Refer to pages 4T-5T of the Teacher Guide for an explanation of the National Science Education Standards correlations.

Section	Objectives	Activities/Features
Section 29.1 **Echinoderms** National Science Education Standards UCP.1-5; A.1, A.2; C.3, C.5, C.6 (1 session, ½ block)	1. **Compare** similarities and differences among the classes of echinoderms. 2. **Interpret** the evidence biologists have for determining that echinoderms are close relatives of chordates.	**MiniLab 29-1:** Examining Pedicellariae, p. 788 **Inside Story:** A Sea Star, p. 790 **Problem-Solving Lab 29-1,** p. 792 **Investigate BioLab:** Observing Sea Urchin Gametes and Egg Development, p. 800 **Physics Connection:** Hydraulics of Sea Stars, p. 802
Section 29.2 **Invertebrate Chordates** National Science Education Standards UCP.1, UCP.2, UCP. 4, UCP.5; A.1, A.2; C.3, C.5, C.6; G.1-3 (2 sessions, ½ block)	3. **Summarize** the characteristics of chordates. 4. **Explain** how invertebrate chordates are related to vertebrates. 5. **Distinguish** between sea squirts and lancelets.	**MiniLab 29-2:** Examining a Lancelet, p. 797 **Inside Story:** A Tunicate, p. 798 **Problem-Solving Lab 29-2**, p. 799

Need Materials? Contact Carolina Biological Supply Company at 1-800-334-5551 or at **http://www.carolina.com**

MATERIALS LIST

BioLab

p. 800 microscope, microscope slides (5), coverslips (5), petri dish, dropper (2), test tube, beaker (2), sea water, live sea urchins (male and female), syringe with needle, potassium chloride solution

MiniLabs

p. 788 microscope, prepared slide of sea star pedicellariae, paper, pencil
p. 797 stereomicroscope, microscope slide, forceps, metric ruler, preserved specimen of *Branchiostoma californiense (Amphioxus)*

Alternative Lab

p. 796 microscope, prepared slides of sea urchin development and lancelets

Quick Demos

p. 789 stereomicroscope, live sea urchin, toothpick
p. 789 dropper
p. 791 heavy book
p. 795 preserved specimens of tunicates and lancelets
p. 796 microscope, prepared slide of lancelet cross section

Key to Teaching Strategies

- **L1** Level 1 activities should be appropriate for students with learning difficulties.
- **L2** Level 2 activities should be within the ability range of all students.
- **L3** Level 3 activities are designed for above-average students.
- **ELL** ELL activities should be within the ability range of English Language Learners.
- **COOP LEARN** Cooperative Learning activities are designed for small group work.
- **P** These strategies represent student products that can be placed into a best-work portfolio.
- These strategies are useful in a block scheduling format.

Teacher Classroom Resources

Section	Reproducible Masters	Transparencies
Section 29.1 **Echinoderms**	**Reinforcement and Study Guide,** pp. 127-129 L2 **Critical Thinking/Problem Solving,** p. 29 L3 **BioLab and MiniLab Worksheets,** p. 129 L2 **Laboratory Manual,** pp. 205-210 L2 **Content Mastery,** pp. 141-142, 144 L1	**Section Focus Transparency 71** L1 ELL **Basic Concepts Transparency 50** L2 ELL **Basic Concepts Transparency 51** L2 ELL
Section 29.2 **Invertebrate Chordates**	**Reinforcement and Study Guide,** p. 130 L2 **Concept Mapping,** p. 29 L3 ELL **Critical Thinking/Problem Solving,** p. 29 L3 **BioLab and MiniLab Worksheets,** pp. 130-132 L2 **Content Mastery,** pp. 141, 143-144 L1	**Section Focus Transparency 72** L1 ELL **Reteaching Skills Transparency 43** L1 ELL

Assessment Resources

Chapter Assessment, pp. 169-174
MindJogger Videoquizzes
Performance Assessment in the Biology Classroom
Alternate Assessment in the Science Classroom
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 29 quiz

Additional Resources

Spanish Resources ELL
English/Spanish Audiocassettes ELL
Cooperative Learning in the Science Classroom COOP LEARN
Lesson Plans/Block Scheduling

NATIONAL GEOGRAPHIC Teacher's Corner

Products Available From Glencoe

To order the following products, call Glencoe at 1-800-334-7344:

CD-ROM
NGS PictureShow: Structure of Invertebrates

Transparency Set
NGS PicturePack: Structure of Invertebrates

Index to National Geographic Magazine

The following articles may be used for research relating to this chapter:

"Pillar of Life," by George Grall, July 1992.

GLENCOE TECHNOLOGY

The following multimedia resources are available from Glencoe.

Biology: The Dynamics of Life

CD-ROM ELL
Exploration: *The Five Kingdoms*
Exploration: *Echinoderms*
Exploration: *Symmetry*
BioQuest: *Biodiversity Park*

Videodisc Program
Starfishes

The Secret of Life Series
Sea Stars
Chordate Body Plan
Action of Tube Feet

Getting Started Demo

Visual-Spatial Use live or preserved sea stars or sea urchins to point out the physical characteristics of echinoderms. Elicit from students how the meaning of the term echinoderm relates to the features of animals in this group. *Echinoderm means "spiny skin." The animals classified in this phylum have spinelike structures covering their bodies.*

Theme Development

Evolution is a major theme in this chapter. Students study how echinoderm larvae and invertebrate chordates show similarities to certain vertebrates. The theme of **systems and interactions** is obvious as students learn how the echinoderms and invertebrate chordates are adapted to and interact with their environments.

0:00 Out of Time?

If time does not permit teaching the entire chapter, use the BioDigest at the end of the unit as an overview.

Chapter 29 Echinoderms and Invertebrate Chordates

What You'll Learn

- You will compare and contrast the adaptations of echinoderms.
- You will distinguish the features of chordates by examining invertebrate chordates.

Why It's Important

By studying how echinoderms and invertebrate chordates function, you will enhance your understanding of evolutionary relationships between these two groups.

Getting Started

Observing a Sand Dollar

Examine the brittle skeleton of a sand dollar. Notice the petal-like marking on its upper surface. *What kind of symmetry does this organism exhibit?*

interNET CONNECTION To find out more about echinoderms and invertebrate chordates, visit the Glencoe Science Web Site. www.glencoe.com/sec/science

A sea star extends its stomach from its mouth and engulfs a sea urchin. Hours later, the sea star draws its stomach back in and moves away. All that's left of the urchin is the bumpy globe you see here. Even its spines are gone.

Section 29.1 Echinoderms

Think about what the best defense might be for a small animal that moves slowly in tide pools on the seashore. Did you think of armor, spines, or perhaps poison as methods of protection? Sea urchins are masters of defense—some use all three methods. The sea urchin looks different from the feather star and from the sea star on the facing page, yet all three belong to the same phylum. What characteristics do they have in common? What features determine whether an animal is an echinoderm?

Feather star (above) and sea urchin (inset)

Section Preview

Objectives

Compare similarities and differences among the classes of echinoderms.

Interpret the evidence biologists have for determining that echinoderms are close relatives of chordates.

Vocabulary

ray
pedicellaria
tube feet
ampulla
water vascular system
madreporite

What Is an Echinoderm?

Members of the phylum Echinodermata have a number of unusual characteristics that easily distinguish them from members of any other animal phylum. Echinoderms move by means of hundreds of hydraulic, suction cup-tipped appendages and have skin covered with tiny, jawlike pincers. Echinoderms (ih KI nuh durmz) are found in all the oceans of the world.

Echinoderms have endoskeletons

If you were to examine the skin of several different echinoderms, you would find that they all have a hard, spiny, or bumpy endoskeleton covered by a thin epidermis. The long, pointed spines on a sea urchin are obvious. Sea stars, sometimes called starfishes, may not appear spiny at first glance, but a close look reveals that their long, tapering arms, called **rays,** are covered with short, rounded spines. The spiny skin of a sea cucumber consists of soft tissue embedded with small, platelike structures that barely resemble spines. The endoskeleton of all echinoderms is made primarily of calcium carbonate, the compound that makes up limestone.

Some of the spines found on sea stars and sea urchins have become modified into pincerlike appendages called **pedicellariae** (PED ih sihl AHR ee ay). An echinoderm uses its jawlike pedicellariae for protection and for cleaning the surface of its body. You can examine these structures in the *MiniLab* on the following page.

Word Origin

echinoderm
From the Greek words *echinos*, meaning "spiny," and *derma*, meaning "skin." Echinoderms are spiny-skinned animals.

pedicellariae
From the Latin word *pediculus*, meaning "little foot." Pedicellariae resemble little feet.

Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

Kinesthetic Meeting Individual Needs, p. 788; Quick Demo, pp. 789, 791; Activity, p. 795

Visual-Spatial Quick Demo, pp. 789, 796; Tech Prep, p. 789; Project, p. 790; Portfolio, p. 795; Reteach, p. 799

Linguistic Biology Journal, p. 790

Naturalist Portfolio, p. 792; Check for Understanding, p. 793; Reteach, p. 793; Quick Demo, p. 795

Assessment Planner

Portfolio Assessment
MiniLab, TWE, pp. 788, 797
Assessment, TWE, p. 789
Problem-Solving Lab, TWE, p. 792
Portfolio, TWE, p. 792

Performance Assessment
BioLab, SE, pp. 800-801
MiniLab, SE, pp. 788, 797
Alternative Lab, TWE, pp. 796-797
Assessment, TWE, pp. 793, 799
Problem-Solving Lab, TWE, p. 798

Knowledge Assessment
Section Assessment, SE, pp. 793, 799
Chapter Assessment, SE, pp. 803-805
Assessment, TWE, p. 796
BioLab, TWE, pp. 800-801

Skill Assessment
Alternative Lab, TWE, pp. 796-797

Prepare

Key Concepts

The characteristics common to echinoderms are presented. The diversity of echinoderms is considered. Deuterostome development is examined in terms of its evolutionary significance.

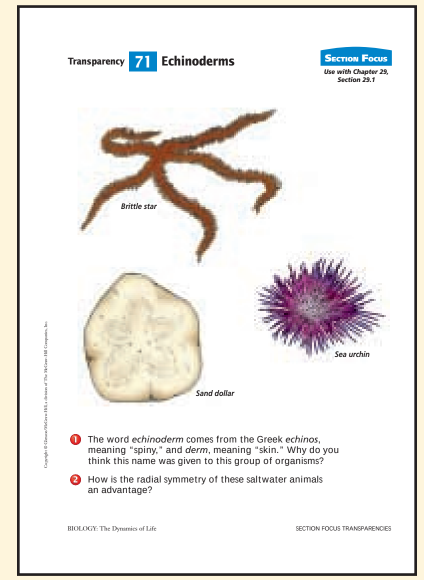
Planning

- Obtain droppers for the Quick Demos.
- Make photocopies of the inner, shaded area of Figure 29.6 for the Reteach.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 71** on the overhead projector and have students answer the accompanying questions. L1 ELL



Resource Manager

Section Focus Transparency 71 and Master L1 ELL

2 Teach

MiniLab 29-1

Purpose
Students will observe the pincherlike structure of pedicellariae.

Process Skills
observe and infer, compare and contrast, draw a conclusion, measure in SI

Teaching Strategies
- Review the procedure for measuring objects under the microscope.
- Prepared slides are available from biological supply houses.

Expected Results
Students will observe that pedicellariae have a pincherlike appearance and measure close to 250μm in length.

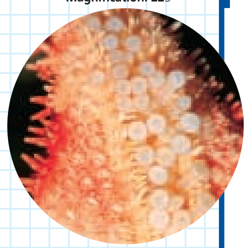
Analysis
1. Student answers will vary—pincherlike, plierslike, forcepslike
2. allows animal to grasp objects, clean itself of debris, protection
3. These pincherlike organs allow the sea star to pinch potential predators when they touch the animal. Their shape also allows the sea star to clean itself by picking off materials that become stuck to its body.

Assessment
Portfolio Have students write a lab report that summarizes their results and place it in their portfolios. Use the Performance Task Assessment List for Lab Report in **PASC**, p. 47. L2 P

Visual Learning
Have students examine the animals shown in Figure 29.1 closely. Challenge them to identify the lines of symmetry for each organism that has radial symmetry. L1

MiniLab 29-1 Observing and Inferring

Examining Pedicellariae Echinoderms move by tube feet. They also have tiny pincers on their skin called pedicellariae.



Pedicellariae

Procedure
1. Observe a slide of sea star pedicellariae under low-power magnification. **CAUTION:** *Use caution when working with a microscope and slides.*
2. Record the general appearance of one pedicellaria. What does it look like?
3. Make a diagram of one pedicellaria under low-power magnification.
4. Record the size of one pedicellaria in micrometers.

Analysis
1. Describe the general appearance of one pedicellaria.
2. What is the function of this structure?
3. Explain how the structure of pedicellariae assists in their function.

Echinoderms have radial symmetry

You may remember that radial symmetry is an advantage to animals that are stationary or move slowly. Radial symmetry enables these animals to sense potential food, predators, and other aspects of their environment from all directions. Observe the radial symmetry, as well as the various sizes and shapes of spines, of each echinoderm pictured in *Figure 29.1.*

The water vascular system

Another characteristic unique to echinoderms is the water vascular system that enables them to move, exchange gases, capture food, and excrete wastes. Look at the close-up of the underside of a sea star in *Figure 29.2.* You can see that grooves filled with tube feet run from the area of the sea star's mouth to the tip of each ray. **Tube feet** are hollow, thin-walled tubes that end in a suction cup. Tube feet look somewhat like miniature droppers. The round, muscular structure called the **ampulla** (AM puh lah) works something like the bulb of a dropper. The end of a tube foot works like a tiny suction cup. Each tube foot works independently of the others, and the animal moves along slowly by alternately pushing out and pulling in its tube feet. You can learn more about the operation of the water vascular system in the *Physics Connection* at the end of this chapter.

The **water vascular system** is a hydraulic system that operates under water pressure. Water enters and leaves the water vascular system of a sea star through the **madreporite** (MAH dray pohr ite), a sievelike, disk-shaped opening on the upper surface of the echinoderm's body. You can think of this disk as being like the little strainer that fits into the drain in a sink and keeps large particles out of the pipes. You can find out how a sea star eliminates wastes by reading the *Inside Story* on the next page.

Finally, tube feet function in gas exchange and excretion. Gases are exchanged and wastes are eliminated by diffusion through the thin walls of the tube feet.

Figure 29.1
All echinoderms have radial symmetry as adults and an endoskeleton composed primarily of calcium carbonate.


A A brittle star's long, snakelike rays are composed of overlapping, calcified plates covered with a thin layer of skin cells.


B A living sand dollar has a solid, immovable skeleton composed of flattened plates that are fused together.


C A sea lily's feathery rays are composed of calcified skeletal plates covered with an epidermis.

Echinoderms have varied nutrition

All echinoderms have a mouth, stomach, and intestines, but their methods of obtaining food vary. Sea stars are carnivorous and prey on worms or on mollusks such as clams. Most sea urchins are herbivores and graze on algae. Brittle stars, sea lilies, and sea cucumbers feed on dead and decaying matter that drifts down to the ocean floor. Sea lilies capture this suspended organic matter with their tentaclelike tube feet and move it to their mouths.

Echinoderms have a simple nervous system

Echinoderms have no head or brain, but they do have a central nerve ring that surrounds the mouth. Nerves extend from the nerve ring down each ray. Each radial nerve then branches into a nerve net that provides sensory information to the animal. Echinoderms have cells that detect light and touch, but most do not have sensory organs. Sea stars are an exception. A sea star's body consists of long, tapering rays that extend from the animal's central disk. At the tip of each ray, on the underside, is an eyespot, a sensory organ consisting of a cluster of light-detecting cells. When walking, sea stars curve up the tips of their rays so that the eyespots are turned up and outward. This enables a sea star to detect the intensity of light coming from every direction.


Figure 29.2
Tube feet enable sea stars and other echinoderms to creep along the ocean bottom or to pry open the shells of bivalves.

Echinoderms have bilaterally symmetrical larvae

If you examine the larval stages of echinoderms, you will find that they have bilateral symmetry, a feature more common to chordates. The ciliated larva that develops from the fertilized egg of an echinoderm is shown in *Figure 29.3.* Through metamorphosis, the free-swimming larvae make dramatic changes in both body parts and in symmetry. The bilateral symmetry of echinoderm larvae indicates that echinoderm ancestors also may have had bilateral symmetry, suggesting a close relationship to the chordates. You can observe sea urchin development in the *BioLab* at the end of this chapter.


Figure 29.3
These sea urchin larvae are only 1 mm in size. The larval stage of echinoderms is bilateral, even though the adult stage has radial symmetry.

Quick Demo

Visual-Spatial Have students observe the pedicellariae of a live sea urchin under a stereomicroscope and make sketches of their observations. Have them touch one pedicellaria with a toothpick to observe the structure's response. L2 ELL

Quick Demo

Kinesthetic Provide each student with a dropper. Have them squeeze the air from the dropper, and then, while still applying pressure to the rubber end of the dropper, touch the dropper tip to their finger. They should release the pressure on the dropper and observe how the dropper holds to their finger. Explain that this is similar to the suction action of the tube feet of a sea star. L2 ELL

Assessment
Portfolio Ask students to make a table showing the different groups of echinoderms, the type of food they eat, and whether or not they move around to find their food. Ask them to relate the type of food to the animals' methods of locomotion. Have them include their table and explanation in their portfolios. L2 P

Resource Manager
BioLab and MiniLab Worksheets, p. 129 L2

Meeting Individual Needs

Visually Impaired

Kinesthetic Provide visually impaired students with dried specimens of various echinoderms. Allow students to handle the specimens so they can feel the shapes, sizes, and characteristic spiny skins of these animals. L1 ELL

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *The Five Kingdoms*
Disc 3

TechPrep

Raising Sea Stars

Visual-Spatial Ask students to visit a saltwater aquarium at a local zoo or pet shop. Have them visit when the sea stars and sea urchins are being fed. Ask students to observe and record sea star feeding behavior when live clams or oysters are added to the tank. Ask them to interview the person in charge of taking care of the aquarium to find out what daily tasks the caretaker must perform to maintain the sea stars and sea urchins. Have students report their findings to the class. L2 COOP LEARN

INSIDE STORY

Purpose

Students will learn about the structural and behavioral adaptations of a sea star.

Teaching Strategies

- Ask students to observe a live sea star in action. They can use a hand lens to observe the tube feet as the sea star "walks" or "climbs" a surface of a marine aquarium. L1 ELL

Visual Learning

- Make photocopies of the Inside Story diagram without the labels of the structures. Number the parts and explain to students how each part functions and how the parts enable the sea star to survive in its environment. Have students use this information to label the diagram. L1

Critical Thinking

Radial symmetry enables animals that move slowly to sense and obtain potential food, escape predators, and sense other aspects of their environment from all directions.

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *Echinoderms*
Disc 4
Exploration: *Symmetry*
Disc 4

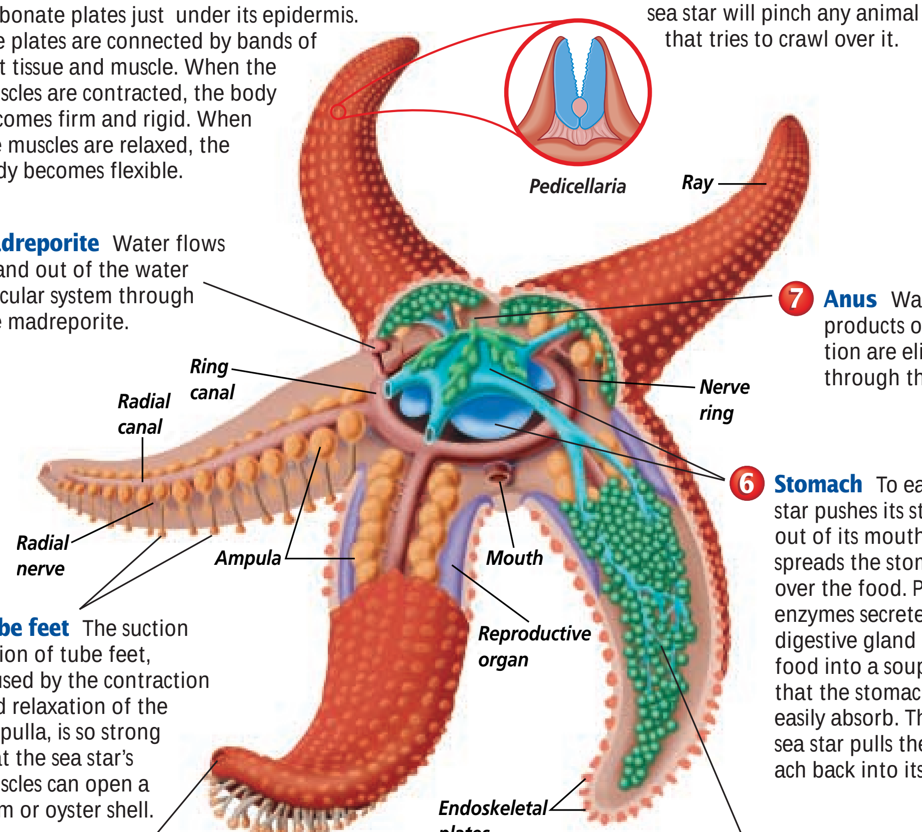
INSIDE STORY

A Sea Star

If you ever tried to pull a sea star from a rock where it is attached, you would be impressed by how unyielding and rigid the animal seems to be. Yet at other times, the animal shows great flexibility, such as when it rights itself after being turned upside down.

Critical Thinking *How is radial symmetry useful to a sea star?*

Blood sea star



1 Endoskeleton A sea star can maintain a rigid structure or be flexible because it has an endoskeleton in the form of calcium carbonate plates just under its epidermis. The plates are connected by bands of soft tissue and muscle. When the muscles are contracted, the body becomes firm and rigid. When the muscles are relaxed, the body becomes flexible.

2 Madreporite Water flows in and out of the water vascular system through the madreporite.

3 Tube feet The suction action of tube feet, caused by the contraction and relaxation of the ampulla, is so strong that the sea star's muscles can open a clam or oyster shell.

4 Eyespots When moving, a sea star curves up the tips of its rays so that the eyespots are turned up and outward. Echinoderm eyespots distinguish between light and dark but do not form images.

5 Digestive gland The digestive gland gives off chemicals for digestion.

6 Stomach To eat, a sea star pushes its stomach out of its mouth and spreads the stomach over the food. Powerful enzymes secreted by the digestive gland turn solid food into a soupy liquid that the stomach can easily absorb. Then the sea star pulls the stomach back into its body.

7 Anus Waste products of digestion are eliminated through the anus.

8 Pedicellariae The pincerlike pedicellariae on the rays of the sea star will pinch any animal that tries to crawl over it.

Diversity of Echinoderms

Approximately 6000 species of echinoderms exist today. More than one-third of these species are in the class Asteroidea (AS tuh royd ee uh), to which the sea stars belong. The four other classes of living echinoderms are Ophiuroidea (OH fee uh royd ee uh), the brittle stars; Echinoidea (eh kihn OYD ee uh), the sea urchins and sand dollars; Holothuroidea (HOH loh thuh royd ee uh), the sea cucumbers; and Crinoidea (cry NOYD ee uh), the sea lilies and feather stars.

Sea stars

Most species of sea stars have five rays, but some have more. Some species may have more than 40 rays. The rays are tapered and extend from the central disk. You have already read about the characteristics of sea stars that make them a typical example of echinoderms.

Brittle stars

As their name implies, brittle stars are extremely fragile, *Figure 29.4*. If you try to pick up a brittle star, parts of its rays will break off in your hand. This is an adaptation that helps the brittle star survive an attack by a predator. While the predator is busy with the broken-off ray, the brittle star can escape. A new ray will regenerate within weeks.

Brittle stars do not use their tube feet for locomotion. Instead, they propel themselves with the snakelike, slithering motion of their flexible rays. They use their tube feet to pass particles of food along the rays and into the mouth in the central disk.

Sea urchins and sand dollars

Sea urchins and sand dollars are globe- or disk-shaped animals covered with spines, as *Figure 29.4* shows. They do not have rays. The circular, flat skeletons of sand dollars have a five-petaled flower pattern on the surface. A living sand dollar is covered with minute, hairlike spines that are lost when the animal dies. A sand dollar has tube feet that protrude from the petal-like markings on its upper surface. These tube feet are modified into gills. Tube feet on the animal's bottom surface aid in bringing food particles to the mouth.

Sea urchins look like living pincushions, bristling with long, usually

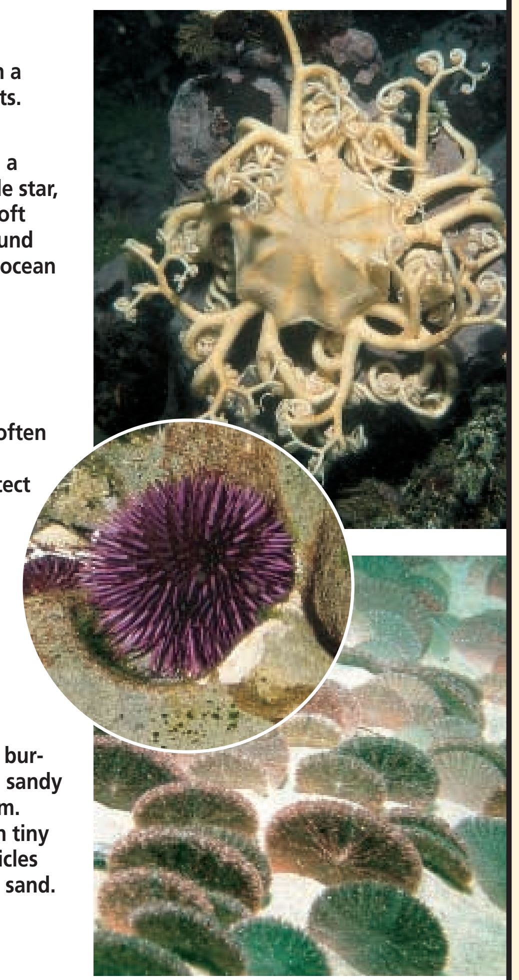


Figure 29.4
Echinoderms are adapted to life in a variety of habitats.

A Basket stars, a kind of brittle star, live on the soft substrate found below deep ocean waters.

B Sea urchins often burrow into rocks to protect themselves from predators and rough water.

C Sand dollars burrow into the sandy ocean bottom. They feed on tiny organic particles found in the sand.

Quick Demo

Kinesthetic When a sea star tries to open a clam or oyster, its muscles must overcome the force exerted by mollusk muscles that are trying to keep the shells closed. A sea star opens a bivalve by applying a steady, unrelenting pressure until the bivalve's muscles tire. Tell students to hold their arms straight out to the side with their palms up. Their arm muscles represent the bivalve's muscles. Have a partner place a heavy book on the students' open palms. Ask them to time how long they can hold their arms out before dropping the book. The book represents the sea star's muscles. L2 ELL

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Sea Stars

Biology: The Dynamics of Life
Starfishes (Ch. 39)
Disc 1, Side 2, 49 sec.

Resource Manager

Laboratory Manual, pp. 205-210 L2
Critical Thinking/Problem Solving, p. 29 L3
Basic Concepts Transparency 50 and Master L2 ELL

PROJECT

Echinoderm Display

Visual-Spatial Ask a group of students to create a bulletin board display of echinoderms. Have them highlight the features of echinoderms. Ask them to find examples of everyday objects that show similar traits. Students may use sandpaper to model the texture of echinoderm skin. L2 ELL COOP LEARN

BIOLOGY JOURNAL

Sea Star Life

Linguistic Have students write an essay in which they describe one day in the life of a sea star. Allow a few students to read their essays. Have other students discuss which parts of the essays were scientific and which were creative fiction. L3

Cultural Diversity

Japan and the Sea Urchin Industry in Maine

Introduce students to what is rapidly becoming a $100 million international industry—the importation of Maine sea urchins to Japan. Once a remote destination in winter, coastal Maine has become a magnet for Japanese businesspeople because of the sea urchin, a creature once considered to be a pest to commercial fisheries.

Sea urchins are prized in Japan as uni, a sushi delicacy. The Japanese value the sea urchin for the quality of its eggs, called roe. Today more than 95% of all sea urchins harvested in Maine are sent to Japan. The harvesting of sea urchins is also becoming big business in California.

Problem-Solving Lab 29-1

Purpose
Students will design an experiment to determine the stimulus for release of sea cucumber gametes.

Process Skills
design an experiment, identify and control variables

Teaching Strategies
■ Ask students to think of strategies that animals may use to ensure aquatic fertilization. *Likely answers will include releasing large numbers of eggs and sperm, and releasing eggs and sperm at the same time.*

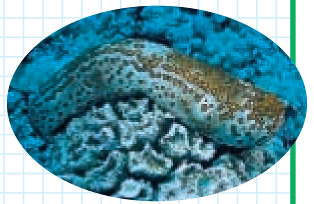
Thinking Critically
To design an experiment, students may decide to keep a group of female sea cucumbers in aquariums, control all environmental variables, and then release sperm into the water to see if this causes the release of eggs.

Assessment
Portfolio Explain to students that sea stars have been found to spawn on the same day as sea cucumbers. Ask if this indicates that the stimulus for spawning is environmental or is in response to one male first releasing sperm. Ask students to write their responses in their portfolios. Use the Performance Task Assessment List for Making Observations and Inferences in **PASC**, p. 17. L2 P

Resource Manager
Content Mastery, p. 142 L1
Reinforcement and Study Guide, pp. 127-129 L2
Basic Concepts Transparency 51 and Master L2 ELL

Problem-Solving Lab 29-1 Designing an Experiment

What makes sea cucumbers release gametes? The orange sea cucumber lives in groups of 100 or more per square meter. In the spring, these sea cucumbers produce large numbers of gametes (eggs and sperm), which they shed in the water all at the same time. The adaptive value of such behavior is that fertilization of many eggs is assured. When one male releases sperm, the other sea cucumbers in the population, both male and female, also release their gametes. Biologists do not know whether the sea cucumbers release their gametes in response to a seasonal cue, such as increasing day length or increasing water temperature, or whether they do this in response to the release of sperm by one sea cucumber.


Orange sea cucumber

Analysis
Design an experiment that will help to determine whether sea cucumbers release eggs and sperm in response to the release of sperm from one individual or in response to a seasonal cue.

Thinking Critically
If you find that female sea cucumbers release 200 eggs in the presence of male sperm and ten eggs in the presence of water that is warmer than the surrounding water, what would you do in your next experiment?

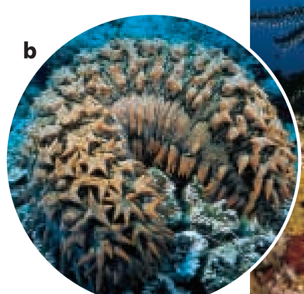



Figure 29.5 Sea lilies and feather stars use their feathery rays to capture downward-drifting organic particles (a). Sea cucumbers trap organic particles by sweeping their mucous-covered tentacles over the ocean bottom (b).

pointed spines. They have long, slender tube feet that, along with the spines, aid the animal in locomotion.

The sea urchin's spines protect it from predators. In some species, sacs located near the tips of the spines contain a poisonous fluid that is injected into an attacker, further protecting the urchin. The spines also aid in locomotion and in burrowing. Burrowing species move their spines in a circular motion that grinds away the rock beneath them. This action, which is aided by a chewing action of the mouth, forms a depression in the rock that helps protect the urchin from predators and from wave action that could wash it out to sea.

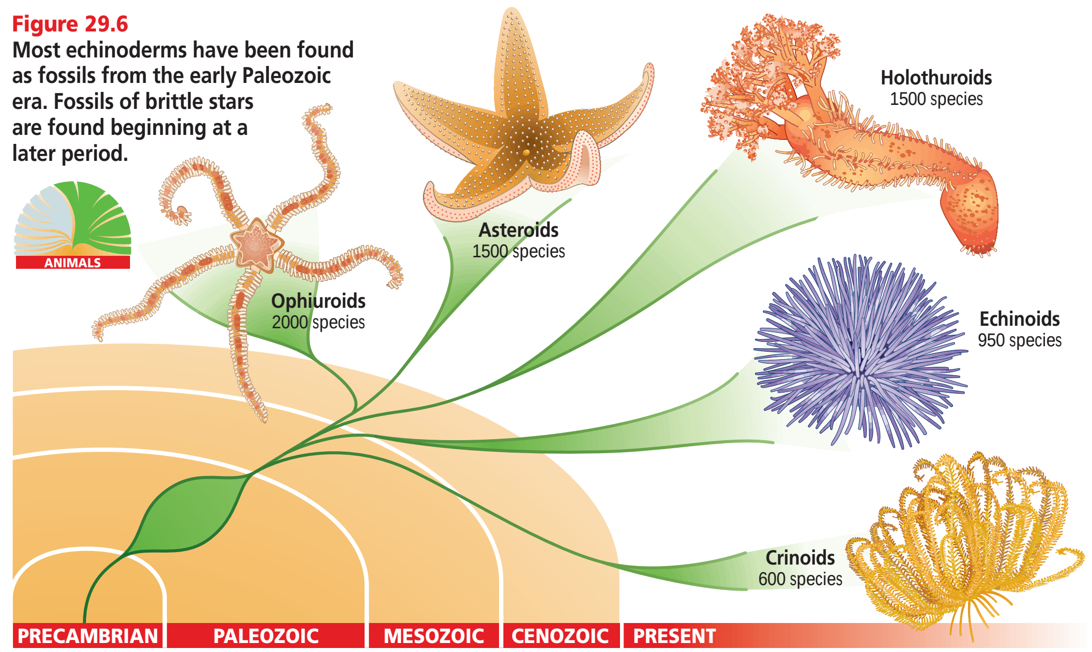
Sea cucumbers

Sea cucumbers are so called because of their vegetablelike appearance, shown in ***Figure 29.5.*** Their leathery covering allows them to be more flexible than other echinoderms; they pull themselves along the ocean floor using tentacles and tube feet. When sea cucumbers are threatened, they exhibit a curious behavior. They may expel a tangled, sticky mass of tubes through the anus, or they may rupture, releasing some internal organs that are regenerated in a few weeks. These actions confuse their predators, giving the sea cucumber an opportunity to move away. Sea cucumbers reproduce by shedding eggs and sperm into the water, where fertilization occurs. You can find out more about sea cucumber reproduction in the *Problem-Solving Lab* on this page.

Sea lilies and feather stars

Sea lilies and feather stars resemble plants in some ways. Sea lilies are the only sessile echinoderms. Feather stars are sessile only in larval form. The adult feather star uses its feathery arms to swim from place to place.

Figure 29.6
Most echinoderms have been found as fossils from the early Paleozoic era. Fossils of brittle stars are found beginning at a later period.



Origins of Echinoderms

The earliest echinoderms may have been bilaterally symmetrical as adults, and probably were attached to the ocean floor by stalks. Another view of the earliest echinoderms is that they were bilateral and free-swimming. The development of bilateral larvae is one piece of evidence biologists have for placing echinoderms as the closest invertebrate relatives of the chordates.

Recall that most invertebrates show protostome development, whereas deuterostome development appears mainly in chordates. The echinoderms represent the only major group of deuterostome invertebrates.

Because the endoskeletons of echinoderms easily fossilize, there is a good record of this phylum. Echinoderms, as a group, date from the Paleozoic era, as shown in ***Figure 29.6.*** More than 13 000 fossil species have been identified.

Section Assessment

Understanding Main Ideas
1. How does a sea star move? Explain in terms of the water vascular system of echinoderms.
2. Describe the differences in symmetry between larval echinoderms and adult echinoderms.
3. How are sea cucumbers different from other echinoderms?
4. Compare how sea urchins and sea cucumbers obtain food.

Thinking Critically
5. How do the various defense mechanisms among the echinoderm classes help deter predators?

Skill Review
6. **Classifying** Prepare a key that distinguishes among classes of echinoderms. Include information on features you may find significant. For more help, refer to *Organizing Information* in the **Skill Handbook.**

3 Assess

Check for Understanding
Naturalist Ask students to use Figure 29.6 to explain the phylogenetic history of echinoderms. L2

Reteach
Naturalist Give students photocopies of the inner, shaded part of the phylogenetic diagram in Figure 29.6. Have them place each class in its correct position. Ask them to list also the identifying features of each class. L1

Extension
Have students research and report on the relationship between the crown-of-thorns sea star and coral reefs. L3

Assessment
Performance Have students prepare a demonstration for third graders that explains the water vascular system of a sea star. Ask them to present this demonstration to the class using a working model. L2 ELL

4 Close

Activity
Show a film about echinoderms and their interactions with other marine organisms.

Portfolio

Echinoderm Phylogeny
Naturalist Provide students with echinoderm fossils. Include as many different kinds as possible and use photographs of fossils you don't have. Ask students to arrange the fossils and photographs to illustrate the phylogeny of this group. L3 P

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
BioQuest: *Biodiversity Park*
Disc 3, 4

Section Assessment

1. A sea star moves by regulation of its water vascular system. Tube feet attach to a surface, the sea star moves itself forward, and the suction is released.
2. Larval echinoderms are bilaterally symmetrical, whereas adult echinoderms are radially symmetrical.
3. Sea cucumbers are tubular and have a leathery outer covering instead of hard plates.
4. Sea urchins graze on algae; sea cucumbers feed on dead matter that drops to the ocean floor.
5. The rigid endoskeleton helps protect echinoderms from their enemies. Spines and poison glands also protect echinoderms. Adult echinoderms move by walking, whereas larval forms are free swimming. If an echinoderm such as a sea star loses part of a ray, it can be regenerated. Sea cucumbers can expel their digestive tracts and grow new ones.
6. Students' keys will vary considerably, but all should utilize the branching nature of keys described in the Skill Handbook.

Section 29.2

Prepare

Key Concepts

Students will learn about invertebrate chordates. They will distinguish between sea squirts and lancelets and study the relationships of these animals to the vertebrates.

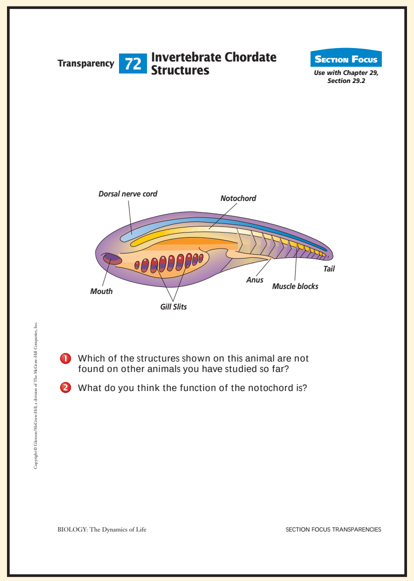
Planning

- Prepare syringes with potassium chloride and gather beakers, glass slides, coverslips, and test tubes for the BioLab.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 72** on the overhead projector and have students answer the accompanying questions. L1 ELL


Transparency 72 Invertebrate Chordate Structures

Section Focus
Use with Chapter 29, Section 29.2

1. Which of the structures shown on this animal are not found on other animals you have studied so far?
2. What do you think the function of the notochord is?

BIOLOGY: The Dynamics of Life — SECTION FOCUS TRANSPARENCIES

SECTION PREVIEW

Objectives

Summarize the characteristics of chordates.

Explain how invertebrate chordates are related to vertebrates.

Distinguish between sea squirts and lancelets.

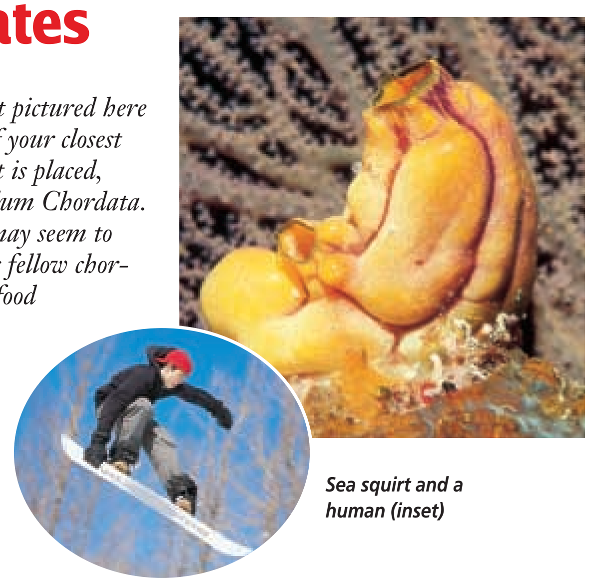
Vocabulary

notochord
dorsal hollow nerve cord
gill slit

Section

29.2 Invertebrate Chordates

The brightly colored object pictured here is a sea squirt. As one of your closest invertebrate relatives, it is placed, along with humans, in the phylum Chordata. At first glance, this sea squirt may seem to resemble a sponge more than its fellow chordates. It is sessile, and it filters food particles from water it takes in through the opening at the top of its body. What characteristics could a human—or a fish or a lizard, for that matter—share with this colorful, ocean-dwelling organism?

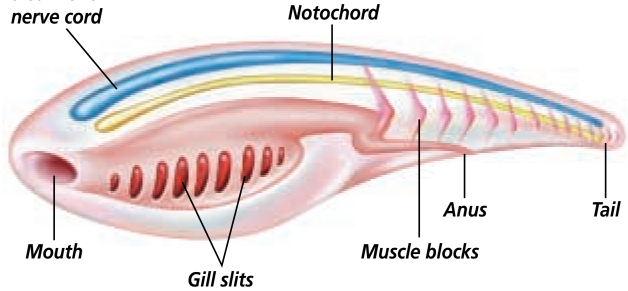

Sea squirt and a human (inset)

What Is an Invertebrate Chordate?

The chordates most familiar to you are the vertebrate chordates—chordates that have backbones, such as birds, fishes, and mammals, including humans. But the phylum Chordata (kor DAHT uh) includes three subphyla: Urochordata, the tunicates (sea squirts); Cephalochordata, the lancelets; and Vertebrata, the vertebrates. In this section you will examine the tunicates and lancelets—invertebrate chordates that have no backbones. You will study the vertebrate chordates in the next unit.

Invertebrate chordates may not look much like fishes, reptiles, or humans, but like all other chordates, they have a notochord, a dorsal hollow nerve cord, gill slits, and muscle blocks at some time during their development. In addition, all chordates have bilateral symmetry, a well-developed coelom, and segmentation. The features shared by invertebrate and vertebrate chordates are illustrated in *Figure 29.7.* You can observe these features in invertebrate chordates in the *Problem-Solving Lab* later in this section.

Figure 29.7
Chordate characteristics—the notochord, dorsal hollow nerve cord, gill slits, and muscle blocks—are shared by invertebrate as well as vertebrate chordates.



All chordates have a notochord

All chordate embryos have a **notochord** (NOHT uh kord)—a long, semirigid, rodlike structure located between the digestive system and the dorsal hollow nerve cord. The notochord is made up of large, fluid-filled cells held within stiff, fibrous tissues. In invertebrate chordates, the notochord is retained into adulthood. But in vertebrate chordates, this structure is replaced by a backbone. Invertebrate chordates do not develop a backbone.

The notochord develops just after the formation of a gastrula from mesoderm on what will be the dorsal side of the embryo. The physical support provided by a notochord enables invertebrate chordates to make powerful side-to-side movements of the body. These movements propel the animal through the water at a great speed.

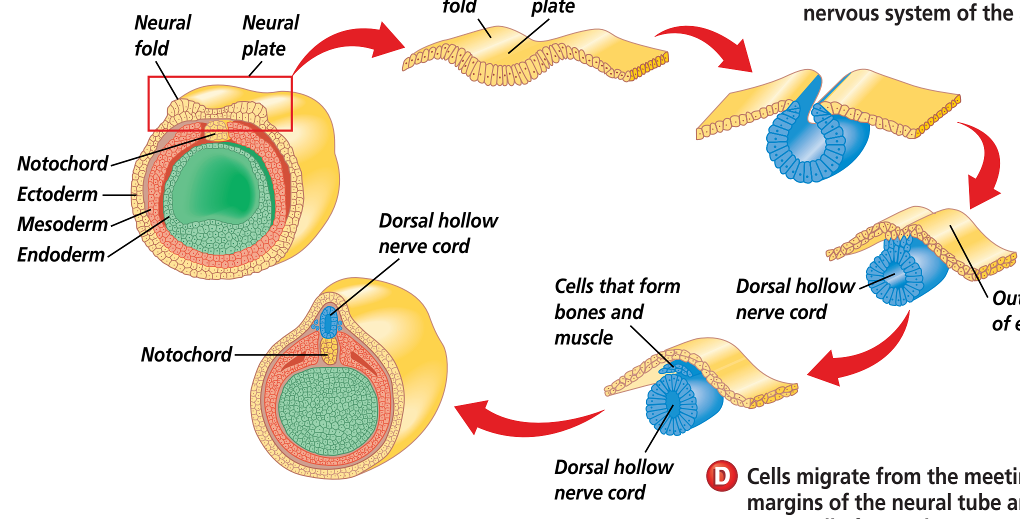
All chordates have a dorsal hollow nerve cord

The **dorsal hollow nerve cord** in chordates develops from a plate of ectoderm that rolls into a hollow tube. This occurs at the same time as the development of the notochord. The sequence of development of the dorsal hollow nerve cord is illustrated in *Figure 29.8.* This tube is composed of cells surrounding a fluid-filled canal that lies above the notochord. In most adult chordates, the cells in the posterior portion of the dorsal hollow nerve cord develop into the spinal cord. The cells in the anterior portion develop into a brain. A pair

Word Origin

chordata
From the Latin word *chorda,* meaning "cord." The phylum Chordata consists of animals with notochords.

Figure 29.8
After gastrulation, organs begin to form in a chordate embryo.



A The notochord forms from mesoderm on the dorsal side of a developing embryo.

B The dorsal hollow nerve cord originates as a plate of dorsal ectoderm just above the developing notochord.

C The edges of this plate of ectoderm fold inward, eventually meeting to form a hollow tube surrounded by cells. The dorsal hollow nerve cord pinches off from the ectoderm and develops into the central nervous system of the animal.

D Cells migrate from the meeting margins of the neural tube and eventually form other organs, including bones and muscles.

2 Teach

Quick Demo

Naturalist Ask students to observe preserved or mounted specimens of tunicates and lancelets. Ask them if they can see any characteristics that link these animals to vertebrate chordates. Elicit whether the animals might have unseen characteristics that link them to vertebrate chordates. L2

Activity

Kinesthetic Have students run their fingers along their backs to feel their backbones. Explain that the backbone is unique to vertebrates and forms from the notochord—the structure that identifies all members of the phylum Chordata. Although all chordates have a notochord at some time during their development, not all chordates have backbones. L1 ELL

Visual Learning

Have students explain how the Inside Story on development in Chapter 25 relates to Figure 29.8.

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Chordate Body Plan

Resource Manager

Section Focus Transparency 72 and Master L1 ELL
Concept Mapping, p. 29 L3 ELL
Reteaching Skills Transparency 43 and Master L1 ELL

Biology Journal

Tunicate Research

Ask students to use the Internet and their local library to do research on tunicates. Ask them to find out where tunicates live and if any tunicate species are threatened or endangered. Have students place their completed findings in their journals. L2

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

Portfolio

Water Movement in Tunicates

Visual-Spatial Have students use the diagram in the Inside Story on page 798 to make a flowchart that traces the path of water through a sea squirt. Have students place their completed flowcharts in their portfolios. L2 P

Quick Demo

Visual-Spatial Have students examine a prepared slide of a cross section of a lancelet. Explain that in lancelets the notochord is present throughout the life of the animal, while in vertebrates the notochord is replaced by a backbone. They should also find the dorsal hollow nerve cord above the notochord and compare it with the notochord. Emphasize that the function of the notochord is to provide support for the animal. L2 ELL

Assessment

Knowledge Ask students to separate the following animals into groups based on the type of nervous system each has. Their lists should identify animals that have a ventral nerve cord, those that have a dorsal hollow nerve cord, and those that have some other nervous system arrangement: earthworm, snail, planarian, sea star, tunicate, clam, grasshopper, lancelet, spider, human. L3

Resource Manager

BioLab and MiniLab Worksheets, p. 130 L2

of nerves connects the nerve cord to each block of muscles.

All chordates have gill slits

The **gill slits** of a chordate are paired openings located in the pharynx, behind the mouth. Many chordates have several pairs of gill slits only during embryonic development. Invertebrate chordates that have gill slits as adults use these structures to strain food from the water. In some vertebrates, especially the fishes, the gill slits develop into internal gills that are adapted to exchange gases during respiration.

All chordates have muscle blocks

Muscle blocks are modified body segments that consist of stacked muscle layers. You have probably seen muscle blocks when you ate a cooked fish. The blocks of muscle cause the meat to separate easily into flakes. Muscle blocks are anchored by the notochord, which gives the muscles a firm structure to pull against. As a result, chordates tend to be more muscular than members of other phyla.

Muscle blocks also aid in movement of the tail. At some point in development, all chordates have a muscular tail. As you know, humans are chordates, and during the early development of the human embryo, there is a muscular tail that disappears as development continues. In most animals that have tails, the digestive system extends to the tip of the tail, where the anus is located. Chordates, however, usually have a tail that extends beyond the anus. You can observe many of the chordate traits in a lancelet in the *MiniLab* on the next page.

a

b

Figure 29.9
Tunicate larvae are about 1 cm long and are able to swim freely through the water **(a)**. As adults, tunicates become sessile filter feeders enclosed in a tough, baglike layer of tissue called a tunic **(b)**.

Diversity of Invertebrate Chordates

The invertebrate chordates belong to two subphyla of the phylum chordata: subphylum Urochordata, the tunicates (TEW nuh kaytz), also called sea squirts, and subphylum Cephalochordata, the lancelets.

Tunicates are sea squirts

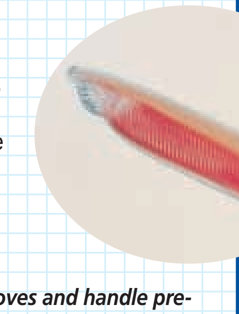
Members of the subphylum Urochordata are commonly called tunicates, or sea squirts. Although adult tunicates do not appear to have any shared chordate features, the larval stage, as shown in ***Figure 29.9***, has a tail that makes it look similar to a tadpole. Tunicate larvae do not feed, and are free swimming only for a few days after hatching. Then they settle and attach themselves with a sucker to boats, rocks, and the ocean bottom. Many adult tunicates secrete a tunic, a tough sac made of cellulose, around their bodies. Colonies of tunicates sometimes secrete just one big tunic that has a common opening to the outside. You can find out how tunicates eat in the *Inside Story* on the next page.

Only the gill slits in adult tunicates indicate their chordate relationship. Adult tunicates are small, tubular animals that range in size from microscopic to several centimeters long, about as big as a large potato. If you remove a tunicate from its sea home, it might squirt out a jet of water for protection—hence the name *sea squirt.*

Lancelets are similar to fishes

Lancelets belong to the subphylum Cephalochordata. They are small, streamlined, and common marine animals, usually about 5 cm long, as ***Figure 29.10*** shows. They spend most of their time buried in the sand with only their heads sticking out. Like tunicates, lancelets are filter feeders. Unlike tunicates, however, lancelets retain all their chordate features throughout life.

MiniLab 29-2 Observing



Examining a Lancelet *Branchiostoma californiense* is a small, sea-dwelling lancelet. At first glance, it appears to be a fish. However, its structural parts and appearance are quite different.

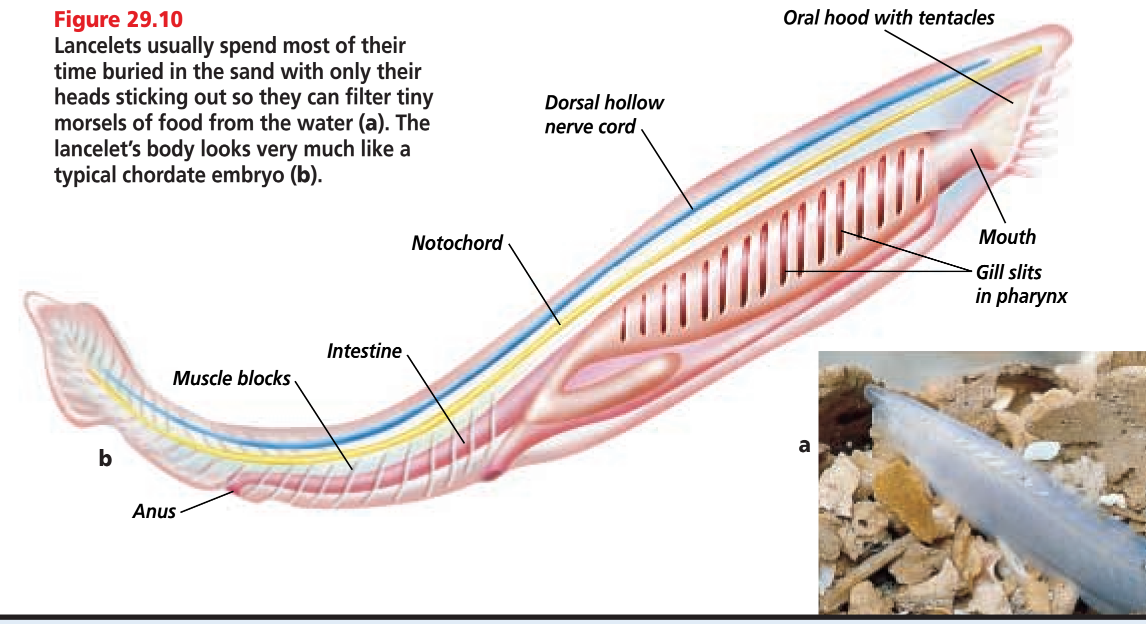
Procedure

1. Place the lancelet onto a glass slide. **CAUTION:** *Wear disposable latex gloves and handle preserved material with forceps.*
2. Use a dissecting microscope to examine the animal. **CAUTION:** *Use care when working with a microscope and slides.*
3. Prepare a data table that will allow you to record the following: General body shape, Length in mm, Head region present, Fins and tail present, Nature of body covering, Sense organs such as eyes present, Habitat, Segmented body.
4. Indicate on your data table if the following can easily be observed: gill slits, notochord, dorsal hollow nerve cord.

Analysis

1. How does *Branchiostoma* differ structurally from a fish? How are its general appearance and habitat similar to those of a fish?
2. Explain why you were not able to see gills, notochord, and a dorsal hollow nerve cord.
3. Using its scientific name as a guide, where might the habitat of this species be located?

Figure 29.10
Lancelets usually spend most of their time buried in the sand with only their heads sticking out so they can filter tiny morsels of food from the water (a). The lancelet's body looks very much like a typical chordate embryo (b).



MiniLab 29-2

Purpose
Students will observe the external appearance of lancelets.

Process Skills
compare and contrast, interpret data, make and use tables, measure in SI, observe and infer

Teaching Strategies

- Specimens are available from biological supply houses.
- A hand lens may be substituted for a binocular microscope.

Expected Results
Lancelets have a long, tubular body shape; length close to 50 mm, head region, tail-like posterior; smooth body; no sense organs. Students will not be able to see a notochord, gill slits, or a dorsal hollow nerve cord.

Analysis

1. It has no sense organs, gills, or fins. But it does have a distinct head area. Fishes are classified in the same phylum as lancelets—Chordata—but in subphylum Vertebrata, whereas lancelets are in subphylum Cephalochordata.
2. These structures are all internal organs.
3. in the ocean along the coast of California

Assessment

Portfolio Have students write a paragraph explaining why lancelets are important in evolution. Use the Performance Task Assessment List for Writing in Science in **PASC,** p. 87. L2 P

Alternative Lab

Comparison of Sea Urchins and Lancelets

Purpose
Students will compare sea urchin larvae with adult lancelets.

Materials
compound microscope, prepared slides of sea urchin development, prepared slides of lancelets

Procedure
Give students the following directions.

1. Observe slides of the unfertilized sea urchin egg, zygote, 2-cell stage, 4-cell stage, 8-cell stage, blastula, gastrula, and sea urchin larvae. Use low-power magnification at first, then switch to high-power magnification.
2. Draw a diagram of each stage in the order listed. Label each diagram with the name of the stage.
3. Note how the size of the blastula compares with the size of the zygote. Note also the size of the cells at each stage.
4. Examine a prepared slide of a lancelet.
5. Find the following parts of the lancelet and label them on a diagram you make: dorsal hollow nerve cord, notochord, gill slits, muscle blocks, tail.
6. Note the fishlike form of the lancelet.

Expected Results
Students should see all of the features listed above.

Analysis

1. How does the size of the sea urchin blastula compare with that of the zygote? *The blastula and the zygote are the same size. The cells become smaller as development proceeds.*
2. What does the symmetry of the larva of a sea urchin imply about the evolutionary relationship between echinoderms and chordates? *Echinoderms are closely related to chordates.*
3. What features of the lancelet place it in the phylum Chordata? *dorsal hollow nerve cord, notochord, gill slits, muscle blocks, tail*

Assessment

Skill Set up microscopes with slides showing features of lancelets and various stages of sea urchin development. Ask students to identify the part or sequence of development and state the importance of the part for chordates. Use the Performance Task Assessment List for Making Observations and Inferences in **PASC,** p. 17. L2

INSIDE STORY

Purpose
Students will learn about the structural and behavioral characteristics of tunicates.

Teaching Strategies
- Ask students to compare the filter feeding of tunicates with the filter feeding of sponges and bivalves.

Visual Learning
- Review with students the characteristics of tunicates that make them invertebrate chordates.
- Show students live specimens of tunicates and have them compare the specimens with the diagram.

Critical Thinking
Sponges and tunciates are both filter feeders.

Problem-Solving Lab 29-2

Purpose
Students will interpret a cross-section slice of a lancelet.

Process Skills
interpret scientific illustrations, observe and infer, think critically

Teaching Strategies
- Review the procedure for making a cross-section slice.
- Review the orientation of the cross-section slice in relation to the whole animal. Use a cucumber to illustrate the view and orientation by making a cross-section slice through the fruit.

Thinking Critically
1. Gill slits, muscle blocks, notochord, dorsal hollow nerve cord; student answers should agree that these are present.

2. Echinoderms would have tube feet and a water vascular system, but no notochord, dorsal hollow nerve cord, gill slits, or muscle blocks.
3. An adult tunicate would have gill slits but no notochord or dorsal hollow nerve cord. A young developing tunicate has all of these structures.

Assessment
Performance Ask students to draw an events chain that sequences the steps they would need to take to determine that a specimen is a lancelet rather than an immature fish. Use the Performance Task Assessment List for Events Chain in **PASC,** p. 91. L2

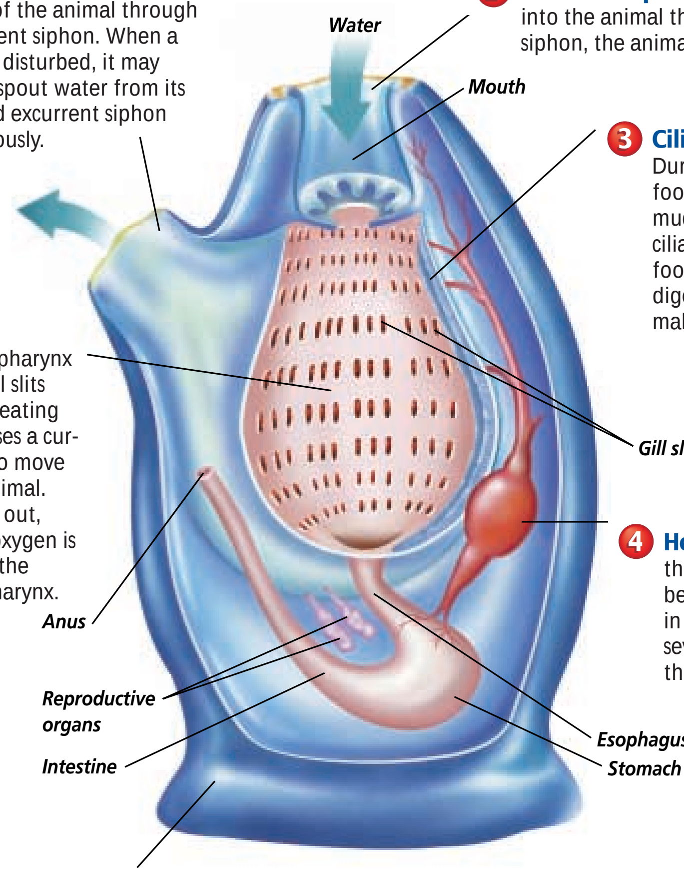
INSIDE STORY

A Tunicate

***T**unicates, or sea squirts, are a group of about 1250 species that live in the ocean. They may live near the shore or at great depths. They may live individually, or several animals may share a tunic to form a colony.*

Critical Thinking *In what ways are sponges and tunicates alike?*


Purple bell tunicate



Although lancelets look somewhat similar to fishes, they have only one layer of skin, with no pigment and no scales. Lancelets do not have a distinct head, but they do have light sensitive cells on the anterior end. They also have a hood that covers the mouth and the sensory tentacles surrounding it. The tentacles direct the water current and food particles toward the animal's mouth.

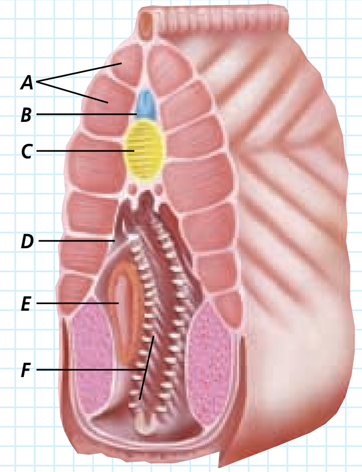
Origins of Invertebrate Chordates

Because sea squirts and lancelets have no bones, shells, or other hard parts, their fossil record is incomplete. Biologists are not sure where sea squirts and lancelets fit in the phylogeny of chordates. According to one hypothesis, echinoderms, invertebrate chordates, and vertebrates all arose from ancestral sessile animals that fed by capturing food in tentacles. Modern vertebrates probably arose from the free-swimming larval stages of ancestral invertebrate chordates. Recent discoveries of fossil forms of organisms that are similar to living lancelets in rocks 550 million years old show that invertebrate chordates probably existed before vertebrate chordates.

Problem-Solving Lab 29-2
Interpreting Scientific Illustrations

What does a slice through an invertebrate chordate show? Why are tunicates and lancelets important? Being invertebrate chordates, they show three major structures that are present at some time during all chordate development.

Analysis
The diagram at right shows a cross section of an invertebrate chordate. Your task is to determine what the various structures marked A-F are.



Thinking Critically
1. What three structures are present in all chordates at some time during their development? Does the cross-section diagram of the lancelet confirm your answer? Explain.
2. How would you know that the cross section was not from an echinoderm?
3. How might the cross section differ if it were taken from an adult tunicate? A young developing tunicate?

Section Assessment

Understanding Main Ideas
1. Describe the four features of chordates.
2. How are invertebrate chordates different from vertebrates?
3. Compare the physical features of sea squirts and lancelets.
4. How do sea squirts and lancelets protect themselves?

Thinking Critically
5. What features of chordates suggest that you are more closely related to invertebrate chordates than to echinoderms?

Skill Review
6. **Designing an Experiment** Assume that you have found some tadpolelike animals in the water near the seashore and that you can raise them in a laboratory. Design an experiment in which you will determine whether the animals are larvae or adults. For more help, refer to *Practicing Scientific Methods* in the **Skill Handbook.**

3 Assess

Check for Understanding
Ask students to list invertebrate chordate characteristics. L1

Reteach
Visual-Spatial Give student groups a large piece of paper. Have them diagram a lancelet and label its typical invertebrate chordate parts and their functions. L2 ELL

Extension
Ask students to research the phyla Hemichordata and Chaetognatha. Ask them to report about the structural and behavioral adaptations of these animals and their evolutionary relationships with echinoderms and chordates. L3

Assessment
Performance Have students plan an exhibit for tunicates at a public aquarium. Ask them to include in their plan suggestions about capture, transport, habitat, feeding, and general maintenance. L2 COOP LEARN

4 Close

Activity
Develop a table that compares lancelets and tunicates, discussing which features are common to vertebrates and invertebrates.

Resource Manager
Content Mastery, pp. 141, 143-144 L1
Reinforcement and Study Guide, p. 130 L2

Section Assessment

1. notochord, dorsal hollow nerve cord, gill slits, muscle blocks
2. In invertebrate chordates, the notochord is not replaced by a backbone.
3. Sea squirts are small, tubular, stationary filter feeders. Lancelets are shaped like fishes and can swim freely, but they spend most of their time buried in the sand.
4. Sea squirts are covered with a thick tunic, and lancelets bury themselves in sand.
5. notochord, gill slits, muscle blocks, and dorsal hollow nerve cord
6. Watch the animals for several weeks to see if they change their body shape and symmetry. Watch for reproductive behavior or release of gametes.

INVESTIGATE BioLab

Time Allotment
One class period the first day; 15 minutes the second day

Process Skills
make and use tables, collect data, communicate, compare and contrast, measure in SI, observe and infer, organize data, use numbers

Safety Precautions
Caution students to use care when working with syringes and chemicals. Make sure they return syringes to the designated place.

PREPARATION

Alternative Materials
- If time and cost prohibit the purchase of live sea urchins, the experiment can be done with prepared slides available from biological supply houses.

Resource Manager

BioLab and MiniLab Worksheets, pp. 131-132 L2

INVESTIGATE BioLab

Observing Sea Urchin Gametes and Egg Development

Sea urchins are typical of most echinoderms in that their sexes are separate, fertilization is external, and development of a fertilized egg is quite rapid. Thus, these animals are excellent choices for studying gametes, watching fertilization, and observing changes occurring in a fertilized egg.

Red sea urchin

PREPARATION

Problem

How can you induce a sea urchin to release its gametes?

Objectives

In this BioLab, you will:
- **Induce** sea urchins to release their gamete cells.
- **Observe** living sperm and egg cells under the microscope.
- **Observe** developmental changes in a fertilized sea urchin egg.

Materials

live sea urchins	beakers
sea water	petri dish
glass slides and cover slips	dropper
syringe filled with potassium chloride	microscope
	test tube

Safety Precautions

Always wear goggles in the lab.

Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

PROCEDURE

1. Fill a small beaker (250 mL) with sea water.
2. Obtain a live sea urchin from your teacher and locate an area of soft tissue next to its mouth.
3. Using a syringe, your teacher will insert the needle into this soft tissue and inject the syringe contents into the sea urchin.
4. Turn your animal so that its mouth is facing up and place it in a petri dish. **CAUTION:** ***Use care in handling live animals.***
5. Wait a minute or two, then check the petri dish. If the sea urchin is male, a milky white mass of sperm will be present in the dish. If it is female, a yellow orange mass of eggs will be seen.
6. If you have a female sea urchin, hold her upside down directly over the seawater-filled beaker and allow the eggs to fall directly into the water.
7. If your urchin is male, use a dropper to add several drops of sperm from the petri dish to your beaker of sea water.
8. Check with your classmates to see who has a male and who has a female sea urchin. Share gamete cells.
9. Use a clean dropper to transfer a drop of sperm from the beaker to a microscope slide. Observe under low power without a cover slip.
10. Add a cover slip and observe under high power. Note the movement of sperm. Draw several sperm cells and indicate their size in µm. Note the approximate number of sperm cells present.
11. Repeat steps 9 and 10 for egg cells. In step 10, use only low power to observe egg cells.
12. For this step, work with a partner. While one partner transfers some sperm to the slide with egg cells using a clean dropper, the other partner should observe under low power.
13. Observe the process of fertilization and note any changes that occur to the egg. Record your observations in a data table.
14. When fertilization has been accomplished, place the fertilized eggs in a test tube filled with 10 mL of seawater. Label your tube and observe the eggs 24 hours later under low power. Record any changes that you see. **CAUTION:** ***Wash your hands immediately after working with animals.***

ANALYZE AND CONCLUDE

1. **Compare and Contrast** Compare eggs and sperm, noting numbers released, numbers observed under low power, size, and ability to move.
2. **Predicting** Based on the pattern of fertilization, predict the reason for the large number of gametes released in nature.
3. **Observing** Describe the behavior of sperm when they first come in contact with an egg.
4. **Observing** How does an unfertilized egg differ in appearance from a fertilized egg? Draw both eggs in your data table.

Going Further

Project Continue to observe fertilized eggs and note the stages of development. Keep a record of time after fertilization and corresponding changes in development.

interNET CONNECTION To find out more about echinoderm development, visit the Glencoe Science Web Site. www.glencoe.com/sec/science

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INVESTIGATE BioLab

ANALYZE AND CONCLUDE

1. Sperm are motile, thousands are present on a slide, the size is close to 10 µm; eggs are not motile, fewer than 100 on a slide, size is close to 150 µm.
2. Student answers may vary; fertilization is external, so chances of a sperm meeting an egg are less; a large number of gametes released improves the chances of fertilization.
3. Sperm tend to cluster around the outer edge of the egg.
4. A fertilized egg forms a clear membrane around the outside edge of the egg shortly after fertilization.

Assessment

Knowledge Have students correlate their observations of sea urchin gametes with the pattern seen throughout the animal kingdom. Is there that much variation between sperm and eggs of different species? Use the Performance Task Assessment List for Making Observations and Inferences in **PASC**, p. 17. L2

Going Further

Have students determine how long sperm cells will remain alive (as judged by their motility) after being released from the male sea urchin.

PROCEDURE

Teaching Strategies
- Student groups of at least four are recommended. Each student should be assigned a specific duty or role.
- Sea urchins will typically arrive in a large foam container and can remain there for at least 24-48 hours before using. Ordering so that animals arrive early in the week is recommended. Animals are available from biological supply houses.
- Use 2 mL of a 0.5*M* potassium chloride (KCl) solution for each injection.
- The container in which the urchins arrive will contain enough seawater for classroom use.
- To reduce the number of sea urchins needed, have the first morning class do the injecting and capturing of gametes. Store sperm and eggs as follows for later classes: Cover petri dish with sperm, store in a refrigerator at 10°C; store eggs in beaker of seawater at same temperature as sperm. Try to use stored gametes the same day.

Troubleshooting
- Some sea urchins may not release gametes with the initial injection. Repeat if necessary.
- Make sure that you collect the same number of syringes as handed out.

Data and Observation
Students will observe the differences between egg and sperm. They will determine that developmental changes occur within minutes after fertilization.

Fertilization membrane appears	2-5 minutes
First cleavage	50-70 minutes
Second cleavage	78-107 minutes
Third cleavage	103-205 minutes
Blastula	6 hours
Gastrula	12-20 hours
Larva	24-48 hours

Physics Connection

Purpose

Students learn the application of physical principles to biological systems.

Teaching Strategies

- Have students refer to the Inside Story of a sea star earlier in this chapter to see how the water vascular system is connected to the ampullas and tube feet.
- Explain that hydraulics is the practical application of liquids in motion and that in living systems the liquid is usually water. The term *hydraulic* means "operated, moved, or effected by water."
- Have students discuss how flow of fluids in the body is essential to life. Topics might include the delivery of oral medication, distribution of hormones secreted by glands, or the removal of toxic substances in urine. L1

Connection to Biology

Scallops take in water and then clap their shells together, forcing water out quickly to move the animal in the opposite direction from the water flow. Earthworms have a hydrostatic skeleton (rigid, water-filled coelom) that their muscles brace against for movement through the soil.

Physics Connection

Hydraulics of Sea Stars

Many organisms use hydraulic systems to supply food and oxygen to, and remove wastes from, cells lying deep within the body. Hydraulics is a branch of science that is concerned with the practical applications of liquids in motion. In living systems, hydraulics is usually concerned with the use of water to operate systems that help organisms find food and move from place to place.


Sea star opening a mollusk to feed

The sea star uses a unique hydraulic mechanism called the water vascular system for movement and for obtaining food. The water vascular system provides the water pressure that operates the tube feet of sea stars and other echinoderms.

The water vascular system On the upper surface of a sea star is a sievelike disk, the madreporite, which opens into a fluid-filled ring. Extending from the ring are long radial canals running along a groove on the underside of each of the sea star's rays. Many small lateral canals branch off from the sides of the radial canals. Each lateral canal ends in a hollow tube foot. The tube foot has a small muscular bulb at one end, the ampulla, and a short, thin-walled tube at the other end that is usually flattened into a sucker. Each ray of the sea star has many tube feet arranged in two or four rows on the bottom side of the ray. The tube feet are extended or retracted by hydraulic pressure in the water vascular system.

Mechanics of the water vascular system The entire water vascular system is filled with water and acts as a hydraulic system, allowing the sea star to move. The muscular ampulla contracts and relaxes with an action similar to the squeezing of a dropper bulb. When the muscles in the wall of the ampulla contract, a valve between the lateral canal and the ampulla closes so that water does not flow backwards into the radial canal. The pressure from the walls of the ampulla acts on the water, forcing it into the tube foot's sucker end, causing it to extend.

When the extended tube foot touches a rock or a mollusk shell, the center of the foot is retracted slightly. This creates a vacuum, enabling the tube foot to adhere to the rock or shell. The tip of the tube foot also secretes a sticky substance that helps it adhere. To move forward, muscles in the ampulla relax, and muscles in the tube foot wall contract. These actions shorten the tube foot and pull the sea star forward. Water is forced back into the relaxed ampulla. When the muscles in the ampulla contract, the tube foot extends again. This pattern of extension and retraction of tube feet results in continuous movement. It is the coordinated movement of many tube feet that enable the sea star to move slowly along the ocean floor.

CONNECTION TO BIOLOGY

In what way do scallops and earthworms also use hydraulic pressure for locomotion?

interNET CONNECTION To find out more about hydraulic pressure systems, visit the Glencoe Science Web Site.
www.glencoe.com/sec/science

Chapter 29 Assessment

SUMMARY

Section 29.1

Echinoderms

Main Ideas

- Echinoderms have spines or bumps on their endoskeletons, radial symmetry, and water vascular systems. Most move by means of the suction action of tube feet.
- Echinoderms include sea stars, sea urchins, sand dollars, sea cucumbers, sea lilies, and feather stars.
- Deuterostome development, an internal skeleton, and bilaterally symmetrical larvae are indicators of the close phylogenetic relationship between echinoderms and chordates.

Vocabulary

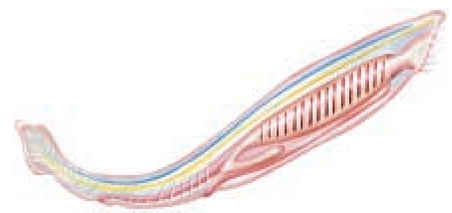
ampulla (p. 788)
madreporite (p. 789)
pedicellaria (p. 787)
ray (p. 787)
tube feet (p. 788)
water vascular system (p. 789)

Section 29.2

Invertebrate Chordates

Main Ideas

- Chordates have a dorsal hollow nerve cord, a notochord, muscle blocks, gill slits, and a tail at some stage during development.



- Sea squirts and lancelets are invertebrate chordates.
- Vertebrate chordates may have evolved from larval stages of ancestral invertebrate chordates.

Vocabulary

dorsal hollow nerve cord (p. 795)
gill slit (p. 796)
notochord (p. 795)

UNDERSTANDING MAIN IDEAS

1. Sea stars, sea urchins, sand dollars, sea cucumbers, sea lilies, and feather stars are examples of echinoderms that all have _______.
   a. exoskeletons
   b. jointed appendages
   c. tube feet
   d. larvae with radial symmetry
2. Of the following, which is NOT a characteristic of chordates?
   a. dorsal hollow nerve cord
   b. notochord
   c. pedicellariae
   d. muscle blocks
3. When a sea star loses a ray, it is replaced by the process of _______.
   a. regeneration
   b. reproduction
   c. metamorphosis
   d. parthenogenesis
4. Animals that have spines or bumps on their endoskeletons, radial symmetry, and water vascular systems are _______.
   a. invertebrate chordates
   b. chordates
   c. vertebrates
   d. echinoderms
5. A close phylogenetic relationship between echinoderms and some chordates is indicated by the fact that both have similar _______.
   a. habitats
   b. larvae
   c. sizes
   d. gills

Chapter 29 Assessment

Main Ideas

Summary statements can be used by students to review the major concepts of the chapter.

Using the Vocabulary

To reinforce chapter vocabulary, use the Content Mastery Booklet and the activities in the Interactive Tutor for Biology: The Dynamics of Life on the Glencoe Science Web Site.
www.glencoe.com/sec/science

THE PRINCETON REVIEW *All Chapter Assessment questions and answers have been validated for accuracy and suitability by The Princeton Review.*

UNDERSTANDING MAIN IDEAS

1. c
2. c
3. a
4. d
5. b

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Action of Tube Feet

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

GLENCOE TECHNOLOGY

VIDEOTAPE
MindJogger Videoquizzes
Chapter 29: *Echinoderms and Invertebrate Chordates*
Have students work in groups as they play the videoquiz game to review key chapter concepts.

Resource Manager

Chapter Assessment, pp. 169-174
MindJogger Videoquizzes
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 29 quiz

6. b
7. a
8. c
9. d
10. d
11. release
12. notochord
13. light or dark
14. strong and flexible
15. asteroids
16. filter feeding
17. evolved later
18. sand dollar
19. invertebrate chordates
20. bilateral symmetry

Applying Main Ideas

21. Sea stars regenerate and the cut-up parts may become new sea stars.
22. Sea squirts are sessile, filter feeders that can shoot jets of water to protect themselves.

Chapter 29 Assessment

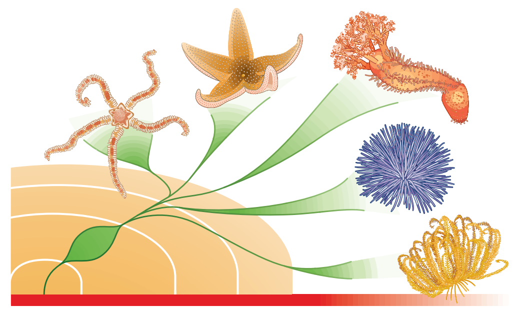
Chapter 29 Assessment

6. Spines on sea stars and sea urchins are modified into pedicellariae used for _______.
   a. feeding **c.** breathing
   b. protection **d.** reproduction
7. The water vascular system operates the tube feet of sea stars and other echinoderms by means of _______.
   a. water pressure **c.** water pumps
   b. water exchange **d.** water filtering
8. Tube feet, in addition to functioning in locomotion, also function in _______.
   a. gas exchange and digestion
   b. digestion and circulation
   c. gas exchange and excretion
   d. excretion and digestion
9. Water enters and leaves the water vascular system of a sea star through the _______.
   a. radial canal **c.** tube feet
   b. ampulla **d.** madreporite
10. Sea squirts and lancelets are invertebrate chordates that have _______.
    a. pedicellariae
    b. exoskeletons
    c. tube feet
    d. larvae with bilateral symmetry
11. When a sea cucumber is threatened, it can _______ its internal organs.
12. The _______ is a semirigid, rodlike structure common to all members of the phylum Chordata.
13. When a sea star lifts up the tips of its rays, it is detecting _______.
14. Muscle blocks attached to the notochord enable chordates to be more _______.

THE PRINCETON REVIEW — Test-Taking Tip

All or None
When filling in answer ovals, remember to fill in the whole oval. A computer will be scoring your answers. Don't give the right answer for a problem only to lose points on it because the computer couldn't read your oval.

15. Examine the diagram below. From which group did brittle stars most likely evolve?



16. Tunicates and lancelets get food by _______.
17. Most echinoderms flourished in the Paleozoic era. Brittle stars require habitat similar to other echinoderms, but they did not flourish during the Paleozoic because they most likely _______.
18. A _______ is a flat, disc-shaped echinoderm without rays, and only minute hairlike spines.
19. Sea stars are more likely to leave a fossil record than _______ such as tunicates and lancelets.
20. The _______ of this larva shows its close relationship to chordates.

Applying Main Ideas

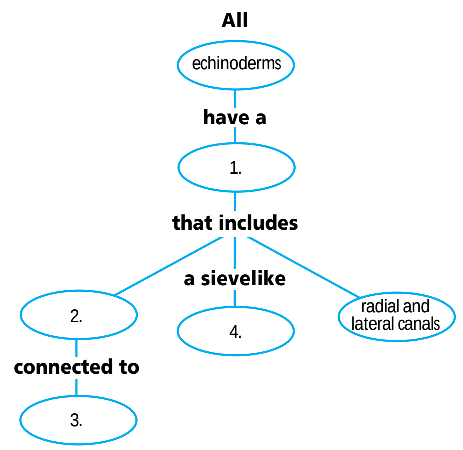
21. If you were an oyster farmer, why would you be advised not to break apart and throw back any sea stars that were destroying the oyster beds?
22. How does a sessile animal such as a sea squirt protect itself?

Chapter 29 Assessment

23. Relate the various functions of the water vascular system to the environment in which echinoderms live.
24. How is the ability of echinoderms to regenerate an adaptive advantage to these animals?
25. Explain how a sea squirt maintains homeostasis.

Thinking Critically

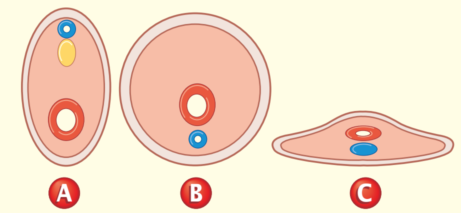
26. **Observing and Inferring** Explain why the tube feet of a sand dollar are located on its upper surface as well as on its bottom surface.
27. **Comparing and Contrasting** Compare the pedicellariae of echinoderms with the nematocysts of cnidarians.
28. **Concept Mapping** Complete the concept map by using the following vocabulary terms: ampulla, madreporite, tube feet, water vascular system.



CD-ROM
For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web Site.
www.glencoe.com/sec/science

Assessing Knowledge & Skills

The diagrams below represent cross sections of larvae. The intestines are shown in red and the nerve cords are shown in blue.



Interpreting Scientific Illustrations Use the diagram to answer the following questions.

1. Which of the diagrams shows a cross section of a lancelet?
   a. A
   b. B
   c. C
   d. none of the diagrams
2. Which of the diagrams would represent segmented worms and echinoderms?
   a. A
   b. B
   c. C
   d. none of the diagrams
3. What does the yellow, solid area represent?
   a. nerve cord **c.** notochord
   b. intestines **d.** spinal cord
4. What is wrong with diagram C if it represents an invertebrate chordate?
   a. The notochord is ventral.
   b. The nerve cord is ventral and there is no notochord.
   c. It is too flat.
   d. The intestine should be round.
5. **Interpreting Scientific Illustrations** Using the same color code and the same three organs, draw a diagram of a cross section of a larval sea squirt, sea star, and earthworm.

Chapter 29 Assessment

23. Tube feet enable sea stars to move and open bivalve mollusks for food. Tube feet are also used for gas exchange and excretion. This water vascular system works well in a water environment.
24. Regeneration enables a sea star to survive and escape an attack by a predator. If a predator bites off a ray, the sea star can escape while the predator is feeding on that ray. A new ray will grow within weeks.
25. Sea squirts filter feed and take in oxygen from the water. They maintain a balance with their watery environment by filtering out what they require and giving off wastes into the water.

Thinking Critically

26. The tube feet on the upper surface are modified to function as gills.
27. Pedicellariae of echinoderms pinch potential predators but are not used in capturing prey and do not have immobilizing toxins as do nematocysts.
28. 1. Water vascular system; 2. Ampulla; 3. Tube feet; 4. Madreporite

Assessing Knowledge & Skills

1. a
2. b
3. c
4. b
5. The sea squirt will look like A, the sea star like B, and the earthworm like B.

BioDigest

National Science Education Standards: UCP.1, UCP.2, UCP.5, C.1, C.4, C.5, C.6, F.1

Prepare

Purpose

This BioDigest can be used as an overview of the invertebrate animal phyla. You may wish to use this unit summary to teach about invertebrates in place of the chapters in the Invertebrate unit.

Key Concepts

Students learn about the phyla of invertebrates, including sponges, cnidarians, flatworms, roundworms, arthropods, and echinoderms, as well as the invertebrate chordates. They learn about cell organization in animals and observe differences in physical forms as organisms become more complex, with cells organized into tissues, and tissues organized into organs and organ systems.

1 Focus

Bellringer

Bring an assortment of live invertebrates into the classroom and have students examine them. Ask students to identify traits that these animals share. They should discover that invertebrates are animals without backbones. L1 ELL

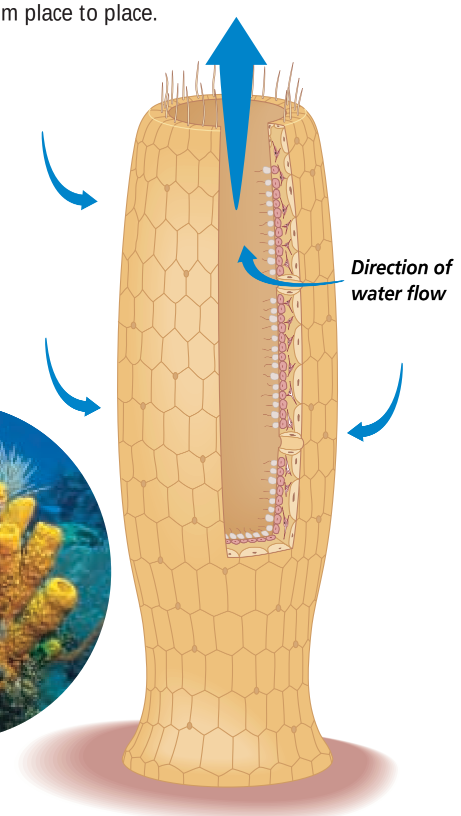
For a **preview** of the invertebrate unit, study this BioDigest before you read the chapters. After you have studied the invertebrate chapters, you can use the BioDigest to **review** the unit.

Invertebrates

How are jellyfishes, earthworms, sea stars, and butterflies alike? All of these animals are invertebrates—animals without backbones. The ancestors of all modern invertebrates had simple body plans. They lived in water and obtained food, oxygen, and other materials directly from their surroundings, just like present-day sponges, jellyfishes, and worms. Some invertebrates have external coverings such as shells and exoskeletons that provide protection and support.

Sponges

Sponges, phylum Porifera, are invertebrates made up of two cell layers. Most sponges are asymmetrical. They have no tissues, organs, or organ systems. Most adult sponges do not move from place to place.



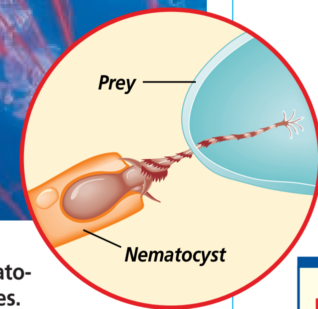
Sponges are filter feeders. A sponge takes in water through pores in the sides of its body, filters out food, and releases the water through the opening at the top.

Cnidarians

Like sponges, cnidarians are made up of two cell layers and have only one body opening. The cell layers of a cnidarian, however, are organized into tissues with different functions. Cnidarians are named for stinging cells that contain nematocysts that are used to capture food. Jellyfishes, corals, sea anemones, and hydras belong to phylum Cnidaria.

Vital Statistics

Cnidarians
Size ranges: Smallest: *Haliclystus salpinx*, jellyfish, diameter, 25 mm; largest: giant jellyfish medusa, diameter, 2 m; largest coral colony: Great Barrier Reef, length, 2027 km
Most poisonous: The sting of an Australian box jelly can kill a human within minutes.
Distribution: Worldwide in marine, brackish, and freshwater habitats.
Numbers of species:
Phylum Cnidaria
- Class Hydrozoa—hydroids, 2700 species
- Class Scyphozoa—jellyfishes, 200 species
- Class Anthozoa—sea anemones and corals, 6200 species



Jellyfishes and other cnidarians have nematocysts on their tentacles.

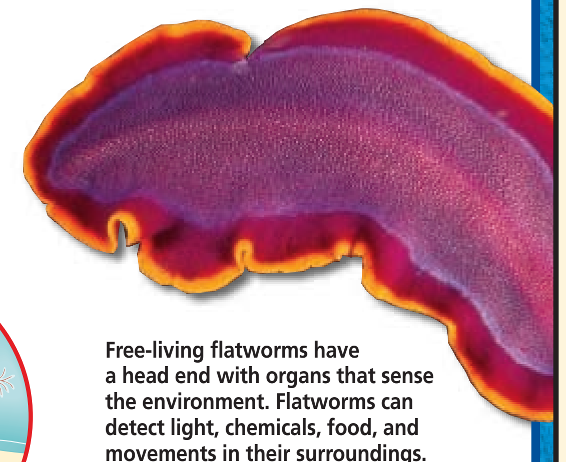
Roundworms

Roundworms, phylum Nematoda, have a pseudocoelom and a tubelike digestive system with two body openings. Most roundworms are free-living, but many plants and animals are affected by parasitic roundworms.

Parasitic roundworms such as this *Trichinella* are contracted by eating undercooked pork. Other roundworms can be contracted by walking barefoot on contaminated soil.

Flatworms

Flatworms, phylum Platyhelminthes, include free-living planarians, parasitic tapeworms, and parasitic flukes. Flatworms are bilaterally symmetrical animals with flattened solid bodies and no body cavities. Flatworms have one body opening through which food enters and wastes leave.



Free-living flatworms have a head end with organs that sense the environment. Flatworms can detect light, chemicals, food, and movements in their surroundings.

Vital Statistics

Flatworms
Size ranges: Largest, beef tapeworm, length, 30 m
Distribution: Worldwide in soil, marine, brackish, and freshwater habitats
Numbers of species:
Phylum Platyhelminthes:
- Class Turbellaria—free-living planarians, 3000 species
- Class Cestoda—parasitic tapeworms, 3500 species
- Class Trematoda—parasitic flukes, 8000 species

BioDigest

2 Teach

Activity

Visual-Spatial Many of the invertebrate phyla are best observed in nature films. Select several nature films that highlight invertebrates. Ask students to list all the invertebrates they see in the films, and group the animals into phyla. Ask them to identify the characteristics they used to classify the animals. L2

Visual Learning

Interpersonal Ask student groups to make a labeled diagram of a planarian worm on the chalkboard. Ask them how the shape of a planarian reflects its living habits. *Planarians are flattened, thereby enabling them to slip easily under rocks and debris in streams.* L2 ELL COOP LEARN

Activity

Visual-Spatial Provide students with binocular microscopes, watch glasses, toothpicks, dropping pipettes, and a planarian worm culture. Ask them to place a few drops of water in the watch glass, then, using a toothpick, gently move a planarian to the watch glass. Have students observe the worm under the microscope and describe its movement. L1 ELL

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *The Five Kingdoms*
Disc 3
BioQuest: *Biodiversity Park*
Disc 3, 4
Video: *Ocean Cnidarians*
Disc 4

Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

- ***Kinesthetic*** Activity, p. 808; Meeting Individual Needs, pp. 809, 810
- ***Visual-Spatial*** Activity, pp. 807, 808, 809, 810, 811; Quick Demo, pp. 810, 811
- ***Interpersonal*** Visual Learning, p. 807
- ***Linguistic*** Biology Journal, p. 808
- ***Naturalist*** Visual Learning, p. 810; Check for Understanding, p. 812

Assessment Planner

Portfolio Assessment
Assessment, TWE, pp. 812, 813
Performance Assessment
BioDigest Assessment, TWE, p. 813
Knowledge Assessment
BioDigest Assessment, SE, p. 813
Skill Assessment
Assessment, TWE, p. 809

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Flatworm Cross Section

Activity

Visual-Spatial Ask students to observe the movement of a live land snail. As the snail moves, ask students to describe its behavior when the antennae are touched with a cotton swab. L1 ELL

Microscope Activity

Ask students to observe the development of snail eggs with hand lenses or binocular microscopes.

Activity

Kinesthetic Ask students to set up a saltwater aquarium and add marine mollusks that can be obtained live from the supermarket. Clams, mussels, and oysters are generally available. Have students care for and make observations of their aquarium. L2 ELL

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *Mollusks*
Disc 4

Mollusks

Slugs, snails, clams, squids, and octopuses are members of phylum Mollusca. All mollusks are bilaterally symmetrical and have a coelom, two body openings, a muscular foot for movement, and a mantle, which is a thin membrane that surrounds the internal organs. In shelled mollusks, the mantle secretes the shell.

Classes of Mollusks

The three major classes of mollusks are gastropods with one shell or no shell; bivalves with two hinged shells; and cephalopods. Cephalopods include octopuses, squids, and shelled nautiluses that all have muscular tentacles and are capable of swimming by jet propulsion. All mollusks, except bivalves, have a rough, tongue-like organ called a radula used for obtaining food.

VITAL STATISTICS

Mollusks
Size ranges: Largest: tropical giant clam, length, 1.5 m; North Atlantic giant squid, length, 18 m; Pacific giant octopus, length, 10 m; smallest: seed clam, length, less than 1 mm
Distribution: Worldwide in salt-, fresh-, and brackish water, and on land in moist temperate and tropical habitats.
Numbers of species:
Phylum Mollusca
Class Gastropoda—snails and slugs, 80 000 species
Class Bivalvia—bivalves, 10 000 species
Class Cephalopoda—octopuses, squids, and nautiluses, 600 species

Gastropods, such as snails, use their radulas to scrape algae from rock surfaces.

Bivalves, such as clams, strain food from water by filtering it through their gills.

Cephalopods, such as octopuses, are predators. They capture prey using the suckers on their long tentacles.

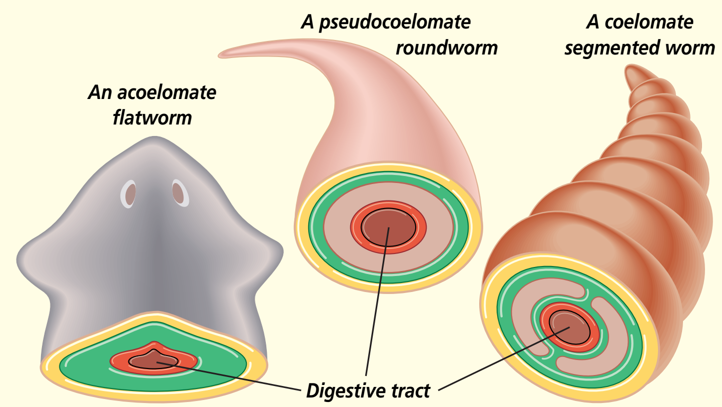
FOCUS ON ADAPTATIONS

Body Cavities

Marine flatworm

The type of body cavity an animal has determines how large it can grow and how it takes in food and eliminates wastes. Acoelomate animals, such as planarians, have no body cavity. Water and digested food particles travel through a solid body by the process of diffusion.

Animals such as roundworms have a fluid-filled body cavity called a pseudocoelom that is partly lined with mesoderm. Mesoderm is a layer of cells between the ectoderm and endoderm that differentiates into muscles, circulatory vessels, and reproductive organs. The pseudocoelom provides support for the attachment of muscles, making movement more efficient. Earthworms have a coelom, a body cavity surrounded by mesoderm in which internal organs are suspended. The coelom acts as a watery skeleton against which muscles can work.



Segmented Worms

Bristleworms, earthworms, and leeches are members of phylum Annelida, the segmented worms. Segmented worms are bilaterally symmetrical, coelomate animals that have segmented, cylindrical bodies with two body openings. Most annelids have setae, bristlelike hairs that extend from body segments, that help the worms move.

Segmentation is an adaptation that provides these animals with great flexibility. Each segment has its own muscles. Groups of segments have different functions, such as digestion or reproduction.

Classes of Segmented Worms

Phylum Annelida has three classes: Hirudinae, the leeches; Oligochaeta, the earthworms; and Polychaeta, the bristleworms.

Leeches have flattened bodies with no setae. Most species are parasites that suck blood and body fluids from ducks, turtles, fishes, and mammals.

Most bristleworms have a distinct head and a body with many setae.

VITAL STATISTICS

Segmented Worms
Size ranges: Largest: giant tropical earthworm, length, 4 m; smallest: freshwater worm, *Aeolosoma,* length, 0.5 mm
Distribution: Terrestrial and marine, brackish, and freshwater habitats worldwide, except polar regions and deserts.
Numbers of species:
Phylum Annelida
Class Hirudinea—leeches, 500 species
Class Oligochaeta—earthworms, 3100 species
Class Polychaeta—bristleworms, 8000 species

Activity

Visual-Spatial Give each group of students a live earthworm in one dish and a bristleworm in another dish. Ask them to observe their behavior and movements. Tell students to make a table that shows the similarities and differences between earthworms and bristleworms. Earthworms may be obtained from bait shops and bristleworms can be obtained from biological supply houses or bait shops near the sea. L2

Assessment

Skill Ask students to find objects in the room that have bilateral and radial symmetry. Ask them to explain why they have identified particular objects as having one type of symmetry or another. Objects such as a pencil and a test tube have radial symmetry. If an object has radial symmetry, it can be divided along any plane through a central axis into roughly equal halves. Objects such as books and chairs have bilateral symmetry. If an object has bilateral symmetry, it can be divided along only one plane to form right and left halves that are mirror images. L2

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Earthworm

BIOLOGY JOURNAL

Invertebrate Advertisements

Linguistic Ask students to prepare a classified newspaper advertisement for a homesite for three animals, one in each of the classes of mollusks. Provide students with a page of the real estate section of the newspaper to review how such advertisements for homes are written. Students should be creative with their language but keep the precise habitat requirements of each animal in mind. L3

MEETING INDIVIDUAL NEEDS

Visually Impaired

Kinesthetic Provide poster board cut-outs of flatworms, roundworms, and segmented worms. Ask visually-impaired students to describe their tactile impressions of each worm. L1

BioDigest

Activity

Visual-Spatial Ask students to bring in jars of many types of arthropods. Number the jars and pass them from group to group, asking students to write the name of the arthropod and obvious arthropod features beside the name. For each arthropod, ask them to infer what features helped to make that particular arthropod successful. L2

Quick Demo

Visual-Spatial Show students a live water strider on the surface of pond water in a container with a large surface area. Ask students to hypothesize how the water strider stays on top of the water. Ask them to identify adaptations that enable it to skate on the water surface. L2

Visual Learning

Naturalist Ask students to examine the diagrams of arthropods on this page and identify adaptations that enable each animal to survive in its habitat. L1

Activity

Have students design and conduct an experiment to determine the effect of temperature on the jumping ability of crickets. L2

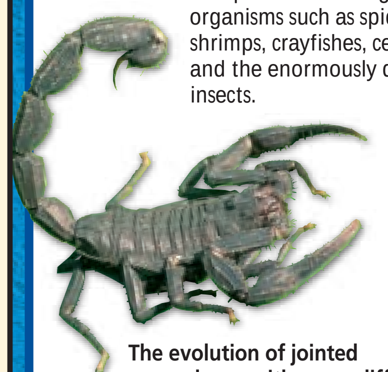
Arthropods

Arthropods are bilaterally symmetrical, coelomate invertebrates with tough outer coverings called exoskeletons and jointed appendages that are used for walking, sensing, feeding, and mating. Exoskeletons protect and support their soft internal tissues and organs. Jointed appendages allow for powerful and efficient movements.

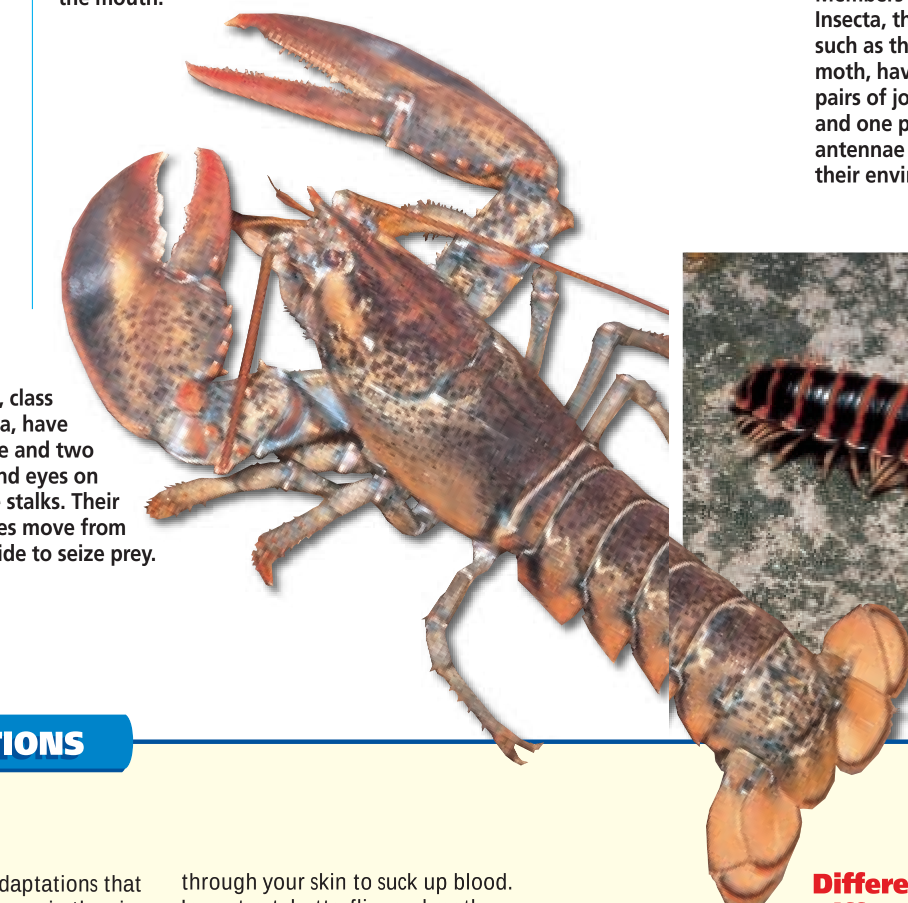
Like other members of class Arachnida, the black widow spider has four pairs of jointed legs and chelicerae, a pair of biting appendages near the mouth.

Arthropod Diversity

Two out of three animals on Earth today are arthropods. The success of arthropods can be attributed to adaptations that provide efficient gas exchange, acute senses, and varied types of mouthparts for feeding. Arthropods include organisms such as spiders, crabs, lobsters, shrimps, crayfishes, centipedes, millipedes, and the enormously diverse group of insects.



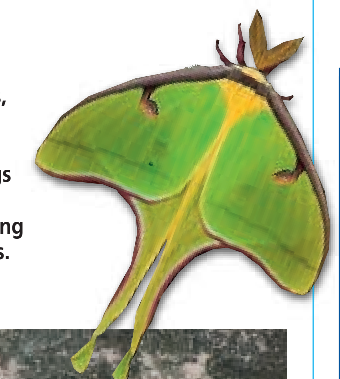
The evolution of jointed appendages with many different functions probably led to the success of the arthropods as a group.



Lobsters, class Crustacea, have antennae and two compound eyes on movable stalks. Their mandibles move from side to side to seize prey.

Arthropod Origins

Arthropods most likely evolved from segmented worms; they both show segmentation. However, an arthropod's segments are fused and have a greater complexity of structure than those of segmented worms. Because arthropods have exoskeletons, fossil arthropods are frequently found, and consequently more is known about their origins than about the phylogeny of worms.



Members of class Insecta, the insects, such as this luna moth, have three pairs of jointed legs and one pair of antennae for sensing their environments.

Millipedes, class Diplopoda, are herbivores. Millipedes have up to 100 body segments, and each segment has two pairs of legs.

Vital Statistics

Arthropods

Size ranges: Largest insects: tropical stick insect, length, 33 cm; Goliath beetle, mass, 100 g; smallest insect: fairyfly wasp, length, 0.21 mm

Distribution: All habitats worldwide.

Numbers of species:

Phylum Arthropoda
- Class Arachnida—spiders and their relatives, 57 000 species
- Class Crustacea—crabs, shrimps, lobsters, crayfishes, 35 000 species
- Class Merostomata—horseshoe crabs, 4 species
- Class Chilopoda—centipedes, 2500 species
- Class Diplopoda—millipedes, 10 000 species
- Class Insecta—insects, 750 000 species

Focus on Adaptations

Insects

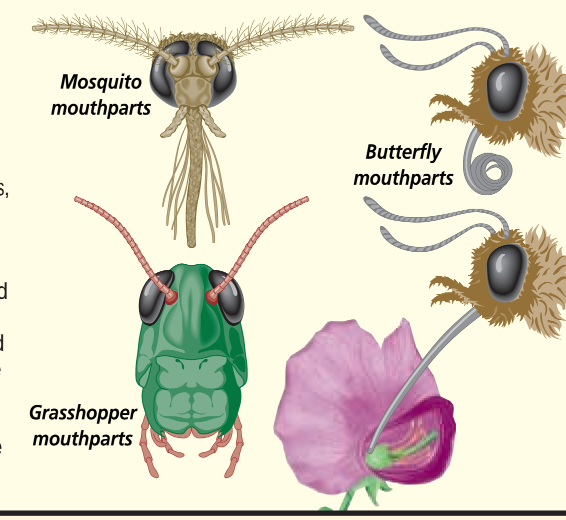
Staghorn beetle

Insects have many adaptations that have led to their success in the air, on land, in freshwater, and in salt water. For example, insects have complex mouthparts that are well adapted for chewing, sucking, piercing, biting, or lapping. Different species have mouthparts adapted to eating a variety of foods.

If you have ever been bitten by a mosquito, you know that mosquitoes have piercing mouthparts that cut through your skin to suck up blood. In contrast, butterflies and moths have long, coiled tongues that they extend deep into tubular flowers to sip nectar. Grasshoppers and many beetles have hard, sharp mandibles they use to cut off and chew leaves. But the heavy mandibles of staghorn beetles no longer function as jaws; instead, they have become defensive weapons used for competition and mating purposes.

Different Foods for Different Stages

Because insects undergo metamorphosis, they often utilize different food sources at different times of the year. For example, monarch butterfly larvae feed on milkweed leaves, whereas the adults feed on milkweed flower nectar. Apple blossom weevil larvae feed on the stamens and pistils of unopened flower buds, but the adult weevils eat apple leaves. Some adult insects, such as mayflies, do not eat at all! Instead, they rely on food stored in the larval stage for energy to mate and lay eggs.



Meeting Individual Needs

English Language Learners

Kinesthetic For students who are English language learners or are kinesthetic learners, purchase plastic arthropods. Ask them to work in groups and point out features of the arthropods as they pass them around their group. Features that they might be able to find include head, thorax, abdomen, spiracles, claws, flippers, jointed legs, cephalothorax, antennae, mouthparts, pedipalps, chelicerae, compound and simple eyes, wings, tympanum, and mandibles. L2 ELL COOP LEARN

Project

Hydraulics of Tube Feet

Have students research the science of hydraulics. Have them describe how hydraulics helps to operate the tube feet of echinoderms. Have them compare and contrast this hydraulic system with other hydraulic systems in the plant or animal kingdom. L3

Glencoe Technology

CD-ROM

Biology: The Dynamics of Life

Exploration: *Arthropods*

Disc 4

BioDigest

Visual Learning

Ask students to examine the photo of the moth and explain how it is adapted to its way of life. *The color provides camouflage from predators. Large wings permit long-distance flight while conserving energy during the gliding parts of the flight.* L1

Quick Demo

Visual-Spatial Borrow a collection of preserved butterflies from a nearby college or museum and call students' attention to the enormous variety in wing shapes, sizes, and colors. L2

Activity

Visual-Spatial Provide students with a culture of mealworms. Ask them to find and make diagrams of the stages of metamorphosis they find in the culture. L1 ELL

Glencoe Technology

VIDEODISC

The Infinite Voyage

Insects: The Ruling Class, Insects and Their Behavior (Ch. 1), 7 min.

Caterpillars: Altering Appearances (Ch. 5), 5 min.

BioDigest

Assessment

Portfolio Have students visit a local zoo or pet shop that maintains a saltwater aquarium. Have them time their visit so they are present when it is feeding time for echinoderms such as sea stars, brittle stars, and feather stars. Have students watch one echinoderm as it feeds, then describe the behavior of the animal in their portfolios.

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *Echinoderms*
Disc 4

3 Assess

Check for Understanding

Naturalist Set up a lab practical with stations with preserved or live invertebrates. Ask students to identify the phylum and group within the phylum to which each animal belongs, and explain the visible features that helped them classify the invertebrates. L2

Echinoderms

Echinoderms, phylum Echinodermata, are radially symmetrical, coelomate animals with hard, bumpy, spiny endoskeletons covered by thin epidermis. The endoskeleton is comprised of calcium carbonate. Echinoderms move using a unique water vascular system with tiny, suction-cuplike tube feet. Some echinoderms have long spines also used in locomotion.

The tube feet of a sea star operate by means of a hydraulic water vascular system. Sea stars move along slowly by alternately pushing out and pulling in their tube feet.

Echinoderm Diversity

There are five major classes of echinoderms. They include sea stars, brittle stars, sea urchins, sea cucumbers, sand dollars, sea lilies, and feather stars.

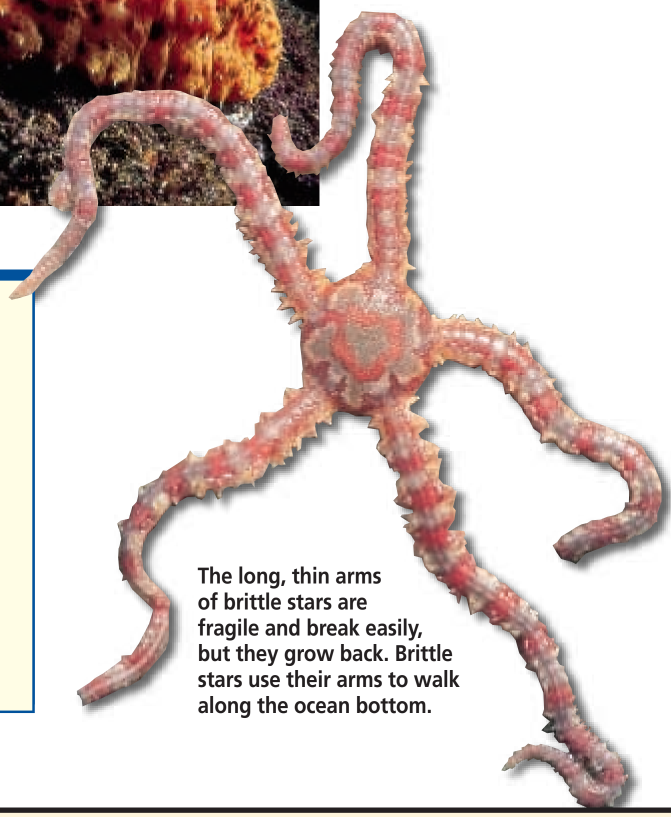
Echinoderms have bilaterally symmetrical larvae, a feature that suggests a close relationship to the chordates.

Invertebrate Chordates

All chordates have, at one stage of their life cycles, a notochord, a dorsal hollow nerve cord, gill slits, and muscle blocks. A notochord is a long, semirigid, rodlike structure along the dorsal side of these animals. The dorsal hollow nerve cord is a fluid-filled canal lying above the notochord. Gill slits are paired openings in the pharynx that, in some invertebrate chordates, are used to strain food from the water. In other chordates, gill slits develop into internal gills used for gas exchange. Muscle blocks are modified body segments consisting of stacked muscle layers. Muscle blocks are anchored by the notochord.

Invertebrate chordates have all of these features at some point in their life cycles. The invertebrate chordates include the lancelets and the tunicates, also known as sea squirts.

Sea cucumbers have a leathery skin and are flexible. Like most echinoderms, they move using tube feet.



The long, thin arms of brittle stars are fragile and break easily, but they grow back. Brittle stars use their arms to walk along the ocean bottom.

Vital Statistics

Echinoderms
Size ranges: Largest: sea urchin, diameter, 19 cm; longest: sea cucumber, length, 60 cm
Distribution: Marine habitats worldwide.
Numbers of species:
Phylum Echinodermata
Class Asteroidea—sea stars, 1500 species
Class Crinoidea—sea lilies and feather stars, 600 species
Class Ophiuroidea—brittle stars, 2000 species
Class Echinoidea—sea urchins and sand dollars, 950 species
Class Holothuroidea—sea cucumbers, 1500 species

The lancelet is an example of an invertebrate chordate. Notice that the lancelet's body is shaped like that of a fish even though it is a burrowing filter feeder.

BioDigest Assessment

Understanding Main Ideas

1. An animal that is a filter feeder, takes in water through pores in the sides of its body, and releases water from the top is a ________.
   a. roundworm c. sponge
   b. gastropod d. lancelet
2. Nematocysts are unique to ________.
   a. sponges c. annelids
   b. mollusks d. cnidarians
3. An example of a free-living flatworm is a ________.
   a. planarian c. nematode
   b. tapeworm d. vinegar-eel
4. Which of the following is used by segmented worms for movement?
   a. chelicerae
   b. nematocysts
   c. setae
   d. water vascular system
5. Which of the following are invertebrate chordates?
   a. sea anemones c. bivalves
   b. lancelets d. squid
6. Parasitism is a way of life for most ________.
   a. flukes c. cnidarians
   b. sponges d. annelids
7. An example of an animal with no body cavity is a(n) ________.
   a. sea star c. earthworm
   b. flatworm d. clam
8. An octopus belongs to phylum Mollusca because it has a mantle, bilateral symmetry, two body openings, and ________.
   a. an external shell
   b. a muscular foot
   c. a pseudocoelom
   d. segmentation
9. Leeches feed by ________.
   a. grazing on aquatic plants
   b. stinging prey
   c. filter feeding
   d. sucking blood
10. Which of the following characteristics is unique to arthropods?
   a. nematocycts c. filter feeding
   b. jointed appendages d. tube feet

Thinking Critically

1. A radula is to a snail as a(n) ________ is to a jellyfish. Explain your answer.
2. Why is more known about animals with hard parts than is known about animals with only soft parts?
3. In what ways are echinoderms more similar to vertebrates than to other invertebrates?
4. You are examining a free-living animal that had a thin, solid body with two surfaces. Into what phylum is this organism classified? Explain.
5. In what two ways are spiders different from insects?

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

BioDigest Assessment

Understanding Main Ideas

1. c	4. c	7. b	10. b
2. d	5. b	8. b	
3. a	6. a	9. d	

Thinking Critically

1. nematocyst; a snail obtains food with its radula; a jellyfish obtains its food with nematocysts
2. Hard parts leave fossil evidence while soft parts leave little fossil evidence.
3. Echinoderms have bilaterally symmetrical larvae, as do chordates.
4. It belongs to the phylum Platyhelminthes because it is a free-living flatworm.
5. Spiders have four pairs of legs; insects have three. Spiders have chelicerae; insects have many different types of mouthparts. Insects have antennae; spiders do not.

BioDigest

Reteach

Ask students to make a table in which they compare the characteristic features of invertebrate animals. L1

Extension

Ask students to make a collection of local insects and identify the features of these animals that make them adapted to the local environment. L2 ELL

Assessment

Portfolio Using large poster paper and markers, and their knowledge of invertebrate structure, have students design an invertebrate that is adapted to living in the school parking lot. Ask them to make a diagram and a list of adaptations. Have students include their posters in their portfolios. L2 P

4 Close

Activity

Have students conduct an invertebrate survey of a nearby pond, meadow, wetland, or woodland. If time permits, ask them to compare the types of invertebrates found in different habitats.

Resource Manager

Content Mastery, pp. 145-148 L1
Reinforcement and Study Guide, pp. 131-132 L2