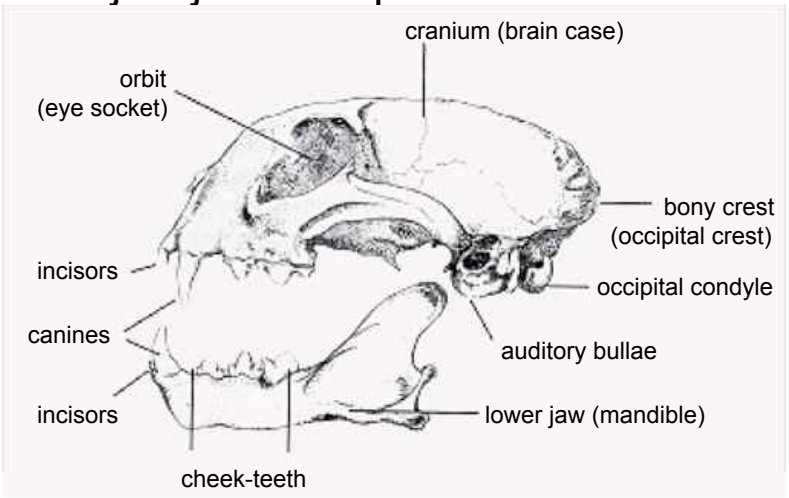
Classification of the Major Taxa of Mammalia

	examples
Phylum Chordata	
Subphylum Vertebrata	
Class Mammalia	
Subclass Prototheria	monotremes or egg-layers
Order Monotremata	platypuses, echidna
Subclass Theria	
Infraclass Metatheria	marsupials
Order Marsupialia	kangaroos, opossums
Infraclass Eutheria	placentals
Order Edentata	armadillos, sloths, anteaters
Order Pholidota	pangolins
Order Carnivora	seals, bears, wolfs, badgers
Order Rodentia	rodents
Order Lagomorpha	rabbits
Order Cetacea	dolphins and whales
Order Artiodactyla	even-toed ungulates: goats, hippos, giraffes
Order Tubuldentata	aardvarks
Order Dermoptera	colugos
Order Insectivora	moles and shrews
Order Chiroptera	bats
Order Primates	primates
Order Perissodactyla	odd-toed ungulates: horses, rhinos, tapirs
Order Hyracoidea	hyraxes
Order Proboscidea	elephants
Order Sirenia	manatees

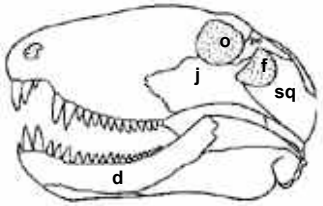
These four orders are more closely related to each other than to other orders

ANATOMICAL and PHYSIOLOGICAL FEATURES of MAMMALS

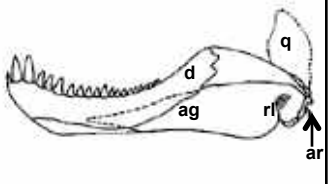
Mammals have a few skeletal features that distinguish their class. They have three middle ear bones used in hearing - two of these bones derived from bones used for eating by their ancestors. The earliest therapsids (mammal-like reptiles) had a jaw joint composed of the articular (a small bone at the back of the lower jaw) and the quadrate (a small bone at the back of the upper jaw). Reptiles and birds also use this system. In contrast, mammals' jaw joint is composed only of the dentary (the lower jaw bone jaw bone that carries the teeth) and the squamosal. In mammals the quadrate and articular bones have become the incus and malleus bones in the middle ear.

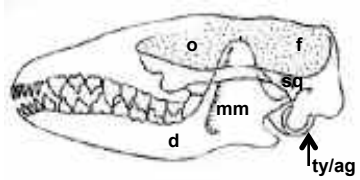


Mammals have a neocortex region in the brain. Most mammals also possess specialized teeth and utilize a placenta in their ontogeny. Mammals also have a double occipital condyle: they have two knobs at the base of the skull which fit into the topmost neck vertebra, whereas other vertebrates have a single occipital condyle. Paleontologists use the jaw joint and middle ear as criteria for identifying fossil mammals.

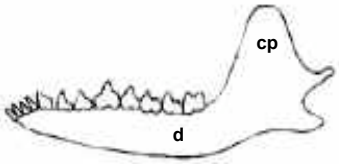


Sphenacodon
(early therapsid from Upper Pennsylvanian)





Asioryctes
(early placental mammal from Upper Cretaceous)



Abbreviations: ag = angular; ar = articular; cp = coronoid process; d = dentary; f = lateral temporal fenestra; j = jugal; mm = attachment site for mammalian jaw muscles; o = eye socket; q = quadrate; rl = reflected lamina; sq = squamosal; ty = tympanic.

ANATOMICAL and PHYSIOLOGICAL FEATURES of MAMMALS

It would be correct to say that mammals are a group of warm-blooded animals with backbones and a four-chambered heart, whose bodies are insulated by hair, that have sweat glands including milk producing sweat glands that they use to nurse their infants, and that share a unique jaw articulation. This, however, fails to convey how these few shared characteristics underpin the evolution of a group with astonishingly intricate adaptations, thrilling behavior and highly complex societies. Mammals are also the group to which humans belong, and through them we can understand much about ourselves. Another answer to the question “What is a mammal?” would therefore be that the essence of mammals lies in their complex diversity of form and function, and above all their individual flexibility of behavior.

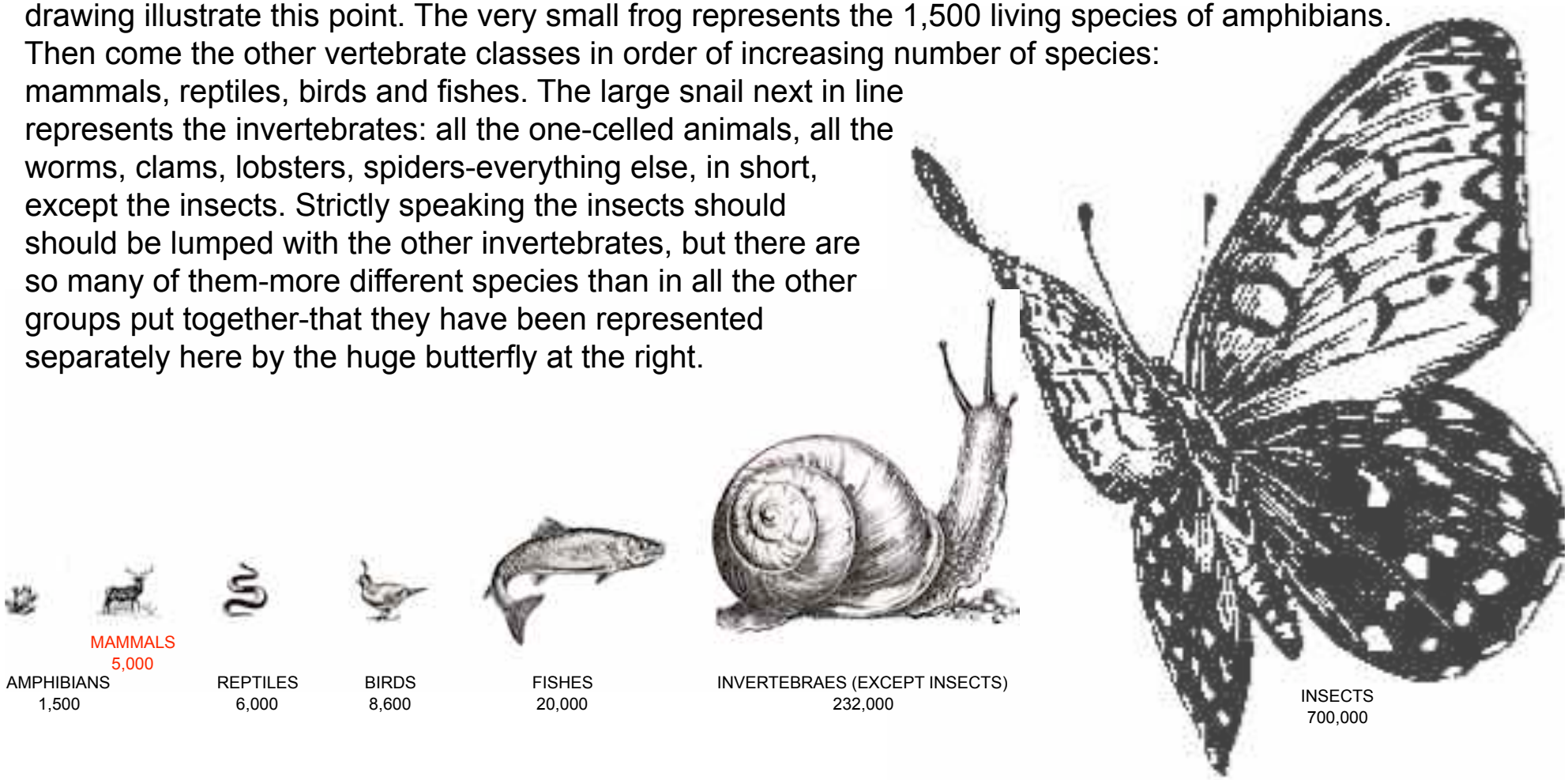
Harem of Elephant seals resting on a beach

Pack of wolves howling to define and defend territory, and to reinforce social hierarchy.

Herd of African savannah elephants led by a matriarch

HOW ABUNDANT ARE MAMMALS?

Although mammals are generally considered to be the dominant and probably most diversified class of living vertebrates, they are far from being the most numerous. If the total numbers of species for all the major animal groups are compared, mammals come out near the bottom. The sizes of the different creatures in this drawing illustrate this point. The very small frog represents the 1,500 living species of amphibians. Then come the other vertebrate classes in order of increasing number of species: mammals, reptiles, birds and fishes. The large snail next in line represents the invertebrates: all the one-celled animals, all the worms, clams, lobsters, spiders-everything else, in short, except the insects. Strictly speaking the insects should should be lumped with the other invertebrates, but there are so many of them-more different species than in all the other groups put together-that they have been represented separately here by the huge butterfly at the right.



AMPHIBIANS 1,500

MAMMALS 5,000

REPTILES 6,000

BIRDS 8,600

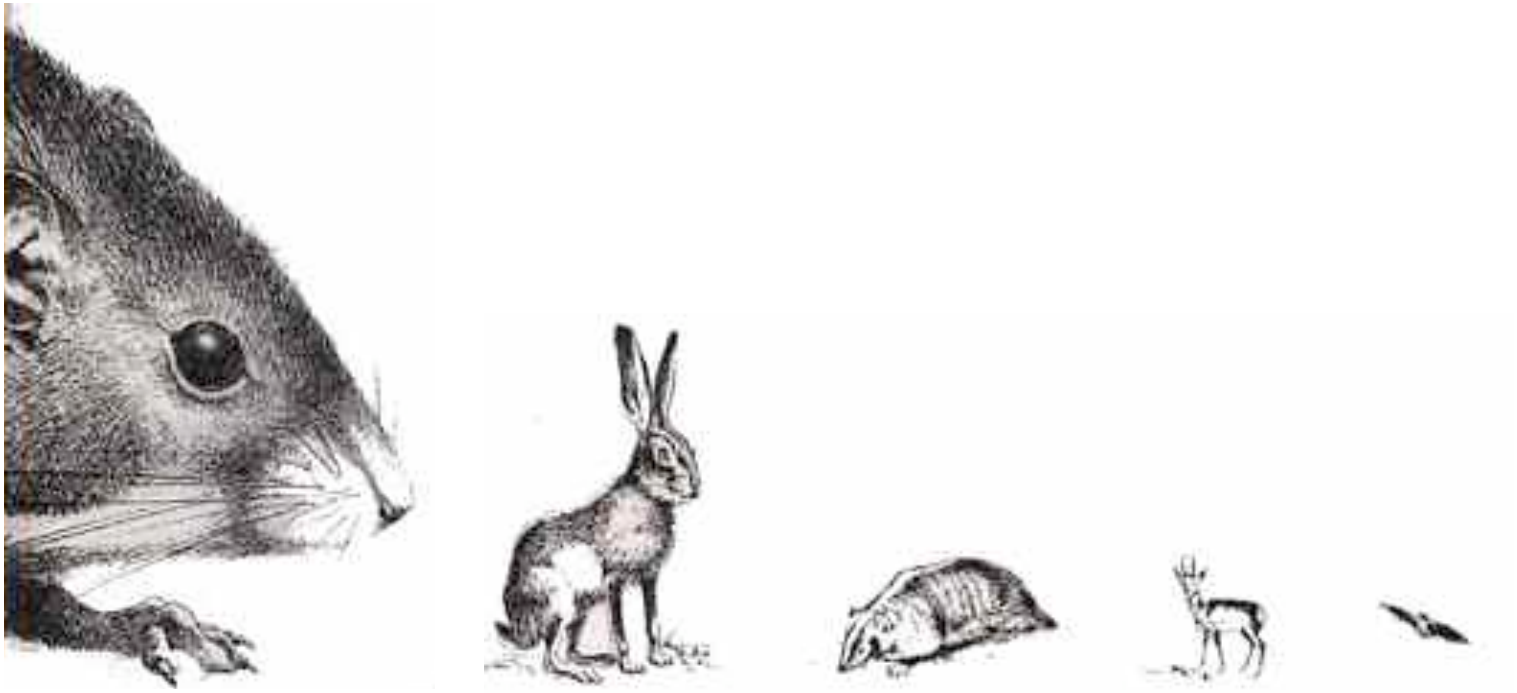
FISHES 20,000

INVERTEBRAES (EXCEPT INSECTS) 232,000

INSECTS 700,000

What Are the Most Common Mammals?

With mammals placed in proper numerical perspective vis-à-vis other animals, what about the relative abundance of the different mammals themselves? Counting actual numbers of animals is far more difficult than numbers of species. The only way it can be done is to take a small sample area and laboriously count every nose in it. This has been done many times in different parts of the world. While results vary widely depending on the terrain and the time of year, nevertheless in most areas the rodents turn out to have by far the largest populations. The five mammals pictured here show what lives on 250 acres of sagebrush country in the western U.S., based on a study of a 2.5-acre sample area. They illustrate two general principles: 1) carnivores (in this case, badgers) tend to be far less numerous than the animals they eat and 2) the smaller the animal, the larger its population in a given area.



RODENTS (Rodentia) 5,770	RABBITS (Lagomorpha) 60	BADGERS (Carnivora) 30	PRONGHORNS (Artiodactyla) 10	BATS (Chiroptera) 8

Lactation and the Rise of Mammals

The decline of the huge, naked, ectothermic dinosaurs may have been triggered by the cooling climate of the Mesozoic era, with its daily and seasonal fluctuations in temperature. But these would have affected smaller (or infant) dinosaurs more than the giants that predominated among dinosaurs, due to the smaller reptile's relatively greater surface-area-to-volume ratio and hence more rapid heat loss. So why did the mammals finally prosper, and the dinosaurs decline?

Early mammals may have avoided competition with dinosaurs by becoming nocturnal, and the key that unlocked this chilly niche to them may have been the evolution of endothermy (internal self-regulation of body temperature). In addition to allowing them to forage out of the sun's warming rays, endothermy may have improved mammals' competitive ability by allowing them to grow faster and therefore breed more prolifically than reptiles, whose bodies more or less "switch off" when they cool down.

Another possibility is that the mammals usurped the dinosaurs' supremacy on account of one critical difference: the development of lactation and parental care in mammals.

An Olive baboon nursing her young (right), and an Orca nursing her calf while swimming (below). When a mammalian infant sucks at its mother's nipple it may withdraw a little milk, but more importantly it stimulates "let-down," whereby muscles squeeze much more milk out of a honeycomb of tubes and cavities in the mammae; this milk collects in ducts from which it can be sucked. Some 30-60 seconds of preliminary sucking are required to stimulate let-down. Thus the process is not controlled simply by nerves (as they transmit messages almost instantaneously), but by a chemical envoy (a hormone) that travels within the mother's bloodstream. In fact, sucking triggers a nerve impulse which races to the pituitary, and in response this organ releases two chemicals into the blood. When these chemical couriers reach the mammae, one (lactogenic hormone) stimulates the secretion of milk by the glands, the other (oxytocin) prompts the ejection of stored milk from the nipple.

Lactation and the Rise of Mammals

Young dinosaurs, like modern crocodiles, hatched as minuscule replicas of their parents; their small size required that they ate quite different food from the adults of their species. They grew slowly at a rate dependent upon their foraging success, gradually approaching adulthood, as feeble inferiors until they finally attained full size. In contrast, the evolution of lactation enabled an infant mammal to grow rapidly towards adult competence under the protection of parental care. At independence the young mammal is almost fully grown and unlike the still infantile reptile of the same age, enters roughly the same niche as adult members of its species. For example, a Grizzly bear is born at roughly the same percentage of its mother's weight (1-2 percent) as was a hatching dinosaur, but remains dependent on her for protection for up to 4 1/2 years. The dinosaur, on the other hand, had to fend for itself in a series of niches that changed as it grew. In the inconstant, unpredictable environment of the cooling Mesozoic, dinosaurs may have been at a disadvantage to mammals because they required a succession of different food supplies to become available exactly on cue as their young grew, and faced a protracted period when young were at a competitive disadvantage to adults. If this reconstruction is correct, then it was parental care (also evolved by birds), and particularly lactation, that assured the supremacy of mammals. The protracted parent-offspring bond established during nursing in turn set the scene for the subsequent evolution of intricate mammalian societies.

A NURSING MONOTREME

The most primitive mammals are the monotremes, whose mammary glands have not concentrated into milk -producing organs, as they have in the higher mammals. The milk of the platypus, for example, seeps from a number of porelike holes in her abdomen and is lapped up by the little ones.

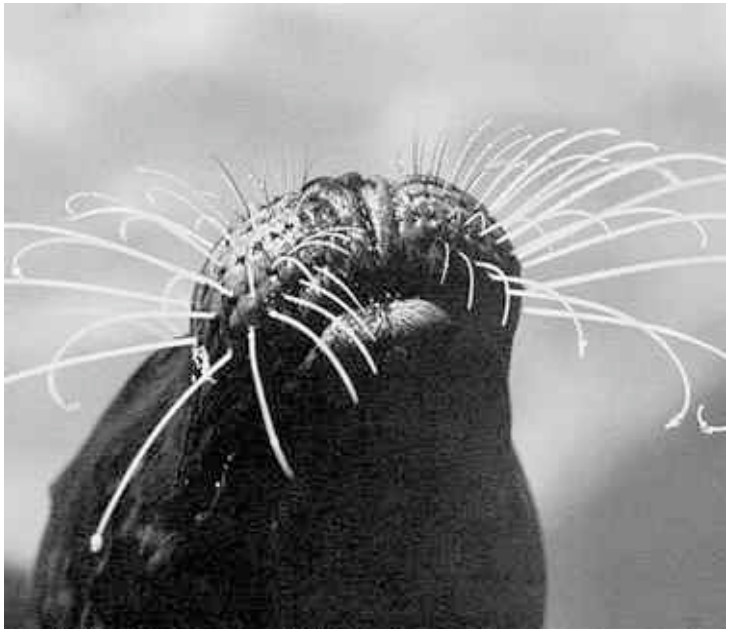
NURSING MARSUPIALS

More advanced are the marsupials such as opossums and kangaroos shown here. They have true nipples, but these are located inside a pouch, or marsupium, to which their comparatively unformed babies crawl at birth. They live there for several months until they are much larger and more developed.

HAIR TYPES

Hair is composed of keratin and is modified epidermis. Mammalian hair is highly variable. It varies in form, shape, density and color location not only within an organism but also throughout the year. Most of this variability relates form and function. All hairs have a nerve plexus at their base. Hair is categorized as vibrissae (whiskers), fur, or guard. Vibrissae are specialized tactile organs that are long, thick and are typically straight or slightly bent. Vibrissae are usually few in number and are typically found on the head or feet. Fur hairs are numerous, short, thin and are typically found in a group. Guard hairs are longer, thick and are usually distributed within the fur. Examine a few pelts and try to identify the three types. You may even notice more than three types as some hairs in the fur are intermediate between guard and fur.

A Musk Ox, northernmost of hoofed mammals. Their long, coarse guard hairs and fine underfur exclude the arctic cold.

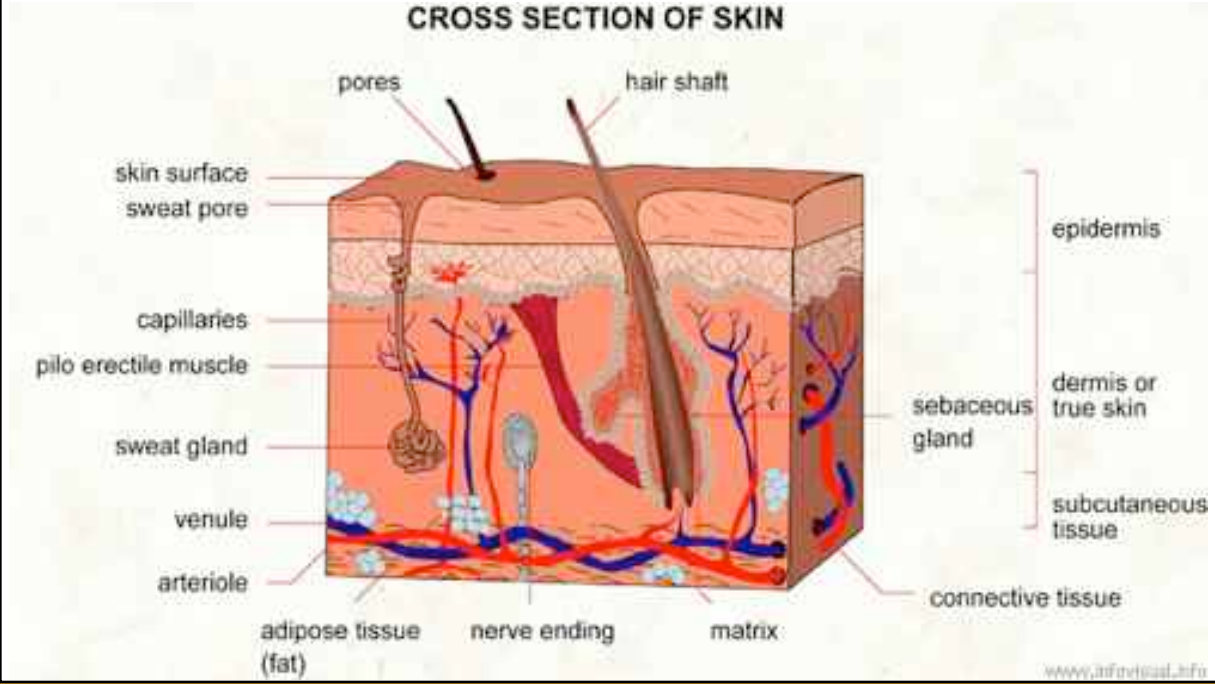


The vibrissae of this harbor seal are attached to a substantial nerve network. Tactile information is transmitted from the vibrissae to the brain.

HAIR FUNCTION

Two fundamental traits of mammals lie not in their skeletons, but at the boundaries to their bodies - the skin. These two features are hair and skin glands, including the mammary glands that secrete milk, and the sweat and sebaceous glands. None may seem spectacular, and some or all may have evolved before the mammal-like reptiles crossed the official divide. But these traits are associated with endothermy, a condition that affects every aspect of mammalian life.

Endothermic animals are those whose internal body temperature is maintained “from within” (endo-) by the oxidation (essentially, the burning) of food within the body. Some endotherms maintain a constant internal temperature (homoethermic), whereas that of others varies (heterothermic). The temperature is regulated by a “thermostat” in the brain, situated within the hypothalamus. In regulating their body temperature independent of the environment, mammals (and birds) are unshackled from the alternative, ectothermic, condition typical of all other animals and involving body temperatures rising and falling with the outside temperature.



A cross-section of the skin and fur of a fur seal.

HAIR FUNCTION

Endothermy is costly. Mammals must work, expending energy either to warm or cool themselves depending on the vagaries of their surroundings. There are many adaptations involved in minimizing these running costs and the most ubiquitous is mammalian hair. The coat may be adapted in many ways, but there is often an outer layer of longer, more bristle-like, water-repellent guard hairs that provide a tough covering for densely packed, soft underfur. The volume of air trapped amongst the hairs depend on whether or not they are erected by muscles in the skin. Hair may protect the skin from the sun's rays or from freezing wind, slowing the escape of watery sweat in the desert or keeping aquatic mammals dry as they dive. Hairs are waterproofed by sebum, the oil secretions of sebaceous glands associated with their roots.

Sea otter

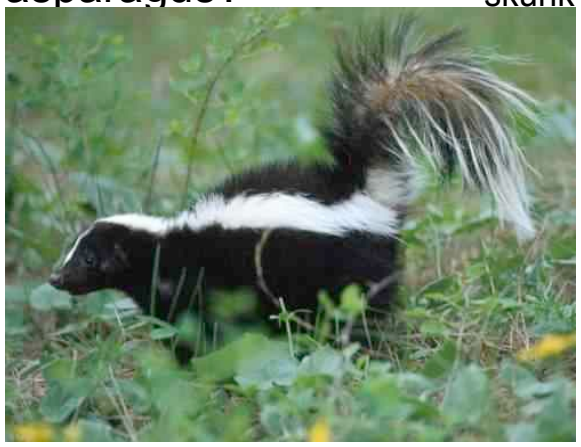
Fur seals

The skin plays an important part in maintaining a constant body temperature. Horses sweat profusely over most of their bodies to cool themselves. The coyote sweats through its tongue by panting and depends on its fur to prevent heat loss in cold weather. Mammals must eat regularly to maintain their high temperatures.

THE SCENT OF A MAMMAL

Mammals are unique among animals with backbones in the potency and social importance of their smells. This quality also stems from their skin, wherein both sebaceous and sweat glands become adapted to produce complicated odors with which mammals communicate. The sites of scent glands vary between species: capybaras have them aloft their snout, mule deer have them on the lower leg, elephants have them behind the eyes and hyraxes have them in the middle of their back. It is very common for scent glands to be concentrated in the ano-genital region (urine and feces also serve as socially important odors); the perfume gland of civets lie in a pocket between the anus and genitals and for centuries their greasy secretions have been scooped out to make the base of expensive perfumes. Glands around the genitals of Musk deer are a similarly unwholesome starting point of other odors (musk) greatly prized by some people. Most carnivores have scent-secreting anal sacs, whose function is largely unknown, although in the case of the skunk it is quite clear enough. The evolution of scent glands has led to a multitude of scent-marking behaviors. Scent marks have the advantage of being a long lasting form of communication. Probably the messages being communicated include the sex, status, age and diet of the sender. Most people are familiar with animals demarking their territory by leaving traces of urine. Have you noticed a remarkable change in the smell of your urine after eating asparagus?

skunk



Indian civet

Musk deer

ODOR IN RODENT REPRODUCTION

Reproduction - from initial sexual attraction and the advertisement of sexual status through courtship, mating, the maintenance of pregnancy and the successful rearing of young - is influenced, if not actually controlled, by odor signals.

Male rats are attracted to the urine of females that are in the sexually receptive phase of the estrous cycle and sexually experienced males are more strongly attracted than naive males. Furthermore, if an experienced male is presented with the odor of a novel mature female alongside the odor of his mate he prefers the novel odor. Females, on the other hand, prefer the odor of their stud male to that of a stranger. The male's reproductive fitness is most improved by his seeking out and impregnating as many females as possible. The female needs to produce many healthy young so her fitness is maximized by mating with the best quality male who has already proved himself. The otherwise solitary female Golden hamster must attract a male when she is sexually receptive. She does this by scent marking with strong-smelling vaginal secretions in the two days before her peak of receptivity. If no male arrives she ceases marking, to start again two days before the next peak.

In gregarious species such as the House mouse, a dominant male can mate with 20 females in 6 hours if their cycles are synchronized. The odor of urine of adult sexually mature male rodents (e.g. mice, voles, deer mice) accelerates not only the peak of female sexual receptivity but also the onset of sexual maturity in young females, and brings sexually quiescent females into breeding condition. This effect is particularly strong in dominant males, whereas urine from castrated males has no such effect. It would appear that the active ingredient - a pheromone - is made from, or dependent upon the presence of, the male sex hormone testosterone. Male urine has such a powerful effect that if a newly pregnant female mouse is exposed to the urine odor of a male who is a complete stranger to her she will resorb her litter and come rapidly into heat. If she then mates with the stranger she will become pregnant and carry the litter to term. The odor of the urine of females has either no effect upon timing of the onset of sexual maturity in young females, or slightly retards it. If female mice are housed together in groups of 30 or more and males are absent, the normal 4- or 5- day estrous cycles start to lengthen and the incidence of pseudopregnancy increases, indicating the power of the odor of female

urine. However, the presence of the urine odor of an adult male will regularize all the lengthened cycles within 6-8 hours and the females will come into heat synchronously.

Female mice also produce a pheromone in the urine which has the effect of stimulating pheromone production in the male, but the female pheromone is not under the control of the sex glands (ovaries). It is not known what controls its production. A sexually quiescent female could stimulate pheromone production in a male, which would then bring her into sexual readiness.

It is thought that the reproductive success of the House mouse owes much to this system of pheromonal cuing. Although only the House mouse has been studied in such detail, parts of the model have been discovered in other species and it may be of widespread occurrence.

About 8 days after giving birth, female rats start to produce a pheromone - an odor produced in the gut and broadcast via the feces - which inhibits *Wanderlust* in the young. It ceases to be produced when the young are 27 days old and almost weaned.

Finally, some studies have involved a surgical removal of part of the brain which is involved with smell (the main accessory olfactory bulbs). Removal of the bulbs in the Golden hamster, irrespective of previous sexual experience, brings an immediate cessation of all sexual behavior. In sexually experienced rats ,the operation has little effect, but in sexually naive rats the effect is as severe as in hamsters. Thus it appears that rats can learn to do without their sense of smell once they have gained some sexual experience.

a Golden hamster carrying a baby

a house mouse

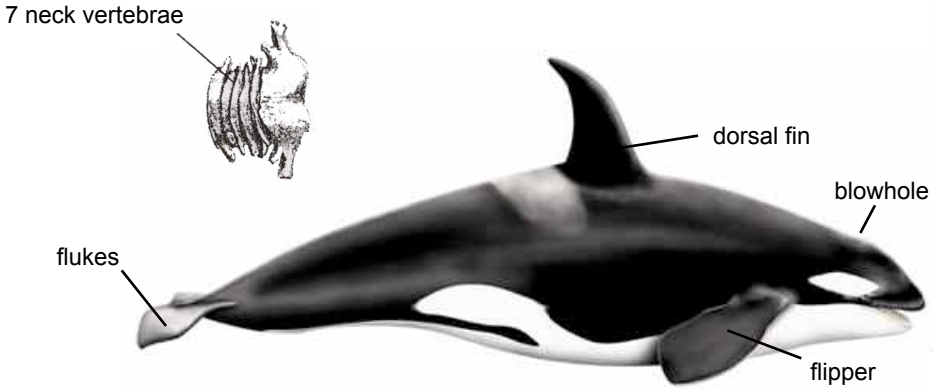
WHALES, DOLPHINS, and PORPOISES

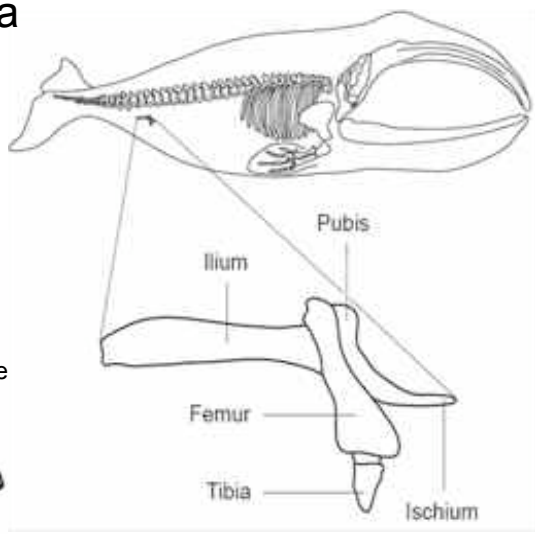
ORDER: CETATEANS

The cetaceans, which total approximately 75 species, are exclusively aquatic, more completely so than any other mammals; at no stage of life do they leave the water. Cetaceans range in size from the gigantic Blue Whale, believed to be the largest animal that has ever existed, to medium-sized dolphins and porpoises, some of which are only about 3 feet long. Typically a cetacean's head is joined to its body without a distinct neck. Except in a few species, the head cannot be turned independently. Characteristic of mammals, however, cetaceans do possess seven neck vertebrae, though much compressed. In some larger whales these are fused into a single disc only a few inches thick.

A cetacean's body is streamlined, and in some species the head is extended into a "beak." Many have a definite dorsal fin consisting of a thick folded ridge of skin without a bony support, adding to their general fishlike appearance. A cetacean's front legs are flippers, with no exposed claws or digits. A much reduced bony structure for a pelvic girdle is still in evidence internally, but external hind limbs are lacking. The tail, which provides the principal driving force for swimming, is extended into a broad horizontal appendage, separated into two flukes by a notch in the middle. The thin skin lacks hairs except for a few bristles around the mouth and on the belly in some species. Underneath the skin is a thick layer of blubber (mostly fat) that serves as a heat insulator as well as a food reserve. Blubber may be 2 feet thick in some of the larger whales and may account for more than 40 percent of the animal's total weight.

a full thickness of blubber from an Orca





Rudimentary pelvic girdle of a whale

BALEEN WHALES

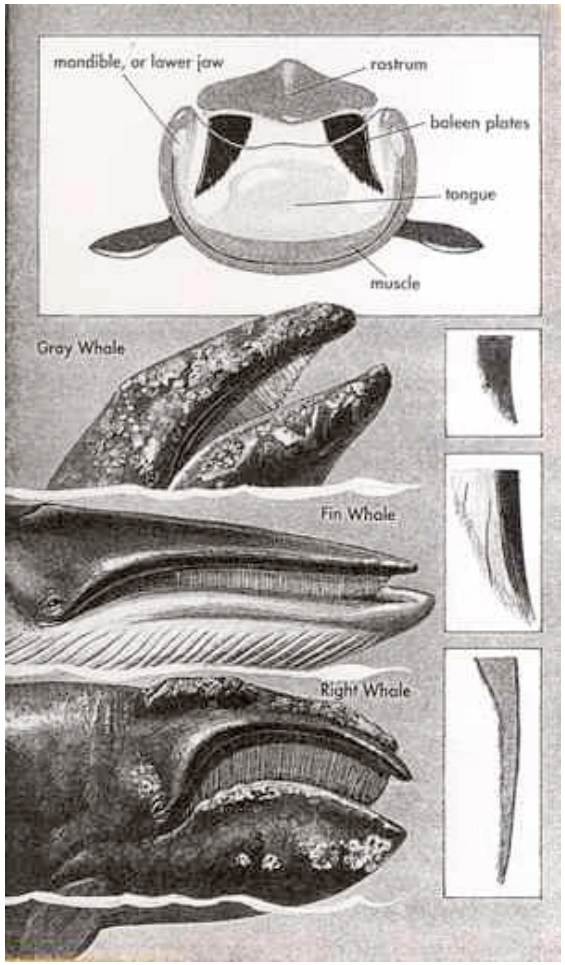
SUBORDER: MYSTICETI

Whales of this suborder (about 15 species) do not have functional teeth. Instead they have baleen, or “whalebone,” frayed, flexible horny sheets of oral epithelium suspended from the hard palate. Made of keratin, baleen can be white, black, yellowish, or two-toned. In a large whale, more than 300 plates of baleen hang down like stiff curtains from the upper jaw on each side of the mouth. A plate may be as much as 12 feet long, and a foot or more in width. The outer edge (or tongue side) is extended into bristles that form a hair-like fringe of thin tubes. Baleen continues to grow throughout the whale’s life, replacing material worn away by the action of water and the tongue.

When feeding, a whale swims into a swarm of small crustaceans with its mouth open. As it closes its mouth, water is forced out at the sides and through the sieve-like screen of baleen. Small crustaceans or even small fish become caught on the bristly fringes. The whale then uses its tongue to move them into its throat for swallowing. Even the largest whale has a throat passageway not much larger than an orange - not large enough to accommodate anything the size of the Bible’s Jonah.

The tough, pliable baleen was one of the highly valued commercial products obtained from whales. It was used in corsets and in similar products in which stiffness with flexibility was important. Today, these products typically use plastics decreasing the need to harvest whales.

Baleen whales can be distinguished from the toothed whales by having two blowholes instead of one. When they blow, the twin spouts are distinctive. In contrast to toothed whales, baleen whales do not echolocate. Instead they often vocalize, such as the unique and complex songs of Humpback whales. Baleen whales are gentle giants of the ocean.



THE BLUE WHALE

The Blue Whale, the largest animal that has ever lived on land or in the sea, can measure more than 100 feet long and weigh as much as 200 tons. Females are slightly larger than the males. A Blue Whale's gigantic head is about a quarter of the animal's total length.

Because of its streamlined body, the Blue Whale appears to be a fast swimmer. Ordinarily its top speed is only about 15 miles per hour, and it can continue swimming at this speed for two hours or longer. Harpooned whales, however, have been known to go twice as fast, though they cannot maintain this faster speed for a long time.

Only a few thousand Blue Whales still exist. Whaling has reduced their numbers from an estimated 250,000. They are now protected by international agreements, but not all countries abide by the regulations. Unfortunately, the regulations are not always based on the best biological data, and represent the interests of whalers as much as, or more than, the welfare of the whales.

Flencing of a sperm whale (stripping the blubber from the body) in 1958.

WALRUSES, SEALS and SEA LIONS

SUPERFAMILY: PINNIPEDIA

Pinnipeds include walruses (Family Odobenidae), earless (true) seals (Family Phocidae), and eared seals (Family Otariida). On land, eared seals are much more agile than the other groups. When moving, the weight of the body is supported off the ground by the outwardly turned foreflippers, and the hindflippers are flexed forwards under the body. When the animal is moving slowly, the foreflippers are moved alternately and the hindflippers advanced on the opposite side. Only the heel of the foot is placed on the ground, the digits being held up. As its speed increases, first the hindflippers and then the foreflippers are moved together, the animal moving forward in a gallop. In this form of locomotion, the counterbalancing action of the neck is very important, the body being balanced over the foreflippers. It has been suggested that if the neck were only half its length, eared seals would be unable to move on land. Walruses move in a similar, though much more clumsy, manner.

On land, true seals crawl along on their bellies, humping along by flexing their bodies, taking the weight alternately on the chest and pelvis. Some, such as the elephant seal or Grey seal, use the foreflippers to take the weight of the body. Grey seals may also use the terminal digits of the foreflippers to produce a powerful grip when moving on rocks. Other true seals, such as the Weddell seal, make no use of the foreflippers. Ribbon and Crabeater seals can make good progress over ice or compacted snow by alternate backwards strokes of the foreflippers and vigorous flailing movements of the hindflippers and hind end of the body, almost as though they were swimming on the surface of the ice.

Sea lion (eared seal) on land supporting weight with foreflippers and hindflippers turned out for walking.

Weddell seals (true seal) on land with full weight on torso.

Station 2. Aquatic Adaptations

Grooming, which is an important subsidiary function of the limbs, is generally carried out by the hindflippers in eared seals and by the foreflippers in true seals. How the Ross seal, which has practically no claws, grooms itself is a mystery.

The anatomical differences of eared and true seals is also reflected in different swimming techniques. The main source of power in the eared seal comes from the front end of the body, and it is here that the main muscle mass is concentrated. True seals, on the other hand, have their main muscles in the lumbar region. The muscles of the hindlimb itself are mainly concerned with orientation of the limb and spreading and contracting the digits. They propel themselves forward by moving their hind flippers left and right.

Sea lion (eared seal, note the ears in the photo) swimming, with most of propulsive force coming from its hindlimbs.

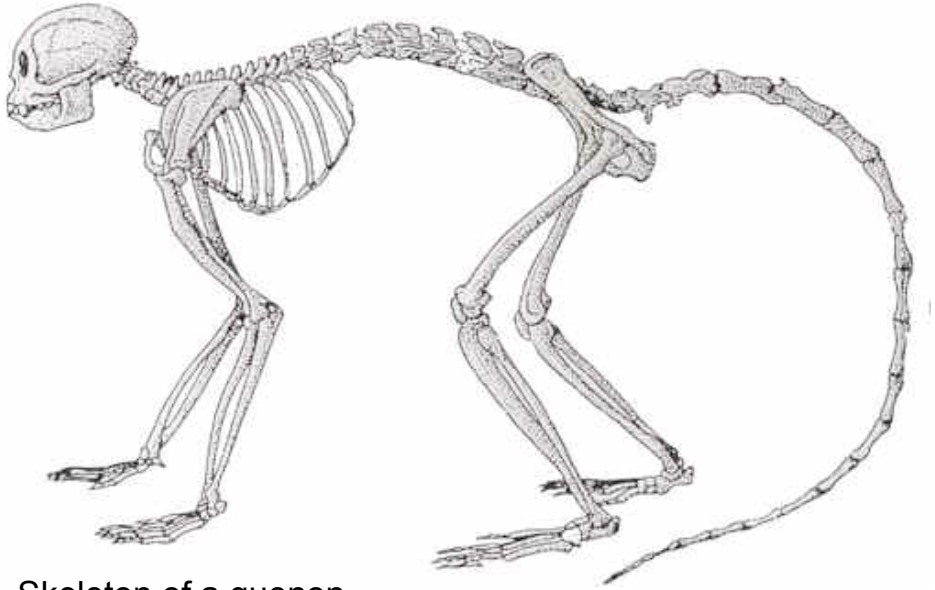
A Grey seal (earless/true seal) swimming, with most of propulsive force coming from its lumbar region and hind flippers.

SKELETAL ADAPTATIONS of PRIMATES

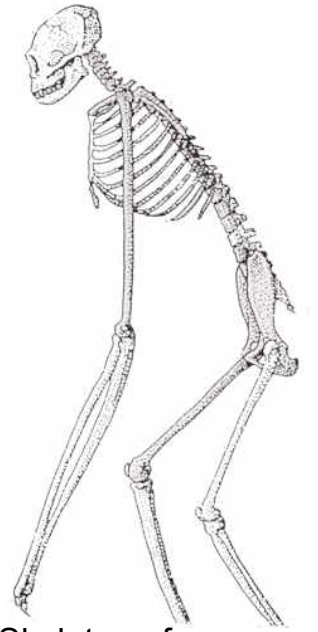
BIPEDAL vs. ARBOREAL

Skeletons: The quadrupedal lemurs and most monkeys, like the guenons, retain the basic shape of early primates - a long back, a short, narrow rib-cage, long narrow hip bones, and legs as long as or longer than the arms. Most live in trees and move about by running along or leaping between branches. Their long tail serves as a rudder or balancing aid while climbing and leaping. Ground-living monkeys, such as the baboons, generally have more rudimentary tails.

Neither apes nor the slower-moving Prosimians have tails. In the orangutan and other apes, the back is shorter, the rib cage broader and the pelvis bones more robust - features related to a vertical posture. Arms are longer than legs, considerably so in species, such as the gibbons and orangutan, that move by arm-swinging (brachiation). Further dexterity of the hands has accompanied the development of the vertical posture in apes, some of which (and more rarely some monkeys) may at times move about bipedally like man.

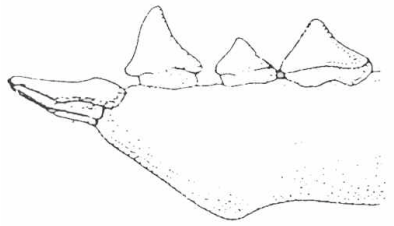


Skeleton of a guenon



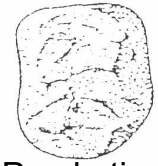
Skeleton of an orangutan

BODY PLAN of PRIMATES



Lemur

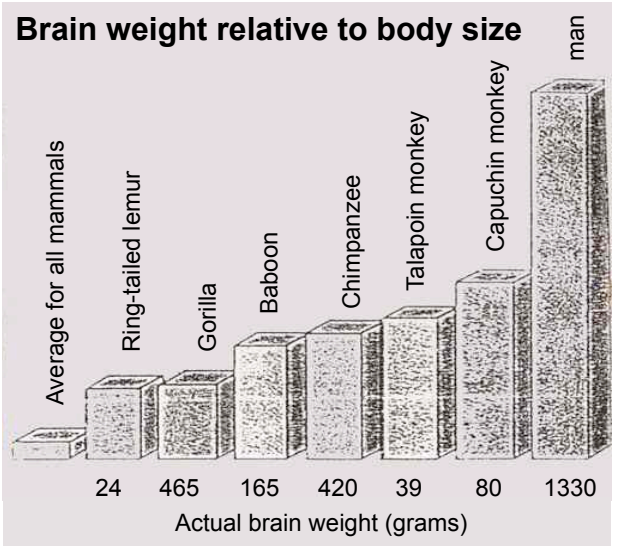
Teeth: Insectivorous precursors of primates had numerous teeth with sharp cusps. In Prosimians (lower primates) such as Lemur, the first lower premolar is almost canine-like in form, while the crowns of the lower incisors and canines lie flat to form a tooth-comb, as in bush babies, which is used in feeding and grooming. In leaf-eating monkeys of the Old World, such as Presbytis, the squared-off molars bear four cusps joined by transverse ridges on the large grinding surface that helps break up the fibrous diet. In apes such as the gorilla, the lower molars have five cusps and a more complicated pattern of ridges.



Presbytis

Gorilla

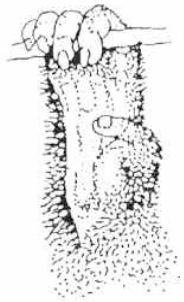
Relative brain size: The degree of flexibility in the behavior of a species is related to both absolute and relative brain size. It is no surprise that in terms of actual brain weight, the great apes are closest to man. But when comparison is based on brain size relative to body size it is the versatile Capuchin monkey that turns out to be closest to man.



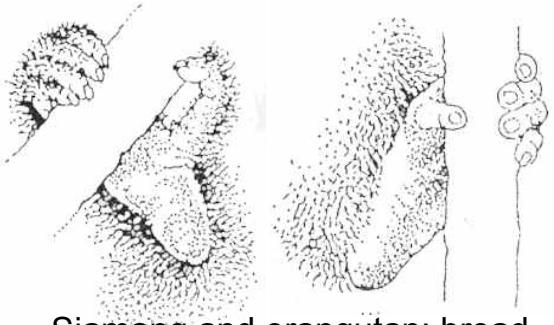
BODY PLAN of PRIMATES

Hands and feet: The structure of primate hands and feet varies according to the ways of life of each species.

Baboon: long slender foot of ground-living monkey.

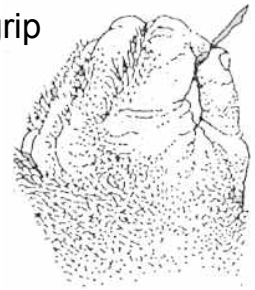


Gibbon: short opposable thumb well distant from arm-swinging (brachiating) grip of fingers.



Siamang and orangutan; broad foot with long grasping big toe for climbing.

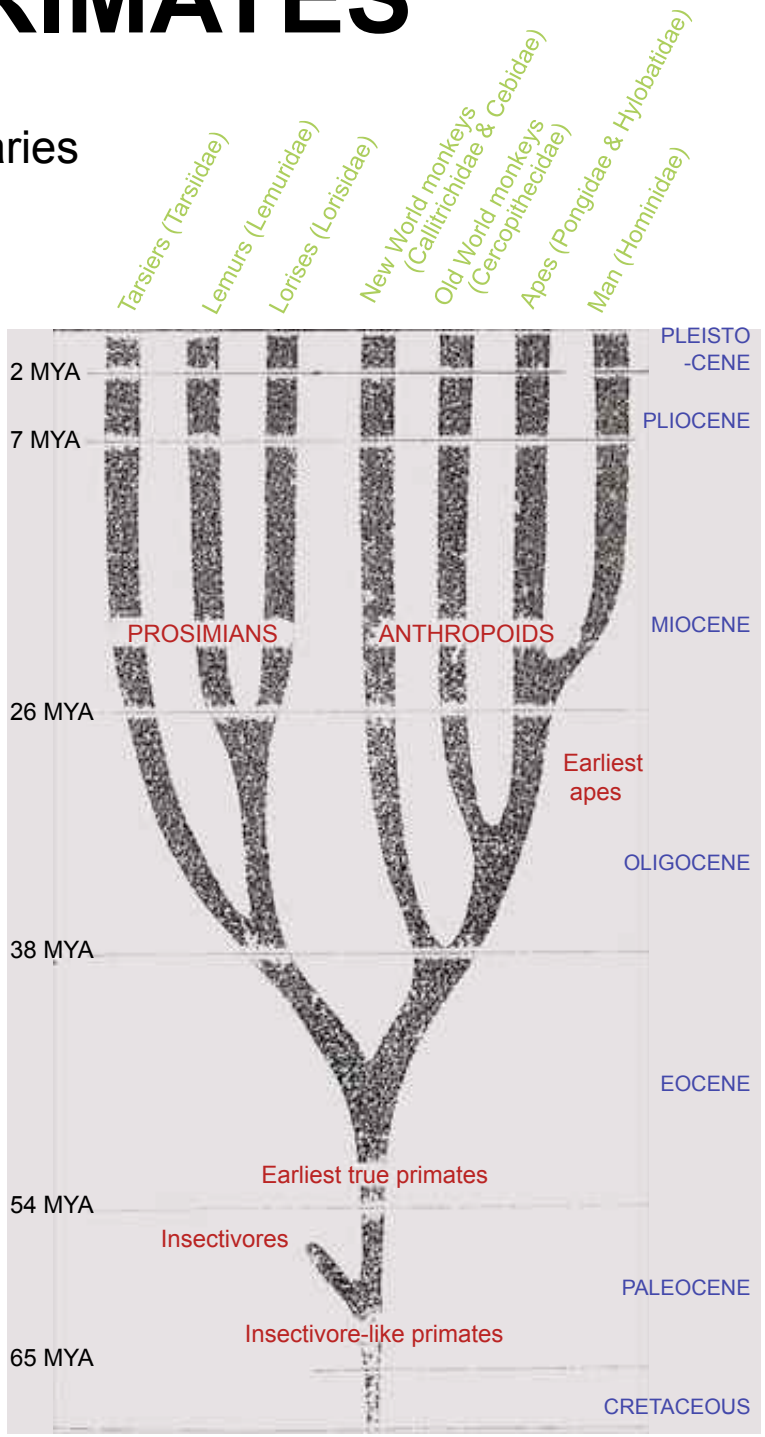
Macaque: short opposable thumb in hand adapted for walking with palm flat on ground.



Gorilla: thumb opposable to other digits, allows precision grip.

Hand of a spider monkey, showing the much reduced thumb of an arm -swinging species.

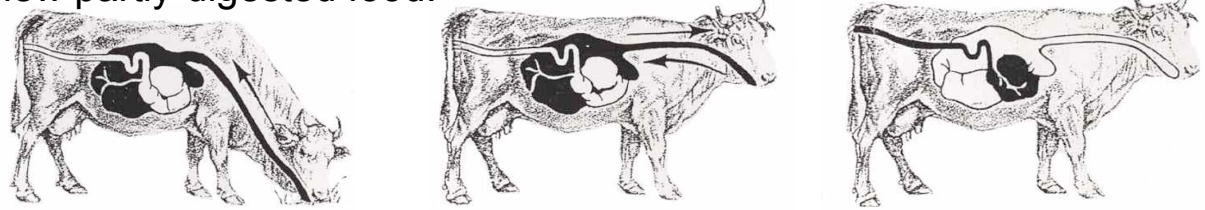
Tamarin: long foot of branch-running species with claws on all digits except big toes for anchoring (all other monkeys and apes have flat nails on all digits)



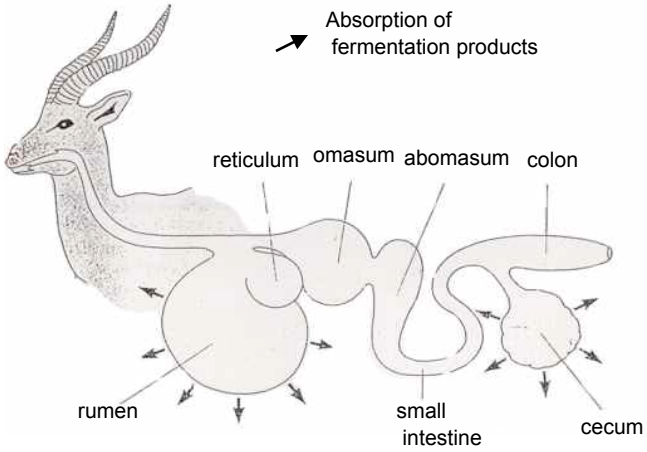
UNGULATES

Ungulates ("hoofed animal") are mammals that use the tips of their toes, usually hoofed, to sustain their bodyweight while moving. They comprise the majority of large land mammals. In addition to hooves, most ungulates have reduced canine teeth, bunodont molars (molars with low, rounded cusps), and an astragalus (one of the ankle bones at the end of the lower leg) with a short, robust head. Another characteristic of most ungulates is the fusion of the radius and ulna along the length of the forelimb. This fusion prevents an ungulate from rotating its forelimb.

Even-toed ungulates' (Artiodactyla) weight is borne roughly equally by the third and fourth toes. The appearance and spread of coarse, hard-to-digest grasses favored the development of their complex digestive systems. Pigs and hippos have short legs, four toes of fairly equal size, simpler molars, and canine teeth that are often enlarged to form tusks. Camels and ruminates tend to be longer-legged, walk on the central two toes, and have more complex teeth suited to grinding up tough grasses. They have a multi-chambered stomach called a rumin, which allows them to digest cellulose with the aid of fermenting microorganisms. Ruminates (cattle, goats, deer) "chew the cud", which means they regurgitate and rechew partly-digested food.

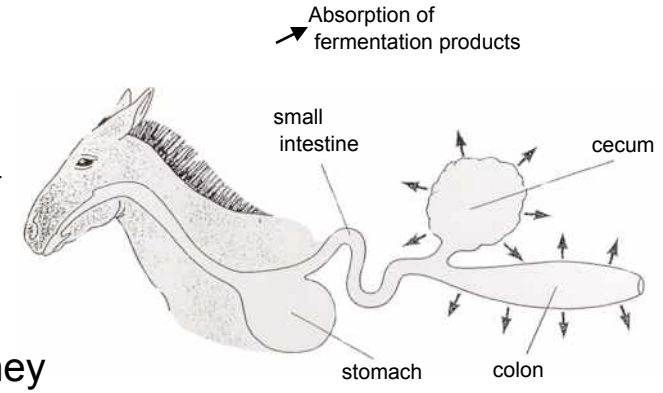


The progress of food through the four stomach chambers of a cow is indicated in black. The vegetation is swallowed after being only partially chewed. It goes into two connecting chambers, the rumen and the reticulum, where it is broken down into pulp by bacteria and then regurgitated as cud. After rechewing, it is passed to the other two chambers, the omasum and the abomasum where it is worked on by gastric juices before entering the intestine.



Food is chewed several times. It takes approximately 80 hours for digestion, and about 60% of the cellulose is used.

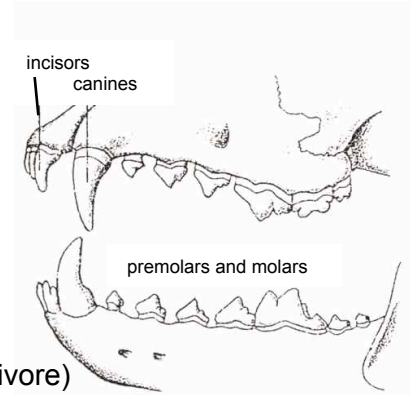
Odd-toed ungulates (Perissodactyla) are hindgut fermenters; that is, they digest plant cellulose in their intestines rather than their stomach. They include fast runners with long legs and only one toe like the horse, zebra, and donkey, as well as heavier, slower animals with several functional toes like tapirs and rhinoceroses.



Food is chewed once. It takes about 48 hours for digestion, and about 45% of the cellulose is used.

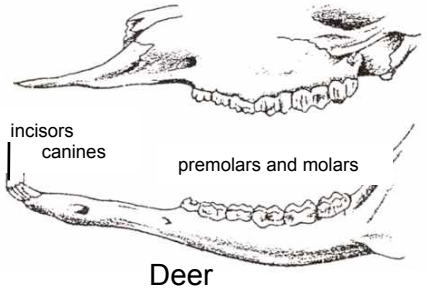
MAMMAL TEETH

Diet greatly influences teeth form and function. Carnivores have large, sharp canine teeth used for stabbing and tearing meat. Their premolars and molars have been adapted for shearing rather than grinding.



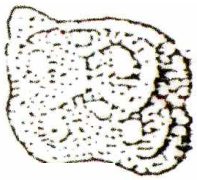
Wolf
(carnivore)

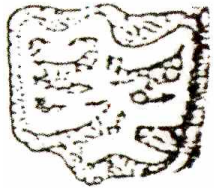
Ruminates have teeth adaptations for grinding grasses. Primitive herbivorous mammals have molars with separate cusps (bunodont), designed to pulp and crush relatively soft food. Fibrous vegetation is tough and ungulates have developed modifications of the bunodont pattern. In addition to their bunodont molars, these grazers have replaced their canines and incisors in the upper jaw with a horny pad. They use this together with the lower front teeth for cropping vegetation.



Deer
(ruminate)

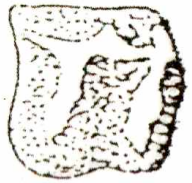
Bunodont molar seen in pigs.

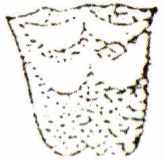




In horses the lophs are very complex and folded (hypsodont).

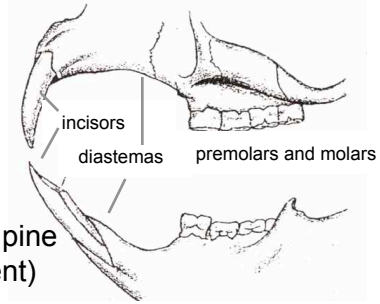
In perissodactyls, such as the rhinoceros, shearing edges (lophs) have formed by a coalescing of the cusps to form two crosswise lophs and one lengthwise (lophodont).





In ruminant artiodactyls, such as the ox, the cusps take on a crescent shape (selenodont)

Rodents have no canines at all. The gap left by their absence is called the diastema. Rodent's most prominent teeth are long, self-sharpening incisors used for gnawing. Mouse-like rodents lack premolars, but squirrel- and cavy-like rodents have one or two on each side.

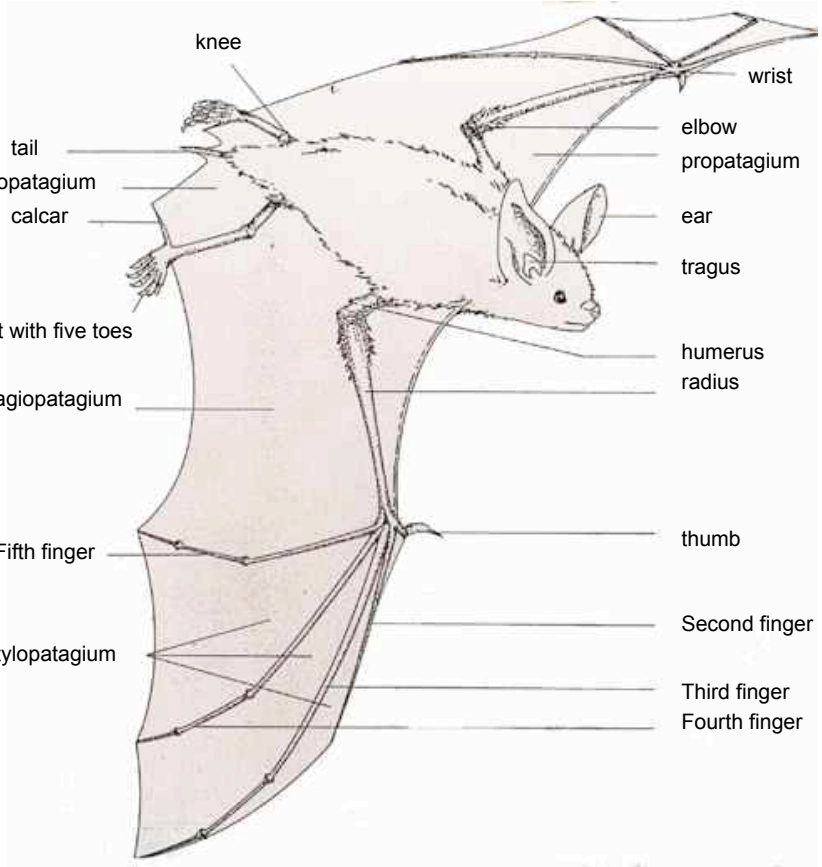


Porcupine
(rodent)

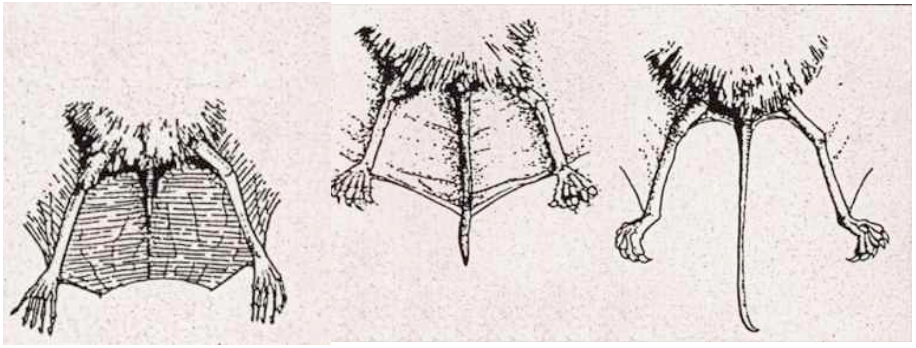
CHIROPTERA

There are two suborders of bats: megabats and microbats. The major distinctions are that:

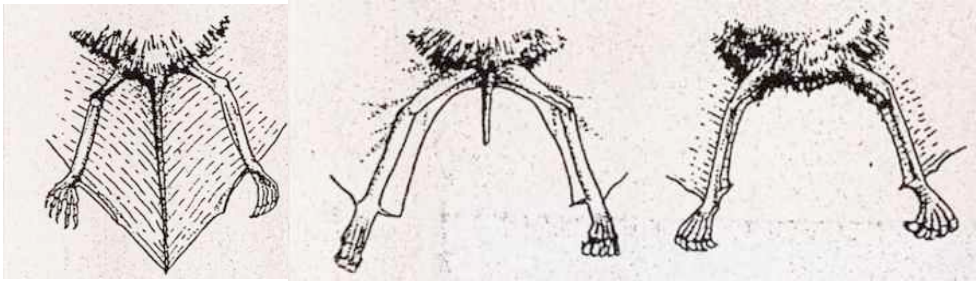
* Microbats use echolocation, whereas megabats do not (except for Rousettus and relatives).
* Microbats lack the claw at the second toe of the forelimb.
* The ears of microbats do not form a closed ring, but the edges are separated from each other at the base of the ear.
* Microbats lack underfur; they have only guard hairs or are naked.
* Megabats eat fruit, nectar or pollen while microbats eat insects, small amounts of blood, small mammals, and fish.



Major variations in the tail shape of bats:



Sheath-tailed bat | Free-tailed bat | Mouse-tailed bat



Mouse-eared bat | Tube-nosed fruit bat | Flying fox

FEEDING TYPES: Bloodsuckers and Nectar Drinkers

In evolution, the “success” of a species or group of species is measured by its ability to survive. Survival is made more likely by a process known as adaptive radiation - the branching out of a group of animals into a variety of niches not previously occupied. Bats started out as insect eaters, and although the majority are still insectivorous, there are now bats that live on fruit, fish, nectar, blood, rodents, frogs and even other bats. With this great variability in their way of life, bats have become the second largest mammalian order and are now spread over most of the globe.

A fringe-lipped bat eating a túngara frog. These bats learn socially the call of new prey frogs through acoustic cues.

An Epauletted fruit bat feeding on wild figs.

A nectar eating bat’s tongue can be as much as 150% as long as its body - the longest of any mammal. Nectar droplets cling to the tip of the tongue when it is withdrawn from a flower.

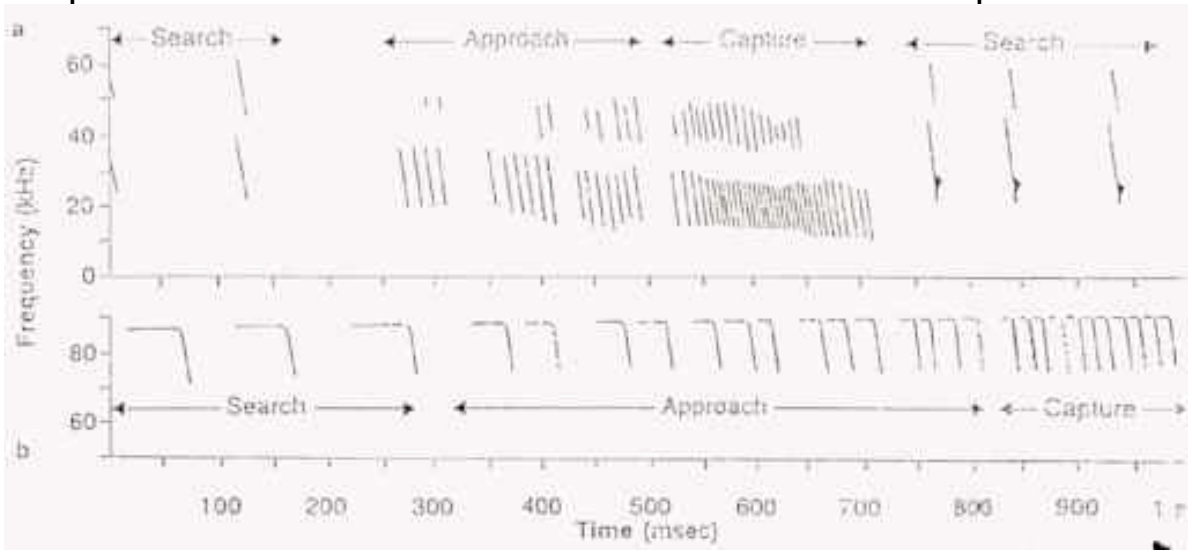
Vampire bats gently scrapes the skin of sleeping mammals and birds, and laps up the oozing blood.

INSECTIVORY AND ECHOLOCATION

Sonograms show the search, approach and terminal phases of the hunt in two species of bat.

(a) The North American big brown bat produces frequency modulated (FM) calls steeply sweeping from 70-30 kHz. While foraging the bat emits 5-6 pulses per second, each of about 10 milliseconds (msec) duration until an insect is located. Immediately the pulse rate increases, duration shortens, with the frequency sweep starting at a lower frequency. As an insect is caught (or just missed) the repetition rate peaks at 200 per second, with each pulse lasting about 1 msec.

(b) Hunting horseshoe bats produce their long (average 50 msec) constant frequency (CF) calls at a rate of 10 per second. They often feed among dense foliage. A problem facing a bat is how to distinguish fluttering insect wings from leaves and twigs oscillating in the wind. While foliage produces a random background scatter of echoes, the insect with a relatively constant rapid wing beat frequency will appear like a flashing light to a bat using a CF component. As the bat closes on the insect, the CF component of each pulse is suppressed in amplitude and reduced to under 10 msec while the amplified terminal FM sweep is used for critical location and capture of the prey.



A Greater horseshoe swoops on a butterfly. Such a battle is not necessarily one-sided. Some moths and butterflies have evolved listening membranes that detect the bat's sonar pulses giving the moth opportunity to escape. To counter this some tropical bats only send out signals at wavelengths that cannot be detected by the moths.