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Animals

Animals

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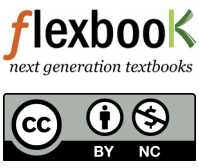

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CHAPTER 1

Introduction to Living Things

Chapter Outline

1.1 CLASSIFICATION OF LIVING THINGS
1.2 CHARACTERISTICS OF LIVING ORGANISMS
1.3 REFERENCES

1.1 Classification of Living Things

Lesson Objectives

- Explain what makes up a scientific name.
- Explain what defines a species.
- List the information scientists use to classify organisms.
- List the three domains of life and the chief characteristics of each.

Check Your Understanding

- What are the basic characteristics of life?
- What are the four main classes of organic molecules that are building blocks of life?

Vocabulary

- Archaea
- bacteria
- binomial nomenclature
- classify
- domain
- Eukarya
- genus
- species
- taxonomy

Classifying Organisms

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they **classify**, or put in categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears. It turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean System of Classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carl Linnaeus (1707-1778) (**Figure** 1.1) built on Aristotle's work to create his own classification system. He invented the way we name organisms today. Linnaeus is considered the inventor of modern **taxonomy**, the sci-

ence of naming and grouping organisms. See http://www.ucmp.berkeley.edu/history/linnaeus.html for additional information.

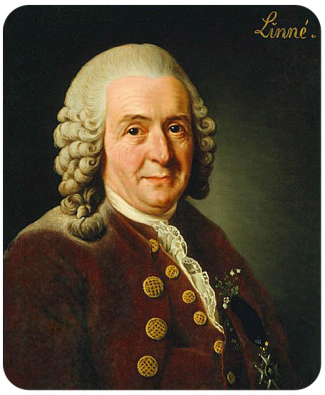

FIGURE 1.1

In the 18^{th} century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

Linnaeus developed **binomial nomenclature**, a way to give a scientific name to every organism. Each species receives a two-part name in which the first word is the **genus** (a group of species) and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals.

Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum*, are both in the same genus and they look similar (**Figure** 1.2). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. The names may seem strange, but they are written in a language called Latin.

FIGURE 1.2

These leaves(left and center) are from one of two different species of trees in the Acer, or maple, genus. One of the characteristics of the maple genus is winged seeds (right).

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** 1.3).

Difficulty Naming Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** 1.4).

So how is a species defined? A **species** is group of individuals that can interbreed with one another and produce fertile offspring; a species does not interbreed with other groups. By this definition, two species of animals or

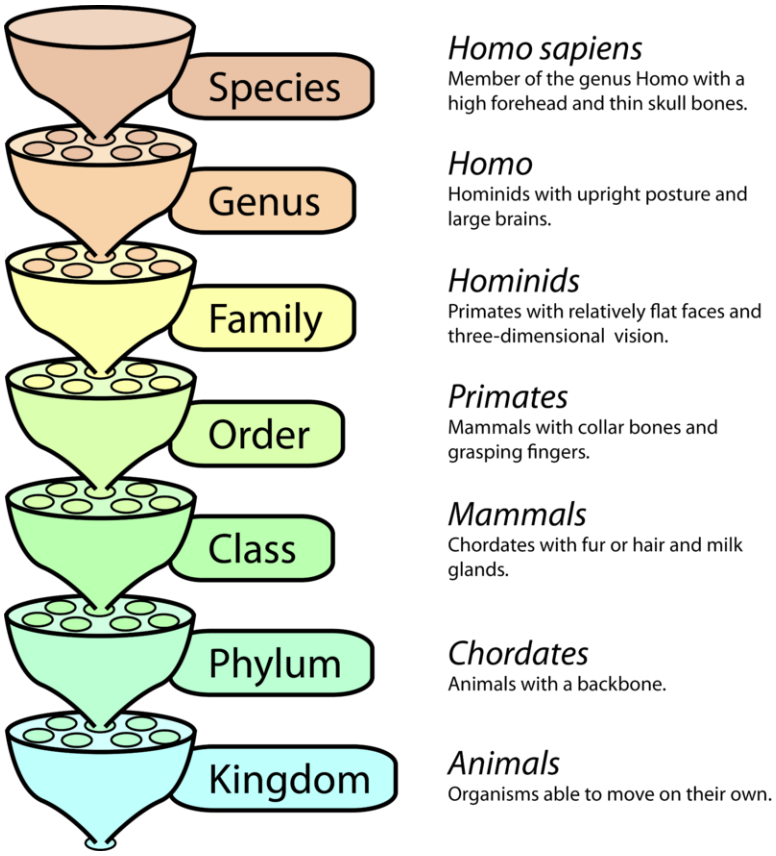

FIGURE 1.3

This diagram illustrates the classification categories for organisms, with the broadest category (Kingdom) at the bottom, and the most specific category (Species) at the top.

plants that do not interbreed are not the same species. See *Biological Classification of Organisms* for additional information: http://www.physicalgeography.net/fundamentals/9b.html .

FIGURE 1.4

These children are all members of the same species, Homo sapiens.

Domains of Life

Let's explore the least specific category of classification, called a **domain**.

All of life can be divided into 3 domains, which tell you the type of cell inside of an organism:

1. **Bacteria**: Single-celled organisms that do not contain a nucleus
2. **Archaea**: Single-celled organisms that do not contain a nucleus; have a different cell wall from bacteria
3. **Eukarya**: Organisms with cells that contain a nucleus.

Archaea and Bacteria

Archaea and Bacteria (**Figure** 1.5 and **Figure** 1.6) seem very similar, but they also have significant differences.

Similarities:

- Do not have a nucleus
- Small cells
- One-celled
- Can reproduce without sex by dividing in two

Differences:

- Cell walls made of different material
- Archaea often live in extreme environments like hot springs, geysers, and salt flats while bacteria can live almost everywhere.

FIGURE 1.5

The Group A Streptococcus organism is in the domain Bacteria, one of the three domains of life.

FIGURE 1.6

The Halobacterium is in the domain Archaea, one of the three domains of life.

Eukarya

All of the cells in the domain Eukarya keep their genetic material, or DNA, inside the nucleus. The domain Eukarya is made up of four kingdoms:

1. Plantae: Plants, such as trees and grasses, survive by capturing energy from the sun, a process called photosynthesis.
2. Fungi: Fungi, such as mushrooms and molds, survive by "eating" other organisms or the remains of other organisms.
3. Animalia: Animals survive by eating other organisms or the remains of other organisms. Animals range from tiny ants to the largest dinosaurs (reptiles) and whales (mammals), including all sizes in between. (**Figure** 1.7).
4. Protista: Protists are not all descended from a single common ancestor in the way that plants, animals, and fungi are. Protists are all the eukaryotic organisms that do not fit into one of the other three kingdoms. They include many kinds of microscopic one-celled organisms, such as algae and plankton, but also giant seaweeds that can grow to be 200 feet long (an alga protist is shown in **Figure** 1.8).

Plants, animals, fungi, and protists might seem very different, but remember that if you look through a microscope, you will find similar cells with a membrane-bound nucleus in all of them. The main characteristics of the three domains of life are summarized in **Table** 1.1.

FIGURE 1.7

The Western Gray Squirrel is in the domain Eukarya, one of the three domains of life.

FIGURE 1.8

This microscopic alga is a protist in the domain Eukarya.

TABLE 1.1: Three domains of life: Bacteria, Archaea, and Eukarya

	Archaea	Bacteria	Eukarya
Multicelluar	No	No	Yes
Cell Wall	Yes, without peptidoglycan	Yes, with peptidoglycan	Varies. Plants and fungi have a cell wall; animals do not.
Nucleus (DNA inside a membrane)	No	No	Yes
Organelles inside a membrane	No	No	Yes

Viruses

We have all heard of viruses. The flu and many other diseases are caused by viruses. But what is a virus? Based on the material presented in this chapter, do you think viruses are living?

The answer is actually "no." A virus is essentially DNA or RNA surrounded by a coat of protein (**Figure** 1.9). It is not a cell and does not maintain homeostasis. Viruses also cannot reproduce on their own – they need to infect a host cell to reproduce. Viruses do, however, change over time, or evolve. So a virus is very different from any of the organisms that fall into the three domains of life.

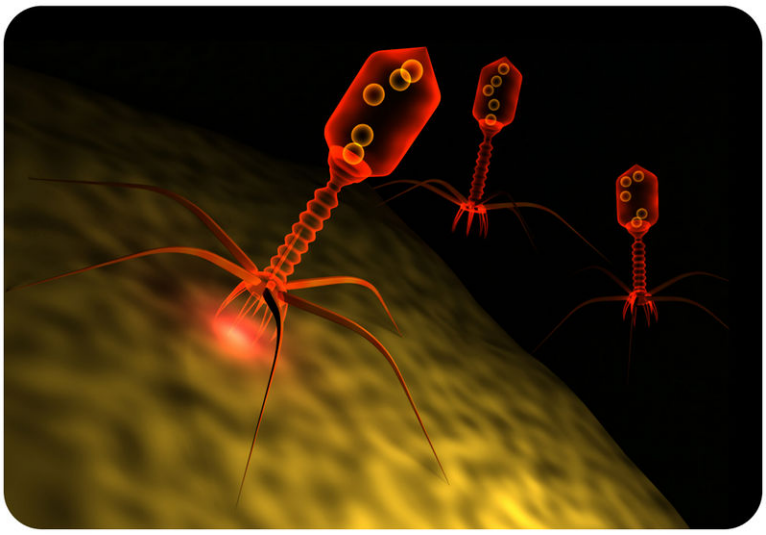

FIGURE 1.9

These "moon lander" shaped viruses infects *Escherichia coli* bacteria.

Lesson Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.
- Scientists classify organisms according to their evolutionary histories and how related they are to one another - by looking at their physical features, the fossil record, and DNA sequences.
- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.

Review Questions

Recall

1. Who designed modern classification and invented the two-part species name?
2. Define a species.
3. What kingdoms make up the domain Eukarya?
4. What is the name for the scientific study of naming and classifying organisms?
5. How are organisms given a scientific name?

Apply Concepts

6. In what domain are humans?
7. *Quercus rubra* is the scientific name for the red oak tree. What is the red oak's genus?
8. In what domain are mushrooms?
9. What information do scientists use to classify organisms?

Think Critically

10. Is it possible for organisms in two different classes to be in the same genus?
11. If molecular data suggests that two organisms have very similar DNA, what does that say about their evolutionary relatedness?
12. Can two different species ever share the same scientific name?
13. If two organisms are in the same genus, would you expect them to look much alike?

Points to Consider

- This Section introduced the diversity of life on Earth. Do you think it is possible for cells from different organisms to be similar even though the organisms look different?
- Do you think human cells are different from bacterial cells?
- Do you think it is possible for a single cell to be a living organism?

1.2 Characteristics of Living Organisms

Lesson Objectives

- List the defining characteristics of living things.
- List the needs of all living things.

Vocabulary

- cell
- embryo
- homeostasis
- organism

Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or **organisms**. It might seem hard to think of similarities among such different organisms, but they actually have many things in common. Living things are similar to each other because all living things evolved from the same common ancestor that lived billions of years ago. See http://vimeo.com/15407847 for a powerful introduction to life.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.
3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment (**homeostasis**).

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. The work you do each day, from walking to writing and thinking, is fueled by energy. But you are not the only one. In order to grow and reproduce, all living things need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat. Here is how animals, plants and fungi obtain their energy:

- All animals must eat plants or other animals in order to obtain energy and building materials.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of photosynthesis.
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (**Figure** 1.10).

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

FIGURE 1.10

Orange bracket fungi on a rotting log in the Oak Openings Preserve in Ohio. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Living Things Are Made of Cells

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells (**Figure** 1.11). **Cells** are the smallest unit of living things. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the paramecium shown in **Figure** 1.12 are made of just one cell. Other organisms have millions of cells. On the other hand, eggs are some of the biggest cells around. A chicken egg is just one huge cell.

All cells share at least some structures. Although the cells of different organisms are built differently, they all function much the same way. Every cell must get energy from food, be able to grow and reproduce, and respond to its environment.

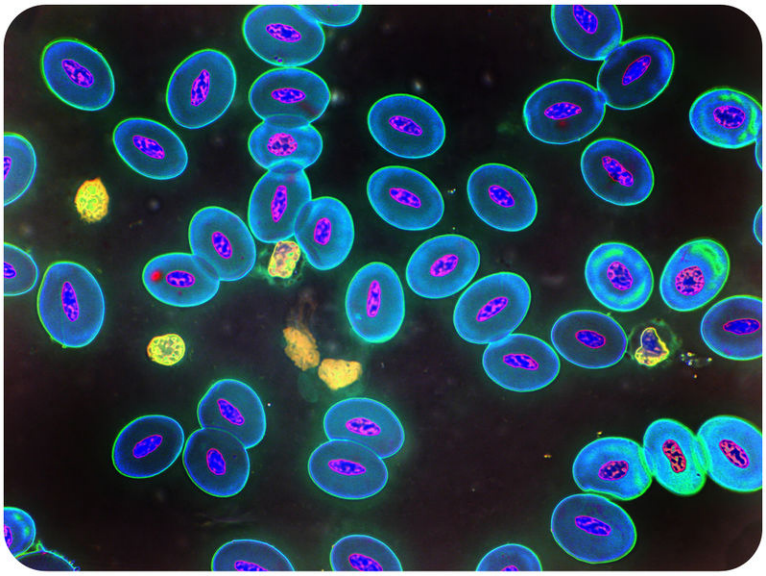

FIGURE 1.11

Reptilian blood cell showing the characteristic nucleus. A few smaller white blood cells are visible. This image has been magnified 1000 times its real size.

Living Things Respond to their Environment

All living things are able to react to something important or interesting in their external environment. For example, living things respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, and taste buds.

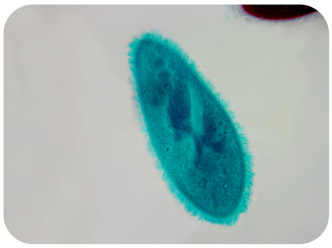

FIGURE 1.12

This paramecium is a single-celled organism.

Living Things Grow and Reproduce

All living things reproduce to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce (**Figure** 1.13).

FIGURE 1.13

Like all living things, cats reproduce themselves and make a new generation of cats. When animals and plants reproduce they make tiny undeveloped versions of themselves called **embryos**, which grow up and develop into adults. A kitten is a partly developed cat.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living thing gets thrown off balance, its body or cells help them return to normal. In other words, living things have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis**. Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm (**Figure** 1.14).

Lesson Summary

- All living things grow, reproduce, and maintain a stable internal environment.
- All organisms are made of cells.
- All living things need energy and resources to survive.

Review Questions

Recall

1. Define the word organism.
2. What are three characteristics of living things?

FIGURE 1.14

A bird fluffs its feathers to stay warm (keep from losing energy) and to maintain homeostasis.

Apply Concepts

3. What are a few ways organisms can get the energy they require?
4. What is a cell?

Think Critically

5. Think about fire. Can fire be considered a living thing? Why or why not?

Points to Consider

- DNA is considered the "instructions" for the cell. What do you think this means?
- What kinds of chemicals do you think are necessary for life?
- Do you expect that the same chemicals can be in non-living and living things?

1.3 References

1. Alexander Roslin. http://commons.wikimedia.org/wiki/File:Carolus_Linnaeus_%28cleaned_up_version%29.jpg . Public Domain
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CHAPTER 2 Animals

Chapter Outline

2.1 OVERVIEW OF ANIMALS
2.2 ANIMAL BEHAVIORS
2.3 LEARNED BEHAVIOR OF ANIMALS
2.4 INNATE BEHAVIOR OF ANIMALS
2.5 ANIMAL COMMUNICATION
2.6 SOCIAL BEHAVIOR OF ANIMALS
2.7 REPRODUCTIVE BEHAVIOR OF ANIMALS
2.8 CYCLIC BEHAVIOR OF ANIMALS
2.9 REFERENCES

Introduction

Fighting or playing?

You might think that these young tigers are fighting, but they're really just playing. Like most other young mammals, tigers like to play. Why do mammals play? Is playing just for fun, or does it serve some other purpose as well? Playing is actually an important way of learning. By playing, these tigers are learning moves that will help them become successful predators as adults. Playing is just one of many ways that mammals and other animals learn how to behave.

2.1 Overview of Animals

Lesson Objectives

- Identify characteristics that all animals share.
- Give an overview of animal classification.

Vocabulary

- amniote
- animal
- exoskeleton
- invertebrate
- notochord
- vertebral column
- vertebrate

Introduction

There is great variation among species that make up the animal kingdom. Some of this variation is shown in **Figure** 2.1. Despite the variation, there are a number of traits that are shared by all animals. The fact that all animals have certain traits in common shows that they share a common ancestor. How did such a diverse group of organisms evolve? What traits do all animals share? Read on to find out.

Characteristics of Animals

Animals are a kingdom of multicellular eukaryotes. They cannot make their own food. Instead, they get nutrients by eating other living things. Therefore, animals are heterotrophs.

Animal Cells

Like the cells of all eukaryotes, animal cells have a nucleus and other membrane-bound organelles (see **Figure** 2.2). Unlike the cells of plants and fungi, animal cells lack a cell wall. This gives animal cells flexibility. It lets them take on different shapes so they can become specialized to do particular jobs. The human nerve cell shown in **Figure** 2.3 is a good example. Its shape suits it for its function of transmitting nerve impulses over long distances. A nerve cell would be unable to take this shape if it were surrounded by a rigid cell wall.

Animal Structure and Function

Animals not only have specialized cells. Most animals also have tissues and organs. In many animals, organs form organ systems, such as a nervous system. Higher levels of organization allow animals to perform many complex functions. What can animals do that most other living things cannot? Here are some examples. All of them are illustrated in **Figure** 2.4.

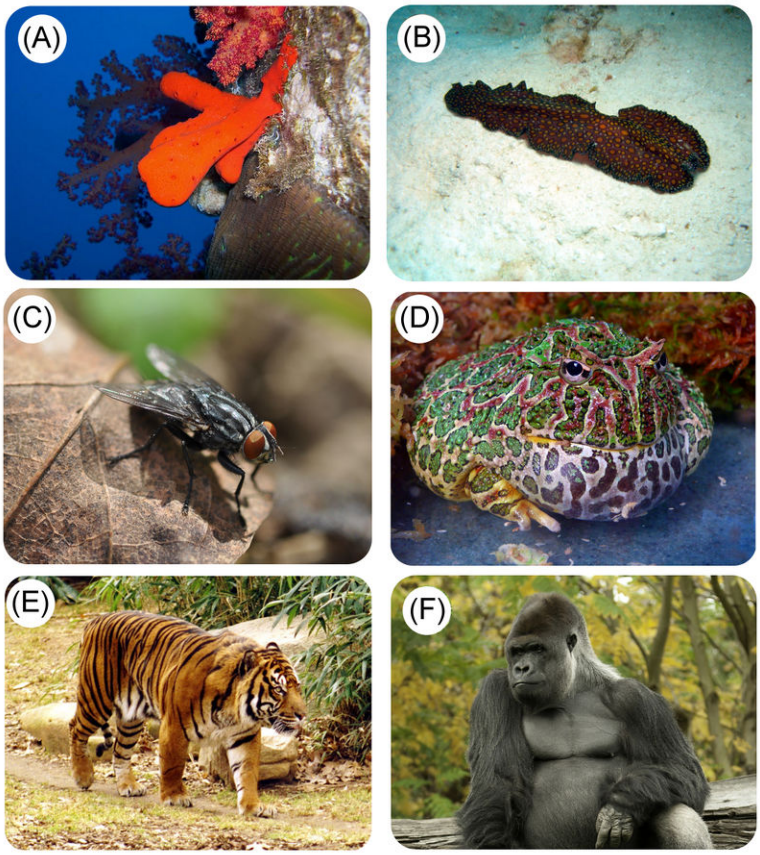


FIGURE 2.1

Diversity of Animals. These photos give just an inkling of the diversity of organisms that belong to the animal kingdom. (A) Sponge (B) Flatworm (C) Flying Insect (D) Frog (E) Tiger (F) Gorilla.

- Animals can detect environmental stimuli, such as light, sound, and touch. Stimuli are detected by sensory nerve cells. The information is transmitted and processed by the nervous system. The nervous system, in turn, may direct the body to respond.
- All animals can move, at least during some stage of their life cycle. Muscles and nerves work together to allow movement. Being able to move lets animals actively search for food and mates. It also helps them escape from predators.
- Virtually all animals have internal digestion of food. Animals consume other organisms and may use special tissues and organs to digest them. (Many other organisms absorb nutrients directly from the environment.)

Animal Life Cycle and Reproduction

Many animals have a relatively simple life cycle. A general animal life cycle is shown in **Figure** 2.5. Most animals spend the majority of their life as diploid organisms. Just about all animals reproduce sexually. Diploid adults undergo meiosis to produce sperm or eggs. Fertilization occurs when a sperm and an egg fuse. The zygote that forms develops into an embryo. The embryo eventually develops into an adult.

Classification of Animals

All animals share basic traits. But animals also show a lot of diversity. They range from simple sponges to complex humans.

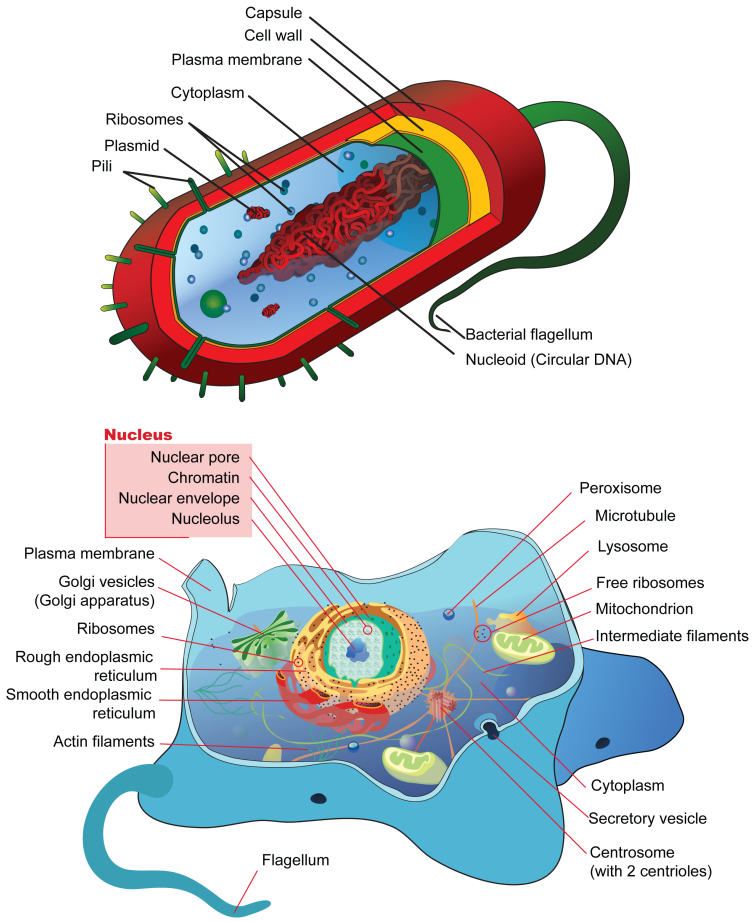


FIGURE 2.2

Animal Cell. The shape of an animal cell is not constrained by a rigid cell wall. A bacterial cell is shown above for comparison.

Major Animal Phyla

Members of the animal kingdom are divided into more than 30 phyla. **Table** 2.1 lists the 9 phyla with the greatest number of species. Each of the animal phyla listed in the table have at least 10,000 species.

The first eight phyla listed in **the table** below include only invertebrate animals. **Invertebrates** are animals that lack a **vertebral column**, or backbone. The last phylum in the table, the Chordata, also includes many invertebrate species. Tunicates and lancelets are both invertebrates. Altogether, invertebrates make up at least 95 percent of all animal species. The remaining animals are vertebrates. **Vertebrates** are animals that have a backbone. All vertebrates belong to the phylum Chordata. They include fish, amphibians, reptiles, birds, and mammals.

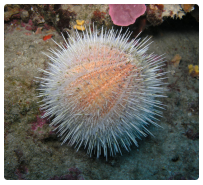
TABLE 2.1: Major Phyla of the Animal Kingdom

	Phylum	Animals It Includes
	Porifera	sponges

TABLE 2.1: (continued)

	Phylum	Animals It Includes
	Cnidaria	jellyfish, corals
	Platyhelminthes	flatworms, tapeworms, flukes
	Nematoda	roundworms
	Mollusca	snails, clams, squids
	Annelida	earthworms, leeches, marine worms
	Arthropoda	insects, spiders, crustaceans, centipedes

TABLE 2.1: (continued)

	Phylum	Animals It Includes
	Echinodermata	sea stars, sea urchins, sand dollars, sea cucumbers
	Chordata	tunicates, lancelets, fish, amphibians, reptiles, birds, mammals

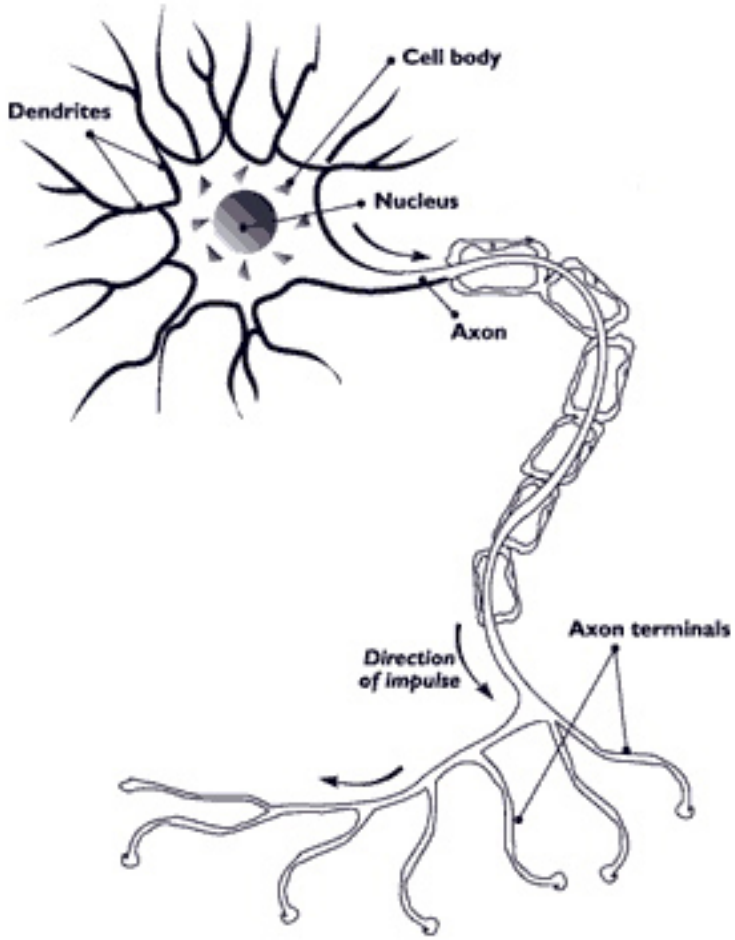


FIGURE 2.3

Human Nerve Cell. A human nerve cell is specialized to transmit nerve impulses. How do you think the cell's shape helps it perform this function?

FIGURE 2.4

Characteristics of Animals. Most animals share these characteristics: sensory organs, movement, and internal digestion.

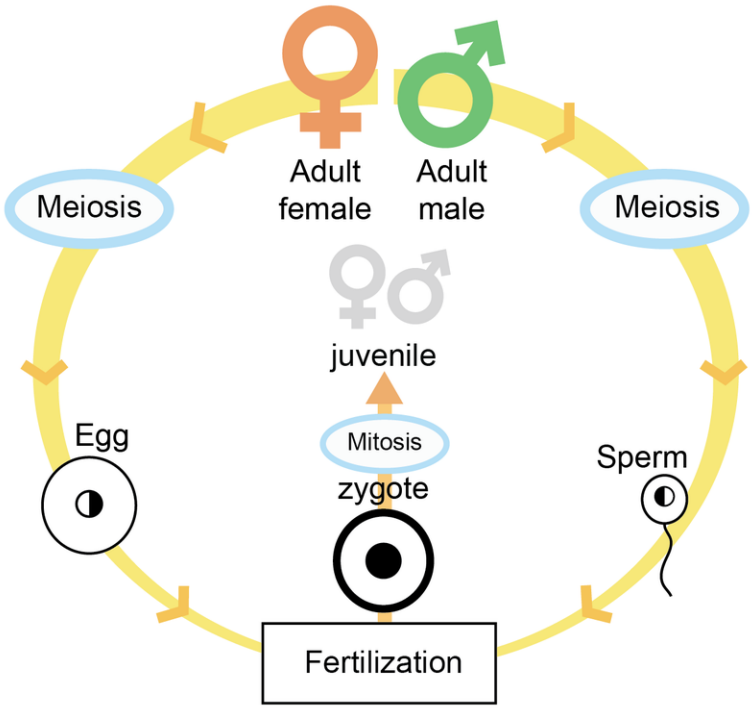


FIGURE 2.5

Animal Life Cycle. An animal life cycle that includes only sexual reproduction is shown here. Some animals also reproduce asexually. How does the animal life cycle compare with the life cycle of a plant?

Lesson Summary

- Animals are multicellular eukaryotes that lack cell walls. All animals are heterotrophs. They have sensory organs, the ability to move, and internal digestion. They also have sexual reproduction.
- Vertebrates have a backbone, but invertebrates do not. Except for the chordates, all animal phyla consist only of invertebrates. Chordates include both vertebrates and invertebrates.
- The earliest animals evolved from colonial protists more than 600 million years ago. Many important animal adaptations evolved in invertebrates, including tissues and a brain. The first animals to live on land were invertebrates. Amphibians were the first vertebrates to live on land. Amniotes were the first animals that could reproduce on land.

Review Questions

Recall

1. Identify traits that characterize all animals.
2. State one way that animal cells differ from the cells of plants and fungi. What is the significance of this difference?
3. Describe a general animal life cycle.
4. State how the phylum Chordata differs from other animal phyla.

Apply Concepts

5. Assume that a new species of animal has been discovered. It is an egg-laying animal that lives and reproduces on land. Explain what you know about its eggs without ever seeing them.

Think Critically

6. Compare and contrast invertebrates and vertebrates.

Points to Consider

Vertebrates are the animals with which we are most familiar. But there are far more invertebrates than vertebrates on the planet. The next lesson provides an overview of invertebrate animals.

- Before reading the next lesson, think about what you now know about invertebrates. Can you identify some invertebrate traits?
- Invertebrates are sometimes referred to as “lower” animals. This is because they evolved earlier and are simpler than vertebrates. Do you think invertebrates are also less adapted to their environments than vertebrates? Why or why not?

2.2 Animal Behaviors

- Explain the meaning of animal behavior.
- Give examples of animal behaviors.
- Discuss the importance of animal behavior.
- Explain how animal behaviors can increase fitness.

Why do spiders spin webs?

You have probably seen a spider web before. You may even know that spiders create webs to catch their prey. This is an example of animal behavior. Animals have many different behaviors.

Introduction to Animal Behavior

Barking, purring, and playing are just some of the ways in which dogs and cats behave. These are examples of animal behaviors. **Animal behavior** is any way that animals act, either alone or with other animals.

Examples of Animal Behavior

Can you think of examples of animal behaviors? What about insects and birds? How do they behave? Pictured below are just some of the ways in which these, and other animals act (**Figure** 2.6). Look at the pictures and read about the behaviors. Think about why the animal is behaving that way.

FIGURE 2.6

These pictures show examples of animal behaviors. Why do the animals behave these ways?

Importance of Animal Behavior

Why do animals behave the way they do? The answer to this question depends on what the behavior is. A cat chases a mouse to catch it. A mother dog nurses her puppies to feed them. All of these behaviors have the same purpose: getting or providing food. All animals need food for energy. They need energy to move around. In fact, they need energy just to stay alive. Energy allows all the processes inside cells to occur. Baby animals also need energy to grow and develop.

Birds and wasps build nests to have a safe place to store their eggs and raise their young. Many other animals build nests for the same reason. Animals protect their young in other ways, as well. For example, a mother dog not only nurses her puppies. She also washes them with her tongue and protects them from strange people or other animals. All of these behaviors help the young survive and grow up to be adults.

Rabbits run away from foxes and other predators to stay alive. Their speed is their best defense. Lizards sun themselves on rocks to get warm because they cannot produce their own body heat. When they are warmer, they can move faster and be more alert. This helps them escape from predators and also find food.

All of these animal behaviors are important. They help the animals get food for energy, make sure their young survive, or ensure that they, themselves, survive. Behaviors that help animals or their young survive, increase the animals' **fitness.** Animals with higher fitness have a better chance of passing their **genes** on to the next generation. If genes control behaviors that increase fitness, the behaviors become more common in the species. This occurs through the process of evolution by natural selection.

Vocabulary

- **animal behavior**: Way in which animals act, either alone or with other animals.
- **fitness**: Relative ability of an organism to survive and produce fertile offspring.
- **gene**: Unit of DNA that contains code for the creation of one protein.

Summary

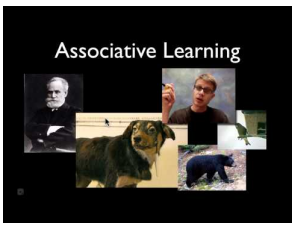
- Animal behavior is any way that animals act, either alone or with other animals.
- Animal behavior may be aimed at getting food for energy, making sure their young survive, or ensuring that

they, themselves, survive.

Practice

Use the resource below to answer the questions that follow.

- **Animal Behavior** at http://www.youtube.com/watch?v=6hREwakXmAo (9:52)



MEDIA

Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57409

1. When do animals learn innate behavior?
2. Can you think of why "grasping" behavior would help human babies survival?
3. A crow vending machine is associated with what type of learning?
4. Compare and contrast "trial and error" learning and "observational" learning.
5. How do "mirror neurons" work?

Review

1. What are two examples of animal behaviors that are aimed at getting food?
2. What are two examples of animal behaviors that are aimed at protecting the young?
3. What is meant by fitness? What is the relationship between animal behaviors and fitness?
4. Is there a relationship between genes and fitness? Explain your answer.

2.3 Learned Behavior of Animals

- Describe the ways in which behavior can be learned.

Learned Behavior

Just about all human behaviors are learned. **Learned behavior** is behavior that occurs only after experience or practice. Learned behavior has an advantage over **innate behavior**: it is more flexible. Learned behavior can be changed if conditions change. For example, you probably know the route from your house to your school. Assume that you moved to a new house in a different place, so you had to take a different route to school. What if following the old route was an innate behavior? You would not be able to adapt. Fortunately, it is a learned behavior. You can learn the new route just as you learned the old one.

Although most animals can learn, animals with greater intelligence are better at learning and have more learned behaviors. Humans are the most intelligent animals. They depend on learned behaviors more than any other species. Other highly intelligent species include apes, our closest relatives in the animal kingdom. They include chimpanzees and gorillas. Both are also very good at learning behaviors.

Quick Link: A Conversation with Koko at http://www.pbs.org/wnet/nature/koko .

Think about some of the behaviors you have learned. They might include riding a bicycle, using a computer, and playing a musical instrument or sport. You probably did not learn all of these behaviors in the same way. Perhaps you learned some behaviors on your own, just by practicing. Other behaviors you may have learned from other people. Humans and other animals can learn behaviors in several different ways.

Habituation

Habituation is learning to get used to something after being exposed to it for a while. Habituation usually involves getting used to something that is annoying or frightening, but not dangerous. Habituation is one of the simplest ways of learning. It occurs in just about every species of animal.

You have probably learned through habituation many times. For example, maybe you were reading a book when someone turned on a television in the same room. At first, the sound of the television may have been annoying. After a while, you may no longer have noticed it. If so, you had become habituated to the sound.

Another example of habituation is shown below (**Figure** 2.7). Crows and most other birds are usually afraid of people. They avoid coming close to people, or they fly away when people come near them. The crows landing on this scarecrow have become used to a "human" in this place. They have learned that the scarecrow poses no danger. They are no longer afraid to come close. They have become habituated to the scarecrow.

Can you see why habituation is useful? It lets animals ignore things that will not harm them. Without habituation, animals might waste time and energy trying to escape from things that are not really dangerous.

Observational learning is learning by watching and copying the behavior of someone else. Human children learn many behaviors this way. When you were a young child, you may have learned how to tie your shoes by watching your dad tie his shoes. More recently, you may have learned how to dance by watching a pop star dancing on TV. Most likely, you have learned how to do math problems by watching your teachers do problems on the board at school. Can you think of other behaviors you have learned by watching and copying other people?

Other animals also learn through observational learning. For example, young wolves learn to be better hunters by watching and copying the skills of older wolves in their pack. Another example of observational learning is

FIGURE 2.7

This scarecrow is no longer scary to this crow. The crow has become used to its being in this spot and learned that it is not dangerous. This is an example of habituation.

how some monkeys have learned to wash their food. They learned by watching and copying the behavior of other monkeys.

Conditioning is a way of learning that involves a reward or punishment. Did you ever train a dog to fetch a ball or stick by rewarding it with treats? If you did, you were using conditioning. Another example of conditioning is shown in the video below; the rats have been taught to "play basketball" by being rewarded with food pellets. What do you think would happen if the rats were no longer rewarded for this behavior?

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/75743

Conditioning also occurs in wild animals. For example, bees learn to find nectar in certain types of flowers because they have found nectar in those flowers before.

Humans learn behaviors through conditioning, as well. A young child might learn to put away his toys by being rewarded with a bedtime story. An older child might learn to study for tests in school by being rewarded with better grades. Can you think of behaviors you have learned by being rewarded for them?

Conditioning does not always involve a reward. It can involve a punishment, instead. A toddler might be punished with a time-out each time he grabs a toy from his baby brother. After several time-outs, he may learn to stop taking his brother's toys.

A dog might be scolded each time she jumps up on the sofa. After repeated scolding, she may learn to stay off the sofa. A bird might become ill after eating a poisonous insect. The bird may learn from this "punishment" to avoid eating the same kind of insect in the future.

Learning by playing is one young mammals learn the skills that they will need as adults. Think about how kittens play. They pounce on toys and chase each other. This helps them learn how to be better predators when they are older. Big cats also play. The lion cubs pictured below are playing and practicing their hunting skills at the same time (**Figure** 2.8). The dogs are playing tug-of-war with a toy (**Figure** 2.8). What do you think they are learning by playing together this way?

Human children learn by playing as well. For example, playing games and sports can help them learn to follow rules and work with others. Other young animals play in different ways. For example, young deer play by running and kicking up their hooves. This helps them learn how to escape from predators.

FIGURE 2.8

Left: These two lion cubs are playing. They are not only having fun, but they are also learning how to be better hunters. Right: These dogs are really playing. This play fighting can help them learn how to be better predators.

Insight learning is learning from past experiences and reasoning. It usually involves coming up with new ways to solve problems. Insight learning generally happens quickly. An animal has a sudden flash of insight. Insight learning requires relatively great intelligence. Human beings use insight learning more than any other species. They have used their intelligence to solve problems ranging from inventing the wheel to flying rockets into space.

Think about problems you have solved. Maybe you figured out how to solve a new type of math problem or how to get to the next level of a video game. If you relied on your past experiences and reasoning to do it, then you were using insight learning.

One type of insight learning is making tools to solve problems. Scientists used to think that humans were the only animals intelligent enough to make tools. In fact, tool-making was believed to set humans apart from all other animals.

In 1960, primate expert Jane Goodall discovered that chimpanzees also make tools. She saw a chimpanzee strip leaves from a twig. Then he poked the twig into a hole in a termite mound. After termites climbed onto the twig, he pulled the twig out of the hole and ate the insects clinging to it. The chimpanzee had made a tool to "fish" for termites. He had used insight to solve a problem. Since then, chimpanzees have been seen making several different types of tools. For example, they sharpen sticks and use them as spears for hunting. They use stones as hammers to crack open nuts.

Scientists have also observed other species of animals making tools to solve problems. A crow was seen bending a piece of wire into a hook. Then the crow used the hook to pull food out of a tube.

An example of a gorilla using a walking stick is shown below (**Figure** 2.9). Behaviors such as these show that other species of animals can use their experience and reasoning to solve problems. They can learn through insight.

Vocabulary

- **conditioning**: Process of learning through reward or punishment.
- **habituation**: Learning to get used to something after being exposed to it for a while.
- **insight learning**: Learning from past experiences and reasoning.
- **learned behavior**: Behavior that occurs only after experience or practice.
- **observational learning**: Learning by watching and copying the behavior of someone else.

Summary

- Learned behavior is behavior that occurs only after experience or practice.
- Methods of learning include habituation, observational learning, conditioning, play, and insight learning.

FIGURE 2.9

This gorilla is using a branch as a tool. She is leaning on it to keep her balance while she reaches down into swampy water to catch a fish.

Practice

Use the resource below to answer the questions that follow.

- **Octopus Tool Use: The World's Smartest Invertebrate** at http://www.youtube.com/watch?v=AP_dpbTbess (1:21)

MEDIA

Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57415

1. What sort of behavior do you feel this octopus is exhibiting? Explain your reasoning fully.
2. Do you think this behavior counts as "tool use"? Explain your thinking fully.

Review

1. What is observational learning? Give an example.
2. What is conditioning?
3. Why are some crows not afraid of scarecrows?
4. Describe insight learning. Give an example.

2.4 Innate Behavior of Animals

- Explain and give examples of innate behavior.

How do kittens know how to "hunt"?

This kitten was probably adopted and separated from its mother at a young age. It never got a lesson in how to stalk and pounce on prey. So how does this kitten know how to attack the ball of yarn? Some behaviors do not need to be learned.

Innate Behavior

Many animal behaviors are ways that animals act, naturally. They don't have to learn how to behave in these ways. Cats are natural-born hunters. They don't need to learn how to hunt. Spiders spin their complex webs without learning how to do it from other spiders. Birds and wasps know how to build nests without being taught. These behaviors are called innate.

An **innate behavior** is any behavior that occurs naturally in all animals of a given species. An innate behavior is also called an **instinct**. The first time an animal performs an innate behavior, the animal does it well. The animal does not have to practice the behavior in order to get it right or become better at it. Innate behaviors are also predictable. All members of a species perform an innate behavior in the same way. From the examples described above, you can probably tell that innate behaviors usually involve important actions, like eating and caring for the young.

There are many other examples of innate behaviors. For example, did you know that honeybees dance? The honeybee pictured below has found a source of food (**Figure** 2.10). When the bee returns to its hive, it will do a dance. This dance is called the **waggle dance**. The way the bee moves during its dance tells other bees in the hive where to find the food. Honeybees can do the waggle dance without learning it from other bees, so it is an innate behavior.

Besides building nests, birds have other innate behaviors. One example occurs in gulls, which are pictured below (**Figure** 2.11); one of the chicks is pecking at a red spot on the mother's beak. This innate behavior causes the mother

FIGURE 2.10

When this honeybee goes back to its hive, it will do a dance to tell the other bees in the hive where it found food.

to feed the chick. In many other species of birds, the chicks open their mouths wide whenever the mother returns to the nest (**Figure** 2.11). This innate behavior, called **gaping**, causes the mother to feed them.

FIGURE 2.11

Left: This mother gull will feed her chick after it pecks at a red spot on her beak. Both pecking and feeding behaviors are innate. Right: When these baby birds open their mouths wide, their mother instinctively feeds them. This innate behavior is called gaping.

Another example of innate behavior in birds is egg rolling. It happens in some species of water birds, like the graylag goose (**Figure** 2.12). Graylag geese make nests on the ground. If an egg rolls out of the nest, a mother goose uses her bill to push it back into the nest. Returning the egg to the nest helps ensure that the egg will hatch.

Innate Behavior in Human Beings

All animals have innate behaviors, even human beings. Can you think of human behaviors that do not have to be learned? Chances are, you will have a hard time thinking of any. The only truly innate behaviors in humans are called **reflex behaviors**. They occur mainly in babies. Like innate behaviors in other animals, reflex behaviors in human babies may help them survive.

An example of a reflex behavior in babies is the sucking reflex. Newborns instinctively suck on a nipple that is placed in their mouth. It is easy to see how this behavior evolved. It increases the chances of a baby feeding and surviving. Another example of a reflex behavior in babies is the grasp reflex (**Figure** 2.13). Babies instinctively grasp an object placed in the palm of their hand. Their grip may be surprisingly strong. How do you think this behavior might increase a baby's chances of surviving?

FIGURE 2.12

This female graylag goose is a ground-nesting water bird. Before her chicks hatch, the mother protects the eggs. She will use her bill to push eggs back into the nest if they roll out. This is an example of an innate behavior. How could this behavior increase the goose's fitness?

FIGURE 2.13

One of the few innate behaviors in human beings is the grasp reflex. It occurs only in babies.

Vocabulary

- **gaping**: Wide opening of a baby bird's mouth in expectation of feeding.
- **innate behavior**: Any behavior that occurs naturally in all animals of a given species.
- **instinct**: Ability of an animal to perform a behavior the first time it is exposed to the proper stimulus.
- **reflex behaviors**: Any behavior that occurs without conscious thought as a response to a stimulus.
- **waggle dance**: Way a honeybee moves to tell other bees in the hive where to find the food.

Summary

- Innate behavior, or instinct, is any behavior that occurs naturally in all animals of a given species.
- Examples of innate behavior include honeybees doing the waggle dance or spiders spinning a web.

Practice

Use the resource below to answer the questions that follow.

- **Spider Crabs vs. Stingray** at http://www.youtube.com/watch?v=fjwWLOIk1oA (2:37)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/94450

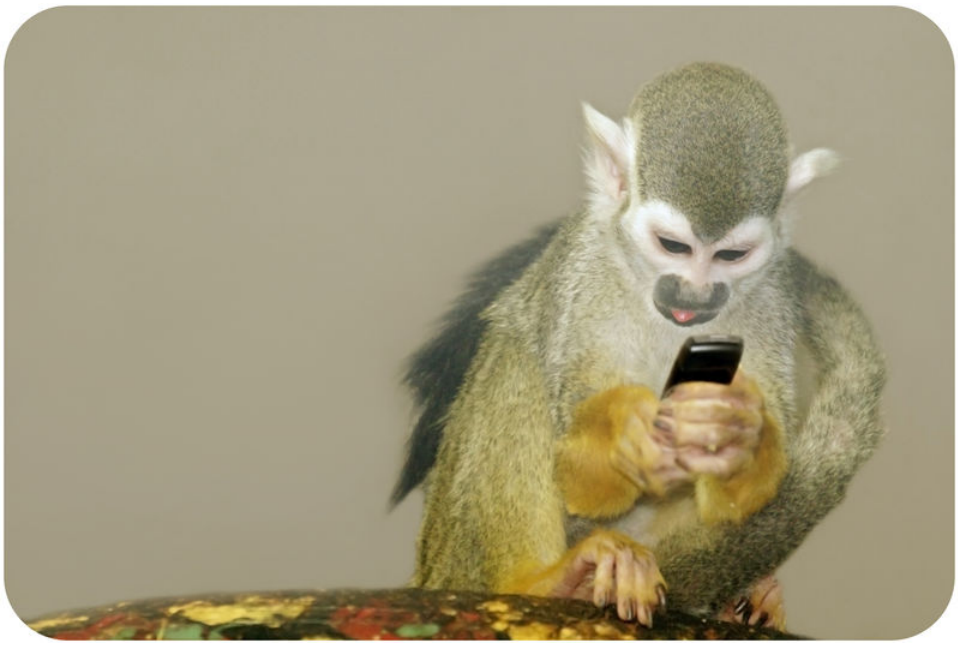
1. How many different types of behavior can you see in the crabs in this video? Which behaviors of the crabs do you think are innate and which are learned?
2. How many different types of behavior can you see in the stingray? Which behaviors of the stingray do you feel are innate and which are learned?

Review

1. What is an innate behavior?
2. What are two examples of reflex behaviors in humans?
3. What are two examples of innate behavior in animals?
4. Is an instinct an innate behavior? Explain your answer.

2.5 Animal Communication

- List ways in which animals communicate.



How do monkeys communicate?

You won't find a monkey texting a friend. They make noises. They make faces. They even use scents to pass along a message. Just because monkeys don't talk like you and me doesn't mean that they don't communicate!

Communication

What does the word "communication" make you think of? Talking on a cell phone? Texting? Writing? Those are just a few of the ways in which human beings communicate. Most other animals also communicate. **Communication** is any way in which animals share information, and they do this in many different ways.

Do all animals talk to each other? Probably not, but many do communicate. Like human beings, many other animals live together in groups. Some insects, including ants and bees, are well known for living in groups. In order for animals to live together in groups, they must be able to communicate with each other.

Animal communication, like most other animal behaviors, increases the ability to survive and have offspring. This is known as fitness. Communication increases fitness by helping animals find food, defend themselves from predators, mate, and care for offspring.

Communication with Sound

Some animals communicate with sound. Most birds communicate this way. Birds use different calls to warn other birds of danger, or to tell them to flock together. Many other animals also use sound to communicate. For example, monkeys use warning cries to tell other monkeys in their troop that a predator is near. Frogs croak to attract female frogs as mates. Gibbons use calls to tell other gibbons to stay away from their area.

Communication with Sight

Another way some animals communicate is with sight. By moving in certain ways or by "making faces," they show other animals what they mean. Most primates communicate in this way. For example, a male chimpanzee may raise his arms and stare at another male chimpanzee. This warns the other chimpanzee to keep his distance. The chimpanzee pictured below may look like he is smiling, but he is really showing fear (**Figure** 2.14). He is communicating to other chimpanzees that he will not challenge them.

FIGURE 2.14

This chimpanzee is communicating with his face. His expression is called a "fear grin." It tells other chimpanzees that he is not a threat.

Look at the peacock pictured below (**Figure** 2.15). Why is he raising his beautiful tail feathers? He is also communicating. He is showing females of his species that he would be a good mate.

FIGURE 2.15

This peacock is using his tail feathers to communicate. What is he "saying"?

Communication with Scent

Some animals communicate with scent. They release chemicals that other animals of their species can smell or detect in some other way. Ants release many different chemicals. Other ants detect the chemicals with their antennae. This explains how ants are able to work together. The different chemicals that ants produce have different meanings. Some of the chemicals signal to all of the ants in a group to come together. Other chemicals warn of danger. Still other chemicals mark trails to food sources. When an ant finds food, it marks the trail back to the nest by leaving behind a chemical on the ground. Other ants follow the chemical trail to the food.

Many other animals also use chemicals to communicate. You have probably seen male dogs raise their leg to urinate on a fire hydrant or other object. Did you know that the dogs were communicating? They mark their area with a chemical in their urine. Other dogs can smell the chemical. The scent of the chemical tells other dogs to stay away.

Human Communication

Like other animals, humans communicate with one another. They mainly use sound and sight to share information. The most important way in which humans communicate is with language. **Language** is the use of symbols to communicate. In human languages, the symbols are words. They stand for many different things. Words stand for things, people, actions, feelings, or ideas. Think of several common words. What does each word stand for? Another important way in which humans communicate is with facial expressions. Look at the face of the young child pictured below (**Figure** 2.16). Can you tell from her face how she is feeling? Humans also use gestures to communicate. What are people communicating when they shrug their shoulders? When they shake their head? These are just a few examples of the ways in which humans share information without using words.

FIGURE 2.16

What does this girl's face say about how she is feeling?

Vocabulary

- **communication**: Any way in which animals share information.
- **language**: Method of communication using signs or symbols.

Summary

- Animals communicate, or share information, through sound, sight, and scent.
- Humans primarily communicate through use of language, facial expressions, and gestures.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Can Monkeys Talk?** at http://www.youtube.com/watch?v=3lsF83rHKFc (3:36)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/117082

1. How do the vervet monkeys (*Chlorocebus pygerythrus*) respond when they hear a "leopard" call?
2. How do the vervet monkeys respond when they hear an "eagle" call?
3. How do the vervet monkeys respond when the hear a "snake" call?
4. Given the vervet monkeys responses to specific calls, do you think they are using language? Explain your reasoning fully.

Practice II

- **How Do Tigers Communicate?** at http://www.youtube.com/watch?v=LL99pufzHjo (1:33)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57411

1. What are some of the different ways tigers (*Panthera tigris*) communicate?
2. In what sort of ways do tigers communicate through smell?
3. Do you think using different smells to communicate is analogous to using different words? Explain your reasoning.

Review

1. What is communication?
2. Why is communication important?
3. Give two examples of how animals communicate with scent.
4. Give two examples of how animals communicate through sight.
5. Define language.

2.6 Social Behavior of Animals

- Describe social behavior in animals.

How are you social?

When you think about being social, do you think about hanging out and chatting with friends? Sending a text or posting to Facebook? Humans socialize in many ways. Social behavior is not limited to humans, however. Many animals are social.

Social Behavior

Why is animal communication important? Without it, animals would not be able to live together in groups. Animals that live in groups with other members of their species are called **social animals**. Social animals include many species of insects, birds, and mammals. Specific examples of social animals are ants, bees, crows, wolves, and humans. To live together with one another, these animals must be able to share information.

Highly Social Animals

Some species of animals are very social. In these species, members of the group depend completely on one another. Different animals within the group have different jobs. Therefore, group members must work together for the good of all. Most species of ants and bees are highly social animals.

Ants live together in large groups called colonies (**Figure** 2.17). A colony may have millions of ants. All of the ants in the colony work together as a single unit. Each ant has a specific job. Most of the ants are workers. Their job is to build and repair the colony's nest. Worker ants also leave the nest to find food for themselves and other colony members. The workers care for the young as well. Other ants in the colony are soldiers. They defend the colony against predators. Each colony also has a queen. Her only job is to lay eggs. She may lay millions of eggs each

month. A few ants in the colony are called drones. They are the only male ants in the colony. Their job is to mate with the queen.

FIGURE 2.17

The ants in this picture belong to the same colony. They have left the colony's nest to search for food.

Honeybees and bumblebees also live in colonies (**Figure** 2.18). Each bee in the colony has a particular job. Most of the bees are workers. Young worker bees clean the colony's hive and feed the young. Older worker bees build the waxy honeycomb or guard the hive. The oldest workers leave the hive to find food. Each colony usually has one queen that lays eggs. The colony also has a small number of male drones. They mate with the queen.

FIGURE 2.18

All the honeybees in this colony work together. Each bee has a certain job to perform. Notice the queen to the left. She is the largest bee in the colony.

Cooperation

Ants, bees, and other social animals must cooperate. **Cooperation** means working together with others. Members of the group may cooperate by sharing food. They may also cooperate by defending each other. Look at the ants pictured below (**Figure** 2.19). They show very clearly why cooperation is important. A single ant would not be able to carry this large bee back to the nest to feed the other ants. With cooperation, the job is easy.

Animals in many other species cooperate. For example, lions live in groups called prides (**Figure** 2.20). All the lions in the pride cooperate. Male lions work together to defend the other lions in the pride. Female lions work

FIGURE 2.19

These ants are cooperating. By working together, they are able to move this much larger insect prey back to their nest. At the nest, they will share the bee with other ants that do not leave the nest.

together to hunt. Then, they share the meat with other pride members. Another example is meerkats. Meerkats are small mammals that live in Africa. They also live in groups and cooperate with one another. For example, young female meerkats act as babysitters. They take care of the baby meerkats while their parents are away looking for food.

FIGURE 2.20

Members of this lion pride work together. Males cooperate by defending the pride. Females cooperate by hunting and sharing the food.

Vocabulary

- **cooperation**: Working together with others.
- **social animals**: Animals that live in groups with other members of their species.

Summary

- Social animals, or animals that live in groups with other members of their species, include ants, bees, crows, wolves, and humans.
- Social animals must cooperate (work together) with others.

Practice

Use the resource below to answer the questions that follow.

- **Wolf Hunting Tactics** at http://www.youtube.com/watch?v=2jXxtQRy47A (2:54)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57421

1. Observe the wolves (*Canis lupus*) in this video:
    a. Do you think they are displaying learned behavior, innate behavior, or both? Explain your reasoning fully.
    b. As social animals, which behavior do you think is most important to them? Explain your reasoning.
    c. Does your answer apply to all situations?

Review

1. What makes social animals unique?
2. Give three examples of social animals.
3. What is one example of how social animals cooperate?

2.7 Reproductive Behavior of Animals

- Explain the purpose of mating behavior.
- Describe how animals defend their territory.

Why do these birds pair up?

These birds are pairing up so that they can produce offspring. Many birds keep the same mate for an entire season. In some species, they even stay paired for their entire life.

Mating Behavior and Defending Territory

Some of the most important animal behaviors involve mating. **Mating** is the pairing of an adult male and female to produce young. Adults that are most successful at attracting a mate are most likely to have offspring. Traits that help animals attract a mate and have offspring increase their fitness. As the genes that encode these traits are passed to the next generation, the traits will become more common in the population.

Courtship Behaviors

In many species, females choose the male they will mate with. For their part, males try to be chosen as mates. They show females that they would be a better mate than the other males. To be chosen as a mate, males may perform **courtship behaviors**. These are special behaviors that help attract a mate. Male courtship behaviors get the attention of females and show off a male's traits.

Different species have different courtship behaviors. One example is a peacock raising his tail feathers. The colorful peacock is trying to impress females of his species with his beautiful feathers. Another example of courtship behavior in birds is the blue-footed booby. He is doing a dance to attract a female for mating. During the dance, he spreads

out his wings and stamps his feet on the ground. You can watch the following video of a blue-footed booby doing his courtship dance at: http://www.youtube.com/watch?v=oYmzdvMoUUA .

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/94451

Courtship behaviors occur in many other species. For example, males in some species of whales have special mating songs to attract females as mates. Frogs croak for the same reason. Male deer clash antlers to court females. Male jumping spiders jump from side to side to attract mates.

Courtship behaviors are one type of display behavior. A **display behavior** is a fixed set of actions that carries a specific message. Although many display behaviors are used to attract mates, some display behaviors have other purposes. For example, display behaviors may be used to warn other animals to stay away, as you will read below.

Caring for the Young

In most species of birds and mammals, one or both parents care for their offspring. Caring for the young may include making a nest or other shelter. It may also include feeding the young and protecting them from predators. Caring for offspring increases their chances of surviving. Birds called killdeers have an interesting way of protecting their chicks. When a predator gets too close to her nest, a mother killdeer pretends to have a broken wing. The mother walks away from the nest holding her wing as though it were injured (**Figure** 2.21). The predator thinks she is injured and will be easy prey. The mother leads the predator away from the nest and then flies away.

FIGURE 2.21

This mother killdeer is pretending she has a broken wing. She is trying to attract a predator's attention in order to protect her chicks. This behavior puts her at risk of harm. How can it increase her fitness?

In most species of mammals, parents also teach their offspring important skills. For example, meerkat parents teach their pups how to eat scorpions without being stung. A scorpion sting can be deadly, so this is a very important skill. Teaching the young important skills makes it more likely that they will survive.

Defending Territory

Some species of animals are **territorial**. This means that they defend their area. The area they defend usually contains their nest and enough food for themselves and their offspring. A species is more likely to be territorial if there is not very much food in their area. Animals generally do not defend their territory by fighting. Instead, they are more likely to use display behavior. The behavior tells other animals to stay away. It gets the message across without the need for fighting. Display behavior is generally safer and uses less energy than fighting. Male gorillas use display behavior to defend their territory. They pound on their chests and thump the ground with their hands to warn other male gorillas to keep away from their area. The robin displays his red breast to warn other robins to stay away (**Figure** 2.22).

FIGURE 2.22

The red breast of this male robin is easy to see. The robin displays his bright red chest to defend his territory. It warns other robins to keep out of his area.

Some animals deposit chemicals to mark the boundary of their territory. This is why dogs urinate on fire hydrants and other objects. Cats may also mark their territory by depositing chemicals. They have scent glands in their face. They deposit chemicals by rubbing their face against objects.

Vocabulary

- **courtship behaviors**: Special behaviors that help attract a mate.
- **display behavior**: Fixed set of actions that carries a specific message.
- **mating**: Pairing of an adult male and female to produce young.
- **territorial**: Defending a particular area.

Summary

- Males of some species may perform courtship behaviors, special behaviors that help attract a mate.
- Some species of animals are territorial and defend their area.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Dominant Male Elephant Seal** at http://www.youtube.com/watch?v=9UYFGSyUxRc (2:26)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57418

The Northern elephant seal (*Mirounga angustirostris*) has a harem based mating system, where a dominant male defends the females in his harem from other males attempting to mate with them.

1. Does the dominant male father all the pups from his harem?
2. How do you think the size of a harem affects a male's ability to defend his harem? Explain your reasoning.

Practice II

- **Behavior on a Sage Grouse Lek** at http://www.youtube.com/watch?v=QYMHbFUTgAY (1:15)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57419

1. What is a lek? What sort of behavior is seen in a lek?
2. When do sage grouse (*Centrocercus urophasianus*) put on the most weight? How does this affect their reproductive success?

Practice III

- **Elk Fighting in River** at http://www.youtube.com/watch?v=GUQcMZLZpx8 (2:45)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57420

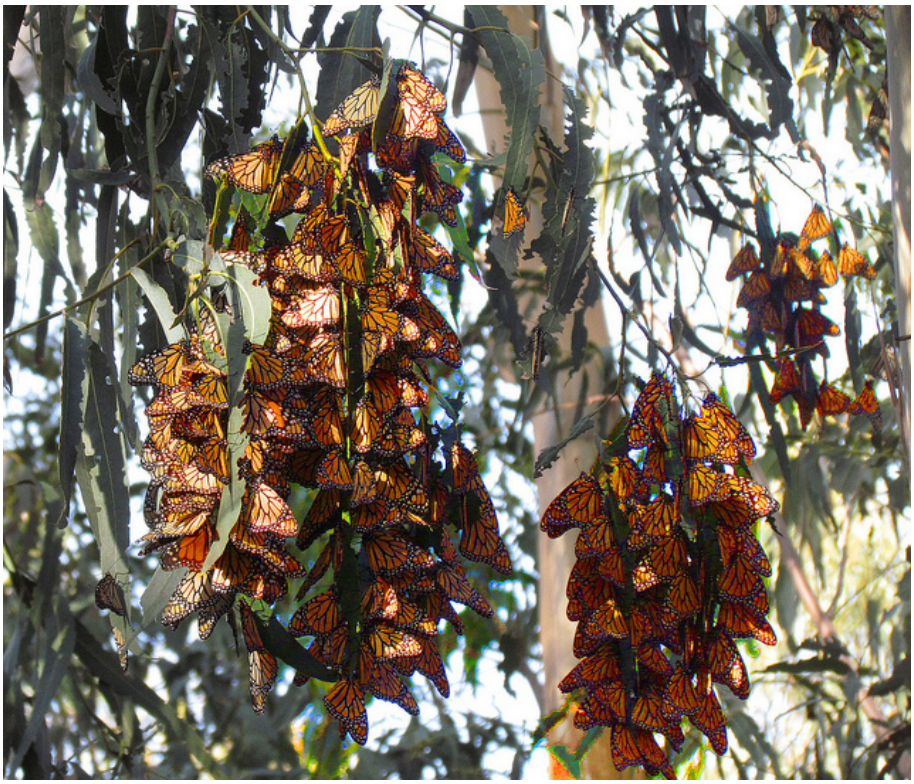
1. Notice the male elk (*Cervus canadensis*) which enters the video at the 2:05 mark. What do you think it is trying to do? Do you think its behavior helps or hurts the survival of elk in Yellowstone National Park?
2. What sort of behavior are the male elk displaying?

Review

1. What is a courtship behavior. Give an example.
2. Give an example of display behavior exhibited by a territorial animal.

2.8 Cyclic Behavior of Animals

- Identify animal behaviors that occur in cycles.



What are these butterflies doing?

Monarch butterflies gather in large groups as they migrate 2,500 miles south each fall. They return to the north in the spring. This migration is a cycle that repeats every year.

Cycles of Behavior

Many animal behaviors change in a regular way. They go through cycles. Some cycles of behavior repeat each year. Other cycles of behavior repeat every day.

Yearly Cycles

An example of a behavior with a yearly cycle is **hibernation**. Hibernation is a state in which an animal's body processes are slower than usual, and its body temperature falls. An animal uses less energy than usual during hibernation. This helps the animal survive during a time of year when food is scarce. Hibernation may last for weeks or months. Animals that hibernate include species of bats, squirrels, and snakes.

Most people think that bears hibernate. In fact, bears do not go into true hibernation. In the winter, they go into a deep sleep. However, their body processes do not slow down very much. Their body temperature also remains about the same as usual. Bears can be awakened easily from their winter sleep.

Another example of a behavior with a yearly cycle is **migration**. Migration is the movement of animals from one place to another. Migration is an innate behavior that is triggered by changes in the environment. For example, animals may migrate when the days get shorter in the fall. Migration is most common in birds, fish, and insects. In the Northern Hemisphere, many species of birds, including robins and geese, travel south for the winter. They migrate to areas where it is warmer and where there is more food. They return north in the spring.

Birds and other migrating animals follow the same routes each year. How do they know where to go? It depends on the species. Some animals follow landmarks, such as rivers or coastlines. Other animals are guided by the position of the sun, the usual direction of the wind, or other clues in the environment.

Daily Cycles

Many animal behaviors change at certain times of day, day after day. For example, most animals go to sleep when the sun sets and wake up when the sun rises. Animals that are active during the daytime are called **diurnal**. Some animals do the opposite. They sleep all day and are active during the night. These animals are called **nocturnal**. Examples of nocturnal animals include bats, foxes, possums, skunks and coyotes. Many mammals (including humans), insects, reptiles and birds are diurnal.

Animals may eat and drink at certain times of day as well. Humans have daily cycles of behavior, too. Most people start to get sleepy after dark and have a hard time sleeping when it is light outside. Daily cycles of behavior are called **circadian rhythms**.

In many species, including humans, circadian rhythms are controlled by a tiny structure called the **biological clock**. This structure is located in a gland at the base of the brain. The biological clock sends signals to the body. The signals cause regular changes in behavior and body processes. The amount of light entering the eyes helps control the biological clock. The clock causes changes that repeat every 24 hours.

Vocabulary

- **biological clock**: Structure that controls the activities of an organism whose activities change on a regular 24-hour cycle.
- **circadian rhythms**: Regular change in biology or behavior that occurs in a 24-hour cycle.
- **diurnal**: Animals that are active during the daytime and rest during the night.
- **hibernation**: State in which an animal's body processes are slower than usual, and its body temperature falls in order to conserve energy when food is scarce.
- **migration**: Regular movement of animals each year, usually to find food, mates, or other resources.
- **nocturnal**: Animals that are active during the night and sleep all day.

Summary

- Yearly cycles of behavior include hibernation and migration.
- Daily cycles of behavior, including sleeping a waking, are called circadian rhythms.

Practice

Use the resources below to answer the questions that follow.

- **Red Knot Migration - Port Royal Sound** at http://www.youtube.com/watch?v=P21xTCFrJbU (2:07)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57412

- **Thousands of Red Knots migrate through New Jersey** at http://www.youtube.com/watch?v=TE5EHoBWdAA (2:55)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57413

1. How far do Red Knots (*Calidris canutus*) migrate each year?
2. Are Red Knots the only species of bird to use horseshoe crab (*Limulus polyphemus*) eggs as a resource?
3. What information do scientists collect from the red Knots? How do they use this information?
4. Why do scientists think Red Knot populations are declining? How is this connected to their extremely long migration?

Review

1. What are two examples of yearly cycles of behavior?
2. What is the difference between a nocturnal and a diurnal animal?
3. What is a circadian rhythm?
4. What controls circadian rhythms in humans? Explain how this process works.

Summary

Animals. Currently the end of the line for evolution. But there are all sorts of animals, from the extremely simple to the extremely complex. Along with this range of animals comes a range of behaviors. These behaviors are discussed in this concept.

2.9 References

1. (A) Flickr:tsnoni; (B) Richard Ling; (C) Erica; (D) Rusty Clark; (E) Jeff Kubina; (F) Roger Luijten. (A) http://www.flickr.com/photos/tsnoni/4275153356/; (B) http://www.flickr.com/photos/chikawatanabe/1888251649/; (C) http://www.flickr.com/photos/fantasticalnature/8087272748/; (D) http://www.flickr.com/photos/rusty_clark/6315952681/; (E) http://www.flickr.com/photos/kubina/7601553/; (F) http://www.flickr.com/photos/66555186@N02/6312198231/ . CC BY 2.0
2. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Top: http://commons.wikimedia.org/wiki/File:Average_prokaryote_cell-_en.svg; Bottom: http://commons.wikimedia.org/wiki/File:Animal_cell_structure_en.svg . Public Domain
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10. Thangaraj Kumaravel. When this honeybee goes back to its hive, it will do a dance to tell the other bees in the hive where it found food. CC BY 2.0
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14. Frans de Waal/Emory University. Chimpanzee showing a fear grin. CC BY 2.5
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20. Rick Marin. Members of this lion pride work together. Public Domain
21. audreyjm529. This mother killdeer is pretending she has a broken wing in order to protect her chicks. CC BY 2.0
22. Dwight Sipler. The robin displays his bright red chest to defend his territory. CC BY 2.0

CHAPTER 3

Invertebrates

Chapter Outline

3.1 INVERTEBRATES

3.2 SPONGES

3.3 CNIDARIANS

3.4 FLATWORMS

3.5 ROUNDWORMS

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3.7 MOLLUSKS

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3.10 ECHINODERMS

3.11 TYPES OF ECHINODERMS

3.12 IMPORTANCE OF ECHINODERMS

3.13 ARTHROPODS

3.14 IMPORTANCE OF ARTHROPODS

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3.16 CENTIPEDES AND MILLIPEDES

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3.19 INSECT FOOD

3.20 INSECT REPRODUCTION AND LIFE CYCLE

3.21 IMPORTANCE OF INSECTS

3.22 CONTROL OF INSECTS

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Introduction

Why does not having a backbone make things so complex?

Invertebrates could be described as simple animals. And though some are very simple, the vastness of the invertebrate species makes this group of animals anything but simple.

3.1 Invertebrates

- Distinguish between invertebrates and vertebrates.

How are these jellyfish like an insect?

Jellyfish and insects don't seem to have much in common. They look much different. They live in very different environments. But both of these animals are classified as invertebrates.

What Are Invertebrates?

Animals are often identified as being either invertebrates or vertebrates. These are terms based on the skeletons of the animals. **Vertebrates** have a backbone made of bone or cartilage (**cartilage** is a flexible supportive tissue. You have cartilage in your ear lobes.). **Invertebrates**, on the other hand, have no backbone (**Figure** 3.1). Invertebrates live just about anywhere. There are so many invertebrates on this planet that it is impossible to count them all. There are probably billions of billions of invertebrates. They come in many shapes and sizes, live practically anywhere and provide many services that are vital for the survival of other organisms, including us. They have been observed in

FIGURE 3.1
Snails are an example of invertebrates, animals without a backbone.

the upper reaches of the atmosphere, in the driest of the deserts and in the canopies of the wettest rainforests. They can even be found in the frozen Antarctic or on the deepest parts of the ocean floor.

All vertebrate organisms are in the phylum Chordata. Invertebrates, which make up about 95% (or more) of the animal kingdom, are divided into over 30 different phyla, some of which are listed below (**Table** 3.1). Numerous invertebrate phyla have just a few species; some have only one described species, yet these are classified into separate phyla because of their unique characteristics.

TABLE 3.1: Invertebrate Phyla

Phylum	Meaning	Examples
Porifera	Pore bearer	Sponges
Cnidaria	Stinging nettle	Jellyfish, corals
Platyhelminthes	Flat worms	Flatworms, tapeworms
Nematoda	Thread like	Nematodes, heartworm
Mollusca	Soft	Snails, clams
Annelida	Little ring	Earthworms, leeches
Arthropoda	Jointed foot	Insects, crabs
Echinodermata	Spiny skin	Sea stars, sea urchins

Vocabulary

- **cartilage**: Firm tissue that provides flexible support in animal skeletons.
- **invertebrates**: Animals that lack backbones.
- **vertebrates**: Animals that have backbones of bones or cartilage.

Summary

- Invertebrates are animals without a backbone.
- Invertebrates include insects, earthworms, jellyfish, and many other animals.

Review

1. What are three examples of invertebrates?

3.2 Sponges

- Describe the key features of sponges.

Do animals wash your dishes?

Natural sponges, like the one in the picture above, are actually animals taken from the sea! The sponges in your home, however, were most likely never living things. Most sponges used in kitchens today are made from unnatural materials.

Sponges

Sponges (**Figure** 3.2) are classified in the phylum Porifera, from the Latin words meaning "having pores." These pores allow the movement of water into the sponges' sac-like bodies. Sponges must pump water through their bodies in order to eat. Because sponges are **sessile**, meaning they cannot move, they filter water to obtain their food. They are, therefore, known as **filter feeders.** Filter feeders must filter the water to separate out the organisms and nutrients they want to eat from those they do not.

You might think that sponges don't look like animals at all. They don't have a head or legs. Internally, they do not have brains, stomachs, or other organs. This is because sponges evolved much earlier than other animals. In fact, sponges do not even have true tissues. Instead, their bodies are made up of specialized cells (cell-level organization) that do specific jobs. Sponge cells perform a variety of bodily functions and appear to be more independent of each other than are the cells of other animals. For example, some cells control the flow of water, in and out of the sponge, by increasing or decreasing the size of the pores.

Sponges are characterized by a feeding system unique among animals. As sponges don't have mouths, they must feed by some other method. Sponges have tiny pores in their outer walls through which water is drawn. Cells in

FIGURE 3.2

The sponges often have tube-like bodies with many tiny pores. There are roughly 5,000 sponge species.

the sponge walls filter food from the water as the water is pumped through the body and out other larger openings. The flow of water through the sponge is unidirectional, driven by the beating of flagella, which line the surface of chambers connected by a series of canals.

Sponges reproduce by both asexual and sexual means. Sponges that reproduce asexually produce buds or, more often, structures called **gemmules**, which are packets of several cells of various types inside a protective covering. Freshwater sponges often produce gemmules prior to winter, which then develop into adult sponges beginning the following spring. Most sponges that reproduce sexually are hermaphroditic and produce eggs and sperm at different times. Sperm are frequently released into the water, where they are captured by sponges of the same species. The sperm are then transported to eggs, fertilization occurs and the zygotes develop into larvae. Some sponges release their larvae, where others retain them for some time. Once the larvae are in the water, they settle and develop into juvenile sponges.

Vocabulary

- **filter feeder**: Animals that feed by filtering suspended matter and food particles from water.
- **gemmule**: Internal buds found in sponges that are the result of asexual reproduction.
- **sessile**: Unable to move.
- **sponges**: Ocean-dwelling, sessile invertebrates in the phylum Porifera.

Summary

- Sponges are sessile filter feeders.
- Sponges lack true tissues.

Practice

Use the resource below to complete the section on your note worksheet.

- **Sponges: Origins** at http://vimeo.com/37032195 (14:02)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57285

Review

1. What is a sea sponge?
2. How do sponges gain nutrition?
3. What is meant by cell-level organization?
4. Define sessile.

3.3 Cnidarians

- Describe the key features of the cnidarians.

Are corals animal, plant, or mineral?

Some corals may look like rocks. But they are alive! And some corals may look like plants, but they are actually animals. Just like all other animals, they eat food to get energy.

Cnidarians

Cnidarians, in the phylum *Cnidaria*, include organisms such as the jellyfish, corals, and sea anemones. These animals are found in shallow ocean water. You might know that these animals can give you a painful sting if you step on them. That's because cnidarians have stinging cells known as **nematocysts**. Cnidarians use nematocysts to catch their food. When touched, the nematocysts release a thread of poison that can be used to paralyze prey. Cnidarians are among the simplest of the so-called "higher" organisms, but are also among the most beautiful.

Body plan

The body plan of cnidarians is unique because these organisms show radial symmetry. This means that they have a circular body plan, and any cut through the center of the animal leaves two equal halves.

The cnidarians have two basic body forms:

1. **Polyp**: The polyp is a cup-shaped body with the mouth facing upward, such as a sea anemone and coral.
2. **Medusa**: The medusa is a bell-shaped body with the mouth and tentacles facing downward, such as a jellyfish.

Unlike the sponges, the cnidarians are made up of true tissues. The inside of a cnidarian is called the **gastrovascular cavity**, a large space that helps the organism digest and move nutrients around the body. The cnidarians also have nerve tissue organized into a net-like structure, known as a nerve-net. Cnidarians do not have true organs, however.

Reproduction is by asexual budding (polyps) or sexual formation of gametes (medusae, some polyps). The result of sexual reproduction is a larva, which can swim on its own.

Cnidarian Colonies

Some types of cnidarians are also known to form colonies. Two examples are described below.

1. The Portuguese Man o' War (**Figure** 3.3) looks like a single organism but is actually a colony of polyps. One polyp is filled with air to help the colony float, while several feeding polyps hang below with tentacles. The tentacles are full of nematocysts. The Portuguese Man o' War is known to cause extremely painful stings to swimmers and surfers who accidentally brush up against it in the water.

FIGURE 3.3

The Portuguese Man o' War can deliver nasty stings with its tentacles.

2. Coral reefs (**Figure** 3.4) look like big rocks, but they are actually alive. They are built from cnidarians called corals. The corals are sessile polyps that can use their tentacles to feed on ocean creatures that pass by. Their skeletons are made up of calcium carbonate, which is also known as limestone. Over long periods of time, their skeletons build on each other to produce large structures known as coral reefs. Coral reefs are important habitats for many different types of ocean life.

Vocabulary

- **cnidarians**: Invertebrate animals including jellyfish and corals; they are characterized by radial symmetry and stinging cells called nematocysts.
- **gastrovascular cavity**: Internal space that is the site of digestion and distribution of nutrients.
- **medusa**: Bell-shaped body plan of some Cnidarians with mouth and tentacles facing downward.
- **nematocyst**: Stinging cells characteristic of the Cnidarians.
- **polyp**: Cup-shaped body plan of some Cnidarians with mouth and tentacles facing upward.

FIGURE 3.4
Corals are colonial cnidarians.

Summary

- Cnidarians have radial symmetry and true tissues.
- Some cnidarians form colonies, such as corals.

Practice

Use the resource below to answer the questions that follow.

Practice I

- **Cnidarians: Life on the Move** at http://vimeo.com/37267733 (14:44)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57274

1. How do cnidarians move?
2. Why was movement a useful innovation for cnidarians?
3. What is a nematocyst? For what purpose(s) are they used?
4. What allowed cnidarians to swim the world's oceans?

Practice II

- **Cnidarians: Moon Jelly Life Cycle** at http://vimeo.com/40232821 (3:15)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57275

1. How do polyps differ from medusas?
2. Describe the mating of moon jellies.

Review

1. What are three examples of cnidarians?
2. What is an nematocyst? What does it do?
3. Distinguish between the two body plans of a cnidarian.
4. How is a jellyfish different from a Portuguese Man o' War?

3.4 Flatworms

- Describe the major features of flatworms.

Do worms have eyes?

You might think that worms can't see. But some worms, such as the above *Dugesia* flatworm, do have eyespots. These are not exactly like your eyes, however. Eyespots can only detect light in their environment.

Flatworms

The word "worm" is not very scientific. But it is a word that informally describes animals (usually invertebrates) that have long bodies with no arms or legs. (Snakes are vertebrates, so they are not usually described as worms.) Worms show bilateral symmetry, meaning that the right side of their bodies is a mirror of the left.

One type of worm is the **flatworm**. Worms in the phylum *Platyhelminthes* are called flatworms because they have flattened bodies. There are more than 18,500 known species of flatworms.

Features of Flatworms

The main characteristics of flatworms (**Figure** 3.5) include:

1. Flatworms have no true body cavity, but they do have bilateral symmetry.
2. Flatworms have an incomplete digestive system. This means that the digestive tract has only one opening. Digestion takes place in the gastrovascular cavity.

3. Flatworms do not have a respiratory system. Instead, they have pores that allow oxygen to enter through their body. Oxygen enters the pores by diffusion.
4. There are no blood vessels in the flatworms. Their **gastrovascular cavity** helps distribute nutrients throughout the body.
5. Flatworms have a ladder-like nervous system; two interconnected parallel nerve cords run the length of the body.
6. Most flatworms have a distinct head region that includes nerve cells and sensory organs, such as eyespots. The development of a head region, called **cephalization**, evolved at the same time as bilateral symmetry in animals.

FIGURE 3.5

Marine flatworms can be brightly colored, such as this one from the class Turbellaria. These worms are mostly carnivores or scavengers.

Flatworms in the Environment

Flatworms live in a variety of environments. Some species of flatworms are free-living organisms that feed on small organisms and rotting matter. These types of flatworms include marine flatworms and freshwater flatworms, such as *Dugesia*.

Other types of flatworms are parasitic. That means they live inside another organism, called a host, in order to get the food and energy they need. For example, **tapeworms** have a head-like area with tiny hooks and suckers (known as the **scolex**) that help the worm attach to the intestines of an animal host (**Figure** 3.6). There are over 11,000 species of parasitic flatworms.

Vocabulary

- **cephalization**: Concentration of the sense organs and nervous tissue in a head region.
- **flatworm**: Invertebrate animals with bilateral symmetry and an elongated, flattened body.
- **gastrovascular cavity**: Internal space that is the site of digestion and distribution of nutrients.
- **scolex**: The front end of a tapeworm, bearing suckers and hooks for attachment.
- **tapeworm**: Parasitic flatworm, which lives in the intestines of vertebrates.

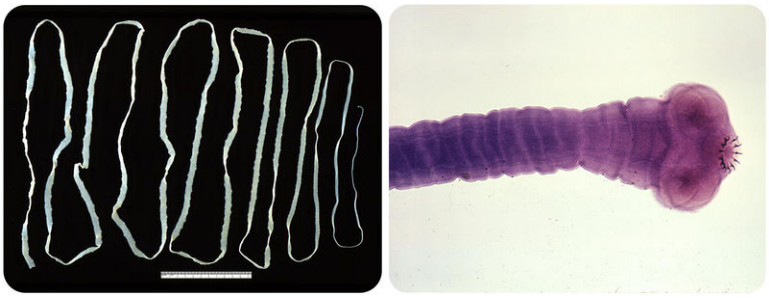


FIGURE 3.6

Tapeworms are parasitic flatworms that live in the intestines of their hosts. They can be very long (*left*). Tapeworms attach to the intestinal wall with a head region that has hooks and suckers (*right*).

Summary

- Flatworms have no true body cavity and no blood vessels.
- Flatworms can be free-living or parasitic. Tapeworms are parasitic flatworms.

Review

Go to http://www.biology4kids.com/files/invert_flatworm.html to help you answer these questions.

1. How many different species of flatworms can be found on Earth?
2. What is a fluke?
3. Where are planaria found?
4. What develops from mesoderm?
5. How are flame cells used?

Review

1. What is a flatworm?
2. What is cephalization?
3. How do flatworms transport oxygen and nutrients?
4. Describe the flatworm nervous system.
5. What is one example of a flatworm?

3.5 Roundworms

- Describe the major features of the roundworms.

What is heartworm?

You may have heard that you need to protect your pets from heartworm. Heartworms are a type of roundworm. They can be parasites in cats and dogs. That means, once they infect your pet, they can cause harm. However, there are preventative treatments available.

Roundworms

Worms with round, non-segmented bodies are known as nematodes or **roundworms** (**Figure** 3.7). They are classified in the phylum *Nematoda*, which has over 28,000 known species. Some scientists believe there could be over a million species of Nematodes.

Nematodes are slender bilaterally symmetrical worms, typically less than 2.5 mm long. The smallest nematodes are microscopic, while free-living species can reach as much as 5 cm, and some parasitic species are larger still, reaching over a meter in length. The worm body is often covered with ridges, rings, bristles, or other distinctive structures. The radially symmetrical head of a nematode also has distinct features. The head is covered with sensory bristles and, in many cases, solid "head-shields" around the mouth region. The mouth has either three or six lips, which often have a series of teeth on their inner edges.

FIGURE 3.7

Nematodes can be parasites of plants and animals.

Features of Roundworms

1. Unlike the flatworms, the roundworms have a body cavity with internal organs.
2. A roundworm has a complete digestive system, which includes both a mouth and an anus. This is a significant difference from the incomplete digestive system of flatworms. The roundworm digestive system also include a large digestive organ known as the gut. Digestive enzymes that start to break down food are produced here. There is no stomach, but there is an intestine which produces enzymes that help absorb nutrients. The last portion of the intestine forms a rectum, which expels waste through the anus.
3. Roundworms also have a simple nervous system with a primitive brain. There are four nerves that run the length of the body and are connected from the top to the bottom of the body. At the anterior end of the animal (the head region), the nerves branch from a circular ring which serves as the brain. The head of a nematode has a few tiny sense organs, including chemoreceptors, which sense chemicals.

Roundworms in the Environment

Roundworms can be free-living organisms, but they are probably best known for their role as significant plant and animal parasites. Most Nematodes are parasitic, with over 16,000 parasitic species described. Heartworms, which cause serious disease in dogs while living in the heart and blood vessels, are a type of roundworm. Roundworms can also cause disease in humans. Elephantiasis, a disease characterized by the extreme swelling of the limbs (**Figure** 3.8), is caused by infection with a type of roundworm.

Most parasitic roundworm eggs or larvae are found in the soil and enter the human body when a person picks them up on the hands and then transfers them to the mouth. The eggs or larvae also can enter the human body directly through the skin. The best solution to these diseases is to try to prevent these diseases rather than treat or cure them. Many parasitic diseases caused by roundworms result from poor personal hygiene. Contributing factors may include

- lack of a clean water supply,
- inadequate sanitation measures,
- crowded living conditions, combined with a lack of access to health care and low levels of education.

Vocabulary

- **roundworm**: Invertebrate animals with a round, elongated body that are often parasites of plants and animals.

Summary

- Roundworms have a body cavity with internal organs and a simple nervous system.

FIGURE 3.8
One roundworm parasite causes elephantiasis, a disease characterized by swelling of the limbs.

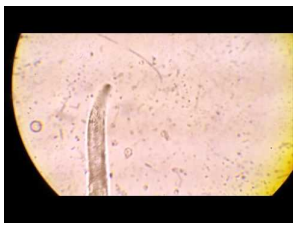
- Roundworms can be free-living or parasitic.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Nematode Movement** at http://www.youtube.com/watch?v=SpgjnXEFadg (1:52)



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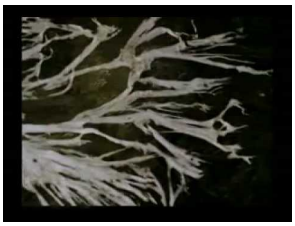
1. Why can't a nematode move like an earthworm?
2. What is the purpose of the nematode's cuticle?

Practice II

- **Mushroom Mycelium Feeding on Nematodes** at http://www.youtube.com/watch?v=0n04wCkIpuQ (1:41)



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1. What is an example of a fungi?
2. Why do some fungi trap nematodes?

Review

1. What is a roundworm?
2. How are the internal structures of the roundworms different from flatworms?
3. What is the main cause of many parasitic diseases caused by roundworms?

3.6 Segmented Worms

- Describe the major features of the segmented worms

Does an earthworm have a brain?

Just like you, earthworms do have a brain. Their brains are much simpler than yours, however. Earthworms' brains allow them to sense and respond to light and touch.

Segmented Worms

When you think of worms, you probably picture earthworms. There are actually many types of worms, including flatworms, roundworms, and segmented worms. Earthworms are segmented worms.

Segmented worms are in the phylum *Annelida*, which has over 22,000 known species. These worms are known as the **segmented worms** because their bodies are segmented, or separated into repeating units. Besides the earthworm, the segmented worms also include leeches and some marine worms. Most segmented worms like the earthworm, feed on dead organic matter. **Leeches** (**Figure** 3.9), however, can live in fresh water and suck blood from their animal host. You may have noticed many earthworms in soil. Earthworms support terrestrial ecosystems both as prey and by aerating and enriching soil.

Features of Segmented Worms

Segmented worms have a number of characteristic features.

1. The basic form consists of multiple segments, each of which has the same sets of organs and, in most a pair of **parapodia** that many species use for locomotion.

FIGURE 3.9
Leeches are parasitic worms. Notice the presence of segments.

2. Segmented worms have a well-developed body cavity filled with fluid. This fluid-filled cavity serves as a **hydroskeleton**, a supportive structure that helps move the worm's muscles.
3. Segmented worms also tend to have organ systems that are more developed than the roundworms' or flatworms'. Earthworms, for example, have a complete digestive tract with two openings, as well as an esophagus and intestines. The circulatory system consists of paired hearts and blood vessels. Actually there are five pairs of hearts that pump blood along the two main vessels. And the nervous system consists of the brain and a ventral nerve cord.

Comparison of Worms

The following table compares the three worm phyla (**Table** 3.2).

TABLE 3.2: Comparison of the Three Worm Phyla

Phylum	Common Name	Body Cavity	Segmented	Digestive System	Example
Platyhelminthes	Flatworm	No	No	Incomplete	Tapeworm
Nematoda	Roundworm	Yes	No	Complete	Heartworm
Annelida	Segmented worm	Yes	Yes	Complete	Earthworm

Vocabulary

- **hydroskeleton**: Fluid-filled cavity used as support for contracting muscles.
- **leech**: Segmented worm that feeds on the blood of animals.
- **parapodia**: Paired, un-jointed lateral outgrowths used for locomotion.
- **segmented worm**: Worm with a body plan of repeating segments.

Summary

- Segmented worms include the common earthworm and leeches.
- Segmented worms have a digestive system, nervous system, and circulatory system.

Practice

MEDIA

Click image to the left or use the URL below.

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1. What new realms did animals like *Abarenicola* open up for other animals?
2. Where are the eyes of feather duster worms (*Sabellidae*) located?
3. What effect do tube dwelling worms have on mudflat ecosystems?
4. How much can a giant tube dwelling worm from a hydrothermal vent grow in a year?
5. How do earthworms help breakdown leaf litter?

Review

1. What features distinguish Phylum Annelida from the other worms?
2. Describe the skeletal system of the segmented worms.
3. Describe the circulatory system and nervous system of the earthworm.

3.7 Mollusks

- Discuss what characteristics define mollusks.

What does this snail have in common with a clam?

You might notice that both have a shell. That is one feature of the group they both belong to, the mollusks. Mollusks are a very diverse group. They include animals that live on land and in the ocean. With well over 100,000 species, there can be a lot of shells.

What are Mollusks?

When you take a walk along a beach, what do you find there? Sand, the ocean, lots of sunlight. You may also find shells. The shells you find are most likely left by organisms in the phylum *Mollusca*. On the beach, you can find the shells of many different mollusks (**Figure** 3.10), including clams, mussels, scallops, oysters, and snails. **Mollusks** are invertebrates that usually have a hard shell, a mantle, and a radula. Their glossy pearls, mother of pearl, and abalone shells are like pieces of jewelry. Some mollusks, such as squid and octopus, do not have shells.

Features of the Mollusk

The Mollusk's body is often divided into different parts (**Figure** 3.11):

FIGURE 3.10
On the beach, you can find a wide variety of mollusk shells.

1. A head with eyes or tentacles.
2. In most species, a muscular foot, which helps the mollusk move. Some mollusks use the foot for burrowing into the sand, and others use it for jet-propulsion.
3. A **mantle**, or fold of the outer skin lining the shell. The mantle often releases calcium carbonate, which creates an external shell, just like the ones you find on the beach. The shell is also made of **chitin**, a tough, semitransparent substance.
4. A mass housing the organs.
5. A complete digestive tract that begins at the mouth and runs to the anus.
6. Most ocean mollusks have a gill or gills to absorb oxygen from the water.
7. Many species have a feeding structure, the **radula**, found only in mollusks. The radula can be thought of as a "tongue-like" structure. The radula is made mostly of chitin. Types of radulae range from structures used to scrape algae off of rocks to the beaks of squid and octopuses.

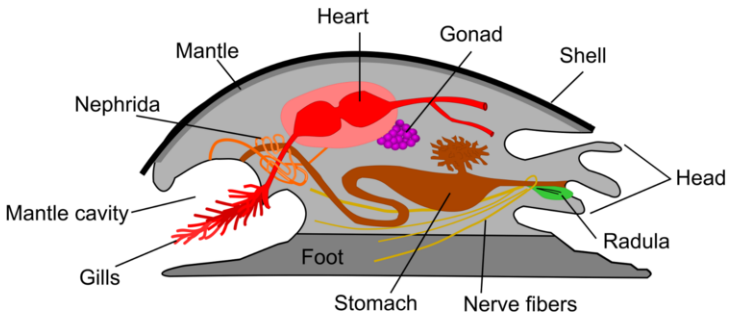

FIGURE 3.11
This is the basic body plan of a mollusk. Note the mantle, gills, and radula. Keep in mind the basic body plan can differ slightly among the mollusks.

Evolution of Mollusks

Mollusks are probably most closely related to organisms in the phylum *Annelida*, also known as segmented worms. This phylum includes the earthworm and leech. Scientists believe these two groups are related because, when they are in the early stage of development, they look very similar. Unlike segmented worms, however, mollusks do not

have body segmentation. The basic mollusk body shape is usually quite different as well.

Vocabulary

- **chitin**: Tough carbohydrate found in the shells of animals and cell walls of fungi.
- **mantle**: Fold of the outer skin, which secretes the external shell in some mollusks.
- **mollusk**: Invertebrate that usually has a hard shell, a mantle, and a radula.
- **radula**: Feeding organ found in mollusks with teeth made of chitin.

Summary

- The mollusk body often has a head with tentacles, a muscular foot, a feeding organ called the radula, and a complete digestive tract.
- Mollusks have a mantle, which often secretes an external shell.
- Mollusks are most closely related to segmented worms.

Practice

Use the resource below to answer the questions that follow.

- **Molluscs: The Survival Game** at http://vimeo.com/37325960 (15:08)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57277

1. How does the shell of the leafy hornmouth (*Ceratostoma foliatum*) help it against crushing predators?
2. For what purpose do cockles use their foot?
3. How and why do the radula of different mollusks vary?
4. For what purpose has the nautilus adapted its foot?
5. What change in predatory fish behavior seems to have led to a squid body plan being advantageous over a nautiliod body plan?

Review

1. What is a mollusk?
2. Give three examples of mollusks.
3. Describe three main characteristics of mollusks?
4. What evidence shows that mollusks and segmented worms are related? How are they different?

3.8 Types of Mollusks

- Describe the different types of mollusks.

What's the world's largest mollusk?

The colossal squid, one of the largest invertebrates, measures 14 feet in length here. Some of these squids are even larger and can grow up to almost 50 feet long! The smallest mollusks are snails that are microscopic in size.

Types of Mollusks

There are approximately 160,000 living species and probably 70,000 extinct species of mollusks. They are typically divided into ten classes, of which two are extinct. The major classes of living mollusks include gastropods, bivalves, and cephalopods (**Figure** 3.12).

Gastropods

Gastropods include snails and slugs. They use their foot to crawl. They have a well-developed head. There are many thousands of species of sea snails and sea slugs, as well as freshwater snails, freshwater limpets, land snails and land slugs. Gastropods live in many diverse habitats, from gardens to deserts and mountains. They also live in rivers, lakes and the ocean. Most shelled gastropods have a one-piece shell that is typically coiled or spiraled. Gastropods have no sense of hearing, but they can see and have a keen sense of smell. In land-based gastropods, the olfactory organs (for smell) are the most important. These are located on the tentacles.

Bivalves

Bivalves include clams, scallops, oysters, and mussels. As their name implies, they have two parts of their shell, which can open and close. Bivalves live in both marine and freshwater habitats. Most bivalves have a pair of large

gills that enable them to extract oxygen from the water (to breathe) and to capture food. Water is drawn into the bivalve and washes over the gills. Mucus on the gills helps capture food and cilia transfer the food particles to the mouth. Once in the mouth, food passes into the stomach to be digested. Bivalves have a mouth, heart, intestine, gills, and stomach, but no head. Bivalves have a muscular foot, which in many species such as clams, is used to anchor their body to a surface or dig down into the sand.

Cephalopods

Cephalopods include the octopus and squid. They have a prominent head and a well-developed brain. Typically the foot has been modified into a set of arms or tentacles. Members of this class can change color. They can also change texture and body shape, and, and if those camouflage techniques don't work, they can still "disappear" in a cloud of ink. Cephalopods have three hearts that pump blue blood, they're jet powered, and they're found in all oceans of the world. Cephalopods are thought to be the most intelligent of invertebrates. They have eyes and other senses that rival those of humans.

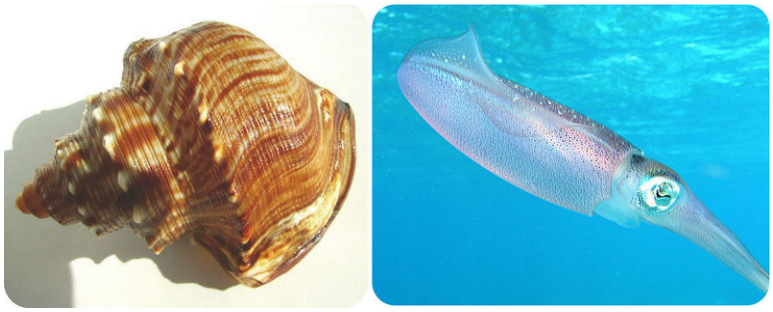

FIGURE 3.12

(left) An example of a gastropod species, the ostrich foot. (right) A Caribbean reef squid, an example of a cephalopod.

Vocabulary

- **bivalve**: Class of mollusks that use their foot to attach themselves to rocks or to burrow into mud, i.e. clams.
- **cephalopod**: Class of mollusks characterized by a set of arms or tentacles; i.e. octopus.
- **gastropod**: Class of mollusks that use their foot to crawl, i.e. snails.

Summary

- Mollusks are divided into ten living classes, including the familiar gastropods, cephalopods, and bivalves.
- Mollusks live in marine and freshwater habitats, as well as on land.

Practice

Use the resources below to answer the questions that follow.

- **Mollusk Animation: Abalone Body Plan** at http://vimeo.com/42588195 (1:22)

MEDIA
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- **Mollusk Animation: Nautilus Body Plan** at http://vimeo.com/42588196 (2:35)

MEDIA
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- **Mollusk Animation: Squid Body Plan** at http://vimeo.com/37431310 (1:34)

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1. How does the foot compare between abalone, nautilus, and a squid?
2. How does the shell of an abalone differ from the shell of a nautilus?
3. How many hearts does a squid have? How do these hearts help the squid?
4. Describe the mantle of a squid.

Review

1. Name five examples of mollusks.
2. What habitats do gastropods live in?
3. What is the defining feature of a bivalve?
4. What mollusk is through to be very intelligent?
5. Describe the foot of a gastropod, bivalve, and cephalopod.

3.9 Importance of Mollusks

- Explain why mollusks are important to humans.

Where do pearls come from?

Pearls are highly valued as gemstones. Most gemstones come from the Earth, but pearls come from living things. They are created by mollusks, such as oysters.

Importance of Mollusks

Mollusks are important in a variety of ways; they are used as food, for decoration, in jewelry, and in scientific studies. They are even used as roadbed material and in vitamin supplements.

Mollusks as Food

Edible species of mollusks include numerous species of clams, mussels, oysters, scallops, marine and land snails, squid, and octopuses. Many species of mollusks, such as **oysters**, are farmed in order to produce more than could be found in the wild (**Figure** 3.13).

Today, fisheries in Europe, Japan and the US alone produce over 1 billion pounds of oyster meat each year. Abalone (a marine gastropod mollusk), a great delicacy, can fetch up to three hundred dollars per pound. Eating mollusks is associated with a risk of food poisoning from toxins that accumulate in molluscs under certain conditions, and many countries have regulations to reduce this risk. At certain times of the year, (usually the warmer months) many species of saltwater mollusks become very poisonous due to an algal bloom known as "red tide." The mollusks filter feed on the tiny creatures (called "dinoflagellates" in the bloom) that produce the toxins. Eating shellfish during a red tide can cause serious illness and even death to humans.

FIGURE 3.13
Low tide reveals oyster beds at a farm in Ireland.

Tastes in molluscan food vary tremendously from one person to the next and from culture to culture; however, when it comes to a question of survival, most mollusks are edible. Some are considered delicacies such as oysters and escargot while others such as the clams and mussels of freshwater ponds and streams are less likely to be consumed due to taste, but none-the-less are very edible. Land-based mollusks are also eaten. France alone consumes 5 million pounds of escargot (a snail that lives in trees) every year. Of course, some people are allergic to mollusks and need to be careful about consuming any kind of shelled animals.

Mollusks in Decoration and Jewelry

Two natural products of mollusks used for decorations and jewelry are pearls and nacre. A **pearl** is the hard, round object produced within the mantle of a living shelled mollusk. Pearls are produced by many bivalves when a tiny particle of sand or grit is trapped between the mantle and the shell. It's as if the mollusk has a splinter. The mollusk forms a protective covering around the irritant. Most pearls used as jewelry are made by pearl oysters and freshwater mussels; most of the ones sold are cultured and not wild. Natural pearls have been highly valued as gemstones and objects of beauty for many centuries. The most desirable pearls are produced by oysters and river mussels. The substance used to form the pearl covering, is made from the mother of pearl material that lines the interior of the shell.

Mother of pearl is also known as nacre. **Nacre** is the iridescent inner shell layer. It can be found in buttons, watch faces, knives, guns, and jewelry. It is also used to decorate various musical instruments.

Mollusks in Scientific Studies

Several mollusks are ideal subjects for scientific investigation of the nervous system. The giant squid has a sophisticated nervous system and a complex brain for study. The California sea slug, also called the California sea hare, is used in studies of learning and memory because it has a simple nervous system, consisting of just a few thousand large, easily identified neurons. These **neurons** are responsible for a variety of learning tasks. Some slug brain studies have even allowed scientists to better understand human brains. Some octopuses and squid are incredibly smart. They are capable of learning to solve problems and do mazes.

Vocabulary

- **nacre**: Or, mother of pearl, is an iridescent inner shell layer.
- **neuron**: Nerve cell.
- **oyster**: Mollusk with a rough irregular shell; lives in coastal waters and provides a food source.
- **pearl**: Hard, round object produced within the mantle of a living shelled mollusk.

Summary

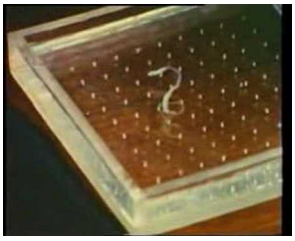
- Some mollusks, such as oysters and scallops, are important food sources.
- Mollusks are used for decoration and are important in scientific studies.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **The Squids Giant Axons** at http://www.youtube.com/watch?v=omXS1bjYLMI (4:49)



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1. What large tubular structures did Professor Young find in squids?
2. Why were the size of these structures important to Professor Young's work?
3. What did scientists discover when they were able to empty the contents of a squid axon?
4. How did World War II help the study of neuron functioning?

Practice II

- **How are pearls made?** at http://www.whyzz.com/how-are-pearls-made

1. How are natural pearls made?
2. How are cultured pearls made?

Review

1. Name three mollusks that are used for food.
2. What is a pearl?
3. What mollusks produce pearls? How are they made?
4. What makes the California sea slug ideal for studies of learning and memory?

3.10 Echinoderms

- Discuss the major features of echinoderms.

What is a sea cucumber?

A sea cucumber is not a vegetable! It is an invertebrate animal found in the ocean. Note the spines on this sea cucumber. The spines are a key feature of echinoderms.

What are Echinoderms?

You're probably familiar with starfish and sand dollars (**Figure** 3.14). They are both **echinoderms**. **Sea urchins** and sea cucumbers are also echinoderms. What's similar between these three organisms? They all have **radial symmetry**. This means that the body is arranged around a central point.

Echinoderms belong to the phylum *Echinodermata*. This phylum includes 7,000 living species. It is the largest animal phylum without freshwater or land-living members.

FIGURE 3.14

A starfish (*left*) and a keyhole sand dollar (*right*), showing the radial symmetry characteristic of the echinoderms. Starfish are also known as sea stars.

Characteristics of Echinoderms

As mentioned earlier, echinoderms show radial symmetry. Other key echinoderm features include an internal skeleton and spines, as well as a few organs and organ systems. Although echinoderms look like they have a hard exterior, they do not have an external skeleton. Instead, a thin outer skin covers an internal skeleton made of tiny plates and spines. This provides rigid support. Some groups of echinoderms, such as sea urchins (**Figure** 3.15), have spines that protect the organism. Sea cucumbers use these spines to help them move.

FIGURE 3.15

Another echinoderm, a sea urchin (*Echinus esculentus*), showing its spines.

Echinoderms have a unique **water vascular system**. This network of fluid-filled tubes helps them to breathe, eat, and move. Therefore, they can function without gill slits. Echinoderms also have a very simple digestive system, circulatory system, and nervous system. The digestive system often leads directly from the mouth to the anus. The echinoderms have an open circulatory system, meaning that fluid moves freely in the body cavity. But echinoderms have no heart. The echinoderm nervous system is a **nerve net**, or interconnected neurons with no central brain.

Many echinoderms have amazing powers of regeneration. For example, some sea stars are capable of regenerating lost arms. In some cases, lost arms have been observed to regenerate a second complete sea star! Sea cucumbers often release parts of their internal organs if they perceive danger. The released organs and tissues are then quickly regenerated.

How do Echinoderms Eat?

Feeding strategies vary greatly among the different groups of echinoderms. There's no one food or technique that's shared by all echinoderms. Different eating-methods include:

1. Passive filter-feeders, which are organisms that absorb suspended nutrients from passing water. Some echinoderms use their long arms to capture food particles floating past in the currents.
2. Grazers, such as sea urchins, are organisms that feed on available plants. Sea urchins are omnivorous, eating both plant and animals. The sea urchin mainly feeds on algae on the coral and rocks, along with decomposing matter such as dead fish, mussels, sponges, and barnacles.
3. Deposit feeders, which are organisms that feed on small pieces of organic matter, usually in the top layer of soil. Sea cucumbers are deposit feeders, living on the ocean floor. They eat the tiny scrap particles that are usually abundant in the environments that they inhabit.

4. Active hunters, which are organisms that actively hunt their prey. Many sea stars are predators, feeding on mollusks like clams by prying apart their shells and actually placing their stomach inside the mollusk shell to digest the meat.

How do Echinoderms Reproduce?

Echinoderms reproduce sexually. In most echinoderms, eggs and sperm cells are released into open water, and fertilization takes place when the eggs and sperm meet. This is called external fertilization. The release of sperm and eggs often occurs when organisms are in the same place at the same time. Internal fertilization takes place in only a few species. Some species even take care of their offspring, like parents!

Vocabulary

- **echinoderm**: Invertebrate, such as a sea star or a sand dollar, that is characterized by a spiny endoskeleton, radial symmetry as adults, and a water vascular system.
- **nerve net**: Interconnected neurons with no central brain.
- **radial symmetry**: Symmetry of a body plan in which there are no head or rear ends, so the body can be divided into two identical halves at any point, like a pie.
- **sea urchin**: Echinoderm with a round, soft body enclosed in a shell covered with long spines.
- **water vascular system**: A network of fluid-filled tubes found in echinoderms.

Summary

- Echinoderms show radial symmetry and have an endoskeleton and a unique water vascular system. Some have spines.
- Echinoderms generally reproduce by external fertilization; regeneration is fairly common among echinoderms.

Practice

Use the resource below to answer the questions that follow.

- **Echinoderms: The Ultimate Animal** at http://vimeo.com/37295088 (13:54)

MEDIA
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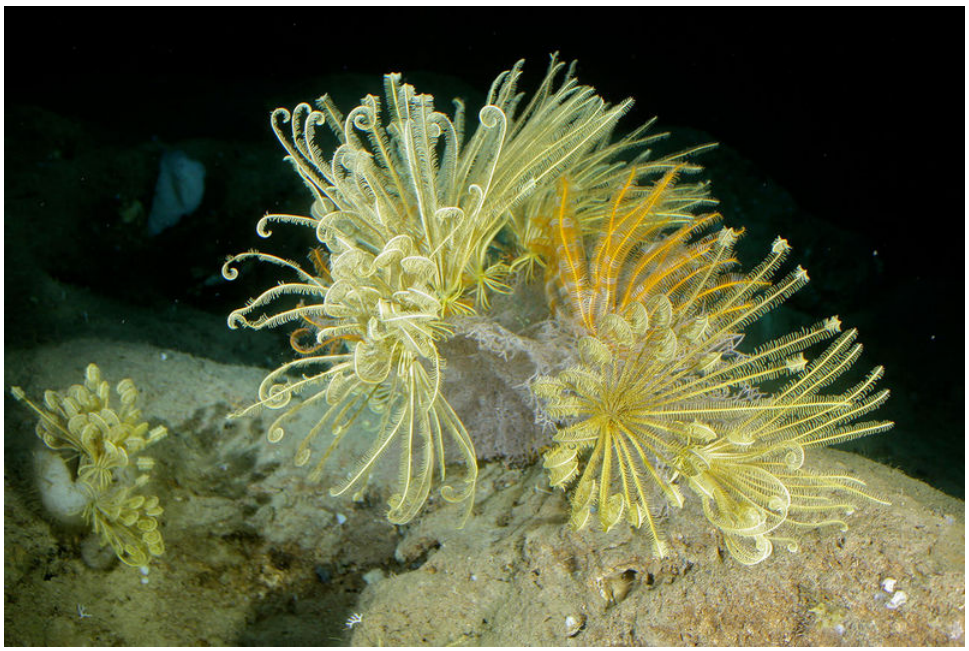
1. What can sea star muscles do that our muscles cannot? How would this trait help sea stars living in the intertidal zone?
2. How are deep-sea sea cucumbers like earthworms?
3. Why are brittle stars often found with their arms raised in the water current?
4. What organ system do echinoderms possess that is not seen in any other animal group?
5. Where do sea stars have their "eyes"? How does this arrangement help them coordinate movement?
6. Some sea stars evert their stomachs to digest their prey, but *Pycnopodia* can do something else as well. What does *Pycnopodia* do to some of its prey?

Review

1. List three examples of echinoderms.
2. What is radial symmetry?
3. What are two important characteristics of echinoderms (other than radial symmetry)?
4. How do sea urchins eat?
5. Give an example of an echinoderm that is an active hunter.

3.11 Types of Echinoderms

- List several types of echinoderms.



How can you find feathers in the ocean?

Birds aren't the only creatures that have feathers. One type of echinoderm, the feather star, has feathery arms. These animals don't fly or even move much at all. They usually cling to rocks, using a root-like structure.

Types of Echinoderms

The echinoderms can be divided into two major groups:

1. Eleutherozoa are the echinoderms that can move. This group includes the starfish and most other echinoderms.
2. Pelmatozoa are the immobile echinoderms. This group includes **crinoids**, such as the **feather stars**.

Listed below are the four main classes of echinoderms present in the Eleutherozoa Group (**Table** 3.3).

TABLE 3.3: Classes of Eleutherozoa Echinoderms

Class	Representative Organisms	Characteristics
Asteroidea	Starfish and asteroids	Capture prey for their own food
Ophiuroidea	Brittle stars (**Figure** 3.16)	Bottom feeders with long, narrow arms that allow relatively fast movement
Echinoidea	Sea urchins and sand dollars	Have movable spines
Holothuroidea	Sea cucumbers	Armless, elongated, generally soft-bodied animals

FIGURE 3.16
The giant red brittle star, an ophiuroid echinoderm.

Habitat

Echinoderms are spread all over the world at almost all depths, latitudes, and environments in the ocean. Most feather stars (crinoids) live in shallow water. In the deep ocean, sea cucumbers are common, sometimes making up 90% of the organisms. Most echinoderms, however, are found in reefs just lying beneath the surface of the water. No echinoderms are found in freshwater habitats or on land. This makes *Echinodermata* the largest animal phylum to only have ocean-based species.

Do Echinoderms Move?

While almost all echinoderms live on the sea floor, some sea-lilies can swim at great speeds for brief periods of time, and a few sea cucumbers are fully floating. Some echinoderms find other ways of moving. For example, crinoids attach themselves to floating logs, and some sea cucumbers move by attaching to the sides of fish.

On the underside side of a sea star, there are hundreds of tiny feet usually arranged into several rows on each ray of the star. These are called tube feet, or podia, and are filled with seawater in most echinoderms. The water vascular system within the body of the animal is also filled with seawater. By expanding and contracting chambers within the water vascular system, the echinoderm can force water into certain tube feet to extend them. The animal has muscles in the tube feet, which are used to retract them. By expanding and retracting the right tube feet in the proper order, the animal can walk.

Vocabulary

- **crinoid**: Echinoderm with a somewhat cup-shaped body and feathery arms.
- **feather star**: Crinoid that is missing a stalk during the later part of its life cycle.

Summary

- Echinoderms include the star fish, sea urchins, sand dollars, and feather stars.
- Echinoderms are found in many different ocean environments, but most are found in reefs.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Feather Stars and Sea Lilies** at http://www.youtube.com/watch?v=IFWeqDcAYGk (1:49)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57291

1. What is the difference between sea lilies and feather stars?
2. Some crinoids can be seen at night in shallow tropical waters, but where have they been found to be most abundant?

Practice II

- **Brittle Star Food Fight** at http://www.youtube.com/watch?v=Myhp8ifW6ig (1:59)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57292

1. What kind of feeding behavior are these brittle stars displaying?
2. How is this feeding behavior related to the ecosystem in which they live?

Practice III

- **The Sand Dollar** at http://www.youtube.com/watch?v=O3uKWy5Vljs (4:16)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57293

1. Where is a sand dollar's mouth located?
2. How do the sand dollars in this video feed? What are they eating?

Practice IV

- **Sea cucumbers** at National Geographic http://animals.nationalgeographic.com/animals/invertebrates/sea-cucumber/

1. Where do sea cucumbers live?
2. How do sea cucumbers eat?

Review

1. Name four examples of echinoderms.
2. Where are most echinoderms found?
3. Describe the land-based echinoderms.
4. How do sea stars move?

3.12 Importance of Echinoderms

- Explain how echinoderms are important to humans and the ecosystem.

What do sea otters eat?

Sea otters are known for being playful and frisky. They are serious eaters, however! A major part of a sea otter's diet are echinoderms, such as sea urchins. They manage to eat the soft part of the sea urchins while avoiding the huge sea urchin spines.

Importance of Echinoderms

Echinoderms are important for the ecosystem. They are also a source of food and medicine for humans.

Ecological Role

Echinoderms play numerous ecological roles. Sand dollars and sea cucumbers burrow into the sand, providing more oxygen at greater depths of the sea floor. This allows more organisms to live there. In addition, starfish prevent the growth of algae on coral reefs. This allows the coral to filter-feed more easily. And many sea cucumbers provide a habitat for parasites such as crabs, worms, and snails.

Echinoderms are also an important step in the ocean food chain. Echinoderms are the staple diet of many animals, including the sea otter. On the other hand, echinoderms eat seaweed and keep its growth in check. Recall that the sea urchin is a grazer, mainly feeding on algae on the coral and rocks. Recently, some marine ecosystems have been overrun by seaweed. Excess seaweed can destroy entire reefs. Scientists believe that the extinction of large quantities of echinoderms has caused this destruction (**Figure** 3.17).

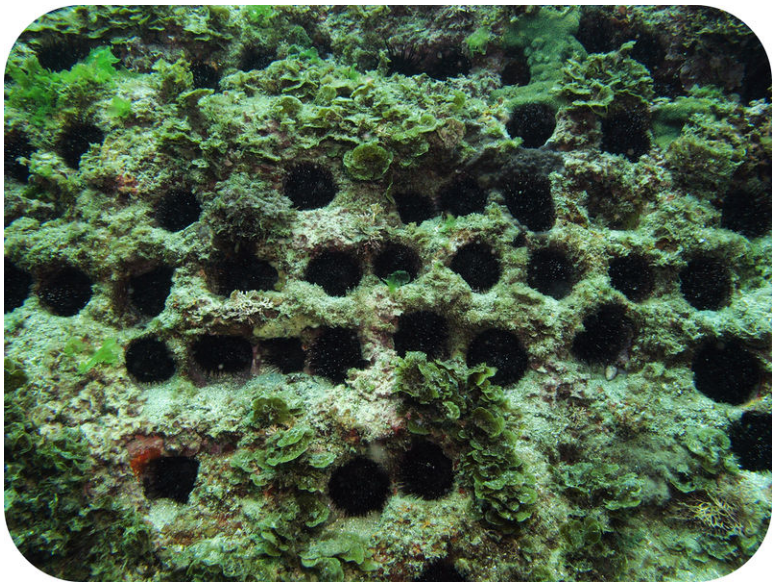


FIGURE 3.17

A large die-off of the sea urchin, *Diadema antillarum*, in the Caribbean Sea coincided with increases in algal growth in some areas but not others.

Echinoderms as Food

In some countries, echinoderms are considered delicacies. Around 50,000 tons of sea urchins are captured each year for food. They are consumed mostly in Japan, Peru, Spain and France. Both male and female gonads of sea urchins are also consumed. The taste is described as soft and melting, like a mixture of seafood and fruit. Sea cucumbers are considered a delicacy in some southeastern Asian countries. In China they are used as a basis for gelatinous soups and stews.

Echinoderms as Medicine

Echinoderms are also used as medicine and in scientific research. For example, some sea cucumber toxins slow down the growth rate of tumor cells, so there is an interest in using these in cancer research.

Sea urchins are also model organisms used in developmental biology research. Sea urchins have been used to study the mechanisms of fertilization and egg activation, physiological processes that occur during early development, and the regulation of differentiation in the early embryo. In addition, the molecular basis of early development was studied in sea urchins. Gametes can be obtained easily, sterility is not required, and the eggs and early embryos of many commonly used species are beautifully transparent. In addition, the early development of sea urchin embryos is a highly conserved process. When a batch of eggs is fertilized, all of the resulting embryos typically develop at the same time. This makes biochemical and molecular studies of early embryos possible in the sea urchin, and has led to a number of major discoveries.

Echinoderms in Farming

The hard skeleton of echinoderms is used as a source of lime by farmers in some areas where limestone is unavailable. **Lime** is added to the soil to allow plants to take up more nutrients. About 4,000 tons of the animals are used each year for this purpose.

Vocabulary

- **lime**: White substance added to the soil to reduce acidity and improve fertility.

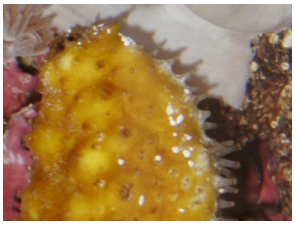
Summary

- Echinoderms are an important part of the ocean food chain, keeping seaweed in check as grazers and serving as food sources for animals like otters.
- Echinoderms are used as food, medicine, and a source of lime for farmers.

Practice

Use the resource below to answer the questions that follow.

- **Smart Polymer Inspired by Sea Cucumbers** at http://www.youtube.com/watch?v=tZ2HZVxsZ5U (0:59)



MEDIA

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1. What characteristics of the sea cucumbers inspired scientists to use them to develop new polymers?
2. Why do scientists feel these new polymers may be useful for medical implants?

Review

1. How are sand dollars important to the ecosystem?
2. What role do echinoderms play in the food chain?
3. How has the sea urchin been used in research?

3.13 Arthropods

- Describe the characteristics of the arthropods.

What does this lobster have in common with a wasp?

You might notice that their bodies have segments. And they both have a hard outer layer. Because they share these and other features, they are both classified as arthropods.

What are Arthropods?

How often do you think you see an arthropod? Well, have you ever looked up close at an ant? A spider? A fly? A moth? With over a million described species (and many more yet to be described) in the phylum containing arthropods, chances are, you encounter one of these organisms every day, without even leaving your house. Arthropods are a very diverse group of animals. In fact, they are the biggest group of animals on the planet, with upwards of 5 million distinct species.

Types of Arthropods

Arthropods belong to the phylum Arthropoda, which means "jointed feet," and includes four living subphyla.

- Chelicerata, which includes spiders (**Figure** 3.18), mites, and scorpions. In these animals, the first pair of appendages are often modified as fangs or pincers, and are used to manipulate food.
- Myriapoda, which includes centipedes and millipedes. All of these animals live on land, and can have anywhere from ten to nearly 200 pairs of appendages.
- Hexapoda, which includes the insects. These animals dominate the land. All hexapods have three pairs of walking appendages.
- Crustacea, which includes lobsters, crabs, barnacles, crayfish, and shrimp. These animals dominate the ocean, and usually have a set of anterior appendages that are modified as mandibles, which function in grasping, biting, and chewing food.

FIGURE 3.18
Spiders are one type of arthropod.

Characteristics of Arthropods

Characteristics of arthropods include:

1. A segmented body (**Figure** 3.19) with a head, a thorax, and abdomen segments.
2. Appendages on at least one segment. They can be used for feeding, sensory reception, defense, and locomotion.
3. A nervous system.
4. A hard exoskeleton made of chitin, which gives them physical protection and resistance to drying out. In order to grow, arthropods shed this covering in a process called **molting**.
5. An open circulatory system with **hemolymph**, a blood-like fluid. A series of hearts move the hemolymph into the body cavity where it comes in direct contact with the tissues.
6. A complete digestive system with a mouth and an anus.
7. Aquatic arthropods use gills to exchange gases. These gills have a large surface area in contact with the water, so they can absorb more oxygen.
8. Land-living arthropods have internal surfaces that help exchange gasses. Insects and most other terrestrial species have a tracheal system, where air sacs lead into the body from pores in the exoskeleton. Others use book lungs, gills modified for breathing air, as seen in species like the coconut crab. Some areas of the legs of soldier crabs are covered with an oxygen absorbing skin. Land crabs sometimes have two different structures: one used for breathing underwater, and another used to absorb oxygen from the air.

Vocabulary

- **arthropods**: Invertebrate animals with jointed limbs, a segmented body, and an exoskeleton made of chitin.
- **hemolymph**: Blood-like circulatory fluid of some invertebrates.
- **molting**: Shedding of the old shell to make way for a new growth.

FIGURE 3.19
The blue American lobster illustrates the segmented body plan of the arthropods.

Summary

- The arthropods include four living subphyla: chelicerates, including spiders, mites, and scorpions; myriapods, including centipedes and millipedes; hexapods, including insects; and crustaceans.
- Arthropods are characterized by a segmented body, a hard exoskeleton, and appendages used for feeding, sensory structures, defense, and locomotion.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Marine Arthropods: A Successful Design** at http://vimeo.com/37289745 (9:28)

Multimedia

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57284

1. Why are jointed limbs significant for Arthropods?
2. How are appendage adaptations and segmentations key to the success of Arthropods as a group?
3. Soft shell crabs are delicacies in some restaurants. Where do soft shell crabs come from?
4. What aspect of horseshoe crabs' behavior do scientists feel gives clues to why Arthropods first left the ocean?

Practice II

- **Arthropod** at http://animal.discovery.com/animal-facts/arthropod-info.htm

1. What are five examples of arthropods?
2. How do arthropods affect people? Give three examples.

Review

1. What are three examples of arthropods?
2. What are three distinguishing features of the arthropods?
3. Describe the arthropod circulatory system.
4. Describe how insects obtain oxygen.

3.14 Importance of Arthropods

- Describe the importance of arthropods to humans and the environment.

Are arthropods just creepy and scary?

Many arthropods, such as scorpions, insects, and spiders, have a reputation of being a nuisance or even harmful. But even if they are a little scary to you, that doesn't mean that the world would be fine without them.

Importance of Arthropods

Have you ever been startled by a bee landing on a flower? Or surprised by a swarm of pill bugs when you overturned a rock? These arthropods might seem a little scary to you, but they are actually performing important roles in the environment. Arthropods are important to the ecosystem and to humans in many ways.

Arthropods as Food

Many species of crustaceans, especially crabs, lobsters (**Figure** 3.20), shrimp, prawns, and crayfish, are consumed by humans, and are now farmed on a large commercial scale. Nearly 10,000,000 tons of arthropods as food were produced in 2005. Over 70% by weight of all crustaceans caught for consumption are shrimp and prawns. Over 80% is produced in Asia, with China producing nearly half the world's total.

Insects and their grubs are at least as nutritious as meat, and are eaten both raw and cooked in many cultures. Beetles, locusts, butterflies, ants, and stinkbugs (which have an apple flavor) are insects that are regularly eaten by people in dozens of countries. In fact, there are more than 1,900 edible insect species on Earth, hundreds of which are already part of the diet of about two billion people worldwide. This is just under one of every three people worldwide, and this number should continue to grow in the future.

The intentional cultivation of arthropods and other small animals for human food, referred to as minilivestock, is now emerging in animal husbandry as an ecologically sound concept. However, the greatest contribution of arthropods to human food supply is by pollination. Three-fourths of the world's flowering plants and about 35% of the world's food crops depend on animal pollinators to reproduce and increase crop yields. More than 3,500 species of native bees pollinate crops. Some scientists estimate that one out of every three bites of food we eat exists because of animal pollinators, including birds and bats and arthropods like bees, butterflies and moths, and beetles and other insects.

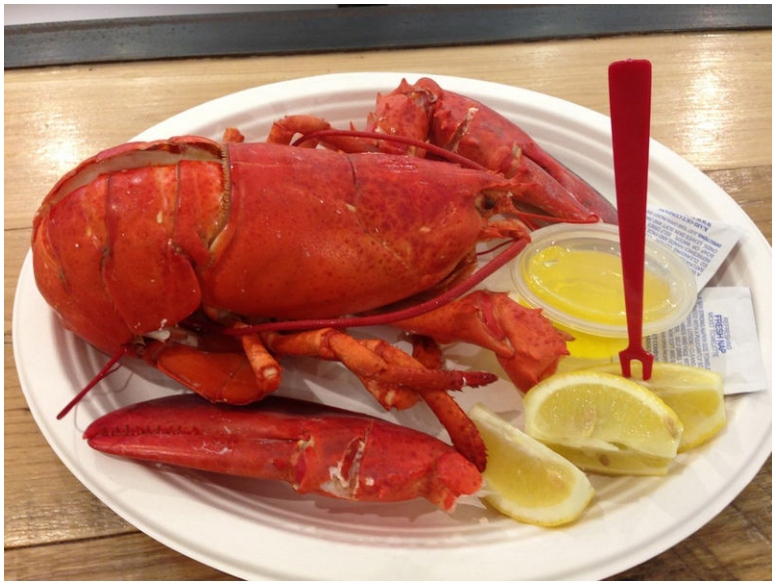

FIGURE 3.20

Lobsters are one kind of arthropod food source.

Arthropods in Pest Control

Humans use mites to prey on unwanted arthropods on farms or in homes. Other arthropods are used to control weed growth. Populations of whip scorpions added to an environment can limit the populations of cockroaches and crickets. Millipedes also control the harmful growth of destructive fungi and bacteria. When the numbers of millipedes is low, the imbalance between predator and prey can cause harmful microorganisms to flourish, and it can became difficult to manage plagues and diseases through natural processes.

Cockroaches, spiders, mites, ticks and all other insects considered as carnivorous, prey on smaller species to maintain ecological balance. Thus, communities that have a good balance of these arthropods tend to have better pest control.

Ecological Roles

Many arthropods have extremely important roles in ecosystems. Arthropods are of ecological importance because of their sheer numbers and extreme diversity. As mentioned above, bees, wasps, ants, butterflies, moths, flies and beetles are invaluable agents of pollination. Pollens and grains became accidentally attached to their chests and legs and are transferred to other agricultural crops as these animals move about, either by walking or flying. Most plants actually produce scents to send signals to insects that food (in the form of nectar) is available.

Mites, ticks, centipedes, and millipedes are **decomposers**, meaning they break down dead plants and animals and turn them into soil nutrients. This is an important role because it supplies the plants with the minerals and nutrients necessary for life. It also keeps dead material from accumulating in the environment. Plants then pass along those minerals and nutrients to the animals that eat the plants.

Human Uses

Arthropods are also invaluable to humans, as they are used in many different human-made products. Examples are:

- Bees produce honey and their honeycombs contain beeswax, widely used for making candles, furniture wax and polishes, waxed papers, antiseptics, and fillings for surgical uses.
- The pollens stored in honeycombs were discovered to have a rich mixture of vitamins, enzymes, and amino acids that could provide medical benefits. They were used as ingredients for supplements and medications that could provide relief for colds, asthma, and hay fever.
- Silk produced by arthropods, like those produced by caterpillars to protect their cocoons, is strong enough to use and be woven into fabrics, a discovery first used in ancient China's silk industry.
- The spiders' web was discovered as an additional material that could provide strength, and has became essential raw materials for Kevlar vests, fishing nets, surgical sutures, and adhesives, as they contained natural antiseptics.

Vocabulary

- **decomposer**: Organism that breaks down dead plants and animals and turns them into soil nutrients.

Summary

- Many crustaceans, especially crabs, lobsters, shrimp, prawns, and crayfish, are food sources for humans.
- Mites, ticks, centipedes, and millipedes are decomposers, meaning they break down dead plants and animals and turn them into soil nutrients.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Arthropod Locomotion: Engineering** at http://vimeo.com/37341942 (7:15)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57271

1. Why do scientists study the movement of arthropods?
2. What arthropod characteristic(s) have been integrated into the robot, Ariel?
3. What benefits may we see from robots like Ariel?

Practice II

- **Lobster Mariculture** at http://www.marinebio.net/marinescience/06future/lobsterfarm.htm

1. What is one of the biggest obstacles to raising lobsters?
2. How many eggs will a female lobster produce at one time?
3. What is done with the fourth stage juvenile lobsters? Why?

Review

1. Name three examples of an arthropod used as a food source for humans.
2. Describe one important role that arthropods play in the ecosystem.
3. What is one human use of material produced by an arthropod.

3.15 Crustaceans

- Describe the features of the crustaceans.

What are shrimp?

Shrimp are an example of crustaceans, one group within the arthropods. Shrimp live on the ocean floor in many parts of the world. Shrimp are not only food for humans; they are also an important food source for larger marine animals.

Crustaceans

Crustaceans are a large group of arthropods, consisting of almost 52,000 species. The majority of crustaceans are aquatic. Some live in the ocean, while others live in fresh water. A few groups have adapted to living on land, such as land crabs, hermit crabs, and woodlice (**Figure** 3.21). Crustaceans are among the most successful animals and are found as much in the oceans as insects are on land.

Classes of Crustaceans

Six classes of crustaceans are generally recognized (**Table** 3.4).

TABLE 3.4: Classes of Crustaceans

Class	Characteristics	Examples
Branchiopoda	Mostly small, freshwater animals that feed on plankton and detritus	Brine shrimp
Remipedia	A small class of blind organisms found in deep caves connected to salt water	Nectiopoda

TABLE 3.4: (continued)

Class	Characteristics	Examples
Cephalocarida	Small crustaceans, with an eyeless head covered by a horseshoe-shaped shield; has two pairs of antennae and two pairs of jaws	Horseshoe shrimp
Maxillopoda	Mostly small, with a small abdomen, and generally no appendages	Barnacles, copepods
Ostracoda	Small animals with bivalve shells	Seed shrimp
Malacostraca	The largest class, with the largest and most familiar animals	Crabs, lobsters, shrimp, krill, woodlice

FIGURE 3.21
A terrestrial arthropod, a species of woodlice.

Can Crustaceans Move?

Remember that crustaceans are an arthropod subphylum, and that arthropod means "jointed feet." As expected, the majority of crustaceans can move. A few groups are parasitic and live attached to their hosts. Adult barnacles (**Figure** 3.22) cannot move, so they attach themselves headfirst to a rock or log.

FIGURE 3.22
Barnacles are non-moving crustaceans.

Characteristics of Crustaceans

Characteristics of crustaceans include:

1. An exoskeleton that may be bound together, such as in the **carapace**, the thick back shield seen in many crustaceans that often forms a protective space for the gills.

2. A main body cavity with an expanded circulatory system. Blood is pumped by a heart located near the back.
3. A digestive system consisting of a straight tube that has a **gastric mill** for grinding food and a pair of digestive glands that absorb food.
4. Structures that function like kidneys to remove wastes. These are located near the antennae.
5. A brain that exists in the form of **ganglia**, or connections between nerve cells.
6. Crustaceans periodically shed the outer skeleton, grow rapidly for a short time, and then form another hard skeleton. They cannot grow underneath their outer exoskeleton.

Crustaceans Reproduction

Most crustaceans have separate sexes, so they reproduce sexually using eggs and sperm. Many land crustaceans, such as the Christmas Island red crab, mate every season and return to the sea to release the eggs. Others, such as woodlice, lay their eggs on land when the environment is damp. In some crustaceans, the females keep the eggs until they hatch into free-swimming larvae.

Vocabulary

- **carapace**: Thick back shield seen in many crustaceans that often forms a protective space for the gills.
- **crustaceans**: Group of mostly aquatic arthropods that includes lobsters, crabs, and barnacles.
- **ganglia**: Network of nerve cells.
- **gastric mill**: Specialized organ for grinding food.

Summary

- Crustaceans include crabs, lobsters, shrimp, krill, and woodlice.
- Features of crustaceans include an exoskeleton that may be bound together.

Practice

Use the resource below to answer the questions that follow.

- http://www.darwinsgalapagos.com/animals/custacea_crustaceans.htm

1. How do some crustaceans strengthen their exoskeleton?
2. How many antennae do crustaceans have? How does this differ from a butterfly?
3. How does filter feeding among crustaceans differ from filter feeding among mollusks?
4. Why do scientists feel filter feeding evolved multiple times among crustaceans?
5. What are three functions of appendages in the crustacean?

Review

1. What are three examples of crustaceans?
2. What are two characteristics of crustaceans?
3. Why do crustaceans shed their outer skeleton.
4. What is the carapace?

3.16 Centipedes and Millipedes

- Describe the characteristics of centipedes and millipedes.

How many legs does a centipede have?

You might think that centipedes have a hundred legs. But many species of centipedes don't have quite that many legs! The common house centipide has only 15 pairs of legs.

Centipededs and Millipedes

Centipedes and **millipedes** belong to the subphylum Myriapoda, which contains 13,000 species. They all live on land. They are divided among four classes: (1) Chilopoda (centipedes), (2) Diplopoda (millipedes), (3) Symphyla (symphylans), and (4) Pauropoda (pauropods). They range from having over 750 legs to having fewer than ten legs. They have a single pair of antennae and simple eyes.

Habitat

Myriapoda are mostly found in moist forests, where they help to break down decaying plant material. A few live in grasslands, semi-arid habitats, or even deserts. The majority are herbivores, but centipedes are nighttime predators. They roam around looking for small animals to bite and eat; their prey includes insects, spiders, and other small invertebrates. If the centipede is large enough, it will even attack small vertebrates, like lizards. Although not generally considered dangerous to humans, many from this group can cause temporary blistering and discoloration of the skin.

Centipedes

Centipedes (**Figure** 3.23) are fast, predatory carnivores, and venomous. There are around 3,300 described species, ranging from one tiny species (less than half an inch in length) to one giant species (the Peruvian giant yellow-leg centipede or Amazonian giant centipede), which may grow larger than 12 inches. This giant centipede has been known to attack, kill and eat much larger animals, including tarantulas. Centipedes have one pair of legs per body

segment, with the first pair of legs behind the head modified into a pair of fangs containing a poison gland. Many centipedes also guard their eggs and young by curling around them.

FIGURE 3.23
Centipede.

Millipedes

Most millipedes are slower than centipedes and feed on leaf litter and loose organic material. They can be distinguished from centipedes by looking at the number of legs per body segment. Millipedes have two pairs of legs per body segment, while centipedes have a single pair of legs per body segment. Millipedes protect their eggs from predators in a nest of hard soil. Millipedes are not poisonous. They lack the pair of fangs containing a poison gland that centipedes have.

Symphyla

The third class, Symphyla, contains 200 species. **Symphylans** resemble centipedes but are smaller and translucent. These arthropods have an elongated body, with three pairs of thoracic and about nine pairs of abdominal legs. Many spend their lives in the soil, but some live in trees.

Pauropods

The **pauropods** are typically 0.5-2.0 mm long and live on all continents except Antarctica. They are usually found in soil, leaf litter, or other moist places. They feed on fungi and decaying organic matter. Adult pauropods have 11 or 12 body segments and 9-11 pairs of legs. They also possess unique forked antennae and a distinctive pattern of movement characterized by rapid burst of movement and frequent abrupt changes in direction. Over 700 species have been described, and they are believed to be closely related to millipedes.

Vocabulary

- **centipede**: Predatory arthropod with one pair of legs per segment.
- **millipede**: Slow-moving arthropod that has two pairs of legs per segment.
- **pauropod**: Arthropod resembling centipedes that feeds on fungi and decaying matter.
- **symphylan**: Arthropod that resembles centipedes but is smaller and translucent.

Summary

- Myriapoda are usually found in moist forests, where they break down decaying plant material.
- Millipedes have two pairs of legs per body segment, while centipedes have a single pair of legs per body segment.

Practice

Use the resource below to answer the questions that follow.

- **Arthropod Animation: Millipede Breathing Tubes** at http://vimeo.com/37410640

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57295

1. How do millipedes draw air into their body?

Review

1. Where do centipedes and millipedes generally live?
2. List two ways centipedes are different from millipedes.
3. What are the differences between the legs of a centipede and millipede.
4. What are the main food sources of centipedes?

3.17 Arachnids

- Describe the characteristics of the arachnids.

Is a spider a type of insect?

Although spiders and insects are both arthropods, a spider is not an insect. One key difference is that insects have six legs, while spiders have eight legs.

Arachnids

Arachnids are a class of joint-legged invertebrates in the subphylum Chelicerata. They live mainly on land but are also found in fresh water and in all marine environments, except for the open ocean. There are over 100,000 named species, including many species of spiders, scorpions, daddy-long-legs, ticks, and mites (**Figure** 3.24). There may be up to 600,000 species in total, including unknown ones.

Characteristics of Arachnids

Arachnids have the following characteristics:

1. Four pairs of legs (eight total). You can tell the difference between an arachnid and an insect because insects have three pairs of legs (six total).
2. Arachnids also have two additional pairs of appendages. The first pair, the **chelicerae**, serve in feeding and defense. The next pair, the **pedipalps**, help the organisms feed, move, and reproduce.
3. Arachnids do not have antennae or wings.

FIGURE 3.24

(*left*) A daddy-long-legs spider. (*right*) Various diseases are caused by bacteria that are spread to humans by arachnids, like the tick shown here.

4. The arachnid body is organized into the **cephalothorax**, a fusion of the head and thorax, and the abdomen.
5. To adapt to living on land, arachnids have internal breathing systems, like a trachea or a book lung.
6. Arachnids are mostly carnivorous, feeding on the pre-digested bodies of insects and other small animals.
7. Several groups are venomous. They release the venom from specialized glands to kill prey or enemies.
8. Several mites are parasitic, and some of those are carriers of disease.
9. Arachnids usually lay eggs, which hatch into immature arachnids that are similar to adults. Scorpions, however, give birth to live young.

Arachnid Subgroups

The arachnids are divided into eleven subgroups. Below are the four most familiar subgroups, with a description of each (**Table** 3.5).

TABLE 3.5: Subgroups of Arachnids

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics

TABLE 3.5: (continued)

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics
Araneae	Spiders	40,000	• Found all over the world, ranging from tropics to the Arctic, some in extreme environments. • All produce **silk**, which is used for trapping insects in webs, aiding in climbing, producing egg sacs, and wrapping prey. • Nearly all spiders inject venom to protect themselves or to kill prey. Only about 200 species have bites that can be harmful to humans.

TABLE 3.5: (continued)

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics
Opiliones	Daddy-long-legs	6,300	• Known for extremely long walking legs. No silk nor poison glands. • Many are omnivores, eating small insects, plant material, and fungi. Some are scavengers, eating decaying animal and other matter. • Mostly **nocturnal** (come out at night) and colored in hues of brown. A number of **diurnal** (come out during the day) species have vivid patterns of yellow, green, and black.

TABLE 3.5: (continued)

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics
Scorpiones	Scorpions	2,000	• Characterized by a tail with six segments, the last bearing a pair of venom glands and a venom-injecting barb. • Predators of small arthropods and insects. They use pincers to catch prey. Then they either crush it or inject it with a fast-acting venom, which is used to kill or paralyze the prey. Only a few species are harmful to humans. • Nocturnal; during the day, they find shelter in holes or under rocks. • Unlike the majority of arachnids, scorpions produce live young. The young are carried about on the mother's back until they have molted at least once. They reach an age of between four to 25 years.

TABLE 3.5: (continued)

Subgroup	Representative Organisms	Approximate Number of Species	Characteristics
Acarina	Mites and ticks	30,000	• Most are small (no more than 1.0 mm in length), but some ticks, and one species of mite, may grow to be 10-20 mm in length. • Live in nearly every habitat, including aquatic and terrestrial. • Many are parasitic, affecting both invertebrates and vertebrates. They may transmit diseases to humans and other mammals. Those that feed on plants may damage crops.

Vocabulary

- **arachnid**: Class of arthropods having four pairs of legs which includes the spiders, scorpions, and ticks.
- **cephalothorax**: Fusion of the head and thorax.
- **chelicerae**: Fanglike appendages near the mouth that serve in feeding and defense.
- **diurnal**: Active in the daytime.
- **nocturnal**: Active at night.
- **pedipalps**: Appendages near the mouth that are modified for reproduction, catching prey, and other functions.
- **silk**: Threads spun by spiders to make webs, enclose their eggs, and to serve other functions.

Summary

- Arachnids have four pairs of legs, specialized appendages, and a fused head and thorax.
- Arachnids include spiders, daddy-long-legs, scorpions, and ticks.

Practice

Use the resource below to answer the questions that follow.

- **Spiders** at http://www.youtube.com/watch?v=ALsnmm-ghlA (4:03)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57287

1. How do spiders differ from insects?
2. What are some of the uses of their silk?
3. How do spiders keep from becoming stuck in their own webs?
4. What role do spiders play in their ecosystem?

Review

1. List three types of arachnids.
2. What are two key features of arachnids?
3. Arachnids also have two additional pairs of appendages. Describe these two pairs.
4. List two specific features of spiders.
5. List two specific features of scorpions.

3.18 Insects

- Describe the characteristics of the insects.
- Summarize the insect head, thorax, and abdomen.
- Describe insect movement and communication.
- Explain the meaning of insects as a social animal.
- Give examples of winged insects.

What animals were the first to evolve wings?

When someone says the word "wing," you probably think of soaring birds. Or maybe chicken wings smothered in hot sauce. But insects were actually the first animals to evolve wings.

What are Insects

Insects, with over a million described species, are the most diverse group of animals on Earth. They may be found in nearly all environments on the planet. No matter where you travel, you will see organisms from this group. Adult insects range in size from a minuscule fairy fly to a 21.9-inch-long stick insect (**Figure** 3.25).

Characteristics of Insects

Characteristics of Insects include:

- Segmented bodies with an **exoskeleton**. The outer layer of the exoskeleton is called the **cuticle**. It is made up of two layers. The outer layer, or **exocuticle**, is thin, waxy, and water-resistant. The inner layer is much thicker. The exocuticle is extremely thin in many soft-bodied insects, such as caterpillars.
- The segments of the body are organized into three distinct but joined units: a head, a thorax, and an abdomen (**Figure** 3.26 and **Table** 3.6).

FIGURE 3.25
A stick insect, showing how well it blends into its environment.

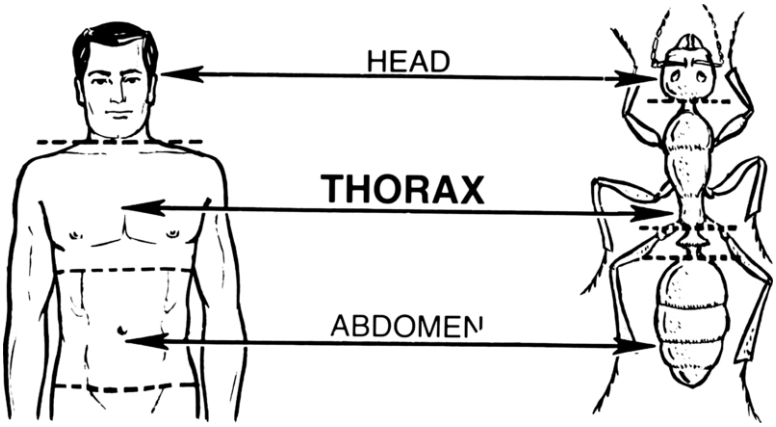

FIGURE 3.26
A diagram of a human and an insect, comparing the three main body parts: head, thorax, and abdomen.

TABLE 3.6: Insect Structures

Structure	Description
Head	A pair of antennae, a pair of compound eyes, and three sets of appendages that form the mouthparts.
Thorax	Six segmented legs and two or four wings.
Abdomen	Contains most of the digestive, respiratory, excretory, and reproductive structures.

- A nervous system that is divided into a brain and a ventral nerve cord.
- Respiration that occurs without lungs. Insects have a system of internal tubes and sacs that oxygen travels through to reach body tissues. Air is taken in through the **spiracles**, openings on the sides of the abdomen.
- A closed digestive system, with one long enclosed coiled tube which runs lengthwise through the body, from the mouth to the anus.
- A circulatory system that is simple and consists of only a single tube with openings. The tube pulses and circulates blood-like fluids inside the body cavity.
- Various types of movement. Insect movement can include flight, walking, and swimming. Insects were the only invertebrates to develop the ability to fly, and this has played an important role in their success. Many adult insects use six legs for walking, and they walk in alternate triangles touching the ground. This allows the insect to walk quickly while staying stable. A few insects have evolved to walk on the surface of the water,

TABLE 3.7: Insect Communication

Types of Communication	Representative Organisms	Description
Visual		
Bioluminescence	Fireflies	Reproduction and predation: Some species produce flashes to attract mates; other species to attract prey.
Sound Production		
By moving appendages	Cicadas	Loudest sounds among insects; have special muscles to produce sounds.
Ultrasound clicks	Moths	Predation: Produced mostly by moths to warn bats.
Chemical		
Wide range of insects have evolved chemical communication; chemicals are used to attract, repel, or provide other kinds of information; use of scents is especially well developed in social insects.	Moths	Antennae of males (**Figure** 3.28) can detect **pheromones** (chemicals released by animals that influence the behavior of others within the same species) of female moths over distances of many miles.
Dance Language	Honey bees	Honey bees are the only invertebrates to have evolved this type of communication; length of dance represents distance to be flown.

FIGURE 3.28
A yellow-collared scape moth, showing its feathery antennae.

Insects are Social

Social insects, such as termites, ants, and many bees and wasps (**Figure** 3.29), are the most familiar social species. They live together in large, well-organized colonies. Only those insects which live in nests or colonies can home.

Homing means that an insect can return to a single hole among many other apparently identical holes, even after a long trip or after a long time.

A few insects migrate in groups. For example, the monarch butterfly flies between Mexico and North America each spring and fall (**Figure** 3.29).

FIGURE 3.29

(*left*) Damage to this nest brings the workers and soldiers of this social insect, the termite, to repair it. (*center*) A wasp building its nest. (*right*) Monarch butterflies in an overwintering cluster.

Two Major Groups of Insects

Insects are divided into two major groups:

1. Wingless: Consists of two orders, the bristle tails and the silverfish.
2. Winged insects: All other orders of insects. They are named below.

Mayflies; dragonflies and damselflies; stoneflies; webspinners; angel insects; earwigs; grasshoppers, crickets, and katydids; stick insects; ice-crawlers and gladiators; cockroaches and termites; mantids; lice; thrips; true bugs, aphids, and cicadas; wasps, bees, and ants; beetles; twisted-winged parasites; snakeflies; alderflies and dobsonflies; lacewings and antlions; hangingflies (including fleas); true flies; caddisflies; and butterflies, moths, and skippers.

Vocabulary

- **cuticle**: Protective, waxy layer covering an insect.
- **exocuticle**: Thin, waxy, and water-resistant outer layer of an insect; part of cuticle.
- **exoskeleton**: External protective covering of an animal.
- **homing**: Ability to return to a home base after traveling a distance away from it.
- **phermones**: Chemicals produced by animals that influence the behavior of others within the same species.
- **spiracles**: Pores on the body of an insect that allow oxygen to enter the body.

Summary

- Characteristics of insects include segmented bodies, a system of internal tubes and sacs through which oxygen travels, and a simple circulatory system.
- Insects use many types of communication, including bioluminescence, sounds, and pheromones.
- Some insects are social and live in groups.

Explore More

Use the resource below to answer the questions that follow.

- **Terrestrial Arthropods: The Conquerors** at http://vimeo.com/37321126 (13:41)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57294

1. How many times did arthropods invade the land?
2. Describe the rapid underwater movement of the dragonfly larva.
3. What arthropod adaptations led to the class Insecta? Which adaptation do you think was key?
4. Where are insect wings the thickest?
5. How have flowers taken advantage of the complex eyes of insects?
6. How may the type of food available to arthropods when they first left the sea be connected to present day insects' role as decomposers?

Review

1. What are three key characteristics of insects?
2. What are two ways in which insects communicate?
3. What are the five components of the insect head?
4. What are the features of the insect thorax?
5. Name five types of winged insects.

3.19 Insect Food

- Explain how insects obtain food.

How do butterflies eat?

You might have seen butterflies searching for food on a flower before. They have long, tube-like mouthparts that can reach deep within a flower. The butterfly uses this mouth-tube to siphon nectar from the flower, as if sucking through a straw.

Insect Food

What do insets eat? Practically anything they want. There are so many different insects, that among all of them, no potential food is safe. Lots of insects eat plants, some insects eat other insects, and some even drink blood. Many insects eat nectar from plants. And some insects will eat whatever scraps of food you leave lying around.

A few insects, such as mayflies and some moths, never eat. That's because their lives are over in just a few hours or days. Once these insects become adults, they lay eggs, and then die. On the other hand, some insects are very healthy eaters. A silkworm eats enough leaves to increase its weight more than 4,000 times in just 56 days, as the silkworm increases in size about 10,000 times since birth. A locust eats its own weight in plants every day. Just imagine eating your own weight in food every day. You probably couldn't. You would most likely get very sick even if you tried.

How do Insects Eat?

Insects eat in many different ways and they eat a huge range of foods. Around half are plant-eaters, feeding on leaves, roots, seeds, nectar, or wood. Aphids and leafhoppers suck up the sap from plants. Praying mantises are

predators, hunting other small creatures. Insects like mosquitoes and aphids have special mouthparts that help them pierce and suck. Others, like assassin bugs (**Figure** 3.30) and certain species of female mosquitoes, eat other insects. Fleas and lice are parasites, eating the flesh or blood of larger animals without killing them.

Insects have different types of appendages (arms and legs) adapted for capturing and feeding on prey. They also have special senses that help them detect prey. Furthermore, insects have a wide range of mouthparts used for feeding.

FIGURE 3.30
An assassin bug feasts on a beetle.

Examples of chewing insects include dragonflies, grasshoppers, and beetles. These insects use one pair of jaws to bite off bits of food and grind them down. Another pair of jaws helps to push the food down the throat. Some larvae also have chewing mouthparts, as in the caterpillar stages of moths and butterflies (**Figure** 3.31).

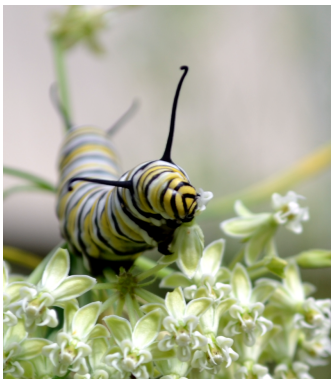

FIGURE 3.31
Caterpillar feeding on a host plant.

Some insects use siphoning, as if sucking through a straw, like moths and butterflies. This long mouth-tube that they use to suck up the nectar of the flower is called a **proboscis**. Some moths, however, have no mouthparts at all. Some insects obtain food by **sponging**, like the housefly. Sponging means that the mouthpart can absorb liquid food and send it to the esophagus. The housefly is able to eat solid food by releasing saliva and dabbing it over the food. As the saliva dissolves the food, the sponging mouthpart absorbs the liquid food.

TABLE 3.8: How Insects Eat

Method	Description	Examples
Piercing-sucking	Used to penetrate solid tissue and then suck up liquid food	Cicadas, aphids, sucking lice, stable flies, mosquitoes
Sponging	Used to sponge and suck liquids	House fly, blow fly
Chewing	Used for biting and grinding solid foods	Dragonflies, termites, beetles, ants, cockroaches, grasshoppers, crickets, caterpillars
Siphoning	Used to suck liquids	Bees

Vocabulary

- **proboscis**: Tube-like mouthpart modified for sucking and feeding.
- **sponging**: Process of liquefying solid food using saliva, then soaking it up.

Summary

- Some insects, such as aphids, have piercing-sucking mouthparts. Other insects, like grasshoppers, have chewing mouthparts.
- Insects can have specialized mouthparts, such as a proboscis, to siphon the nectar from a flower.

Review

1. How do butterflies obtain their food?
2. What do fleas and lice eat?
3. What is sponging? Explain how insects use sponging to obtain their food.
4. What is meant by the piercing-sucking method of eating?

3.20 Insect Reproduction and Life Cycle

- Describe the reproduction and life cycle of insects.

What is this?

These butterfly eggs look like tiny pearls on a leaf. The adult butterfly often lays her eggs on a specific type of plant. This ensures that the future caterpillars will have plenty of food to eat.

Insect Reproduction and Life Cycle

Most insects can reproduce very quickly within a short period of time. With a short generation time, they evolve faster and can quickly adjust to environmental changes. Most insects reproduce by **sexual reproduction**. The female produces eggs, which are fertilized by the male, and then the eggs are usually placed near the required food. In some insects, there is **asexual reproduction** during which the offspring come from a single parent. In this type of reproduction, the offspring are almost identical to the mother. This is most often seen in aphids and scale insects.

With a few exceptions, all insect life begins as an egg. After leaving the egg, insects must grow and transform until reaching adulthood. Only the adult insect can mate and reproduce. The physical transformation of an insect from one stage of its life cycle to another is known as **metamorphosis**.

Three Types of Metamorphosis

An insect can have one of three types of metamorphosis and life cycles (**Table** 3.9). Metamorphosis describes how insects transform from an immature or young insect into an adult insect in at least two stages. Insects may undergo gradual metamorphosis (incomplete), where transformation is subtle, or complete metamorphosis, where each stage of the life cycle appears quite different from the others. In some insects, there may be no true metamorphosis at all with the only difference between adult and young insects is size.

TABLE 3.9: Types of Metamorphosis

Type of Metamorphosis	Characteristics	Examples
Incomplete	• Three stages: egg, nymph, and adult. • Young, called **nymphs**, usually similar to adult. • Growth occurs during the nymph stage. • Wings then appear as buds on nymphs or early forms. • When last molt is completed, wings expand to full adult size.	Dragonflies, grasshoppers, mantids, cockroaches, termites
Complete	• Most insects undergo this type. • Each stage of the life cycle—egg, larva, pupa, and adult—looks different from the others. • Immature and adult stages have different forms, have different behaviors, and live in different habitats. • Immature form is called larvae and remains similar in form but increases in size. • Larvae usually have chewing mouthparts even if adult mouthparts are sucking ones. • At last larval stage of development, insect forms into pupa (**Figure** 3.32) and does not eat or move. • During **pupa** stage, wing development begins, after which the adult emerges.	Butterflies, moths, flies, ants, bees, beetles

Vocabulary

- **asexual reproduction**: Offspring come from a single parent.
- **larvae**: Immature form of an insect.
- **metamorphosis**: Process of transformation from an immature form into an adult.
- **nymph**: Immature form of some insects that somewhat resembles the adult.

FIGURE 3.32

The chrysalis (pupal stage) of a monarch butterfly.

- **pupa**: Non-feeding stage between the immature form and adult in the metamorphosis of some insects.
- **sexual reproduction**: Offspring come from combining the genetic material of two parents.

Summary

- Insects reproduce rapidly, usually by sexual reproduction.
- Metamorphosis, or how insects transform from an immature form into an adult, can be part of the insect life cycle.

Review

1. Describe how most insects reproduce.
2. Define metamorphosis.
3. What is the difference between complete and incomplete metamorphosis.
4. What are the four stages of complete metamorphosis?
5. Describe the differences between the immature and adult forms of most insects.
6. Give three examples of insects that go through complete metamorphosis.

3.21 Importance of Insects

- Discuss the importance of insects to people and the ecosystem.

Would you like to try a grasshopper taco?

It might seem disgusting to you, but insects are an important food source in many places across the globe. Crickets, ants, grasshoppers, and other insects are traditional foods in parts of Latin America, Africa, and Asia.

Importance of Insects

Many insects are considered to be pests by humans. However, insects are also very important for numerous reasons.

Ecological Importance

Insects can be found in every environment on Earth. While a select few insects, such as the Arctic Wooly Bear Moth, live in the harsh Arctic climate, the majority of insects are found in the warm and moist tropics. Insects have adapted to a broad range of habitats, successfully finding their own niche, because they will eat almost any substance that has nutritional value.

Insects are crucial components of many ecosystems, where they perform many important functions. They aerate the soil, pollinate blossoms, and control insect and plant pests. Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees, thereby recycling nutrients back into the soil. As **decomposers**, insects help create top soil, the nutrient-rich layer of soil that helps plants grow. Burrowing bugs such as ants and beetles dig tunnels that provide channels for water, benefiting plants. Bees, wasps, butterflies and ants **pollinate** flowering plants (**Figure** 3.33). Gardeners love the big-eyed bug and praying mantis because they control the size of certain insect populations, such as aphids and caterpillars, which feed on new plant growth. Finally, all insects fertilize the soil with the nutrients from their droppings.

FIGURE 3.33
Bees are important pollinators of flowering plants.

Economic Importance

Insects have tremendous economic importance. Some insects produce useful substances, such as honey, wax, lacquer, and silk. Honeybees have been raised by humans for thousands of years for honey. The silkworm greatly affected human history. When the Chinese used worms to develop silk, the silk trade connected China to the rest of the world. Adult insects, such as crickets, as well as insect larvae, are also commonly used as fishing bait.

Insects as Food

Insects, of course, are not just eaten by people. Insects are the sole food source for many amphibians, reptiles, birds, and mammals, making their roles in food chains and food webs extremely important. It is possible that food webs could collapse if insect populations decline.

In some parts of the world, insects are used for food by humans. Insects are a rich source of protein, vitamins, and minerals, and are prized as delicacies in many third-world countries. In fact, it is difficult to find an insect that is not eaten in one form or another by people. Among the most popular are cicadas, locusts, mantises, grubs, caterpillars, crickets, ants, and wasps. Many people support this idea to provide a source of protein in human nutrition. From South America to Japan, people eat roasted insects, like grasshoppers or beetles.

Insects in Medicine

Insects have also been used in medicine. In the past, fly larvae (**maggots**) were used to treat wounds to prevent or stop gangrene. Gangrene is caused by infection of dead flesh. Maggots only eat dead flesh, so when they are placed on the dead flesh of humans, they actually clean the wound and can prevent infection. Some hospitals still use this type of treatment.

Vocabulary

- **decomposer**: Organism that feeds on and breaks down dead plant or animal matter.
- **maggot**: Immature or larvae stage of flies.

- **pollinate**: To transfer pollen between flowers to allow fertilization to take place.

Summary

- In the environment, some insects pollinate flowering plants.
- Insects produce useful substances, such as honey, wax, lacquer, and silk.
- Insects are food sources in some parts of the world.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Maggot Medicine** at http://www.youtube.com/watch?v=6Xt6NWkgydM (3:33)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57296

1. What characteristic of maggots make them useful in medicine?
2. How do maggots help wounds heal?

Practice II

- **Creature Feature: Silkworms** at http://www.abc.net.au/creaturefeatures/facts/silkworms.htm

1. What is the best food for silkworms?
2. Why does the silkworm make silk?

Review

1. Where are the majority of insects found?
2. Name two ways in which insects are important to the ecosystem.
3. Give three examples of insects that act as pollinators.
4. List three products produced by insects.
5. Give an example of how insects are used in medicine?

3.22 Control of Insects

- Explain methods to control insects.

Are ladybugs dangerous?

Ladybugs won't hurt you. But they are dangerous to some other insects! This ladybug is eating plant-harming bugs known as aphids. Since they have an appetite for aphids, ladybugs are a farmer's friend.

Control of Insects

Though insects can be very important, some are also considered pests. Common insect pests include:

1. Parasitic insects, such as mosquitoes, lice, and bed bugs.
2. Insects that transmit diseases, including mosquitoes and flies.
3. Insects that damage structures, such as termites (**Figure** 3.34).
4. Insects that destroy crops, including locusts and weevils.

Many scientists who study insects are involved in various forms of pest control. Most utilize insect-killing chemicals, but more and more rely on other methods. Ways to control insect pests are described below.

Biological Control

Biological control of pests in farming is a method of controlling pests by using other insects (or other natural predators of the pests). Biological control of insects relies on predation and parasitism. Insect predators, such as ladybugs and lacewings, consume a large number of other insects during their lifetime. If you add ladybugs to your farm or garden, they will help keep insect pests, such as aphids, under control. Aphids are among the most destructive insect pests on cultivated plants in temperate regions, so any control of these pests is beneficial.

FIGURE 3.34
Termites can destroy wooden structures.

Ladybugs also consume mites, scale insects and small caterpillars. The larvae of many hoverfly species also feed upon aphids, with one larva consuming up to fifty aphids a day, which is about 1,000 in its lifetime. They also eat fruit tree spider mites and small caterpillars. Dragonflies are important predators of mosquitoes, and can be used to control this pest. Parasitic insects include insects such as wasps and flies that lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae. The host is ultimately killed. Caterpillars also tend to be one likely target of parasitic wasps.

Chemical Control

Chemical control of pests involves the use of insecticides. **Insecticides**, which are also known as pesticides, are most often used to kill insects. Insecticides are chemicals that kill insects. The U.S. spends $9 billion each year on pesticides. Disadvantages to using pesticides include human, fish, and honeybee poisonings, and the contamination of meat and dairy products.

When choosing to use an insecticide, there are numerous points to consider. Negative effects of the pesticide should try to be minimized. Important questions to consider include the following.

- What is the chemical's success against the target pest? Will the insecticide provide the desired level of control of the pest? If the answer is no, other methods of control should be considered.
- Does the chemical have an impact on natural enemies of the pest? In large scale efforts to rid areas of mosquitoes, the insecticide used also killed the dragonfly. This effort removed a natural predator of the mosquito. This may be an unacceptable negative effect of using the insecticide.
- How susceptible is the crop to insect damage? If the crop is not heavily damaged, only minor pest control may be needed. This may affect the amount or type of insecticide used.
- How toxic is the chemical to the environment and humans? Some older insecticides are extremely poisonous. Keep in mind that users of these poisons have a community responsibility to minimize the contamination of the surrounding environment, as well as keeping animals, surrounding crops and humans safe.
- Does using the pesticide result in the development of resistance? If so, this can make additional use of the pesticide less effective. As the resistance will be passed to future generations of the insect (which is natural selection in action), this could be considered a negative side-effect of pesticide use.

Vocabulary

- **biological control**: Control of pests by using organisms that are their natural predators.
- **insecticide**: Chemical used to kill insects.

Summary

- Harmful insects include those that can destroy buildings and crops or transmit disease.
- Insecticides are commonly used to control insect pests, but they can have harmful effects on the environment.

Practice

Use the resource below to answer the questions that follow.

- **Biological Control** at Cornell University's Department of Entomology: http://www.biocontrol.entomology.cornell.edu/kids.php

1. What is an entomologist?
2. What is a danger of introducing a new insect as a biological control mechanism?
3. Why do people like biological control for food crops?

Review

1. What are three examples of insects that are pests?
2. Name two ways that insects can be pests.
3. What is meant by biological control of insects?
4. What are two disadvantages to pesticides?

Summary

Invertebrates describes eight invertebrate phyla with the greatest number of species. From the simple sponge to the echinodermata, this diverse group of organisms is anything but simple. Essentially, the only common characteristic among all the groups is the lack of a backbone. Many people may not even recognize the sponge as an animal. But it is. And how many people think a worm is an insect? But it is not. Add to this group all the different species of insects, and the diverseness of this group is easily apparent.

3.23 References

1. Flickr:darkfur93. Snails are an example of invertebrates, animals without a backbone. CC BY 2.0
2. Flickr:icelight. Sea sponges often have tube-like bodies with many tiny pores. CC BY 2.0
3. Courtesy of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. A Portuguese Man o' War is a cnidarian colony. Public Domain
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30. Audrey (Flickr:audreyjm529). An assassin bug feasts on a beetle. CC BY 2.0
31. Jo Naylor. Caterpillar feeding on a host plant. CC BY 2.0

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33. Thomas Quine (Flickr:quinet). Bees are important pollinators of flowering plants. CC BY 2.0
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CHAPTER 4 Vertebrates

Chapter Outline

4.1 CHORDATES

4.2 VERTEBRATE CHARACTERISTICS

4.3 FISH

4.4 JAWLESS FISH

4.5 CARTILAGINOUS FISH

4.6 BONY FISH

4.7 AMPHIBIANS

4.8 SALAMANDERS

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4.10 ROLE OF AMPHIBIANS

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4.12 LIZARDS AND SNAKES

4.13 ALLIGATORS AND CROCODILES

4.14 TURTLES

4.15 IMPORTANCE OF REPTILES

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4.18 DIVERSITY OF BIRDS

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4.26 REFERENCES

Introduction

What do all animals—from fish to mammals—have in common?

Vertebrates. From the smallest of fish to us. One of the main features we all have in common is our backbone. *Vertebrates* describes main biological features of fish, amphibians, reptiles, birds, and mammals.

4.1 Chordates

- Describe the features of the chordates.

What do these two animals have in common with you?

Notice the orange fish. Around him is another type of animal, a tunicate, in blue. Tunicates, fish, and humans seem very different from one another, but they do have some things in common. They are all chordates.

Chordates

Did you know that fish, amphibians, reptiles, birds, and mammals are all related? They are all chordates. **Chordates** are a group of animals that includes vertebrates, as well as several closely related invertebrates. Chordates (phylum *Chordata*) are named after a feature they all share, a notochord. A **notochord** is a hollow nerve cord along the back.

Characteristics of the Chordates

Chordates are defined by a set of four characteristics that are shared by these animals at some point during their development. In some chordates, all four traits are present in the adult animal and serve important functions. However, in many chordates, including humans, some traits are present only during the embryonic stage. After that, these traits may disappear.

All chordates have four main traits (**Figure** 4.1):

1. **Post-anal tail**: The tail is opposite the head and extends past the anus.

2. **Dorsal hollow nerve cord**: "Dorsal" means that the nerve cord runs along the top of the animal. In some animals, the nerve cord develops into the brain and spinal cord.
3. Notochord: The notochord lies below the nerve cord. It is a rigid structure where muscles attach.
4. **Pharyngeal slits**: Pharyngeal slits are used to filter out food from water by some simple chordates. In most chordates, however, they are only present during the embryonic stages and serve no apparent purpose.

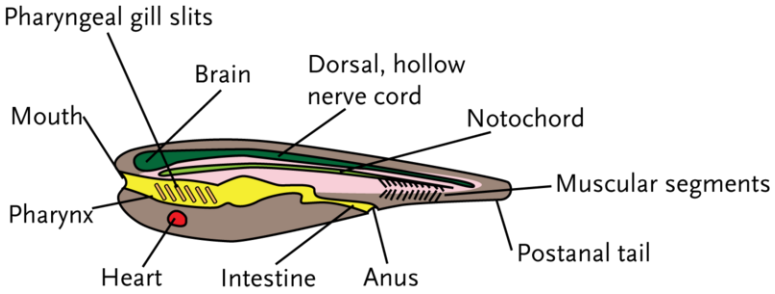


FIGURE 4.1
Body Plan of a Typical Chordate. The body plan of a chordate includes a post-anal tail, notochord, dorsal hollow nerve cord, and pharyngeal slits.

Classification of the Chordates

The chordates are divided into nine classes. Five of the classes are the fish, amphibians, reptiles, birds, and mammals. There are actually five classes of marine chordates (for example, sharks are cartilaginous fish which are distinct from bony fish), and these will be discussed in additional concepts.

The chordate phylum is broken down into three subphyla:

1. Urochordata: The tunicates, pictured in the introduction, make up this group. The urochordates are sessile (non-moving) marine animals with sack-like bodies and tubes for water movement. Urochordates have a notochord and nerve cord only during the larval stage.
2. Cephalochordata: Cephalochordates include the lancelets (**Figure** 4.2), fish-like marine animals often found half-buried in the sand. Cephalochordates have a notochord and nerve cord but no backbone.
3. Vertebrata: Humans and other mammals, along with fish, amphibians, reptiles, and birds, fall in this category. The notochord is typically smaller and surrounded by a backbone.

FIGURE 4.2
The lancelet, an example of a chordate, is found in shallow ocean waters.

Vocabulary

- **chordate**: Animal with a notochord, dorsal hollow nerve cord, post-anal tail, and pharyngeal slits during at least some stage of its life.
- **dorsal hollow nerve cord**: Hollow cord above the notochord; sometimes includes a brain and spinal cord.
- **notochord**: Support rod that runs along the back.
- **pharyngeal slit**: Organ that aids in filter-feeding.
- **post-anal tail**: Tail that is opposite the head and extends past the anus.

Summary

- Chordates are animals that have a notochord, post-anal tail, dorsal hollow nerve cord, and pharyngeal slits.
- Chordates include all vertebrates and some invertebrates.

Practice

Use the resource below to answer the questions that follow.

(*Note*: this resource refers to human embryos as having gill slits. This is a commonly held misconception which seems to have originated in a now defunct theory by Ernst Haeckel. In the embryonic development of chordates, there is a stage where an invagination, called "gill pouches" or "pharyngeal pouches," appear in vertebrate embryos. This invagination does develop into gills in some species, but in other species the invagination develops into other structures. So, while parallels in the development of chordates are accurate, it is misleading to say human embryos have gill slits. You can find out more here http://www.angelfire.com/journal/Philsviews/Science/embryo.html .)

- **Chordate Animation: Amphioxus to Vertebrate Body Plan** at http://vimeo.com/37411858 (1:31)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57375

1. What does the nerve cord in *Amphioxus* do?
2. What is a notochord, and what characteristics does it give *Amphioxus*?
3. What signs of a notochord do we see in human beings (*Homo sapiens*)?
4. What is the relationship of the vertebrate backbone to the vertebrate skeleton?

Review

1. What is the main common feature of all chordates?
2. Name three examples of chordates.
3. List three characteristics of chordates.
4. What is the dorsal hollow nerve cord?

4.2 Vertebrate Characteristics

- List the general features of vertebrates.

What animals have a backbone?

You have a backbone, or vertebrate (or vertebral) column. Can you guess what other animals also have a backbone? Frogs, snakes, birds, and many other animals all have backbones. Animals that have backbones are known as vertebrates.

Introduction to Vertebrates

Vertebrates are animals with backbones. These include fish, amphibians, reptiles, birds, and mammals.

Characteristics of Vertebrates

The primary feature shared by all vertebrates is the **vertebral column**, or backbone. The vertebral column protects the spinal cord.

Other typical vertebrate traits include:

- The **cranium** (skull) to protect the brain. The brain is attached to the spinal cord.
- An internal skeleton. The internal skeleton supports the animal, protects internal organs, and allows for movement.
- A defined head region with a brain. The head region has an accumulation of sense organs.

Living vertebrates range in size from a carp species, as little as 0.3 inches, to the blue whale, which can be as large as 110 feet (**Figure** 4.3).

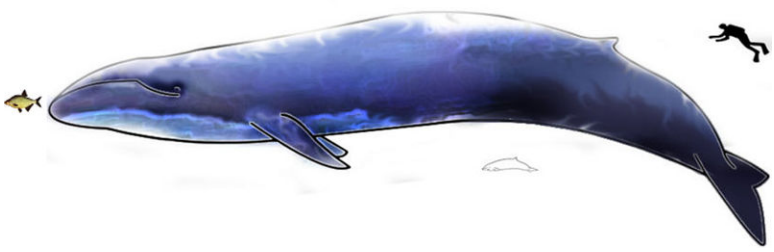


FIGURE 4.3

A species of carp and an image of the blue whale (a mammal), the largest living vertebrate, reaching up to 110 feet long. Shown below it is the smallest whale species, Hector's dolphin (about 5 feet in length), and beside it is a human. These images are not to scale. The carp is greatly exaggerated in size and is even smaller than depicted when compared to the blue whale.

Classification of Vertebrates

Vertebrates, or subphylum Vertebrata, are all members of the phylum Chordata. Although there is some disagreement on how to classify animals, the traditional system divides the vertebrates into seven classes (**Table** 4.1).

TABLE 4.1: Classes of Vertebrates

Class	Common Name	Characteristics	Examples
Agnatha	Jawless fishes	No jaws or scales	Lampreys, hagfish
Chondrichthyes	Cartilaginous fishes	Skeletons consisting of hard, rubber-like cartilage	Sharks, rays
Osteichthyes	Bony fishes	Skeletons made of bone	Tuna, bass, salmon, trout
Amphibia	Amphibians	Spend part of their lives under water and part on land	Frogs, toads, salamanders
Reptilia	Reptiles	Have lungs to breathe on land and skin that does not need to be kept wet, and produces a watertight (**amniotic**) egg	Turtles, snakes, lizards, alligators
Aves	Birds	Produces watertight eggs and protects eggs from predators	Ostriches, penguins, flamingos, parrots
Mammalia	Mammals	Nourish young with milk through **mammary glands**	Dogs, cats, bears, monkeys, humans

Vocabulary

- **amniotic egg**: A shelled egg that can be laid on land; prevents embryo from drying out.
- **cranium**: Protective brain case; also called the skull.
- **mammary gland**: Milk-producing gland of female mammals.
- **vertebral column**: Bony support structure that runs along the back of a vertebrate animal; also called the backbone.
- **vertebrate**: Animal with backbone; these include mammals, birds, reptiles, amphibians, and fish.

Summary

- Vertebrates are animals with a backbone.
- Vertebrates include the mammals, birds, reptiles, amphibians, and fish.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Chordates: We're All Family** at http://vimeo.com/42588192 (15:43)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57389

1. What do scientists feel was a key factor in vertebrates getting "big"?
2. What advantages do big animals have over small animals?
3. What advantages do small animals have over big animals?
4. What did jaws allow vertebrates to do?
5. What is a "larvacean"? How does it feed?

Practice II

- **Vertebrates** at http://paleobiology.si.edu/dinosaurs/interactives/tree_life/tree.html

1. What is a phylogeny?
2. When did the evolution of archosaurs begin?
3. What are the living members of archosaurs?

Review

1. What are five examples of vertebrates?
2. What are the primary feature shared by vertebrates? What is the role of this feature?
3. What is the defining characteristic of the cartilaginous fish?

4. What are the defining characteristics of reptiles?
5. What is the defining characteristic of mammals?

4.3 Fish

- List the general traits of fish.
- Describe how fish are important to people.

Is this animal a fish?

This mudskipper might not seem like a fish. It's not swimming in a lake or an ocean, and it appears to be using its fins like legs. Mudskippers can breathe through their skin and burrow in the mud, essentially living on land for a brief amount of time. These features are not typical of fish, and, yet, mudskippers are still classified as fish. So what features define a fish?

Characteristics of Fish

What exactly is a fish? You probably think the answer is obvious. You may say that a fish is an animal that swims in the ocean or a lake, using fins. But as we saw with the mudskipper, not all fish spend all their time in water. So how do scientists define fish?

Some characteristics of fish include:

1. They are **ectothermic**, meaning their temperature depends on the temperature of their environment. Ectothermic animals are cold-blooded in that they cannot raise their body temperature on their own. This is unlike humans, whose temperature is controlled from inside the body.
2. They are covered with scales.
3. They have two sets of paired fins and several unpaired fins.
4. They also have a streamlined body that allows them to swim rapidly.

Fish are aquatic vertebrates, meaning they have backbones. They became a dominant form of sea life and eventually evolved into land vertebrates. There are three classes of fish: Class Agnatha (the jawless fish), Class Chondrichthyes

(the cartilaginous fish), and Class Osteichthyes (the bony fish). All have the characteristics of fish in common, though there are differences unique to each class.

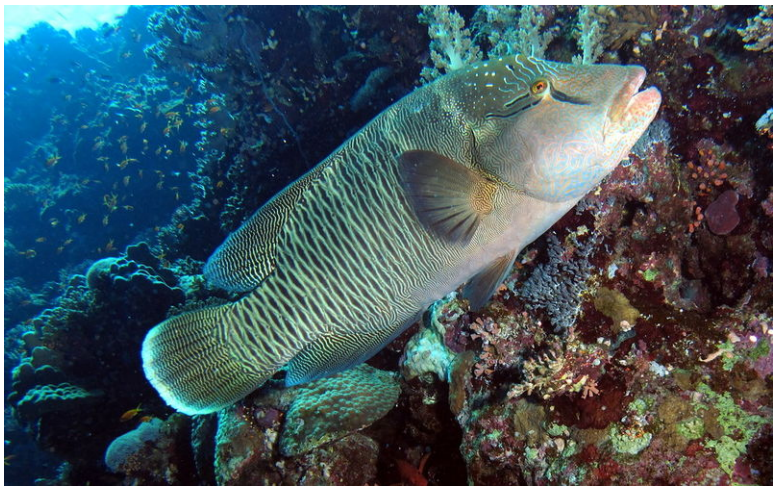


FIGURE 4.4

The humphead or Napoleon wrasse shows some of the general traits of fish, including scales, fins, and a streamlined body.

How do Fish Breathe?

In order to absorb oxygen from the water, fish use gills (**Figure** 4.5). **Gills** take dissolved oxygen from water as the water flows over the surface of the gill.

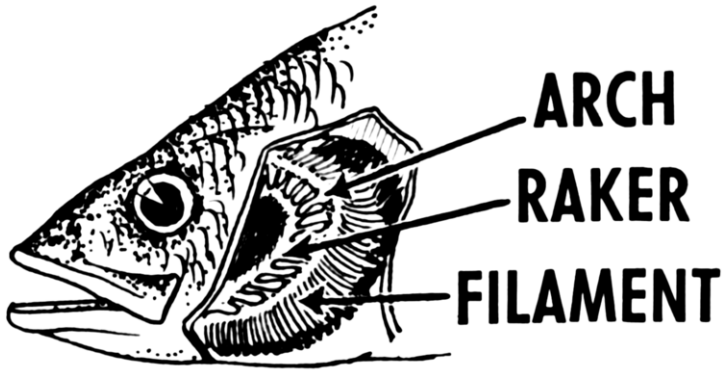


FIGURE 4.5

Gills help a fish breathe.

How Do Fish Reproduce?

Fish reproduce sexually. They lay eggs that can be fertilized either inside or outside of the body. In most fish, the eggs develop outside of the mother's body. In the majority of these species, fertilization also takes place outside the mother's body. The male and female fish release their gametes into the surrounding water, where fertilization occurs. Female fish release very high numbers of eggs to increase the chances of fertilization.

How Big Are Fish?

Fish range in size from the 65-foot, 75,000 pound whale shark (**Figure** 4.6) to the stout infantfish, which is about 0.33 inches (8.4 mm), and the *Paedocypris progenetica* carp species of the Indonesian island of Sumatra, which is about 0.31 inches (7.9 mm) long, making it also the smallest known vertebrate animal. The second-largest fish is the basking shark, which grows to about 40 feet and 8,000 pounds. Both of the large sharks may look ferocious, and would probably scare anyone who comes across one in the water, but both species are filter-feeders, and feed on tiny fish and plankton. The tiny carp species is unique in that it has the appearance of larvae, with a reduced skeleton which leaves the brain unprotected by bone. The fish lives in dark acidic waters, having a pH of 3.

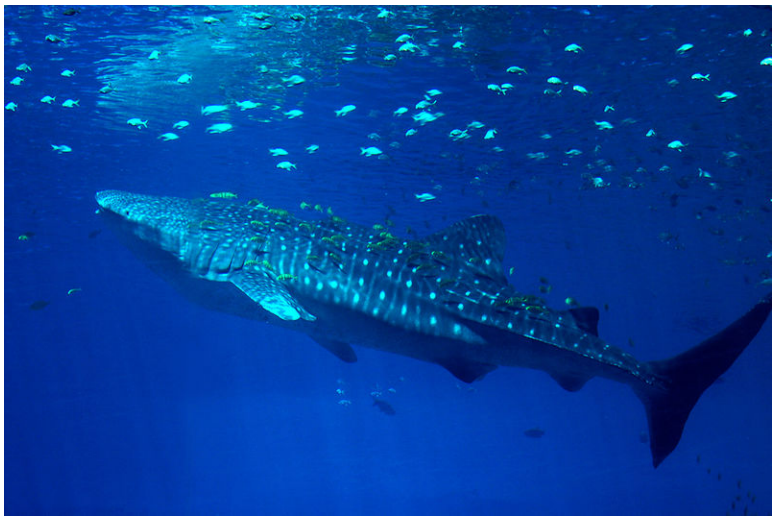


FIGURE 4.6
Whale sharks are the largest cartilaginous fish.

Exceptions to Common Fish Traits

There are exceptions to many of these fish traits. For example, tuna, swordfish, and some species of shark show some warm-blooded adaptations and are able to raise their body temperature significantly above that of the water around them.

Some species of fish have a slower, more maneuverable swimming style, like eels and rays (**Figure** 4.7). Body shape and the arrangement of fins are highly variable, and the surface of the skin may be naked, as in moray eels, or covered with scales. Scales can be of a variety of different types.

Why Fish are Important

How are fish important? Of course, they are used as food (**Figure** 4.8). In fact, people all over the world either catch fish in the wild or farm them in much the same way as cattle or chickens. Farming fish is known as **aquaculture**. Fish are also caught for recreation to display in the home or in a public aquarium.

Vocabulary

- **aquaculture**: Farming fish for food.
- **ectothermic**: Having an internal temperature that depends on the temperature of their environment.
- **gills**: Organs that take dissolved oxygen from water.

FIGURE 4.7

One of the cartilaginous fish, a stingray, shows very flexible pectoral fins connected to the head.

FIGURE 4.8

Workers harvest catfish from the Delta Pride Catfish farms in Mississippi.

Summary

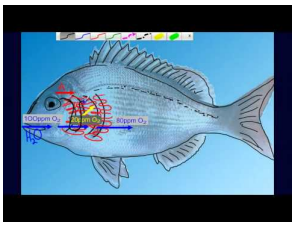
- Fish are ectothermic, have a streamlined body covered with scales, and have two sets of paired fins and several unpaired fins.
- To obtain fish for food, people catch fish in the wild or farm them.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Countercurrent Gas Exchange in Fish Gills** at http://www.youtube.com/watch?v=cVFqME-NW9s (4:50)



MEDIA

Click image to the left or use the URL below.

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1. Why do gills appear bright red?
2. When a fish breathes, where does it take in water and where does it expel water?
3. What direction does a fish's blood flow through its gills?
4. Why does this system in fishes' gills allow for more energetic fish?

Practice II

- **Lung Fish** at http://www.youtube.com/watch?v=iT3UgDz_6nM (2:42)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57374

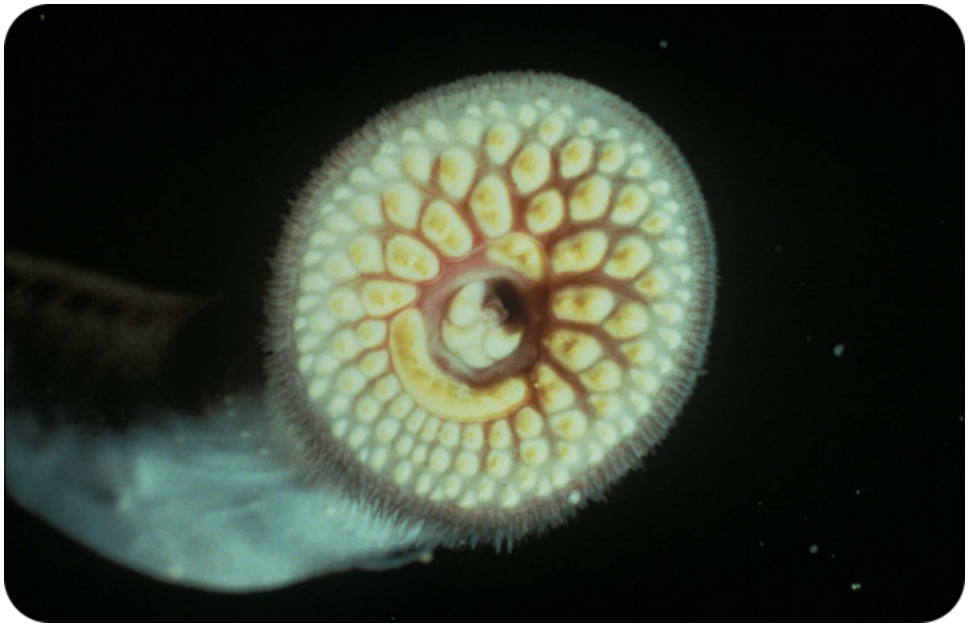
1. How does the lung fish get oxygen?
2. How does the lung fish escape heat and drought?
3. Why is the lung fish's behavior adaptive to its environment?

Review

1. What are three main features that define fish?
2. How do fish breath?
3. Explain how most fish reproduce?
4. How are fish important to humans?

4.4 Jawless Fish

- Describe the features of jawless fish.



What is this organism?

With this huge sucker lined with teeth, this organism might look like something out of science fiction. But this is a real fish found in the ocean, known as a lamprey. They use their teeth and sucker to bore into other fish and suck their blood. The lamprey is an example of a jawless fish.

Jawless Fish

What defines a jawless fish? You can probably guess. A jawless fish is a fish without a jaw. But there are other features that are shared by this class of organisms. Why would such an organism evolve? These fish were the first vertebrates to evolve. Logically, this makes sense, in that the vertebral column would evolve first, with the more complex jaw bones evolving later. The early jawless fish are thought to have relied on filter feeding to capture their food, and most likely would have sucked water and debris from the seafloor into their mouth, releasing water and waste out of their gills. As other sea life evolved, these jawless fish began to feed on other fish species, and are now considered a pest in their habitat. Lampreys have no natural predators.

Features of Jawless Fish

Jawless fish are missing the following parts:

1. Jaws.
2. Paired fins.
3. A stomach.

Characteristics they do have include:

1. A notochord, both in larvae and adults. Recall a **notochord** is a support rod that runs along the back of the fish.
2. Seven or more paired **gill pouches**. These organs take dissolved oxygen from water.
3. The **branchial arches**, a series of arches that support the gills of aquatic amphibians and fishes. They lie close to the body's surface.
4. A light sensitive **pineal eye**, an eye-like structure that can detect light.
5. A **cartilaginous skeleton**, a skeleton made of a flexible rubber-like supportive material called cartilage. This is similar to the skeleton of cartilaginous fish, which includes sharks and rays.
6. A heart with two chambers.
7. Reproduction using external fertilization.
8. They are **ectothermic**. This means that their internal temperature depends on the temperature of their environment.

Classification of Jawless Fish

Most scientists agree that the jawless fish are part of the the superclass Agnatha. They belong to the phylum Chordata, subphylum Vertebrata. There are two living groups of jawless fish, with about 100 species in total: lampreys and hagfish (**Figure** 4.9). Although hagfish belong to the subphylum Vertebrata, they do not technically have vertebrae (though they do have a skull), whereas lampreys do have vertebrae. For this reason, scientists still disagree on the classification of jawless fish.

FIGURE 4.9
A hagfish.

Vocabulary

- **branchial arches**: Series of arches that support the gills of aquatic amphibians and fishes.
- **cartilaginous skeleton**: Skeleton made of bone-like material called cartilage, a tough yet flexible material that lends support.
- **ectothermic**: Having an internal temperature that depends on the temperature of the environment.
- **gill pouches**: Series of arches that support the gills of aquatic amphibians and fishes.
- **notochord**: Support rod that runs along the back.
- **pineal eye**: Eye-like structure on top of the head that is capable of light detection.

Summary

- The jawless fish include the lampreys and the hagfish.

- Jaws, fins, and stomachs are absent in the jawless fish.
- Features of the jawless fish include a notochord, paired gill pouches, a pineal eye, and a two-chambered heart.

Practice

Use the resources below to answer the questions that follow.

- **Invading Species Awareness PSA - Sea Lamprey** at http://www.youtube.com/watch?v=x-KJZ22-wTQ (2:06)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57376

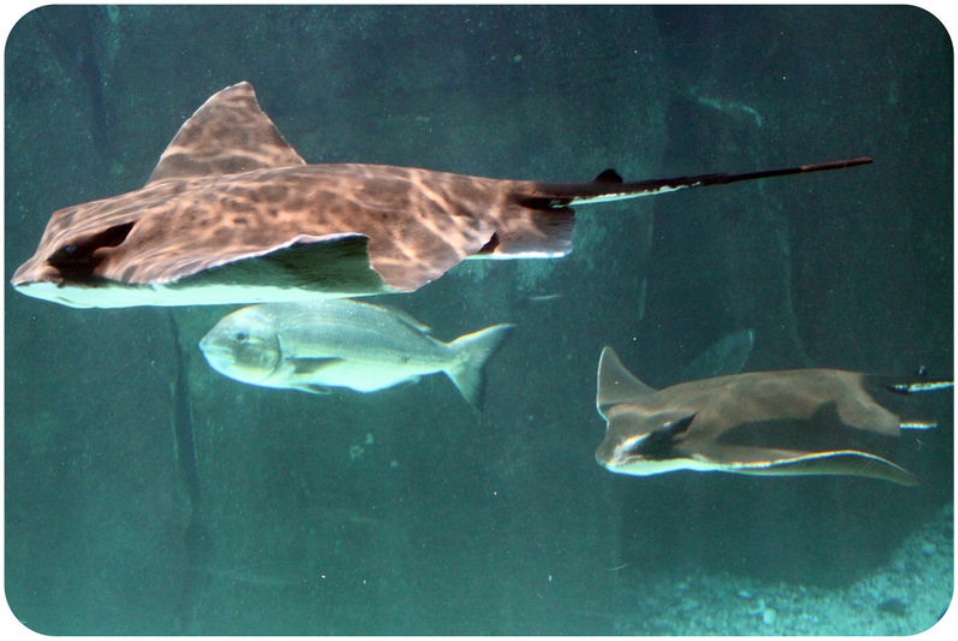
1. How do lamprey eat?
2. How did lampreys reach the Great Lakes?
3. What techniques are people using to try to control lampreys in the Great Lakes?

Review

1. What are two examples of jawless fish?
2. What are three characteristics of jawless fish?
3. What is the pineal eye?

4.5 Cartilaginous Fish

- Describe the features of the cartilaginous fish.



How are these organisms different?

The two rays and the other fish pictured here do have a lot in common. They have streamlined bodies well suited for movement in the ocean. One difference, however, is their skeletons. The lone fish has a skeleton of bone. The rays have a skeleton of cartilage, and so they are known as cartilaginous fish.

Cartilaginous Fish

The 1,000 or so species of **cartilaginous fish** are subdivided into two subclasses: the first includes sharks, rays, and skates; the second includes chimaera, sometimes called ghost sharks. Fish from this group range in size from the dwarf lanternshark, at 6.3 inches, to the over 50-foot whale shark. Sharks obviously have jaws, as do the other cartilaginous fish. These fish evolved from the jawless fish. So why did fish eventually evolve to have jaws? Such an adaptation would allow fish to eat a much wider variety of food, including plants and other organisms.

Other characteristics of cartilaginous fish include:

- Paired fins.
- Paired nostrils.
- Scales.
- Two-chambered hearts.
- Skeletons made of **cartilage** rather than bone. Cartilage is supportive tissue that does not have as much calcium as bones, which makes bones rigid. Cartilage is softer and more flexible than bone.

Blood, Skin, and Teeth

Since they do not have bone marrow (as they have no bones), red blood cells are produced in the spleen, in special tissue around the reproductive organs, and in an organ called **Leydig's organ**, only found in cartilaginous fishes. The tough skin of this group of fish is covered with **placoid scales**, which are hard scales formed from modified teeth. The scales are covered with a hard enamel. The hard covering and the way the scales are arranged, gives the fish skin rough, sandpaper-like feel. The function of these scales is for protection against predators.

The shape of sharks' teeth differ according to their diet. Species that feed on mollusks and crustaceans have dense flattened teeth for crushing, those that feed on fish have needle-like teeth for gripping, and those that feed on larger prey, such as mammals, have pointed lower teeth for gripping and triangular upper teeth with serrated edges for cutting. Sharks continually shed and replace their teeth, with some shedding as much as 35,000 teeth in a lifetime.

Superorders

The sharks, rays, and skates (which are similar to stingrays) are further broken into two superorders:

1. Rays and skates.
2. Sharks.

Sharks are some of the most frequently studied cartilaginous fish. Sharks are distinguished by such features as:

- The number of gill slits.
- The number and type of fins.
- The type of teeth.
- The size of their jaws.
- Body shape.
- Their activity at night.
- An elongated, toothed snout used for slashing the fish that they eat, as seen in sawsharks.
- Teeth used for grasping and crushing shellfish, a characteristic of bullhead sharks.
- A whisker-like organ named **barbels** that help sharks find food, a characteristic of carpet sharks.
- A long snout (or nose-like area), characteristic of groundsharks.
- **Ovoviviparous** reproduction, where the eggs develop inside the mother's body after internal fertilization, and the young are born alive. This trait is characteristic of mackerel sharks. All sharks mate by internal fertilization. Some sharks then lay their eggs, others allow internal development.

Vocabulary

- **barbels**: Whisker-like organs that sense the environment to help the sharks find food.
- **cartilage**: Tough yet flexible material that lends support.
- **cartilaginous fish**: Class of fish, including sharks and rays, with a skeleton of cartilage.
- **Leydig's organ**: Organ that produces red blood cells; found only in sharks and rays.
- **placoid scales**: Tough scales that originate from modified teeth.
- **ovoviparous**: Describes an organism that retains fertilized eggs inside the body, so that the young hatch internally and are born alive.

Summary

- The cartilaginous fish are jawed fish with paired fins, paired nostrils, scales, two-chambered hearts, and skeletons made of cartilage rather than bone.
- Examples of the cartilaginous fish include sharks, rays, and skates.

FIGURE 4.10

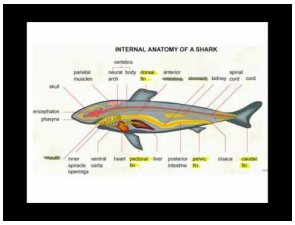
A spotted Wobbegong shark showing skin flaps around the mouth and camouflage coloration.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Chondrichthyes** at http://www.youtube.com/watch?v=6i6wlz8V5x0 (13:15)



MEDIA

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1. How do Chondrichthyes differ from jawless fish (Agnatha)?
2. How is the keel shape of their scales beneficial?
3. What is the function of the cloaca in sharks?
4. What is a nodochord made of in sharks?
5. How do sharks sense prey? Explain.

Practice II

- **Skates and Rays** at http://animals.howstuffworks.com/fish/skate-and-ray-info.htm

1. What do skates and rays have in common with sharks?
2. What part of the ocean do skates and rays inhabit?

Practice III

- http://www.pbs.org/wnet/nature/episodes/sharkland/interactive-anatomy-the-great-whites-weapons/4093/

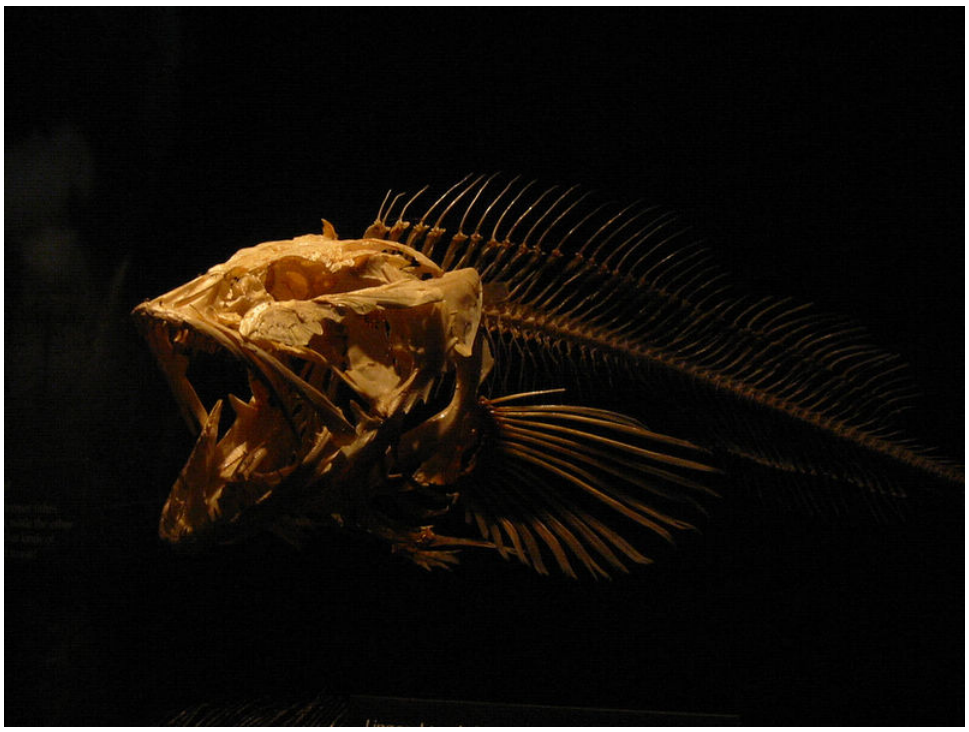
1. What are the ampullae of Lorenzini used for?
2. What is the relationship between the surface area of gill filaments and the amount of gas they can exchange? Why is this important to the shark?
3. Why do great white sharks have to roll their eyes back to protect them when they attack?
4. What do sharks use to strengthen their cartilaginous skeleton?

Review

1. What are three features of cartilaginous fish?
2. What are three examples of cartilaginous fish?
3. What is Leydig's organ?
4. List three features that distinguish sharks.

4.6 Bony Fish

- Describe the characteristics of the bony fish.



Can fish have bones?

Of course. Many fish have bones. They serve the same function as our bones: protection and support. Notice how the skeleton protects the fish's brain. Also, notice the bones along the body of the fish would allow muscles to attach to aid in movement.

Bony Fish

There are about 27,000 species of bony fish (**Figure** 4.11), which are divided into two classes: ray-finned fish and lobe-finned fish. Most bony fish are ray-finned. These thin fins consist of webs of skin over flexible spines. Lobe-finned fish, on the other hand, have fins that resemble stump-like appendages.

Characteristics of Bony Fish

Most fish are bony fish, making them the largest group of vertebrates in existence today. They are characterized by:

1. A head and **pectoral girdles** (arches supporting the forelimbs) that are covered with bones derived from the skin.
2. A lung or **swim bladder**, which helps the body create a balance between sinking and floating by either filling up with or emitting gases such as oxygen.
3. Jointed, segmented rods supporting the fins.

FIGURE 4.11
Fins of bony fish: ray fin (left) and lobe fin (right).

4. A cover over the gill called the **operculum**, which helps them breathe without having to swim.
5. The ability to see in color, unlike most other fish.

Ray-finned Fish

The ray-finned fish have fin rays, with fins supported by bony spines known as rays. The ray-finned fish are the dominant class of vertebrates, with nearly 99% of fish falling into this category. They live in all aquatic environments, from freshwater and marine environments from the deep sea to the highest mountain streams.

Lobe-finned fish

The lobe-finned fish are characterized by fleshy lobed fins, as opposed to the bony fins of the ray-finned fish. There are two types of living lobe-finned fish: the coelacanths and the lungfish. The pectoral and pelvic fins have joints resembling those of tetrapod (four-limbed land vertebrates) limbs. These fins evolved into legs of amphibians, the first tetrapod land vertebrates. They also possess two dorsal fins with separate bases, as opposed to the single dorsal fin of ray-finned fish. All lobe-finned fishes possess teeth covered with true enamel.

How Big Are Bony Fish?

The ocean sunfish is the most massive bony fish in the world, up to 11 feet long and weighing up to 5,070 pounds (**Figure** 4.12). Other very large bony fish include the Atlantic blue marlin, the black marlin, some sturgeon species, the giant grouper, and the goliath grouper. The long-bodied oarfish can easily be over 30 feet long, but is not nearly as massive as the ocean sunfish. In contrast, the dwarf pygmy goby measures only 0.6 inches. Fish can also be quite valuable. In January 2013, at an auction in Tokyo's Tsukiji fish market, a 222-kilogram (489-pound) tuna caught off northeastern Japan sold for 155.4 million yen, which is $1,760,000.

Vocabulary

- **operculum**: A hard bony flap covering and protecting the gills.
- **pectoral girdles**: Bony structure supporting the fins.
- **swim bladder**: Gas-filled organ that helps a fish to control its buoyancy.

Summary

- The bony fish are divided into two classes: ray-finned fish and lobe-finned fish.
- The bony fish are characterized by a lung or swim bladder, a cover over the gills, and bones covering the head and pectoral girdles.

FIGURE 4.12

An ocean sunfish, the most massive bony fish in the world, can reach up to 11 feet long and weigh up to 5,070 pounds!

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Bony Fish (Perch) Anatomy** at http://www.youtube.com/watch?v=pNZQEmGp11k (5:55)

MEDIA

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1. What is one of the purposes of the operculum?
2. What is the lateral line used for? Where is it located?
3. Not all fish have swim bladders, but, for those who do, what are they used for? Why do you think some fish don't have swim bladders?

Practice II

- **Pregnant Males** at http://www.youtube.com/watch?v=EaOHLQy_bjU (2:25)

MEDIA

Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57391

1. What type of fish is a seahorse?
2. What is unusual about seahorse reproduction?
3. How wide is a seahorse's field of vision? How is it so wide?
4. What do seahorses feed on?

Review

1. What is the largest group of vertebrates in existence today?
2. Name three characteristics of the bony fish?
3. What are the two classes of the bony fish?
4. What is the swim bladder?
5. What is the operculum?

4.7 Amphibians

- Describe the characteristics of the amphibians.

What were the first land vertebrates?

Amphibians! In order for water-dwelling animals to adapt to life on land, many new adaptations had to take place. First, they needed to be able to breathe air instead of obtaining oxygen from water. And fins don't work well as legs! They needed to be able to move around well on land.

Characteristics of Amphibians

What group of animals begins its life in the water, but then spends most of its life on land? Amphibians! Amphibians are a group of vertebrates that has adapted to live in both water and on land. Amphibian larvae are born and live in water, and they breathe using gills. The adults live on land for part of the time and breathe both through their skin and with their lungs.

There are approximately 6,000 species of amphibians. They have many different body types, physiologies, and habitats, ranging from tropical to subarctic regions. Frogs, toads, salamanders (**Figure** 4.13), newts, and caecilians are all types of amphibians.

How did Amphibians Adapt to Living on Land?

In order to live on land, amphibians replaced gills with another respiratory organ, the lungs. Other adaptations include:

FIGURE 4.13
One of the many species of amphibian is this dusky salamander.

- Skin that prevents loss of water.
- Eyelids that allow them to adapt to vision outside of the water.
- An eardrum developed to separate the external ear from the middle ear.
- A tail that disappears in adulthood (in frogs and toads).

Classification of the Amphibians

Like fish, amphibians are ectothermic vertebrates. They belong to the class Amphibia. There are three orders:

1. Urodela, containing salamanders and newts.
2. Anura, containing frogs and toads.
3. Apoda, containing caecilians.

Where do Amphibians Live?

Most amphibians live in fresh water, not salt water. Their habitats can include areas close to springs, streams, rivers, lakes, swamps and ponds. They can be found in moist areas in forests, meadows and marshes. Amphibians can be found almost anywhere there is a source of fresh water. Although there are no true saltwater amphibians, a few can live in brackish (slightly salty) water. Some species do not need any water at all, and several species have also adapted to live in drier environments. Most amphibians still need water to lay their eggs.

How do Amphibians Reproduce?

Amphibians reproduce sexually. The life cycle of amphibians happens in the following stages:

1. Egg Stage: Amphibian eggs are fertilized in a number of ways. **External fertilization**, employed by most frogs and toads, involves a male gripping a female across her back, almost as if he is squeezing the eggs out of her. The male releases sperm over the female's eggs as they are laid. Another method is used by salamanders, whereby the male deposits a packet of sperm onto the ground. The female then pulls it into her **cloaca**, a single

opening for her internal organ systems. Therefore, fertilization occurs internally. By contrast, caecilians and tailed frogs use **internal fertilization**, just like reptiles, birds, and mammals. The male deposits sperm directly into the female's cloaca.
2. Larval stage: When the egg hatches, the organism is legless, lives in water, and breathes with gills.
3. During the larval stage, the amphibian slowly transforms into an adult by losing its gills and growing four legs. Once development is complete, it can live on land.

Vocabulary

- **cloaca**: External opening that serves as the exit (and entrance) for the intestinal, reproductive, and urinary tracts.
- **external fertilization**: Fertilization of the egg outside the body.
- **internal fertilization**: Fertilization of the egg within the body of the female.

Summary

- Amphibians live in both water and on land; amphibian larvae are born and live in water, and they breathe using gills. The adults live on land for part of the time and breathe both through their skin and with their lungs.
- Adaptations for land in amphibians include protective skin and eyelids that allow them to adapt to vision outside of the water.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **San Diego Zoo Amphibians** at http://kids.sandiegozoo.org/animals/amphibians

1. Describe the skin of an amphibian.
2. What is metamorphosis?
3. What is meant by "ectothermic"? How does this affect an animals behavior?

Practice II

- **Respiratory Organs In Amphibians** at http://www.youtube.com/watch?v=Nfojq4ikHH0 (3:29)

MEDIA

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1. How do frogs fill their lungs?
2. Why do amphibians need less oxygen than birds or mammals?
3. How do frogs breathe when they are underwater?

Review

1. List three adaptions amphibians have for life on land?
2. List four examples of amphibians.
3. How do amphibians reproduce?
4. Describe the amphibian larval stage. What changes occur during this stage?

4.8 Salamanders

- Describe the features of salamanders.

What type of animal is this?

A salamander! You might have mistaken it for a lizard, but lizards are very different from salamanders. Salamanders have moist skin, while lizards have dry scales on their skin. Furthermore, lizards live their entire lives on land. Salamanders must reproduce in water.

Salamanders

Salamanders are characterized by slender bodies, short legs, and long tails. They are most closely related to the caecilians, little-known legless amphibians (**Figure** 4.14). Most of the animals in the salamander order look like a cross between a lizard and a frog. They have moist, smooth skin like frogs and long tails like lizards.

Salamanders are found in most moist or arid habitats in the Northern Hemisphere, but can also be found south of the equator. They live on all continents except Antarctica and Australia. Salamanders live in or near water or on moist ground, often in a swamp. Some species live in water most of their life, some live their entire adult life on land, and some live in both habitats. Some salamanders live in caves. These salamanders have pale skin and reduced eyes as they have adapted to living in complete darkness in underground pools of water.

Salamanders are **carnivorous**, eating only other animals, not plants. They will eat almost any smaller animal, such as worms, centipedes, crickets, spiders, and slugs. Some will even eat small invertebrates. Finally, salamanders have the ability to grow back lost limbs, as well as other body parts. This process is known as **regeneration**.

Salamanders have developed ways not to be eaten. Most salamanders have brightly colored, poisonous skin. The bold color tells predators not to eat the salamander. Many salamanders have glands on the back of the neck or on the

tail that give off a poisonous or bad-tasting liquid. Some species can even shed their tail during an attack and grow a new one later. Some salamanders stand high on its legs and waves its tail to scare away danger. One particular salamander, the ribbed newt, has needle-like rib tips. It can squeeze its muscles to make the rib tips pierce through its skin and into its enemy, telling the predator to stay away.

FIGURE 4.14

The marbled salamander (*left*) shows the typical salamander body plan: slender body, short legs, long tail, and moist skin. Caecilian (*right*) are a type of legless amphibian most closely related to salamanders.

How Do Salamanders Breathe?

Different salamanders breathe in different ways. In those that have gills, breathing occurs through the gills as water passes over the gill slits. Sirens keep their gills all their lives, which allows them to breathe underwater.

Species that live on land lose their gills as they grow older. These salamanders develop lungs that are used in breathing, much like breathing in mammals. Other land-living salamanders do not have lungs or gills. These are called lungless salamanders. Instead, they "breathe," or exchange gases, through their skin. This requires blood vessels that exchange gases to be spread throughout the skin.

How Big Are Salamanders?

Salamanders are generally small. However, some can reach a foot or more, as in the mudpuppy of North America. In Japan and China, the giant salamander reaches 6 feet and weighs up to 66 pounds (**Figure** 4.15).

FIGURE 4.15

The Pacific giant salamander can reach up to 6 feet in length and weigh up to 66 pounds.

Classification of Salamanders

Salamanders belong to a group of approximately 500 species of amphibians. The order Urodela, containing salamanders and newts, is divided into three suborders:

1. Giant salamanders, including the hellbender and Asiatic salamanders.
2. Advanced salamanders, including lungless salamanders, mudpuppies, and newts. Newts are salamanders that spend most of each year living on land.
3. Sirens. Sirens are salamanders that have lungs as well as gills and never develop beyond the larval stage.

Sirens have only two legs, but the other salamander species develop four legs as adults, with fleshy toes at the end of each foot. The legs on four-legged salamanders are so short that the salamander belly drags on the ground as the animal walks. Sirens have long, strong tails that are flat to help sirens swim like a fish, with the tail swinging from side to side.

Vocabulary

- **carnivorous**: Feeds on other animals.
- **regeneration**: Growing back missing body parts.

Summary

- Salamanders live in or near water or on moist ground, often in a swamp.
- Salamanders can breathe with the help of gills, lungs, or their skin surface.

Practice

Use the resources below to answer the questions that follow.

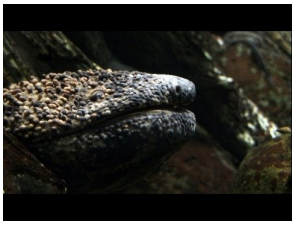
Practice I

- **Spotted Salamander** at http://animals.nationalgeographic.com/animals/amphibians/spotted-salamander/

1. Where does the spotted salamander live?
2. How does the spotted salamander discourage predators?
3. Describe the diet of the spotted salamander.

Practice II

- **Giant Salamander as Big as a Dog** at http://www.youtube.com/watch?v=buzqM1kHS5M (3:40)



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1. What led to the giant salamanders (*Andrias japonicus*) being threatened with extinction?
2. What effect have dams had on giant salamanders?
3. How does the habitat of the giant salamander differ from the habitat of the spotted salamander?

Review

1. What are the main characteristics of salamanders?
2. Where do salamanders live?
3. How do salamanders breathe?
4. Describe the salamander known as the siren.

4.9 Frogs and Toads

- Describe the characteristics of frogs and toads.

Frog or toad?

Although there is actually little difference between toads and frogs, this animal would most often be called a toad. Frogs have moist skin, while toads have dry, bumpy skin.

Frogs and Toads

Frogs and toads are amphibians in the order Anura. In terms of classification, there is actually not a big difference between frogs and toads. Frogs often have long legs that are good for hopping, skin that is smooth and moist, and special pads on their toes that help them climb. Toads are more heavyset with shorter legs, and usually have drier skin, often with warty-looking bumps. Frogs are more likely to live in or near water than toads.

Frogs are found in many areas of the world, from the tropics to subarctic regions, but most species are found in tropical rainforests. Consisting of more than 5,000 species (about 88% of amphibian species are frogs), they are among the most diverse groups of vertebrates. Frogs range in size from less than 0.5 inches in species in Brazil and Cuba to the over 1-foot (33 cm) long goliath frog of Cameroon, which can weigh up to 7 pounds. That is 1-foot from the nose to the back of the body, not including the length of the legs.

Characteristics of Frogs

Adult frogs are characterized by long hind legs, a short body, webbed finger-like parts, and the lack of a tail. They also have a three-chambered heart, as do all tetrapods except birds and mammals. Most frogs live part of the time in water and part of the time on land. They move easily on land by jumping or climbing. To become great jumpers,

frogs evolved long hind legs and long ankle bones. They also have a short backbone with only ten vertebrae. Frog and toad skin hangs loosely on the body, and skin texture can be smooth, warty, or folded.

Frogs and toads don't have fur, feathers, or scales on their skin. Instead, they have a moist and permeable skin layer covered with mucous glands. Their special skin allows them to breathe through their skin in addition to using their lungs. They are vulnerable to water loss through the skin in dry conditions, which is why they need to live near water or in moist environments. The thin layer of mucous keeps the skin moist.

In order to live on land and in water, frogs have three eyelid membranes: one is see-through to protect the eyes underwater, and the two other ones let them see on land. Frogs also have a **tympanum**, which acts like a simple ear. They are found on each side of the head. In some species, the tympanum is covered by skin.

FIGURE 4.16

A tree frog. Notice the powerful muscles in the limbs and the coverings around the eyes.

How do Frogs Reproduce?

Frogs typically lay their eggs in puddles, ponds, or lakes. Their larvae, or **tadpoles**, have gills, a tail, but no legs. Tadpoles develop into adult frogs in water (**Figure** 4.17). During this transformation, they develop lungs, lose their tails and form their four legs.

You may hear males "ribbiting," producing a mating call used to attract females to the bodies of water best for mating and breeding. Frog calls can occur during the day or night. Each frog species has a different call that is used to attract mates and warn off rivals. When a female picks a male whose call she likes, the male grabs her and squeezes across her back and around her abdomen. This causes the female to release her eggs. The male then fertilizes the eggs and, in some species, also guards them.

How Do Frogs Eat?

Adult frogs are meat-eaters and eat mostly insects, spiders, slugs and worms. Larger species will eat mice, birds, and even other small reptiles and amphibians. Frogs do not have teeth on their lower jaw, so they usually swallow their food whole. Some frogs have teeth on the upper jaw that are used to hold the prey in place.

Frogs and toads are responsible for keeping a large part of the world's insect population under control. They catch these insects using their long tongue. The frog tongue is about a third the length of the frog's body, though they can

FIGURE 4.17

Frogs develop from tadpoles, which develop from eggs. Notice the formation of the two powerful back legs used for jumping.

grow even longer. They can easily reach 12 inches long in an adult frog. Frog's tongues are attached to the front of their mouths rather than at the back like humans. They release a sticky substance at the precise moment of impact with their food. When a frog catches an insect it throws its sticky tongue out of it's mouth and wraps it around its prey. The frog's tongue then snaps back and throws the food down its throat. This happens about as fast as a blink of your eyes.

Vocabulary

- **tadpole**: Larval stage of the frogs.
- **tympanum**: Hearing organ in frogs.

Summary

- Frogs are characterized by long hind legs, webbed finger-like parts, a tympanum, and the lack of a tail.
- A frog's "ribbit" is a mating call used to attract females.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Amazing Rain Frogs - Life in Cold Blood** at http://www.youtube.com/watch?v=mISMwN-0ggE (3:30)

MEDIA
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1. Where do Rain Frogs spend most of their time?
2. How does the Rain Frog mate?
3. Why is "glue" used in Rain Frog mating? What problems can this cause?
4. Why do Rain Frogs make their nurseries?
5. How is the Rain Frog's behavior adaptive to its environment.

Practice II

- **Frogs and Toads: Red-Eyed Tree Frog's Life Cycle** at http://video.nationalgeographic.com/video/animals/amphibians-animals/frogs-and-toads/frog_greentree_lifecycle/ (2:50)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57397

1. What characteristics are important to where the red-eyed tree frog lays its eggs?

Review

1. Distinguish between frogs and toads.
2. What are three characteristics of frogs?
3. What allowed frogs to become effective jumpers?
4. Why do frogs "ribbit"?
5. Describe the frog tadpole and the changes it undergoes.

4.10 Role of Amphibians

- Describe the importance of amphibians to humans.

Would you eat this?

This is a plate of frog legs! Many people would view this dish as a tasty treat. As you can see, one way amphibians are important to people is that they can be used as a food source.

Role of Amphibians

Humans have used amphibians for a number of purposes for thousands of years, if not longer. Amphibians play significant roles in many food webs and are thus an important part of many ecosystems. Humans have also consumed amphibians, especially frogs, probably since they first ate meat. More recently, amphibians have been tremendously useful in research.

Amphibians as Foods

Amphibians play important roles in many ecosystems, especially as middle players in many food chains and food webs. In addition to consuming many worms and insects and other arthropods, and even some small reptiles and mammals and fish, they are prey for turtles and snakes, as well as some fish and birds. Tadpoles keep waterways clean by feeding on algae.

Frogs are raised as a food source for humans. Frog legs are a delicacy in China, France, the Philippines, northern Greece, and the American south, especially the Frensh-speaking parts of Louisiana. Only the upper joint of the hind leg is served, which has a single bone similar to the upper joint of a chicken or turkey wing. They are commonly

prepared by grilling or deep frying, sometimes breaded, though they can also be served with garlic, or turned into a soup or stew. Some estimates have well over a billion frogs harvested a year as food.

Amphibians in Research

Amphibians have long been used in scientific research, especially developmental and physiological processes, largely due to their unique ability to undergo metamorphosis, and in some species, to regenerate limbs.

Amphibians are also used in cloning research. **Cloning** involves making identical copies of a parent organism, and the large amphibian egg helps in this process. They are also used to study embryos because their eggs lack shells, so it is easy to watch their development.

The African clawed frog, *Xenopus laevis*, is a species that is studied to understand aspects of developmental biology. It is a good model organisms because it is easy to raise in a lab and has a large embryo, which is easy to study (**Figure** 4.18). Many *Xenopus* genes have been identified and cloned, especially those involved in development. Developing *Xenopus* embryos can be easily observed and studied with a basic microscope, though the eggs are large enough to see without a microscope. Because of their size, the exact developmental stage after fertilization can be easily determined. This allows proteins that are used at a specific developmental time to be collected and analyzed.

Many environmental scientists believe that amphibians, including frogs, indicate when an environment is damaged. When species of frogs begin to decline, it often indicates that there is a bigger problem within the ecosystem. This could have dramatic effects on food webs and ecosystems.

FIGURE 4.18

Frog embryos are often studied to better understand how development works.

Amphibians in Popular Culture

Amphibians can be found in folklore, fairy tales, and popular culture. Numerous legends have developed over the centuries around the salamander. Its name originates from the Persian words for “fire” and “within," so many of these legends are related to fire. This connection likely originates from the tendency of many salamanders to live

inside rotting logs. When placed into the fire, salamanders would escape from the logs, lending to the belief that the salamander was created from flames.

Unforgettable amphibians Kermit the Frog (**Figure** 4.19) and his popular saying "It's not easy being green." Frogger, from the video game of the same name, has been teaching children about the dangers of the road and alligator-filled moats for years. And all it takes is a kiss from a princess to turn a frog into a prince, as told in *The Frog Prince* story.

FIGURE 4.19

Kermit the Frog balloon is flown at the Annual Macy's Thanksgiving Day Parade.

Vocabulary

- **cloning**: To make an identical copy of an organism.

Summary

- Frogs are raised as a food source in many parts of the world.
- Amphibian embryos are ideal to study development since they lack a shell.

Practice

Use the resource below to answer the questions that follow.

- **Global Warming: Rocky Mountain Bio Lab: Amphibians** at http://video.nationalgeographic.com/video/environment/global-warming-environment/rm-amphibians/ (3:14)

Adobe Flash

MEDIA

Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57406

1. What is an "indicator" species? Why are amphibians considered to be good indicator species?

2. What yearly fluctuations are seen in these alpine salamander populations?

Review

1. Describe the role of amphibians in the food chain.
2. How are amphibians important in environmental science?
3. Describe one way amphibians are used in research?

4.11 Reptiles

- Describe the main features of reptiles.

What does this chameleon have in common with a snake?

Though they are both reptiles and seem very different, chameleons and snakes actually share several traits. For example, they both have skin covered in scales and are cold-blooded animals. But notice the distinct eyes and "horns" on the chameleon. Snakes don't have these. And some chameleons have the ability to change color.

Characteristics of Reptiles

What reptiles can you name? Snakes, alligators, and crocodiles are all reptiles. Modern reptiles live on every continent except Antarctica. They range in size from the newly-discovered Jaragua Sphaero (a dwarf gecko), at 0.6 inches, to the saltwater crocodile, at up to 23 feet.

There are four living orders of reptiles:

1. Squamata, which includes lizards, snakes, and amphisbaenids (or "worm-lizards").
2. Crocodilia, which includes crocodiles, gharials (**Figure** 4.20), caimans, and alligators.
3. Testudines, which includes turtles and tortoises.
4. Sphenodontia, which includes tuatara (**Figure** 4.20).

FIGURE 4.20

A gharial crocodile (*left*). A tuatara (*right*).

Traits of Reptiles

Reptiles are tetrapods (four-legged) and **ectothermic**, meaning their internal temperature depends on the temperature of their environment. This is why you may see reptiles sunbathing as they use the energy from the sun to warm their bodies. Usually the sense organs of reptiles, like ears, are well developed, though snakes do not have external ears. All reptiles have advanced eyesight. Reptiles also have a sense of smell. Crocodilians, turtles, and tortoises smell like most other land vertebrates. But, some lizards, and all snakes, smell with their tongues, which is flicked out of the mouth to pick up scent molecules from the air.

Reptiles also have several adaptations for living on land. They have a skin covered in scales to protect them from drying out. All reptiles have lungs to breathe air. Reptiles are also **amniotes**, which means their embryos are surrounded by a thin membrane. This membrane protects the embryo from the harsh conditions of living on land. Reptile eggs are also surrounded by a protective shell, which may be either flexible or inflexible.

How Do Reptiles Reproduce?

Most reptiles reproduce sexually, meaning there are two parents involved. In some families of lizards and one snake family, however, **asexual reproduction** is possible. This is when only one parent is involved in creating new life. For example, the gecko females can make tiny clones of themselves without the aid of a male.

All reptiles have a **cloaca**, a single exit and entrance for sperm, eggs, and waste, located at the base of the tail. Most reptiles lay amniotic eggs covered with leathery or hard shell. These eggs can be placed anywhere as they don't have to be in a moist environment, like the eggs of amphibians. However, not all species lay eggs, as certain species of squamates can give birth to live young.

Unlike the amphibians, there are no larval stages of development. The young reptiles look like miniature versions of the adult. The young reptiles are generally left to fend for themselves. However, some reptiles provide care for their young. For example, crocodiles and alligators may defend their young from predators.

Vocabulary

- **amniote**: Embryos are surrounded by a thin, protective membrane.
- **asexual reproduction**: Reproduction involving only one individual.
- **cloaca**: External opening that serves as the exit (and entrance) for the intestinal, reproductive, and urinary tracts.
- **ectothermic**: Having an internal temperature that depends on the temperature of their environment.

Summary

- Reptiles are also amniotes, which means their embryos are surrounded by a thin membrane.

- Reptiles typically reproduce sexually and lay eggs.

Practice

Use the resources below to answer the questions that follow.

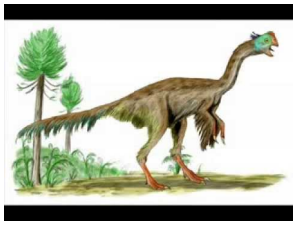
Practice I

- **Fun Facts About reptiles and Amphibians** at http://nationalzoo.si.edu/animals/reptilesamphibians/facts/

1. Which continent does not have any reptiles?
2. Compare the amount of food eaten by reptiles and birds and mammals.
3. Name three poisonous snakes found in the United States.
4. What is the largest venomous snake anywhere?

Practice II

- **Greatest Misconception 1: Birds Evolved from Dinosaurs** at http://www.youtube.com/watch?v=EUBcHOYls20 (2:06)



MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/117081

1. How does the stance of reptiles compare to the stance of birds?
2. Compare and contrast modern reptiles to modern birds. Include as many characteristics for both groups as you can.
3. Do ancient "reptiles" have all the same characteristics as present day reptiles? Explain your answer fully.

Review

1. Name four examples of reptiles.
2. What is ectothermic?
3. What are the reptilian adaptations for life on land?
4. Compared to the amphibian egg, what is special about the reptile egg?

4.12 Lizards and Snakes

- Describe the major traits of lizards and snakes.

Are snakes deadly?

Some snakes are poisonous, but the majority of snakes are fairly harmless if they are left alone. This rat snake is actually beneficial to humans because it eats mice and rats, keeping those populations in balance. Some related species are so tame that they are often kept as pets.

Lizards and Snakes

Lizards and snakes belong to the largest order of reptiles, Squamata. Lizards are a large group of reptiles, with nearly 5,000 species, living on every continent except Antarctica.

Characteristics of Lizards and Snakes

Lizards and snakes are distinguished by scales or shields and movable **quadrate bones**, which make it possible to open the upper jaw very wide. Quadrate bones are especially visible in snakes, because they are able to open their mouths very wide to eat large prey (**Figure** 4.21).

Characteristics of Lizards

Key features of lizards include:

- Four limbs.
- External ears.

FIGURE 4.21
A corn snake swallowing a mouse.

- Movable eyelids.
- A short neck.
- A long tail, which they can shed in order to escape from predators.
- They eat insects.

Vision, including color vision, is well-developed in lizards. You may have seen a lizard camouflaged to blend in with its surroundings. Since they have great vision, lizards communicate by changing the color of their bodies. They also communicate with chemical signals called **pheromones**.

Adult lizards range from one inch in length, like some Caribbean geckos, to the nearly 10-foot-long Komodo dragon (**Figure** 4.22).

FIGURE 4.22
A Komodo dragon, the largest of the lizards, attaining a length of ten feet. Komodo dragons will eat just about anything and they often attack deer, goats, pigs, dogs and, occasionally, humans.

With 40 lizard families, there is an extremely wide range of color, appearance, and size of lizards. Many lizards are capable of regenerating lost limbs or tails. Almost all lizards are **carnivorous**, meaning they eat animals, although most are so small that insects are their primary prey. However, some have reached sizes where they can prey on birds and mammals. On the other hand, a few species of lizards exclusively eat plants.

Lizard Behavior

Many lizards are good climbers or fast sprinters. Some can run on two feet, such as the collared lizard. Some, like the basilisk, can even run across the surface of water to escape danger. Many lizards can change color in response to their environments or in times of stress (**Figure** 4.23). The most familiar example is the chameleon, but more subtle color changes can occur in other lizard species.

FIGURE 4.23

A species of lizard, showing general body form and camouflage against background.

Legless Lizards

Some lizard species, including the glass lizard and flap-footed lizards, have evolved to lose their legs, or their legs are so small that they no longer work. This provides these species an evolutionary advantage in their way of life. Legless lizards almost look like snakes, though structures leftover from earlier stages of evolution remain. For example, flap-footed lizards can be distinguished from snakes by their external ears.

Characteristics of Snakes

Snakes are different from legless lizards because they do not have eyelids, limbs, external ears, or forelimbs. The more than 2,700 species of snake can be found on every continent except Antarctica and range in size from the tiny, 4-inch-long thread snake to pythons, to the over 17-foot-long anaconda (**Figure** 4.24).

In order to fit inside of snakes' narrow bodies, paired organs, such as kidneys, appear one in front of the other instead of side by side. Snakes' eyelids are transparent "spectacle" scales which remain permanently closed. Most snakes are not venomous, but some have venom capable of causing painful injury or death to humans. However, snake venom is primarily used for killing prey rather than for self-defense.

Most snakes use specialized belly scales, which grip surfaces to move (**Figure** 4.25). In the shedding of scales, known as **molting**, the complete outer layer of skin is shed in one layer (**Figure** 4.26). Molting replaces old and worn skin, allows the snake to grow, and helps it get rid of parasites such as mites and ticks.

Although different snake species reproduce in different ways, all snakes use **internal fertilization,** where fertilization of the egg takes place inside the female. The male uses sex organs stored in its tail to transfer sperm to the female. Most species of snakes lay eggs, and most species abandon these eggs shortly after laying them.

FIGURE 4.24
A species of anaconda, one of the largest snakes, which can be as long as 17 feet.

FIGURE 4.25
A close-up of scales on a scarlet kingsnake, showing a tricolored pattern of red, black, and white bands. Notice the distinction between the belly scales and the rest of the snake's scales.

How do Snakes Eat?

All snakes are strictly carnivorous, eating small animals including lizards, other snakes, small mammals, birds, eggs, fish, snails, or insects. Because snakes cannot bite or tear their food to pieces, prey must be swallowed whole. Therefore, the body size of a snake has a major influence on its eating habits.

The snake's jaw is unique in the animal kingdom. Snakes have a very flexible lower jaw, the two halves of which are not rigidly attached. They also have many other joints in their skull, allowing them to open their mouths wide enough to swallow their prey whole.

FIGURE 4.26
A Centralian carpet python shedding its skin.

Some snakes have a venomous bite, which they use to kill their prey before eating it. Other snakes kill their prey by strangling them, and still others swallow their prey whole and alive. After eating, snakes enter a resting stage, while the process of digestion takes place. The process is highly efficient, with the snake's digestive enzymes dissolving and absorbing everything but the prey's hair and claws!

Vocabulary

- **carnivorous**: Eating other animals.
- **internal fertilization**: Fertilization of the egg within the body of the female.
- **molting**: Shedding of the complete outer layer of skin; this helps snakes get rid of parasites, such as mites and ticks.
- **pheromones**: Chemical signal that alters the behavior of other animals of the same species.
- **quadrate bones**: Part of the skull and jaw; in snakes, it is elongated and very mobile, allowing them to swallow very large prey.

Summary

- Snakes and lizards are both in the order Squamata, distinguished by horny scales or shields and movable quadrate bones, which make it possible to open the upper jaw very wide.
- Snakes are different from legless lizards because they do NOT have eyelids, limbs, external ears, or forelimbs.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Lizards, Snakes, and Poisonous Animals Roaming the Deserts of Australia** at http://www.youtube.com/watch?v=bWfslaxznGw (3:01)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57369

1. How many species of reptiles can be supported by a single sand dune in the Australian desert?
2. Are there more mammals or reptiles in the Australian desert?
3. How does the physiology of reptiles and mammals explain their observed abundances in the Australian desert?
4. Where do goanna lizards (*Varanus spp.*) lay their eggs? What about the environment they live in leads them to choose this location?

Practice II

- Go to this link to see how a Komodo dragon (*Varanus komodoensis*) hunts: http://dsc.discovery.com/tv-shows/life/videos/komodo-dragons-hunt-buffalo.htm

1. Would the hunting strategy of a Komodo dragon be effective for mammals? Explain and defend your answer

Practice III

- **Amazing Arctic Snakes Mating and Fighting - Deadly Vipers** at http://www.youtube.com/watch?v=7TF7d4jvays (3:50)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57370

1. How many months a year are snakes active above the Arctic Circle?
2. Why is black a good color for snakes above the Arctic Circle? How does this explain why the black snakes tend to be bigger than the zigzag patterned snakes?
3. Why is it advantageous for females above the Arctic Circle to be black? Consider how this impacts their reproductive success.

Review

1. List three characteristics of lizards.
2. How are snakes different from legless lizards?
3. How do snakes eat? Describe the snake jaw.

4.13 Alligators and Crocodiles

- Describe the features of alligators and crocodiles.

Crocodile or Alligator?

This picture is a crocodile, identified by it's V-shaped snout. Alligators have more of a U-shaped snout. Although crocodiles and alligators have a few differences, they are very much alike and belong to the same order, Crocodilia.

Alligators and Crocodiles

Crocodilia, containing both alligators and crocodiles, is an order of large reptiles. Reptiles belonging to Crocodilia are the closest living relatives of birds. Reptiles and birds are the only known living descendants of the dinosaurs.

The basic crocodilian body plan (**Figure** 4.27) is a very successful one and has changed little over time. Modern species actually look very similar to their Cretaceous ancestors of 84 million years ago. All species of crocodilians have similar body structures, including an elongated snout, powerful jaws, muscular tail, large protective scales, streamlined body, and eyes and nostrils that are positioned on top of the head.

Characteristics of Crocodiles

Crocodilians have a flexible, semi-erect posture. They can walk either in a low, sprawled "belly walk," or hold their legs more directly underneath them to perform the "high walk." Most other reptiles can only walk in a sprawled position.

All crocodilians have, like humans, teeth set in bony sockets. But unlike mammals, they replace their teeth throughout life. Crocodiles and gharials (large crocodilians with longer jaws) have salivary glands on their tongue, which are used to remove salt from their bodies. Crocodilians are often seen lying with their mouths open, a behavior called **gaping**. One of its functions is probably to cool them down.

FIGURE 4.27
Nile crocodiles display the basic crocodilian body plan.

Crocodilians are known to swallow stones, known as **gastroliths**, which help digest their prey. The crocodilian stomach is divided into two chambers. The first is powerful and muscular. The other stomach is the most acidic digestive system of any animal. It can digest mostly everything from their prey, including bones, feathers, and horns!

All crocodilians are carnivores. They feed on live animals such as birds, small mammals and fish. Crocodilians use several methods of attack when pursuing live prey. One approach is that of the ambush. The crocodilian lies motionless beneath the water's surface with only their nostrils above the water line. This keeps them concealed while they watch for prey that approaches the water's edge. The crocodilian then lunges out of the water, taking their prey by surprise and dragging it from the shoreline into deep water where the prey is killed.

The sex of developing crocodilians is determined by the temperature of the eggs during **incubation**, when eggs are kept warm before they hatch. This means that the sex of crocodilians is not determined genetically. If the eggs are kept at a cold or a hot temperature, then their offspring may be all male or all female. To get both male and female offspring, the temperature must be kept within a narrow range.

Female crocodilians care for the young after they hatch, providing them with protection until they grow large enough to defend themselves. In many species of crocodilians, the female carries her tiny offspring in her mouth.

Evolving More Complex Structures

Like all reptiles, crocodilians have a relatively small brain, but the crocodilian brain is more advanced than those of other reptiles. Because of their aquatic habitat, the eyes, ears, and nostrils are all located on the same "face" in a line one after the other.

The crocodiles have advanced sensory organs. They see well during the day and may even have color vision, and they also have excellent night vision. A third transparent eyelid, the **nictitating membrane**, protects their eyes underwater. The eardrums are located behind the eyes and are covered by a movable flap of skin. This flap closes, along with the nostrils and eyes, when they dive. This prevents water from entering their external head openings. Their jaws are covered with **sensory pits**, which hold bundles of nerve fibers that respond to the slightest disturbance in surface water. Crocodiles can detect vibrations and small pressure changes in water. This makes it possible for

them to sense prey and danger even in total darkness.

Like mammals and birds, and unlike other reptiles, crocodiles have a four-chambered heart. But, unlike mammals, blood with and without oxygen can be mixed.

See *Supersize Crocs* at http://www.pbs.org/wnet/nature/episodes/supersize-crocs/interactive-crocodile-anatomy/1747/ for additional material on the anatomy of a crocodile.

Vocabulary

- **gaping**: Lying with the mouth open, possibly to cool down.
- **gastroliths**: Swallowed stones in the stomach that aid in digestion.
- **incubation**: Keeping eggs warm before they hatch.
- **nictitating membrane**: Transparent eyelid that protects the eyes.
- **sensory pits**: Nerve fibers that respond to vibrations.

Summary

- Crocodilians swallow stones, known as gastroliths, which help digest their prey.
- The sex of developing crocodilians is determined by the temperature of the eggs during incubation.
- The crocodiles have advanced sensory organs, including keen eyesight, eardrums, and sensory pits that detect disturbances in the water.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **American Alligator** at http://animals.nationalgeographic.com/animals/reptiles/american-alligator/

1. Where do American alligators live?
2. What do alligators eat?
3. What conditions have led to the recovery of the American alligator?

Practice II

- **Bubble-Blowing Saltwater Crocodiles** at http://www.youtube.com/watch?v=5OntFsIwGEw (1:53)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57387

1. In what kind of courting displays do saltwater crocodiles (*Crocodylus porosus*) engage?
2. Do saltwater crocodiles have internal or external fertilization?

Practice III

- **Baby Siamese Crocodiles** at http://www.youtube.com/watch?v=CUQMkS8Et2s (4:05)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57388

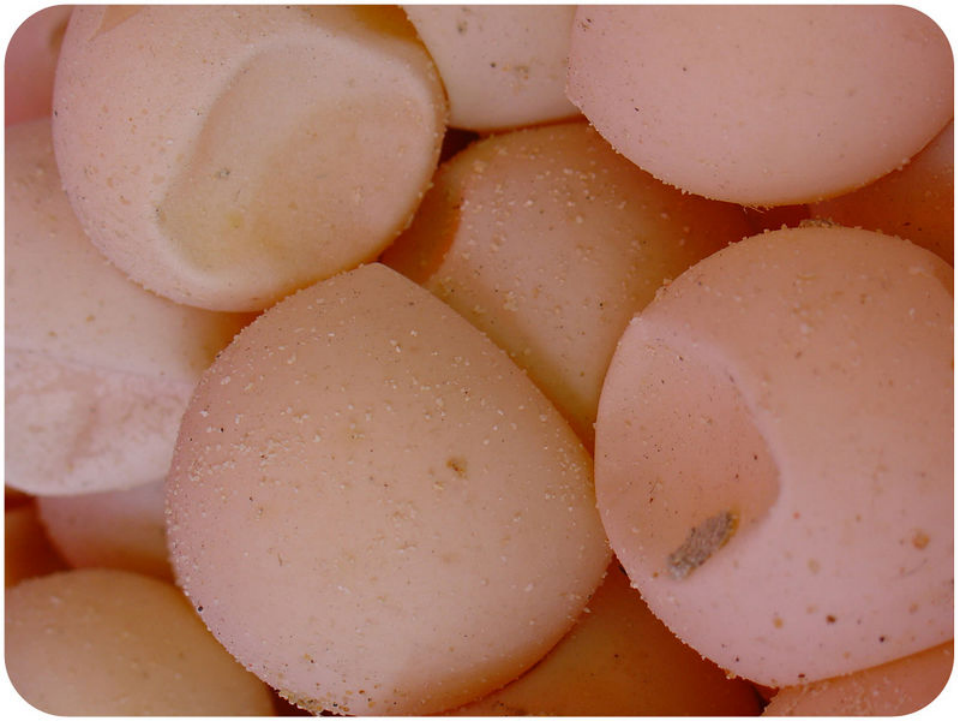
1. What kind of maternal care do crocodile mothers show their young? When does this care begin?
2. What do baby crocodiles do as soon as they hatch?
3. Why is it important for mother crocodiles to guard their nests?

Review

1. Name four features that all crocodilians share.
2. How is the sex of alligators and crocodiles determined?
3. Describe digestion in the crocodilians.
4. Describe the special sensory organs of crocodiles.

4.14 Turtles

- Describe the features of the turtles.



What are these?

This picture might look like a bunch of ping-pong balls, but actually it's a picture of turtle eggs. Notice the soft, leathery shell that is typical of reptile eggs.

Turtles

Turtles are reptiles in the order Testudines. If you have seen turtles before, what is the most noticeable thing about them? Their shells. Most turtle bodies are covered by a special shell developed from their ribs. Their shells can be bony or **cartilaginous**, made from a more flexible supportive tissue. About 300 species are alive today, and some are highly endangered. Like other reptiles, turtles cannot regulate their body temperature, except with behavioral means, such as burrowing underground. The major difference between turtles and tortoises is that the land dwelling ones are called Tortoises and water dwelling are called Turtles.

Turtles are broken down into two groups, based on how they bring their neck back into their shell:

1. Cryptodira, which can draw their neck inside and under their spine.
2. Pleurodira, which fold their necks to one side.

Characteristics of Turtles

Although many turtles spend large amounts of their lives underwater, they can also spend much of their lives on dry land and breathe air. Turtles cannot breathe in water, but can hold their breath for long periods of time. Turtles must

surface at regular intervals to refill their lungs.

The position of a turtle's eyes can give a clue to their natural habitat. Most turtles that spend most of their lives on land have their eyes looking down at objects in front of them. Some aquatic turtles, such as snapping turtles and soft-shelled turtles, have eyes closer to the top of the head. These species of turtles can hide from predators in shallow water, where they lie entirely submerged in water except for their eyes and nostrils.

Sea turtles (**Figure** 4.28) have glands near their eyes that produce salty tears, which remove excess salt taken in from the water they drink.

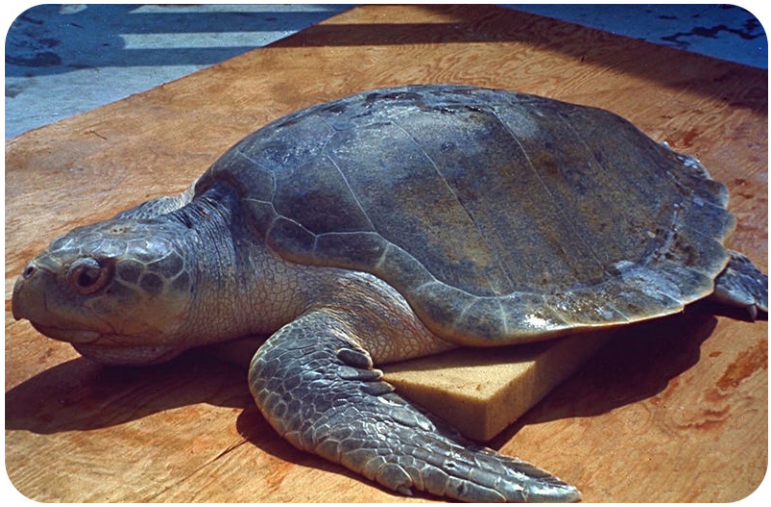


FIGURE 4.28

A species of sea turtle, showing placement of eyes, shell shape, and flippers.

Turtles have exceptional night vision due to the unusually large number of cells that sense light in their eyes. Turtles also have color vision.

Turtles don't lay eggs underwater. Turtles lay slightly soft and leathery eggs, like other reptiles. The eggs of the largest species are spherical, while the eggs of the rest are longer in shape. After internal fertilization, a female is ready to lay her eggs, she places a large numbers of eggs in holes dug into mud or sand. They are then covered and left to grow and develop by themselves. When the turtles hatch, they squirm their way to the surface and head toward the water. They need to get to the water as fast as possible before they are fed upon by animals such as seabirds, crabs, and raccoons.

How do Turtles Eat?

Turtles can be either herbivores or carnivores, with most sea turtles **carnivorous**. Turtles have a rigid beak and use their jaws to cut and chew food. Instead of teeth, the upper and lower jaws of the turtle are covered by horny ridges. Carnivorous, or animal-eating turtles usually have knife-sharp ridges for slicing through their prey. But as the turtle is not a very fast animal, and it cannot quickly turn its head to snap at prey, it does have some limitations. Sea turtles typically feed on jellyfish, sponges and other soft-bodied organisms. Some species of sea turtle with stronger jaws, eat shellfish while some species, such as the green sea turtle do not eat any meat at all. Herbivorous turtles have serrated ridges that help them cut through tough plants.

How Big Are Turtles?

The largest turtle is the great leatherback sea turtle (**Figure** 4.29), which can have a shell length of seven feet and can weigh more than 2,000 pounds. The only surviving giant tortoises are on the Seychelles and Galápagos Islands and

can grow to over four feet in length and weigh about 670 pounds (**Figure** 4.30). The smallest turtle is the speckled padloper tortoise of South Africa, measuring no more than three inches in length, and weighing about five ounces. The largest ever turtle was the know extinct *Archelon* genus, a Late Cretaceous sea turtle known to have been up to 15 ft long, and 16 ft wide from flipper to flipper. The closest living relative of this genus is the leatherback sea turtle.

FIGURE 4.29

The leatherback turtle can reach up to seven feet in length and weigh over 2,000 pounds.

FIGURE 4.30

A giant tortoise can grow to over feet ft in length and weigh about 670 lb. These animals can easily live over 100 years, spending their days grazing on grass, leaves, and cactus, basking in the sun, and napping nearly 16 hours each day.

Vocabulary

- **carnivorous**: Eating other animals.
- **cartilaginous**: Made of a flexible, supportive tissue.

Summary

- Most turtle bodies are covered by a special bony or cartilaginous shell developed from their ribs.
- Turtles cannot breathe in water, although many turtles spend large amounts of their lives underwater.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **A Moment of Science** at http://www.youtube.com/watch?v=963t4MN80eM (1:25)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57394

1. How does cloacal respiration work?
2. Why is this sort of respiration vital for the turtles?

Practice II

- **The Leatherback Turtles and Ocean Currents** at http://www.youtube.com/watch?v=mPH8LI_EgPk (4:06)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57395

1. How many populations of leatherback turtles (*Dermochelys coriacea*) are there in the Pacific Ocean?
2. Why do scientists feel that beaches like Playa Grande are important to the survival of this species?
3. How could natural selection explain why leatherback turtles favor beaches like Playa Grande?

Review

1. How are turtles divided into two groups?
2. How and what do turtles eat?
3. Do turtles breath underwater? Explain.

4.15 Importance of Reptiles

- Describe how reptiles are important to humans.

What good are reptiles?

There is a lot of fear surrounding snakes and other reptiles. What you might not realize is that reptiles do a lot of good. For example, snakes eat rats and other small animals. Rats can carry diseases to people, so keeping their population under control is very important.

Importance of Reptiles

Reptiles play an important role in the life of humans. In addition to playing an important role in many food chains, which keep the populations of small animals under control, reptiles serve as food, pets, and have played roles in art and culture for thousands of years.

Reptiles as Food

Reptiles are important as food sources for people:

- Green **iguanas**, a type of large lizard, are eaten in Central America.
- The tribals of Irulas from Andhra Pradesh and Tamil Nadu in India are known to eat some of the snakes they catch.
- Cantonese snake soup is consumed by local people in the fall to prevent colds. The soup is believed to warm up their body of those who eat it.
- Cooked rattlesnake meat is commonly consumed in parts of the Midwestern United States.
- Turtle soup is consumed throughout the world.

Reptiles as Pets

Reptiles also make good pets. In the Western world, some snakes, especially less aggressive species, like the ball python or corn snake, are kept as pets. Turtles, particularly small land-dwelling and freshwater turtles, are also common pets. Among the most popular are Russian tortoises, Greek spur-thighed tortoises, and terrapins. Large constrictor snakes like pythons, boa constrictors, and anacondas are powerful wild animals capable of killing an adult human, and they are commonly kept as pets. Many people don't think this is a wise idea, as these reptiles pose dangerous threats to people, especially children.

Reptiles are capable of recognizing people by voice, sight and smell; many are capable of learning. Some species actually benefit from interaction with humans. When cared for properly, all live as long or longer than mammalian pets of similar size. Having a reptile as a pet, you get to learn about everything from adaptation, behavior and the environment, to nutrition, camouflage and reproductive strategies. Learning about the natural history and proper captive care of these animals just might change your world outlook and get you thinking more about the environment as a whole.

Keep in mind that if you want to have a snake as a pet, that there are no herbivorous snakes, and you must be willing to feed it a proper diet. Be prepared to feed your snake or other reptile mice, rats, birds' eggs, insects, or fish. And these need to be served raw. Of course, the herbivorous reptiles, such as the green iguanas and some tortoises, are much easier to feed. They eat foods such as chopped collard greens, romaine lettuce, chopped squash and bananas.

Reptiles in Art and Culture

Finally, reptiles play a significant role in folklore, religion, and popular culture. The Moche people of ancient Peru worshipped reptiles and often put lizards in their art. Snakes or serpents are connected to healing and to the Devil. Since snakes shed and then heal again, they are a symbol of healing and medicine, as shown in the **Rod of Asclepius** (**Figure** 4.31). In Egyptian history, the Nile cobra is found on the crown of the pharaoh. This snake was worshiped as one of the gods.

FIGURE 4.31

The Rod of Asclepius, where the snake is a symbol of healing and medicine.

Reptiles have also played roles in more recent popular culture. Unforgettable reptiles include Leonardo, Donatello, Michaelangelo, and Raphael, otherwise known as the Teenage Mutant Ninja Turtles, and Godzilla, one of the most famous movie reptiles who has been terrorizing Japanese cities for years. Dino, from *The Flintstones* is one of the

more lovable television reptiles. On the other hand is Nagini from the *Harry Potter* series. This tremendously long snake (roughly 12 feet) is difficult to forget as she was very important to Lord Voldemort. Though her appearances are far and few between, her unwavering loyalty to the Dark Lord makes her one of the more infamous reptiles.

Vocabulary

- **iguana**: Large lizard native to tropical areas of Mexico, Central America, and the Caribbean.
- **Rod of Asclepius**: Symbol of healing and medicine featuring a serpent-entwined rod.

Summary

- Reptiles are eaten as food and kept as pets.
- Reptiles have served as symbols in folklore, religion, and popular culture.

Practice

Use the resource below to answer the questions that follow.

- **From Hairy Feet to High Tech** at http://www.youtube.com/watch?v=uEYcY7WfDTY (5:46)

MEDIA
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URL: http://www.ck12.org/flx/render/embeddedobject/57403

1. Explain how gecko lizards can climb walls and walk across ceiling?
2. What do you find on the tips of the hairs on geckos' feet? Why are these important to their climbing ability?
3. What is gecko tape?
4. What uses can you imagine for gecko tape? List two uses.

Review

1. What would be the downside if you exterminated all snakes?
2. What dangerous snakes are kept as pets? Why is this not a good idea?
3. What reptile is your favorite? Why?

4.16 Birds

- Describe the characteristics of birds and their adaptations for flight.

Can all birds fly?

No, not all birds can fly. And not all birds have wings. This penguin is a good example. Their wings have evolved into flippers, adapted for swimming instead of flying. The kiwi of New Zealand is another bird without wings.

Characteristics of Birds

How many different types of birds can you think of? Robins, ostriches, hummingbirds, chickens, and eagles. All of these are birds, but they are very different from one another. There is an amazingly wide variety of birds.

Like amphibians, reptiles, mammals, and fish, birds are **vertebrates**. What does that mean? It means they have a backbone. Almost all birds have forelimbs modified as wings, but not all birds can fly. In some birds, the wings have evolved into other structures.

Birds are in the class Aves. All birds have the following key features: they are **endothermic** (warm-blooded), have two legs, and lay eggs.

Birds range in size from the tiny two-inch bee hummingbird to the nine-foot ostrich (**Figure** 4.32). With approximately 10,000 living species, birds are the most numerous vertebrates with four limbs. They live in diverse habitats around the globe, from the Arctic to the Antarctic.

FIGURE 4.32

The ostrich can reach a height of nine feet! Pictured here is an ostrich with her young in the Negev Desert, southern Israel.

Features of Birds

The digestive system of birds is unique, with a **gizzard** that contains swallowed stones for grinding food. Birds do not have teeth. What do you think the stones do? They help them digest their food. Defining characteristics of modern birds also include:

- Feathers.
- High metabolism.
- A four-chambered heart.
- A beak with no teeth.
- A lightweight but strong skeleton.
- Production of hard-shelled eggs.

Which of the above traits do you think might be of importance to flight?

Adaptations for Flight

In comparing birds with other vertebrates, what do you think distinguishes them the most? In most birds, flight is the obvious difference. Birds have adapted their body plan for flight:

- Their skeleton is especially lightweight, with large, air-filled spaces connecting to their respiratory system.
- Their neck bones are flexible. Birds that fly have a bony ridge along the breastbone that the flight muscles attach to (**Figure** 4.33). This allows them to remain stable in the air as they fly.
- Birds also have wings that function as an **aerofoil**. The surface of the aerofoil is curved to help the bird control and use the air currents to fly. Aerofoils are also found on planes.

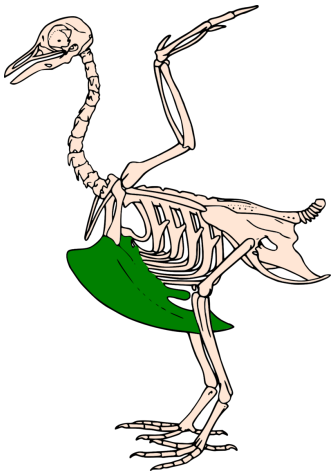


FIGURE 4.33

A bony ridge along the breastbone (green) allows birds to remain stable as they fly.

What other traits do you think might be important for flight? Feathers help because they're more lightweight than scales or fur. A bird's wing shape and size will determine how a species flies. For example, many birds have powered flight at certain times, requiring the flapping of their wings, while at other times they soar, using up less energy (**Figure** 4.34).

FIGURE 4.34

One bird's flight.

About 60 living bird species are flightless, such as penguins, as were many extinct birds. Flightlessness often evolves when birds live on isolated islands. The absence of land predators might make flying no longer necessary. Other birds evolved into new niches where flying was no longer necessary. This may have been in response to limited resources. For example, the flightless cormorant can no longer fly, but its wings are now adapted to swim in the sea (**Figure** 4.35).

FIGURE 4.35
A flightless cormorant can no longer fly, but it uses its wings for swimming.

Vocabulary

- **aerofoil**: Device that provides lift for birds or a plane in flight.
- **endothermic**: Generating heat to maintain body temperature; warm-blooded.
- **gizzard**: An organ found in the digestive system.
- **vertebrate**: Animal with a backbone.

Summary

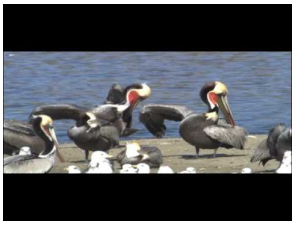
- Birds are endothermic (warm-blooded), have beaks, and lay eggs.
- Adaptations for flight include a lightweight skeleton and flexible neck bones.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Birds Vertebrates** at http://www.youtube.com/watch?v=jGkP7IrDp_4 (5:19)



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1. What benefits do birds gain from being able to fly?

2. Where do you see scales on birds?
3. What do scientists think was the first use of feathers?
4. How are the feathers of birds similar to the fur of mammals? Consider this question in terms of form and function.
5. How do the oxygen requirements of birds differ from the oxygen requirements of reptiles? Why does this difference exist?

Practice II

- **Emperor Penguin** at http://animals.nationalgeographic.com/animals/birds/emperor-penguin/

1. Where do Emperor penguins live?
2. How do they conserve warmth?
3. What do they eat?

Review

1. Can all birds fly?
2. What are three key features of birds?
3. What is unique about a bird's digestive system?
4. How are birds adapted for flight?

4.17 Bird Reproduction

- Describe how birds reproduce and how parents care for offspring.

Why do peacocks have huge, bright feathers?

Male peacocks use their colorful feathers to attract females. Females tend to mate with the males with the largest, brightest feathers. A large, bright tail indicates the male is healthy and likely to produce healthy offspring. You've probably also heard birds "sing." Eagles do aerial acrobatics and tumbling. These are other ways to attract mates.

Reproduction in Birds

How do birds reproduce? We know that chickens lay eggs. But how do they do that?

It all starts with behavior aimed at attracting a mate. In birds, this will involve a type of display, usually performed by the male. Some displays are very elaborate and may include dancing, aerial flights, or wing or tail drumming. Most male birds also sing a type of song to attract females. If they are successful at attracting a female, it will lead to breeding.

Birds reproduce by **internal fertilization**, during which the egg is fertilized inside the female. Like reptiles, birds have **cloaca**, or a single exit and entrance for sperm, eggs, and waste. The male brings his sperm to the female cloaca. The sperm fertilizes the egg. Then the hard-shelled egg develops within the female. The hard-shelled eggs have a fluid-filled **amnion**, a thin membrane forming a closed sac around the embryo. Eggs are usually laid in a nest.

Protecting Offspring

Why do you think eggs come in so many different colors? Birds that make nests in the open have camouflaged eggs (**Figure** 4.36). This gives the eggs protection against predation. Some species, like ground-nesting nightjars, have

pale eggs, but the birds camouflage the eggs with their feathers.

To protect their young, different species of birds make different nests. Birds of all types, from hummingbirds to ostriches, make nests. Many can be elaborate, shaped like cups, domes, plates, mounds, or burrows. However, some birds, like the common guillemot, do not use nests. Instead, they lay their eggs on bare cliffs. Emperor penguins do not have a nest at all; they sit on eggs to keep them warm before they hatch, a process called **incubation**.

How else might a bird help protect its young from predators? Most species locate their nests in areas that are hidden, in order to avoid predators. Large birds, or those that nest in groups, may build nests in the open, since they are more capable of defending their young.

FIGURE 4.36

Nest and eggs of the common moorhen, showing camouflaged eggs.

Parental Care

In birds, 90% to 95% of species are **monogamous**, meaning the male and female remain together for breeding for a few years or until one mate dies. Birds of all types, from parrots to eagles and falcons, are monogamous. Usually, the parents take turns incubating the eggs. Birds usually incubate their eggs after the last one has been laid. In **polygamous** species, where there is more than one mate, one parent does all of the incubating. The wild turkey is an example of a polygamous bird.

The length and type of parental care varies widely amongst different species of birds. At one extreme, in a group of birds called the magapodes (which are chicken-like birds), parental care ends at hatching. In this case, the newly-hatched chick digs itself out of the nest mound without parental help and can take care of itself right away. These birds are called **precocial**. Other precocial birds include the domestic chicken and many species of ducks and geese. At the other extreme, many seabirds care for their young for extended periods of time. For example, the chicks of the Great Frigatebird receive intensive parental care for six months, or until they are ready to fly, and then take an additional 14 months of being fed by the parents (**Figure** 4.37). These birds are the opposite of precocial birds and are called **altricial**.

In most animals, male parental care is rare. But it is very common in birds. Often both parents share tasks such as defense of territory and nest site, incubation, and the feeding of chicks. Since birds often take great care of their young, some birds have evolved a behavior called **brood parasitism.** This happens when a bird leaves her eggs in another bird's nest. The host bird often accepts and raises the parasite bird's eggs.

FIGURE 4.37

Great Frigatebird adults are known to care for their young for up to 20 months after hatching, the longest in a bird species. Here, a young bird is begging for food.

Vocabulary

- **altricial**: Hatched in an undeveloped state; offspring require extensive care from parents.
- **amnion**: Thin membrane forming a closed sac around the embryo.
- **brood parasitism**: When a bird of one species lays its eggs in the nest of a bird of another species.
- **cloaca**: Single exit and entrance for sperm, eggs, and waste.
- **incubation**: Act of a bird sitting on the eggs to warm them.
- **internal fertilization**: Fertilization of the egg within the body of the female.
- **monogamous**: Having exclusively one mate at a time.
- **polygamous**: Having more than one mate at a time.
- **precocial**: Hatched in a well-developed state; able to feed itself and be independent almost immediately.

Summary

- Birds often use flashy displays to attract mates.
- Breeding in birds is through internal fertilization, where the egg is fertilized inside the female.
- Birds generally are monogamous, and both parents help to care for the young.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Male Birds Show Off** at http://www.youtube.com/watch?v=gqsMTZQ-pmE (3:24)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57365

1. Describe two of the displays used by male pheasants to attract females.
2. Why might a display be dangerous for the African widow bird?
3. Why do you think birds maintain mating displays which are dangerous to them? What benefit do they seem to gain?

Practice II

- **Reproduction in Fish and Birds** at http://www.youtube.com/watch?v=jGnTTcVA5xk (5:07)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57366

1. Do you think that the complexity of birds' mating behavior is reflective of their intelligence? Explain your response.
2. How long do mated bird pairs stay together?
3. Why is parental care by both parents important for some birds?

Review

1. What are examples of displays used by birds to attract mates?
2. Describe parental care of offspring in birds.
3. Distinguish between altricial and precocial birds.
4. Give three examples of precocial birds.
5. What is brood parasitism?

4.18 Diversity of Birds

- Describe how birds can vary.

How are birds different?

Not all birds look the same. They are obviously different in many ways. They come in all colors and sizes. They live in a variety of habitats. They eat a variety of foods.

Diversity of Birds

Turkey, hummingbird, penguin, parrot, owl and eagle. These are just some of the many different types of birds. If you just think about the birds in this list, the differences are striking. About 10,000 bird species belong to 29 different orders within the class Aves. They live and breed on all seven continents. The tropics are home to the greatest biodiversity of birds. The diversity among birds is striking. Birds can vary greatly in size and color. Some fly, some swim, some just walk or run. Some are savage carnivores, others are gentle herbivores. Some are low on the food chain, others are at the top.

Birds live in a variety of different habitats. Birds that live in different habitats will encounter different foods and different predators. Birds can be **carnivores** (feeding on other animals), **herbivores** (feeding on plants), or **generalists** (feeding on a variety of foods). The lifestyle of the bird can affect what it looks like. For example, can you think of some examples of beaks that are adapted to the type of food a bird eats? Carnivorous birds include hawks, falcons, eagles, osprey, vultures and owls. Herbivorous birds include the goose, cockatoo and parrot. The American Crow is an example of a generalist. In addition, a specialist is a bird (or other animal) that is specially adapted to eat a certain food. An example of a specialist is a hummingbird, whose long, thin beak is excellent for reaching into flowers for nectar, but not very good for eating other foods.

Waterfowl are birds that live on the water. These include ducks, geese, swans, and pelicans, to name a few. Landfowl are ground-feeding birds such as chickens and turkeys. Penguins are a group of flightless birds adapted for life in the water with flippers. Diurnal raptors are birds of prey that hunt during the day. These include falcons, eagles and hawks. Nocturnal raptors hunt during the night. These include various types of owls. Parrots are brightly colored and very intelligent. They are found in the tropics and include cockatoos, parrots, and parakeets.

Beaks

The size and shape of the beak is related to the food the bird eats and can vary greatly among different birds. Parrots have down-curved, hooked bills, which are well-adapted for cracking seeds and nuts (**Figure** 4.38). Hummingbirds, on the other hand, have long, thin, pointed bills, which are adapted for getting the nectar out of flowers (**Figure** 4.38). Hawks, eagles, falcons and owls have a sharp, hooked beak.

FIGURE 4.38

(*left*) The down-curved, hooked bill of a scarlet macaw, a large colorful parrot. (*right*) A long, thin and pointed bill of the hummingbird.

Feet

Bird feet can also vary greatly among different birds. Some birds, such as gulls and terns and other waterfowl, have webbed feet used for swimming or floating (**Figure** 4.39). Other birds, such as herons, gallinules, and rails, have four long spreading toes, which are adapted for walking delicately in the wetlands (**Figure** 4.39). You can predict how the beaks and feet of birds will look depending on where they live and what type of food they eat. Flightless birds also have long legs that are adapted for running. Flightless birds include the ostrich and kiwi.

Raptors have clawed feet. They also have strong legs. Hawks, eagles and falcons also have excellent vision and they hunt by sight. Owls, with excellent hearing, can hunt by that sense alone.

See **Wild African Vulture Birds Scavage Bones of Dead Animals** at http://www.youtube.com/watch?v=zxj9YO4Qtx0 and **Ruby-Throated Hummingbird** at http://animals.nationalgeographic.com/animals/birds/ruby-throat-hummingbird/ for additional information.


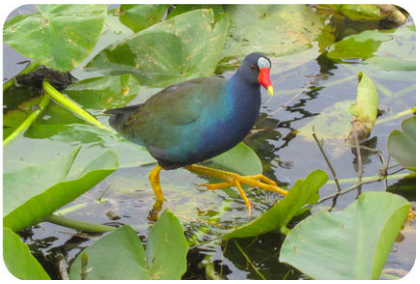

FIGURE 4.39

(*left*) The webbed feet of a great black-backed gull. (*right*) The long spreading toes of an American purple gallinule.

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Vocabulary

- **carnivore**: Animal that eats other animals.
- **herbivore**: Animal that eats plants or parts of plants, such as seeds.
- **generalist**: Animal that feeds on a variety of foods.

Summary

- Birds have beaks adapted for what foods they eat.
- The feet of birds can be adapted for their specific habitat.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Evolution Birds Dinosaurs** at http://www.youtube.com/watch?v=ah_9qmAj5k8 (6:58)

MEDIA

Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57399

1. How big were velociraptors?
2. How does the skeleton of a bird compare to the skeleton of a velociraptor? Cite as many examples as you can.

3. Were birds descended from herbivorous dinosaurs or carnivorous dinosaurs? What evidence leads scientists to this conclusion?
4. What is the significance of the fossil, "Dave" from China?
5. Why do the teeth of velociraptors suggest they preyed on animals larger than themselves?

Practice II

- **Diving with Penguins** at http://www.youtube.com/watch?v=OyNuupV-09U (3:58)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57400

1. What are the penguins in the video feeding on?
2. How do penguins store oxygen differently than other birds? How is this related to their lifestyle?
3. Why do penguins control how much oxygen they carry in their lungs when they dive?

Practice III

- **Flying with the Fastest Birds on the Planet: Peregrine Falcon Gos Hawk** http://www.youtube.com/watch?v=p-_RHRAzUHM (3:02)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57401

1. What is the fastest animal on the planet? How fast is this animal?
2. How much g-force can a diving raptor experience? How would humans respond to these forces?

Review

1. What is a generalist? Name one bird that is a generalist.
2. List three carnivorous birds.
3. Give two examples of flightless birds.
4. Give two examples of how a bird's beak is adapted to a specific food source.
5. Give two examples of how a bird's feet are adapted to a specific environment.

4.19 Importance of Birds

- Describe how birds are important to people and the ecosystem.

Do you eat birds?

If you've eaten a turkey or a chicken nugget, then you've eaten a bird! Providing a food source is just one way that birds are important to humans. In the United States, more than 230 million turkeys are consumed each year, with almost 50 million of those turkeys being eaten at Thanksgiving.

Importance of Birds

You are probably familiar with birds as food. People have always hunted birds for food. People eventually discovered that certain wild fowl (ducks, chickens, turkeys) could be tamed. This discovery led to the development of poultry, which is domesticated fowl that farmers raise for meat and eggs. Chickens are probably the oldest kinds of poultry. Chickens were domesticated in Asia at least 3,000 years ago. Since then, farmers have developed other poultry, including ducks, geese, guineafowl, pheasants, and turkeys. Around the world, people consume all these birds, and even more exotic birds, like ostriches. Today, chickens rank as the most widely raised poultry by far. Farmers throughout the world produce hundreds of millions of chickens annually for meat and eggs. Ducks and turkeys rank second and third in production worldwide. Ducks are raised for both meat and eggs. Turkeys are raised mainly for meat.

Can you think of other ways that birds are important?

Birds and Humans

1. In agriculture, humans harvest bird droppings for use as fertilizer. These droppings have a high content of nitrogen, phosphate, and potassium, three nutrients essential for plant growth.

2. Chickens are also used as an early warning system of human diseases, such as West Nile virus. Mosquitoes carry the West Nile virus, bite young chickens and other birds, and infect them with the virus. When chickens or other birds become infected, humans may also become infected in the near future.
3. Birds have important cultural relationships with humans. Birds are common pets in the Western world. Common bird pets include canaries, parrots, finches, and parakeets. Sometimes, people act cooperatively with birds. For example, the Borana people in Africa use birds to guide them to honey that they use in food.
4. Birds also play prominent and diverse roles in folklore, religion, and popular culture. They have been featured in art since prehistoric times, when they appeared in early cave paintings. Many young child know of Big Bird, a very large canary of *Sesame Street* fame.
5. Feathers are also used all over the world to stuff pillows, mattresses, sleeping bags, coats, and quilting. Goose feathers are preferred because they are soft. Manufacturers often mix goose feathers with down feathers to provide extra softness.

Birds and the Ecosystem

Birds are obviously important members of many ecosystems. They are integral parts of food chains and food webs. In a woodland ecosystem for example, some birds get their food mainly from plants. Others chiefly eat small animals, such as insects or earthworms. Birds and bird eggs, in turn, serve as food for such animals as foxes, raccoons, and snakes. The feeding relationships among all the animals in an ecosystem help prevent any one species from becoming too numerous. Birds play a vital role in keeping this balance of nature. In addition to being important parts of food webs, birds play other roles within ecosystems.

1. Birds eat insects. They are a natural way to control pests in gardens, on farms, and other places. A group of birds gliding through the air can easily eat hundreds of insects each day. Insect eating birds include warblers, bluebirds and woodpeckers.
2. Nectar-feeding birds are important **pollinators**, meaning they move the pollen from flower to flower to help fertilize the sex cells and create new plants. Hummingbirds, sunbirds, and the honey-eaters are common pollinators.
3. Many fruit-eating birds help disperse seeds. After eating fruit, they carry the seeds in their intestines and deposit them in new places. Fruit-eating birds include mockingbirds, orioles, finches and robins.
4. Birds are often important to island ecology. In New Zealand, the kereru and kokako are important browsers, or animals that eat or nibble on leaves, tender young shoots, or other vegetation (**Figure** 4.40). Seabirds add nutrients to soil and to water with their production of **guano**, their dung.

FIGURE 4.40

The kereru (*left*) and the kokako (*right*) are important browser species in New Zealand

Vocabulary

- **pollinator**: Animal that transfers pollen from one flower to another.
- **guano**: Feces and urine of seabirds, cave-dwelling bats, and seals.

Summary

- Birds are important to humans in many ways; they are a source of food and fertilizer.
- Birds are important to the ecosystem in many ways; they pollinate flowers and disperse seeds.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Dispersal of Seeds by Animals** at http://theseedsite.co.uk/sdanimal.html

1. Why are seeds enclosed in a tasty pulp?
2. Give two examples of how animals disperse seeds.

Practice II

- **One Century On, the Guano Boom is Back** at http://www.youtube.com/watch?v=HOq8PKX18A4 (2:10)

1. How many seabirds were there at the 19th-century peak of guano collection? How many are there now? What direction is the population going?
2. How has the Peruvian government changed the way guano is collected?

Practice III

- **Bird Poop and Its Surprising Uses** at http://www.youtube.com/watch?v=UKPn2lEUVYI (1:24)

MEDIA

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1. For what purposes are people using guano?
2. How does climate affect the quality of bird guano? Why is this quality important to the use of guano as fertilizer?

Review

1. What is poultry?
2. What are two ways birds are important to humans?
3. What are two ways birds are important to the ecosystem?
4. How to birds disperse seeds? Give two examples of fruit-eating birds.

4.20 Mammal Characteristics

- Describe the characteristics of mammals.

What do you have in common with a bat?

Both humans and bats have body hair, and both humans and bats can nurse their young. These are both characteristics of mammals, the class that both bats and humans belong to.

Characteristics of Mammals

What is a mammal? These animals range from bats, cats, and rats to dogs, monkeys, elephants, and whales. They walk, run, swim, and fly. They live in the ocean, fly in the sky, walk on the prairies, and run in the savanna. There is a tremendous amount of diversity within the group in terms of reproduction, habitat, and adaptation for living in those different habitats.

What allows them to live in such diverse environments? They have evolved specialized traits, unlike those of any other group of animal. Mammals (class Mammalia) are **endothermic** (warm-blooded) vertebrate animals with a number of unique characteristics. In most mammals, these include:

- The presence of hair or fur.
- Sweat glands.
- Glands specialized to produce milk, known as **mammary glands**.
- Three middle ear bones.
- A **neocortex** region in the brain, which specializes in seeing and hearing.
- Specialized teeth.
- A four-chambered heart.

There are approximately 5,400 mammalian species, ranging in size from the tiny 1-2 inch bumblebee bat to the 108-foot blue whale. These are distributed in 29 orders, 153 families, and about 1,200 genera.

There are three types of mammals, characterized by their method of reproduction. All mammals, except for a few, are **viviparous**, meaning they produce live young instead of laying eggs. The **monotremes**, however, have birdlike and reptilian characteristics, such as laying eggs and a cloaca. An example of a monotreme is the platypus with its birdlike beak and egg-laying characteristics. The echidnas are the only other monotreme mammals. A second type of mammal, the marsupial mammal, includes kangaroos, wallabies, koalas and possums. These mammals give birth to underdeveloped embryos, which then climb from the birth canal into a pouch on the front of the mother's body, where it feeds and continues to grow. The remainder of mammals, which is the majority of mammals, are placental mammals. These mammals develop in the mother's uterus, receiving nutrients across the placenta. Placental mammals include humans, rabbits, squirrels, whales, elephants, shrews, and armadillos. Dogs and cats, and sheep, cattle and horses are also placental mammals.

Mammals are also the only animal group that evolved to live on land and then back to live in the ocean. Whales, dolphins, and porpoises have all adapted from land-dwelling creatures to a life of swimming and reproducing in the water (**Figure** 4.41). Whales have evolved into the largest mammals.

FIGURE 4.41

Dolphins have adapted to swimming and reproducing in water.

See **Mammals- San Diego Kids** at http://kids.sandiegozoo.org/animals/mammals and **The Cheetah Orphans** at http://www.pbs.org/wnet/nature/episodes/the-cheetah-orphans/interactive-anatomy-of-a-cheetah/662/ for additional material.

Listen to *They Might Be Giants - Mammal* at http://www.youtube.com/watch?v=mXD7YOoHpAs for a description of numerous mammal traits.

MEDIA

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Vocabulary

- **endothermic**: Having an internal temperature that is not dependent on the temperature of their environment; warm-blooded.
- **mammary gland**: Milk-producing gland of female mammals.
- **monotreme**: Mammal with some birdlike and reptilian characteristics, such as laying eggs.
- **neocortex**: Part of the brain in mammals that is involved with sight and hearing.
- **viviparous**: Giving birth to live young.

Summary

- Mammals have several traits in common, including the presence of hair or fur, sweat glands, and mammary glands.
- Some mammals, such as dolphins and whales, evolved to live back in the ocean by adapting from land-dwelling creatures.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **What is a Mammal?** at http://www.youtube.com/watch?v=0jw74pfWfxA (1:36)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57379

1. How do mammals differ from other vertebrates?
2. What characteristics are unique to mammals?

Practice II

- **Famous Fossil "Ida" (Plate B): Analysis with Dr. Robert Bakker** at http://www.youtube.com/watch?v=vyx-ryWHB2s (3:17)

MEDIA
Click image to the left or use the URL below.
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1. What characteristics does "Ida" display?
2. What did she probably eat based on her dentition?
3. What do her eyes tell us about her probable behavior?
4. What type of mammal was Ida? How is this known?

Review

1. What are three characteristics of mammals?
2. What is meant by viviparous?
3. What are monotremes? Give an example.
4. What is the largest land mammal?

4.21 Mammal Reproduction

- Describe how mammals reproduce.

Do mammals lay eggs?

Could a rabbit really lay eggs? Rabbits are mammals, and most mammals do not lay eggs. Mammals usually give birth to live offspring. But there are some mammals that do lay eggs.

Mammal Reproduction

You probably realize that cats, dogs, people, and other mammals don't typically lay eggs. There are exceptions, however. Egg-laying is possible among the **monotremes**, mammals with birdlike and reptilian characteristics. Recall that mammals can be classified into three general groups, based on their reproductive strategy: the monotremes, the marsupials and the placental mammals.

The egg-laying monotremes, such as echidnas (**Figure** 4.42) and platypuses (**Figure** 4.42), use one opening, the **cloaca**, to urinate, release waste, and reproduce, just like birds. They lay leathery eggs, similar to those of lizards, turtles, and crocodilians. Monotremes feed their young by "sweating" milk from patches on their bellies, as they lack the nipples present on other mammals.

All other mammals give birth to live young and belong to one of two different categories, the marsupials and the placental mammals. A **marsupial** is an animal in which the embryo, which is often called a joey, is born at an immature stage. Development must be completed outside the mother's body. Most female marsupials have an abdominal pouch or skin fold where there are mammary glands. The pouch is a place for completing the development of the baby. Although blind, without fur, and with only partially formed hind legs, the tiny newborns have well developed forelimbs with claws that enable them to climb their way into their mother's pouch where they drink their mother's milk and continue their development. Marsupials include kangaroos, koalas, and opossums. Other marsupials are the wallaby and the Tasmanian Devil. Most marsupials live in Australia and nearby areas. (**Figure** 4.43).

FIGURE 4.42

The echidna (*right*) is a member of the monotremes, the most primitive order of mammals. Another monotreme, the platypus (*left*), like other mammals in this order, lays eggs and has a single opening for the urinary, genital, and digestive organs.

The majority of mammals are **placental** mammals. These are mammals in which the developing baby is fed through the mother's placenta. Female placental mammals develop a **placenta** after fertilization. A placenta is a spongy structure that passes oxygen, nutrients, and other useful substances from the mother to the fetus. It also passes carbon dioxide and other wastes from the fetus to the mother. The placenta allows the fetus to grow for a long time within the mother.

FIGURE 4.43

A marsupial mammal, this eastern gray kangaroo has a joey (young kangaroo) in its abdominal pouch.

Some mammals are alone until a female can become pregnant. Others form social groups with big differences between sexes, such as size differences, a trait called **sexual dimorphism**. Dominant males are those that are the largest or best-armed. These males usually have an advantage in mating. They may also keep other males from mating with females within a group. This is seen in elephant seals (**Figure** 4.44), and also with elk, lions and non-human primates, including the orangutans and gorillas. Male elk grow antlers, while female elk do not have antlers. Adult male lions are not only larger than females, they have a mane of long hair on the side of the face and top of the head.

Vocabulary

- **cloaca**: Single exit and entrance for sperm, eggs, and waste.
- **marsupial**: Mammal in which the young are born in an immature state and continue development in the pouch.
- **monotreme**: Mammal with some birdlike and reptilian characteristics, such as laying eggs.

FIGURE 4.44

A mating system with a group of many females and one male, as seen in the seal species. Male elephant seals can grow to 14 feet long, whereas females can grow to 11 feet long.

- **placenta**: Spongy structure that passes oxygen, nutrients, and other useful substances from the mother to the fetus.
- **placental**: Mammal with an organ that feeds the fetus and removes waste products.
- **sexual dimorphism**: Distinct difference in appearance between the males and females.

Summary

- Monotremes can lay eggs, but most mammals give birth to live young.
- Mammals can be marsupial, where the embryo is born at an immature stage and develops in the pouch.
- Mammals can be placental, where substances are passed from the mother to the fetus so that it can stay longer in the womb.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Marsupials** at http://www.biokids.umich.edu/critters/Didelphimorphia/

1. What are four examples of marsupials?
2. Where are most marsupials found?
3. What is the primary difference between marsupial and placental mammals? Explain your response.

Practice II

- **Marsupial Reproduction Process** at http://www.youtube.com/watch?v=IloOJ3kc8us (4:06)

MEDIA

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1. How does parental care in marsupial mammals differ from parental care in placental mammals?
2. Why do marsupials lick themselves during birth?
3. How do scientists think marsupial babies find the pouch?

Practice III

- **Creation of Placenta** at http://www.youtube.com/watch?v=I8sqaJVZRmo (3:51)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57405

1. What are two of the purposes of the placenta?
2. What does the placenta allow to pass to the embryo?
3. What does the placenta keep from the embryo?
4. What is the function of the umbilical cord?

Review

1. How are monotremes more like reptiles and birds than other mammals?
2. What's the difference between marsupial and placental animals?
3. What are three marsupials?
4. Define and describe the role of the placenta.
5. What is sexual dimorphism?

4.22 Mammal Classification

- Describe the various groups that mammals can be divided into.

To what group do rats belong?

Rats are mammals, but this class can be divided into more specific groups. Rats are in a group known as rodents. Rodents are gnawing animals that include beavers, mice, and squirrels.

Groups of Mammals

Traditionally, mammals were divided into groups based on their characteristics. Scientists took into consideration their **anatomy** (body structure), their habitats, and their feeding habits. Mammals are divided into three subclasses and about 26 orders. Some of the groups of mammals include:

1. **Lagomorphs** include hares and rabbits. Rabbits and hares characteristically have long ears, a short tail, and strong hind limbs that provide for a bouncing method of locomotion. They are all are small to medium-sized terrestrial herbivores.
2. **Rodents** include rats, mice, and other small gnawing mammals. They have a single pair of continuously growing incisors (teeth) in each of the upper and lower jaws that must be kept short by gnawing.
3. **Carnivores** include cats and lions and tigers, dogs and wolves, polar bears, and other meat eaters.
4. **Insectivores** include moles and shrews (**Figure** 4.45). These mammals eat primarily insects, other arthropods, and earthworms.

5. **Bats** include the vampire bat. These mammals have forelimbs that form webbed wings, making bats the only mammals naturally capable of true and sustained flight.

FIGURE 4.45
One of the subgroups of mammals is the insectivores, including this shrew.

6. **Primates** include monkeys, apes and humans. These mammals are characterized by detailed development of the hands and feet, a shortened snout, and a large brain.
7. **Ungulates** include hoofed animals, such as deer, sheep, goats, pigs, buffalo, and giraffe (**Figure** 4.46). These mammals use their hoofs to sustain their whole body weight while moving. Hoofs are formed by a thick nail rolled around the tip of the toe.

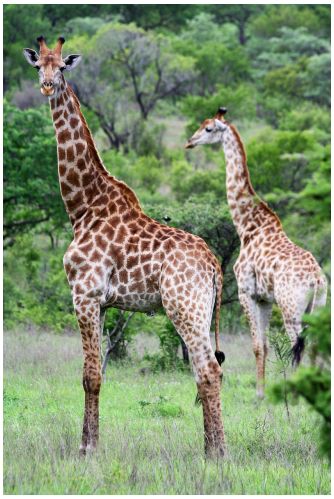

FIGURE 4.46
The ungulates (hoofed animals), like the giraffe here, is one of the subgroups of mammals.

Mammals can also be grouped according to the adaptations they form to live in a certain habitat. For example, terrestrial mammals with leaping kinds of movement, as in some marsupials and lagomorphs, typically live in open

habitats. Other terrestrial mammals are adapted for running, such as dogs or horses. Still others, such as elephants, hippopotamuses, and rhinoceroses, move slowly. Other mammals are adapted for living in trees, such as many monkeys (**Figure** 4.47). Others live in water, such as manatees, whales, dolphins, and seals. Still others are adapted for flight, like bats.

FIGURE 4.47

This howler monkey shows adaptations for life among the trees.

Vocabulary

- **anatomy**: Structure of the body.
- **bat**: Mammal with forelimbs that form webbed wings.
- **carnivore**: Animal that feeds on other animals.
- **insectivore**: Animal that feeds on insects.
- **lagomorph**: Large gnawing animal, including rabbits and hares.
- **primate**: Mammal characterized by refined development of the hands and feet, a shortened snout, and a large brain.
- **rodent**: Small gnawing animal, including rats and mice.
- **ungulate**: Hoofed animal, such as deer, pigs, and elephants.

Summary

- Traditionally, mammals were divided into groups based on their anatomy (body structure), their habitats, and their feeding habits.
- Subgroups of the mammals include rodents, carnivores, insectivores, bats, and primates.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Mammal Conservation in Island Ecosystems** at http://www.youtube.com/watch?v=JlsbH-MGsMI (5:21)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/57367

1. What is the average size of a mammal?
2. What groups of mammals are most abundant?
3. How often does Dr. Healey find new species in his work?
4. How does the diversity of bats compare to the diversity of other mammals in the Philippines? What does this tell you about generalized statements about species diversity?

Practice II

- **Platypus Parts** at http://www.youtube.com/watch?v=QNoQvjlmGdk (3:44)

MEDIA
Click image to the left or use the URL below.
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1. Where does the platypus (*Ornithorhynchus anatinus*) live?
2. What do platypus eat?
3. How do platypus look for food?
4. What is the purpose of the "spur" on males?

Practice III

- **Ungulates: Animal Planet** at http://animals.howstuffworks.com/animal-facts/ungulate-info.htm

1. What distinguishes the ungulates?
2. What are three examples of ungulates?

Review

1. What are rodents? Give two examples.
2. What are characteristics of primates. Give three examples of primates.
3. What are ungulates? Give four examples.
4. List five examples of carnivores.

4.23 Importance of Mammals

- Describe how mammals are important to humans and the ecosystem.

How are mammals helpful?

An example of a helpful mammal is a service dog. Like many dogs, service dogs can pick up or retrieve objects for their owners. They can also perform many other tasks for a disabled person, depending on the type of disability.

Importance of Mammals

Mammals play many important roles in ecosystems, and they also benefit people.

Importance to Ecosystems

Mammals have important roles in the food webs of practically every ecosystem. Mammals are important members of food chains and food webs, as grazers and predators. Mammals can feed at various levels of food chains, as herbivores, insectivores, carnivores and omnivores.

Mammals also interact with other species in many symbiotic relationships. For example, bats have established mutually beneficial relationships with plants. Nectar-feeding bats receive a tasty treat from each flower, and, in return, they **pollinate** the flowers. That means they transfer pollen from one flower to another, allowing the plant to reproduce. Non-flying mammalian pollinators include of marsupials, primates, and rodents. In most cases, these animals visit flowers to eat their nectar, and end up with pollen stuck to their bodies. When the animal visits another flower to eat the nectar, the pollen is transferred to that flower.

Fruit-eating bats (**Figure** 4.48) also receive food from plants. In return, they help these plants spread their seeds. When bats consume fruit, they also consume the seeds within the fruit. Then they carry the seeds in their guts to far-away locations.

Zebras have been known to befriend ostriches. In this symbiotic relationship, both species benefit. The ostrich, with its terrible senses of smell and hearing and the zebra with its poor eyesight, are both able to warn the other when danger is near. The zebra can smell or hear certain dangers approaching, while the ostrich can see other dangers. Both are prepared to warn one another at a moment's notice so they can each flee when necessary.

Baboons and impala have a similar relationship. Impala are one of the most common prey species for all predators and need to be constantly alert. Impala have good hearing and eyesight, raising an alarm when danger is near. Baboons use trees to check for danger and bark an alarm when danger is sensed. What do the baboons receive? Male baboons sometimes prey on young antelope soon after birth. So, though both alert others to dangers, sometimes this is not the best of relationships for young antelope.

Zebra and wildebeest are found together on the African savanna grazing different parts of the same grass. The zebra grazes the tougher parts of the plant, saving the softer parts for the wildebeest. A zebra will move into an area of tall grass before other herbivores and graze the grass down to the area that the wildebeest prefers.

FIGURE 4.48

Bats, like this Egyptian fruit bat, play an important role in seed dispersal.

Importance to Humans

We see examples of mammals (other than people!) serving our needs everywhere. We have pets that are mammals, such as dogs and cats. Mammals are also used around the world for transport. For example, horses, donkeys, mules, or camels (**Figure** 4.49) may be the primary means of transport in some parts of the world. Mammals also do work for us. **Service dogs** can be trained to help the disabled. These include guide dogs, which are assistance dogs

trained to lead blind and visually impaired people around obstacles. Horses and elephants can carry heavy loads. Humans also use some mammals for food. For example, cows and goats are commonly raised for their milk and/or meat. Mammals' more highly developed brains have made them ideal for use by scientists in studying such things as learning, as seen in maze studies of mice and rats.

FIGURE 4.49
This camel provides transportation in Egypt.

Cultural Importance

Mammals have also played a significant role in different cultures' folklore and religion. For example, the grace and power of the cougar have been admired in the cultures of the native peoples of the Americas. The Inca city of Cuzco is designed in the shape of a cougar, and the thunder god of the Inca, Viracocha, has been associated with the animal. In North America, mythological descriptions of the cougar have appeared in the stories of several American Indian tribes.

Important mammals include Dolly the sheep, Lassie the dog, and flipper the dolphin. Dolly was the first mammal to be cloned from an adult somatic (body) cell, using the process of nuclear transfer. Lassie was a collie dog who appeared in seven full length feature films in the 1940s and 1950s, starting with *Lassie Come Home* in 1943. Additional Lassie movies were made as recently as 2005. Between 1954 and 1973, the *Lassie* television series aired, with plenty of additional productions as recently as 2007. Flipper was a bottle nose dolphin that starred in a television series between 1964 and 1967. The most famous mammal may be *King Kong,* the giant gorilla that terrorized New York City in 1933 in the movie of the same name.

Vocabulary

- **pollinate**: Transfer of pollen from one flower to another to allow reproduction.
- **service dog**: Dog that has been trained to assist disabled people.

Summary

- Ecologically, nectar-feeding and fruit-eating bats play an important role in plant pollination and seed dispersal, respectively.

- Mammals meet people's needs by serving as pets, transport, food, or research subjects.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Sled Dogs: An Alaskan Epic** at http://www.pbs.org/wnet/nature/episodes/sled-dogs-an-alaskan-epic/interactive-dogsledding-101/4355/

1. What breed of dogs were originally used for sled pulling?
2. What kind of weather is optimal for sled dogs?
3. Why do the dogs like these conditions?
4. What are the two most common types of sleds?

Practice II

- **Arctic: Greenland Sled Dogs** at http://www.youtube.com/watch?v=QeDv3hVcc8A (3:02)

MEDIA

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1. How many sled dogs are there living above the Arctic Circle in Greenland?
2. How far can a sled dog team travel in a day?
3. What advantages do sled dogs have over snowmobiles?
4. What are some ways in which the Inuit depend on sled dogs?

Review

1. How do mammals impact ecosystems? Describe two ways.
2. Describe one symbiotic relationship between mammals.
3. How do mammals help people? Describe two ways.
4. Which mammals is your favorite? Why?

4.24 Primates

- Describe the features of the primates.

How are the monkey and the girl alike?

Both are intelligent and can learn new things quickly. They both like to play. And they are both primates.

What Are Primates?

If primates are mammals, what makes them seem so different from most mammals? Primates, including humans, have several unique features. Some adaptations give primates advantages that allow them to live in certain habitats, such as in trees. Other features have allowed them to adapt to complex social and cultural situations.

Primates are mostly **omnivorous**, meaning many primate species eat both plant and animal material. The order contains all of the species commonly related to lemurs, monkeys, and apes. The order also includes humans (**Figure** 4.50).

Key features of primates include:

- Five fingers, known as **pentadactyl**.
- Several types of teeth.
- Certain eye orbit characteristics, such as a **postorbital bar**, or a bone that runs around the eye socket.
- An **opposable thumb**, a finger that allows a grip that can hold objects.

What's the difference between monkeys and apes? The easiest way to distinguish monkeys from the other primates is to look for a tail. Most monkey species have tails, but no apes or humans do. Monkeys are much more like other mammals than apes and humans are.

FIGURE 4.50

(*top left*) Ring-tailed lemurs. Lemurs belong to the prosimian group of primates. (*top right*) One of the New World monkeys, a squirrel monkey. (*bottom left*) Chimpanzees belong to the great apes, one of the groups of primates. (*bottom right*) Reconstruction of a Neanderthal man, belonging to an extinct subspecies of *Homo sapiens*. This subspecies of humans lived in Europe and western and central Asia from about 100,000 –40,000 BCE.

Big Brains

In intelligent mammals, such as primates, the cerebrum is larger compared to the rest of the brain. A larger cerebrum allows primates to develop higher levels of intelligence. Primates have the ability to learn new behaviors. They also engage in complex social interactions, such as fighting and play.

Social Relationships

Old World species, such as apes and some monkeys (**Figure** 4.50 and **Figure** 4.51), tend to have significant size differences between the sexes. This is known as **sexual dimorphism**. Males tend to be slightly more than twice as heavy as females. This dimorphism may have evolved when one male had to defend many females. *Old World* generally refers to monkeys of Africa and Asia. *New World* refers to monkeys of the Americas.

New World species, including tamarins (squirrel-sized monkeys) and marmosets (very small primitive monkeys) (**Figure** 4.51), form **pair bonds**, which is a partnership between a mating pair that lasts at least one season. The pair cooperatively raise the young and generally do not show a significant size difference between the sexes. Old World monkeys do not tend to form monogamous relationships.

Where Do Non-human Primates Live?

Non-human primates live mostly in Central and South America, Africa, and South Asia. Since primates evolved from animals living in trees, many modern species still live mostly in trees. Other species live on land most of the time, such as baboons (**Figure** 4.52) and the Patas monkey. Only a few species live on land all of the time, such as the gelada and humans.

FIGURE 4.51

(*left*) An Old World monkey, a species of macaque, in Japan. (*center*) A New World species of monkey, a tamarin. (*right*) Another New World species of monkey, the pygmy marmoset.

FIGURE 4.52

Baboons are partially terrestrial. Pictured here is a mother baboon and her young.

Primates live in a diverse number of forested habitats, including rain forests, mangrove forests and mountain forests to altitudes of over 9,800 feet. The combination of opposable thumbs, short fingernails, and long, inward-closing fingers has allowed some species to develop the ability to move by swinging their arms from one branch to another (**Figure** 4.53). Another feature for climbing are expanded finger-like parts, such as those in tarsiers, which improve grasping (**Figure** 4.53).

A few species, such as the proboscis monkey, De Brazza's monkey, and Allen's swamp monkey, evolved webbed fingers so they can swim and live in swamps and aquatic habitats. Some species, such as the rhesus macaque and the Hanuman langur, can even live in cities by eating human garbage.

Vocabulary

- **omnivorous**: Feeding on food derived from both plants and animals.
- **opposable thumb**: Finger that allows an animal to grasp objects.
- **pair bonds**: Temporary or permanent relationship that develops between a male and female as they mate and raise their young.

FIGURE 4.53

(*left*) A gibbon shows how its limbs are modified for hanging from trees. (*right*) A species of tarsier, with expanded digits used for grasping branches.

- **pentadactyl**: Having five fingers.
- **postorbital bar**: Bone that runs around the eye socket.
- **sexual dimorphism**: Distinct difference in appearance between the males and females.

Summary

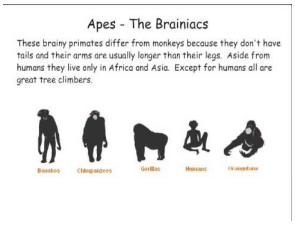
- Features of primates include five fingers, several types of teeth, an opposable thumb, and a large brain.
- Primates live in a variety of places, including trees, swamps, and on land.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Primate Classification** at http://www.youtube.com/watch?v=Zd7syFmutjU (2:15)



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1. How do primates differ from other animals?
2. How do prosimians differ from monkeys?
3. How do Old World monkeys differ from New World monkeys?
4. How do apes differ from monkeys?

Practice II

- **Ring-Tailed Lemurs** at http://kids.nationalgeographic.com/kids/animals/creaturefeature/ring-tailed-lemur/

1. Why are lemurs endangered?
2. Where do lemurs live?
3. How do lemurs mark their territory?

Review

1. What's the difference between monkeys and apes?
2. What is an opposable thumb?
3. What is the significance of a large cerebrum?
4. What is meant by pentadactyl?

4.25 Humans and Primates

- Describe the characteristics of the great apes.

What animals are humans' closest cousins?

Looking at our evolutionary tree, our closest relatives include the orangutans pictured here. Notice the way this mother cradles her child; they look very human-like. Orangutans are also highly intelligent. Notice the detail in the hand. In the wild, they can create and use tools.

Humans and Primates

The great apes are the members of the biological family Hominidae, which includes four living genera: chimpanzees, gorillas, orangutans and humans. Among these four genera are just seven species, two of each except humans, which has only one species, *Homo sapiens.*

Characteristics

The Great Apes are large, tailless primates, ranging in size from the pygmy chimpanzee, at 66-88 pounds in weight, to the gorilla, at 300-400 pounds (**Figure** 4.54). In all species, the males are, on average, larger and stronger than

the females.

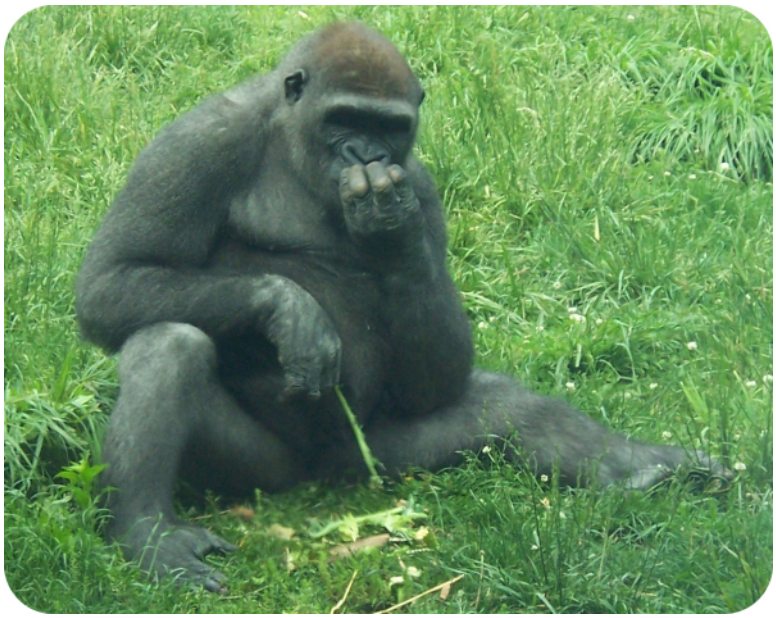

FIGURE 4.54
A Western Lowland gorilla, member of the great apes. The gorilla is the largest of the hominids, weighing up to 309-397 lbs.

Most living primate species are four-footed, but all are able to use their hands for gathering food or nesting materials. In some cases, hands are used as tools, such as when gorillas use sticks to measure the depth of water (**Figure** 4.55). Chimpanzees sharpen sticks to use as spears in hunting; they also use sticks to gather food and to "fish" for termites.

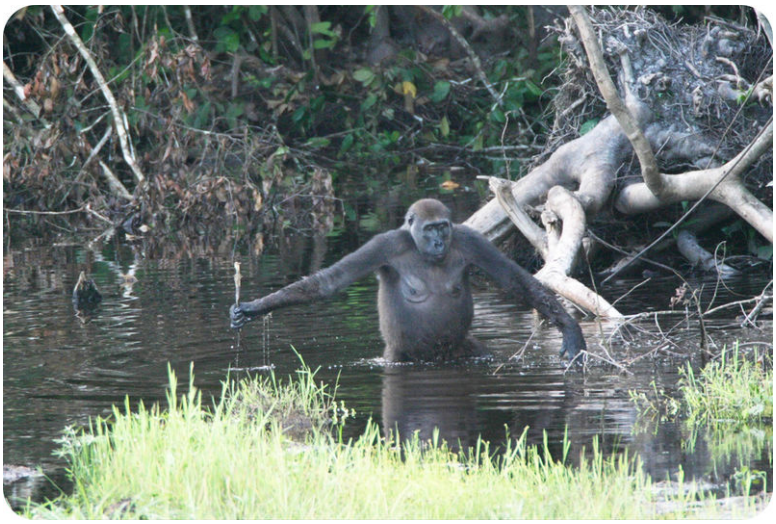

FIGURE 4.55
Tool using in a primate. A gorilla uses a stick to determine the water's depth.

Most primate species eat both plants and meat (**omnivorous**), but fruit is the preferred food among all but humans. In contrast, humans eat a large amount of highly processed, low fiber foods, and unusual proportions of grains and vertebrate meat. As a result of our diets, human teeth and jaws are markedly smaller for our size than those of other apes. Humans may have been eating cooked food for a million years or more, so perhaps our teeth adapted to eating cooked food.

Gestation (pregnancy) lasts 8-9 months and usually results in the birth of a single offspring. The young are born helpless, and thus, they need parental care for long periods of time. Compared with most other mammals, great apes have a long adolescence and are not fully mature until 8-13 years of age (longer in humans). Females usually give birth only once every few years.

Gorillas and chimpanzees live in family groups of approximately five to ten individuals, although larger groups are sometimes observed. The groups include at least one dominant male, and females leave the group when they can mate. Orangutans, however, generally live alone.

Genetic and Behavioral Similarities

Gorillas, chimpanzees, and humans have more than 97% of their DNA sequence in common. This means that a similar percent of the amino acid sequences of the proteins will be the same, resulting in many proteins with similar or identical functions.

All organisms in the Hominidae communicate with some kind of language. They can also create simple **cultures** beyond the family or group of animals. Having a culture means that knowledge and behaviors can be passed on from generation to generation.

Specialized Human Features

Specialized features of *Homo sapiens* include the following:

- small front teeth (canines and incisors) and very large molars relative to other primate species,
- a fully upright posture resulting in bipedalism (walking on two limbs instead of four),
- shortening of the arms relative to the legs,
- increased usefulness (dexterity) of the hands,
- increase in brain size, especially in the frontal lobes
- and a decrease in bone mass of the skull and face.

See *Communication - the Jane Goodall Institute* at http://www.janegoodall.org/chimpanzees/communication , *Comparing the Human and Chimpanzee Genomes* at http://wrl.it/show/197403/12898478 , and *Discovering Gibbons* at http://www.youtube.com/watch?v=C6HucIWKsVc for additional material.

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Vocabulary

- **culture**: Behavior and knowledge that is taught and passed on to succeeding generations.
- **omnivorous**: Eating foods derived from both plant and animal origins.

Summary

- The biological family Hominidae includes four living genera: chimpanzees, gorillas, humans, and orangutans.

- Gorillas, chimpanzees, and humans have more than 97% of their DNA in common.
- All organisms in the family Hominidae can develop language and culture.

Practice

Use the resources below to answer the questions that follow.

Practice I

- **Human and Primate Relationship**' at http://www.youtube.com/watch?v=i8PNWZDhGq4 (1:21)

MEDIA
Click image to the left or use the URL below.
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1. Where do chimpanzees (*Pan troglodytes*) live geographically?
2. What tool are the chimpanzees in the video using?

Practice II

- **Silverback Gorilla and Family** at http://www.youtube.com/watch?v=l1GZC3lQGbg (2:51)

MEDIA
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1. What do gorillas do when they approach each other or feel other gorillas are around?
2. Who is the leader of a gorilla family?

Practice III

- **Amazing DIY Orangutans** at http://www.youtube.com/watch?v=IFACrIx5SZ0 (2:41)

MEDIA
Click image to the left or use the URL below.
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1. Are the orangutans in the video displaying learned or innate behavior? Explain your answer.

Review

1. What organisms share the same biological family as humans?
2. Why do chimpanzees and humans have many similar proteins?
3. What is important about a primate culture?
4. What are three specialized human features?

Summary

Vertebrates. From fish to mammals. Obviously, there is a tremendous amount of differences among these groups of species. But there also exist many similarities. Fish had to evolve first. Then they moved onto land as amphibians, but they still had to live close to the water. Then they moved farther away from the water as reptiles. Reptiles could live anywhere, and they did. Reptiles became very large and dominated life on the planet. Some reptiles evolved flight and turned into birds. Others stayed small and became mammals. When all the large reptiles were extinct, what remained? Smaller animals, including mammals, which then became the dominant form of life.

4.26 References

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