The Cell Membrane
Phospholipids

- **Phosphate head**
  - hydrophilic
- **Fatty acid tails**
  - hydrophobic
- Arranged as a **bilayer**

Aaaah, one of those structure-function examples
Arranged as a Phospholipid bilayer

- Serves as a cellular barrier / border

- Polar hydrophilic heads
- Nonpolar hydrophobic tails

Impermeable to polar molecules

- Sugar
- H₂O
- Salt
- Waste
- Lipids
Cell membrane defines cell

- Cell membrane **separates** living cell from aqueous environment
  - thin barrier = 8nm thick
- Controls traffic in & out of the cell
  - allows some substances to cross more easily than others
    - hydrophobic (nonpolar) vs. hydrophilic (polar)
Permeability to polar molecules?

- **Membrane becomes semi-permeable via protein channels**
  - specific channels allow specific material across cell membrane
Cell membrane is more than lipids…

- Transmembrane proteins embedded in phospholipid bilayer
  - create semi-permeable channels
Why are proteins the perfect molecule to build structures in the cell membrane?
### Classes of amino acids

What do these amino acids have in common?

<table>
<thead>
<tr>
<th>Nonpolar</th>
<th>Glycine (Gly)</th>
<th>Alanine (Ala)</th>
<th>Valine (Val)</th>
<th>Leucine (Leu)</th>
<th>Isoleucine (Ile)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(H_3N^+)C(=)O(-)</td>
<td>(H_3N^+)C(=)O(-)</td>
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<td>(H_3N^+)C(=)O(-)</td>
</tr>
<tr>
<td></td>
<td>(\text{H})</td>
<td>(\text{H}_3\text{C})</td>
<td>(\text{CH}_3\text{CH}_3)</td>
<td>(\text{CH}_3\text{CH}_3)</td>
<td>(\text{CH}_3\text{CH}_3)</td>
</tr>
<tr>
<td></td>
<td>Methionine (Met)</td>
<td>Phenylalanine (Phe)</td>
<td>Tryptophan (Trp)</td>
<td>Proline (Pro)</td>
<td></td>
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<tr>
<td></td>
<td>(\text{H}_3\text{C})</td>
<td>(\text{H}_2\text{C})</td>
<td>(\text{H}_3\text{C})</td>
<td>(\text{H}_3\text{C})</td>
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<td>(\text{CH}_2)</td>
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<td>(\text{S})</td>
<td>(\text{CH}_3)</td>
<td>(\text{CH}_3)</td>
<td>(\text{CH}_3)</td>
<td></td>
</tr>
</tbody>
</table>

Nonpolar & hydrophobic
### Classes of amino acids

What do these amino acids have in common?

<table>
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<tr>
<th>Polar</th>
<th>Acidic</th>
<th>Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Serine" /> Serine (Ser)</td>
<td><img src="image2.png" alt="Aspartic acid" /> Aspartic acid (Asp)</td>
<td><img src="image3.png" alt="Lysine" /> Lysine (Lys)</td>
</tr>
<tr>
<td><img src="image4.png" alt="Threonine" /> Threonine (Thr)</td>
<td><img src="image5.png" alt="Glutamic acid" /> Glutamic acid (Glu)</td>
<td><img src="image6.png" alt="Arginine" /> Arginine (Arg)</td>
</tr>
<tr>
<td><img src="image7.png" alt="Cysteine" /> Cysteine (Cys)</td>
<td><img src="image8.png" alt="Tyrosine" /> Tyrosine (Tyr)</td>
<td><img src="image9.png" alt="Histidine" /> Histidine (His)</td>
</tr>
<tr>
<td><img src="image10.png" alt="Tyrosine" /> Tyrosine (Tyr)</td>
<td><img src="image11.png" alt="Asparagine" /> Asparagine (Asn)</td>
<td></td>
</tr>
<tr>
<td><img src="image12.png" alt="Glutamine" /> Glutamine (Gln)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I like the polar ones the best!

**polar & hydrophilic**
Proteins domains anchor molecule

- **Within membrane**
  - **nonpolar** amino acids
    - hydrophobic
    - anchors protein into membrane
- **On outer surfaces of membrane in fluid**
  - **polar** amino acids
    - hydrophilic
    - extend into extracellular fluid & into cytosol
Examples

aquaporin = water channel in bacteria

Porin monomer \( \text{H}_2\text{O} \)

\( \beta \)-pleated sheets

Bacterial outer membrane

function through conformational change = protein changes shape

proton pump channel in photosynthetic bacteria

Examples

\( \text{H}_2\text{O} \)}
Many Functions of Membrane Proteins

Outside

Plasma membrane

Inside

Transporter

Enzyme activity

Cell surface receptor

Cell surface identity marker

Cell adhesion

Attachment to the cytoskeleton
Membrane Proteins

- Proteins determine membrane’s specific functions
  - cell membrane & organelle membranes each have unique collections of proteins

- Classes of membrane proteins:
  - **Peripheral proteins**
    - loosely bound to surface of membrane
    - ex: cell surface identity marker (antigens)
  - **Integral proteins**
    - penetrate lipid bilayer, usually across whole membrane
    - *transmembrane* protein
    - ex: transport proteins
      - channels, permeases (pumps)
Cell membrane must be more than lipids...

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

It's like a fluid...
It's like a mosaic...
It's the Fluid Mosaic Model!
Membrane is a collage of proteins & other molecules embedded in the fluid matrix of the lipid bilayer.

Membrane carbohydrates

- Play a key role in **cell-cell recognition**
  - ability of a cell to distinguish one cell from another
    - **antigens**
  - important in organ & tissue development
  - basis for rejection of foreign cells by **immune system**
Any Questions??
Movement across the Cell Membrane
Diffusion

- **2nd Law of Thermodynamics** governs biological systems
  - universe tends towards disorder (entropy)

**Diffusion**
- movement from **HIGH** → **LOW** concentration
Simple Diffusion

- Move from **HIGH** to **LOW** concentration
  - “passive transport”
  - no energy needed
Facilitated Diffusion

- Diffusion through protein channels
  - channels move specific molecules across cell membrane
  - no energy needed

“Facilitated” = with help
open channel = fast transport

“Hydrophilic region” of protein

“Hydrophobic region” of protein

“High”

“Low”

“The Bouncer”
Active Transport

- Cells may need to move molecules against concentration gradient
  - conformational shape change transports solute from one side of membrane to other
  - protein “pump”
  - “costs” energy = ATP
Active transport

- Many models & mechanisms

ATP

antiport

symport
Getting through cell membrane

- **Passive Transport**
  - **Simple diffusion**
    - diffusion of nonpolar, hydrophobic molecules
      - lipids
      - HIGH $\rightarrow$ LOW concentration gradient
  - **Facilitated transport**
    - diffusion of polar, hydrophilic molecules
    - through a protein channel
      - HIGH $\rightarrow$ LOW concentration gradient

- **Active transport**
  - diffusion *against* concentration gradient
    - LOW $\rightarrow$ HIGH
  - uses a protein pump
  - requires ATP
Transport summary

- **Simple diffusion**
- **Facilitated diffusion**
- **Active transport**

**Passive transport**

- ATP
How about large molecules?

- Moving large molecules into & out of cell
  - through vesicles & vacuoles
  - **endocytosis**
    - **phagocytosis** = “cellular eating”
    - **pinocytosis** = “cellular drinking”
  - **exocytosis**
Endocytosis

- **Phagocytosis**:fuse with lysosome for digestion
- **Pinocytosis**:non-specific process
- **Receptor-mediated endocytosis**:triggered by molecular signal
The Special Case of Water

Movement of water across the cell membrane
Osmosis is just diffusion of water

- Water is very important to life, 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
Managing water balance

- Cell survival depends on balancing water uptake & loss

**Hypotonic solution**
- Lysed

**Isotonic solution**
- Normal

**Hypertonic solution**
- Shriveled

**freshwater**
- Turgid (normal)

**balanced**
- Flaccid

**saltwater**
- Plasmolyzed
Managing water balance

- **Hypotonic**
  - a cell in *fresh water*
  - high concentration of water around cell
    - problem: cell gains water, swells & can burst
    - example: *Paramecium*
      - ex: water continually enters *Paramecium* cell
    - solution: contractile vacuole
      - pumps water out of cell
      - ATP
  - plant cells
    - turgid = full
    - cell wall protects from bursting

ATP

KABOOM!

No problem, here
Pumping water out

- Contractile vacuole in *Paramecium*
Managing water balance

- Hypertonic
  - a cell in **salt water**
  - low concentration of water around cell
    - **problem**: cell loses water & can die
    - **example**: shellfish
    - **solution**: take up water or pump out salt

- plant cells
  - **plasmolysis** = wilt
  - can recover
Managing water balance

- **Isotonic**
  - animal cell immersed in *mild salt* solution
  - no difference in concentration of water between cell & environment
    - **problem**: none
      - no net movement of water
        - flows across membrane equally, in both directions
      - cell in equilibrium
      - volume of cell is stable
    - **example**: blood cells in blood plasma
      - slightly salty IV solution in hospital
Aquaporins

- Water moves rapidly into & out of cells
  - evidence that there were water channels
    - protein channels allowing flow of water across cell membrane
Do you understand Osmosis…

Cell (compared to beaker) → \textbf{hypertonic or hypotonic}

Beaker (compared to cell) → \textbf{hypertonic or hypotonic}

Which way does the water flow? → \textbf{in} or out of cell
Any Questions??
Ghosts of Lectures Past
(storage)
Diffusion through phospholipid bilayer

- What molecules can get through directly?
  - fats & other lipids

- What molecules can **NOT** get through directly?
  - polar molecules
  - ions (charged)
  - large molecules
    - salts, ammonia
    - starches, proteins
Membrane fat composition varies

- Fat composition affects flexibility
  - membrane must be fluid & flexible
    - about as fluid as thick salad oil
  - % unsaturated fatty acids in phospholipids
    - keep membrane less viscous
    - cold-adapted organisms, like winter wheat
      - increase % in autumn
  - cholesterol in membrane

Diffusion across cell membrane

- Cell membrane is the boundary between inside & outside...
  - separates cell from its environment

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**