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This is a question and answer forum for students, teachers and general visitors for exchanging articles, answers and notes. Answer Now and help others. Answer Now Here's how it works: Anybody can ask a question Anybody can answer The best answers are voted up and rise to the top Science Biology To stay alive, grow, and reproduce, an animal must find food, water, and oxygen, and it must eliminate the waste products of metabolism. The organ systems typical of all but the simplest of animals range from those highly specialized for one function to those participating in many. The more basic functional systems are treated below from a broadly comparative basis. A skeleton can support an animal, act as an antagonist to muscle contraction, or, most commonly, do both. Because muscles can only contract, they require some other structure to stretch them to their noncontracted (relaxed) state. Another set of muscles or the skeleton itself can act as an antagonist to muscle contraction. Only elastic skeletons can act without an antagonist; all antagonistic muscles act through a skeleton, which can be either rigid, flexible, or hydrostatic. Hydrostatic skeletons are the most prevalent skeletal systems used by animals for movement and support. A minimal hydrostatic skeleton resembles a closed container. The walls are two layers of muscles (one muscle oriented at right angles to one another; the inside contains an incompressible fluid or gel. The contraction of one set of muscles exerts a pressure on the fluid, which is forced to move at right angles to the squeezing antagonist. The movement of the fluid stretches the other set of muscles, which can then contract to stretch its antagonist back to its relaxed position. The net result is an alternating change in the shape of the container. Locomotion as varied as crawling, burrowing, somersaulting, looping, or even walking is possible when the container has some means of traction against a substrate; the system extends forward from the point of attachment, attaches at a more forward point, releases posteriorly, and contracts forward. Hydrostatic skeletons are also important in nonlocomotory muscular systems, such as hearts or intestines, which move blood or food, respectively. Contraction-relaxation cycles push in one direction only when the system has structures that prevent backflow. Hydrostatic skeletons become less efficient when fluid is lost. The optimal volume of fluid for a particular system must remain constant for effective contraction and expansion of the antagonistic muscles. If too much fluid is lost, the animal becomes limp and neither muscle can stretch; when too much fluid is gained, the animal becomes bloated and neither muscle can contract. Those coelenterates that use a hydrokeleton regularly face a loss of pressure because their skeleton is also their gut. Freshwater animals tend to become bloated as water diffuses into their salty cells, but terrestrial animals with hydrostatic skeletons tend to become limp as they dry. Solutions to water loss tend to be partial because impermeable barriers, such as a shell, tend not to be very flexible, thus negating the use of a hydrokeleton for movement. Terrestrial animals with locomotory hydrostatic skeletons (e.g., snails and earthworms) are restricted in their activity to moist conditions. Partitioning a hydrokeleton into many small, separate, but coordinated units facilitates locomotion. In an earthworm, for example, a front group of segments narrows together, thereby elongating that part of the body. Likewise, the relative massiveness of jaws reflects the toughness of the food eaten. Two animal phyla, Chordata (vertebrate only) and Arthropoda, exploit jointed skeletons. Although the skeleton is internal in vertebrates and external in arthropods, the principles of movement are the same. A jointed skeleton is ideal for moving on land because adaptations for protection against dehydration (such as the cuticle) do not interfere with the action of the skeletal system. Indeed, the arthropod cuticle serves jointly a protective and a skeletal role. Moreover, the diverse range of precise movements made possible by this skeleton facilitates all sorts of locomotory patterns: swimming, digging, running, climbing, and flying. Jointed skeletons are also used directly for feeding (jaws). Arthropod jaws are derived from legs, while vertebrate jaws are derived from gill arches. Although all animals can move, not all locomote or displace the body over a distance. Locomotion serves the animal in finding food and mates and in escaping predators or unsuitable habitats. These functions of locomotion are typically correlated among different animals, so that those using the same mechanism of locomotion usually also feed, seek mates, and avoid danger in similar ways. Some of the correlations between mode of locomotion and mode of feeding are described here, but space precludes discussion of the rich diversity found among animals past and present. The locomotory/feeding system of animals is the heart of their adaptation to their physical and biotic environments. Locomotory strategies for finding or gathering food include the following techniques. Sitting still and waiting for food to arrive is particularly prevalent in aquatic habitats but is not rare on land. Sessile animals tend to develop strong defenses that are sometimes incompatible with effective locomotion. They rely on water or air currents or on the locomotion of their potential prey to bring food within reach. Because food may come from any direction, many sessile animals evolve radial symmetry. Settlement may be permanent or temporary, but in all cases one stage of the life cycle is capable of moving actively or passively from its place of origin. The choice of attachment site can also be active or passive; passive choice is often associated with an ability to grow in such a way as to maximize feeding efficiency. As with plants, passive settlers do well only with luck. The retention of locomotory capabilities requires energy and nutrients that can otherwise be diverted into growth or the production of offspring. Sessile feeders need to move if feeding and resting sites differ. Sessile animals include filter feeders, predators, and even photosynthesizers; the latter include corals that house symbiotic algae. Internal parasites are usually sessile because they live within their lifetime food supply. Mobile animals that pursue sedentary strategies for seeking prey include web-spinning spiders (a terrestrial mode of filter feeding) or deep-sea fishes with morphological adaptations that lure prey. Burrowing animals typically eat the rich organic substrates they move through. Others burrow for protection and either temporarily emerge and gather organic sediments at the top of their burrows or pump water with potential food through the burrow. Instead of digging or finding burrows, some animals move into the centre of sponges, where they find protection and a renewing source of food. Active movement in search of food requires energy, but this expenditure is more than made up for by an ability to seek out areas of concentrated food. This method of feeding applies to burrowing animals that eat the substrate through which they move, as well as to animals that move over solid surfaces, swim, or fly. Active moving animals can feed on organisms that do not move, a rich variety coating virtually the entire solid surface of Earth, from the depths of the oceans to the peaks of many mountains. The main problem with this most productive avenue of food gathering is protection. Shells and poisons are the major types of defenses, although innovative detoxification metabolism and jaws of various kinds breach the defenses in part. This is an escalating battle in which the defenses, as well as the weapons to penetrate them are continually improving. Nudibranchs, shell-less marine snails, incorporate the defensive stinging cells of prey ctenidarians into their own skin. Poisonous plants are eaten by specialized insects that avoid or detoxify the poison. In fresh water, for reasons not known, the arms race has not proceeded as far as in the sea. Cooperation of individuals enables social animals to obtain food in novel ways. Uncannily like humans, some ants farm and herd other organisms for food. For example, some cultivate a fungus on leaves they specialized directly digest, while others herd aphids from which they milk nectar (actually the phloem sap of plants). Some ants even raid the nests of other species and make slaves of them. Another form of cooperation is the mutualism between species that trade advantage for advantage. Some fishes feed on parasites on the surfaces of other fishes, which benefits all but the parasites. In many animals, including termites and ruminants, microorganisms thrive in the gut and digest cellulose for them. Share – copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt – remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. 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Fact Checked Content Last Updated: 14.04.2023 16 min reading time Content creation process designed by Content cross-checked by Content quality checked by Save Article Save Article As with any other living organism, an animal's body is made up of building blocks called cells. Cells are so small that we typically cannot see them with our naked eye, so how do cells form something as complex as a living organism?Cells are organized into successive layers, each with its own specific form and function (Fig. 1). Cells that look similar and perform similar functions come together to form tissues. Different types of tissues combine to form functional organs.Organs that work together make up an organ system (or body system).Different organ systems work together to perform specific functions to sustain the life of an organism.With that, we can define the animal body system as follows:An animal body system is a collection of organs that work together to perform specific life-sustaining functions in animals. There are animals that lack organs or even well-defined tissues. Examples of these simple animals are sponges, corals, and placozoans. You may have heard of sponges and corals before, but they are known inhabitants of the coral reef ecosystem. On the other hand, you may be unfamiliar with placozoans and you are not alone. Not much is known about them, even in the scientific community. These simple organisms are even simpler than sponges: whereas sponges are made up of 10 to 20 cell types, placozoans are made up of just four! What are the different organ systems in animals? What are their main components and functions? As we move along, keep in mind that not all organ systems are the same; not all animals have all of these organ systems and some of them don't have organs at all! As we mentioned before, organ systems are composed of organs, which in turn are formed by different tissues. Importantly, organs have different types of specialized cells that coordinate to perform the organ's function.Each organ system has its own organ composition, with tissues that can be specific to only that organ, or shared among different organs. To understand this better we will go into more detail about some specific organ systems.Each animal organ system also has its own function. It's of vital importance for the animal's life that all organ systems perform their function well. The digestive system is in charge of ingesting and breaking down nutrients so that they can be absorbed into the animal's system. The skeletal system is meant to provide support for the body and allow movement, working together with the skeletal muscle.And these are just a few examples of the very specific and different functions of some animal body systems!Each organ system has its own components and function, and we'll touch upon some of them to understand how they may vary. The main parts of the digestive system are the stomach, the esophagus that connects the mouth to the stomach, the cone-shaped passageway called the pharynx, the liver, the pancreas, and the coiled uterine fallopian tubesThe ovaries are not only the site for egg production, but are also a gland; they produce estrogen and progesterone, essential hormones for female holistic health. Apart from regulating egg maturation, estrogen and progesterone regulate bone density in females, as well as promoting cardiovascular health or a successful pregnancy. The uterus generates the endometrium (which is released during the period) and is also the site for embryo implantation during pregnancy. Fig. 5. Human female reproductive system. The male human reproductive system is made up of the penis and corpus cavernosum,the epididymis,the testis,the prostate gland,the seminal vesicle,the urethra,the vas deferensAs with the ovaries, the testes are not only the site for sperm production but are also a gland that produces testosterone, which is also important for the holistic health of males. Testosterone is not only important for sperm production but also regulates muscle strength and bone density, among other functions. The male reproductive system shares components and ducts with the excretory system, i.e. the urine and semen exit the male body through the same channel, the urethra. In the female reproductive system, though, urine and vaginal discharge exit the body through different channels (the urethra and the vagina, respectively).Fig. 6. Human male reproductive system.The respiratory system is composed of:the nose,the lungs,the trachea,the bronchi,the lungs, andthe bronchi.The diaphragm and intercostal muscles are also essential for the respiratory system, as they expand and contract the lungs, which is where gas exchange takes place.Fig. 7. Human respiratory system.The respiratory system is responsible for gas exchange or the uptake of oxygen and the removal of carbon dioxide from the body.The circulatory system is made up of:the heart,the blood vessels, andthe blood itself.Fig. 8. Diagram of the human circulatory system.The circulatory system is in charge of distributing materials such as oxygen, carbon dioxide, nutrients, hormones, and wastes within the body, as well as (in part) maintaining homeostasis in the body. The immune and lymphatic systems are made up of:lymph vessels, in charge of distributing lymphatic fluid with white blood cells throughout the body;lymph nodes, the bone marrow, where the immune cells are produced; a small gland called the thymus, andthe spleen.Fig. 9. Diagram of the human lymphatic system.The immune and lymphatic systems are responsible for fighting against infections, viruses, and even cancerous cell growth.The endocrine system is a complex interconnected system composed of:the pituitary gland,the thyroid gland,the pancreas,the adrenal gland, andother hormone-secreting glands.Hormones are chemicals that travel through the bloodstream to send messages to other parts of the body.The endocrine system works with the nervous system to control the body's internal organs and coordinate responses to stimuli from the external environment. Fig. 10. The main organs of the human endocrine system.The nervous system is made up of:the brain,the spinal cord,nerves, and sensory organs (eyes, ears, nose, tongue, and skin).The nervous system (along with the endocrine system) coordinates the body's activities. It also detects stimuli from the environment and comes up with responses to them.Stimuli (singular: stimulus) are things in the environment that elicit behavioural or physiological responses from organisms.Fig. 11. Diagram of the human nervous system (central and peripheral).The main components of the excretory system are:the kidneys,the ureters,the urinary bladder, andthe urethra.It is responsible for disposing of organic wastes and regulating the volume of internal body fluids. Table 1. Animal organ systems and their components and functionsAnimal organ systemComponentsFunctionDigestive systemMouth,Stomach,OesophagusPharynx,Intestines,Liver,PancreasRectum and anus. Nutrition: breaking down food and absorbing nutrientsSkeletal systemBones,Tendons,Ligaments,Cartilage. Provide structural support to the bodyProtect the internal organsEnable the body to moveProduce blood cells in the bone marrowStore minerals like calcium and phosphorus. Keep the acid-base balance in the bodyMuscular systemSupport and movement of the bodyBlood pressure regulationIntegument systemSkinHairNailsSweat glandsProtection from injuries and infectionsHeat regulationReproductive systemFemale reproductive system:VulvaVagina and cervixUterusFallopian tubesOvariesMale reproductive system:Penis and corpus cavernosumEpididymisTestesProstate glandSeminal vesiclesUrethraVas deferensProducing gametes for animals that reproduce sexuallySexual hormone production (progesterone, estrogen, testosterone)Respiratory systemNoseLungs,Larynx,Trachea,LungsBronchi.Gas exchange (uptake of oxygen and removal of carbon dioxide from the body)Circulatory systemNutrient and other substance distribution around the bodyMaintaining homeostasis in the bodyImmune and lymphatic systemsLymph vesselsLymph nodes,Bone marrowThymusSpleenFighting against infections and cancerous cellsEndocrine systemPituitary glandThyroid glandPancreasAdrenal glandOther hormone-secreting glands (e.g. ovary, testis)Control systemCoordinate responsesNervous systemBrainSpinal cordNervesSensory organsControl systemCoordinate responsesProcess stimuliExcretory systemKidneysUretersUrinary bladderUrethraDisposing of organic wasteRegulating internal body fluidsOrgans that make up organ systems each have specific roles, so they are made up of specialized tissues and cells. The stomach plays a major role in breaking down nutrients. To carry out this function, the stomach uses a churning motion powered by stomach muscles and digestive fluids released by the stomach lining. In turn, the production of digestive fluids requires specialized cell types: one that produces protein-digesting enzymes, another that produces hydrochloric acid, and yet another type that produces mucus to protect the stomach lining.Some organs perform more than one role in the body and can thus belong to more than one organ system. The pancreas not only produces enzymes that play a major role in the digestive system but also regulates the sugar level in the blood as part of the endocrine system.The different organ systems work together to maintain homeostasis, the ability of a living system to maintain dynamic equilibrium while responding to changing external conditions. What we mean by dynamic equilibrium is that there is a fixed point that the body tries to maintain; when there are deviations from the set point, the body makes adjustments to get back to that point.A cell tries to maintain a balance between having too little or too much water compared to its external environment. Likewise, the human body tries to maintain temperatures close to 37 °C (or 98.6 °F). Think thermostat: you set a temperature that you'd like to keep. This is the fixed point. When the room temperature is higher than the set temperature, the thermostat turns on the air conditioning system to lower the room temperature and bring it back to the fixed point. Likewise, when the room temperature is lower than the set temperature, the thermostat turns on the heater to raise the room temperature back to the fixed point.Why do animals-and all living things for that matter-need to maintain homeostasis? This is because the body operates optimally within a set of internal and external conditions. Homeostasis is so important that the failure to maintain it can be harmful or even fatal to the organism. So how does the body maintain homeostasis? When there is a change in the animal's external environment, cellular receptors sense these changes and send signals to the control center (usually the brain), which in turn, generates a response that is sent to an effector, a muscle that contracts or relaxes or a gland that secretes. A body uses negative and positive feedback mechanisms to maintain homeostasis.A negative feedback loop is any homeostatic process that either increases or decreases the stimulus. If the level of the stimulus is too high, these processes lower it, and if a level is too low, these processes raise it. This is the primary mechanism used in homeostasis. A positive feedback loop maintains or amplifies the direction of the stimulus, moving the level farther away from the set point. Unlike negative feedback, there are very few examples of positive feedback loops in animal bodies.Various body systems may be involved in homeostasis, but all negative and positive feedback mechanisms that maintain homeostasis are controlled by the body's nervous and endocrine systems.Example of how an animal organ system maintains homeostasisLet's look at how different organ systems work together to maintain blood glucose levels in animals. When an animal eats, the following changes take place:The digestive system breaks down food into glucose and other energy-rich molecules.Cells in the intestine absorb glucose and release it into the bloodstream.Blood glucose levels rise.The nervous system senses this change and sends signals to specialized cells in the pancreas. The pancreas produces and releases a hormone called insulin into the bloodstream. Insulin lowers blood glucose levels. On the other hand, when an animal has not eaten, its blood glucose levels will decrease, so the pancreas releases a different hormone-glucagon-to increase blood sugar levels. This process of glucose regulation is just one example of the body's various negative feedback loop mechanisms. Now, let's discuss an example of positive feedback. When a blood vessel is damaged, the following changes take place:The damaged blood vessel initiates the clotting process.Platelets in the blood start to stick to the damaged area.These platelets release chemicals that recruit even more platelets.As the platelets accumulate, more chemicals are produced, and more platelets are drawn to the location of the clot, forming a platelet plug.Small molecules called clotting factors bring together components in the blood known as fibrin, sealing the inside of the wound.In this case, we can see how the positive feedback loop speeds up the clotting process until the clot is big enough to stop the bleeding.Cells are organized into successive layers, each with its own specific form and function.A animal body system is a collection of organs that work together to perform specific life-sustaining functions in animals. The different animal body systems are: digestive, skeletal, muscular, integument, reproductive, respiratory, circulatory, immune, lymphatic, endocrine, nervous, and excretory systems. Organ systems may vary among different species of animals; some may not have all organ systems while other don't have organs at all.The different organ systems work together to maintain homeostasis. How many body systems are found in animals? There are around 12 animal body systems: digestive, skeletal, muscular, integument, reproductive, respiratory, circulatory, immune, lymphatic, endocrine, nervous, and excretory systems. Note that organ systems may vary among different species of animals; some may not have all organ systems while others don't have organs at all. How do animal body systems function together? Different organ systems work together to ensure life-sustaining processes, including those that maintain homeostasis. For example, the digestive system breaks down food into glucose and other energy-rich molecules, which are then absorbed by cells in the intestine and released into the bloodstream. This causes blood glucose levels to rise. The nervous system responds to this by signaling pancreatic cells to release insulin, which then brings down blood glucose levels. Do all animals have the same organ systems? No, not all animals have the same organ systems; some may not have all organ systems while others don't have organs at all. Which animal body systems may be involved in homeostasis? Various body systems may be involved in homeostasis, but all negative and positive feedback mechanisms that maintain homeostasis are controlled by the nervous and endocrine systems. What are the different organ systems involved in transport in the animal body? The circulatory system is one of the organ systems whose major role is to transport substances such as oxygen, carbon dioxide, nutrients, hormones, and wastes in the animal body. Save Article Access over 700 million learning materials Study more efficiently with flashcards Get better grades with AI Sign up for free Already have an account? Log in Good job! Keep learning, you are doing great. Don't give up! Next Open in our app At StudySmarter, we have created a learning platform that serves millions of students. Meet the people who work hard to deliver fact based content as well as making sure it is verified. Lily Hulatt is a Digital Content Specialist with over three years of experience in content strategy and curriculum design. She gained her PhD in English Literature from Durham University in 2022, taught in Durham University's English Studies Department, and has contributed to a number of publications. Lily specialises in English Literature, English Language, History, and Philosophy. Get to know Lily Gabriel Freitas is an AI Engineer with a solid experience in software development, machine learning algorithms, and generative AI, including large language models (LLMs) applications. Graduated in Electrical Engineering at the University of São Paulo, he is currently pursuing an MSc in Computer Engineering at the University of Campinas, specializing in machine learning topics. Gabriel has a strong background in software engineering and has worked on projects involving computer vision, embedded AI, and LLM applications. Get to know Calorix StudySmarter is a globally recognized educational technology company, offering a holistic learning platform designed for students of all ages and educational levels. 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As you have learned, specialized cells in the animal body are organized into tissues, organs, and organ systems, which efficiently localize functions, such as the digestion of food and the elimination of wastes. As we explore the information in this section, our primary focus is homeostasis—the ability to maintain dynamic equilibrium around a set point. Animals need to maintain their “normal” internal environments while also responding to external environmental changes. In our study of biology thus far, we have seen numerous examples of structure-function relationships, and the design of the animal body is no exception. Specialization in multicellular animals contributes to efficiency in cell processes. For example, animals must be able to procure nutrients and eliminate wastes, and cells that line the small intestine allow for diffusion. Furthermore, the relationship between metabolic rate and body mass is typically an inverse one: The smaller the animal, the higher its metabolism, with mice having a higher metabolic rate than, for example, elephants. Because mice have a greater surface area-to-volume ratio for their mass than larger animals, they lose heat at a faster rate and, consequently, require more energy to maintain constant body temperature. Speaking of temperature, we learned that the body temperature of ectothermic animals varies according to environmental temperatures. When snakes need to warm up, they bask in the sun; when they need to cool down, they seek the shade. Other animals, including mice, kangaroos and humans, are endothermic because they are able to maintain a fairly constant internal body temperature despite environmental temperatures; for example, shivering generates heat, whereas sweating returns our body temperature to its normal set point of 37 °C. We will explore the content of these responses in more detail in the Homeostasis section. The information presented and the examples highlighted in the section support concepts outlined in Big Idea 2 of the AP® Biology Curriculum Framework. The AP® Learning Objectives listed in the Curriculum Framework provide a transparent foundation for the AP® Biology course, an inquiry-based laboratory experience, instructional activities, and AP® exam questions. A learning objective merges required content with one or more of the seven Science Practices. Animals vary in form and function. From a tongue to a worm to a goat, an organism has a distinct body plan that limits its size and shape. Animals' bodies are also designed to interact with their environments, whether in the deep sea, a rainforest canopy, or the desert. Therefore, a large amount of information about the structure of an organism's body (anatomy) and the function of its cells, tissues and organs (physiology) can be learned by studying that organism's environment. Figure 24.2 Animals exhibit different types of body symmetry. The sponge is asymmetrical, the sea anemone has radial symmetry, and the goat has bilateral symmetry. Animal body plans follow set patterns related to symmetry. They are asymmetrical, radial, or bilateral in form as illustrated in Figure 24.2. Asymmetrical animals are animals with no pattern or symmetry; an example of an asymmetrical animal is a sponge. Radial symmetry, as illustrated in Figure 24.2, describes when an animal has an up-and-down orientation: any plane cut along its longitudinal axis through the organism produces equal halves, but not a definite right or left side. This plan is found mostly in aquatic animals, especially organisms that attach themselves to a base, like a rock or a boat, and extract their food from the surrounding water as it flows around the organism. Bilateral symmetry is illustrated in the same figure. Bilateral symmetry has a unique and lower symmetry in that it has a definite right and left side. Additional terms used when describing positions in the body are anterior (front), posterior (rear), dorsal (toward the back), and ventral (toward the front). Bilateral symmetry is found in both land-based and aquatic animals; it enables a high level of mobility. Animals with bilateral symmetry that live in water tend to have a fusiform shape; this is a tubular shaped body that is tapered at both ends. This shape decreases the drag on the body as it moves through water and allows the animal to swim at high speeds. Table 24.1 lists the maximum speed of various animals. Certain types of sharks can swim at fifty kilometers an hour and some dolphins at 32 to 40 kilometers per hour. Land animals frequently travel faster, although the tortoise and snail are significantly slower than cheetahs. Another difference in the adaptations of aquatic and land-dwelling organisms is that aquatic organisms are constrained in shape by the forces of drag in the water since water has higher viscosity than air. On the other hand, land-dwelling organisms are constrained mainly by gravity, and drag is relatively unimportant. For example, most adaptations in birds are for gravity not for drag. Maximum Speed of Assorted Land Marine Animals Table 24.1 Most animals have an exoskeleton, including insects, spiders, scorpions, horseshoe crabs, centipedes, and crustaceans. Scientists estimate that, of insects alone, there are over 30 million species on our planet. The exoskeleton is a hard covering or shell that provides benefits to the animal, such as protection against damage from predators and from water loss (for land animals); it also provides for the attachments of muscles. As the tough and resistant outer cover of an arthropod, the exoskeleton may be constructed of a tough polymer such as chitin and is often biomineralized with materials such as calcium carbonate. This is fused to the animal's epidermis. Ingrowths of the exoskeleton, called apodemes, function as attachment sites for muscles, similar to tendons in more advanced animals (Figure 24.3). In order to grow, the animal must first synthesize a new exoskeleton underneath the old one and then shed or molt the original covering. This limits the animal's ability to grow continually, and may limit the individual's ability to mature if molting does not occur at the proper time. The thickness of the exoskeleton must be increased significantly to accommodate any increase in weight. It is estimated that a doubling of body size increases body weight by a factor of eight. The increasing thickness of the chitin necessary to support this weight limits most animals with an exoskeleton to a relatively small size. The same principles apply to endoskeletons, but they are more efficient because muscles are attached on the outside, making it easier to compensate for increased mass. Figure 24.4 Apodemes are ingrowths on arthropod exoskeletons to which muscles attach. The apodemes on this crab leg are located above and below the fulcrum of the claw. Contraction of muscles attached to the apodemes pulls the claw closed. An animal with an endoskeleton has its size determined by the amount of skeletal system it needs in order to support the other tissues and the amount of muscle it needs for movement. As the body size increases, both bone and muscle mass increase. The speed achievable by the animal is a balance between its overall size and the bone and muscle that provide support and movement. The exchange of nutrients and wastes between a cell and its watery environment occurs through the process of diffusion. All living cells are bathed in liquid, whether they are in a single-celled organism or a multicellular one. Diffusion is effective over a specific distance and limits the size that an individual cell can attain. If a cell is a single-celled microorganism, such as an amoeba, it can satisfy all of its nutrient and waste needs through diffusion. If the cell is too large, then diffusion is ineffective and the center of the cell does not receive adequate nutrients nor is it able to effectively dispel its waste. An important concept in understanding how efficient diffusion is as a means of transport is the surface area to volume ratio. Recall that any three-dimensional object has a surface area and volume; the ratio of these two quantities is the surface-to-volume ratio. Consider a cell shaped like a perfect sphere: it has a surface area of 4πr², and a volume of 4/3πr³. The surface-to-volume ratio of a sphere is 3/r; as the cell gets bigger, its surface area to volume ratio decreases, making diffusion less efficient. The larger the size of the sphere, or animal, the less surface area for diffusion it possesses. The solution to producing larger organisms is for them to become multicellular. Specialization occurs in complex organisms, allowing cells to become more efficient at doing fewer tasks. For example, circulatory systems bring nutrients and remove waste, while respiratory systems provide oxygen for the cells and remove carbon dioxide from them. Other organ systems have developed further specialization of cells and tissues and efficiently control body functions. Moreover, surface area-to-volume ratio applies to other areas of animal development, such as the relationship between muscle mass and cross-sectional surface area in supporting skeletons, and in the relationship between muscle mass and the generation and dissipation of heat. Visit this interactive site to see an entire animal (a zebrafish embryo) at the cellular and sub-cellular level. Use the zoom and navigation functions for a virtual microscopy exploration. What can be said about the fish shown in the image? It shows bilateral symmetry. It shows dorsal symmetry. It shows radial symmetry. It does not show any symmetry. All animals must obtain their energy from food they ingest or absorb. These nutrients are converted to adenosine triphosphate (ATP) for short-term storage and use by all cells. Some animals store energy for slightly longer times as glycogen, and others store energy for much longer times in the form of triglycerides housed in specialized adipose tissues. No energy system is one hundred percent efficient, and an animal's metabolism produces waste energy in the form of heat. If an animal can conserve that heat and maintain a relatively constant body temperature, it is classified as a warm-blooded animal and called an endotherm. The insulation used to conserve the body heat comes in the forms of fur, fat, or feathers. The absence of insulation in ectothermic animals increases their dependence on the environment for body heat. The amount of energy expended by an animal over a specific time is called its metabolic rate. The rate is measured variously in joules, calories, or kilocalories (1000 calories). Carbohydrates and proteins contain about 4.5 to 7 kcal, and fat contains about 9 kcal/g. Metabolic rate is estimated as the basal metabolic rate (BMR) in endothermic animals at rest and as the standard metabolic rate (SMR) in ectotherms. Human males have a BMR of 1600 to 1800 kcal/day, and human females have a BMR of 1300 to 1500 kcal/day. Even with insulation, endothermal animals require extensive amounts of energy to maintain a constant body temperature. An ectotherm such as an alligator has an SMR of 60 kcal/day. Smaller endothermic animals have a greater surface area for their mass than larger ones (Figure 24.4). Therefore, smaller animals lose heat at a faster rate than larger animals and require more energy to maintain a constant internal temperature. This results in a smaller endothermic animal having a higher BMR, per body weight, than a larger endothermic animal. Figure 24.4 The mouse has a much higher metabolic rate than the elephant. (credit: "mouse"; modification of work by Magnus Kjaergaard; credit: "elephant"; modification of work by "TheLizardQueen"/Flickr) The more active an animal is, the more energy is needed to maintain that activity, and the higher its BMR or SMR. The average daily rate of energy consumption is about two to four times an animal's BMR or SMR. Humans are more sedentary than most animals and have an average daily rate of only 1.5 times the BMR. The diet of an endothermic animal is determined by its BMR. For example: the type of grasses, leaves, or shrubs that an herbivore eats affects the number of calories that it takes in. The relative caloric content of herbivore foods, in descending order, is tall grasses > legumes > short grasses > forbs (any broad-leaved plant, not a grass) > subshrubs > annuals/biennials. Animals adapt to extremes of temperature or food availability through torpor. Torpor is a process that leads to a decrease in activity and metabolism and allows animals to survive adverse conditions. Torpor can be used by animals for long periods, such as entering a state of hibernation during the winter months, in which case it enables them to maintain a reduced body temperature. During hibernation, ground squirrels can achieve an abdominal temperature of 0° C (32° F), while a bear's internal temperature is maintained higher at about 37° C (99° F).If torpor occurs during the summer months with high temperatures and little water, it is called estivation. Some desert animals use this to survive the harshest months of the year. Torpor can occur on a daily basis, as seen in bats and hummingbirds. While endothermy is limited in smaller animals by surface-to-volume ratio, some organisms can be smaller and still be endotherms because they employ daily torpor during the part of the day that is coldest. This allows them to conserve energy during the colder parts of the day, when they consume more energy to maintain their body temperature. This activity is an application of Learning Objective 2.35 and Science Practice 4.2 because students are designing a plan for collecting data to investigate the timing and coordination of physiological events with metabolism. Students are asked to come up with a hypothesis and design an experiment that would allow them to test it. The first Think About It question is an application of AP® Learning Objective 2.1 and Science Practice 6.2 because students are explaining how the size of an animal affects energy input and metabolic processes. This second Think About It is an application of Learning Objective 2.36 and Science Practice 6.1 because students are justifying a claim about the timing and coordination of physiological events with evidence. Smaller mammals have higher metabolic rates and also lose heat more readily due to their smaller body sizes. This requires smaller mammals to take in additional food during winter, preventing them from being able to hibernate the entire winter. Instead, they periodically emerge to access stored food caches throughout the winter. The second Think About It question is an application of Learning Objective 2.37 and Science Practice 7.2 because students can connect concepts relating to hibernation and torpor with the timing of physiological events. A hummingbird's high metabolic rate allows it to move very quickly and hover while flying. However, this high metabolic rate is not needed to support the bird while sleeping, which requires considerably less energy. A standing vertebrate animal can be divided by several planes. A sagittal plane divides the body into right and left portions. A midsagittal plane divides the body exactly in the middle, making two equal right and left halves. A frontal plane (also called a coronal plane) separates the belly (ventral) or stomach from the back (dorsal). A transverse plane (or, horizontal plane) is perpendicular to the sagittal planes and the long axis of the body. This is sometimes called a cross section, and, if the transverse cut is at an angle, it is called an oblique plane. Figure 24.5 illustrates these planes on a goat (a four-legged animal) and a human being. Figure 24.5 Shown are the planes of a quadruped goat and a bipedal human. The midsagittal plane divides the body exactly in half into right and left portions. The frontal plane divides the front and back, and the transverse plane divides the body into upper and lower portions. Vertebrate animals have a number of body cavities, as illustrated in Figure 24.6. Two of these are major cavities that contain smaller cavities within them. The dorsal cavity contains the cranial and the vertebral (or spinal) cavities. The ventral cavity contains the thoracic cavity, which in turn contains the pleural cavity around the lungs and the pericardial cavity, which surrounds the heart. The ventral cavity also contains the abdominopelvic cavity, which can be separated into the abdominal and the pelvic cavities. Figure 24.6 Vertebrate animals have two major body cavities. The dorsal cavity, indicated in green, contains the cranial and the spinal cavity. The ventral cavity, indicated in yellow, contains the thoracic cavity and the abdominopelvic cavity. The thoracic cavity is separated from the abdominopelvic cavity by the diaphragm. The thoracic cavity is separated into the abdominal cavity and the pelvic cavity by an imaginary line parallel to the pelvis bones. (credit: modification of work by NCI) Physical anthropologists study the adaptation, variability, and evolution of human beings, plus their living and fossil relatives. They can work in a variety of settings, although most will have an academic appointment at a university, usually in an anthropology department or a biology, genetics, or zoology department. Non-academic positions are available in the automotive and aerospace industries where the focus is on human size, shape, and anatomy. Research by these professionals might range from studies of how the human body reacts to car crashes to exploring how to make seats more comfortable. Other non-academic positions can be obtained in museums of natural history, anthropology, archaeology, or science and technology. These positions involve educating students from grade school through graduate school. Physical anthropologists serve as education coordinators, collection managers, writers for museum publications, and as administrators. Zoos employ these professionals, especially if they have an expertise in primate biology; they work in collection management and captive breeding programs for endangered species. Forensic science utilizes physical anthropology expertise in identifying human and animal remains, assisting in determining the cause of death, and for expert testimony in trials.