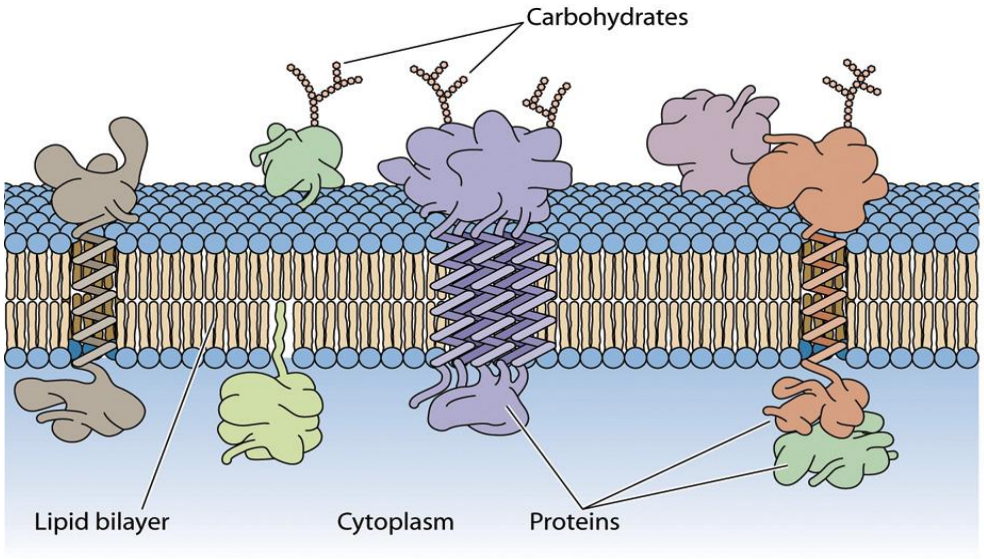
Chapter 7

Cells Maintain Their Internal Environments

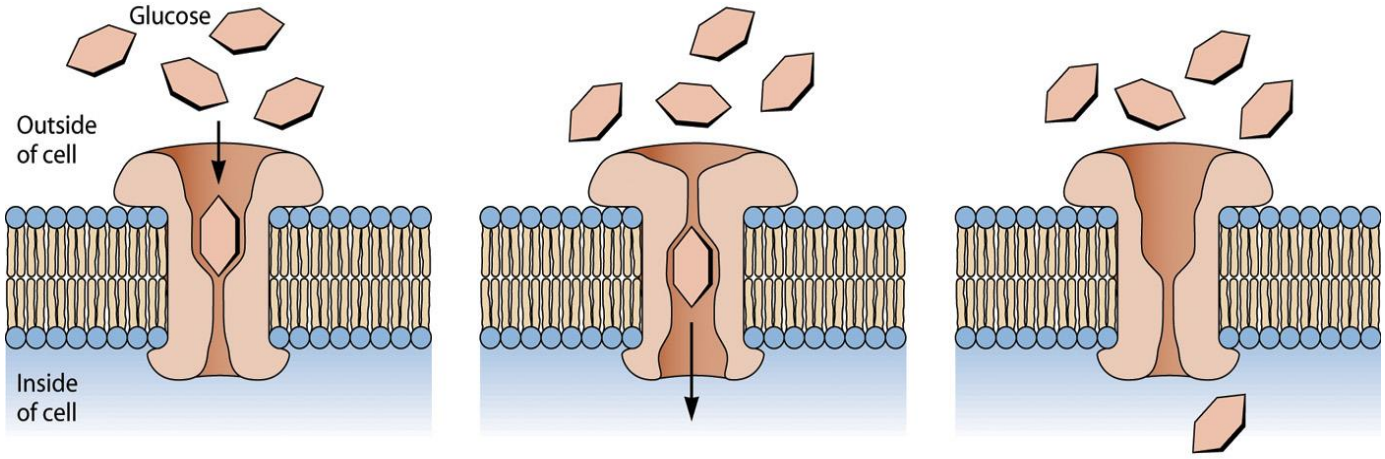
Cell Membrane

- Components of cell membrane
  - Lipid: phospholipids, sterols
  - Embedded proteins : receptor proteins, adhesion proteins, recognition proteins, transport proteins
    - Transmembrane proteins
    - Attachment to cytosolic or exterior face of membrane



Cell Membrane

- Membrane-spanning domains of membrane proteins
  - Hydrophobic surface and hydrophilic core
  - Transport of sugars, amino acids and ions (hydrophilic) through the hydrophilic core of transport proteins



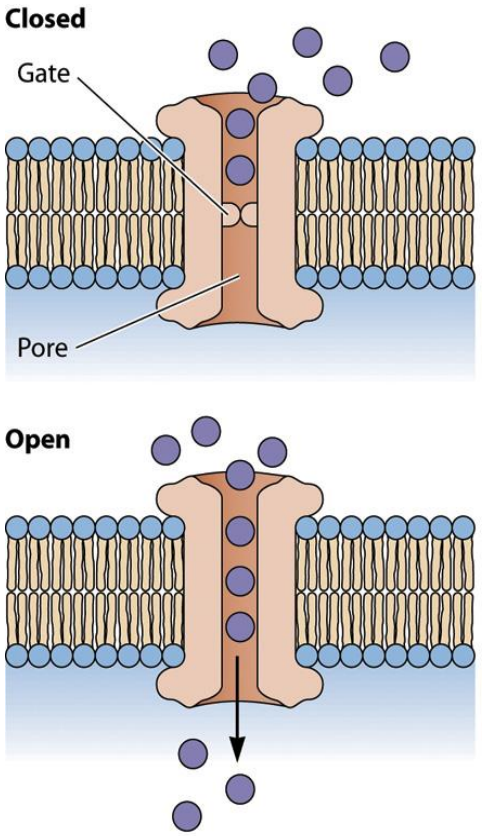
Transport Across Membrane

- Hydrophobic substances and very small molecules can cross the membrane unassisted.

- Diffusion
  - Free diffusion by concentration gradient
  - Hydrophobic substance, nonpolar molecules (O_2, CO_2), small polar molecules (water, ethanol)

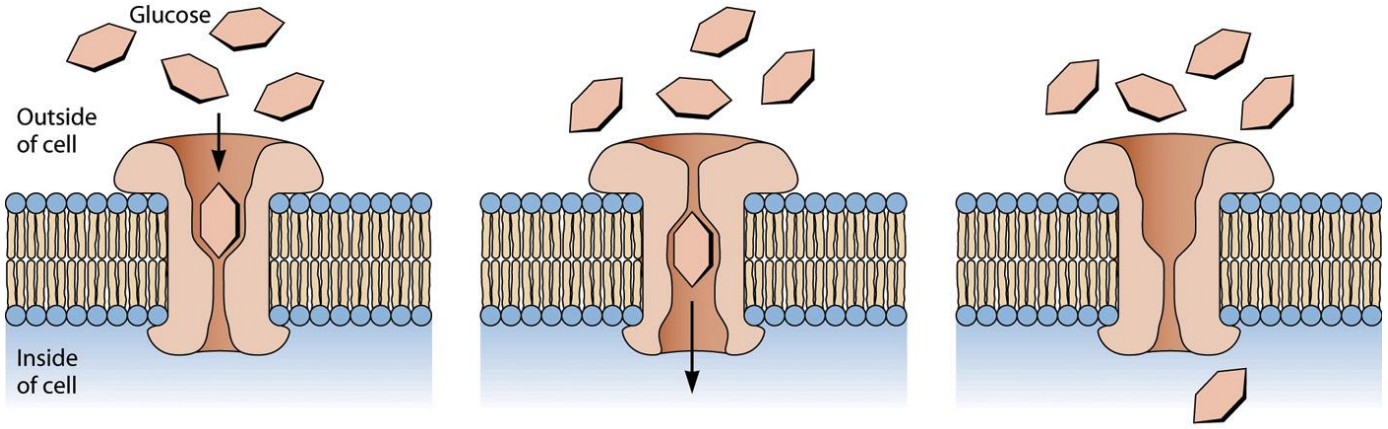
Transport Proteins

- Channel proteins
  - Transport of ions (Na^+, K^+, Ca^{2+}, Cl^-)
  - Along their concentration gradients
  - Aquaporin: channel for water (much faster than the diffusion across the membrane)
  - Gated channel



Transport Proteins

- Carrier proteins
  - Escort energy substrates and metabolic building blocks, such as glucose, amino acids, and nucleosides
  - Along the concentration gradient
  - Slower than simple diffusion



Active Transport

- Pump
  - One type of proteins that uses energy to move substances
  - Transport against the concentration gradient
  - Different concentrations between intracellular and extracellular fluids are maintained through pumps.

Table 7.1 Approximate concentrations of ions in intracellular and extracellular fluids

Ion[a]	Intracellular concn (mM)	Interstitial concn (mM)
Sodium (Na^+)	10	145
Potassium (K^+)	150	5
Calcium (Ca^{2+})	0	3
Chloride ($C1^-$)	5	110

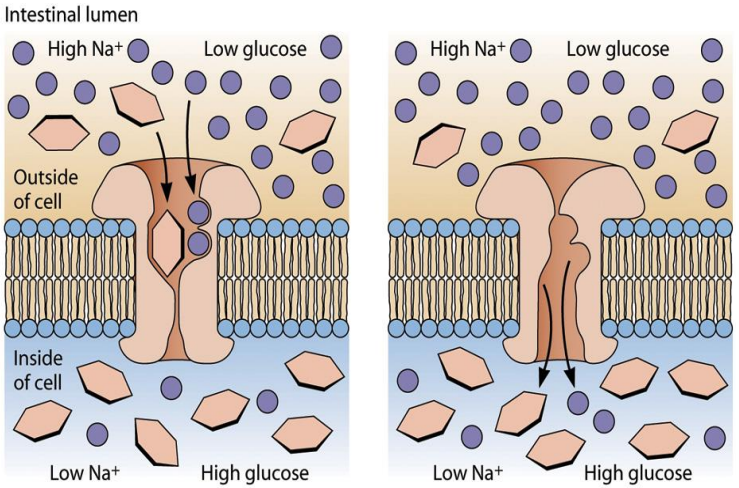
[a]The most abundant ions in interstitial fluid are sodium and chloride ions, which are the components of table salt.

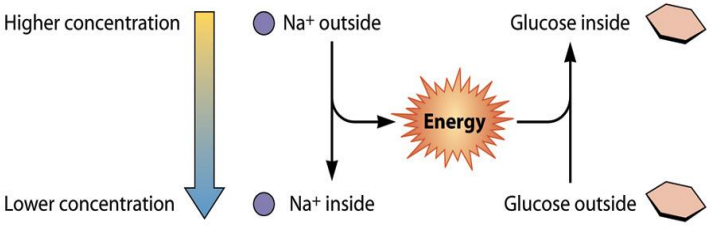
Pump

- Two different energy sources
  - ATP

    -- e.g. Pumping Na^+ and K^+ against their gradients using ATP

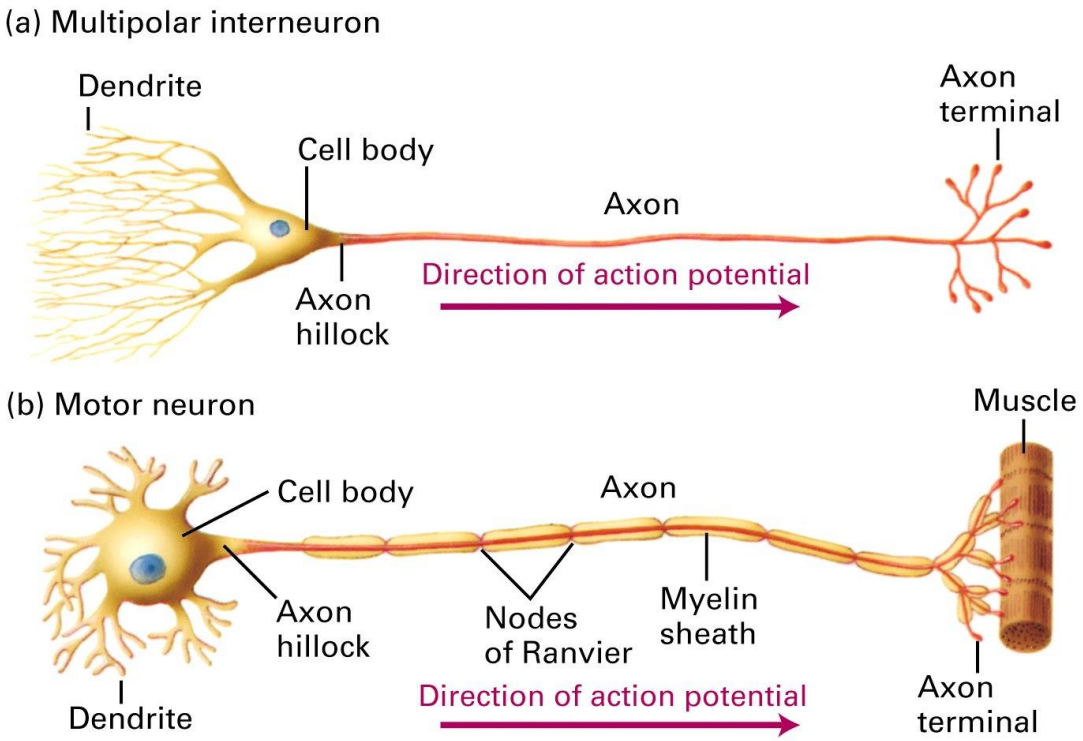
    (Na^+/K^+ ATPase)
  - Energy inherent in gradient





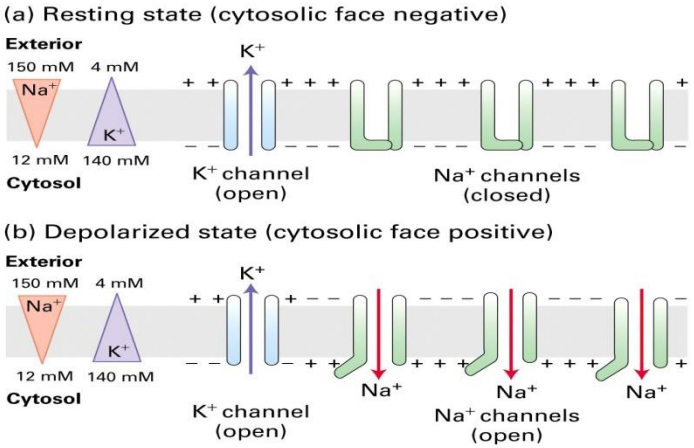
Transport Proteins in Animals

- Nerve Impulses



Nerve Impulses

- Key players: Na^+, K^+
- Resting membrane potential of -70mV
  - (Some K^+ channels are open.)
- Opening of Na^+ channel by stimulation
  - Generation of action potential 50 mV



- Opening of voltage-gated K^+ channel
  - Repolarization of membrane potential
- Restoration of membrane potential by Na^+/K^+ ATPase

Muscle Contraction

- Key player: Ca^{2+}
- Inside muscle cells, Ca^{2+} are packed into a membrane-bound compartment called the sarcoplasmic reticulum (SR).
- When the nerve impulse (powered by Na^{+}/K^{+} gradients) reaches the muscle cells, it triggers Ca^{2+} channel in the SR to open.
- Opening of Ca^{2+} channel in SR

  → Release of Ca^{2+}

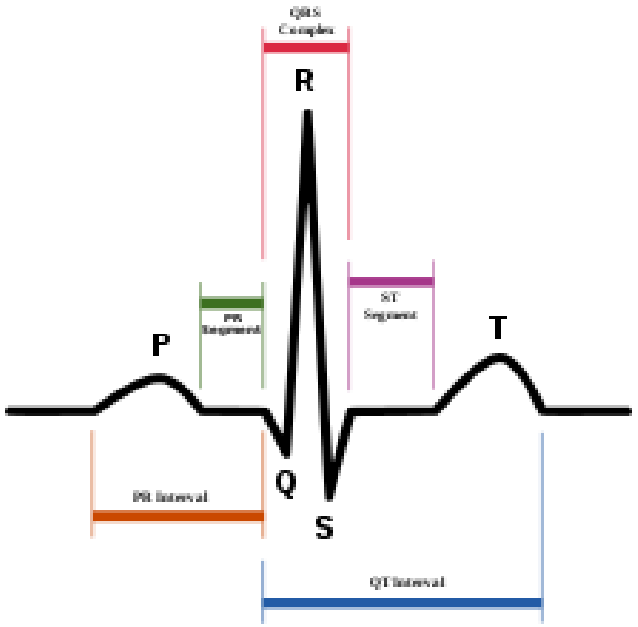
  → Released Ca^{2+} binding to troponin (protein)

  → Muscle contraction

When Gradients Fail

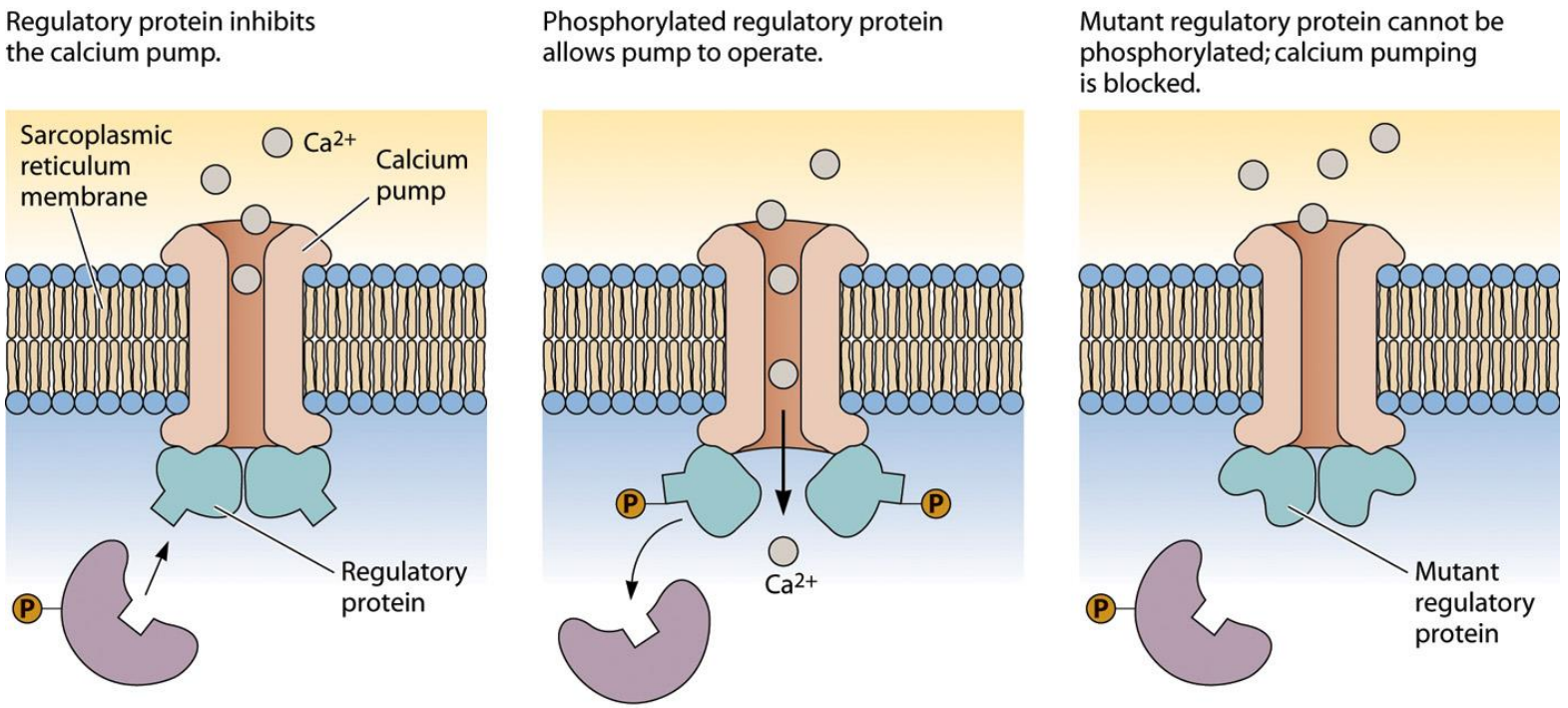
- Long QT (LQT) syndrome
  - Long recovery periods before new heart contraction
  - Cell to cell variation of recovery periods
    - Can cause arrhythmia (lack of rhythm)
  - Defects in K^+ or Na^+ channels

Electrocardiogram (ECG)



When Gradients Fail

- Inherited heart failure
  - Mutation in the regulatory protein of Ca^{2+} channel in SR (The pump can not transport Ca^{2+} back into SR)



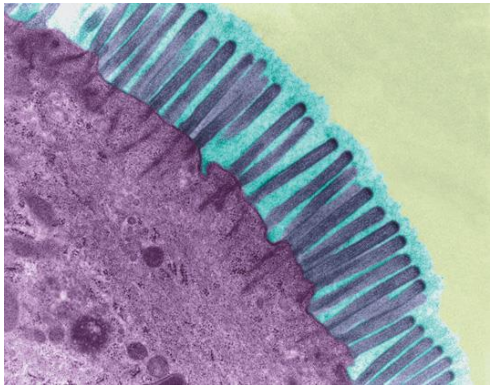
Pumps, Carriers, and Nutrient Distribution

- Nutrient components must move from the intestine to the blood stream through intestinal epithelium.
- Epithelium
  - The body's version of a cell's membrane
  - Epithelial cells
    - Cells cover body surfaces and line internal organs
- Intestinal epithelium
  - Cells lining the digestive tract

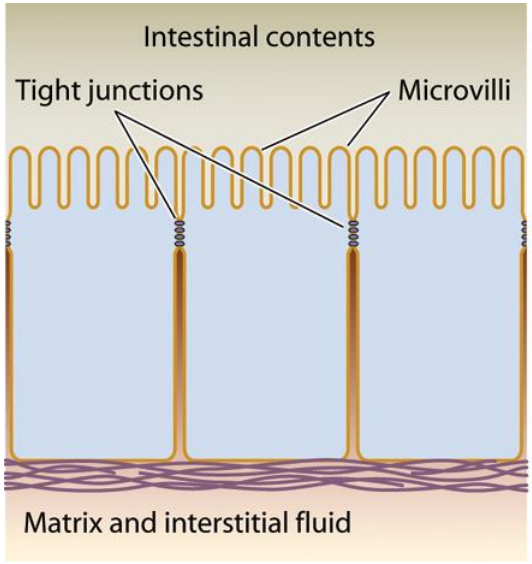
Intestinal Epithelium

- Microvilli
  - Facing the intestinal track
  - Enzymes and transport proteins are located.
    - The enzymes break down complex sugars into simple sugars.

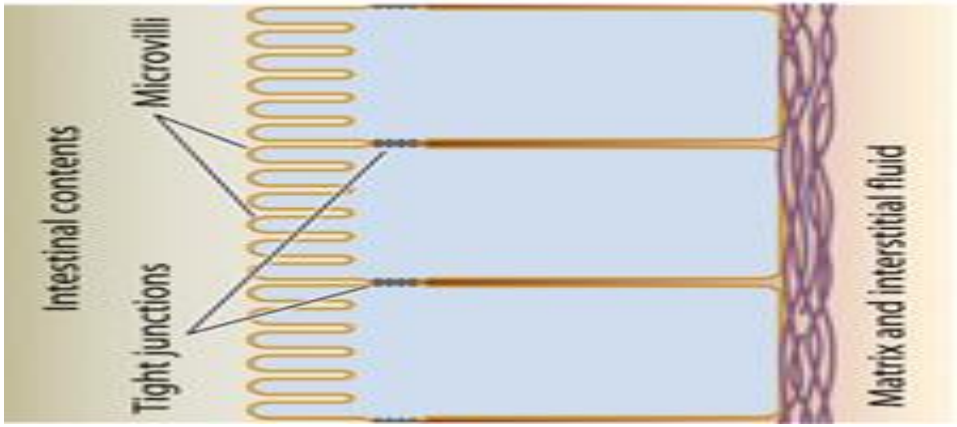
      lactose, sucrose → glucose

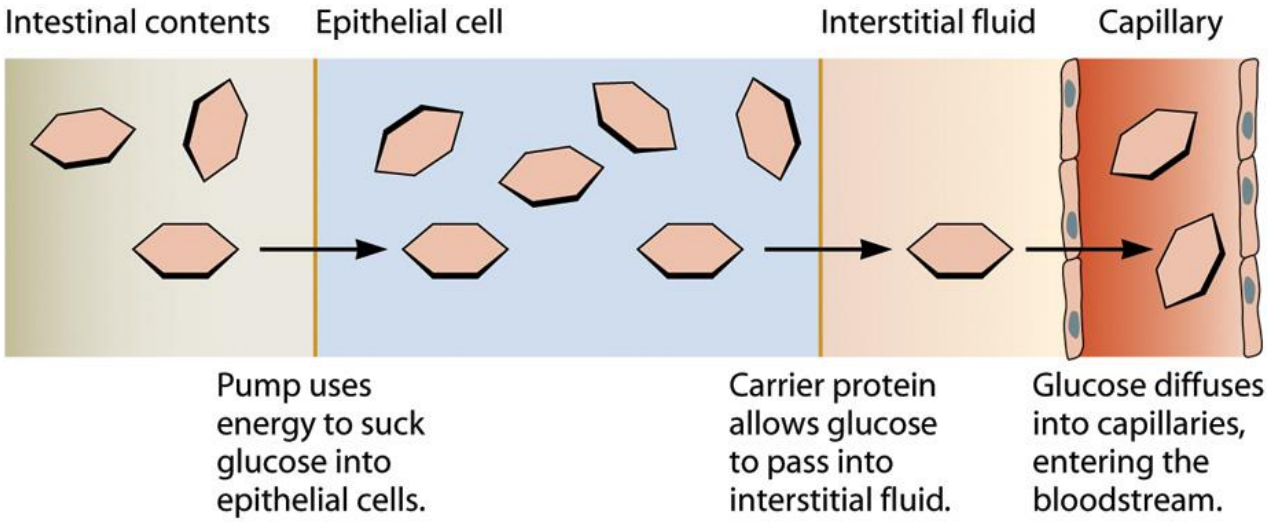


- Tight Junction between Cells
  - Preventing transport of large molecules
  - Barrier between the intestinal contents and the interstitial fluid
- Extracellular Matrix
  - Supporting epithelial cells
  - Tough network of extracellular proteins and carbohydrates



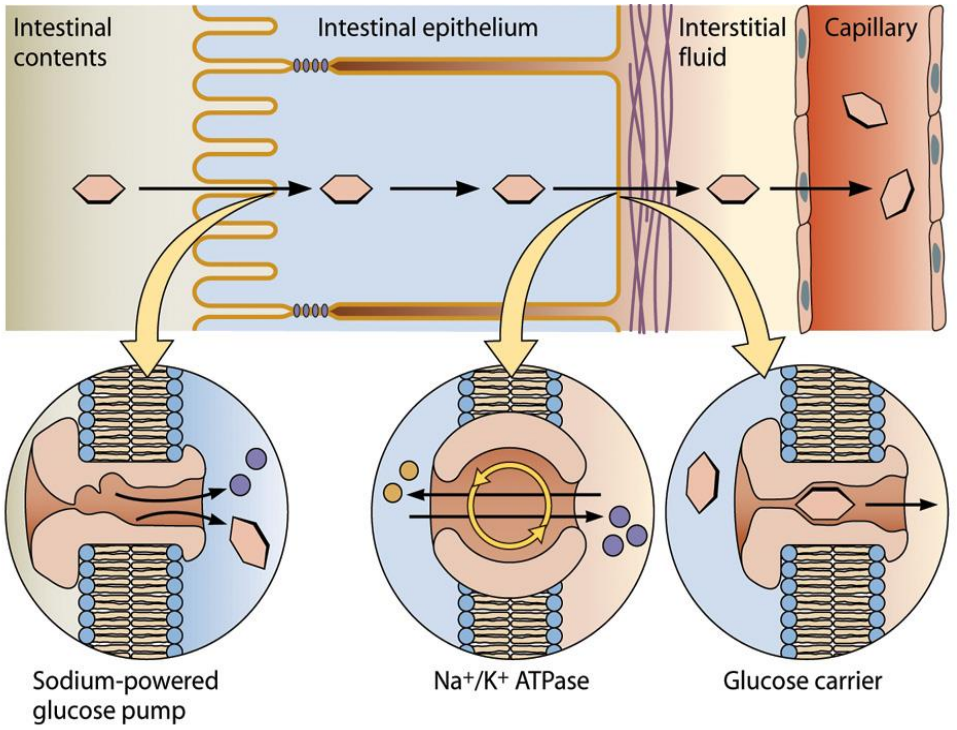
Transport of Nutrients across Epithelial Cells





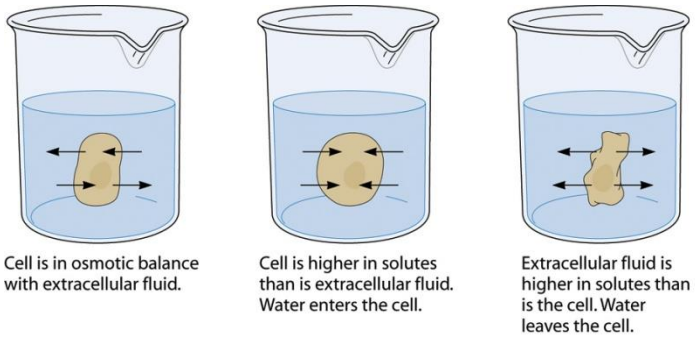
Transport of Nutrients across Epithelial Cells

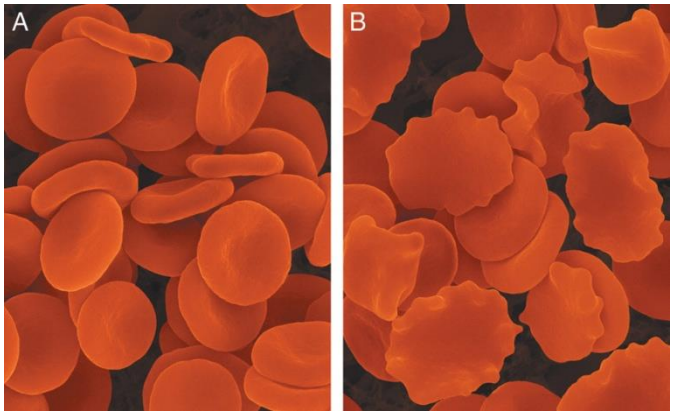
- Intestinal side
  - active transport of glucose powered by Na^+ gradient
  - co-transport of two Na^+ and one glucose molecule
- Interstitial fluid side
  - glucose
    -- by carrier proteins
  - Na^+
    -- by Na^+/K^+ ATPase
- Capillary wall
  - Glucose diffusion
  - Designed to let all but the large molecules (e.g. blood proteins) cross over



Cells, Salts, and Water Balance

- Movement of water across the cell
  - Water movement to equalize the total concentration of solutes
  - Osmosis: movement of water across membranes
  - Osmotic balance: no net water movement





  - Cells in osmotic balance
    - Cells contain many proteins, amino acids, and other small molecules.
    - Concentration of total ions is higher outside than inside cells to keep the osmotic balance.

Water follows salt

- Water in human body (75 kg man)
  - 45 L of water
    - 30 L: intracellular
    - 3.75 L: blood plasma
    - 11.25 L: extracellular fluid

  Almost same solute (salt), since blood capillaries are permeable to small molecules
- Water balance
  - Lactose intolerance
    - Lack of lactase breaking lactose into glucose and galactose
    - No digestion of lactose → movement of water into the intestine
    - Metabolize of lactose by intestinal bacteria → gas production
  - High-magnesium laxative : relieving constipation
  - Cystic fibrosis (by impaired salt transport)
    - Mutation in Cl^- channel : reduced water secretion → thick mucus in epithelia of respiratory and gastrointestinal tracts

Biotechnology

- Rehydration therapy
  - Diarrhea: kill 2 million children/year by dehydration
  - Solution of sugar and salt is effective to treat dehydration: e.g. sports drinks
- Enzyme treatments
  - Lactose intolerance
    - Add lactase (β-galactosidase) in milk or dairy products
  - When you eat a bean-rich meal in a Mexican restaurant
    - Beans contain galactose-containing sugars (galactosides)
    - Humans lack enzymes for breaking down galactosides.
    - Microbial munching on galactosides → gas production
    - Buy α-galactosidase (Beano) in a drugstore