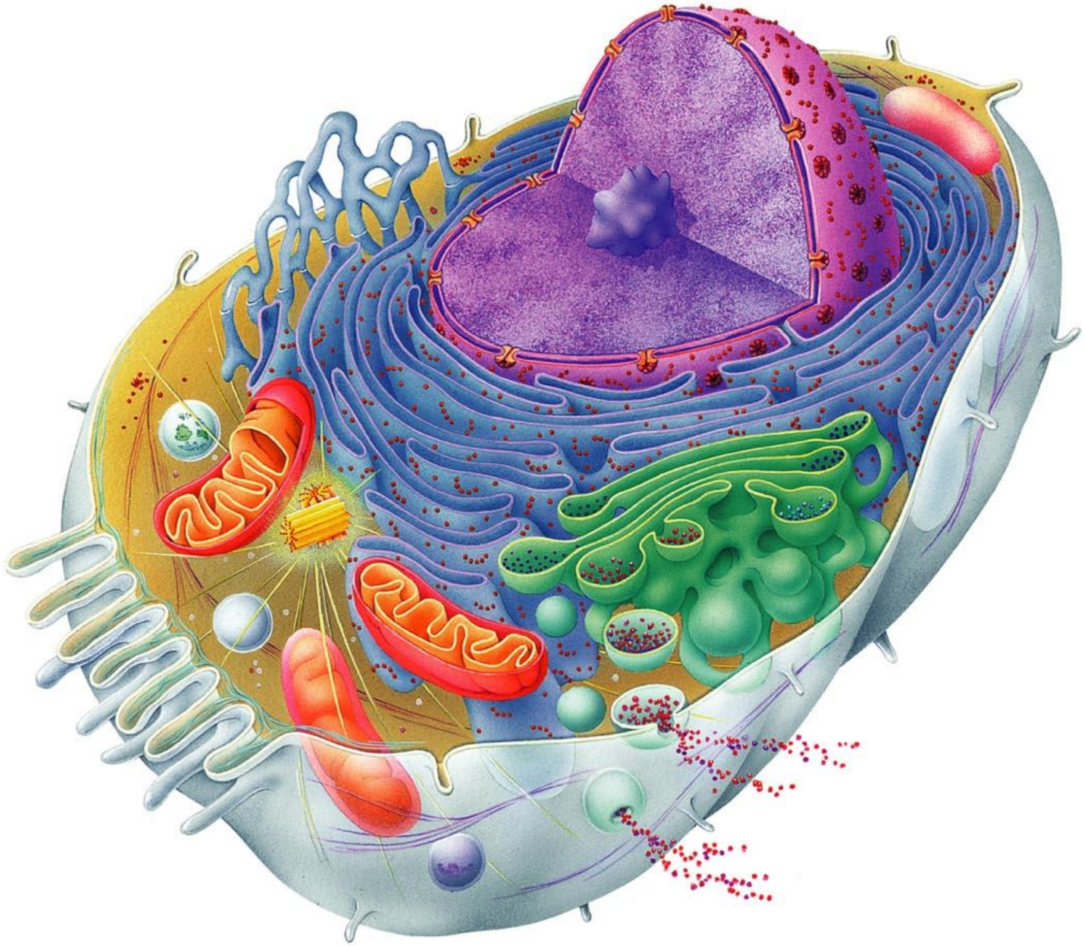
The Cell



Cell Doctrine

- All living things are composed of cells
- A single cell is the smallest unit that exhibits all of the characteristics of life
- All cells come only from preexisting cells

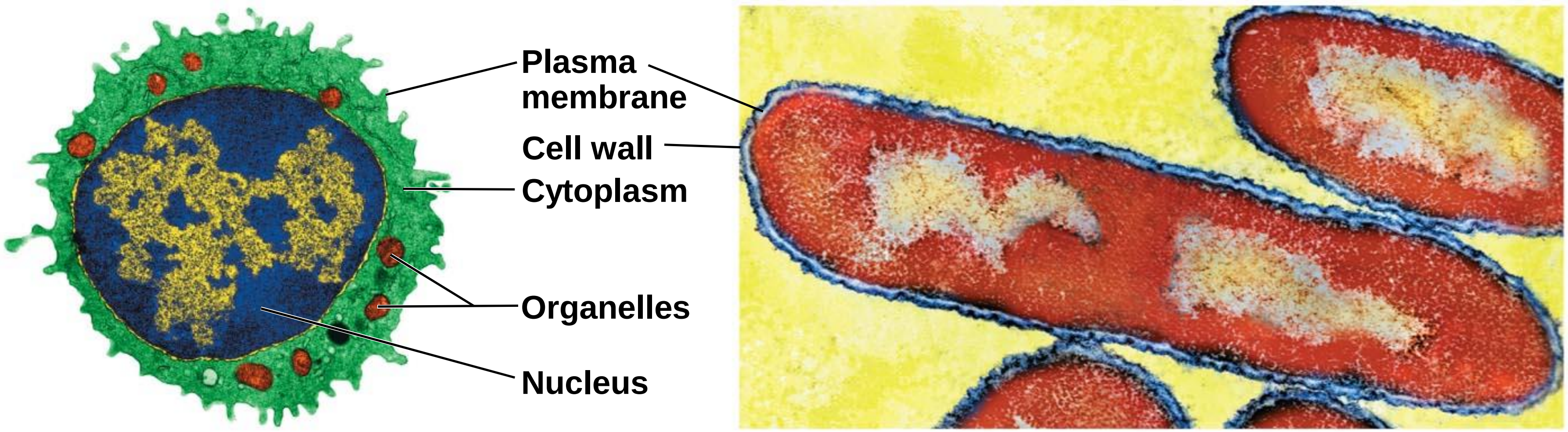
Two Basic Cell Types Classified by Internal Organization

Prokaryotic Cells

- Plasma membrane
- No nucleus
- Cytoplasm
  - fluid within membrane
- No true organelles

Eukaryotic Cells

- Plasma membrane
- Nucleus
  - information center
- Cytoplasm
  - fluid within membrane
- Organelles
  - structures with specialized functions
- All human cells are eukaryotic

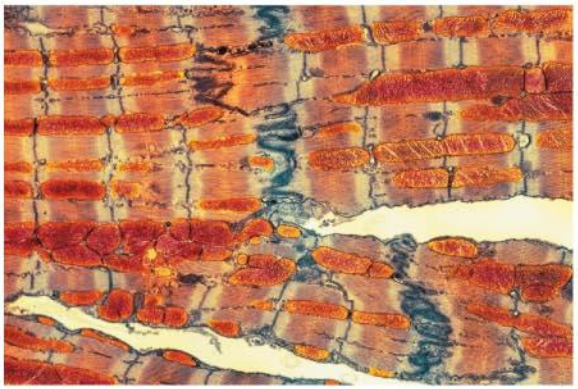


a) A eukaryotic animal cell has a large nucleus and numerous small organelles. The cytoplasm is enclosed by a flexible plasma membrane.

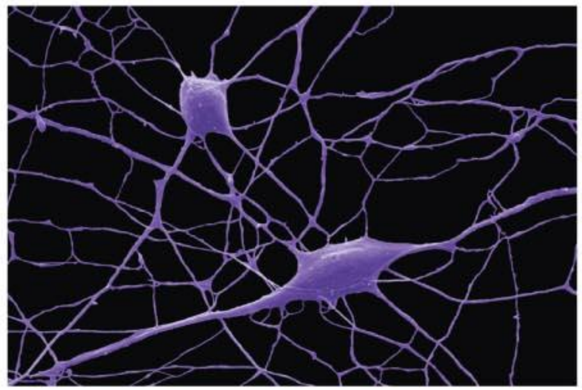
b) Prokaryotic cells such as this bacterium have a rigid cell wall surrounding the plasma membrane. The genetic material is not surrounded by a membrane, and there are no organelles in the cell. The elongated bacterium in the center of the photo is about to divide in two, as its genetic material is concentrated at both ends of the cell.

Cell Structure Reflects Cell Function

- Though eukaryotic cells are remarkably similar, there are structural differences
  - Examples:
    - Muscle cells
      - Contain numerous organelles providing energy needed for muscle contraction
    - Nerve cells
      - Long and thin to carry impulses over distance



a) A portion of several muscle cells of the heart (X 1,500).

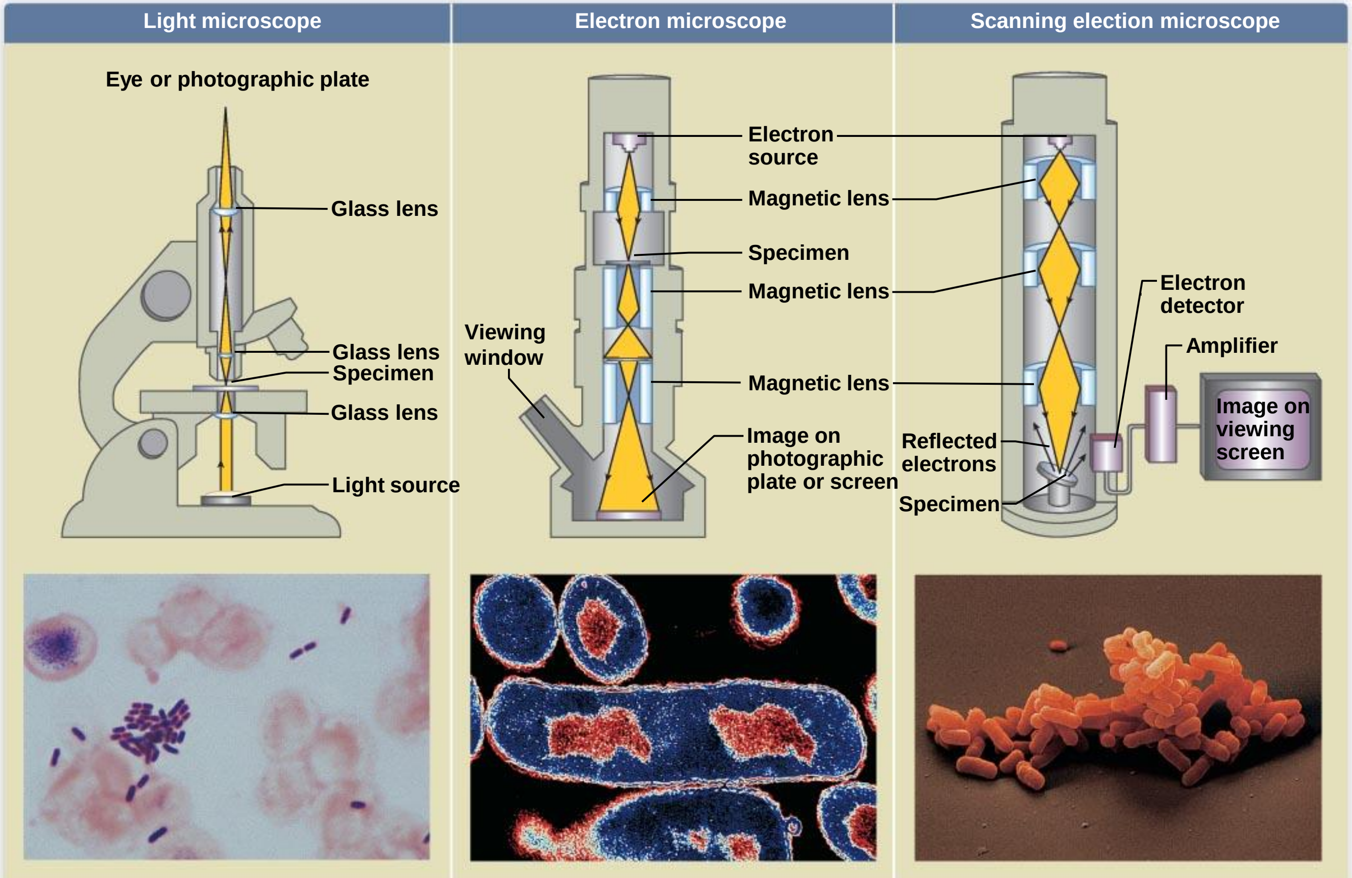


b) Nerve cells of the central nervous system (X 830).

c) Cells lining a tubule of a kidney (X 250).

Cells Remain Small to Stay Efficient

- Most cells cannot be seen without magnification
  - Ideas on a large cell that we can see with our eyes?



a) The light microscope (LM). Most of us have seen or used a light microscope. The light microscope uses visible light and a series of glass lenses to magnify a small sample as much as 1,000-fold. Focus can be difficult to maintain if objects are at different depths in a sample. Light does not transmit well through very dense or thick samples. Light microscopes have been in use for over 300 years.

b) The transmission electron microscope (TEM). A transmission electron microscope bombards the sample with a beam of electrons, some of which pass through the sample. Electrons behave like light waves, but since the wavelengths of electrons are shorter than visible light, the image has greater clarity at any magnification. A good electron microscope can magnify up to about 100,000 times, a hundred times greater than the light microscope. The images are two-dimensional (flat) because the sample must be very thin, but the magnification is sufficiently high that one can see the structural details of organelles within single cells.

c) The scanning electron microscope (SEM). The scanning electron microscope also focuses beams of electrons on the object. It produces what appears to be a three-dimensional view of the *surface* of an object. A narrow beam of electrons is scanned over the surface of an object that has been coated with a thin coat of metal so that the electron beam cannot penetrate. As the beam passes, the metal gives off secondary electrons, which can be recorded to produce a visual picture of the object's surface. Scanning electron microscopes have revealed stunning images of the relationships between cells and of the outer surfaces of cells. The scanning electron microscope can also magnify up to about 100,000 times.

Cells Remain Small to Stay Efficient

- Small cells have a higher surface to volume ratio
- High surface to volume ratio promotes efficiency in
  - Acquisition of nutrients
  - Disposal of wastes

a) One large cell.

b) Eight small cells.

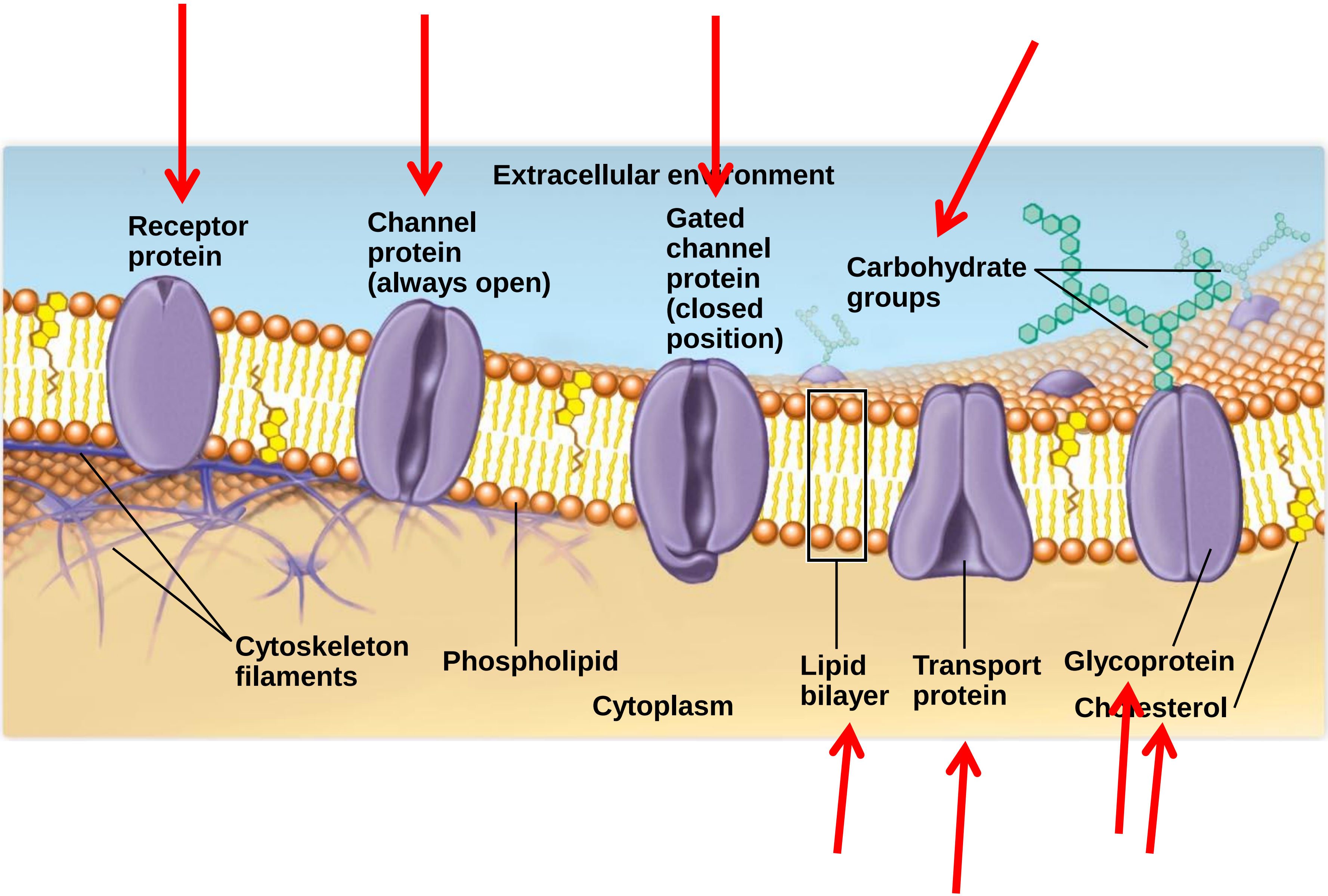
c) Cell with microvilli on one surface.

Plasma Membrane Surrounds the Cell

- Separates a cell from its environment
- Selectively permeable
  - Permits movement of some substances into and out of the cell, but blocks others
- Enables transfer of information between environment and cell

A Plasma Membrane Surrounds the Cell

- Plasma membrane is a lipid bilayer
  - Phospholipids
    - polar head and nonpolar tail
  - Cholesterol
    - makes membrane a bit more rigid
  - Proteins
    - provide means of transport through membrane
  - Carbohydrates
    - recognition patterns (‘fingerprints’) for cells and organisms
- Nonrigid
- Fluid mosaic



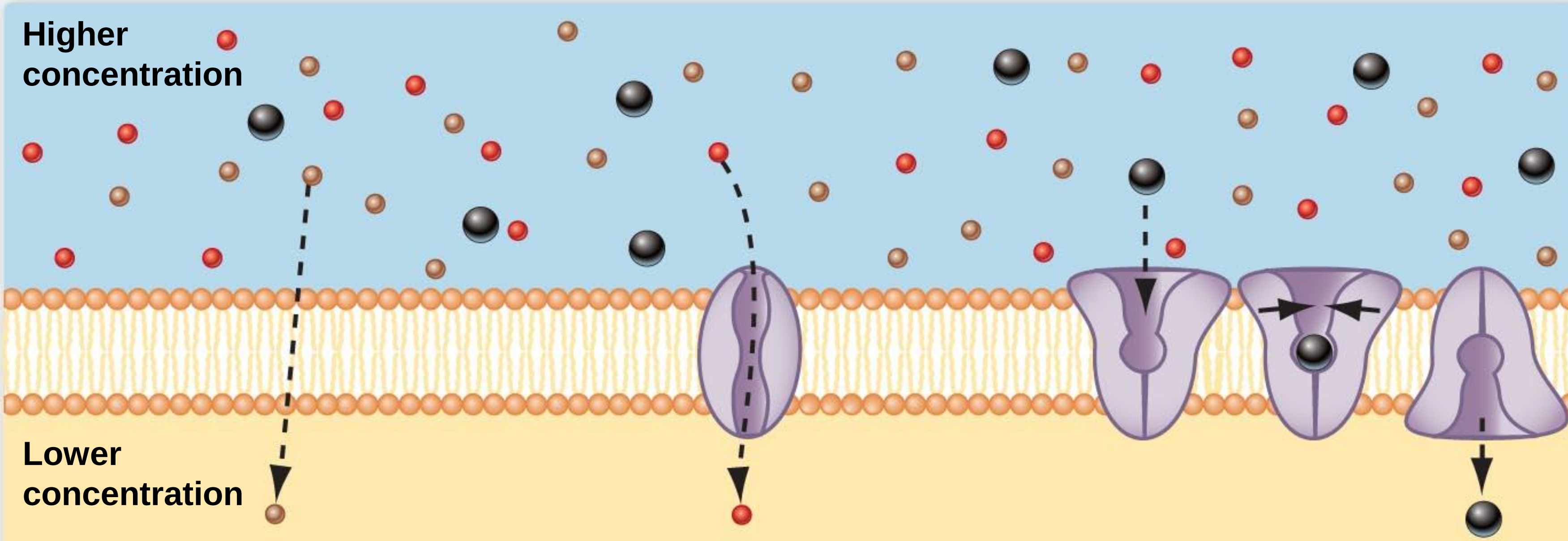
Extracellular environment
Receptor protein
Channel protein (always open)
Gated channel protein (closed position)
Carbohydrate groups
Cytoskeleton filaments
Phospholipid
Cytoplasm
Lipid bilayer
Transport protein
Glycoprotein
Cholesterol

Molecules Cross the Plasma Membrane in Several Ways

- Passive transport
  - Cell does not need to expend energy for this
    - Diffusion
    - Osmosis
- Active transport – cell must expend energy
- Bulk transport
  - Involves membranous vesicles to move larger substances
    - Endocytosis
    - Exocytosis

Passive Transport Moves with the Concentration Gradient

- Passive transport is powered by the concentration gradient.
  - Diffusion through lipid layer
  - Diffusion through protein channels
  - Facilitated transport
    - Transport or carrier proteins in the membrane assist



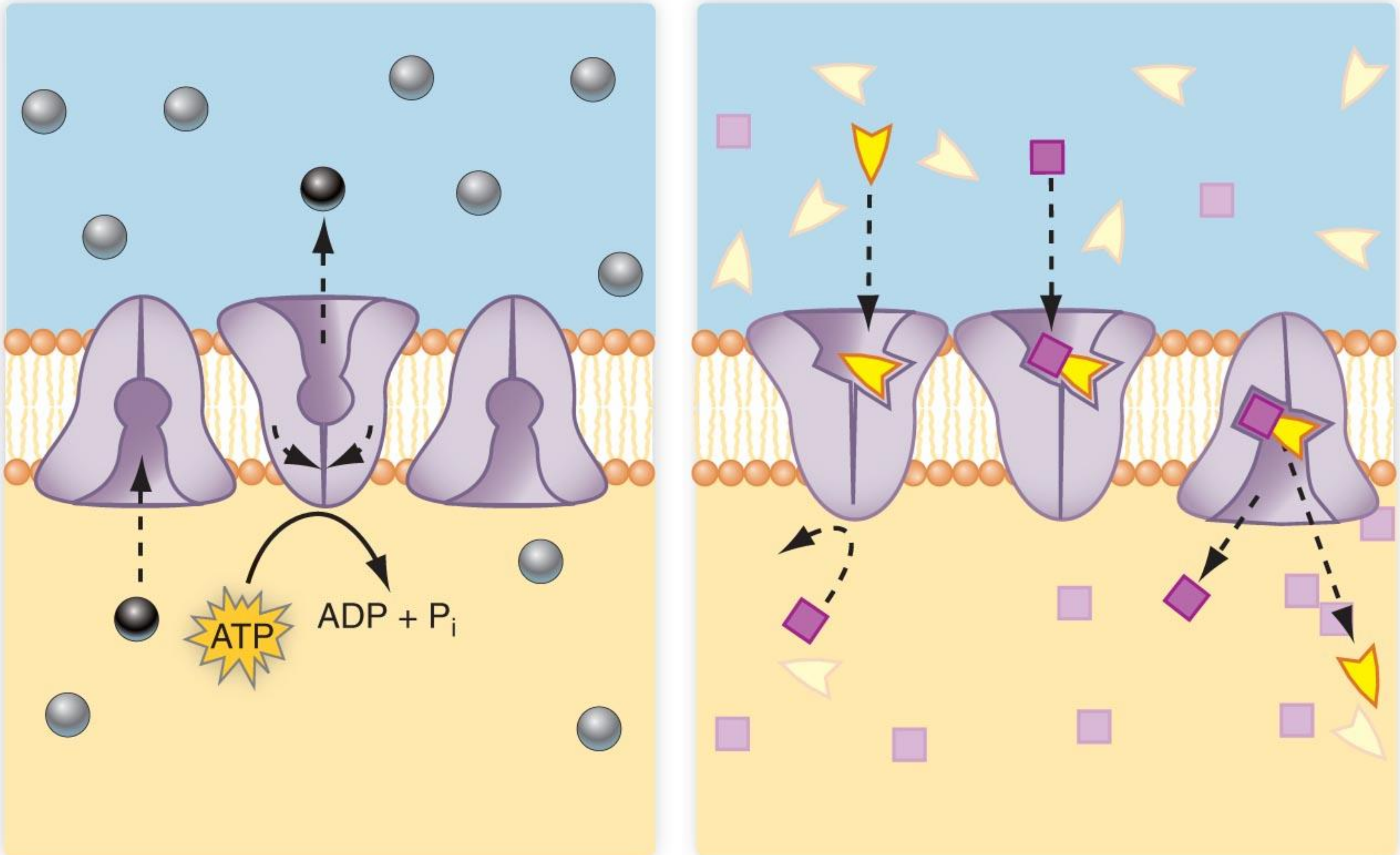
Diffusion through the lipid layer. Lipid-soluble molecules such as O_2 and CO_2 diffuse freely through the plasma membrane.

Diffusion through channels. Some polar and charged molecules diffuse through protein channels that span the membrane. Water is a typical example.

Facilitated transport. Certain molecules bind to a protein, triggering a change in protein shape that transports the molecule across the membrane. Glucose typically enters cells by this method.

Active Transport

- Active transport moves substances from an area of lower concentration to an area of higher concentration
  – Requires a membrane protein (transporter)
  – Requires ATP or other energy source

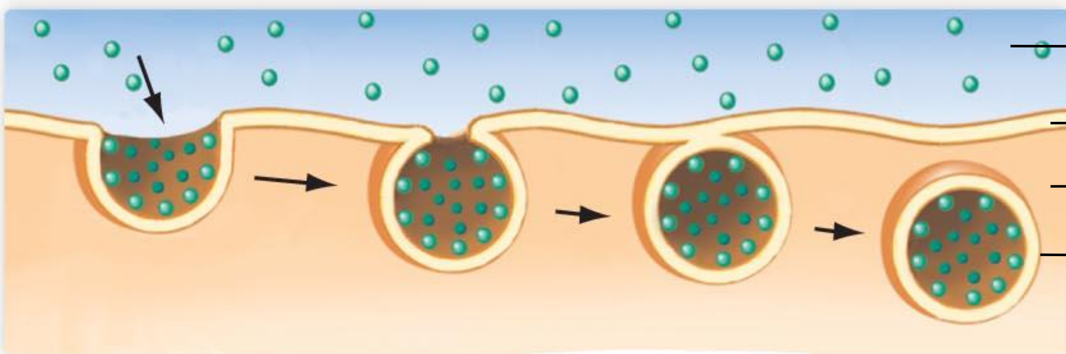


a) In active transport using ATP, energy derived from the breakdown of ATP is used to change the shape of the carrier protein.

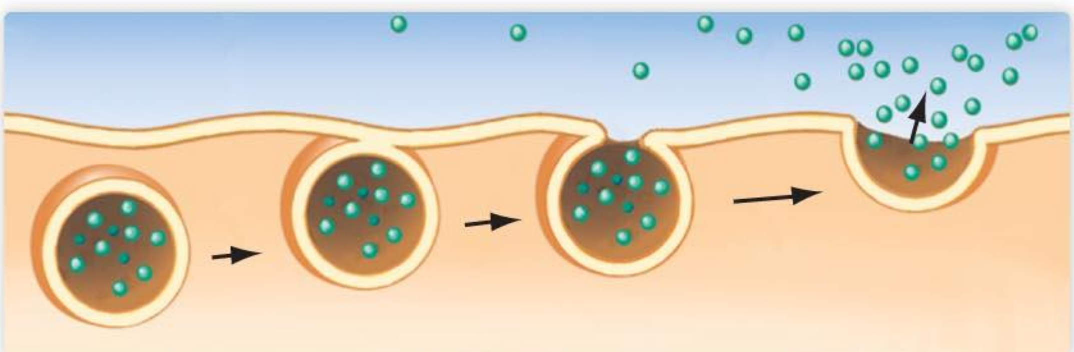
b) Some carrier proteins use energy derived from the downhill transport of one molecule to transport another molecule uphill. In this example, the energy to transport the square molecules comes from the facilitated transport of the spearhead molecules.

Endocytosis and Exocytosis Move Materials in Bulk

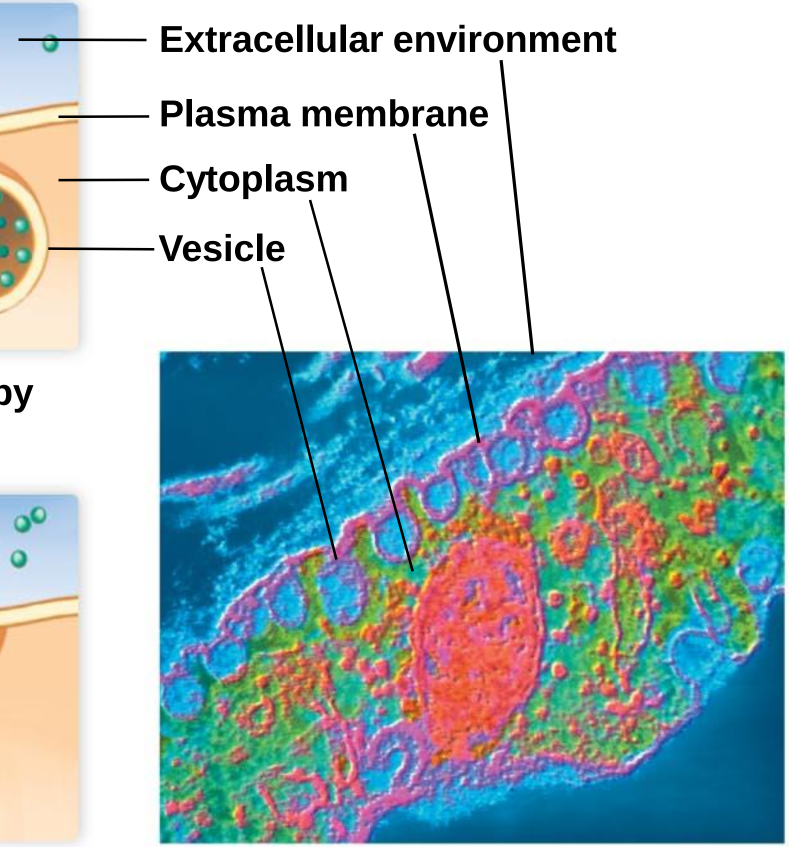
- Used to move larger molecules
  - Endocytosis: brings substances into the cell
  - Exocytosis: expels substances from the cell



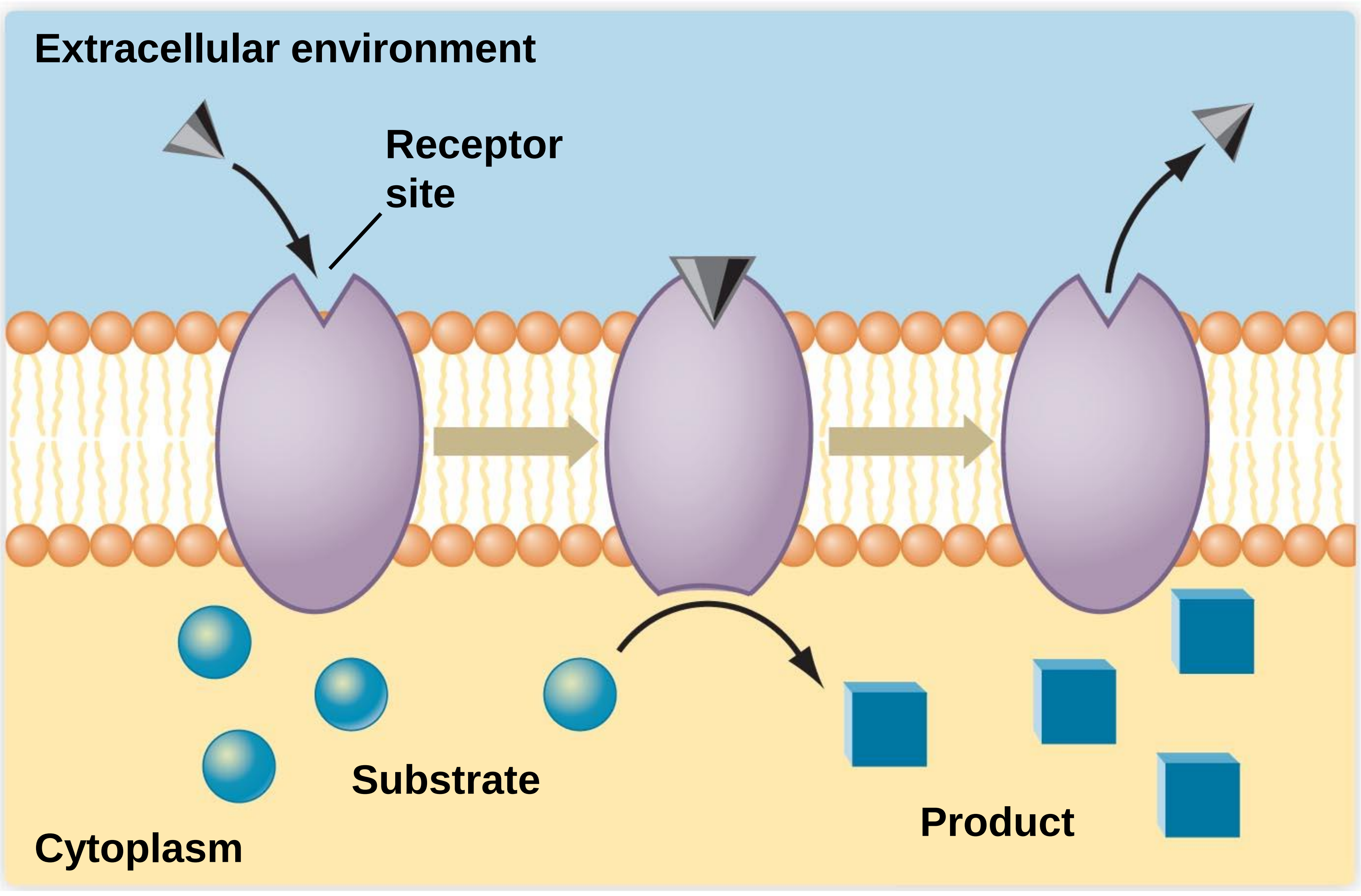
a) Endocytosis. In endocytosis, material is surrounded by the cell membrane and brought into the cell.



b) Exocytosis. In exocytosis, a membranous vesicle fuses with the plasma membrane, expelling its contents outside the cell.

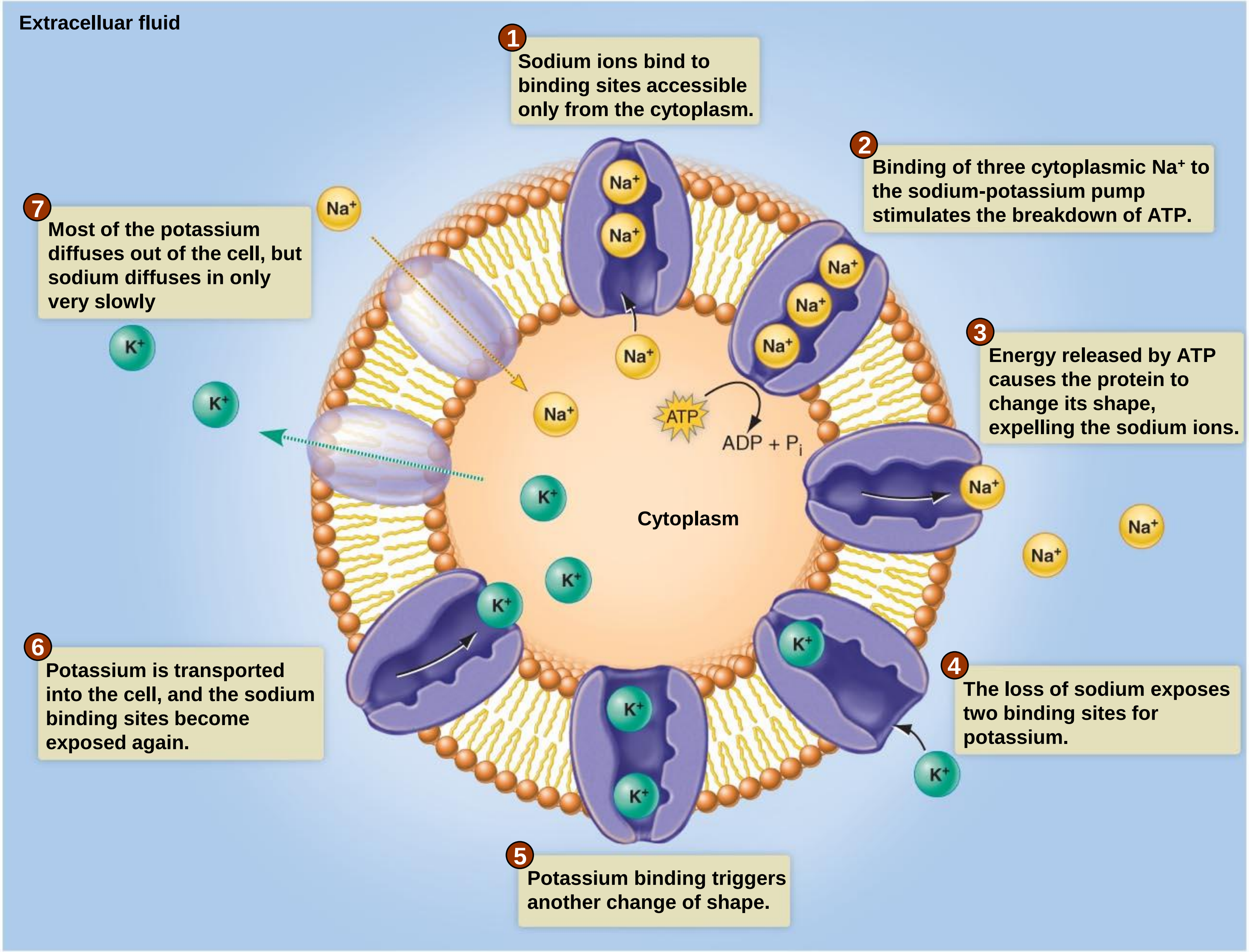


c) Photomicrograph showing various stages of endocytosis.

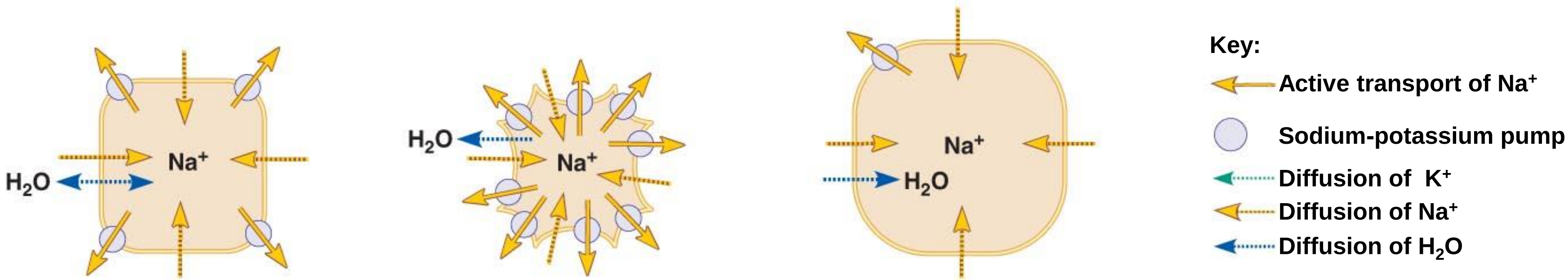

Extracellular environment
Receptor
site
Substrate
Cytoplasm
Product

The Sodium–Potassium Pump: Helps Maintains Cell Volume

- Sodium–potassium pump expels unwanted ions, keeps needed ones, and maintains cell volume
- ATP is used to expel 3 sodium ions for every 2 potassium ions brought into the cell



a) The cell membrane contains Na^+ - K^+ pumps, and also channels that permit the rapid outward diffusion of K^+ but only a slow inward diffusion of Na^+.



In the steady-state, the rate of outward sodium transport equals the rate of inward diffusion.

When the rate of outward sodium transport exceeds inward diffusion, water diffuses out and the cell shrinks.

When the rate of outward sodium transport is less than the rate of inward diffusion, water diffuses in and the cell swells

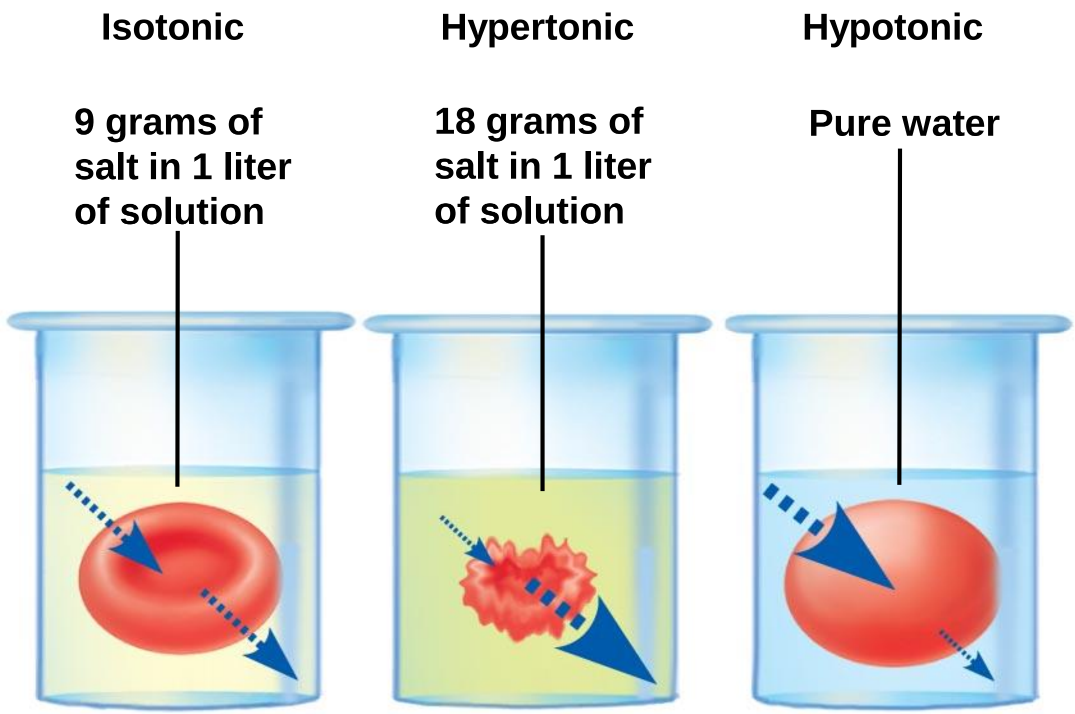
b) The rate of transport by the Na^+ - K^+ pumps determines cell volume.

Isotonic Extracellular Fluid Maintains Cell Volume

- Tonicity: relative concentration of solutes in two fluids
- Isotonic
  - Extracellular and intracellular ionic concentrations are equal

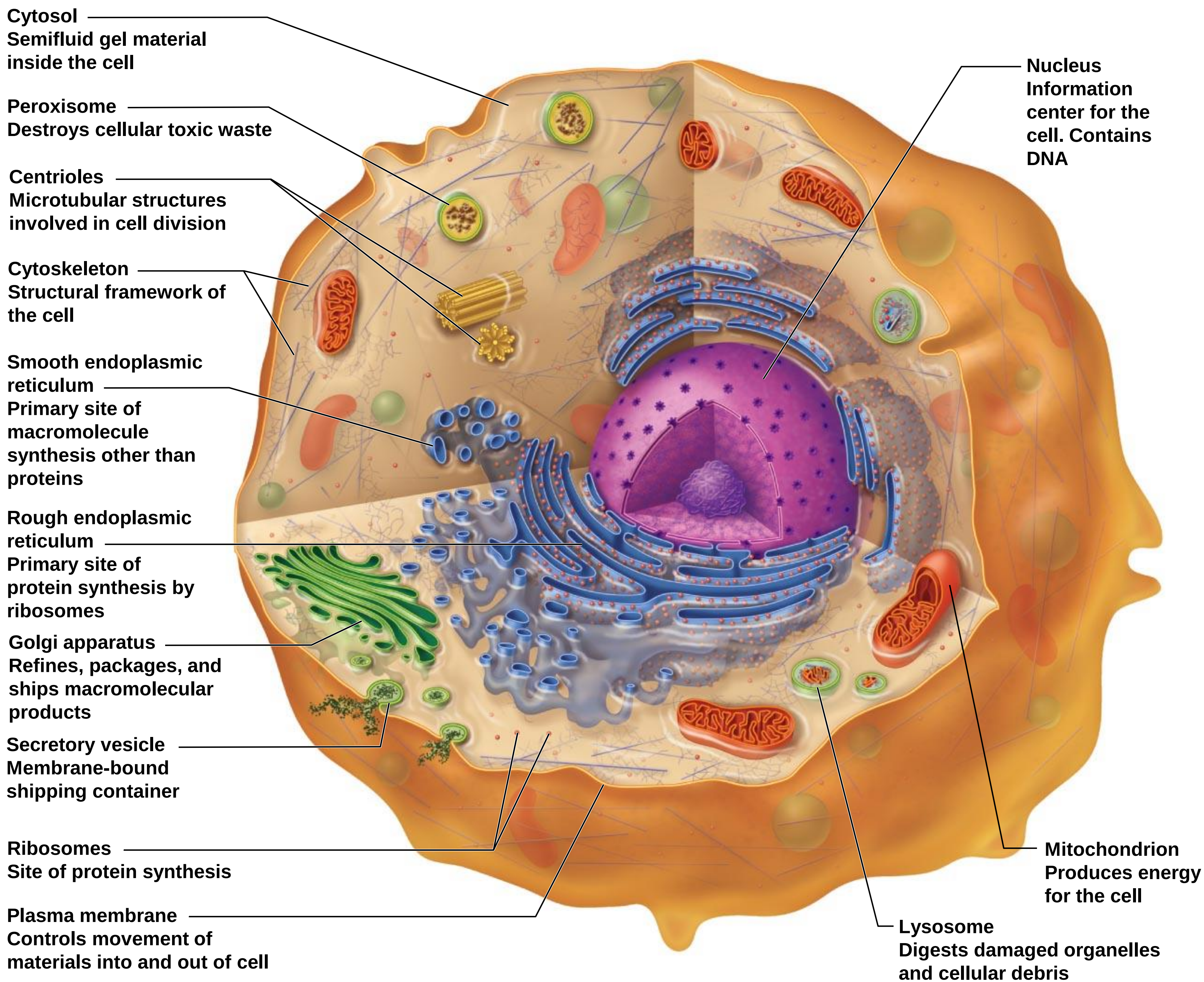
Isotonic Extracellular Fluid Maintains Cell Volume

- Hypertonic
  - Extracellular ionic concentration higher than intracellular
  - Water will diffuse out of cell
  - Cell will shrink and die
- Hypotonic
  - Extracellular ionic concentration lower than intracellular
  - Water will diffuse into cell
  - Cell may swell and burst



a) Water movement into and out of human red blood cells placed in isotonic, hypertonic, and hypotonic solutions. The amount of water movement is indicated by the sizes of the arrows.

b) Scanning of electron micrographs of red blood cells placed in similar solutions.


Cytosol
Semifluid gel material inside the cell
Peroxisome
Destroys cellular toxic waste
Centrioles
Microtubular structures involved in cell division
Cytoskeleton
Structural framework of the cell
Smooth endoplasmic reticulum
Primary site of macromolecule synthesis other than proteins
Rough endoplasmic reticulum
Primary site of protein synthesis by ribosomes
Golgi apparatus
Refines, packages, and ships macromolecular products
Secretory vesicle
Membrane-bound shipping container
Ribosomes
Site of protein synthesis
Plasma membrane
Controls movement of materials into and out of cell
Nucleus
Information center for the cell. Contains DNA
Mitochondrion
Produces energy for the cell
Lysosome
Digests damaged organelles and cellular debris

Nucleus

- Functions
  - Contains the genetic information of the cell
  - Controls the cell
- Structural features
  - Double-layered nuclear membrane
  - Nuclear pores
  - Chromosomes/chromatin
  - Nucleolus

Ribosomes

- Site of protein synthesis
- Location
  - Free: floating in cytoplasm
  - Bound: attached to outer surface of endoplasmic reticulum

Endoplasmic Reticulum (ER)

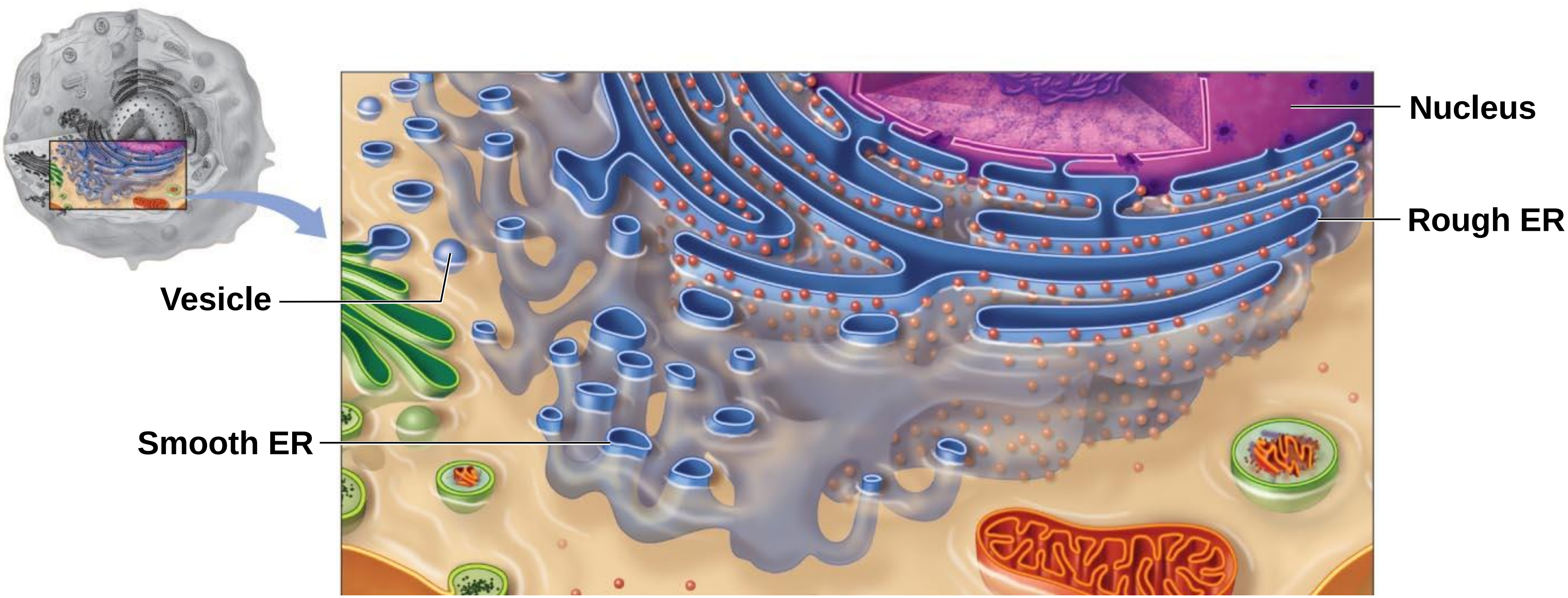
- Two types of endoplasmic reticulum (ER)

– Rough ER

- Has ribosomes on surface
- Protein manufacturing, modifications

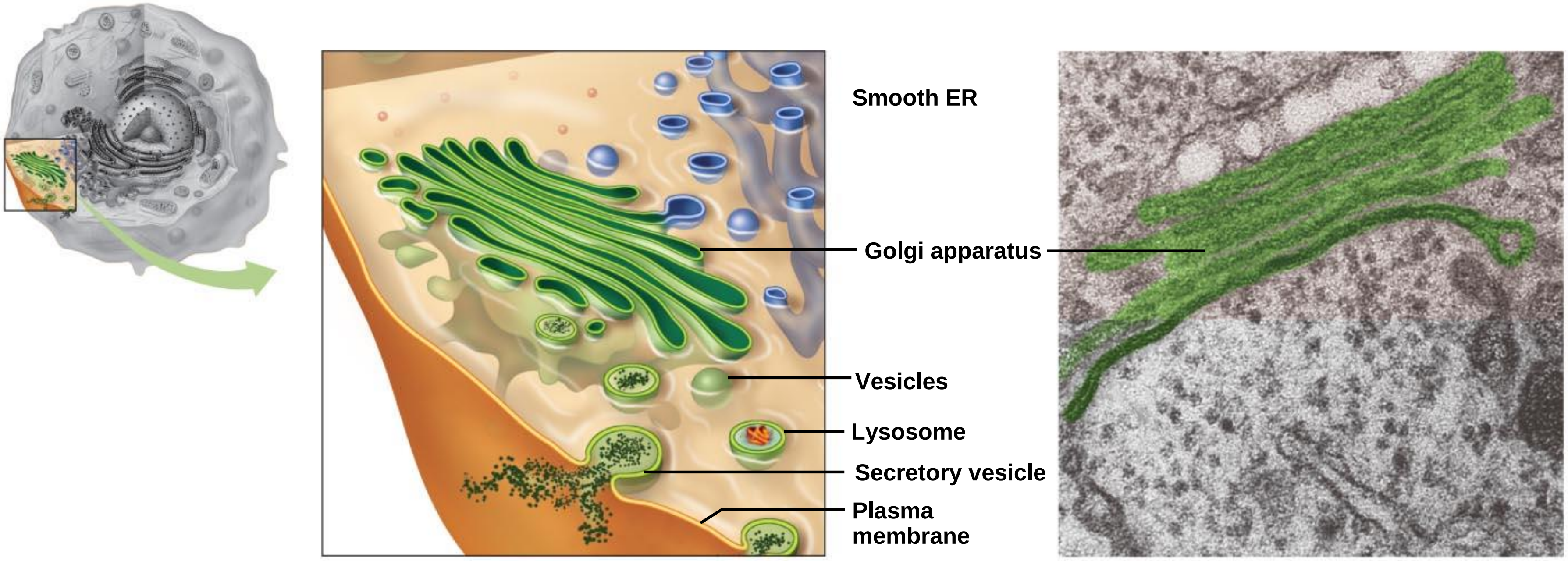
– Smooth ER

- No ribosomes on surface
- Lipid synthesis
- Packages the proteins



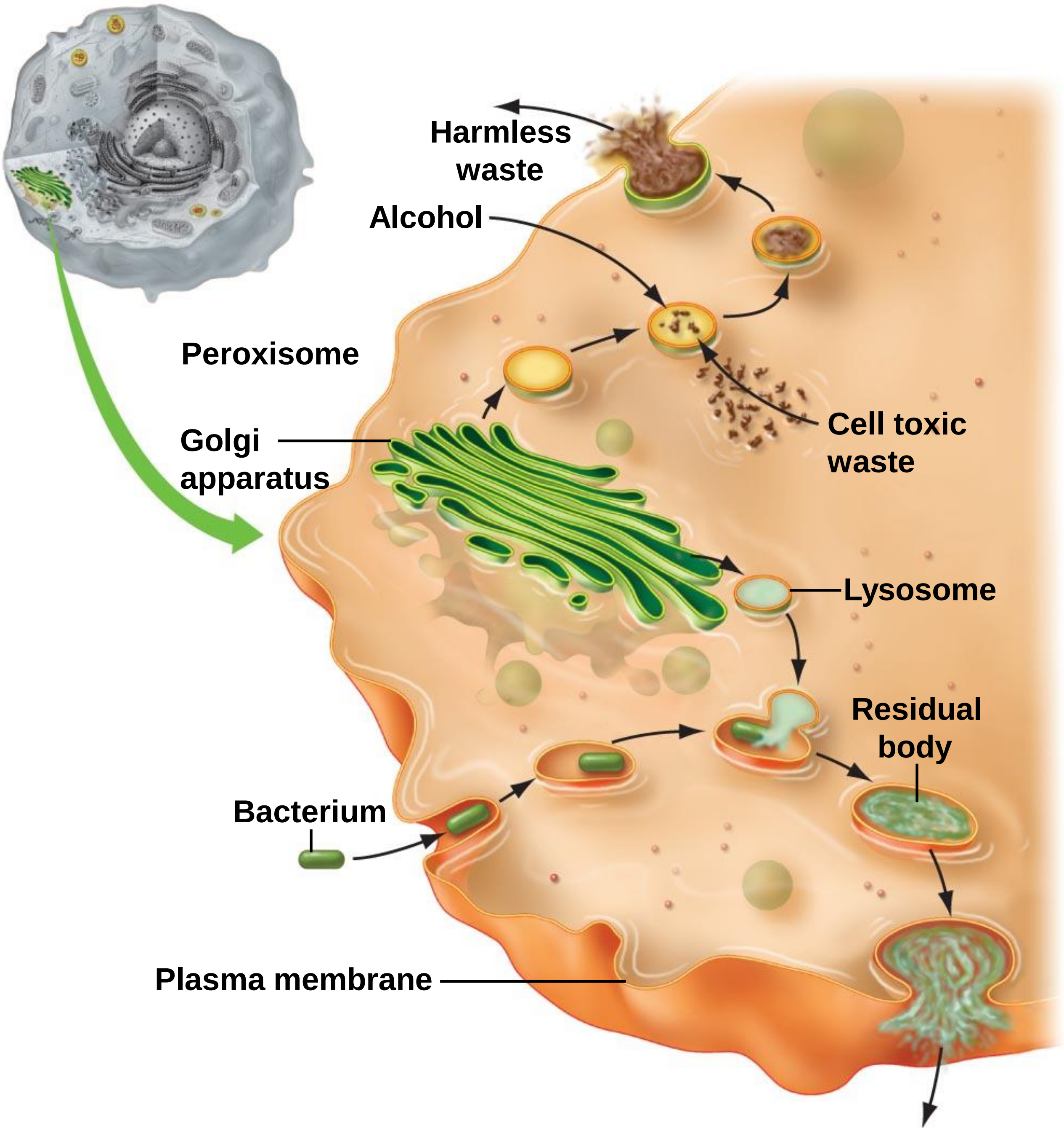
Golgi Apparatus

- Refines synthesized products
- Packaging and shipping center
- Products are packaged into vesicles



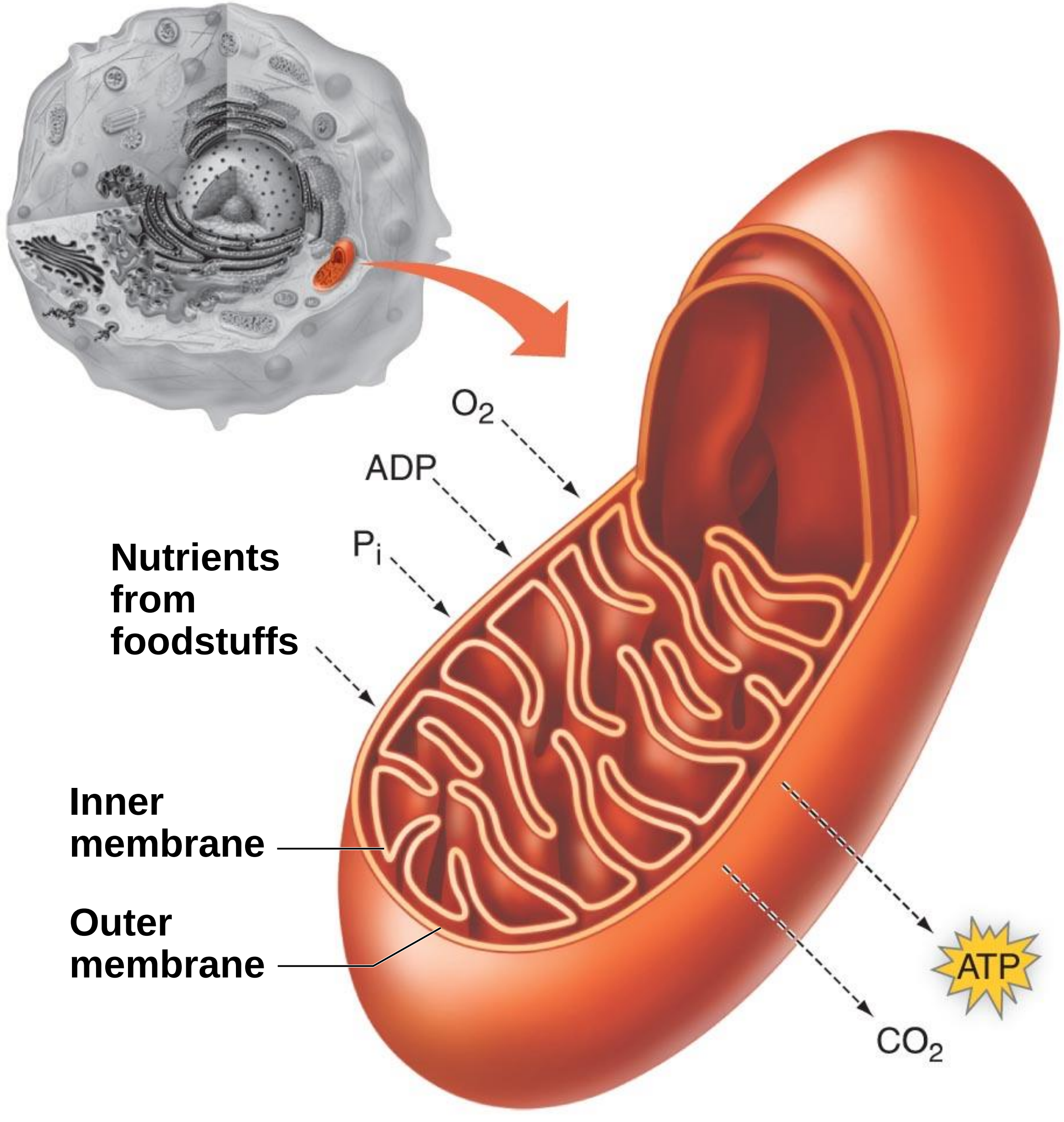
Vesicles

- Storage and shipping vesicles
  - Peroxisomes
    - Contain enzymes that detoxify
  - Lysosomes
    - Contain digestive enzymes



Mitochondria

- "Power plant" of the cell
- Surrounded by a double membrane
- Utilizes O_2 and produces CO_2
- Generates ATP



a) The structure and overall function of a mitochondrion.

Sources of Energy

- Fat
  - Triglycerides
  - Long-term energy storage in animals
- Glycogen
  - Carbohydrate storage
  - Short-term energy storage in animals

Cell Structures for Support and Movement

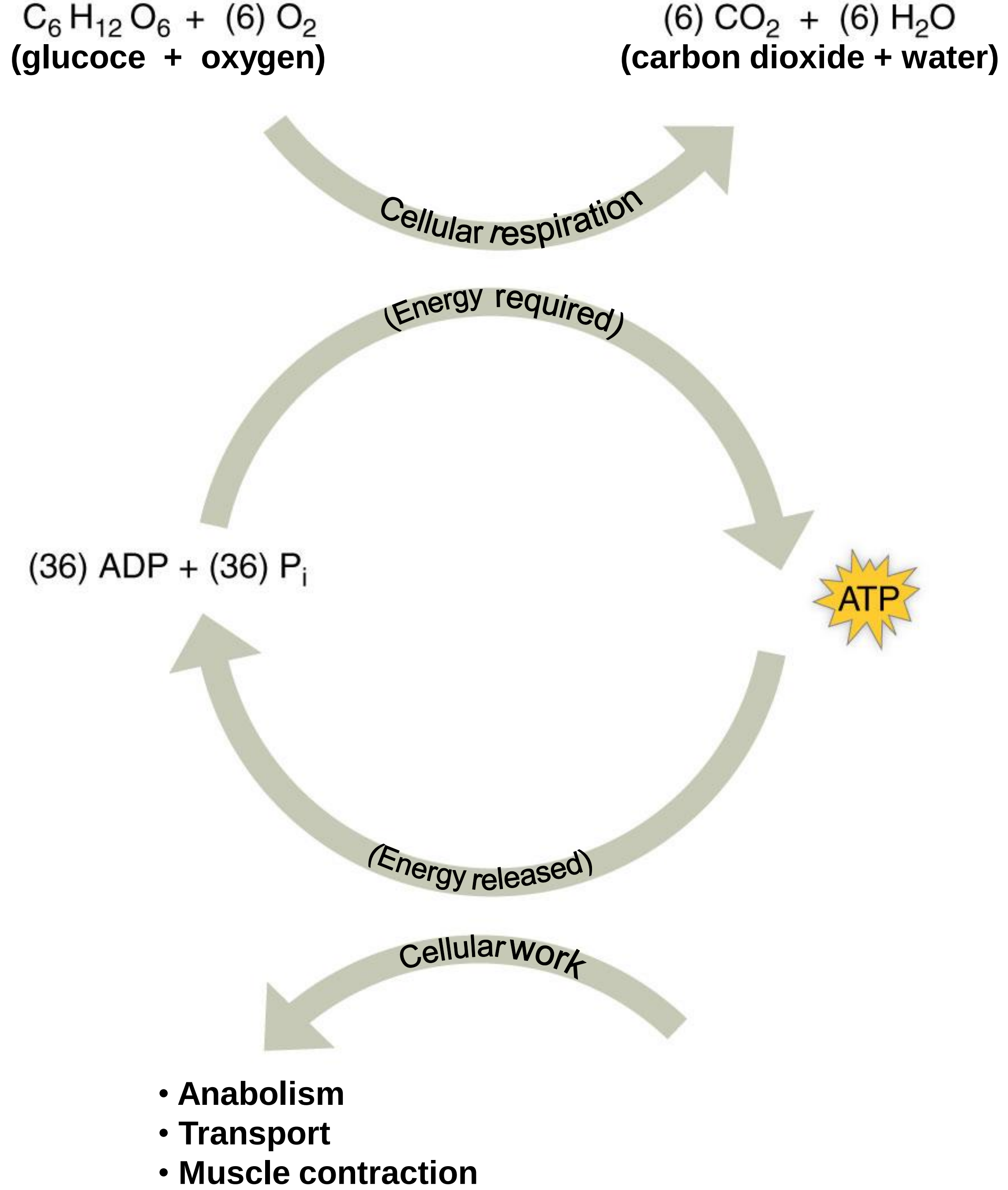
- Cytoskeleton
  - Structural support
- Cilia
  - Short, many
- Flagella
  - Long, single
- Centrioles
  - Cell division

Cells Use and Transform Matter and Energy

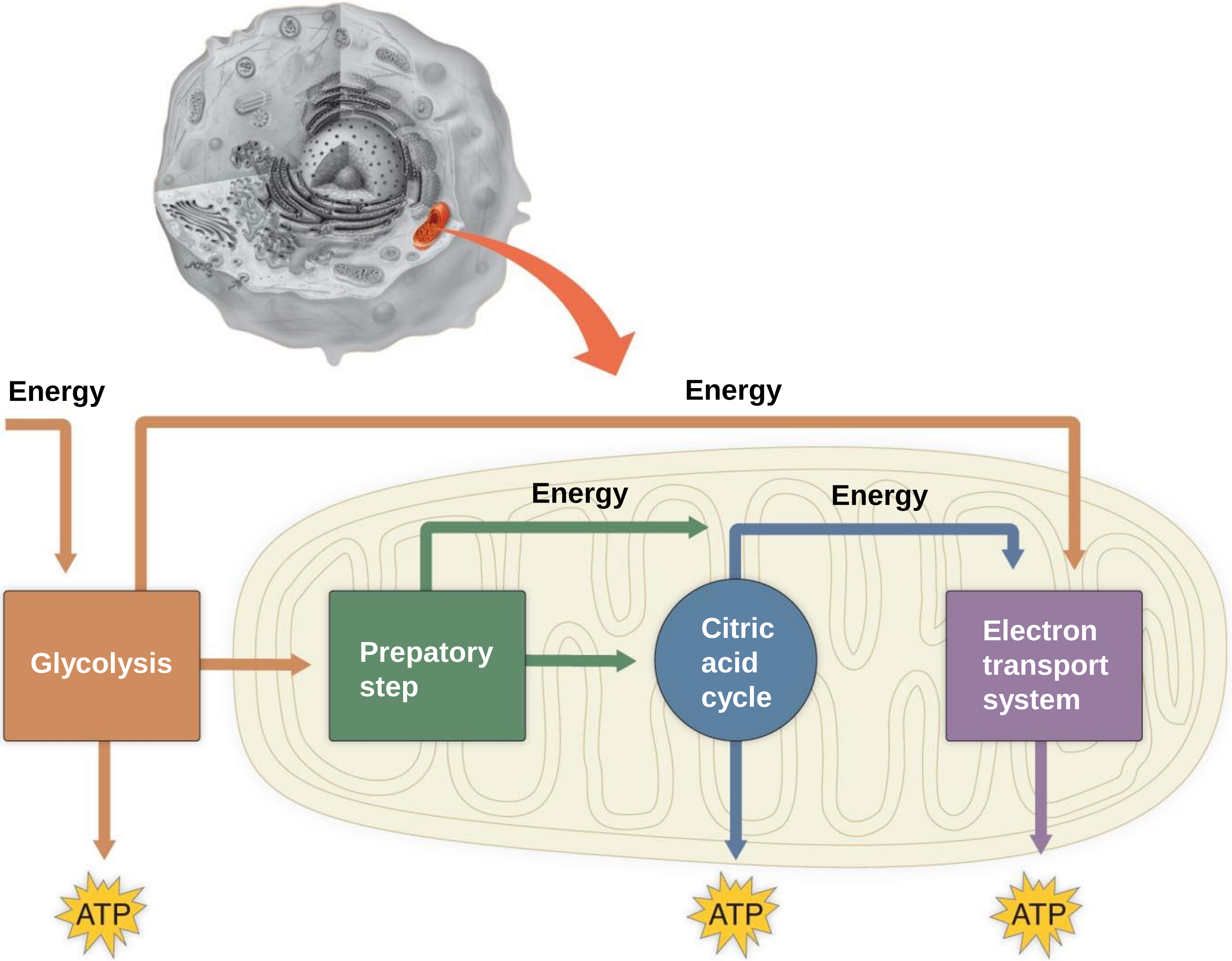
- Anabolism
  - Requires enzymes
  - Used in making/assembling large molecules
  - May require energy (ATP)
- Catabolism
  - Requires enzymes
  - Breakdown of molecules
  - May release energy

Glucose Provides the Cell with Energy

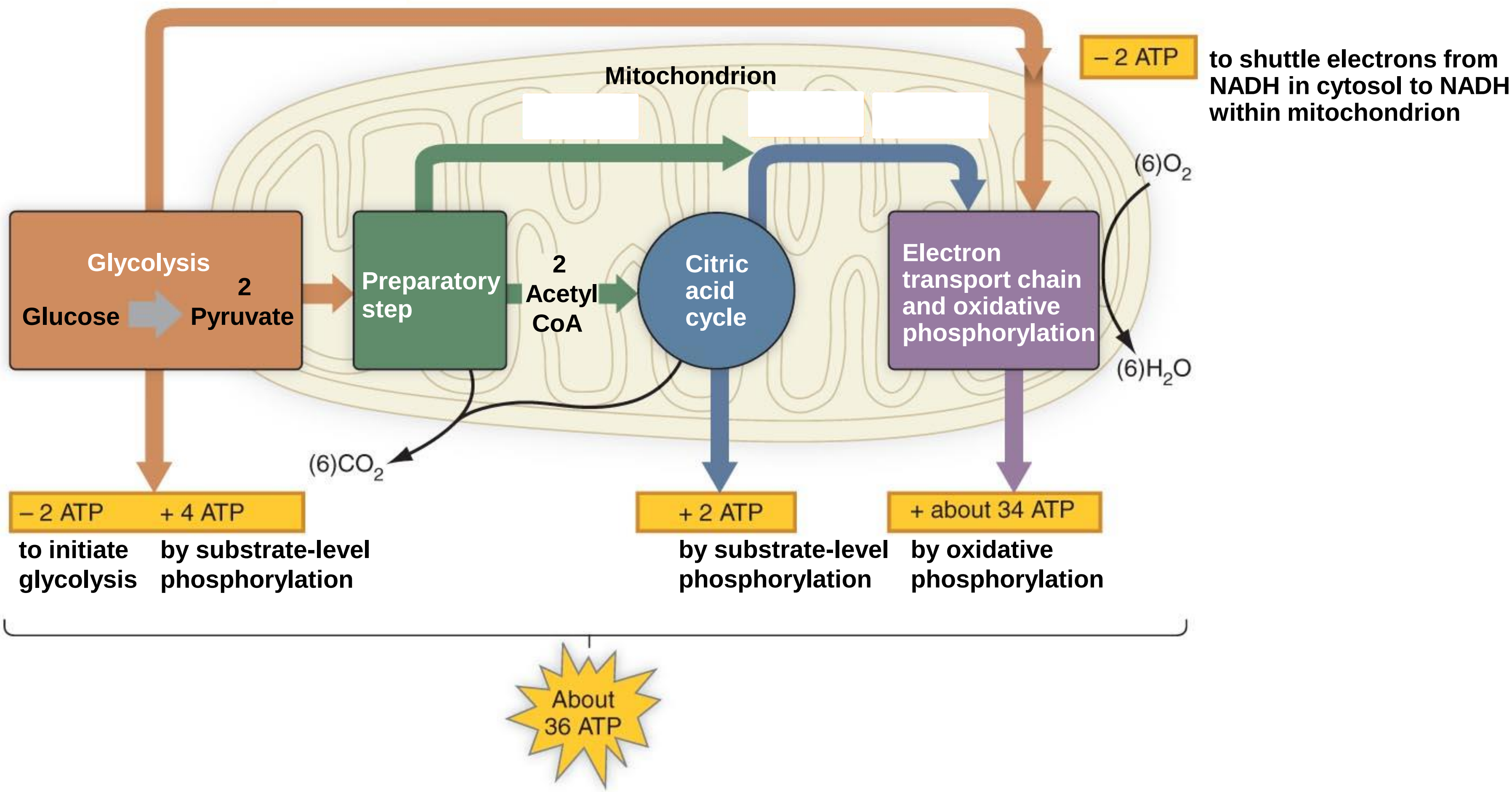
- Energy in glucose is used to generate ATP
- In absence of glucose, other carbohydrates, fats, and protein can be catabolized to generate ATP



$C_6H_{12}O_6$ + (6) O_2
(glucoce + oxygen)
(6) CO_2 + (6) H_2O
(carbon dioxide + water)
Cellular respiration
(Energy required)
(36) ADP + (36) P_i
ATP
(Energy released)
Cellular work
• Anabolism
• Transport
• Muscle contraction



Energy
Energy
Energy
Energy
Glycolysis
Prepatory step
Citric acid cycle
Electron transport system
ATP
ATP
ATP



a) Most of the ATP generated during cellular respiration is synthesized in the electron transport system.

Additional Energy Sources

- Glycogen
- Fats
  - Triglycerides have twice the energy of carbohydrates
- Proteins
  - Have the same energy as carbohydrates

Anaerobic Pathways