Fats Oils and Detergents

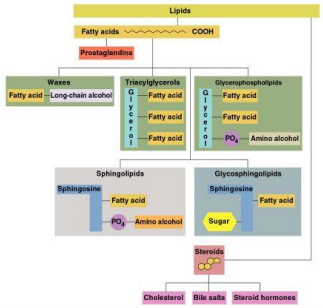
What are Lipids?

- Lipids are a group of naturally occurring molecules that include fats, waxes, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), monoglycerides, diglycerides, triglycerides, phospholipids, and others.
- The main biological functions of lipids include storing energy, signaling, and acting as structural components of cell membranes.

What are Lipids?

- **A family of compounds that includes**
  - **Triglycerides (fats & oils)**
    - **Fats: lipids that are solid at room temperature**
    - **Oils: lipids that are liquid at room temperature**
  - **Phospholipids**
  - **Sterols (cholesterol)**

Classification of Lipids



Lipids

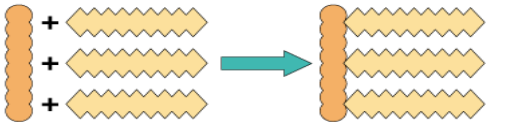
- Basic functions in the body
  - **Fats**
    - Store and provide energy (9 kcal per gram)
    - Provide insulation
    - Provide structure
  - **Cholesterol**
    - Cell membrane structure
    - Used to make steroid hormones, bile, and provitamin D
  - **Phospholipids**
    - Help transport fat-soluble nutrients in the blood
    - Cell membrane structure

Lipid Terminology

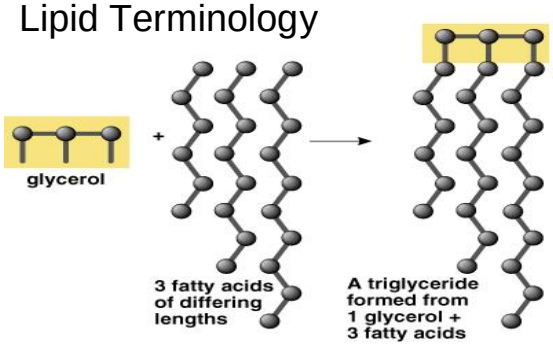
- Triglycerides
  - The major class of dietary lipids, including fats & oils
    - Made up of 3 units known as fatty acids and 1 unit called glycerol (backbone)
    - Comprise about 95% of lipids in food and the human body

Lipid Terminology

Glycerol + 3 fatty acids = Triglyceride

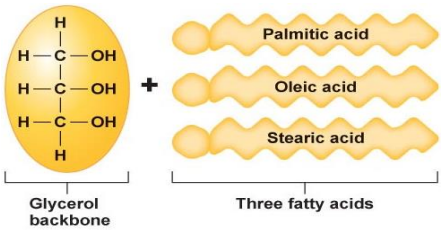


Lipid Terminology



Triglycerides

- Three fatty acids connected to a glycerol backbone



Triglycerides

- Most common lipid both in foods and in the body
- Make up about 95% of lipids found in foods
- Functions
  - Add texture
  - Add flavor to foods
  - Make meats tender
  - Energy storage in adipose tissue

Caution: High levels in the blood are a risk factor for heart disease

Lipid Terminology

- **Phospholipids:**
  - **2nd of three main classes of lipids**
  - **similar to a triglyceride, but contains phosphorous**
- **Sterols**
  - **3rd of three main classes of lipids;**
  - **Cholesterol**
    - **one of the sterols**
    - **manufactured in the body for a variety of purposes**

Lipid Terminology

- **Fatty acids**
  - Basic units of fat composed of chains of carbon atoms
  - An acid group at one end and hydrogen atoms attached all along their length

Fats and Fatty Acids

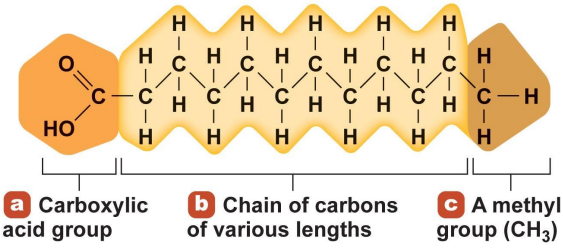
- Fatty acids are the building blocks of fat molecules
- Fat molecules are a compound made up of three fatty acids and one glycerol

Fats and Fatty Acids

- A free fatty acid is a carboxylic acid with the long hydrocarbon tail.
- Three free fatty acids can combine with a fourth molecule called glycerol through an esterification reaction to create a fat molecule

Fatty Acids

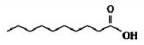
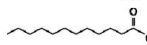
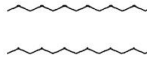
- Building blocks for triglycerides and



Fatty Acids

- Higher ratio of carbon and hydrogen to oxygen than in carbohydrates and protein
- 20 different fatty acids with varied length, saturation, and shape
- Different structures impart different characteristics

Common Fatty Acids

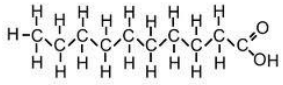
Name	Carbon Atoms	Structure	Melting Point (°C)	Source
Saturated Fatty Acids				
Capric acid	10		32	Saw palmetto
Lauric acid	12		43	Coconut
Myristic acid	14		54	Nutmeg
Palmitic acid	16		62	Palm
Stearic acid	18		69	Animal fat
Arachidic acid	20		76	Peanut oil, vegetable and fish oils

Fatty Acids Vary in Length

- **Short-chain fatty acids**
  - Two to four carbons
  - Liquid at room temperature
- **Medium-chain fatty acids**
  - Six to ten carbons
- **Long-chain fatty acids**
  - 12 or more carbons
  - Most common type of fatty acid in foods

Fatty Acids Vary in Saturation

- **Saturated fatty acids**
  - All the carbons on the fatty acid are bound to hydrogen
  - Usually more solid at room temperature
  - Higher melting point
  - More stable

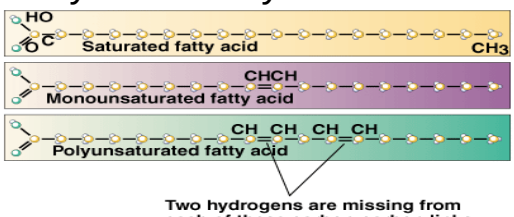


Saturated Fatty Acid

Fatty Acids Vary in Saturation

- **Unsaturated fatty acids**
  - Some carbons form a double bond with each other instead of binding to hydrogen
  - **Monounsaturated fatty acid** (MUFA)
    - Has one carbon to carbon (C=C) double bond
  - **Polyunsaturated fatty acid** (PUFA)
    - Has two or more carbon to carbon (C=C)double bonds
    - More liquid at room temperature
    - Lower melting point
    - Less stable

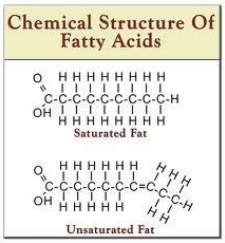
Fatty Acids Vary in Saturation



Two hydrogens are missing from each of these carbon-carbon links, making the fatty acid polyunsaturated. With fewer hydrogens to attach to, these carbons are doubly bonded to each other. Monosaturated fatty acids have only one carbon-carbon bond.

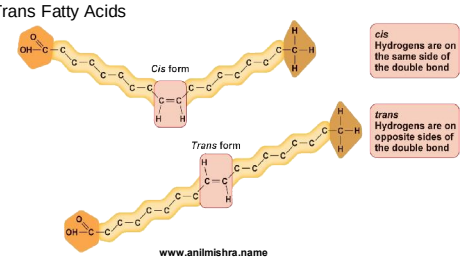
Fatty Acids Vary in Saturation

- Saturated and Monounsaturated Fatty Acids



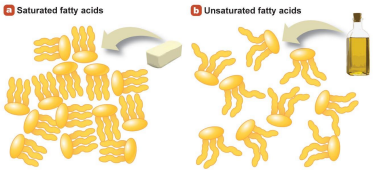
Fatty Acids Vary in Saturation

- Unsaturated fatty acids form two different shapes
  - Cis Fatty Acids
  - Trans Fatty Acids



Fatty Acids Vary in Saturation

- Saturated and Unsaturated Fatty Acids Help Shape Foods



The Essential Fatty Acids

Fatty Acids Differ in Double-Bond Location

- The location of the first double bond in unsaturated fatty acids affects the naming and characteristics of the unsaturated fatty acids

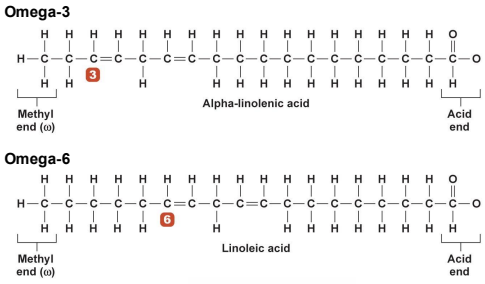
- **Omega-3 fatty acid**
  - First double bond is between the third and fourth carbon from the **omega** end
  - Example: alpha-linolenic acid (ALA)
    - One of the two essential fatty acids

The Essential Fatty Acids

Fatty Acids Differ in Double-Bond Location

- **Omega-6 fatty acid**
  - First double bond is between the sixth and seventh carbon from the **omega** end
  - Example: linoleic acid
    - One of the two essential fatty acids

The Essential Fatty Acids



What is a fat?

FAT

- Is a nutrient
- Is a source of energy
- Adds taste and texture to foods
- Makes us feel full longer
- Helps absorb fat-soluble vitamins

What is a fat?

- Fats are nutrients in food that the body uses to build nerve tissue (including the brain and nerves) and hormones.
- The body also uses fat as fuel.
- Unused fats are stored by the body in fat cells.

Where is fat found?

- **Easy to see**
  - **Fat added to foods**
    - Butter, margarine, oil
  - **Fat on the outside of foods**
    - Chicken skin, outside trim on meat
- **Hidden**
  - **Ingredient**
    - Snack foods, baked products, desserts
  - **Added in cooking**
    - Fried foods, cream soups, sauces

Oils and Fats

- Fats that are LIQUID at room temperature are called OILS.
  - **Examples: vegetable oil, canola oil, olive oil, etc.**

Oils and Fats

- Fats that are SOLID or firm at room temperature are called FATS.
  - Examples: lard, butter, shortening, etc.

Types of Fat

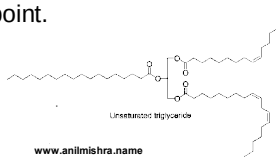
- All fat-containing foods have a mixture of different fats
- Types of fats include:
  - Polyunsaturated fats (PUFA)
  - Monounsaturated fats (MUFA)
  - Saturated fats (SFA)
  - Trans fats (TFA)

Unsaturated Fats

- Found in plant foods and fish, these fats are seen as neutral or even beneficial to heart health.
- The types of unsaturated fats are:
  - **Monounsaturated**,
  - **Polyunsaturated**,
    - found in most vegetable oils
  - **Omega-3 fatty acids**,
    - a type of polyunsaturated fat found in oily fish like tuna and salmon

Unsaturated Fats

- Unsaturated triglyceride molecules cannot pack closely together because of *cis* double bonds - causes kinks!
- Intermolecular forces are weaker.
- Less energy needed to separate molecules - lower melting point.



Unsaturated Fats

Monounsaturated Fats

- Considered ñgoodòfats because they help decrease the risk of heart disease
- Examples: Olive oil, canola oil, margarine made with canola, peanuts, nuts (almonds, cashews, hazelnuts, pecans)

Unsaturated Fats

Polyunsaturated Fats

- **Some are "essential" because the body cannot make them:**
  - Omega-3 fats can help decrease the risk of heart disease
  - Omega-3 fats are found in fish, flaxseed and omega-3 eggs
- **Other foods with PUFA are**
  - vegetable oils (corn, soybean, sunflower), margarines made with vegetable oils, walnuts, sunflower seeds, sesame seeds

Saturated Fats

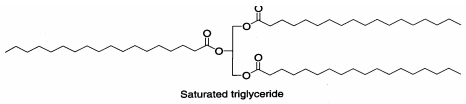
- Saturated fats are found in meat and other animal products, such as butter, shortening, lard, cheese, and milk (except skim or nonfat),
- Saturated fats are also in palm and coconut oils, which are often used in commercial baked goods.
- Eating too much saturated fat can raise blood cholesterol levels and increase the risk of heart disease.

Saturated Fats

- Diets high in saturated fats can increase the risk of heart disease
  - Examples: butter, cakes and pastries, chocolate bars, coconut, coffee whitener are all high in saturated fat
- Other sources of saturated fat include untrimmed meat and higher fat dairy products (e.g., cheese, cream)

Saturated Fats

- Fatty acids present in mixture affect the properties.
- Saturated triglycerides pack closely together.
- Attractive forces - higher melting point.



Saturated triglyceride

Saturated Fats

- These are solid at room temperature due to their molecular shape.
- The term saturated is in reference to an sp^3 carbon chain that has its remaining sp^3 orbitals bonded with hydrogen atoms.
- Thus the term ñsaturatedò Itôs ñsaturatedò with hydrogen.

Saturated Fats

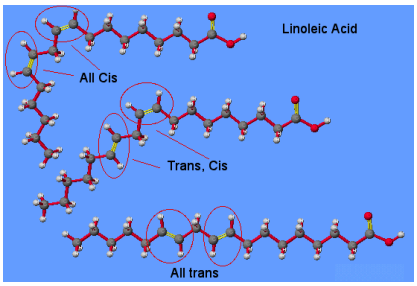
- Saturated fats have a chain like structure which allows them to stack very well forming a solid at room temperature.
- Unsaturated fats are not linear due to double bonded carbons which results in a different molecular shape because the sp^2 carbons are trigonal planar, not tetrahedral (sp^3 carbons) as the carbons are in saturated fats.

Saturated Fats

- This change in structure will cause the fat molecules to not stack very well resulting in fats that are liquid at room temperature.
  - Butter is mostly saturated fat, that's why it's solid at room temperature.
  - Olive Oil is liquid at room temperature, thus it's an unsaturated fat.
- An unsaturated fat can be made in to a saturated fat via hydrogenation reactions.

Unsaturated Fats

Cis and Trans Fats



Trans Fats

- Trans fatty acids are unsaturated fatty acids that have at least one double bond in the trans configuration.
- While most unsaturated fatty acids in foods have the cis configuration, trans fatty acids may also be present.

Trans Fats

- Trans fatty acids in foods originate from three main sources:
  - Bacterial transformation of unsaturated fatty acids in the rumen of ruminant animals.
    - They can subsequently be present in the meat and milk of the animal
  - Hydrogenation and deodorization of unsaturated vegetable oils (or occasionally fish oils) high in polyunsaturated fatty acids
  - During the heating and frying of oils at high temperatures

Trans Fats

- Trans fats (also called trans fatty acids) are created when vegetable oils are hydrogenated
  - Hydrogen atoms are added to the fat molecule so they remain solid at room temperature.

Trans Fats

- Are made from hydrogenation
  - This makes oils more firm.
- Act like saturated fats in the body
- Most found in commercially prepared foods
  - some French fries, potato chips, donuts, cookies, crackers, cereals, shortening, muffins, pizza crusts, buns, cakes

Trans Fats

- Trans fat is a fatty acid formed through a chemical process called hydrogenation.
- Hydrogen is added to liquid vegetable oils to reconfigure the fat molecules into solid fat.
  - Partial hydrogenation because it increases shelf life and flavor stability.
- Trans fat is most commonly found in processed foods: baked goods, crackers, snack foods, shortening and some margarines.

Fats and Health

Saturated vs Unsaturated Fats and Health:

- **Saturated fats** tend to **increase** the blood level of the "bad" LDL cholesterol.
- **Monounsaturated** (one double bond) and **polyunsaturated** fats (two or more double bonds) found primarily in vegetable oils tend to **lower "bad" LDL cholesterol.**
- An elevated LDL-C increases the risk of developing coronary heart disease.

Fats and Health

Why is trans fat unhealthy?

- TFAs, like saturated fats are also associated with increasing cholesterol in the blood.
- Although saturated fats also produce the 'good' cholesterol (HDL), trans fats increase levels of the 'harmful' cholesterol (LDL) and decrease the good cholesterol.
- Trans fat raises low-density lipoprotein (LDL, or ñbadò cholesterol) and reduces high-density lipoprotein (HDL, or ñgoodò cholesterol).

Oils

- Almost all oils and fats come from seeds (except for olive and avocado). They are required in the diet of most animals.
- Margarine and shortening are made by hydrogenation.

Extraction Methods

- The seeds are usually cleaned and then dehusked.
- Crushing - today done mostly with rollers.
  - A screw press makes it possible to have a continuous feeding of seeds.
  - The oil flows out Because there is still 2-4% oil in the meal, the material is extracted again with solvents in some cases.
- In some cases, the kernels are broken or flaked before extraction.

Extraction Methods

- Expression - cold and hot (where seeds are cooked first).
- Extraction - solvents (petroleum ether (hexane), chlorinated solvents).
- Boiling - centrifugation

Extraction Methods

Subsequent treatment of oils

- After isolation, the oils are treated for several reasons.
- In many cases, the oils are treated with caustic soda to remove any free fatty acids present.
- The oil may then be degummed, bleached, deodorized, and/or winterized.
  - Degumming is done by mixing the oil with water and centrifuging.

Extraction Methods

Subsequent treatment of oils

- Bleaching is usually done with Fuller's earth or activated charcoal.
- Deodorizing is often done with steam.
- Winterizing is cooling down the oil and removing materials that precipitate out.
- The fatty acids and triglycerides that precipitate out are called "foots".
- Most oils are treated to render them odorless and tasteless (and interchangeable).

Linseed oil

- This is probably the oldest domesticated oil seed crop.
- Flax or linseed (*Linum usitatissimum*, Linaceae) is from the Near Eastern Center.
- Fossil linseed shows signs of selection by 6000 B.C.

Linseed oil

- Linseed oil alone still used to finish many wood products.
- Linseed oil is used as an edible oil in some parts of the world, but has largely been replaced by other oils.
- Flax seed a major source of omega-3-fatty acids and may be valuable in human diets.

Flax, *Linum usitatissimum*, Linaceae

Tung Oil

***Aleurites fordii*, Euphorbiaceae**

- Tung oil is mostly from China.
- This small tree has fruits that contain a highly unsaturated but inedible oil.
- Tung oil one of the best quality furniture finishing oils.

Tung Oil

***Aleurites fordii*, Euphorbiaceae**

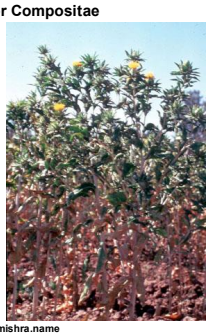
Safflower oil

***Carthamus tinctorius*, Asteraceae or Compositae**

- Safflower oil is unsaturated and is considered to be a good quality salad oil.
- Safflower was domesticated in the Mediterranean area. This species is only known in cultivation.
- Safflower was probably first grown for the yellow dye it produces.

Safflower oil

***Carthamus tinctorius*, Asteraceae or Compositae**



Soybeans

- Soybeans are, of course, an ancient crop
- In the Orient they are not usually used for oil purposes. Europeans began to press them back in the 1700's.
- Soybean is pressed for oil
  - The soybean is about 13-25% oil.
- The press cake is used for feeding livestock and as a human food additive.

Soybeans

Sunflower

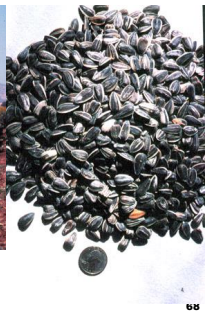
(*Helianthus annuus*) Asteraceae

- The sunflower was domesticated about 5000 years ago in Mexico and has become a major crop.
- The seeds were widely eaten by the American Indians.

Sunflower

- The cultivated types of sunflowers today are much larger than the wild ones.
- The plant is still a common weedy species in much of the Midwest.

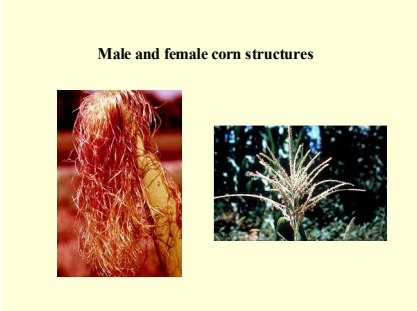
Sunflower

Corn or Maize

- Corn, of course, is cultivated for other purposes, but also for oil.
- The oil is a minor by-product of corn milling to isolate starch.
- The corn is steeped in sulfurous acid and then lightly macerated to separate the embryo from the endosperm.
  - The oil is isolated from the embryos.
- Most refined corn oil used for margarine and salad oils.

Corn or Maize



Sesame

(***Sesamum indicum*, Pedaliaceae**)

- Sesame oil an ancient crop. It probably arose in India.
- The oil has a relatively strong flavor and is much used in Chinese cooking.
- Sesame oil commonly used in Africa, the Middle East, India, and China.
- The seeds themselves are also widely eaten.

Sesame seed

Cotton

(***Gossypium hirsutum***, **Malvaceae**)

- Cotton widely grown for fiber.
- The seeds used as a source of edible oil for thousands of years.
- Cotton seed contains a toxic compound, gossypol. A problem in utilizing the press cake.
- David Wesson's process of purification with caustic soda, steam and fuller's earth removed much of the gossypol.
- Shortening was first made by hydrogenation of cottonseed oil.

Cotton field and cotton boll

Rapeseed or Canola

Brassica napus, **Brassicaceae or Cruciferae**

- Rapeseed or canola commonly grown in Canada and in Europe.
- The oil used for both a lubricant and as an edible oil. It is largely used to make margarine in Europe.
- Selection for low erucic acid lines (canola) for edible purposes and cultivation of erucic acid lines for lubricant purposes.
- The press cake of limited value for feeding livestock.

Peanut Oil

Arachis hypogaea, **Fabaceae or Leguminosae**

- Peanut oil widely used in the tropics.
- It is especially common in Africa and in France.
- Peanut oil higher boiling than most other oils and imparts a pleasant taste to the food.

Olive oil

(***Olea europaea***, **Oleaceae**)

- Olive oil is another ancient crop from the Near East. At least 3500 B.C. in Crete.
- Olive oil was also used as a cleanser, for annointing, as a lamp oil, for medicine, and as a food stuff.
- Olive oil comes from both the fruit pulp and from the seed.
- There are many different grades of olive oil.

Olives, *Olea europaea*, Oleaceae

Castor Bean

(***Ricinus communis***, **Euphorbiaceae**)

- Castor bean probably grew in both Asia and Africa when it was domesticated.
- Seeds at least 6000 years old have been found in Egyptian tombs.
- The oil was probably used in medicine and as a lamp oil.
- Castor oil is also a precursor for plastics.

Castor Bean

- Castor oil is still used as a laxative. The seeds are highly toxic but the compounds responsible are not soluble in the oil.
- Today most castor oil is used for soaps, paints, and Turkey red oil. It is also used widely as a lubricant.
- The press cake is too toxic for any use except fertilizer.

Castor Bean

(***Ricinus communis***, **Euphorbiaceae**)

Palm and palm kernel oils

- Oil palms (*Elaeis guineensis*, Arecaceae) differ from most other oil seeds in that both the fruit pulp and the seed are used.
- Actually a series of palms are used. Another one is *Oribignya oleifera* (native to S. America). There is also a comparable Asian species.

Coconuts

(***Cocos nucifera***, **Arecaceae**)

- Coconut oil is isolated from copra, the ñmeatò that is removed from the seeds and dried. Coconuts are widely used in the tropics for just about everything.
- Coconuts originated in southeastern Asia.
- In the 1800's, people started to use coconut oils to make soap.
- Coconut oil also mixes with many other oils and has a pleasant taste.

Coconuts

Hydrogenation of Oils

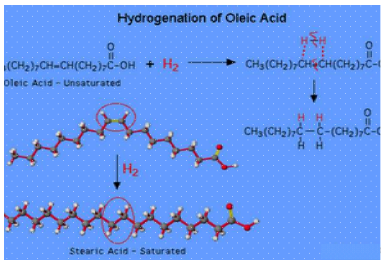
- Oils (such as vegetable, olive, sunflower) are liquids at room temperature. In the food industry, hydrogen is added to oils (in a process called hydrogenation) to make them more solid, or 'spreadable'.
- Hydrogenated oils can be sold directly as 'spreads', but are also used in the food industry in the manufacture of many foodstuffs such as biscuits and cakes.
- The use of hydrogenated helps to prolong the shelf-life of the food and maintain flavour stability.

Hydrogenation of Oils

- Since the process of hydrogenation adds hydrogen atoms to oil, it will reduce the number of unsaturated fatty acids and increase the number of saturated fatty acids in the oil.
- Consumption of a high level of saturated fatty acids is associated with increasing the level of cholesterol in the blood and this may lead to coronary heart disease.
- Therefore, as part of a healthy diet, it is advised to try to lower their intake of saturated fatty acids.

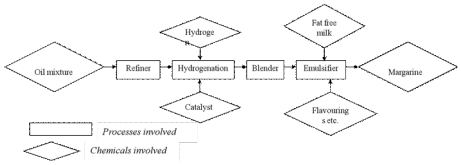
Hydrogenation of Oils

- Adding Hydrogen to an unsaturated fatty acid



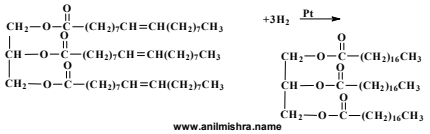
Hydrogenation of Oils

- Most natural oils need processing to make them fit for use.
- **Hydrogenation** of unsaturated oils - make margarine.
- *Controlled* hydrogenation makes oils more solid.
- Pass H_2 through heated oil - nickel or platinum catalyst.
- Add flavourings, salt, vitamins etc.



Hydrogenation of Oils

- Hydrogenation converts alkenes to alkanes
- So, hydrogenation of unsaturated oils produces saturated fats
- Hydrogenation is typically carried out by bubbling H_2 gas through the heated oil, in the presence of a metal catalyst (such as nickel or platinum)
- Unsaturated oils are usually only partially hydrogenated, so that the product is not completely saturated, giving a soft semisolid fat such as margarine



Hydrogenation of Oils

- **Benefits of hydrogenation**
  - Makes food fats more stable, increasing shelf life
  - Changes the texture of the fat
    - Oils become more spreadable
    - Changes the characteristics of baked goods
- **Risks of hydrogenation**
  - Increases amount of *trans* fatty acids in foods with partially hydrogenated oils
    - Increases liver production of LDLs
    - Decreases liver production of HDLs