LIFE ON EARTH
UNIT THREE
SUMMARY

UNIT THREE MATERIAL

The videotapes to watch for this unit are:

Video Program 5 – THE CONQUEST OF THE WATERS
Video Program 6 - THE INVASION OF THE LAND

Read the CONCEPTS in the study guide:

CONCEPTS FOR EPISODE 5
CONCEPTS FOR EPISODE 6

Answer the QUESTIONS in the study guide:

QUESTIONS FOR EPISODE 5
QUESTIONS FOR EPISODE 6

OVERVIEW OF LEARNING OBJECTIVES

Video Episode 5

To become acquainted with:

1. characteristics of the chordates
2. the invertebrates that are closely related to the vertebrates: sea squirts (tunicates) and lancelets
3. characteristics of the vertebrates
4. characteristics of jawless fishes: lampreys and hagfishes
5. the development of the jaw
6. characteristics of the cartilaginous fishes: sharks, rays and skates
7. characteristics and adaptations found within the bony fishes
8. the importance of the swim bladder
9. the importance of the lateral line system
10. characteristics of electric fishes

Video Episode 6

To become acquainted with:

1. problems that had to be solved by the early land animals
2. solutions to these problems
3. characteristics of coelacanths and lungfishes
4. characteristics of amphibians
5. characteristics found in the various groups of amphibians: newts and salamanders, caecilians, toads and frogs
6. methods of reproduction used by the frogs
7. characteristics of the amphibian egg

CONCEPTS FOR EPISODE 5: THE CONQUEST OF THE WATERS

CHORDATES

This episode deals with the evolution of the chordates, a phylum that is of particular evolutionary interest to us for several reasons. First, humans belong to this group. Secondly, the bodies of many chordates have hard components that are well represented in the fossil record. Thirdly, many of the chordates are highly specialized with intricate bodies and complex organization.

Chordates include two invertebrate groups (lancelets and sea squirts) and one vertebrate group that include many other subgroups. The earliest chordate fossils appear about 545 million years ago, although the earliest chordates probably had soft bodies and left few fossil traces.

Whether invertebrate or vertebrates, all chordates share certain characteristics in their body plan, at least at some stage:

(1) a **notochord** is present. This is a slender support rod that runs down the back (dorsal surface) of the animal. In some chordates, the notochord is only present in the embryo.

(2) the body has **pharyngeal slits**. The pharynx is part of the digestive tract located just behind the mouth. (You probably call the pharynx your “throat”.) At some stage of development, the pharynx of a chordate has slits. In some chordates, the pharyngeal slits develop in the embryo and are retained in the adult stage. In others, the pharyngeal slits appear in the embryo and then disappear.

(3) There is a **dorsal hollow nerve cord**. This structure appears in the embryo. The nerve cord is on the back (dorsal) surface, is hollow and surrounds a fluid-filled cavity.

(4) The body has a **muscular tail** that extends beyond the anus, at least in some stage of development.

Humans are chordates, too. The notochord is in the human embryo and traces remain in the intervertebral discs. Pharyngeal slits? Well, where do you think that Eustachian tube (auditory tube) comes from? Our spinal cord is the dorsal hollow nerve cord. In most humans, the tail is present only in the embryo. There have been only a few documented cases of human babies that were born with tails.

SEA SQUIRTS

Sea squirts (also known as **tunicates**) belong to an invertebrate group of chordates that are called the urochordates. The adult sea squirts are sessile (attached) filter feeders and their bodies bear little resemblance to most chordates. However, if you examine the body of the free-swimming planktonic larva, you will find all four of the chordate characteristics.

In the video, you will see both the adult form and the larval form of a sea squirt. (Note: plankton are organisms carried around by water currents because they either cannot swim or cannot swim strongly.)

LANCELETS

Lancelets (also known as amphioxus) belong to an invertebrate group of chordates that are known as the cephalochordates. These simple animals contain all four of the chordate characteristics as adults: notochord, pharyngeal slits, dorsal hollow nerve cord and a tail that extends beyond the anus.

The lancelets feed by filtering particles out of the water. Water enters the mouth by currents created by cilia, passes into the pharynx where particles are filtered out, and exits through the pharyngeal slits.

VERTEBRATES

Vertebrates get their name because they have **vertebral columns**. A vertebral column is a stucture made of separate bony or cartilagenous vertebrae that form a firm backbone for the animal. The vertebrae are separated from each other by pads of cartilage known as intervertebral disks. The earliest vertebrates apparently relied mainly upon a strong notochord. As the early fishes began to evolve, the vertebral column became more and more important in support and movement.

Another major evolutionary advance seen in the vertebrates is the development of a **cranium** (braincase) made of bone or cartilage that encloses and protects the brain and provides support for sensory organs, like eyes. (For a website with a comparative skulls exhibit, see: http://www.calacademy.org/exhibits/skulls.

JAWLESS FISHES

Vertebrates apparently evolved in the oceans. The earliest vertebrate fossils are jawless fishes. Apparently, these early jawless fishes relied upon muscles in their pharynx to pass water through their bodies. These muscles created a "pump" to suck loose mud and sediments from the ocean floor into the mouths of the jawless fishes. Suspended food particles were collected out of the mud and passed into the digestive tract. Many of the fossils show bony armor on the head but their internal skeleton was **not** made of bone.

The only living jawless fishes are the lampreys and hagfishes. They have a single nostril located in the middle of the head. The mouth is round or oval. **Hagfishes** are marine and look like eels. They are scavengers which feed on dead or dying invertebrates and fishes. Their tongues have rough projections which they use to scrape tissue off their food. Hagfishes are the most primitive of the living vertebrates.

Lampreys are parasitic jawless fishes. A parasitic lamprey will grab onto live prey with its sucker-like mouth and use its tongue to rasp away flesh. Most lampreys occur in freshwater but there are some marine species (which must spawn in fresh water). Watch the video to see the visible similarities between larval lampreys and lancelets.

CARTILAGINOUS FISHES

The internal skeletons of these fishes are composed mainly of **cartilage**. Another common characteristic is the presence of pointed or cone-shaped **scales** (called placoid scales). A major evolutionary advance seen in this group is the development of **jaws** that allow for biting or crushing prey. Once jaws developed, animals were able to eat bigger prey. Another change is the development of two sets of paired fins: **pectoral fins** located in the front and **pelvic fins** located in the back. Paired fins provide stability, support and the ability to maneuver for a swimming fish.

Cartilaginous fishes include sharks, rays and skates. The bodies of these cartilaginous fishes (like most fishes) are more dense than water, so they tend to sink. The cartilaginous fishes that inhabit open water, such as sharks, must use energy to overcome this tendency. Most cartilaginous fishes produce relatively few young. The video contains several examples of this group. For an introduction to cartilaginous fishes, see this website:

http://www.ucmp.berkeley.edu/vertebrates/basalfish/chondrintro.html

BONY FISHES

This group, the bony fishes, has more different vertebrate animals than any other group. Obviously, one change seen in these fishes is the development of an internal skeleton made of **bone**, which is stronger than cartilage. Another change is the development of a **swim bladder**, a gas-filled internal structure that allows the fish to maintain its position in the water without expending a great deal of energy.

The majority of the bony fishes have fins that are supported by slender rods or rays. These are often called the “ray-finned” fishes. This video episode looks at the ray-finned fishes.

Reference: Kardong, Kenneth. 1998. *Vertebrates: Comparative Anatomy, Function, Evolution*, 2nd ed. McGraw Hill, Boston.

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Websites about Bony Fishes:

General information: **http://www.seaworld.org/infobooks/BonyFish/home.html**

Ray-finned fishes: **http://www.ucmp.berkeley.edu/vertebrates/actinopterygii/actinintro.html**

Lobe-finned fishes: http://www.ucmp.berkeley.edu/vertebrates/sarco/sarcopterygii.html

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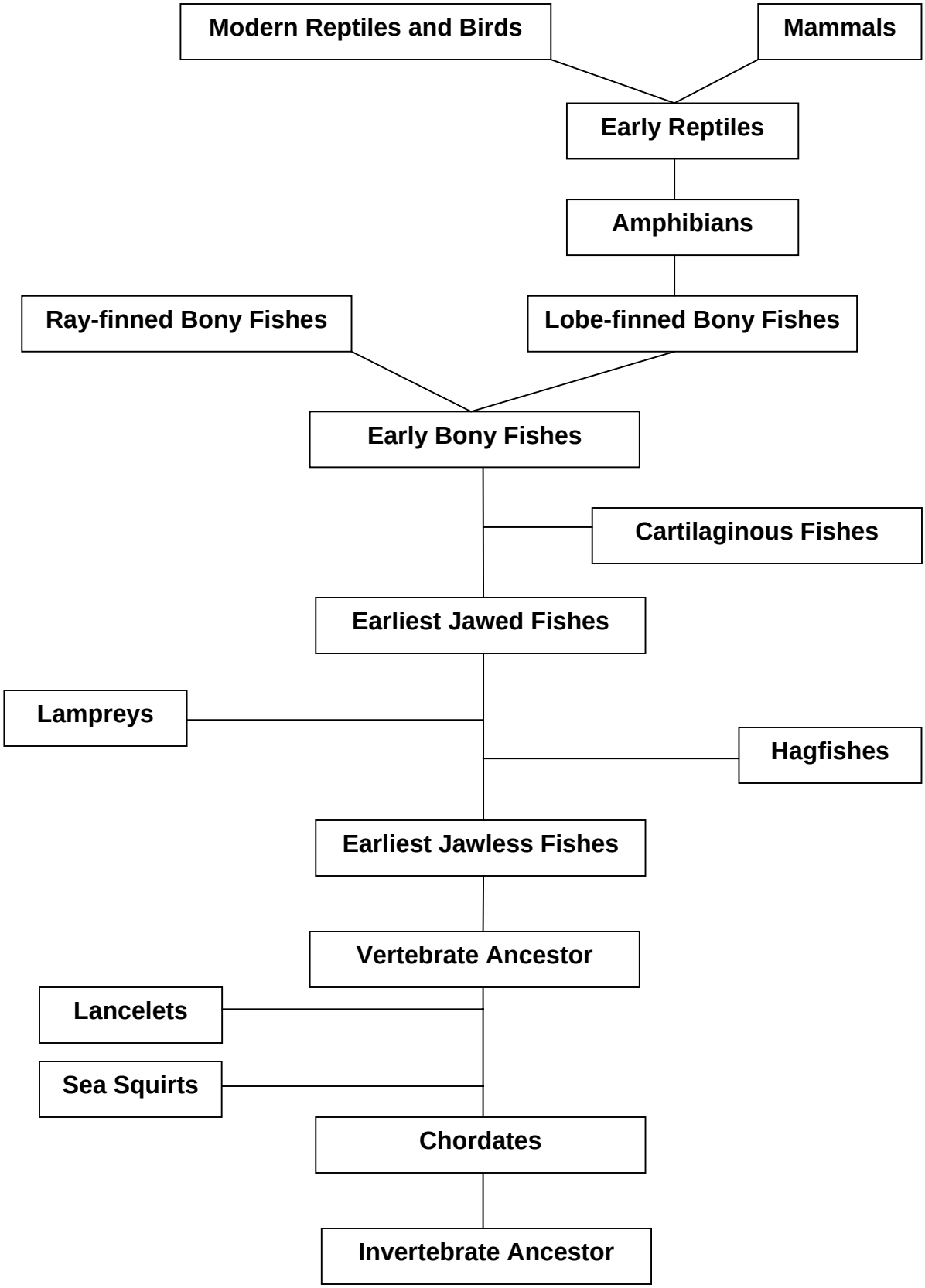
EVOLUTIONARY POINTS OF INTEREST:

1. The ancestor of bony fishes apparently lived in stagnant, fresh-water pond environments. One adaptation that evolved in the ancestral bony fish was the lung. The swim bladder is derived from the lung.

2. The scales of cartilaginous fishes (called denticles) are similar to the structure of their teeth, complete with enamel and dentin. One evolutionary possibility is that denticles led to the development of teeth within the jaw.

ONE EVOLUTIONARY TREE FOR THE VERTEBRATES



QUESTIONS FOR EPISODE 5: THE CONQUEST OF THE WATERS

1. Describe the sea squirts.

2. What characteristic of the sea squirt's larva support the conclusion that the sea squirts are related to the vertebrates?

3. Describe the lancelet.

4. What fossil evidence supports the idea that the ancestral form of the vertebrates was similar to the lancelet?

5. a. What characteristics are shared by the young lamprey and the lancelet?

   b. Describe the lamprey.

   c. Where do hagfish live?

d. How do the hagfish and lamprey differ from other fish?

e. What fossil evidence supports the argument that lamprey and hagfish are descended from primitive creatures that never developed jaws?

Locator: Western Australia, Kimberley Ranges

6. a. What structures of early fish can be seen from the fossils collected from the ancient sea bed in Western Australia?

b. How old are these fossils?

c. What are the advantages of jaws?

SHARKS

7. a. The largest fossil shark, based on jaw size, was about _____ feet long.

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AUTHORS' NOTE: These fossil sharks are now thought to be only 40-60 feet long. The biggest reconstructed jaw is 9.5 feet high and 11 feet wide but is probably exaggerated.
Megalodon Website: http://www.elasmo-research.org/education/evolution/origin_megalodon.htm

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b. How do sharks gather information from the environment?

c. What is the skeleton of sharks composed of?

d. How do sharks swim? What structures keep the shark balanced in the water?

e. What is unusual about the wobbegong shark of Australia?

8. Describe the changes in body shapes found in the following organisms that allowed them to transition from continuous swimming to life on the bottom.

a. angel shark

b. ray

c. swordfish shark

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Shark Websites:

http://www.pbs.org/wnet/nature/sharks/index.html
http://www.ucmp.berkeley.edu/vertebrates/basalfish/chondrintro.html
http://www.ucmp.berkeley.edu/vertebrates/Doug/shark.html
http://www.mote.org/ (search for sharks or stingrays)

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9. What two main body shapes developed in the cartilaginous fishes? Give examples.

10. Describe the manta rays.

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Skates and Manta Rays Websites:

http://www.mote.org/ then search for **manta rays**

http://members.tripod.com/~ranndino/animals.html

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11. Why is filter feeding an effective manner of gathering food? Give two examples of large filter feeding sharks.

BONY FISH

12. When did bony fish evolve?

13. What is unusual about the location of bone in the sturgeon?

14. How did the bony fishes deal with the problem of poorly-oxygenated water?

15. What are the advantages of a swim bladder?

16. Describe the body modifications that have developed in the modern bony fish.

17. What is the lateral line system? How does the lateral line system work?

Locator: Coral Reef

18. What changes in swimming patterns and life styles can be seen in the bony fish that inhabit coral reefs?

19. Why are many of the bony fish brightly colored, with striking markings?

20. Describe the eyes of the bony fish. How do their eyes differ from the eyes of the cartilagenous fish?

21. What similarities in body shape can be found in bony fish who live in open water and rely upon speed to elude predators?

22. How do flying fish escape predators?

23. What major changes have occurred in the flat, bottom dwelling fish, such as the turbot and flounder?

24. What changes in the fin have occurred in bottom dwelling fishes, such as the:
    a. stone fish

    b. angler fish

    c. bearded ghoul

    d. gurnard

25. What is the thermocline? What major environmental change occurs at the thermocline?

26. What modifications are found in the bony fish that live at 750 meters and below?

27. Why do electric fish generate electricity? How do they create the electricity? What do the various types of electric fish have in common with regards to body shape?

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Electric Fishes Websites:

http://www.people.virginia.edu/~mk3u/mk_lab/electric_fish_E.htm

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28. How is the electric eel different from other electric fishes?

29. Give two examples of fish that live in extreme temperatures. Briefly describe their habitats.

30. Describe the migratory behavior of the salmon. Identify the various changes that occur to the salmon body at different times of its life cycle.

CONCEPTS FOR EPISODE 6: THE INVASION OF THE LAND

EVOLUTIONARY PATHWAY FROM AQUATIC FISHES TO LAND

As discussed in the previous episode, the majority of the bony fishes are "ray-finned fishes" with fins supported by slender rays. The other group of bony fishes is called the "fleshy-finned" fishes or "lobe-finned" fishes. In this group, the fins are at the end of appendages that project from the body of the fish. These appendages are supported by bones. The "lobe-finned" fishes are important from an evolutionary standpoint because they gave rise to the first terrestrial vertebrates, the amphibians.

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Website: http://www.ucmp.berkeley.edu/vertebrates/sarco/sarcopterygii.html

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The only living lobe-finned fishes today are three types of lungfishes and the coelacanth. Look for these on the video. While the ancestor of the amphibians is now extinct, it probably looked a lot like the coelacanth or the fossil fish *Eusthenopteron*, which is discussed in the video. The transition from a lobe-finned fish to the first four-limbed land-dwelling vertebrate is now well represented in the fossil record. We have fossils from Greenland, Nova Scotia and Russia that show several transitional states, beginning with an organism living totally in water to a fossil that resembles a salamander on steroids (6-8 feet long, big mouth, lots of teeth, not something to meet in a dark, damp alley).

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Website: http://www.pbs.org/wgbh/nova/link/

This is a web site for the Nova episode *The Missing Link* which describes recent scientific studies of the origin of the land vertebrates. It has information on recent fossil finds that have displaced *Eusthenopteron* as a possible direct ancestor of all land vertebrates, and some great reflections on the excitement of working with these fossils.

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AMPHIBIANS

The first group of vertebrates to move to land was the amphibians. Amphibians are usually divided into three groups: two extinct and known only from fossils and the modern amphibians, which include newts and salamanders ("tailed ones"), caecilians ("legless ones"), frogs and toads ("tailless ones").

Many evolutionary changes are seen in the amphibians. First, several changes had to occur in the skeleton. Fins were replaced by jointed limbs. Ankles and wrists also evolved. The bones that support the fins had to evolve into limb girdles that attach the limbs to the rest of the internal skeleton. The vertebral column had to become larger, in order to support the supporting girdles for the limbs.

Amphibians are not perfectly adapted to living on land. Since the amphibian egg does not have a shell, the eggs must be laid either in water or in a moist habitat. Frogs and toads still have external fertilization, where the eggs and sperm are released outside the body of the parents. Even though amphibians have paired lungs, they are usually small with few internal compartments. Some salamanders lack lungs altogether. As a result of the reduced (or absent) lung surface, the majority of an adult amphibian's gas exchange occurs across its moist skin. This is a real problem for an animal living on land. If the skin dries out, the animal cannot exchange sufficient oxygen and carbon dioxide and it dies.

Watch the video for examples of modern amphibians. The living amphibians are subdivided into three groups: (1) salamanders and newts that have tails, (2) frogs and toads with long jumping hindlimbs, and (3) caecilians which are legless burrowing amphibians.

Reference: Kardong, Kenneth. 1998. *Vertebrates: Comparative Anatomy, Function, Evolution*, 2nd edition. McGraw Hill, Boston.

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Information about Amphibians Website:

http://www.livingunderworld.org/gymnophiona/

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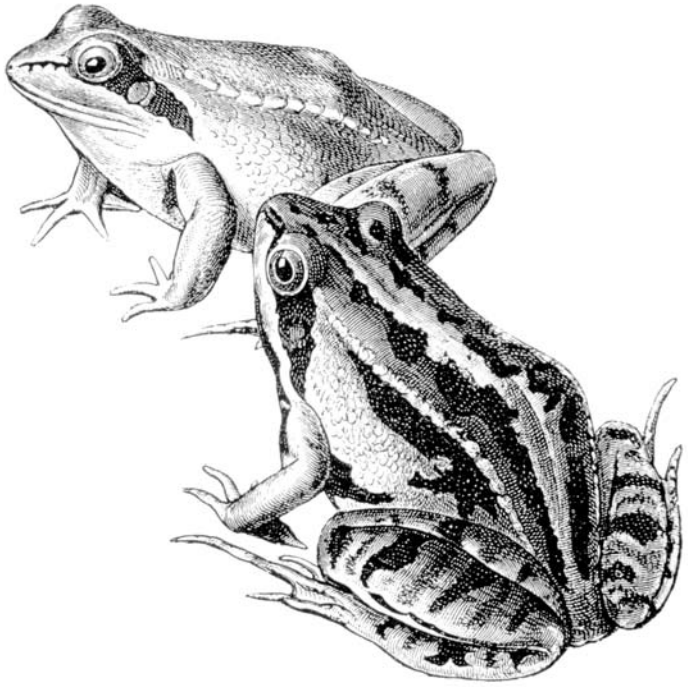

QUESTIONS FOR EPISODE 6: THE INVASION OF THE LAND

1. When did the first vertebrate move onto land?

2. What two major problems were faced by the early land vertebrates? How were these problems solved?

3. a. Describe the way that mudskippers move on land.

   b. What is unusual about their fins?

4. What is a coelacanth? What is significant about the coelacanths?

5. Where is the present-day coelacanth found today?

6. How does the coelacanth use its fins?

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AUTHORS' NOTE: A new population of coelacanths has been found in Indonesia in 1998. You can get more information about coelacanths:

http://www.ucmp.berkeley.edu/vertebrates/coelacanth/coelacanths.html

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7. Describe the solution to breathing air that is used by the African lungfish.

8. Why are both the coelacanth and the lungfish disqualified as the ancestor of the amphibians?

9. What is significant about the fossil fish, *Eusthenopteron*?

10. What reasons may have motivated animals to make the move to land?

11. How did peat form? How did coal form?

Locator: Coal Mine

12. Describe the early amphibians.

13. Identify the largest amphibian alive today. How does the size of this amphibian compare to the fossil amphibians?

NEWTS AND SALAMANDERS

14. Describe the characteristics and natural history of the newt. In particular, be able to discuss the following:
    a. permeable skin

    b. method of breathing

c. courtship and reproduction

d. similarities to fish

e. larval form

15. What is unusual about the axolotl of Mexico?

16. How do adult salamanders breathe?

CAECILIANS

17. a. Describe the caecilians.

b. What major changes are found in their body structure when compared to the newts and salamanders?

c. How many species of caecilians exist today?

FROGS AND TOADS

18. What type of movement is used by the frogs and toads?

19. Describe the Goliath frog.

20. What modifications to the legs and feet are found in the flying frog? What is the function of these modifications?

21. What methods to avoid or confuse predators are used by the frogs and toads?

22. Why do many frogs develop brightly-colored skin patterns? When are these frogs active?

23. Many frogs have skin glands. List some of the secretions that are produced by these glands.

24. Describe the amphibian tongue.

25. What modifications to the eyes were required in order for the amphibians to use them on land?

26. What modification was required in order to hear in air instead of water?

27. How do frogs and toads produce sound? What is the significance of these sounds?

28. Compare different methods of reproduction that are found in the frogs and toads. Be able to give examples of the following:
    a. Many eggs laid in water

    b. Private pools of water used for the eggs

    c. Eggs laid on land (as in trees)

d. Elimination of the tadpole stage that is dependent upon a source of water

e. Retained **on** the body of the parent

f. Retained **in** the body of the parent

29. What is the **one** thing that all frog eggs require? (The answer is also true for all amphibians.)

30. Describe ways that some frogs and toads have partially avoided the limitations of their moist skins in order to live in desert areas.

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ADDITIONAL INFORMATION: The oldest fossil of a frog was recently discovered and dated to 190 mya (*National Geographic*, August 1996.)

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31. What evolutionary change took place in the reptiles that allowed the reptiles to colonize harsh environments?

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THREATS TO DIVERSITY:

Threat 1. Amphibians in Decline:

Starting in the 1960s, scientists have determined that the world's amphibian populations are in a steep decline and some species have gone extinct, such as the gastric-brooding frog featured in the video. In many areas, human activities have destroyed habitat or caused pollution to the point that frogs and salamanders cannot survive. In other, less directly modified habitats, like national parks and nature preserves, amphibians have also declined, perhaps due to climate change and the cross-border influences of air and water pollution. For more information about this disturbing phenomenon and its possible causes, see the following web sites:

Declining Amphibian Populations Taskforce:
http://www.open.ac.uk/daptf/index.htm

AmphibiaWeb: http://elib.cs.berkeley.edu/aw/
This great site has information on all the world's amphibian species and maps to show which species are in the steepest declines or have gone extinct.

Threat 2. Amphibian Malformations:

Another disturbing phenomenon involving amphibians that has popped up recently is a rash of discoveries of malformed frogs in various parts of North America. We're talking extra legs, etc. As is the case with amphibian declines, the causes are unknown in most cases. The malformations may be due to pollution or parasites or global warming or a combination of all of the above. The following website is the place to go to report any deformed frogs, and to learn lots more about the problem.

North American Reporting Center for Amphibian Malformations:
http://frogweb.nbii.gov/

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