Group Translocation

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Group Translocation

- Many procaryotes also take up molecules by group translocation, a process in which a molecule is transported into the cell while being chemically altered.
- Eucaryotic microorganisms do not appear to employ group translocation but take up nutrients by endocytosis.
- This can be classified as a type of energy-dependent transport because metabolic energy is used.
- The best-known group translocation system is the phosphoenolpyruvate: sugar phosphotransferase system (PTS).
- It transports a variety of sugars into procaryotic cells while phosphorylating them using phosphoenolpyruvate (PEP) as the phosphate donor.

$$\text{PEP} + \text{sugar (outside)} \rightarrow \text{pyruvate} + \text{sugar-P (inside)}$$

… **Group Translocation**

- The PTS is quite complex.
- In *E. coli* and *Salmonella typhimurium,* it consists of:
  - two enzymes
    - Enzyme I (EI): Cytoplasmic
    - Enzyme II (EII): is more variable in structure and often composed of three subunits or domains
      - EIIA (formerly called EIII) is cytoplasmic and soluble.
      - EIIB also is hydrophilic but frequently is attached to EIIC
      - EIIC, a hydrophobic protein that is embedded in the membrane
  - a low molecular weight heat-stable protein (HPr): Cytoplasmic
- A high-energy phosphate is transferred from PEP to enzyme II with the aid of enzyme I and HPr (figure 5).
- Then, a sugar molecule is phosphorylated as it is carried across the membrane by enzyme II.
- Enzyme II transports only specific sugars and varies with PTS, whereas enzyme I and HPr are common to all PTSs.

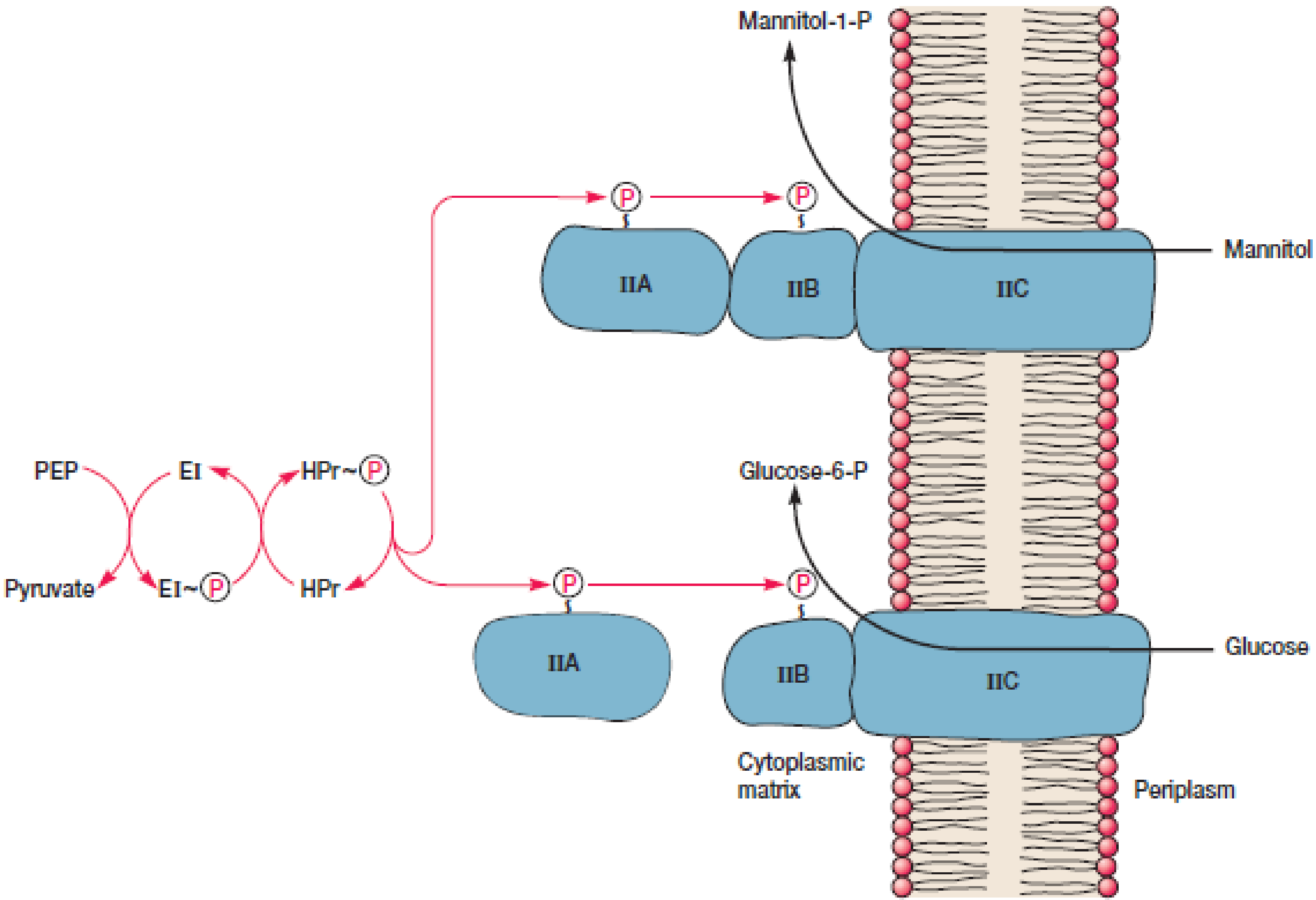
Mannitol-1-P
P
P
IIA
IIB
IIC
Mannitol
PEP
EI
HPr~P
Glucose-6-P
Pyruvate
EI~P
HPr
P
P
IIA
IIB
IIC
Glucose
Cytoplasmic matrix
Periplasm

Figure 5.

… **Group Translocation**

- PTSs are widely distributed in procaryotes.
- Except for some species of *Bacillus* that have both glycolysis and the phosphotransferase system, aerobic bacteria seem to lack PTSs.
- Members of the genera *Escherichia, Salmonella, Staphylococcus*, other facultatively anaerobic bacteria have phosphotransferase ystems.
- Some obligately anaerobic bacteria (e.g., *Clostridium)* also have PTSs.
- Many carbohydrates are transported by these systems.
- *E. coli* takes up glucose, fructose, mannitol, sucrose, acetylglucosamine, cellobiose, and other carbohydrates by group translocation.
- Besides their role in transport, PTS proteins can act as chemoreceptors for chemotaxis.

Iron Uptake

- Almost all microorganisms require iron for use in cytochromes and many enzymes.
- Iron uptake is made difficult by the extreme insolubility of ferric iron (Fe^{3+}) and its derivatives, which leaves little free iron available for transport.
- Many bacteria and fungi have overcome this difficulty by secreting siderophores.
- Siderophores are low molecular weight molecules that are able to complex with ferric iron and supply it to the cell.
- These iron-transport molecules are normally either hydroxamates or phenolates, catecholates.
- Ferrichrome is a hydroxamate produced by many fungi; enterobactin is the catecholate formed by *E. coli* .
- Microorganisms secrete siderophores when little iron is available in the medium.
- Once the iron-siderophore complex has reached the cell surface, it binds to a siderophore-receptor protein.
- Then the iron is either released to enter the cell directly or the whole iron-siderophore complex is transported inside by an ABC transporter.
- In *E. coli* the siderophore receptor is in the outer membrane of the cell envelope; when the iron reaches the periplasmic space, it moves through the plasma membrane with the aid of the transporter.
- After the iron has entered the cell, it is reduced to the ferrous form (Fe^{2+}).
- Iron is so crucial to microorganisms that they may use more than one route of iron uptake to ensure an adequate supply.

Bacteriorhodopsin

- The halophilic bacterium *Halobacterium salinarium* (formerly *H. halobium*) normally depends on respiration for the production of energy.
- However, under conditions of low oxygen and high light intensity, the bacteria synthesize a deep-purple pigment called bacteriorhodopsin, which closely resembles the sensory pigment rhodopsin from the rods and cones of vertebrate eyes.
- Bacteriorhodopsin's chromophore is the carotenoid derivative retinal (the aldehyde of vitamin A) that is covalently attached to the pigment protein by a Schiff base with the amino group of a lysine.
- The protein has seven membrane-spanning helices connected by loops on either side; its retinal rests in the center of the membrane.
- Individual bacteriorhodopsins aggregate in the membrane to form crystalline patches called the purple membrane.
- Bacteriorhodopsin functions as a light-driven proton pump.

… Bacteriorhodopsin

- When retinal absorbs light, the double bond between carbons 13 and 14 changes from a trans to a cis configuration and the Schiff base loses a proton (figure 6b).
- Protons are moved across the plasma membrane to the periplasmic space during these alterations, and the Schiff base changes are directly involved in this movement**.**
- **The bacteriorhodopsin** protein undergoes several conformational changes during the photocycle.
- These conformational changes also are involved in proton transport.
- The light driven proton pumping generates a pH gradient that can be used to power the synthesis of ATP by a chemiosmotic mechanism (figure 6b).
- This photosynthetic capacity is particularly useful to *Halobacterium* because oxygen is not very soluble in concentrated salt solutions and may decrease to an extremely low level in its habitat.
- When the surroundings become temporarily anaerobic, the bacterium uses light energy to synthesize sufficient ATP to remain alive until the oxygen level rises again.
- *Halobacterium* cannot grow anaerobically because it requires oxygen for continued retinal synthesis, but it can survive the stress of temporary oxygen limitation by means of photosynthesis.

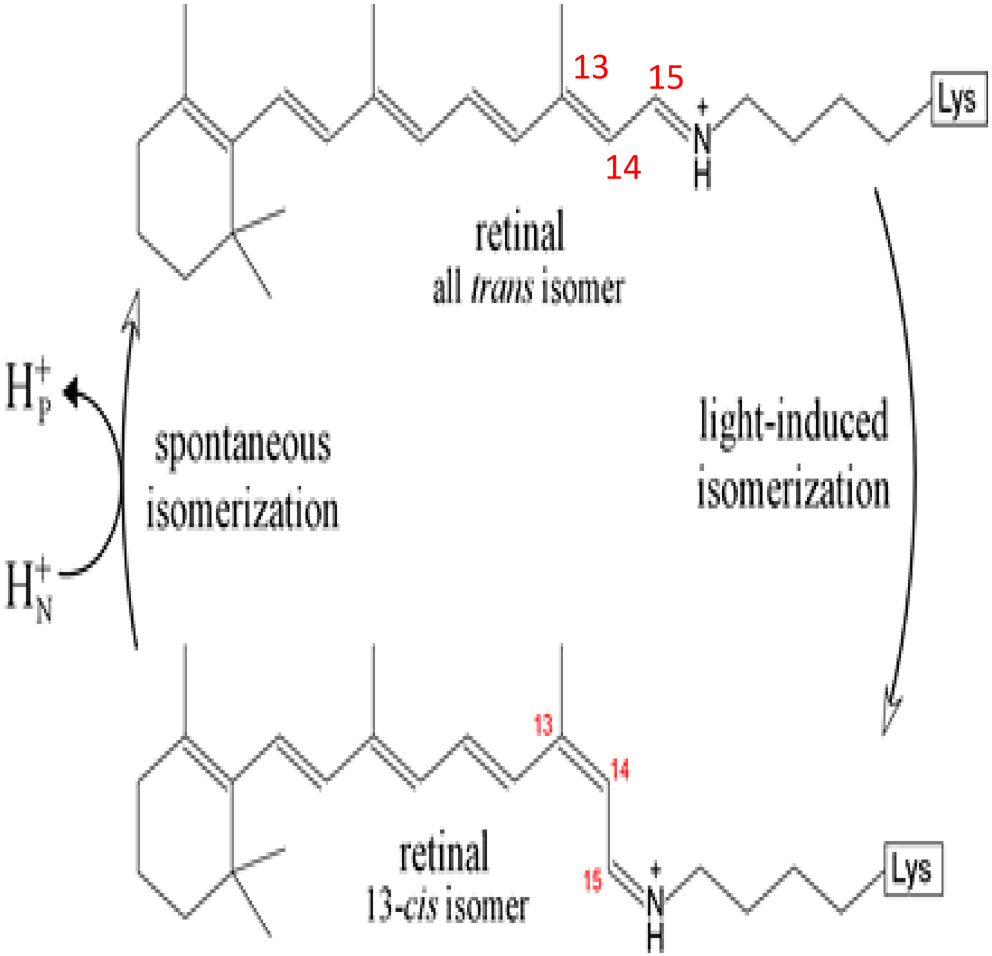

Figure 6a.

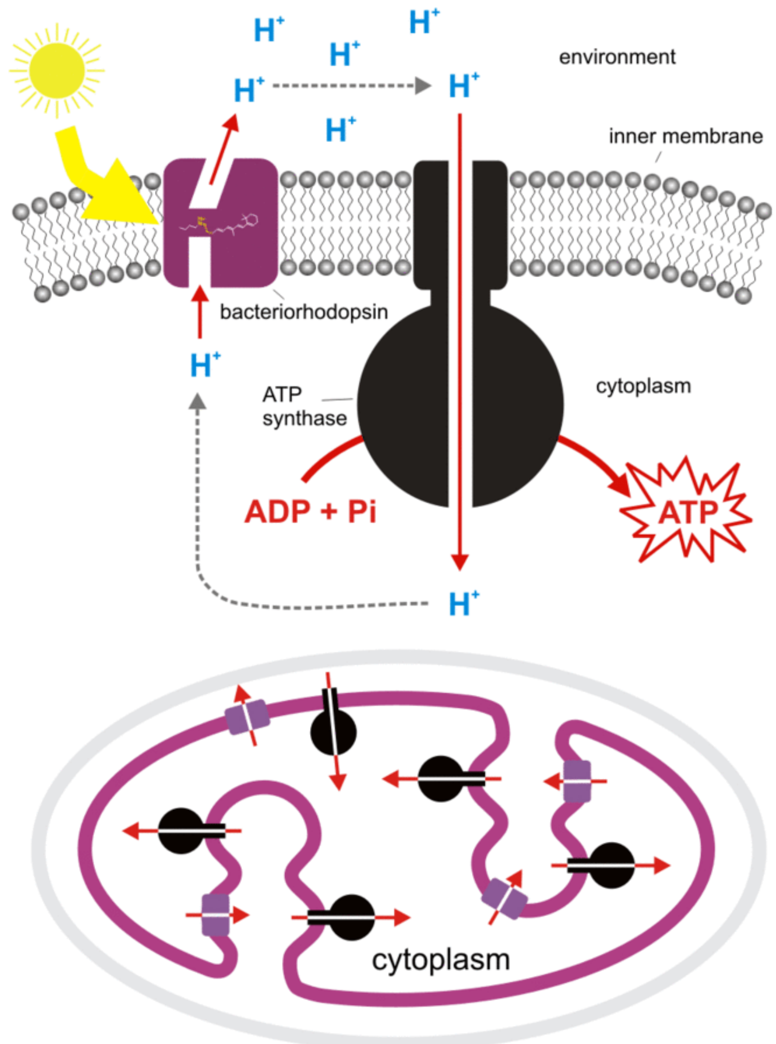

Figure 6b.

Rhodopsins

- *Halobacterium* actually has four rhodopsins, each with a different function.
- As already mentioned, bacteriorhodopsin drives outward proton transport for purposes of ATP synthesis.
- Halorhodopsin uses light energy to transport chloride ions into the cell and maintain a 4 to 5 M intracellular KCl concentration.
- Finally there are two rhodopsins that act as photoreceptors, one for red light and one for blue.
- They control flagellar activity to position the organism optimally in the water column.
- *Halobacterium moves to a location of* high light intensity, but one in which ultraviolet light is not sufficiently intense to be lethal.

Questions

- Why are transport proteins necessary? Compare in detail group translocation and active transport.
- Write short note on PEP-PTS.
- Write short note on iron transport.
- Briefly discuss bacteriorhodopsin.