LESSON 28.1

Getting Started

Objectives

28.1.1 Describe how animals respond to stimuli.

28.1.2 Summarize the trends in the evolution of nervous systems in animals.

28.1.3 Describe some of the different sensory systems in animals.

Student Resources

Study Workbooks A and B, 28.1 Worksheets

Spanish Study Workbook, 28.1 Worksheets

BIOLOGY.com Lesson Overview • Lesson Notes • Activity: Art Review • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition,** see pages 668–673.

Activate Prior Knowledge

Switch on a classroom light, and ask students to imagine turning on an outside light at night during summer.

Ask What would the light attract? *(flying insects)*

Ask How would the insects know the light is on? *(Insects have eyes that can see the light.)*

Discuss the sense organs of various animals that students have observed.

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, V

CONTENT

C.1.f, C.3.a, C.5.d, C.6.a, C.6.b

INQUIRY

A.1.a, A.1.b, A.2.a

28.1 Response

Key Questions

How do animals respond to events around them?

What are the trends in nervous system evolution?

What are some types of sensory systems in animals?

Vocabulary

neuron • stimulus • sensory neuron • interneuron • response • motor neuron • ganglion • cerebrum • cerebellum

Taking Notes

Preview Visuals Before you read, preview the diagram of neural circuits in **Figure 28–1.** Take note of any questions you have about it and try to answer them as you read.

THINK ABOUT IT Imagine that you are at a favorite place—a beach or the basketball court. Think about how the sun and wind feel on your face or how good it feels to make the perfect layup. Now, think about the way you experience that place. You gather information about your surroundings through senses such as vision and hearing. Your nervous system collects that information. Your brain decides how to respond to it. The same is true for all animals—though the structures that perform these functions vary from phylum to phylum.

How Animals Respond

How do animals respond to events around them?

Animals must often respond to events or environmental conditions within seconds, or even tiny fractions of a second. Sometimes they need to catch food. Other times, they need to escape predators. Most animals have evolved specialized nervous systems that enable them to respond to events around them. Nervous systems are composed of specialized nerve cells, or **neurons.** The structure of neurons enables them to receive and pass on information. Working together, neurons acquire information from their surroundings, interpret that information, and then "decide" what to do about it.

Detecting Stimuli Information in the environment that causes an organism to react is called a **stimulus** (plural: stimuli). Chemicals in air or water can stimulate the nervous system. Light or heat can also serve as a stimulus. The sound of your phone ringing on a Friday night is a stimulus to which you might respond by running to answer it!

Animals' ability to detect stimuli depends on specialized cells called **sensory neurons.** Each type of sensory neuron responds to a particular stimulus such as light, heat, or chemicals. Humans share many types of sensory cells with other animals. For that reason, many animals react to stimuli that humans notice, including light, taste, odor, temperature, sound, water, gravity, and pressure. But many animals have types of sensory cells that humans lack. That's one reason why some animals respond to stimuli that humans cannot detect, such as very weak electric currents or Earth's magnetic field.

UbD Teach for Understanding

ENDURING UNDERSTANDING Animals have evolved diverse ways to carry out basic life processes and maintain homeostasis.

GUIDING QUESTION How do animals sense and respond to the environment?

EVIDENCE OF UNDERSTANDING *After completing the lesson, assign students the following assessment to show their understanding of how animals respond to stimuli in their environment.* Ask each student to choose an animal and create a cartoon strip showing how it responds to a stimulus in its environment. Tell students their cartoons can be humorous but should include accurate information about the animal's nervous system and the neurons involved in the response. Post finished cartoon strips on the classroom wall.

Processing Information When sensory neurons detect a stimulus, they pass information about it to other nerve cells. Those neurons, which typically pass information to still other neurons, are called **interneurons,** as shown in **Figure 28–1.** Interneurons process information and determine how an animal responds to stimuli.

Does a particular odor mean food . . . or danger? Is the immediate environment too hot, too cold, or just right? The number of interneurons an animal has, and the ways those interneurons process information, determine how flexible and complex an animal's behavior can be.

Some invertebrates, such as cnidarians and worms, have very few interneurons. These animals are capable of only simple responses to stimuli. They may swim toward light or toward a chemical stimulus that signals food. Vertebrates have more highly developed nervous systems with larger numbers of interneurons. The brain is made up of many of these interneurons. That's why the behaviors of vertebrates can be more complex than those of most invertebrates.

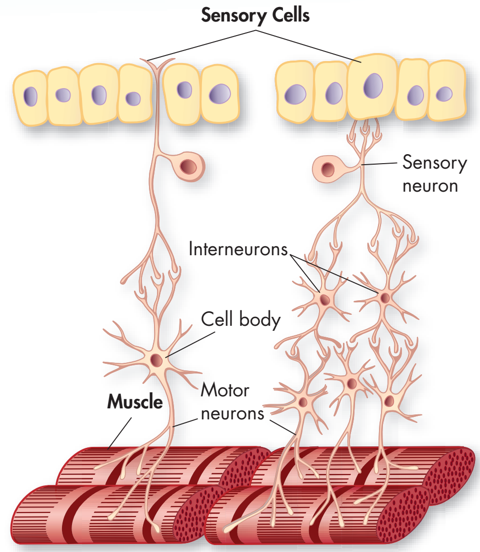


FIGURE 28–1 Neural Circuits In some neural circuits, sensory neurons connect to motor neurons in ways that enable fast but simple responses (left). In others, specialized sensory cells connect to sensory neurons, which connect to interneurons, which connect to motor neurons (right). The more complex a circuit is, the more complex an animal's responses to stimuli can be.

Responding A specific reaction to a stimulus is called a **response.** For example, waking up when you hear the alarm is a response. **When an animal responds to a stimulus, body systems—including the nervous system and the muscular system—work together to generate a response.** Responses to many stimuli are directed by the nervous system. However, those responses are usually carried out by cells or tissues that are not nerve cells. A lion's decision to lunge at prey, as in **Figure 28–2,** is carried out by muscle cells that produce movement. In that case, nerve cells called **motor neurons** carry "directions" from interneurons to muscles. Other responses to environmental conditions may be carried out by other body systems, such as respiratory or circulatory systems.

FIGURE 28–2 Response Mammals, like the lion and wart hog shown here, have complex sensory organs and many interneurons. These animals can therefore process and respond to information in complex ways. Lions stalk and pursue their prey, and wart hogs try to evade their attackers.

Teach

Use Visuals

Use **Figure 28–1** to discuss how the different types of neurons work together in an animal's response. Explain that students will learn more about neurons in Chapter 31, including parts of neurons. Point out that the largest part of a neuron is called the cell body, one of which is labeled in the figure. Then, describe a common stimulus—an object too hot to touch. Call on volunteers to identify which neurons detect the stimulus *(sensory neurons)* and which pass information from the sensory neurons to other neurons *(interneurons).*

Ask If sensory neurons in an animal's paw were to detect the stimulus of a hot rock, which muscles might motor neurons direct to respond? *(the muscles in the animal's leg)*

DIFFERENTIATED INSTRUCTION

LPR Less Proficient Readers List the main ideas about neural circuits on the board in simplified language. For example, write these sentences:

- Sensory neurons detect a stimulus.
- Interneurons pass information to motor neurons.
- Motor neurons give directions to muscles.
- Muscles carry out a response.

Suggest students keep these concepts in mind as they read the text and study **Figure 28–1.**

ELL Focus on ELL: Build Background

ALL SPEAKERS Give each student a **T-Chart** to help them organize terms and concepts referring to the nervous system. Ask them to write terms they have previous knowledge of as well as the vocabulary terms in the left-hand column and add translations, definitions, and drawings in the right-hand column.

Study Wkbks A/B, Appendix S30, T-Chart. **Transparencies,** GO15.

Quick Facts

FOR ARTHROPODS, EVERY DECISION IS A NO-BRAINER

One of the most important differences between animals such as arthropods and "higher" animals is that the responses of arthropods depend only on the various stimuli received by their nerves. Although arthropods have a well-developed nervous system and a simple brain, it is a mistake to attribute "thought" to these animals. Arthropods do not depend on "decision making"; most of their behaviors are genetically programmed. Their reactions in a particular situation are almost totally predictable. Aristotle, a great observer of natural phenomena, was the first to document the fact that wasps remain at almost normal activity levels for a while after their heads have been removed.

LESSON 28.1

Teach continued

Build Reading Skills

Before students read **Trends in Nervous System Evolution,** suggest they start an outline of the section. Explain that the blue headings, **Invertebrates** and **Chordates,** can be used for the first level of the outline. The run-in heads, such as **Nerve Nets, Nerve Cords, and Ganglia,** can be used for the second level. Then, under each second-level head, students can add important details for the third level. Tell students that making an outline helps them understand the content more fully and that the outline will also be useful for later review.

DIFFERENTIATED INSTRUCTION

ELL English Language Learners Pair English language learners with native English speakers for composition of the outline described above. Suggest English language learners add drawings to their outlines to help them remember basic concepts.

L3 Advanced Students Enrich students' understanding of invertebrate nervous systems by having them do further research on one of the phyla represented in **Figure 28–3.** Ask students to present what they learned to the class.

Quick Lab GUIDED INQUIRY

Does a Planarian Have a Head?

1. Cover half of the outside of a petri dish with black paper.
2. Place a white sheet of paper under the other half.
3. Place a planarian in the center of the dish, and add spring water to keep it moist.
4. Observe the planarian for 2 minutes. Record how long it stays on each side of the dish.

Analyze and Conclude

1. Form a Hypothesis When the planarian moved, did one end always lead the way? Form a hypothesis that explains your observation.

Trends in Nervous System Evolution

What are the trends in nervous system evolution?

Nervous systems vary greatly in organization and complexity across the animal kingdom. **Animal nervous systems exhibit different degrees of cephalization and specialization.**

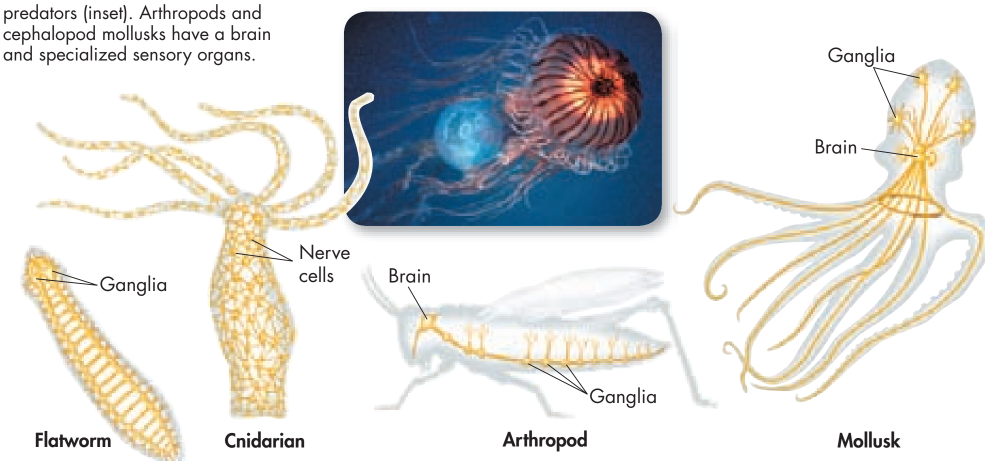
Invertebrates Invertebrate nervous systems range from simple collections of nerve cells to complex organizations that include many interneurons. You can see some examples in **Figure 28–3.**

▶ ***Nerve Nets, Nerve Cords, and Ganglia*** Cnidarians, such as jellyfishes, have simple nervous systems called nerve nets. As the name implies, nerve nets consist of neurons connected into a netlike arrangement with few specializations. In other radially symmetric invertebrates, echinoderms such as sea stars, for example, some interneurons are grouped together into nerves, or nerve cords, that form a ring around the animals' mouths and stretch out along their arms. In still other invertebrates, a number of interneurons are grouped together into small structures called **ganglia** (singular: ganglion), in which interneurons connect with one another.

▶ ***"Heads"*** As you learned in Chapter 25, bilaterally symmetric animals often exhibit cephalization, the concentration of sensory neurons and interneurons in a "head." Certain flatworms and roundworms show some cephalization. Some cephalopod mollusks and many arthropods show higher degrees of cephalization. In these animals, interneurons form ganglia in several places. Typically, the largest ganglia are located in the head region and are called cerebral ganglia.

▶ ***Brains*** In some species, cerebral ganglia are further organized into a structure called a brain. The brains of some cephalopods, such as octopi, enable complex behavior, including several kinds of learning.

FIGURE 28–3 Invertebrate Nervous Systems Invertebrate nervous systems have different degrees of cephalization and specialization. Flatworms have centralized nervous systems with small ganglia in their heads. Cnidarians have a nerve net which, despite its simplicity, enables them to be successful predators (inset). Arthropods and cephalopod mollusks have a brain and specialized sensory organs.



Quick Lab

PURPOSE Students investigate the responses to stimuli in planaria.

MATERIALS planarian, petri dish, black paper, white paper, spring water, clock or watch

SAFETY Tell students to treat the planarians with care to avoid injuring them. Have students wear disposable plastic gloves during the lab and wash their hands afterward.

PLANNING Have students read the procedure and discuss any questions they have about what to do. You may want to place the planarians in the petri dishes for the students.

ANALYZE AND CONCLUDE

1. Sample answer: Yes, the head end always led the way. A planarian's head end leads the way because its eyespots sense light.

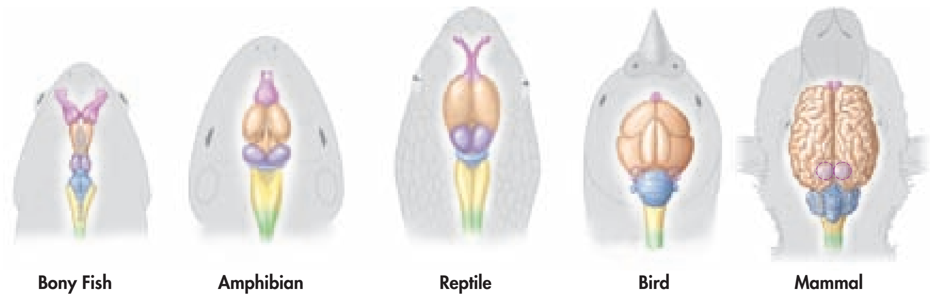


FIGURE 28–4 Vertebrate Brains The cerebrum and cerebellum increase in size from fishes to mammals. In fishes, amphibians, and reptiles, the cerebrum, or "thinking" region, is relatively small. In birds and mammals, and especially in primates, the cerebrum is much larger and may contain folds that increase its surface area. The cerebellum is also most highly developed in birds and mammals.

Chordates Nonvertebrate chordates, which have no vertebrate-type "head" as adults, still have a cerebral ganglion. Vertebrates, on the other hand, show a high degree of cephalization and have highly developed nervous systems. Vertebrate brains are formed from many interneurons within the skull. These interneurons are connected with each other and with sensory neurons and motor neurons in the head and elsewhere in the body. The human brain contains more than 100 billion nerve cells, each of which sends signals to as many as 1000 other nerve cells and receives signals from up to 10,000 more.

▶ ***Parts of the Vertebrate Brain*** Regions of the vertebrate brain include the cerebrum, cerebellum, medulla oblongata, optic lobes, and olfactory bulbs. The **cerebrum** is the "thinking" region of the brain. It receives and interprets sensory information and determines a response. The cerebrum is also involved in learning, memory, and conscious thought. The **cerebellum** coordinates movement and controls balance, while the medulla oblongata controls the functioning of many internal organs. Optic lobes are involved in vision, and olfactory bulbs are involved in the sense of smell. Vertebrate brains are connected to the rest of the body by a thick collection of nerves called a spinal cord, which runs through a tube in the vertebral column.

▶ ***Vertebrate Brain Evolution*** Brain evolution in vertebrates follows a general trend of increasing size and complexity from fishes, through amphibians and reptiles, to birds and mammals. **Figure 28–4** shows how the size and complexity of the cerebrum and cerebellum increase.

FIGURE 28–5 Not Such a Bird Brain The brains of some chickadee species are so sophisticated that the part responsible for remembering locations gets bigger when the bird stores food in the fall. When winter comes, the tiny bird is better able to find its hundreds of storage places. (In spring, its brain returns to normal size.) **Infer** *Which of the six main parts of the chickadee brain would you expect to grow in the fall?*

In Your Notebook *Construct a figure of speech that explains, in terms of another object, how the folds of the mammalian cerebellum increase its surface area.*

Use Visuals

Discuss the regions of vertebrate brains using **Figure 28–4.** Begin by focusing students' attention on the key, which lists the different regions of the brain. For each region, ask a volunteer to describe its function. Then, after making sure students understand the color coding of the regions, discuss differences among vertebrates.

Ask Do amphibians or reptiles likely have a better sense of smell, and how can you tell? *(Reptiles probably have a better sense of smell, because the olfactory bulbs are relatively larger in reptiles than in amphibians.)*

Ask What indicates that a bird is probably more capable of learning than a reptile? *(The cerebrum in a bird is relatively larger and more complex than it is in a reptile.)*

DIFFERENTIATED INSTRUCTION

L1 Special Needs Provide students with a model of a brain that differentiates in a tactile way between the different regions. (Most often, this will be a model of the human brain, which can be used to represent the mammalian brain.) As students handle the brain, explain how the sizes of the different regions differ in the different groups of vertebrates.

L1 Struggling Students Provide students with unlabeled drawings of the five vertebrate brains shown in **Figure 28–4.** Have pairs of students work together to label the different regions in each brain.

BIOLOGY.com Have students find out more about the comparative anatomy of vertebrate brains by using **Art Review: Vertebrate Brains.**

Quick Facts

BIRD BRAINS

The brains of birds are suprisingly complex organs. Here are some interesting facts about bird brains.

- The cerebellum is well developed in birds; it is relatively larger in birds than in mammals. This part of the brain is involved in muscle coordination and the regulation of balance, both of which are necessary for flight.
- In most birds, the optic lobes are relatively large, while the olfactory bulbs are relatively small. Most birds can see very well but smell poorly.
- The hippocampus, the part of the cerebrum involved in memory, is relatively large in some birds, especially those that must remember where they have stored seeds. In some species, it becomes enlarged as the bird stores seeds, later shrinking back to its original size.

Answers

FIGURE 28–5 the cerebrum

IN YOUR NOTEBOOK Sample answer: The folds of the mammalian cerebrum increase its surface area like the folds of an accordion increase the surface area of its bellows.

Teach continued

Use Visuals

Begin a discussion with students of invertebrate sense organs with a focus on the invertebrate eyes shown in **Figure 28–6.** Point out that the planarian included in the figure is the same organism they observed in the **Quick Lab.**

Ask What can a planarian "see" with its eyespot? *(changes in the amount of light)*

Explain that each type of invertebrate eye detects light or forms images in a different way, and students should not assume that an invertebrate "sees" objects in the same way that humans do.

DIFFERENTIATED INSTRUCTION

LPR **Less Proficient Readers** Struggling readers may have difficulty understanding the subcaptions in the figure. Help them make bulleted lists of characteristics of each of the four invertebrate eyes. For example, on the board, write this bulleted list for the scallop eye:

Scallop

- 40–60 simple eyes
- Do not form images
- Detect movement well
- Enable scallop to detect predators

Call on students to help you make similar lists for the three other invertebrate eyes.

L3 **Advanced Students** Challenge students to write a paragraph explaining how the complex eye of the octopus might have evolved as an adaptation that gives this cephalopod an advantage in its environment. *(Answers may vary. Students should mention that an octopus is a predator, and the complex eye allows it to identify prey.)*

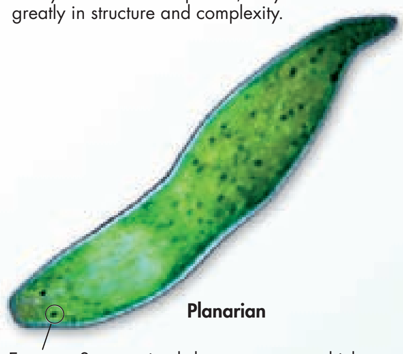
Sensory Systems

What are some types of sensory systems in animals?

The more complex an animal's nervous system is, the more developed its sensory systems tend to be. **Sensory systems range from individual sensory neurons to sense organs that contain both sensory neurons and other cells that help gather information.**

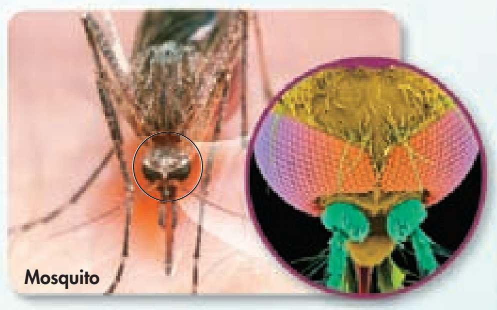
Invertebrate Sense Organs Many invertebrates have sense organs that detect light, sound, vibrations, movement, body orientation, and chemicals in air or water. Invertebrate sense organs vary widely in complexity. Flatworms, for example, have simple eyespots that detect only the presence and direction of light. More-cephalized invertebrates have specialized sensory tissues and well-developed sense organs. Some cephalopods and arthropods, for example, have complex eyes that detect motion and color and form images. In **Figure 28–6,** you can see a variety of invertebrate visual systems.

FIGURE 28–6 Invertebrate Eyes Invertebrate sense organs, such as the eyes shown in the photos, vary greatly in structure and complexity.



Eyespot: Some animals have eyespots, which are groups of cells that can detect changes in the amount of light (LM 50×).

Simple Eye: The 40–60 simple eyes of a scallop do not form images. They do, however, detect movement well enough to enable the scallop to escape its predators.



Compound Eye: The compound eyes of arthropods are made up of many lenses that detect minute changes in movement and color but produce less-detailed images than human eyes do.

Complex Eye: Octopi and squid have eyes as complex as fishes and humans, though their structures differ.

UbD Check for Understanding

INDEX CARD SUMMARIES

Give students each an index card, and ask them to write one main idea from the lesson on the front of the card. This idea could be about how animals respond, animal nervous systems, or animal sense organs. Then, ask them to write an idea that they don't understand on the back of the card.

ADJUST INSTRUCTION

Read over the cards to determine which concepts students understand and which they are having trouble with. For concepts that students don't understand, call on volunteers to explain to the class what a term means, how one structure differs from another, or how a process occurs.

Chordate Sense Organs Nonvertebrate chordates have few specialized sense organs. In tunicates, sensory cells in and on the siphons and other internal surfaces help control the amount of water passing through the pharynx. Lancelets have a cerebral ganglion with a pair of eyespots that detect light.

In contrast, most vertebrates have highly evolved sense organs. Many vertebrates have very sensitive organs of taste, smell, and hearing. Some sharks, for example, can sense 1 drop of blood in 100 liters of water! And although all mammalian ears have the same basic parts, they differ in their ability to detect sound, as you can see in **Figure 28–7.** In fact, bats and dolphins can even find objects in their environment using echoes of their own high-frequency sounds. A great many species of fishes, amphibians, reptiles, birds, and mammals have color vision that is as good as, or better than, that of humans.

Some species, including certain fishes and the duckbill platypus, can detect weak electric currents in water. Some animals, such as sharks, use this "electric sense" to navigate by detecting electric currents in seawater that are caused by Earth's magnetic field. Other "electric fishes" can create their own electric currents. These fishes use electric pulses to communicate with one another, in much the same way that other animals communicate using sound. Many species that can detect electric currents use the ability to track down prey in dark, murky water. Some birds can detect Earth's magnetic field directly, and they use that ability to navigate during long-distance migrations.

Animal	Hearing Range (Hz)
Tree frog	50–4000
Canary	250–8000
Dog	67–45,000
Bat	2000–110,000
Human	30–23,000
Elephant	16–12,000
Bottlenose dolphin	75–150,000

FIGURE 28–7 Vertebrate Hearing Human senses are not necessarily superior to those of other animals. **Interpret Tables** *Would you expect to be able to hear the highest pitch a dog can hear? Explain.*

28.1 Assessment

Review Key Concepts

1. a. **Review** List three body systems that work together to create a response to a stimulus.
   b. **Explain** What is the role of a motor neuron?
   c. **Sequence** What is the correct sequence of the roles played by the following in the response to a stimulus: interneuron, motor neuron, sensory neuron, muscle.
2. a. **Review** What are two general ways in which nervous systems differ among animal groups?
   b. **Compare and Contrast** Describe the degree of cephalization shown by cnidarians, flatworms, octopi, and vertebrates.
3. a. **Review** Give an example of an animal with a very simple sensory system and an example of one with a complex sensory system.
   b. **Infer** What is the general relationship between the complexity of an animal's nervous system and that of its sensory system?

WRITE ABOUT SCIENCE

Explanation

4. The compound eyes of insects detect movement better than they distinguish details. How might the ability to detect movement be more important to an insect than the ability to see fine details? (*Hint:* Consider the size of an insect in relation to that of its predators.)

BIOLOGY.com Search Lesson 28.1 GO • Self-Test • Lesson Assessment

LESSON 28.1

Assess and Remediate

EVALUATE UNDERSTANDING

Read aloud each boldface Key Concept in the lesson. For each, call on a volunteer to provide a supporting detail. Then, ask other students for additional supporting details. After students have provided support for the Key Concept, ask a volunteer to explain the importance of it in understanding response in animals. After reviewing all Key Concepts, have students complete the 28.1 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If students have difficulty answering **Question 1c,** have them review the text material that defines each term and then make a **Flowchart** that begins with a stimulus and ends with a physical response by an animal.

Study Wkbks A/B, Appendix S25, Flowchart. **Transparencies,** GO8.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

Answers

FIGURE 28–7 No; The range of a dog's hearing goes up to 45,000 Hz, while the range of human hearing goes up to only 23,000 Hz.

Assessment Answers

1a. sensory neurons, the nervous system, and muscles

1b. Motor neurons carry "directions" from interneurons to muscles.

1c. sensory neuron, interneuron, motor neuron, muscle

2a. Sample answer: whether or not the nervous system has sensory neurons and interneurons centralized in a head region (cephalization), and the degree to which sensory cells are specialized (specialization)

2b. Cnidarians have no cephalization; flatworms have some cephalization; octopi and vertebrates have high degrees of cephalization.

3a. Sample answer: Cnidarians have a very simple sensory system that consists of a nerve net and no sensory organs. Octopi have a complex sensory system, including a brain and eyes as complex as human eyes.

3b. The more complex an animal's nervous system is, the more developed its sensory systems tend to be.

WRITE ABOUT SCIENCE

4. Sample answer: An insect must be able to detect movement in order to detect the presence of predators in its area, but it has no need to see fine details of the predator in order to escape it.