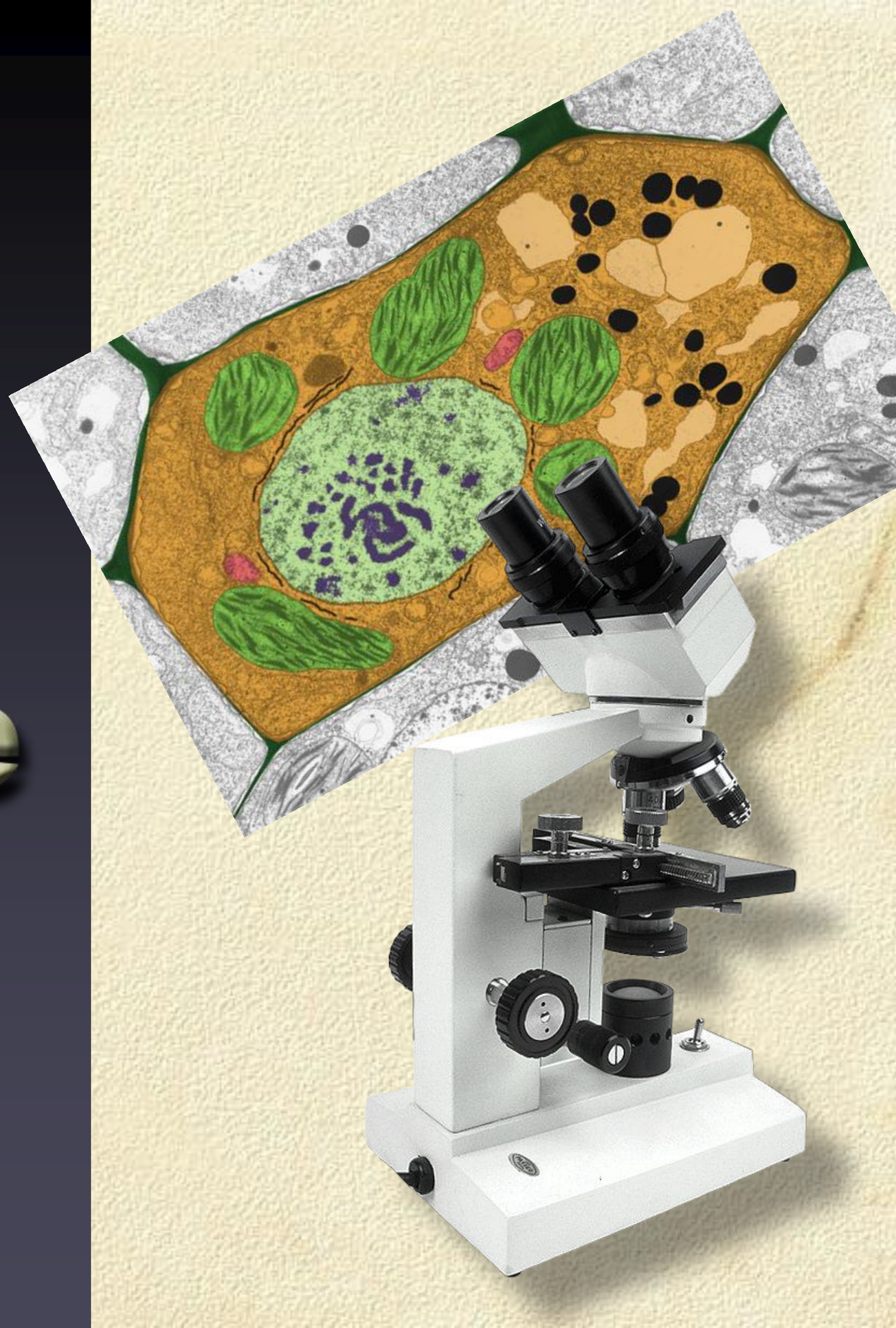
Cell Biology & Biochemistry

Series: **Set 3**

Cell Structure

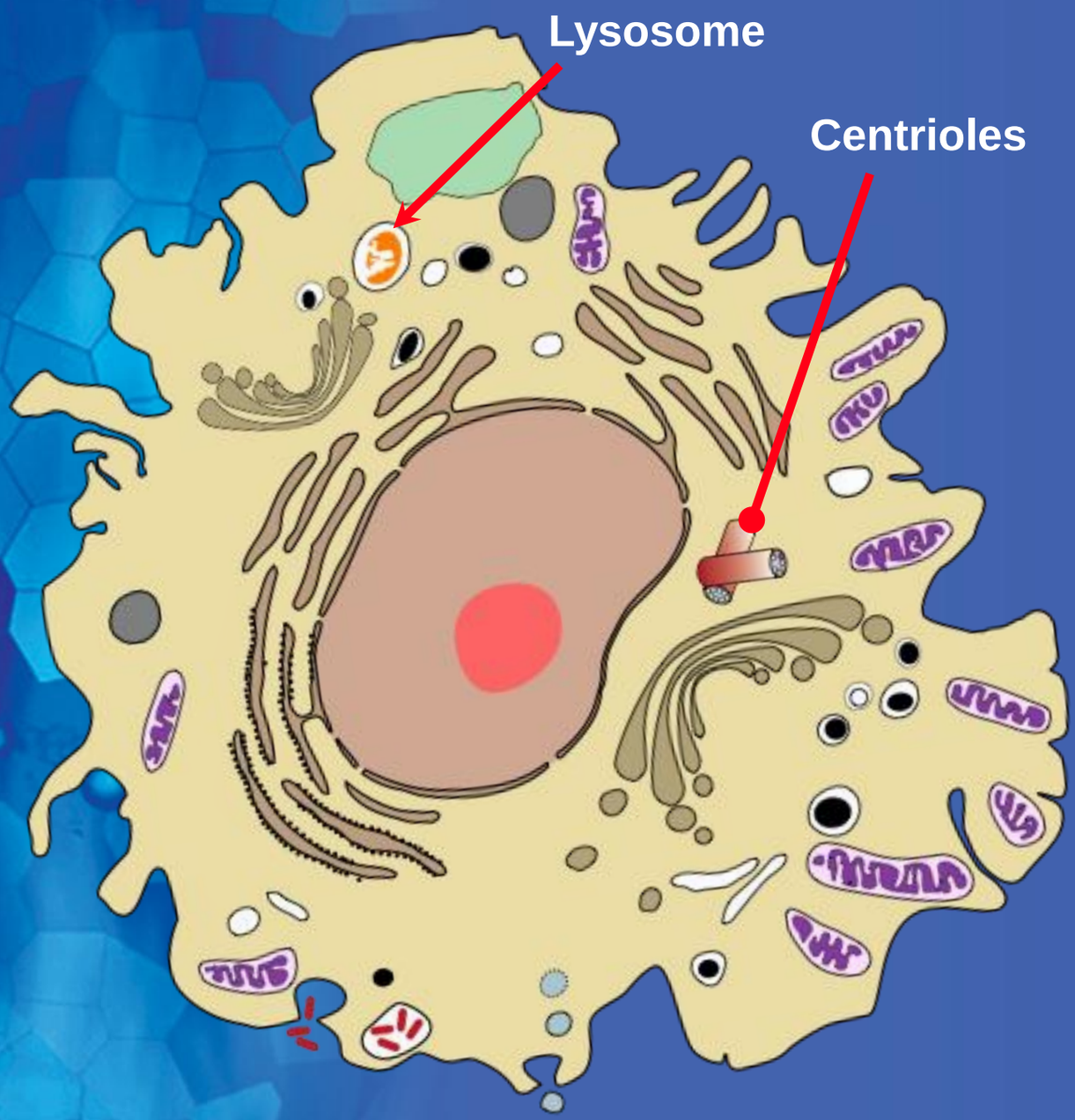
Version: 1.0



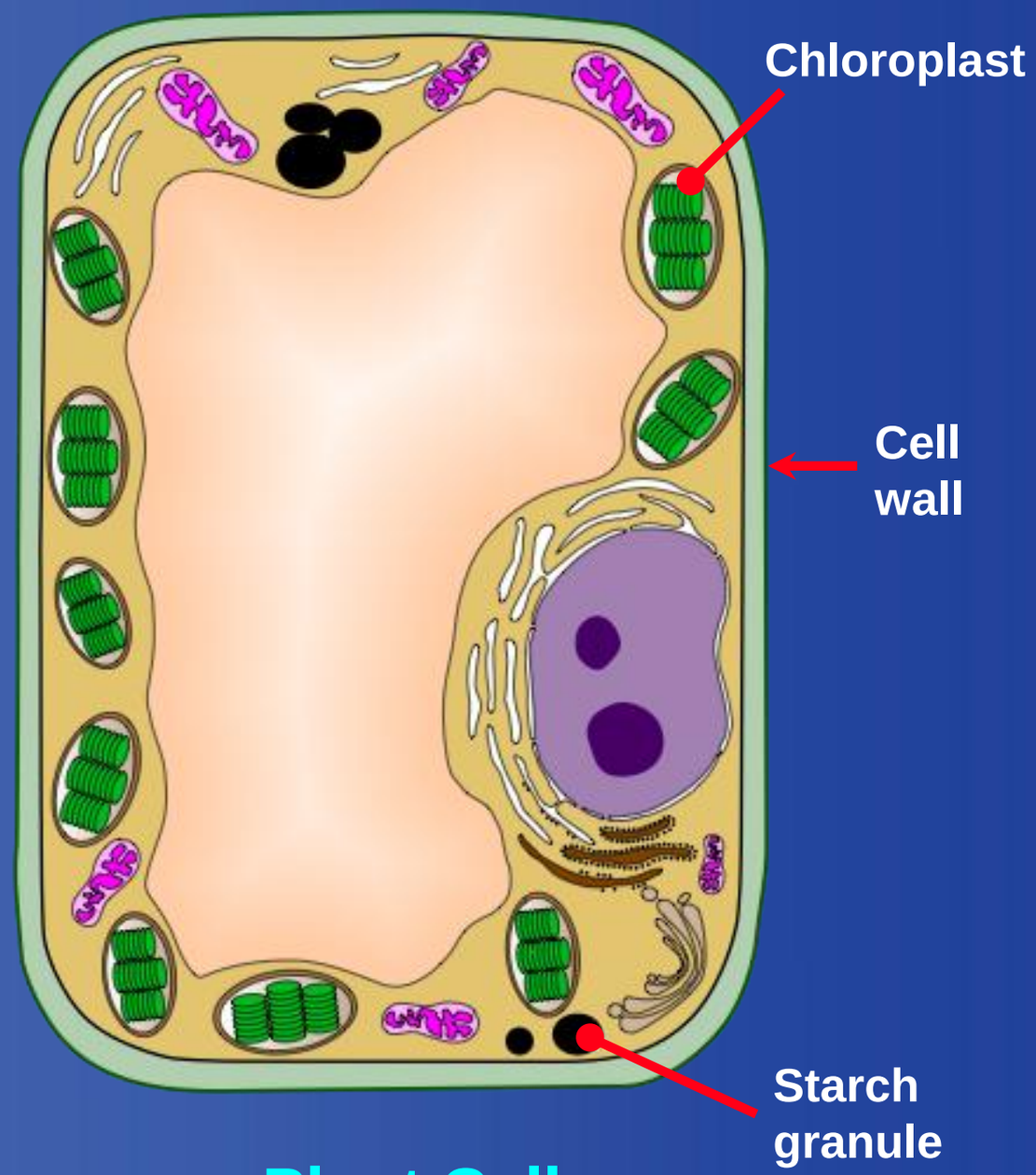
BIOZONE

Animal & Plant Cells

- Animal and plant cells have many organelles in common, as well as several features specific to each. **Specialized features** of each are labelled on the diagrams of a animal cell and an plant cell below.



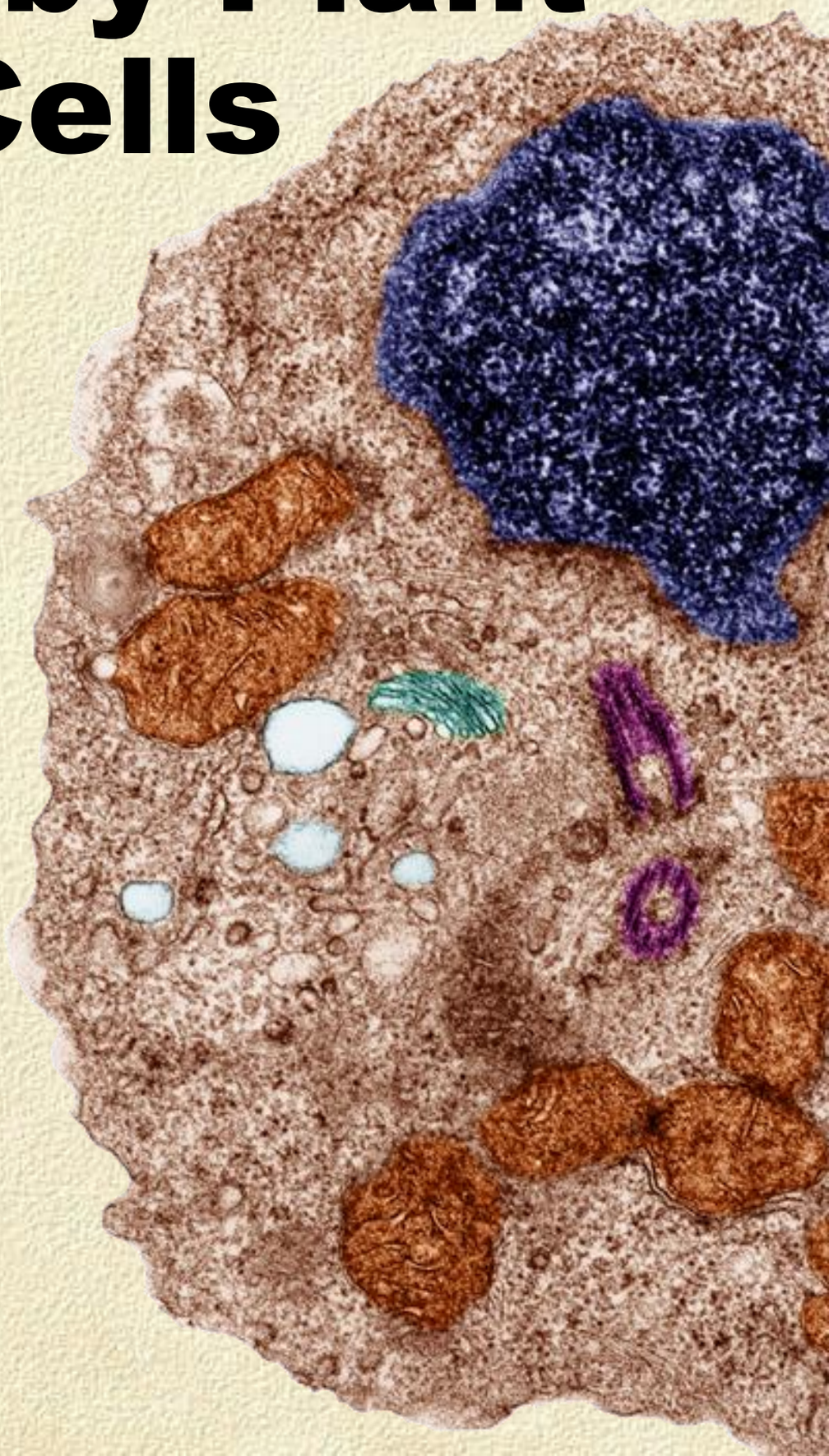
Animal Cell



Plant Cell

Features Shared by Plant and Animal Cells

- Some cellular organelles are commonly found in both plant and animal cells, while others are found exclusively in just one or the other cell type.
- Organelles and structures common to both plant and animal cells include:
  - nucleus
  - plasma membrane
  - ribosomes
  - mitochondria
  - Golgi apparatus
  - endoplasmic reticulum (rough and smooth)
  - cytoskeleton
  - vacuoles and vesicles, although these differ in size and function in plants and animal cells.



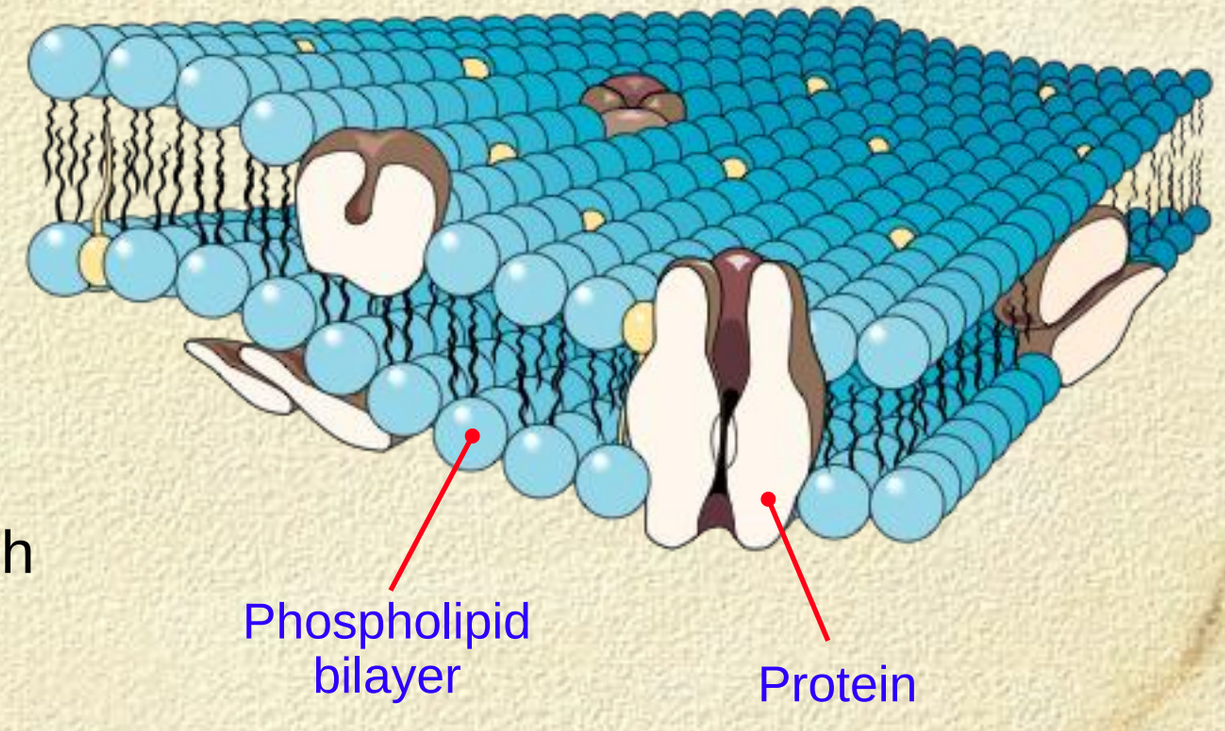
Plasma Membrane

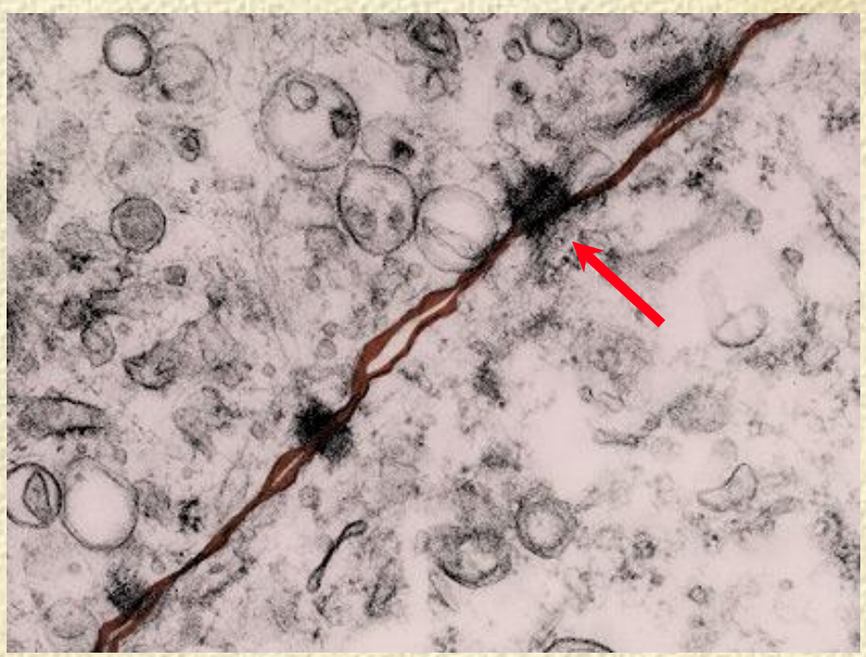
- **Located**:
  Surrounds the cell forming a boundary between the cell contents and the extracellular environment.

- **Structure**:
  Semi-fluid phospholipid bilayer in which proteins are embedded. Some of the proteins fully span the membrane.

- **Function**:
  - Forms the boundary between the cell and the extracellular environment.
  - Regulates movement of substances in and out of the cell.

- **Size**: 3–10 nm thick.

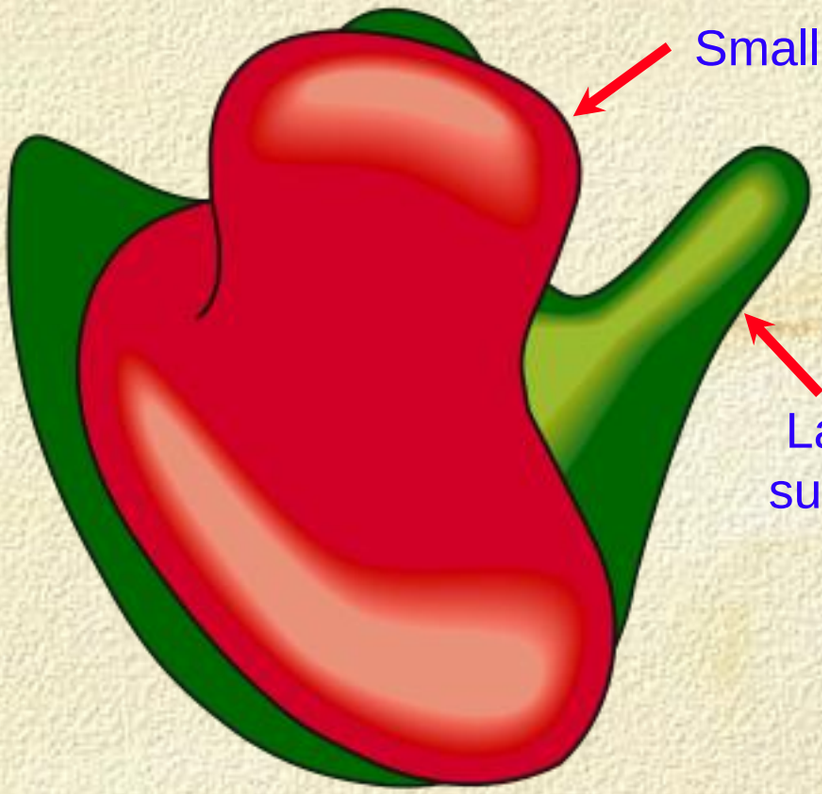


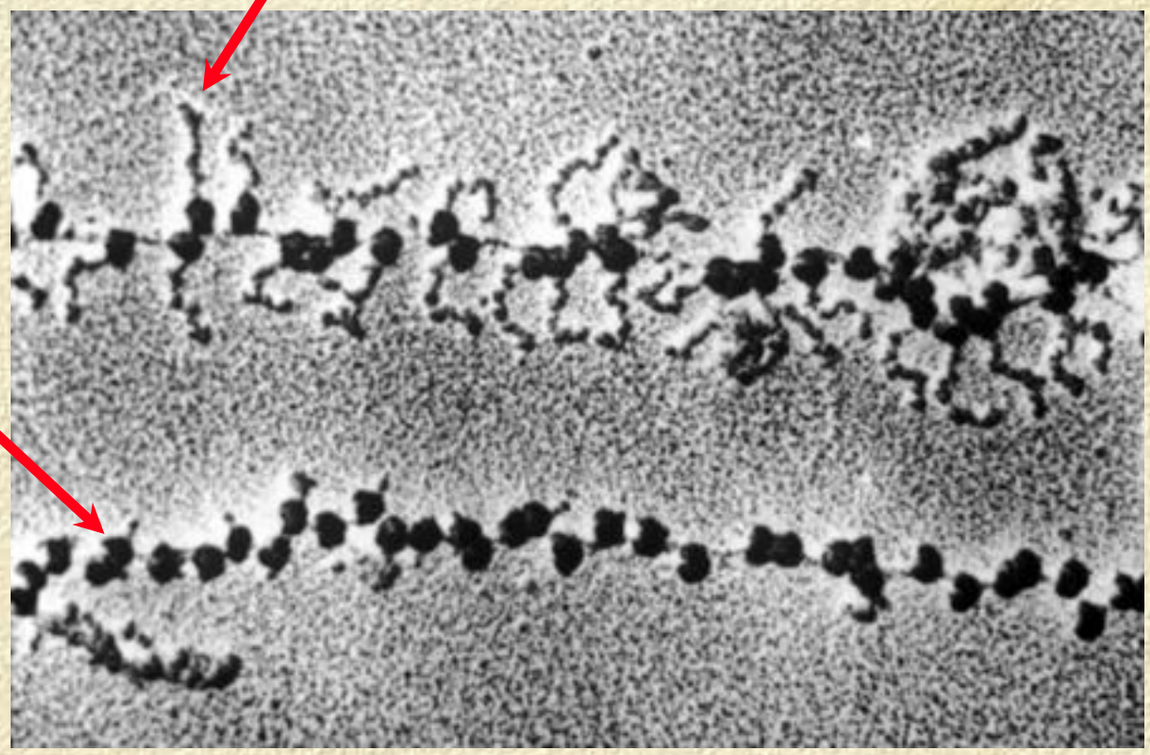


The plasma membranes of two adjacent cells joined with **desmosomes**

Ribosomes

- **Located**:
  Free in the cytoplasm or bound to rough endoplasmic reticulum.
- **Structure**:
  Made up of ribosomal RNA and protein and composed of two subunits, a larger and a smaller one.
- **Function**:
  Synthesis of polypeptides (proteins).
- **Size**: 20 nm.





Polypeptides being produced on a **polyribosome** system

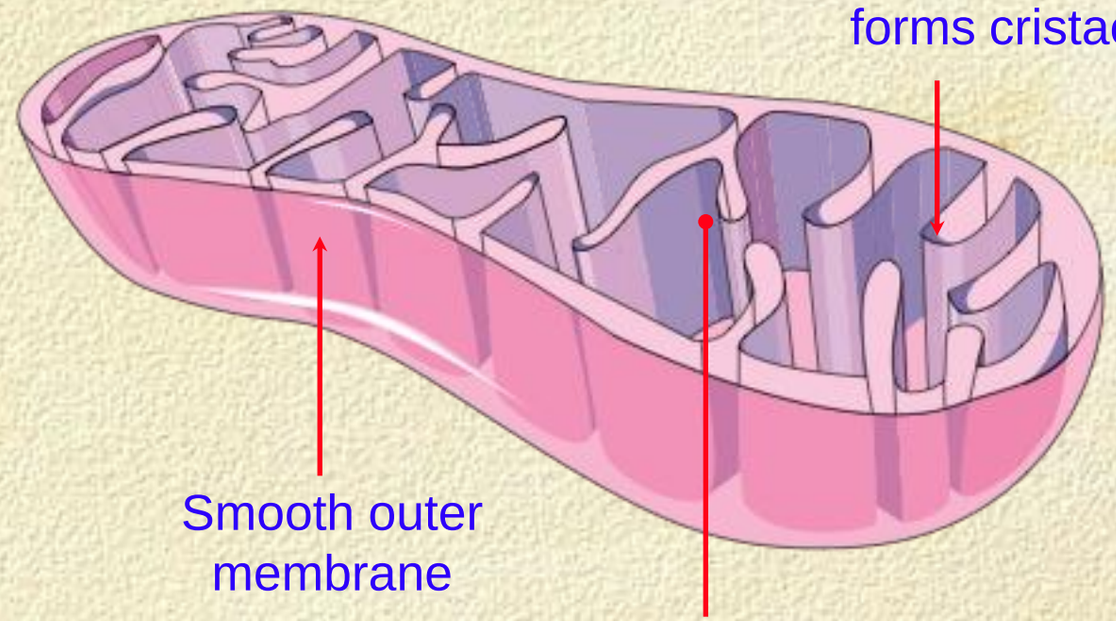
Mitochondria

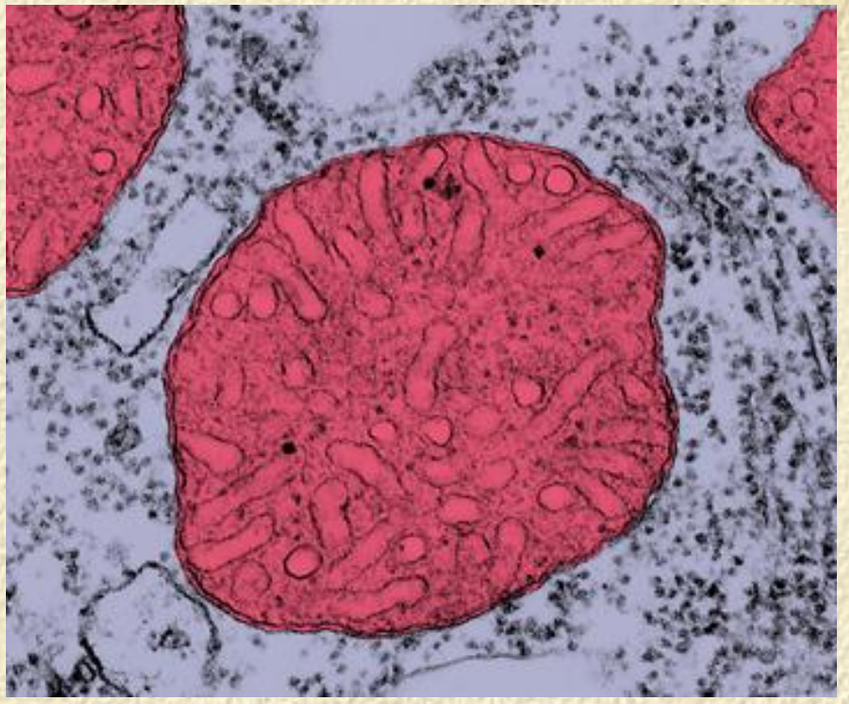
- **Located**:
  Cytoplasm

- **Structure**:
  Rod shaped or cylindrical organelles occurring in large numbers, especially in metabolically very active cells. Bounded by a double membrane; the inner layer is extensively folded to form partitions called **cristae**. Mitochondria contain some DNA.

- **Function**:
  The site of cellular respiration (the production of ATP).

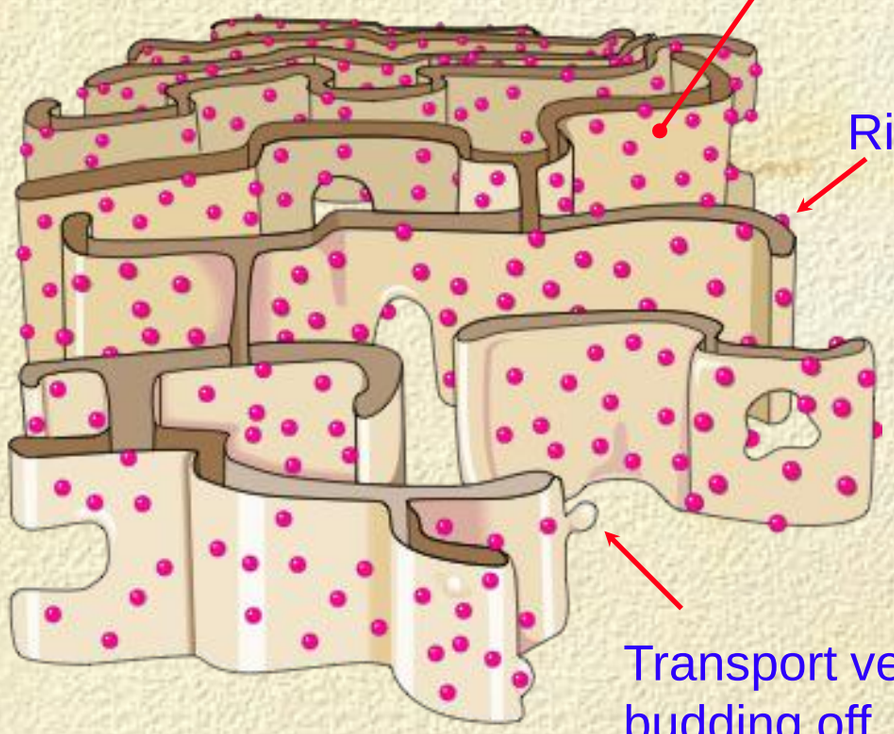
- **Size**: Variable but 0.5–1.5 µm wide and 3.0–10 µm long.





A single **mitochondrion** in cross section

Rough Endoplasmic Reticulum

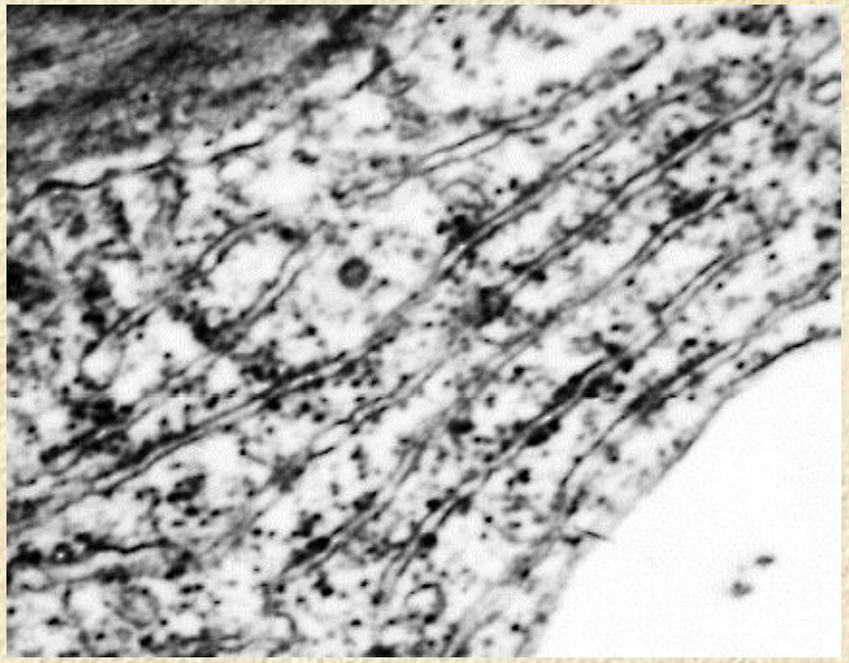


- **Located**:
  Continuous with the nuclear membrane and extending to the cytoplasm as part of the endomembrane system.

- **Structure**:
  A complex system of membranous tubules studded with ribosomes. Connected to the smooth ER but structurally and functionally distinct from it.

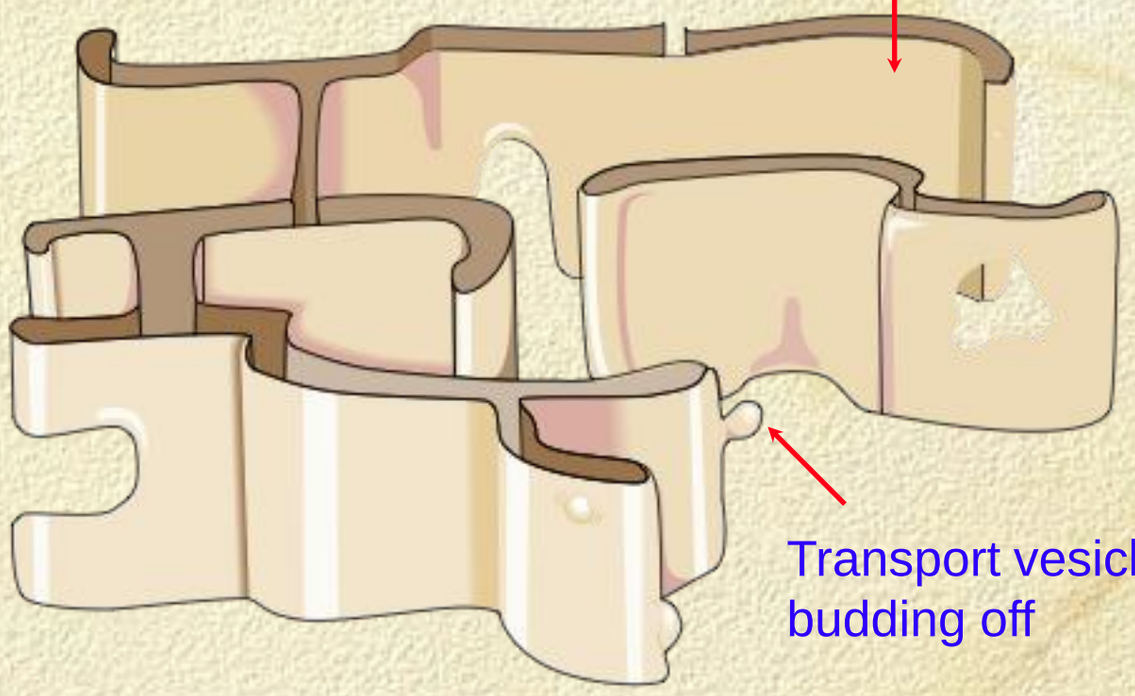
- **Function**:
  - **Synthesis**, **folding**, and **modification** of proteins.
  - **Transport** of proteins through the cell.
  - **Membrane production**.

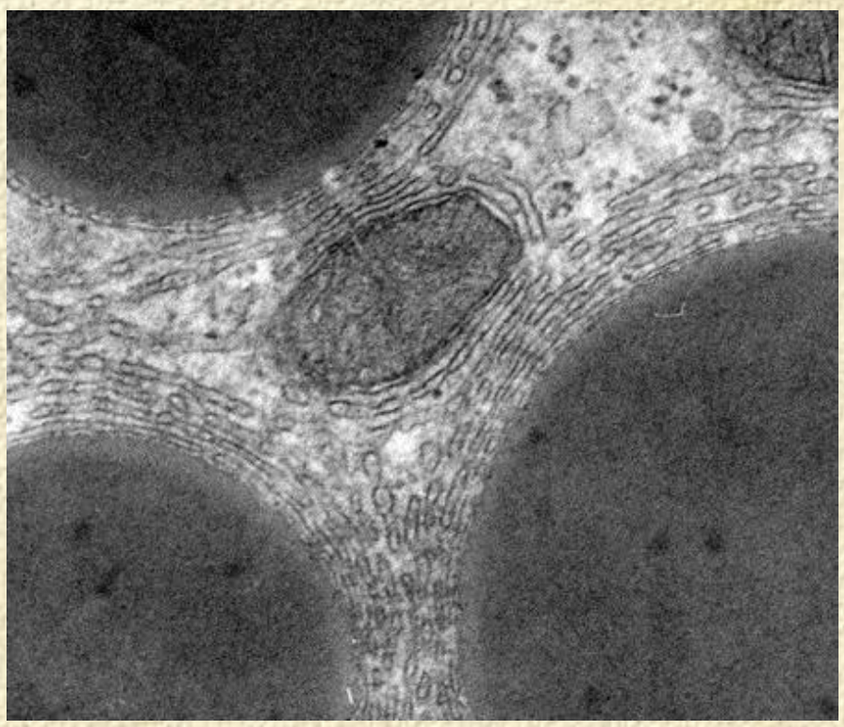
- **Size**: Variable according to cell size.



Smooth Endoplasmic Reticulum

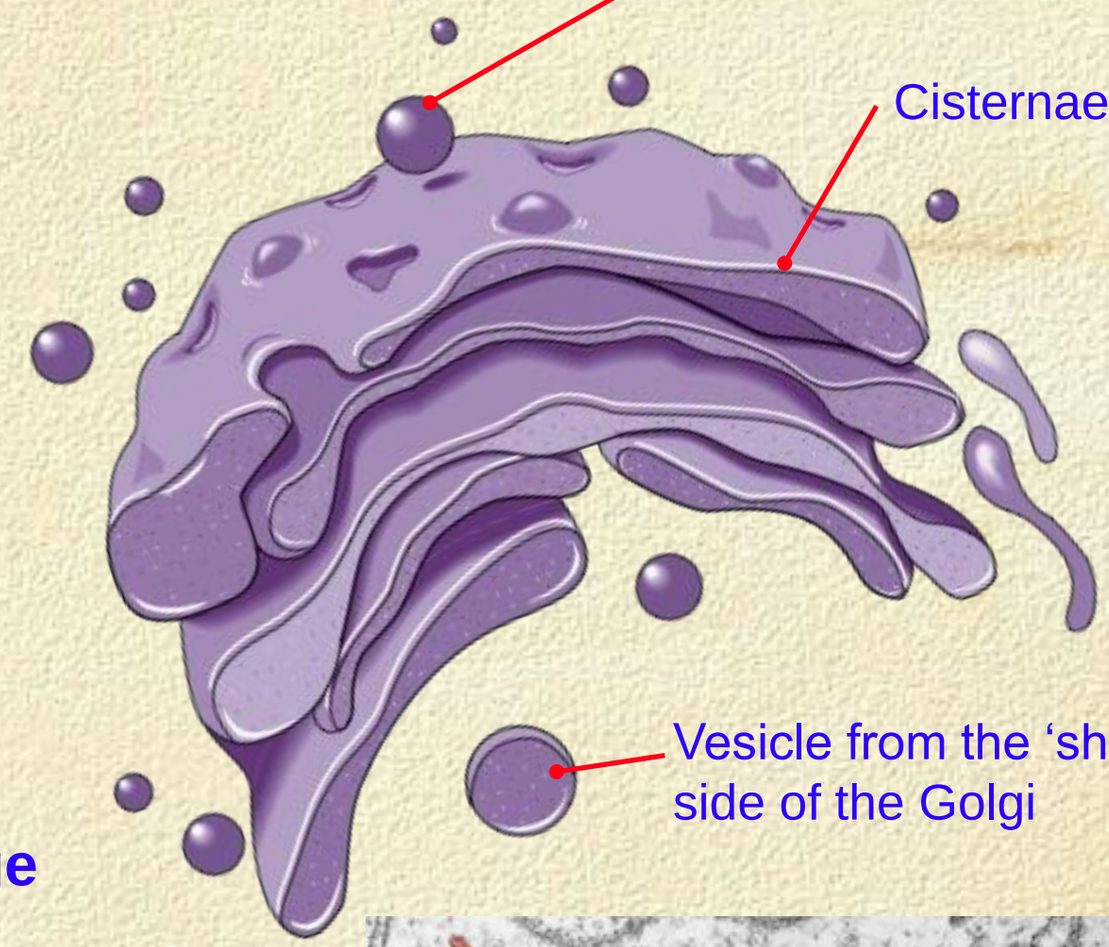
- **Located**:
  In the cytoplasm as part of the endomembrane system.
- **Structure**:
  A system of membranous tubules similar in appearance to the rough ER but lacking ribosomes.
- **Function**:
  - **Synthesis** of lipids, including oils, phospholipids, and steroids.
  - Carbohydrate metabolism.
  - **Transport** of these materials through the cell.
  - **Detoxification** of drugs and poisons.
- **Size**: Variable according to cell size.

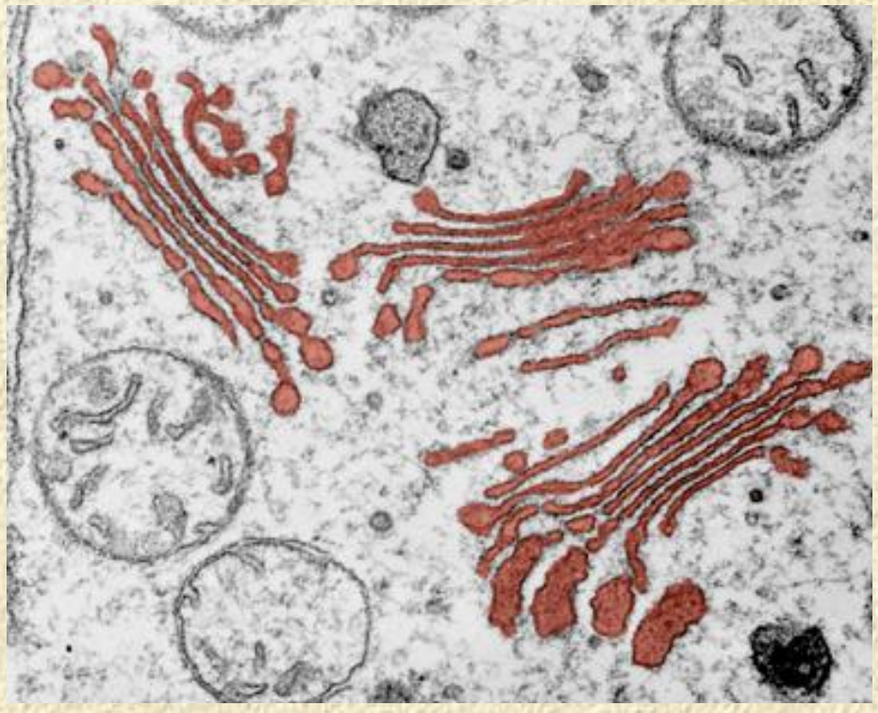




Golgi Apparatus

- **Located**:
  Cytoplasm, associated with the ER.
- **Structure**:
  Stack of flattened, membranous sacs called **cisternae**.
- **Function**:
  - **Modification** of proteins and lipids received from the ER.
  - **Sorting**, **packaging**, and **storage** of proteins and lipids.
  - **Transport** of these materials in vesicles through the cell.
  - **Manufacture** of some certain macromolecules, e.g. hyaluronic acid.
- **Size**: 1-3 µm diameter
- **Also called**: Golgi, Golgi body





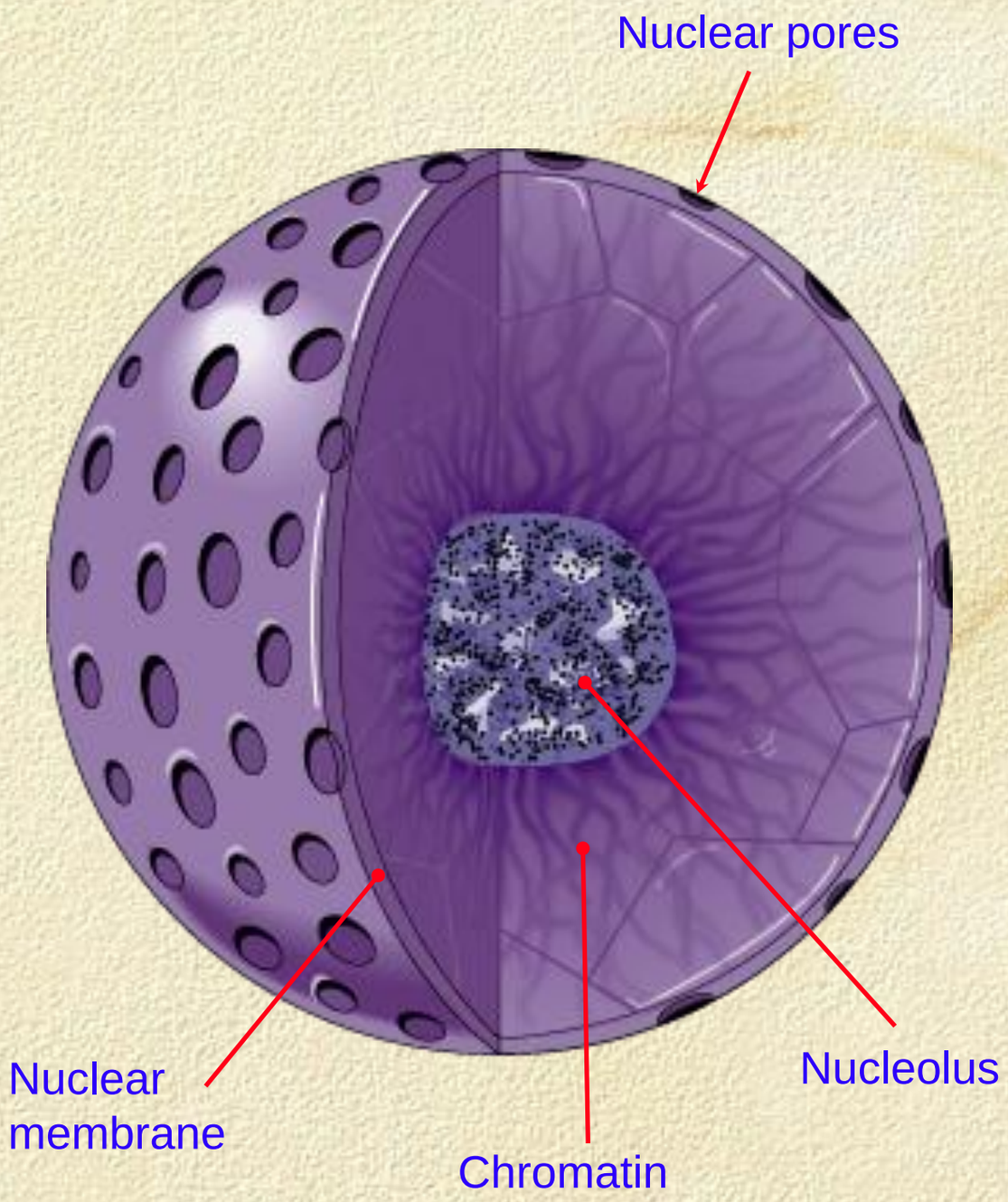
Nucleus

- **Located**:
  Variable location; not necessarily near the center of the cell.

- **Structure**:
  Surrounded by a **nuclear envelope** and encloses the genetic material (chromatin). Nuclear envelope comprises a double membrane perforated by pores ~100 nm in diameter. The two membranes are separated by a space of ~20-40 nm.

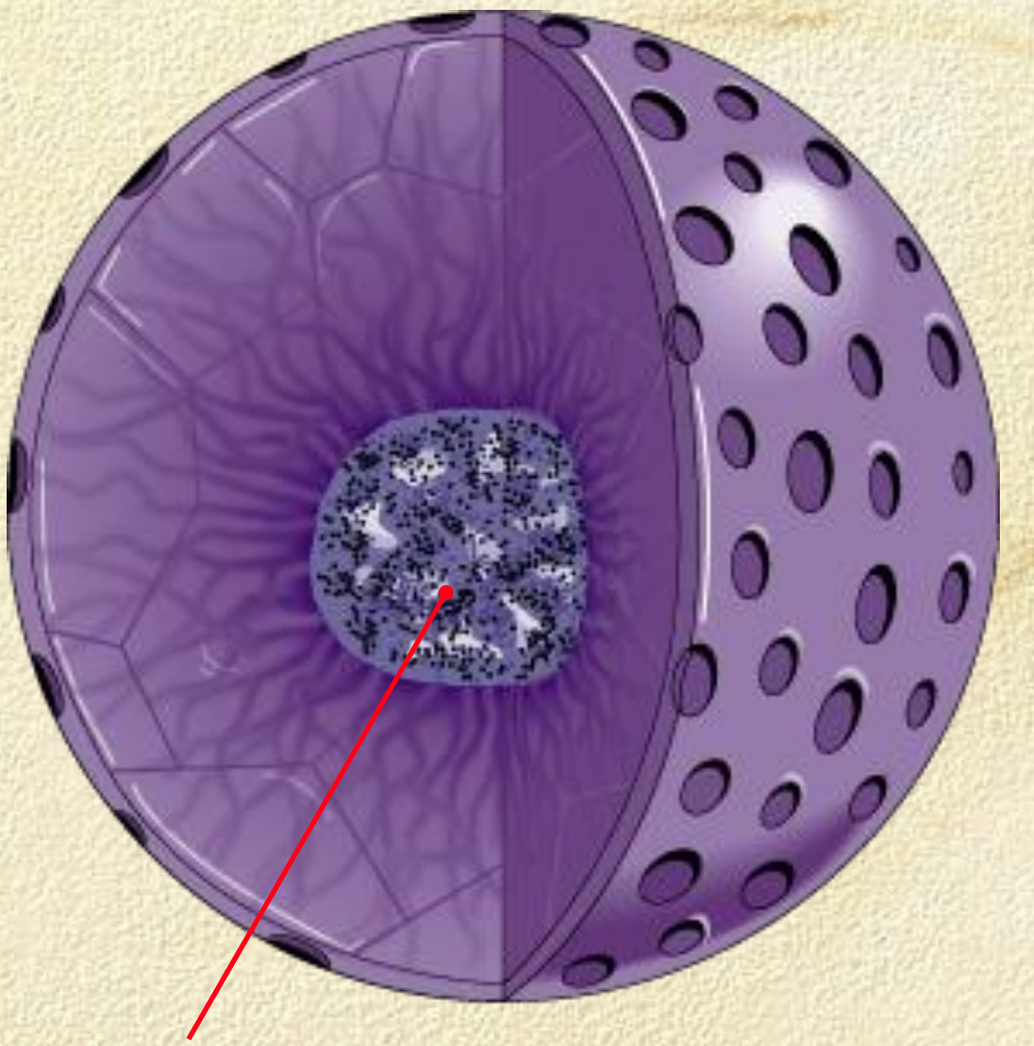
- **Function**:
  Contains most of the cell's genetic material, which regulates all the activities of the cell.

- **Size**: 5 µm diameter.



Nucleolus

- **Located**:
  Within the nucleus.
  Depending on the organism, there may be more than one.
- **Structure**:
  A prominent structure which appears under EM as a mass of darkly stained granules and fibers adjoining part of the chromatin.
- **Function**:
  - Synthesis of ribosomal RNA
  - Assembly of ribosomal subunits.
- **Size**: 1-2 µm diameter.



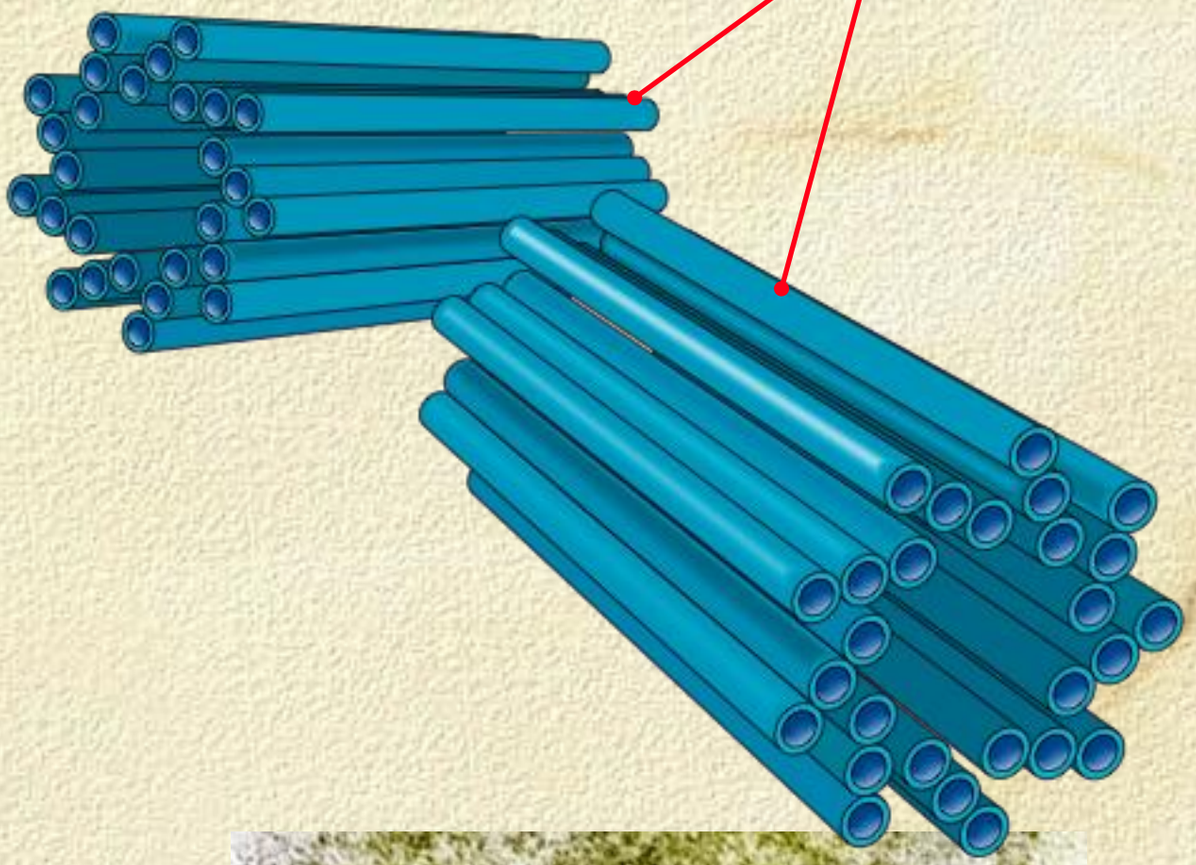
Centrioles

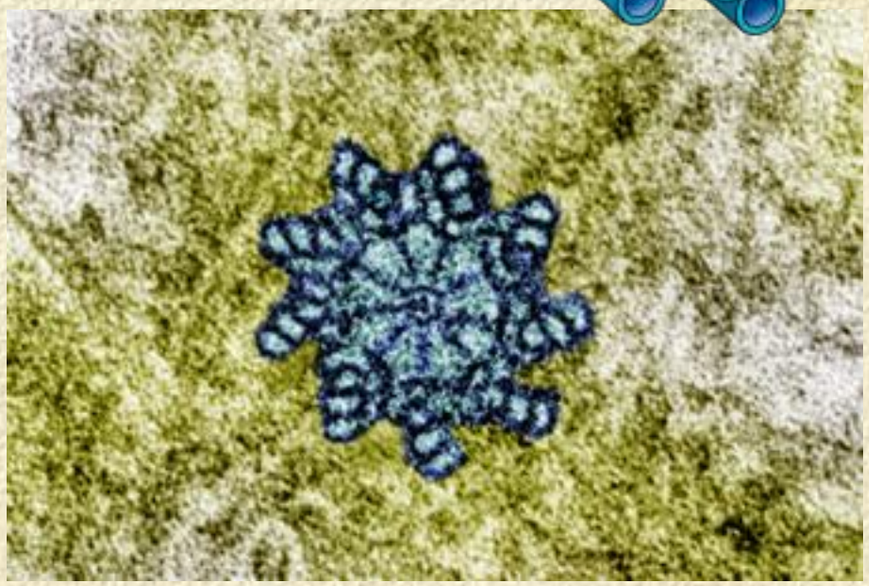
- **Located**:
  In the cytoplasm, as part of the cell **cytoskeleton**. Usually next to or close to the nucleus.

- **Structure**:
  Found as a pair, each one composed of nine sets of triplet **microtubules** arranged in a ring.

- **Function**:
  Involved in organizing microtubule assembly (spindle formation) but not essential as they are **absent** from the cells of **higher plants**.

- **Size**: 0.25 µm diameter.





Centriole in cross section

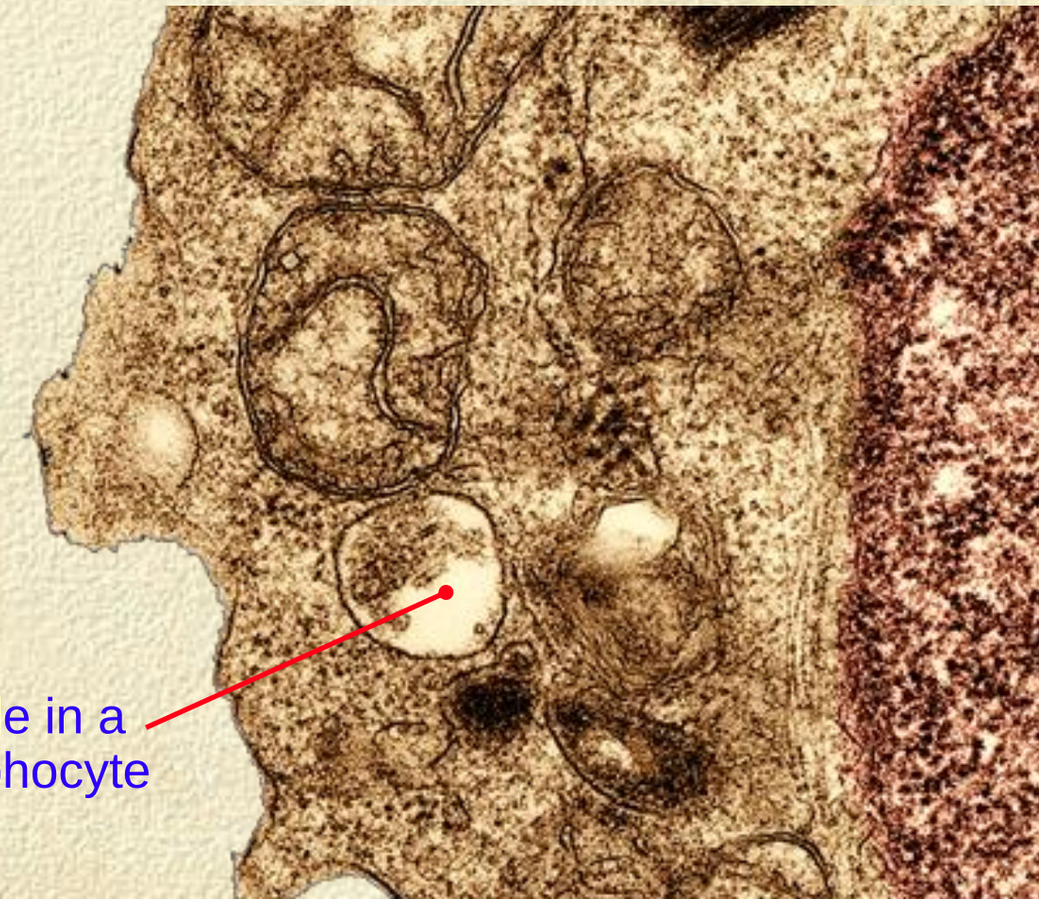
Vacuoles and Vesicles

- **Located**:
  In the cytoplasm; often numerous.

- **Structure**:
  Vacuoles and vesicles are both membrane-bound sacs, but vacuoles are larger.

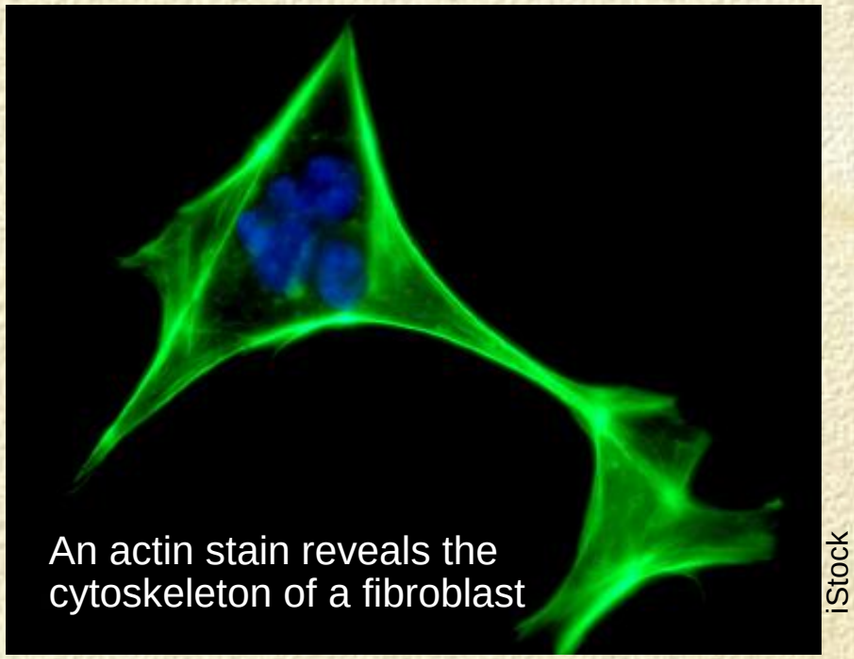
- **Function**:
  - **food vacuoles** in animal cells are formed by phagocytosis of food particles.
  - **contractile vacuoles** of freshwater protists pump excess water from the cell.
  - **central vacuole** of plants provides cell volume and stores inorganic ions and metabolic wastes.

- **Size**: varies according to cell type and size.

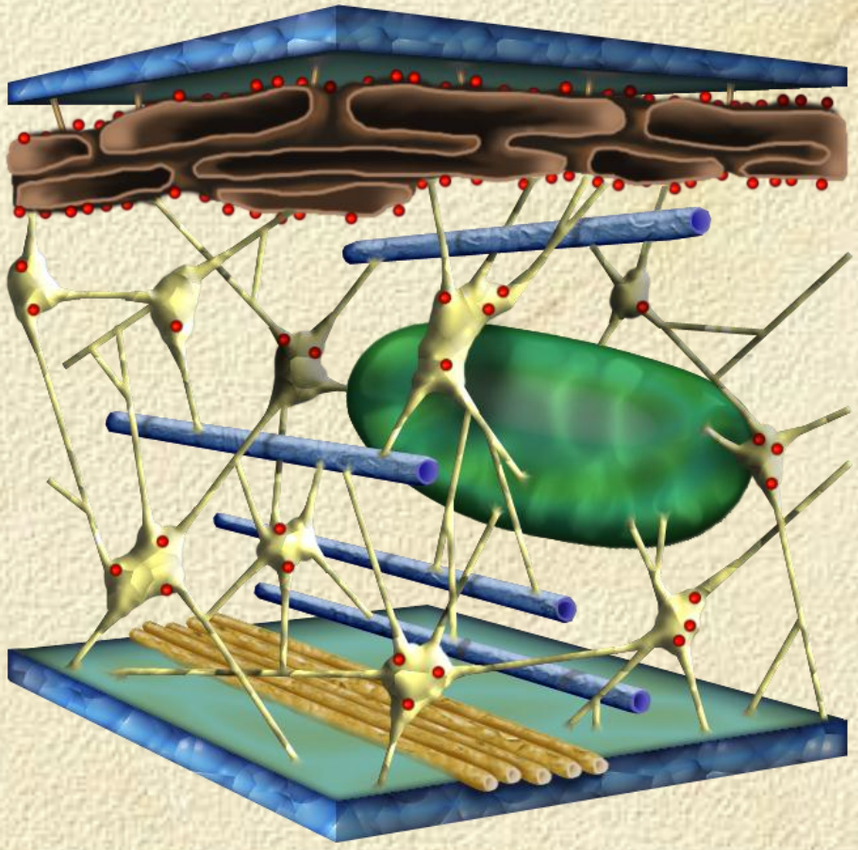


The Cell Cytoskeleton

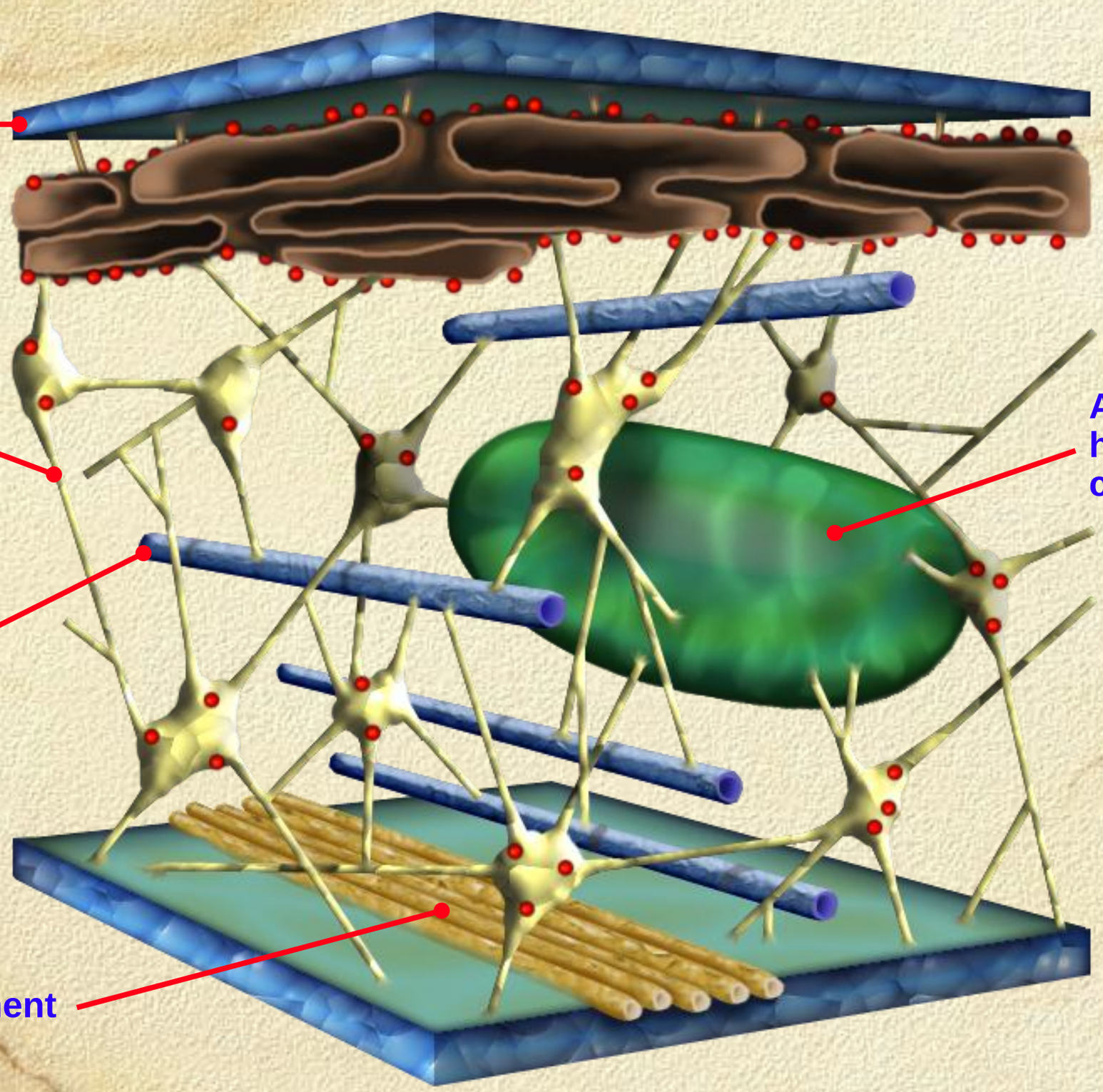
- **Located**:
  A network throughout the cytoplasm.
- **Structure**:
  A dynamic system of **microtubules**, **microfilaments**, and intermediate filaments.
- **Function**:
  - shape and mechanical support for the cell
  - regulation of cellular activities, e.g. guiding secretory vesicles.
  - especially important in animal cells.
  - involved in cell movement (**motility**).
- **Size**:
  - microtubules: 25 nm
  - microfilaments (actin filaments): 7 nm
  - intermediate filaments: 8-12 nm


An actin stain reveals the cytoskeleton of a fibroblast

iStock

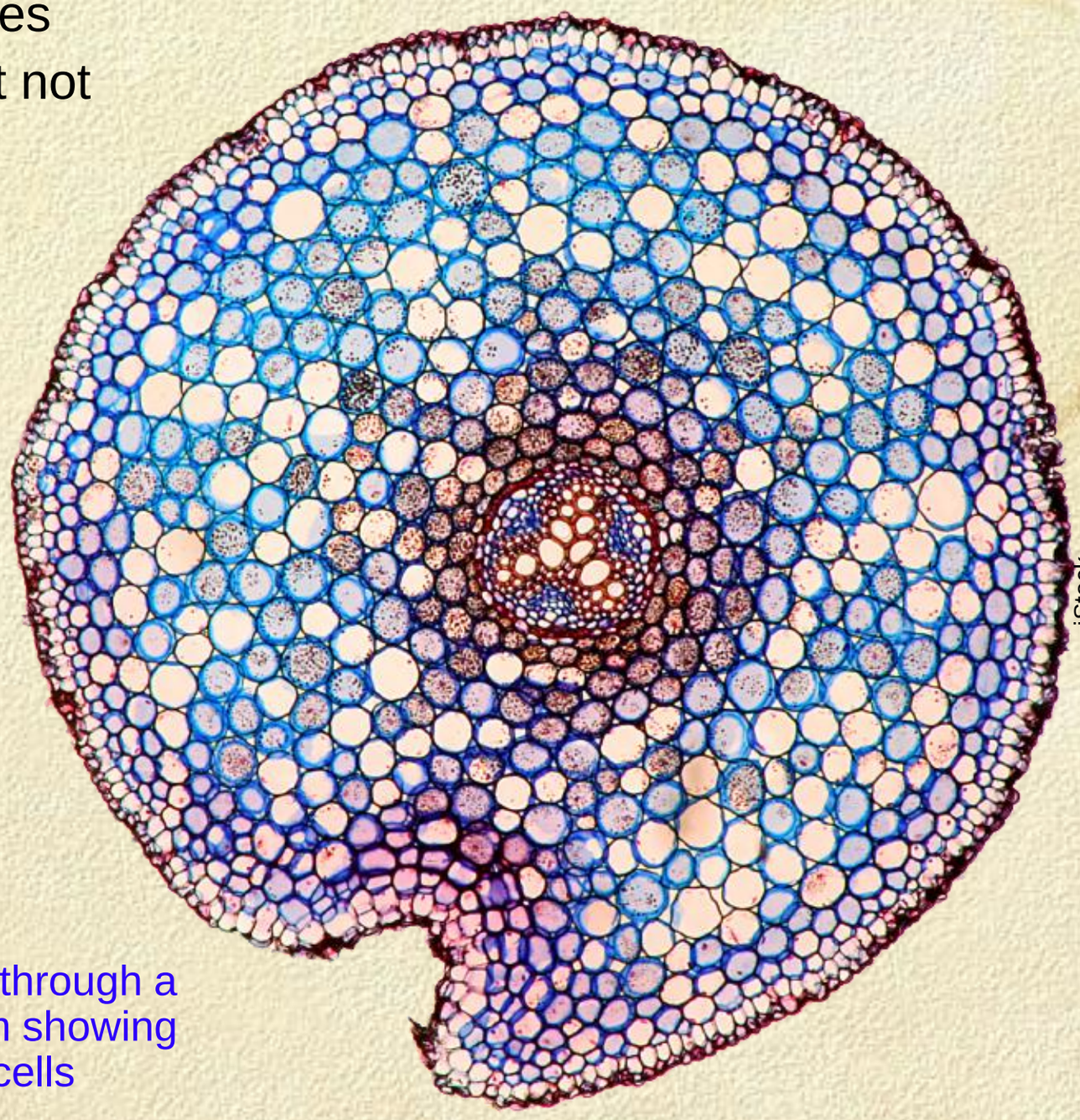


The Cell Cytoskeleton



Specialist Plant Cell Features

- A small number of cellular organelles are typically found in plant cells but not in animal cells.
- Organelles and structures found in plant cells are:
  - cellulose **cell wall**
  - plastids
    - **chloroplasts**
    - **amyloplasts**
    - **chromoplasts**



Cross section through a buttercup stem showing the individual cells

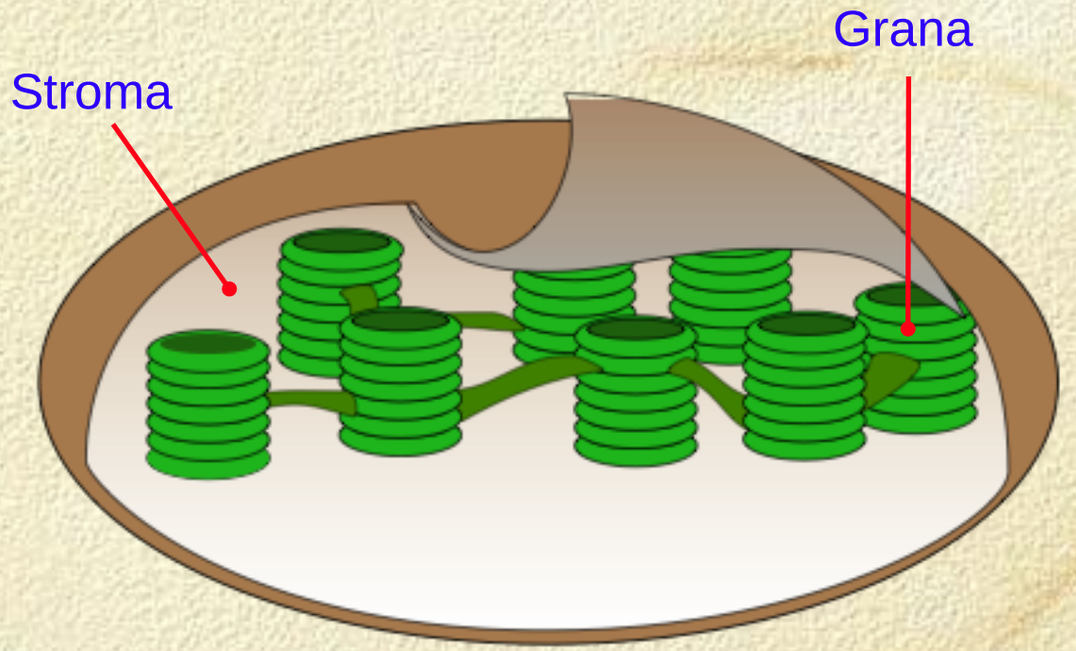
Chloroplasts

- **Located**:
  Within the cytoplasm of plant leaf (and sometimes stem) cells.

- **Structure**:
  - Specialized plastids containing the green pigment chlorophyll.
  - Two outer membranes are separated by a narrow inter-membrane space.
  - Inside the chloroplasts are stacks of flattened sacs or **thylakoids** which are stacked together as **grana**.
  - Chloroplasts contain some DNA

- **Function**:
  The site of photosynthesis

- **Size**: 2 X 5 µm.



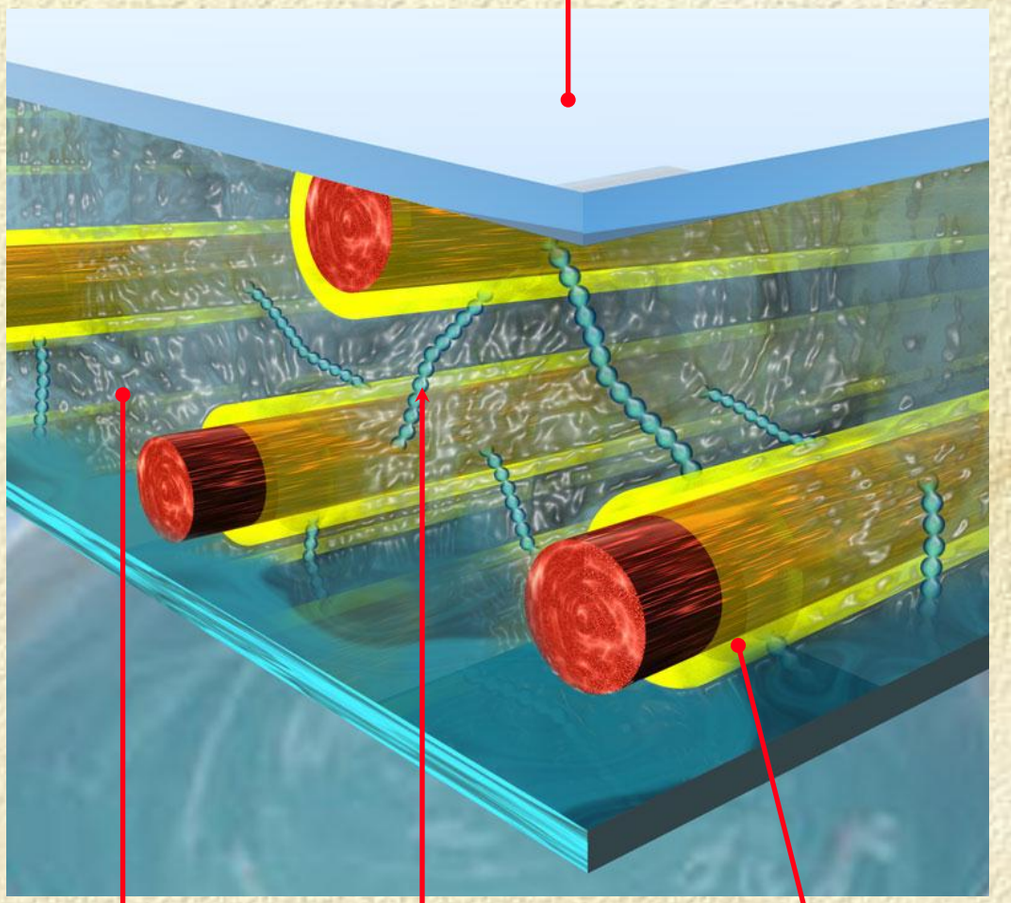
Cellulose Cell Wall

- **Located**:
  Surrounds the plant cell and lies outside the plasma membrane.

- **Structure**:
  Cellulose fibers, with associated hemicelluloses (branched polysaccharides) and pectins. Between the walls of adjacent cells, is a sticky substance called the **middle lamella**.

- **Function**:
  - protects the cell
  - maintains cell shape
  - prevents excessive water uptake

- **Size**: 0.1 µm to several µm thick.



Diagrammatic representation of plant cell wall structure

Plastids

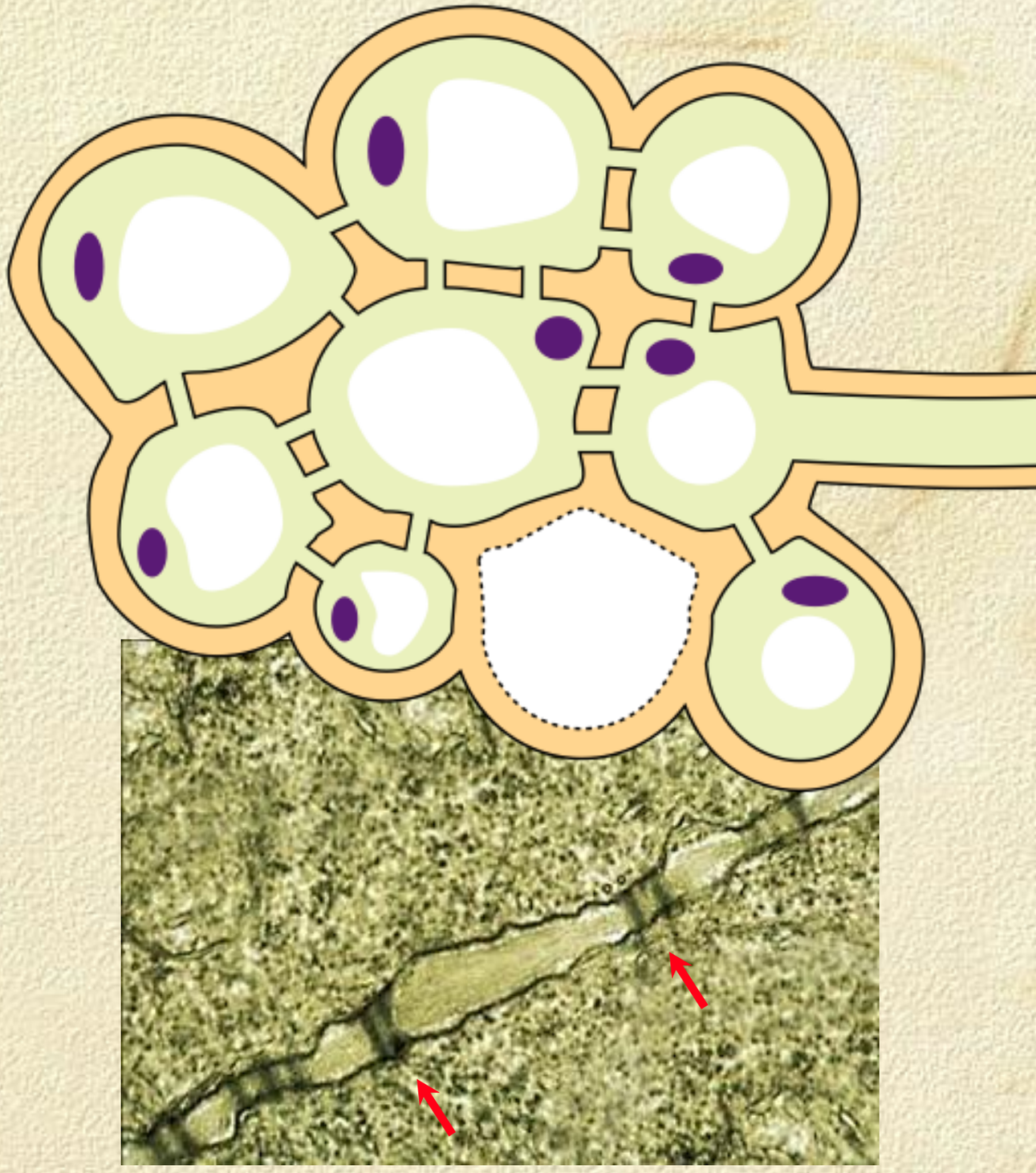
- **Located**:
  In the cytoplasm.
- **Structure**:
  Double membrane-bound structures.
  The inner membranes typically possess the enzymes that determine what plastids do.
- **Function**:
  Different plastids have particular roles:
  - **Chloroplasts**; site of photosynthesis
  - **Chromoplasts**: contain red, orange, and/or yellow pigments and give color to plant organs such as flowers and fruits. They serve as attractants and identifiers.
  - **Amyloplasts**: storage of starch and fats.
- **Size**: variable depending on type

Colorless **amyloplasts** in potato tubers

Chromoplasts provide the bright color of flowers and fruit

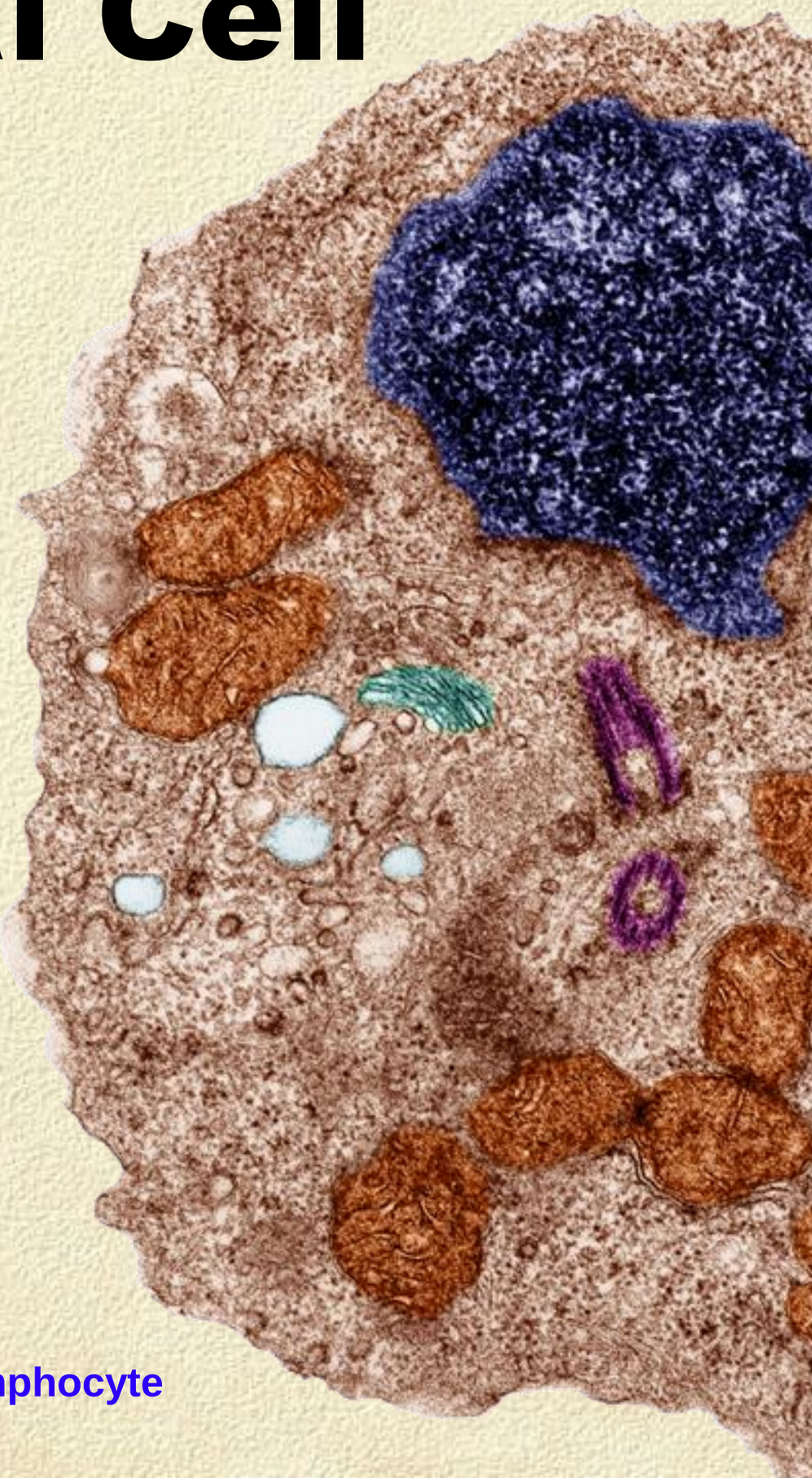
Intercellular Connections in Plant Cells

- The cells of a plant or animal are organized into tissues, organs, and organ systems.
- Neighboring cells often interact, adhere, and communicate through special regions of direct physical contact.
- In plant cells these connections are called **plasmodesmata**.
  - Plant cell walls are perforated with channels or plasmodesmata.
  - Cytosol passes through the plasmodesmata and connects the living contents of adjacent cells.



Specialist Animal Cell Features

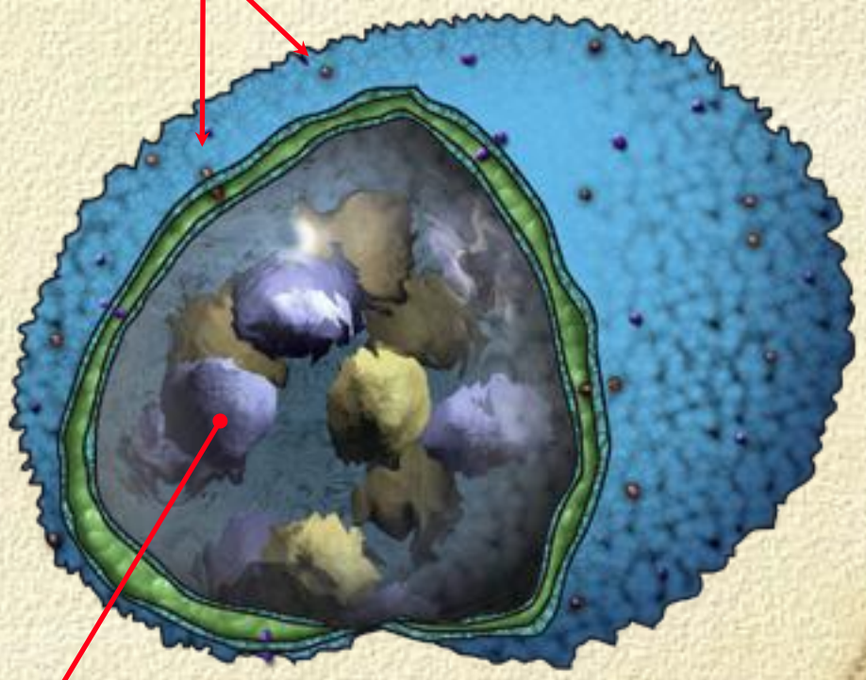
- A small number of cellular organelles are typically found in animal cells but not in plant cells.
- Organelles and structures found in animal cells are:
  - **lysosomes**
  - **cilia**
  - **flagella**

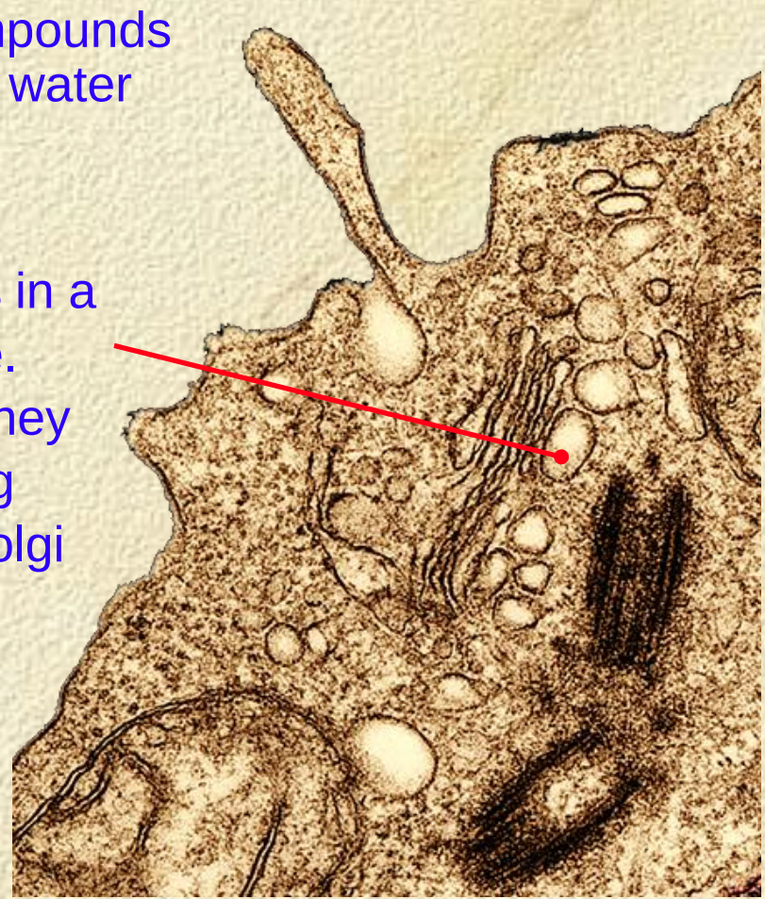


TEM of a human lymphocyte

Lysosomes

- **Located**:
  Free in the cytoplasm.
- **Structure**:
  Single-membrane-bound sac of **hydrolytic enzymes**. Lysosomes bud off the Golgi apparatus.
- **Function**:
  - intracellular digestion of macromolecules (fats, protein, polysaccharides, and nucleic acids)
  - recycling of cellular components (autophagy)
  - low internal pH maintained by H^+ pump in the lysosomal membrane
- **Size**: varies according to cell size





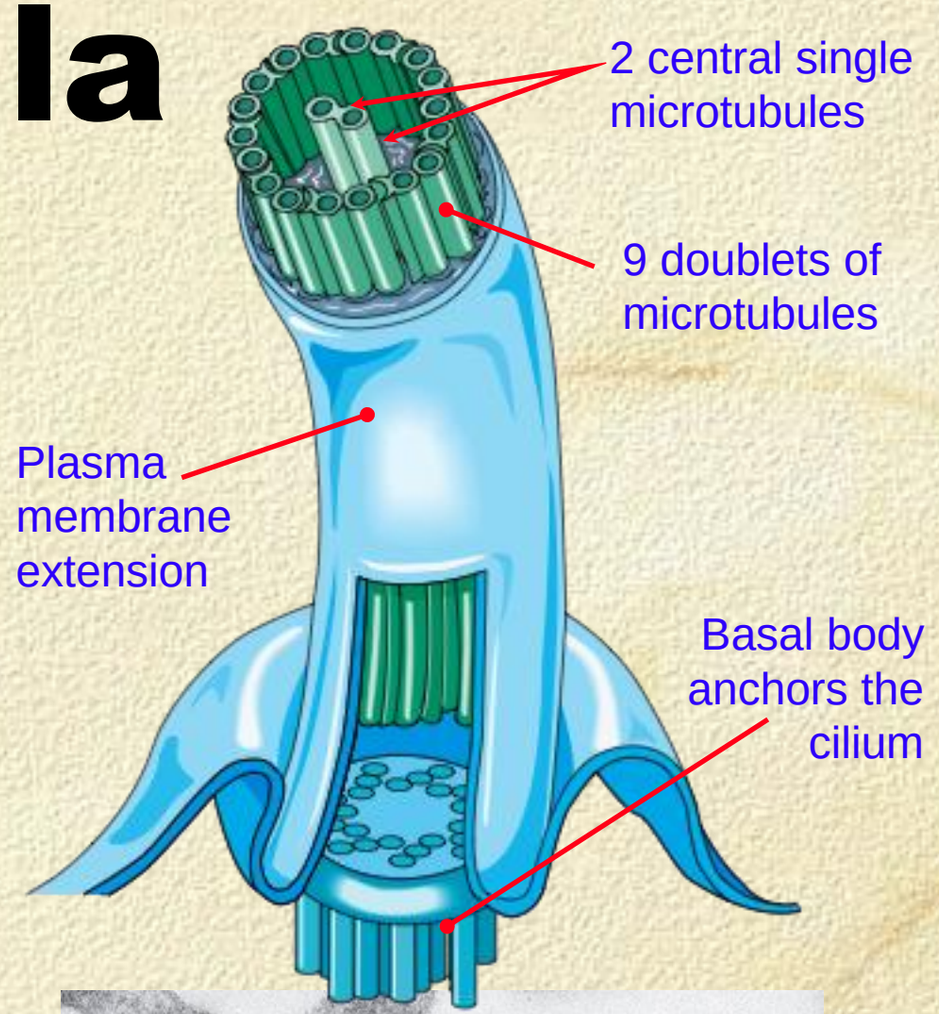
Cilia and Flagella

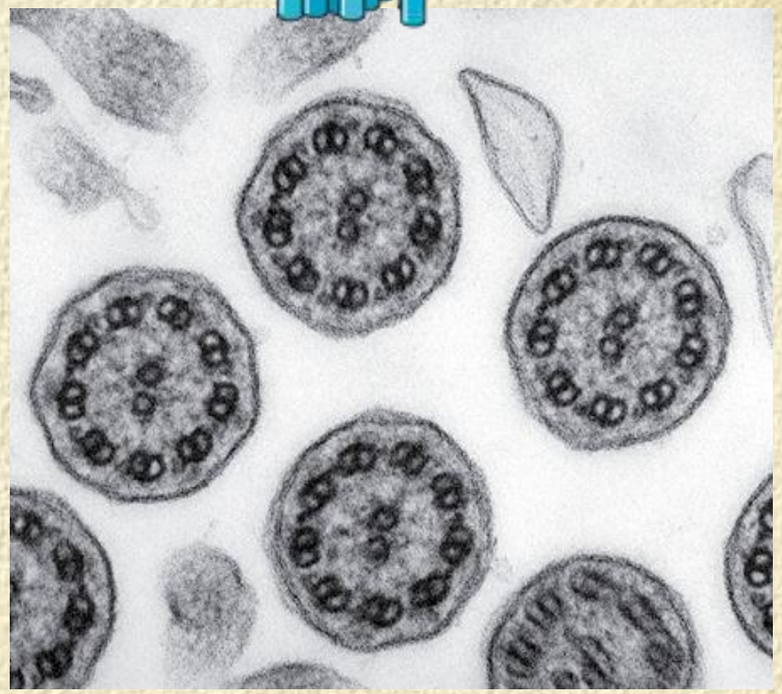
- **Located**:
  Anchored to the cell membrane of some animal cells and unicellular eukaryotes.

- **Structure**:
  Core of microtubules sheathed in an extension of the plasma membrane. Microtubules are arranged in a **9+2** pattern with nine doublets of microtubules arranged in a ring around two single microtubules.

- **Function**:
  Cell motility or, in cells held in place, they move fluid across the cell surface.

- **Size**:
  - **Cilia**: 0.25 µm X 2-20 µm
  - **Flagella**: 0.25 µm X 10-200 µm

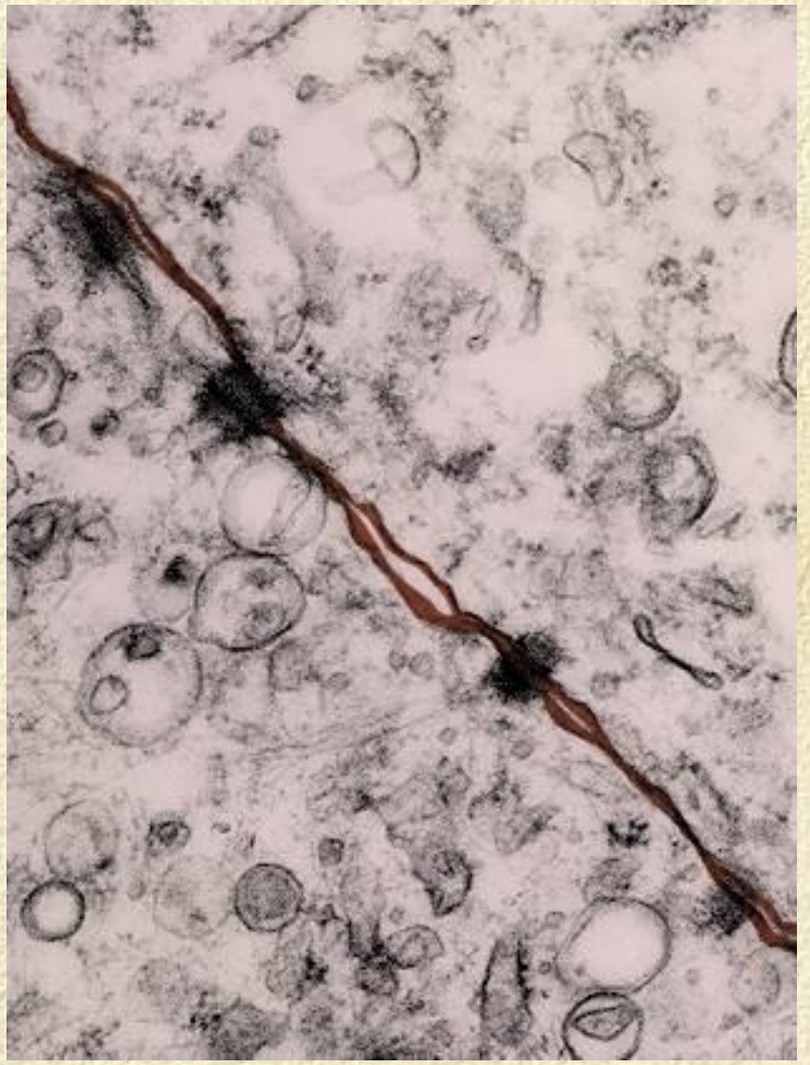




TEM of cilia in cross section

Intercellular Connections in Animal Cells

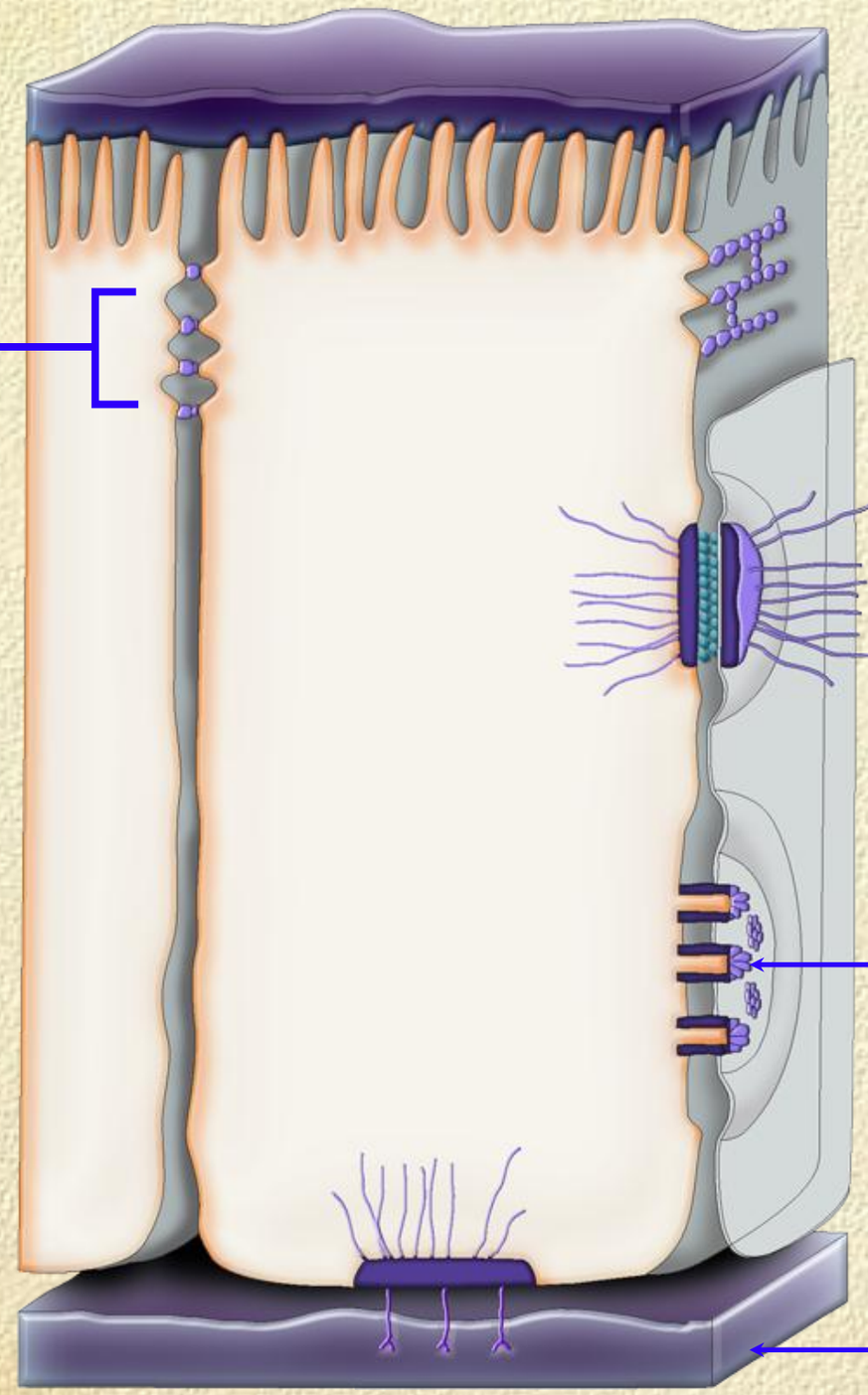
- **Desmosomes** (anchoring junctions)
  - Act as rivets, fastening cells together into strong sheets.
- **Gap junctions** (communicating junctions)
  - Cytoplasmic channels between adjacent cells.
  - Each pore is surrounded by special membrane proteins.
  - Pores allow passage of small molecules such as salt ions, sugars, and amino acids.
- **Tight junctions** of animal cells.
  - Membranes of neighboring cells are fused.
  - Prevent leakage of extracellular fluid across a layer of epithelial cells.



The plasma membranes of two adjacent cells joined with **desmosomes**

Intercellular Connections in Animal Cells

Tight junction: The fusion of adjacent cell membranes prevent leakage of extracellular fluid. Tight junctions form a continuous belt around cells.



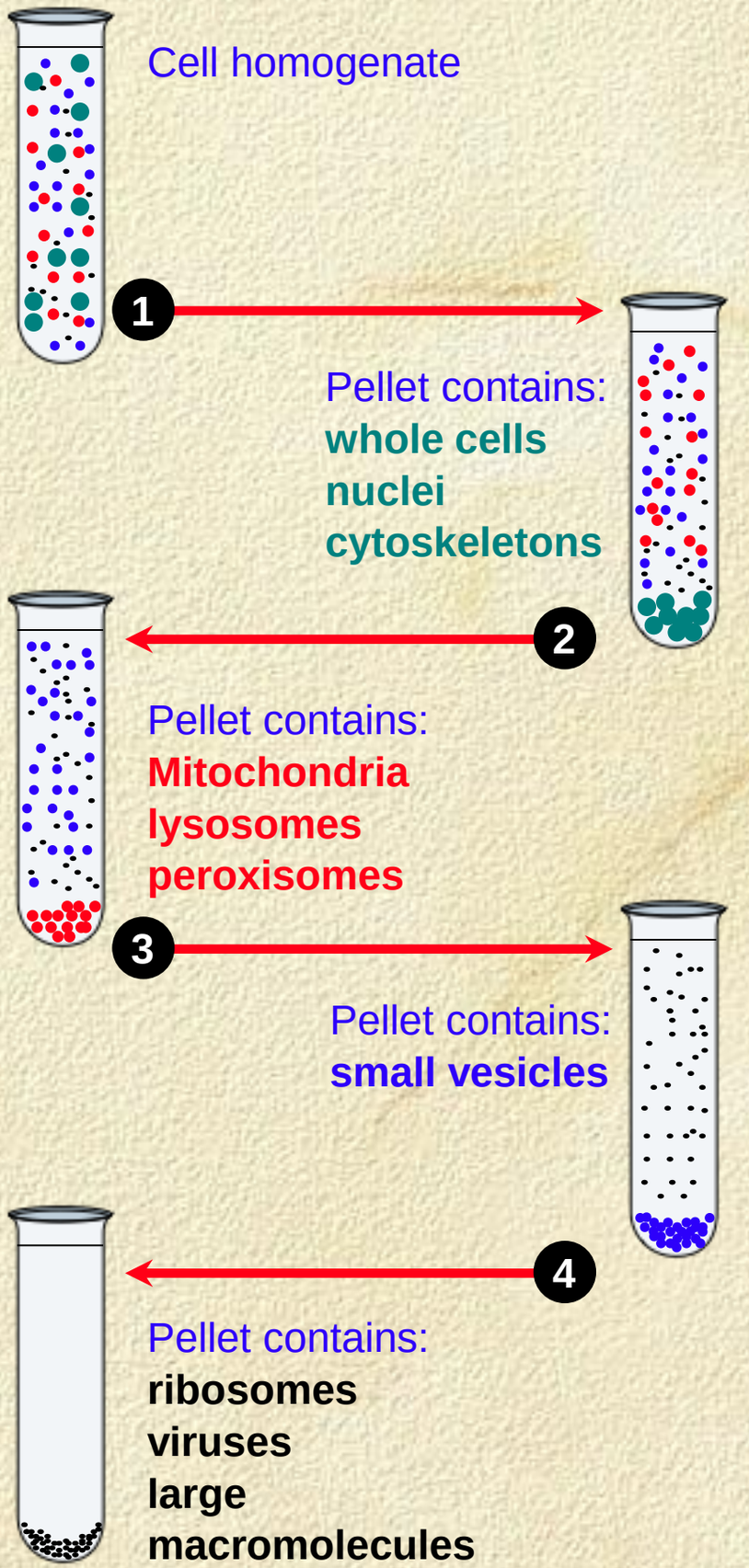
Desmosome: An anchoring junction fastens cells into sheets. Desmosomes are strengthened by keratin protein filaments.

Gap junction: A communicating junction provides a narrow channel between neighboring cells.

Extracellular matrix

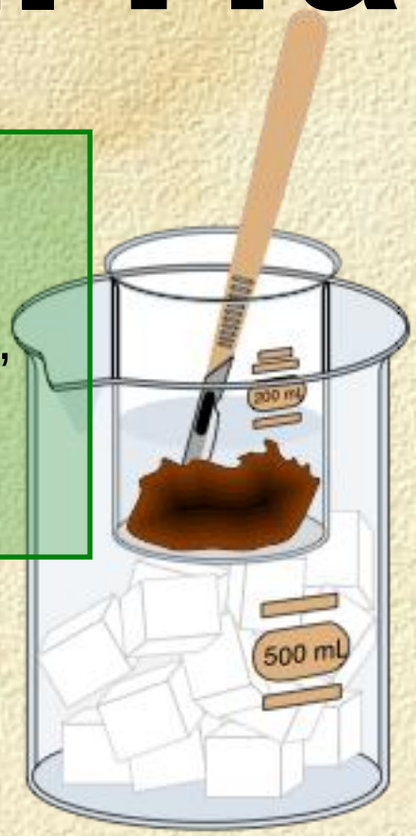
Cell Fractionation

- **Differential centrifugation** is also called **cell fractionation**. It is a widely used tool which enables the extraction of organelles from cells.
- The aim is to isolate and identify cellular fractions (organelles of a particular type) from a **heterogeneous** (mixed) sample.
- Isolating organelles in this way has allowed their structure and function to be explored.
- During cell fractionation, samples are:
  - kept cold to prevent self digestion
  - kept in a **buffered isotonic solution** to prevent changes in volume and enzyme denaturation.
  - spun down at increasing centrifugation speeds (steps 1-4)

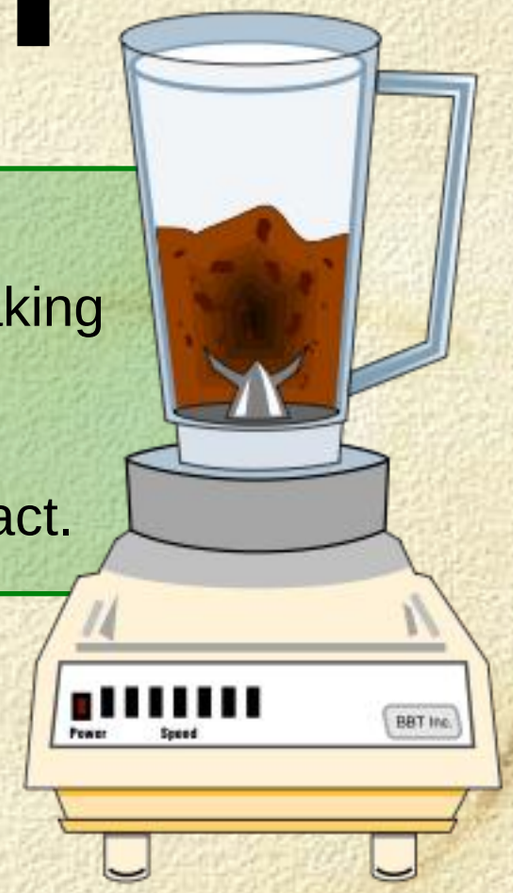


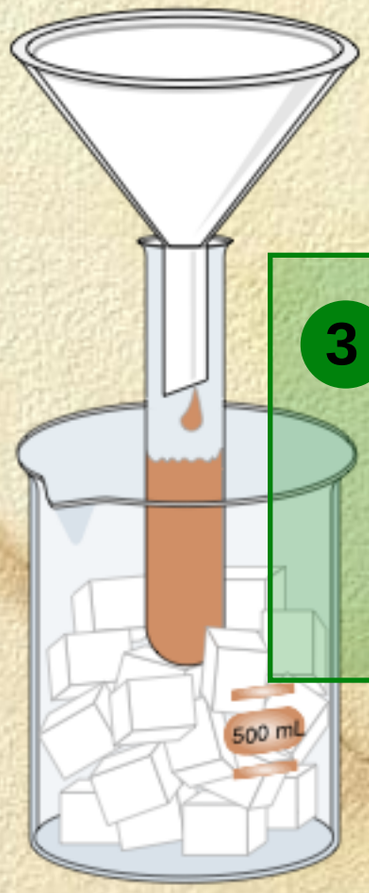
Cell Fractionation

1. The sample is chilled over ice and cut into small pieces in a cold, buffered, isotonic solution.

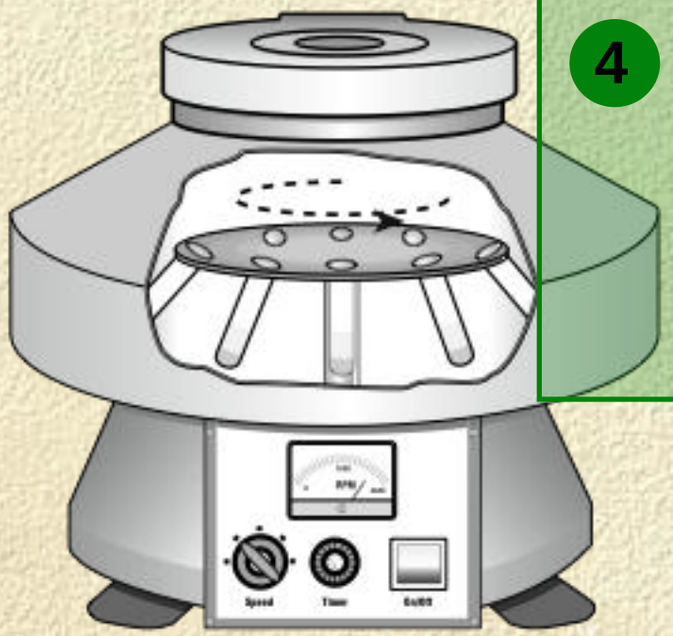


2. The sample is homogenized by breaking down the cells' outer membranes. The cell organelles remain intact.



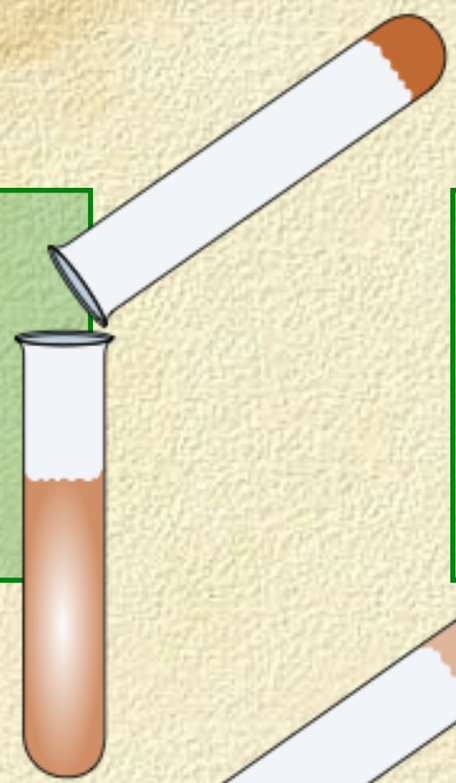


3. The homogenized suspension is filtered to remove cellular debris. It is kept cool throughout.

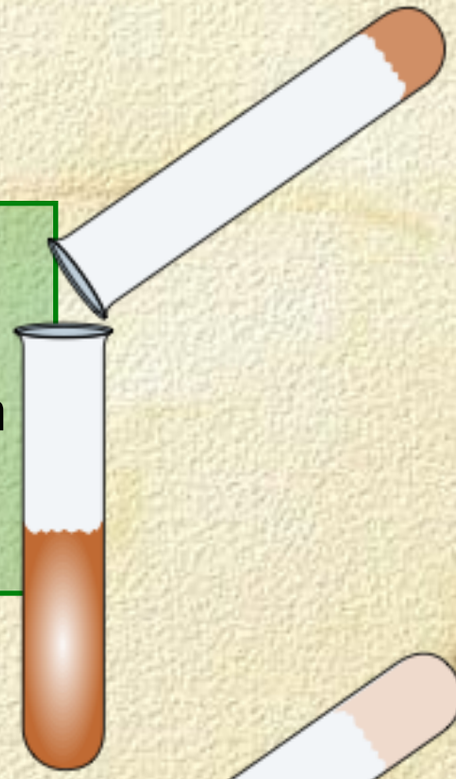


4. The filtrate is centrifuged at low speed to remove partly opened cells and small pieces of debris.

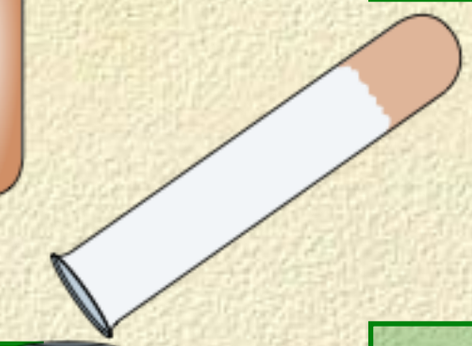
Cell Fractionation



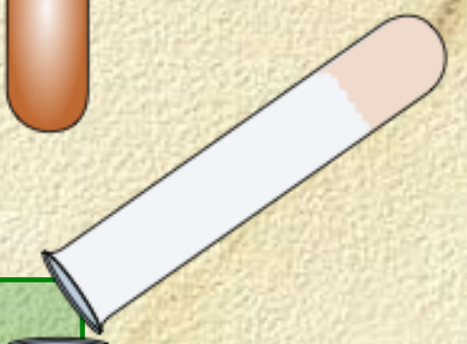
5 The supernatant containing the organelles is carefully decanted off.



6 The sample is centrifuged at 500-600 *g* for 5-10 minutes then decanted.



7 The sample is centrifuged at 10,000-20,000 *g* for 15-20 minutes and then decanted.



8 The sample is centrifuged at 100,000 *g* for 1 hour and decanted.