Phylum Chordata – Vertebrates
Amphibia

6,000 species

1st *vertebrate* group to make transition onto land

arthropods	→	plants	→	amphibians	→	reptiles
420MY		400MY		370MY		280MY

all vertebrates are basically alike in overall body plan

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

→basic differences between water and land:

1. air contains 20x's more oxygen than water also with faster diffusion rate

   but respiratory surfaces must be kept moist

2. water is 800x's more dense than air

   water is harder to move through but does buoy up the body

   land animals need strong limbs and remodeled skeleton to get around

3. water fluctuates little in temperature

ocean temperatures are constant

land has harsh cycles of freezing and drying

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

eg. terrestrial arthropods and plants

Origin of Tetrapods

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

~370MY ago the earth was becoming dryer with alternating droughts and floods

during these dry periods freshwater ponds & pools often dried up

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

fishermen collect them with spades

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

→ fins were used for walking

these same fish had a lung-like sac that allowed them to breath air for short periods of time as well

→ lungs and limbs evolved for fish to survive in water

amphibians are descendants of these lobe finned fishes

all the survivors of this period had a kind of lung that had developed as an outgrowth of the pharynx

its efficiency was enhanced by development of additional capillary beds

only later used to move onto land

The First Amphibians

the earliest amphibians (***Ichthyostega***, 360 MY) shares many features with lobe finned fish (***Eusthenopteron***):

1. both ~ 1 M long and lived during Devonian
2. skull are very similar in structure
3. both had "third eye" (**pineal eye**)
4. had middle ear that could hear sound vibrations in air
5. had similar teeth (=labyrinthodont)

6. had short stocky appendages with digits

7. tail still had tail fins with fin rays

8. had bony **operculum** as in ancestor

9. still had **lateral line system**

10. *Ichthyostega* had an ear design that allowed it to hear better underwater than on land

→ probably spent considerable time in water

but transition wasn't complete

→ still need moist environment

→ must return to water for reproduction

eggs must be laid in water

immature stage is aquatic

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

= Age of Amphibians

land was covered with vast fern forests

primitive insects, some flying insects

today, many amphibians have adapted even more to a dry land existence:

most amphibians move from pond to pond for

food during droughts

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

a few don't require water for reproduction

largest: African bulfrog, *Gigantorana goliath*

→ 30 cm (~1') long, nose to anus; 7.5 lbs; eats prey as big as rats & ducks

[largest US bulfrog gets to 20 cm (<8")]

smallest: cuban frog

→ less than 1 cm (.5")

Body Form

great variation in form:

eg. **salamanders**: head-trunk-tail

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

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

no limbs, no post-anal tail

limbs usually 4 digits on forelimbs & 5 digits on hindlimbs

Skin

most with thin moist, glandular skin without scales
(~1.5-4mm vs humans 30-80x's thicker)

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

consists of 2 layers

epidermis including thin dead cornified layer
→ shed periodically and eaten

dermis

thinness of skin and vascularization allows it to be used for **respiration** if kept moist

often with many **glands**:

eg. mucous glands

make skin slippery → harder for predators to get a hold

eg. poison glands

usually concentrated in areas behind eyes

when stressed poison gland secretes toxin

skin is often brightly colored

→contains **chromatophores** in dermis

many can adjust their color for camoflage

many toxic amphibians are brightly colored as warning coloration

less toxic species use color for camoflage

darkening of skin color controlled by light sensitive **pineal eye** which is connected to pineal gland

→ triggers release of **MSH** from **pituitary gland**

Support & Movement

stronger, skeleton, mostly of bone, supports body weight on land

rigid framework for muscle action; esp leg muscles

→ muscle mass shifted from trunk to legs

strengthened rib cage and axial skeleton to support internal organs

abdominal organs hang down from axial skeleton which bears most body weight

stronger limbs with toes for land locomotion

→ made up of the same set of bones found in all land vertebrates

legs don't support body very well,
→body touches ground at rest

still move in very fish-like fashion

most **muscles** have lost the "segmentation" seen in fish myomeres

instead modified into "**opposing pairs**" to flex/extend or abduct/adduct limbs, etc

swimming

aquatic forms have fish-like undulating swimming motion

gliding frogs:

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

large webbed feet

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

Feeding and Digestion

most are **predators** (carnivores)

eat mostly insects

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

other frogs

some aquatic forms filter zooplankton from water

many have sticky **tongue** to capture prey

in some frogs its attached at front of mouth

[some take <.5 sec to catch prey with tongue]

food swallowed whole, not chewed

Respiration

amphibians can take in oxygen in four ways:

a. lungs
b. through skin (cutaneous breathing)
c. mouth (buccal breathing)
d. gills

a. lungs

most amphibians have lungs

very simple lungs; essentially air sacs

→ lungs are not very efficient

[mammal lungs are >15 x's more efficient]

nostrils open directly into mouth cavity

→ cant eat and breath at the same time

and **no diaphragm**

→ must gulp air to force it into lungs

b. skin

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

even when lungs are used for oxygen; most carbon dioxide is lost through the skin

c. mouth

can also use **mouth lining** for respiration

some salamanders have dispensed with lungs and gills and use cutaneous or mouth respiration only

d. gills

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

some species retain gills as adults

Circulation

circulatory system is improved over that of fish

have **3 chambered heart**; 2 atria, 1 ventricle

two complete **circuits** of blood flow

pulmonary circuit & **systemic circuit**

picks up O_2 in lungs and returns to heart

then sends oxygenated blood to rest of body

→ much more efficient; heart is a double pump

Nervous System & Senses

based on body mass

→amphibian brain is about same as fish

cerebrum, esp optic centers, are relatively larger in amphibians than fish

cerebellum is relatively smaller than fish

Senses:

a. lateral line

many purely aquatic species have retained the lateral line system

in air there is not sufficient density to activate receptors in lateral line

→ use **touch**, **pressure** and **temp** are sensed mainly by free nerve endings in skin

senses of **smell** and **hearing** became more important than lateral line

b. vision

vision is dominant sense in many amphibians

eye is similar to ours with a few differences:

has lacrimal gland and eyelids to protect from drying

lower lid has a nictitating membrane
→ sweeps over eye when blinking

accommodation (focus) by moving lens in and out
→ not changing its shape as we do

retina has rods & cones → color vision

much visual processing occurs in the eye before signals reach the brain

c. smell

smell due to olfactory epithelia in nasal cavities

also have "**Jacobson's Organ**" in roof of mouth

d. hearing & sound

have middle and inner ear, no outer ear

→ eardrum is on outside of head

a single ear bone (=columella or stapes) (not 3 earbones as in us)

transmits sound vibrations from eardrum to inner ear

most amphibians have a **larynx** with vocal cords

frogs pass air back and forth over vocal cords between **lungs** and **vocal sac** in floor of mouth

use sound to attract a mate

better developed in males than females

→ males do most of the calling

some sound is also transmitted through forelimbs, muscles and soft tissues to inner ear

→ esp low frequency "seismic" vibrations

→may warn of large predators

e. balance and equilibrium

like fish, amphibians have inner ear that detects position and acceleration via **otolith organ** and **semicircular canals**

Excretion & Salt/Water Balance

Nitrogen wastes are eliminatyed as ammonia or urea;

a few desert frogs can produce uric acid
→ requires much less water to eliminate

skin and kidneys are the may way salts and water are gained or lost

amphibians cannot conserve water by producing a concentrated urine

most amphibians can store urine up to 1/3rd body wt in bladders and lymph sacs beneath skin

kidneys conserve salts by reabsorbing them from urine to compensate

most amphibians do not actively drink water

Protection

many amphibians have **poison glands** in skin

can cause blindness or death

Reproduction & Development

dioecious

since they are cold blooded
→ life is controlled by seasonal climatic conditions

most breed soon after spring emergence from hibernation

males often take posession of a perch near water

then males call to females

breed for several weeks

amplexus:

male frog holds onto female

female deposits eggs in water anchored by sticky jelly
male deposits sperm over eggs

some can reproduce by parthenogenesis

eggs typically hatch into tadpoles in ~ 1 week
with gills, suckers and spiracle

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

- legs appear
- tail is reabsorbed (in frogs)
- lungs develop

embryos of salamanders resemble adults

→ undergo less pronounced metamorphosis

some retain gills as adults

Migration

some amphibians have a strong homing instinct

→ return to the same pond each year for mating

guided by olfactory cues

Kinds of Amphibians

3 main orders:
- "with tail" (O. Caudata)
- "without tail" (O. Anura)
- "without feet" (O. Apoda)

A. Salamanders & Newts (Order Urodela or Caudata)

3 species of salamanders in Travis County

least specialized, resemble ancestor

limbs at right angles to trunk

→ walk with "S" motion of trunk

most have aquatic larva that metamorphoses into terrestrial adult

mainly in N America

mostly nocturnal

some up to 4' long

live in cool damp places

including along mountain streams

→ most cold tolerant of all amphibians

a few are arboreal and avoid water

both larvae and adults are **carnivores**

eat worms, small arthropods & molluscs

some have teeth in roof of mouth

some with prehensile tongue up to half body length

some without lungs or gill → breath through skin

in most, fertilization is internal but not by copulation:

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

some adults guard eggs

some reproduce without metamorphosis

→larvae resembles adult

aquatic forms retain gills
(paedomorphosus)

eg. *Necturus*, mud puppies

terrestrial forms lose gills and develop lungs

examples:

eg. Barton Springs salamander

B. Frogs and Toads (order Anura (="no tail"))

17 species of frogs in Travis County

by far the most successful & widespread group

5283 species or 88% of all living amphibians

an ancient group

→ known from Triassic (250 MY)

hind legs specialized for jumping

occupy a great variety of habitats

especially common in tropical swamps and forests

but found in all habitats; even dry areas

frogs are more aquatic and generally live in or near water

toads are more terrestrial and only move to water to reproduce

more dependent on lungs than other amphibians

those that are completely aquatic usually lack tongue

highly specialized for jumping locomotion

- some can glide like flying squirrels
  - eg. flying frog of tropical Asia

most larger frogs are solitary except during breeding season

most have long flexible tongues attached to the front of the mouth for capturing prey

tree frogs have large, adhesive pads on the ends of their toes

tongue of frogs is connected to front of mouth

- free end produces sticky secretions to adhere to prey

some have teeth to hold onto prey and prevent its escape

protection

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

frogs tend to stay very still

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

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

some can give them a painful bite

many frogs & toads have poison glands

eg. poison arrow frogs

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

its skin is collected for fine leather

hibernation

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

use energy from glycogen and fat stores

more terrestrial frogs hibernate in humus on forest floor

some can survive freezing

eg. woodland frog is the only vertebrate able to survive after its been frozen
- they live north of the arctic circle
- glucose in blood acts as antifreeze
- up to 65% of its body water may be frozen and heart stops completely
- what freezes is the water outside its cells, not water inside cells

reproduction

most frog eggs hatch as herbivorous **tadpole larvae**

at **metamorphosis**: lose gills and tail

one genus of tropical terrestrial frogs the eggs hatch circtly into "froglets"; no aquatic stage

frogs & toads have a variety of unique reproductive behaviors

rely on characteristic vocalizations from vocal cords & vocal sacs

a few tree frogs build nests: cuplike crates

along streambank

another makes waterproof depressions in tree hollows using beeswax

some brood young in stomach

eg. Surinam toad; *Pipa*

completely aquatic

fertilized eggs are deposited on the back of female

the eggs sink into the spongy skin forming separate incubation chambers

each chamber is covered by thin sheet of skin

larvae undergo metamorphosis in these chambers and emerge as adult toads

eg. midwife toad

female lays eggs fastened together like beads on a string

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

male then takes eggs to his burrow

he comes out only at night to search for food

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

eg. one species of frog broods young in its stomach

C. **Caecilians** (O. Gymnophiona; Apoda)

~173 species

elongated, limbless, burrowing or aquatic animals

10 cm to >1.5 M long

in tropical forests of central and south America, Africa, India

skin is smooth and slimy

but some with small calcified dermal scales under skin

also skin has folds that make them look like large segmented earthworms

small eyes → most ar blind as adults

sensory tentacles on snout

feed on worms and small invertebrates

skin has squirt gland that secretes irritant

→causes sneezing in humans

internal fertilization, most viviparous

fetuses feed on secretions and tissues they

scrape from lining of moms oviduct

Ecology & Human Interactions with Amphibians

A. Beneficial Effects of amphibians

→Frogs eat **disease-carrying insects**

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

B. As Food

not a major part of human diet
→frog legs

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

led to the death of some 26 million frogs annually.

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

Now Indonesia supplies most of the frogs for restaurants

C. Education & Research

most commonly dissected laboratory animal:
in science classes and research

20M frogs/yr in US

→ much of our medical knowledge came from frog dissections

→ embyrological studies

→ isolation of pharmaceuticals

D. Poisons

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

several species of tropical frogs secrete potent neurotoxins
distasteful
induces paralysis

often brightly colored

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

some of these toxins are hallucinogenic

(frog licking)

E. As environmental Indicators

amphibians are extremely sensitive to environmental indicators

in 80's & 90's noted declines

→ since 80's 120 species have become extinct

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

→ one of largest extinction spasms in vertebrate history

unsure of exact causes of declines:

Probable causes of decline:

1. The number one cause of amphibian decline is habitat loss

   most amphibians feed and breed in wetlands,

   In the past half-century the lower 48 states have lost more than half of their estimated original wetlands.

2. pollution

   deformities from animals in polluted water

3. water molds

most recently has been tied to worldwide spread of a primitive protist (water mold) pathogen

this is the first water mold known to attack vertebrates.

→ *Batrachochytrium dendrobatidis* (chytridiomycota)

(including in and around central Texas)

spreads very rapidly; don't know how it kills frogs

Barton springs salamander has natural antibiotics in its skin that seem to protect it from the pathogen)

scientists have mobilized to collect and save representative species in safe haven protected from fungus

4. deadly virus is the likely culprit in several recent die-offs of frogs,

5. Increased exposure to ultraviolet radiation may damage the eggs

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