

# Phylum Chordata - Vertebrata

## Mammals

relatively small group

4800 species

~half # of birds; ~1/5<sup>th</sup> # of fish species

today, is one of most successful group of vertebrates

**Cenozoic** = age of mammals

occupy every major habitat on earth

**size:**

most massive of **all** animals today or that ever existed

blue whale → 105', to 150 tons

blue whale, *Balaenoptera musculus*,

Mature blue whales typically measure anywhere from 75 feet (23 m) to 100 feet (30.5 m) from head to tail

and can weigh as much as 150 tons (136 metric tons).

The largest blue whale on record is a 110' female that weighed 195 tons (177 tonnes).

their bulk is several times greater than the largest dinosaur

elephants are largest land mammal

11' tall, 14,500 lbs (=6,590 kg)

smallest mammals:

pygmy shrew → ~0.1oz (4 cm, few grams)

Kitti hognosed bat → 0.05 oz (1.5 g)

mammals are also the vertebrate group most affected by human activities:

- domestication
- food
- clothing
- beasts of burden
- pets
- research
- education
- hunting
- alien animals
- pleistocene extinctions
- modern extinctions

## **Unique mammal characteristics:**

hair

set of middle ear bones

large brain with unique neocortex

muscular diaphragm

highly developed sense of smell

vascular placenta

specialized teeth and jaw muscles

## **Origin of Mammals**

mammals developed from mammal-like reptiles  
(therapsids; from synapsids) >200 MY ago

mammal-like reptiles share many skeletal features  
with mammals

- legs held closer to body  
not splayed out as in most reptiles  
→faster more agile
- decreased stability due to new gait lead to  
increased development of cerebellum for  
muscle coordination
- palate separates nasal and mouth cavities
- many reptiles had hair (none today do)
- some were warm blooded

but:

mammals have lower jaw consisting of a single  
bone with articulation between jaw and  
squamosal bone

mammal-like reptiles lack this articulation

mammals diversified and expanded soon after  
dinosaurs went extinct

may have been 2 separate lines of mammal origin & evolution:

**prototheria** → egg laying mammals; poor thermoregulation

**theria** → all others

when dinosaurs vanished near beginning of Cenozoic mammals diversity greatly increased

mammals were agile, warm blooded, well insulated, suckled young, more intelligent

moved into habitats vacated by dinosaurs

## **Skin & derivatives**

skin is thicker and more complex than in other vertebrate groups (or any other animal)

- thicker layers esp dermis (hide=leather)
- many different glands
- sensory structures
- hair

### **a. Hair**

body covered with complex layer of skin with **hair (fur)**

today, especially characteristic of mammals

- in past, some reptiles had fur and/or feathers

grows from follicle in epidermis and dermis

- cells at base of follicle produce hair

when it reaches a certain length, it stops growing

made of **keratin** (protein)

- same as nails, claws, hooves, feathers of birds and scales of reptiles and birds

most mammals have two kinds of hair:

#### **underhair**

- dense and soft for insulation

→ traps layers of insulating air

in aquatic mammals (fur seal, otter, beaver)  
its almost impossible to *wet* skin

## **guard hair**

coarse and long

protection against wear

coloration

some also have hair modifications:

### **a. defensive hairs**

eg. porcupines, hedgehogs

### **b. horny or bony plates**

eg. armadillo, pangolins

### **c. some have lost most of their fur**

eg. hippos, elephants, porpois,us

## **shedding (molting)**

in most mammals entire coat is periodically molted

eg. foxes and seals → 1x/yr

eg. most have 2 annual molts

spring → replaced by thinner hairs

fall → replaced by thicker hairs

in humans hair is shed and replaced  
continuously throughout life

## **coloration of hair:**

### **camouflage**

protective camouflage:

eg. arctic

→ white

eg. outside arctic

→ somber colors

disruptive camouflage

eg. leopard spots

eg. tiger stripes

eg. fawn spots

### **warning**

eg. skunk

## **modified hairs:**

bristles of hogs

spines of porcupines

vibrissae (whiskers) → tactile, sensory hairs

## **b. horns and antlers:**

horns or antlers are found in only 5 families  
of ungulates:



Rhinoceri  
cattle, sheep, goats, etc  
pronghorns  
moose, caribou, elk, deer

[virtually all even toed ungulates with ruminant (4-chambered) stomachs have horns or antlers]

## **1. horns**

esp cattle, sheep, goats, rhinos, etc

unbranched

horns originated early, >100M yrs ago, in large reptiles

hollow sheaths of keratinized epidermis  
(same as hair, scales, feathers, claws, nails, hooves)

surrounds bony core

grow continuously throughout life

not normally shed; do not regenerate if cut off

usually used as a weapon for protection

eg. only pronghorn seasonally sheds its horns

eg. rhino horn has been collected for >1000 yrs

## **2. antlers**

esp deer, caribou, moose, elk

antlers originated in mammals ~50M years after horns

entirely bone, no keratinized layer covering it

tend to be large complex and ornate

used mainly for sexual display during mating season

sometimes require a significant investment in resources  
to grow them (esp. large amounts of minerals)

eg. moose or elk need 50lbs of Calcium/season to  
grow them

eg. antlers of irish elk weighed more than the rest  
of its skeleton; 3 M across, 154 lbs

living tissue; sensitive to touch and pain

develop beneath highly vascularized sheath= **velvet**

velvet dropped off after breeding season

### 3. Giraff Horns

antler-like but retain skin covering; are not shed

## c. Glands

mammals have a great variety of skin glands

the glands confer some of the most important  
mammalian traits

### 1. sweat glands (eccrine glands)

→important in warmbloodedness; temperature control

esp on hairless regions; eg foot pads  
simple, tubular, highly coiled  
only mammals have sweat glands  
heat regulation

part excretory organ

## 2. **scent glands & apocrine glands**

→ smell important in most mammal social behaviors

almost all mammals, inc humans  
their location and function vary greatly  
used for communication:

- territory
- warning
- defense
- mating

## 3. **oil (sebaceous) glands**

associated with hair follicles  
used to keep skin and hair pliable and waterproof

## 4. **mammary glands**

→ parental care; secrete milk

all mammals feed their young milk  
all females; rudimentary in males  
probably modified sweat glands  
in all female mammals  
rudimentary in males

## **Skeleton & Support**

each species has a typical adult size

→ skeleton doesn't keep growing throughout  
life as in amphibians and reptiles

4 limbs for locomotion (=tetrapods)

→ **pectoral** & **pelvic** appendages

most have fore and hind limbs similar

limbs are up under the body  
not sprawled out to the sides

→ much more efficient movement than other  
land animals

many mammals walk more on their toes

→ greater speed for both predators and prey

often smaller mammals can move at same speed  
as larger mammals

eg. horse vs greyhound

(but larger need more powerful limbs and muscles)

predators tend to have retractable claws

## **Muscles & Movement**

mammals display a wide variety of movements other  
than walking and running:

### **hopping**

provides sudden bursts of speed and quick changes of  
direction

at high speeds, the metabolic act of hopping is

much lower than that of running on all 4's

eg kangaroo

## **brachiation**

tree life

arms longer than legs

eg. primates

## **burrowing**

limbs are short and powerful

eg. badgers, marmots, moles

have very large ears to pick up sounds

## **flying**

only bats

moved into niche largely unoccupied by birds

→ night flying

for wing, skin is stretched between elongated fingers and attached to legs and tail

beats up to 20x's/second

use echolocation to avoid objects and find prey

emit high frequency sound waves that bounce off objects and return

→ can detect distance from objects

bats generally have large ears to pick up sound  
a few bats don't use echolocation  
large eyes & good sense of smell  
feed on fruits & nectar  
some bats migrate up to 500 miles annually

## **gliding**

generally nocturnal  
can travel 40-50 M at a time  
"flying" squirrels, marsupials, lemurs

## **Feeding and Digestion**

teeth more than any other physical characteristic  
reveal the life habit of a mammal

all but a few mammals have teeth

eg. monotremes, anteaters, some whales

most other vertebrates continuously replace teeth as  
needed

mammals typically have 2 sets; **milk teeth** &  
**permanent teeth**

earliest mammals were **insectivores**

→teeth were all the same peglike shape

as mammals diversified teeth became **specialized** for different lifestyles and feeding types

<b>incisors</b>	→ snipping and biting
<b>canines</b>	→ piercing and holding
<b>premolars</b>	→ shearing and slicing
<b>molars</b>	→ crushing and chewing

the digestive system may also be modified in various ways determined by their diet:

- a. **herbivores** (horses, deer, antelope, cattle, sheep, goats, many rodents, rabbits and hares)

canines reduced or absent

large flattened grinding teeth (molars)

require lots of plant food for nutrition since most of it is "indigestible"

eg. elephant = 4 tons eats 300-400 lbs/day

often have **symbiotic bacteria** and microorganisms that can produce enzymes to digest plant material

long large digestive tract

large **caecum** and **stomach**

eg. ruminants (cattle, bison, goats, sheep, deer, giraffe)

food is bitten off and swallowed, at first - not chewed,

food is periodically regurgitated and chewed then reswallowed

have 4 chambered stomachs with 1 way valves  
**rumen** → bacterial action → cud  
**reticulum** → fermentation  
**omasum** → water soluble foods absorbed  
**abomasum** → pepsin & HCl

**rumen:** >30B bacteria/oz of rumen material and 1000-100M protists/oz

forage remains in rumen up to 36 hrs

**omasum:** undigested portion passes to omasum via reticulum

omasum is a holding chamber → soluble nutrients are absorbed and large particles are prevented from proceeding further

**abomasum:** after screening and absorption food passes to abomasums → functions as our stomach: secretes pepsin and HCl; also digests microbes that accompany food

eg. rabbits and many rodents eat their fecal pellets giving food a **second pass** through the digestive system

b. **carnivores** (foxes, dogs, weasels, wolverines, cats, etc)

biting and piercing teeth



long **sharp canines** and **incisors**

powerful claws and limbs

much shorter digestive tract

smaller or no caecum (part of lg intestine)

C. **omnivores** (pigs, raccoons, many rodents, bears, most primates including us)

teeth lack extreme adaptations of herbivores and carnivores

d. **insectivores** (moles, shrews, anteaters, bats)

eat larval and adult insects

some mammals **store food** for winter

→ collect nuts, seeds, fungi, etc

eg. all tree squirrels, chipmonks, gophers

eg. some mice

the **amount of food** a mammal must consume is inversely proportional to its size

→ generally smaller animals need more food per gram body weight than do larger animals

eg. a 3 g mouse consumes 5x's more food **per gram body weight** than a 10 kg dog

and 30x's more than a 5000kg elephant

eg. small shrews, bats and mice must spend much more time hunting and eating than large mammals

eg. a shrew must consume its weight in food each day; it will starve to death in a few hours if it stops feeding

eg. large carnivores can easily survive on 1 meal every few days

eg. average (100 ton) blue whale requires ~ 2 tons a krill (2% body wt) daily for sustenance

## **Respiration**

mammals are **warm blooded** (endothermic & homeothermic) and therefore have a relatively high metabolism and therefore a high oxygen demand

all mammals have **lungs** and breathe air

whether terrestrial or aquatic

lungs are very efficient, second only to birds

→ contain **alveoli** → blind ended sacs surrounded by capillaries

→ provide much greater surface area for gas exchange

eg. humans: 760 sq ft (~tennis court)

mammals also have a **muscular diaphragm** which  
"sucks" air into the lungs

much more efficient than gulping air or  
expanding chest cavity

## **Circulation**

mammals have 4 chambered heart

→ completely separates the two circuits of blood  
flow

## **Nervous System**

relatively large, highly developed brain

→ disproportionately larger per body wt

well developed cerebrum

cortex is folded to increase surface area

→ more intelligent

→ capable of complex social behaviors

cerebellum also larger & folded

## **& Senses**

### **a. vision**

**vision** and **hearing** well developed in most mammals

moveable eyelids

vision especially good in daytime predators

## **b. hearing**

fleshy external ears

hearing adaptations:

### **eg. bats**

#### **echolocation**

emit high frequency sound waves that bounce off objects and return

→ can detect distance from objects with the information

→ avoid obstacles in dark

human limit = 20,000Hz; bats 30-100,000Hz

10/sec to 200/sec if prey near

bats have very large ears to receive signals

bats have also been found to be able to sense the earth's magnetic field like birds. The only other mammal known to be able to do this are the naked mole rat and Siberian hamsters

### **eg. whale communication**

low frequency "songs" for communication  
low frequencies travel well through water

explosive sounds  
stuns or kills fish

toothed whales have highly developed echolocation

not emitted by larynx; originates near blow hole

produce clicks that are focused by "melon" in forehead

return sounds perceived through lower jaw

### **c. touch**

moles feel their way through their burrows with  
their noses

eg. star nosed mole

### **Excretion**

**kidneys** effectively filter blood to remove waste  
products

→ usually urea

kidneys also very effective at maintaining salt/water  
balance

### **Reproduction**

dioecious, internal fertilization, bear live young

nurse young with milk → mammary glands

most mammals have definite mating season

usually winter or spring

usually limited by female estrous (ovulation; in heat)

female advertises receptivity by distinctive visual, behavioral or pheromonal signals

a few mammals (eg some primates) females show no obvious signs of ovulation and are receptive year round

= concealed ovulation

3 patterns of reproduction

characteristic of the three major mammal groups:

## **1. egg laying**

monotremes

produce thin leathery shell

→ no pregnancy (gestation)

after hatching, young are fed milk

## **2. marsupials**

brief gestation

then crawl to pouch and attach to nipple

= embryonic diapause

### 3. Placental mammals

relatively long gestation period

eg. mice → 21 d  
rabbits → 30 d  
cats/dogs → 60 d  
cattle → 280 d  
elephants → 22 mo

## Hibernation

## Migration

migration is much more difficult for mammals than for birds

walking requires much more energy than swimming or flying

<b>Energy Consumption/kg body wt/km:</b>	
<b>swimming:</b>	0.39 kcal (salmon)
<b>flying:</b>	1.45 kcal (gull)
<b>walking:</b>	5.43 kcal (squirrel)

only a few mammal migrate  
most of these are in N. America

**eg. caribou**

migrate 100-700 miles (160-1100 km) twice/yr

**eg. plains bison**

**eg. seals**

northern fur seals → 1740 miles (2800 km)

**eg. whales**

gray whales → 11,250 miles (18000 km); twice/year

the oil with which they store energy makes them more buoyant and poor heat conductor

**eg. a few bats migrate**

Mexican free tailed bats in Austin



# Classification of Mammals

3 major mammal groups identified by the type of **gestation**

also, mammals have developed a great variety of **teeth types** for eating many different kinds of foods

→ individual teeth, esp molars can often identify the species of mammal

## 1. Monotremes

(single hole or opening for reproductive, urinary and digestive systems)

reptilian structure

horny birdlike beak for mouth  
lost all traces of teeth

lay eggs

in Australia only

### **eg. platypus**

aquatic  
muskrat habitats  
false marsupium

### **eg. echidna**

ant eater

has pouch for young

## 2. Marsupials

eg. possums, kangaroo, koala

very short gestation period

eg. opossum → 12 days

abdominal pouch for rearing young

mainly Australia, Tasmania, New Zealand

diversified into niches taken by other kinds of mammals in the rest of the world:

Tasmanian devil

Tasmanian wolf

Marsupial moles

bandicoot

weasel

wolf

moles

rabbit

opossum only marsupial in Americas

## 3. Placental Mammals (Eutherians)

most successful group

increased reproductive investment

→ relatively long gestation period

→ lots of parental care

placental mammals are subdivided into orders based on teeth and skeletal characteristics

# Some Kinds of Placental Mammals:

## a. insect eating mammals

usually small animals

eat mainly invertebrates, esp. insects

all Mesozoic Mammals (age of dinosaurs) were insect eating

earliest placental mammals were insect eating as well

eg. shrews, moles,

## b. carnivores

require keen sensory perception

diet mainly of other vertebrates esp. rodents

at least 1 pr of specialized shearing or carnassial teeth to slice meat

most are medium sized animals

more highly evolved carnivores hunt in packs to get larger prey

compared to herbivores carnivores have a relatively few anatomical and physiological specializations

skeleton needs flexibility and strength

in running forms, feet are lightly built and only toes touch ground

most cats have retractable claws to keep them sharp

brain is usually relatively large & convolutions more complex

eyes give stereoscopic vision

ears have greater frequency range

olfactory senses well developed

eg. dogs, cats, bears,

### **c. Paddlers and Swimmers**

total number of aquatic mammal species is large: 9 orders

aquatic invasion could never have been an easy option to competition on land

heat retention is a major problem for aquatic mammals

→ thermal conductivity of water is 25x's that of air

→ aquatic mammals grow large (less surface to volume ratio-less heat loss)

some are **carnivores** some are **herbivores**

#### **herbivores** (vegetarians)

tend to be less specialized,

browse near shore, none cruise the ocean,

most are large

relatively few in numbers

eg. hippos, sea cows

#### **carnivores**

often large breeding colonies

simplified dentition

some can dive very deep

eg. sea lion can dive to 200 meters

eg. seals, sea lions, otters, walruses,

## **d. Whales and Dolphins**

largest animals that have ever lived

→ blue whale: 30M long 130 tonnes

most specialized of all mammals

→completely adapted to aquatic life except for their need for air

hind limb is absent

forelimbs are short, webbed

bones are filled with oil for floatation and energy reserve

thick fat layer

no sweat glands

large complex brain

communication skills second only to humans

poor smell, poor vision

acute touch and exceptional hearing

large tidal volume (10x's humans)

can extract 10% of O<sub>2</sub> in air (humans use 4%)

average (100 ton) blue whale requires ~ 2 tons a krill  
(2% body wt) daily for sustenance

there are freshwater whales in rivers of India, China and So.  
America

## **e. gliders & fliers**

animals can move through air in 3 ways:

parachute, glide, or fly

gliding: 3 orders - marsupials, lemurs, flying squirrels

flying: bats only

ancient writers: bats were peculiar birds; Pliny called them winged mice; only birds with teeth and bore live young that they suckled with milk

powered flight

echolocation used by insectivores, whales and bats

bats emit and pick up high frequency sounds

most bats 20-80 kHz

sound is produced in larynx and emitted through mouth or nose

returning sound is picked up by ears → ear often large

each bat species has distinctive signal

one nectar eating bat has tongue that extends over 1.5 x's its body length (only chameleons can top that)

## **f. gnawers**

includes largest of orders = rodentia (40% of all mammal species)

most are mouse to rat sized

but some fossil forms were much bigger

all have at least 1 pr of large, curved, continuously growing incisors

→ need to bite continuously to wear them down or would be unable to close jaws

gap (or diastema) behind incisors

eg rodents, lagomorphs, a few extinct orders

### **eg. naked mole rats**

only mammal that lives in colonies like the social insects  
native to Ethiopia, Somalia and Kenya  
3.5" long and weigh 1-3 oz  
pinkish or yellowish wrinkled skin look naked  
live in well organized colonies of 20-30 individuals  
only one pair breeds  
the other males and females belong to 2 castes  
small working castes: dig the burrows and carry food and  
nesting material  
larger working castes: spend most time in nest with breeding  
female; may help defend her and colony  
large communal nest  
has a large communal nest chamber  
with smaller tunnels where animals forage for tubers,  
roots and corms  
all mole rats care for young but only breeding female suckles  
them  
once weaned, the juveniles join the worker caste

### **g. rooters and browsers**

1st great wave of vegetarians

medium to elephant sized creatures

only two groups survive today

feed on tubers

→ food is mashed and ground by cheek teeth

eg. elephants

2nd incisor teeth become tusks for food gathering and  
display

elephant head can weigh 1 ton

eg. moles & elephants

### **h. hoofed herbivores**

even or odd toed; 2 orders perissodactyla and artiodactyla

gut is more complex than that of insectivores and carnivores

microorganisms in gut digest cellulose

many have horns or antlers for defense

domestication of wild animals is one of the greatest achievements of mankind

→ ~7000 BC

eg. horses, rhinos, pigs, deer cattle, antelope,

## **i. primates**

adaptations of primates are mainly anatomical trends related to behaviors

→free and precise hand and forelimb movements

→shift from reliance on smell to vision leads to good spatial perception

→cerebral cortex increased in size and complexity

→lengthening of prenatal and postnatal life required prolonged care of dependent young and allowed time for learning

overall primate evolution shows an increasing dependence on **intelligence** as a way of life



# Orders of Mammals

## Sirenia

- manatees

- ancestors were terrestrial mammals that also gave rise to elephants, hyraxes and possibly aardvarks

- in past were exploited for food eg 1950's 7000 were killed each year in So America for food

- graze on aquatic plants

- much lower metabolism than other mammals their size

- can go 7 months without eating

- reproduction: 1 calf every 2-3 years for 20 years

# Ecological & Economic Impact of Mammals

## 1. Domestication

3.3 billion cattle, sheep and goats worldwide

food and milk

domestication began about the same time as origin of agriculture

dogs might have been first animal domesticated

cattle: domesticated ~8500 yrs ago  
today 1.4 Billion cattle  
1200 distinct breeds

## 2. Pollination & Plant Dispersal

### **bat pollinated**

mainly in tropics  
strong odor  
dull color  
open only at night

### **seeds dispersed in edible fruits**

attracts birds or mammals  
may eat whole fruit or spit out pits  
if swallowed seeds resistant to digestive juices  
squirrels and birds bury fruits and seeds  
nuts stored underground are forgotten

### **seeds passively carried by animals**

hooks or spines to catch in fur or on skin

in mud on feet of birds, etc.  
burs, beggars ticks, devils claw, etc.

### **3. Food and Crop Loss**

rodents and rabbits cause “staggering” amounts of damage to crops and stored food each year

### **4. Sickness & Disease**

rodents & others carry diseases

eg. **bubonic plague, typhus**

eg. **tularemia**: reservoirs; rabbits, muskrats & other rodents(vector=wood tick)

eg. **rocky mtn spotted fever**: squirrels & dogs (ticks)

eg. **lyme disease**: deer (ticks)

### **5. Illegal Trade in mammal products**

2006: 510 sp of mammals critically endangered

**eg. Rhino horns**

used in China to reduce fever & treat heart, liver and skin disease

some breeds on brink of extinction

1970-1997: horns from 22350 rhinos were imported into Yemen alone

### **6. Pollution**

cattle lots, hog farms