LIPIDS (Fats)

Chemistry

- A fat may be described as repeating units of a lipid-carboxylic acid (an organic acid containing a functional carboxyl group–COOH) coupled to a glycerol (an alcohol) molecule forming a chain (also known as a triglyceride).
- Fatty acids are classified by the number of carbon atoms (designated C*n)* in each molecule chain; a second number indicates the number of double bonds–representing saturated, unsaturated (monounsaturated or polyunsaturated) fats. A third designation indicates the position of the endmost (omega) double bond, counting from the methyl (CH_3) carbon.
- The more double bonds, the more unsaturated the fatty acid; fatty acids with no double bonds are saturated.
- Fats with up to 8 carbons are liquid at room temperature; those containing 10 carbons are liquid at body temperature; fats with more than 10 carbons are solid at room and body temperature.
- Triglycerides are considered short-chain (C4–C10), medium-chain (C11–C17), and long-chain (C18–C24). Most natural fats contain an even number of carbons within the chain; odd numbers of carbons constitute only a small fraction of natural triglycerides. C16 and C18 triglycerides are the most abundant in nature.
- Natural fats–those not hydrogenated–are of a "cis-isomer" configuration. These molecules are "C"-shaped and "bend" easily. Trans fatty acids, described later, are straight and rigid, and are implicated in disease states caused by free-radical damage to cells.

Name	Carbons:#of Double Bonds	(position of double bond)
• Butyric acid	4:0	
• Palmitic acid	16:0	
• Oleic acid	18:1	(9)
• Linoleic acid	18:2	(9, 12)
• Linolenic acid	18:3	(9, 12, 15)
• Arachidonic acid	20:4	(5, 8, 11, 14)
• Eicosapentaenoic acid	20:5	(5, 8, 11, 14, 17)
• Docosahexaenoic acid	22:6	(4, 7, 10, 13, 16, 19)

A "superunsaturated" fat is commonly referred to as an* omega-3 *fatty acid:

Name	Designation	Source or Target
• Stearidonic acid (SDA)	(18:4Ω3)	black current seed oil
• Eicosapentaenoic acid (EPA)	(20:5Ω3)	cold water fish; series 3 prostaglandin synthesis
• Docosahexaenoic acid (DHA)	(22:6Ω3)	cold water fish, marine animals, organs

Compound Lipids

Lipid	Source or Target	Activity
Phospholipids (phosphatides)		
Lecithin	animal tissues, myelin sheaths brain, egg yolk, organs; phosphatidyl choline or serine; phosphatide linked to choline	a lipotropic agent; crucial to fat metabolism and transport
Cephalin	nervous tissue	phosphatidyl ethanolamine; phosphatide linkage to serine or ethanolamine; plays a role in blood clotting
Plasmalogen	brain, heart, and muscle	phosphatidal ethanolamine or choline; phosphatide containing an aliphatic aldehyde
Lipositol	brain, heart, kidneys; plant tissues with phytic acid	phosphatidyl inositol; phosphatide linked to inositol; rapid synthesis and degradation in brain; role in cell transport processes
Sphingomyelin	nervous tissue, brain, red blood cells	sphingosine-containing phosphatide; yields fatty acids, choline, sphingosine, phosphoric acid, and no glycerol; source of phosphoric acid in body tissue
Glycolipids		
Cerebroside	myelin sheaths of nerves, brain, other tissues	yields on hydrolysis of fatty acids: sphingosine, galactose (or glucose), but not fatty acids; includes kerasin and phrenosin
Ganglioside	brain, nerve tissue, spleen, other tissues	contains a ceramide linked to hexose (glucose or galactose), neuraminic acid, sphingosine, and fatty acids
Sulfolipid	white matter of brain, liver, testicles, plant chloroplasts	sulfur-containing glycolipid; sulfate present in ester linkage to galactose
Proteolipids	brain and nerve tissue	complexes of protein and lipids with solubility properties of lipids
Terpenoids and Steroids		
Terpenes	essential oils, resin acids, rubber, plant pigments such as carotenoids and lycopenes, vitamin A, camphor	large group of compounds composed of repeating isoprene units; vitamin A of nutritional interest; fat-soluble vitamin E and K–related chemically to terpenes
Sterols	cholesterol, egg yolk, dairy products, animal tissues	constituent of bile acids, precursor of vitamin D
Ergosterol	plant tissues, yeast, fungi	converted to Vitamin D_2 on irradiation
7-dehydrocholesterol	animal tissues, underneath skin	converted to vitamin D_3 on irradiation
Androgens and estrogens	ovaries, testes	
Adrenal corticosteroids	adrenal cortex, blood	

* Palmitoleic acid (POA) is an omega-7 fatty acid; oleic acid (OA) is an omega-9.

Lipid Classes

- There are two major lipid categories: triglycerides and phospholipids. Triglycerides are used as an energy source, stored as adipose tissue, and are essential to steroid hormone production. Phospholipids (triglycerides with an attached phosphate molecule) are incorporated into cell membranes and myelin sheaths of neurons.
- There are basically two kinds of triglycerides: saturated fats in which the molecules are completely filled by hydrogen atoms and are solid at room temperature, and unsaturated fats in which there are empty places on each molecule where some hydrogen atoms are missing. Unsaturated fats include polyunsaturates and monounsaturates.
- Polyunsaturated fatty acids are often referred to as *omega-6* fatty acids. Omega-6 fatty acids have two or more double bonds between the carbon atoms. Some common omega-6 acids include:
  - **Linoleic acid** (LA) (18:2Ω6)
  - **Gamma-Linolenic acid** (GLA) (18:3Ω6)
  - **Arachidonic acid** (AA) (20:4Ω6)
- Avocado and peanut oils are chiefly monounsaturated; the most monounsaturated oil of all is *canola*, an oil from rapeseed, a relative of mustard. Canola oil is beneficial only if cold pressed, but commercial canola oil is usually processed like most other refined oils.
- Fatty waxes are fatty acid esters (combined with alcohols other than glycerol, while removing a water molecule), and include beeswax, sperm whale head oil, cerumen, carnauba oil, and lanolin.
- The phospholipids sphingomyelin and cerebroside play critically important roles in physiology. Sphingomyelin is found in peripheral nerve tissue; cerebroside is found in central nerves, cell membranes, and is responsible for the different blood types.
- Blood group antigens include cerebrosides with multiple sugars attached. In cerebroside, the phosphate group is replaced by galactose. The number and type of sugars attached define the antigen, and therefore, the blood type:
  - **Type O** blood has no extra sugars (it lacks the enzyme that attaches the sugars to the phospholipid).
  - **Type A** blood has N-acetyl galactose added to the core sugar.
  - **Type B** type blood has an altered from of the enzyme that links galactose to the core sugar.

Metabolism

- Lipids are important to physiology as a source of fuel, in the protective lining of cells and nerve tissue as phospholipids (lecithin), for hormone production, for bile production, as a carrier for fat-soluble vitamins, and as stored energy and body insulation (adipose tissue). Response to energy needs is slower from stored fatty acids than from the release of glucose from glycogen (body starch found in the liver and muscles).
- Most dietary fatty acids are metabolized by beta-oxidation in mitochondria (the cell powerhouse) to provide a source of energy; other fatty acids (specifically, C20 and C22 fatty acids), are incorporated into structural membrane phospholipids.
- Medium-chain fatty acids contain up to 12-carbon fatty acids; MCFAs (sometimes designated MCTs) are used as energy and are not stored as adipose tissue.
- Fatty acids are synthesized in adipose (body fat) tissue, mammary glands (breasts), and the in liver using acetyl-coenzyme A (acetyl-CoA) as a catalyst.
- Acyl carrier protein (ACP) serves as a chaperone for the synthesis of fatty acids.

ACP is one of the most abundant proteins in cells, as it is critical to cell membrane formation.

- Fatty acids form *micelles,* aggregates of fatty acids with a polar (charged) surface and a hydrophobic, waterless, interior.
- Most fatty acids in the diet are not essential–the body can make them from simple precursors. The essential fatty acids are the omega-6 fatty acid *linoleic acid* and the omega-3 fatty acid *linolenic acid*.

Beneficial Oils

- "Cold-pressed" oils are extracted mechanically by crushing the grain seeds or nuts and adding water. Temperatures rarely exceed 140°F. Oils prepared in this manner (except olive oil) require refrigeration to prevent peroxidation. Sesame seed and olive oils are the only true cold-pressed oils, as these are not heated after pressing.
- Cold-pressed oils are more intense in taste and color than refined oils, contain 25–50% more vitamin E, and 45% more beta-sitosterols than commercial heat/chemical extracted oils. Cold-pressing preserves the essential fatty acids. Cold-pressed oils contain significantly lower levels of trans fatty acids than refined oils.

Olive Oil

- Olive oil is the only oil sold on supermarket shelves that is not heated above 150°C. It is also the only non-processed oil that does not deteriorate quickly, retaining most of its original nutritive value.
- Olive oil, a monounsaturated fat, reduces serum cholesterol levels with frequent and moderate use. Resistance to coronary artery disease noted in Mediterranean cultures may be due to the high intake of olive oil (rich in oleic acid), although wine, garlic, and fresh vegetable consumption may also play roles.
- **Extra Virgin Olive Oil**: extracted from the first pressing of olives; the highest quality. It has full flavor and aroma, and contains most of the naturally present beneficial substances in olives.
- **Virgin Olive Oil**: comes from the first or second pressing and is obtained by pressure or centrifuge; it is the second–highest-quality olive oil.
- **Refined Olive Oil**: extracted from the husks with a solvent and mixed with the originally pressed oil.

Compounds in olive oil:

1. **Palmitic Acid**: can raise cholesterol levels, but other substances in olive oil seem to ameliorate this effect.
2. **Stearic Acid**: fatty acid which neither raises nor lowers cholesterol.
3. **Lecithin**: a small amount.
4. **Beta-Carotene and Vitamin E**: antioxidants.
5. **Chlorophyll**: good source of magnesium.
6. **Squalene**: a precursor of phytosterols; inhibits cholesterol absorption from foods.
7. **Modified Sterols**: triterpenic substances; benefit the cardiovascular system and have anti-inflammatory properties. Triterpenic acids (oleanolic and maslinic) found only in olive oil, stimulate pancreatic enzyme production.
8. **Polyphenols**: mainly oleoeuropein, lowers blood pressure.
9. **Beta-Sitosterol**: lowers high cholesterol levels.
10. **Caffeic and Gallic Acids**: stimulate bile flow. Gallic acid also inhibits lactic dehydrogenase activity–an enzyme indicating liver malfunction.
11. **Phenolic Compounds**: protect against

peroxidation of fatty acids and cholesterol.

12. **2-Phenylethanol**: stimulates production of lipases in the pancreas.
13. **Cycloartenol**: stored in the liver, lowers circulating cholesterol levels and increases bile excretion.
14. **Triterpenic Acids and 2-Phenylethanol Combination**: slows cholesterol digestion and its absorption from foods.

Coconut Oil

- Coconut and palm oils are the most saturated fats, followed by dairy products, lamb, beef, pork, poultry, and rabbit.
- Because coconut and palm oils are almost completely saturated, they do not oxidize in storage or when heated to sauté foods, and do not produce trans fatty acids. Coconut oil will not go rancid, even after a year in storage.
- Coconut oil is unusually rich in short- and medium-chain fatty acids. Short-chain fatty acids do not require the carnitine transport system for metabolism; unsaturated fatty acids do. Carnitine, though necessary for long-chain fatty acid metabolism, promotes oxidation of fatty acids and therefore, oxidative damage to cells.
- Coconut oil may be useful in weight loss. Medium-chain fatty acids, plentiful in coconut oil, have been found to increase metabolism and inhibit the liver's formation and storage of fat.
- Consumption of coconut oil reduces the dietary need for vitamin E.
- Tropical fats (coconut and palm) cause fewer health problems than fried oils.

Exotic Oils

- **Flaxseed**: very rich in omega-3 fatty acids. Whole flaxseed or flaxseed meal can produce omega-6 and vitamin B6 deficiencies. Flax oil is used as therapy for omega-3 deficiency, cancer, inflammatory conditions, high triglycerides, cardiovascular disease, and diabetes.
- **Kukui, or Candlenut Tree**: grows only in tropical climates of Hawaii, Pacific Islands, and New Zealand. Candlenut tree oil contains about 40% LA (Ω6) and 29% LNA (Ω3).
- **Psyllium Seeds**: contain about 40% LA and 30% LNA.
- **Lignans**: fatty acids with antiviral/fungal/bacterial and anticancer properties. Flax contains 100 times the lignans of wheat bran, the next best source. Flax meal must be taken with plenty of water as it absorbs five times the original weight of the seed.

Omega Fatty Acids

- Human enzymes cannot insert double bonds in triglycerides into positions closer than 7 carbons from the methyl end. Plants insert double bonds closer to the methyl end; this enables plants to produce two families of fatty acids known as omega-3 and -6. Initial double bonds at the 3^{RD} carbon from the methyl end create omega-3 fatty acids; first double bonds on the 6^{TH} carbon from the methyl end result in omega-6 fatty acids. These two fats are essential to human health.
- The essential fatty acids linoleic acid–LA (C18:2Ω6) and alpha-linolenic acid–LNA (C18:3Ω3) are representative of the omega-6 and omega-3 series of fatty acids. These fatty acids are acted upon by a series of desaturase (which introduce double bonds into molecules) and elongase (which chain molecules together) enzymes in the liver, giving rise to a range of polyunsaturated fatty acids (PUFAs).

Alpha Linolenic Acid (LNA) (allcis-Ω3,6,9-octadecatrienoic acid) produces:

1. Stearidonic acid (SDA) (18:4Ω3)	black current seed oil (15%)
2. Eicosapentaenoic acid (EPA) (20:5Ω3)	manufactured by the body to make series 3 prostaglandins
3. Docosahexaenoic acid (DHA) (22:6Ω3), and EPA	cold water fish, marine animals

Linoleic Acid (LA) produces:

1. Gamma linolenic acid (GLA) (18:3Ω6)	evening primrose oil (9%), borage leaves (20%), spirulina; synthesized in the body from alpha-linolenic acid (LNA)
2 Arachidonic acid (AA) (20:4Ω6)	animal fats; synthesized from LA (arachidic–*not* arachidonic–acid is found in peanuts)

- The fate of linoleic acid is determined by the protein to carbohydrate ratio in the diet.
- The most biologically significant omega-6 and omega-3 polyunsaturated fatty acids (PUFAs) are arachidonic acid, EPA, and DHA.
- Arachidonic acid is found abundantly in meat; EPA and DHA are present in high concentrations in marine fish oils. Oils rich in either arachidonic acid or EPA are potent modulators of tissue phospholipid fatty acid composition.
- Omega-3 fatty acids are available from seafood; omega-6 fatty acids are typically available in land plants (bushes, trees, grasses) and vegetable oils. Safflower and corn oils are devoid of omega-3 fatty acids.
- Evening primrose oil contains *only* omega-6 fatty acids; it must be combined with an omega-3 source to be effective.

Protective Properties

- Omega-6 fatty acid deficiency has been recognized for years; omega-3 fatty acid deficiency, with its more subtle signs, is just now being appreciated.
- Fish oils increase palmitic, palmitoleic, eicosapentaenoic, and docosahexanoic acids, while decreasing linoleic and arachidonic acids.
- Omega-3 fatty acids protect the arterial wall from damage and inhibit thrombus formation by decreasing platelet aggregation, two processes critical to the development of coronary artery disease.
- Dietary supplementation with 2–4 grams of marine omega-3 fatty acids (EPA) per day may beneficially affect many chronic diseases, especially coronary artery disease. The markedly reduced incidence of coronary artery disease in Greenland Eskimos can be directly attributed to EPA. Omega-3 fatty acids have can help prevent reinfarction in myocardial infarction survivors.
- Physical stress (exercise, combat) shortens bleeding times through both increased fibrinogen production (necessary to reduce blood loss during physical conflict) and dehydration (which thickens the blood). This effect can be blunted by omega-3 fatty acid supplementation, reducing the risk of thrombus formation.
- EPA reduces blood clotting and extends bleeding times (as much as doubling it); one

of the symptoms of excessive EPA intake is recurrent bloody noses.

- Fish oil (EPA) supplementation in Type II diabetics augments the vascular release of nitric oxide (endothelium-dependent relaxation factor), affording some protection against vasospasm and thrombosis in patients who are at significant risk for developing coronary artery disease. However, some diabetics experience a rise in blood sugar levels with fish oil–use with caution.
- Omega-3 fatty acids may influence gestation time: the average duration of gestation is increased by four days with omega-3 fatty acid supplementation.
- DHA, if not a nutrient essential for life, is required for optimal visual functioning. Breast-fed babies have more DHA in their erythrocytes and better visual acuity.

Omega-6 Fatty Acids in Foods

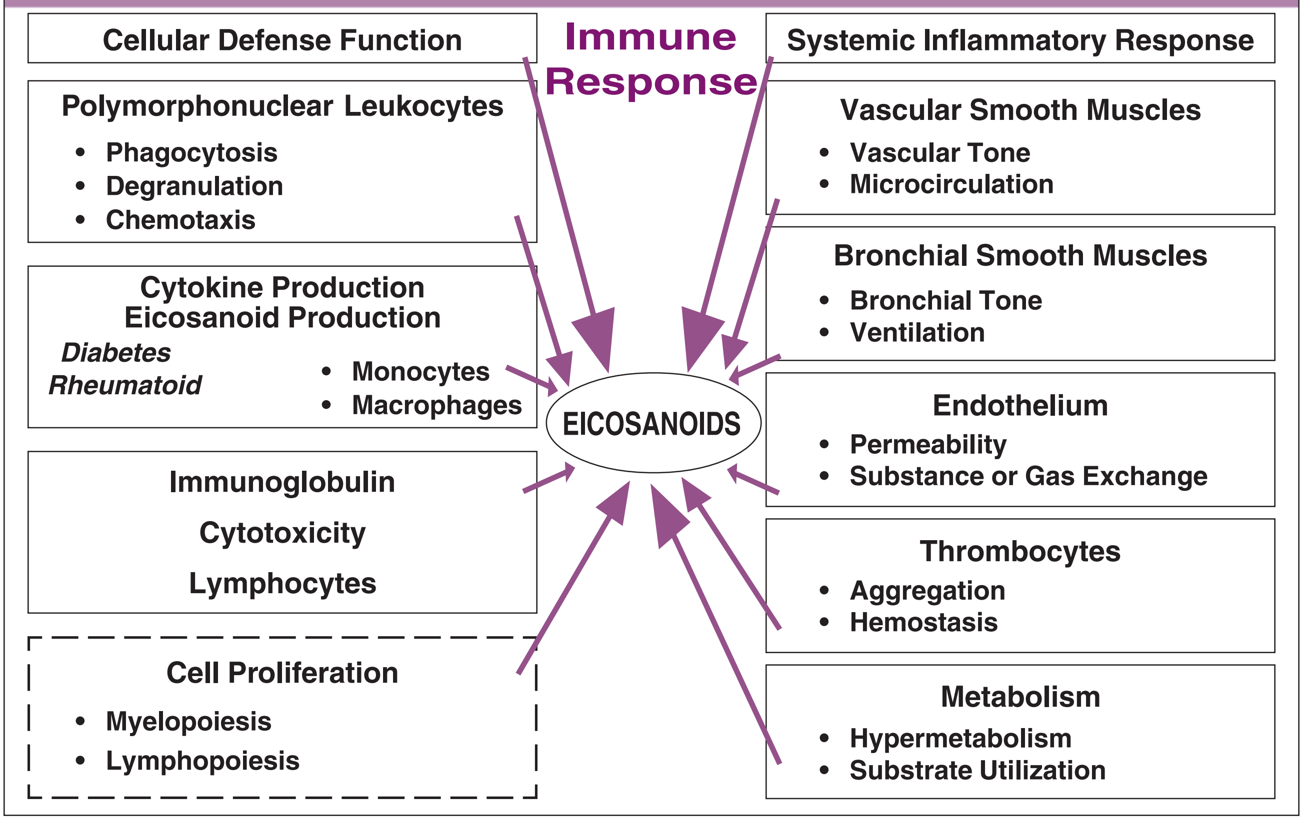
Canola oil	up to 10%
Walnut oil	3% to 11%
Soybean oil	5% to 7%

- Cod has a ratio of omega-3 to omega-6 of 40:1; the human body has a ratio of 1:1.
- An important contributor to disease in the industrialized world's diet is the ratio of omega-6 (linolenic acid) to omega-3 (linolenic acid), ranging from 10:1 to 30:1.
- Supplements high in GLA (gamma-linoleic acid) contain erucic acid–a toxic monounsaturated 22-carbon fatty acid found in rapeseed and other vegetable seed oils, and in the Crucifer plant family, particularly Brassica (mustard). The rapeseed and mustard seed oils are particularly high in erucic acid at 20–55%. Canola oil–from a special variety of rape seed–does *not* contain erucic acid.

Eicosanoids

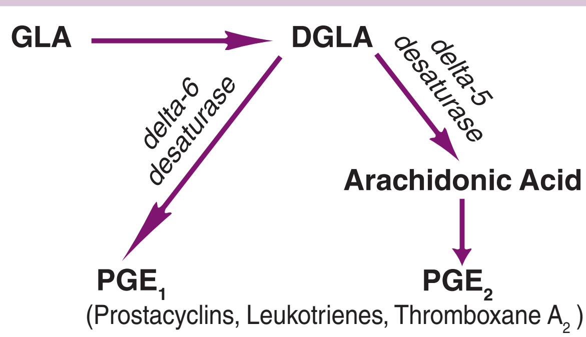
- *Eicosanoid* refers to the family of potent substances derived from 20-carbon polyunsaturates that serve as signaling molecules in host defense, inflammation, and hemodynamics. Eicosanoid biosynthesis is a part of leukocyte (white blood cell) function.
- Eicosanoids are oxidative derivatives of arachidonic acid (AA). Under normal conditions, eicosanoids act as physiological antagonists to maintain homeostasis. The overproduction of any one particular eicosanoid can result in pathophysiological proinflammatory or prothrombotic conditions mediated by certain kinds of *prostaglandins*–prostanoids, prostacyclins (cyclooxygenase-derived products), thromboxanes, leukotrienes, and lipoxins (lipoxygenase-derived products).
- Prostaglandins (PGG_2, PGD_2, PGF_2, and especially PGE_2) are hormone-like substances that regulate other hormones (and are regulated *by* them). Prostaglandins regulate the inflammatory response, blood clotting, fever, pain, labor, and blood pressure. The insulin-glucagon axis (see "Hyperinsulinism" section) is especially sensitive to prostaglandin activity, and *affects* prostaglandin activity.
- The effects of dietary arachidonic acid (AA) and omega-3 polyunsaturated fatty acids such as eicosapentaenoic acid (EPA) are diametrically opposed. Dietary EPA reduces arachidonic acid activity; arachidonic acid reduces EPA activity. High dietary arachidonic acid levels can eliminate the modulating hepatic phospholipid fatty acid effect of EPA.
- Gamma-linolenic acid (GLA) is the precursor of arachidonic acid (AA), of dihomo-gamma-linolenic acid–DGLA (the precursor to prostaglandin 1–PG_1), and also of PG_2–a damaging prostaglandin.

Eicosanoid Pathways



- The enzyme delta-6-desaturase catalyzes the conversion of linoleic acid (LA) to gamma-linolenic acid (GLA).
- GLA is converted to DGLA (dihomo-gamma-linoleic acid), which is then converted to PGE_1 (a beneficial eicosanoid) in the presence of delta-6-desaturase, or to arachidonic acid in the presence of delta-5-desaturase.

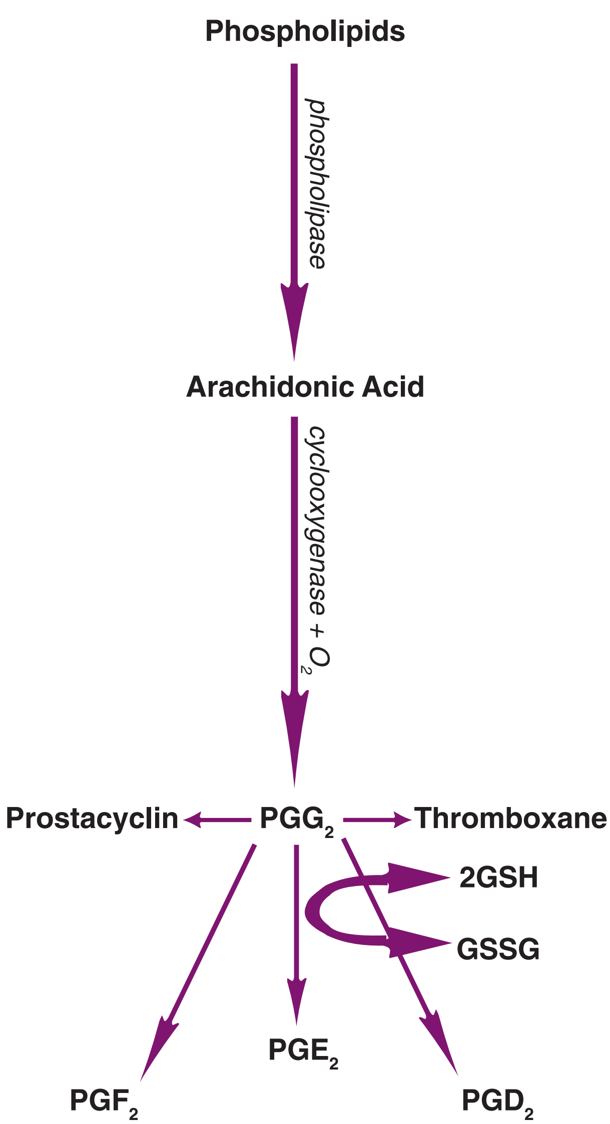
DGLA Pathways



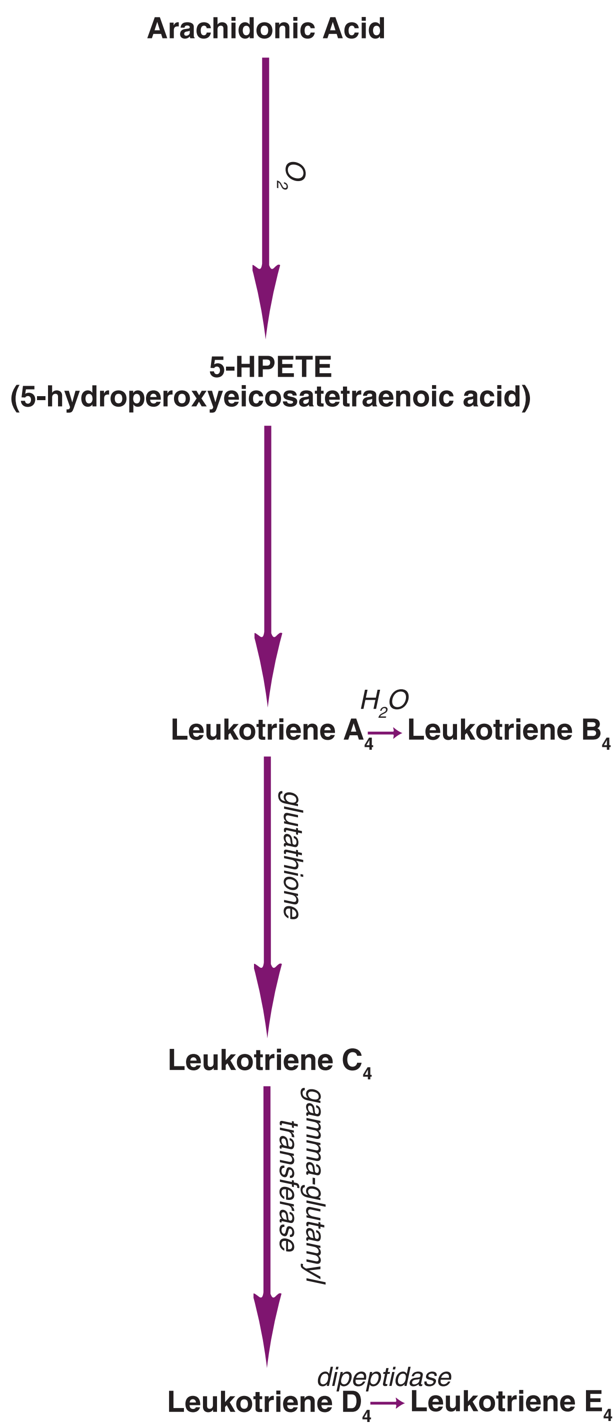
- The GLA to eicosanoid pathway declines after age 30.
- DGLA–dihomo-gamma-linolenic acid (C20:3Ω6)–can be desaturated to produce arachidonic acid (C20:4Ω6). The omega-3 fatty acid alpha-linolenic acid (LNA) can similarly act as a substrate for the synthesis of eicosapentaenoic acid–EPA (C20:5Ω3) and docosahexaenoic acid–DHA (C22:6Ω3).
- Delta-5-desaturase is activated by insulin and inhibited by glucagon and eicosapentaenoic acid (EPA). EPA also inhibits cyclooxygenase, preventing prostaglandin and thromboxane production.
- Prostacyclins (PGI_2) are synthesized from PGG_2, regulate and inhibit platelet aggregation, and cause vasodilation.
- Thromboxanes are synthesized from PGG_2 and specifically initiate blood clotting.

- Lipoxins and hydroxylated fatty acids initiate inflammation in the soft tissues and regulate the immune response.
- Leukotrienes, synthesized from PGE_2, are powerful bronchoconstrictors when oxidized. They also sensitize cells to histamine and may cause increases in the production of eosinophils and neutrophils (kinds of white blood cells implicated in allergies, cancer, and autoimmune response).

Simple Pathway of Phospholipids



Arachidonic Acid to Leukotriene Conversion



Cyclooxygenase Inhibition

- There are two *isoforms* of PGH_2 synthase, designated *COX-1* and *COX-2* (cyclooxygenase I and II).
- **COX-1** is present in low levels in many cell types. Specifically, COX-1 is known to be essential for maintaining the integrity of the gastrointestinal epithelium.
- **COX-2** expression is stimulated by growth factors, cytokines, and endotoxins. COX-2 levels increase in inflammatory disease states such as arthritis and cancer. Up-regulation of COX-2 is responsible for the increased formation of prostaglandins associated with inflammation.
- Cancer cells express elevated COX-2. Regular use of either the less specific NSAIDs (nonsteroidal anti-inflammatories) or COX-II inhibitors has been shown to decrease the risk of developing colorectal cancer.
- Most NSAIDs block both COX isoforms and cause gastric irritation (by inhibiting COX-1). More selective *COX-2 inhibitors* (COXIBs) have been developed, e.g., Celebrex® and Vioxx®, which are less gastrically irritating.
- Prostaglandin E_2 and thromboxane A_2 (TXA_2) levels are significantly greater in those who consume foods rich in arachidonic acid (fatty meats), compared with those who consume oleic-acid rich foods (olive oil, avocados). Those who consume oleic–acid-rich foods have prostaglandin E_2 and thromboxane A_2 (TXA_2) levels still lower than those who supplement with EPA.
- Reducing arachidonic acid in platelet phosphatidylcholine may result in a decrease in TXA_2 production.
- Hyperinsulinism is a major cause of hypertriglyceridemia, which stimulates a pronounced overproduction of inflammatory and thrombogenic compounds from eicosanoids (see "Hyperinsulinism" section).
- Hyperinsulinism (caused by high-glycemic carbohydrate intake) decreases delta-6-desaturase activity (and therefore GLA production).
- Alpha-linoleic acid (ALA)—as found in flaxseed and walnuts, trans fatty acids as found in hydrogenated (artificially saturated) fats, viral infections, and stress (causing a release of adrenaline and cortisols, which triggers insulin release) decreases delta-6-desaturase production.
- The beneficial eicosanoids (PGE_1) decrease hepatic cholesterol production.
- Low-density lipoproteins (often referred to as "bad" cholesterol) carry linolenic acid (LA) to cells to make eicosanoids. This is a pivotal and important role for LDLs. The enzyme delta-6-desaturase converts LA to gamma-linoleic acid—GLA—thereby activating it.
- Prostaglandins are potent regulators of bone formation and bone resorption that can have both stimulatory and inhibitory effects. They are likely to play a central role in the ability of the skeleton to respond to mechanical forces as well as to humoral mediators.

Undesirable Oils

- **Brominated Oils**: manufactured by adding bromine to the unsaturated fatty acid component of vegetable oils. They are made from olive, corn, sesame, and cottonseed oils. Brominated oils have been used for more than fifty years to enhance cloud stability in carbonated beverages and to prevent ring formation around bottle necks. Brominated oils are known to interfere in thyroid function and cause fatty liver, kidney damage, and changes in the heart tissue.
- **Cottonseed Oil**: contains cyclopropene fatty acid, which has a toxic effect on the liver and gallbladder slowing down maturity, destroying enzymes, and interfering with essential fatty acids (EFA). Cottonseed oil contains gossypol, a benzene substance that

irritates the digestive tract and causes water retention in the lungs, and paralysis. This oil also contains high levels of pesticide residue.

- **Castor Oil**: contains 80% ricinoleic acid, known to be an intestinal purgative. Prolonged use can inhibit nutrient absorption.
- **Herring Oil**: contain 10–20% of cetoleic acid, which is toxic.

Fat Substitutes

- **Olestra® by Proctor and Gamble or Simplesse® by Monsanto**: non-digestible fats containing a glycerol with many "OH"s such that enzymes cannot hydrolyze the ester bonds. (Despite heavy promotion, sales of this synthetic food additive have been a big disappointment to Monsanto, as it causes diarrhea and "anal leakage" or "rectal seepage.")

Oil Processing

- Polyunsaturated fats are processed commercially in two ways: cold pressing and chemical extraction.
- The most common grain and nut crops used for oil extraction are: cotton seed, corn, safflower, sunflower, peanut, walnut, and olive. All crops are sprayed with pesticides and because most pesticides are oil-soluble, significant levels of them remain in the finished oil product. Cotton and corn are the most heavily sprayed crops.
- Processing seeds to produce oil involves heating them and adding chemical solvents. Such bombardment converts or removes nutrients. Conversion produces health-damaging substances such as trans fatty acids, aldehydes, ketones, polymers, cyclic compounds, epoxides, hydroperoxides.
  - **Preparation**: seeds are heated and dehulled, and then chopped or ground to break the cell walls. During this phase, the object is to deactivate enzymes early through heat. For example, with canola or rapeseed, the enzyme myrosinase can influence quality because it catalyses glucosinolate hydrolysis to produce glucose, sulphate, isothiocyanates, oxazolinine thiones, among other undesirable compounds.
  - **Extraction**: gasoline-like solvents such as hexane and heptane, benzene, carbon disulfide, and/or lye are added to the seed mash, which is then steam heated at temperatures around 300°F to evaporate the solvents.
  - **Degumming**: caustic soda (an alkali such as sodium hydroxide–commonly known as Drano®–or a mixture of sodium hydroxide and sodium carbonate) is used to remove free fatty acids that cause rancidity and decrease oil quality. Alkali solutions combine with free fatty acids to form soaps and help remove toxic substances naturally present in many plants. Temperatures again reach 75°C (167°F). Degumming converts the phosphatides to hydrated gums which are insoluble in oil and readily separated as sludge. The hydrated gums are vacuum dried for crude lecithin processing. This process also involves the addition of phosphoric acid and water at temperatures of 60°C (140°F).

    Degumming is a critical process in food oil production:

    - It is necessary to remove the lecithin, which can cause rancidity.
    - It provides a product free of impurities that settle out during shipment and storage.
    - It substantially decreases refinery waste load because of the lower neutral oil losses and the reduction of discharged gums.
    - It prepares the oil for steam refining.

Degummed oil is more suited to this refining technique because nonvolatile impurities such as phosphatides and metallic pro-oxidants are reduced.

- **Bleaching**: oils are usually a yellow or reddish pigment that is considered undesirable. In the bleaching process, oils are mixed with a clay substance that absorbs pigment, and are then heated to temperatures of 175°–225°C for about 4 hours.
- **Deodorization**: odors and tastes are removed from the oil through pressurized steam distillation at temperatures of 240°–270°C (464–518°F) for 30 to 60 minutes. Deodorizing reduces residues, toxins, and products of oxidation formed during the bleaching stage, as well as removing sulfur, monoglycerides, sterols, beta carotene, and tocopherols (vitamin E). Deodorizing renders the oil tasteless and indistinguishable from other oils.
- **Preserving**: Finally, preservatives such as BHT (butylated hydroxytoluene), BHA (butylated hydroxyanisole), propyl gallate, TBHQ (tertiary butylhydroquinone), citric acid, or methylsilicone are added. A defoamer may also be added to prevent turbidity when the oil is refrigerated.

Hydrogenation

- Hydrogenated (artificially saturated) fat molecules are trans fatty acids (rigid "trans-isomer" shaped) and have been implicated in the *free-radical* cause of disease and aging. These molecules can become incorporated into the body's fat stores and directly damage cells. (Free radicals are damaged atoms or molecules with unpaired electrons, making them very bioreactive.)
- Hydrogenation is a process that saturates oils for use in margarine and shortening, present in processed foods like bakery products (up to 34% hydrogenated fats) and snacks (35–39% hydrogenated fats). In some partially-hydrogenated margarines, the trans fatty acid content may exceed 60%.
- The hydrogenation process forces pressurized hydrogen gas into liquid oil at temperatures of 120–210°C (248–410°F) for six to eight hours using a metal catalyst (nickel, platinum, or copper). Nickel catalyst (50% nickel and 50% aluminum) residue remains in the final products of hydrogenated or partially-hydrogenated goods.
- Trans fatty acids can very quickly increase blood cholesterol levels by as much as 15% and blood triglyceride levels by 47%. The effect of trans fatty acids on the serum lipoprotein profile is at least as unfavorable as that of the cholesterol-raising saturated fatty acids, because they not only raise LDLs, but they also lower HDLs. Trans fatty acids are not metabolically equivalent to the natural cis-isomers (their hydrogen atoms are in a different spatial arrangement and they change cell membrane permeability, impairing the protective barrier) and they affect the serum lipoprotein profile adversely.
- Frying oils are dangerous not only because heating oils creates free radicals, but because of acrolein production. Acrolein is a volatile mucous–membrane-damaging aldehyde formed when fats reach the smoke point.

Trans Fats and Free Radicals

- Free radicals are unstable molecules containing one or more unpaired electrons. To achieve stability, a free radical steals an electron from a stable molecule. The formerly stable molecule then becomes reactive, causing oxidation that interferes with normal cell function and mutates cells.
- Fatty acids are sensitive to heat. At temperatures above 150°C (302°F), unsaturated fatty acids become mutagenic

(DNA transcription mistakes leading to cancer); above 160°C (320°F), trans fatty acids begin to form; above 200°C (392°F), trans fatty acids multiply substantially; and above 220°C, trans fatty acids proliferate exponentially.

- Every cell in the body is subjected to an estimated 10,000 free-radical reactions per day.
- Polyunsaturated fatty acids increase production of free radicals and contribute to lipid peroxidation. Peroxide free radicals are formed from fat molecules reacting with oxygen. Monounsaturated and saturated fatty acids are markedly more resistant to peroxidation than are polyunsaturated fatty acids.
- Cis-isomer fats have not been shown to cause free radical damage to any significant degree *providing vitamin E intake is adequate*. Insufficient vitamin E intake can cause peroxidation of fats in tissues and contribute to disease states and aging. Increased consumption of polyunsaturates therefore can produce an *increased need for vitamin E.*
- Diets rich in oleic acid (from olive oil or oleate-rich sunflower seed oil) produce LDL particles more resistant to oxidation than "normal" diets or diets rich in linoleate.
- There is a highly significant correlation between LDL linoleate levels and the susceptibility of LDL to oxidation.
- Free radicals are responsible for the formation of brown ("liver") spots on the skin and internal organs, and are a sign of fatty degeneration. Liver spots contain denatured oils and protein (lipofuscin) and are found mostly on the hands and face, as well as in heart muscle cells and the brains of elderly people.

Health Effects

- Fat and oil consumption in 1975 was 41 million tons; by 1992, that figure had more than doubled and continues to rise.
- The average American dietary intake of fats is 140–170 grams. Table fats and oils (margarine, butter, salad and frying oils) account for 57%; meat, poultry, and fish, 31%; and dairy products, 7%.
- Not all dietary saturated fatty acids elevate serum cholesterol levels; in fact, most do not. The short-chain saturates found in butter fat, coconut, and palm oils (C4:0 through C10:0) are absorbed portally and do not raise cholesterol levels. The most common long-chain saturate (C18:0–stearate) likewise has minimal impact.
- Unsaturated fatty acids have an immunosuppressive effect; parenteral (tube) feeding typically employs coconut oil rather than unsaturated fats; unsaturated fats are useful as an immunosuppressive agent in organ-transplant patients.
- Excess monounsaturated fats in the diet can lead to health problems due to interference in prostaglandin production from essential fatty acids.
- Trans fatty acids (hydrogenated fats present in processed foods) raise LDLs and reduce HDLs.

Saturated Fats

- Saturated fats are important to blood vessel wall integrity. Very low-fat diets (20 grams or less), and especially those very low in saturated fats (less than 50% of fat calories), may contribute to a rare type of stroke called intraparenchymal hemorrhage in those with hypertension.
- Removal of saturated fatty acids from the diet lowers both of the major cholesterol-rich lipoprotein particles–LDL and HDL.

- The saturated fatty acids *lauric* (present in coconut oil), *myristic* (present in butter and nutmeg), and *palmitic* (present in animal and vegetable fats) raise cholesterol levels in susceptible individuals. These same fatty acids, however, have antiviral activity. *Stearic* acid (found in animal and vegetable fats), may contribute to thrombosis.

Low-Fat Diets

- Reducing total dietary fat–without reducing saturated fat–does not lower LDL cholesterol levels. On the other hand, such a regimen will not lower HDL cholesterol levels either.
- Diets low in total *and* saturated fat reduce HDLs, suggesting that saturated fatty acids affect both LDL and HDL cholesterol levels.
- A decrease in HDLs creates a greater risk for coronary artery disease. Replacing saturated fatty acids in the diet with carbohydrates or polyunsaturated fatty acids appears to lower HDL cholesterol levels, whereas replacing saturated fatty acids with monounsaturated fatty acids generally does not.
- Those switching to completely vegetarian diets may expect blood cholesterol levels to drop significantly (20–36%) in only 6 months, however, HDL cholesterol levels will also fall 30–39%–a recognized coronary risk.
- The best diets are those that minimize LDL and maximize HDL. A monounsaturated fatty–acid-rich diet (37% of total calories, based on avocados) produces higher HDL cholesterol levels and a lower LDL cholesterol levels compared to a standard low-fat diet.

Atherosclerosis

- The heart's normal fuel is fatty acids, hence its enhanced susceptibility to atherosclerosis.
- Oxidation of unsaturated fats causes cellular mitochondria damage. Unsaturated oxidation of unsaturated fats (as in the essential fatty acid linoleic acid) and lipoproteins may contribute to the pathogenesis of atherosclerosis. Oxidized (or modified) LDL particles are now believed to play a critical role in foam cell formation, endothelial damage, and plaque generation in arterial walls.
- Atherosclerosis is not only influenced by high serum cholesterol, but also by perversions in calcium absorption, white blood cell accumulation at scarred artery wall sites, and platelet aggregation at these sites. The resulting narrowed arterial lumen can cause hypertension, which then steps up the deposition of cholesterol, platelets, and minerals in arteries.

The Progression of Atherosclerosis

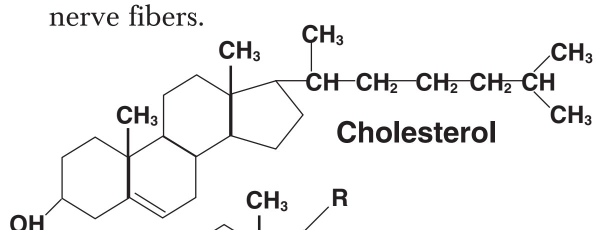
- Atherosclerosis is a multifactorial process characterized by progressive cellular proliferation and deposition of lipids in artery walls. However, exact mechanisms that lead to the formation of the atheromatous plaque remain somewhat hypothetical.
- Atherosclerosis may begin with repeated hypertensive events, elicited by multiple stress responses in day–to–day modern life. High arterial pressure causes damage, even in the short-term. The body repairs damage through the inflammatory response, which activates a deposition of low-density lipoproteins (LDLs–also known as "bad" cholesterol) and minerals on artery walls that build up as atheromatous plaque over the years.
- Atherosclerosis starts with an early atheromatous lesion and the subsequent formation of lipid-laden foam cells beneath the arterial endothelium. Foam cells arise from subendothelial monocytes and medial smooth muscle cells that have become loaded with cholesteryl esters accumulated predominantly as a result of uptake of plasma-derived LDL particles.

- Native LDL appears to be insufficient to induce the development of foam cells and atherosclerotic plaques. Native plasma LDL particles cannot stimulate the formation of foam cells because LDL receptor-mediated uptake of LDL particles is rapidly down-regulated in response to an increase in cellular content of cholesteryl esters, thereby blocking excess accumulation of LDL-derived cholesterol. Therefore, some type of biologic modification must be required to activate the atherogenic potential of LDL.
- Foam cell formation and atherogenesis most likely require the presence of biologically modified forms of LDL particles. The prime candidate for a biologically relevant mechanism for LDL modification is oxidation. Oxidative metabolism is an essential aspect of many cellular functions, but excessive oxidative activity may cause free–radical-mediated damage to nearby molecules, including lipids, proteins, DNA, and carbohydrates. Highly reactive free radicals of oxygen are generated in living organisms primarily as the superoxide radical, hydroxyl radical, and hydroperoxyl radical.
- Oxidized LDL particles have several properties that potentially may contribute to the progression of atherogenesis: 1) increased rate of cellular uptake via the scavenger receptor, 2) stimulation of foam cell formation from macrophages and smooth muscle cells, 3) stimulation of smooth muscle cell proliferation, 4) delayed uptake by the LDL receptor, 5) chemotactic for circulating monocytes, 6) inhibition of motility of arterial wall macrophages, 7) *adhesion of leukocytes to the endothelium,* 8) induction of expression of monocyte chemoattractant protein-1 (MCP-1), macrophage colony stimulating factors (M-CSFs), tissue factor, and other cytokines, 9) stimulation of interleukin-1 release, 10) inhibition of endothelin-1 secretion (interfering in arterial wall repair), 11) decreased endothelium-dependent arterial relaxation (contributing to arterial pressure), 12) immunogenic 13) cytotoxic proof that oxidation of LDL contributes to the pathogenesis of atherosclerosis is still lacking, but much evidence supports the notion that oxidized LDL is present in atherosclerotic lesions.
- Atherosclerosis may have an autoimmune component. Autoantibodies against oxidized LDL can be detected in plasma.

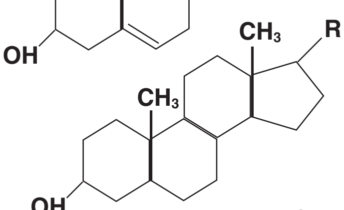
The Cholesterol Mystery

Cholesterol's Role

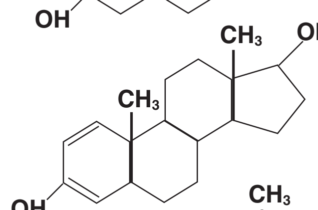
- There are over thirty natural sterols; the most recognized sterol is cholesterol. Cholesterol–a fat-like steroid alcohol ($C_{27}H_{45}OH$)–is necessary for steroid hormone (corticosteroids, and the sex hormones, estrogen, progesterone, and testosterone) production. Bile acids, vital to lipid digestion, are derived from cholesterol. Cholesterol is also a constituent of the myelin sheaths of nerve fibers.



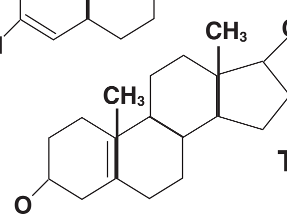
Cholesterol



Basic Steroid



Estradiol



Testosterone

- Cholesterol plays a vital physiological role, yet the American public and even the medical profession have been deceived into thinking that cholesterol *alone* causes arterial disease. The pharmaceutical industry capitalizes on the fear of "bad cholesterol" and markets seriously toxic pharmaceuticals that minimally lower serum cholesterol levels, and in the process cause liver damage to thousands of people, some of whom die as a result of using the medication. Drugs that lower cholesterol without reducing heart attacks or deaths prove that cholesterol is not the real issue. Cholesterol consumption has stayed relatively the same over the past ninety years, yet cardiovascular disease continues to rise in the general population.
- Cholesterol is bound to proteins in serum which are often referred to as *lipoproteins*. The lipoproteins include *chylomicrons, very low-density lipoproteins* (VLDLs), *low-density lipoproteins* (LDLs), and *high-density lipoproteins* (HDLs).
- Seventy to 150 grams of triglyceride (fat) is transported through the blood daily in a healthy individual; about 7 grams (less than ½ ounce) of cholesterol is transported. Cholesterol in the brain and spinal cord accounts for about 25% of the body's total stores.
- The liver provides long-chained essential fatty acids to surround cholesterol molecules with protein to make lipoproteins. HDL (high density lipoprotein), often referred to as the "good" cholesterol, carries cholesterol from the cells back to the liver, where it is incorporated into bile, then excreted into the intestine for removal in the feces. The liver uses 80% of circulating cholesterol to produce bile salts.
- Cholesterol is stored primarily in lean tissue in all animals. Fish, poultry, beef, and pork all contain about the same amount of cholesterol (50–70 mg per 4 ounces). A food does not have to be high in saturated fat to be high in cholesterol—eggs (about 3½ grams of saturated fat) contain about 275 mgs of cholesterol; shrimp (less than a gram of fat in four ounces) contains 170 mgs.
- Chylomicron levels dramatically increase for two to ten hours after a meal. All cholesterol testing should therefore be done after at least a 12-hour fast.
- Chylomicrons and VLDLs contain the least protein and carry triglycerides to the tissues to be used as fuel or stored as adipose tissue. Remnants are removed by the liver. Chylomicrons and VLDLs are the two lipoproteins most associated with heart disease and atherosclerosis. An LDL serum reading of 60–75% is considered a cardiac risk. Age increases serum cholesterol, perhaps because of slowed hepatic function.
- The most remarkable visual changes in a blood sample containing high levels of chylomicrons and VLDLs is its thick, milky appearance upon refrigeration.
- HDLs take cholesterol to the liver, where it may be removed via bile synthesis. HDLs are considered the "good " cholesterol. Twenty to 25% HDLs in a serum sample is inversely associated with cardiac risk.
- Hypercholesterolemia associated with elevated plasma concentrations of low density lipoprotein (LDL) cholesterol is an important risk factor for atherosclerosis. Dietary interventions designed to reduce plasma levels of total and LDL cholesterol can reduce the risk of myocardial infarction and induce regression of established coronary atherosclerosis.
- High serum cholesterol is strongly associated with some cancerous tumors. Xanthomas (tiny yellowish fat nodules) on the skin are visual evidence that serum cholesterol may be too high. Xanthelasmas (fat nodules on the eyelids) are most common.
- Cholesterol protects the skin, where it is converted to vitamin D by the sun.
- The major lipid in the much-maligned egg

yolk is lecithin–a phospholipid praised for its cholesterol-lowering powers.

- Plant foods contain sterols; beta-sitosterol inhibits cholesterol absorption.
- In the absence of dietary fiber, up to 94% of serum cholesterol and bile acids are reabsorbed and recycled.

Factors Contributing to High Serum Cholesterol

- Normal serum cholesterol readings are 150 to 190 mg/dl in the average American; half of American males exceed 200 mg/dl; levels approaching 300 mg/dl constitute a serious risk for atherosclerosis.
- The liver becomes saturated with cholesterol at a dietary intake of 400–500 mgs per day.
- The average American dietary intake of cholesterol is 500–650 milligrams–twice the suggested limit of 300 milligrams.
- Cholesterol accumulates in arteries at the rate of about 1–2% a year in the average American.
- The liver will produce up to 3000 milligrams of cholesterol daily when dietary intake is zero. Increases in dietary intake result in a decrease in liver production of cholesterol. It is the malfunction of this homeostatic mechanism that is most strongly implicated in atherosclerosis and heart disease, and is probably most influenced by genetics. (Several hereditary cholesterol disorders have been identified, such as Familial Hypercholesterolemic Xanthomatosis, Dysbetalipoproteinemia and Familial Lecithin Cholesterol Acyltransferase Deficiency, to name a few).
- Stress plays a *major role* in serum cholesterol levels (see "Stress' section). Inactivity and excessive refined carbohydrates are second in causing of hypercholesterolemia; dietary overindulgence in saturated fats comes in third.
- High saturated-fat and refined carbohydrate intake increases blood chylomicrons and VLDLs, leading to high serum triglycerides–a setup for high cholesterol.
- Hypothyroidism, renal disease (especially nephrotic syndrome), acute porphyria, and alcoholism also dramatically raise serum triglycerides.
- Weight changes, illness, drugs, and exercise (or lack thereof) can cause marked changes in cholesterol readings–raising or lowering them.
- Recent research positively correlates chlorine in drinking water with atherosclerosis. Chlorine raises LDLs and oxidizes (strips electrons from) polyunsaturated fatty acids (PUFAs), thereby creating free radicals. Until recently, monochloramine (more common in municipal water treatment than free chlorine) had not been found to have a bioreactive effect, but is now implicated along with free chlorine. By-products of chlorine (Cl_2) and chloramine (NH_2Cl) both show evidence of causing cellular damage, especially of the kidneys, bladder, and colon–promoting cancerous tumors. Keep in mind that not only is water treated with chlorine, so are butchered meats and white flour.
- Because steroids, the stress hormones, are dependent on cholesterol for their manufacture, stress increases the output of steroid hormones, which then increases serum cholesterol (see "Stress" section).
- Beneficial HDLs are decreased in serum by smoking, obesity, inactivity, and progestin-containing contraceptives.

Strategies to Lower Serum Cholesterol

- Dietary reduction of saturated fats is effective in reducing cholesterol in some people (about 20% of the population) suffering from hypercholesterolemia. Reduction of *dietary cholesterol alone* rarely has a beneficial effect.

- Cholesterol intakes of less than 100 milligrams of dietary cholesterol may reverse atherosclerosis in some individuals.
- Increased soluble fiber intake has been shown conclusively to lower serum cholesterol (see "Fiber" section). Regular ingestion of vegetable gums–guar, konjac, and locust bean–has been successful in reducing serum cholesterol. Essential fatty acids– found in small quantities of polyunsaturated fats, fish liver oils, and *saponins* as found in beans, peanuts, and alfalfa, can lower serum cholesterol when used with other dietary measures.
- HDLs may be raised by frequent aerobic exercise, and moderate alcohol intake (especially red wine, which contains *resveratrol).*
- Eating nuts five times a week has been shown to alter blood lipids and reduce the risk of atherosclerotic disease and heart attack by 50%. Nuts once per week reduced the risk 25%. Walnuts, almonds, and peanuts provide the most benefit, in that order.
- Garlic and onions also reduce cholesterol and therefore, atherosclerosis.
- Mega-doses of niacin (1000–4000 mgs daily) have been used clinically with good results. In conjunction with inositol and choline, niacin therapy is even more effective. Vitamins B6 and C reduce cholesterol levels. Calcium with yogurt, chromium, and copper show cholesterol-lowering effects when used in conjunction with other vitamins and life-style changes.
- Cholesterol oxides are strongly implicated in coronary artery disease. Handling and preparing foods properly prevents atherosclerotic lesions. The villain foods are fried meats, fried potatoes, smoked meats and fish, and fried and hard-boiled eggs. Scrambled eggs have not been shown to contain significant levels of cholesterol oxides.
- A 5% reduction in serum cholesterol will translate to a 10% reduction in cardiac risk; a 10% reduction, in a 20% lessened risk.

Food Supplements

Antioxidants

- Antioxidants either stabilize free radicals or prevent the free-radical chain reaction by tying up chemicals that increase the rate of oxidation. A vitamin A, E, or C molecule protects against free radical damage by giving up one of its own electrons to stabilize the free radical.
- Treatment of experimental animals with various antioxidants (probucol, vitamin E, butylated hydroxytoluene (BHT), MDL29311, and N,N'-diphenyl-phenylenediamine) inhibits the development and progression of atherosclerosis.
- Numerous naturally occurring dietary components possess antioxidant properties. These dietary antioxidants include: tocopherols, tocotrienols, ascorbic acid, carotenoids, selenium, lycopene, ubiquinol, cryptoxanthin, canthaxanthin, phytofluene, and bioflavinoids.

Tocopherols (Vitamin E)

- Plasma vitamin E levels have been inversely related to the risk of angina.
- Tocopherols are the most abundant lipid-soluble antioxidant in tissues, plasma, and the LDL particle. Six molecules of tocopherol are present in each LDL particle.
- D-alpha-tocopherol and other isomers of vitamin E are chain-breaking antioxidants that prevent oxidation by trapping peroxyl free radicals, thereby providing first-line protection against lipid peroxidation.
- Polyunsaturate peroxidation shortens the life-span of red blood cells by damaging cellular membrane proteins. Vitamin E can prevent

premature hemolysis by retarding or inhibiting this peroxidation.

- There is an apparent 34–41% lower risk of coronary artery disease among women and men with the highest vitamin E intake.
- Pharmacologic doses of d-alpha tocopherol decrease the susceptibility of LDL to oxidative modification in nondiabetic subjects.

Carotenoids (provitamin A)

- Beta-carotene and other carotenoids are lipid-soluble antioxidants that function to trap free radicals and quench singlet oxygen.
- Low plasma beta-carotene concentrations are associated with increased risk of cardiovascular mortality.
- Experimentally, those who received 50 mg (178,571 units–a *very* high dose)) of beta-carotene every other day experienced an average 54% reduction in subsequent total cardiovascular and cerebrovascular events.

Ascorbate (vitamin C)

- Ascorbate (vitamin C) has chain-breaking properties; reacts directly with superoxide, hydroxyl radicals, and singlet oxygen; and also regenerates tocopherol.
- Vitamin C also may improve the risk of atherosclerosis by favorably altering the lipid profile, inhibiting platelet aggregation, and reducing blood pressure.
- Diabetic patients, smokers, and individuals with coronary artery disease tend to have lower plasma concentrations of vitamin C.
- Several flavonoid compounds (quercetin, rutin, morin, fisetin, gossypetin) have been found to inhibit LDL oxidation. Quercetin and rutin also appear to directly block the cytotoxic effects of oxidized LDL. However, quercetin appears to be a mutagen (causes DNA damage) in high doses.
- Additional unidentified antioxidants or other cardioprotective compounds may be present in fruits and vegetables. Diets rich in fruits and vegetables are associated with decreased frequency of atherosclerotic events.

Carnitine

- Carnitine (beta-hydroxy-gamma-trimethylammonium butyrate) is widely distributed in the body including the nervous system. Its function as a carrier of long-chain fatty acids through the inner mitochondrial membrane.
- Carnitine-deficiency syndromes are often associated with alterations in lipid metabolism and cardiac function. Cardiac function during workload conditions was depressed in carnitine-deficient hearts.
- Carnitine may have effects other than the "physiological" function–it may be a potent protector of the brain.
- Prostacyclin production is higher in those given carnitine or its derivatives.
- L-carnitine (2–4 grams) supplementation can reduce glucose plasma level increase induced by infusion of glucose solution.

Fatty Acid Formulas and Sources

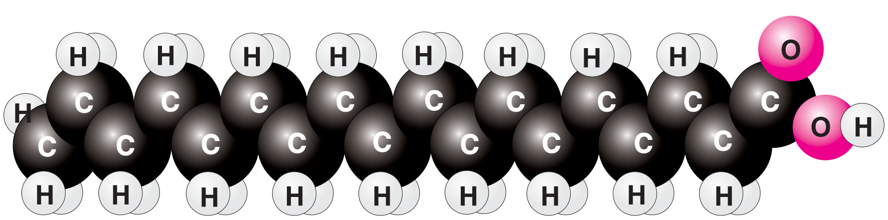
Saturated Fatty Acids

Carbons	Name	Source	Formula
C4	Butyric Acid	butter	$CH_3(CH_2)_2C0_2H$
C6	Caproic Acid	butter	$CH_3(CH_2)_4C0_2H$
C8	Caprylic Acid	coconut oil	$CH_3(CH_2)_6C0_2H$
C10	Capric Acid	palm oil	$CH_3(CH_2)_8C0_2H$
C12	Lauric Acid	coconut oil	$CH_3(CH_2)_{10}C0_2H$
C14	Myristic Acid	butter, nutmeg	$CH_3(CH_2)_{12}C0_2H$
C16	Palmitic Acid	animal, vegetable fat	$CH_3(CH_2)_{14}C0_2H$
C18	Stearic Acid	animal, vegetable fat	$CH_3(CH_2)_{16}C0_2H$
C20	Arachidic Acid	peanut oil	$CH_3(CH_2)_{18}C0_2H$
C24	Lignoceric Acid		$CH_3(CH_2)_{22}C0_2H$

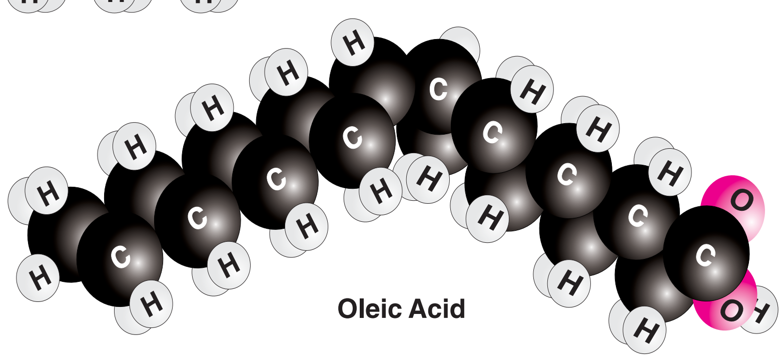
Unsaturated Fatty Acids

Carbons	Name	Source	Formula
	Crotonic Acid		$CH_3CH{=}CHCO_2H$
C16	Palmitoleic Acid	butter	$CH_3(CH_2)_5CH{=}CH(CH_2)_7CO_2H$
C18	Oleic acid*	olive oil	$CH_3(CH_2)_7CH{=}CH(CH_2)_7CO_2H$
C18	Linoleic acid*	linseed and other oils	$CH_3(CH_2)_3(CH_2CH{=}CH)_2(CH_2)_7CO_2H$
C18	Linolenic acid	linseed and other oils	$CH_3(CH_2CH{=}CH)_3(CH_2)_7CO_2H$
C20	Arachidonic acid	meats, lecithin, peanut oil	$CH_3(CH_2)_3(CH_2CH{=}CH)_4(CH_2)_3CO_2H$
	Nervonic acid		$CH_3(CH_2)_7CH{=}CH(CH_2)_{13}CO_2H$

* major constituent of human adipose tissue



Stearic Acid



Oleic Acid

Molecular Configuration of Triglycerides

H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C=C-C-C=C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H

H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C=C-C-C=C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H

H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C=C-C-C=C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H

UNSATURATED FAT (LINOLEIC ACID)

H H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H H H H H H

H H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H H H H H H

H H H H H H H H H H H H H H H H H O
H-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-OH
H H H H H H H H H H H H H H H H H

SATURATED FAT (PALMITIC ACID)

PERCENTAGE of SATURATED FAT in SELECTED FOODS

Food	Quantity	Total Gms.	Fat Grams and Percent: Saturated		Fat Grams and Percent: Unsaturated (poly and mono)	
MEATS						
Beef, heart	4 oz	3.18	1.25	39%	1.93	61%
Beef, lean ground	4 oz	11.35	5.79	51%	5.56	49%
Beef, roast	4 oz	18.75	9.56	51%	9.19	49%
Beef, sirloin	4 oz	28	14.28	51%	13.72	49%
Bologna, meat	4 oz	33.2	14.61	44%	18.59	56%
Chicken, dark	4 oz	7.68	2.46	32%	5.22	68%
Chicken, light	4 oz	4.5	1.49	33%	3.01	67%
Chicken, livers	4 oz	4.67	2.05	44%	2.62	56%
Franks, meat	2	20	8.8	44%	11.21	56%
Lamb, chops	4 oz	24.25	13.82	57%	10.43	43%
Lamb, roast leg	4 oz	15.43	8.8	57%	6.63	43%
Pork, bacon	4 oz	78.5	32.19	41%	46.32	59%
Pork, chops	4 oz	22.25	9.12	41%	13.13	59%
Pork, roast	4 oz	26	10.66	41%	15.34	59%
Pork, sausage	4 oz	57.5	23.58	41%	33.92	59%
Pork, spareribs	4 oz	22.43	9.20	41%	13.23	59%
Turkey, dark	4 oz	9.4	2.91	31%	6.49	69%
Turkey, light	4 oz	4.43	1.37	31%	3.06	69%
Veal, cutlet	4 oz	10.3	5.25	51%	5.05	49%
GAME						
Duck	4 oz	35.5	9.1	26%	23.4	74%
Goose	4 oz	38.5	12.32	32%	26.18	68%
Pheasant	4 oz	11.75	4	34%	7.75	66%
Rabbit	4 oz	7.25	1.81	25%	5.44	75%
Venison	4 oz	4.5	3.11	69%	1.4	31%
DAIRY						
Buttermilk	1 cup	5	3.3	66%	1.7	34%
Cheese, American	1 oz	8.86	5.85	66%	3.01	34%
Cheese, Bleu	1 oz	8.4	5.32	65%	2.66	35%
Cheese, cheddar	1 oz	9.4	5.98	64%	2.93	36%
Cheese, cottage low-fat	4 oz	2	1.32	66%	.68	34%
Cheese, cottage reg.	4 oz	5	3.3	66%	1.7	34%
Cheese, cream	1 oz	10.6	7	66%	3.6	34%
Cheese, Mozzarella	1 oz	4.85	3.2	66%	1.65	34%
Cheese, Muenster	1 oz	8.52	5.42	64%	2.66	36%
Cheese, Parmesan	1 oz	7.3	4.65	66%	2.29	34%

Percentage of Saturated Fat in Selected Foods, continued

Food	Quantity	Total Gms.	Fat Grams and Percent: Saturated		Unsaturated (poly and mono)	
DAIRY, *continued*						
Cheese, Parmesan, dry	1 oz	3	1.9	63%	.94	37%
Cream, heavy	1 oz	11.01	7.27	66%	3.74	34%
Eggs	1 large	6	2.7	45%	3.3	55%
Ice cream	8 oz	14.3	9.44	66%	4.86	34%
Ice milk	8 oz	5.63	3.51	62%	1.84	38%
Milk, low-fat	1 cup	4.68	2.92	66%	1.52	34%
Milk, whole	1 cup	8.15	5.38	66%	2.77	34%
Yogurt, low-fat	1 cup	3.52	2.27	64%	1.07	36%
NUTS						
Almonds, raw	2 oz	19.25	1.55	8%	16.75	92%
Brazils nuts	2 oz	23.43	4.68	20%	17.33	80%
Cashews	2 oz	16	2.73	17%	12.33	83%
Coconut meat	2 oz	7.05	6.98	99%	.07	1%
Peanuts	2 oz	17.53	4.03	23%	13.5	77%
Pecans	2 oz	19.23	1.54	8%	17.69	92%
Pistachios	2 oz	32	4.4	14%	26	86%
Pumpkin seeds	2 oz	16.35	3.11	19%	13.24	81%
Sunflower seeds	2 oz	17.15	2.23	13%	14.92	87%
FATS, OILS						
Butter	1 T	11	7.26	66%	3.74	34%
Lard	1 T	11	4.4	40%	6.6	60%
Margarine	1 T	11	2.09	19%	8.91	81%
Oil, canola	1 T	14	1	7%	13	93%
Oil, corn	1 T	14	1.54	11%	12.46	89%
Oil, olive	1 T	14	1.68	12%	12.32	88%
Oil, peanut	1 T	14	1.68	12%	12.32	88%
Oil, safflower	1 T	14	1.26	9%	12.74	91%
Oil, soy	1 T	14	2.38	17%	11.62	83%
Oil, sunflower	1 T	14	1.82	13%	12.18	87%
Oil, wheat germ	1 T	14	2.94	21%	11.06	79%
Shortening, vegetable	1 T	11	2.86	26%	8.14	74%

FATS GROUPED by PERCENT (of Total Calories)

1% to 15%	
alfalfa sprouts	12
apple	2
apricot	1
artichoke	3
asparagus	7
bamboo shoots	8
banana	2
beans, garbanzo	12
beans, green	5
beans, kidney	4
beans, lima	3
beans, pinto	3
beans, white Northern	4
beets	3
blackberries	13
blueberries	6
bran, wheat	12
bread, French	10
bread, pita	13
bread, raisin	9
bread, rye	5
bread, white	12
bread, whole wheat	11
broccoli	9
brussels sprouts	8
cabbage	5
cantaloupe	3
carrots	4
catsup	4
cauliflower	8
celery	7
cherries	4
clams, canned	13
cod	9
corn	8
cornflakes	1
cream of wheat cereal	3
cucumber	5
dates	1
eggplant	8
figs	3
garlic	4
grapefruit	2
grapes	2
haddock	8
halibut	11
honeydew melon	8
kumquat	1
lemon	6
lentils	0
lettuce, Boston	10

1% to 15%	
lettuce, iceberg	7
lettuce, romaine	15
mango	5
muffin, English	1
mushrooms, can	12
mushrooms, fresh	8
nectarine	1
noodles, pasta	5
okra	8
onions, dry	3
onions, green	4
orange	4
papaya	13
parsley	11
parsnips	7
peach	2
pear	5
peas, green	5
pepper, bell	6
persimmon	3
pineapple	3
plum	1
pomegranate	1
popcorn	11
potato, baked	2
potatoes, mashed	10
prunes	2
pumpkin, canned	7
radishes	0
raisins	1
raspberries	7
red snapper	12
rice, brown	6
rice, white	2
scallops, fresh	2
shredded wheat	5
shrimp, steamed	8
sole	14
spinach, raw	10
squash, summer	6
squash, winter	5
strawberries	4
tangelo	2
tangerine	4
tomato	7
tortilla, corn	8
tuna, in water	11
turnips	7
watermelon	6
wheat flakes	15
yam	2
yeast	4

16% to 25%	
bass	20
beef, round steak	24
buns, hotdog	17
cheese, cottage, lowfat	20
chicken, white	21
clams, fresh	22
crab, canned	23
crab, fresh	19
lobster	19
milk, condensed, swt	24
Noodles, Parmesano	21
oatmeal	16
oysters	25
perch	23
pork and beans	23
roll, dinner	18
soup, bean	23
soup, chicken	22
soup, split pea	17
spinach, canned	17
tortilla, flour	17
turkey, ground, lean	24
turkey, light meat	19
yogurt, plain, lowfat	22

26% - 38%	
beef, chipped	29
beef, ground, x-lean	28
Beef-a-Roni	30
bread, corn	31
cheese, cottage, reg.	38
chicken, dark	31
CornNuts	30
cracker, saltine	27
Din. Class. chic nood.	36
Din. Class turkey	38
ice milk	27
milk, butter	36
milk, low fat	35
muffin, bran	30
noodles, Top Ramen	37
nuts, Brazil	36
pancake, white flour	32
potatoes, mash, inst.	30
rabbit	27
Ravioli, canned	26
soup, chic. rice/nood.	32
spaghetti w/meat sce	32
swordfish	34
turkey, dark	36
venison	27

39% to 68%	
BBQ sauce	62
beef, chuck roast	43
beef, ground, regular	52
beef, porterhouse	57
beef, sirloin	49
beef, T-bone	58
beef, tenderloin	52
beef, veal cutlet	56
biscuit, enriched	42
cheese, Mozzarella	56
cheese, Parmesan	60
cheese, Swiss	66
chili w/beans	41
chili, no beans	68
Din. Class. Beef ribs	47
Din. Class. sal. steak	49
duck	52
eggs	68
fish sticks	45
goose	50
hash, corned beef	50
ice cream	47
lamb, chops	50
lamb, leg roast	41
LeMenu sliced turkey	47
macaroni w/cheese	39
milk, whole	48
noodles, chow mien	52
pancake, buckwheat	41
pork, chops	66
pork, ham	55
pork, roast	63
potato chips	62
potatoes, french fry	42
potatoes, hash browns	45
potatoes, scalloped	47
salmon, sockeye, can	41
sardines, can in oil	51
scallops, fried	39
soup, cream of...	52
stew, beef, canned	43
stuffing, Stove Top	46
taco shell	40
trout, rainbow	58
Vandekamps mw sole	55

69% to 100%	
almonds	76
avocado	81
bologna	80
butter	100
cashews	69
cheese American	74
cheese, Cheddar	73
cheese, cream	89
cheese, Jack	73
coconut meat	81
cream, heavy	95
cream, sour	88
dressing, Bleu	91
dressing, Italian	95
dressing, lite Bleu	78
franks	74
half-and-half	78
macadamias	90
mayonnaise	98
oil, vegetable	100
olives, green	90
olives, ripe	92
peanuts	76
pecans	87
pepperoni	80
pistachios	76
pork, bacon	80
pork sausage	77
pork, spareribs	81
salami	72
sandwich spread	85
sesame seeds	77
spam	77
sunflower seeds	71
tartar sauce	87
walnuts	82

CHOLESTEROL in SELECTED FOODS

Food	Amount	Mgs.
Beef, chuck roast	4 oz	67.4
Beef, lean ground	4 oz	73.8
Brownie	1 average	25.3
Butter	1 T	35.6
Cake, sponge	1/10 cake	123
Cheese, American	1 oz	27
Cheese, cheddar	1 oz	30
Cheese, cottage, low-fat	1 cup	19
Cheese, cottage, non-fat	1 cup	10
Cheese, cottage, regular	1 cup	31
Cheese, cream	1 oz	31
Cheese, mozzarella, part skim	1 oz	15
Cheese, Muenster	1 oz	27
Cheese, Parmesan	1 oz	8
Cheese, Roquefort	1 oz	26
Chicken, back w/skin	½	64
Chicken, breast, no skin	½	73
Chicken, breast, w/skin	½	83
Chicken, drum, no skin	1	41
Chicken, drum, w/skin	1	48
Chicken, gizzards	4 oz	164.5
Chicken, liver	4 oz	629.3
Chicken, thigh, no skin	1	49
Chicken, thigh, w/skin	1	58
Clams, canned	4 oz	120
Cornbread	2" square	30
Crab, fresh	4 oz	113.3
Cream, heavy	1 T	40.8
Cream, sour	1 T	6.4
Custard, cooked	1 cup	278
Egg	1 large	274
Fish, haddock	4 oz	68
Fish, halibut	4 oz	56.8
Fish, perch	4 oz	79.3
Fish, salmon, fresh	4 oz	68
Franks	1	22
Ice cream	1 cup	59
Lamb, chop	4 oz	67.5
Lobster	1 tail	225
Mackerel, fresh	4 oz	107.8
Milk, canned	8 oz	104
Milk, low-fat	8 oz	18
Milk, non-fat	8 oz	10
Milk, whole	8 oz	33
Noodles, egg, cooked	1 cup	50
Oysters, canned	4 oz	54
Pie, apple	1/6–9" pie	156
Pork, bacon	1 strip	5
Pork, chop	4 oz	65
Potatoes, au gratin	1 cup	36
Pudding, bread	1 cup	170
Rabbit	4 oz	73.8
Sardines, canned in oil	1 oz	20
Scallops, fresh	4 oz	39.8
Shrimp, steamed	4 oz	170
Tuna, canned in H_2O	6.5 oz	102.4
Turkey, dark	4 oz	115
Turkey, light	4 oz	87.3
Yogurt, plain low-fat	1 cup	14

OMEGA-3 FATTY ACIDS in FISH and SEAFOOD

Seafood	mg/4 oz
Bass, sea	800
Clams	274
Cod	229
Flounder	343
Haddock	229
Halibut	1486
Lobster	69
Mackerel	2171
Mussels	491
Oysters, domestic	583
Perch, freshwater	229
Red snapper	686
Salmon, pink	2514
Sardines, in oil	5829
Scallops, bay	149
scallops, sea	206
Shrimp	229
Sole	114
Swordfish	1029
Trout, freshwater	1600
Tuna, albacore	2400