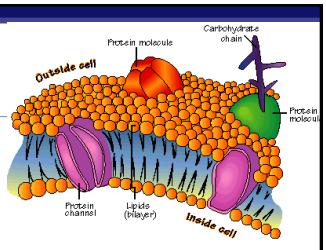
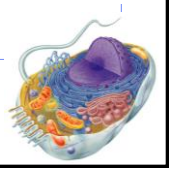
AICE Biology: Cell Membranes and Transport

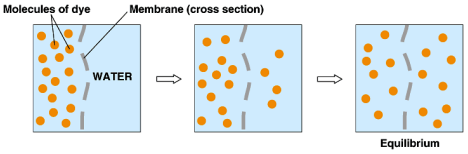


Cell Membranes & Transport



Diffusion

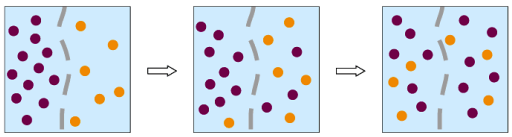
- 2nd Law of Thermodynamics governs biological systems
  - Universe tends towards disorder



- Diffusion
  - movement from high → low concentration

Diffusion of 2 solutes

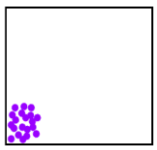
- Each substance diffuses down its *own* concentration gradient, independent of concentration gradients of other substances



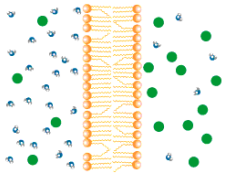
(b) Diffusion of two solutes

Diffusion

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



diffusion



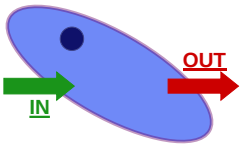
osmosis

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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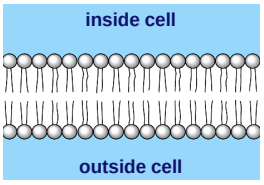
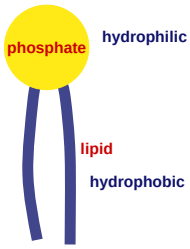
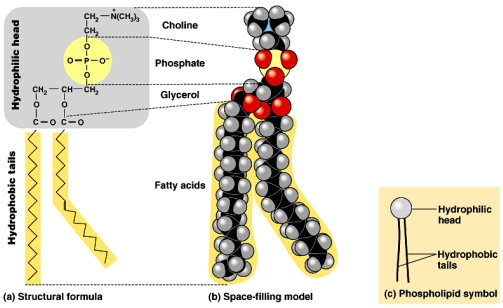
Lipids of cell membrane

- Membrane is made of phospholipids
  - phospholipid bilayer





Phospholipids—Remember them?



Semi-permeable membrane

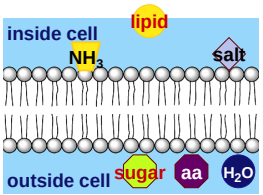
- Need to allow passage through the membrane
- But need to control what gets in or out
  - membrane needs to be semi-permeable

sugar aa lipid H_2O salt NH_3

So how do you build a semi-permeable membrane?

Phospholipid bilayer

- What molecules can get through directly?

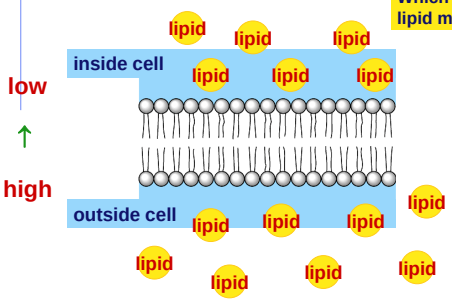


fats & other lipids can slip directly through the phospholipid cell membrane, but…

what about other stuff?

Simple diffusion across membrane

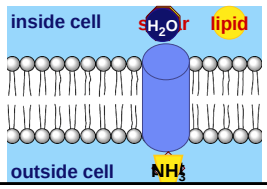
Which way will lipid move?



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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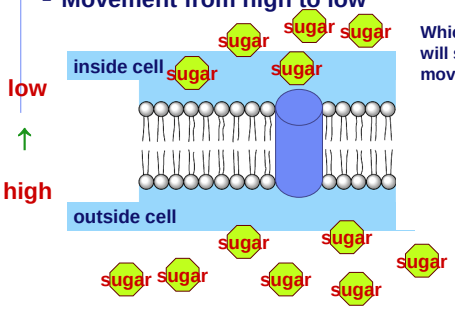
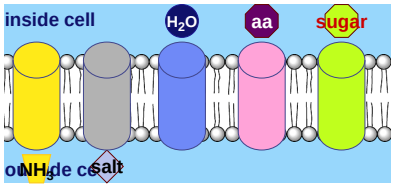
Diffusion through a channel

- Movement from high to low



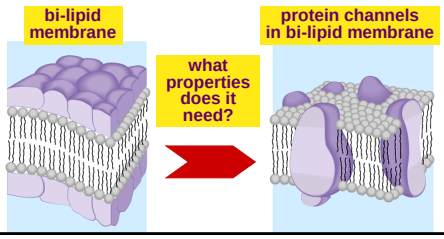
Semi-permeable cell membrane

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



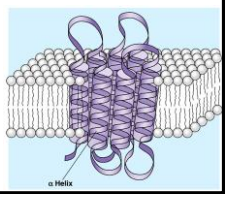
How do you build a semi-permeable cell membrane?

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



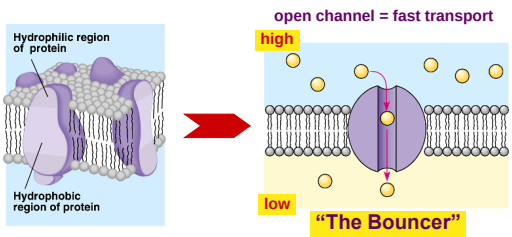
Why proteins?

- 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



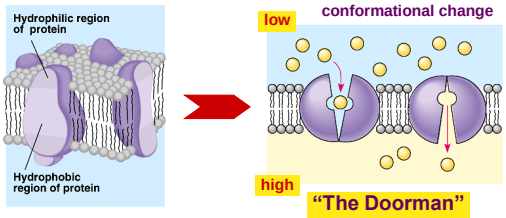
Facilitated Diffusion

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



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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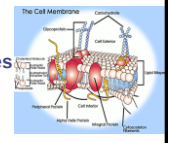
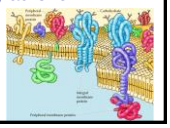
Getting through cell membrane

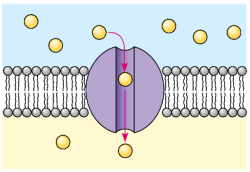
- Passive transport
  - diffusion of hydrophobic (lipids) molecules
    - high → low concentration gradient
- Facilitated transport (passive)
  - diffusion of hydrophilic molecules
  - through a protein channel
    - high → low concentration gradient
- Active transport
  - diffusion against concentration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





Facilitated diffusion

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



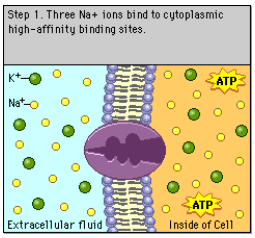
Gated channels

- 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

Active transport

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

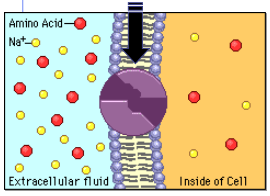
Na+/K+ pump in nerve cell membranes



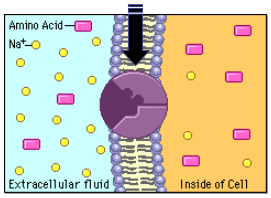
Active transport

- Many models & mechanisms

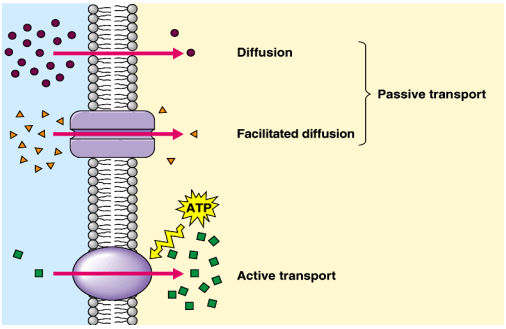
using ATP



using ATP



Transport summary



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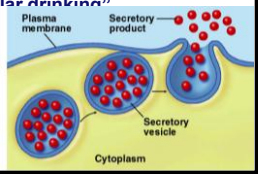
How about large molecules?

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



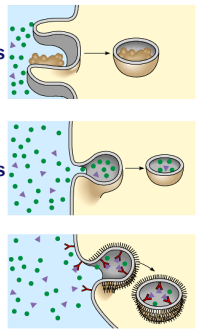
exocytosis

Endocytosis

phagocytosis → fuse with lysosome for digestion

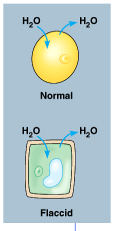
pinocytosis → non-specific process

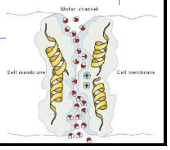
receptor-mediated endocytosis → triggered by ligand signal



The Special Case of Water

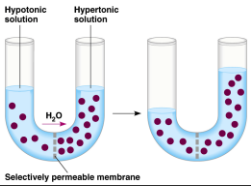
Movement of water across the cell membrane





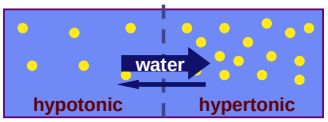
Osmosis is diffusion of water

- 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



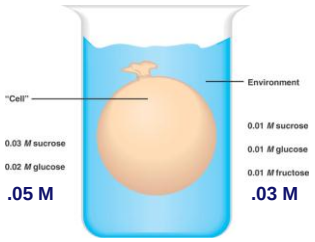
Concentration of water

- 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

Osmosis…



Cell (compared to beaker) → hypertonic or hypotonic

Beaker (compared to cell) → hypertonic or hypotonic

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

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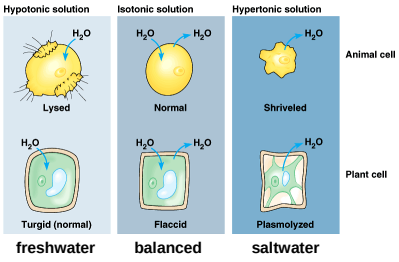
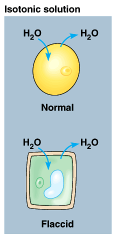
Managing water balance

- Cell survival depends on balancing water uptake & loss



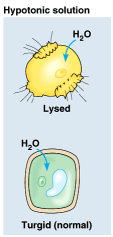
Managing water balance

- 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



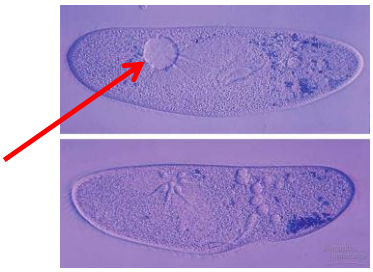
Managing water balance

- 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
    - Turgidity! Super important!!!



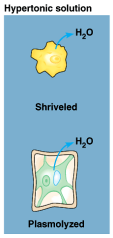
Water regulation

- Contractile vacuole in *Paramecium*



Managing water balance

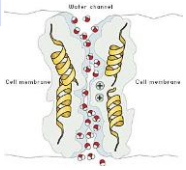
- Hypertonic
  - animal cell in hypertonic solution will loose water, shrivel & probably die
    - salt water organisms are hypotonic compared to their environment
    - they have to take up water & pump out salt
  - plant cells
    - plasmolysis = wilt (Wednesday's lab)



Aquaporins

1991 | 2003

- Water moves rapidly into & out of cells
  - evidence that there were water channels
  - Special proteins JUST for water



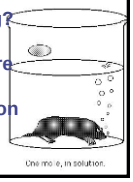
Peter Agre
John Hopkins

Roderick MacKinnon
Rockefeller

AICE Biology: Cell Membranes and Transport

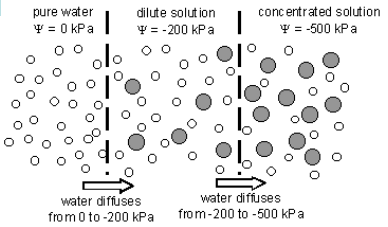
Water potential

- Hypo, hyper, and isotonic environments can be put in the context of water potential
- Water's ability to move is its potential
- Water ALWAYS moves from higher to lower water potential
  - Less negative → more negative numbers
  - Why is this so unnecessarily confusing? The negative number comes from how much solute is in concentration. A more negative number means more solute and thus water will move in that direction
  - This is called osmosis!



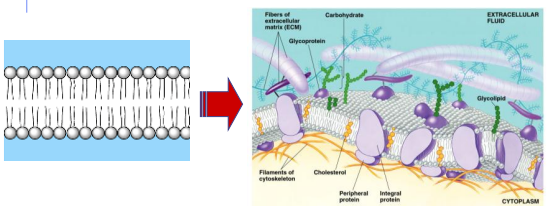
Water potential

Water potential = solute potential + pressure potential



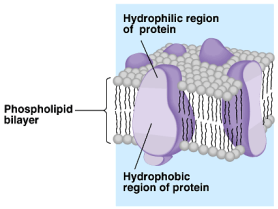
More than just a barrier…

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

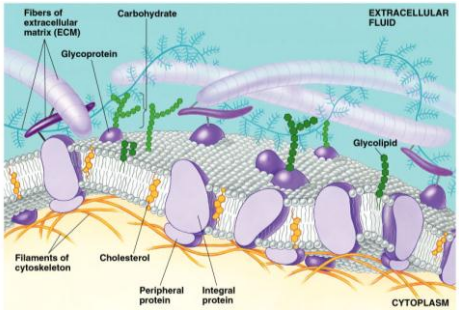


Fluid Mosaic Model

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

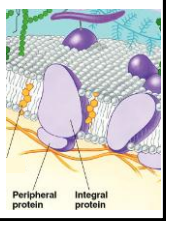


A membrane is a collage of different proteins embedded in the fluid matrix of the lipid bilayer



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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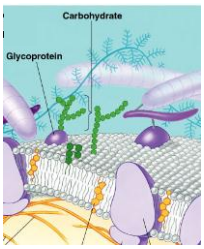
Membrane Carbohydrates

- 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



Membranes provide a variety of cell functions

Transport

Enzymatic activity

Signal transduction

Intercellular joining

Cell-cell recognition

Attachment to the cytoskeleton and extracellular matrix (ECM)

Any Questions??

Fluid Mosaic Model