SECTION 25.1 VERTEBRATE ORIGINS

Study Guide

KEY CONCEPT
All vertebrates share common characteristics.

VOCABULARY
- chordate
- notochord
- endoskeleton

MAIN IDEA: The phylum Chordata contains all vertebrates and some invertebrates.

1. What three groups make up the phylum Chordata?

Choose the correct term from the box below to fit each description.

<table>
<thead>
<tr>
<th>notochord</th>
<th>hollow nerve cord</th>
<th>pharyngeal slits</th>
<th>tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>__________</td>
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</tr>
<tr>
<td>2. extends beyond the anal opening, and contains segments of muscle tissue used for movement</td>
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<tr>
<td>__________</td>
<td>_________________</td>
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</tr>
<tr>
<td>3. runs along the animal’s back, forms from a section of ectoderm</td>
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<td>__________</td>
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<tr>
<td>4. slits through the body wall in the pharynx</td>
<td></td>
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<tr>
<td>__________</td>
<td>_________________</td>
<td>_______________</td>
<td>__________</td>
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<tr>
<td>5. flexible skeletal support rod embedded in the animal’s back</td>
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</tr>
</tbody>
</table>

MAIN IDEA: All vertebrates share common features.

6. What is an endoskeleton?

7. How does the growth of an animal with an endoskeleton differ from the growth of an animal with an exoskeleton?
Complete the following chart with the missing information for each vertebrate class.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Agnatha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Chondrichthyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Osteichthyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Amphibia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Reptilia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Aves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Mammalia</td>
<td></td>
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</tr>
</tbody>
</table>

**MAIN IDEA:** Fossil evidence sheds light on the origins of vertebrates.

15. Where has most of the early vertebrate fossil evidence been found?

16. Which animals are recognized as the first vertebrates?

17. Which two groups of jawless fish still exist today?

**Vocabulary Check**

18. The prefix *endo-* means “inside,” while the prefix *exo-* means “outside.” How does this help you to distinguish between an endoskeleton and an exoskeleton?
KEY CONCEPT  All vertebrates share common characteristics.

At some point during development, all chordates exhibit four distinctive characteristics. These characteristics include:
- a notochord, which is a flexible skeletal support rod embedded in an animal's back
- a hollow nerve cord that runs along the animal's back
- pharyngeal slits, which are slits through the body wall in the pharynx
- a tail that extends beyond the anal opening

A characteristic that lets vertebrates grow to large sizes is the endoskeleton. An endoskeleton is an internal skeleton made of bone or cartilage. There are four distinct parts to an endoskeleton:
- A braincase, or cranium, protects the brain.
- A series of short stiff vertebrae, separated by joints, protect the spinal cord.
- Bones support and protect the body's soft tissues and provide points for muscle attachment.
- Gill arches, which are found in the pharynx of fish and some amphibians, support the gills.

There are seven classes of vertebrates. These classes include jawless fish, cartilaginous fish, bony fish, amphibians, reptiles, birds, and mammals. The first recognizable vertebrates were fish. Two primitive jawless fish that still exist today are lampreys and hagfish.

1. What are the four features shared by chordates at some point in their development?

2. What is an endoskeleton?

3. List the four components of an endoskeleton. Which part is only found in fish and some amphibians?

4. What type of animal was the first recognizable vertebrate?

5. What are the two types of jawless fish that still exist today?
SECTION 25.2  | FISH DIVERSITY
Study Guide

KEY CONCEPT
The dominant aquatic vertebrates are fish.

VOCABULARY
<table>
<thead>
<tr>
<th>gill</th>
<th>lateral line</th>
</tr>
</thead>
<tbody>
<tr>
<td>countercurrent flow</td>
<td>operculum</td>
</tr>
</tbody>
</table>

MAIN IDEA: Fish are vertebrates with gills and paired fins.

Choose a word or words from the box below to complete the following sentences.

- blood capillaries
circulatory countercurrent flow gills opposite
tissue

1. Fish use specialized organs called ___________ to take in oxygen dissolved in water.
   Gills are large sheets of frilly ___________ filled with ___________.

2. Fish ___________ systems pump blood in a single loop through a heart with two main chambers.

3. ___________ ___________ is the ___________ movement of water against the flow of ___________ in the fish’s gills.

4. Explain how countercurrent flow works.

   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________

5. Draw a simple sketch of a fish and label the five main types of fins on its body.
MAIN IDEA: Jaws evolved from gill supports.

6. What are gill arches?

7. What is an advantage of having jaws?

MAIN IDEA: Only two groups of jawed fish still exist.

Use the box below to choose the correct word or words to complete the following sentences.

<table>
<thead>
<tr>
<th>cartilage</th>
<th>electrical</th>
<th>lateral line</th>
<th>sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td>chimeras</td>
<td>Holocephali</td>
<td>muscular</td>
<td>sharks</td>
</tr>
<tr>
<td>Elasmobranchs</td>
<td>internal</td>
<td>rays</td>
<td>skates</td>
</tr>
</tbody>
</table>

8. Members of phylum Chondrichthyes have skeletons made of ________.

9. The two groups within phylum Chondrichthyes are the ________ and the _________. The Holocephali include _________, also called ratfish. The Elasmobranchs include ________, ________, and ________.

10. While the cartilaginous fish as a group may be ancient, they have many advanced features. They have ________ fertilization, and many species give birth to live young.

11. Fish can sense their prey’s movements at a distance with a sensory system called the ________.

12. Many fish also have ________ organs that detect the electrical currents made by ________ contractions in other animals. These sensory organs are called ________ cells because they receive electrical signals.

Vocabulary Check

13. The term operculum comes from a Latin word which means “to cover.” Explain how this meaning is related to the definition of an operculum.
Gills are:

Countercurrent Flow

Cartilaginous Fish

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

Lateral line system is:
KEY CONCEPT  The dominant aquatic vertebrates are fish.

Fish use the large surface area of their gills to exchange carbon dioxide and oxygen with the water in which they live. A fish’s circulatory system pumps blood in a single loop through its two-chambered heart. Blood returning from the body is collected in the atrium and moved into the ventricle. The ventricle pumps the blood through the gills, where carbon dioxide is released and oxygen is picked up by the blood. The oxygen is carried by the blood directly to the tissues, where it is exchanged for carbon dioxide. The blood then returns to the heart, starting the process over again.

**Countercurrent flow** is the opposite movement of water against the flow of blood in a fish’s gills. Because oxygen dissolved in the water is at a greater concentration than the oxygen in the fish’s blood, countercurrent flow maximizes the amount of oxygen the fish can pull from the water by diffusion.

A fish uses its fins to move around in the water. In addition to helping it maneuver in the water, a fish’s fins also help to keep it stable. Each set of fins helps the fish move in a different direction.

Fish jaws evolved from gill supports. As a result of the evolution of jaws, fish were able to become effective and efficient hunters, shooting them to the top of the food web. Two groups of jawed fish that still exist today are the cartilaginous fish and the bony fish.

Cartilaginous fish have skeletons made of cartilage. These fish include chimeras, sharks, rays, and skates. Cartilaginous fish are efficient hunters, powerful swimmers, and have an excellent sense of smell. Like all fish, they are able to detect the movement of prey at a distance by the use of a sensory system called the lateral line. The **lateral line** system lets fish feel the movement in the water currents created by more distant animals as they swim through the water. Bony fish have skeletons made of bone. These fish are quite abundant—there are more than 20,000 different species of bony fish. One structure distinctive to bony fish is the **operculum**, which is a protective plate that covers the fish’s gills.

1. What organ do fish use to breathe?

2. What is countercurrent flow?

3. What structure did fish jaws evolve from?

4. What are the two group of jawed fish that still exist today?
A CLOSER LOOK AT BONY FISH

SECTION 25.3

Study Guide

KEY CONCEPT

Bony fish include ray-finned and lobe-finned fish.

VOCABULARY

<table>
<thead>
<tr>
<th>ray-fin</th>
<th>lobe-fin</th>
</tr>
</thead>
<tbody>
<tr>
<td>swim bladder</td>
<td></td>
</tr>
</tbody>
</table>

MAIN IDEA: Ray-finned fish have a fan of bones in their fins.

1. Describe the shape of a ray-fin and list three reasons why its shape helps a ray-finned fish move.

2. Describe the diversity of ray-finned fish. How does the number of species of ray-finned fish compare to the total number of vertebrate species?

3. What is the function of the swim bladder?

MAIN IDEA: Lobe-finned fish have paired rounded fins supported by a single bone.

4. What is the evolutionary significance of lobe-finned fish?

5. Describe the structure of a lobe-fin.
6. Complete the following Y-diagram to outline the similarities and differences between ray-fins and lobe-fins.

[Diagram with Ray-fin on the left side and Lobe-fin on the right side]

7. Name two types of lobe-finned fish that still exist today.

______

Vocabulary Check

8. Use a comparison (for example, consider how a scuba diver travels to lower and higher depths) to describe how a swim bladder works.

______

______

______
Anatomy of a Bony Fish

Two Types of Bony Fish

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ray-fin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lobe-fin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ray-finned fish include ray-finned and lobe-finned fish. All ray-finned fish have fins supported by a fan-shaped array of bones. These fins are embedded in a thin layer of skin and connective tissue. The muscles that move the bones are found in the fish’s body wall. This arrangement of bones and muscle makes the fin light, collapsible, and easy to move.

A swim bladder is a buoyancy organ that helps a fish to float higher or lower in the water. Oxygen is added to the swim bladder from the bloodstream, increasing its buoyancy. To float lower in the water, oxygen is reabsorbed into the bloodstream from the swim bladder, decreasing the fish’s buoyancy.

Lobe-finned fish include the ancestors of all terrestrial vertebrates. Only seven species of lobe-finned fish still exist today. In contrast to the fin shape of a ray-finned fish, a lobe-fin is round in shape. The paired fins are arranged around a series of bony struts, similar in shape to the limb of a land vertebrate. The thick and fleshy shape of a lobe-fin makes it much less maneuverable than a ray-fin. However, a lobe-fin is able to support weight, which was key for the evolution of land vertebrates. Coelacanths and lungfish are both lobe-finned fish. Evidence suggests that lungfish are the closest living relatives of land vertebrates.

1. What is the difference between the shape of a ray-fin and the shape of a lobe-fin?

2. What is the function of a swim bladder?

3. What quality of a lobe-fin helped lead to the evolution of land vertebrates?

4. What are two types of lobe-finned fish that still exist today?
KEY CONCEPT
Amphibians evolved from lobe-finned fish.

MAIN IDEA: Amphibians were the first animals with four limbs.
Choose a word or words from the box below to complete the following sentences.

<table>
<thead>
<tr>
<th>amphibians</th>
<th>four</th>
<th>land</th>
<th>water</th>
<th>vertebrate</th>
</tr>
</thead>
</table>

1. A tetrapod is a ________________ that has ________________ limbs.
2. ________________ are animals that can live both on ________________ and in ________________.
3. Complete the following concept map with information about amphibian adaptations.

Amphibians

- have
  - to support
  - to capture
  - to hear
STUDY GUIDE, CONTINUED

4. What are the different methods amphibians use to breathe?

______________________________________________________________

MAIN IDEA: Amphibians return to the water to reproduce.

5. Why can’t amphibians travel too far away from a source of water?

______________________________________________________________

6. List three strategies used by amphibians to keep their eggs moist.

______________________________________________________________

7. Describe the changes a tadpole goes through during metamorphosis into an adult frog.

______________________________________________________________

MAIN IDEA: Modern amphibians can be divided into three groups.

8. Write a short phrase to describe each amphibian group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>salamander</td>
<td></td>
</tr>
<tr>
<td>frog</td>
<td></td>
</tr>
<tr>
<td>caecilian</td>
<td></td>
</tr>
</tbody>
</table>

Vocabulary Check

9. If the suffix -pod means “foot,” then what does the term tetrapod mean?

______________________________________________________________

10. How is an amphibious vehicle different than a normal vehicle driven on the road?

______________________________________________________________
SECTION 25.4 | AMPHIBIANS

**Power Notes**

Amphibian Anatomy

1. 
2. 
3. 
4. 
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6. 
7. 
8. 
9.

### Three Groups of Amphibians

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
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</tr>
</tbody>
</table>
SOURCE 25.4
Reinforcement

KEY CONCEPT Amphibians evolved from lobe-finned fish.

All vertebrates that live on land and their descendants that have returned to the water are tetrapods. A tetrapod is a vertebrate that has four limbs. Each limb evolved from a lobe-fin. Animals such as snakes, which do not have four limbs, are still considered to be tetrapods because they evolved from limbed ancestors.

The development of limbs and lungs led to the evolution of amphibians. Amphibians are animals that can live both on land and in water. Other important amphibian adaptations include the development of large shoulder and hip bones to support more weight, a mobile and muscular tongue to capture food, and middle ear development to help the amphibian hear outside of the water. Amphibians are able to breathe outside of water either through their skin or with the use of gills or lungs.

The skin of an amphibian is thin and wet. Because water is constantly evaporating from its skin, an amphibian cannot move too far from a source of water without risk of drying out. A nearby source of moisture is also important for amphibian reproduction. An amphibian egg does not have shell, and without a source of moisture the embryo within the egg may dry out and die. Strategies that amphibians use to keep their eggs moist include laying eggs directly in water or on moist ground, wrapping eggs in leaves, or even brooding the eggs in pouches on the amphibian’s back.

To develop into an adult frog, a tadpole, or frog larva, must undergo metamorphosis. During metamorphosis, a number of changes occur to the tadpole as it transforms into an adult frog. Gills are reabsorbed and lungs develop, internal systems are reorganized, the tail is reabsorbed, and limbs develop.

Salamanders, frogs, and caecilians are the three groups of modern amphibians. With its long body, four walking limbs, and tail, a salamander looks like an ancestral tetrapod. Frogs are the largest group of amphibians. A frog’s familiar body form includes a tailless body, long muscular hind limbs, webbed feet, exposed eardrums, and bulging eyes. Caecilians are the most distinctive group of amphibians with their legless, earthwormlike appearance.

1. What is a tetrapod?

2. Why must amphibians remain near a source of water?

3. What are the three groups of modern amphibians?
KEY CONCEPT
Reptiles, birds, and mammals are adapted for life on land.

VOCABULARY

<table>
<thead>
<tr>
<th>amniote</th>
<th>amniotic egg</th>
</tr>
</thead>
<tbody>
<tr>
<td>keratin</td>
<td>placenta</td>
</tr>
</tbody>
</table>

MAIN IDEA: Amniotes can retain moisture.

1. What is an amniote?

2. List three examples of familiar animals that are amniotes. Are humans amniotes? Explain why or why not.

3. What is keratin used for?

4. How do an amniote’s kidneys and intestines help it to retain moisture?

MAIN IDEA: Amniotes do not need to return to water to reproduce.

5. How does the amniotic egg allow amniotes to live permanently on land?

6. What is the advantage for rattlesnakes to retain their eggs until they hatch?

7. What is the function of placenta?
**Vocabulary Check**

Choose a term from the box below that best fits each description.

<table>
<thead>
<tr>
<th>term</th>
<th>definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>amniote</td>
<td>8. I am a vertebrate that has a thin, tough, membranous sac that encloses the embryo or fetus during development.</td>
</tr>
<tr>
<td>amniotic egg</td>
<td>9. I am a protein that binds to lipids inside a skin cell, forming a water-repellent layer that keeps water from escaping.</td>
</tr>
<tr>
<td>keratin</td>
<td>10. I am an almost completely waterproof container that keeps the embryo within from drying out.</td>
</tr>
<tr>
<td>placenta</td>
<td>11. I am a membranous organ that develops in female mammals during pregnancy.</td>
</tr>
</tbody>
</table>

**Be Creative**

12. Draw a cartoon that illustrates the benefits of the amniotic egg.
An amniote is ____________________________

______________________________

______________________________

Set of Characteristics that Prevents Water Loss in an Amniote

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Function</th>
</tr>
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<tr>
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<td></td>
</tr>
</tbody>
</table>

An amniotic egg is ____________________________

______________________________

______________________________

A placenta is ____________________________

______________________________

______________________________
KEY CONCEPT  Reptiles, birds, and mammals are adapted for life on land.

An **amniote** is a vertebrate that has a thin, tough, membranous sac that encloses the embryo or fetus during development. All amniotes share a set of characteristics that help to prevent water loss. Skin cells are waterproofed with keratin. **Keratin** is a protein that binds to lipids inside skin cells, forming a water repellent layer that keeps the water inside the animal from evaporating through the skin. This waterproofing means that amniotes lose less water to evaporation than do amphibians. It also means that amniotes cannot exchange gases across their skin. Amniotes instead rely on lungs for respiration. In addition, kidneys and large intestines are bigger in amniotes than in amphibians. The increased surface area of these tissues lets amniotes absorb more water internally, so they lose less water to excretion.

Unlike amphibians, amniotes do not need to return to a water source to reproduce. The **amniotic egg** is an almost completely waterproof container that keeps the embryo from drying out as it develops. Some amniotes, such as snakes, make eggs but do not lay them. Instead, the female keeps the egg in her oviduct until it hatches. This method protects the eggs from predation. Most mammal embryos develop inside their mother’s reproductive tract. Although the eggs lack shells, the embryos have the same series of membranes that are found in a typical amniotic egg. The **placenta** is a membranous organ that develops in female mammals during pregnancy and is used both to carry nutrients from the mother to the embryo and also remove metabolic wastes from the embryo.

1. What is an amniote?
   __________________________________________________________
   __________________________________________________________

2. What is the function of keratin?
   __________________________________________________________
   __________________________________________________________

3. What adaptation allowed amniotes to reproduce on land?
   __________________________________________________________
   __________________________________________________________

4. What is the function of placenta?
   __________________________________________________________
The Ohio Department of Natural Resources collected data while trawling the bottom of Lake Erie from 1969 to 1996. The number of each species of fish that was caught per hour of trawling was recorded. The graph below shows the number of quillback caught per hour of trawling over a 27-year period. The quillback is a bottom-feeding, freshwater fish that can tolerate low oxygen concentration in the water.

**GRAPH 1. NUMBER OF QUILLBACK CAUGHT PER HOUR**

1. **Interpret Data** How did the population of quillback change in Lake Erie from 1969 to 1996?

   _______________________________________________________________________

2. **Infer** In 1972, a water quality agreement was passed in which the amount of phosphorus that could be released into Lake Erie was greatly reduced compared to the past 50 years. Lake Erie went from being a highly eutrophic lake to a very oligotrophic lake by about 1980. How might this change in productivity have affected the population of quillback in Lake Erie?

   _______________________________________________________________________

   _______________________________________________________________________

   _______________________________________________________________________
As you have learned in Chapter 25, cartilaginous fish—the sharks, skates, and rays—use internal fertilization to start the reproductive process. Many of these species lay eggs, but some species give birth to well-developed young after a long gestation period.

**OVIPARITY**

All skates and many shark species are oviparous, meaning they lay leathery egg cases containing a developing embryo. The similarity between oviparity and viviparity is that in both, the embryos are held in the uterus for months before being released. The difference is, oviparous embryos are still in an egg case when they are released, and they must grow and develop before they can hatch. The number of young produced by viviparous and oviparous species is limited in large part by the size of the mother. A 35-foot-long whale shark can give birth to 300 pups. A two-foot-long skate may lay 10 or 20 egg cases.

**VIVIPARITY**

Viviparity is a reproductive strategy in which an organism gives birth to live offspring. This strategy has evolved into several forms in the class Chondrichthyes.

1. **Placental viviparity** — Embryos are nourished by a placenta, an organ that links the embryo to the uterus. At first, all cartilaginous fish embryos are nourished by a yolk sac attached to their bellies by a yolk stalk. In placental species, once the yolk is depleted the stalk is modified into an umbilical cord and the yolk sac combines with uterine tissues to form a placenta. The placenta allows the embryo, or “pup,” to receive nutrients and oxygen and carries away waste products.

2. **Aplacental viviparity** — Embryos are not nourished by a placental connection with their mother. Instead they feed in one of three ways:
   - Some are nourished solely by the yolk sac. Once the yolk is gone, the fish is born. Species that have this type of aplacental viviparity include the tiger shark and the spiny dogfish.
   - After the yolk is depleted, embryos receive additional nourishment from a milk-like substance called histotroph that is secreted from the uterine walls.
   - Embryos that have depleted their yolk then feed on eggs that are continually released from the ovaries. The embryos of some of the most well-known shark species, such as the great white, sand tiger, porbeagle, and mako, feed in this way. The embryos are essentially bathed in pea-shaped eggs that they can feed on within the uterus. This is called oophagy. The sand tiger shark, *Carcharias taurus*, takes oophagy a step further. After feeding on eggs released from the ovaries, the embryos begin to eat each other. This rare strategy is called embryophagy or intrauterine cannibalism. The unborn sandtigers eat each other until just one is left in the uterus. All sharks have two uteri, so the sand tiger usually bears two pups.

**BONY FISH REPRODUCTION**

By comparison, the reproductive strategy of most bony fish is external fertilization involving thousands or millions of eggs released in the same vicinity as millions of sperm. This strategy, which is generally known as spawning, is an example of “strength in numbers.” Many eggs will not be fertilized, many will be eaten by predators, and many larvae or juvenile
fish will not survive until adulthood. But there are so many eggs released that the odds are good that some of them will make it to adulthood.

1. Create a concept map for fish reproductive strategies, using the map below as a starting point. Include the following terms: aplacental, placental, egg case, internal fertilization, external fertilization, placenta, bony fish, cartilaginous fish.

   ![REPRODUCTIVE STRATEGIES OF FISH](image)

2. If you were to research how much energy is expended by reproductive female fish of different species in the production and development of their young, what trend would you expect to see if you compared bony fish, oviparous sharks and skates, and viviparous sharks and rays? How might this expenditure or allocation of energy be related to the odds of these fish reaching adulthood? Write your answer on a separate sheet of paper.
In Chapter 25, you have learned that some tropical frogs make toxins to protect themselves from predators. The most poisonous type of frogs, the poison dart frogs, make up the family Dendrobatidae. Different types of toxins are found in these frogs. In this activity you will learn about several of these toxins and how scientists think the frogs acquire them.

**FAMILY DENDROBATIDAE**

Poison dart frogs, known for their bright coloration and toxic secretions, are found throughout the tropical regions of Central and South America. There are eight genera and less than 200 species of these frogs, with the greatest diversity occurring in the northwestern regions of South America. Poison dart frogs have cutaneous granular glands that are scattered over their bodies. When a frog is threatened, toxins are secreted from these glands onto their skin. These toxins are alkaloids, organic compounds that contain nitrogen. More than 500 different types of alkaloids that can be secreted. If a predator comes into contact with a toxin, the reaction can range from mild (numbness) to severe (death). Most toxins secreted by poison dart frogs are neurotoxins, which affect nerve transmission and the contraction of muscle cells. Two such toxins, which are also the two most poisonous, are batrachotoxins and pumiliotoxins.

**BATRACHOTOXINS**

This type of toxin is commonly found in poison dart frogs belonging to the genus *Phyllobates*. Batrachotoxins increase the permeability of the outer membrane of nerve and muscle cells, allowing more sodium ions to enter. This prevents nerve cells from signaling muscle cells to relax. The muscle cells stay contracted, which can lead to heart arrhythmias, convulsions, heart failure, and death. The Emberá and Noanamá Chocó Indians of western Colombia have used batrachotoxins secreted from frogs to poison the darts used in their blowguns, hence the common name of these frogs. Batrachotoxins are among the world’s most deadliest substances and there is no antidote.

One of the most poisonous animals on Earth is *Phyllobates terribilis*, the golden poison frog. One individual contains between 700 to 1900 µg of batrachotoxins. The minimum lethal dose required to kill a 20 g mouse is 0.05 µg, meaning one frog contains enough toxin to kill more than 20,000 mice. In comparison, the minimum lethal dose required to kill a 68 kg (150 pound) human is 136 µg. This means that one frog has enough toxin to kill ten humans. The only known predator of *P. terribilis* is the snake *Leimadopis epinephelus*, which is immune to batrachotoxins.

**PUMILIOTOXINS**

Pumiliotoxins are found in poison dart frogs belonging to the genus *Phyllobates* and *Dendrobates* and are 100 to 1000 times less toxic than batrachotoxins. There are more than 100 pumiliotoxins that are classified into three groups: Pumiliotoxins A, B, and C. These toxins are not yet fully understood, but it is thought that they affect calcium and sodium–dependent processes in nerve and muscle cells, thereby causing problems with movement. Pumiliotoxins belonging to groups A and B are more toxic than those in group C. When 100 g of pumiliotoxin A or B are injected into mice, restricted movement, convulsions, partial paralysis, and death can occur.
TOXIC DIET

Scientists have been researching how the poison dart frogs acquire the toxins they secrete. It appears as if the frogs’ diet may have something to do with it. By eating formicine ants and other invertebrates that are rich in alkaloids, the frogs are able to accumulate pumiliotoxins and store them in their skin. This conclusion was reached after studies were conducted using frogs raised in captivity. One group of captive frogs were fed a diet of fruit flies and crickets, which lack alkaloids. Over time, those frogs lost the ability to secrete toxins. Another group of captive frogs were fed a diet of invertebrates collected from their native leaf litter. These frogs were able to secrete toxins. Other studies have shown that at least three species of Dendrobates frogs can modify alkaloids gained through food sources and make them five times as poisonous.

It may also be possible that poison dart frogs can manufacture toxins independently. Batrachotoxins are not known to exist in any other animal except for the hooded pitohui bird of New Guinea. These toxins are not found in the poison dart frogs’ diet, which leads scientist to believe that the frogs may produce some poisons internally.

1. Compare the defense mechanisms used by poison dart frogs to that of non–poisonous frogs.

2. From an evolutionary perspective, describe a sequence of selection events that would lead to the bright, warning coloration that is now characteristic of poison dart frogs. Assume that at one time, both poisonous frogs and non–poisonous frogs had the same dull coloration.

3. Epibatidine is a rare alkaloid secreted by the phantasmal poison frog, Epipedobates tricolor. This alkaloid has been shown to be 200 times more potent than morphine, a painkiller. Why do you think medical scientists might be very interested in researching frog toxins? Explain.
### Vocabulary Practice

<table>
<thead>
<tr>
<th>Definitions</th>
<th>Word</th>
<th>Analogies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D1.</strong> An internal skeleton</td>
<td>1. Endoskeleton</td>
<td><strong>A1.</strong> Private pool</td>
</tr>
<tr>
<td><strong>D2.</strong> Waterproof container in which an amniote develops</td>
<td>2. Swim bladder</td>
<td><strong>A2.</strong> Steel beams inside a building’s walls</td>
</tr>
<tr>
<td><strong>D3.</strong> An organ that helps a fish float higher or lower in the water</td>
<td>3. Amniotic egg</td>
<td><strong>A3.</strong> Scuba buoyancy belt</td>
</tr>
<tr>
<td><strong>D4.</strong> Protective plate that covers a fish’s gills</td>
<td>4. Gills</td>
<td><strong>A4.</strong> Safety glasses</td>
</tr>
<tr>
<td><strong>D5.</strong> Specialized organs used by a fish to breathe</td>
<td>5. Tetrapod</td>
<td><strong>A5.</strong> Four-leaf clover</td>
</tr>
<tr>
<td><strong>D6.</strong> Animals that can live both on land and in water</td>
<td>6. Operculum</td>
<td><strong>A6.</strong> Lungs</td>
</tr>
<tr>
<td><strong>D7.</strong> A vertebrate with four limbs</td>
<td>7. Amphibian</td>
<td><strong>A7.</strong> Waterproof watch</td>
</tr>
</tbody>
</table>
Vocabulary Practice Unit 8 Resource Book
McDougal Littell Biology

CHAPTER 25
Vertebrate Diversity

B. Secret Message Next to each definition, fill in the blanks with the vocabulary word that best fits each description. When complete, unscramble the boxed letters to discover the distinctive feature of a vertebrate.

1. A vertebrate that has four limbs

2. A membranous organ that develops in female mammals during pregnancy

3. A fin that is round in shape and supported by a single bone

4. An internal skeleton made of bone or cartilage

5. An almost completely waterproof container that keeps an embryo from drying out as it develops

6. A flexible skeletal support rod embedded in an animal’s back

7. A protein that binds to lipids inside skin cells, creating a water repellent layer

8. A buoyancy organ that helps a fish float higher or lower in the water

Unscramble the boxed letters to name the distinctive feature:

__ __ __ __ __ __ __ __
C. Who Am I? Choose among these terms to answer the riddles below:

<table>
<thead>
<tr>
<th>Term 1</th>
<th>Term 2</th>
<th>Term 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>amniote</td>
<td>keratin</td>
<td>placenta</td>
</tr>
<tr>
<td>amniotic egg</td>
<td>lateral line</td>
<td>ray-fin</td>
</tr>
<tr>
<td>amphibian</td>
<td>lobe-fin</td>
<td>swim bladder</td>
</tr>
<tr>
<td>endoskeleton</td>
<td>notochord</td>
<td>tadpole</td>
</tr>
<tr>
<td>gill</td>
<td>operculum</td>
<td>tetrapod</td>
</tr>
</tbody>
</table>

1. I am an internal skeleton: __________
2. I am a frog larva: __________
3. I am a buoyancy organ found in a fish: __________
4. I am a vertebrate with four limbs: __________
5. I am a protein that binds to lipids inside skin cells, forming a water repellent layer: __________
6. I am a protective plate that covers the gills of a bony fish: __________
7. I am a flexible skeletal support rod embedded in an animal’s back: __________
8. I am a fan-shaped fin: __________
9. I am a waterproof container in which an amniote develops as an embryo: __________
10. I am a sensory organ used by fish to detect movements in the water: __________
11. I am a tetrapod that can live in either the water or on land, but I must return to a water source to reproduce: __________
12. I am a specialized organ used by fish to breathe: __________
13. I am a fin with a round shape: __________
14. I am a membranous organ that develops in female mammals during pregnancy: __________
15. I am a vertebrate that has a thin, tough, membranous sac that encloses the embryo or fetus during development: __________
D. Crossword Puzzle  Use the clues to solve the puzzle.

**Across**
1. Group that includes vertebrates, tunicates, and lancelets
2. Type of fin that goldfish and most other fish have
3. Internal skeleton made of cartilage or bone
4. Buoyancy organ
5. A sensory system used to detect the presence of other animals in the water
6. Frog, salamander, or caecilian
7. Container in which a chicken or lizard embryo develops
8. Protective plate that covers a bony fish’s gills
9. A newly hatched frog
10. Large sheets of frilly tissue that form a specialized organ used by fish to breathe
11. Opposite movement of water against the flow of blood in a fish’s gills

**Down**
1. Type of fin that a coelacanth has
2. Container in which a chicken or lizard embryo develops
3. Protective plate that covers a bony fish’s gills
4. A newly hatched frog
5. Opposite movement of water against the flow of blood in a fish’s gills
6. Group that includes vertebrates, tunicates, and lancelets
7. Type of fin that goldfish and most other fish have
8. Internal skeleton made of cartilage or bone
9. Buoyancy organ
10. A sensory system used to detect the presence of other animals in the water
11. Frog, salamander, or caecilian
12. Large sheets of frilly tissue that form a specialized organ used by fish to breathe