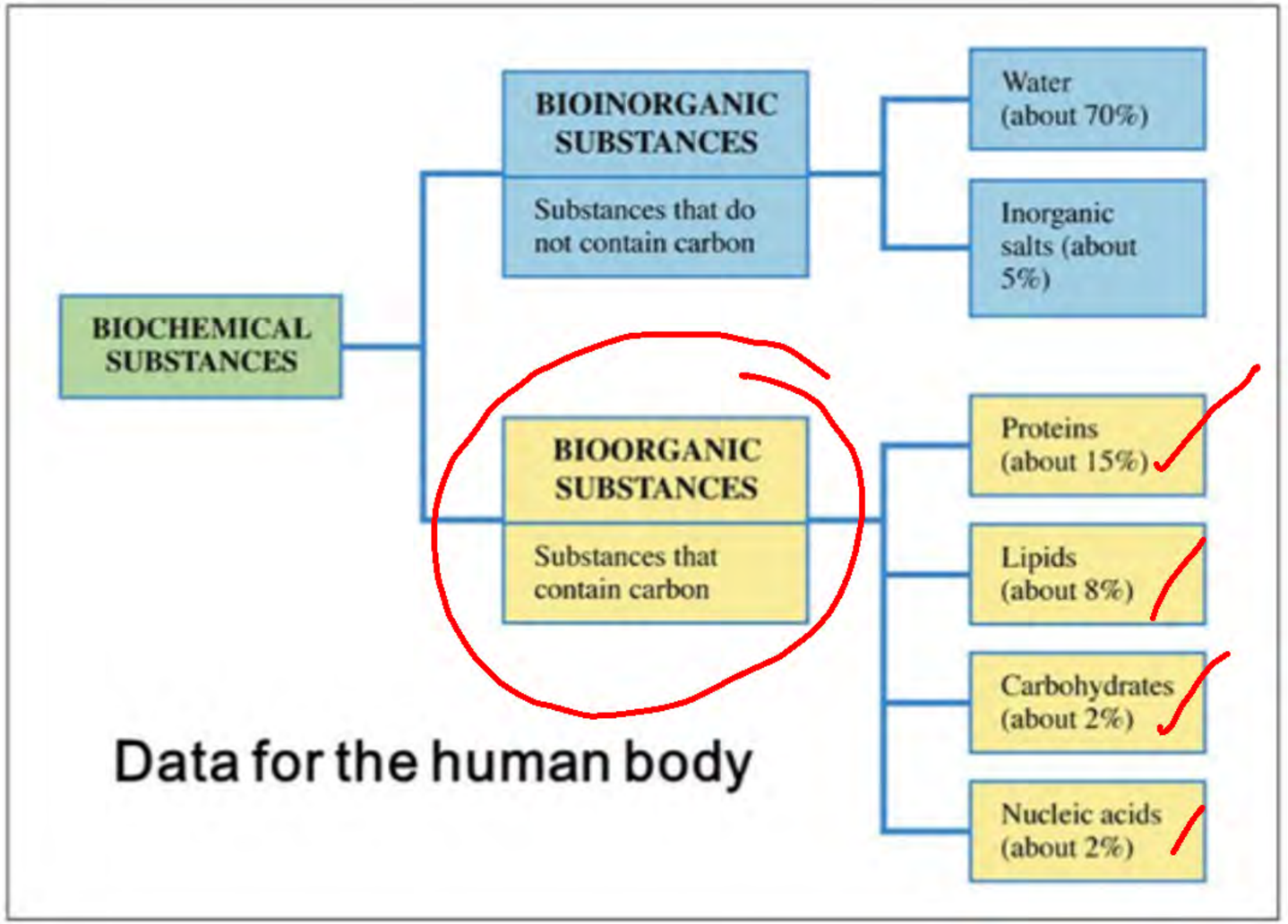
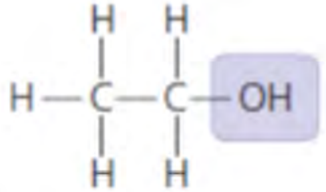
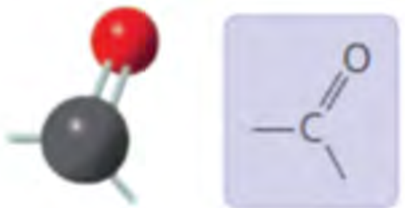
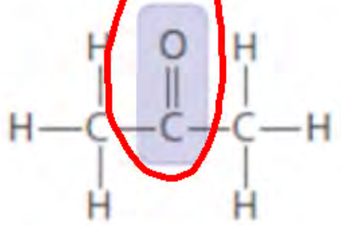
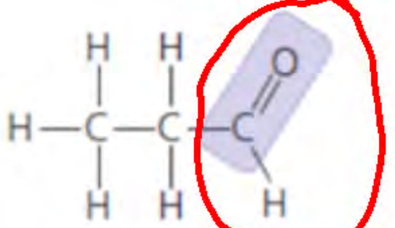
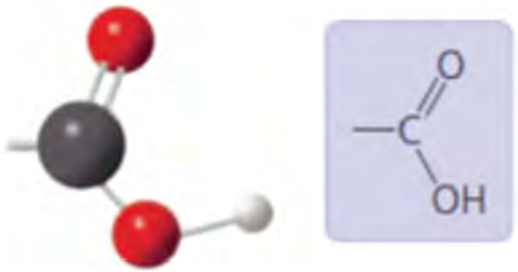
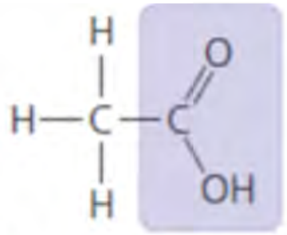
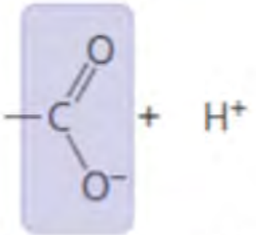
Biomolecules

C, H, O

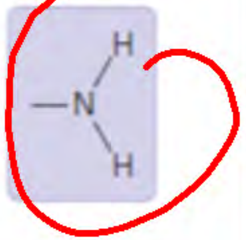
Mass composition data for the human body in terms of major types of biochemical substances.



▼ Figure 4.9 Some biologically important chemical groups.

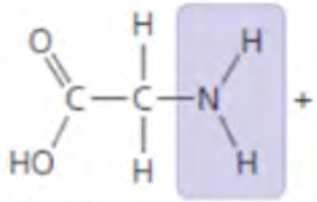
Chemical Group	Group Properties and Compound Name	Examples
Hydroxyl group (—OH)  (may be written HO—)	Is polar due to electronegative oxygen. Forms hydrogen bonds with water, helping dissolve compounds such as sugars. Compound name: Alcohol (specific name usually ends in *-ol*)	 **Ethanol**, the alcohol present in alcoholic beverages
Carbonyl group (>C=O) 	Sugars with ketone groups are called ketoses; those with aldehydes are called aldoses. Compound name: Ketone (carbonyl group is within a carbon skeleton) or aldehyde (carbonyl group is at the end of a carbon skeleton)	 **Acetone**, the simplest ketone  **Propanal**, an aldehyde
Carboxyl group (—COOH) 	Acts as an acid (can donate H^+) because the covalent bond between oxygen and hydrogen is so polar. Compound name: Carboxylic acid, or organic acid	 **Acetic acid**, which gives vinegar its sour taste ⇌  Ionized form of —COOH (carboxylate ion), found in cells

Amino group (—NH_2)

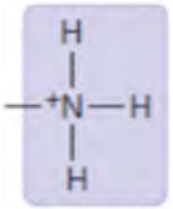


Acts as a base; can pick up an H^+ from the surrounding solution (water, in living organisms).

Compound name: Amine



Glycine, an amino acid (note its carboxyl group)



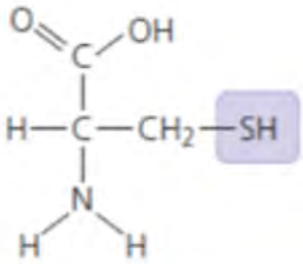
Ionized form of —NH_2, found in cells

Sulfhydryl group (—SH)

(may be written HS—)

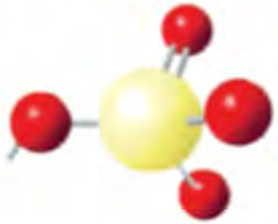
Two —SH groups can react, forming a "cross-link" that helps stabilize protein structure. Hair protein cross-links maintain the straightness or curliness of hair; in hair salons, permanent treatments break cross-links, then re-form them while the hair is in the desired shape.

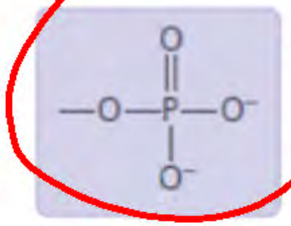
Compound name: Thiol



Cysteine, a sulfur-containing amino acid

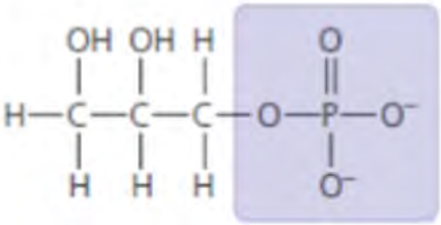
Phosphate group (—OPO_3^{2-})





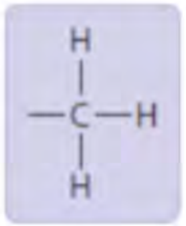
Contributes negative charge (1– when positioned inside a chain of phosphates; 2– when at the end). When attached, confers on a molecule the ability to react with water, releasing energy.

Compound name: Organic phosphate



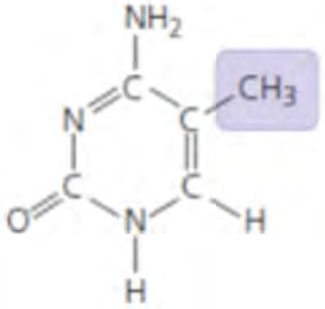
Glycerol phosphate, which takes part in many important chemical reactions in cells

Methyl group (—CH_3)



Affects the expression of genes when on DNA or on proteins bound to DNA. Affects the shape and function of male and female sex hormones.

Compound name: Methylated compound



5-Methyl cytosine, a component of DNA that has been modified by addition of a methyl group

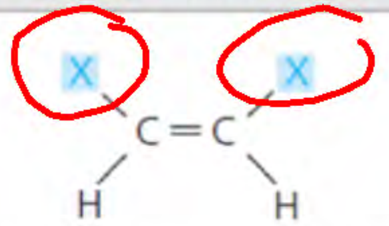
สารประกอบที่มีสูตรโมเลกุลเหมือนกันอาจมีโครงสร้างที่แตกต่างกันและมีผลทำให้สารประกอบนั้นมีสมบัติต่างกัน

สารประกอบที่เป็นไอโซเมอร์กันอาจมีสมบัติทางฟิสิกส์และเคมีไม่แตกต่างกัน แต่อาจมีชื่อเรียกแตกต่างกัน

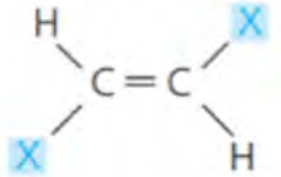
โดยทั่วไปจะมีเพียงไอโซเมอร์เดียวที่สามารถแสดงสมบัติทางชีวภาพได้

Isomers

(b) *Cis-trans* isomers



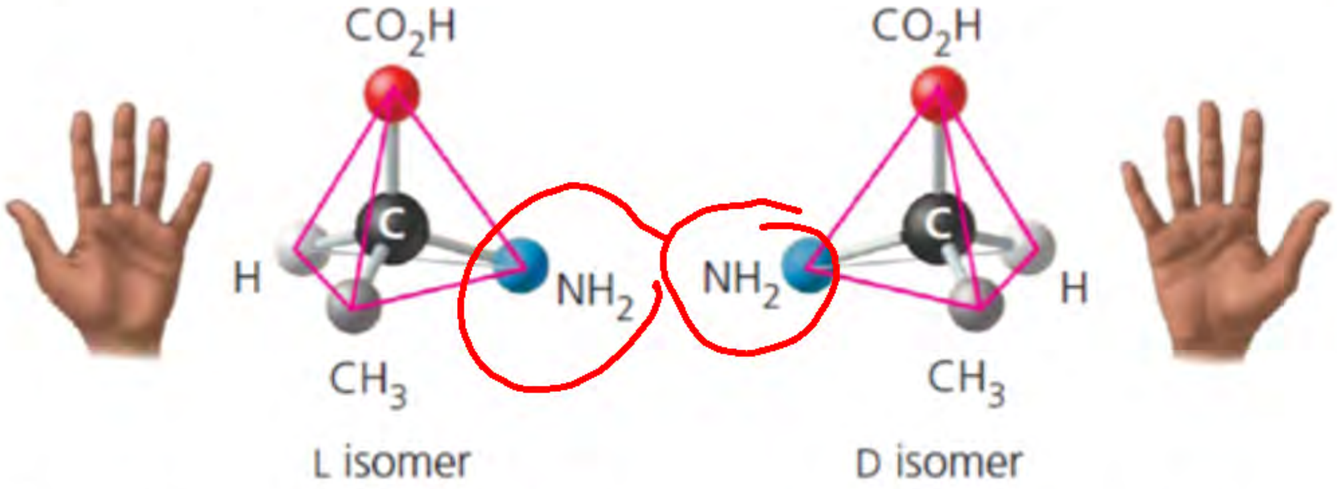
cis isomer: The two Xs are on the same side.



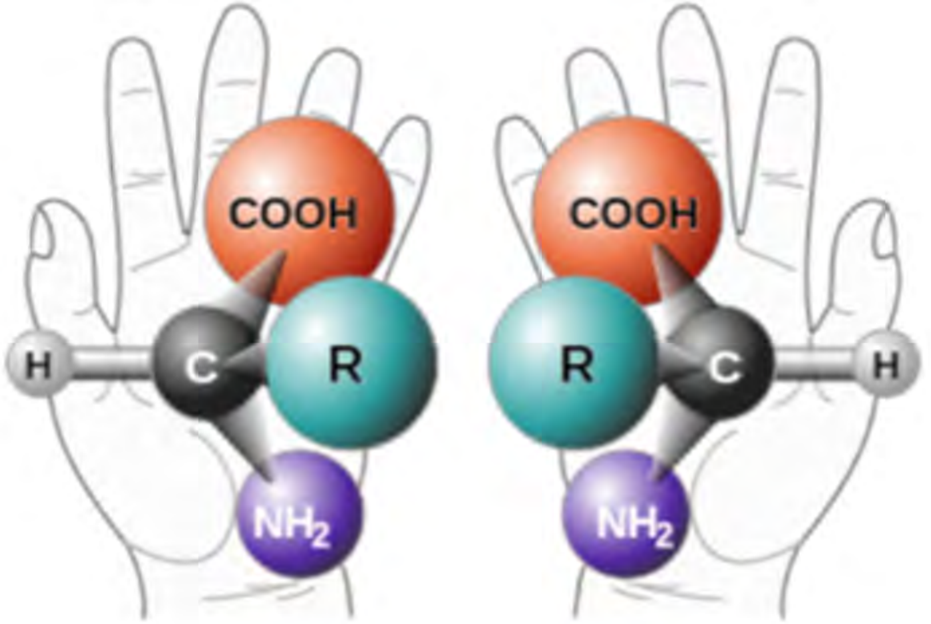
trans isomer: The two Xs are on opposite sides.

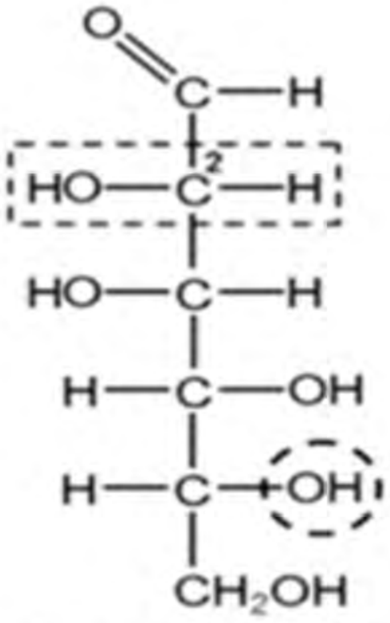
Cis-trans isomers differ in arrangement about a double bond. In these diagrams, X represents an atom or group of atoms attached to a double-bonded carbon.

(c) Enantiomers

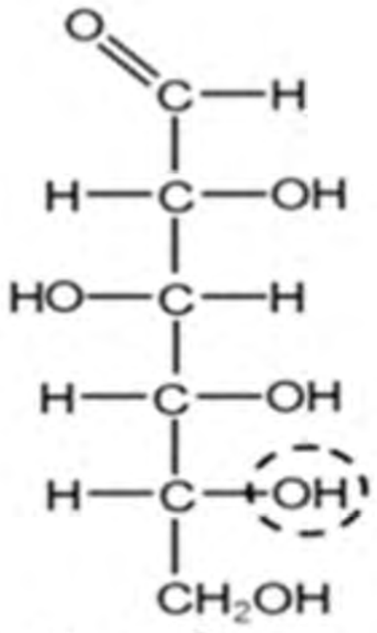


Enantiomers differ in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. The two isomers here are designated the L and D isomers from the Latin for "left" and "right" (*levo* and *dextro*). Enantiomers cannot be superimposed on each other.

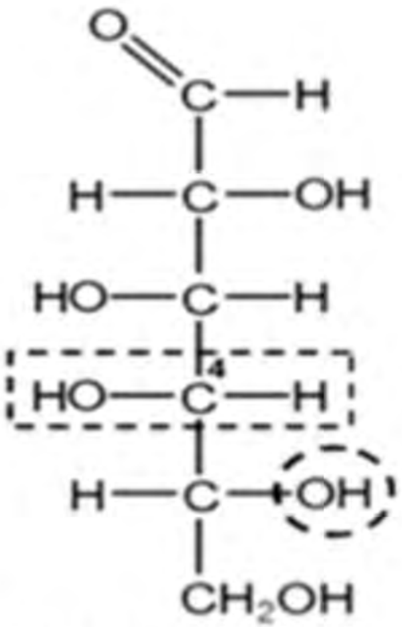




ดี-แมนโนส



ดี-กลูโคส



ดี-แกแลกโทส

ตัวอย่างอีพิเมอร์ (epimer) ของมอโนแซ็กคาไรด์

Diastereoisomer = isomer ที่ไม่เป็นเงาในกระจกซึ่งกันและกัน เช่น อีพิเมอร์

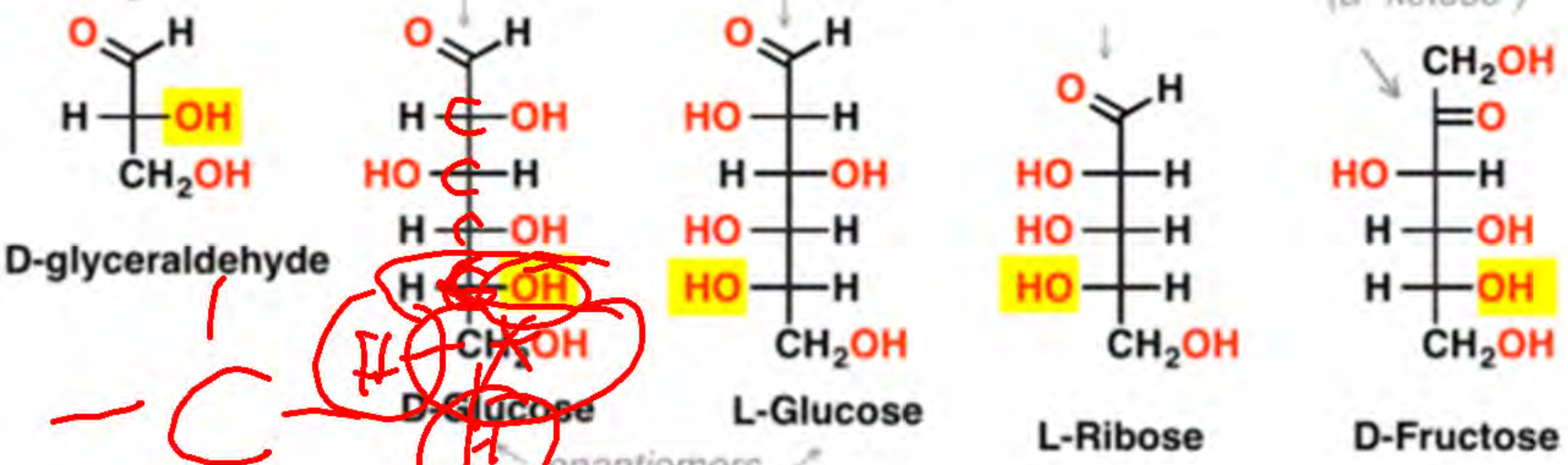
D- and L- Sugars

For a sugar drawn in the Fischer projection with the most oxidized carbon at the top:

- If the OH on the bottom chiral center points to the **right**, the sugar is **D**
- If the OH on the bottom chiral center points to the **left**, the sugar is **L**

most oxidized carbon (aldehyde) at top: these are "aldoses"

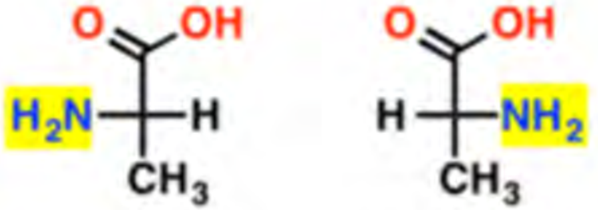
ketone (a "ketose")



L- and D- is a means of describing the **absolute configuration** of a molecule that pre-dates *R* and *S* but is still used for some biological molecules (sugars, amino acids). It's a quick way of denoting enantiomers: e.g. L-glucose and D-glucose are enantiomers.

L- and D- have no relation to the optical rotation of a molecule.

The D- L- system can also be applied to other chiral molecules, e.g. amino acids:



enantiomers

- Organic molecules consisting only of **carbon** and **hydrogen** are called ***hydrocarbons.***
- Macromolecules are polymers, built from monomers
- The Synthesis and Breakdown of Polymers

Figure 5.2a

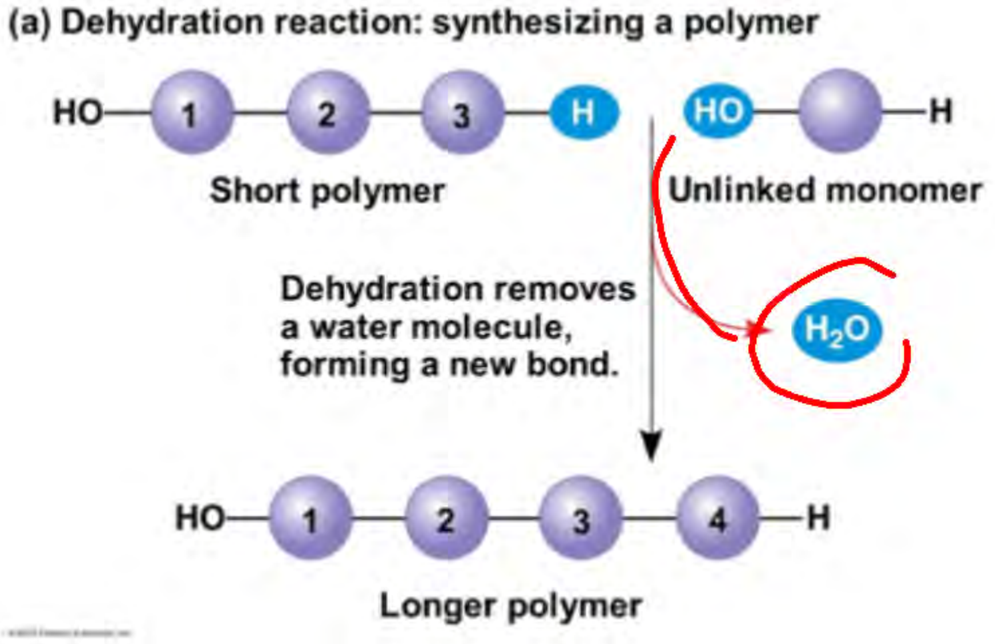
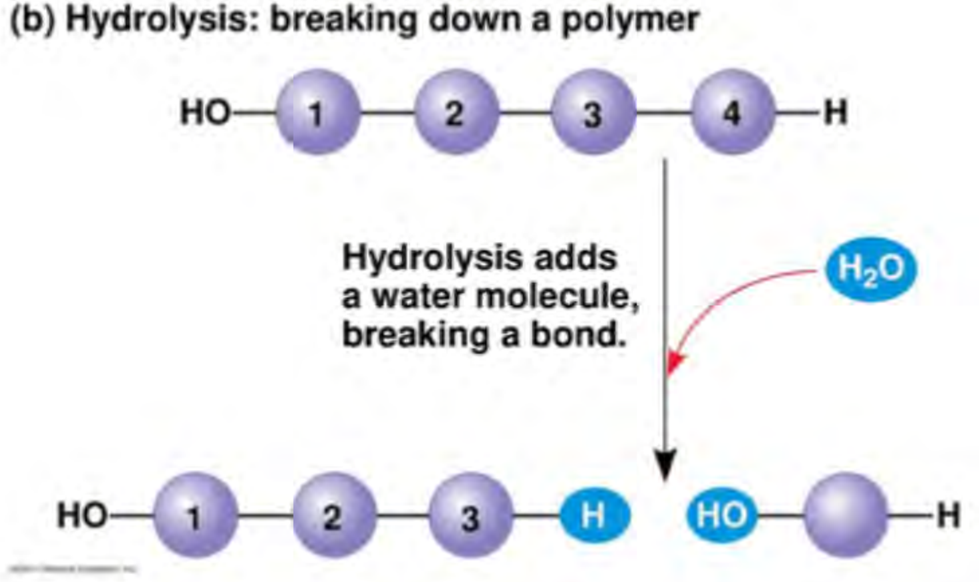


Figure 5.2b



Carbohydrates

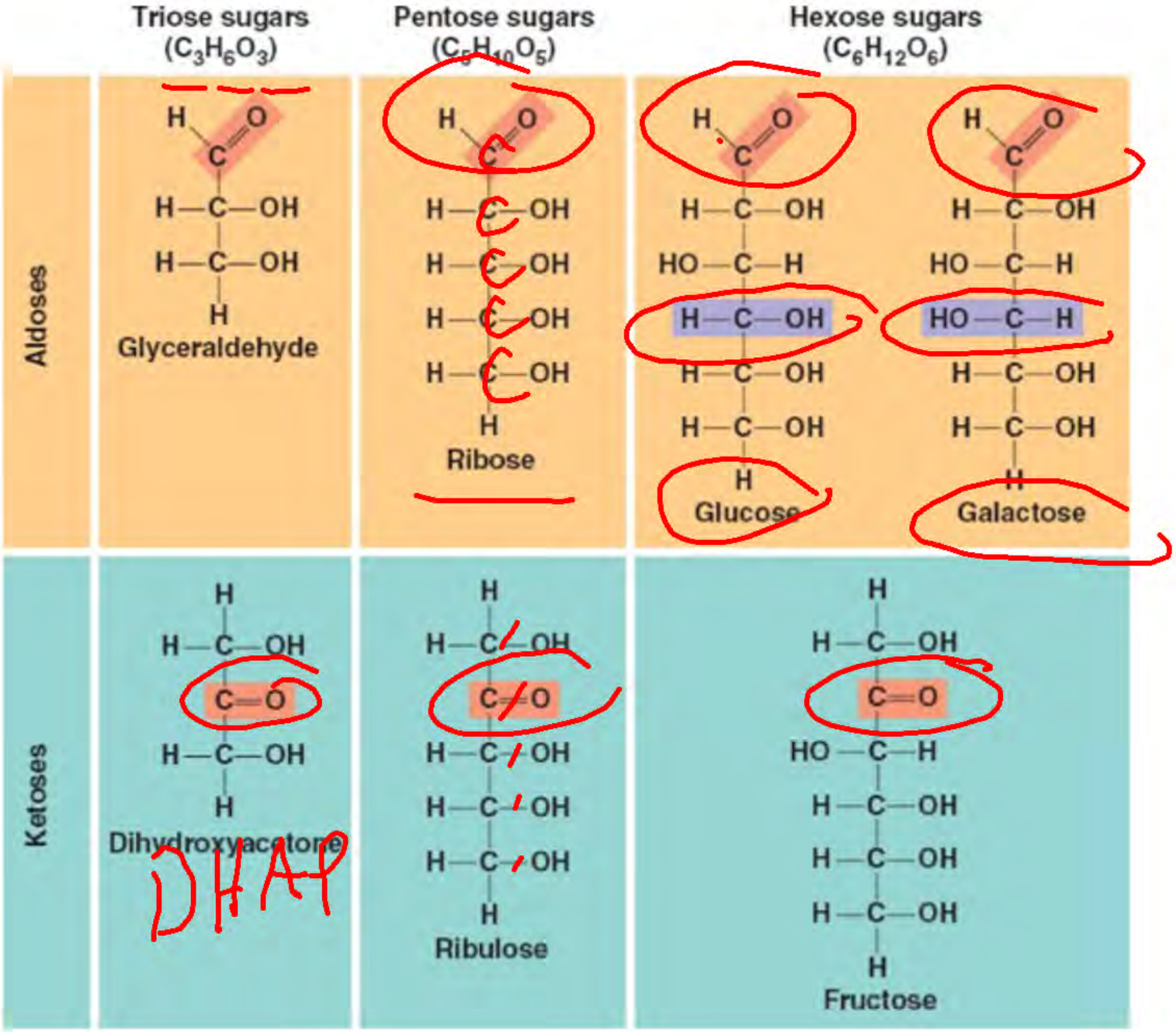
The **carbohydrates** are a loosely defined group of molecules that contain **carbon, hydrogen, and oxygen** in the molar **ratio 1:2:1.** Their empirical formula is $(CH_2O)_n$, where n is the number of carbon atoms.

2 : 1

3 H : O

$C_3H_6O_3$

The structure and classification of some monosaccharides.



รู้ หรือไม่ ?

เพื่อบ่งบอกจำนวนคาร์บอนในมอโนแซ๊กคาไรด์ เรามักจะเรียกชื่อตาม จำนวนคาร์บอน ที่เป็นองค์ประกอบ โดยมีขั้นตอนการอ่าน ดังนี้

1.อ่านจำนวนคาร์บอนเป็นภาษากรีก

สาม อ่านว่า ไตร (tri)

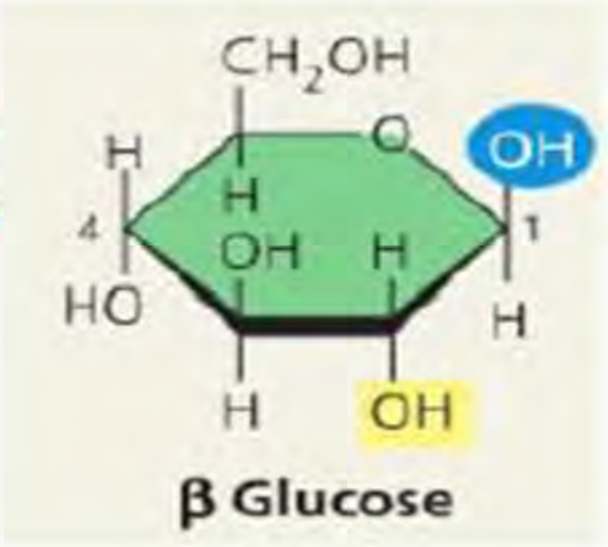
สี่ อ่านว่า เตตระ (tetra)

ห้า อ่านว่า เพนตะ (penta)

หก อ่านว่า เฮกซะ (hexa)

เจ็ด อ่านว่า เฮปตะ (hepta)

2. อ่านลงท้ายเสียง ด้วยคำว่า-โอส (-ose)



= Hexose

จำนวนอะตอมคาร์บอน	ชื่อมอโนแซ็กคาไรด์	สูตรโมเลกุล	ตัวอย่าง
3			
4			
5			
6			

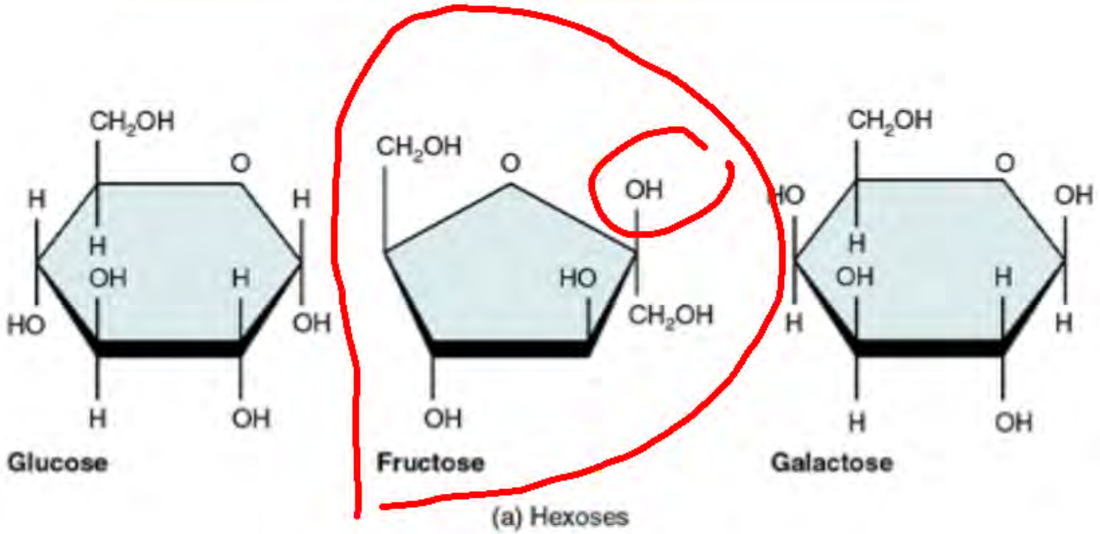
Carbohydrates

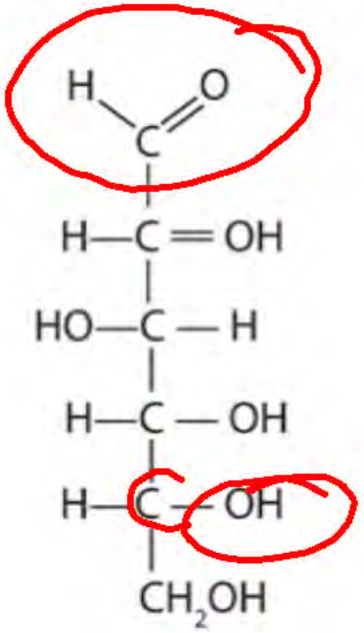
Monosaccharide

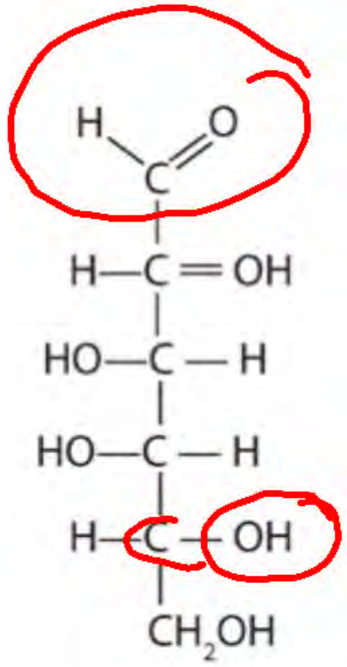
Oligosaccharide

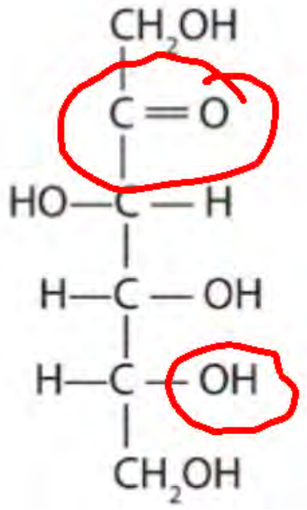
Polysaccharide

Monosaccharide

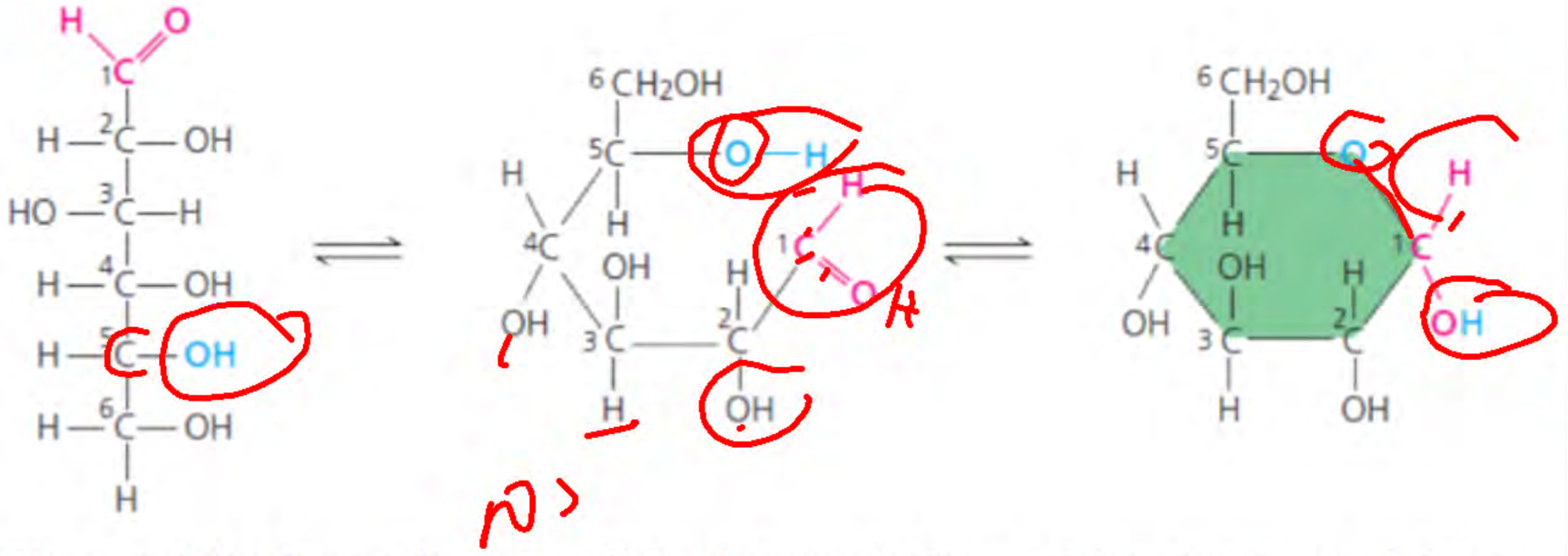



D-(+)-glucose

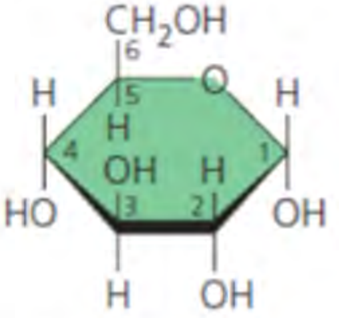

D-(+)-galactose


D-(–)-fructose

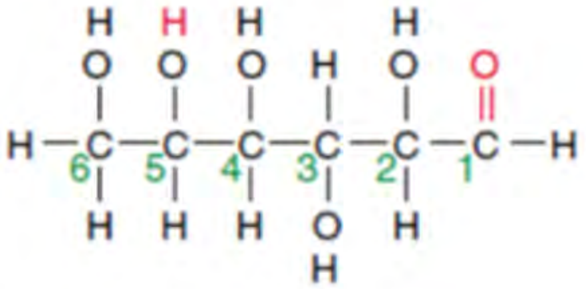
➤ เพิ่มเติม : Linear and ring forms of glucose.

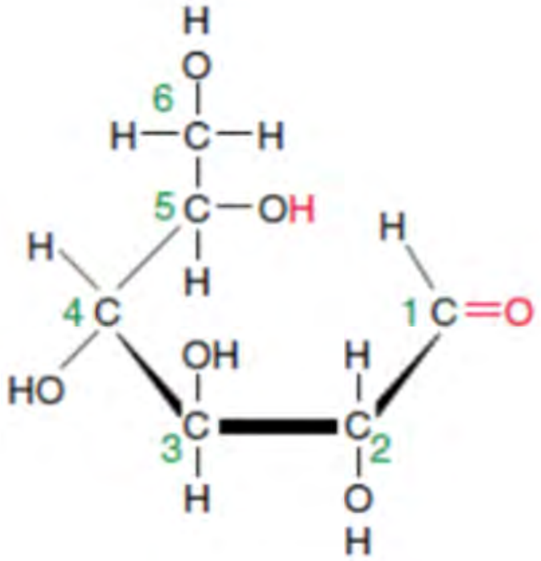


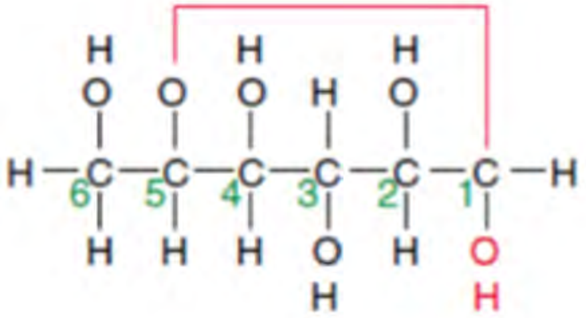
(a) **Linear and ring forms.** Chemical equilibrium between the linear and ring structures greatly favors the formation of rings. The carbons of the sugar are numbered 1 to 6, as shown. To form the glucose ring, carbon 1 (magenta) bonds to the oxygen (blue) attached to carbon 5.

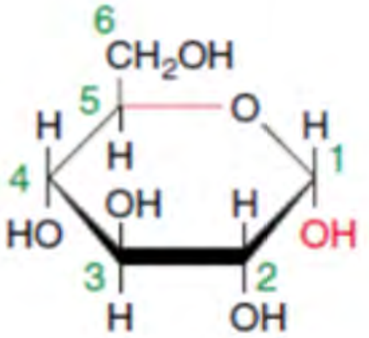


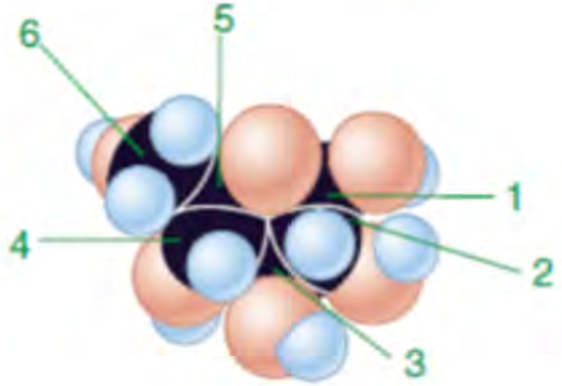
(b) **Abbreviated ring structure.** Each unlabeled corner represents a carbon. The ring's thicker edge indicates that you are looking at the ring edge-on; the components attached to the ring lie above or below the plane of the ring.

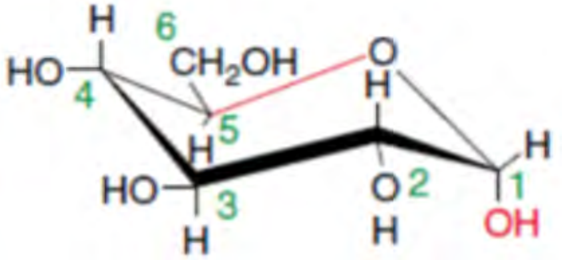


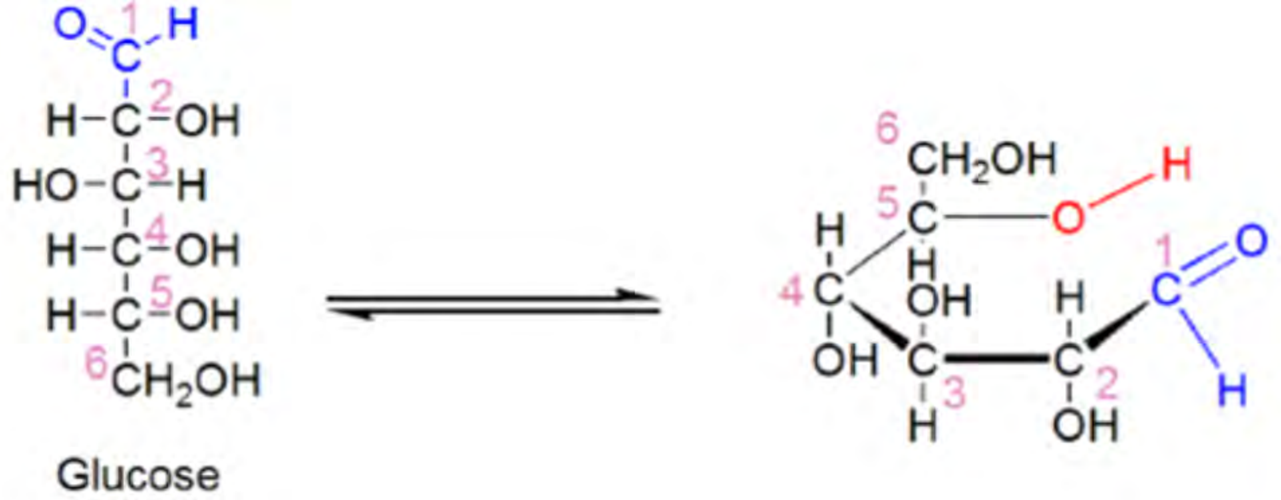




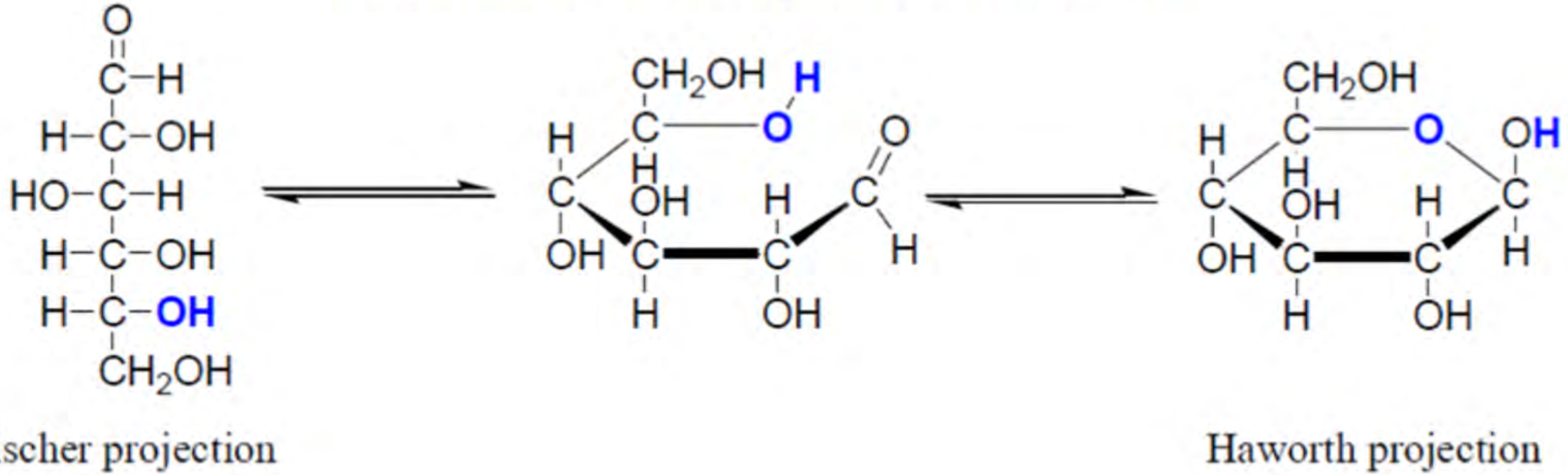






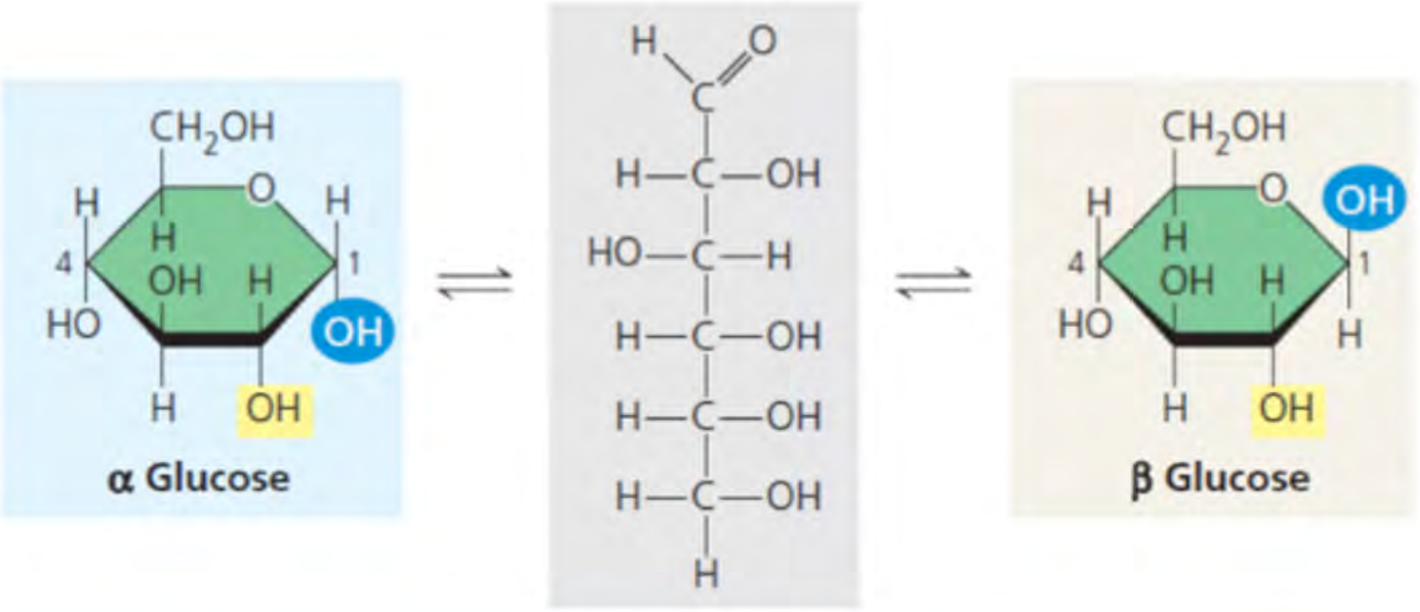


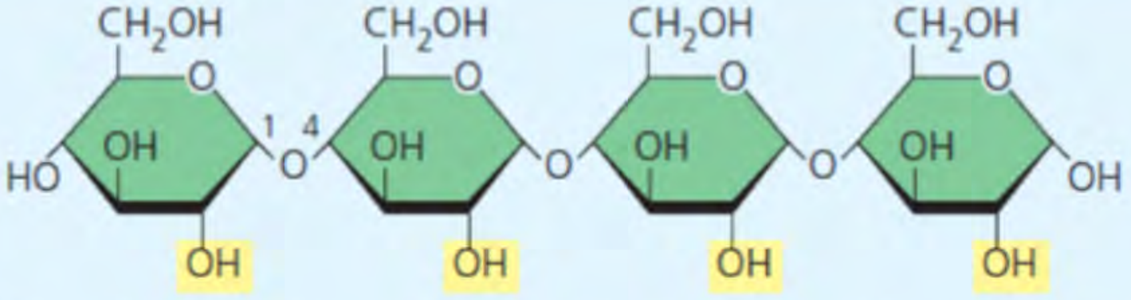
ภาพ Fischer Projection ของกลูโคสและเปิดบิดโครงสร้าง



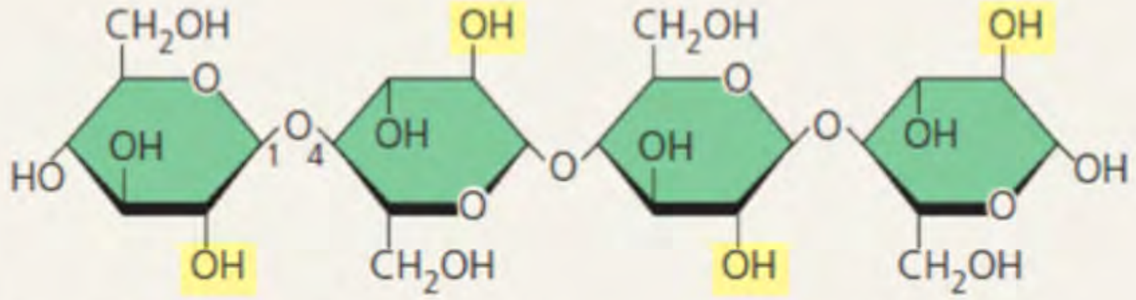
ภาพ การเกิดโครงสร้างแบบวงของกลูโคส

(a) α and β glucose ring structures. These two interconvertible forms of glucose differ in the placement of the hydroxyl group (highlighted in blue) attached to the number 1 carbon.





(b) Starch: 1–4 linkage of α glucose monomers. All monomers are in the same orientation. Compare the positions of the —OH groups highlighted in yellow with those in cellulose (c).



(c) Cellulose: 1–4 linkage of β glucose monomers. In cellulose, every β glucose monomer is upside down with respect to its neighbors. (See the highlighted —OH groups.)

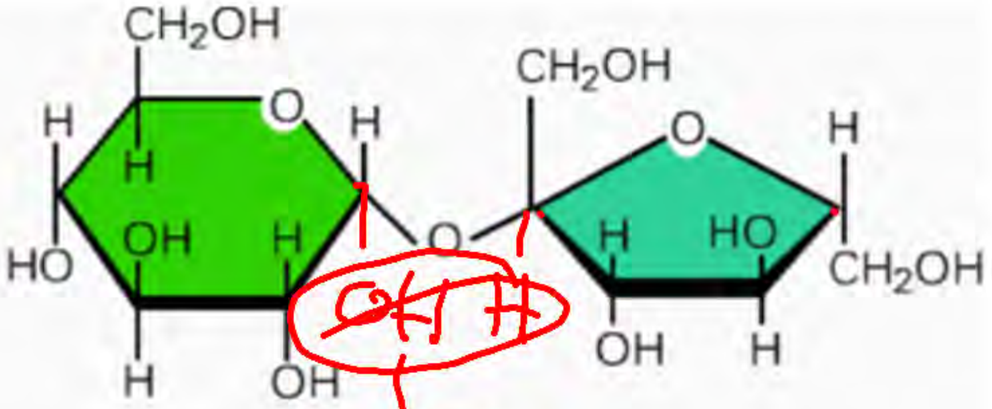
▲ Figure 5.7 Starch and cellulose structures.

oligosaccharide

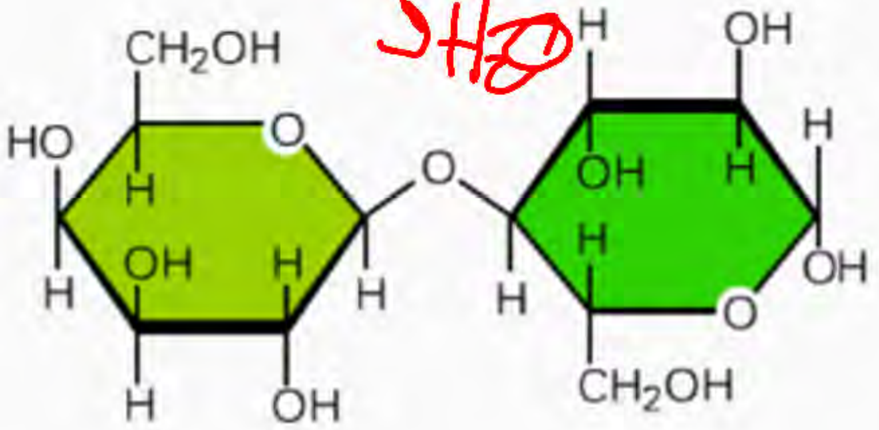
Disaccharide

trisaccharide

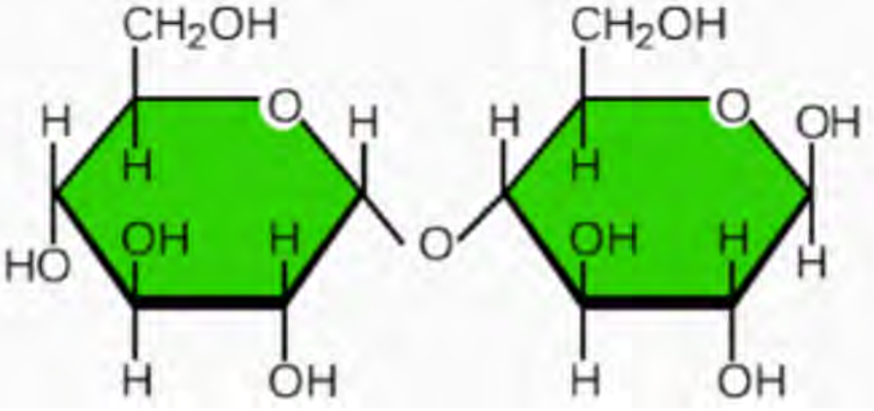
Sucrose
(glucose and fructose)



Lactose
(galactose and glucose)

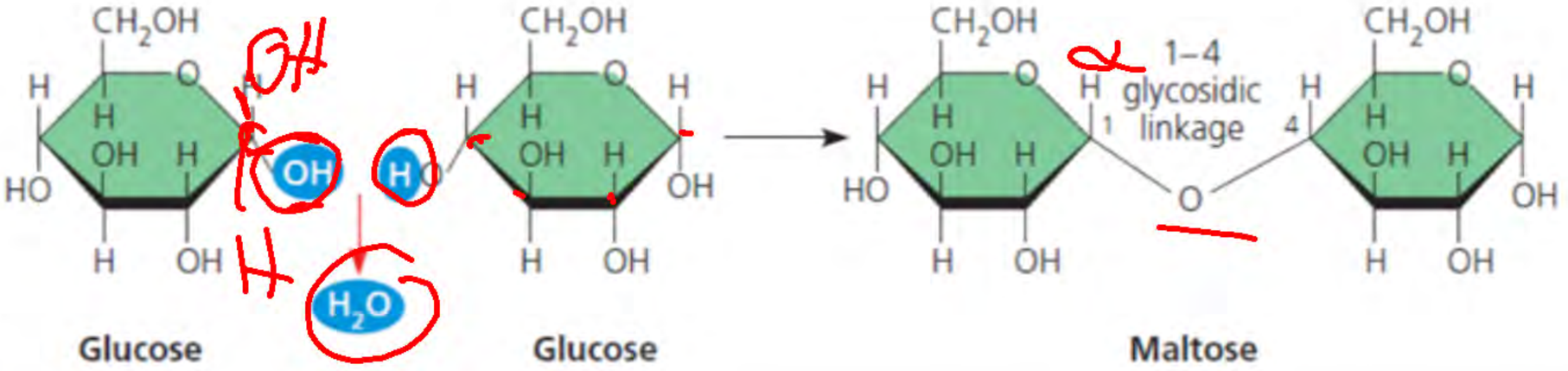


Maltose
(glucose and glucose)

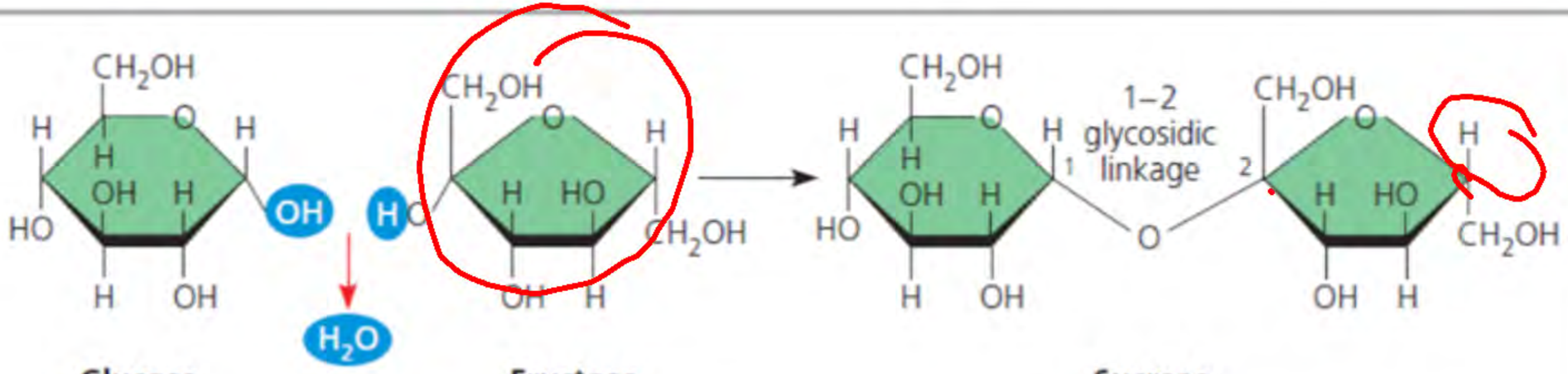


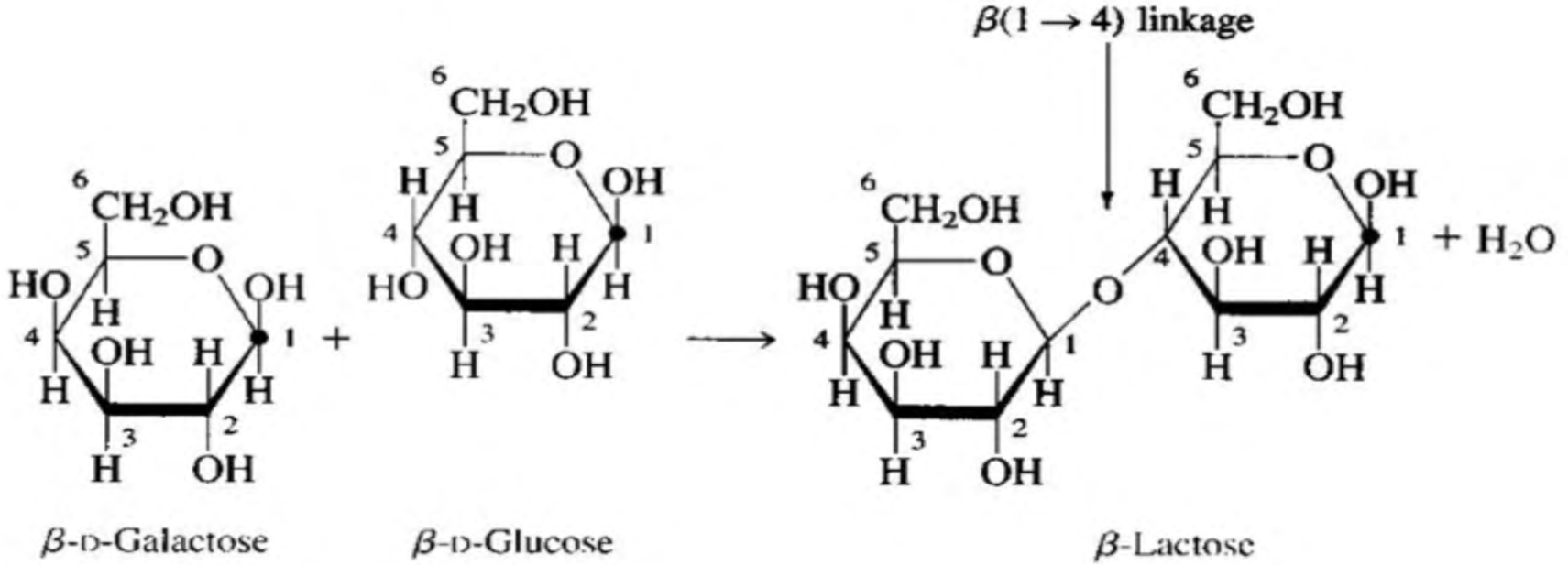
➢ Examples of disaccharide synthesis.

(a) Dehydration reaction in the synthesis of maltose. The bonding of two glucose units forms maltose. The 1–4 glycosidic linkage joins the number 1 carbon of one glucose to the number 4 carbon of the second glucose. Joining the glucose monomers in a different way would result in a different disaccharide.



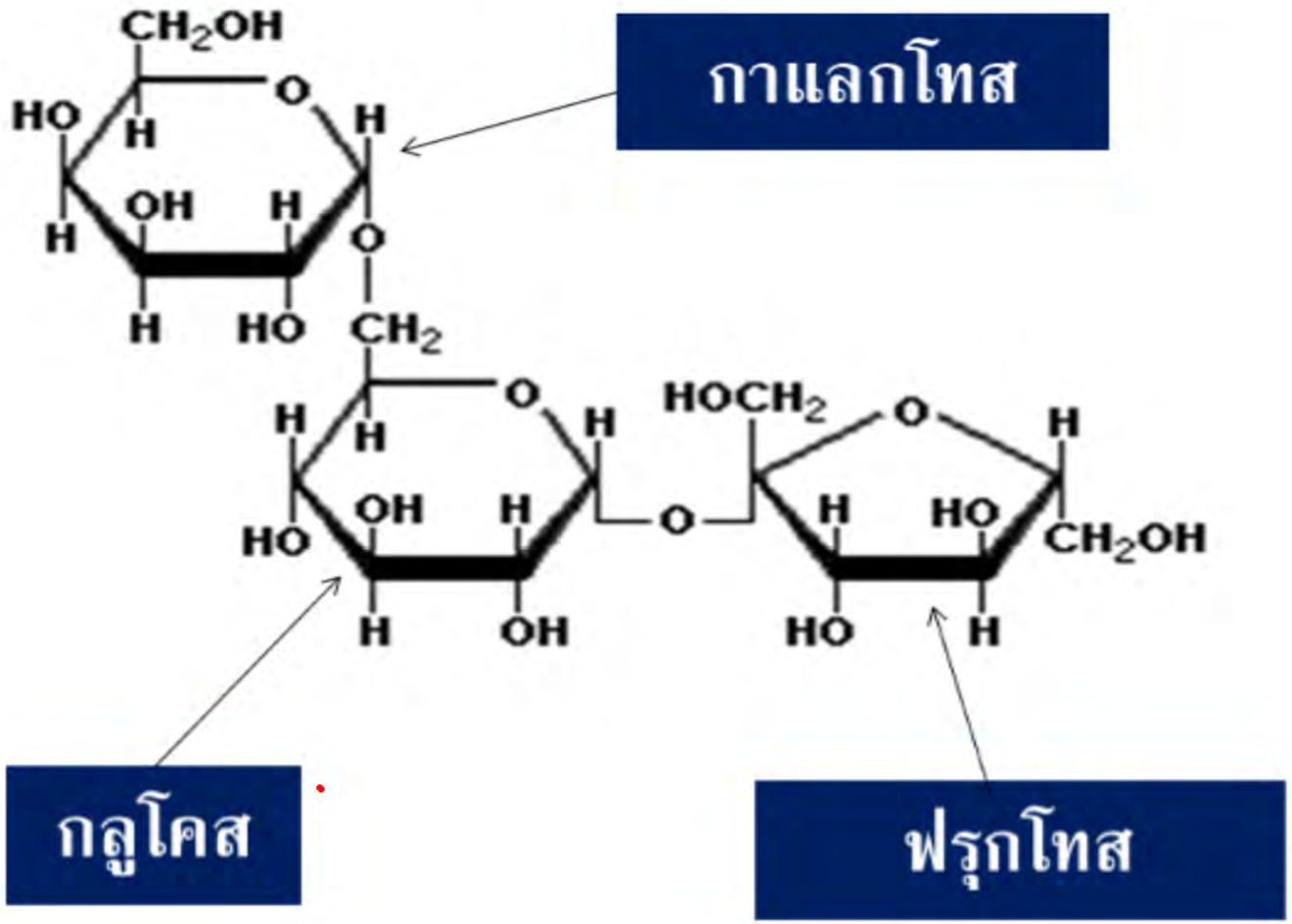
(b) Dehydration reaction in the synthesis of sucrose. Sucrose is a disaccharide formed from glucose and fructose. Notice that fructose forms a five-sided ring, though it is a hexose like glucose.




β(1 → 4) linkage
+ H2O
β-D-Galactose
β-D-Glucose
β-Lactose

MILK
MILK


milk
milk

trisaccharide	แหล่งที่พบ
raffinose  	หัวบีทรูท (*Beta vulgaris* L.) 

Polysaccharide

Polysaccharides are macromolecules, polymers with a few hundred to a few thousand monosaccharides joined by glycosidic linkages.

Storage structures (plastids) containing starch granules in a potato tuber cell

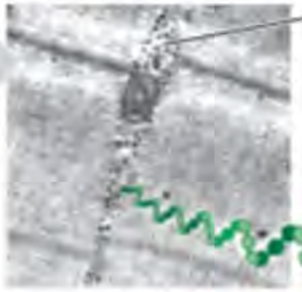
50 µm

(a) Starch

Amylose (unbranched)

Glucose monomer

Amylopectin (somewhat branched)

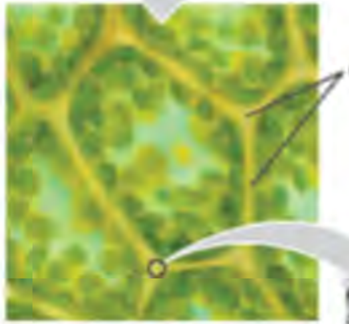


Glycogen granules in muscle tissue

1 µm

(b) Glycogen

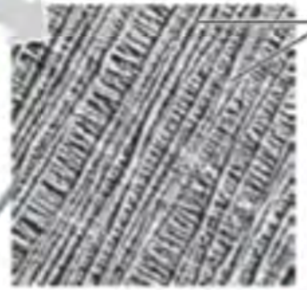
Glycogen (branched)



Cell wall

Plant cell, surrounded by cell wall

10 µm



Cellulose microfibrils in a plant cell wall

Microfibril (bundle of about 80 cellulose molecules)

0.5 µm

Cellulose molecule (unbranched)

OH

Hydrogen bonds between parallel cellulose molecules hold them together.

(c) Cellulose

เปรียบเทียบ Glycogen & Amylopectin

ข้อเหมือน

โครงสร้าง : โมเลกุลของกลูโคสเรียงตัวต่อกัน และมีการแตกแขนง

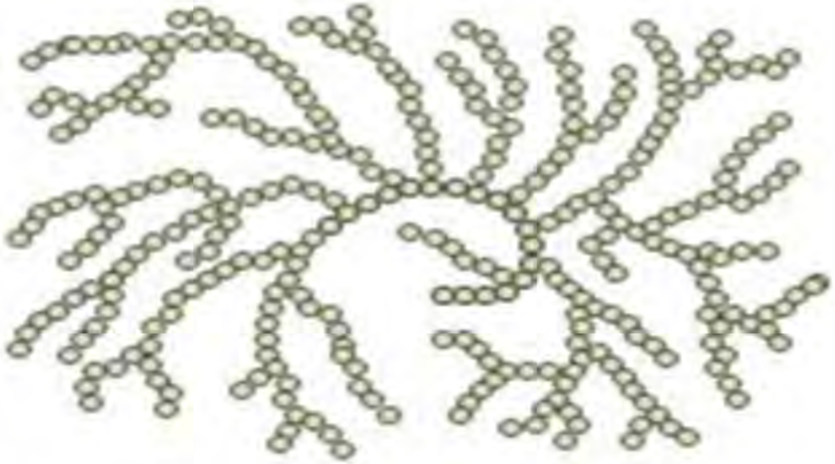
Amylopectin

ข้อต่าง

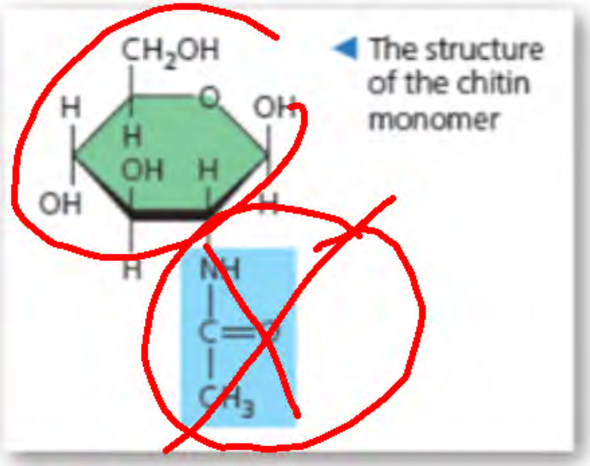
มีขนาดเล็ก เพราะความถี่ในการแตกกิ่งน้อยกว่า (ทุก ๆ 20-24 หน่วย)

Glycogen

โครงสร้าง : โมเลกุลของกลูโคสเรียงตัวต่อกัน และมีการแตกแขนง



มีขนาดใหญ่ เพราะความถี่ในการแตกกิ่งมากกว่า (ทุก ๆ 8-12 หน่วย)



◀ The structure of the chitin monomer

◀ Chitin, embedded in proteins, forms the exoskeleton of arthropods. This cicada is molting—shedding its old exoskeleton and emerging in adult form.

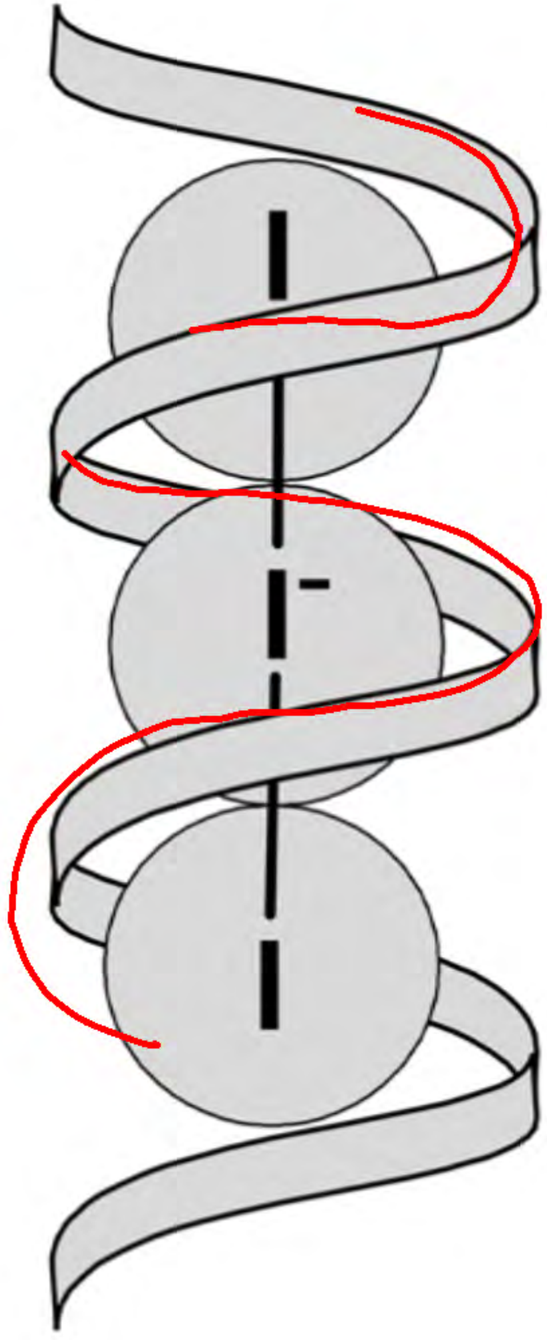
▶ Chitin is used to make a strong and flexible surgical thread that decomposes after the wound or incision heals.

▲ Figure 5.8 Chitin, a structural polysaccharide.

ตารางที่ 2.12 ความหวานสัมพัทธ์ (relative sweetness) ของน้ำตาลและสารแทนน้ำตาล (sugar substitute)

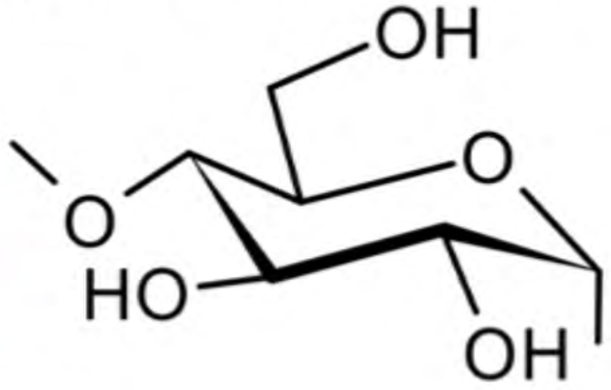
ชนิดของน้ำตาล	ความหวานสัมพัทธ์	ชนิดของสารให้ความหวานสังเคราะห์	ความหวานสัมพัทธ์
แลกโทส (น้ำตาลนม)	0.16	ไซคลาเมต (cyclamate)	30.00
มอลโทส (น้ำตาลมอลต์)	0.33	แอสพาร์แทม (aspartame)	150.00
กลูโคส (น้ำตาลในเลือด)	0.75	สเตเวียหรือหญ้าหวาน (stevia)	300.00
ซูโครส (น้ำตาลทราย)	1.00	แซ็กคาริน (saccharin)	350.00
ฟรุกโทส (น้ำตาลผลไม้)	1.75	ซูคราโลส (sucralose)	600.00

ที่มา: Enger, Ross and Bailey, 2009, หน้า 52



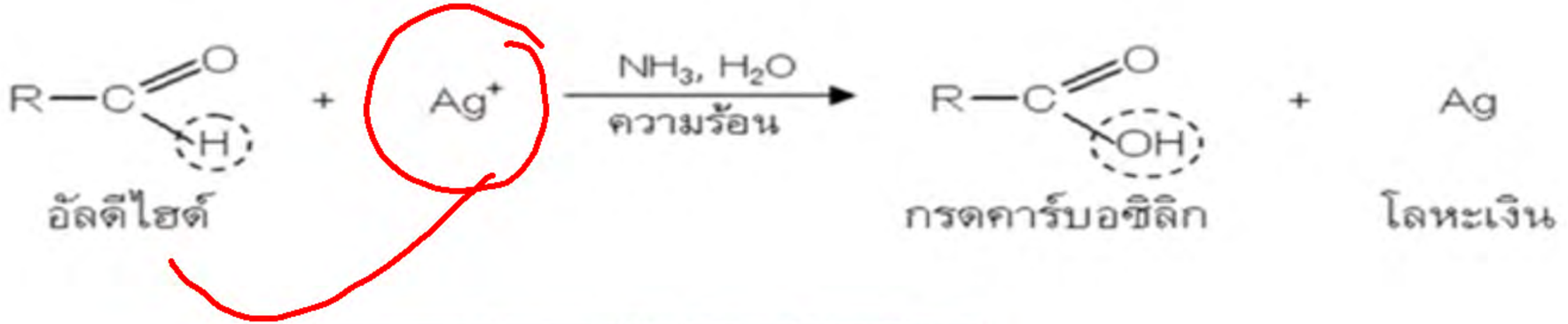
Amylosehelice with the

glucose-monomerunit:



(2) การทดสอบน้ำตาลรีดิวซ์ (reducing sugar)

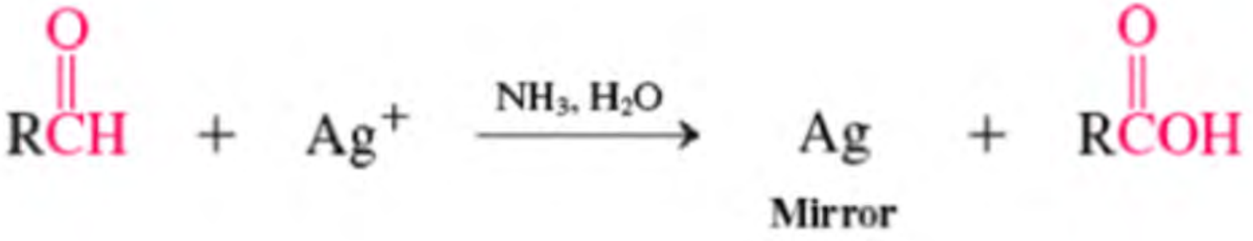
การทดสอบด้วยสารละลายทอลเลนซ์ (Tollens' test)



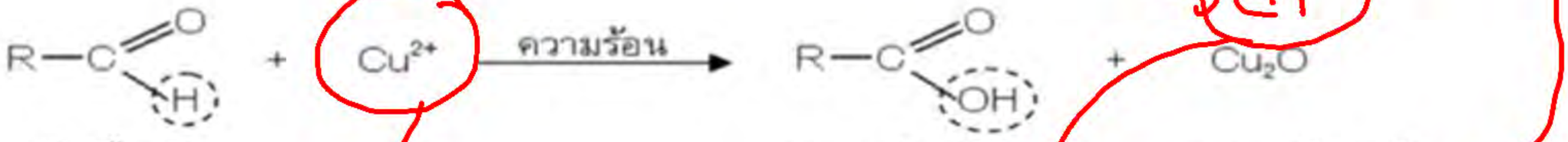
Tollens' reagent

Aldehydes ถูกออกซิไดซ์ได้ด้วยตัวออกซิไดซ์อย่างอ่อน เช่น

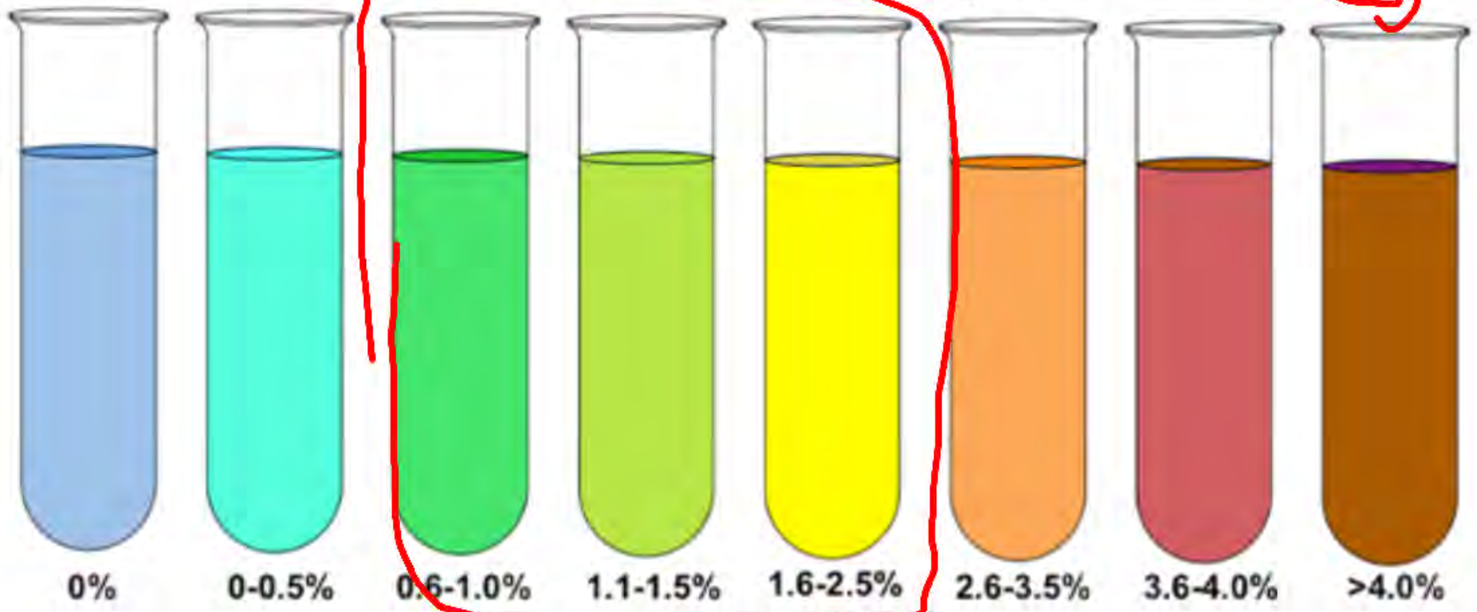
Tollens' reagent (silver ion in ammonia solution) โดยเห็นโลหะเงินจับที่ข้างหลอดคล้ายกระจกเงา เรียกว่า silver mirror



การทดลอบด้วยสารละลายเบเนดิกส์ (Benedicts' test)



อัลดีไฮด์ กรดคาร์บอซิลิก ตะกอนสีแดงอิฐ



Fehling's solution

$CuSO_4$ + NaOH + K-tartrate ⟶ Cu(II)tartrate complex

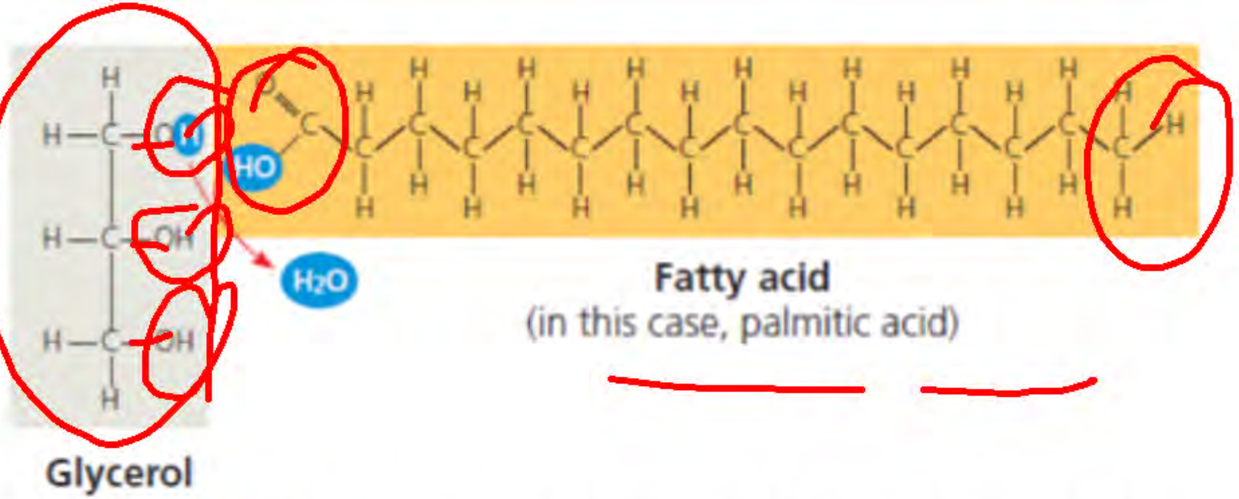
ตะกอนสีแดงอิฐ

Cu จะอยู่ในรูป Cu^{2+} เมื่อเกิดปฏิกิริยา

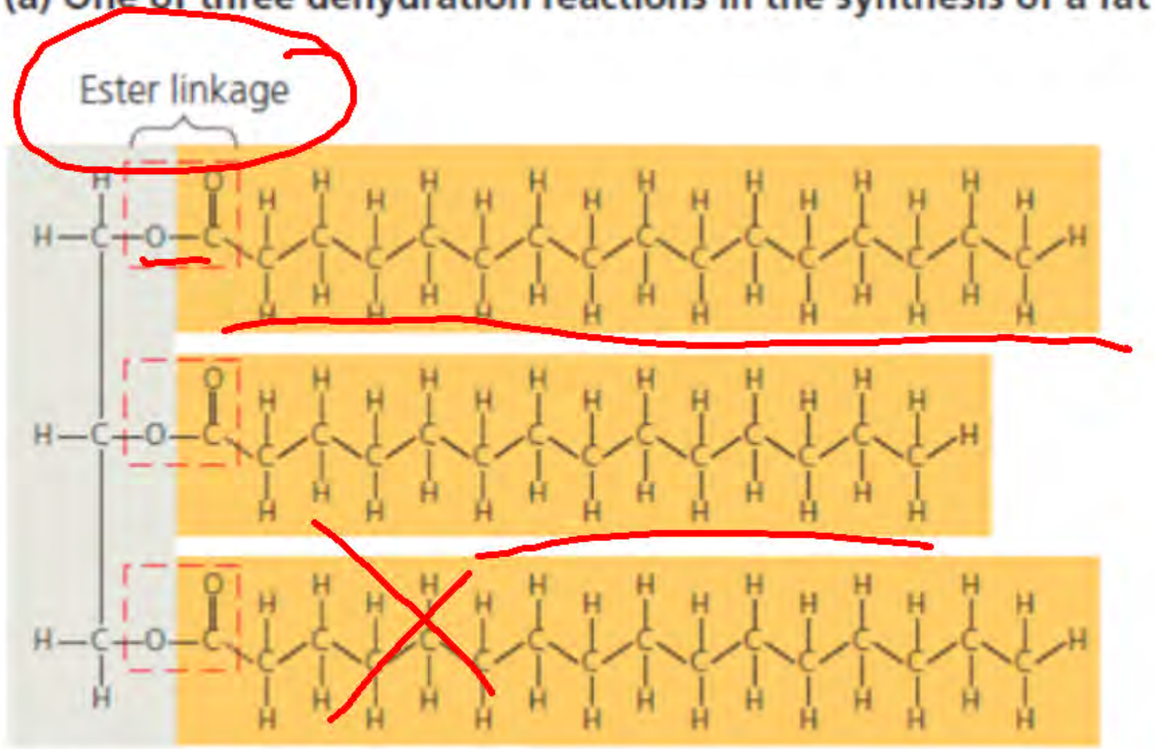
Cu^{2+} จะถูกรีดิวซ์เป็น Cu^{+}

Lipids

- Although fats are not polymers, they are large molecules assembled from smaller molecules by dehydration reactions.
- A fat is constructed from two kinds of smaller



(a) One of three dehydration reactions in the synthesis of a fat



(b) Fat molecule (triacylglycerol)

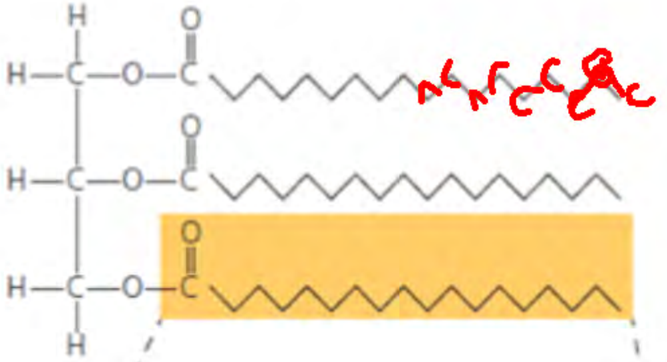
- **Glycerol is an alcohol**; each of its three carbons bears a hydroxyl group.
- **A fatty acid** has a long carbon skeleton, usually 16 or 18 carbon

The terms **saturated fats** and **unsaturated fats** are commonly used in the context of nutrition.

(a) Saturated fat

At room temperature, the molecules of a saturated fat, such as the fat in butter, are packed closely together, forming a solid.

Structural formula of a saturated fat molecule (Each hydrocarbon chain is represented as a zigzag line, where each bend represents a carbon atom and hydrogens are not shown.)

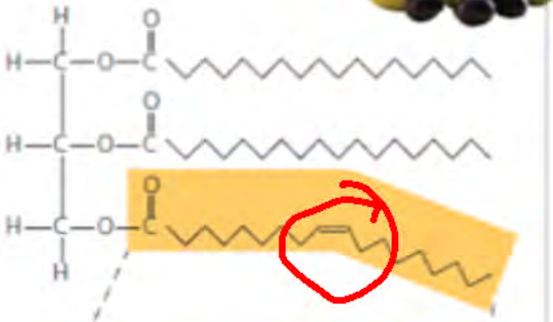


Space-filling model of stearic acid, a saturated fatty acid (red = oxygen, black = carbon, gray = hydrogen)

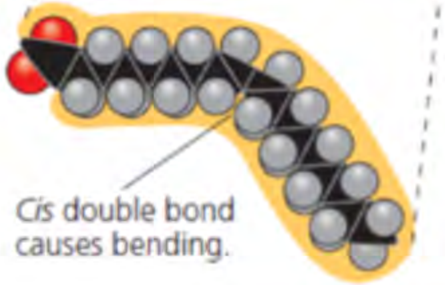
(b) Unsaturated fat

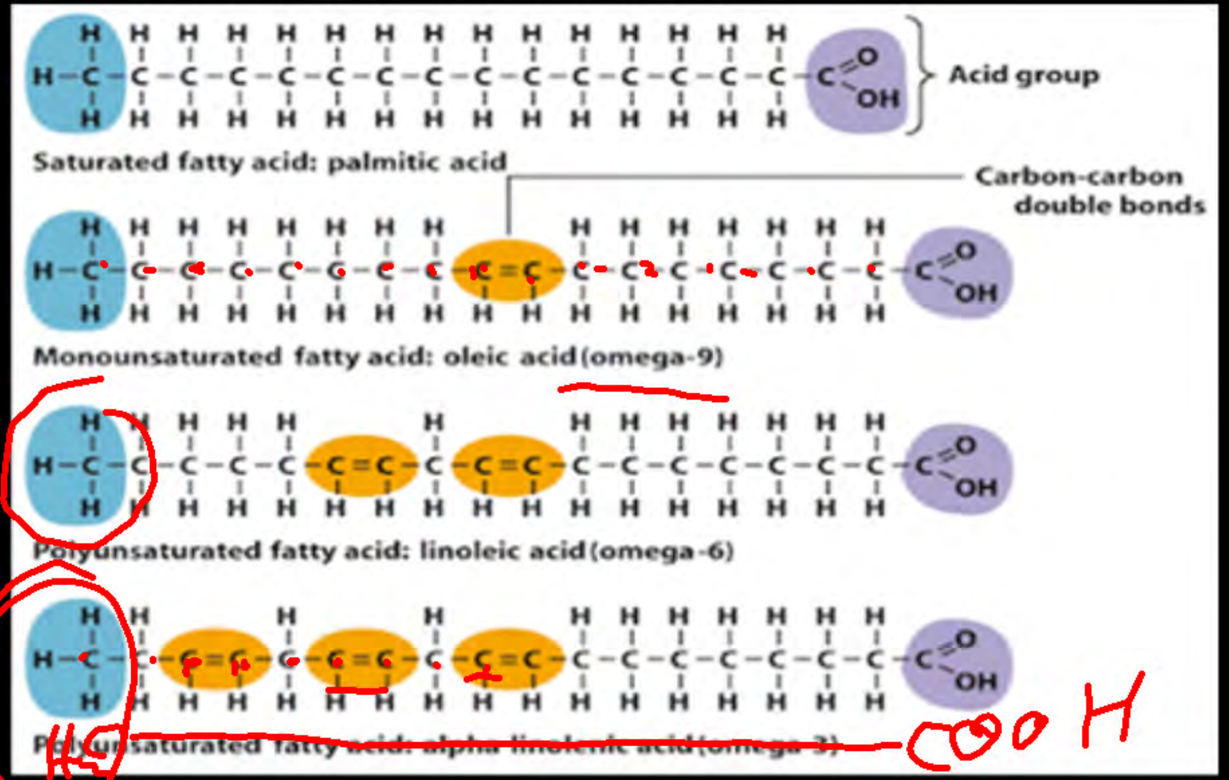
At room temperature, the molecules of an unsaturated fat such as olive oil cannot pack together closely enough to solidify because of the kinks in some of their fatty acid hydrocarbon chains.

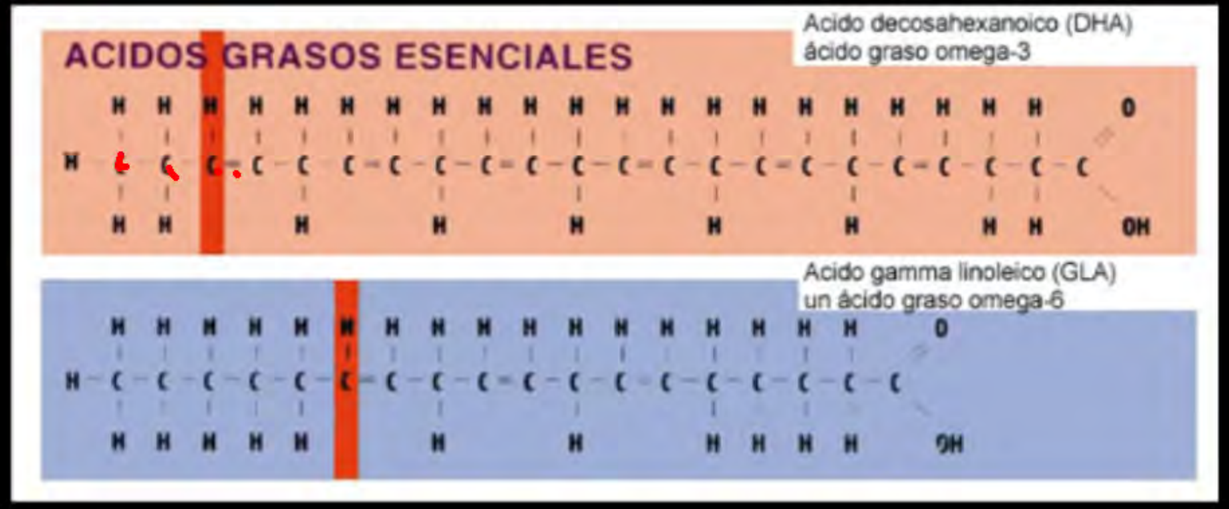
Structural formula of an unsaturated fat molecule



Space-filling model of oleic acid, an unsaturated fatty acid



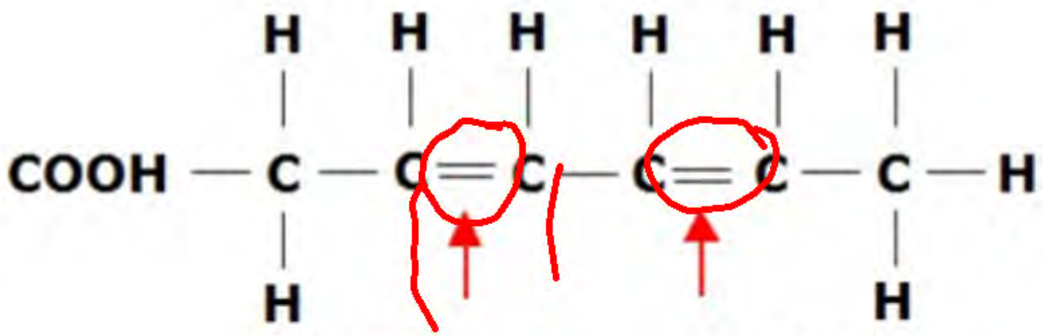

Acid group
Saturated fatty acid: palmitic acid
Carbon-carbon double bonds
Monounsaturated fatty acid: oleic acid (omega-9)
Polyunsaturated fatty acid: linoleic acid (omega-6)
Polyunsaturated fatty acid: alpha-linolenic acid (omega-3)


ACIDOS GRASOS ESENCIALES
Acido decosahexanoico (DHA)
ácido graso omega-3
Acido gamma linoleico (GLA)
un ácido graso omega-6


OMEGA 3
OMEGA 6

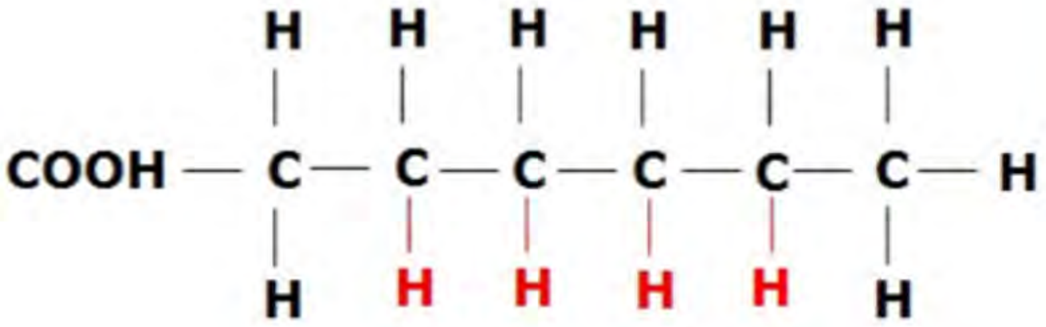
The phrase **“hydrogenated vegetable oils”** on food labels means that unsaturated fats have been synthetically converted to saturated fats by adding hydrogen.

- Peanut butter, margarine, and many other



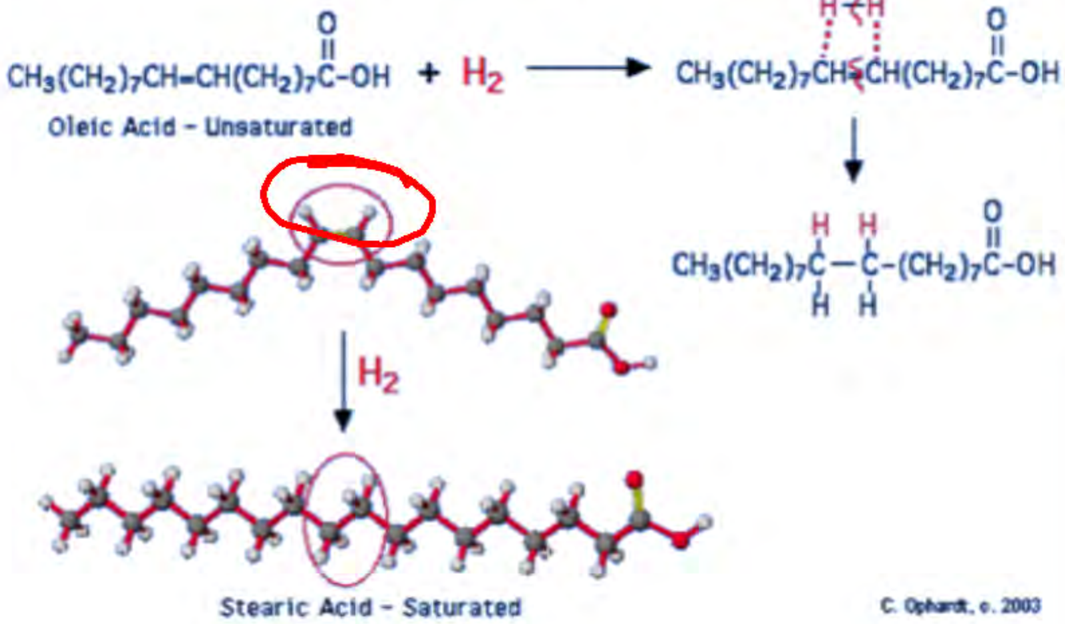
Polyunsaturated Fat

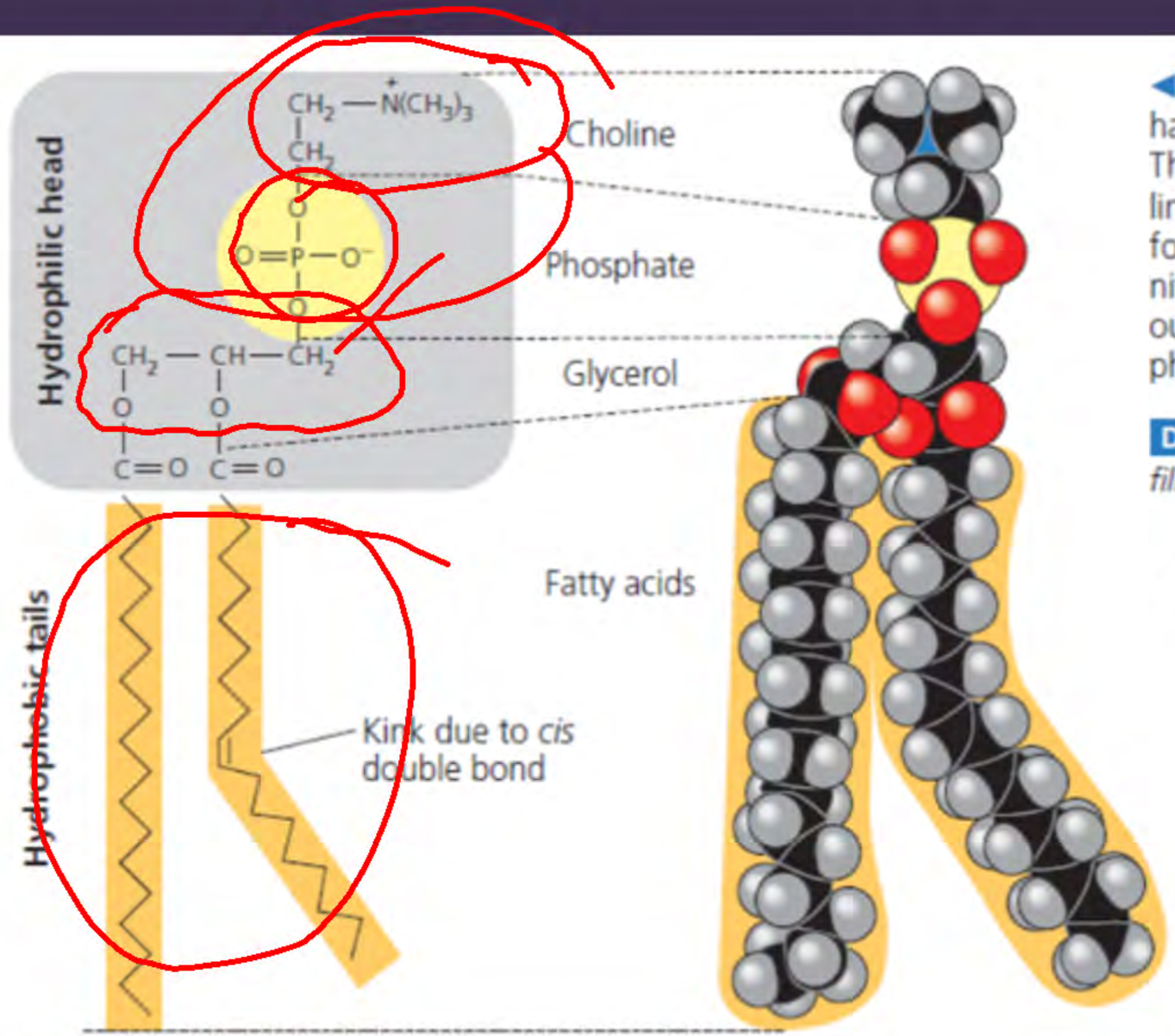
Hydrogenation



Hydrogenated Fat

Hydrogenation of Oleic Acid



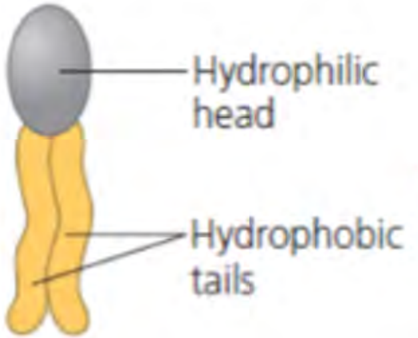


(a) Structural formula

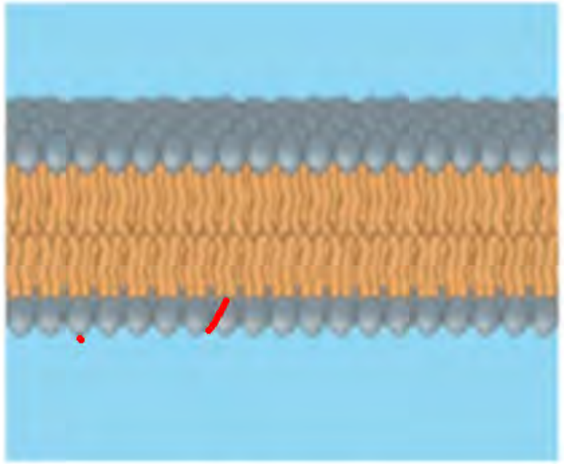
(b) Space-filling model

◀ Figure 5.11 The structure of a phospholipid. A phospholipid has a hydrophilic (polar) head and two hydrophobic (nonpolar) tails. This particular phospholipid, called a phosphatidylcholine, has a choline attached to a phosphate group. Shown here are **(a)** the structural formula, **(b)** the space-filling model (yellow = phosphorus, blue = nitrogen), **(c)** the symbol for a phospholipid that will appear throughout this book, and **(d)** the bilayer structure formed by self-assembly of phospholipids in an aqueous environment.

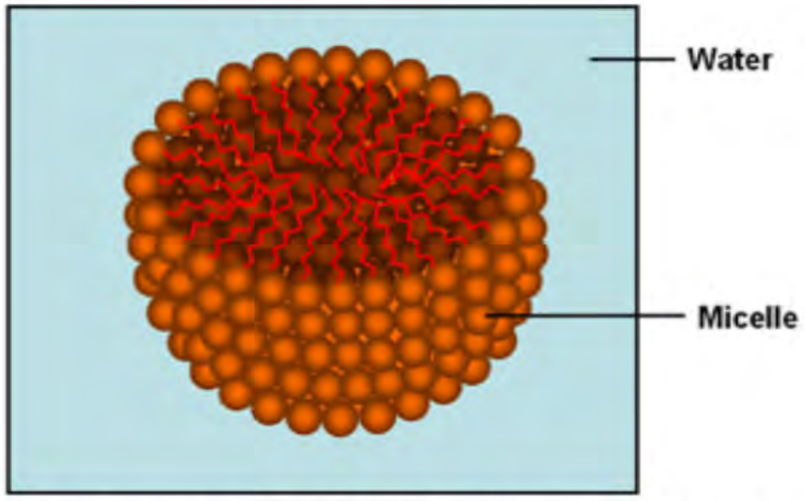
DRAW IT *Draw an oval around the hydrophilic head of the space-filling model.*



(c) Phospholipid symbol

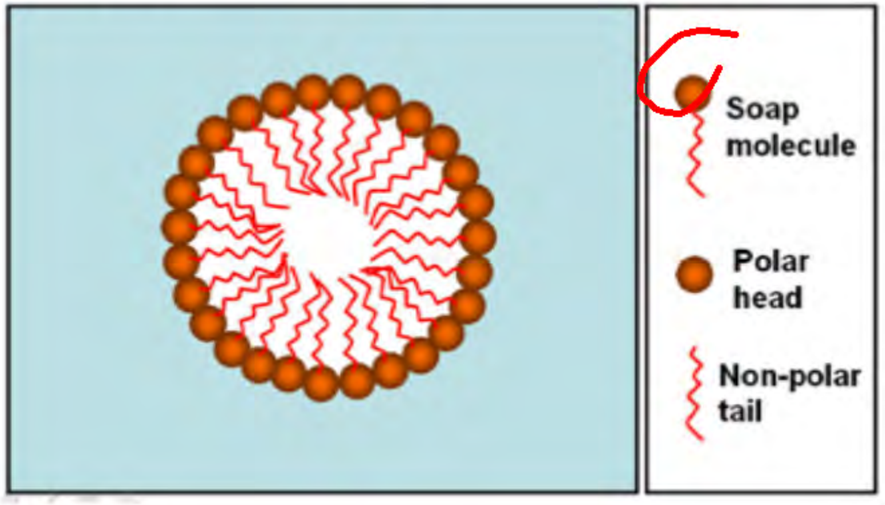


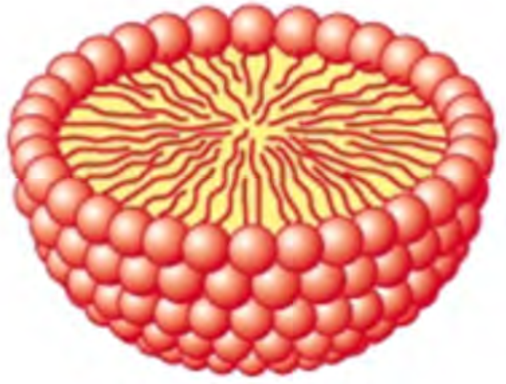
(d) Phospholipid bilayer



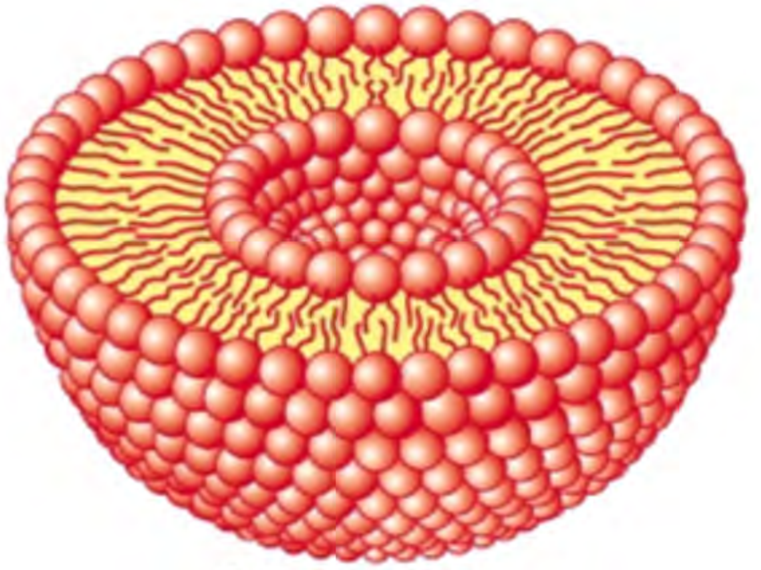
Above: a soap micelle with its top cut off – note the oil-like hydrocarbon non-polar tails aggregated in the centre and the polar heads on the outside facing the surrounding water.

Below: a slice through the same micelle.

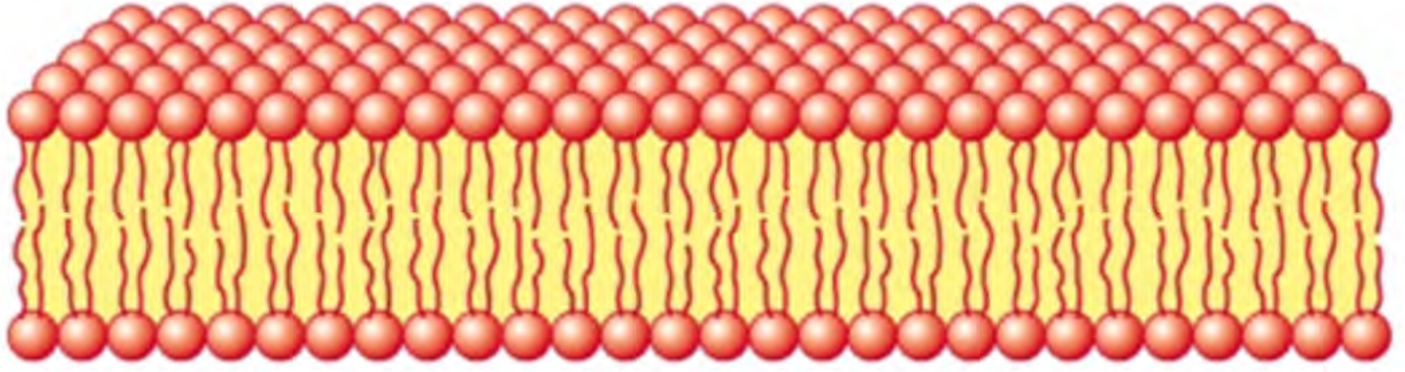




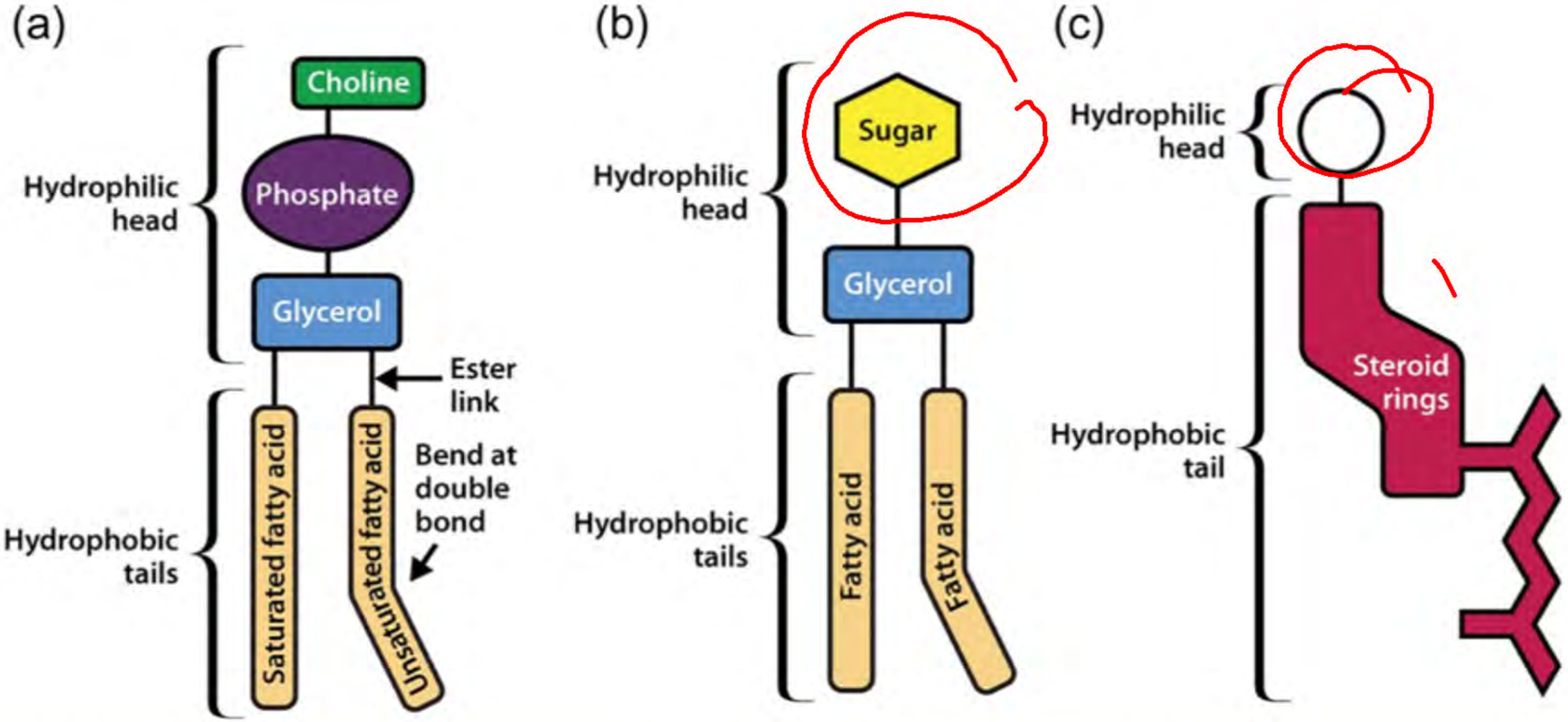
Micelle



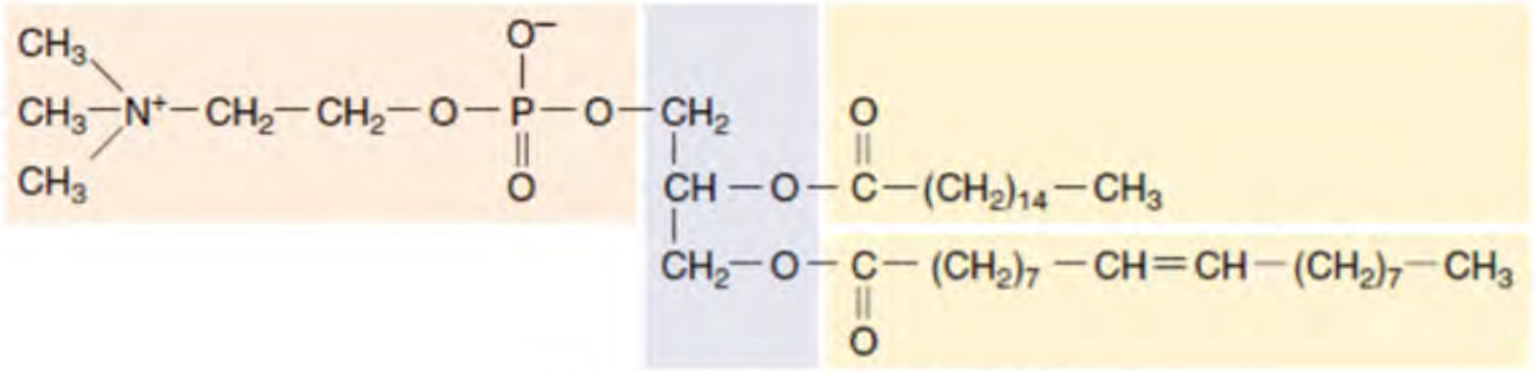
Liposome



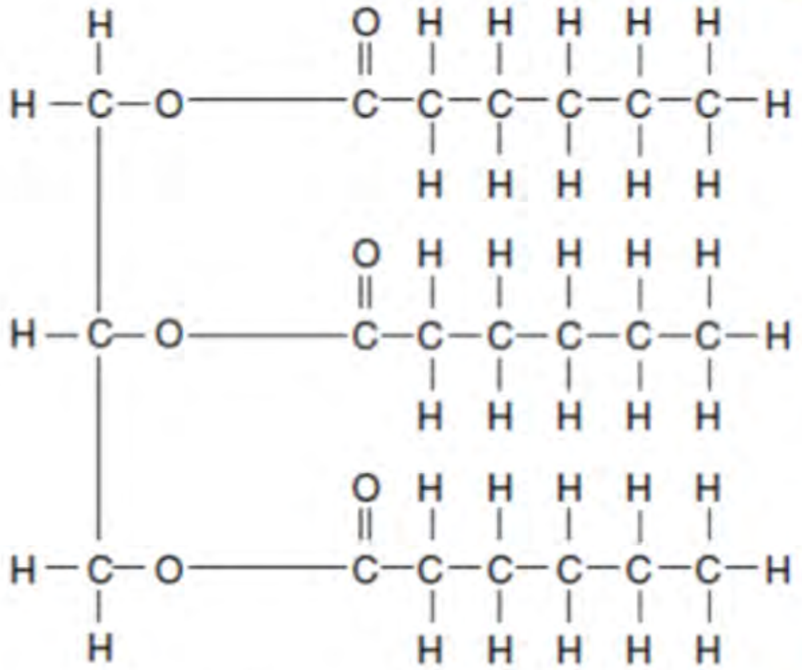
Bilayer sheet



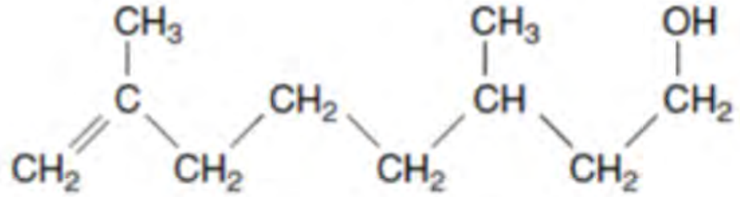
chematic representations of three types of membrane lipid.



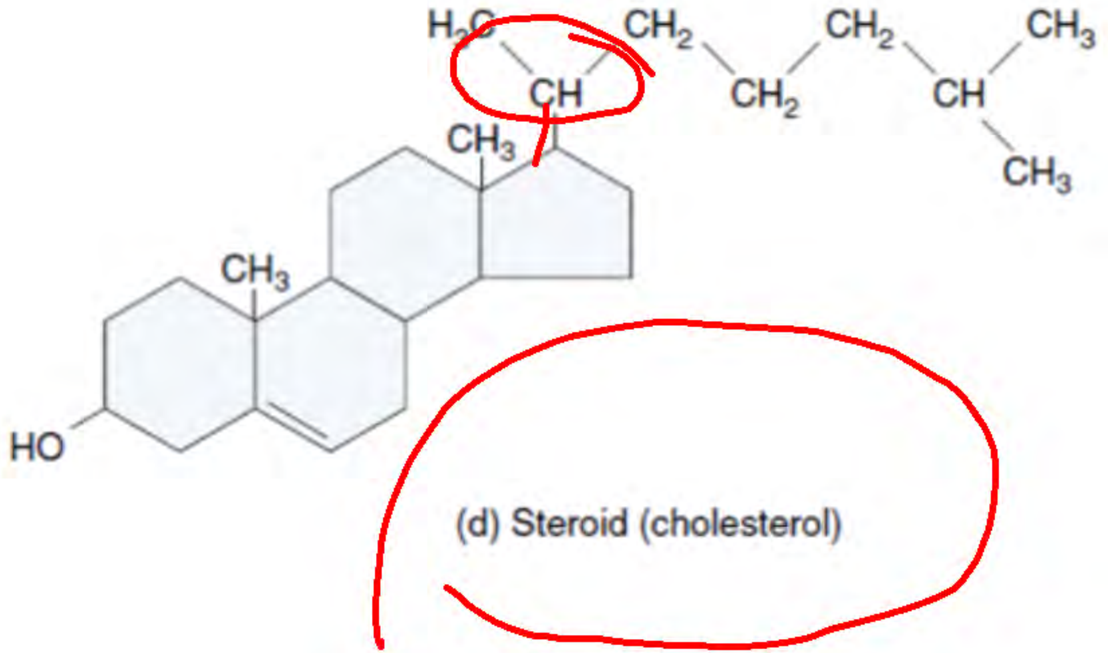
(a) Phospholipid (phosphatidyl choline)



(b) Triacylglycerol molecule



(c) Terpene (citronellol)

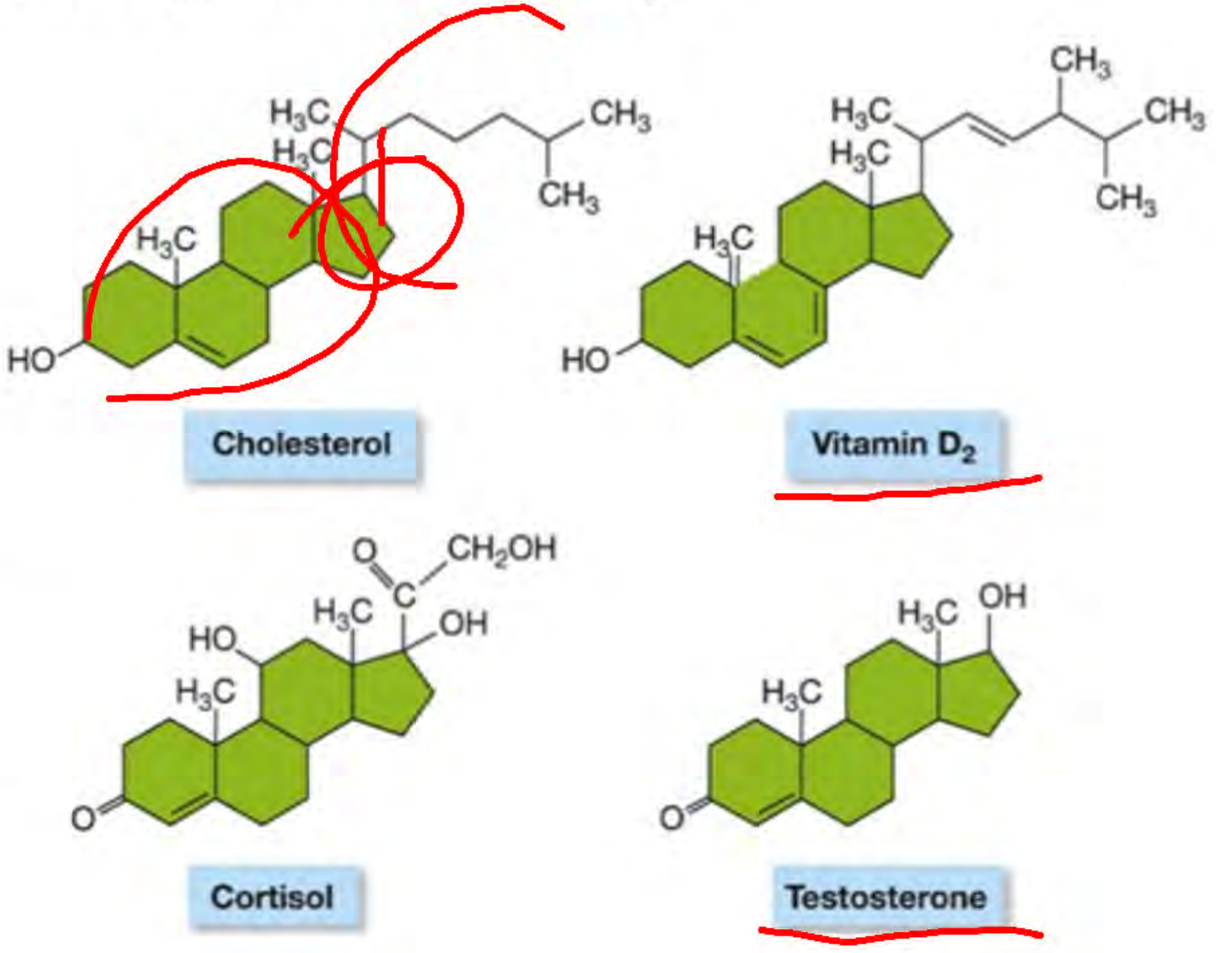


(d) Steroid (cholesterol)

FIGURE 3.19
Lipids. These structures represent four major classes of biologically important lipids: (*a*) phospholipids, (*b*) triacylglycerols (triglycerides), (*c*) terpenes, and (*d*) steroids.

Lipid (Steroids)

- Steroids
  - Are lipids characterized by a carbon skeleton consisting of four fused rings
  - Many hormones, including vertebrate sex hormones, are steroids produced from cholesterol
  - Steroids play a role in regulating cell activities



Cholesterol

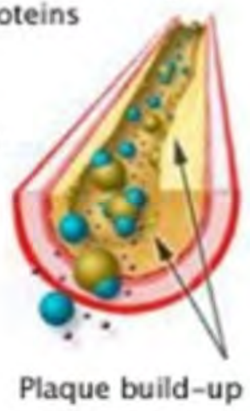
Cholesterol is a waxy fat carried through the bloodstream by lipoproteins

LDL: low density lipoproteins, or "bad cholesterol"

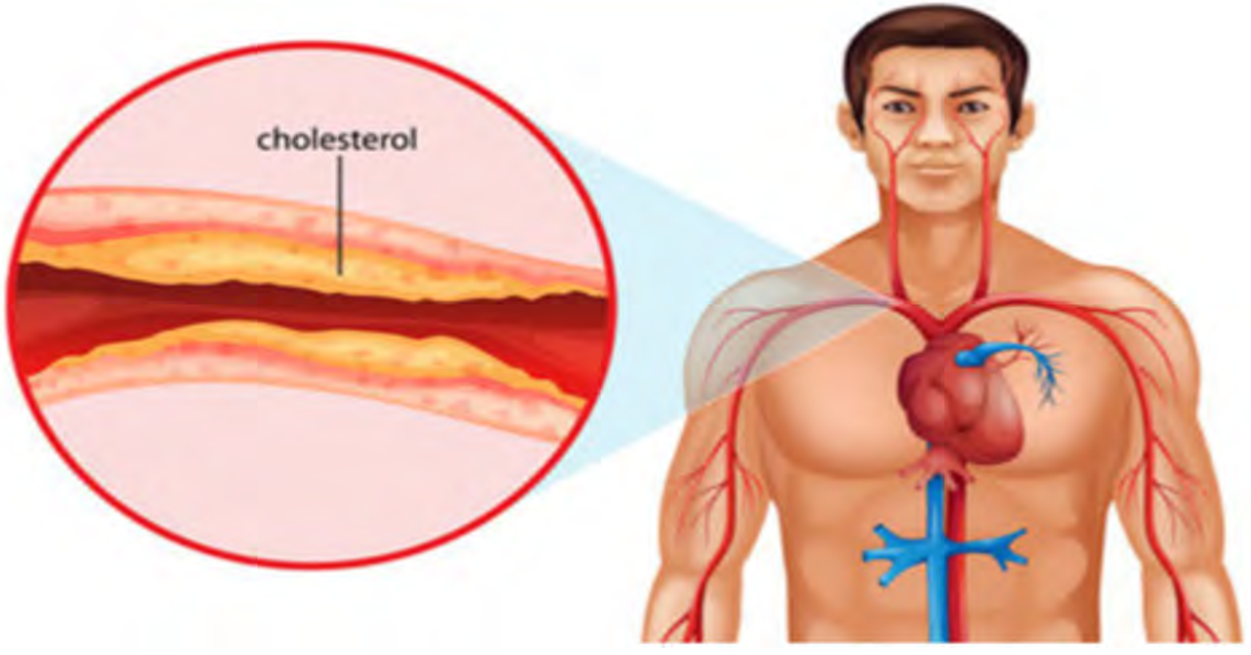
HDL: high-density lipoproteins, or "good cholesterol"

Triglycerides

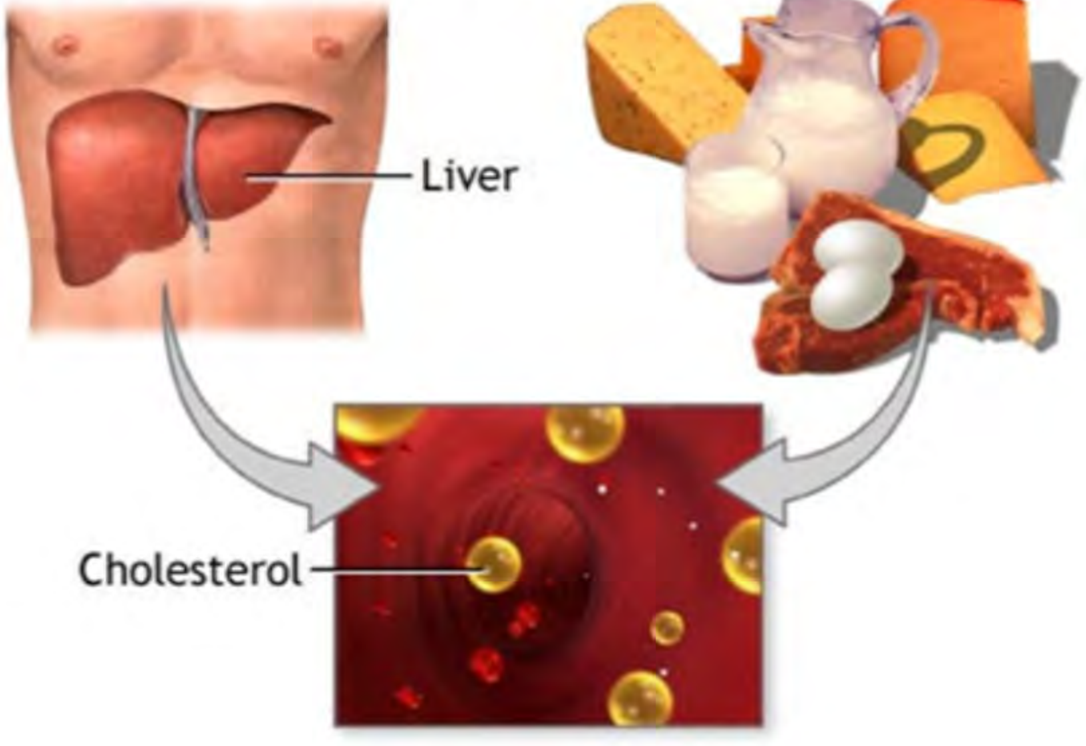
Total cholesterol



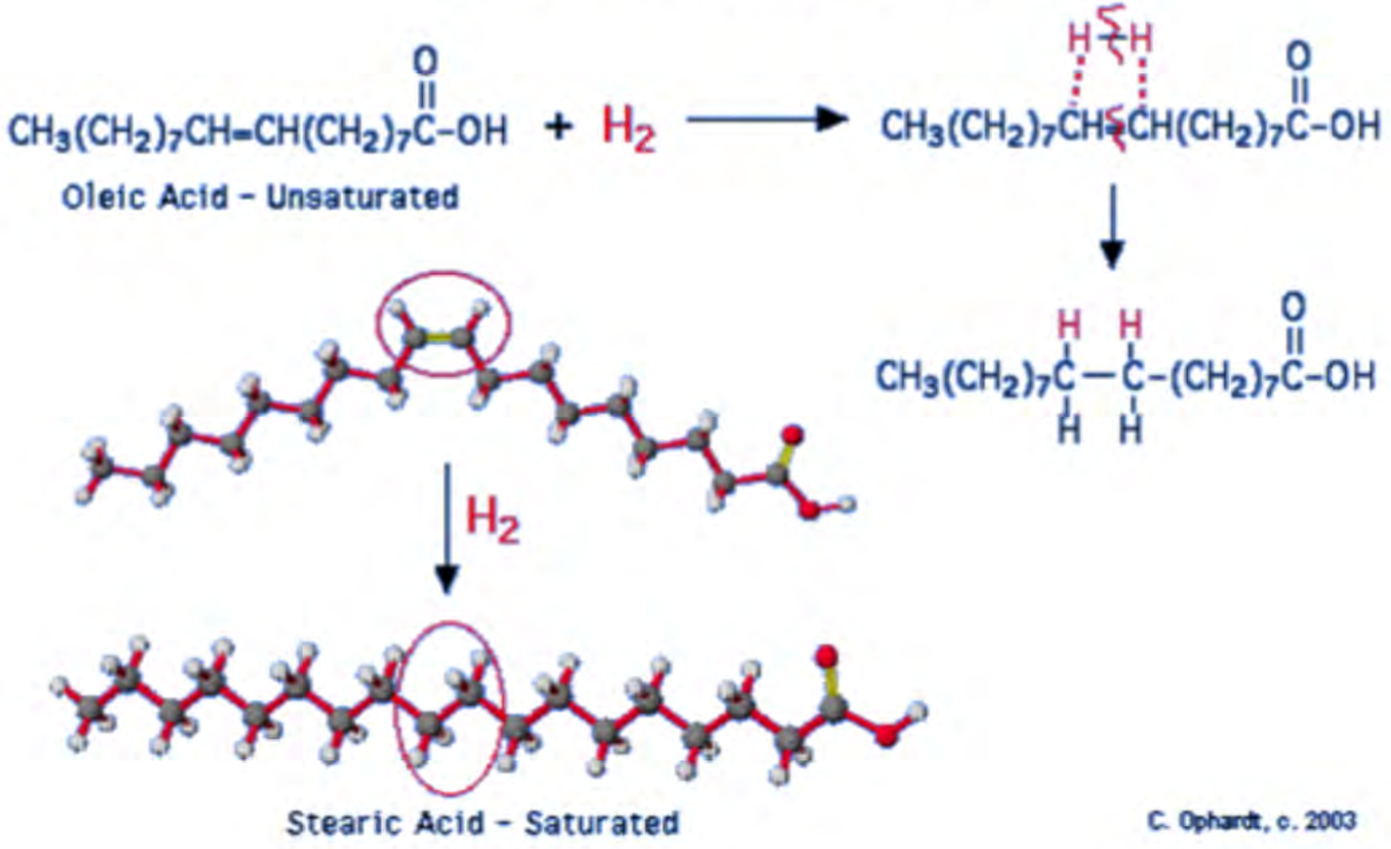
Plaque build-up

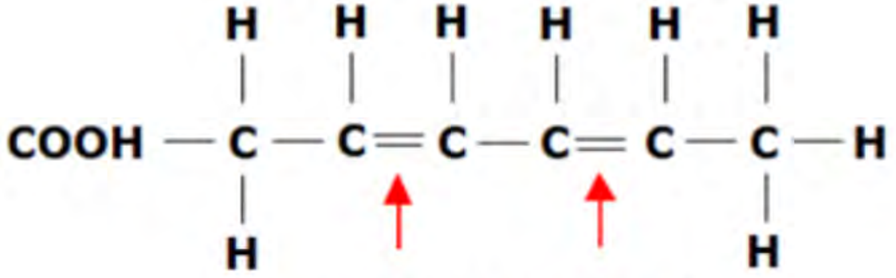


Cholesterol is produced by the liver and we consume it from meat and dairy products



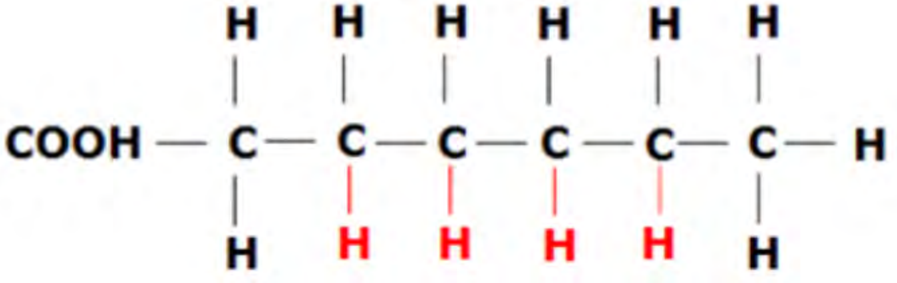
Hydrogenation of Oleic Acid



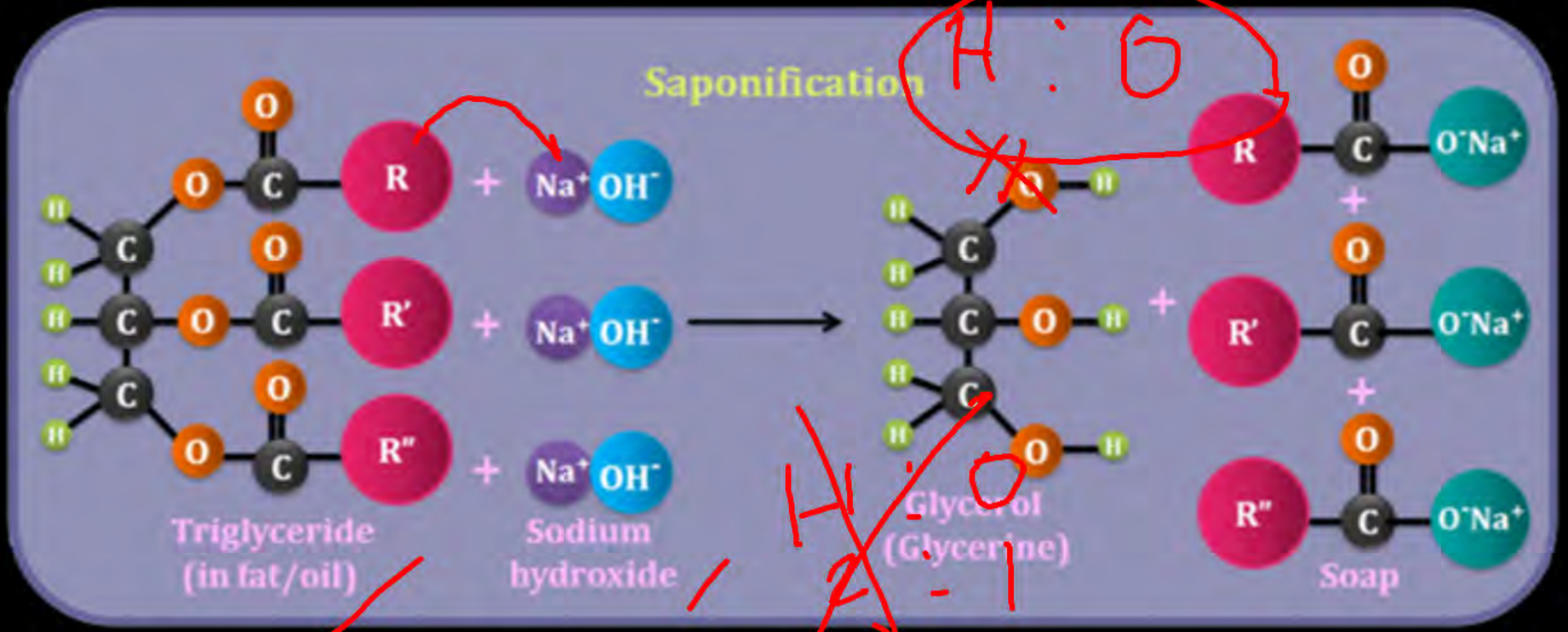


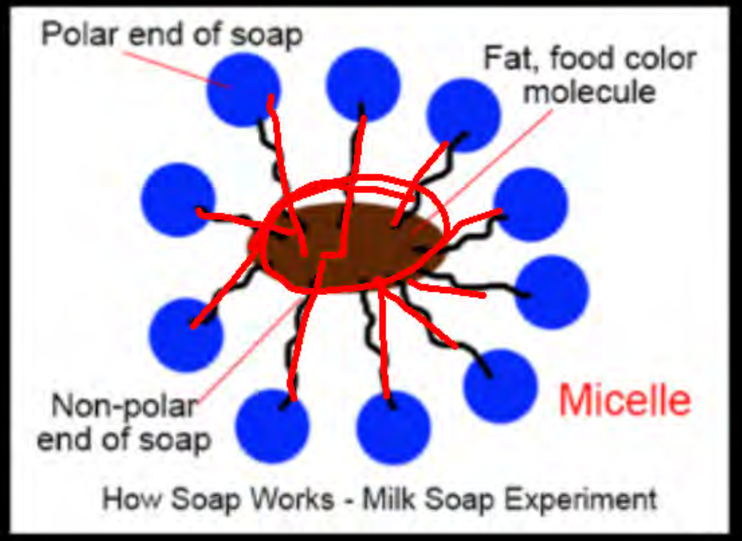
Polyunsaturated Fat

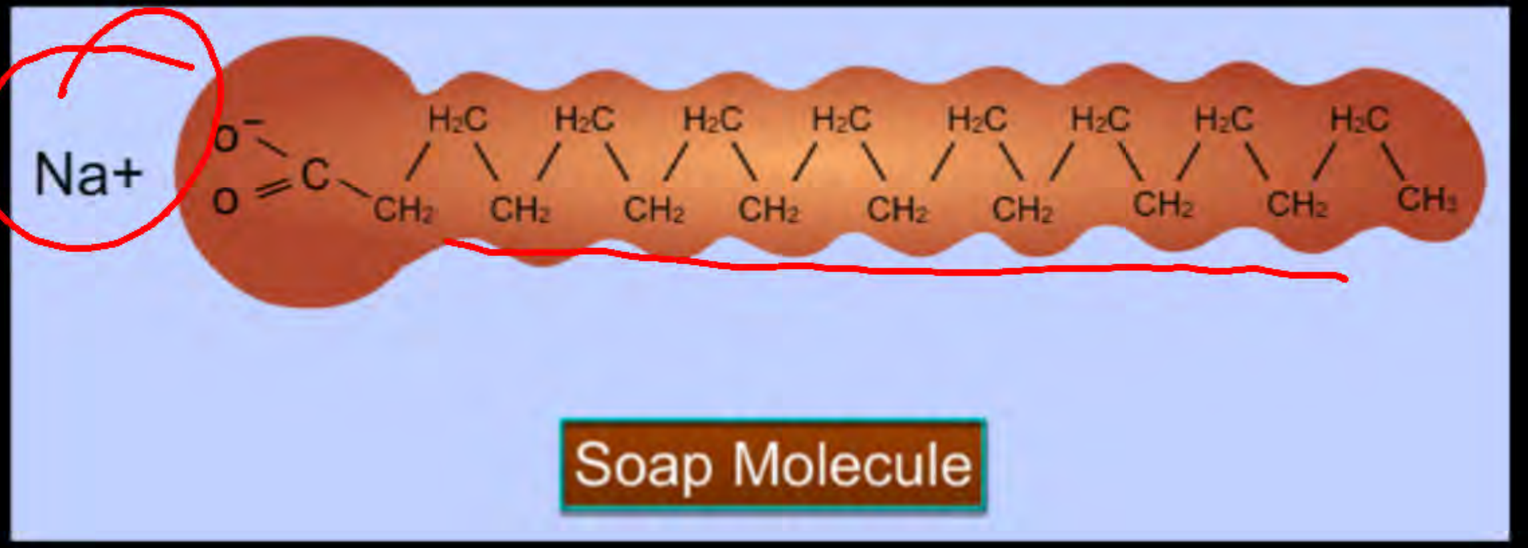
Hydrogenation



Hydrogenated Fat


Saponification
Triglyceride
(in fat/oil)
Sodium
hydroxide
Glycerol
(Glycerine)
Soap


Polar end of soap
Fat, food color molecule
Non-polar end of soap
Micelle
How Soap Works - Milk Soap Experiment


Na+
Soap Molecule

Protein