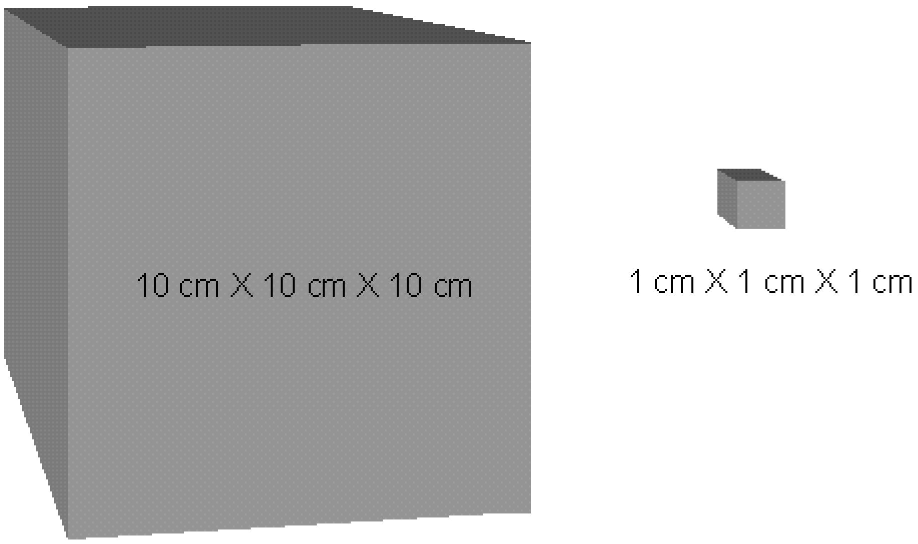
Lecture 3 - Cells

Exercise - Surface:Volume

Compare the surface to volume ratio (surface:volume) of a cube that is 1 cm X 1 cm X 1 cm with that of a cube that is 10 cm X 10 cm X 10 cm.



Smaller cube (1 cm X 1 cm X 1 cm)

The surface area of one side = 1 cm X 1 cm = 1 square cm (or 1 cm^2).

There are 6 sides, so the total surface area = 6 X cm^2 = 6 cm^2.

Volume = 1 cm X 1 cm X 1 cm = 1 cubic cm (or 1 cm^3)

Surface:Volume = 6 cm^2/1 cm^3 = 6 cm^2/cm^3 (or 6 square cm of surface area for each cubic cm of volume)

Larger cube (10 cm X 10 cm X 10 cm)

The surface area of one side = 10 cm X 10 cm = 100 square cm (or 100 cm^2).

There are 6 sides, so the total surface area = 600 X cm^2 = 600 cm^2.

Volume = 10 cm X 10 cm X 10 cm = 1000 cubic cm (or 1000 cm^3)

Surface:Volume = 600 cm^2/1000 cm^3 = 0.6 cm^2/cm^3 (or 0.6 square cm of surface area for each cubic cm of volume).

Cells

Notice that the larger cube has more surface area and more volume but less surface area for each cubic centimeter of volume. For any given geometric object (cubes, spheres, etc.), smaller objects have a greater surface to volume ratio (surface:volume) than larger objects of the same shape.

Every cell is surrounded by a plasma membrane (discussed below and in the next chapter). Most cells are very small and therefore have a high ratio of plasma membrane surface to cell volume.

Cell Theory

All organisms are composed of cells, and a cell is the smallest unit of living matter.

Cells come only from preexisting cells.

Major Kinds of Cells

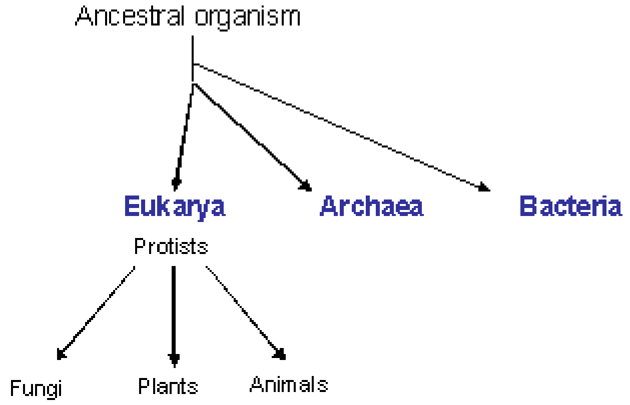
Prokaryotic Cells

Bacteria are prokaryotes. Their cells are very small and very simple. They will be discussed later.

Eukaryotic cells

All other cells are eukaryotic cells. These include protists, fungi, plants, and animals.

The diagram below shows evolutionary relationships between bacteria, archaea, and the four kingdoms of eukaryotic organisms.



Eukaryotic Cells

Cells contain structures called ***organelles***. The structure and function of the major organelles found in eukaryotic cells are described below.

Plasma membrane

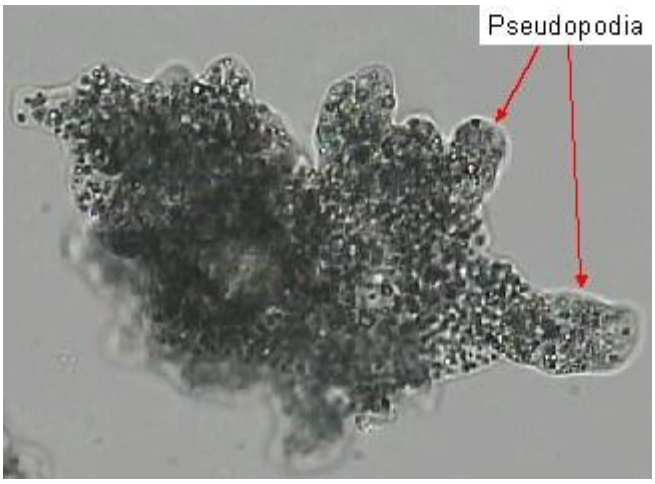
All cells are surrounded by a plasma membrane. It separates the contents of the cell from its environment and regulates the passage of molecules into and out of the cell.

The membrane contains proteins that have a variety of functions. For example, some proteins are receptors which can detect the presence of certain kinds of molecules in the surrounding fluids. The function of membrane proteins will be discussed in more detail in the chapter on membranes.

An actively metabolizing cell needs a large surface area. Cells are limited in size because larger cells have a smaller surface to volume ratio.

Cells that are specialized for absorption (ex: intestinal cells) have folds in the plasma membrane called ***microvilli*** that increase the surface area.

Pseudopodia are temporary extensions of the plasma membrane used for movement or to engulf particles. Pseudopodia can be seen in the *Amoeba* below.

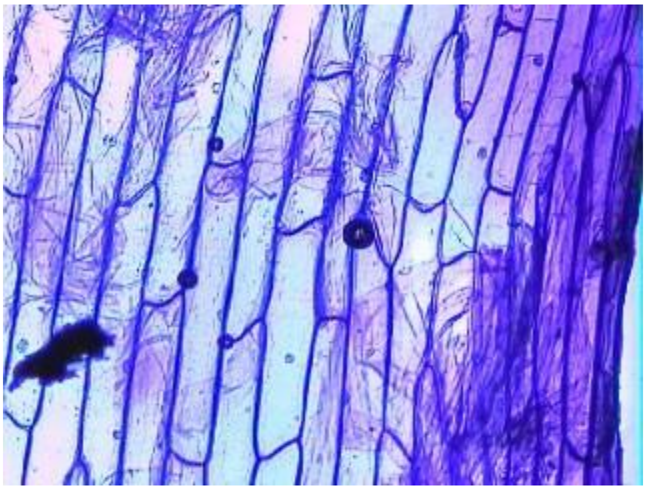


Cell Wall

The cell wall functions to support and protect the cell.

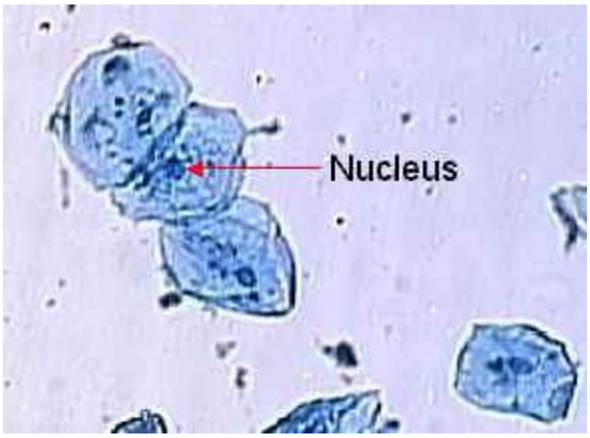
Plants have cell walls composed of cellulose; fungi have walls composed of chitin.

The cell walls of these onion skin cells can be easily seen.



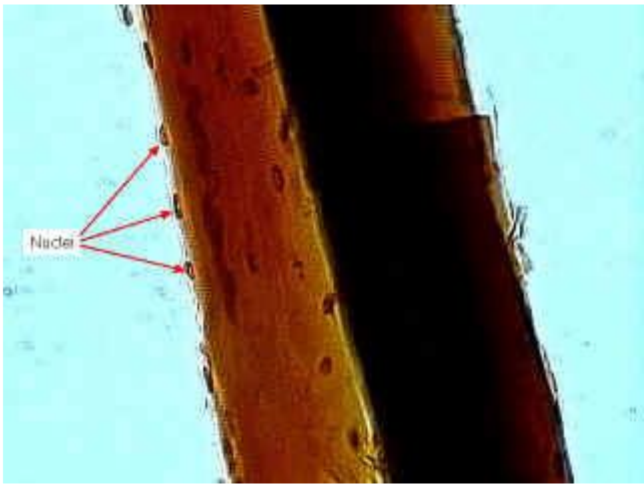
Nucleus

The nuclei can be seen in the photograph of human cheek cells below.



The nucleus contains DNA; it is therefore the control center of the cell because DNA contains instructions needed to produce proteins that control metabolism and other cell functions.

One nucleus can serve a limited amount of cytoplasm, so large cells are often ***multinucleate***, that is, they contain several nuclei.



Teased skeletal muscle X 200

Note the many nuclei visible in the cell on the left.

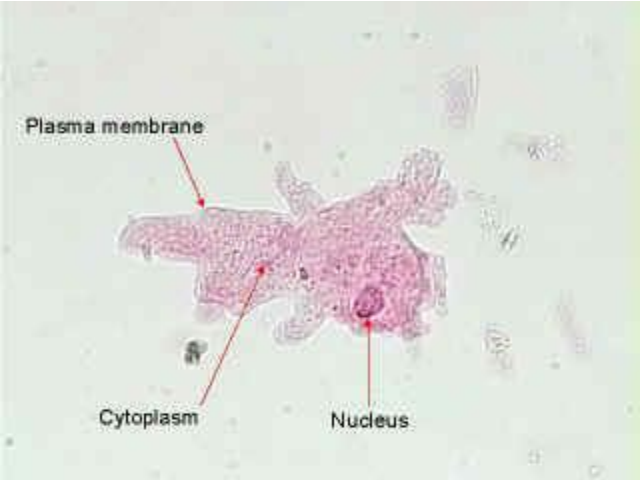
Chromatin is the grainy threadlike DNA. During cell division, the nuclear membrane disintegrates and the DNA becomes coiled producing visible structures called ***chromosomes***.

The material within the nucleus is referred to as the ***nucleoplasm***.

A double membrane (nuclear envelope) surrounds the nucleus. ***Nuclear pores*** allow materials to pass into and out of the nucleus.

Cytoplasm

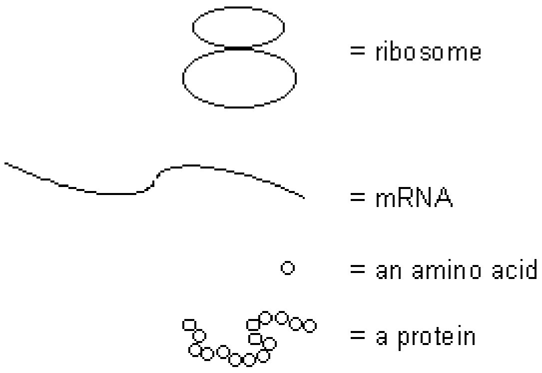
Cytoplasm is the material enclosed by the plasma membrane, excluding the nucleus.

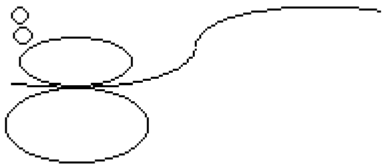


Ribosomes

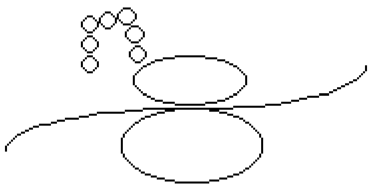
Ribosomes read the code in mRNA and synthesize protein accordingly.

The symbols to the right are used in the drawings of protein synthesis below.

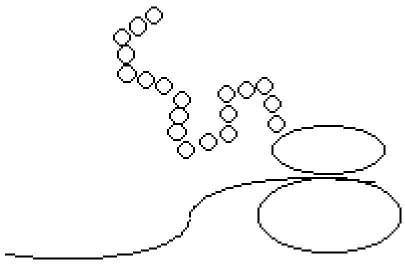




The ribosome attaches to the mRNA.



As ribosomes move along messenger RNA (mRNA), the amino acids are added to a growing chain to form a particular protein. In these drawings, the ribosome moves from left to right.



In this drawing, the protein is nearly complete. When the ribosome reaches the end of the genetic message, it will become detached from the mRNA.

Several ribosomes may be attached to a strand of mRNA forming a unit called a polysome.

A ribosome is composed of 2 subunits. In eukaryotic cells, the subunits are synthesized in the ***nucleolus*** and move into the cytoplasm. During the process of protein synthesis, two subunits will come together along with mRNA..

Ribosomes are composed of both ***RNA*** (called ribosomal RNA or rRNA) and ***protein***.

Ribosomes in eukaryotes about 1/3 larger than those in prokaryotes.

Nucleolus

The nucleolus is a structure within the nucleus where the ribosomal subunits are produced.

In cells that have been stained, it appears darker than the nucleus.

Endoplasmic Reticulum

The endoplasmic reticulum is a membranous network that extends throughout the cell.

It is continuous with the nuclear envelope and the plasma membrane.

Rough Endoplasmic Reticulum

The rough appearance of rough endoplasmic reticulum is due to the presence of ribosomes on the membrane.

The rough ER functions in protein synthesis, especially proteins that are to be secreted to outside the cell (example: hormones). Proteins enter the lumen (interior) of the endoplasmic reticulum while being synthesized.

In addition to protein synthesis, the rough endoplasmic reticulum also functions in the modification of newly formed proteins. For example, some enzymes may add carbohydrate chains forming glycoproteins. Other enzymes function to fold the newly-synthesized proteins into their proper shape.

Vesicles are small sacs that pinch off the endoplasmic reticulum or Golgi apparatus (discussed below) and transport molecules to other parts of the cell.

Smooth Endoplasmic Reticulum

Smooth endoplasmic reticulum has no ribosomes attached to it. It is continuous with rough endoplasmic reticulum.

The smooth endoplasmic reticula have a variety of different functions but often function to produce lipid compounds such as phospholipids, steroids, and fatty acids.

Certain kinds of cells have smooth endoplasmic reticulum with a specialized function. The following are some examples:

Smooth endoplasmic reticulum is abundant in the adrenal cortex and the testes where it produces steroid hormones.

The smooth endoplasmic reticulum of liver cells helps detoxify drugs in the blood.

Calcium ions needed for contraction are stored in the smooth endoplasmic reticulum of muscle cells.

Vesicles pinch off the smooth endoplasmic reticulum and carry materials to other parts of the cell such as the plasma membrane or Golgi apparatus.

Golgi Complex (also Golgi Apparatus or Golgi Body)

The Golgi complex is a stack of 3 to 20 flattened, slightly curved saccules which appear like a stack of pancakes.

It receives vesicles that contain molecules from the endoplasmic reticulum. Chemical reactions within the Golgi complex modify the molecules. Materials are passed from one saccule to the next through vesicles that form at the end of the saccule, pinch off, and fuse with the next. Processed molecules are pinched off in a vesicle.

Vesicles arriving at the Golgi complex from the endoplasmic reticulum are received into the forming face. The processed molecules leave at the maturing face.

Lysosomes

Lysosomes are membrane-bound vesicles containing *hydrolytic* (digestive) enzymes produced by the Golgi complex.

They fuse with other vesicles formed around material that has entered the cell, allowing the digestion of the vesicle contents. For example, bacteria that are engulfed by white blood cells are destroyed by enzymes contained within the lysosomes.

Cells also use lysosomes to kill themselves. This important process occurs during the formation of fingers during embryonic development, the reduction in the size of a tadpole tail as it matures, and the abscission of tree leaves in the autumn.

Peroxisomes

Peroxisomes are vesicles that contain enzymes which oxidize (remove hydrogen) from a variety of different compounds and pass the hydrogen to oxygen. During these reactions, hydrogen peroxide (H_2O_2) is formed.

Hydrogen peroxide is toxic but the enzyme ***catalase*** converts it to water and oxygen.

$2H_2O_2 \rightarrow 2H_2O + O_2$

Vacuoles

Vacuoles are membranous sacs similar to, but larger than vesicles.

Vacuoles store water and dissolved substances.

They are more important in plant cells. Most of the center of a plant cell is occupied by a ***central vacuole.***

The central vacuole gives support because pressure within the vacuole makes the cell rigid (turgid). The cell wall prevents the cell from bursting.

Some protists have specialized ***contractile vacuoles*** for eliminating excess water and ***food vacuoles*** that contain food within the cell.

Cellular Respiration

Cellular respiration refers to the chemical reactions that break down glucose to CO_2 and H_2O, releasing the energy stored within its bonds.

The energy is temporarily stored in the bonds of ATP (adenosine triphosphate).

$ADP + P_i + \text{energy} \rightarrow ATP$

This process requires oxygen in ***aerobic*** organisms. ***Anaerobic*** organisms do not require oxygen, but produce much less ATP per glucose molecule.

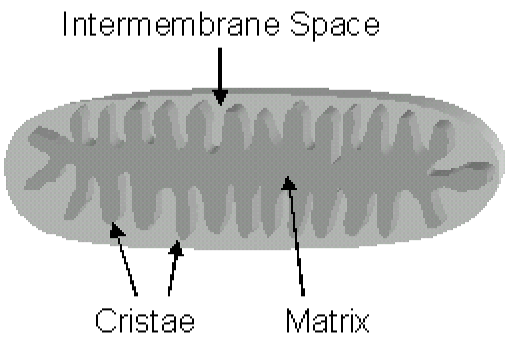
Aerobic cellular respiration occurs in the ***mitochondria***.

Prokaryotes do not have mitochondria.

Mitochondria

Mitochondria have an external membrane and an inner membrane with numerous folds called ***cristae***.

The cristae that project into the gel-like ***matrix.*** Enzymes involved in cellular respiration are found in the matrix and embedded in the membrane of the cristae.



Cytoskeleton

The cytoskeleton is a network of protein elements that extend through the cytoplasm in eukaryotic cells.

It provides for the distinctive shape of cells such as red blood cells, muscle cells, and nerve cells (neurons). It produces movement of cells and is associated with movement of materials within cells.

It is composed of three types of protein fibers: ***microtubules***, ***actin filaments***, and ***intermediate filaments***. The general function of each of these is listed in the table below.

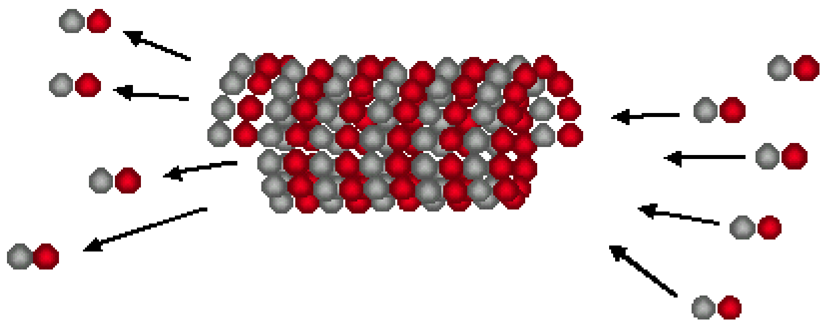
Cytoskeleton Element	**General Function**
Microtubules	Move materials within the cell Move the cilia and flagella
Actin Filaments	Move the cell
Intermediate Filaments	Provides mechanical support

Microtubules

Microtubules are small cylindrical fibers that change in length by assembling (polymerizing) and disassembling (depolymerizing).

They are made of a protein called tubulin. Tubulin dimers are arranged to form a long hollow cylinder.

The fibers are lengthened and shortened as tubulin dimers assemble or disassemble from one or both ends of the filament.



The assembly of microtubules is controlled by an area near the nucleus called the ***centrosome*** or microtubule organizing area..

Microtubules act as tracts along which organelles can move. For example, they are associated with movement of vesicles from the Golgi complex to the plasma membrane.

Microtubules are responsible for the movement of cilia and flagella.

They move the chromosomes during cell division.

Cilia and Flagella

Cilia and ***flagella*** are hairlike structures projecting from the cell that function to move the cell by their movements. They contain cytoplasm and are enclosed by the plasma membrane.

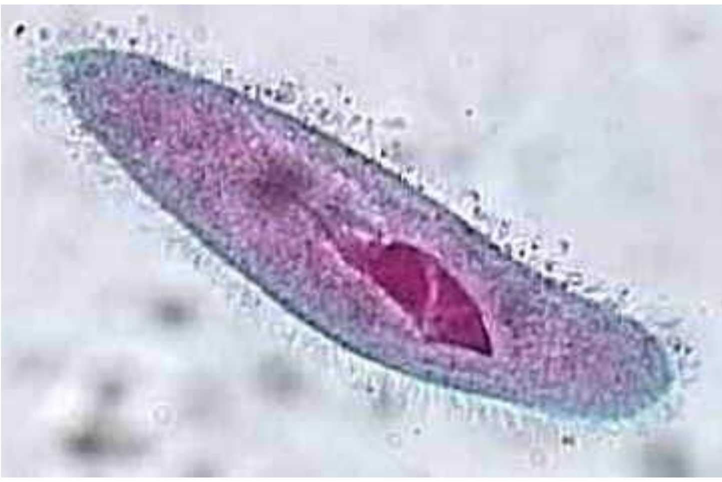
Cells that contain cilia are ***ciliated***.

Cilia are shorter than flagella but are similar in construction.

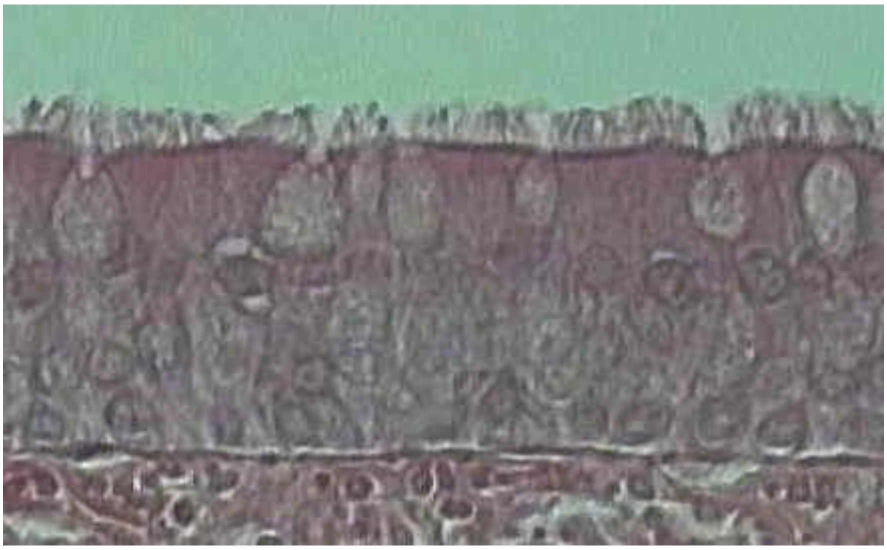
Examples:

Sperm use flagella to move.

Many kinds of single-celled organisms such as the *Paramecium* in the photograph below move by cilia or flagella. The cilia can be seen covering the cell in the photograph.

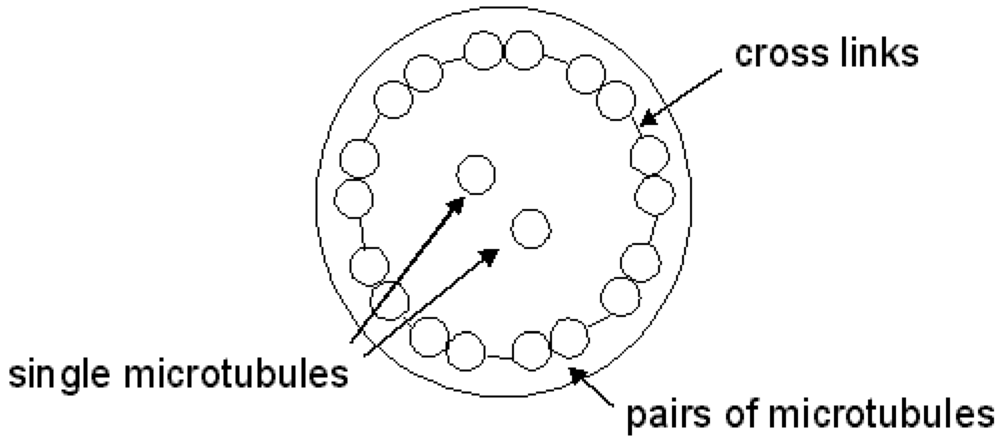


Cells lining the human upper respiratory tract are ciliated (have cilia). The cilia move mucous and debris upward to the mouth where it is swallowed. The photograph below is a cross section of a human trachea (400 X). Note the cilia on the upper surface.



Eukaryotes have 9 doublets (pairs) of microtubules arranged in a circle around 2 central microtubules. This 9 + 2 pattern is characteristic of all eukaryotic cilia and flagella but not those of prokaryotes.

The pairs of microtubules are cross-linked. The shifting positions of the cross-links move the cilia or flagella.



Basal Body

Each cilium or flagellum has a ***basal body*** located at its base.

Basal bodies anchor the cilia or flagella and are thought to be responsible for their formation.

Basal bodies contain triplets of microtubules along the periphery but do not have central microtubules (9 + 0).

They look like centrioles (discussed below) and are believed to be derived from them.

Centrioles and Centrosome

The structure of centrioles is similar to that of basal bodies in that they have 9 triplets of microtubules. Centrioles occur in pairs; each one oriented at a right angle to the other.

Centrioles are contained within a structure called a ***centrosome***. The centrosome and centrioles are involved in the formation of the microtubules.

Actin Filaments (Microfilaments)

Actin filaments are long, thin fibers composed of 2 chains of protein wrapped around each other.

They occur in bundles or meshlike networks which provide mechanical support and determine the shape of the cell.

Because they can assemble and disassemble quickly, the shape of a cell can change rapidly.

Movement in eukaryotic cells

Actin filaments assist in the movement of nearly all eukaryotic cells.

Microvilli and pseudopodia move by the action of actin filaments.

Actin filaments are important in muscle contraction.

During cell division a ring of actin filaments that surrounds the cell constricts, pinching the cell into two.

The chloroplasts of plant cells move (circulate) by following actin filaments, a process called ***cytoplasmic streaming***.

Intermediate Filaments

Intermediate filaments are composed of long, threadlike protein molecules wrapped around one another like the strands of a cable.

As the name suggests, they are intermediate in size. Actin filaments are smallest and microtubules are largest.

Intermediate filaments are important in maintaining the cell's shape, providing mechanical support; preventing excessive stretching, and supporting other organelles. For example, some intermediate filaments support the plasma membrane and others support the nuclear membrane. Skin cells contain intermediate filaments that provide mechanical strength. They also function to attach cells together (desmosomes).

Prokaryotic Cells

Prokaryotic cells are small; eukaryotic cells are typically 10 times bigger in diameter and 100 to 1000 times bigger in volume.

Prokaryotic cells do not have a true ***nucleus***. They have few organelles, and have ***no membrane-bound organelles***. In cyanobacteria, the cell membrane folds inward in a number of places allowing for the attachment of enzymes.

The DNA of prokaryotes is a single, circular ***chromosome*** located in a region called the ***nucleoid***. There may be small rings of accessory DNA called ***plasmids***.

Some prokaryotic cells are photosynthetic (example: cyanobacteria).

The cells have a cell wall and some contain a gelatinous sheath outside the cell wall.

Motile bacteria have ***flagella***.

Prokaryote ***ribosomes*** are smaller than those in eukaryotes.

Cell reproduction is by ***binary fission***, not mitosis. By this process, a second chromosome is produced that is an identical copy of the first. The cell elongates and the chromosomes separate so that each new cell receives a chromosome. The elongated cell pinches into two, forming two cells each with one chromosome.