A cell is a chemical system that is able to maintain its structure and reproduce. Cells are the fundamental unit of life. All living things are cells or composed of cells.

The interior contents of cells is the **cytoplasm**. The cytoplasm is isolated from the surrounding environment by the _________.

There are two fundamentally different forms of cells.

_________ cells - relatively simple cells - lack nuclear membrane and many organelles - bacteria and their relatives are all prokaryotic

_________ cells - more complex cells - have a nucleus and many organelles - all cells of plants, animals, fungi, and protists
Most cells are small
Prokaryotic: 1-10 μm
Eukaryotic: 10 - 100 μm
(1 μm = .001 mm)

Organelles, Macromolecules, & Atoms
Why are cells small?

As cell size increases the volume increases much faster than the surface area.

Cells obtain nutrients, gain information and rid waste through their plasma membrane.

<table>
<thead>
<tr>
<th>Cell radius (r)</th>
<th>1 unit</th>
<th>10 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area (4πr²)</td>
<td>12.57 units²</td>
<td>1257 units²</td>
</tr>
<tr>
<td>Volume (4πr³/3)</td>
<td>4.189 units³</td>
<td>4189 units³</td>
</tr>
<tr>
<td>Surface/Volume (S/V)</td>
<td>3.000</td>
<td>0.300</td>
</tr>
</tbody>
</table>

As cell size increases, a cell’s ability to exchange with its environment becomes limited by the amount of membrane area that is available for exchange.

Robert Hooke - 1665 - using an early microscope viewed cork and saw many repeating box-like structures and called them “cells.”

What he saw were spaces surrounded by walls that once contained living cells.

Since Hooke’s first observations what is known about cells has increased greatly.
Cell Theory
- Cells are the fundamental unit of life - nothing less than a cell is alive.
- All organisms are constructed of and by cells.
- All cells arise from preexisting cells. Cells contain the information necessary for their own reproduction. No new cells are originating spontaneously on earth today.
- Cells are the functional units of life. All biochemical processes are carried out by cells.
- Groups of cells can be organized and function as multicellular organisms.
- Cells of multicellular organisms can become specialized in form and function to carry out subprocesses of the multicellular organism.

Prokaryotic cell structure
small, with a plasma membrane surrounded by a rigid cell wall - in many the cell wall is made of _____________ - a carbohydrate cross-linked with polypeptides
cell wall may be covered with a capsule made of polysaccharides
few or no membrane enclosed spaces within the cytoplasm
no nucleus - DNA is in a region called the nucleoid
DNA is circular and naked (has no protein associated with it)
Bacteria often have flagella with a single protein core (flagellin) that they can use to move in a rotary corkscrew like fashion. The rotary motor of prokaryotic flagella is powered by proton flow through the cell membrane. Rotating structures are rare in nature.

Membrane enclosed spaces allow cell functions to be compartmentalized and isolated from other functions. Prokaryotes lack membrane enclosed spaces in their cytoplasm. Some prokaryotes are photosynthetic. The biochemical machinery for trapping light energy is contained within a highly folded plasma membrane.
Eukaryotic cell structure
larger, with a typical plasma membrane - some with a cell wall
Many _________________________ and other interior spaces
enclosed by membranes:
  **Nucleus, Endoplasmic reticulum, Golgi apparatus,**
  **Mitochondria, Chloroplasts, Lysosomes, Vacuoles, Vesicles**
Cytoplasm with a **cytoskeleton** - protein tubules and fibers
cell wall found in plants (cellulose), fungi (chitin), some protists

Cellular Organelles
  **Nucleus** - the largest and most obvious membrane bound
  compartment - controls cell activities
contains the **nucleolus** - a darkened region where ribosomal RNA is
  synthesized
contains **chromosomes** - consist of DNA wrapped around proteins
Nucleus is surrounded by the **nuclear envelope** - a double membrane

Nuclear membrane has **nuclear pores** that control entry and exit of materials

![Diagram of nucleus and nuclear pores](image)

**Chromosome** - “colored body”

consists of both DNA and protein - seen as chromosomes when highly condensed in preparation for cell division

At other times the DNA and protein are threadlike and called ________.

The most common proteins are **histones**. DNA is coiled around histones in a regular pattern that produces structures called **nucleosomes**.

![Diagram of chromosome structure](image)
Endoplasmic reticulum (ER) - a web-like series of membranes within the cytoplasm in the form of flattened sheets, sacs, tubes, creates many membrane enclosed spaces - spreads throughout the cytoplasm - has connections with the outer membrane of the nucleus and the plasma membrane

interior space is called the ______

Functions:
- circulation and transport
- storage of proteins and minerals
- synthesis of lipids, carbohydrates, and proteins
- A large surface area for enzyme action.

Two types of ER - rough and smooth

**Rough ER** - studded with ribosomes
- site of synthesis of many proteins
- all ribosomes on rER are actively involved in protein synthesis -

**Smooth ER** - site for synthesis of steroids and other lipids
- Ca++ storage in muscles
- detoxification of drugs, toxins, alcohol (especially in liver)

The highly convoluted surface provides a large surface area for enzymatic activities. Many enzymes are imbedded in the membranes.
**Ribosomes** - protein synthetic machinery
- two subunits - large and small - each made of protein and ribosomal RNA (rRNA)
- subunits associate when they are synthesizing proteins
- protein synthesis occurs on ribosomes that are free-floating in the cytoplasm and on ribosomes attached to ER
- rRNA is synthesized in the nucleolus

**Golgi Apparatus** -
a collection of membranes associated with the ER composed of flatten sacs called ________ concentrates and packages proteins synthesized on the ER

The Golgi is functionally associated with the ER.
Proteins synthesized on the ER are concentrated internally and transport vesicles are budded off

**Transport vesicles** fuse with the Golgi, dump their contents into the Golgi.

Golgi packages proteins in vesicles so that they may be excreted from the cell, or used within the cell.

**Secretory vesicles** - used for excretion - leave the Golgi and move to plasma membrane where they fuse and dump their contents outside - seen in many glands.

The Golgi Apparatus also forms lysosomes.

Lysosomes - vesicles filled with digestive enzymes - used for intracellular digestion.

Particles can be taken into cell by **phagocytosis** and vesicle fused with lysosome.

The components of organelles can be recycled after digestion by lysosomes.
Microbodies: Peroxisomes and Glyoxisomes
vesicles that form through growth and division within the cytoplasm
Glyoxisomes are found in plants - contain enzymes that convert fats into carbohydrates
Peroxisomes - used for removing reactive compounds from the cytoplasm - create H₂O₂ as a byproduct and degrade it with the enzyme catalase

Mitochondria - cellular powerhouses - the site of much of the energy harvest by cells
have double membrane structure
inner membrane folded into inward projections called cristae
two spaces within the mitochondrion - the matrix and the intermembrane space
Mitochondria -
• The site of oxygen consumption within cells
• Have their own DNA that is similar to prokaryotic DNA
• Have their own ribosomes that are similar in construction to prokaryotic ribosomes
• Synthesize many, but not all, of their own proteins
• Mitochondria replicate by binary fission - similar to prokaryotic cell division

Chloroplasts - sites of photosynthesis - in nearly all plants and some protists
trap light energy and convert it into chemical energy
have double membrane structure - inner space is the stroma

Within the stroma
have a series of stacks of flattened membrane structures called thylakoids - the stacks are called granum

The light energy trapping molecules of photosynthesis are found in the membranes of the thylakoids.
Chloroplasts
have their own DNA, similar to prokaryotic DNA
Can synthesize many of their own proteins using prokaryote-like ribosomes
Synthesize many, but not all, of their own proteins
Replicate through division similar to prokaryotic cell division

Chloroplasts can take on other functions

____________ synthesize and store starch in roots and tubers
____________ have pigments and give fruits ripened color

Centrioles - are part of specialized region of the cell called the **centrosome** (cell center)

found in animals and most protists
the centrioles are involved in the production of **microtubules**
microtubules have many functions including moving chromosomes during cell division
centriole structure - 9 triplets of microtubules surrounding a hollow core - ____________
similar to the basal body of flagella
Cytoskeleton - scaffolding of proteins that transport materials, position and move organelles, maintain and change cell shape, and organize enzymes into functional associations

3 components - **actin filaments, microtubules**, and **intermediate filaments**

all are polymers of smaller protein subunits - lengthen through addition of polymer subunits, shorten through

**actin filaments** - involved in cell movements and in membrane deformations - smallest components of the cytoskeleton

**microtubules** - hollow tubes made of proteins called tubulins responsible for cell movements and movements of organelles within the cytoplasm, movement of chromosomes during cell division - largest components of the cytoskeleton

**intermediate filaments** - 8 stranded protein fibers - play a role in cell structure, anchoring organelles and in transport of materials within the cytoplasm anchor neighboring cells to each other in tissues
Flagella and Cilia - cellular appendages can propel cells or propel materials over the cell surface.

Cells that have flagella have few (usually 1 or 2), while cells that have cilia have many - covering the surface. Flagella move with whip-like movements to propel the cell, whereas cilia have a more regular stroke and groups of cilia appear to move in unison, resulting in a wave-like motion. Flagella are 5 to 20x longer than cilia.

Structure:

- The basal body has a 9+0 structure of microtubules.
- The flagellum is membrane-bound with pairs of microtubules in a 9+2 pattern.
- Each pair of tubules has short arms of another protein - dynein - that extend to neighboring tubules.
- Movement of the flagellum is produced by sliding of the microtubule pairs.
Plant Cells have, in addition to the collection of organelles found in other groups, a **central vacuole** for storage and for producing _______ pressure inside the the cell.

The central vacuole is usually filled with water and solutes. A high solute concentration draws water into the vacuole, expanding the vacuole and the cell.

Because plant cells are enclosed by a cell wall, the expansion of the vacuole can exert pressure on the cell without causing the cell to burst.

Plants have cell walls made of cellulose.

During cell division plant cells build dividing walls between the two new cells called the **cell plate**. An adhesive layer - the **middle lamella** - is laid down between the new cell walls.

Cell walls can be thickened through the addition of materials to the inside of the primary cell wall.
Where did Eukaryotic Cells come from?
The oldest rocks with evidence of fossil cells date to 3.5 billion years. The oldest rocks with cells large and complex enough to be eukaryotic date to 1.0 billion years.
For 2.5 billion years only prokaryotic cells existed on earth.
The best hypothesis for the origin of eukaryotic cells was proposed by Lynn Margulis in the early 1970s. This hypothesis is now called the _____________ ___________.

Eukaryotic cells appear to be the product of a collaboration among different types of prokaryotic cells. Some prokaryotic cells became the host for other prokaryotic cells that lived inside them. Some of the complex organelles of eukaryotes provide evidence for this theory.

Mitochondria and chloroplasts appear to be the direct descendants of energy producing bacteria. Mitochondria are the descendants of bacteria that were capable of oxidative respiration. Chloroplasts are the descendants of photosynthetic bacteria.
Evidence:
Both have their own DNA and ribosomes that are similar to those found in prokaryotes. Both make many of their own proteins and both multiply in a fashion similar to prokaryotic cell division. Both are double membrane organelles - the inner membrane descended from the ancestral guest cell, and the outer membrane descended from the vacuole membrane that was formed around the guest.

Other organelles may also be the product of endosymbiosis. Some centrioles and basal bodies have naked DNA as part of their structure.

There are many modern examples of endosymbiosis involving organisms that can live together or live independently. The same was probably true of the ancestors of endosymbiotic organelles in the distant past.