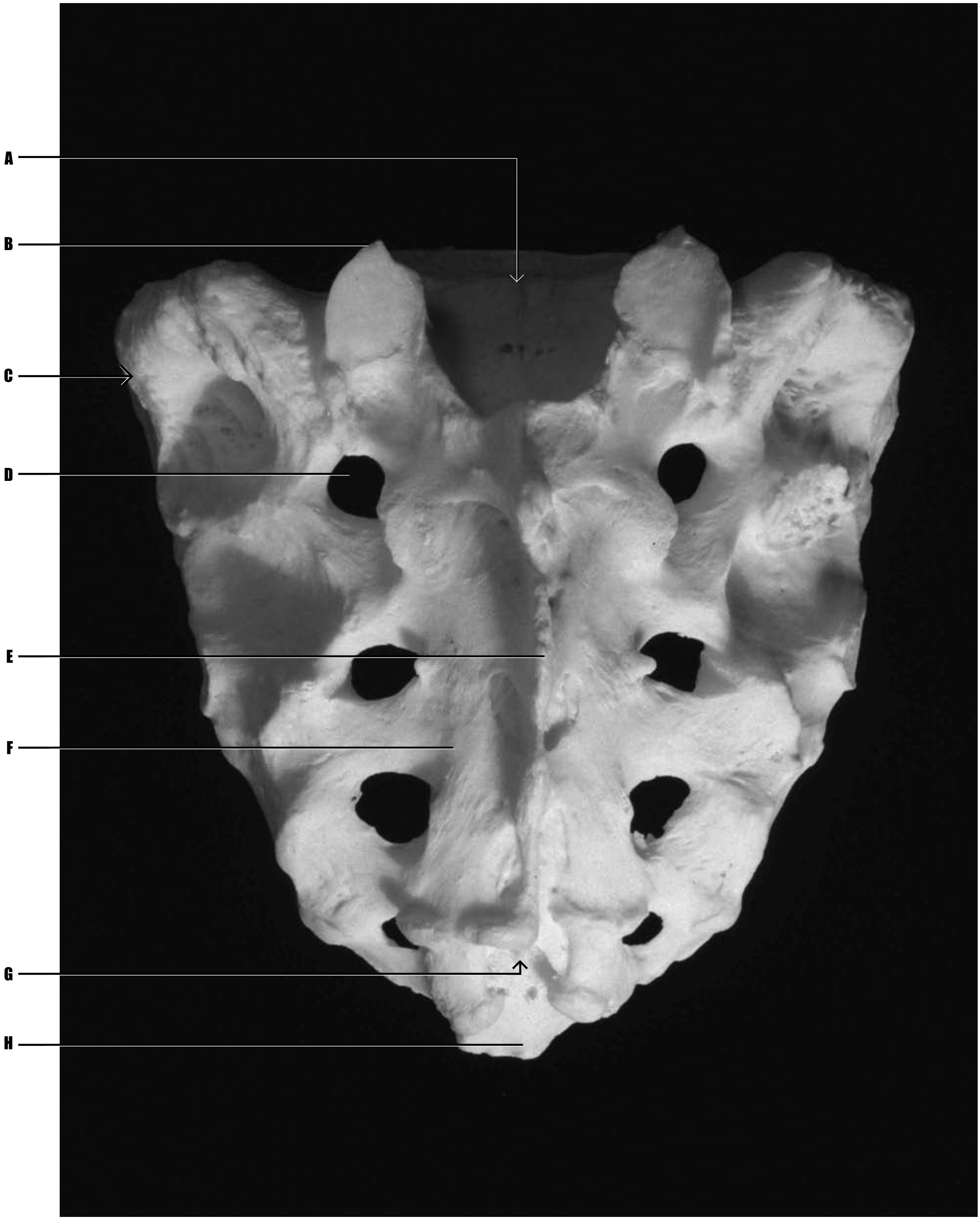
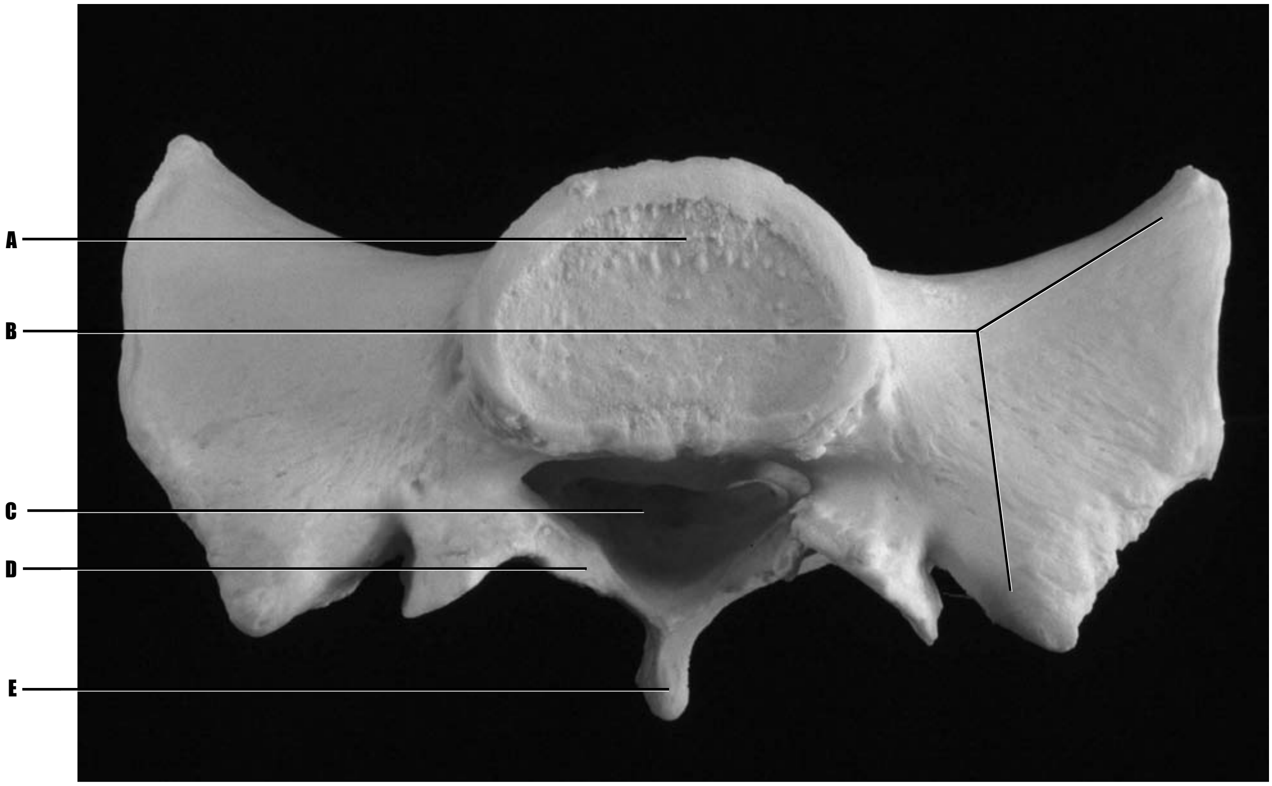


Image 3.91
Sacrum, posterior view.

Image 3.91

A - vertebral canal
B - superior articular facet
C - auricular surface
D - dorsal sacral foramen
E - medial sacral crest
F - intermediate sacral crest
G - sacral hiatus
H - articular surface for coccyx



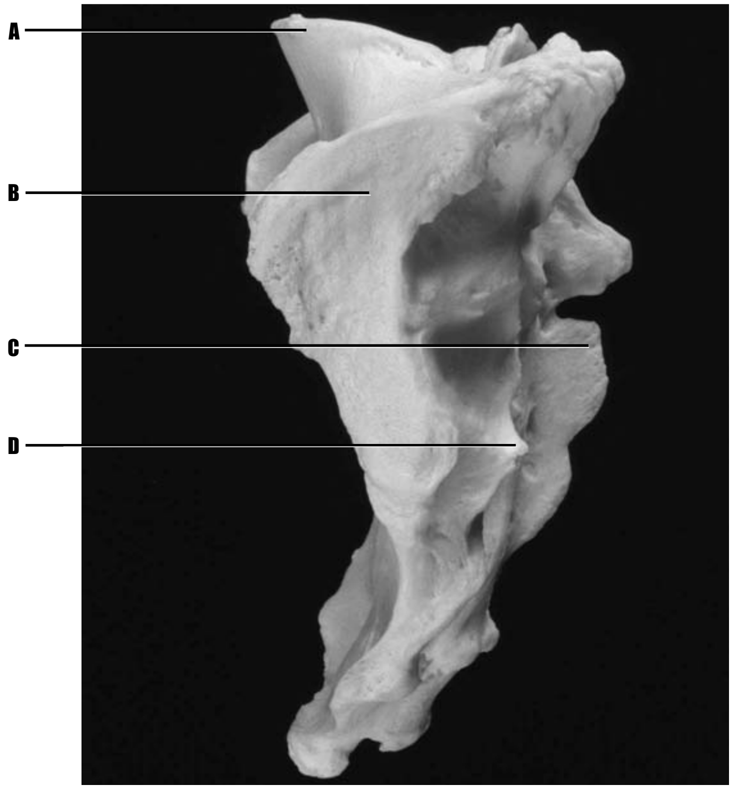


Image 3.92 (above)
Sacrum, superior view.
Image 3.93 (below)
Sacrum, left lateral view.

Image 3.92

A - articular surface for L5
B - ala of sacrum
C - sacral canal
D - lamina
E - spinous process (medial sacral crest)

Image 3.93

A - promontory
B - auricular surface (for ilium)
C - medial sacral crest
D - intermediate sacral crest

3.13 COCCYX

Image 3.94 • *Coccyx, anterior view.*

- this small collection of bones is our vestigial tail
- its function is to provide an anchor point for various muscles and ligaments of the pelvis
- is generally formed by three to five rudimentary vertebrae
- the base is formed by the upper surface of the first coccygeal vertebra with an articular surface that joins the apex of the sacrum
- the coccygeal cornua articulate with the sacral cornua
- articulates superiorly with the inferior aspect of the sacrum, as well as the coccygeal cornua (superiorly projecting tubercles)
- with the exception of the first coccygeal vertebra, the coccygeal verterbae fuse with each other by adulthood

Landmarks

- base
- apex
- transverse process
- fused coccygeal vertebrae
- coccygeal cornu

Looking at Fragments

- isolated coccygeal vertebrae are often mistaken for hyoid fragments
- often, the first coccygeal vertebra articulates with fused inferior coccygeal vertebrae
- the first coccygeal vertebra may also be fused with the inferiormost part of the sacrum

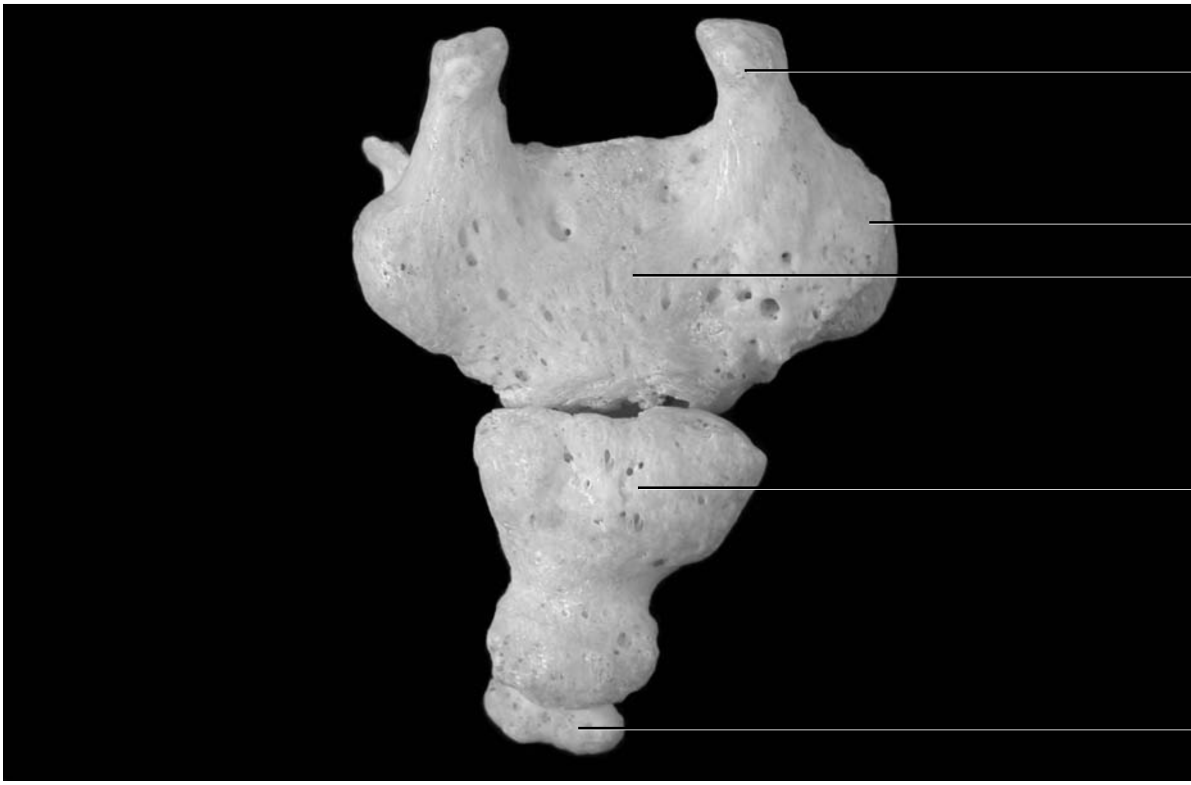


Image 3.95
Coccyx, anterior view.
Image 3.96
Coccyx, posterior view.
A - coccygeal cornu, **B** - transverse process, **C** - body, **D** - fused coccygeal vertebrae, **E** - apex.

Chapter Four

The Sternum and Ribs

Although their anatomy is relatively simple, the sternum and ribs play multiple vital roles. These include protection of the thoracic viscera (heart, lungs and associated structures), assistance in respiration, and blood cell production.

The sternum is actually comprised of three individual parts that unite as one ages. The *manubrium* is a roughly triangular bone found superior to the *body (gladiolus)*. The body is superior to the smallest portion, the *xiphoid process*. The ribs can be classified in several ways – one of which describes if or how a rib articulates with the sternum. True ribs articulate directly with the sternum via their respective costal cartilages (ribs 1-7), while false ribs articulate indirectly via the costal cartilage of rib 7 (8-10). Floating ribs (11, 12), do not attach to the sternum or the seventh rib and both their bony and cartilaginous portions appear to 'float' within the tissues of the body wall.

Ribs can also be classified as *typical* or *atypical*. Typical ribs have relatively uniform shapes with identical anatomical structures (see discussion, page 231). The atypical ribs are deemed as such because of the variation in their overall shapes or identifying landmarks.

4.1 STERNUM

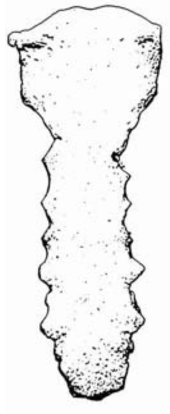


Image 4.1 • *Sternum, anterior view.*

- also known as the "breast bone"
- unpaired flat plate of bone in the midline of the chest
- serves as a point of attachment for the ribs and clavicles
- has a slightly concave posterior surface and relatively flat anterior surface
- it is composed of three separate segments that fuse together throughout life: manubrium, body (gladiolus), and xiphoid process
- the manubrium is a broad and relatively thick portion of bone with an irregular shape
  - the inferiormost portion, the sternal angle (of Louis), can be palpated in life as the bony landmark near the top of the breastbone where the manubrium meets the sternal body
  - clinically, this is a landmark for the location of the second costal cartilage
- the body is a narrow and relatively thin piece of bone that forms from four sternebrae in early life
  - it has many costal notches for articulation with the ribs
  - a sternal foramen may be present in the lower third of the bone
- the xiphoid process is a small, inferior bony tip that ossifies to the gladiolus in late life
  - it can have a bizarre shape, and may possess facets for articulation with the seventh costal cartilages

Landmarks

- suprasternal (jugular) notch
- clavicular notch
- manubrium
- sternal angle (angle of Louis)
- body
- individual costal notches
- xiphisternal junction
- xiphoid process

Looking at Fragments

- it has an extremely low density – this helps to separate it from other more dense bones
- the anterior surface of the manubrium is flatter or even subtly convex, when compared with the slightly concave posterior portion
- the anterior surface of the sternal body is generally flatter than the subtly convex posterior surface
  - the anterior surface is typically smoother than the posterior side
  - any fragment of bone that contains a row of concave depressions could be a section of sternal body
- a small fragment of bone with a bizarre shape could be part of the xiphoid process
  - look for a smooth (posterior) surface, and the possible presence of articular facets (for the seventh costal cartilages)
- be sure to study an unfused sternum from a younger individual so that you can identify the manubrium, body and xiphoid individually

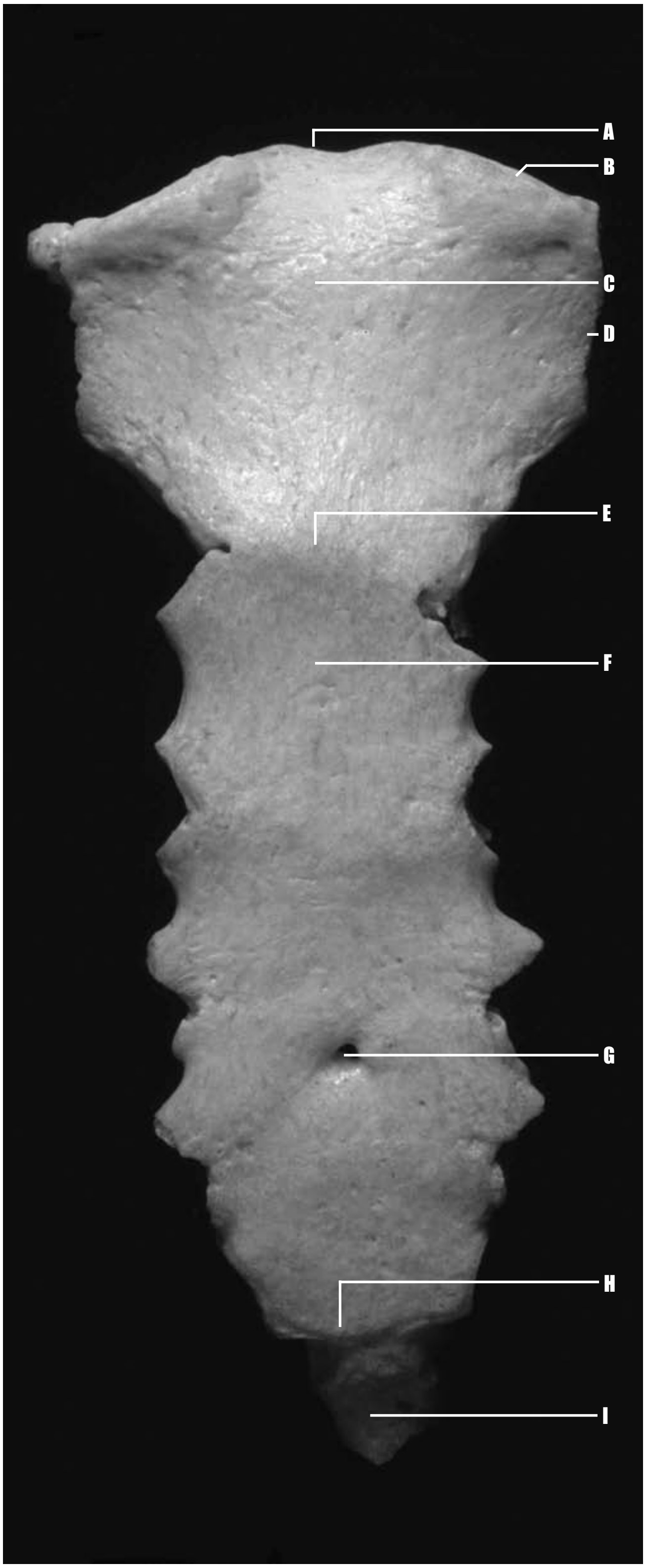


Image 4.2
Sternum, anterior view.

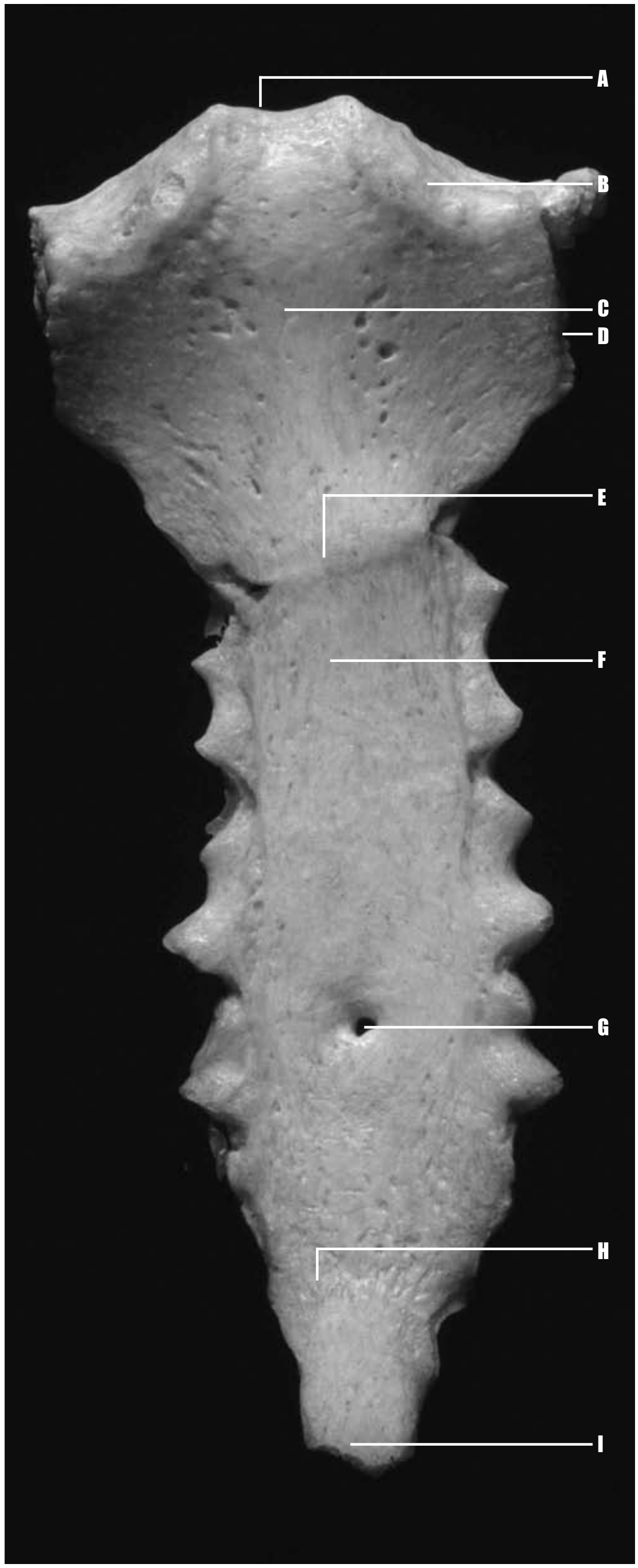


Image 4.3
Sternum, posterior view.

A - suprasternal (jugular) notch; **B** - clavicular notch; **C** - manubrium; **D** - first costal notch; **E** - manubriosternal joint; **F** - body (gladiolus); **G** - sternal foramen (inconstant); **H** - xiphisternal junction; **I** - xiphoid process.

4.2 RIBS

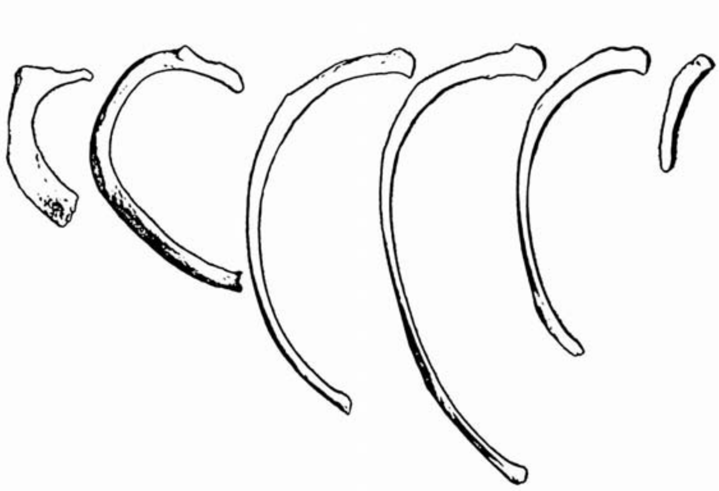


Image 4.4 • *Ribs: first, second, typicals, eleventh and twelfth (left to right).*

- there are twelve ribs on each side of the body
- these obliquely oriented, curved bones are of two main types: true and false
  - <u>true</u> ribs articulate directly to the sternum via costal cartilage (ribs (R) 1-7)
  - <u>false</u> ribs articulate indirectly with the sternum via the costal cartilage of the seventh rib (R 8-10); or they may not articulate with the sternum at all (R 11-12)
- the ribs can be further subdivided into typical and special
- typical ribs are said to have a head (with two articulating demifacets for the superior and inferior demifacets of its two articulating vertebrae), a neck (interposed between the head and tubercle), a tubercle (for articulation with the transverse process of the rib's articulating vertebra), a body, angle, and sternal end
  - the typical ribs are considered to be ribs three through nine
- special ribs (R 1, 2, 10-12) have special identifying features
  - R1
    - is a flat, broad, harshly angled rib
    - has a smooth inferior surface, but roughened superior surface due to the attachment of a prominent muscle (anterior scalene) and grooves formed by the presence of the subclavian artery and vein
    - there is no costal groove on the inferior surface of this rib
    - has a small head that bears only one articular facet
  - R2
    - is somewhat intermediate between atypical R1 and typical R3
    - it has the *typical* rib structures, but it is somewhat wider than the average rib and has a more acute angle
    - instead of having a prominent tubercle for muscle attachment, it has a roughened tuberosity on the lateral aspect of the angle for the serratus anterior muscle
  - R10
    - is essentially a typical rib except that the head has only one articular facet (recall that the T10 vertebra has one complete articular facet on its body and NOT two demifacets)
  - R11
    - has only a single articular surface on its head
    - does not have a tubercle (recall that the T11 has no articular facet on its transverse processes; it is the tubercle which articulates with the transverse process facet)
    - the angle of the shaft is less prominent than preceding ribs
    - there is only a shallow costal groove on the inferior surface
    - there is no neck
  - R12
    - has only a single articular surface on its head
    - no neck
    - no tubercle
    - no angle
    - no costal groove
    - extremely short

Landmarks

- *where applicable*
  - head
  - neck
  - tubercle
  - angle
  - body (shaft)
  - sternal end
  - costal groove

Determining Right from Left

- hold the body of the rib with the superior surface facing upwards (toward the ceiling), the inferior surface down (toward the floor), the rib head toward you, and the sternal facet away from you
  - the rib has now sided itself as it is positioned as if it was in your own body
  - if you are still unsure, the head and sternal facet will both be pointing toward the opposite side as that to which the rib belongs
- to "side" individual ribs, use the information presented on page 222

Looking at Fragments

- rib fragments may be frustrating to identify
- begin by determining whether or not you have a proximal fragment, a portion of shaft, or the distal costal end (for articulation with the sternum)
- there is an increase in rib length from ribs one through seven, and then a gradual decrease until the twelfth rib, which may be quite short
- the superior surface of each rib is typically round and smooth
- the inferior surface of each rib is less smooth due to the presence of a costal groove, which houses the neurovascular bundle
- using your knowledge of rib curvature and the costal groove (see **Images 4.5** and **4.6** below), attempt to side the fragments
- if the ribs have been heavily fragmented and there are segments you are unable to side with anatomical knowledge, you may simply need to "treat the fragments like a huge puzzle," and try to fit everything together
  - if this does not further your goal, you may simply need to create a pile of *undifferentiated rib fragments*

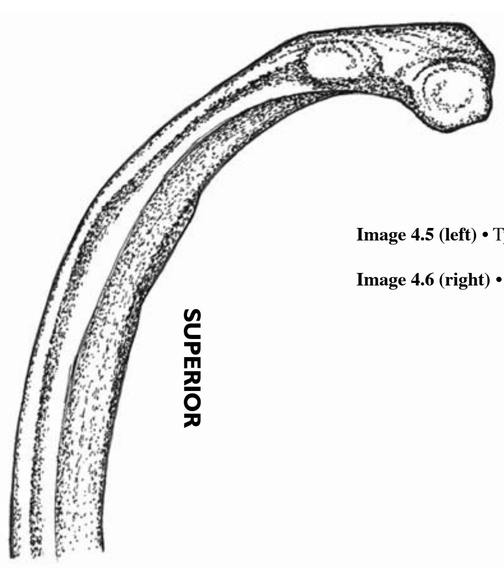
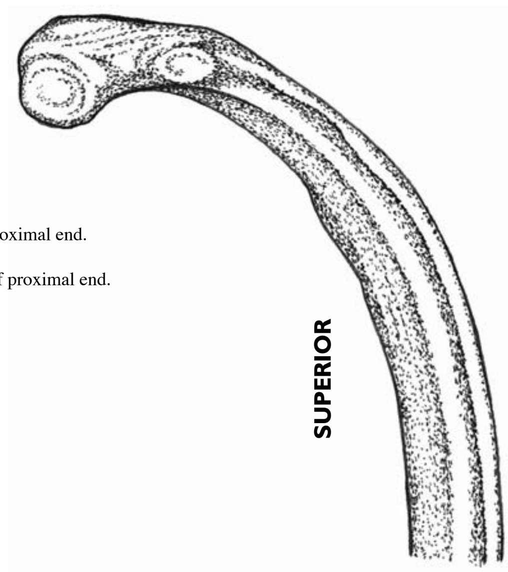


Image 4.5 (left) • Typical rib, left, medial view of proximal end.

Image 4.6 (right) • Typical rib, right, medial view of proximal end.



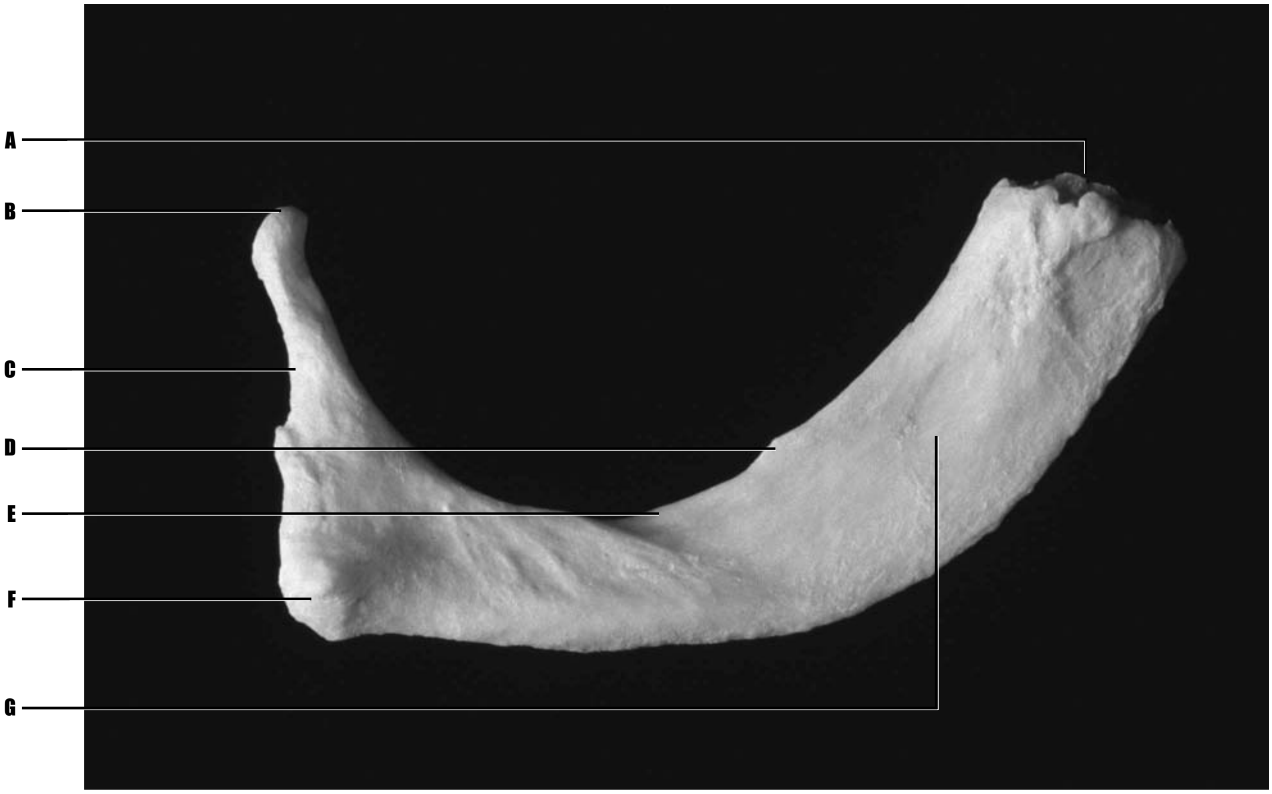


Image 4.7 (above)
First rib, superior view.
Image 4.8 (below)
First rib, inferior view.

Image 4.7

A - surface for costal cartilage
B - head
C - neck
D - scalene tubercle
E - groove for subclavian artery
F - tubercle
G - groove for subclavian vein

Image 4.8

A - tubercle
B - body
C - neck
D - articular surface of head
E - surface for costal cartilage

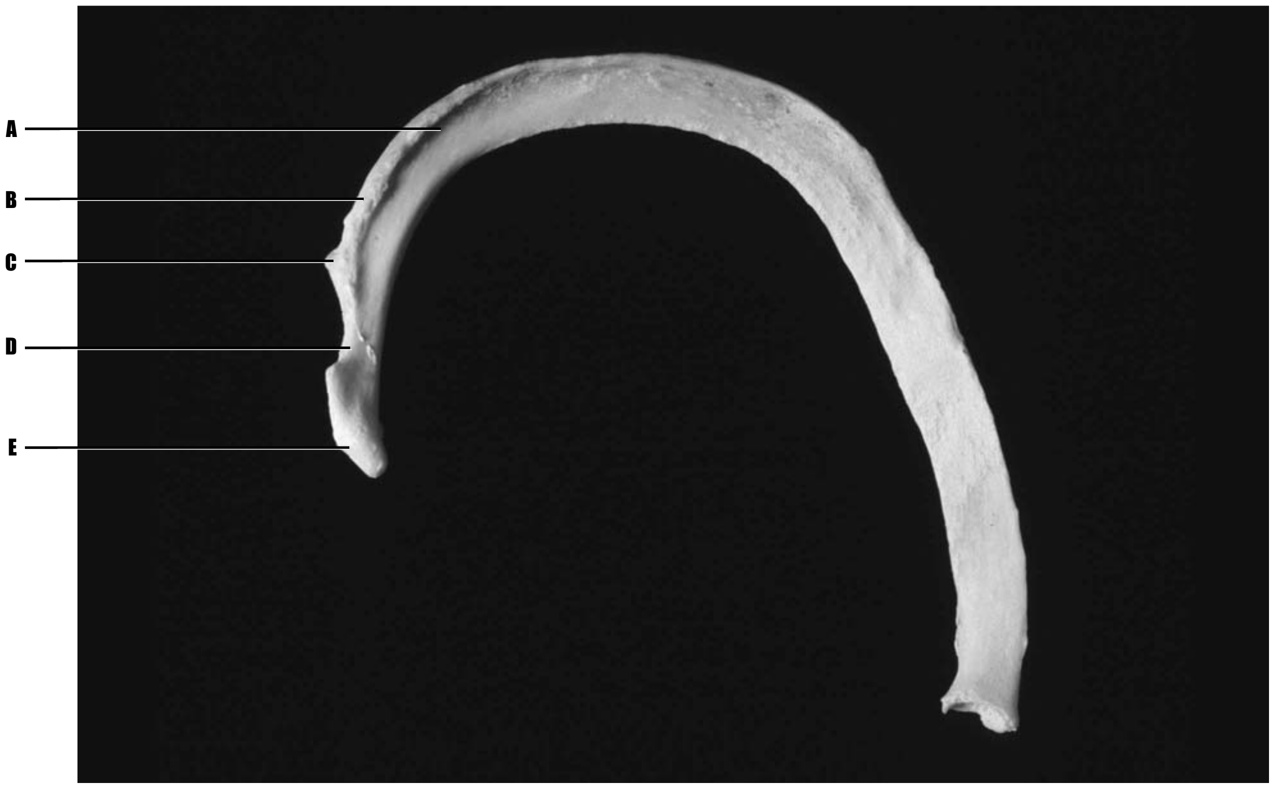


Image 4.9
Second rib, superior view.
Image 4.10
Second rib, inferior view.

Image 4.9

A - head
B - neck
C - tubercle
D - tuberosity for serratus anterior
E - angle

Image 4.10

A - subcostal groove
B - non-articular part of tubercle
C - articular part of tubercle
D - neck
E - articular surface of head

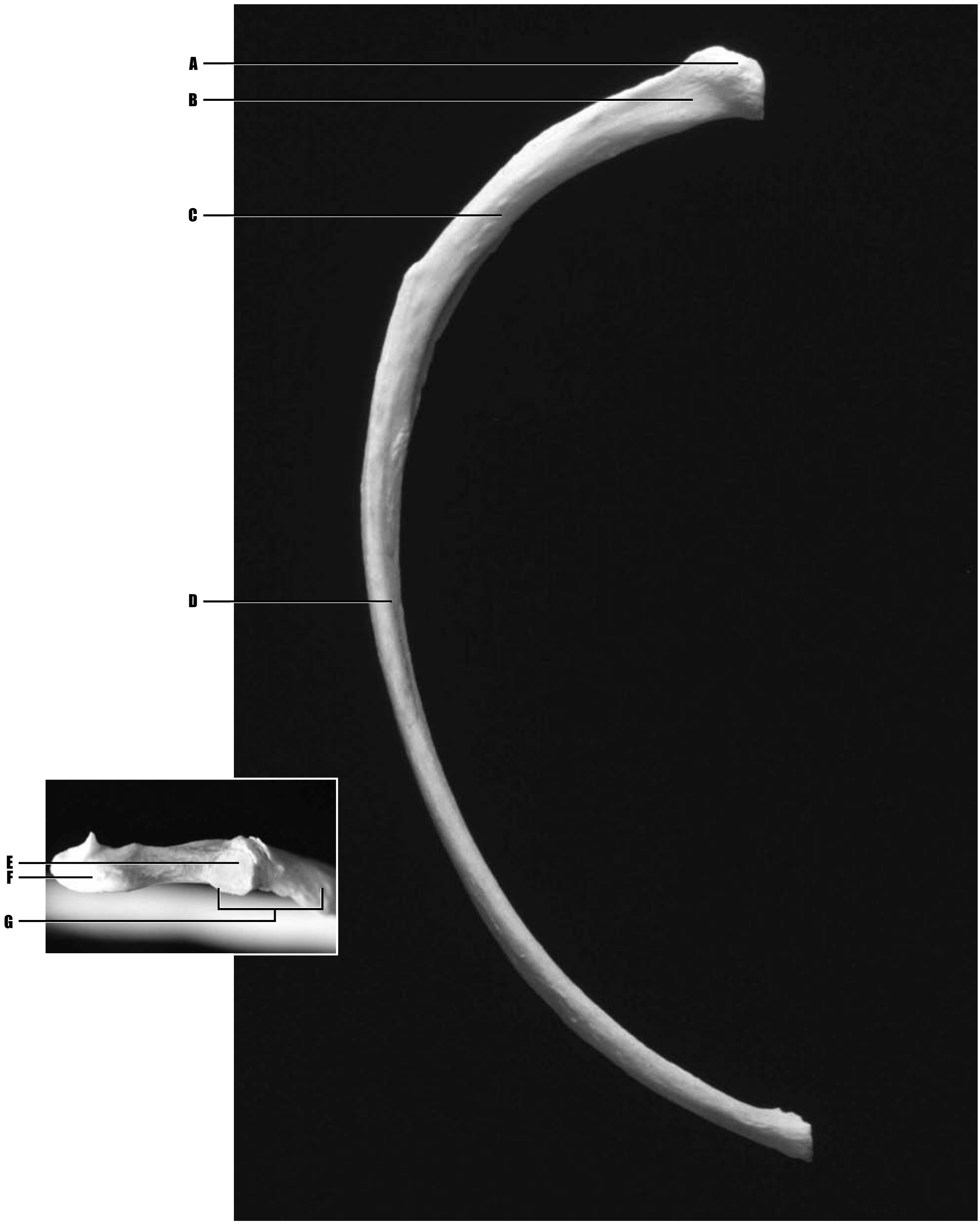


Image 4.11
Fifth rib, superior view. This is an example of a *typical* rib. The inset photograph is of the rib head (proximal end).

Image 4.11

A - head
B - neck
C - angle
D - body
E - facet for articulation with vertebral transverse process
F - articular surface of head
G - tubercle

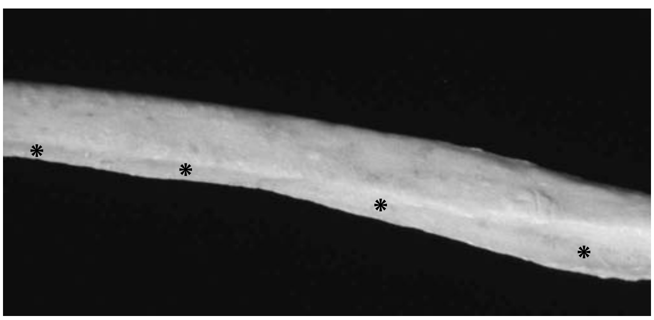


Image 4.12
Medial surface of typical rib demonstrating costal groove for subcostal vein, artery and nerve.

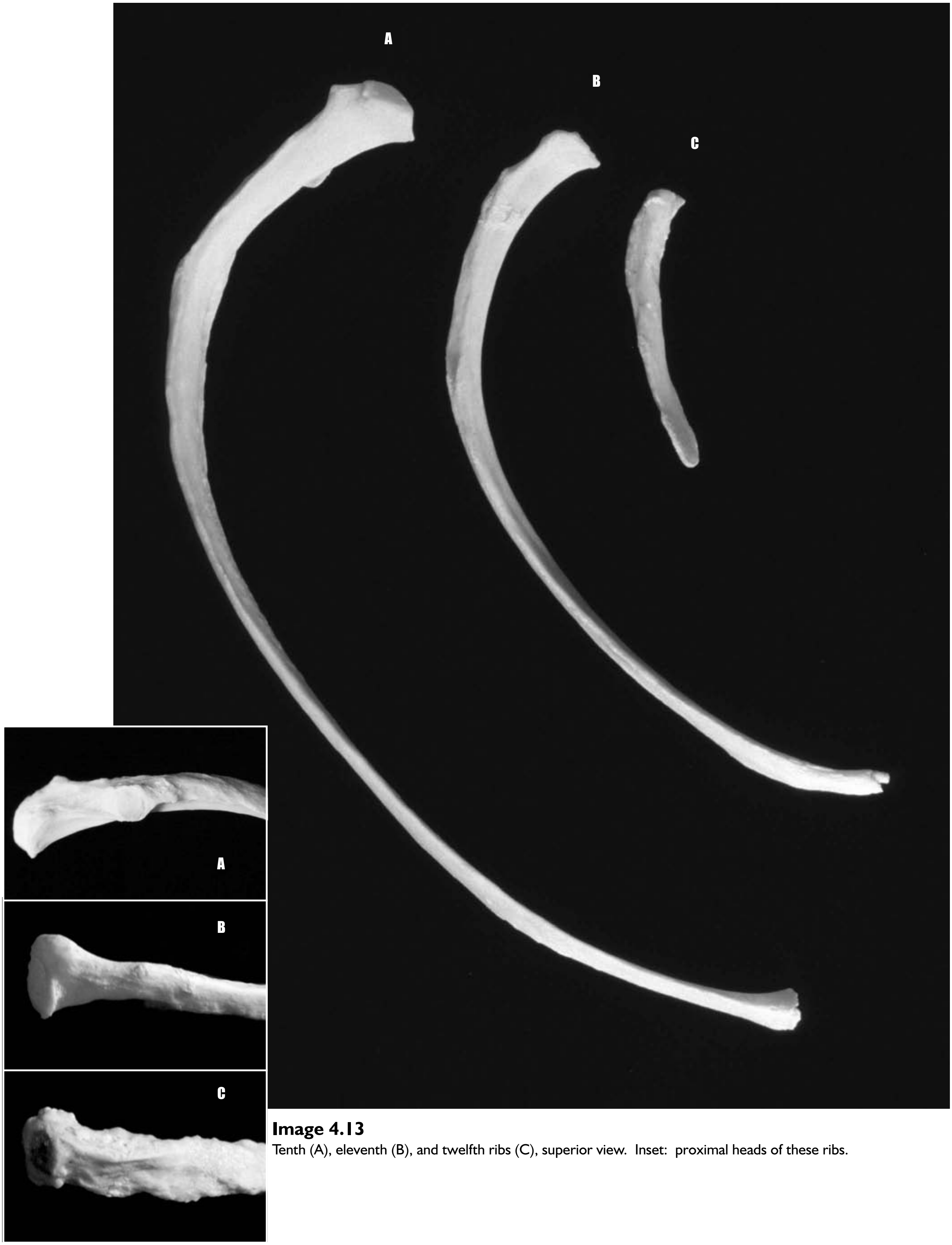


Image 4.13
Tenth (A), eleventh (B), and twelfth ribs (C), superior view. Inset: proximal heads of these ribs.

The Anatomy of a Rib

If one were to examine the anatomy of a typical rib, such as that in **Image 4.11**, he or she would find a head posteriorly, a depression or surface for reception of the costal cartilage anteriorly, and an intervening shaft which bends obliquely along its course. The inferomedial surface of this shaft bears a groove, the costal groove (see **Image 4.12**), along which runs a *neurovascular bundle* that consists of a vein, artery and nerve that supply the anterior and lateral walls of the trunk. The proximal part of the rib bears a head, neck and tubercle. The head has upper and lower articulating demifacets which are separated by a transverse crest. Think back to our discussion of typical thoracic vertebrae (page 172). Recall that typical thoracic vertebral bodies have superior and inferior demifacets. These are for articulation with the demifacets on the head of the ribs. The neck of the ribs is a flattened portion between the head and the tubercle and it lies in front of the transverse process of its corresponding vertebra. The tubercle can be divided into a medial articular portion and a lateral non-articular portion. It is this tubercle which articulates with the transverse processes of the vertebrae.

There is a great deal of variation amongst the atypical ribs. The **first rib** is the most curved, may be the broadest, and has an angle that allows it to sit flat on a table. It has a very prominent tubercle, and a head with a single articular facet - recall, it articulates only with the complete articular facet on the body of the first thoracic vertebra. The scalene tubercle can be found on the superior surface of this rib, and is the site of attachment of the anterior scalene muscle. Grooves for the subclavian artery and vein can be found on either side of this landmark. There is no costal groove on the underside of the first rib. An examination of the **second rib** reveals it to be a thinner and longer version of the first. It differs in that it has a costal groove, and lacks a scalene tubercle and subclavian grooves. The **tenth**, **eleventh** and **twelfth ribs** have only a single articular facet on their heads, and they lack both necks and tubercles. This is important because the tenth through twelfth thoracic vertebrae do not have articular facets on their transverse processes (hence, no necks or tubercles on the ribs), and these vertebrae articulate only with their own ribs (and therefore, the ribs need only one articular facet on their heads). Additionally, the shape of the sternal end of the rib changes from oval to circular with progression to T1 inferiorly.

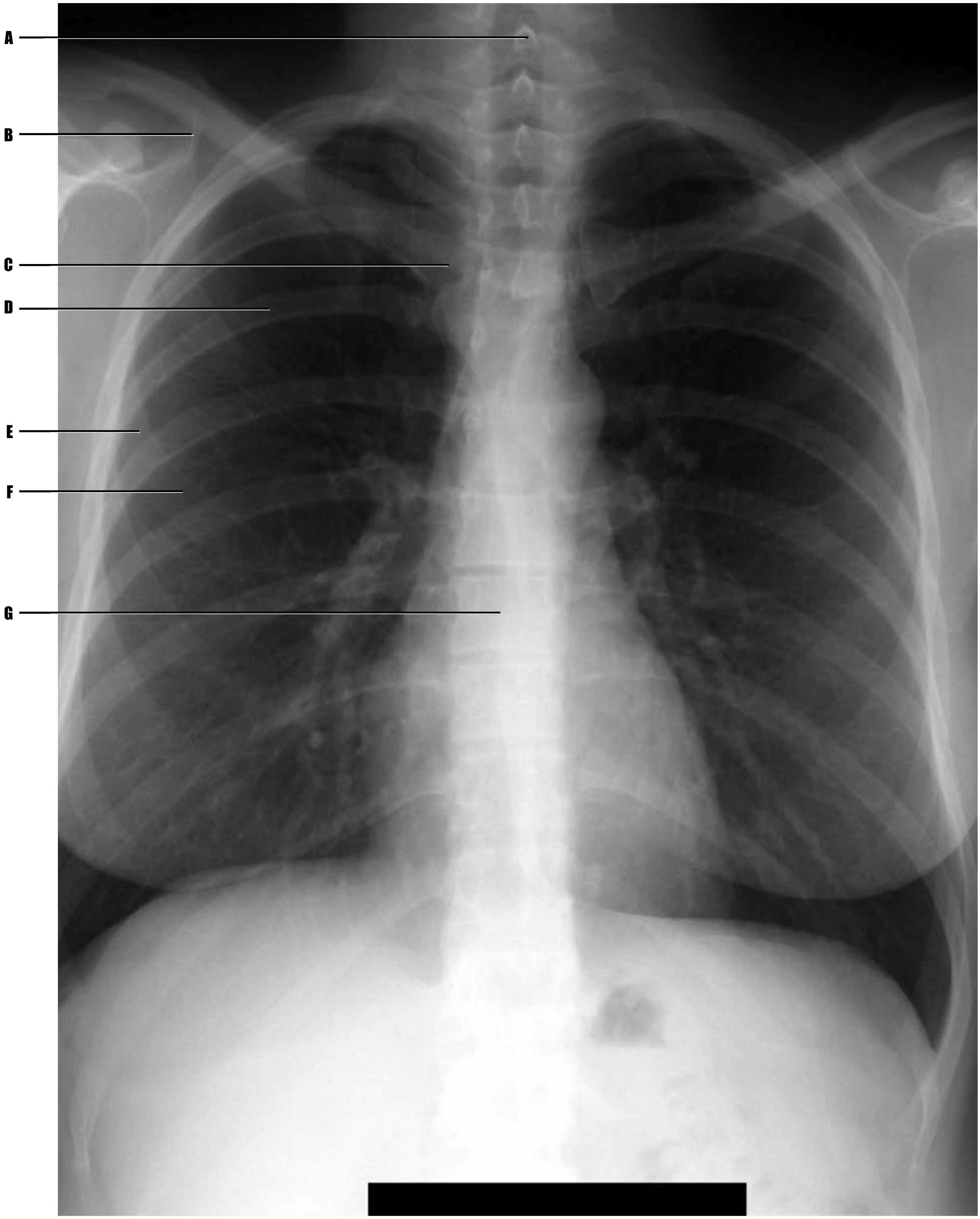


Image 4.14
Adult patient, plain film radiograph, posteroanterior view of chest.

Image 4.14

A - spinous process of T1
B - spine of scapula
C - medial end of clavicle
D - posterior segment of rib
E - lateral segment of rib
F - anterior segment of rib
G - vertebral body

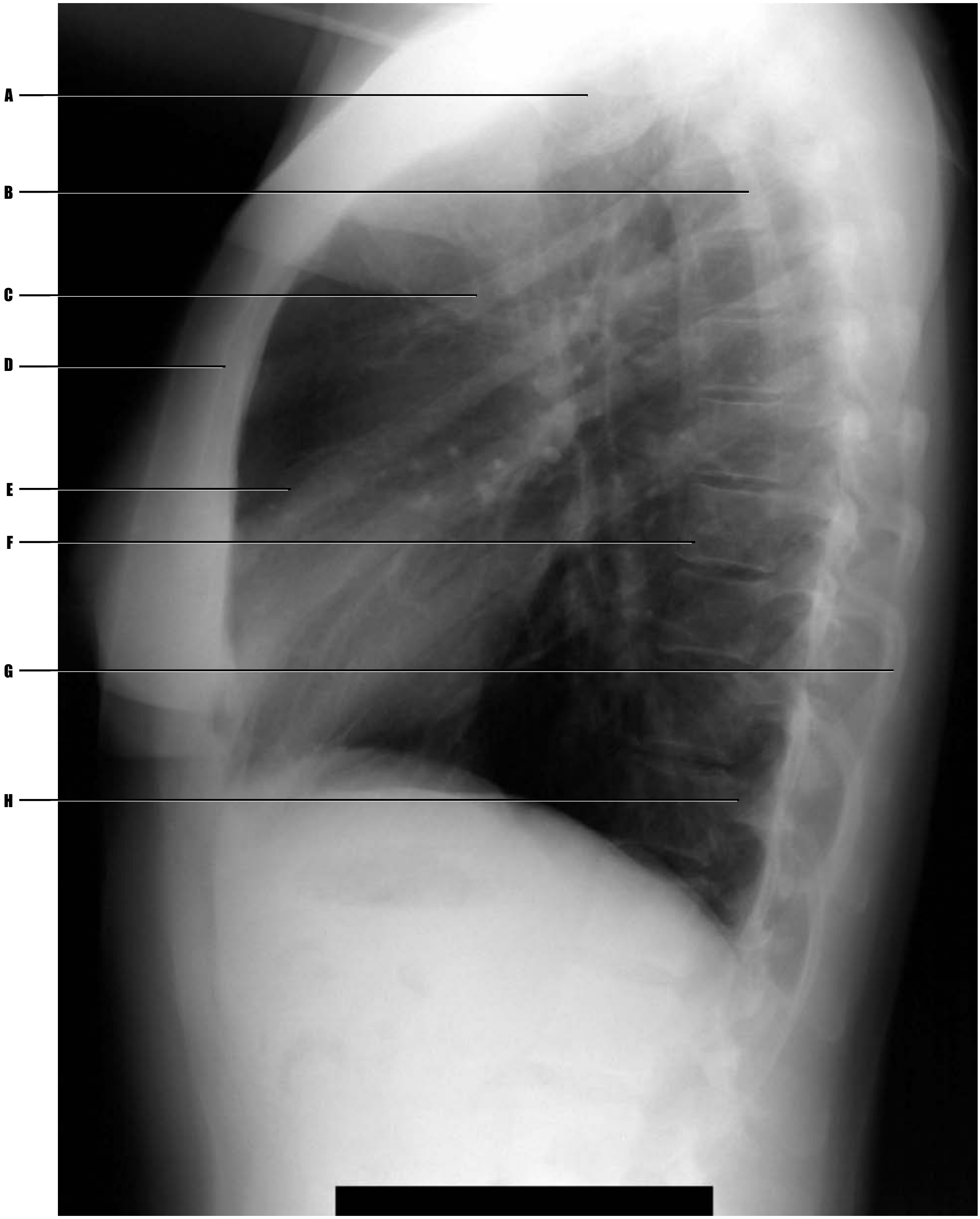


Image 4.15
Adult patient, plain film radiograph, lateral view of chest.

Image 4.15

A - head of humerus
B - body of scapula
C - lateral segment of rib
D - sternum
E - anterior segment of rib
F - vertebral body
G - posterior segment of rib
H - pedicle (of mid-thoracic vertebra)

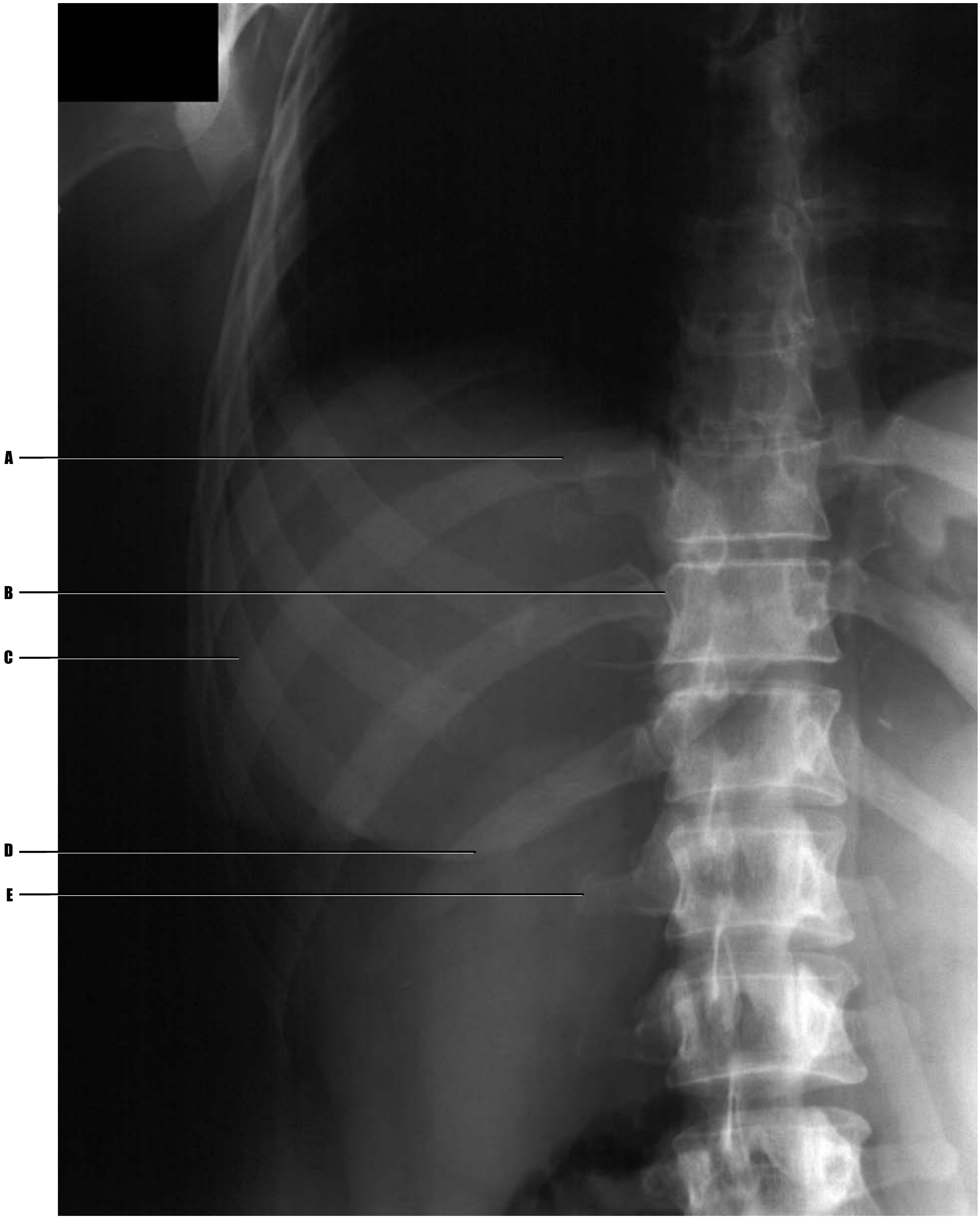


Image 4.16
Adult patient, plain film radiograph, "rib view" of posteroanterior right chest.

Image 4.16

A - posterior segment of rib

B - costovertebral joint

C - anterior segment of rib

D - twelfth rib

E - transverse process of vertebra

Unit Two:
The Appendicular Skeleton

The appendicular skeleton is comprised of those elements that make up the limbs and their supporting bases. To the students' dismay, there are a great many bones constituting the wrists, hands and feet. Understanding their relationships in standard anatomical position is important for clinical practice. Having a notion of their individual properties is important for surgery, or for those encountering individual bones, such as when examining isolated skeletal remains.

Chapter Five

The Shoulder and Upper Limb

The shoulder (pectoral) girdle is the portion of the skeleton that acts as the point of connection between the arms and the thorax. It consists of the scapula and clavicle. Medially, the clavicle articulates with the sternum; laterally, with the acromion of the scapula. The humeral head articulates with the scapula at the glenoid fossa. The glenoid fossa is shallow, allowing a great range of motion.

5.1 CLAVICLE

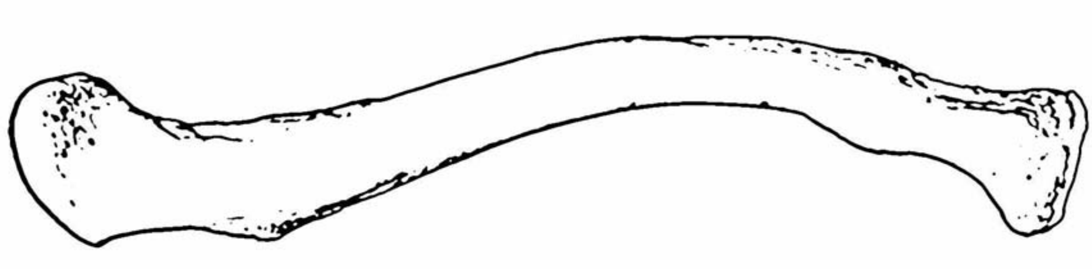


Image 5.1 • *Left clavicle, superior view.*

- also known as the *collar bone*
- has a subtle "S"-like double curvature
- has a more robust and squarish medial end that articulates with the manubrium of the sternum
- has a flatter lateral end for articulation with the acromion of the scapula
- the superior surface of the clavicle is much smoother than the rougher inferior surface which is studded with the conoid process, subclavius muscle groove and costoclavicular groove

FUNCTION

The clavicle provides support to the shoulder and keeps the arm held in a lateral position. People with a congenital or surgical absence of the clavicle tend to have a more medially and anteriorly displaced arm.

Image 5.2 • Surface Anatomy • Shoulder in oblique anterior plane. * Marks clavicle.

Landmarks

- sternal (medial) end
- acromial (lateral) end
- deltoid tubercle
- conoid tubercle
- trapezoid line
- groove for the subclavius muscle
- tuberosity/groove for the costoclavicular ligament

Differentiating Right from Left

- hold the body/shaft of the clavicle as if it were a pencil (between your thumb and index/third fingers; see **Images 5.3** and **5.4**).
- the smooth superior surface must be directed upwards
- the bulbous sternal end is medial; the flatter acromial end is lateral
- toward the medial end of the bone, the shaft has a convexity directed in the anterior plane
- you now have the bone held in proper anatomical position and the acromial end now points to the same side as that to which the bone belongs

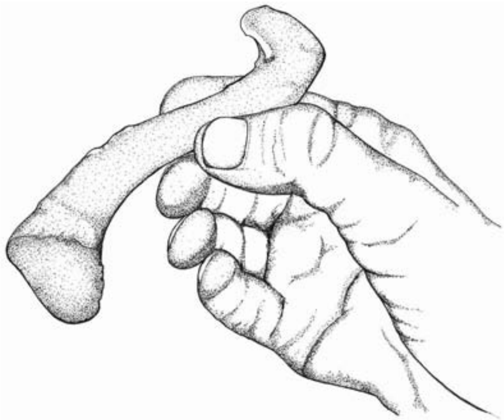


Image 5.3 • Right clavicle.

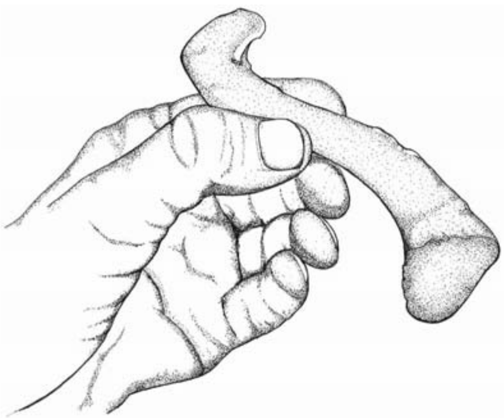
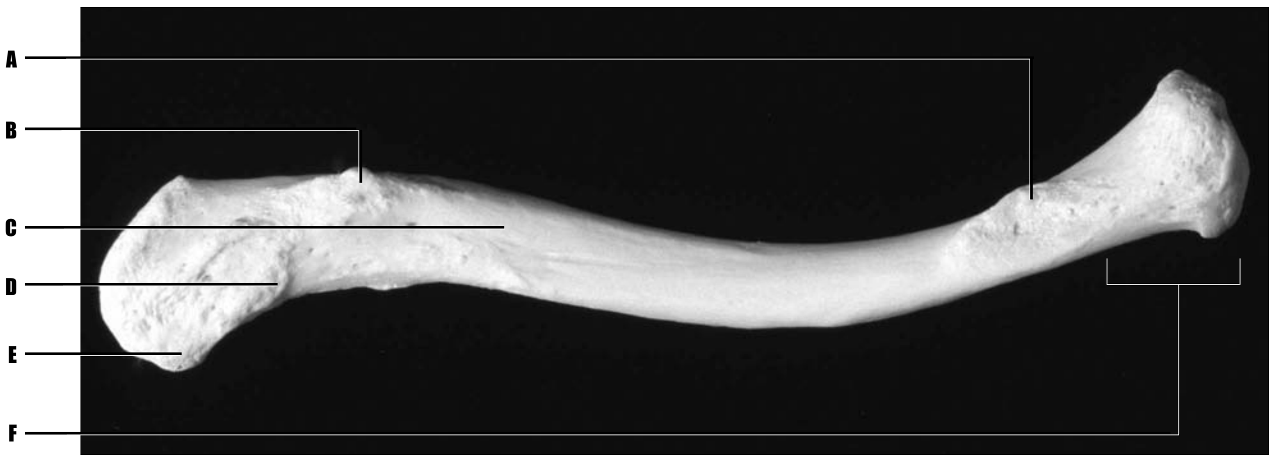


Image 5.4 • Left clavicle.

Looking at Fragments

- the clavicle is a long bone, just like the humerus or femur, but has a relatively thin shaft akin to the radius, ulna and possibly the fibula
- if presented with fragments of clavicle, keep in mind:
  - the clavicle is a relatively flat bone from the lateral acromial end until the midline where there is a gradual shift in cross-sectional morphology as the bone becomes increasingly round toward the sternal end
- some people have confused the rough, flat acromial end with fragments of acromion (of scapula), as well as fragments of ischial ramus (of the pelvis)



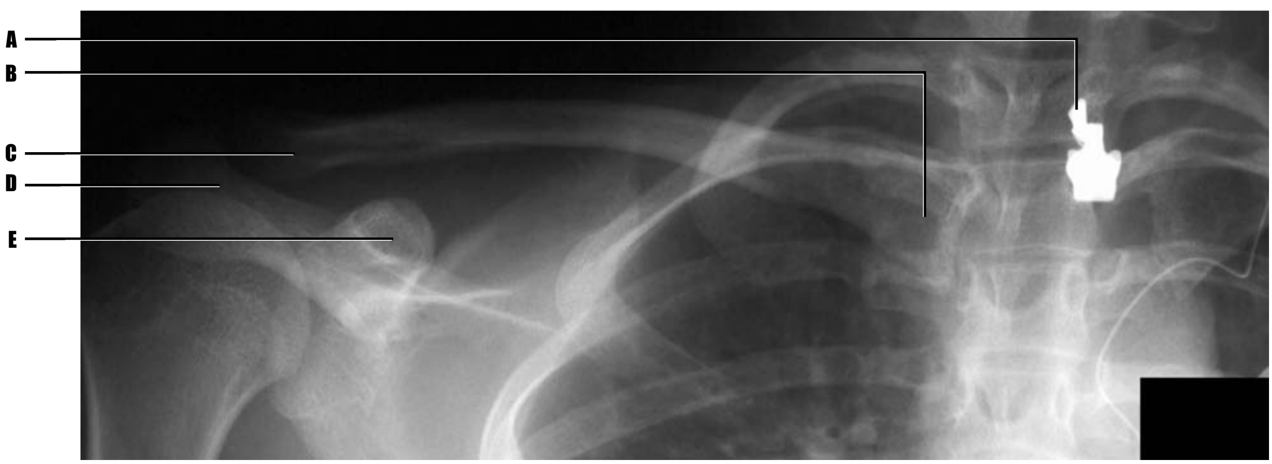


Image 5.5 (above)

Clavicle, left, superior view.

Image 5.6 (middle)

Clavicle, left, inferior view.

Image 5.7 (below)

Adult patient, plain film radiograph, posteroanterior view of right chest.

Image 5.5

A - sternal (medial) end
B - deltoid tuberosity
C - acromial (lateral) end
D - conoid tubercle

Image 5.6

A - tuberosity/groove for costoclavicular ligament
B - conoid tubercle
C - groove for subclavius muscle
D - trapezoid line
E - lateral (acromial) end
F - medial (sternal) end

Image 5.7

A - medical device
B - sternal end
C - acromial end
D - acromion of scapula
E - coracoid process of scapula

5.2 SCAPULA

Image 5.8 • *Left scapula, anterior view.*

- is part of the shoulder girdle
- is found on the upper back where the concave anterior surface rests against the posterior chest wall
- has a roughly triangular body with an overall irregular appearance
- has a smooth lateral cuplike surface that articulates with the head of the humerus at the shoulder (glenohumeral) joint
- has a large, flat, medially arching process (the acromion) which articulates with the lateral end of the clavicle at the acromioclavicular joint

FUNCTION

The scapula is a major site for muscle attachment in the upper extremity and shoulder girdle. As a result, it plays a major role in supporting shoulder movement.

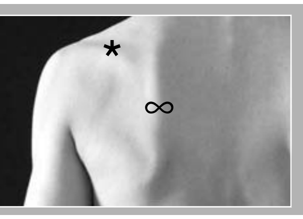


Image 5.9 • Surface Anatomy • Posterior aspect of left shoulder. ∞ Marks medial border; * marks spine.

Landmarks

- superior angle
- supraspinous fossa
- suprascapular notch
- conoid tubercle
- coracoid process
- acromion
- spine
- glenoid fossa
- glenoid tubercle
- infraspinous fossa
- lateral scapular border
- medial scapular border
- inferior angle
- articular facet for the clavicle (on the acromion)
- neck of scapula
- subscapular fossa
- supraglenoid tubercle
- infraglenoid tubercle

Differentiating Right from Left

- with an intact bone, this is an easy task (see **Images 5.10 and 5.11**)
- with the concave anterior surface away from you, and the inferior scapular angle pointing toward the floor, the glenoid fossa is now pointing toward the same side as that to which the bone belongs

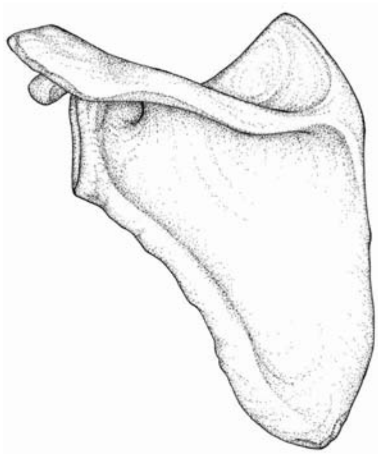


Image 5.10 • *Left Scapula.*

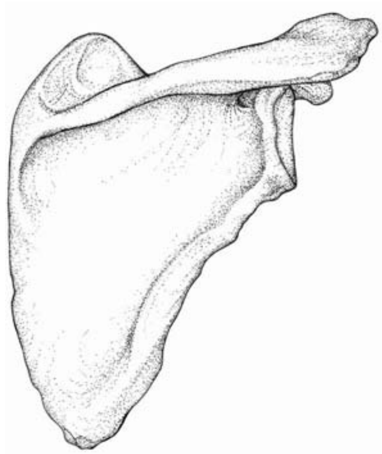


Image 5.11 • *Right Scapula.*

Looking at Fragments

- scapular body might be confused with fragments of thin iliac wing, but scapula is usually less smooth that the ilium
- the scapular spine and acromion may resemble fragments of ischium, but pelvic bones are typically much more robust than scapula
- fragments of glenoid fossa could be confused with acetabulum, supraorbital margin, or the orbital surface of zygomatic bone
  - however, the glenoid fossa is typically much flatter than the markedly concave acetabulum and orbit
- might also be confused with cranial bone fragments, but, the cranium is usually much thicker, on cross section has diploë (see **Image 5.12** below), and has suture lines (in younger specimens)
- could resemble orbital shelf, but the scapular body is much less corrugated than the orbital shelf region of the frontal bone
- use the following anatomical features to assist you in identifying scapular fragments:
  - the acromion projects posteriorly and then anteriorly at its most lateral aspect
  - the scapular spine progresses posteriorly and laterally from the medial edge
  - the coracoid process is an anteriorly projecting landmark
  - the supraglenoid notch can vary widely in appearance
  - the suprascapular ligament can ossify to produce a complete foramen at the site of the supraglenoid notch
  - the body of the scapula is a broad, flat, thin plate that is thicker laterally than medially
  - the lateral border becomes progressively thicker toward the glenoid fossa

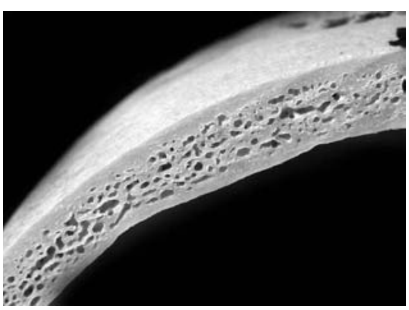


Image 5.12 • Diploë of skull – parietal bone cut in horizontal section.
The bone appears to have many empty chambers or spaces which in life house bone marrow cells, responsible in part for the production of new blood in adults.

Image 5.13

Scapula, left, posterior view.

Image 5.13

A - superior angle
B - supraspinous fossa
C - suprascapular notch
D - conoid tubercle
E - coracoid process
F - acromion
G - glenoid fossa
H - infraglenoid tubercle
I - infraspinous fossa
J - lateral scapular border
K - inferior angle

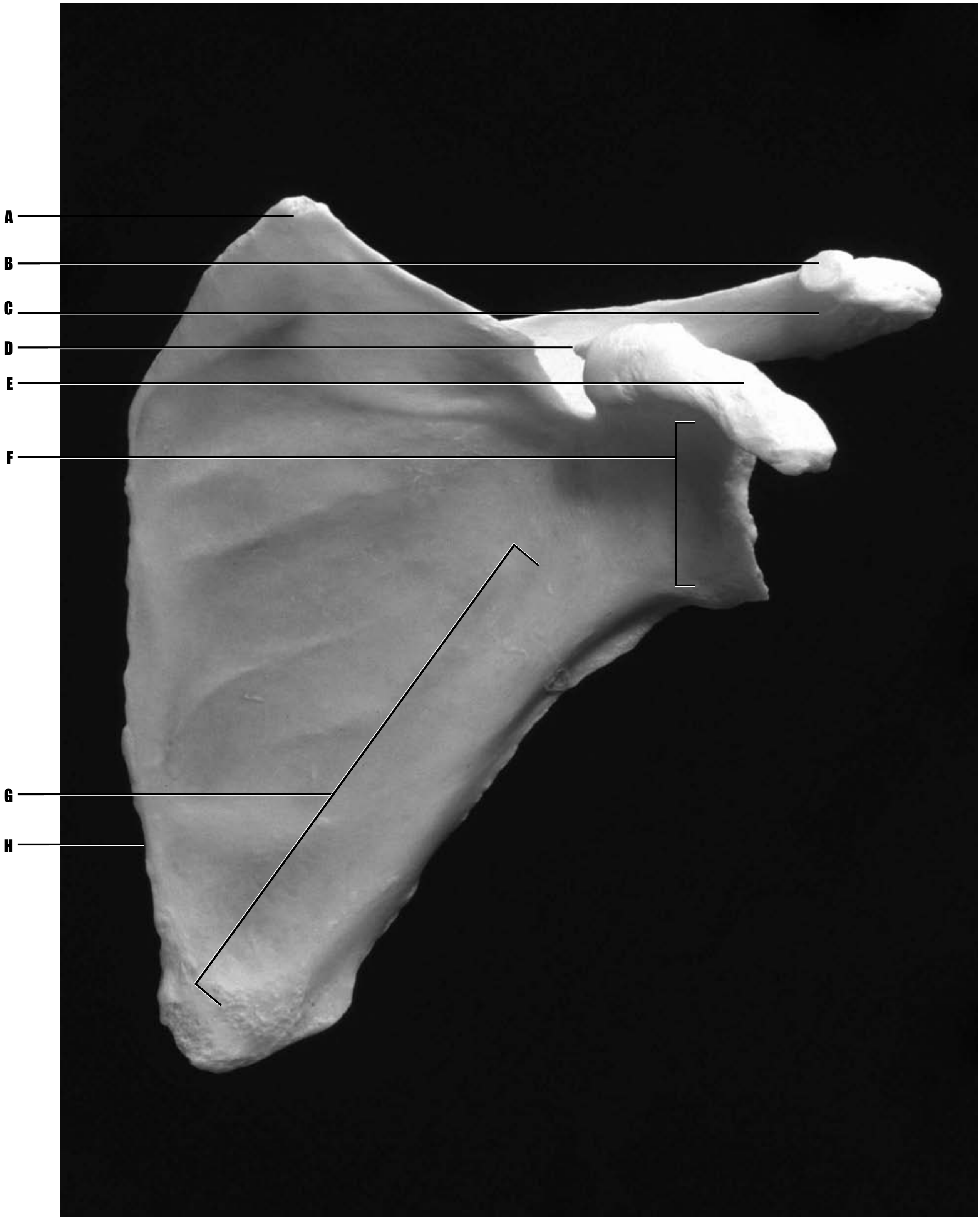


Image 5.14

Scapula, left, anterior view.

Image 5.14

- **A** - superior angle
- **B** - articular facet for clavicle on acromion
- **C** - acromion
- **D** - conoid tubercle
- **E** - coracoid process
- **F** - neck of scapula
- **G** - subscapular fossa
- **H** - medial border of scapula

Image 5.15
Scapula, left, superior view.

Image 5.15

A - coracoid process
B - conoid tubercle
C - suprascapular notch
D - acromion

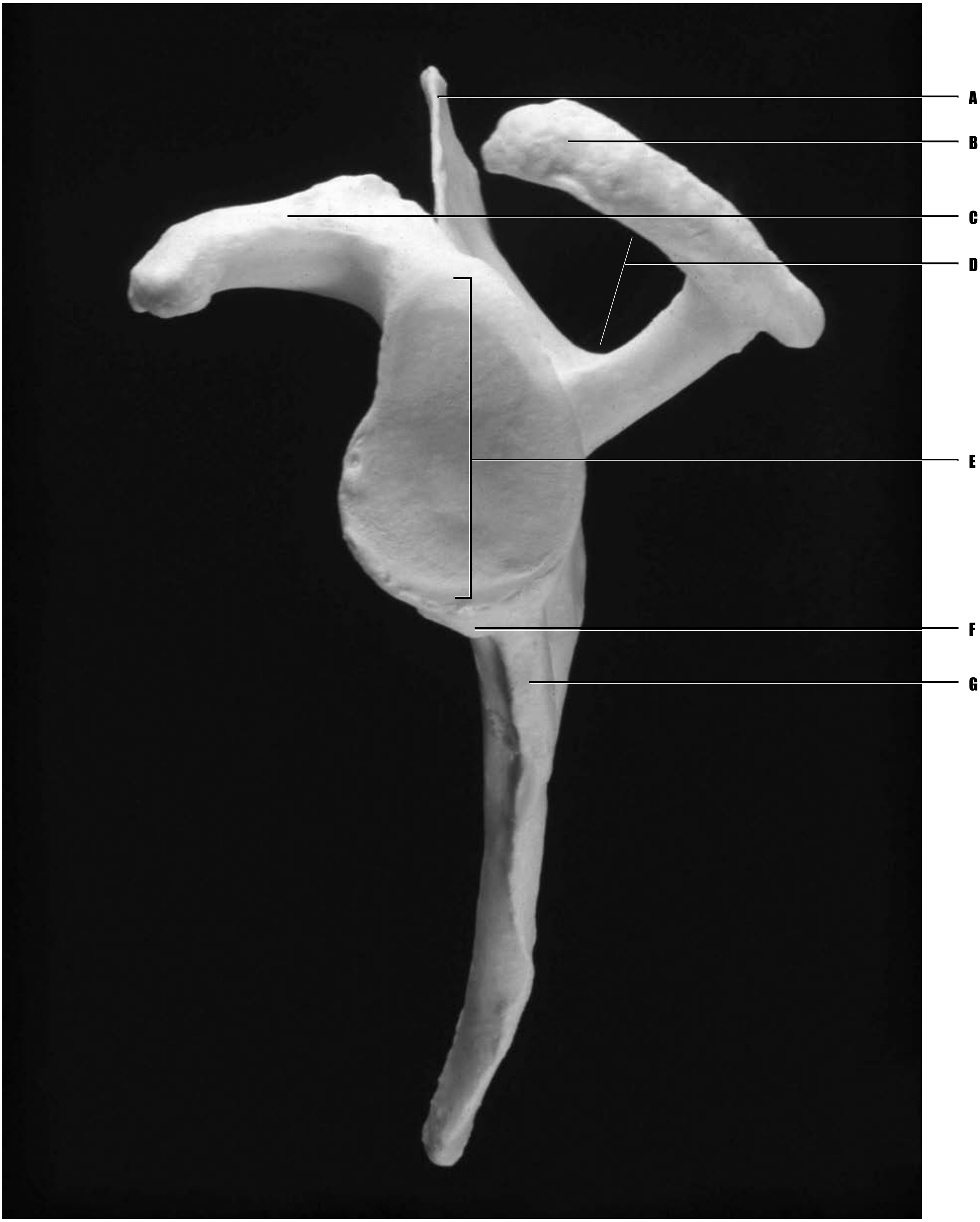
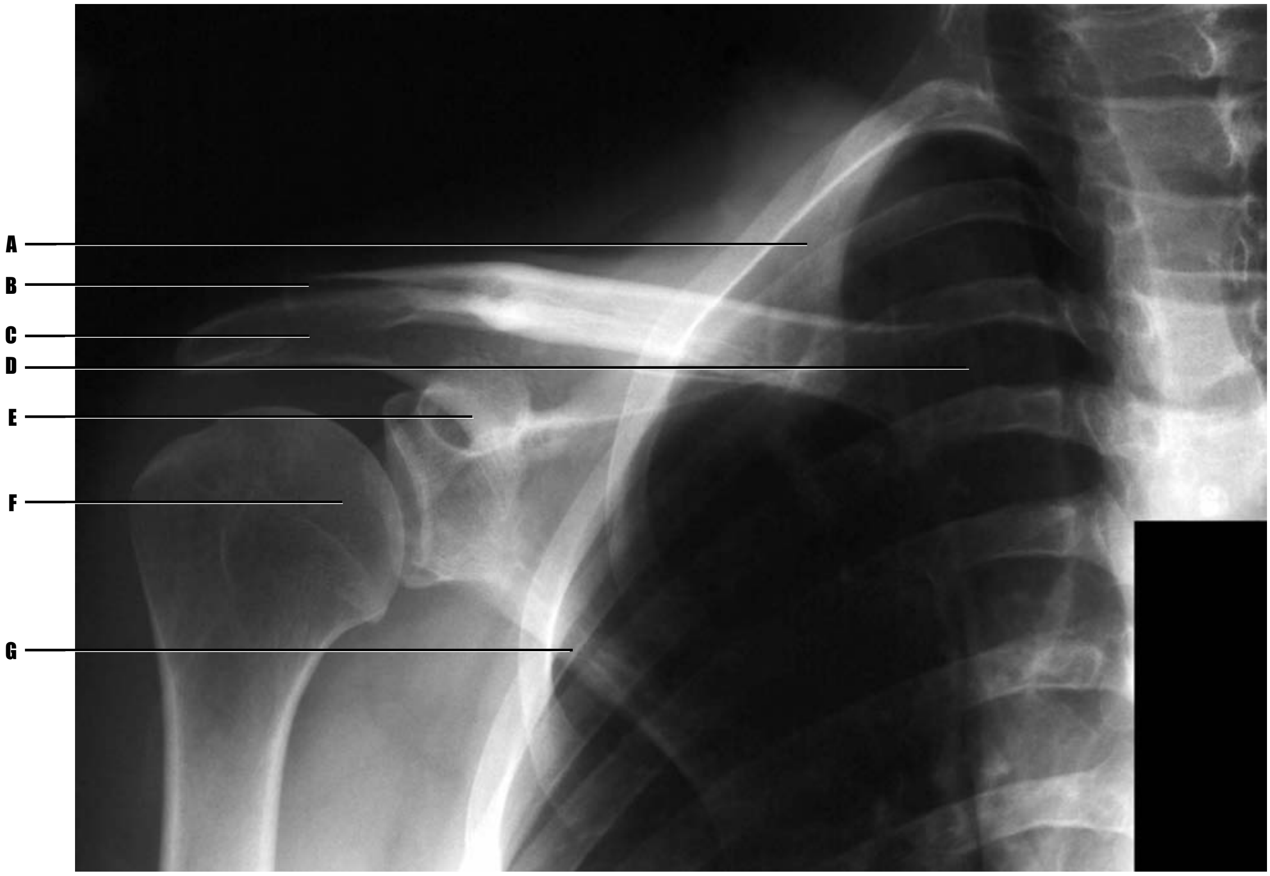


Image 5.16
Scapula, left, lateral view.

A - superior angle; **B** - acromion; **C** - coracoid process; **D** - scapular notch (leading to suprascapular fossa); **E** - glenoid fossa; **F** -infraglenoid tubercle; **G** - body (in this example, this point could also be referred to as the lateral border of the scapula).



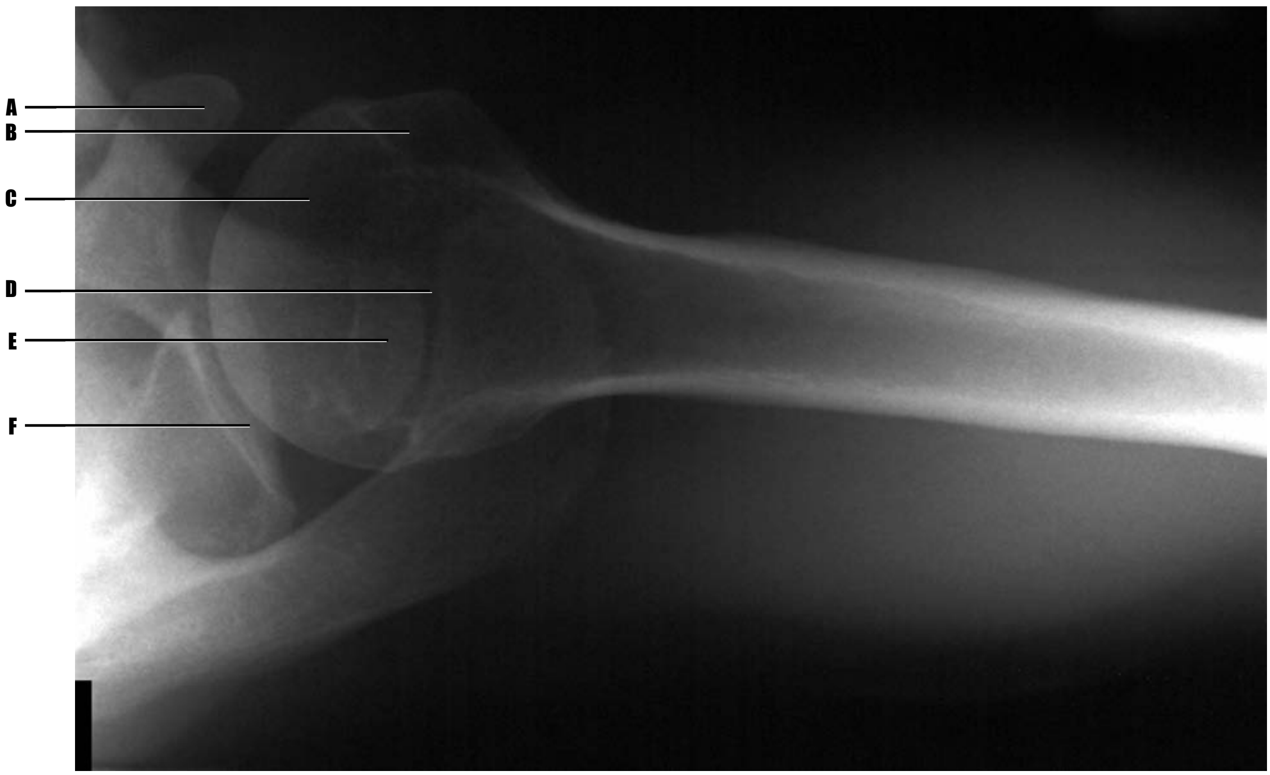


Image 5.17 (above)

Adult patient, plain film radiograph of postero-anterior right shoulder.

Image 5.18 (below)

Adult patient, plain film radiograph, axillary view of shoulder.

Image 5.17

A - anterior segment of first rib
B - acromioclavicular joint
C - acromion
D - medial end of clavicle
E - coracoid process
F - head of humerus
G - lateral border of scapula

Image 5.18

A - coracoid process
B - greater tuberosity of humerus
C - head of humerus
D - acromioclavicular joint
E - lateral end of clavicle
F - glenoid fossa

Image 5.19
Adult patient, plain film radiograph, oblique view of scapula.

Image 5.19

A - inferior articular process of C7 vertebra
B - acromioclavicular joint
C - spinous process of T1 vertebra
D - coracoid process
E - humeral head
F - greater tuberosity of humerus
G - body of scapula

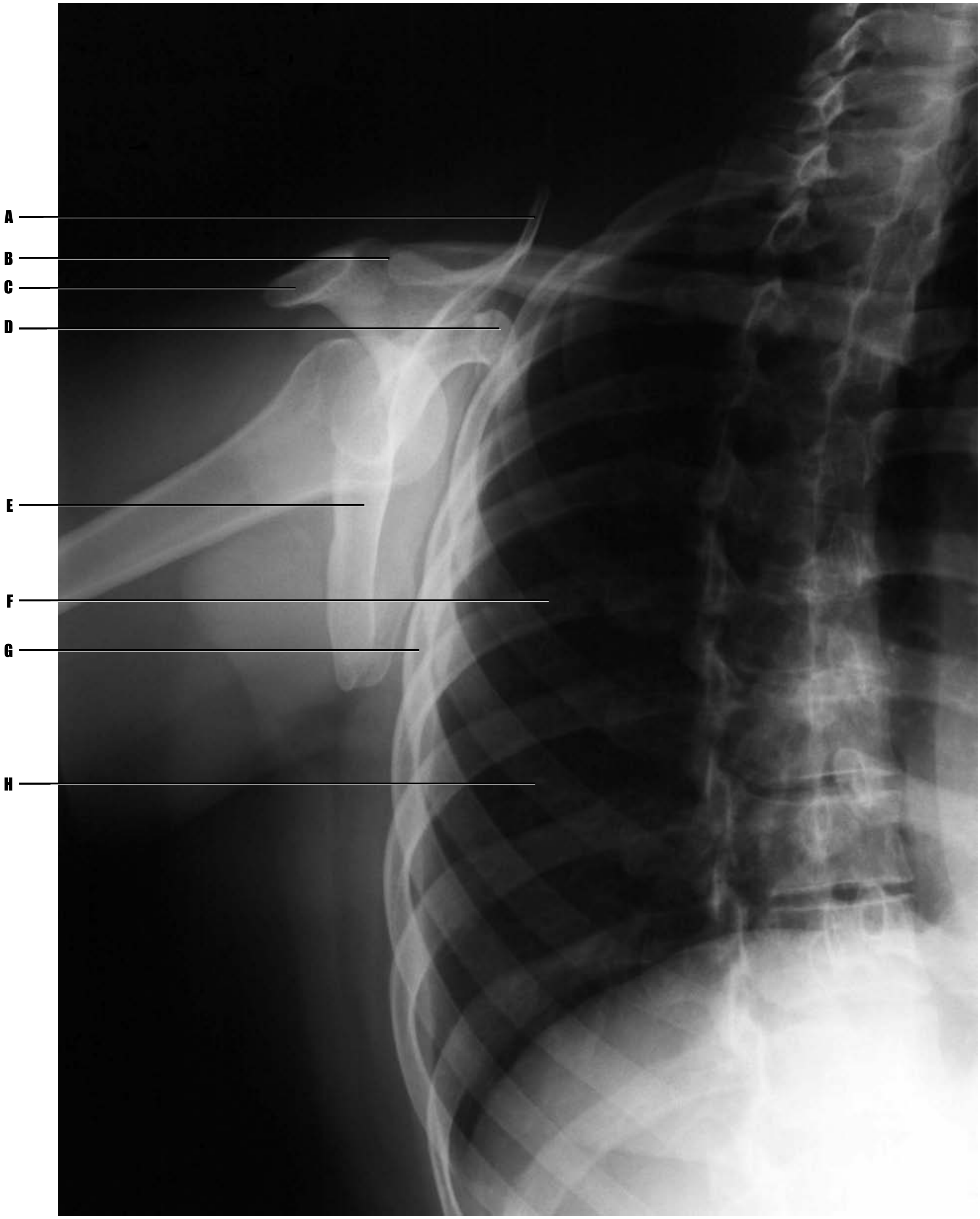


Image 5.20
Adult patient, plain film radiograph of right scapula.

Image 5.20

A - anterior margin of scapula
B - acromioclavicular joint
C - acromion
D - coracoid process
E - body of scapula
F - posterior segment of rib
G - lateral segment of rib
H - anterior segment of rib

5.3 HUMERUS

Image 5.21 • *Humerus, anterior view.*

- has a bulbous proximal end that articulates with the scapula at the shoulder (glenohumeral) joint
- has an irregular distal end that articulates with the radius and ulna (of the forearm)
- has a long, semi-smooth shaft that is twisted in appearance because of the deltoid tuberosity
- the round head is medial and somewhat posteriorly directed
- the intertubercular groove can be seen to progress distally through much of the superior half of this bone

FUNCTION

The humerus is the only bone of the arm. It provides multiple sites for attachment of the muscles of the arm and forearm (the limb distal to the elbow).

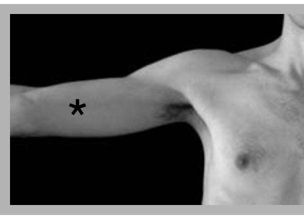


Image 5.22 • Shoulder with arm in abduction. * Marks humerus.

Landmarks

- greater tuberosity
- lesser tuberosity
- head
- anatomic neck
- intertubercular groove
- surgical neck
- deltoid tuberosity
- shaft
- lateral supracondylar ridge
- medial supracondylar ridge
- radial fossa
- coronoid fossa
- medial epicondyle
- lateral epicondyle
- capitulum
- trochlea
- radial groove
- olecranon fossa

Differentiating Right from Left

- very easy to side intact bones
- hold the humerus so that the head is up, and the lesser tuberosity is toward you (as pictured in **Images 5.23** and **5.24**); the head is now directed toward the same side as that to which the bone belongs

Looking at Fragments

- use your knowledge of the relationship of the humeral head to the greater and lesser tuberosities to help you side fragments of head (see **Images 5.23** and **5.24**)
  - the lesser tuberosity is strictly anterior, and is separated from the greater tuberosity along its anterolateral border by the intertubercular (bicipital) groove
  - the greater tuberosity is posterolaterally and somewhat anteriorly located
- proximal shaft fragments can be sided with consideration of the location of the deltoid tuberosity and intertubercular groove
  - the deltoid tuberosity is always lateral and slightly posterior to the intertubercular groove
- as the shaft progresses inferiorly, there is a gradual and subtle decrease in overall shaft diameter
- the distal quarter of shaft is progressively widened and thinned, and the medial margin is remarkable for the presence of a thin and somewhat rough edge
- the distal end of the humerus can be sided as pictured in **Images 5.25** and **5.26**
  - hold the anterior surface toward you (i.e., the olecranon fossa away from you) with the most distal end away from you
  - the medial epicondyle is now on the opposite side as that to which the bone belongs
- make sure to use your knowledge of cortical nutrient foramina to help orient your fragments – note that in the humerus, the openings of nutrient foramina face superiorly (see *page 275* for more information)

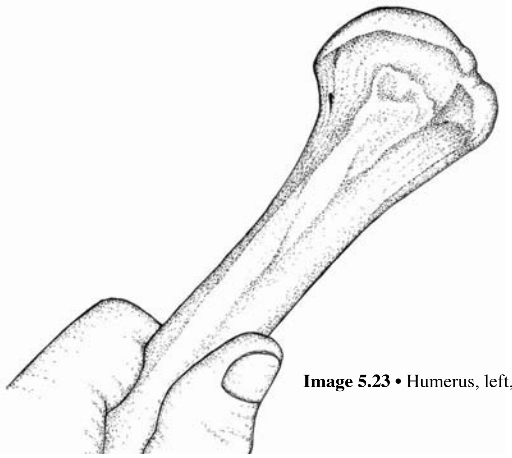


Image 5.23 • Humerus, left, proximal anterior.

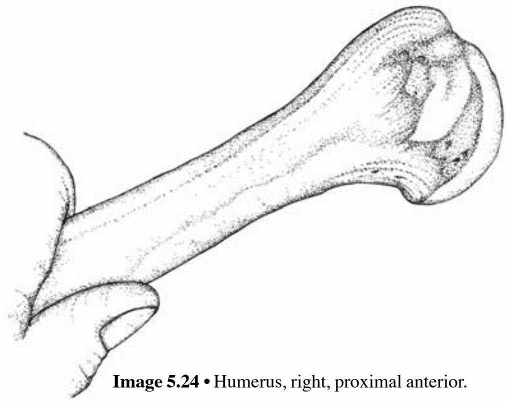


Image 5.24 • Humerus, right, proximal anterior.

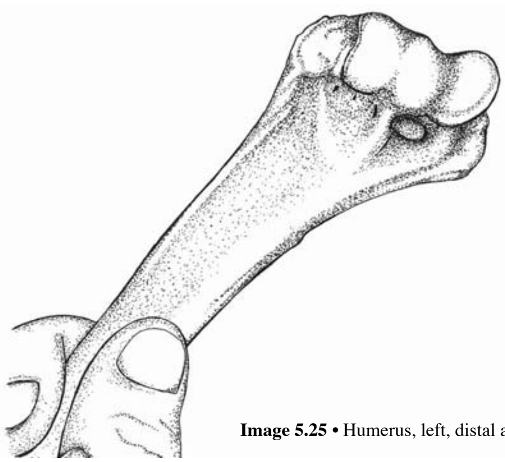


Image 5.25 • Humerus, left, distal anterior.

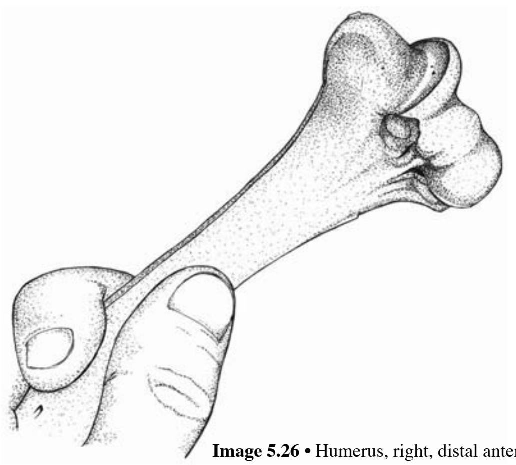


Image 5.26 • Humerus, right, distal anterior.

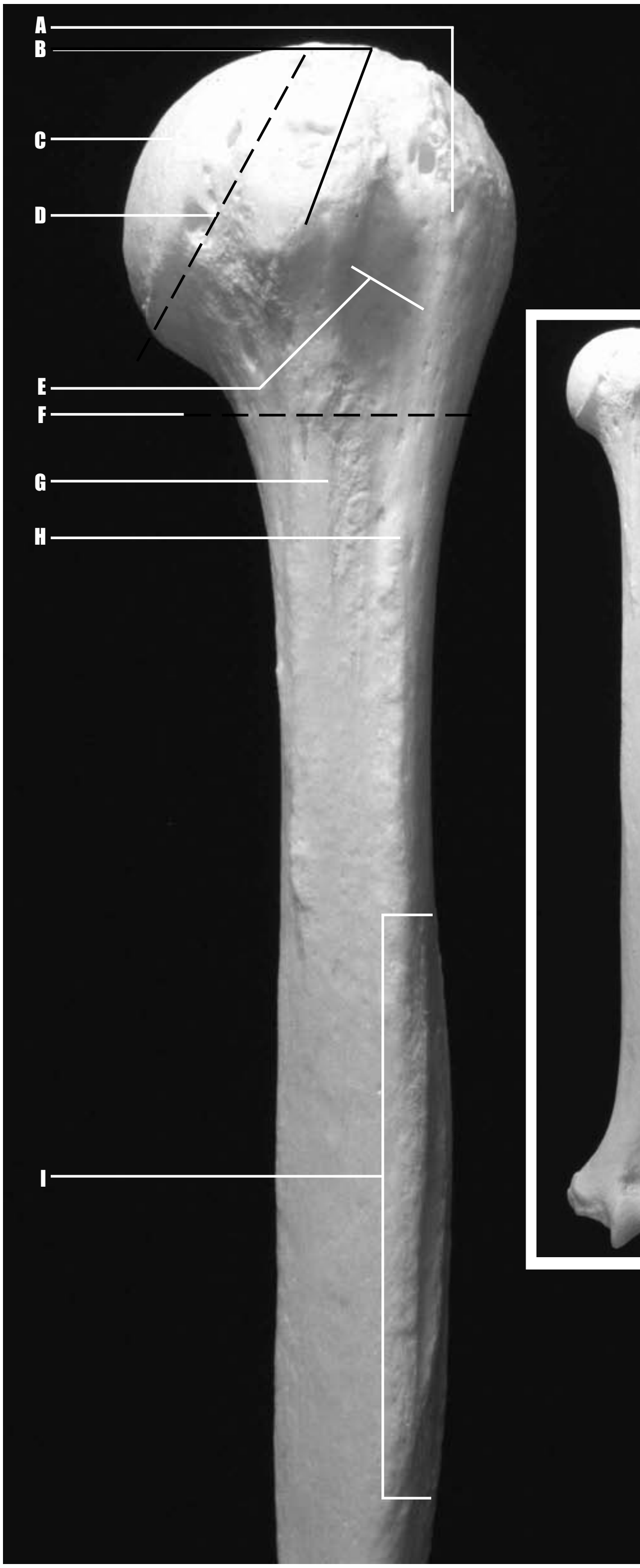


Image 5.27

Humerus, left, anterior view, proximal half.

Image 5.28

Humerus, left, anterior view, distal half.

Image 5.27

A - greater tuberosity
B - lesser tuberosity
C - head
D - anatomical neck *(indicated by dashed line)*
E - intertubercular groove
F - surgical neck *(indicated by dashed line)*
G - medial lip of intertubercular groove
H - lateral lip of intertubercular groove
I - deltoid tuberosity

Image 5.28

A - shaft
B - lateral supracondylar ridge
C - medial supracondylar ridge
D - radial fossa
E - coronoid fossa
F - medial epicondyle
G - lateral epicondyle
H - capitulum
I - trochlea

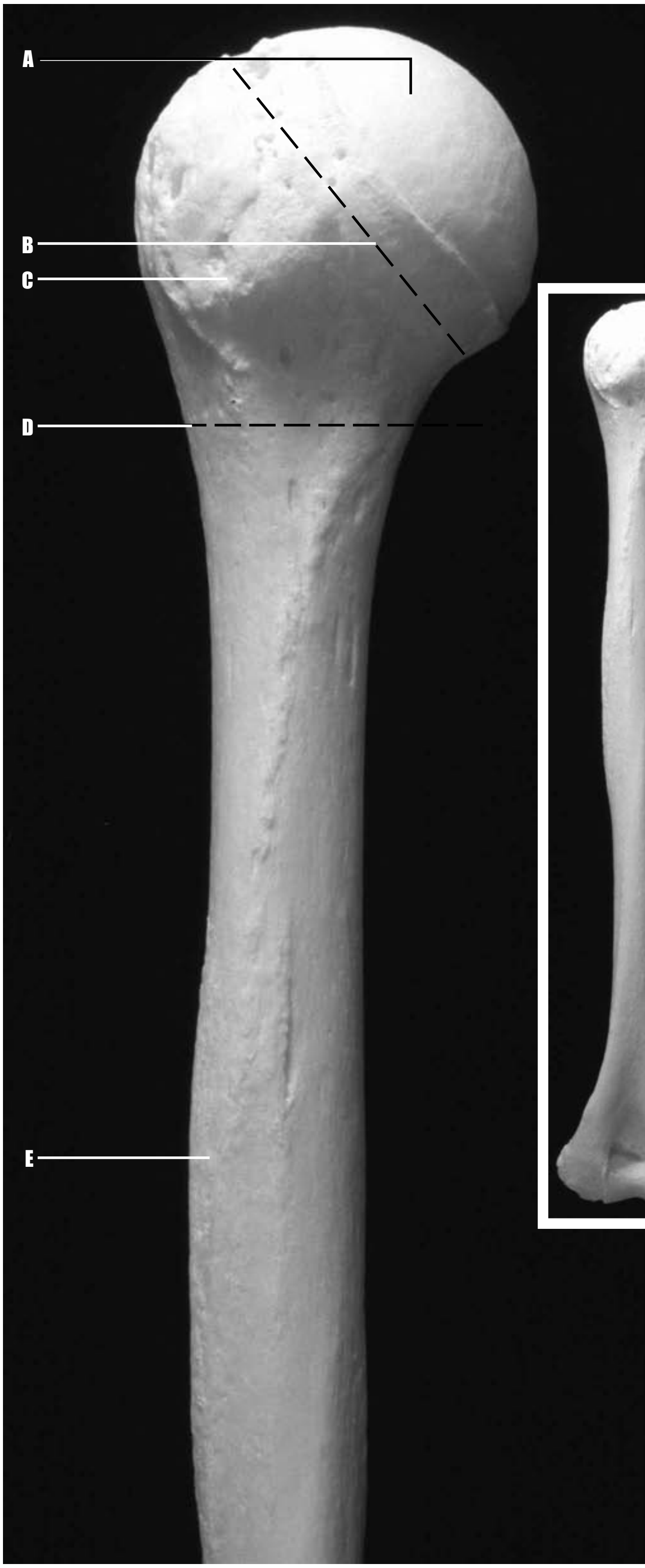


Image 5.29

Humerus, left, posterior view, proximal half.

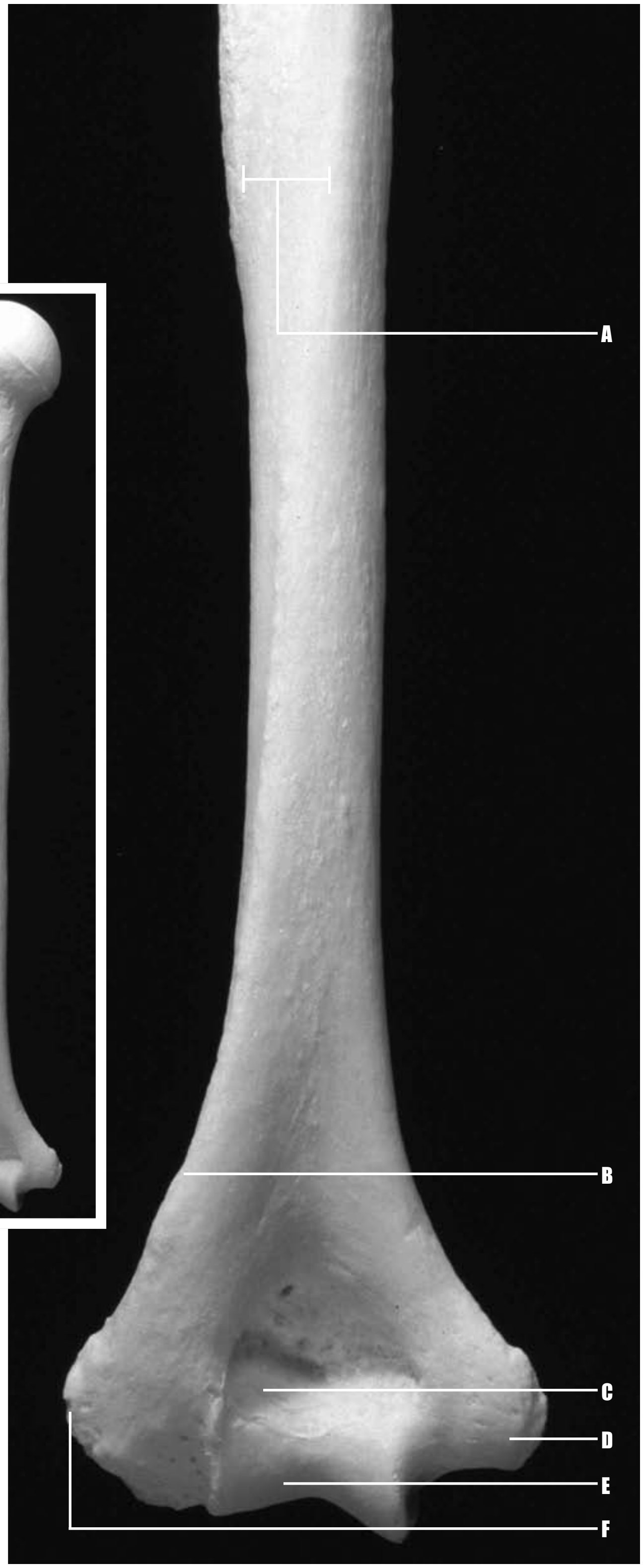


Image 5.30

Humerus, left, posterior view, distal half.

Image 5.29

A - head
B - anatomical neck *(indicated by dashed line)*
C - greater tuberosity
D - surgical neck *(indicated by dashed line)*
E - deltoid impression

Image 5.30

A - radial groove
B - lateral supracondylar ridge
C - olecranon fossa
D - medial epicondyle
E - trochlea
F - lateral epicondyle

Image 5.31
Adult patient, plain film radiograph, anteroposterior view of left humerus.

Image 5.32
Adult patient, plain film radiograph, lateral view of left humerus.

Images 5.31 and 5.32

A - clavicle
B - coracoid process
C - acromion
D - greater tuberosity of humerus
E - shaft of humerus
F - medial epicondyle of humerus
G - olecranon of ulna
H - lateral epicondyle of humerus
I - head of humerus
J - lateral supracondylar ridge
K - coronoid process of ulna

5.4 RADIUS

Image 5.33 • *Radius, superior view.*

- forms the lateral aspect of the forearm
- is a long bone with two articulating ends and an intervening shaft
- the proximal end articulates with the capitulum of the humerus
- the distal end articulates with the scaphoid and lunate bones of the wrist
- medially, the radius articulates with the ulna at both the proximal and distal radio-ulnar joints
- the head of this bone is disc-like and has a concave articular facet – the radial head corresponds with the radial fossa of the humerus
- the shaft is relatively round and smooth except for a sharp, thin medial border
- anterior surface of the distal radius is smooth and somewhat concave
- the posterior surface of the distal radius is more rough, and bears the prominent dorsal (Lister's) tubercle

FUNCTION

Is a major bony support of the forearm. In addition to being a site of muscle attachment, it also serves as an insertion site for the dense interosseous membrane between the radius and ulna.

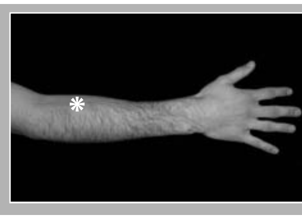


Image 5.34 • Surface Anatomy • Forearm. * Marks location of radius.

Landmarks

- head
- neck
- radial tuberosity
- interosseous border/ridge
- pronator ridge (may be difficult to see)
- dorsal tubercle
- articular surface for scaphoid
- articular surface for lunate
- ulnar notch

Differentiating Right from Left

- direct the round head toward you, the expanded distal end away from you, and the rough posterior surface toward the floor (as illustrated in **Images 5.35** and **5.36**)
- now, the styloid process is pointing toward the same side as that to which the bone belongs

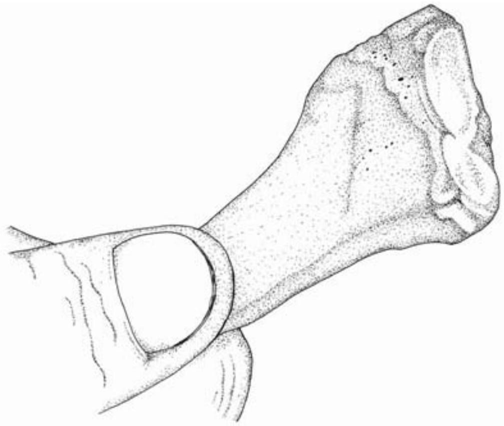


Image 5.35 • Radius, left, distal end.

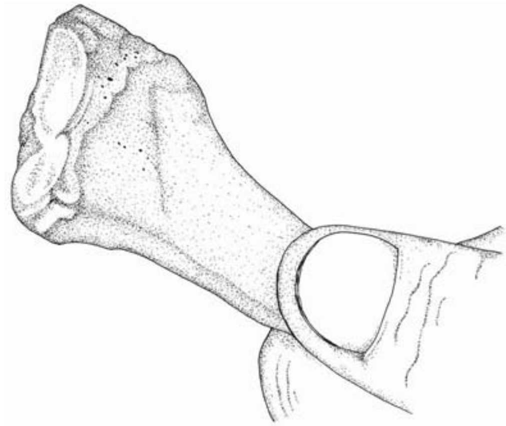


Image 5.36 • Radius, right, distal end.

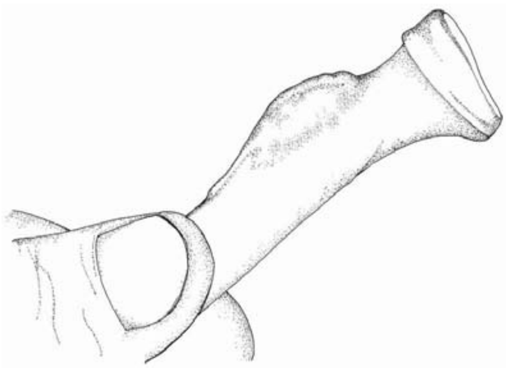


Image 5.37 • Radius, left, proximal end.

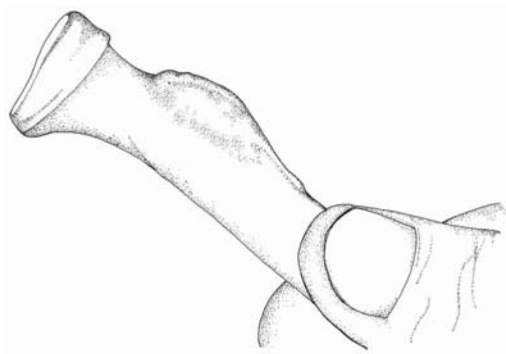


Image 5.38 • Radius, right, proximal end.

Looking at Fragments

- the radius could be confused with other thin long bones, however:
  - unlike the clavicle, the radius has no significant curvature
  - furthermore, the radius has a prominent, flat interosseous border which is absent on the clavicle
  - the fibula is generally much thinner than other long bones, and the borders of its shaft are more prominently irregular than the radius
- unlike the ulna which has a somewhat more robust proximal end that tapers to the distal end, the radial shaft is roughly uniform in size along its length, and only expands laterally toward its distal end
- fragments of radial head are unlikely to be confused with ulnar distal end, because the ulna has a styloid process, and the radial head is a flat, concave disc
- the radial shaft, like the ulna, has a prominent interosseous crest
  - but, unlike the flatter, somewhat more irregular ulnar shaft, the radial shaft is much more round and smooth
- when examining radial fragments, keep in mind:
  - the radial articular circumference of the head is thicker on the medial surface
  - the radial tuberosity "bulges out" from the medial surface of the radius; its posterior edge is much more prominent than the anterior edge, which seems to blend into the body of the shaft (see **Images 5.37** and **5.38**)
  - in relation to the interosseous crest, the anterior side of the radial shaft appears to be more concave than the subtly convex posterior surface
  - the styloid process is on the lateral side of the bone
  - the ulnar notch is on the medial side of the bone
  - the dorsal tubercle is on the posterior side of the bone
- use your knowledge of nutrient foramina to orient radial fragments
  - the opening of the nutrient foramina of the radial shaft face inferiorly

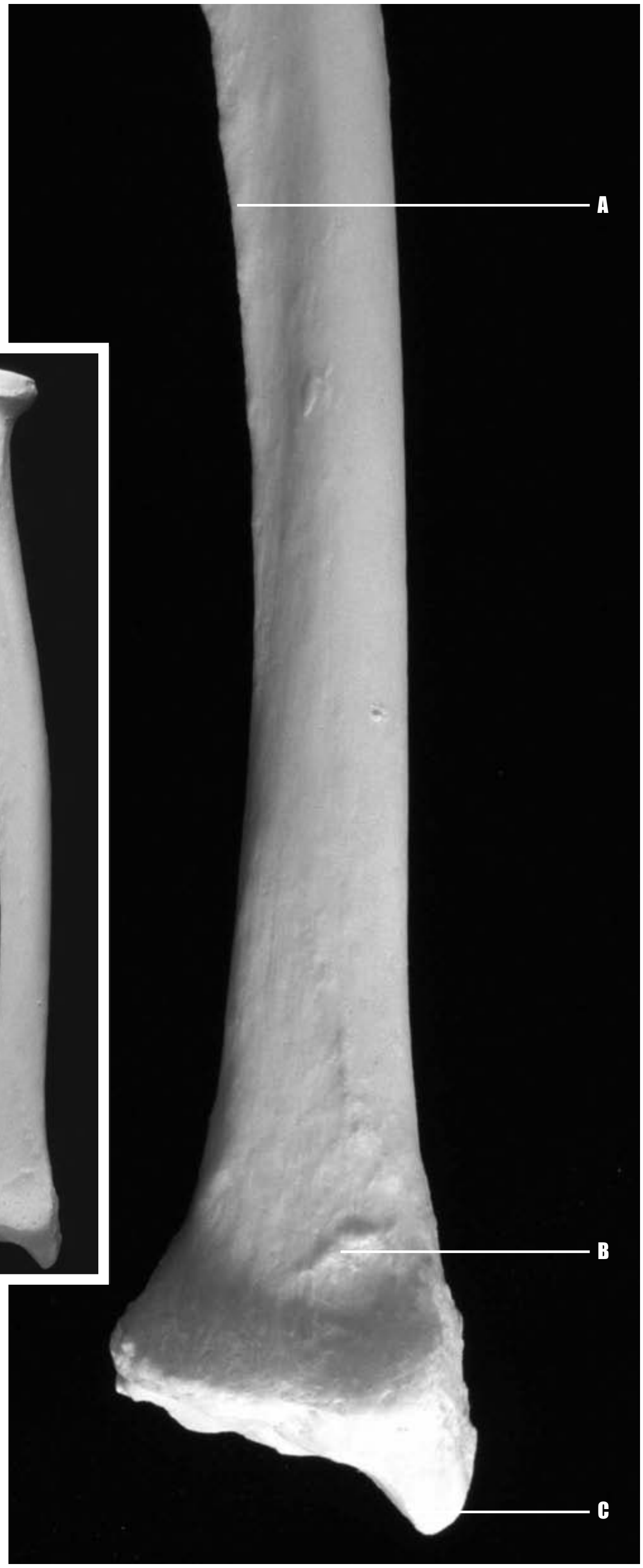


Image 5.39
Radius, left, anterior view, proximal half.

Image 5.40
Radius, left, anterior view, distal half.

Image 5.39

A - articular circumference of radial head
B - neck
C - radial tuberosity

Image 5.40

A - interosseous border
B - pronator ridge
C - styloid process

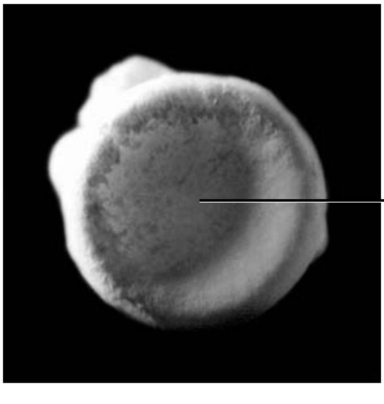


Image 5.41
Radius, left, proximal end.
A - articular surface for humeral capitulum.

Image 5.42

Adult radius, left, posterior view, proximal half.

Image 5.43

Adult radius, left, posterior view, distal half.

Image 5.42

A - interosseous border
B - shaft
C - radial tuberosity
D - neck
E - articular circumference of head

Image 5.43

A - styloid process
B - dorsal (Lister's) tubercle
C - groove for tendon (of extensor pollicus longus)
D - shaft
E - interosseous border

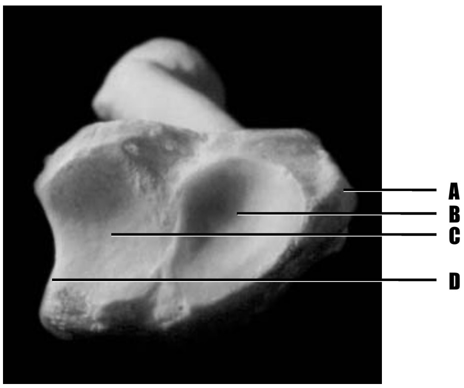


Image 5.44
Radius, left, distal end.
A - styloid process; **B** - articular surface for scaphoid; **C** - articular surface for lunate; **D** - ulnar notch.

5.5 ULNA

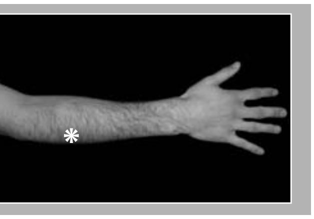
Image 5.45 • *Ulna, left, lateral view.*

- forms the medial aspect of the forearm
- is a long bone with two articular ends and an intervening shaft
- the proximal end is very irregular and robust in appearance
  - it articulates with the trochlea of the humerus at the elbow joint as well as laterally at the proximal and distal radio-ulnar joint
  - the olecranon process fits into the olecranon fossa of humerus, the trochlear notch articulates with the trochlea of the humerus, and the coronoid process corresponds with the coronoid fossa of the humerus
- the shaft has a slight sigmoid curvature
  - the interosseous border is on the lateral side of the shaft
  - the shaft itself is more irregular than other long bones (except the fibula)
- the expanded proximal shaft becomes progressively smaller distally, but it bulges out at the ulnar head
  - the head/radial articulation has a small styloid process
  - when viewed "head on," the styloid process is on the medial aspect of the ulnar head

FUNCTION

Is a site of muscle attachment as well as insertion for the dense interosseous membrane found between the radius and ulna. It is also a major bony support of the forearm.

Image 5.46 • Surface Anatomy • Forearm. * Marks location of ulna.



Landmarks

- olecranon process
- trochlear notch (for trochlea of humerus)
- coronoid process (for coronoid notch of humerus)
- radial notch (for circumference of radial head)
- supinator crest
- interosseous border
- groove for extensor carpi ulnaris tendon
- styloid process
- ulnar tuberosity
- radial articulation

Differentiating Right from Left

- put the irregular proximal end toward you and the thin distal end away (as pictured in **Images 5.47** and **5.48**)
- the trochlear notch should be upwards
- the radial notch is now on the same side of the bone as that to which the bone belongs
- alternatively, the styloid process is on the side opposite that to which the bone belongs

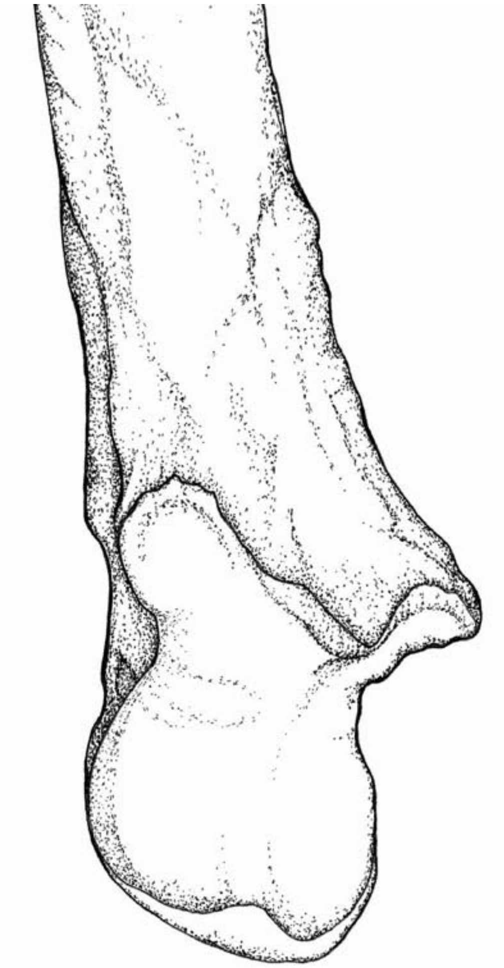


Image 5.47 • Ulna, left, proximal end.

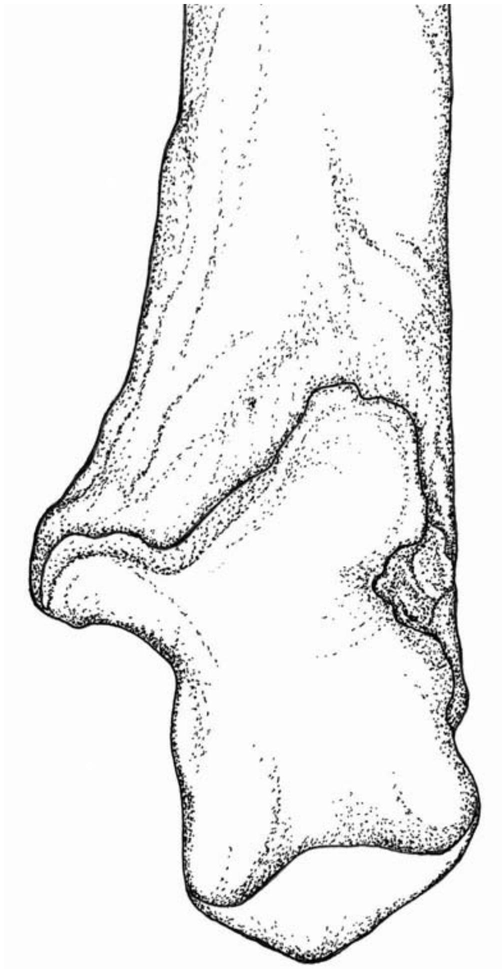


Image 5.48 • Ulna, right, proximal end.

Looking at Fragments

- some people have confused pieces of proximal ulna with fragments of ischium (of the pelvis); however
  - the ulna has smooth articular surfaces (trochlea, radial notch)
  - also, the ulna is relatively more straight than the curved ischium
- the ulnar shaft is less rounded than the radius, but far less irregular than the fibula
- the presence of a prominent interosseous border helps narrow your options to ulna and proximal radius
- the distal ulna might be confused with the radial head
  - but, the radius has a circumferentially bevelled head, while the ulna is bevelled only superiorly
  - there is no concavity of the ulnar head
- do not forget, the groove for the extensor carpi ulnaris is always located laterally
- use your knowledge of nutrient foramina to help place shaft fragments in sequence; the openings of nutrient foramina in the ulna face inferiorly

Image 5.49

Ulna, left, lateral view, proximal half.

Image 5.50

Ulna, left, lateral view, distal half.

Image 5.49

A - olecranon process
B - trochlear notch
C - coronoid process
D - radial notch
E - supinator crest
F - interosseous border

Image 5.50

A - interosseous border
B - head (radial articulation)
C - groove for extensor carpi ulnaris tendon
D - styloid process

5.5a NUTRIENT FORAMINA

- bone, like other tissues of the body, needs oxygenated, nutrient-rich blood to support metabolism
- the openings by which blood vessels enter the bone are known as nutrient foramina
- when visible on the shafts of fragmented long bones, these may be useful with fragment orientation
- this is because nutrient foramina are known to open to the surface in a predictable fashion
- as a general rule, in the upper limb, the proximal bones (humerus) have nutrient foramina whose openings face superiorly; the foramina of the distal bones (radius and ulna) have openings that face inferiorly

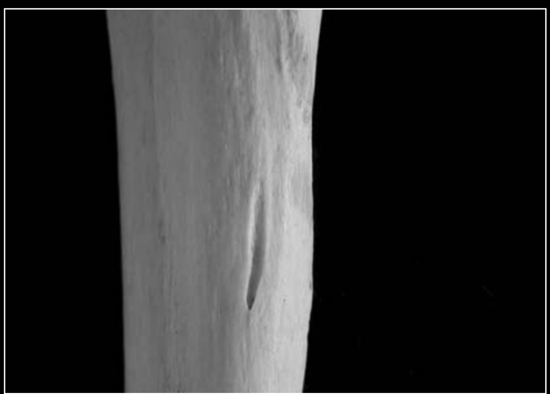


Image 5.51
Tibia, posterior, close-up of prominent nutrient foramen. This opening faces *superiorly*.

Image 5.52
Femur, posterior, close-up of prominent nutrient foramen on linea aspera.

Image 5.53
Ulna, left, medial view, proximal half.

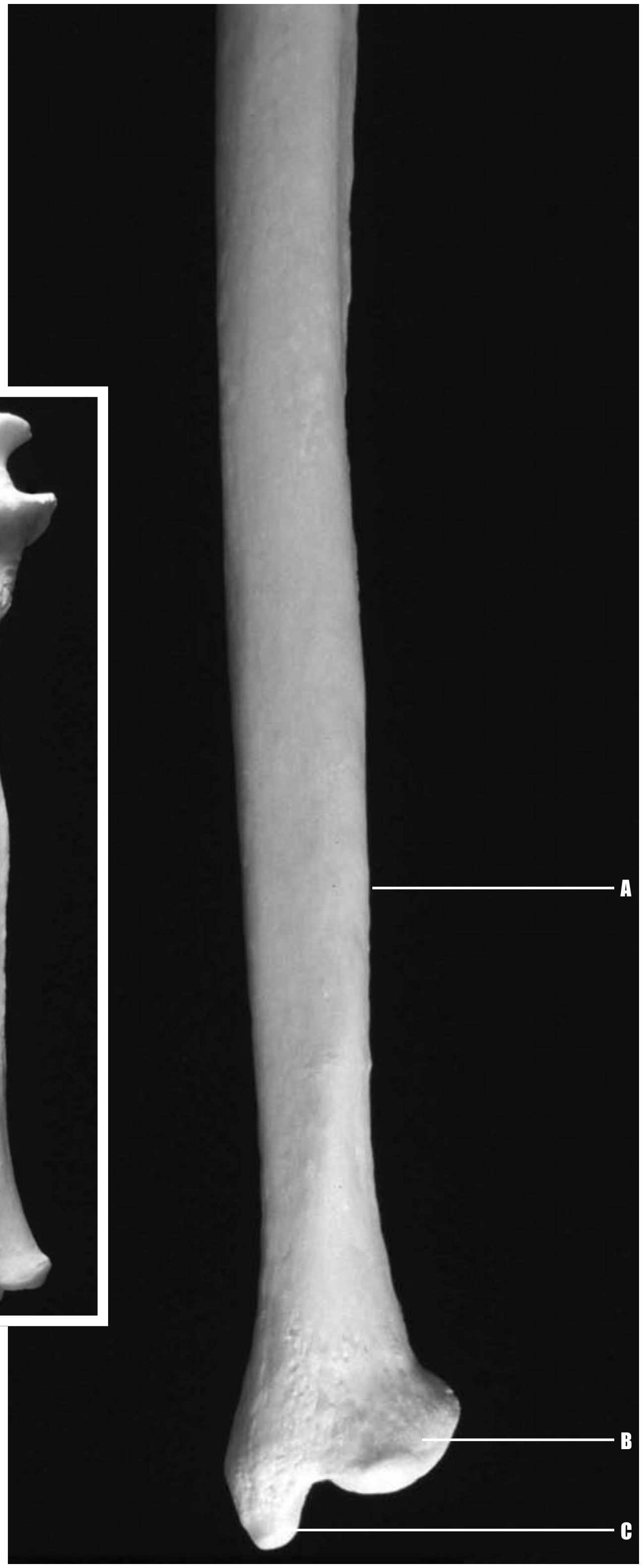


Image 5.54
Ulna, left, medial view, distal half.

Image 5.53

A - olecranon process
B - coronoid process
C - ulnar tuberosity
D - interosseous border

Image 5.54

A - interosseous border
B - head (radial articulation)
C - styloid process

Image 5.55
Adult patient, plain film radiograph, anteroposterior view of left forearm.

Image 5.56
Adult patient, plain film radiograph, lateral view of forearm.

Image 5.55

A - humeral shaft
B - olecranon fossa
C - lateral epicondyle
D - medial epicondyle
E - capitulum
F - trochlea
G - radial head
H - radial styloid process
I - carpal bones

Image 5.56

A - supracondylar ridge
B - olecranon of ulna
C - radial head
D - tuberosity of radius
E - ulnar shaft
F - lunate

Image 5.57

Adult patient, plain film radiograph, oblique view of wrist. This view shows the relationship of the forearm (radius and ulna), with the carpal bones at the wrist.
A - radius; **B** - ulna; **C** - scaphoid; **D** - lunate; **E** - triquetral; **F** - pisiform; **G** - trapezium; **H** - trapezoid; **I** - capitate; **J** - hamate.

5.6 HAND

Image 5.58 • *Hand, right, dorsal view.*

- the general arrangement of the hand is similar to that of the foot
- there are twenty-seven bones in each hand (one more than in each foot)
- is composed of eight carpal bones (four per row in two rows), five metacarpal bones, and fourteen phalanges (three per finger except for the thumb, which only has two)
- sesamoid bones (bones which form within tendons) may also be present

FUNCTION

Is the major 'functional' unit of the upper extremities. In addition to being capable of a wide variety of movements, the hand's complex anatomy allows for such important actions as grasping and fine touch.

Image 5.59 • Surface Anatomy • Hand.

Landmarks

- scaphoid
- lunate
- triquetral
- pisiform
- trapezium
- trapezoid
- capitate
- hamate
- metacarpals
- phalanges

*** study the overall arrangement of the hand first so that you are aware of the basic relationships between each bone*

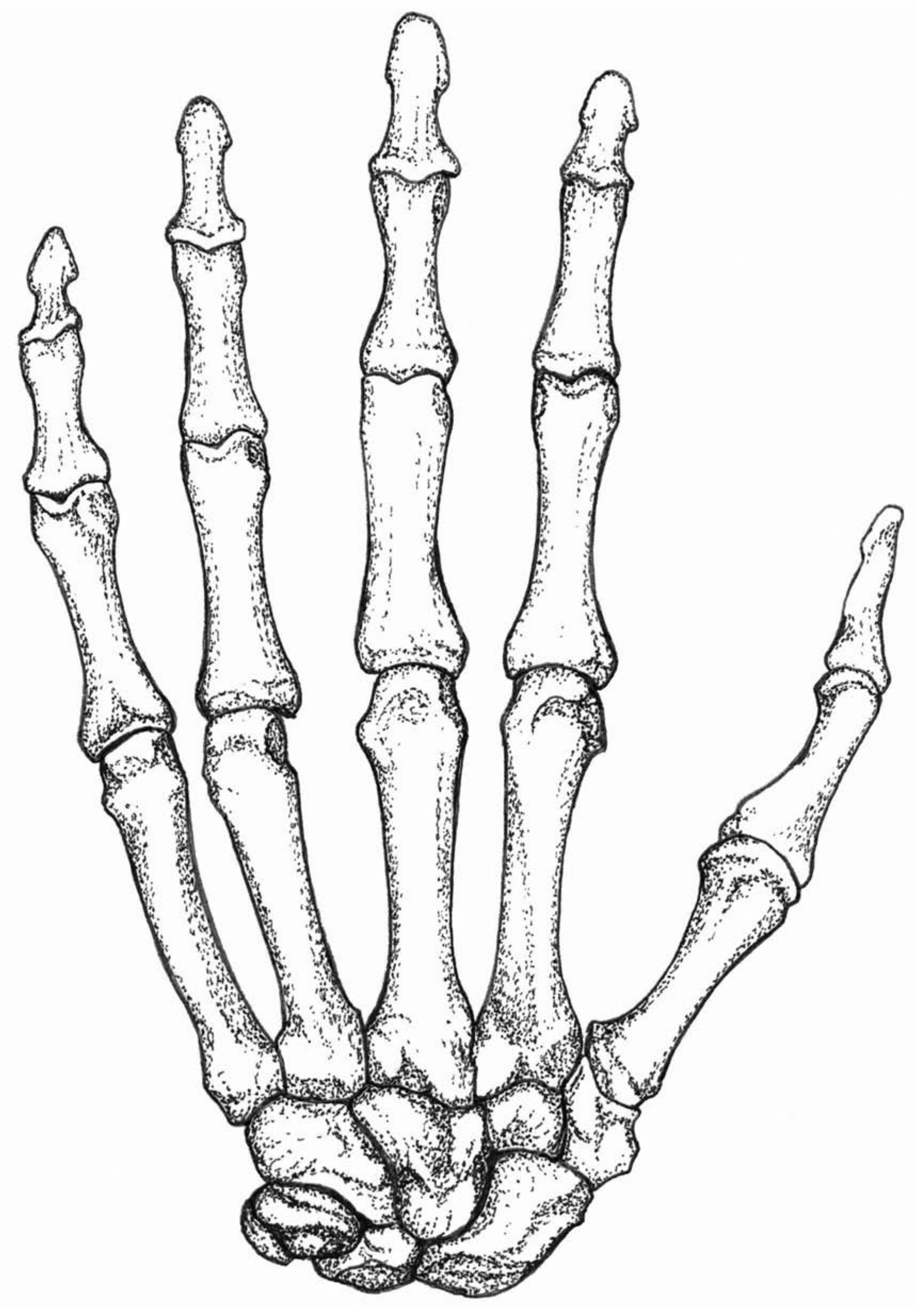


Image 5.60 • Hand, left, dorsal view.

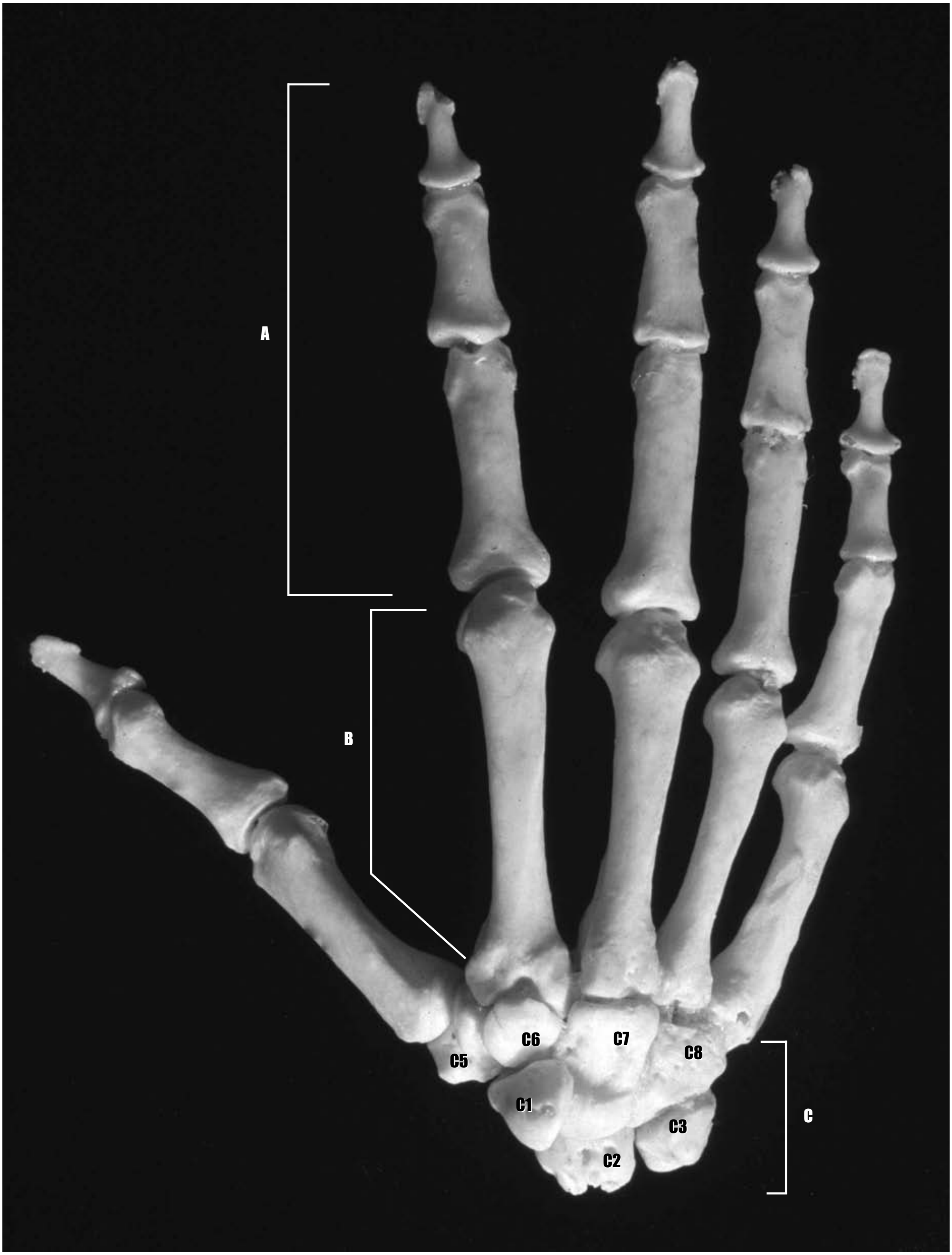


Image 5.61
Hand, right, dorsal view.

Image 5.61

A - phalanges
B - metacarpals
C - carpals
C1 - scaphoid
C2 - lunate
C3 - triquetral
C4 - pisiform *(not pictured)*
C5 - trapezium
C6 - trapezoid
C7 - capitate
C8 - hamate

Image 5.62

Hand, right, palmar view.

Image 5.62

A - phalanges

B - metacarpals

C - carpals

C1 - scaphoid

C2 - lunate

C3 - triquetral *(not pictured)*

C4 - pisiform

C5 - trapezium

C6 - trapezoid

C7 - capitate

C8 - hamate

Image 5.63
Adult patient, plain film radiograph, anteroposterior view of hand and wrist.

Image 5.63

A - phalanges

B - metacarpals

C - carpals

C1 - scaphoid

C2 - lunate

C3 - triquetral

C4 - pisiform

C5 - trapezium

C6 - trapezoid

C7 - capitate

C8 - hamate

D - radius

E - ulna

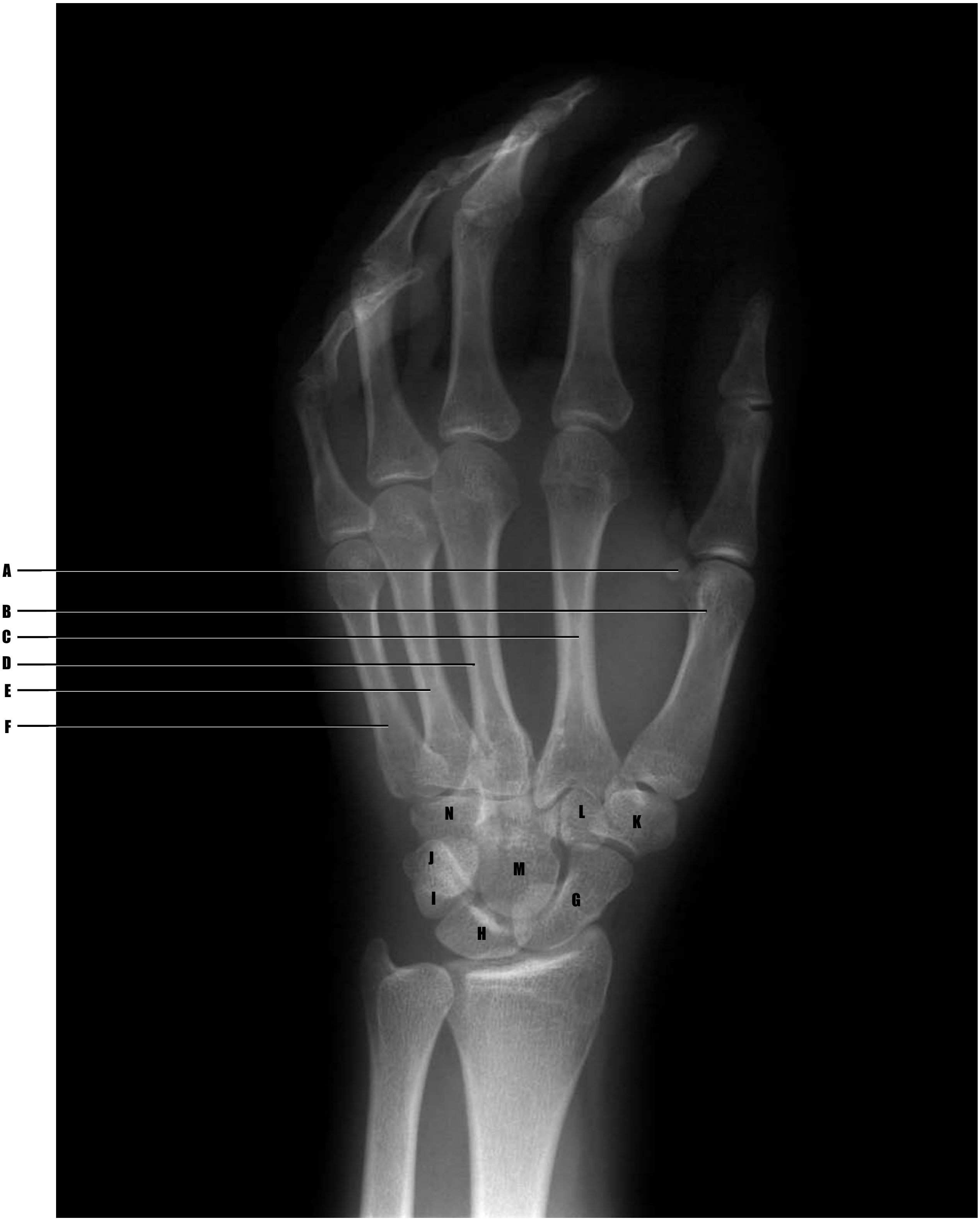


Image 5.64
Adult patient, plain film radiograph, oblique view of hand and wrist.

Image 5.64

A - sesamoid bone
B - first metacarpal
C - second metacarpal
D - third metacarpal
E - fourth metacarpal
F - fifth metacarpal
G - scaphoid
H - lunate
I - triquetral
J - pisiform
K - trapezium
L - trapezoid
M - capitate
N - hamate

Image 5.65
Adult patient, plain film radiograph, lateral view of hand and wrist.

Image 5.65

A - sesamoid bone

B - soft tissue shadow

C - trapezium

D - capitate

E - distal scaphoid

F - lunate

5.6a-1 SCAPHOID

Image 5.66 • *Scaphoid.*

- is the most lateral bone in the proximal carpal row
- has an irregular shape some authors liken to a *boat*
- has a large, smooth concave articular surface for capitate
- has an opposing smooth convex articular surface for distal radius
- has prominent non-articular structures
- articulates with the radius, lunate, trapezium, trapezoid and capitate

Landmarks

- facet for radius
- facet for capitate
- scaphoid tubercle
- scaphoid ridge
- scaphoid prong

*Differentiating Right from Left**

- hold the scaphoid between your thumb and forefinger (i.e., in a pincer grasp)
- your thumb should be in the concave capitate facet, and your forefinger on the convex radial facet
- the scaphoid ridge **must** be toward you
- the scaphoid prong is now on the same side of the scaphoid as that to which the bone belongs

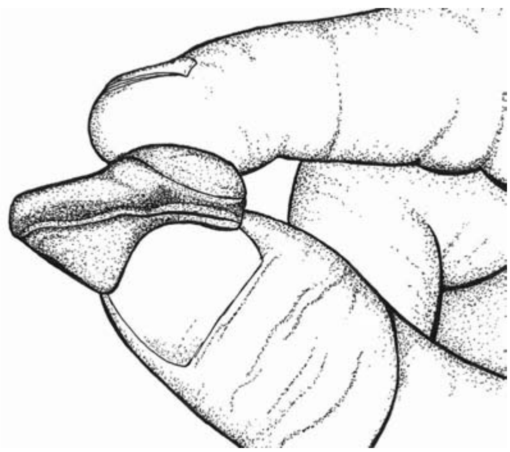


Image 5.67 • Scaphoid bone, left.

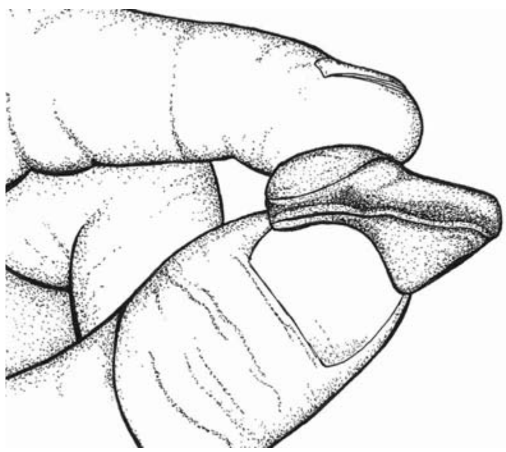
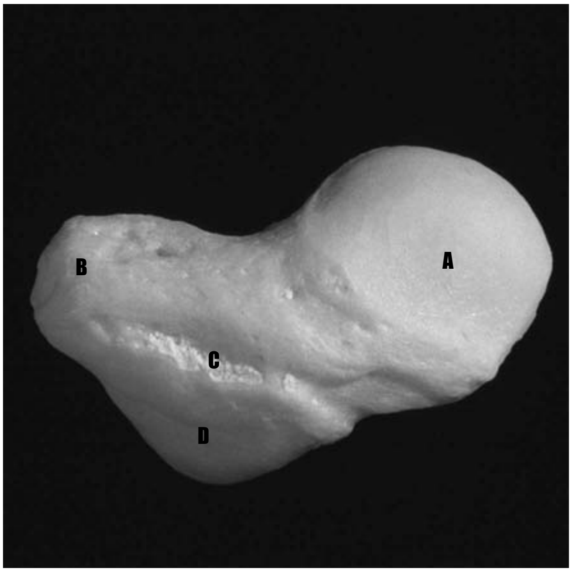
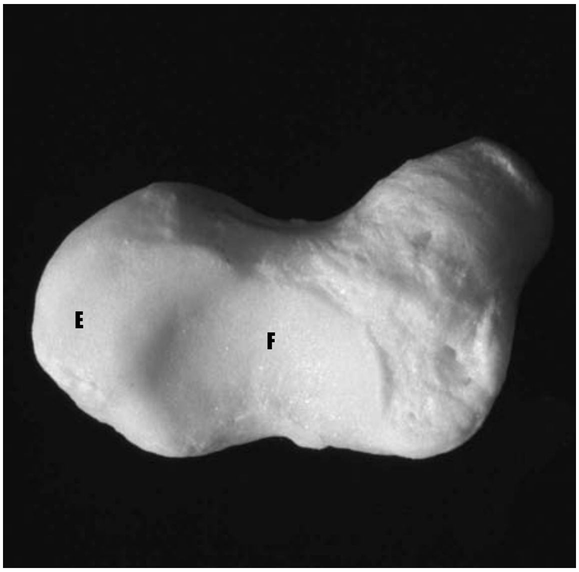


Image 5.68 • Scaphoid bone, right.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.





Images 5.69-71

A - facet for radius

B - scaphoid tubercle

C - scaphoid ridge

D - scaphoid prong (bears articular facets for trapezium and trapezoid)

E - articular surface for lunate

F - facet for capitate

G - distal scaphoid

H - scaphoid neck

I - proximal pole of scaphoid

Image 5.69 (top left)
Scaphoid, left, proximal view.

Image 5.70 (top right)
Scaphoid, left, distal view.

Image 5.71 (bottom)
Adult patient, plain film radiograph of wrist highlighting scaphoid bone.

5.6a-2 LUNATE

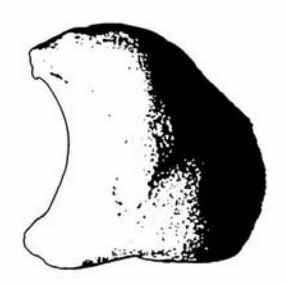


Image 5.72 • *Lunate*.

- is the second bone of the proximal carpal row
- is medial to the scaphoid
- has a roughly *half-moon* shape (hence the name *lunate*)
- the large concave depression is for articulation with the scaphoid
- opposite this is a convex eminence that articulates with the distal radius
- articulates with the radius, scaphoid, triquetral, capitate and hamate

Landmarks

- facet for radius
- facet for capitate
- facet for scaphoid
- facet for hamate
- facet for triquetral

*Differentiating Right from Left**

- it is often a difficult appraisal for the novice
- place the flattest edge of the bone against the table top (see **Images 5.73** and **5.74**)
- thus the scaphoid facet is down and the triquetral facet is up
- the concave capitate facet should be toward you
- the triquetral facet is now on the same side of the lunate as that to which the bone belongs

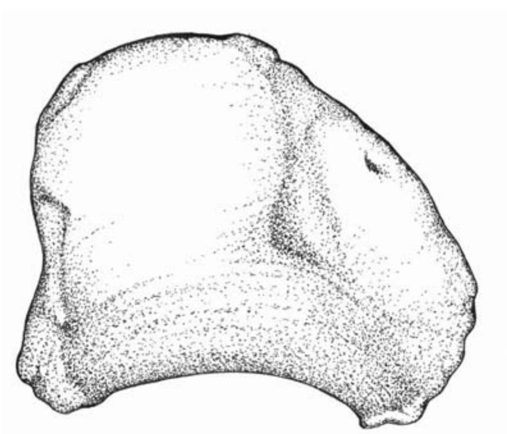


Image 5.73 • Adult left lunate.

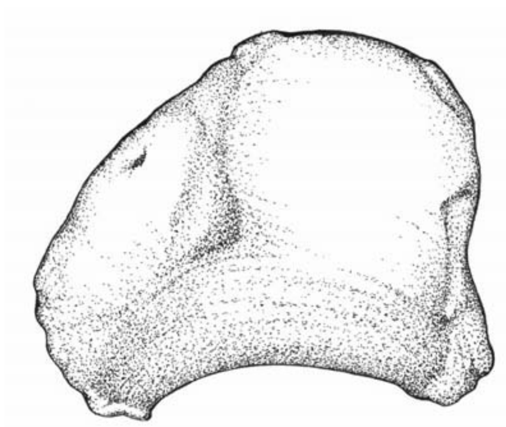
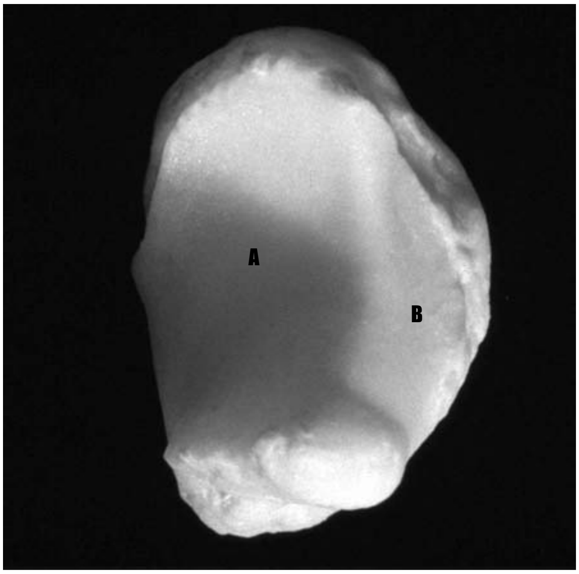
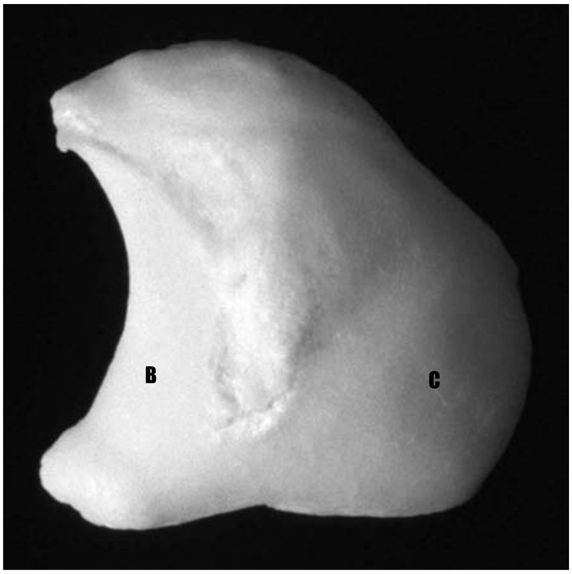
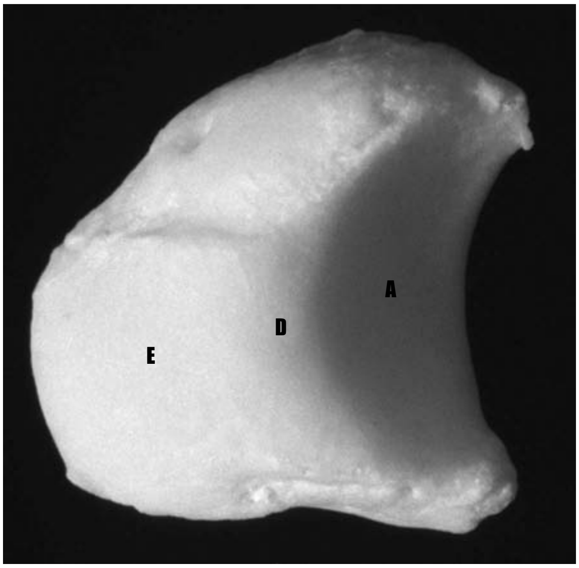


Image 5.74 • Adult right lunate.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.







Images 5.75-5.77

- **A** - facet for capitate
- **B** - facet for scaphoid
- **C** - facet for radius
- **D** - facet for hamate
- **E** - facet for triquetral

Image 5.75 (top left)
Lunate, left, view from capitate.

Image 5.76 (top right)
Lunate, left, proximal view.

Image 5.77 (bottom)
Lunate, left, distal view.

5.6a-3 TRIQUETRAL

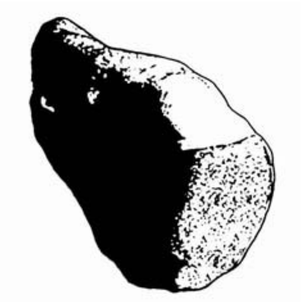


Image 5.78 • *Triquetral*.

- is the third bone of the proximal carpal row
- is medial to the lunate
- has three articular surfaces (hence ***tri***quetral), two of which meet along a common edge (hamate and lunate facets)
- articulates with lunate, pisiform and hamate

Landmarks

- facet for pisiform
- facet for hamate
- facet for lunate

*Differentiating Right from Left**

- put your thumb into the concave facet for hamate when the facet is facing you
- place your index finger onto the isolated facet for pisiform
- the facet for lunate should now be facing you if you are holding the bone in the same hand as that to which the bone belongs
- if a rough, irregular ridge is facing you, you are holding it in the wrong hand

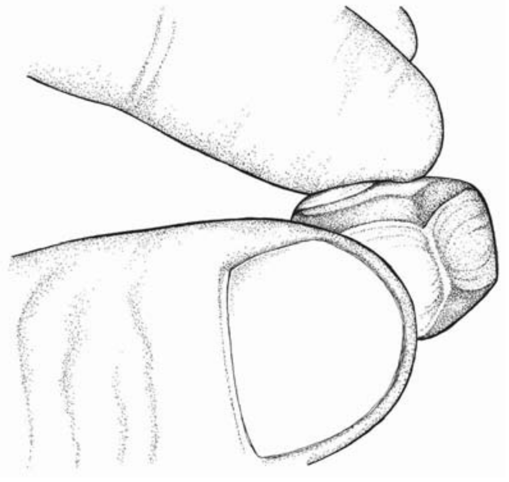


Image 5.79 • Triquetral, left.

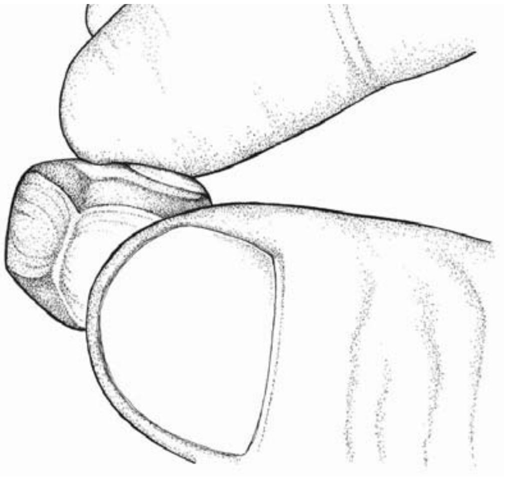


Image 5.80 • Triquetral, right.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.

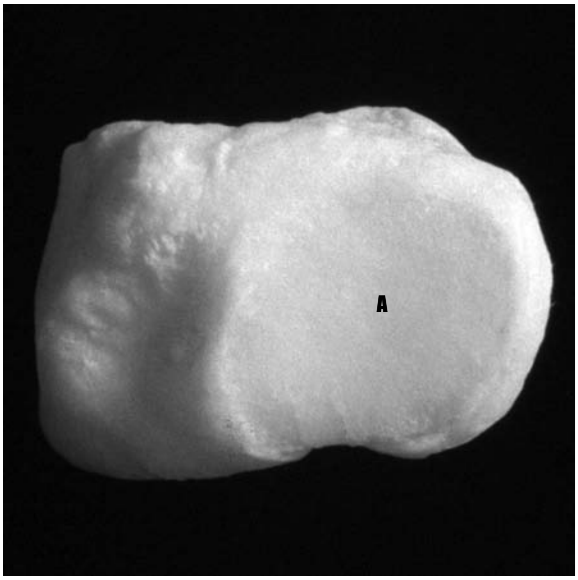


Image 5.81
Triquetral, left, dorsomedial view.

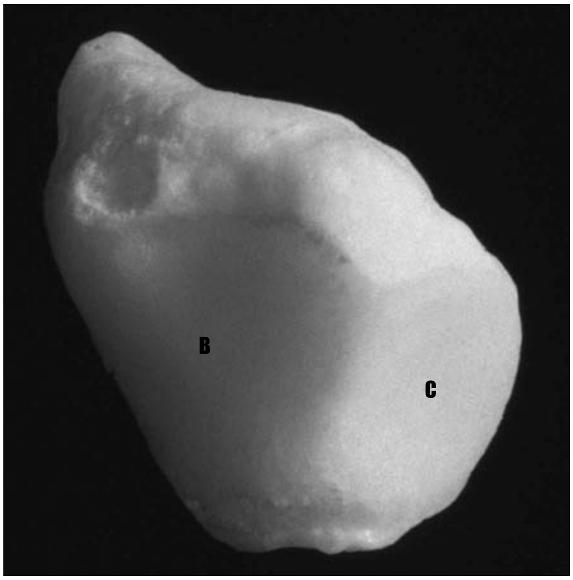


Image 5.82
Triquetral, left, palmar view.

Images 5.81 and 5.82

A - facet for pisiform
B - facet for hamate
C - facet for lunate

5.6a-4 PISIFORM

Image 5.83 • *Pisiform.*

- is the fourth bone in the proximal carpal row
- is medial to the triquetral
- has a shape remarkably similar to a small macadamia nut
- is the smallest of the carpals
- it develops within a tendon and is therefore a sesamoid bone
- articulates only with triquetral

Landmarks

- facet for triquetral
- tubercle (opposite the facet)

Differentiating Right from Left

- when oriented with the facet toward you and the tubercle downwards, the inferior most lip of the facet appears to subtly angle toward the same side as that to which the bone belongs (as pictured in **Images 5.84** and **5.85**)

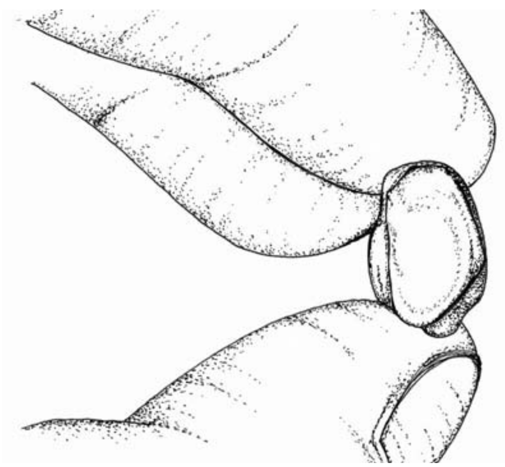


Image 5.84 • Adult left pisiform.

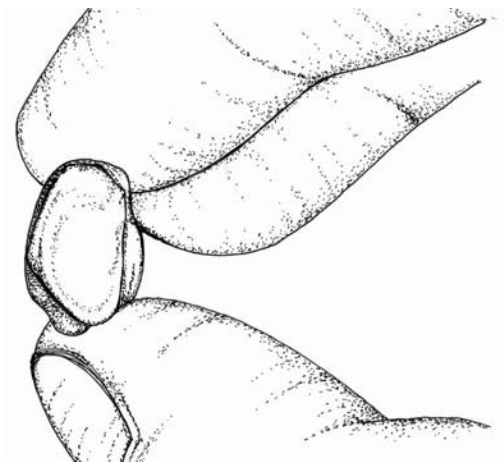


Image 5.85 • Adult right pisiform.

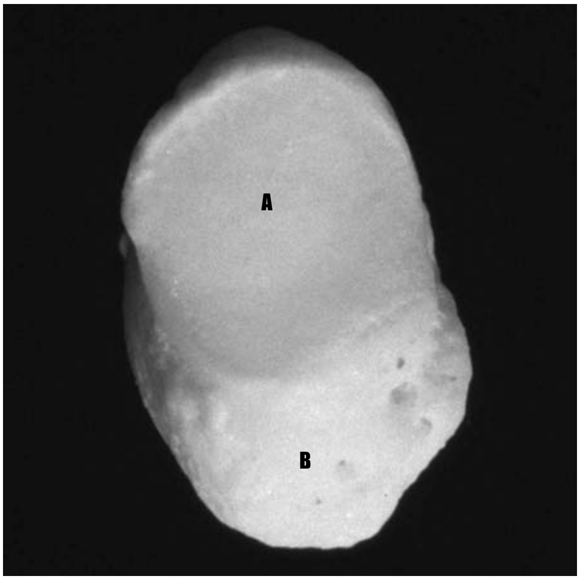


Image 5.86
Pisiform, left, medial view.

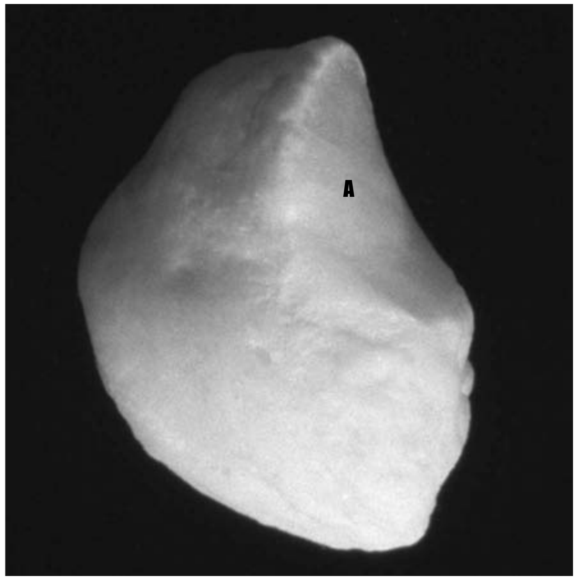


Image 5.87
Pisiform, left, palmar view.

Images 5.86 and 5.87

A - facet for triquetral
B - tubercle

5.6a-5 TRAPEZIUM

Image 5.88 • *Trapezium.*

- is the most lateral bone in the distal carpal row
- has a very irregular shape
- has a large saddle-shaped facet for metacarpal 1
- has a long crest – the palmar ridge
- has an elongated articular region (composed of three distinct yet contiguous facets) that articulates with metacarpal 2, trapezoid and scaphoid
- articulates with the metacarpals 1 and 2, scaphoid and trapezoid

Landmarks

- facet for trapezoid
- facet for scaphoid
- facet for metacarpal 1
- facet for metacarpal 2
- palmar ridge
- groove for tendon of flexor carpi radialis muscle

*Differentiating Right from Left**

- the dorsum of this bone is the flattest surface
  - place this down against the table
- the palmar ridge should now be facing away from the table (toward the ceiling, see **Images 5.89** and **5.90**)
- the metacarpal 2 facet should be facing toward you
- now, look at the palmar ridge – the groove for the tendon of the flexor carpi radialis muscle is lying either left or right of this groove
- if the groove is lying to the right of the ridge, the bone is from the right side of the body
- if the groove is lying to the left, the bone is from the left side of the body

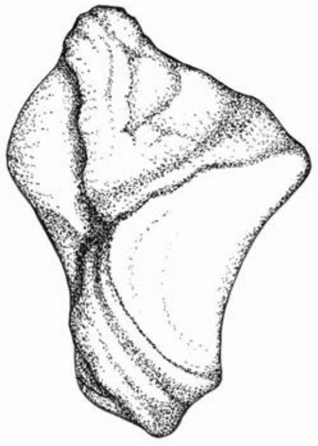


Image 5.89 • Trapezium, left.

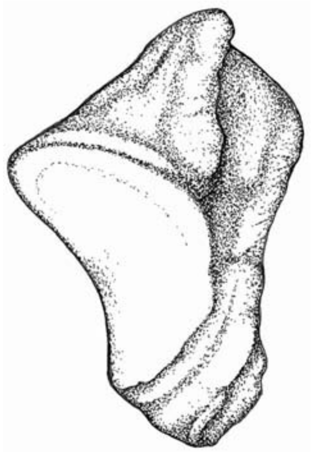
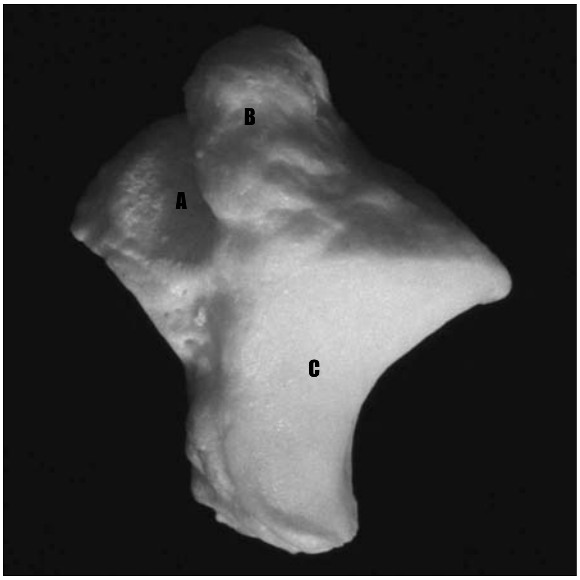
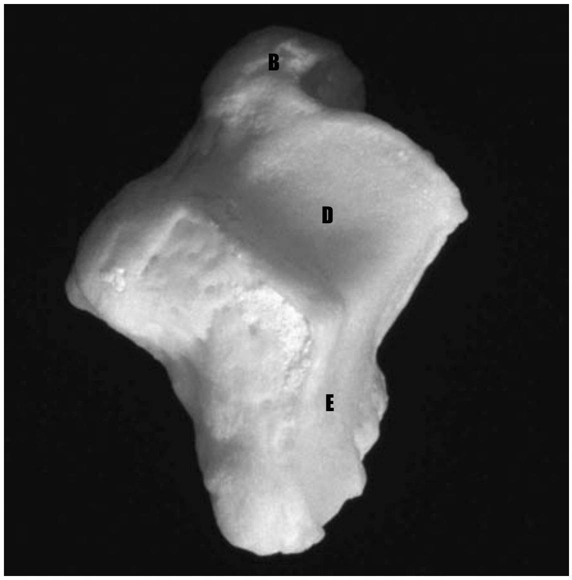
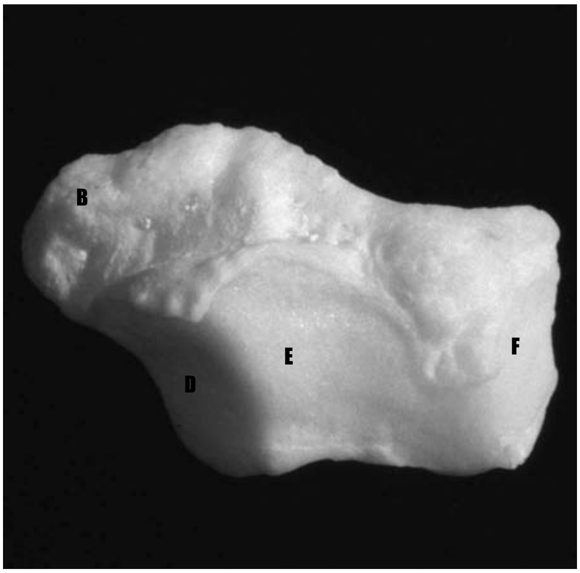


Image 5.90 • Trapezium, right.

*After: (1) Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.
(2) White T. Human Osteology. 2 ed. San Diego: Academic Press; 2000.







Images 5.91 to 5.93

A - groove for tendon of flexor carpi radialis muscle
B - palmar ridge
C - facet for metacarpal 1
D - facet for scaphoid
E - facet for trapezoid
F - facet for metacarpal 2

Image 5.91 (top left)
Trapezium, left, palmar view.
Image 5.92 (top right)
Trapezium, left, dorsal view.
Image 5.93 (bottom)
Trapezium, left, medial view.

5.6a-6 TRAPEZOID

Image 5.94 • *Trapezoid.*

- is the second bone of the distal carpal row
- is medial to the trapezium
- is shaped roughly like a *boot*
- articulates with metacarpal 2, trapezium, capitate, and scaphoid

Landmarks

- facet for trapezium
- facet for metacarpal 2
- facet for capitate
- facet for scaphoid
- trapezoid groove (non-articular; on palmar surface; may contain one or more semicircular depressions)
- dorsal non-articular surface

*Differentiating Right from Left**

- place the bone into a "boot position" with the flat non-articular dorsal surface on the tabletop and the "V-shaped" trapezoid groove toward you
- with this orientation, the toe end of the boot now points toward the same side of the body as that which the bone belongs

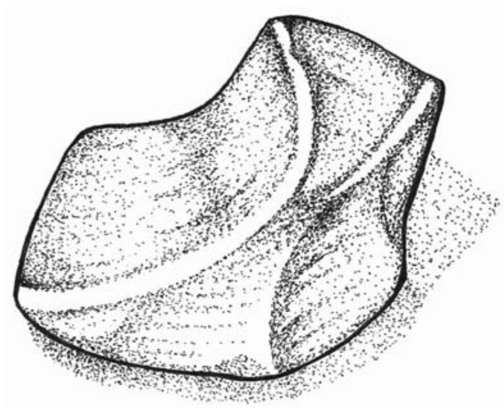


Image 5.95 • Trapezoid, left.

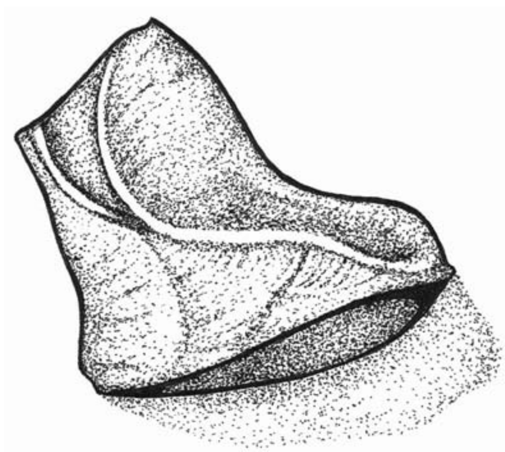


Image 5.96 • Trapezoid, right.

*After: (1) White T. Human Osteology. 2 ed. San Diego: Academic Press; 2000.
(2) Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.

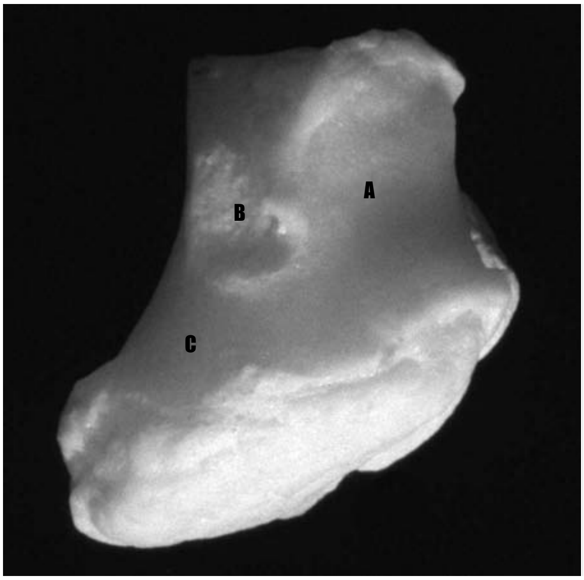


Image 5.97
Trapezoid, left, medial view.

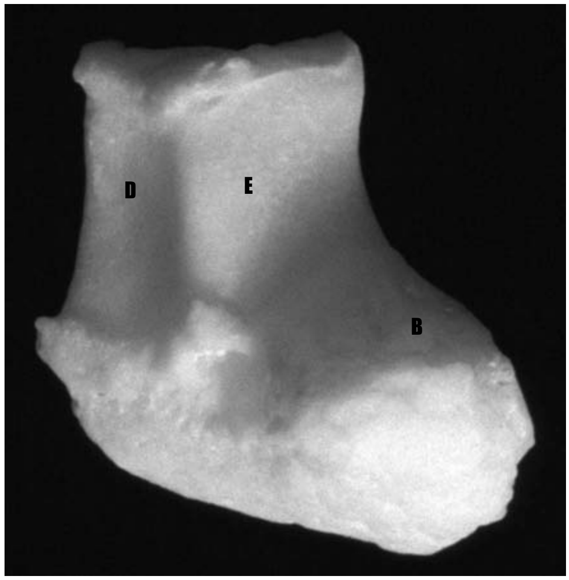


Image 5.98
Trapezoid, left, proximal view.

Images 5.97 and 5.98

A - facet for trapezium
B - trapezoid groove
C - facet for metacarpal 2
D - facet for scaphoid
E - facet for capitate

5.6a-7 CAPITATE

Image 5.99 • *Capitate.*

- is the third bone of the distal carpal row
- is lateral to the hamate
- is an irregularly shaped bone
- has a rounded proximal head that articulates with the scaphoid
- has a squared distal end (for articulation with metacarpal 3)
- articulates with metacarpals 2, 3, 4, scaphoid, lunate, trapezoid and hamate

Landmarks

- facet for lunate
- facet for hamate
- facet for metacarpal 2
- facet for metacarpal 3
- facet for metacarpal 4 (may be difficult to identify)
- facet for scaphoid
- facet for trapezoid
- capitate line (from head to base)

Differentiating Right from Left

- place the flat metacarpal 3 facet on the tabletop – the rounded head (facet for scaphoid) should now be away from the table
- place the capitate line toward you
- let go and watch the bone fall toward the same side as it originates
  - if it doesn't fall notice that in the above orientation:
    (a) the head leans toward the same side as that which the bone belongs
    (b) the capitate line travels upwards toward the same side as that which the bone belongs

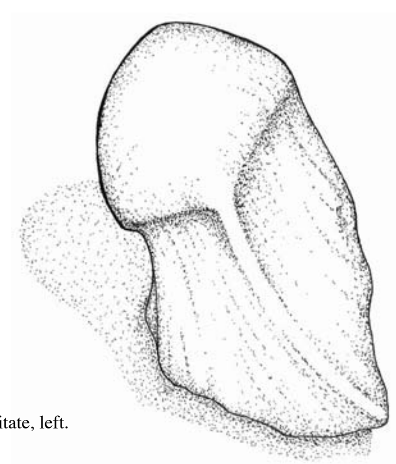


Image 5.100 • Capitate, left.

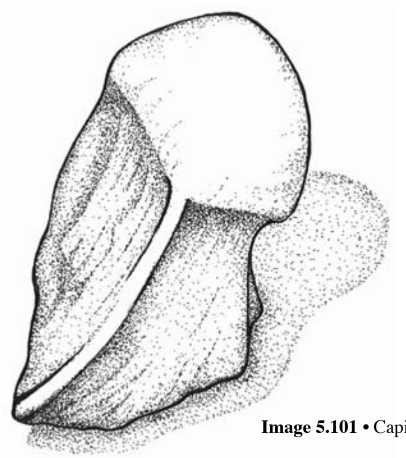


Image 5.101 • Capitate, right.

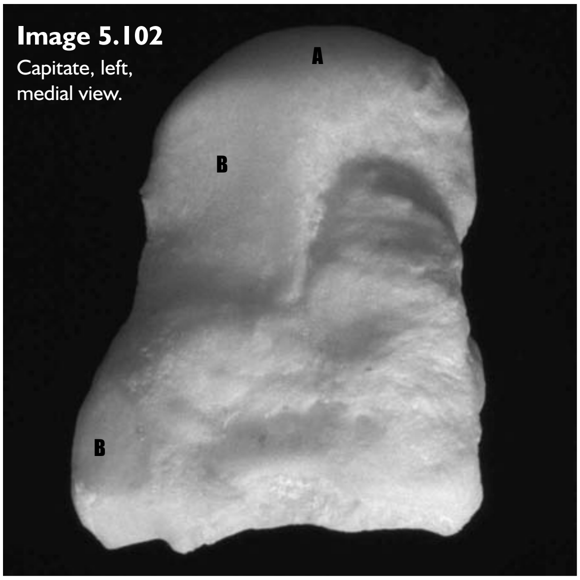


Image 5.102
Capitate, left,
medial view.

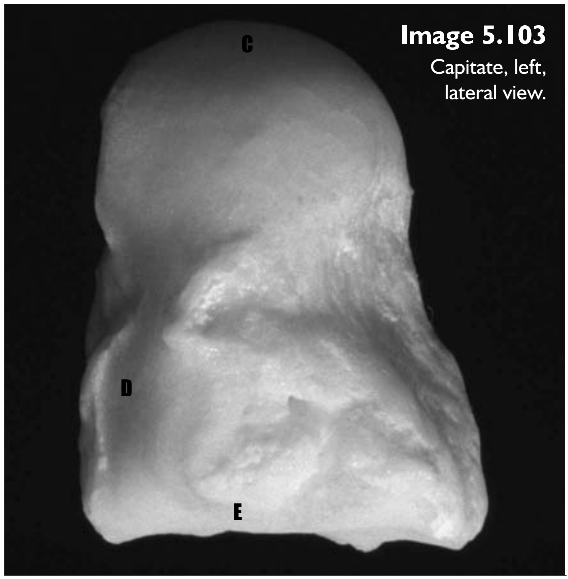


Image 5.103
Capitate, left,
lateral view.

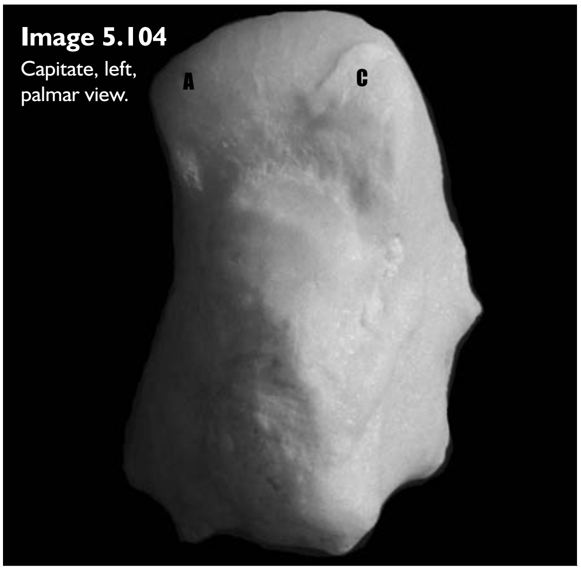


Image 5.104
Capitate, left,
palmar view.

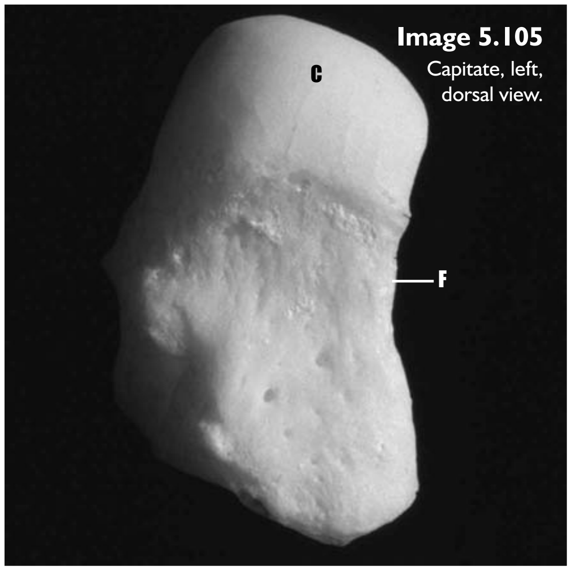


Image 5.105
Capitate, left,
dorsal view.

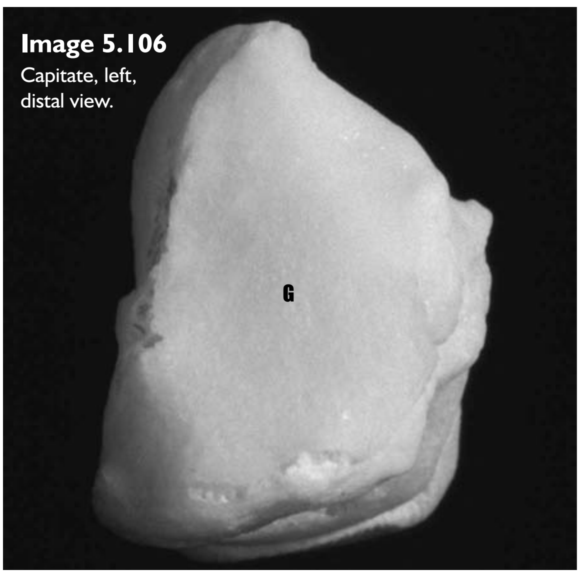


Image 5.106
Capitate, left,
distal view.

Images 5.102 to 5.106

A - facet for lunate
B - facet for hamate *(note: this facet has two separate faces)*
C - facet for scaphoid
D - facet for trapezoid
E - facet for metacarpal 2
F - capitate line
G - facet for metacarpal 3

5.6a-8 HAMATE

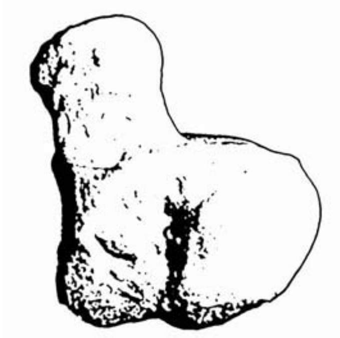


Image 5.107 • *Hamate*.

- is the fourth and most medial carpal in the distal row
- is the only metacarpal with a large palmar hook-like projection
- articulates with metacarpals 4, 5, capitate, lunate, triquetral

Landmarks

- hook of hamate
- facet for metacarpal 4
- facet for metacarpal 5
- facet for capitate
- facet for lunate
- facet for triquetral

*Differentiating Right from Left**

- place the flat, roughened, non-articular surface on the tabletop
- the hook of hamate should now be pointing away from the table (see **Images 5.108** and **5.109**)
- place the L-shaped capitate facet toward you
- the hook of hamate is now on the same side of the bone as that to which the bone belongs

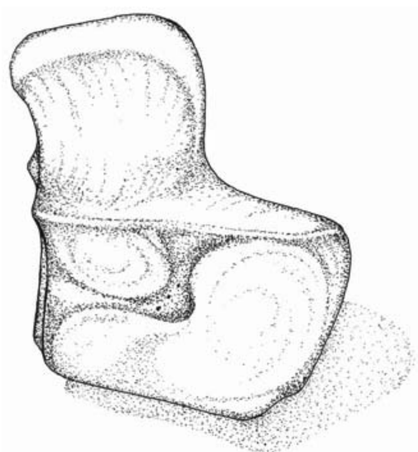


Image 5.108 • Hamate, left.

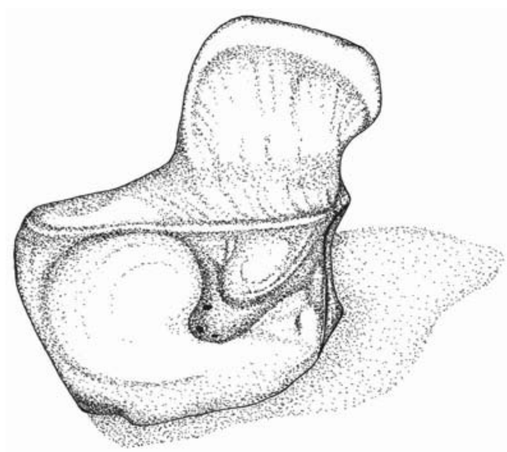
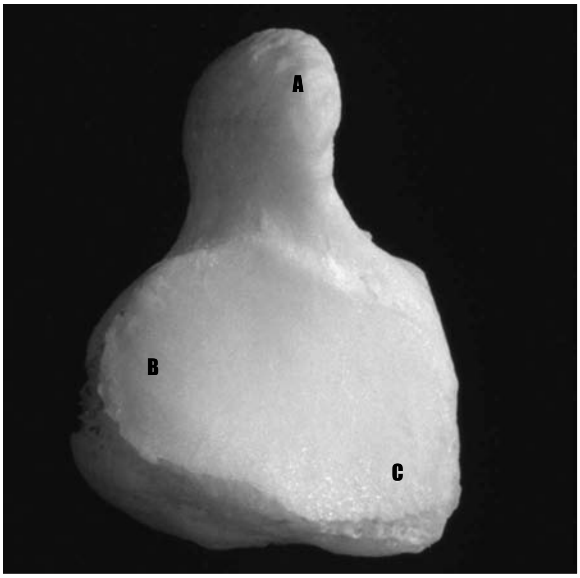
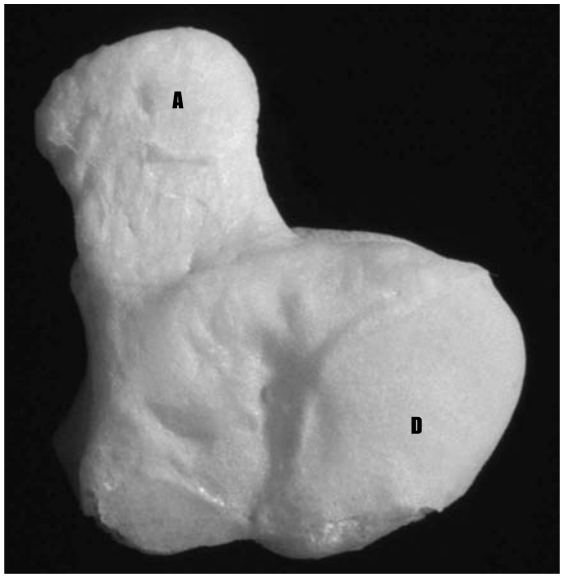
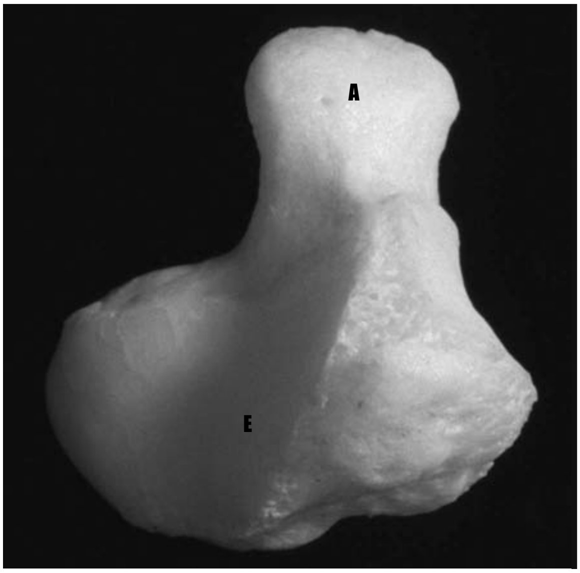


Image 5.109 • Hamate, right.

*After: (1) White T. Human Osteology. 2 ed. San Diego: Academic Press; 2000.
(2) Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.







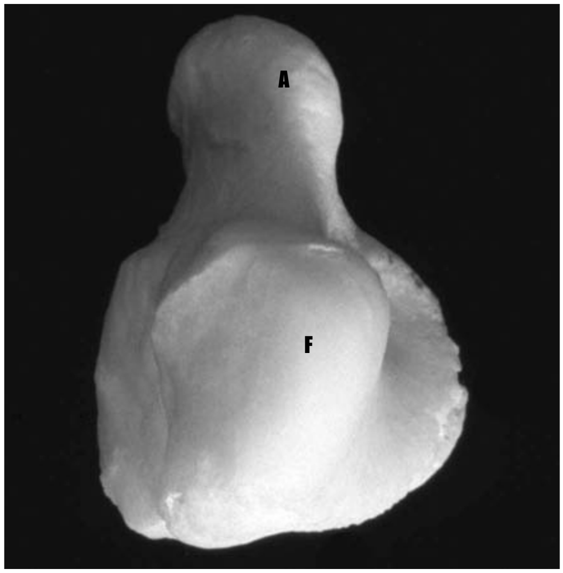


Image 5.110
Hamate, left, distal view.

Image 5.112
Hamate, left, medial view.

Image 5.111
Hamate, left, lateral view.

Image 5.113
Hamate, left, proximal view.

Images 5.110 to 5.113

A - hook of hamate
B - facet for metacarpal 5
C - facet for metacarpal 4
D - facet for capitate
E - facet for triquetral
F - facet for lunate

5.6b METACARPALS

- the metacarpals (of the hand) are homologous to the metatarsals (of the foot)
- there are five metacarpals, numbered 1 - 5, with metacarpal 1 being the thumb
- all are tubular bones
  - they have thin shafts that separate the angular bases (proximal ends) from the round heads (distal ends)
  - the palmar surface is concave
- each bone is identified and sided mostly based on the appearance of the proximal end
- note that metacarpals and metatarsals differ significantly in their appearance
  - for example, metacarpal heads are much rounder and bulbous than metatarsal heads, and metatarsal shafts are much longer and thinner than those of metacarpals
- the bases of metacarpals 2 through 5 articulate with their neighboring metacarpals
- furthermore, trapezium articulates with metacarpal 1 and 2; trapezoid with metacarpal 2; capitate with metacarpal 2, 3 and possibly 4; hamate with metacarpal 4 and 5
- note that the heads articulate with the proximal row of phalanges

Landmarks

- head
- base (you will need to memorize the characteristic appearance of each base to be able to properly identify these bones when isolated)
- shaft

Image 5.114
Hand, left, metacarpals, dorsal view.
Metacarpals 1 through 5 are presented right to left.

Image 5.115

Adult patient, plain film radiograph, oblique view of hand.

A - terminal phalanges; **B** - intermediate phalanges; **C** - proximal phalanges; **D** - metacarpals I-V.

5.6b-1 METACARPAL 1

Image 5.116 • *First metacarpal.*

- is the most lateral metacarpal
- is the shortest but most robust of the metacarpals
- articulates with the trapezium and proximal first phalanx

Landmarks

- facet with articular surface for trapezium
- head (for the proximal phalanx)

Differentiating Right from Left

- if intact: hold the shaft so that the proximal end is facing you (i.e., you are facing the trapezium facet)
  - the facet appears to slant toward the same side of the body as that to which the bone belongs
- if fragmented: pieces of proximal metacarpal 1 can be identified as above; keep in mind,
  - on the palmar surface at the distal end are two nodular eminences along which muscle tendons run during life
    - the most prominent nodule is on the same side of the bone as that to which the bone belongs (when oriented as in **Image 5.121**)
  - the proximal end has a characteristic appearance – study it.

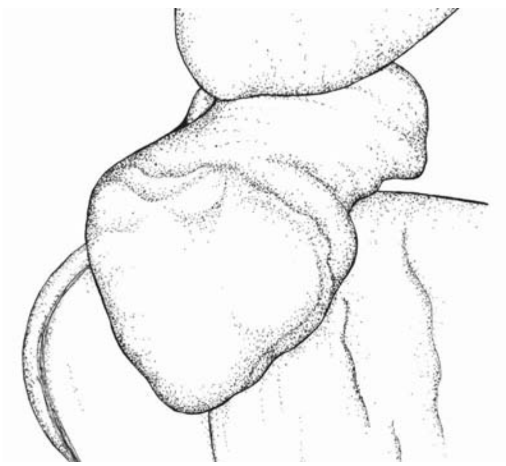


Image 5.117 • First metacarpal, left, proximal end.

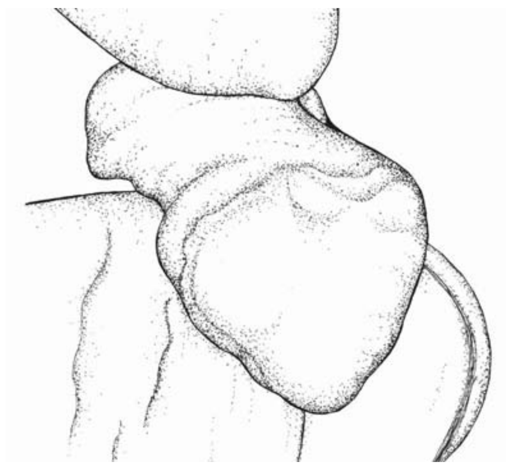
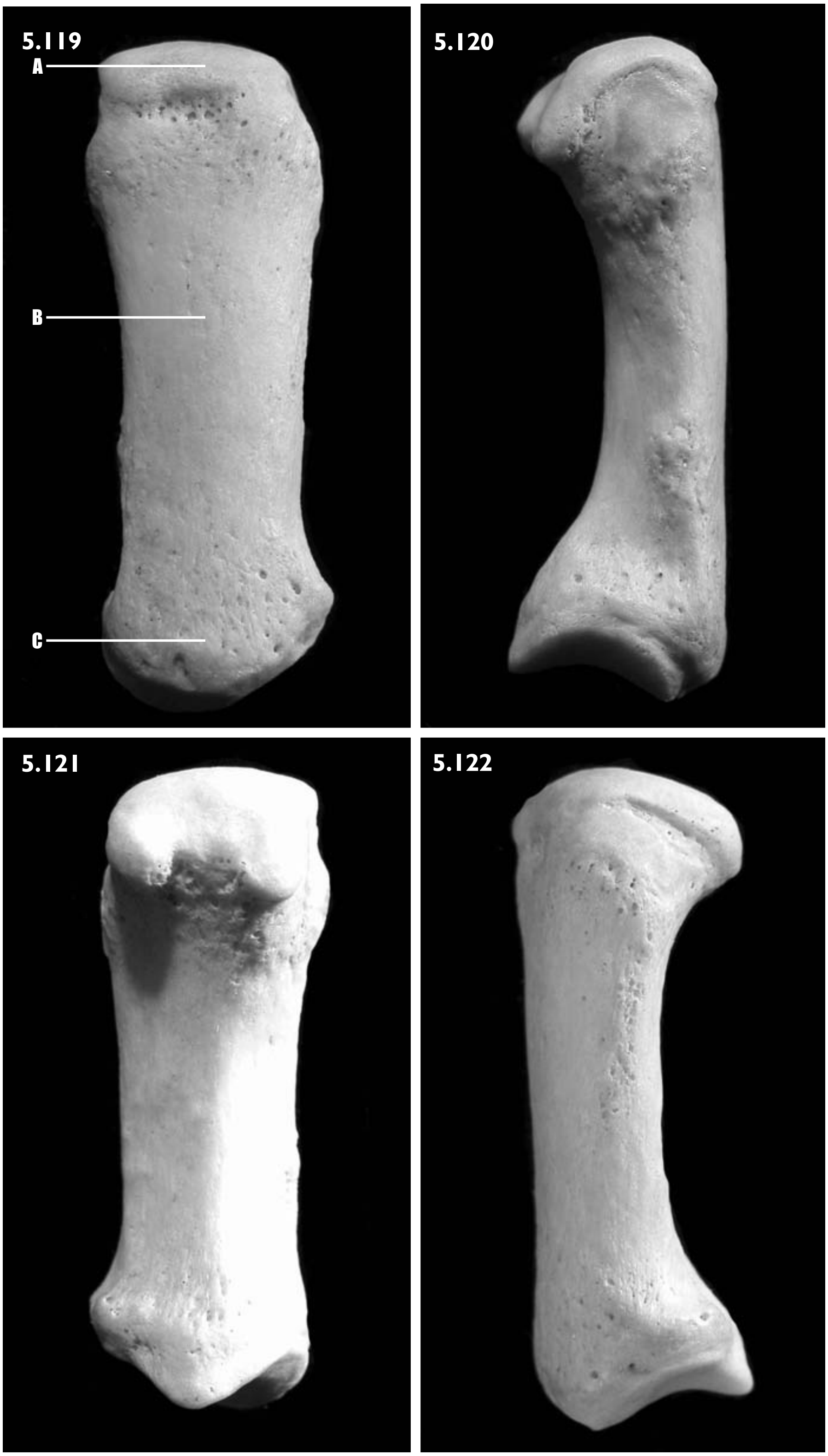


Image 5.118 • First metacarpal, right, proximal end.



Images 5.119 to 5.122 • First metacarpal, left (dorsal, lateral, palmar and medial views, respectively).
A - head, **B** - shaft, **C** - base.

5.6b-2 METACARPAL 2

Image 5.123 • *Second metacarpal.*

- is medial to metacarpal 1
- is the longest metacarpal
- is the only metacarpal with a wedge-shaped base
  - i.e., when viewed dorsally, it appears as if someone has removed a small triangular piece of bone from the base
- articulates with metacarpal 3, trapezium, trapezoid, capitate, proximal phalanx

Landmarks

- facet for metacarpal 3
- facet for trapezium
- facet for trapezoid
- facet for capitate
- metacarpal 2 ridge
- head with articular surface for proximal phalanx

Differentiating Right from Left

- hold the bone as pictured in **Images 5.124** and **5.125** with the head facing up and the base facing down
- the divot-shaped base will appear to slant off more toward the same side as that to which the bone belongs
- only the lateral edge of the base bears a large articular facet; therefore, when oriented as in **Image 5.126** with the head up, base down and dorsum toward you, the facet will be on the same side as that to which the bone belongs
- on the palmar surface at the distal end are two nodular eminences along which muscle tendons run during life
  - the most prominent nodule is on the same side of the bone as that to which the bone belongs (when oriented as in **Image 5.128**)
- also, the metacarpal ridge can be appreciated to progress obliquely from medial to lateral, beginning on the same side of the head as that to which the bone belongs

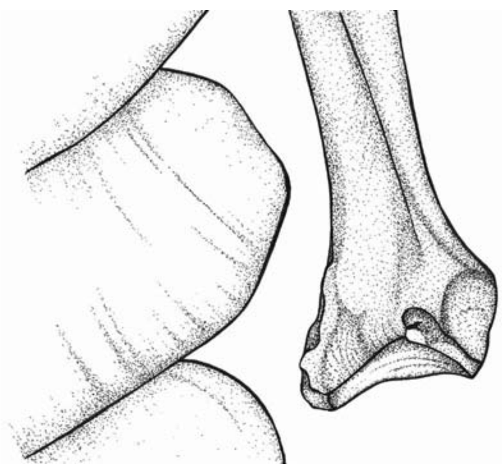


Image 5.124 • Second metacarpal, left.

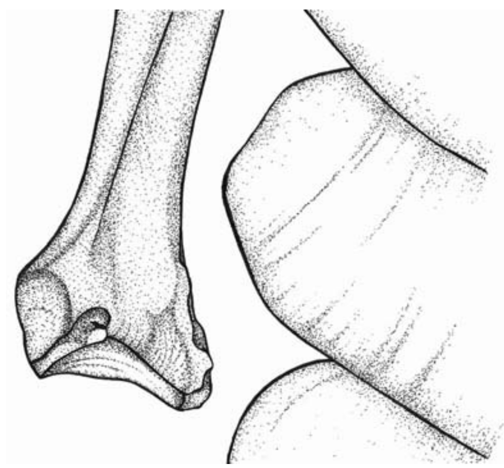


Image 5.125 • Second metacarpal, right.

Images 5.126 to 5.129 • Second metacarpal, left (dorsal, lateral, palmar and medial views, respectively).
A - metacarpal 2 ridge, **B** - facet for metacarpal 3, **C** - tubercle, **D** - facet for trapezium, **E** - facet for capitate.

5.6b-3 METACARPAL 3

Image 5.130 • *Third metacarpal*.

- is medial to metacarpal 2
- is unique amongst metacarpals because of the styloid process found at its base
- articulates with metacarpals 2 and 4, capitate, proximal phalanx

Landmarks

- facet for metacarpal 2
- facet for metacarpal 4
- facet for capitate
- styloid process
- facet for proximal phalanx

Differentiating Right from Left

- hold the bone as pictured in **Images 5.131** and **5.132** with the head facing up and the base facing down
  - the dorsum should be facing you
  - in this orientation the styloid process is on the side opposite that to which the bone belongs
- if fragmented: use the above principles to identify fragments from the base, and keep in mind:
  - an obliquely oriented ridge may be found on the dorsal shaft, but, in a study of twenty-five skeletonized hands, these ridges were found to be inconstant and varied as to which side they were on
  - one might have more success with isolated shafts by recognizing that the metacarpal 3 shaft, when oriented with the dorsal surface toward you (as oriented in **Image 5.133**), has a relatively flat (lateral) edge on the same side as that to which it belongs
  - like metacarpal 1 and 2, the palmar surface of the distal end bears two small nodules along which muscle tendons are found in life
  - although it is often true that the largest or most prominent nodular eminence is on the same side of the bone as that which the bone belongs (when oriented as in **Image 5.135**), this feature is less reliable in metacarpal 3, as illustrated by our example (**Image 5.135**)

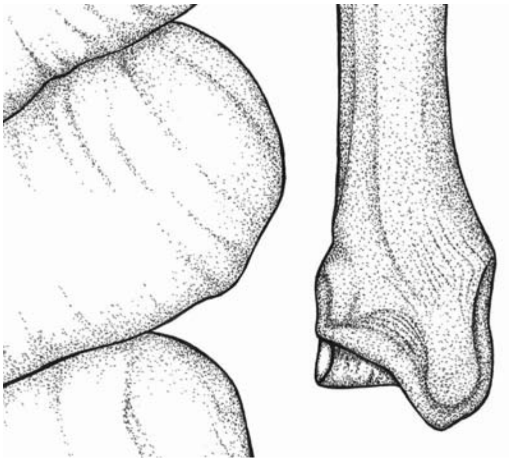


Image 5.131 • Third metacarpal, left.

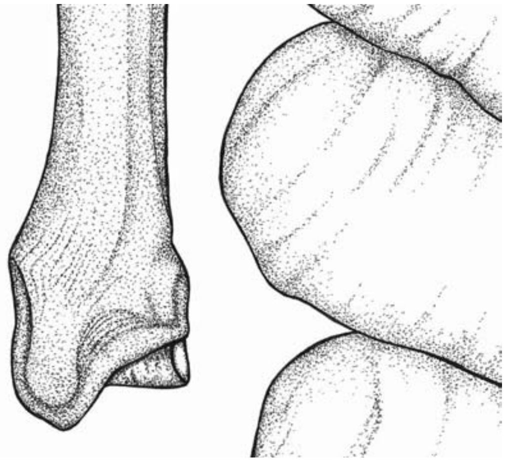
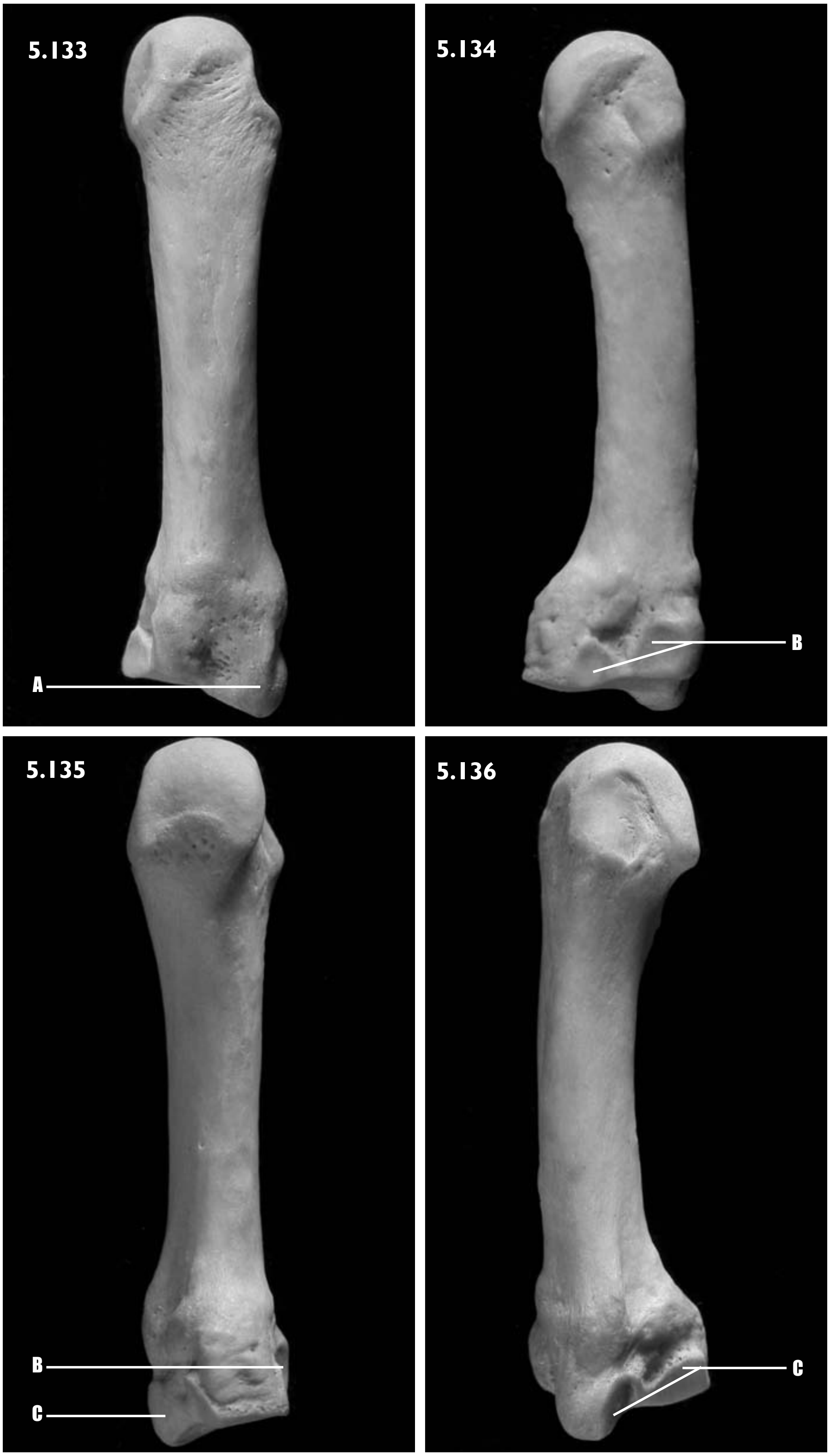


Image 5.132 • Third metacarpal, right.



Images 5.133 to 5.136 • Third metacarpal, left (dorsal, lateral, palmar and medial views, respectively).
A - styloid process, **B** - facet for fourth metacarpal, **C** - facet for second metacarpal.

5.6b-4 METACARPAL 4

Image 5.137 • *Fourth metacarpal.*

- is medial to metacarpal 3
- is shorter and more gracile than metacarpal 2 or 3
- the proximal shaft appears to bend or twist obliquely
- articulates with metacarpals 3 and 5, hamate and proximal phalanx

Landmarks

- facet for metacarpal 3
- facet for metacarpal 5
- facet for hamate
- ridge on shaft
- head for articulation with proximal phalanx

Differentiating Right from Left

- if oriented as in **Images 5.138** and **5.139** with the dorsal surface toward you, head up, and base down, the base is "bent toward" the same side as that which the bone belongs
- if fragmented: like metacarpal 2, the dorsal surface of the shaft bears a groove that runs obliquely from head to base, ending on the same side of the bone as that to which the bone belongs

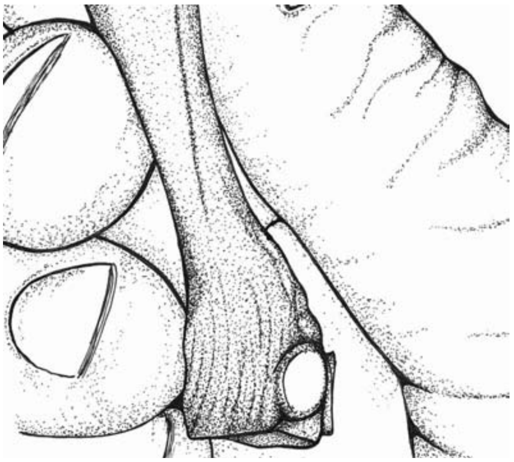


Image 5.138 • Fourth metacarpal, left.

Image 5.139 • Fourth metacarpal, right.

Images 5.140 to 5.143 • Fourth metacarpal, left (dorsal, lateral, palmar and medial views, respectively).
A - metacarpal ridge, **B** - facet for fifth metacarpal, **C** - facet for third metacarpal.

5.6b-5 METACARPAL 5

Image 5.144 • *Fifth metacarpal.*

- is the thinnest and shortest of the metacarpal bones
- because it is the most medial of the metacarpal bones, it bears only one articular (side) edge
- articulates with metacarpal 4, hamate and proximal phalanx

Landmarks

- facet for metacarpal 4
- facet for hamate
- head with articular facet for proximal phalanx

Differentiating Right from Left

- is easily determined when oriented as in **Image 5.145 and 5.146** with the dorsum toward you, head up and base down
  - here, the non-articular edge can be found on the same side of the bone as that to which the bone belongs
- if fragmented: like metacarpals 2 and 4, an obliquely oriented linear ridge may be found on the dorsal surface of the shaft
  - this runs from head to base, ending on the same side of the bone as that to which the bone belongs

Image 5.145 • Fifth metacarpal, left.

Image 5.146 • Fifth metacarpal, right.

Images 5.147 to 5.150 • Fifth metacarpal, left (dorsal, lateral, palmar and medial views, respectively).
A - rough metacarpal ridge, **B** - rough non-articular edge, **C** - facet for hamate, **D** - facet for fourth metacarpal.

5.6c HAND PHALANGES

Image 5.151 • *Distal hand phalanx.*

- there are fourteen phalanges in each hand, divided between three rows (proximal, intermediate and distal)
  - each digit has three phalanges, with the exception of the thumb, which has two
- the first row has five (proximal) phalanges
- the second row has four (intermediate) phalanges
- the third row has five (distal) phalanges

Row 1
- these phalanges have a large concave (proximal) articular surface for the rounded metacarpal heads
- the distal articular surface has a smooth, round articular surface that bears a groove
  - this groove allows for proper articulation with the angular proximal end of an intermediate phalanx

Rows 2 and 3
- as mentioned, the proximal ends of the intermediate phalanges (row 2) are angular, allowing for articulation with the distal ends of the proximal phalanges
- the distal articular surface has a smooth, round articular surface that is somewhat "pinched" in the midline
- the proximal phalanges (row 3) have a characteristic appearance because of their tapered fingertip-like distal ends

Landmarks
- shaft
- distal end
- proximal end

Determining Right from Left
- extremely difficult to differentiate

Important to Notice
- you must be able to differentiate between hand and foot phalanges
- the phalanges of hand digits two through five are larger than those of the foot
- the two phalanges of the great toe are larger than any hand phalanx
- mid-shaft cross-sections of foot phalanges tend to be round (**Image 5.152**), and those from the hand tend to be flat on the palmar surface (**Image 5.153**)

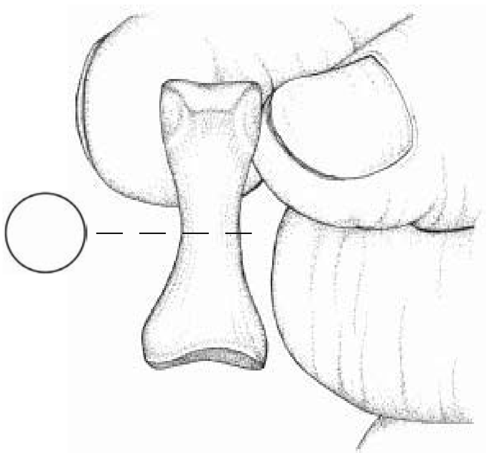
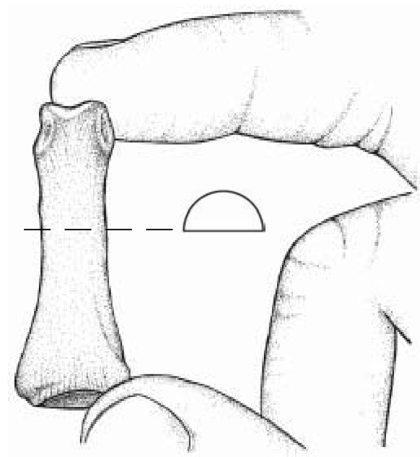


Image 5.152 *(left)* • Proximal hand phalanx.
Image 5.153 *(right)* • Proximal foot phalanx.



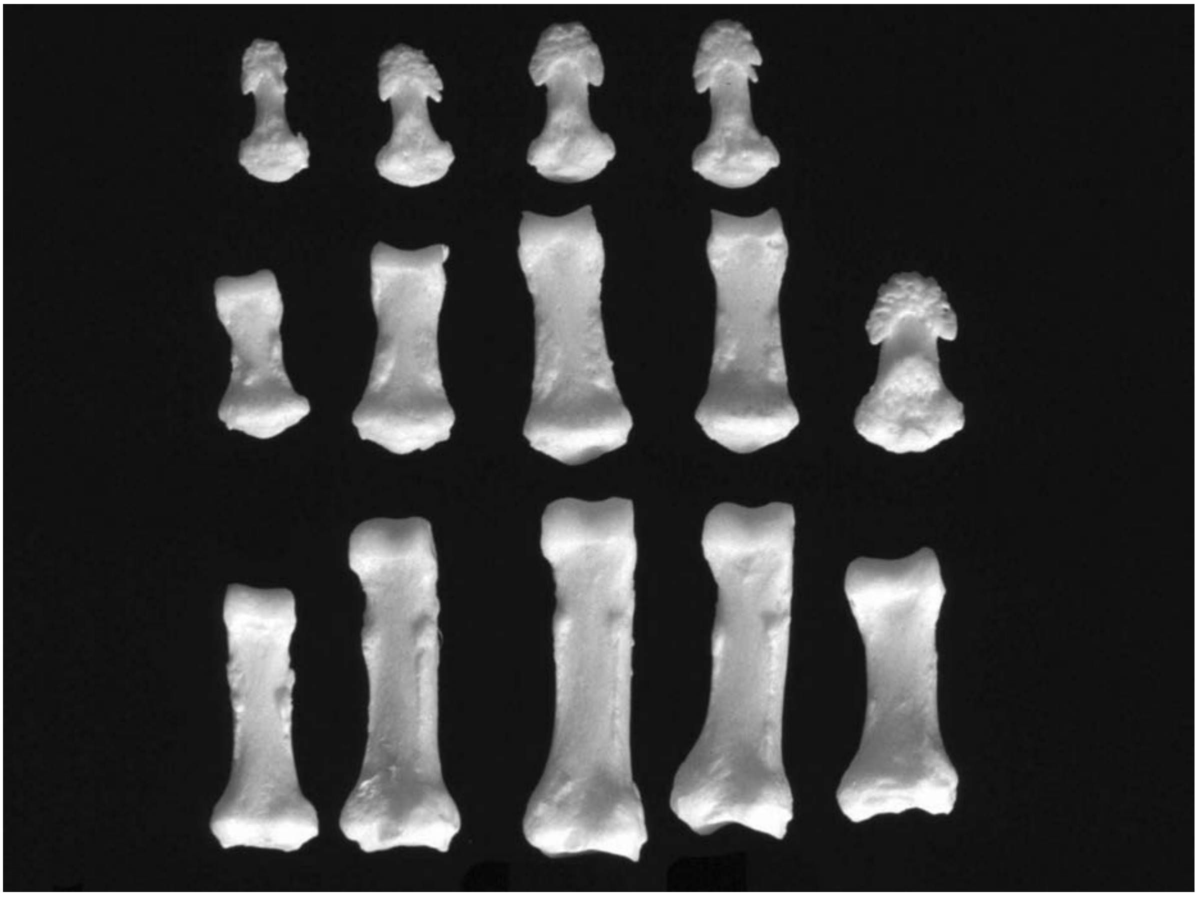


Image 5.154
Hand phalanges, dorsal view.

Image 5.155
Hand phalanges, palmar view.

Image 5.156

A - phalanges

B - metacarpophalangeal joint space

C - metacarpal head

Image 5.156
Adult patient, plain film radiograph of hand, anteroposterior view of fingers.

Image 5.157
Adult patient, plain film radiograph of hand, lateral view of finger.

Image 5.157

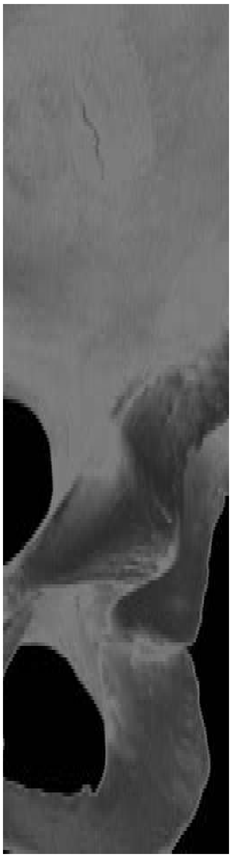
- **A** - phalanges
- **B** - metacarpophalangeal joint space
- **C** - head of second metacarpal
- **D** - head of third metacarpal

Image 5.158

Adult patient, plain film radiograph of hand, anteroposterior view of thumb.

Image 5.158

A - phalanges
B - sesamoid bone
C - metacarpal I
D - metacarpotrapezium joint
E - trapezium
F - scaphoid
G - neck of scaphoid
H - radial styloid process



Chapter Six

The Pelvis

The pelvis is comprised of the right and left ossa coxae (innominate bones), as well as the previously mentioned sacrum and coccyx. Developmentally, each ossa coxae is comprised of three basic elements: the ilium, ischium and pubis (see **Image 6.20**) which unite together by adulthood. We do, however, still refer to these respective areas with the same names. For example, the *ischial* tuberosity, or superior *pubic* ramus.

The pelvis has been regarded as the most reliable bony structure for determining the sex of a specimen as the function of the female pelvis in reproduction and parturition is so very different from that of the male. Examine our very basic introduction to pelvic sexual dimorphism on *pages 328-331*; then try to determine the sex of your study specimen.

6.1 PELVIC GIRDLE

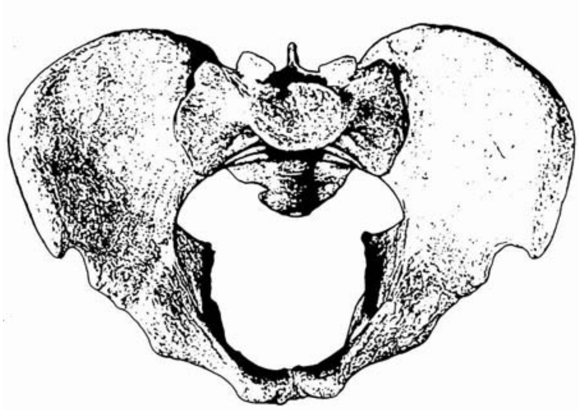


Image 6.1 • *Pelvis.*

- is formed by the union of two innominate bones with the sacrum and coccyx (tailbone)
- is the junction between the trunk and lower limbs
- divided into the greater (false) and lesser (true) pelvis by an oblique plane whose circumference is called the pelvic brim
  - this brim starts at the sacral promontory and runs around to the superior margin of the pubic symphysis
- the <u>false pelvis</u> lies above this plane and is bounded on either side by the blades of the ilium, and in life, by the muscular abdominal wall
  - this contains some of the abdominal organs
- the <u>true pelvis</u> lies below the pelvic brim and is bounded by the sacrum and coccyx, on either side by the innominates, by the bony pubic region, and by fascia, musculature and other soft tissues in life
  - this contains the pelvic part of the colon, urinary bladder, and some of the reproductive organs
- the true pelvis has a pelvic *inlet* superiorly, and a pelvic *outlet* inferiorly

Sexual Dimorphism

- there are a number of differences between the male and female pelves and these differences are all related to adaptations in the female for giving birth – since the baby must pass through the pelvis, these adaptations involve the relative sizes of the pelvic cavity, as well as its inlet and outlet
- the typical female pelvis is adapted to have an increase in the caliber of both the pelvic inlet and outlet
- one of the ways in which this is accomplished is through a widening of the sacral body; this results in an inlet that is more ovally shaped than the heart-shaped inlet seen in males, a fact that may provide some assistance when attempting to determine the sex of an unknown specimen
- the size of the pelvic outlet can be increased by pushing the ischial tuberosities laterally
  - this has the additional effect of greatly increasing the subpubic angle (see **Images 6.7** and **6.8**); this is another indicator of sex: in males, this is generally seventy degrees, while in females, it is ninety
  - another way to increase the size of the pelvic outlet is to move the ischial tuberosities forwards, increasing the outlet's size in the anteroposterior dimension
  - the consequence of this is a change in the greater sciatic notch from being a sharp-angled, deep notch in males, to a broad-angled shallow notch in females
  - there are a number of other differences between typically male and female pelves, for example, the bones of the male are generally more robust, and demonstrate stronger muscular impressions than the bones of the female
  - this difference is markedly affected by the population one is examining as certain groups exhibit fewer sexually dimorphic traits
  - some of the pelves that you will be examining may exhibit ambiguities with respect to sexual characteristics, and it may be difficult to assign a sex to a given pelvis
  - this should not surprise you as a look around any given classroom shows a wide range in variation of human form
- when assigning sex to any skeletal specimen, one can only speak of probabilities, and rarely of certainty

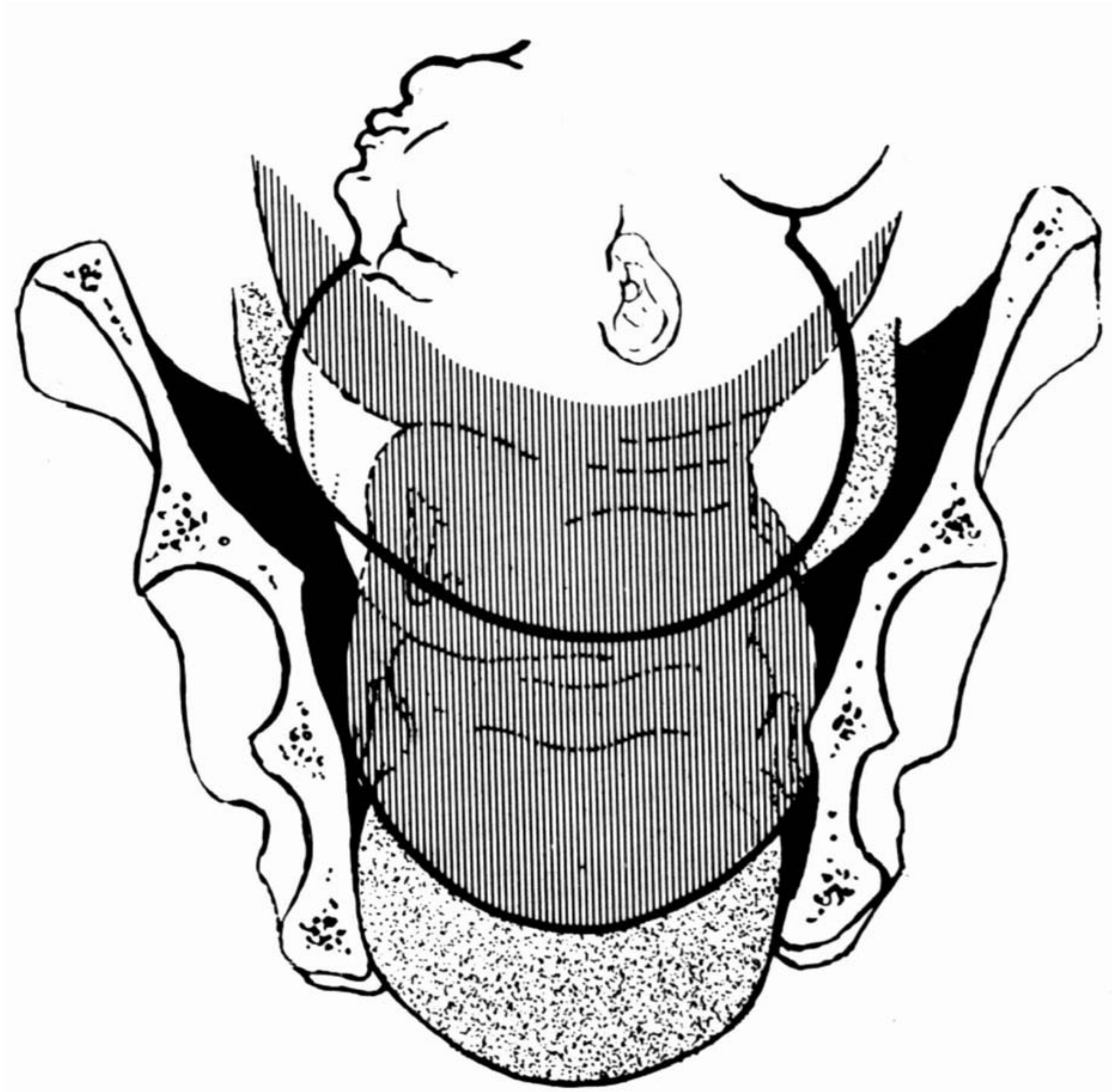


Image 6.2

Adult female bony pelvic anatomy in relationship to the fetal head as it passes through the pelvic outlet.

From Anatomy: A Regional Study of Human Structure by W.B. Saunders. Reprinted with permission of Butterworth-Heinemann.

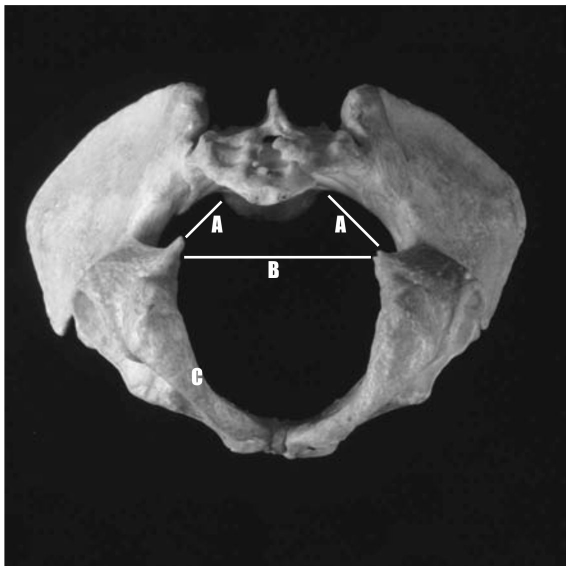


Image 6.3 (above)

Female pelvis, articulated, superior view of pelvic inlet.
Both the sciatic notches (**A**) and distances between the ischial spines (**B**) are comparatively greater than those found in males (see **Image 6.4**).

Image 6.5 (below)

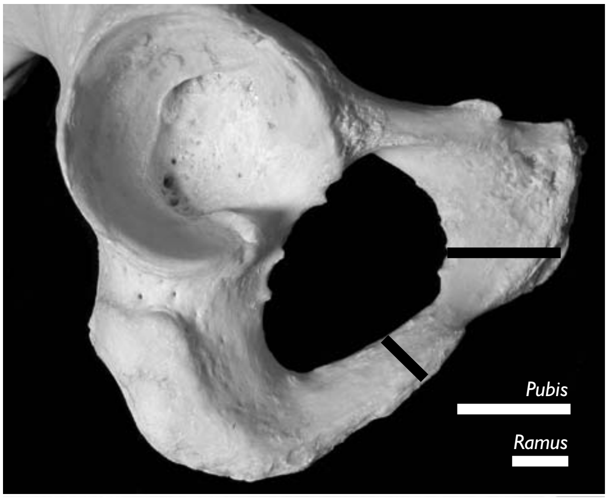
Female pelvis, articulated, inferior view of pelvic outlet.
Note sexually dimorphic traits similar to those indicated in **Image 6.3**. Additionally, notice that the inferior pubic rami (**C**) tend to be longer and thinner in females, with the converse found in males.

Image 6.4 (above)

Male pelvis, articulated, superior view.
Compare labels A and B with those found in **Image 6.3**. Here, the inlet has somewhat of a heart-shape. Compare this with the oval inlet of the female pelvis in **Image 6.3**.

Image 6.6 (below)

Male pelvis, articulated, inferior view.



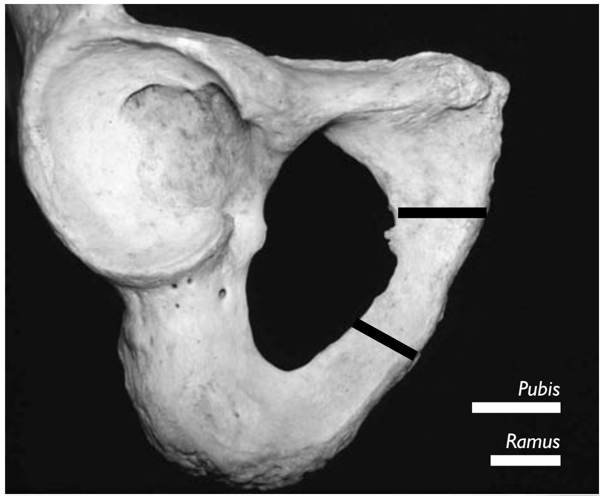


Image 6.7 (above)

Female pelvis, anterolateral view of pubic region.
Notice how wide the pubis appears, when compared to the width of the inferior pubic ramus. The ***pubis:inferior pubic ramus*** ratio in females is generally 1.5:1 or greater. To help visualize this ratio, black lines have been superimposed over the specimens.

Image 6.9 (below)

Female pelvis, medial view of sciatic notch and sacral articular facet.
The female sciatic notch is generally much wider than that found in males. A preauricular sulcus (A) may be noted just anterior to the auricular surface for the sacrum. This is seen more often in female innominate bones than males.

Image 6.8 (above)

Male pelvis, anterolateral view of pubic region.
Notice that the width of the pubis is essentially the same as the width of the inferior pubic ramus. The ***pubis:inferior pubic ramus*** ratio in males is generally 1:1.

Image 6.10 (below)

Male pelvis, medial view of sciatic notch and sacral articular facet.
The male sciatic notch is generally much narrower than that found in females.

6.1a INNOMINATE

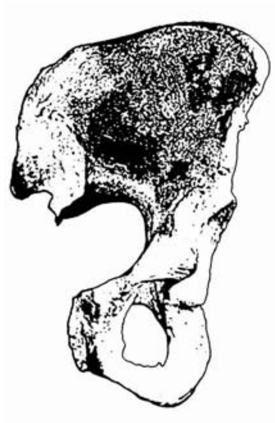


Image 6.11 • *Innominate*.

- large, irregular, blade-shaped bone
- is formed from three separate bones: ilium, ischium, and pubis (see **Image 6.20**)
  - in early adolescence these bones begin to fuse
- the ilium is the large, winglike region of the innominate
- the ischium is a (roughly) C-shaped area of dense bone that makes up the most inferior aspect of innominate
  - one of its functions is to support us while sitting
- the pubis is a relatively flat bone that forms the medial-most aspect of the hip bone
- the adult innominate is the most sexually dimorphic bone in humans (see pages 328 through 331)
- the innominate articulates with the sacrum (sacroiliac joint), with the opposing innominate (pubic symphysis), and with the femur (acetabulum)

FUNCTION

The pelvis is a rough and dense bony framework that houses and protects multiple important structures including the internal organs of reproduction, as well as many important blood vessels and nerves.

Image 6.12 • Oblique view of pelvis. * Marks anterior portion of iliac crest.

Landmarks

- iliac tuberosity
- iliac wing
- iliac crest
- ala of ilium
- pectineal line
- pectin pubis
- anterior superior iliac spine
- anterior inferior iliac spine
- pubis
- posterior superior iliac spine
- posterior inferior iliac spine
- arcuate line
- auricular surface
- iliopubic eminence
- obturator foramen
- pubic tubercle
- symphyseal surface

Landmarks continued

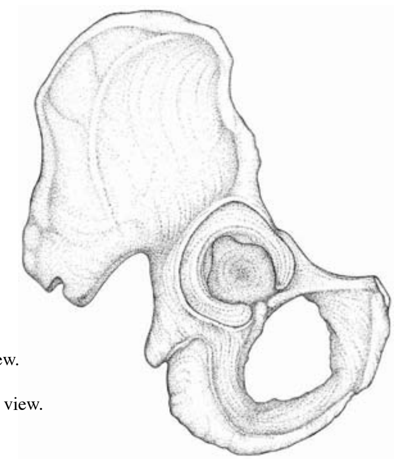
- obturator groove
- acetabulum
- acetabular articular surface
- acetabular notch
- acetabular non-articular surface
- ischial spine
- ischial tuberosity
- anterior gluteal line
- inferior gluteal line
- middle gluteal line
- greater sciatic notch
- lesser sciatic notch
- superior pubic ramus
- inferior pubic ramus

Differentiating Right from Left

- place the innominate toward you with the iliac wing (blade) upward, and the ischium down as pictured in **Images 6.13** and **6.14**
- the pubis is now pointing toward the same side as that to which the bone belongs

Image 6.13 (left) • Innominate, left, lateral view.

Image 6.14 (right) • Innominate, right, lateral view.



Looking at Fragments

- fragmented ilium can be confused with fragmented portions of skull and scapula, however, the body of the scapula tends to be much thinner and more irregular in texture than the ilium
  - also, keep in mind that fragments of ilium may bear rough gluteal lines
- to help you differentiate fragments of skull from those of scapula and innominate, look for sutures, diploë (see **Image 5.12**), vascular grooves, granular foveolae, etc. which are present on some skull bones

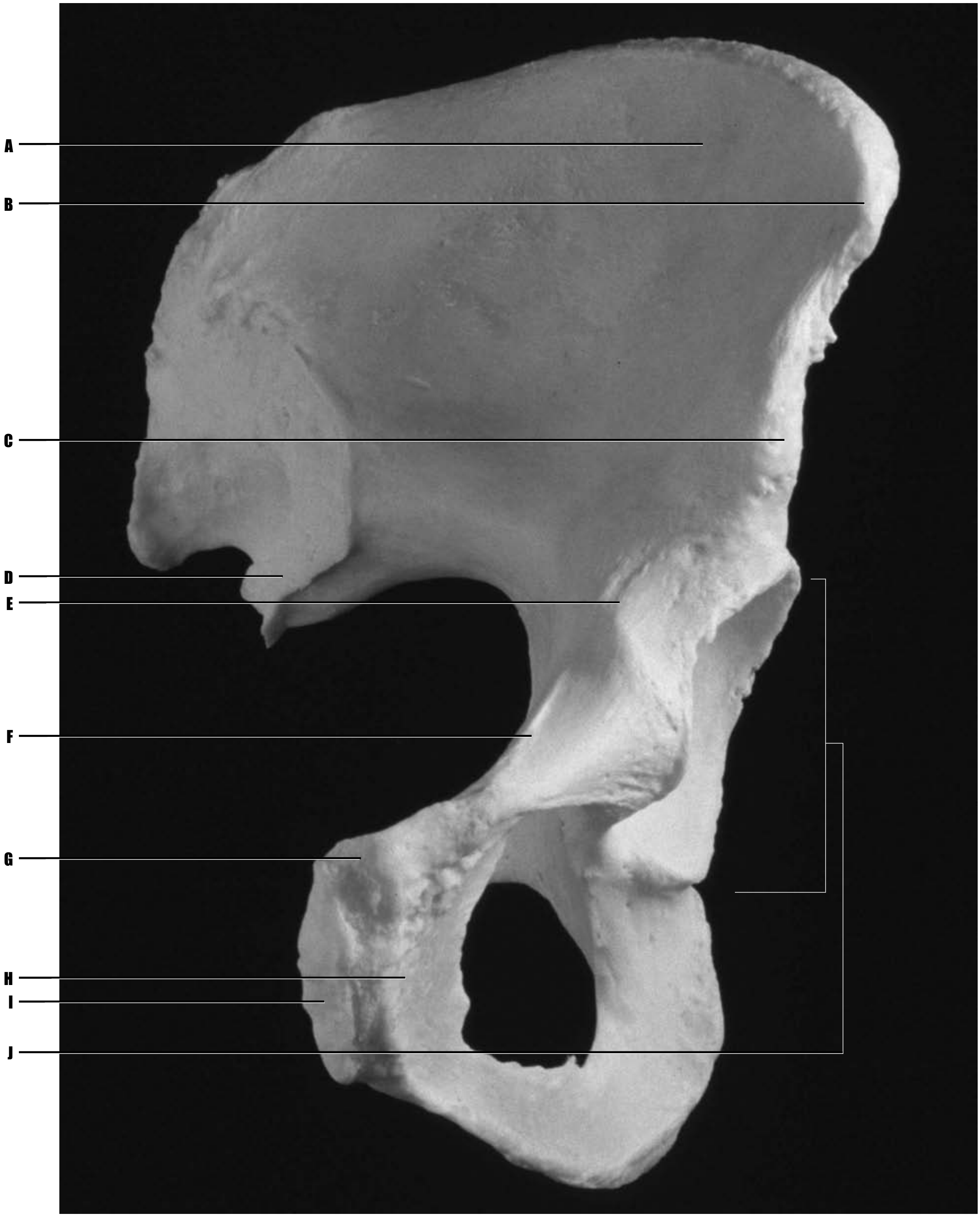


Image 6.15

Innominate (os coxae), left, anterior view.

Image 6.15

A - iliac wing
B - anterior superior iliac spine
C - anterior inferior iliac spine
D - auricular surface
E - iliopubic eminence
F - pectineal line
G - pubic tubercle
H - pubis
I - symphyseal surface
J - acetabulum

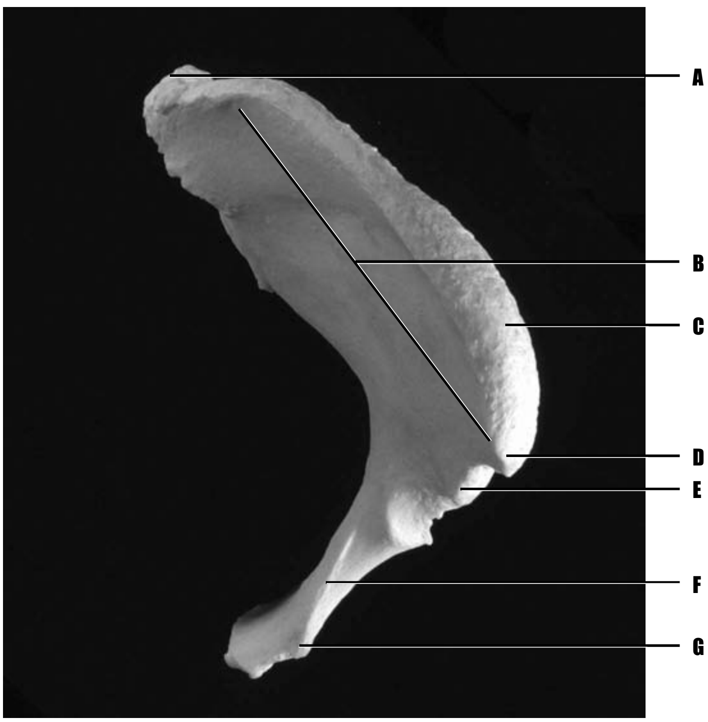


Image 6.16
Innominate, left, superior view.

Image 6.16

A - posterior superior iliac spine
B - iliac wing
C - iliac crest
D - anterior superior iliac spine
E - anterior inferior iliac spine
F - pectineal line
G - pubic tubercle

Image 6.17

Innominate (os coxae), left, lateral view.

Image 6.17

A - anterior superior iliac spine
B - middle gluteal line
C - anterior gluteal line
D - anterior inferior iliac spine
E - posterior gluteal line
F - acetabular articular surface
G - acetabular non-articular surface
H - pubic tubercle
I - acetabular notch
J - greater sciatic notch
K - ischial spine
L - obturator foramen
M - inferior pubic ramus
N - ischial tuberosity
O - posterior inferior iliac spine
P - posterior superior iliac spine

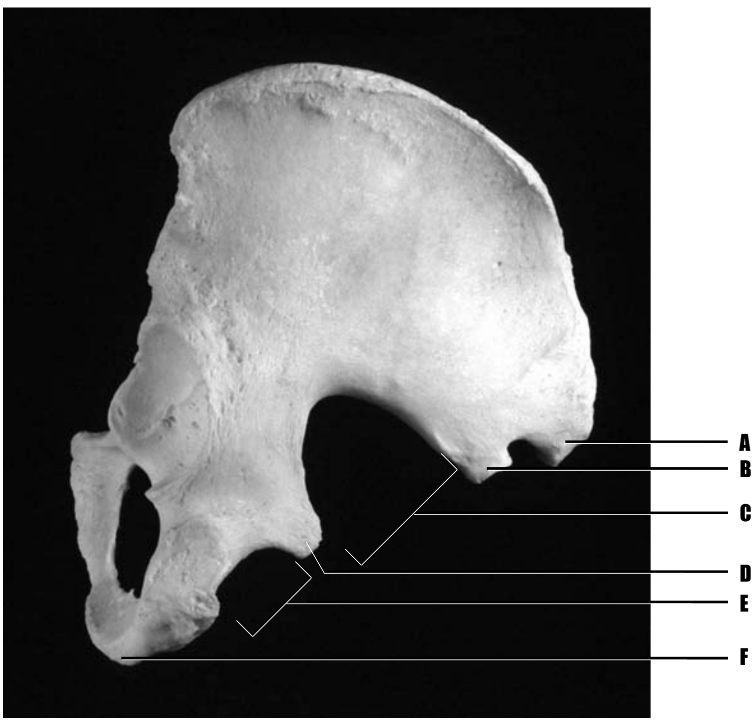


Image 6.18
Innominate (os coxae), left, posterior view.

Image 6.18

A - posterior superior iliac spine
B - posterior inferior iliac spine
C - greater sciatic notch
D - ischial spine
E - lesser sciatic notch
F - ischial tuberosity

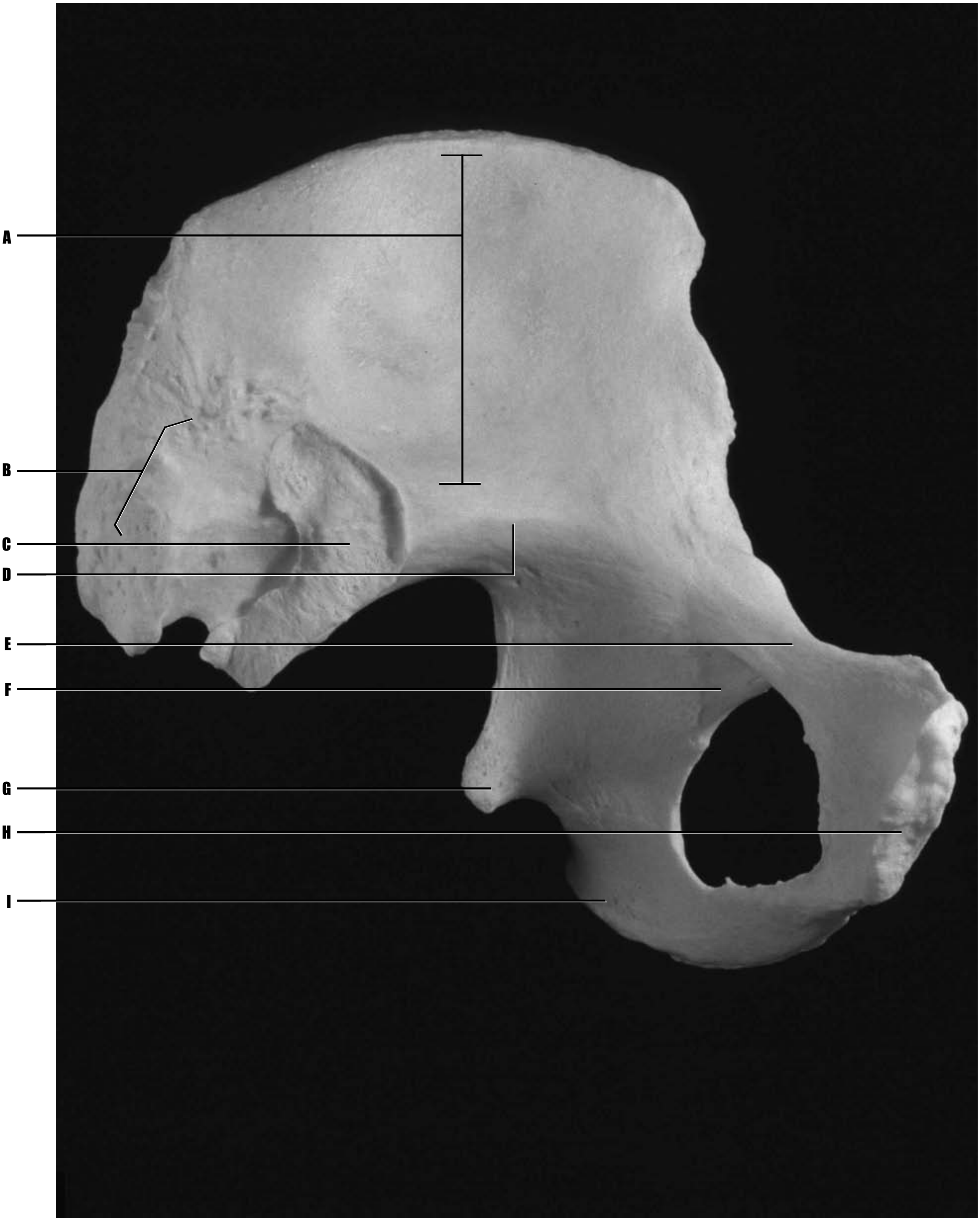


Image 6.19

Innominate, left, medial view.

Image 6.19

A - ala of ilium
B - iliac tuberosity (retro-iliac space)
C - auricular surface
D - arcuate line
E - superior pubic ramus
F - obturator groove
G - ischial spine
H - symphyseal surface
I - inferior pubic ramus

Image 6.20
Juvenile innominate (os coxae), right, lateral view.
A - ilium; **B** - ischium; **C** - pubis.

Image 6.21

Adult patient, plain film radiograph of pelvis, anteroposterior view.

Image 6.21

A - pedicle of L4 vertebra
B- spinous process of L4 vertebra
C - ala of ilium
D - ala of sacrum
E - sacroiliac joint
F - sacral foramen
G - pectineal line
H - fovea capitis of femur
I - ischial spine
J - greater trochanter of femur
K - pubic symphysis
L - soft tissue shadow of penis

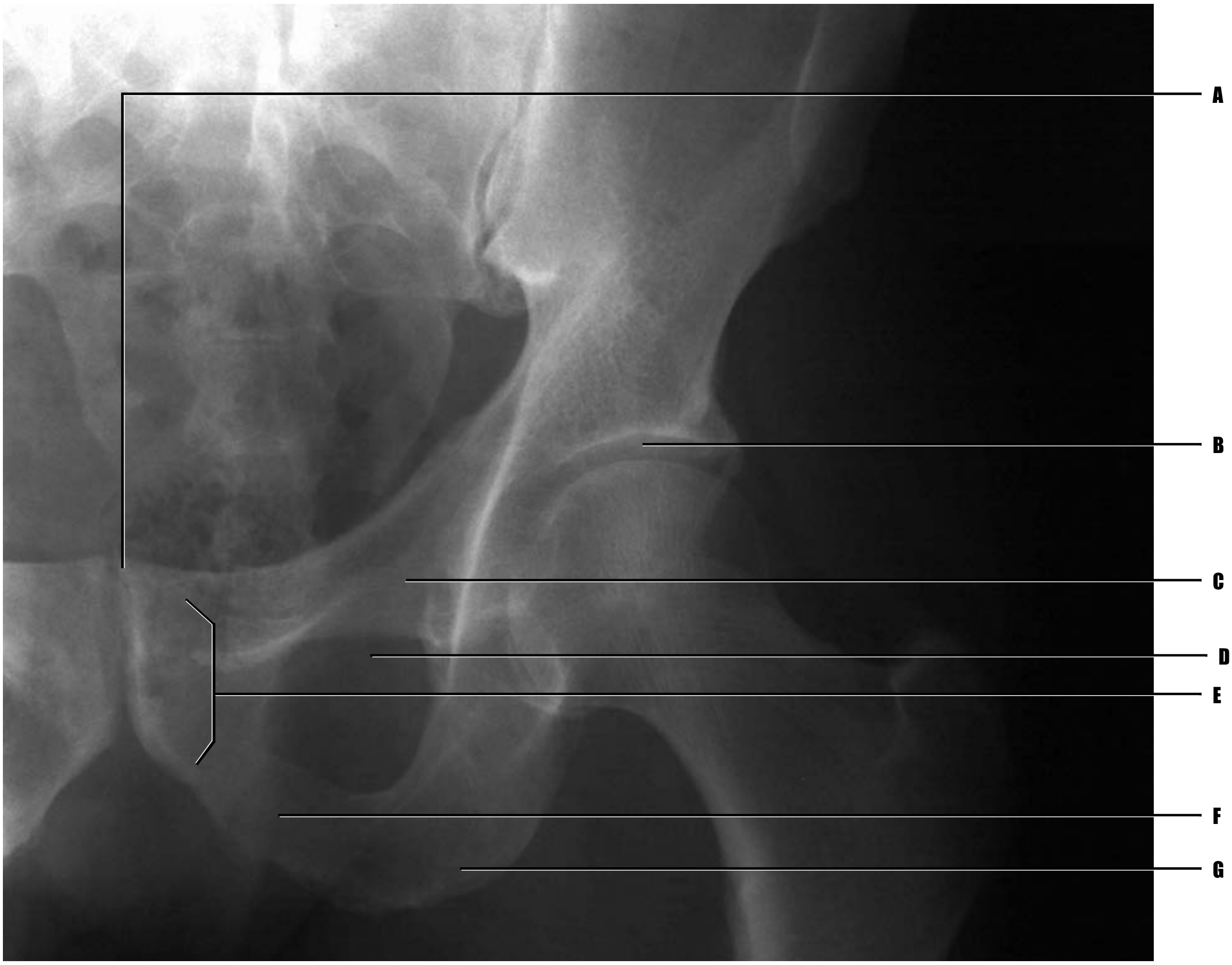


Image 6.22

Adult patient, plain film radiograph of left hemipelvis.

Image 6.22

A - pubic symphysis

B - acetabulum

C - superior pubic ramus

D - obturator foramen

E - pubis

F - inferior pubic ramus

G - ischial tuberosity

Chapter Seven

The Lower Extremity

Unlike the bones of the upper limb which are adapted for more diverse and complex movements, the lower limb differs by demonstrating specific adaptations unique to bipedal locomotion. The bones of the leg are the femur, tibia, fibula, and patella. The long shafts have many large bony prominences, such as the greater and lesser femoral trochanters, and rough bumpy lines like the soleal line, to which the powerful effector muscles of movement attach. As a result, skeletal morphology is important in understanding the soft tissue anatomy of the lower limb.

7.1 FEMUR

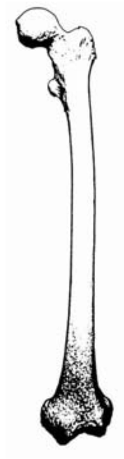


Image 7.1 • *Femur.*

- also known as the "thigh bone"
- is the longest and strongest bone in the human body
- has multiple rough bony prominences that serve as sites of attachment for the very strong muscles found in lower limb
- has a head that is large and somewhat more than a half-sphere in shape
- the body (shaft) is arched anteriorly, and strengthened posteriorly by a prominent linear ridge – the linea aspera
- has a nearly cylindrical shaft that becomes flattened and broader at its lower end forming the medial and lateral condyles
- fractures of this bone represent significant injuries which in normal adults occur because of significant force
- the femur is very valuable in forensic situations in terms of stature determination, and it has a role in the determination of sex
- it articulates with the pelvis (at the acetabulum), the tibia and the patella (at the knee)

FUNCTION

The femur is a major supportive element of the lower extremities. It serves as the site for attachment of many key locomotor and supportive muscles of the hip, thigh and lower leg. These are important for the functions of running, walking and standing.

Image 7.2 • Surface Anatomy • Oblique posterior legs. *Marks the femur.

Landmarks

- head
- shaft
- greater trochanter
- femoral tubercle
- adductor tubercle
- medial epicondyle
- medial condyle
- trochanteric fossa
- gluteal tuberosity
- intercondylar fossa
- neck
- fovea capitis
- lesser trochanter
- intertrochanteric crest
- quadrate tubercle
- lateral epicondyle
- lateral condyle

Landmarks continued

- pectineal line
- linea aspera
- intercondylar line

Differentiating Right from Left

- with the proximal end directed downward and the patellar (anterior) surface toward you, the head points to the same side as that to which the bone belongs

Looking at Fragments

- fragments of the femoral head are easily identified because of their nearly spherical shape
  - the rounded surface is interrupted by a little depression, the fovea capitis – a unique feature
  - the fovea capitis is medial, and is more posterior than anterior
- remember that the great trochanter is located laterally, and more anterior than posterior
- the lesser trochanter is directed posteromedially
- shafts of the humerus, tibia and femur might be confused with each other but:
  - the femur is larger, rounder and more robust than others
  - the femoral shaft has the prominent linea aspera – another feature unique to this bone
  - the linea aspera is posterior, and is linked superiorly with the roughened gluteal tuberosity; inferiorly, the linea aspera fans out in two directions, providing margins for the open, flat, popliteal surface
- use nutrient foramina to orient fragments of femoral shaft
  - the openings of femoral nutrient foramina face inferiorly
- to side fragments of the distal end:
  - put the intercondylar fossa away from you and hold the base as illustrated in **Images 7.3** and **7.4**, with the distal end up and the posterior surface toward you
  - the patellar surface slants toward the same side as that to which the bone belongs
- if you have the distal end, but for some reason the patellar surface has been fractured off, hold the specimen with the intercondylar fossa away, and the condyles on the table top
  - the bone now appears to slant off toward the side opposite that to which the bone belongs

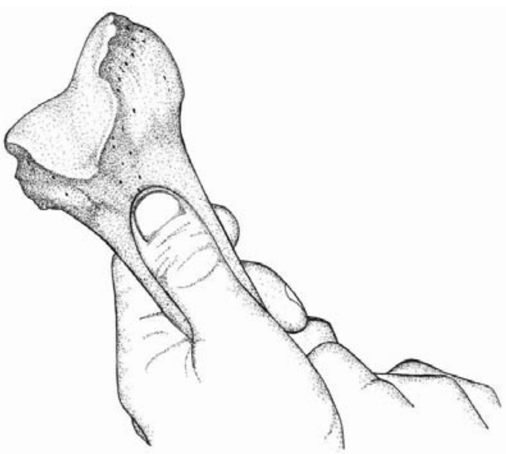


Image 7.3 • Femur, left, distal end.

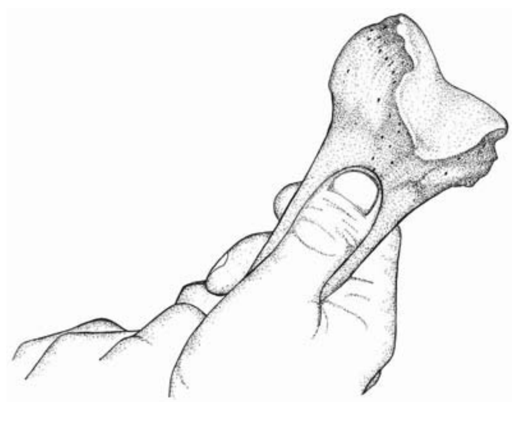


Image 7.4 • Femur, right, distal end.

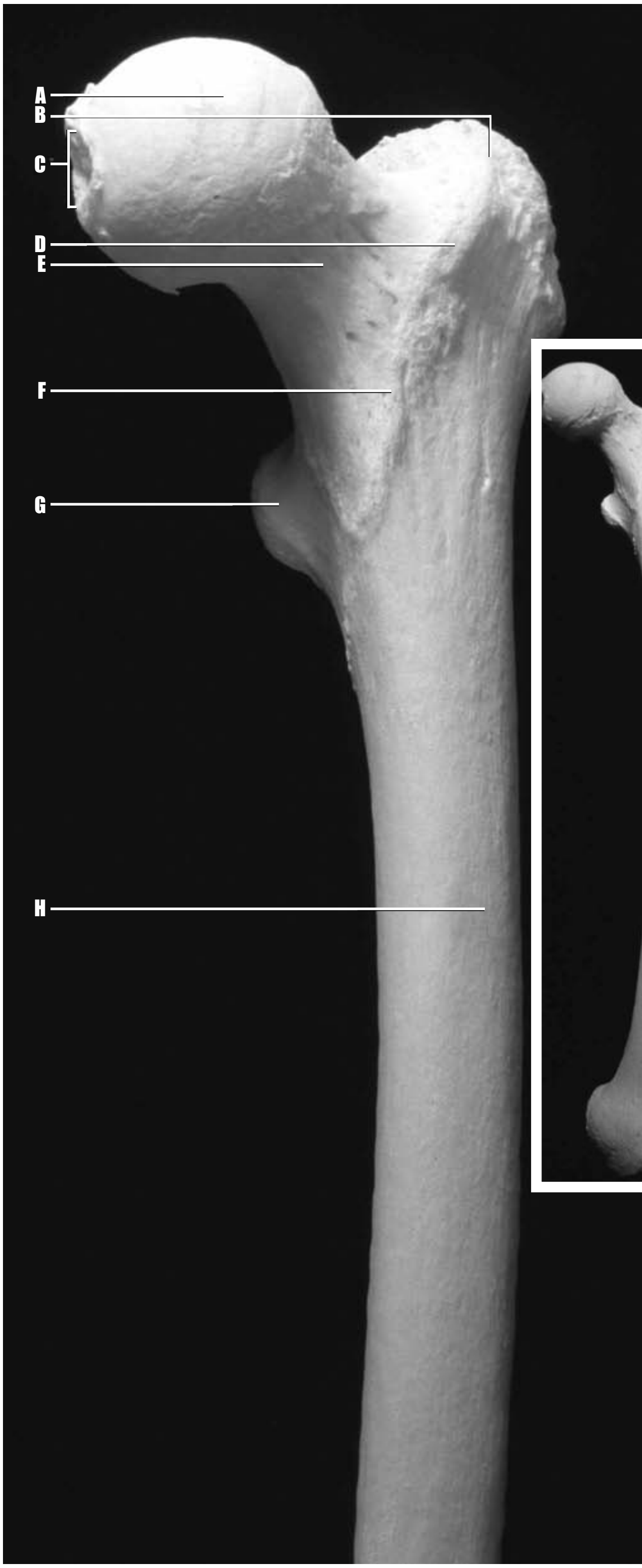


Image 7.5
Femur, left, anterior view, proximal half.

Image 7.6
Femur, left, anterior view, distal half.

Image 7.5

A - head
B - greater trochanter
C - fovea capitis
D - femoral tubercle
E - neck
F - intertrochanteric crest/line
G - lesser trochanter
H - shaft

Image 7.6

A - shaft
B - adductor tubercle
C - medial epicondyle
D - lateral epicondyle
E - patellar surface
F - lateral condyle
G - medial condyle

Image 7.7
Femur, left, proximal end. Anterior is up.

Image 7.8
Femur, left, posterior view, proximal half.

Image 7.9
Femur, left, posterior view, distal half.

Image 7.8

A - greater trochanter
B - trochanteric fossa
C - quadrate tubercle of intertrochanteric crest
D - lesser trochanter
E - pectineal line
F - gluteal tuberosity
G - lateral lip of linea aspera
H - medial lip of linea aspera
I - linea aspera
J - nutrient foramen

Image 7.9

A - linea aspera
B - medial supracondylar ridge
C - popliteal surface
D - lateral epicondyle
E - adductor tubercle (not obvious in this specimen)
F - intercondylar fossa
G - medial epicondyle
H - medial condyle
I - lateral condyle

Image 7.10
Femur, left, distal end. Anterior is up.

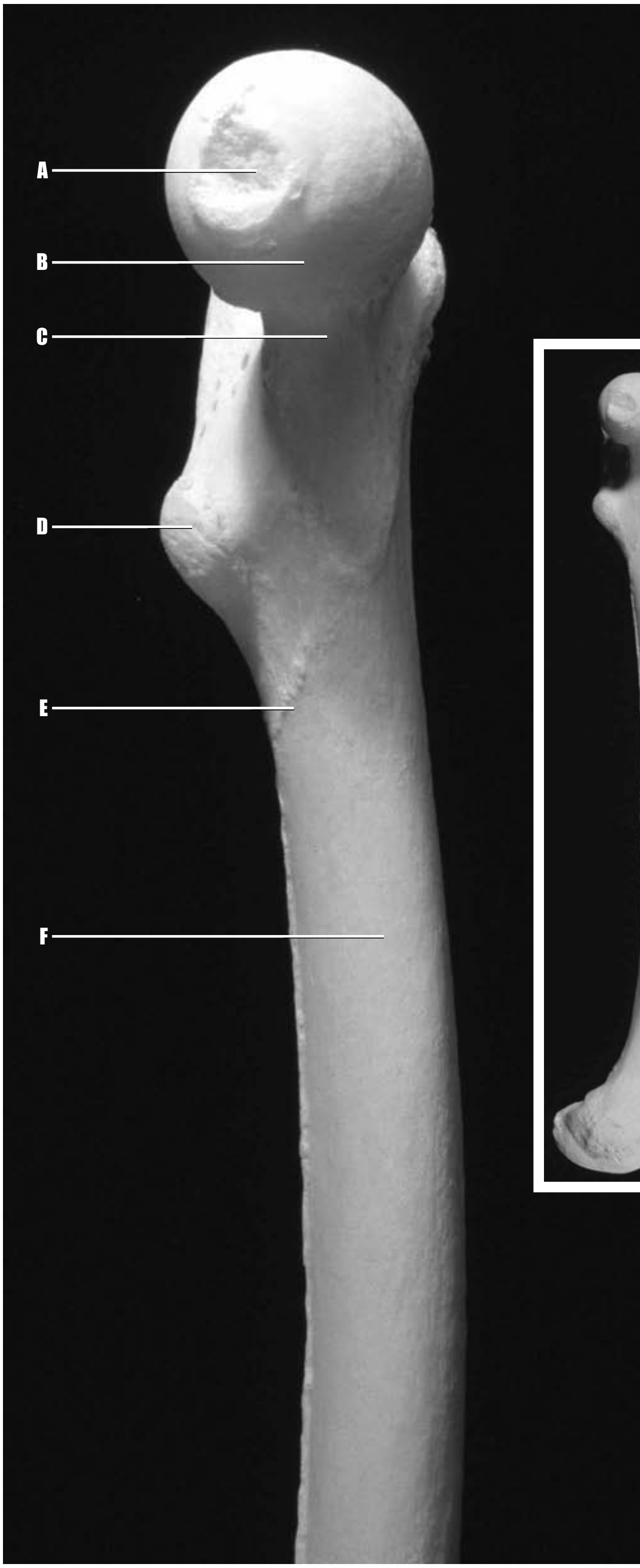


Image 7.11
Femur, left, medial view, proximal half.

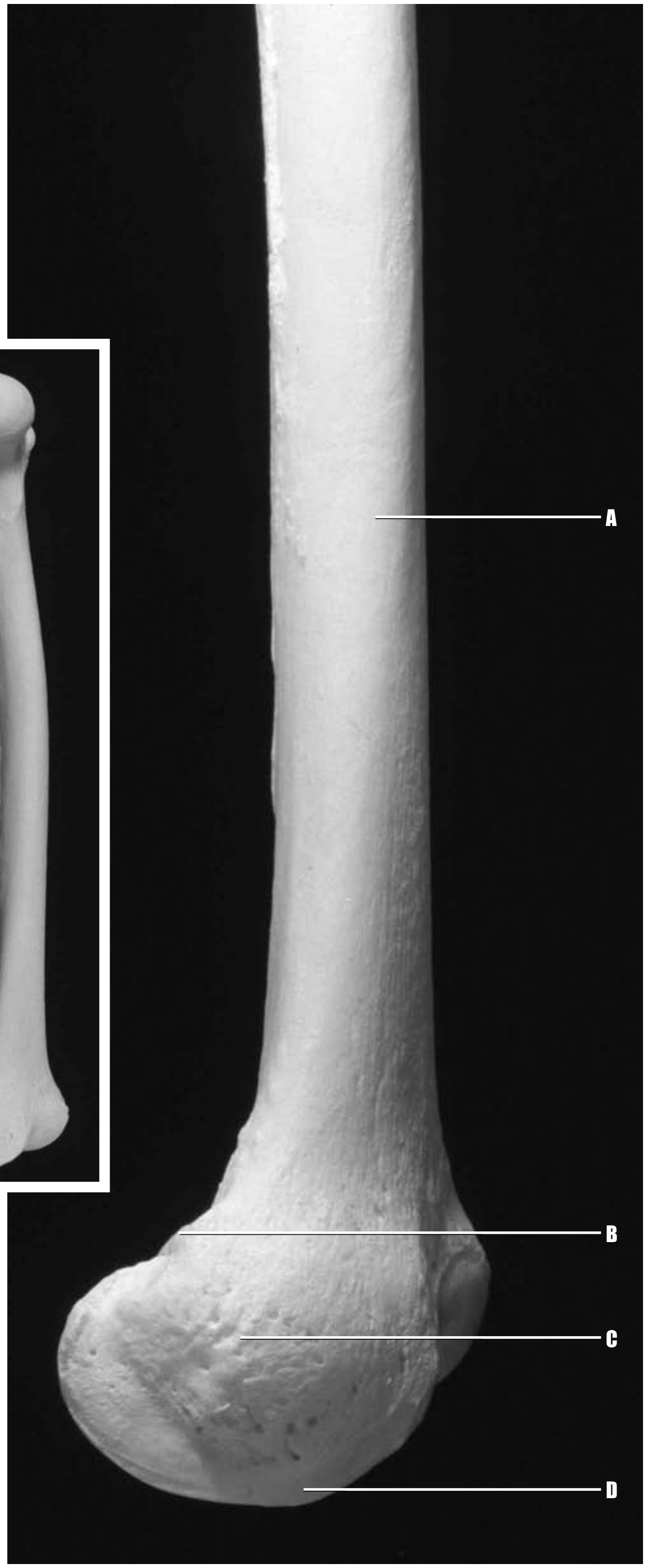


Image 7.12
Femur, left, medial view, distal half.

Image 7.11

A - fovea capitis
B - head
C - neck
D - lesser trochanter
E - spiral line
F - shaft

Image 7.12

A - shaft
B - adductor tubercle
C - medial epicondyle
D - medial condyle

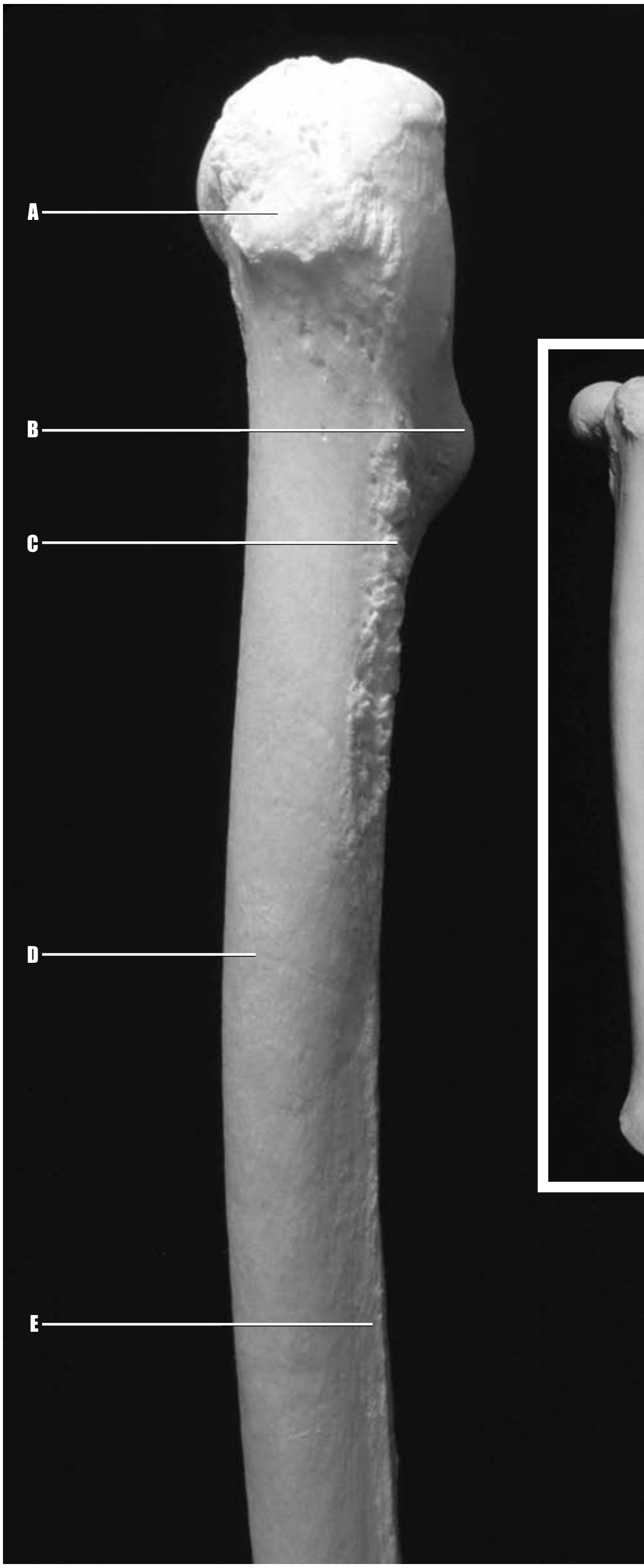


Image 7.13
Femur, left, lateral view, proximal half.

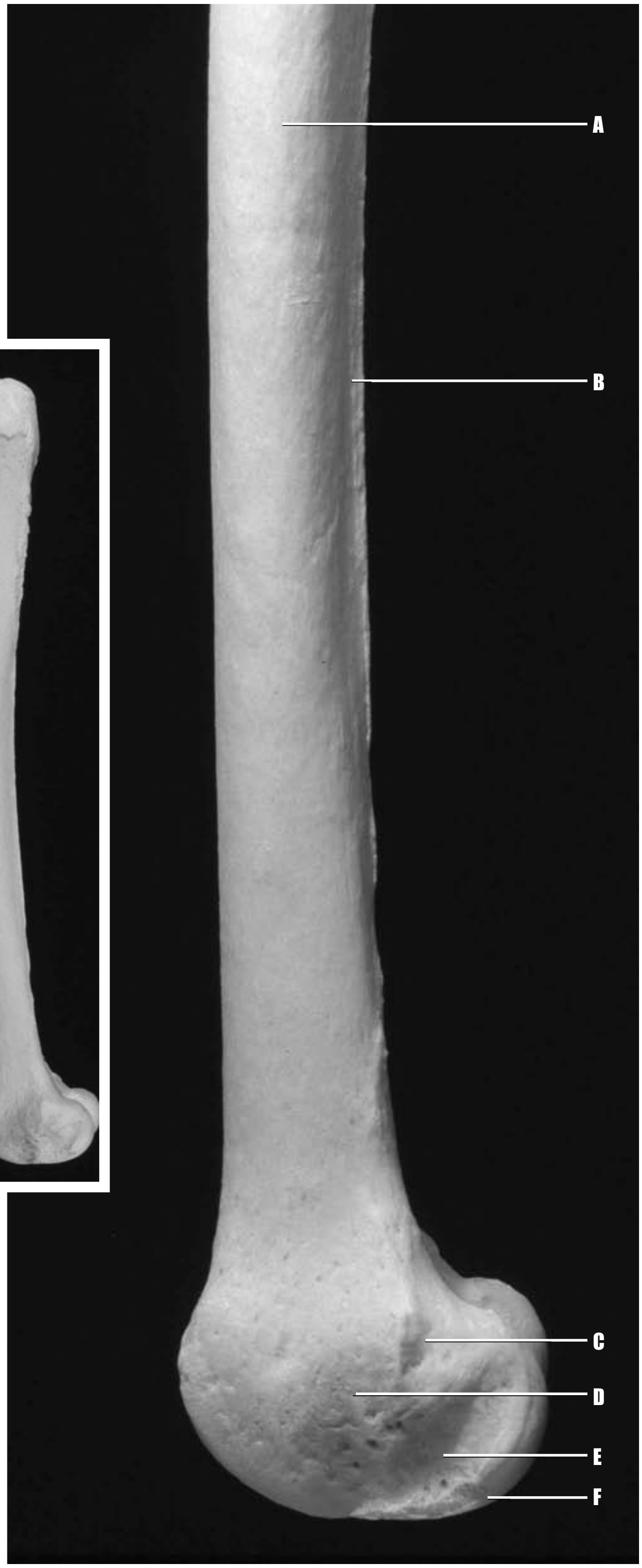


Image 7.14
Femur, left, lateral view, distal half.

Image 7.13

A - greater trochanter
B - lesser trochanter
C - gluteal tuberosity
D - shaft
E - linea aspera

Image 7.14

A - shaft
B - linea aspera
C - groove for gastrocnemius
D - lateral epicondyle
E - groove for popliteus (during flexion)
F - lateral condyle

Image 7.15

Adult patient, plain film radiograph, left hip in abduction.

Image 7.15

A - anterior superior iliac spine
B - sacroiliac joint
C - anterior inferior iliac spine
D - greater sciatic notch
E - acetabulum
F - femoral head
G - greater trochanter of femur
H - lesser trochanter of femur
I - soft tissue shadow of scrotum

7.2 PATELLA

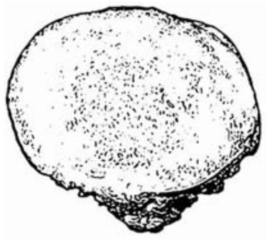


Image 7.16 • *Patella.*

- the patella is the largest sesamoid bone in the body
- it is found in the tendon of a large extensor muscle, the quadriceps femoris, which is present on the front of the thigh
- it has an elliptical, round or triangular shape
- the anterior surface is quite rough
- the posterior surface is smooth and bears two contiguous articular surfaces (for the patellar surface of the femur) separated by a groove
- the patella articulates only with the femur
- the patella is occasionally comprised of right and left halves that failed to fuse

FUNCTION

The patella sits within the patellofemoral ligament at the front of the knee joint. During flexion and extension of the knee, the patella slides up and down, across the smooth patellar surface of the femur.

Image 7.17 • Surface Anatomy • Anterior view of the knees. *Marks the patella.

Landmarks

- base
- apex
- medial (small) facet
- lateral (large) facet

*Differentiating Right from Left**

- with the apex inferiorly directed and the facets toward you as illustrated in **Images 7.18** and **7.19**, the largest (lateral) facet points toward the same side as that to which the bone belongs

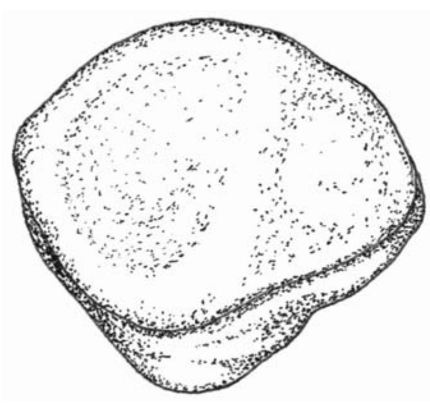


Image 7.18 • Patella, left.

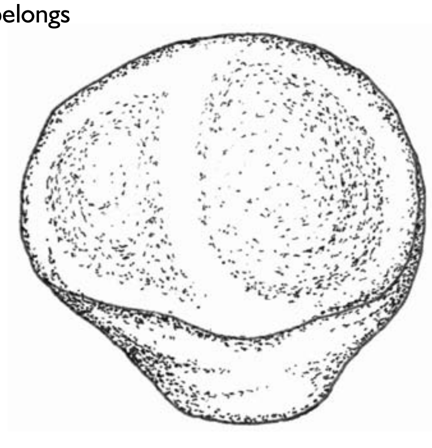
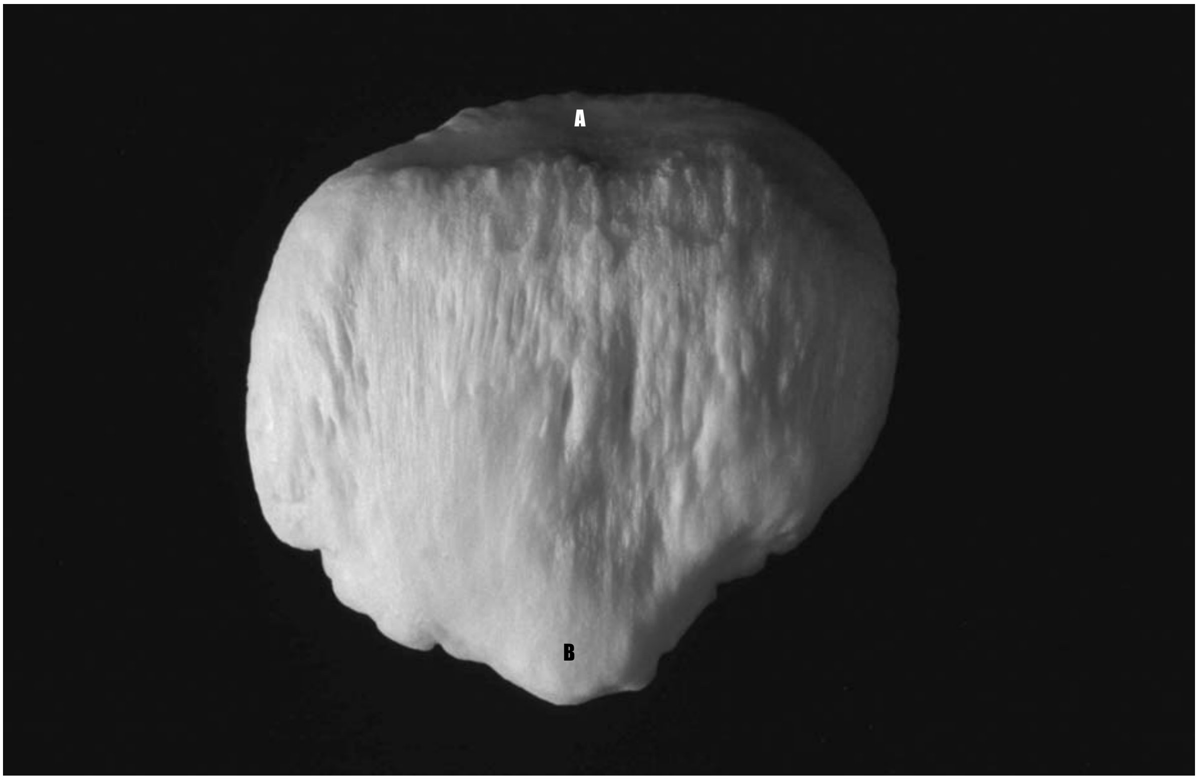


Image 7.19 • Patella, right.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.



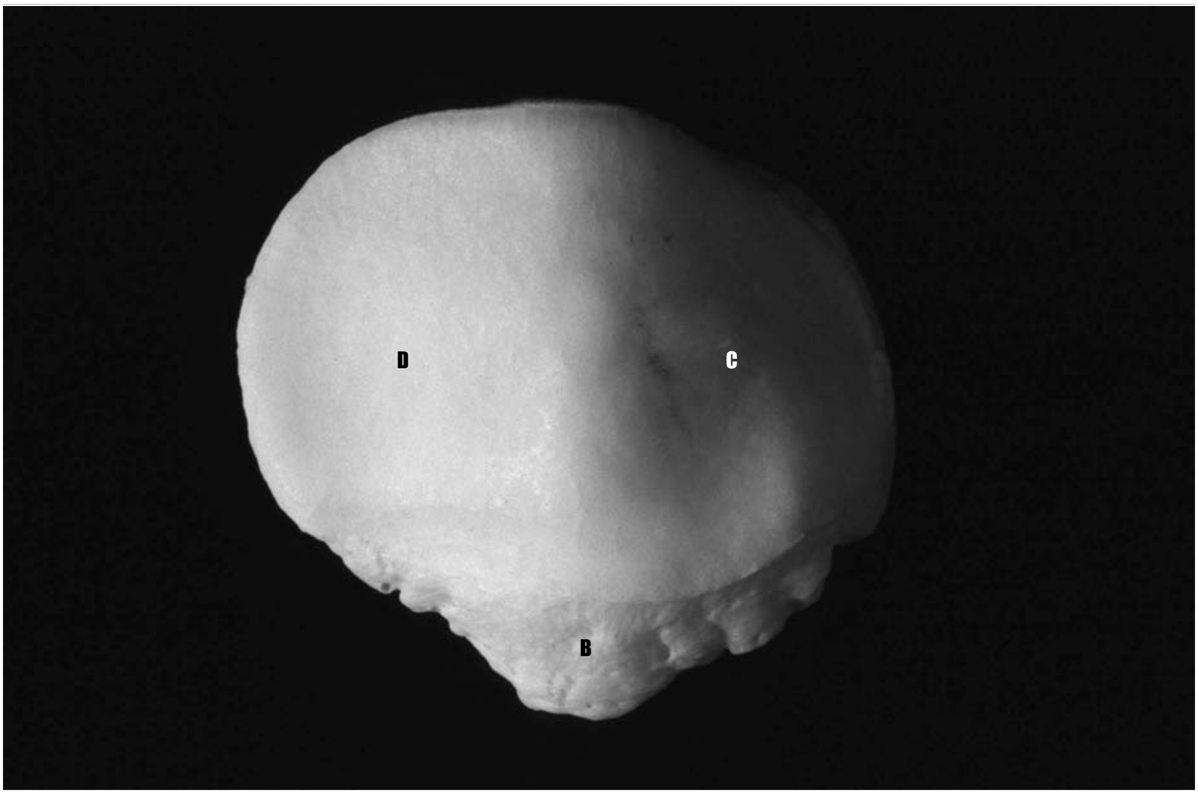


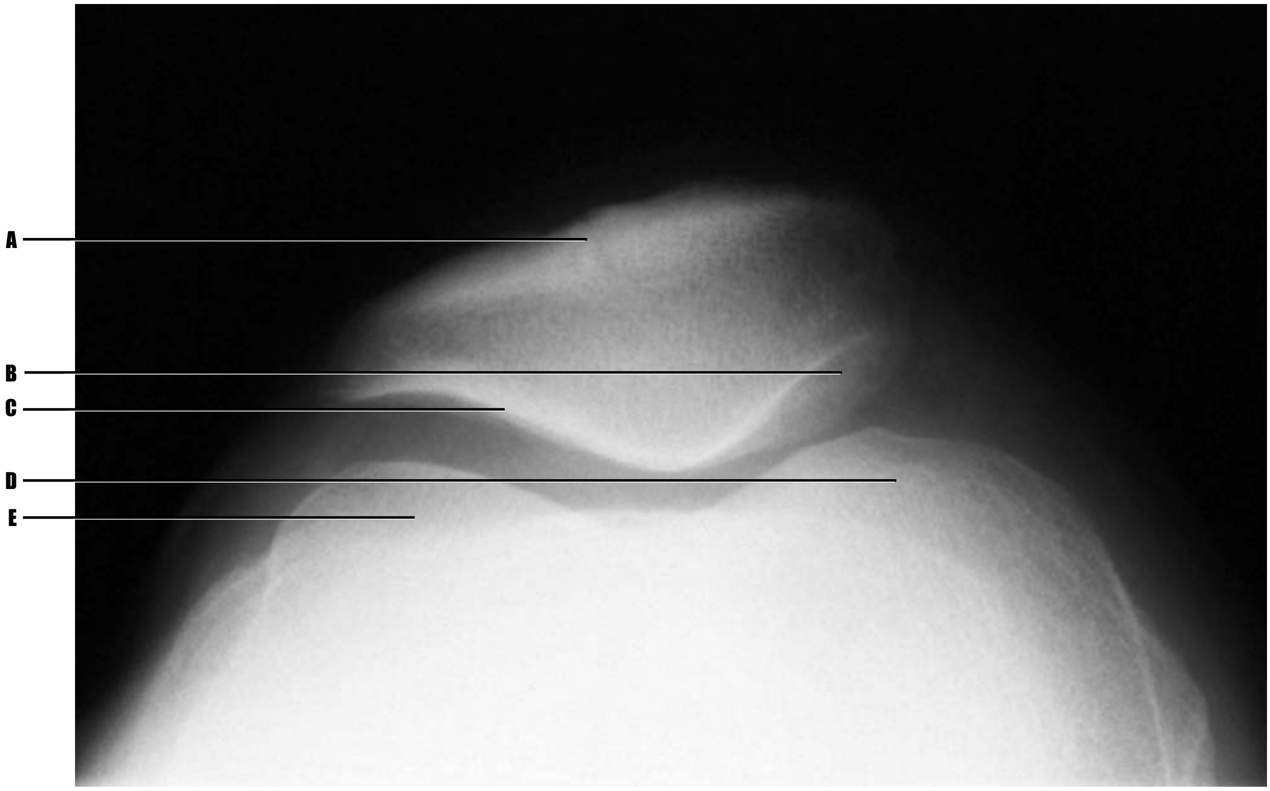
Image 7.20 (above)

Patella, left, anterior view.

Image 7.21 (below)

Patella, left, posterior view.

A - base, **B** - apex, **C** - medial facet, **D** - lateral facet.



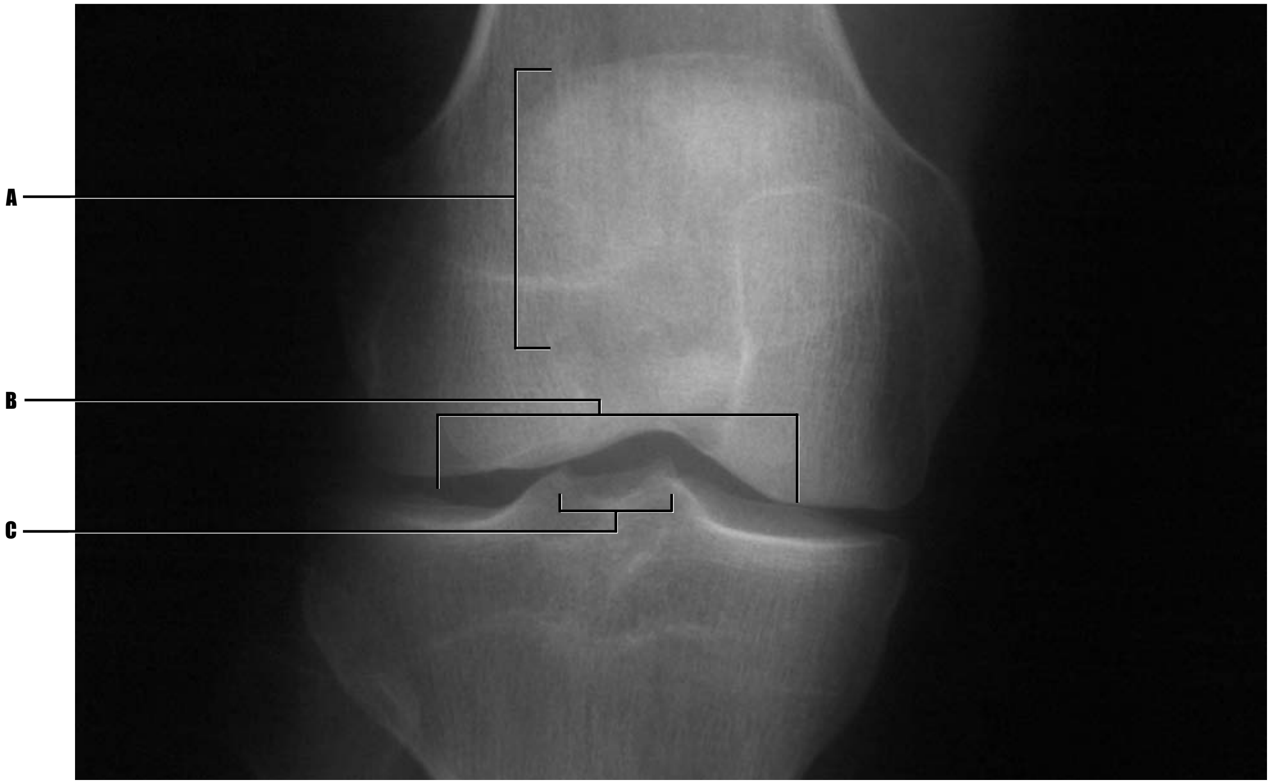


Image 7.22 (above)

Adult patient, plain film radiograph, patellar skyline view of right knee.
A "skyline view" of the knee is a radiographic projection used to permit examination of the patella. This is done by flexing the patient's knee, and then acquiring the image.

Image 7.23 (below)

Adult patient, plain film radiograph, anteroposterior view of right knee.

Image 7.22

A - anterior patellar surface

B - medial patellar articular surface

C - lateral patellar articular surface

D - medial femoral condyle

E - lateral femoral condyle

Image 7.23

A - patellar shadow

B - tibial plateau

C - intercondylar eminence of tibia

7.3 TIBIA

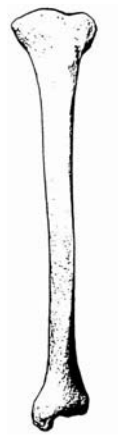


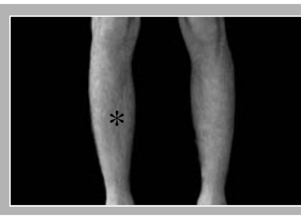
Image 7.24 • *Tibia.*

- forms the skeleton of the medial lower leg
- articulates proximally with the femoral condyles at the knee joint and distally with the body of the talus at the ankle joint (tibiotalar joint)
- furthermore, it articulates both proximally and distally with the fibula

FUNCTION

The tibia forms the medial border of the lower leg. Colloquially, it is referred to as the shin bone. The medial malleolus of the distal tibia is the large bony prominence found at the medial ankle.

Image 7.25 • Surface Anatomy • Anterior view of lower legs. *Marks the tibia.

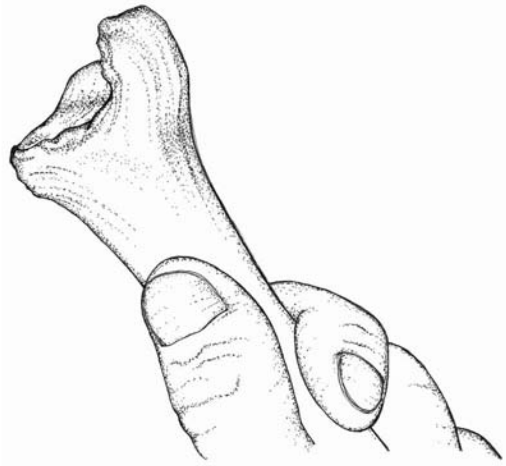


Landmarks

- intercondylar eminence
- medial condyle
- lateral condyle
- tibial tuberosity
- shaft
- inferior articular surface
- medial malleolus
- articular facet for medial malleolus
- soleal line
- fibular articular surface
- fibular groove
- interosseous margin

Differentiating Right from Left

- the medial malleolus is key to determining the side
  - with the tibia oriented as in **Images 7.26** and **7.27**, with the tibial plateau directed downward, the anterior surface and tibial tuberosity toward you, the medial malleolus is found on the opposite side of bone as that to which the bone belongs



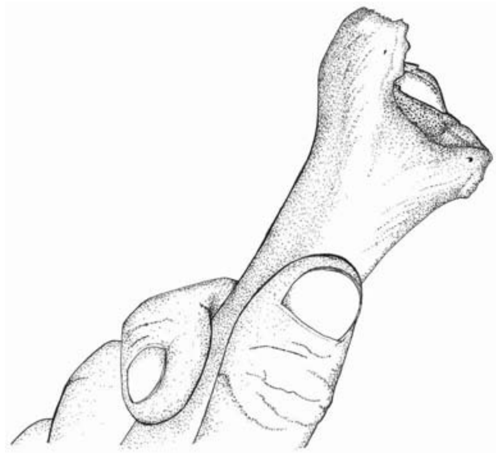
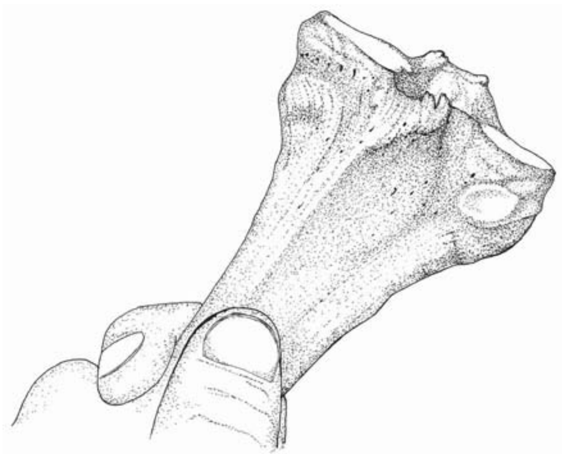
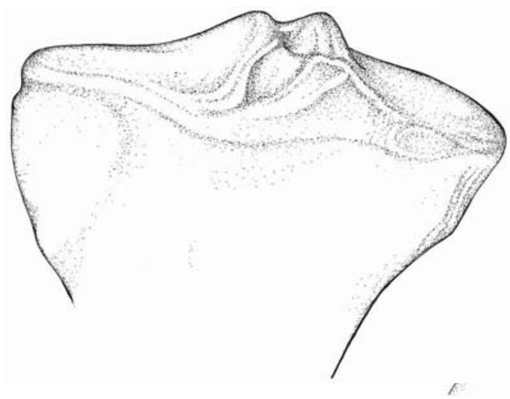


Image 7.26 • Tibia, left, anterior, distal.

Image 7.27 • Tibia, right, anterior, distal.





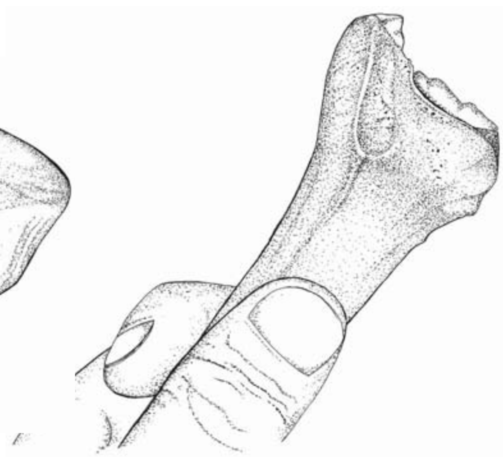


Image 7.28 • Tibia, right, posterior, proximal.

Image 7.29 • Tibial plateau, right, anterior.

Image 7.30 • Tibia, left, posterior, distal.

Looking at Fragments

- if fragmented, proximal fragments can be identified as follows:
  - the superior fibular articular surface is located posterolaterally as seen in **Image 7.28**
  - when held as in **Image 7.29** with the tibial tuberosity toward you, the intercondylar eminence appears to bend toward the same side of the body from that to which it belongs
  - the soleal line progresses from superior to inferior, beginning on the same side of the bone as that to which it belongs
- with fragments of the shaft:
  - the interosseous border is lateral
  - in cross-sections, the shaft progresses from a more triangular to rectangular shape by the distal one third
  - although the tibia has a triangular shaft, and might therefore resemble fragmented radius, the tibia is much larger and more robust that the typical radius
- with distal fragments:
  - the medial malleolus is medial
  - the malleolar groove is posterior as seen in **Image 7.30**
  - the fibular notch is lateral

Image 7.31
Tibia, left, anterior view, proximal half.

Image 7.32
Tibia, left, anterior view, distal half.

Image 7.31

A - intercondylar eminence
B - lateral epicondyle
C - medial epicondyle
D - tibial tuberosity
E - anterior margin of shaft

Image 7.32

A - anterior margin of shaft
B - inferior articular surface of tibia
C - medial malleolus

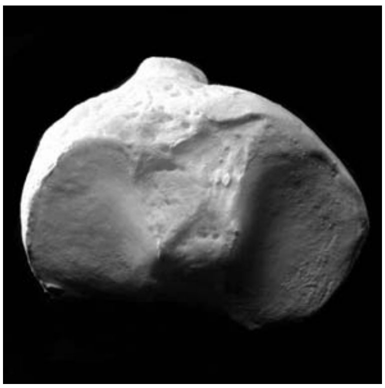


Image 7.33
Tibia, left, proximal end. Anterior is up.

Image 7.34

Tibia, left, posterior view, proximal half.

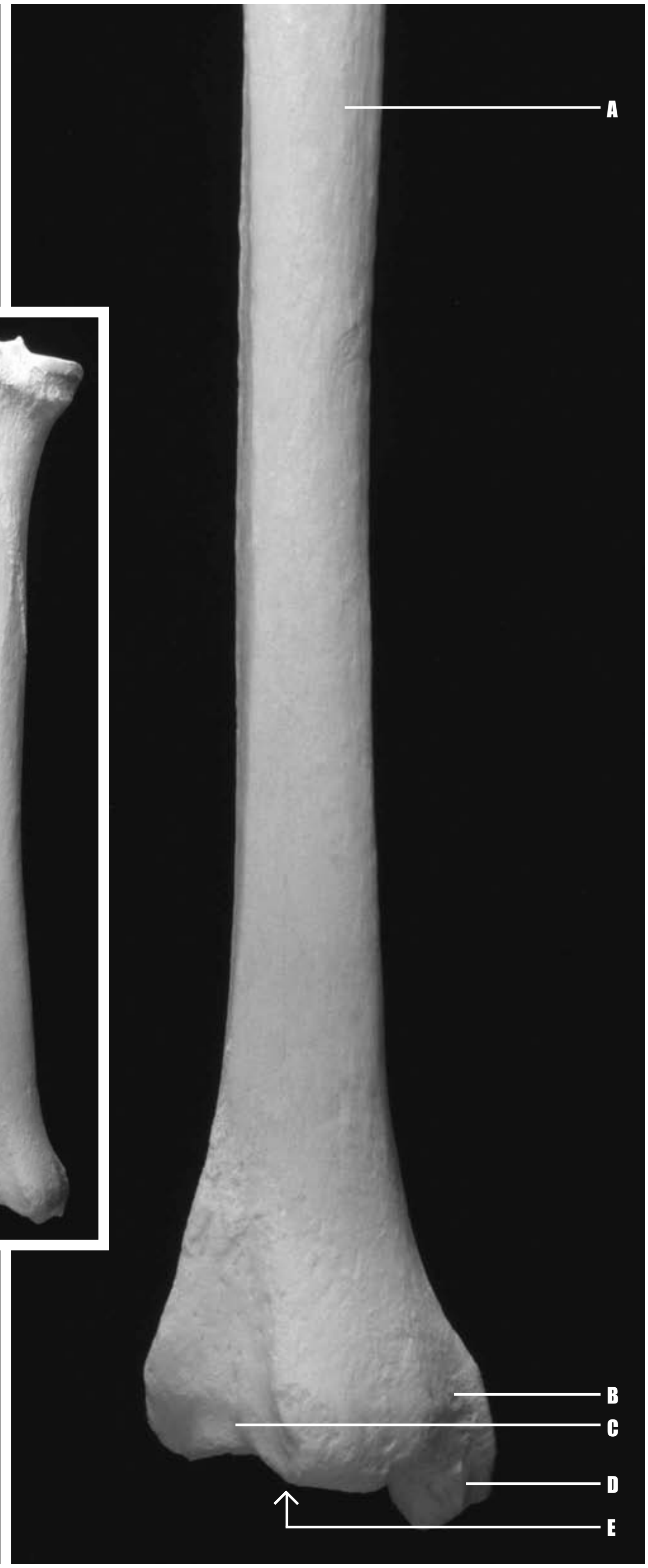


Image 7.35

Tibia, left, posterior view, distal half. NOTE - this specimen has a subtle curvature to the distal shaft, and consequently, the above photograph illustrates more of the medial aspect than expected.

Image 7.34

A - intercondylar eminence

B - posterior intercondylar area

C - superior fibular articular surface

D - groove for semimembranosus tendon insertion

E - soleal line

F - shaft

Image 7.35

A - shaft

B - malleolar groove

C - fibular notch

D - medial malleolus

E - inferior articular surface

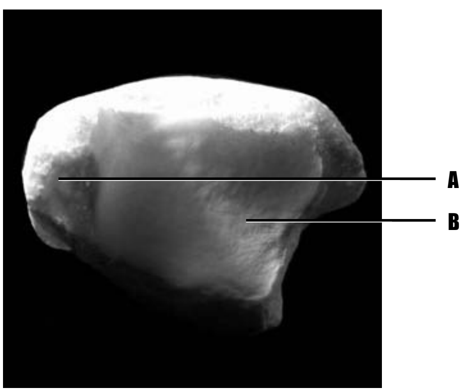


Image 7.36

Tibia, left, distal end. Anterior is up.
A - medial malleolus; **B** - talar articular surface.

Image 7.37
Tibia, left, medial view, proximal half.

Image 7.38
Tibia, left, medial view, distal half.

Image 7.37

- **A** - intercondylar eminence
- **B** - medial condyle
- **C** - tibial tuberosity
- **D** - medial border of shaft

Image 7.38

- **A** - shaft
- **B** - medial malleolus
- **C** - notch for deltoid ligament

Image 7.39
Tibia, left, lateral view, proximal half.

Image 7.40
Tibia, left, lateral view, distal half.

Image 7.39

A - superior fibular articular facet
B - tibial tuberosity
C - soleal line
D - interosseous border
E - shaft

Image 7.40

A - shaft
B - interosseous border
C - fibular notch

7.4 FIBULA

Image 7.41 • *Fibula.*

- forms the skeleton of the lateral lower leg
- is a thin, long bone with a bulbous proximal head and a somewhat more flattened distal end
- in proportion to its length, it is the most slender of all bones
- articulates both proximally and distally to the tibia at the superior and inferior tibiofibular joints

FUNCTION

The fibula forms the lateral border of the lower leg. In the average North American person, it is only palpable at the knee (fibular head), and at the ankle joint (lateral malleolus). It bears no weight, serves as a site of muscle attachment, and contributes to the formation of the ankle joint.

Image 7.42 • Surface Anatomy • Lateral view of left lower leg. *Marks the fibula.

Landmarks

- styloid process
- head
- shaft
- distal end
- malleolar fossa
- lateral malleolus

*Differentiating Right from Left**

- this bone can be difficult for some people to side
  - the (cuboid-ish) head is superior, the (more flattened) base is inferior
  - the articular facets for tibia are medial
  - the malleolar fossa of the base is posterior
- orient the bone as pictured in **Images 7.43** and **7.44** with the proximal end upward and the distal downward
  - use the above anatomical landmarks to orient the bone – articular facets placed medially, and the malleolar fossa posteriorly
  - when the distal end is now viewed medially, the malleolar fossa is on the same side of the bone as that to which the bone belongs

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.

Image 7.43 • Fibula, left, medial, distal.

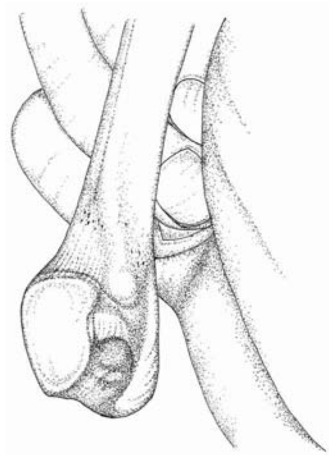


Image 7.44 • Fibula, right, medial, distal.

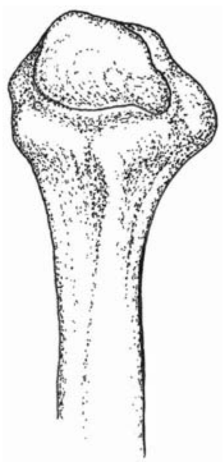


Image 7.45 • Fibula, left, medial, proximal.

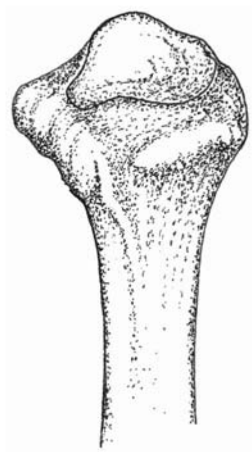


Image 7.46 • Fibula, right, medial, proximal.

Looking at Fragments

- it is conceivable that one might confuse fragments of the fibula with those of radius and ulna
- the fibula has a very irregular cross-sectional appearance because of its many (four or five) distinct sides
  - this differs from the radius because radial shaft is shaped much more like a teardrop, and its only distinct edge is that of the interosseous crest
  - although the ulna has an irregular shaft, the medial margin is smooth and rounded, and the only angled edge is that of the interosseous crest
- when examining fragments:
  - proximal end
    - the styloid process is lateral and posterior
    - articular surfaces are medial and somewhat posterior as seen in **Images 7.45** and **7.46**
    - the neck is roughest laterally
  - shaft
    - best to compare with an intact specimen of known side
    - the openings of nutrient foramina face superiorly
    - the sharpest crest on the triangular proximal end is the interosseous crest; this becomes increasingly prominent as one progresses distally
  - distal end
    - the malleolar fossa is always posterior and the articular facet is medial
    - the apex (of the lateral malleolus) points inferiorly

Image 7.47
Fibula, left, anterior view, proximal half.

Image 7.48
Fibula, left, anterior view, distal half.

Image 7.47

A - apex of fibular head (styloid process)
B - fibular head
C - interosseous margin
D - medial surface

Image 7.48

A - interosseous margin
B - lateral margin
C - medial surface
D - lateral malleolus

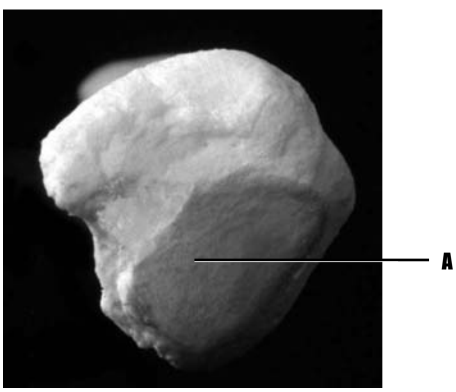


Image 7.49
Fibula, left, proximal end.
A - articular facet for lateral tibial condyle.

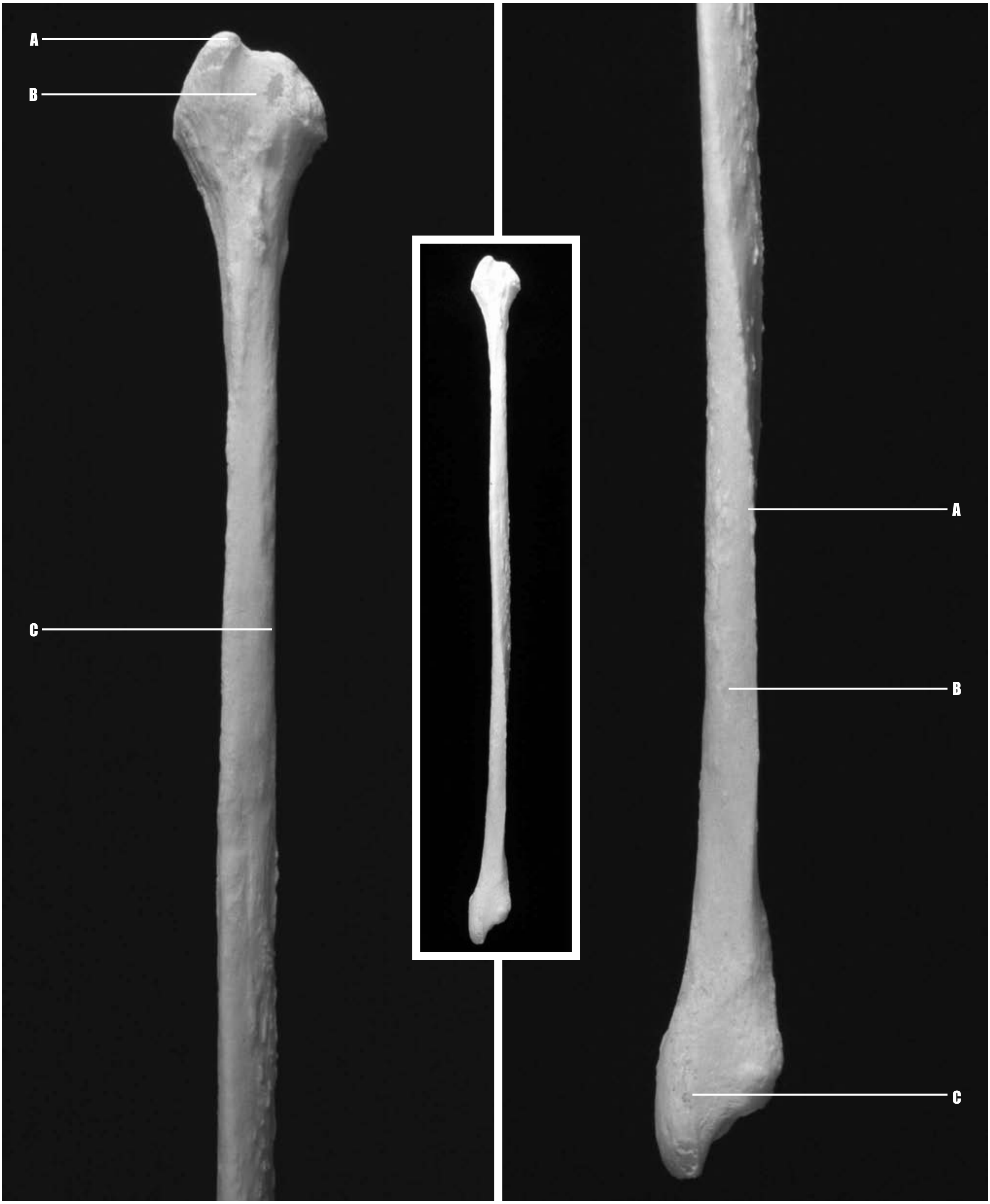


Image 7.50
Fibula, left, posterior view, proximal half.

Image 7.51
Fibula, left, posterior view, distal half.

Image 7.50

A - styloid process of head
B - head of fibula
C - medial border

Image 7.51

A - interosseous margin
B - posterior surface
C - lateral malleolus

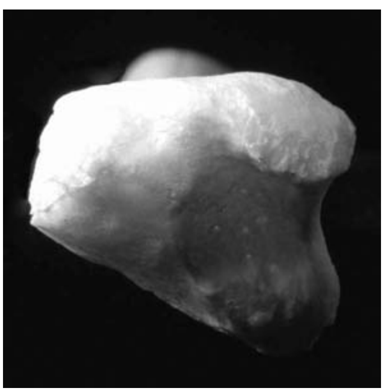



Image 7.52 (left)
Fibula, left distal end.
Image 7.53 (right)
Fibula, left distal end, medial view.

Image 7.54 (left)

Adult patient, plain film radiograph, posteroanterior view of right lower leg.

Image 7.55 (right)

Adult patient, plain film radiograph, lateral view of right leg.

Image 7.54

A - lateral condyle of femur
B - medial condyle of femur
C - intercondylar eminence of tibia
D - fibular head
E - lateral malleolus
F - medial malleolus
G - talus

Image 7.55

A - patella
B - medial and lateral condyles of femur
C - apex of fibular head
D - tibial tuberosity
E - lateral malleolus

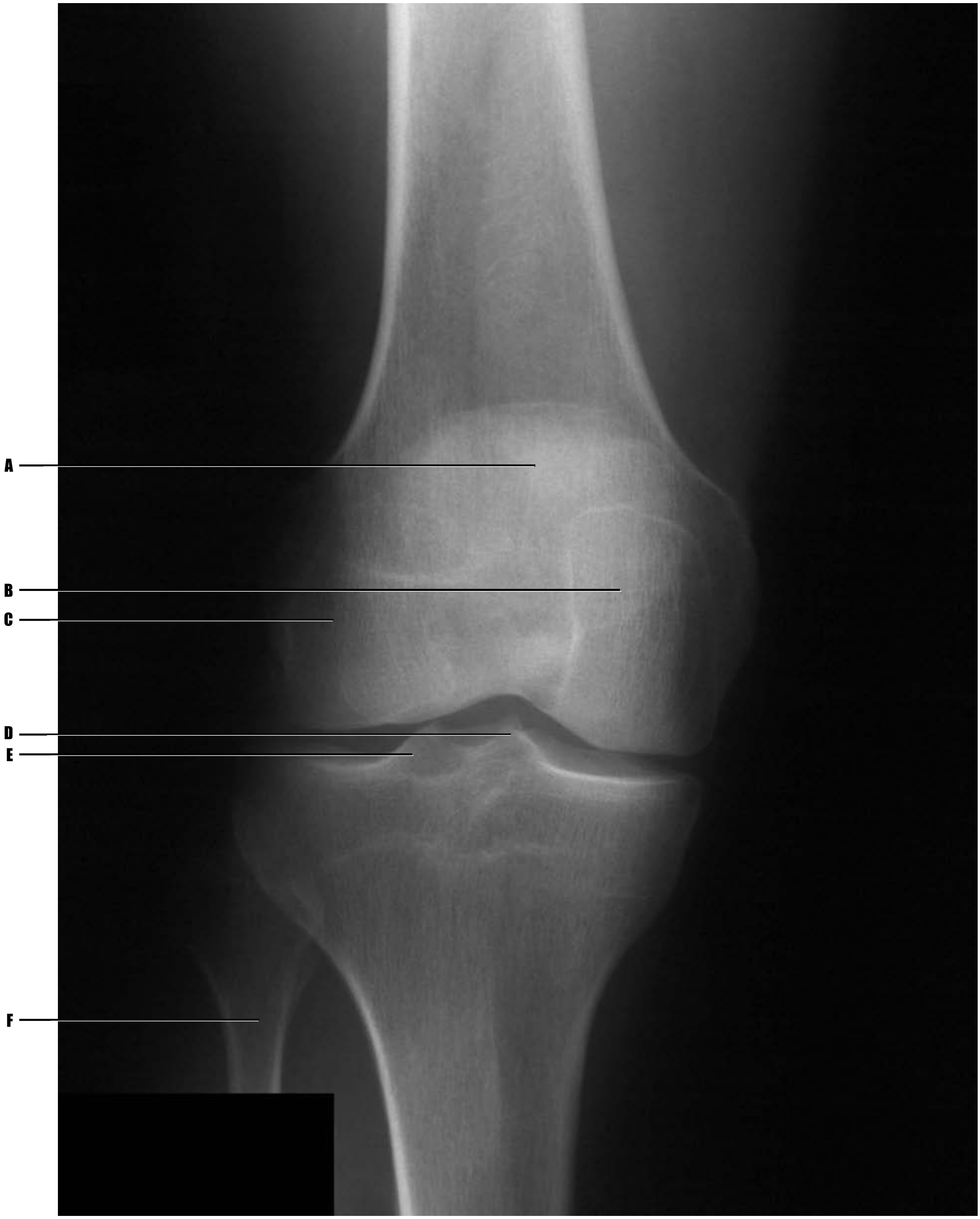


Image 7.56 (above)
Adult patient, plain film radiograph, posteroanterior view of left knee.

Image 7.56

A - patellar shadow

B - medial condyle of femur

C - lateral condyle of femur

D - medial intercondylar tubercle of tibia

E - lateral intercondylar tubercle of tibia

F - fibular neck

Image 7.57 (above)
Adult patient, plain film radiograph, lateral view of right knee.

Image 7.57

A - femur
B - lateral femoral condyle
C - patella
D - medial femoral condyle
E - fibular head
F - tibial tuberosity

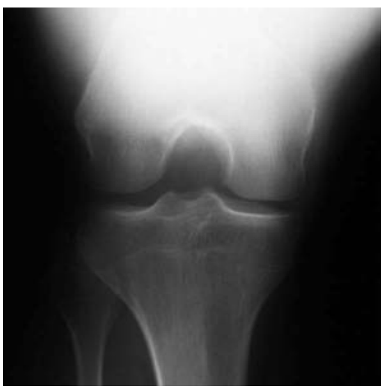


Image 7.58
Adult patient, plain film radiograph, anteroposterior view of flexed knee.

7.5 FOOT

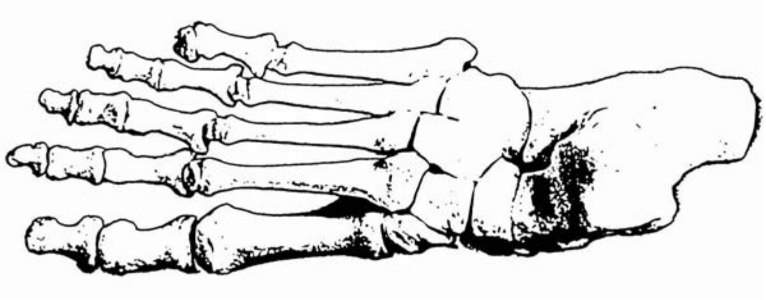


Image 7.59 • *Foot.*

- the general arrangement of the foot is similar to that of the hand
- there are twenty-six bones in each foot (one less than in each hand)
- is composed of seven tarsal bones (four in the distal row, two in the proximal row, and one in between the two rows), five metatarsal bones, and fourteen phalanges (three per toe except for the great toe [hallux], which only has two)
- sesamoid bones (bones which form within tendons) may also be present

FUNCTION

The human foot is wonderfully adapted to the functions of standing, walking, running, jumping, etc. In addition to the many foot bones, the foot itself is comprised of many different muscles, ligaments and tendons, and fatty (protective) connective tissue underlying skin.

Image 7.60 • Surface Anatomy • Foot • Dorsal surface.

Landmarks

- talus
- calcaneus
- navicular
- cuboid
- medial cuneiform
- intermediate cuneiform
- lateral cuneiform
- metatarsals
- phalanges

Image 7.61 • Foot, right, dorsal view.

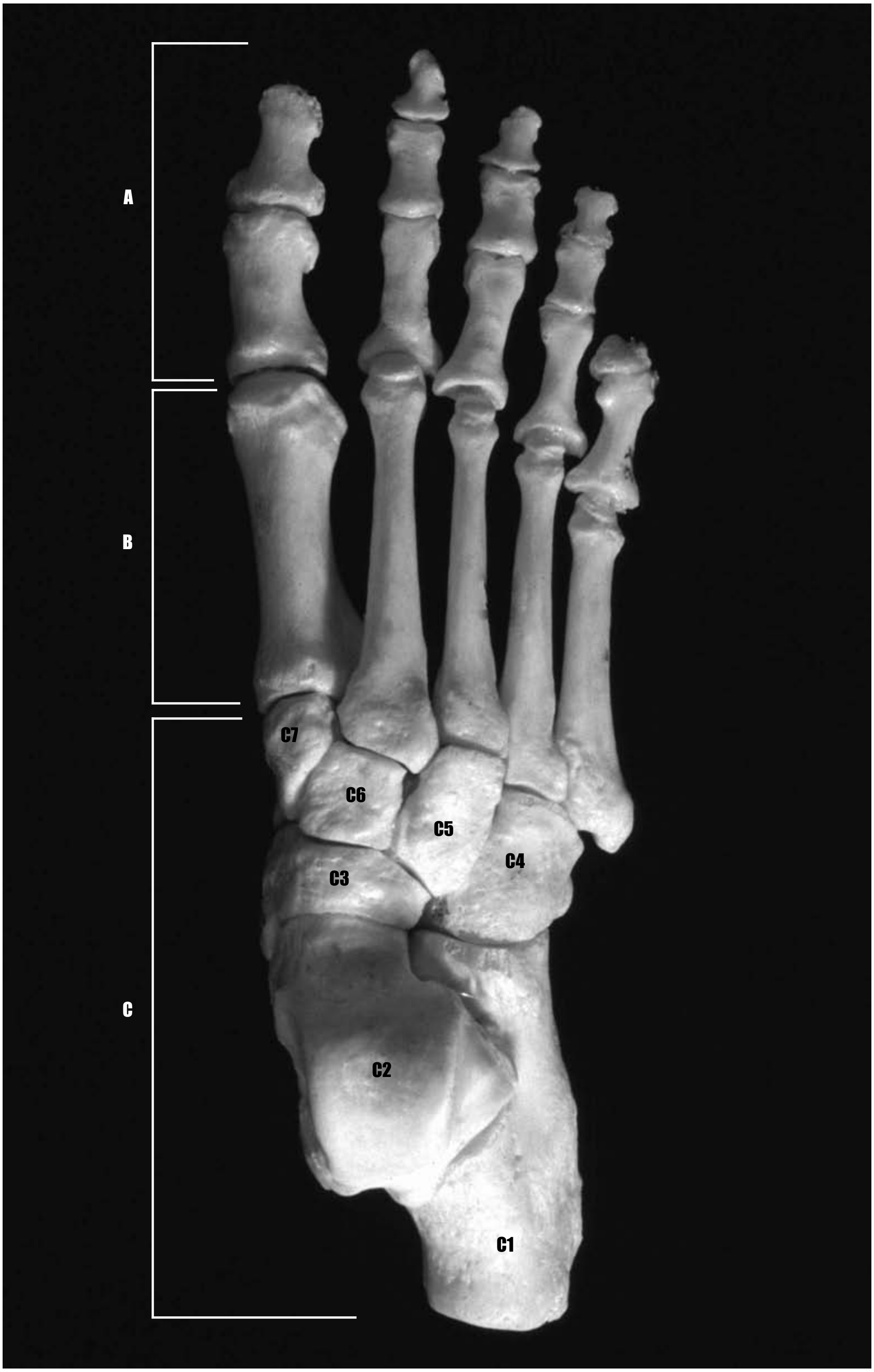


Image 7.62

Foot, right, articulated, dorsal (superior) view.

Image 7.62

A - phalanges
B - metatarsals
C - tarsals
C1 - calcaneus
C2 - talus
C3 - navicular
C4 - cuboid
C5 - lateral cuneiform
C6 - intermediate cuneiform
C7 - medial cuneiform

Image 7.63
Foot, right, articulated, plantar (inferior) view.

Image 7.63

A - phalanges

B - metatarsals

C - tarsals

C1 - calcaneus

C2 - talus

C3 - navicular

C4 - cuboid

C5 - lateral cuneiform

C6 - intermediate cuneiform

C7 - medial cuneiform

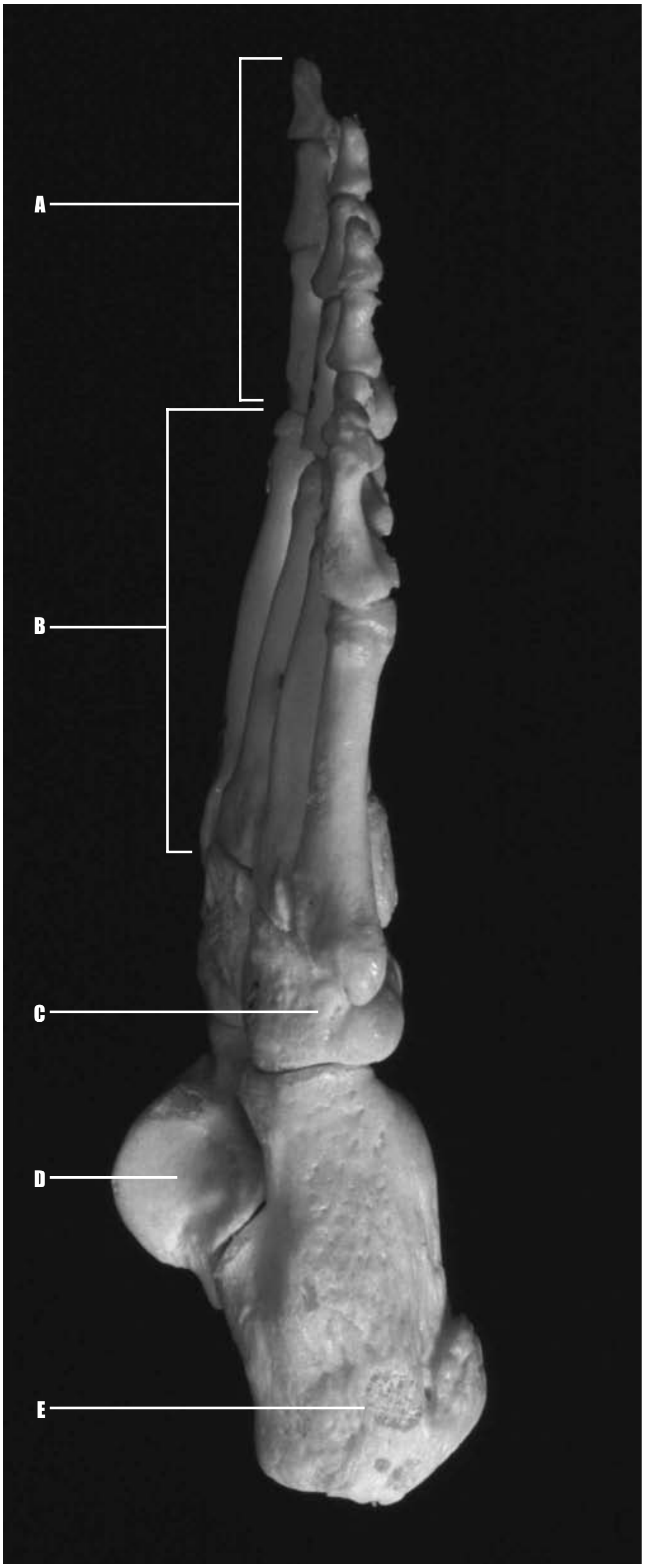


Image 7.64
Foot, right, lateral view.

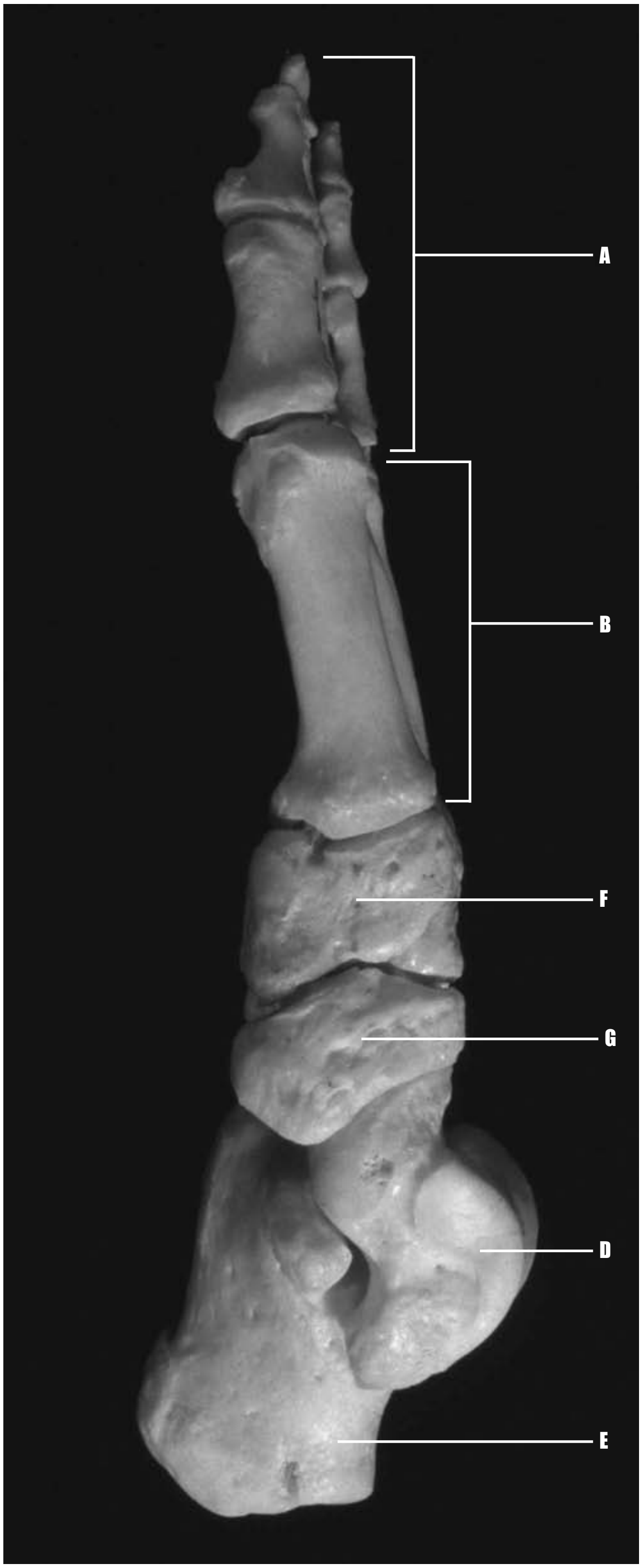


Image 7.65
Foot, right, medial view.

Images 7.64 and 7.65

A - phalanges

B - metatarsals

C - cuboid

D - talus

E - calcaneus

F - medial cuneiform

G - navicular

Image 7.66
Adult patient, plain film radiograph of right foot.

Image 7.67
Adult patient, plain film radiograph of oblique right foot.

Images 7.66 and 7.67

A - sesamoid bone
B - first metatarsal
C - medial cuneiform
D - intermediate cuneiform
E - lateral cuneiform
F - cuboid
G - navicular
H - talus
I - calcaneus

Image 7.68
Adult patient, plain film radiograph of lateral foot.

Image 7.68

A - phalanges

B - metatarsals

C - intermediate cuneiform

D - navicular

E - talus

F - fibula

G - calcaneus

7.5a-1 TALUS

Image 7.69 • *Talus.*

- has a very irregular shape
- has extensive weight bearing capabilities as it must bear the entire body weight during both locomotion and standing
- is special in that it has no site of muscle attachment – only ligaments insert onto this bone
- articulates with the tibia, fibula, calcaneus, navicular

Landmarks

- head (with facet for navicular)
- neck
- facet for medial malleolus of tibia
- trochlea
- lateral process
- anterior calcaneal articular surface
- medial calcaneal articular surface
- posterior calcaneal articular surface
- sulcus tali

*Differentiating Right from Left**

- when oriented as pictured in **Images 7.70** and **7.71**, with the trochlear (superior articular) surface toward you, and the head facing up, the lateral process points toward the same side as that to which the bone belongs

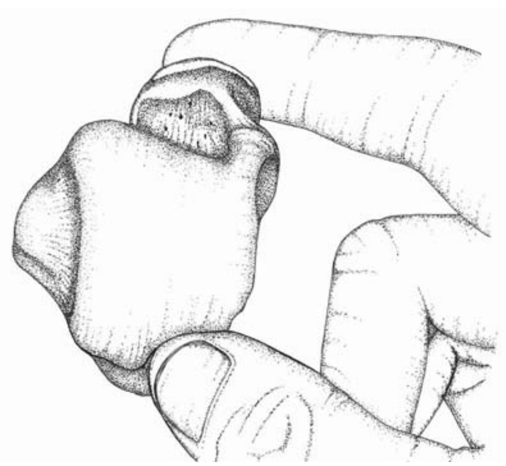


Image 7.70 • Talus, left, dorsal view.

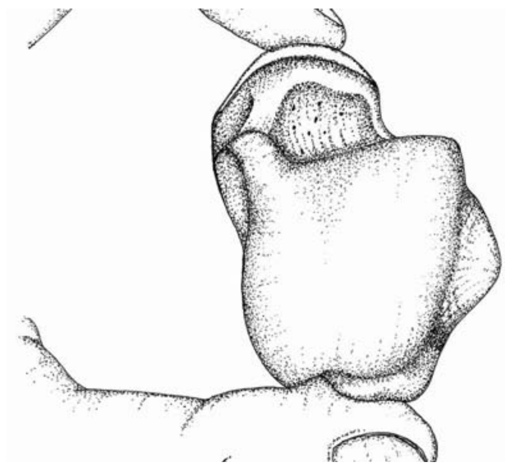
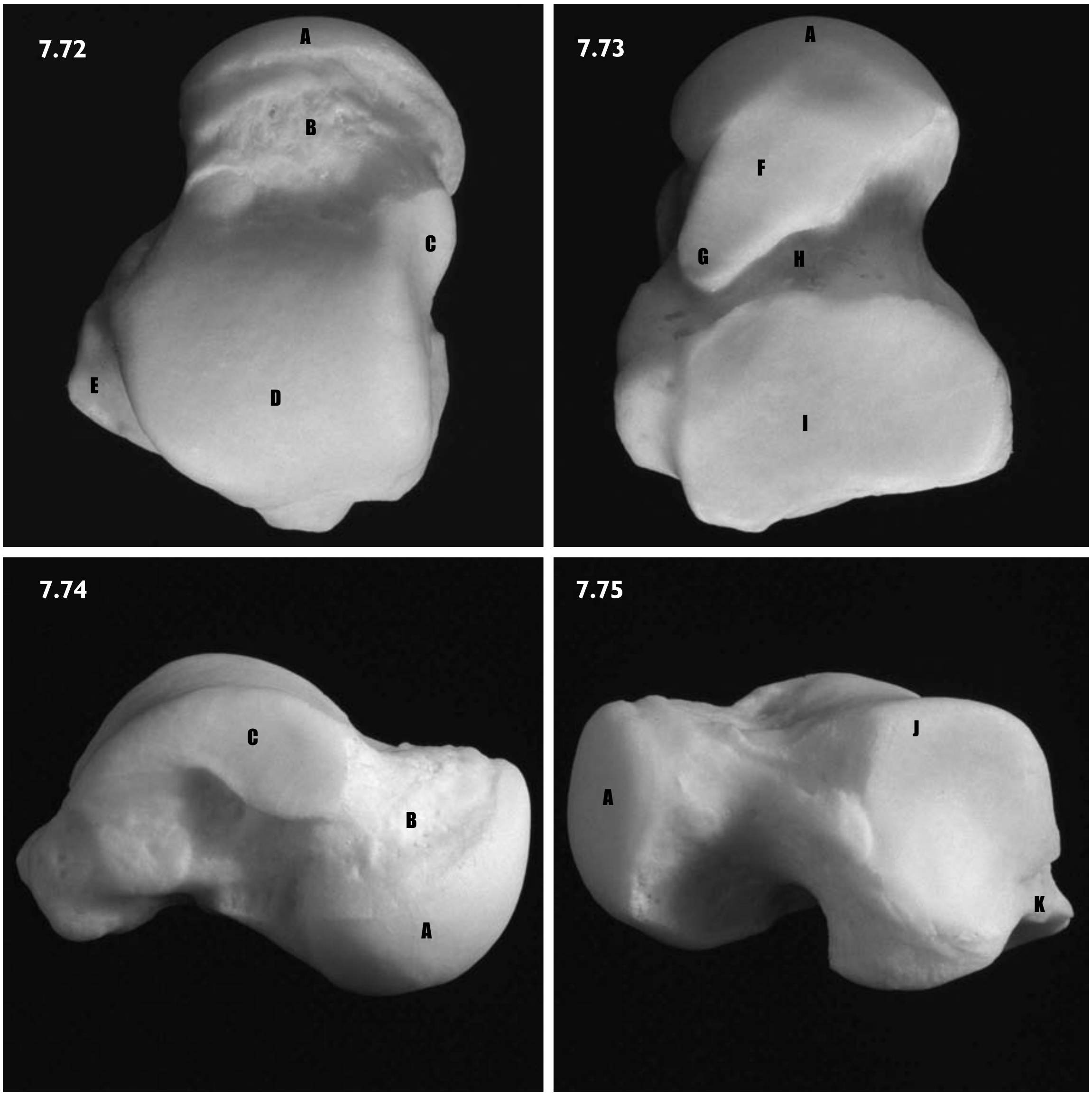


Image 7.71 • Talus, right, dorsal view.

Looking at Fragments

- the majority of fragmented tali have the head fractured off at the neck
- the head can be sided by differentiating between the dorsal and plantar surfaces – recall that the plantar surface bears the flat and smooth anterior and medial calcaneal articular surfaces; these surfaces are angled off toward the same side as that to which the bone belongs when the bone is oriented as pictured in **Image 7.73**
- the dorsal surface of the talar head has a relatively sharp margin that separates the head from the neck; this is lacking on the plantar surface
- fragments of talar body can be sided using the information presented above in "differentiating right from left"

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.



Images 7.72 through 7.75 • Talus, left (superior, inferior, lateral, medial, respectively).

A - head, **B** - neck, **C** - facet for medial malleolus of tibia, **D** - trochlea, **E** - lateral process, **F** - anterior calcaneal articular surface, **G** - medial calcaneal articular surface, **H** - sulcus tali, **I** - posterior calcaneal articular surface, **J** - facet for lateral malleolus, **K** - lateral posterior tubercle.

7.5a-2 CALCANEUS

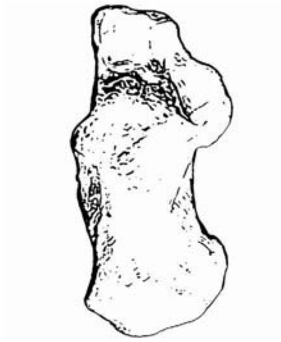


Image 7.76 • *Calcaneus.*

- also known as the *heel bone* or *calcaneum*
- is the largest bone in the foot
- articulates distally with the cuboid, and superiorly with the talus

Landmarks

- anterior talar articular surface
- medial talar articular surface
- posterior talar articular surface
- calcaneal tuberosity
- sustentaculum tali
- sustentacular sulcus
- articular surface for cuboid
- peroneal tubercle
- lateral process of calcaneal tuberosity
- medial process of calcaneal tuberosity

Differentiating Right from Left

- with the talar articular surface pointing toward you and the cuboid articular facet pointing up, the sustentaculum tali points to the side opposite that to which the bone belongs (see **Images 7.77** and **7.78**)

Looking at Fragments

- when fragmented, the calcaneal tuberosity could look like fragmented femoral greater trochanter or ischial tuberosity
- keep in mind, the calcaneus is much more robust than the pelvic bones
- fragmented portions of the plantar surface may also be used to determine side
- use **Image 7.79** to see the orientation of the thin lateral, and fat medial processes of the calcaneal tuberosity
  - when oriented as in this image, with the cuboid articular surface up and heel down, with the plantar surface toward you, the fat medial process will always be on the same side as that to which the bone belongs

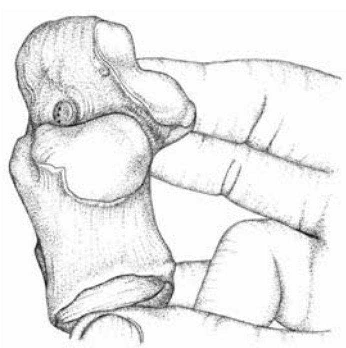


Image 7.77 • Calcaneus, left, dorsal view.

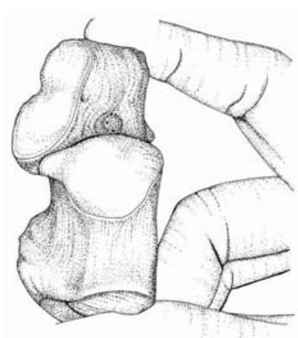


Image 7.78 • Calcaneus, right, dorsal view.

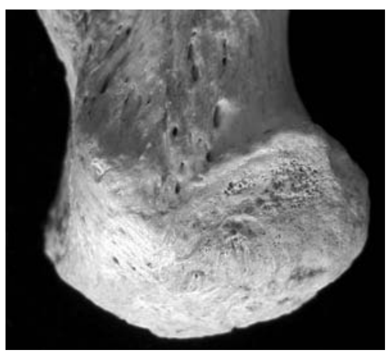
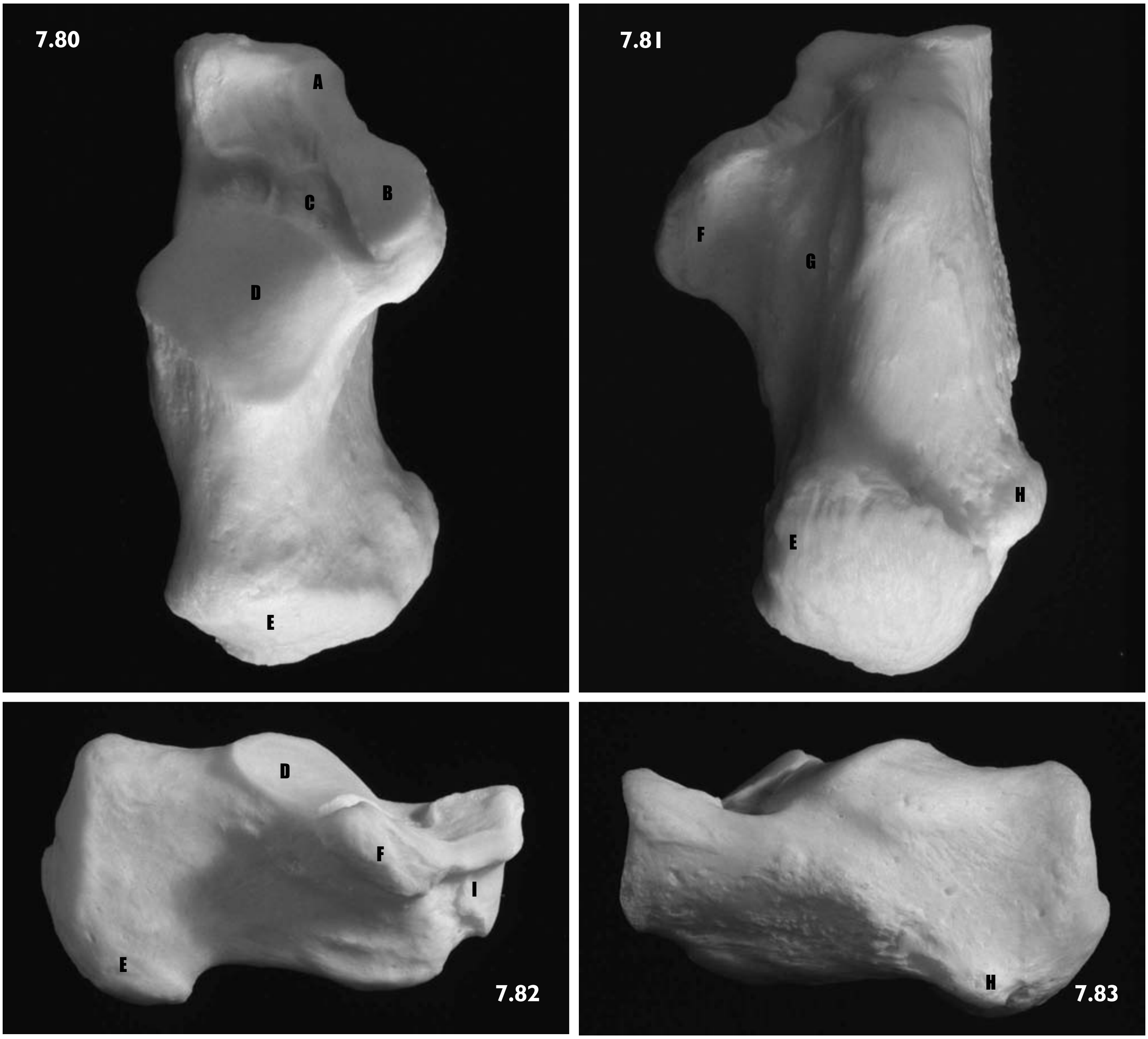
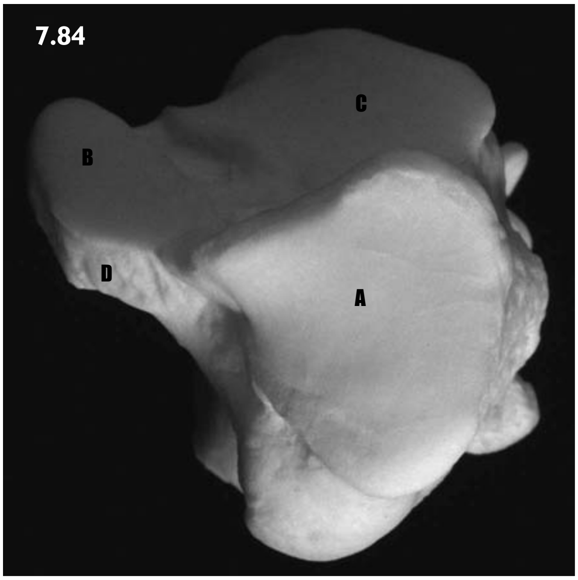


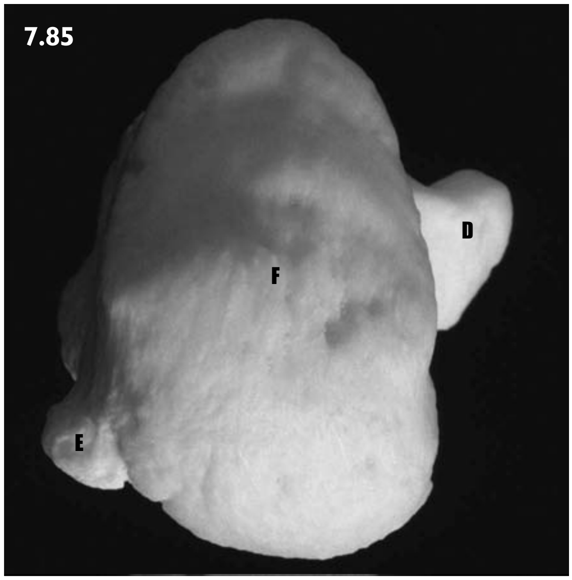
Image 7.79 • Calcaneus, right, plantar view of calcaneal tuberosity.



Images 7.80 through 7.83 • Calcaneus, left (superior, inferior, lateral, medial, respectively).

A - anterior talar articular surface, **B** - middle talar articular surface, **C** - sulcus calcanei, **D** - posterior talar articular surface, **E** - calcaneal tuberosity, **F** - sustentaculum tali, **G** - sustentacular sulcus, **H** - peroneal tuberosity, **I** - articular surface for cuboid.





Images 7.84 to 7.86 • Calcaneus, left (anterior, posterior, anteroposterior radiograph, respectively)

A - articular surface for cuboid, **B** - middle talar articular surface, **C** - posterior talar articular surface, **D** - sustentaculum tali, **E** - peroneal tuberosity, **F** - calcaneal tuberosity, **G** - lateral malleolus, **H** - medial malleolus, **I** - talus, **J** - calcaneus

Images 7.87 and 7.88

A - fibula
B - tibia
C - talus
D - navicular
E - calcaneus
F - cuboid
G - fifth metatarsal

Image 7.87
Adult patient, plain film lateral radiograph of medial ankle.

Image 7.88
Adult patient, plain film lateral radiograph of oblique ankle.

7.5a-3 CUBOID

Image 7.89 • *Cuboid.*

- has a cube-like shape
- has a flat, somewhat roughened non-articular superior (dorsal) surface
- opposite this surface is the irregular inferior (plantar) side which bears a prominent tuberosity
- articulates with the calcaneus, the lateral cuneiform, and metatarsals 4 and 5

Landmarks

- articular facet for calcaneus
- cuboid tuberosity
- facet for lateral cuneiform
- facet for metatarsals

Differentiating Right from Left

- hold the cuboid tuberosity away from you with the metatarsal articular surface directed upward (as demonstrated in **Images 7.90** and **7.91**)
  - the concave border of the bone is found on the lateral side – therefore, the concave surface is on the same side of the bone as that to which the bone belongs

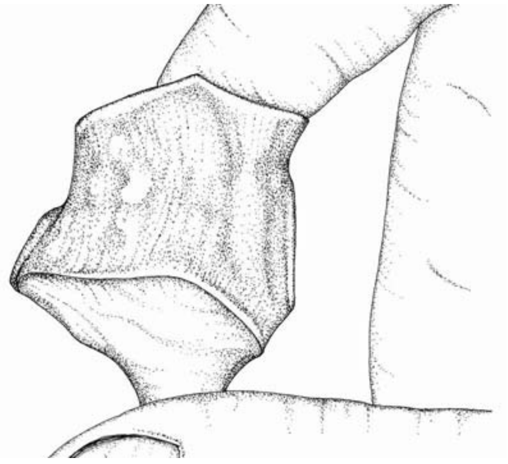


Image 7.90 • Cuboid, left, dorsal view.

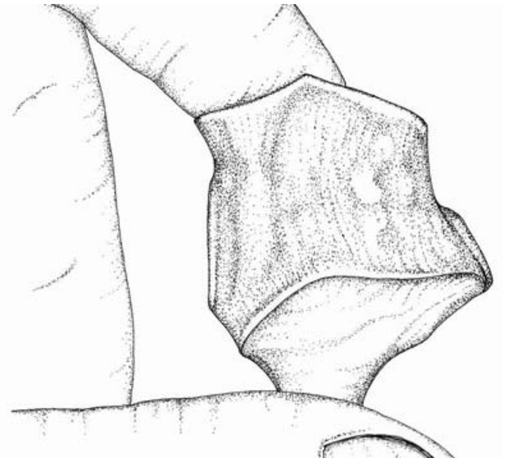
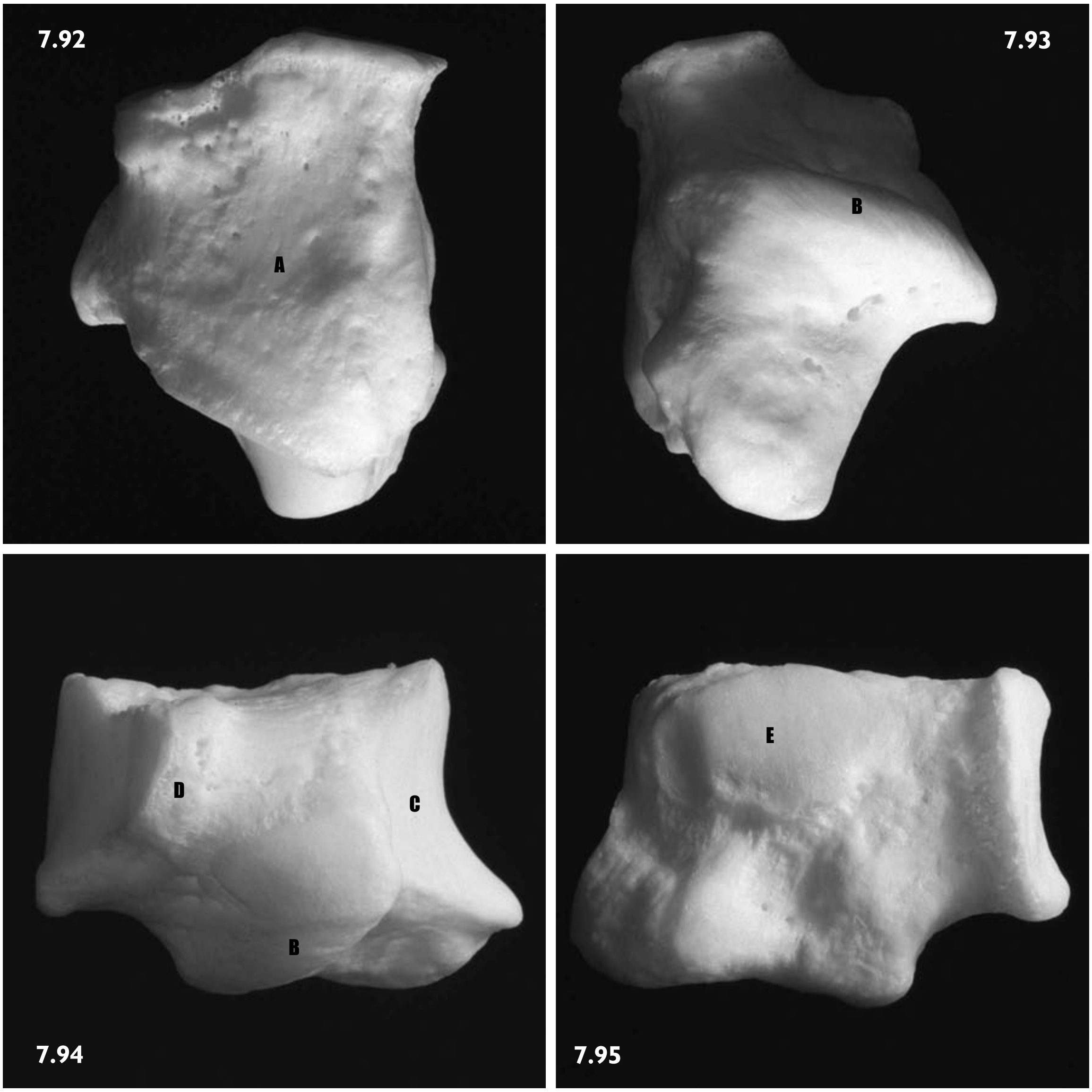


Image 7.91 • Cuboid, right, dorsal view.



Images 7.92 to 7.95 • Cuboid, left (superior, inferior, lateral, medial, respectively).

A - nonarticular surface of cuboid, **B** - cuboid tuberosity, **C** - articular surface for calcaneus, **D** - groove for peroneus longus muscle, **E** - facet for lateral cuneiform.

7.5a-4 NAVICULAR

Image 7.96 • *Navicular.*

- means "little ship"
- has a large, blunt tubercle on the medial side of the bone
- the distal surface has three individual, yet contiguous articular facets divided by two ridges – one for each of the cuneiform bones

Landmarks

- tubercle
- facet for talus
- facet for medial cuneiform
- facet for lateral cuneiform
- facet for intermediate cuneiform

*Differentiating Right from Left**

- with the talar articular surface toward you (concave facet), hold the robust navicular tubercle between your thumb and forefinger (see **Images 7.97** and **7.98**)
  - your forefinger must be on the superior surface of the bone and <u>not</u> the inferior
  - now, the bone points in the same direction as that to which the bone belongs
- one might confuse the fragmented navicular with the scaphoid bone, acetabulum or orbital rim, however:
  - the acetabulum is far more dense than navicular, and the acetabulum is far more concave than the navicular facet for the head of talus
  - the orbital rim is much more concave than the aforementioned facet for the talar head, and the orbital margin may contain sutures or foramina
  - the navicular is a very porous, cancellous bone that is much different from skull bone on cross-section
  - the non-articular portion of the navicular is not easily confused with the outer table of the skull as the navicular is far more rough in texture

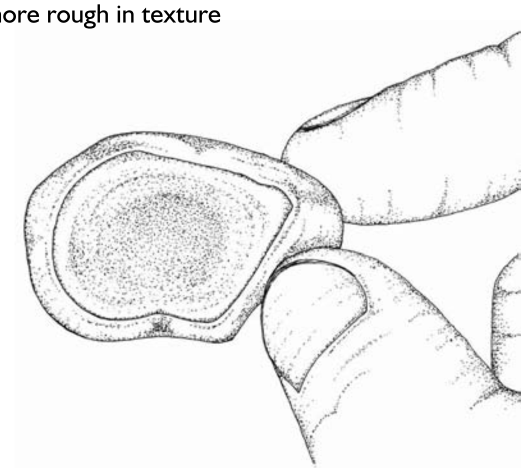


Image 7.97 • Navicular, left, proximal view.

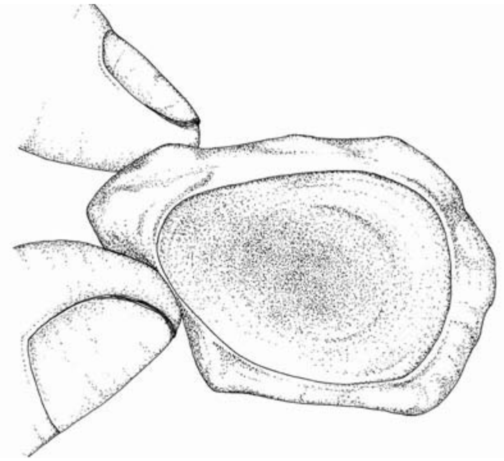
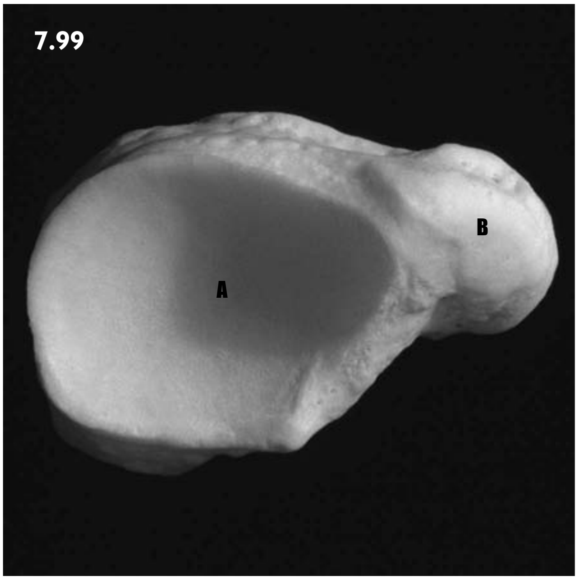
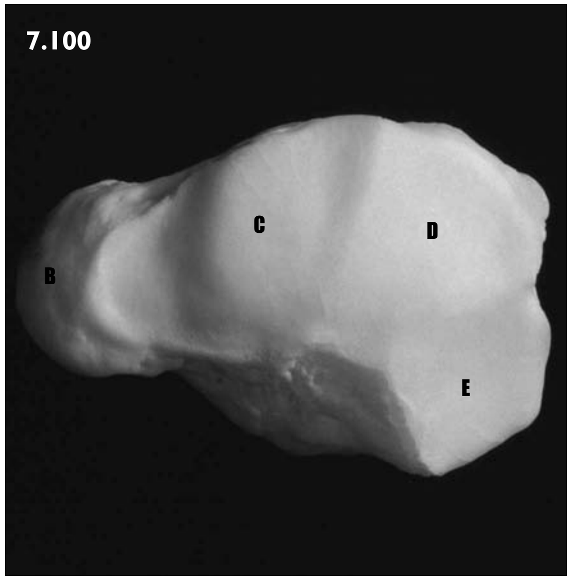


Image 7.98 • Navicular, right, proximal view.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.





Images 7.99 and 7.100 • Navicular, left (proximal and distal, respectively).

A - facet for head of talus, **B** - tubercle, **C** - facet for medial cuneiform, **D** - facet for intermediate cuneiform, **E** - facet for lateral cuneiform.

7.5a-5 MEDIAL CUNEIFORM

Image 7.101 • *Medial cuneiform.*

- is the largest cuneiform
- the medial surface is rough, convex, and is non-articular
  - however, it may have a well-circumscribed smooth area caused by the tendon of the tibialis anterior muscle
- the concave lateral surface bears a large "L-shaped" facet
- the proximal end varies from being triangular to round in shape
- the distal end is shaped like a kidney
- articulates with the navicular, intermediate cuneiform, and metatarsals 1 and 2

Landmarks

- facet for metatarsal 1
- facet for metatarsal 2
- facet for intermediate cuneiform
- facet for navicular

Differentiating Right from Left

- first, you must orient this bone as pictured in **Images 7.102** and **7.103**, with the blunted inferior edge down, and the kidney-shaped facet (for the first metatarsal) toward you
  - the teardrop-shaped facet (for navicular) should be away from you
  - the whole specimen now appears to be bowing toward the same side as that to which the bone belongs

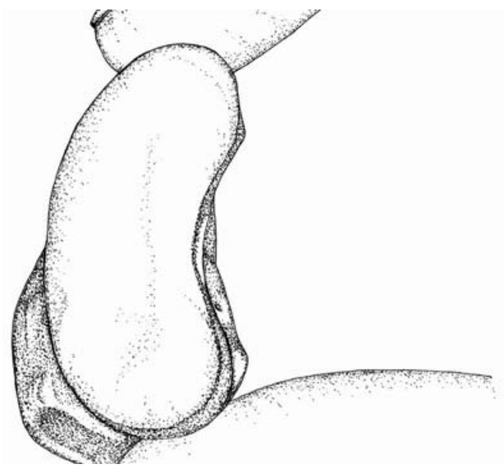


Image 7.102 • Medial cuneiform, left, proximal view.

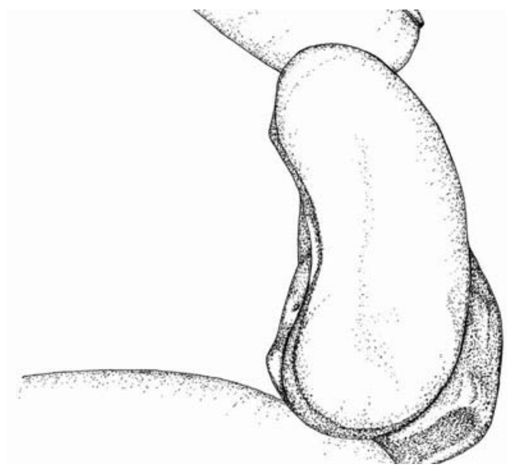
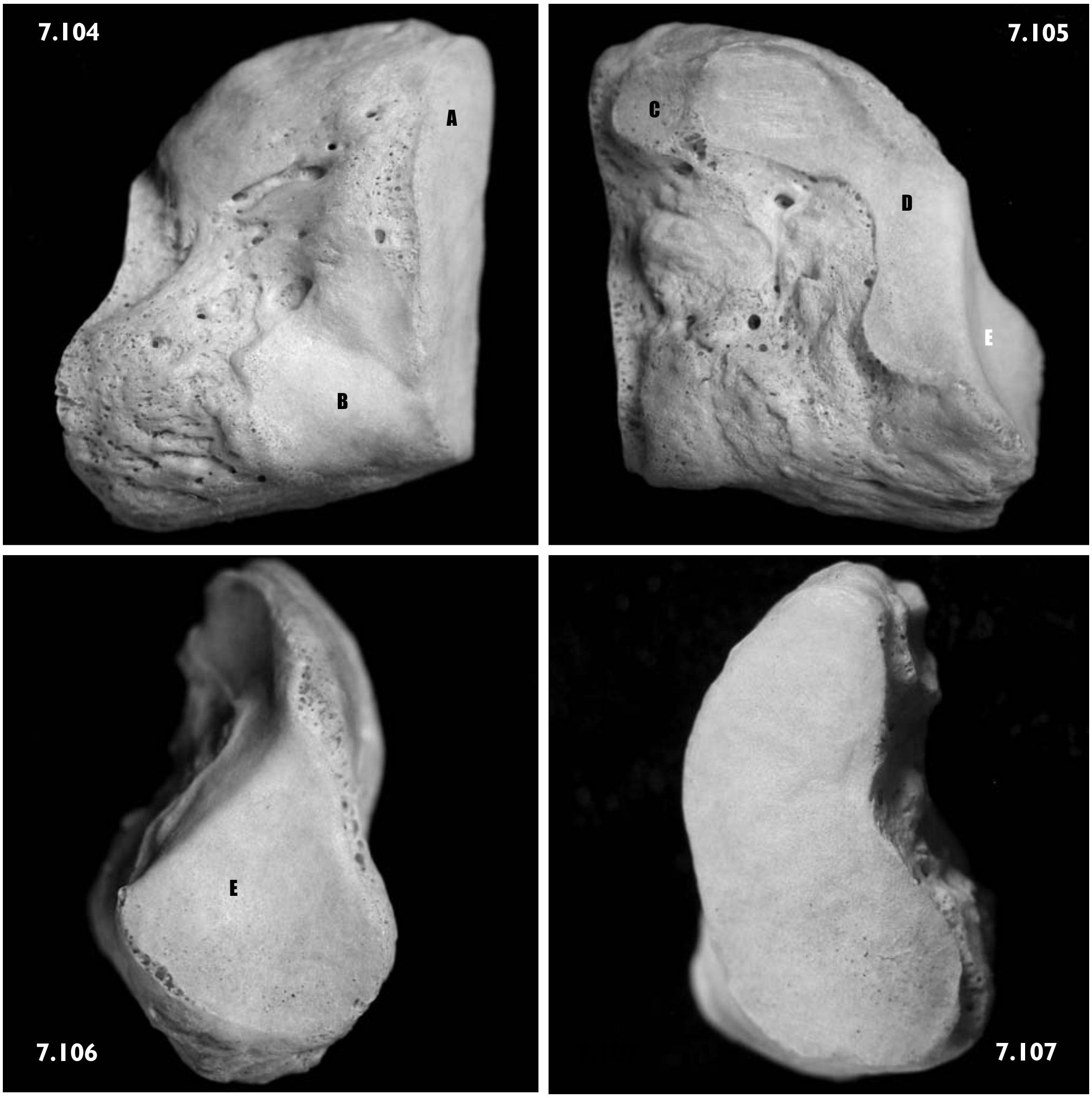


Image 7.103 • Medial cuneiform, right, proximal view.



Images 7.104 to 7.107 • Medial cuneiform, left (medial, lateral, proximal, distal, respectively).

A - facet for metatarsal 1, **B** - impression for tendon of tibialis anterior muscle, **C** - facet for metatarsal 2, **D** - facet for intermediate cuneiform, **E** - articular surface for navicular.

7.5a-6 INTERMEDIATE CUNEIFORM

Image 7.108 • *Intermediate cuneiform.*

- is the smallest of the three cuneiform bones
- the medial surface is convex and bears a large "L-shaped" facet
- the lateral surface is concave and bears a broad articular facet along one edge
- the proximal end is concave and the distal end is convex
- articulates with the navicular, metatarsal 2, and the medial and lateral cuneiform bones

Landmarks

- facet for medial cuneiform bone
- facet for lateral cuneiform bone
- facet for navicular (concave side)
- facet for metatarsal 2

Differentiating Right from Left

- place the flat non-articular (dorsal/superior) surface on the table with the remainder of this triangular bone facing upward toward the sky as oriented in **Images 7.109** and **7.110**
  - the concave (navicular) facet <u>must</u> be pointing toward you
  - the plantar surface of the bone now appears to project away from the table, and slants toward the side opposite that to which the bone belongs

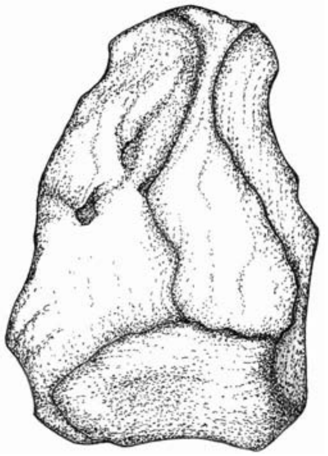


Image 7.109 • Intermediate cuneiform, left, distal view..

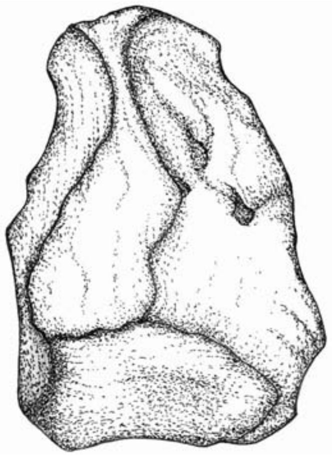
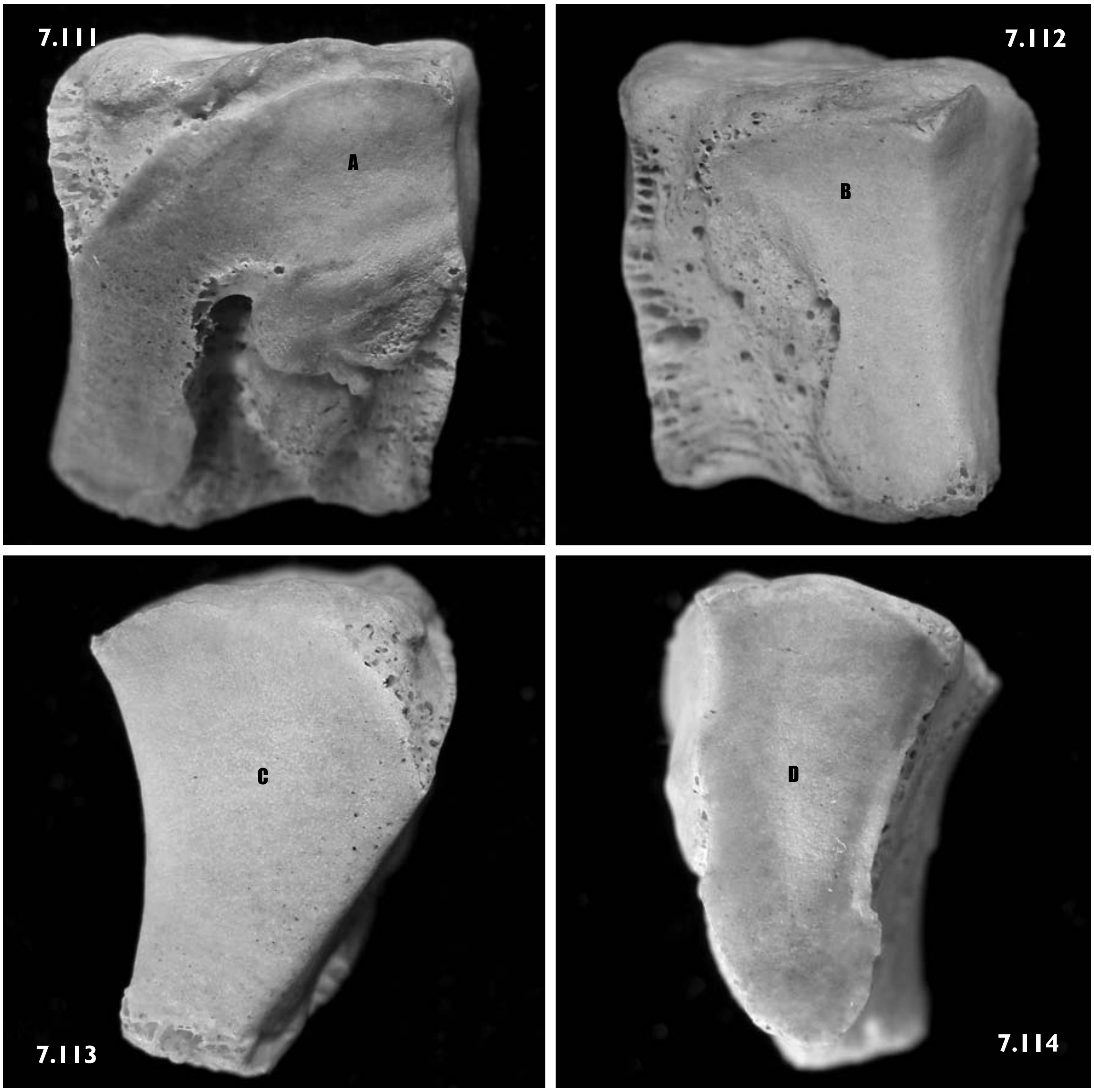


Image 7.110 • Intermediate cuneiform, right, distal view.



Images 7.111 to 7.114 • Intermediate cuneiform, left (medial, lateral, proximal, distal, respectively).
A - facet for medial cuneiform, **B** - facet for lateral cuneiform, **C** - facet for navicular, **D** - facet for metacarpal 2.

7.5a-7 LATERAL CUNEIFORM

Image 7.115 • *Lateral cuneiform.*

- the medial surface bears multiple articular facets
- the lateral surface typically has one large articular facet, with or without other small articular facets
- the proximal end bears a triangular facet for the navicular
- the distal end has a large, subtly convex, triangular facet for metatarsal 2
- although both intermediate and lateral cuneiforms bear plantar ridges, the ridge on the lateral cuneiform is shorter, and is not continuous along its length
- this can be useful in differentiating between lateral and intermediate cuneiform bones
- articulates with the navicular, cuboid, intermediate cuneiform and metatarsals 2 through 4

Landmarks

- facet for intermediate cuneiform
- facet for cuboid
- facet for navicular
- tuberosity

Differentiating Right from Left

- place the flat, non-articular (dorsal/superior) surface on the table top with the navicular facet toward you, i.e., the edge of the ridge not flush with the bone should be directed toward you
  - the tubercle now points toward the opposite side as that to which the bone belongs

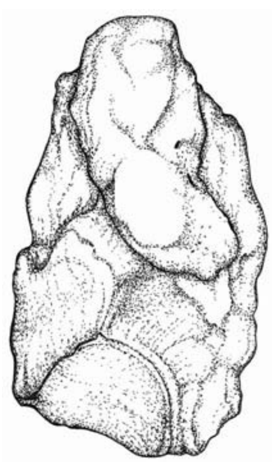


Image 7.116 • Lateral cuneiform, left, proximal view.

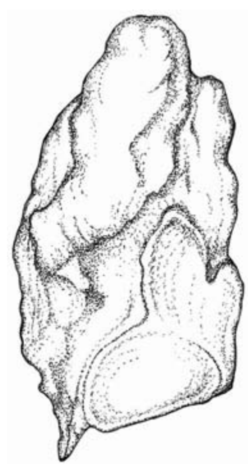
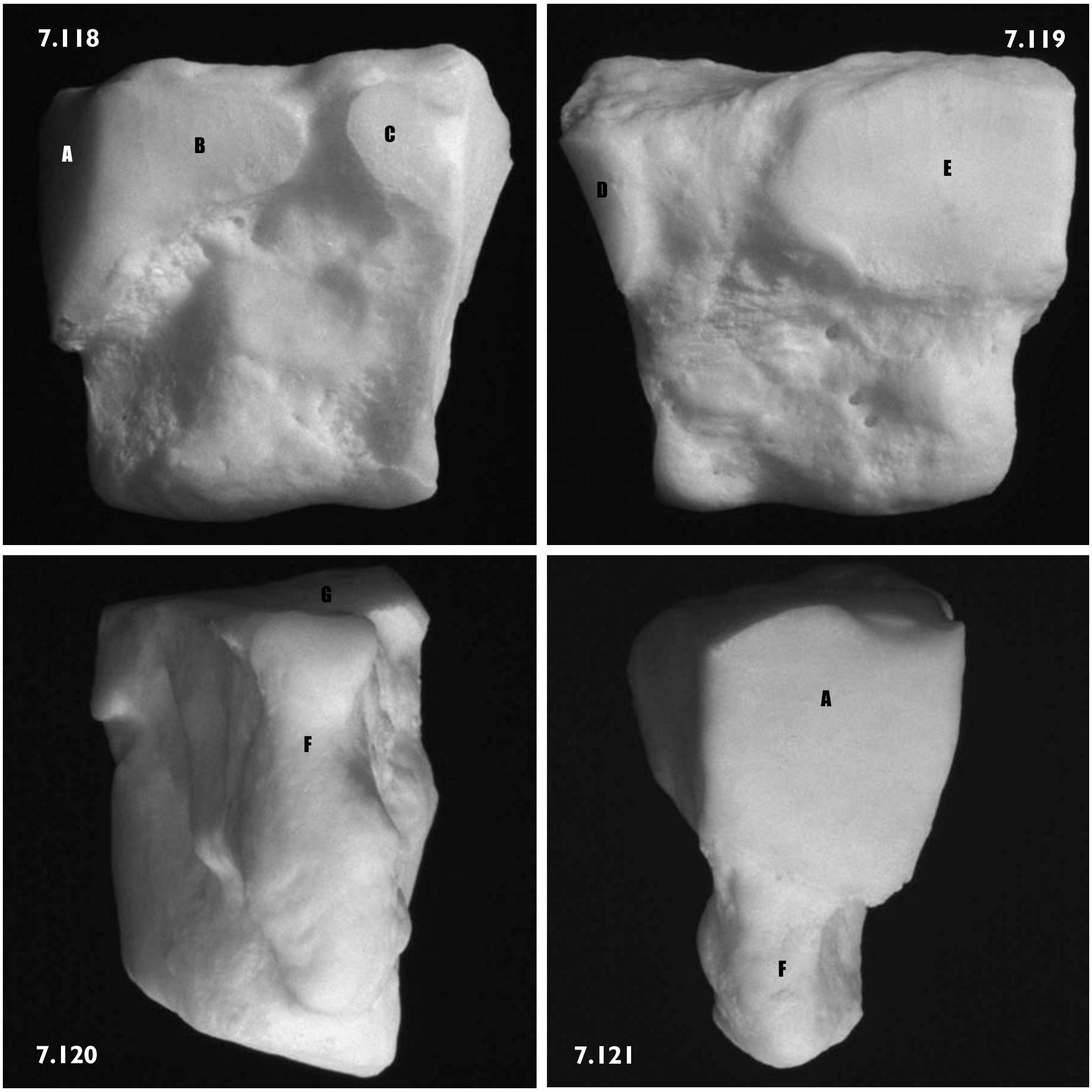


Image 7.117 • Lateral cuneiform, right, proximal view.



Images 7.118 to 7.121 • Lateral cuneiform, left (medial, lateral, plantar, proximal, respectively).
A - facet for navicular, **B** - facet for intermediate cuneiform, **C** - facet for metatarsal 2, **D** - facet for metatarsal 4, **E** - facet for cuboid, **F** - tuberosity, **G** - facet for metatarsal 3.

7.5b METATARSALS

- the metatarsals (of the foot) are homologous to the metacarpals (of the hand)
- there are five metatarsals, numbered 1 - 5, with metatarsal 1 being the great toe (hallux)
- all are tubular bones
  - they have thin shafts that separate the angular bases (proximal ends) from the round heads (distal ends)
  - the plantar surface is concave
- each bone is identified and sided mostly based on the appearance of the proximal end
- note that metacarpals and metatarsals differ significantly in their appearance
  - for example, metacarpal heads are rounder and more bulbous than metatarsal heads, and metatarsal shafts are much longer and thinner than those of metacarpals
- the bases of the metatarsals articulate with each other
- furthermore, metatarsal 1 articulates with the medial cuneiform, metatarsal 2 articulates with both the medial and intermediate cuneiforms, metatarsal 3 articulates with the lateral cuneiform, and metatarsals 4 and 5 articulate with cuboid
- note that the heads articulate with the proximal row of phalanges

Landmarks

- head
- base (you will need to memorize the characteristic appearance of each base to be able to properly identify these bones when isolated)
- shaft

Image 7.122
Foot, disarticulated, dorsal (superior) view of left metatarsals.
A - metatarsal 1, **B** - metatarsal 2, **C** - metatarsal 3, **D** - metatarsal 4, **E** - metatarsal 5.

Image 7.123

Adult patient, plain film radiograph of right foot.

A - metatarsal 1, **B** - metatarsal 2, **C** - metatarsal 3, **D** - metatarsal 4, **E** - metatarsal 5, **F** - medial cuneiform, **G** - intermediate cuneiform, **H** - lateral cuneiform, **I** - cuboid, **J** - navicular, **K** - talus, **L** - calcaneus.

7.5b-1 METATARSAL 1

Image 7.124 • *First metatarsal.*

- is the most medial metatarsal
- is the shortest and biggest of the metatarsals
- has a large kidney-shaped facet on its proximal end
- articulates proximally with the medial cuneiform and distally with the proximal toe phalanx

Landmarks

- base
- shaft
- head

*Differentiating Right from Left**

- hold the bone as depicted in **Images 7.125** and **7.126**, with the base toward you
  - the two poles of the kidney-shaped facet will be located on the same side of the bone as that to which the bone belongs

Looking at Fragments

- the metatarsal I shaft is quite robust on cross-section and the midshaft is nearly triangular in appearance
- to help side this bone from an isolated fragment of shaft, note that when held with the dorsum (flattest edge) toward you, as in **Image 7.127**, with the head up and base down, the medial shaft margin is flatter than the lateral shaft margin which is more concave
- when viewed "head on", the metatarsal I head has three small nodular eminences
  - if one ignores the centrally located nodule, the largest nodule is found to be on the same side of the base as that to which the bone belongs

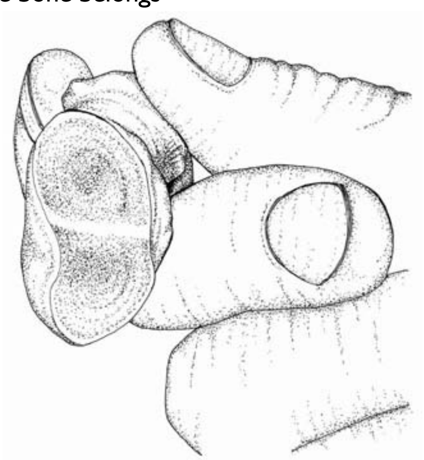


Image 7.125 • First metatarsal, left, proximal end.

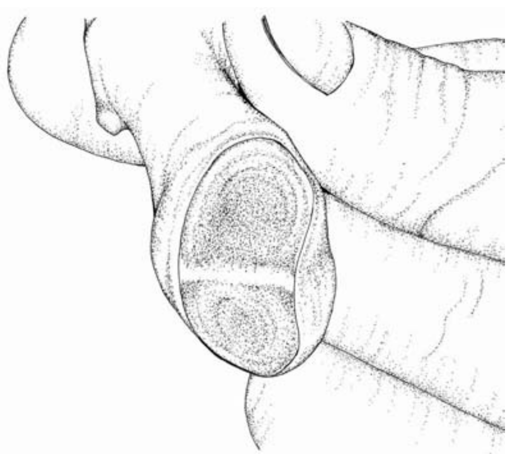


Image 7.126 • First metatarsal, right, proximal end.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.

Images 7.127 to 7.130 • First metatarsal, left (dorsal, lateral, plantar, medial, respectively).

A - tuberosity, **B** - grooves for sesamoid bones, **C** - pressure facet for metatarsal 2 (*inconstant*).

7.5b-2 METATARSAL 2

Image 7.131 • *Second metatarsal.*

- is lateral to metatarsal 1
- is the longest and thinnest metatarsal
- has a small styloid process located on the dorsal surface of the base – a feature found only on metatarsals 2 and 5
- articulates with the intermediate and medial cuneiforms, as well as a proximal phalanx

Landmarks

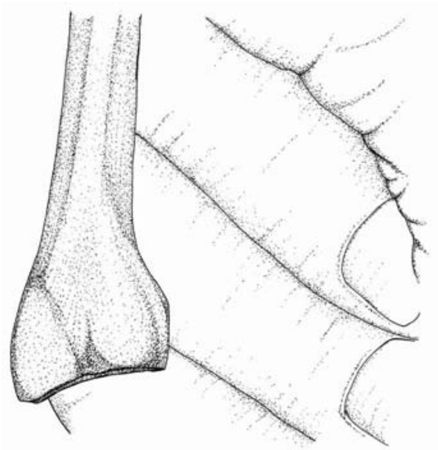
- head
- base
- shaft
- styloid process

Differentiating Right from Left

- when oriented as seen in **Images 7.132** and **7.133** with the flattest edge (dorsum) toward you, the head up and the base down, the styloid process can be found on the same side as that to which the bone belongs

Looking at Fragments

- differentiation between shaft fragments of different metatarsals can be difficult
- keep in mind, though, the basic principles of :
  - metarsal 3 and 4 become progressively more obliquely twisted allowing differentiation between 2, 3 and 4
- fragments of base are generally easily identified because of the small styloid process
- arthritis and other pathological processes can alter the appearance of metatarsal 3, creating some confusion as bony exostosis at the dorsal inferolateral margin may mimic the appearance of a styloid process
- differentiation between the metatarsals based solely on an examination of metatarsal heads is very difficult and usually of little use
- it is important, though, that you be able to differentiate between the metacarpal and metatarsal heads



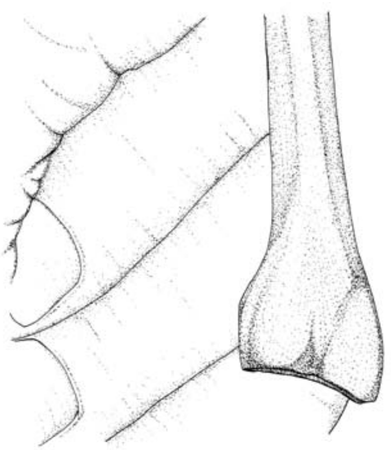
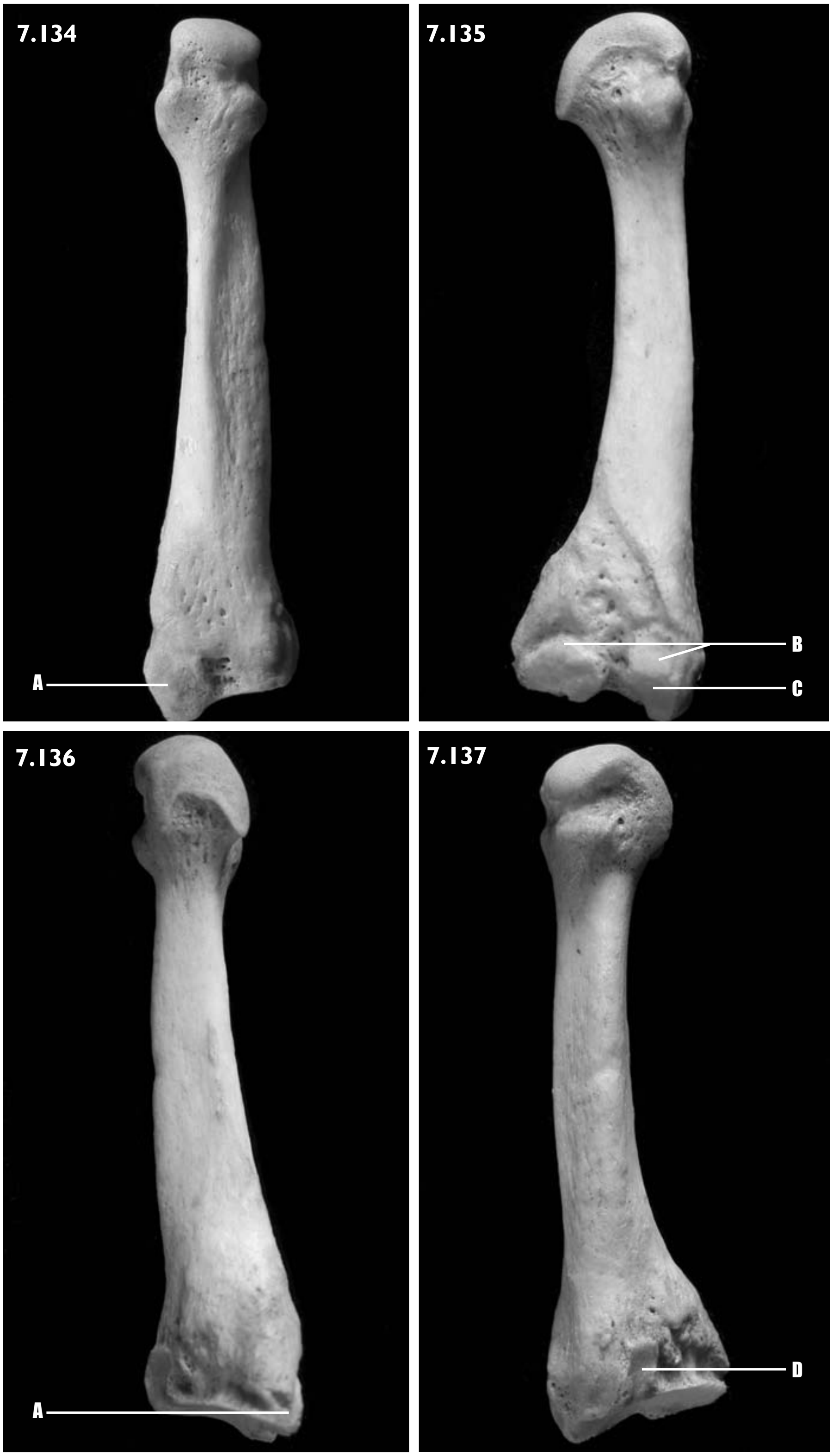


Image 7.132 • Second metatarsal, left (left).
Image 7.133 • Second metacarpal, right (right).



Images 7.134 to 7.137 • Second metatarsal, left (dorsal, lateral, plantar, medial, respectively).

A - styloid process, **B** - facet for metatarsal 3, **C** - facet for lateral cuneiform, **D** - facet for medial cuneiform.

7.5b-3 METATARSAL 3

Image 7.138 • *Third metatarsal.*

- is lateral to metatarsal 2
- is very similar in morphology to metatarsal 2, but is lacking a styloid process
- the mid to proximal portions of the shaft appear to be somewhat twisted, and show lateral expansion
- articulates with the lateral cuneiform, as well as a proximal phalanx

Landmarks

- base
- shaft

*Differentiating Right from Left**

- hold the bone as pictured in **Images 7.139** and **7.140** with the head up, base down and flattest side (dorsum) toward you
  - in this position, the base appears to angle toward the same side as that to which the bone belongs

Looking at Fragments

- the base can be easily identified as it differs markedly from metatarsals 1, 4 and 5 and lacks the styloid process found on metatarsal 2
- this shaft is somewhat intermediate in configuration between metatarsals 2 and 3, with a notable twist being imparted to the proximal half of its shaft

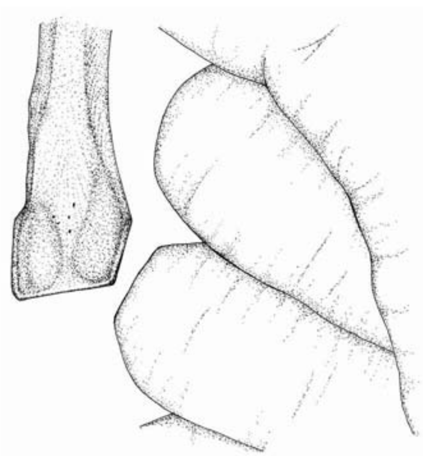


Image 7.139 • Third metatarsal, left, dorsal view.

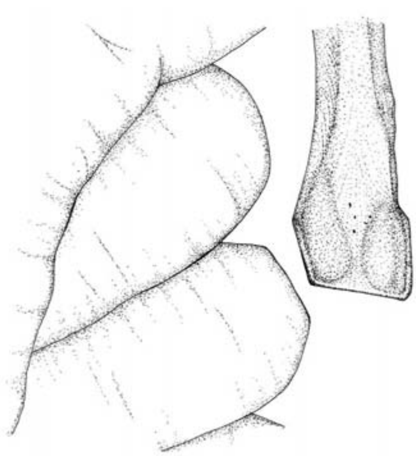


Image 7.140 • Third metatarsal, right, dorsal view.

*After Bass W. Human Osteology: A Laboratory and Field Manual. 4 ed. Columbia, MO: Missouri Archaeological Society; 1995.

Images 7.141 to 7.144 • Third metatarsal, left (dorsal, lateral, plantar, medial, respectively).

A - tubercle, **B** - facets for metatarsal 4, **C** - facet for metatarsal 2.

7.5b-4 METATARSAL 4

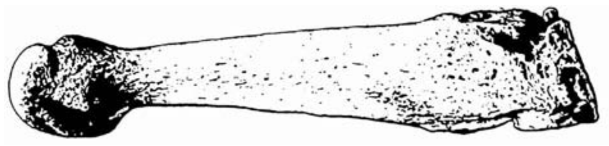


Image 7.145 • *Fourth metatarsal.*

- is lateral to metatarsal 3
- has an overall morphology intermediate between metatarsals 3 and 5
- is much shorter than metatarsals 2 and 5
- twisting of the shaft is markedly demonstrated in this bone (recall metatarsals 2 and 3)
- articulates with metatarsals 3 and 5, the cuboid proximally, as well as a proximal phalanx

Landmarks

- head
- base
- shaft

Differentiating Right from Left

- when oriented as in **Images 7.146** and **7.147**, with the head up, base down, and dorsum toward you, the inferiormost margin is found to project on the same side as that to which the bone belongs

Looking at Fragments

- one could become confused between fragments of proximal metatarsal 3 and 4 as both have similarly appearing articular facets, and overall morphology
  - keep in mind, that as a general rule, if you are comparing two fragments, those fragments belonging to metatarsal 4 will generally have much larger facets for articulation with its neighboring fifth metatarsal
- shaft fragments of metatarsal 4 are more markedly twisted in appearance than the other metatarsals, and are becoming more robust like the shaft of metatarsal 5

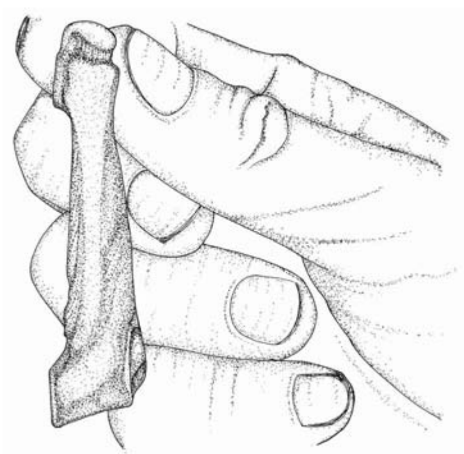


Image 7.146 • Fourth metatarsal, left, dorsal view.

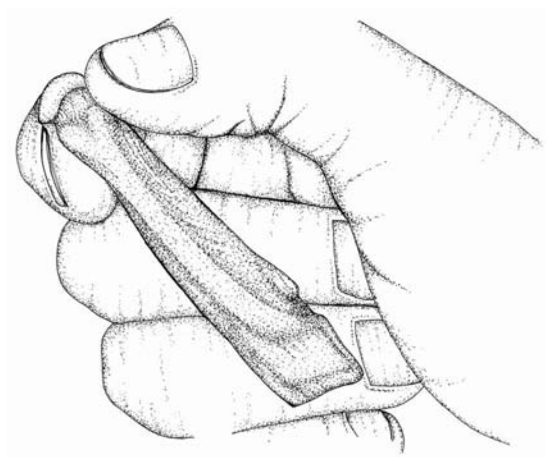


Image 7.147 • Fourth metatarsal right, dorsal view.

Images 7.148 to 7.151 • Fourth metatarsal, left (dorsal, lateral, plantar, medial, respectively).

A - facet for metatarsal 5, **B** - facet for metatarsal 3, **C** - facet for lateral cuneiform.

7.5b-5 METATARSAL 5

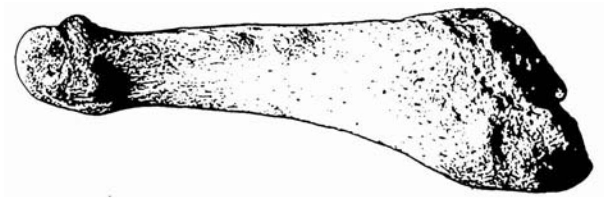


Image 7.152 • *Fifth metatarsal.*

- is the most lateral metatarsal
- has the flattest profile of all metatarsals
- has a narrow head and a base that is markedly enlarged in horizontal plane
- bears a large styloid process (which some refer to as a tuberosity) on its lateral margin
- articulates with metatarsal 4, the cuboid, as well as a proximal phalanx

Landmarks

- head
- base
- shaft

Differentiating Right from Left

- first you must differentiate between plantar and dorsal surfaces
  - generally, the shaft of the dorsal surface is smooth and not grooved, whereas the plantar surface tends to be more irregular and may bear a long groove for tendons of the foot muscles
  - hold the bone as pictured in **Images 7.153** and **7.154**, with the smoothest (dorsal) surface up, and the head away from you
  - the large styloid process will now be on the same side as that to which the bone belongs

Looking at Fragments

- the base of metatarsal 5 is not easily confused with other bases, although when very fragmented it could conceivably be confused with fragments of the ischial ramus, greater trochanter of the femur, or possibly even very fragmented mastoid process of the temporal bone (keep in mind, though, that the mastoid process has innumerable visible air cells)
- the very wide shaft, combined with the generalized flatness of this element, helps to confirm the identity of this bone

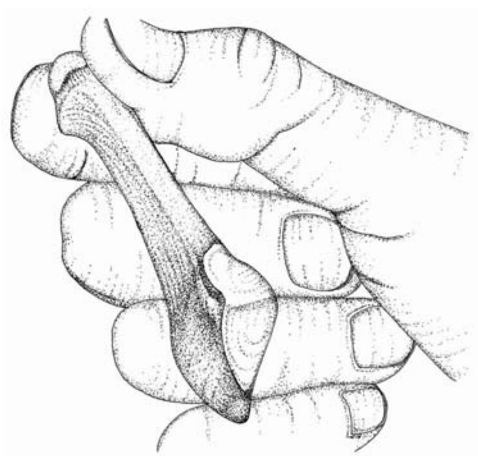


Image 7.153 • Fifth metatarsal, left, dorsal view.

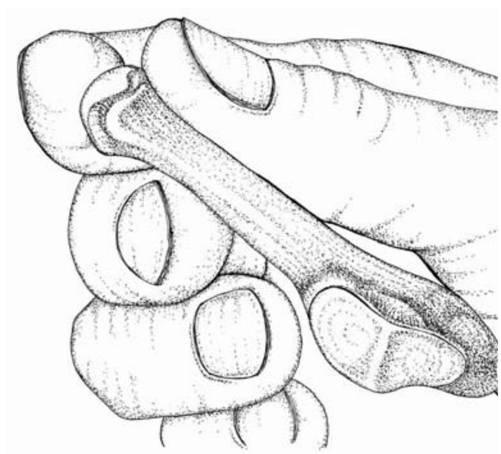


Image 7.154 • Fifth metatarsal, right, dorsal view.

Images 7.155 to 7.158 • Fifth metatarsal, left (dorsal, lateral, plantar, medial, respectively).

A - styloid process/tuberosity, **B** - facet for metatarsal 4, **C** - facet for cuboid.

7.5c PHALANGES

Image 7.159 • *First toe distal phalanx.*

- there are fourteen phalanges in each foot, divided between three rows (proximal, intermediate and distal)
  - each digit has three phalanges, with the exception of the great toe (hallux), which has two
- the first row has five (proximal) phalanges
- the second row has four (intermediate) phalanges
- the third row has five (distal) phalanges

Row 1

- in the proximal row, the phalanges are rather "dumbbell-shaped" with enlarged bases and heads and narrow shafts
  - the base is deeply concave
  - the head is subtly grooved in the midline to allow for articulation with the angular proximal end of the intermediate phalanges

Rows 2 and 3

- the intermediate phalanges are very small cubes of bone
- as mentioned, the proximal ends of the intermediate phalanges (row 2) are angular, allowing for articulation with the distal ends of the proximal phalanges
- the distal articular surface has a smooth, round articular surface that is somewhat "pinched" in the midline
- the proximal phalanges (row 3) have a characteristic appearance because of their tapered fingertip-like distal ends

Important to Notice

- you must be able to differentiate between hand and foot phalanges
- the phalanges of hand digits two through five are larger than those of the foot
- the two phalanges of the great toe are larger than any hand phalanx
- mid-shaft cross-sections of foot phalanges tend to be round (**Image 7.160**), and those from hand phalanges tend to be flat on the palmar surface (**Image 7.161**)

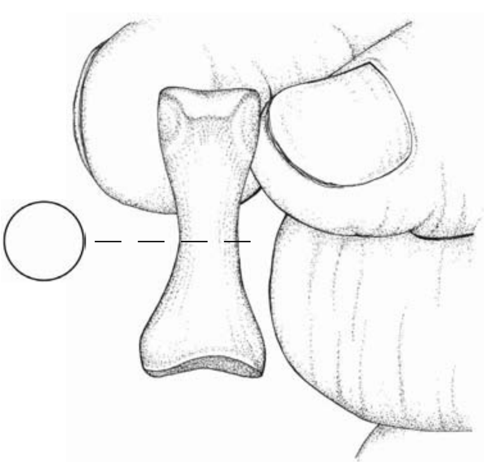


Image 7.160 • Proximal foot phalanx.

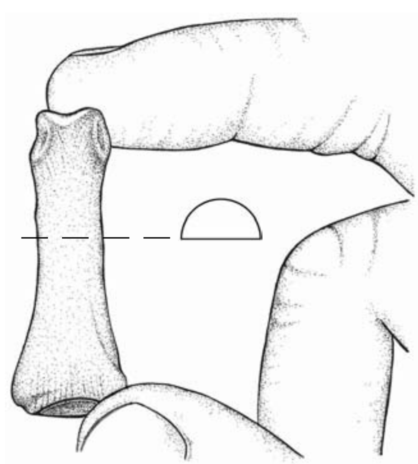
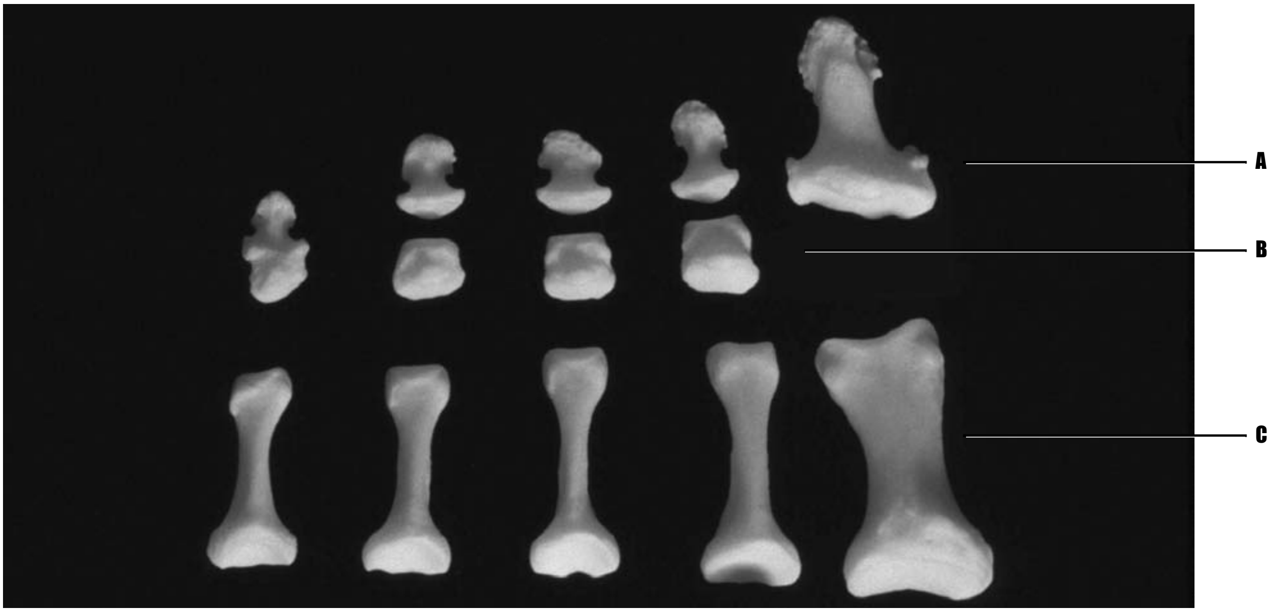


Image 7.161 • Proximal hand phalanx.



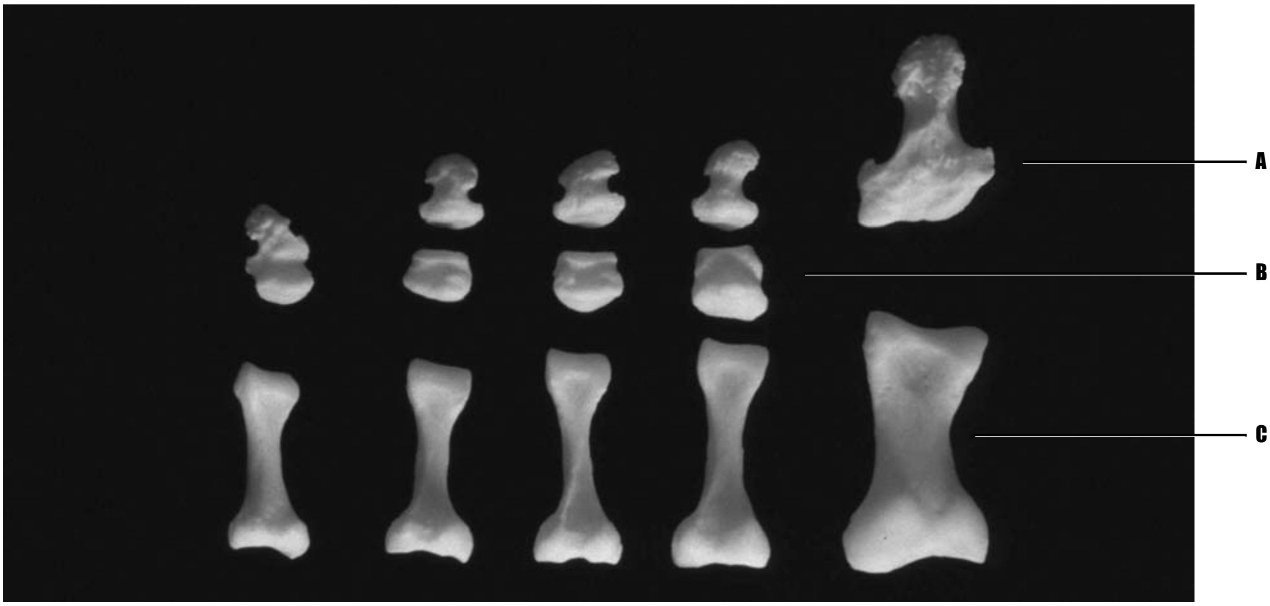


Image 7.162 (above)

Adult foot phalanges, dorsal view.

Image 7.163 (below)

Adult foot phalanges, plantar view.

A - distal phalanges, **B** - intermediate phalanges, **C** - proximal phalanges. Note that in this example, the fifth toe shows fusion of the intermediate and distal phalanges. This is a very common variation of normal, and a common consequence of the arthritic processes typically seen with aging.

Unit Three: Wrapping it Up

As humans, we are on a constant mission to better ourselves; a reality more than common in academic settings. If reading this book has sparked an interest in human osteology, you may wish to seek out other literature that approaches the subject from a slightly different perspective. Our reference list cites those works we made use of in the process of writing this text. You may find them useful in your academic pursuits.

We have also provided you with an index of the items presented within this book. We have tried to maintain a structured approach to simplify your search for specific topics and landmarks.

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An interesting website is: http://medstat.med.utah.edu/kw/osteo/forensics/

8.2 INDEX

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