

## Geo 302D: Age of Dinosaurs

### LAB 5: The vertebrate skeleton

Bone is a connective tissue unique to vertebrates. It serves several purposes:

- It is a reservoir for chemicals used in metabolic processes,
- It provides structural support for soft tissues,
- It acts as armor to shield vulnerable body parts,
- It is a framework upon which muscles can exert forces to facilitate movement.

In addition to being biologically important in the day to day lives of animals, bone is useful to paleontologists because it readily preserves as fossils. Most of the information we use to reconstruct the evolutionary relationships between fossil vertebrates comes from their bones and teeth. Because of this, you must have at least a basic knowledge of the bones of the vertebrate skeleton. You must also be able to identify these elements from figures or on specimens in upcoming quizzes and lecture exams.

**Terms of orientation:** You may notice your TA using, and you will read in this handout, words such as “dorsal”, “lateral”, “medial” and “ventral”. These terms are used to describe the relative relationships in space between anatomical features. You must be able to understand what they mean.

- **Anterior:** towards the front, or head.
- **Posterior:** towards the rear, or behind.
- **Dorsal:** towards the back side.
- **Ventral:** towards the belly side.
- **Medial:** towards the middle, or midline.
- **Lateral:** towards the side, or outside.
- **Proximal:** relatively closer to the body’s center of mass .
- **Distal:** relatively further away from the body’s center of mass.

### The axial and appendicular skeleton

The vertebrate skeleton is easily divided into two distinct parts. These are the **axial**, and the **appendicular**, skeletons. The axial skeleton includes the skull, vertebral column, ribs, and sternum. The appendicular skeleton includes the bones of the limbs and the limb girdles that attach the limbs to the rest of the body.

### Axial skeleton

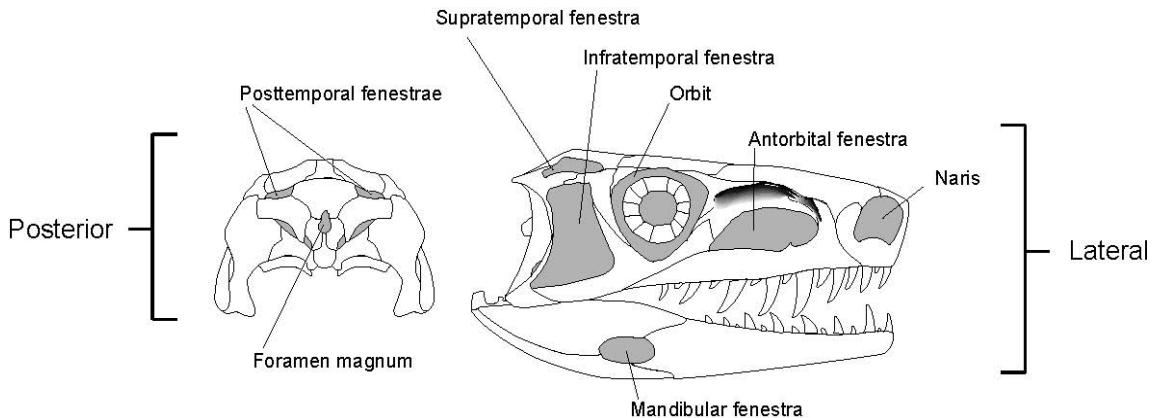
**The skull:** The skull, or cranium, is an important and complex piece of vertebrate anatomy. It is a complex structure that performs a variety of tasks. These include:

- Housing and protecting the delicate brain and sensory organs,
- Housing feeding structures such as the jaws and teeth,
- Providing attachment points and space for the powerful muscles that close and open the jaw.

You are not expected to identify the bones of the skull. You **are** expected to know and identify the various openings in the skull. A list of openings and their relative positions is given below. **You are expected to use the correct tense (singular [sing.] or plural [pl.]) when identifying or talking about all anatomical features.**

- **Foramen Magnum:** the opening in the rear of the skull through which the spinal chord passes to reach the brain.
- **Naris (pl. nares):** the bony external opening for the nostril. Air or water enters the nasal cavity through the naris. In water-breathing vertebrates, water enters and exits the naris the same way. In air-breathing vertebrates, air passes through the naris, down the nasal passages, and enters the mouth or pharynx through the choanae.
- **Choana (pl. choanae):** bony openings in the roof of the mouth (or pharynx in mammals and crocodilians) that communicate with the nares.
- **Orbit (pl. orbits):** The bony socket that houses the eyeball.
- **Antorbital fenestra (pl. antorbital fenestrae):** “Fenestra” means “window”. This particular fenestra is found only in archosaurs (crocodilians, dinosaurs and a few other extinct groups). It is located between the orbit and the naris, on the side of the snout.

These fenestrae are found in most dinosaurs (including birds), primitive crocodilians (modern crocs have closed these openings), pterosaurs, and many other extinct archosaurs. Several hypotheses have been put forth to explain the function of these fenestrae. The most popular hypothesis now is that the antorbital fenestra houses a large pneumatic sinus in the side of the face.

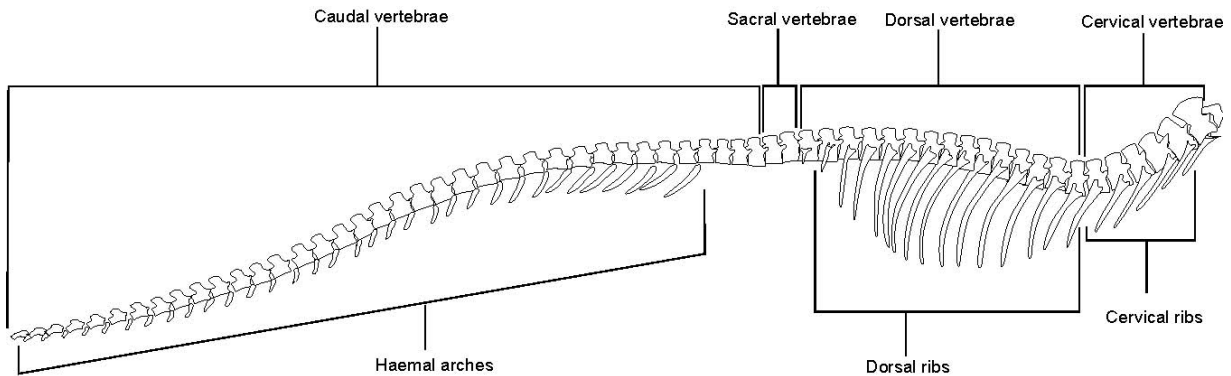


**Openings for jaw muscles:** The temporal region of the skull, behind the orbit, is the attachment zone for numerous jaw muscles. Primitively, the braincase lies deep below the outer bones and jaw muscles of the temporal region. As a muscle contracts, it gets shorter, but the volume remains constant. This means that as muscles shorten they also get wider. The jaw muscles of vertebrates originate on the inside of the temporal bones of the skull, between them and the braincase. This means that when a primitive vertebrate flexes its jaw muscles (e.g. during biting) the muscles bulge, putting strain on the bones of the skull and braincase. The earliest vertebrates and tetrapods had a skull that was fully enclosed in bone. This meant that these animals had to keep their jaw muscles small to keep from seriously damaging their skull or brain, or they had to find a way to make more room for muscles. Many tetrapods chose the latter strategy, with different groups evolving fenestrae in the temporal region to allow large muscles to bulge. Keep in mind that lineages can secondarily (after it already evolved) lose a feature, and close over these openings.

- **Posttemporal fenestrae** (sing. **fenestra**): The earliest terrestrial vertebrates have this pair of openings, located on the rear of the skull. Among reptiles these are especially large in turtles, exposing most of the braincase.
- **Infratemporal fenestrae** (sing. **fenestra**): paired openings in the lower, temporal region. They have evolved independently between reptiles more derived than turtles and in the lineage leading to mammals. In lizards and snakes the lower border of the infratemporal fenestra is lost, exposing the side of the braincase.
- **Supratemporal fenestrae** (sing. **fenestra**): paired openings in the upper part of the temporal region, above the infratemporal fenestrae. Among living animals these openings are present in the tuatara, lizards, snakes (where they are secondarily lost), crocodylians, and birds.
- **Mandibular fenestrae** (sing. **fenestra**): Many ancient animals, as well as modern birds and crocodylians, allow their jaw muscles to invade the space within the lower jaw. The mandibular fenestrae allow these muscles to expand, in much the same manner the temporal fenestrae do around the cranium.

In the past, terrestrial vertebrates were divided into three groups based upon their arrangement of temporal fenestrae. The **anapsid** skull type possesses no lateral (side) temporal fenestrae, but did possess posttemporal fenestrae (e.g. turtles). The **synapsid** skull condition exhibits only an infratemporal fenestra on each side of the skull (e.g. mammals and their extinct relatives). The **diapsid** skull type possesses an infratemporal and a supratemporal fenestra on each side of the skull (e.g. lizards, snakes, crocs, birds).

## Vertebral column



The vulnerable spinal chord of vertebrates is protected by a series of spool-shaped bones meeting end to end, called **vertebrae** (sing. **vertebra**). Together the series makes up the vertebral column. In terrestrial vertebrates, the vertebral column also braces and supports the weight of the body. The column is divided into four basic sections.

- **Cervical vertebrae:** the vertebrae of the neck.
- **Dorsal vertebrae:** the vertebrae of the back, extending from the last cervical vertebra to the vertebrae to which the pelvis attaches.
- **Sacral vertebrae:** the vertebrae to which the pelvic bones, specifically the ilium, attach. They are often modified and strongly built to withstand the forces of bearing the weight of the animal. There may be as few as one or over a dozen in a given species.
- **Caudal vertebrae:** The vertebrae of the tail.

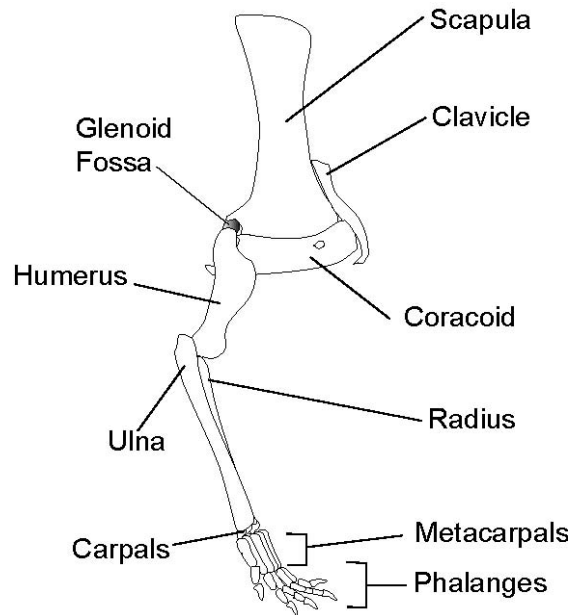
Other components of the axial skeleton include:

- **Ribs:** Ribs are associated with and connect to most types of vertebrae. Depending upon their location along the column, and with which vertebrae they articulate, they are called **cervical, dorsal, sacral, or caudal ribs**.
- **Haemal arches:** Caudal vertebrae are often equipped with these downwardly projecting bones that articulate in the spaces below and between adjacent vertebrae. Viewed from the front or behind, a haemal arch has a vaguely “Y” shaped profile. In life, blood vessels and nerves run along the underside of the caudal vertebrae, in the notch formed by the two branches of the “Y”.
- **Sternum:** the breastbone. This single element is located along the ventral side (belly side) of the chest cavity. The tips of many of the dorsal ribs directly or indirectly connect to it via cartilage. It also serves as an attachment site for the pectoral (chest) muscles. The sternum of flying birds is greatly modified to support the huge pectoral muscles needed for powered flight.

## Appendicular skeleton

**Pectoral girdle:** The bones of the pectoral girdle evolved to provide a firm foundation for the forelimbs and their muscles, while maintaining a loose muscular connection to the axial skeleton.

- **Scapula:** the shoulder blade. This is the largest bone of the pectoral girdle. It generally extends upward (dorsally) from the articulation of the forelimb.
- **Coracoid:** This bone abuts the bottom end of the scapula and extends towards the body's midline. In mammals the coracoid is very strongly reduced.
- **Glenoid fossa:** not a bone, but rather the shoulder socket itself. The humerus articulates with it. The glenoid fossa is made up of both scapula and coracoid in most vertebrates.
- **Clavicle:** the collar bone. It forms a bony articulation between the appendicular skeleton of the pectoral girdle and the midline of the axial skeleton.



**Forelimb:** Although they can be highly modified to perform different tasks and functions, the bones of the forelimb remain remarkably consistent in number and arrangement.

- **Humerus** (pl. **humeri**): the single, large bone of the upper arm. It articulates with the glenoid fossa to make the shoulder joint.
- **Radius** (pl. **radii**): one of the two bones of the lower arm. The distal (far) end of the radius always articulates on the thumb side of the wrist. In tetrapods that can flip the hand over (such as humans and other primates), the proximal (near) end of the radius is loosely attached to the elbow joint, allowing it to rotate on its axis. The far end of the bone travels in a radial arc, lending the name to the bone.
- **Ulna** (pl. **ulnae**): the second bone in the lower arm. The proximal end of the ulna articulates strongly with the humerus to make the elbow joint (the radius also makes up the elbow, but does not have such a solid connection in some animals). The distal end always connects to the “pinky” finger side of the wrist.
- **Carpals** (sing. **carpal**): the small bones of the wrist. Each one has a name, but you are not responsible for them. Just collectively call these elements the “carpals”.
- **Metacarpals** (sing. **metacarpal**): the long bones of the palm of the hand.
- **Phalanges** (sing. **phalanx**): the bones of the fingers (and toes).

**Pelvic girdle:** The bones of the pelvic girdle evolved to provide a solid connection between the hind limbs and the axial skeleton. The solid connection ensures that as much power as possible is transmitted from the hind legs to the body of the animal. Primitively in terrestrial vertebrates the pelvic girdle consists of three bones.

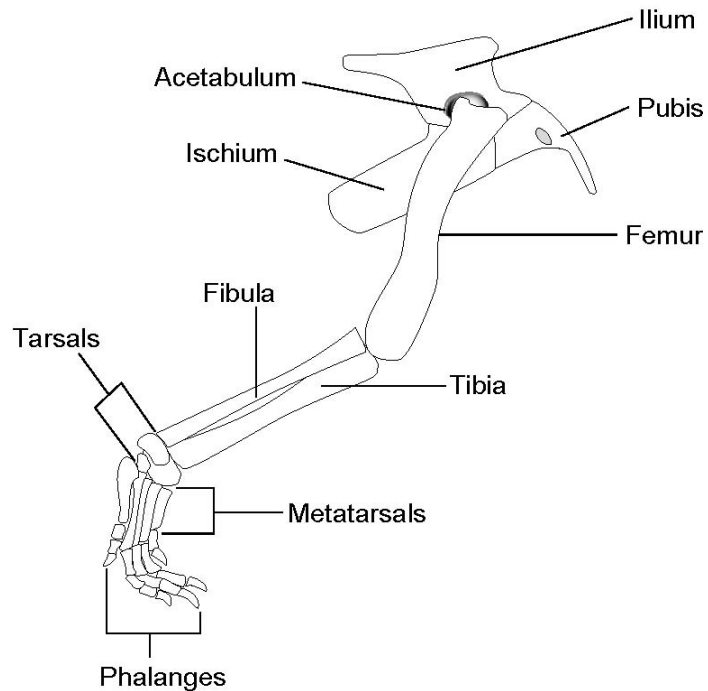
- **Acetabulum** (pl. **acetabula**):

This is not a bone, but rather is the hip socket itself. It lies near the center of the pelvic girdle. In primitive tetrapods and mammals, the acetabulum is a solid socket. In dinosaurs it is open, or perforated.

- **Ilium** (pl. **ilia**): The ilium is the one bone of the pelvic girdle that attaches to the sacral vertebrae, and usually the largest bone of the girdle. It forms the upper third of the acetabulum.

- **Pubis** (pl. **pubes**): The pubis forms the lower, front portion of the acetabulum. It extends forward and downward from the socket.

- **Ischium** (pl. **ischia**): The ischium forms the lower, rear portion of the acetabulum. It projects downward and rearward from the socket.



**Hindlimb:** As with the forelimb, the bones of the hindlimb can be highly modified to perform a wide range of tasks and functions. The main purpose of the hindlimb in most terrestrial vertebrates is to provide the main propulsive force for the animal. Obviously this is not the case with vertebrates that have greatly reduced or lost their limbs.

- **Femur** (pl. **femora**): the thighbone. It articulates with the acetabulum.

- **Tibia** (pl. **tibiae**): the shinbone. The tibia is the larger of the two bones in the lower leg, and forms the medial (inner) side of the ankle joint.

- **Fibula** (pl. **fibulae**): the smaller, lateral (outside) bone in the lower leg.

- **Tarsals** (sing. **tarsal**): These are the small, individually named bones that make up the ankle joint. You do not have to know the names of each one. Collectively call them “tarsals”.

- **Metatarsals** (sing. **metatarsal**): the long bones of the sole of the foot.

- **Phalanges** (sing. **phalanx**): the bones of the toes (and fingers).

## Exercises

1. Identify the labeled features on the human skeleton.

A.

B.

C.

D.

E.

2. Identify the labeled features on the pigeon skeleton.

A.

B.

C.

D.

3. Identify the labeled features on the *Caiman* skeleton.

A.

B.

C.

D.

4. Identify the labeled features on the *Compsognathus* cast.

A.

B.

C.

D.

E.

5. Identify the features labeled on the *Dimetrodon* skull. !! FRAGILE!!

A.

B.

C.

D.

6. Here is a cast of the forelimb of a primitive tetrapod. Identify the bones as they are labeled.

A.

B.

C.

D.

E.

7. This is a cast of *Euparkeria*, from Triassic aged sediments of South Africa. Identify the features labeled. !! Be careful, the snout breaks off easily!!

A.

B.

C.

D.

E.