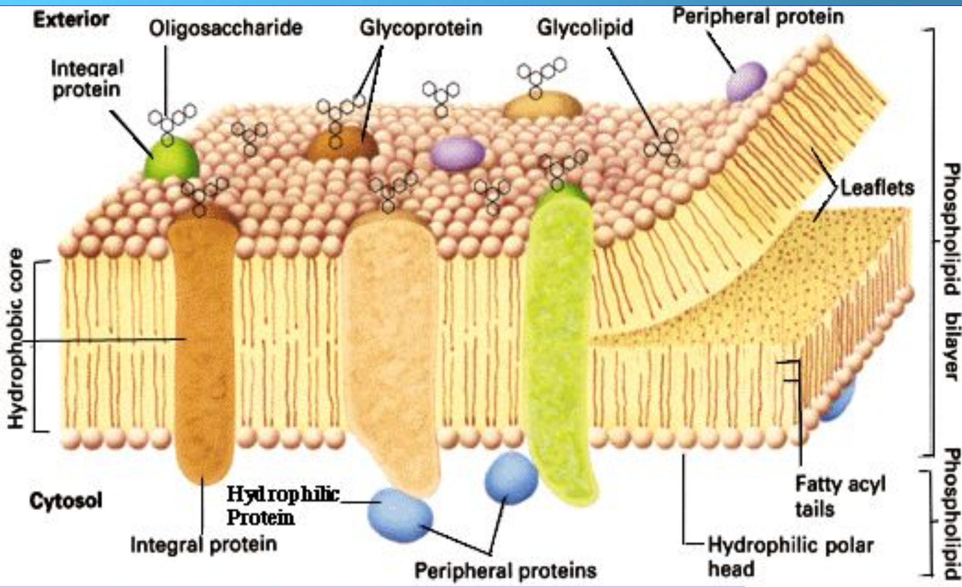
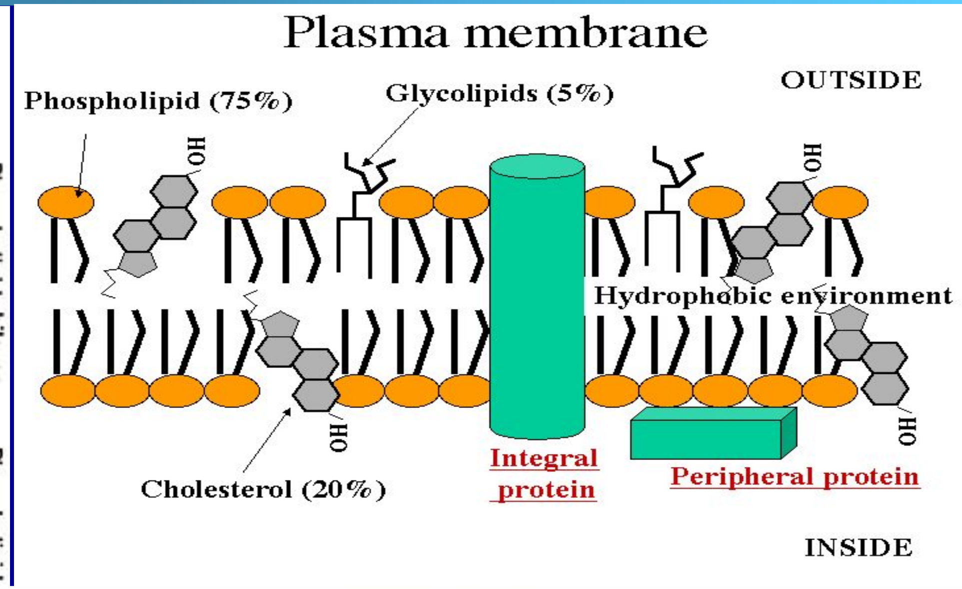
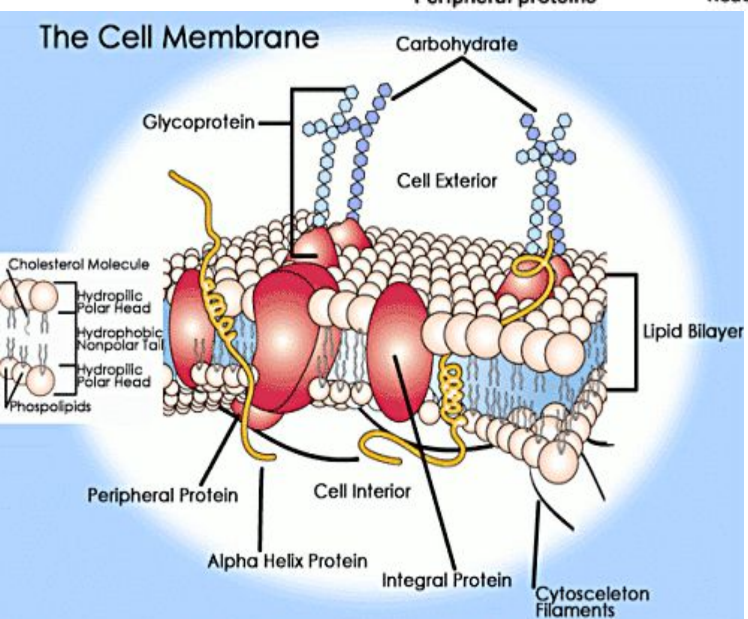
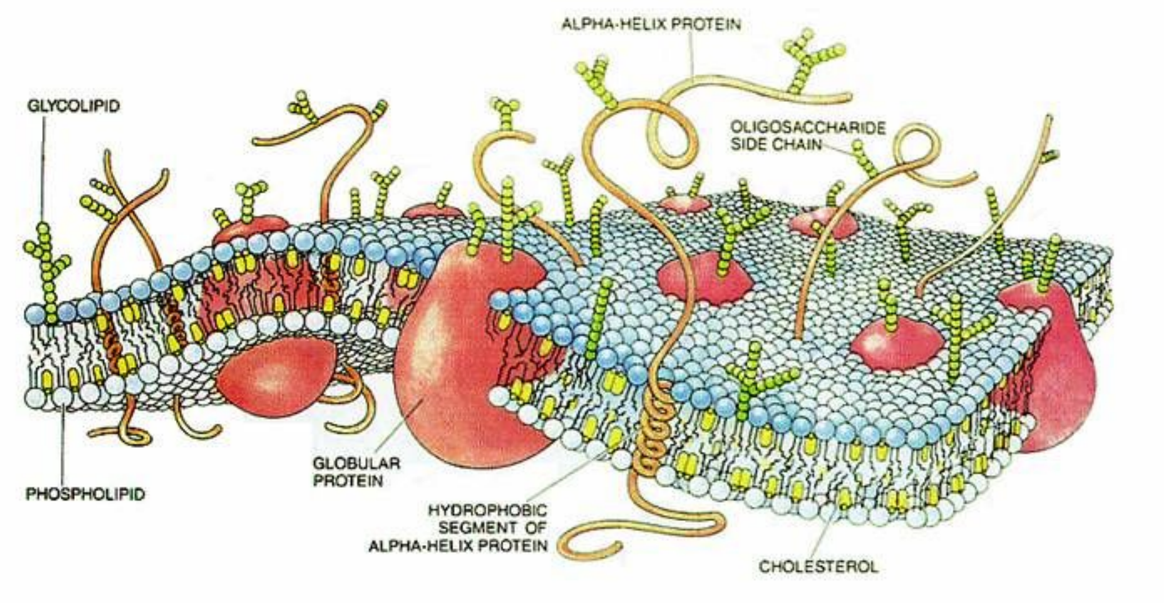
Cell Surface Membrane









Membrane History

- Charles Overton 1890
- Langmuir 1917
- Gorter & Grendel 1925
- Davson & Daneili 1935
- David Robertson 1957
- Singer & Nicholson 1972
- Karnovsky 1982
- Unwinn & Henderson 1984
- Simmons & van Meer 1988

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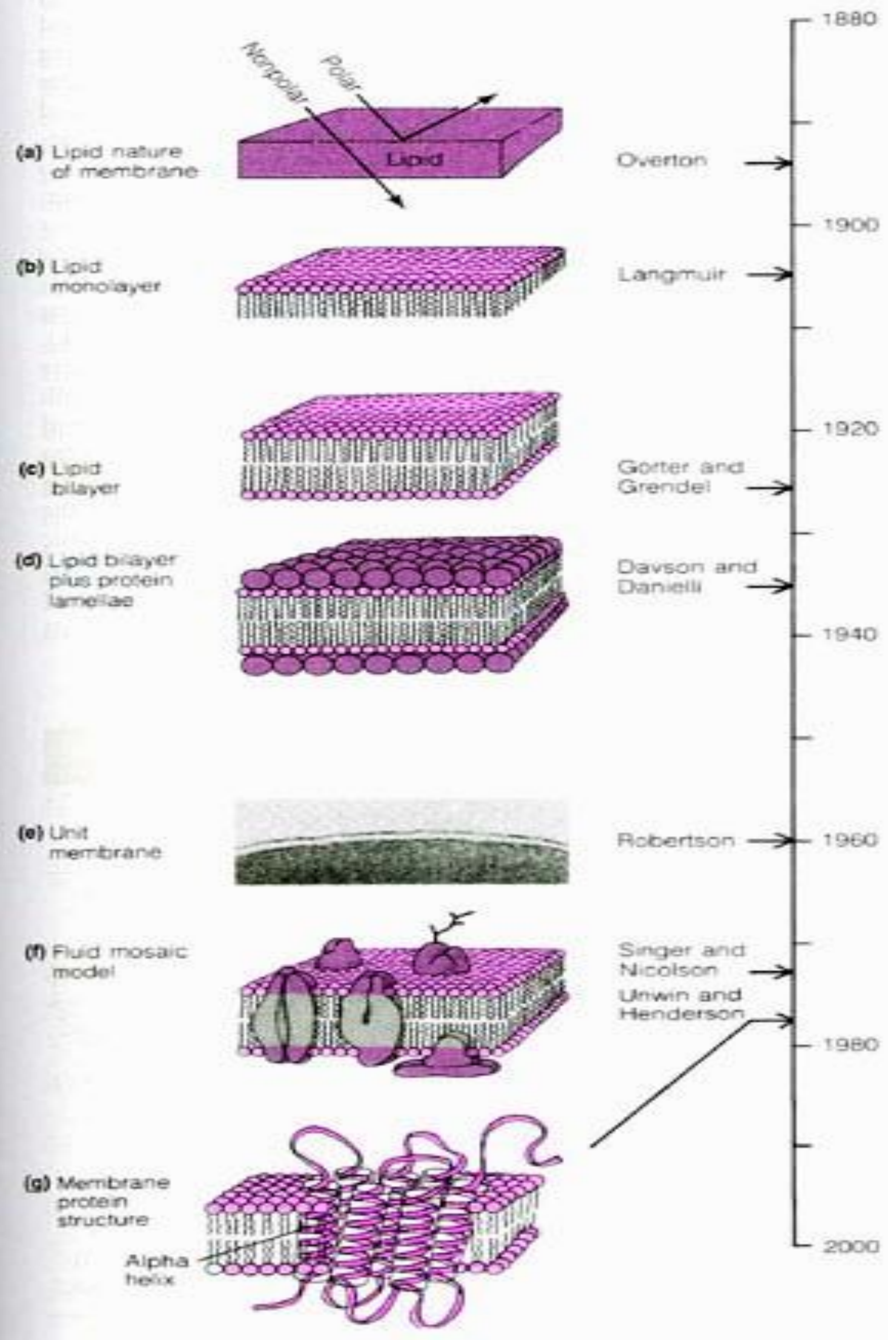
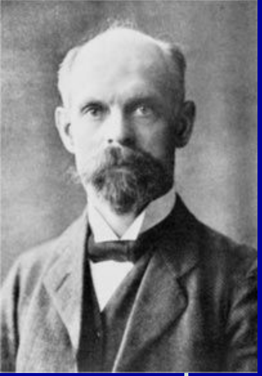


Learning outcomes: Membrane structure

- Mono- and bi- layers of lipid
- Integral and peripheral proteins
- The fluid Mosaic model of membrane structure
- Raft model of membranes
- Phospholipids, sphingolipid, glycoprotein, glycolipid and cholesterol
- Variation in lipid: protein content
- Viscosity of membrane depends on lipid content

Learning outcomes: Role of membrane

- Boundary layer but also an active part of the biochemical functioning of the cell
- Passage of hydrophilic and hydrophobic material across the membrane
- Pores



Where does our picture of the cell membrane come from?

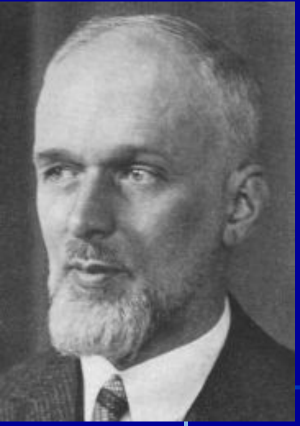
Charles Ernest Overton (1865-1933)

- First indications that lipids are important
- Observed lipid soluble substances past through membrane more easily than others
- Conclusion large part of the membrane must be lipid

Where does our picture of the cell membrane come from?

Observations on the behaviour of cell surface membranes

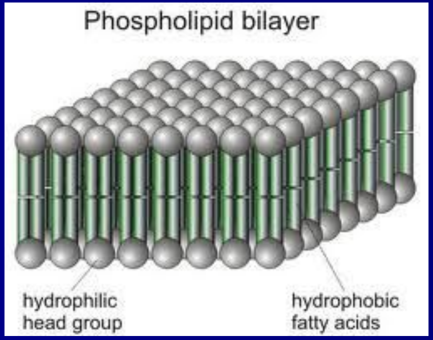
- Most membranes seal themselves when punctured by a fine needle
- Led to the idea that membranes are fluid



Where does our picture of the cell membrane come from?

Evert Gorter and F Grendal

- Measured the total size of the monolayer film formed by lipid from human red blood cells
- Found measured area of monolayer was twice the estimated surface area of a red blood cell
- Conclusion cell membrane was a lipid bilayer

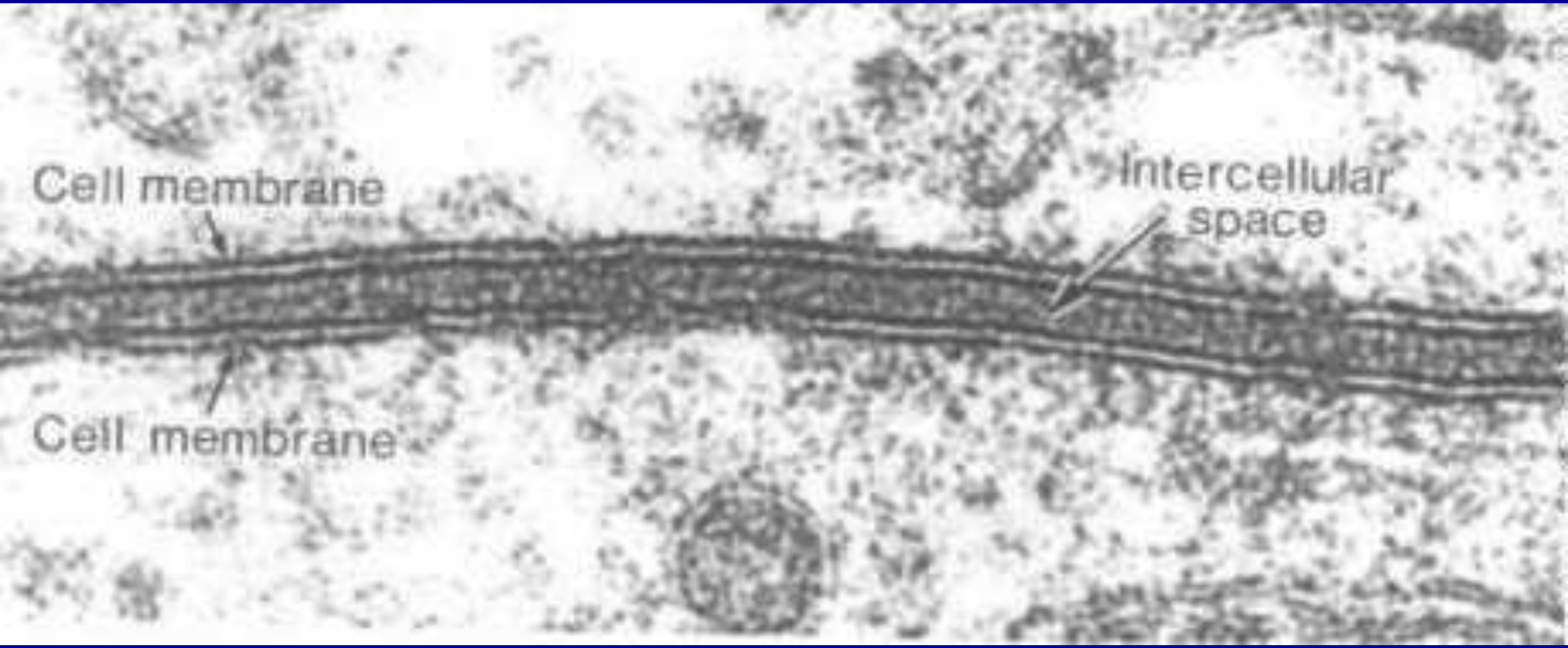


Gorter and Grendel, 1925

TABLE I.

Animal.	Amount of blood used for the analysis.	No. of chromocytes per c.mm.	Surface of one chromocyte.	Total surface of the chromocytes (*a*).	Surface occupied by all the lipoids of the chromocytes (*b*).	Factor *a*:*b*.
	gm.		*sq. μ*	*sq. m.*	*sq. m.*	
Dog A	40	8,000,000	98	31.3	62	2
	10	6,890,000	90	6.2	12.2	2
Sheep 1	10	9,900,000	29.8	2.95	6.2	2.1
	9	9,900,000	29.8	2.65	5.8	2.2
Rabbit A	10	5,900,000	92.5	5.46	9.9	1.8
	10	5,900,000	92.5	5.46	8.8	1.6
	0.5	5,900,000	92.5	0.27	0.54	2
" B	1	6,600,000	74.4	0.49	0.96	2
	10	6,600,000	74.4	4.9	9.8	2
	10	6,600,000	74.4	4.9	9.8	2
Guinea Pig A	1	5,850,000	89.8	0.52	1.02	2
	1	5,850,000	89.8	0.52	0.97	1.9
Goat 1	1	16,500,000	20.1	0.33	0.66	2
	1	16,500,000	20.1	0.33	0.69	2.1
	10	19,300,000	17.8	3.34	6.1	1.8
	10	19,300,000	17.8	3.34	6.8	2
	1	19,300,000	17.8	0.33	0.63	1.9
Man.	1	4,740,000	99.4	0.47	0.92	2
	1	4,740,000	99.4	0.47	0.89	1.9

Basic unit membrane structure under Electron microscope



Where does our picture of the cell membrane come from?

Hugh Davson and James Danielli 1935

- Produced model with lipid centre coated on each side with protein

James Robertson

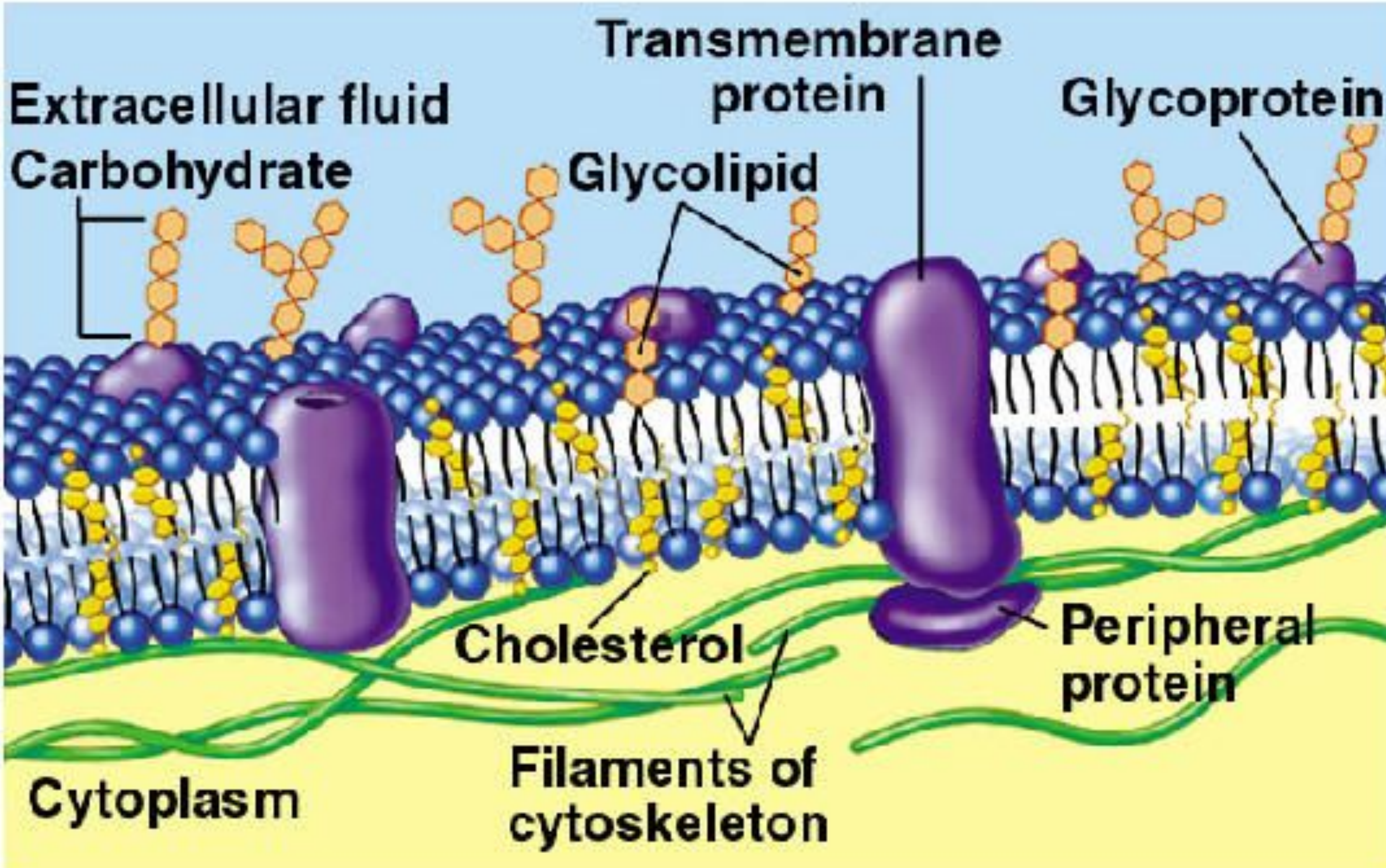
- Electron microscope work showed three layered structure – two distinct lines with a gap in the middle

Where does our picture of the cell membrane come from?

Singer and Nicholson (1972)

- Proposed the fluid mosaic model
- A dynamic structure in which much of the protein floats about although some is anchored to organelles within the cell
- Lipid also moves about

Fluid Mosaic Model



Units of size used in biology

- 1 centimetre (cm) 10^{-2}metre (1/100)
- 1 millimetre (mm) 10^{-3}metre (1/1000)
- 1 micrometre (µm) 10^{-6}metre (1/000,000)
- 1 nanometre (nm) 10^{-9}metre (1/000,000,000)
- 1 picometre (pm) 10^{-12}metre (1/000,000,000,000)

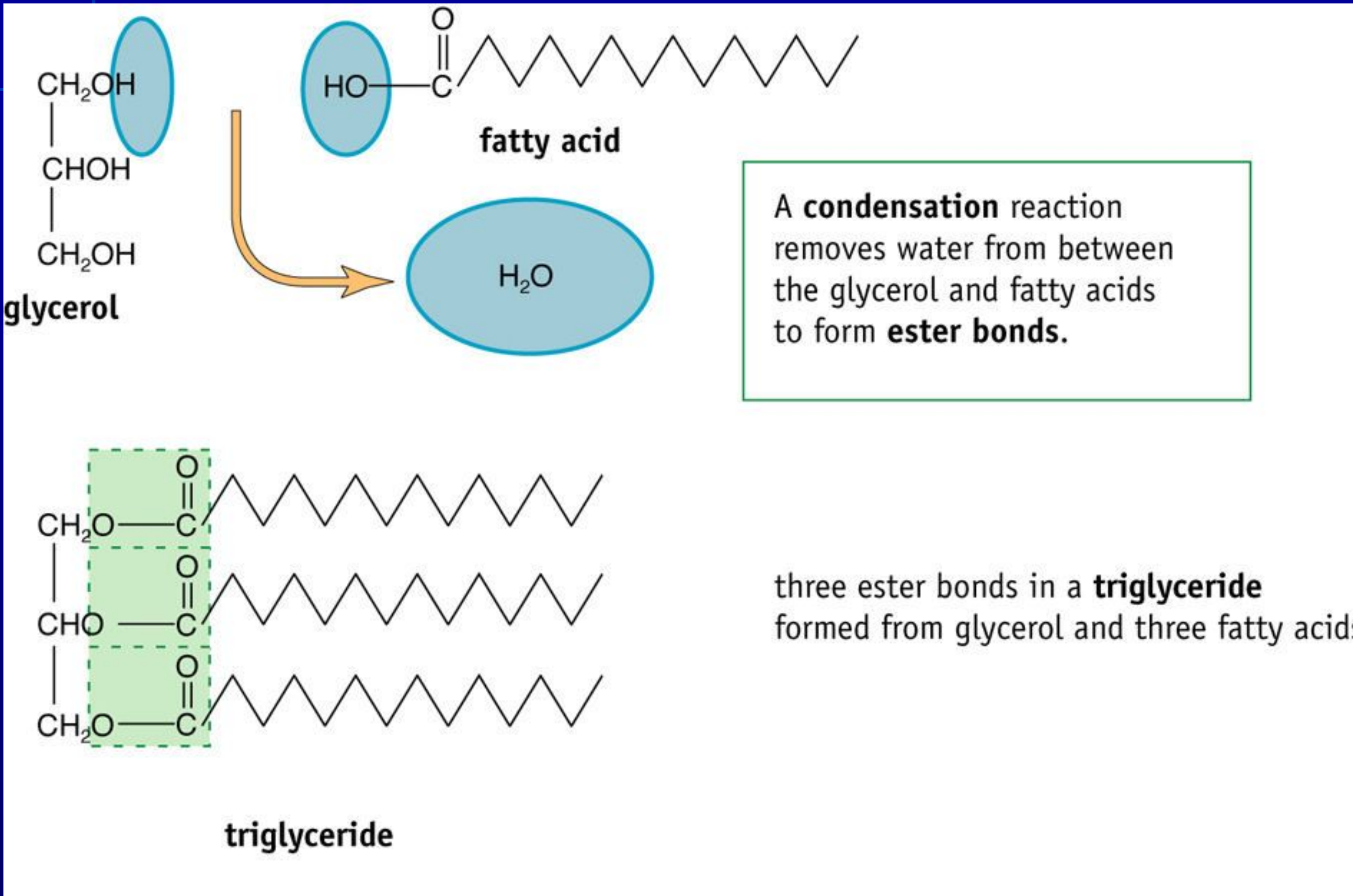
Cell Surface Membrane Structure

- Under the electron microscope bilayer structure is revealed
- Two distinct lines 7nm wide (1nm $=10^{-9}$metre)
- Basic structure is 2 layers of phospholipids

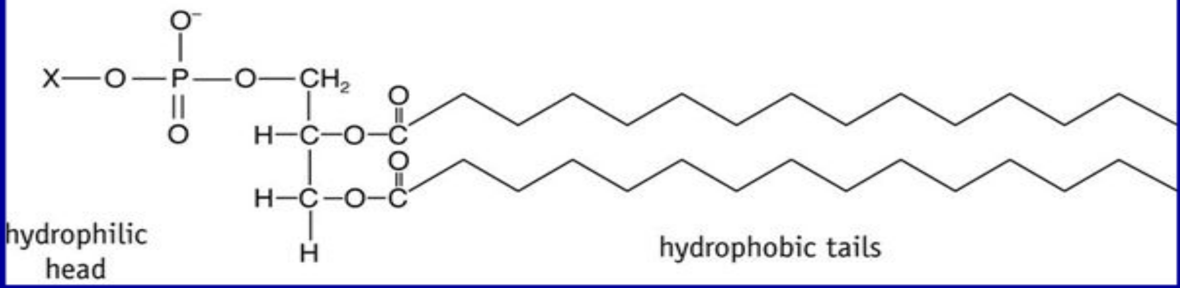
Phospholipids

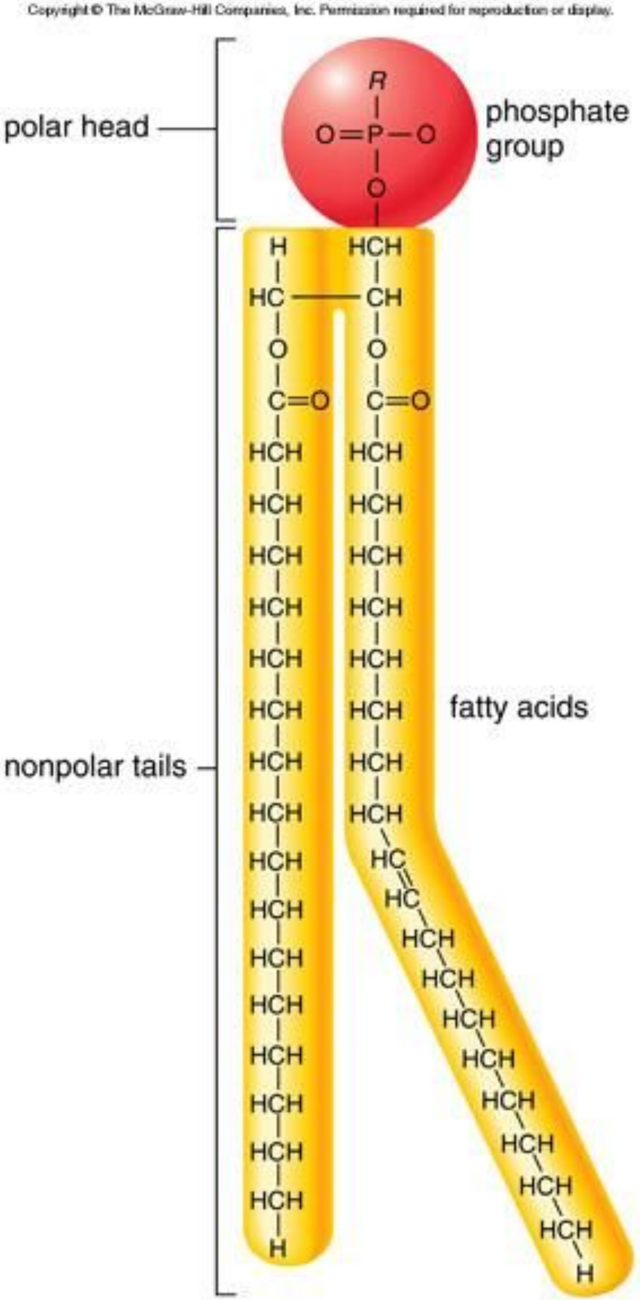
- Lipid molecule three fatty acid molecules and a glycerol
- Phospholipid only two fatty acids, a negatively charged phosphate group replaces the third fatty acid

Lipid molecule



Phospholipid





Phospholipid structure

Phospholipid bilayer

- Phophate head of the molecule is polar; one end is slightly positive and the rest slightly negative
- This makes the phosphate head attract other molecules , like water and is therefore hydrophilic (water loving)

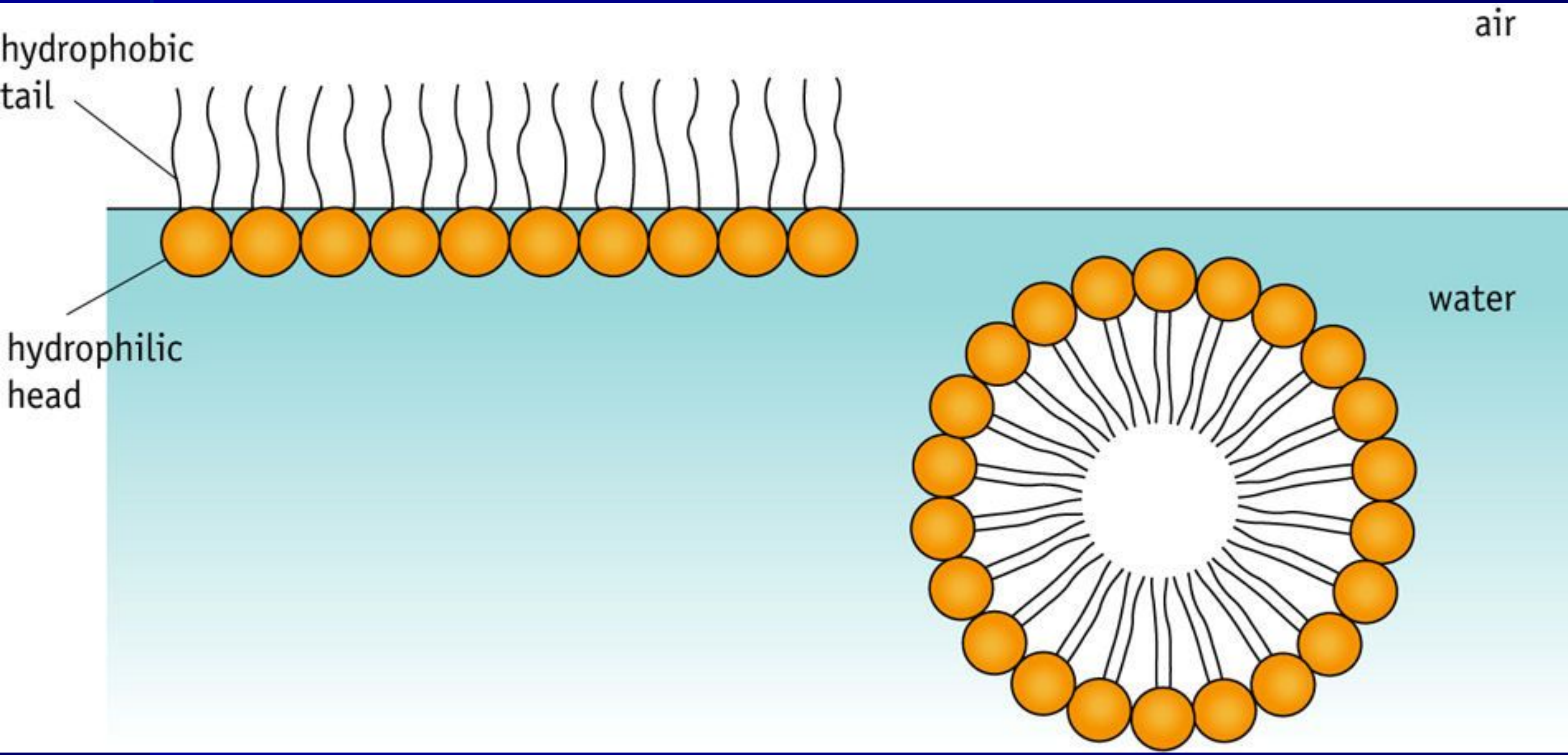
Phospholipid bilayer 2

- Fats and water don’t mix
- When added to water phospholipids arrange themselves to avoid contact with between hydrophobic tails and the water

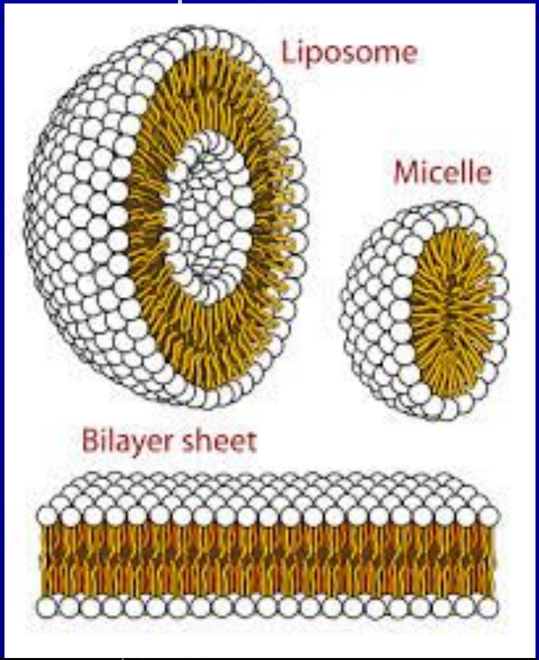
Phospholipid bilayer 3

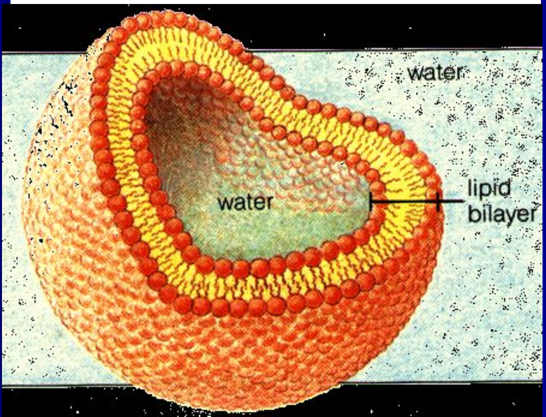
- They form a layer on the surface with their hydrophobic tails directed out of the water, arrange themselves into spherical cluster (micelles) or form a bilayer

Phospholipids in water form a monolayer on the surface or spherical micelles



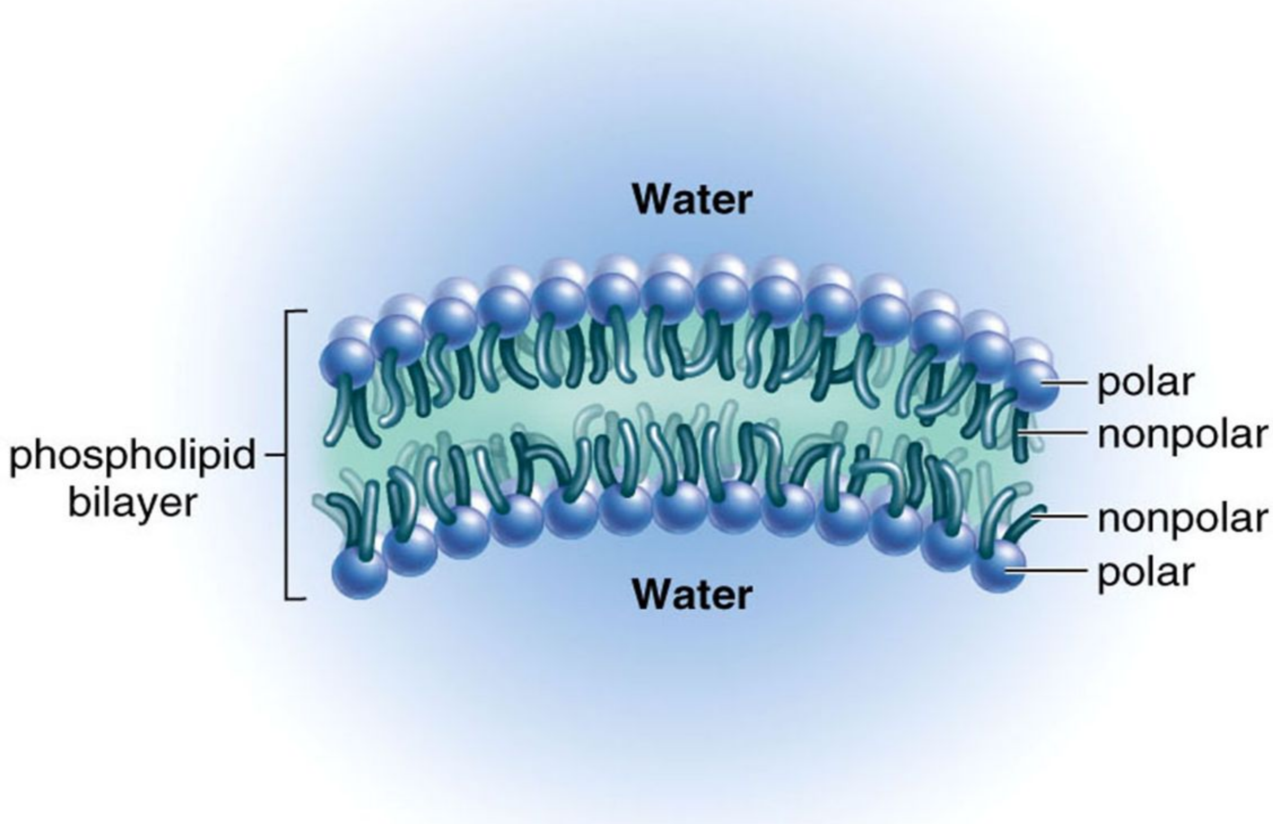
Phospholipid 4





- Cells are filled with a watery or aqueous cytoplasm and are surrounded by aqueous tissue fluid
- The cell surface membrane phospholipids tend to adopt their most stable arrangement, which is a bilayer

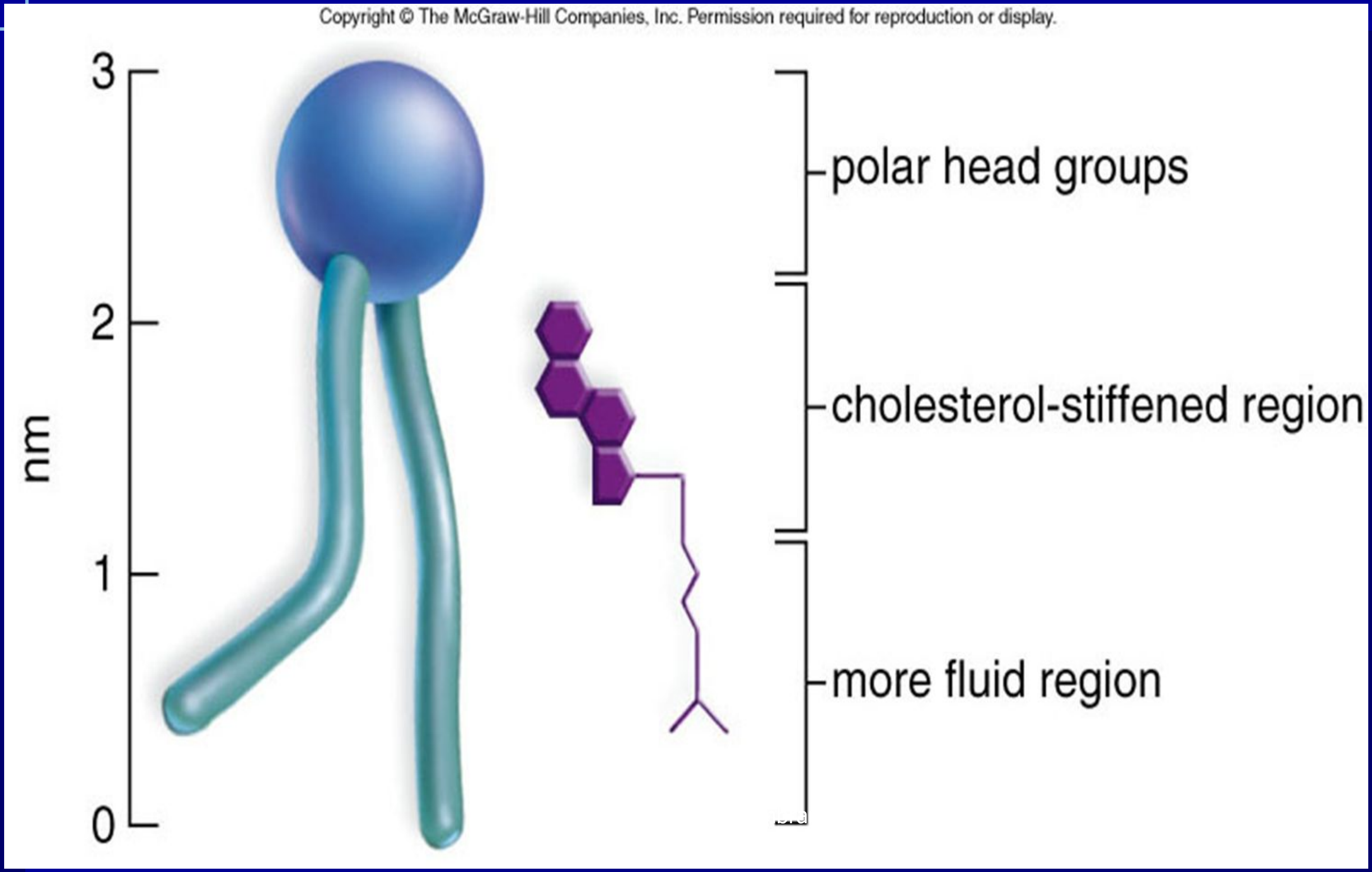
Phospholipid



Phospholipid 5

- This arrangement avoids the hydrophobic fatty acid tails having any contact with water on either side of the membrane but ensures that the hydrophilic phosphate heads are in contact with the water.

Phospholipids



Fluid-Mosaic Model 1

- The cell surface membrane is not just a phospholipid bilayer
- It also contains proteins, cholesterol, glycoproteins (protein molecule with polysaccharide attached) and glycolipid (lipid molecule with polysaccharide attached)

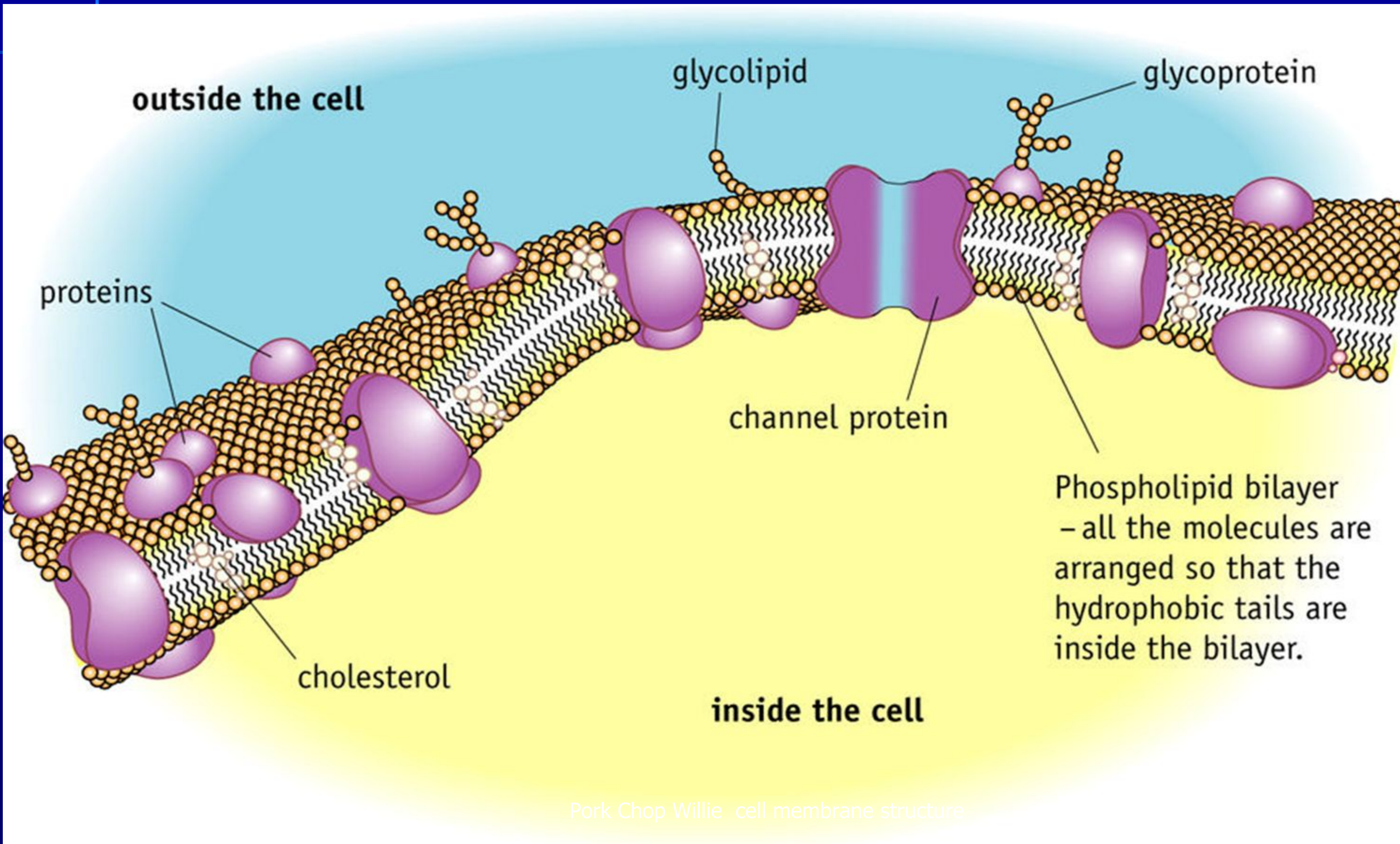
Fluid-Mosaic Model 2

- Some of the proteins span the layer
- Other proteins are found only within the inner layer or only within the outer layer
- Membrane proteins have hydrophobic areas and these are positioned within the membrane bilayer

Fluid-Mosaic Model 3

- It is thought that some of the proteins are fixed within the membrane and others are not and can move in the fluid phospholipid bilayer.
- This arrangement is known as the fluid Mosaic Model of membrane structure

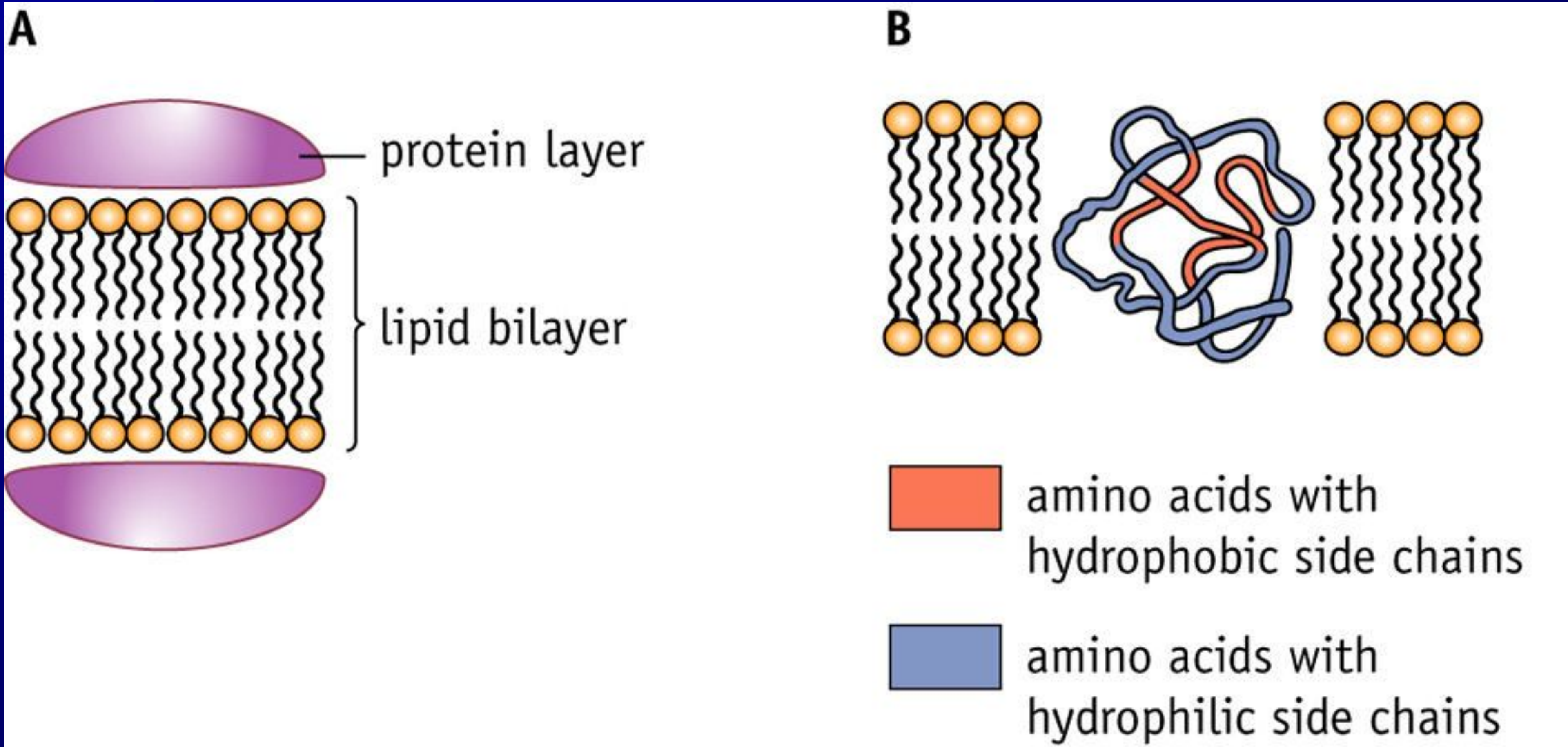
Fluid Mosaic Model



Evidence for the model 1

- The most widely accepted model until the early 1970s was a three layer protein-lipid layer sandwich based on electron micrographs (diagram A)
- However this model does not allow the hydrophillic head to come into contact with water

(A) Phospholipid sandwich model
(B) in the Fluid mosaic integral protein have polar and non polar regions



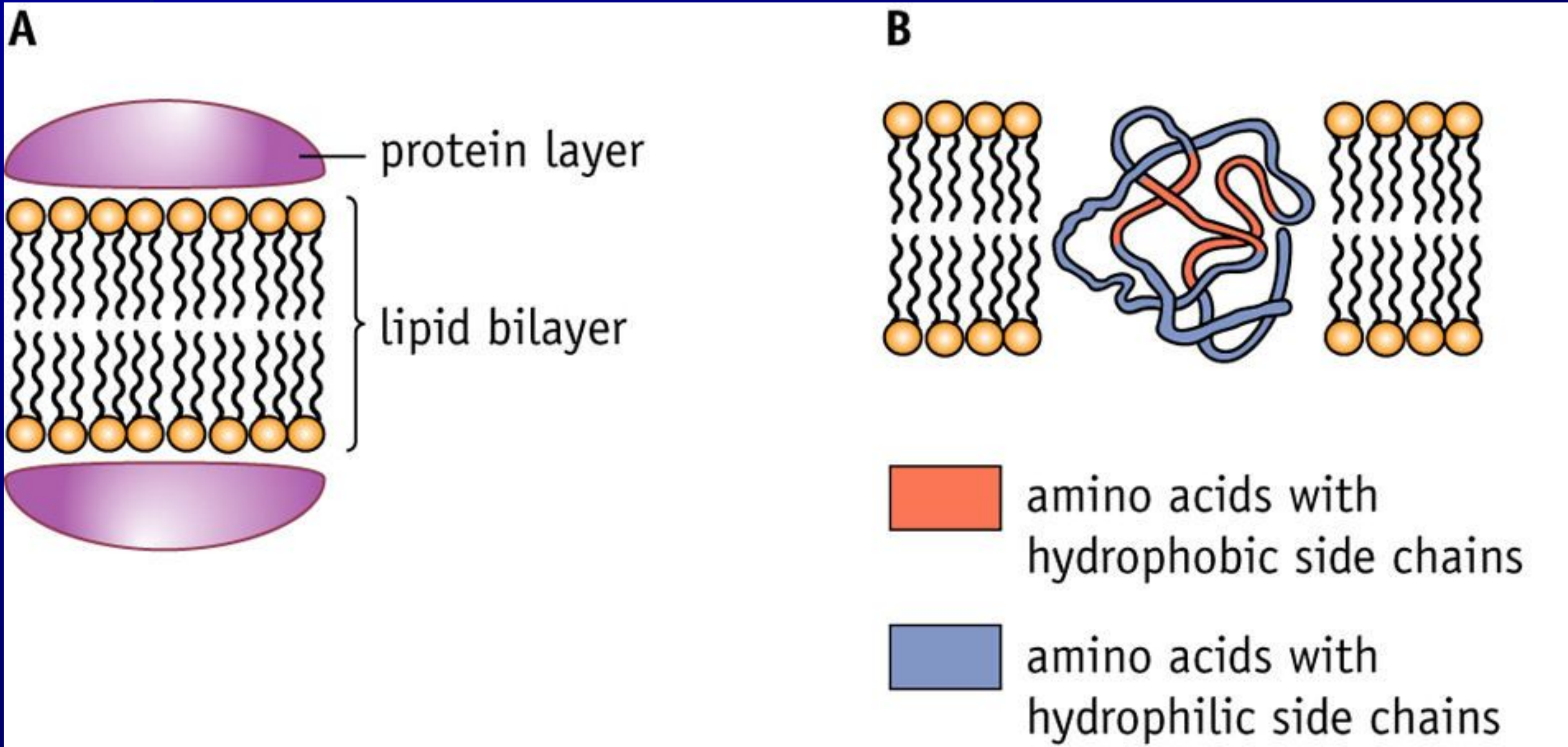
Evidence for the model 2

- Experiments showed that there were two types of protein- those that could be dissociated easily by increasing the ionic strength of the surrounding solution and those that could only be removed with detergent
- This evidence indicated some proteins were loosely attached and some are fully embedded

Evidence for the model 3

- Several integral proteins were shown to have regions at their ends that had polar hydrophilic amino acids, with the middle portion composed mainly of non polar hydrophobic amino acids (diagram B)

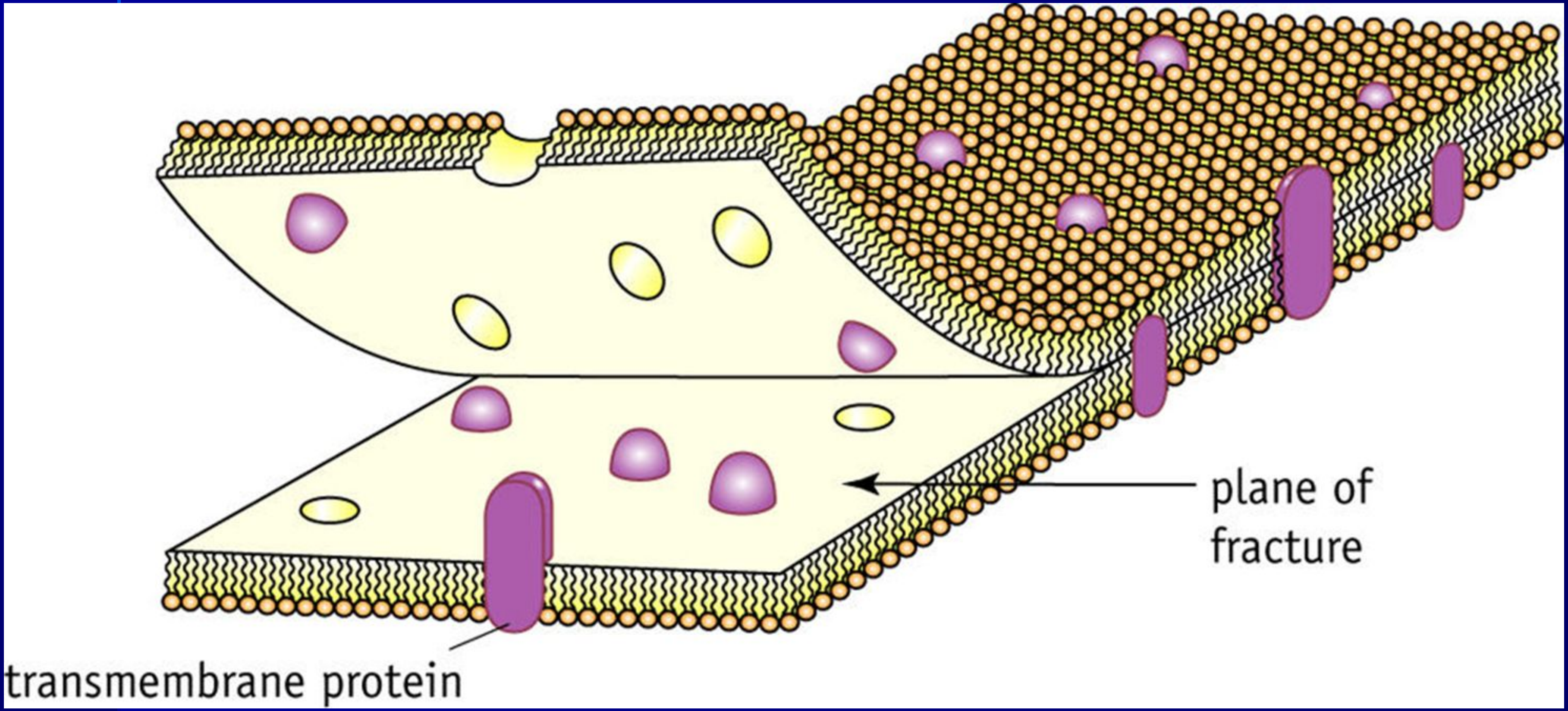
(A) Phospholipid sandwich model
(B) in the Fluid mosaic integral protein have polar and non polar regions



Evidence for the model 4

- Additional evidence for integral proteins came from freeze-fracture electron microscope studies
- Freeze-fracture sections were fractured along their weak point between lipid layers
- Scanning Electron microscopy gave a three dimensional image

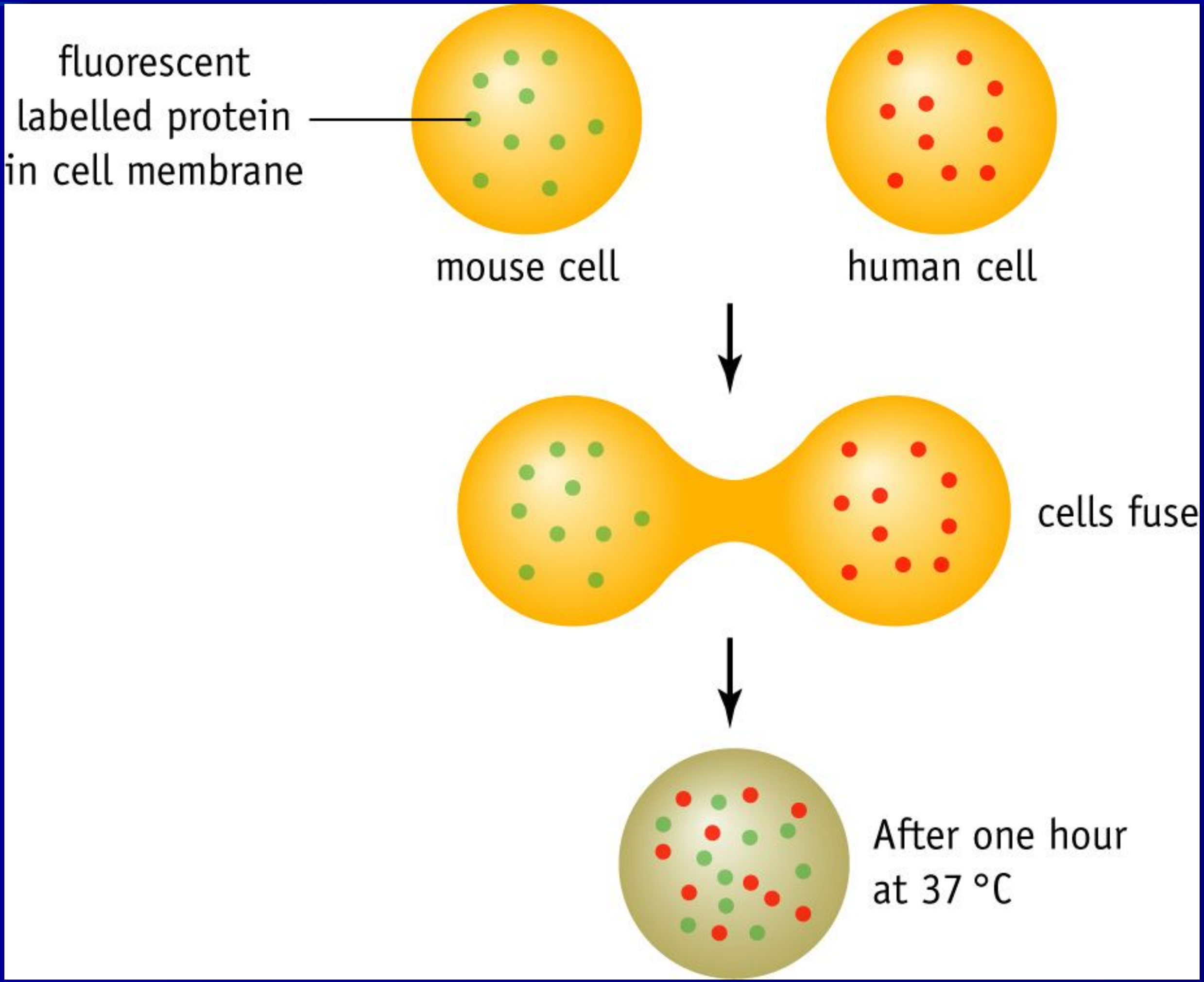
Freeze-fracture of membrane revealing intregral proteins



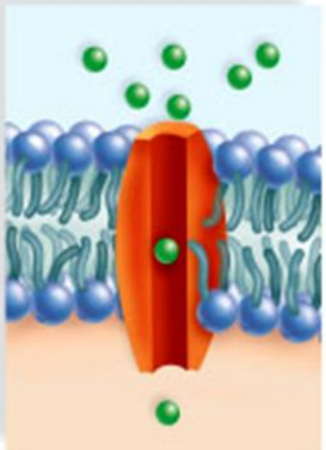
Evidence for the model 5

- Fusion of mouse cells with human cells
- Before cells were fused a specific membrane protein was labelled in each cell type
- Mouse – green fluorescent label
- Human – red fluorescent label

Movement of membrane Proteins within cell surface membranes

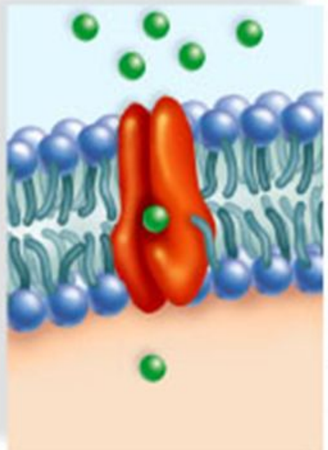


Membrane Protein Diversity



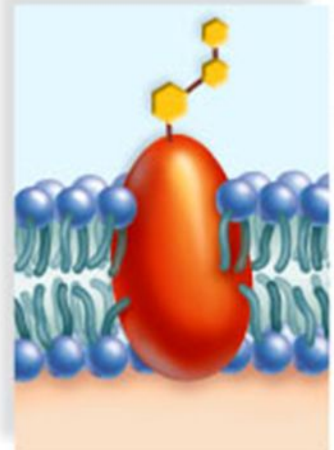
Channel Protein
Allows a particular molecule or ion to cross the plasma membrane freely. Cystic fibrosis, an inherited disorder, is caused by a faulty chloride (Cl^-) channel; a thick mucus collects in airways and in pancreatic and liver ducts.

a.



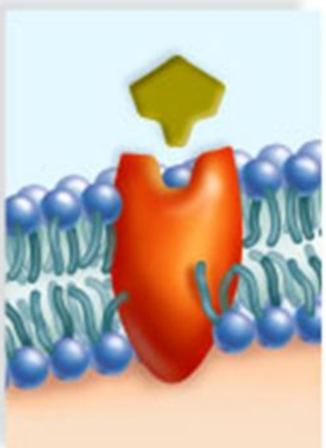
Carrier Protein
Selectively interacts with a specific molecule or ion so that it can cross the plasma membrane. The inability of some persons to use energy for sodium-potassium (Na^+–K^+) transport has been suggested as the cause of their obesity.

b.



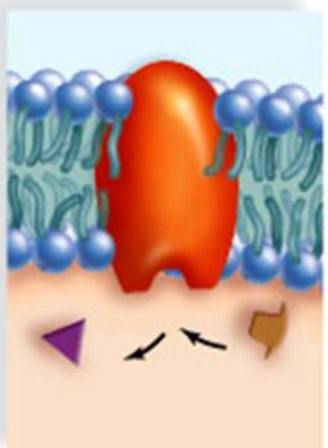
Cell Recognition Protein
The MHC (major histocompatibility complex) glycoproteins are different for each person, so organ transplants are difficult to achieve. Cells with foreign MHC glycoproteins are attacked by white blood cells responsible for immunity.

c.



Receptor Protein
Is shaped in such a way that a specific molecule can bind to it. Pygmies are short, not because they do not produce enough growth hormone, but because their plasma membrane growth hormone receptors are faulty and cannot interact with growth hormone.

d.



Enzymatic Protein
Catalyzes a specific reaction. The membrane protein, adenylate cyclase, is involved in ATP metabolism. Cholera bacteria release a toxin that interferes with the proper functioning of adenylate cyclase; sodium ions and water leave intestinal cells, and the individual may die from severe diarrhea.

e.

Functions of Membrane Proteins

- Channel Proteins:
  - Tubular
  - Allow passage of molecules through membrane
- Carrier Proteins:
  - Combine with substance to be transported
  - Assist passage of molecules through membrane
- Cell Recognition Proteins:
  - Provides unique chemical ID for cells
  - Help body recognize foreign substances
- Receptor Proteins:
  - Binds with messenger molecule
  - Causes cell to respond to message
- Enzymatic Proteins:
  - Carry out metabolic reactions directly

More unsaturated phospholipids – more fluid

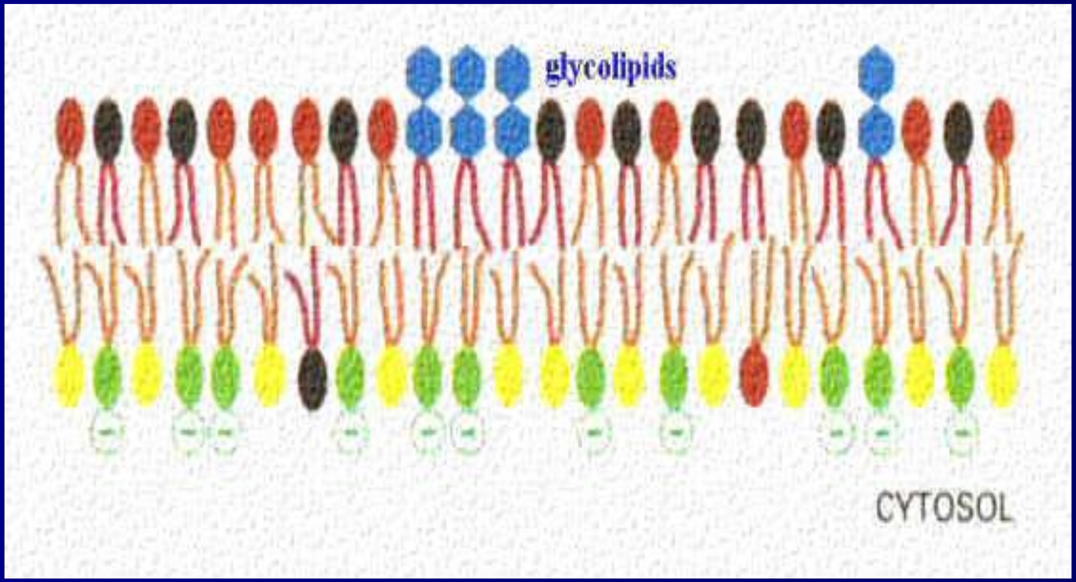
- The more phospholipids containing unsaturated fatty acids the more fluid the membrane
- The ‘kinks’ in the hydrocarbon tails of the unsaturated tails prevents them from packing closely together, so more movement is possible

Cholesterol

- Cholesterol reduces the fluidity of the membrane by preventing movement of the phospholipids

Membrane Glycolipids

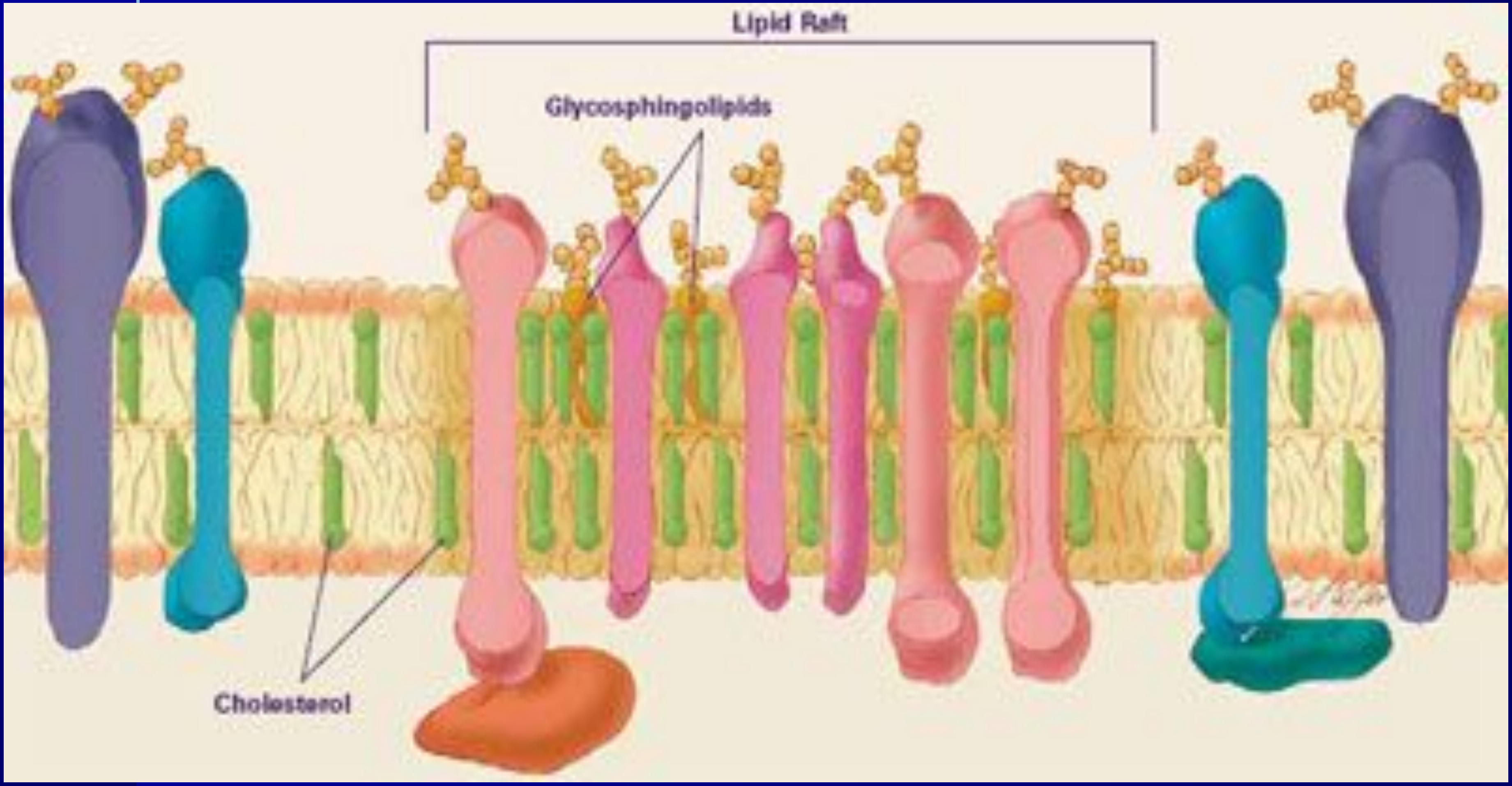
- Glycolipids shown as blue sugar groups projecting into the extracellular space.
- These components of the membrane may be protective, insulators, and sites of receptor binding.
- Among the molecules bound by glycososphingolipids include cell poisons such as cholera and tetanus toxins.



Sphingolipid

- Structural lipid of which the parent structure is sphingosine rather than glycerol.
- Synthesised in the Golgi complex
- Form the lipid rafts

Raft Model



Raft Model

- Lipid rafts are possible island like structure present in cellular membranes.
- They are enriched in cholesterol and sphingolipids.
- Cellular membranes with lipid rafts have a higher concentration of glycosphingolipids and cholesterol than do non-raft parts of membrane.

Raft Model

- The existence of lipid rafts in cell membrane has not yet been approved completely by all scientists, but many think they serve as communication hubs by recruiting proteins that need to come together in order to transmit a signal.

Q1

According to the fluid-mosaic model for the plasma membrane, there is a ______________ bilayer in which proteins are scattered throughout the membrane.

The _____________ (water loving) polar heads of the phospholipids face the intracellular and extracellular fluid. The ________________ (water hating) nonpolar tails of the phospholipid molecules face each other.

A1

According to the fluid-mosaic model for the plasma membrane, there is a phospholipid bilayer in which proteins are scattered throughout the membrane.

The hydrophilic (water loving) polar heads of the phospholipids face the intracellular and extracellular fluid. The hydrophobic (water hating) nonpolar tails of the phospholipid molecules face each other.

Q2

Phospholipids have their hydrophilic polar heads facing the ____________ and ________________fluid. The hydrophobic nonpolar tails face each other.

The other two types of lipids present in the plasma membrane are the ________________and _________________.

A2

Phospholipids have their hydrophilic polar heads facing the intracellular and extracellular fluid. The hydrophobic nonpolar tails face each other.

The other two types of lipids present in the plasma membrane are the glycolipids and cholesterol.

Q3

The proteins found in the plasma membrane may be ___________ proteins, which are found within the membrane, or _______________ proteins, which occur either on the cytoplasmic side or the outer surface side of the membrane.

A3

The proteins found in the plasma membrane may be integral proteins, which are found within the membrane, or peripheral proteins, which occur either on the cytoplasmic side or the outer surface side of the membrane.

Q 4

State two roles of cholesterol in the membrane (2 marks)

A 4

State two roles of cholesterol in the membrane (2 marks)

- Regulates membrane fluidity;
- Mechanical stability;
- Reduces leakage of polar ions by diffusion;

Q5

There are many types of proteins in a membrane. Describe the role of two (2 marks)

A5 There are many types of proteins in a membrane. Describe the role of two (2 marks)

- Channel proteins to allow facilitated diffusion;
- Carrier proteins for active transport of molecules in/out of ;cell;
- Receptor molecules for hormones/ neurotransmitters;
- Recognition site;
- Enzymes for digestion/ respiration;