The Cell Theory

- postulated by Schleiden, Schwann, and Virchow
- is composed of three (3) tenets:

1. Cells are the smallest and most basic unit of structure and function of organisms

2. All organisms are composed of cells

3. Cells arise from pre-existing cells

Cells – Identification and Classification

- First record of seeing a cell and identifying it belongs to Robert Hooke
- All cells share common structural features:

<u>1. Cell/plasma membrane</u>

-the outer boundary of the cell which separates its contents from the environment. It varies in composition.

<u>2. Cytoplasm</u>

-a gel-like substance that constitutes the cells internal environment and holds all of the structural components of the cell.

<u>3. Genetic material</u>

-Deoxyribose nucleic acid (DNA) is the genetic material which holds information for cell activities and function

<u>4. Ribosomes</u>

-structures that manufacture proteins which are needed for cell function

- Cells can differ in number, size, components, and composition
- Based on structural differences, cells can be classified as either <u>Prokaryotic</u> or <u>Eukaryotic</u>

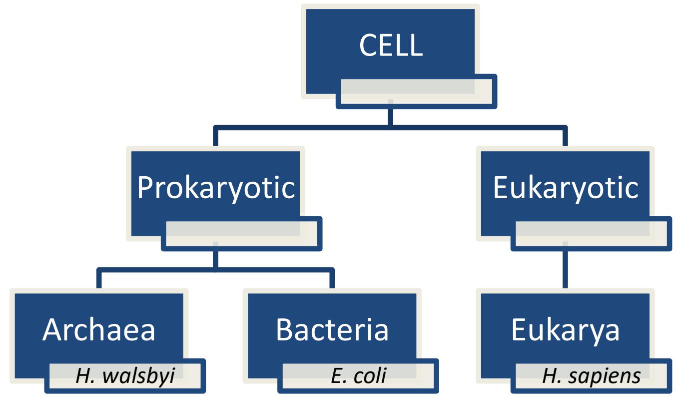

Figure 1.0 Classification of Organisms Based on Cell Structure

Pro= before, Eu= true, karyon= kernel. The main difference between prokaryotes and eukaryotes, therefore, is the presence of an enclosed structure to separate the genetic material of the cell, known as the <u>Nucleus</u>.

Prokaryotic Cells

- Earliest and most primitive cells
- Contains only simple structures with very little differentiation
- Size varies from 0.1-5 µm (with few exceptions)
- Consists of organisms from the Domain Archaea and Bacteria

For Structure	
Capsule	The outermost layer that encases the entire cell for additional protection. Usually composed of polysaccharides
Cell wall	A rigid case that encloses the entire cell and gives it shape. For <u>Bacteria: Peptidoglycans</u> are present, while for <u>Archaea: No peptidoglycans</u> are present.
Plasma membrane	A semipermeable membrane that encloses the internal structures of the cell that regulates the passage of molecules into and out of the cell. For <u>Bacteria: Fatty acids</u> are what composes this membrane, while for

	Archaea: Non-fatty acid lipids are its composition.
Mesosome	Folds of the plasma membrane that enter the area of the cytoplasm. This is where the electron transport system for the creation of cell energy is located.
Cytoplasm & Cytosol	The gel-like substance that fills the interior of the cell. It holds the other components of the cell. The cytosol is the liquid portion of the cytoplasm

Table 1.0 Components of a Prokaryotic Cell used for Structural Integrity

For Activities and Function	
Ribosome	Small structures that are scattered throughout the cytoplasm for the process of protein synthesis. Prokaryotes have a 50s and 30s subunit, forming a 70s ribosome.
Pili	Tubular structures present in the cell surface for cell-to-cell communication and passing of genetic material.
Flagellum	A tail-like appendage anchored to the cell membrane and wall that allows a prokaryote locomotion through a circular motion. This can either be seen at the end of the cell or scattered randomly.
Fimbriae	Additional small and bristle-like fibers scattered throughout the cell surface. They are used for attachment, navigation, and propelling certain molecules or objects toward the cell.

Table 1.1 Components of a Prokaryotic Cell used for Cell Activities and Motor Function

For Genetic Material	
Nucleoid	Region of the cell where DNA is present. Prokaryotes do not have an enclosed structure for its genetic material such as a nucleus. Ribosomes and enzymes are seen near this region
Plasmid	Small independent loops of DNA which are separate from the chromosomal DNA found in the nucleoid. This is important for the genetic advantages of prokaryotes.

Table 1.2 Components of a Prokaryotic Cell used for Genetic Function

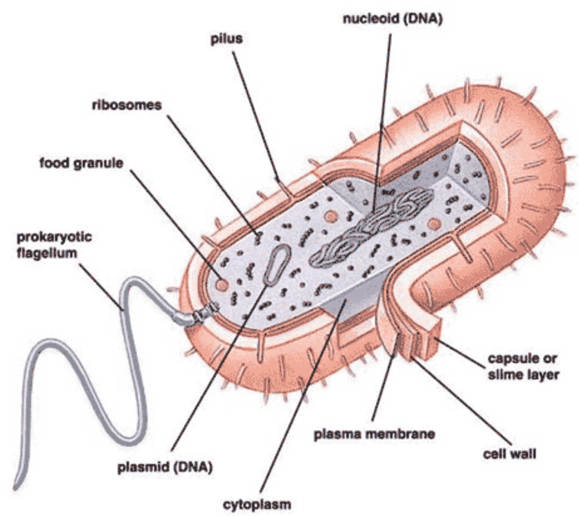

Image 1.0 A Labeled diagram of a Prokaryotic Cell
Source: https://owlcation.com/stem/Biolog-101-Cells

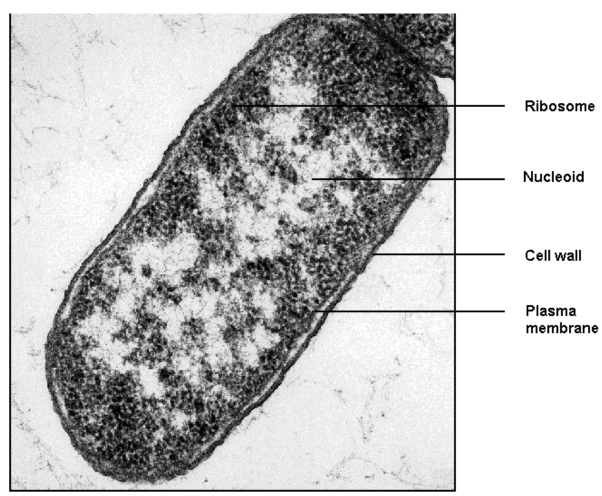

Image 1.1 A Labeled micrograph of a *E. coli*
Source: http://ibbiology.wikifoundry.com/

Eukaryotic Cells

- Highly evolved, complex structures, and larger size compared to prokaryotes
- Size varies from 10-100 µm (with few exceptions)
- Exhibits heavy Compartmentalization of internal structures known as Organelles
- Divided into Protista, Fungi, Plantae, and Animalia
- Derivations vary per classification, but all have the general components of a typical eukaryotic cell
- Cell structures can be categorized as either for:
  1. Structures for protection
  2. Genetic control organelles
  3. Manufacturing, Storing, Distributing, and Breakdown organelles
  4. Energy processing organelles
  5. Organelles for structural support, movement, and communication between cells

I. STRUCTURES FOR PROTECTION

Cell Membrane

- Functions as a barrier to separate the environment and the internal structures of the cell
- Also regulates the passage of molecules to and from the cell
- Composed of two (2) sheets of phospholipids, hence the name Phospholipid bilayer
  - Phospholipids are organic molecules that exhibit both polar (hydrophilic) and non-polar (hydrophobic) ends.
  - The cause of its bipolar nature is due to the three (3) key structures it possesses:
    - Charged Phosphate group
    - Three carbon glycerol molecule
    - Two fatty acid tails
  - The charged phosphate group and the glycerol molecule form the phospholipids polar head
  - The two (2) fatty acids makeup the non-polar hydrophobic tail
  - The hydrophobic tails move away from the environment and cluster together forming the middle portion of the lipid bilayer of the plasma membrane, while the hydrophilic heads are faced toward the environment.
  - Because the middle portion of the membrane is non-polar, this causes it to have selective permeability, meaning non-polar molecules such as glucose cannot pass freely through the cell

Membrane Proteins

- The cell membrane is also composed of proteins and other molecules which are randomly scattered
- The presence of membrane proteins and other molecules is why the cell membrane is termed as Fluid Mosaic (coined by Nicolson and Singer).

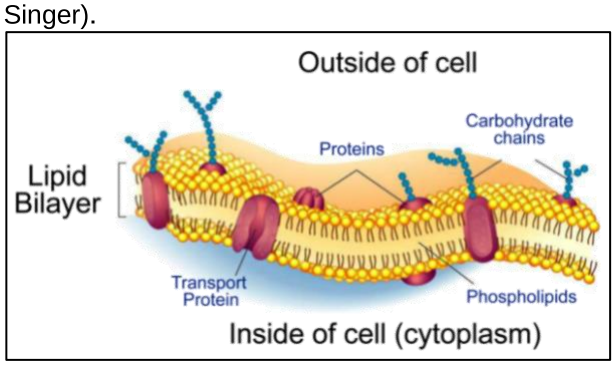

Image 2.0 A Fluid Mosaic Model Showing the Structures of the Cell Membrane
Source: https://biofoundations.org/repairing-the-cell-membrane/

Structures Embedded in Cell Membrane	
Transport Proteins	Create passageways for ions and non-polar molecules to pass freely through the cell membrane
Channel Proteins	Form tunnels for the import and export of materials and wastes
Cell Recognition Proteins	Enable cells to distinguish own cells from that of other organisms
Junction Proteins	Assist in cell-to-cell adhesion and communication between cells
Receptor Proteins	Facilitate exchange of signals between cells by changing its shape to allow specific molecules (ligands) to bind to it
Enzymatic Proteins	Participate in metabolic reactions such as degradation and synthesis to sustain life in the cell
Carbohydrate Chains	Serve as identification tags for the cell recognition proteins
Cholesterol	Strengthens the cell membrane by making it more flexible but less fluid. It also makes the membrane less permeable to water-soluble substances

Table 2.0 Structures Embedded in the Cell Membrane and their Functions

Cell Wall

- An additional boundary between the cell membrane and the environment for added structural support and protection
- Only found in plant cells (but also present in prokaryotic bacteria)
- Composition varies per classification. Some examples would be:

  1. Plants and algae: Polysaccharide cellulose

     Because cellulose is rigid and does not allow free passage of molecules, plants and algae have openings which allow water and molecules to diffuse

  2. Fungi: Chitin

Cytoplasm

- It is the jellylike substance contained within the cell membrane. Generally composed of the cell organelles (not including the nucleus) and cytosol
- Cytosol is the liquid component of the cytoplasm and is largely composed of water
- Organelles are compartmentalized structures which offer efficiency and provides the cell the ability to do different complex metabolic reactions in localized areas

  1. Membranous organelles (single membrane)

     Golgi body, lysosomes, smooth and rough endoplasmic reticulum, vesicle, vacuole

  2. Membranous organelles (double membrane)

     Nucleus, mitochondria, plastids

  3. Non-membranous organelles

     Ribosome, centriole

II. GENETIC CONTROL ORGANELLES

Nucleus

- The storehouse of genetic information (DNA). It functions to prevent damage to the DNA and direct all cell activity.
- Numerous proteins are needed for genetic function, so the nucleus has specialized structures to facilitate their entry:

  1. Nuclear envelope

     A two (2) membrane structure that encloses the nucleus and separates it from the cytoplasm

  2. Perinuclear space

     The space between the two (2) membranes of the nuclear envelope

  3. Nucleoplasm

     The semifluid substance inside the nucleus

  4. Nuclear pores

     Perforations in the nuclear envelope that regulate the passage of materials (usually proteins, ribosomes, and RNA)

  3. Nucleolus

     Condensed region of the nucleus where synthesis of ribosomal RNA (or rRNA) and ribosomal subunits are centralized

     rRNA is combined with imported proteins to form the large and small ribosomal subunits. These subunits exit through the nuclear pores and combine once within the cytoplasm

DNA

- The long-chain molecule of inheritance made of segmented portions called genes which contains the information needed for cell activities (such as protein synthesis)
- The molecule is compacted by proteins called histones which form a condense structure called chromatin and condenses further into chromosomes when cell division is occurring.
- There are two types of chromatin seen in the nucleus:

  1. Euchromatin

     Contains active DNA, stains lightly when viewed under the microscope

  2. Heterochromatin

     Contains inactive DNA, stains deeply when viewed under the microscope

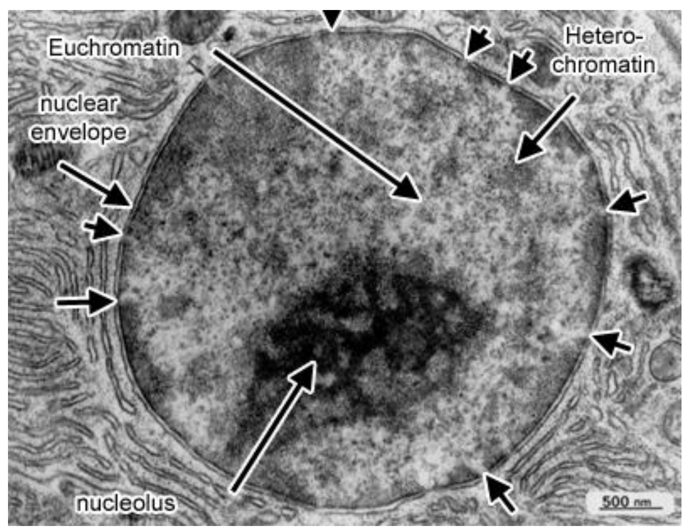

Image 2.1 A Micrograph of a Nucleus Showing its Specialized Structures
Source: https://www.histology.leeds.ac.uk /cell/nucleus.php

III. MANUFACTURING, STORING, DISTRIBUTING, AND BREAKDOWN ORGANELLES

Endoplasmic Reticulum (ER)

- An extensive folded membrane that occupies a large space in the cytoplasm.
- Due to its large size, the ER is folded like a maze where the membranous tubules and flattened sacs are called cisternae, while the spaces between them are the cisternal space
  - The cisterna (singular) is continuous with the nuclear envelope, and so the perinuclear space is also continuous with the cisternal space
  - This connection allows the synthesized ribosomes from the nucleolus to be transported directly to the ER

The presence of ribosomes in the ER allows it to be classified into two (2) regions:

1. Rough ER (RER)

Region closest to the nucleus whose cisternae are flattened sacs, and are studded with ribosomes, giving it a rough appearance when viewed from the microscope

Proteins are formed and temporarily stored in the cisternal space

A short carbohydrate attaches to the formed protein (converting it into a glycoprotein, a secretory protein) thereby making it ready for cell use

Secretory proteins are moved to the specialized transitional ER, where transport vesicles take them to the Golgi body for further packaging

Secretory proteins made from the RER are typically used by specialized cells (i.e. pituitary glands: hormones), or can even be secreted outside the cell (i.e. mammary glands: milk proteins)

2. Smooth ER (SER)

Region adjacent to the RER where no ribosomes are present and whose cisternae are membranous tubules

Its main functions are mostly involving metabolic processes such as synthesis and transport of lipids, metabolism of carbohydrates, and detoxification of drugs and poisons.

A specialized form of SER in muscle cells is the sarcoplasmic reticulum where calcium ions are stored and released. When a nerve signal stimulates the muscle the release of ions triggers a contraction

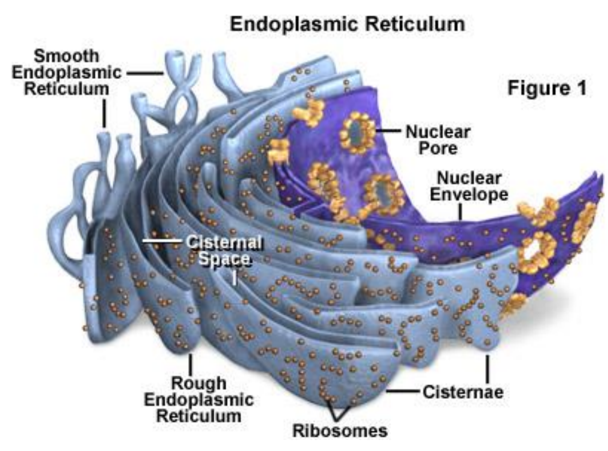

Image 2.2 Diagram of an Endoplasmic Reticulum Showing its Specialized Regions
Source: https://cellsorganelles.weebly.com/packaging-shipping-and-producing.html

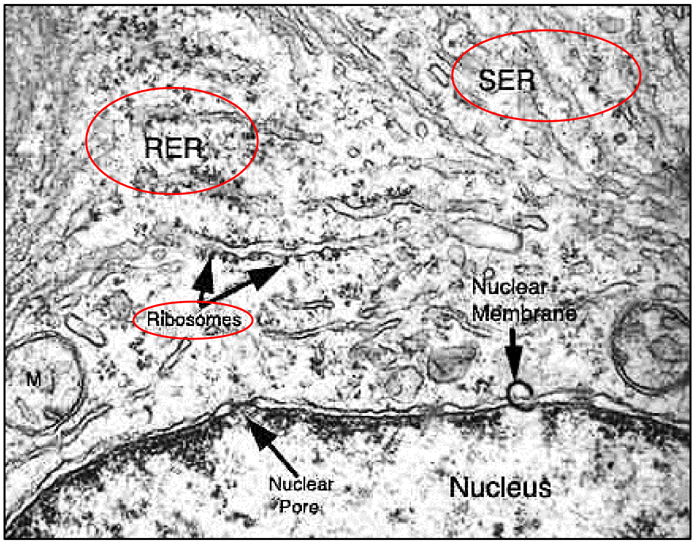

Image 2.3 Micrograph of an Endoplasmic Reticulum Showing its Specialized Regions
Source: http://ibbio.pbworks.com/w/page/59800989/Prokaryotic %20and%20Eukaryotic%20Cells

Ribosomes

- Sites of protein synthesis
- Spherical granules composed of two subunits, the <u>large subunit</u> and <u>small subunit,</u> synthesized in the nucleolus. These subunits exit to the cytoplasm and combine to form ribosomes
- Each ribosome consists of ~70 proteins and several ribosomal RNA (rRNA)
- Found as either <u>bound ribosomes</u> attached to the RER and nuclear membrane, or <u>free ribosomes</u> suspended in the cytosol
    - They are structurally identical and can alternate roles depending on the needs of the cell
- Proteins synthesized by free ribosomes function as <u>enzymes</u> or <u>structural proteins</u>
- Proteins synthesized by bound ribosomes function as <u>secretory proteins</u> or <u>hormones</u>

Golgi Apparatus/Body

- Stacks of cisternae which acts as a processing system that sorts, modifies, and packages products from the ER
- Proteins finish their folding here to become functional
- Enzymes in the Golgi body manufacture and attach carbohydrates that serve as name tags for the cell
- The Golgi has specialized regions that interact with the ER, the rest of the cell, and with each other through vesicles budding off from the Golgi cisternae
- These regions are arranged from the closest to the ER up to the ones near the plasma membrane:

<u>1, Cis-face</u>

The receiving end of the Golgi. Where transport vesicles from the ER are fused with the cisterna of the Golgi. Also responsible for the returning incorrectly sent proteins back to the ER

<u>2. Dictyosome/medial-face</u>

Bulk or main stacks of cisternae. Responsible for processing proteins and lipids and directing them to their destinations.

<u>3. Trans-face</u>

The shipping end of the Golgi. Sorts and directs the modified proteins to their destination by budding off <u>secretory vesicles</u>

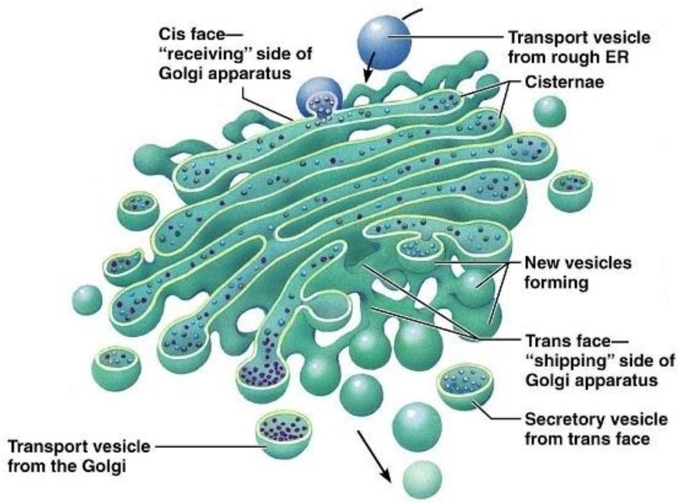

Image 2.4 Diagram of Golgi Body
Source: http://animalia-life.club/other/golgi-apparatus-labeled-diagram.html

Image 2.5 Micrograph of Golgi Body
Source: https://www.thinglink.com/scene/698921523674611713

Lysosomes

- Free floating organelles that contain enzymes that dismantle and recycle food particles, captured bacteria, worn-out organelles, and debris
- The enzymes, known as lysozyme, originates from the RER, is recognized, refined, and packaged by the Golgi body where it fuses with transport vesicles carrying cell debris
- The main function of lysosomes is intracellular digestion by means of autophagy

Peroxisome

- Structurally identical to lysosomes however, the enzymes present are from the Golgi body and have much higher concentrations than lysosomes
- Mainly function to dispose of toxic substances and lipids

IV. ENERGY PROCESSING ORGANELLES

Mitochondria

- Double membranous structures that supply energy to the cell by means of cellular respiration
- Consists of their own ribosomes and DNA, which is the basis of the endosymbiotic theory
- The space between the double membranes is called the intermembrane space
- The two membranes of the mitochondria allow it perform functions for cellular respiration:

  1, Outer Membrane

  Smooth continuous boundary that encapsulates all the contents of the mitochondria

  2. Inner Membrane

  Has intricately folded structures called cristae where enzymes responsible for cellular respiration are located. The number of cristae is proportional to the energy requirements of the cell In between these folds is the mitochondrial matrix

This region also contains DNA and ribosomes for the genetic function of the mitochondria

- Mitochondria are the sites of energy production where adenosine triphosphate (ATP), the cell's source of chemical energy, is synthesized
- The process of converting energy-rich molecules (e.g. pyruvate) is known as the Kreb's Cycle which makes use of pyruvate oxidation and produces carbon dioxide as a waste product
- Mitochondria are considered semi-autonomous organelles because they can grow and divide on their own

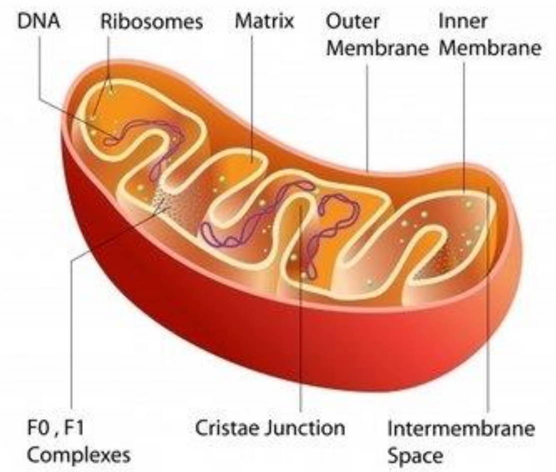

Image 2.6 Diagram of Mitochondria
Source: https://biology.tutorvista.com/animal-and-plant-cells/mitochondria.html

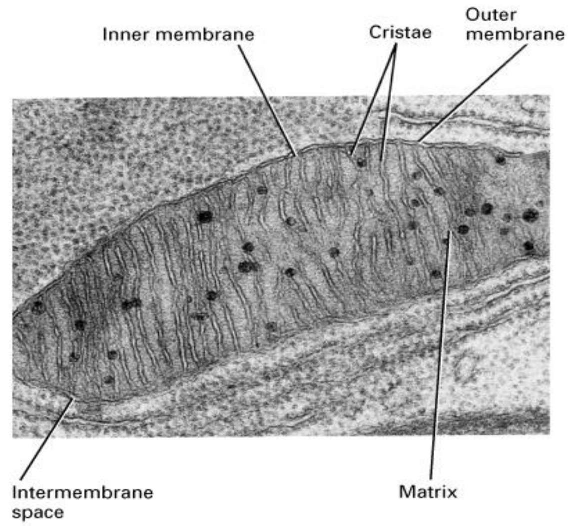

Image 2.7 Micrograph of Mitochondria
Source: https://www.thestudentroom.co.uk/show thread.php?t=1422067

Plastids

- A group of large organelles only found in plant cells and not animal cells. Can be divided into 3 groups:

  1. Chloroplasts

  Green colored plastids due to the green pigments: chlorophyll a and bChloroplasts are the sites of energy production in plants because this is where photosynthesis occurs. This process makes use of solar energy and transforms it into energy-rich molecules

  Chloroplasts are parallel to mitochondrion due to their double membrane features and the presence of their own DNA. It has other specialized structures such as:

  a. Outer Membrane

  b. Inner Membrane

  c. Thylakoid

The third membrane system folded into flattened sacs. Photosynthetic pigments such as chlorophyll a and b are found here, which is why this is where light-dependent reactions occur here

The thylakoid membrane separates the stroma and the grana

d. Granum

Stacks of thylakoids that increase the surface area for the attachment of chlorophyll

Each chloroplast has around 50 grana, and each granum is made of around 50 thylakoids

Each granum is connected to the other by an intergranal lamellae

e. Stroma

An enzyme-rich gel-like matrix found inside the chloroplast. It contains DNA, ribosomes, photosynthetic enzymes, lipid droplets, and starch.

This is where light-independent reactions occur via the enzymes present

2. Chromoplasts

Colored plastids rich in pigments such as carotenoids instead of chlorophyll which give fruits, flowers, and leaves their orange, yellow, and red colors

Chromoplasts can arise from chloroplasts that have lost their chlorophyll (i.e. ripening of fruits)

3. Leucoplasts

Non-colored plastids that do not contain pigments. They function mainly as storage for nutrients

Starch filled leucoplasts are called Amyloplasts. Those that store oil are called Elaioplsts, and those that store proteins are called Aleuroplasts

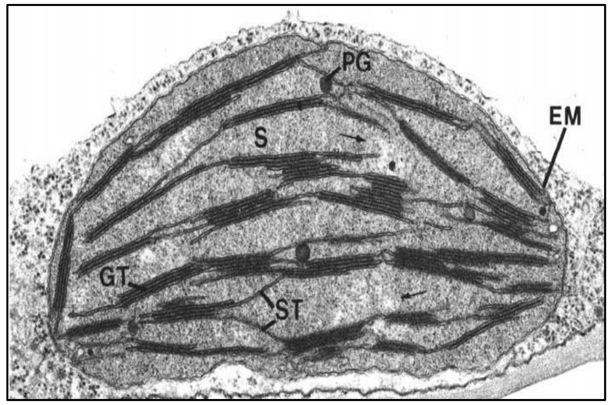

Image 2.8 Micrograph of Chloroplast

S: Stroma, **EM**: Envelope Membrane, **GT**: Granular Thylakoid, **ST**: Stroma thylakoid

Source: https://www.researchgate.net/figure/Thin-section-electron-micrograph-of-a-young-tobacco-chloroplast-Two-envelope-membranes_fig2_7536996

V. ORGANELLES FOR STRUCTURAL SUPPORT, MOVEMENT, AND COMMUNICATION BETWEEN CELLS

Cytoskeleton

- A flexible network of protein threads and fibers that provide mechanical and structural framework of support throughout the cell. Additionally, it helps in directing cell movement, transport, and responses
- There are three (3) major protein components of the cytoskeleton:

1. Microtubule

The thickest and longest filament composed of tubulin assembled into hollow tubes that can rapidly add or remove tubulin molecules

It can function as a trackway where specialized proteins use it as a path to carry cargo such as vesicles

2. Intermediate Filament

Smaller than microtubules and appears ropelike. Provides the cell tensile strength, thus allowing it to stretch without breaking. It is composed of multiple protein subunits

3. Microfilament

The thinnest filament composed of actin which is present in nearly all cell types of eukaryotes. It can provide strength to resist stretching, compression, and assists in anchorage

Actin filaments are especially notable in muscle cells, where it works together with myosin to produce muscle contractions

Centrosomes and Centrioles

- A small dense region in the cytoplasm where microtubules are assembled and arranged, thus termed the Microtubule Organizing Center (MTOC)
- Inside the centrosome are two hollow cylinders made of filaments (which are microtubule triplets) called the centriole
- The centriole is composed of 9 filaments arranged in a circular pattern
- Centrosome division is crucial in preceding and stimulating cell division:

1. Division of Centriole

Each centriole will divide into two (2), and each of the two (2) pairs will move into opposite poles of the cell

2. Formation of asters and spindle fibers

From the pair of centrioles, asters will form and will be the source of a system of microtubules called spindle fibers where chromosomes can attach and be pulled toward the respective poles. Plant cells do not form asters when dividing

Centrioles can also divide to form basal bodies where cilia and flagella are formed:

a. Cilia

Both cilia and flagella have a 9+2 pattern regarding the microtubules that compose them

Short, numerous extensions that move in a coordinated to propel the cell

b. Flagella

Longer extensions which occur singly or in pairs. Movement is done by means of a propeller motion.

Cell Surface and Junctions

- Cells are joined to each other by structures called junctions. In plants, the plasma membrane and cytoplasmic fluid extend specialized structures between cells called plasmodesmata to communicate and pass molecules effectively
- Animal cells have different types of junctions depending on their location and function:

1. Tight Junctions

   Fuses cells together to form an impassable barrier using actin fibers attaching to membrane-anchored proteins, forming cell sheets

   Important in controlling biochemical movement (e.g. stomach fluids should not seep into the surrounding tissue)

2. Adhesion Junctions

   Connects two (2) neighboring cells together or a cell to the extracellular matrix. Acts like screws using cytoskeletal fibers to form strong sheets with spaces between them

3. Gap Junctions

   Similar to plasmodesmata, wherein a channel protein links with the cytoplasm of an adjacent cell to allow exchange of ions and nutrients

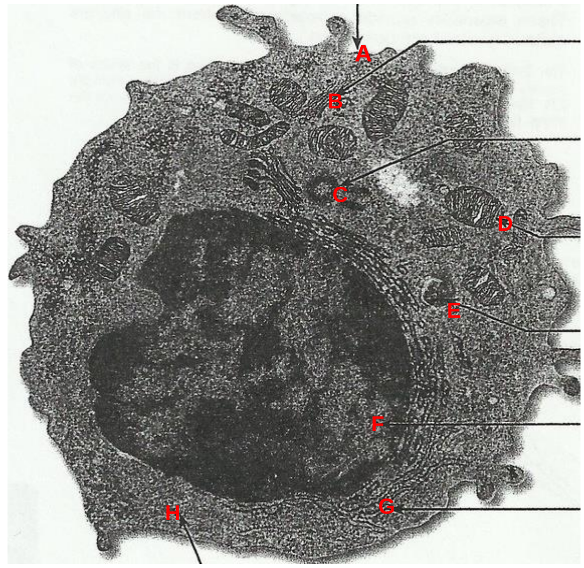

Image 2.9 Micrograph of Animal Cell

A: Plasma membrane, **B:** Golgi body, **C:** Centrosome, **D:** Mitochondria, **E:** Lysosome, **F:** Nucleus, **G:** Endoplasmic Reticulum, **H:** Cytoplasm

Source: https://quizlet.com/219495003/aice-biology-chapter-1-animal-cell-electron-micrograph-labeling-diagram/

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DEFINITIONS BOX

Cell membrane	**DNA**
Cytoplasm	**RNA**
Cytosol	**Genes**
Ribosomes	**Histones**
Prokaryote	**Ribosomal subunits**
Eukaryote	**Secretory protein**
Electron transport system	**Glycoprotein**
Compartmentalization	**Transitional ER**
Organelles	**Transport vesicles**
Hydrophilic	**Enzymes**
Hydrophobic	**Hormones**
Phospholipids	**rRNA**
Fluid Mosaic Model	**Endosymbiotic Theory**
Chlorophyll	**Photosynthesis**
Krebs Cycle	**Tubulin**
Actin and Myosin	**Centrosomes**
Centrioles	**Cilia**
Flagella	**Asters and Spindle Fibers**