Prokaryotes and Eukaryotes

Identify the different kinds of cells that make up different kinds of organisms

There are two types of cells: prokaryotic and eukaryotic. In this section, we'll explore the similarities and differences between these two types.

LEARNING OBJECTIVES

- Identify features common to all cells
- Contrast the composition and size of prokaryotic and eukaryotic cells

Cells fall into one of two broad categories: prokaryotic and eukaryotic. The single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes (*pro* = before; *karyon*– = nucleus). Animal cells, plant cells, fungi, and protists are eukaryotes (*eu* = true).

Components of Prokaryotic Cells

All cells share four common components: (1) a plasma membrane, an outer covering that separates the cell's interior from its surrounding environment; (2) cytoplasm, consisting of a jelly-like region within the cell in which other cellular components are found; (3) DNA, the genetic material of the cell; and (4) ribosomes, particles that synthesize proteins. However, prokaryotes differ from eukaryotic cells in several ways.

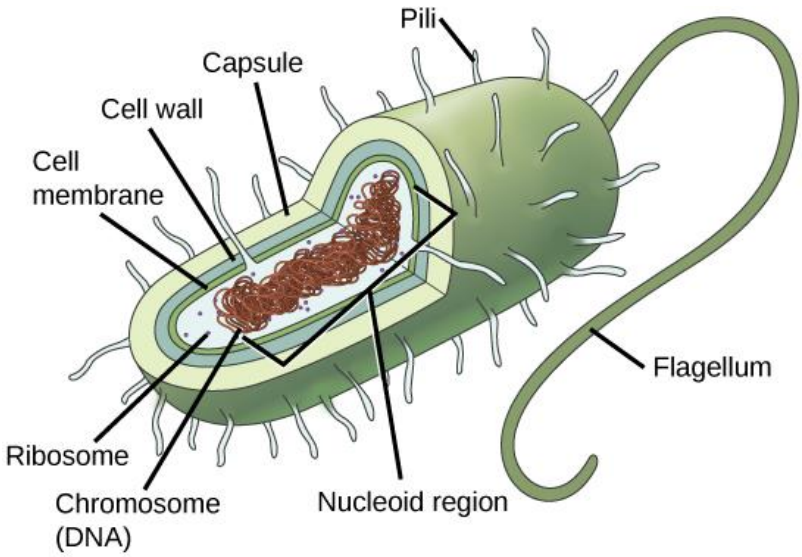


Figure 1. This figure shows the generalized structure of a prokaryotic cell.

A **prokaryotic cell** :Is a simple, single-celled (unicellular) organism that lacks a nucleus, or any other membrane-bound organelle. We will shortly come to see that this is significantly different in eukaryotes. Prokaryotic DNA is found in the central part of the cell: a darkened region called the nucleoid (Figure 1).

Unlike Archaa and eukaryotes, bacteria have a cell wall made of peptidoglycan, comprised of sugars and amino acids, and many have a polysaccharide capsule (Figure 1). The cell wall acts as an extra layer of protection, helps the cell maintain its shape, and prevents dehydration. The capsule enables the cell to attach to surfaces in its environment. Some prokaryotes have flagella, pili, or fimbriae. Flagella are used for locomotion, while most pili are used to exchange genetic material during a type of reproduction called conjugation.

Eukaryotic Cells

In nature, the relationship between form and function is apparent at all levels, including the level of the cell, and this will become clear as we explore eukaryotic cells. The principle “form follows function” is found in many contexts. It means that, in general, one can deduce the function of a structure by looking at its form, because the two are matched. For example, birds and fish have streamlined bodies that allow them to move quickly through the medium in which they live, be it air or water.

A **eukaryotic cell** is a cell that has a membrane-bound nucleus and other membrane-bound compartments or sacs, called **organelles**, which have specialized functions. The word eukaryotic means "true kernel" or "true nucleus," alluding to the presence of the membrane-bound nucleus in these cells. The word "organelle" means "little organ," and, as we learned earlier, organelles have specialized cellular functions, just as the organs of your body have specialized functions.

Cell Size

At 0.1–5.0 µm in diameter, prokaryotic cells are significantly smaller than eukaryotic cells, which have diameters ranging from 10–100 µm (Figure 2). The small size of prokaryotes allows ions and organic molecules that enter them to quickly spread to other parts of the cell. Similarly, any wastes produced within a prokaryotic cell can quickly move out. However, larger eukaryotic cells have evolved different structural adaptations to enhance cellular transport. Indeed, the large size of these cells would not be possible without these adaptations. In general, cell size is limited because volume increases much more quickly than does cell surface area. As a cell becomes larger, it becomes more and more difficult for the cell to acquire sufficient materials to support the processes inside the cell, because the relative size of the surface area across which materials must be transported declines.

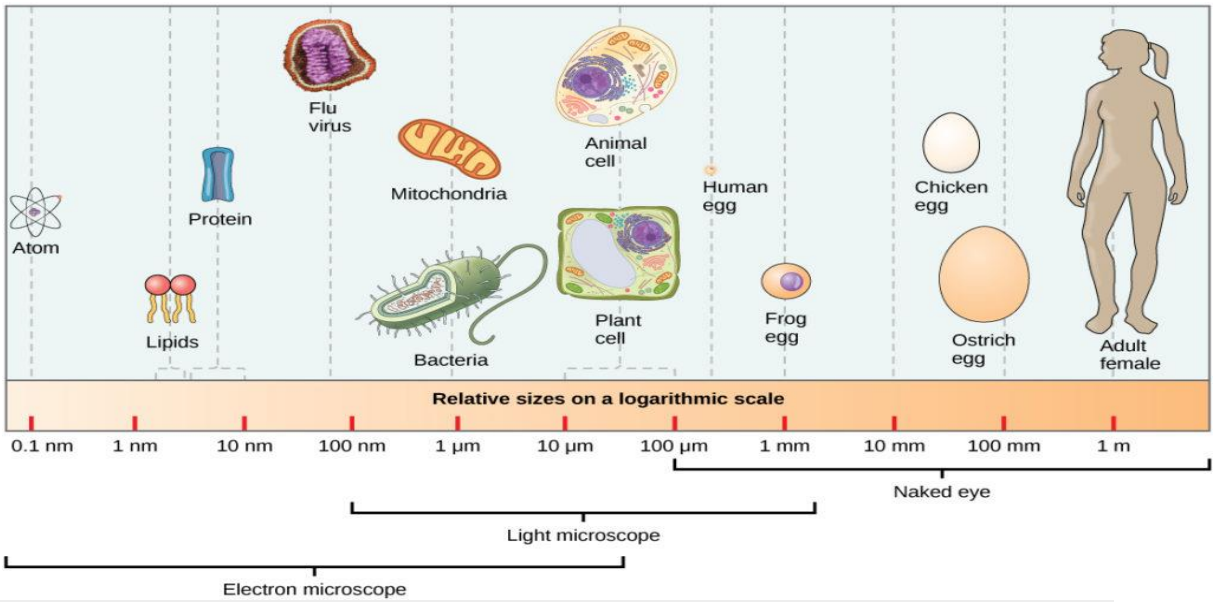


Figure 2. This figure shows the relative sizes of different kinds of cells and cellular components. An adult human is shown for comparison.

IN SUMMARY: COMPARING PROKARYOTIC AND EUKARYOTIC CELLS

Prokaryotes are single-celled organisms of the domains Bacteria and Archaea. All prokaryotes have plasma membranes, cytoplasm, ribosomes, a cell wall, DNA, and lack membrane-bound organelles. Many also have polysaccharide capsules. Prokaryotic cells range in diameter from 0.1–5.0 µm.

Like a prokaryotic cell, a eukaryotic cell has a plasma membrane, cytoplasm, and ribosomes, but a eukaryotic cell is typically larger than a prokaryotic cell, has a true nucleus (meaning its DNA is surrounded by a membrane), and has other membrane-bound organelles that allow for compartmentalization of functions. Eukaryotic cells tend to be 10 to 100 times the size of prokaryotic cells.

Similarities between eukaryotic and prokaryotic cells

Cell Membrane

Both eukaryotic and prokaryotic cells bear a lipid bilayer, which is an arrangement of phospholipids and proteins that acts as a selective barrier between the internal and external environment of the cell.

Genetic Material

Eukaryotic and prokaryotic cells both use deoxyribonucleic acid (DNA) as the basis for their genetic information. This genetic material is needed to regulate and inform cell function through the creation of RNA by transcription, followed by the generation of proteins through translation.

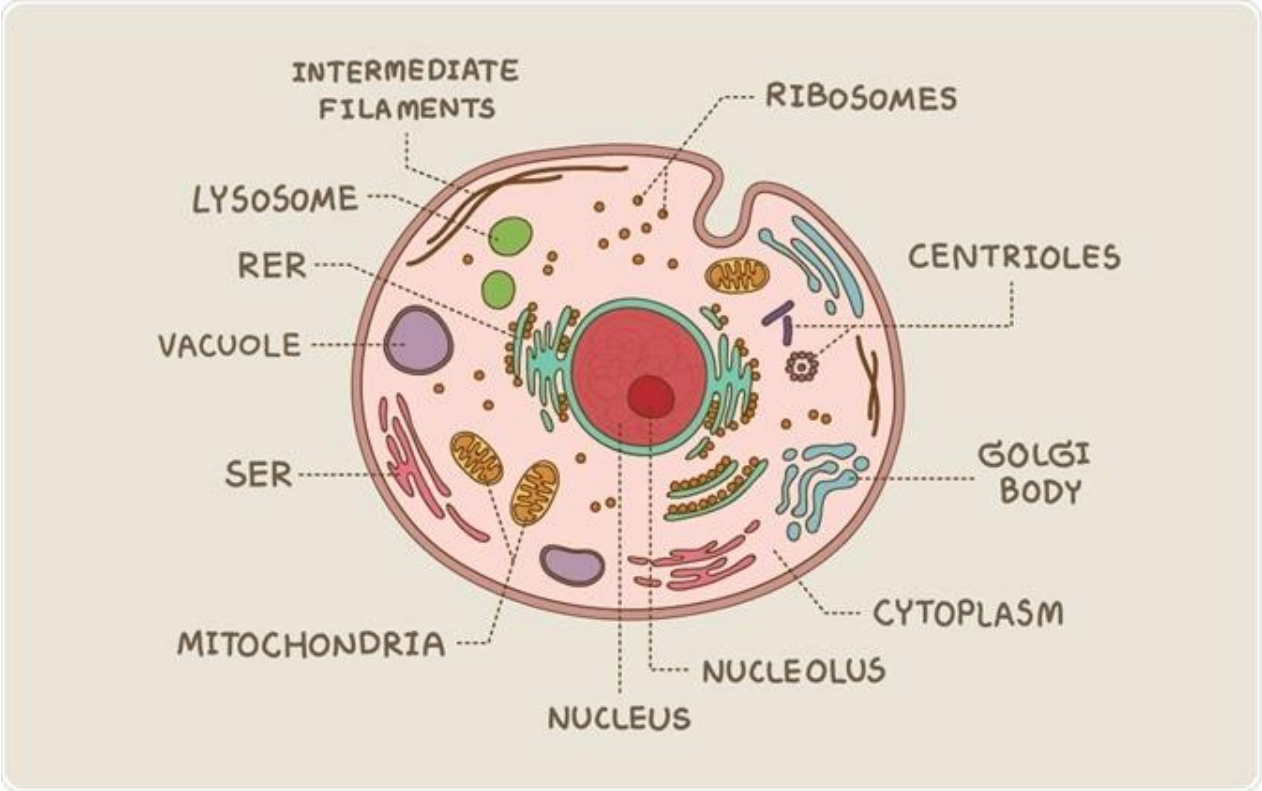
Ribosomes

Ribosomes facilitate RNA translation and the creation of protein, which is essential to the functioning of both eukaryotic and prokaryotic cells.

Cytoplasm

The cytoplasm is the medium in which the biochemical reactions of the cell take place, of which the primary component is cytosol.

In eukaryotic cells, the cytoplasm comprises everything between the plasma membrane and the nuclear envelope, including the organelles; the material within the nucleus is termed the nucleoplasm. In prokaryotes the cytoplasm encompasses everything within the plasma membrane, including the cytoskeleton and genetic material.



Structure of a eukaryotic cell. (Arisa_J / Shutterstock)

Differences between eukaryotic and prokaryotic cells Cell size:

Eukaryotic cells are ordinarily larger (10 – 100um) than prokaryotic cells (1 – 10um).

Cell arrangement

Eukaryotes are often multicellular whereas prokaryotes are unicellular. There are however some exceptions –unicellular eukaryotes include amoebas, paramecium, yeast.

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True membrane-bound nucleus

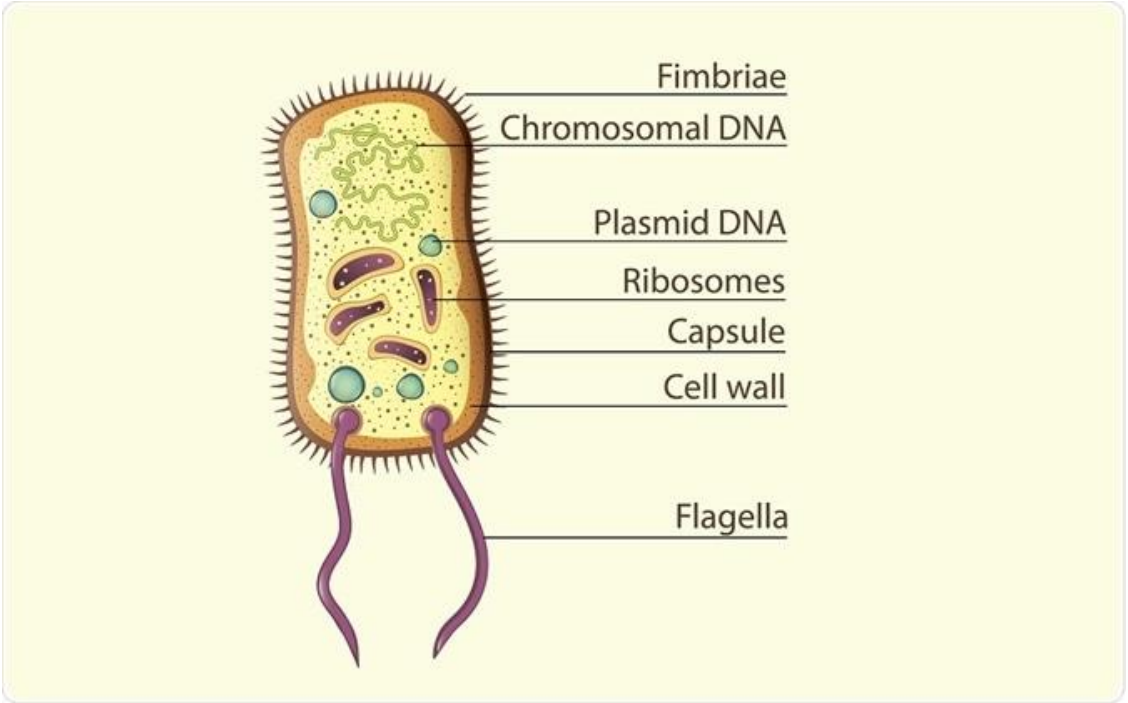
Eukaryotic cells have a true nucleus bound by a double membrane. It contains the DNA-related functions of the large cell in a smaller enclosure to ensure close proximity of materials and increased efficiency for cellular communication and functions.

In contrast, the smaller prokaryotic cells have no nucleus. The materials are already fairly close to each other and there is only a "nucleoid" which is the central open region of the cell where the DNA is located.

DNA structure

Eukaryotic DNA is linear and complexed with packaging proteins called "histones," before organization into a number of chromosomes

Prokaryotic DNA is circular and is neither associated with histones nor organized into chromosomes. A prokaryotic cell is simpler and requires far fewer genes to function than the eukaryotic cell. Therefore, it contains only one circular DNA molecule and various smaller DNA circlets (plasmids).



Structure of a prokaryotic cell. (In Art / Shutterstock)

Membrane-bound organelles

Eukaryotic cells contain many membrane-enclosed, large, complex organelles in the cytoplasm whereas prokaryotic cells do not contain these membrane-bound organelles.

This is a key difference because it allows a high level of intracellular division of labor and contributes to the greater complexity characteristic of eukaryotic cells.

Due to the larger size of the eukaryotic cells, confining certain cellular process to a smaller area also increases the efficiency of functions by improving communication and movement within the cell.

Only eukaryotes possess a membrane-bound nucleus and membrane-bound organelles such as the mitochondria, golgi apparatus, lysosomes, peroxisomes and ER.

Ribosome size

Both eukaryotic and prokaryotic cells contain many ribosomes; however the ribosomes of the eukaryotic cells are larger than prokaryotic ribosomes i.e. 80S compared to 70S.

Eukaryotic ribosomes also show more complexity than prokaryotic – they are constructed of five kinds of ribosomal RNA and about eighty kinds of proteins. In contrast, prokaryotic ribosomes are composed of only three kinds of rRNA and about fifty kinds of protein.

Cytoskeleton

This is a multicomponent system in eukaryotes composed of microtubules, actin filaments and intermediate filaments. It is required for maintaining cell shape, providing internal organization and mechanical support. It is also paramount in movement and cell division.

Sexual reproduction

Most eukaryotes undergo sexual reproduction whilst prokaryotes reproduce asexually. Sexual reproduction in eukaryotes results in offspring with genetic material which is a mixture of the parents' genome and during this process, genetic variation is generated via sexual recombination.

On the other hand, a prokaryote will reproduce clones of itself via binary fission and relies more on horizontal genetic transfer for variation.

Cell division

This occurs by mitosis for eukaryotic cells and binary fission for prokaryotic cells.

Eukaryotic cells undergo mitosis then cytokinesis. This involves numerous stages - the nuclear membrane disintegrates then the chromosomes are sorted and separated to ensure that each daughter cell receives two sets (a diploid number) of chromosomes. Following this, the cytoplasm divides to form two genetically identical daughter cells i.e. cytokinesis.

In contrast, prokaryotes undergo a simpler process of binary fission. This is faster than mitosis and involves DNA (nucleoid) replication, chromosomal segregation, and ultimately cell separation into two daughter cells genetically identical to the parent cell. Unlike mitosis, this process does not involve the nuclear envelope and centromere and spindle formation.