# Properties of Life

*NGSS Performance Expectations:*

MS-LS1-1 Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

The content and activities in this topic will work towards building an understanding of how certain properties and processes define living organisms.

## What is Life?

**Biology** is the study of life. Although this may sound straightforward, the word *life* is charged with personal meaning, and some passionate debates revolve around the definition of human life. For example, people debate when life begins and when life ends. This debate influences social and political decisions—such as whether parents can harvest stem cells from their child's umbilical cord and whether a person nearing the end of life has the right to refuse extreme medical procedures. From these debates, it is clear that *living* means different things to different people.

A definition of life is difficult to produce because life is a complex process. At first glance, some organisms do not even appear to be alive (Fig. 1.2). However, biologists generally agree on the overall characteristics and common processes that unify all living organisms. An **organism** is any single individual life form.

Fig. 1.2. (A) Giant leaf insect (*Phyllium giganteum*) rests on a green leaf in Malaysia.
Image courtesy of Benard DUPONT, Wikimedia Commons

Fig. 1.2. (B) A stick insect (*Ctenomorpha* sp.) blends into a eucalyptus plant in Australia.
Image courtesy of Fir0002, Wikimedia Commons

Fig. 1.2. (C) A “living stone” or pebble plant (*Lithops optica*) is seen among pebbles.
Image courtesy of Abu Shawka, Wikimedia Commons

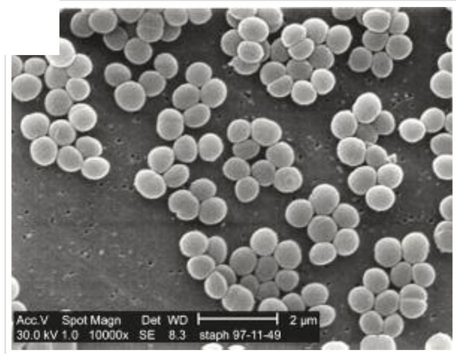


Fig. 1.2. (D) The bacterium *Staphylococcus aureus* is invisible to the humans without the aid of a powerful scanning electron microscope.
Image courtesy of Janice Carr, Centers for Disease Control and Prevention (CDC), adapted from Wikimedia Commons

ACTIVITY

### Activity: Is It Alive?

Form a working definition of alive.

## Defining Life

The following are characteristics that most scientists agree all living things share.

**Living organisms**

1. use enzymes to speed and mediate reactions.
2. store hereditary information.
3. adapt to the environment and have an evolutionary history.
4. maintain homeostasis.
5. have cellular organization.

If properties 1–3 are used to define life, a virus is considered alive.
If properties 4–5 are also included in the definition of life, a virus would not be considered alive.

**Heredity** is the passing of information about traits from one generation to the next. Trait information can include physical and biochemical characteristics such as eye color in humans or fur patterning in cats. All living organisms store hereditary information in the form of nucleic acid molecules, such as DNA or RNA. **DNA** (deoxyribonucleic acid) is a molecule that is stored in a cell and contains the genetic blueprint to make an entire new organism. In most organisms, **RNA** (ribonucleic acid) comes from DNA and is the part of the genetic blueprint that codes for individual genes and proteins.

A **gene** is a portion of DNA that contains the information for a certain trait or molecule. Genes can produce proteins, some of which are specialized proteins called enzymes. **Enzymes** are proteins that allow organisms to accelerate life processes. Enzymes are essential to life because they help chemical reactions occur quickly and at relatively low temperatures. For example, enzymes transform raw chemical materials and convert them into energy and wastes. Enzymes also assist organisms in reproduction and in responding to their surrounding environment.

Proteins are also important because they help produce different physical or biochemical traits, such as body shape, growth rate, and hair color. Many of these traits are inherited, which means that information was passed down from a parent to an offspring. In the case of humans, we inherit one set of traits from each parent, creating genetically unique offspring.

All living organisms evolve and adapt to their environments through a process called natural selection. **Adaptation** is the term for a population that changes over time. Specific traits—coded by genes—influence an organism's chances of survival and reproduction. The organisms with favorable traits survive in greater numbers and pass these genes on to their offspring. Over millions of years and billions of generations, life on Earth has adapted through the process of evolution by natural selection. The term **evolutionary history** describes this cumulative, and ongoing process, of adaptation and change in the traits of living organisms (Fig. 1.3). Living organisms fulfill the properties of life.

**Fig. 1.3.** (A) Marine tunicate embryo cell division.
Image courtesy of Dr. Brian Nedved, University of Hawai'i

**Fig. 1.3.** (B) Symbionts inside sea anemones convert sun energy into chemical energy.
Image by Narrissa Spies

**Fig. 1.3.** (C) Laysan albatross parents feed their offspring at Midway Atoll.
Image by Narrissa Spies

**Fig. 1.3.** (D) A Hawaiian monk seal interacts with the marine environment.
Image courtesy of U.S. Fish & Wildlife Service (USFWS)

With the exception of viruses, all life on Earth is able to maintain homeostasis. **Homeostasis** is the ability of an organism to regulate its internal environment. In homeostasis, an organism maintains a constant state relative to the external environment. One example of homeostasis is the way humans maintain a stable body temperature even when the outside temperature changes.

A **cell** is the smallest basic unit of life that maintains homeostasis (Fig. 1.4). Most living organisms are composed of at least one cell. Organisms can be made of a single cell, like bacteria or some plankton, or they can be made of many cells, like plants and humans. Most plant and animal cells, with dimensions between 1 and 100 micrometers, are visible only under a microscope. Eukaryotic organisms also have membrane-bound structures inside their cells called organelles.

**Fig. 1.4.** (A) This compound microscope image of moss shows multiple plant cells.
Image courtesy of Kelvinsong, Wikimedia Commons

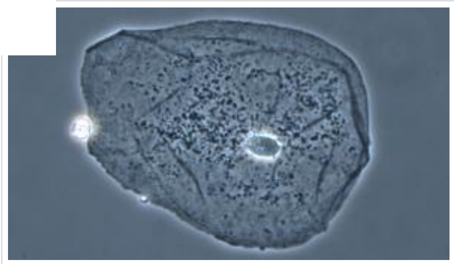

**Fig. 1.4.** (B) This contrast microscope image shows a human cheek epithelial cell.
Image courtesy of Spencer Diamond, University of California, Berkeley

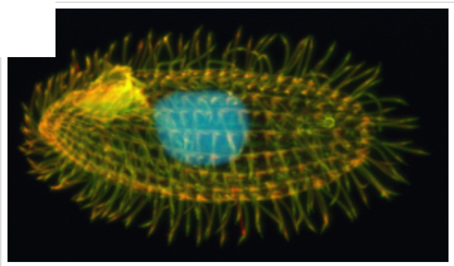

**Fig. 1.4.** (C) This is a confocal fluorescence microscope shows *Tetrahymena thermophilia*, a single-celled organism commonly used in biomedical research.
Image courtesy Richard Robinson, PLOS Biology

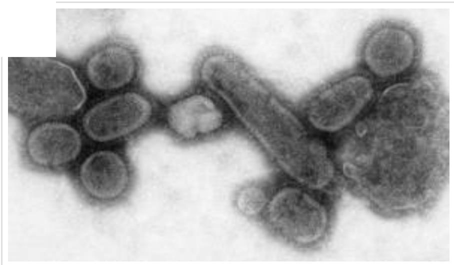

**Fig. 1.4.** (D) A transmission electron microscope image of *Influenza A* H1N1 flu virus particles shows the detail of their small structures.
Image courtesy of Cynthia Goldsmith, Centers for Disease Control and Prevention (CDC)

A **virus** is a small, infectious parasite that replicates inside the living cells of another organism (Fig. 1.4 D). Viruses possess genetic material (DNA or RNA) and evolve by natural selection. However, viruses do not have a cellular structure, do not maintain homeostasis, and cannot reproduce on their own. Because they lack the ability to maintain homeostasis and lack cellular organization, viruses are not considered cells. Viruses are instead referred to as particles.

Virus particles are enclosed within a protein shell called a capsid. Genetic information is contained within the capsid and is needed for viral replication. Viruses cannot replicate themselves. They must use a host cell's machinery to make the proteins necessary for new viral particles. Some viruses, called retroviruses, contain a single strand of RNA (instead of DNA) and must incorporate their genetic material into the host cell genome in order to reproduce. Sometimes, pieces of viral genome remain in the host genome after infection. These viruses are known as endogenous retroviruses. It is estimated that the average person's genome contains about eight percent viral genetic material.

Most viruses are small, but some viruses are relatively large, with even more genetic material than bacteria (which do have cellular organization). Opinions still differ as to whether viruses are truly alive, and scientists continue to debate whether viruses should be acknowledged as living things. However, there is little doubt among scientists that viruses are an important part of the microbial biota and that viruses have the ability to affect living organisms on this planet. Indeed, viruses are the most abundant organisms in the ocean and make up most of the genetic diversity. Marine viruses play a major role in biogeochemical cycling in the ocean and can influence the community composition of marine organisms.

QUESTION SET

Question Set: Properties of Life

WEIRD SCIENCE

Weird Science: Cryptobiosis

PRACTICES OF SCIENCE

Practices of Science: The Language of Science

## Cell: The Self-contained Unit

Most living things are composed of cells that have the ability to perform many different types of functions (Fig. 1.4 A, B, C). A **cell** is defined as the basic unit for an organism that is able to maintain homeostasis. One way to understand cells is to compare them to rooms in a house. Every cell has an outer cell membrane that separates it from other cells nearby just as a room has walls to separate it from other rooms inside a house. Most cells contain genetic information to create an entire new organism and also contain the cellular machinery to reproduce.

Just as some houses have only one room, some organisms are composed of only one cell. Such one-celled organisms are called **unicellular** or **single-celled**. They tend to be very small—often only visible through a microscope. The term **microbe** is also used to describe these single-celled microorganisms.

Some houses are filled with many rooms, and some organisms are made of many cells. The term **multicellular** is used to describe an organism made of many cells. In contrast to an individual microbe with only one cell, an individual human is composed of many trillion cells. In addition to the cells that we are made of, humans also have billions of microbes living on our skin and inside our bodies.

A detailed exploration of cells and cell biology can be found in the next unit.

FURTHER INVESTIGATIONS

## Further Investigations: Properties of Life