fluxes it is converted into the dioxide, and hydrofluoric acid acts upon it the same as upon the dioxide.

The ingot of metallic aluminum here shown contains less silicon and iron than the average commercial metal, although no special care was taken to obtain a pure product. It was made by methods which are controlled by patents held by the company, and experiments are in progress which it is expected will lead to results that will cheapen very materially the cost of its production.

CARBOHYDRATE AND FATTY FOODS.

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Under the general heading of Fats is recognized a certain group of bodies composed of carbon, hydrogen and oxygen, which are capable of saponification and of emulsification, and which are insoluble in water. The true or neutral fats belong to one of three groups; stearine, palmitine and oleine; margarine being usually accounted a combination of the first and third. Chemically, each of these bodies is analogous in composition to any of the neutral salts. In the fats, however, the acid radical is represented by a fatty acid, and the base by glycerin. Thus, stearine may be regarded as the union of stearic acid with glycerin, and palmitine and oleine as respectively a palmitate and an oleate of glycerin. The fatty acid is, however, by far the preponderant portion of the molecule, the glycerin never exceeding from eight to ten per cent. of the substance. The fats named have been mentioned in the order of their solidity at ordinary temperatures, stearine being hard and oleine entirely fluid under usual conditions, while palmitine occupies an intermediate position in regard to density. As foods, these bodies are of extreme importance, though their full value has not been appreciated until a comparatively recent period, because, when taken to the exclusion of other foods, continued nutrition becomes impossible.

We eat fat in a nearly pure state in lard, in oils and in butter. It exists in varying amount in every organic food. Thus we find in

Meats, five to ten per cent.

Eggs, twelve per cent.

Milk, three to four per cent.

Butter, eighty to ninety per cent.

Cheese, from eight to thirty per cent.

Almonds, and nuts in general, fifty-three to sixty-six per cent.

And in all vegetables, from traces to two and three per cent.

Fat is an integral constituent of the higher animals, being entirely absent only in the lowest. It is found not simply in the great reservoirs of the subcutaneous connective tissue, in the omentum, and around the kidneys, but also, finely divided and invisible to the naked eye, in every organ and fluid of the body. Its subdivision is so minute, and its distribution so wide, that especially for muscular tissue it has been well described as being "amalgamated" with the tissue. The chemical composition of fats of different animals is comparatively constant. The mean of eight analyses, including the fat of the ox, sheep, pig, dog, man, cat, horse and butter, revealed an average constitution of $C_{76\cdot5}H_{11\cdot9}O_{11\cdot6}$, while in the separate analyses these figures differ scarcely one per cent. from one another. Curiously enough, however, the difference in the chemical constitution of the fats of different animals gives to these animals their characteristic odors.

Just as in the body as a whole we find an inverse ratio between its fatty and watery constituents, so in the fatty tissues proper we find a similar relationship. This is strictly correlated with the histogenesis of adipose tissue—*i. e.*, the fat globules are produced in the connective-tissue corpuscle at the expense of the contained watery protoplasm. From figures gained by actual analyses, it may be stated that in the average healthy adult, the fat equals eighteen per cent. of the entire body-weight, or forty-four per cent. of the weight of the dried body.

The extremes in the proportion of fat in the body coincident, apparently, with health, have been most carefully studied in the domestic animals. Thus, in sheep of different degrees of fatness, the following percentage relations in their proximate composition have been found to obtain:

	Per cent. Water.	Per cent. Albumen	Per cent. Fat.	Per cent. Ash.
Thin sheep, ...	57·3	18·4	18·7	3·16
Moderately fat sheep, . . .	50·2	14·0	23·5	3·17
Fat sheep, ...	43·4	12·2	35·6	2·81
Very fat sheep, ...	35·2	10·9	45·8	2·90

In order to appreciate the importance of fats in the economy, we must turn to the phenomena occurring as a result of abstinence from food. In this condition, there is constant disintegration of albumen and fat, the destruction of the latter being twice as great as that of the former. To prevent further loss of fat, either albumen, fat or carbohydrates must be given.

That by its metabolic activity the body can make fat out of other than fatty substances is fully established. A cow subsisting on hay alone accumulates and secretes many times as much fat as she takes in her food. A woman in lactation also secretes much more fat than is ingested. In the process of fattening pigs it has been shown by direct analysis at the end of the experiment that for every 100 parts of fat in the food consumed, 472 parts of fat are stored up in the body. Perhaps the most striking illustration of metabolic fat production is found in the experiments conducted by Hoffmann on a maggot's eggs. The fat percentage in a given weight of these eggs was determined, and a corresponding quantity were allowed to develop in defibrinated blood. When the maggots became mature, it was found that the fat in the eggs from which they were developed, plus the fat in their food, constituted a little less than one-tenth of the fat extracted from their bodies. Here the fat production could be attributed only to separation of albuminoids into other nitrogenous matters and fats.

Pathologically, we frequently see a retrograde metamorphosis of albumen, which constitutes fatty degeneration. Somewhat similar in nature is the post-mortem production of adipocere, in which the proteids of the body have been broken up, possibly by bacterial agency, with the production of the higher fatty acids. The bodies last named unite with earthy and ammoniacal bases to form an insoluble soap, which replaces and assumes the form of the destroyed tissues. As a result of poisoning, especially by phosphorus, there is also noted a similar production of fat resulting from the decomposition of albumen.

Admitting, now, that fat may be made in the body from albumens, it becomes interesting to note the amount of albumen requisite in the otherwise starving animal to prevent for a time any loss of fat. This quantity is large, and is in inverse ratio to the amount of fat already in the body. In very meagre individuals, it would be impossible to prevent loss of fat under these circumstances, as the requisite amount of albumen would be more than could be digested. By the addition, however, of a small quantity of fat to the albumen, a much smaller quantity of the latter is sufficient to prevent decrease either of the albuminous or of the fatty tissues. As we shall see in studying the history of the proteids of the economy, the most rapid destruction of these compounds takes place not in the formed tissues, as was formerly supposed, but in the circulating fluids. Close chemical studies have shown that when fats are present in company with the circulating albumens they greatly retard the destruction of the latter. In other words, the functionally active cell in any part of the body is bathed in a fluid containing both proteid matter and fat. Only a portion of the force of that active cell is derived from the disintegration of the albuminoid, the remainder being gained from the destruction of the fat. It is especially under muscular activity that the destruction of the fats is most marked, and for this reason they form a most important element in the dietary of the laboring classes. This power of fats to prevent the destruction of the albumens of the body is illustrated by the fact that a moderately fat individual will resist starvation for a longer period than will one of equal muscularity but greater specific gravity. Nevertheless, fat alone is a very insufficient food. It retards the destruction of the albumens, and therefore prolongs, though it cannot sustain life. Thus, Magendie fed two dogs, one on butter, the other on lard, without other food. The first lived sixty-eight days, the other fifty-six. The post-mortem examination showed an accumulation of subcutaneous fat, but general atrophy of the organs. Rats, also, which, in the absence of all food, starve in from three to nine days, will live upon fat for from twenty-six to twenty-nine days.

Under normal conditions, the fats ingested are absorbed with remarkable completeness and in surprising quantity. Thus, in a dog of nearly eighty pounds weight, to which was given in one day eleven ounces of fat in conjunction with other food, a little less than a drachm of fat could be obtained from the fæces. The maximum limit of fat absorption is not yet established, but it is doubtful whether the amount last mentioned could be absorbed during many successive days. On the contrary, it is highly probable that a degree of saturation of the circulating fluids would be obtained beyond which further absorption would not occur. Experiments instituted by the writer (aided by Dr. Roussel) upon twenty healthy individuals (both infants and adults) with a view of determining the question of the cutaneous absorption of fats, gave the following results:

At the beginning of the experiments, the fæces were, in each case, found to be practically free from fat. After continued inunction of cod liver oil, applied twice daily for a period of two weeks, there was found not only a gain in weight of the individuals (with whom the general dietary had been unchanged), but a notable quantity of fat present in the alvine dejections. This could only be attributed to a kind of saturation of the fluids of the body, which, as a result, prevented further absorption of fat from the intestinal surface, the fat found in the dejections corresponding, therefore, to unabsorbed fat taken in the food. This supposition is strengthened by the observations of Berthé, who showed that pure cod liver oil, given internally, could be taken for a longer time without appearing in the fæces, than could an equal amount of butter or any of the other animal and vegetable fats.

When we remember that the absorption of ingested fats is, in all probability, a result of the purely vital activity of the protoplasm of the intestinal epithelium, it is not difficult to understand the rejection of a needless aliment by this absorbent surface. It is a manifestation of protoplasmic selective power analogous to that exhibited by two dissimilar plants drawing from the same soil each its distinct and special pabulum. Such intestinal selection is illustrated by the behavior of petrolatum (cosmoline, vaseline) in the digestive tract. This substance, while non-saponifiable and chemically distinct from the fats, presents many points of physical resemblance. Prompted by this resemblance, the query arose in my mind, a few months ago, as to the possible absorption of this soft hydrocarbon by the human digestive tract and its subsequent oxidation in the tissues; in other words, whether it could or could not be utilized as a food. On each of eight days I swallowed half an ounce of commercial vaseline, and caused my laboratory assistant to do the same. Digestion was not disturbed in either case, and no noticeable effects ensued. Later, to each of two healthy adults there was given, in the course of forty-eight hours, one ounce of vaseline. Their fæces for three days from the beginning of this experiment were collected, dried, and extracted with petroleum ether. From the extract the vaseline ingested was entirely recovered—evidence of its complete rejection by the intestinal surface. In further experiments upon other individuals, I have found that petrolatum, administered internally, is often sufficient to check rather severe diarrhœas of irritation, apparently acting simply as a mechanical lubricant, which exerts its soothing effect upon the entire irritated surface. It is a curious fact that petrolatum is also efficient in relieving constipation, its action being, of course, that of an unabsorbable diluent of the intestinal contents. The amount requisite to produce the desired result is in this case, however, too large to render the method one of any general usefulness.

In abnormal conditions, such as mechanically obstructed or otherwise impaired biliary or pancreatic secretion, or from diminished activity (from any cause) of the intestinal epithelium, fatty stools are noted. In health, however, fat is found in but minimal amounts in the excreta, although other unabsorbed food elements—bits of muscle fibre, starch, etc.—are readily found. Curiously enough, the presence in the intestinal contents of bran, woody fibre, and the like, materials which impede the proper digestion and absorption of the proteid foods, have little or no effect upon the practically complete absorption of fats. Rubner has shown that the human intestine can absorb large quantities of fat—much larger, indeed, than in the case of the dog just cited; but the length of time during which such absorption could be continued was not determined. In comparison with ham fat, he found butter to be by far the more readily absorbed. Previous accurate observations, already cited, have shown that cod liver oil is absorbed with greater ease and to a greater degree than any of the other fats. The vegetable oils, on the other hand, are the least readily absorbed.

In every sound nutritive schema we find that the fats occupy a prominent position. It is very significant, in this connection, to note that in the first food of the mammal the fats and albumens are present in practically equal parts. It. of course, goes without saying that a fat which is not entirely fluid at the temperature of the viscera is with difficulty susceptible of emulsification and absorption, and may prove an irritant to weak digestive organs. Although the fats of high melting point contain olein, which is fluid at ordinary temperatures, there is also present sufficient stearin to render a higher temperature requisite for melting the mixture. Thus, the melting point for the fat of mutton is from 41° to 52° C.; for beef, 41° to 50° C.; for pork fat, 42° to 48° C.; whereas the fat of the horse, rabbit and goose is fluid at from 24° to 30° C. These facts suggest the cause of the widespread preference for fats which, in popular phrase, "melt in the mouth."

When digestion and absorption are imperfect, fats may become irritants by undergoing a decomposition which exceeds physiological bounds, with the production of volatile and irritant fatty acids possessing characteristic rancid odors. Somewhat similar decompositions occur at the temperature requisite for frying. This we must regard as one factor in the frequent cases of indigestion of fried foods; and a further reason that the fats, especially when cooked with other foods, are frequently found to be unwholesome is that, in the process of cooking, they so surround and saturate the tissues of the substance with which they are combined that it is rendered nearly inaccessible to the action of the saliva and gastric juice, and at times digestion is in so far delayed that the fried substance does not become entirely freed from this more or less impervious coating of fat until subjected to the action of the pancreatic juice.

Under ordinary circumstances, the fatty acids of the neutral fats are not taken into the economy as such, but in combination with a small amount of glycerin. The fatty acids, however, alone are fully capable of replacing the neutral fats as a food. When administered to a dog in the form of soaps, in conjunction with meat from which all fat had been removed, Munk found that the animal gained in weight in precisely the same way that it would have done had the acid been given in its more usual combination. No nutritive value, strictly speaking, has as yet been determined for the glycerin found in fats, but it is believed that, in the form of glycero-phosphoric acid, it carries phosphoric acid to the tissues where the latter acid is needed. It is quite well established that the lecithins, which are important constituents of brain tissue, are direct derivatives of glycero-phosphoric acid.

A Carbohydrate is a compound of carbon, hydrogen and oxygen, in which the elements last named are in the proportion requisite for the formation of water. The carbohydrates of the economy and of its foods may be grouped in four classes.

The first includes the glucoses, which possess the formula $C_6H_{12}O_6$. The word glucose may be used as synonymous with grape sugar, dextrose, starch sugar and liver sugar. Glucose is constantly found, in minute quantity, in blood, chyle and muscle. An excess above the small maximum normal to these tissues is immediately rejected and excreted; thus, a solution of glucose injected into a vein at once makes its appearance in the urine, and the glycosuria of diabetes mellitus is attributed to a nervous disturbance of the hepatic function, which permits the entrance into the circulating fluids of a greater amount of this substance than is normal.

In the vegetable kingdom glucose is widespread, being found in the sweet juices of ripe fruits and in the honey of flowers. It is physiologically produced in germinating seeds by the action of the amylolytic ferment therein contained. It is crystallizable, combines feebly with bases, salts, acids and alcohols, and has a reducing action on many metallic oxides. By fermentation with yeast it separates into alcohol and carbonic acid, and in the presence of decomposing albumen it splits into two molecules of lactic acid, which, in alkaline solutions under the same conditions, may be yet further decomposed into butyric and carbonic acids and hydrogen. To this group belong, also, galactose, produced by the action of diluted acid upon sugar of milk, and levulose, an isomeric body, which, however, rotates the ray of polarized light to the left. It is a by-product in the intestinal digestion of starches.

The second division of the carbohydrates contains those of the formula $C_{12}H_{22}O_{11}$, commonly called the saccharoses. They may be regarded as anhydrides of the double glucose molecule. Their physiological type is lactose, or milk sugar, and their type, from a dietetic point of view, is cane or beet sugar. Lactose is capable of change by direct fermentation into lactic acid, and indirectly by yeast into alcohol, as in the production of koumiss. Cane sugar is, in some degree at least, transformed into glucose before it is absorbed.

The third group includes the carbohydrates of the formula $C_6H_{10}O_5$—*i. e.*, starches, dextrin, cellulose, gums and glycogen. One of the most striking differences between the green plants and all animals lies in the power possessed by the former of manufacturing starch from inorganic substances. The chlorophyl of the green plant, when stimulated by sunlight, can induce the union of six molecules of atmospheric carbon dinoxide with five molecules of water, with the resultant production of one molecule of starch and the liberation of oxygen. No such synthetic power is possessed by any animal, and for the manufacture of a carbohydrate in the animal there is requisite, therefore, either a pre-existing carbohydrate or the destruction of an albuminoid. Starch, in its raw state, is entirely insoluble in water. When boiled, the granulose, which constitutes the major portion of the starch grain, and which is contained within an enveloping membrane of cellulose, becomes swollen and ruptures the membrane, with the production of the common starch jelly or paste. Such mechanical hydration of the starch granule is very essential to its digestibility, as the cellulose envelope is but little affected by the saliva. The pancreatic juice, however, is fairly useful in dissolving even raw starch. Starch frequently causes indigestion, when eaten in large quantities, from the following causes:

(1.) Glucose may be formed more quickly than it can be absorbed, and, by its presence, retard the further digestion of the starch.

(2.) Starch, when long retained, is liable to fermentation, with the evolution of butyric acid, thus causing persistent diarrhœas, especially in early childhood.

Much diversity of opinion exists as to the digestion of starches in infancy. I have settled this point to my own satisfaction by the microscopic examination of the fæces of twenty-four starch-fed infants, aged from forty-five days to eighteen months.

The results of this study will be found in the following table.

No.	Age.	Food.	Starch Present.	REMARKS.
1	45 days.	Condensed milk and cracker-dust.	None.	
2	2 mos.	"	Traces.	
3	2+ "	"	"	
4	3 "	"	"	Twice examined: no fat before inunction, about 10 per cent. after.
5	3 "	"	"	
6	3 "	"	About ¼ starch.	
7	3 "	"	Traces.	
8	4 "	Corn-starch and milk.	"	
9	4 "	Condensed milk and cracker-dust.	None.	Many broken cellulose envelopes.
10	4+ "	"	Traces.	Evidences of potato surreptitiously given.
11	5 "	"	About ½ starch.	
12	5+ "	"	None.	
13	5+ "	"	"	Many bacteria.
14	6+ "	"	"	10 per cent. fat; had had inunctions.
15	8+ "	Breast and cracker food.	Traces.	
16	10+ "	Condensed milk and cracker-dust.	More than normal.	Many bacteria; evidences of potato surreptitiously given.
17	13— "	"	20 to 30 per cent.	Some glucose present, and indications of dextrin; saliva was found to be inefficient.
18	14— "	"	Traces.	
19	14 "	"	"	
20	14 "	"	10 per cent starch.	Sick.
21	14+ "	"	None.	Except a few large cells containing starch from potato.
22	17— "	"	"	
23	17— "	"	Over ¾ starch.	Syphilitic; saliva was found to be inefficient
24	18 "	"	Traces.	Indications of dextrin.

It should be observed that the word "traces," applied to the presence of starch in the fæces, does not indicate inefficiency of starch digestion. Similar traces of starch are found in the fæces of nearly every healthy adult upon a mixed diet.

It may legitimately be deduced from this study that in *many* cases starch is well digested in early infancy, that the individual variations in this regard are too numerous to permit any sweeping statement, and that the physician may assure himself as to the peculiarities of the case in hand only by a direct examination of the dejecta.

If an infant cannot digest starch, it is self-evident that starch is worse than useless as an ingredient in its food. The converse of this does not obtain; the mere fact that a given infant can digest a certain quantity of a farinaceous material is in itself no proof that such material is a useful ingredient in the dietary of that infant. The ratios existing in human milk between carbohydrate, fat and proteid cannot with safety be greatly altered in an artificial food for early infant life.

Dextrin is prepared by superheating dry starch, and is also found as an intermediate product in the action of dilute acids, and of digestive juices upon starch. It is chemically isomeric with the starch, but presents certain physical differences from this body, being soluble in water, and also much more tenacious as a mucilage. Dextrin is probably absorbed to some degree unchanged from the digestive cavities, inasmuch as there is found in the blood of the portal vein during digestion a substance which gives characteristic reactions, and possesses its properties.

Cellulose is found inseparably associated with the formed tissues of the vegetable kingdom, being one of the chief constituents of the vegetable cell-wall. Its digestibility depends largely upon its age, and upon the extent to which it has been cooked. When young and tender, as in celery, asparagus, and salads, about one-half of its substance is digested, the remainder being of service in giving the proper bulk and consistence to the intestinal contents. This it does, however, at the expense of the complete absorption of the proteid food-stuffs.

The gums possess no permanent nutritive value. Many authors claim that they are entirely unaffected by the digestive processes, but later studies have shown that they are absorbed to the extent of from forty to fifty per cent.

Glycogen, besides being a normal constituent of the human economy, is found in many foods. It is always present in the normal liver in varying amounts, the maximum being obtained in the livers of cattle, where it forms from fourteen to seventeen per cent. of the entire liver substance. It is further found in muscle, in most embryonal tissues, and, according to Pavy, also in the spleen, pancreas, eggs, brain and blood. It is present in considerable amount in the large livers of oysters and other mollusks.

The fourth division contains but one member, viz., inosite. This is a sweetish sugar, isomeric with glucose, but entirely incapable of other fermentation than the sarcolactic. It is variously known as muscle-sugar, bean-sugar and phaseomannite. It exists normally in muscle, where it is decomposed by each muscular contraction, with the resultant production of saracolactic acid. It has also been found in lung, liver, spleen, kidney and brain of oxen. It exists normally in the human kidney and pathologically in the urine. It is found in all the leguminosæ, and also in grape-juice.

We have seen that there are present in the tissues of the body both fats and carbohydrates. The origin of the various carbohydrates is, in greater part at least, directly or indirectly from similar carbohydrates taken as food. Thus, for instance, the glycogen of the liver greatly diminishes in amount in the absence of carbohydrate food stuffs. This is not the case with the fats. Foods containing starch and sugar are well known to be fattening. The explanation of this would at first sight seem to be that fat is made out of these bodies by the metabolic activity of the tissues. This explanation, however, is not correct. The true cause of the increase of body fat upon a mixed diet containing an excess of carbohydrates lies simply in the fact that these bodies become oxidized in the place of the albumens, thereby sparing the latter to fulfil their nutritive functions, and finally to produce fat. The ingested fats aid in the production of fat in the economy, both in this indirect manner and also directly replacing fats already oxidized and disintegrated.

It will be seen from this brief statement that in a mixed diet containing inorganic foods, proteids, fats and carbohydrates, the members of the last two groups are capable of replacing one another to a large extent, for their functions are practically the same, *i. e.*, each sacrifices itself in the oxidation flame of life for the sake of the more valuable proteid tissues and fluids. This is more marked in the case of the carbohydrates, which are able almost entirely to replace the fats in a dietary. Under these circumstances, however, there is found to be a considerable tax upon the metabolic activity of the tissues in manufacturing the fats. In like manner, animals fed exclusively on meat will manufacture from their own tissues the needed carbohydrates in much greater quantity than that in which they exist in the food taken. But here again comes a strain on tissue metabolism, and practically it is found that, other things being equal, it is best to have both the carbohydrates and fats present in the food.

Thus far we have considered similarity in the two groups of organic non-nitrogenous foods. There are, however, certain differences. Thus, a given weight of fat represents one and three-fourths times the nutritive value of the same weight of sugar or starch. Although both of these bodies are heat producers, the fats again have the advantage, and it is for this reason that they assume such high nutritive importance in cold countries and are consumed by us to a much greater extent in winter than in summer.

The direct bearing which these facts have upon the subject of corpulence is evident. The man who is fat does not of necessity partake too freely of starch and sugar or of oils. He is simply a man who eats too much. His powers of digestion, absorption, and especially of assimilation, are usually far superior to those of his thin neighbor, who may, and often does, eat far more than his obese friend. The plump patient, therefore, must not console himself with his relative temperance in food. He stands perpetually self-convicted as a man who consumes more nutriment than is needed to repair his daily wear and tear. So active are the nutritive processes in his body that he can say with poor Byron, "Everything I eat turns to tallow and sticks to my ribs." He can, of course, reduce his fat by abstinence from carbohydrates and fats, but in so doing he not only violates his nature by turning carnivore, and seriously taxes his emunctories in eliminating an excess of nitrogenous waste, but he needlessly alienates too much tissue-force by the tax and strain of excessive metabolic activity. To permanently and harmlessly reduce his bulk it is necessary simply to very gradually reduce the daily total of his aggregate mixed diet. The popular belief that the ingestion of much fluid is fattening probably arises from observations of the use of fluids other than water.

Given the same degree of obedience on the part of a fat and of a thin patient, it is generally much easier to reduce the former than to fatten the latter. In the first case it is purely a question of abstemiousness. In the second, the simple administration of food in excess of the bodily needs, if unaided by a corresponding stimulation of the assimilating powers, is not infrequently worse than useless. Such a nutritive stimulus may be obtained by the conjoint use of enforced rest, passive exercise by massage and electricity, and a dietary gradually increasing in bulk and variety, the chief factor in which is milk.

For the details of this latter process, I would refer the reader to that gem of medical monographs, Mitchell's *Fat and Blood.*