# Chapter 6 Lipids

## 6.4
## Waxes, Fats, and Oils



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## 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 | $CH_3(CH_2)_{14}-C(=O)-O-(CH_2)_{29}CH_3$ | Honeycomb | Candles, shoe polish, wax paper |
| Carnauba wax | $CH_3(CH_2)_{24}-C(=O)-O-(CH_2)_{29}CH_3$ | Brazilian palm tree | Waxes for furniture, cars, floors, shoes |
| Jojoba wax | $CH_3(CH_2)_{18}-C(=O)-O-(CH_2)_{19}CH_3$ | Jojoba | Candles, soaps, cosmetics |



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## 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

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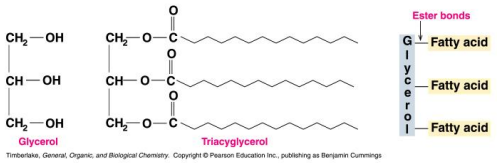
## Triacylglycerols

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



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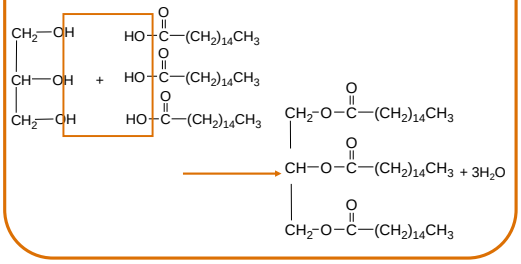
## Formation of a Triacylglycerol

**glycerol + three fatty acids → triacylglycerol**



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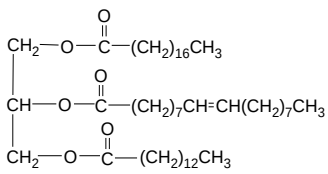
## Learning Check

What are the fatty acids in the following triacylglycerol?



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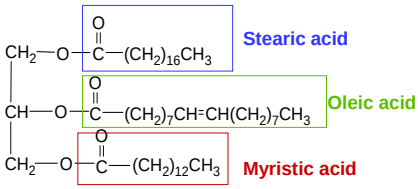
## Solution

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## 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.

Melting points are determined by the fatty acids in the triglyceride.

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## 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.


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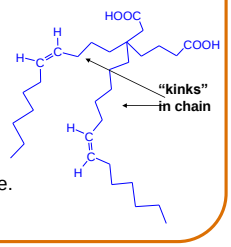
## Properties of Unsaturated Fatty Acids

**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.

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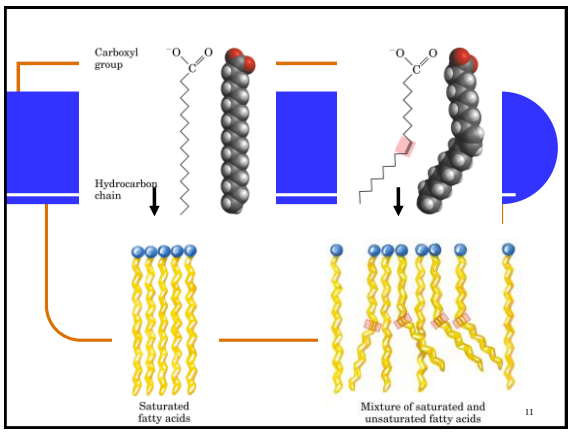


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chain length ⟶ melting point ↑

unsaturation ⟶ melting point ↓

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## Melting Points of Some Fatty Acids

| Name | Carbon Atoms | Double Bonds | Structure | Melting Point (°C) |
|---|---|---|---|---|
| **Saturated** | | | | |
| Lauric acid | 12 | 0 | $CH_3—(CH_2)_{10}—COOH$ | 43 |
| Myristic acid | 14 | 0 | $CH_3—(CH_2)_{12}—COOH$ | 54 |
| Palmitic acid | 16 | 0 | $CH_3—(CH_2)_{14}—COOH$ | 62 |
| Stearic acid | 18 | 0 | $CH_3—(CH_2)_{16}—COOH$ | 69 |
| **Unsaturated** | | | | |
| Palmitoleic acid | 16 | 1 | $CH_3—(CH_2)_5—CH=CH—(CH_2)_7—COOH$ | 0 |
| Oleic acid | 18 | 1 | $CH_3—(CH_2)_7—CH=CH—(CH_2)_7—COOH$ | 13 |
| Linoleic acid | 18 | 2 | $CH_3—(CH_2)_4—CH=CH—CH_2—CH=CH—(CH_2)_7—COOH$ | −9 |



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## COMMON STRAIGHT CHAIN SATURATED FATTY ACIDS

| No of C atoms | STRUCTURE | SYSTEMATIC NAME | COMMON NAME | MP °C | SHORTHAND |
|---|---|---|---|---|---|
| 10 | $CH_3(CH_2)_8COOH$ | n-decanoic acid | capric acid | 31.6 | $C_{10:0}$ |
| 12 | $CH_3(CH_2)_{10}COOH$ | n-dodecanoic acid | lauric | 44.2 | $C_{12:0}$ |
| 14 | $CH_3(CH_2)_{12}COOH$ | n-tetradecanoic | myristic | 53.9 | $C_{14:0}$ |
| 16 | $CH_3(CH_2)_{14}COOH$ | n-hexadecanoic | palmitic | 63.1 | $C_{16:0}$ |
| 18 | $CH_3(CH_2)_{16}COOH$ | n-octadecanoic | stearic | 69.6 | $C_{18:0}$ |
| 20 | $CH_3(CH_2)_{18}COOH$ | n-eicosanoic | arachidic | 76.5 | $C_{20:0}$ |
| 24 | $CH_3(CH_2)_{22}COOH$ | n-tetracosanoic | lignoceric | 86.0 | $C_{24:0}$ |

2. Biophysical/fatty acids

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## STRAIGHT CHAIN UN-SATURATED

| No of C atoms | STRUCTURE / SYSTEMATIC NAME | COMMON NAME | MP °C | SHORTHAND |
|---|---|---|---|---|
| 16 | $CH_3(CH_2)_5CH=CH(CH_2)_7COOH$ cis-9-hexadecanoic acid | palmitoleic | −0.5 | $C_{16:1}\ \Delta^9$ |
| 18 | $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ cis-9 octadecanoic acid | oleic | 13.4 | $C_{18:1}\ \Delta^9$ |
| 18 | $CH_3(CH_2)_4CH=CH-CH_2-CH=CH(CH_2)_7COOH$ cis cis-9,12 octadecanoic acid | linoleic | −5.0 | $C_{18:2}\ \Delta^{9,12}$ |
| 18 | $CH_3CH_2CH=CH-CH_2-CH=CH-CH_2-CH=CH(CH_2)_7COOH$ all cis-9,12,15 octadecanoic acid | linolenic | −11.0 | $C_{18:3}\ \Delta^{9,12,15}$ |
| 20 | $CH_3(CH_2)_4CH=CH-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH(CH_2)_3COOH$ | arachidonic | −49.5 | $C_{20:4}\ \Delta^{5,8,11,14}$ |

2. Biophysical/fatty acids

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## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting

**Fats**

- Fat, derived from animals, is a solid or semi-solid at room temperature,
- Intermolecular attractions explain why fats are solid and oils are liquids at room temperature.

## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- When the hydrocarbon chains of fatty acids are mostly saturated, the triglyceride is a *fat*.
- The saturated hydrocarbon chains allow the fatty acid chains in a fat to be closer together, allowing for more London forces.

## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- The increase in molecular interactions in a fat slows the motion of the molecules down, thereby allowing the molecules of a fat to form a solid.
- Fats melt at body temperature because the intermolecular forces that must be disrupted are weak London forces.
- Because the melting points are low, fats are often referred to as ***semisolids***.

## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- **Oil** is a liquid at room temperature.
- If the chains are mostly unsaturated, the triglyceride is an *oil*.
- The unsaturated hydrocarbon chains of an oil are farther apart, which results in a decrease in attractive forces between the chains.



## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

**Oils**

- Oils are derived from plants and are liquids at room temperature.
- The hydrocarbon chains of oils are unsaturated, containing double bonds with a cis configuration.
- The cis configuration forms kinks in the hydrocarbon chains, preventing chains from stacking together as closely as those in a fat.

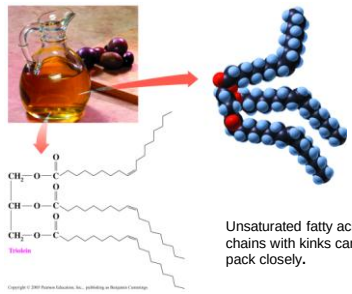



## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- This decrease in interaction results in less London forces, which means the chains in oils are less attracted to one another and move more freely.
- Greater molecular movement of the hydrocarbon tails in an oil does not allow enough stacking of the tails to form a solid, therefore oils are liquids at room temperature.



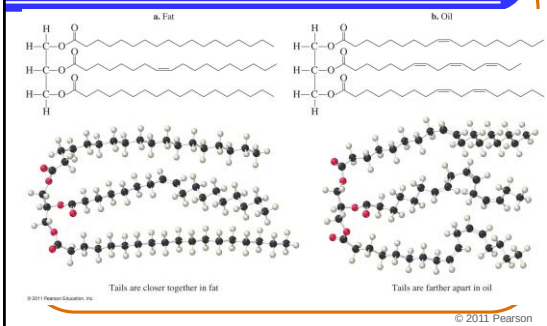

## Diagram of Triacylglycerol with Unsaturated Fatty Acids



Unsaturated fatty acid chains with kinks cannot pack closely.



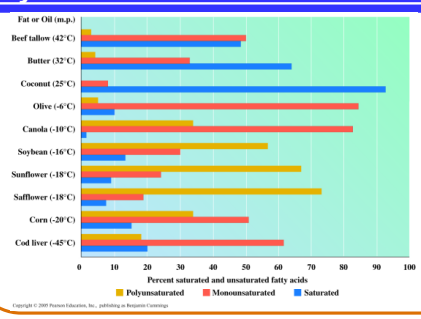
## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued







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



## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- Oils derived from plants are healthier alternatives for human dietary fat requirements.
- Oils are not always the most convenient form of triglycerides. They are unstable. So food chemists have come up with a way to stabilize them called **hydrogenation.**

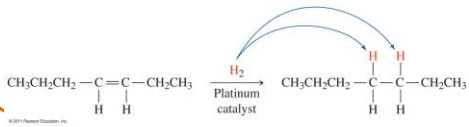
## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- Chemists have developed methods to convert liquid plant oils into solids like margarine.
- Conversion of liquid oils to margarine requires a process known as ***hydrogenation***.

## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- Hydrogenation involves the addition of hydrogen atoms to the carbon–carbon double bond of an unsaturated compound.
- Hydrogenation progresses more rapidly if a catalyst is included in the reaction. A ***catalyst*** speeds up a reaction but remains unchanged at the completion of the reaction.



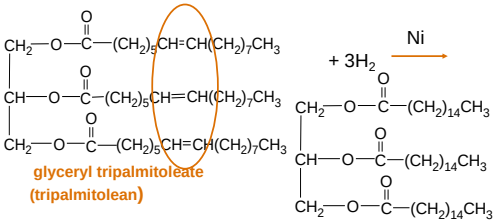
## Summary Hydrogenation of Oils

The **hydrogenation** of oils

- adds hydrogen ($H_2$) to the carbon atoms of double bonds.
- converts double bonds to single bonds.
- increases the melting point.
- produces solids such as margarine and shortening.




## Hydrogenation






## Learning Check

What products are obtained from the complete hydrogenation of glyceryl trioleate?

1. Glycerol and 3 oleic acids
2. Glyceryltristearate
3. Glycerol and 3 stearic acids

## Solution

What products are obtained from the complete hydrogenation of glyceryl trioleate?

2. Glyceryltristearate

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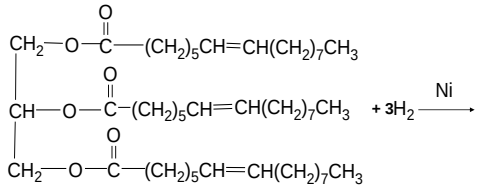
## Learning Check

Write the product of the following reaction.

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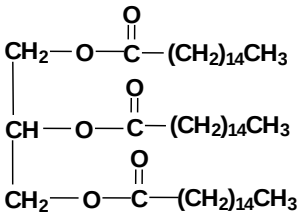
## Solution



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## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

### Partial Hydrogenation

- This controlled process, known as ***partial hydrogenation***, allows production of margarines that are solid yet easier to spread than more solid butter.
- Partial hydrogenation produces margarines that are less saturated than butter, making them easier to spread.




## Hydrogenation and Trans Fatty Acids

Most naturally occurring fatty acids have *cis* double bonds.

- During hydrogenation, some *cis* double bonds are converted to *trans* double bonds.
- In the body, *trans* fatty acids behave like saturated fatty acids.
- It is estimated that 2-4% of our total Calories is in the form of *trans* fatty acid.
- Several studies reported that *trans* fatty acids raise LDL-cholesterol and lower HDL-cholesterol.

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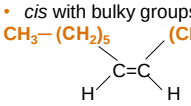
## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued

- **Partial hydrogenation** of double bonds causes the favorable cis configuration of the double bonds to convert to the less favorable trans configuration, resulting in the compounds known as ***trans fats***.
- Some studies have shown that trans fats have deleterious health effects. This led to consideration of alternatives. Food labels must contain the amounts of trans fatty acids present in food.

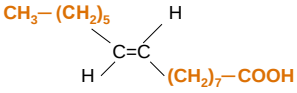
## *Cis* and *Trans* Fatty Acids

Unsaturated fatty acids can be

- *cis* with bulky groups on same side of C=C.




- *trans* have bulky groups on opposite sides of C=C.

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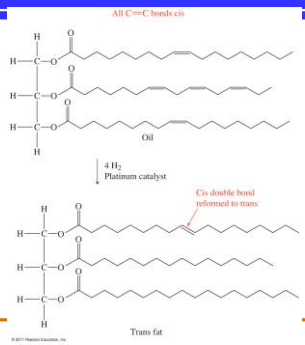
## 6.4 Fats, Oils, and Margarine—Solid to Liquid and Back Again: Melting, Continued







## Learning Check

(1) True or (2) False

A. There are more unsaturated fats in vegetable oils.
B. Vegetable oils have higher melting points than fats.
C. Hydrogenation of oils converts some *cis*-double bonds *to trans*- double bonds.
D. Animal fats have more saturated fats.

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## Solution

(1) True or (2) False

A. **T** There are more unsaturated fats in vegetable oils.
B. **F** Vegetable oils have higher melting points than fats.
C. **T** Hydrogenation of oils converts some *cis*-double bonds *to trans*- double bonds.
D. **T** Animal fats have more saturated fats.

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## 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.

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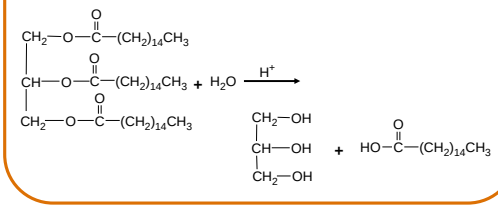
## Hydrolysis

In **hydrolysis**,

- triacylglycerols split into glycerol and three fatty acids.
- an acid or enzyme catalyst is required.

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## 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.

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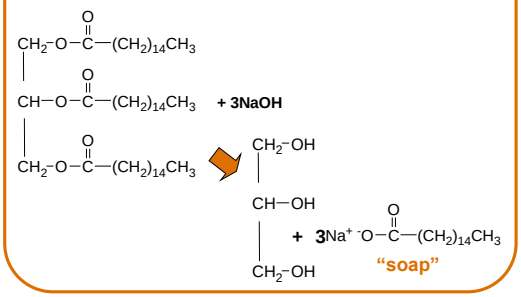
## Saponification

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## Learning Check

What products are obtained from the complete hydrolysis of glyceryl trioleate?

1. Glycerol and 3 oleic acids
2. Glyceryl tristearate
3. Glycerol and 3 stearic acids

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## Solution

What products are obtained from the complete hydrolysis of glyceryl trioleate?

1. Glycerol and 3 oleic acids

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