
Introduction to Physiology and Transport

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Syllabus: Introduction to Physiology (0501110)
FOR MEDICAL STUDENTS
Spring 2016

Subjects	Lect. No.	Pages in Guyton 12 th	Pages in Guyton 13 th
Introduction to Physiology: General outline of physiology. Homeostasis, control systems, negative & positive feedback mechanism	1	FM 3-9	3-10
Cell Membrane	2	FM 11-14	11-14
Units: moles, osmoles and equivalent. Osmosis and osmotic pressure	3	MK	
Transport-I (Passive) A. Simple Diffusion B. Facilitated Diffusion C. Osmosis	4	MK 45-52	47-54
Transport-II (Active) A. Primary Active. B. Secondary Active: Co-and Counter-Transport C. Vesicular transport	5-6	MK 52-56	54-59
Excitable Membranes: Resting Membrane Potential: Origin And Determinants. Distribution Of Different Ions Across Cell Membranes	7	MK 57-69	61-74
Electrochemical Equilibrium (Nernst Equation) As a Predictor For RMP - $E_{Na^{+}}$, $E_{K^{+}}$, $E_{Ca^{++}}$, $E_{Cl^{-}}$. -Other Equations Which Predict RMP: Goldman-Hodgkin-Katz Equation And Chord Conductance Equation	8-9		
Autonomic Nervous System (I) Organization: Sympathetic and Parasympathetic	10	MK 729-740	773-785
Autonomic Nervous System (II)	11		
Body Water: Distribution & Measurements	12	MK	
Abnormalities of body fluid volume regulation Hypo-osmotic dehydration & overhydration. Hyper-osmotic dehydration & overhydration. Edema (definition, types, difference between IC & EC edema).	13	285-296	305-316
All or none versus graded potential	14	MK 560-562	596-598
Excitatory Post Synaptic Potential EPSP And Inhibitory Post Synaptic Potential IPS	15	MK 552-557	587-592
Basic neuronal circuits: Synapses: types, transmission of AP, neurotransmitters, facilitation, inhibition, summation, electrical events, processing, fatigue...etc. Excitatory and Inhibitory postsynaptic potential	16-17	FM 550-552 563-570	584-587 599-606

Subjects	Lect. No.	Pages in Guyton 12th	Pages in Guyton 13th
<ul style="list-style-type: none"> - Neurotransmitters, types, synthesis, location (pre-and postganglionic) - Receptors: types and location. - Adrenal medulla. 	18		
Neurons: Types and classifications	19	FM 563-564	599-600
Microcirculation: Capillary Structure; Fluid Filtration (Forces) & Reabsorption <ul style="list-style-type: none"> - Starling Law Of Capillary Exchange - Lymphatic System 	20-21	YS 177-186	189-198
Action Potential: Cardiac Action Potential (Fast Response AP) Vs Slow Response AP (The Pacemaker Concept)	22-23	YS 101-104 115-120	109-113 123-129
Receptors: types and adaptation <ul style="list-style-type: none"> - Membrane or intracellular - Ion channels - G-protein - Enzyme linked - Intracellular - Second messengers - cAMP and cGMP, Phospholipid <ul style="list-style-type: none"> - Calcium calmodulin and IRS 	24-25	EZ 881-891	925-036
Signal Transduction (Regulation of cellular machinery) Extracellular regulators: nervous, endocrine, paracrine and autocrine	26-27	EZ 910-912 940-941	954-956 984-985
Steroids: Their Signal Transduction And Mechanism Of Action	28	EZ 926-927 931	970-971 976

Midterm Exam 40%

Final Exam 60%

Textbook: Guyton and Hall Textbook of Medical Physiology: 13th edition 2016

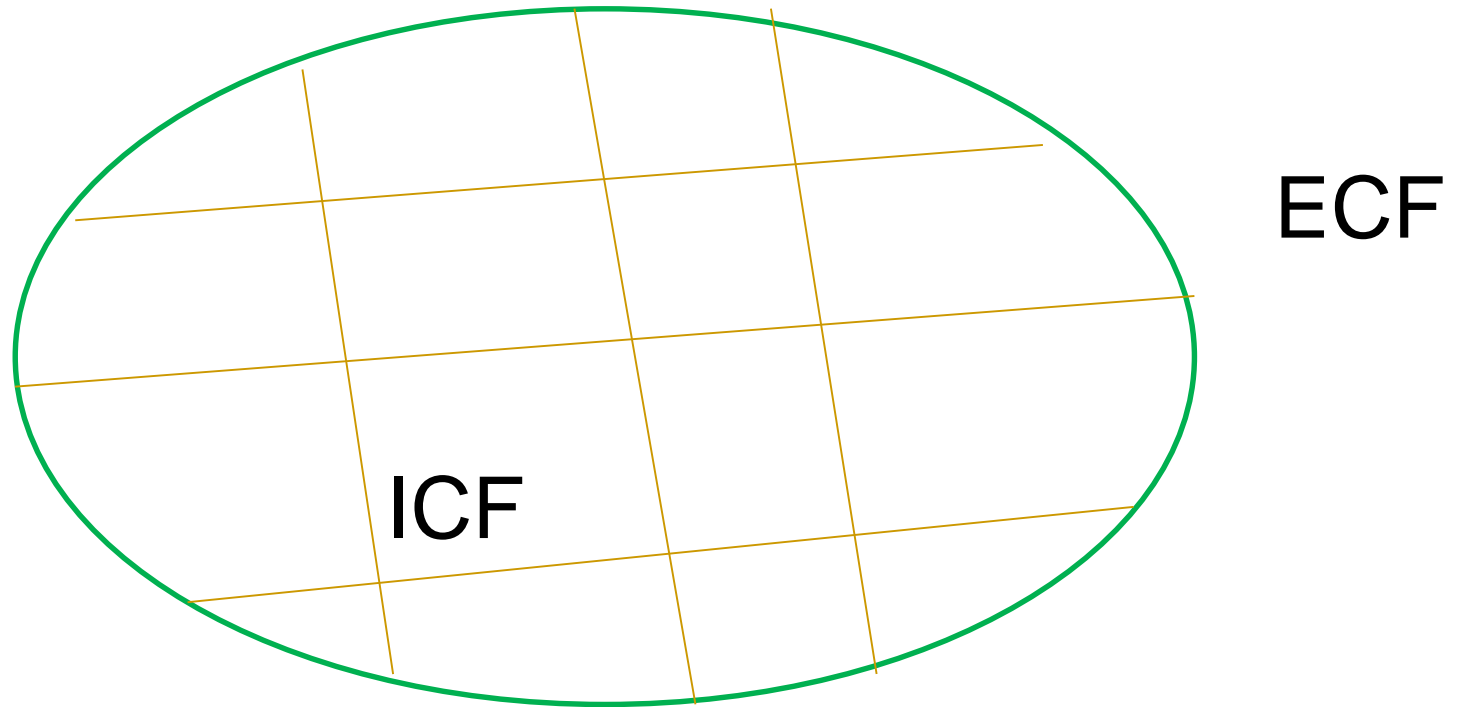
Anatomy and Physiology Defined

- Two branches of science that deal with body's parts and function
 - **Anatomy**
 - The science of body structures and relationships
 - First studies by dissection (cutting apart)
 - Imaging techniques
 - **Physiology**
 - The science that is concerned with the function of the living organism and its parts, and of the physical and chemical processes involved.
 - The science of body functions
-

Zygot

Intracellular fluid =(ICF)

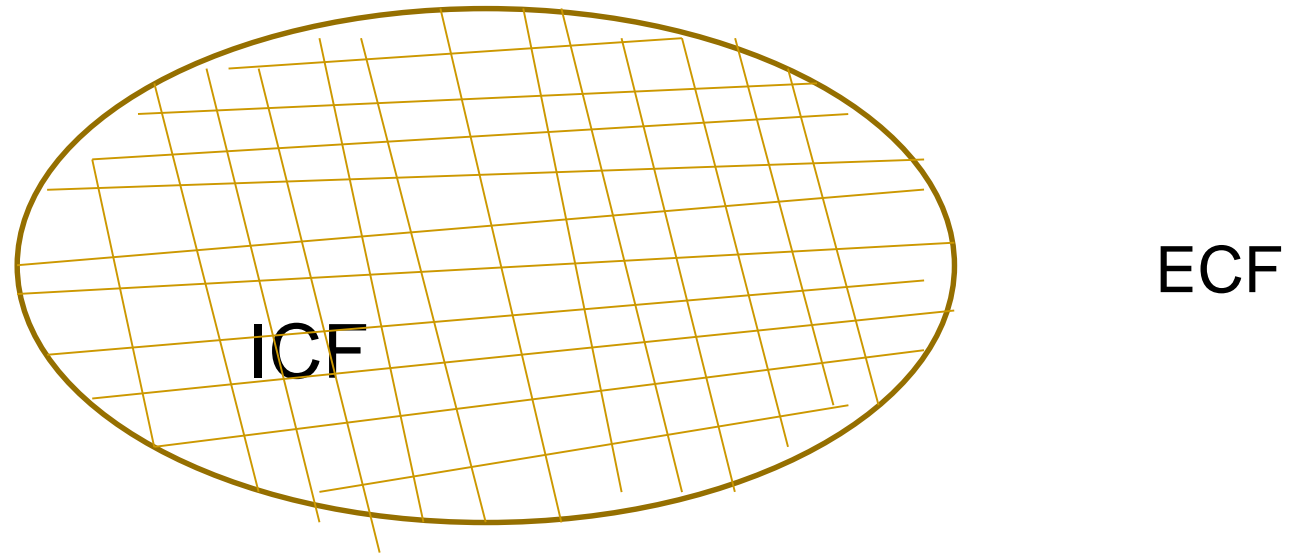
Extracellular fluid (ECF)



Zygot

Intracellular fluid =(ICF)

Extracellular fluid (ECF)



Emergence of systems to meet the need for supplying the cells with the nutrients it
needs.

Levels of structural organization

- SYSTEM LEVEL

- A **system** consists of related organs with a common function
 - Organ-system level
 - Digestive system breaks down and absorbs food
 - It includes organs such as the mouth, small and large intestines, liver, gallbladder, and pancreas
 - Eleven systems of the human body
-

Eleven organ systems of the human body, part 1



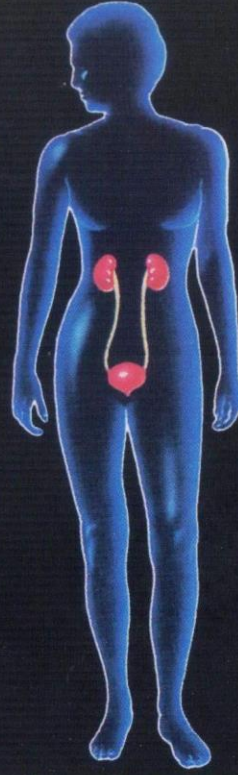
Circulatory system
heart, blood,
blood vessels



Digestive system
mouth, pharynx,
esophagus,
stomach,
small intestine,
large intestine,
salivary glands,
exocrine pancreas,
liver, gallbladder



Respiratory system
Nose, pharynx, larynx,
trachea, bronchi, lungs



Urinary system
kidneys, ureters,
urinary bladder,
urethra

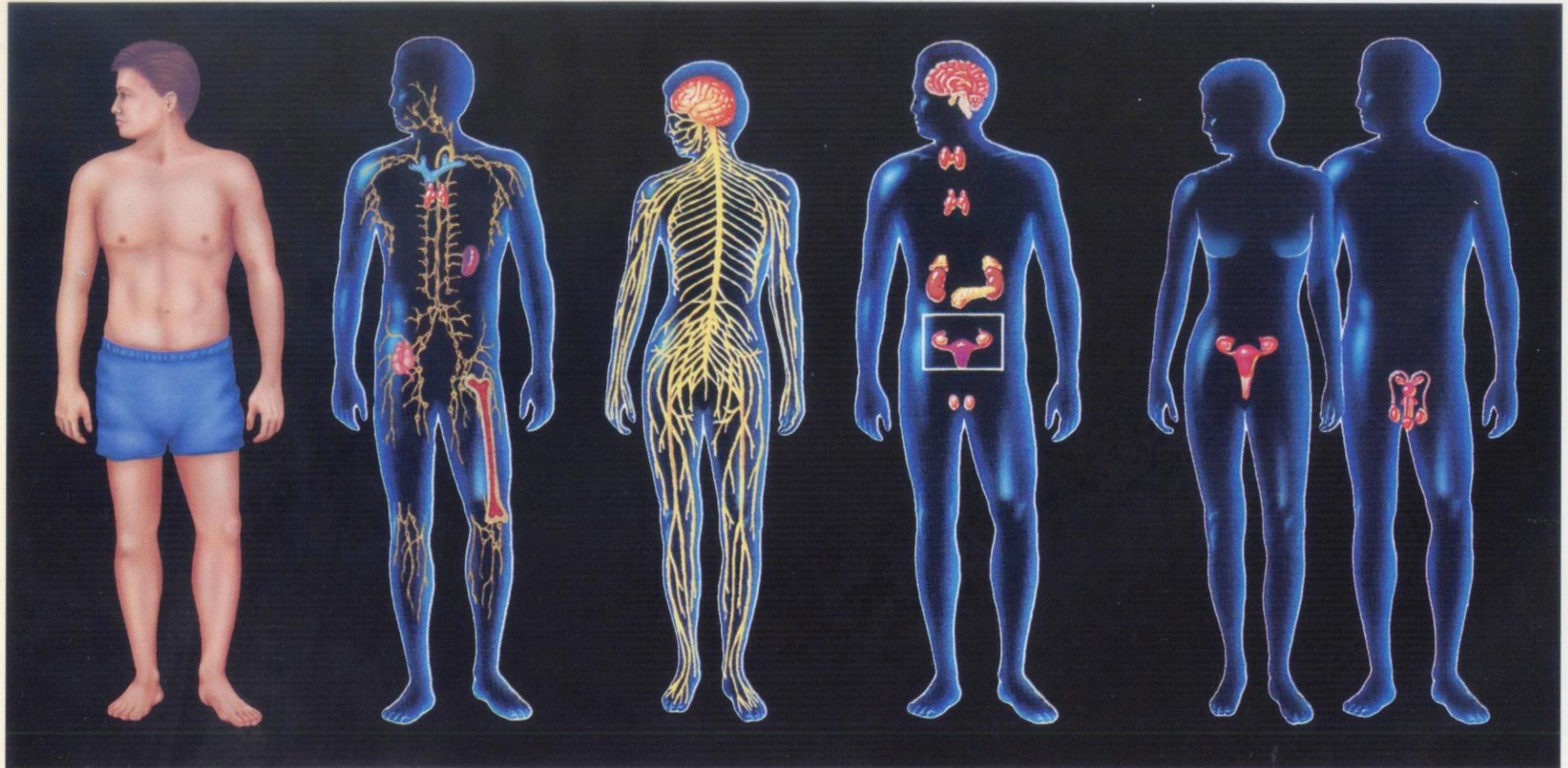


Skeletal system
bones, cartilage,
joints



Muscular system
skeletal muscles

Eleven organ systems of the human body, part 2



Integumentary system
skin, hair, nails

Immune system
lymph nodes, thymus, bone marrow, tonsils, adenoids, spleen, appendix, and, not shown, white blood cells, gut-associated lymphoid tissue, and skin-associated lymphoid tissue

Nervous system
brain, spinal cord, peripheral nerves, and, not shown, special sense organs

Endocrine system
all hormone-secreting tissues, including hypothalamus, pituitary, thyroid, adrenals, endocrine pancreas, gonads, kidneys, pineal, thymus, and, not shown, parathyroids, intestine, heart, and skin

Reproductive system
Male: testes, penis, prostate gland, seminal vesicles, bulbourethral glands, and associated ducts

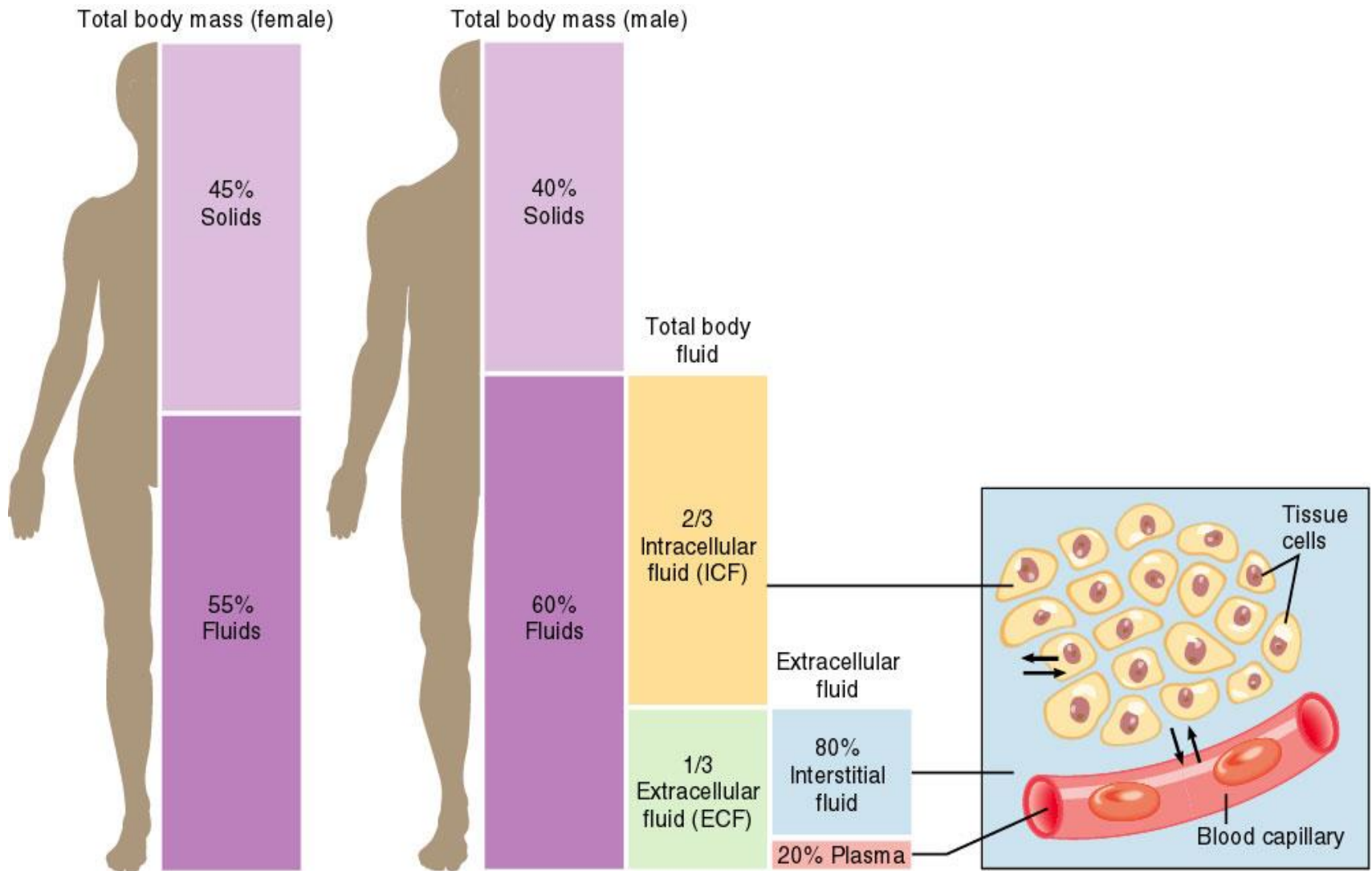
Female: ovaries, oviducts, uterus, vagina, breasts

Homeostasis

- A condition of **equilibrium** (balance) in the body's internal environment. Maintain an almost constant internal environment
 - Dynamic condition
 - Narrow range is compatible with maintaining life
 - Example
 - Blood glucose levels range between 70 and 110 mg of glucose/dL of blood
 - Whole body contributes to maintain the internal environment within normal limits
-

Homeostasis and Body Fluids

- Maintaining the volume and composition of body fluids are important
 - **Body fluids** are defined as dilute, watery solutions containing dissolved chemicals inside or outside of the cell
 - **Intracellular Fluid (ICF)**
 - Fluid within cells
 - **Extracellular Fluid (ECF)**
 - Fluid outside cells
 - **Interstitial fluid** is ECF between cells and tissues
-



(a) Distribution of body solids and fluids in an average lean, adult female and male

(b) Exchange of water among body fluid compartments

Interstitial Fluid and Body Function

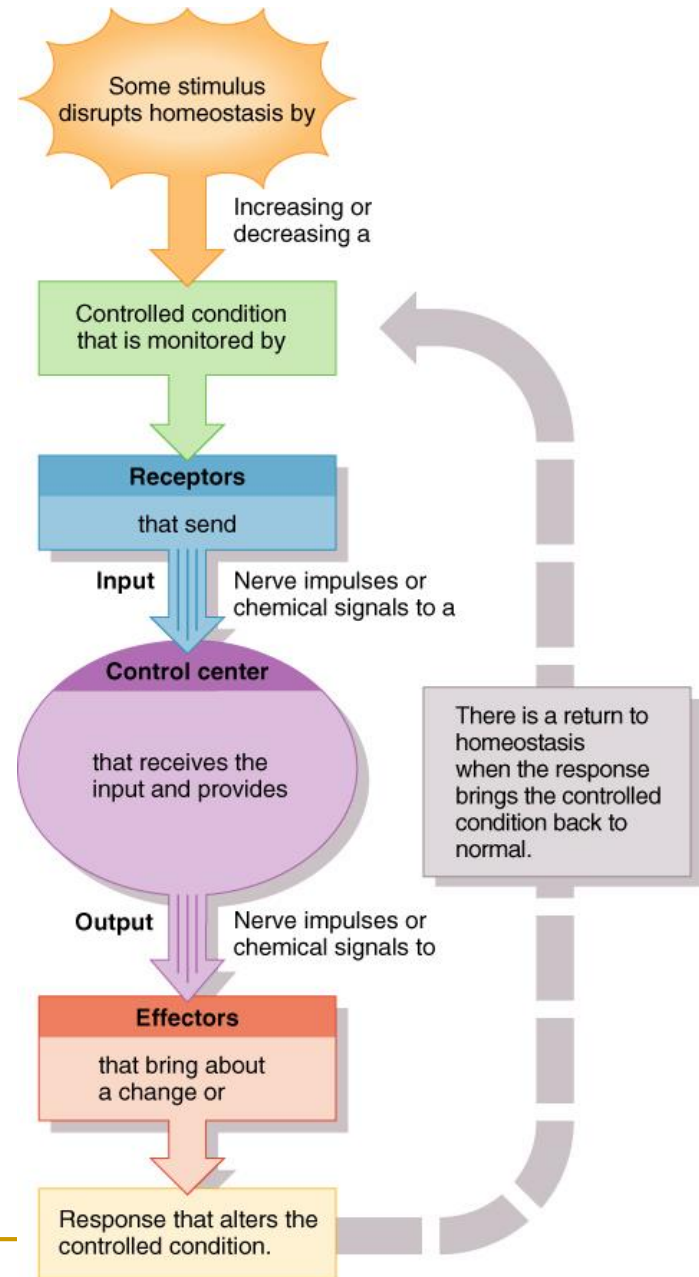
- Cellular function depends on the regulation of composition of interstitial fluid
 - Body's internal environment
 - Composition of interstitial fluid changes as it moves
 - Movement back and forth across capillary walls provide nutrients (glucose, oxygen, ions) to tissue cells and removes waste (carbon dioxide)
-

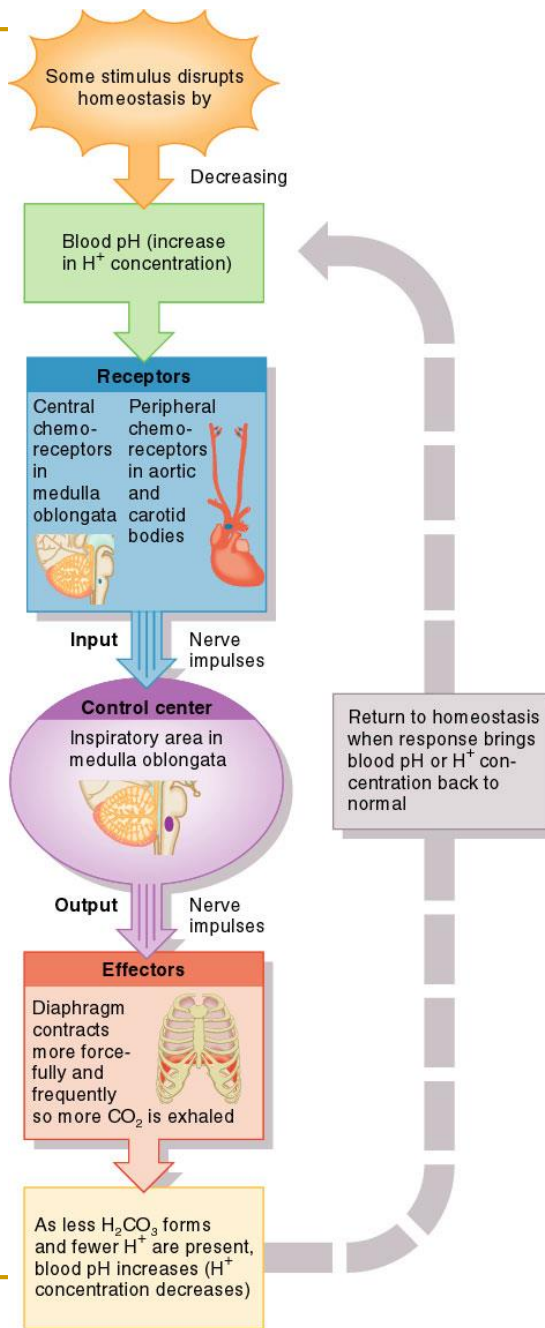
Control of Homeostasis

- Homeostasis is constantly being disrupted
 - **Physical insults**
 - Intense heat or lack of oxygen
 - **Changes in the internal environment**
 - Drop in blood glucose due to lack of food
 - **Physiological stress**
 - Demands of work or school
 - **Disruptions**
 - Mild and temporary (balance is quickly restored)
 - Intense and Prolonged (poisoning or severe infections)
-

Feedback System

- Cycle of events
 - Body is monitored and re-monitored
 - Each monitored variable is termed a controlled condition
- Three Basic components
 - Receptor
 - Control center
 - Effector





Feedback Systems

- **Receptor**

- Body structure that monitors changes in a controlled condition
- Sends **input** to the control center
 - Nerve ending of the skin in response to temperature change



Feedback Systems

- **Control Center**

- Brain

- Sets the range of values to be maintained

- Evaluates input received from receptors and generates **output** command

- Nerve impulses, hormones

- Brains acts as a control center receiving nerve impulses from skin temperature receptors

Feedback Systems

- **Effector**

- Receives output from the control center
 - Produces a response or effect that changes the controlled condition
 - Found in nearly every organ or tissue
 - Body temperature drops the brain sends an impulse to the skeletal muscles to contract
 - Shivering to generate heat
-

Negative and Positive Feedback systems

- **Negative Feedback systems**

- Reverses a change in a controlled condition

- Regulation of blood pressure (force exerted by blood as it presses against the walls of the blood vessels)

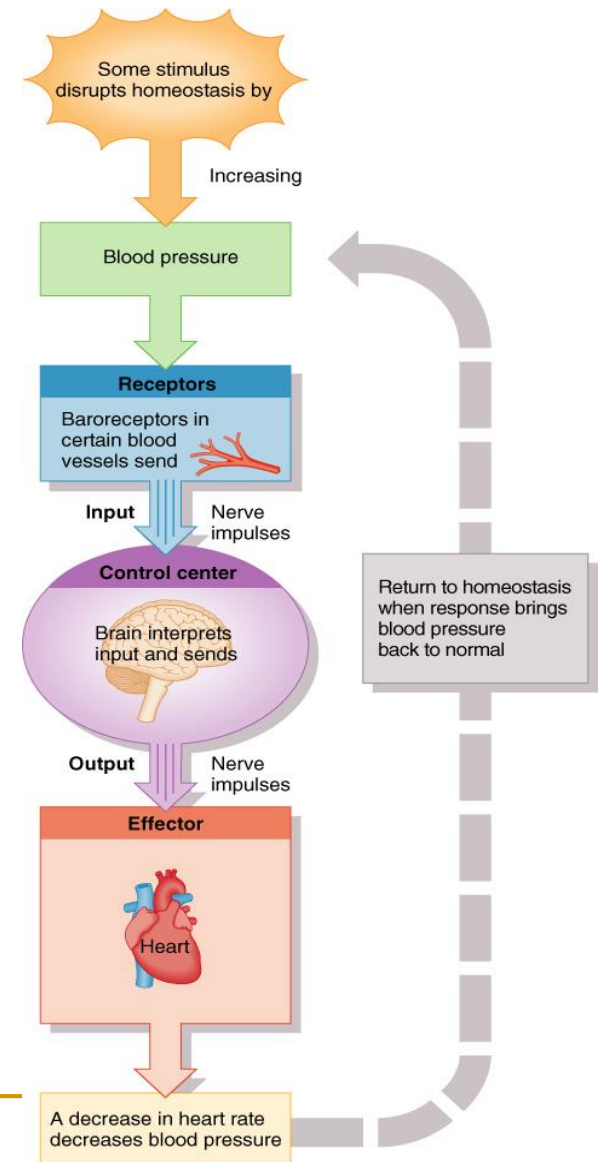
- **Positive Feedback systems**

- Strengthen or reinforce a change in one of the body's controlled conditions

- Normal child birth

Negative Feedback: Regulation of Blood Pressure

- External or internal stimulus increase BP
 - Baroreceptors (pressure sensitive receptors)
 - Detect higher BP
 - Send nerve impulses to brain for interpretation
 - Response sent via nerve impulse sent to heart and blood vessels
 - BP drops and homeostasis is restored
 - Drop in BP negates the original stimulus



Positive Feedback: Blood Loss

- Normal conditions, heart pumps blood under pressure to body cells (oxygen and nutrients)
 - Severe blood loss
 - Blood pressure drops
 - Cells receive less oxygen and function less efficiently
 - If blood loss continues
 - Heart cells become weaker
 - Heart doesn't pump
 - BP continues to fall
-

Feedback Gain

A measure of the effectiveness of a feedback system

$$\text{Gain} = \frac{\text{Correction}}{\text{Error}}$$

Homeostatic Imbalances

- Normal equilibrium of body processes are disrupted
 - **Moderate imbalance**
 - Disorder or abnormality of structure and function
 - Disease specific for an illness with recognizable signs and symptoms
 - **Signs** are objective changes such as a fever or swelling
 - **Symptoms** are subjective changes such as headache
 - **Severe imbalance**
 - Death
-

A Generalized Cell

1. Plasma membrane

- forms the cell's outer boundary
 - separates the cell's internal environment from the outside environment
 - is a selective barrier
 - plays a role in cellular communication
-

Plasma Membrane

- Flexible yet sturdy barrier
 - The *fluid mosaic model* - the arrangement of molecules within the membrane resembles a sea of lipids containing many types of proteins
 - The lipids act as a barrier to certain substances
 - The proteins act as “gatekeepers” to certain molecules and ions
-

Structure of a Membrane

- Consists of a lipid bilayer - made up of phospholipids, cholesterol and glycolipids
 - **Integral proteins** - extend into or through the lipid bilayer
 - **Transmembrane proteins** - most integral proteins, span the entire lipid bilayer
 - **Peripheral proteins** - attached to the inner or outer surface of the membrane, do not extend through it
-

Structure of the Plasma Membrane

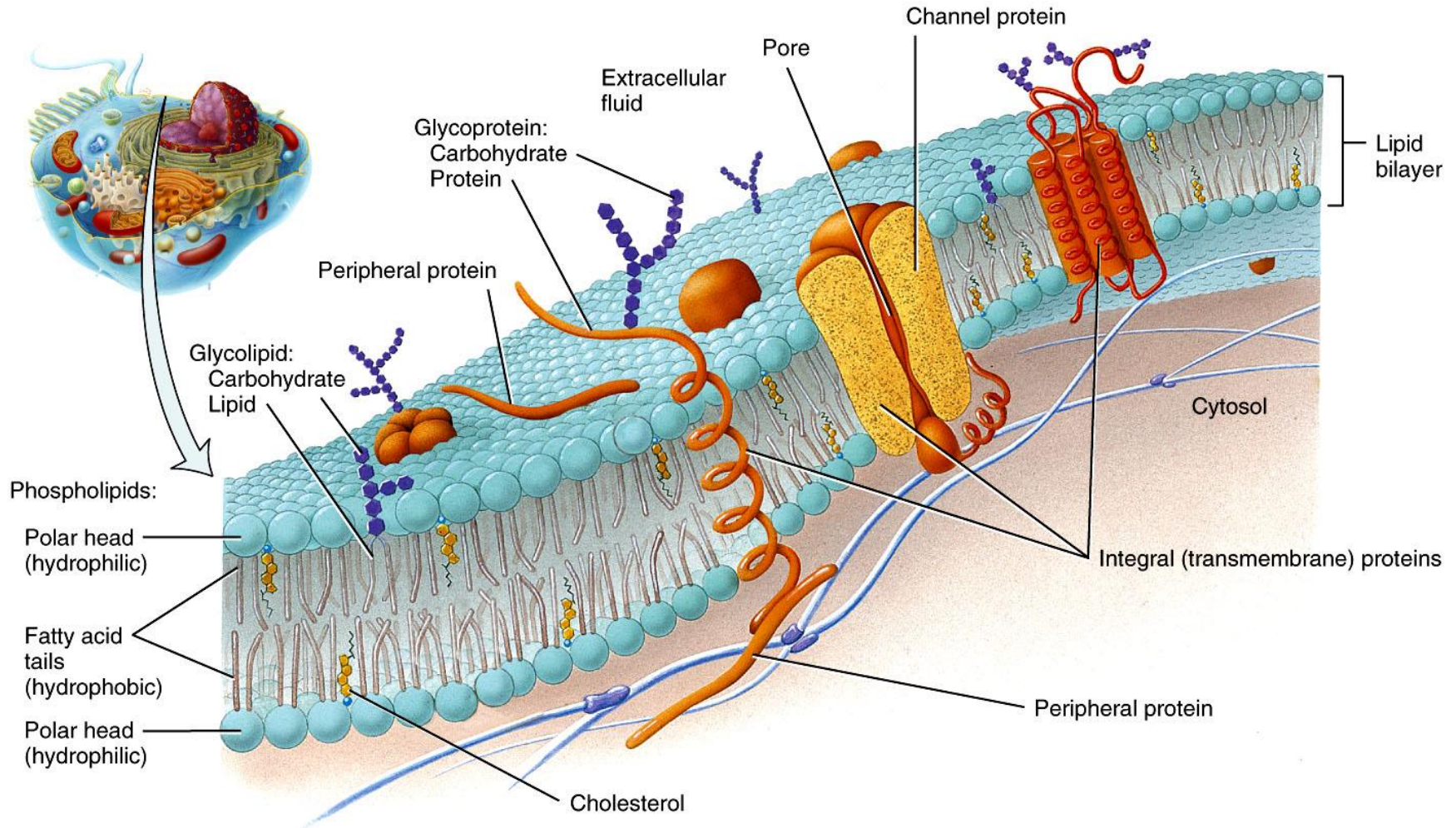


Figure 03.02 Tortora - PAP 12/e
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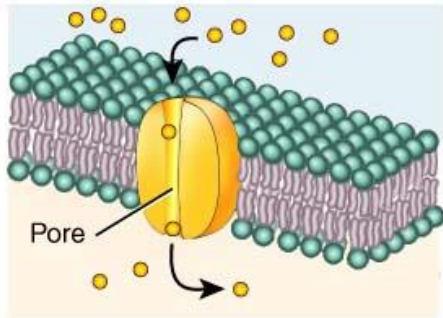
Structure of a Membrane

- **Glycoproteins** - membrane proteins with a carbohydrate group attached that protrudes into the extracellular fluid
 - **Glycocalyx** - the “sugary coating” surrounding the membrane made up of the carbohydrate portions of the glycolipids and glycoproteins
-

Functions of Membrane Proteins

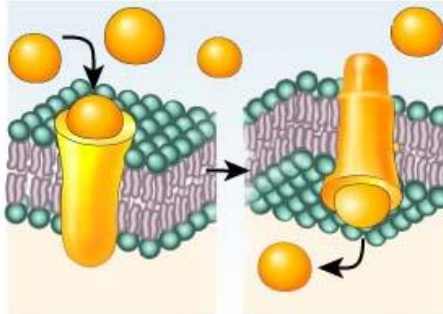
- Some integral proteins are **ion channels**
 - **Transporters** - selectively move substances through the membrane
 - **Receptors** - for cellular recognition; a **ligand** is a molecule that binds with a receptor
 - **Enzymes** - catalyze chemical reactions
 - Others act as **cell-identity markers**
-

Extracellular fluid Plasma membrane Cytosol



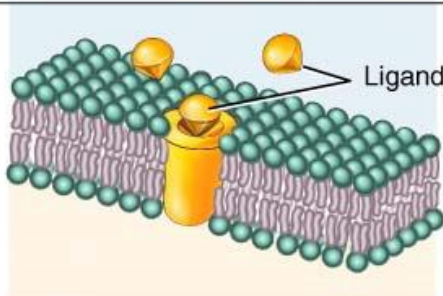
Ion channel

Allows specific ion (●) to move through water-filled pore. Most plasma membranes include specific channels for several common ions.



Transporter

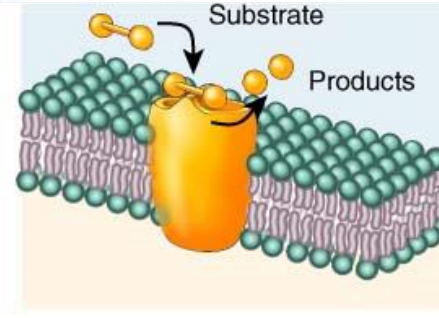
Transports specific substances (●) across membrane by changing shape. For example, amino acids, needed to synthesize new proteins, enter body cells via transporters.



Receptor

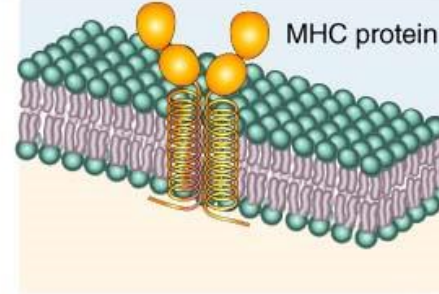
Recognizes specific ligand (◊) and alters cell's function in some way. For example, antidiuretic hormone binds to receptors in the kidneys and changes the water permeability of certain plasma membranes.

Extracellular fluid Plasma membrane Cytosol



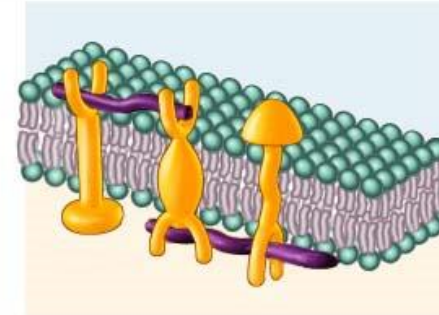
Enzyme

Catalyzes reaction inside or outside cell (depending on which direction the active site faces). For example, lactase protruding from epithelial cells lining your small intestine splits the disaccharide lactose in the milk you drink.



Cell Identity Marker

Distinguishes your cells from anyone else's (unless you are an identical twin). An important class of such markers are the major histocompatibility (MHC) proteins.



Linker

Anchors filaments inside and outside to the plasma membrane, providing structural stability and shape for the cell. May also participate in movement of the cell or link two cells together.

Membrane Permeability

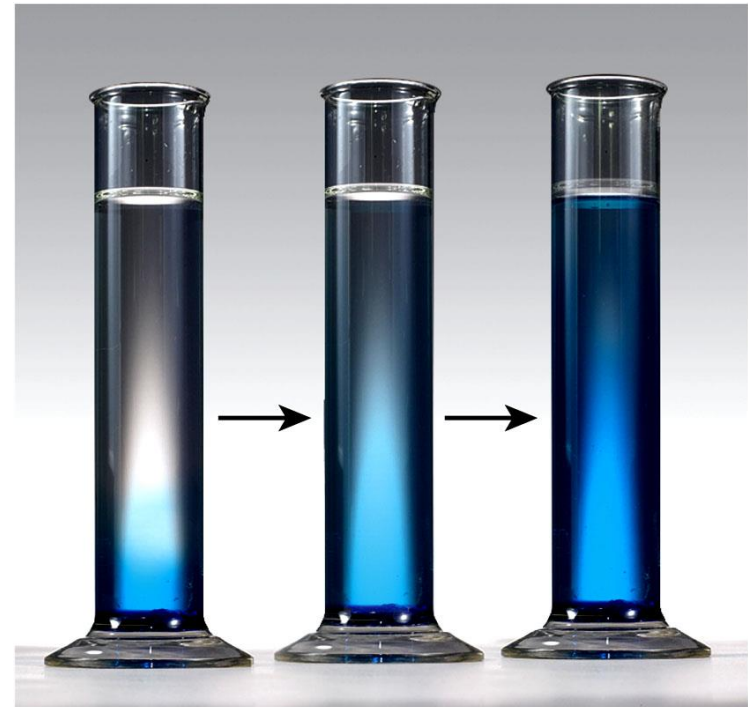
- The cell is either permeable or impermeable to certain substances
 - The lipid bilayer is *permeable* to oxygen, carbon dioxide, water and steroids, but *impermeable* to glucose
 - Transmembrane proteins act as channels and transporters to assist the entrance of certain substances, for example, glucose and ions
-

Passive vs. Active Processes

- Passive processes - substances move across cell membranes without the input of any energy; use the *kinetic energy* of individual molecules or ions
 - Active processes - a cell uses energy, primarily from the breakdown of ATP, to move a substance across the membrane, i.e., against a concentration gradient
-

Diffusion

- Steepness of
- concentration gradient
- Temperature
- Mass of diffusing substance
- Surface area
- Diffusion distance



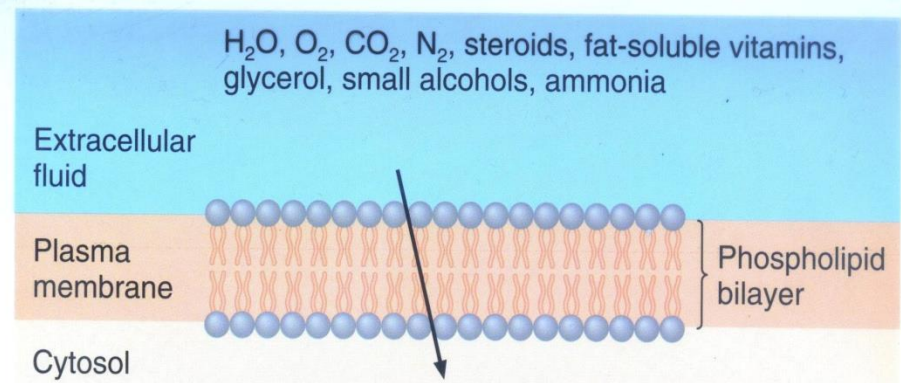
Beginning
(a)

Intermediate
(b)

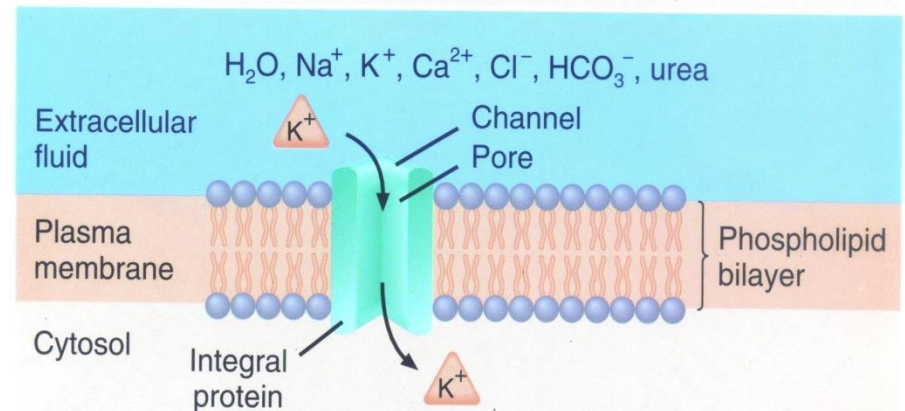
Equilibrium
(c)

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Simple diffusion through the membrane of lipid soluble substances



(a) Diffusion through the phospholipid bilayer



(b) Diffusion through the water-filled pore of a channel formed by an integral protein

Key:

H_2O = Water

O_2 = Oxygen

CO_2 = Carbon dioxide

N_2 = Nitrogen

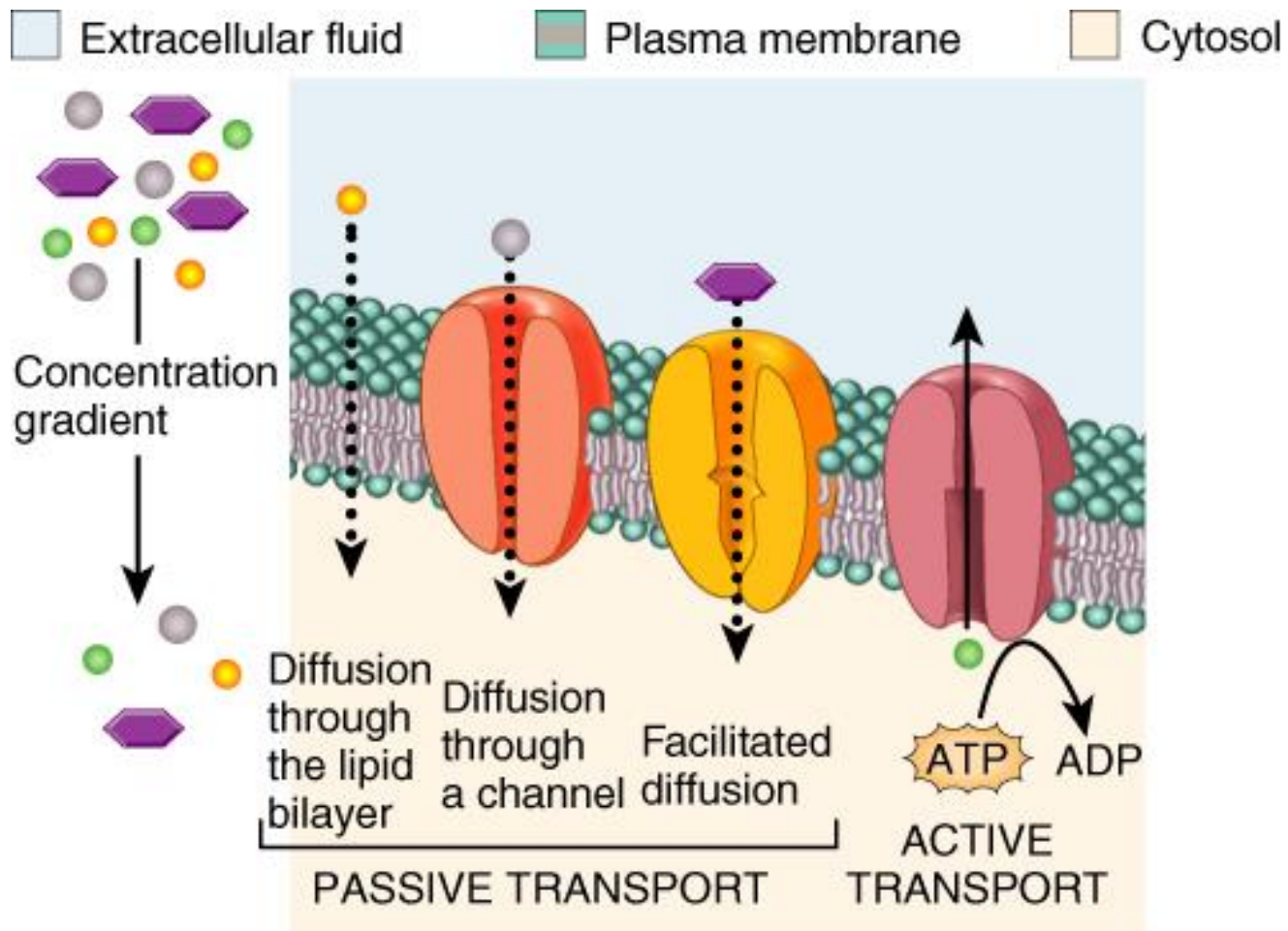
Na^+ = Sodium ion

K^+ = Potassium ion

Ca^{2+} = Calcium ion

Cl^- = Chloride ion

HCO_3^- = Bicarbonate ion



Simple Diffusion, Channel-mediated Facilitated Diffusion, and Carrier-mediated Facilitated Diffusion

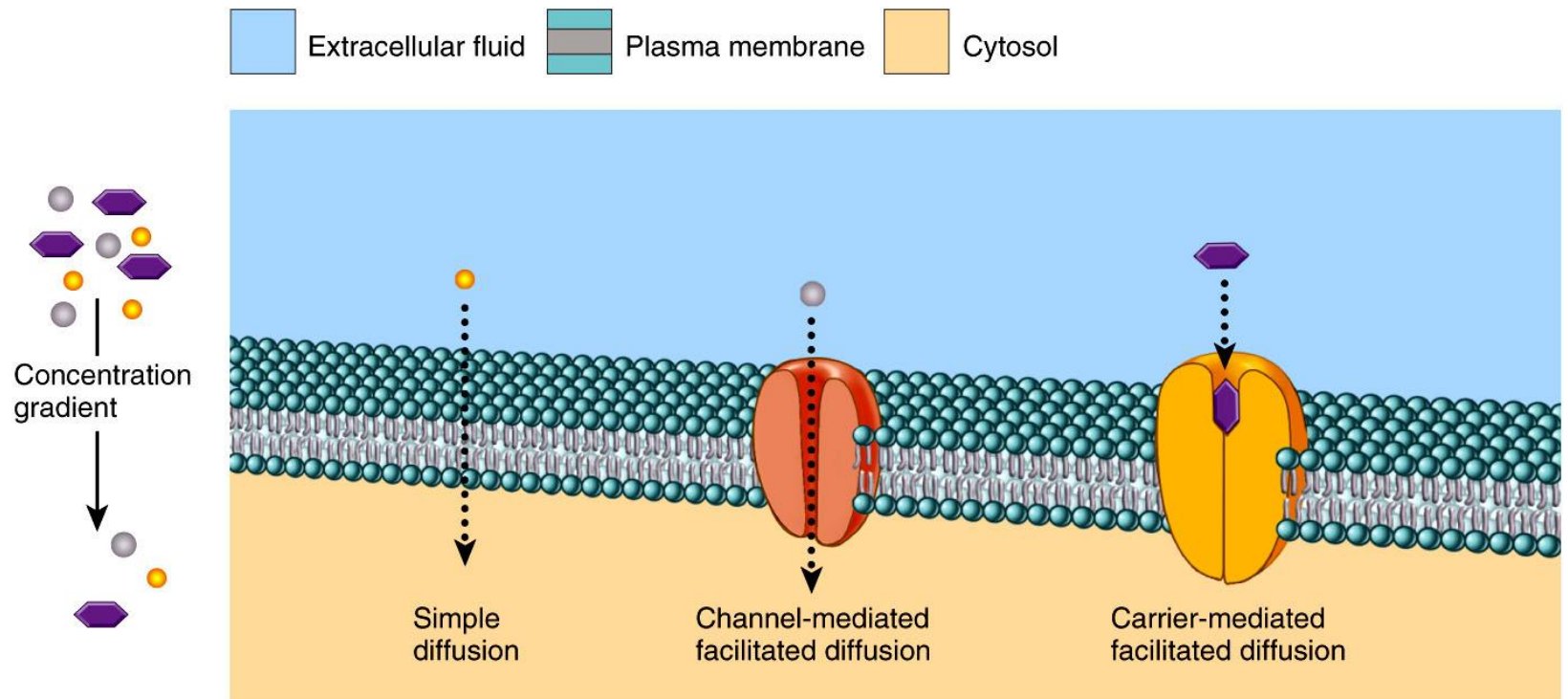
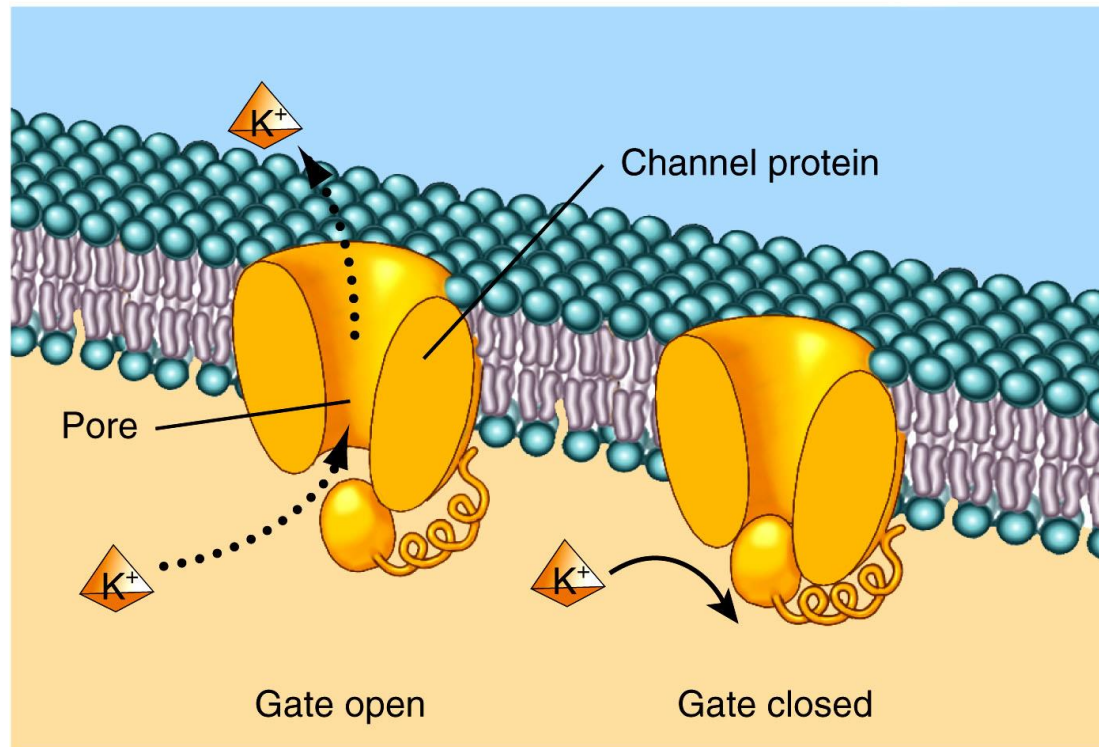
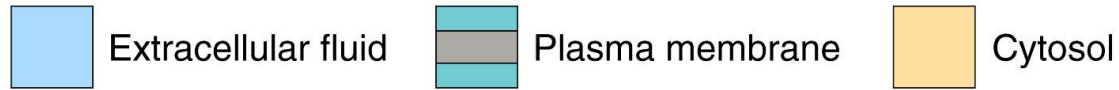
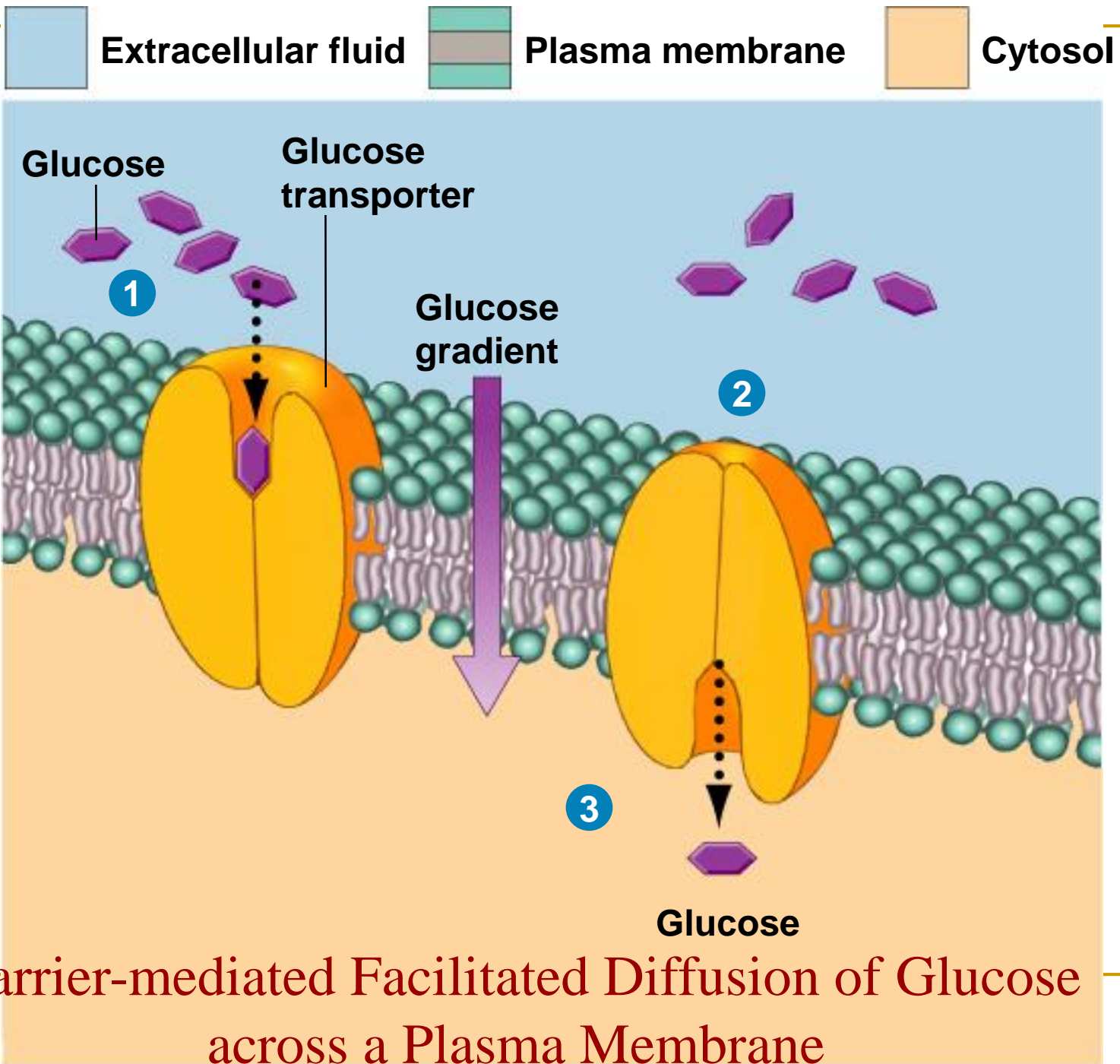


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Channel-mediated Facilitated Diffusion of Potassium ions through a Gated K^+ Channel



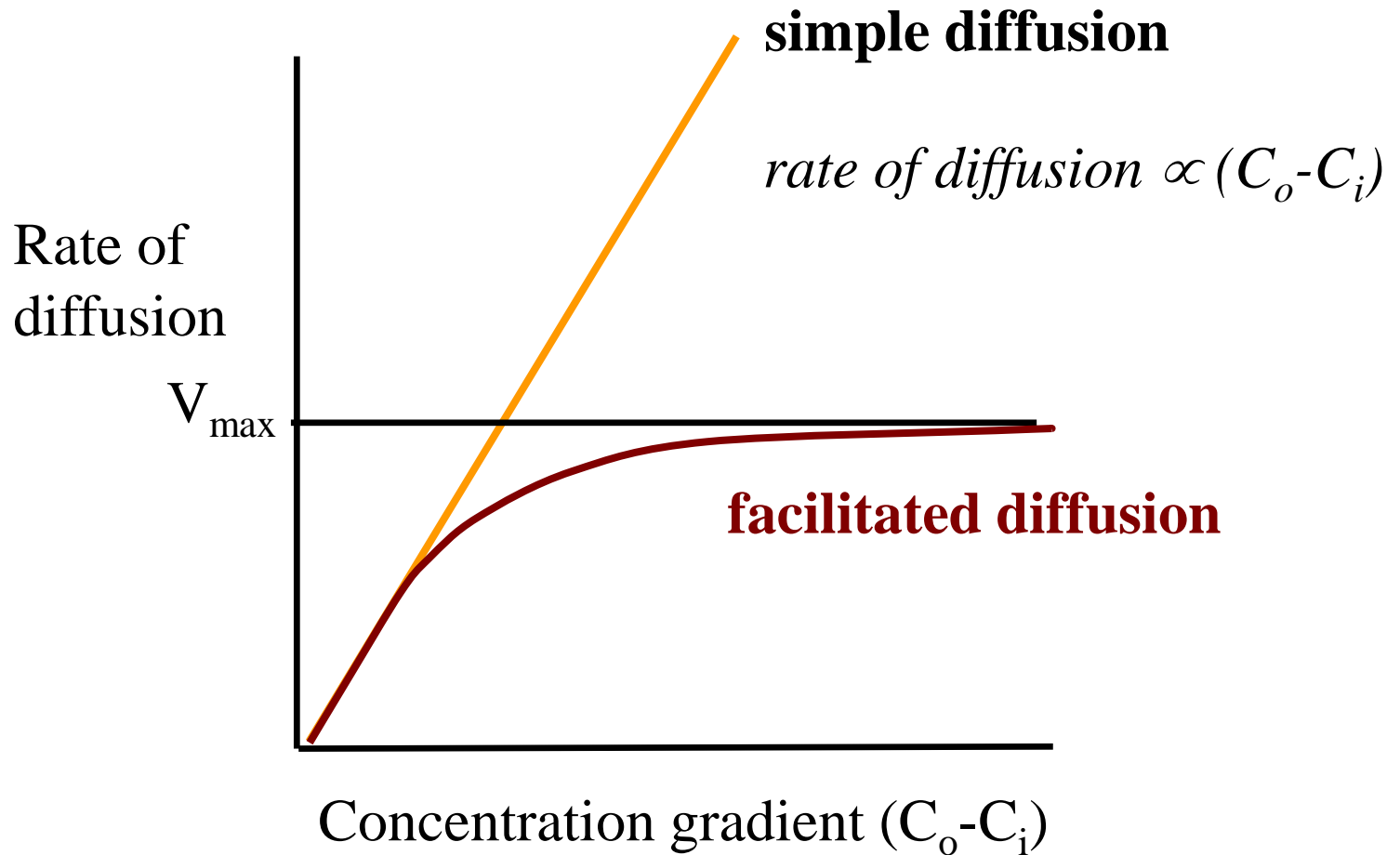
Details of the K^+ channel



Carrier-mediated Facilitated Diffusion of Glucose across a Plasma Membrane

Simple diffusion

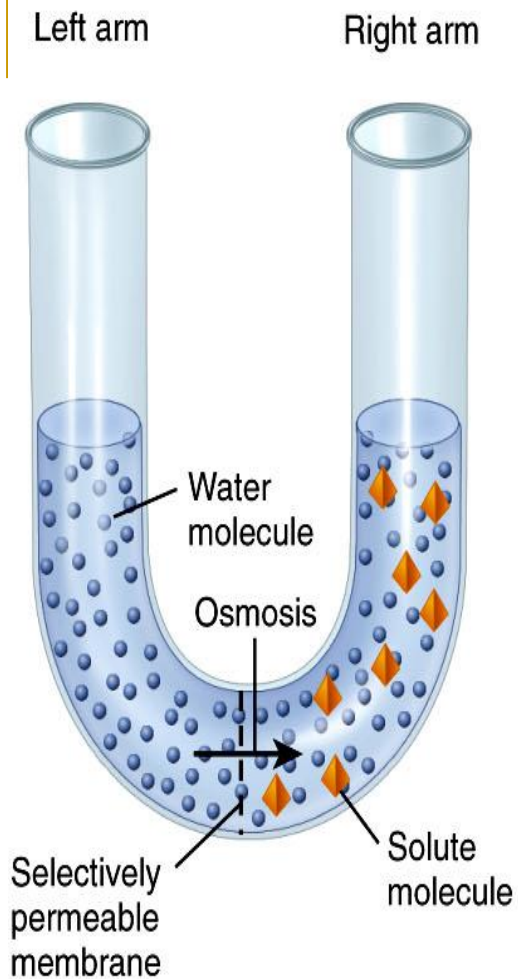
- Diffusion rate is directly proportional to the concentration gradients and solubility in lipids. It is inversely proportional to the square root of the molecular weight and thickness of the membrane.
 - Facilitated diffusion is saturable because the binding sites are limited and has transport maximum
-



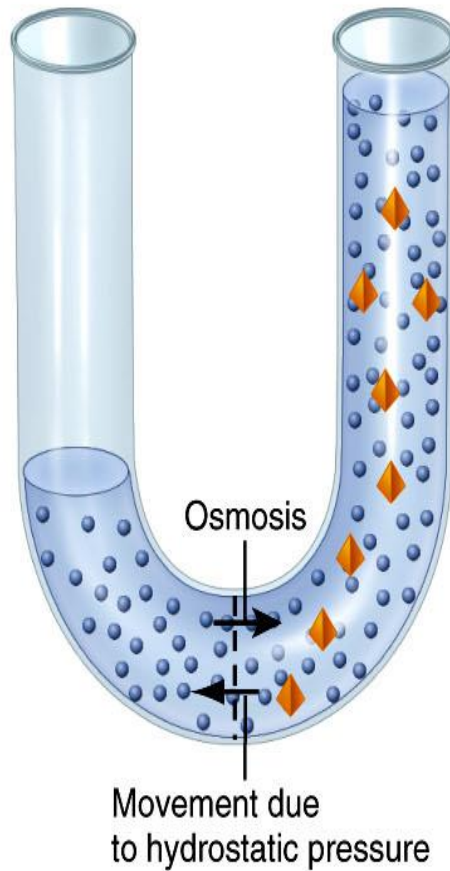
What limits maximum rate of facilitated diffusion?

Osmosis

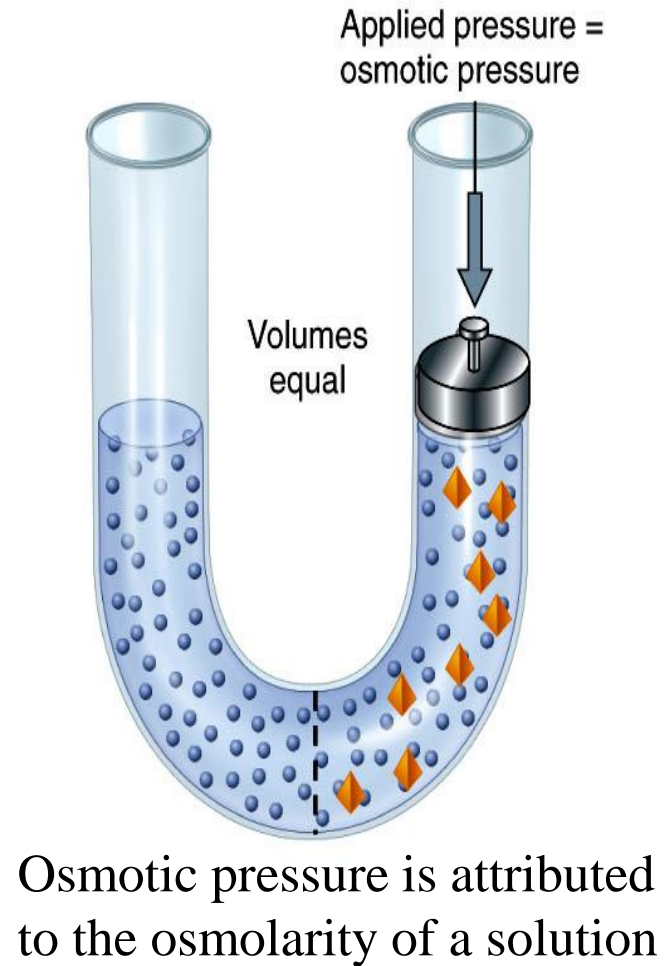
- Net movement of water through a selectively permeable membrane from an area of high concentration of water (lower concentration of solutes) to one of lower concentration of water
 - Water can pass through plasma membrane in 2 ways:
 1. through lipid bilayer by simple diffusion
 2. through aquaporins, integral membrane proteins
-



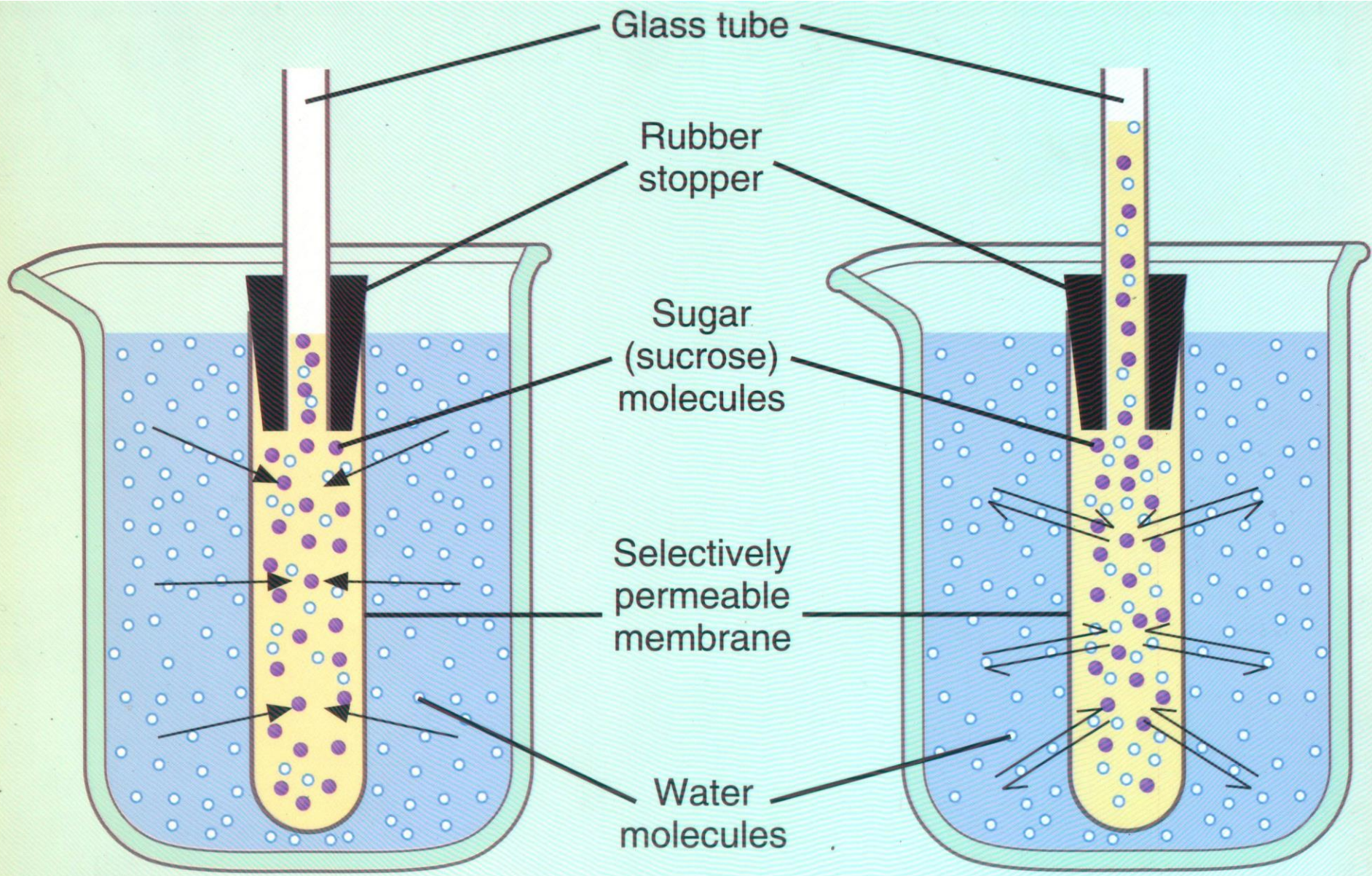
(a) Starting conditions



(b) Equilibrium

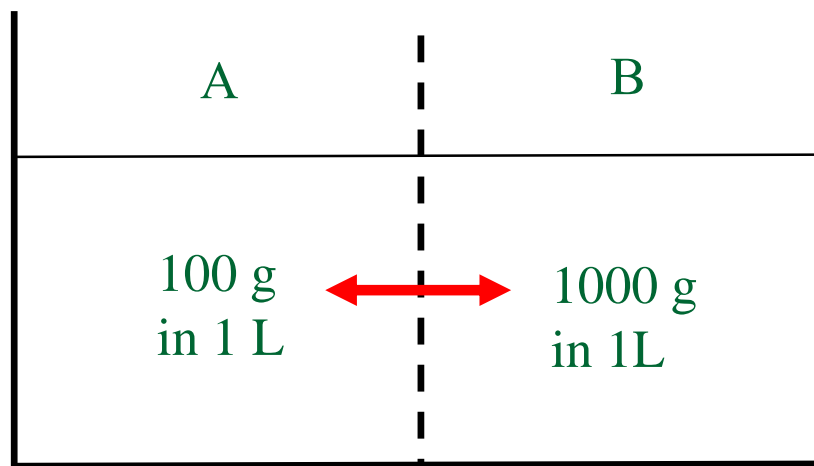


(c) Restoring starting conditions



(a) At start of experiment

(b) At equilibrium



Solute A
Mw = 100

Solute B
Mw = 1000

Which solution has the greatest osmolarity?

Which has the greatest molar concn?

Which has the greatest number of molecules?

(6.02×10^{23} particles)

Relation between osmolarity and molarity

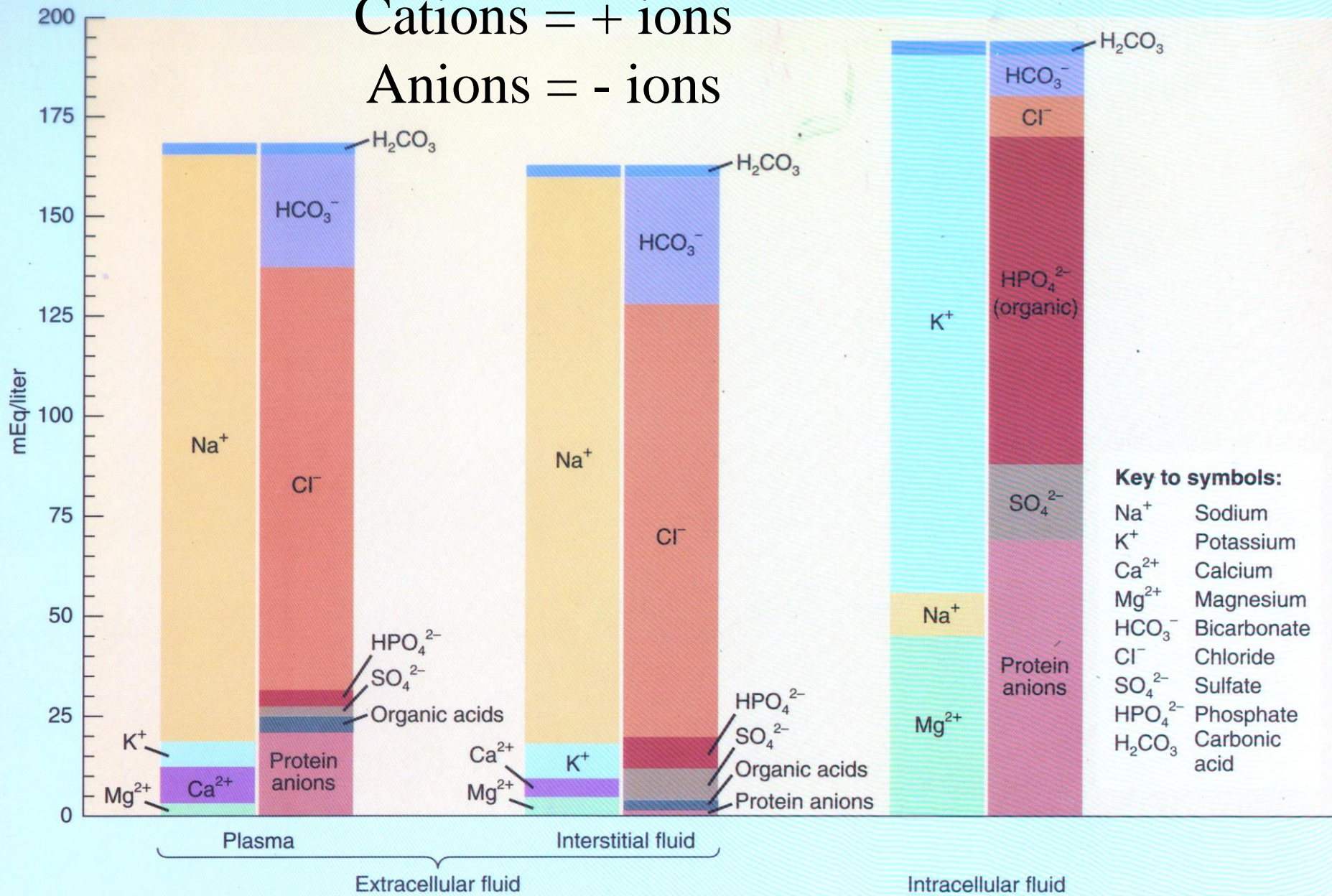
mOsm (millisomolar) = index of the concn
or mOsm/L of **particles** per liter soln

mM (millimolar) = index of concn of
or mM/L **molecules** per liter soln

150 mM NaCl = 300 mOsm

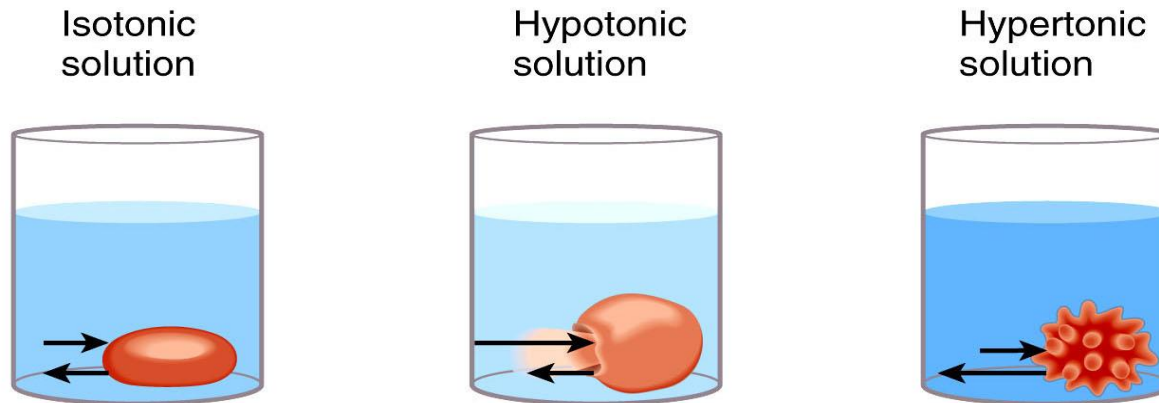
300 mM glucose = 300 mOsm

Cations = + ions
Anions = - ions

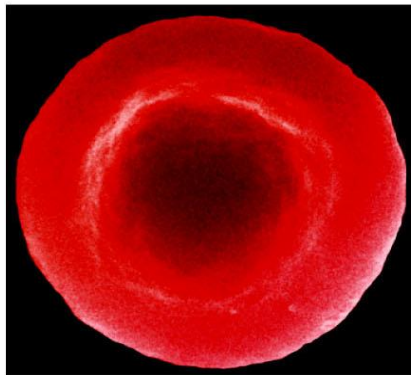


Comparison of Electrolyte and Protein Anion Concentrations in the Body Fluid Compartments,

Tonicity and its effect on RBCs



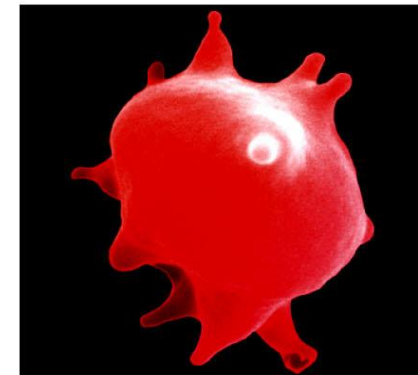
(a) Illustrations showing direction of water movement



Normal RBC shape



RBC undergoes hemolysis



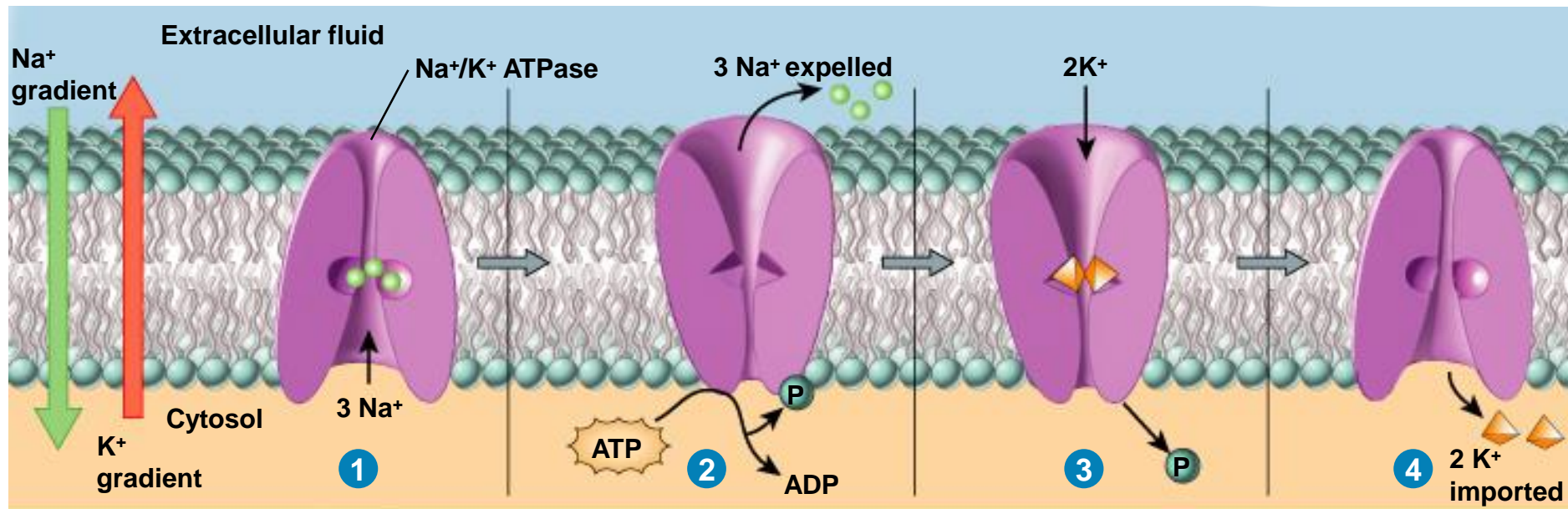
SEM

RBC undergoes crenation

(b) Scanning electron micrographs (all 15,000x)

Active Transport

Solute are transported across plasma membranes with the use of energy, from an area of lower concentration to an area of higher Concentration Sodium-potassium pump



Active Transport

Primary Active Transport

- Molecules are “pumped” against a concentration gradient at the expense of energy (ATP)
 - *direct use of energy*

Secondary Active Transport

- Transport is driven by the energy stored in the concentration gradient of another molecule (Na⁺)
 - *indirect use of energy*
-

Saturation

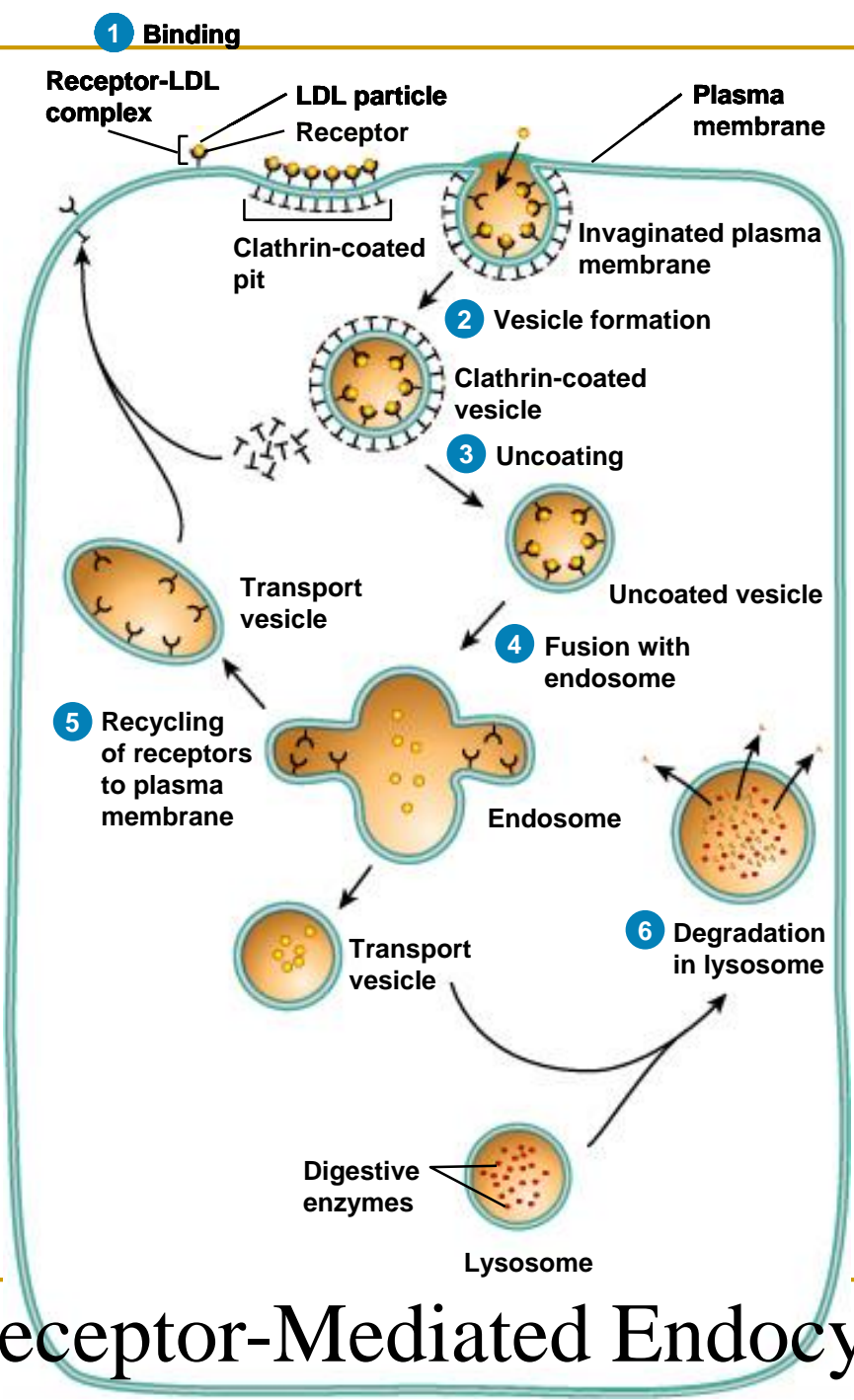
- Similar to facilitated diffusion
- Rate limited by V_{\max} of the transporters

Energetics

- Up to **90%** of cell energy expended for active transport!
-

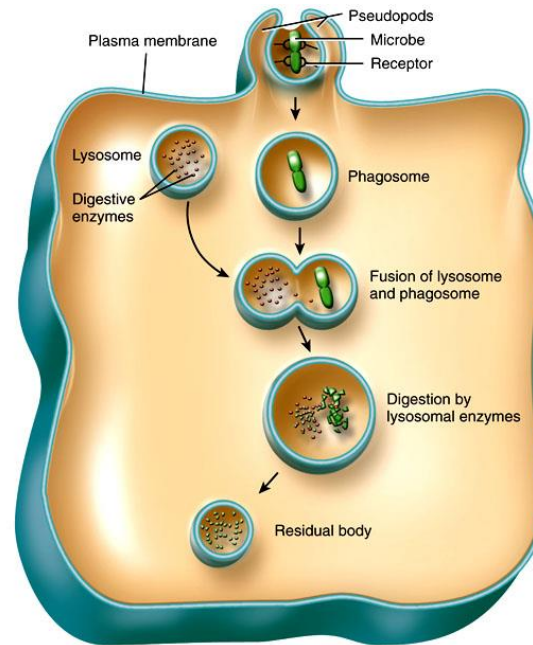
Transport in Vesicles

- **Vesicle** - a small spherical sac formed by budding off from a membrane
 - **Endocytosis** - materials move into a cell in a **vesicle** formed from the plasma membrane
 - three types: receptor-mediated endocytosis
 - phagocytosis
 - bulk-phase endocytosis (pinocytosis)
 - **Exocytosis** - vesicles fuse with the plasma membrane, releasing their contents into the extracellular fluid
 - **Transcytosis** - a combination of endocytosis and exocytosis
-

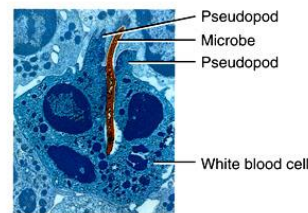


Receptor-Mediated Endocytosis

Phagocytosis

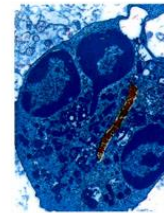


(a) Diagram of the process



TEM about 3700x

(b) White blood cell engulfs microbe



TEM about 3700x

(c) White blood cell destroys microbe

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Bulk-phase Endocytosis

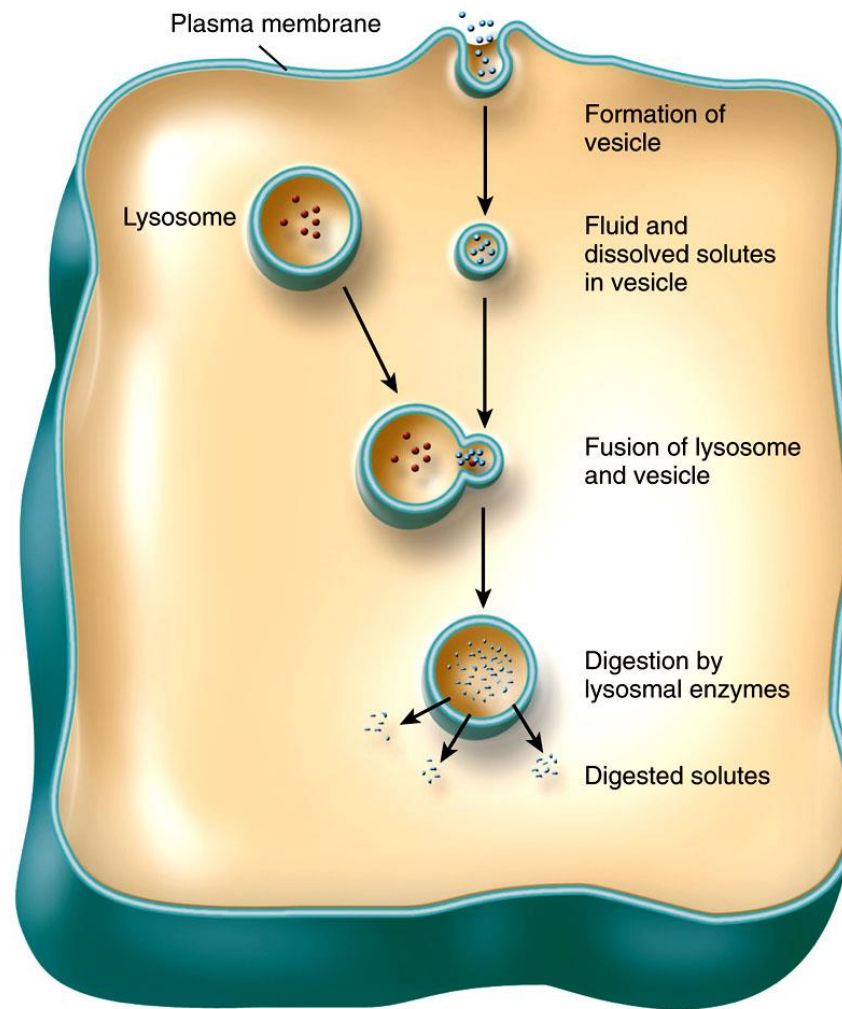
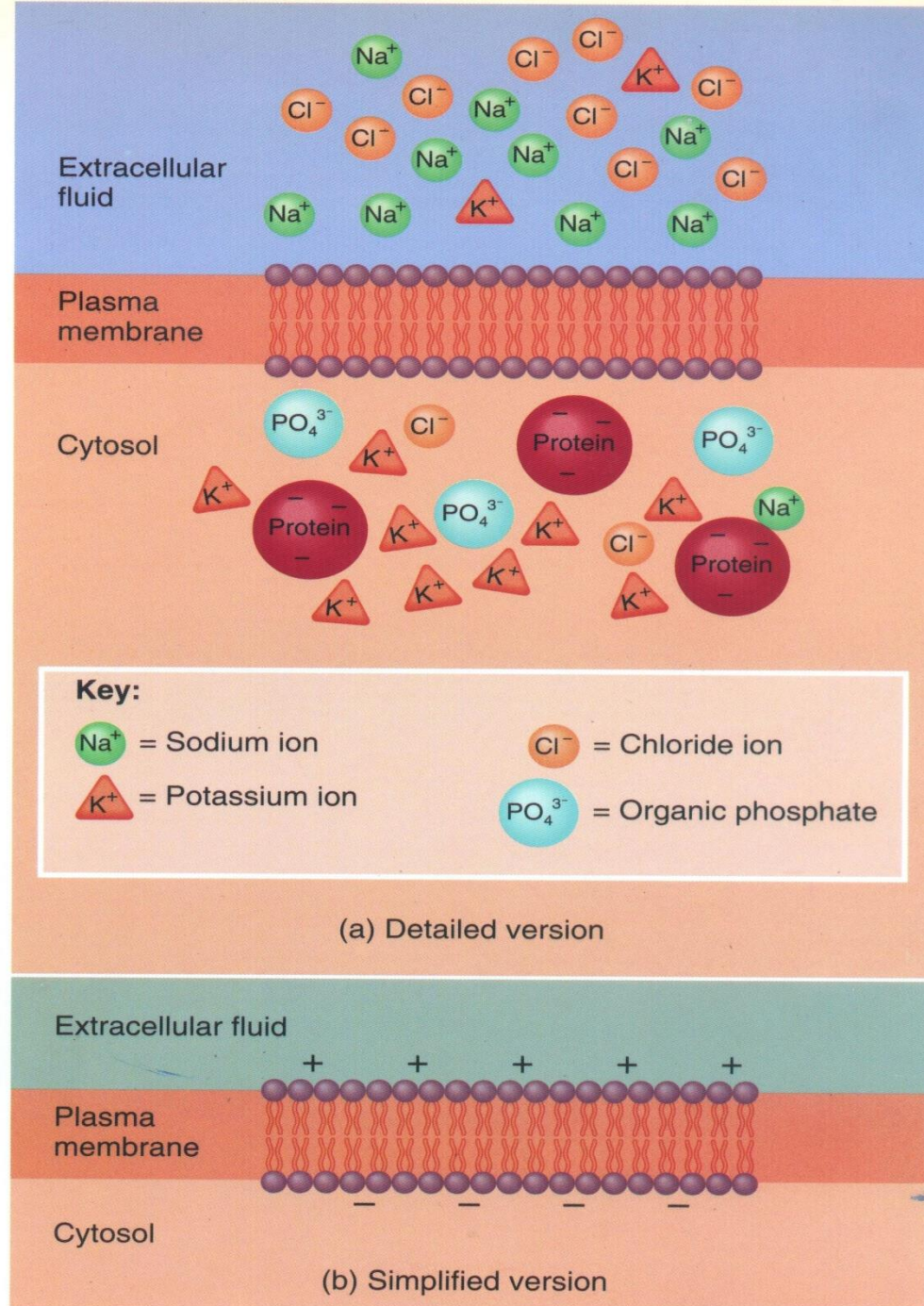


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Resting Membrane Potential and polarization of cell membranes



Thank You