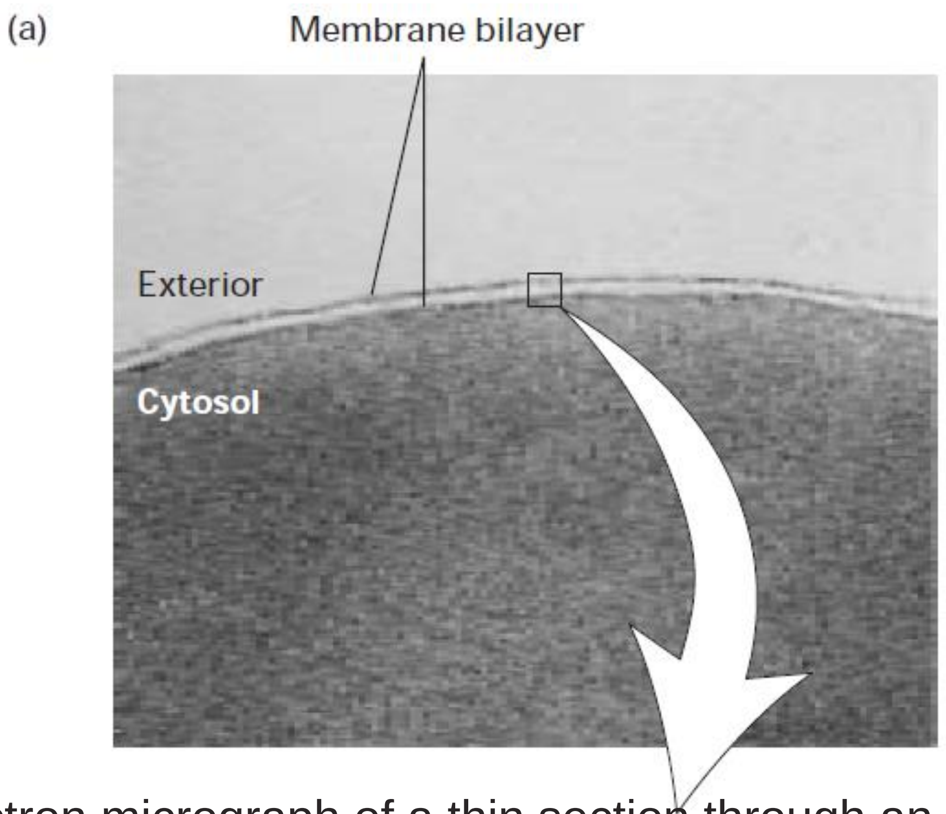
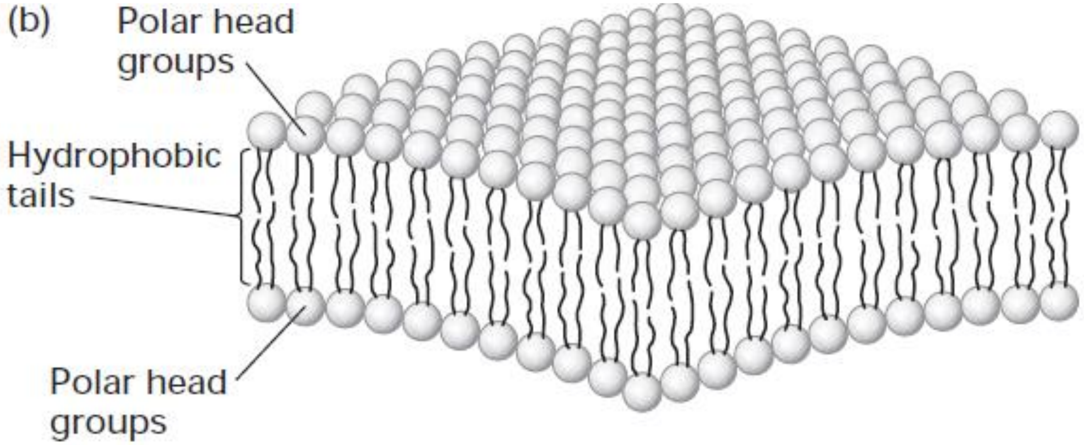
Lecture 2

Biomembranes



Electron micrograph of a thin section through an erythrocyte membrane stained with osmium tetroxide.



Schematic interpretation of the phospholipid bilayer

Function of plasma membrane in all cells

(1) The flexibility of the membrane and its capacity for expansion allow the cell to grow, change shape, and move.

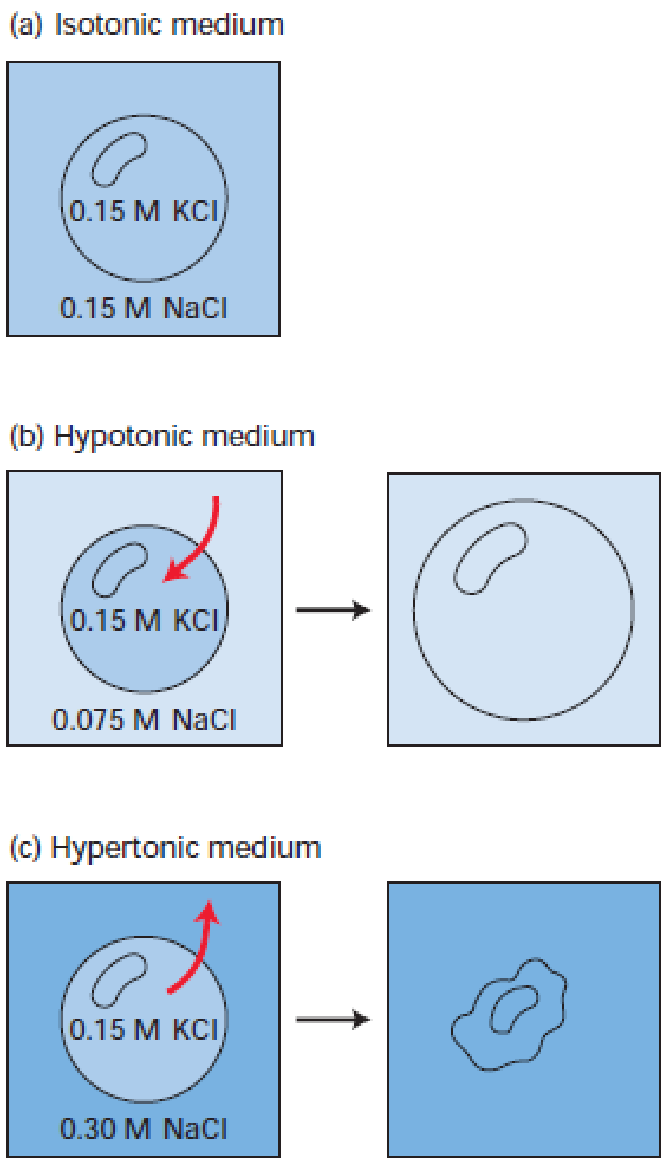
(2) Receptor proteins in the plasma membrane enable the cell to receive signals from the environment

(3) Transport proteins in the membrane enable the import and export of small molecules

When most animal cells are placed in an **isotonic** solution (i.e., one with total concentration of solutes equal to that of the cell interior), there is no net movement of water into or out of cells.

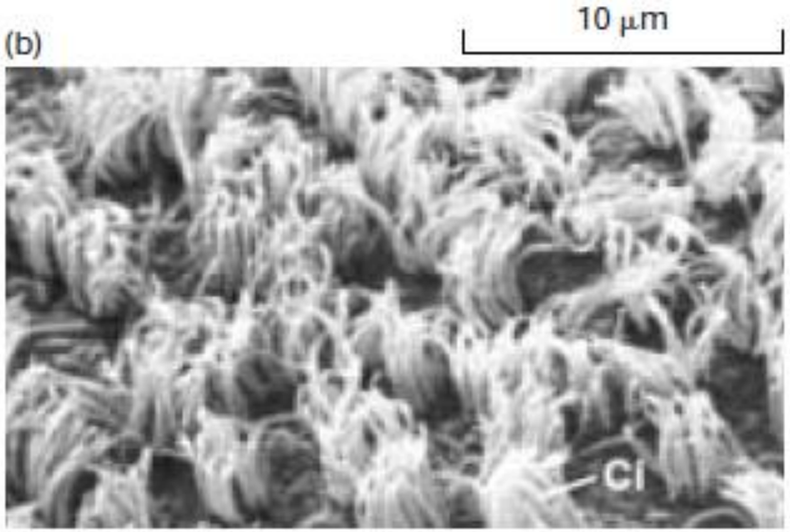
When cells are placed in a **hypotonic** solution (i.e., one with a lower solute concentration than that of the cell interior), water flows into the cells, causing them to swell.

Conversely, in a **hypertonic** solution (i.e., one with a higher solute concentration than that of the cell interior), water flows out of cells, causing them to shrink.

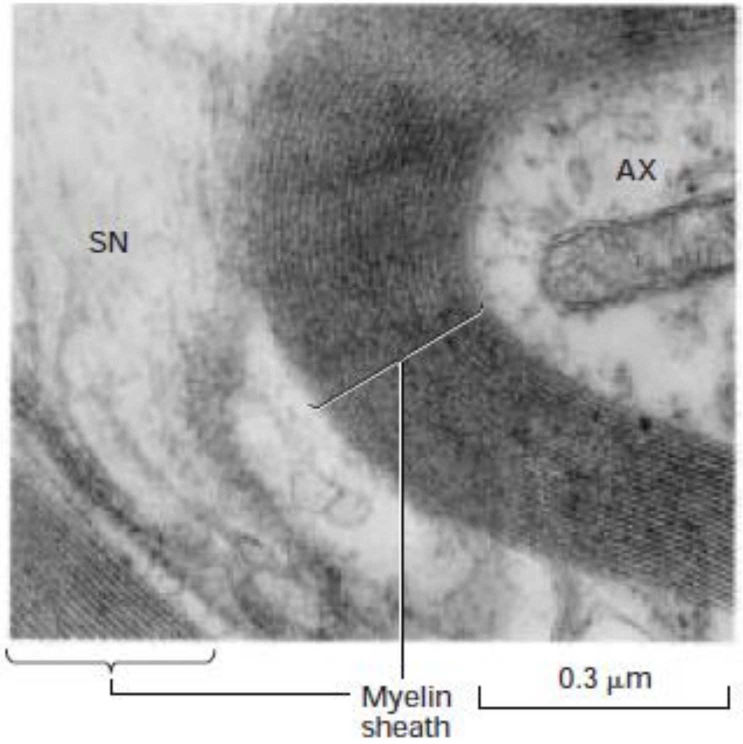


Variation in the Biomembranes

a) A smooth, flexible membrane covers the surface of the discoid erythrocyte cell

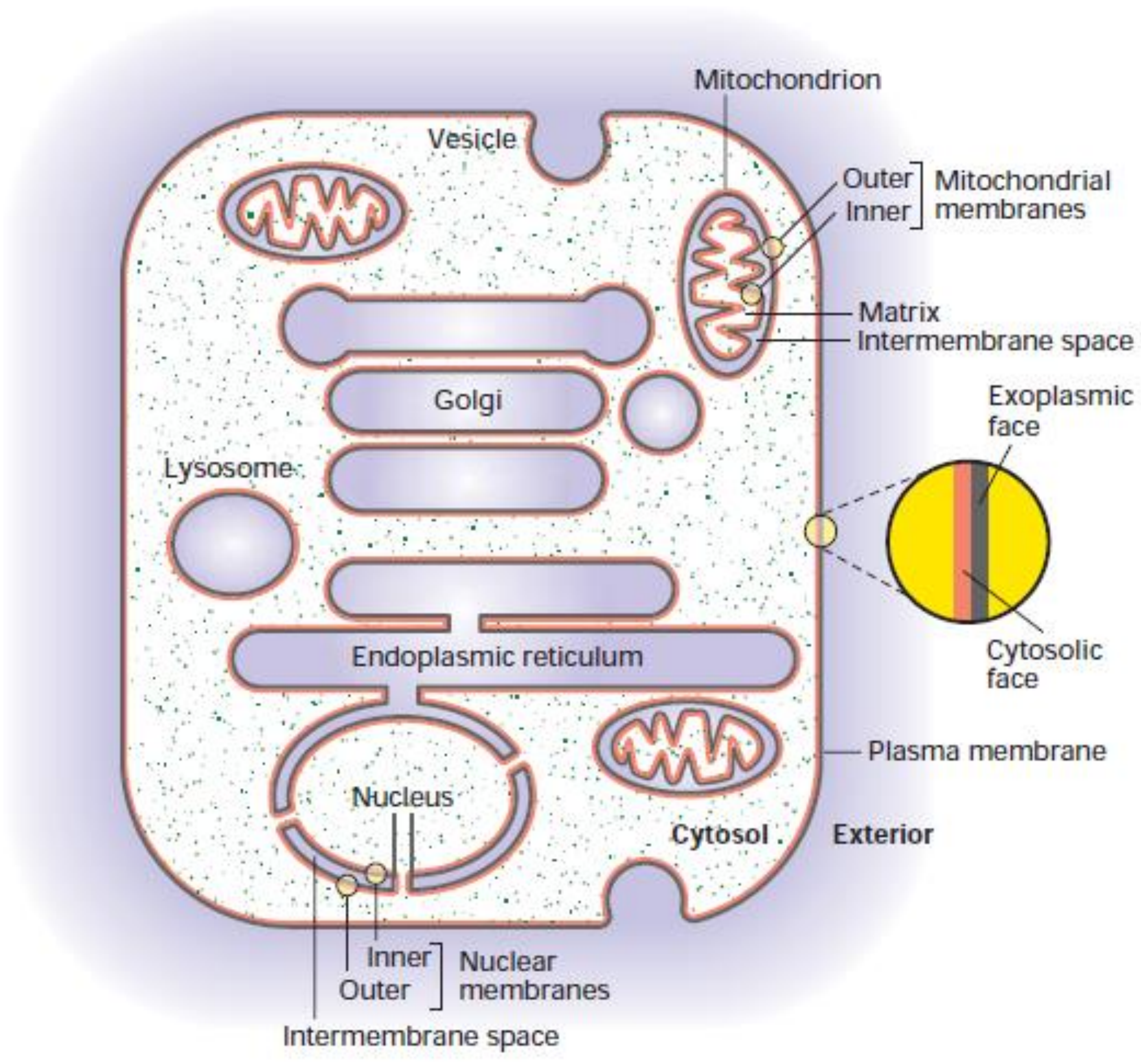


(b) Tufts of cilia (Ci) project from the ependymal cells that line the brain ventricles



(c) Many nerve axons are enveloped in a myelin sheath composed of multiple layers of modified plasma membrane.

Prokaryotes, which represent the simplest and smallest cells, about 1–2 m in length, are surrounded by a **plasma membrane** but contain no internal membrane limited subcompartments



The Fluidity of a Lipid Bilayer Depends on Its Composition

The fluidity of a cell membrane—the ease with which its lipid molecules move within the plane of the bilayer—is important for membrane function and has to be maintained within certain limits.

Just how fluid a lipid bilayer is at a given temperature depends on its phospholipid composition and, in particular, on the nature of the hydrocarbon tails:

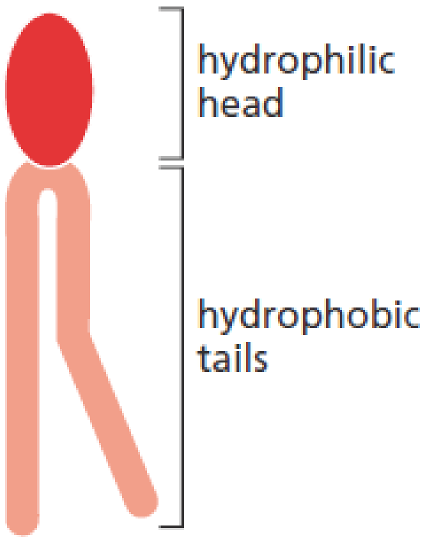
the closer and more regular the packing of the tails, the more viscous and less fluid the bilayer will be.

Two major properties of hydrocarbon tails affect how tightly they pack in the bilayer: their length and the number of double bonds they contain.

Three classes of lipids in the membranes

A typical biomembrane is assembled from phosphoglycerides, sphingolipids, and sterols.

All three classes of lipids are **amphipathic** molecules having a polar (hydrophilic) head group and hydrophobic tail.



Three classes of lipids in the membranes

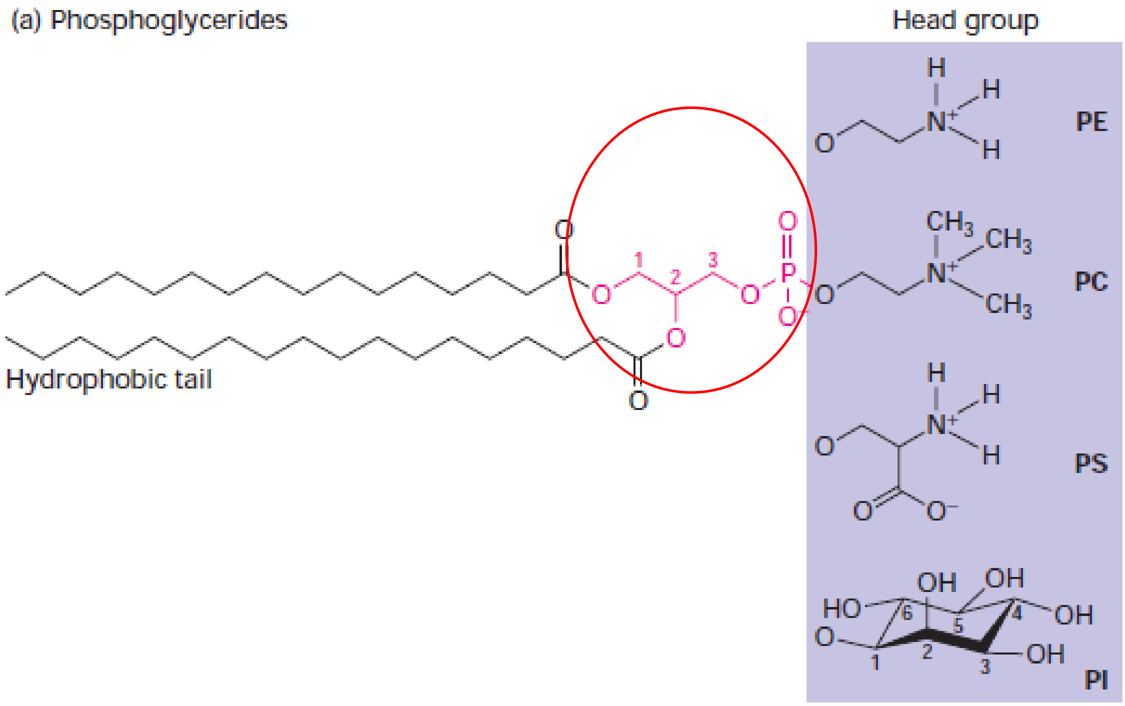
Phosphoglycerides, the most abundant class of lipids in most membranes, are derivatives of glycerol 3-phosphate

Typical phosphoglyceride molecule consists of a hydrophobic tail composed of two fatty acyl chains esterified to the two hydroxyl groups in glycerol phosphate and a polar head group attached to the phosphate group.

The two fatty acyl chains may differ in the number of carbons that they contain (commonly 16 or 18) and their degree of saturation (0, 1, or 2 double bonds).

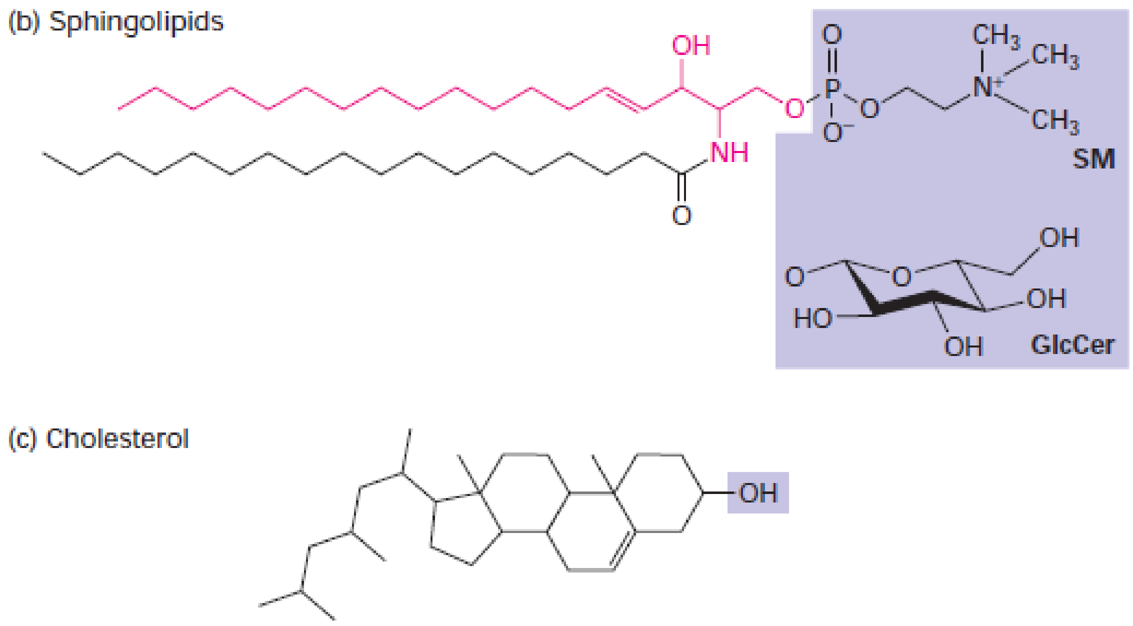
A phosphoglyceride is classified according to the nature of its head group.

In phosphatidylcholines, the most abundant phospholipids in the plasma membrane, the head group consists of choline, a positively charged alcohol, esterified to the negatively charged phosphate.



A second class of membrane lipid is the **sphingolipids.**

All of these compounds are derived from sphingosine, an amino alcohol with a long hydrocarbon chain, and contain a long-chain fatty acid attached to the sphingosine amino group.
In sphingomyelin, the most abundant sphingolipid, phosphocholine is attached to the terminal hydroxyl group of sphingosine.
Thus sphingomyelin is a phospholipid, and its overall structure is quite similar to that of phosphatidylcholine.

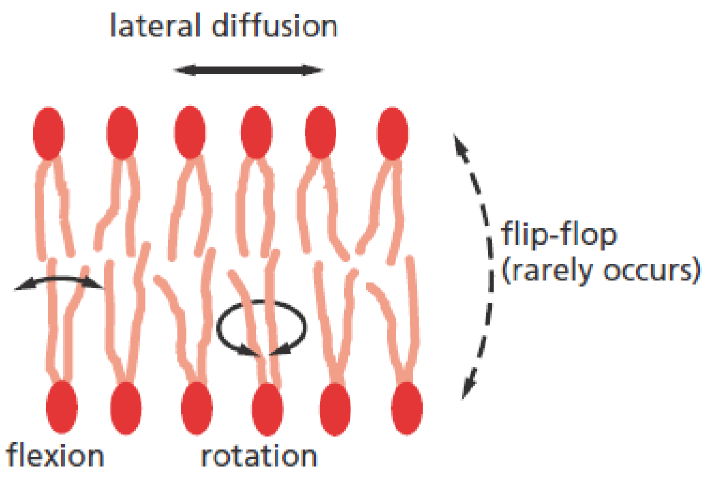


Cholesterol and its derivatives constitute the third important class of membrane lipids, the **sterols.**

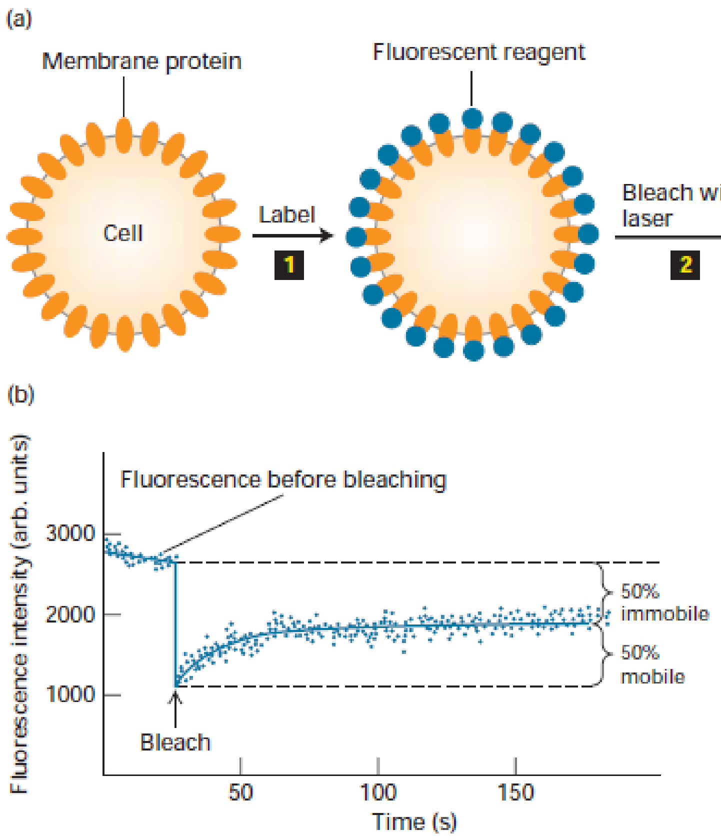
The basic structure of steroids is a four-ring hydrocarbon.
Although cholesterol is almost entirely hydrocarbon in composition, it is amphipathic because its hydroxyl group can interact with water.

Cholesterol is especially abundant in the plasma membranes of mammalian cells but is absent from most prokaryotic cells.
As much as 30–50 percent of the lipids in plant plasma membranes consist of certain steroids unique to plants

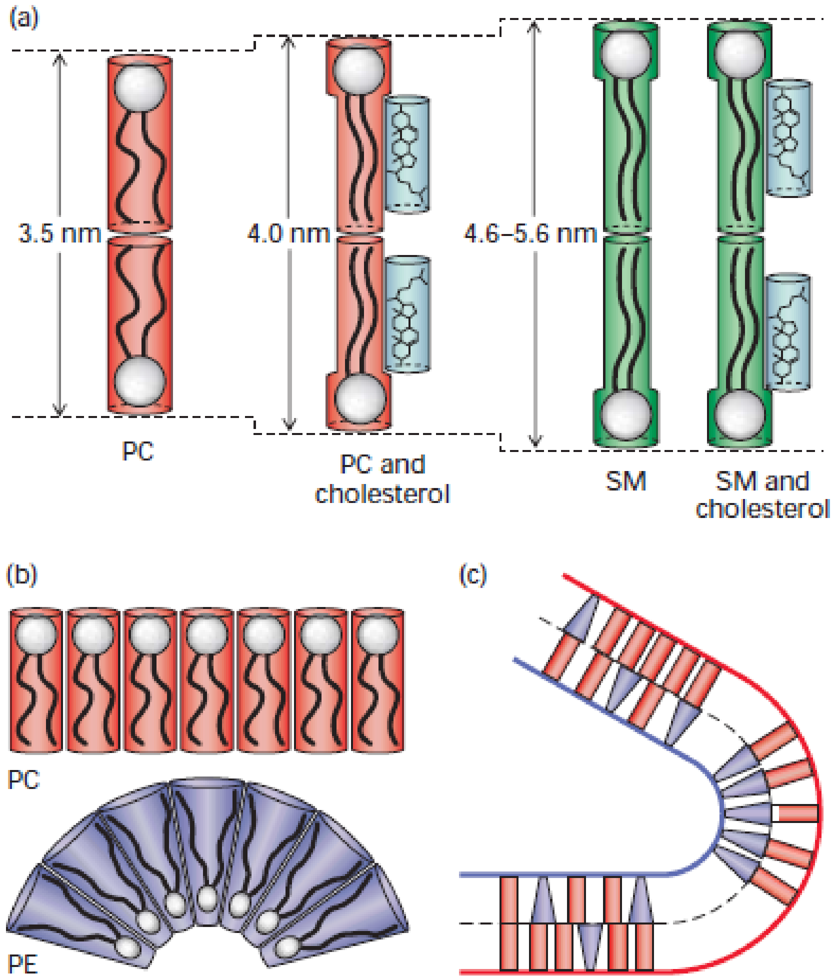
Most Lipids and Many Proteins Are Laterally Mobile in Biomembranes



A typical lipid molecule exchanges places with its neighbors in a leaflet about 10^7 times per second and diffuses several micrometers per second at 37 C.



Effect of lipid molecules on membrane curvature and thickness



(a) A pure sphingomyelin (SM) bilayer is thicker than one formed from a phosphoglyceride such as phosphatidylcholine (PC).
Cholesterol has a lipid-ordering effect on phosphoglyceride bilayers that increases their thickness but
does not affect the thickness of the more ordered SM bilayer.

(b) Phospholipids such as PC have a cylindrical shape and form more or less flat monolayers, whereas those with smaller head groups such as phosphatidylethanolamine (PE) have a conical shape.

(c) A bilayer enriched with PC in the exoplasmic leaflet and with PE in the cytosolic face, as in many plasma membranes, would have a natural curvature

Asymmetry in lipid composition across the bilayer

For instance, in plasma membranes from human erythrocytes and certain canine kidney cells grown in culture, almost all the sphingomyelin and phosphatidylcholine, both of which form less fluid bilayers, are found in the exoplasmic leaflet.

In contrast, phosphatidylethanolamine, phosphatidylserine, and phosphatidylinositol, which form more fluid bilayers, are preferentially located in the cytosolic leaflet.

This segregation of lipids across the bilayer may influence membrane curvature.

Unlike phospholipids, cholesterol is relatively evenly distributed in both leaflets of cellular membranes.

Membrane proteins

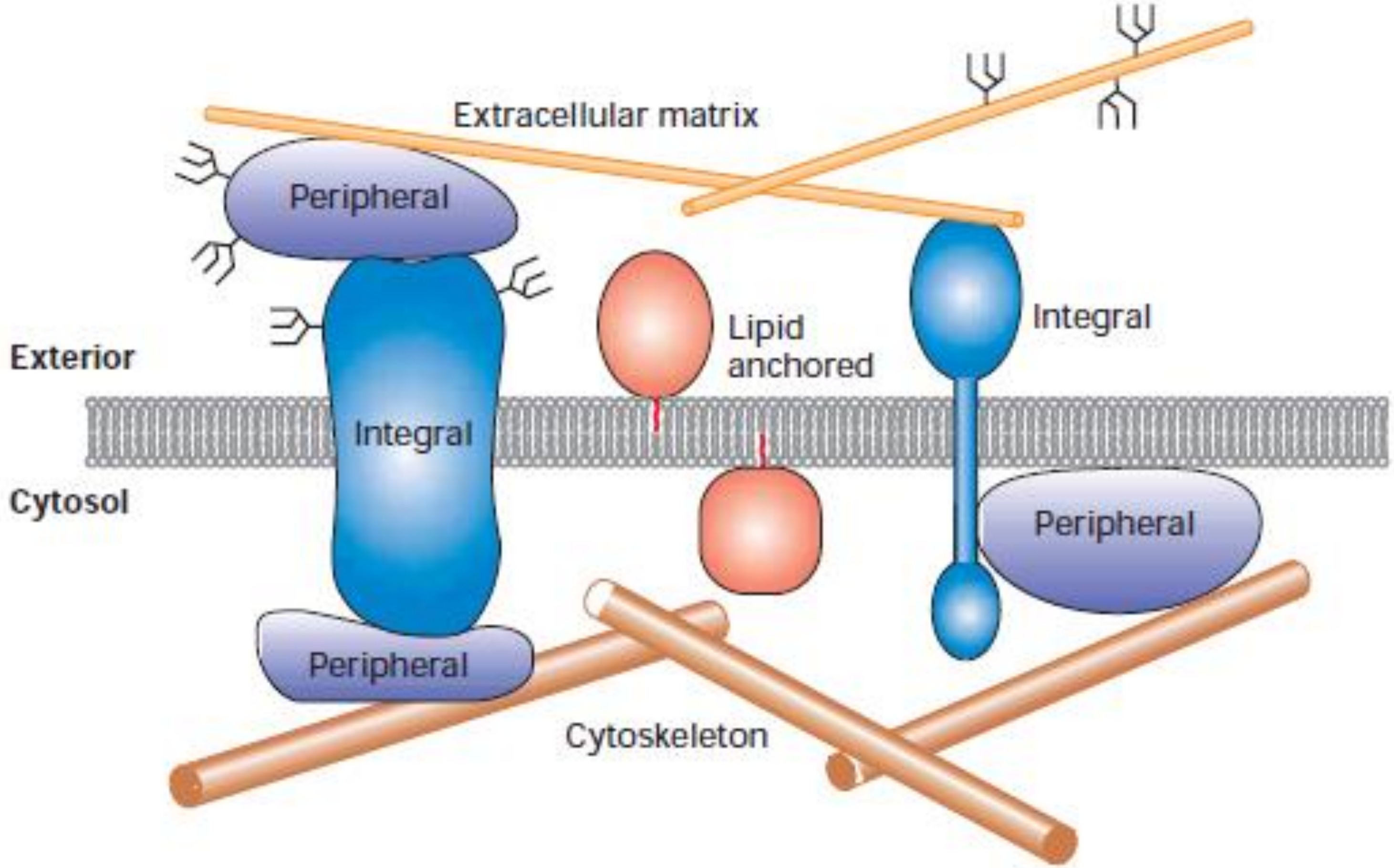
Although every biological membrane has the same basic bilayer structure, the proteins associated with a particular membrane are responsible for its distinctive activities.

The density and complement of proteins associated with biomembranes vary, depending on cell type and subcellular location.

For example, the inner mitochondrial membrane is 76 percent protein; the myelin membrane, only 18 percent.

Different ways how proteins interact with the membrane

1. Integral membrane protein
2. Lipid anchored membrane proteins
3. Peripheral membrane proteins



a cell membrane typically contains about 50 times more lipid molecules than protein molecules

Like their lipid neighbors, the *transmembrane proteins* are amphipathic, having both hydrophobic and hydrophilic regions.

Their hydrophobic regions lie in the interior of the bilayer, nestled against the hydrophobic tails of the lipid molecules.

Their hydrophilic regions are exposed to the aqueous environment on either side of the membrane.

In all transmembrane proteins examined to date, the membrane-spanning domains consist of one or more helices or of multiple strands.