Lipids

Lipids are one of the macronutrients. Lipids provide a concentrated source of energy. The term 'lipid' refers to both fats (solid at room temperature) and oils (liquid at room temperature).

Elemental composition of lipids

Lipids are made up of three elements: carbon (C), hydrogen (H) and oxygen (O).

Chemical structure of lipids

Lipids are composed of triglycerides. A triglyceride contains one glycerol molecule and three fatty acid molecules.

Glycerol molecule: glycerol is a trihydric alcohol. It contains three hydroxyl (OH) groups.

Chemical structure

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CH2OH
CHOH
CH2OH
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Fatty acid molecule: a fatty acid is an organic compound. It is represented by the formula R-COOH (the R represents the hydrocarbon chain).

Chemical structure

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                 O
                 ||
        H—O — C — R
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Triglyceride formation: each hydroxyl (OH) group of the glycerol molecule combines with hydrogens (H) from three fatty acids, resulting in the loss of three water molecules. This is known as a condensation reaction.

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                 O                     O
                 ||                    ||
 CH2OH   H—O — C — R       CH2 — O — C — R
                 O                   O
                 ||      —           ||
 CHOH    H—O — C — R       CH — O — C — R
                 O                     O
                 ||                    ||
 CH2OH   H—O — C — R       CH2 — O — C — R
```

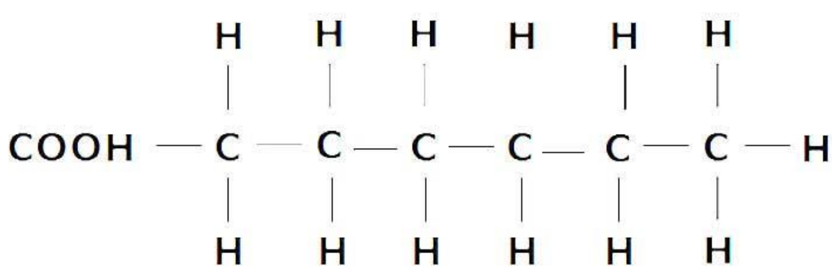
Classification of fatty acids

Fatty acids are long hydrocarbon chains with a carboxyl group (COOH) at one end and a methyl group (CH3) at the other. The number of carbon atoms differs in each fatty acid. The chemical formula of a fatty acid is CH3(CH2)nCOOH. Fatty acids are classified into three main groups, depending on their degree of saturation: saturated, monounsaturated and polyunsaturated.

Saturated fatty acids

Structure	Consistency and melting point	Sources	Examples
Each carbon atom is fully saturated with its full quota of hydrogen atoms. No double bonds occur between the carbon atoms.	Solid at room temperature (18°C). High melting point.	Generally found in animal sources.	Butyric acid in butter. Stearic acid in meat.

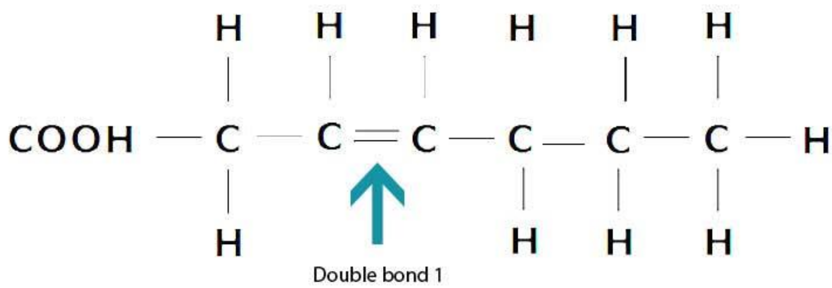
Chemical structure



Monounsaturated fatty acids

Structure	Consistency and melting point	Sources	Examples
Each carbon atom is not fully saturated with its full quota of hydrogen atoms. There is on double bond between the carbon atoms.	Soft or liquid at room temperature (18°C). Low melting point.	Generally found in plant and marine sources.	Oleic acid in olive oil.

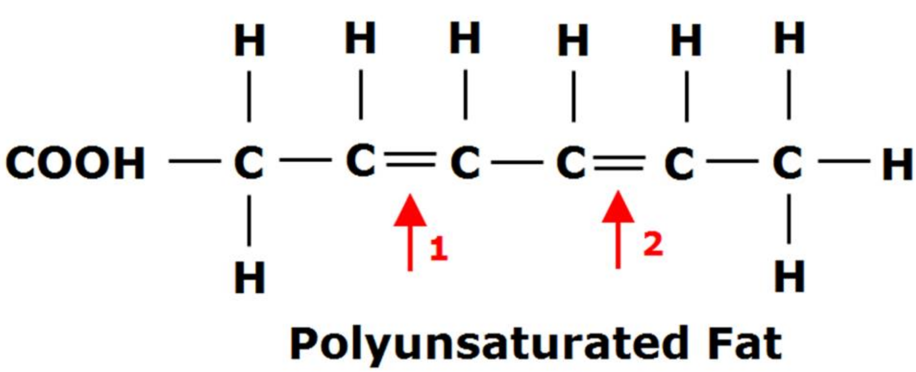
Chemical structure



Polyunsaturated fatty acids (PUFAs)

Structure	Consistency and melting point	Sources	Examples
Each carbon atom is not fully saturated with its full quota of hydrogen atoms. There is more than one double bond between the carbon atoms.	Soft or liquid at room temperature (18°C). Lowest melting point of all the fatty acids.	Generally found in plant and marine sources.	Alpha linolenic acid (three double bonds) in seed oil. Linoleic acid (two double bonds) in nuts. Linolenic acid (three double bonds) in seeds. Arachidonic acid (four double bonds) in oily fish.

Chemical structure



Distribution of Saturated, Monounsaturated and Polyunsaturated fatty acids in food

Animal fats	Saturated	Monounsaturated	Polyunsaturated
Butter	52%	21%	3%
Lard	40%	43%	10%

Suet	50%	30%	2%
Dripping (from beef)	50%	38%	3%
Vegetable fats	Saturated	Monounsaturated	Polyunsaturated
Olive oil	14%	73%	8%
Sunflower oil	12%	20%	63%
Block margarine	26%	34%	12%

Essential fatty acids

Essential fatty acids are fatty acids that can't be manufactured by the body, and therefore must be obtained from food. Linoleic acid, a type of omega-6, and alpha linoleic acid, a type of omega-3, are both EFAs because they can't be synthesised by the body. The other polyunsaturated fatty acids, linolenic acid and arachidonic acid, are not essential fatty acids as they can be synthesised by the body in small amounts from linoleic acid.

Sources of EFAs

Nuts

Seeds

Olive Oil

Oily fish

Functions of EFAs

EFAs aid cell membrane formation, which is essential for growth.

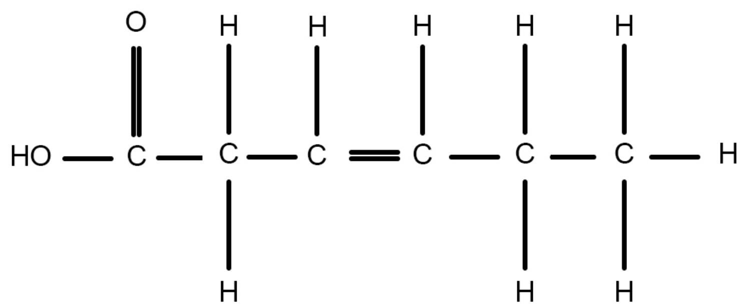
EFAs reduce the risk of coronary heart disease by raising high-density lipoprotein (HDL), which helps remove cholesterol from the blood, and lowering low-density lipoprotein (LDL), which deposits cholesterol in the blood.

Omega-3 fatty acids

Omega-3 fatty acids have a double bond between the third and fourth carbon atoms along their hydrocarbon chain.

There are two main types of omega-3 fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Chemical structure



Structure of an omega-3 fatty acid

Sources of omega-3 fatty acids

Oily fish

Fish oils, e.g., cod liver oil

Seeds

Nuts

Fortified eggs with added omega-3

Functions of omega-3 fatty acids

Reduces the risk of coronary heart disease (CHD), heart attacks and strokes by raising HDL and lowering LDL.

Decreases the viscosity of blood, preventing clots or blockages in the coronary arteries.

Aids foetal brain development during pregnancy, as well as helping to improve memory and cognitive functioning throughout life.

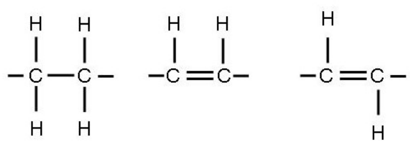
Cis and trans fatty acids

Monounsaturated and polyunsaturated fats can be either cis fatty acids or trans fatty acids.

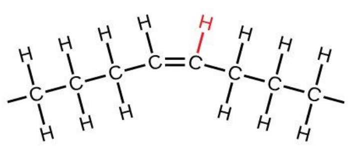
	Cis fatty acids	Trans fatty acids
Chemical structure	Hydrogen atoms are on the same side of the double bond (either above or below).	Hydrogen atoms are on opposite sides of the double bond.
Sources	Naturally occurring in foods such as olive oil and oily fish.	Formed from cis fatty acids during the heating or frying of oils at high temperatures and during industrial

		processing, e.g., the addition of hydrogen atoms to oil to produce margarine. Also present in foods that contain hydrogenated fats, e.g., pastries and crisps.
Health effects	Generally good for health as they raise HDL while lowering LDL, decreasing the risk of coronary heart disease.	Generally bad for health as they lower HDL, while raising LDL, increasing the risk of coronary heart disease.

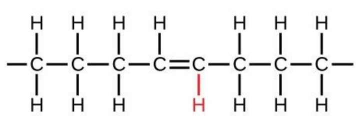
Chemical structure



Saturated Fat Unsaturated Fat Trans fat



cis-fat molecule



trans-fat molecule

Classification of lipids by source

Animal	Plant	Marine
Mainly saturated	Mainly unsaturated	Mainly polyunsaturated
Meat, meat fats, butter, cream, cheese, egg yolks and milk.	Vegetable oils, nuts and nut oils, seeds and seed oils, margarine, avocados, olives and soya beans.	Oily fish and fish liver oils.

Properties of lipids

Solubility

Lipids are insoluble in water. They are soluble in solvents such as ether and benzene.

Absorbtion of flavours

Lipids absorb flavours easily.

Culinary application: infused oils, e.g., chilli; flavoured butter, e.g., garlic butter.

Heating lipids

Melting (slip) point: solid fats melt when heated to 30-40°C.

Smoke point: if lipids are heated to 200°C (fats) or 250°C (oils), they begin to decompose, causing the glycerol to separate from the fatty acids. Glycerol is then broken down into acrolein and produces a blue smoke or haze and an acrid smell.

Flash point: extreme overheating of lipids to 310°C (fats) and 325°C (oils) causes a vapour to be emitted that can spontaneously ignite.

Emulsions

An emulsion is a colloidial solution, formed when two immiscible liquids are forced to mix together. Emulsions can be described as water in oil emulsions and oil in water emulsions.

Water in oil emulsions: e.g., butter and margarine. Tiny droplets of water are dispersed throughout the oil or fat.

Oil in water emulsions: e.g., milk and mayonnaise. Tiny droplets of oil are dispersed throughout the water.

Emulsions may be temporary or permanent.

Temporary emulsions: formed when the two immiscible liquids, e.g., vinegar and oil, are shaken vigorously. If left to stand they will separate.

Emulsifiers

Emulsifiers are molecules that have a hydrophilic (water-loving) head, and a hydrophobic (water-hating) tail. When an emulsifier is added to a mixture of two immiscible liquids the hydrophilic head attaches itself to the water and the hydrophobic tail attaches itself to the oil. This prevents the liquids from separating, creating a permanent emulsion.

Culinary application: lecithin, a natural emulsifier found in egg yolks, is used in the production of mayonnaise. Glycerol monostearate (GMS), a commercial emulsifier, is used in ice cream.

Hydrogenation

Hydrogenation is a process whereby hydrogen gas, in the presence of a nickel catalyst, is forced through the double bond of an unsaturated oil, converting the unsaturated oil into a saturated solid fat.

Culinary application: used in the production of margarine.

Rancidity

Rancidity is the spoilage or decomposition of lipids. This results in an unpleasant odour and taste. There are two types of rancidity: oxidative rancidity and hydrolytic rancidity.

Oxidative rancidity: (most common) occurs when enzymes or bacteria break down lipids into glycerol and fatty acids. This results in an unpleasant odour and taste.

Plasticity

Plasticity describes how soft, pliable and malleable a fat is at a given temperature. It is determined by the degree of saturation. The more saturated fatty acids present, the more solid the lipid. As a result, butter is solid at room temperature compared to margarine, which is soft and spreadable.

Culinary application: lipids with a low saturation level, e.g., margarine, are used for creaming during cake making.

Biological functions of lipids

Lipids supply the body with heat and energy. This helps to keep the body at 37°C and provides energy for all activities.

Lipids form a protective layer that surrounds delicate organs, e.g., the kidneys.

Lipids supply the body with the fat-soluble vitamins A, D, E and K, which are necessary for overall health.

Lipids provide the body with the essential fatty acids that can't be made by the body, e.g., linoleic acid.

Excess lipid intake is stored as adipose tissue under the skin. This insulates the body and acts as an energy reserve.

Recommended Daily Allowance (RDA)/Reference Intake (RI)

The total fat intake for adults should be no more than 70 g per day. On average, men should eat no more than 30 g saturated fat per day and women should eat no more than 20 g.

Energy value of lipids

Associated dietary disorders

Dietary disorders occur when we consume too many saturated fats and too few unsaturated fats. This can result in obesity, coronary heart disease, high cholesterol and strokes.

Digestion of lipids

During digestion, water and enzymes break lipids into one glycerol and three fatty acid molecules. This process is called hydrolysis.

Mouth: food is chewed into small pieces by the teeth.

Stomach: the heat from with the stomach causes some fat to melt.

Liver: secretes bile into the duodenum (the first part of the small intestine) via the bile duct. This emulsifies large fat molecules to produce smaller molecules.

Pancreas: secretes pancreatic juice into the duodenum. The pancreatic juice contains the enzyme lipase, which begins to break down lipids into fatty acids and glycerol.

Small intestine: the ileum (final section of the small intestine) secretes intestinal juice containing the enzyme lipase, which continues to break down lipids into fatty acids and glycerol.

Fatty acids and glycerol are now ready to be absorbed and utilised by the body.

Organ or gland	Secretion	Enzymes	Substrate	Product
Liver	Bile		Large fat molecules	Emulsified fat (small molecules)
Pancreas	Pancreatic juice	Lipase	Lipids	Fatty acids and glycerol
Small intestine (ileum)	Intestinal juice	Lipase	Lipids	Fatty acids and glycerol

Absorption and utilisation of lipids

After digestion the fatty acids and glycerol are ready to be absorbed by the small intestine. They pass through the wall of the villi into lacteal, which form part of the lymphatic system.

The lymphatic system transports the digested lipids to the thoracic duct, where they are despositled into the bloodstream through the subclavian vein (near the left side of the neck).

In the liver and muscles, digested lipids are oxidised to produce heat and energy and form cell membranes.

Excess digested lipids are stored as adipose tissue under the skin to insulate the body and act as an energy reserve.