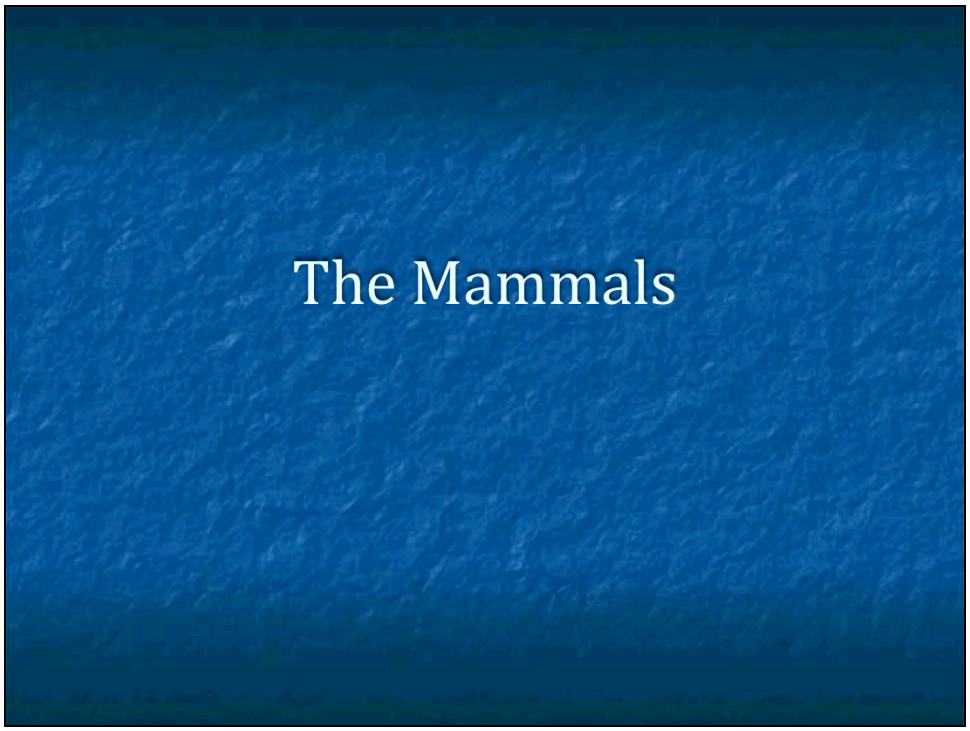
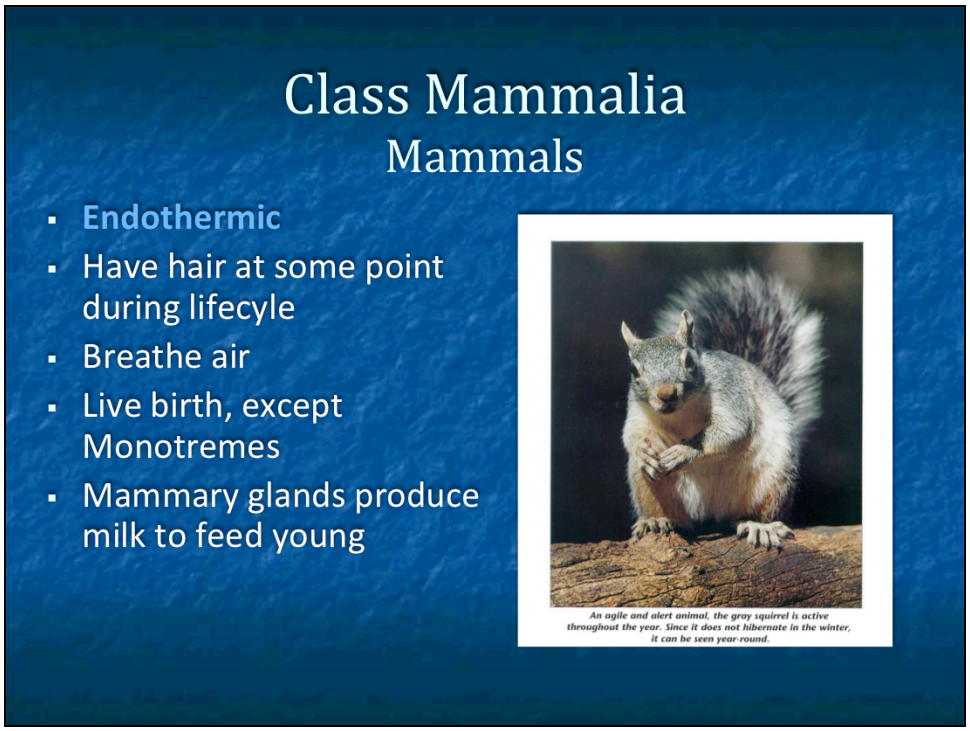


The last Class of vertebrates is the mammals. Mammals have a relatively larger brain to body size than reptiles and has many folds or convolutions; a larger brain to body size provided multiple advantages for mammals, allowing an increased degree of muscle coordination, higher intelligence, better memory development and more complex emotions and the capacity for emotional bonds.

Mammal ancestors were mammal-like reptiles that existed about the same time as the emergence of dinosaurs. The earliest identifiable mammals were tiny, shrew-like animals that emerged during the late Triassic Period. After the extinction of the dinosaurs, the Cenozoic Era became the "Age of Mammals"; flowering plants and mammals underwent rapid diversification at this time and filled in open niches; mammals took advantage of the new abundant food sources provided by the evolving flowering plants.

Monotremes, **marsupials** and **placental mammals** represent the three divergent lines of mammals, which still exist today. These three differ in their reproductive systems.



Mammals are **endothermic** and have hair at some point during their lifecyle. Endothermy frees vertebrates from depending on the ambient temperature of their surroundings for warmth. Endothermy however requires that the animals generate their own heat internally and this requires more calories. The caloric need of an endotherm is 4–5 times more than a similar size ectotherm. Hair helps maintain its body temperature and insulates it from the temperature of the environment.

Mammals breathe air. Females have mammary glands and produce milk to feed their young. Note: “mammalia” means “of the breasts”.

All mammals have live births, except Monotremes, who lay eggs. Marsupials are born after a short gestation period and the placental mammals have longer gestations periods while getting nourishment from the placenta.

A mnemonic for mammal characteristics is **WHALE**: **W**arm blooded, **H**air or fur, **A**ir to breathe, **L**ive birth, **E**ats mom’s milk.

We will be discussing only those Mammalian Orders that we have at the Zoo. The Sculpture Learning Plaza has a platypus, gray whale, Arctic hare, pangolin, Indian flying fox, Tasmanian devil, aye-aye, star-nosed mole and an Ethiopian wolf.

Monotremes, **marsupials** and **placental mammals** rely on **internal fertilization** but differ strongly in their reproductive anatomy and pattern.

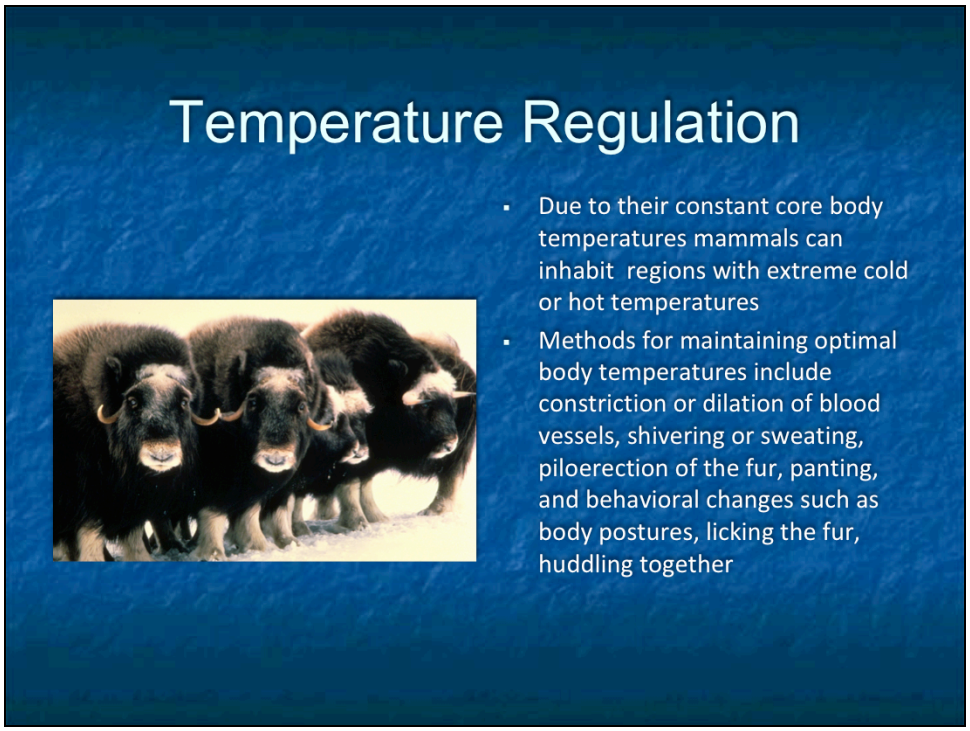
The **monotremes** are typified by laying eggs rather than bearing live young. Monotreme means “single opening” in Greek, referring to the single duct for urination, defecation, and reproduction (egg-laying). The mother has no teats, instead monotremes secrete milk through mammary gland openings in the skin and the baby laps it off the mother’s hair on her abdomen.

Marsupials have a double reproductive tract and give birth to a relatively undeveloped embryo after a short gestation and the baby does most of its development attached to a teat, which in most cases is in a pouch. They lack a true placenta.

The **placental** reproductive system is more advanced. The placental mammals develop within the mother's womb and are nourished by a placenta. The developing young spend proportionately more time within the female's reproductive tract. The young are later released to survive on their own, with varying amounts of help from the parents depending on the species.

The **mammary glands** are not part of the reproductive system but are important to mammalian reproduction. Mammary glands produce the mother’s milk to nurture their young until they are able to eat the typical food their species consumes. Nursing requires extended periods of parental care, but improves the survival rate of their offspring. Note: in primates, nursing helps in social bonding and in development.

Mammals have a **secondary palate**, which separates the mouth from the airway and allows mammals to breath while sucking milk from the mammary glands or chewing food. It also provides a surface on which the tongue can manipulate food, facilitating chewing.



Due to their constant core body temperatures, (**homeothermic**) mammals can inhabit regions with extreme cold or hot temperatures. Dense fur and blubber help mammals to maintain a high body temperature and to explore cooler climates. To maintain their correct body temperature, mammals must be able to produce and conserve body heat in colder temperatures as well as dissipate excess body heat in warmer temperatures. Being **endothermic** gives mammals a distinct advantage in many habitats, allowing them to be active when reptiles are hardly able to move.

Mammals spend the majority of their time in search of food in order to provide the energy necessary to maintain a fairly constant body temperature. An area of the brain (neocortex) probably evolved as a part of a set of adaptations related to temperature homeostasis; this area stores information about the structure of the environment so that the mammal can readily find food and other resources necessary for its survival.

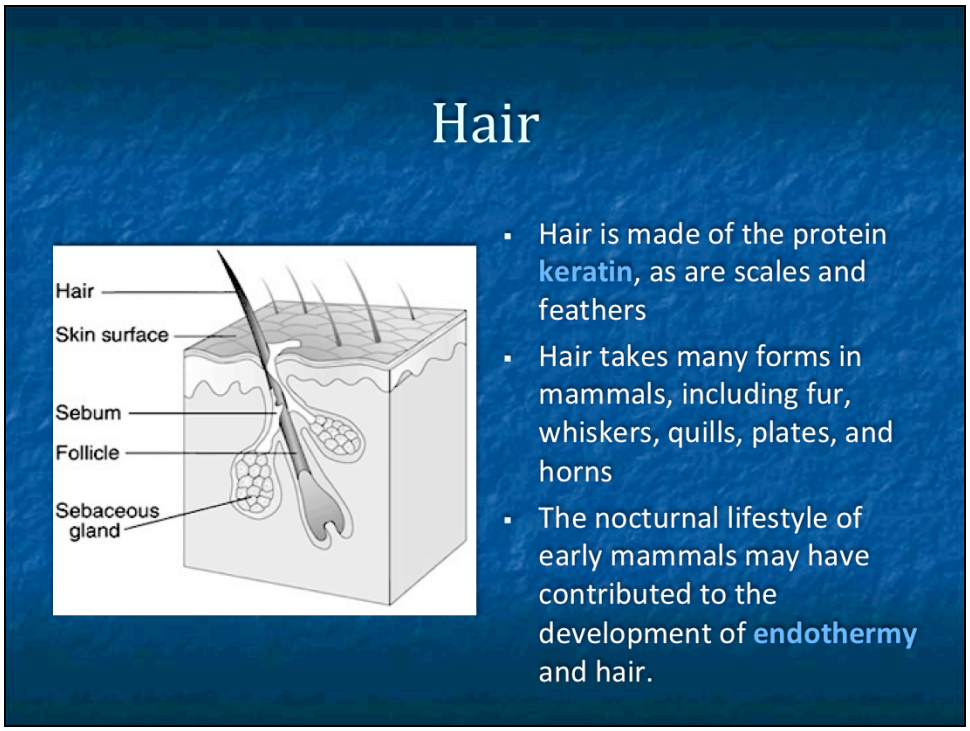
Methods for maintaining optimal body temperatures include **constriction or dilation of the blood vessels**, **shivering or sweating**, **piloerection of the fur**, **panting**, and **behavioral changes** such as body postures, licking the fur, and huddling together.

A special circulatory adaptation called **countercurrent heat exchange** enables animals to maintain the appropriate body temperature in their extremities with variable external temperatures. Warmer blood from the interior of the animal flows down the arteries to cold extremities. The arteries lie next to the veins which are returning the cold blood from the extremities. The warmer blood gives up some of its heat to the colder blood returning from the extremities in these veins, thereby moderating the temperature of the more exposed limb. A counter current exchange in the respiratory passages conserves heat as well as water.

Larger mammals have less heat loss than smaller mammals due to the fact that heat loss is proportional to surface area; individuals from cooler climates tend to be larger than individuals of the same species living in warmer climates. Their appendages, such as limbs, nose, tail and ears, tend to be shorter in the cooler climates as well.

Desert mammals must dissipate heat or avoid it to maintain a constant body temperature. Desert mammals cope with a lack of water by producing dry feces. Evaporative cooling from the respiratory tract is a major avenue of water loss but is also an important device for cooling. Temperature regulation is also influenced by changes in insulation, metabolic rate and body size. Small mammals avoid extreme heat by adhering to definite periods of activity, and/or by occupying burrows during the heat of the day. Larger animals, such as the scimitar-horned oryx, save water by allowing their body temperatures to rise before it is necessary to pant to cool off thus reducing water loss. The scimitar-horned oryx is able to live in the desert without water for extended periods of time; they have specialized kidneys that prevent excess loss of water by producing very concentrated urine.

Lighter fur in desert animals reflects direct sunlight and the fur is also an excellent insulation against heat. Kangaroos will lick their paws as an evaporative cooling method.



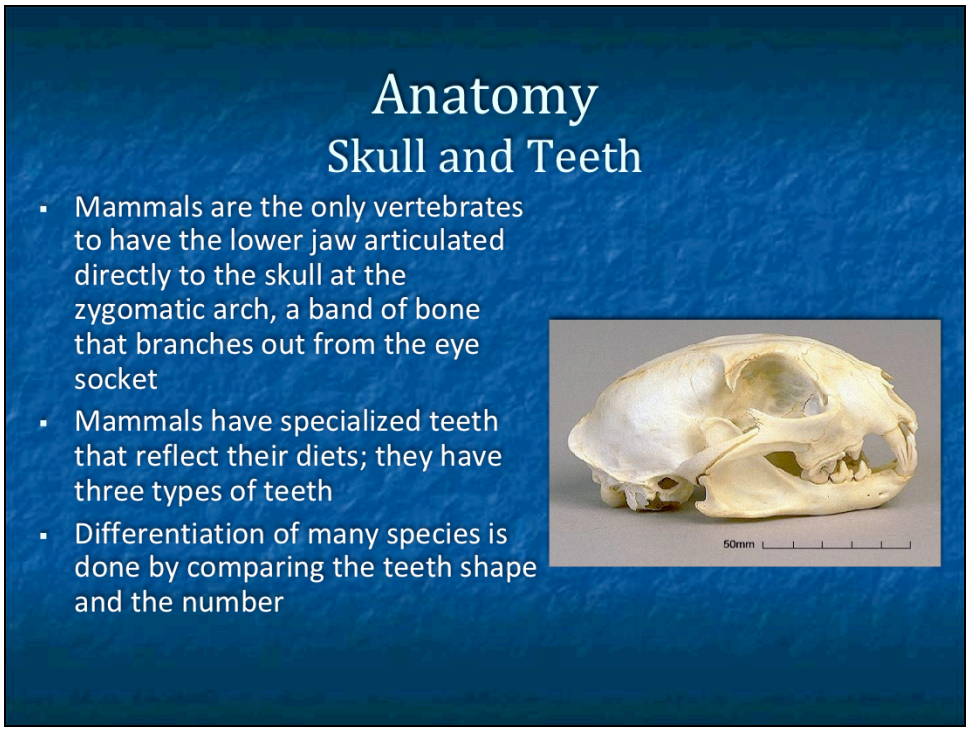
Hair is one of the defining characteristics of mammals; all mammals have hair covering at least part of their body at some time during their life. Mammalian hair is made of the protein **keratin**, just as scales, feathers, fingernails and the baleen of whales. Hair takes many forms in mammals, including fur, whiskers, quills, plates, and horns. **Note:** The horn of the rhino is made of keratin.

Hair aids in thermoregulation. The most important function of hair in mammals is to insulate against cold by conserving body heat. Thick fur allows mammals to explore cooler climates.

The **pelage** (fur or pelt) of most mammals consists of two layers. The most conspicuous hairs on most mammals are the **guard hairs**, which overlay the fur and serve to protect it and provide coloration. Beneath the guard hairs is usually a layer called the **underfur**. The underfur provides insulation by trapping in warm air against the skin. Most hair is shed periodically in a **molt**, which is essential to survival.

Hair may provide camouflage for many animals and for others it provides signals to other animals such as warnings, mating, or other communicative displays and for some animals hair provides defensive functions and, rarely, even offensive protection. Hair also has a sensory function, extending the sense of touch beyond the surface of the skin. The guard hairs give warnings that may trigger a recoiling reaction.

Note: See training unit on Biofact Pelt Interpretation.



Often, characteristics of **skulls** and dentition are used to define and differentiate mammalian groups. The lower jaw or mandible of mammals consists only of a single bone in contrast to the reptiles where the lower jaw is comprised of several different bones. Mammals are the only vertebrates to have the lower jaw articulated directly to the skull at the **zygomatic arch**, a band of bone that branches out from the eye socket, allowing muscles to pass through that move the jaw. Note: The lower jaws of all other vertebrates are hinged through the quadrate bone to the skull. In mammals, this quadrate bone migrated to the inner ear and became one of the three middle ear bones.

In mammals, the occipital condyle has two points of contact to the first neck or cervical vertebrate. The reptilian skull is attached to the spine by a single point of contact.

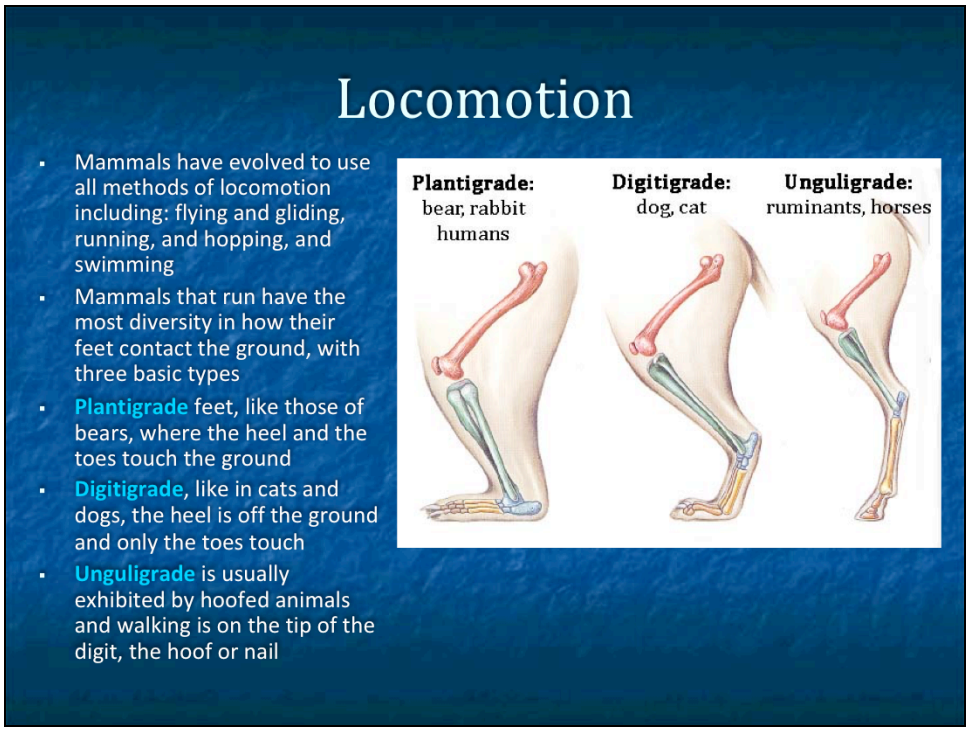
Mammalian teeth are more efficient and are specialized for different functions allow them to exploit a diverse range of food. Most mammals have three types of teeth: incisors, canines, and molars; they are **heterodonts,** which means some teeth are different. Incisors are the front teeth, canines are the pointed teeth between the incisors and the back teeth, the molars. Note: In fish and reptiles, the teeth are all basically the same, some bigger than others, but the same basic shape (**homodonts**).

The differentiation of many species is done by comparing the teeth shape and the number. **Herbivores** have large, flat ridged molars for grinding and clipper like incisors. **Carnivores** have sharp molars for tearing and cutting, and canines for slashing. **Omnivore** have something in between with more “peaks and valleys”; they are less specialized than most mammals.

Mammals have two sets of teeth, the first emerges soon after birth, often called the '**milk teeth**' and a larger set they acquire as an adult. The larger set has both more and larger teeth to fill the larger jawbones. In all other toothed vertebrates, such as reptiles, teeth just keep coming, no matter how many are lost there is always another one ready to take its place. In other words, fish, amphibians, reptiles and birds either have no teeth or numerous sets.

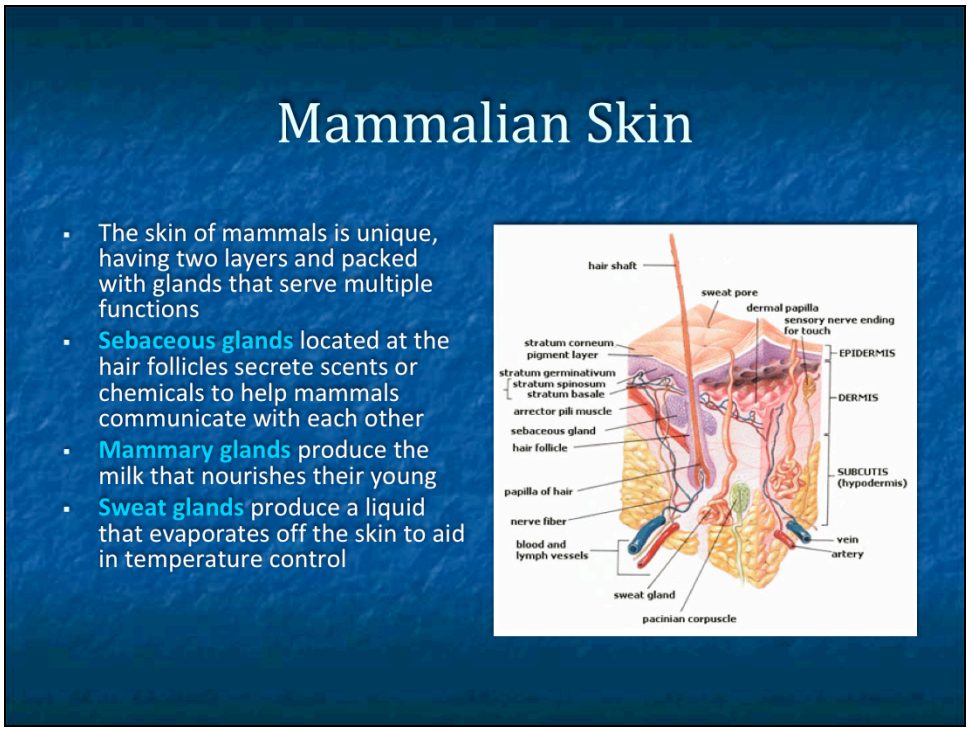
There are two groups of mammals that don’t have teeth: pangolins and anteaters. Both of these animals have long sticky tongues for capturing ants and other insects. In the case of the anteater, its tongue is long and sticky, and covered with spines. When it gets hungry, the anteater flicks its tongue deep inside an ant colony, and the ants inside are glued to the sticky surface. It then grounds the ants against hard growths inside the anteater’s mouth. They have also been known to swallow rocks to crush the ants in its tough stomach.

Note: See training unit on Biofact Skulls Interpretation.



Mammals have evolved to use all methods of locomotion including: walking and running, flying and gliding, jumping, climbing, digging and burrowing and swimming. The development of the four-chambered heart gave mammals a distinct advantage over reptiles. A four chambered heart allows for much longer endurance to feed the oxygen demand of the tissues. Mammals were able to actively hunt down prey or in the case of the prey, elude predators. Mammals have a better stamina than reptiles due to their higher metabolic rate.

Mammals that run have the most diversity in how their feet contact the ground, with three basic types; **plantigrade** feet, like those of squirrels, rabbits, bears and humans, where the heel and the toes touch the ground; they are flat-footed; **digitigrade**, like in cats and dogs, the heel is off the ground and only the toes touch; **unguligrade** is usually exhibited by hoofed animals and walking is on the tip of the digit, the hoof or nail.



The skin of mammals is unique; it has two layers and is packed with glands that release different types of biochemicals, serving multiple functions. We have already mentioned the function of **mammary glands** in its role in reproduction.

Sebaceous glands secrete the oily, waxy substance that lubricates and waterproofs the skin and hair of mammals; they serve to protect the body against germs; the secretions prevent the growth of bacteria. Sebaceous glands are responsible for the acne that one has during puberty.

Sebaceous glands secrete scents or chemicals to help mammals communicate with each other. P**heromones**, secreted by the sebaceous glands, trigger a social response in members of the same species. Pheromones are released in response to stress, alarm, danger, and sexual fertility. In the ungulates and felids species, the animal may curl back its upper lips exposing its front teeth, inhale with the nostrils usually closed and then often hold this position for several seconds. The behavior facilitates the transfer of pheromones and other scents into the **vomeronasal organ (VMO or Jacobson organ)** located above the roof of the mouth via a duct which exits just behind the front teeth of the animal. **Note:** the evolution of bigger brains in mammals enabled a stronger sense of smell.

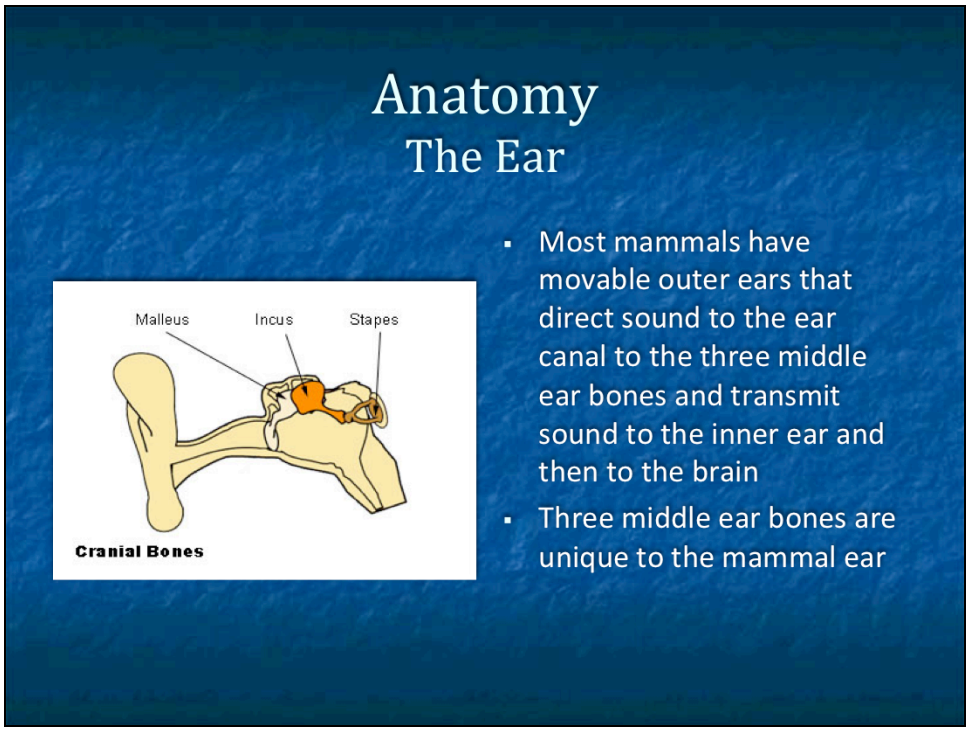
The **sweat glands** of mammals produce a liquid that evaporates off the skin to aid in temperature control. Maintaining a constant body temperature allows an organism to function effectively in a broad range of environmental conditions. Only mammals sweat, but not all mammals have the same number of sweat glands. Canids (dogs) posses very few sweat glands and cool primarily by panting.

A few mammals lack sweat glands such as the hippopotamus. The hippo spends most of its time in water, which helps regulate its body temperature.

The rhinoceros and pigs also do not have sweat glands. They frequently roll in mud to cover their skin in order to cool themselves and protect themselves from insects and parasites.

Whales, dolphins and porpoises are marine mammals and do not have sweat glands. They depend on the surrounding water to regulate their body temperature.

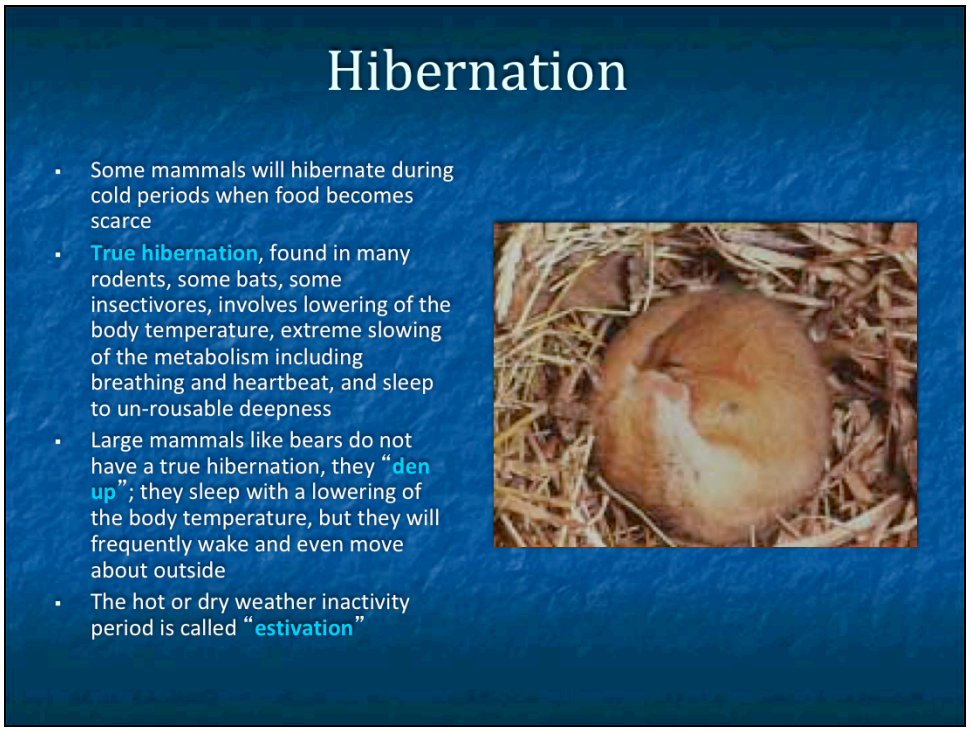
Note: fish, amphibians, reptiles, and birds all lack sweat glands and use other methods for heat loss.



Most mammals have movable external ears that direct sound through the ear canal to the **three middle ear bones**, which transmit sound to the inner ear and then to the brain. In some mammals, the direction of the external ear can be adjusted to locate sounds. This is especially important in prey animals so they can locate the source of danger. Some animals, the left and right ear can move independently of each other for more precise location of a sound.

Three middle ear bones are unique to the mammal ear and amplify the sounds and provide more acute hearing. The middle ear is why mammals, as a group, have the sharpest hearing on Earth and the greatest diversity of listening styles, from the bats and dolphins that can detect ultrasonic pressure waves, to elephants and humpbacked whales that can hear infrasound. The mammalian ear is also a master at detecting very quiet sounds. Early mammals were probably nocturnal, the better to avoid day-hunting dinosaurs, and even today most mammals prefer to come out after dark.

Note: Reptiles have one middle ear bone, while the upper and lower jaws contain several bones not found in mammals. During mammalian evolution, the single middle ear bone of the reptile was combined with one lower and one upper reptilian jaw bone forming the three mammalian middle ear bones. Improved hearing occurred in parallel with the evolving jaw and dentition in mammals.



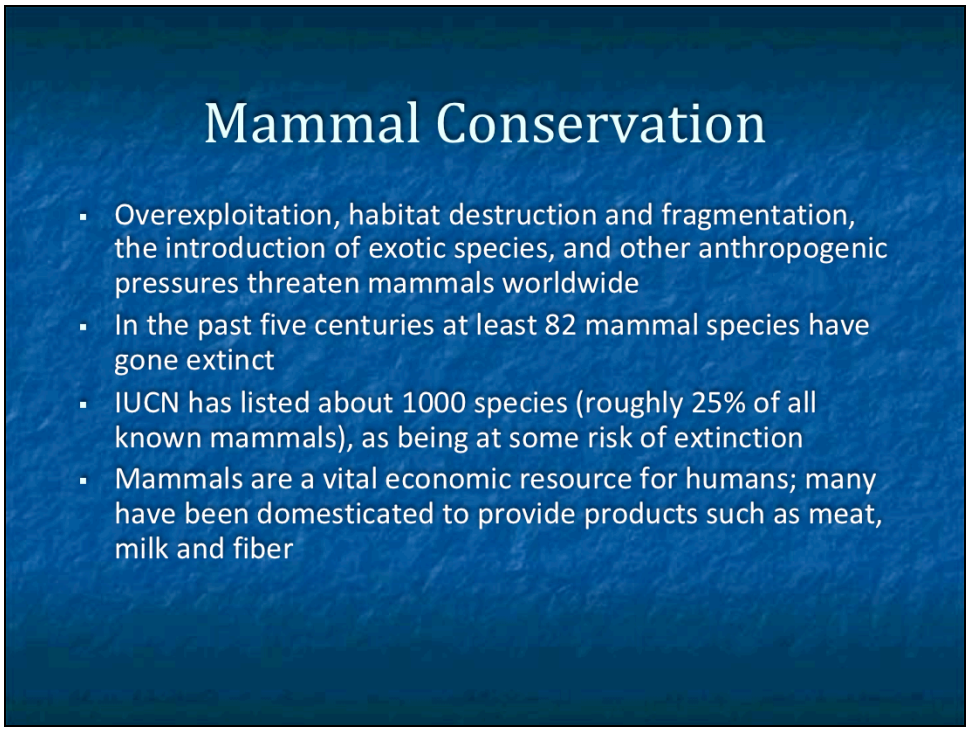
Some mammals will **hibernate** during cold periods when food becomes scarce. True hibernation, found in many rodents, some bats, and some insectivores, involves lowering of the body temperature, extreme slowing of the metabolism including breathing and heartbeat, and sleeping to an unrousable deepness. Hibernation is often associated with low temperatures; its function is to conserve energy during a period when sufficient food is unavailable.

Large mammals like bears do not have a true hibernation, instead they "**den up**"; they sleep with a lowering of the body temperature, but they will frequently wake and even move about outside. This helps them to respond to the needs of their young which they deliver during these times.

The hot or dry weather inactivity period is called "**estivation**".

Reptiles are said to "**brumate**" which is a hibernation-like state that ectothermic animals utilize during very cold weather. Physiological changes which are independent of body temperature occur in brumation.

Some mammals travel have developed other ways to escape extreme temperatures and food scarcity periods - they travel long distances; migration often follows the seasons and food and water availability. Caribou herds travel south for the winter and back north for the summer. Gray whales will also migrate up to 12,500 miles/year to find krill, plankton or shrimp. The Great Migration of Africa occurs each year; over a million wildebeest along with gazelle and zebra move towards better grazing areas and water supplies. These are all ways mammals have dealt with temperature changes and food scarcity.

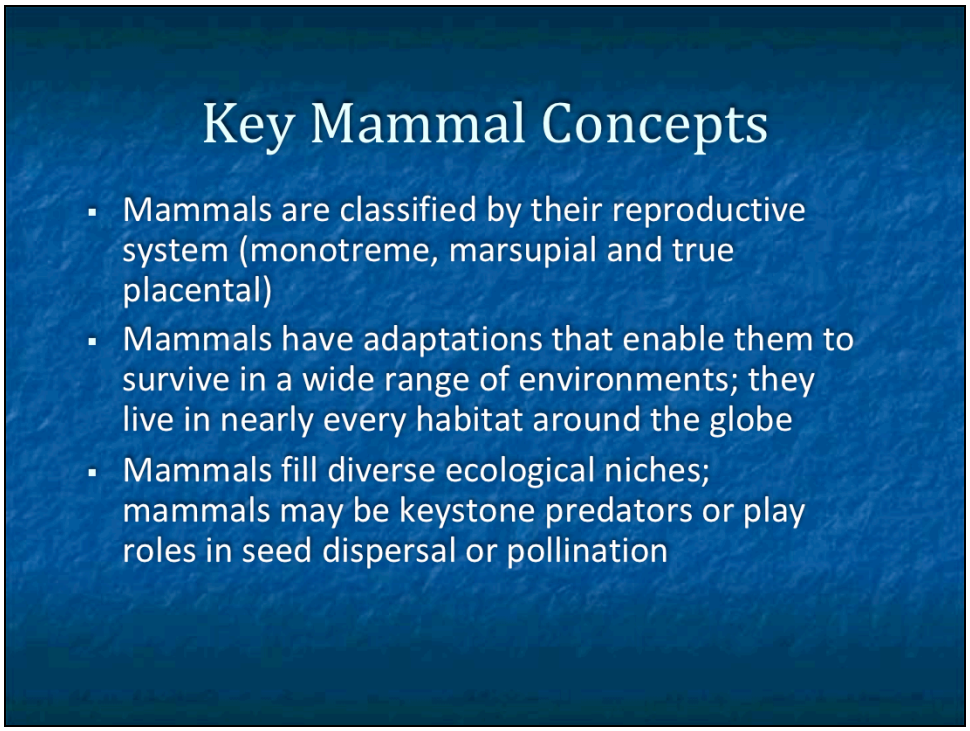


Mammals fill diverse ecological niches and are an important part of their communities. Mammals are predators and prey, carnivores, omnivores, and herbivores. Many mammals may be keystone animals in their communities or play important roles in seed dispersal or pollination. Despite their low species diversity, compared to other animal groups, mammals have a substantial impact on global biodiversity.

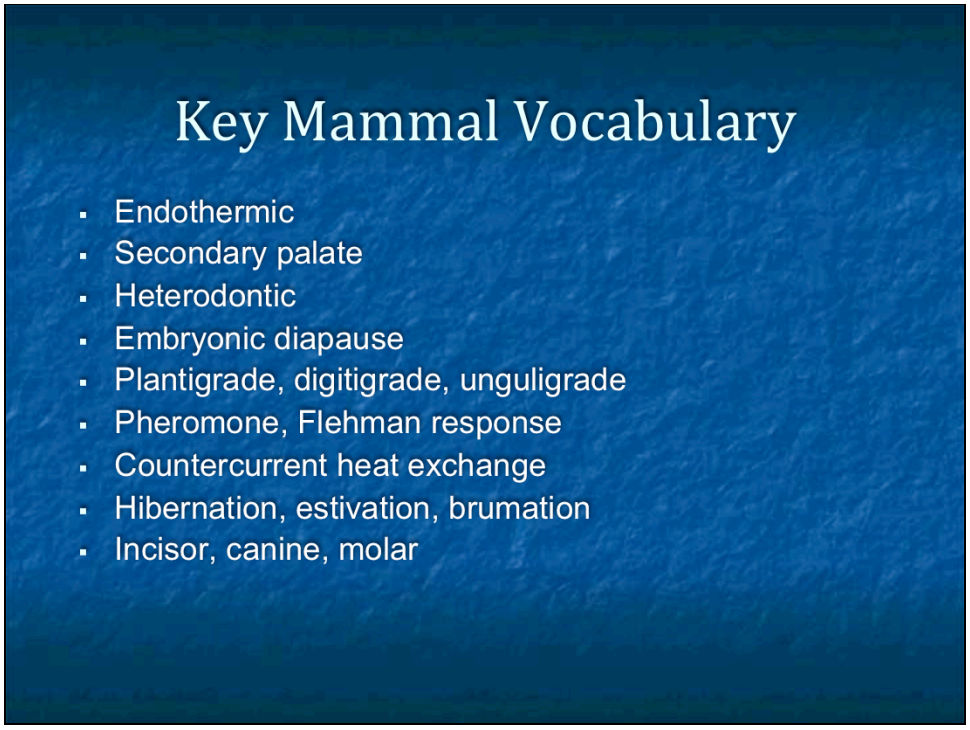
Overexploitation, habitat destruction and fragmentation, the introduction of exotic species, and other anthropogenic pressures threaten mammals worldwide. IUCN has listed about 1000 species (roughly 25% of all known mammals), as being at some risk of extinction. In the past five centuries at least 82 mammal species have gone extinct.

Mammals are a vital economic resource for humans; many have been domesticated to provide products such as meat, milk and fiber. They constitute the largest biomass of land mammals by weight and dramatically affect human's ecological footprint.

Note: refer to the Conservation training unit for more information on conservation.



Corresponds to the Mammalia Study Guide in the Docent Notebook. For specifics on the Zoo's mammal collection read the Mammalian Fact Sheets in the Docent Notebook and go to the SF Zoo's website (sfzoo.org)



Definition:

Brumation: the hibernation-like state that cold-blooded animals utilize during very cold weather.

Canine: any of the pointed conical teeth located between the incisors and the first molars.

Countercurrent heat exchange: an arrangement of blood vessels that allows peripheral cooling particularly of appendages and at the same time maintains an adequate blood supply without excessive heat loss; enables arteries and veins flowing in opposite directions to exchange their heat content without mixing.

Digitigrade: an animal that stands or walks on its digits, or toes. Includes cats, dogs, and birds.

Embryonic diapause: a period of arrested development of an embryo at the stage of blastocyst (70- to 100-cell stage); found in some Kangaroos, wallaroos and wallabies; may result in having three young in different stages of development dependent on the mother at one time.

Endothermic: any animal dependent on or capable of the internal generation of heat. The animal is able to maintain a relatively constant internal temperature, irrespective of the temperature of the surroundings.

Estivation: prolonged torpor or dormancy of an animal during a hot or dry period.

Flehman response: is a behavior whereby an animal curls back its upper lips exposing its front teeth, inhales with the nostrils usually closed and then often holds this position for several seconds. The behavior facilitates the transfer of pheromones and other scents into the **vomeronasal organ (VMO or Jacobson organ)** located above the roof of the mouth via a duct which exits just behind the front teeth of the animal. This is seen in ungulates and felids.

Heterodont: animals which have different kinds of teeth; for example, most mammal teeth are differentiated into incisors, canines and molars.

Hibernation: a a state of inactivity and metabolic depression in endotherms. Hibernation is characterized by low body temperature, slow breathing and heart rate, and low metabolic rate.

Incisor: any of the anterior teeth in each jaw, used for cutting and gnawing.

Molar: any one of the teeth back of the incisors and canines. Also known as **cheek teeth**.

Pheromone: a secreted or excreted chemical factor that triggers a social response in members of the same species.

Plantigrade: an animal that walks on the sole with the heel touching the ground. Includes humans and bears.

Secondary palate: an anatomical structure that divides the nasal cavity from the oral cavity in many vertebrates.

Unguligrade: walk on the tips of their toes, usually hoofed, to sustain their whole body weight. Includes horses and cattle.