

## Chapter 15 Lipids

### 15.1 Lipids 15.2 Fatty Acids



Copyright © 2005, by Pearson Education, Inc.  
Publishing as Benjamin Cummings

1

## Lipids

Lipids are

- biomolecules that contain fatty acids or a steroid nucleus.
- soluble in organic solvents, but not in water.
- named for the Greek word *lipos*, which means "fat."
- extracted from cells using organic solvents.

2

## Types of Lipids

The types of lipids containing fatty acids are

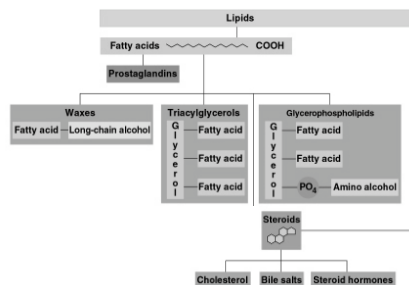
- waxes
- fats and oils (triacylglycerols)
- glycerophospholipids
- prostaglandins

The types of lipids that do not contain fatty acids are

- steroids

3

## Classes of Lipids



4

## Fatty Acids

Fatty acids are

- long-chain carboxylic acids.
- typically 12-18 carbon atoms.
- insoluble in water.
- saturated or unsaturated.



Olive oil contains 84% unsaturated fatty acids and 16% saturated fatty acids

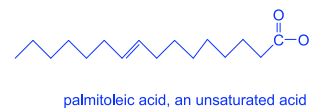
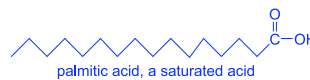
Copyright © 2005, by Pearson Education, Inc.  
Publishing as Benjamin Cummings

5

## Saturated and Unsaturated Fatty Acids

Fatty acids are

- **saturated** with all single C-C bonds.
- **unsaturated** with one or more double C=C bonds.




6

### Properties of Saturated Fatty Acids

**Saturated fatty acids**

- contain only single C–C bonds.
- are closely packed.
- have strong attractions between chains.
- have high melting points.
- are solids at room temperature.

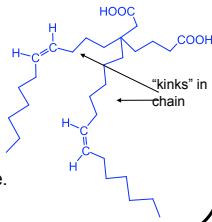


7

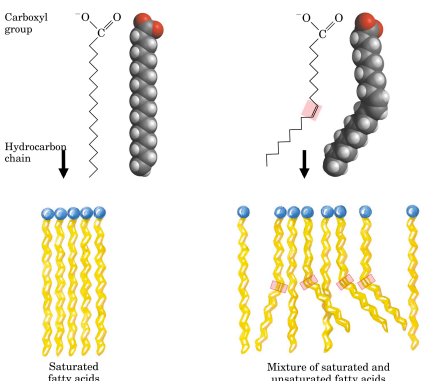
### Properties of Unsaturated Fatty Acids

**Unsaturated fatty acids**

- contain one or more *cis* double C=C bonds.
- have "kinks" in the fatty acid chains.
- do not pack closely.
- have few attractions between chains.
- have low melting points.
- are liquids at room temperature.

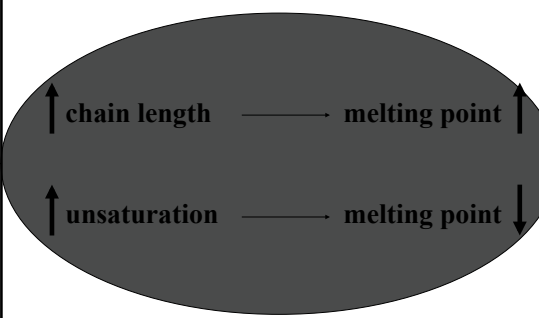


8



Saturated fatty acids      Mixture of saturated and unsaturated fatty acids

9



10

### Melting Points of Some Fatty Acids

Name	Carbon Atoms	Double Bonds	Structure	Melting Point (°C)
<b>Saturated</b>				
Lauric acid	12	0	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>10</sub> -COOH	43
Myristic acid	14	0	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>12</sub> -COOH	54
Palmitic acid	16	0	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>14</sub> -COOH	62
Stearic acid	18	0	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>16</sub> -COOH	69
<b>Unsaturated</b>				
Palmitoleic acid	16	1	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>7</sub> -CH=CH-(CH <sub>2</sub> ) <sub>7</sub> -COOH	0
Oleic acid	18	1	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>7</sub> -CH=CH-(CH <sub>2</sub> ) <sub>7</sub> -COOH	13
Linoleic acid	18	2	CH <sub>3</sub> -(CH <sub>2</sub> ) <sub>4</sub> -CH=CH-CH <sub>2</sub> -CH=CH-(CH <sub>2</sub> ) <sub>7</sub> -COOH	-9

11

### COMMON STRAIGHT CHAIN SATURATED FATTY ACIDS

No. of Carbons	STRUCTURE	SYSTEMATIC NAME	COMMON NAME	MP °C	SUBSTANCE
10	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>8</sub> COOH	n-decanoic acid	capric acid	31.6	C <sub>10</sub> :0
12	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>10</sub> COOH	n-dodecanoic acid	lauric	44.2	C <sub>12</sub> :0
14	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>12</sub> COOH	n-tetradecanoic acid	myristic	53.9	C <sub>14</sub> :0
16	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>14</sub> COOH	n-hexadecanoic acid	palmitic	63.1	C <sub>16</sub> :0
18	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>16</sub> COOH	n-octadecanoic acid	stearic	69.6	C <sub>18</sub> :0
20	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>18</sub> COOH	n-eicosanoic acid	arachidic	76.5	C <sub>20</sub> :0
24	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>22</sub> COOH	n-tetracosanoic acid	lignoceric	86.0	C <sub>24</sub> :0

2. Biophysical/fatty acids


12

### STRAIGHT CHAIN UN-SATURATED

NO. of C atoms	STRUCTURE / SYSTEMATIC NAME	COMMON NAME	MP °C	SMOELMAN'S
16	$\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$ <i>cis-9-hexadecenoic acid</i>	palmitoleic	-0.6	$\text{C}_{16:1} \Delta^9$
18	$\text{CH}_3(\text{CH}_2)_3\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$ <i>cis-9 octadecenoic acid</i>	oleic	13.4	$\text{C}_{18:1} \Delta^9$
18	$\text{CH}_3(\text{CH}_2)_6\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$ <i>cis-cis-9,12 octadecenoic acid</i>	linoleic	-5.0	$\text{C}_{18:2} \Delta^{9,12}$
18	$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$ <i>all-cis-9,12,15 octadecenoic acid</i>	linolenic	-11.0	$\text{C}_{18:3} \Delta^{9,12,15}$
20	$\text{CH}_3(\text{CH}_2)_2\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}(\text{CH}_2)_3\text{COOH}$ <i>arachidonic</i>	arachidonic	-49.5	$\text{C}_{20:4} \Delta^{6,9,12,15}$

2. Biophysical/fatty acids

## 15.3 Waxes, Fats, and Oils



Copyright © 2005 by Pearson Education, Inc. Publishing as Benjamin Cummings

## Waxes

**Waxes are:**

- esters of saturated fatty acids and long-chain alcohols.
- coatings that prevent loss of water by leaves of plants.


Some Typical Waxes			
Type	Structural Formula	Source	Uses
Beeswax	$\text{CH}_3(\text{CH}_2)_{14}-\text{C}(=\text{O})-\text{O}-(\text{CH}_2)_{25}\text{CH}_3$	Honeycomb	Candles, shoe polish, wax paper
Carnauba wax	$\text{CH}_3(\text{CH}_2)_{22}-\text{C}(=\text{O})-\text{O}-(\text{CH}_2)_{25}\text{CH}_3$	Brazilian palm tree	Waxes for furniture, cars, floors, shoes
Jajoba wax	$\text{CH}_3(\text{CH}_2)_{13}-\text{C}(=\text{O})-\text{O}-(\text{CH}_2)_{17}\text{CH}_3$	Jajoba	Candles, soaps, cosmetics

Timberlake, General, Organic, and Biological Chemistry. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

## Fats and Oils: Triacylglycerols

**Fats and oils are**

- also called triacylglycerols.
- esters of glycerol.
- produced by esterification.
- formed when the hydroxyl groups of glycerol react with the carboxyl groups of fatty acids.



Vegetable oils

## Triacylglycerols

In a **triacylglycerol**, glycerol forms ester bonds with three fatty acids.

$\begin{array}{c} \text{CH}_2-\text{OH} \\ | \\ \text{CH}-\text{OH} \\ | \\ \text{CH}_2-\text{OH} \end{array}$ 

Glycerol

$\begin{array}{c} \text{O} \\ || \\ \text{CH}_2-\text{O}-\text{C}-\text{C}_6\text{H}_{13} \\ \text{O} \\ || \\ \text{CH}-\text{O}-\text{C}-\text{C}_6\text{H}_{13} \\ \text{O} \\ || \\ \text{CH}_2-\text{O}-\text{C}-\text{C}_6\text{H}_{13} \end{array}$ 

Triacylglycerol

Ester bonds

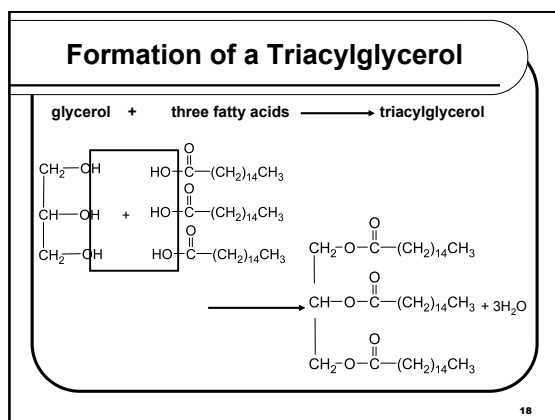
Glycerol

Fatty acid

Fatty acid

Fatty acid

Timberlake, General, Organic, and Biological Chemistry. Copyright © Pearson Education Inc., publishing as Benjamin Cummings



## Melting Points of Fats and Oils

### A fat

- is solid at room temperature.
- is prevalent in meats, whole milk, butter, and cheese.

### An oil

- is liquid at room temperature.
- is prevalent in plants such as olive and safflower.

19

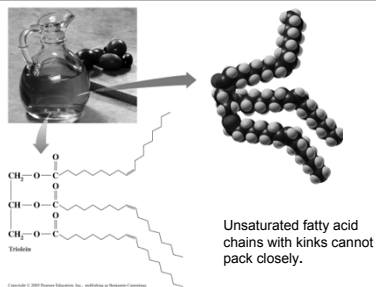
## Oils with Unsaturated Fatty Acids

### Oils

- have more unsaturated fats.
- have *cis* double bonds that cause “kinks” in the fatty acid chains.
- with “kinks” in the chains do not allow the triacylglycerol molecules to pack closely.
- have lower melting points than saturated fatty acids.
- are liquids at room temperature.

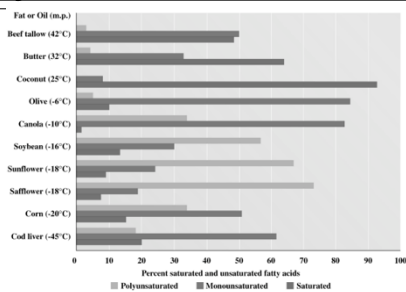
20

## Diagram of Triacylglycerol with Unsaturated Fatty Acids



21

## Percent Saturated and Unsaturated Fatty Acids In Fats and Oils



22

## 15.4 Chemical Properties of Triacylglycerols



23

## Chemical Properties of Triacylglycerols

The chemical reactions of triacylglycerols are similar to those of alkenes and esters.

- In **hydrogenation**, double bonds in unsaturated fatty acids react with  $H_2$  in the presence of a Ni or Pt catalyst.
- In **hydrolysis**, ester bonds are split by water in the presence of an acid, a base, or an enzyme.

24



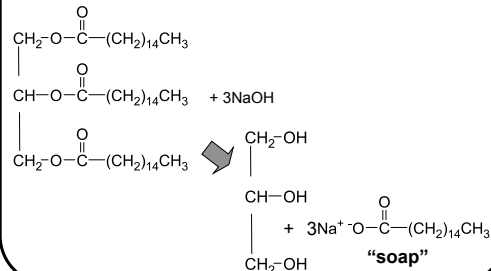
## Saponification and Soap

### Saponification

- is the reaction of a fat with a strong base.
- splits triacylglycerols into glycerol and the salts of fatty acids.
- is the process of forming "soaps" (salts of fatty acids).
- with KOH gives softer soaps.

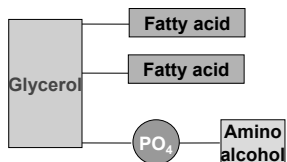
31

## Saponification



32

## 15.5 Glycerophospholipids

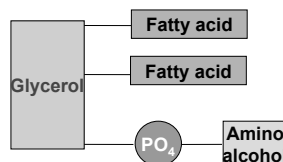


33

## Glycerophospholipids

### Glycerophospholipids are

- the most abundant lipids in cell membranes.
- composed of glycerol, two fatty acids, phosphate, and an amino alcohol.

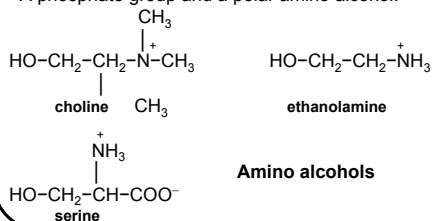


34

## Polarity of Glycerophospholipids

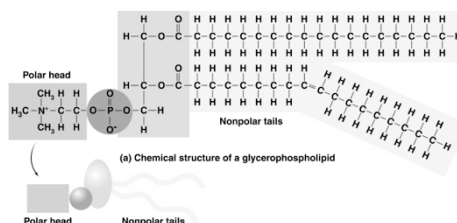
### A glycerophospholipid has

- two nonpolar fatty acid chains.
- A phosphate group and a polar amino alcohol.



35

## Structure and Polarity of A Glycerophospholipid



36

### Lecithin and Cephalin

**Lecithin and cephalin** are glycerophospholipids

- abundant in brain and nerve tissues.
- found in egg yolk, wheat germ, and yeast.

$$\begin{array}{c}
 \text{CH}_2-\text{O}-\text{C}(=\text{O})-(\text{CH}_2)_{14}\text{CH}_3 \\
 | \\
 \text{CH}-\text{O}-\text{C}(=\text{O})-(\text{CH}_2)_{14}\text{CH}_3 \\
 | \\
 \text{CH}_2-\text{O}-\text{P}(=\text{O})(\text{O}^-)-\text{O}-\text{CH}_2\text{CH}_2\text{N}(\text{CH}_3)_3 \\
 \text{O}^-
 \end{array}$$

A lecithin

$$\begin{array}{c}
 \text{CH}_2-\text{O}-\text{C}(=\text{O})-(\text{CH}_2)_{14}\text{CH}_3 \\
 | \\
 \text{CH}-\text{O}-\text{C}(=\text{O})-(\text{CH}_2)_{14}\text{CH}_3 \\
 | \\
 \text{CH}_2-\text{O}-\text{P}(=\text{O})(\text{O}^-)-\text{O}-\text{CH}_2\text{CH}_2\text{NH}_2 \\
 \text{O}^-
 \end{array}$$

A cephalin

Timberlake, General, Organic, and Biological Chemistry, Copyright © Pearson Education Inc., publishing as Benjamin Cummings

There are different kinds of head group:

Membrane phospholipid	Percent of total membrane phospholipid	Distribution in membrane	
		Inner monolayer	Outer monolayer
Phosphatidylethanolamine	30	100	0
Phosphatidylcholine	27	0	100
Sphingomyelin	23	0	100
Phosphatidylserine	15	100	0
Phosphatidylinositol	5	100	0
Phosphatidylinositol 4-phosphate		100	0
Phosphatidylinositol 4,5-bisphosphate		100	0
Phosphatidic acid		100	0

### 15.6 Steroids: Cholesterol, and Steroid Hormones

Copyright © 2005 by Pearson Education, Inc. Publishing as Benjamin Cummings

### Steroid Nucleus

A **steroid nucleus** consists of

- 3 cyclohexane rings.
- 1 cyclopentane ring.
- no fatty acids.

steroid nucleus

### Cholesterol

**Cholesterol**

- is the most abundant steroid in the body.
- has methyl  $\text{CH}_3$ - groups, alkyl chain, and  $-\text{OH}$  attached to the steroid nucleus.

### Cholesterol in the Body

**Cholesterol**

- is obtained from meats, milk, and eggs.
- is synthesized in the liver.
- is needed for cell membranes, brain and nerve tissue, steroid hormones, and Vitamin D.
- clogs arteries when high levels form plaque.

A normal, open artery.

An artery clogged by cholesterol plaque

### Cholesterol in Foods

**Cholesterol**

- is considered elevated if plasma cholesterol exceeds 200 mg/dL.
- is synthesized in the liver and obtained from foods.

Cholesterol Content of Some Foods		
Food	Serving Size	Cholesterol (mg)
Liver (beef)	3 oz	370
Egg	1	250
Lobster	3 oz	175
Fried chicken	3½ oz	130
Hamburger	3 oz	85
Chicken (no skin)	3 oz	75
Fish (salmon)	3 oz	40
Butter	1 tablespoon	30
Whole milk	1 cup	35
Skim milk	1 cup	5
Margarine	1 tablespoon	0

Tanaka, General, Organic, and Biological Chemistry, Copyright © Pearson Education Inc., publishing as Benjamin Cummings.

43

### LIPID TRANSPORT

**Lipoproteins**

- Lipids are transported in the blood as lipoproteins
- are soluble in water because the surface consists of polar lipids.

44

- Combine lipids with proteins and phospholipids.

Lipids:

Cholesterol

Apolipoproteins + Cholesteryl esters → lipoproteins

Triacylglycerols

Phospholipids

Lipid transport

45

Phospholipid monolayer

ApoB-100

Triacylglycerols

Free (unesterified) cholesterol

Cholesteryl esters

46

### There are 4 types of lipoprotein

- The lipoprotein formed depends on the constituent protein and lipids

Chylo    VLDL    LDL    HDL

47

### Composition of lipoproteins

**Table 21-2**

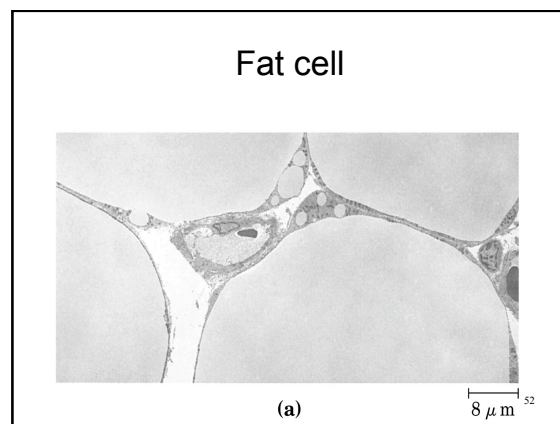
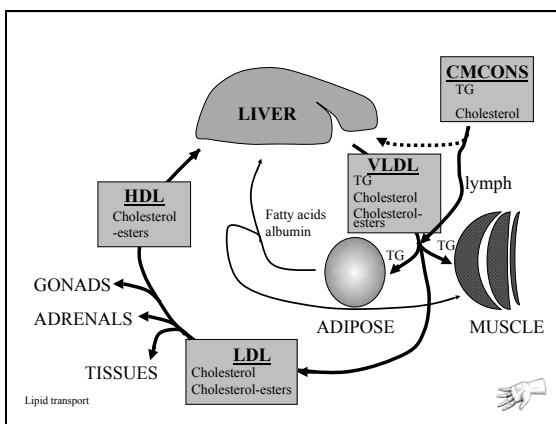
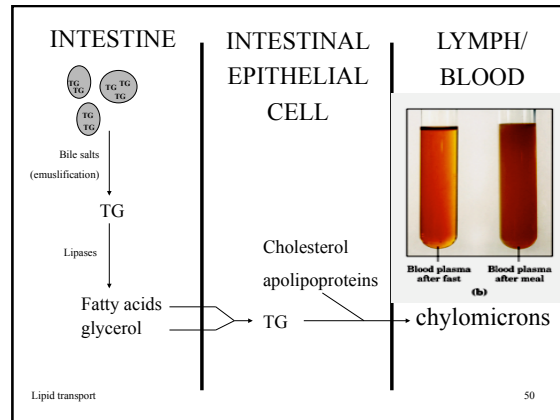
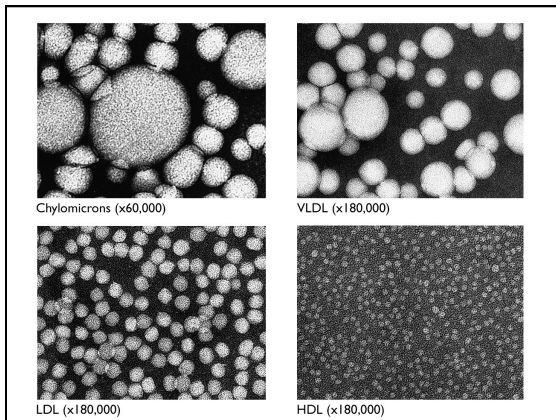
Major Classes of Human Plasma Lipoproteins: Some Properties

Lipoprotein	Density (g/mL)	Composition (wt %)				
		Protein	Phospholipid	Free cholesterol	Cholesteryl ester	Triacylglycerol
Chylomicrons	<1.000	2	9	1	3	85
VLDL	0.95-1.006	10	14	7	12	57
LDL	1.026-1.063	23	20	8	37	12
HDL	1.063-1.210	55	24	2	15	4

Source: Modified from Kritchewsky, G. (1986) Atherosclerosis and nutrition. Nutr. Rev. 2, 290-297.

48





### Steroid Hormones

**Steroid hormones are**

- chemical messengers in cells.
- sex hormones.
  - Androgens in males (testosterone)
  - Estrogens in females (estradiol)
- Adrenocortical hormones from adrenal glands.
  - mineralocorticoids (electrolyte balance)
  - glucocorticoids regulate glucose level

53

### Steroid Hormones

- are produced from cholesterol.
- include sex hormones such as androgens (testosterone) in males and estrogens (estradiol) in females.

Hormone	Biological Effects
<chem>CC12CCC3=C1C(=O)CC4=CC(=O)C=C34</chem> Testosterone (androgen) (produced in testes)	Development of male organs; male sexual characteristics including muscles and facial hair; sperm formation
<chem>CC12CCC3=C1C(=O)CC4=CC(=O)C=C34</chem> Estradiol (estrogen) (produced in ovaries)	Development of female sexual characteristics; ovulation
<chem>CC12CCC3=C1C(=O)CC4=CC(=O)C=C34</chem> Progesterone (produced in ovaries)	Prepares uterus for fertilized egg

54

## Adrenal Corticosteroids

Steroid hormones called **adrenal corticosteroids**

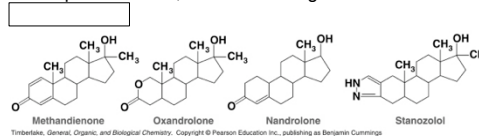
- are produced by the adrenal glands located on the top of each kidney.
- include *aldosterone*, which regulates electrolytes and water balance by the kidneys.
- include *cortisone*, a glucocorticoid, which increases blood glucose level and stimulates the synthesis of glycogen in the liver.

55

## Anabolic Steroids

**Anabolic steroids**

- are derivatives of testosterone.
- are used illegally to increase muscle mass.
- have side effects including fluid retention, hair growth, sleep disturbance, and liver damage.

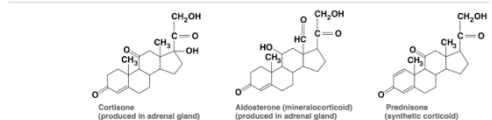


Timberlake, General, Organic, and Biological Chemistry, Copyright © Pearson Education Inc., publishing as Benjamin Cummings

56

## Adrenal Corticosteroids

Corticosteroids



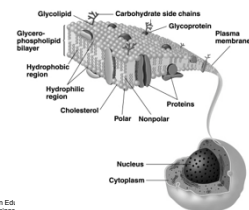
**Biological Effects**

Increases the blood glucose and glycogen levels from fatty acids and amino acids	Increases the reabsorption of Na <sup>+</sup> in kidneys; retention of water	Reduces inflammation; treatment of asthma and rheumatoid arthritis
--	--	--

Timberlake, General, Organic, and Biological Chemistry, Copyright © Pearson Education Inc., publishing as Benjamin Cummings

57

## 15.7 Cell Membranes



Copyright © 2005 by Pearson Education, Inc. Publishing as Benjamin Cummings

58

## Cell Membranes

**Cell membranes**

- separate cellular contents from the external environment.
- consist of a lipid bilayer made of two rows of phospholipids.
- have an inner portion made of the nonpolar tails of phospholipids with the polar heads at the outer and inner surfaces.

59

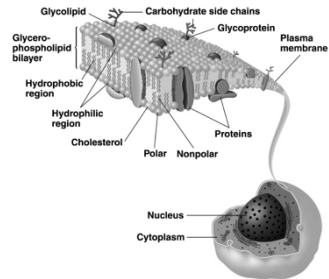
## Fluid Mosaic Model of Cell Membranes

**The lipid bilayer**

- contains proteins, carbohydrates, and cholesterol.
- has unsaturated fatty acids that make cell membranes fluid-like rather than rigid.
- has proteins and carbohydrates on the surface that communicate with hormones and neurotransmitters.

60

## Fluid Mosaic Model of Cell Membranes



61

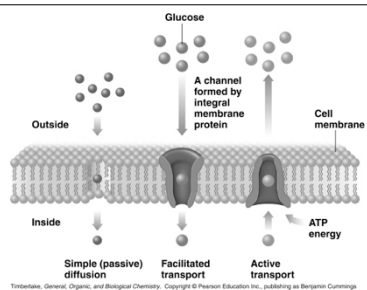
## Transport Through Cell Membranes

The transport of substances through cell membranes involves

- **diffusion (passive transport)**, which moves particles from a higher to a lower concentration.
- **facilitated transport**, which uses protein channels to increase the rate of diffusion.
- **active transport**, which moves ions against a concentration gradient.

62

## Transport Pathways Through Cell Membranes



63