Components of prokaryotic cells

There are some key ingredients that a cell needs in order to be a cell, regardless of whether it is prokaryotic or eukaryotic. All cells share four key components:

1. The **plasma membrane** is an outer covering that separates the cell's interior from its surrounding environment.
2. **Cytoplasm** consists of the jelly-like cytosol inside the cell, plus the cellular structures suspended in it. In eukaryotes, cytoplasm specifically means the region outside the nucleus but inside the plasma membrane.
3. **DNA** is the genetic material of the cell.
4. **Ribosomes** are molecular machines that synthesize proteins.

Despite these similarities, prokaryotes and eukaryotes differ in a number of important ways. A **prokaryote** is a simple, single-celled organism that lacks a nucleus and membrane-bound organelles. We'll talk more about the nucleus and organelles in the next article on eukaryotic cells, but the main thing to keep in mind for now is that prokaryotic cells are not divided up on the inside by membrane walls, but consist instead of a single open space.

The majority of prokaryotic \text{DNA}DNAD, N, A is found in a central region of the cell called the **nucleoid**, and it typically consists of a single large loop called a circular chromosome. The nucleoid and some other frequently seen features of prokaryotes are shown in the diagram below of a cut-away of a rod-shaped bacterium.

Image of a typical prokaryotic cell, with different portions of the cell labeled.

_Image credit: modified from "Prokaryotic cells: Figure 1" by OpenStax College, Biology, CC BY 3.0 _

Bacteria are very diverse in form, so not every type of bacterium will have all of the features shown in the diagram.

Most bacteria are, however, surrounded by a rigid cell wall made out of **peptidoglycan**, a polymer composed of linked carbohydrates and small proteins. The **cell wall** provides an extra layer of protection, helps the cell maintain its shape, and prevents dehydration. Many bacteria also have an outermost layer of carbohydrates called the capsule. The **capsule** is sticky and helps the cell attach to surfaces in its environment.

Some bacteria also have specialized structures found on the cell surface, which may help them move, stick to surfaces, or even exchange genetic material with other bacteria. For instance, **flagella** are whip-like structures that act as rotary motors to help bacteria move.

Fimbriae are numerous, hair-like structures that are used for attachment to host cells and other surfaces. Bacteria may also have rod-like structures known as **pili**, which come in different varieties. For instance, some types of pili allow a bacterium to transfer \text{DNA}DNAD, N, A molecules to other bacteria, while others are involved in bacterial locomotion—helping the bacterium move.
[Are fimbriae considered pili?]
^1start superscript, 1, end superscript

Archaea may also have most of these cell surface features, but their versions of a particular feature are typically different from those of bacteria. For instance, although archaea also have a cell wall, it's not made out of peptidoglycan—although it does contain carbohydrates and proteins.

Cell size

Typical prokaryotic cells range from 0.1 to 5.0 micrometers (µm) in diameter and are significantly smaller than eukaryotic cells, which usually have diameters ranging from 10 to 100 µm.

The figure below shows the sizes of prokaryotic, bacterial, and eukaryotic, plant and animal, cells as well as other molecules and organisms on a logarithmic scale. Each unit of increase in a logarithmic scale represents a 10-fold increase in the quantity being measured, so these are big size differences we're talking about!

Graph showing the relative sizes of items from, in order, atoms to proteins to viruses to bacteria to animal cells to chicken eggs to humans.

Image credit: "Prokaryotic cells: FIgure 2" by OpenStax College, Biology, CC BY 3.0

With a few cool exceptions—check out the single-celled seaweed *Caulerpa*—cells must remain fairly small, regardless of whether they're prokaryotic or eukaryotic. Why should this be the case? The basic answer is that as cells become larger, it gets harder for them to exchange enough nutrients and wastes with their environment. To see how this works, let's look at a cell's **surface-area-to-volume ratio**.

Suppose, for the sake of keeping things simple, that we have a cell that's shaped like a cube. Some plant cells are, in fact, cube-shaped. If the length of one of the cube's sides is l*l*l, the surface area of the cube will be 6l^26*l*26, l, start superscript, 2, end superscript, and the volume of the cube will be l^3*l*3l, start superscript, 3, end superscript. This means that as l*l*l gets bigger, the surface area will increase quickly since it changes with the square of l*l*l. The volume, however, will increase even faster since it changes with the cube of lll.

Thus, as a cell gets bigger, its surface-area-to-volume ratio drops. For example, the cube-shaped cell on the left has a volume of 1 mm^3^{3}start superscript, 3, end superscript and a surface area of 6 mm^2^{2}start superscript, 2, end superscript with a surface-area-to-volume ratio of six to one, whereas the cube-shaped cell on the right has a volume of 8 mm^3^{3}start superscript, 3, end superscript and a surface area of 24 mm^2^{2}start superscript, 2, end superscriptwith a surface area-to-volume ratio of three to one.

Image of two cubes of different sizes. The cube on the left has 1 mm sides, while the cube on the right has 2 mm sides.

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Surface-area-to-volume ratio is important because the plasma membrane is the cell's interface with the environment. If the cell needs to take up nutrients, it must do so across the membrane, and if it needs to eliminate wastes, the membrane is again its only route.

Each patch of membrane can exchange only so much of a given substance in a given period of time – for instance, because it contains a limited number of channels. If the cell grows too large, its membrane will not have enough exchange capacity (surface area, square function) to support the rate of exchange required for its increased metabolic activity (volume, cube function).

The surface-area-to-volume problem is just one of a related set of difficulties posed by large cell size. As cells get larger, it also takes longer to transport materials inside of them. These considerations place a general upper limit on cell size, with eukaryotic cells being able to exceed prokaryotic cells thanks to their structural and metabolic features—which we’ll explore in the next section.

Some cells also use geometric tricks to get around the surface-area-to-volume problem. For instance, some cells are long and thin or have many protrusions from their surface, features that increase surface area relative to volum