Cell Membrane

Fluid Mosaic Model

- Fluid
  - Dynamic structure which comprises of phospholipids and proteins which are free to move laterally within a layer
  - Phospholipids can flip flop from one layer to the other although rarely
- Mosaic
  - Random arrangement of proteins embedded amongst phospholipid molecules

Components

1. Phospholipids
   - Structure:
     - **Amphipathic**: Hydrophilic charged phosphate head + Hydrophobic non-polar hydrocarbon tail
     - Forms phospholipid bilayer in aqueous medium with a hydrophobic core
     - Cell membranes with higher proportion of phospholipids with unsaturated hydrocarbon tails freeze at lower temperatures
       - Kinks of cis double bonds of unsaturated hydrocarbon tails prevent close packing of phospholipids
       - Phospholipids packed further apart -> Membrane more fluid (i.e. Regulates membrane fluidity)
   - Function:
     - Results in selectively permeable membrane by acting as a barrier to movement of ions as well as polar and large molecules
2. Cholesterol
   - Structure:
     - Hydrophobic fused four-ring structure
     - Hydrophilic polar hydroxyl group ⇒ Slightly amphipathic but largely hydrophobic
   - Function:
     - **Regulates membrane fluidity
       - Prevents membrane from being overly fluid at warmer temperatures by interacting with the phospholipids, hence restricting phospholipid movement
       - Prevents membrane from being overly firm at lower temperatures by preventing close packing of phospholipids, hence hindering solidification of the phospholipid bilayer
       - Membrane fluidity important as it affects the permeability of membranes (ability to serve as a barrier) and transportation of membrane proteins to specific regions of the membrane
3. Membrane Proteins
   - Intrinsic proteins (Unilateral/Transmembrane)
     - Inserted into the membranes

        - May be attached to fibres of extracellular matrix on exterior side or filaments of cytoskeleton on interior side
            - Helps to maintain cell shape and fix location for some membrane proteins
        - Amphipathic
            - Allows it to be inserted into the plasma membrane
    - Extrinsic proteins
        - Loosely attached to surface of membrane or integral proteins through weak ionic and hydrogen bonds
        - May be attached to fibres of extracellular matrix on exterior side or filaments of cytoskeleton on interior side
            - Helps to maintain cell shape and fix location for some membrane proteins
    - Functions:
        1. *Transport
            - Allow for facilitated diffusion of polar/charged molecules or ions across the membrane via channel or carrier proteins
            - Assist in the active transport of polar/charged molecules or ions across the membrane via protein pumps against the concentration gradient using ATP
        2. *Enzymatic activity
            - Act as enzymes that catalyse chemical reactions such as acetylcholinesterase which is found on the post-synaptic membrane to hydrolyse the neurotransmitter, acetylcholine
        3. *Receptor proteins for signal transduction
            - Act as receptor proteins for specific ligands to bind to, forming a ligand-receptor complex which will initiate an intracellular signalling cascade for signal transduction
        4. Attachment to cytoskeleton and extracellular matrix to stabilise membrane strucutre
4. Glycoproteins and glycolipids
    - Structure:
        - Carbohydrates of glycoproteins and glycolipids project out of cell into extracellular matrix
    - Functions:
        1. Act as markers for cell-cell recognition
            - Results in cell adhesion which allows cells to be attached to one another to form tissues and organs
            - Ability to determine if other cells are self or non-self to aid in the rejection of foreign cells by the immune system
            - Cell markers to differentiate one cell type from another
        2. Cell receptors
            - Receptors for hormones in cell-signalling
            - Receptors for bacterial toxins (glycolipids) and viruses to bind to host cells
            - Receptors for white blood cell recognition
        3. Glycolipids found in myelin sheath and used for electrical insulation of nerve impulses

Functions

1. **Compartmentalisation**
    - **Selectively permeable nature of cell membrane allows for formation of unique environment with optimal conditions and high concentration of required enzymes for greater efficiency of enzyme reactions
    - **Spatial separation of biological processes allows for their sequential operation within a cell
    - Accumulation of charged ions and formation of chemical gradients across membranes
    - Storage of food source
2. **Localisation of proteins of a related function along a membrane
    - Allows for the enzymes to be attached in an ordered sequence and hence allows chemical reactions to occur in a sequential manner, improving the efficiency of the processes
3. **Increase surface area for chemical reactions
    - Allows for the attachment of many enzymes e.g. ATP synthase, electron carriers in ETC, photosynthetic pigments/chlorophyll molecules etc., involved in the processes
4. Regulate movement of substances
    - Selectively permeable → Acts as a boundary
        - Hydrophobic core of phospholipid bilayer repels ions, charged molecules and polar molecules
        - Only allows small, non-polar molecules molecules to cross the membrane directly without assistance
            - Small non-polar molecules and gases can move across membrane through transient pores formed by vibrating phospholipids
        - Movement of large or polar molecules and charged ions across the phospholipid bilayer are regulated by transport proteins
    - Makes compartmentalisation possible
5. Cell-cell recognition and adhesion
6. Signal transduction

Transport of substances

Passive (i.e. does not require ATP):

1. Simple diffusion
    - Small, non-polar molecules move down the concentration gradient without ATP or the assistance of any transport proteins
    - Small, non-polar molecules can pass through the hydrophobic core of the phospholipid bilayer readily
    - Until there is no net movement of particles
    - Each type of molecule is independent of other concentration gradients
2. Facilitated diffusion
    - Transport of molecules down the concentration gradient via transport proteins without ATP

- Polar/charged molecules or ions are unable to diffuse through the hydrophobic core of the membrane
- **Channel proteins** provide a hydrophilic pore across the membrane that is selective for a specific solute
- **Carrier proteins** undergo changes in conformation to bring the solute from one side of the membrane to the other when a specific solute binds to it

3. Osmosis
    - Movement of water molecules from region of higher water potential to region of lower water potential through a selectively permeable membrane
    - Water, although polar, is small enough to diffuse directly across the membrane through transient pores that arise when phospholipids are in lateral motion
    - Or through aquaporin proteins that facilitate their diffusion of water across the membrane down the concentration gradient

Active (i.e. requires ATP):

1. Active transport
    - Polar/charged molecules or ions are transported against the concentration gradient requiring ATP
    - Involves protein pumps and is solute specific
    - e.g. Sodium-potassium pump
        1. 3 cytoplasmic sodium ions bind to sodium-potassium pump
        2. Binding stimulates phosphorylation of ATP
        3. Phosphorylation causes conformational change in protein, expelling sodium ions to outside
        4. 2 extracellular potassium ions bind to protein and trigger release of phosphate group
        5. Protein returns to original conformation, releasing potassium ions inside the cell
2. Bulk transport
    - To transport macromolecules or molecules in large quantity with the use of ATP to rearrange microtubules of cytoskeleton
    - Endocytosis (i.e. uptake of macromolecules or molecules in large quantities into cell)
        - **Phagocytosis** (solid matter)
            1. Pseudopodia extend outwards, wrap around and engulf the macromolecule
            2. Ends of pseudopodia fuse and vesicle containing solid matter is pinched off and enters cytoplasm
        - **Pinocytosis** (liquid matter)
            1. Small area of plasma membrane invaginates to form tiny vesicles of aqueous medium which are brought into the cell
        - **Receptor-mediated endocytosis**
            1. For transport of molecules in large quantities against the concentration gradient, receptor mediated endocytosis occurs where specific ligands bind to protein receptors on the membrane

        2. Plasma membrane invaginates to form vesicles containing the ligand-vesicle complexes which are then transported within the cell
- Exocytosis (i.e. secretion of macromolecules)
    1. Transport vesicles containing the macromolecule bud off from Golgi apparatus and moves to cell surface
    2. Membrane of vesicle fuses with cell membrane to release contents of vesicle to extracellular environment