MEDICAL UNIVERSITY – PLEVEN
FACULTY OF MEDICINE
DISTANCE LEARNING CENTER

Lecture № 1

Introduction to Physiology. Principles of control and regulation in the human body. Homeostasis. Function of the cell membrane. Transport through the cell membrane - passive and active transport. Transport through cellular sheets

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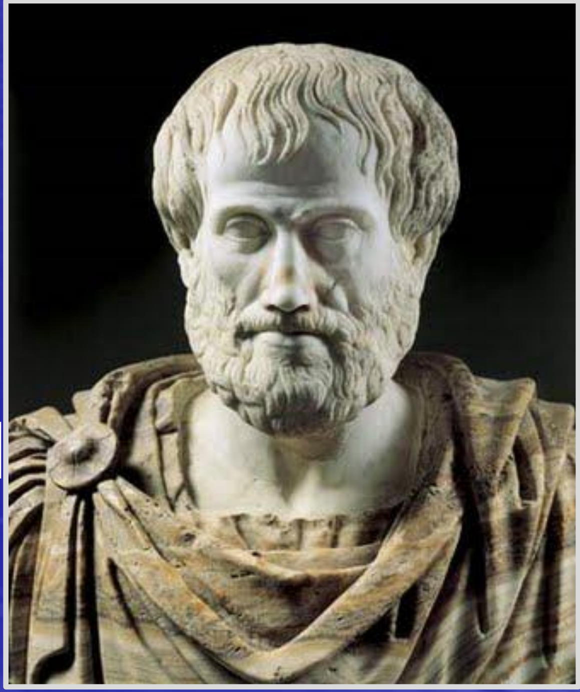
- **Physiology** from Ancient Greek *(physis)*, meaning "nature, origin", and *(-logia)*, meaning "study of", is the scientific study of function in living systems. This includes how organisms, organ systems, organs, cells, and bio-molecules carry out the chemical or physical functions that exist in a living system.

- **Human physiology** is the science of the mechanical, physical, and biochemical functions of humans, their organs, and the cells of which they are composed.

- The principal level of focus of physiology is at the level of organs and systems within systems. Much of the foundation of knowledge in human physiology was provided by animal experimentation.
- Physiology is closely related to anatomy; anatomy is the study of form, and physiology is the study of function. Due to the frequent connection between form and function, physiology and anatomy are intrinsically linked and are studied in tandem as part of a medical curriculum.

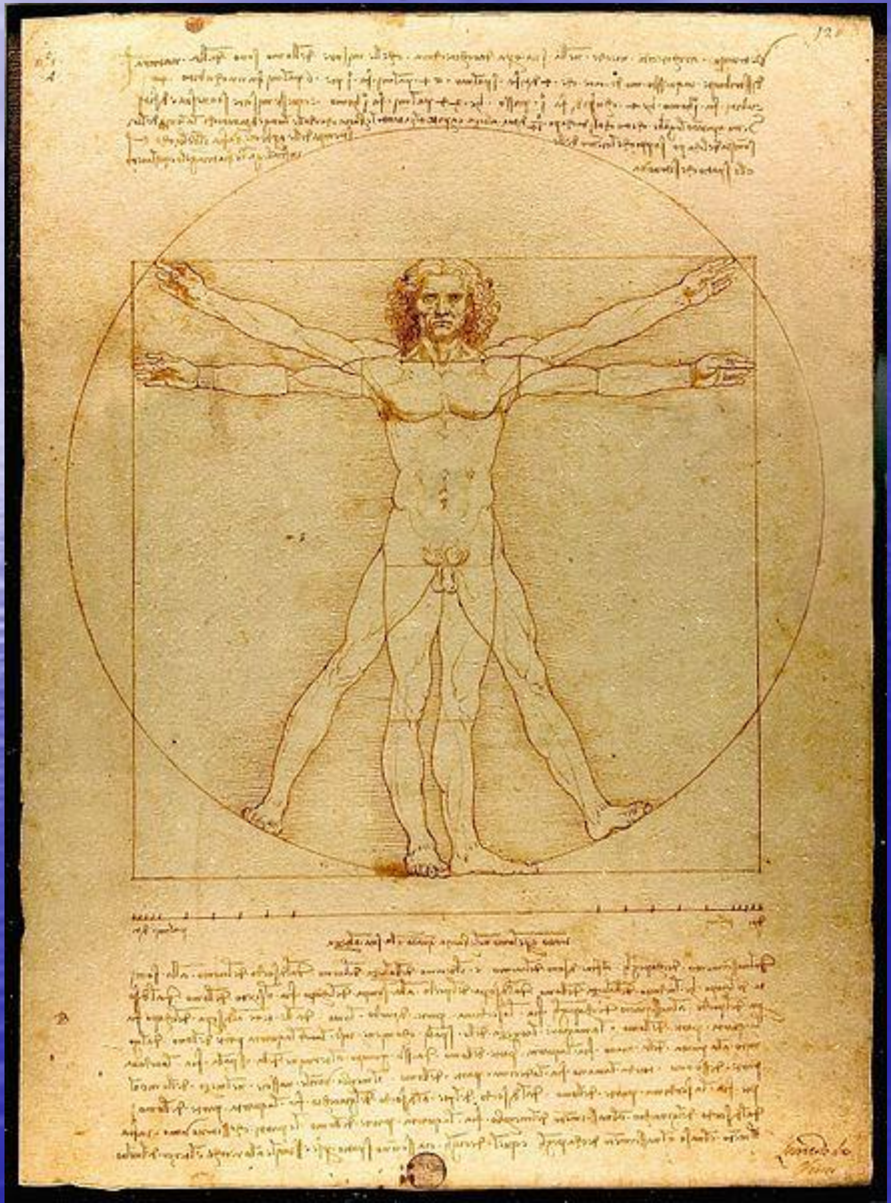
- The study of human physiology dates back to at least 420 BC and the time of Hippocrates, also known as the father of medicine.

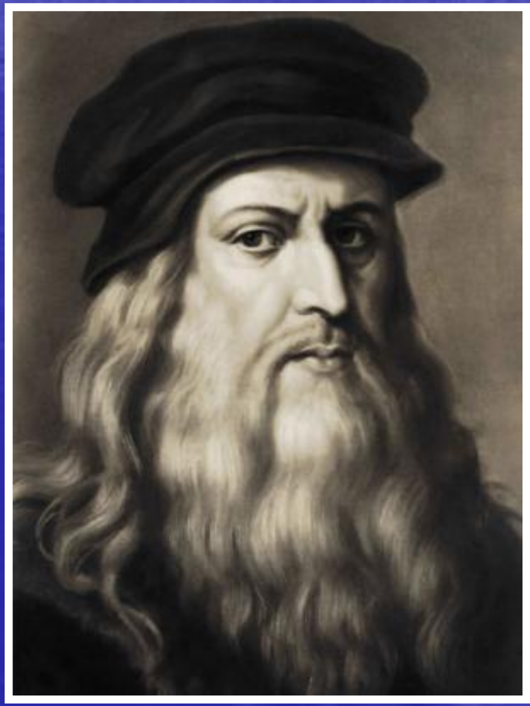


- The critical thinking of Aristotle and his emphasis on the relationship between structure and function marked the beginning of physiology in Ancient Greece.

- Claudius Galenus (c. 126–199 AD), known as Galen, was the first to use experiments to probe the function of the body.
- Galen was the founder of experimental physiology.

The Vitruvian Man is a world-renowned drawing created by Leonardo da Vinci c.1487.
It is one commonly associated with the science of physiology.





Jean Fernel, a French physician, introduced the term "physiology" in 1525.

- In the 19th century, physiological knowledge began to accumulate at a rapid rate, in particular with the 1838 appearance of the Cell theory of Matthias Schleiden and Theodor Schwann. It radically stated that organisms are made up of units called cells.
- Claude Bernard's (1813–1878) further discoveries ultimately led to his concept of *milieu interieur* (internal environment), which would later be taken up and championed as "homeostasis" by American physiologist Walter Cannon (1871–1945).

- In the 20th century, biologists also became interested in how organisms other than human beings function, eventually spawning the fields of comparative physiology and ecophysiology. Major figures in these fields include Knut Schmidt-Nielsen and George Bartholomew. Most recently, evolutionary physiology has become a distinct subdiscipline.

- **The highest honor awarded in physiology is the Nobel Prize in Physiology or Medicine, awarded since 1901 by the Royal Swedish Academy of Sciences.**

- The Nobel Prize in Physiology or Medicine **2016** was awarded to Yoshinori Ohsumi *"for his discoveries of mechanisms for autophagy"*.

Nobel Prize in Physiology or Medicine

- The Nobel Prize in Physiology or Medicine **2014** was divided, one half awarded to John O'Keefe, the other half jointly to May-Britt Moser and Edvard I. Moser *"for their discoveries of cells that constitute a positioning system in the brain"*.

- **The 2013 Nobel Prize in Physiology or Medicine** *was awarded* jointly to James E. Rothman, Randy W. Schekman and Thomas C. Südhof “for their discoveries of machinery regulating vesicle traffic, a major transport system in our cells”

- ***The Nobel Prize in Physiology or Medicine 2004*** *was awarded jointly to Richard Axel and Linda B. Buck "for their discoveries of odorant receptors and the organization of the olfactory system"*

Nobel Prize in Physiology or Medicine

- ***The Nobel Prize in Physiology or Medicine 1998*** *was awarded jointly to Robert F.Furchgott, Louis J. Ignarro and Ferid Murad "for their discoveries concerning nitric oxide as a signalling molecule in the cardiovascular system".*
- ***The Nobel Prize in Physiology or Medicine 1981*** *Roger W. Sperry "for his discoveries concerning the functional specialization of the cerebral hemispheres"*
- ***The Nobel Prize in Physiology or Medicine 1981*** *- David H. Hubel and Torsten N. Wiesel "for their discoveries concerning information processing in the visual system"*
- **The Nobel Prize in Physiology or Medicine 1936** - **Sir Henry Hallett Dale** and **Otto Loewi**

"for their discoveries relating to chemical transmission of nerve impulses"

Human homeostasis

- **Human homeostasis** is derived from the Greek, homeo or "constant", and stasis or "stable" and means remaining stable or remaining the same.

- The human body manages a multitude of highly complex interactions to maintain balance or return systems to functioning within a normal range.
- These interactions within the body facilitate compensatory changes supportive of physical and psychological functioning.
- This process is essential to the survival of the person and to our species.

- Cells are the living units of the body. Each organ is an aggregate of many cells held together by intercellular supporting structures.
- The entire body contains about 75 to 100 trillion cells, each of which is adapted to perform special functions.
- These individual cell functions are coordinated by multiple regulatory systems operating in cells, tissues, organs, and organ systems.
- Essentially all of the organs and tissues of the body perform functions that help maintain the constituents of the extracellular fluid relatively constant.

Human homeostasis

- The liver, the kidneys, the brain (hypothalamus, the autonomic nervous system), and the endocrine system) help maintain homeostasis.
  - The liver is responsible for metabolizing toxic substances and maintaining carbohydrate metabolism.
  - The kidneys are responsible for regulating blood water levels, re-absorption of substances into the blood, maintenance of salt levels in the blood, control of blood pressure, regulation of blood pH, and excretion of urea and other wastes.
- An inability to maintain homeostasis may lead to death or a disease, a condition known as *homeostatic imbalance*.

Principles of control and regulation in the human body

- The human body has thousands of control systems that are essential for homeostasis.
- *Two types systems of regulation*:

❑ Opened - if between the output and input of a system has no connection.

❑ Closed - where information from the output of a system is returned to the input of the same system:

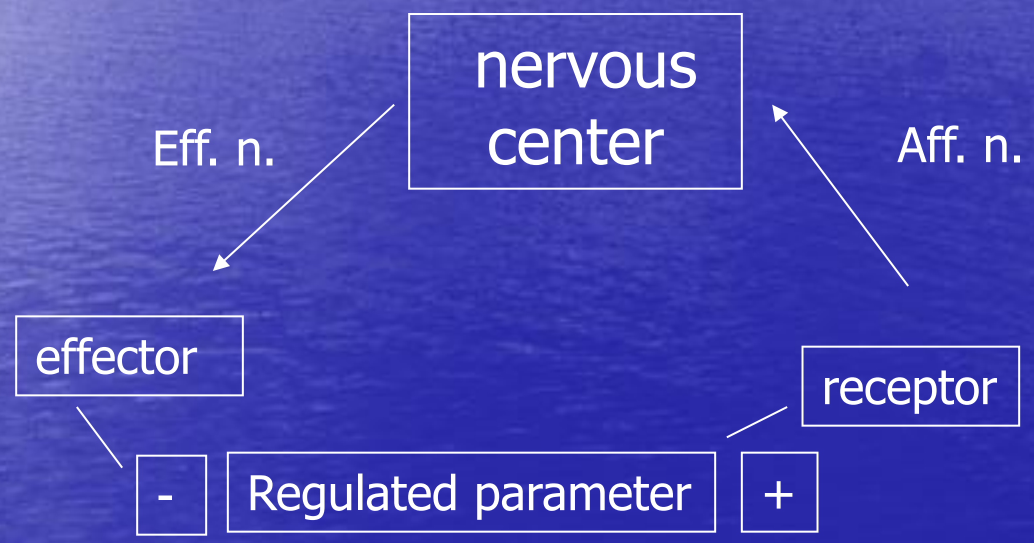
➢ negative feedback loop

➢ positive feedback loop

Principles of control and regulation in the human body

- A negative feedback loop is a type of self-regulating system where increased output *from* the system inhibits future production *by* the system. In other words, the system controls how much product it makes by shutting down manufacturing when levels of output or the amount of accumulated product gets too high.
- Negative feedback systems are responsible for many types of hormone regulation in the human body since they are good at maintaining relatively constant levels of output.

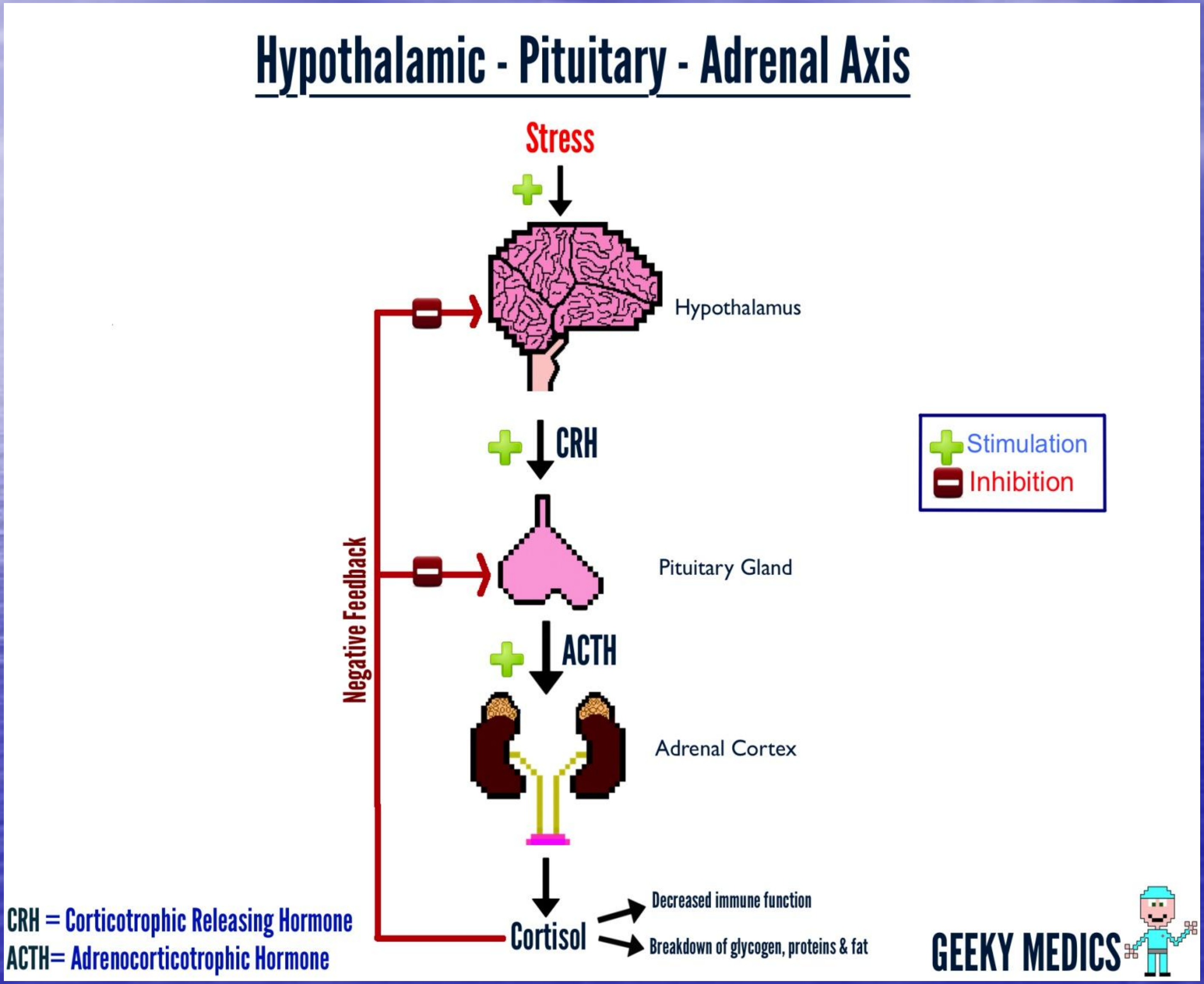
- Most Control Systems of the Body Operate by Negative Feedback.



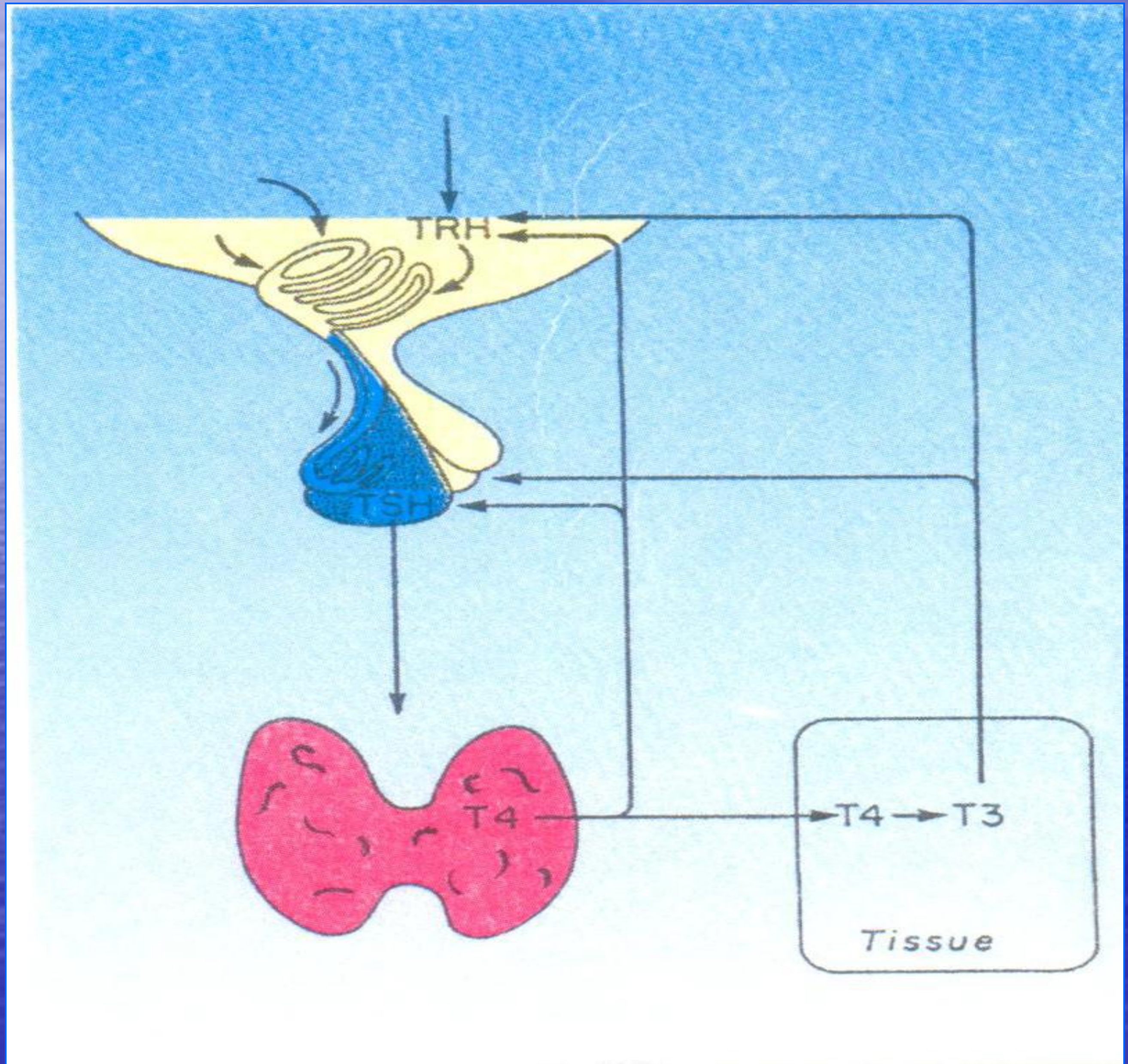
Scheme of negative feedback loop

- The degree of effectiveness with which a control system maintains constant conditions is determined by the gain of the negative feedback.
- The gain is calculated according to the following formula.
- Gain=Correction/Error
- Some control systems, such as those that regulate body temperature, have feedback gains as high as –33, which simply means that the degree of correction is 33 times greater than the remaining error.

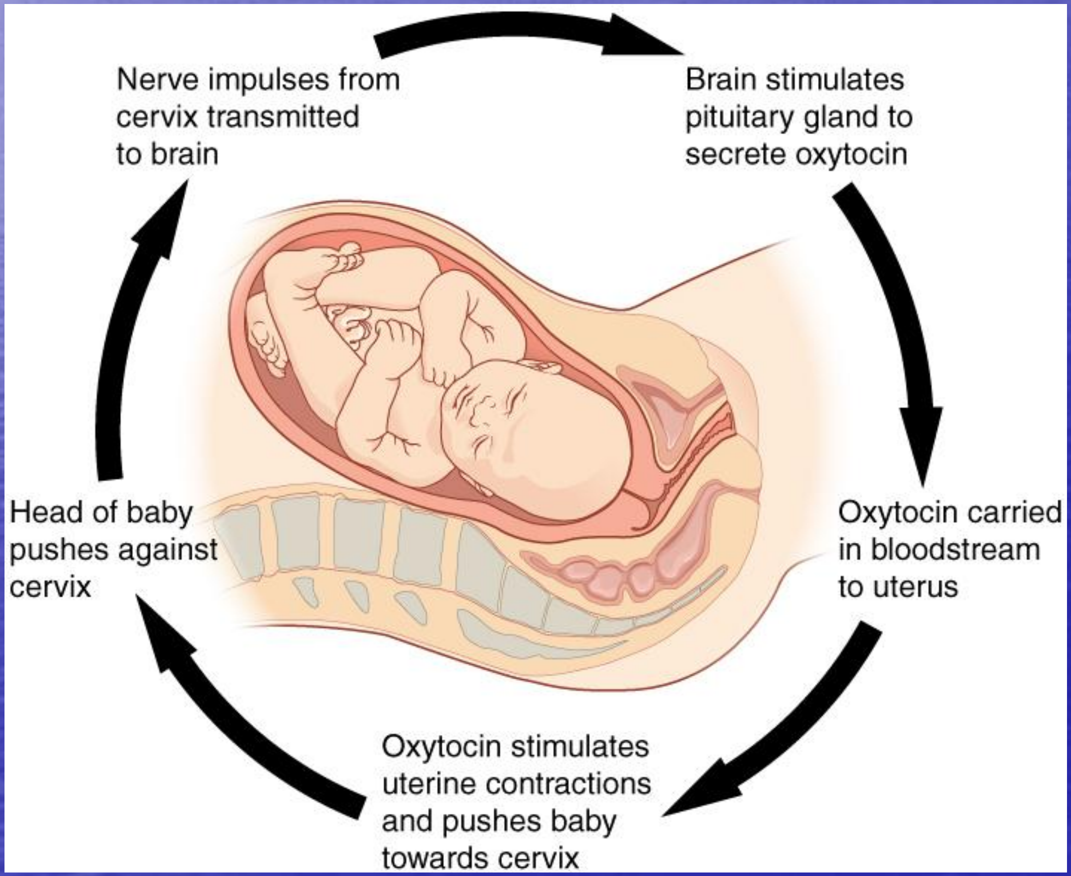
Control of adrenal cortex hormones secretion



Control of thyroid hormones secretion

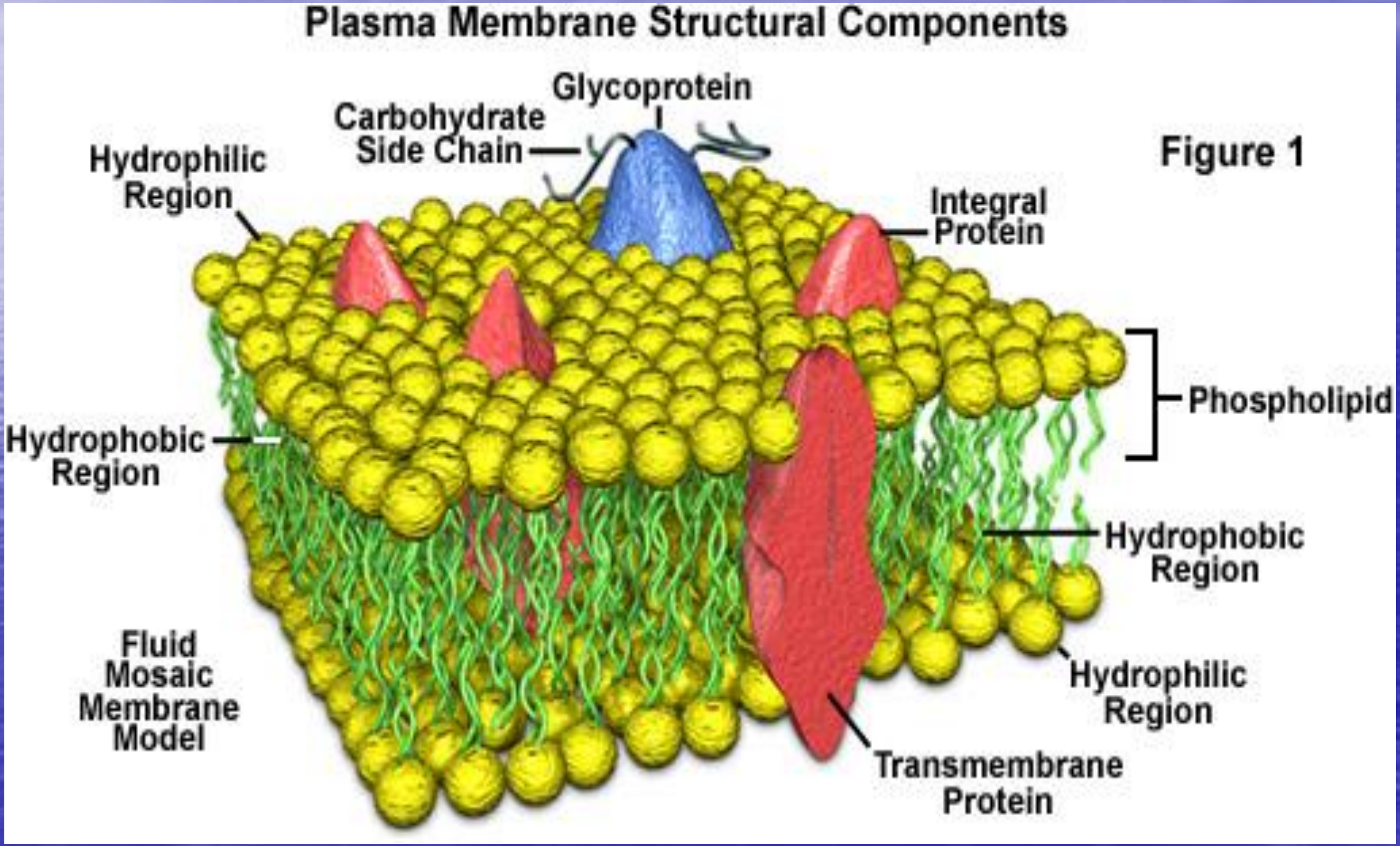


- A positive feedback is a process in which an initial change will bring about an additional change in the same direction.

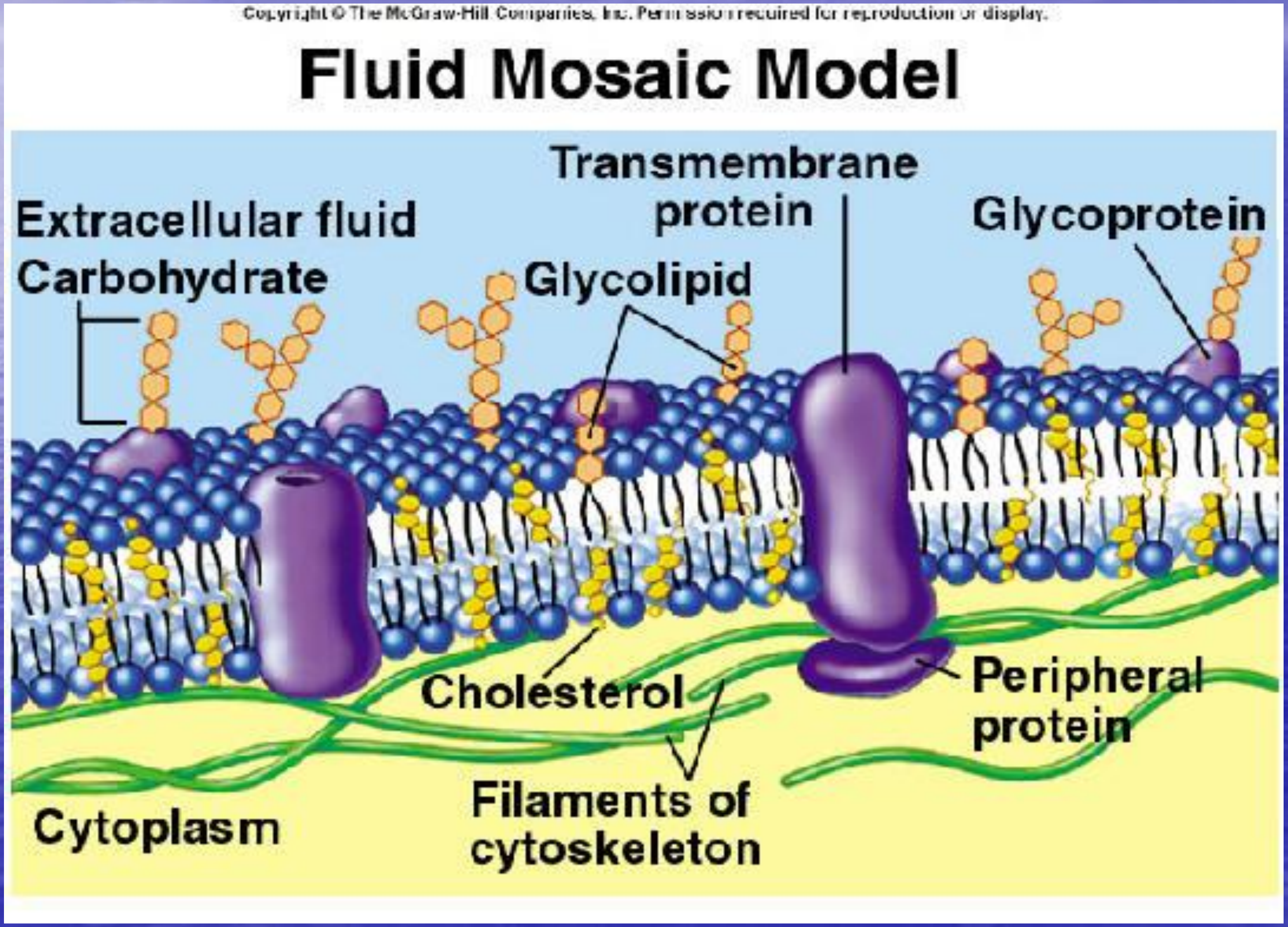


- Positive Feedback Can Sometimes Cause Vicious Cycles and Death, and Other Times Can Be Useful.
- A system that exhibits positive feedback responds to a perturbation with changes that amplify the perturbation and therefore leads to instability rather than stability.
- For example, severe hemorrhage may lower blood pressure to such a low level that blood flow to the heart is insufficient to maintain normal cardiac pumping; as a result, blood pressure falls even lower, further diminishing blood flow to the heart and causing still more weakness of the heart. Each cycle of this feedback leads to more of the same, which is a positive feedback or a vicious cycle.

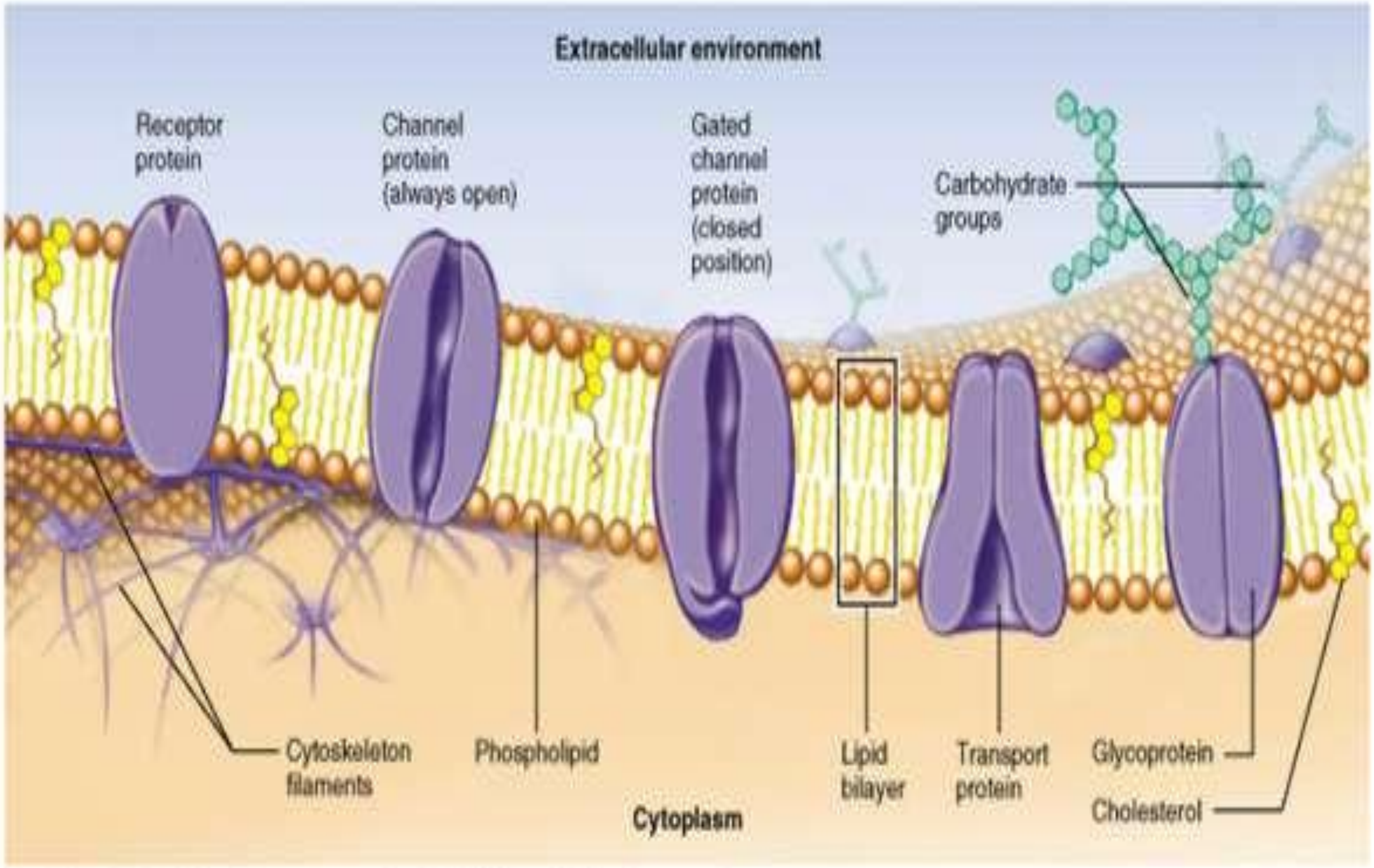
Cell membrane structure



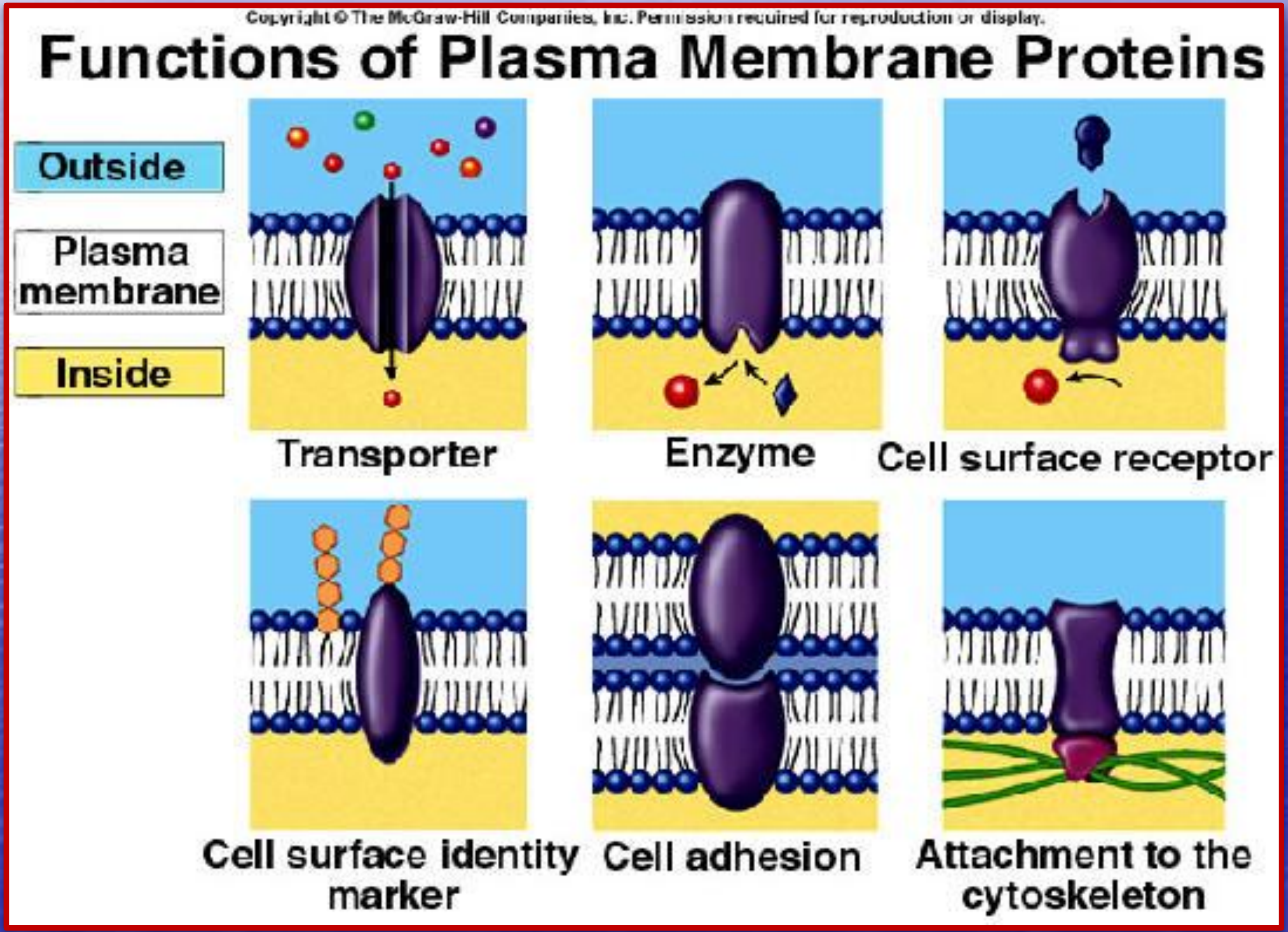
Cell membrane structure



Cell membrane structure



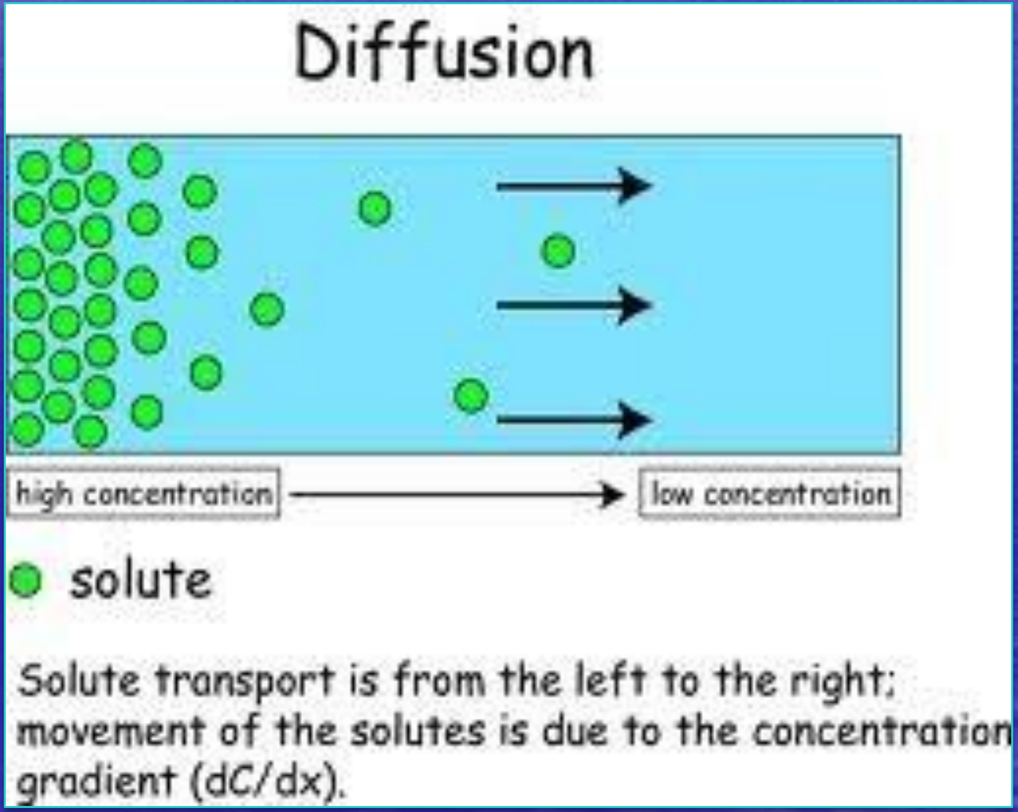
<u>Functions of proteins</u>: transport of ions and molecules; serve as enzymes; receptors for hormones & other substances; self-identity markers; cell to cell adhesion; attachment to internal cytoskeleton.



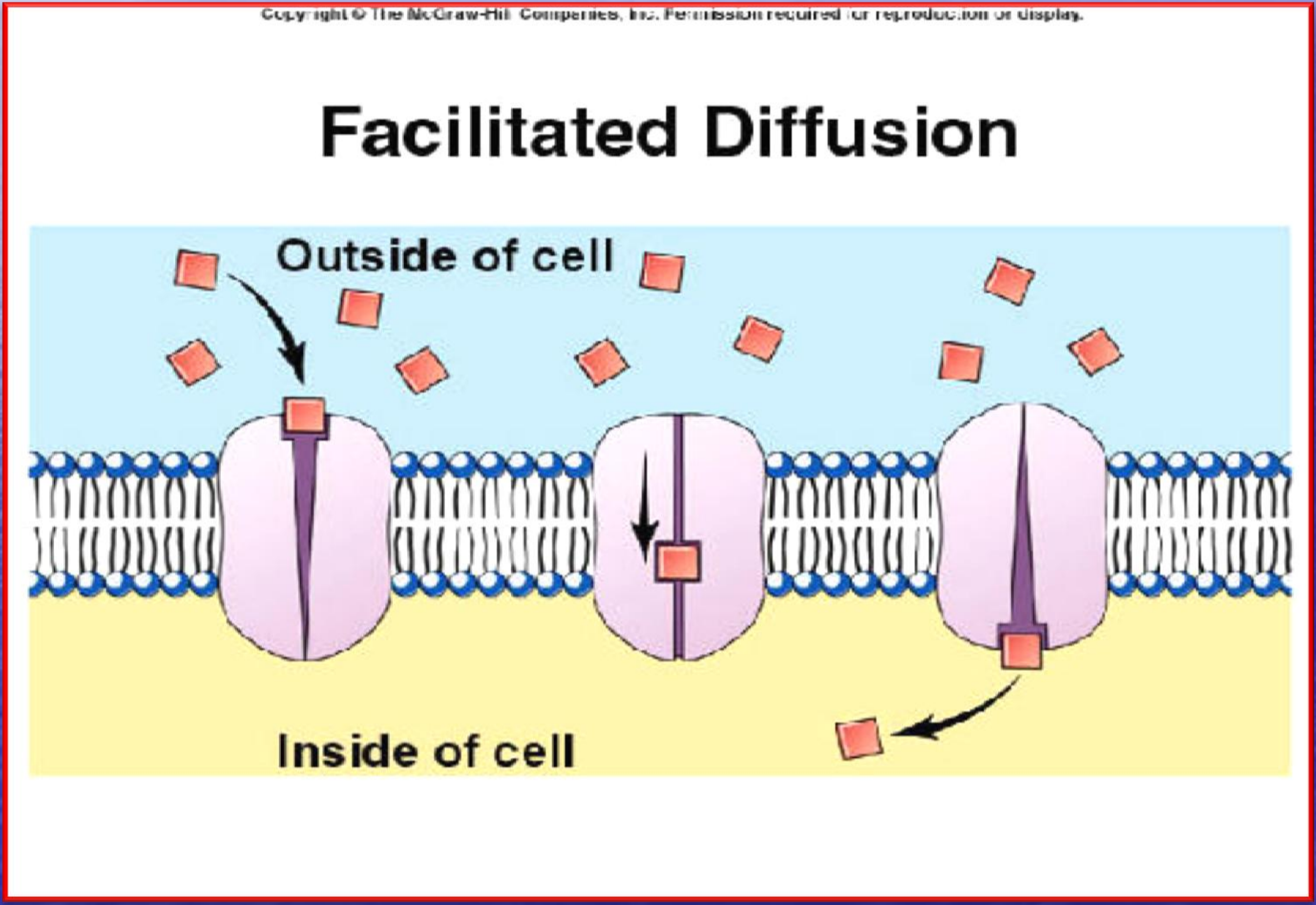
- **Passive transport: *Diffusion* - the movement of a substance from an area of high concentration to an area of lower concentration (a concentration gradient).**

- Factors on which the rate of diffusion depends:

  - *concentration gradient*
  - *permeability of membrane*
  - *distance*
  - *surface area*
  - *temperature*

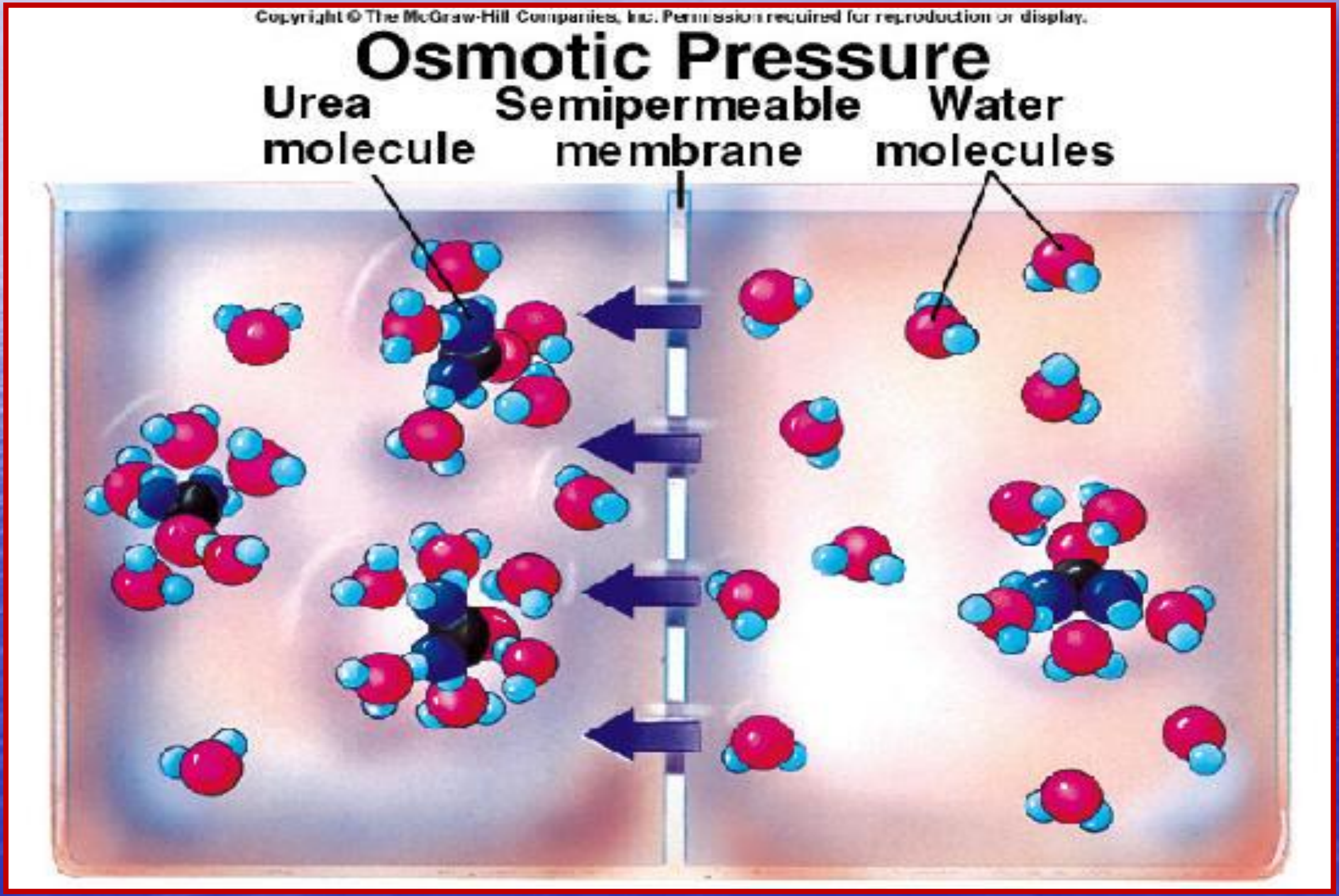


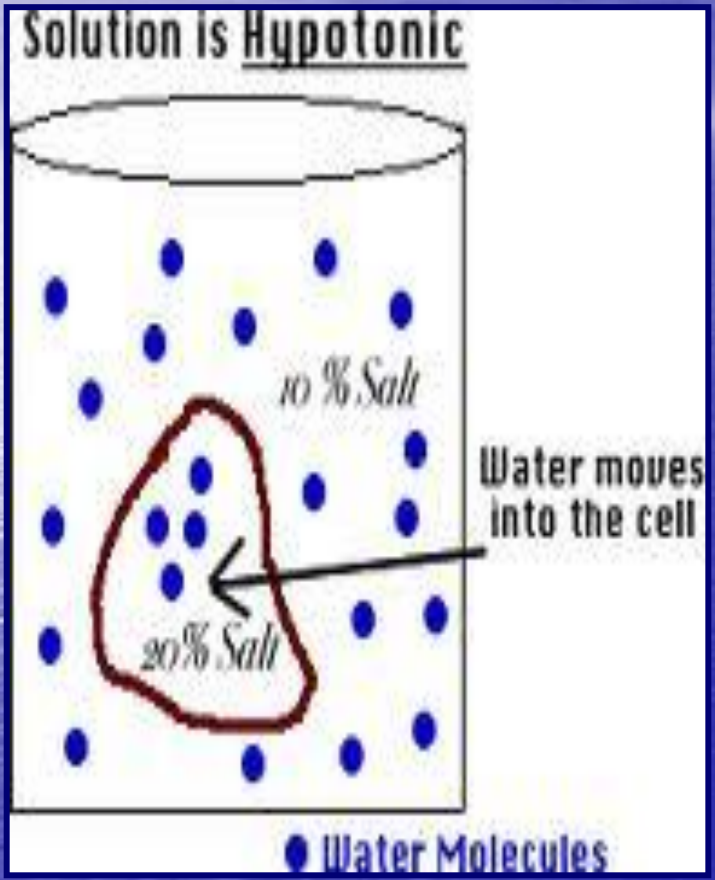
Facilitated diffusion - diffusion through carrier proteins within cell membranes.

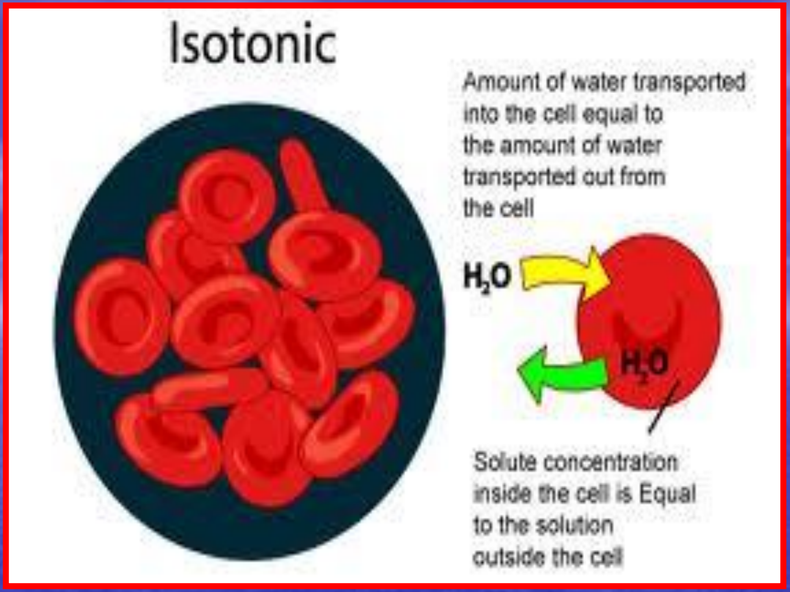


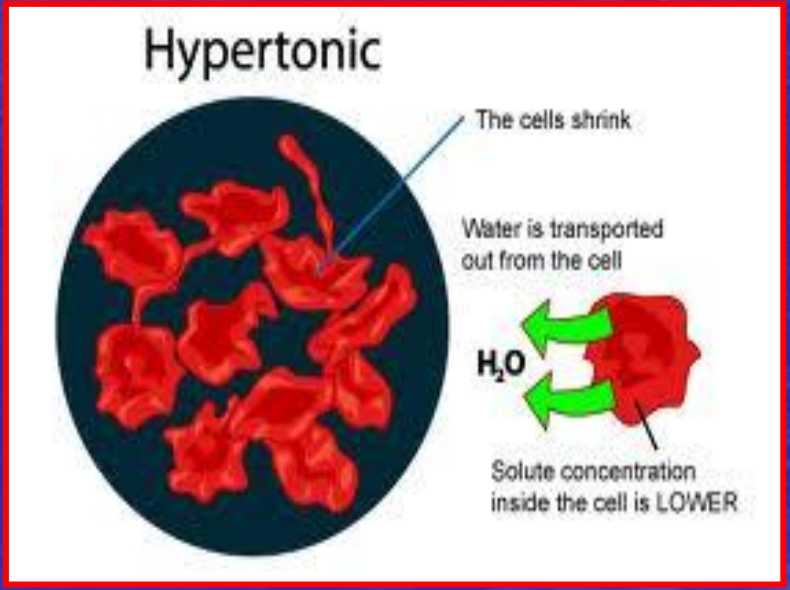
<u>Osmosis</u> - diffusion of water through a selectively permeable membrane.

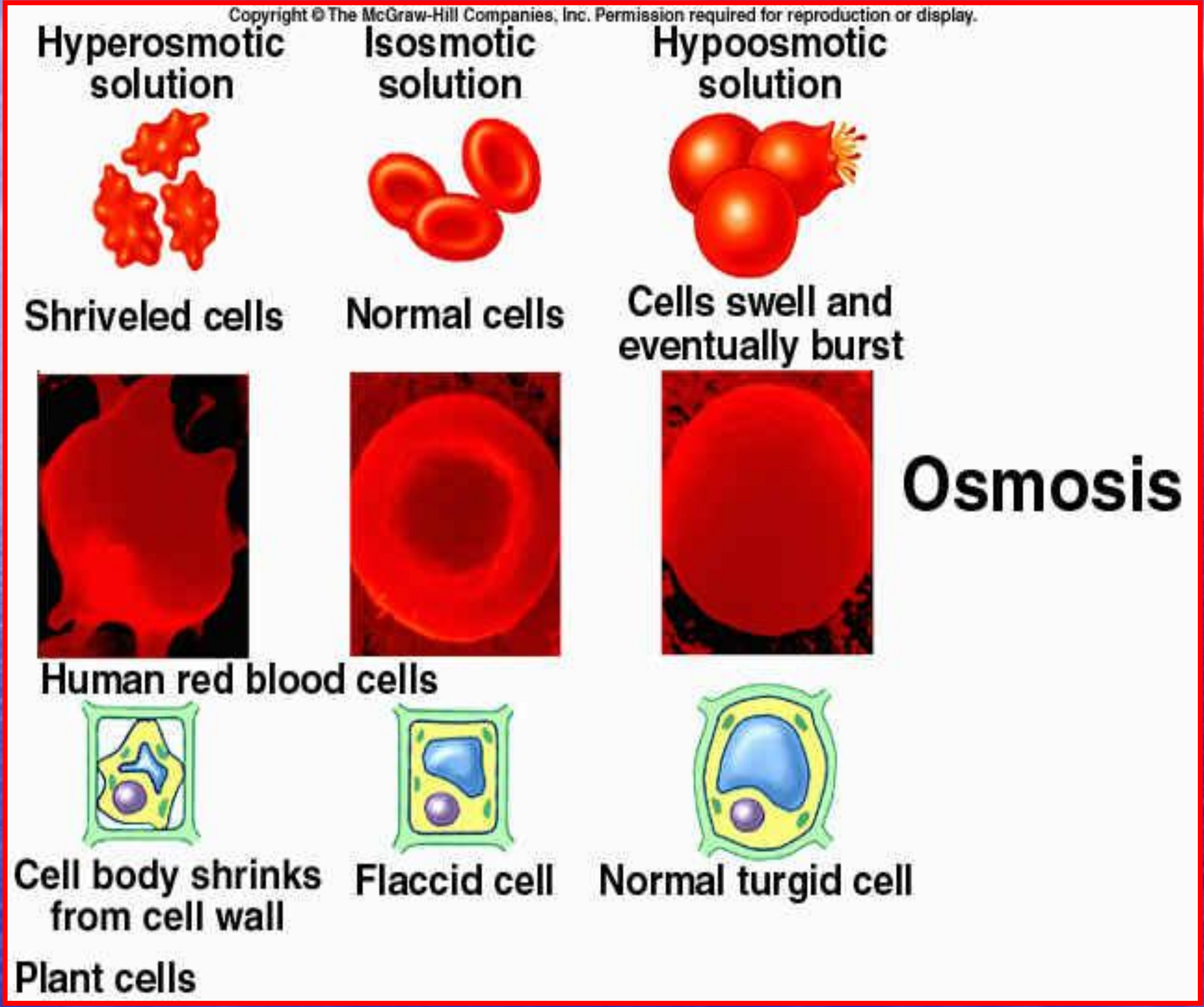
Osmotic pressure always moves water toward the hypertonic side (the side containing the least amount of water) of a membrane.




Solution is Hypotonic
10 % Salt
20% Salt
Water moves into the cell
Water Molecules


Isotonic
Amount of water transported into the cell equal to the amount of water transported out from the cell
H_2O
H_2O
Solute concentration inside the cell is Equal to the solution outside the cell


Hypertonic
The cells shrink
Water is transported out from the cell
H_2O
Solute concentration inside the cell is LOWER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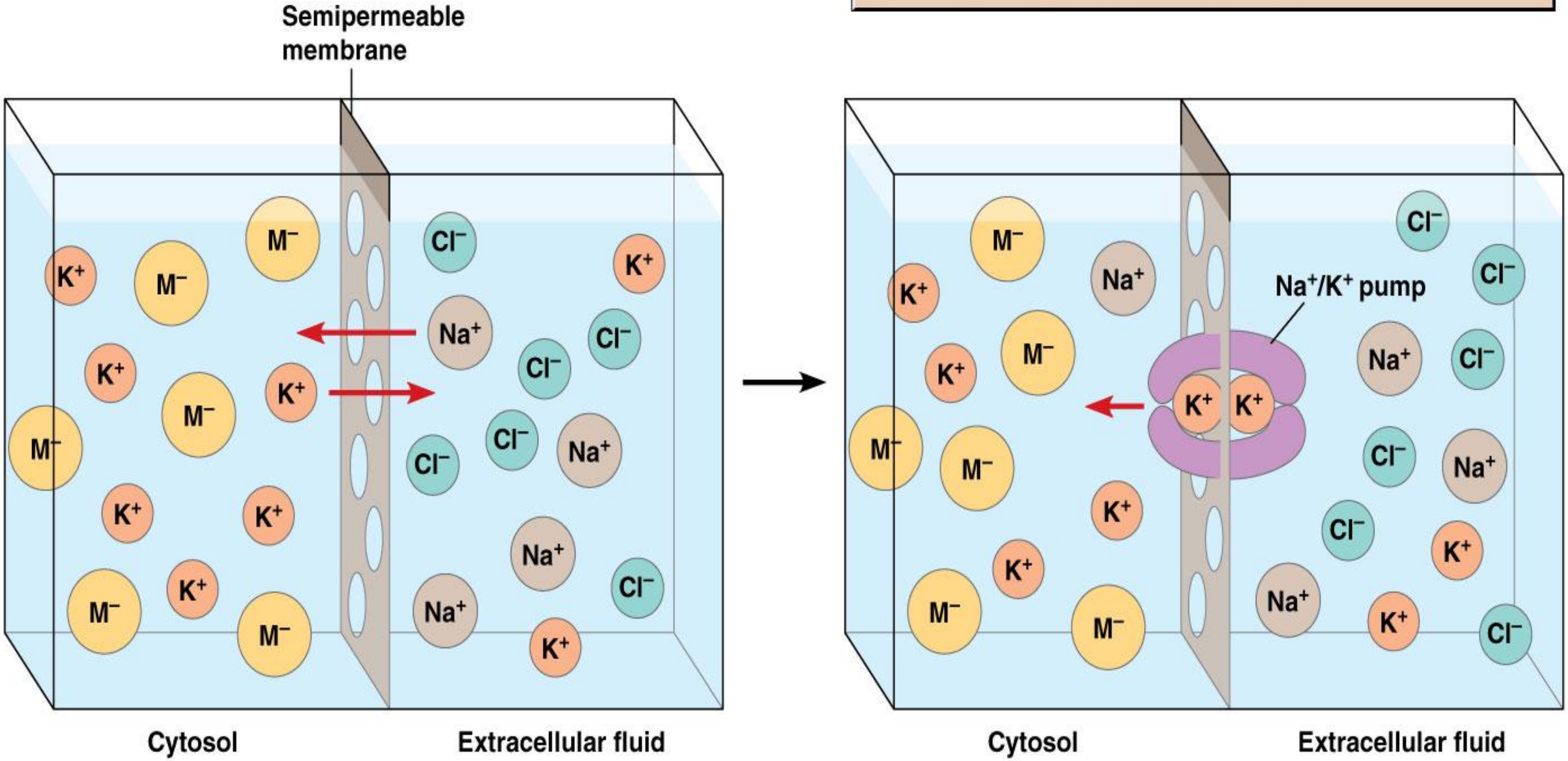
Hyperosmotic solution
Isosmotic solution
Hypoosmotic solution
Shriveled cells
Normal cells
Cells swell and eventually burst
Osmosis
Human red blood cells
Cell body shrinks from cell wall
Flaccid cell
Normal turgid cell
Plant cells

Table 54.1 The Ionic Composition of Cytoplasm and Extracellular Fluid (ECF)

Ion	Concentration in Cytoplasm (mM)	Concentration in ECF (mM)	Ratio	Equilibrium Potential (mV)
Na^+	15	150	10:1	+60
K^+	150	5	1:30	–90
Cl^-	7	110	15:1	–70

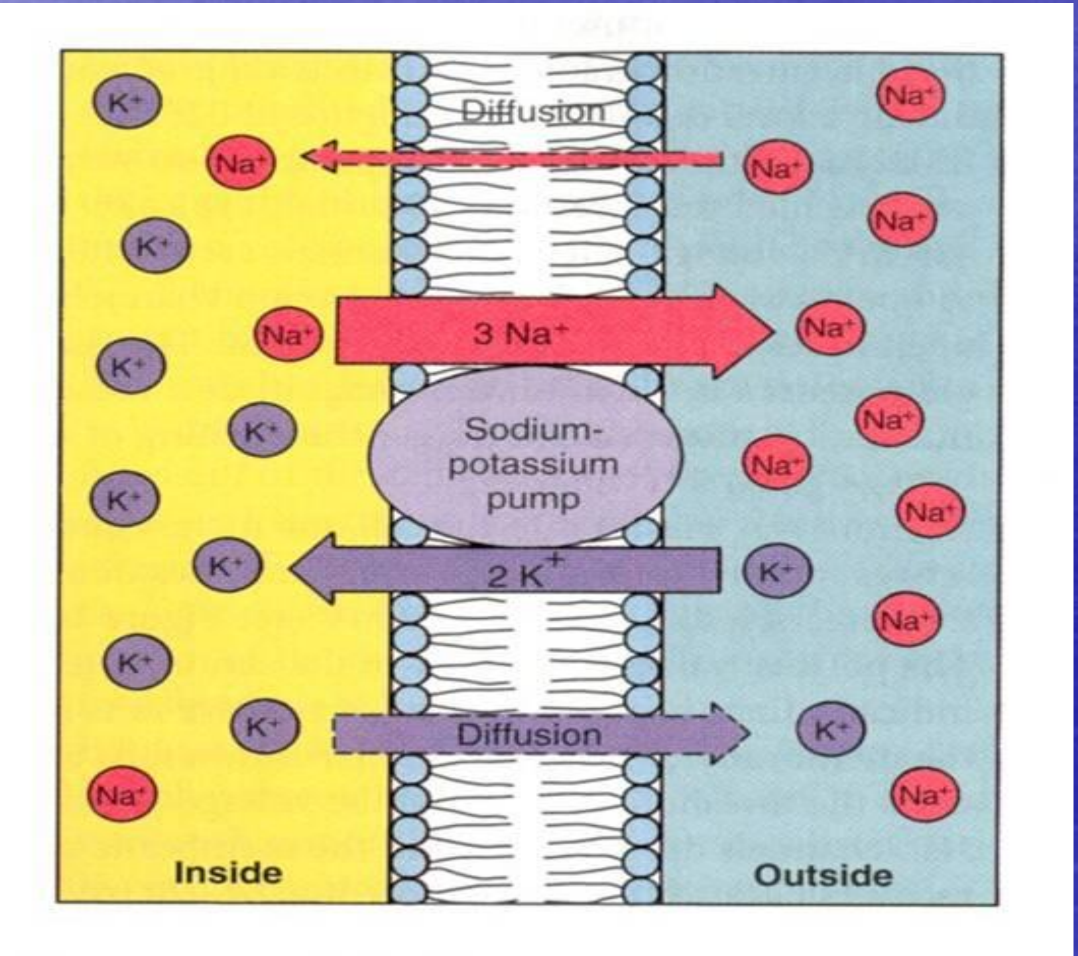
A small number of sodium (Na^+) ions continually leak into the cell. This makes the membrane potential more positive, weakening the electrical restraint on the movement of potassium (K^+) ions. A small number of ions now leak out of the cell.

As Na^+ ions accumulate in the cytosol, they are pumped outward in exchange for potassium ions by the Na^+/K^+ pump. The result is a low concentration of Na^+ ions inside the cell. Some Na^+ ions in the cytosol cause the membrane potential to be more positive than the equilibrium membrane potential for K^+.



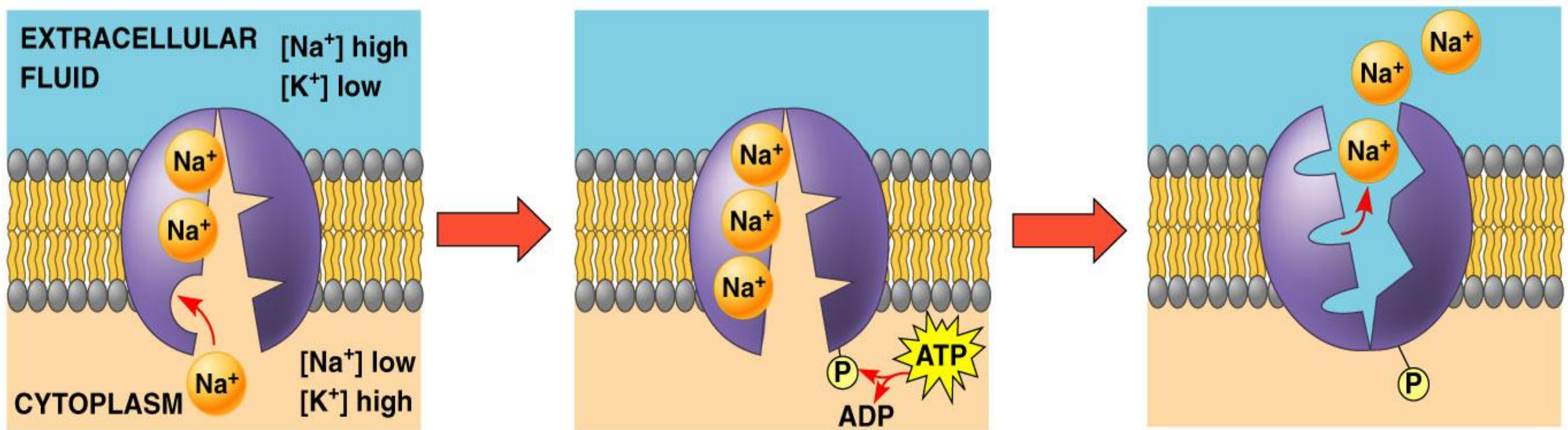
Active transport - transport proteins within the membrane must use metabolic energy (from ATP) to move substances either to the inside or outside of the membrane.

- Sodium-potassium pump



- The sodium-potassium pump must break ATP down into ADP in order to pump sodium three ions outside the cell (continued below), while it pumps two potassium ions into the cell. The ATP phosphorylates (adds a phosphate to) the membrane protein as it binds to the sodium and breaks down, and it dephosphorylates the protein as it binds with the potassium. Cellular respiration must occur to add the phosphate

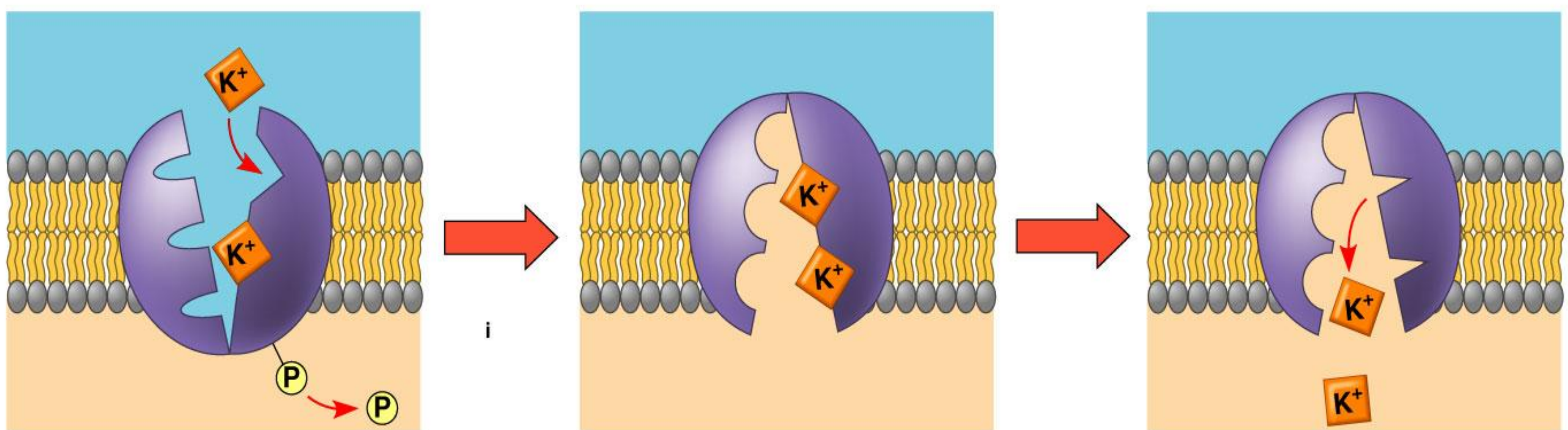
  back to ADP, thus restoring the ATP.



1 Cytoplasmic Na^+ binds to the sodium-potassium pump.

2 Na^+ binding stimulates phosphorylation by ATP.

3 Phosphorylation causes the protein to change its conformation, expelling Na^+ to the outside.

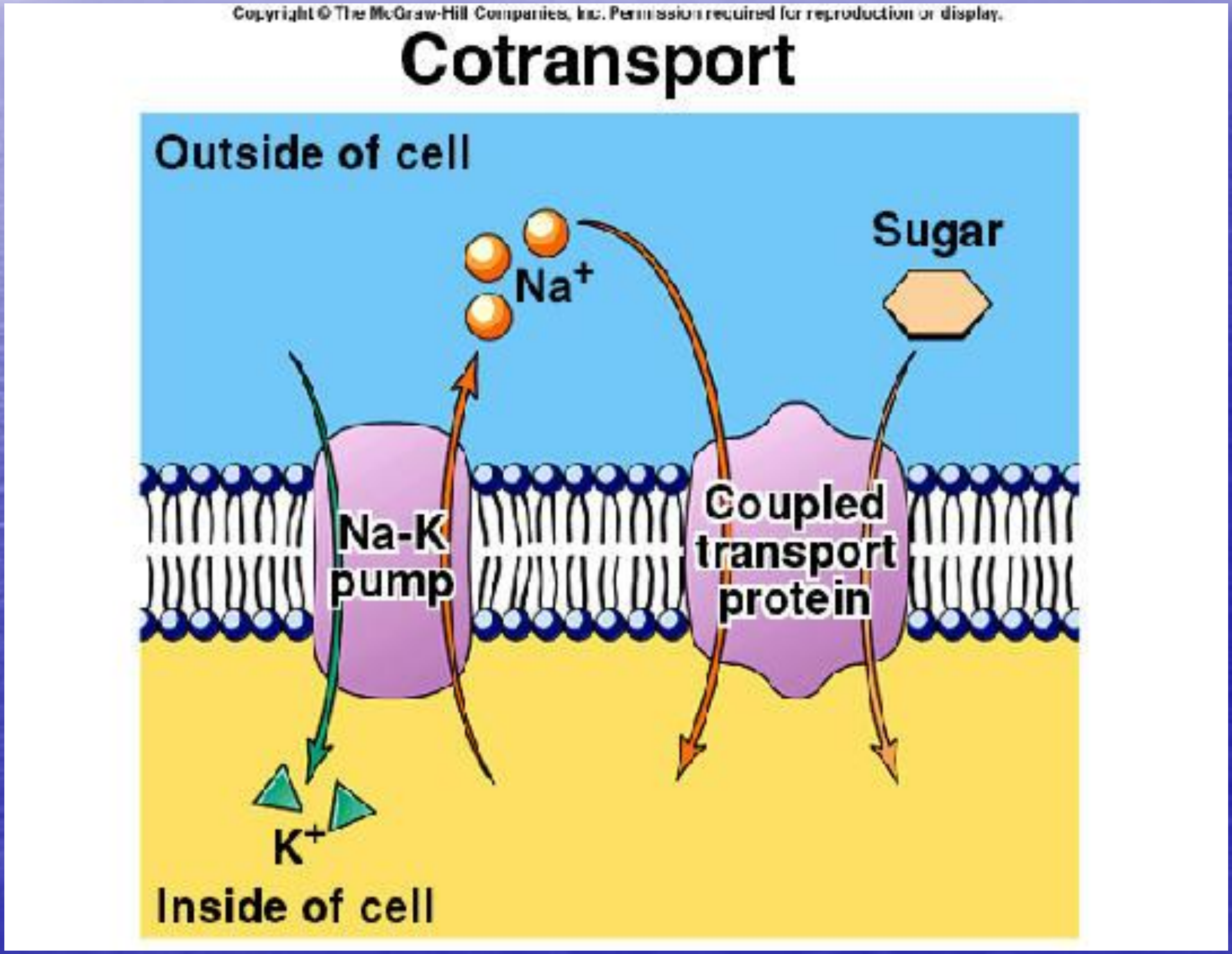


4 Extracellular K^+ binds to the protein, triggering release of the phosphate group.

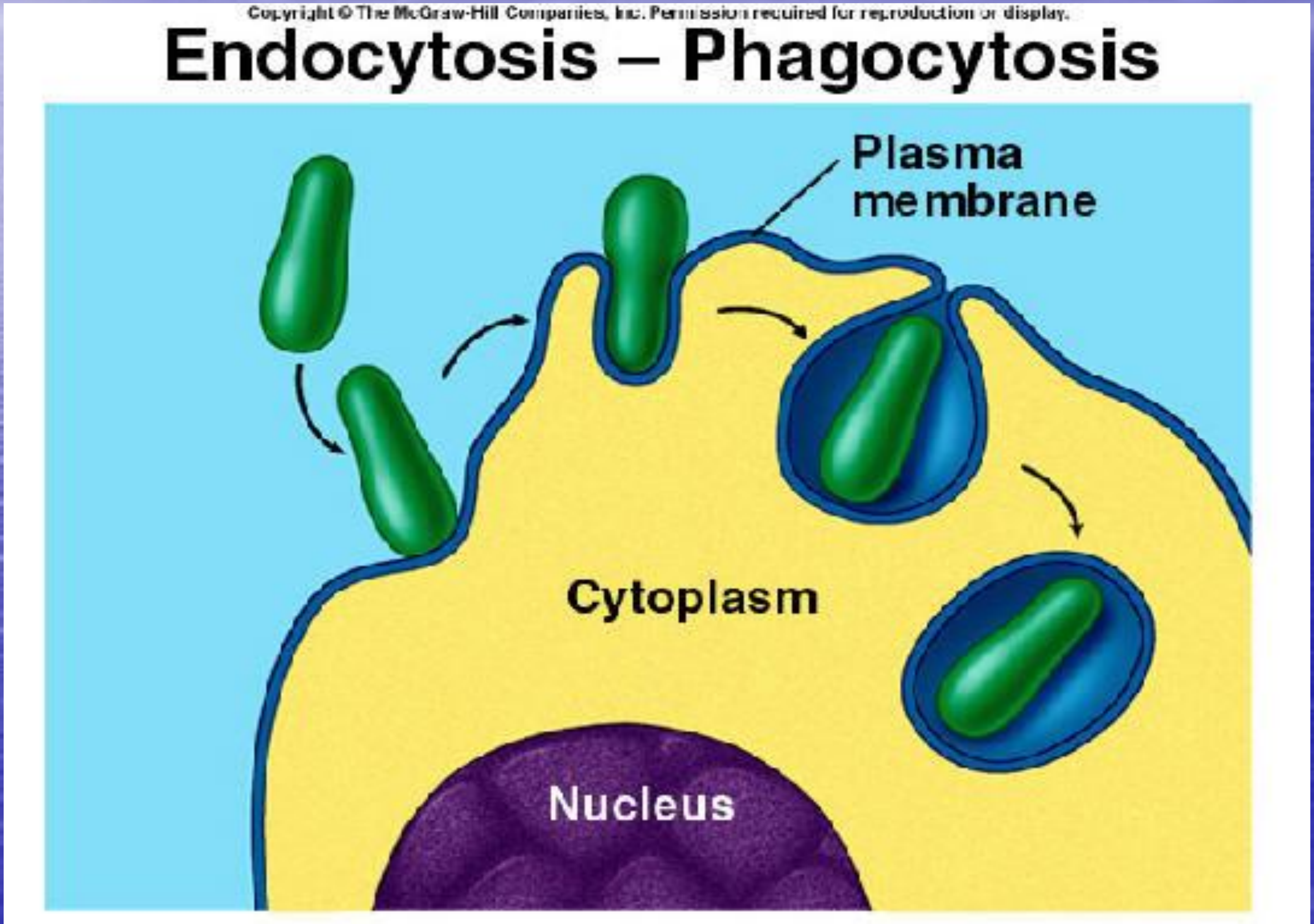
5 Loss of the phosphate restores the protein's original conformation.

6 K^+ is released and Na^+ sites are receptive again; the cycle repeats.

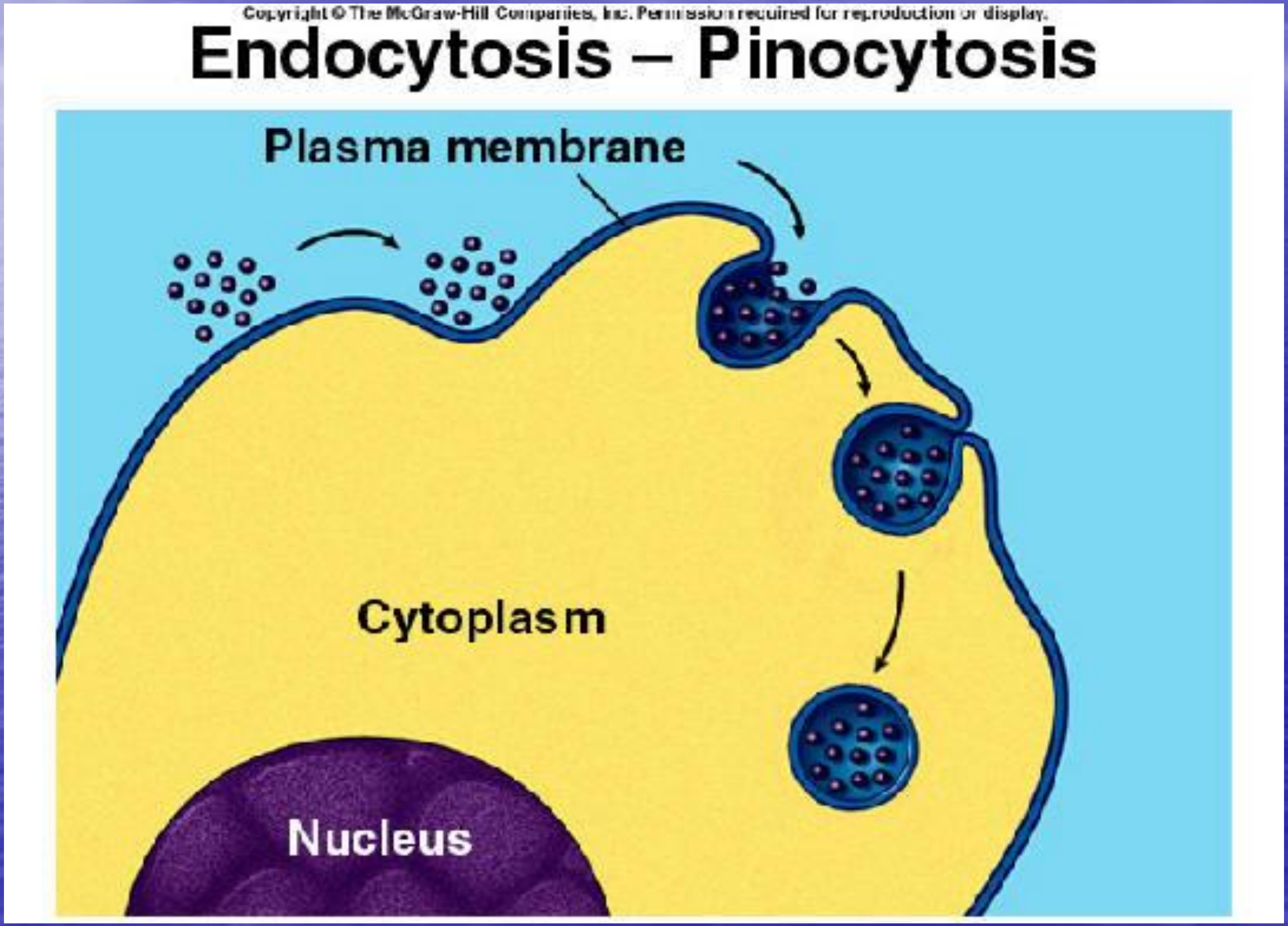
In cotransport, one process (the Na-K pump), is coupled with movement of a molecule of sugar (glucose) out of the cell, while allowing sodium to enter through the protein.



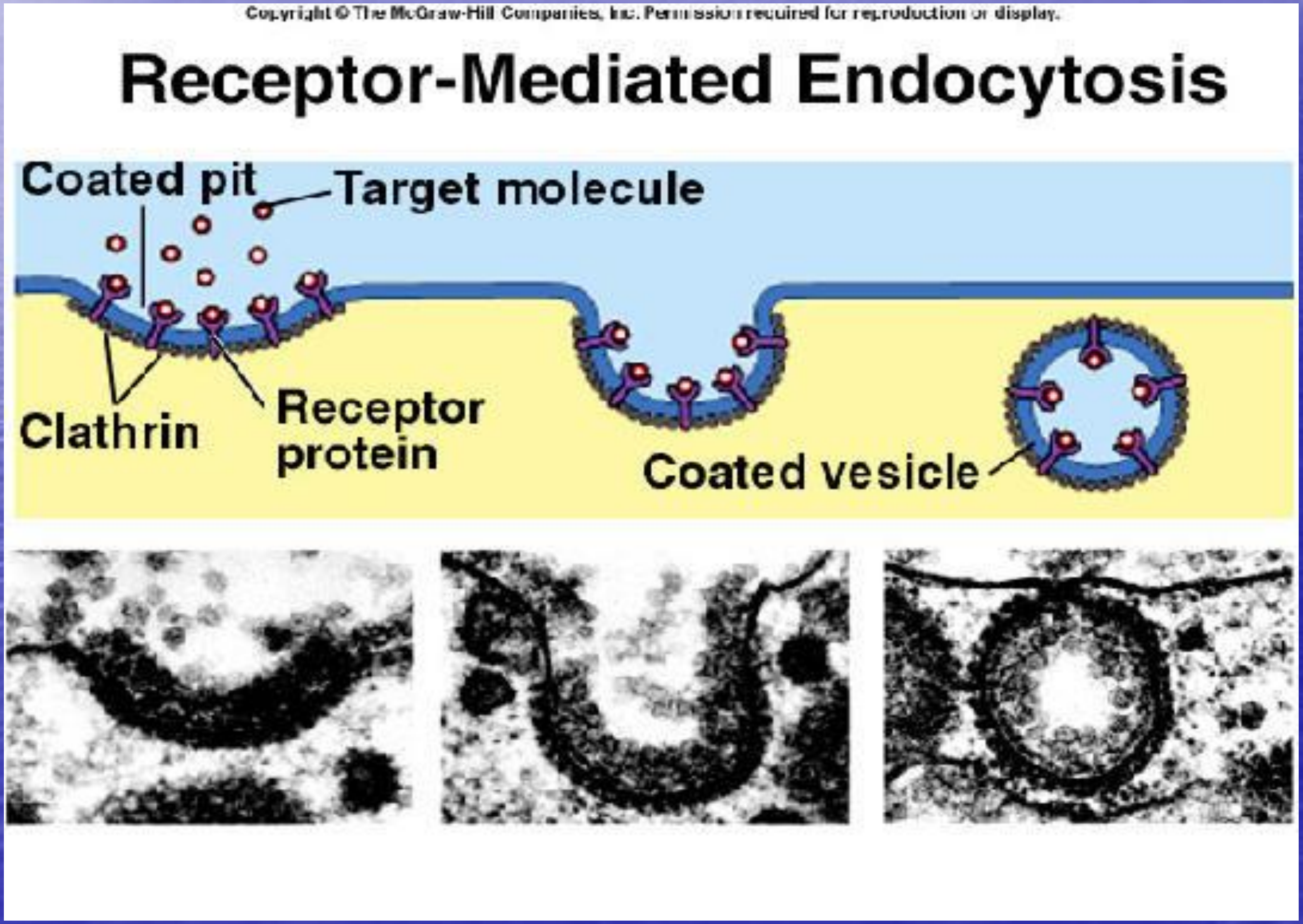
<u>Endocytosis</u> - An <u>active process</u> of taking in something through a cell membrane, which uses energy (ATP). Phagocytosis - cell eating.



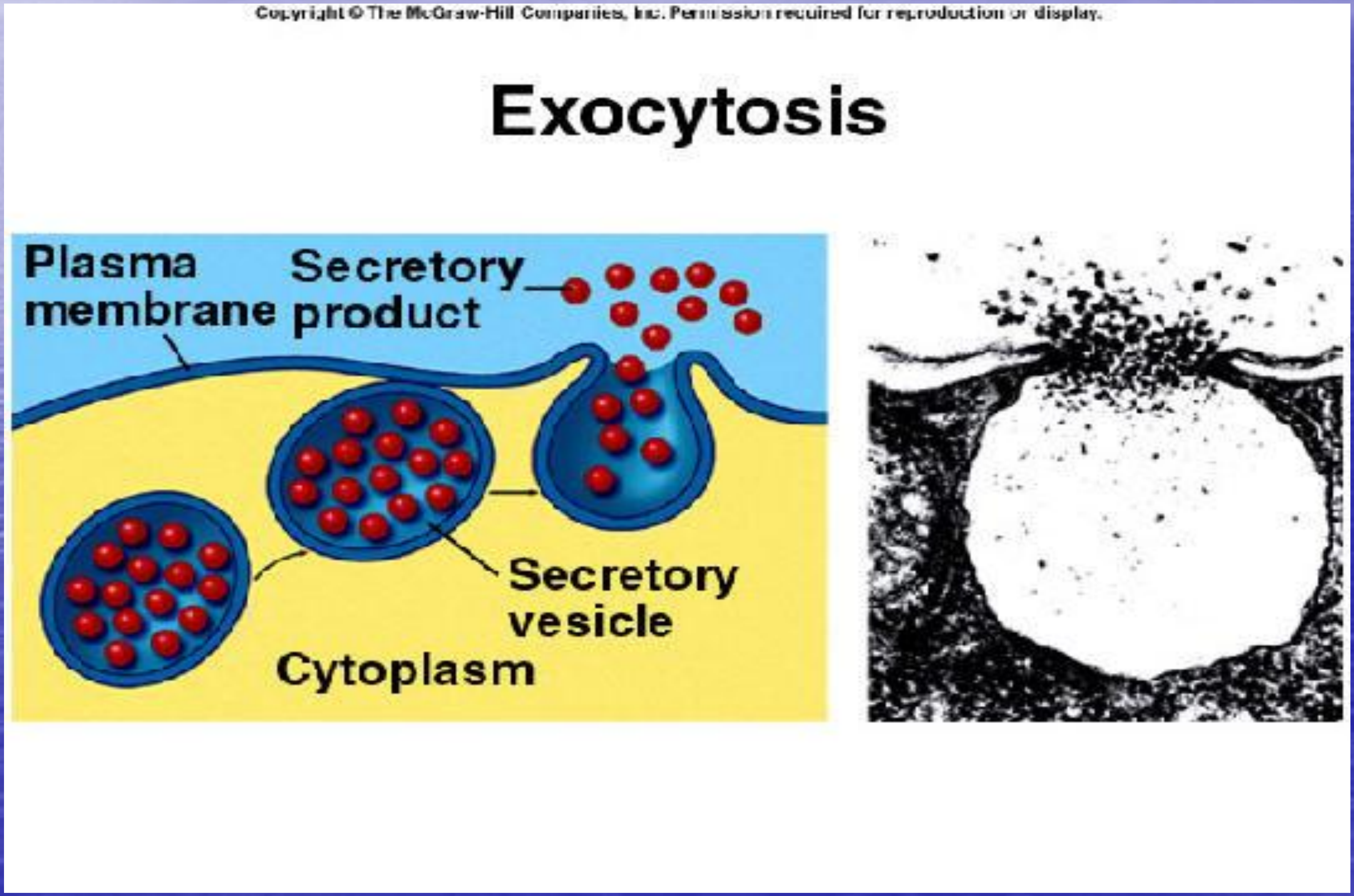
Pinocytosis - Cell drinking.



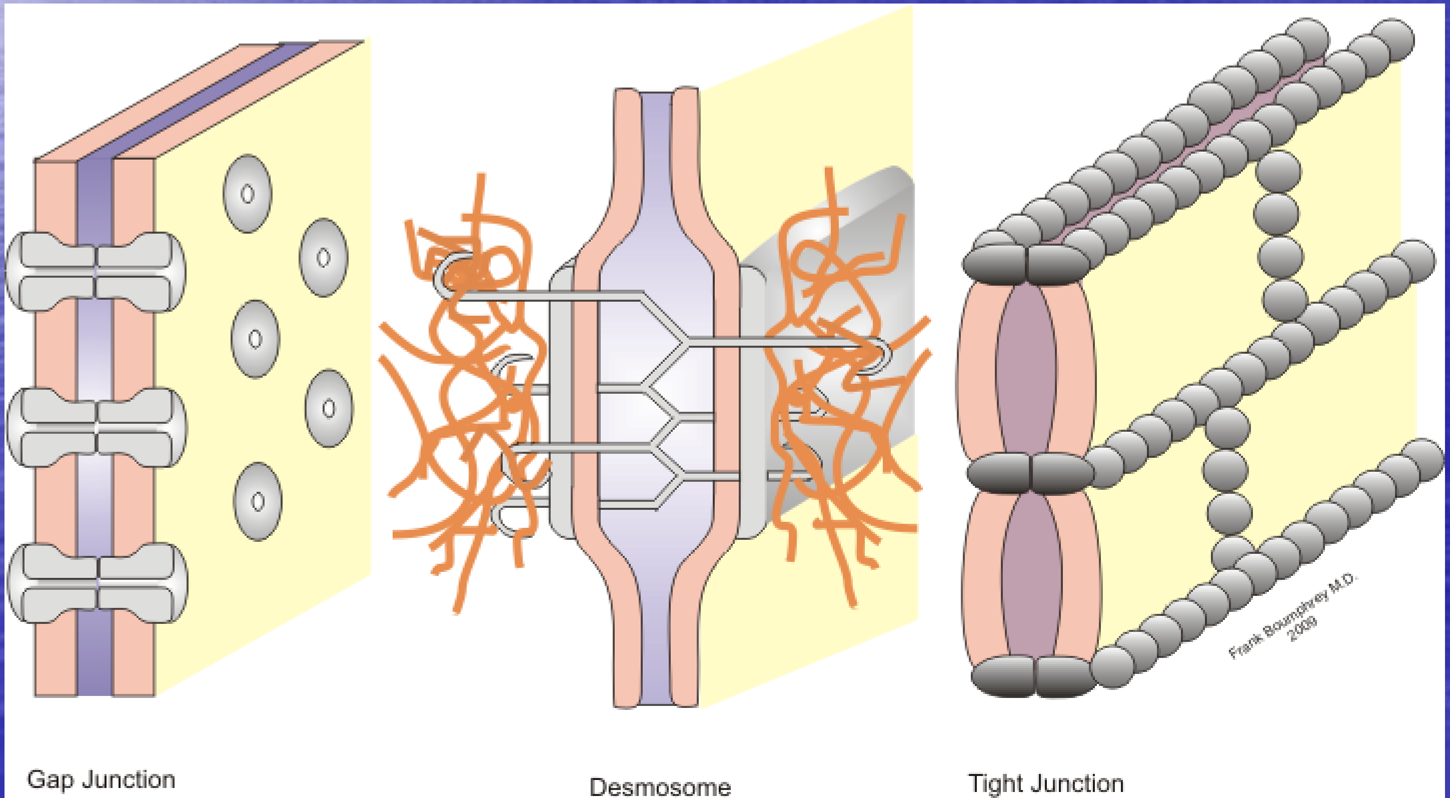
Receptors help to attach molecules to the membrane before taking them in.



Exocytosis - the opposite of endocytosis, is also an active process.



- Cells are organized to form tissues, and tissues are organised to form organs. Tissues are formed by an aggregation of like cells carrying out a like function. Cells are linked together by **cell junctions** and are supported by a **matrix** which they themselves secrete.
- The cell junctions are basicaly of three types, **tight**, **desmosomal**, and **gap**.



Histologists classify the tissues according to their physical features, physiologists tend to classify tissues acording to their function. There are four major types of tissue : **epithelial**; **connective**; **neural**; and **muscular**.

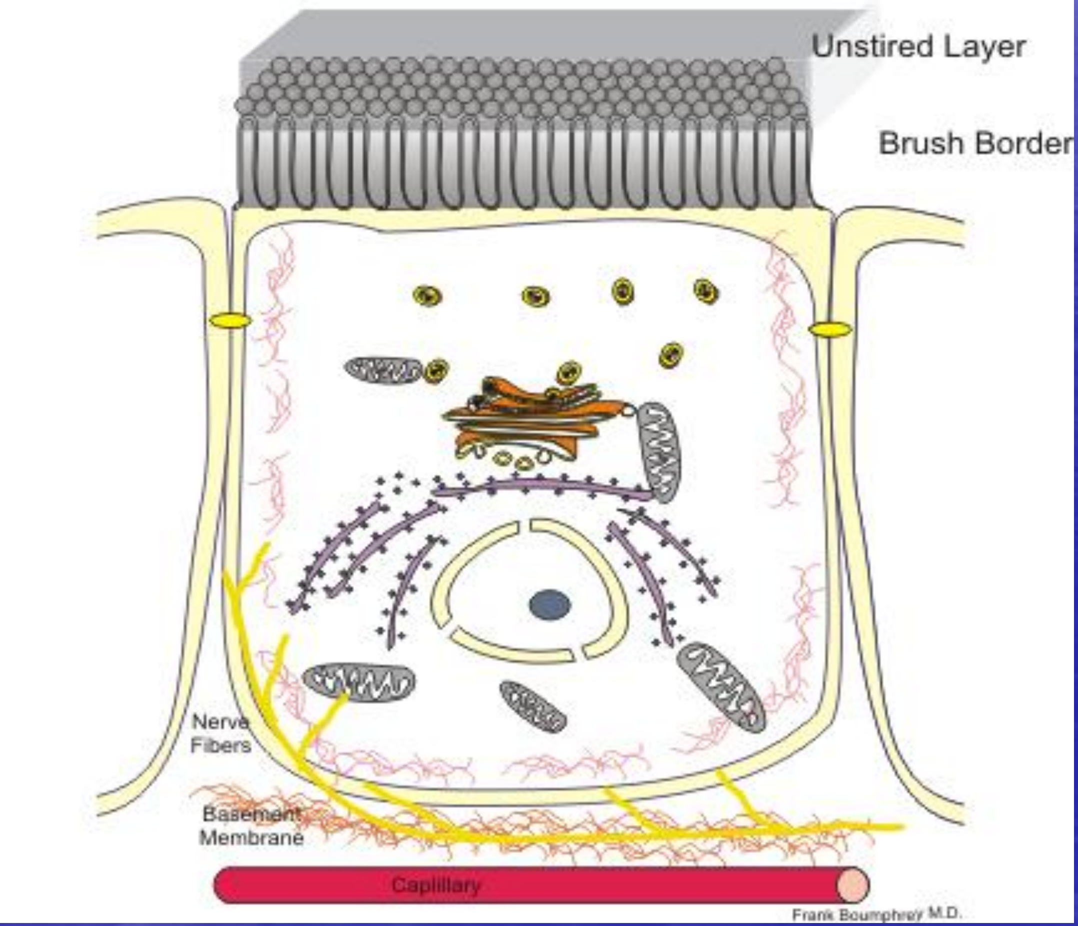
- **Summary of Epithelial Tissue Properties**

➢ Organized in sheets. Provides covering: Lines body surface, hollow organs, cavities and tubes. Provides tissues for secretory glands.

➢ Matrix is minimal in ammount, forming the **basement membrane** of the sheets of epithelial cells.

➢ Cells are polarized with a 'surface' and 'basement' side.

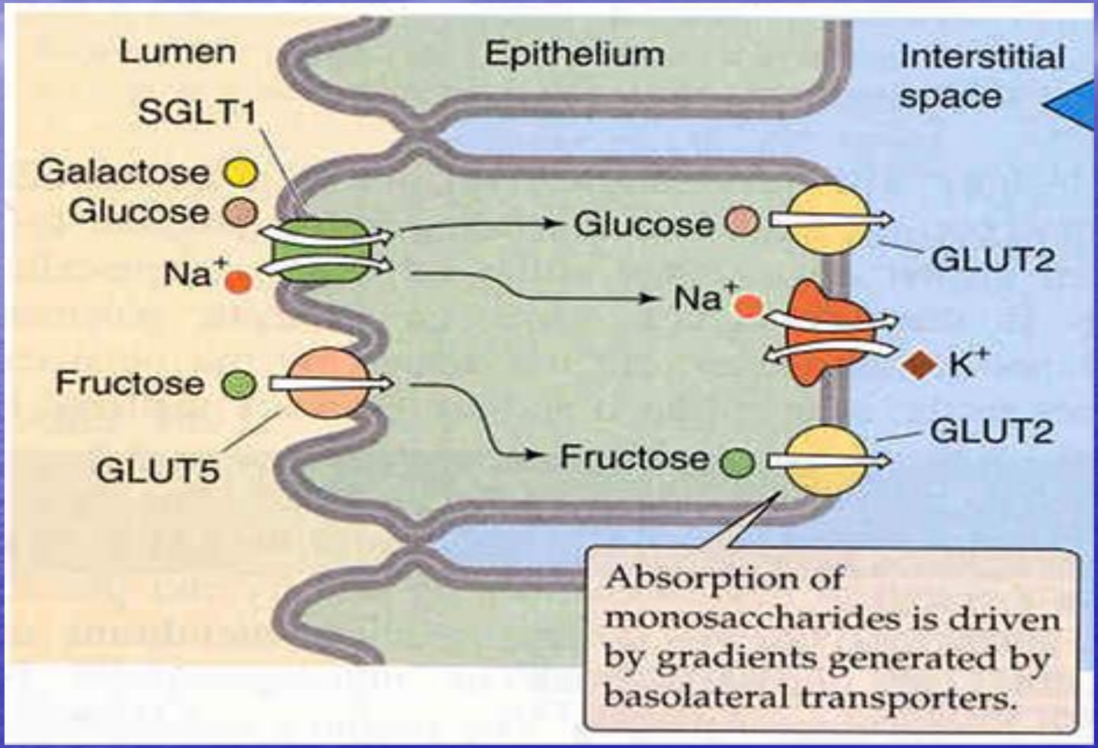
Illustration showing an enterocyte, a small intestine epithelial cell. These cells are bound by tight junctions, depicted by the yellow ovals in the illustration. Note the microvilli which increase the absorptive area about a hundredfold.



➢ Transport across luminal membrane

✓ *Glucose and galactose* are transported by sodium-glucose transport protein (SGLT1) through the apical membrane. The transport is secondary active one.

✓ *Fructose* is transported by GLUT5 - facilitated diffusion.



➢ Transport across basolateral membrane

✓ Glucose, galactose and frucrose are transported by GLUT2.

The reabsorbed substances in intersticial space increase osmotic pressure -> water flows to it -> increase of hydrostatic pressure -> reabsorption through capillary walls.

Благодаря за вниманието!