Phylum Chordata - Vertebrata
Mammals

relatively small group

4800 species

~half # of birds; ~1/5th # 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 $\rightarrow$ ~0.1oz (4 cm, few grams)

Kitti hognosed bat $\rightarrow$ 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, porpoises

**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:
Animals: Phylum Chordata-Vertebrata; Mammals; Ziser Lecture Notes, 2008

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 of 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 (ecrine 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

et 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*

  \( \rightarrow \) teeth were all the same peglike shape
as mammals diversified teeth became **specialized** for different lifestyles and feeding types

- **incisors** → snipping and biting
- **canines** → piercing and holding
- **premolars** → shearing and slicing
- **molars** → 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 the 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 breath 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

<table>
<thead>
<tr>
<th>Energy Consumption/kg body wt/km:</th>
<th>0.39 kcal (salmon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>swimming:</td>
<td>1.45 kcal (gull)</td>
</tr>
<tr>
<td>flying:</td>
<td>5.43 kcal (squirrel)</td>
</tr>
</tbody>
</table>

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$_2$ 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, Soimalia 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 cast: dig the burrows and carry food and
nesting material
larger working cast: 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. conies & 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
Animals: Phylum Chordata-Vertebrata; Mammals; Ziser Lecture Notes, 2008

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