CK-12 Life Science For Middle School

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CHAPTER 2

What is a Living Organism?

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CHAPTER 2

Studying the Life Sciences

2.1 Characteristics of Living Organisms

Lesson Objectives

- List the defining characteristics of living things.
- List the needs of all living things.

Vocabulary

- cell
- embryo
- homeostasis
- organism

Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or organisms. It might seem hard to think of similarities among such different organisms, but they actually have many things in common. Living things are similar to each other because all living things evolved from the same common ancestor that lived billions of years ago.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.
3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment (**homeostasis**).

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. The work you do each day, from walking to writing and thinking, is fueled by energy. But you are not the only one. In order to grow and reproduce, all living things need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat.

Here is how animals, plants and fungi obtain their energy:

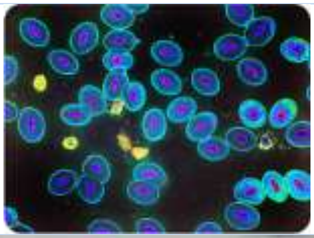
- All animals must eat plants or other animals in order to obtain energy and building materials.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of photosynthesis.
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (Figure 2.1).

	Orange bracket fungi on a rotting log in the Oak Openings Preserve in Ohio. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

Living Things Are Made of Cells

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells (Figure 2.2).

Figure 2.2 Reptilian blood cell showing the characteristic nucleus. A few smaller white blood cells are visible. This image has been magnified 1000 times its real size.	
Figure 2.3 This paramecium is a single-celled organism.	

Cells are the smallest unit of living things. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the paramecium shown in Figure 2.3 are made of just one cell. Other organisms have millions of cells. On the other hand, eggs are some of the biggest cells around. A chicken egg is just one huge cell.

All cells share at least some structures. Although the cells of different organisms are built differently, they all function much the same way. Every cell must get energy from food, be able to grow and reproduce, and respond to its environment.

Living Things Respond to their Environment

All living things are able to react to something important or interesting in their external environment. For example, living things respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, and taste buds.

Living Things Grow and Reproduce

All living things reproduce to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce. For example, like all living things, cats reproduce themselves and make a new generation of cats. When animals and plants reproduce they make tiny undeveloped versions of themselves called embryos, which grow up and develop into adults. A kitten is a partly developed cat.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living thing gets thrown off balance, its body or cells help them return to normal. In other words, living things have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis**. Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm.

Lesson Summary

- All living things grow, reproduce, and maintain a stable internal environment.
- All organisms are made of cells.
- All living things need energy and resources to survive.

Check Your Understanding

- What are the main properties of all living things?
- What is homeostasis?

Review Questions

Recall

1. Define the word organism.
2. What are three characteristics of living things?

Apply Concepts

3. What are a few ways organisms can get the energy they require?
4. What is a cell?

Think Critically

5. Think about fire. Can fire be considered a living thing? Why or why not?

Points to Consider

- DNA is considered the “instructions” for the cell. What do you think this means?
- What kinds of chemicals do you think are necessary for life?
- Do you expect that the same chemicals can be in non-living and living things?

2.2 Chemicals of Life

Lesson Objectives

- Define matter, element, and atom.
- Name the four main classes of organic molecules that are building blocks of life.

Vocabulary

- atom
- atomic number
- carbohydrate
- chemical reaction
- compound
- electron
- element
- enzyme
- lipid
- macromolecule
- matter
- molecule
- neutron
- nucleic acid
- organic compound
- Periodic Table
- product
- protein
- proton
- reactant

The Elements

If you pull a flower petal from a plant and break it in half, and take that piece and break it in half again, and take the next piece, and break it half and so on and so on, until you cannot even see the flower anymore — what do you think you will find? Scientists have broken down matter, or anything that takes up space and has mass, into the smallest pieces that cannot be broken down anymore. Rocks, animals, flowers, and your body are all made up of matter.

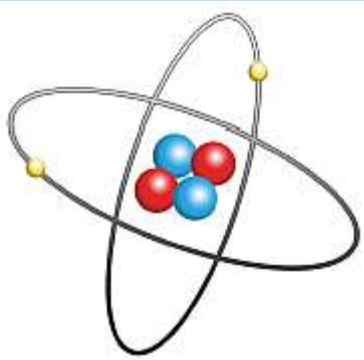
Matter is made up mixture of things called elements. **Elements** are substances that cannot be broken down into simpler substances. There are more than 100 known elements, and 92 occur naturally around us. The others have been made only in the laboratory.

Inside of elements, you will find identical atoms. An **atom** is the simplest and smallest particle of matter that still has chemical properties of the element. Atoms are the building block of all of the elements that make up the matter in your body or any other living or non-living thing. Atoms are so small that only the most powerful microscopes can see them. Each element has a different type of atom, and is represented with a one or two letter symbol. For example, the symbol for oxygen is **O** and the symbol for helium is **He**.

Atoms themselves are composed of even smaller particles, including positively charged **protons**, uncharged **neutrons**, and negatively charged **electrons**. Protons and neutrons are located in the center of the atom, or the nucleus, and the electrons move around the nucleus. How many protons an atom has determines what element it is. For example, Helium (He) always has two protons (Figure 2.7), while Sodium (Na) always has 11. All the atoms of a particular element have the exact same number of protons, and the number of protons is that element's atomic number.

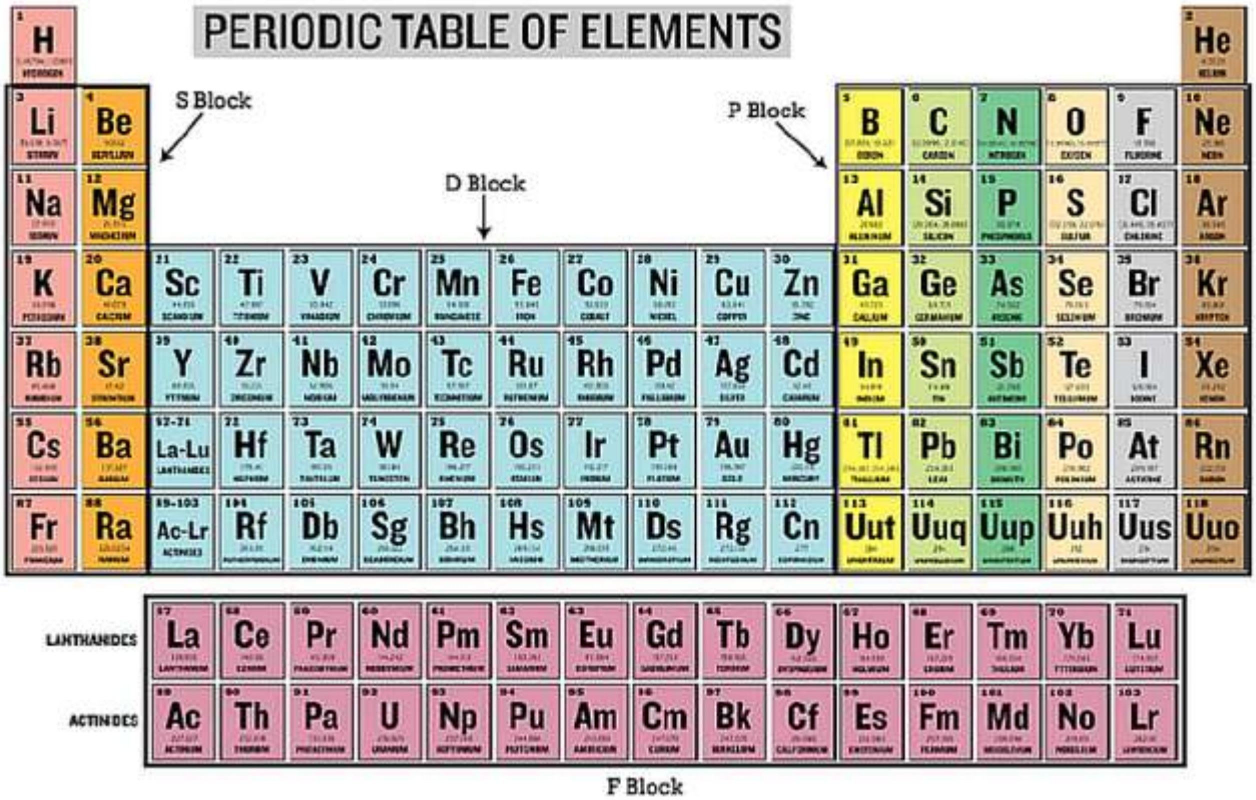
Figure 2.7

An atom of Helium (He) contains two positively charged protons (red), two uncharged neutrons (blue), and two negatively charged electrons (yellow).



The Periodic Table

In 1869, a Russian scientist named Dmitri Mendeleev created the Periodic Table, which is a way of organizing elements according to their unique characteristics, like atomic number, density, boiling point, and other values (see Figure 2.8). Each element has a one or two letter symbol. For example, H stands for hydrogen and Au for gold. The vertical columns in the periodic table are known as groups, and elements in groups tend to have very similar properties. The table is also divided into rows, known as periods.



Chemical Reactions

A molecule is any combination of two or more atoms. The oxygen in the air we breathe is two oxygen atoms connected by a chemical bond to form O2, or molecular oxygen. A carbon dioxide molecule is a combination of one carbon atom and two oxygen atoms. Because carbon dioxide includes two different elements it is a compound as well as a molecule.

A compound is any combination of two or more elements. A compound has different properties from the elements that it contains. Elements and combinations of elements make up all the many types of matter in the universe. A chemical reaction is a process that breaks or forms the bonds between atoms. For example, hydrogen and oxygen bind together to form water. The molecules that come together to start a chemical reaction are the reactants. So hydrogen and oxygen are reactants. The product is the end result of a reaction. In this example, water is the product.

Organic Compounds

The chemical components of living organisms are known as organic compounds. Organic compounds are molecules built around the element carbon (C). Living things are made up of very large molecules. These large molecules are called macromolecules because “macro” means large. Our body gets the organic molecules we need from the food we eat (Figure 2.9). Which organic molecules do you recognize from the list below?

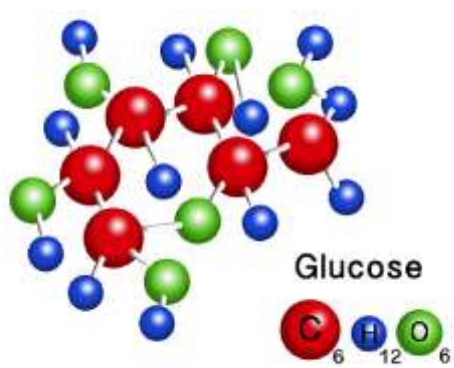
The four main macromolecules found in living things, shown in Table 2.1, are:

1. Proteins
2. Carbohydrates
3. Lipids
4. Nucleic Acids

TABLE 2.1: The Four Main Classes of Organic Molecules				
	Proteins	Carbohydrates	Lipids	Acids
Elements	C,H,O,N,S	C,H,O	C,H,O,P	C,H,O,P,N
Examples	Enzymes, muscle fibers, antibodies	Sugar, Starch, Glycogen, Cellulose	Phospholipids in membranes, fats, oils, waxes, steroids	DNA, RNA, ATP
Monomer (small building block molecule)	Amino acids	Monosaccharides (simple sugars)	Often include fatty acids	Nucleotides

Carbohydrates

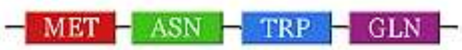
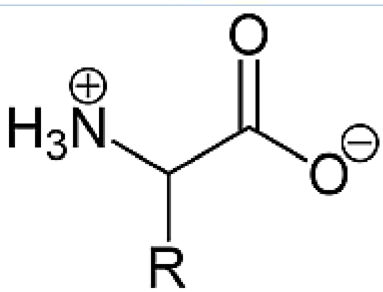
Carbohydrates are sugars or long chains of sugars. An important role of carbohydrates is to store energy. Glucose (Figure 2.10) is a simple sugar molecule with the chemical formula $C_6H_{12}O_6$.



Carbohydrates also include long chains of connected sugar molecules. Plants store sugar in long chains called starch, whereas animals store sugar in long chains called glycogen. You get the carbohydrates you need for energy from eating carbohydrate-rich foods, including fruits and vegetables, as well as grains, such as bread, rice, or corn.

Proteins

Proteins are molecules that have many different functions in living things. All proteins are made of small molecules called amino acids that connect together like beads on a necklace (Figure 2.11 and Figure 2.13).

	FIGURE 2.11 Amino acids connect together like beads on a necklace.
	FIGURE 2.12 Muscle fibers are made mostly of protein.
	FIGURE 2.13 General Structure of Amino Acids. This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

There are only 20 common amino acids needed to build proteins. These amino acids form in thousands of different combinations, making 100,000 or more unique proteins in humans. Proteins can differ in both the number and order of amino acids. Small proteins have just a few hundred amino acids. The largest proteins have more than 25,000 amino acids. Many important molecules in your body are proteins. Enzymes are a type of protein that speed up chemical reactions. For example, your stomach would not be able to break down food if it did not have special enzymes to speed up the rate of digestion. Antibodies that protect you against disease are proteins. Muscle fiber is mostly protein (Figure 2.12).

It’s important for you and other animals to eat food with protein because we cannot make some amino acids ourselves. You can get proteins from plant sources, such as beans, and from animal sources, like milk or meat. When you eat food with protein, your body breaks the proteins down into individual amino acids and uses them to build new proteins. You really are what you eat!

Lipids

Have you ever tried to put oil in water? They don’t mix. Oil is a type of lipid. Lipids are molecules such as fats, oils, and waxes. The most common lipids in your diet are probably fats and oils. Fats are solid at room temperature, whereas oils are fluid. Animals use fats for long-term energy storage and to keep warm. Plants use oils for long-term energy storage. When preparing food, we often use animal fats, such as butter, or plant oils, such as olive oil or canola oil.

There are many more type of lipids that are important to life. One of the most important are the phospholipids (see the chapter titled Cell Functions) that make up the protective outer membrane of all cells (Figure 2.14).

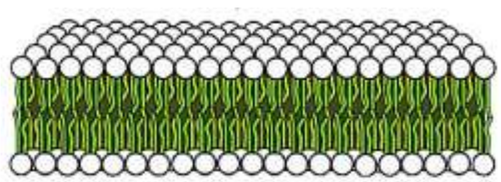


FIGURE 2.14
Phospholipids in a membrane.

Nucleic acids

Nucleic acids are long chains of nucleotides. Nucleotides are made of a sugar, a nitrogen-containing base, and a phosphate group. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two main nucleic acids. DNA is the molecule that stores our genetic information (Figure 2.15).

RNA is involved in making proteins. ATP (adenosine triphosphate), known as the "energy currency" of the cell, is also a nucleic acid.

Arsenic in Place of Phosphorus?

In late 2010, scientists proposed that the notion that the elements essential for life - carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur - may have additional members. Scientists have trained a bacterium to eat and grow on a diet of arsenic, in place of phosphorus. Phosphorus chains form the backbone of DNA, and ATP is the principal molecule in which energy in the cell is stored. Arsenic is directly under phosphorus in the Periodic Table, so the two elements have similar chemical bonding properties. This finding raises the possibility that organisms could exist on Earth or elsewhere in the universe using biochemicals not currently known to exist.

These results will expand the notion of what life could be and where it could be. It could be possible that life on other planets may have formed using biochemicals with other elements.

Lesson Summary

- Elements are substances that cannot be broken down into simpler substances with different properties.
- Elements have been organized by their properties to form the periodic table.
- Two or more atoms can combine to form a molecule.
- Molecules consisting of more than one element are called compounds.
- Reactants can combine through chemical reactions to form products.
- Enzymes can speed up a chemical reaction.
- Living things are made of just four classes of macromolecules: proteins, carbohydrates, lipids, and nucleic acids.

Review Questions

Recall

1. What are the 4 main classes of organic compounds?
2. Sugar is what kind of organic compound?
3. What is an atom?
4. Name a few examples of proteins.
5. Name a few examples of lipids in organisms.
6. What are two nucleic acids?

Apply Concepts

7. Would water, with the symbol H2O, be considered an element or a compound?
8. How many types of atoms make up gold?

Think Critically

9. Why do you think you need fats in your diet?

Points to Consider

- Do you expect the genetic information in the DNA of a cow to be the same or different from that in a crow?
- If we are all composed of the same chemicals, how do all organisms look so different?
- What characteristics would you use to distinguish and classify living things?

2.3 Classification of Living Things

Lesson Objectives

- Explain what makes up a scientific name.
- Explain what defines a species.
- List the information scientists use to classify organisms.
- List the three domains of life and the chief characteristics of each.

Check Your Understanding

- What are the basic characteristics of life?
- What are the four main classes of organic molecules that are building blocks of life?

Vocabulary

- Archaea
- bacteria
- binomial nomenclature
- classify
- domain
- Eukarya
- genus
- species
- taxonomy

Classifying Organisms

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they classify, or put in categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears. It turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean System of Classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carl Linnaeus (1707-1778) built on Aristotle's work to create his own classification system. He invented the way we name organisms today. Linnaeus is considered the inventor of modern taxonomy, the science of naming and grouping organisms.

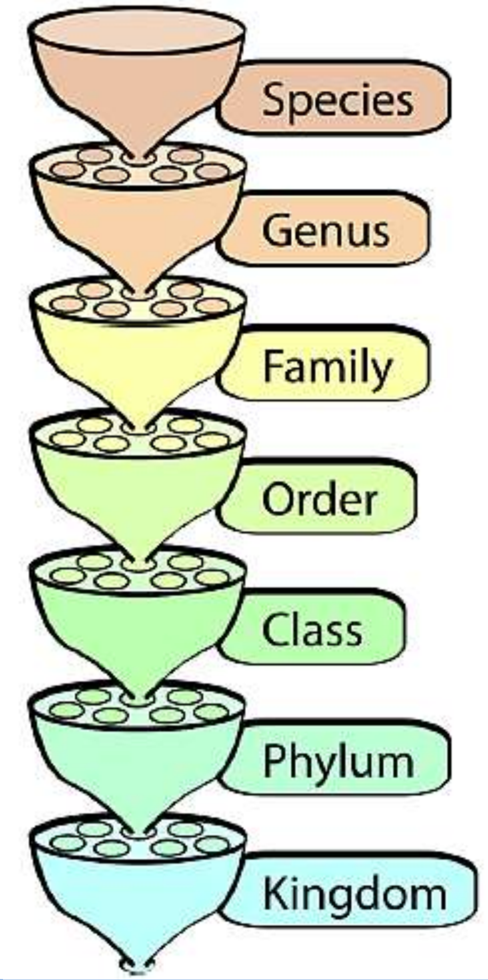
Linnaeus developed binomial nomenclature, a way to give a scientific name to every organism. Each species receives a two-part name in which the first word is the genus (a group of species) and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals. Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum,* are both in the same genus and they look similar (Figure 2.17). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. The names may seem strange, but they are written in a language called Latin.

FIGURE 2.17
These leaves (left and center) are from one of two different species of trees in the Acer, or maple, genus. One of the characteristics of the maple genus is winged seeds (right).

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (Figure 2.18).

FIGURE 2.18
This diagram illustrates the classification categories for organisms, with the broadest category (Kingdom) at the bottom, and the most specific category (Species) at the top.



Homo Sapiens Member of the genus Homo with a high forehead and thin skull bones.
Homo Hominids with upright posture and large brains.
Hominids Primates with relatively flat faces and three-dimensional vision.
Primates Mammals with collar bones and grasping fingers.
Mammals Chordates with fur or hair and milk glands.
Chordates Animals with a backbone.
Animals Organisms able to move on their own.

Difficulty Naming Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species.

So how is a species defined? A species is group of individuals that can interbreed with one another and produce fertile offspring; a species does not interbreed with other groups. By this definition, two species of animals or plants that do not interbreed are not the same species.

Domains of Life

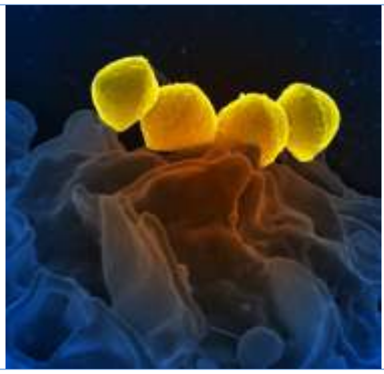
Let’s explore the least specific category of classification, called a domain. All of life can be divided into 3 domains, which tell you the type of cell inside of an organism:

1. **Bacteria:** Single-celled organisms that do not contain a nucleus
2. **Archaea:** Single-celled organisms that do not contain a nucleus; have a different cell wall from bacteria
3. **Eukarya:** Organisms with cells that contain a nucleus.

Archaea and Bacteria

Archaea and Bacteria (Figure 2.20 and Figure 2.21) seem very similar, but they also have significant differences.

Similarities:	Differences:
• Do not have a nucleus • Small cells • One-celled • Can reproduce without sex by dividing in two	• Cell walls made of different material • Archaea often live in extreme environments like hot springs, geysers, and salt flats while bacteria can live almost everywhere.

	
FIGURE 2.21 The Halobacterium is in the domain **Archaea**, one of the three domains of life.	FIGURE 2.20 The Group A Streptococcus organism is in the domain **Bacteria**, one of the three domains of life.

Eukarya

All of the cells in the domain Eukarya keep their genetic material, or DNA, inside the nucleus. The domain Eukarya is made up of four kingdoms:

1. **Plantae:** Plants, such as trees and grasses, survive by capturing energy from the sun, a process called photosynthesis.
2. **Fungi:** Fungi, such as mushrooms and molds, survive by "eating" other organisms or the remains of other organisms.
3. **Animalia:** Animals survive by eating other organisms or the remains of other organisms. Animals range from tiny ants to the largest dinosaurs (reptiles) and whales (mammals), including all sizes in between. (Figure 2.22).
4. **Protista:** Protists are not all descended from a single common ancestor in the way that plants, animals, and fungi are. Protists are all the eukaryotic organisms that do not fit into one of the other three kingdoms. They include many kinds of microscopic one-celled organisms, such as algae and plankton, but also giant seaweeds that can grow to be 200 feet long.

Plants, animals, fungi, and protists might seem very different, but remember that if you look through a microscope, you will find similar cells with a membrane-bound nucleus in all of them.

The main characteristics of the three domains of life are summarized in Table 2.2.

TABLE 2.2: Three domains of life: Archaea, Bacteria, and Eukarya			
	Archaea	**Bacteria**	**Eukarya**
Multicelluar	No	No	Yes
Cell Wall	Yes, without peptidoglycan	Yes, with peptidoglycan	Varies. Plants and fungi have a cell wall; animals do not.
Nucleus (DNA inside a membrane)	No	No	Yes
Organelles inside a membrane	No	No	Yes

Viruses

We have all heard of viruses. The flu and many other diseases are caused by viruses. But what is a virus? Based on the material presented in this chapter, do you think viruses are living? The answer is actually “no.” A virus is essentially DNA or RNA surrounded by a coat of protein. It is not a cell and does not maintain homeostasis. Viruses also cannot reproduce on their own – they need to infect a host cell to reproduce. Viruses do, however, change over time, or evolve. So a virus is very different from any of the organisms that fall into the three domains of life.

Lesson Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.
- Scientists classify organisms according to their evolutionary histories and how related they are to one another - by looking at their physical features, the fossil record, and DNA sequences.
- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.

Review Questions

Recall

1. Who designed modern classification and invented the two-part species name?
2. Define a species.
3. What kingdoms make up the domain Eukarya?
4. What is the name for the scientific study of naming and classifying organisms?
5. How are organisms given a scientific name?

Apply Concepts

6. In what domain are humans?
7. *Quercus rubra* is the scientific name for the red oak tree. What is the red oak's genus?
8. In what domain are mushrooms?
9. What information do scientists use to classify organisms?

Think Critically

10. Is it possible for organisms in two different classes to be in the same genus?
11. If molecular data suggests that two organisms have very similar DNA, what does that say about their evolutionary relatedness?
12. Can two different species ever share the same scientific name?
13. If two organisms are in the same genus, would you expect them to look much alike?

Points to Consider

- This Section introduced the diversity of life on Earth. Do you think it is possible for cells from different organisms to be similar even though the organisms look different?
- Do you think human cells are different from bacterial cells?
- Do you think it is possible for a single cell to be a living organism?