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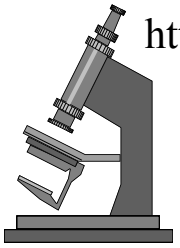
Cytology

John R. Hoffman

http://www.tinyurl.com/AUHistology



Objectives: At the end of this lecture, the student will be able to:

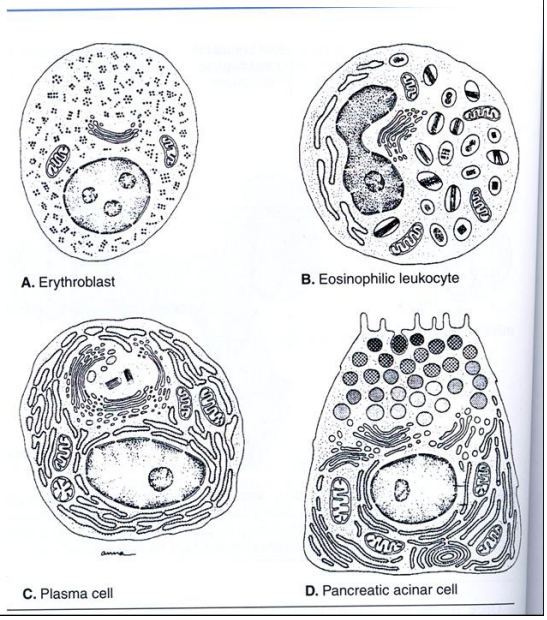
1. Describe the functioning of the plasma membrane.
   A. Explain the importance and function of phospholipids in the plasma membrane.
   B. Explain the importance and function of proteins in the plasma membrane.
   C. Compare and contrast integral and peripheral membrane proteins.
   D. Explain the importance and function of glycolipids associated with the plasma membranes.
   E. Compare and contrast endocytosis and exocytosis.
2. Describe how the appearance of the nucleus provides information on the activity of the cell.
   A. Compare and contrast euchromatin and heterochromatin.
3. Identify and describe the appearance and function of basic subcellular structures.

Objectives: At the end of this lecture, the student will be able to:

4. Predict which subcellular structures will be present in a cell when provided with a general description of the cell.
   A. Predict and explain the appearance of a protein-synthesizing and secreting cell.
   B. Predict and explain the appearance of a cell synthesizing proteins of cytoplasmic usage.
5. Explain and give examples of cellular differentiation.

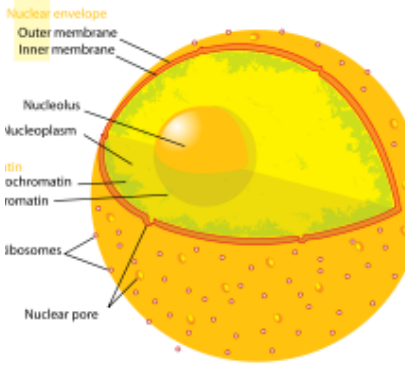
Cellular Differentiation

- Immature cells:
  -stem cells
  -very generic
- Mature cells:
  -distinct functions.
  -specialized
  - ex. Muscle cells
    neuron cells
    epidermal cells



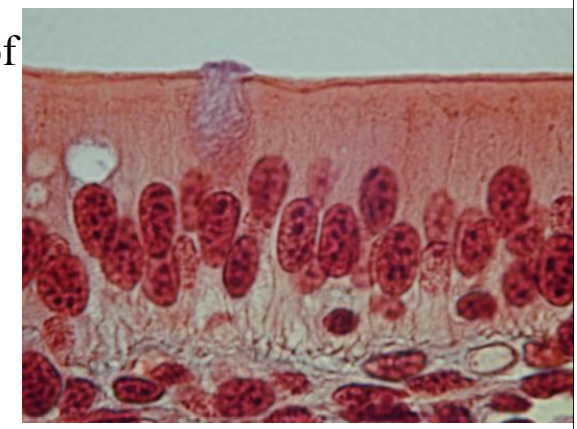
Nucleus

- Contains DNA and associated proteins
- Central role in gene expression and heredity.



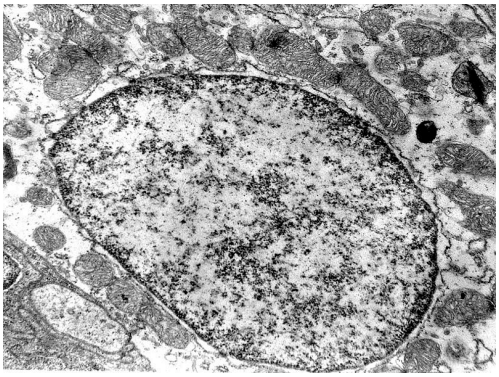
Differ in appearance between cell types:

- Size: absolute and relative to amount of cytoplasm.
- Shape: round, oval, segmented
- Number: enucleate, mono, bi, multi-nucleate.
- Location: basal, central, eccentric



Chromatin Pattern

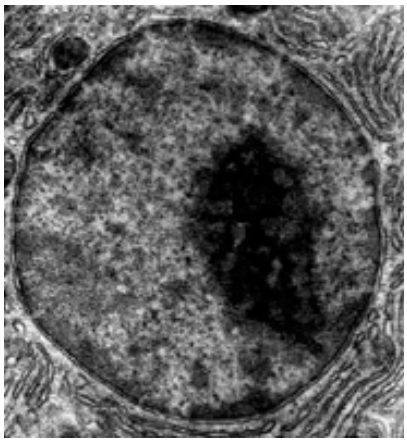
- Chromatin:
  - DNA and associated proteins.
  - intensely basophilic
- Euchromatin
  - "true chromatin"
  - Less compact
  - Lighter staining



Cell nucleus of a chloride cell
Wikimedia Commons

Chromatin Pattern

- Heterochromatin
  - Denser staining
- Nucleolus: site of rRNA synthesis



Micrograph of a cell nucleus published in Inside the Cell, a publication of the US National Institute of General Medical Sciences/National Institutes of Health.

Any Questions?

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  hoffmanj@arcadia.edu
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Cytology:
Plasma Membrane

John R. Hoffman

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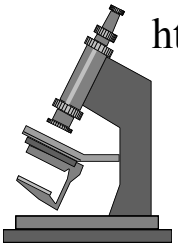
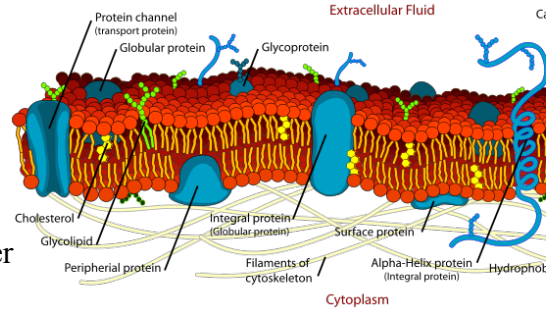


Plasma membrane (a.k.a. cell membrane) has 3 biochemical components.

Not visible with light microscopy.

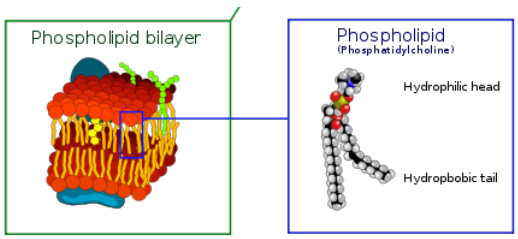
- Phospholipids:
  - Hydrophobic barrier
- Proteins:
  - Semi-permeable barrier
- Carbohydrates:
  - external cell recognition



Cell membrane detailed diagram
Wikimedia Commons

The hydrophobic properties of the membrane are based on phospholipids, sphingolipids, and cholesterol.

- Phospholipids:
- Amphipathic
  - Polar phosphate-containing heads
  - nonpolar (hydrophobic) fatty acid tails.

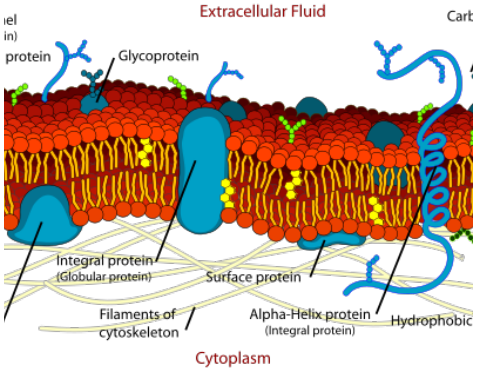


- Lipid bilayer

Cell membrane detailed diagram
Wikimedia Commons

The proteins provide special functions to the membrane.

- More than 50% of membrane weight.
- Integral membrane proteins
  - lodged in lipid bilayer
- Peripheral membrane proteins
  - loosely associated with inner or outer membrane surface.



Cell membrane detailed diagram
Wikimedia Commons

Examples of Membrane Protein Functions

1. Pumps:
   - actively transport materials
2. Channels:
   - passage of small ions and molecules.
3. Receptors:
   - recognition and localized binding of substances.

Examples of Membrane Protein Functions

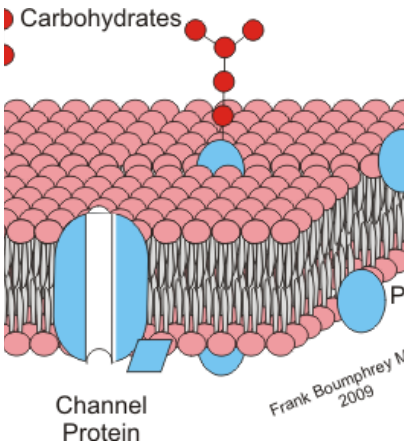
4. Transducers:
   - convert outside signal into internal message (ex. cAMP)

5. Enzymes:
   - control chemical reactions

6. Structural:
   - within and outside of cell

Carbohydrates on the external surface of the plasma membrane form the glycocalyx.

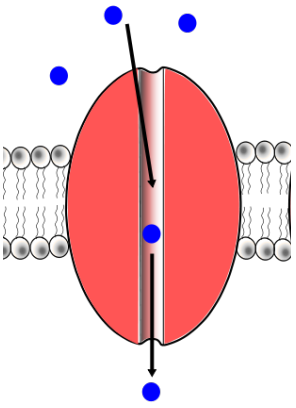
- Oligosaccharide moeities
  - attached to membrane glycolipids and glycoproteins.
- Allows cell adhesion and recognition.



The plasma membrane is selectively permeable forming a barrier to control movement.

1. Passive diffusion:
   - follows concentration gradient,
   - does not require energy.

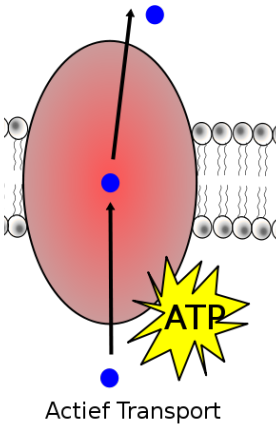
2. Facilitated diffusion:
   - helped across membrane
   - unidirectional,
   - follows concentration gradient,
   - does not require energy.



Passive and Active Transport
Wikimedia commons

The plasma membrane is selectively permeable forming a barrier to control movement.

- Active transport:
  - move non-diffusible molecules across membrane.
  - Or move against concentration gradient
  - requires energy such as ATP.



Passive and Active Transport
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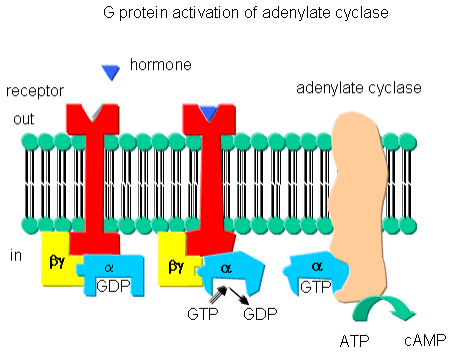
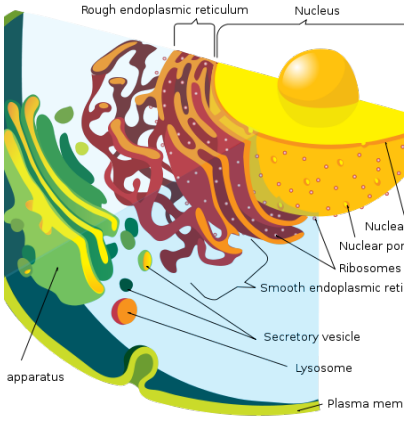
Cell membrane receptors are involved with signal transduction

- cell membrane proteins
  - Bind to signal molecules (ligands)
  - Transmit signal into the cell interior.



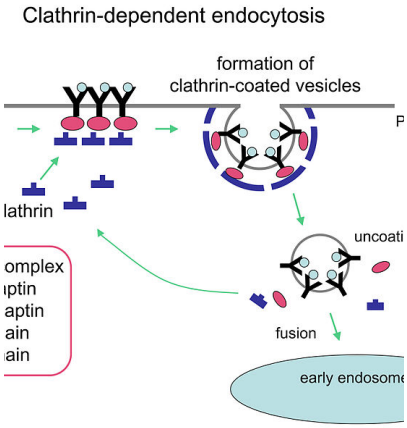
Plasma membranes are involved with compartmentalization of subcellular structures.

- Storage, transport, secretion
- Isolate substance during intracellular processes.
- Organelles have different concentrations of substances (different environments).



Endocytosis and Exocytosis involve movement of materials in membrane-bound structures.

- Endocytosis: absorbing substances into cell.
  - phagocytosis:
    - "cell eating" of macromolecules
  - pinocytosis:
    - "cell-drinking" of small amounts of fluids.
  - receptor-mediated endocytosis:
    - use receptors to concentrate materials
- Exocytosis: secretion or excretion from cell.



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Any Questions?

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Cytology: Cytoplasm I – protein synthesis and movement of membrane bound organelles

John R. Hoffman

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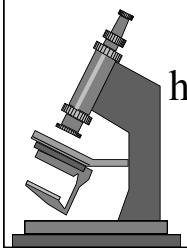


Cytoplasm

- Cytosol:
  water, ions, metabolites, enzymes, etc.
- Organelles:
  "little organs" distinct structure and function.
  Membrane and non-membrane bound.
- Cytoplasmic inclusions:
  deposits of carbohydrates, lipids, pigments.

Ribosomes

- Protein-synthesizing organelles
  - Ribosomal RNA (rRNA)
  - Proteins and enzymes
  - 2 subunits (large and small)

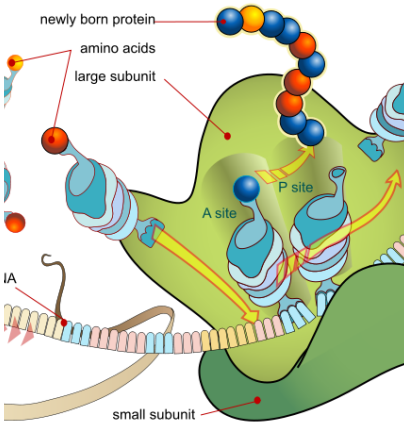
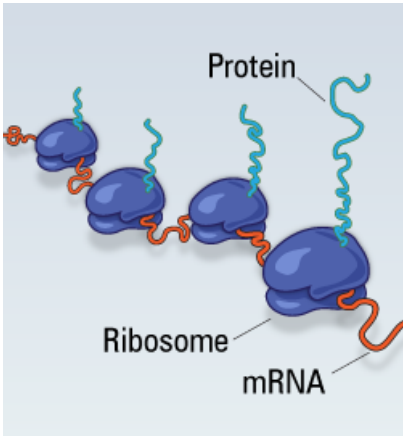


diagram showing how the translation of the mRNA and the synthesis of proteins is made by ribosomes.

Protein synthesis for cytoplasmic protein can occur on free ribosomes and polysomes

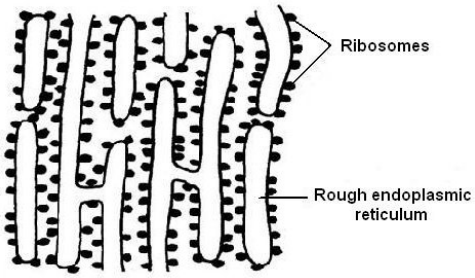
- Free ribosomes:
  - individual ribosomes in cytoplasm.
- Polysomes:
  - multiple ribosomes along single strand of mRNA.
- Free polysomes:
  - make structural proteins and enzymes for intracellular cytoplasmic use.



http://www.broadinstitute.org/blog/it's-trap

Ribosomes on the Rough Endoplasmic Reticulum build proteins for secretion or sequestration.

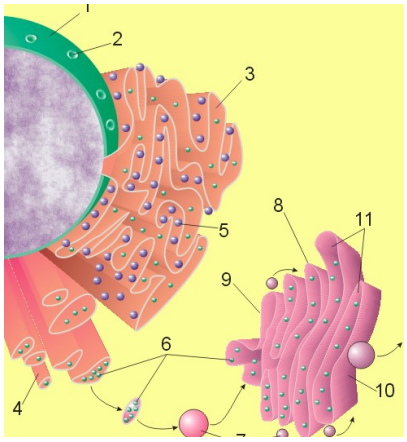
- Rough Endoplasmic Reticulum
  - Polysomes on membrane-bound organelle.
- Ribosomes dock on membrane.
- Synthesize proteins for secretion or sequestration.



Rough endoplasmic reticulum
Wikimedia Commons

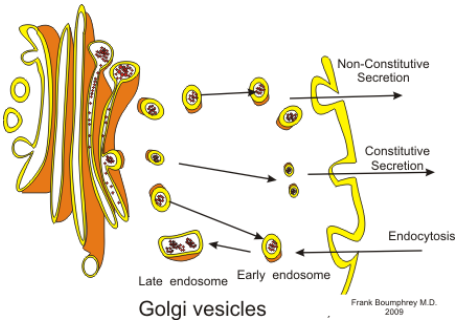
Golgi Apparatus is involved in protein modification and sorting.

- Stack of slightly curved, flattened cisternae.
  - Cis-face-convex, forming.
  - Trans-face: concave, maturing
  - Pale: does not stain with H&E.
- Well developed in secretory cells
  - ex. Glandular and nerve cells



Golgi Apparatus: function

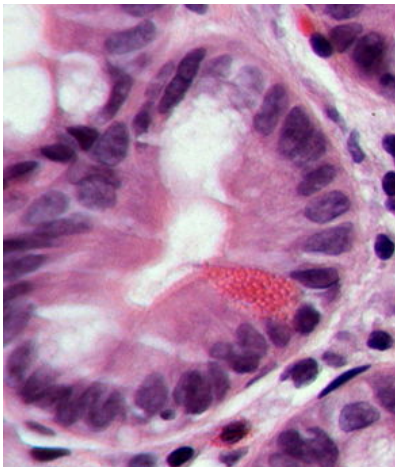
- Post-translational modification
  - glycosylates proteins:
  - lengthens/shortens polysaccharide and oligosaccharide chains.
- Sorts proteins to proper membrane domain or organelle.
- Package secretory products for release.



Golgi apparatus and secretory vesicles. Wikimedia Commons

Transport, Storage, Secretory Vesicles

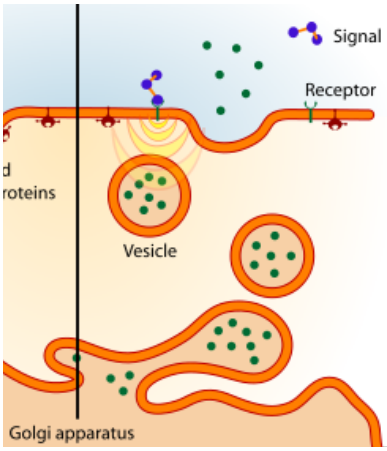
- Membrane bound vesicles
  - Sequester materials
  - Transport between other structures.
  - Endocytosis
  - exocytosis



Complete intestinal metaplasia in a case of chronic gastritis. Wikimedia Commons

Exocytosis

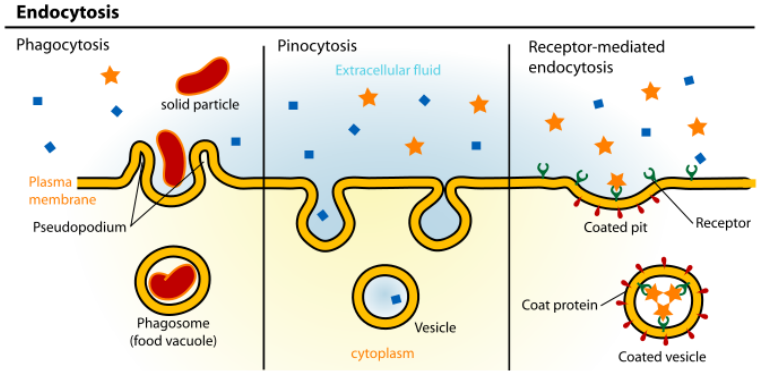
- Controlled release of materials from cell.
- Minimal loss of cytoplasm.
- Fusion of membrane bound vesicles with surface membrane.



Exocytosis
Wikimedia Commons

Endocytosis

- Controlled uptake of materials by a cell.
- Creation of membrane bound vesicle pocketing in surface membrane.



Endocytosis types, Wikimedia commons

Lysosomes are involved with intracellular digestion.

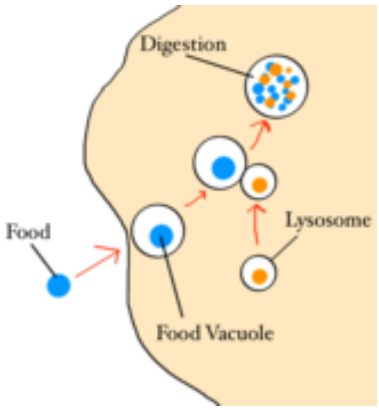
- Membrane-bound
- Filled with enzymes
  - Ex. Acid phosphatase
- Filled with acids

- Abundant in phagocytic cells such as macrophages and neutrophils.
- Also present in long-lived cells (ex. Neurons).

Intracellular Digestive system

- Primary lysosomes:
  - inactive enzymes
- Endosome/Phagosome
  - material to be digested
- Secondary lysosome:
  - combine enzymes and materials for cellular digestion.

- Residual bodies:
  - contain undigestible materials.



http://www.sophia.org/lysosome-concept

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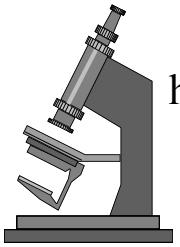
Cytology: Cytoplasm II – smooth endoplasmic reticulum; mitochondria; and cytoskeleton



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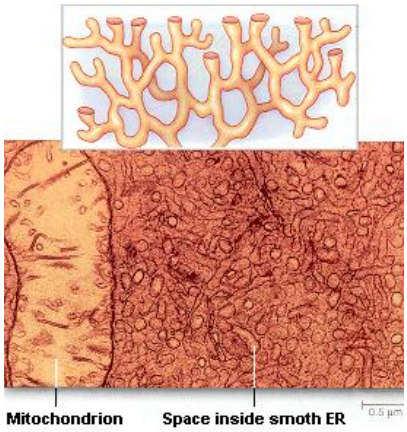
Smooth Endoplasmic Reticulum

- Membrane bound network.
- Cisternae more tubular or vesicular than RER.
- Lacks ribosomes
  - cant make proteins



http://www.tutorvista.com/content/biology/biology-iii/cell-organization/membranous-cell-organelles.php

Smooth Endoplasmic Reticulum: functions

Steroid hormone secreting cells.

- Lipid metabolism
- Steroid hormone synthesis

Liver cells

- Glycogen breakdown
- Detoxification

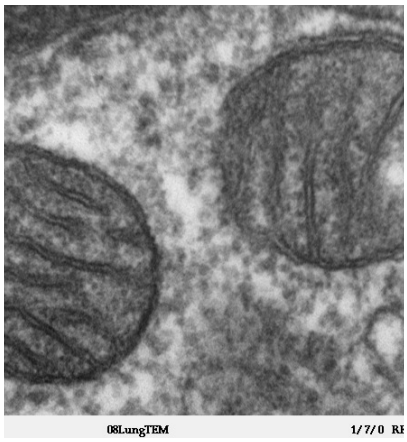
Muscle cells

- Calcium storage

http://sfrankfortcell.weebly.com/smooth-endoplasmic-reticulum.html

Mitochondria provide energy for the cell through cellular respiration.

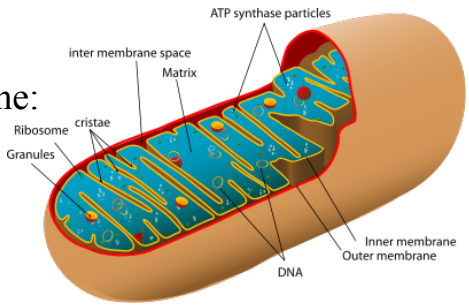
- Largest organelle
- Double membrane
  - Majority have shelf-like cristae.
- Prevalent in cells expending lots of energy.
  - Muscle cells,
  - kidney tubule cells



Mitochondria, mammalian lung – TEM

Mitochondria have specialized compartments for generating energy.

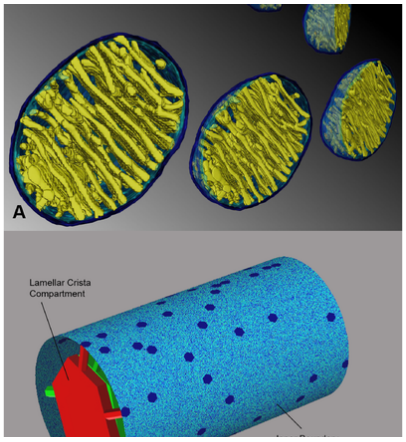
- Outer mitochondrial membrane:
  - smooth, porous,
  - permeable to small molecules.
- Intermembrane space:
- Inner mitochondrial membrane:
  - less permeable, ATPase,
  - electron transport system.
- Mitochondrial matrix
  - enzymes for Kreb's cycle.



Animal mitochondrion diagram
Wikimedia Commons

Mitochondria with tubular cristae are found in steroid-hormone secreting cells.

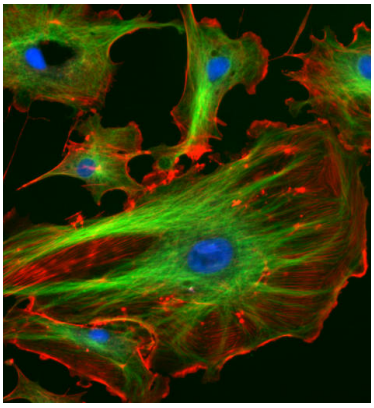
- Alternative form of cristae:
- Tubular
  - rather than shelf-like.
- Steroid-hormone secreting cells.



Mitochondrion cristae tomogram
Wikimedia commons

The cytoskeleton supports the cell and is involved in movement.

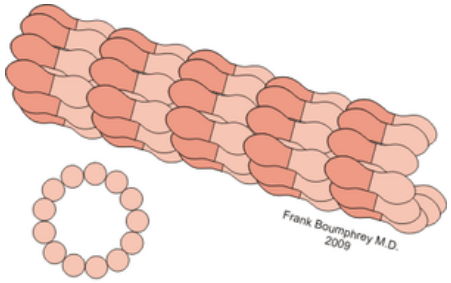
- Filamentous proteins.
- Structural stability
  - maintenance of cell shape.
  - cell movement
  - rearrangement of cytoplasmic components.



Endothelial cell
Red actin; green = microtubules
Wikimedia Commons

Microtubules

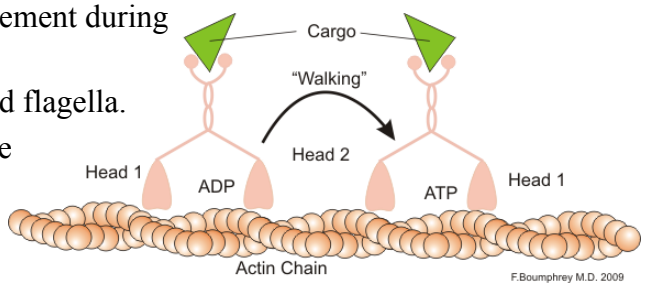
- Thickest cytoskeletal element.
  - 24 nanometer diameter
  - Hollow, non-branching cylinders.
  - Formed by tubulin dimers.
- Cannot contract
  - Shorten by depolymerization.



Construction of Microtubules from α & β Tubulins

Molecular motors and microtubule function

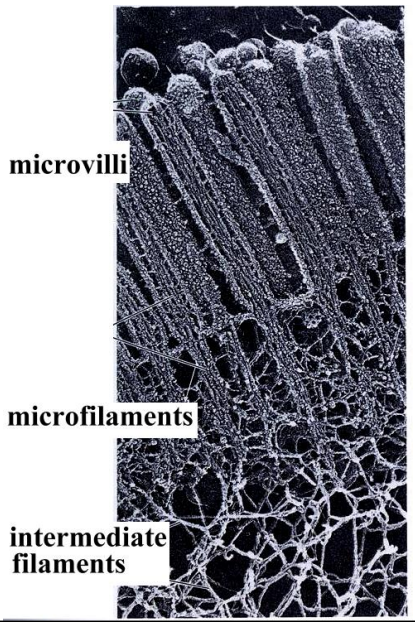
- Interact with molecular motors.
  - Ex. Dynein, kinesin
- Shuttle cytoplasmic vesicles.
- Chromosome movement during mitosis.
- Located in cilia and flagella.
- Maintain cell shape



Cytoplasmic kinesin walking down Actin Chain

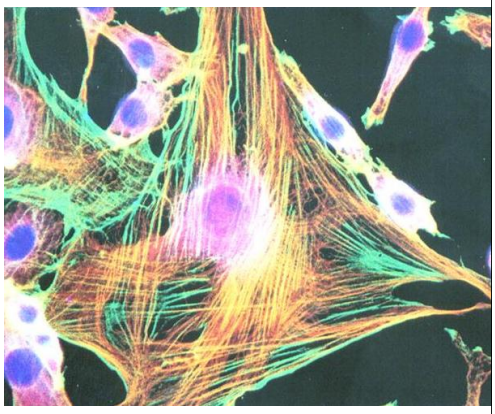
Microfilaments

- Thinnest cytoskeletal element.
  - 5 – 7 nanometer diameter
- Actin: solid rods



Microfilament: function

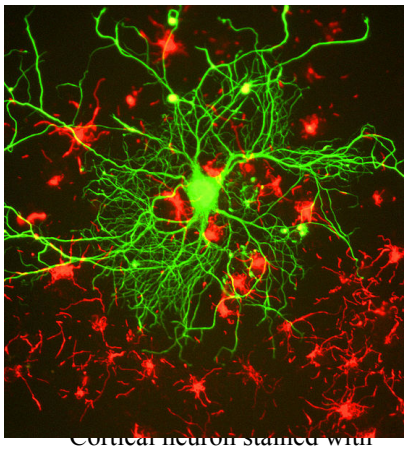
- Form sliding filament through interaction with myosin.
- Equatorial constriction during cytokinesis.
- Maintain cell shape.
- Amoeboid cell movement.
- Core of microvilli
- Movement of cytoplasmic organelles.
- Maintenance of cell shape.



Actin-red; tubulin-green

Intermediate Filaments

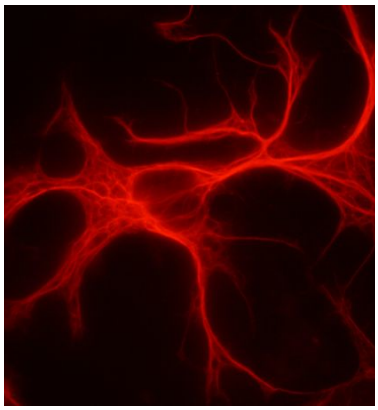
- Intermediate diameter
  - 10 – 12 nanometer.
- Differ by cell type
  - Main function to maintain cell shape.
  - Distribute stresses throughout cell.
  - Mechanical stabilization.



Cortical neuron stained with antibody to neurofilament subunit NF-L in green.

Examples of intermediate filaments

- Keratin:
  - epithelial cells
- Neurofilaments:
  - Neurons
- Glial Fibrillary acidic proteins
  - non-neuronal cells of nervous system.



Astrcoyte from cell culture – GFAP staining

Any Questions?

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- **http://www.tinyurl.com/AUHistology**