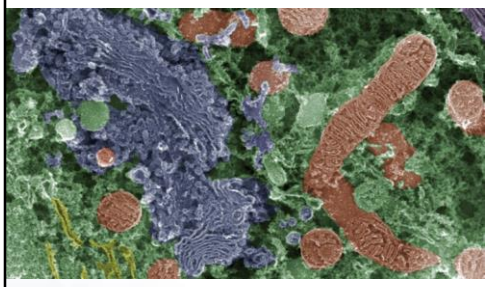

Internal cell structures (organelles) shown in red are mitochondria. The organelle in blue is the Golgi apparatus.

SEM © Dr. David Furness, Wellcome Images, CC-BY-NC-ND 4.0.

The Structure of Cells

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The Structure of Cells

False color scanning electron micrograph showing cellular organelles present in a spiral ganglion neuron. The structures shown in red/orange are mitochondria, which are the energy production units of the cell. The structure in blue is the Golgi apparatus, which is responsible for packaging and secreting lipids and proteins for transport around the cell. These organelles are found in all eukaryotic (plant and animal) cells. This particular image shows organelles in a spiral ganglion neuron. This is a specialist nerve cell of the inner ear that transmits sound signals from the cochlea to the brain.

Image Reference

SEM © Dr. David Furness, Wellcome Images\B0008190. CC-BY-NC-ND 4.0. http://www.wellcome images.org

Key Words

cell, cell structure, eukaryote, prokaryote, animal cell, plant cell, algae, bacteria,

What Are Cells?

- All known living organisms are made up of cells.
- Most genetic material is contained within the central portion of the cell (nucleus).
- The remaining portion of the cell interior is filled with cytoplasm.
- The cell is enveloped in a plasma membrane.

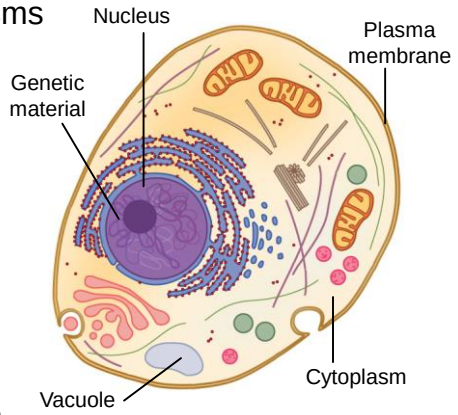

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Illustration courtesy of OpenStax College CC-BY-4.0.

What Are Cells?

•A cell is the simplest collection of matter that can live. There are single-celled organisms, as well as more complex multicellular organisms.
•Cells contain DNA, the genetic material containing genes that code for proteins synthesized by the cell.
•The cytoplasm suspends membrane-bound organelles, which have a specific function, and it contains chemicals that the cell utilizes every day, such as sugars and amino acids. The plasma membrane is a bilayer, made up of phospholipids, which separates the cell from its surroundings.
•Vacuoles are membrane-bound organelles present in all plant and fungal cells, and in some protist, animal and bacterial cells. A vacuole's structure and size varies, depending on the needs of the cells. Some functions include isolating harmful materials, containing waste products, maintaining internal hydrostatic pressure within the cell, maintaining an acidic internal pH, and exporting unwanted substances from a cell.

References

1.Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.
2.Vacuole. Wikipedia CC-BY-SA 4.0. http://en.wikipedia.org/wiki/Vacuole

Image Reference

OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words

cell, cell structure, cytoplasm, genetic material, nucleus, plasma membrane,

Cell Size

- A cell can be seen using a light microscope.
- Prokaryotic cells typically range between 1-10µm in size.
- Eukaryotic cells typically range between 10-100µm in size.
- Cells must be small to allow proteins and other materials to diffuse in and out quickly.
- The size of most cells is limited by their surface area to volume ratio.

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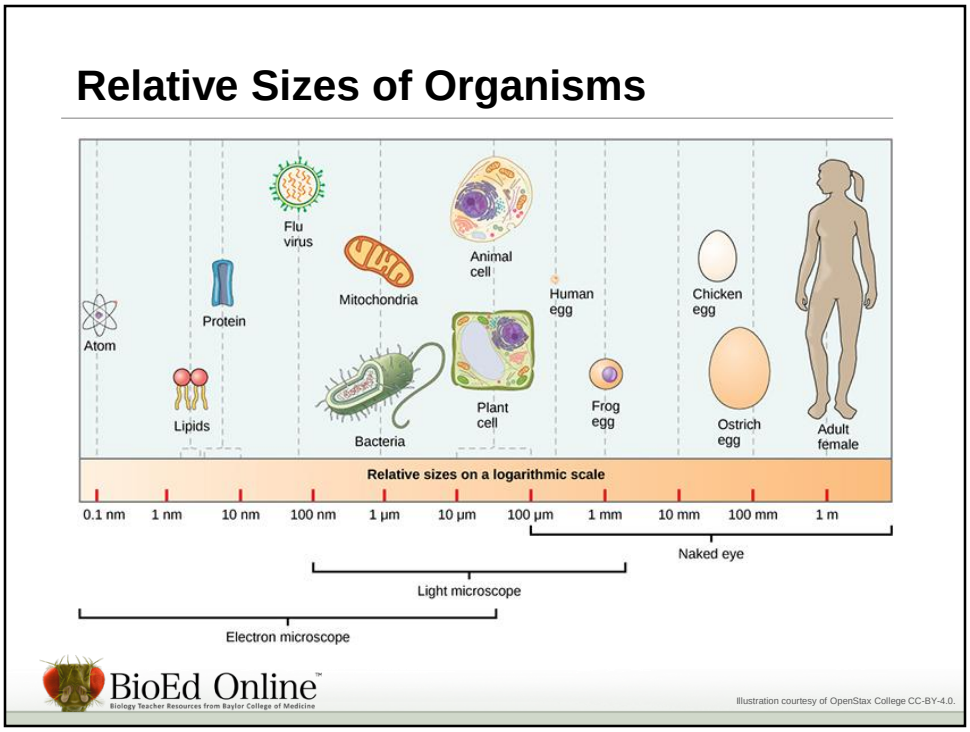
Cell Size
Although cells can be distinguished using a light microscope, smaller organelles must be resolved using a higher power electron microscope.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

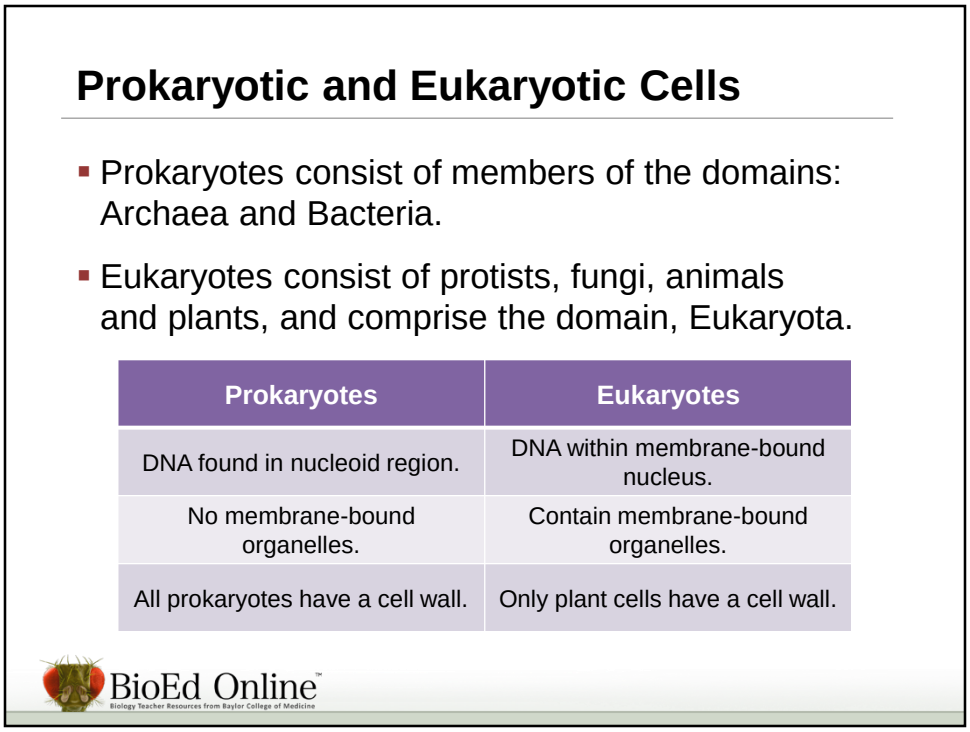
Key Words
cell, cell structure, eukaryote, prokaryote, cell size,



Cell Size: Logarithmic Scale
The image above shows the relative sizes of microbes on a logarithmic scale (10-fold increase in the quantity being measured).

Image Reference
OpenStax College. The Cell: Cell Structure (modified). *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:17/Biology

Key Words
cell, cell structure, eukaryotic, prokaryotic, cell size,



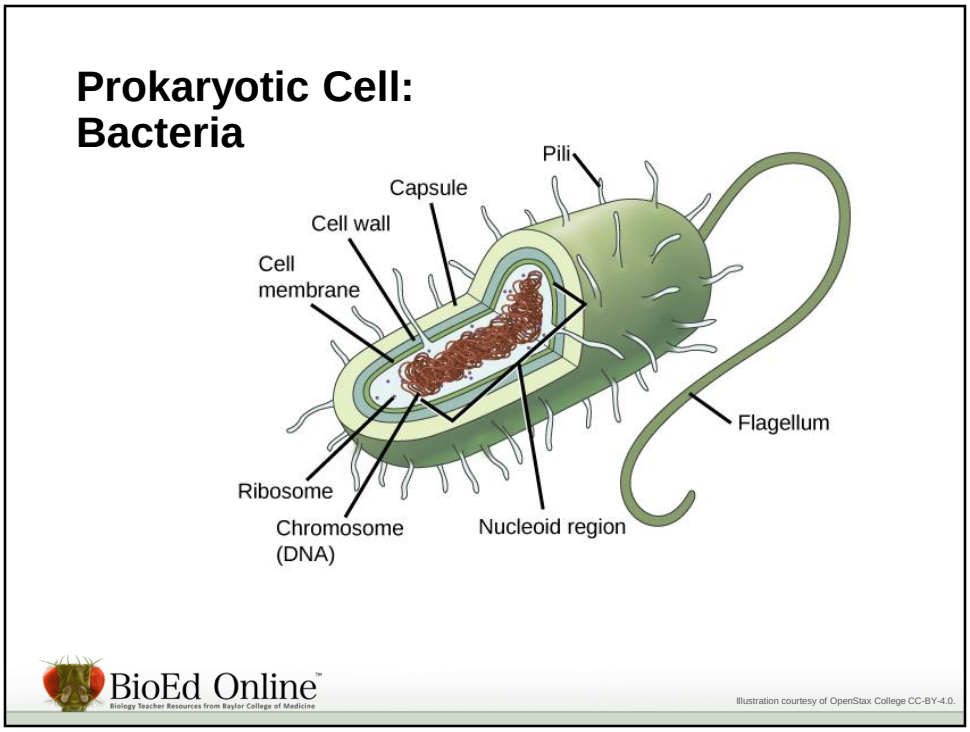
Prokaryotic and Eukaryotic Cells
The basic cell unit can be one of only two types: prokaryotic or eukaryotic.

Prokaryotic cells
Prokaryotes are generally smaller than eukaryotic cells. The major difference between eukaryotic and prokaryotic cells is the location of their DNA. Prokaryotic DNA is located in a central non-membrane bound region, called the nucleoid. No membrane bound organelles are present, only ribosomes that synthesize proteins. Prokaryotes have a rigid cell wall surrounding their plasma membrane.

Eukaryotic cells
Protists, fungi, animals and plants consist of eukaryotic cells. Eukaryotic DNA is located in the membrane-bound nucleus. Eukaryotes also contain many membrane-bound organelles, suspended in cytoplasm, which perform specialized cellular functions. Each cell is enclosed by a cytoskeleton, made up of microtubules and filaments, that helps define the cell's shape.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Key Words
cell, cell structure, eukaryote, prokaryote,

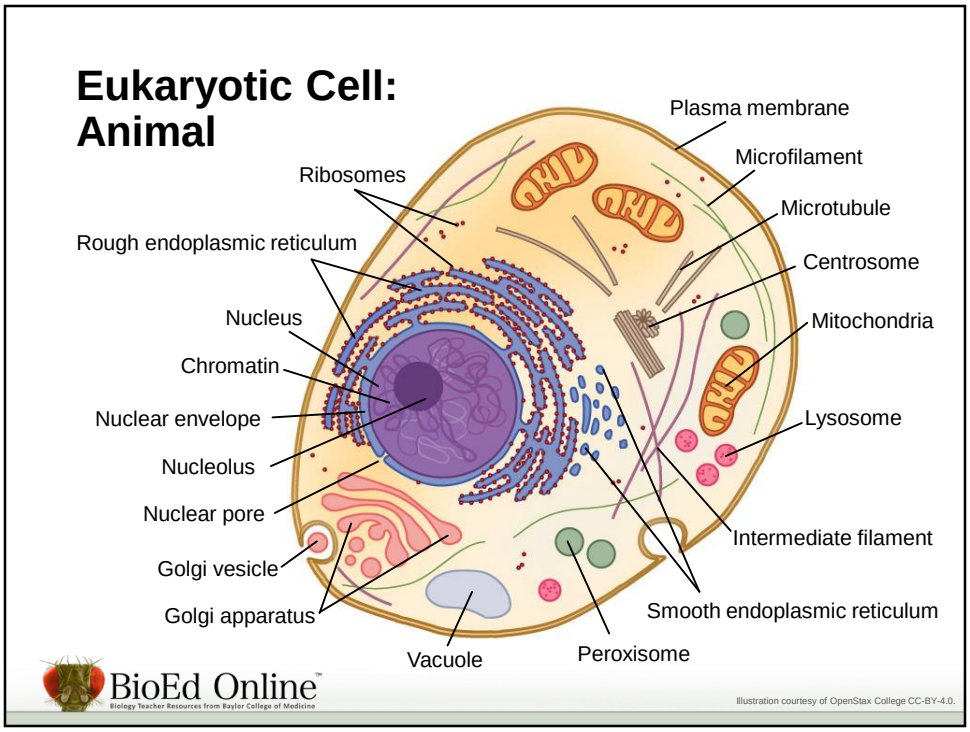


Prokaryotic Cell: Bacteria
A prokaryote is a single-celled organism without a membrane-bound nucleus or other organelles. All of the cell's components are enclosed by its cell membrane. With some exceptions, a prokaryotic cell generally consists of a flagellum to aid in movement, a cell membrane, a cell wall to provide shape, cytoplasm, ribosomes and a nucleoid.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:17/Biology

Key Words
cell, cell structure, prokaryote,



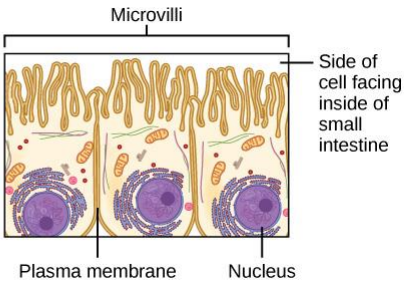
Eukaryotic Cell: Animal
Some major components of an animal cell are the nucleus, rough endoplasmic reticulum, smooth endoplasmic reticulum, Golgi apparatus, ribosomes, mitochondria, lysosomes, peroxisomes, centrosomes, cytoskeleton, plasma membrane, cytoplasm, and sometimes, a flagellum.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words
cell, cell structure, eukaryote,

Plasma Membrane



- Separates the cell from the external environment.
- Made up of lipids and proteins.
- Functions include selective transport and cell-to-cell recognition.

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Plasma Membrane
The plasma membrane encloses the cell, creates defined boundaries, and maintains differences between the cytosol and the external environment. It is comprised of a lipid bilayer that contains proteins and cholesterol, and provides a fluid structure relatively impermeable to water-soluble molecules.

Microvilli, shown above as they appear on cells lining the small intestine, increase the surface area available for absorption. These microvilli are found only on areas of the plasma membrane facing the cavity from which substances will be absorbed.

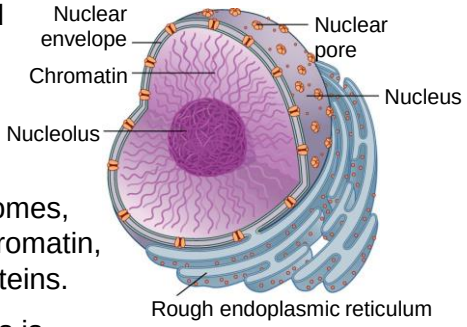
Reference
OpenStax College. Biology: Eukaryotic Cells. OpenStax-CNX CC-BY-4.0. Jan 21, 2015. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.77:18/Biology

Image References
1.TEM courtesy of Jean Paul Revel and Sanford Palay. The Cell: An Image Library. CC-BY-NC-ND 3.0. http://www.cellimagelibrary.org/images/11106
2.OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words
cell, cell structure, eukaryote, plasma membrane,

The Nucleus

- The nuclear envelope is a double membrane that separates the nuclear material from the rest of the cell.
- The envelope is perforated by nuclear pores that regulate transport into and out of the nucleus.
- Within the nucleus, DNA is organized into chromosomes, which are composed of chromatin, a complex of DNA and proteins.
- The dark-staining nucleolus is located within the nucleus and is the site of rRNA synthesis.



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The Nucleus
The nuclear envelope contains proteins, and the nuclear pores are important in regulating the entry and exit of protein and RNAs.

When the cell is in growth and maintenance phases, proteins are attached to its chromosomes, resulting in a thread-like appearance (see illustration above). When a cell is ready to divide, its chromatin condenses into different chromosomes.

The nucleolus—prominent in a nucleus that is not dividing—is the site of ribosomal RNA production.

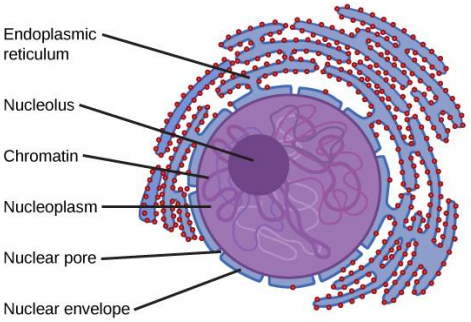
Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. Levels of Organization: The Cellular Level of Organization. *Anatomy & Physiology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@7.24:19/Anatomy_&_Physiology

Key Words
cell, cell structure, eukaryote, nucleus, nuclear envelope, chromatin, nucleolus, nuclear pore,

Rough Endoplasmic Reticulum

- Ribosomes are bound to the cytoplasmic membrane.
- The function of the rough endoplasmic reticulum is to manufacture proteins, which are exported from the cell.



- The rough ER also produces membrane proteins and synthesizes phospholipids for its own membrane.

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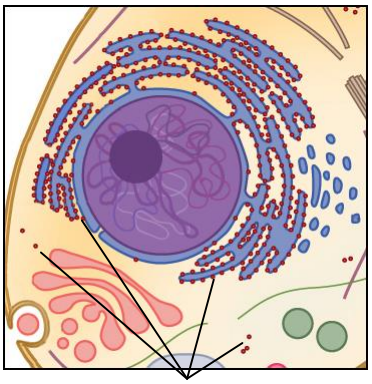
Rough Endoplasmic Reticulum
The rough ER is associated with ribosomes, which make secretory and membrane proteins. Exported proteins are placed in a transport vesicle that allows them to move to another part of the cell. Insulin and glycoproteins are produced by the ribosomes attached to the rough ER.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words
cell, cell structure, eukaryote, rough endoplasmic reticulum, organelle,

Ribosomes



Ribosomes

- The function of ribosomes (red dots) is to synthesize proteins.
- They can be found free within the cytoplasm, making proteins that most often function as enzymes.
- Ribosomes also may be found bound to the rough endoplasmic reticulum or nucleus, making proteins to be used in the membrane, packaged for other organelles, or exported from the cell.

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Ribosomes

Ribosomes are made up of ribosomal RNA and protein, and are composed of two subunits. The more ribosomes found in a cell, the more active the cell is in protein synthesis. Ribosomes may be bound or free, depending on the needs of the cell.

Reference

Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference

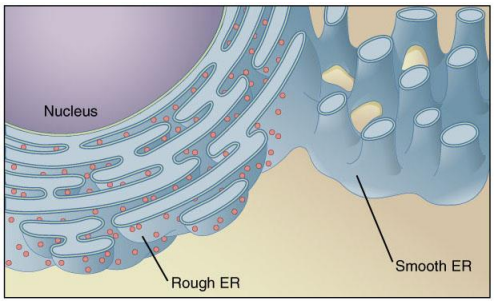
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words

cell, cell structure, eukaryote, ribosome, organelle,

Smooth Endoplasmic Reticulum

- Functions of the smooth endoplasmic reticulum (ER) include lipid synthesis, carbohydrate metabolism, and detoxification of drugs and poisons.
- The smooth ER consists of a network of tubules, called the cisternae. Its cytoplasmic membrane is devoid of ribosomes.



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Smooth Endoplasmic Reticulum
The smooth ER produces oils, steroids and phospholipids. Testes and ovaries are especially rich in smooth ER, as they produce sex hormones. Liver cells store carbohydrates which, when hydrolyzed, must be dephosphorylated by the smooth ER before they can exit the cell. The smooth ER also detoxifies drugs and poisons in the liver.

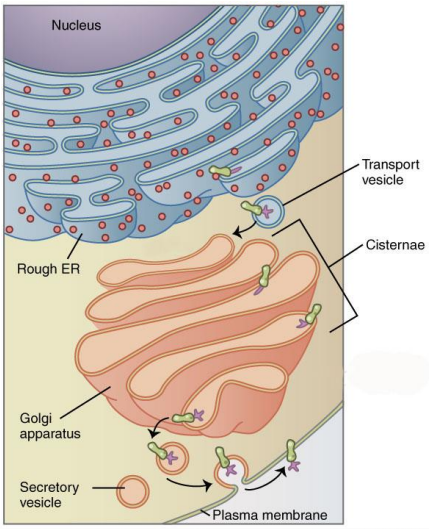
Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. Modification of work by Magnus Manske. Levels of Organization: The Cellular Level of Organization. *Anatomy & Physiology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@7.24:18/Anatomy_&_Physiology

Key Words
cell, cell structure, eukaryote, smooth endoplasmic reticulum, organelle,

Golgi Apparatus

- The Golgi apparatus modifies, stores and ships products from the endoplasmic reticulum.
- Composed of flattened stacks of cisternae, it has a *cis* face and *trans* face.



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Golgi Apparatus
The Golgi apparatus modifies proteins. Transport vesicles from the ER fuse into the *cis* face of the Golgi apparatus. Products being modified make their way from the *cis* face to the *trans* face. Once modification is complete, the *trans* face pinches off and creates vesicles to transport the products.

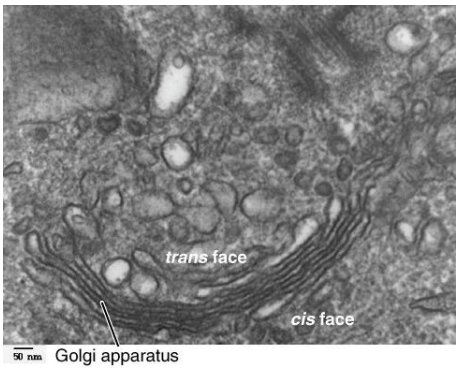
Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. Modification of work by Magnus Manske. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.77:19/Biology

Key Words
cell, cell structure, eukaryote, Golgi apparatus, organelle,

Cis Face and *Trans* Face

- The *cis* face, located near the endoplasmic reticulum, receives the transport vesicles.
- The *trans* face, directed toward plasma membrane, sends out modified products in vesicles.



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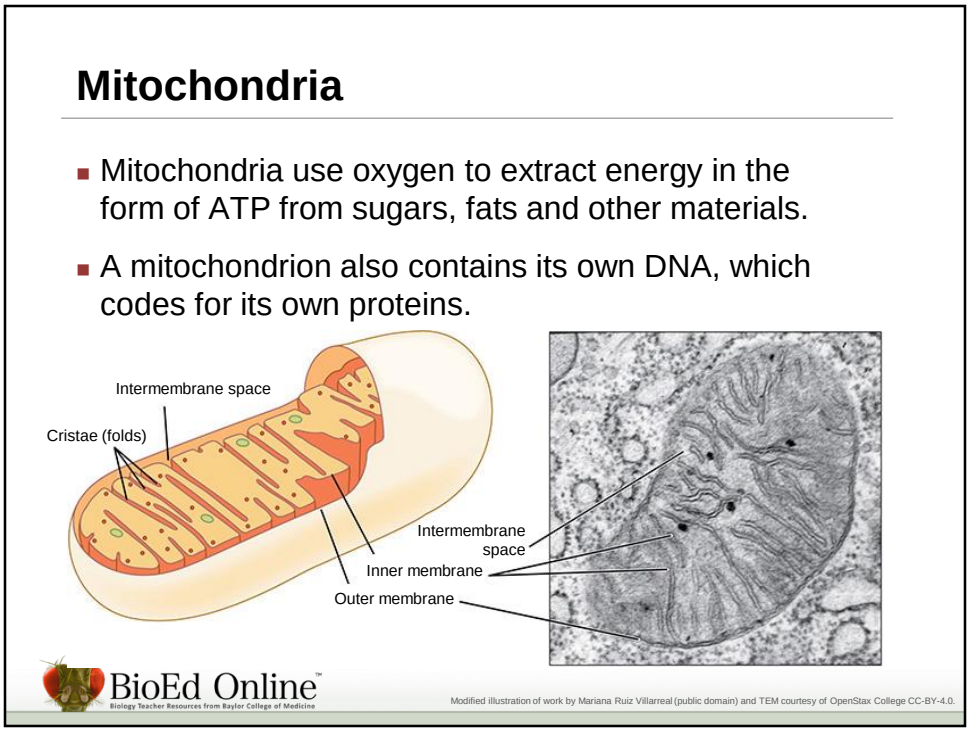
TEM courtesy of OpenStax College CC-BY-4.0.

Cis Face and _Trans_ Face
The *cis* face is located near the endoplasmic reticulum; the *trans* face is directed toward the plasma membrance.

Image Reference
OpenStax College. Modification of work by Linda Howard. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.77:19/Biology

Key Words
cell, cell structure, eukaryote, Golgi apparatus, cis face, trans face, organelle,



Mitochondria
Mitochondria, the cell's powerhouses, consist of a double membrane separated by an intermembrane space. They are found in greater quantity in tissues with high energy needs. Cristae are folds of the inner membrane.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
1.OpenStax College. Modification of work by Mariana Ruiz Villarreal. Levels of Organization: The Cellular Level of Organization. *Anatomy & Physiology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@7.24:18/Anatomy_&_Physiology
2.OpenStax College. TEM courtesy of the Regents of University Medical School. Levels of Organization: The Cellular Level of Organization. *Anatomy & Physiology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@7.24:18/Anatomy_&_Physiology

Key Words
cell, cell structure, eukaryote, mitochondria, organelle,

Lysosomes

- A lysosome is a membrane-bound sac containing hydrolytic enzymes.
- Lysosomes digest cell by and they also play a role in death.

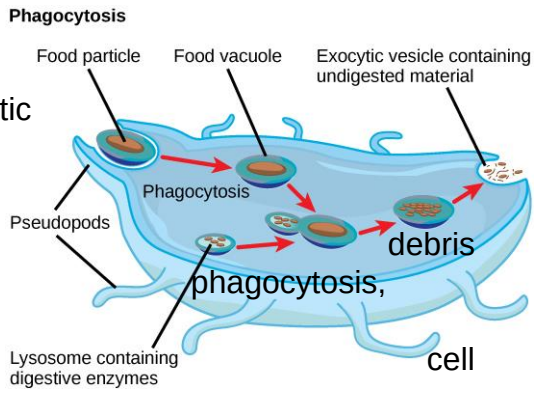


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Illustration courtesy of OpenStax College CC-BY-4.0.

Lysosomes

Lysosomes digest food and waste materials through phagocytosis of food vacuoles that enter the cell. They also can break down damaged organelles and recycle the cell's material, through a process called autophagy.

The enzymes within lysosomes work best in an acidic environment.

Reference

Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference

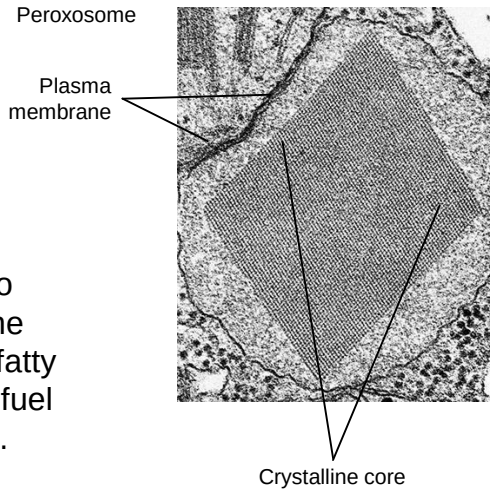
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.77:19/Biology

Key Words

cell, cell structure, eukaryote, lysosome, organelle, phagocytosis,

Peroxisomes

- Peroxisomes are membrane-bound organelles that transfer hydrogen and produce hydrogen peroxide as a by-product.
- They may function to detoxify alcohol in the liver or break down fatty acids to be used as fuel for the mitochondria.



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TEM by D.W. Fawcett, et al., The Cell: An Image Library CC-BY-NC-ND 3.0.

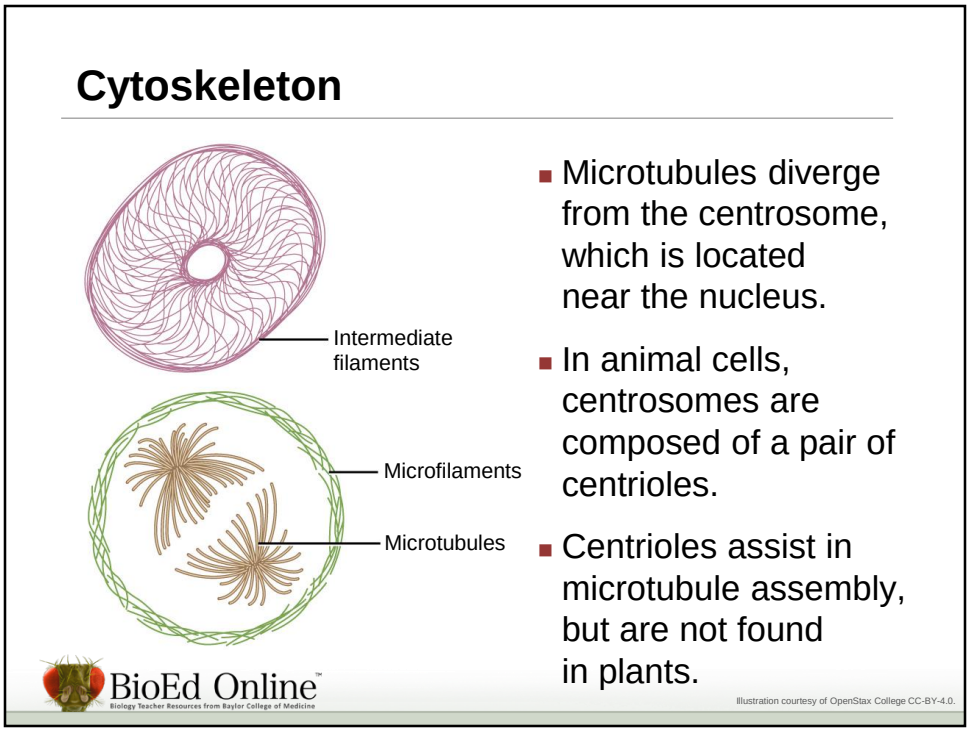
Peroxisomes
Specialized peroxisomes, called glyoxysomes, are found in plant seeds. They convert fatty acids into sugar, which can be used as energy by plant cells until they can undergo photosynthesis. Peroxisomes metabolize wastes.

Image Notes
A peroxisome (microbody) from a cell in a leaf of tobacco (*Nicotiana tabacum*). Crystals within microbodies are common, and these organelles appear in plant, as well as animal cells.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
Image courtesy of Don W. Fawcett, S.E. Frederick and E.H. Newcomb. The Cell: An Image Library. CC-BY-NC-ND 3.0. http://www.cellimagelibrary.org/images/35989

Key Words
cell, cell structure, eukaryote, peroxisome, organelle.



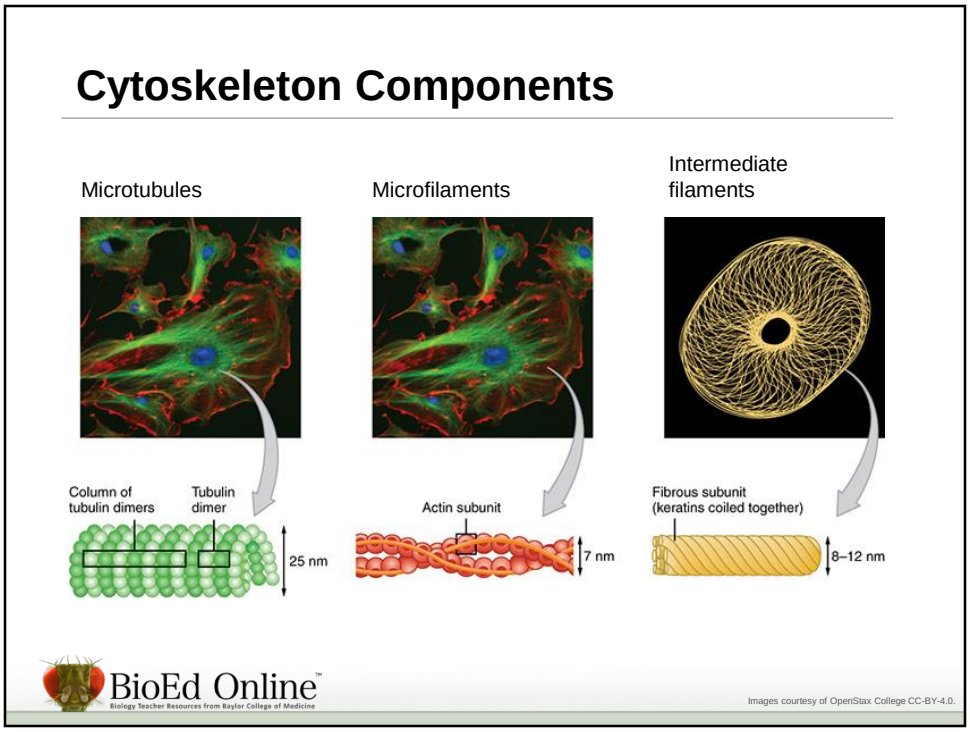
Cytoskeleton
The cytoskeleton is composed of several parts. Microtubules help to maintain cell shape. Centrioles are composed of nine sets of triplet microtubules, arranged in a ring. Cilia and flagella consist of nine doublets of microtubules, arranged in a ring with two single microtubules in the center. Microfilaments are fibrous proteins that hold organelles in place, and also form the cellular cortex.

Cilia beat in a back-and-forth motion. Flagella are normally found one per cell and have an undulating, or snakelike, motion.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:20/Biology

Key Words
cell, cell structure, eukaryote, cytoskeleton, centrioles, centrosome, microtubule,



Cytoskeleton Components
The components of the cytoskeleton are important to cell structure and shape, cell movement and cell division.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference
OpenStax College. Levels of Organization: The Cellular Level of Organization. *Anatomy & Physiology*. OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@7.24:18/Anatomy_&_Physiology

Key Words
cell, cell structure, eukaryote, cytoskeleton, microtubule, microfilament, intermediate filament,

Cytoskeleton Components

Property	Microtubules	Microfilaments	Intermediate Filaments
Diameter	**25 nm**	**7 nm**	**8-12 nm**
Functions	• Maintain cell shape • Cell motility (cilia and flagella) • Chromosome movement • Organelle movement	• Maintain cell shape • Changes in cell shape • Cell motility (pseudopodia) • Muscle contraction • Cytoplasmic streaming • Cleavage furrow	• Maintain cell shape • Anchor nucleus • Form nuclear lamina

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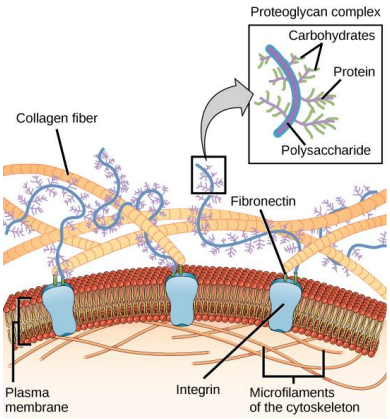
Cytoskeleton Components
The cytoskeleton functions in structural support, intra-cellular transport, and cell motility.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Key Words
cell, cell structure, organelle, microtubule, microfilament, intermediate filament,

Extracellular Matrix: Animal Cells



- The extracellular matrix (ECM) of animal cells consists of collagen, fibronectin, and proteoglycan complexes.
- The ECM can regulate cell behavior, and it communicates through mechanical and chemical signaling.

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Illustration courtesy of OpenStax College CC-BY-4.0.

Extracellular Matrix: Animal Cells

Collagen is the most abundant glycoprotein in the extracellular matrix (ECM). The ECM can transmit signals to the cytoskeleton through membrane proteins, known as integrins.

Reference

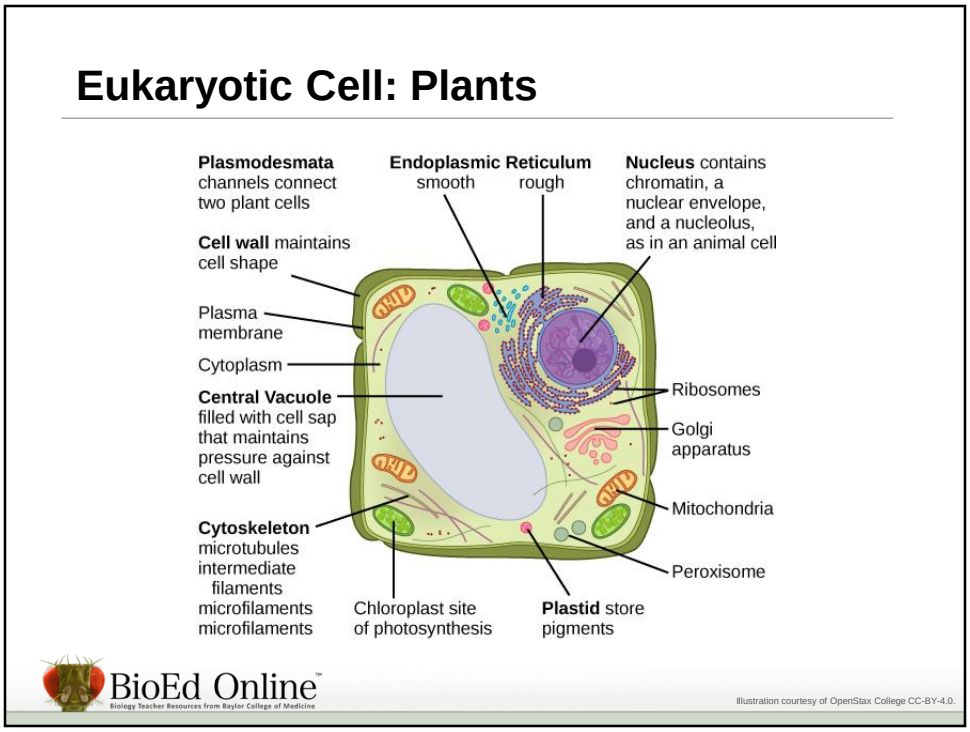
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image Reference

OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:21/Biology

Key Words

cell, cell structure, animal, eukaryote, extracellular matrix,



Eukaryotic Cell Structure: Plants
Some major components of the plant cell are the: nucleus, rough ER, smooth ER, golgi apparatus, ribosomes, mitochondria, peroxisomes, cytoskeleton, plasma membrane, cytoplasm, chloroplasts, central vacuole, cell wall and plasmodesmata.

Present in plant cells, but not in animal cells, are the chloroplasts, central vacuole, cell wall, and plasmodesmata. Plant cells have no lysosomes, flagella, or centrosomes with centrioles.

The central vacuole is formed by the aggregation of smaller vacuoles. Central vacuoles elongate as they absorb water, allowing cells to increase in size without having to make more cytoplasm.

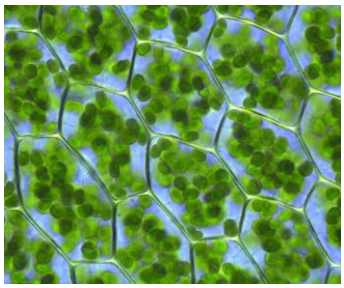
Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

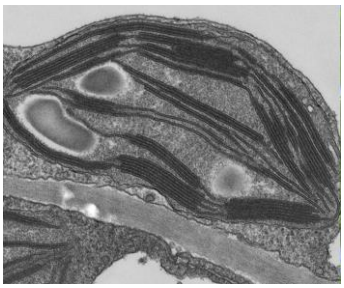
Image Reference
OpenStax College. The Cell: Cell Structure. *Biology.* OpenStax-CNX CC-BY-4.0. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.80:18/Biology

Key Words
cell, cell structure, eukaryote, plants,

Chloroplasts

- Chloroplasts are found in plants and algae cells, and are the sites of photosynthesis.
- They absorb solar energy and convert it into chemical energy, which can be used by the cell and transported.





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Chloroplasts
Chloroplasts are enclosed in a double membrane system. They consist of flattened sacs, called thylakoids, which can be stacked into granum. Thylakoids are surrounded by fluid called stroma. Within the stroma are DNA, ribosomes and enzymes.

Grana are stacks of thylakoids (organelles) that join together to form one functional unit. This is the site of light-dependent photosynthetic reactions with photosynthetic pigment in the membrane.

Image Notes
On the left is a light-microscopic image of chloroplasts in the cells of *Plagiomnium affine*, the many-fruited thyme moss. On the right is a transmission electronic image of a single chloroplast within *Coleus blumei* leaf. The three large round areas are starch granules. The dark “lines” are grana.

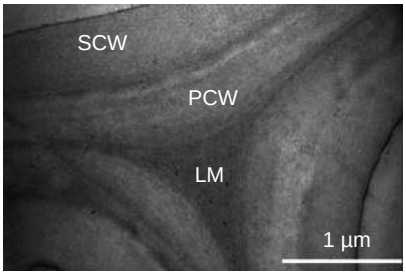
References
1.Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.
2.Wikipedia. Thylakoid. CC-BY-SA 4.0. http://en.wikipedia.org/wiki/Thylakoid

Image References
1.Light microscopic photo © Kristian Peters, CC-BY-SA 3.0. http://en.wikipedia.org/wiki/Chloroplast#mediaviewer/File:Plagiomnium_affine_laminazellen.jpeg
2.TEM courtesy of Linda Howard and Charles Daghlian, PhD. Public domain. Electron Microscope Facility, Dartmouth College. http://remf.dartmouth.edu/Botanical_TEM/images/06%202b-coleusleaf-4.jpg

Key Words
cell, cell structure, eukaryote, algae, chloroplast, grana, photosynthesis, plant, thylakoid,

Cell Wall of Plants

- Plants' cell walls maintain the rigidity of the plant cell and regulate water uptake in the cell.
- Plant cell walls are thicker than the plasma membrane and consist of three layers: Middle lamella (LM), primary cell wall (PCW), and secondary cell wall (SCW).
- Cellulose is a major component of the cell wall.



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TEM courtesy of RC Corrales, et al., Open *i*, CC-BY-SA 2.0.

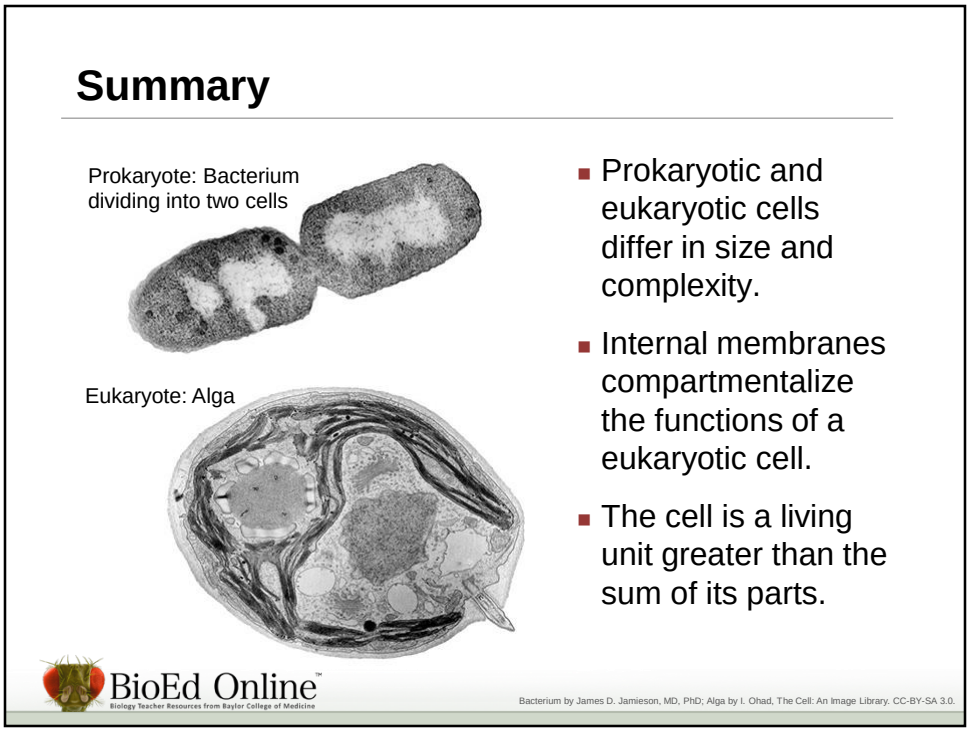
Cell Wall of Plants
Cellulose provides structural integrity to the cell wall. As a plant grows, its cell wall will become thicker to provide more support.

Image Note
TEM image of untreated sugar cane bagasse clearly showing the primary cell wall (PCW), secondary cell wall (SCW), and middle lamella (LM).

Reference
1.Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.
2.Wikipedia. Vacuole. CC-BY-SA 4.0. http://en.wikipedia.org/wiki/Vacuole

Image Reference
Corrales RC, FM Mendes, CC Perrone, C Sant'anna, W de Souza, Y Abud, EP Bon, V Ferreira-Leitão. Open *i*: An Open Access Biomedical Image Search Engine. National Library of Medicine, NIH. CC-BY-SA 2.0. http://openi.nlm.nih.gov/detailedresult.php?img=3431990_1754-6834-5-36-2&query=middle%20lamella&req=4&npos=25

Key Words
cell, cell structure, eukaryote, plant, cell wall, lamella, middle lamella,



Summary
Cells can be classified as either unicellular (bacteria and archaea) or multi-cellular (plants and animals). Different types of cells with different functions can exist within one organism.

Image Notes
1.Prokaryote: TEM of a longitudinal thin section of a dividing *Escherichia coli* bacterium. The centrally located nucleoid is prominent.
2.Eukarote: TEM showing a central longitudinal section of a unicelluar green alga *Chlamydomonas reinhardtii*. Internal membranes of different types of organelles can be clearly seen, including a pyrenoid surrounded by starch granules within the cup-shaped chloroplast, Golgi organelles, mitochondria and the nucleus.

Reference
Campbell, N.A., and J.B. Reece. (2008). *Biology,* 8th Edition. San Francisco, CA: Pearson Benjamin Cummings.

Image References
1.TEM of *C. reinhardtii* by I. Ohad. George E. Palade EM Slide Collection. Department of Cell Biology, Yale University School of Medicine/The Cell: An Image Library. CC-BY-NC-SA 3.0. http://www.cellimagelibrary.org/images/37252
2.TEM of *E. coli* by James D. Jamieson, MD, PhD. George E. Palade EM Slide Collection. Department of Cell Biology, Yale University School of Medicine/The Cell: An Image Library. CC-BY-NC-SA 3.0. http://www.cellimagelibrary.org/images/37254

Key Words
cell, cell structure, eukaryote, prokaryote, bacteria, bacterium, alga, algae