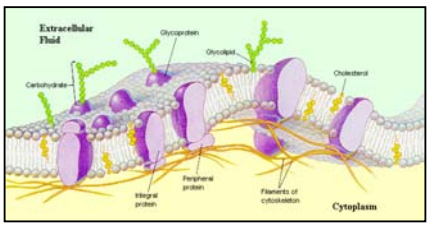
Biomembranes
Structure and function

Biological membranes

- Form cell's boundary
- Divide eukaryotic cells into compartments (organelles)
- Place of communication and transport between compartments

Biomembrane - composition

- Assembly of a phospholipid bilayer and proteins embedded in it



Biomembranes

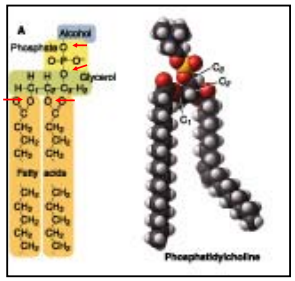
- All biomembranes of eukaryotes and eubacteria have the same phospholipid bilayer structure
  - Archebacteria have membranes that are monolayers but look and behave like bilayers
- Specific function of each membrane depends on the membrane proteins that are present in that membrane

Phospholipid bilayer

- Built from lipids and steroid derivatives
- Phospholipids = Phosphoglycerides
  - Phosphoglycerides are main ingredient
- Glycolipids
  - Sphingolipids
- Steroids
  - Cholesterol

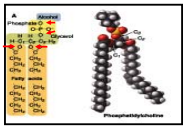
Phospholipid structure

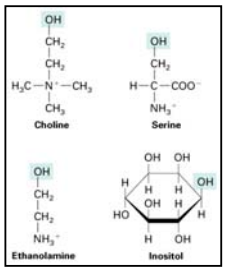
- Glycerol backbone
- Connected by ester bonds to fatty acid chains
  - Phosphoric acid
  - Alcohol



Alcohols

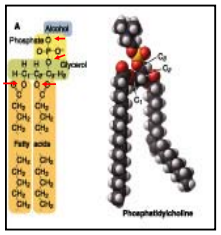
- Give a phospholipid its name
  - Phosphatydylinositol
  - Phosphatydylcholine
- Alcohol end is extremely polar (hydrophilic)
- Form head groups





Alcohols in biological membranes

- Decide about the properties of the phospholipid
- When cleaved become important signaling molecules

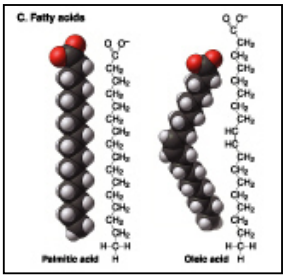


Fatty acids

- Fatty acid end of a phospholipid molecule is strongly nonpolar (hydrophobic)
  - Forms internal tails in the membrane
- Usually even number of carbons
  - Myristate 14
  - Palmitate 16
  - Arachidonate 20

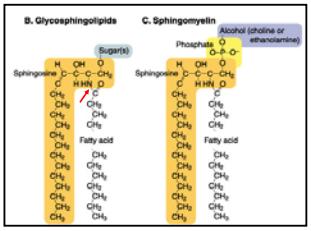
Fatty acids

- Double bonds in unsaturated fatty acid create a bend and "loosen up" membrane packing



Sphingolipids

- Sphingosine (base) backbone
- Amide link to an additional fatty acid chain
- Ether link to sugars or phosphoric acid and alcohol

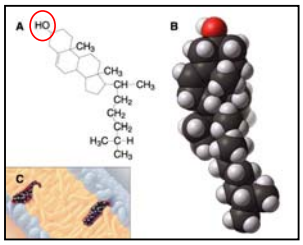


Sphingolipids

- Glycosphingolipids
  - Receptors for viruses
- Sphingomyelins
  - Signaling molecules

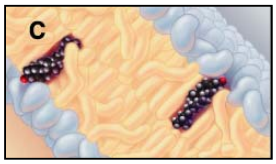
Sterols

- Another class of membrane lipids
- All have four hydrocarbon rings
- Cholesterol has a hydroxyl substituent on one ring



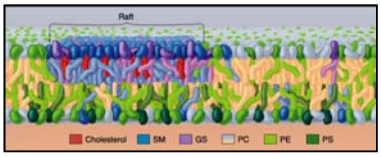
Cholesterol

- Hydroxyl group can interact with water what makes the molecule amphipathic
- Cholesterol is very abundant and necessary in membranes of eukaryotic cells



Phospholipid bilayer

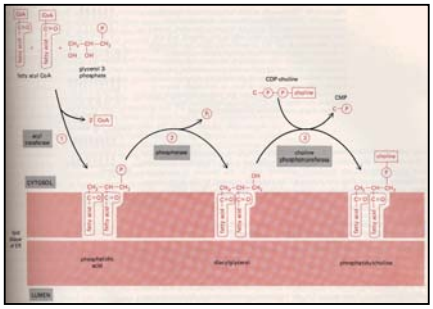
- In a bilayer
  - Fatty acid tails point inward
  - Alcohol heads point outward
- Each phospholipid layer is called a leaflet
- Leaflets are different in composition



How do the phospholipid bilayers form?

- Driving force are hydrophobic interactions between the fatty acid chains of phospholipids and glycolipids molecules
- Hydrogen bonds between polar groups stabilize the bilayer
- Phospholipids in biological membranes are synthesized in 2-step enzymatic reaction

Synthesis of membrane lipids



Synthesis of membrane lipids

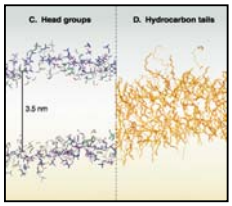
1. Two fatty acids are added to glycerol 3-phosphate to produce phosphatidic acid (acyl transferases)
2. Phosphatase and phosphotransferase attach head groups

This step enlarges lipid bilayer

This step determines the chemical nature of the bilayer

Physical properties of the phospholipid bilayer

- Highly dynamic
  - Lateral mobility
  - Flipping between leaflets
- Imperfectly packed fatty acid chains (double bonds in fatty acid chains) are responsible for membrane permeability

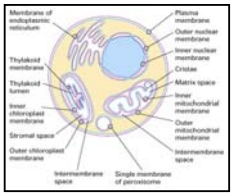


Physical properties of the phospholipid bilayer (not a biological membrane)

- High electrical resistance
- Impermeable to ions
- Permeable to gases and small lipid soluble molecules
- Slightly permeable to water
- Ability to self seal (always form closed compartments)

Phospholipid bilayer

- Spontaneously assemble to form closed bilayers
- Phospholipid bilayers spontaneously seal to form closed compartments
- The two faces of a membrane (cytosolic and exoplasmic) are asymmetrical in lipid and protein composition



Membrane proteins

- Each cell membrane has a set of specific membrane proteins
- Membrane proteins allow the membrane to carry out its distinctive functions
- Are either integral (intrinsic) or peripheral

Functions of membrane proteins

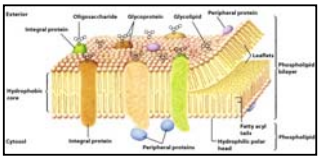
- Transport of nutrients
- Passage of water
- Selective transport of molecules (keep the unwanted molecules out, secrete metabolic byproducts)
- Maintenance of proper ionic composition inside the cell

Functions of membrane proteins

- Reception of signals from the extracellular environment
- Expression of cell identity
- Physical and functional connection with other cells or the extracellular matrix (in multicellular organisms)

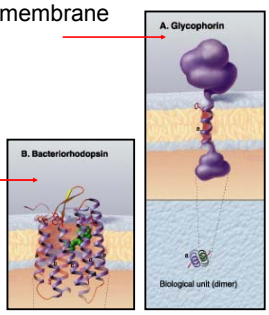
Integral (intrinsic) membrane proteins

- Cross the bilayer (transmembrane)
- Transmembrane segment is usually α helix
  - A segment of 25 hydrophobic residues
- Examples: G protein coupled receptors, ion channels, pumps, transporters



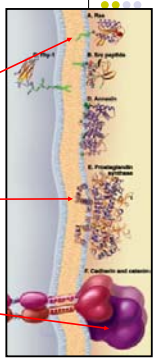
Examples of intrinsic membrane proteins

- Glycophorin: single transmembrane domain protein
- Bacteriorhodopsin: multiple transmembrane domains protein



Peripheral membrane proteins

- Do not interact with hydrophobic core of the bilayer
- Are associated with membranes through
  - Lipid anchors
  - Interactions with bilayer (but not complete crossing)
  - Or contact with integral membrane proteins



Asymmetry of the membrane

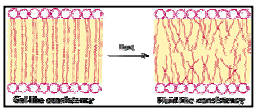
- The two faces of a membrane are asymmetrical in lipid and protein composition
- All integral and membrane bound proteins are distributed asymmetrically
- Each protein has a single, specific orientation with respect to cytosolic and exoplasmic faces of the membrane
- Glycolipids are located exclusively on the exoplasmic leaflet

Lipid bilayer is a fluid

- Both lipids and integral membrane proteins can move laterally within the membrane
- Can also flip-flop between leaflets

Lateral mobility in biomembranes

- Mobility (diffusion) of a given membrane components depends on:
  - Lipid composition (tails, cholesterol)
  - The size of the molecule
  - Its interactions with other molecules
  - Temperature
    - Temperature "melts" the membrane



Plasma membranes have different protein:lipid ratio

- !!!Protein:lipid ratio in the membrane depends on the function
- Mitochondrial membrane is 76% protein (has many transporters and enzymes)
- Myelin (Schwann cell) membrane has 18% protein (phospholipids are great insulators)

Summary

- Biomembrane is an assembly of phospholipid bilayer and proteins
- Phospholipid bilayer is responsible for structural features
- Biological membranes contain both integral or peripheral membrane proteins
- Membrane proteins are responsible for specific function of each membrane
- Membranes spontaneously assemble to form bilayers and closed compartments