Phylum Chordata - Vertebrata Mammals

relatively small group

5,100 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

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

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

→secondary palate separates nasal and mouth cavities

→teeth differentiated into incisors, canines, cheek teeth

→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 first appeared 200 MY ago

$\rightarrow$ early Mesozoic
(same time as 1st dinosaurs)

1st mammal:
very closely resembled their reptile ancestors
about size of mouse (or ground shrew)
reptilian skeleton
had sharp teeth
$\rightarrow$ ate insects, worms, fruits, vegetables
large eyes
$\rightarrow$probably nocturnal
warm blooded
(many reptiles were warm blooded then)

for 160 MY they lived in the shadow of the dinosaurs

most were small, shrew-like animals, largest were 3' long.

"suddenly" the dinosaurs disappeared ~65 MY ago

when dinosaurs vanished near beginning of Cenozoic mammals diversity greatly increased

the first modern (placental) mammals appeared and diversified

the most successful group, placental mammals, originated and diversified

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

moved into habitats vacated by dinosaurs and became the dominant "large animals" on land and in sea

→ Dawn of Cenozoic = "**age of mammals**"

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

prototheria → egg laying mammals; poor
thermoregulation

theria → all others

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

hair (fur) replaced scales as main covering for better insulation

some facial hairs (=vibrissae) became sensory in function

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, humans

shedding (molting)

in most mammals entire coat is periodically

molted

eg. foxes and seals → 1x/yr

eg. most mammals 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:

camoflage

protective camoflage:

eg. arctic   → white
eg. outside arctic   → somber colors

disruptive camoflage

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 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 of mammal 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

typically require modifications of bones of the appendages

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, some marsupials, lemurs

Feeding and Digestion

mammals are warmblooded and much more active than reptiles

→require 10-13 x's the food energy as living reptiles and amphibians to maintain the same body mass

teeth

all but a few mammals have **teeth**

eg. monotremes, anteaters, some whales

earliest mammals were **insectivores**

→teeth were all the same peglike shape

today, teeth represent the greatest evolutionary diversification of the mammalian skeleton

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

all major mammal groups can be identified from a single molar
→ often even to species

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

most other vertebrates continuously replace teeth as needed and their teeth continue to grow throughout life

rather than all teeth in the mouth being the same, mammals developed 4 major kinds of teeth

incisors	→ snipping and biting
canines	→ piercing and holding

premolars	→	shearing and slicing
molars	→	crushing and chewing

each set of teeth then became **specialized** for different lifestyles and feeding types

Digestive Tract (GI tract)

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 accompahy 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, chipmunks, 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 mamals

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

smaller mammals with higher metabolism have faster heartrate

> eg. shrews heart beats 760 times/minute (10 x's ours)

Nervous System

relatively large, highly developed brain

> → disproportionately larger per body weight

cerebrum most highly developed in mammals

> unique "**neocortex**" that is folded to increase surface are
>
> > many more interconnections
> >
> > > → more intelligent

→ capable of complex social behaviors

→ behaviors based more on "learning"

cerebellum also relatively larger & folded

allows for more complex movements

Senses

a. smell

the sense of smell is particularly well developed in most mammals

in most olfaction is more important than vision

new (2013) evidence indicates that an improved sense of smell was the first stimulus for an enlarged brain

smell is an integral part of feeding and social activities for mammals

humans are unusual mammals since they have largely lost their sense of smell

eg. dogs have 100 M – 300 M smell receptors in their noses; humans have 6 M

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

sonar (echolocation) is the ability to emit sounds then to detect their return to estimate distances from objects

in general the higher the frequency of emitted sound, the better echolocation works

sonar has evolved in several vertebrates; marine mammals, a few birds and bats

bats seem to have perfected it

bats emit very high frequency sound waves

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

rate=10/sec to 200/sec if prey near

bats have very large ears to receive signals

many insects have evolved defensive measures to avoid bat predation

they have learned to detect the sonar signal of bats and fly defensive patters to avoid them

some use sonar themselves to confuse bats

eg. whale communication

low frequency "songs" for communication

low frequencies travel well through water

can use explosive sounds to stun 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

some fish have adapted to detect and avoid them

c. touch

the sense of touch is also extremely well developed in mammals

the earliest mammals were mainly nocturnal and depended on touch for most social activities

eg. star nosed mole - feel their way through their burrows with their noses

d. detection of earth's magnetic field

bats have been found to be able to sense the earth's magnetic field like birds.

the only other mammals known to be able to do this are the naked mole rat and Siberian hamsters

Excretion

kidneys effectively filter blood to remove waste products

→ usually urea

kidneys also very effective at maintaining salt/water balance

Protection and Defenses

mammals use a variety of methods to protect themselves from predators:

→some have hairs modified into relatively hard outer "shell"

eg. armadillo

→or sharp spines

eg. porcupine

→others may play dead when approached by danger

    eg. opossum

→shrews are one of the few **venomous** mammals

    can send a mouse into a coma (wont hurt us)

Reproduction

most mammals are **dioecious** with **internal fertilization**

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

Courtship Behaviors

In many, especially the larger mammals, courtship begins active competitions between males to demonstrate their strength and fittness to the females

sometimes it's bluster; the animal with the loudest longest call shows he is the most macho

sometimes it's actual battles; eg elk; only in rare cases is one hurt or killed, the challenger will usually back off before then

of all mammals, Bonobo's whole society revolves around sex more than any other vertebrate (even humans)

they use sex as greetings, for solving disputes, making up after fights and as favors in exchange for food

"Chimpanzees and Bonobos both evolved from the same ancestor that gave rise to humans, and yet the Bonobo is one of the most peaceful, unaggressive species of mammals living on the earth today.

They have evolved ways to reduce violence that permeate their entire society. They show us that the evolutionary dance of violence is not inexorable."

all but one small group of mammals are **viviparous** (=bear live young)

mammals generally produce few young but devote considerably parental care to insure their survival

it is rare for parental duties to be shared

usually the female does most of the work

nurse young with milk → mammary glands

some mammals (eg mongoose) give **synchronous birth:**

a females in the group give birth on the same day as the dominant female, regardless of when they became pregnant

subordinate mothers can slip their kids into the communal litter where they will be safer

3 patterns of reproduction

characteristic of the three major mammal groups:

1. **egg laying** (arose ~140 MY ago)

monotremes

most ancient kind of mammals

produce thin leathery shell
→ no pregnancy (gestation)

after hatching, young are fed milk

2. **marsupials** (arose ~130 MY ago)

brief gestation

then crawl to pouch and attach to nipple

= embryonic diapause

3. **Placental mammals** (~65 MY ago)

most recent evolutionary strategy

relatively long gestation period

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

Hibernation

eg. black bears

in winter they can lower their body temperature up to 5.5º C (~15º F) and their total metabolic rate to only 25% of its normal rate. Heartrate drops from 55bpm to 14 irratic bpm's

in spring their metabolism takes several weeks to return to normal

Migration

migration is much more difficult for mammals than for birds

walking requires much more energy than swimming or flying

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

only a few mammal migrate

most of these are in North 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

humpback whales have the longest migration of any mammal; over 5000 miles

migrate to warmer waters to raise their young

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

when mammals began their explosive evolutionary
   radiation 65-70 MY ago Eurasia, Greenland and
   North America were still joined together and
   shared a common fauna

   Africa and Australia were isolated and developed
      their own fauna

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	weasel
Tasmanian wolf	wolf
Marsupial moles	moles
bandicoot	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 carnaissial 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

evolved from an aquatic four legged deer-like creature no larger
than a fox

whales are the 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

deep diving cetaeans can last an hour or more on one breath:
    have considerably more (up to 10 x's more)muscle
        myoglobin than in most land mammals
    these muscles can work much longer anaerobically than in
        most land mammals

hearing is probably more important in cetaceans than any of
    their other senses

whale sonar is extremely precise & can apparently produce a
    mental image as precise as vision can

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; Pliney 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 casts: 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 owrker 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)
>first appeared ~50 MY ago
>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
>>$\rightarrow$ can go 7 months without eating
>
>reproduction: 1 calf every 2-3 years for 20 years

Seals & Sea lions
>evolved ~25 MY ago from 2 different groups; mustelids and
>>ursids, respectively

Rodentia
>40% of all living mammal species are in this order; largest
>>mammal order

Chiroptera (bats)
>20% of all living mammal species are in this order; 2nd largest
>>mammal order

Insectivora
>10% of all mammal species are in this order; 3rd largest mammal
>>order

Primates
>earliest fossils ~65 MY ago

Ecological Roles of Mammals

1. Mammals are important at most levels of the food chain

eg. predatory mammals help to control population sizes of prey species

eg. salmon-eating bears in northern forests play a significant role in fertilizing northern forests with fish remains

eg. many mammals are scavengers and omnivores that help to recycle dead plants and animals

2. Pollination

bat pollinated
mainly in tropics
strong odor
dull color
open only at night

mice, rats, shrews, gerbils

mainly in tropics

visit several of the low-to-the-ground species

"Rodents are attracted by a strong musty odour

they are rewarded with a syrupy sugar which is secreted in large quantities.

In order to prevent birds and insects from stealing this nectar, rodent-pollinated flowers are an inconspicuous brown or black.

the flowers are usually hidden inside the bush at ground level, where they are more accessible.

the center of the flower may be pale white and the tips of
the flowers may be shiny red

→ both serve to guide the rodent to the nectar
in the dark.

3. Seed Dispersal

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.

Human Impacts of Mammals

1. Domestication of Mammals

a. Agricultural Animals

by far the largest use of mammals is as **food**

3.3 billion cattle, pigs, sheep and goats worldwide

cattle:	1.4 Billion	(42 M in US; 24% world use)
pigs:	1 Billion	(97 M pigs in US)
sheep:	1 Billion	(>4 M in US)
goats:	700 Million	
rabbits:	450 Million	
domestic buffalo:	162 Million	

meat and milk, fiber production

694 Million tonnes of milk/yr globally

domestication began about the same time as origin of agriculture

dogs might have been first animal domesticated

sheep were probably first domesticated farm animals (~11,000 yrs ago)

cattle: domesticated ~8500 yrs ago; 1200 distinct breeds

horses: ~5500 yrs ago horses were tamed

b. Pets

>105 Million mammals are sold as pets in US each year

    cats 51 M
    dogs 50 M (300,000-500,000 from puppy mills)
    rabbits 1.4 M
    hamsters 600,000
    guinea pigs 400,000
    gerbils 400,000

can improve physical and mental well being

provide companionship

→especially effective for lonely and depressed

but: up to 20 Million cats and dogs are abandoned each year to starve or be put to sleep

c. Service Animals

horses: 61 Million worldwide

donkeys: 43 Million worldwide

mules: 14 Million worldwide

camels: 19 Million worldwide

llamas & alpacas: 5.5 Million worldwide

seeing eye dogs, search and rescue

military --dolphins

2. Hunting

140 Million wild animals are killed in the US/yr:

60 Million wild mammals are hunted & killed in the US/yr for sport:

> **deer** → 3 M
> **rabbits** → 27 M
> **squirrels** → 32 M
> **bear, caribou, moose, antelope** → 250,000

> for each animal killed at least 2 are wounded

hunting is also having an effect on marine mammals:

while large scale whaling has decreased in the last several decades the consumption of small whales, dolphins and manatees is on the rise in poor nations

largely due to the decline in coastal fish catch and more unintentional kills as bycatch

3. Furskin production

the US is the world's largest volume producer of furskins derived from wild animals

about 30 M/yr mammals are hunted for their fur

provide 85% of furskin production per year worldwide

there are ~150,000 licensed trappers in the US

over 50 million animals are raised in captivity for
their fur in the US each year

mink and fox are the most common furbearing
animals

eg. mink pelt production in the US was 2.6 million
pelts in 2002

4. Zoos

conservation and management of wildlife

breeding programs for endangered and threatened
species

education of general public to value and plight of
wildlife

but many problems in keeping animals in
unnatural captivity

4. Animal By-Products

Many uses of animal products are hidden:

eg. **medicines, film, rubber, ceramics, plastics,
paint, perfumes, glue, explosives, cosmetics,
shaving cream** all contain materials from slaughter
houses

eg. **cellophane** → made with animal fats

eg. **freon**→ animal fats used to make it

eg. makers of **synthetic fibers** use tallow based products
  to control static cling

eg. animal based **lubricants** are used in jet engines
   → all flying miles are animal based

eg. used in **corrosion inhibitors** for oil pipelines

eg. **cars** manufacture alone:
  galvanized steel body, fan belts, gaskets, anti freeze,
  hydraulic brake fluid, battery, steering wheel,
  dashboard, tires

eg. animal fats and hides are even used in **asphalt** on the
  roads the car drives on.

The animal by-products industry brings in over $2 Billion/yr

eg. 1000 lb steer:
  432 lbs retail beef
  568 lbs by products
    27 lbs: variety meats; hearts, livers, brain,
      tongue, kidneys
    358 lbs hide, hair, bones, horns, hoofs, glands
      and organs
    46 lbs blood
    183 lbs fat

eg. hide: $50-$75/hide

  → US sends 90% of hides overseas for fabrication then
    back to US for product sale

  hide: clothing, insulation, ointment base, binder for
      plaster and asphalt

hair: toothbrush bristles, mattresses, air filters, upholstery covers

hair from inside of cows ear
→ "camel's hair" paint brushes

eg. hides and connective tissues, cartilage, blood, bones:

glue in plywood, paper matches, textiles, cardboard, window shades

eg. bones, horns, hoofs: gelatin for photofilm and pharmaceuticals (gelatin capsules)

cattle horns: imitation tortoise shell

hooves: white → imitation ivory
black → potassium cyanide → used to extract gold from ore

eg. bones: electrical bushings, dice, chessmen, crochet needles, piano keys, buttons, knife handles,

bone charcoal is used as refining material to purify steel, filter sugar cane, manufacture high grade steel ball bearings

eg. blood: dried and used in cattle, turkey and hog feeds; pet food, fertilizers, clotting factors are extracted for pharmaceuticals

eg. glands: >130 different medicines and pharmaceuticals

eg. tallow and lard:

(tallow→ hydrolysis→ glycerine and crude fatty acids→ stearic & oleic acids)

glue, agricultural chemicals, candles, cosmetics, detergents, drugs, metal castings, paints, inks, paper, shaving cream

eg. if animal has **gall stones**

→ in orient $1000-$2000/lb of gallstones used as aphrodisiac

Ambergris one of the most rare and unusual animal by-products

formed from the undigestible parts of >1 ton of squid eaten per day by the whale

this undigestible mass occasionally damages the intestinal lining and accumulates with impacted feces to coalesces into a dense concretion

may be passed by the whale or may block the intestine and kill the whale

when released the up to 1 ton "boulders" float in seawater for decades and "matures"

has a complex, hard to describe, smell

rare and extremely valuable; up to $10,000/lb

has been used for centuries as an ingredient in fine perfumes, medicines, incense and flavorings and, of course, as an aphrodisiac

5. Education

most commonly dissected mammals are fetal pigs and cats

fetal pigs: 500,000

cats: >100,000

6. Research

probably one of the most contentious issues with animal welfare advocates

Biomedical research is a major enterprise

>115 Million mammals are used in research each year, worldwide

>70 Million/yr in US alone

		__US__	Worldwide
/yr:	**rats & mice**	60 M	115 M
	guinea pigs	204,809	
	hamsters	167,571	
	dogs	87,000	140,016

→*most from shelters; ~40,000 bred for research*

	cats	21,637	35,004

→*most from shelters*

	primates	62,315

→*many from breeding colonies*

		US	Worldwide
	pigs	57,000	175,020
	rabbits	554,385	1,003,448
	sheep	3,700	

90% of research animals are rodents bred specifically for research

What kinds of research?

animals are used for both basic and applied research

some argue that they should only be used for applied research but you can't separate the two

diagnostics
1-5% of all lab animals are used to diagnose disease
eg. TB, diptheria, anthrax, burcellosis, etc

disease models:
eg. inbred mice for Hodgkins lymphoma
eg. primates for HIV

organ transplantation:
eg. tissue typing techniques, immunosuppression
drugs

bionics research

development of new drugs

determine treatment regimens, treatment regimens, study of side effects, etc

surgical procedures:
eg. balloon angioplasty

extraction of medical products
eg. hormones, blood for culture media

production of antisera, antibodies, & vaccines:
eg. diptheria, whooping cough, tetanus, polio
eg. smallpox vaccine from skin of calves or sheep

eg. rabbits as antisera factories

antibiotic testing

toxicity testing

food and water safety

search for new drugs

examples of specific mammals used in research:

mice & rats: 95% of all animal research are done on mice
and rats.

used in virtually every kind of scientific investigations

cows: narcolepsy, reproductive physiology, vaccine testing,
infectious disease research, heart studies

pigs: very important animal model for human physiological
studies; cardiovascular research, blood dynamics,
nutritional deficiencies, alcoholism & drug abuse,
general metabolism, digestive related disorders,
respiratory disease, diabetes, kidney and bladder
disease, organ toxicity studies, dermatology,
neurological studies, burn studies, cystic fibrosis
research

sheep: pregnancy related research, multiple sclerosis,
medical implant studies, burn and injury evaluation,
smoke inhalation

goats: studies in cartilage repair, respiratory physiology,
medical diagnostics, gene therapy, anesthetics
research, used to produce antibodies, and to produce
genetically engineered products

dogs: heart and lung research, transplantation
experiments, cancer research, microbiology, genetics,

orthopedics, surgeries, vet medicine, toxicity studies of drugs, additives and industrial chemicals

cats: neurological research, spinal cord injury, used to study vision, sleep and hearing problems, Parkinsons disease, cancer, genetic disorders, HIV/AIDS research

rabbits: toxicity testing for cosmetics and household products; also used as models for eye diseases, skin, heart and immune system studies, asthma research, cystic fibrosis studies, diabetes and used to produce antibodies for research and diagnosis

guinea pigs: toxicity & safety testing, effects of cigarette smoke, alcohol and drugs, spinal cord injury investigations, TB research, kidney function, osteoarthritis research, nutrition and genetics studies, reproductive biology and study of infectious diseases

hamsters: taste and vision research, cardiopulmonary research, cancer and muscular dystrophy investigations, studies of aging, asthma, and biorhythms

7. Food and Crop Loss

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

8. 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)

9. 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

10. Herbal Medicine

especially in China:

the skulls of fgazelles are ground into powder taken to improve strength

gallstones of bulls are highly valued as a treatment for fevers and inflammation

elephant skin is taken for acne

monkey heads are eaten for headaches

11. Bycatch

dolphins bycatch of Tuna fisheries: 115,000 US/yr

12. Pollution

cattle lots, hog farms

13. Tourism, Wildlife Photography, Art

There is a wildlife refuge in every state and within an hour's drive of most American cities

More than 35 million people visit refuges annually, generating nearly $1.7 billion for local economies and supporting almost 27,000 private sector jobs

14. Entertainment

eg. circuses, rodeos, movies, horse racing, dog racing, dog fights

Animal Welfare

more than any other group of animals, mammals are most closely associated with "**animal welfare**" concerns

the original phrase used was "animal rights" but most (not all) now agree that the legal connotations of that phrase are not possible

animals can't have "rights"

→ implies ability of animals to reason with humans and agree on mutually accepted principles

→ implies lives of all animals, including humans, are equal

→ implies that it is unethical to use animals as pets or for any other purpose

eg. food, clothing, recreation, education, research

eg. pets = form of **slavery**

eg. killing rats is **murder** punishable by execution

Animal Welfare requires that:

→ any use of animals should be motivated by humanitarian goals

→ we are obligated to minimize pain

→ we are required to show accountability for our actions

there are many animal welfare movements

need to define "**animal**"

warm blooded vs cold blooded

vertebrates vs invertebrates

does a sponge or an earthworm deserve the same consideration as a primate?

if so, why draw the line at animals
what about protozoa, fungi, plants, bacteria?

avoiding all contact with animal products is virtually impossible

many uses of animal products are hidden:

eg. **medicines, film, rubber, ceramics, plastics, paint, perfumes, glue, explosives, cosmetics, shaving cream** all contain materials from slaughter houses

eg. **cellophane** → made with animal fats

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eg. **cars** manufacture alone:
galvanized steel body, fan belts, gaskets, anti freeze,
hydraulic brake fluid, battery, steering wheel, dashboard,
tires

animal fats and hides are even used in **asphalt** on the
roads the car drives on.

Our extent of animal products "exposure":

foods ~75%

↓

clothing ~10-20%

↓

soaps & cosmetics ~5-10%
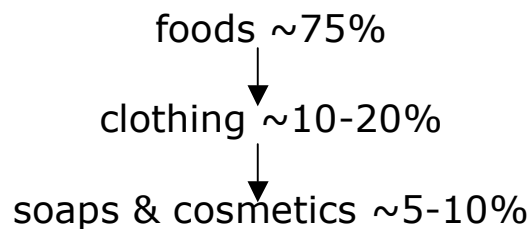
scientific research using animals is probably one of
the most contentious issues of "animal welfare"

What is the value of animal research?

a. some of this information cannot be learned any
other way

→ its unethical to test surgeries or drugs in
humans 1st (=human *rights* issue)

→ can set up controlled experiments that you
cannot do with humans

eg. genetically identical pairs
eg. exact feeding regimes

b. many surgical and medical procedures used in research had spinoffs in veterinary sciences

→pets, livestock, zoo animals generally live longer, are healthier and live more comfortably because of animal experimentation

c. animal experimentation has helped to preserve endangered species :

treat illnesses,
eliminate parasites,
promote breeding (eg. artificial insemination, embryo transfer, capitve breeding)

Criticisms of animal researchers:

a. inadequate self regulation

standards of care been dramatically improved; they were slow in coming

biomedical research has always been closely regulated but really are not many inspections done

b. slow to replace animal models with alternatives

few incentives to change even when alternatives are available

c. tend to point fingers in other directions

it's the other groups, not us, who are mistreating animals

Criticisms of animal "rights" activists:

a. oversimplistic generalizations, loose thinking

eg. animal testing compared to Nazi legacy of human abuses for "research"

but:
ironic that animal research was almost banned in Nazi Germany before the war

b. misstatements, misrepresentation of the problem

eg. development of polio vaccine cost 2 M monkeys and didn't reduce polio rate from 1916 to 1962

but:
polio research only started in 1953
by '70's polio rate dropped to near 0 in US

eg. thalidomide is touted as drug that got through animal testing and still proved dangerous

also has been stated that many tests were performed on pregnant animals

but:
actually, didn't get enough animal testing
no pregnant animals were used in research

eg. some believe that all animals suffer agony at some stage of research

tout statistic that 80% of experiments are done without anesthetic

but:
most didn't require any, there was no pain involved

c. some antivivisectionists tactics result in more
    pain and mistreatment than the research they
    oppose

      eg. "freeing" lab animals
          most will be hunted and killed by wild animals

      eg. one group was charged with animal abuse for keeping
          over 200 dogs on a 1 acre enclosure to prevent their
          use in medical research

d. the "animal rights" movement has:
    driven up the cost of research

      more money spent on tighter security and to repair
          damaged facilities

may slow development of therapies and
    treatments

      reduces the amount of research being done

      some research must be started over when facility is
          damaged or animals released

Are there alternatives?

other methods are often cheaper and require less
    paperwork:

      → scientists tend to use them whenever they can

      animals are used only when it is the best way
          to get the appropriate information

eg. some aspects of the causation, treatment or prevention of blindness cannot be studied in bacteria, fungi or plants → need complex animals

eg. high blood pressure cannot be studied in invertebrates

still, there is an effort to find alternatives when possible

eg. many toxicity tests are done using cell or tissue cultures now

eg. new chemical and mechanical simulations can provide valuable information about how a tissue or organ will react to certain medications

eg. we are beginning to develop the first realistic software models of human and animal organs that can show thousands of molecular interactions & can manipulate physiological processes

however, most researchers hold that these non-animal techniques cannot completely *replace* animals:

Pain

probably one of the biggest concern is causing pain to animals

most animals are capable of experiencing pain

→ generally scientists acknowledge and accept that all warmblooded animals and most coldblooded vertebrates (frogs, fish, etc) experience pain

even though experiencing pain, many animals may not show any external signs of pain

animals that show distress in nature might attract a predator

eg. recent evidence has shown that even fish have pain
receptors and experience pain when caught on fishing line

one simple test for pain:

"a stimulus is said to be painful if it is consistently
terminated or escaped by subject"

animals tend to begin to escape pain sensations at
about the same intensity that humans begin to
report pain

Most animals experience only minimal pain in research
settings:

eg. Animal Welfare Enforcement Report (1988)

94% of all lab animals are not exposed to
painful procedures or given drugs to relieve any pain

6% are exposed to painful procedures which
are usually not severe or long lasting

eg. Biomedical Research Study (1989)

58% experienced no pain, received no pain medication

35% received anaesthesia → little or no pain

7% experienced significant pain

eg. there are safeguards to insure animals for research are
well cared for:

→ unhealthy animals can lead to erroneous results

→ animal research is expensive; can only afford high quality research

→ pain can invalidate an experiment because stress induces physiological changes in virtually all body systems

some kinds of research subject animals to considerable pain:

eg. orthodontic research

eg. car crash studies
originally used human cadavers, but their use was banned

eg. oral radiation research
subject animals to enough radiation to cause death

eg. tumor therapies

there are also cases of:

inadequate use of anaesthesia and

inadequate care of laboratory animals

Additional perspective on animal welfare:

→ 1000x's more mammals are killed for food than used for research

→ for every dog or cat used in research ~100 are killed at shelters and pounds

→ many more pets and farm animals are neutered, some without anaesthetic, than are subjected to experimental surgery for research

→ about half of the biomedical research carried out in US would not have been possible without lab animals

→ about 2/3rd's of projects that led to Nobel Prizes in Physiology and Medicine used animal experimentation

→ habitat destruction kills many **millions** more animals, and whole species are lost, yet this is NOT a major issue with "animal welfare" advocates