

**Standards-Based Module
(Lesson/Unit Plan)**

Cover Page

Content Area: Life Science

Grade Level: 6, 7, or 8

Title of Lesson/Unit: Mammal Teeth and Skulls - Adaptations and Identification

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**Standards-Based Module
(Lesson/Unit Plan)**

Content Area(s): Life Science

Grade Level: 6, 7, or 8

Time to Complete: (3-4) 50 minute class periods

Title of Lesson/Unit: Mammal Teeth and Skulls - Adaptations and Identification

1. South Carolina State Standards Addressed

Grade 6

The student will demonstrate an understanding of technological design and scientific inquiry, including process skills, mathematical thinking, controlled investigative design and analysis, and problem solving.

6-1.1 Use appropriate tools and instruments (including a spring scale, beam balance, barometer, and sling psychrometer) safely and accurately when conducting a controlled scientific investigation.

6-1.2 Differentiate between observation and inference during the analysis and interpretation of data.

6-1.3 Classify organisms, objects, and materials according to their physical characteristics by using a dichotomous key.

The student will demonstrate an understanding of structures, processes, and responses of animals that allow them to survive and reproduce. (Life Science)

6-3.1 Compare the characteristic structures of invertebrate animals (including sponges, segmented worms, echinoderms, mollusks, and arthropods) and vertebrate animals (fish, amphibians, reptiles, birds, and mammals).

6-3.2 Summarize the basic functions of the structures of animals that allow them to defend themselves, to move, and to obtain resources.

6-3.4 Explain how environmental stimuli cause physical responses in animals (including shedding, blinking, shivering, sweating, panting, and food gathering).

6-3.5 Illustrate animal behavioral responses (including hibernation, migration, defense, and courtship) to environmental stimuli.

Grade 7

The student will demonstrate an understanding of technological design and scientific inquiry, including process skills, mathematical thinking, controlled investigative design and analysis, and problem solving.

7-1.1 Use appropriate tools and instruments (including a microscope) safely and accurately when conducting a controlled scientific investigation.

Grade 8

The student will demonstrate an understanding of technological design and scientific inquiry, including process skills, mathematical thinking, controlled investigative design and analysis, and problem solving.

8-1.4 Generate questions for further study on the basis of prior investigations.

8-1.6 Use appropriate tools and instruments (including convex lenses, plane mirrors, color filters, prisms, and slinky springs) safely and accurately when conducting a controlled scientific investigation.

The student will demonstrate an understanding of Earth's biological diversity over time. (Life Science, Earth Science)

8-2.1 Explain how biological adaptations of populations enhance their survival in a particular environment.

8-2.2 Summarize how scientists study Earth's past environment and diverse life-forms by examining different types of fossils (including molds, casts, petrified fossils, preserved and carbonized remains of plants and animals, and trace fossils).

8-2.7 Summarize the factors, both natural and man-made, that can contribute to the extinction of a species.

2. Lesson/Unit Description:

Students will be introduced to the differentiation of teeth and skull adaptations in mammals in general and 14 common terrestrial mammals (found in South Carolina) in particular. They will then learn more about these mammals, their natural history, their adaptations, and their identification through an interactive CD, completing student worksheet #1 as they go. The students will also be given a case of 14 mammal skulls (provided in the SC LIFE Natural History Equipment Footlocker) in which they will: make inferences about the animal's natural history based on the skull and tooth characteristics they learned about from the lesson and then identify the skull using a dichotomous key (using student worksheets #2 and #3).

3. Focus Question(s) for Students:

1. What are the different types of mammalian teeth and how can you tell them apart?
2. What can the shape of the teeth tell us about the natural history of that mammal?
3. What skull features can be seen that indicate specific adaptations and what can those adaptations tell us about the natural history of that mammal?
4. How do you use a dichotomous key?

4. Culminating Assessment:

1. Show pictures of various mammal skulls and discuss tooth types, tooth formulas, and what the teeth can infer about the animal's natural history (refer to presentation).
2. As you show the presentation, discuss what characteristics of the skull might indicate something about that animal's natural history (carnivore or herbivore, predator or prey, specialized for jumping, specialized for swimming, specialized for echolocation, etc.).
3. Discuss the tooth types (and their indications of that animal's natural history), skull features (and their indications of that animal's natural history), and identifying skull characteristics for 14 common terrestrial mammals found in South Carolina (refer to presentation).
4. Computer lab: reinforce what was discussed in class by using the SC LIFE Interactive CD Series: Natural History and Identification of Fourteen Common Terrestrial Mammals Found in South Carolina and complete student handout #1.
5. Let the students handle the skulls, being very careful with them (especially the bat and mouse skulls) so that they can see, touch, and measure the skull features for themselves. Have them complete student handout #2 using student handout #3.

Student Directions for Assessment:

1. Infer part of the mammals natural history (in general and the 14 common mammals in particular) based on physical characteristics of the teeth and skulls shown in the presentation. Discuss this as a class.
2. Complete student handout #1 using the interactive mammal CD during computer lab.
3. Using the skulls provided, investigate them for the adaptations discussed in class, and using the dichotomous key (student handout #3), complete student handout #2.

5. Materials/Equipment/Resources:

Per Class:

Natural History and Identification of Fourteen Common Terrestrial Mammals Found in South Carolina (*in SC LIFE equipment footlocker or available through the website www.clemson.edu/SCLIFE*)

Other mammal field guides (*see Additional Resources section*)

Set of mammal skulls (*in SC LIFE equipment footlocker*)

beaver, bobcat, eastern cottontail, eastern mole, short-tailed shrew, deer mouse, eastern gray squirrel, gray fox, little brown bat, mink, muskrat, opossum, raccoon, and striped skunk

****Deer mouse, shrew, mole, and bat skulls are very fragile; Handle carefully****

SC LIFE Interactive CD Series: Natural History and Identification of Fourteen Common Terrestrial Mammals Found in South Carolina (*in SC LIFE equipment footlocker or contact SC LIFE at www.clemson.edu/SCLIFE to order a copy*)

(you can copy the entire contents of the CD onto multiple PCs and run the program from there – no special computer programs are required to run this CD)

Per Student:

Student handout #1

Student handout #2

Student handout #3

6. Teacher Preparation:

1. Read Background Information and be prepared to discuss skull and tooth structures of mammals and the inferences that can be made about the animals natural history based on these tooth and skull structures.
2. Make sure PowerPoint presentation is ready and make copies of the student handouts.
3. Prepare and obtain materials/equipment (refer to teacher supplement if needed).
4. Copy the interactive mammal CD program onto all the PCs that students will use in the computer lab. You may need someone with administrator privileges for this.

Background Information

1. True Teeth
 - A. First arose in at least two lines of extinct fishes
 - B. True teeth are suspected to have arisen in the line of fish that led to the sharks and bony fish living today.
 - i. Mammals have the same kind of teeth that fish do, but mammalian teeth are more evolved and specialized.
 - a. Mammalian teeth and fish teeth are examples of **homologous characters**. These are characteristics that have the same developmental origins, but appear to be different.

- b. Another example of homologous characters is a human hand and a whale flipper. Although they look very different at first glance, they both have the same bones, and they both evolved from the same basic tetrapod limb plan.
 - C. True teeth have also recently been shown to have evolved in a separate line of fish, the placoderms. These fish that have since gone extinct and have no living relatives.
 - i. The placoderms are found in the fossil record from the Silurian to the early Devonian periods during the Paleozoic era, 465mya-420mya.
 - ii. These fish had lots of hard, bony plates covering their body; which served as armor.
 - iii. The evolution of teeth in placoderms is an example of convergent evolution.
 - a. **Convergent evolution** is observed when two unrelated animals independently develop similarities of form or structures, usually in response to the same environmental pressures. The characteristics that are the result of convergent evolution are called **analogous characters**.
 - b. Another example of analogous characters is a bird wing and an insect wing. Both are used to fly but they have entirely different developmental origins and are unrelated except for the fact that they are both in the animal kingdom.
2. Teeth have evolved from simple to complex, and in some cases back to simple again.
- A. **Homodont dentition** is typical of most fish, amphibians, and reptiles. Homodont dentition is the condition of having teeth of the same shape and size throughout the mouth. These animals use teeth mainly to capture food and move it to the back of the mouth for swallowing.
 - B. Most mammals have **heterodont dentition**. Heterodont dentition is the condition of having teeth of varying shapes, sizes, and functions. Their teeth are specialized to do different things like chew, grasp, and many other functions (some not even related to eating).
3. There are four kinds of teeth that all mammals have.
- A. The **incisors** are the flat front teeth used for cutting or nipping something off.
 - B. **Canines** are the sharp, pointed “fangs.” They are next to the incisors and are used to pierce and tear meat.
 - C. **Premolars** are located between the molars and the canines and they have characteristics of both types of teeth. Premolars usually have 2 cusps (unless they have adapted over time for a specific purpose). These teeth can be sharp enough to cut and yet broad and flat enough to act as a grinding surface.
 - D. **Molars** come after the premolars. They are usually flat and wide, usually with 3 to 5 cusps (again unless they have adapted over time for a specific purpose), and are used for grinding food. Unlike incisors, canines, and premolars, mammals do not replace their molars. These grow into place only once, like wisdom teeth or twelve year molars in humans.
 - E. It is very difficult sometimes to distinguish the premolar from the molar in an unfamiliar mammal skull. As a result, premolars and molars are often referred to collectively as cheek teeth.

4. Teeth are very useful for identifying mammals, and they can give us clues about the natural history and diet of the animal. Different kinds of mammals have different numbers and shapes of teeth.
 - A. Scientists use **tooth formulas** to identify the number of each kind of tooth and the total number of teeth in the jaw. The formula gives the total number of each kind of teeth on the top and bottom of one side of the jaw.
 - B. Both sides of the jaw have an equal number of teeth, so if you multiply each number by two, that gives the total number of each kind of tooth.
 - C. For example, if the tooth formula was I (incisor) 3/3, C (canine) 1/1, P (premolar) 4/4, M (molar) 2/3, the animal would have six top incisors, six bottom incisors, two top canines, two bottom canines, eight top premolars, eight bottom premolars, four top molars and six bottom molars, and forty-two total teeth.
 - D. In student handout #3, the total number of teeth is emphasized first and the tooth formula is listed second, as the premolars and molars may not be readily distinguishable. Once you have the animal tentatively identified, you can double check your identification by first counting the number of molars beginning from the back. The remaining teeth located between the canines and the molars are going to be the premolars. If the molars and premolars cannot be differentiated, count them together as cheek teeth. If the total number of cheek teeth does not match your initial identification, try again.
 - E. Also, if some teeth have fallen out on one side, remember that the other side is a mirror image.
 - F. Inferences can be made about the natural history of a mammal from their teeth
 - i. The presence of canines indicates that this animal may be a **carnivore** (meat eater) or **omnivore** (eats meat and plants). The absence of canines indicates that this animal may be an **herbivore** (plant eater).
 - ii. In the presence of canines...
 - a. Some animals that have canines may also have small, not well developed, molars which indicates that this animal is a more of a carnivore than an omnivore and does not spend much time chewing plants.
 - b. Some animals that have canines may also have premolars that are an intermediate between canines with some cusps for cutting, yet still has a somewhat flat surface for grinding like the molar which indicates that this animal may be more of an omnivore than a carnivore. If, however, the molars and premolars are not flat for grinding plants, but have really pointed cusps, this indicates that the animal may specialize in eating insects (**insectivore**) or is perhaps a primitive mammal.
 - c. Some animals that have canines may also have their last upper premolar and the first lower molar quite sharp and prominent. When these teeth come together as the jaw closes, they are able to cut flesh effectively, like a pair of scissors. This is called **carnassial dentition** and indicates that they are a carnivore (in fact, those with carnassial dentition are found in the order Carnivora). In those animals that have canines, but these same teeth are more rounded and not as prominent, the indication is that they are more of an omnivore.

- iii. In the absence of canines...
 - a. Premolars that are indistinguishable from molars, with large flat grinding surfaces, and the absence of canines, indicate that this animal may be an herbivore.
- 5. Most mammals have teeth that are recognizable; they look at least somewhat like human teeth. Some mammals, however, have very extreme adaptations to their teeth.
 - A. For example, the tusks of an elephant are actually its incisors. These are used in fighting for mates, digging up plant roots, and prying bark from trees.
 - B. Animals in the order Xenarthra (sloths, anteaters, armadillos, etc.) have very few teeth, and those in the anteater family don't have any teeth at all. They use small rocks that get inadvertently picked up by their long sticky tongues to help grind up the ants and termites that they eat.
 - C. In some advanced mammals, homodont dentition has evolved secondarily to fit the environment.
 - i. Dolphins and other toothed whales now have homodont dentition; their teeth are all conically shaped. The shape of these teeth helps them to quickly catch and maneuver fish in the water; they have no need to chew their food, so their molars are not shaped in a flat, grinding surface.
 - a. Although the teeth come from the same developmental sequences as humans, dolphins have adapted to their environment in the water by evolving homodont dentition, secondarily.
 - b. Some members of Edentata (armadillos) also have very peg-like teeth. They usually have only premolars and molars which are all the same shape and used to grind up insects.
 - D. Many primates have teeth that are shaped the way they are for social reasons.
 - i. The lemurs of Madagascar have tiny lower incisors that are shaped like a comb. They use these teeth to groom each other.
 - ii. Gorillas, which are herbivores, have huge canines! These are used to scare away other gorillas, potential predators, or invaders.
- 6. Mammal skulls have made many changes during their evolution.
 - A. They are set apart from reptile skulls because of their jaw articulation (reptile jaw articulation is quadro-articular, and mammal articulation is dentary-squamosal)
 - i. In mammals, the quadrate and articular have migrated inward and changed size to form the inner ear bones, the incus and the malleus, respectively (see PowerPoint illustration).
 - B. The earliest mammals and mammal-like reptiles had general teeth and skull patterns; they were all very small and probably mainly insectivores and scavengers.
 - C. As the first true mammals began to radiate into different niches, their bodies (and skulls) changed shape to adapt to their environment.
- 7. Mammal skulls are very helpful in identifying the animal and can give useful information about the natural history of the animal. This is true especially for paleontologists when trying to learn about dinosaurs, and who often only have bones and/or impressions of bones to work with.

- A. Many mammal skulls may look similar, but the few distinctive characteristics they exhibit may allow us to identify them to order, family, genus, or sometimes even species level.
- i. For instance, the rabbit skull is filled with holes; it looks like a bony web which is called **amplified fenestration**. This makes the skull lighter, so the rabbit can hop more easily and move quicker. Rabbits and hares (members of the Order Lagomorpha) have this bony webbing.
 - ii. Also, antlers and horns are found in many hoofed mammals (ungulates – order Artiodactyla, even-toed and order Perissodactyla, odd-toed) and are important in mating (antlers fall off and grow back every year, and horns are permanent bony extensions—whitetail deer have antlers, goats have horns)
 - a. Males use them to fight for territories
 - b. Females often prefer males with larger horns or antlers
 - iii. There are two suborders of bats: Megachiroptera and Microchiroptera.
 - a. The microchiropterans have a “U” shaped notch on their maxillary bone (the bone of the upper jaw) called an **intermaxillary notch**. This provides less resistance to the sound waves coming and going in **echolocation** (when animals use sound waves bouncing off objects in their surroundings to navigate, find food, or perceive their surroundings).
 - b. The majority of the Megachiropterans (fruit bats and flying foxes) do not have this intermaxillary notch; they do not use sound waves to hunt or navigate.
- B. Many distinctive characteristics also have adaptive functions that allow us to infer things about the animal’s natural history.
- i. For example, the position of the **orbits** (the hole where the eyes are) gives an indication of whether a mammal has good depth perception or a wide range of vision.
 - a. Orbits located on the front of the skull indicate that the eyes are forward facing. This allows for better depth perception. In many tree dwelling primates, the orbits are on the front of the skull which is an important feature to have when you are arboreal and trying to jump from branch to branch.
 - b. Good depth perception would also be helpful if you are a predator tracking your prey.
 - c. Orbits located on the side of the head indicate that the eyes are located laterally. This allows for enhanced **peripheral vision** (vision that allows the animal to see “out of the corner of its eyes”). This is important for many mammals that need to be aware of possible danger in their surroundings, including becoming prey.
 - ii. The location of the joint where the lower jaw rests against the skull will give an indication of how the teeth meet.
 - a. If the jaw joint is in line with the height of the teeth on the lower jaw, the teeth will come together back to front, like a pair of scissors, with the molars meeting first and the incisors meeting last, when the animal chews which allows the teeth to cut and shear meat. This indicates that the animal may be a carnivore or omnivore.

- b. If the jaw joint is higher than the height of the teeth on the lower jaw, the teeth will come together at the same time when the animal chews. This indicates that the animal may be an herbivore.
 - iii. Many mammals have an enlarged **saggital crest**. This is represented by a ridge that runs the length of the top of the skull. It is a region where one of the jaw closing muscles (the temporalis) attach; if there is more room for attachment, the animal will have a stronger bite.
 - iv. Mammals may also have an enlarged **nuchal crest**. This is represented by ridge that runs across the back of the top of the skull and is where the neck muscles attach to the cranium. A crest provides more surface area for the muscles to attach therefore stabilizing and supporting the head.
 - a. For example, many carnivores need additional support for their head in order to counteract the thrashing movements of their prey during capture.
 - b. Also, animals that carry or move heavy objects with their jaws need additional support for the head.
 - c. In addition, mammals that have a heavy skull (i.e. horses, hogs, and cows) must also have strong neck muscles to support that skull.
 - v. Elongated snouts in mammals also have a couple of adaptive benefits.
 - a. A long, wide snout can provide more room for organs related to smell.
 - b. A long, narrow snout may allow the animal to reach into crevices to get its prey.
 - vi. The size of the **auditory bullae** (the part of the skull that surrounds the bones of the inner ear) often indicates how well an animal can hear.
 - a. If auditory bullae are rotund, looking like a small inflated balloon, there is extra space surrounding the ear bones which acts like a reverberating chamber—it makes the sound louder. Therefore, those animals with rotund auditory bullae may have better hearing.
 - b. If the auditory bullae are not rotund, then they do not have that extra space surrounding their ear bones, which indicates that they may not hear as well.
8. Animals in the Natural History Equipment Footlocker and their skull/teeth characteristics
- A. Virginia Opossum
- i. Scientific name: *Didelphis virginiana*, found in the order Marsupialia, family Didelphidae
 - ii. Skull
 - a. The skull measures 79-127mm in length (3.125-5in), and 57-69mm (2.25-2.75in) in width. (Skull is measured at its widest and longest points, see Teacher Supplement for more information).
 - b. The orbits are somewhat forward facing indicating that this animal is probably a predator or maybe is arboreal.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. The large saggital crest indicates a strong bite.
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue

- struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. It has an elongated rostrum (snout) indicating that this animal either has an enhanced sense of smell or that it can get into tiny crevices looking for its prey.
 - g. The auditory bullae are quite small and not remotely rotund, indicating that opossums probably do not hear well.
 - iii. Teeth
 - a. The opossum has 50 teeth.
 - b. The tooth formula is: incisors 5/4, canines 1/1, premolars 3/3, and molars 4/4 = 50.
 - c. The presence of canines indicates that this animal is probably a carnivore or an omnivore
 - d. Its premolars are distinguishable from the molars, however, the molars and premolars are not flat for grinding plants, but instead have really pointed cusps, that indicates that the animal either is either an insectivore or perhaps is a primitive mammal.
 - e. The opossum has the most teeth out of any mammal in North America.
 - This is considered to be a primitive characteristic
- B. Eastern Mole
 - i. Scientific name: *Scalopus aquaticus*, found in the order Insectivora, family Talpidae
 - ii. Skull
 - a. The skull of the eastern mole measures from 28-38mm (1.125-1.5in) in length, and is approximately 19mm (0.75in) wide.
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. There is not an enlarged saggital crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. It has an elongated rostrum (snout) indicating that this animal either has an enhanced sense of smell or that it can get into tiny crevices looking for its prey.
 - g. The auditory bullae are slightly rotund, indicating that moles probably hear well.
 - h. The hard palate of the mole extends beyond the last upper molar.
 - iii. Teeth
 - a. The eastern mole has 36 teeth.
 - b. The tooth formula is: incisors 3/2, canines 1/0, premolars 3/3, and molars 3/3 = 36.

- c. The presence of canines indicates that this animal is probably a carnivore or an omnivore
 - d. Its premolars are distinguishable from the molars, however, the molars and premolars are not flat for grinding plants, but instead have really pointed cusps, that indicates that the animal either is either an insectivore or perhaps is a primitive mammal.
 - e. The first incisors of the mole are very large and recurved which may help them grasp food items.
- C. Short-tailed Shrew
- i. Scientific name: *Blarina brevicauda*, found in the order Insectivora, family Soricidae
 - ii. Skull
 - a. The skull of the short-tailed shrew measures approximately 19-25mm in length (0.75-1in) and 12mm in width (0.5in).
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that it is probably a carnivore or omnivore.
 - d. There is not an enlarged sagittal crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. It has an elongated rostrum (snout) indicating that this animal either has an enhanced sense of smell or that it can get into tiny crevices looking for its prey.
 - g. The auditory bullae are not rotund, instead there is a ring like bone surrounding the inner ear. This is common to all shrews.
 - h. There is no zygomatic arch.
 - iii. Teeth
 - a. The short-tailed shrew has 32 teeth.
 - b. Because of the lack of specialization of the teeth, the shrew's tooth formula is given in two ways, depending on how the teeth are designated: incisors 3/1, canines 1/1, premolars 3/1, and molars 3/3 = 32 or incisors 4/2, canines 1/0, premolars 2/1, molars 3/3 = 32.
 - c. The presence of canines indicates that this animal is probably a carnivore or an omnivore
 - d. Its premolars are somewhat distinguishable from the molars, however, the molars and premolars are not flat for grinding plants, but instead have really pointed cusps, that indicates that the animal either is either an insectivore or perhaps is a primitive mammal.
 - e. The tips of the shrew's teeth are pigmented. They appear to be brown, or burnt orange.
 - f. The two larger upper molars have an obvious "W" pattern.

- g. Salivary glands in the mouth located between the bases of the lower incisors contain a poison that flows with the saliva and enters an animal when it is bitten by a shrew.
 - This poison slows the heart and breathing (neurotoxin) and may cause disintegration of muscle.
 - These glands contain enough poison to kill 200 mice
 - The poison acts slowly which extends the time that fresh food is available

D. Little Brown Bat

- i. Scientific name: *Myotis lucifugus*, found in the order Chiroptera, family Vespertilionidae
- ii. Skull
 - a. The skull of the little brown bat measures approximately 15mm in length (0.625in) and 9mm in width (0.275in).
 - b. The orbits are located in the front of the skull indicating that this animal is probably a predator (as it is really not an arboreal species).
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. There is not an enlarged sagittal crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. The snout is not really elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - e. It is very hard to see, as the skull is so small, but the auditory bullae are slightly rotund, but look like they have a big hole in them. This opening is in fact the external ear opening.
 - f. There is a large notch in the snout of the little brown bat
 - When viewed from the front, the skull appears to have a hole in front
 - This hole helps with sound emission in **echolocation** (a process for locating distant or invisible objects (as prey) by means of sound waves reflected back to the emitter (the bat) by the target objects)
- iii. Teeth
 - a. The bat has 38 teeth.
 - b. The tooth formula is: incisors 2/3, canines 1/1, premolars 3/3, and molars 3/3 = 38.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. Its premolars are distinguishable from the molars, however, the molars and premolars are not flat for grinding plants, but instead have really pointed cusps, that indicates that the animal either is either an insectivore or perhaps is a primitive mammal.
 - e. The first two upper molars have a “W” shaped pattern

E. Eastern Cottontail

- i. Scientific name: *Sylvilagus floridanus*, found in the order Lagomorpha, family Leporidae
- ii. Skull
 - a. The skull is between 60-82mm (2.4-3.25in) in length and between 34-38mm (1.4-1.5in) in width.
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.
 - c. The jaw joint is higher than the height of the teeth of the lower jaw indicating that the animal may be an herbivore.
 - d. There is not an enlarged sagittal crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. The snout is not really elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
 - h. The skulls of all lagomorphs share a unique characteristic: **amplified fenestration**.
 - This means that there is a bony “web” of holes in different places throughout the skull. This gives the skull a porous or foamy appearance
 - The most prominent area of fenestration is anterior to the eye, in the snout
 - This bony web also makes the cottontail's skull light so that it can hop easier and even get away from predators faster.
- iii. Teeth
 - a. The cottontail rabbit has 28 teeth.
 - b. The tooth formula is: incisors 2/1, canines 0/0, premolars 3/2 and molars 3/3 = 28.
 - c. The absence of canines indicates that this animal is an herbivore. In fact, there is a large **diastema** (gap) between the incisors and the premolars where the canines should be.
 - d. The premolars are indistinguishable from molars, with large flat grinding surfaces, which indicate that this animal may be an herbivore.
 - e. The front of these incisors is coated with enamel (the hard material that human teeth are also made out of), but the back of these teeth is dentine.
 - Dentine is softer than enamel, so the back of the teeth are worn down more quickly than the front. This gives the incisors their chisel-like character, which helps the cottontail rabbit nip tough plant material

- f. Cottontails have a tiny pair of “supporter” or peg incisors directly behind the large front ones. These help brace the front incisors during cutting.
- F. Eastern Gray Squirrel
- i. Scientific name: *Sciurus carolinensis*, found in the order Rodentia, family Sciuridae
 - ii. Skull
 - a. The skull is between 60-63mm (2.375in-2.5in) long and 31-34mm (1.25-1.375in) wide.
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.
 - c. The jaw joint is higher than the height of the teeth of the lower jaw indicating that the animal may be an herbivore.
 - d. There is not an enlarged saggital crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. The snout is not really elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
 - iii. Teeth
 - a. The eastern gray squirrel has 22 teeth.
 - b. The tooth formula is: incisors 1/1, canines 0/0, premolars 2/1, and molars 3/3 = 22.
 - c. The absence of canines indicates that this animal is an herbivore. In fact, there is a large diastema between the incisors and the premolars where the canines should be.
 - d. The premolars are indistinguishable from molars, with large flat grinding surfaces, that indicate that this animal may be an herbivore.
 - e. The incisors are a dark orange color on the front, and they are **ever-growing**, meaning that they grow continuously.
 - If the squirrel does not gnaw on things like wood to wear its teeth down, they will grow through its skull! This is true of all rodents.
 - f. The front of these incisors is also coated with enamel (the hard material that human teeth are also made out of), but the back of these teeth is dentine, giving these teeth a chisel-like appearance.
- G. Beaver
- i. Scientific name: *Castor canadensis*, found in the order Rodentia, family Castoridae
 - ii. Skull
 - a. The skull is between 114-139mm (4.5-5.5in) in length and between 79-101mm (3.125-4.0in) in width.

- b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.
- c. The jaw joint is higher than the height of the teeth indicating that the animal may be an herbivore.
- d. There is not a very large sagittal crest which indicates that this animal does not have a very strong bite.
- e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
- f. The snout is not elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
- g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
- h. The front of the beaver skull is open, and a slit can be seen in the nasal area
 - This is the location of the muscular flaps that close the beaver's nose underwater

iii. Teeth

- a. The beaver has 20 teeth.
- b. The tooth formula is: incisors 1/1, canines 0/0, premolars 1/1, and molars 3/3 = 20
- c. The absence of canines indicates that this animal is an herbivore. In fact, there is a large diastema between the incisors and the premolars where the canines should be.
 - Beavers use this space to wrap their lips behind their incisors so that they can nip vegetation underwater.
- d. The premolars are indistinguishable from molars, with large flat grinding surfaces, that indicate that this animal may be an herbivore.
- e. The incisors are a dark orange color on the front, they are ever-growing, and they have a chisel-like character, which helps the beaver cut tough plant material

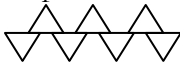
H. Deer mouse

- i. Scientific name: *Peromyscus maniculatus*, found in the order Rodentia, family Muridae
- ii. Skull
 - a. The deer mouse skull is tiny; its width is approximately 12mm (0.5in) and its length is between 22 and 25mm (0.875in).
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.

- c. The jaw joint is higher than the height of the teeth of the lower jaw indicating that the animal may be an herbivore.
 - d. There is not an enlarged saggital crest indicating that this animal probably does not have a strong bite.
 - e. There is no large nuchal crest which indicates that this animal is probably not a predator that uses its jaws to subdue struggling prey, or a mammal that carries heavy objects in its jaws, or has a heavy skull.
 - f. It has an elongated rostrum (snout) indicating that this animal either has an enhanced sense of smell or that it can get into tiny crevices looking for its prey.
 - g. It is very hard to see, as the skull is so small, but the auditory bullae are slightly rotund, but look like they have a big hole in them. This opening is in fact the external ear opening.
- iii. Teeth
- a. The deermouse has 16 teeth.
 - b. The tooth formula is: incisors 1/1, canines 0/0, premolars 0/0, and molars 3/3 = 16.
 - c. The absence of canines indicates that this animal is an herbivore. There is a large diastema between the incisors and the molars where the canines and the premolars should be.
 - d. The molars have large flat grinding surfaces that indicate that this animal may be an herbivore.
 - e. The incisors are a dark orange color on the front, they are ever-growing, and they have a chisel-like character.

I. Muskrat

- i. Scientific name: *Ondatra zibethicus*, found in the order Rodentia, family Muridae
- ii. Skull
 - a. The skull of the muskrat can be from 60-69mm in length (2.375-2.75in) and from 38-44mm in width (1.5-1.75in).
 - b. Orbits located on the side of the head indicate that the eyes are located laterally allowing for enhanced peripheral vision which is important for many mammals that need to be aware of the danger in their surroundings, including becoming prey of carnivores.
 - c. The jaw joint is higher than the height of the teeth indicating that the animal may be an herbivore.
 - d. There is not an enlarged saggital crest indicating that this animal probably does not have a strong bite.
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. The snout is not really elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.

- iii. Teeth
 - a. The muskrat has 16 teeth.
 - b. The tooth formula is: incisors 1/1, canines 0/0, premolars 0/0, and molars 3/3 = 16.
 - c. The absence of canines indicates that this animal is an herbivore. There is a large diastema between the incisors and the molars where the canines and the premolars should be.
 - d. The molars have large flat grinding surfaces that indicate that this animal may be an herbivore.
 - e. The incisors are a dark orange color on the front, they are ever-growing, and they have a chisel-like character.
 - f. The cheek teeth have a grinding surface pattern (called prismatic dentition) unique to the muskrat that looks like this 

J. Bobcat

- i. Scientific name: *Lynx rufus*, found in the order Carnivora, family Felidae
- ii. Skull
 - a. The skull varies between 101-139mm (4-5.5in) in length, and between 69 and 104mm (2.75-4.125in) in width.
 - b. The orbits are large and forward facing indicating that this animal is probably a predator or maybe is arboreal.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. The presence of a short saggital crest indicates a strong bite.
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. The snout is not elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
- iii. Teeth
 - a. The bobcat has 28 teeth.
 - b. The tooth formula is: incisors 3/3, canines 1/1, premolars 2/2, and molars 1/1 = 28.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. This animal has small, not well developed, molars which indicates that it is a more of a carnivore than an omnivore and does not spend much time chewing on plants.
 - e. The last upper premolar and the first lower molar are also quite sharp and prominent. When these teeth come together as the jaw closes, they are able to cut flesh effectively, like scissors. This is called **carnassial dentition** and indicates that they eat meat (those with carnassial dentition are found in the order Carnivora).

K. Gray Fox

- i. Scientific name: *Urocyon cinereoargenteus*, found in the order Carnivora, family Canidae
- ii. Skull
 - a. The skull measures between 120-130mm (4.75-5.125in) long, and is between 66-73mm (2.625-2.875in) wide.
 - b. The orbits are large and forward facing indicating that this animal is probably a predator or maybe is arboreal.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. The presence of a saggital crest indicates a strong bite (although the saggital crest is rather short).
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. It has an elongated rostrum (snout) indicating that this animal either has an enhanced sense of smell or that it can get into tiny crevices looking for its prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
 - h. A distinguishing skull characteristic is the “U” shaped temporal ridges not found in other canid skulls.
 - The red fox, a closely related species has more “V” shaped temporal ridges
- iii. Teeth
 - a. The gray fox has 42 teeth.
 - b. The tooth formula is: incisors 3/3, canines 1/1, premolars 4/4, and molars 2/3 = 42.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. This animal has premolars that are an intermediate between canines with some cusps for cutting, yet still has a somewhat flat surface for grinding like the molar which indicates that this animal may be more of an omnivore than a carnivore.
 - e. The last upper premolar and the first lower molar are also quite sharp and prominent, in an example of carnassial dentition and indicate that they eat meat.

L. Raccoon

- i. Scientific name: *Procyon lotor*, found in the order Carnivora, family Procyonidae
- ii. Skull
 - a. The raccoon skull measures 107-127mm in length (4.25-5in), and between 69-73mm (2.75-2.875in) wide.
 - b. The orbits are large and forward facing indicating that this animal is probably a predator or maybe is arboreal.

- c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. There is not an enlarged saggital crest indicating that this animal probably does not have a strong bite.
 - e. The somewhat large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. The snout is only slightly elongated indicating that this animal probably does not have a really enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are rotund indicating that this animal may have a good sense of hearing.
 - h. The bone that makes up the **hard palate** (the bones that make up the roof of the mouth) on the roof of the mouth extends past the last molars
- iii. Teeth
- a. The raccoon has 40 teeth.
 - b. The tooth formula is: incisors 3/3, canines 1/1, premolars 4/4, and molars 2/2 = 40.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. This animal has premolars that are an intermediate between canines with some cusps for cutting, yet still has a somewhat flat surface for grinding like the molar which indicates that this animal may be more of an omnivore than a carnivore.
 - e. The last upper premolar and the first lower molar are somewhat sharp and prominent, in an example of carnassial dentition and indicate that they eat meat.

M. Mink

- i. Scientific name: *Mustela vison*, found in the order Carnivora, family Mustelidae
- ii. Skull
 - a. The skull of the mink measures 60-69mm in length (2.275-2.75in) in males and 57-60mm (2.25-2.375in) in females. Male skulls are 31-38mm (1.25-1.5in) in width and females are 31mm (1.25in).
 - b. The orbits are large and forward facing indicating that this animal is probably a predator or maybe is arboreal.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. The presence of a large saggital crest indicates a strong bite.
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. The snout is not elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.

- g. The mink's skull has rotund, yet rectangular auditory bullae rotund indicating that this animal may have a good sense of hearing.
- h. The back of the skull is very flattened, a characteristic common to mustelids
- iii. Teeth
 - a. The mink has 34 teeth.
 - b. The tooth formula is: incisors 3/3, canines 1/1, premolars 3/3, and molars 1/2 = 34.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. This animal has small, not well developed, molars which indicates that it is a more of a carnivore than an omnivore and does not spend much time chewing on plants.
 - e. The last upper premolar and the first lower molar are also quite sharp and prominent, in an example of carnassial dentition and indicate that they eat meat.
 - f. Mink have a special "I" or dumbbell shaped molar
- N. Striped Skunk
 - i. Scientific name: *Mephitis mephitis*, found in the order Carnivora, family Mustelidae
 - ii. Skull
 - a. The skull of the striped skunk measures from 57-79mm (2.25-3.125in) in length, and between 38-50mm (1.5-2.0in) in width.
 - b. The orbits are large and forward facing indicating that this animal is probably a predator or maybe is arboreal.
 - c. The jaw joint is in line with the tops of the teeth of the lower jaw indicating that is probably a carnivore or omnivore.
 - d. The presence of a saggital crest indicates a strong bite.
 - e. The large nuchal crest indicates that this animal may be a predator that needs additional head stabilization while using its jaws to subdue struggling prey or an animal that carries heavy objects in its jaws or an animal with a heavy skull.
 - f. The snout is not elongated indicating that this animal probably does not have an enhanced sense of smell or that it doesn't need to get into tiny crevices looking for insects prey.
 - g. The auditory bullae are not very rotund indicating that this animal may not have very good hearing.
 - iii. Teeth
 - a. The skunk has 34 teeth.
 - b. The tooth formula is: incisors 3/3, canines 1/1, premolars 3/3, and molars 1/2 = 34.
 - c. The presence of canines indicates that this animal is probably a carnivore or omnivore.
 - d. This animal has premolars that are an intermediate between canines with some cusps for cutting, yet still has a somewhat flat surface for grinding like the molar which indicates that this animal may be more of an omnivore than a carnivore.

- e. The last upper premolar and the first lower molar are also quite sharp and prominent, in an example of carnassial dentition and indicate that they eat meat.
- f. The molars are large and square in shape.

7. Procedures:

1. Introduction to the Topic:
 - A. Use the PowerPoint presentation to introduce the diversity of and adaptations for teeth shape (incisors, canines, molars, and premolars) and skull features in general.
 - B. Use the PowerPoint presentation to introduce the students to 14 common terrestrial mammals found in South Carolina, their teeth shape, skull features, and other identifying characteristics.
2. Teacher Directed Discussion:
 - A. During the presentation, discuss what teeth and skull features can tell us about an animal's natural history. Have the students come up with other examples of mammal teeth and skull form and function.
 - B. Discuss the teeth, skull features, and other key identifying characteristics of the 14 mammals discussed in detail in the Background Information section. What do these features tell about the animal's natural history?
3. Equipment and Skills Demonstration:
 - A. Show the students how to use the interactive CD.
 - B. Show the students how to measure the length and width of the mammal skull.
 - C. Show the students how to use a dichotomous key.
4. Student Activity:
 - A. Use the interactive CD to complete handout #1.
 - B. While investigating the mammal skulls, complete handout #2 with the help of handout #3.

8. Differentiation of Instruction:

1. Gifted and talented students can access web sources from the recommended list to enrich their learning experience.

9. References:

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<http://www.bt.cdc.gov/agent/tularemia/facts.asp>

Center for Disease Control Website. Rabies. Accessed 11/15/03.

<http://www.cdc.gov/ncidod/dvrd/rabies/introduction/intro.htm>

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<http://www.dlia.org/atbi/species/animals/vertebrates/mammals.html>

National Institute of Health Website. Rabies. Accessed 11/15/03.
<http://www.niaid.nih.gov/factsheets/rabies.htm>

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<http://www.dnr.state.sc.us/etc/rulesregs/furregs.html>

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Vaughan, T. A., Ryan J. M., and Czaplewski, N. J. 2000. Mammalogy. Saunders College Publishing, Fort Worth.

Whitaker, J. O. 1996. National Audubon Society Field Guide to North American Mammals. Knopf, New York.

Whitaker, J. O. Jr. and Hamilton, J. W. Jr. 1998. Mammals of the Eastern United States. Cornell University Press, Ithaca.

10. Additional Resources

Web Sources:

<http://www.csuchico.edu/tlp/info/projects/skull/>
<http://www.gwc.maricopa.edu/class/bio201/skull/skulltt.htm>
<http://www7.nationalgeographic.com/ngm/0504/feature1/bridgemap.html>
<http://archives.cnn.com/2002/TECH/science/07/10/ancient.skull/index.html>
http://news.nationalgeographic.com/news/2006/03/0327_060327_skull.html