

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 (notacase)

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

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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,

Segmented skeletal muscles(myotomes)

especially seen in fish

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

provided more control over body movements

complexskin

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

numerous of sensory receptors

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

keratin structures: scales, hair, feathers

more efficient digestivesystem

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complete digestive tract with more efficient kidneys (most cephalochordates had none) collect and get rid of metabolic wastes & toxins greater role in sa
areas for food processing **9. almost all are dioecious and reproduce only sexually**

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 circulatorysystem

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 excretorysystem

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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

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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 infant fish, *Schindleria brevipinguis*, (Australia)
males 7 mm long (~1/4th), female 8.4 mm and weighs 1 mg

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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

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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 along
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. 2 ft salmon  14 mph

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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 O₂ from water

Respiration

Gills are thin feathery sheets with lots of blood vessels for efficiently getting O₂ from water

some fish can also breathe through their skin

a few fish can breathe 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

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

as much as 10°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

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themselves in sand or spin "sleeping bags" 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 immovable **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":

jawless fish (Agnatha)

108 species

cartilaginous fish (Chondrichthyes)

970 species

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

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 predator 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 accidents 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 depleted food

expensive control measures

 expensive larvae displaced in ~~and~~ 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 (streamlined shape) = **sharks**

 very good swimmer

s 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 dorsoventrally 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'); world's 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

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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 'claspings')

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

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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

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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 host's feces rather than pieces of dropped food

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Human Impacts of sharks

Shark attacks

60-70 per year (2000-2011); 1-12 fatalities especially great white (to 6 M long)
mako
tiger bull
hammerhead

more casualties 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)

Shark fishing

~40 Million/yr (26-73M 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

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 vertebrates 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 (44° C)

others under antarctic ice at -2° 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. wolfish, eels)

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

laterally compressed (eg. angelfish)

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

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

elaborate 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

Coloration of bony fish shows a variety of colors and texture
Common: 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, camouflage

countershading

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

few 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 camouflage

mimicry

another form of camouflage

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: camouflage

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

(2/5ths of body volume in most; 3/4ths 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. 1ft trout  6.5 mph
eg. 2ft salmon  14 mph

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 (O₂) 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

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Piranhas are known as vicious 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, densely packed teeth
rap; can be very aggressive but are only rarely known to bite and injure humans

are considered a nuisance to commercial and sport fishers

used for aquaria but illegal in most states in US occasionally found in US rivers but generally can't survive cold winters

herbivores

many freshwater fish eat plants, grasses, algae, etc
mollies, some cichlids, headstanders, etc

scavengers & detritivores

catfish, suckers & minnows

parasites

Toothpick fish (Candiru)

parasitic freshwater catfish in Amazon river

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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 murky 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 orifice;

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

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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 commercial fish are plankton feeders
eg. herring, anchovies, menhaden

travel in large schools

plankton are strained with sieve-like gillrakers

eg. predators

teeth used to seize prey

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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 "breathe" 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

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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 camouflage

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

✍ upto 40% of body weight

most powerful electric organ of all fish

✍ can produce upto 600 voltstostun or kill prey

✍ can give several 100 shocks upto 300 V each/second

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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)

✍ generally little or no parental care

most fish produce large numbers of eggs:

eg. halibut ✍ 3.5M
Meg. cod ✍ 4 - 6M

✍ 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

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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 and 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 fertilize 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

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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' 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, silver, 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 breathe 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 consumption is by the developing world (2008)

Commercial fishing employs 200 Million people worldwide

marine fisheries are in trouble:

World 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

World's 17 major fisheries are overfished and in decline

Some of the problems:

Overfishing has encouraged overfishing which makes it a non-sustainable resource

World spent \$124 billion to catch \$70 billion of fish the difference was paid for by taxpayers

Commercial fisheries are near shore where most pollution and damage occurs

World fish catch only two thirds are used

mainly for human consumption,

rest is converted to fish meal and oil,

and pet and livestock food

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

examples:

eg. commercial fishers 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

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

93milliontonnes2002

133milliontonnes

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

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

noneoftheseshavebeenshowntohaveany scientifically validvalue

(1980 only 9%)

Animals: Vertebrates ; Ziser LectureNotes,2013.6

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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 andland:

aircontains20x'smoreoxygenthanwater

water is 800x's more dense than air

airtemperaturesfluctuatemuchmorethanwater temperatures

landoffersnumerousnew,unoccupiedhabitats and untapped foodresources:

virtuallynolargepredatorsonlandyetwhenamphibians moved ontoland

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adaptations needed to survive on land

respiratory surfaces must be kept moist, usually internal

outer surface of body must reduce desiccation/water loss

landanimalsneedstronglimbsandremodeledskeletontoget around onland

mustberesistanttoextremeseasonaltemperature; hibernation,migration

eyes and ears become dominant sense organs

greaterneedformoveabletonguetomanipulatefood in mouth wheneating

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

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 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 limb 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

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 most must return to water for reproduction

eggs must be laid in water

immature stage is aquatic

once the first amphibians 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 (300MYago)

= Age of Amphibians

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

live and breed in protected moist areas:

under logs 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

Body Form

great variation in form:

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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

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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' (30cm) 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 "" (1cm)

Skin

most amphibians have thin moist skin without scales

very delicate

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

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but allows it to be used for **respiration** if kept moist
their skin has lots of **glands**: **eg. mucous glands**
makeskinlippery/harderforpredatorstogetat helpskeepitmoistforbreathing

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 camouflage many toxic amphibians are brightly colored as
warning coloration

less toxic species use color for camouflage

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

g from extracting oxygen from water to extracting it from air required major changes in both the respiratory and the circulatory systems

in several ways:

ole lungs

ed in fish lungs

ing as well as sensory

n cavity

ime

ntinolungs

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 O₂ 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 amphibians 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

larva resembles adult aquatic forms retaining gills

(paedomorphosis)

eg. *Necturus*, mudpuppies

terrestrial forms lose gills and develop lungs embryos of salamanders resemble adults

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 caecilians 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

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 directly 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

Ecology & Human Interactions with Amphibians

A. Beneficial Effects of amphibians

 Frog 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

 embryological 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 world's 6,000 amphibian species are threatened

 one of the 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

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 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

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

 very effective waterproofing

****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

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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 walkin

g toes with **claws**

most land reptiles can **burrow** into mud

eg. turtles and small lizards

most reptiles **swim** wit 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 *Ptychozoon* sp.

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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

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food is swallowed whole

stomach often has pebbles to help grind food (= **gastroliths**) common find at dinosaurs 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 breathe 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

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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

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some reptiles (crocodilians) produce musk 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 camouflaged 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

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Reproduction and Development

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

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

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 off its tail with a sharp twist

the tail twitches and writhes 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 **warmblooded**

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. Turtles

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

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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 berries
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. Lizards & Snakes

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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

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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 sidewinding 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

Animals: Vertebrates ; Ziser Lecture Notes, 2013.6

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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. Crocodiles & Alligators

mostly unchanged for 200MY

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

larger robust skull with massive jaws with powerful
closing muscles

Animals: Vertebrates; Ziser Lecture Notes, 2013.6

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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

Animals: Vertebrates; Ziser Lecture Notes, 2013.6

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-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

Animals: Vertebrates; Ziser Lecture Notes, 2013.6

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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 Kemp's Ridley sea turtle

eg. Kemp's Ridley sea turtle
1947: 40,000
1985: ~200
1994: 580

they like the same beaches we do

Animals: Vertebrates; Ziser Lecture Notes, 2013.6

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eggs and meat
poached, broiled, fried, or sautéed during nesting season
affected by pollution & fishing
requires exclusion devices or shrimp nets

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

akes

World Trade in Live Reptiles/ Pet Trade

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

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

1 the United States imported just under
live reptiles.

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

00,000 were **green iguanas** (*Iguana iguana*) from Central and South America.

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 studded (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

Herbal Medicine

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

turtle blood is available at Walgreens in China turtle heads are consumed for labor pains
powdered snake gall bladder is used as a cure for bronchitis
coin snakes 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

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

Animals: Vertebrates; Ziser Lecture Notes, 2013.6

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flightless bird, related to emus

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

birds are found in all habitats:

forests, deserts, mountains, prairies, 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

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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

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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 have a variety of feathers designed for:

flight (contour feathers)

insulation (downy feathers)

decoration & display

sense of touch

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birds spend much time on feather maintenance:

preening ✎ reconnects barbs & bathes ✎ 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:

in most birds only the legs have scales instead of feathers arctic birds have NO bare areas
head and neck in some birds have combs or wattles often brightly colored "ornaments"
used for dominance or sexual signaling

vulture head is bare

✎ keeps feathers clean while feeding on carcass

ostriches & relatives

✎ unfeathered legs used for cooling after heavy exertion

Molting

feathers are shed regularly = **molting**

Animals: Vertebrates ; Ziser Lecture Notes, 2013.6

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highly orderly process

(except for penguins 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

Animals: Vertebrates ; Ziser Lecture Notes, 2013.6

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

es, most greens and some purples animals

birds, indigo buntings, bluebirds eg. there is no "color" in blue jay feathers

color used for:

camouflage

species, juveniles and females are camouflaged with melanin pigments

birds white in winter, darker in summer

feeding/communication

feeding plumage often brightly colored

warning

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

Support & Movement

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

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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

frigatebird: 7' wingspan ✎ skeleton = 4oz
✎ less than weight of feathers

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

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

Animals: Vertebrates ; Ziser Lecture Notes, 2013.6

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most mammals have 7 vertebrae
birds have 11-25 vertebrae

the major flight muscles attach 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*

✍️ 22kg (~10lbs)

when flying 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

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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

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Feeding & Digestion

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

birds 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, dismember 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 ✍️ basket like sac below beak to catch fish

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

hummingbird has the fastest metabolism of all birds

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

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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

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✍️ they maintain a constant body temperature independent of environment

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

flight is energy intensive; requires a consistently high metabolism

higher than land mammals (eg. 110° vs 98° 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 inhaled & exhaled
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 O₂ 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 **syrix** (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 chickadee 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

stereovision=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 ritual to bring female into the territory a

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 futilely with its reflection in a window pane

during sex the male will "sweetly" put its wings over the female's 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 not transfer organ ✍ press cloaca together

a few birds have erectile penis with external groove to guide sperm into female's cloaca

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

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 spread 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

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 weaverbirds

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 lb (the weight of almost 3 cars)

thesame 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 Madagascar

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

Human Interactions

meat and eggs

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

chickens 13 B/yr
turkeys 304M/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

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 NAm birds

✍ 1830's Audubon saw a single flock

little if any odor
fused petals with nectary
produce copious 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

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.

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

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

Introduced pests

eg. starling

eg. house sparrow

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 of soft 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"

birdwatching

more lucrative than bird hunting

hunting

91 M birds are hunted each year worldwide 21 M waterfowl

~2 injured / 1 taken

research

5 M birds are used for research each yr

bycatch

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

wildlife photography, art

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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 (=6,590kg)

smallest mammals:

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

Kitti hog-nosed bat  0.05 oz (1.5g)

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, ~~veg~~ large eyes

 probably ~~not~~ warm blooded

(many reptiles were warm blooded then)

for 160 MY they lived in the shadow of the dinosaurs

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"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.

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shedding (molting)

in most mammals entire coat is periodically molted

eg. foxes and seals  by reg. 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:

camouflage

protective camouflage:

eg. arctic 
eg. outside arctic  somber  disruptive camouflage

eg. leopard spots eg. tiger stripes eg. fawn spots

warning

eg. skunk

hair can be modified to serve a variety of functions:

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not normally shed; do not regenerate or 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 (eccrine glands)

 important in warm bloodedness; temperature  to esp on hairless regions; eg foot pads

simple, tubular, highly coiled

only mammals have sweat glands heat regulation

part excretory organ

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sensory hairs

vibrissae (whiskers) ✎ tactile, sensory
eg. cats

defensive hairs

eg. spines porcupines, hedgehogs

horny or bony plates

eg. armadillo, pangolins

some have lost most of their fur

eg. hippos, elephants, porpoises, 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

scent glands & apocrine glands

✎ smell important in most mammals social animals
in most mammals social animals in most mammals, in humans
their location and function vary greatly

used for communication: territory
warning defense mating

oil (sebaceous) glands

associated with hair follicles

used to keep skin and hair pliable and waterproof

mammary glands

all mammals feed their young milk

Support & Movement

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

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 sliding
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 mammals

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

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

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

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"

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

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

often have **sympiotic 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

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Respiration

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

all mammals have **lungs** and breath air

whether terrestrial or aquatic

lungs are very efficient, second only to birds

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

 provide much greater surface area for gas exchange

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

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

much more efficient than gulping air or expanding rib cage

Circulation

like birds mammals have **4 chambered heart & two separate circuits** of blood flow

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smaller mammals with higher metabolism have faster heart rate

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

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 shrews are one of the few venomous mammals

send a mouse into a coma (won't 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 fitness to the females

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

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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

egg laying

monotremes

produce thin leathery shell

no pregnancy (gestation) after hatching, young are fed milk

marsupials

brief gestation

then crawl to pouch and attach to nipple

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

= embryonic diapause

3. Placental mammals

by far the most common relatively long gestation period
eg. mice 21 days, rabbits 30 days, cats/dogs 60 days, cattle 280 days, elephants 22 months

Hibernation

eg. black bears

in winter they can lower their body temperature up to 5.5°C (~15°F) and their total metabolic rate to only 25% of its normal rate. Heart rate drops from 55 bpm to 14 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 mammals migrate
most of these are in N. America

Ecological Roles of Mammals

major parts of food chains in most ecosystems

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

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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:

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60M 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

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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**  madewith animal fat

tseg. **freon**  animal fat used to make it

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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 & back to US for products sale

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

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

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

Education

most commonly dissected mammals are fetal pigs and cats

fetal pigs: 500,000

cats: >100,000

Research

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

>70 Million/yr in US alone

US	Worldwide
/yr: rats & mice 60 M	115 M
guinea pigs 204,809	
hamsters 167,571	
dogs 87,000	140,016
cats	most from shelters; ~40,000 bred for research 21,637 35,004
primates	most from shelters 62,315
pigs rabbits sheep	many from breeding colonies 57,000 175,020 554,385 1,003,448 3,700

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: 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 of glycerine and crude fatty acids: stearic & oleic acid)

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

eg. if animal has gall stones

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90% of research animals are rodents bred specifically for research
What kinds of research?

animals are used for both basic and applied research

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

diagnostics

1-5% of all lab animals are used to diagnose disease eg. TB, diphtheria, 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:

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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 research

guinea pigs: toxicity & safety testing, effects of cigarette smoke, alcohol and drugs, spinal cord injury investigations, TB research, kidney function, osteoarthritis research, nutrition and genetic research

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

Food and Crop Loss

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

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 gazelles 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

Pollution

cattle lots, hog farms

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

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 animal 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

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✎ 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 fat

✎ eg. **freon** ✎ animal fat used to make it

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

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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

✎ it is 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

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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, captive 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:

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oversimplistic generalizations, loosethinking

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

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

some antivivisectionists tactics result in more pain and mistreatment than the research they oppos

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 resear

the "animal rights" movement has: driven up the cost of research
more money spent on tighter security and to repair damaged facilities

may slow development of therapies and treatments

reduces the amount of research being done

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

Are there alternatives?

other methods are often cheaper and require less paperwork:

scientists tend to use them whenever they can animals are used only when it is the best way to get the appropriate information

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

eg. high blood pressure cannot be studied in invertebrates

still, there is an effort to find alternatives when possible

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

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

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

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

Pain

probably one of the biggest concern is causing pain to animals

most animals are capable of experiencing pain

generally scientists acknowledge and accept that all warm blooded animals and most cold blooded 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

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 in shelters and pounds
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✍ many more pets and farm animals are eutherated, 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

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