Biology 3315 – Comparative Vertebrate Morphology
Skulls and Visceral Skeletons

1. **Head skeleton of lamprey**
   Cyclostomes are highly specialized in both the construction of the chondrocranium and visceral skeleton. The main mass of cartilage surrounding the brain is broadly homologous with the neurocranium (= chondrocranium) of other fishes, but a number of accessory cartilages, including the “piston” of the “tongue”, are also present; these cannot be adequately homologized with any structure in other vertebrates. The visceral skeleton is atypical in consisting of a fused latticework of branchial cartilages. This “branchial basket” has special elastic properties important to the peculiar mode of respiration used by cyclostomes. Observe the well-developed notochord.

2. **Chondrocranium of the Chondrichthyes**
   Because the cartilagenous fishes lack the dermal bones that gave protection to the brain, the chondrocranium is very solid, with complete lateral walls and a roof. The chondrocranium of the shark is not typical of that structure for vertebrates in general. Although it never ossifies, it is sometimes so hardened with granules of calcium salts that it cannot be cut with a knife. Examine the shark chondrocrania on display.

3. **Chondrocranium of bony fish**
   These specimens are of the holostean Amia and the chondrostean Ascipeuser (sturgeon). Note the general form of the isolated chondrocranium and its several centers of ossification. How does it compare with that of the shark? Examine the sturgeon to see the relationship of the overlying dermatocranium to the chondrocranium. Notice the unossified member between some of the dermal bones. Which portions of the visceral component of the skull are visible in this specimen?

4. **Class Osteichthyes**
   Locate the bones listed on the handout. Note that several additional bones have been interposed between the quadrate and hyomandibula in these fishes (compare with the shark at station 2).

5. **Lissamphibia Skulls**
   The lissamphibians have derived skulls compared to the ancestral amphibians. Ancestral amphibians had nearly a full complement of bones, including both endochondral elements of the chondrocranium and dermal roofing bones. Lissamphibia have lost many of the endochondral bones, lacking even such usually prominent bones as the basioccipital and basisphenoid. The exoccipitals are retained as the sites of articulation with the vertebral column.

6. **Turtle skull**
   Modern turtles, like this sea turtle, retain the anapsid condition on the skull roof. Nevertheless, turtles have lost a number of the dermal roofing bones primitively present in reptiles (compare with the Crocodilian skull at station 7). Which ones are lost? What bones form the jaw articulation?

7. **Crocodilian skull**
   Archosaurs exhibit an unmodified diapsid skull. Locate the upper and lower temporal openings (fenestrae). Which pair of bones forms the upper temporal arch? Which form the lower temporal arch? A characteristic feature of crocodilian skulls is the extensive secondary palate. Find the internal nares (nostrils) and identify the bones that compose the **secondary palate**. How does this palate differ from that of mammals? What is its function?

8. **Skulls of Lepidosaurs: tuatara, lizards and snakes**
   Tuataras (order Sphenodonta) have a primitive diapsid skull (unmodified) with two temporal fenestrae. Lizards and snakes (order Squamata) possess modified diapsid skulls that are specialized (to varying degrees) for cranial kinesis. Most lizards retain a complete upper temporal arch (postorbital + squamosal), but, in snakes, this has been eliminated as well. Note the calcified cartilage remains of the neurocranium in the orbital region of the lizard skull. Cranial kinesis reaches its extreme in snakes. The braincase of snakes is solid, but all the tooth-bearing bones (which are they?) are capable of considerable movement relative to the braincase. Kinesis is further enhanced by the elongated and moveable **suspensorium** (quadrate and squamosal) for the lower jaw. The open junction between the dentary and postdentary bones also allows some kinesis within the mandible.

9. **Cranial kinesis**
   Modern birds possess a modified diapsid skull (which temporal arch has been lost?) permitting some degree of intracranial movement or kinesis. Notice that most of the cranial bones of the skull roof and braincase are fused. There is a well-developed streptostylic jaw suspension and the beak is nor-mally quite moveable on the posterior region of the cranium.

10. **Sclerotic ossicles**
    The wall of the eyeball is strengthened in many vertebrates by a series of overlapping cartilages or bones. These sclerotic bones are especially well developed in birds, where they help prevent deformation of the eye by the contraction of very strong intrinsic eye muscles. The skull seen here is from a barn owl.

11. Representative mammal skulls

After identifying the bones and structures listed in the additional handouts using the puma skull then test your ability to locate these same features on a variety of mammalian skulls.

12. Sagittal section of a cat skull

On this sectioned skull, identify the following structures:

Cranial fossae:

Rostral/Anterior - small and houses the olfactory bulbs of the brain

Middle – large; contains the bulk of the brain, including the cerebral hemisphers

Posterior – smaller than the middle fossa, posterior to tentorium, encloses the rear portion of the brain including the cerebellum.

Tentorium – dorsally located bony partition between the middle and posterior cranial fossae.

Internal auditory meatus – foramen for the entrance of the auditory (CN VIII) and facial (CN VII) nerves into the petrosal bone.

Sella turcica – cavity in the floor of the middle pituitary fossa for the pituitary gland. What bone forms it?

Cribriform plate and foramina cribrosa – a perforated bony septum at the front of the anterior cranial fossa. What passes through these formaina?

Air sinuses – Several air-filled cavities or sinuses develop within the cranial bones of mammals. The sphenoidal and frontal sinuses are visible in this preparation.

Turbinate bones – The turbinate bones (conchae) are scroll-like structures in the nasal passages of mammals. What is the functional significance of these bones?

13. Growth in mammal skulls

There are significant changes in the proportions of the skull during growth in most tetrapods. These are particularly dramatic in mammals. Thus, the areas surrounding the sensory structures (eyes, ears) and the braincase are proportionately larger in juvenile mammals, while the facial region is generally smaller. Compare these and other points of morphology between the skulls of the adult deer and newborn fawn. Notice that the dorsal cranial bones do not meet in the fawn, leaving a central fontanel or “soft spot”. This feature is important in allowing the large head of the fetus to pass through the narrow birth canal. **Handle fawn skull with care!**

14. Mammalian ectotympanic and entotympanic bones.

The ectotympanic bone of mammals forms a simple ring for support of the eardrum in the primitive therians and monotremes. The ectotympanic bone is derived from a projecting process (reflecting lamina) of the angular bone of cynodonts. In advanced therian mammals, a new bone, the **entotympanic**, expands to form a bony housing or tympanic bulla around the middle ear chamber. Examine the bullae of the red fox and compare with the armadillo. The tympanic bulla of the desert rodents (see skull of kangaroo rat) is often greatly enlarged - a modification of the middle ear cavity that presumably increases sensitivity to lower frequency sounds produced by potential predators (e.g. owls).

15. Mammalian ear ossicles

Mammals differ from all other tetrapods in having three (rather than one) auditory bones. The bones forming this chain of ossicles are derived from the visceral skeleton (which portions?). In the middle ear cavity of this fawn skull (station 13), the articulated ear bones are visible. Identify the **malleus**, **incus**, and **stapes**; as well as the **fenestra ovalis** of the inner ear or petrosal bone, into which the stapes fits. Also, observe the human auditory ossicles. What are these bones homologous with in lower vertebrates?

16. Tetrapod visceral skeletons

Examine the structure of the visceral skeleton in the shark. In tetrapods, the lower portions of the second visceral arch (hyoid arch) are usually retained at the base of the tongue, where they help to support that structure. Other posterior visceral arches (3 and 4) may also be well ossified as in the snapping turtle shown here.

Only the second arch is generally well formed in mammals. The third arch is represented by two small rods that join the base of the hyoid arch and the **thyroid cartilage**. Both major laryngeal cartilages, the **thyroid** and **cricoid** cartilages (and possibly some of the ring-shaped **tracheal cartilages** , as considered by some) are derivatives of posterior visceral arches. However other evidence suggests that the tracheal cartilages do not arise from the visceral arches. Identify the visceral arches and the laryngeal cartilages of the dog.

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Lab 6: Bones of the Vertebrate Skull

The following summary omits bones not studied in class. Each bone should be identified in the animal group(s) indicated.

Bones of the chondrocranium:

• Basioccipital (single)	Reptiles, mammals
• Exoccipital (paired)	Reptiles, mammals
• Supraoccipital (single)	Reptiles, mammals
• Basisphenoid (single)	Reptiles, mammals
• Presphenoid (single)	Mammals only
• Orbitosphenoids (paired)	Mammals only
• Otic bones (2 pairs, often fused)	Reptiles, mammals (best seen on inside of braincase)

Bones of the visceral skeleton (all paired):

Bones of the palatoquadrate cartilage of the first arch:
- Epiterygoid (lepidosaurs) = alisphenoid (mammals)
- Quadrate (bony fish, reptiles, birds) = incus (mammals)

Bones of the mandibular cartilage (shark) of the first arch:
- Articular (bony fish, reptiles) = malleus (mammals)

Bones of other arches:
- Hyomandibula (bony fish) = columella (reptiles) = stapes (mammals)
- Hypobranchial skeleton (bony fishes) = hyoid and laryngeal skeleton (reptiles, mammals)

Membrane bones (all paired, except where otherwise noted):

Skull roof (in sequence, anterior to posterior):
- Nasal (reptiles, mammals)
- Frontal (reptiles, mammals)
- Parietal (reptiles, mammals)

Around orbit (in sequence, clockwise for left orbit):
- Lacrimal (reptiles, mammals)
- Prefrontal (reptiles)
- Postfrontal (lepidosaurs)
- Postorbital (reptiles)
- Jugal (reptiles, mammals)

Cheek region (all paired):
- Operculum (bony fish)
- Quadratojugal (archosaurs, turtles)
- Squamosal (reptiles, mammals) – note: squamosal of mammals + otic bones = temporal

Palate (some prominent ancestral bones omitted):

- Palatine (reptiles, birds, mammals)
- Pterygoid (reptiles, birds, mammals)
- Ectopterygoid (archosaurs, lepidosaurs)
- Vomer (mammals only; single)

Upper jaw (form around, not within, the visceral arch):

- Premaxilla (bony fish, reptiles, mammals)
- Maxilla (bony fish, reptiles, mammals)

Lower jaw (form around, not within, the visceral arch – several prominent ancestral bones omitted):

- Dentary (bony fish, reptiles, mammals)
- Angular (bony fish, reptiles) = Ectotympanic (mammals)

Additional features of the skull

Except where noted, the following features need only be learned for the mammalian skull. These features have been selected because of their prominence or because of their relationship with other organ systems (i.e. the muscular system).

Tympanic Bulla	Mastoid Process	Coronoid Process
External Auditory Meatus	Jugular (Paroccipital) Process	Masseteric Fossa
Zygomatic Arch	Internal Nares (nostril)	Mandibular Condyle
Sagittal Crest	Nuchal Crest	Postglenoid Process (behind mandibular fossa)
Occipital Condyles	Mandibular Fossa	

Foramina

Learn the following major foramina of the mammalian skull and know which structure passes through them where applicable.

Optic Foramen	Jugular (Posterior Lacerate) Foramen
Foramen Ovale[1]	Hypoglossal Foramen
Infraorbital Foramen	Foramen Magnum
Anterior Palatine Foramen	Pineal Foramen (lizards)
Posterior Palatine Foramen	Mental Foramen
Foramina cribrosa of Ethmoid	Carotid Foramen
Internal Nares[2]	Internal Acoustic Meatus
External Nares[2]	External Acoustic Meatus[2]

[1] In the dog and bear, a unique foramen extends from the foramen ovale, forward to the foramen rotundum, through which the mandibular branch of the trigeminal nerve passes.

[2] There is no structure that passes through this opening.

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Lab 6: Homologous Bones of the Vertebrate Skull

Below is a table of the key bones of the skull and the visceral skeleton in bony fishes, reptiles, and mammals that you should be able to identify. Bones listed in the same horizontal row are homologous to one another.

	Bony Fishes	**Reptiles**	**Mammals**
Chondrocranium		Basioccipital	Basioccipital
		Exoccipital	Exoccipital
		Supraoccipital	Supraoccipital
		Basiphenoid	Basiphenoid
			Preshenoid
			Orbitosphenoid
		Otic bones	Otic bones (petrous temporal)
Visceral Skeleton		Epiterygoid (lepidosaurs)	Alisphenoid
	Quadrate	Quadrate	Incus
	Articular	Articular	Malleus
	Hyomandibular	Columella	Stapes
Membrane (dermal) Bones		Nasal	Nasal
		Frontal	Frontal
		Parietal	Parietal
		Lacrimal	Lacrimal
		Prefrontal	
		Postfrontal (lepidosaurs)	
		Post orbital	
		Jugal	Jugal
		Quadratojugal (archosaurs, turtles)	
		Squamosal	Squamosal (temporal)
		Palatine	Palatine
		Pterygoid	Pterygoid
		Ectoterygoid (archosaurs, lepidosaurs)	
			Vomer
	Premaxilla	Premaxilla	Premaxilla
	Maxilla	Maxilla	Maxilla
	Dentary	Dentary	Dentary
	Angular	Angular	Ectotympanic (temporal)
			Entotympanic (temporal)
	Opercular bones		