LABORATORY MANUAL FOR MAMMALOGY

The Skull

Skull morphology provides important information for identifying mammals and understanding their biology. Familiarize yourself with the basic elements and landmarks of the mammalian skull, as exemplified in a dog or horse skull.

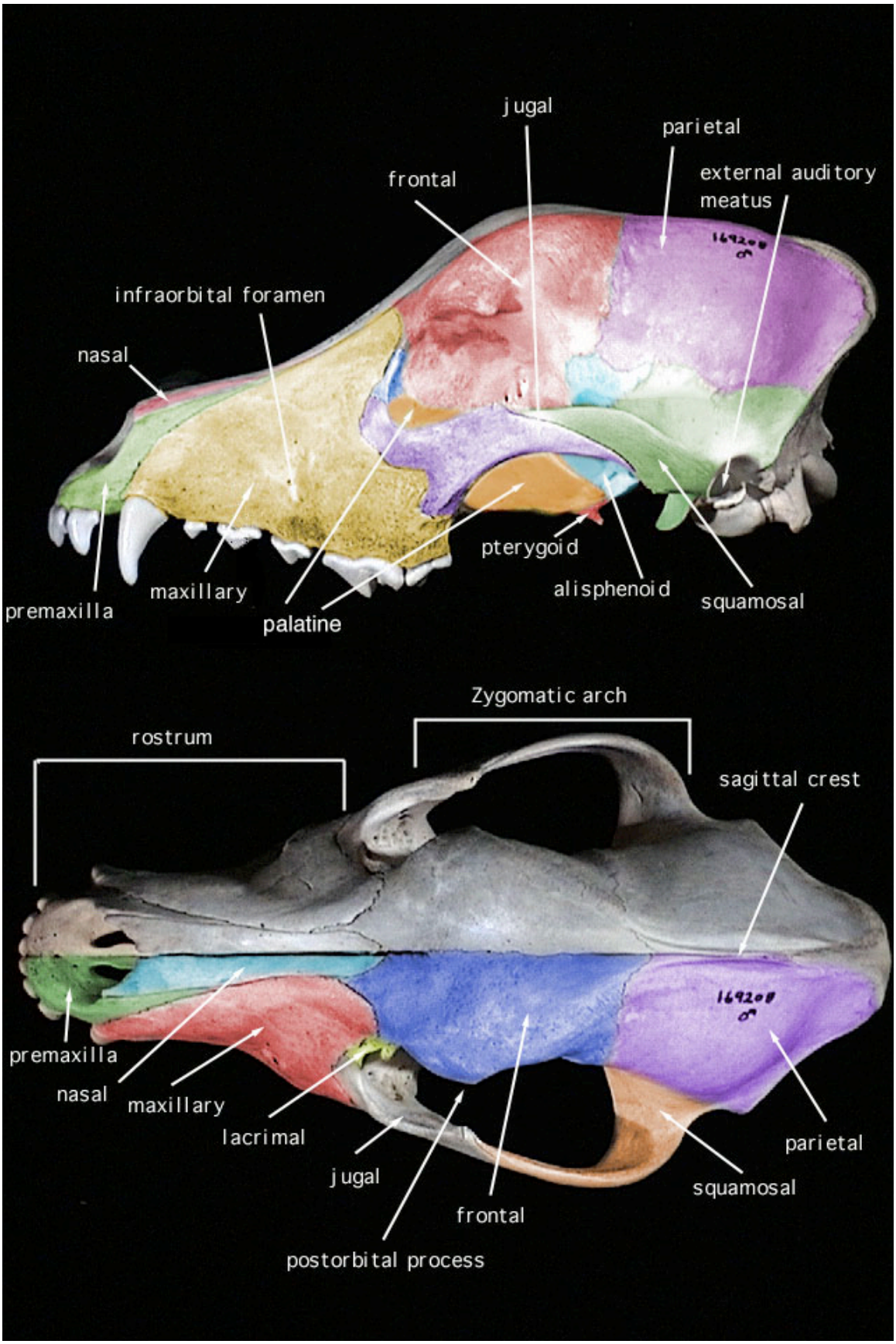
Be sure to find the following bones and landmarks:

Bones

nasal
lacrimal
premaxilla
maxilla
palatine
pterygoid
alisphenoid
jugal
frontal
parietal
squamosal
occipital (supraoccipital, exoccipital, basioccipital)
dentary

Landmarks

narial opening
orbit
(secondary) palate
supraorbital process
postorbital process
internal nares
zygomatic arch
glenoid (mandibular) fossa
sagittal crest/temporal fossa
nuchal crest
occipital condyle
auditory bulla
mandibular symphysis
coronoid process
mandibular condyle
angle of mandible
infraorbital foramen
lacrimal foramen
alisphenoid canal
foramen ovale
foramen magnum


jugal
parietal
frontal
external auditory meatus
infraorbital foramen
nasal
pterygoid
premaxilla
maxillary
palatine
alisphenoid
squamosal
Zygomatic arch
rostrum
sagittal crest
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nasal
maxillary
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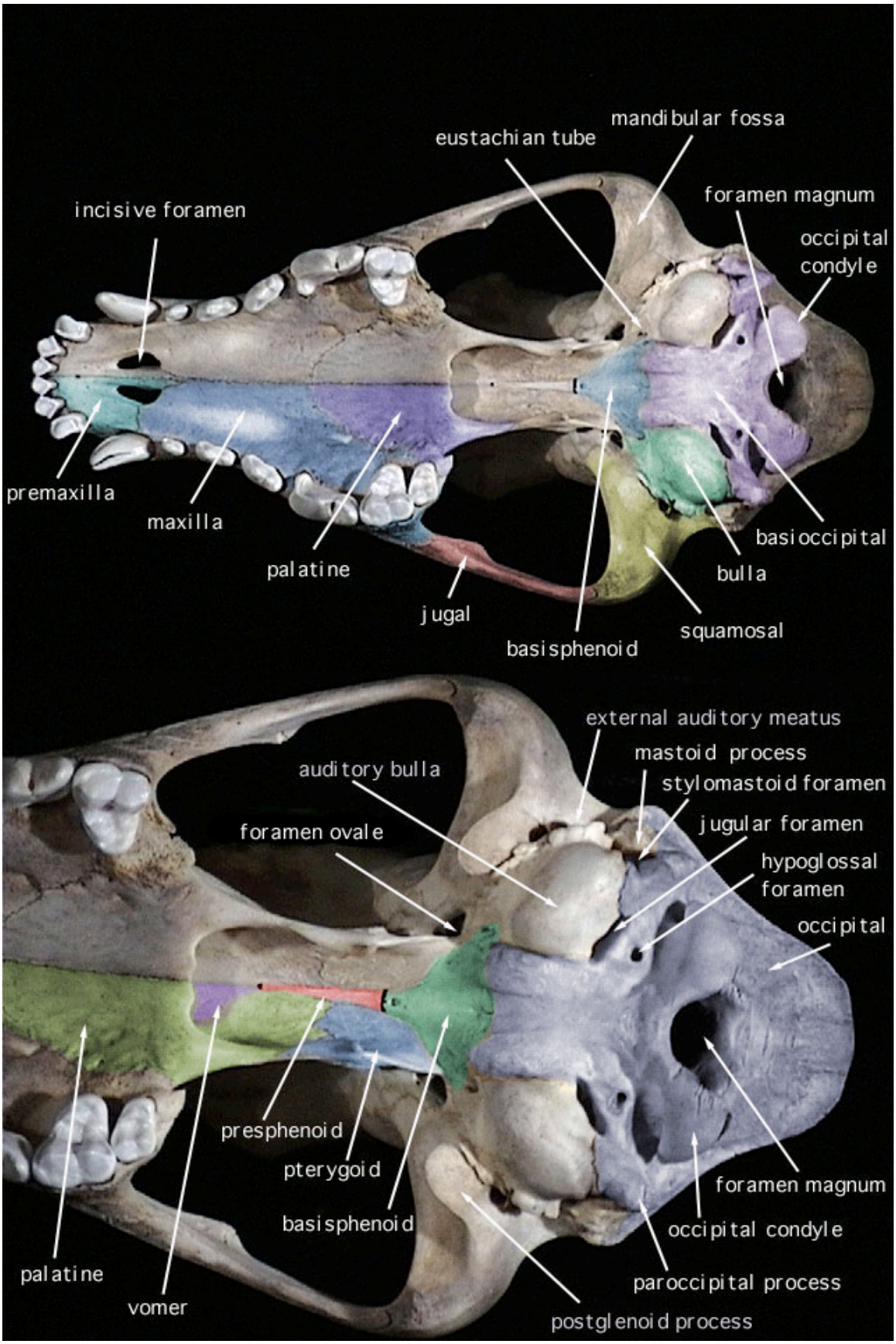
frontal
parietal
squamosal
postorbital process


mandibular fossa
eustachian tube
foramen magnum
incisive foramen
occipital condyle
premaxilla
maxilla
palatine
basioccipital
bulla
jugal
squamosal
basisphenoid
external auditory meatus
mastoid process
auditory bulla
stylomastoid foramen
jugular foramen
foramen ovale
hypoglossal foramen
occipital
presphenoid
pterygoid
foramen magnum
basisphenoid
occipital condyle
palatine
paroccipital process
vomer
postglenoid process

Postcranial skeleton

The rest of the skeleton apart from the skull is known as the postcranial skeleton. Postcrania can be important for distinguishing different types of mammals and for understanding their locomotion.

Familiarize yourself with the following bones and their indicated landmarks:

Vertebrae

- Atlas and axis: first two cervicals
- Cervical: possess transverse foramina
- Thoracic: attached to ribs
- Lumbar: stout lower back vertebrae
- Sacral: connected to the pelvis usually fused into a single element, the sacrum
- Caudal: tail vertebrae
- Spinous process (neural spine)
- zygapophyses: the processes that form the joints between vertebrae

ribs

clavicle

scapula
- glenoid fossa
- spine

humerus

radius

ulna

carpals

metacarpals

phalanges

innominate (pelvic bone)
(actually three bones: ilium, ischium, pubis)
- acetabulum

femur
- greater, lesser, and third trochanters

tibia
- medial malleolus

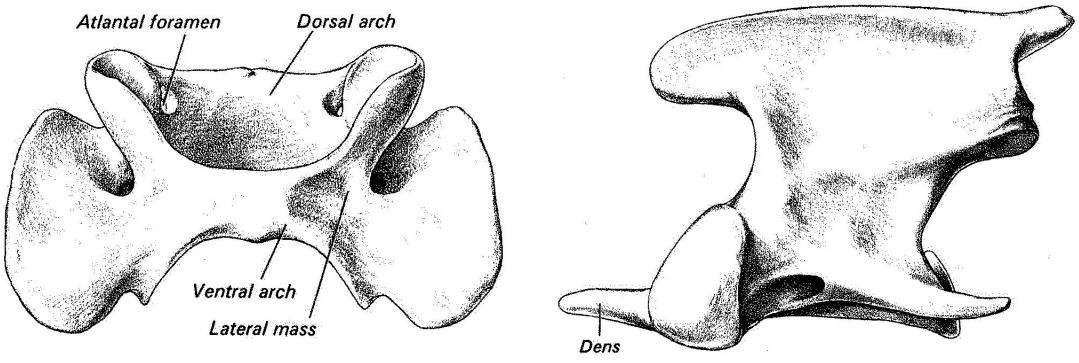
fibula

patella

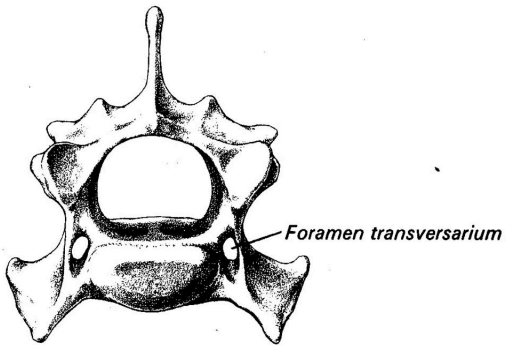
tarsals
- astragalus
- calcaneum

metatarsals

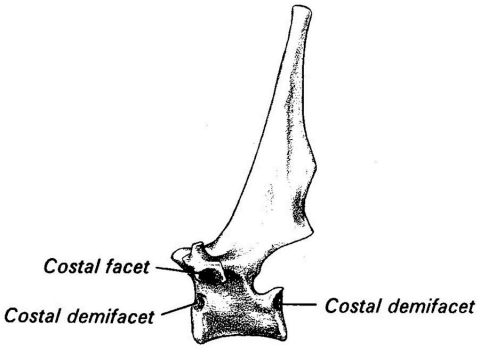
phalanges



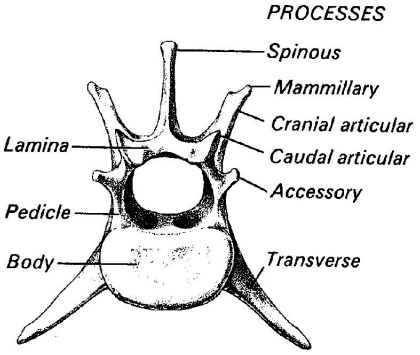
Atlas and axis: first two cervicals

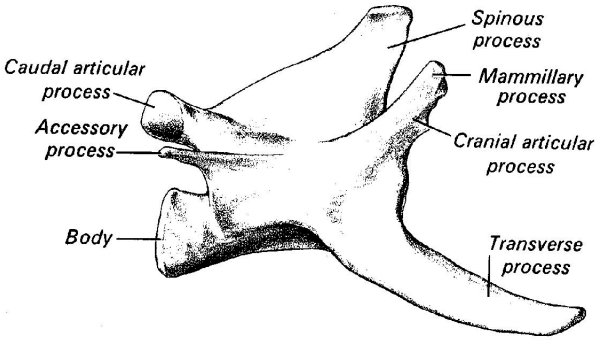


Cervical: possess transverse foramina

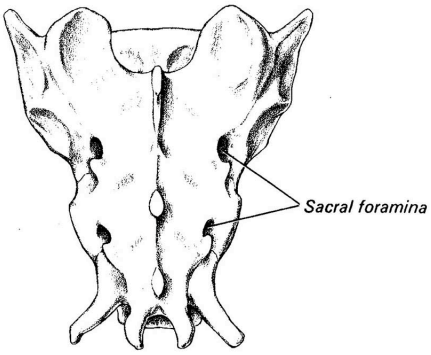


Thoracic: attached to ribs

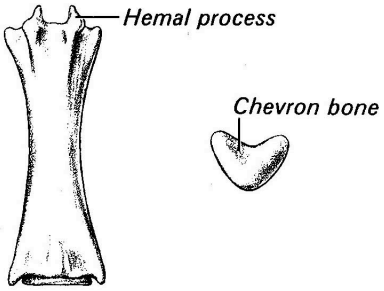




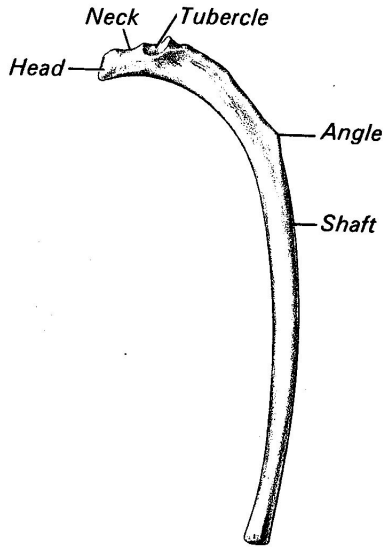
Lumbar: stout lower back vertebrae



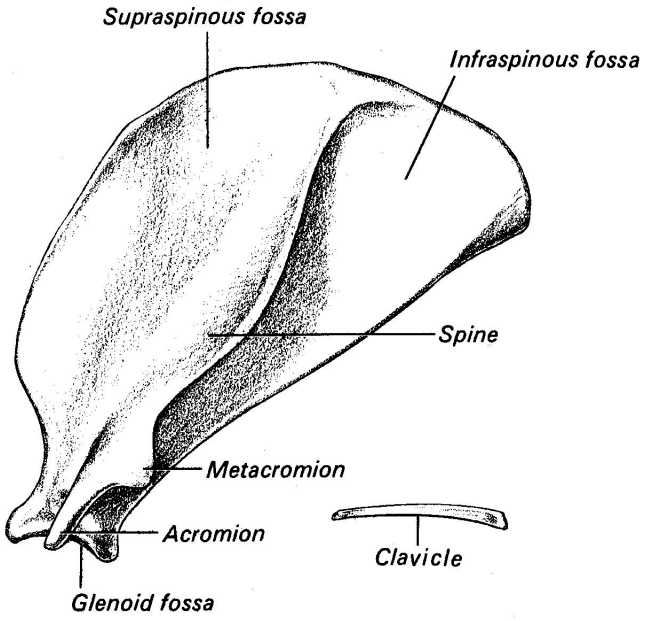
Sacral: connected to the pelvis;
usually fused into a single element, the sacrum



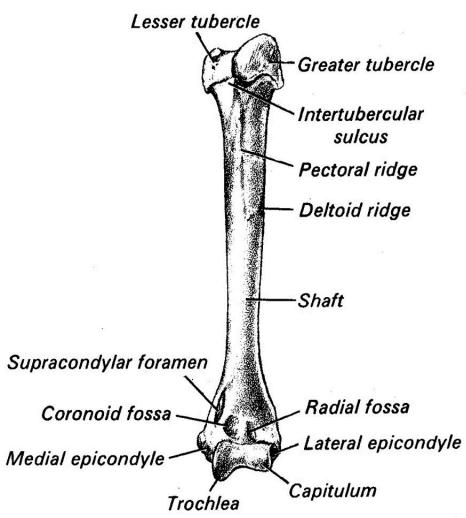
Caudal: tail vertebrae



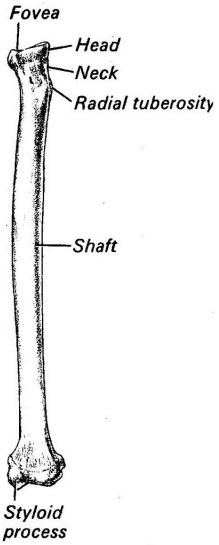
Rib



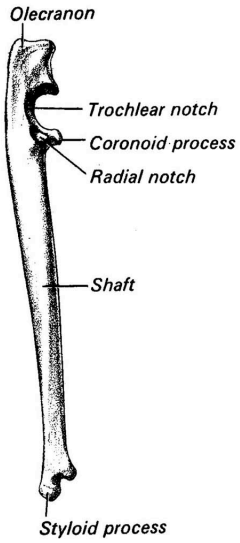
scapula clavicle



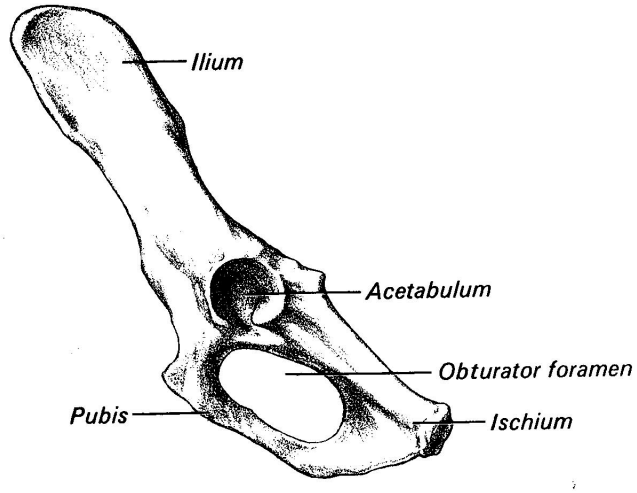
humerus



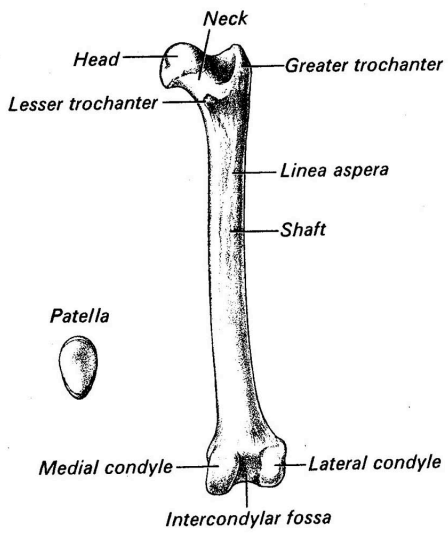
radius



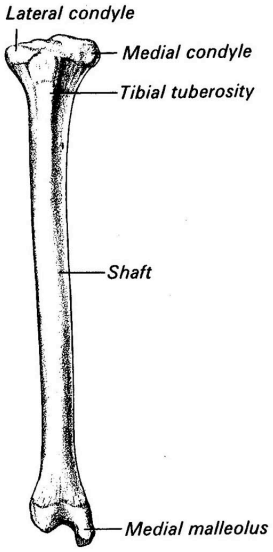
ulna



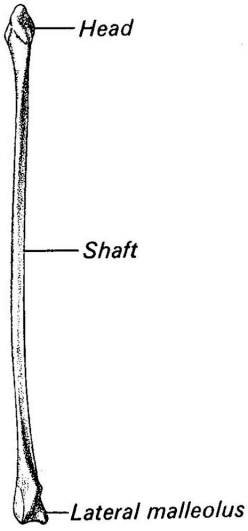
innominate (pelvic bone) (actually three bones: ilium, ischium, pubis)



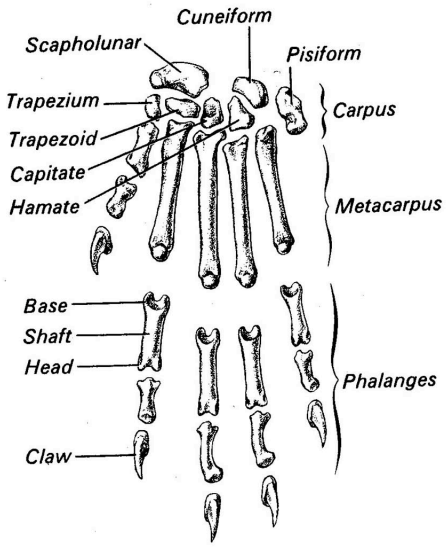
femur and patella



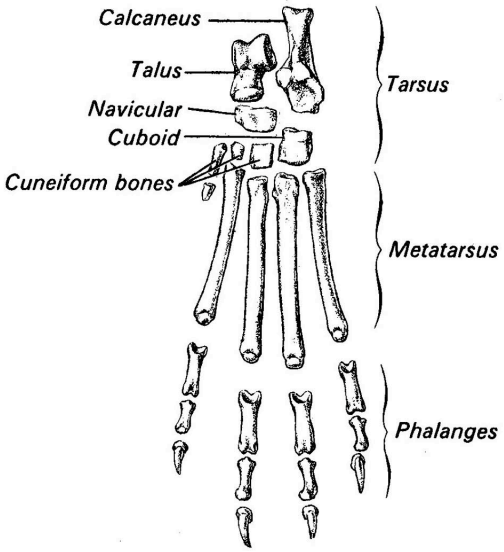
tibia



fibula



manus



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TEETH

In this lab you will learn about the morphology of mammalian teeth. By the end of this lab, you should be able to 1) identify the different types of teeth in the mammalian dentition, 2) determine dental formulae for various mammals, 3) identify the different cusps on molars of various mammals, and 4) understand how molars are modified for different diets.

Terms to Know for This Lab

Anterior: towards the front of the mouth. Incisors are the most anterior teeth.
Posterior: towards the back of the mouth. Molars are the most posterior teeth.
Labial or **Buccal**: towards the lip or cheek. Generally this means the outer side of the teeth. Remember that, unlike you, the lips of most mammals extend back along the side of the mouth.
Lingual: towards the tongue. Generally this means the inner side of the teeth.
Occlusal: referring to the "top" of the teeth, the part involved with chewing. The occlusal surface of an upper tooth contacts the occlusal surface of the corresponding lower tooth during chewing. Occlusal view is the view of the chewing surface of a tooth.
Deciduous: referring to the first generation of teeth, i.e., your "baby" teeth. Adult teeth usually replace these teeth around the time of weaning; thus they are sometimes called milk teeth.

Where You Find Teeth

Mammals have teeth in three different bones. Upper teeth are found in the premaxilla and maxilla; all lower teeth are found in the dentary.

The Types of Mammalian Teeth

Most mammals have a heterodont dentition, meaning that different teeth in the jaw have different shapes, and, therefore, functions. We identify these different tooth types by several criteria, namely position, shape, and whether or not they are replaced. The four types of teeth are incisors, canines, premolars, and molars.

Incisors: When present, these are the anteriormost teeth. Upper incisors are always found in the premaxilla. The incisors of many mammals, such as yours, are designed for nipping off bits of food, but many variations exist. Incisors are usually replaced.

Canines: When present, canines lie right behind the incisors. Upper canines are therefore the anteriormost teeth in the maxilla. Canines are generally conical, pointy teeth used for holding onto prey and in defense or intraspecific combat. The size of canines differs among mammals, usually being largest in carnivores, whereas many herbivorous mammals have small canines or have lost them altogether. Canines are usually replaced.

Premolars and molars: Premolars and molars are together referred to as the cheek teeth. Both types of teeth are usually specialized for grinding or processing food items before swallowing. Both types of upper teeth are found in the maxilla. Premolars are posterior to canines, and molars are posterior to premolars. Some premolars are replaced, whereas molars are never

replaced. In fact molars are defined as the unreplaced teeth that are posterior to the last replaced tooth.

Molars are often more similar to deciduous premolars than to adult premolars, and you can actually think of molars as part of the deciduous generation that comes in late and is never replaced.

Dental Formulae

The number of each type of tooth differs from taxon to taxon. In some cases, the number of a type of tooth differs in the upper and lower jaws of the same species, but right and left are always the same. Thus, we can characterize each mammal taxon by a dental formula, representing the number of incisors, canines, premolars, and molars found in each half (right or left) of the upper and lower jaws. We write this formula as **I n/n C n/n P n/n M n/n**. **I**, **C**, **P**, and **M** refer to the four types of teeth (incisor, canine, premolar, and molar), and n/n refers to the number of upper and lower teeth of each type found on one side.

As an example, consider our own dentition. Humans have a total of 32 teeth (including wisdom teeth), 16 in the upper jaw and 16 in the lower jaw. Of course, the 8 teeth on the right side of your upper jaw are basically a mirror image of the 8 on the left, and the same can be said of the lower jaw. Thus, the dental formulae reflects the 16 teeth (8 upper, 8 lower) found on each side and looks like this: **I 2/2 C1/1 P 2/2 M 3/3**. It just so happens that humans have the same number of each tooth type in their upper and lower jaws, but this is not the case for every mammal. Here, for instance, is the dental formula of an opossum: **I 5/4 C 1/1 P 3/3 M 4/4**.

The different dental formulae that we observe today are thought to be derived from an ancestral mammal that had the following formula: **I 5/4 C 1/1 P 4/4 (or P 5/5) M 3/3**. We can also make inferences about which particular teeth have been lost in various mammals. In order to identify a particular tooth position, or locus, we number each tooth according to its type, with the numbers going from anterior to posterior. Capital letters indicate upper teeth, and lowercase indicates lower teeth. Thus, your upper molars are numbered **M1**, **M2**, and **M3**, whereas your lower molars are **m1**, **m2**, and **m3**. Compared to the primitive formula, we have lost some incisors and premolars. It is thought that the incisors were lost from the posterior end, whereas the premolars were lost from the anterior end. Thus, our upper teeth are considered to be **I1**, **I2**, **C1**, **P3**, **P4**, **M1**, **M2**, and **M3**; our lowers are **i1**, **i2**, **c1**, **p3**, **p4**, **m1**, **m2**, and **m3**. Deciduous teeth are indicated by a lowercase "d", e.g., **dP4** would refer to the deciduous fourth upper premolar.

Molar Morphology

Cheek teeth show a wide variety of specializations among mammals. Many species can be identified by the morphology of a single molar. In order to understand the evolution of mammalian molars, it is important to be able to recognize homologous structures on teeth. Looking at the occlusal surface of a molar, its topography is made up of little hills, valleys, and ridges. The "hills" or bumps we call **cusps**; the ridges we call **lophs**. All mammalian teeth can ultimately be derived from a primitive pattern of cusps that we call the **tribosphenic molar**.

Tribosphenic molars are basically triangles of three cusps (plus an extra pair on the lower molars), but the upper and lower triangles are reversed in their orientation.

Examine the morphology of an upper tribosphenic molar in an opossum. Make sure you can identify the following cusps: **protocone**, **paracone**, and **metacone**. Note the orientation of the triangle that they form. Next, examine the lower molar of an opossum. Identify the following cusps: **protoconid**, **paraconid**, **metaconid**, **entoconid**, and **hypoconid**. Note the orientation of the triangle formed by the protoconid, paraconid, and metaconid. This triangle is called the **trigonid**. The entoconid and hypoconid form a "heel" to the tooth that is called the **talonid**. Note that the talonid forms a deep depression, called the **talonid basin**. The protocone fits into the talonid basin during chewing. Observe this when you move the jaws of the opossum skull together.

Many mammals have added cusps to the tribosphenic pattern in order to increase the chewing surface. The **hypocone** is present in many mammals posterior to the protocone. This fourth cusp allows the occlusal surface to form a rectangle. A similar result is obtained in the lower teeth by reducing or losing a cusp, the paraconid. Examine a number of herbivorous or omnivorous mammals and identify the hypocone.

Examine the teeth of a human skull. Identify the cusps of the molars. Note that the cusps are low and rounded, compared to those of an opossum. Compare this condition with that of a pig. Molars with low, rounded cusps are referred to as **bunodont**.

Examine the teeth of a dog skull. Note the large blade-like upper premolar and first lower molar. These teeth are specialized for shearing or slicing and function in a scissors-like manner. They are a specialization for eating meat. Such teeth are called **sectorial**. Note that dog upper molars are bunodont and retain the tribosphenic pattern. Dogs are as much omnivores as carnivores. (Check out the ingredients of dry dog food if you're skeptical.)

Lophs are present on many mammalian teeth. The outer (labial/buccal) edge of the molar is called the **ectoloph**. Many herbivorous mammals possess multiple lophs crossing the tooth so that they act like a file or millstone to grind and shred vegetation. Such teeth are referred to as **lophodont**. **Lophodonty** (the condition of being lophodont) has evolved multiple times in multiple ways. Sometimes a loph is formed by building up a ridge between two or more cusps. In other cases, a cusp may be stretched into a loph. In many cases, it is still possible to identify the homologues of the cusps of a tribosphenic molar on a lophodont tooth. Some mammals have teeth with numerous lophs that defy any identification of cusps. Examine some of the lophodont teeth on display and identify cusps when possible.

Subclass Prototheria
Order Monotremata

Two living families of mammals represent the Order Monotremata: Ornithorhynchidae (platypuses) and Tachyglossidae (echidnas or spiny anteaters). Both of these families are found only in Australia and New Guinea. Monotremes are unusual, specialized animals, but they share the primitive feature of laying shelled eggs.

Among other primitive features that monotremes display are their shoulder girdles, which resemble those of non-mammalian synapsids and reptiles more than those of other mammals. Examine the skeleton of a platypus and of an opossum and note the differences.

Family Ornithorhynchidae

Platypuses (*Ornithorhynchus anatinus*) are semiaquatic and live in streams and rivers, eating invertebrates and nesting in bankside burrows.

Examine the cast of a platypus skull. Note the bill, which in life would be covered by sensitive skin possessing electroreceptors. The electroreceptors allow the platypus to find prey in murky water. Platypuses have no teeth, but they possess horny plates on their jaws, with which they crush their prey.

Male platypuses possess tarsal spurs, sharp clawlike appendages on their ankles that secrete venom, one of the few instances of poison production in mammals.

Family Tachyglossidae

Echidnas or spiny anteaters (genera *Tachyglossus* and *Zaglossus*) are burrowing animals that have a lifestyle similar to that of anteaters in South America. They use their claws to tear into the nests of social insects like termites and ants. They then lap up the insects using a long sticky tongue. Echidna skulls, like those of other anteaters, are elongate and toothless.

Echidnas possess thick, sharp spines (in fact modified hairs) for protection. Echidnas will burrow when faced with danger, so that only their spiny backs are exposed, but they can also roll into a ball, presenting a predator with nothing but sharp spines. We presently don't have any material of echidnas, but pictures and other information are available in your text.

Infraclass Metatheria (Marsupialia)

Marsupial characteristics

Examine a skull and the mounted skeleton of an opossum. A number of features of the skeleton distinguish marsupials from other mammals. Note the following:

Skull:

Palatal vacuities: Note the openings in the secondary palate. All marsupials possess these palatal vacuities, but few placental mammals do.

Alisphenoid bulla: The auditory bulla, which houses the middle ear, is formed (at least in part) by the alisphenoid bone only in marsupials.

Jugal contribution to jaw articulation: Note that the glenoid fossa, the part of the jaw joint found on the skull, is formed mainly by the squamosal but also by a small portion of the end of the jugal bone. This is found in all marsupials, but also in a number of placentals.

Inflected angle of mandible: Note that the angle of the lower jaw is inflected, or bent inwards. This is characteristic of marsupials.

Dentition:

Number of incisors: Marsupials are classified partly on the basis of the number of incisors they possess. The opposum possesses the primitive number of incisors for marsupials, 5 upper and 4 lower. This condition is called **polyprotodont**. Marsupials almost always have unequal numbers of upper and lower incisors. Many Australian marsupials are characterized by the possession of only a single enlarged incisor in each half of the lower jaw. This condition is called **diprotodont**. Placental mammals never have more than three upper or lower incisors.

Premolars and molars: Marsupials commonly possess 3 premolars and 4 molars (upper and lower), whereas placental mammals primitively possess 4 premolars and 3 molars. Of the premolars, only the last is replaced. Note the deciduous premolars still in place in the jaws of the juvenile opossum. Deciduous premolars ("milk" or "baby" teeth) usually look like molars.

Postcranial skeleton:

Epipubic bones: The two bones attached to the front of the pubes are the epipubic bones. Epipubic bones are characteristic of marsupials and are also found in monotremes and some Cretaceous placentals. Epipubic bones are sometimes called "marsupial" bones, but they are not found only in marsupials, and they are found in both sexes, so they are not simply providing support for the pouch.

Order Didelphimorphia
Family Didelphidae

We have representatives in lab of four families of marsupials, Didelphidae, Thylacinidae, Macropodidae, and Vombatidae. Didelphids are commonly called opossums. They are generally arboreal (tree-climbing) and omnivorous. They are the largest living family of marsupials in the western hemisphere, many of them found in South America.

Local species: *Didelphis virginiana*

Numerous examples of the only North American marsupial, the Virginia opossum, are displayed in today's lab. Opossums are common throughout the eastern United States, including in New Jersey, and are thus a local species.

Didelphids are polyprotodont marsupials; they have more than one lower incisor in each mandible.

Note the skull of *Marmosa*. *Marmosa* is a small didelphid from South America. What is its dental formula?

Order Dasyuromorpha
Family Thylacinidae

The order Dasyuromorpha includes several families of Australian polyprotodont marsupials. The most diverse family is the Dasyuridae, which includes a wide variety of insectivorous or carnivorous species, including mouse-sized "rat opossums", cat-sized quolls, and the most famous member of the family, the Tasmanian devil, which gets up to 12 kilograms in weight. Other dasyuromorph families were at one time included in the Dasyuridae but were then given their own families to recognize their distinctiveness from more typical dasyurids. One such family is the Thylacinidae, which includes a single genus, *Thylacinus*, the Tasmanian "wolf" or "tiger", also called the thylacine.

Now thought to be extinct, thylacines were found on the Australian mainland in prehistoric times, but by the time Europeans came to Australia these animals could only be found on the large southeastern island of Tasmania. The appearance of a thylacine was generally dog-like, with stripes on the hindquarters that inspired the name "tiger". Thylacines were the largest carnivorous marsupials to survive into historical times, and Europeans living in Tasmania considered thylacines to be threat to their sheep, so bounties were paid for killed thylacines, until no more were left in the wild. The last known living thylacine died in a European zoo at the beginning of the twentieth century.

Thylacines provide one of the most striking examples of **parallelism**, when species in the same group (mammals in this case) evolve similar forms as adaptations to similar lifestyles in different locations. The wolves and thylacines independently evolved similar body types, adapted for running and hunting large prey, filling similar large carnivore niches on different continents. Compare the cast of a thylacine skull with the skull of a wolf. Note the general similarity in

shape of the skull, as well as the sectorial teeth. At the same time, you should still be able to identify the distinctive marsupial characters (see the beginning of this section) in the thylacine specimen.

Order Diprotodontia

This order contains the vast majority of the diprotodont marsupials. Most of these animals are herbivorous.

Family Macropodidae

One of the diprotodont families of marsupials on display here today is the Macropodidae or kangaroos. Examine the kangaroo skulls on display. Kangaroos are diprotodont; that is, they have only one large lower incisor in each mandible. Kangaroos share this condition with a number of other Australian marsupials, including wombats, koalas, and possums.

Like most diprotodont marsupials, kangaroos are herbivores. Examine the teeth of a kangaroo skull. Note that they consist of two transverse crests. This pattern is termed bilophodont. Note other herbivorous features in this skull, particularly the extra attachments for the masseter (note the process sticking off of the front of the zygomatic arch) and the height of the mandibular condyle relative to the tooth row.

Family Vombatidae

Wombats are fossorial herbivores, sort of analogous to large groundhogs. Examine the cast of a wombat skull. There is a single incisor on each side of the upper and lower jaws. Note the simple cheek teeth, including one premolar and four two-lobed molars in each quadrant.

Syndactyly: Diprotodont marsupials are syndactylous, a feature they share with the polyprotodont Peramelidae, the bandicoots. Syndactyly refers to the condition where two digits of the foot, in this case digits II and III, share a common skin sheath. (Digits on the hand and foot are identified by Roman numerals, so that the thumb or big toe is digit I, and the pinky or pinky toe is digit V. Note that digits retain their numbers, even if a species has lost a digit; e.g., horses run on their third digits, the only functional digits that they have.) Thus, syndactyly gives the appearance of a digit with two claws.

Examine the illustrations of syndactylous feet. Note that the syndactylous digits are often reduced in size relative to the others. Many marsupials use their syndactylous digits for grooming.

Ant-eating (Myrmecophagy)

A number of different groups of mammals include members that have evolved adaptations for eating social insects, e.g., ants and termites. These insects are very common in tropical regions and live in huge colonies, often in enormous nests of dried mud, hard as concrete, but also within

vegetation. Anteating mammals can be found in the Orders Monotremata, Marsupialia, Xenarthra, Pholidota, and Tubulidentata, and in several families of the Carnivora, including anteating bears, hyaenas, and viverrids.

Ant-eating, or **myrmecophagous**, species share a number of specializations. The most obvious is an elongate, tube-like snout that can be more easily probed into the tunnels of termite mounds. The snout also contains an extremely long and sticky tongue, with which the numerous insects are caught and brought into the mouth. The teeth of ant-eating mammals are reduced or absent (perhaps to eliminate the chance of biting one's tongue). Because getting at termites often requires digging, most ant-eating mammals have fossorial adaptations (i.e., for burrowing), such as strong claws and forelimbs.

Compare the skulls of the giant anteater, aardvark, and aardwolf. What adaptations for ant-eating can you observe in these skulls?

Infraclass Eutheria (Placentalia)
Order Xenarthra

Xenarthrans are a group of unusual mammals from the Americas, originally from South America. Despite their varied specializations, all xenarthrans share a number of derived features. The one that gives them their name is the possession of xenarthrous vertebrae. The lumbar vertebrae of xenarthrans possess additional articulations not found in other mammals. Note these xenarthrous joints on an illustration from your textbook. Xenarthrans are sometimes referred to as edentates, meaning toothless, but whereas anteaters are toothless, sloths and armadillos possess teeth, although their teeth have no enamel.

Family Megalonychidae and Family Bradypodidae

Sloths are members of these two families. Both genera of living sloths (*Choloepus* and *Bradypus*, the two-toed and three-toed sloths, respectively) are slow moving, herbivorous creatures that hang from branches by their curved claws and munch leaves all day. Algae growing in their fur provide them with some camouflage in the foliage. Even though their teeth are simple, sloths are able to digest leaves, thanks to a multi-chambered stomach that contains cellulose-digesting bacteria.

Fossil sloths include a number of ground-dwelling species, some of which became very large. The two genera of living sloths have long been classified in the Family Bradypodidae, but a number of studies have determined that *Choloepus* is actually more closely related to some of the ground sloths and should be placed in the Family Megalonychidae.

Examine the skull of *Choloepus*. Note that the peg-like teeth have no enamel (just dentine) and are difficult to identify as premolars, molars, etc., so it is difficult to determine their dental formulae. In fact, the teeth that appear to be canines are likely to be something else, perhaps incisors. The upper "canines" of sloths sit in front of the lower "canines" when the jaws are closed. Look at the skull of an opossum, wolf, or other mammal with typical canines, and notice that the upper canines are placed behind the lower ones when the jaws are closed.

Family Dasypodidae

Armadillos are distinguished by their armor, composed of bony dermal scutes covered by horny scales. Armadilloes are generally fossorial and omnivorous, eating mainly invertebrates. One species, the nine-banded armadillo (*Dasypus novemcinctus*) is found in the southern United States, but most armadillo species are South American.

Examine the skull of an armadillo. Like sloths, armadillos have peg-like teeth with no enamel and little indication as to the dental formula. The specimens in this lab come from the nine-banded armadillo.

Family Myrmecophagidae

The three species of anteaters are found in Central and South America. The smallest, the silky anteater, is about the size of a squirrel, but the largest, the giant anteater, reaches the size of a large dog.

Examine the cast of a skull of a giant anteater (*Myrmecophaga tetradactyla*). The skull is toothless and has the characteristic long, thin shape found in ant-eating mammal species.

Order Tubulidentata

Family Orycteropodidae

The single species of aardvark (*Orycteropus afer*) is a mammal whose relationship to other mammals is not well understood. Aardvarks are found in Africa where they feed on termites that live in concrete-hard castle-like mounds. Aardvarks are legendary diggers; one man who grabbed an aardvark by the tail in order to catch it within minutes found himself waist deep in the hard sun-baked African earth, as the aardvark had attempted to burrow to safety.

Aardvarks are distinguished from other mammals by their tubular dentine (the source of the name for the order); tiny tubes pierce the dentine in their peg-like teeth. Examine the skull of an aardvark under a dissecting scope and see if you can see these tubules in the tooth surface.

O. Insectivora

A variety of mammals have been classified as "insectivorans," largely because they were small, primitive, or of mysterious affinities. The Order Insectivora is now restricted to lipotyphlans (and the order is sometimes called Lipotyphla). Lipotyphlans are distinguished from other putative insectivorans by the lack of a caecum on the colon. (The caecum is a blind pouch; it is often enlarged in herbivorous mammals like rabbits.)

Apart from the caecum, few characters unite lipotyphlans as a monophyletic group. These include reduction of the pubic symphysis and reduction of the jugal, as well as some other traits that are found in some members of other orders. Some recent molecular studies have challenged the monophyly of Insectivora.

F. Erinaceidae

Erinaceids are best known as hedgehogs, although some members that have no spines are known as moonrats. They are found throughout the Old World. Examine the skull of a hedgehog. Note that the molars are bunodont with a prominent hypocone. Like marsupials, hedgehogs have palatal vacuities.

F. Soricidae

Shrews are small predatory mammals that are found on every continent except Australia and Antarctica. Shrews have very high metabolic rates and must eat often in order to provide enough energy to live. This is partly due to their small size, which results in a high surface area-volume ratio that causes them to lose heat rapidly. Some of the smallest mammals in the world are shrews, weighing as little as a few grams. Shrews have large, distinctive incisors, simple premolars (often referred to as unicuspids), and dilambdodont molars.

Local species: *Blarina brevicauda*, short-tailed shrew
Local species: *Sorex cinereus*, masked shrew
Local species: *Sorex palustris*, water shrew

New Jersey is the home to several species of shrews, two of which are displayed here. *Blarina brevicauda* is the most common shrew that you might encounter, as it often falls prey to cats. *Blarina* is larger than *Sorex* and has more mole-like features, such as no visible ear pinnae, very small eyes, and dark grey fur. *Blarina* hunts under the cover of leaf litter and lawns, searching for insects but also hunting prey as large as mice and voles (which are larger than the shrew). Short-tailed shrews are unusual for mammals in that they are venomous, producing a neurotoxin that paralyzes small prey.

There are several species of *Sorex* present in New Jersey, which can be difficult to sort out, but only the relatively common masked shrew is represented in our teaching collection.

Note the red pigment on the teeth of the shrews. The function of this pigment (from an iron compound), if any, is unknown, but it is found only in the subfamily Soricinae, to which all New World shrews belong.

F. Talpidae

This family actually includes three different types of animals, moles, shrew moles (which are less fossorial), and desmans (which are semiaquatic). Moles are specialized for subterranean life, i.e., they spend most of their lives burrowing through the earth, rarely coming to the surface. They are found throughout the holarctic region.

Talpids all share an unusual feature, a humeroclavicular joint. In most mammals, the shoulder joint is formed only by an articulation between the head of the humerus and the glenoid fossa of the scapula. In talpids, the humeral head also articulates with the clavicle. One consequence (or possibly cause) of this unusual anatomy is that talpids use a "breaststroke" motion when they dig. Most mammals are "scratch" diggers, moving their limbs beneath them, as when a dog digs

Local species: *Scalopus aquaticus*, Eastern mole
Local species: *Parascalops brewerii*, hairy-tailed mole
Local species: *Condylura cristata*, star-nosed mole

Three species of moles are found in New Jersey. The star-nosed mole is readily distinguished by the ring of tentacles around the tip of its snout, which are very sensitive to touch. Star-nosed moles burrow but also are known to swim in streams looking for prey. The Eastern and hairy-tailed moles are more typical and look similar; the Eastern mole can be distinguished by the absence of fur on its tail.

F. Tenrecidae
F. Solenodontidae
F. Chrysochloridae

These three families are currently not represented in today's lab.

Tenrecids are a family of diverse insectivorans found in Madagascar and Africa. Tenrecs have undergone an adaptive radiation in Madagascar, including forms that resemble hedgehogs and opossums. The only African tenrecids are the semiaquatic otter shrews.

Solenodon is a rare insectivoran now found only in Haiti, where introduced mammals and hapitat destruction by humans threaten it with extinction. It is large for an insectivoran (about the size of a muskrat). It also produces venomous saliva, like some soricids.

Chrysochlorids, or golden moles, are native to Africa. Like true moles in the family Talpidae, they are subterranean burrowers feeding on invertebrates. They differ from talpids in that they are scratch diggers.

O. Macroscelidea

F. Macroscelididae

Elephant shrews, as their name suggests, were once included in the Insectivora, but they are now considered to be only distantly related at best. In fact, some workers consider this group to be related to rodents and rabbits. Hence, they are now placed in their own order. Elephant shrews take their first name from the fact that their snouts are long and somewhat mobile (though nothing like an elephant's trunk). They are generally terrestrial, and some have adaptations for bipedal hopping (like a little kangaroo). They are found in parts of Africa.

Examine the skull of an elephant shrew. Note the long-snouted skull and some of the features that distinguish it from lipotyphlans: complete zygomatic arch, large orbits, large auditory bulla. Examine the teeth under a microscope. The molars are squarish, with a large hypocone on the upper teeth, and they are lophodont and high-crowned, resembling the teeth of some large hoofed mammals.

O. Scandentia

F. Tupaiidae

Like the previous group, tree shrews were previously included in the Insectivora. Some workers consider tree shrews to be closely related to primates, and they are usually considered to resemble the ancestral primate. Tree shrews are small, squirrel-like animals that live above the ground in trees and low-lying vegetation. They are generally omnivorous, although fruit forms the majority of their diet. They are found in certain tropical forests of Southeast Asia.

Examine the skull of a tree shrew. Note the complete postorbital bar, a primate-like feature. Examine the teeth; the molars have the primitive tribosphenic form, with only a small hypocone.

O. Primates

The Order Primates includes humans and the animals commonly referred to as apes and monkeys. Several characters diagnose primates, including the presence of a petrosal bulla, reduction of incisors to two upper and lower on each side, and the presence of a postorbital bar. Primates show great diversity in diet and locomotion, but most are arboreal to at least some degree. Unlike most mammals, most primates are diurnal rather than nocturnal, and most have highly developed vision that is stereoscopic and usually color. Many primate species are social, meaning that they habitually live in groups of multiple individuals. Primates are generally found in tropical regions.

There are two major divisions of primates, the Strepsirhini and the Haplorhini. Strepsirhines, sometimes referred to as prosimians, share many primitive features, but they also share some derived features, such as the formation of a tooth comb from the lower incisors and canines. This tooth comb is used for grooming. The term strepsirhine refers to "split nose," describing the primitive form of the nose in this group, which resembles that of a dog. Haplorhines include tarsiers, monkeys, apes, and humans.

F. Lemuridae

Strepsirhines appear to have undergone a significant adaptive radiation on the large oceanic island of Madagascar. The most diverse family of Malagasy (i.e., from Madagascar) strepsirhines is the Lemuridae. Examine the lemur skull and note its primitive features in comparison to a monkey skull. What is the dental formula of this lemur?

F. Tarsiidae

Tarsiers are small, nocturnal, insectivorous primates. They have enormous eyes and long spindly legs specialized for leaping from branches. Examine the skull of a tarsier. Note the huge orbits, and note the postorbital septum. This is the "wall" of bone separating the orbit from the temporal fossa, a feature that tarsiers share with monkeys, apes, and humans. The teeth of tarsiers include standard tribosphenic molars.

F. Callitrichidae and F. Cebidae

Haplorhines include the tarsiers and the Anthropoidea, which includes monkeys, apes, and humans. Anthropoids are divided into two subgroups, the Platyrrhini and the Catarrhini. Platyrrhines are the New World monkeys, whereas catarrhines are the Old World monkeys and apes (including humans).

There are two families of platyrrhines, cebids and callitrichids, both found only in South and Central America. Callitrichids include the marmosets and tamarins, small monkeys that are generally insectivorous. Cebids include larger New World monkeys like howler monkeys and spider monkeys. Cebids lack opposable thumbs, but many have prehensile tails. Both cebids and callitrichids possess three premolars, but callitrichids have only two molars.

Examine the display of platyrrhine skulls. The smaller skulls at the top are callitrichids, whereas the larger skulls near the bottom are cebids. Can you determine the dental formula of these animals?

F. Cercopithecidae

Old World monkeys are placed in the Family Cercopithecidae. Cercopithecids are united by the presence of an anterior lower premolar that shears against the back of the canine in a derived manner. Identify this tooth on one of the macaque specimens. Cercopithecids, like New World monkeys, often have long tails, but the tails are never prehensile. Cercopithecid molars are generally bilophodont, with two transverse crests. Examine the teeth of a macaque to confirm this. What is the dental formula of a cercopithecid?

F. Hylobatidae

Apes and humans are placed together in the Hominoidea. Hominoids share a number of characters, including the absence of a tail. Hylobatids, or gibbons, constitute one of the two families of hominoids. Compare the gibbon skull to that of a macaque. Gibbons are characterized by their elongate limbs, especially their long arms that they use to swing themselves from branch to branch, a type of locomotion termed brachiation.

F. Hominidae

Great apes (orangutans, gorillas, and chimpanzees) and humans were formerly separated into the families Pongidae and Hominidae, respectively. A number of lines of evidence, including DNA, support the idea that humans are closely related to African apes (gorillas and chimpanzees) and that humans therefore should be placed in the same family as the great apes. Because it is older than the name Pongidae, the family name Hominidae is used for this family.

Examine the casts of skulls of a female and male gorilla. Gorillas exhibit a striking degree of secondary sexual dimorphism in certain features. Note the larger size and the prominent sagittal crest of the male relative to the female.

Compare the gorilla skulls to that of a human. What differences can you see between them? Compare these skulls to those of the early human relatives *Australopithecus*, *Homo erectus*, and *Homo neanderthalensis* (possibly a variety of *Homo sapiens*). Note particularly the differences in size of the braincase, development of a chin, development of brow ridges, and the length of the face.

O. Dermoptera

F. Cynocephalidae

Flying lemurs, or colugos, are arboreal gliding mammals of Southeast Asia once included in the Insectivora. Colugos glide using flaps of skin stretched between their limbs, similar to that

of a flying squirrel. Unlike flying squirrels, colugos also have a web of skin stretched between their fingers that contributes to the gliding surface. This is a feature that they share with bats, to which they may be closely related.

Dermopterans have dilambdodont molars but actually feed mainly on leaves. Upper incisors are reduced, and the lower incisors have distinctive spine-like projections like the tines of a comb, which they use for grooming their fur. Examine a colugo skull and observe this tooth comb.

O. Chiroptera

Bats are the only mammals that truly fly. They have wings formed by stretching a membrane of skin between their fingers. This membrane also extends between the limbs and to the tail. Bats are one of the largest orders of mammals, representing about 25% of all living species.

Suborder Megachiroptera

F. Pteropodidae

Examine the skull of an Old World fruit bat. Note the dog-like rostrum that inspired the other common name for these bats, "flying foxes." The long rostrum, with its large orbits, is a primitive feature for these crepuscular bats, which cannot echolocate (with one exception) and which rely on vision. All bats retain a claw on the thumb, but megabats also have a claw on digit II; this is another primitive feature. The teeth of pteropodids, on the other hand, are derived. Note the simple cheek teeth with more or less flat surfaces. Articulate the lower jaw with the skull; note that the teeth do not actually occlude. These teeth are specialized for pulping fruit. The bats squish the fruit between their teeth and swallow the juice; the pulp is spit out. (Never stand below a fruit bat roost without covering your head!) One specialized subfamily of pteropodids feeds on nectar.

Suborder Microchiroptera

By far, most bats are in this suborder, and they are often referred to as microbats. They are generally much smaller than megabats. Their skulls are quite derived, with very short faces modified for echolocation. Many microbats have lost their incisors, which would interfere with pulses generated through the mouth, whereas others emit pulses through the nose and have elaborate facial features that focus the pulses. Microbats are also derived in that they lack a claw on digit II. The teeth of microbats are dilambdodont and are considered to be primitive. Many microbats are insectivorous, but there are microbats that feed on other things, including fruit, fish, frogs, nectar, and blood.

F. Vespertilionidae

All of New Jersey's bats belong to this generally insectivorous family of north temperate regions, the evening bats. New Jersey is home to a number of species, but only two are available for today's lab.

Local species: *Eptesicus fuscus*, big brown bat
Local species: *Lasiurus borealis*, red bat

Order Carnivora

F. Canidae

Examine the skulls of various canids in lab. Domestic dogs (*Canis familiaris*) are thought to be derived from gray wolves (*Canis lupus*). Compare the skulls of a gray wolf and a dog. Note the prominent "brow" of the dog, a feature that distinguishes dogs and wolves. The skull of a red wolf, a rare species from North America, is also on display. Note also that the cheek teeth of canids are less specialized for carnivory than those of cats.

Three wild canids are found in New Jersey. Coyotes (*Canis latrans*) are the largest local wild canids. There are also two species of foxes.

Local species

Canis latrans	**coyote**
***Vulpes vulpes* (or *Vulpes fulva*)**	**red fox**
Urocyon cinereoargenteus	**gray fox**

Examine the skulls and illustrations of red and gray foxes in lab. These two species are readily distinguished by their coats, but their skulls are also distinguishable by the shape of the ridges forming the sagittal crest. Conveniently, the ridges in *Vulpes* look like a "V", whereas the ridges in *Urocyon* form a "U".

F. Ursidae

Bears are large omnivores found mainly in the Northern Hemisphere, the main exception being the spectacled bear of South America. Examine the skull of a black bear and note the bunodont cheek teeth.

Local species

Usrus americanus	**black bear**

F. Procyonidae

Procyonids include a number of New World species, but only the raccoon (*Procyon lotor*) is native to New Jersey. Examine the skull of a raccoon. Note the bunodont, quadritubercular molars.

Procyon lotor	**raccoon**

F. Mustelidae

Mustelids include a variety of smaller carnivorans with elongate bodies. New Jersey is home to several mustelid species, but only three are represented in lab.

Local species

Mustela vison	**mink**
Mephitis mephitis	**skunk**
Lutra canadensis	river otter

Note the reduced molars of the mink compared to the skunk, and the sharp shearing blades formed by the minks teeth.

We also have a skull of a European badger (*Meles meles*). Compare that with the other mustelids. Note that, like other mustelids, the badger retains only one molar on each side, but this molar has become elongated and bunodont to deal with the omnivorous diet of this animal.

F. Felidae

A number of cats are represented in today's lab, although none are local species. Cats all have similar short-faced skulls with highly carnivorous dental adaptations.

F. Hyaenidae

Hyenas include three genera of animals specialized for crushing bones and hypercarnivory. However, the one hyena represented in lab is the fourth genus, *Proteles*, the aardwolf, which specializes in eating termites.

F. Viverridae

Viverrids are known only from Eurasia and Africa but are similar to mustelids in being smaller carnivorans. Two examples of viverrids are given in lab, a binturong (*Paradoxurus*) and a palm civet (*Nandinia*).

Lagomorphs and Rodents I

The two orders examined in this lab, rodents and lagomorphs, are at least superficially similar and probably related. Both of these groups have distinctive, enlarged, ever-growing incisors, which are referred to as gliriform. Only the anterior aspect of the incisors is covered by enamel; the effect is that the incisors are self-sharpening.

O. Lagomorpha

There are two families of living lagomorphs, one of which is represented in today's lab. Lagomorphs look superficially like rodents, but they can be distinguished by the presence of a small second pair of upper incisors behind the large gliriform pair. Lagomorphs are also distinguished by the possession of a fenestrated skull, where parts of the skull have a thin, lattice-like appearance. All lagomorphs have hypsodont teeth with no roots.

F. Leporidae

Leporids include rabbits and hares. Examine the skulls of various leporids to observe the diagnostic features of lagomorphs. Leporids are unique among mammals in possessing a joint within the skull, encircling the skull just in front of the ear region. The slight movements allowed by this joint are thought to help absorb the shock produced by the bounding gait of leporids.

Local species: ***Sylvilagus floridanus*** **Eastern cottontail**

New Jersey is actually home to a number of leporids, including two different genera, but the Eastern cottontail is the only one represented by material in this lab.

O. Rodentia

Rodents are the most diverse order of mammals. Rodents account for 40% of mammalian diversity, and 25% of mammalian diversity is found in one family, the Muridae. Rodents possess only a single pair of gliriform incisors in the upper and lower jaws. Notice the orientation of the glenoid fossa on the skulls of various rodents. The jaw articulation is designed to allow propalinal (fore and aft) movement of the jaw, a distinctive feature of rodents.

Rodents have traditionally been identified and classified according to the arrangement of their jaw muscles, which is reflected by distinctive morphologies of the skull and jaw. Four types of rodent skulls can be identified:

Protrogomorphous: This represents the primitive condition, where the muscles have not expanded significantly from the positions found in other mammals. None of the rodents in this lab are protrogomorphous, and only one living species of rodent is protrogomorphous.

Sciuromorphous: The lateral portion of the masseter in this condition expands onto the anterior aspect of the zygomatic arch, which is expanded into a flattened plate. Examine a beaver skull to see a good example of sciuromorphy.

Hystricomorphous: In this condition, another portion of the masseter, the medial masseter, expands and actually passes through an enlarged infraorbital foramen. Good examples of this condition can be observed in the skulls of the porcupine and the nutria.

Myomorphous: This condition appears to combine the previous two. The result is a flattened anterior aspect of the zygomatic arch, with a somewhat enlarged, keyhole-shaped infraorbital foramen. A good example of this condition can be seen in the muskrat.

There is little agreement as to how these conditions evolved and how often. Only myomorphy is considered to be a derived feature characteristic of a monophyletic group. The other types may have evolved more than once, and different groups that have similar skull morphologies may not in fact be closely related.

Another feature that is used to distinguish groups of rodents is the morphology of the jaw. Two conditions are observed, **sciurognathy** and **hystricognathy**. In hystricognathy, the angular process is in a more lateral position relative to the alveoli of the incisors. Use the diagram in your book (Figure 18-3) to figure out the distinction between these two morphologies. Hystricognathy is considered to be a shared derived condition, whereas sciurognathy is primitive.

For today's lab, we'll cover the families of sciuromorphous and hystricomorphous rodents; next week we'll look at myomorphous families and all of the local species of rodents.

F. Aplodontidae

Mountain beavers are found in the Pacific Northwest. They are the only living protrogomorphous rodents, and some have argued that they have reverted to this condition from one of the others. They have distinctive peg-like teeth and broad, flat skulls.

F. Sciuridae

Sciurids include tree squirrels, ground squirrels, chipmunks, and marmots. Examine the representative sciurids and note their sciuromorphous and sciurognathous morphology. Note the dental formula; at least one premolar is present in the upper and lower jaws. The teeth are relatively low-crowned.

F. Castoridae

Beavers are one of the largest rodents in body size. Examine the sciuromorphous and sciurognathous skull of a beaver. Note the presence of a single premolar in the upper and lower jaws and the high-crowned, lophodont cheek teeth.

F. Geomyidae

Pocket gophers are subterranean burrowers. Many burrowing rodents, including geomyids, actually rely on their incisors for digging, rather than on their limbs. Geomyids are sciuromorphous and sciurognathous. Geomyids have hypsodont cheek teeth, with three simple cylindrical molars and a large 8-shaped premolar in each half of the upper and lower jaw.

F. Heteromyidae

Pocket gophers are thought to be closely related to heteromyids, the kangaroo rats and pocket mice. Kangaroo rats have saltatorial or ricochetal locomotion, i.e., they jump around on their hind legs, not unlike their marsupial namesake. Both heteromyids and geomyids possess fur-lined cheek pouches, as well as being similar in having sciuromorphous skulls, sciurognathous jaws, and fairly simple hypsodont cheek teeth. Examine the teeth of the kangaroo rat and the pocket mouse. Note the more complex, two-lobed molars of the pocket mouse compared to those of the kangaroo rat. Note also the enlarged auditory bullae of the kangaroo rat.

F. Dipodidae

We have only a skin of a dipodid, that of a jumping mouse. Dipodids, including jumping mice, jerboas, and birch mice, include a number of saltatorial forms, convergent on the similar heteromyids. Dipodids, however, are not closely related to heteromyids. Dipodids are hystricomorphous and sciurognathous.

Suborder Hystricognathi

Two families of hystricognathous rodents are represented in lab. Hystricognathous rodents comprise their own suborder, the Hystricognathi. All hystricognaths are also hystricomorphous.

F. Erithizontidae

New World porcupines are included in this family, including our own local species. Note the relatively low-crowned lophodont cheek teeth, including one upper and lower premolar.

F. Myocastoridae

The nutria is also a local species, but it was introduced to this area accidentally by humans who wanted to raise nutrias for their fur. Nutrias are superficially beaver-like, although they have laterally compressed tails, instead of horizontally flattened tails. Note the high-crowned lophodont cheek teeth and compare them to those of the beaver. Examine the jaw of a nutria and note the near absence of the coronoid process.

F. Hydrochaeridae

The capybara is the world's largest rodent, with the largest weighing in around 175 lbs. They are ecologically equivalent to small hippos, grazing on land, swimming in the water, and living in large groups. Note the extremely lophodont cheek teeth.

Rodents II

Today's lab covers the murids and all of the local species of rodents that you need to know.

F. Sciuridae

Local species:	***Sciurus carolinensis***	**eastern gray squirrel**
	Tamiasciurus hudsonicus	**red squirrel**
	Tamias striatus	**eastern chipmunk**
	Marmota monax	**woodchuck**
	Glaucomys volans	**southern flying squirrel**
	Glaucomys sabrinus	**northern flying squirrel**

F. Castoridae

Local species:	***Castor canadensis***	**beaver**

F. Dipodidae

Local species:	***Napaeozapus insignis***	**woodland jumping mouse**

F. Erithizontidae

Local species:	***Erethizon dorsatum***	**porcupine**

F. Myocastoridae

Local species:	***Myocastor coypus***	**nutria (introduced)**

F. Muridae

Murids are the most diverse family of mammals, including the various mice, rats, and voles. All murids are myomorphous. Use the key included for Massachusetts "mice" to identify different local species of murids.

Local species:	***Peromyscus leucopus***	**white-footed mouse**
	Synaptomys cooperi	**southern bog lemming**
	Microtus pennsylvanicus	**meadow vole**
	Microtus (Pitymys) pinetorum	**pine vole**
	Clethrionomys gapperi	**red-backed vole**
	Ondatra zibethica	**muskrat**
	Rattus norwegicus	**Norway rat**
	Neotoma floridanus	**Eastern woodrat**

O. Artiodactyla

Artiodactyls are "even-toed" ungulates (hoofed mammals). Their feet are paraxonic; this means that the axis of the foot runs between digits 3 and 4. Artiodactyls have a distinctive astragalus with a double-pulley form. Examine the astragalus of a fossil artiodactyl that we have on display. Artiodactyls have other diagnostic features, including absence of an alisphenoid canal.

F. Suidae and F. Tayassuidae

Suids are pigs. Pigs have bunodont teeth and are omnivorous. Tayassuids, peccaries and javelinas, are similar to pigs in their morphology and habits. Note the large alveoli for the canines in the pig. The canines of pigs flare out laterally, whereas those of peccaries are straight. Note the canines of the juvenile peccary skull.

F. Cervidae

Cervids, deer and their relatives, are distinguished by the presence of antlers, usually in males but sometimes in both sexes. Antlers differ from other skull ornaments in that they are formed from bone initially covered by velvet and are shed annually. Examine the skull and antlers of a deer and a moose. Note the selenodont dentition. Note also the depression in the area of the lacrimal bone, where a scent gland is located.

Local species: ***Odocoileus virginianus*** **whitetail deer**

F. Antilocapridae

Pronghorns, or pronghorn "antelope", are distinguished by the presence of a pronghorn head ornament, which consists of a bony core covered by a keratinous sheath that is shed annually. Once a very diverse family in North America, antilocaprids are represented today by a single species found in the prairies of western North America. This animal is also one of the fastest mammals on earth.

F. Bovidae

Bovids are the most diverse family of artiodactyls, including cattle, sheep, goats, and antelopes. (Note: This does not include the pronghorn "antelope" of western North America.) Horns are a diagnostic feature of bovids; they can be present in one or both sexes. Horns consist of a bony core covered by a horny (keratinous) sheath. Examine the skull of a bull or cow. Note the horn cores and examine the sheath. Note the selenodont dentition.

O. Cetacea

Cetaceans include whales and dolphins, mammals highly adapted to aquatic life. We won't go into families of cetaceans here. Examine the skull of a Risso's dolphin. See if you can

identify the skull bones. The nostrils are placed on top of the head, so that the surrounding bones are modified in a manner called telescoping. Examine the forelimb of the dolphin (hindlimbs are absent in living cetaceans). Note the paddle-like form and identify the bones. Note that cetaceans have hyperphalangy, the increase in number of the phalanges. Examine the vertebrae of the dolphin and note how simple they are in form relative to terrestrial mammals.

O. Perissodactyla

Perissodactyls are the "odd-toed" hoofed mammals, including horses, rhinoceroses, and tapirs. The axis of the foot runs through the middle (third) digit of the feet. Perissodactyls also have a diagnostic astragalus, with a saddle-shaped facet for the navicular bone. Examine the fossil astragalus of a perissodactyl on display.

F. Equidae

Equids include horses and zebras. The feet of horses are largely composed of a single digit (digit 3), with vestiges of the second and fourth digits. Horses have hypsodont, lophodont teeth. Examine the skull of a horse.

F. Rhinocerotidae

Rhinoceroses are distinguished by their horns, which are formed from keratin (essentially matted hair) and have no bony core. Rhinoceros teeth have distinctive "pi" shape to them. Examine the specimen of a fossil rhinoceros (actually a member of a different family, which had no horns) and note the shape of the teeth.

O. Hyracoidea

F. Procaviidae

Hyraxes (or hyraces) are a group of rabbit-sized mammals thought to be related to either perissodactyls or elephants. Examine the skull of a hyrax. Note the "pi" shaped teeth, convergent with those of rhinoceroses. Note the supraorbital process, which is formed partly by the parietal bone, a distinctive feature of hyraxes.

O. Proboscidea

F. Elephantidae

Elephants have many distinctive features related to their size and their trunks. Examine the jaw of a baby mammoth (a fossil). Note the lophodont teeth with many lophs. The reddish material on the outside of the tooth is cementum, a substance that helps resist abrasion by grasses that the animal ate in life. Mammoths and Asian elephants are very similar. Note that only one

tooth is functional in each half of the jaw. As one tooth wears out, the next comes in behind and the old one is pushed forward.