The Living World

Fourth Edition

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4 Cells

PowerPoint® Lectures prepared by Johnny El-Rady

4.1 Cells

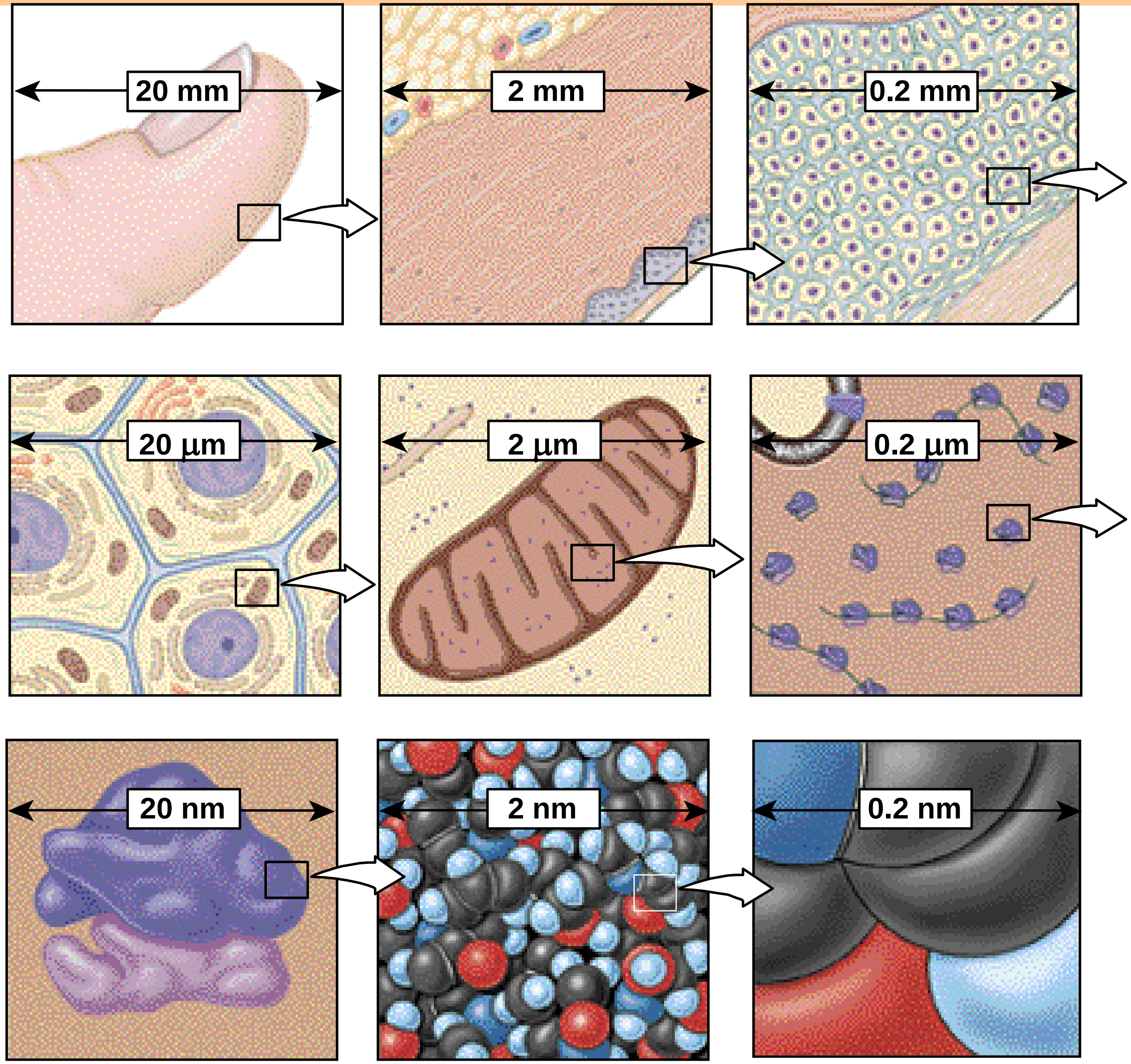


Fig. 4.1 The size of cells and their contents

The Cell Theory

- Robert Hooke (1665)
  - Examined a thin slice of cork tissue
  - Observed honeycombed compartments he called *cellulae* (L, small rooms)
    - The term became cells

- Matthias Schleiden and Theodor Schwann
  - Proposed the first two statements of the cell theory in 1838-39

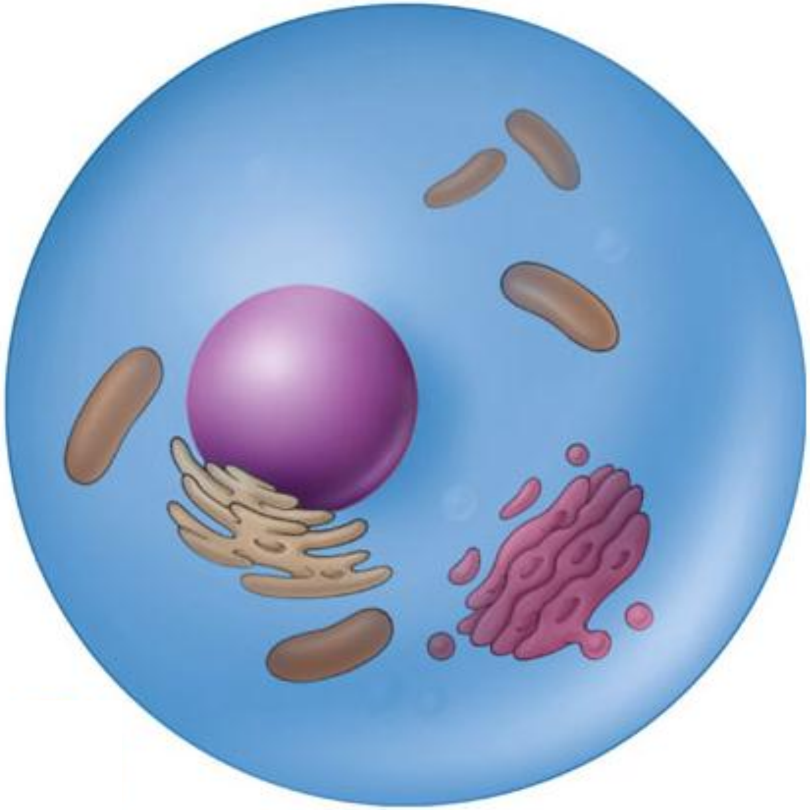
The Cell Theory

- In its modern form, the cell theory includes three principles
  - 1. All organisms are composed of one or more cells
  - 2. Cells are the smallest living things
  - 3. Cells arise only by division of a previously existing cell

Cell Size

- Cells range in size from a few micrometers to several centimeters
- Most cells are small because larger cells do not function efficiently
- It is advantageous to have a large surface-to-volume ratio
  - As cell size increases, volume grows much faster than surface area

Fig. 4.2 Surface-to-volume ratio

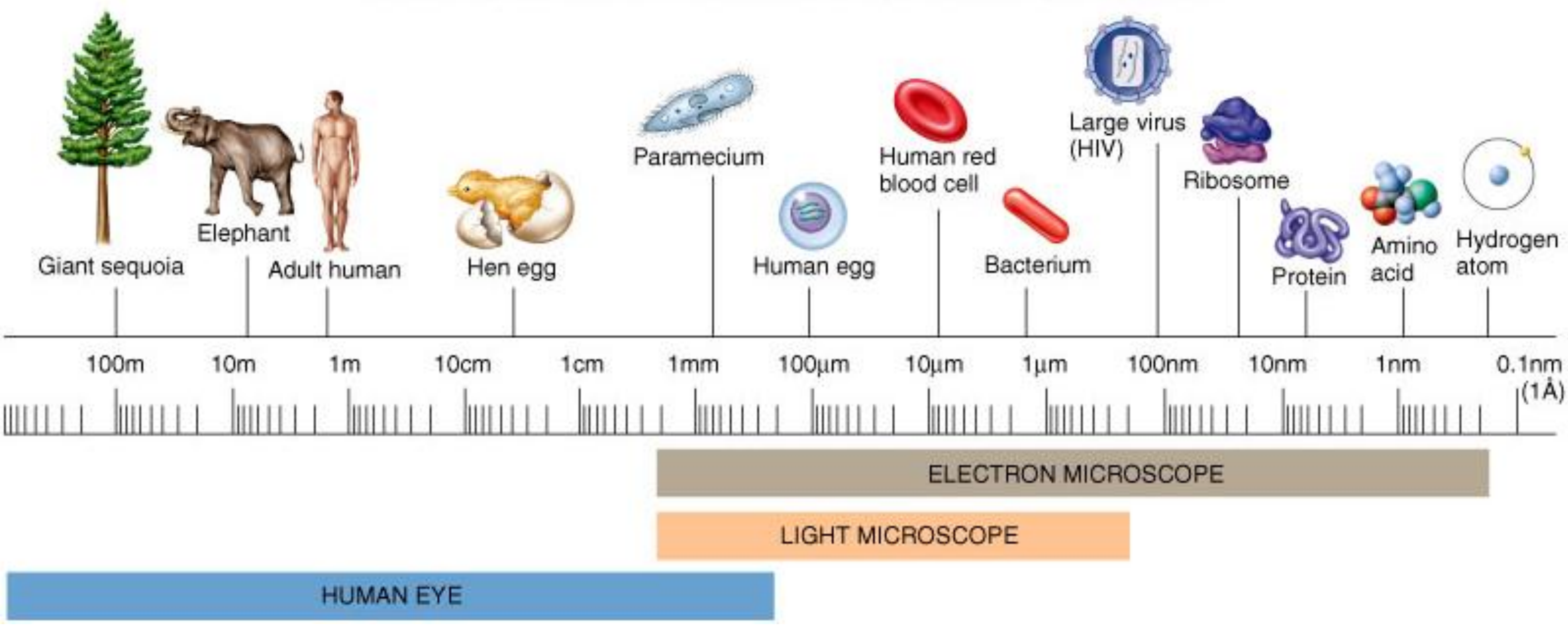


Cell radius (r)	1 cm	10 cm
Surface area ($4\pi r^2$)	12.57 cm^2	1,257 cm^2
Volume ($\frac{4}{3}\pi r^3$)	4.189 cm^3	4,189 cm^3

Visualizing Cells

- Few cells can be see with the unaided eye

Fig. 4.3 A scale of visibility



Visualizing Cells

- We can’t see most cells because of the limited resolution of the human eye
  - Resolution is the minimum distance two points can be apart and still be seen as two points
  - Resolution of the human eye is 100 μ
- One way to increase resolution is to increase magnification, using microscopes
- There are two main types of microscopes

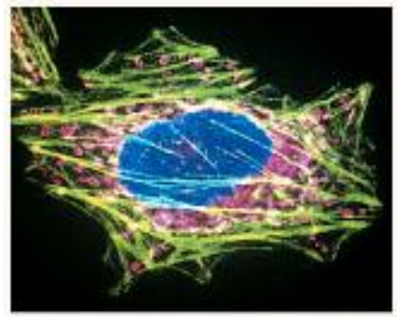
Light Microscopes

- Use light as the illuminating source

TABLE 4.1 TYPES OF MICROSCOPES

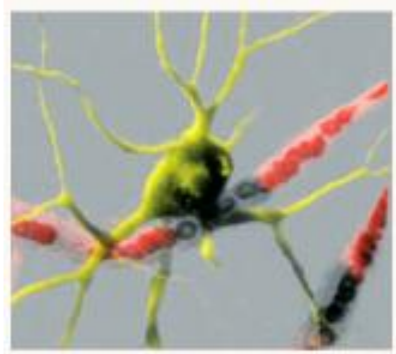
Light Microscopes

Bright-field microscope: Light is simply transmitted through a specimen in culture, giving little contrast. Staining specimens improves contrast but requires that cells be fixed (not alive), which can cause distortion or alteration of components.



Fluorescence microscope: A set of filters transmits only light that is emitted by fluorescently stained molecules or tissues.

Dark-field microscope: Light is directed at an angle toward the specimen; a condenser lens transmits only light reflected off the specimen. The field is dark, and the specimen is light against this dark background.



Confocal microscope: Light from a laser is focused to a point and scanned across the specimen in two directions. Clear images of one plane of the specimen are produced, while other planes of the specimen are excluded and do not blur the image. Fluorescent dyes and false coloring enhances the image.

Light Microscopes

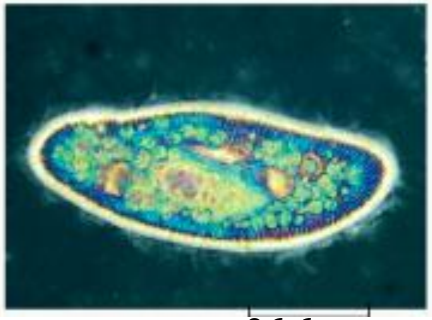
- Use light as the illuminating source

TABLE 4.1 TYPES OF MICROSCOPES

Light Microscopes

32.81 µm

Phase-contrast microscope: Components of the microscope bring light waves out of phase, which produces differences in contrast and brightness when the light waves recombine.



26.6 µm

Differential-interference-contrast microscope: Out-of-phase light waves to produce differences in contrast are combined with two beams of light travelling close together, which create even more contrast, especially at the edges of structures.

Electron Microscopes

- Use a beam of electrons to produce the image

TABLE 4.1 TYPES OF MICROSCOPES

Electron Microscopy

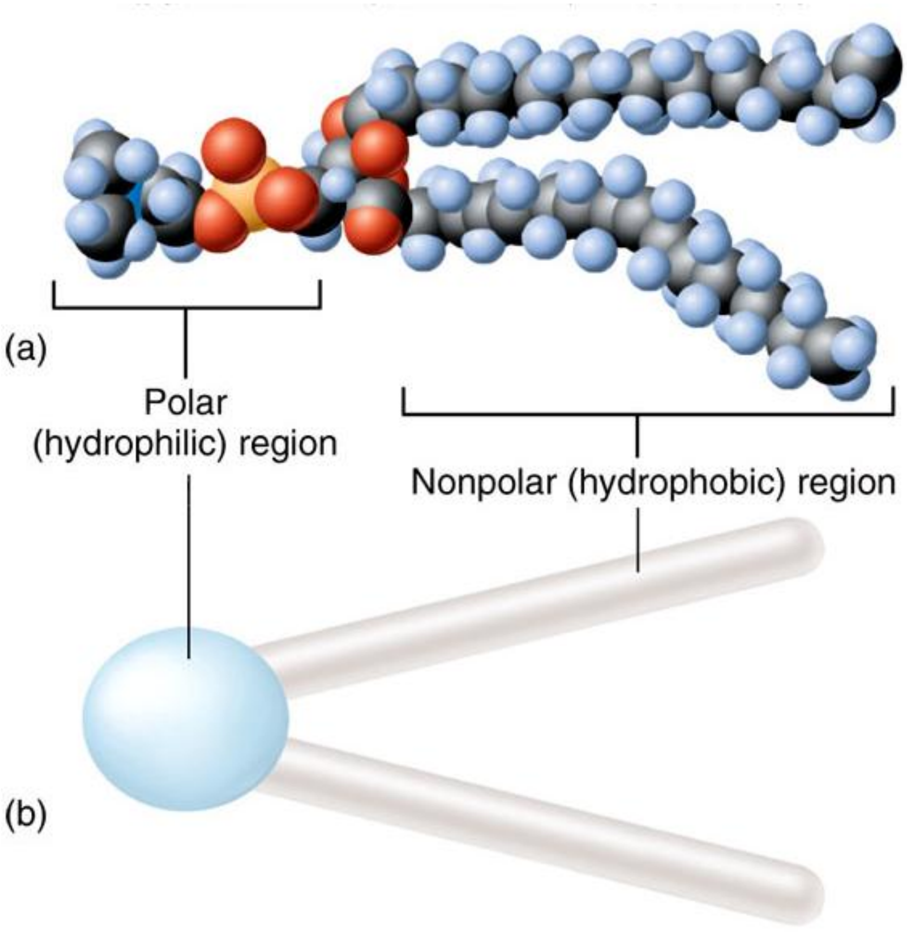
Transmission electron microscope: A beam of electrons is passed through the specimen. Electrons that pass through are used to form an image. Areas of the specimen that scatter electrons appear dark. False coloring enhances the image.

Scanning electron microscope: An electron beam is scanned across the surface of the specimen, and electrons are knocked off the surface. Thus, the surface topography of the specimen determines the contrast and the content of the image. False coloring enhances the image.

4.2 The Plasma Membrane

- Encases all living cells
- Its basic structure is represented by the fluid-mosaic model
  - Phospholipid bilayer with embedded proteins

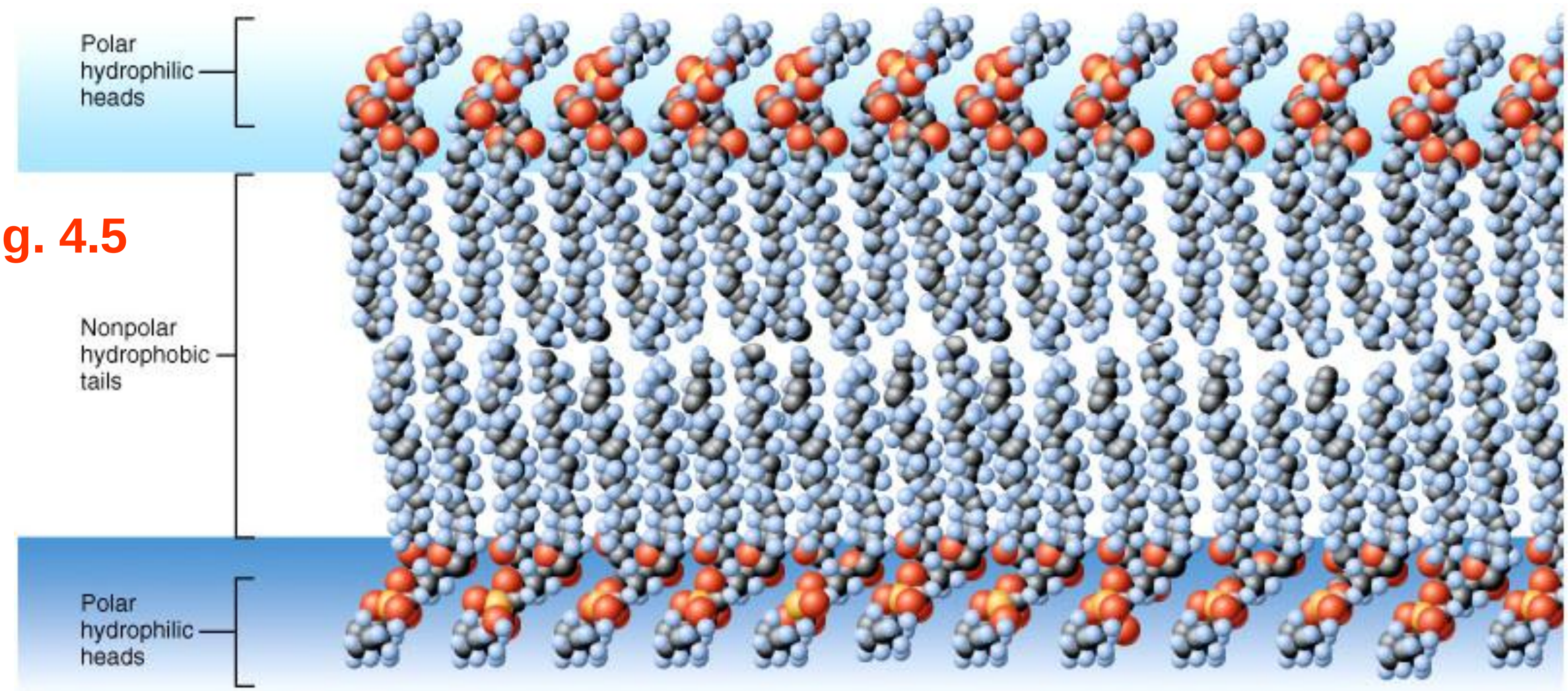
Fig. 4.4 Phospholipid structure



4.2 The Plasma Membrane

- In water, phospholipids spontaneously form a bilayer

Fig. 4.5

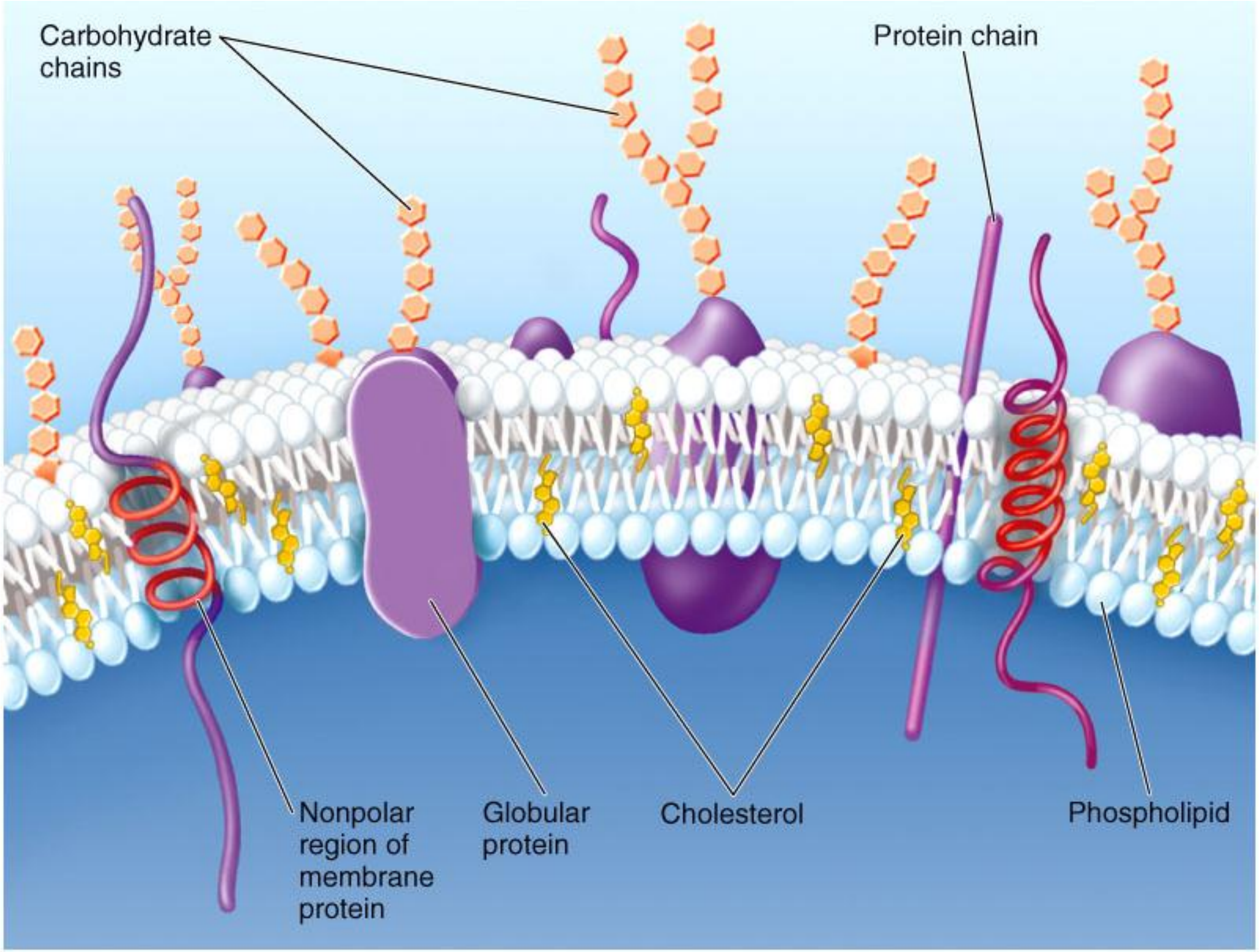


- Cell membranes contain zones called lipid rafts
  - Heavily enriched in cholesterol

Proteins Within the Membrane

- Two main types
  - Cell-surface proteins
    - Project from the surface of the membrane
    - Act as markers or receptors
  - Transmembrane proteins
    - Extend all the way across the bilayer
    - Provide channels in and out of the cell

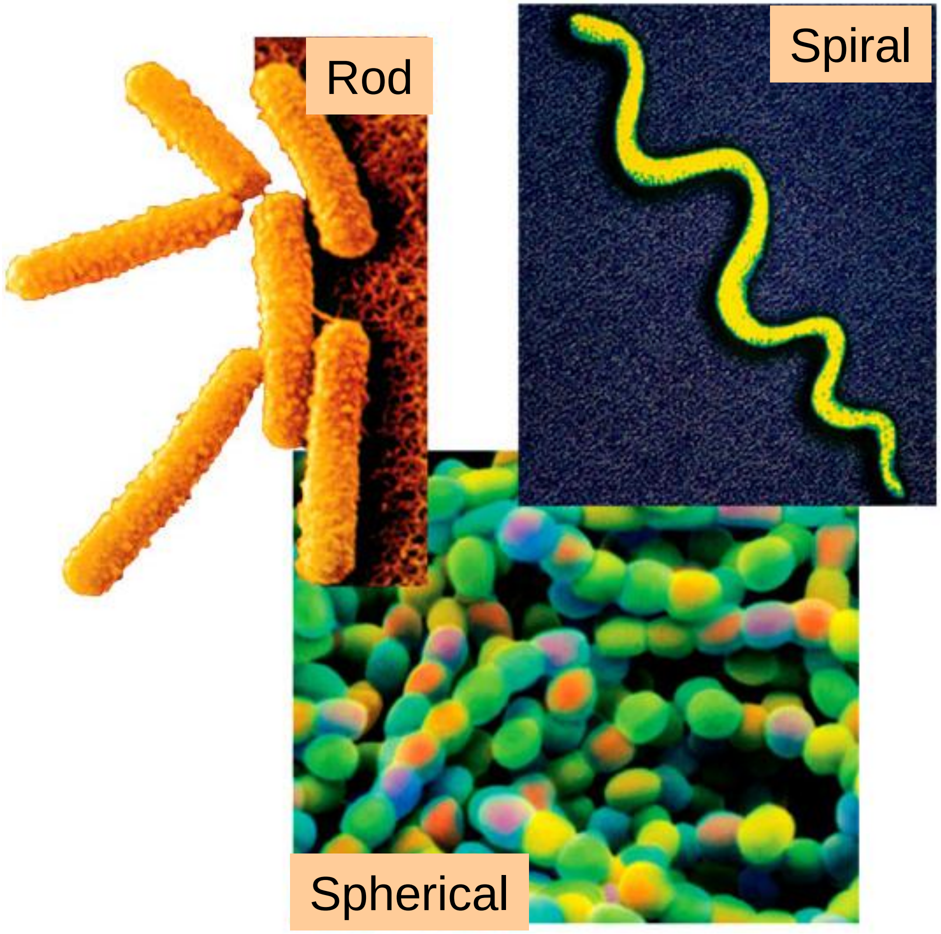
Fig. 4.6 Proteins are embedded within the lipid bilayer



4.3 Prokaryotic Cells

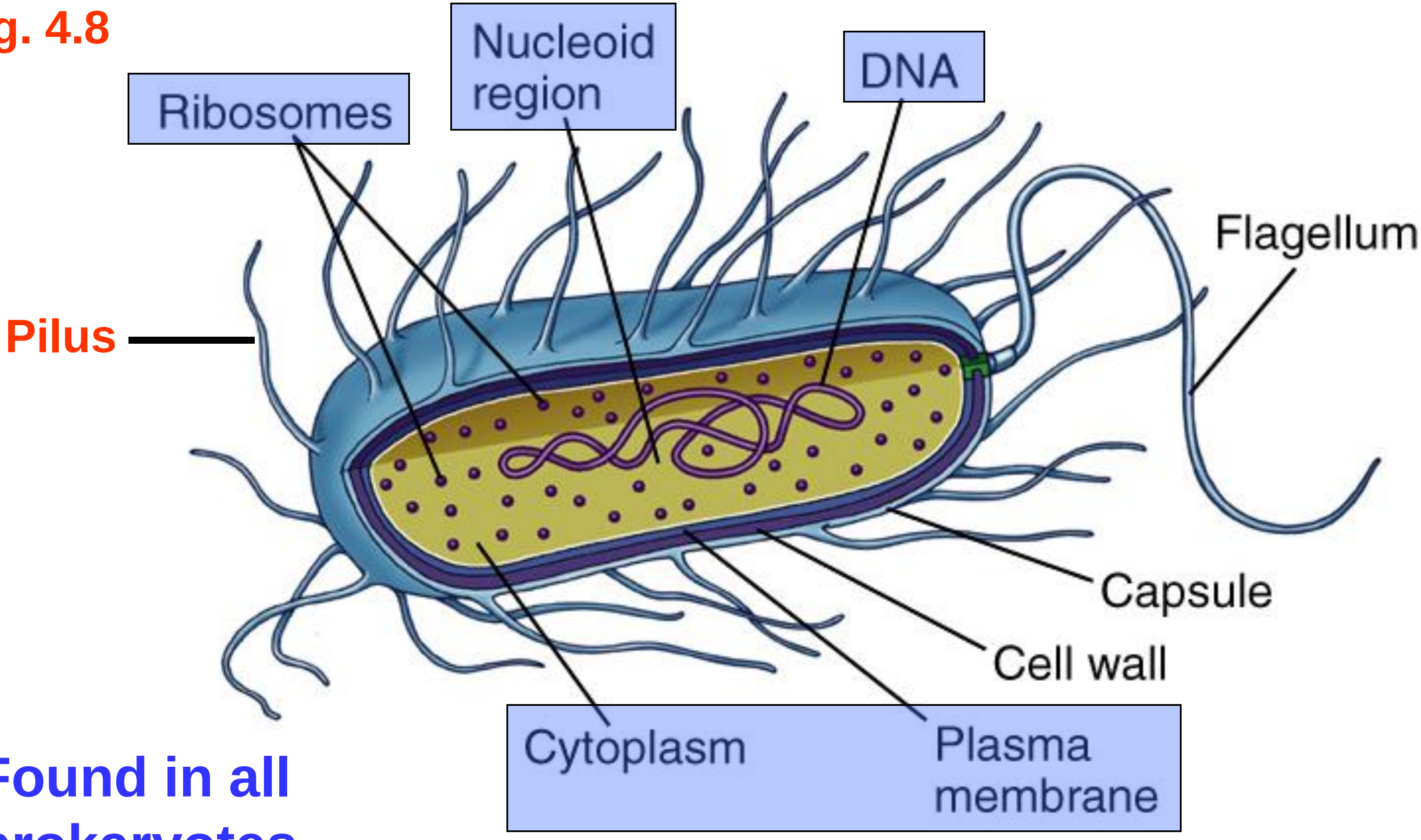
- There are two major kinds of cells
  - Prokaryotes
  - Eukaryotes
- Prokaryotes include bacteria and archaea
  - Over 5,000 species are recognized
- Prokaryotes come in three main shapes

Fig. 4.9



- Prokaryotes have a very simple architecture
  - They lack a nucleus and organelles

Fig. 4.8



Found in all prokaryotes

4.4 Eukaryotic Cells

- Appeared about 1.5 billion years ago
- Include all cells alive today except bacteria and archaea
- Are larger than prokaryotic cells
- Have a much more complex architecture
  - Possess nucleus and a variety of organelles

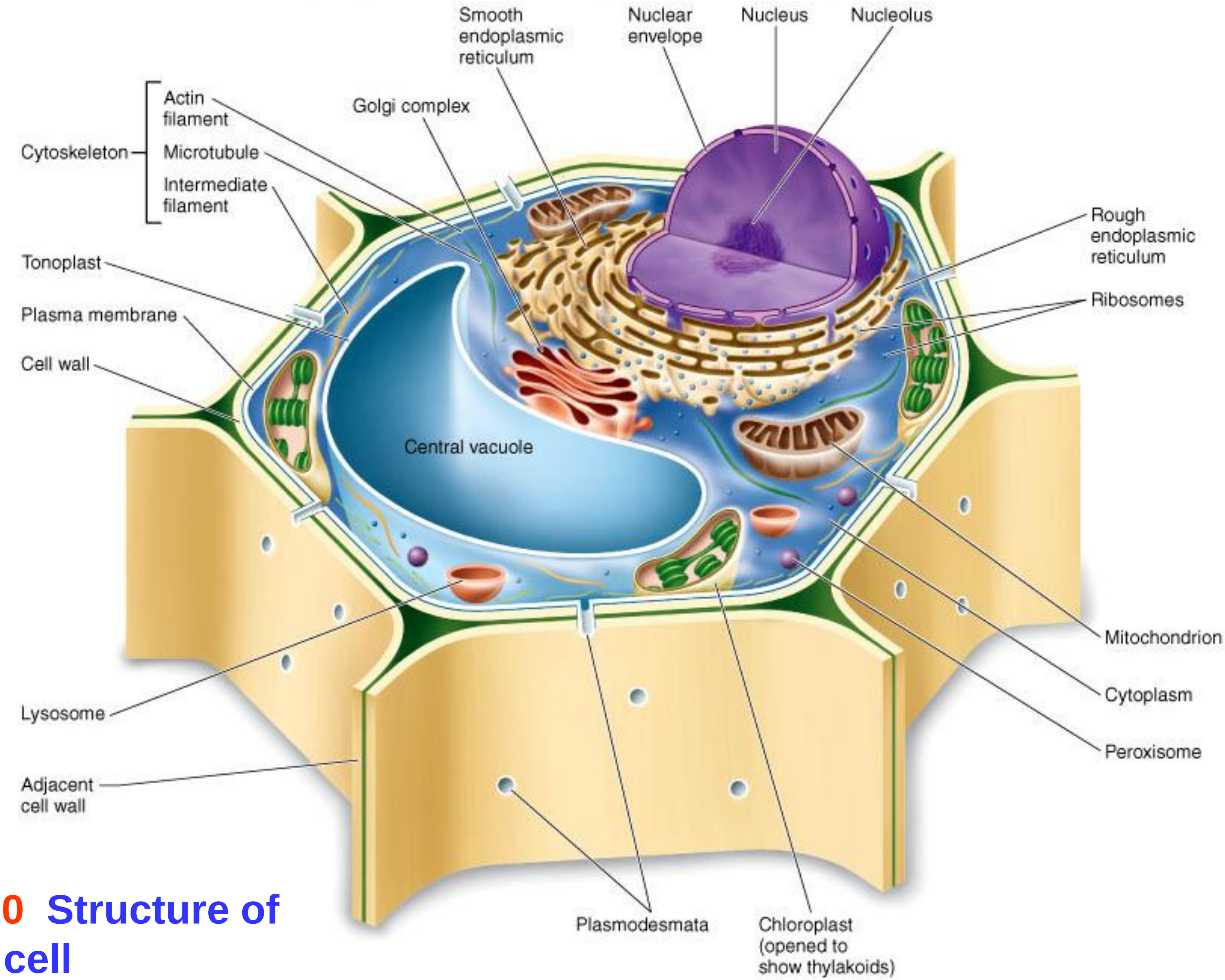


Fig. 4.10 Structure of a plant cell

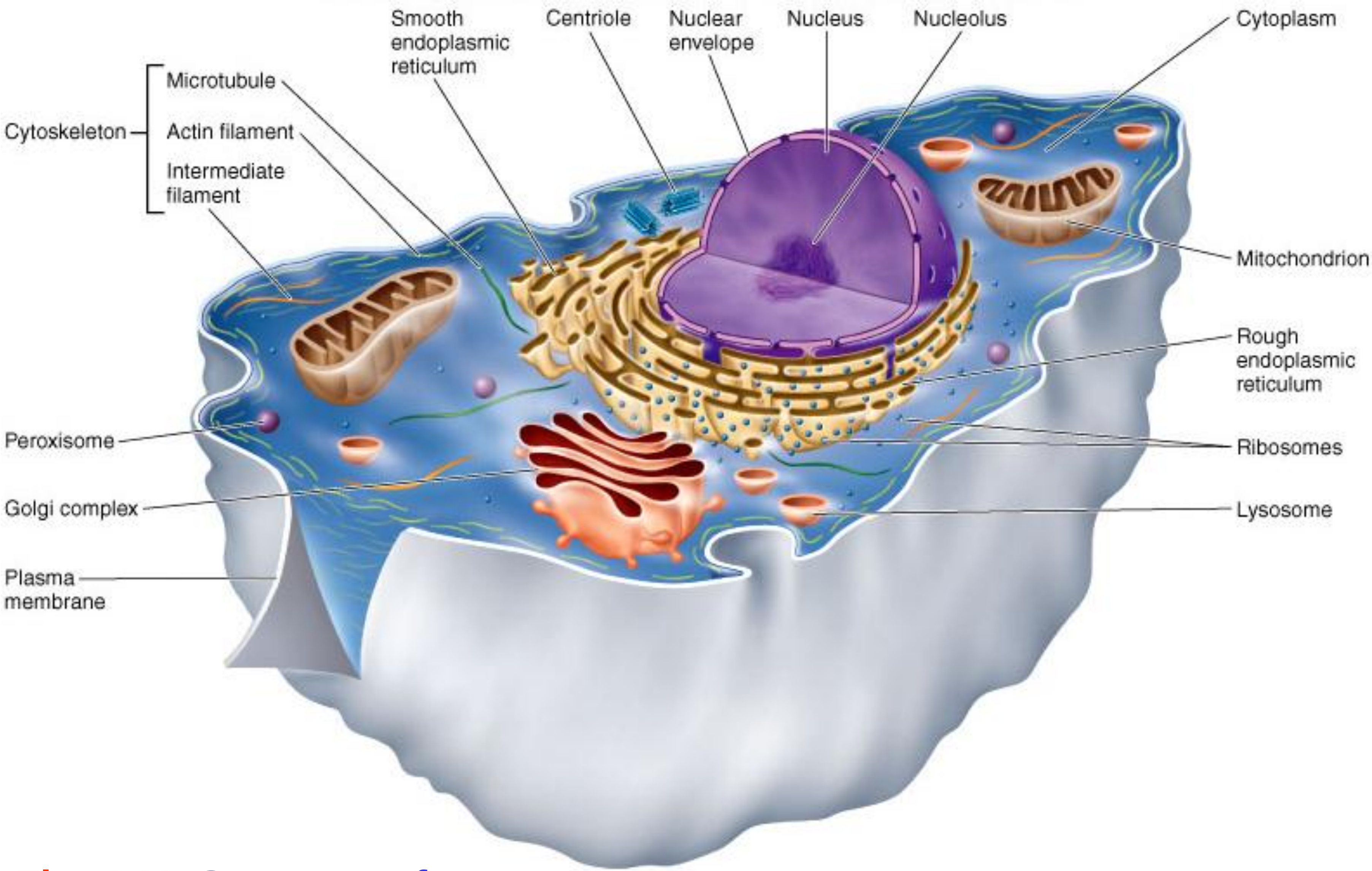


Fig. 4.11 Structure of an animal cell

4.5 The Nucleus: The Cell's Control Center

- The nucleus is the command center of the cell
  - It directs all of its activities
- It also stores the cell's hereditary information
  - The DNA is associated with proteins
  - During cell division, it condenses into chromosomes
  - After cell division, it relaxes to form chromatin

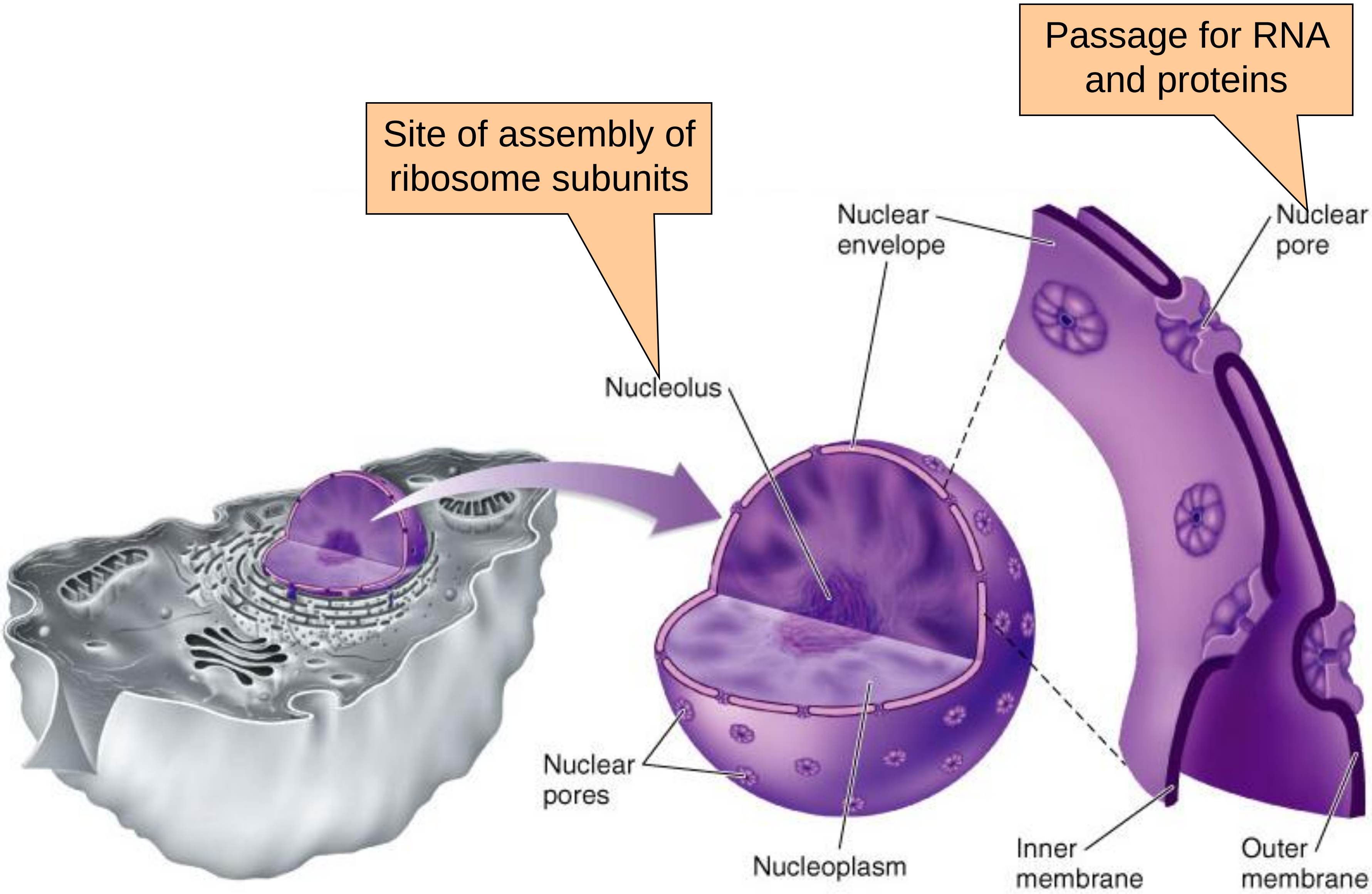


Fig. 4.12 The nucleus

4.6 The Endomembrane System

- An extensive system of interior membranes that divides the cell into compartments

- It consists of
  - Endoplasmic reticulum
  - Golgi complex
  - Lysosomes
  - Peroxisomes

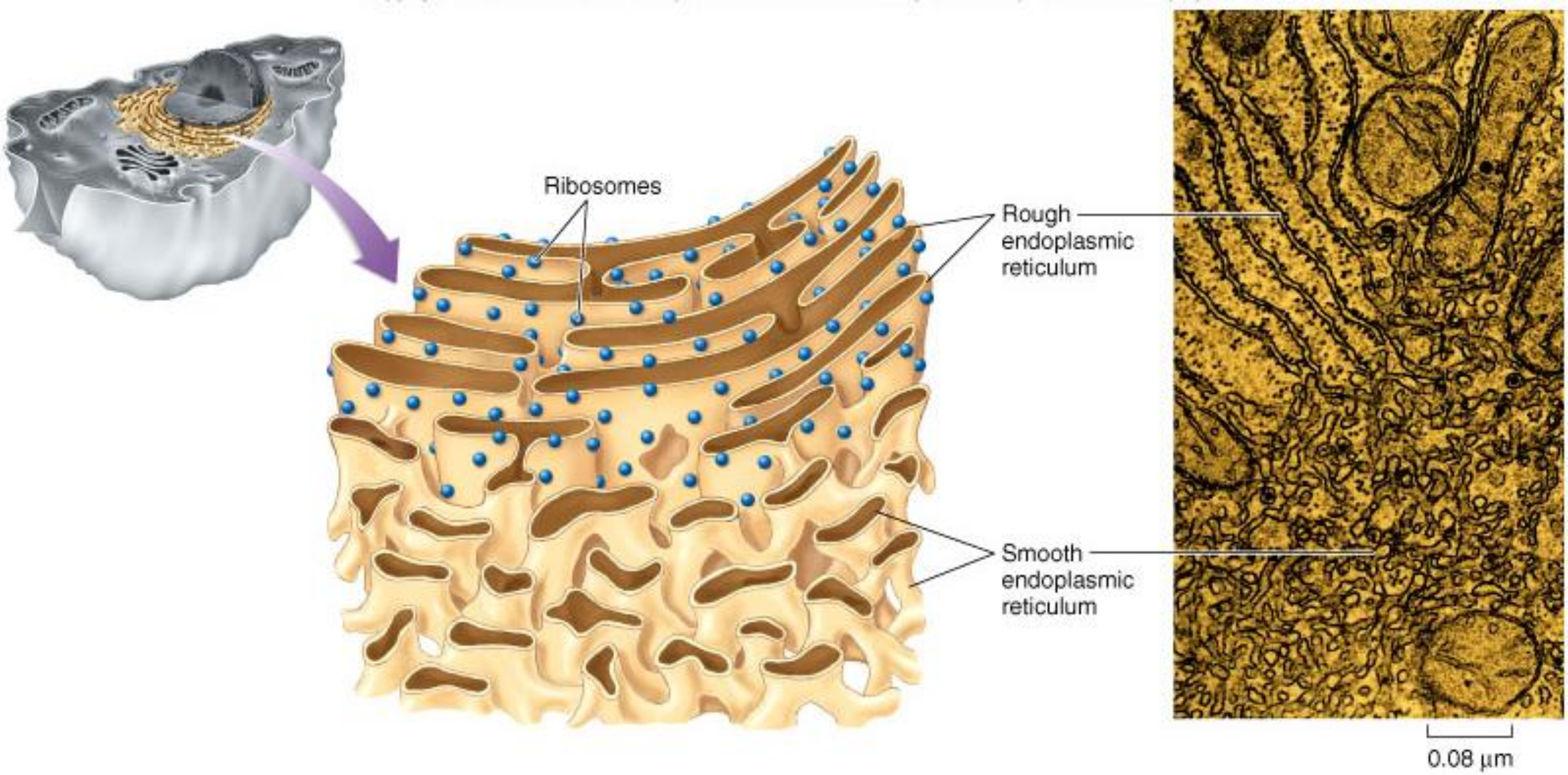
Endoplasmic Reticulum (ER)

- Internal membrane system creating channels and membrane-bound vesicles

- Consists of two distinct regions
  - Rough ER
    - Studded with ribosomes
    - Involved in protein synthesis

  - Smooth ER
    - Embedded with enzymes
    - Involved in lipid and carbohydrate synthesis

Fig. 4.13 The endoplasmic reticulum

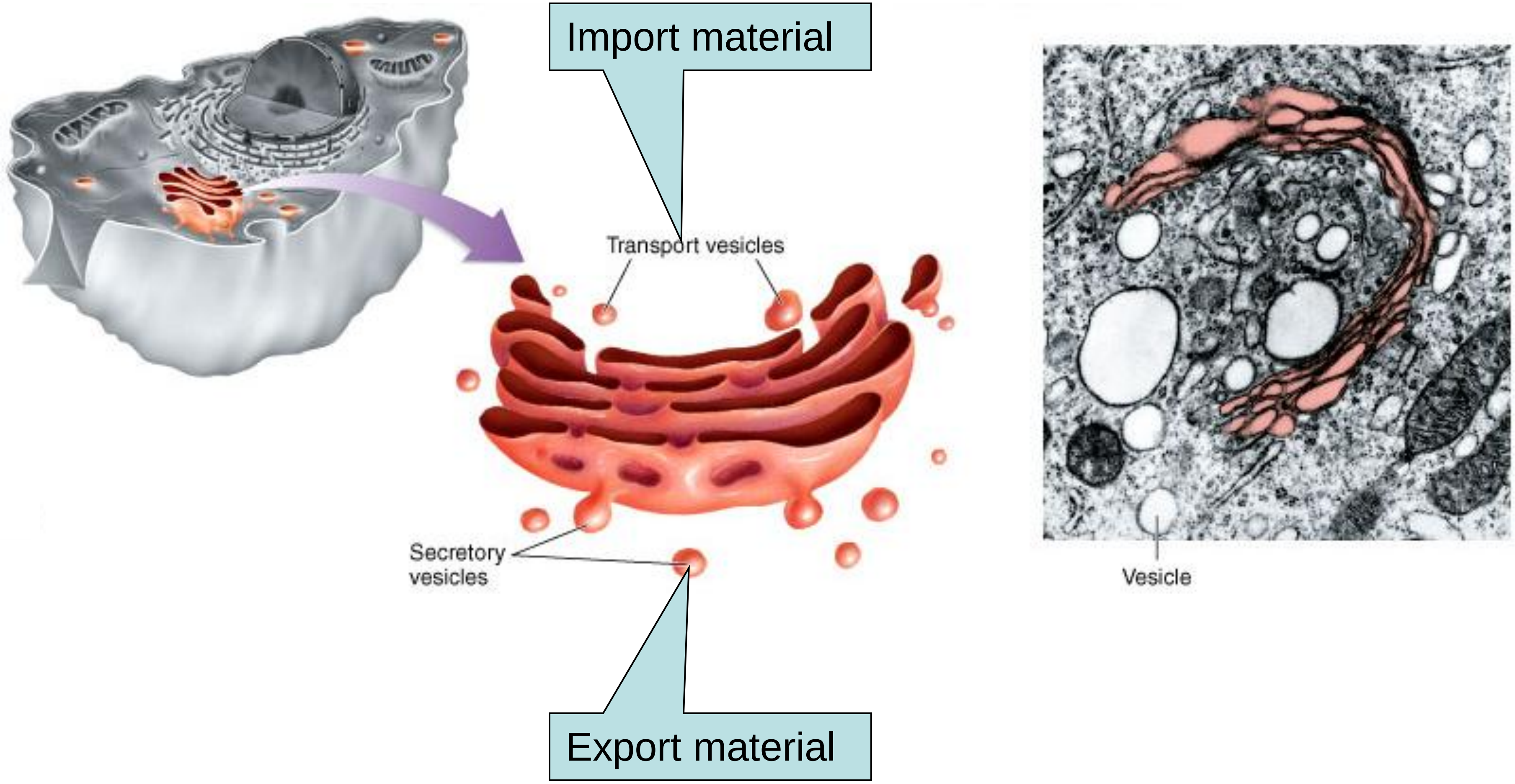


- The ER transports the molecules it synthesizes to the Golgi complex

The Golgi Complex

- Golgi bodies are flattened stack of membranes that are scattered throughout the cytoplasm
- Depending on the cell, the number of Golgi bodies ranges from a few to several hundred
  - These are collectively referred to as the Golgi complex
- The Golgi complex collects, packages, modifes and distributes molecules

Fig. 4.14 Golgi complex



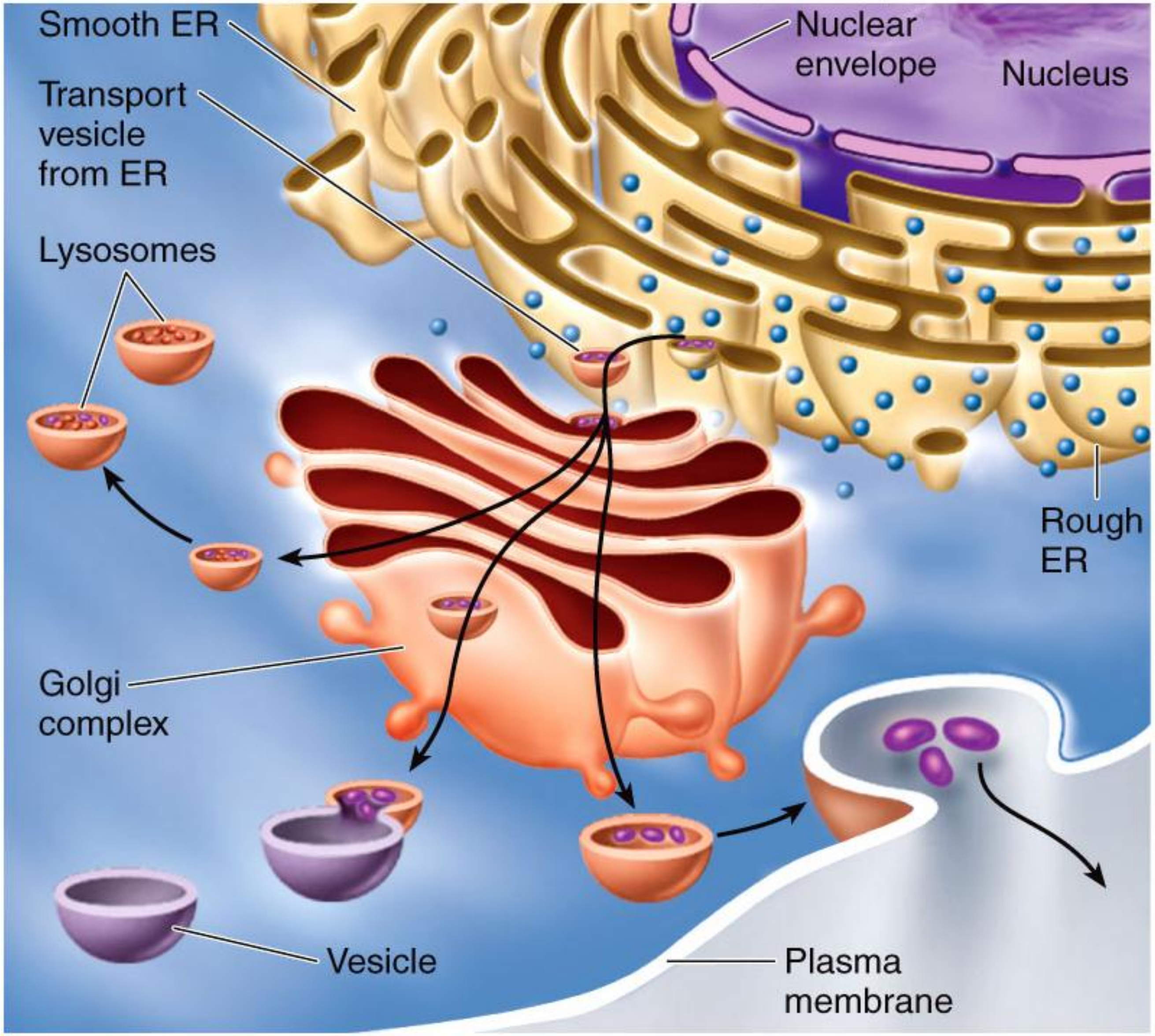
Lysosomes

- Arise from the Golgi complex
- They contain enzymes that break down macromolecules
- Function in intracellular digestion of
  - Worn-out cellular components
  - Substances taken into cells
  - The resulting material is then recycled

Peroxisomes

- Arise from the ER
- They contain two sets of enzymes
  - One set is found in plants
    - Converts fats to sugars
  - The other set is found in animals
    - Detoxifies various harmful molecules

Fig. 4.15 How the endomembrane system works



4.7 Organelles That Contain DNA

- Two cell-like organelles contain DNA
  - Mitochondria
    - Found in almost all eukaryotes
  - Chloroplasts
    - Found only in plants and algae

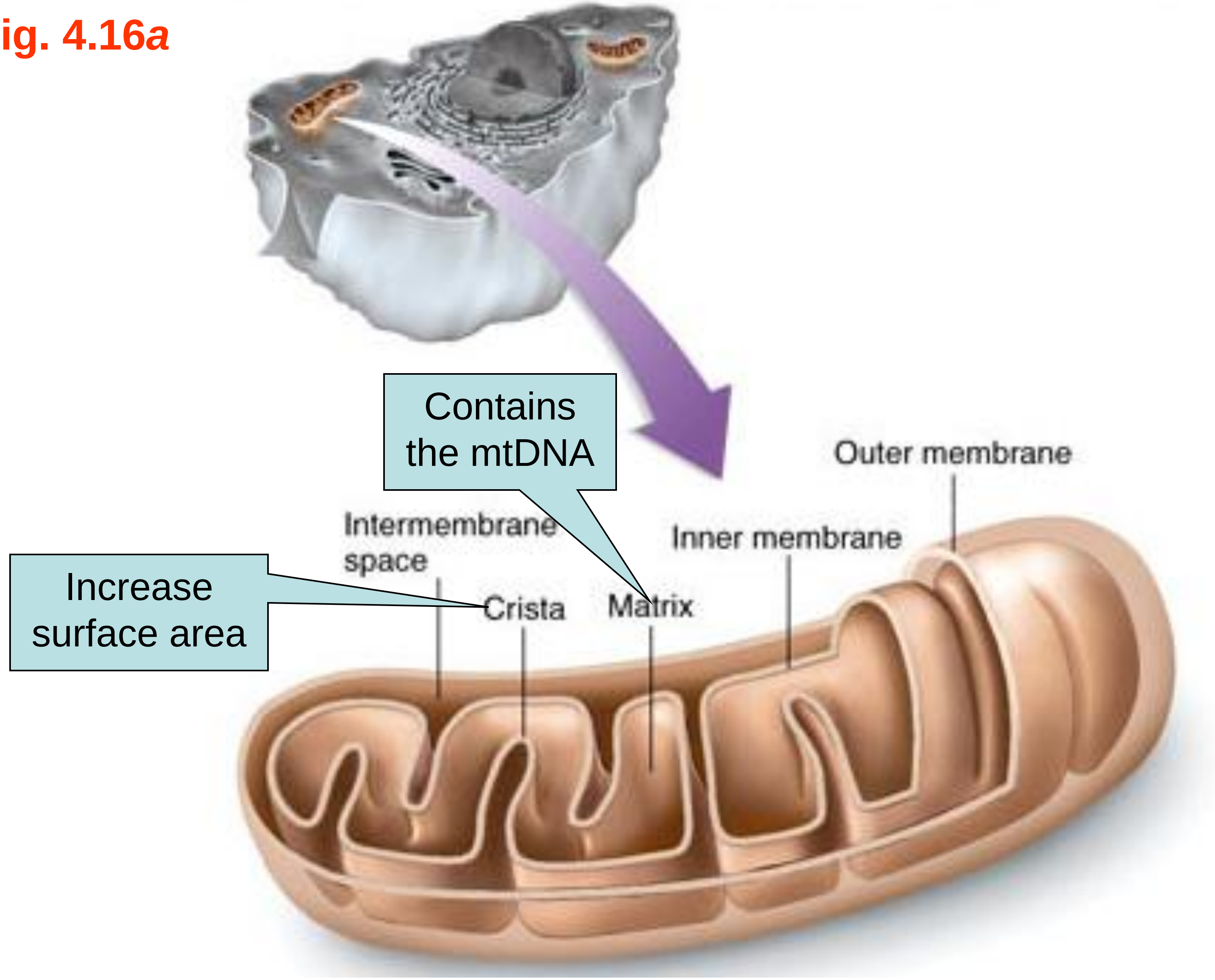
Mitochondria

- Powerhouses of the cell
  - Extract energy from organic molecules through oxidative metabolism
- Sausage-shaped organelles, about the size of a bacterial cell

Fig. 4.16*b*

- Like bacteria, they
  - 1. Possess circular DNA
  - 2. Divide by simple fission

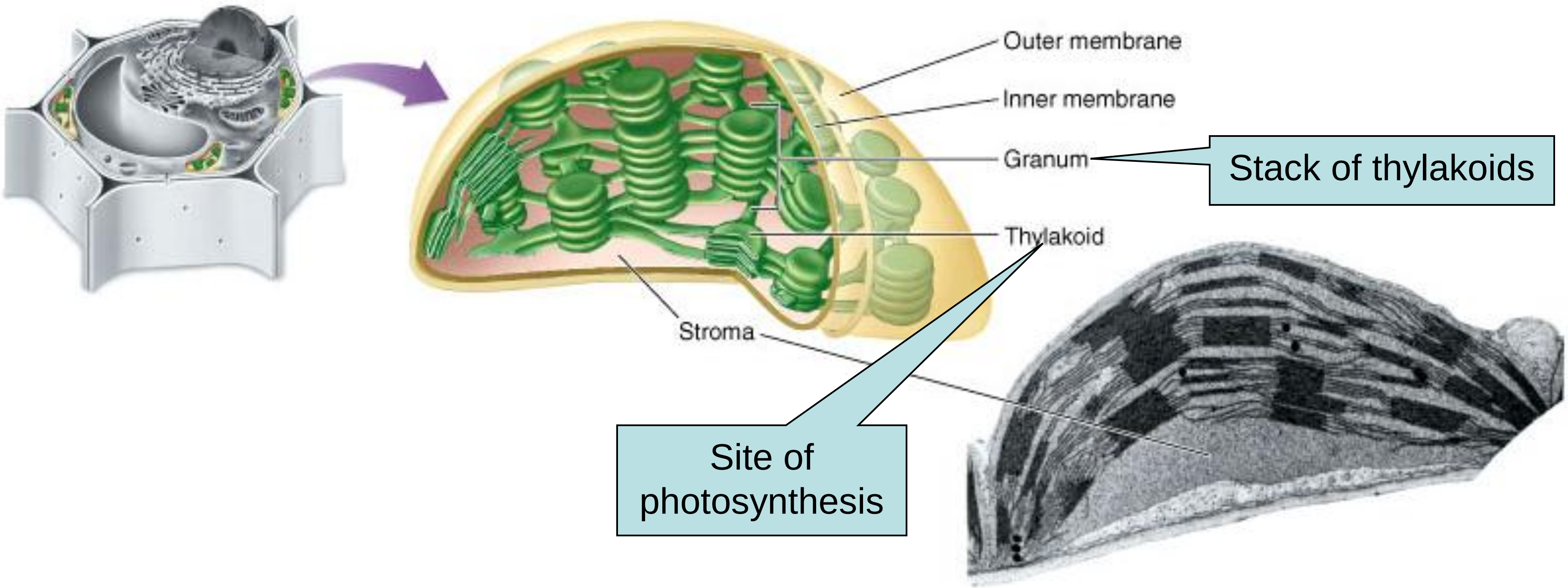
Fig. 4.16*a*


Contains
the mtDNA
Outer membrane
Intermembrane
space
Inner membrane
Increase
surface area
Crista
Matrix

Chloroplasts

- Energy-capturing centers
  - Sites of photosynthesis in plants and algae
- Like bacteria, they
  - 1. Possess circular DNA
  - 2. Divide by simple fission
- Like mitochondria, they are surrounded by two membranes
  - However, inner membrane much more complex

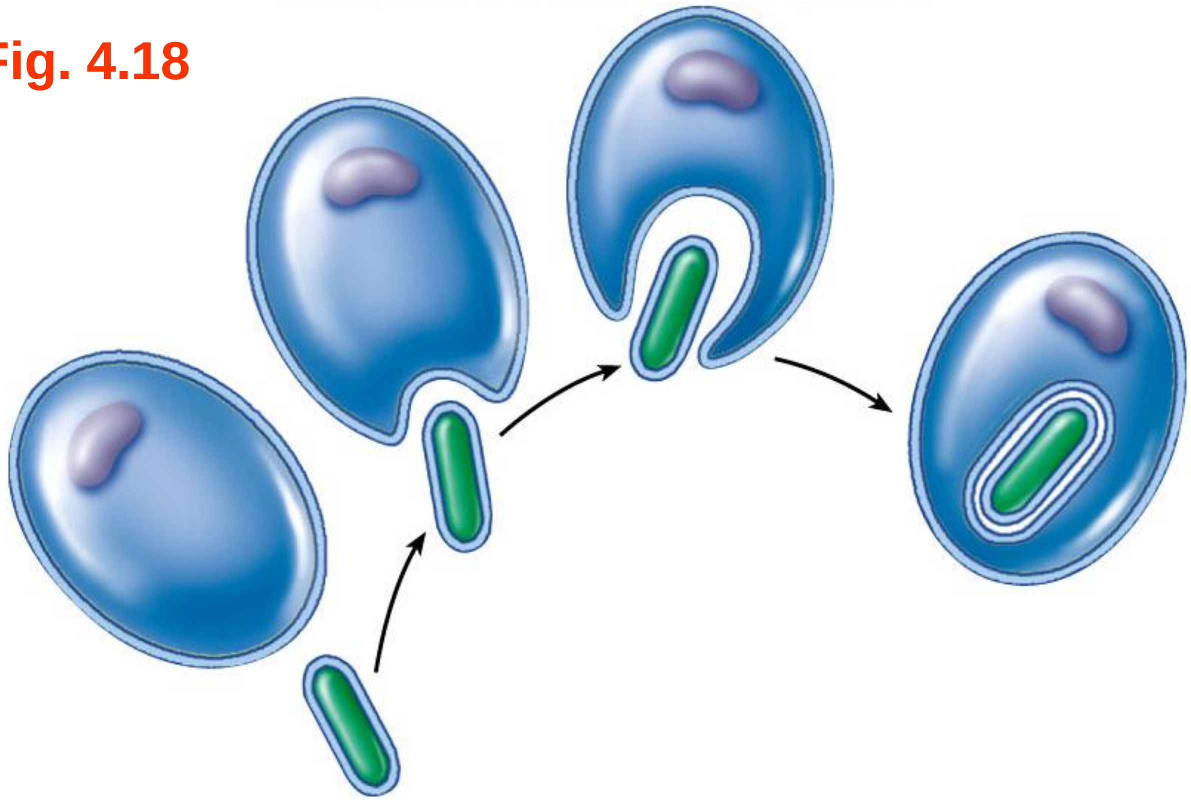
Fig. 4.17


Outer membrane
Inner membrane
Granum
Stack of thylakoids
Thylakoid
Stroma
Site of photosynthesis

The Endosymbiotic Theory

- Proposes that mitochondria and chloroplasts arose by symbiosis from ancient bacteria

Fig. 4.18

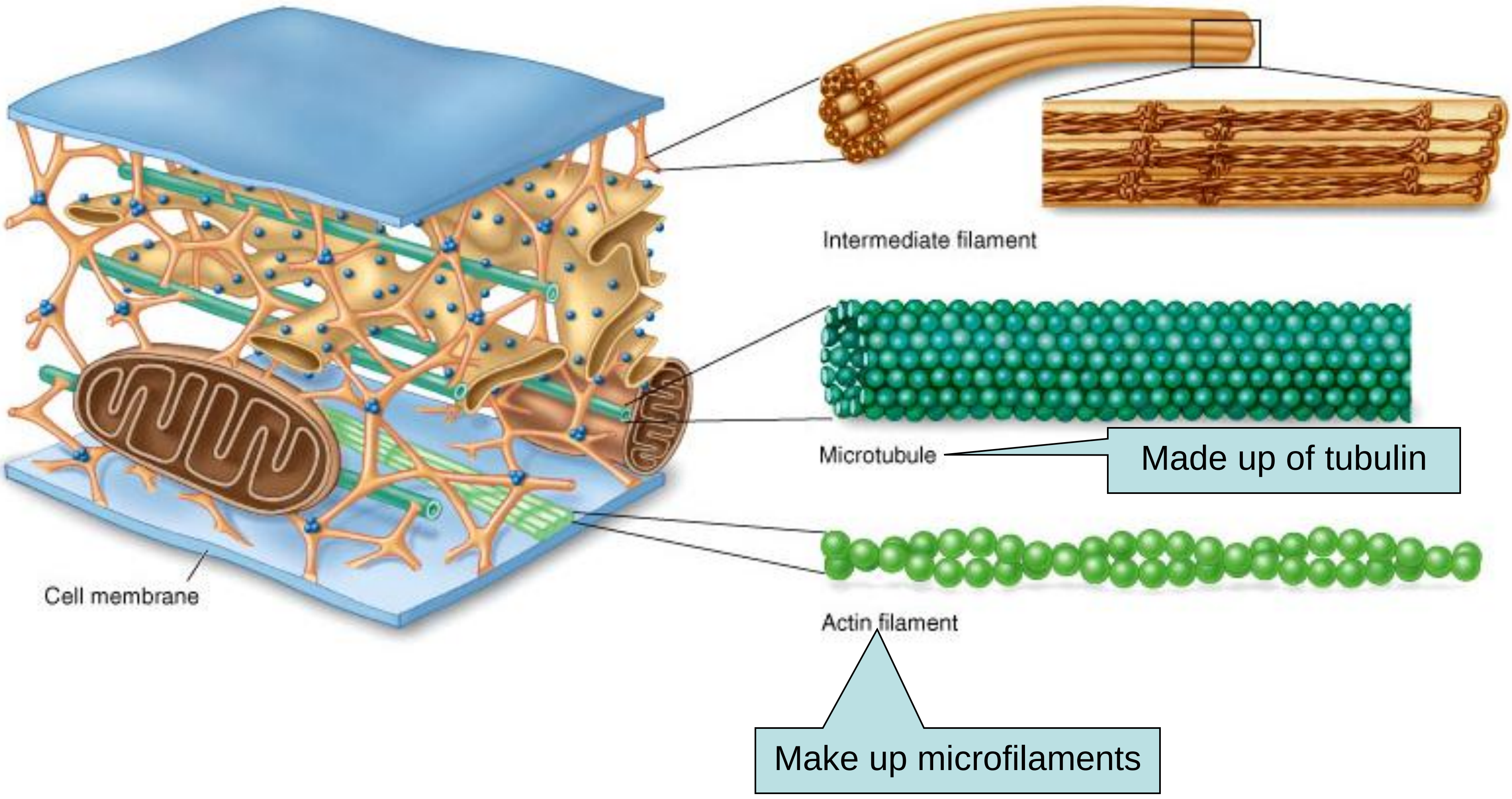


- This theory is supported by a wealth of evidence

4.8 The Cytoskeleton: Interior Framework of the Cell

- A dense network of protein fibers that
  - 1. Supports the shape of the cell
  - 2. Anchors organelles
- Three different kinds of protein fibers
  - Microfilaments
  - Microtubules
  - Intermediate filaments

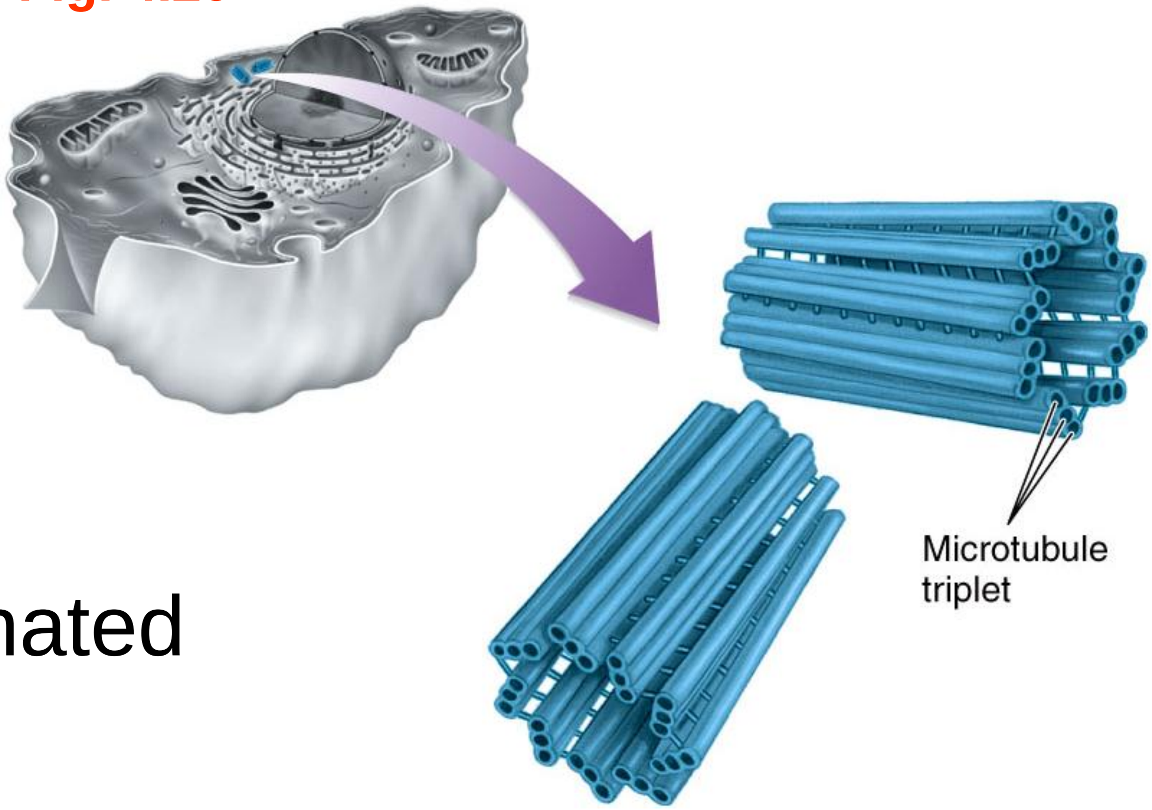
Fig. 4.19


Intermediate filament
Microtubule
Made up of tubulin
Actin filament
Make up microfilaments
Cell membrane

Centrioles

- Anchor and assemble microtubules
- Not found in higher plants and fungi
- May have originated as symbiotic bacteria

Fig. 4.20



Cell Movement

- Essentially, all cell motion is tied to the movement of microfilaments and microtubules

- Changes in the shape of microfilaments
  - Enable some cells to change shape quickly
  - Allow some cells to crawl
  - Cause animal cells to divide

Cell Movement

- Flagella and cilia
  - Consist of a 9 + 2 arrangement of microtubules
  - Anchored in the cell by a basal body

- Flagella
  - Long and few in number

- Cilia
  - Short and numerous

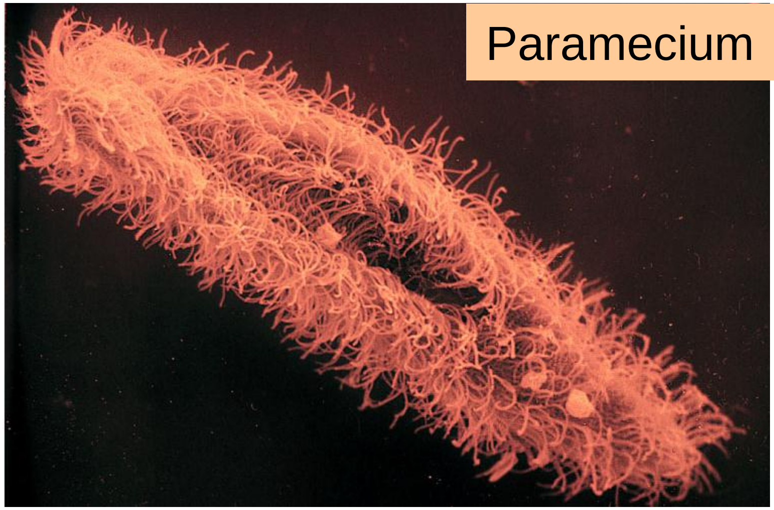
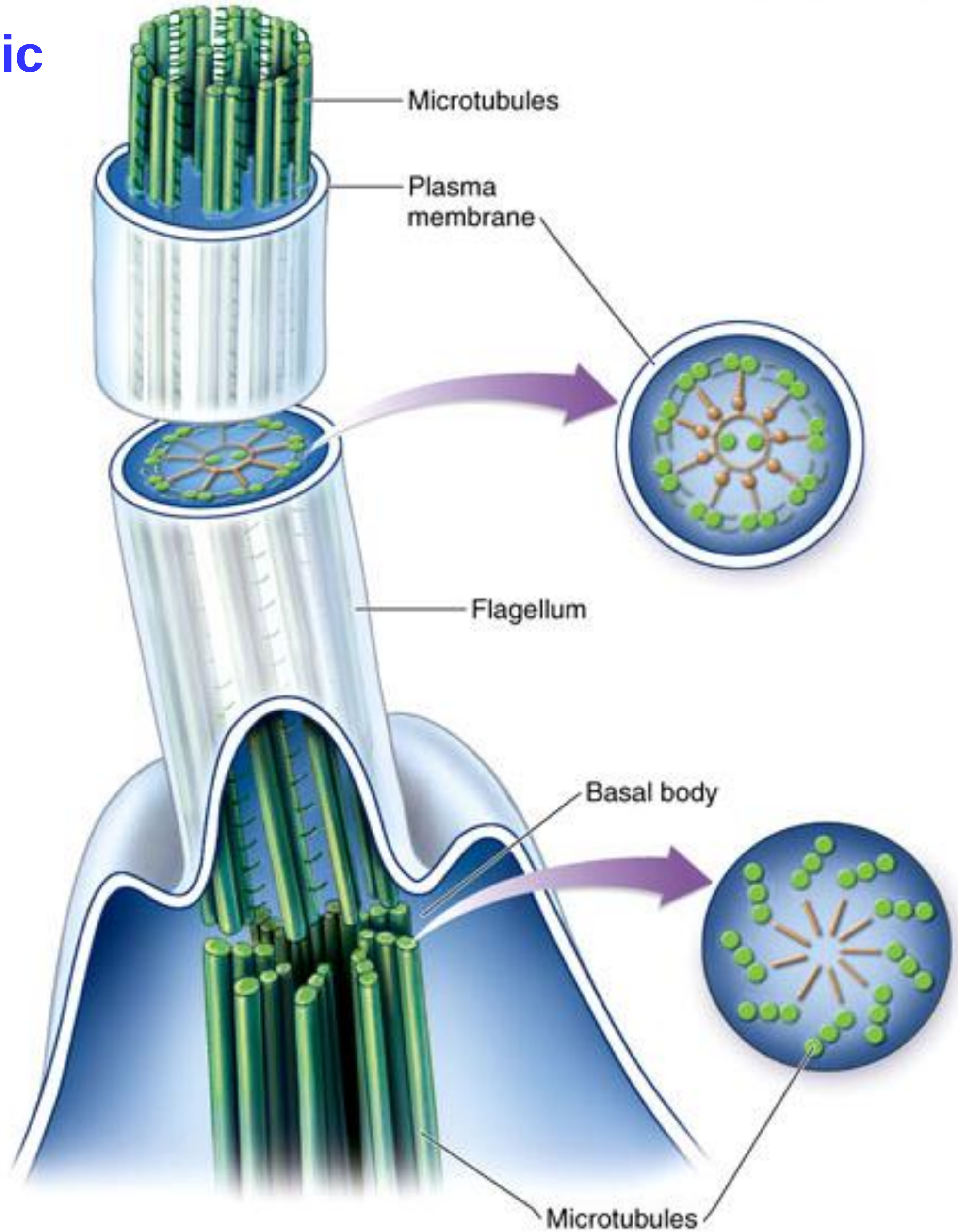


Fig. 4.21*b* Cilia

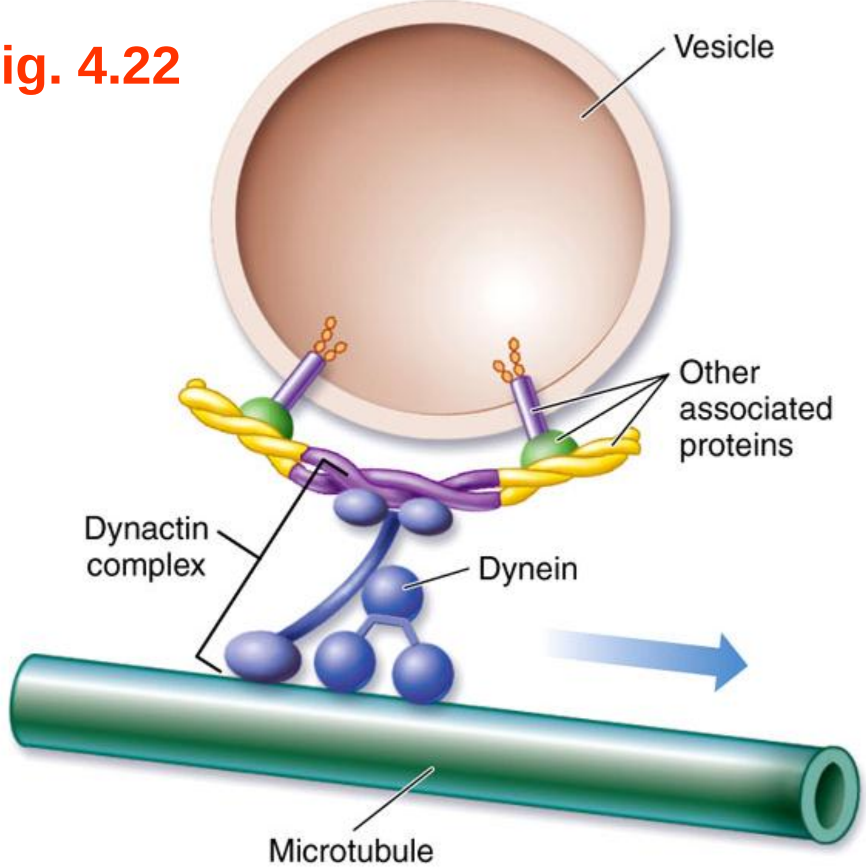
Fig. 4.21*a* Eukaryotic flagellum



Moving Material Within the Cell

- Eukaryotic cells have developed high speed locomotives that run along microtubular tracks
- Kinesin
  - Motor protein that moves vesicles to the cell's *periphery*
- Dynein
  - Motor protein that moves vesicles to the cell's *interior*

Fig. 4.22



Vacuoles

- In plants
  - Store dissolved substances
  - Can increase the cell's surface area
- In protists
  - Contractile vacuoles are used to pump excess water

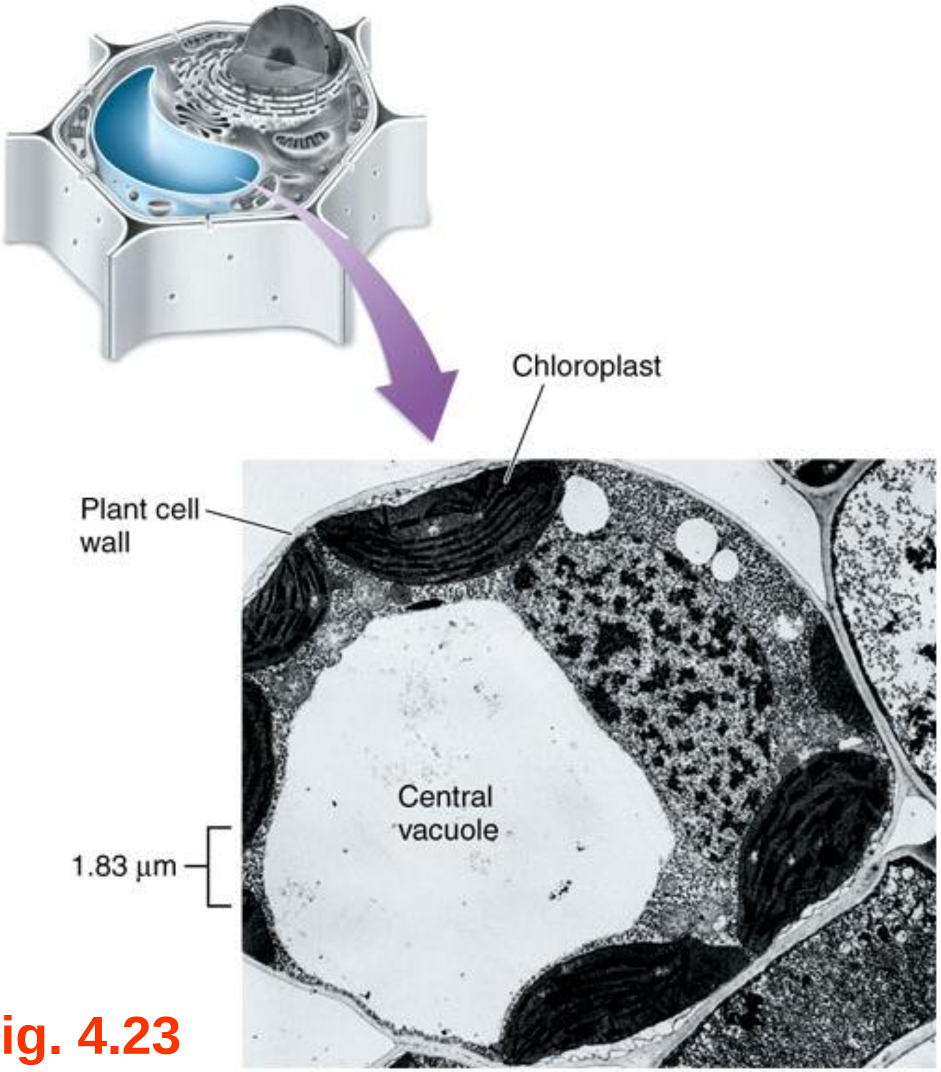
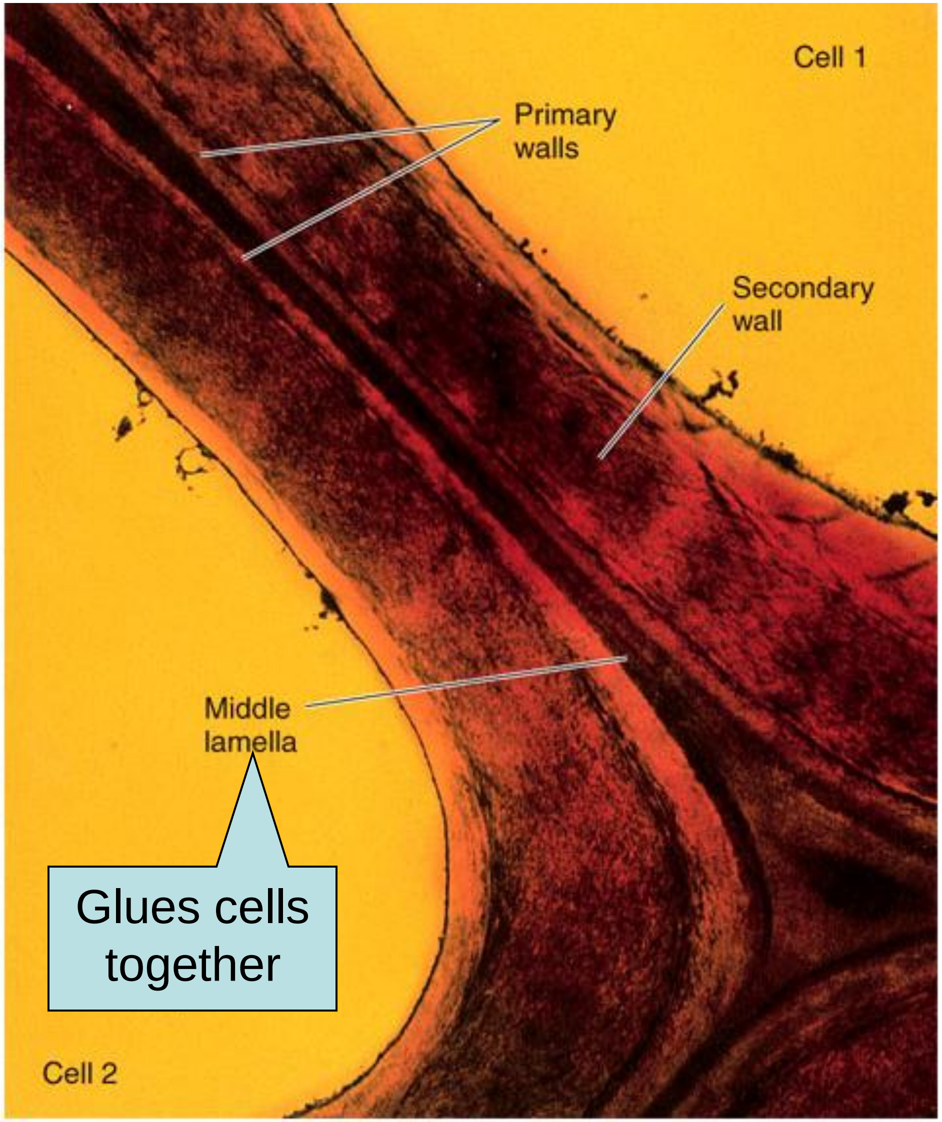


Fig. 4.23

4.9 Outside the Plasma Membrane

- Cell Walls
  - Offer protection and support
  - Fungal cell walls are made up of chitin
  - Plant cell walls are made up of cellulose

Fig. 4.24



4.9 Outside the Plasma Membrane

- Extracellular Matrix
  - A mixture of glycoproteins secreted by animal cells
  - Helps coordinate the behavior of all cells in a tissue

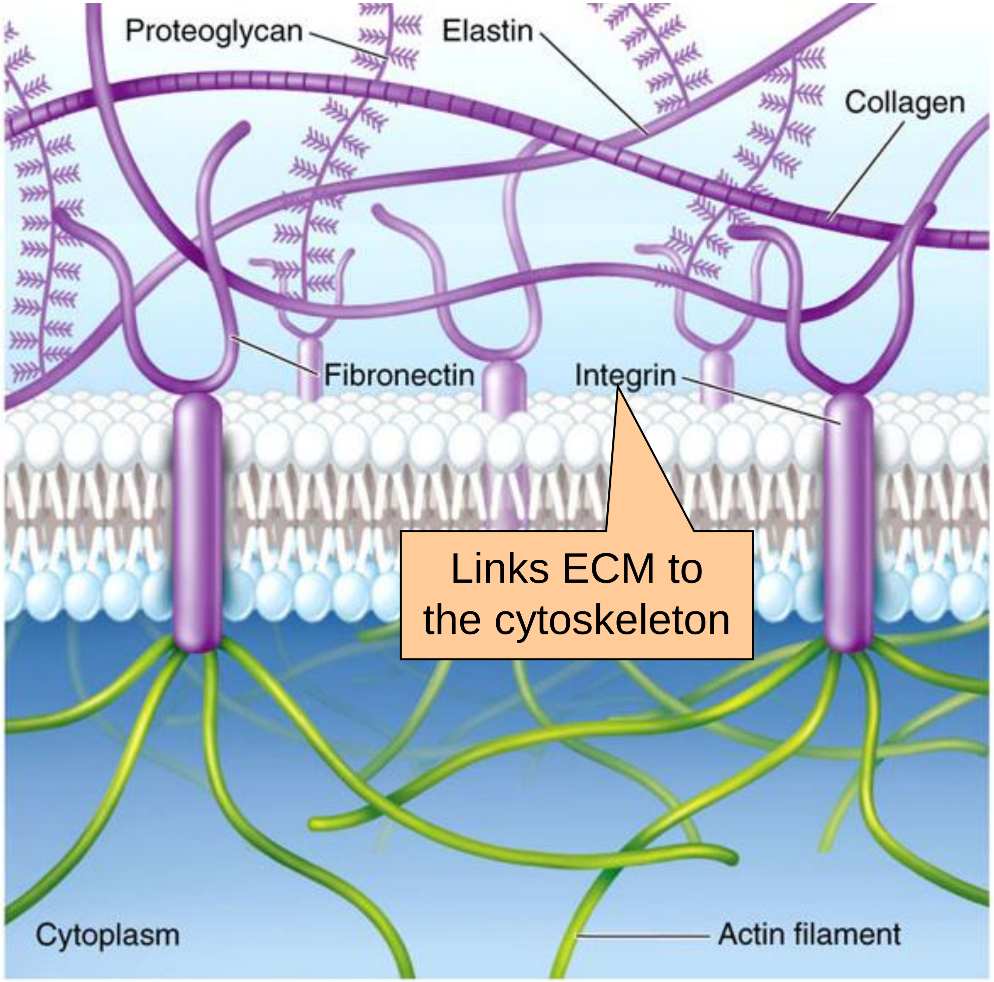


Fig. 4.25

4.10 Diffusion and Osmosis

- Diffusion is the movement of molecules down their concentration gradient

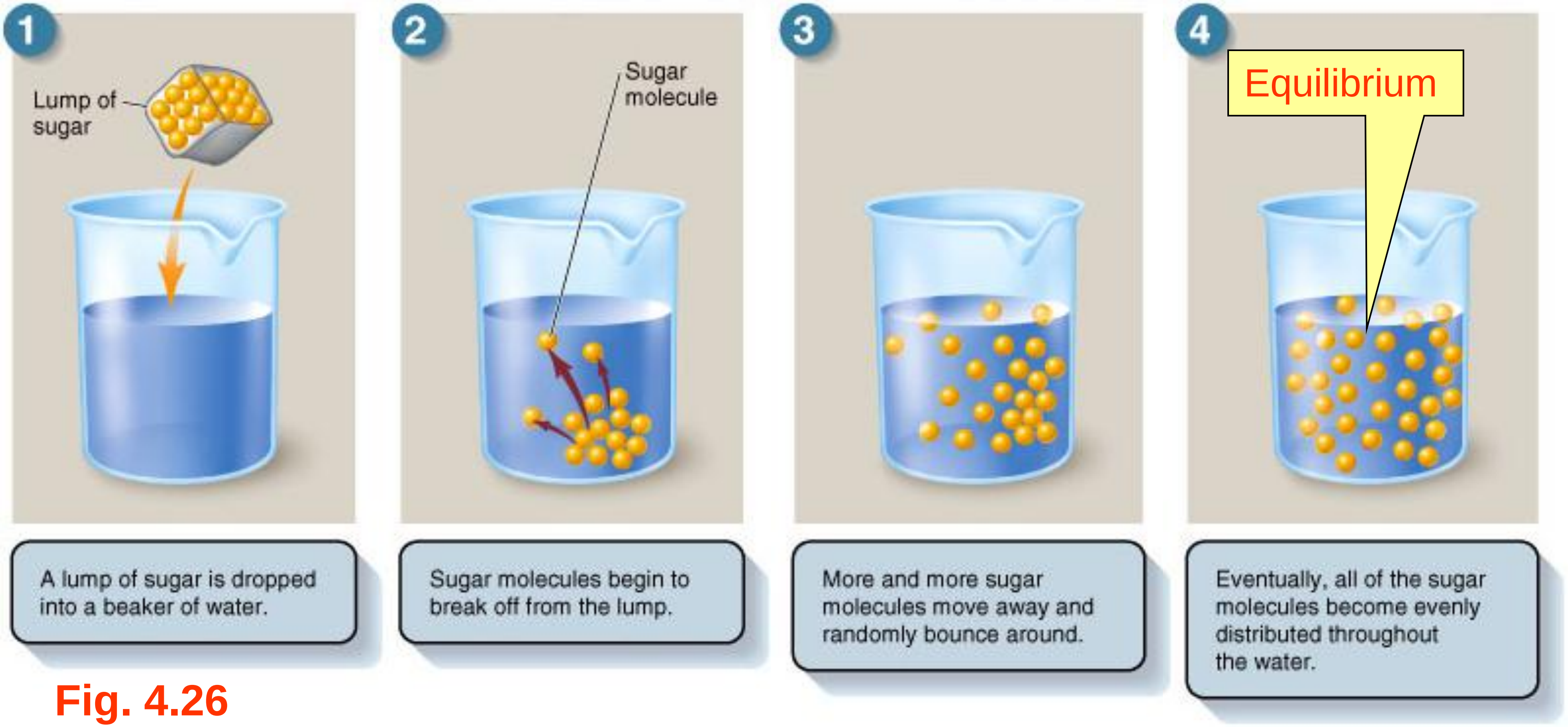
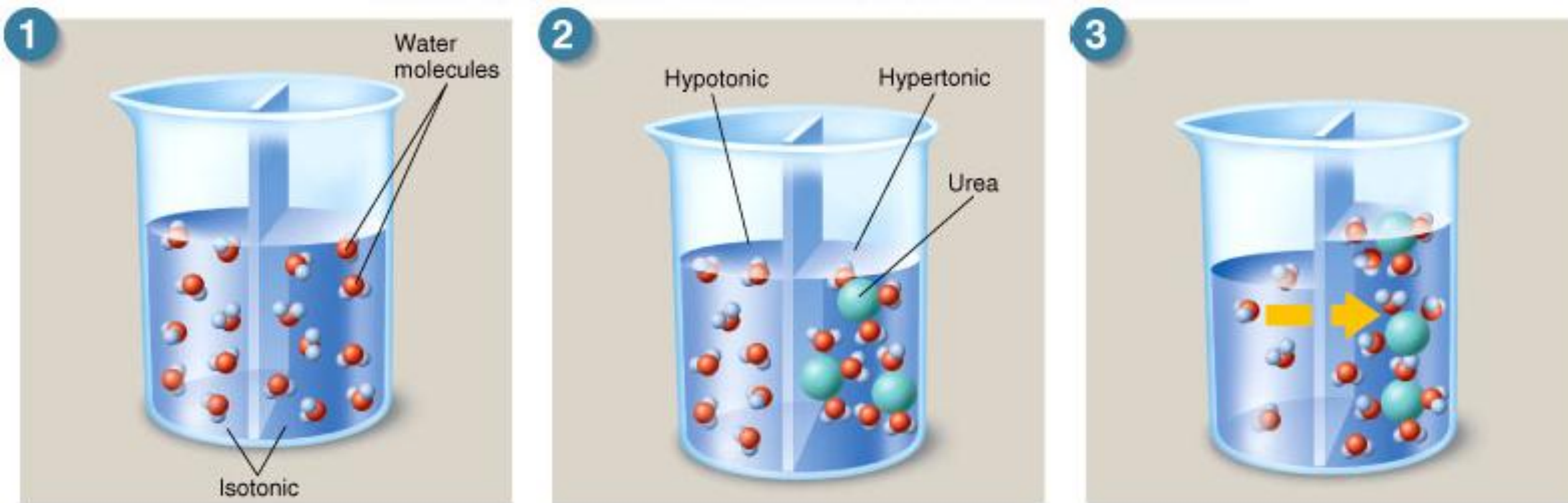


Fig. 4.26

Osmosis

- Diffusion of water through a semi-permeable membrane
- Solutes are substances dissolved in a solution
  - Hypertonic solution contains higher concentration of solutes than the cell
  - Hypotonic solution contains lower concentration of solutes than the cell
  - Isotonic solution contains equal concentration of solutes as the cell

Osmosis



Diffusion causes water molecules to distribute themselves equally on both sides of a semipermeable membrane.

Addition of solute molecules that cannot cross the membrane reduces the number of free water molecules on that side, as they bind to the solute.

Diffusion then causes free water molecules to move from the side where their concentration is higher to the solute side, where their concentration is lower.

Fig. 4.27

Osmosis

- Movement of water into a cell creates osmotic pressure
  - This can cause a cell to swell and burst

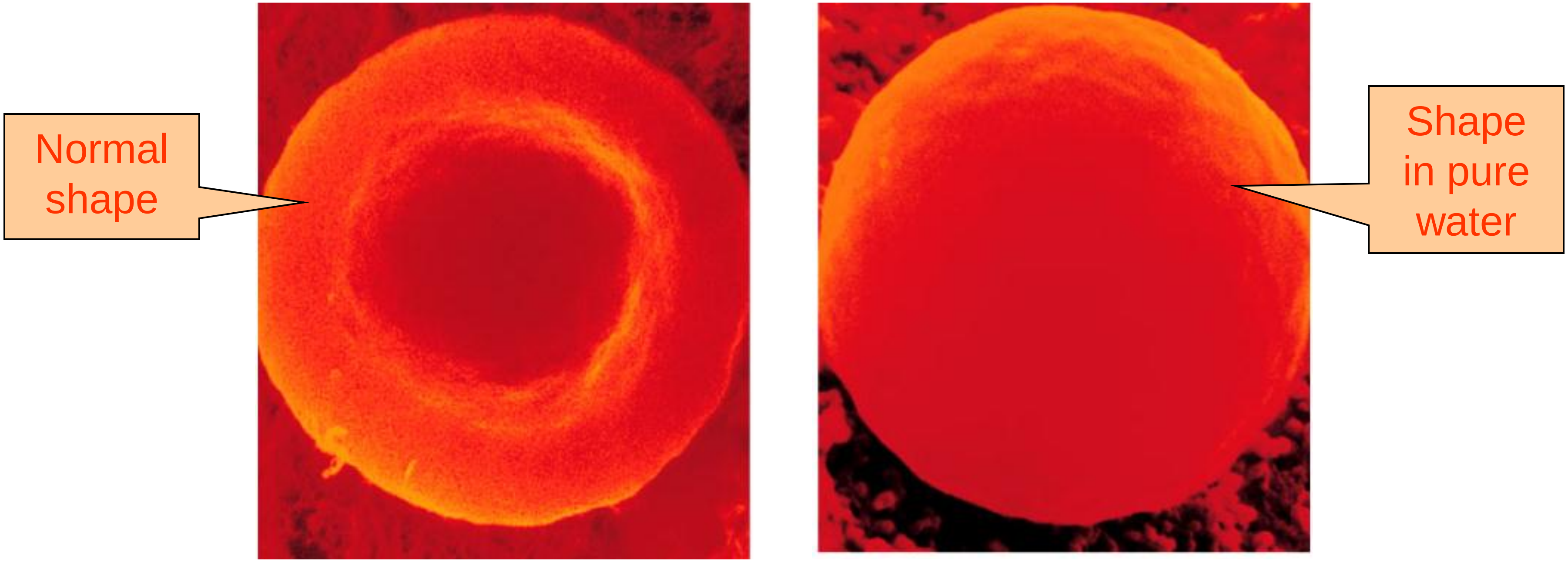


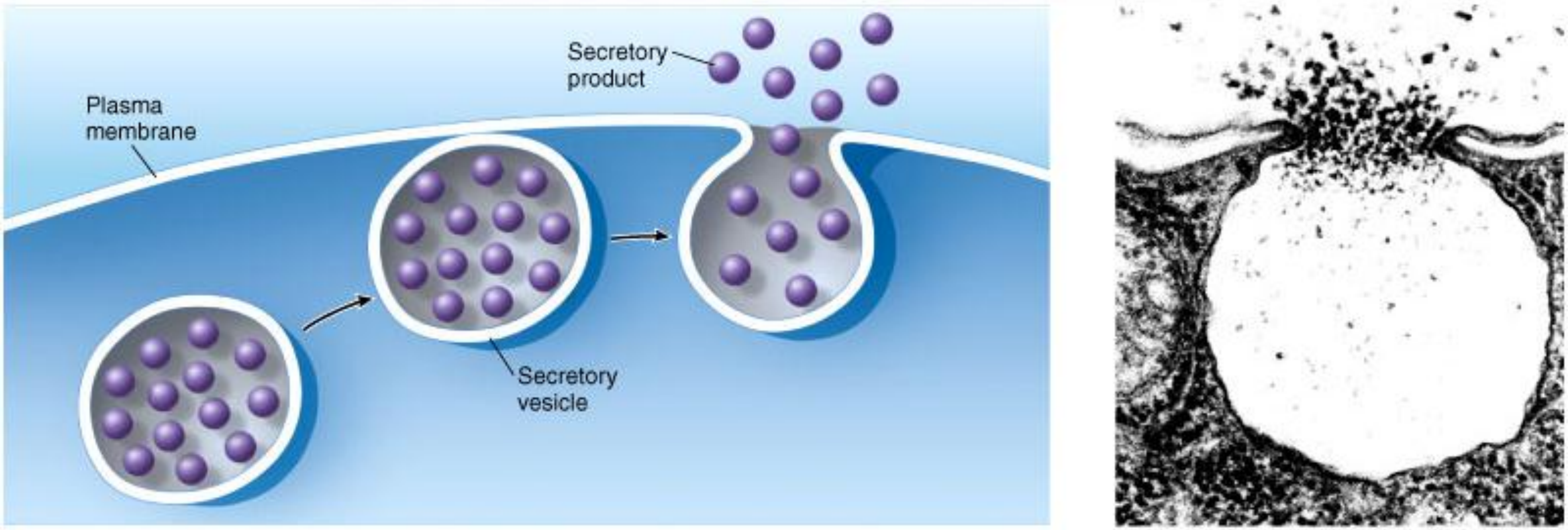
Fig. 4.28 Osmotic pressure in a red blood cell

4.11 Bulk Passage into and out of Cells

- Large amounts of material can be moved in and out of cells by membrane-bound vesicles
- Exocytosis
  - Discharge of material from vesicles at the cell surface
- Endocytosis
  - The plasma membrane envelops particles and brings them into the cell interior

Exocytosis

Fig. 4.30



(a) (b)

- Means by which hormones, neurotransmitters and digestive enzymes are secreted in animal cells

Endocytosis

- Has three major forms
- 1. Phagocytosis
  - Engulfment of particulate material
- 2. Pinocytosis
  - Engulfment of liquid material

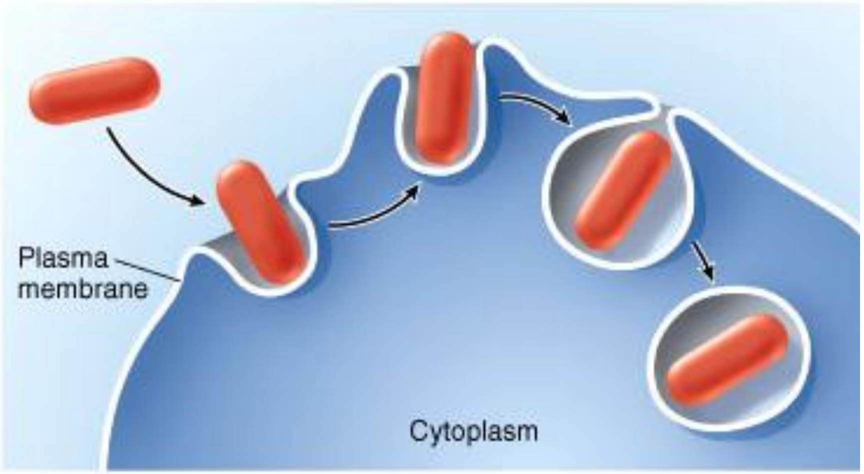


Fig. 4.29*a*

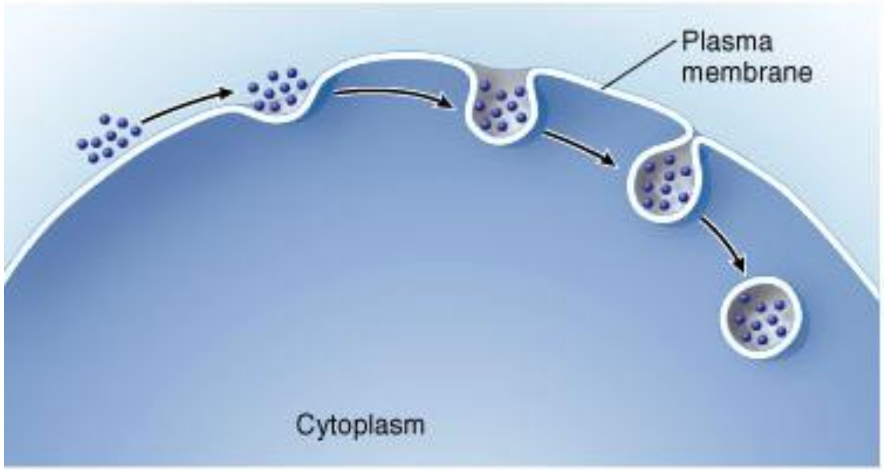


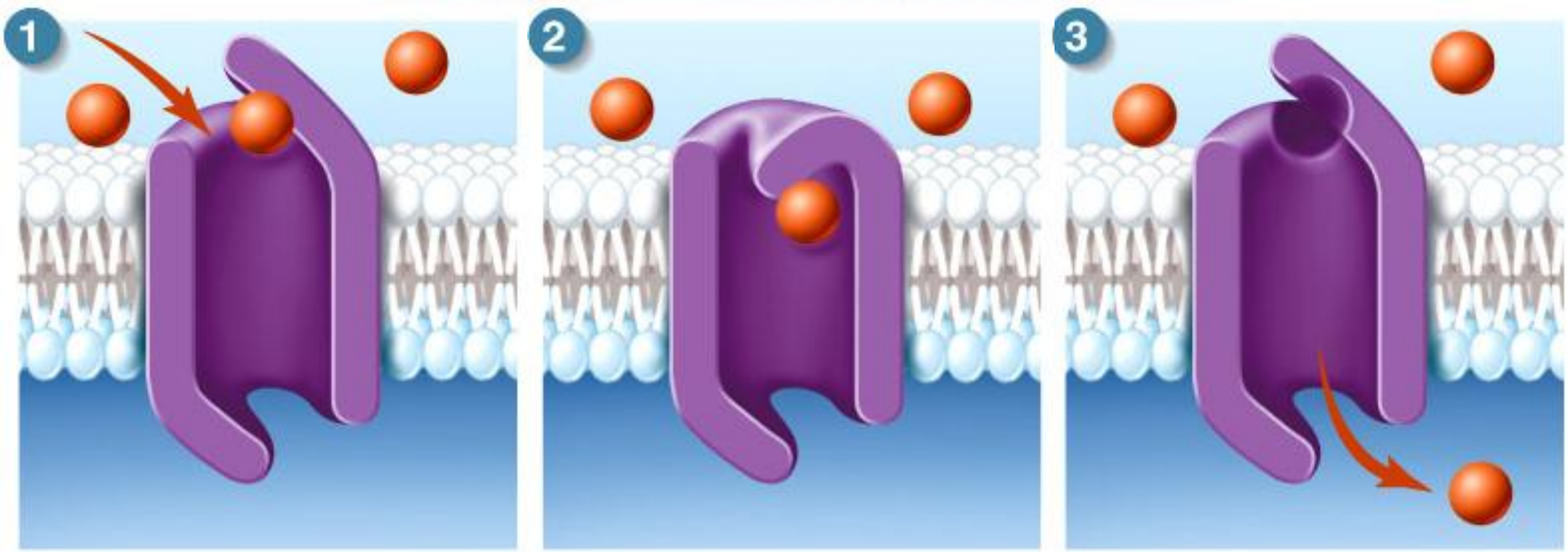
Fig. 4.29*b*

4.12 Selective Permeability

- Cell membranes have selective permeability
  - They contain protein channels that allow only certain molecules to pass
- Selective Diffusion
  - Allows molecules to pass through open channels in either direction
  - Ion channels
    - If the ion fits the pore, it goes through

Facilitated Diffusion

- Net movement of a molecule down its concentration gradient facilitated by specific carrier proteins



Particular molecules can bind to special protein carriers in the plasma membrane.

The protein carrier helps (facilitates) the diffusion process and does not require energy.

The molecule is released on the far side of the membrane. Protein carriers transport only certain molecules across the membrane but will take them in either direction down their concentration gradients.

Fig. 4.32

Facilitated Diffusion

- The rate can be saturated
  - It increases up to a certain level and then levels off

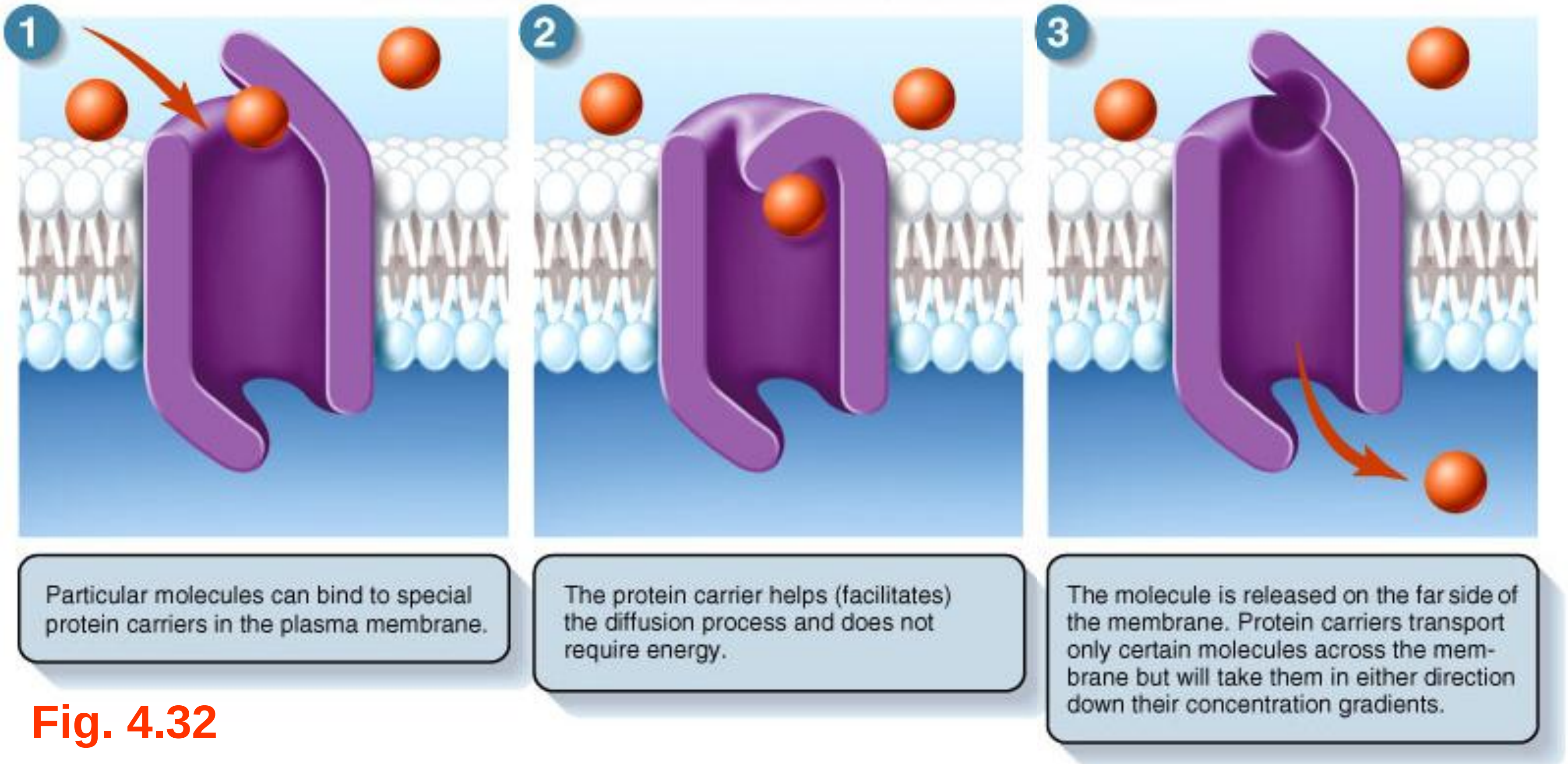


Fig. 4.32

Active Transport

- The movement of molecules across a membrane against a concentration gradient
  - This is possible by the expenditure of energy

- Two types of channels are mainly used
  - 1. Sodium-Potassium Pump
  - 2. Proton Pump

The Sodium-Potassium Pump

- Uses the energy of one ATP molecule to pump 3 Na^+ outward and 2 K^+ into the cell

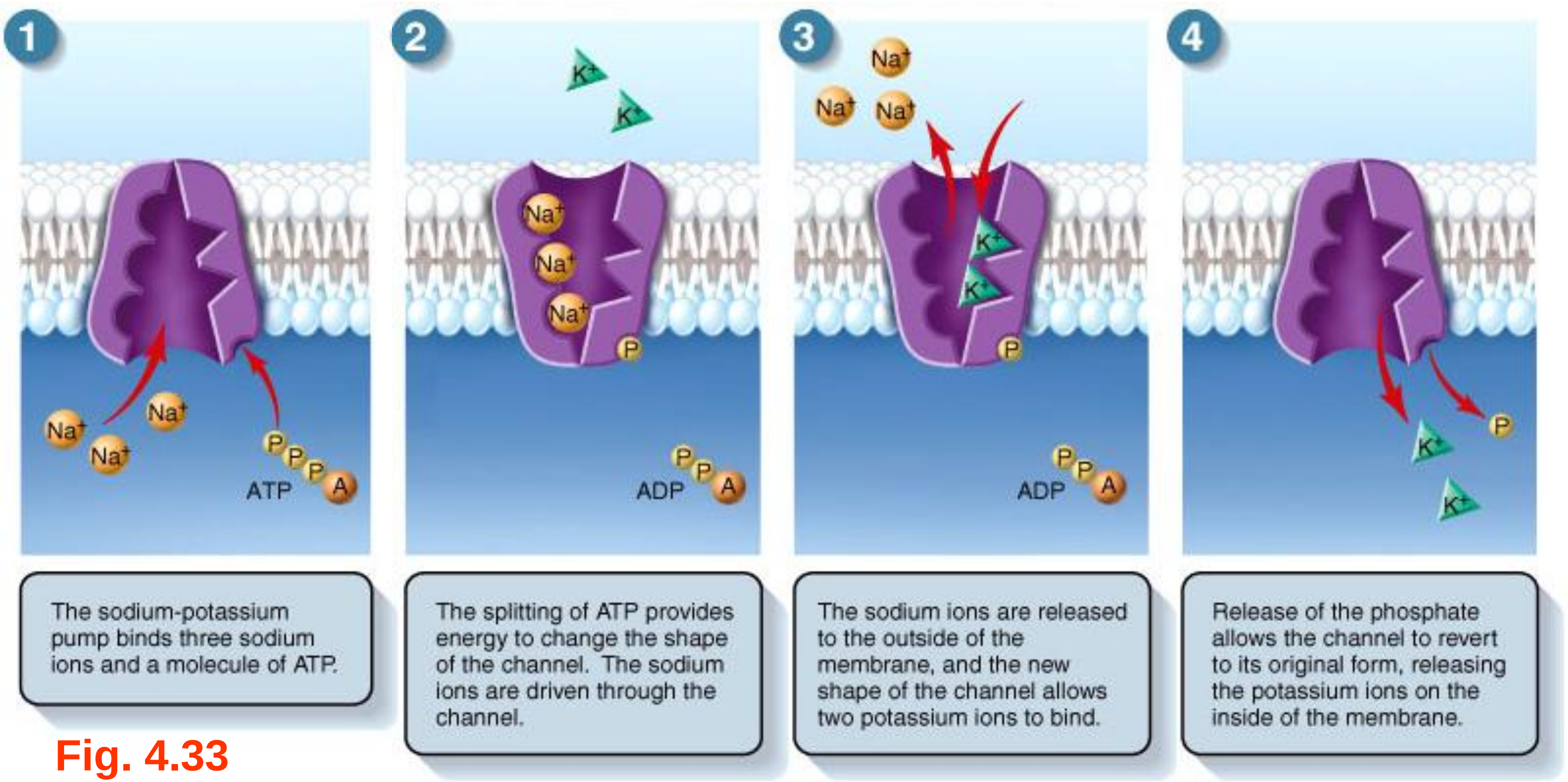
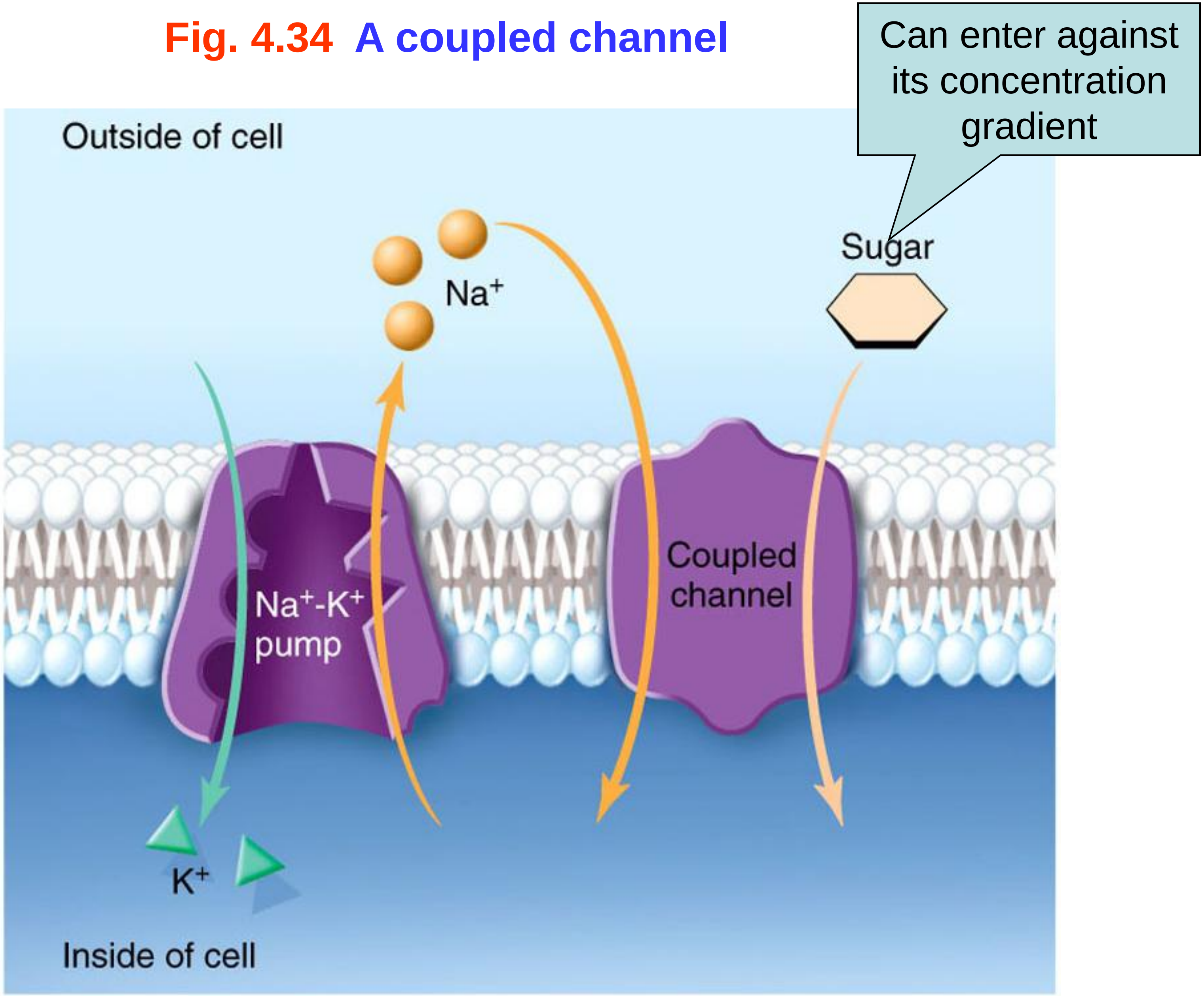


Fig. 4.33

- The Sodium-Potassium Pump
  - Leads to fewer Na^+ in the cell
  - This concentration gradient is exploited in many ways, including
    - 1. The conduction of signals along nerve cells
      - Chapter 28
    - 2. The transport of material into the cell against their concentration gradient
      - Coupled channels

Fig. 4.34 A coupled channel



- ## The Proton Pump
  - Expends metabolic energy to pump protons across membranes

This process is termed chemiosmosis

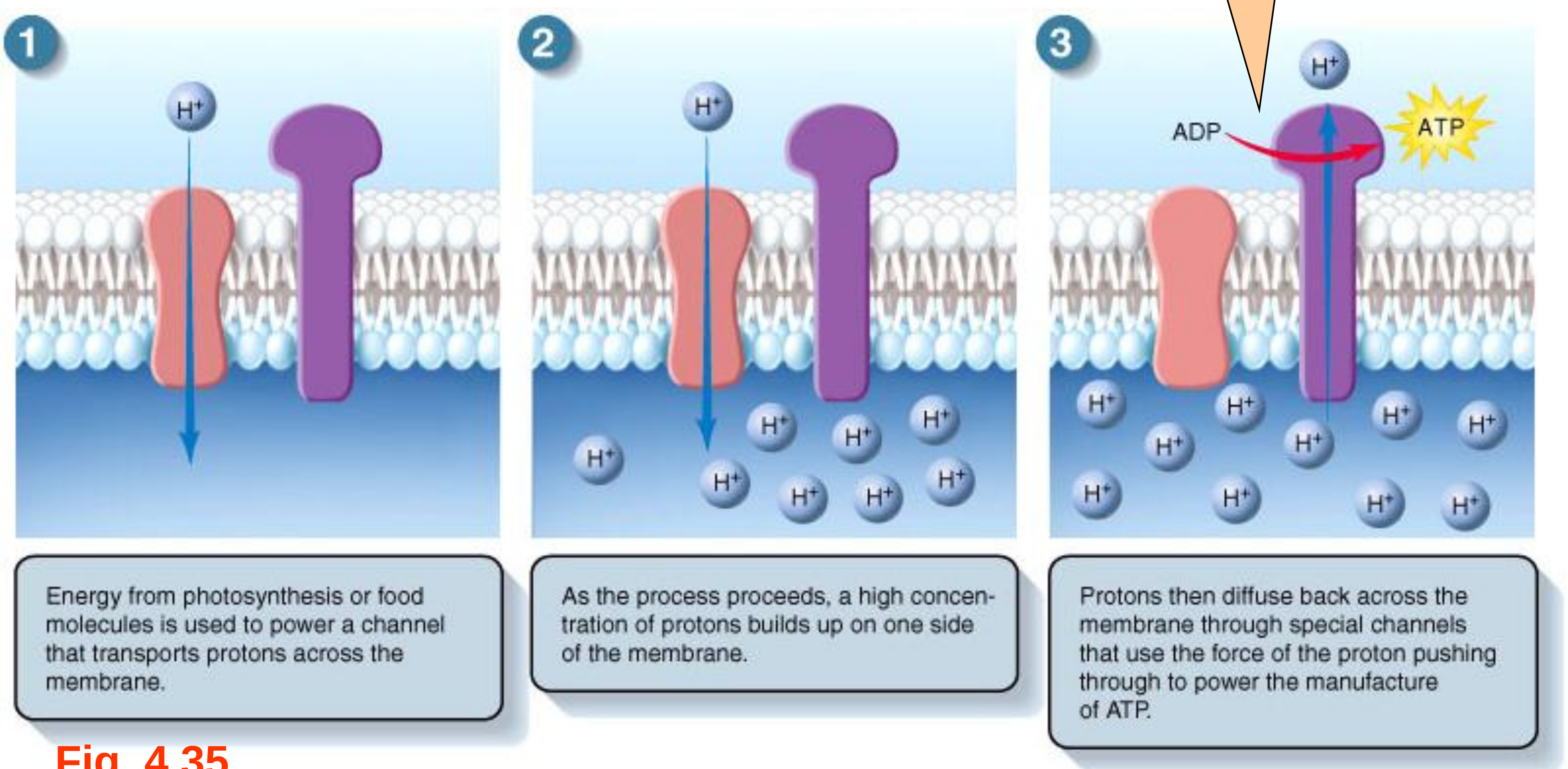


Fig. 4.35

How Cells Get Information

- Cells sense chemical information by means of cell surface receptor proteins
  - These bind specific molecules and transmit information to the cell
- Cells sense electrical information by means of voltage-sensitive channels
  - These allow ions into or out of the cell in response to electric signals