


29–2 Form and Function in Invertebrates



To survive, all animals perform the same essential tasks: feeding and digestion, respiration, circulation, excretion, response, movement, and reproduction. In many ways, each animal phylum represents an “experiment” in the adaptation of body structures to carry out these tasks. The appearance of each phylum in the fossil record, therefore, represents the evolutionary development of a unique body plan. The continued history of each phylum is the story of further evolutionary changes to that plan.

Biologists can learn a great deal about the nature of life by comparing body systems among groups of living invertebrates. Body systems that perform the essential tasks of life have taken many different forms in different phyla. Each phylum has a particular type of breathing device, a certain type of body support system, and numerous variations on other physiological functions. More complicated systems are not necessarily better than simpler ones. The fact that any system is found in living animals testifies to its success in performing functions. This section reviews the basic evolutionary trends in each body system, using examples from a variety of invertebrate groups.


Feeding and Digestion

Invertebrates have evolved many different ways of obtaining food. The spider in **Figure 29–7**, for example, is feeding on a caterpillar after killing it with venom. Before food can be used for energy, the food must be broken down, or digested. The digested food must then be absorbed into the animal’s body. Complex animals accomplish the physiological process of digestion in different ways than simpler animals.

Intracellular and Extracellular Digestion Invertebrates have evolved different ways of digesting food.  **The simplest animals break down food primarily through intracellular digestion, but more complex animals use extracellular digestion.** Sponges digest their food inside archaeocytes, which pass nutrients to other cells by diffusion. Because food is digested inside cells, this process is known as **intracellular digestion**. In contrast, mollusks, annelids, arthropods, and echinoderms rely almost entirely on extracellular digestion. In **extracellular digestion**, food is broken down outside the cells in a digestive cavity or tract and then absorbed into the body. Flatworms and cnidarians use both intracellular and extracellular digestion.

 **Figure 29–7**  **Complex animals break down food using extracellular digestion.** The spider’s venom is breaking down the tissues of the caterpillar. Later, the broken-down food molecules will be absorbed into the spider’s digestive tract.

Guide for Reading

 **Key Concept**
• How do different invertebrate phyla carry out life functions?

Vocabulary
intracellular digestion
extracellular digestion
open circulatory system
closed circulatory system
hydrostatic skeleton
exoskeleton
endoskeleton
external fertilization
internal fertilization

Reading Strategy:
Finding Main Ideas Before you read, skim the section to identify the key ideas. Then, carefully read the section, making a list of supporting details for each main idea.



Section 29–2

1 FOCUS

Objective

29.2.1 Describe how the different invertebrate phyla carry out their essential life functions.

Guide for Reading

Vocabulary Preview

Before students read the section, have them locate each Vocabulary term and read its definition.

Reading Strategy

Suggest that students copy key ideas into their notebooks, leaving enough space for supporting details. Then, as they read the section, they should look for support for each key idea.

2 INSTRUCT

Feeding and Digestion

Build Science Skills

Observing Set up an aquarium in the classroom, and encourage volunteers to collect water, gravel and other sediment, plants, and invertebrates from a local freshwater pond. In the pond, students should be able to find planaria, snails, leeches, insect larvae, and hydras, which can often be found attached to rocks and stems of water plants. Ask students to make multiple trips to the pond, first building the habitat in the aquarium and then adding any invertebrates they can find. Once the aquarium contains invertebrates, encourage students to keep a daily record of what they observe about how the animals move about, feed, respond to stimuli, and defend themselves.

L2 L3



SECTION RESOURCES

Print:

- **Teaching Resources**, Lesson Plan 29–2, Adapted Section Summary 29–2, Adapted Worksheets 29–2, Section Summary 29–2, Worksheets 29–2, Section Review 29–2
- **Reading and Study Workbook A**, Section 29–2
- **Adapted Reading and Study Workbook B**, Section 29–2
- **Laboratory Manuals A/B**, Chapter 29 Lab

- **Lab Worksheets**, Chapter 29 Design an Experiment
- **Biotechnology Manual**, Lab 7

Technology:

- **iText**, Section 29–2
- **Animated Biological Concepts DVD**, 38 Circulatory Systems
- **Transparencies Plus**, Section 29–2
- **Virtual Labs**, Lab 17

29-2 (continued)

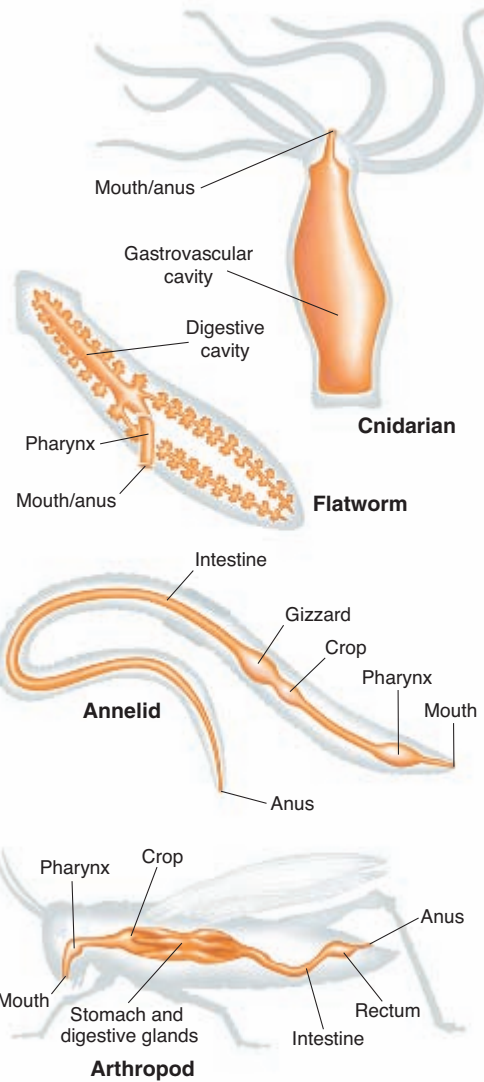
Use Visuals

Figure 29-8 After students have examined the figure, ask: **Which of the four invertebrates shown ingest food and expel waste through a single opening?** (The cnidarian and the flatworm) **What specialized regions can you see in the digestive tracts of any of the invertebrates?** (The digestive tract of the cnidarian has no specialized regions, and the tract of the flatworm has only a pharynx. The one-way digestive tract of the annelid has a pharynx, crop, gizzard, intestine, and anus. The one-way digestive tract of the arthropod has a pharynx, crop, stomach and digestive glands, intestine, rectum, and anus.) Point out that the digestive tracts shown represent the great variety of digestive systems in the invertebrate phyla. **L2**

Respiration

Build Science Skills

Using Analogies To help students understand that larger surface areas are more efficient at gas exchange than are smaller surfaces, compare diffusion of gases through the skin to absorption of water by paper towels. Show students two pieces of paper towel: a whole sheet and a small section cut from another sheet. Ask: **Which of these pieces will absorb more water?** (The larger piece) You might also provide students with two large beakers containing equal volumes of water. Have them put the small piece of paper towel in one beaker and the large piece in the other. Students can remove the paper towels and then compare the amount of water remaining in each beaker. **L1 L2**



▲ **Figure 29-8** Cnidarians and flatworms have a digestive system with only one opening. In more complex animals, the digestive system has two openings. In addition, the digestive organs have become more specialized. **Interpreting Graphics** Which of these animals has the least specialized digestive system?

Patterns of Extracellular Digestion

Invertebrates have a variety of digestive systems, as shown in **Figure 29-8**. Simple animals such as cnidarians and most flatworms ingest food and expel wastes through a single opening. Food is digested in a cavity through both extracellular and intracellular means. Some cells of the gastrovascular cavity secrete enzymes and absorb the digested food. Other cells surround food particles and digest them in vacuoles. Digested food then diffuses to cells throughout the body.

More-complex animals digest food in a tube called the digestive tract. Food enters the body through the mouth, and wastes leave through the anus. A one-way digestive tract (which is characteristic of roundworms, annelids, mollusks, arthropods, and echinoderms) often has specialized regions, such as a stomach and intestines. Specialization of the digestive tract allows food to be processed more efficiently, because each step in the process takes place in order, at a specific place along the digestive tract.

CHECKPOINT What is the difference between intracellular digestion and extracellular digestion?

Respiration

All animals must exchange oxygen and carbon dioxide with the environment. The more surface area that is exposed to the environment, the greater the amount of gas exchange that can occur. In addition, gases diffuse most efficiently across a thin, moist membrane. Given these principles, all respiratory systems share two basic features. **Respiratory organs have large surface areas that are in contact with the air or water. Also, for diffusion to occur the respiratory surfaces must be moist.**

Aquatic Invertebrates Aquatic animals, such as cnidarians and some flatworms, naturally have moist respiratory surfaces. Many animals even respire through their skins. However, for most active animals larger than worms, skin respiration alone is not sufficient. Aquatic mollusks, arthropods, and many annelids exchange gases through gills. Gills are feathery structures that expose a large surface area to the water. Gills are rich in blood vessels that bring blood close to the surface for gas exchange.

ESL

SUPPORT FOR ENGLISH LANGUAGE LEARNERS

Comprehension: Modified Cloze

Beginning Distribute a modified paragraph about extracellular digestion, but leave some strategic words blank. For example, "Simple animals such as _____ and most flatworms take in food and eliminate wastes through the same opening. Food is digested in the _____ cavity. Some cells that line this cavity _____ digested food." Provide students with a list of the correct answers, and have them fill in each

blank with one of those words. Tell students to refer to Figure 29-8 for help. **L1**

Intermediate Distribute the cloze paragraph described for Beginning Level, but add two additional sentences that explore the subject in greater depth, each with a blank. To check students' comprehension, have them form collaborative groups to write a question or a response about what they have read. **L2**

Quick Lab

How do clams and crayfishes breathe?

Materials live clam, food coloring, crayfish, small container of water

Procedure

1. Do not touch the clam or crayfish. Put a drop of food coloring in the water near a clam's siphons. Observe what happens to the coloring.
2. Put a drop of food coloring in the water near the middle of a crayfish's carapace. **CAUTION:** Keep your fingers away from the crayfish's pincers. Observe what happens to the coloring.

Analyze and Conclude

1. **Observing** Describe what happened to the coloring in step 1. How does water move through a clam's gills?
2. **Inferring** What is the clam's main defense? How is the location of the clam's siphons related to this defense?
3. **Comparing and Contrasting** What happened in step 2? Compare the flow of water through the gills of clams and crayfish.
4. **Inferring** Why do you think the crayfish has gills rather than spiracles, as some other arthropods do?



Quick Lab

Objective Students will be able to relate differences in the mechanism of gas exchange to overall adaptation in a clam and a crayfish. **L2 L3**

Skills Focus **Observing, Inferring, Comparing and Contrasting**

Materials live clam, food coloring, crayfish, small container of water

Time 20 minutes

Advance Prep You can keep marine clams alive for a few days in a 4% solution of sodium chloride.

Safety Make sure students do not touch the organisms.

Expected Outcome Students should observe that the food coloring enters one of the clam's siphons and exits through the other. They should also observe the turbulence around the middle of the crayfish's ventral surface, revealing the location of its gills.

Analyze and Conclude

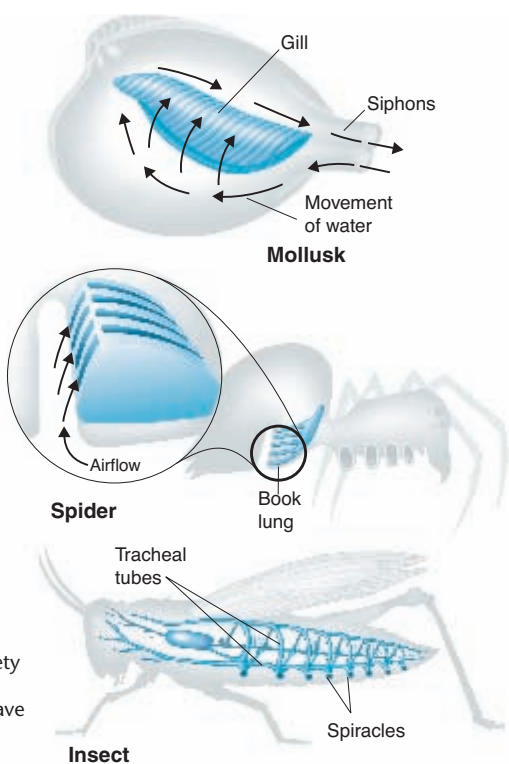
1. The coloring entered one siphon and left through the other. Inside the clam, it flowed over the gills.
2. Its main defense is the shell. The location of the siphons allows the clam to pump water through its gills without opening its shell very wide.
3. Both clams and crayfishes draw water into the body, pass it over the gills, and then release it. A clam must open its shell to do this, whereas a crayfish has openings through which water passes in and out.
4. Spiracles do not work under water, where crayfishes live.

Terrestrial Invertebrates In terrestrial animals, respiratory surfaces are covered with water or mucus, thereby minimizing water loss. In addition, air is moistened as it travels through the body to the respiratory surface.

Terrestrial invertebrates have several types of respiratory surfaces. The mantle cavity of a land snail is a moist tissue that has an extensive surface area lined with blood vessels. Spiders respire using organs called book lungs, such as the one shown in **Figure 29-9**. Book lungs are made of parallel, sheetlike layers of thin tissues that contain blood vessels. In insects, air enters the body through openings called spiracles. It then enters a network of tracheal tubes, where gases diffuse in and out of surrounding body fluids.

CHECKPOINT How does respiration in aquatic invertebrates differ from respiration in terrestrial invertebrates?

► **Figure 29-9** Invertebrates have a variety of respiratory structures. Clams and other aquatic mollusks have gills. Many spiders have book lungs. Grasshoppers and other insects have spiracles and tracheal tubes. **All respiratory organs have large, moist surface areas in contact with air or water.**



Answers to . . .

CHECKPOINT In intracellular digestion, food is digested inside cells. In extracellular digestion, food is broken down outside the cells.

CHECKPOINT Most aquatic animals have gills for removing oxygen from water and releasing carbon dioxide. Terrestrial animals get oxygen from air; respiratory surfaces are moist.

Figure 29-8 The cnidarian, because its digestive system consists of only a gastrovascular cavity and one opening that serves as both mouth and anus



TEACHER TO TEACHER

When I introduce topics related to invertebrate form and function, I find that my students are almost always fascinated with the diversity of structure and process in both digestion and reproduction. To respond to this interest, I try to provide students with a great variety of examples in both areas. Then, I challenge students to explain the reasons for the success of each adaptation presented. This teaching strategy not only

helps students gain some appreciation of the great diversity among invertebrates, but it also gives them an opportunity to apply their understanding of the processes involved in evolution.

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Circulation

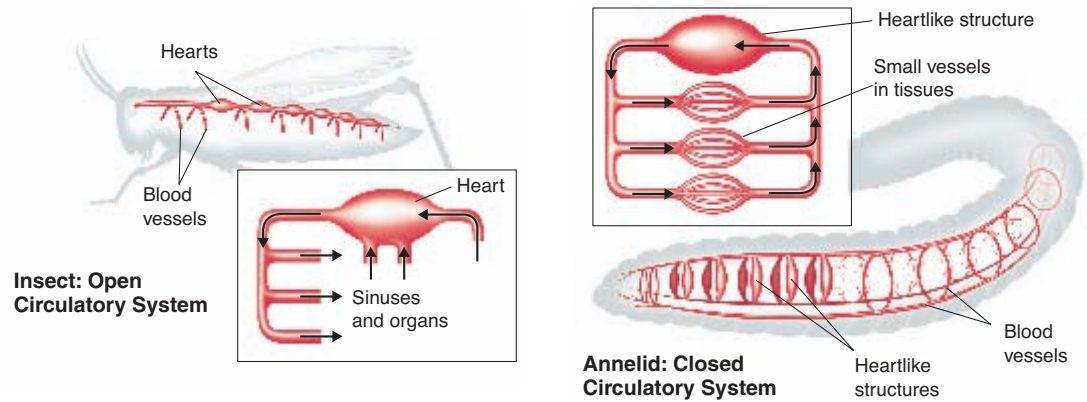
Use Visuals

Figure 29-10 Have students use the figure to compare and contrast the two circulatory systems. Ask: **How does each type of system get blood to tissues and organs?** (In the open circulatory system, blood is pumped to a cavity or sinus, where it comes in direct contact with tissues and organs. In a closed circulatory system, blood is pumped through vessels to tissues and organs.) Explain that the blood in an open system aids many invertebrates in movement, acting as part of the animal's hydrostatic skeleton. Point out that although an open system may not seem as efficient as a closed system, it works well for the invertebrates that have it. **L2**

Excretion

Making Connections

Chemistry Explain that every amino acid contains an amino group, $-\text{NH}_2$. The first step in the breakdown of an amino acid, called deamination, is the removal of the amino group. With the addition of a proton, an amino group becomes ammonia, NH_3 . Use a clear glass beaker to show students some household ammonia. **CAUTION:** Do not perform this demonstration if any students are asthmatic or sensitive to ammonia fumes. Be sure the room is well ventilated and that students don't come close to the beaker. Explain that this commercial product contains ammonia in solution with water and a detergent. Most students will know that even in this dilute solution, the ammonia can be harmful. Emphasize that both urea and uric acid are much less toxic than ammonia, which is why those compounds can be held for long periods of time and excreted by land animals without doing harm to themselves or the environment. **L2 L3**



▲ Figure 29-10 Most complex animals have one or more hearts to move fluid through their bodies in either an open or a closed circulatory system. An insect has an open circulatory system in which blood leaves blood vessels and then moves through sinuses, or body cavities. An annelid has a closed circulatory system in which blood stays in blood vessels as it moves through the body.

Circulation

All cells of multicellular animals require a constant supply of oxygen and nutrients, and cells must also remove metabolic wastes. The smallest and thinnest animals meet this requirement by simple diffusion between their body surface and the environment. But this system is usually insufficient for more complex animals.

Most complex animals move blood through their bodies using one or more hearts and either an open or a closed circulatory system. Both types of circulatory systems are shown in **Figure 29-10**.

Open Circulatory Systems In an **open circulatory system**, blood is only partially contained within a system of blood vessels. Instead, one or more hearts or heartlike organs pump blood through blood vessels into a system of sinuses, or spongy cavities. The blood comes into direct contact with the tissues, collects in body sinuses, and eventually makes its way back to the heart. Open circulatory systems are found in arthropods and most mollusks.

Closed Circulatory Systems In a **closed circulatory system**, a heart or heartlike organ forces blood through vessels that extend throughout the body. The blood stays within these blood vessels. Materials reach body tissues by diffusing across the walls of the blood vessels.

Closed circulatory systems are characteristic of larger, more active animals. Because blood trapped within the blood vessels is kept at high pressure, it can be circulated more efficiently than in an open circulatory system. Among the invertebrates, closed circulatory systems are found in annelids and some mollusks.

Excretion

Multicellular animals must control the amount of water in their tissues. At the same time, all animals must get rid of ammonia. The excretory systems of invertebrates carry out these functions in a variety of ways as shown in **Figure 29-11**.




FACTS AND FIGURES

Benefits of an open circulatory system

In arthropods with an open circulatory system, the blood empties from blood vessels directly into the body cavity, where it bathes the organs. It might seem that this type of system is extremely sloppy and inefficient. Yet, the open circulatory system often has uses to the organism beyond circulation. For example, for many clams and snails, the blood in the body cavities functions as a hydrostatic skeleton, helping the animal in move-

ment and burrowing. The blood also functions as a hydrostatic skeleton in aquatic arthropods when they molt. Many spiders are able to extend their legs by forcing the blood in the open system into the limbs. In addition, for a few insects, the open circulatory system functions as the body's thermal regulator, maintaining the body temperature within the range in which cells can function.

 Most animals have an excretory system that rids the body of metabolic wastes while controlling the amount of water in the tissues.

In aquatic invertebrates, ammonia diffuses from their body tissues into the surrounding water. The water immediately dilutes the ammonia and carries it away. Flatworms use a network of flame cells to eliminate excess water. Fluid travels through excretory tubules and leaves the body through tiny pores in the animal's skin.

Terrestrial invertebrates must conserve water while removing nitrogenous wastes. To do this, many animals convert ammonia into a compound called urea. Urea is eliminated from the body in urine. Urine is highly concentrated, so little water is lost. In annelids and mollusks, urine forms in tubelike structures called nephridia. Fluid enters the nephridia through openings called nephrostomes. Urine leaves the body through excretory pores.

Some insects and arachnids have Malpighian tubules, saclike organs that convert ammonia into uric acid. Both uric acid and digestive wastes combine to form a thick paste that leaves the body through a structure called the rectum. Because the paste contains little water, this process also reduces water loss.

Go Online

 For: Links on invertebrates
 Visit: www.SciLinks.org
 Web Code: cbn-8292



Go Online

 Download a worksheet on invertebrates for students to complete, and find additional teacher support from NSTA SciLinks.

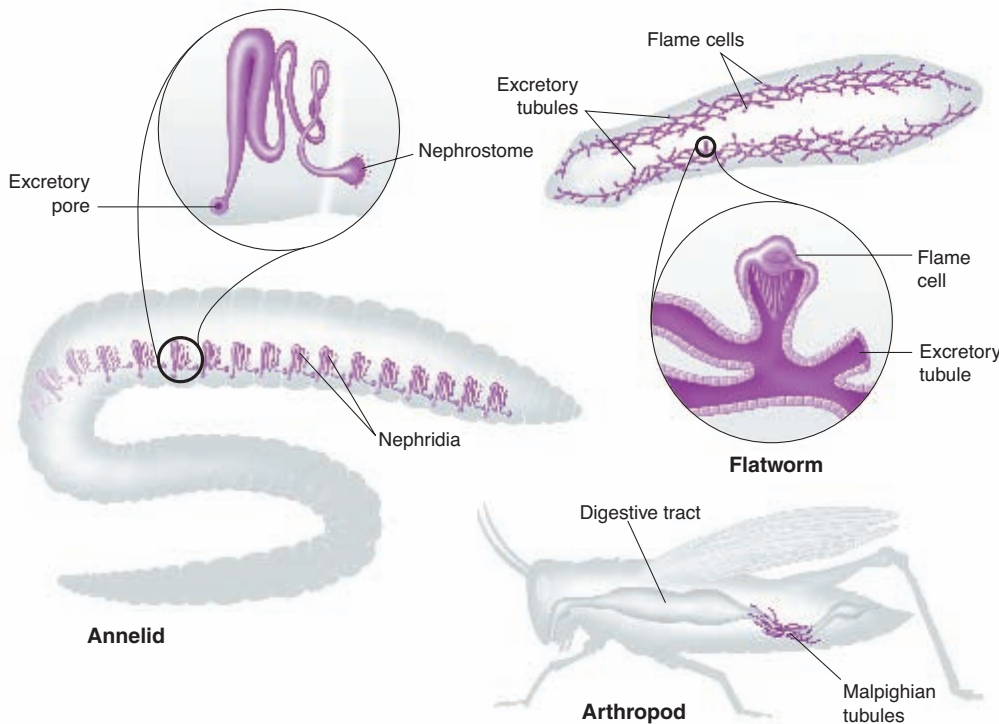
Figure 29-11  Most animals dispose of wastes through excretory systems. Excretory systems also control an organism's water levels. Flatworms excrete ammonia directly into the water and use flame cells to remove excess water. Annelids use nephridia to convert ammonia into urea and to concentrate it in urine. Some arthropods have Malpighian tubules, which convert ammonia into uric acid.

Use Visuals

Figure 29-11 Have students study the examples of the three different methods for disposing of wastes. Then, ask: **How would you compare the environments in which these three invertebrates live?** (*The flatworm lives in an aquatic environment, while the annelid and the arthropod live on land.*) **Why can the flatworm excrete ammonia directly into its environment, while the annelid and arthropod cannot?** (*When the ammonia diffuses from the flatworm's body, it is immediately diluted by the surrounding water. If the land invertebrates excreted ammonia, the ammonia would not be diluted.*) Emphasize that all land organisms must conserve water, and excreting uric acid in solid or semisolid form, as most terrestrial invertebrates do, conserves water. **L2**

Build Science Skills

Comparing and Contrasting
 Divide the class into small groups, and assign each group one of the invertebrate phyla studied in this unit. Have the members of each group work together to make a large chart on poster board that includes labeled drawings of the digestive and excretory systems used by organisms in their phylum. Once all groups have finished, have each group present its work and then display its charts on the classroom wall. **L1 L2**



FACTS AND FIGURES

Getting rid of ammonia

Protein is an essential part of an animal's diet, and the digestion of protein in foods produces amino acids. An organism uses some of these amino acids to produce the proteins and other compounds it needs. Excess amino acids are also used in cellular respiration for energy. This use begins with the nitrogen group, forming ammonia, which is highly poisonous to the organism. The aquatic invertebrates that allow ammonia to dif-

fuse out of their bodies are for that reason limited to aquatic environments, because water is necessary to dilute the ammonia, which would be harmful to all organisms if not diluted. Therefore, the ability to produce the relatively harmless uric acid is an important reason why invertebrates, particularly insects, have been so successful on land. Also, because uric acid is excreted in a solid or semisolid form, a land animal is able to conserve precious water.

29-2 (continued)

Response

Use Visuals

Figure 29-12 After students have compared the four examples in the figure, ask: **Which is the simplest nervous system shown, and what is it called?** (*The simplest is that shown in the cnidarian, and it is called a nerve net.*) **What controls and coordinates the nervous system in the arthropod and the mollusk?** (*The brain*) **Which of the four invertebrates exhibit cephalization?** (*The flatworm, the arthropod, and the mollusk*) **L2**

Demonstration

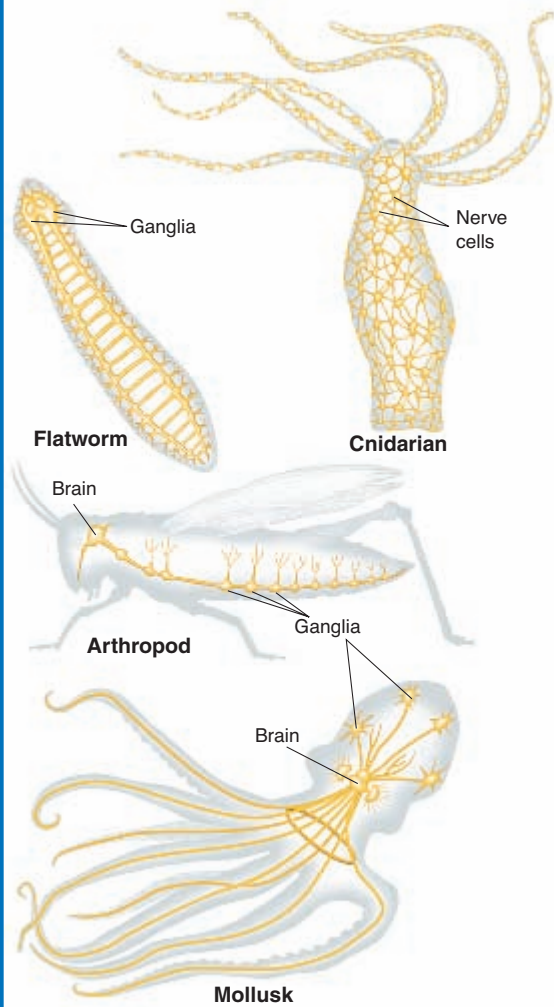
Place live planarians in a petri dish containing a small amount of chlorine-free water, and cover half the dish with a piece of dark paper. Then, shine a flashlight on the uncovered area. Have students observe that the planarians avoid the light by moving under the paper. Have students hypothesize about the selective advantage of planarians' ability to detect light and tendency to move away from light into a dark area.

L1 L2

Movement and Support

Make Connections

Physics Show students a hydraulic pump, such as a hydraulic car jack. Explain that when pressure is applied to a fluid in a confined area, an increase in pressure is transmitted uniformly to all parts of the fluid. This is known as Pascal's principle after the French physicist Blaise Pascal, who first described this idea. The principle is used in hydraulic pumps, as well as by various invertebrates. With a hydraulic jack, a person applies pressure by pushing down on the handle, and when the pressure is uniformly distributed, it pushes up on a piston, which raises the car. Similarly, an invertebrate applies pressure on internal fluid by contracting muscles in one part of its body and relaxing muscles in another part. As the pressure is uniformly distributed, the animal can move forward (worm), extend tube feet (echinoderm), or make any number of other movements. **L2 L3**



▲ Figure 29-12 **👉 Invertebrate nervous systems have different degrees of centralization, cephalization, and specialization.** Cnidarians have a simple nerve net. Flatworms, whose nervous systems are more centralized, have small ganglia in their heads. Arthropods and cephalopod mollusks have a centralized brain and specialized sensory organs.

Response

Nervous systems gather and process information from the environment and allow animals to respond appropriately. **Figure 29-12** shows the nervous system of four invertebrates. **👉 Invertebrates show three trends in the evolution of the nervous system: centralization, cephalization, and specialization.** Different nervous systems have various degrees of each of these characteristics.

Centralization and Cephalization The simplest nervous systems, found in cnidarians, are called nerve nets. Nerve nets consist of individual nerve cells that form a netlike arrangement throughout the animal's body. In flatworms and roundworms, the nerve cells are more concentrated, or centralized. There are a few small clumps of nerve tissue, or ganglia, in the head. In cephalopod mollusks and arthropods, ganglia are organized into a brain that controls and coordinates the nervous system. This concentration of nerve tissue and organs in one end of the body is called cephalization.

Specialization The more complex an animal's nervous system is, the more developed its sense organs tend to be. Flatworms, for example, have simple eyespots that detect only the presence of light. More complex animals, such as insects, have eyes that detect motion and color and form images. Complex animals may have a variety of specialized sense organs that detect light, sound, chemicals, movement, and even electricity to help them discover what is happening around them.

Movement and Support

Most animals use specialized tissues called muscles to move, breathe, pump blood, and perform other life functions. Muscles work by contracting, or becoming shorter. This is the only way that muscle tissue can generate force. When they are not stimulated, muscles relax. In most animals, muscles work together with some sort of skeletal system that provides firm support. **👉 Invertebrates have one of three main kinds of skeletal systems: hydrostatic skeletons, exoskeletons, or endoskeletons.**

Hydrostatic Skeletons Some invertebrates, such as annelids and certain cnidarians, have **hydrostatic skeletons**, shown in **Figure 29-13**. In these animals, muscles surround a fluid-filled body cavity that supports the muscles. When the muscles contract, they push against fluid in the body cavity, causing the body to change shape.

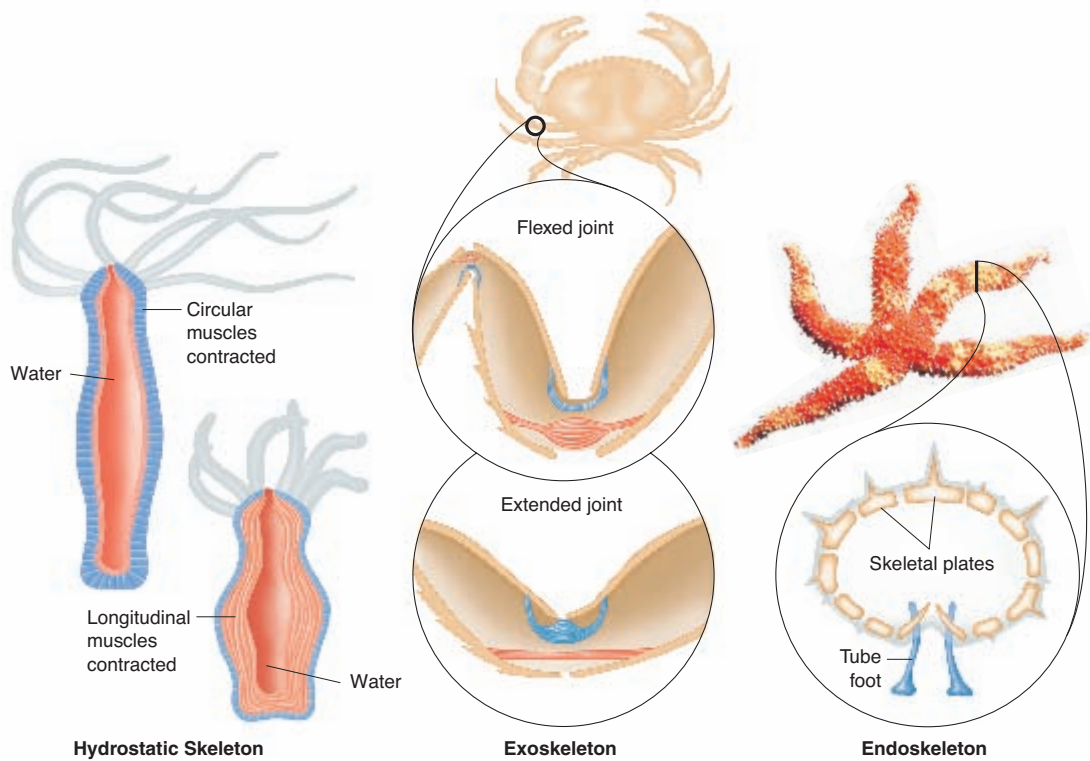


FACTS AND FIGURES

Invertebrate eyes

Almost all invertebrates have some kind of sense organ that responds to light, though light-sensing ability varies greatly. The eyespots, or ocelli, of flatworms and some other invertebrates are composed of light-sensitive cells that give the organism much information about both the intensity and the direction of light. Many arthropods, some annelids, and some mollusks have compound eyes, which are

composed of many units, each with a separate nerve track that leads to a large optic nerve. The fields of vision of each unit overlap somewhat with neighboring units, giving the organism great ability for detecting movement. Some cephalopods, including squids and octopi, have complex, or camera, eyes. These eyes, which are much like vertebrate eyes, form the best images among all invertebrate eyes.



Use Visuals

Figure 29–13 Have students examine the three types of skeletons. Then, ask: **How does a hydra change its shape?** (*It contracts muscles that surround a fluid-filled body cavity.*) **Describe how an invertebrate with an exoskeleton bends and extends a limb.** (*When a limb is bent, or flexed, one muscle contracts while the other relaxes. During extension of the same limb, the opposite muscles contract and relax.*) Point out that muscles can pull but cannot push. Vertebrates, which have endoskeletons, use muscles in the same way to flex and extend limbs.

L2

Sexual and Asexual Reproduction

Build Science Skills

Designing Experiments Divide the class into small groups, and ask each group to design an imaginary experiment to investigate what conditions are best for the reproduction of a specific kind of invertebrate. Tell students to imagine that they have the resources of any university biology department and an unlimited amount of time. Instruct students to write a hypothesis, identify manipulated and controlled variables, describe how they would collect data, and predict the results of the experiment. L2 L3

Exoskeletons In arthropods, the **exoskeleton**, or external skeleton, is a hard body covering made of chitin. Arthropods move by using muscles that are attached to the inside of the exoskeleton. These muscles bend and straighten different joints. The shells of some mollusks can also be considered exoskeletons. Muscles attached to the shell make it possible for snails to withdraw into their shells and for bivalves to close their shells.

Endoskeletons An **endoskeleton** is a structural support located inside the body. Sea stars and other echinoderms have an endoskeleton made of calcified plates. These plates function in support and protection, and also give these animals a bumpy and irregular texture. Vertebrates also have endoskeletons.

▲ **Figure 29–13** The three main types of invertebrate skeletons are hydrostatic skeletons, exoskeletons, and endoskeletons. In animals with hydrostatic skeletons, muscles contract against a fluid-filled body cavity. In animals with exoskeletons, the muscles pull against the insides of the exoskeleton. Echinoderms and some sponges have endoskeletons.

Sexual and Asexual Reproduction

Most invertebrates reproduce sexually during at least part of their life cycle. Depending on environmental conditions, however, many invertebrates may also reproduce asexually. Each form of reproduction has advantages and disadvantages. Asexual reproduction allows animals to reproduce rapidly and take advantage of favorable conditions in the environment. Sexual reproduction, in contrast, maintains genetic diversity in a population by creating individuals with new combinations of genes.

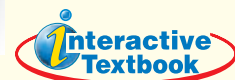


FACTS AND FIGURES

Invertebrate hermaphrodites

In Greek myth, Hermaphroditus, the son of Hermes and Aphrodite, caught the eye of a nymph of the spring in which he was bathing. She fell in love with and clung to him, and they melded into one being—half male and half female. Likewise, a hermaphroditic animal contains both male and female organs and thus can produce both eggs and sperm. Hermaphroditism

is common in invertebrates such as some worms, some gastropods, some leeches, and barnacles. During sexual reproduction, different animals pass sperm from one to the other. As a result, eggs in both organisms become fertilized. That result is an advantage of hermaphroditism, because two organisms, not one, are impregnated by each encounter. Such an event is called mutual cross-fertilization.



If your class subscribes to the iText, use it to review the Key Concepts in Section 29–2.

29-2 (continued)

Build Science Skills

Applying Concepts On the board, write groupings of related terms used in discussing invertebrate structure and function. Have students work in pairs to write short paragraphs using the terms of each group in context, comparing and contrasting kinds of invertebrates. Here are some possible groups:

- gastrovascular cavity, digestive tract
- mantle cavity, book lungs, tracheal tubes
- open circulatory system, closed circulatory system
- ammonia, urea, uric acid
- nerve net, ganglia, brain
- hydrostatic skeleton, exoskeleton, endoskeleton
- asexual reproduction, sexual reproduction **L2**

3 ASSESS

Evaluate Understanding

Read aloud each of the boldface sentences in the section. For each, call on a volunteer to provide a supporting detail for that key idea. Then, ask others in the class for additional supporting details. After students have provided support for the idea, ask for a volunteer to explain the importance of that idea in understanding form and function in invertebrates.

Reteach

Ask each student to choose any two organisms from two different invertebrate phyla and write a paragraph comparing the animals in terms of their feeding and digestion, respiration, circulation, excretion, response, movement and support, and reproduction.

Thinking Visually

Students' Venn diagrams should include the fact that in open systems blood comes in direct contact with tissues, whereas in closed systems blood stays within blood vessels. Open systems are characteristic of arthropods and most mollusks; closed systems are found in annelids and some mollusks.



Figure 29-14 🔄 Invertebrates may reproduce asexually or sexually. Note that the largest sea anemone in this group is undergoing asexual reproduction by splitting into two parts (top). The *Acorpora* coral (bottom) is releasing brown eggs into the water. The eggs will be fertilized externally. This is an example of sexual reproduction.

Sexual reproduction is the production of offspring from the fusion of gametes. Recall that gametes are haploid, meaning that they have half the number of chromosomes found in most body cells. Gametes, such as the eggs in the lower photo in **Figure 29-14**, are produced by meiosis, the process by which the number of chromosomes per cell is reduced to half that of most body cells. When male and female gametes join during fertilization, the zygote, or fertilized egg, has the diploid number of chromosomes. Since the zygote received chromosomes from each parent, its genes are a combination of the genes of both parents. The zygote, which is one cell, grows through ongoing cell divisions, or mitosis, and eventually develops into a multicellular animal.

In most animals, each individual is a single sex. The individual produces either sperm or eggs. But some animals, such as earthworms, are hermaphrodites, or individuals that produce both sperm and eggs. In **external fertilization**, eggs are fertilized outside the female's body. In **internal fertilization**, eggs are fertilized inside the female's body.

In contrast to sexual reproduction, asexual reproduction does not involve the production of gametes by meiosis or the formation of new combinations of genes. The offspring of asexual reproduction grow into multicellular organisms by mitosis of diploid cells. In asexual reproduction, all the offspring are genetically identical to the parent. Asexual reproduction sometimes occurs through budding, in which new individuals are produced by outgrowths of the body wall. Some animals reproduce asexually by dividing in two.

29-2 Section Assessment

1. **Key Concept** In your own words, describe the evolution of three different body systems of invertebrates.
2. **Key Concept** Compare asexual and sexual reproduction. What are the advantages and disadvantages of each?
3. Compare circulation in annelids and arthropods.
4. What are the three main kinds of skeletal systems in invertebrates?
5. **Critical Thinking Applying Concepts** List the three forms of nitrogenous wastes excreted by animals. How are the ways in which animals dispose of these wastes related to each animal's environment?

Thinking Visually

Creating a Venn Diagram

Create a Venn diagram that compares and contrasts open and closed circulatory systems. Be sure to include similarities as well as differences. In your Venn diagram, identify some kinds of animals that have each type of circulatory system.

29-2 Section Assessment

1. Students should describe the evolution of three body systems discussed in the section.
2. Asexual reproduction allows animals to reproduce rapidly and take advantage of favorable environments, where genetic diversity is not so important. Sexual reproduction maintains genetic diversity in a population, but it is not rapid.
3. Annelids have a closed circulatory system; arthropods have an open circulatory system.
4. Hydrostatic skeletons, exoskeletons, endoskeletons
5. Ammonia, urea, and uric acid. The method largely depends on environment: Freshwater animals generally need to get rid of excess water; terrestrial animals must conserve it.