# Amphibians

1) Transition to land
   a) Life on terrestrial earth is a major theme for all non-fish vertebrates also known as Tetrapoda
   b) Of Tetrapoda there are two major groups Amphibians and amniotes
   c) The movement form water to land is one of the most complicated and dramatic events of the evolution of animals
      i) Land is physically hazardous for an animal that evolved in water, is made mostly of water, and all cellular activities occur in water.
      ii) Plants, snails, and many arthropods made the transition before vertebrates, which provided a plentiful food source.
      iii) With the transition to land, vertebrates had to adapt every organ system.
   d) Oxygen on land
      i) Atmospheric air contains 20 times more oxygen than water and diffuses more rapidly through air than water.
      ii) By the Devonian period (400+ million years ago) fish had diversified greatly. Some of these adaptations became useful for a terrestrial life
         (1) Fish had evolved an air sack within their body called a swim bladder. This would allow a space for gas exchange between an organism and air
            (a) These early fishes were most likely freshwater. Freshwater systems are more likely to evaporate or deoxygenate compares to salt water habitats. So having a vascularized swim bladder or lung would be beneficial.
            (b) To this day scientist still debate heavily on whether the swim bladder evolved for buoyancy control or lung first.
         (2) Fish also had evolved external nares for chemoreception. In a terrestrial environment these nares can be used to draw in air to the swim bladder/lung
         (3) Both of these structures show great examples of evolution utilizing existing structures to turn into something new and more adapted
   e) However both of the characteristics are shared among fishes and tetrapods, the big shift came in the bone structure of the limbs.
      i) One of the biggest fights vertebrates had to overcome when moving on shore was how to move in a less dense environment.
         (1) Air is 1000 times less buoyant than water, and 50 times less viscous, thus it provides little support against gravity
      ii) In lobe fin fishes we see robust strengthened fins. These were most likely used to propel themselves across muddy bottoms, or in caves, or highly vegetated areas.
      iii) Some early Devonian groups could use these fins to pull themselves across land, however they did not have the robustness and musculature to fight against gravity.
      iv) The fossil record shows us the evolution of limbs quite well.
         (1) In *eusthenopteron* ( a late lobe fin fish) it evolved a recognizable humorous, radius, ulna, and smaller bones similar to modern wrist bones. However it could still not lift its body off the ground so was restricted to only an aquatic life.

(2) *Tiktaalik* (nicknamed "fishapod") is a mix between lobe fin fishes and modern terrestrial tetrapods.
   (a) Its eyes are on top of the head as compared to the sides, its nares are also on top.
   (b) It most likely lived in shallow oxygen-poor environments using tis limbs to support its body enough to stick its head above water.
   (c) This organism is likely the first tetrapod to be able to leave the water for a matter of time however it likely was unable to sustain life outside of the water for long.
(3) *Acanthostega* had more advanced limbs than *tiktaalik* (having evolved fingers) allowing for more time on land but it still needed to spend most of its time in the water.
(4) *Ichtyostega* had a fully developed shoulder girdle, bulky limb bones and well-developed muscles. This was probably the first organism to be able to walk successfully on land and perhaps hunt on land as well. However, it still retained some aquatic structures such as a tail with fin rays, and opercular bones.
(5) *Limnoscelis* was a true terrestrial vertebrate that we know of from the fossil record. The unique thing about it was it shows the pentadactyl (5 finger) form of all modern tetrapods. Previous species had more than 5 fingers ( *ichthyostega* had 7 digets, *acantostega* had 8).

f) Cardiovascular systems
   i) In fishes blood flows from the heart to the gills (where it gets oxygen) to the body then returns to the heart. However, on land a new style of circulation takes place. Blood flows from the heart to the lungs (to get oxygen) then back to the heart to be pumped to the rest of the body.
      (1) This is much more effective because it allows the heart ( a very important organ) to get oxygen first before going off to the body.

g) Osmoregulation
   i) A body made of water living in the water regulates its osmoregulation different than a terrestrial organism than has to carry its water around and replace any lost from its surroundings.
   ii) In vertebrates two main structures help regulate water in the body, the large intestine, and the kidneys.
      (1) Fish have small kidneys and almost inexistent large intestines
      (2) Terrestrial vertebrates however have larger kidneys to remove waste from the body without loosing to much water.
      (3) Large intestines are used to absorb as much water as they can from food getting ready to be defecated.

2) Amphibians
   a) There are about 7000 species of amphibians known today.
   b) They include three groups: frogs/toads, salamanders, and caecilians
   c) Amphibians represent a group of organisms that live part of their life in water and part of their lives terrestrially
   d) Metamorphosis
      i) Amphibians lay eggs in aquatic environments

ii) These eggs hatch to aquatic offspring
iii) The offspring undergo changes in order to become terrestrial
iv) Adults almost always are terrestrial
(1) Note that there are some species that do not undergo this change however these are derived characteristics and evolved separately.

e) Circulation
i) Living on land has its advantages, like oxygen levels are higher.
ii) To utilize this level of oxygen amphibians have evolved a double circulatory system
iii) Their hearts have three chambers: 2 atrium and one ventricle
(1) Deoxygenated blood comes into the right atrium
(2) then blood pumped into the ventricle out to the lungs to get oxygen
(3) oxygenated blood comes back to the heart into the left atrium
(4) this goes into the ventricle and is pumped out to the body
iv) this is much more efficient than fish, however note it only has one ventricle so at some point deoxygenated blood and oxygenated blood are likely to mix.

f) Respiration
i) In larval forms oxygen is either absorbed by gills, though the skin, or both.
ii) In adults lungs are typically present and allow for oxygen exchange through the capillary beds. However many adults still get oxygen absorbed across the thin layer of highly vascularized skin.

g) Excretion
i) Amphibians have more developed kidneys than fish but they are still reliant on water in their everyday life so excretory structures are still underdeveloped.
ii) Large intestine is present in adult forms however it is proportionally small compared to other terrestrial vertebrates
iii) The waste byproduct of fish is ammonia which is excreted either out the anus or out the gills. Amphibians however produce urea which is a less toxic form of ammonia.

h) Sensory developments
i) Certain structures like lateral lines and ampullae of lorenzini are no longer functional in a terrestrial organisms
ii) Ear's become more functional with the evolution or tympanic membranes (ear drums)
iii) Vision is different above and below the water so the cornea becomes the primary region for refracting light compared to the lens in fishes.
iv) Lacrimal glands (tear glands) are needed to keep eyes from drying out along with eye lids.

3) Caecilians
a) This is a group of limb less burrowing amphibians native to tropical habitats.
b) Eyes are small or nonexistent
c) They feed on worms and other insects found in the ground
d) They reproduce sexually
e) Most lay their eggs in aquatic habitats where larvae hatch into aquatic forms with gills and tails
i) Other species larvae development takes place in the egg

ii) Some species however have been known to keep the eggs hidden in the female folds of her body in order to keep them safe and moist.

4) Salamanders
   a) These are the tailed amphibians
   b) They are most diverse in northern temperate regions like North America, however some do live in tropical region
   c) Size
      i) Most are less than 15cm long
      ii) The giant salamanders of japan can reach up to 1.5m in length
   d) Limbs are set at right angles to the body
      i) Limits mobility?
   e) All are carnivorous preying on worms, arthropods, molluscs, and pretty much anything else smaller than it.
   f) Reproduction and development
      i) Most fertilize eggs internally
         (1) The male lays a sperm packet on a leaf or stick and the female comes and sucks it in her cloaca
         (2) Some do have courting behaviors and a female will mount a male to collect his sperm packet
      ii) The ancestral form is similar to all amphibians with an aquatic larvae and terrestrial adult
      iii) Many modern species have adapted to a truly aquatic or truly terrestrial form.
         (1) In these cases they no longer undergo metamorphosis but rather skip the larval stage and undergo direct development.
         (2) In aquatic species eggs are laid in rows or masses in the water to hatch
         (3) In terrestrial species they are laid in grape like clusters under logs or in holes dug out of the moist dirt.
         (4) Many species guard their eggs and take care of them by rotating them so each egg gets the most oxygen, protecting them from fungal infections and potential predators.
      iv) Some species however have a complex lifecycle where they metamorphous into a terrestrial form then a year or so then later metamorphous into a secondary aquatic form for mating.
   g) Respiration
      i) With various life stages they can have gills, lungs, both, or neither of these structures.
         (1) Necturus
         (2) Axolotl
            (a) Facultative metamorphic
      ii) Almost all will have cutaneous respiration where their skin is heavily vascularized to allow for oxygen and carbon dioxide exchange.
         (1) Longtail salamander

5) Frogs/toads
   a) These are tail less amphibians
   b) All of these are adapted for jumping
   c) All are dependent on water

d) Frogs have thin skin and closely reliant on water
e) True toads belong to one family and have thick skin, lots or warts, and are terrestrial
    i) The term toad has been given to many thick skinned terrestrial frogs as well though.
f) Size
    i) Two species measure less than 1cm (these are the smallest known tetrapods)
    ii) The largest get over 30cm from nose to anus (not including legs)
        (1) In America the bull frog is largest reaching 20cm from nose to anus
g) Distribution
    i) Most frogs are familiar to us near water bodies
    ii) The leopard frog is the most widely distributed frog in north America and can be found in every providence or Canada and state in the US.
    iii) Frogs are mostly solitary predators except for mating season
    iv) Frogs eat the familiar insect or fly, however some eat birds, fish, snakes, and well pretty much anything it can fit into its mouth
    v) During the winter frogs hibernate in cold water that has lots of oxygen
        (1) Some frogs have been recorded as becoming completely frozen in the winter and then thawing themselves out in the spring.
            (a) They do this my eating highly sugary foods and loading their blood with glucose and glycerol to prevent ice formation.
    vi) Frogs are large balls of meat that any predator would love to eat.
        (1) To protect themselves they preform many tasks
            (a) They can inflate to make then difficult to swallow
            (b) They produce bright colors to warm of potential poisons/toxins
                (i) Poison dart frog
            (c) But the most useful thing is the ability to jump
                (i) It seems trivial something so simple but very few other things in the animal kingdom jump so predators wouldn't know how to respond. It is also very quick and makes capture difficult.
h) Reproduction
    i) Males use vocal cords to call females in in order to mate
        (1) Remember sneaker males in fish….
    ii) When a female comes to the calling male he will put a death hug on her called a amplexus
    iii) He rides around on her until she lays the eggs then he fertilizes them and swims away.
        (1) The eggs hatch into a tadpole who feeds on yolk and has no gills
        (2) The yolk is absorbed as the gills and mouth develops. Feeding switches to algae early on.
        (3) As development continues they become predacious and limbs emerge and lungs develop/mature
        (4) In about 3 years from fertilization sexual maturity is reached.
    iv) Most frogs leave the eggs after fertilization but some go to great lengths to protect them
        (1) Marsupial frog
        (2) Surinam frog
        (3) Poison dart frogs

(4) Darwins frog
(5) Australian gastric brooding frog

6) Conservation
   a) Amphibians across the world are declining
   b) No single reason explains everything but habitat loss dominates
   c) Climate change forcing cloudland frogs up
   d) Increased drought
   e) Invasive species
      i) African clawed frog
      ii) Giant toads
      iii) snakes