I. Classification

Phylum Chordata
Class Amphibia

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<th>Order Gymnophiona</th>
<th>Order Caudata</th>
<th>Order Anura</th>
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<td>“Caecilian Worms”</td>
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II. Movement Onto Land

A. Land represents a relatively dangerous habitat for animals. Adaptations must be made to the following challenges...

1. The danger of ________________________________ — animals are made up mostly of water and are constantly at risk of dehydration and death.
2. Oxygen is __________________ more abundant in air and diffuses much more rapidly through air than water.
   a. Animals would have to come up with a new solution to respiration to replace gills (which need to be constantly wet).
3. Air is __________________ less dense and provides less buoyancy than water.
   a. Limbs and the skeleton must therefore support more weight.
   b. Terrestrial habitats selected for...
      1) stronger backbones
      2) muscles to support the body in air
      3) muscles to elevate the head
      4) stronger shoulder and hip girdles
      5) a more protective rib cage
      6) ear structure
      7) longer snout.
   c. Adaptations for life on land further included a skulls, teeth, pectoral girdles and jointed limbs.

4. Air fluctuates in temperature more rapidly than does water; animals must adjust to these extremes.
a. Animals must maintain a fairly narrow range of body temperature in order for the enzymes to carry out __________________________. This led to two solutions in tetrapods...
b. __________________________ – variable body temperature derived from heat acquired from the environment.
   1) This is found in __________________________ and __________________________.
c. __________________________ – a body temperature determined by heat derived from the animal’s own oxidative metabolism.
   1) This is found in __________________________ and __________________________.

5. Animals in water are exposed to much less UV radiation.
a. UV radiation causes DNA damage and ultimately can lead to mutations and cancer.
b. Terrestrial animals had to adapt their skin to this greater intensity of UV radiation.

6. Reproduction was about to become a lot more challenging.
a. Animals in the water can simply squirt their gametes into the water.
b. The sperm can then swim to the egg and fertilize it.
c. The water can serve as the incubator for the young.
d. Terrestrial reproduction would involve some means to ensure fertilization and a way to keep the embryos wet during development.

B. __________________________, __________________________ and __________________________ all made the transition to terrestrial life earlier.
   1. Recall that arthropods made the transition thanks to their __________________________ which was waterproof, UV resistant, and was hard enough to provide protection from the pull of gravity.

C. Amphibians are the animals that are most like the first vertebrates to make this transition.

D. Why would they leave the water?
   1. The water was already crowded with life.
      a. They faced __________________________ for resources from similar animals.
      b. They faced heavy __________________________ pressures in the water.
   2. However, the land was inhabited only by plants, snails, and arthropods.
   3. Further, the variety of terrestrial habitats allows dramatically greater opportunities for adaptation.
E. What might have been the driving force for this transition?
1. Tetrapods evolved from __________________________ during the __________________________, 400 million years ago.
   a. This period was a time of mild temperatures, floods and droughts.

2. The Devonian freshwater environment was unstable.
   a. As pools evaporated, water fouled and levels declined, only fish with some kind of lung could survive.

3. Alfred Romer proposed a seasonal drought hypothesis where amphibian ancestors developed legs from selection for migrating across land to new ponds.
   a. The bony elements of the fins of lobe-finned fishes resemble the limbs of amphibians.

4. A more active lifestyle on land caused these ancestral amphibians made the following adjustments...
   a. More capillaries and arterial blood from the last aortic arch were directed to the air-filled cavity.
      1) This cavity resulted from an ________________ of the ________________ tract.
      2) This pouch became filled with air.
      3) It would eventually become ________________.
   b. Oxygenated blood returned directly to the heart by a pulmonary vein to form a __________________________.
F. So, why are amphibians considered to be ____________________?
   1. In contrast to the varied climate of the Devonian, the ________________
      Period was uniformly warm and wet.
   2. Tetrapods radiated into the swampy moss and fern landscape.
      a. They ate insects, insect larvae and aquatic invertebrates.
   3. During the Carboniferous, amphibians developed additional adaptations for
      living in water.
      a. Bodies became flatter for moving in water.
      b. Early salamanders developed weaker legs and the tail became better
         developed.
      c. Anurans developed webbing on hindlimbs for better swimming.
   4. Today, amphibians are largely confined to wet habitats. They rely upon water
      for…
      a. Exchange of oxygen and carbon dioxide.
         1) Some salamanders have gills.
         2) Some amphibians diffuse gases across their skin.
            a) This requires that their skin remain moist.
         3) Some amphibians diffuse gases across moist mucous
            membranes in their mouth.
      b. Temperature regulation – water loses and gains heat much more
         slowly than air.
      c. Reproduction
         1) Most amphibians deposit eggs and sperm directly in water.
         2) The eggs have no shell and would dehydrate on land. (The
            eggs are aquatic.)
         2) The larvae (e.g. tadpoles) depend on gills for respiration.

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**Life Cycle of a Typical Frog**

- **Frog spawn**
- **Adult frog**
- **2 day old tadpole**
- **2 week old tadpole**
- **8 week old tadpole**
- **10 week old tadpole**

**Life Cycle of the Northwestern Salamander**

- **Egg mass laid in water**
- **Aquatic Larva**
- **Gilled Adult (metamorph)**
- **Terrestrial Adult**
III. Modern Amphibians

A. Amphibian Characteristics
1. Over _______________ living species are known in the three amphibian orders.
2. The olfactory epithelium and the ear are redesigned to improve sensitivity to airborne sound.
3. They remain tied to water; eggs are aquatic, and the larvae depend on gills for respiration.
4. The thin skin loses water rapidly; this restricts even terrestrial forms to moist habitats.
5. Being ectothermic, their body temperature depends on the environment and restricts their range.
6. Eggs easily dessicate and must be shed into water or kept moist.
   a. A few amphibians brood their young.

B. Caecilians: Order ______________________ (Apoda) "Caecilian worms"
1. About 160 living species of elongate, ____________________, burrowing caecilians are known.
2. They live in tropical forests in South America, Africa and Southeast Asia.
3. They eat primarily ______________ and small underground invertebrates.
   a. A few amphibians brood their young.

C. Salamanders: Order ______________________ (Urodela)
1. About 360 species of living salamanders are found mostly in northern temperate regions.
2. Most are small, under 15 centimeters long, but the Japanese giant salamander is 1.5 meters long.
3. Usually their limbs are at right angles to the body; forelimbs and hindlimbs are about equal in length.
   a. Burrowing species and some aquatic forms may have lost their limbs.
4. Salamanders are ______________ as both larvae and adults, eating worms, small arthropods and molluscs
5. They are ectotherms with a low metabolic rate.
6. Respiration - Salamanders have a wide array of respiratory mechanisms.
   a. They have extensive vascular nets in their skin that exchange both oxygen and carbon dioxide.
      1) Many species in the terrestrial family Plethodontidae lack lungs and use only __________________________ respiration.
   b. Respiratory gases may also be exchanged across the vascularized lining of the mouth cavity.
   c. At various stages, they may also have external gills, lungs, both gills and lungs, or neither.
   d. Salamanders with an aquatic stage hatch with gills and lose them at metamorphosis.
      1) Where present, lungs are present from birth and become functional following metamorphosis.
      2) Aquatic amphibians lose their gills and respire by lungs, holding nostrils above the water surface.
   e. Several diverse lineages fail to undergo metamorphosis and retain gills and a fin-like tail.
      1) __________________________________ - the preservation of pre-adult features into adulthood.

D. Frogs and Toads: Order __________________________ (Salientia)
   1. Over 3450 species of frogs and toads compose the order Anura.
   2. This group is known from the Jurassic period, 150 million years ago.
   3. Tied to an aquatic mode of reproduction and a water-permeable skin, they must be near water.
   4. Ectothermy keeps anurans from inhabiting polar and subarctic habitats.
   5. All pass through a tailed larval stage to become tailless, jumping adults.
   6. Eggs hatch into __________________________ with a long, finned tail, no legs, internal and external gills and specialized mouthparts for (usually) herbivorous feeding.
   7. There are 21 families of frogs and toads.
      a. Family __________________________ contains the common larger frogs in North America.
      b. Family __________________________ includes the tree frogs.
      c. Family __________________________ contains toads with thicker skins and prominent warts.
   8. Anurans are declining worldwide and becoming patchy in distribution; a potential culprit is an ancient fungus.
      Read more about this: http://www.sciencedaily.com/releases/2008/10/081014111403.htm
   9. Life Cycle
      a. Most larger frogs are __________________________ until breeding season.
      b. During the breeding season, males are especially noisy when trying to attract a female.
Check out these frog calls: [http://animaldiversity.org/collections/frog_calls/](http://animaldiversity.org/collections/frog_calls/)

c. During winter in temperate climates, they ______________________ in soft mud in the bottom of pools.

d. Frost-tolerant frogs prepare for freezing by accumulating ____________________ and ____________________ in body fluids; this protects them from the otherwise damaging effects of ice-crystal formation.

Watch this video on frozen frogs: [http://youtu.be/hlGtLKxoFeA](http://youtu.be/hlGtLKxoFeA)

e. Many are easy prey; they defend themselves by aggression, concealment, and poison glands.

10. Integument and Coloration

a. Frog skin is thin, moist and attached loosely to the body at a few points.
b. The inner layer of epidermis has two types of integumentary glands...

1) _______________ glands produce a protective, waterproofing secretion.
2) large _____________________ glands produce a whitish, watery poison.

c. Specialized pigment cells, ______________________ produce skin color in frogs.
d. Many frogs can adjust their color to blend with their background and thus camouflage themselves.

11. Skeletal and Muscular Systems

a. A well-developed ______________________ of bone and cartilage provides protection and muscle anchorage.
b. Anurans show dramatic changes in the musculoskeletal system for jumping and swimming.
c. The vertebral column lost much of its flexibility in order to transmit force from limbs to the body.
d. The front of the frog skull, containing the brain, eyes, and nose is lightweight and flattened; the back of the skull, which contained the gill apparatus in fishes, is reduced.
e. The foot generally has five rays and the hand is four-rayed; both have several joints in the digits.

1) This system is derived from the pattern in rhipidistian lobe-finned fish.

12. Respiration and Vocalization

a. Amphibians use three respiratory surfaces for gas exchange in air.

1) The skin provides cutaneous breathing.
2) The mouth provides _____________________ breathing.
3) Lungs are usually present in adults.
b. Frogs and toads depend on lung breathing more than salamanders.
c. Unlike reptiles, birds, and mammals, frogs & toads don’t suck air into their lungs.

1) Air is forced into the lungs by the mouth muscles.
d. Carbon dioxide is mostly lost across the __________ while oxygen is absorbed across the ___________.
e. The absorptive surface in a frog lung is 20 cm$^2$ per cc of air compared to 300 cm$^2$ for humans.

13. Circulation  
a. The circulatory system is __________________________, with a pumping __________________________. 
b. Separating the oxygenated blood from the deoxygenated blood circuit is not completed. 
c. Frog Heart  
1) The frog heart has a single undivided __________________________ and two separate __________________________. 
2) Blood from the body enters through the sinus venosus and right atrium. 
3) Blood from the lung enters the left atrium. 
4) Both atria contract at the same time, driving blood into the ventricle. 
5) When the ventricle contracts, blood moves to the lungs or body. 
6) Although there is no septum, deoxygenated blood goes primarily to the lungs and oxygenated blood goes mostly to the body due to separation by a spiral valve in the conus arteriosus.

14. Feeding and Digestion  
a. Most adult amphibians are carnivorous, feeding on insects, spiders, worms, slugs, etc. 
b. They catch prey with a tongue that is attached at the front of the mouth. 
c. The free end of the tongue is glandular; a sticky secretion adheres to prey. 
d. Any teeth that are present function to hold prey; they do not bite or chew. 
e. Larval stages or tadpoles are usually __________________________; their digestive tract is relatively long.

15. Nervous System and Special Senses  
a. The brain has three fundamental parts.  
1) The forebrain or __________________________ interprets the sense of smell. 
2) The midbrain or __________________________ perceives vision. 
3) The hindbrain or __________________________ perceives hearing and balance. 
b. The brain is gradually assuming more information processing ability independent of the spine. 
c. However, a headless frog still has highly
coordinated behavior based on spinal cord alone.
d. The ear becomes specialized for detecting airborne sounds.
   1) A large tympanic membrane or eardrum passes vibrations to the
      inner ear via the columella.
   2) The inner ear has a utricle with three semicircular canals and a
      saccule with a lagena.
   3) A lagena is covered with a tectorial membrane that is similar to
      the mammalian cochlea.
e. Except for blind caecilians, _______________ is the dominant sense
   in many amphibians.
f. Lachrymal glands and eyelids evolved to keep the eye moist, free of
   dust, and protected.
   1) The upper eyelid is fixed.
   2) the lower is folded into a transparent nictitating membrane.
g. The amphibian retina contains both rods and cones; the cones provide
   frogs with color vision.

16. Reproduction and Development
   a. Frogs and toads are ectothermic; therefore they breed, feed, and grow
      during the warm seasons.
   b. In the spring, males call to attract females.
   c. When the eggs are mature, females enter the water and the males
      clasp them in ____________________.
   d. As the female lays eggs, the male discharges sperm over the
   e. The jelly layers absorb water and swell; the eggs are usually laid in
      large masses.
   f. Development begins immediately; a tadpole may hatch in 6-9 days.
   g. Three pairs of external gills soon develop into internal gills covered with
      a flap of skin.
   h. Metamorphosis
      1) Hindlegs are first to appear; the forelegs are temporarily hidden
         in folds of the operculum.
      2) The tail is resorbed.
      3) The intestine becomes shorter.
      4) The mouth transforms to the adult condition.
      5) Lungs develop and the gills are resorbed.