BIOL 2210L
Unit 4: Introduction to Bones and the Skull

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Terms to Know for Unit 4

Skeletal System
- Axial skeleton
- Appendicular skeleton

Bone Structure
- Diaphysis
- Epiphysis
- Epiphyseal plate
- Epiphyseal line
- Medullary cavity
- Endosteum
- Periosteum
- Yellow bone marrow
- Red bone marrow
- Articular cartilage

Bone shapes
- Long bones
- Short bones
- Flat bones
- Irregular bones

Microscopic Bone Structure
- Spongy bone
- Compact bone
- Osteon
- Central canal
- Perforating canals
- Lamellae
- Canaliculi
- Osteocytes

Cranial Bones of Skull
- Frontal bone
- Parietal bones
  - Sagittal suture
  - Coronal suture
- Temporal bones
  - Squamous suture
  - External auditory meatus
  - Internal auditory meatus
  - Styloid process
  - Zygomatic process
  - Mastoid process
  - Mandibular fossa
  - Jugular foramen
  - Carotid canal
  - Foramen lacerum
- Occipital bone
  - Lambdoid suture
  - Foramen magnum
  - Hypoglossal canal
  - Occipital condyles
- Sphenoid bone
  - Sella turcica
  - Superior orbital fissures
  - Optic canals
  - Foramen rotundum
  - Foramen spinosum
  - Foramen ovale
- Ethmoid bone
  - Crista galli
  - Cribriform plate
  - Superior nasal conchae
  - Middle nasal conchae

Facial Bones
- Mandible
  - Mandibular condyle
  - Coronoid process
- Maxillae
  - Palatine process
- Palatine bones
- Zygomatic bones
- Lacrimal bones
- Nasal bones
- Inferior nasal conchae
- Vomer

Other Bone Structures
- Hyoid

Fetal Skull
- Anterior fontanel
- Posterior fontanel

Additional Instructor Terms

Learning Objectives (modified from HAPS learning outcomes)

1. General functions of bone & the skeletal system
    a. Describe the major functions of the skeletal system.
2. Structural components – microscopic anatomy
    a. List and describe the cellular and extracellular components of bone tissue.
    b. Identify the internal structural components of compact bone.
    c. Identify the types of cartilage tissues found in the skeletal system and explain the functions of each.
3. Structural components – gross anatomy
    a. Identify the structural components of a long bone.
4. Organization of the skeletal system.
    a. Define the two major divisions of the skeletal system (axial and appendicular) and list the general bone structures contained within each.
5. Gross anatomy of bones
    a. Identify the types of bones based on shape and composition (compact vs. spongy) and relate the shapes of bones to their functions.
    b. Identify the individual bones and their location within the body.
    c. Identify bone markings (spines, processes, foramina, etc.) and describe their function (e.g., point of articulation, muscle tendon attachment, ligament attachment, passageway for nerves and vessels).

Explanation of Anatomy

First in our exploration of the skeleton we'll learn the two main divisions of the skeleton: axial and appendicular. Following that we'll learn how bone is structured, the names of different bone shapes, and different types of bone. Specific care will be given to the structural unit of compact bone and we'll learn the first A&P pathway: the flow of nutrients from blood vessels outside of bone, through compact bone, ending at their delivery to a bone cell.

Second, we'll learn the cranial and facial bones of the skull. Not only do these bones protect the brain and aid in forming our facial features, they contain bone structures for muscle attachment and passage of blood vessels and nerves.

We'll end the unit discussing the clinical significance of a couple of fetal skull structures.

Think about how bone remains when all soft tissue has disintegrated after death. The soft tissue of our bodies contains proteins, fluids, and cells that other life can reuse. Large animals scavenge on this soft tissue while smaller life forms like insects, bacteria, and fungi decompose the easily consumed soft tissue. Since it is difficult to "eat" the minerals in the bone itself, eventually hardened bones remain. There is organic matter still in that bone and that is why scientists can extract DNA from ancient Neandertal bones; however, most of the organic parts are encased by the hard-to-eat minerals. The bones after death can last hundreds to thousands of years. The Kennewick Man and Anzick boy skeletons found in North America were believed to be from 9,000 and 12,500 years ago, respectively. The persistence of human skeletons can help inform archeologists and anthropologists of who and how humans and our ancestors lived hundreds, even thousands of years ago!

Skeletal System

The skeletal system is a collection of approximately 206 bone organs that make up two divisions: an axial and an appendicular skeleton (see Image 1). The **axial skeleton** contains the skull, vertebral column, sternum, and ribcage. It forms the bony walls that protect internal organs. The **appendicular skeleton** is made of bones that are within the upper and lower limbs of the body, including the pectoral and pelvic girdles. The appendicular skeleton acts as levers where whole skeletal muscles attach to bony projections to assist in body movement.

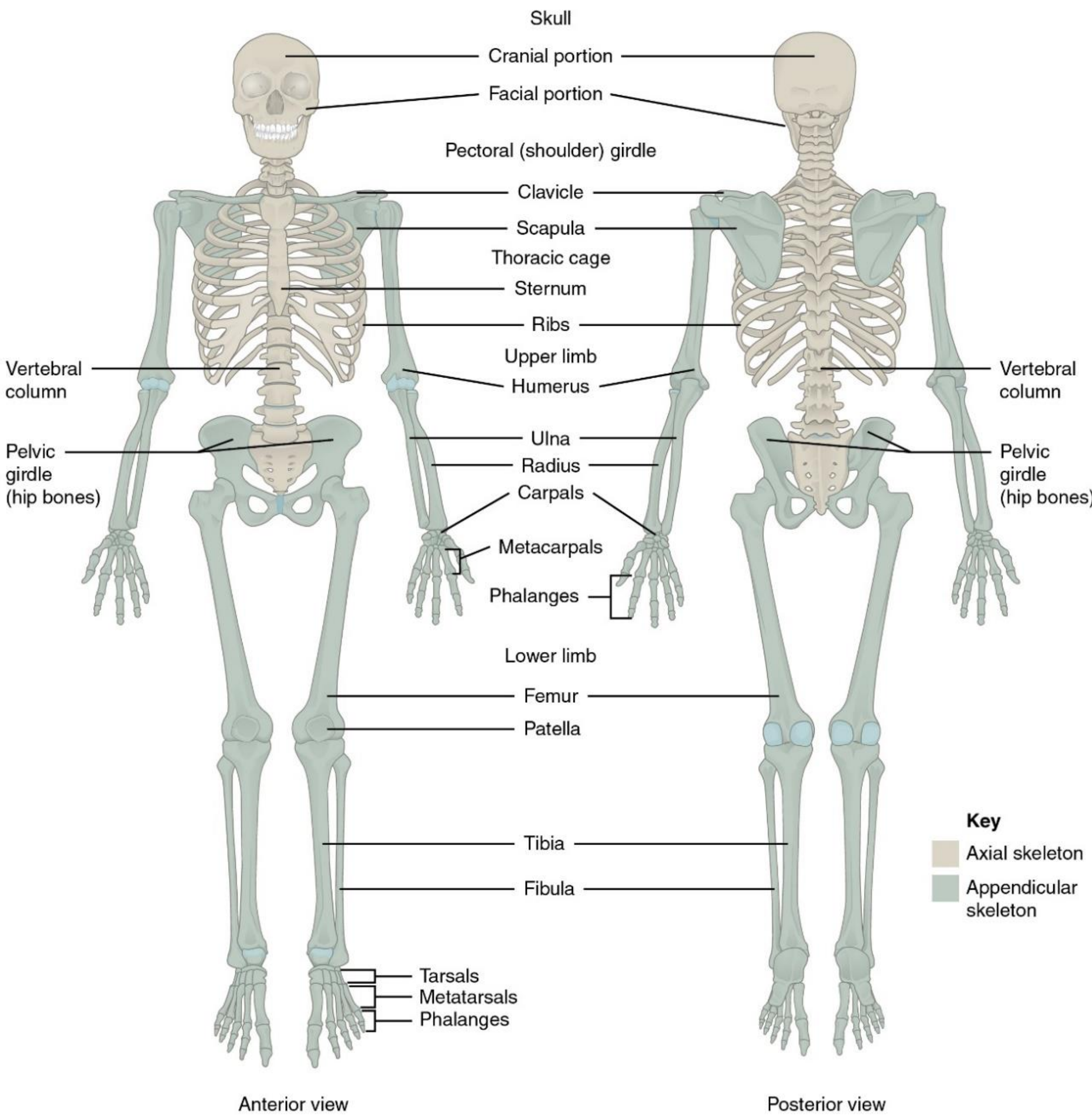


Image 1: Axial and appendicular skeletons

The skeleton provides protection by encasing fragile organs like the brain and heart and it helps the muscular system perform the function of movement, but it has other functions as well. The skeleton stores minerals like calcium and phosphates along with storing triglycerides contained in the **yellow bone marrow's** adipose tissue. The **red bone marrow** makes all types of blood cells. Collagen fibers of bone provide strength and its inorganic material gives bone its hardness; bones offer structure and support to our soft tissues.

Bone structure and Bone shapes

Many bones of the appendicular skeleton are called **long bones** (see Image 2) because they have a long central shaft called the **diaphysis**. *Dia-* means across and *-physis* is the part of bone that grows. The diaphysis of a long bone is the part that connects or "goes across" the two parts where the bone grows. *Epi-* means above. The part of the long bone on either end that is "above" or in the case of the distal ends, below, where the bone grows is called the **epiphysis**.

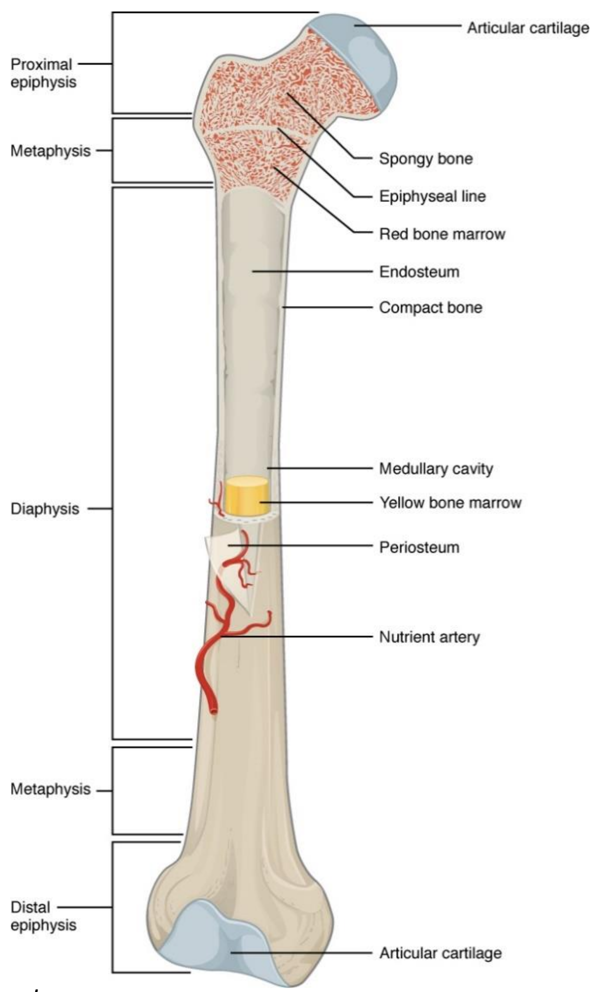


Image 2: Long bone and its parts

When we are young the growing part that is between the diaphysis and epiphysis, is made of hyaline cartilage. This is commonly called the "growth plate." The proper anatomical name for this wedge of growing hyaline cartilage is the **epiphyseal plate;** this is where linear growth occurs in long bones. Since this type of bone growth involves cartilage, it is called endochondral ossification. The word ossification means to turn something into bone.

As chondrocytes multiply, they enlarge and release chemicals that stimulate ossification. This causes minerals to get laid down into the cartilage matrix around the chondrocytes, starting the ossification process. Osteoblasts come and use the partially calcified cartilage as a scaffold to lay down a more organized pattern of mineral to fully ossify the tissue. As needed, osteoclasts will remodel the ossifying tissue to maintain a good shape. This dynamic process causes the diaphysis and **medullary cavity** to lengthen. As long bones get longer a person increases their height. When we are in our late teens and twenties, depending on the bone and epiphyseal plate, this type of growth ends, and the epiphyseal plate turns into a line called the **epiphyseal line**. Eventually, after a few more years, the epiphyseal line will disappear as the bone is remodeled by normal cellular activity.

In addition to the cartilage in the epiphyseal plate, everyone also has articular cartilage coating the surfaces at either ends of long bones. At these ends, one long bone meets another bone. Where two or more bones meet is a joint, an articulation. It is for this reason that hyaline cartilage at this location is called **articular cartilage**. Articular cartilage weeps lubricant between the bones, preventing friction at moveable joints.

Finally, each bone has a membrane that surrounds its outside surface called the **periosteum**. On the inner surfaces, connecting tubules (e.g., central canal), and coating trabeculae, is a similar membrane called **endosteum**. *Peri-* means surround and *-osteum* means of bone. *Endo-* means inner. The membranes of bones contain blood vessels to provide nutrients to bone tissue. Periosteum is a fibrous connective tissue that provides support to bone organs and endosteum is areolar connective tissue that has many capillaries to provide nutrients for bone cells to stay healthy. Both membranes contain stem cells that can differentiate into bone cells.

There are other bone shapes besides long bones in the skeleton. **Short bones**, like the wrist and ankle bones, are cube shaped. **Flat bones** are flattened and usually curved. Cranial skull bones are examples of flat bones. Bones that are not shaped like any other bones are lumped together as **irregular bones**, like the hip bones and vertebrae.

Microscopic Bone Structure

Bone has two forms: spongy and compact bone. **Spongy bone** is found lining the medullary cavity along the diaphysis and filling-in the inner core of the epiphyses and inner core of flat, irregular, and short bones. Spongy bone is also called cancellous bone or trabecular bone or diplöe in cranial bones.

Spongy bone looks like a sponge, but its structure provides support to resist forces that are put onto our bones. Trabeculae are the struts of spongy bone. These “little beams” are like a roof’s wooden beams. While trabeculae might look haphazard in their arrangement, they are growing along lines of stress that the bone experiences. The open spaces between the trabeculae contain red or yellow bone marrow.

The remainder of this section will focus on the microscopic structure of compact bone; spongy bone is structured differently and is not covered in this lab course. **Compact bone** is denser than spongy bone and forms the thick, or compact, outer cortex of bone that is encased by the periosteum. Compact bone has many column-like pillars that make up the outside cortex of both diaphysis and epiphyses. These pillars are called **osteons** and they are the *structural units* of compact bone (see Image 3).

The osteon is made up of two main parts: (1) a central canal surrounded by concentric layers or rings of (2) mineralized lamellae. The **central canal** (haversian canal) contains blood vessels, lymphatic vessels, and nerves. **Lamellae** are cylindrical columns. Osteons have multiple lamellae that nest within one another like [Russian dolls](). Lamellae are the extracellular matrix of bone. Collagen fibers run through the lamellae in opposing alternating patterns to resist twisting forces. In between each ring of lamella are the lacunae that contain mature bone cells, **osteocytes**. Osteocytes within their lacunae are connected to each other through tiny canals called **canaliculi** that run through the lamellae (singular – canaliculus). Each osteocyte has many long arm-like projections that run through the canaliculi and meet the projections of their neighboring osteocyte in the middle of adjoining canaliculi. This allows osteocytes to communicate and share electrolytes, nutrients, and gases, through gap junctions.

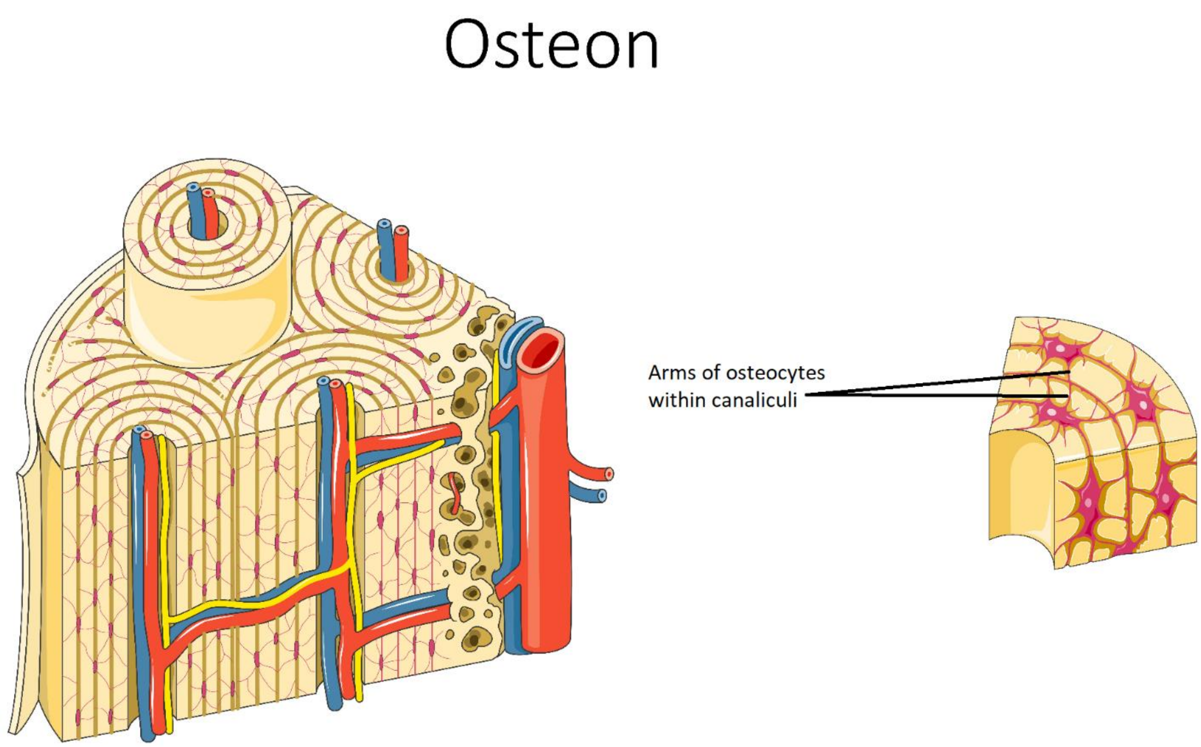


Image 3: Cross-section of an osteon, including osteocyte arms within canaliculi

Modified [CC BY-SA 3.0]() by Laboratoires Servier URL: [Cross-section of an osteon]()

Osteocytes monitor the condition of adjacent bone. To do this, and to stay healthy, they need to have a supply of blood. Blood vessels from the periosteum connect to blood vessels that run through the bone in canals that penetrate the diaphysis. These penetrating canals punch into, or perforate, the compact bone of the diaphysis. The blood vessels of the **perforating canals** connect with the blood vessels that are within the central canals of osteons. The central canal is adjacent to the deepest canaliculi (containing osteocyte projections) and allows nutrients, gases, and electrolytes to diffuse into the osteocyte. To "nourish" the osteocytes farther away from the innermost ring, the many canaliculi connect the networks of osteocytes through gap junction. Thanks to the tiny canaliculi that connect the osteocytes to one another, important nutrients and gases can move from the central canal to each and every osteocyte (see Image 4).

This is the first pathway that you will learn in your studies of Anatomy of Physiology (A&P): the pathway of blood to an osteocyte within compact bone.

Mini Activity: Outline first A&P pathway

Starting at blood vessels in the periosteum and ending with the canaliculi within the lamellae, outline the pathway of blood nutrients to an osteocyte within compact bone. There are five structures you should list in the correct directional flow order. You might need to read the above material again to list out the structures or you can reference the image below. Try to complete this activity on your own before you read ahead.

1.

2.

3.

4.

5.

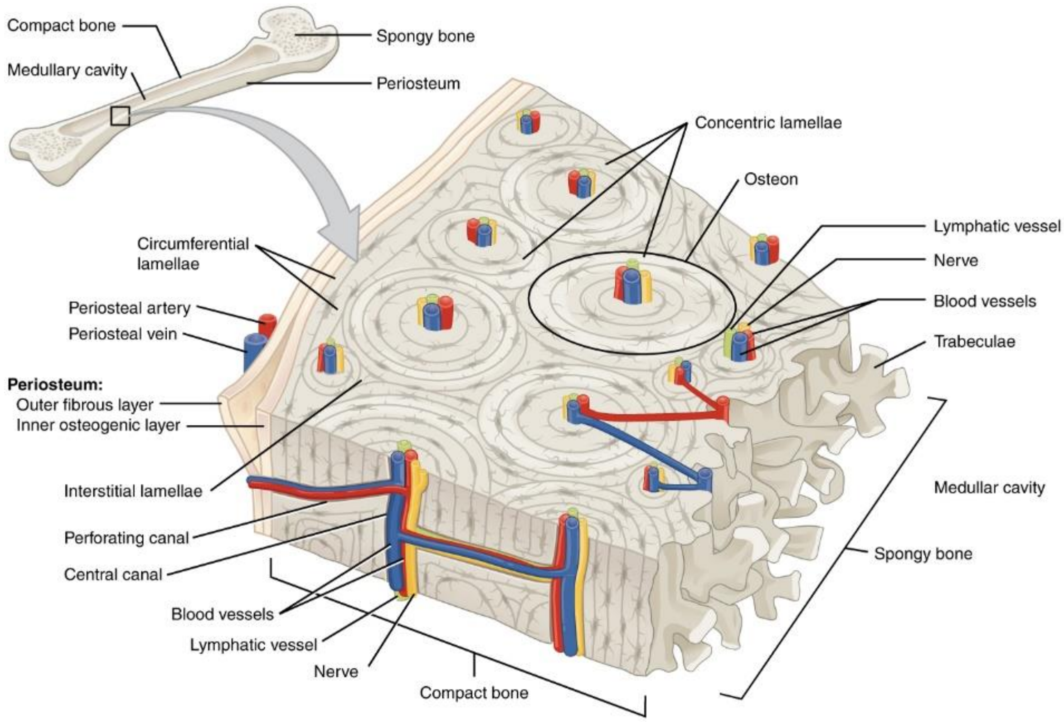


Image 4: Pathway of nutrients to an osteocyte in compact bone

Below is the pathway but with one more additional step: osteocytes located in middle lamellae of an osteon.

1. blood within blood vessels of the periosteum→2. blood within blood vessels of the perforating canals→3. blood within blood vessels of the central canal→4. nutrients delivered to the arm-like projections of osteocytes in the canaliculi→ 5. nutrients delivered to the cell body of an osteocyte located in a lacuna in the first lamella → 6. nutrients delivered to the cell body of an osteocyte in the middle lamella via gap junctions

Cranial Bones of the Skull

The first individual bones that we will study in this lab are the eight cranial bones that make up the bony wall of the skull (see Image 6). Some of the cranial bone names you already learned in Unit 1 as surface anatomy terms. The most anterior forehead cranial bone is the **frontal bone** and the most posterior cranial bone is the **occipital bone**. You've also already learned the names of the two bones that make up most of the bony wall of the cranial body cavity. Remember that parietal means "wall" and the paired cranial bones that make up most of the bony wall are the left and right **parietal bones**. Another pair of cranial bones are the two lateral bones called the **temporal bones**. The last two cranial bones are not paired and form part of the bony floor wall of the cranial body cavity. The more prominent of the two, making up more of the bony floor wall, looks like a bat and is named the **sphenoid bone** (see Image 5). The **ethmoid bone** only takes up a small portion of the bony wall of the skull, but its "chicken comb" structure, the **crista galli**, helps anchor the brain meninges within the cranial body cavity (see Image 8).

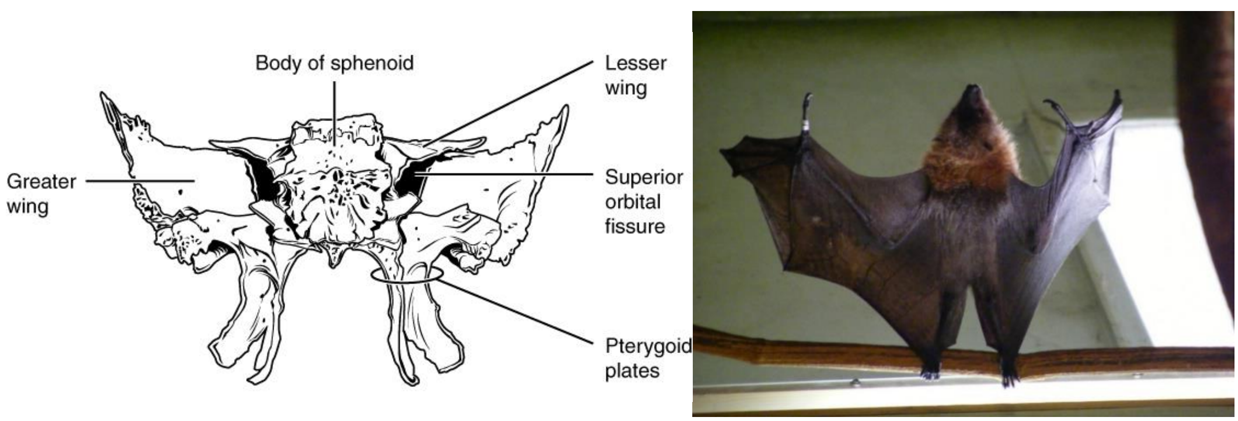


Image 5: Posterior View of sphenoid bone next to a fruit bat

In review, below is the list of the eight cranial bones of the skull:

1. Frontal bone
2. Occipital bone
3. Two Parietal bones
4. Two Temporal bones
5. Sphenoid bone
6. Ethmoid bone

Mini Activity: Labeling cranial skull bones

Using the image of the skull and instructor provided painter's tape, label the cranial bones on the skull model assigned to you and your lab partner.

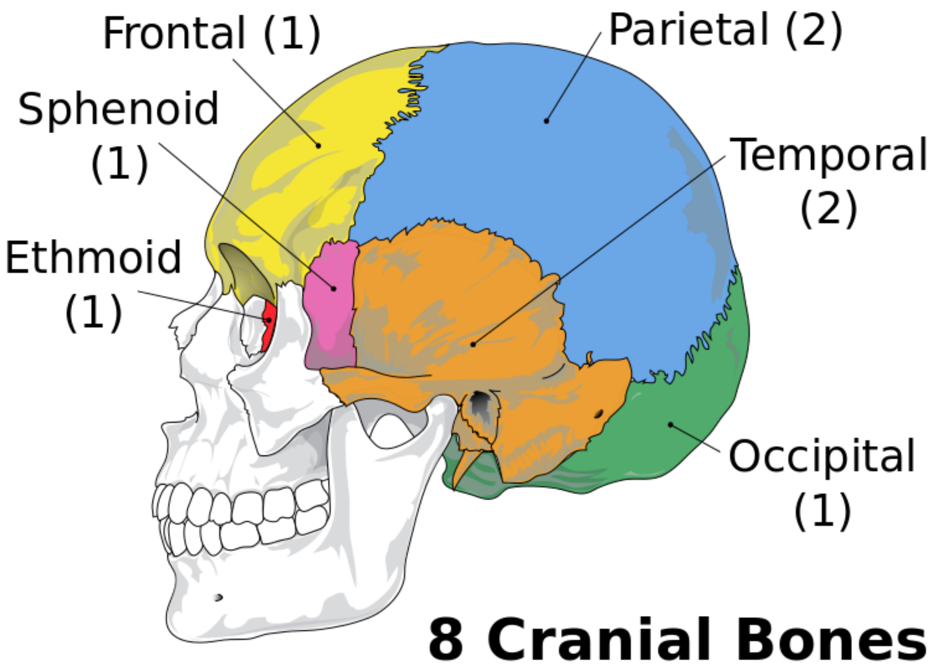


Image 6: Skull showing all cranial bones

Creative Commons Public Domain URL: Skull showing all cranial bones

Where two cranial bones articulate, or meet, is an *immoveable fibrous joint called a suture*. The suture that connects the frontal bone with the parietal bones is called the **coronal suture**; this is where the name of the coronal plane comes from. The suture that articulates the two parietal bones is within the sagittal plane, as such, it is called the **sagittal suture**. The parietal bone on either side articulates with its corresponding temporal bone through the **squamosal suture** (squamous suture), named because the body of the temporal bone looks like a fish scale. The last suture connects the occipital bone with the two parietal bones and is named the **lambdoidal suture** (lambdoid suture) since it resembles the Greek letter lambda. The other bones of the skull are also connected by joints called sutures and are named according to which bones are being connected.

Facial Bones of the Skull

The bones of our face are called, logically, facial bones and there is a total of fourteen of them (see Image 7). Many of the paired facial bones have names that indicate where they are in the face. **Nasal bones** are located at the bridge of our nose, **palatine bones** form part of the hard palate (roof of our oral cavity), **lacrimal bones** are adjacent to the lacrimal sac that catches tears at the medial corner of our eyes, and the **inferior nasal conchae** form the lateral-inferior walls of the nasal cavity. It should be noted that the inferior nasal conchae are separate bones where the superior and middle nasal conchae are features of the cranial ethmoid bone. **Maxillae** means "jaws" and these paired bones form the upper jaws of the face. The last paired facial bones, **zygomatic bones**, are commonly known as the cheekbones. The **vomer** is a single blade shaped bone that forms the posteroinferior portion of the nasal septum; however, the superior portion of the nasal septum is a bony projection off the ethmoid bone. The last facial bone is the strongest bone of the skull; the **mandible** makes up the lower jaw.

In review, below is the list of the fourteen facial bones of the skull:

1. Two Nasal bones
2. Two Palatine bones
3. Two Lacrimal bones
4. Two Inferior Nasal Conchae
5. Two Maxillae (singular – maxilla)
6. Two Zygomatic bones
7. Vomer
8. Mandible

Mini Activity: Labeling facial skull bones

Using the image of the skull and painter's tape (a different color from what you used to label the cranial bones), label the facial bones on the skull model assigned to you and your lab partner.

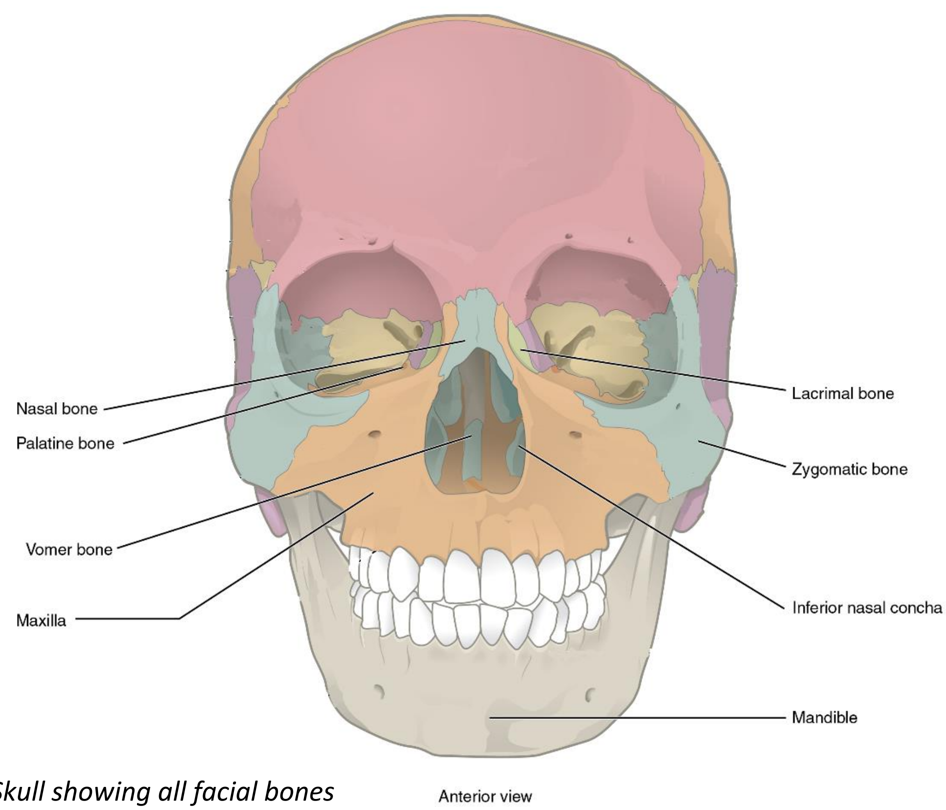


Image 7: Skull showing all facial bones

Modified [Creative Commons](#) [Attribution 4.0 International](#) Openstax URL: [Skull showing all facial bones](#)

Bone Markings and Openings

You'll have noticed by now that the skull is not smooth and contains many bumps, projections, grooves, and holes. Bony projections are called processes and most of the time these are created by the pulling of muscles at an attachment point. Smooth, rounded projections covered in articular cartilage are called condyles, and this is where you find moveable joints. Fossae (singular – fossa) are depressions in bone that can either be a part of a moveable joint or are a depression that holds a whole skeletal muscle. The openings called foramina (singular – foramen) allow for blood vessels and nerves to pass through to get to brain structures or allow blood vessels and nerves to travel to/from structures outside of the cranial body cavity. Canals are openings that have a bony wall and resemble a tunnel of bone rather than a shallow foramen opening. A meatus is also a passageway and the two you need to know for this class, the internal auditory meatus and external auditory meatus, are passageways to the inner ear and middle ear respectively.

Mini Activity: Describe bone structures

From what you've learned about the different bone structures, describe each structure below.

Structure	**Description**
Process	
Condyle	
Fossa	
Foramen	
Canal	
Meatus	

When naming bone markings and openings, there are some patterns. Processes are named based on their shape, like the **styloid process** of the temporal bone which is a long slender projection that might remind you of a stylus you would use with your phone or laptop. Processes that are articulating with other skull bones are named after the bone that they are articulating with. For example, the process of the temporal bone that articulates with the zygomatic bone is called the **zygomatic process**.

What do you think is the name of the process of the maxilla bone that articulates with the palatine bone?

If you said **palatine process**, you're correct!

Condyles in the skull are named based on the bone that they are on. For example, the mandible has a free-moving joint with the temporal bone, and its condyle at this joint is called the **mandibular condyle**. What about the smooth rounded surface of the occipital bone that is a free-moving joint with the first vertebra that allows you to nod your head yes?

Yes, you're correct, it is called the **occipital condyle**!

Many foramina and canals are named based on the name of the blood vessel or nerve that travels through them. For example, the **jugular foramen** is an opening that allows the internal jugular vein to travel through it, the **carotid canal** is a passageway for the carotid artery, and the **hypoglossal canal** allows the hypoglossal nerve to make its way towards the bottom of the tongue. *Hypo-* means under or below and *glossal* means tongue! Openings are also named based on their shape, like the **foramen ovale**, which is an oval shape, and the **foramen rotundum**, which is a rounded shape. Both these openings, the foramen ovale and the foramen rotundum, allow for the passage of nerve branches that contain motor fibers that excite chewing muscles while also containing sensory fibers involved with facial skin sensations.

There are other bone structures that don't necessarily adhere to a general pattern. The **superior orbital fissures** are slit-like openings that allow for nerves to travel through to the eyes to excite skeletal muscles involved with eyeball movement. The **sella turcica** is a depression of the sphenoid bone. This bone structure looks like a saddle and its name means "Turkish Seat." The sella turcica holds the pituitary gland. The **cribriform plate** of the ethmoid bone is where olfactory (smelling) nerve structures pass through from the brain to the nasal cavity. And the crista galli of the ethmoid you already know anchors the brain and forms a small part of the bony wall of the cranial body cavity.

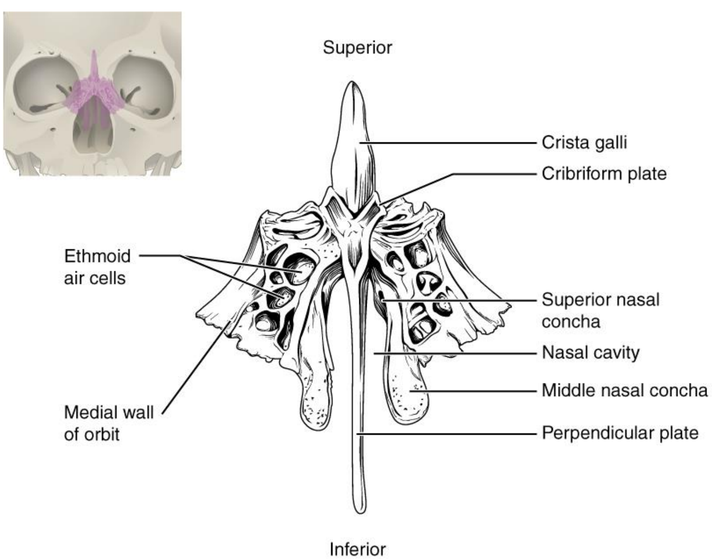


Image 8: Ethmoid bone showing crista galli, chicken's comb, and what a chicken's comb on a chicken looks like.

You will see again many of these structures when you learn about muscle attachments in muscular system units, passageways for cranial nerves in Unit 11, and in A&P II lab when you learn about blood vessels.

Look at the following skull images that have labeled bone markings and openings that you need to know for this lab. Your instructor might want you to know additional terms; circle or highlight the terms you need to know for your lab.

Structures to circle or highlight from the right lateral view of the skull.

1. Zygomatic process

2. External acoustic meatus

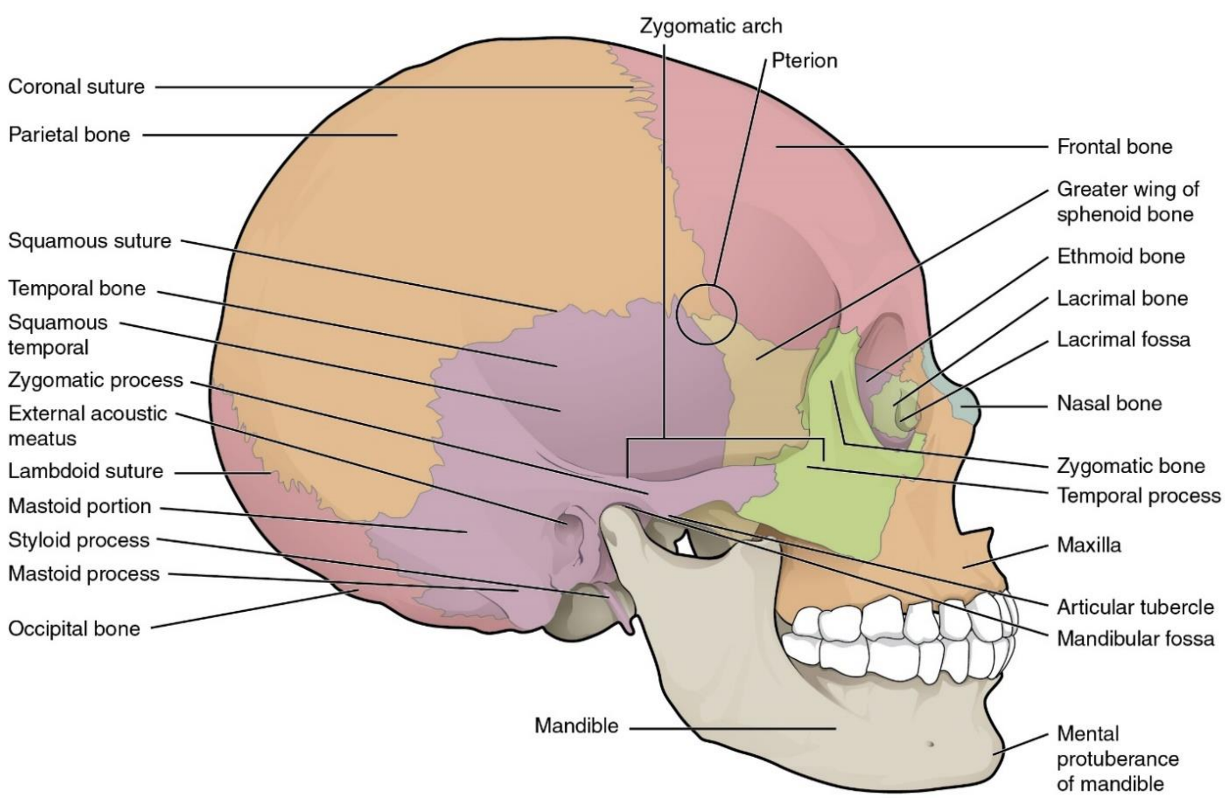
3. Styloid process

4. Mastoid process

5. Mandibular fossa

6. Other features your instructor has listed: _______________

Take note of bone names and sutures that you need to know for lab.



Right lateral view

Structures to circle or highlight from the anterior view of the skull.

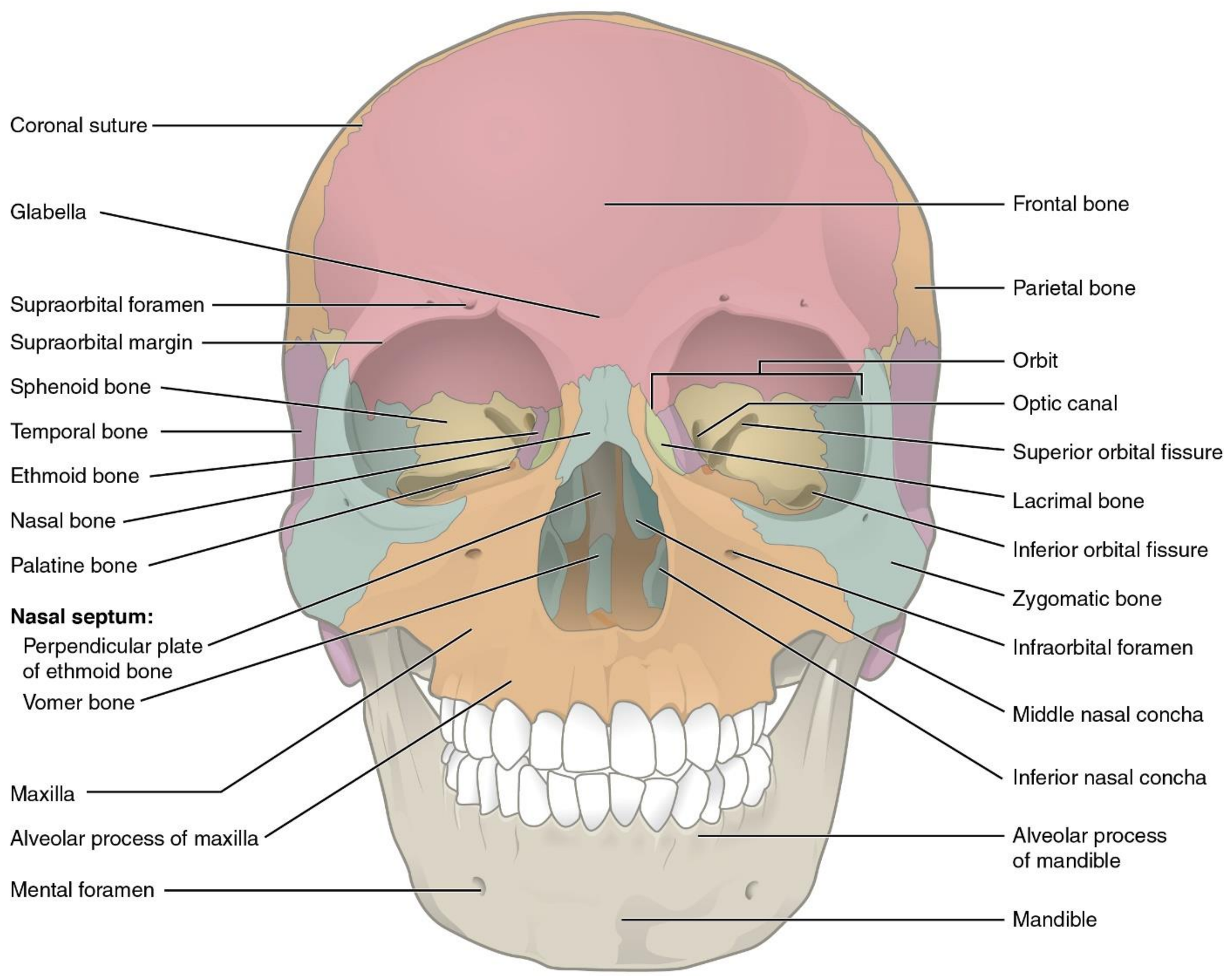
1. Optic canal

2. Superior orbital fissure

3. Middle nasal concha

4. Other: _______________

Again, note the bones and sutures that you need to know for lab.



Anterior view

Structures to circle or highlight from the inferior view of the skull.

1. Foramen spinosum

2. Foramen lacerum

3. Jugular foramen

4. Occipital condyle

5. Foramen magnum

6. Palatine process

7. Foramen ovale

8. Mandibular fossa

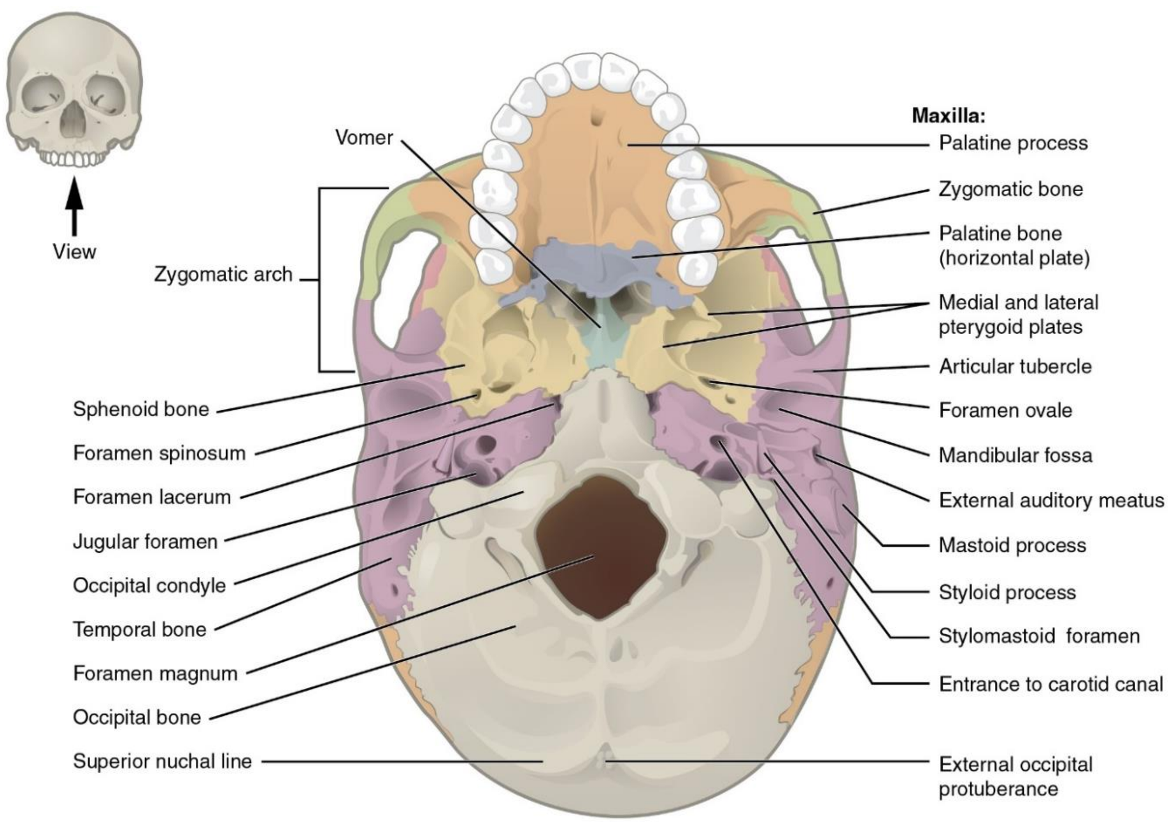
9. External auditory meatus

10. Mastoid process

11. Styloid process

12. Other: _______________

Note bones and sutures.



(a) Inferior view

Structures to circle or highlight from the superior view of the skull.

1. Superior orbital fissue

2. Foramen rotundum

3. Foramen ovale

4. Foramen spinosum

5. Internal acoustic meatus

6. Hypoglossal canal

7. Foramen magnum

8. Crista galli

9. Cribriform plate

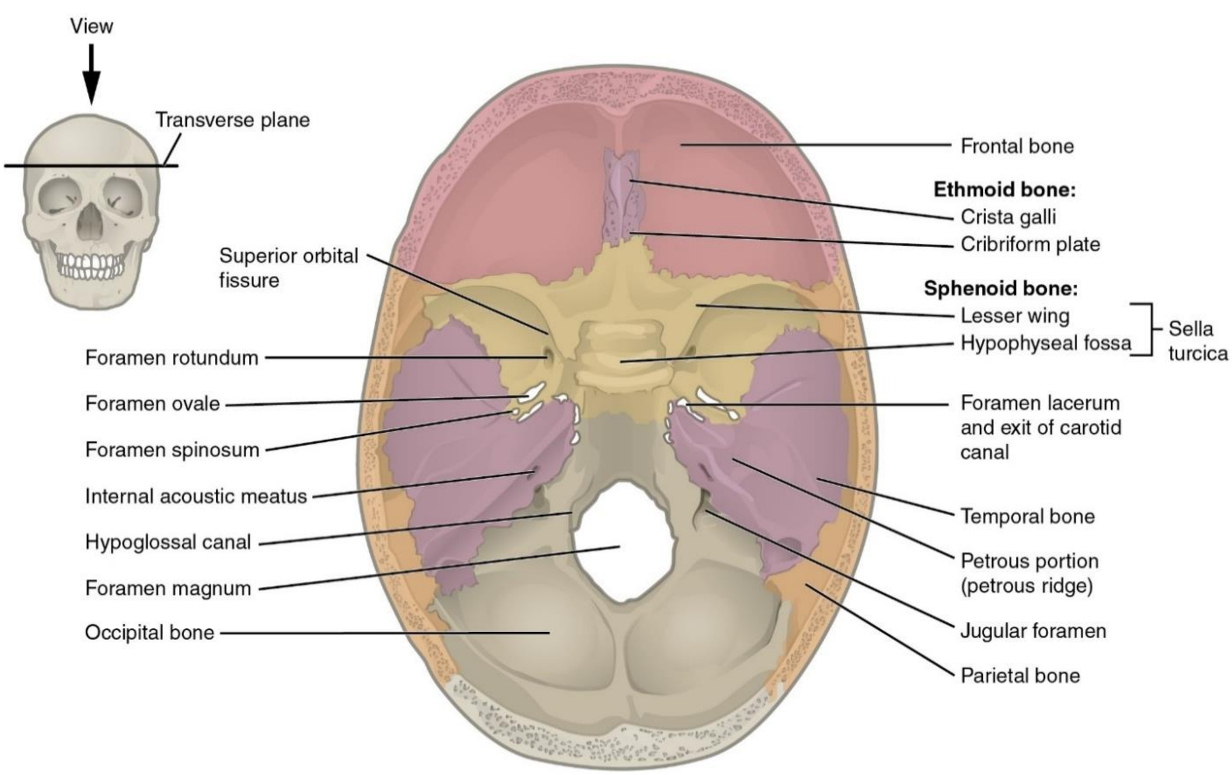
10. Sella tucica

11. Foramen lacerum

12. Jugular foramen

13. Other: _____________

Note cranial bones.



(b) Superior view

Structures to circle or highlight from an interior view of the skull.

1. Internal acoustic meatus

2. Hypoglossal canal

3. Styloid process

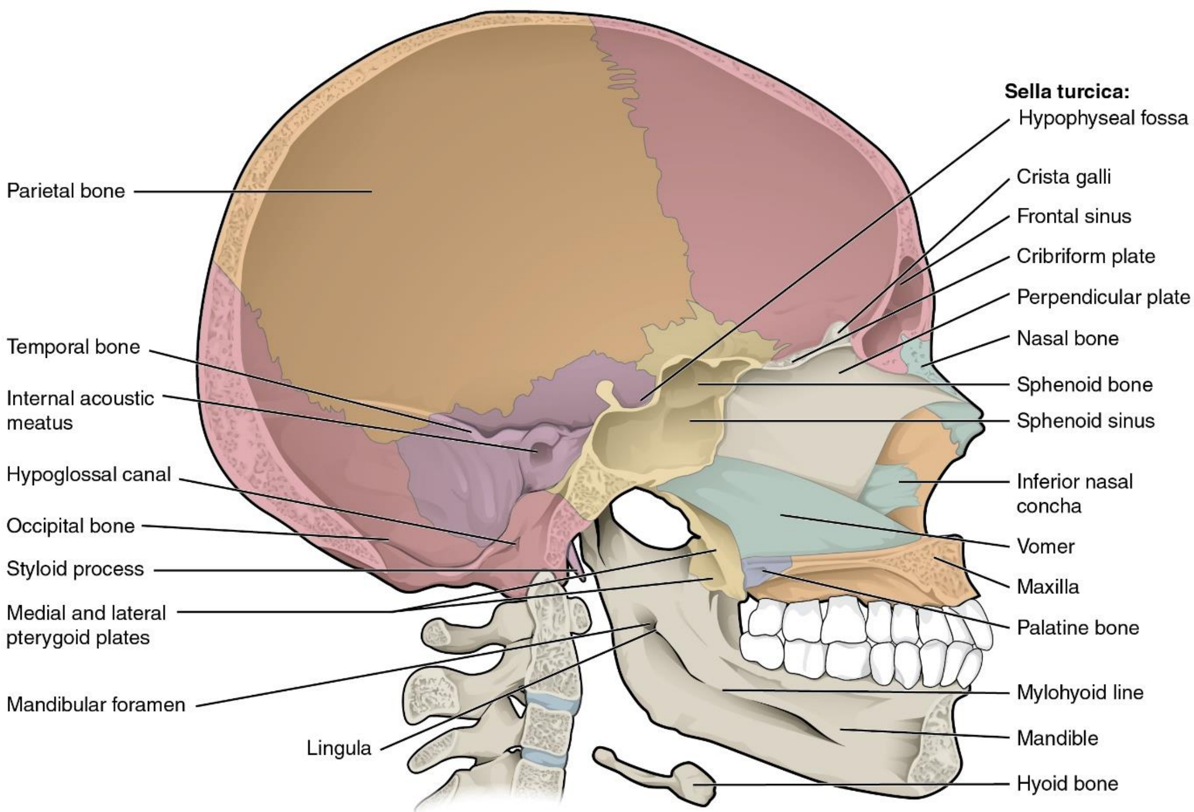
4. Sella turcica

5. Crista galli

6. Cribriform plate

7. Other: ________

Note both facial and cranial bones.



Structures to circle or highlight from the posterior view of the skull.

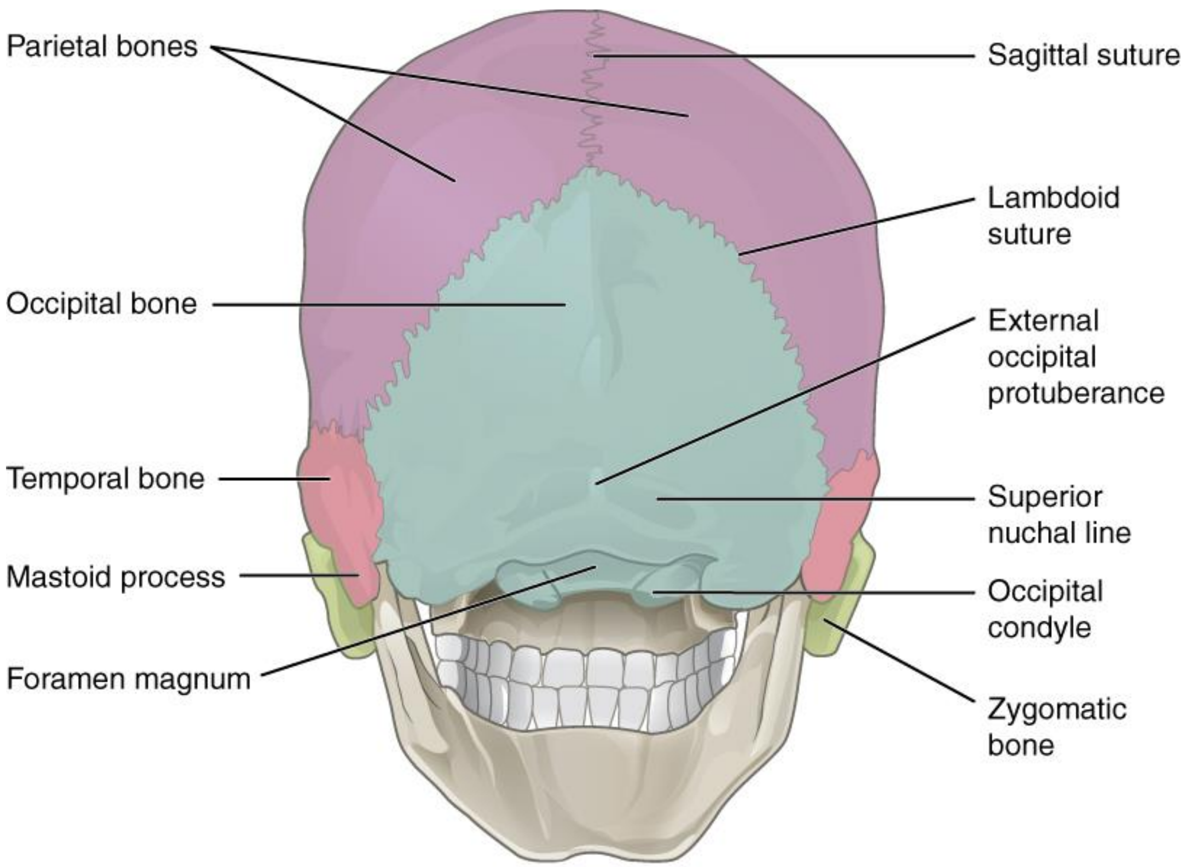
1. Mastoid process

2. Foramen magnum

3. Occipital condyle

4. Other: _____

Note bones and sutures.



Posterior view

Other Bone Structures and Fetal Skull

The hyoid bone is the only bone in the human skeleton that doesn't articulate with any other bones (see Image 9). Several skeletal muscles attach to it and it is kept in place through a connective tissue membrane with the voice box, larynx. This "C" shaped bone is examined in forensics to determine if strangulation is the cause of death during criminal investigations.

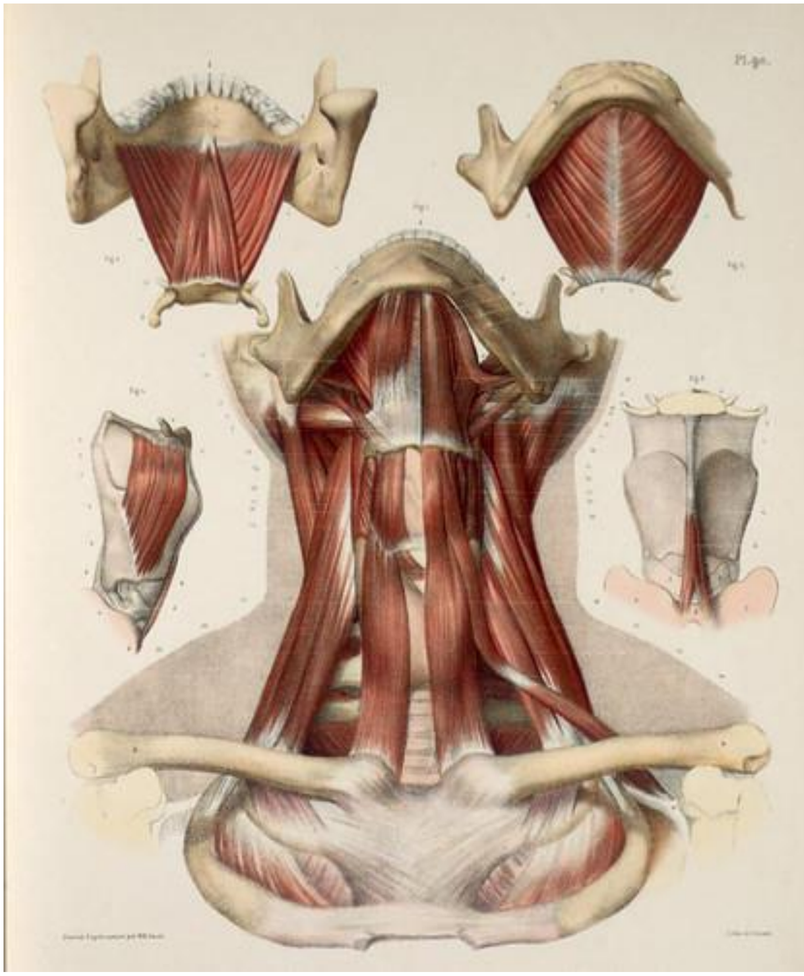


Image 9: Hyoid bone

The anterior and posterior fontanels (fontanelles) are two important fetal skull structures for clinical applications. Fontanels are soft connective tissues of the fetal skull that by the age of one become ossified (see Image 10). Since these fontanels are not hardened in newborns, nurses and pediatricians can determine whether there is water on the brain (hydrocephalus) or dehydration. This is done by visually noticing if the fontanels have expanded in hydrocephalus or shrunk inward during dehydration.

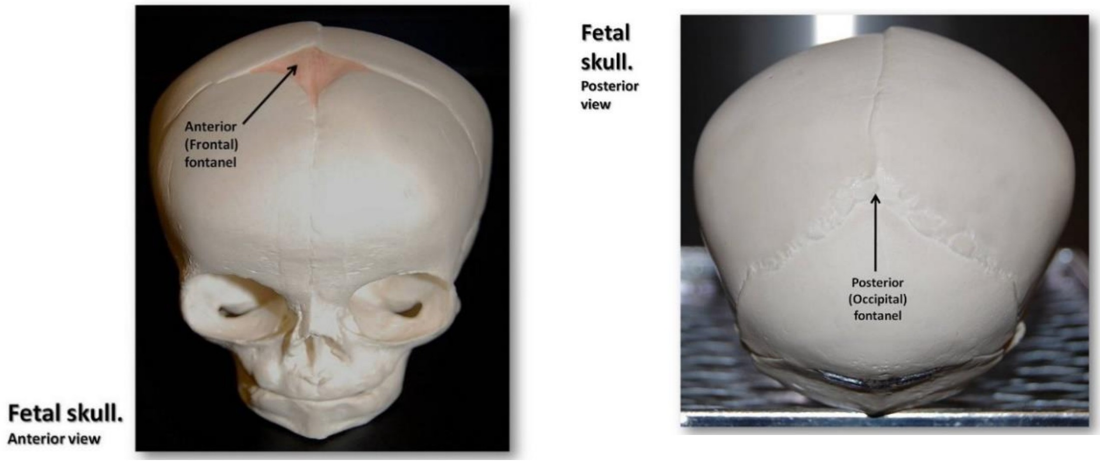


Image 10: Fetal fontanels

Activity 1: Art Project Describing Endochondral Ossification

In groups design an art activity to demonstrate what happens during bone development.

This art activity can use any kind of materials: chalk, paper, cut pasta shapes, clay, and any other supplies you would use to show how the bone develops during endochondral ossification.

In your activity, list supplies, and either outline or sketch how your art activity teaches how bone starts with a hyaline cartilage template but ends with a longer (grown-up) long bone that has a diaphysis with a medullary cavity, epiphyseal plate, and epiphyses coated with articular cartilage.

Use the space below to start writing out ideas. Use additional paper or start your own word document to write up your final activity.

Activity 2: Regulating Blood Calcium Levels

1. Outline, draw out steps, or describe the negative feedback homeostatic mechanism. Hint: It starts with a change in the environment (stimulus) and ends with an effector bringing a variable back into normal range.

2. Looking at your description above, where do bones fit in if you were to apply the above mechanism to regulating blood calcium levels? Hint: think of what makes up bones.

3. What do you think is the control center in maintaining blood calcium levels? Hint: What normally is the control center within a homeostatic mechanism?

4. And what is the stimulus that is being detected during the homeostatic mechanism to maintain blood calcium levels?

Activity 3: Labeling Skull Features

With provided instructor pipe cleaners, label the openings, canals, and tunnels that you need to identify within the skull.

- Superior orbital fissure
- Optic canal
- Foramen ovale
- Foramen rotundum
- Foramen lacerum
- Hypoglossal canal
- Foramen magnum
- Jugular foramen
- Carotid canal
- External auditory meatus (use Instructor provided painter's tape instead)
- Internal auditory meatus (use Instructor provided painter's tape instead)
- Other features per your instructor: _______________

After you've labeled skull models check your labels with your instructor or the available labeled skull in the lab.

Activity 4: Find Bones and Bone Features on Models

Your instructor will have various models on display throughout the lab. Observe these models to find bones and bone features to fill out the table below. Find at least three bone features and two bones within the provided models.

Term	**Found It**	**Model Name**	**If feature, what is its function?**	**If bone, what does it articulate with?**