A Tour of the Cell

Outline

I. Cell Theory
II. Studying cells
III. Prokaryotic vs Eukaryotic
IV. Eukaryotic
   A. Animal cells
   B. Plant cells

Cells

- Cells are the basic unit of life
- Cells maintain homeostasis
- They are enclosed in a phospholipid membrane - the Plasma Membrane
- Cells vary in size but there is a limit on how big a cell can be and survive
- There are different types of cells – specialized cells

Cell Theory

- Cells were discovered in 1665 by Robert Hooke.
- Early studies of cells were conducted by
  - Mathias Schleiden (1838)
  - Theodor Schwann (1839)
- Schleiden and Schwann proposed the Cell Theory.

Cell Size

- Cell size is limited.
  - As cell size increases, it takes longer for material to diffuse from the cell membrane to the interior of the cell.
- Small cells have a greater surface area relative to volume
- **Surface area-to-volume ratio**: as a cell increases in size, the volume increases 10x faster than the surface area
Surface area increases while total volume remains constant.

Total surface area
(sum of the surface areas (height \( \times \) width) of all box sides \( \times \) number of boxes)

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Surface-to-volume (S-to-V) ratio
(surface area \( \div \) volume)

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<td>6</td>
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Some organisms are just one cell - yeast

Multi-celled organisms have specialized cells

Blood Cells

Nerve Cells

Some cells are very small

Human height

Length of some nerve and muscle cells

Chicken egg

Frog egg

Human egg
As the size of a cell increases, the surface area:volume ratio increases.

1. Increase
2. Decrease
3. Stays the same

Cell fractionation

- Used to study organelles
- Homogenize the sample
- Lyse the cells (break open) and the resulting cell extract spun in a centrifuge

Cell fractionation

- Centrifugal force separates extract
  - Pellet – bottom of tube, contains large components of cell, organelles like nucleus
  - Supernatant – liquid on top of pellet, contains lighter components

Homogenate

Centrifugation

1,000 g
10 min

Supernatant poured into next tube

20,000 g
20 min

Pellet rich in nuclei and cellular debris

80,000 g
60 min

Pellet rich in mitochondria and chloroplasts

150,000 g
3 hr

Differential centrifugation

Pellet rich in "microsomes"

Pellet rich in ribosomes
Cell Fractionation

- 1000 g x 10 min = nuclei in pellet
- 20,000 g x 20 min = mitochondria, chloroplast
- 80,000 g x 60 min = microsomal fraction contains:
  - ER, Golgi, plasma membrane
- 150,000 g x 3 hr = ribosomes

To separate the ER, Golgi and plasma membrane you can use a density gradient centrifuge

If you centrifuge cells at 80,000 g which fraction will contain the endoplasmic reticulum?

1. Pellet
2. Supernate

Inner Life of a Cell - Harvard

- Inner life of a cell - short version, music only

Cell Structures

All cells have certain structures in common.

1. genetic material – in a nucleoid region or nucleus
2. cytoplasm – a semifluid matrix (fluid portion is the cytosol)
3. plasma membrane – a phospholipid bilayer
4. Ribosomes (make proteins)

Plasma Membrane

- The plasma membrane is a selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell
- The general structure of a biological membrane is a double layer of phospholipids

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The main component of the plasma membrane is:

1. Triglycerides
2. Cholesterol
3. Protein
4. Phospholipids

Eukaryotic cells have internal membranes that compartmentalize their functions

- The basic structural and functional unit of every organism is one of two types of cells: prokaryotic or eukaryotic
- Only organisms of the domains Bacteria and Archaea consist of prokaryotic cells
- Protists, fungi, animals, and plants all consist of eukaryotic cells

Prokaryotic vs Eukaryotic

- **Prokaryotic** – Pro (before) karyotic (nucleus)
- **Eukaryotic** – Eu (true) karyotic (nucleus)

- The presence or absence of a nucleus is the most obvious difference between these types of cells.

Prokaryotic Cells – Characteristics and Features

1. Include bacteria and archaea
2. Has no nucleus, have nucleoid region
3. Also lack membrane bound compartments (organelles)
4. Many use folds in the plasma membrane to accomplish the tasks of organelles
5. Many prokaryotic cells have cell walls
6. Some have a capsule
Prokaryotic Cells – Characteristics and Features

6. Have a plasma membrane
7. Have cytoplasm
8. Many have flagella for locomotion
9. Contain ribosomes for protein production
10. Have storage granules – contain glycogen, lipids, and phosphate compounds
11. Some can perform photosynthesis

Prokaryotic cells have a nucleus

1. True
2. False

Do prokaryotic cells contain ribosomes?

1. Yes
2. No
3. Some do

Eukaryotic cells

- Highly organized, have organelles including a nucleus. Eukaryotic cells are generally much larger than prokaryotic cells
  - Animal cells
  - Plant cells
  - Protists
  - Fungi

Major Features of Animal Cells

- Structures:
  1. Plasma membrane – controls entry in/out of cell
  2. Cytoplasm – semi-fluid matrix outside the nucleus, liquid portion is the cytosol
  3. Ribosomes - assembling polypeptide chains
  4. Chromosomes – DNA + proteins
  5. Cytoskeleton - gives shape, structure, transport
  6. Flagella - movement

Major Features of Animal Cells

- Membrane bound Organelles
  1. Nucleus – contains the DNA
  2. Mitochondria – energy production
  3. Endoplasmic reticulum – modifies new polypeptide chains (rough) and synthesizes lipids (smooth)
  4. Golgi body – modifies, sorts, ships new proteins and lipids
  5. Vesicles – storage, transport, digestion
  6. Lysosomes – digestion
  7. Peroxisomes – lipid metabolism
What kind of tissue is this?

Human cells from lining of uterus (colorized TEM)

Cell Membranes

1. **Plasma membrane**: Divides outside from inside of cell
2. **Organelles**: specialized membrane bound compartments

Organelles

- Compartments allow the cells to keep reactive compounds from causing injury
- Some membranes form vesicles that are used for transporting things
- Some membranes are attached to other membranes

<table>
<thead>
<tr>
<th>Organelle/feature</th>
<th>Function</th>
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<tr>
<td>Nucleus</td>
<td>Contains DNA DNA is copied to make RNA</td>
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<tr>
<td>Ribosomes</td>
<td>“reads” mRNA to assemble amino acids into a polypeptide chain</td>
</tr>
<tr>
<td>Rough Endo Ret</td>
<td>Polypeptide chain that are to be exported or membrane bound are processed here</td>
</tr>
<tr>
<td>Golgi complex</td>
<td>Further processes and sorts proteins to be exported or membrane bound</td>
</tr>
<tr>
<td>Vesicles</td>
<td>Transports proteins</td>
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The eukaryotic cell’s genetic instructions are housed in the nucleus and carried out by the ribosomes

- The nucleus contains most of the DNA in a eukaryotic cell
- Ribosomes use the information from the DNA to make proteins

The Nucleus: Information Central

- The nucleus contains most of the cell’s genes and is usually the most conspicuous organelle
- The nuclear envelope encloses the nucleus, separating it from the cytoplasm
- The nuclear membrane is a double membrane; each membrane consists of a lipid bilayer

Nucleus

- Nucleus protects DNA
- Separates DNA from rest of cell
- Place where DNA replicates itself
- Place where DNA is copied to make RNA

- Pores regulate the entry and exit of molecules from the nucleus
- The shape of the nucleus is maintained by the nuclear lamina, which is composed of protein and lines the inside of the nuclear envelope
In the nucleus, DNA is organized into discrete units called **chromosomes**.

- Each chromosome is composed of a single DNA molecule associated with proteins.
- The proteins are called **histones**.
- The DNA and the histones are together called **chromatin**.
- Chromatin condenses to form discrete chromosomes as a cell prepares to divide.

**Parts of the Nucleus**

2. **Nucleolus** – dense area in the nucleus is where rRNA are produced and ribosomes are assembled.

3. **Nucleoplasm** – area within nucleus.

**Ribosomes: Protein Factories**

- **Ribosomes** are particles made of ribosomal RNA and protein.
- **Proteins are made at ribosomes**.
- Ribosomes carry out protein synthesis in two locations:
  - In the cytosol (free ribosomes)
  - On the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes).

**Ribosomes**

- Has two components: a small subunit and a large subunit.
- Each subunit is made up of strands of rRNA and many proteins.
- The ribosome is like the workbench for assembling polypeptide chains. It is here that amino acids are bound together with a peptide bond.

**The endomembrane system regulates protein traffic and performs metabolic functions in the cell**

- Components of the **endomembrane system**:
  - Nuclear envelope
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes
  - Vacuoles
  - Plasma membrane
- These components are either continuous or connected via transfer by **vesicles**.
**The Endoplasmic Reticulum: Biosynthetic Factory**

- The endoplasmic reticulum (ER) accounts for more than half of the total membrane in many eukaryotic cells.
- The ER membrane is continuous with the nuclear envelope.
- There are two distinct regions of ER:
  - **Smooth ER**, which lacks ribosomes.
  - **Rough ER**, surface is studded with ribosomes.

**Endoplasmic reticulum**

- Network of folded internal membranes located in the cytoplasm.
- Attached to nucleus.
- Lumen = space inside endoplasmic reticulum.

**Functions of Smooth ER**

- Functions of the smooth ER
  1. Synthesizes lipids.
  2. Metabolizes carbohydrates.
  3. Detoxifies drugs and poisons.
  4. Stores calcium ions.

**Functions of Rough ER**

- The functions of the rough ER
  1. Important in protein production = folds and tags the newly made proteins.
  2. Creates transport vesicles that go to the golgi.

**Rough Endoplasmic Reticulum (RER)**

- RER has bound ribosomes.
- Ribosomes that are producing polypeptide chains for export or to be embedded in membranes dock with the surface of the RER.
- The growing polypeptide chain enters the lumen of the RER.
Functions of Rough Endoplasmic Reticulum (RER)

- In the RER the polypeptide chain is folded
  - Enzymes called molecular chaperones aid in the folding of the polypeptide chains into proteins
- Some of the polypeptide chains may get modified here “tagged” with carbohydrate chain = glycoproteins
- The polypeptide chains/proteins are put into transport vesicles

The Golgi Apparatus: Shipping and Receiving Center

- The Golgi apparatus consists of flattened membranous sacs called cisternae

Functions of the Golgi apparatus
1. Modifies products of the ER
2. Sorts and packages materials into transport vesicles
3. Produces lysosomes

V Cell Movie

- Golgi – Protein Trafficking

Protein Production - Overview

1. DNA in the nucleus are the instructions for making protein
2. A copy of the DNA is made = mRNA
3. mRNA leaves the nucleus
4. mRNA docks with a ribosome to assemble a chain of amino acids.
5. tRNA brings amino acids to ribosomes
6. At the ribosome the amino acids are linked together with a peptide bond to form a polypeptide chain
Protein Production Cont

7. Ribosome with the growing polypeptide chain docks with the rough endoplasmic reticulum if the protein is to be exported or embedded in a membrane.

8. The polypeptide chain enters the lumen of the RER where they are folded and may get a carbohydrate “tag” attached to it.

9. The RER buds off a transport vesicles that can carry the newly formed proteins to the golgi.

Protein Production Cont

10. The golgi processes, sorts, packages proteins and lipids from the RER and SER.

11. Proteins that are exported are shipped in transport vesicles to the plasma membrane.

12. Proteins may be put into lysosomes.

13. Proteins that are membrane bound are embedded in the transport vesicles membrane.

Cytosolic proteins

- Proteins that are not shipped out of cell are made on free floating ribosomes.
- Chaperone proteins fold the proteins in the cytosol.

Lysosomes

- Produced by the Golgi.
- Lysosomes are small membrane bound sacs that contain digestive enzymes. The pH is relatively acidic (pH 5) in the lysosomes.
- Because the lysosomes are acidic and contain digestive enzymes, their contents must be kept separate from the rest of the cell.
- Some types of cell can engulf another cell by phagocytosis; this forms a food vacuole.
- A lysosome fuses with the food vacuole and digests the molecules.
- Lysosomes also use enzymes to recycle the cell’s own organelles and macromolecules, a process called autophagy.

Lysosomes

1. Contain strong acids and enzymes.
2. Engulf molecules and digest them or.
3. Fuse with other organelles and vesicles to destroy them.
5. Destroy bacteria.

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**Video: Phagocytosis in Action**

![Coronin in Phagocytosis](image)

*Coronin in Phagocytosis © 1995 by Cell Press
Marcik et al. Cell 83, 913-924, 1995*

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**Figure 6.13**

(a) Phagocytosis

(b) Autophagy

- Vesicle containing two damaged organelles
- Mitochondrion fragment
- Peroxisome fragment

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**Scavenger cells**

Throughout the body there are scavenger cells that engulf bacteria, foreign material or old cellular material.

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**Tay-Sachs Disease**

- **Tay-Sachs** is a hereditary disease –

  - people with this disease don’t have an enzyme normally found in lysosomes that breaks down lipids in nerve cells.

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**Vacuoles: Diverse Maintenance Compartments**

- Plant cell, protists, and fungal cells may have one or several **vacuoles**, derived from endoplasmic reticulum and Golgi apparatus.

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Vacuoles: Diverse Maintenance Compartments

- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells
- **Central vacuoles**, found in many mature plant cells, hold organic compounds and water

Mitochondria produce ATP

- **Mitochondria** are the sites of cellular respiration, a metabolic process that uses oxygen to generate ATP

Mitochondria

- Most all Eukaryotic cells (plants, animals, fungi and protists) contain mitochondria
- **Produces energy** for the cell (ATP)
- Cells that require lots of energy have lots of mitochondria (liver cells can have over 1000 mitochondria)
- Requires oxygen = site of aerobic respiration
- Important in **apoptosis** (programmed cell death)

Mitochondria - Structure

- Bound by a double membrane
  - Forms two compartments
  - Outer membrane faces cytoplasm
  - Inner membrane folded forming **cristae** which increases surface area
  - The cristae contain many enzymes and other proteins important for cellular respiration
  - Intermembrane space is between outer and inner membrane
- Mitochondria contain its own DNA

Mitochondria

- The double membrane structure is important in its function (cellular respiration) and to keep dangerous oxygen species and free radicals from damaging the cells.
Apoptosis is planned cell death.

In contrast, necrosis is uncontrolled cell death.

When a cell is no longer needed or is not functioning properly, the cell will undergo apoptosis.

Mitochondria can initiate apoptosis in several ways – one way is through a cascade of enzymatic reactions.

When the mitochondria gets the signal to begin apoptosis it releases cytochrome c, which activates a group of enzymes called caspases.

Peroxisomes are membrane bound vesicles that contain oxidative enzymes.

These enzymes function by oxidizing their substrates (many of their substrates are fatty acids).
**Peroxisomes**

- **Oxidation** is when a substance *loses* an electron
  - \( \text{RH} + \text{O}_2 \rightarrow \text{RH} + \text{H}_2\text{O}_2 \)
  - This produces \( \text{H}_2\text{O}_2 \) which is dangerous therefore another enzyme, **catalase**, removes the \( \text{H}_2\text{O}_2 \)
  - \( 2\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}_2\text{O} \)

**Functions of Peroxisomes**

- Involved in lipid metabolism and detoxification
- Contain enzymes that produce and degrade hydrogen peroxide

**What organelle produces energy (ATP)?**

1. Ribosomes
2. Golgi complex
3. Mitochondria
4. SER
5. Lysosomes

**Where are polypeptide chains assembled?**

1. Ribosomes
2. Golgi complex
3. SER
4. RER

**Where are lipids synthesized?**

1. Ribosomes
2. Golgi complex
3. Peroxisomes
4. SER
5. Lysosomes
These are membrane bound sacs with digestive enzymes

1. Ribosomes
2. Golgi complex
3. Mitochondria
4. SER
5. Lysosomes

Cytoskeleton

- Interconnected system of fibers and lattices
- Gives cells their organization, shape, ability to move, transport things in cell, important in cell division
- Some permanent others only present when needed

Components of the Cytoskeleton

- Three main types of fibers make up the cytoskeleton
  - Microtubules are the thickest of the three components of the cytoskeleton
  - Microfilaments, also called actin filaments, are the thinnest components
  - Intermediate filaments are fibers with diameters in a middle range
Microtubules

- Thickest type of cytoskeleton
- Important in
  - The structure of cell – cell shape
  - Cell division – separates the chromosomes
  - Transport of organelles in the cell
  - Movement of cells (cilia and flagella)

Microtubules are composed of two proteins that form a dimer: \( \alpha \)-tubulin and \( \beta \)-tubulin.

These assemble by adding dimers and disassemble by removing them.

Structural microtubule-associated proteins (MAPs) regulate microtubule assembly.

Microtubule Anchoring

- Microtubules may be anchored in the microtubule-organizing centers (MTOCs)
- In animal cells the main MTOC is the centrosome – this is important in cell division
- The centrosome is composed of two centrioles
- The centrioles have nine sets of three microtubules
**Microtubules – cell division**

- During cell division much of the cytoskeleton breaks down and microtubule form that will help in cell division = spindles
- Spindles move the chromosomes so when the cell divides the chromosomes are evenly divided

**Microtubule – transport of organelles**

- Microtubule can be used to transport vesicles and other structures.
- The microtubule is stationary, transport proteins (kinesin and dynein) move the item.
  - **Kinesin** moves items in one direction
  - **Dynein** moves items in the opposite direction

**Cilia and flagella**

- Microtubules important in movement of the cell
- Project from cell surface
- **Flagella** are long microtubules
- **Cilia** are short microtubules
- Flagella are found on sperm and many one celled organisms
- Cilia found on many one celled organisms and on cells that line passageways in multi-celled organisms
Flagella and Cilia

- Both flagella and cilia have nine pairs of microtubules in an outer ring and a pair in the center (9 pairs + pair in center).
- Anchored by a basal body (9 triplets)
- A motor protein called dynein, which drives the bending movements of a cilium or flagellum
Microfilaments

- Microfilaments are made two chains of actin protein molecules

Important in:
1. providing support for cell structures
2. movement of cells (ameoba-like movement)
3. dividing cells in two
4. stabilizing microvilli structure

Microfilaments (Actin Filaments)

- Microfilaments are solid rods about 7 nm in diameter, built as a twisted double chain of actin subunits
- The structural role of microfilaments is to bear tension, resisting pulling forces within the cell
- They form a 3-D network just inside the plasma membrane to help support the cell's shape
- Bundles of microfilaments make up the core of microvilli of intestinal cells

Microfilaments are in green

Microfilaments

- Actin molecules will assemble to form microfilaments
- Microfilaments are important in formation of microvilli
Microfilaments Role in Movement - Muscle

- Microfilaments that function in muscles contain the protein **myosin** in addition to **actin**
- In muscle cells, thousands of actin filaments are arranged parallel to one another
- Thicker filaments composed of myosin interact with the thinner actin fibers

Microfilaments Role in Movement - Pseudopodia

- **Pseudopodia** (cellular extensions) extend and contract through the reversible assembly of actin subunits into microfilaments
- Localized contraction brought about by actin and myosin also drives amoeboid movement
Cytoplasmic streaming is a circular flow of cytoplasm within cells. This streaming speeds distribution of materials within the cell. In plant cells, actin-myosin interactions drive cytoplasmic streaming.

Intermediate filaments

- Do not self assemble/disassemble – permanent
- Important in cell shape
- Tough but flexible fibers
- Found in high amounts in cells that are subjected to mechanical stress (in skin)

Amyotrophic lateral sclerosis

- Amyotrophic lateral sclerosis (ALS) is caused by abnormal intermediate filaments in nerve cells

Cilia and flagella are composed of this type of cytoskeleton

1. Microtubules
2. Microfilaments
3. Intermediate filaments
Microfilaments are composed of:

1. Kinesin
2. Actin
3. Tubulin
4. Dynein

This type of cytoskeleton is more permanent

1. Microtubules
2. Microfilaments
3. Intermediate Fibers

Extracellular components and connections between cells help coordinate cellular activities

- Most cells synthesize and secrete materials that are external to the plasma membrane
- These extracellular structures include
  - Cell walls of plants
  - The extracellular matrix (ECM) of animal cells
  - Intercellular junctions

The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate extracellular matrix (ECM)
- The ECM is made up of glycoproteins
- ECM proteins bind to receptor proteins in the plasma membrane called integrins

Functions of the Extracellular Matrix (ECM) of Animal Cells

- Functions of the ECM
  - Support
  - Adhesion
  - Movement
  - Regulation
Cell Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact.
- Intercellular junctions facilitate this contact.
- There are several types of intercellular junctions:
  - Plasmodesmata (in Plants)
  - Tight junctions
  - Desmosomes
  - Gap junctions

Plasmodesmata in Plant Cells

- Plasmodesmata are channels that perforate plant cell walls.
- Plasmodesmata allow water and small solutes (and sometimes proteins and RNA) to pass from cell to cell.

Cell Junctions in Animal Cells

- At tight junctions, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid.
- Desmosomes (anchoring junctions) fasten cells together into strong sheets.
- Gap junctions (communicating junctions) provide cytoplasmic channels between adjacent cells.
Tight junctions

- **Tight junctions**: prevent substances from leaking across tissues
- Found in high concentration between cells:
  - Lining the digestive system
  - Lining capillaries in the brain

Desmosomes Anchoring junctions

- **Desmosomes** - Anchoring junctions: hold adjacent cells together (like glue) and allow tissues to be flexible
  - Found in high concentration in skin epithelial cells
  - **Integrin** and **Cadherin** proteins
  - Attach to cytoskeleton

Communicating Junctions

- **Gap junctions** – open channels between cells allowing rapid communication due to quick transfer of ions and small molecules between neighboring cells
  - These junctions can be opened or closed
  - High concentration of gap junctions are found in heart tissue

Animal and Plant cells

- Both animal and plant cells have:
  - Plasma membrane
  - Nucleus
  - Smooth and rough endoplasmic reticulum
  - Ribosomes
  - Golgi complex
  - Vesicles
  - Peroxisomes
  - Mitochondria
  - Cytoskeleton
  - Lysosomes
Plant Cells

- Plant cell components not present in animal cells
  - Cell wall
  - Vacuoles (usually central)
  - Plastids including Chloroplast
  - Glyoxysomes

- Not present in plant cells: centrioles

Cell Walls of Plants

- The **cell wall** is an extracellular structure that distinguishes plant cells from animal cells
- Prokaryotes, fungi, and some protists also have cell walls
- The cell wall protects the plant cell, maintains its shape, and prevents excessive uptake of water
- Plant cell walls are made of cellulose fibers embedded in other polysaccharides and protein
Cell Wall

- Composed of:
  1. Cellulose
  2. Lignins
  3. Sticky polysaccharides
  4. Glycoproteins

Glyoxysomes

- Plants also have a type of organelle called **glyoxysomes**
- Glyoxysomes contain enzymes that convert stored fatty acids to sugar that is used for energy, this is especially important in germinating seedlings.
- Animal cells do not have these type of peroxisomes (we can’t convert fatty acids to sugar)

Plastids

- **Chromoplasts** – contain pigments, give plant color, attract pollinators
- **Amyloplasts** – store starch
- **Chloroplasts** – contain a green pigment, chlorophyll and carotenoids – yellow and orange pigments. Site of photosynthesis.

Central Vacuole in Plants

- Plant central vacuoles
  - Large area of cell space – up to 90%
  - Fluid filled with water, amino acids, sugars, H^+ ions, and wastes.
  - Stores nutrients
  - Digests wastes – similar to lysosomes in animal cells

Chloroplasts

- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
Chloroplasts: Capture of Light Energy

- Chloroplasts contain the green pigment chlorophyll, as well as enzymes and other molecules that function in photosynthesis.
- Chloroplasts are found in leaves and other green organs of plants and in algae.

- Chloroplast structure includes:
  - Thylakoids, membranous sacs, stacked to form a granum.
  - Stroma, the internal fluid.
- The chloroplast is one of a group of plant organelles, called plastids.

The Evolutionary Origins of Mitochondria and Chloroplasts

- Mitochondria and chloroplasts have similarities with bacteria.
  - Enveloped by a double membrane.
  - Contain free ribosomes and circular DNA molecules.
  - Grow and reproduce somewhat independently in cells.

- The Endosymbiонт theory
  - An early ancestor of eukaryotic cells engulfed a nonphotosynthetic prokaryotic cell, which formed an endosymbiotic relationship with its host.
  - The host cell and endosymbiont merged into a single organism, a eukaryotic cell with a mitochondrion.
  - At least one of these cells may have taken up a photosynthetic prokaryote, becoming the ancestor of cells that contain chloroplasts.
Plant cells do not contain:

1. Mitochondria
2. Centrioles
3. Nucleus
4. Ribosomes

Important Concepts

- Know the vocabulary in the lecture
- Be able to describe cell theory and the properties of cells and structures common to all cells.
- How are cells studied using centrifugation techniques? How would you separate the organelles of the cell?
- What are the main difference between prokaryotic cells and eukaryotic cells, and examples of each type?

Important Concepts

- What are the features and characteristics of prokaryotic cells?
- What is apoptosis and what organelle is an important player in the process? What molecules are released and activated during apoptosis?
- What are the major features of eukaryotic cells, their features, structure, and their functions – in both plants and animals?

Important Concepts

- Describe the steps needed to make a protein and ship it out of the cells, or embed the protein in a membrane, or have the protein stay in the cytosol.
- What is the cause of Tay Sachs disease?
- What are the differences between plant and animal cells?
- Be able to describe the endosymbiont theory

Important Concepts

- What are the types of cytoskeleton – what are their functions, structure, what proteins are they composed of, and how they are assembled?
- How are microtubules assembled, anchored, how do they transport items and what proteins are used by microtubules to transport items.
- What is the cause of ALS?
- What are cell walls composed of, what are the layers?
Know the types of cell junctions, their functions and locations where they are found in high concentration.

Know the role and components of extracellular matrix.