General Biology

Course No: BNG2003
Credits: 3.00

3. A Tour of the Cell

Prof. Dr. Klaus Heese

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The Fundamental Unit of Life – The Cell

- All organisms are made of cells
- The cell is the simplest collection of matter that can live
- Cell structure is correlated to cellular function
- All cells are related by their descent from earlier cells

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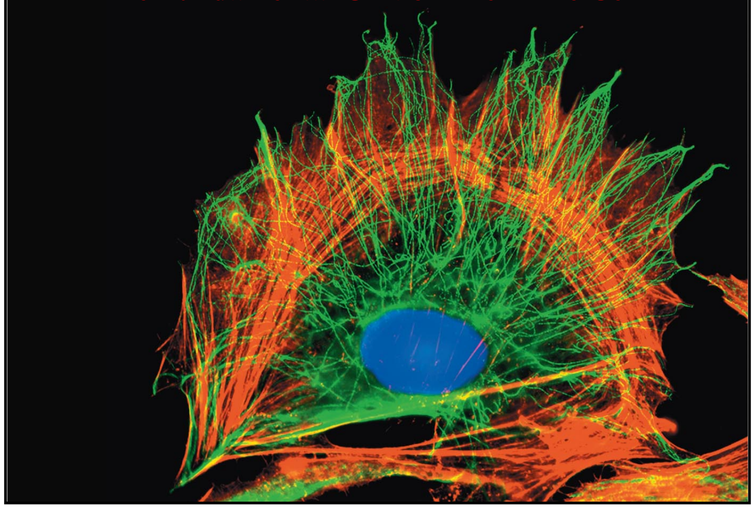
The Fundamental Unit of Life – The Cell



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To study cells, biologists use microscopes and the tools of biochemistry

- Though usually too small to be seen by the unaided eye, cells can be complex

Microscopy

- Scientists use microscopes to visualize cells too small to see with the naked eye
- In a **light microscope (LM)**, visible light passes through a specimen and then through glass lenses, which magnify the image

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- The quality of an image depends on
  - *Magnification*, the ratio of an object's image size to its real size
  - *Resolution*, the measure of the clarity of the image, or the minimum distance of two distinguishable points
  - *Contrast*, visible differences in parts of the sample

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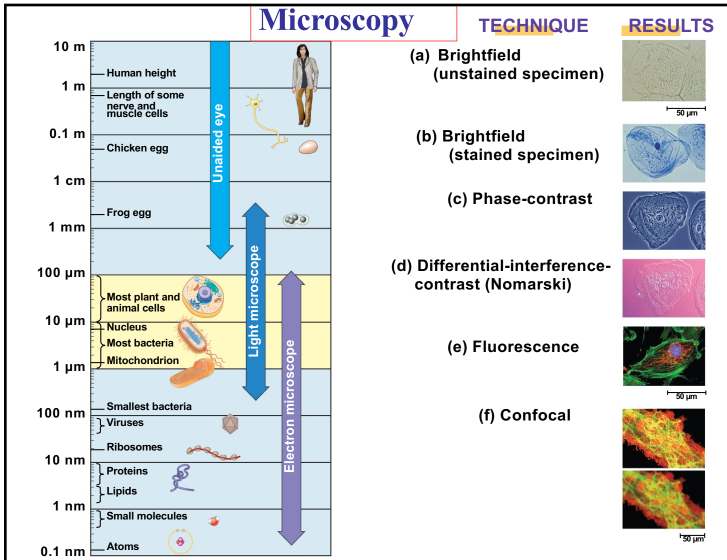
Microscopy



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- **LMs** can magnify effectively to about 1,000 times the size of the actual specimen
- Various techniques enhance contrast and enable cell components to be stained or labeled
- Most subcellular structures, including **organelles** (membrane-enclosed compartments), are too small to be resolved by an LM

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Microscopy - Applications

- Two basic types of **electron microscopes (EMs)** are used to study subcellular structures.
- **Scanning electron microscopes (SEMs)** focus a beam of electrons onto the surface of a specimen, providing images that look 3-D.
- **Transmission electron microscopes (TEMs)** focus a beam of electrons through a specimen. TEMs are used mainly to study the internal structure of cells.

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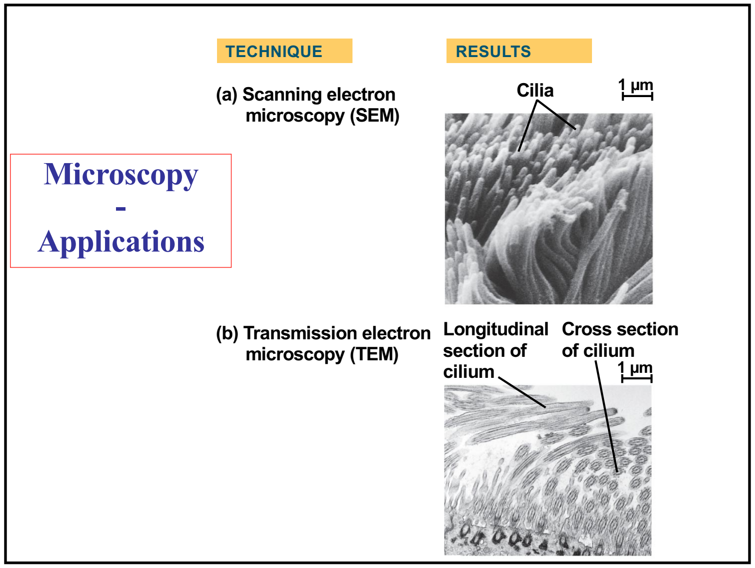
Microscopy
-
Applications
TECHNIQUE
RESULTS
(a) Scanning electron microscopy (SEM)
Cilia
1 µm
(b) Transmission electron microscopy (TEM)
Longitudinal section of cilium
Cross section of cilium
1 µm

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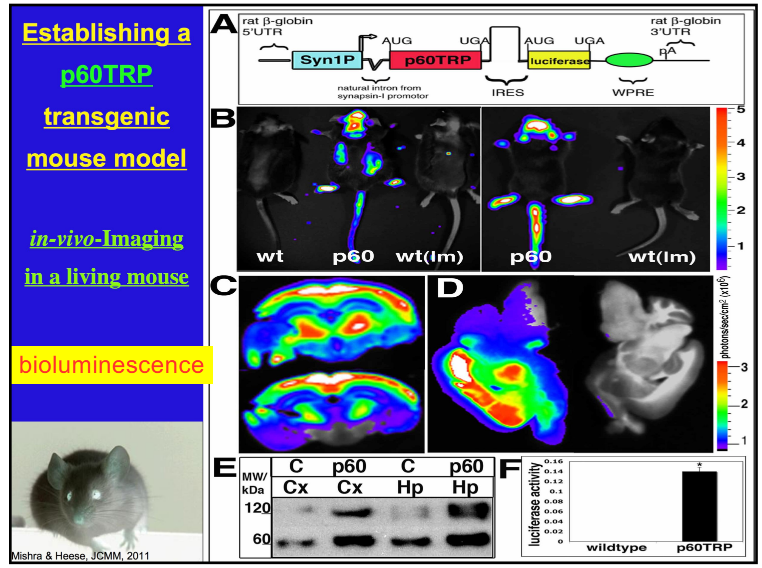
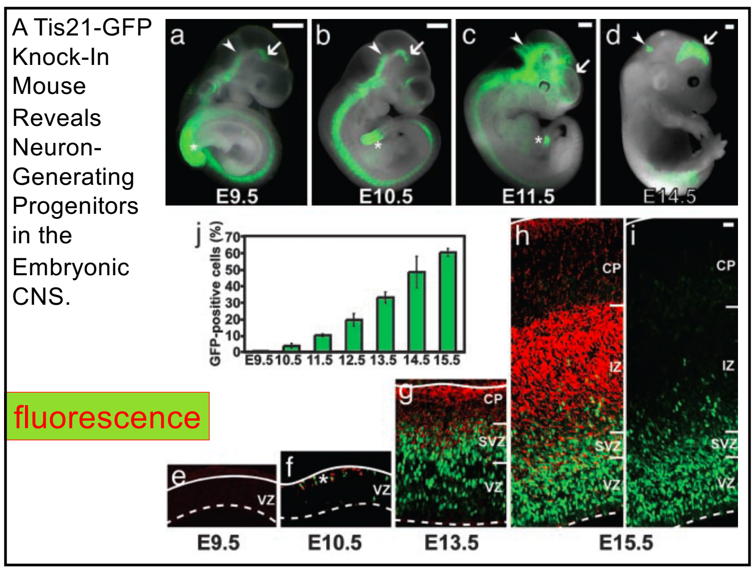

Establishing a p60TRP transgenic mouse model
in-vivo-Imaging in a living mouse
bioluminescence
Mishra & Heese, JCMM, 2011
A
rat β-globin 5'UTR
Syn1P
AUG
p60TRP
UGA
AUG
luciferase
UGA
rat β-globin 3'UTR
pA
natural intron from synapsin-I promotor
IRES
WPRE
B
wt
p60
wt(Im)
p60
wt(Im)
C
D
E
MW/ kDa
C Cx
p60 Cx
C Hp
p60 Hp
120
60
F
luciferase activity
wildtype
p60TRP

10


A Tis21-GFP Knock-In Mouse Reveals Neuron-Generating Progenitors in the Embryonic CNS.
fluorescence
a
b
c
d
E9.5
E10.5
E11.5
E14.5
j
GFP-positive cells (%)
E9.5 10.5 11.5 12.5 13.5 14.5 15.5
h
i
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f
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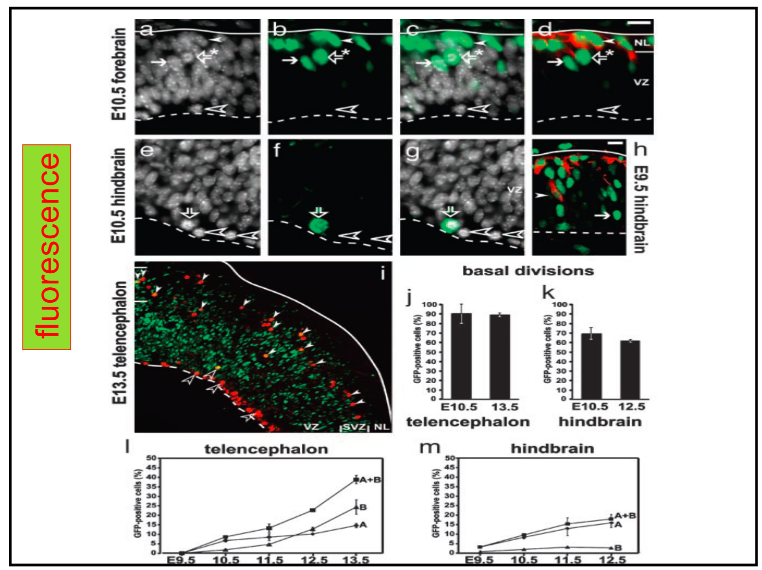
E10.5
E13.5
E15.5

11


fluorescence
E10.5 forebrain
E10.5 hindbrain
E9.5 hindbrain
E13.5 telencephalon
basal divisions
j
k
E10.5 13.5
telencephalon
E10.5 12.5
hindbrain
l
telencephalon
m
hindbrain
A+B
B
A

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Kinesin Walking (by Atomic Force Microscopy (**AFM**))

http://www.youtube.com/watch?v=YAva4g3Pk6k

http://www.youtube.com/watch?v=4TGDPotbJV4

Moving vesicle
http://www.youtube.com/watch?v=y-uuk4Pr2i8

http://www.se.kanazawa-u.ac.jp/bioafm_center/movies/Walking_myosinV-2.gif

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Cell Fractionation

- **Cell fractionation** takes cells apart and separates the major organelles from one another
- Ultracentrifuges fractionate cells into their component parts
- Cell fractionation enables scientists to determine the functions of organelles
- Biochemistry and cytology help correlate cell function with structure

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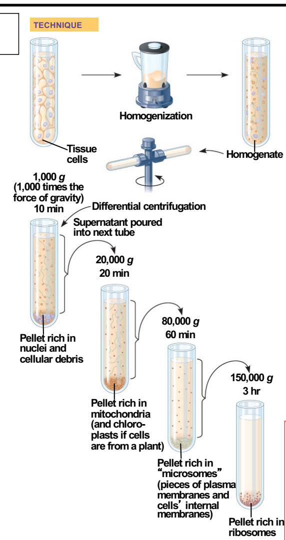
Cell Fractionation

by
high speed
centrifugation



Ph/CHCl3 – H_2O-buffer
separation of Proteins
vs
28S rRNA
18S rRNA
5S rRNA

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Comparing Prokaryotic and Eukaryotic Cells

- Basic Features of All Cells:
  - Plasma membrane
  - Semifluid substance called **cytosol**
  - Chromosomes (carry genes)
  - Ribosomes (make proteins)

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Comparing Prokaryotic and Eukaryotic Cells

- 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

Eukaryotic cells have internal membranes that compartmentalize their functions

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Comparing Prokaryotic and Eukaryotic Cells

- **Prokaryotic cells** are characterized by having
  - No nucleus
  - DNA in an unbound region called the **nucleoid**
  - No membrane-bound organelles
  - **Cytoplasm** bound by the plasma membrane

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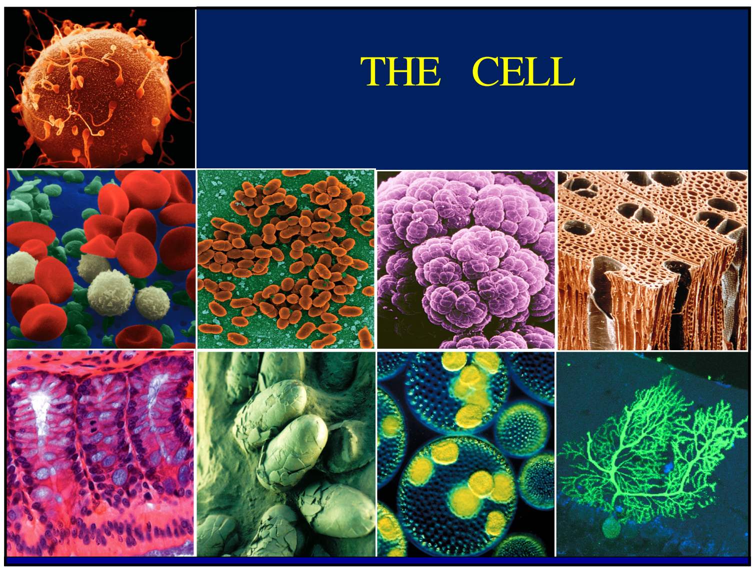

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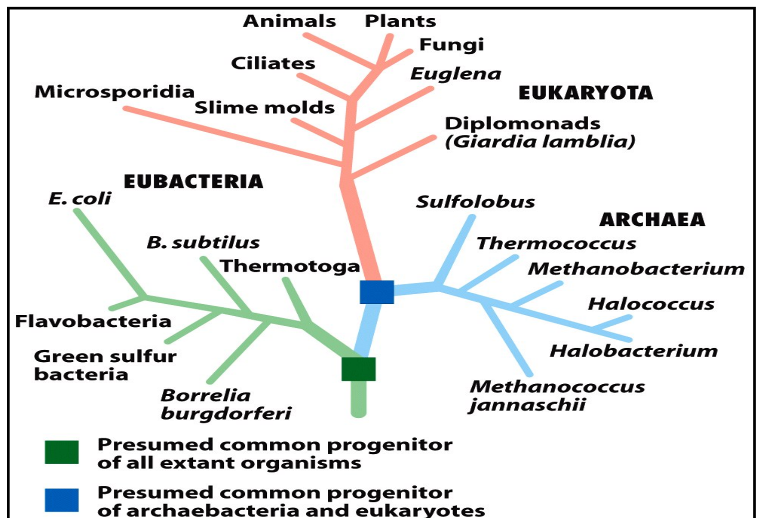

Taxonomy

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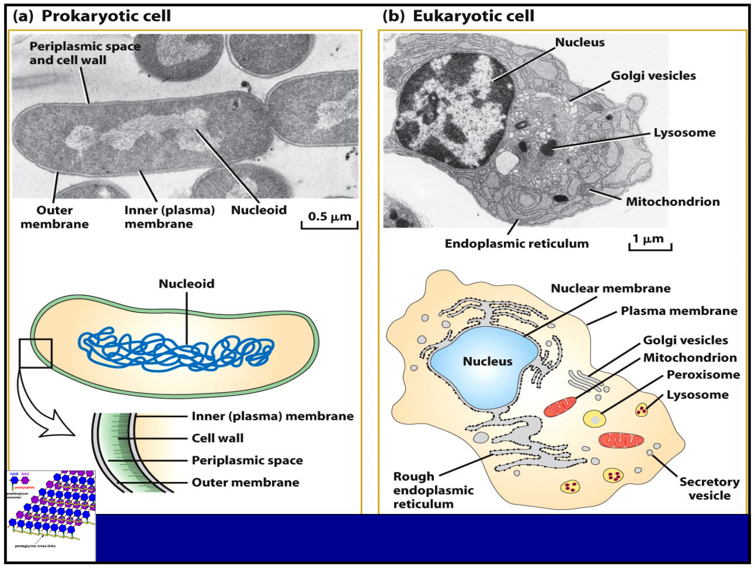

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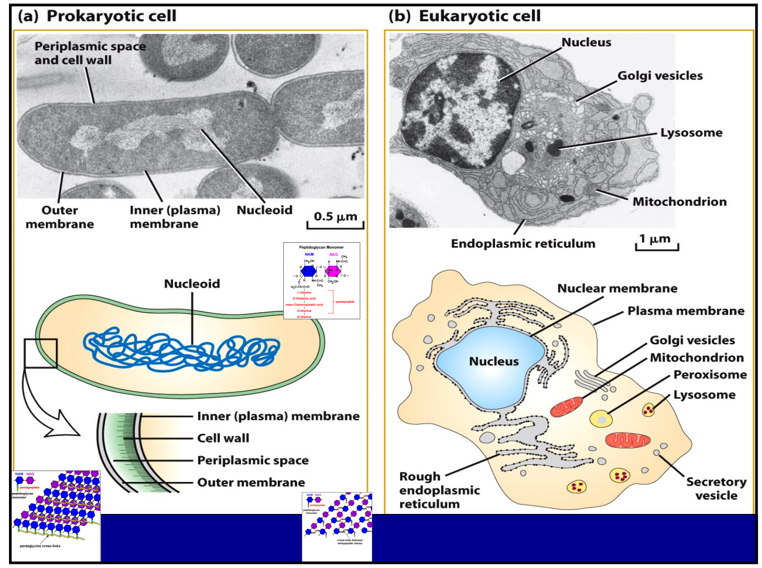

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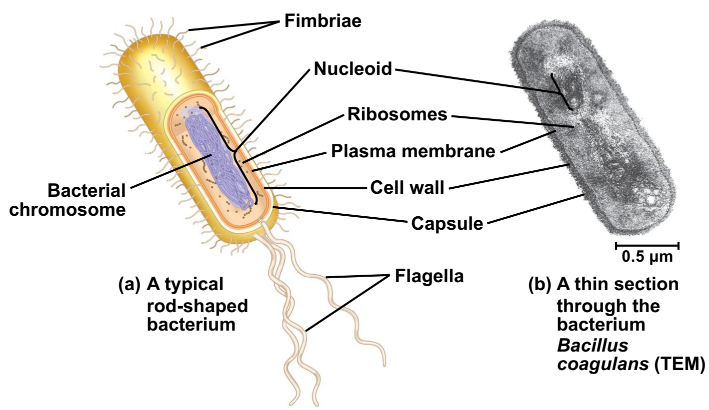
Comparing Prokaryotic and Eukaryotic Cells

example of bacterial / prokaryotic cell:



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Comparing Prokaryotic and Eukaryotic Cells

- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a membranous nuclear envelope
  - Membrane-bound organelles
  - *Cytoplasm* in the region between the plasma membrane and nucleus
- Eukaryotic cells are generally much larger than prokaryotic cells

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The Plasma Membrane of Cells

- 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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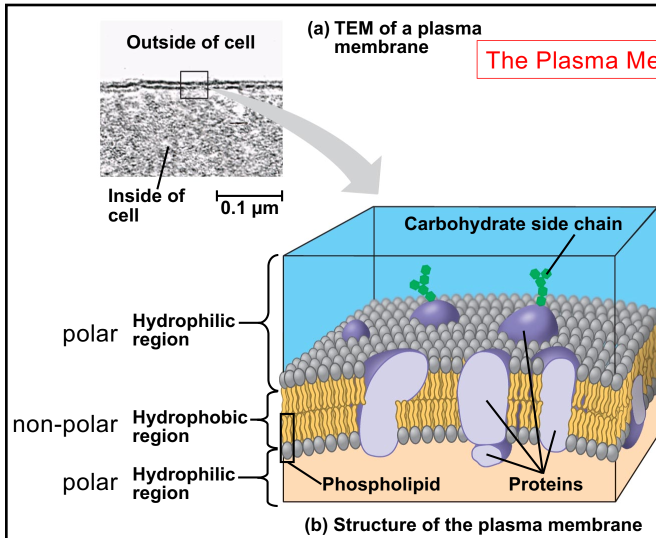
The Plasma Membrane



(b) Structure of the plasma membrane

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- *The logistics of carrying out cellular metabolism sets limits on the size of cells*
- The surface area to volume ratio of a cell is critical
- As the surface area increases by a factor of n^2, the volume increases by a factor of n^3
- Small cells have a greater surface area relative to volume

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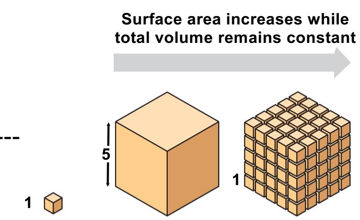
The surface area to volume ratio of a cell is critical

see:
brain surface – and:
mitochondria,
chloroplast

<-----



Total surface area [Sum of the surface areas (height × width) of all boxes sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

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A Panoramic View of the Eukaryotic Cell

- A eukaryotic cell has internal membranes that partition the cell into organelles
- Plant and animal cells have most of the same organelles

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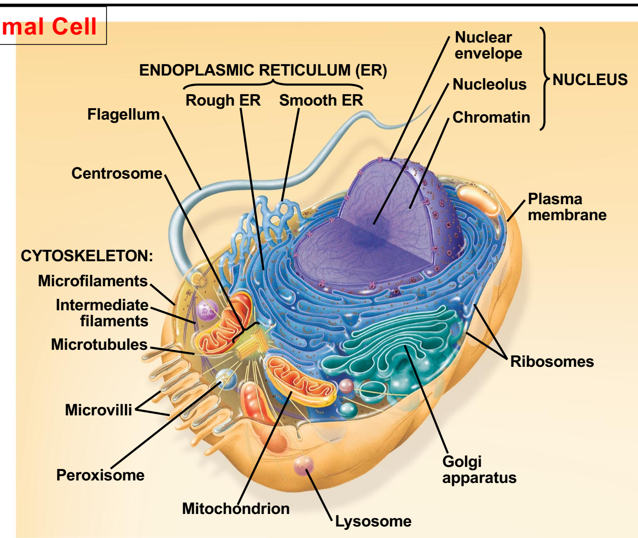
Animal Cell



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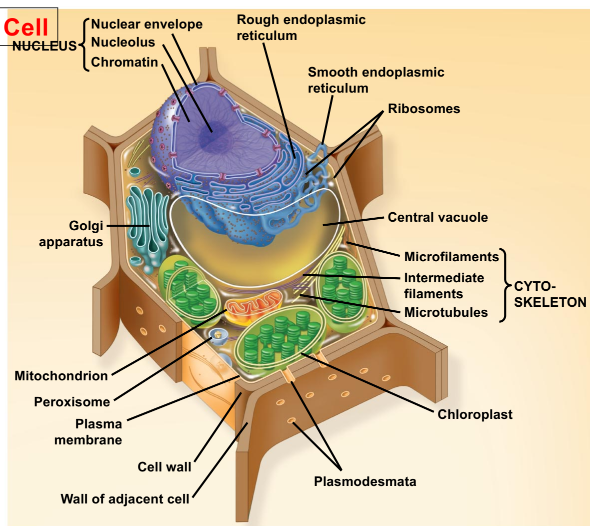
Plant Cell



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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

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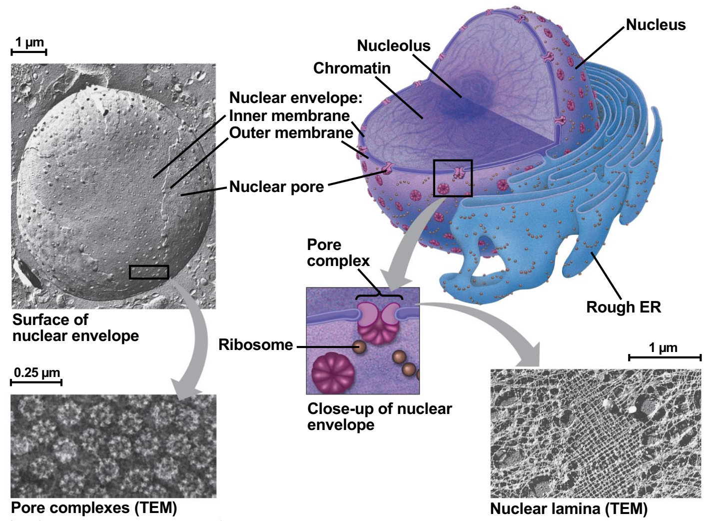

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- Pores regulate the entry and exit of molecules from the nucleus (*specialized proteins serve as carriers as do specific protein motif sequences*)
- The shape of the nucleus is maintained by the **nuclear lamina**, which is composed of protein

- In the nucleus, DNA and proteins form genetic material called **chromatin**
- Chromatin condenses to form discrete **chromosomes**
- The **nucleolus** is located within the nucleus and is the site of ribosomal RNA (rRNA) synthesis

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Ribosomes: Protein Factories

- **Ribosomes** are particles made of ribosomal RNA and protein
- 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)

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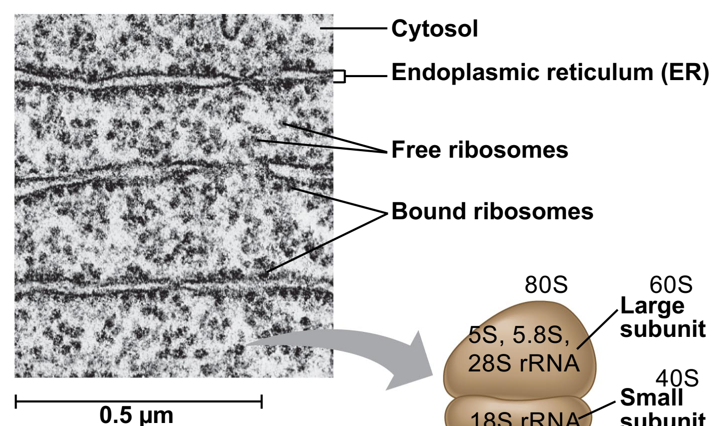
Ribosomes: Protein Factories



TEM showing ER and ribosomes

Diagram of a ribosome

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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**

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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**, with ribosomes studding its surface

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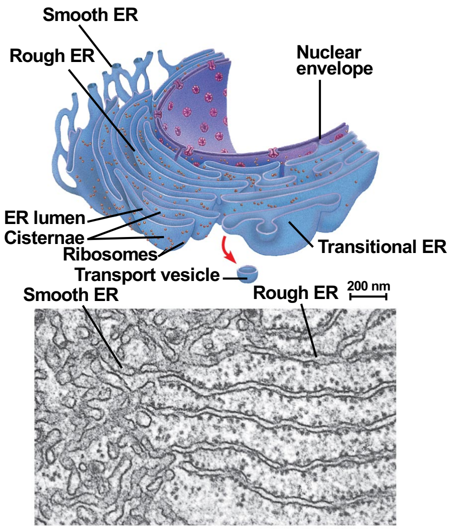

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Functions of Smooth ER

- The smooth ER
  - Synthesizes lipids
  - Metabolizes carbohydrates
  - Detoxifies poison
  - Stores calcium

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Functions of Rough ER

- The rough ER
  - has bound ribosomes, which secrete **glycoproteins** (proteins covalently bonded to carbohydrates)
  - distributes **transport vesicles,** proteins surrounded by membranes
  - is a membrane factory for the cell

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The Golgi Apparatus: Shipping and Receiving Center

- The **Golgi apparatus** consists of flattened membranous sacs called cisternae
- Functions of the Golgi apparatus:
  - modifies products of the ER
  - manufactures certain macromolecules
  - sorts and packages materials into transport vesicles

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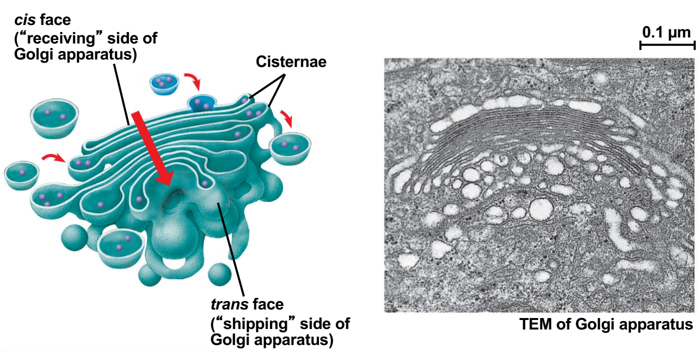

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Lysosomes: Digestive Compartments

- A **lysosome** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids

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- 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** (---> cell death and disease)

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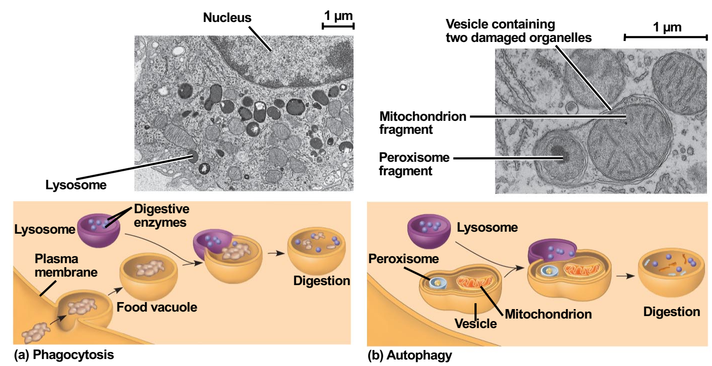
Lysosomes: Digestive Compartments



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Vacuoles: Diverse Maintenance Compartments

- A plant cell or fungal cell may have one or several vacuoles

- **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

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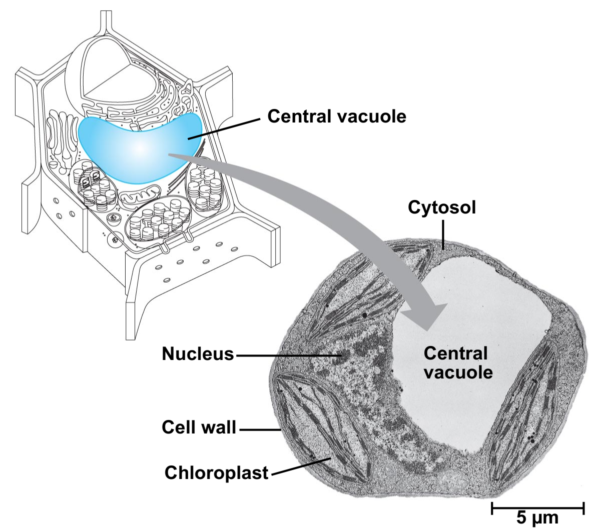

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The Endomembrane System: *A Review*

- The endomembrane system is a complex and dynamic player in the cell's compartmental organization

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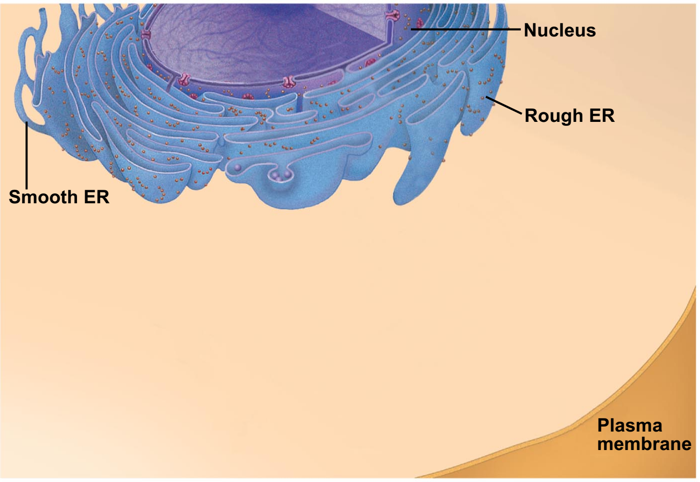

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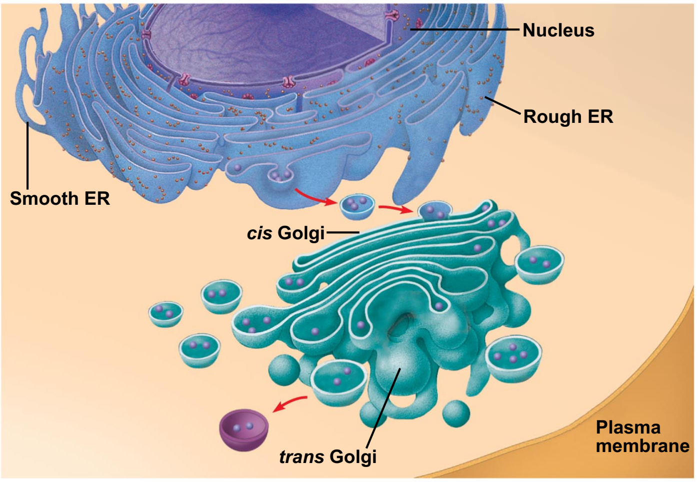

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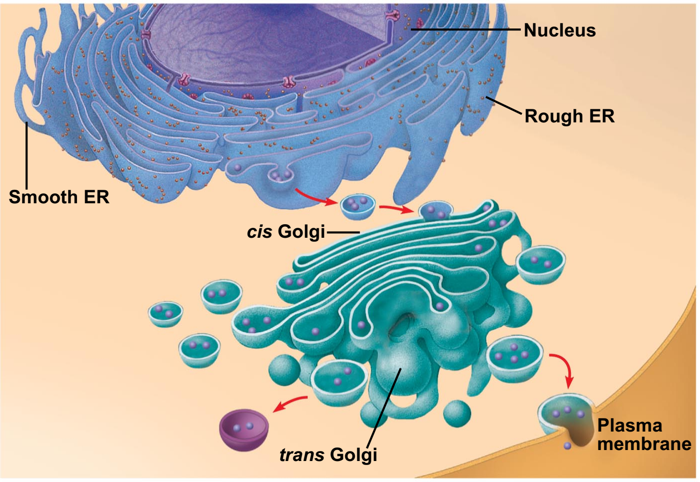

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Mitochondria and chloroplasts change energy from one form to another

- **Mitochondria** are the sites of cellular respiration, a metabolic process that generates ATP
- **Chloroplasts**, found in plants and algae, are the sites of **photosynthesis**
- **Peroxisomes** are oxidative organelles

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- Mitochondria and **chloroplasts**
  - Are not part of the endomembrane system
  - Have a double membrane
  - Have proteins made by free ribosomes
  - Contain their own DNA

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Mitochondria: Chemical Energy Conversion

- Mitochondria are in nearly all eukaryotic cells
- They have a smooth outer membrane and an inner membrane folded into **cristae**
- The inner membrane creates two compartments: intermembrane space and **mitochondrial matrix**
- Some metabolic steps of cellular respiration are catalyzed in the mitochondrial matrix
- Cristae present a large surface area for enzymes that synthesize ATP

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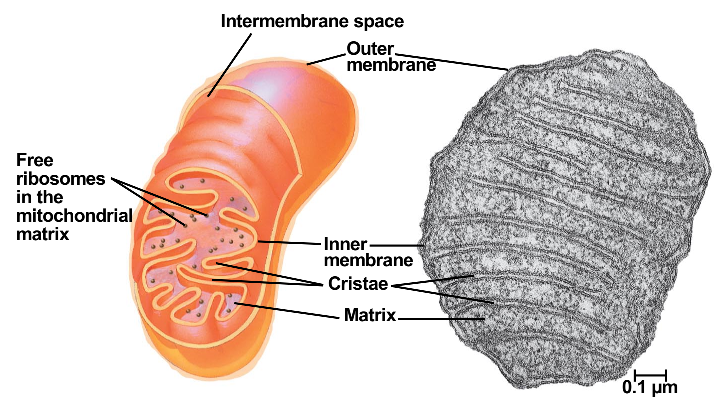
Mitochondria are the sites of cellular respiration, a metabolic process that generates ATP



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Chloroplasts: Capture of Light Energy

- The chloroplast is a member of a family of organelles called **plastids**
- 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

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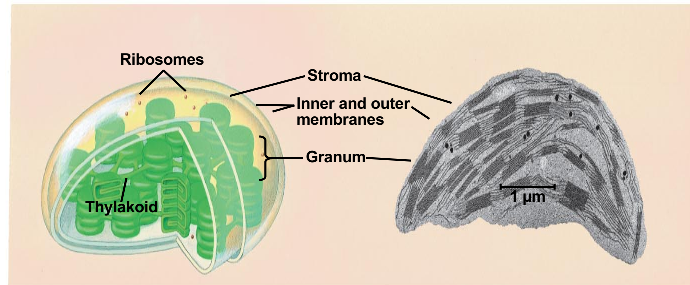
Chloroplasts: Capture of Light Energy

Chloroplasts, found in plants and algae, are the sites of **photosynthesis**



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Peroxisomes: Oxidation

- Peroxisomes are specialized metabolic compartments bounded by a single membrane
- Peroxisomes produce hydrogen peroxide and convert it to water
- *Oxygen is used to break down different types of molecules*

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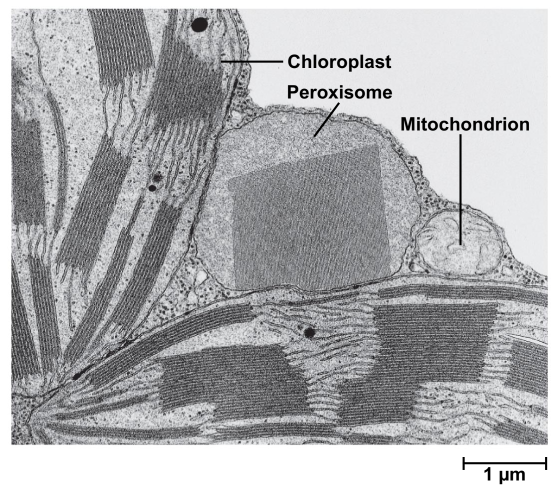

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