28.4 Homeostasis

THINK ABOUT IT A herd of wildebeests plods across Africa's Serengeti Plain. The land is parched, so they are on the move toward greener pastures. They move mechanically, their steps using as little energy as possible. With no food in their guts, their bodies mobilize energy stored in fat deposits for distribution to body tissues. Between drinking holes, their bodies conserve water by producing as little urine as possible. All their body systems work together in a joint effort to survive this difficult passage.

Key Questions

Why is the interdependence of body systems essential?

How do animals control their body temperature?

Vocabulary

endocrine gland • ectotherm • endotherm

Taking Notes

Venn Diagram Draw a Venn diagram comparing and contrasting the temperature control strategies of ectotherms and endotherms.

Interrelationship of Body Systems

Why is the interdependence of body systems essential?

Homeostasis, or control of internal conditions, is essential to an organism's survival. Wildebeest brain cells, like those of humans, must be kept at a stable temperature and supplied with a steady stream of glucose for energy—even when the animal is under stress. The brain cells must be bathed in fluid with a constant concentration of water and be cleansed of metabolic waste products. These conditions must not change during droughts, floods, famines, heat, or cold. Failure of homeostasis, even for a few minutes, would lead to permanent brain injury or death.

You've learned about digestive, respiratory, circulatory, excretory, nervous, muscular, and skeletal systems separately. Yet all of these systems are interconnected. **All body systems work together to maintain homeostasis.** In most animals, respiratory and digestive systems would be useless without circulatory systems to distribute oxygen and nutrients. Similarly, the excretory system needs a circulatory system to collect carbon dioxide and nitrogenous wastes from body tissues and deliver them to the lungs and excretory organs. Muscles wouldn't work without a nervous system to direct them and a skeletal system to support them.

In addition to the organ systems that you have already learned about, you will now learn about other body systems, those that fight disease, produce and release chemical controls, and manage body temperature—all to help ensure homeostasis.

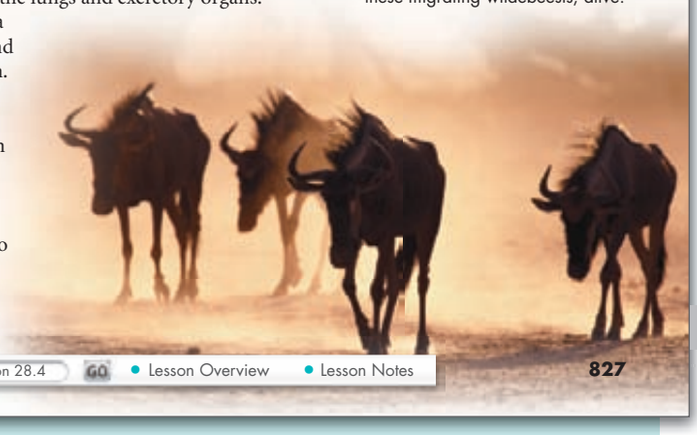


FIGURE 28–26 Interrelationship of Body Systems All body systems must work together to keep stressed animals, such as these migrating wildebeests, alive.

Teach for Understanding

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

GUIDING QUESTION How do animals maintain homeostasis?

EVIDENCE OF UNDERSTANDING *After students have studied the lesson, assign the following assessment to show their understanding of the difference between ectotherms and endotherms.* Have students meet in small groups to discuss differences between ectotherms and endotherms. Then, arbitrarily divide the class in half. Assign one half to argue for the advantages of being ectothermic, and assign the other half to argue for the advantages of being endothermic. Have the class stage a mock debate on the issue of body temperature control.

Getting Started

Objectives

28.4.1 Explain how homeostasis is maintained in animals.

28.4.2 Describe the importance of body temperature control in animals.

Student Resources

Study Workbooks A and B, 28.4 Worksheets

Spanish Study Workbook, 28.4 Worksheets

Lab Manual B, 28.4 Data Analysis Worksheet

BIOLOGY.com Lesson Overview • Lesson Notes • Activity: Data Analysis • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition,** see pages 684–687.

Activate Prior Knowledge

List on the board all the animal body systems students have learned about so far in Chapters 27 and 28. Call on students to describe ways these systems interact in an animal to help it maintain homeostasis. *(Sample answer: The respiratory system has membranes in which gas exchange occurs; the circulatory system carries the products of this gas exchange—oxygen to cells and carbon dioxide back to lungs, gills, or other respiratory structures where gas exchange occurs.)*

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, IV, V

CONTENT

C.3.a, C.5.d

INQUIRY

A.1.a, A.1.c, A.2.a

Teach

Lead a Discussion

Discuss with students how an immune system and chemical controls help animals maintain homeostasis. Explain that in later chapters they will learn specifically about the immune system and the endocrine system in humans.

Ask What are examples of pathogens that can enter an animal's body and cause disease? *(Sample answer: viruses and bacteria)*

Ask In what part of the process of metamorphosis in insects does a juvenile hormone play a role? *(the change from larva to pupa in complete metamorphosis)*

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Help students organize the information in the subsections, **Fighting Disease** and **Chemical Controls,** by using several short sentences to summarize the content. For example, write these sentences on the board:

- Most environments contain pathogens.
- Pathogens that enter the body can cause disease.
- An animal's immune system recognizes pathogens as "others."
- The immune system attacks invading pathogens.

Ask students to help you generate short sentences that summarize information about chemical controls.

ELL **English Language Learners** Write the word *homeostasis* on the board, and have students repeat the word after you. Draw a box around the prefix *homeo-* and explain that it means "same." Explain that maintaining homeostasis, then, means keeping a steady state—or "sameness"—in the body. Then, pair English language learners and ask partners to work together to construct sentences that summarize how the immune system and the endocrine glands restore or maintain homeostasis in an organism's body. Call on partners to share their sentences with the class.

Fighting Disease The controlled environment within an animal's body is a comfortable place for hostile invaders as well as for its own cells. Most environments contain disease-causing microorganisms, or pathogens, that may take advantage of steady supplies of oxygen and nutrients intended for body tissues. If pathogens enter the body and grow, they may disrupt homeostasis in ways that cause disease.

Most animals have an immune system that can distinguish between "self" and "other." Once the immune system discovers "others" in the body, it attacks the invaders and works to restore homeostasis. Your body experiences this process regularly, any time you catch a cold or fight off other kinds of infections. During the process, you may develop a fever and feel other effects of the battle going on within your body.

BUILD Vocabulary

WORD ORIGINS Not all hormones are produced by endocrine glands. Erythropoietin is released by the kidneys. It prompts the body to make more red blood cells, which carry oxygen through the body. And when you look at the Greek words *erythropoietin* is made from—*erythros,* meaning "red," and *poiesis,* meaning "a making"—the hormone's function isn't much of a surprise.

Chemical Controls Vertebrates, such as the migrating wildebeest, along with arthropods and many other invertebrates, regulate many body processes using a system of chemical controls. **Endocrine glands** are part of that system. Endocrine glands regulate body activities by releasing hormones into the blood. Hormones are carried by blood or body fluids to organs. Some hormones, as you have learned, control growth, development, and metamorphosis in insects.

Mammals, like other vertebrates, have endocrine glands that are part of an endocrine system. Some hormones control the way the body stores energy or mobilizes it—as in the case of the wildebeests. Other hormones regulate the amount of water in the body and the amount of calcium in bones.

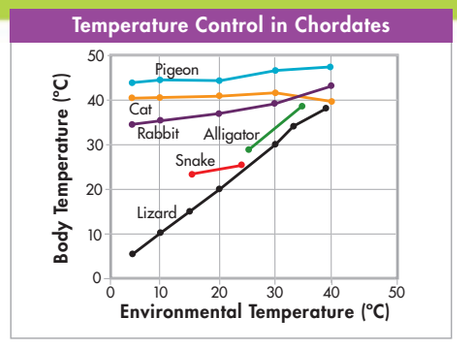
Analyzing Data

Comparing Ectotherms and Endotherms

The graph shows the internal body temperatures maintained by several ectotherms and endotherms at different environmental temperatures.

1. Interpret Graphs Which animal has the highest body temperature when the environmental temperature is between 0°C and 10°C? Which has the lowest body temperature under those conditions?

2. Infer Which animals represented in the graph are ectotherms? Which are endotherms? Explain your answers.



3. Predict If these animals lived in your area, would you expect all of them to be equally active year-round? If not, why not?

Analyzing Data

PURPOSE Students will interpret a graph to compare ectotherms and endotherms.

PLANNING Have students discuss how ectotherms and endotherms control body temperature.

ANSWERS

1. highest: pigeon; lowest: lizard

2. The lizard, snake, and alligator are ectotherms. Their body temperatures fluctuate based on the temperature of the environment. The pigeon, cat, and rabbit are endotherms. Their body temperatures are regulated mostly from within.

3. Answers will vary. In all areas, the pigeon, cat, and rabbit would be expected to be active year-round. In colder areas, the alligator, snake, and lizard would probably not be as active in the colder months of the year.

Body Temperature Control

How do animals control their body temperature?

Control of body temperature is important for maintaining homeostasis, particularly in areas where temperature varies widely with time of day and with season. Why is temperature control so important? Because many body functions are influenced by temperature. For example, muscles cannot operate if they are too cold or too hot. Cold muscles contract slowly, making an animal slow to react. If muscles get too hot, on the other hand, they may tire easily.

Body temperature control requires three components: a source of heat, a way to conserve heat when necessary, and a method of eliminating excess heat when necessary. An animal may be described as an ectotherm or endotherm based on the structures and behaviors that enable it to control its body temperature.

Ectotherms On cool, sunny mornings, lizards bask in the sun. This doesn't mean that they are lazy! A lizard is an **ectotherm**—an animal whose regulation of body temperature depends mostly on its relationship to sources of heat outside its body. **Most reptiles, invertebrates, fishes, and amphibians are ectotherms that regulate body temperature primarily by absorbing heat from, or losing heat to, their environment.**

Ectotherms have relatively low metabolic rates when resting, so their bodies don't generate much heat. When active, their muscles generate heat, just as your muscles do. However, most ectotherms lack effective body insulation, so their body heat is easily lost to the environment. That's why ectotherms warm up by basking in the sun. They also have to regulate their body temperature in hot conditions. The lizard in **Figure 28–27** is "stilting" to cool off. Ectotherms also often use underground burrows, where there are fewer temperature extremes. On hot, sunny days, they might seek shelter in a burrow that is cooler than the land surface. On chilly nights, those same burrows are warmer than the surface, enabling the animal to conserve some body heat.

In Your Notebook *Explain in your own words why the word coldblooded is an incorrect way to describe an ectotherm.*

Endotherms An **endotherm** is an animal whose body temperature is regulated, at least in part, using heat generated by its body. **Endotherms, such as birds and mammals, have high metabolic rates that generate heat, even when they are resting.** Birds conserve body heat primarily with insulating feathers, such as fluffy down. Mammals use combinations of body fat and hair for insulation. Some birds and most mammals can get rid of excess heat by panting, as the dingo in **Figure 28–28** is doing. Humans sweat to help reduce their body temperature. As sweat evaporates, it removes heat from the skin and the blood in capillaries just under the surface of the skin. Thus, as warm blood flows through the cooled capillaries, it loses heat.

FIGURE 28–27 Ectotherm This shovel-snouted lizard, an ectotherm, lives in the Namib Desert in Africa, one of the hottest places on Earth. It is regulating its body temperature by stilting—raising its body off the hot sand by performing a sort of push-up. **Infer** *Do you think stilting is more likely to raise or lower body temperature? Explain.*

FIGURE 28–28 Endotherm Many endotherms, such as this dingo, pant when they are very warm. Panting allows air to evaporate some of the moisture in the blood-vessel rich mouth and respiratory tract, cooling the blood.

Check for Understanding

ORAL QUESTIONING

Use the following questions to gauge understanding of body temperature control.

- What three components are required for body temperature control?
- What do ectotherms lack that causes their body heat to be easily lost to the environment?
- How do birds and most mammals get rid of excess heat?

ADJUST INSTRUCTION

Assess students' answers to determine what concepts they understand and what concepts they are having trouble with. Review difficult concepts in class discussion so students can hear how others explain terms and processes.

Connect to the Real World

Explain that an ectotherm is like a house with no central heating or air conditioning and no insulation. The temperature inside the house is going to be similar to the temperature outside the house. An endotherm is like a house with central heating (which is always on low), air conditioning, and insulation.

Ask Which house would you prefer in a cold climate? Why? *(the "endothermic house," because it would be easier to get warm)*

Ask Which house would you prefer in a hot climate? *(Answers may vary, but many will decide on the "ectothermic house," because there's no central heating that's on all the time.)*

DIFFERENTIATED INSTRUCTION

LPR Less Proficient Readers Help struggling readers reinforce differences between ectotherms and endotherms by having them make a bulleted list under each term. The lists should include the definition of the term, ways each group regulates body heat, and examples of animals that are ectotherms and endotherms.

BIOLOGY.com Have students access **Data Analysis: Winter Survival** to evaluate the effectiveness of strategies mammals use to survive cold temperatures.

Address Misconceptions

Coldblooded Animals Because ectotherms are often referred to as "coldblooded," some students may think the blood of fish, reptiles, and amphibians is always cold. Explain that when its environment is cold, an ectotherm's body, including its blood, may be relatively cold. This is because ectotherms have little body insulation and low metabolic rates that generate little heat, unlike birds or mammals. But when the environmental temperature is warm, such as in the direct sun, an ectotherm's body, including its blood, becomes warm. In fact, in areas with high temperatures, such as deserts, ectotherms need to keep their body—and blood—from becoming too *hot*. An ectotherm, therefore, is not always "coldblooded."

Answers

FIGURE 28–27 It is more likely to lower body temperature by exposing more of the body to the air, which is cooler than the hot sand.

IN YOUR NOTEBOOK Sample answer: The blood of an ectotherm can be quite warm when the environmental temperature is hot.

Assess and Remediate

EVALUATE UNDERSTANDING

Ask each student to write a brief paragraph describing how an animal of their choosing maintains homeostasis. Call on students at random to share their paragraphs with the class. Then, have students complete the 28.4 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If students have trouble answering **Question 2b,** review how a high metabolic rate requires more Calories.

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.**

FIGURE 28–29 Endotherm Insulation Like some of their dinosaur ancestors, modern birds such as this pine grosbeak use feathers to stay warm. When a bird gets cold, its dense, fluffy undercoat of down feathers stands up and creates spaces next to the bird's skin in which body heat is trapped.

Comparing Ectotherms and Endotherms Ectothermy and endothermy each have advantages and disadvantages in different situations. Endotherms move around easily during cool nights or in cold weather because they generate and conserve body heat. That's how musk oxen live in the tundra and killer whales swim through polar seas. But the high metabolic rate that generates this heat requires a lot of fuel. The amount of food needed to keep a single cow alive would be enough to feed ten cow-sized lizards!

Ectothermic animals need much less food than similarly sized endotherms. In environments where temperatures stay warm and fairly constant, ectothermy is a more energy-efficient strategy. But large ectotherms run into trouble if it gets very cold at night or stays cold for long periods. It takes a long time for a large animal to warm up in the sun after a cold night. That's one reason why most large lizards and amphibians live in tropical or subtropical areas.

Evolution of Temperature Control There is little doubt that the first land vertebrates were ectotherms. But questions remain about when and how often endothermy evolved. Although modern reptiles are ectotherms, a great deal of evidence suggests that at least some dinosaurs were endotherms. Many feathered dinosaur fossils have been discovered recently, suggesting that these animals, like modern birds such as that in **Figure 28–29,** used feathers for insulation. Current evidence suggests that endothermy has evolved at least twice among vertebrates. It evolved once along the lineage of ancient reptiles that led to birds, and once along the lineage of ancient reptiles that led to mammals.

28.4 Assessment

Review Key Concepts

1. a. Review How do the immune system and endocrine glands help to maintain homeostasis?

b. Explain Give an example of how multiple body systems function together to maintain homeostasis.

c. Apply Concepts Describe how the circulatory and endocrine systems of the migrating wildebeests in **Figure 28-26** help them maintain homeostasis.

2. a. Review Define *ectotherm.* Define *endotherm.*

b. Explain Why must an endotherm eat more food than an ectotherm of the same size?

c. Form a Hypothesis How might birds and mammals have evolved different means of insulating their bodies?

VISUAL THINKING

3. Construct a table that compares ectothermy and endothermy. Include the ways body temperature is controlled, relative rates of metabolism, relative amounts of food eaten, advantages, disadvantages, and examples of animals with each method of temperature regulation.

BIOLOGY.com Search Lesson 28.4 GO • Self-Test • Lesson Assessment

Assessment Answers

1a. The immune system can distinguish between "self" and "other"; it attacks invaders and works to restore homeostasis. Endocrine glands regulate body activities by releasing hormones into the blood.

1b. Sample answer: After gas exchange occurs in the respiratory system, the circulatory system carries oxygen to muscle cells, where cellular respiration takes place. The energy supplied by cellular respiration to the muscular system allows the body to move.

1c. The hormones produced by the endocrine system are carried throughout the body by the circulatory system. Hormones control the way the body stores energy or mobilizes it, helping to ensure homeostasis while the animal is undergoing the stresses of migration.

2a. ectotherm—an animal whose regulation of body temperature depends mostly on its relationship to sources of heat in its environment; endotherm—an animal whose body temperature is regulated, at least in part, using heat generated by its body

2b. because endotherms have a higher metabolic rate than ectotherms

2c. Sample answer: Different adaptations for body insulation evolved in different animal populations.

VISUAL THINKING

3. Tables may vary but should include accurate information from the lesson. Endothermy: body temperature controlled by heat generated by the body; high metabolic rates; relatively more food needed; ability to live in cold environments an advantage; need for fuel a disadvantage. Ectothermy: body temperature mainly controlled by sources of heat in its environment; low metabolic rates; relatively less food needed; need for less fuel an advantage; less ability to live in cold environments a disadvantage.

Biology & Society

Head for the Hills?

The Miami soccer coach was upset. The Denver team *was* tops in the league. But his players were well-trained—and several had *still* collapsed from fatigue in the second quarter. He knew that "the mile-high city" was aptly named: its air was less dense than his players were accustomed to. But he'd flown his team in three days early. Why didn't that help? He decided to do some research.

He learned that the lower air density in Denver means that every breath has 15 percent less oxygen than it has at sea level. This means that there is less oxygen for the lungs and blood to deliver to muscles. Less oxygen decreases the performance of muscles that work for long periods. The body can adapt to altitude, but it takes about a week—so his strategy of arriving three days early fell short.

High-altitude adaptation includes an increase in the lung's ability to get oxygen into blood, as well as an improvement in the ability of muscle cells to use oxygen. The body's production of active red blood cells also increases, stimulated by low oxygen availability. So people who live or train at high altitudes have an advantage over "flatlanders." This information helps explain why runners from places like Nairobi, Kenya (altitude 5450 feet), compete so well in endurance events.

High-Altitude Training Should Not Be Restricted

Several training regimes legally use the effects of altitude to maximize performance. Some coaches have their players live or train at high altitude. Other players sleep in special tents whose air contains less oxygen. So even teams that live at low altitudes can mimic the effects of high altitude in their training. These techniques cause a natural increase in the body's production of the hormone erythropoietin (EPO), which stimulates the production of red blood cells that carry oxygen.

Elite marathoners, such as this Kenyan runner, often live and/or train in high-altitude areas.

High-Altitude Training Should Be Restricted

The injection of extra EPO during training—a biotech method of what is called "blood doping"—is illegal. High-altitude training regimes are just a "natural" way to accomplish exactly what blood doping does. It is unfair and possibly unsafe.

Research and Decide

Analyze the Viewpoints Using the Internet, research high-altitude training and "blood doping." Compare and contrast the effects of high-altitude training regimes with the effects of blood doping.

Form an Opinion Are current regulations fair to athletes from low-altitude states and countries?

Quick Facts

WORLD ANTI-DOPING AGENCY

In 1999, the International Olympic Committee established the World Anti-Doping Agency (WADA) to coordinate the fight against doping in sports. Various substances used in blood doping, including EPO, are on WADA's list of prohibited substances, and tests to detect blood doping were introduced at the 2000 Olympics. In 2006, WADA considered banning the use of oxygen tents but decided against it. Low-oxygen tents—also called altitude tents—simulate high-altitude conditions with lower oxygen levels in the air. By sleeping in these tents, some athletes have tried to gain the benefits of training at high altitudes without moving to high-altitude training facilities.

Teach

Lead a Discussion

Define blood doping and explain the effects of anabolic steroids for students. Have students discuss the fairness of athletes using blood doping. Many students will condemn such methods as unfair, though some may accept the injection of extra EPO as a part of modern sports, just as some find the use of anabolic steroids acceptable. Then, turn the discussion to the fairness of high-altitude training.

Ask Do athletes who live and/or train at high-altitudes have an unfair advantage over athletes who live and/or train at low altitudes? *(Answers will vary. Accept any response that is backed by sound reasoning.)*

Ask Is it unfair for athletes to train at high altitudes just to get the benefits of high-altitude adaptation? *(Answers will vary. Challenge students to back their opinions with persuasive arguments.)*

Answers

RESEARCH AND DECIDE

1. Answers may vary. Students should find that the effects of blood doping and high-altitude training are similar. How similar they are depends on substances used for blood doping and techniques used in high-altitude training. Students should cite reliable online sources for their information.
2. Students' paragraphs should clearly express an opinion, backed by logical reasoning, about whether current regulations are fair.

NATIONAL SCIENCE EDUCATION STANDARDS

CONTENT F.1, G.1
INQUIRY A.1.f

CHAPTER LAB

Pre-Lab

Introduce students to the concepts they will explore in the chapter lab by assigning the Pre-Lab questions.

Lab

Tell students they will perform the chapter lab *Comparing Bird and Mammal Bones* described in **Lab Manual A.**

L1 **Struggling Students** A simpler version of the chapter lab is provided in **Lab Manual B.**

SAFETY Students should wear gloves and aprons. Caution them to be careful when handling glassware. At the end of the lab, have students wash their hands in warm, soapy water.

BIOLOGY.com Look online for **Editable Lab Worksheets.**

For corresponding pre-lab in the **Foundation Edition,** see page 688.

NATIONAL SCIENCE EDUCATION STANDARDS

UCP V
CONTENT C.5.d
INQUIRY A.1.a

Pre-Lab Answers

BACKGROUND QUESTIONS

a. Sample answer: Vertebrates have an endoskeleton, which can grow as the vertebrate grows.

b. Sample answer: Muscle contraction can cause a tendon to pull on a bone but it cannot cause the tendon to push the bone back to its original position. So pairs of muscles are needed to generate a full range of motion around a joint.

c. Sample answer: Many small movements are required for a hand to grasp and manipulate objects.

PRE-LAB QUESTIONS

1. Sample answer: In Part A, the data will be qualitative. In Part B, the data will be quantitative.

2. Sample answer: I will be able to observe whether the bones are solid or contain air spaces.

3. Sample answer: No, because density is ratio of mass to volume.

Real-World Lab — OPEN-ENDED INQUIRY

Pre-Lab: Comparing Bird and Mammal Bones

Problem Is the density of an animal's bones related to the way the animal moves?

Materials cross-sections of chicken, duck, and cow bones; hand lens; small chicken, duck, and cow bones; balance

Lab Manual Chapter 28 Lab

Skills Focus Form a Hypothesis, Design an Experiment, Measure

Connect to the Big idea In order to move, an animal must generate physical force and apply this force against the air, the water, or the ground. The force is generated by the contraction of muscles. In vertebrates, the muscles are attached to bones. The joints that connect bones bend or straighten when groups of muscles contract. There is a close link between the structure of an animal's skeletal and muscular systems and how the animal moves. In this lab, you will investigate whether there is a similar link between the density of bones and how an animal moves.

Background Questions

a. Review What type of skeleton do vertebrates have? List one advantage of this type of skeleton.

b. Explain Why are pairs of muscles or two different groups of muscles needed to bend and straighten a joint?

c. Apply Concepts Why do you think humans have only 4 bones in each arm and shoulder, but 27 bones in each wrist and hand? *Hint:* Compare the movement of your arm and your hand when you button a shirt?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Compare and Contrast Compare the type of data you will collect in Part A to the type of data you will collect in Part B.

2. Predict How might looking at cross-sections of bones help you form a hypothesis about the relative density of the bones?

3. Design an Experiment Will you need to use samples with the same mass in Part B? Why or why not?

BIOLOGY.com Search Chapter 28 GO

Visit Chapter 28 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Join the Untamed Science crew as they interview experts to learn more about how the sex of offspring is determined in some animals.

Art in Motion Watch an animation that shows the motion of joints in both exoskeletons and endoskeletons.

Art Review Review your understanding of vertebrate brains.

InterActive Art Look at the structure and function of the water vascular system in a sea star.

Data Analysis Investigate some of the ways mammals survive in cold temperatures.