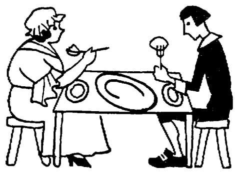
Fats and Fatty Acids

CALLIE MAE COONS



FATS often have been prized articles of diet in man's struggle for food. From early times they have denoted prosperity and hospitality, as when the fatted calf was prepared for merrymaking and the widow shared her oil with the prophet.

Scientific and economic concern about dietary fats goes in cycles.

Sometimes the cycle is geared to war and famine, when fats tend to be scarce and are among the first foods to be conserved and rationed. When food surpluses mount, fats float to the top and are among the first to be used extravagantly.

Pioneers in every civilization have been ingenious in ways of conserving and using fats and in bartering them in international trade. Still today many peoples have a low consumption of fats and oils.

Our food technology in the United States has made possible improved supplies of separated fats and oils from meats, grains, cottonseed, soybeans, peanuts, olives, and coconut.

Agricultural research has led to higher acreage yields of the oilseeds and grains and meat animals of high fatness. The flavors of cooked fats have been imparted to many kinds of processed foods, from roasted nuts to main dishes.

Our total and proportional consumption of fats and oils has climbed to an alltime peak, and the kind and amount of fats we eat have come under the scrutiny of economists and scientists.

Fat makes our meals palatable and satisfying. It is the most concentrated dietary source of energy—9 Calories a gram, compared to 4 Calories in carbohydrate and protein. It promotes efficiency in the utilization of protein and carbohydrate. It facilitates the utilization of fat-soluble vitamins.

Some fats and oils are important sources of vitamins A, D, E, and K.

Fats provide various amounts of fatty acids known to be essential in diets and many other fatty acids, which may have nutritional functions that we do not know now.

The amounts of fat, visible and invisible, in food supplies in the United States at retail level have been estimated at 32 percent of the Calories in 1910, 35 percent in 1930, and 40 percent in 1950. They have continued to rise more steeply during the 1950's.

The amounts used in households are much the same—about 30 to 33 percent of the Calories before 1900, 35 to

38 in the mid-1930's, and 42 to 44 in the mid-1950's.

Farm families tend to use more fat than city families do, and northern families more than southern families.

As the proportion of Calories from protein has remained about the same—an average of 11 to 12 percent at the household level—the shift to larger proportions of Calories from fat has been at the expense of carbohydrate.

Thus, in the North Central States, farm families in 1955 had 44 to 46 percent of their Calories from fat and about the same proportion from carbohydrate; 40 years earlier, Calories from fat ran 33 to 35 percent and from carbohydrate 53 to 55 percent.

Families with high incomes tend to have even more Calories from fat than from carbohydrate. Low-income groups select more Calories from carbohydrate.

The few reports of individual food intake—the amounts people actually ingest—by adults since 1900 indicate 38 to 42 percent of Calories from fat, 45 to 55 percent from carbohydrates, and 13 to 15 percent from protein. The proportions are about the same for women as for men and for the few groups of elderly people on whom reports were made.

These scattered figures on individual intake do not confirm the time trends noted for household diets and retail food supplies, but they confirm the tendency to a high level of intake of fat in the United States.

Figures from chemically analyzed diets and school lunches support the conclusion that the average diet carries more than 40 percent of its Calories from fat and that diets of some individuals carry 50 percent or more.

The fat may drop to 30 percent or even 20 percent of the Calories in times of war or economic stress.

Often 25 to 30 percent is recommended as desirable for any population at any time. The lowest averages reported from any study in the United States, however, was for two groups of families in the southern mountains just after 1900. Their diets contained, respectively, 26 and 30 percent of the Calories from fat, 8 and 9 percent from protein, and 66 and 61 percent from carbohydrate.

People in densely populated countries are said to subsist on such food patterns, often with even less than 30 percent from fats at any time. People in some countries who have fat intakes that are one-third to one-half that in the United States get less than 20 percent of the dietary fat from all animal sources, as much as 40 percent from cereal grains, and 25 percent from peanuts and other oilseeds.

THE SOURCES of fats consumed in the United States follow changing food patterns. The proportions of Calories from dairy and meat products and from separated fats and oils have increased steadily since 1900.

The average household diet in 1955 had about 25 percent of its fats from dairy products; 24 percent from pork products; 14 percent from beef, veal, and lamb; 13 percent from margarines and shortenings; 6 percent from oils and salad dressings; 6 percent from poultry, fish, and eggs; and 12 percent from baked goods, nuts, fruit, and vegetables.

Of the 25 percent from dairy products, more than half was from milk and cheese; 7 percent was from butter, separated from the other milk nutrients; and the rest was from cream and ice cream.

We should bear in mind that natural unseparated fats are associated with the protein, minerals, and vitamins characteristic of the food, as in milk or pork, and also carry some vitamins, such as A, D, and E, which are useful in the metabolism of fats.

HOW SHALL we choose fats to eat when we have much and many kinds of them in the store and on the table?

Some who want to control weight may be interested in whether the fat is visible (as in butter, shortening, salad oils, and other separated fats or in the visible fat on meat). The fat on meat can be trimmed away, but that means waste. The less readily apparent fats, those mingled, blended, or absorbed into food products, make good eating, but they cannot be trimmed away by the consumer.

Some fats are solid—more or less firm—at room temperature. Others are plastic. Many come naturally as oils. These characteristics are important for baking, deep frying, and making salad dressings.

Almost any fat can be used for any culinary purposes by suitable adaptations in cooking procedures, however. The melting point of a fat can be altered in many ways by the technologist, but consistency does not always denote properties important in diet.

One will do well to understand the composition and structure of fats and fatty acids in order to know their complicated role in nutrition. The details are technical, however, and some readers may wish to skip this section.

A pure fat is composed of molecules of glycerol (a trihydroxy alcohol, the same as glycerin), to each of which 1, 2, or 3 fatty acids are linked to form monoglycerides, diglycerides, or triglycerides, respectively.

Fatty acids are hydrocarbons consisting of a chain series of carbons, each of which is able to carry 2 hydrogens, but with 3 hydrogens (methyl group) at one end, and an acid (carboxyl) group at the other end, which connects to the glycerol.

Natural fats, as in meats, grains, and nuts, are made up mostly of triglycerides with only trace amounts of the mono- and di- forms and some free fatty acids. Processed fats, such as hydrogenated commercially hardened shortenings, may contain up to 20 percent of monoglycerides and diglycerides.

It makes some difference nutritionally which fatty acid is attached in the middle position on the glycerol molecule and whether an outer position is open or is linked to another substance.

Much variety in fats comes from the kinds of fatty acids linked to the glycerol—whether all three are alike or all are different, whether all are saturated (contain all the hydrogen they can carry) or of various degrees of unsaturation, and whether they are mostly short-chain (under 12 carbons), long-chain (12 to 18 carbons), or extra long-chain (20 carbons or more) fatty acids.

Fatty acids that have 18 carbons in a chain make up about 80 percent and those with 16 carbons comprise about 10 to 15 percent of the fatty acids in average diets.

Short-chain fatty acids occur mostly in milk fat and in coconut oil. Extra long chains occur in fish oils.

Fatty acids that are common in food fats and oils fall into three broad classes according to their degree of saturation.

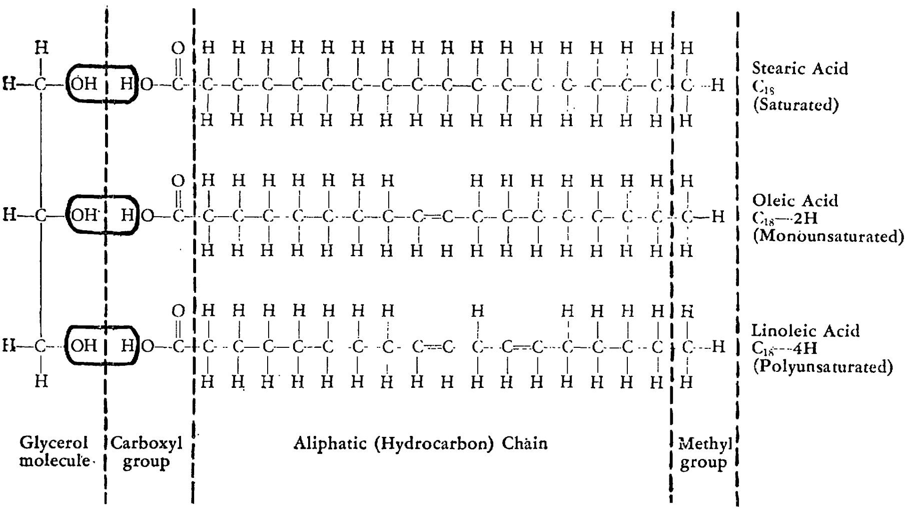
The fully saturated fatty acids make up about 40 to 45 percent of those in average diets in this country. They are rather stable chemically and account for much of the firmness of fats at room temperatures.

Saturated fatty acids may be of any chain length, from 4 to 18 or more carbons. The most common ones and their chain lengths are: Stearic (18), palmitic (16), myristic (14), and lauric (12).

Beef fat contains 20 percent of stearic acid and lard about 12 percent. Other animal fats run higher. Most animal fats and cottonseed oil contain about 25 to 30 percent of palmitic acid. Palm oil has about 40 percent.

The monounsaturated fatty acids (monoenoic) are those with one reactive unsaturated ("doublebond") linkage, which has 2 hydrogens missing. The best example and the one most abundant in foods is oleic acid containing 18 carbons, which alone furnishes about 40 percent of all the fatty acids in the average diet in this country. It represents 70 to 75 percent of the fatty acids in olive oil and the hydrogenated (commercially hardened) shortenings; 50 percent or more of the fatty acids in lard and peanut oil; and 40 percent in beef, lamb, and poultry fat. Its nutri-

Structure of Mixed Triglyceride—A Monosaturated Fat



tional role in man has not been fully defined, however.

The polyunsaturated fatty acids, a heterogeneous group, include some essential fatty acids and the extra long-chain fatty acids (20 to 26 carbons) common in fish oils. The degree of unsaturation may involve 2, 3, 4, or more linkages in the chain, with correspondingly 4, 6, 8, or more hydrogens missing. Polyunsaturated fatty acids are sometimes classed as dienoic, trienoic, and tetraenoic, and so on, depending on the number of linkages affected.

The position of unsaturation along the chain is important chemically and nutritionally as well as technologically in processing.

Nutritionally, the position of unsaturation may determine the point of breakup of the chain in metabolism and how well the body can handle the remaining fragments.

The positions of carbons in fatty acids are numbered successively, beginning at the carboxyl (acid) end of the chain, which attaches to the glycerol. The position of linkage carries the number of the lower or first of the 2 carbons that it joins.

Most common monounsaturated fatty acids, including oleic, have the reactive unsaturated linkage in the 9th position—that is, between the 9th and 10th carbons. Linoleic acid, with 2 reactive linkages, has them in the 9th and 12th positions. The descriptive chemical name is 9,12-octadecadienoic. Arachidonic acid, with 4 reactive linkages, has this chemical name: 5,8,11,14-eicosatetraenoic.

The polyunsaturated fatty acids considered essential for nutrition are linoleic, linolenic, and arachidonic.

Because arachidonic acid can be formed from linoleic acid in the body, it is not really a dietary essential. Besides, it constitutes less than 1 percent of animal fats (except in liver and some pig fats, which contain more than 2 percent) and less than 1 percent or none of vegetable fats. Therefore it may be disregarded in choosing dietary fats.

Linolenic acid has a different and perhaps less important nutritional role than linoleic and occurs only in small amounts in food fats. Soybean oil, with 7 percent, is the highest.

Of the three, linoleic becomes the center of dietary importance. It is relatively more abundant in foods than the other two and must come from diet because it cannot be formed by the human body.

Sources of linoleic acid include many grain oils and seed oils, which contain 50 percent or more. Fats from nuts, peanuts, and poultry carry 20 to 30 percent. Outstanding exceptions are fat from walnuts, which has more than 60 percent of linoleic acid, and fat from coconuts, which has about 2 percent.

Fats from such fruits as avocado and olive contain about 10 percent of linoleic acid. Those from leafy vegetables and legumes run higher, 30 percent or more, but the total amount of fat in greens is low.

Doubtless the diet should provide some linoleic acid every day unless the body (as in weight reduction) is mobilizing tissue fat known to contain this fatty acid.

Linoleic acid is necessary for growth and reproduction and helps protect the animal against excessive loss of water and damage from radiation. It is essential for normal skin conditions in babies, who require about 5 percent of the Calories from this source.

When it is fed as 25 percent or more of the fat, linoleic acid lowers blood cholesterol in adults under certain dietary conditions. It appears to have other metabolic functions that have not yet been defined fully. (Cholesterol is a complex, fatlike material that occurs in all animal tissues, notably nerve tissue, bile, gallstones, egg yolk, liver, spleen, brain tissue.)

Some animal fats and vegetable fats or oils are fairly similar chemically. Both butterfat and coconut oil, for example, contain high proportions of short-chain fatty acids. Beef fat and coconut oil contain less than 2 percent of linoleic, one of the fatty acids that are essential in the diet. Corn oil contains more than 6 times as much linoleic as olive oil, and chicken fat up to 10 times as much as the fat of ruminant animals.

Both animal and vegetable fats contain up to 5 percent of various fatty substances that are not true fats but may be nutritionally important.

There are processed fats and natural fats and many kinds in each class, so that this distinction is not a good basis for selection by consumers.

Hydrogenation, one type of processing, induces hydrogen to enter points of unsaturation in the fatty acid chains to increase the saturation of the fat and achieve varying degrees of firmness sought for specific uses. It also prevents oxidative rancidity and thus greatly prolongs the storage life of the fat. Only about 15 percent of the dietary fat that reaches the consumer has been exposed to hydrogenation.

When hydrogenation was first used, only a fraction of the fat was exposed to the process and then blended with the untreated oil to a desired consistency.

A later practice is to expose an entire lot in a continuous controlled process, so that more fatty acids are altered but to lesser degrees of saturation. This process tends to cover up most of the essential linoleic acid and convert it to the already abundant oleic acid.

The technologist refers to nonselective hydrogenation, by which saturation of monounsaturated and polyunsaturated fatty acids proceed simultaneously, and to selective hydrogenation, by which polyunsaturated fatty acids are converted largely to monounsaturated before much of either is converted to saturated. Selective hydrogenation thus changes most of the essential linoleic acid to oleic acid, which is already abundant.

By changing the conditions of hydrogenation, the technologist can get various physical and chemical characteristics in the finished product. Many of the characteristics can be obtained also by blending proper assortments of natural fats and oils.

The chemist has not yet found out all that happens to a fat or oil during processing. Biochemists and physiologists cannot yet tell us how the body utilizes some of the products formed during hydrogenation, such as isoacids, transisomers, and conjugated fatty acids.

At least one study has shown these "unnatural" products to be ineffective as essential fatty acids. Another study indicated that conjugated forms favor high blood cholesterol.

Obviously it is not enough to distinguish saturated and unsaturated "fats" for nutrition purposes, because there are varying degrees of saturation in all fats. All oils contain some saturated fatty acids. All solid fats contain some unsaturated fatty acids even though fats that are firm at room temperatures consist mostly of saturated fatty acids.

Fats that are soft or liquid at room temperature may be called unsaturated but may contain different assortments of fatty acids. Olive oil, for example, is liquid because it contains 75 percent or more of oleic acid (one linkage unsaturated); safflower oil contains nearly 75 percent linoleic acid (two linkages unsaturated); linseed oil may contain up to 65 percent of linolenic acid (with three linkages unsaturated).

Iodine value, based on a laboratory test showing uptake of iodine by all unsaturated points in the fatty acid chains, is a gross measure of total unsaturation or potential hydrogen uptake, but it does not indicate the particular fatty acids present.

Iodine value runs below 10 in a near-saturated fat like coconut oil, more than 100 in most vegetable oils, and up to 200 in a highly unsaturated oil, such as linseed oil and some fish oils.

The use of radioactive elements makes it possible to follow fatty acids, cholesterol, and other lipids (fatlike substances) through digestion and absorption to their destinations in the body organism.

In the digestive tract, fat-splitting enzymes in the gastric, pancreatic, and intestinal juices take their turn in separating some of the fatty acids from glycerol. Those in the outer position on the glycerol molecule are split off first. Those in the middle position are split off less rapidly, if at all.

The rate of digestion and absorption depends also on chain length and on the amount and position of the saturated fatty acids, if any, on the glycerol.

The rate depends at first on the degree of emulsification (separation into fine droplets) of the fat, which is none in separated fats or oils and partial in others, as in egg yolk, milk fat, and mayonnaise. Emulsification in the intestinal tract is greatly aided by the bile.

Persons with defective or limited secretions of bile have less efficient digestion of fats than normal persons.

Early experiments showed digestibility by normal young adults to be 90 percent or more for various fats, but we need new studies with fats fed in customary mixed diets and a better understanding of the chemistry of fats and the physiology of absorption and transport.

The various products of fat digestion—some diglycerides and monoglycerides, but mostly free fatty acids and glycerol—are absorbed from the intestine along with lecithin, cholesterol, and other lipids, which also are linked with some fatty acids.

Some fatty acids may be recombined into glycerides, and some positions may be interchanged for others in passing across the intestinal wall into blood and lymph systems. The short-chain fatty acids appear less likely to be reformed and may go more directly through the blood to the liver. They may present more problems in metabolism than the common long-chain ones.

After absorption, about half of the fatty acids in circulation appear linked with cholesterol and phospholipids, the remainder as glycerides or free.

The proportions in such combinations are indicators of normalcy in lipid metabolism and of the effects of various food fats and diets. Values regarded normal in the plasma of persons after fasting overnight are 45 percent of the fatty acids in glycerides, 35 percent in phospholipids (mostly lecithin), and 15 percent in cholesterol. The rest are free or in loose protein combinations.

In plasma of blood and lymph, the products of fat absorption, some of which have been through the liver, are transported to tissues along with other lipids from internal body sources. The lipids travel as parts of complex particles of various sizes called lipoproteins, in "wraps" of protein, which keep the fatty substances miscible with the watery plasma during transport.

The largest of these particles, called chylomicrons, may cause the plasma to appear milky after fat-rich meals. Other particles, graded into successively smaller sizes down to ultramicroscopic, are known as alpha- (the heavier) and beta- (the lighter) lipoproteins, and probably are elaborated in the liver.

The level of beta-lipoproteins is often elevated in abnormal fat metabolism and can be raised experimentally by feeding some fatty acids. Ratios of alpha- to beta-lipoproteins below 0.5 are found in myocardial infarction (coronary artery damage). Ratios around 0.7 or more occur in persons considered well.

Levels of lipoproteins normally are elevated after meals and are cleared out of the plasma in 3 to 6 hours. The various lipids are delivered where they are needed to the skin, brain, and nerve tissues or to fat depots or are oxidized by the tissues to produce energy for heat or activity.

During high lipid levels, the blood tends to clot more easily, regardless of the kind of fat ingested, but clotting also depends on the age of the person, the blood enzyme levels, and other metabolic states.

High lipid levels after meals return to normal more slowly—in 12 hours or longer—in extremely obese persons, in elderly persons with atherosclerosis (a condition accompanied by thickened walls in arteries of the heart), and in persons with high blood lipid levels from other causes, including liver injury.

The lipid levels return to normal more readily in persons accustomed to physical activity than in persons sedentary or inactive for hours before and after meals. Lipids arising within the body, such as during conversion of excessive nonfat Calories to fat, may augment the burden of disposal.

Sustained elevated plasma lipid levels are considered undesirable. The underlying cause may be that the body has lost some hormone or enzyme capacity to convert, oxidize, or dispose of excesses, or that the circulatory system is being flooded continually with lipids from the foods eaten as well as from internal biosynthesis, but in any case the longtime consequences may be serious.

Fatty acids that are used for muscular energy may be oxidized in any tissue of the body.

The first step in oxidation is breaking off from the fatty acid chain, a two-carbon fragment known as an active acetate. Failure in oxidation may arise from inability to break off the acetates because of the unnatural structure of the fatty acid chain or because of physiologic defects of the body. The failure is due more commonly to lessened ability of the body to proceed with completion of the oxidation of the acetate to carbon dioxide and water as a result of deficiency of some hormone, enzyme, or vitamin.

If the kind of fat being laid down in adult human tissues comes mainly from absorbed fatty acids, it will resemble the fat from the food eaten, especially the long-chain saturated and unsaturated fatty acids.

If the fat is synthesized internally from excess total Calories, such as from sugars and proteins, saturated fatty acids will predominate in the fat deposits, and none will be linoleic, because the body cannot synthesize it. In this respect man metabolizes fat as do pigs, which lay down a firmer, more saturated fat on a corn ration high in carbohydrate, from which fat must be synthesized, than on a peanut-containing ration, from which a preformed oil containing as much as 20–25 percent linoleic acid is absorbed.

Ruminant animals, like cows, absorb short-chain fatty acids, which have been synthesized by micro-organisms in the rumen. Short-chain fatty acids thus predominate in the fat of cow's milk. The shortest is butyric acid, with a chain length of only 4 carbons. More than 30 kinds of fatty acids occur in butterfat.

The fat in human milk contains 2 to 4 times as much linoleic acid as the fat of cow's milk, but we do not know whether this is merely a reflection of diet or is due to liver function or to some special activity of the mammary gland to meet particular needs of the offspring.

Human body fat contains about 11 percent of linoleic acid, according to German analyses made nearly 30 years ago. This figure is only a little higher than the 10 percent estimated content of the average diet in the United States in 1955.

THE IMPORTANCE of blood cholesterol in the metabolism of fat and what regulates its formation and distribution in the body has been an area of intensive research, which so far has given us only partial answers.

Common indicators of abnormal fat metabolism include plasma cholesterol levels, cholesterol-phospholipid ratio in plasma, serum lipoprotein patterns, and the distribution of fatty acids among the lipid fractions—glyceride, cholesterol, and phospholipid—in the blood. Measurement of the plasma cholesterol is the oldest and simplest method of testing, and the results are most easily interpreted.

High cholesterol levels in plasma are among the complications in diabetes in consequence of abnormal metabolism of fats (as well as sugars), although the high levels are somewhat better controlled since insulin began to be used in the 1920's. More than 100 years ago (1847) cholesterol was found present in atheroma (plaque formations on arterial walls).

Modern analytical methods have shown that the total free and combined cholesterol in atheroma is no higher than the total in normal circulating blood plasma, but that the free cholesterol is about five times as high as that in normal blood. Oleic acid also has been shown to be twice as high in atheroma as in normal plasma.

Many investigators have reached a conclusion that atherosclerosis, with its generalized thickening of the inner arterial wall, might be a consequence of abnormal cholesterol metabolism, whatever the metabolic failure.

This view has been supported also by studies with experimental animals—rabbits, chickens, mice, rats, guinea pigs, dogs, and monkeys—in which elevated blood cholesterol produced by diet, drugs, or other means tended to result eventually in arterial damages resembling in many respects those found in human atherosclerosis. Thus attention has continued to be centered on blood cholesterol.

In the depression of the 1930's, a paucity of atheroma was noted in the poorly nourished bodies on which autopsies were performed. As early as 1904, an increase of 40 percent was observed in diseases of the circulatory apparatus and kidneys and a 15-percent increase in cancer in one generation.

Attention was directed in 1940 to the fact that heart disease was then a worldwide problem. The war period, however, imposed food restrictions on peoples throughout the world and slackened the mortality rates from diabetes and other metabolic disorders as well as from cardiovascular diseases.

The trends reversed after the war to accelerated rates, particularly from coronary damage, and aroused worldwide attention of scientists and clinicians, while cardiovascular diseases rose rapidly to top place as the reported cause of deaths in the United States.

Revived interest in metabolism of cholesterol has continued as research

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has associated atherosclerosis with high plasma cholesterol and more or less with an estimated high level of fat consumption.

Other observers linked it with a high level of protein from foods of animal origin. The availability of radioactive elements after the war made it possible to use labeled carbon to follow the course and fate of different parts of the cholesterol molecule in metabolism and thus greatly refined the techniques of research.

Cholesterol is a normal and essential constituent of blood, nerve tissue, and other parts of the body of animals. Corresponding substances found in plants are known as plant sterols and include the sitosterols commonly found in vegetable oils. They may be poorly absorbed by people, however. Some may prevent the absorption of some fats. Others elevate blood cholesterol.

Cholesterol is normally synthesized in all cells of the body and especially in the liver from a substance called squalene, which has been formed from acetates (2-carbon fragments). Squalene fed to human beings causes a rise in blood cholesterol in an hour. It reaches a maximum in 7 to 21 hours.

Dietary fat is not essential for the formation of cholesterol, but some fatty acids favor its absorption, and excessive lipids in circulation may favor its formation.

Dietary cholesterol from food, about 0.5 gram daily in the average diet, usually is a minor source compared with the amounts, 2 to 3 grams daily, that the body is capable of forming.

Excessive intakes of cholesterol-rich foods can push the amount up toward 5 grams daily, but that is seldom the case. Moreover, high dietary cholesterol tends to suppress normal body synthesis of cholesterol.

Cholesterol normally transports about 15 percent of the fatty acids of the blood, mostly the unsaturated. It may influence some immunological reactions in protecting the body from certain injurious substances.

Cholesterol is used in the production of steroid or sex hormones. Cholesterol is converted by the liver into bile acids and secreted into the intestines, where part of the cholesterol is reused in the emulsification of fats and absorption of fatty acids. This initiates another metabolic round for the cholesterol, which is shown by isotope measurements to require 2 to 3 days.

Some cholesterol in various forms may be disposed of through the bowel, eventually half or more, and such disposal seems to be favored by diets high in linoleic acid. Failure of conversion to bile acids or of disposal through the bowel may result in backlog accumulations that show up in high blood cholesterol. Within limits, however, the level of plasma cholesterol may be less important to the system than is the kind of fatty acids carried, its relation to the phospholipid level, or to the level of beta-lipoprotein, which also transports cholesterol.

A cholesterol-phospholipid ratio (C/P) of 0.70 to 0.80 is characteristic in persons with normal or low cholesterol. Higher ratios, 0.90 to 1.0 and above, suggest abnormal fat metabolism, whether due to high cholesterol or to low phospholipid in the plasma.

Human plasma cholesterol levels differ widely because of many conditions, the most common of which are associated with advancing age.

Other conditions include the kinds and amounts of fat and other constituents in the diet, the planes of regular physical activity, the nature and extent of emotional stress, and periods of menstruation and menopause in women.

In the same individuals over periods of months, the level may fluctuate in a wide range, 15 percent above and below in normal persons and as much as 30 to 40 percent in persons with high cholesterol.

In children, cholesterol levels in the plasma range from 150 to 250 milligrams percent, with erratic trends in adolescence.

In this country, women before menopause have levels of 180 to 200 milligrams percent or even less.

Men under 50 years of age have levels around 200 to 220 milligrams.

After these ages, the average level in men continues to rise gradually. The average level in women rises sharply and exceeds that of men after about 55 years of age, when both are in the range of 240 to 260 or even 300.

A lower average level has been noted in persons older than 65 years, but that may mean persons with low levels are more likely to live beyond that age.

Men with histories of coronary artery damage have been found to have much higher plasma cholesterol levels, especially in ages 25 to 40 years, when the levels were 50 to 100 milligrams above the average for men apparently normal.

Men living in a county home on a limited diet were found to have plasma cholesterol levels markedly below retired men of like ages who lived in their own homes on more liberal, freely chosen diets.

Plasma cholesterol is elevated in diabetes, during periods of gain in weight, low thyroid activity, and other conditions of depressed energy metabolism. It is elevated by several dietary factors, including calories in excess of energy needs, high intakes of fat, particularly certain saturated fatty acids and dietary cholesterol; by high protein intakes, especially of animal proteins and those high in the sulfur-containing amino acids (methionine and cystine and perhaps others); and by choline and rapidly absorbed sugars.

High cholesterol in the plasma is lowered by relatively high intakes of linoleic and perhaps other polyunsaturated fatty acids, by high intakes of nicotinic acid, by dietary starches in place of sugars, and by strict vegetarian-type diets, as well as by stepped-up energy metabolism such as from regular exercise, thyroid hormone, and other agents that stimulate metabolism.

Damage to arterial walls in the presence of high plasma cholesterol has been lessened or averted in experimental animals by higher dietary intakes of magnesium, pyridoxine, and vitamin E. Dietary levels of sodium, potassium, and calcium appear also to be involved.

The low cholesterol levels characteristic of some nationality groups doubtless reflect a combination of factors—hereditary, hormonal, dietary, occupational, or other environmental factors—although usually a diet low in fat is one factor.

For example, Yemenites are said to have lived apart for some 2,000 years on diets of grain, vegetables, and vegetable oils, with less than 18 percent of the Calories from fat.

Yemenite immigrant men arriving in Israel have been found to have average cholesterol levels of 160 milligrams at ages 55 to 60 years. Those who had lived in Palestine 20 years or more, having diets containing more than 20 percent of the Calories from fat, including some animal fats, averaged 200 milligrams. European Jewish immigrants, who had more liberal diets, averaged more than 240 milligrams percent at similar ages.

The death rates from atherosclerosis in the three groups were reported to be around 5, 35, and 85 per 100,000, respectively.

Similar observations have been made on the cholesterol levels of Japanese living in Japan with less than 15–20 percent of the Calories from fat; those in Hawaii, with about 20 percent; and those in the United States, with more than 30 percent.

Differences in the amount and kind of dietary fat among these groups, however, appear small compared to levels of 40–45 percent in diets in this country and certainly were not the only dietary differences in these situations. The occupations, physical activity, and emotional stresses also were different. For example, laboring Japanese who worked on the plantations had cholesterol levels well below the average for this race in the same location.

Fatty Acids in Some Animal and Plant Products

[Grams per 100 grams of total fatty acids]

Source of fat	Saturated fatty acids			Unsaturated fatty acids		
	Total	Palmitic C 16	Stearic C 18	Oleic C 18–2 H	Linoleic C 18–4 H	Other unsaturated
MILK:						
Buffalo	66	31	15	27	1	6
Cow	59	27	12	35	3	3
Goat	66	29	8	26	5	5
Human	48	23	7	36	8	8
Mare	41	16	3	19	8	32
MEATS:						
Pork:						
Bacon	33	22	10	50	10	7
Fatback	40	27	12	48	6	6
Pork cuts	38	22	14	44	9	9
Pork liver	36	14	19	28	5	31
Rabbit	39	29	4	37	12	11
Ruminant animals:						
Beef	50	29	20	46	2	2
Deer	66	25	35	25	3	6
Goat	61	28	26	35	2	2
Lamb	59	30	26	37	2	2
POULTRY PRODUCTS:						
Egg	34	26	7	47	8	11
Chicken	34	26	7	40	21	5
Duck	27	(20)	(5)	42	24	7
Goose	30	(22)	(6)	57	8	5
Turkey	30	23	6	46	22	4
FISH PRODUCTS:						
Cod-liver oil	15	12	2	26		59
Eel	24	18	2	38		38
Halibut-liver oil	20	15	2	34		47
Herring	20	12	1	20		60
Menhaden	25	16	3	16	4	55
Salmon	16	12	2	27		55

Tuna	26	19	4	26		48
Whale blubber	27	16	2	37		36
Fruits, Vegetables, Nuts:						
Almond	9	7	2	70	21	....
Avocado	22	20	2	50	15	13
Beechnut	9	5	4	57	33	1
Brazil nut	21	14	6	50	28	1
Cashew	18	6	11	73	8	1
Coconut	91	10	2	7	1	1
Filbert (hazelnut)	6	2	2	56	17	21
Hickory nut	8	6	1	72	19	1
Olive	12	9	2	80	7	1
Peanut	23	12	5	46	30	1
Pecan	8	6	1	70	21	1
Pistachio	10	8	2	69	20	1
Walnut, black	6	4	2	37	50	7
Walnut, English	7	5	2	16	65	12
Grains, Whole:						
Barley	(14)	7	3	26	44	(6)
Corn, white	12	9	1	37	47	4
Millet, foxtail	33	11	15	23	38	6
Oats, rolled	23	13	4	33	43	1
Rice	19	13	2	42	38	1
Sorghum	12	7	5	40	47	1
Wheat	16	12	4	28	48	6
Separated Fats and Oils:						
Butter	59	27	12	35	3	3
Cacao butter	59	24	35	38	2	1
Corn oil	12	8	3	30	55	3
Cottonseed oil	26	23	2	22	51	1
Lard	40	32	8	48	11	1
Linseed oil	10	(8)	(2)	22	18	50
Margarine	27	22	3	60	9	4
Olive oil	12	9	2	80	8	....
Palm oil	48	41	5	42	8	2
Peanut oil	19	8	6	50	31	....
Shortening, hydrogenated	24	15	7	68	8	....
Safflower oil	8	3	4	15	76	1
Sesame oil	15	9	5	40	44	1
Soybean oil	18	9	6	21	55	6
Sunflower oil	12	6	5	21	66	1

A report on one national group continuing in the same environment is of interest in reference to the effect of occupation and physical activity. A study of clinical cases of British men in their sixties revealed that the coronary disease in those in all sedentary occupations combined was twice as frequent as in those who engaged in much activity and was three times as frequent in those sedentary occupations characterized by severe emotional demands—that is, by a combination of emotional stress and limited physical activity.

Thus John Dryden's advice in 1680 echoes almost 300 years later:

"By chase our long-lived fathers earned their food;
Toil strung the nerves, and purified the blood;
But we, their sons, a pampered race of men,
Are dwindled down to threescore years and ten.

"Better to hunt in fields, for health unbought,
Than fee the doctor for a nauseous draught;
The wise, for cure, on exercise depend;
God never made his work, for man to mend."

Although elevated blood cholesterol is often associated with atherosclerosis, the nature and extent of the relationship remain to be defined.

Not all persons with atherosclerosis or coronary disease have high blood cholesterol. Conversely, not all persons with high blood cholesterol have cardiovascular disorders. Nevertheless, continuing high blood cholesterol indicates a disturbed metabolism and is undesirable, whatever the factors involved or the likely ultimate consequences.

DIET has held the attention of scientists as well as laymen because it is one of the contributing factors in the formation of cholesterol.

How well do diets in this country measure up to some of the evolving concepts of desirable kinds and quantities of fats in diets?

Average diets reported by households in this country in 1955 were estimated to supply about 44 percent of the Calories from fat.

This fat was calculated to contain on the average about 42 percent saturated fatty acids, mainly stearic and palmitic, 43 percent oleic, and 10 percent linoleic. These estimates of fatty acids were partly substantiated when a composite sample of fats fairly typical of the proportions consumed in 1955 was found by laboratory analysis to contain 40 percent saturated fatty acids, 46 percent oleic acid, and 9 percent linoleic acid.

FAT FROM MILK and dairy products, beef, veal, and lamb in 1955 furnished 56 percent of the saturated fatty acids and only 10 percent of the linoleic, a ratio of almost 6 to 1. Pork, margarine, and shortenings furnished 30 and 32 percent of each, respectively, or about equal shares of saturated and linoleic acids.

Salad oils furnished only 3 percent of the saturated and 28 percent of the linoleic, a ratio of nearly 1 to 10, or more than the reverse of the first group of foods.

The sources of fatty acids varied characteristically with the four regions of the country—Northeast, North Central, West, and South.

The Northeast had the highest proportion of total fat (39 percent) from fats of ruminant animals, and the lowest (28 percent) from pork, margarines, and shortenings.

The South was at the other extreme—lowest (29 percent) in fat from ruminant animals and highest (40 percent) from pork, margarines, and shortenings.

A statistical analysis by the Public Health Service showed regional differences in death rates in 1950 from heart disease, including coronary, with the Northeast highest, 263 deaths per 100,000 and the South lowest, 169.

OTHER DIETARY factors should not be overlooked.

The South had the lowest dietary protein (113 grams) compared with

Percentages of Fat from Different Sources

	Household consumption, 1955				
	U. S.	*Northeast*	*North Central*	*West*	*South*
Milk, dairy	25	29	28	25	19
Beef, veal, lamb	14	17	16	17	10
Pork, bacon, lard	24	17	21	17	35
Margarine, shortening	13	11	12	14	14
Oils, salad dressings	6	6	5	7	6
Poultry, fish, eggs	6	7	6	7	6
Bakery goods, nuts, et cetera	12	13	12	13	10

the West, where the protein consumption was highest (129 grams), and a death rate of 217. Also, the South had far more Calories from grain products, 1,335, compared with the low of 941 in the Northeast.

The influence of nondietary environmental factors with reference to probable sedentary occupations and emotional stresses of urban life, however, was in the same direction as the dietary factors noted. The Northeast had the highest proportion (79 percent) of its population in towns of 2,500 and over. The South had 49 percent.

Elsewhere are described the shifts in consumption of foods in the United States during the past half century.

Of particular interest is the longtime downward trend in the use of fat (a 30-percent decrease in 50 years) and in the use of grain products, of which we now eat more in the highly processed forms that are lower than natural grains in unsaturated fatty acids, vitamin E, pyridoxine, and other important nutrients.

Also noteworthy is the upward trend in the proportion of dietary fats from meats and milk and the higher intake of animal proteins.

Observations, such as these from several population surveys, present strong challenges to basic research to find out which dietary components are supplementary and which may be antagonistic to normal fat metabolism in the long run and what are the zones of desirable limits for each.

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One of the greatest mysteries of life is the power of growth, that harmonious development of composite organs and tissues from protoplasmic cells, with the ultimate formation of a complex organism with its orderly adjustment of structure and function . . . Development, growth and vital capacity all depend upon the availability of food in proper amounts and proper qualities.—RUSSELL HENRY CHITTENDEN. Quoted in the Journal of Home Economics, February 1957.