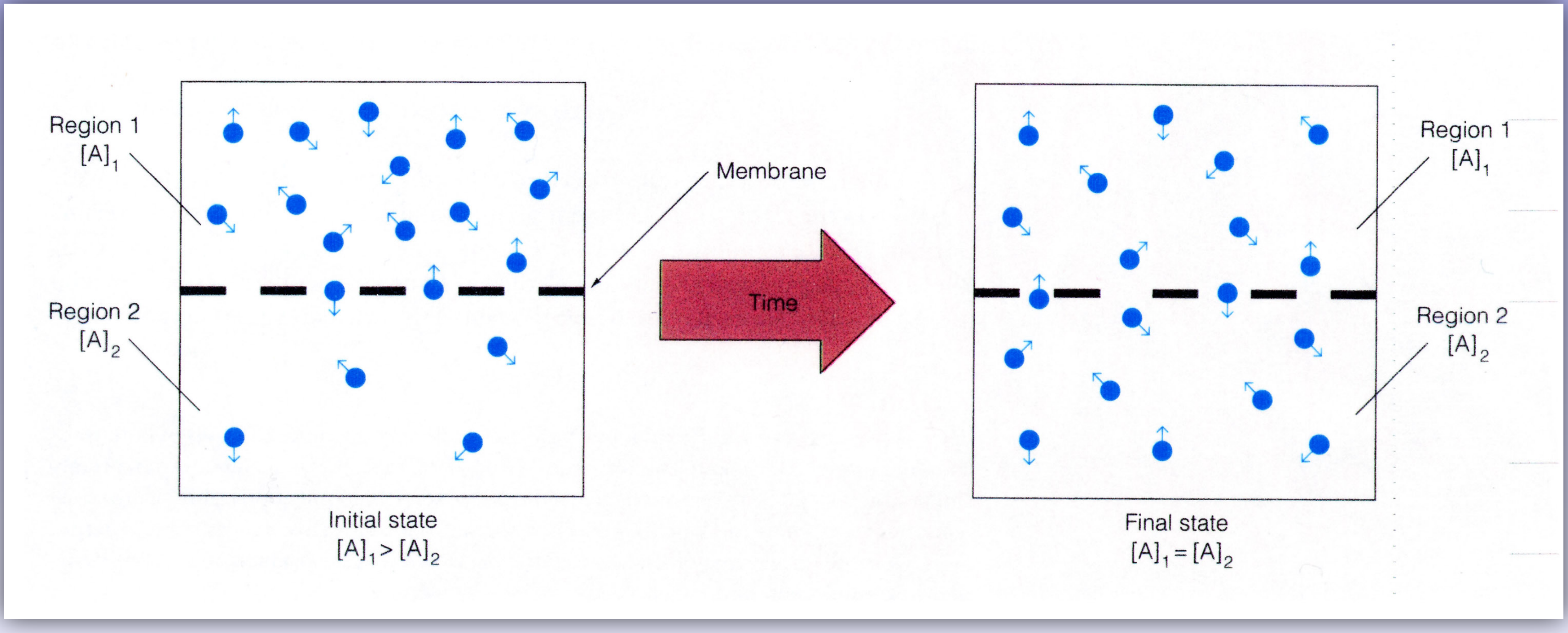
Transport Across Membranes

CHEM 420 – Principles of Biochemistry
Instructor – Anthony S. Serianni

Chapter 20: Voet/Voet, *Biochemistry*, 2011
Fall 2015

From Chapter 2 slides:



Thermodynamics of Transport

For non-ionic solutes:

$$A\ (out) \rightleftharpoons A\ (in)$$

$$\Delta G = RT \ln([A]_{in}/[A]_{out})$$

For transport of an ionic substance:

$$\Delta G = RT \ln([A]_{in}/[A]_{out}) + Z_A \mathcal{F} \Delta\psi$$

Z_A = ionic charge of A
$\mathcal{F}$ = Faraday constant (charge of one mole of electrons; 96,485 C/mol)
$\Delta\psi$ = membrane potential

Membrane potentials of -100 mV (inside negative) are not uncommon.

Types of Transport

1. Non-mediated transport – occurs through simple diffusion

2. Mediated transport – occurs through the action of specific carrier proteins (carriers, permeases, porters, translocases, translocators, transporters)

Types of Mediated Transport

1. Passive-mediated transport or facilitated transport: Specific molecules flow from high concentration to low concentration to equilibrate a concentration gradient

2. Active transport: specific molecules are transported from low concentrations to high concentrations. This process is *endergonic* and must be coupled to a sufficiently *exergonic* process to make it favorable.

Non-mediated transport: A plot of the flux (rate of passage per unit area) of A increases linearly with the magnitude of the concentration gradient

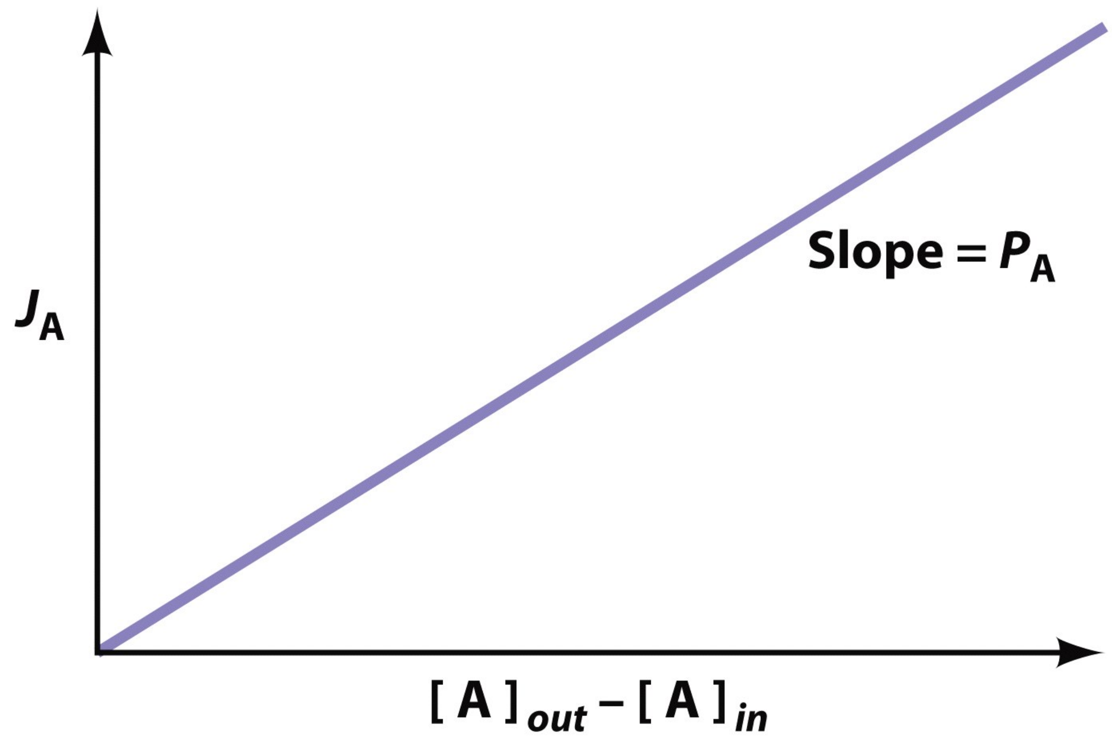


Figure 20-1

The permeability of a solute (tendency to transfer from aqueous solution to the membrane's hydrophobic core) correlates with the oil-water partition coefficient.

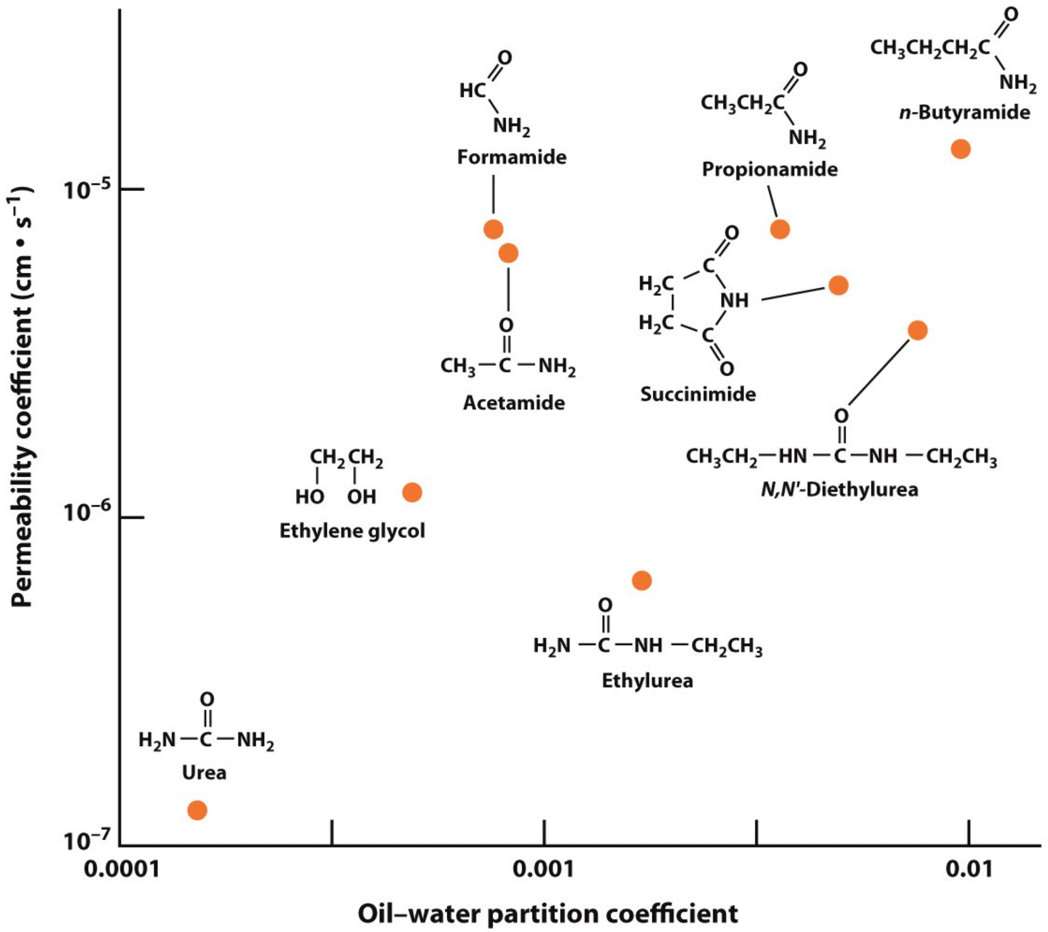


Figure 20-2

Suggests that the rate-limiting step for non-mediated entry of a molecule into a cell is its passage through the membrane's hydrophobic core.

The kinetics of mediated transport:
Glucose transport into erythrocytes

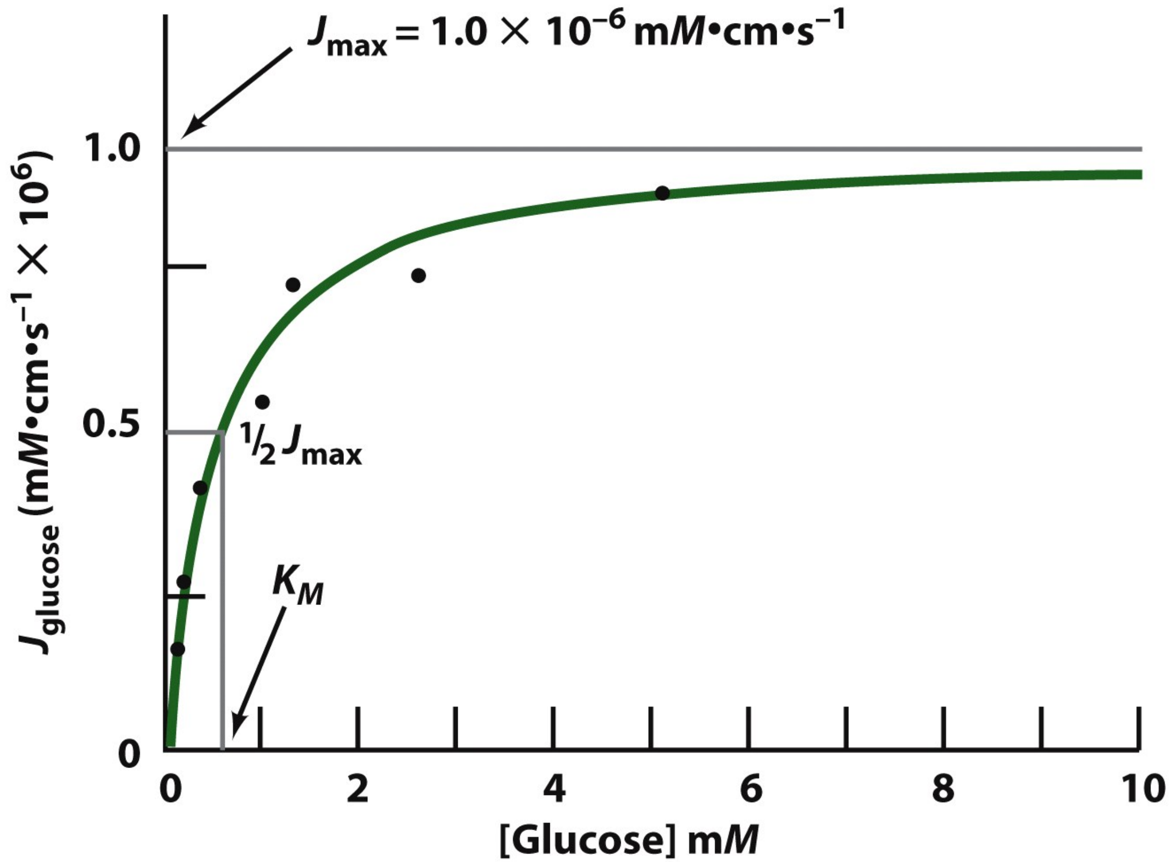


Figure 20-3

A plot of the glucose flux into cells *vs* external glucose concentration: Saturation kinetics

Characteristics of the erythrocyte glucose transporter

1. Speed and specificity
2. Saturation kinetics
3. Susceptible to competitive inhibition
4. Susceptible to chemical inactivation

Saturation kinetics: Kinetic scheme for mediated glucose transport through an erythrocyte membrane (four step process)

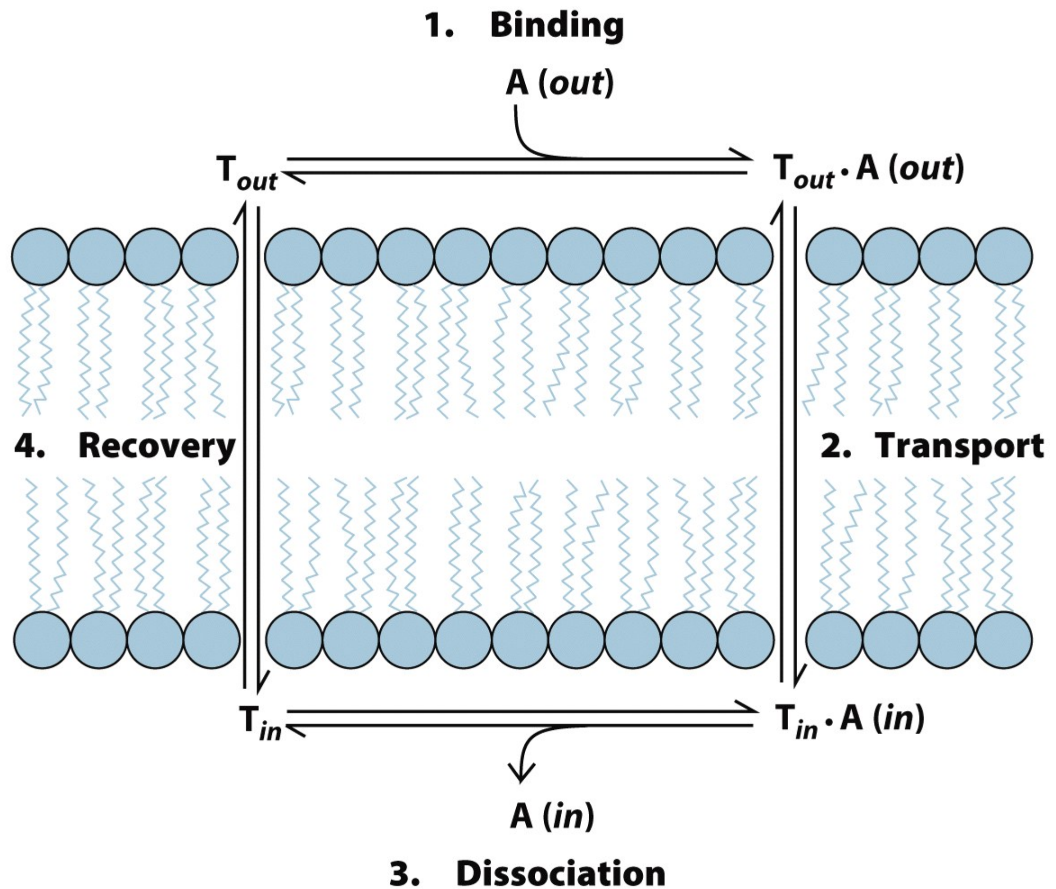


Figure 20-4

Competitive inhibition: Double-reciprocal plots of the net flux of glucose into erythrocytes in the presence and absence of 6-*O*-benzyl-D-galactose

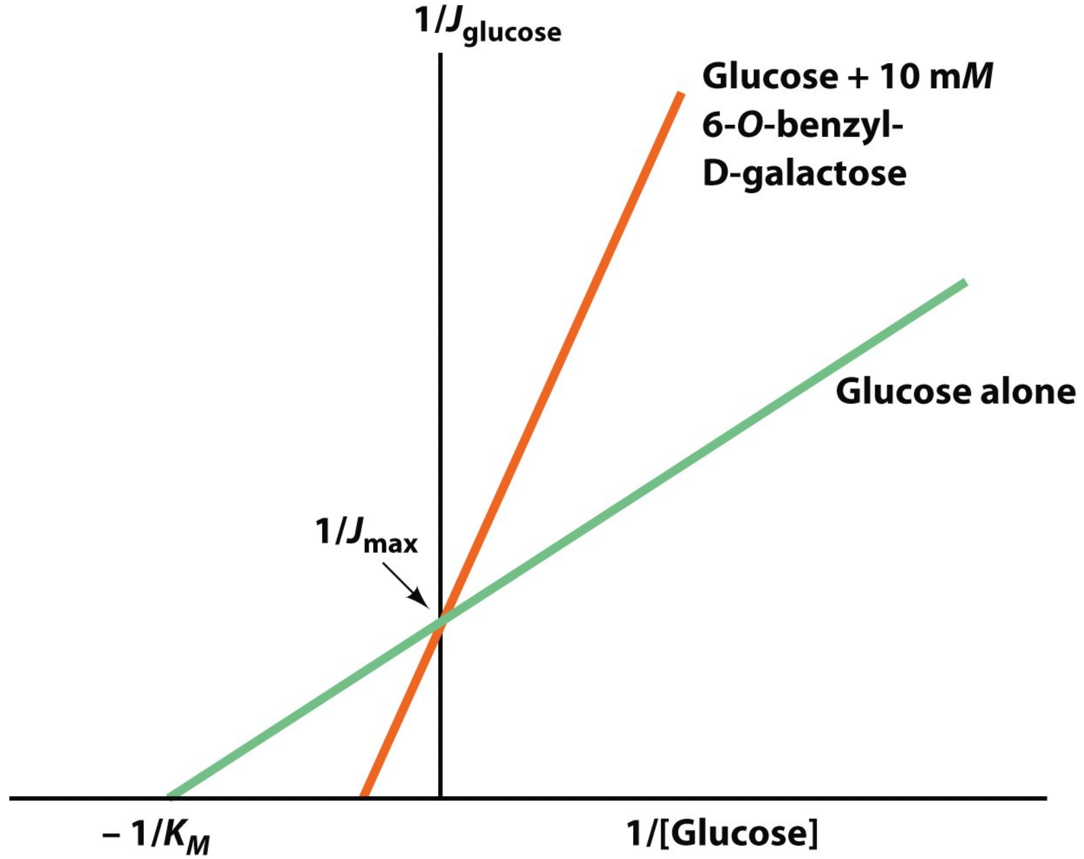


Figure 20-5

Secondary structure and orientation of the glucose transporter in a biological membrane

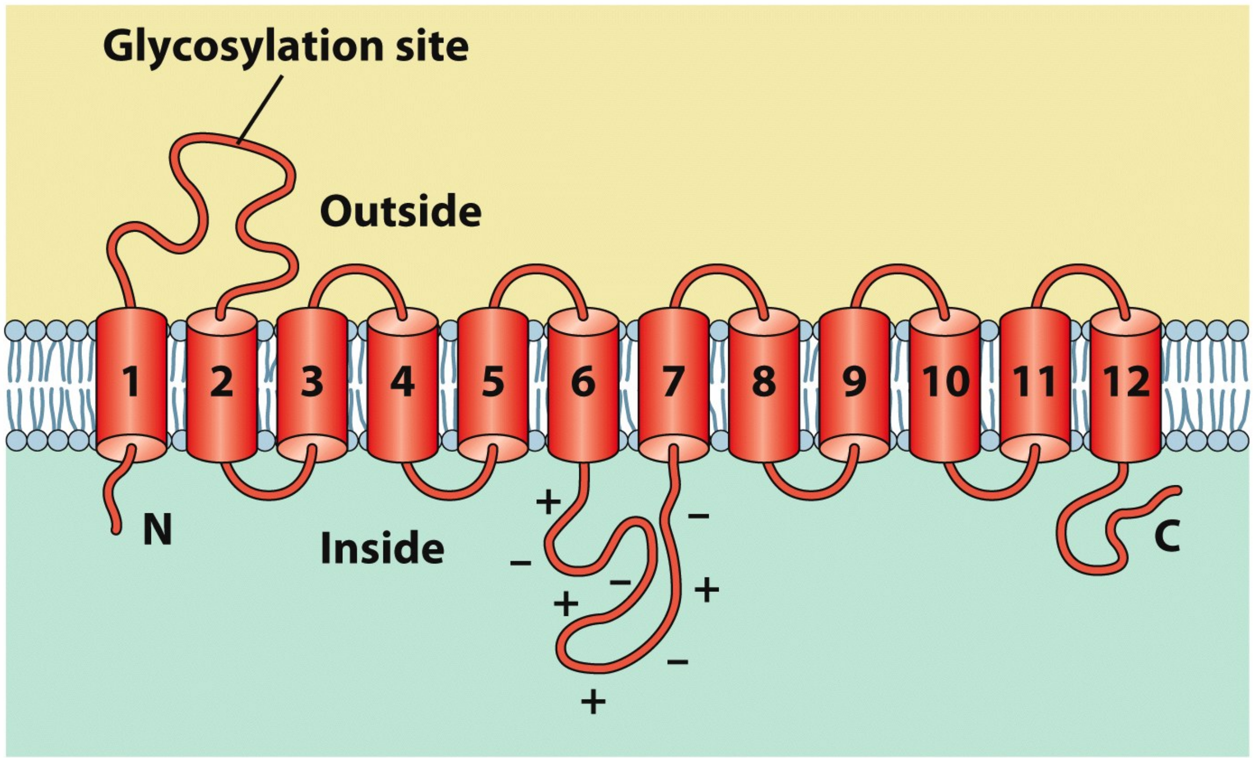


Figure 20-9

Model for mediated transport of glucose into erythrocytes: Alternating conformation model

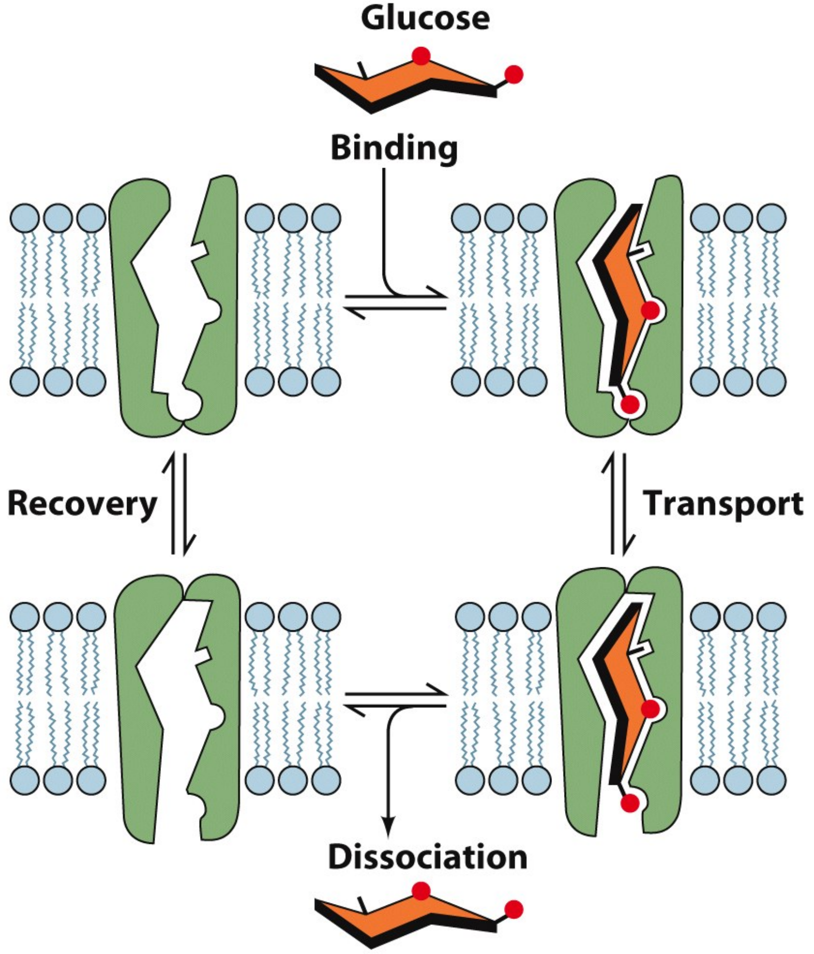


Figure 20-10

There are different types of glucose transporters, GLUTX, where X=1-12. GLUT4 is insulin-dependent (insulin stimulates the display of the transporter on the plasma membrane to allow glucose transport into the cell).

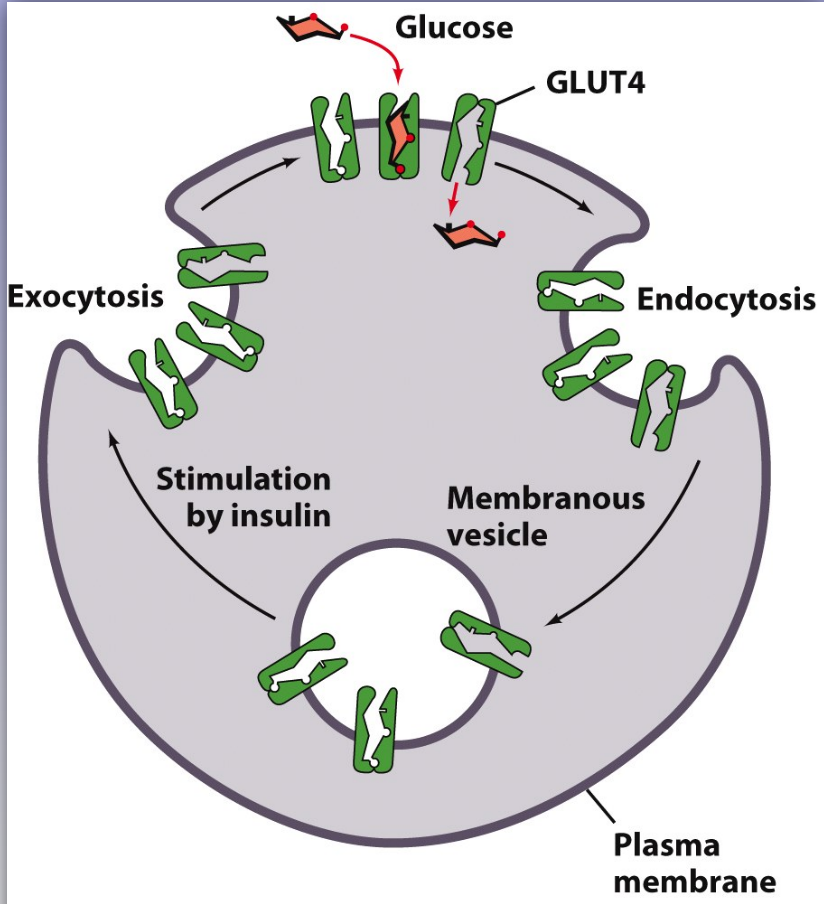


Figure 20-11

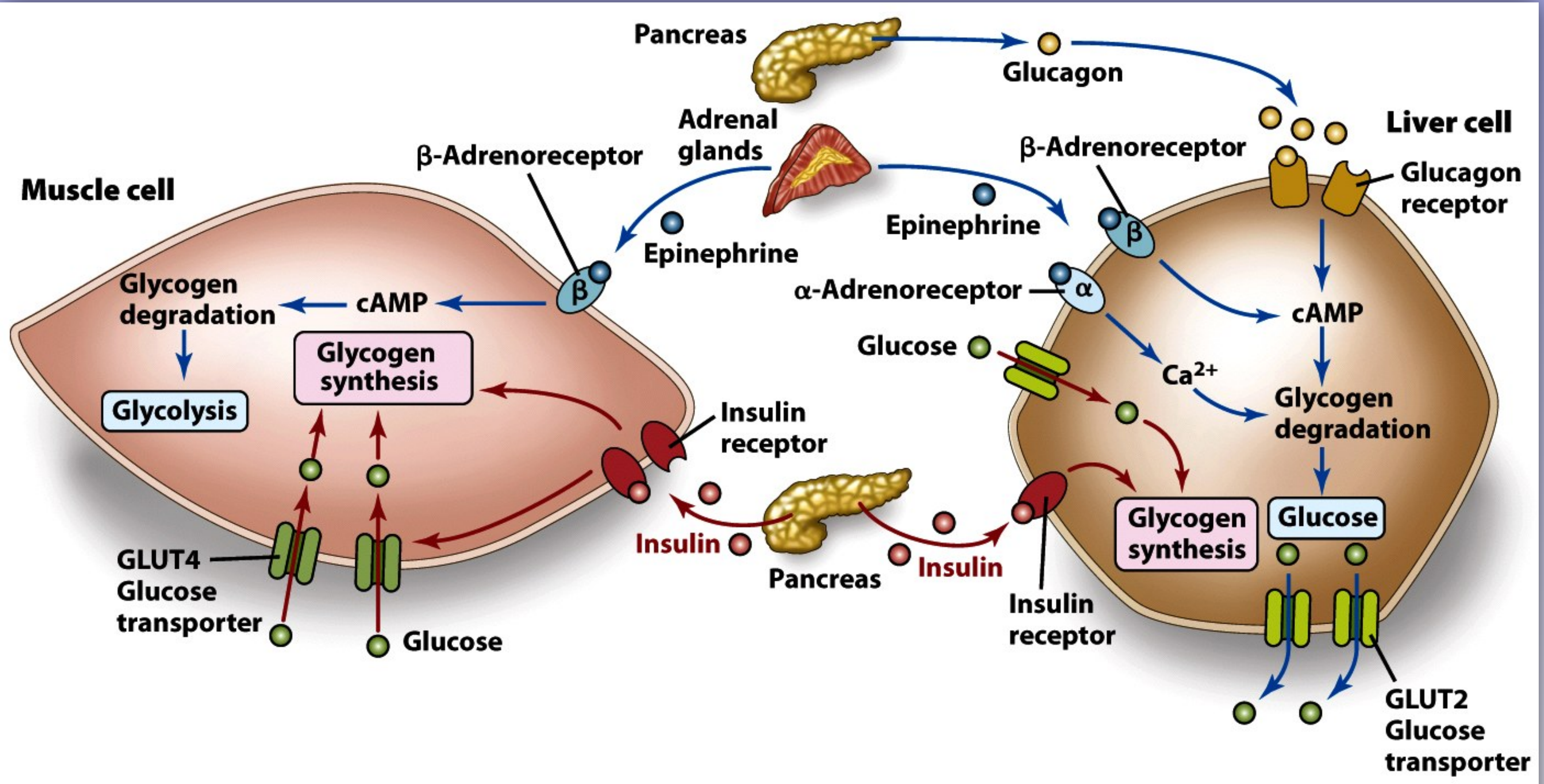
TABLE 12-1 Properties of Selected Members of Human Glucose Transporters (GLUT)

Transporters	Major Tissue Distribution	Properties
GLUT 1	Brain, microvessels, red blood cells, placenta, kidney, and many other cells	Low K_m (about 1 mM), ubiquitous basal transporter
GLUT 2	Liver, pancreatic β-cell, small intestine	High K_m (15–20 mM)
GLUT 3	Brain, placenta, fetal muscle	Low K_m, provide glucose for tissue cells metabolically dependent on glucose
GLUT 4	Skeletal and heart muscle, fat tissue (adipocytes)	K_m (5 mM), insulin responsive transporter
GLUT 5	Small intestine, testes	Exhibits high affinity for fructose
SGLT 1	Small intestine and renal tubules	Low K_m (0.1–1.0 mM)
SGLT 2	Renal tubules	Low K_m (1.6 mM)

GLUT: concentration gradient-dependent facilitated transport with specific carrier; either insulin dependent or insulin independent

SGLT: active transport

Plasma membrane-bound glucose transporters



Other types of mediated transporters: Ionophores that are either carriers or channel formers. Channel formers include gramicidin A and valinomycin, both of which transport K^+ ion.

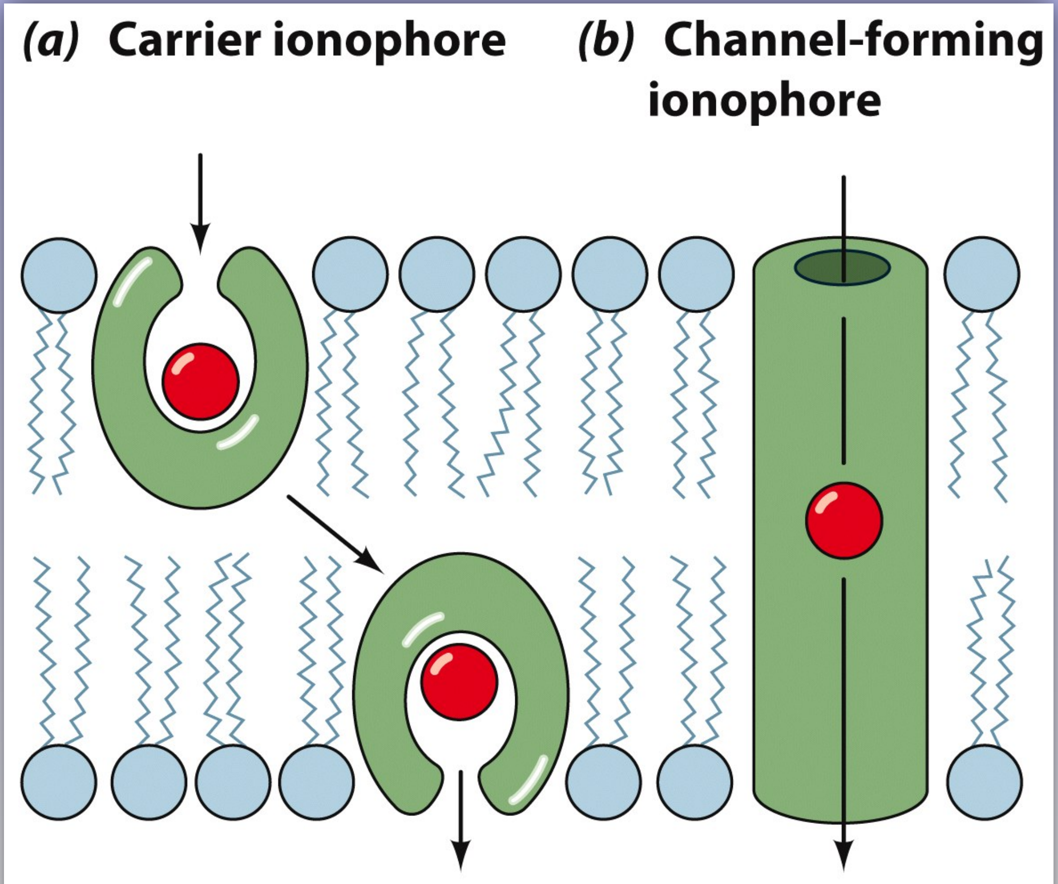
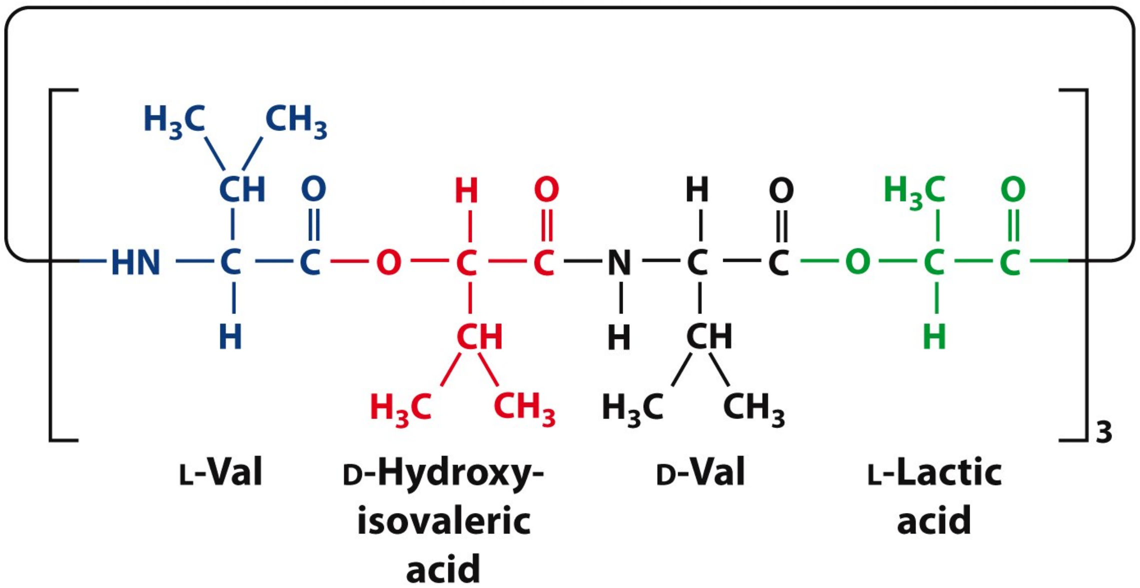


Figure 20-6

The structure of the ionophore, valinomycin



Valinomycin

Figure 20-7a

ATP-Driven Active Transport

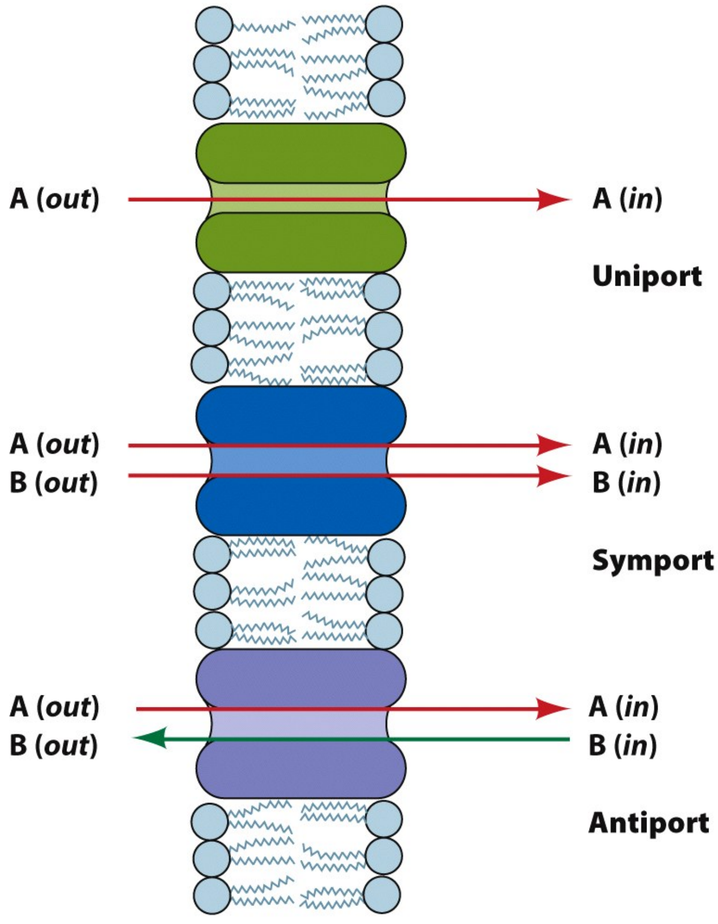


Figure 20-17

Uniport
Symport
Antiport

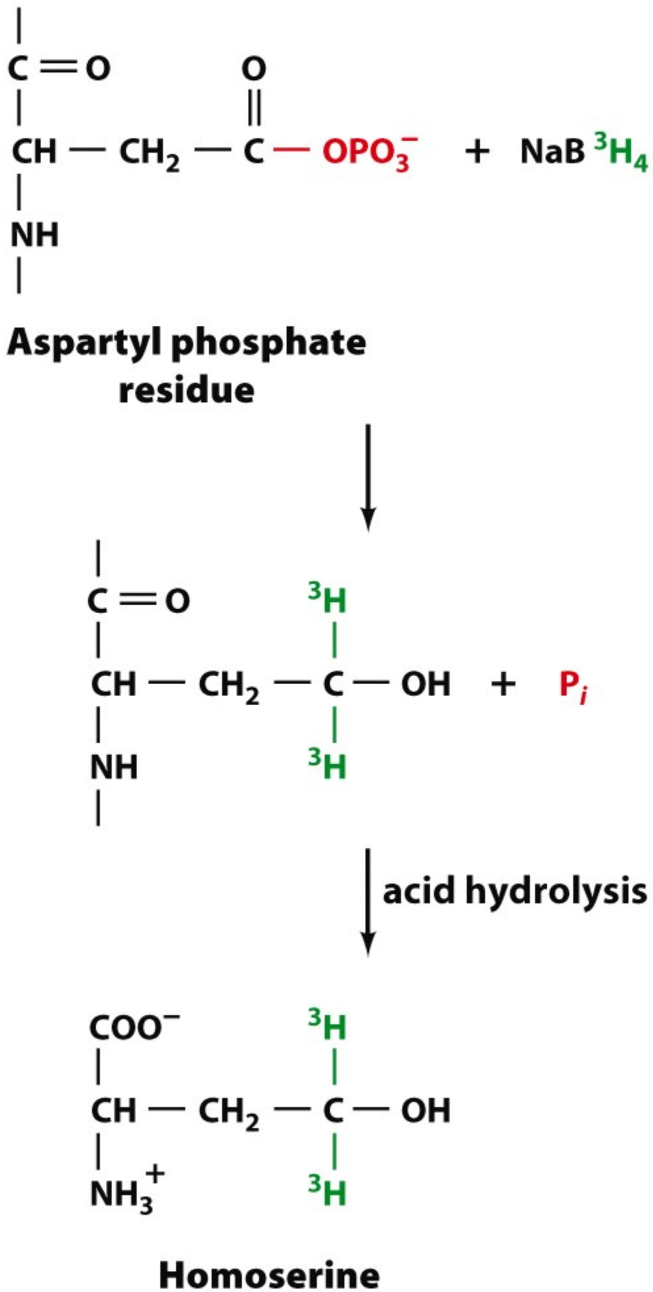


Figure 20-18

$(Na^+$-$K^+)$-ATPase of plasma membranes

The protein gets phosphorylated by ATP in the presence of Na^+ Ions during transport. An aspartic acid residue gets phosphorylated (mixed anhydride).

Kinetic scheme for the active transport of Na^+ and K^+ ions by (Na^+-K^+)-ATPase

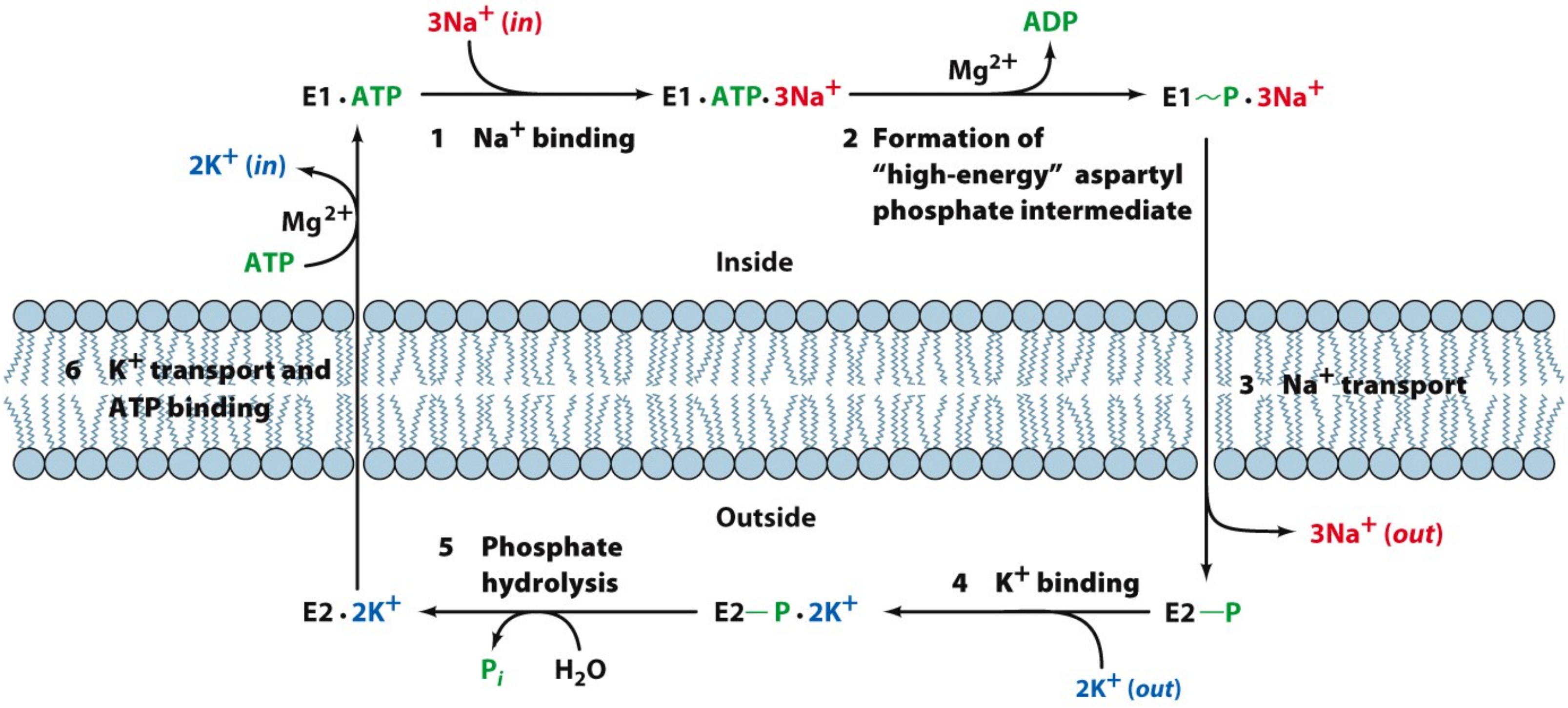


Figure 20-19

The PEP-Dependent Phosphotransferase System (PTS) of *E. coli*

Table 20-2 Some of the Sugars Transported by the *E. coli* PEP-Dependent Phosphotransferase System (PTS)

Glucose	Galactitol
Fructose	Mannitol
Mannose	Sorbitol
N-Acetylglucosamine	Xylitol

Table 20-2

Schematic of the PTS of *E. coli*

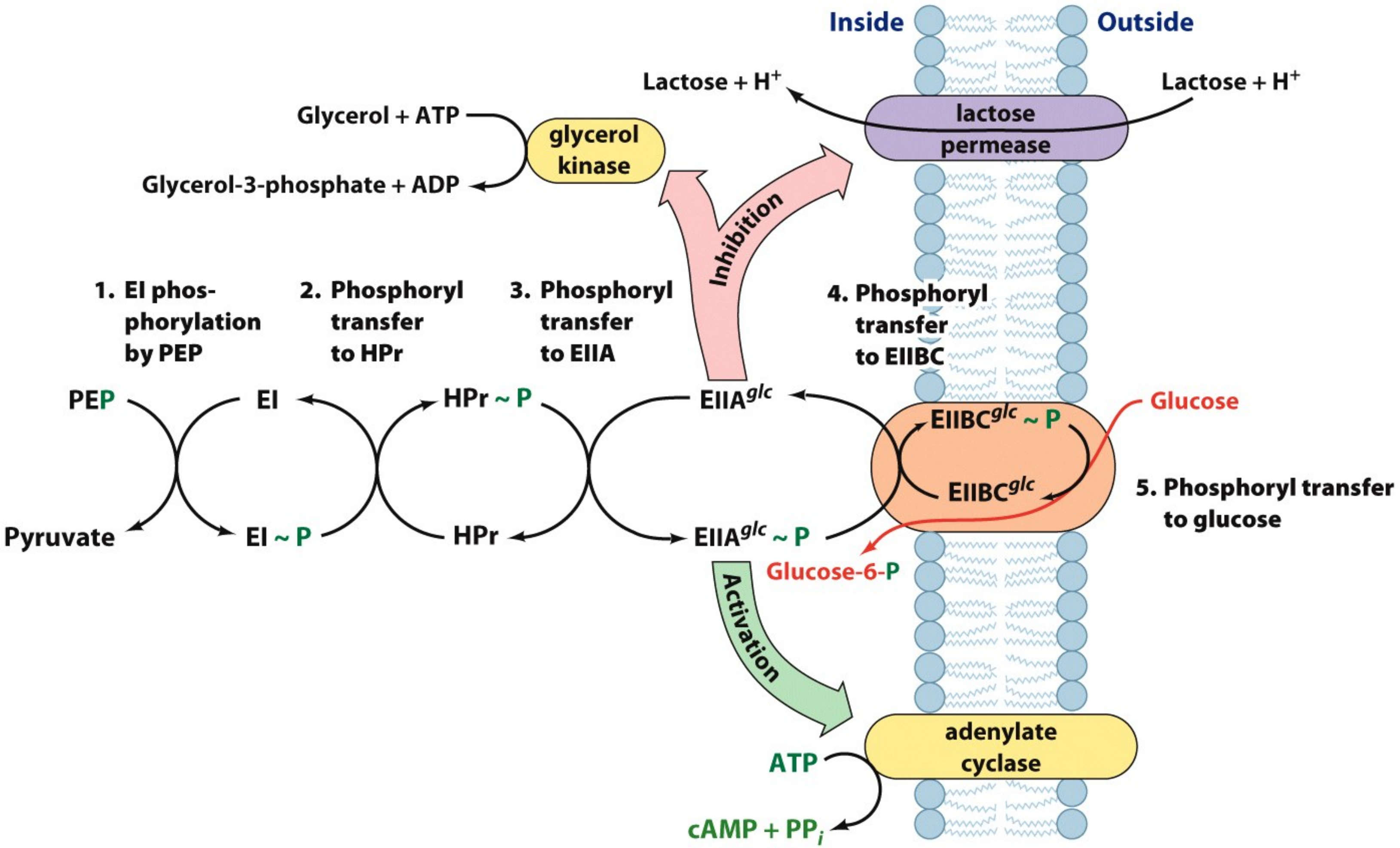
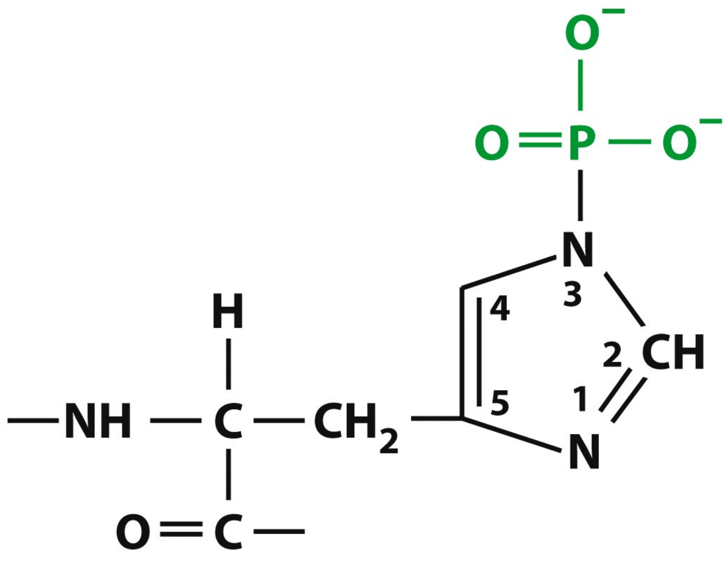


Figure 20-24

Transient covalent phosphorylation of histidine residues during P_i transfer in the PTS



Phosphohistidine residue

Unnumbered 20 p766

Ion-Gradient-Driven Active Transport: Intestinal Na^+-glucose symport

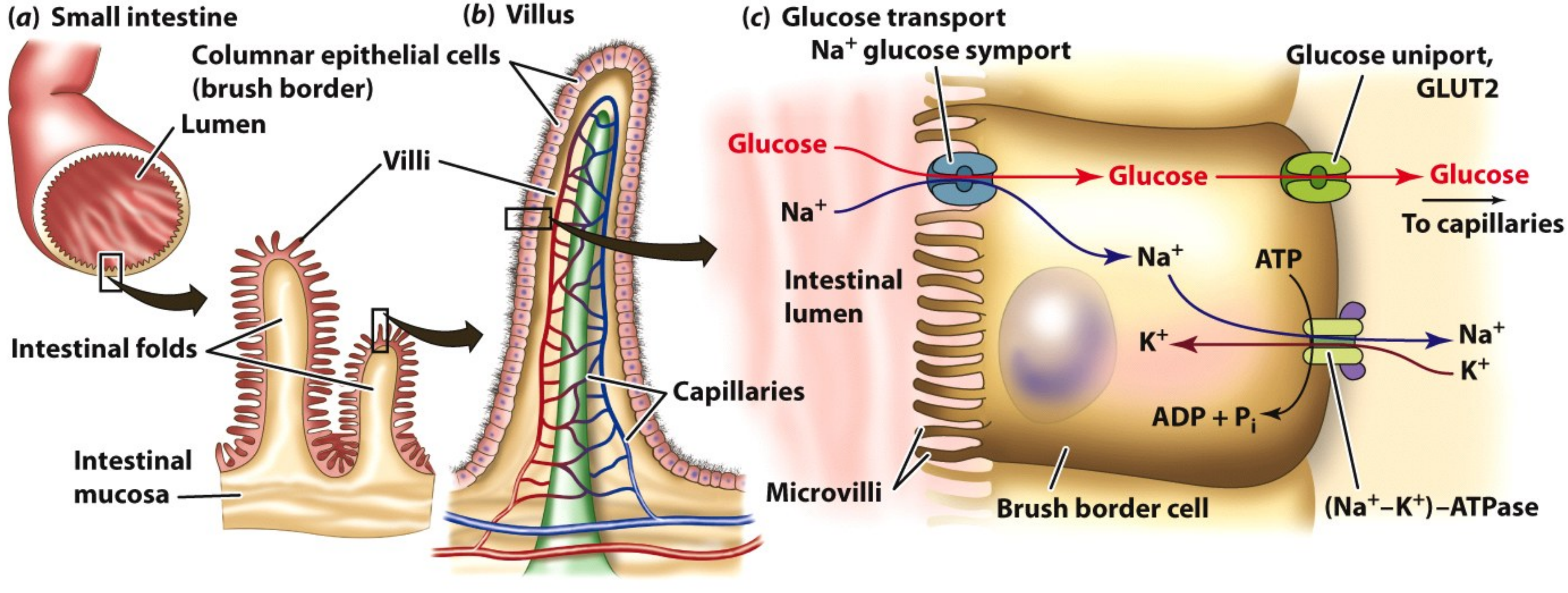


Figure 20-27

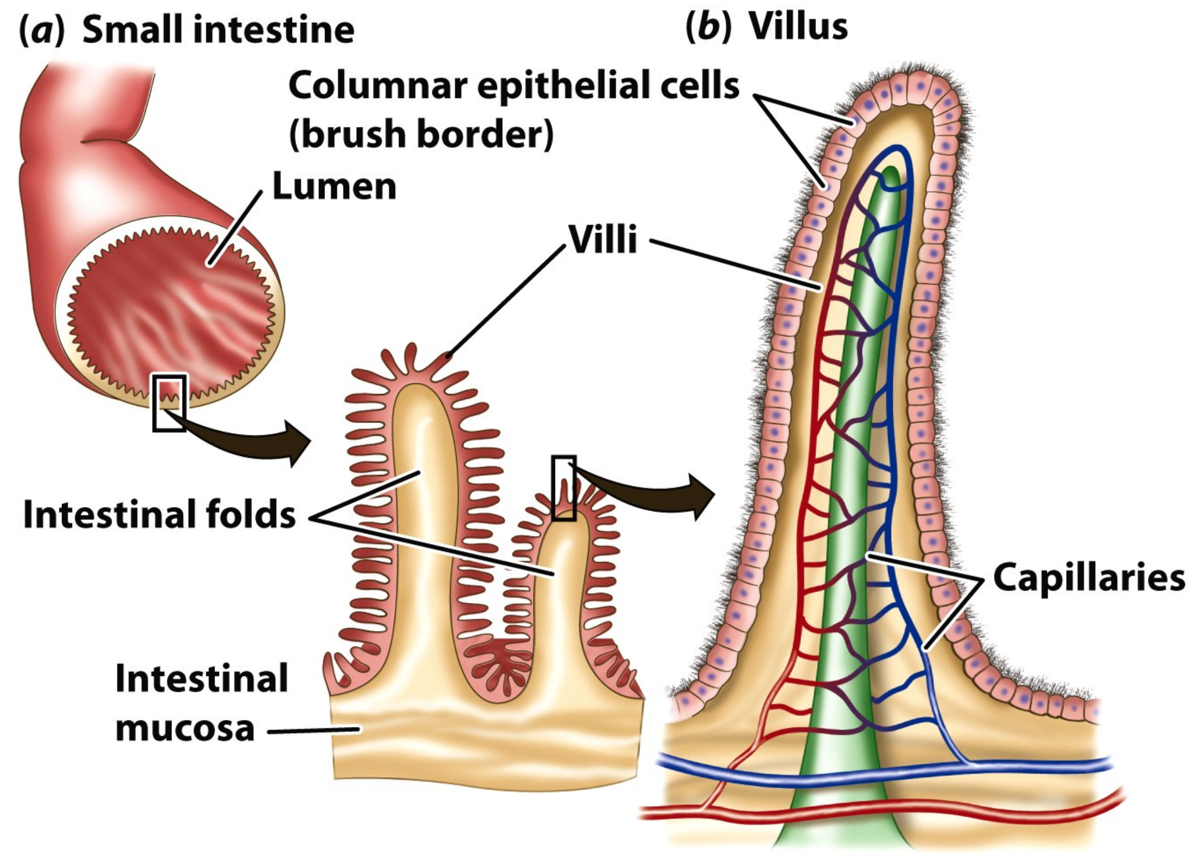


Figure 20-27ab

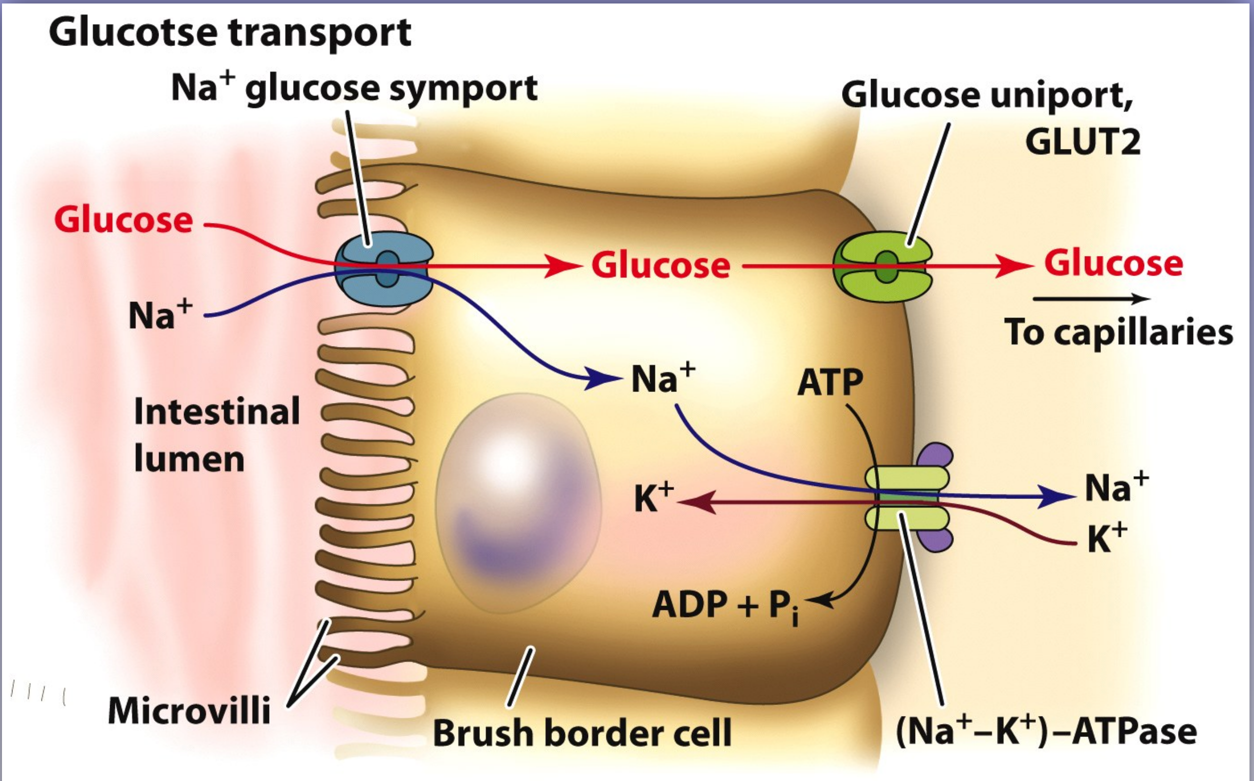


Figure 20-27c

Random Bi Bi kinetic mechanism of the Na⁺-glucose symport of the intestine

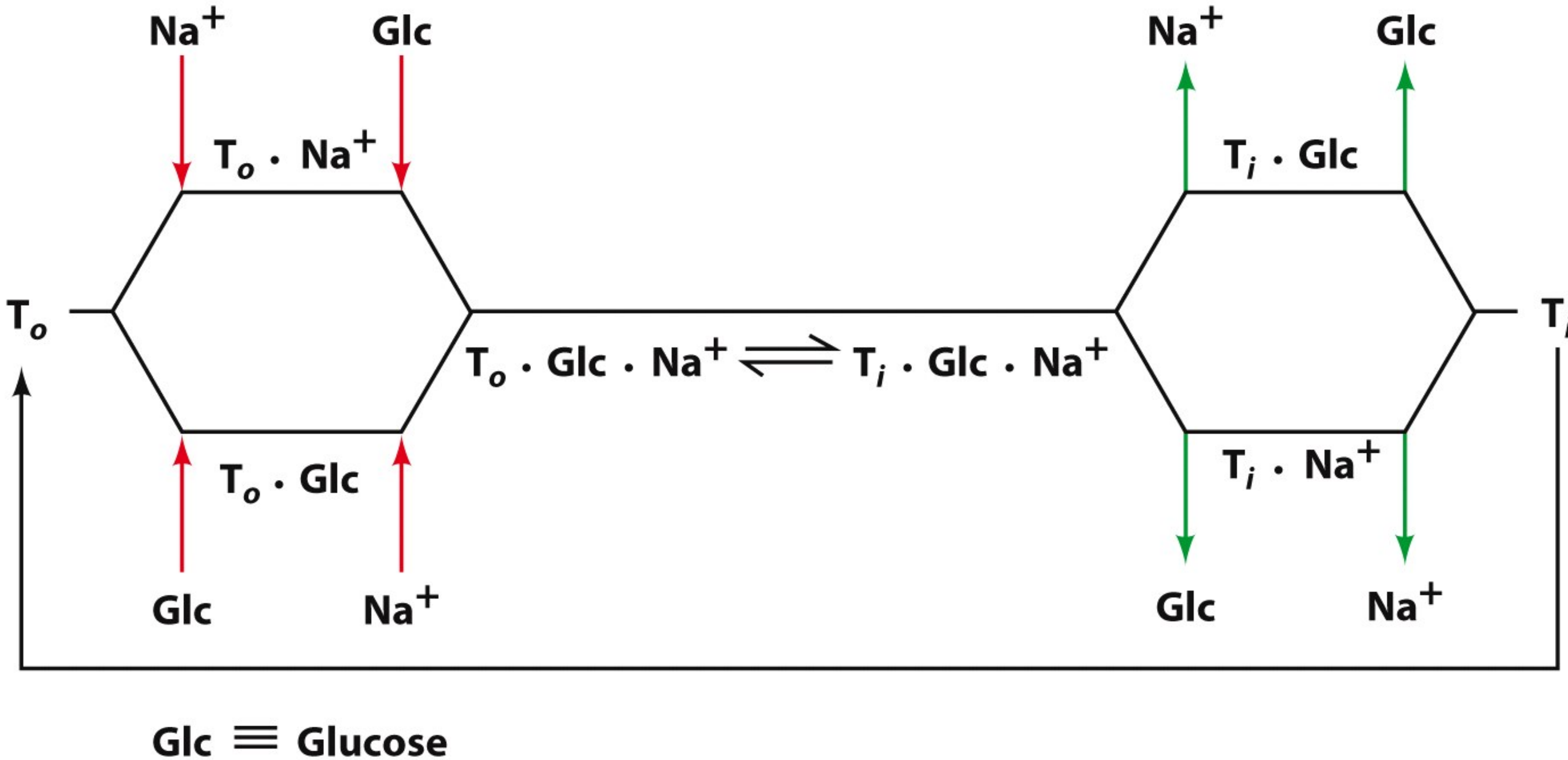


Figure 20-28