Active Transport

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Active transport

- Microorganisms often live in habitats characterized by very dilute nutrient sources, and, to flourish, they must be able to transport and concentrate these nutrients.
- Thus facilitated diffusion mechanisms are not always adequate.
- The most important transport processes in such situations are active transport methods and group translocations.
- Active transport processes
    - ATP binding cassette (ABC) transporters (Primary active transport)
    - Active transport using proton and sodium gradient (Secondary active transport)

Active transport vs. Passive transport

- In passive transport, the transported species always moves down its electrochemical gradient and is not accumulated above the equilibrium concentration.
- Active transport is the transport of solute molecules to higher concentrations, or against a concentration gradient, with the use of metabolic energy input.
- Resemblance with facilitated diffusion:
  - involves protein carrier activity
  - it is also characterized by the carrier saturation effect at high solute concentrations (figure 1).
- Difference from facilitated diffusion:
  - it use of metabolic energy
  - its ability to concentrate substances.
  - Metabolic inhibitors that block energy production will inhibit active transport but will not affect facilitated diffusion.

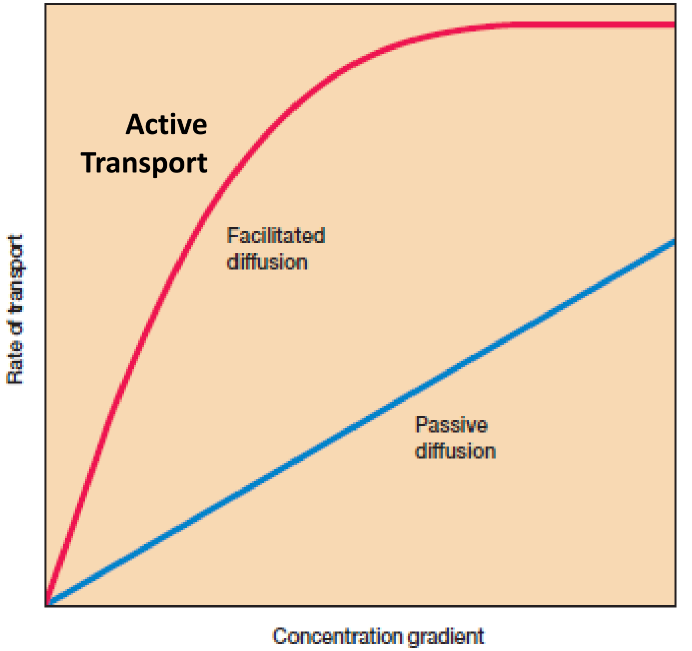


Figure 1.

Active Transport

- Active transport is thermodynamically unfavorable (endergonic) and takes place only when coupled (directly or indirectly) to an exergonic process such as the absorption of sunlight, an oxidation reaction, the breakdown of ATP, or the concomitant flow of some other chemical species down its electrochemical gradient.
- In **primary active transport,** solute accumulation is coupled directly to an exergonic chemical reaction, such as conversion of ATP to ADP Pi.
- **Secondary active transport** occurs when endergonic (uphill) transport of one solute is coupled to the exergonic (downhill) flow of a different solute that was originally pumped uphill by primary active transport.
  - For example, a gradient of Na^+ has been established by primary active transport. Movement of Na^+ down its electrochemical gradient now provides the energy to drive cotransport of a second solute (S) against its electrochemical gradient.

ATP binding cassette (ABC) transporters

- Binding protein transport systems or ABC transporters are active in **bacteria, archaea, and eucaryotes**.
- Usually these transporters consist of **two hydrophobic membrane-spanning domains** associated on their cytoplasmic surfaces with two nucleotide-binding domains (figure 2).
- The membrane-spanning domains form a pore in the membrane and the **nucleotide-binding domains** bind and hydrolyze ATP to drive uptake.
- ABC transporters employ special substrate binding proteins, which are located:
  - in the periplasmic space of gram-negative bacteria
  - attached to membrane lipids on the external face of the gram-positive plasma membrane.
- These binding proteins, also may participate in chemotaxis*, bind the molecule to be transported* and then interact with the membrane transport proteins to move the solute molecule inside the cell.
- E. coli transports a variety of sugars (arabinose, maltose, galactose, ribose) and amino acids (glutamate, histidine, leucine) by this mechanism.

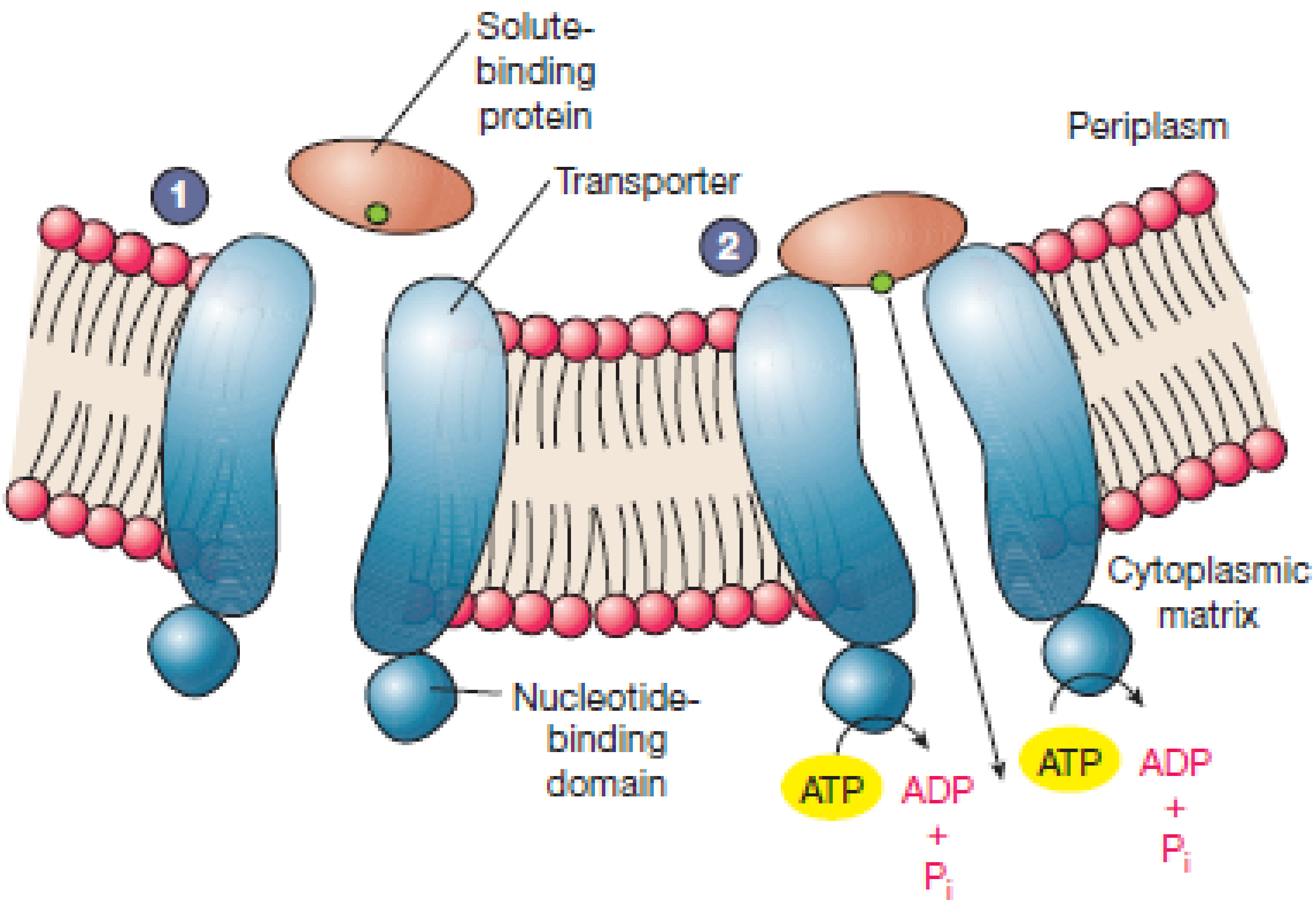


Figure 2. ABC Transporter Function. (*1*) The solute binding protein binds the substrate to be transported and approaches the ABC transporter complex. (2) The solute binding protein attaches to the transporter and releases the substrate, which is moved across the membrane with the aid of ATP hydrolysis. See text for details.

… ABC transporters

- Substances entering gram-negative bacteria must pass through the outer membrane before ABC transporters and other active transport systems can take action.
- There are several ways in which this is accomplished. When the substance is small, a generalized porin protein can be used.
- Larger molecules require specialized porins. In some cases (e.g., for uptake of iron and vitamin B12), specialized high-affinity outer membrane receptors and transporters are used.
- It should be noted that eucaryotic ABC transporters are sometimes of great medical importance.
- Some tumor cells pump drugs out using these transporters.
- Cystic fibrosis results from a mutation that inactivates an ABC transporter that acts as a chloride ion channel in the lungs.

Active transport using proton gradient

- Bacteria also use proton gradients generated during electron transport to drive active transport.
- The lactose permease of *E. coli is a well-studied* example.
- Lactose permease (a single protein of ~ 30,000 mol wt.) transports a lactose molecule inward as a proton simultaneously enters the cell (a higher concentration of protons is maintained outside the membrane by electron transport chain activity) (Figure 3).
- Such linked transport of two substances in the same direction is called **symport.**
- **Here, energy stored as a proton** gradient drives solute transport.
- Although the mechanism of transport is not completely understood, it is thought that binding of a proton to the transport protein changes its shape and affinity for the solute to be transported.
- *E. coli also uses proton symport* to take up amino acids and organic acids like succinate and malate.

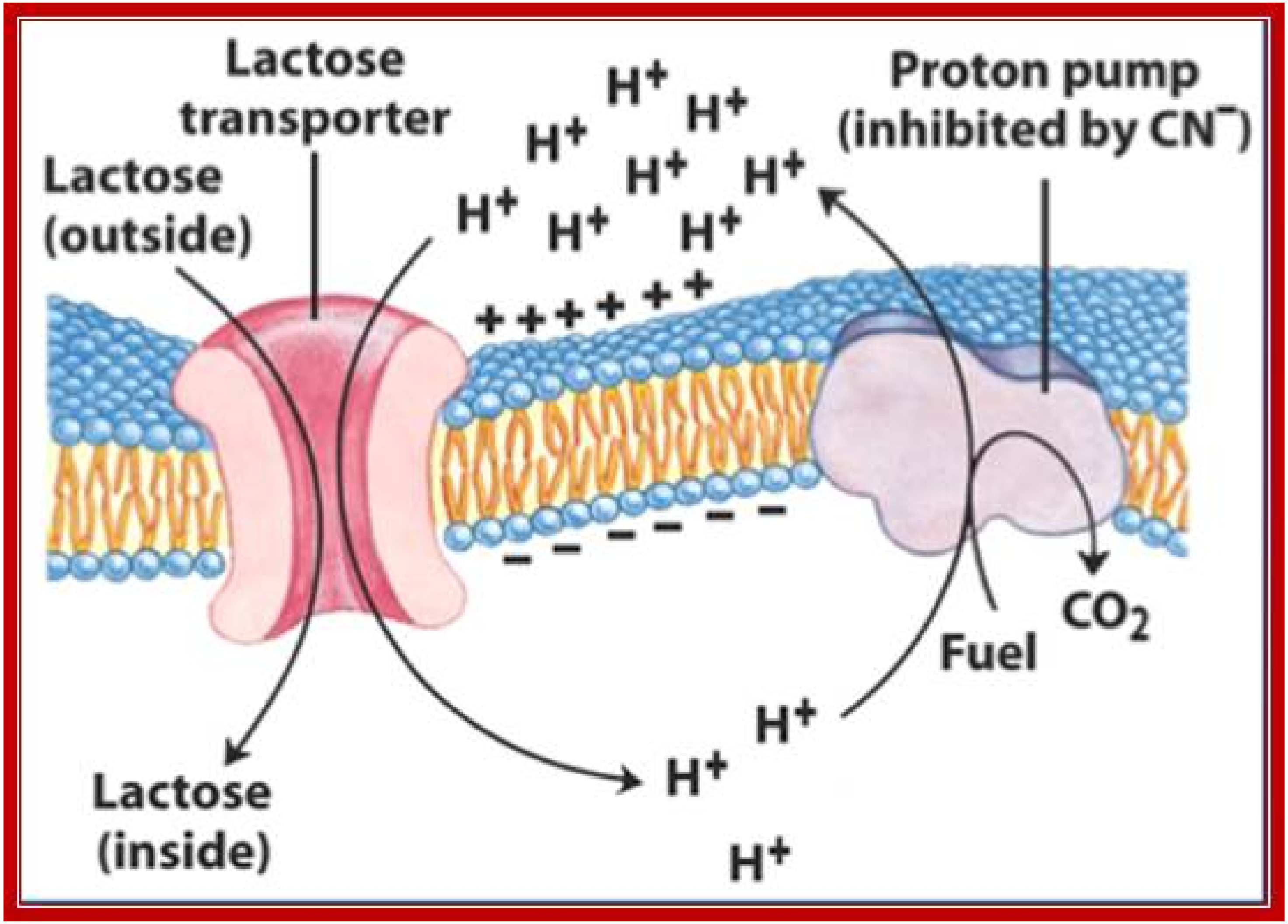
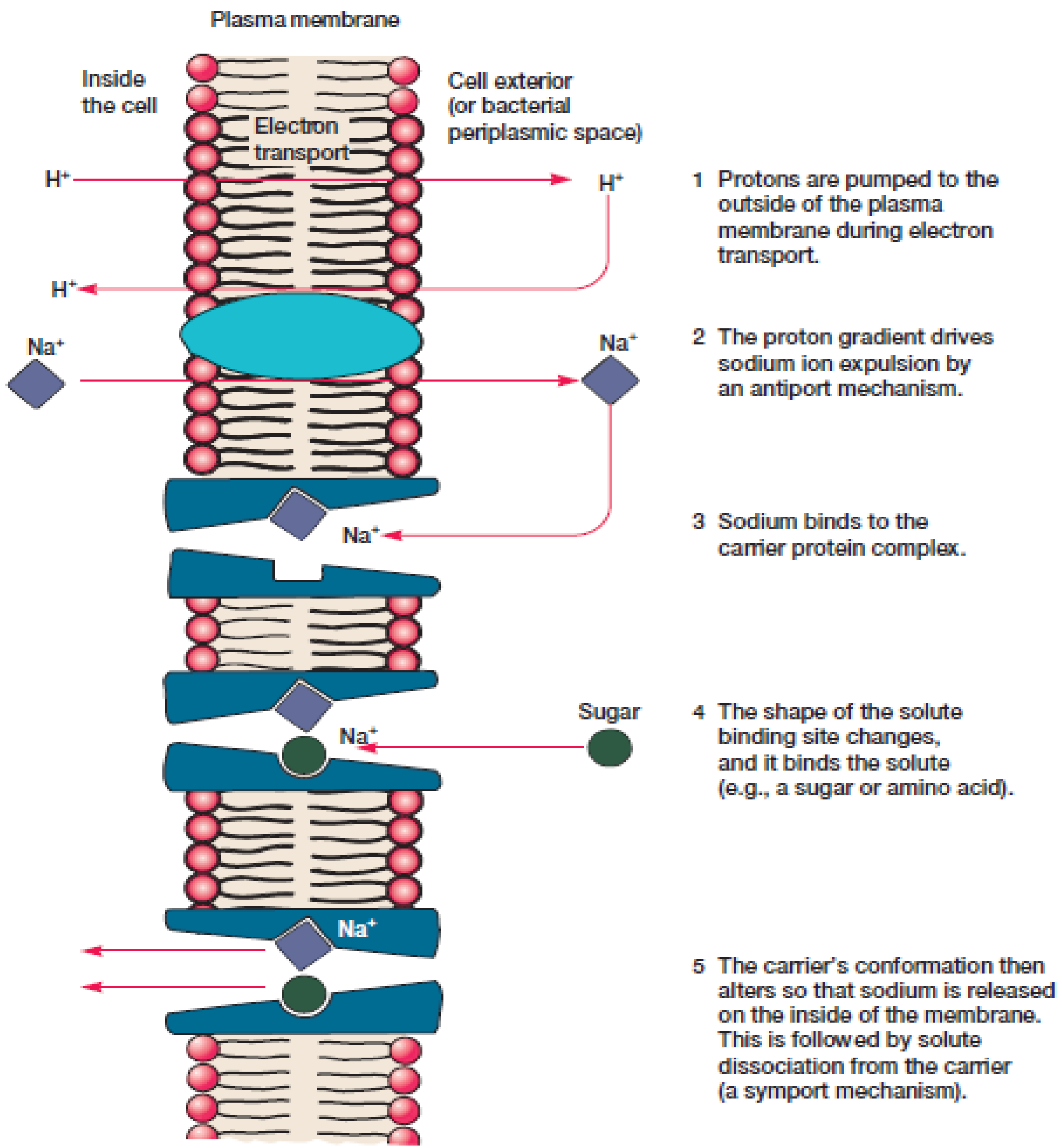


Figure 3. Lactose permease

Active transport using proton and sodium gradient

- A proton gradient also can power active transport indirectly, often through the formation of a sodium ion gradient.
- *E. coli sodium transport system pumps sodium outward in* response to the inward movement of protons (**figure 4).**
- **Such** linked transport in which the transported substances move in opposite directions is termed **antiport.**
- **The sodium gradient generated** by this proton antiport system then drives the uptake of sugars and amino acids.
- A sodium ion could attach to a carrier protein, causing it to change shape.
- The carrier would then bind the sugar or amino acid tightly and orient its binding sites toward the cell interior.
- Because of the low intracellular sodium concentration, the sodium ion would dissociate from the carrier, and the other molecule would follow.
- *E. coli transport proteins carry the* sugar melibiose and the amino acid glutamate when sodium simultaneously moves inward.
- Often a microorganism has more than one transport system for each nutrient, eg. *E. coli has* at least 05 transport systems for the sugar galactose, 03 systems each for glutamate and leucine, and 02 potassium transport complexes.

Figure 4.



Plasma membrane
Inside the cell
Cell exterior (or bacterial periplasmic space)
Electron transport
H+
H+
H+
Na+
Na+
Na+
Sugar
Na+
Na+
1 Protons are pumped to the outside of the plasma membrane during electron transport.
2 The proton gradient drives sodium ion expulsion by an antiport mechanism.
3 Sodium binds to the carrier protein complex.
4 The shape of the solute binding site changes, and it binds the solute (e.g., a sugar or amino acid).
5 The carrier's conformation then alters so that sodium is released on the inside of the membrane. This is followed by solute dissociation from the carrier (a symport mechanism).

Questions

- Why are transport proteins necessary? Compare in detail group translocation and active transport.
- Write an essay on bacterial transport system.
- Write differences among passive diffusion, facilitated diffusion and active transport.
- Explain molecular mechanism of transport of molecules through active transport.
- Write a short note on:
  - ABC transporters
  - Primary active transport
  - Secondary active transport