Characteristics of Life

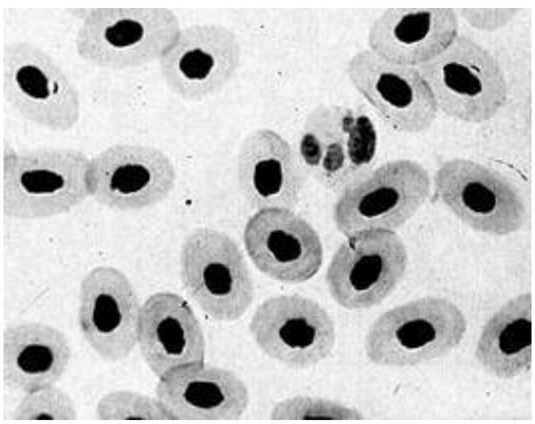
All forms of life share certain characteristics. Organisms can be classified into groups based on the similarities and differences of these characteristics.

The characteristics of living things can be divided into several broad categories.

Complex Organization

Everything that exists in the world is made up of matter, and all matter is made up of atoms. These atoms may be from one element or many elements. When two or more different elements combine, they form compounds. Living organisms are composed of many different compounds, including organic, or carbon-based, molecules (e.g., sugars, fats, etc.), and inorganic molecules (e.g., water).

Living organisms also contain cells. Unicellular organisms only contain one cell, but multicellular organisms contain many cells that are specialized to perform different functions. In complex organisms, these cells are further organized into tissues, organs, and organ systems.



Metabolism (Energy Acquisition and Release)

All living organisms require a constant input of energy in order to function. So, all living organisms must possess the ability to acquire energy and materials (nutrients), and they must possess the ability to release the energy that they acquire.

For example, a plant is a living organism. Structures within the leaves of plants known as chloroplasts allow them to acquire energy from the Sun. Other structures, such as the roots of the plants and stomata in the leaves, allow them to acquire materials, such as water, minerals, and carbon dioxide. Then, through a process known as photosynthesis, the plants make glucose sugar, which can later be broken down in other structures (mitochondria) to release the energy for the plants' usage.

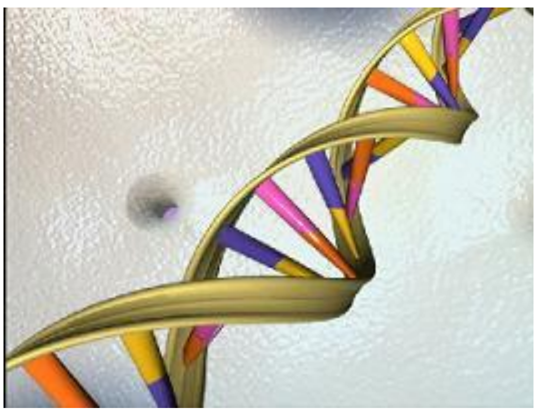
Homeostasis

Many processes that occur within living organisms must occur within a certain temperature and pH range. So, living organisms must possess the ability to maintain a constant internal environment. That is, they must be able to maintain homeostasis.

Sweating and shivering are examples of processes that occur in order to maintain homeostasis. When a person gets too hot, they sweat, so when the sweat evaporates, heat is removed from the person. When a person gets too cold, they shiver. Shivering forces a person's body to move. This movement generates enough energy to increase the person's temperature.

Reproduction and Heredity

All living things contain DNA. DNA, or deoxyribonucleic acid, contains all of the instructions that a living organism needs to maintain its life.



All living things are also able to reproduce, or create offspring. During reproduction, the DNA of the parent(s) is transferred to the offspring. Some living organisms reproduce asexually. Through this process, only one parent is needed, and the offspring is identical to the parent. Other living organisms reproduce sexually. Through this process, each parent contributes half of its DNA to the offspring, so the offspring resembles both of its parents, but it is not identical to either parent.

Growth and Development

When living organisms produce an offspring, the offspring has the ability to grow, or increase in size, through organized patterns of development.

For example, humans begin as a single cell. Then, the cell divides, grows, and divides again until it forms a layered ball of cells. At this point, the cells differentiate. That is, they specialize to become different types of cells (e.g., muscle cells, skin cells, brain cells, etc.). Eventually, all of the basic human structures form, and the embryo becomes a fetus. Then, the fetus grows until it is born and becomes an infant. Finally, the infant continues to grow into a toddler, the toddler becomes a child, the child grows into a teenager, and the teenager becomes an adult.

Responsiveness

Living organisms are able to recognize both internal and external stimuli, and they can respond to these stimuli. For example, plants can detect light from the Sun and respond to this stimuli by bending toward the light.

Living organisms can also adapt or evolve in response to their environments. For example, if an animal's natural habitat suddenly gets colder, it could adapt by growing thicker fur to survive the colder temperatures.

In addition to having the ability to adapt to their environments, living organisms have the ability to change their environments. For example, humans can alter their environment by cutting down trees or planting more trees.

Finally, living organisms also respond to or interact with other living organisms in their environment. For example, a fox and an owl might interact with each other by competing for a food source, such as rabbits.

Cells

*All living organisms on Earth are made up of microscopic structures called **cells**.*

Cell Theory

A scientific theory that serves as one of the foundations of biology is the cell theory. This theory puts forth the following:

- the cell is the basic building block in all living things
- all organisms are made up of one or more cells
- cells arise from other cells through a cellular division process known as mitosis
- cells carry genetic material that is passed on to “daughter” cells during mitosis
- all cells are essentially the same in chemical composition
- energy flow (i.e., metabolism) occurs within cells

The cell theory was gradually developed over time by many different scientists. In the late 1830's, two scientists - Theodor Schwann and Matthias Jakob Schleiden - formally proposed the first two statements in the theory, but they also erroneously thought that cells arose through spontaneous generation. Then, in the late 1850's, another scientist named Rudolf Virchow amended the cell theory by suggesting that new cells must arise from pre-existing cells. Finally, as technology and scientific knowledge improved, the other statements were added to the cell theory.

Cells are complex “basic building blocks” of living organisms, and they all share one purpose – to organize and survive.

Cell Purpose

Cells hold all of the biological equipment necessary for life. In unicellular, or single-celled, organisms, each cell contains all of the components necessary for its own survival. In multicellular, or many-celled, organisms, each cell has a different set of functions, and they are dependent on other cells for their survival.

Humans are multicellular and may have hundreds of different types of cells. While each cell type has a specialized function, they all work together in a system to help the organism survive. In the human body, cells of similar function group together into tissues, which group together with other tissues to form organs. For example, some cells are used to carry oxygen through the blood, while other cells of similar function group together to transmit nerve impulses.

The work of the cell is carried out by the many different types of molecules it assembles, such as proteins, lipids, carbohydrates, and nucleic acids.

Prokaryotes and Eukaryotes

All organisms are composed of one or more cells.

Cells are classified into two main types based on the presence or absence of a nucleus and membrane-bound organelles.

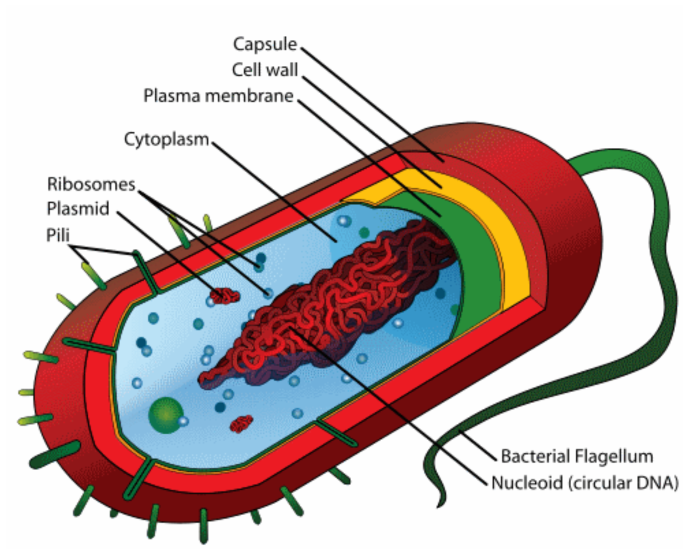
Prokaryotes

Prokaryotic cells do not have a true nucleus or membrane-bound organelles.

The word *prokaryote* comes from the combination of the Greek (*pro-*) "before" and (*karyon*) "kernal" or "nucleus."

This is a diagram of a typical bacterial cell. Notice that the DNA is not enclosed within a nucleus.

Image courtesy of Wikipedia.



Prokaryotic organisms differ from eukaryotic organisms in complexity and structure. Except for a few species, most prokaryotic organisms are unicellular. All lack a well-defined nucleus, and are much smaller and simpler than eukaryotic organisms. Prokaryotes also have simpler stages of growth and development. Simple organisms such as bacteria, blue-green algae, and archaea are examples of prokaryotes.

Eukaryotes

Eukaryotic cells have nuclei and organelles that are separated from the cytoplasm by membranes.

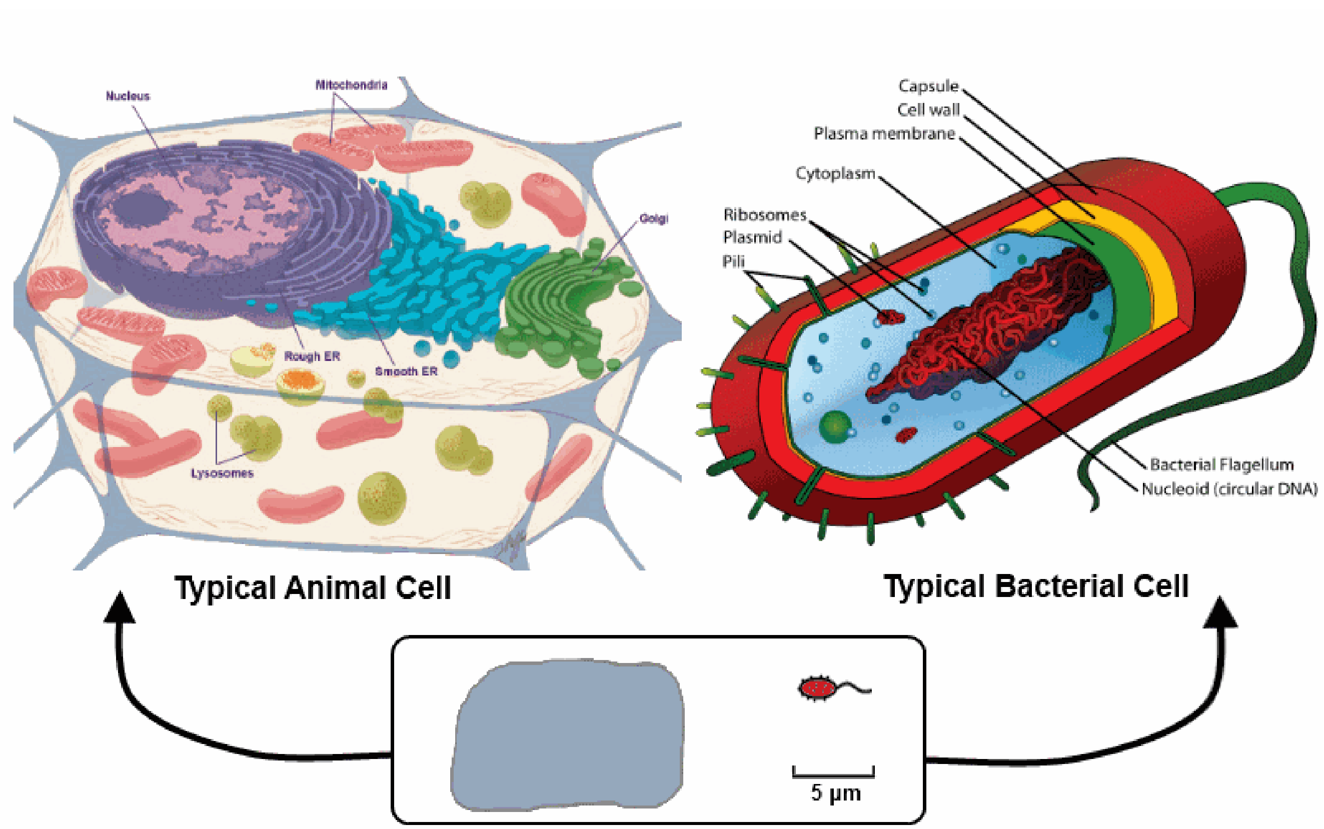
The word *eukaryote* from the combination of the Greek (*eu*-) "true" and (*karyon*) "kernal" or "nucleus."

Eukaryotic organisms are more complex than prokaryotes and have cells with nuclei and membrane-bound organelles. Most types of eukaryotic organisms are multicellular. Cells in multicellular eukaryotes can be organized into tissues, organs, and organ systems.

Developmental stages of single-celled eukaryotes are more complex than prokaryotic stages. Multicellular development is even more complex. Protozoa, fungi, plants, and animals are all examples of eukaryotes.

Comparison of Prokaryotes and Eukaryotes

There are many differences between eukaryotes and prokaryotes, and eukaryotic cells are far more complex than prokaryotic cells



The top portion of this diagram points out the differences between a bacterium (prokaryote) and a typical animal cell (eukaryote). Prokaryotic cells are far simpler and smaller than eukaryotic cells. Eukaryotic cells can be anywhere between 5—500x as large as prokaryotic cells

Adapted from images courtesy of NIH and Wikipedia.

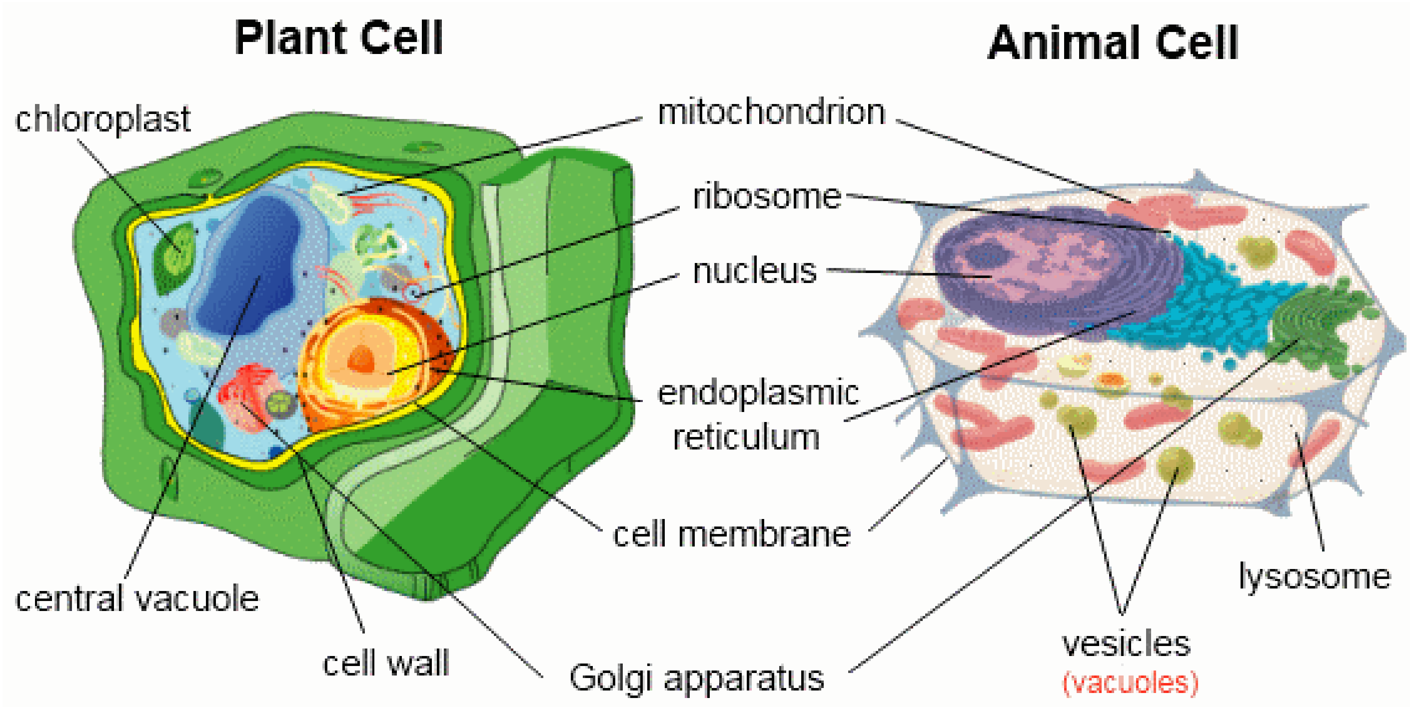
The following table provides a more detailed comparison of prokaryotic and eukaryotic cells.

Characteristic	Prokaryote	Eukaryote
Cells are enclosed within a plasma membrane.	✓	✓
Cells contain DNA.	✓	✓
Cells contain ribosomes.	✓	✓
Cell membranes are surrounded by a cell wall.	✓	plants, most fungi, and some protists
Cells contain a nucleus.		✓
Includes unicellular organisms.	✓	✓
Includes multicellular organisms..		✓
All cells are able to perform all functions necessary for life.	✓	

Cells

*All living organisms on Earth are made up of microscopic structures called **cells**. There are many types of cells. Some organisms are unicellular, while other organisms, including humans, are multicellular. Cells generally share a similar structure.*

Cell Structure



Adapted from images courtesy of NIH and Wikipedia.

Cytoplasm is a suspension fluid that houses the other organelles. The **cell membrane** (or *plasma membrane*) acts as a boundary layer around the cytoplasm thus separating cells from their outside environments. In addition to being able to recognize chemical signals, the cell membrane is selectively permeable to chemicals and controls which molecules enter and leave the cell. Nutrients first enter the cell through the cell membrane. The **cell wall** is a secretion of the cell membrane; it provides protection from physical injury, and with the vacuole, it provides structural support.

A **vacuole** stores water and ingested food in a fluid sack. It also removes waste from cells and produces turgor pressure against the cell wall for cellular support. Other membrane organelles known as **lysosomes** contain enzymes specialized to break down ingested materials, secretions, and wastes. These wastes (and other materials) may then be processed and transported out of the cell by the **Golgi apparatus**, which is sometimes referred to as the *Golgi complex*. In addition to playing an important role in waste disposal, the Golgi apparatus also processes, sorts, and modifies proteins in cells.

The **nucleus** is like the "brain" of the cell. It contains chromosomal information on chromatin. The **chromatin** is composed of long, thin strands of DNA which contains "instructions" that control cell metabolism and heredity. **Ribosomes** are RNA and protein complexes that are found in all cells. These complexes help cells during protein translation by joining amino acids together to form polypeptides.

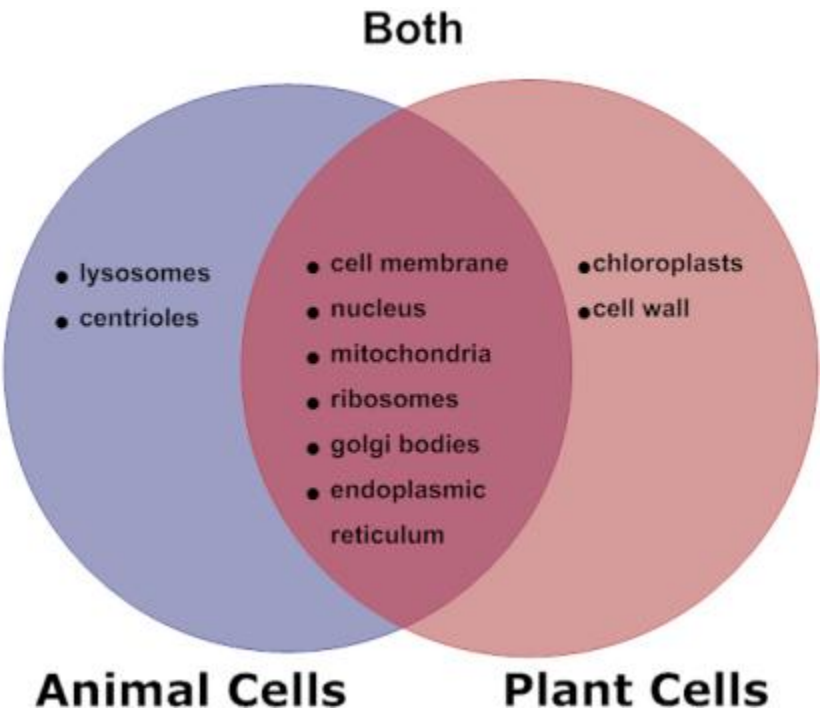
Mitochondria act like a stomach for the cell; they take in nutrients, break them down and create energy for the cell. **Chloroplasts** are the food producers in a plant cell. The **endoplasmic reticulum**

(ER) transports proteins within cells. The endoplasmic reticulum is also the location of lipid synthesis on the *smooth* side, and proteins are synthesized on the ribosome-studded, *rough ER*.

Many organic and inorganic substances dissolved in cells allow chemical reactions that are necessary to maintain life to take place. Large organic food molecules, such as proteins and starches, must initially be broken down, or digested, into amino acids and simple sugars, respectively. These smaller particles are then able to enter the cell through the processes of diffusion and active transport. Once nutrients enter a cell, the cell will use them as building blocks for other compounds that are necessary for life.

Plant vs. Animal Cells

Plant cells and animal cells contain different cellular structures. For example, plant cells possess a cell wall and chloroplasts. Animal cells never contain these structures. Plant cells also always contain large vacuoles. Some animal cells also have vacuoles, but the vacuoles in animal cells are much smaller than those found in plant cells.



It is important to note that all cells do not always have all the organelles. Even within plants, many cells do not contain chloroplasts. Cells located in the roots are not exposed to sunlight and do not photosynthesize. Therefore, chloroplasts are not necessary. The same is true for cells that compose animals and all other complex organisms. *Cells within multicellular organisms are highly specialized for the specific functions they perform*.