Lipids

The nutritionally important lipids are fats (solid) and oils (liquids) that consist of fatty acids with 12-20 carbons. Most of the lipid found in food is in the form of triglycerides which are fatty acid esters of glycerol. Other types of dietary lipids are cholesterol and phospholipids. The dietary requirement for lipids can be satisfied entirely by consumption of sufficient amounts of linoleic and linolenic acids. Both fatty acids are 18 carbon polyunsaturated fatty acids differing in the number and position of the double bonds. Linoleic acid has two double bonds with placement of the first double bond at the sixth carbon numbering from the omega carbon, which is the carbon on the opposite end of the carboxylic acid in the fatty acid chain. Linolenic acid has three double bonds with the first double bond on the third carbon from the omega carbon. The placement of the double bonds relative to the omega carbon is significant because it determines the capacity for endogenous synthesis of the fatty acid. Omega-6 and omega-3 fatty acids cannot be synthesized by human enzymes, while the omega-9 fatty acid, oleic acid, can be synthesized endogenously. Thus linoleic and linolenic acid are essential fatty acids in human nutrition. Neither cholesterol (after age 2) nor phospholipids are essential nutrients.

The particular metabolic fate of a dietary fatty acid is determined by its structural characteristics which include carbon chain length (short, medium, long, or very long chain), number of double bonds or degree of saturation (saturated, monounsaturated, or polyunsaturated), placement of double bonds relative to the omega carbon (omega 3, 6, or 9), and configuration of hydrogens around the double bonds (cis or trans). Fatty acids may be oxidized for energy, incorporated into cell membranes, utilized for synthesis of biologically active compounds, or deposited into adipose tissue to provide an energy reserve. The essential fatty acids are long chain (18 carbons), polyunsaturated, with omega-6 and omega-3 double bonds, and with hydrogens around the double bonds in the cis configuration.

Polyunsaturated fatty acids are utilized as substrates for synthesis of biologically active compounds such as steroid hormones, prostaglandins, and leukotrienes. Saturated fat is preferentially incorporated into adipose tissue stores because the absence of double bonds allows a higher energy yield per carbon than is obtained from oxidation of unsaturated fatty acids. Monounsaturated fatty acids are either oxidized for energy or stored as fat depending upon the demand for energy. The longer chain fatty acids are incorporated into cell membranes as phospholipids regardless of degree of saturation. However, highly excitable membranes such as in brain and nervous tissue are richer in polyunsaturated fatty acids with 20 or more carbons and 4 or more double bonds because the bending in these fatty acids around the cis double bonds allows for greater membrane fluidity. Saturated fatty acids, which are more rigid molecules, will contribute rigidity to membranes. Since dietary fatty acids are exchanged with membrane fatty acids, dietary fat composition is reflected in membrane lipid composition. Thus dietary fatty acids can influence cell function through effects on membrane properties.

Dietary fat provides an average energy intake of 9 kcal/gram which is twice that of carbohydrate or protein at 4 kcal/gram. A minimum amount of dietary fat is necessary to facilitate absorption of fat-soluble vitamins (A, D, E and K) and carotenoids. A minimal amount of body fat is also necessary to provide insulation that prevents heat loss and protects vital organs from shock due to ordinary activities.

The six categories of lipids found in foods and in body fat are listed in the table below.

Types of Lipids

Dietary Forms	
Type	**Description**
Fatty Acid	Hydrocarbon chain with carboxylic acid
Saturated	· Has maximum number of hydrogens on the carbon chain · Solid at room temperature · High melting point · Found in meats, poultry, and dairy foods; coconut and palm oils
Trans	· Product of hydrogenation which increases the saturation of fatty acids within oils and converts natural cis to trans configuration · Consist of straighter chains than natural unsaturated fatty acids · Industrial process that chemically transforms a low melting point oil into a solid fat with a higher melting point to enhance product taste, stability and shelf life. · Found in commercially fried foods, commercial baked goods and snacks, margarine, and vegetable shortenings
Monounsaturated	· Contain one double bond · Liquid at room temperature. · Found in olive, peanut and canola oils; nuts, avocados, and olives.
Polyunsaturated	· Contain two or more double bonds · Liquid at room temperature. · Found in corn, soybean, safflower and sunflower seed oils, and fish. · **ω3 FATTY ACIDS:** 1) Linolenic acid (18:3ω3) 2) Eicosapentaenoic acid (20:5ω3) 3) Docosahexaenoic acid (22:6ω3) · **ω6 FATTY ACIDS** 1) Linoleic acid (18:2ω6) 2) Arachidonic fatty acid (20:4ω6) · **ESSENTIAL FATTY ACIDS** (must be obtained from the diet) 1) Linoleic acid (18:2ω6) 2) Linolenic acid (18:3ω3)
Triglycerides	· Neutral esters of glycerol and fatty acids · Most contain ***different*** types of fatty acids (mixed) · Most common form of dietary fats and oils

Deficiency

Brain, nerves, and other tissues are dependent on omega-6 and omega 3 18-carbon fatty acid precursors which can be enzymatically desaturated and elongated to the more active 20- and 22-carbon fatty acids. Alpha-linolenic acid (18:3ω3) is the precursor for synthesis of the 20 carbon eicosapentanoic acid (20:5ω3) or EPA which may be further elongated to docosahexaenoic acid (22:6ω3) or DHA. Linoleic acid (18:2ω6) is converted to arachidonic acid (20:4ω6). Consumption of 2-4 grams of linoleic acid or 10% of total daily energy intake from vegetable oils will provide a sufficient amount of linoleic acid to meet requirements. Linolenic acid should be consumed in 0.2-0.4 g amounts or 1% of total daily energy intake. To promote optimal utilization of both linoleic and linolenic acid, the dietary ratio should not exceed 10:1. Current intake favors linoleic acid over linolenic acid by a much higher proportion. Since these fatty acids compete for the same enzymes, the higher amount of linoleic acid interferes with utilization of linolenic acid. The result is synthesis of a higher proportion of ω-6 derivative prostaglandins and leukotrienes which

favor vasoconstriction, platelet aggregation, and inflammation. In contrast, ω-3 derived prostaglandins and leukotrienes favor vasodilatory, antiaggregatory and anti-inflammatory effects.

Most vegetable oils are rich in linoleic acid (safflower, sunflower, and corn oils) with fewer sources of linolenic acid. Linseed and flaxseed oils, and to a lesser extent, canola and soybean oils, are sources of linolenic acid. Fish oils are rich in EPA and DHA.

Clinically, essential fatty acid deficiency reflects the type of fat that is lacking in the diet. A deficiency of ω-6 fatty acids is characterized by growth retardation in children, and by skin lesions, dry scaly dermatitis, impaired wound healing, reproductive failure, fatty liver, and polydypsia in adults. Although growth appears to be unaffected by ω-3 fatty acid deficiency, cognitive development and visual acuity may be impaired in children receiving inadequate intakes of these fatty acids.

Toxicity

High fat intake contributes to increased risk of obesity, diabetes, cancer, gall bladder disease and arthritis. However, these conditions can also be attributed to excess energy intake, imbalances in other nutrients, and lack of activity and other lifestyle factors.

A substantial amount of scientific evidence supports the impact of dietary fatty acids on cardiovascular health. Saturated fats and fats rich in trans unsaturated fatty acids can raise blood total and LDL-cholesterol levels while monounsaturated and polyunsaturated fats can lower them. The table below defines dietary fats types, food sources and effects on blood lipid levels.

Fatty Acids and Their Effects of on Blood Lipid Levels

Type of Fat	Dietary Sources	Total cholesterol	LDL-cholesterol	HDL-cholesterol	Triglycerides
Saturated Fat	Red meat, cheese, butter, commercially fried foods and baked goods	↑	↑	No effect	No effect
Trans Fats	Commercially fried foods and commercially prepared snacks and baked goods	↑	↑	Slight ↓	No effect
Monounsaturated Fats	Nuts, olives, avocados, olive & canola oils	↓	↓	No effect	No effect
Polyunsaturated Fats: Omega-6	Corn, soybean and safflower margarine & oils	↓	↓	↓	Unknown
Omega-3	Salmon, mackerel, herring, flaxseed, walnuts, walnut oil, soybean and soybean oil	↓	↓	No effect	↓

Requirements

The metabolic requirement for fat is 10-20 grams daily (2-4 teaspoons) with 5 g from linoleic acid. More than one third of total daily energy is consumed from fat (> 20 teaspoons fat/day) with most of this fat provided as saturated fat and trans unsaturated fatty acids from animal sources (meat and dairy) and processed vegetable oils (hydrogenated oils).

The American Heart Association, American Dietetic Association, and other health organizations recommend that total daily fat intake be limited to < 30% of total daily energy intake with no more than 10% provided by saturated and trans fats. Because polyunsaturated fatty acids may also lower HDL-cholesterol as well as LDL-cholesterol, these fatty acids should be limited to no more than 10% of total daily energy intake with monounsaturated fats comprising the remainder of fat intake. There is no adult requirement for saturated fat or cholesterol. Infants and children under age 2 may require a dietary source of cholesterol to meet needs for the developing nervous system.

Dietary Sources:

Animal sources of fats, especially beef, processed meats and dairy products, are rich in saturated fat and typically in the total amount of fat provided. Plant foods such as nuts, whole grains. and vegetable seed oils are generally high in polyunsaturated and monounsaturated fat. Nuts, avocados, olive oil, and canola oil are rich in monounsaturated fat. A detailed list of the fat content of food sources is provided in the table below.

Fatty Acid Content of Selected Foods

Food	Total Fat (g)	Saturated Fat (g)	Monoun-saturated Fat (g)	Polyun-saturated Fat (g)
Fats Added During Cooking or at the Table				
Butter, stick, 1 Tbl	11.5	7.2	3.3	0.4
Butter, whipped, 1 Tbl	7.7	4.8	2.2	0.3
Margarine, stick, 1 Tbl	11.4	2.0	4.5	4.4
Margarine, tub, 1 Tbl	8.0	1.3	2.6	3.9
Margarine, light tub, 1 Tbl	5.4	1.0	2.5	1.8
Lard, 1 Tbl	12.8	5.0	5.8	1.4
Shortening, 1 Tbl	12.8	3.2	5.7	3.3
Chicken fat, 1 Tbl	12.8	3.8	5.7	2.7
Beef fat, 1 Tbl	9.0	3.7	3.9	0.3
Dressing, blue cheese, 2 Tbl	6.9	1.1	3.7	1.7
Dressing, light Italian, 2 Tbl	6.33	0.9	1.5	3.7
Oils:				
Canola oil, 1 Tbl	13.6	1.0	8.0	4.0
Corn oil, 1 Tbl	13.6	1.7	3.3	8.0
Olive oil, 1 Tbl	13.5	1.8	10.0	1.1
Soybean, 1 Tbl	13.6	2.0	3.2	7.9
Dairy Products				
Cheese, cheddar, regular, 1 oz	9.4	6.0	2.7	0.3
Cheese, cheddar, light, 1 oz	2.0	1.2	0.6	0
Milk, whole, 1 cup	8.2	5.1	2.3	0.3
Milk, 2%, 1 cup	4.7	2.9	1.4	0
Milk, skim, 1 cup	0	0	0	0
Ice cream, gourmet, 1 cup	24.0	14.8	6.9	0.9
Ice cream, light, 1 cup	10.0	6.2	2.9	0.4
Meats:				
Beef, sirloin steak, 3 oz ckd	4.2	1.4	1.6	0.2

Ground sirloin, 3 oz ckd	12.7	4.8	5.6	0.5
Pork chop, 3 oz ckd	8.6	3.0	3.8	0.7
Ham, regular, 3 oz ckd	7.7	2.7	3.8	1.2
Chicken breast, no skin 3 oz ckd	3.8	1.1	1.3	0.8
Chicken, leg, no skin, 3 oz ckd	6.1	2.1	1.4	1.8
Turkey breast, no skin, 3 oz ckd	1.0	0.3	0.2	0.3
Turkey drumstick, no skin, 3 oz	3.7	1.2	0.8	1.1
Fish, orange roughy, 3 oz ckd	1.3	0.3	0.2	0.6
Salmon, 3 oz ckd	5.4	1.5	1.8	1.5
Hot dog, beef, 1 link	12.8	5.4	6.1	0.6
Hot dog, turkey, 1 link	5.8	1.6	2.3	1.3
Burger, 1/4# fast food	20.9	7.6	9.3	1.3
Cheeseburger, fast food	14.0	6.0	5.6	1.0
Breaded chicken sandwich	26	5.2	10.1	8.3
Grilled chicken sandwich	6.9	1.8	2.9	1.4
Sausage, Polish, 3 oz	23.6	8.7	10.9	2.5
Sausage, turkey, 3 oz	10.0	2.8	4.0	2.2
Pizza, sausage, 1/8 14" Diameter	9.3	3.8	3.0	1.9
Pizza, cheese, 1/8 14" Diameter	5.8	3.5	1.6	0.3
Nuts				
Almonds, 1 oz dry roasted	16.0	1.5	10.4	3.4
Cashews, 1 oz dry roasted	13.7	2.8	8.1	2.3
Macadamia, 1 oz dry roasted	21.7	3.3	17.1	0.4
Peanuts, 1 oz dry roasted	14.0	1.9	7.0	4.4
Pecans, 1 oz dry roasted	20.2	1.6	12.6	5.0
Flaxseeds, ground, 1 Tbl	2.6	0.2	0.6	1.7
Sesame seeds, 1 oz dry roasted	15.5	2.2	5.9	6.8
Soybeans, 1 oz dry roasted	7.2	1.0	1.6	4.1
Sunflower seeds, 1 oz roasted	14.1	1.5	2.7	9.3
Walnuts, 1 oz dry roasted	17.5	1.6	4.0	11.1
Sweets and Baked Goods				
Candy, chocolate bar, 1.45 oz	12.3	7.3	4.1	0.4
Candy, fruit chews, 1 pkg	5.0	0.7	2.2	1.9
Cookie, oatmeal raisin, 3.5" Dia	5.1	1.1	2.4	1.4
Cookie, chocolate chip, 3" Dia	12.0	4.2	5.0	2.2
Cake, yellow, frosted, 1 med slice	20.4	12.2	5.0	2.0
Cake, angel food, 1 med slice	0	0	0	0
Pastry, Danish w/ cheese, 1 med	26.2	13.0	8.1	3.7