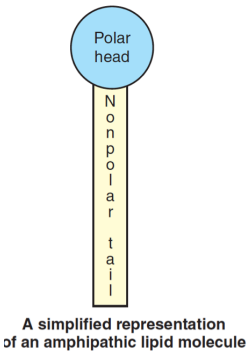
Lipids and Cell Membrane (Slide 7)

§1 Lipids

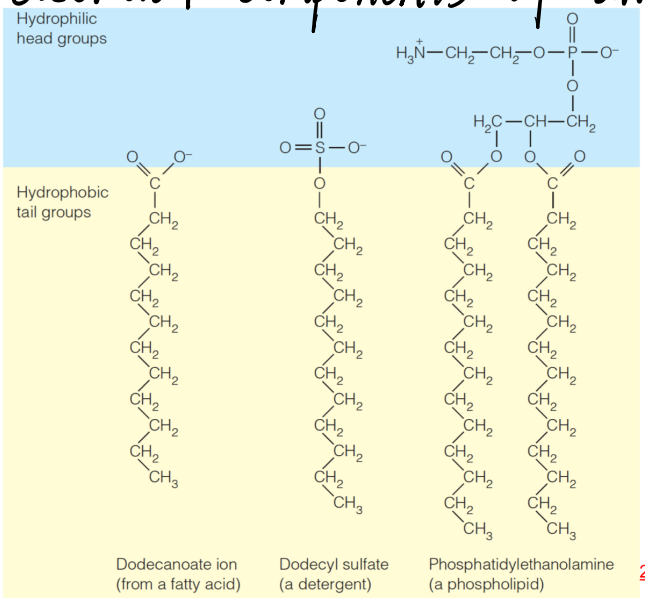
1. Lipid molecules

1° Lipid molecules are often amphipathic (同时具有亲水和疏水部分的)

2° Lipids are essential components of all living organisms.



A simplified representation of an amphipathic lipid molecule



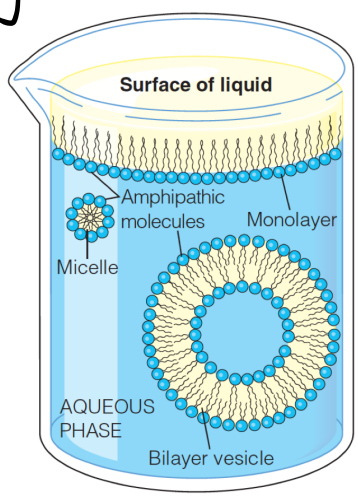
2. The role of water

In aqueous solution, amphipathic lipid molecules may form:

1° Monolayers on the surface

2° Micelles (微团)

3° Bilayer vesicles (双分子层囊泡)



3. Fatty acids (脂肪酸)

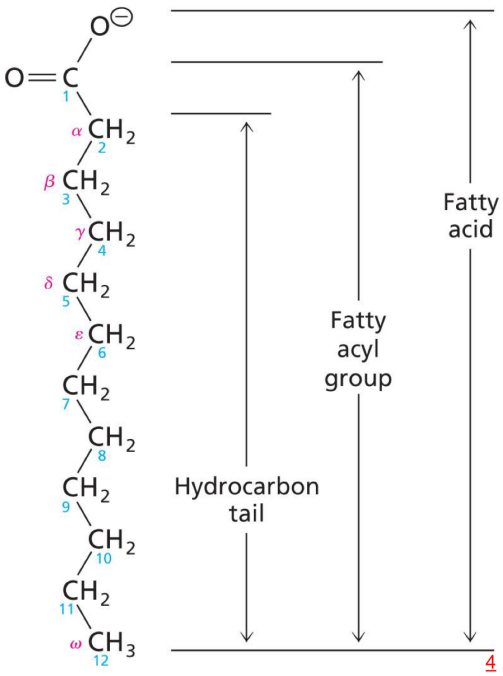
1° Fatty acids consist of a long hydrocarbon tail terminating

with a carboxyl group.

2° The pKa of the carboxyl group is about 4.5–5.0. Fatty acids are anionic (阴离子的) at physiological pH.

3° The carbon atom adjacent to the carboxyl carbon is designated α carbon.

The carbon atom farthest from the carboxyl carbon is designated the ω carbon, whatever the length of the tail.



4° Some common fatty acids (acid forms)

Common Name	Systematic Name	Abbreviation	Structure	Melting Point (°C)
Saturated Fatty Acids				
Capric	Decanoic	10:0	$CH_3(CH_2)_8COOH$	31.6
Lauric	Dodecanoic	12:0	$CH_3(CH_2)_{10}COOH$	44.2
Myristic	Tetradecanoic	14:0	$CH_3(CH_2)_{12}COOH$	53.9
Palmitic	Hexadecanoic	16:0	$CH_3(CH_2)_{14}COOH$	63.1
Stearic	Octadecanoic	18:0	$CH_3(CH_2)_{16}COOH$	69.6
Arachidic	Eicosanoic	20:0	$CH_3(CH_2)_{18}COOH$	76.5
Behenic	Docosanoic	22:0	$CH_3(CH_2)_{20}COOH$	81.5
Lignoceric	Tetracosanoic	24:0	$CH_3(CH_2)_{22}COOH$	86.0
Cerotic	Hexacosanoic	26:0	$CH_3(CH_2)_{24}COOH$	88.5
Unsaturated Fatty Acids				
Palmitoleic	*cis*-9-Hexadecenoic	16:1cΔ9	$CH_3(CH_2)_5CH = CH(CH_2)_7COOH$	0
Oleic	*cis*-9-Octadecenoic	18:1cΔ9	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$	16
Linoleic	*cis,cis*-9, 12-Octadecadienoic	18:2cΔ9,12	$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$	5
Linolenic	all-*cis*-9,12, 15-Octadecatrienoic	18:3cΔ9,12,15	$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7COOH$	−11
Arachidonic	all-*cis*-5,8,11, 14-Eicosatetraenoic	20:4cΔ5,8,11,14	$CH_3(CH_2)_4CH=CHCH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_3COOH$	−50

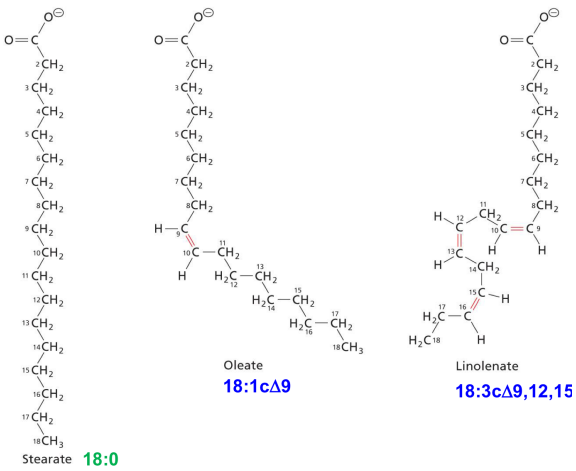
① The simplest lipids are the fatty acids. Most

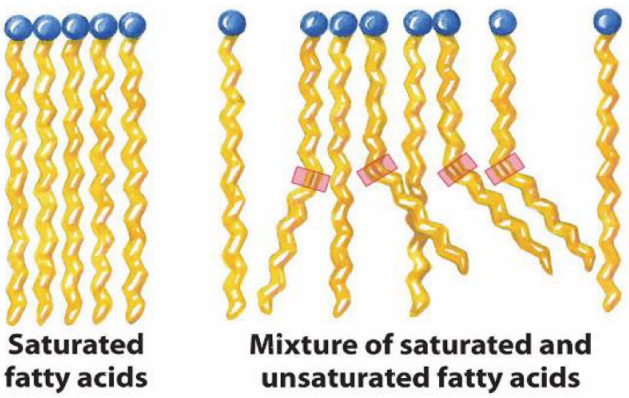
naturally occuring fatty acids contain an even number of carbon atoms (typically 12 to 24 carbons)

② Saturated fatty acid: the carbons of the tail are all saturated with hydrogen atoms.

③ Many important naturally occuring fatty acids are unsaturated, that is, they contain one or more double bonds.

5° The double bonds are usually cis (顺式结构) and not conjugated (共轭：两个双键中只含一个单键)





Double bonds introduce kinks (扭曲) (i.e. a rigid bend about which there is no rotation in the tail and reduce its compaction.

6° The length of the acyl chain (酰基链) and the number of double bonds determine the melting point.

① Longer chains, higher melting point
(longer chains have more van der Waals interactions).

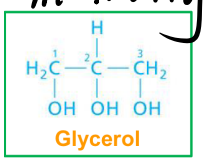
② More double bonds, lower melting point
(double bonds inhibit packing into solid state).

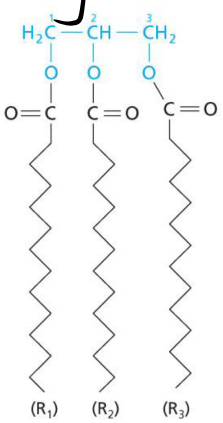
4. Triacylglycerols (甘油三酯)

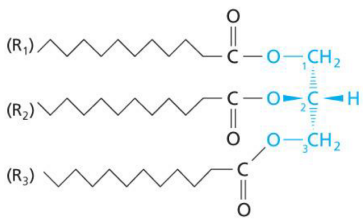
1° Fats, or triacylglycerols (historically called triglycerides), are triesters of fatty acids and glycerol.

2° Triacylglycerols are very hydrophobic and may have a chiral center.

3° Fats are the major long-term energy storage molecules in many organisms.







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Composition of some **natural fats** in percent of total fatty acids:

Number of C Atoms in Chain	Percent Present in: Olive Oil	Butter	Beef Fat
Saturated			
4–12	2	11	2
14	2	10	2
16	13	26	29
18	3	11	21
Unsaturated			
16–18	80	40	46
At 25 °C:	**Liquid**	**Soft solid**	**Hard solid**

4° Three distinct functions

① Energy production

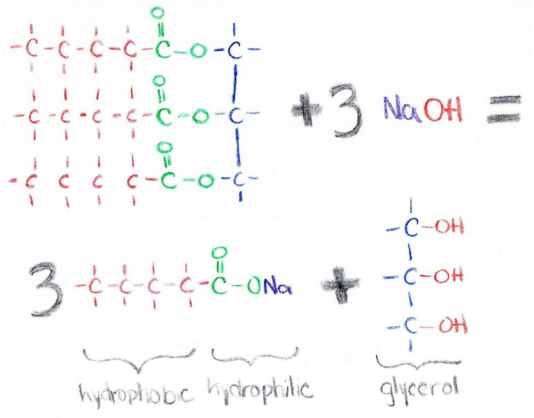
② Heat production

③ Insulation (隔热)

5. Soaps

1° Saponification (皂化反应)

- When **fats** are hydrolyzed with strong bases such as NaOH or KOH, the fatty acids are released as either sodium or potassium salts, which are fully ionized. **Soaps** are salts of **fatty acids**. This process is called ***saponification.***
- The fatty acids are precipitated by the Ca^{2+} and Mg^{2+} present in "hard" water, forming a scum and destroying the emulsifying action. The salts of **dodecyl sulfate** with divalent cations (i.e., Ca^{2+} and Mg^{2+}) are more soluble.



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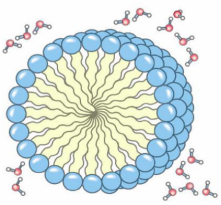
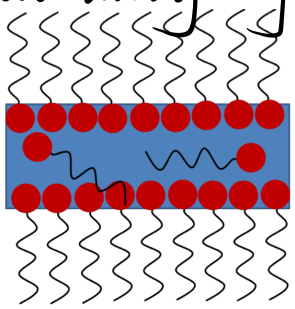
2° Soaps are amphipathic molecules.

3° Oily and greasy dirt are attracted to non-polar "tails" of fatty acids. Dirt globules are surrounded by fatty acid "tails" to form spheres called micelles.
Polar head is surrounded by H_2O. Water-soluble dirt dissolve in H_2O.
Micelles are washed away by H_2O.

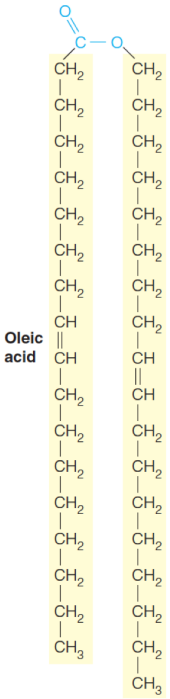

A Micelle


Bubble film

b. Wax (蠟)

1° Wax are formed by esterification of fatty acids and long-chain alcohols.

2° The small head group can contribute little hydrophilicity, in contrast to the significant hydrophobic contribution of the two long tails.
Thus, the waxes are completely water insoluble



3° Usage of waxes

① Often serve as water repellents, as in the feathers of some birds and the leaves of some plants.

② In some marine microorganisms, waxes are used instead of other lipids for energy storage.

③ In beewax, they serve a structure function.

4° As with the triacylglycerols, the firmness of waxes increases with chain length and degree of hydrocarbon saturation.

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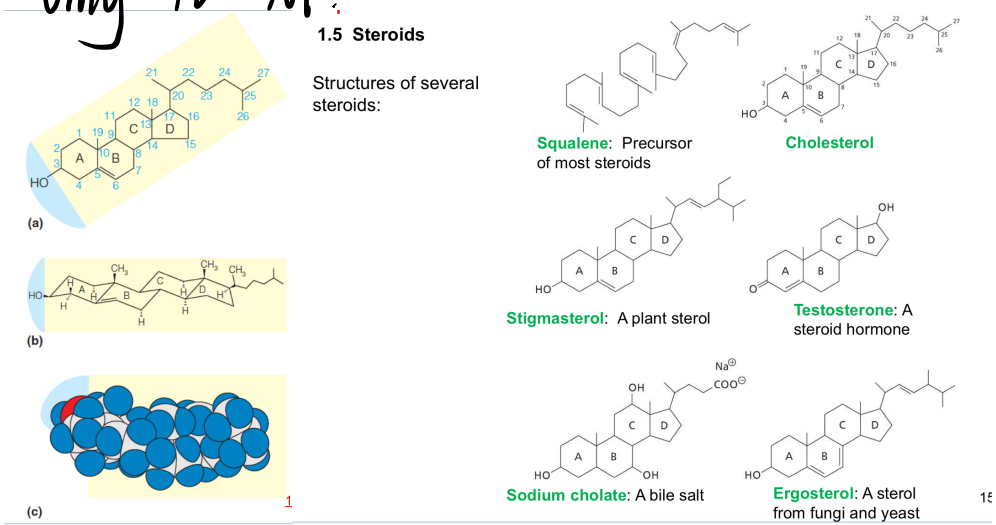
7. Steroids (类固醇)

1° Steroids contain four fused rings (稠环): three six-carbon ring and one five-carbon ring.

2° Cholesterol (胆固醇) is a component of many animal membranes.

① A rigid hydrophobic structure:
Cholesterol influences membrane fluidity by its bulky structure.

② Very poor water solubility:
Free cholesterol's maximal concentration in water is only 10^{-8} M.



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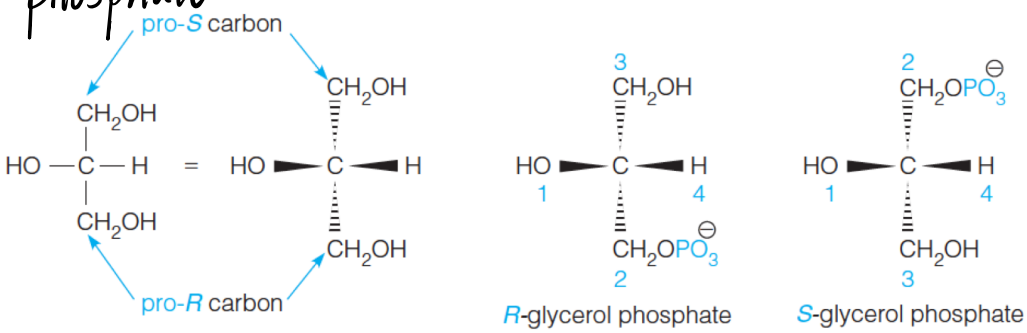
8. Glycerophospholipids (甘油磷脂)

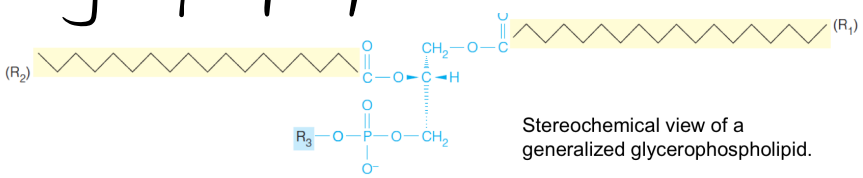
1° Stereochemistry of glycerophospholipids

Glycerol is a prochiral (前手性的) molecule:

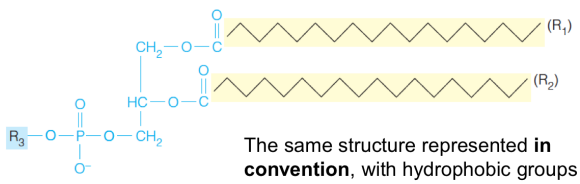
Phosphorylation of one CH_2OH group or the other gives the R- or S-enantiomer (对映异构体) of glycerol phosphate



2° Glycerophospholipid structure (R_3 is a hydrophilic group)



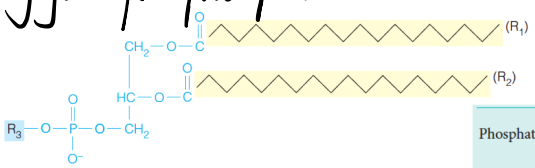
Stereochemical view of a generalized glycerophospholipid.



The same structure represented **in convention**, with hydrophobic groups to the right, hydrophilic to the left.

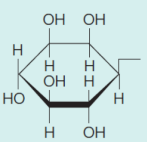
Glycerophospholipids: Modified fat where a phosphate replaces one of the fatty acid chain

3° The hydrophilic groups that distinguish common glycerophospholipids.



In addition to the R_3 group variation, there is also a great deal of variation in the hydrocarbon tails (R_1 and R_2 groups)

R_3 groups:

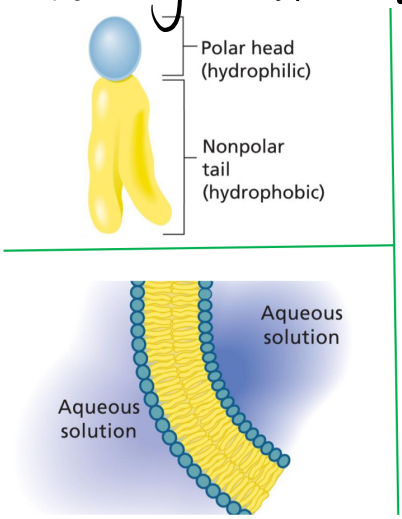
Phosphatidic acid	H— (ionized at neutral pH)
Phosphatidyl-ethanolamine (PE)	$H_3\overset{+}{N}-CH_2-CH_2-$
Phosphatidylcholine (PC)	$(CH_3)_3\overset{+}{N}-CH_2-CH_2-$
Phosphatidylserine (PS)	$H_3\overset{+}{N}-\underset{\displaystyle COO^-}{\underset{|}{C}}H-CH_2-$
Phosphatidyl inositol (PI)	

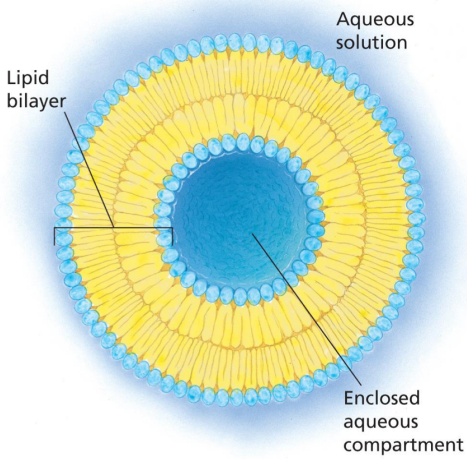
§2 Biological Membranes

1. Bilayer-forming lipids:

1° A large head group attached to a double tail yielding a roughly cylindrical (圆柱形的) molecule.

2° Such cylindrical molecule can easily pack in parallel to form extended sheets of bilayer membranes with the hydrophilic head groups facing outward into the aqueous region on either side.





Lipid vesicle or liposome structure

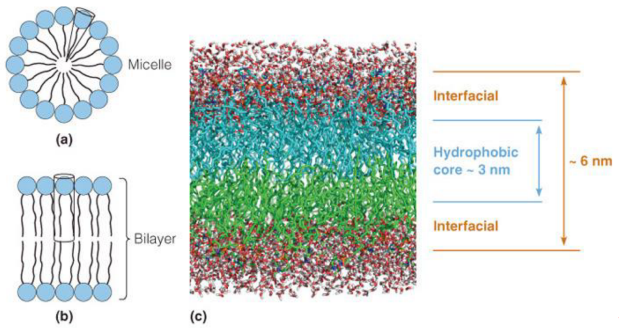
2. Comparison between fatty acids and phospholipids

1° Fatty acids are more wedge-shaped and tend to form single layer spherical micelles.

2° Glycerophospholipids have two hydrophobic tails and are more cylindrical and pack together to form a bilayer structure.

Shown on the bottom right is a computer simulation of a **phospholipid bilayer**.

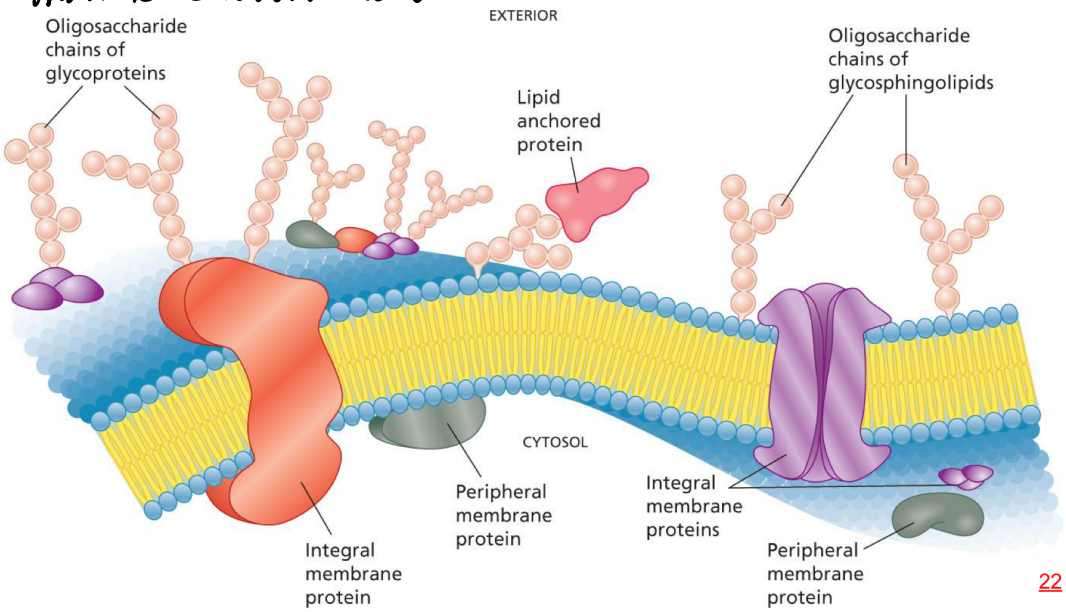
The bilayer is roughly 6 nm thick, with ~1.5 nm of interface on either side of the ~3 nm hydrophobic core.



3. Structure of a typical cell membrane

1° Proteins are embedded in and on the phospholipid bilayer.

2° Most membranes are more densely packed with proteins than is shown here.



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4. Fluid mosaic model (流动镶嵌模型)

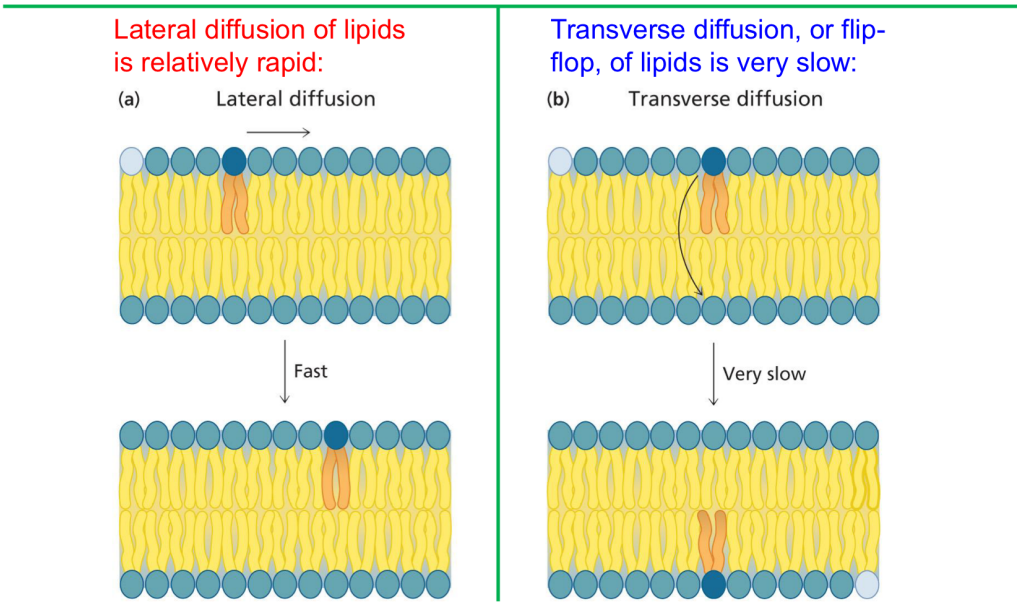
1° Mosaic: integral (transmembrane) (整合蛋白) and peripheral (外周蛋白) membrane proteins form a surface pattern resembling a mosaic.

2° Fluid: Phospholipids and proteins are free to diffuse.

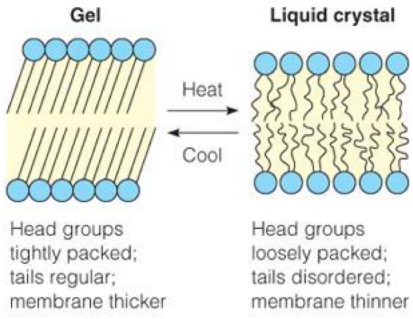
Fluid mosaic model of biological membranes

Mosaic – integral (transmembrane) and peripheral membrane proteins form a surface pattern resembling a mosaic.

Fluid - Phospholipids and proteins are free to diffuse.



3° The transition of fluid mosaic model



① Temperature Tm: The transition temperature for the bilayer

② Fluidity increases with the increasing temperature.

③ Influence factors

(1) Hydrocarbon tail length

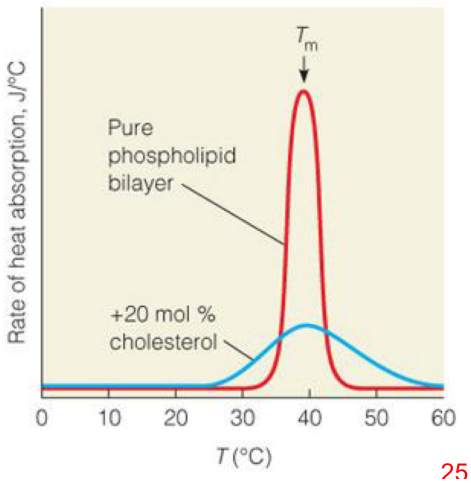
The longer length of the acyl fatty acid tails, the higher the Tm

(2) The level of unsaturation

The more double bonds, the lower the Tm.

(3) Cholesterol

When 20 mol% cholesterol is mixed into the bilayer, the Tm is not changed, but the transition is broadened

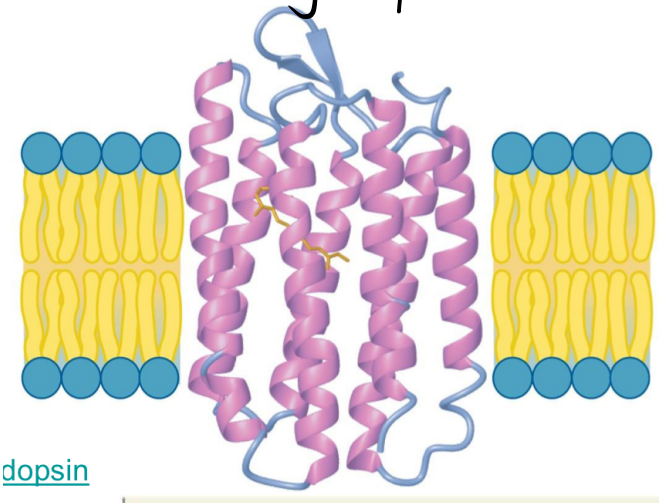


§3 Membrane Proteins

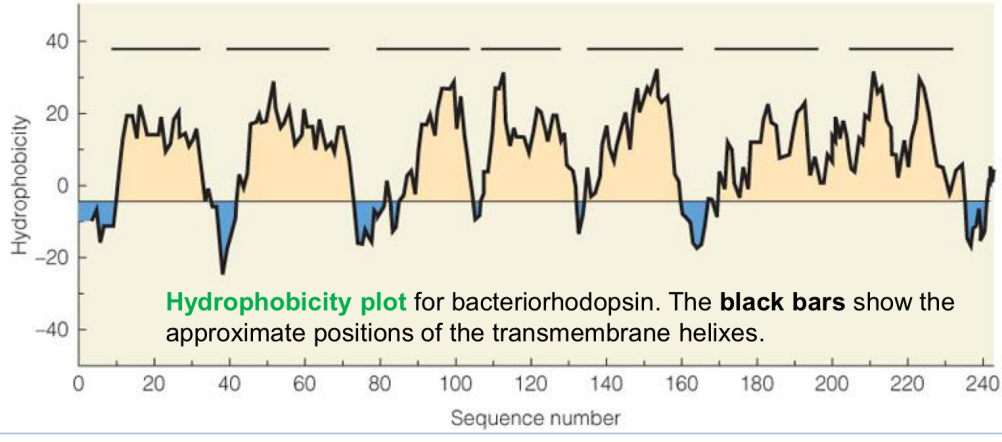
1. Integral membrane protein

1° Bacteriorhodopsin:

An integral membrane protein with seven α-helixes, connected by loops.



dopsin



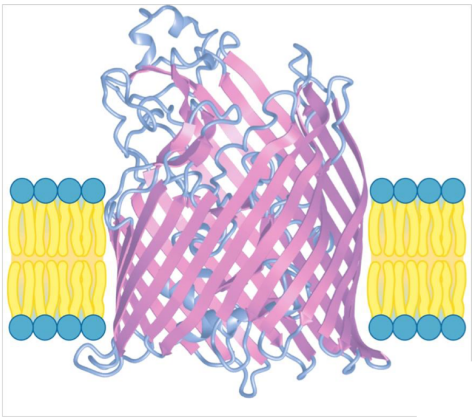
Hydrophobicity plot for bacteriorhodopsin. The **black bars** show the approximate positions of the transmembrane helixes.

2° Integral membrane proteins are more deeply embedded in the bilayer and can only be extracted under conditions that disrupt membrane structure

3° E.coli FhuA porin:

***E. coli* FhuA porin:**

A channel for the passage of iron and other molecules into the bacterium. The channel is formed from 22 antiparallel **β strands** that form a **β-barrel**.



Online link:

2. Peripheral membrane protein

1° Associated with one face of the membrane through charge-charge and hydrogen bonding with integral membrane protein or with the polar head groups of membrane lipids.

2° More readily dissociated from membranes by change in pH or ionic strengh.

3. Lipid anchored membrane protein

1° Tethered to a membrane through a covalent bond to a lipid anchor.

2° Most lipid anchored proteins are permanently associated with the membrane.