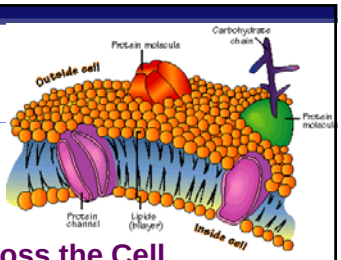
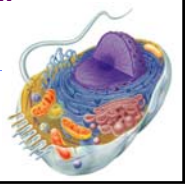
Chapter 7.

Movement across the Cell Membrane

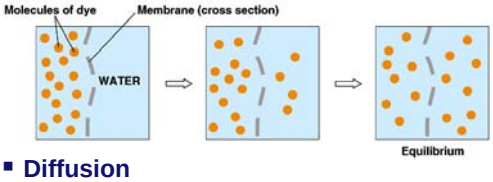




AP Biology

Diffusion

- 2nd Law of Thermodynamics governs biological systems
  - Universe tends towards disorder



- Diffusion
  - movement from high → low concentration

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Diffusion of 2 solutes

- Each substance diffuses down its *own* concentration gradient, independent of concentration gradients of other substances

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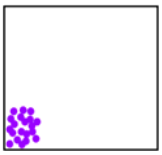
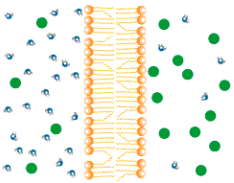
Diffusion

- Move for HIGH to LOW concentration
  - "passive transport"
  - no energy needed





diffusion

osmosis

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by K Foglia
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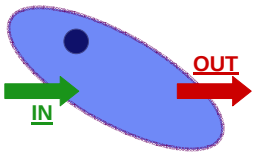
Cell (plasma) membrane

- Cells need an inside & an outside…
  - separate cell from its environment
  - cell membrane is the boundary

Can it be an impenetrable boundary? NO!

IN
food
carbohydrates
sugars, proteins
amino acids
lipids
salts, O_2, H_2O

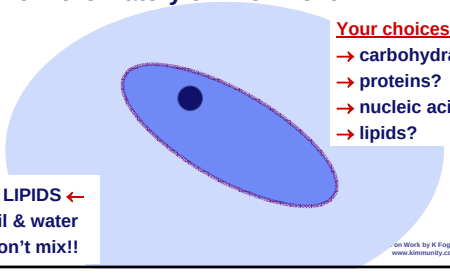


OUT
waste
ammonia
salts
CO_2
H_2O
products

cell needs materials in & products or waste out

Building a membrane

- How do you build a barrier that keeps the watery contents of the cell separate from the watery environment?



Your choices
→ carbohydrates?
→ proteins?
→ nucleic acids?
→ lipids?

→ LIPIDS ←
oil & water
don't mix!!

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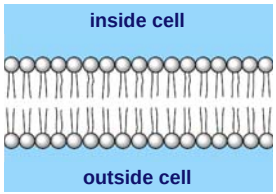
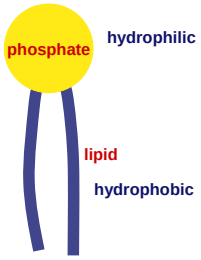
Lipids of cell membrane

- Membrane is made of phospholipids
  - phospholipid bilayer





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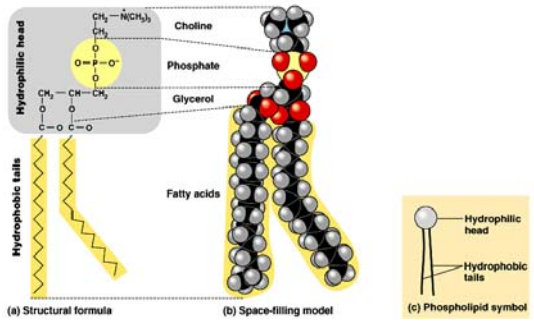
Phospholipids



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Semi-permeable membrane

- Need to allow passage through the membrane
- But need to control what gets in or out
  - membrane needs to be semi-permeable

So how do you build a semi-permeable membrane?

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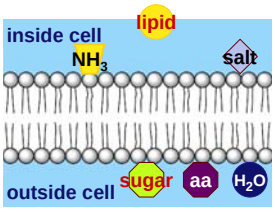
Phospholipid bilayer

- What molecules can get through directly?



fats & other lipids can slip directly through the phospholipid cell membrane, but…

what about other stuff?

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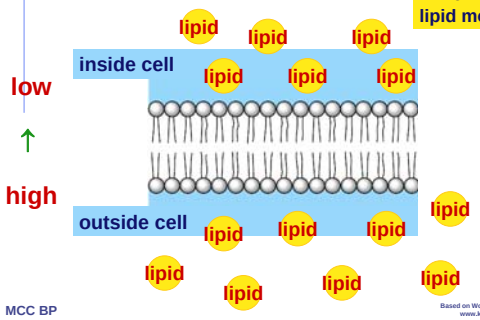
Simple diffusion across membrane

Which way will lipid move?



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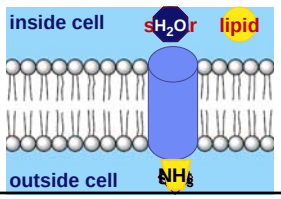
Permeable cell membrane

- Need to allow more material through
  - membrane needs to be permeable to…
    - all materials a cell needs to bring in
    - all waste a cell needs excrete out
    - all products a cell needs to export out

"holes", or channels, in cell membrane allow material in & out



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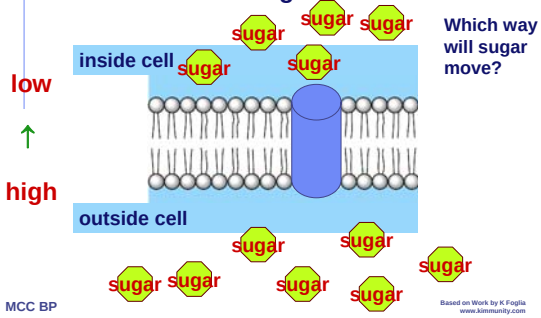
Diffusion through a channel

- Movement from high to low



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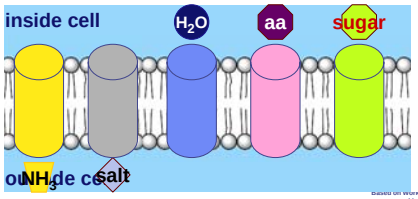
Semi-permeable cell membrane

- But the cell still needs control
  - membrane needs to be semi-permeable
    - specific channels allow specific material in & out



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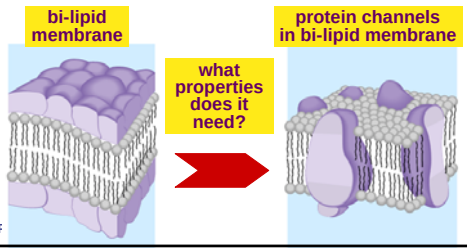
How do you build a semi-permeable cell membrane?

- What molecule will sit "comfortably" in a phospholipid bilayer forming channels



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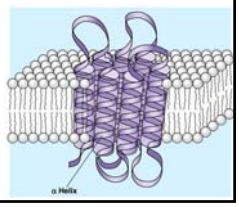
Why proteins?

- Proteins are mixed molecules
  - hydrophobic amino acids
    - stick in the lipid membrane
    - anchors the protein in membrane
  - hydrophilic amino acids
    - stick out in the watery fluid in & around cell
    - specialized "receptor" for specific molecules



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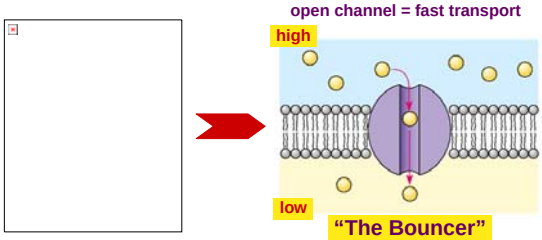
Facilitated Diffusion

- Globular proteins act as doors in membrane
  - channels to move specific molecules through cell membrane



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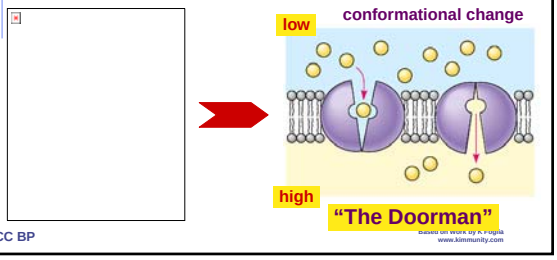
Active Transport

- Globular proteins act as ferry for specific molecules
  - shape change transports solute from one side of membrane to other → protein "pump"
  - "costs" energy



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Getting through cell membrane

- Passive transport
  - diffusion of hydrophobic (lipids) molecules
    - high → low concentration gradient
- Facilitated transport
  - diffusion of hydrophilic molecules
  - through a protein channel
    - high → low concentration gradient
- Active transport
  - diffusion against concentration gradient
    - low → high
  - uses a protein pump
  - requires ATP

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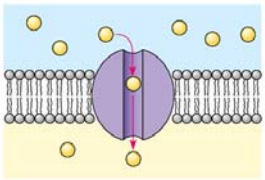
Facilitated diffusion

- Move from HIGH to LOW concentration through a protein channel
  - passive transport
  - no energy needed
  - facilitated = with help



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Gated channels

- Some channel proteins open only in presence of stimulus (signal)
  - stimulus usually different from transported molecule
    - ex: ion-gated channels
      when neurotransmitters bind to a specific gated channels on a neuron, these channels open = allows Na^+ ions to enter nerve cell
    - ex: voltage-gated channels
      change in electrical charge across nerve cell membrane opens Na^+ & K^+ channels

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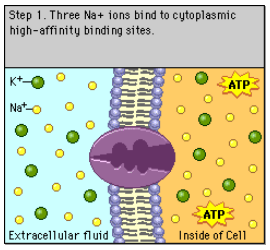
Active transport

- Cells may need molecules to move ***against*** concentration situation
  - need to pump against concentration
  - protein pump
  - requires energy
    - ATP

Na+/K+ pump in nerve cell membranes



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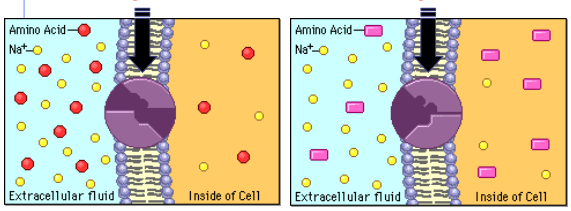
Active transport

- Many models & mechanisms

using ATP

using ATP



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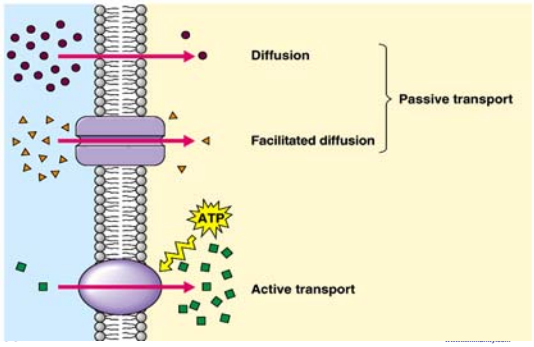
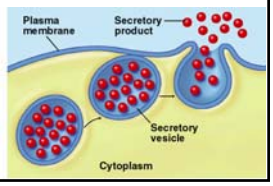
Transport summary



M

How about large molecules?

- Moving large molecules into & out of cell
  - through vesicles & vacuoles
  - endocytosis
    - phagocytosis = "cellular eating"
    - pinocytosis = "cellular drinking"
    - receptor-mediated endocytosis
  - exocytosis



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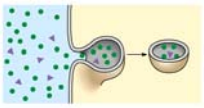
exocytosis

Endocytosis

phagocytosis

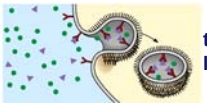
fuse with lysosome for digestion

pinocytosis



non-specific process

receptor-mediated endocytosis



triggered by ligand signal

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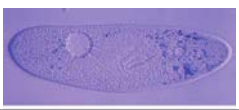
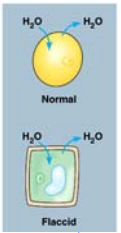
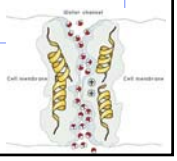
The Special Case of Water

Movement of water across the cell membrane

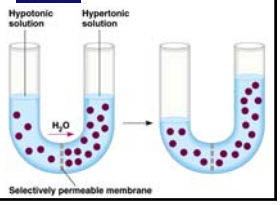






Osmosis is diffusion of water

- Water is very important, so we talk about water separately
- Diffusion of water from *high concentration* of water to *low concentration* of water
  - across a semi-permeable membrane



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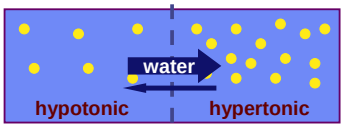
Concentration of water

- Direction of osmosis is determined by comparing total solute concentrations
  - Hypertonic - more solute, less water
  - Hypotonic - less solute, more water
  - Isotonic - equal solute, equal water



net movement of water

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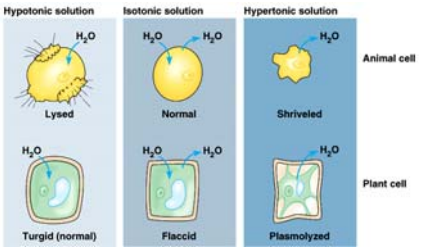
Managing water balance

- Cell survival depends on balancing water uptake & loss



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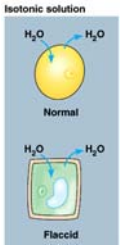
Managing water balance

- Isotonic
  - animal cell immersed in isotonic solution
    - blood cells in blood
    - no net movement of water across plasma membrane
    - water flows across membrane, at same rate in both directions
    - volume of cell is stable



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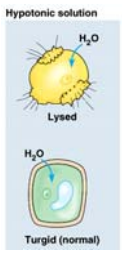
Managing water balance

- Hypotonic
  - animal cell in hypotonic solution will gain water, swell & burst
    - *Paramecium* vs. pond water
    - *Paramecium* is hypertonic
    - H_2O continually enters cell
    - to solve problem, specialized organelle, contractile vacuole
    - pumps H_2O out of cell = ATP
  - plant cell
    - turgid



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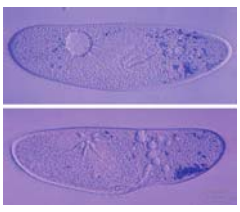
Water regulation

- Contractile vacuole in *Paramecium*



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Managing water balance

- Hypertonic
  - animal cell in hypertonic solution will loose water, shrivel & probably die
    - salt water organisms are hypotonic compared to their environment
    - they have to take up water & pump out salt
  - plant cells
    - plasmolysis = wilt

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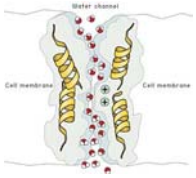
Aquaporins

1991 | 2003

- Water moves rapidly into & out of cells
  - evidence that there were water channels



Peter Agre
John Hopkins

Roderick MacKinnon
Rockefeller

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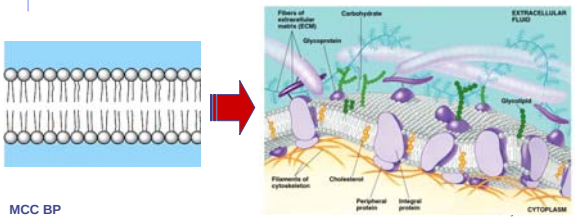
More than just a barrier…

- Expanding our view of cell membrane beyond just a phospholipid bilayer barrier
  - phospholipids plus…



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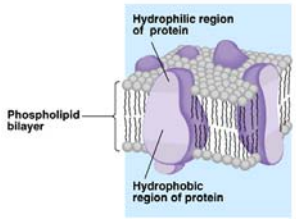
Fluid Mosaic Model

- In 1972, S.J. Singer & G. Nicolson proposed that membrane proteins are inserted into the phospholipid bilayer



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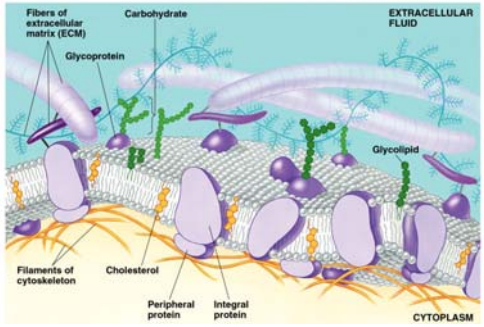
A membrane is a collage of different proteins embedded in the fluid matrix of the lipid bilayer



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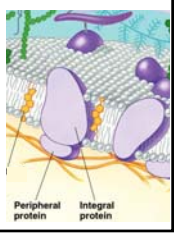
Membrane Proteins

- Proteins determine most of membrane's specific functions
  - cell membrane & organelle membranes each have unique collections of proteins
- Membrane proteins:
  - peripheral proteins = loosely bound to surface of membrane
  - integral proteins = penetrate into lipid bilayer, often completely spanning the membrane = *transmembrane* protein



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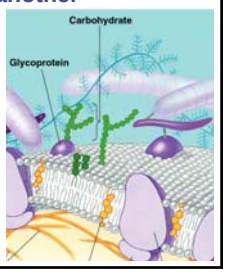
Membrane Carbohydrates

- Play a key role in cell-cell recognition
  - ability of a cell to distinguish neighboring cells from another
  - important in organ & tissue development
  - basis for rejection of foreign cells by immune system



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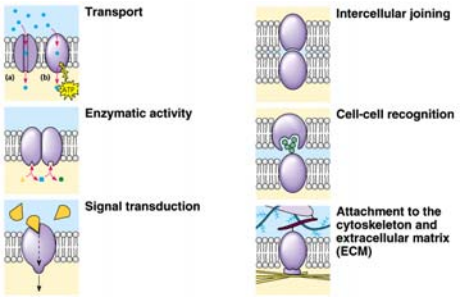
Membranes provide a variety of cell functions



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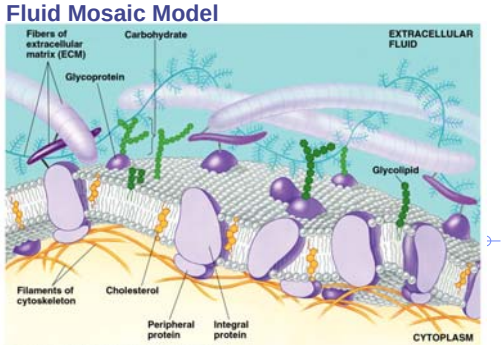
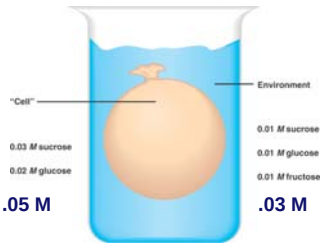
Any Questions??

Fluid Mosaic Model



AP Bi

Osmosis…



Cell (compared to beaker) → hypertonic or hypotonic

Beaker (compared to cell) → hypertonic or hypotonic

MCC Which way does the water flow? → in or out of cell