The Vertebrates

48,000 species

most complex group of animal kingdom

one to which we belong along with **fish**, **amphibians** **reptiles**, **birds** and other **mammals**

some of the largest or most massive animals that have ever existed

Major Characteristics of Vertebrates:

1. internal jointed skeleton of bone or cartilage

an endoskeleton permits unlimited growth

grows with animals (not a case)

doesn't need to shed regularly

a hardened skeleton is also ideal for **muscle attachments**

in the most primitive vertebrates its not much more than a cartilage rod (**= notocord**)

skeletons of some fish remains mainly cartilage in adults

in most the skeleton is divided into:

axial skeleton

"braincase" - surrounds brain
vertebral column
ribcage

appendicular skeleton (limbs)

jointed appendages: pectoral & pelvic
eg. fins, legs, wings,

2. Segmented skeletal muscles (myotomes)

especially seen in fish

the muscles of the body wall exist as "W" – shapled segments along the sides of the body

provided more control over body movements

3. complex skin

multilayered: **epidermis**, **dermis** and much more complex than most invertebrate skins

numerous of sensory receptors

glands (oil, sweat, wax, scent, poison, etc)

keratin structures: scales, hair, feathers

4. more efficient digestive system

complete digestive tract with more efficient areas for food processing

5. efficient respiratory systems closely tied to circulation of blood

blood much more efficient at carrying oxygen than in invertebrates

RBC's (**erythrocytes**) containing **hemoglobin** for efficient distribution of oxygen to tissues

6. increasingly efficient circulatory system

completely closed system of arteries and veins

pumping heart becomes more efficient with 2, 3, or even 4 chambers for pumping

7. most complex and best developed nervous system of all animals

usually well developed **head** with sense organs and brain

increased emphasis on brain and senses

much more opportunity for learning

8. Improved efficiency of excretory system

paired **kidneys** (most cephalochordates had none)

collect and get rid of metabolic wastes & toxins

greater role in salt and water balance

9. almost all are dioecious and **reproduce only sexually**

Major Kinds of Vertebrates

from most primitive to most advanced:

fishes	28,000sp	>500MY
amphibians	4300sp	360MY
reptiles	7000sp	280MY
birds	9700sp	150MY
mammals	4600sp	200MY

Vertebrates - The Fishes

28,000 living species

eg. lampreys, hagfish, salmon, trout, sharks, rays, tuna, sardines, flounder, seahorses, catfish, etc etc

all fish are **aquatic** & and highly adapted for aquatic life: freshwater and saltwater habitats

there are no terrestrial fish; although some can survive considerable time outside of water and can often be found crawling on land

fish are the most diverse and successful group of living vertebrates

→ almost half of all vertebrate species
→ ~28,000 living species

→ ~200 new species described each year

while fish are by far the most abundant and diverse of all vertebrate groups

they remain the least known group of vertebrates

eg. estimates are that we have collected and described only slightly over 1/3rd of fish species in the Amazon river basin

smallest fish (also, smallest living vertebrate)

= stout infantfish, *Schindleria brevipinguis*, (Australia) males 7 mm long (~1/4th "), female 8.4 mm and weighs 1 mg

largest fish = whale shark to ~50', rumors to 70' (40 tonnes)

most fish continue to **grow throughout adult life**

(birds & mammals stop growing at adulthood)

Skin

most with **slimy skin** and/or **scales** embedded in skin

the slime reduces friction to improve swimming efficiency

Support & Movement

fish have a highly flexible "backbone" of **cartilage** or **bone** that is main support and framework for swimming muscles

also, most fish have **paired appendages**

=appendicular skeleton

paired fins: **pectoral** and **pelvic**

→ homologous to our arms and legs

act as rudders, for balance, feelers, weapons, sucking discs, lures to attract prey

most fish are very efficient swimmers

others can walk, crawl, burrow, and "fly" out of the water

most of a fish's body mass is bundles of muscle tissue for swimming = **myotomes**

relatively small body cavity for other organs

muscles are segmented

→ zig-zag "W"-shaped bands of muscles alond sides of fish

produce "S" shaped swimming motion

fish get most propulsion from hind trunk & tail muscles

dorsal and ventral fins improve swimming efficiency

the fastest fish exchange the snake-like motion for more rigid position where most of the flexing is toward the tail only

eg. tuna doesn't flex body at all; all thrust is from the tail

overall, swimming speeds are not particularly fast compared to running or flight due to the high density of water

eg. 1 ft trout → 6.5 mph
eg. 2ft salmon → 14mph

the larger the fish the faster it can usually swim

barracuda is fastest fish → 27 mph

usually cruising speed is much slower

most speeds reported for fish are speeds as they jump out of water so they appear to be much faster

most fish have **gills** for getting O_2 from water

Respiration

Gills are thin feathery sheets with lots of blood vessels for efficiently getting O_2 from water

some fish can also breath through their skin

a few fish can breath air

blood is pumped through arteries and veins with simple heart

most with **2 chambered heart**;

blood is first pumped through gills then out to the rest of the body (ie. single "circuit")

fish are **cold-blooded** (poikilotherms)

→the body temperature of most fish is the same as their environment

some fish eg. tunas, mako sharks, maintain a higher temperature in their swimming muscles

→ as much as 10º C warmer than surrounding water

other fish; eg. marlins, elevate temperature of brains and retinas

elevated temperatures promote swimming and enhance nervous activities

→ such fish are some of the fastest in the world

Nervous System & Senses

fish brains are relatively small and simple compared to other vertebrates

but still considerably more developed than in the invertebrates

brain is made up of several distinct functional areas:

cerebrum (higher centers) very small
cerebellum (coordination of movement) relatively large
brain stem (automatic activities) also relatively large

fish do **sleep**
→ stay motionless for several hours

some marine species (eg. wrasses, Labridae) may bury

themselves in sand or spin "sleeping bags" → cocoons of mucus each night to sleep

the main sense organ of most fish is the **lateral line system** = "distance touch"

interconnected tubes and pores along sides of body

detects vibrations and current

most fish depend mainly on **lateral line system** for sensory information to detect food or danger

most fish have paired immoveable **eyes**

most fish lack eyelids

fish can see in color

most water is pretty murky so most fish depend more on the lateral line system than vision

fish generally have a good sense of "smell" to detect chemicals in the water

Kinds of Fish:

three different classes of vertebrates are categorized as "fish":

1. jawless fish (Agnatha)

108 species

2. cartilaginous fish (Chondrichthyes)

970 species

3. bony fish (Osteichthyes)

27,000 species (96% of all fish)

most abundant living group

The Jawless Fish

most ancient & primitive vertebrate group

only living vertebrate group with **no jaws**

smooth slimy skin, no scales

skeleton is a simple rod of cartilage, no bone

gills are inside several pairs of gill openings

spiracle on top of head can draw water in and over the gills

no appendages; no pectoral or pelvic fins

eg. Hagfish

all are marine

about 18" long; largest known is almost 4' long

found in deep waters

→almost completely blind; eyes have degenerated

hagfish are **scavengers**

→eat dead or dying fish, molluscs, annelids, etc

although almost blind they can quickly find food by touch and smell

enters dead or dying animals through an orifice or by actually digging into the animal

has 2 toothy plates on its tongue used to rasp bits of flesh from carcass

hagfish are noted for their ability to secrete copious amounts of **slime** (500 ml/min) for protection

→ milky fluid from slime sacs along sides of body

→ on contact with seawater forms a very slippery material making them impossible to hold

can secrete enough slime to turn a bucket of water into a gel in a few minutes

→ protection from predators: may be able to extricate them from jaws of preadator by "knot tying" behavior

their breeding habits are still relatively unknown

Human Impacts

hagfish are the bane of some commercial fishermen who use gill or set nets

→by the time they pull catch in hagfish have

often devoured internal contents of fish

today hagfish are collected for "leather" to make golf bags and boots

their slime has unusual properties since it is reinforced with spider silk-like fibers

looking at it for potential uses for stopping bloodflow in acidents and surgeries

some species are in serious decline due to over harvesting

eg. Lampreys

up to 3' long

most lampreys are parasites as adults

attach to prey by sucker like mouth

rasp away flesh with teeth to suck out blood

→inject **anticoagulant**

when finished lamprey releases its hold

host sometimes dies from wound

all lampreys spawn in freshwater streams

lampreys spawn in winter or spring

male builds nest by moving stones to make a shallow depression

female joins him

adults die after spawning

eggs and larvae develop in freshwater

→young of marine species then migrate to ocean until sexually mature

→ others remain in freshwaters their entire lives

Human Impacts

lampreys first invaded the great lakes in 1913-1918 (bioinvasion)

by 1950's destroyed great lakes fisheries

rainbow trout, whitefish, lake herring, and other species populations were destroyed

their numbers began to decline in early 1960's

due to depleated food

expensive control measures

→ expensive larvacides placed in selected spawning streams

today, some native species have been restocked and are now thriving again

The Cartilaginous Fish
(Sharks and Rays)

Origin of Jaws & Paired Fins

evolution of **jaws** was one of the major events in the history of vertebrates

→ freed from bottom feeding; allowed access to a much greater variety of food sources

eg. predators

initially, jaws just "closed the mouth"

later jaws became armed with dermal scales that evolved into **teeth**

→teeth could be used to seize prey

jaws allowed predation on larger active prey

along with jaws came **paired pectoral and pelvic fins** for improved mobility and control

there are two main groups of fish with jaws:

the **cartilage fish** & **the bony fish**

Cartilage Fish
(Sharks & Rays)

many cartilage fish have changed little from earliest fossils

two main body forms

fusiform (streamliined shape) = **sharks**

→ very good swimmers

flattened = **rays**

→ spend most time on or gliding near shallow bottoms

internal anatomy is similar in most

all but a few cartilage fish are marine

most are 6-15' long

includes the largest fish and second largest of all living vertebrates

whale shark → up to 60' long

→ filter feeder

great white gets up to 30' long

skin is very tough & leathery

→ muscles of shark pull on skin rather than pulling on the skeleton

small, hard, knife-like **scales** embedded in skin and stick out from skin

scales have same structure as tooth including enamel, dentin & pulp cavity

scales are continuously shed and replaced throughout life

Support & Movement

skeleton composed mainly of **cartilaginous**

but retained bony in teeth, scales & spine

paired appendages: **pectoral** and **pelvic fins**

pectoral fins are rigid, not flexible

hammerhead shark uses its head for steering since pectoral fins are not moveable

powerful **dorsal** and **caudal fins**

most of body is muscle mass (**myotomes**) is for swimming

sharks are the most graceful and streamlined of all fish and among fastest fish

eg mako shark 60mph
eg. blue shark 43 mph

hammerhead shark uses its head for steering since pectoral fins are not moveable

skates & rays are mainly bottom dwellers

are dorsoventreally flattened with enlarged pectoral fins that allow them to glide above the sediment in wavelike fashion

in sting rays caudal and dorsal fins have been lost

tail is slender and whiplike

armed with 1 or more **spines**

a large **liver** is rich in fats and oils giving sharks near **neutral buoyancy**

→ don't need to use energy to maintain position in the water column

Feeding & Digestion

most cartilage fish are **predators**

top predators in many ocean food chains

yet, by nature, most tend to be timid & cautious

in addition to **lateral line system** sharks also have **electrical receptors** on head to detect electrical fields of prey

→used especially for final lunge in attack

powerful **jaws**

teeth only grasp prey, don't chew

→ the teeth and scales of sharks are essentially the same

→ form replaceable rows of teeth

eg. easily lost, constantly replaced, usually the only part of a shark preserved as fossils: fossil shark teeth

some sharks are **plankton feeders**:

eg. whale shark (>50'); worlds largest fish
eg. basking shark (15-40')

a few are **scavengers**

skates and **rays** have broad, blunt, cobblestone-like teeth for crushing clams, oyster, etc

digestive system is similar to other vertebrates but with **spiral valve** to slow food and increase area of absorption

Respiration

gills used for respiration

rows of separate **gill slits** similar to jawless fish

spiracles can take in water when mouth is occupied

sharks must be moving or there must be some current to move water over the gills

Reproduction

sharks are **dioecious** with **internal fertilization**

male sharks & rays with **claspers** on pelvic fins

→ used to transfer sperm (NOT for 'clasping')

usually produce only a few eggs at a time

some skates produce 2 young each time

most females retain eggs in body till they hatch

→ bear live young

development lasts 6 months to 2 years

some sharks have primitive uterus and placenta and provide "**uterine milk**" for developing young

others get extra nutrition by eating eggs and siblings in uterus

some sharks and skates deposit eggs in horny capsule

= **mermaid's purse**

each "purse" may contain several eggs

often has "tendrils" to attach to objects

no parental care after eggs are laid or young are born

Electric Rays

fish are the only animals that can directly produce an electrical shock

the ability to produce electric shocks is confined to **electric rays** and **some bony fish**

electric rays are generally slow, sluggish fish that live in shallow waters

have some muscles modified into electric organs to shock prey or stun predators

high power output – up to several kilowatts

usually can only give a few shocks before it has to rest and eat

electric rays were used by ancient Egyptians as "electrotherapy" treatment for arthritis and gout

Ecology

1. sharks are **top predators** in many ocean food chains

2. **symbiosis** with shark suckers (remoras)

an example of **commensalism**, although some species may be more mutualistic by removing parasites and pathogens from their host's skin

shark suckers are bony fish with one of the dorsal fins modified into a suction disc

while common to sharks, some are also found in rays, whales, turtles and other marine creatures

some species are host specific

they spend most of their lives attached to the shark and feed on debris produced from the shark's feeding activities

some feed mainly on the hosts feces rather than pieces of dropped food

Human Impacts of sharks

1. Shark attacks

60 - 70 per year (2000-2011); 1-12 fatalities

especially great white (to 6 M long)
mako
tiger
bull
hammerhead

more casualities reported from Australian region than anywhere else

in 2008 in US 4 people were killed in shark attacks; 108 were killed by cows (blunt force trauma)

2. Shark fishing

~40 Million/yr (26-73 M 2011) are harvested worldwide

recent estimates (2012) are that shark populations at inshore reefs worldwide have declined by 90%

the primary cause is China's growing appetite for **shark fin soup**

sells for up to $100/bowl

eg. Dubai alone exports 500 tonnes of shark fins and other shark products/ yr to Hong Kong (~ half the world shark fin production)

its generally a legal harvest but increasingly being banned

eg. "finning" has been outlawed in US

some other countries are setting quotas

3. Medicinal/Pharmaceuticals

electric rays were used by ancient Egyptians as "electrotherapy" treatment for arthritis and gout

chondroitin for joint treatment and health

extracts are being tested for anticancer drugs and weight loss

The Bony Fish

most successful vertebrate class

more species than all other kinds of vertebrates combined

27,000 sp; (96% of all fish)

~200 new species are described each year

probably 5-10,000 more undescribed species

bony fish range in size from the tiniest of all vertebrtates to over 15'

from the oarfish at ~1/2"

to the blue marlin, over 17'

some fossil forms may have reached up to 100' long

bony fish have adapted to every kind of aquatic habitat:

from 8000 M deep to 5200 M in Tibet

some in hot springs (44º C)

others under anarctic ice at -2º C

in totally dark caves

some make excursions onto land

most bony fish are designed for active swimming

eg. streamlined bodies to reduce friction

but great diversity of size & shape due to differences from adapting to every kind of aquatic habitat:

fusiform shape (eg. tuna)

powerful tail

fastest fish, often live in open ocean

streamlined bodies to reduce friction

rod shaped (eg. barracuda)

elongated, arrow-like fish with powerful tails, pelagic predaceous fish

flattened/depressed (eg. flounder)

flattened bodies in bottom forms

spherical shape (eg. puffer fish)

when threatened, can inflate body so they can't be swallowed

ribbon shape (eg. wolffish, eels)

slow swimmers, secretive, move easily wriggle into cracks and crevices for protection or to ambush prey

laterally compressed (eg angelfish)

camoflage; viewed head on are almost invisible; also allows quick, sharp turns

grotesque forms (eg. anglerfish)

many deepwater forms; cryptic or mimic for protection

Skin & Scales

the body of bony fish is generally light and flexible to enhance swimming ability

surface of body is covered with **mucus** secreting **epidermis** to reduce friction and enhance swimming ability

→ can reduce water friction up to 66%

most have thin, overlapping **scales** below the epidermis

some have completely lost scales

unlike sharks, bony fish do not shed scales

they grow throughout life

→ can be used to age fish

skin of bony fish shows a variety of colors and texture

can be: silver, yellow, orange, black

most fish can control their color to some degree due to special skin cells =**chromatophores**

controlled by nervous system

allows fish to change color to blend with substrate

color changing is most highly developed in flounder (flatfish) species

color is used for eg. protection, mimicry, warning, camoflage

countershading

most open ocean fish have dark backs and light bellies making it more difficult for predators to spot them in open water

fw fish shades of green, brown, blue above and silver or yellow white below

→ from below blends with sky,
from above blends with substrate

concealment:

eg. coral reef fish are highly colored but on reef cant see them

eg. often have blotches, spots and bars
→ ~army camoflage

mimicry

another form of camoflage

eg. pipefish, anglerfish, sargassum fish take coloration, texture and form of seaweed

distraction:

eg. false eyespots

draw a predator to the back of the animal allowing fish to escape in other direction

eg. butterfly fish

advertising:

attract attention for a special service

eg. cleaner fish help remove skin parasite

their distinctive color is recognized by their "customers" and they are not harmed by them

warning:

many highly colored fish stand out from their surroundings

→ warn potential predators that they are poisonous

the skin of some fish is **bioluminescent**

→ contain light emitting organs or structures

may be on head; lateral line, sides of belly, on barbels, etc

Support & Movement

most bony fish have a **skeleton of bone**

skeleton is first laid down as cartilage during development then hardened into bone before birth

a few species retain cartilage skeleton

very flexible and moveable **pectoral** and **pelvic fins**

pectoral fins used to steer and swim

dorsal fin is moveable and sometimes becomes highly specialized for:

camoflage

venomous spines (eg. scorpion fish)

lures (eg. anglerfish)

sucker (shark suckers)

like other fish movement of bony fish is mainly swimming using thick **myotomes** that take up most of the body mass

($2/5^{ths}$ of body volume in most; $3/4^{ths}$ in tuna)

but some fish can walk, crawl, burrow, or "fly"

overall, swimming speeds not particularly fast compared to running or flight

→ water is 800x's denser than air

eg. 1 ft trout → 6.5 mph
eg. 2ft salmon → 14mph

the larger the fish the faster it can swim

barracuda is fastest fish → 27 mph

usually cruising speed is much slower

most speeds reported for fish are speeds as they jump out of water so they appear to be much faster

eg. flying fish can achieve launch speeds of 35mph and glide above the water 20-40 seconds

all fish are slightly heavier than water

most bony fish have **swim bladder** to control **buoyancy**

swim bladder arose from **lungs** of some primitive air breathing bony fish

by adjusting the volume of gas (O_2)in the swim bladder a fish can achieve neutral buoyancy and remain suspended indefinitely with no muscular exertion

control of buoyancy probably coevolved with fin modifications to improve and refine locomotion

→ most pelagic fish have swim bladders

→ bottom fish generally lack swim bladders (eg. flounder)

Feeding & Digestion

fish feed in a variety of ways

most bony fish are **carnivores**

small, numerous, sharp **teeth** are used to seize prey

most lack moveable tongues and don't "chew" their food

chewing would produce pieces that might clog gills

→ better to swallow food whole

eg. plankton feeders

most common feeding type

most pelagic species and commerical fish are plankton feeders

eg. herring, anchovies, menhaden

travel in large schools

plankton are strained with sieve-like gill rakers

eg. predators

teeth used to seize prey

eg. Piranhas are known as viscious predators - mainly through movies and TV

several dozen species of carnivores; 6-10" long

found in South American Rivers of the Amazon Basin

jaws bristle with sharp, densly packed teeth

bad rap; can be very aggressive but are only rarely known to bite and injure humans

but are considered a nuisance to commercial and sport fishers

sold for aquaria but illegal in most states in US

occasionally found in US rivers but generally can't survive cold winters

eg. herbivores

many freshwater fish eat plants, grasses, algae, etc

eg mollys, some cichlids, head standers, etc

eg. scavengers & detritivores

eg. catfish, suckers & minnows

eg. parasites

eg. Toothpick fish (Candiru)

parasitic freshwater catfish in Amazon river

eel shaped, translucent → impossible to see in water

up to 6" (15 cm) long

most feared fish in these waters, more than piranha

some species lie in wait in murkey bottom mud

sample water for nitrogen wastes from gills of fish

eg. ammonia, urea

once detected they dart towards the gill cavity with a burst of speed

once inside gills they lodge themselves in place with its spines

gnaws a hole toward a major blood vessel and gorges itself for a few minutes only

it then dislodges itself and sinks back to bottom of river to digest its food

victim usually bleeds to death

is known to attack people and swims into an orifices;

vagina, anus, penis

locates its target when people urinate near the fish

has been known (and videotaped) swimming up a urine stream into penis of victim

almost impossible to remove without surgery

Respiration

fish get oxygen mainly through **gills** like other fish

often have **"gill rakers"** that filter water before passing over gills

→to remove food and bits of debris that might clog the gills

gills are covered by a bony flap = **operculum**

→offers protection and reduces friction when swimming

→ operculum can also actively pump water across gills

fish can still "breath" even if not moving

Nervous System & Senses

bony fish have a simple nervous system and the sense organs as described for fish in general

however, bony fish make much more use of **sound** than the other two fish groups

at least 1000 fish species make and use sounds

clicks, grunts, thumps

sound travels further and faster in water than it does in air

used mainly to attract mates or ward off predators

in fish, the **swim bladder** has secondary function in hearing

acts kind of like an eardrum in humans

helps to amplify even very faint sounds in water

Defenses

color and shape can be used for camoflage

some fish are highly venomous

dorsal spine can inject venom

eg scorpionfish

the ability to produce electric shocks is confined to only 2 groups of vertebrates: electric rays and some bony fish

bony fish: electric eel & electric catfish

eg. electric eel

in rivers in South America

grows to 3 - 7 ft long

electric organ is modified muscle tissue

→ up to 40% of body weight

most powerful electric organ of all fish

→can produce up to 600 volts to stun or kill prey

→ can give several 100 shocks up to 300 V each/second

doesn't need to actually touch victim
→electric field extends several feet around fish

eg. electric catfish

found in the Nile river

Reproduction in Bony Fish

most bony fish are **dioecious**

a few are hermaphrodites

genders cannot be distinguished externally

most with **external fertilization**

a few bear live young (eg. guppies)

→generaly little or no parental care

most fish produce large numbers of eggs:

eg. halibut → 3.5 M
eg. cod → 4 - 6 M

→ less than 1/million will survive to maturity

most fish **spawn** at certain times of the year depending on temperature

in most marine fish: eggs are released and become part of the **zooplankton** through embryonic and larval development

a few fish make **nests** and show rather elaborate **parental care**

in these its most often the male who puts in the "extra effort"

eg. Stickleback
- male constructs very elaborate nest of grass and weeds bound by mucous threads
- then looks for a mate to entice it inside
- if gentle persuasion doesn't work, he may drive 1 or 2 females into nest until enough eggs are laid
- then he jealously guards them for many days until they hatch

eg. some marine catfish
- eggs are incubated in males mouth
- young continue to be carried an protected in males mouth after they hatch
- male doesn't eat for ≥ 1 month

eg. seahorses
- seahorses are only vertebrates in which the male actually becomes pregnant
- male contains a brood pouch, completely sealed except for a tiny hole
- female lays eggs inside the males pouch
- male squirts sperm directly into pouch to fertilze eggs
- males nurture their young, provide food and oxygen and get rid of waste products
- young remain there for ~ 10 days till hatching
- male convulses (as if in labor pains) and muscular contractions eventually force all the seahorses out of the pouch
- almost immediately, the female shows up, an new courtship ritual and the male may again become pregnant by the next day

other fish bear live young but show absolutely no parental care or interest

eg. Gambusia
in an aquarium will eat all their young as soon as they are born

fish continue to **grow throughout life**

annual rings are produced in scales, otoliths and other bony parts

→ the age can be accurately determined

Migrations

some fish spend most of their lives in freshwater but return to sea to spawn

= **catadromous** ("down running")

eg. some eels

each fall large #'s of female eels are seen swimming down rivers toward the sea

when adults leave rivers in Europe and N America they reach ocean and swim at great depths to Sargasso Sea

takes several months to reach this area; here they spawn and die

they tiny larvae begin their return trips to the coastal rivers
→ takes up to 3 yrs in Europe

each spring large #'s of young eels appear in coastal rivers

swimming upstream

males remain in brackish waters near mouth
→ female continue 100's of mile upriver

by 8-15 years females >1 M long; return to sea to rejoin males and spawn

other spend most of adult life in the sea, and return to freshwater to spawn

= **anadromous**

eg. Atlantic species (eg. salmon & steelhead trout)

make spawning runs year after year

eg. pacific species (sockeye, sliver, humpback & chum salmon)

make one spawning run then die

adults spend 4 yrs at sea yet can unerringly return to parent stream
→ only a few stray go to wrong stream

when salmon return to site where they were hatched, they spawn and die

the following spring the newly hatched fry "**imprint**" on the stream as they drift downstream to the sea

How do they find the mouth of the river when they are returning to spawn?

apparently can navigate by orienting to sun's position

but they can also navigate on cloudy days

may also be able to use earth's magnetic field

probably also use ocean currents, temperature gradients, food availability to reach general area

annual run of wild salmon today is ~3% of the 10-16 Million fish that ran 150 yrs ago

Salmon runs in Pacific NW have been devastated by stream degradation:

eg. logging, dam construction (50 dams)

all other vertebrate classes are primarily terrestrial and evolved from fish ancestor

Preadaptations to Terrestrial Environment

all other vertebrate classes are primarily terrestrial and evolved from fish ancestor

for a fish to survive on land would need to be able to breath air and would need pectoral and pelvic fins that could support them on land

a. Air Breathers

many fish can survive out of water for a short time by breathing air

eg. lungs of lungfish & gars

eg. bowfin (*Amia*) at low temp use mostly gills, at higher temperature use mostly lungs

eg. some *Corydoras* Catfishes can process air in the hind part of the gut

eg. freshwater eels can do gas exchange through moist skin

eg. electric eel has degenerate gills and must get most of its oxygen by gulping air

eg. Indian climbing perch (*Anabas*) spends most of its time on land near water's edge

has special chamber above much reduced gills for respiration

can also absorb oxygen from air if skin is moist

eg. mudskipper can be out of water for long periods but prefers to keep tail in water to absorb oxygen from water through its skin

b. some fish can walk on land

eg. Indian climbing perch (*Anabas*) spends most of its time on land near water's edge

only climb in wet weather

eg. freshwater eels commonly make excursions onto land in rainy weather

eg. walking catfish

Human Impacts of Bony Fish

Pets

fish have been kept as pets for 1000's of years

Outdoor fish ponds have been around for at least 2000 years

The Romans were the first to bring fish indoors - for fresh food

10th century Chinese kept bowls of goldfish

in Victorian England marine aquariums became the rage

15-30 Million fish of up to 1000 species are sold globally each year

20 million fish are sold each year as pets in US alone

Research

3.5 - 7 M fish used for research in US each yr

Commercial Fisheries

we have harvested fish throughout all of human history

today 2.6 billion people worldwide depend on fish for protein (2002)

60% of all fish comsumption is by the developing world (2008)

commercial fishing employs 200 Million people worldwide

today, marine fisheries are in trouble:

marine fish catch has peaked at about 100 million tons and remains stable, in spite of increased efforts to catch fish

per capita (per person) fish catch is decreasing as population expands

11 of worlds 17 major fisheries are overfished and in decline

a few of the problems:

a. subsidies have encouraged overfishing which makes it a nonsustainable resource

the world spent $124 billion to catch $70 billion of fish

the difference was paid for by taxpayers

b. most commercial fisheries are near shore where most pollution and damage occurs

c. of the world fish catch only two thirds are used **directly** for human consumption,

the rest is converted to fish meal and oil,

and pet and livestock food

d. much of what is collected is wasted as "**bycatch**", especially in industrial countries,

examples:

eg. shrimpers typically discard 5 to 8 times as many creatures than they keep

eg. gulf of mexico shrimpers killed 34 million red snapper and over 3000 sharks in one year

eg. open ocean fishermen use large drift nets (25'deep & 50 miles long), set out 30,000 miles of net a night worldwide

18 miles of net is lost per night

1000 miles per year become 'ghost nets' and trap and entangle fish for decades as they float in the ocean

these nets killed 42 million seabirds, marine mammals and other nontarget animals

e. there has been an increase in **biomass fishing**:

→collecting all life in an area and grinding it up for meal, to use as animal feed & for fish farming

decimates communities in an area

estimates are that at least **half** of the world's continental shelves are scoured by trawlers at least **once every year**

Freshwater Fisheries

fish from inland waters accounted for 10% of total catch (2002)

many river basins, especially in developing countries support intensive fisheries

inland fish are considered to be the most threatened group among all vertebrates used by humans

Aquaculture (fish farms)

global production from fishing and aquaculture

1999-2001 →93 million tonnes

2002 →133 million tonnes

→ **almost all the increase is due to Aquaculture**

fastest growing animal protein sector

especially in developing countries

currently (2009) produce half of the fish we eat

(1980 only 9%)

contributes almost 1/3rd world supply of fish products

aquaculture produces more than 220 species

carp are the largest group

China and other Asian countries are the largest producers

"Herbal" Uses of Fish

eg. ancient greek writings and herbals from China and other countries have touted the healing properties of **seahorses** for 1000's of years

pulverized and made into a tea used to calm bladder, treat asthma, soothe boils, pustules and ulcers, and as an aphrodisiac

today seahorse powders and tablets are taken to treat throat infections, high cholesterol, kidney and liver disease

today, at least 70 tons (25 Million) seahorses are harvested worldwide, each year, to be roasted, crushed and dissolved to make traditional medicines; whole ones are used as talismen to improve luck in fishing

→ none of the uses have been shown to have any scientifically valid value

Amphibians

6,000 species

includes frogs, toads & salamanders

amphibians were the first **vertebrate** group to move from water to land

Origin of Land Vertebrates

some of the most significant events in evolution were the gradual transition from life in water to life on land:

prokaryotes	arthropods	plants	amphibians	reptiles
2.5 BY	420MY	400MY	370MY	280MY

whereas fish are adapted to an aquatic lifestyle; all other vertebrate groups are adapted to life on land

basic differences between water and land:

→ air contains 20x's more oxygen than water

→ water is 800x's more dense than air

→ air temperatures fluctuate much more than water temperatures

→ land offers numerous new, unoccupied habitats and untapped food resources:

→ virtually no large predators on land yet when amphibians moved onto land

adaptations needed to survive on land

→ respiratory surfaces must be kept moist, usually internal

→ outer surface of body must reduce desiccation/water loss

→ land animals need strong limbs and remodeled skeleton to get around on land

→ must be resistant to extreme seasonal temperature; hibernation, migration

→ eyes and ears become dominant sense organs

→ greater need for moveable tongue to manipulate food in mouth when eating

by Devonian (~400 MY ago) bony fish had developed a significant presence in freshwater habitat

~360MY ago the earth was becoming dryer with alternating droughts and floods

during these dry periods freshwater ponds & pools often dried up

lungfish in Siam today spends up to 4 months per year buried in damp soil, 2-3 ft deep

fishermen collect them with spades

some bony fish (=lobe finned fish) living in these freshwater habitats developed reinforcements in their fins that enabled them to support their weight in shallow water and, for short periods, on land

→ fins were used for walking

these same fish had simple lungs that allowed them to breath air for short periods of time as well

→ lungs and limbs evolved for fish to continue to survive in water

amphibians are descendants of these 'lobe finned' fishes

the earliest amphibians shares many features with fossil lobe finned fish, both:

→ ~ 1 M long and lived during Devonian

→ very similar skull structure

→ had ear that could hear sound vibrations in air

→ had similar short conical teeth ; probably predators

→ had short stocky but flexible appendages with digits

→ tail still had tail fins

→ had bony **operculum** on side of head

9. still had **lateral line system**

but transition wasn't complete

→ most amphibians still need moist environment

→ most must return to water for reproduction

eggs must be laid in water

immature stage is aquatic

once the first amhibians appeared the climate became warmer and more humid (carboniferous)

land was covered with vast fern forests

primitive insects, some flying insects

amphibians were the dominant land animals in the carboniferous (300MY ago)

= Age of Amphibians

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most amphibians today move from pond to pond for food during droughts

live and breed in protected moist areas:
under longs and rocks
under litter on forest floor
in flooded tree holes

some modern amphibians have adapted to a dryer land existence:

a few don't require water for reproduction

<u>Body Form</u>

great variation in form:

eg. **salamanders**: head-trunk-tail
of the amphibians, **salamanders** more closely resemble the earliest amphibians

they tend to be nocturnal and secretive, live in cool moist places and eat worms small insects and snails occur

3 species of salamanders in Travis County

eg. Barton Springs salamander, *Eurycea sosorum*

eg. **frogs**: fused head-trunk, no tail

by far the most successful & widespread group of amphibians are frogs

88% of all living amphibians

17 species of frogs in Travis County

hind legs specialized for jumping

some can glide like flying squirrels

eg. flying frog of tropical Asia

occupy a great variety of habitats

especially common in tropical swamps and forests

but found in all habitats; even dry areas

frogs are more aquatic and generally live in or near water

toads are more terrestrial and only move to water to reproduce

eg. **caecilians**: long slender snake-like body

no limbs, no post-anal tail

largest amphibians:

eg. African bullfrog, *Gigantorana goliath*; 1' (30 cm) long, nose to anus; 7.5 lbs;

eats prey as big as rats & ducks

eg. Japanese giant salamander can get up to 4.5' long

smallest amphibian: cuban frog

→ less than ½" (1 cm)

<u>Skin</u>

most amphibians have thin moist skin without scales

very delicate

→ doesn't provide much protection from abrasion, dehydration or predators

but allows it to be used for **respiration** if kept moist

their skin has lots of **glands**:

eg. mucous glands

make skin slippery → harder for predators to get a hold
helps keep it moist for breathing

eg. poison glands

usually concentrated in areas behind eyes

when stressed poison gland secretes toxin

skin is often brightly colored

→contains **chromatophores**

many can adjust their color for camoflage

many toxic amphibians are brightly colored as warning coloration

less toxic species use color for camoflage

Support and Movement

the **skeleton** of amphibians is stronger than in fish to be able to bear weight on land

most of the **muscles** are shifted from trunk (fish) to legs

legs still don't support body very well

→body touches ground at rest

still move in very fish-like fashion

gliding frogs:

eg. *Polypedates* spp (Africa and SE Asia)

large webbed feet

can glide horizontally 30-40' from a height of 40'

Feeding & Digestion

most amphibians are **predators** (carnivores)

eat mostly insects

but some eat small mammals, birds, snakes, fish & other frogs

many have sticky **tongue** to capture prey

in some frogs its attached at front of mouth

some amphibians have teeth to hold onto prey and prevent its escape

food swallowed whole, not chewed

Respiration

adapations necessary for shifting from extracting oxygen from water to extracting it from air required major changes in both the respiratory and the circulatory systems

amphibians can take in oxygen in several ways:

a. lungs

most amphibians have very simple lungs

→ essentially hollow air sacs derived from fish lungs

lungs are not very efficient

nostrils are now used for breathing as well as sensory

nostrils open directly into mouth cavity

→ cant eat and breath at the same time

no diaphragm

→ amphibians must **gulp** air to force it into lungs

in most amphibians the lungs are not adequate for getting the oxygen they need

most amphibians rely on additional structures to supplement their lungs

b. through skin

thinness of **skin** and blood vessels present allow it to be used as respiratory surface

sometimes whole surface of skin, sometimes just the lining of the mouth

c. gills

most amphibian larvae are aquatic and have **gills** for respiration

some aquatic species retain gills as adults

air breathing also requires a restructuring of the circulatory system

the amphibian circulatory system is improved over that of fish

heart is a **double pump** to push blood through two separate circuits

picks up O_2 in lungs and returns to heart

then sends oxygenated blood to rest of body

Nervous System & Senses

brain and nervous system is similar to fish but with **better vision**

eyes with eyelids to moisten and protect the eyes

many purely aquatic species have retained the **lateral line system**

hearing is better developed but with **eardrum** on outside of head

most amphibians have a "**voice box**" (=larynx) with vocal cords

frogs use sound to attract a mate

→ males do most of the calling

vision is dominant sense in many amphibians

no longer a fixed open stare as in fish

Defense/Protection

amphibians have many enemies: snakes, birds, turtles, raccoons, humans

many frogs and toads in tropics are aggressive and will fight predators

some can give a painful bite

frogs tend to stay very still when threatened

only when they think they have been detected do they jump in water or grasses to get away

when held, they remain motionless to catch us offguard, then jump while voiding urine

most can inflate their lungs making them difficult to swallow

most frogs can also inflate their lungs making them difficult to swallow

all amphibians have **poison glands** in their skin

some toxins are lethal

eg. **Poison Dart Frog**

brightly colored (warning); one of the deadliest frogs

→ poison from a single frog could kill several humans

Choco indians of Central and South America catch them and roast frogs over open fires then collect the highly toxic mucus which exudes from the frog's skin as they die.

use the poison on the tips of their blowgun darts

eg. large **toad** of Panama Canal Zone can squirt a poison that will blind

its skin is collected for fine leather

some frog toxins are hallucinogenic

(frog licking)

a few amphibians use **poisonous spines** to to protect themselves

eg. **sharp ribbed newt** when threatened can arch their back in such a way that the sharp ends of their ribs actually penetrate and poke out of the skin. As the ribs pass through the layer of skin they are coated with a toxic milky liquid to become **venomous spines**

eg. **hairy frog** does a similar thing but uses its toe bones as the spines that it uses to slash at its attacker

Reproduction & Development

most amphibians are dioecious; rarely show sexual dimorphism

mating is controlled by seasonal conditions

most amphibins breed soon after spring emergence from hibernation

breeding season usually lasts for several weeks

no transfer organs or copulation; most amphibians have **external fertilization**

eg. in **salamanders** male deposits **spermatophore** on leaf or stick and maneuvers female over it

fertilization occurs as eggs are released

aquatic species lay eggs in clusters or stringy masses

terrestrial species may deposit eggs in clusters under logs or in moist soil

in some salamanders, the adults guard eggs

eg. **frog** breeding is like an orgie

most larger frogs are solitary except during breeding season

males often take possession of a perch near water

then males call to females

each species has its own unique call

amplexus: male frog holds onto female

female deposits eggs in water anchored by sticky jelly

male deposits sperm over eggs

males will grab almost anything

often jump salamanders or other male frogs

have special release call to get males off

sometimes several males will jump on a female

many females drown from the weight holding them under water

some amphibian species reproduce by **parthenogenesis**

Metamorphosis

salamanders, eggs typically hatch into tadpoles in ~ 1 week

with gills, suckers and spiracle

→larvae resembles adult

aquatic forms retain gills (paedomorphosus)

eg. *Necturus*, mud puppies

terrestrial forms lose gills and develop lungs

embryos of salamanders resemble adults

→ undergo less pronounced metamorphosis

some retain gills as adults

frogs hatch as herbivorous **tadpole larvae**

most frogs undergo **metamorphosis** into adult in a year or less

legs appear
tail is reabsorbed (in frogs)
lungs develop

one genus of tropical terrestrial frogs the eggs hatch dirctly into "froglets"

no aquatic stage

---

frogs & toads have a variety of **unique reproductive behaviors**

a few tree frogs build nests: cuplike crates along streambank

another makes waterproof depressions in tree hollows using beeswax

some brood young in stomach

eg. Surinam toad; *Pipa*

completely aquatic

fertilized eggs are deposited on the back of female

the eggs sink into the spongy skin forming separate incubation chambers

each chamber is covered by thin sheet of skin

larvae undergo metamorphosis in these chambers and emerge as adult toads

eg. midwife toad

female lays eggs fastened together like beads on a string

male thrusts hind legs into the egg mass and wraps them around his body

male then takes eggs to his burrow

he comes out only at night to search for food

when larvae are about to emerge he finds a pool of water to jump in and the larvae swim away

---

a very few amphibians have **internal fertilization** and bear live young

eg. the snakelike caecelians have internal fertilization, most bear live young

fetuses feed on secretions and tissues they scrape from lining of mom's oviduct

eg. the Alpine salamander, *Salamandra atra*, lives in Swiss Alps at ~4500' and has the longest gestation period of any land animal:

2 young are born ~ 3 years after fertilization

Hibernation

during winter most temperate frogs **hibernate** in mud at bottoms of pools and streams

use energy from glycogen and fat stores

toads tend to hibernate in humus on forest floor

some can survive freezing

eg. woodland frog is the only vertebrate able to survive being frozen

they live north of the arctic circle

up to 65% of its body water may be frozen

heart stops completely

glucose in blood acts as antifreeze

what freezes is the water outside its cells, not water inside cells

Migration

some amphibians have a strong homing instinct

→ return to the same pond each year for mating

guided by olfactory cues

Ecology & Human Interactions with Amphibians

A. Beneficial Effects of amphibians

→Frogs eat **disease-carrying insects**

→Frogs are **critical links** between predators and the bottom of the food chain (algae, plants, detritus, and such)

B. As Food

not a major part of human diet
→frog legs

Americans devoured more than 6.5 million pounds of frog legs a year (1984)

led to the death of some 26 million frogs annually.

Ninety percent came from India and Bangladesh, which banned exports after frog declines led to growing hordes of mosquitoes, malaria, and increased use of pesticides.

Now Indonesia supplies most of the frogs for restaurants

C. Education & Research

most commonly dissected laboratory animal: in science classes and research

up to 10 M frogs used for education in US

6 M in high schools alone

~3 M frogs are used for research in the US

→ much of our medical knowledge came from frog dissections

→ embyrological studies

→ isolation of pharmaceuticals

D. Poisons

the skin of all amphibians contains **poison glands**

several species of tropical frogs secrete potent neurotoxins
distasteful
induces paralysis

often brightly colored

natives in Brazil and Costa Rica use toxin to make poison arrows

some of these toxins are hallucinogenic

(frog licking)

E. As environmental Indicators

amphibians are extremely sensitive to environmental indicators

in 80's & 90's noted declines

→ since 80's 120 species have become extinct

today one third of the worlds 6,000 amphibian species are threatened

→ one of largest extinction spasms in vertebrate history

unsure of exact causes of declines:

Probable causes of decline:

→ habitat loss

most amphibians feed and breed in wetlands

In the past half-century continental US has lost more than half of its original wetlands

→ pollution

deformities from animals in polluted water

→ water molds

most recently has been tied to worldwide spread of a pathogenic water mold

spreads very rapidly

→ viral infection is the likely culprit in several recent die-offs

→ environmental pollution

Increased exposure to ultraviolet radiation may damage the eggs

possibly caused by acid precip, deforestation, urbanization, climate change

Reptiles

8000 species

include: lizards, snakes, turtles, crocodiles and dinosaurs

1st truly terrestrial vertebrates

no longer tied to water, even for reproduction

very successful group today

occupy a great variety of terrestrial habitats

some have returned to ocean and freshwaters

largest *living* reptiles:

eg. Komodo dragon (Varanus komodensis)

10 feet long; 300 lbs

eg. Australian saltwater crocodile

up to 28 feet long

eg. leatherback sea turtle

8 feet long; 1500 lbs

largest reptile ever:

eg. largest of all reptiles: *Seismosaurus hallorum* ("Earth-shaking lizard")

120+ feet long (37 m); 30-80 tons

→ largest animal ever to have walked on land

smallest living reptile:

Carribean lizard <3/4ths of an inch nose - tip of tail

reptiles were much more abundant and diverse ~160-100MY ago

= The Age of Reptiles (Mesozoic)

lasted >165 M Y

50 MY after the appearance of the first amphibians,

some amphibians developed the ability to lay eggs on land

→ the first reptiles

while amphibian adults can live on land they must have water to reproduce

complete independence from water didn't occur until the evolution of a self contained egg capable of storing water (=**amniotic egg**)

the appearance of this new type of egg allowed the evolution of **reptiles**, **birds** & **mammals**

Skin & Scales

reptiles have tough dry skin with *epidermal* **scales** of keratin

→ very effective water proofing

epidermal (not dermal) scales

reptile scales ≠ fish scales
(epidermal) (dermal)

[scutes of turtles are modified scales]

→ protection from drying, abrasion, predators

outer layer of skin is shed periodically

some reptiles have **chromatophores** in skin and can change color at will

eg. green anoles

in some reptiles the thick keratinized (horny) skin has been modified into **claws**, **scutes** (large scales of turtles), **horns** and **rattles**

Support & Movement

new features appear in reptile skeleton:

teeth still simple and peg like but in more efficient and stronger jaws

→ more biting force

nasal cavity separated from mouth by shelf of bone = **palate**

→ easier to breath while eating

limbs stronger, more flexible & closer to body

→ better designed for walking

toes with **claws**

most land reptiles can **burrow** into mud

eg. turtles and small lizards

most reptiles **swim** with ease

chameleons have opposable toes to grasp limbs for arboreal life

one extinct group were the second group of animals to be able to **fly**

eg. pterodactyls

some reptiles can **glide**:

eg. *Draco* = flying dragon

uses extended ribs

can glide up to 50'

eg. gliding gecko Ptychizoon sp.

eg. some gliding snakes

Feeding and Digestion

most reptiles are **carnivores**

most reptiles have **teeth**; generally larger and stronger than in amphibians – still all generally the same conical shape

crocodilian teeth are constantly replaced

jaws are more efficient for crushing and gripping prey

(fish use "suction" for feeding; their jaws are not very muscular; amphibians can't "chew")

tongue is muscular and mobile

→used to help catch prey

in some (eg snakes) tongue serves mainly as touch and chemical receptor

in some reptiles the salivary glands are modified into **poison glands**

some large snakes kill their prey by suffocation

→ once wrapped around their prey, each time the prey the snake tightens its grip, until prey can no longer inhale

again, teeth are not used for chewing

food is swallowed whole

stomach often has pebbles to help grind food (=**gastroliths**)→ common find at dinosaur sites

Respiration

no reptiles have gills

most reptiles depend completely on **lungs** for gas exchange

lungs are more developed, more folding, more surface area

→more efficient

use rib cage to expand and contract lungs

but most can't breath while running since many of same muscles are used for both purposes

reptiles have no vocal cords like amphibians

→ reptiles can only hiss

only crocodilians make vocal sounds

Nervous System & Senses

the nervous system is more advanced than amphibians; more similar to mammals in basic

structure, only smaller

→ allows more complex behaviors

but still reptiles are not as dependent on their brain as mammals are

they have "accessory brains=ganglia" along their spinal cord

eg. a turtle lived 18 days after brain was removed

vision is most important sense organ

most reptiles are active during the day

good color vision

some have "third eye" **pineal eye** on top of head

→ detects light intensity and may control biological rhythms

vertical pupils in nocturnal snakes (and some mammals) are better for night time hunting, it also gives them a deeper field of view making it easier for them to sneak up on prey

reptiles also have a good sense of **taste/Smell**

smell is used to find prey

smell is also used during mating

→ some reptiles (crocodilians)produce musky smell to attract mates

Jakobson's organ assists in sense of smell/taste

pits located on roof of mouth in lizards and snakes

→ forked tongue of snakes flicked then touched to Jakobson's organ to follow chemical trails

some snakes have **IR (heat) sensors**

→ can see body heat from warm blooded prey

Protection/Defense

many species are well camoflaged by the color of their skin

venomous snakes use their poisonous fangs for protection as well as for subduing prey

rattle snakes advertise their presence with a threatening rattle (rattle made from modified scales)

horned lizards can puff up their bodies causing its spiny scales to protrude making them hard to swallow

horned lizards can also aim and squirt a stream of blood up to 5' from the corners of their eyes

the blood contains foul-tasting chemicals that deter wolves, coyotes and domestic dogs

Reproduction and Development

reptiles are **dioecious** with **little sexual dimorphism**

copulatory organs and **internal fertilization** first became the common practice in reptiles in the vertebrate line

all reptiles have **internal fertilization**

in order to enclose the embryo inside a thick waterproof protective covering, the egg must be fertilized before the "eggshell" encloses it

so they don't need water for reproduction

reptiles have 1 or 2 copulatory organs

most snakes and lizards have 2 penises (=hemipenes)

→ use only 1 at a time; depending in which testis has more sperm

after copulation, sperm may remain in female for months or years before it is used to fertilize egg

a few are **parthenogenetic**

→ egg develops without fertilization

almost all reptiles go through early development within an **amniotic egg**

(only found in reptiles, birds & mammals)

with protective membranes enclosing embryo

→complete life support system

don't need water for development

embryo & membranes are enclosed within a porous **shell**

can be leathery or hard shell

most reptile eggs require 4 – 6 weeks for development before hatching

no reptiles pass through a free living larval stage

a few reptiles (some pit vipers) bear live young

only a few living reptiles show parental care

eg. crocodilians:

dig nest for 25-50 eggs

cover eggs

hatchlings often chirp
→ encourages mom to uncover nest

she picks them up and carries them to water

mom and dad respond to distress calls

many reptiles have well developed abilities to **regenerate** missing body parts

eg. green anoles can regrow tails

eg. glass snake: when pursued can break of its tail with a sharp twist

the tail twitches and writes to attract pursuer while glass snake escapes

Kinds of Reptiles:

today only 3 major kinds of reptiles survive

100 M years ago there were over 12 distinct kinds of reptiles; including dinosaurs, ichthyosaurs (shark-like), plesiosaurs and pterosaurs (flying reptiles)

eg. Dinosaurs

~450 different species of dinosaurs have been described

2006 study concluded that at least 70% of dinosaur genera remain unknown

dinosaurs generally lived in warmer even tropical parts of the world but a few fossils are also found much closer to poles

dinosaurs share a group of unique features that set

them apart from all other vertebrate groups:

- many dinosaurs were **bipedal**
- considerably stronger knee and ankle joints than other reptiles

  same as in birds

  much less flexibility than in mammals
- most with upright stance; 2 legged

  → legs positioned directly beneath body

  similar to mammals and birds
- dinosaurs walked on their toes

  like many mammals, eg. horses
- many or most dinosaurs were **warm blooded**

  like birds and mammals
- some had feathers &/or fur in addition to scales
- many showed considerable **maternal care**

  most reptiles today have no care of young

were apparently competitively superior to mammals at the time since mammals remained small and inconspicuous until ALL dinosaurs disappeared

→ then mammal diversity exploded

dinosaurs and most of the diversity of reptiles disappeared ~65 MY ago

→ probably meteorite impact

eg. <u>Turtles</u>

very little change in body form over past 200 M years

enclosed within a shell

dorsal **carapace** and ventral **plastron**

outer layer of **keratin**, inner layer of **bone**

→formed from fused vertebrae and covered with dermal bone=carapace & plastron of fused scales

no teeth, instead rough horny plates

low metabolism → live long >100 yrs

many turtles require 6-12 years to attain maturity; some take 20 or more

all turtles bury eggs in ground

nest temperature determines gender of hatchlings

eg. sea turtles

have webbed feet

up to 6' long

migrate 1000's of miles

live, feed and grow in sargasso sea

may take 50 years to reach sexual maturity (low metabolism – some live to 150 yrs old)

they then return to beach where they hatched to lay eggs

(reverse of amphibians)

as soon as they hatch sea turtle swim across 100's of miles of ocean

→ can detect earth's magnetic fields for navigation

eg. box turtle
shell has 2 hinges to close up from predators
omnivorous: fruits and beries
may live up to 100 years

25,000 box turtles/yr are exported to Europe as pets
90% die in transit

eg. snapping turtle
common in ponds in eastern US
grow to 1 ft long
ferocious and short tempered
entirely carnivorous (fish, frogs, birds)
come ashore only to lay eggs

eg. <u>Lizards & Snakes</u>

most successful group
→95% of all living reptiles

very effective jaws to capture prey
very flexible

eg. snake can swallow prey several times its own diameter

cold blooded but can regulate temperature by behavior to maintain a fairly constant body temperature

→ early morning basking in sun to absorb heat
→ hot → turn face to sun to expose less area
→ lift legs on hot substrate
→ hottest part of day may retreat to burrows

most are terrestrial, some are aquatic, some marine

most lizards have moveable eyelids; but snakes eyes are permanently covered with transparent layer; no moveable eyelids

snakes are often considered "strange" and even "evil" by many

for 1000's of years, snakes were looked on as mysterious creatures, often with magical powers and were important in many religious practices

body of snake is very similar to lizards except for legs

most snakes have lost all traces of appendages

locomotion is radically altered, very adaptable

scales grip the ground as they make eel-like movements

essentially walk on their ribs:

→ up to 300 ribs

each rib has separate muscles that control its movement

snakes can climb, leap, swim, stand erect and "run"

→ probably most unusual is side winding of some desert species

sidewinders have only 2 parts of body touching ground at any one time
→ essentially *walking* without legs

most snakes use chemical senses to detect prey

use tongue as "smell" receptor

picks up chemicals with tongue

transfers tongue to Jakobson's organ in mouth

subdues prey by suffocation (constriction) or venom

eg. boas and pythons → wrap and suffocate

many snakes are venomous

venom = saliva with a mixture of digestive enzymes

→ kills and starts the digestive process

some of these enzymes work on nervous system to cause paralysis

[only 2 lizard species are venomous including Gila Monster]

flexible jaws allow snakes to swallow prey several times their own diameter

most snakes lay **eggs**

pit vipers bear live young

eg. <u>Crocodiles & Alligators</u>

mostly unchanged for 200 MY

largest of the living reptiles → up to 6M (18')

large robust skull with massive jaws with powerful closing muscles

the only living reptiles that can make vocal sounds

→ vocal sacs on each side of throat create bellowing mating calls

one of only a few reptile groups that show parental care:

lays 20-50 eggs per nest

tends to and protects eggs & hatchlings

gender temperature dependent

low nest temp → females

higher nest temp → males

Humans Impacts of Reptiles

Humans Impacts

1. Poisonous Snakebites

5 Million people are bitten by poisonous snakes each year

causes at least 100,000 deaths and up to 400,000 amputations/yr

esp India, Pakistan & Mideast

very few have access to adequate medical care and antivenoms are in very short supply

-2009, WHO declared snakebite a neglected disease

but in US the average American is more likely to be killed by another person than to be bitten by a venomous snake

8000 bitten/yr in US (~17,000 homicides)

99.8% chance of survival (~80 die/yr)

Travis county has 5 venomous snakes:

Texas Coral Snake
- small mouth short fangs; coral snakes are nocturnal; only bite under unusual circumstances; have up to 12 hours to get antivenom
(red touch yellow → kill a fellow
red touch black → friend of Jack)

Western Cottonmouth
- can bite underwater

Western Diamondback Rattlesnake
- responsible for more human deaths than any other N. Am. snake

Blacktail Rattlesnake
- rare

Brown Banded Copperhead

most are mistrustful of reptiles in general because a *few* are dangerous

reptiles are much more of a benefit than a threat

eg. keep rodent populations in check

2. Invasive Species

eg. brown tree snake

bioinvader of islands (eg Hawaii)

→has wiped out numerous species of birds and mammals

3. Medical Research

the regenerative abilities of reptiles is under study for possible clues to organ replacement in humans

4. Pharmaceuticals

eg. toxins from a Brazilian viper have provided the key ingredient in a class of drugs called "ACE inhibitors" used to lower blood pressure

5. Farmed Reptiles – semi-domesticated

2.6 Million crocodiles are produced each year worldwide for food and hide

4. Reptiles as Food

eg. sea turtles
such as Kemps Ridley sea turtle

eg. Kemps Ridley sea turtle
1947: 40,000
1985: ~200
1994: 580

they like the same beaches we do

hunted for eggs and meat

→in Mexico armed troops must guard beaches during nesting season

also affected by pollution & fishing
→US now requires exclusion devices on shrimp nets

eg. Alligator meat comprises about 1/3rd of commercial harvests in US

eg. snakes

5. World Trade in Live Reptiles/ Pet Trade

Because reptiles are traded for such a wide variety of reasons, there are many hundreds of species in trade.

millions of live reptiles are sold each year for the pet trade.

eg. In 2001 the United States imported just under **2 million live reptiles.**

eg. The United States annually exports more than 8 million **red-eared slider turtles** (*Trachemys scripta elegans*), the world's most commonly traded live reptile.

eg. over 500,000 were **green iguanas** (*Iguana iguana*) from Central and South America.

eg. Other species commonly found in the pet trade include:

boa constrictor (*Boa constrictor*)
ball python (*Python regius*)
panther chameleon (*Chameleo pardalis*)
red-footed tortoises (*Geochelone carbonaria*)

reptiles are among the most inhumanely treated animals in the pet trade.

90% of wild-caught reptiles die in their first year of captivity because of physical trauma prior to purchase or because their owners cannot meet their complex dietary and habitat needs.

Because they are cheap and easily replaceable, dealers, captive breeders, and retailers factor huge mortality into their operating costs.

6. World Trade in Reptile Products

eg. **exotic skins trade.** reptile hides are used in the "luxury fashion" trade. PETA: virtually every store that sells exotic skins has some hand in their illicit trade

eg. alligators are bludgeoned to death with hammers and steel rods,

snakes and lizards are decapitated and skinned

pythons are studdend (not killed) hoses are inserted into their mouths and they are pumped full of water to swell up to loosen their skin, then each snakes head is impaled on a hook and the animal is skinned alive

eg. curios and jewelry. In many parts of the world, "tortoise shell" curios and jewelry, which are actually made from the shells of hawksbill sea turtles, remain popular, as do leather items made from snakes, lizards, and crocodilians.

eg. Tortoises and turtles fetch high prices in Asian markets - especially in China - where their meat is eaten and their shells are used to make traditional medicines.

eg. American Alligator; brought back from near extinction $30M hide business now

7. Herbal Medicine

tons of turtles are harvested because chinese believe that eating turtles will lenthen lifespan

turtle blood is available at Walmarts in China

turtle heads are consumed for labor pains

powdered snake gall bladder is used as a cure for bronchitis

coin shakes are coiled up like a stack of coins with head on top

they are boiled into a thick black liquid that is sipped like tea for general health

lizards are taken to treat high blood pressure

8. Invasive Species

eg. brown tree snake
bioinvader of islands (eg Hawaii)

→has wiped out numerous species of birds and mammals

---

humans are much more of a threat to reptiles than they are to us

More than 20% of the world's reptiles are now at risk of extinction

Birds

of all higher vertebrates, birds are probably best known

9700 species

→ 2nd most abundant vertebrate group

→ outnumber all other vertebrate groups except fish

smallest bird: bee hummingbird 1.8g (.06oz)

one of smallest warmblooded vertebrates

only slightly larger than a bumblebee

largest living *flying* bird:

is the wandering albatross with a 12 ft wingspan; weighs about 25 lbs

largest known flying bird:

a condor-like bird, ~6 MY ago

155 lbs (70 kg) with 21' (6.4M) wingspan

had to run downhill into a headwind to take off

largest bird: elephant bird of Madagascar is most massive bird that ever lived

2 M tall, 450kg(~1000 lbs)

also: tallest was extinct moas of New Zealand

flightless bird, related to emus

12 ft (3.6 M) to 550 lbs (250kg)

birds are found in all habitats:

forests, deserts, mountains, praries, oceans

some live in caves in total darkness

some can dive to 140' under water to capture prey

birds are even found at the north and south poles

Origin of Birds

for over 50 MY amphibians and reptiles were the sole terrestrial vertebrates

earliest fossil of a true bird ***Archaeopteryx*** (=ancient wing) 150 MY ago

~ size of crow
reptilian skeleton
long reptile like tail
jaws had teeth
clawed fingers

but

feathers may not be similar to modern bird feathers
no keel for flight muscles → probably didn't fly
bones not thin and hollow as in modern birds
brain comparable to reptile not to larger bird brain

first fossil discovered in 1861 –2 yrs after Darwin's origin of species

rare find since delicate bones and feathers

don't fossilize well

if not for impressions of feathers would be classified as a small dinosaur

birds clearly evolved from dinosaurs

more similar to dinosaurs than dinosaurs are to turtles, snakes and lizards

following the rules of taxonomy birds should be in same class as reptiles, not in a separate one

recent genetic analysis indicates that the large flightless birds such as ostrich, kiwi & emu are the most ancient and most "dinosaur-like" birds

Origins of Flight

flight had evolved at least 4 different times in history of life:

insects: 330 MY; carboniferous
reptiles: 200MY; pterosaurs; late jurassic ,
birds: 150MY; coexisted with pterosaurs for~90MY
bats: 54 MY; (Eocene)

in spite of the great diversity of birds they are amazingly similar in structure

→ birds evolved as **flying machines**

entire anatomy is designed around flight

small compact body; reduced weight; with all heavy organs close to center of gravity

Skin

bird **skin** is thin, light and flexible

no sweat glands

single **oil gland** at base of tail for preening

today, **feathers** are the single unique trait that identifies all birds

almost weightless but incredibly strong and tough

feathers smooth the surface and streamline the contour of the body

→ make flying more efficient

feathers are derived from reptile scales

feathers can be moved individually by muscles in skin (**arrector pili**)

most birds haved a variety of feathers designed for:

flight (contour feathers)

insulation (downy feathers)

decoration & display

sense of touch

birds spend much time on feather maintenance:

preening → reconnects barbs & barbules

oiling → waterproofing

bathing

dust baths → to remove ectoparasites

feathers can be replaced individually as need or as a group by molting

skin over most of body is covered by **feathers**

only a few areas are without feathers:

a. in most birds only the legs have scales instead of feathers

arctic birds have NO bare areas

b. head and neck in some birds have combs or wattles

often brightly colored "ornaments"

used for dominance or sexual signaling

c. vulture head is bare

→ keeps feathers clean while feeding on carcass

d. ostriches & relatives

→ unfeathered legs used for cooling after heavy exercise

Molting

feathers are shed regularly = **molting**

highly orderly process

(except for penquins who molt all at once)

frequency of molt depends on wear and tear and seasonal factors

most birds molt once/yr

usually late summer after nesting season

feathers must be shed gradually and symmetrically (matched pairs) to retain ability to fly

replacements emerge before next pair is shed

→ only ducks and geese are grounded during molting

→ wing clipping: removing critical flight feathers on one wing to prevent flight

among vertebrates, only tropical reef fish show the same intensity and diversity of color

a feather is naturally white

coloration due to:

a. chromatophores impart colored pigments into feathers during development

b. some colors are produced by **refraction** or scattering of light rays as they pass through colorless keratin in feathers

→ all blues, most greens and some purples of animals

eg. blue jays, indigo buntings, bluebirds

eg. there is no "color" in blue jay feathers

color used for:

eg. camoflage

in many species, juveniles and females are camouflaged with melanin pigments

arctic birds white in winter, darker in summer

eg. breeding/communication

males breeding plumage often brightly colored

eg. warning

toxins similar to that of poison frogs has been found in skin and feathers of some brightly colored New Guinea species of *Pitohui*

<u>Support & Movement</u>

some of the most important flight adaptations are found in the **skeleton**

the skeletons of bird and mammals does not continue to grow throughout life as in fish, amphibians and reptiles

it has a typical adult size for each species

the skeleton is exceptionally **light and delicate** yet sturdy

frigate bird: 7' wingspan→ skeleton = 4 oz
→ less than weight of feathers

vs humans 6' skeleton (6-7' armspan) weighs ~10 lbs

bones light and hollow with air sacs

Many bones are **fused** together to make them light, but still strong

anterior skull bones are elongated to form **beak** (or **bill)** covered with hardened skin attached to skull

→modified lips

since birds lose the use of their forelimbs their **beaks** are used as tools

long tubular beaks for nectar
sturdy wedge shaped to pry insects from bark
curved overlapping beaks to crack nuts and seeds
long upper beak that curves down over lower to tear flesh

neck is extremely flexible with more vertebrae than most vertebrates

most mammals have 7 vertebrae
birds have 11-25 vertebrae

the major flight muscles attack to large **keel** on **sternum**

collar bones are fused (**wishbone**) and connected to shoulder blade for additional support of wings

flight muscles (breast muscles) often very large % of body weight

eg. pigeon up to 50%

largest bird that can fly is the great bustard *Otis tarda*

→22 kg (~10 lbs)

when flyng in flocks birds use each others energy like fish in shoals

takes advantage of lift turbulence created by the motion of those in front of them

Bird Flight:

some birds spend most of their lives in flight

eg. common swift

feed, communicate and mate in flight

only lands to sleep and nest

average ~135,000 miles/yr (217,300 km/yr)

one recorded a nonstop trip of 310,000 miles (498,00 km)

cruising speeds are usually ~40 km/hr (25 mph)

many birds can hover at 0 mph

highest flying bird recorded:

Alpine Choughs, *Pyrrhocorax graculus* → 8200 M (26,902')

why do some birds fly in "V" formations?

takes advantages of leading birds slipstream; called drafting, like bicyclists; helps conserve energy; take turns at lead position

a birds **feet** nearly devoid of muscles

→ greater agility

→ since mostly bone, tendons & tough skin

very resistant to freezing damage

when perching, toes lock around branch

→ prevents bird from falling off while sleeping

early birds had long reptilian tail

modern birds have replaced tail with up to 1000 tail feathers; each under individual muscular control

Feeding & Digestion

birds feed on a variety of items: insects, worms, vertebrates, plants, nectar, seeds, nuts, etc

bird use **beak/bill** in the place of forelimbs:

head & beak very flexible & versatile; used like a tool or limb:

eg. catch bugs, shatter seeds, crush shells, drill holes, dismemeber carcasses, snare fish

eg. attack enemies, build nests, preen, impress mates and feed young

beaks of birds are highly adapted for their feeding type

eg. crows →generalized type has strong, pointed beak
eg. woodpecker → straight, hard, chisel-like, creates forces of 10 g's when pecking a tree (humans can only survive 9g's for a few seconds); insert sticky tongue into hole to find insects
eg. hummingbird → long tubular, feed on nectar
eg. seagull → basketlike sac below beak to catch fish

contrary to conventional "wisdom" birds are voracious feeders due to **high metabolic rate**

hummingbird has the fastest metabolsim of all birds

eg. 12x's MR of pigeon & 25x's MR of chicken

hummingbird may eat 100% body wt/day

in many birds there is an enlargement at lower end of the esophagus = **crop**

stores food to provide a continuous supply of energy during flight

modern birds have no teeth, grinding is done in **gizzard**

muscular sac with hard plates to help grind food

some birds "eat" pebbles to aid this process just like reptiles

some birds of prey form **pellets** of undigested material (bones and fur) and regurgitate them before digesting the rest of the meal

eg. owl pellets

→ another way to reduce weight

birds have very efficient digestion

eg. shrike - can completely digest a mouse in 3 hours

eg. thrush - berries pass completely through GI tract in 30 minutes

Respiration

birds (& mammals) are **warm blooded**

→ they maintain a constant body temperature independent of environment

flight is energy intensive; requires a consistently high metabolism

higher than land mammals (eg. 110º vs 98º F)

have fast heart rate

eg. hummingbirds 1000 bpm (humans 70bpm)

respiratory system is specially adapted to meet this metabolic demand

→ very different from other vertebrates

bird lungs are relatively small

bird lungs contain microscopic tubes, open at both ends (=**parabronchi**)

in addition to **lungs**, birds have extensive system of **air sacs** that branch throughout the body and enters larger bones

the **air sacs** comprise ~80% of the respiratory system and may completely surround the heart, liver, kidneys, gonads and intestine

→air goes through lungs on inhale & exhale while new air is coming into air sacs

→ much more efficient gas transfer

air sacs and **lungs** often make up 20% of body volume (humans lungs=5%)

new studies indicate that some reptiles (alligators) also have a similar one-way flow of air through lungs; as perhaps did dinosaurs and ancestors of birds from when O_2 levels were ~half what they are today

these air sacs also serve as an **air conditioning system**

→ cool bird during vigorous flight

eg. pigeon produces 27x's more heat flying than at rest

bones with air sacs help to **lighten weight** of bird

The main breathing muscle in mammals is the **diaphragm** which contracts to draw air in and relaxes to push air out of the lungs

birds do not have a diaphragm, instead they use muscular contractions to expand and compress the ribcage for inspiration and expiration

much like reptiles

most birds produce sound from an area in their trachea called the **syrinx** (not from the voice box as amphibians and mammals do

membranes on each side can produce separate sounds to generate chords or harmonies when singing

Circulation

circulation is similar to mammals:

4 chambered heart

2 completely separate circuits: pulmonary & systemic

heart is relatively large

very fast heartbeat (humans ~70-75bpm at rest):

eg. turkey 93 bpm

eg. chicken 250 bpm

eg. blackcapped chicadee 500 bpm

→ exercise to 1000 bpm

actual blood pressure is similar to mammals of similar size

Nervous System & Senses

the bird's brain is same relative size as mammals

eyes are perhaps the most important sense organ

disproportionately large

eg. the eye of the ostrich is ~2" diameter; the largest of any vertebrate

eg. the eyes of most large birds; eg hawks and eagles are larger than human eyes

no eye muscles

→ all space is filled with eyeball

can't move eyes to track objects

→flexible neck compensates

generally:

predatory birds have eyes in front of head

→ **stereo vision** = depth perception

vegetarian birds have eyes that look out to sides

→ greater field of view

visual acuity of hawk is 8x's that of humans

best vision in animal kingdom:

→ can clearly see crouching rabbit >1 mile away

hearing is also well developed in birds

senses of **smell** and **taste** not very well developed

eg. vultures

some birds live over 70 years (eg. Andean condors)

Reproduction, Nesting & Egg Laying

birds are **dioecious, dimorphic** and show often elaborate nesting, mating and parenting behaviors

courtship in birds involves

→ marking and defending a territory

→ and sometimes elaborate rituals to entice a female into the territory

selection of territory usually occurs a few weeks before nesting season

male selects nest location

solitary species defend fairly large area

gregarious species that nest in colonies defend a very small area

sometimes this seasonal instinct to defend territory becomes obsessive

eg. robin or cardinal that returns day after day to struggle futility with its reflection in a window pane

courtship rituals

males are sometimes very colorful during breeding season, dull rest of time

many develop seasonal ornamentation

eg. inflated skin pouch on throat

courtship almost always involves singing to a potential mate

sometimes also involves elaborate dances

eg. lyrebird - to attract a mate:

male will stand on a small mound of dirt and spreat his decorative tail feathers up over his head

he then sings both his own songs and mimicks other bird's songs

he will even mimic the noise of a nearby car

as he sings he jumps about

eg. frigatebird

male has a throat sac that it can inflate over a period of 20 minutes into a heart shaped balloon

he then waggles his head from side to side, shakes his wings and calls the female

a female frigatebird will mate with the male with the largest and shiniest balloon

during sex the male will "sweetly" put its wings over the females eyes … to make sure she doesn't get distracted by a better offer

eg. Long tailed Manakin (of Costa Rica)

males work in pairs who begin perched on a branch near the ground

they both call a whistle-like call for females

a female lands on the branch indicating she is ready to be courted

both birds launch into a prolonged acrobatic display

they step daintily and hop, they somersault and leap-frog, they take turns hovering in the air, all while calling to the female

as the tempo picks up the males emit a buzzing sound and the female becomes even more excited

at the critical point the leading male utters a shrill cry

this is the lesser male's cue to make himself scarce

following a brief dance the male quickly mounts the female

most birds have no transfer organ →press cloacas together

a few birds have erectile penis with external groove to guide sperm into females cloaca

most birds are monogamous while mating but after mating they go their own ways

Nests

some of the most obvious and characteristic features of birds are the nests they make to lay eggs and care for their young

nests vary from simple accumulations of materials on the ground to elaborate refuges above the ground

the most elaborate nests are associated with some swallows and weaver finches,

nests typically take 2 to 7 days to construct but cavity nests in trees can take up to 4 weeks to excavate

the most elaborate nests can take months

nest varies from simple depression to weaver birds communal nests for 100's of birds

eg. typical nest of smaller bird is cup shaped "basket" lined with finer material

eg. barn and cliff swallows mold nests of mud from softened pellets

eg. largest bird nest is that of bald eagle

→ to 10' wide, 20' long and 5,500 lbs (the weight of almost 3 cars)

→ the same nest can be used for decades

Eggs

all birds lay eggs

all bird eggs have hard shells with lots of microscopic pores

egg size & shape

largest: known bird egg is from extinct Elephant bird of Madasgascar

13" long, 9.5" dia; 2 gallon volume

smallest: some hummingbird species <1/4th "

Parental Care

usually female incubates eggs

12-30 days needed for incubation

after hatching young are fed by **regurgitation**

some birds (pigeons, doves, flamingos and some penguins) produce **crop milk**

secretions with a "cottage cheese"-like consistency, very high in proteins and fats

much higher fat content than cow milk

produced by both male and female birds to feed the young for the first few weeks

Bird Ecology

1. pollination

eg. hummingbirds
- do not have a highly developed sense of smell
- but do have excellent sense of vision
- frequently bright red or yellow flowers
- little if any odor
- fused petals with nectary
- produce copius quantities of nectar
- long floral tubes prevent most insects from reaching the nectar
- eg. fuschias, petunias, morning glories, salvias, cardinal flowers, trumpet creepers, columbines, penstemons

2. disperse seeds

eg. 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

eg. 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. pest control

eg. Birds eat many things: beetles, flies, spiders, earthworms, rotting fish, offal, poison oak berries, weed seeds, etc

eg. raptors & owls - eat mice, rats, snakes

Human Interactions

1. meat and eggs

14 B birds are used for food (world/yr):

chickens	13 B/yr
turkeys	304 M/yr
ducks	773 M/yr
geese	209 M/yr

scientists have recently bred a "featherless chicken

→ grows faster

→ don't need to pluck it

~ 91 Billion eggs produced US each year

2. extinct or endangered species due primarily to human activities

2/3rds of bird species are declining in numbers

eg. about 20% of world's bird species have gone extinct in historic past

eg. Passenger Pigeon
- inhabited eastern N America
- 200 yrs ago was the world's most abundant bird
  - → 3-5 Billion
  - →once accounted for ~1/4th - 1/3rd of all N Am birds
  - → 1830's Audubon saw a single flock

estimated at 10 miles wide and 100's miles long (~1 Bill birds)

were easily slaughtered for meat (pigeon pie)
→ they wouldn't fly away if threatened

over 20 yrs of hunting and habitat loss at end of 1800's the population was decimated

last wild bird was shot in 1900

last individual (Martha) died at the Cincinnati Zoo in 1914

eg. Ivory Billed Woodpecker

3. Introduced pests

eg. starling

eg. house sparrow

4. Bird as Pets

some birds have been truly domesticated:

eg. chickens, turkeys, geese, ducks, pigeons

some birds have been semidomesticated

eg. hawks and falcons

earliest domestication ~1700 BC in Persia

Europe ~300 BC

12% of pet sales are birds (19% dogs; 5% cats)

~5 M live birds are sold worldwide

European Countries →buy 3/4th 's of live birds

illegal trade:

bird collectors will pay $10,000 for a rare hyacinth macaw from Brazil

$12,000 for a pair of golden-shouldered parakeets from Australia

mortality rate of live animal trade is enormous:
~50 animals caught or killed for every live animal that gets to "market"

5. bird watching
more lucrative than bird hunting

6. hunting

91 M birds are hunted each year worldwide
21 M waterfowl
→ 2injured/ 1 taken

7. research

5 M birds are used for research each yr

8. bycatch

500,000 - 700,000 birds are killed by getting tangled in fishing nets and hooks

9. wildlife photography, art

Mammals

relatively small group: 4800 species

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

today, is one of most successful group of vertebrates

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

Origin of Mammals

mammals developed from mammal-like reptiles ~200 MY ago

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

for 160 MY they lived in the shadow of the dinosaurs

"suddenly" the dinosaurs disappeared ~65 MY ago

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

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

Skin & Fur

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

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

made of **keratin** (protein)

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

the main function of hair is as insulation from the cold.

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

the color of hair can be for:

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

hair can be modified to serve a variety of functions**:**

a. sensory hairs

vibrissae (whiskers) → tactile, sensory hairs
egg. cats

b. defensive hairs

eg. spines porcupines, hedgehogs

c. horny or bony plates

eg. armadillo, pangolins

d. some have lost most of their fur

eg. hippos, elephants, porpois, us

horns or **antlers** are found in only a few families of one order of mammals:

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

a. horns

esp cattle, sheep, goats, rhinos, etc

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

surrounds bony unbranched core

grow continuously throughout life

not normally shed; do not regenerate of cut off

usually used as a weapon for protection

b. antlers

esp deer, caribou, moose, elk

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

develop beneath highly vascularized sheath= **velvet**

velvet dropped off after breeding season

mammal skin has a variety of **glands**

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

all mammals feed their young milk

<u>Support & Movement</u>

the skeleton of mammals is stronger with the limbs up under the body for better support and more agile movement

→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

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

wing 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 & Digestion

teeth represent the greatest evolutionary diversification of the mammalian skeleton

in fish, amphibians and reptiles teeth were mostly of one kind and used mainly for capturing prey

mammals have a variety of teeth adapted for a variety of foods

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

all but a few mammals have teeth

eg. monotremes, anteaters, some whales

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

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

in most mammals there are several different kinds of teeth

incisors	→ snipping and biting
canines	→ piercing and holding
premolars	→ shearing and slicing
molars	→ crushing and chewing

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

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**

coprophagy is common

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

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

wheather 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 rib cage

Circulation

like birds mammals have **4 chambered heart** & **two separate 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 & Senses

the **nervous system** of mammals contains a relatively large, highly developed brain

→ disproportionately larger per body wt

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

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

mammals are **dioecious**, with **internal fertilization** & most bear **live young**

nurse young with milk from **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

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

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."

3 patterns of reproduction in mammals

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

by far the most common

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

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

Ecological Roles of Mammals

1. major parts of food chains in most ecosystems

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.

Human Impacts of Mammals

1. Domestication

a. Agricultural Animals

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 pets sold 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, Fur & Game Farming

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

60 M for food and sport:
deer → 3 M
rabbits → 27 M
squirrels → 32 M
bear, caribou, moose, antelope → 250,000

80 M US/yr for fur and pelts
→ includes 50 M raised
→ 30 M hunted

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

5. Education

most commonly dissected mammals are fetal pigs and cats

fetal pigs: 500,000
cats: >100,000

6. Research

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

>70 Million/yr in US alone

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

90% of research animals are rodents bred specifically for research

<u>What kinds of research?</u>

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

→ 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

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

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:

<u>Pain</u>

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 rights" advocates