Reflect

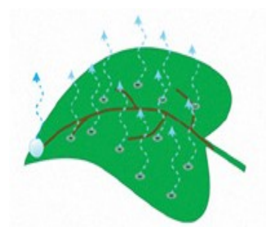
Think about the many interactions that occur inside the human body every moment of every day. Even a simple drink of water involves complex interactions of systems that help transport the water throughout the body and into cells. Our bodies have specialized structures that allow us to meet our basic needs. We have structures that help us break down food into usable energy, undergo reproduction to ensure the continuation of our species, and respond to our environment in order to maintain health and safety.

Both plants and animals must meet their basic needs, and they do so through specialized structures. How do these specialized structures work? What makes them so unique? Let's look at how all organisms have adapted ways to meet their needs. We will start with plants!

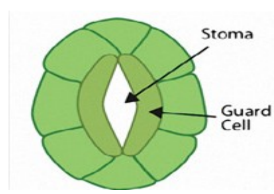
Plants

Water and Nutrient Transport in Plants
Vascular plants have elaborate systems for transporting water, mineral nutrients, and organic compounds that are critical to the plants' survival. Roots, stems, and leaves work together to move these materials throughout a plant.

From the soil, roots absorb water and dissolved minerals such as nitrogen, phosphorus, and potassium. The materials are then transported upward and distributed to the rest of the plant by a specialized transport tissue called *xylem*.



Water escapes a plant through tiny openings in the leaves called **stomata** (**stoma** is the singular form). Stomata are surrounded by **guard cells** that act as a gatekeeper for the stomata. When the guard cells change shape, the stomata open or close.



Phloem is also part of the transport system in vascular plants. Phloem is specialized tissue that takes in the glucose, other sugars, and other organic nutrients produced during photosynthesis and transports these nutrients to the rest of the plant. Like xylem, phloem is made of elongated cells that help move materials throughout a plant. You can remember the function of phloem, as nutrients "flow down." You can remember the function of xylem because water "zips up" xylem tubes.

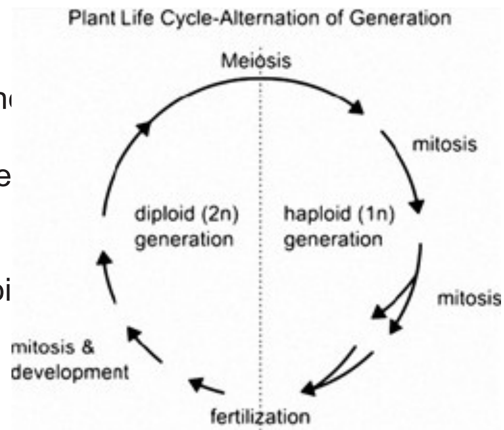
Gas Exchange in Plants
In addition to releasing water during transpiration, stomata are also the site of gas exchange in plants. During photosynthesis, plants take in carbon dioxide and release oxygen through the stomata in their leaves. Stomata are closed at night to reduce water loss. During the day, they are open to allow the exchange of gases.

Reflect

Discover Science: Specialized Leaves Reduce Water Loss

Plants that grow in dry climates have small, narrow leaves to further minimize water loss. Needles on cactus plants and evergreen trees are actually specialized leaves. Although needles generally have the same tissue structure as other leaves, they contain fewer stomata. Needles also have a low surface-to-volume ratio, which helps reduce damage caused by drought conditions or heavy snow.

Plant Life Cycle: Alternation of Generations



The life cycle of land plants alternates between two types of generations: haploid (1n, for one set of chromosomes) and diploid (2n, for two sets of chromosomes). Switching between th two stages is called **alternation of generations**. In the haploid generation, the gametophyte produces male and female gamete by mitosis. The male gametes are the sperm, and the female gametes are the eggs. When the gametes join, they form a zygote that begins the sporophyte generation, which is the diploi generation. The diploid sporophyte produces haploid spores by meiosis. The spores undergo mitosis and grow into new gametophytes.

Reproductive Plant Structures

Plants have specialized structures for sexual reproduction. Different types of plants have different reproductive structures. **Gymnosperms** have gametophytes inside cones, while **angiosperms** have gametophytes inside flowers.

Look Out!

Many plants that reproduce sexually can also undergo asexual reproduction. For example, in vegetative reproduction, new plants arise without the production of spores or seeds. Vegetative reproduction can be done artificially or may occur naturally. A common form of vegetative reproduction is cutting, in which pieces of a parent plant are placed in a suitable environment (such as in a glass of water on a windowsill) so they can grow into an entirely new plant.

Reflect

Responses to Stimuli

Plants respond to changes in their internal and external environments. **Stimuli** are anything that triggers a response or action in an organism. Plants respond to external stimuli, including light, heat, and moisture. Plants also respond to internal stimuli, including water and nutrient levels within the plant cells. Responses to external and internal stimuli help plants meet their basic needs and maintain **homeostasis**.

homeostasis: the process of maintaining a stable, internal environment

Plants are **sessile**, meaning they cannot move from place to place. However, plants do have a limited range of motion toward and away from specific stimuli. Movement in response to a stimulus is called **tropism**. Plant tropisms include:

- **Phototropism**: Plants tend to move and grow toward the Sun in order to maximize the amount of sunlight they receive.
- **Thigmotropism**: Some plants respond to touch from another object. When a vine comes in contact with a wall or a tree, it may change its direction of growth to wrap itself around the object as it grows.
- **Gravitropism**: Plants respond to the force of gravity by growing roots downward into the soil and stems away from the soil. This helps ensure that roots grow downward and that shoots grow upward.

What Do You Think?

Some people believe plants have the ability to respond to such stimuli as music or a person's voice in a way that improves their own overall health and growth. How would you set up a scientific experiment to test this hypothesis?

Try Now

What Do You Know?

This table lists three main processes that occur in plants. For each process, name the primary structures that are involved and describe their functions.

Interactions	Structures and Functions
Water and nutrient transport in vascular plants	
Gas exchange	
Sexual reproduction in flowering plants	

What Do You Think?

Animals

With at least one million species, the animal kingdom contains more species than any other kingdom. It includes insects, birds, mammals, and fish—animals that are often dramatically different in physical appearance and habitat. How do animals meet their specific needs given all this variety?

Animal Systems

The inner body systems of animals reveal part of the answer. All animals have similar body requirements. They ingest nutrients, dispose of waste products, reproduce, protect themselves from diseases, identify and respond to conditions affecting their body, and regulate internal body conditions such as temperature and heart rate.

Animals are made up of cells. In some animals, cells make up tissues specific to areas in the body. Tissues make up organs, and organs are part of organ systems that perform specific tasks that help an animal function and maintain **homeostasis**. Common systems in animals include the digestive, excretory, reproductive, nervous, endocrine, and immune systems. Healthy, functioning animals require each body system to work together with the other systems. If one system fails in its performance with the others, the animal's health will suffer, possibly even resulting in death. The table on the next page lists some of the major organs and organ systems found in mammals.

homeostasis:
the property of maintaining a constant state of balance

Humpback whale
kingdom: *Animalia*

Human baby
kingdom: *Animalia*

Dragonfly kingdom:
Animalia

Look Out!

Not all animals have organ systems. For example, the sponge is an animal that lacks organ systems. Instead, it has a few types of specialized cells. The sponge has open pores and channels that allow water to move through it. The water flow serves as its digestive and excretory systems, flushing nutrients into the body and wastes out. Sponges do not have a circulatory or nervous system—or even tissues and organs. Instead, cells can transform and migrate to areas where they are needed.

Look Out!

Organ Systems, Components, and Their Functions in Mammals

Organ System	Organs and Components	System Functions
Digestive	Mouth, pharynx, stomach, intestines, liver, pancreas, anus	Ingests, digests, and absorbs nutrients
Excretory	Kidneys, ureters, bladder, urethra, skin	Eliminates waste products and regulates body fluids
Reproductive	Ovaries, uterus, vagina, fallopian tubes, penis, and testicles	Produces offspring
Nervous	Brain, spinal cord, nerves, sensory organs (ears, eyes, nose, etc.)	Reacts to stimuli and coordinates body functions
Immune	Adrenal, pituitary, and thymus glands; spleen; white blood cells; bone marrow	Prevents and fights infection and disease

The Digestive System

All animals must eat other organisms in order to survive. Some, called *herbivores*, strictly eat plants. *Carnivores* are animals that eat meat, and *omnivores* eat both plants and meat. Sharp, pointed teeth, fangs, and claws indicate meat eaters because they must be able to tear meat into pieces. Plant eaters have flat broad rows of ridged teeth for grinding plants. Both creatures have to eat on a regular basis because animals are *heterotrophs*, meaning they cannot make organic compounds out of inorganic compounds like plants can. As such, they have to ingest organic compounds such as carbohydrates, proteins, and lipids.

What Do You Think?

Take a look at these photos. Are they carnivores or herbivores? How can you tell by their physical characteristics?

Reflect

Digestive Processes

The processes that take place in the **digestive system** involve ingestion, digestion, absorption of nutrients, and elimination of waste products. Different digestive organs help animals perform each function.

Animals ingest food in four different ways. Many marine animals are **suspension feeders**, sifting small organisms from the water into their mouth. **Substrate feeders**, such as caterpillars, live on or inside their food source. **Fluid feeders** live on the fluids of other organisms. Most animals are **bulk feeders**. They swallow large pieces of meat or plants, using their teeth, fangs, claws, pinchers, or other structures to grip and tear apart the pieces.

Snakes are bulk eaters that are able to unhinge their lower jaws so they can swallow their prey whole.

Cells cannot directly absorb the food that animals ingest, so the digestive system must break the food down into simple nutrients that cells can absorb. This is the process of digestion. Animals such as earthworms and birds have a crop and gizzard. These digestive organs moisten, store, and grind down food before sending it into the intestine.

Some plant-eating animals, called ruminants, have stomachs with four chambers that help them break down tough plant material. Most animals have a digestive tract, which is a tube that runs from the mouth to the anus and includes specialized organs. The stomach, pancreas, and liver make it possible for animals to break down foods chemically without destroying their own cells in the process. These organs produce and secrete enzymes that break the molecular bonds in food. The digested food supplies the nutrients needed by the body, such as macromolecules, vitamins, and minerals.

The intestines absorb broken-down nutrients and water into the bloodstream, which carries them to individual cells. Nutrients provide the body's cells with energy and materials. The intestines also move molecules that cannot be absorbed by the body and combine them with intestinal bacteria to become feces. These are emitted from the digestive tract through the anus.

The Excretory System

The cells, tissues, and organs of every animal operate in a fluid-filled environment. Fluid levels can change based on the amount of solutes (such as sodium and potassium chloride) present.

The presence of solutes can draw fluids into or out of cells. If cells absorb too much water, they can burst. If cells have too little water, they will shrivel up and die. The **excretory system** serves the crucial function of ensuring body fluids stay at optimal levels; in other words, it ensures **homeostasis** by maintaining the proper water balance in the body.

Reflect

The excretory system also gets rid of waste products created in the body. Nitrogen-containing wastes, such as ammonia, urea, and uric acid, are produced when cells break down proteins and nucleic acids.

Different animals produce different kinds of waste products. Marine animals tend to produce more ammonia, the most toxic of the three. They are able to release this product directly into the water around them where it is quickly diluted. Land animals tend to excrete either uric acid or urea as their primary type of excretory waste product.

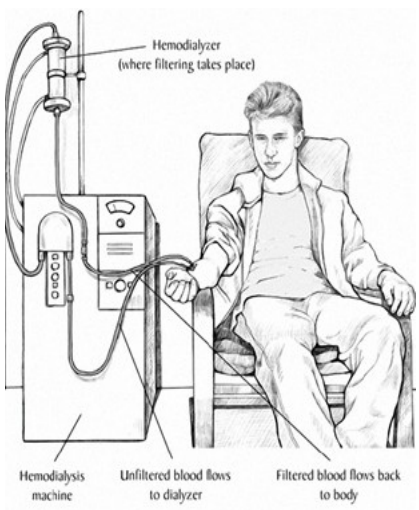
When vampire bats feed, they can become too heavy to fly. Therefore, their excretory systems excrete large amounts of dilute urine as they feed.

Excess water and waste products are excreted in urine. Flatworms, earthworms, and insects all have different types of excretory systems, but they all contain tubules that filter body fluids and dispose of waste products in the urine. Mammalian excretory systems filter waste products from the blood through the kidneys. The waste product flows down long tubes called the ureters, into the urinary bladder, and out of the body through the urethra as urine.

Getting Technical: Dialysis Works When Kidneys Fail

Kidneys are essential for the survival of mammals. When kidneys fail, toxins build up quickly in the bloodstream, which can cause death. In the mid-1940s, a Dutch physician named Willem Kolff built the first successful "artificial kidney," saving a woman's life. This machine was able to mimic the functions of the kidney and filter wastes from her blood.

Kolff's original machine would eventually develop into what we know now as a dialysis machine. Though much has changed since the "artificial kidney" machine, the process of dialysis remains essentially the same. The patient's blood is pumped from the body into the machine, where blood flows through fibers, and a special dialysis solution flows outside of the fibers. Water and waste products are pulled across the fibers, just as they move across the semipermeable membranes in the kidneys. Blood stays within the fibers. After being filtered, the cleaned blood is pumped back into the body. The process takes three to five hours, as only small amounts of blood are being filtered at any time.



Reflect

The Reproductive System

Animals can pass on their genes by producing offspring during **reproduction**. Some animals reproduce asexually, while others, including mammals, reproduce sexually.

Members of colonies, such as the honeybees pictured here, typically reproduce asexually through parthenogenesis.

In **asexual reproduction**, one parent passes on all the genetic information to the offspring. This process can occur through **fission**, in which one individual organism splits into two organisms of a similar size. A sea anemone can reproduce through fission. **Budding** is a similar process in which individuals grow out of the parent organism and either separates from or remains attached to the parent. Corals and sponges fall into this group.

These same animals can also reproduce through **fragmentation**, in which an organism's body is broken into pieces, and some or all of these become separate individuals. The animal must be able to **regenerate**, or grow back, lost body parts, for fragmentation to occur. **Parthenogenesis** is a form of asexual reproduction in which an egg is produced and develops into an individual without fertilization from another organism.

In sexual reproduction, the sex cells of a male and female (called gametes) combine and develop into a new individual. Genes from both parents are passed on to the offspring. Males produce sex cells called sperm, and females produce sex cells called eggs. Fertilization of the egg by sperm can happen in a number of ways. In some insects, males deposit the sperm inside the female, where they are stored. The stored sperm fertilizes the eggs as they pass out of her body. Amphibians rely on a wet environment to keep the eggs moist. The sperm must swim to the eggs to fertilize them. Land animals are adapted to either bear embryos internally or produce amniotic eggs that can withstand drier environments.

Marsupial mammals, such as kangaroos and opossums, carry their embryos for a very short time inside the uterus before giving birth. The embryo crawls into the mother's pouch, where it continues to develop while being nourished through a mammary gland. Placental mammals carry their embryos in their uterus until the offspring are ready to be born. Females have ovaries filled with eggs. During ovulation, the egg is released into the fallopian tube. Males have testes where sperm form. They release sperm into the female vagina through the penis. Then sperm travel into the uterus, and then into the fallopian tube to fertilize an egg. Successful fertilization combines the genes of the mother and the father to create a zygote. The zygote travels down the fallopian tube to the uterus where it develops into an embryo.

The Nervous and Endocrine System

Of all the body systems, the **nervous system** is the first to form in animals. The **brain** is also the first organ to form but the last one to fully develop. This may not be surprising when you consider that the nervous system is essentially the command center of the body, controlling all of an animal's functions—both conscious and unconscious.

Reflect

Sponges are the only animals without a nervous system. The cnidarians are the simplest animals to have a nervous system. For example, a hydra relies on nerve nets to control the opening and closing of its gastrovascular cavity. Animals as small as flatworms, leeches, and grasshoppers all have brains. More complex animals have **neurons** (nerve cells) and **ganglia**, which are clusters of neurons, connected to their brains.

Sea stars have a nerve ring around their mouth opening. Radial nerves extend from the ring into each arm where they terminate in a nerve net.

The nervous system allows an animal to process information about the internal and external environments. Hearing, seeing, touching, feeling, and smelling are all possible because of **sensory neurons**. These specialized cells detect stimuli from the environment and send them through electrical impulses along pathways to the brain. The brain processes the information and tells the body how to respond through **motor neurons** and **effector cells**. These cells either cause the body to react physically or release hormones from the endocrine system.

The **endocrine system** includes all the cells and organs that secrete hormones. **Hormones** are chemicals secreted into the bloodstream that create changes in an animal's body. Only certain types of cells can respond to certain hormones. For example, thyroid-stimulating hormones regulate the function of the thyroid, which sets the animal's metabolism or determines how quickly energy is burned in the body. Hormones regulate many vital functions in an animal, including growth, metabolism, heart rate, excretion, reproduction, and blood pressure.

The Immune System

The immune system is the body's defense against pathogens and other harmful agents that would attack an animal's cells, tissues, organs, or other body parts. These pathogens can occur in water, food, and air, so an animal's immune system is crucial to its survival. The immune system is able to identify and, in most cases, destroy viruses and harmful microorganisms.

The first line of defense is **innate immunity**, which all animals are born with. This type of immunity includes the mechanical features of an organism's body that protect it from dangerous bacteria or viruses. Skin and exoskeletons are good examples of protective barriers. Mucous membranes that line the digestive, respiratory, and urinary tracts can keep out harmful microbes. Tears and saliva can wash them away. If microbes enter with food and water, acids in the stomach and digestive tract can often destroy them before they cause any harm.

An insect's exoskeleton can protect it from potentially harmful microbes.

When microbes reach beyond this first line of defense, the body's inner defenses respond. **Phagocytes**, a type of **white blood cell**, engulf and ingest these microorganisms. The majority of phagocytes that respond are **neutrophils**, and the largest are **macrophages**. They also produce proteins that cause inflammation and keep microorganisms from spreading. In addition, **natural killer cells** patrol the body, attacking foreign invaders and abnormal cells such as cancer cells.

Reflect

Vertebrates benefit from various types of **acquired immunity**, an animal's second line of defense. Acquired immunity develops after microorganisms have entered an animal's body. At this point, white blood cells called **lymphocytes** respond. Certain lymphocytes recognize specific parts of foreign molecules called **antigens** and bind to them. Two types of lymphocytes seek out foreign invaders: **B cells**, created in the bone marrow, and **T cells**, created in the thymus. Once they bind to antigens, B cells produce substances called *antibodies* that effectively "tag" antigens for termination. They are then destroyed by T cells.

The immune system can be deadly to its host if it starts to attack the body's own cells. The resulting conditions are called **autoimmune diseases**. They include rheumatoid arthritis, insulin-dependent diabetes mellitus, and multiple sclerosis.

Try Now

What Do You Know?
Examine the following photographs on the left and think about the different processes that each animal undergoes. Answer the related questions about each animal using what you learned in the lesson. Several photographs are on the next page.

This animal's major waste product is most likely

____

This waste product is the MOST/LEAST toxic of the nitrogenous wastes. (Circle the correct word.)

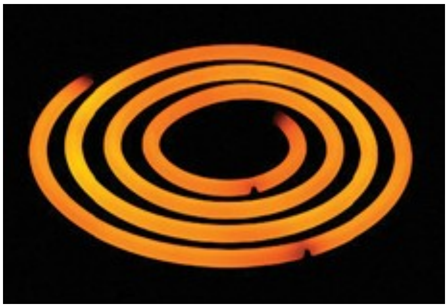
The excretory system regulates water and wastes to help the body maintain ___________________________________

This animal eats __________________________, so it is a ________________________.

Ingestion is a function of the ____________________ system.

During ____________________________, enzymes work to break down the ______________________________in food.

Try Now



The brain can interpret that this burner feels ________________ because of _____________________________________ nerves.

The brain and sensory nerves are part of the ____________________________________ system.

The nervous system allows the body to respond to __________ and __________________ stimuli.

This sick woman's ______________________________ system is fighting the foreign bacteria in her body.

Connecting With Your Child

Experimenting With Plants
To help your child learn more about interactions in plants, set up a few simple experiments to study water transport and tropisms. Begin by brainstorming and discussing possible ways that you can study these two concepts.

One way to observe water transport in a plant is to place celery stalks (which are stems of celery plants) or white carnations in water that has been colored with red or blue food coloring. A way to study gravitropism is to set up a plant experiment in which small bean plants are placed between wet sponges tied together and suspended upside down for a few days.

Provide your child with a list of the following suggested materials and work together to design two experiments. One experiment should test the water transport system in plants, and the other should test the response of plants to gravity. For each experiment, have your child write a prediction and describe a step-by-step procedure, including a method for data collection. Materials may be adjusted, as they are only suggestions.

Materials:
- Celery stalks
- Water
- Clear plastic cup
- Red food coloring
- Knife
- 4 individual bean plants
- 8 sponges
- String

Next, set up each experiment and work with your child to make observations and collect data each day for at least three days.

Ask your child the following questions as a way to summarize the experiments:
- Were you able to observe the xylem in the celery stalks? If so, how?
- What happened to the bean plants after three days? What kind of response was this?
- How might you set up an experiment to observe sexual reproduction in plants?

Connecting With Your Child

Exercising With Your Child

Exercising with your child is a great way to examine body systems and learn about homeostasis while getting in shape together. Try this activity:

1. Record your child's resting heart rate by counting his or her heartbeats for 60 seconds at the radial pulse (at the wrist).
2. Have your child jump rope or jog in place for three minutes while you time the activity.
3. Record his or her heart rate after the activity, and make observations of skin color, breathing intensity, and sweating, or any other changed physical characteristics.
4. Repeat steps 2 and 3 two more times, allowing a short resting period in between each period of activity (use your discretion as to the duration, but make each resting period the same duration).
5. After the last exercise session, wait for a three-minute rest period and record your child's heart rate and observations of skin color, breathing intensity, and sweating or any other changed physical characteristics.
6. Repeat step 5 after another three minutes, then again after an additional three minutes of rest.
7. Reverse roles and follow steps 1–6 while your child times your activity and records your heart rate and observations.
8. Compare the results.

Here are some questions to discuss with your child:

- Why were the heart rates similar or different between you and your child? (Compare the heart rates from the same points of the activity.)
- How were the physical characteristics similar or different between you and your child?
- What accounts for the physical characteristics that you observed during exercise? How were your body systems interacting to try to maintain homeostasis?
- What are some other ways you could design an exercise experiment to study the interaction of systems in your body?