Topic 1: Intro to Cell Biology and the Cell's Features

How did life evolve into organisms and cells?

What are the different types of classes of organisms?

- Prokaryotes & Eukaryotes
- Eukaryotes:
    - Animals, plants & fungi
    - Protists (unicellular)
- Prokaryotes:
    - Eubacteria & cyanobacteria
    - Archaea

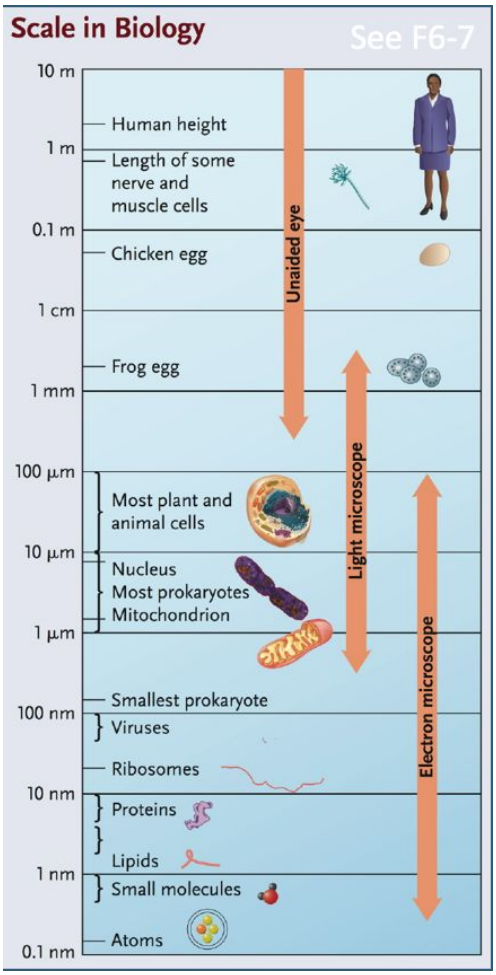
What is a cell made of?

Organelle	Location	Description	Function	Structure/Components
Cell Membrane	- both plant & animal	- plant: inside cell wall - animal: outer layer; cholesterol - selectively permeable	- controls movement of materials in/out - barrier between cell & environment - maintains homeostasis - protection - support	-phospholipid bilayer, protein channels, cholesterol, glycolipids
Nucleus	- both plant/animal	- large, oval	- protects cell's DNA - controls cell function	- nuclear membrane, chromosomes, nucleolus, cytoplasm
Nuclear Membrane	- both plant/animal	- surrounds nucleus - selectively permeable	- encloses the nucleus - protects the nucleus	- double lipid bilayer
Cytoplasm	- both plant/animal	- clear, thick, jelly like material - organelles suspended in	- gives the cell its shape - suspends organelles	-supports/protects cell organelles

		cytoplasm		
Endoplasmic Reticulum	- both plant/animal	- network of tubes encased in membrane	- carries materials through the cell -stores & transports proteins	- joins with outer & nuclear membrane
Ribosome	- both plant/animal	- small bodies that are free or attached to E.R	- produces proteins - rough ER - translating mRNA to proteins - smooth ER - synthesizes lipids & gets rid of toxins	
Mitochondrion	- both plant/animal	- bean shaped with inner + outer membrane	- breaks down sugar molecules into energy - regulates cellular metabolism	- inner/outer membrane, DNA, ribosomes
Vacuole	- both plant/animal	- fluid filled sacs	- store food, water and waste	- membrane bound, fluid filled sac in the cytoplasm
Lysosome	- plant → uncommon - animal → common	- small & round with a membrane	- breaks down large food molecules into smaller molecules - autophagy (cell eating)	- membrane bound organelle containing digestive enzymes
Chloroplasts	- plant only	- green, oval, usually containing chlorophyll (green pigment) - type of plastid	- uses light energy from the sun to make food for the plant via photosynthesis - turgor pressure	- inner/outer membrane surrounding grana and stroma

Cell Wall	- plant only	- outer layer - rigid, stiff, strong - made of cellulose	- support (grow tall) - protection - allows H2O, O2 & CO2 in/out of cell	- 3 unique layers with individual functions - cellulose

What are the different sizes/scales for cells and organelles?

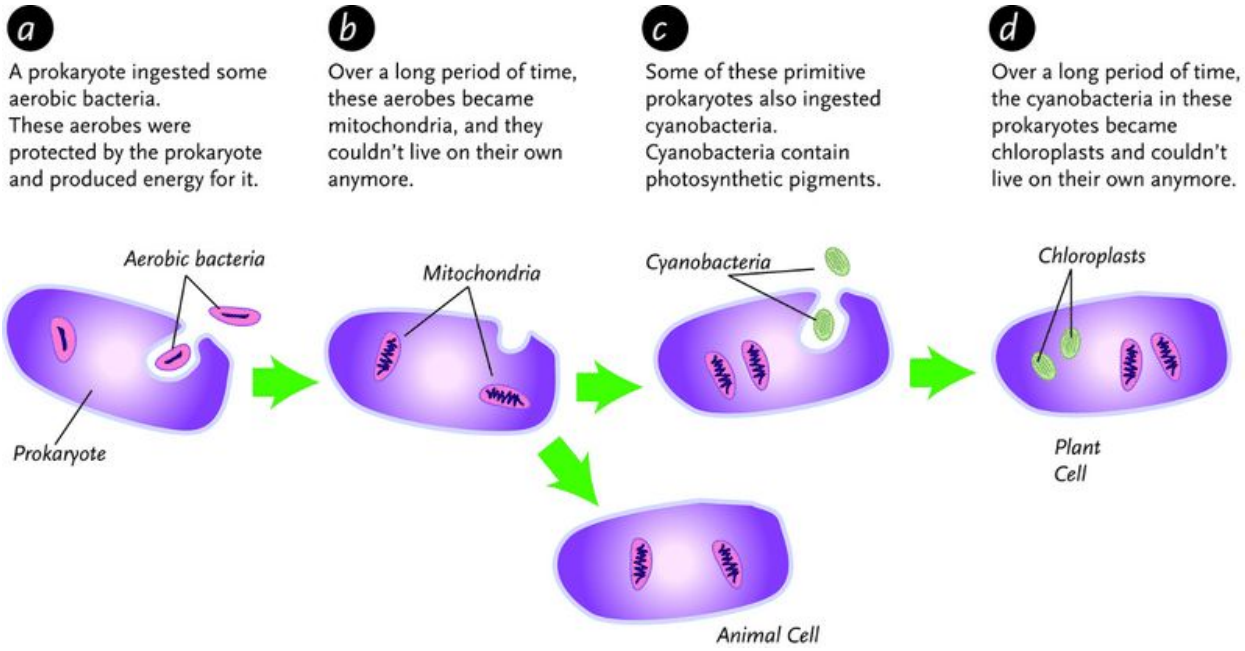


- Prokaryotes: 1-5µ
- Eukaryotes: 10-100µ or larger

Explain the theory of the cell and the theory of endosymbiosis - can you provide some examples?

- The theory of how eukaryotic cells arose:

- The mitochondria and chloroplasts of Eukaryotic cells arose from the symbiotic incorporation of prokaryotic cells by a proto-eukaryotic cell → as a result, both mitochondria and chloroplasts have their own DNA and reproduce proteins and enzymes separately from their host cells
- Both have double membranes → further indication that each was ingested by its primitive host



- In general, endosymbiosis refers to the relationship between two organisms, where one is living inside of another, and both are mutually benefiting from the relationship i.e the spotted salamander and green algae have an endosymbiotic relationship → algal cells infiltrate the embryos, providing O2 while they use the N2 provided by the salamander

<u>What are the main groups or types of cells and how do they differ?</u>

Definitions / Description	Eukaryotic Cell	Prokaryotic Cell
Organisms:	Plants, animals and fungi have eukaryotic cells.	Only bacteria and cyanobacteria have prokaryotic cells.
Cell wall:	No (animals); Yes (plants)	Yes
Centrioles:	Yes (all animals and some lower plant forms)	No
Cilia and Flagella:	Yes, simple	Yes, complex
Golgi Complex:	Yes	No
Lysosomes:	Common in animals; Not present in plants	No
Peroxisomes:	Yes	No
Nucleus:	Yes	No
Plasma membrane:	Yes	Yes
Chromosomes:	Several chromosomes	One long DNA strand
Ribosomes:	Yes	Yes
Endoplasmic Reticulum:	Present	Absent

What are the different types of microscopy and their requirements for use in cell biology?

1) **Bright field**: light passes directly through the specimen
2) **Dark field**: illuminates specimen at an **angle**
3) **Fluorescence**: different cell structures or molecules are stained with specific fluorescent dyes → these dyes glow when the microscope illuminates them with ultraviolet light
4) **Confocal**: lasers scan across a fluorescently stained specimen → provides a sharper 3-D image than other microscopes
5) **Phase-contrast**: differences in refraction caused by differing densities in the cell are visualized as differences in contrast → way to view 'invisible' structures i.e the cytoplasm
6) ***Transmission electron**: beam of electrons is focused on a thin part of a specimen in a vacuum → used to exam structures within cells
7) ***Scanning electron**: beam of electrons is scanned across a whole cell or organisms → produces a 3-D image

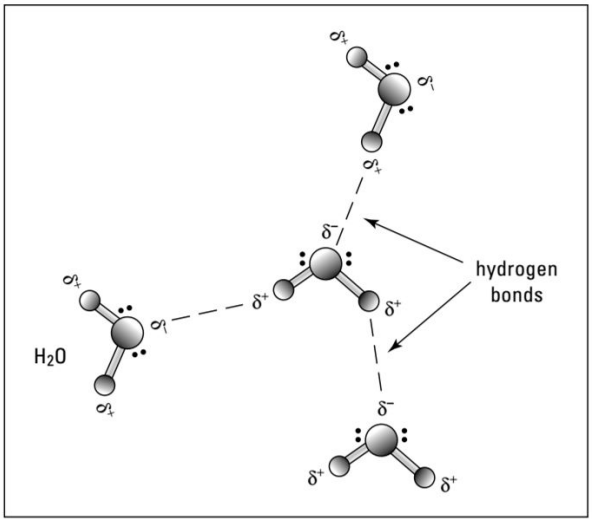
*electron microscopes - anything before these 2 are not electron microscopes

Topic 2: Macromolecules, Amino Acids & Proteins

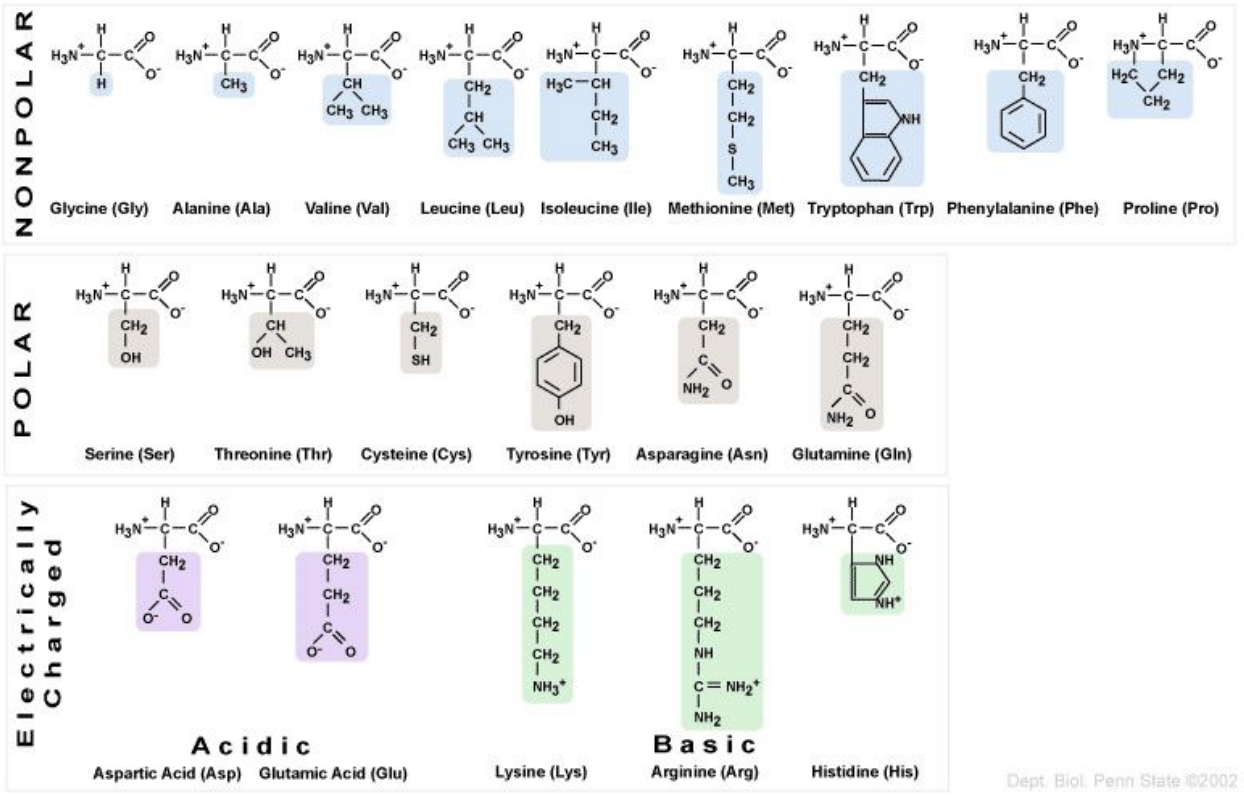
Understand the role, identify areas and determine the importance of a molecule's **polarity (electronegativity)** of different biologically relevant macromolecules (particularly amino acids and proteins)

What are the types of chemical bonds present in cellular macromolecules and how are they relevant to cell biology?

- **Polar Covalent Bonds**: A polar covalent bond is formed when electrons are shared unequally between two atoms
    - The end of the molecule where the electrons orbit more frequently becomes slightly negative, and the end where the electrons orbit less frequently becomes slightly positive
- **Hydrogen Bonds:** weak electrical attractions that form between the ends of polar molecules → the slightly negatively charged end of the molecule is attracted to the slightly positive end of another molecule
    - Keeps molecules together in compounds
    - Sort of like “molecular velcro” - can stick anything together, but the bonds are easily broken
    - *Does not* necessarily refer to a covalent bond with a hydrogen atom
    - I.e Hydrogen bonds hold the two halves of our DNA molecules together so that it can form the double helix structure; holds together the shapes of proteins; water sticks together via hydrogen bonds between H and O
- **Hydrophobic interactions**:
    - Polar molecules can mix right into water because water is considered polar
    - Non-polar molecules lack the slight negative/positive charges of polar molecules, meaning they don’t mix well with polar molecules such as water
    - Non-polar = hydrophobic (they ‘fear water’ a.k.a charged molecules)
    - Polar = hydrophilic (‘water loving’)
    - The interactions between non-polar molecules are called hydrophobic interactions i.e adding oil to water

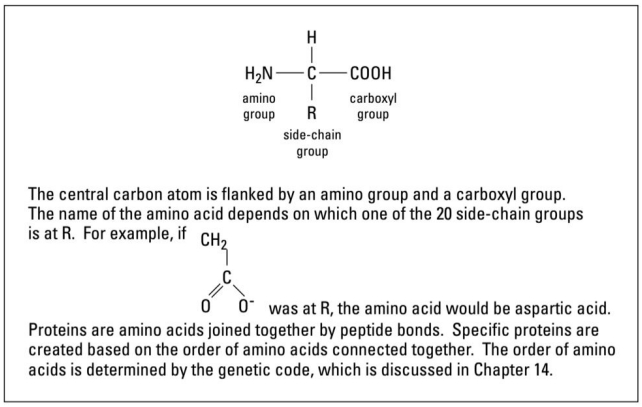


- Amino Acids: Polar or Non-Polar?



- Proteins:
  - Amino acids link together and form a polymer known as a '**polypeptide chain**' → once a polypeptide chain is folded and becomes function, it is known as a **protein**
  - 8 types of proteins:
    1. Hormonal proteins (coordination of an organism's activities)
    2. Receptor proteins (response of cell to chemical stimuli)
    3. Contractile/motor proteins (responsible for movement)
    4. Structural proteins (support)
    5. Enzymatic proteins (selective acceleration of chemical reactions)
    6. Defensive proteins (protection against diseases)
    7. Storage proteins (storage of amino acids)
    8. Transport proteins (transport of substances → sometimes across cell membranes)
  - Amino acids are attached together via a condensation reaction → a water molecule is lost when joining the two amino acids into a polypeptide chain

    - Polypeptide bonds are **polar covalent bonds:**
        - The Nitrogen & Hydrogen in the NH2 amino group → N is slightly -, H is slightly +
        - The Carbon and Oxygen in the Carboxyl group → O becomes slightly -, C becomes slightly +
        - Together, the polypeptide backbone is polar/hydrophilic
- The size of 1 amino acid is ~110 Daltons (Da)
- Structure is important for function:
    - The specific tertiary structure of a protein denotes its particular function → **without the polar backbone of the amino acids, the amino acids would be unable to form hydrogen bonds with other amino acids to form proteins**



<u>Explain the relationship between polarity, molecular structure, cellular location and function – particularly for proteins and lipids</u>

- Polarity denotes molecular structure (i.e polar covalent bonds or hydrogen bonding/hydrophobic interactions) → the polarity of the molecule determines where it will be placed in the cell (in a region where it is going to interact well i.e a hydrophobic molecule will not be put into a hydrophilic region of the cell) → because the polarity determines how a molecule looks/reacts (i.e how polypeptide chains fold into specific proteins), it also determines its specificity in function

<u>What is the importance of water in biology?</u>

- Water is an important molecule in biology because it is a hydrophilic/polar molecule → this enables polar molecules to dissolve into water
- Hydrogen bonds also refer to the bonds that hold polar water molecules together, giving water its weird properties i.e surface tension that allows water bugs to ‘walk’ on water

Know and identify the main classes of macromolecules, recognize their general structures, and interpret these in relation to their cellular location and their roles in cells

- Main classes of macromolecules:
    - Carbohydrates (incl. sugars)
    - Proteins
    - Fats (lipids)
    - Nucleic Acids

	General Structure	**Location**	**Function**
Carbohydrates	- formed from chains of C, H & O - greatest # of OH groups attached to their C atoms - non-polar i.e sugar		- energy source for cells - structural support i.e plant cell walls - markers of cellular identity i.e glycoproteins - imp. Extracellular molecules
Proteins	- carboxyl group, H & amine group attached to a central C + R group that denotes particular amino acid - polar covalent bonds		- enzymes - structural reinforcers - regulating hormones - transport in the organism - communication etc.
Lipids	- hydrocarbons - 4 subcategories: fats and oils, phospholipids, waxes and sterols - phospholipids have a hydrophilic head group - saturated fats contain only single C-C bonds - unsaturated contains more double C=C bonds		- insulation - structure of plasma membrane - water-proofing - signaling by steroid hormones

Nucleic Acids	- composed of a pentose (5 C) sugar + nitrogenous base (ring structure of Ns) + negatively charged phosphate group (P atom surrounded by O's) - polar covalent bonds		- protein structure - RNA structure - regulation of DNA - mRNA etc.

Topic 3: Cytoskeleton and Cellular Interactions/Extracellular Matrix

<u>How is the cell's interior organized?</u>

- Prokaryotes:
    - Unorganized, small, no membrane bound organelles (i.e no mitochondria or chloroplasts)
- Eukaryotes:
    - The 'IKEA' of cells → highly organized with membrane bound organelles → high specificity of function

<u>Compare how each component of the cytoskeleton is formed</u>

- Cytoskeletal proteins run like railway tracks throughout the cells (BOTH prokaryotic and eukaryotic cells have cytoskeletons) → enables the movements of vesicles and other organelles
- When cells swim with cilia or flagella they are using cytoskeletal proteins
- **Microfilaments**:
    - Made of the protein **actin**
    - Muscle cell contraction
    - Railway tracks
    - 5 - 7nm in diameter
    - Polar
- **Microtubules:**
    - Made of the protein **tubulin**
    - Proteins inside cilia & flagella
    - Railway tracks
    - 9 + 2 organization (9 pairs of doublets arranged around 1 doublet)
    - Originate from a central point → MTOC (MicroTubule Organization Center at the centrosome)

    - *remember: made of *tube-u-lin* and are found in tube shaped cilia and flagella
- **Intermediate filaments:**
    - Composed of various proteins
    - Reinforcing proteins
    - Tetramers stack together to form rope-like structures
    - I.e Keratin
- These filaments and tubules combine to give the cell its structure and 'skeleton'

Relate the **structure** of the cytoskeletal fibers to their **roles** in the cells

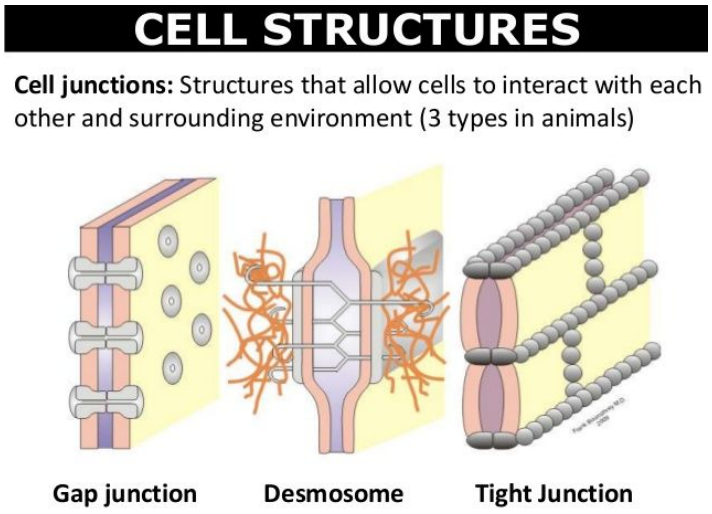
Associate the different cytoskeletal fibers with their preferred molecular motors and contrast their characteristics with respect to their roles

- Actin microfilaments and microtubules are long, cable-like proteins that act as railways for motor proteins to 'walk' along and transport things amongst the cells (using ATP) - they are the roadways of the cell
- Motor proteins:
    - Are classified as **mechanoenzymes**, meaning they use ATP as fuel
    - Drive along the polar cytoskeletal fibers
- Microfilaments:
    - **Myosin** 'walks' along microfilaments i.e in muscle cells when this happens, the actin microfilaments slide past one another, causing muscle contraction
    - Myosin also attaches to chloroplasts and then walks
    - The movement of the motor proteins causes the cellular components to flow around the cell in a process called **cytoplasmic streaming**
- Microtubules:
    - **Dynein** walks along microtubules on one side of cilia or flagella → causes microtubules to bend → this is what causes the cilia and flagella to whip back and forth
    - **Kinesin**: one end attaches to vesicles, and the other walks along the microtubules → causes the vesicles to slide along the microtubules like freight cars on railway tracks

What are the main types of cell-to-cell interactions and their characteristics?

- **Tight Junctions:**
    - Fusion of proteins on external plasma membranes - seals that area so that even ions cannot pass
- **Anchoring Junctions**:
    - Plaques of proteins interact and anchor cells together
    - I.e Actin and Cadherins
- **Gap Junctions**:

- Channels formed by proteins bridging cells (**connexions**) → allows passage of ions and small molecules - cell communication!



Topic 4: Membranes and Membrane Transport

Discuss the role of membranes, and in particular the plasma membrane, of the cell

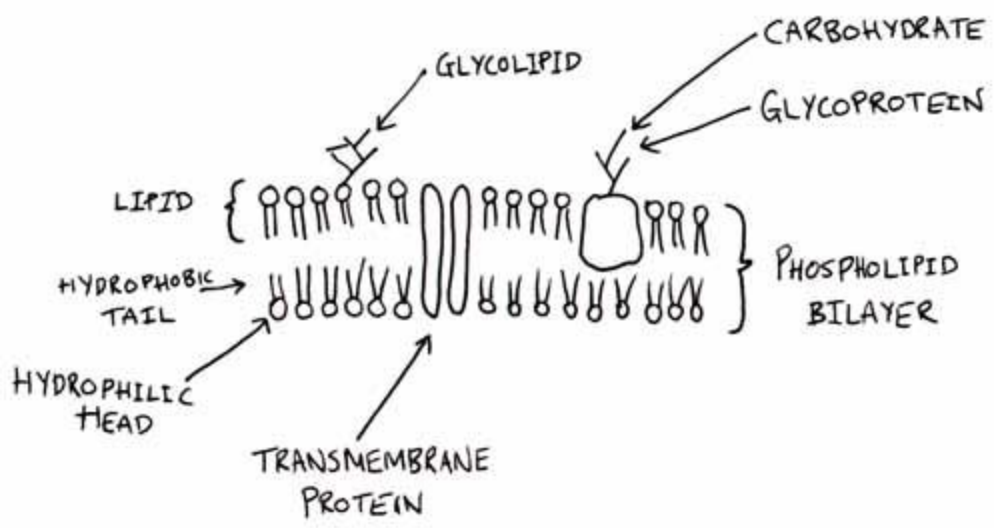
- The membrane has 5 primary roles:
    1. Boundary → selective permeability
    2. Organize and scaffold
    3. Regulate solute transport
    4. Receive signals
    5. Communication

What two key factors affect whether a molecule can cross the membrane or not?

1. **Size**: small molecules cross more easily than large molecules
2. **Attraction to water (polar/non-polar)**:
    - Hydrophobic (non-polar) molecules cross more easily than hydrophilic (polar)
    - The hydrophobic molecules can pass through the hydrophobic interior of the phospholipid bilayer that makes up the membrane
    - Hydrophilic molecules and ions need help from proteins in order to cross the membrane

Understand and explain the fluid mosaic model. Include the membrane's properties in the discussion

- **Fluid mosaic model**:
    - Fluid combination of phospholipids (hydrophilic head and hydrophobic tail = amphipathic), cholesterol, and proteins
    - Hydrophilic (polar) head faces the outside of the membrane, hydrophobic tail end faces the middle/internal part of the membrane → together with transmembrane protein channels (to help large and/or charged molecules move through the phospholipid bilayer), cholesterol in between the phospholipid bilayer (for insulation), and glycoproteins on the outside (for cell-to-cell communication) = fluid mosaic model of the cell
    - Phospholipid: polar head (hydrophilic) + fatty acid tail (non-polar/hydrophobic)
    - Range from 5-10 nm in thickness
    - The plasma membrane is asymmetrical due to the amphipathic qualities of the phospholipid bilayer



What is the membrane made of? Describe and organize the different molecules involved and link them to the membrane's properties

1) Phospholipid: main fabric of the membrane
2) Cholesterol: in between two phospholipid layers; insulation
3) Integral proteins: embedded within the phospholipid layer; most span the entire membrane (**transmembrane protein**)
4) Transmembrane protein: channel for large/charged/polar molecules to pass through the bilayer
5) Glycolipids: lipid + carb, found on outside of membrane; cell communication

Compare the different types of transport across the membrane and give examples for each

Passive Transport: moving **with** the concentration gradient (high concentration → low); no ATP

- **Simple Diffusion:**
  - Molecules cross the membrane without any assistance
  - Water, oxygen, CO_2, ethanol
- **Facilitated diffusion**:
  - Molecules diffuse across membranes with the help of transport proteins
  - Glucose, sodium ions, potassium ions

Active Transport: moving **against** the concentration gradient (low concentration → high); ATP required

- Assisted via pumps (sodium-potassium pump), carrier and channel proteins
- **Sodium Potassium Pump**:
  - **3 sodium ions** picked up inside of cell → ATP attaches phosphate group to pump → pump changes shape to release sodium ions outside cell → pump picks up **2 potassium ions** from outside the cell → pump releases phosphate group → changes shape and lets potassium inside cell
- **Endocytosis:**
  - Substance entering the cell becomes enclosed by a pocket of the cell membrane to form a vesicle
  - Two kinds:
    1. Pinocytosis: transports liquids and solids into cell
    2. Phagocytosis: just transports the solids into the cell
- **Exocytosis**:
  - Movement out of a cell via vesicles

How are membrane dynamics important for transport?

- The polarity of the membrane determines which method of active or passive transport should be used to transport an element/ion/molecule across the plasma membrane