CELL PHYSIOLOGY

Diffusion, Osmosis, Active transport, Pinocytosis, Phagocytosis & Exocytosis

RATIONALE/JUSTIFICATION



Definition of cell physiology

- **Cell Physiology;** *is the study of the functions of the cell and its structure particularly movement in and out of the cell.*

Outline

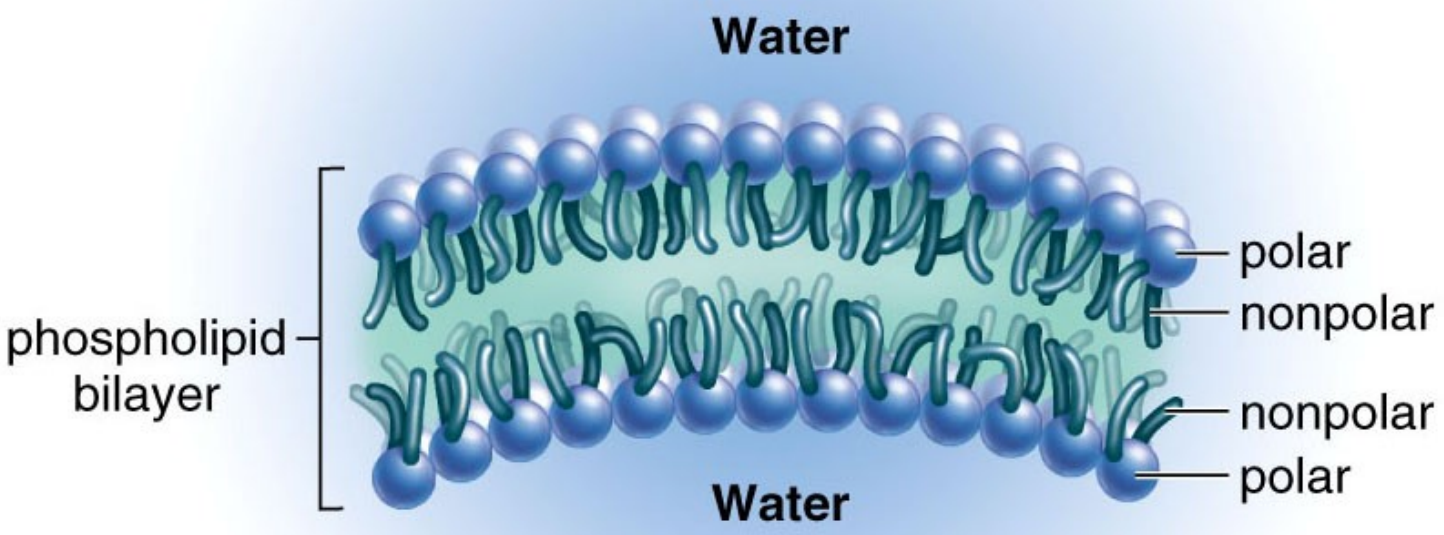
- Membrane Models
  - Fluid-Mosaic
- Plasma Membrane Structure and Function
  - Phospholipids
  - Proteins
- Plasma Membrane Permeability
  - Diffusion
  - Osmosis
  - Transport Via Carrier Proteins
- Cell Surface Modifications

Structure and Function: The Phospholipid Bilayer

- The plasma membrane is common to all cells
- Separates:
  - Internal living cytoplasmic from
  - External environment of cell
- Phospholipid bilayer:
  - External surface lined with hydrophilic polar heads
  - Cytoplasmic surface lined with hydrophilic polar heads
  - Nonpolar, hydrophobic, fatty-acid tails sandwiched in between

Unit Membrane

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

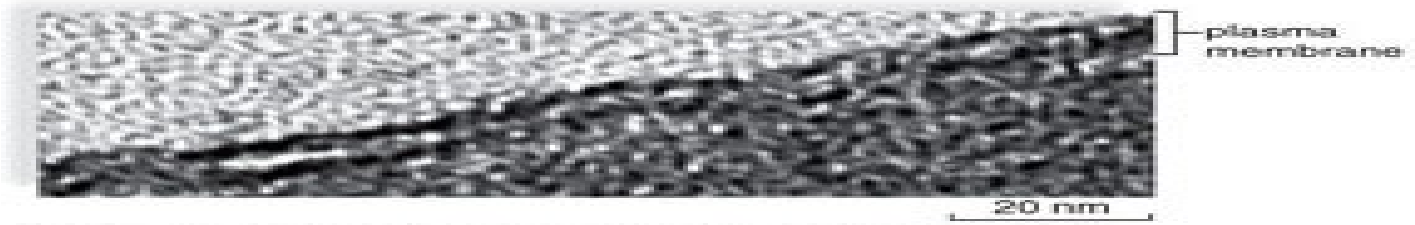


Membrane Models

- Fluid-Mosaic Model
- Three components:
  - Basic membrane referred to as phospholipid bilayer
  - Protein molecules
    - Float around like icebergs on a sea
    - Membrane proteins may be peripheral or integral
      - Peripheral proteins are found *on* the inner membrane surface
      - Integral proteins are partially or wholly embedded (transmembrane) in the membrane
    - Some have carbohydrate chains attached
  - Cholesterol

Membrane Models: Unit Membrane vs. Fluid Mosaic Model

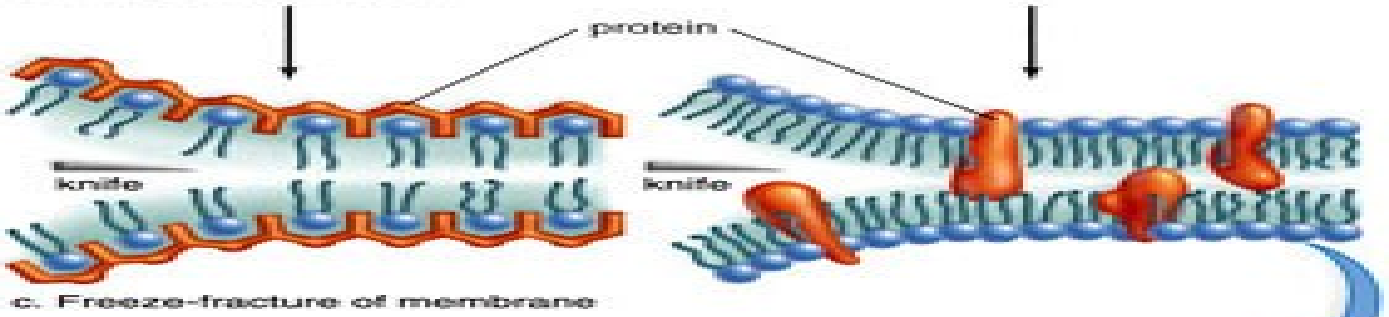
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



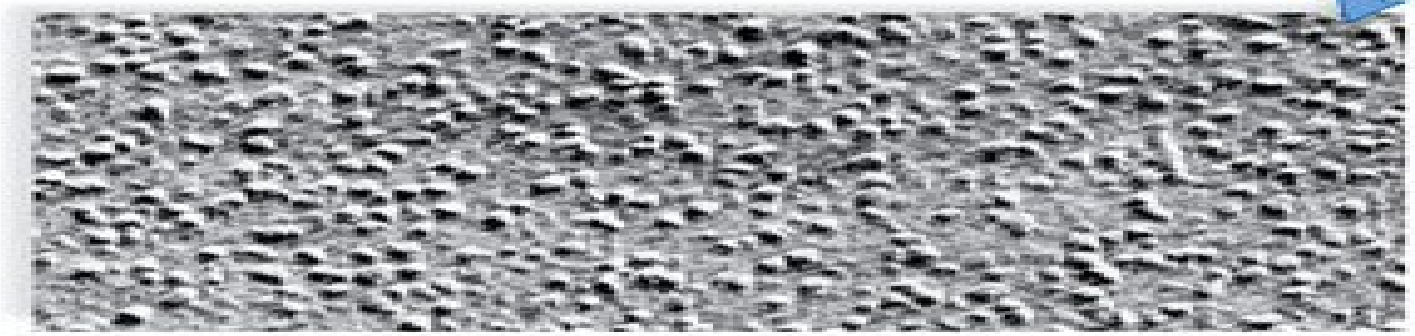
a. Electron micrograph of red blood cell plasma membrane



b. Two possible models

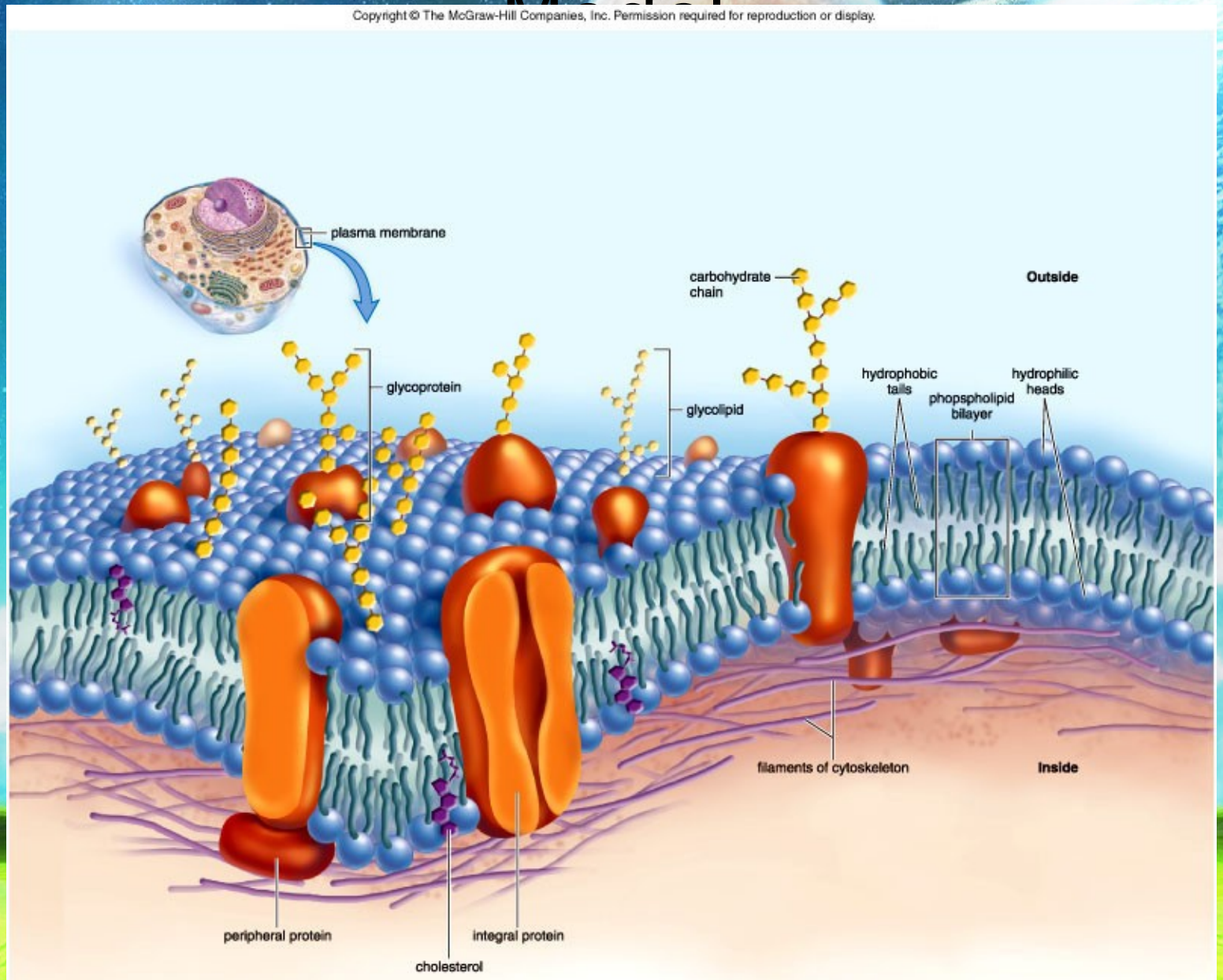


c. Freeze-fracture of membrane



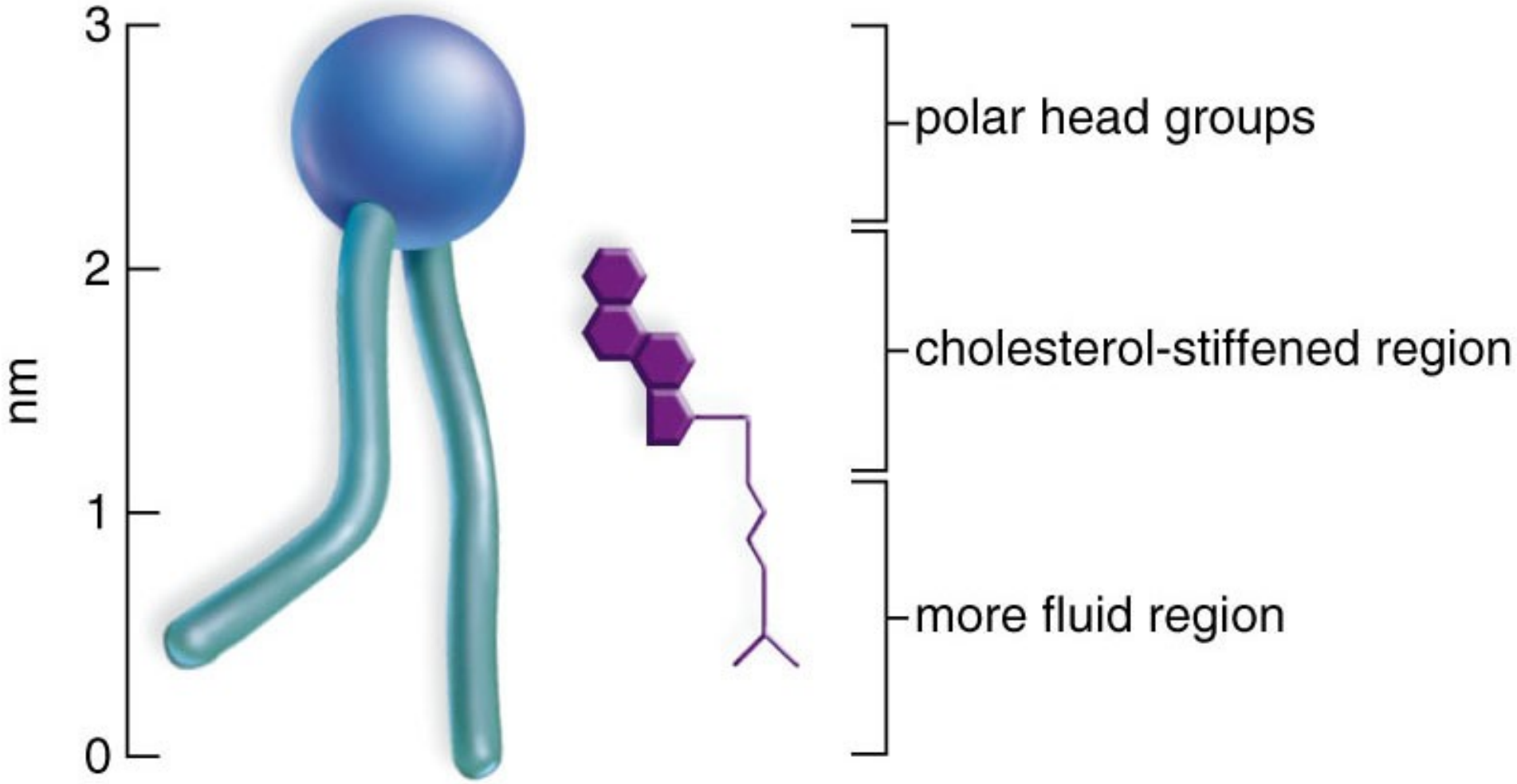
d. Electron micrograph of freeze-fractured membrane shows presence of particles

The Fluid Mosaic Model

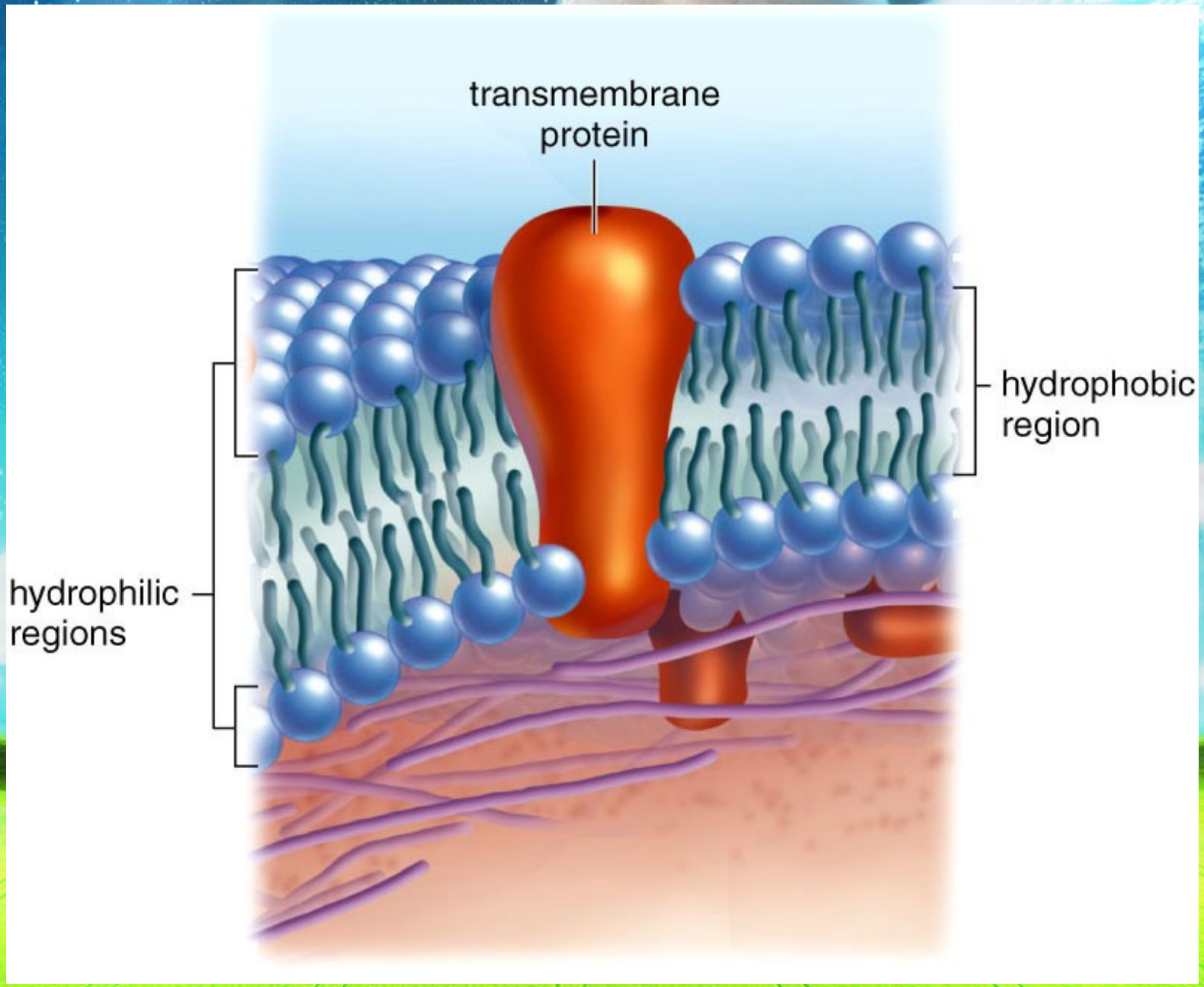


Phospholipid & Cholesterol Molecules

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Trans-membrane Proteins

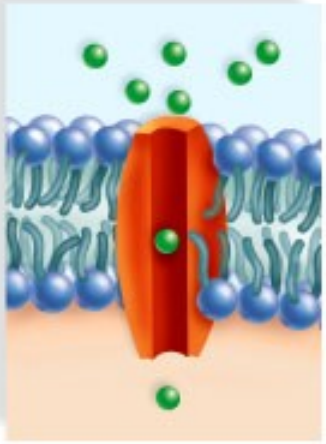


Functions of Membrane Proteins

- Channel Proteins:
  - Tubular
  - Allow passage of molecules through membrane
- Carrier Proteins:
  - Combine with substance to be transported
  - Assist passage of molecules through membrane
- Cell Recognition Proteins:
  - Provides unique chemical ID for cells
  - Help body recognize foreign substances
- Receptor Proteins:
  - Binds with messenger molecule
  - Causes cell to respond to message
- Enzymatic Proteins:
  - Carry out metabolic reactions directly

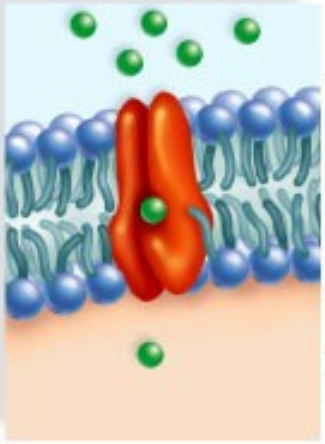
Membrane Protein Diversity

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



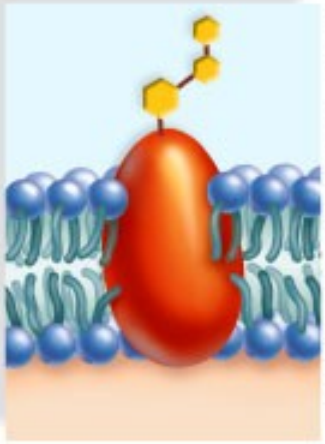
Channel Protein
Allows a particular molecule or ion to cross the plasma membrane freely. Cystic fibrosis, an inherited disorder, is caused by a faulty chloride (Cl^-) channel; a thick mucus collects in airways and in pancreatic and liver ducts.

a.



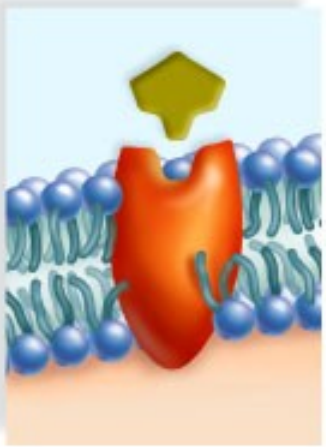
Carrier Protein
Selectively interacts with a specific molecule or ion so that it can cross the plasma membrane. The inability of some persons to use energy for sodium-potassium (Na^+–K^+) transport has been suggested as the cause of their obesity.

b.



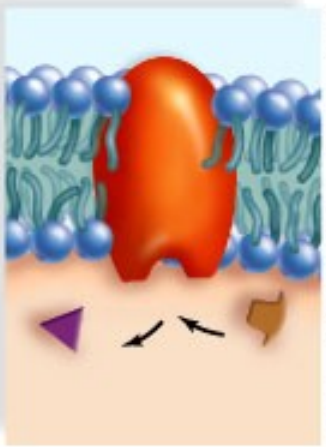
Cell Recognition Protein
The MHC (major histocompatibility complex) glycoproteins are different for each person, so organ transplants are difficult to achieve. Cells with foreign MHC glycoproteins are attacked by white blood cells responsible for immunity.

c.



Receptor Protein
Is shaped in such a way that a specific molecule can bind to it. Pygmies are short, not because they do not produce enough growth hormone, but because their plasma membrane growth hormone receptors are faulty and cannot interact with growth hormone.

d.



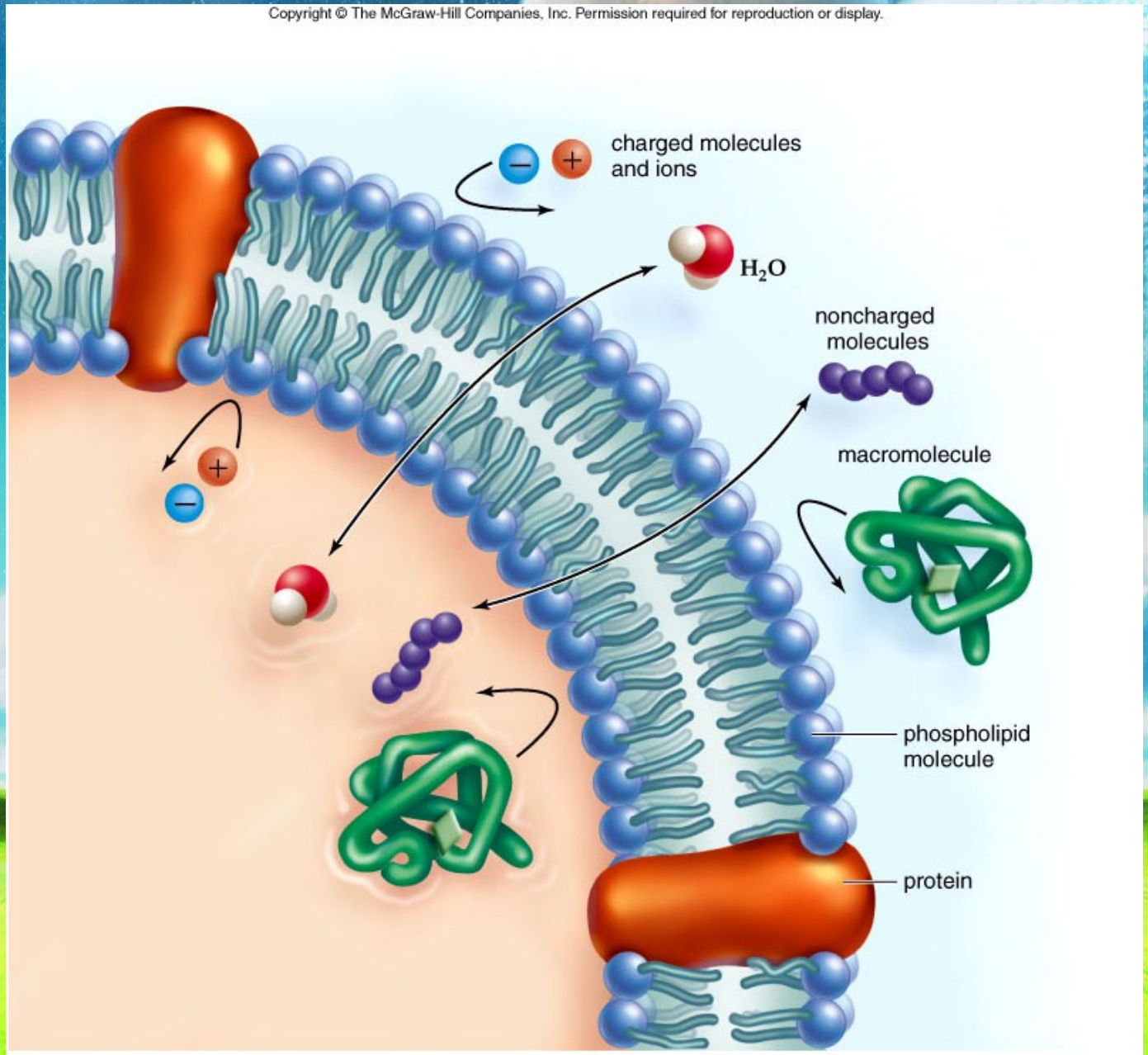
Enzymatic Protein
Catalyzes a specific reaction. The membrane protein, adenylate cyclase, is involved in **ATP** metabolism. Cholera bacteria release a toxin that interferes with the proper functioning of adenylate cyclase; sodium ions and water leave intestinal cells, and the individual may die from severe diarrhea.

e.

Types of Transport: Active vs. Passive

- Plasma membrane is differentially (selectively) permeable
  - Allows some material to pass
  - Inhibits passage of other materials
- Passive Transport:
  - No ATP requirement
  - Molecules follow concentration gradient
- Active Transport
  - Requires carrier protein
  - Requires energy in form of ATP

Types of Membrane Transport:Overview



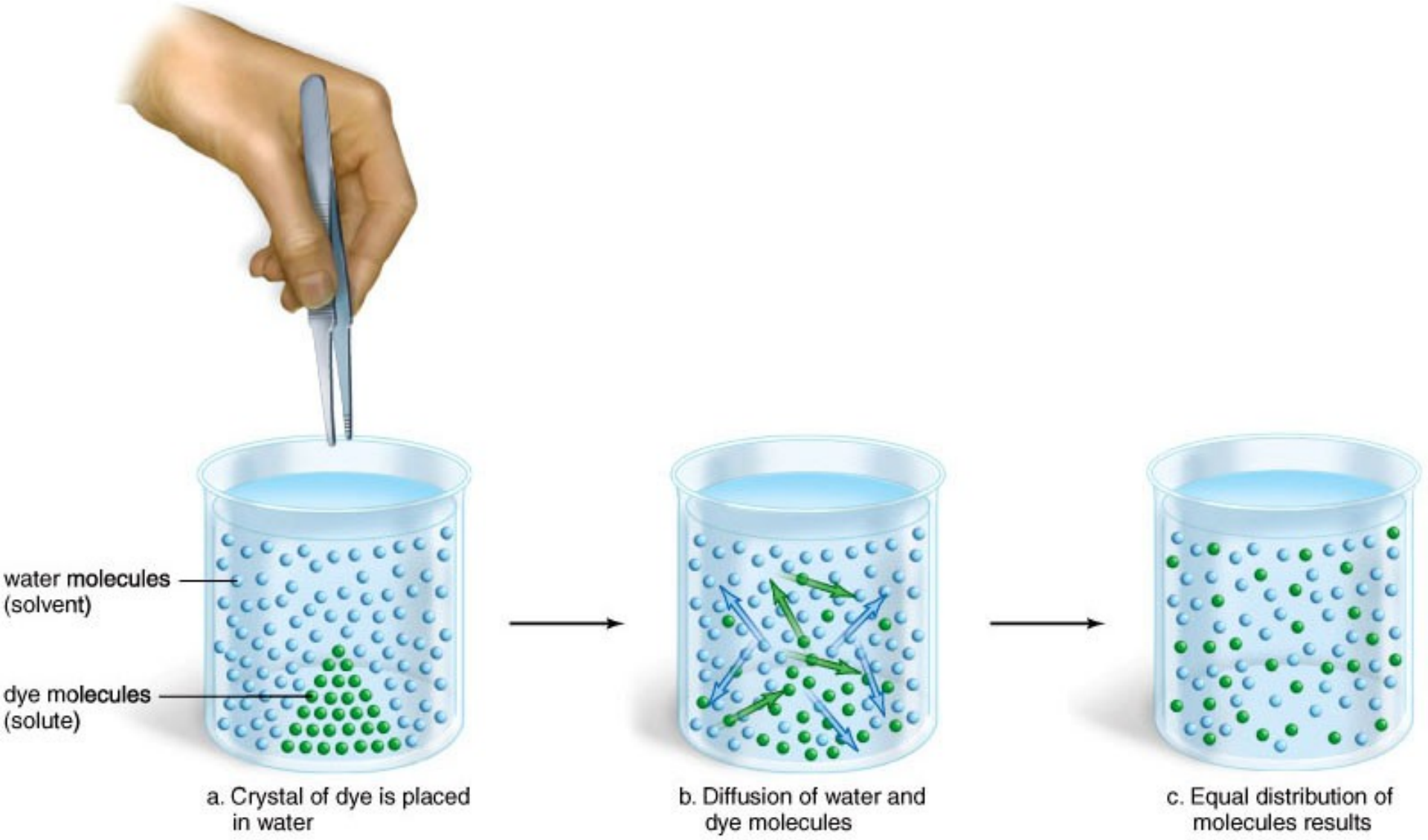
Types of Transport:Diffusion

- A solution consists of:
  - A solvent (liquid) , and
  - A solute (dissolved solid)
- Diffusion
  - Net movement of solute molecules down a concentration gradient
  - Molecules both ways along gradient
  - More move from high to low concentration than vice versa
  - Equilibrium:

Diffusion

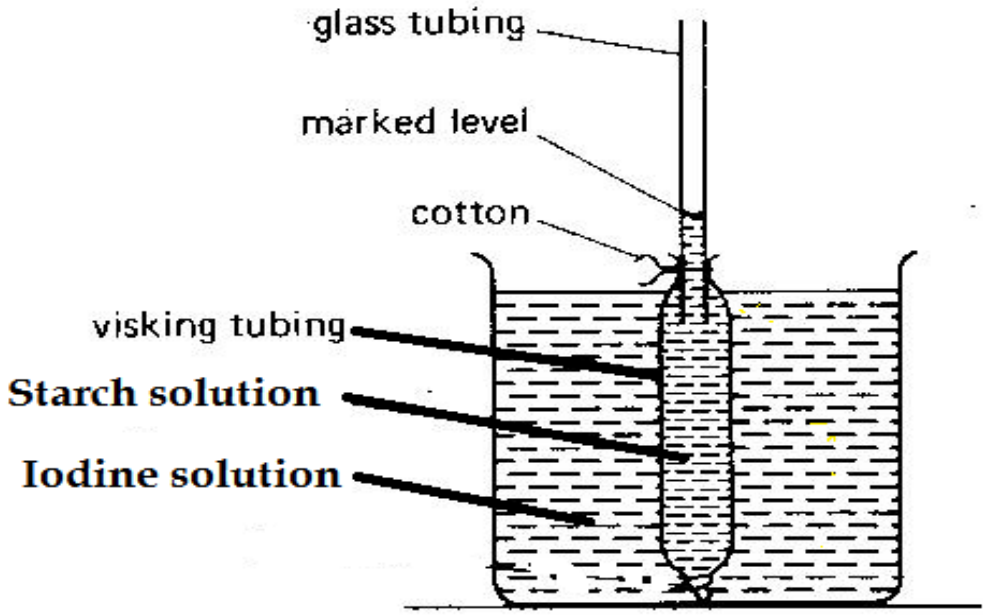
- **Diffusion** is the movement of any substance from a region where it is in high concentration to where it is in low concentration, through random movements.

Types of Membrane Transport: Diffusion



Diffusion through a visking tubing

Experiment to demonstrate diffusion using visking tubing



Observation; At the end of the experiment the content of the visking tubing will be blue black,

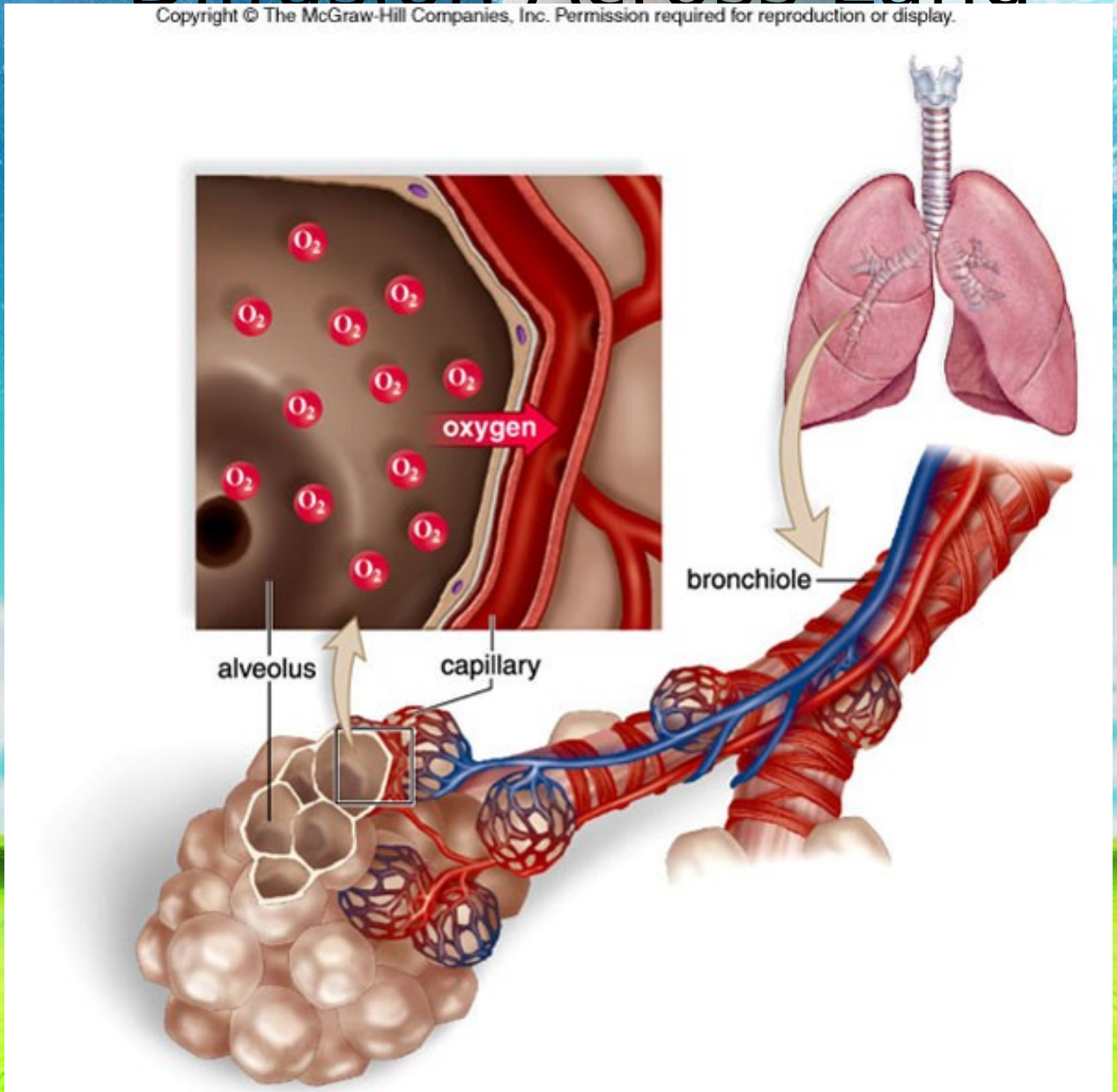
Explaination; Small iodine molecules moved in to react with larger starch molecules, because of selective permeability of the visking tubing,

Importance of diffusion to living organisms

- *Absorption of materials e.g. mineral salts in root hair cells, and some end products of digestion ileum.*
- *Gaseous exchange occurs by diffusion at respiratory surfaces like lungs, gills, skin, leaf mesophyll, lenticels, epidermis of leaf & stem, root epidermis*

Types of Membrane Transport: Diffusion Across Lung

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

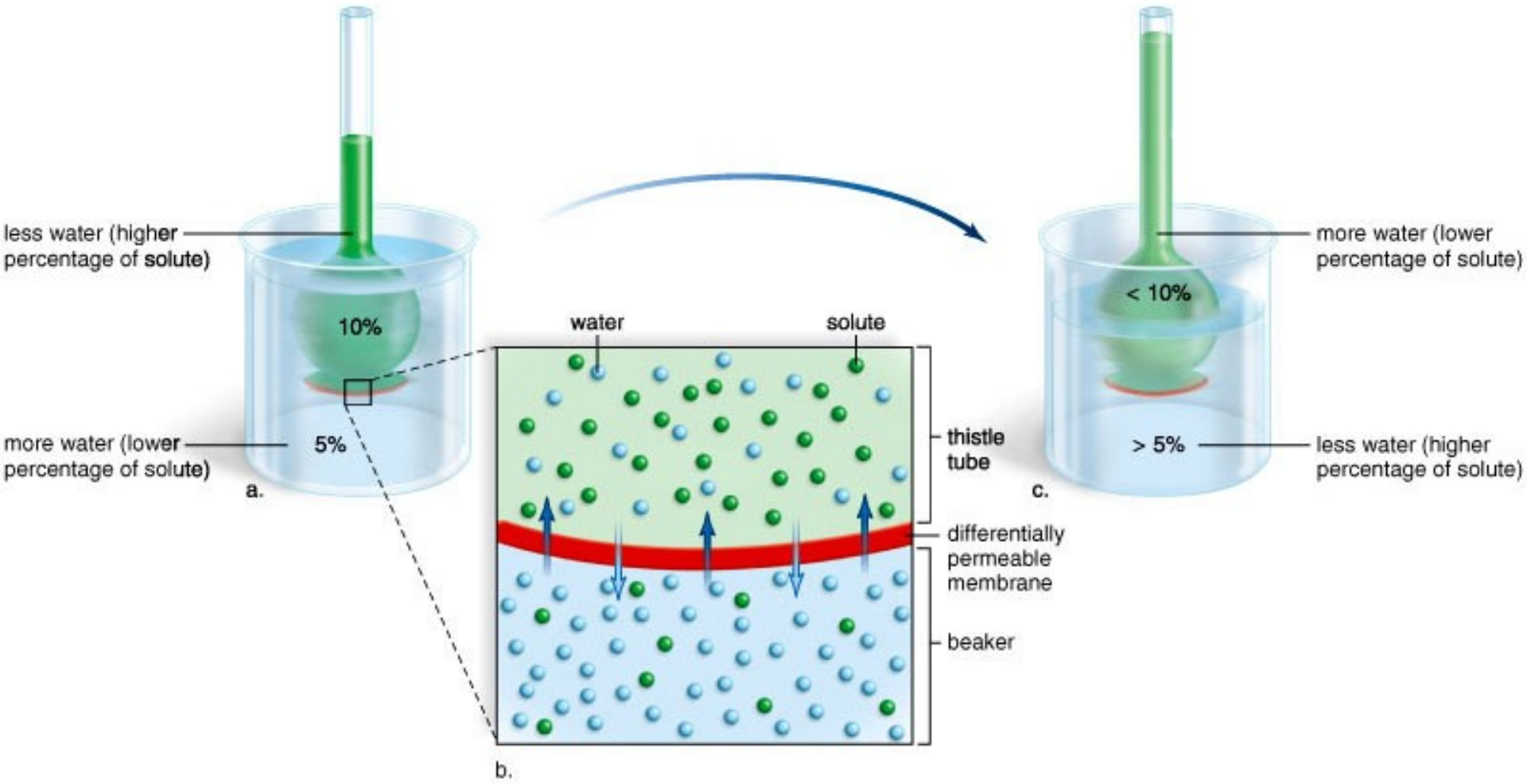


Types of Transport: Osmosis

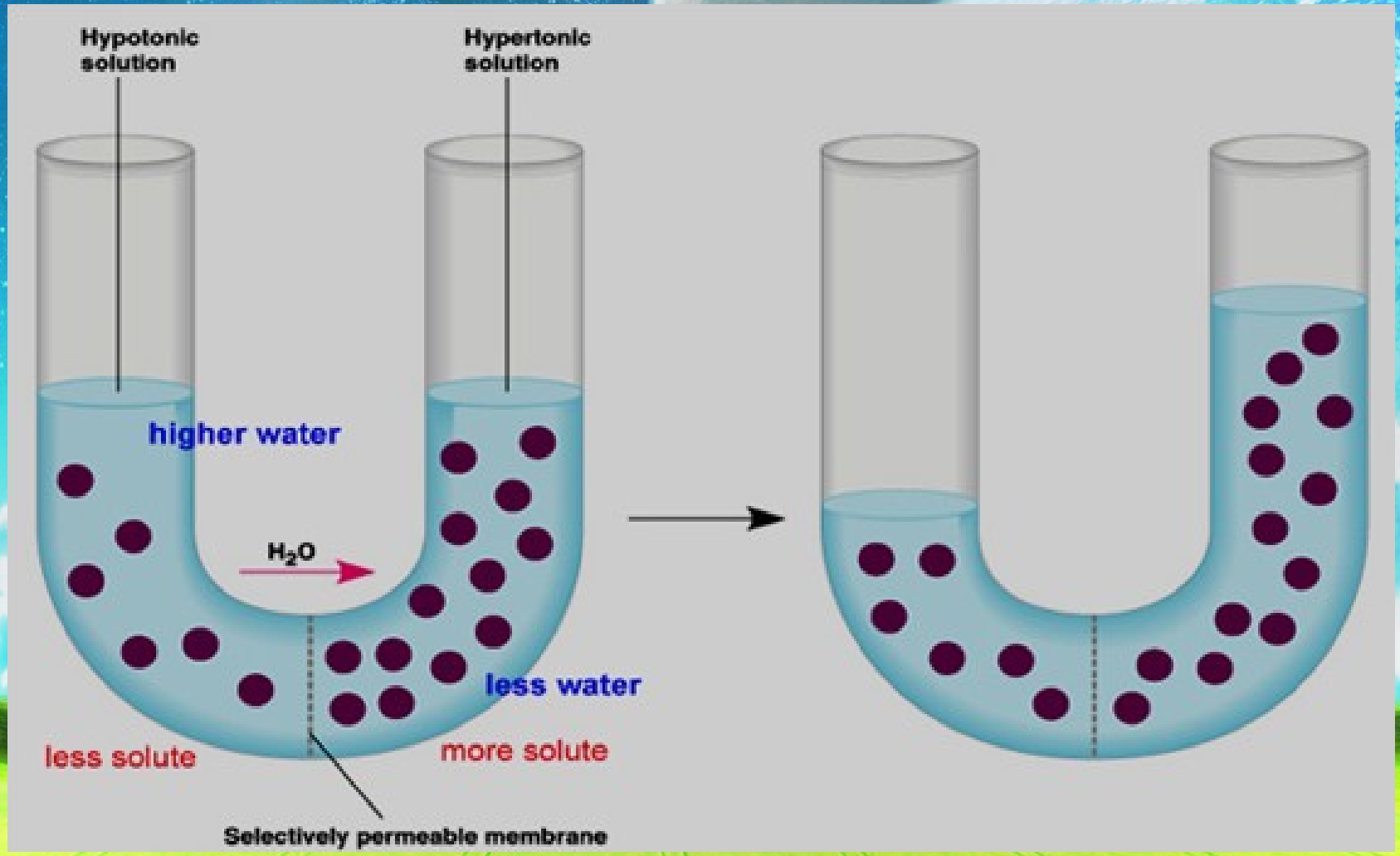
- Osmosis:
  - Special case of diffusion
  - Focuses on solvent (water) movement rather than solute
  - Diffusion of water across a differentially (selectively) permeable membrane
    - Solute concentration on one side high, but water concentration low
    - Solute concentration on other side low, but water concentration high
  - Water diffuses both ways across membrane but solute can't
  - Net movement of water is toward low water (high solute) concentration
- Osmotic pressure is the pressure that develops due to osmosis

Types of Membrane Transport: Osmosis

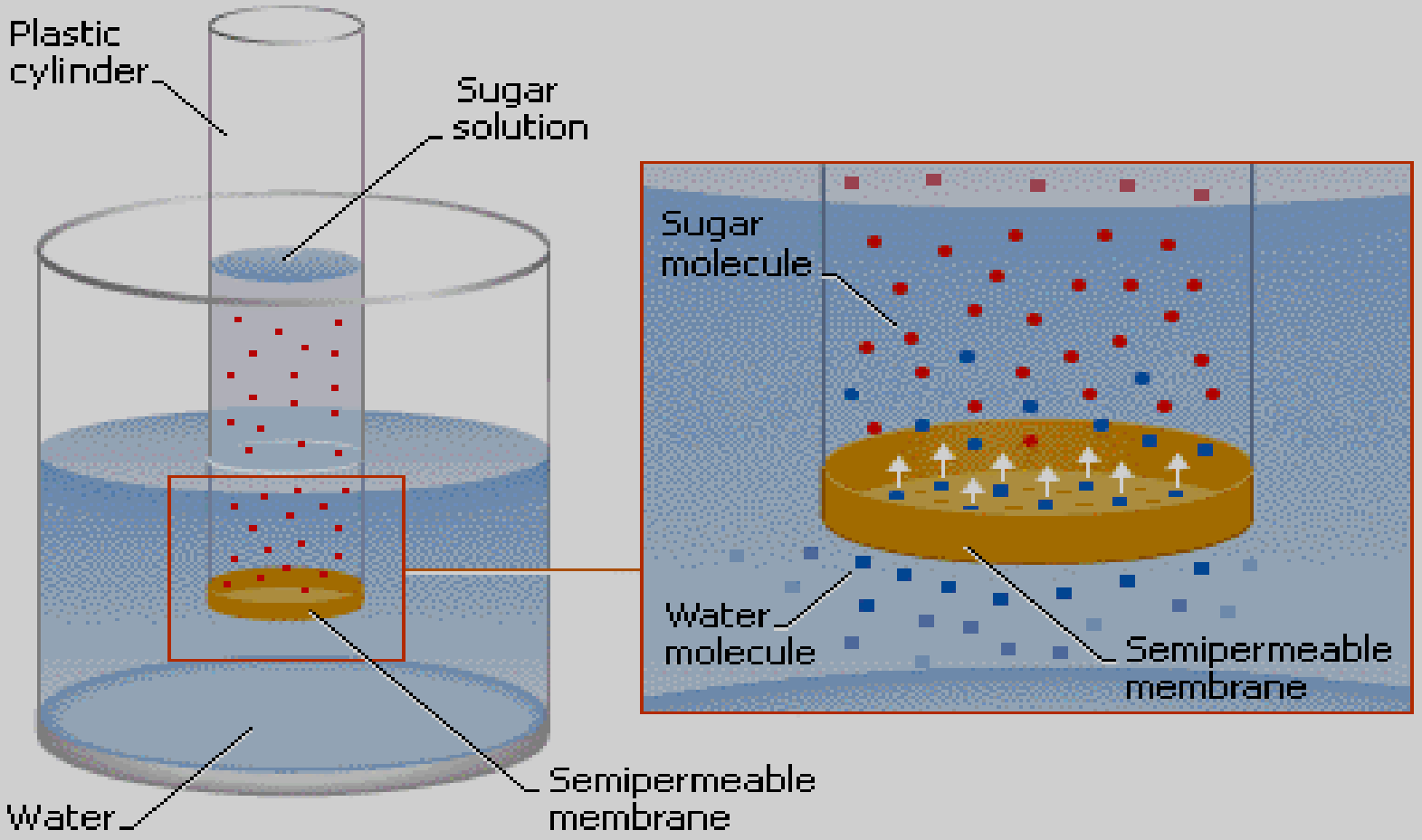
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Hypertonic & Hypotonic solution



Demonstrating Osmosis



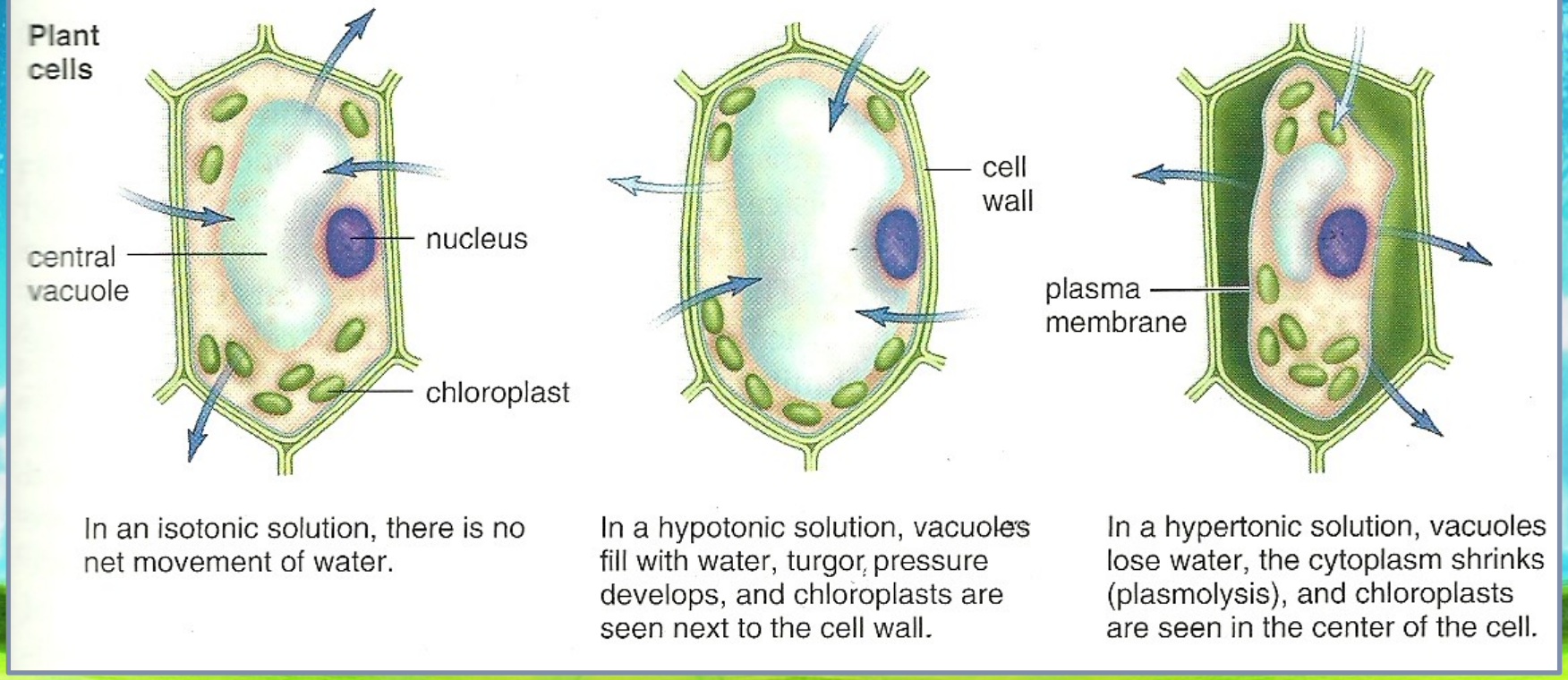
Explanation

- Water flows by osmosis through a semipermeable membrane into hypertonic sugar solution, diluting the solution.
- The larger sugar molecules cannot pass through the membrane, so the water outside remains pure.

Types of Transport: Osmosis

- Isotonic Solution
  - Solute and water concentrations equal on both sides of membrane
- Hypotonic Solution
  - Concentration of solute *lower* than on other side
  - Cells placed in a hypotonic solution will swell
  - May cause cells to break – Lysis
- Hypertonic Solution
  - Concentration of solute *higher* than on other side
  - Cells placed in a hypertonic solution will shrink – Plasmolysis

Plant cells & Osmosis



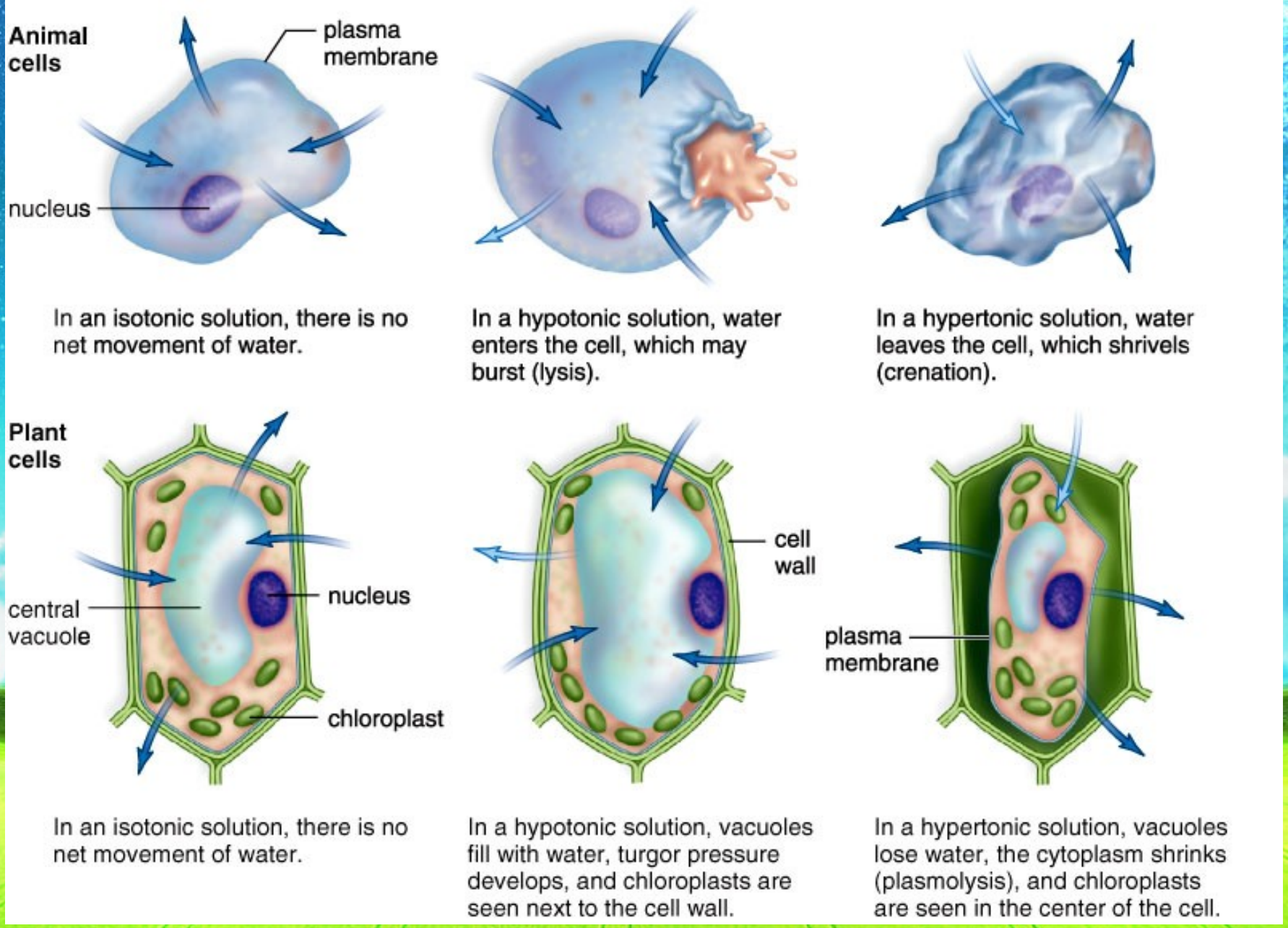
In an isotonic solution, there is no net movement of water.

In a hypotonic solution, vacuoles fill with water, turgor pressure develops, and chloroplasts are seen next to the cell wall.

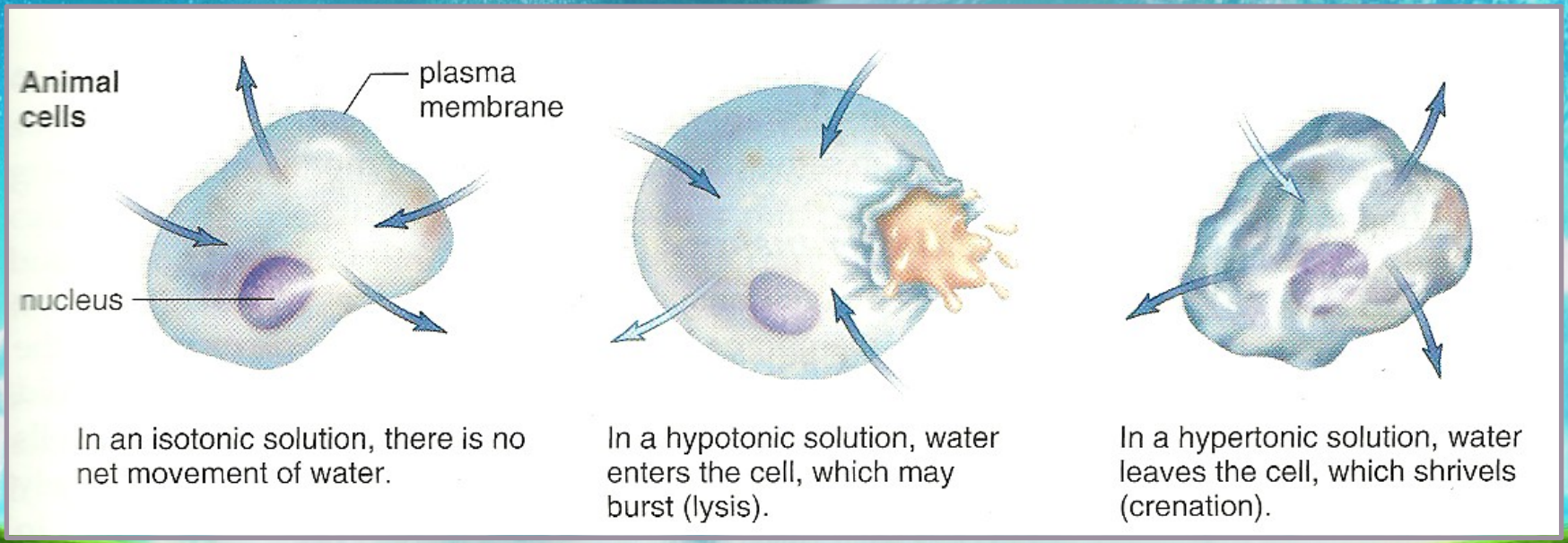
In a hypertonic solution, vacuoles lose water, the cytoplasm shrinks (plasmolysis), and chloroplasts are seen in the center of the cell.

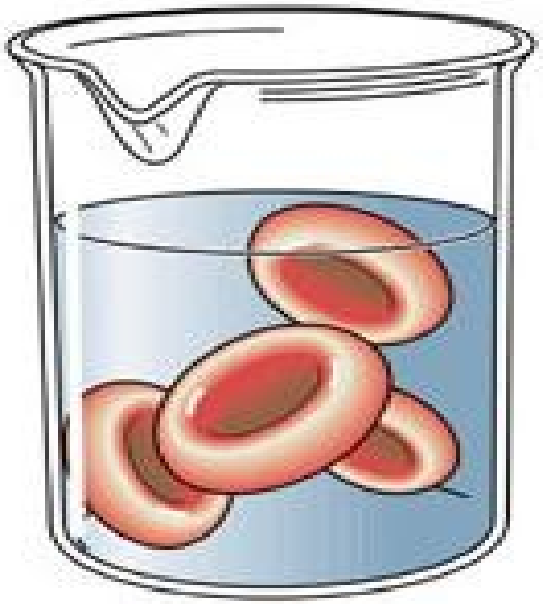
Osmotic Effects on Cells

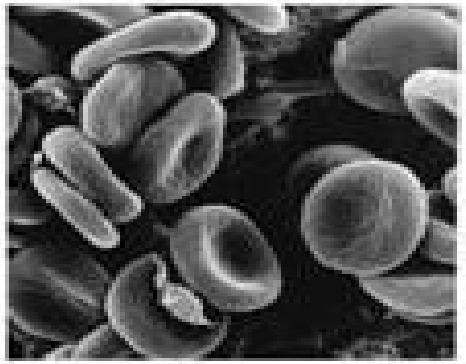
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Animal cells & Osmosis

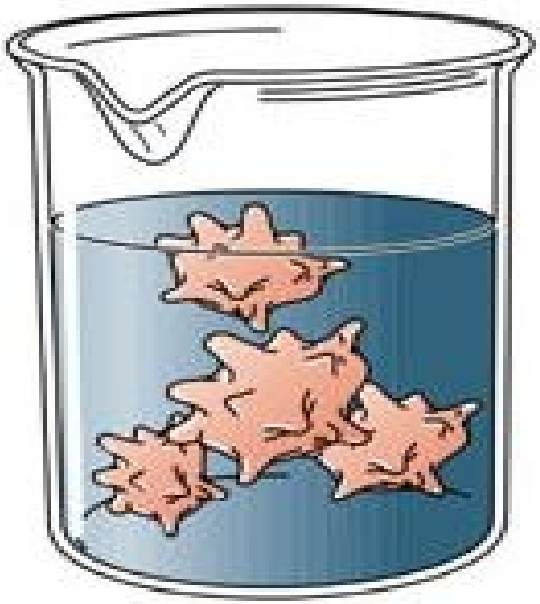


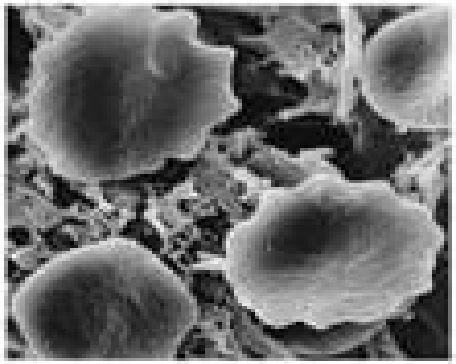




A.

Isotonic solution (equal concentration of ions in solution and cell)





B.

Hypertonic solution (higher concentration of ions in solution than in cell)





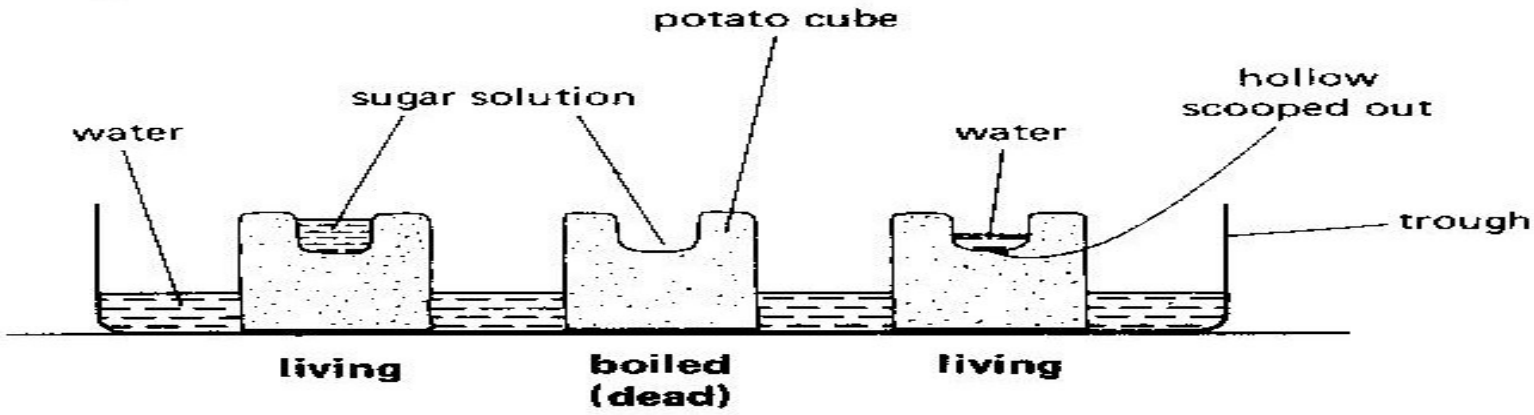
C.

Hypotonic solution (lower concentration of ions in solution than in cell)

Osmosis in living cells

To investigate osmosis in living cells

Hollows are scooped out of three potatoes and they are set up as below:



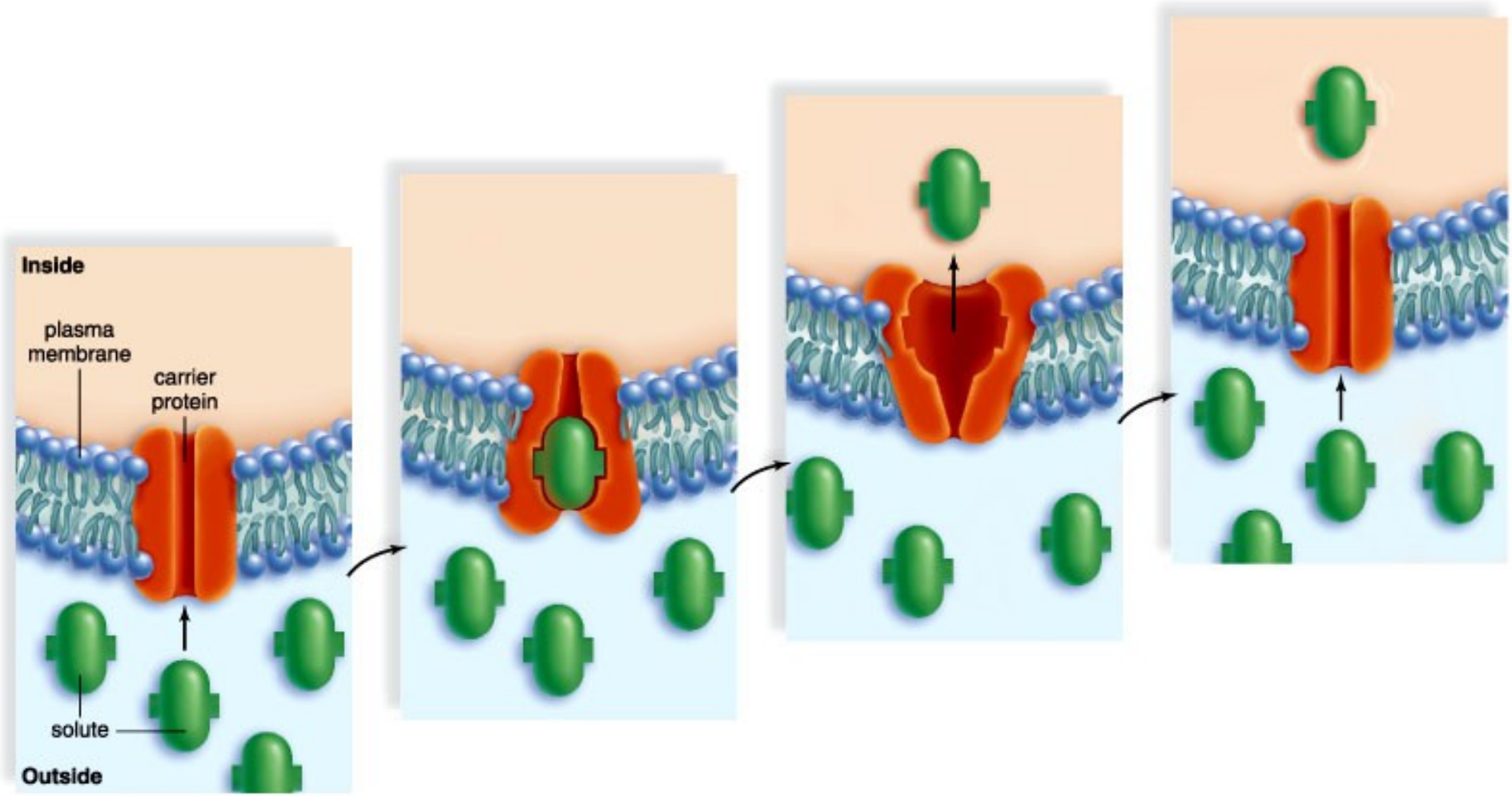
1. The level of sugar solution rises in the hollow surrounded by living cells.
2. Boiling has destroyed the cell membranes which cease to be semi-permeable and the sugar solution seeps out of the hollow.
3. The water level shows little change but some is absorbed by the surrounding cells.

Types of Transport: Carrier Proteins

- Facilitated Transport
  - Small molecules
  - Can’t get through membrane lipids
  - Combine with carrier proteins
  - *Follow* concentration gradient
- Active Transport
  - Small molecules
  - Move *against* concentration gradient
  - Combining with carrier proteins
  - Requires energy

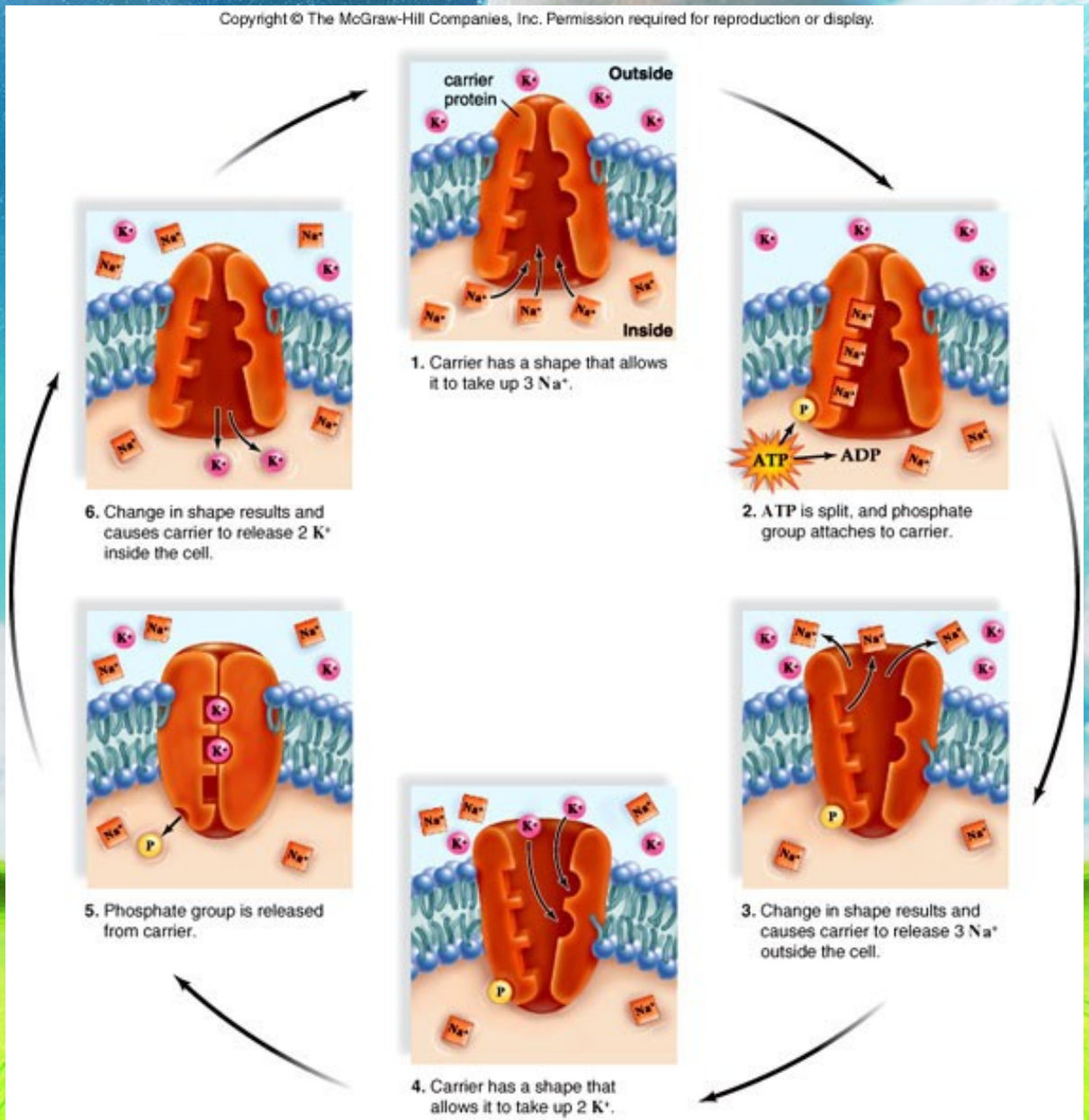
Types of Membrane Transport: Facilitated Transport

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Facilitated Transport: The Sodium-Potassium Pump

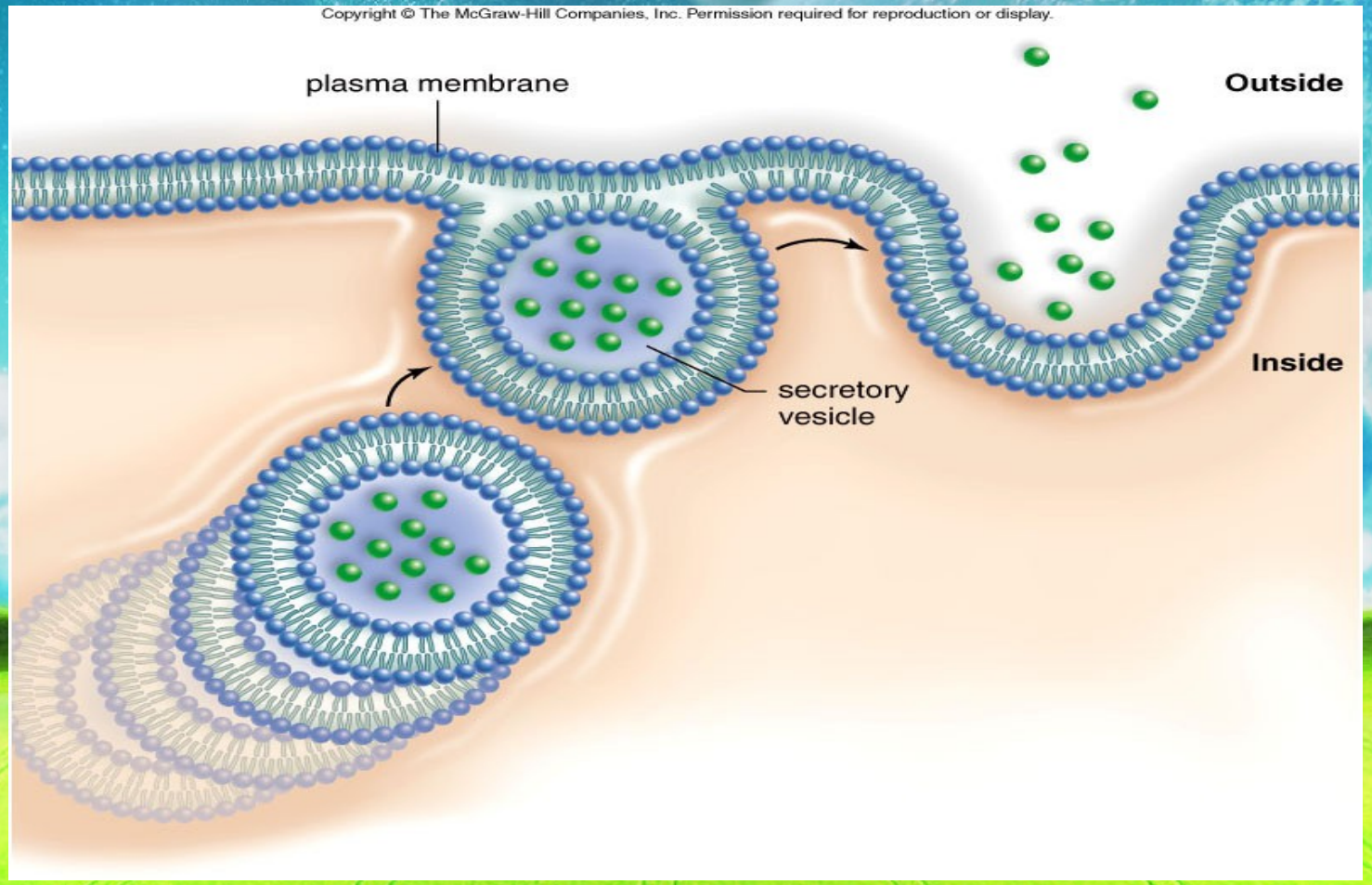
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Types of Transport: Membrane-Assisted Transport

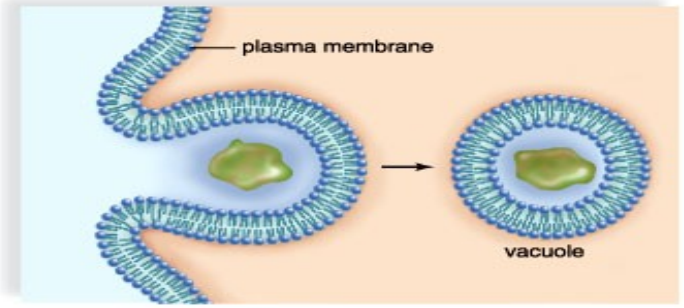
- Macromolecules transported into or out of the cell inside vesicles
  - Exocytosis – Vesicles fuse with plasma membrane and secrete contents
  - Endocytosis – Cells engulf substances into pouch which becomes a vesicle
    - Phagocytosis – Large, solid material into vesicle
    - Pinocytosis – Liquid or small, solid particles go into vesicle
    - Receptor-Mediated – Specific form of pinocytosis using a coated pit

Membrane-Assisted Transport:Exocytosis

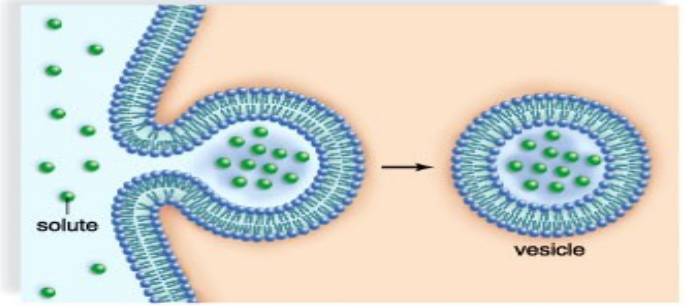


Membrane-Assisted Transport: Three Types of Endocytosis

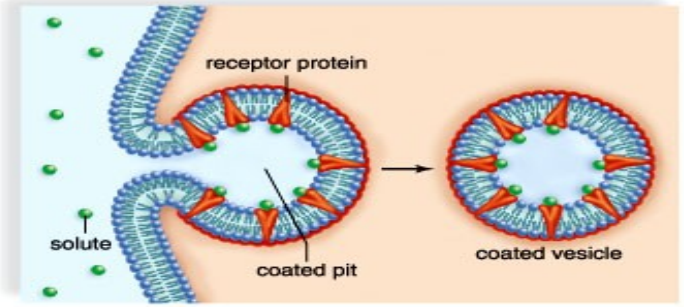
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



a. Phagocytosis

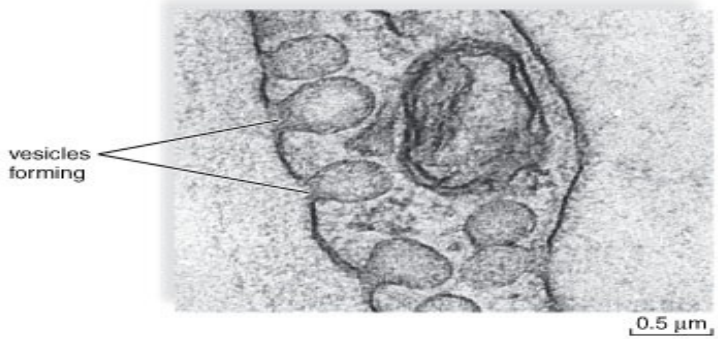


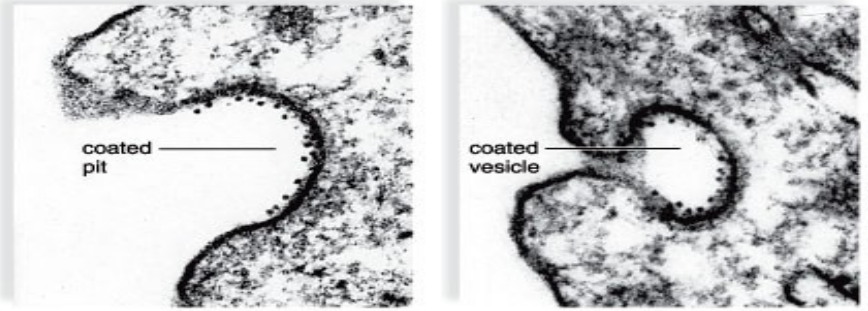
b. Pinocytosis



c. Receptor-mediated endocytosis





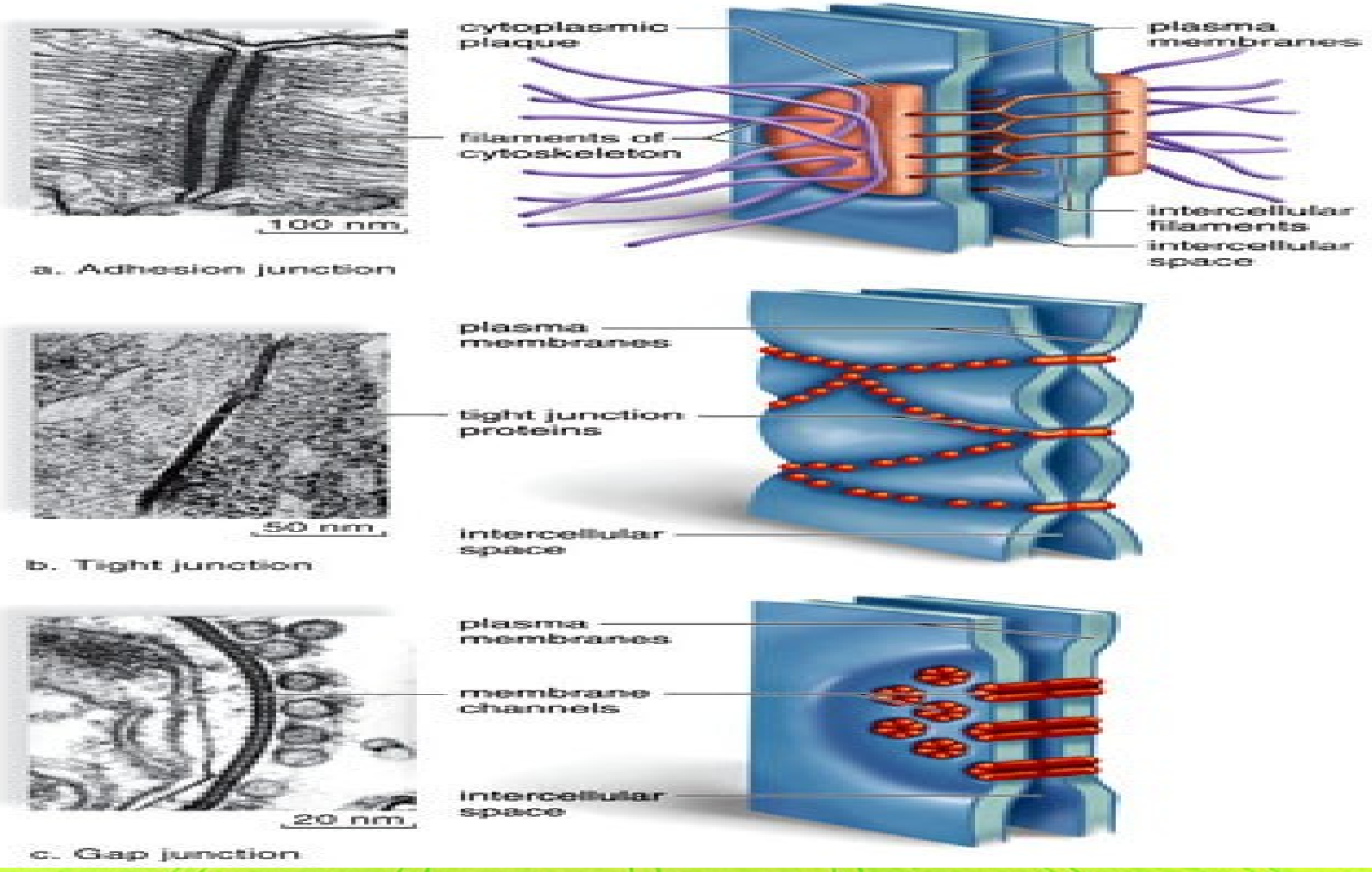


Cell Surface Modifications: Junctions

- Cell Surfaces in Animals
  - Junctions Between Cells
    - Adhesion Junctions
      - Intercellular filaments between cells
    - Tight Junctions
      - Form impermeable barriers
    - Gap Junctions
      - Plasma membrane channels are joined (allows communication)

Cell-Surface Modifications: Junctions

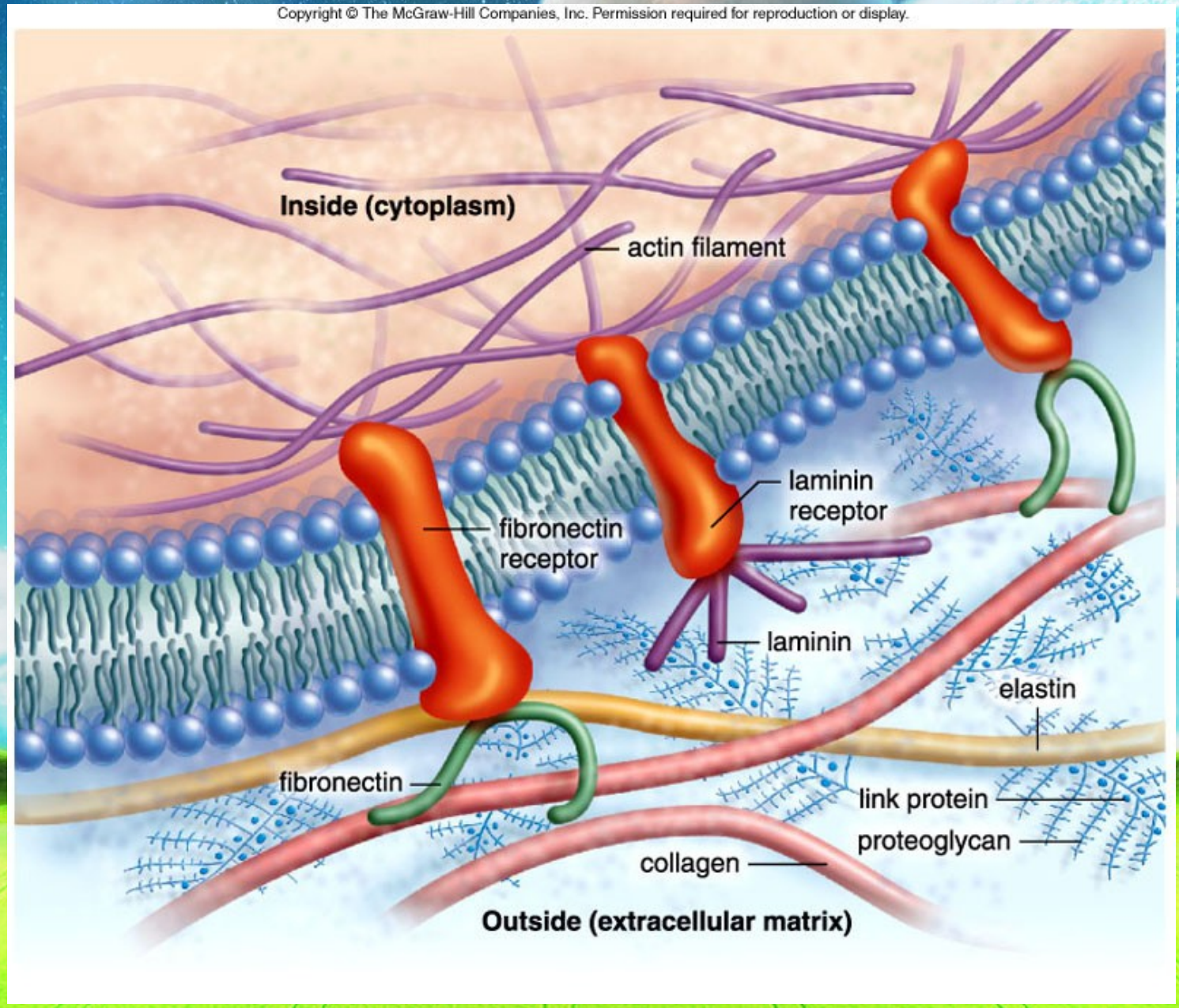
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Cell Surface Modifications

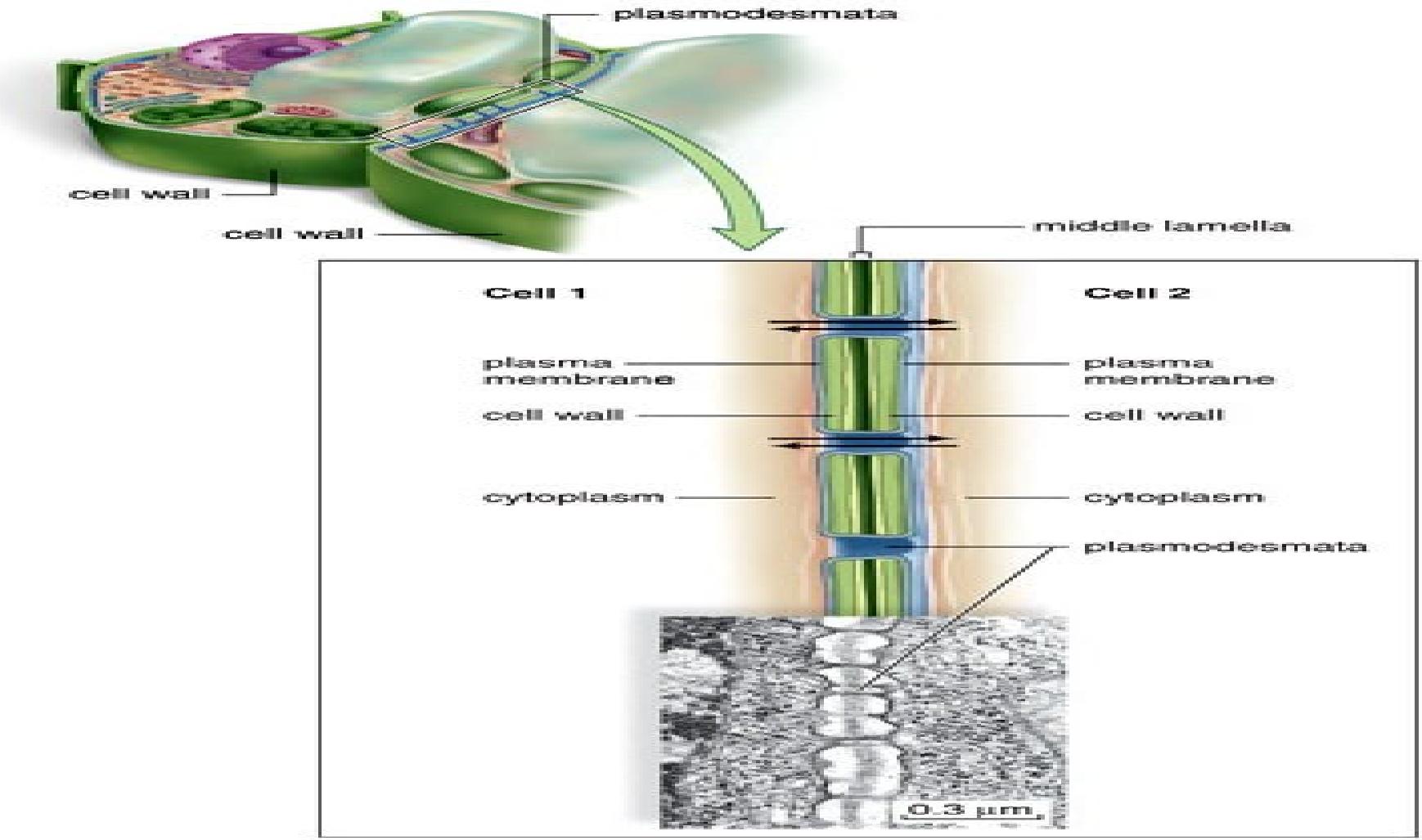
- Extracellular Matrix
  - External meshwork of polysaccharides and proteins
  - Found in close association with the cell that produced them
- Plant Cell Walls
  - Plants have freely permeable cell wall, with cellulose as the main component
    - Plasmodesmata penetrate cell wall
    - Each contains a strand of cytoplasm
    - Allow passage of material between cells

Cell-Surface Modifications: Extracellular Matrix



Cell-Surface Modifications: Plasmodesmata

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



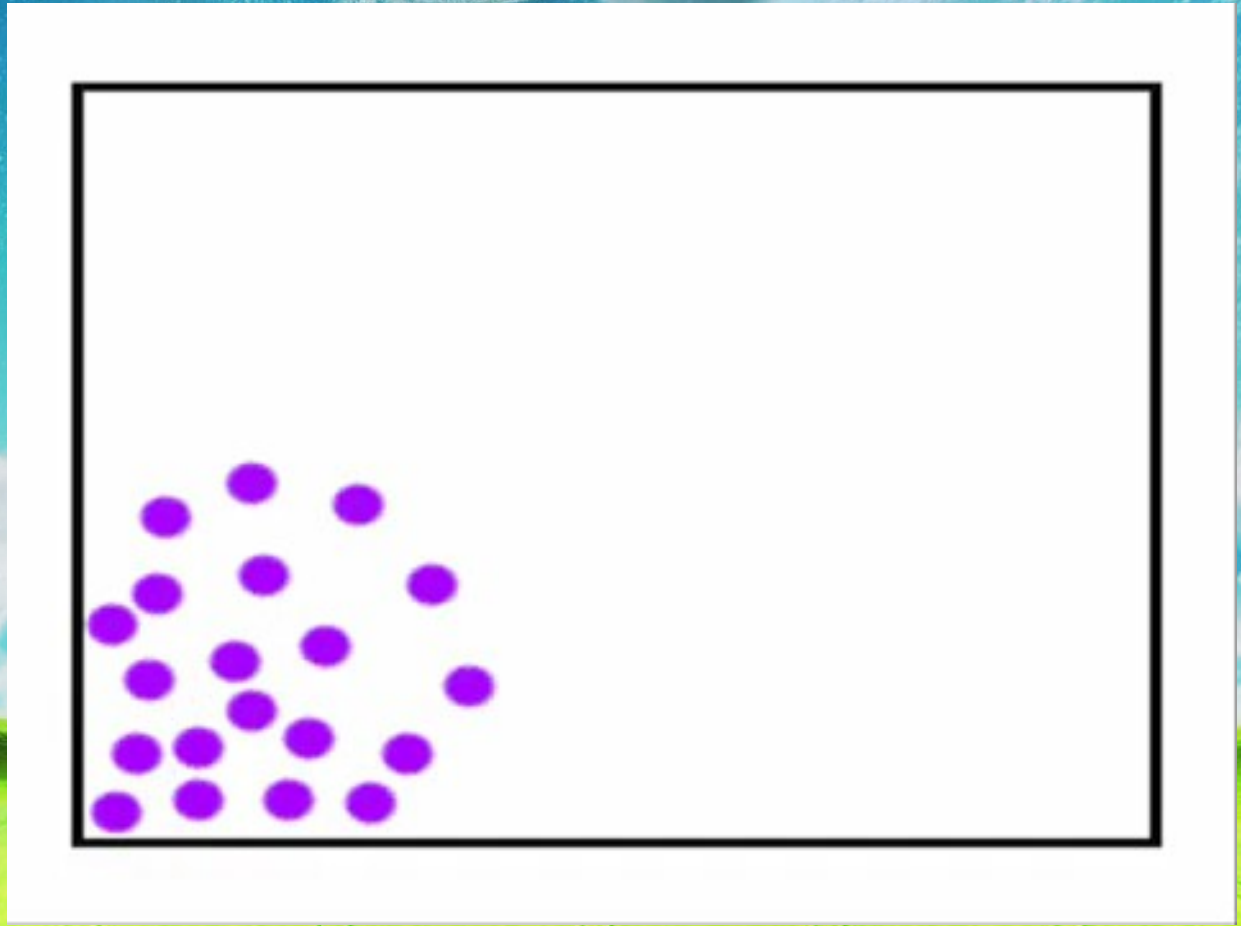
Review

- Membrane Models
  - Fluid-Mosaic
- Plasma Membrane Structure and Function
  - Protein Functions
  - Plasma Membrane Permeability
    - Diffusion
    - Osmosis
    - Transport Via Carrier Proteins
- Cell Surface Modifications

Factors determining the diffusion rate

- *Concentration /diffusion gradient.*
- *Size and density of molecules.*
- *Temperature.*
- *Surface area to volume ratio*
- *Thickness of surface/distance over which diffusion has to take place.*
- *Medium through which diffusion is taking place.*
- *Extent of agitation.*

Diffusion & concentration gradient



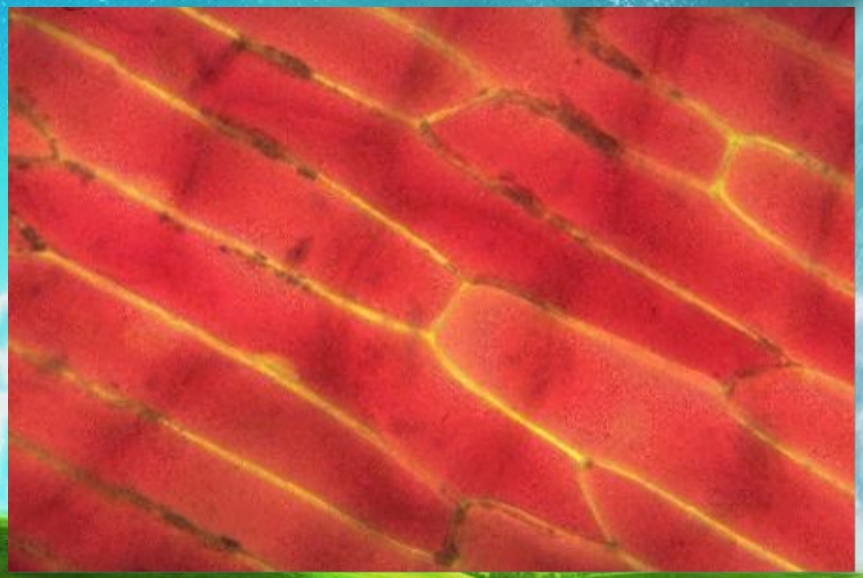
Osmosis

Definitions

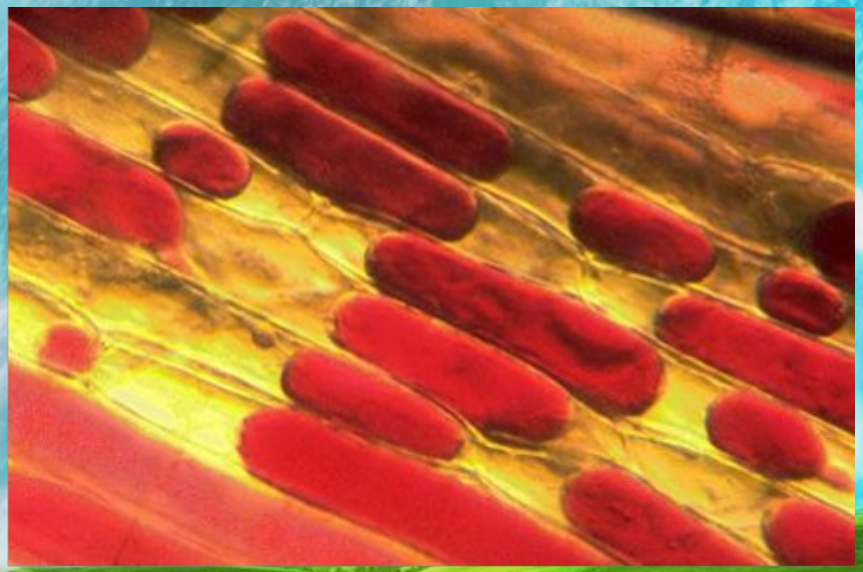
- *Osmosis is the movement of water through a semi-permeable membrane from a hypotonic solution to a hypertonic solution.*
- *Osmosis is the diffusion of water molecules through a semi-permeable membrane.*

Plant cells in Isotonic & hypertonic solution

Normal plant cells



Flaccid plant cells



ACTIVE TRANSPORT

Definition

Active transport is the use of energy molecules to move molecules against a concentration gradient.

Active transport & carrier proteins

