

alkaline without being ammoniacal; in the urine of the herbivora; and in the lymph, cephalo-rachidian fluid and bone. The analyses by different chemists, with regard to this substance, are very contradictory, on account of its formation during the process of incineration; but there is no doubt that it is found in the above situations. The following table gives the quantities which have been found in some of the fluids and solids:

TABLE OF QUANTITIES OF SODIUM CARBONATE.

	Parts per 1,000.
In blood of the ox (Marcet) .....	1.62
In lymph (Nasse) .....	0.56
In cephalo-rachidian fluid (Lassaigne) .....	0.60
In compact tissue of the tibia in a male of 38 years (Valentin) .....	2.00
In spongy tissue of the same (Valentin) .....	0.70

*Uses of Sodium Carbonate.*—This substance has a tendency to maintain the fluidity of the albuminoid constituents of the blood, and it assists in preserving the form and consistence of the blood-corpuscles. Its office in nutrition is rather accessory, like that of sodium chloride, than essential, like calcium phosphate, in the constitution of certain structures.

*Origin and Discharge of Sodium Carbonate.*—This substance is not introduced into the body as sodium carbonate, but it is formed, as is calcium carbonate in part, by a decomposition of the malates, tartrates etc., which exist in fruits. It is discharged occasionally in the urine of the human subject, and a great part of it is decomposed in the lungs, carbon dioxide being set free, which latter is discharged in the expired air.

*Potassium Carbonate.*—This salt exists particularly in herbivorous animals. It is found in the human subject under a vegetable diet. Under the heads of uses, origin and discharge, what has been said with regard to sodium carbonate will apply to potassium carbonate.

*Magnesium Carbonate and Sodium Bicarbonate.*—It is most convenient to take up these two salts in connection with the other carbonates, though they are among the least important of the inorganic constituents of the body. Traces of magnesium carbonate have been found in the blood of man, and it exists normally in considerable quantity in the urine of herbivora. In the human subject it is discharged in the sebaceous matter.

Liebig has indicated the presence of sodium bicarbonate in the blood. In this form a certain quantity of carbon dioxide is carried to the lungs, to be exhaled in the expired air.

*Magnesium Phosphate, Sodium Phosphate (neutral) and Potassium Phosphate.*—These salts are found in all the fluids and solids of the body, though not in a very large proportion as compared with calcium phosphate. In their relations to organized structures, they are analogous to calcium phosphate, entering into the composition of the tissues and existing there in a state of intimate combination. They are all taken into the body with food, especially by the carnivora, in the fluids of which they are found in much greater abundance than the carbonates, which latter are in great part the result of the decomposition by carbon dioxide of the malates, tartrates, oxa-

lates etc. With respect to their uses, it can only be said that with calcium phosphate they go to form the organized structures of which they are necessary constituents. They are discharged from the body in the urine and faeces.

*Sodium Sulphate, Potassium Sulphate and Calcium Sulphate.*—Sodium sulphate and potassium sulphate are identical in their situations and apparently in their uses. They are found in all the fluids and solids of the body except in the milk, bile and gastric juice. Their origin in the body is from the food, in which they are contained in small quantity, and they are discharged in the urine. Their chief office appears to be in the blood, where they tend to preserve the fluidity of the albuminoid matters and the form and consistence of the blood-corpuscles. Calcium sulphate is found in the blood and faeces. It is introduced into the body in solution in the water which is used as drink, and it is discharged in the faeces. Its office is not understood and is probably not very important.

*Ammonium Chloride.*—This substance has simply been indicated by chemists as existing in the gastric juice of ruminants, the saliva, tears and urine. It is discharged in the urine, in which it exists in the proportion of 0.41 part per 1,000 (Simon). Its origin and uses are unknown. Various combinations of bases with organic acids taken as food, as the acetates, tartrates etc., found in fruits, undergo decomposition in the body and are transformed into carbonates. In this form they behave precisely like the other inorganic salts.

## SUBSTANCES CONSUMED IN THE ORGANISM.

All of the assimilable organic matters taken as food are consumed in the organism, and none are ever discharged from the body in health in the form in which they entered. The matters thus consumed in nutrition have been divided into nitrogenized and non-nitrogenized; and although they both disappear in the organism, they possess certain marked differences in their properties and probably, also, in their relations to nutrition.

*Nitrogenized Constituents of the Body (Albuminoids).*—The organic constituents of the body are composed of carbon, hydrogen, oxygen, nitrogen and sulphur. The exact proportions of these elements are not definitely fixed, and the nitrogenized matters may change in their general characters without undergoing corresponding changes in their actual ultimate constitution, unless it be in the arrangement of their atoms. They are coagulable and non-crystallizable. They possess certain properties in common with each other, which have already been described more or less fully in connection with the physiological history of the blood, alimentation, the secreted fluids etc. One of these properties is a tendency to decomposition by putrefaction, under certain conditions of heat and moisture. They also undergo certain changes under chemical manipulation, analogous to those already described as effected by the prolonged action of the pancreatic juice. The type of substances of this class is the albumin of white of egg, and as a class, they are generally known as albuminoids. Artificial subdivisions of these substances have been made into proteids and albuminoids, the latter



name, in this subdivision, being restricted to certain albuminoids which closely resemble proteids but possess some distinctive characters. Inasmuch as proteine is an hypothetical compound and the so-called proteids do not differ much from other nitrogenized substances, it seems better to designate the entire class as albuminoids.

The so-called proteids are the albuminoid constituents of the blood, lymph and chyle, and the characteristic albuminoid constituents of the various tissues. These are sometimes called colloids. They pass through membranes with difficulty, or are very slightly osmotic. In this regard they present a striking contrast to the peptones, which are very osmotic, passing easily through animal membranes. This distinction is important, and it has already been fully described in connection with the physiology of digestion and absorption.

Nitrogenized matters constitute an important class of alimentary substances, and the corresponding constituents of the body are all originally derived from food. The condition of existence of these substances in the body is always one of union with more or less of the class of inorganic matters. Nitrogenized matters are found in all of the tissues and liquids of the body, except the bile and urine. They undergo changes in digestion before they become a part of the blood, they are changed in the blood into the nitrogenized constituents of this fluid and are again changed as they are deposited in the tissues in the process of nutrition. They are not discharged from the body in health, but are destroyed or changed into excrementitious matters, chiefly urea, and in this form are eliminated in the excretions. An excess of these substances taken as food is not discharged in the fæces, nor does it pass out, in the form in which it entered, in the urine; but it undergoes digestion, becomes absorbed by the blood, and increases the quantity of nitrogenized excrementitious matters discharged, particularly the urea. This fact is shown by the great increase in the elimination of urea produced by an excess of nitrogenized food. Whether the nitrogenized matter that is not actually needed in nutrition be changed into urea in the blood, in the so-called *luxus-consumption* process, or whether it be appropriated by the tissues, increasing the activity of their disassimilation, is a question difficult to determine experimentally. Certain it is, however, that an excess of nitrogenized food is thrown off in nearly the same way as an excess of inorganic matter; the difference being that the latter passes out in the form in which it has entered, and the former is discharged in the form of nitrogenized excrementitious matters.

The nutrition of the nitrogenized constituents of the tissues may be greatly modified by the supply of new matter. For example, a diet composed of nitrogenized matter in a readily assimilable form will undoubtedly affect favorably the development of the corresponding tissues of the body; and on the other hand, a deficiency in the supply will produce a corresponding diminution in power and development. The modifications in nutrition due to supply have, however, certain well defined limits. As regards the muscular tissue, proper exercise increases nutritive activity, the development and power of muscles

and the capacity for muscular work and endurance. The nutritive activity of other parts and organs is limited and is not sensibly affected by an excess of nitrogenized food.

In addition to the albuminoids of the blood, lymph, chyle and secreted fluids, and those which have been described as alimentary matters, the following have been found in various tissues and organs of the body.

Cystalline, a nitrogenized substance in the crystalline lens.

Myosine, a substance extracted from muscular tissue, of which it is the chief nitrogenized constituent.

Keratine, found in the epidermis and its appendages.

Elastine, the nitrogenized constituent of the elastic tissues.

Osseine, in bones, and chondrine, in cartilage.

Gelatine, probably not a normal constituent of the body, but a substance formed from the connective tissues by prolonged boiling in water.

Certain nitrogenized substances containing phosphorus, found in the nervous tissues, which will be described in connection with the chemistry of the nervous system.

The changes involved in nutrition, assimilation, or nutritive metabolism, are apparently dependent upon properties belonging to the nitrogenized constituents of the tissues. When the supply of new matter is equal to the destructive metabolism, the system is in what is called a condition of equilibrium, and the body neither gains nor loses in weight. In growth, the supply exceeds the waste, and in the opposite condition, the waste exceeds the supply.

Certain liquids and tissues of the human body may be restored after their destruction. The blood and its corpuscles undergo regeneration. Blood-vessels, also, may be regenerated, being developed first as capillaries and afterward as arteries and veins. The same is probably true of lymphatics. The epidermis and its appendages and certain parts of the true skin may be regenerated after destruction. Muscular substance, after certain kinds of degeneration in disease, as in fevers, may be restored. Portions of nerves may be regenerated after division or exsection. A divided tendon may become reunited by connective tissue. Portions of cartilage or bone may be regenerated, if the perichondrium or the periosteum remain intact. When wounded or lost parts are not absolutely restored, the divided tissue is reunited or the lost tissue is supplied by what is called cicatricial connective tissue.

*Non-Nitrogenized Constituents of the Body.*—Under the head of alimentation, the general properties of non-nitrogenized matters (starch, sugars and fats) have been fully described. These are important constituents of food, but in themselves they are incapable of supporting life. They are introduced as food, but are destroyed in the organism and are never discharged from the body in health in the form in which they entered.

The carbohydrates (starch and sugars) are all converted into glucose in digestion. As glucose they are taken up by the blood and carried to the liver, where they are in great part and probably entirely converted into glycogen. The glycogen thus formed is stored up in the liver and is gradually transformed into animal sugar, which passes into the blood slowly and gradually, and



promptly disappears as sugar, usually in the passage of the blood through the lungs. In addition to the glycogen formed from the carbohydrates of food, the liver is capable of forming glycogen from other substances, as is shown by the presence of glycogen in the liver of carnivorous animals. It is probable that the glycogen thus produced is formed from albuminoid matters and not from fats. The exact mechanism of the destruction of carbohydrates in the organism has not been fully understood, although it is admitted that these substances are important factors in the production of animal heat. The presence of alcohol in very small quantity in the normal blood has been demonstrated by Ford (1872). If this be admitted—and the accuracy of the observations by Ford seems to have been absolute—it is reasonable to suppose that the small quantity of sugar constantly discharged into the blood by the liver is converted into alcohol, which is promptly oxidized, being converted into carbon dioxide and water. The carbohydrates, in contributing to calorification, are very important in saving destruction of the albuminoid constituents of the body. In this process the carbohydrates and the fats act together and in the same way; and in this action they are capable of mutually replacing each other.

The fats taken as food are either consumed in the organism or are deposited in the form of adipose tissue. That the fats are consumed, there can be no doubt; for in the normal alimentation of man, fat is a constant article, and it is never discharged from the body. For a time, during absorption, fat may exist in certain quantity in the blood; but it soon disappears and is either destroyed directly in the circulatory system or is deposited in the form of adipose tissue to supply a certain quantity of this substance consumed. That it may be destroyed directly, is proved by the consumption of fat in instances where the quantity of adipose matter is insignificant; and that the adipose tissue of the organism may be consumed, is shown by its rapid disappearance in starvation.

*Formation and Deposition of Fat.*—The question of the formation of fat in the economy is one of great importance. Whatever the exact nature of the changes accompanying the destruction of non-nitrogenized matters may be, it is certain that the fat stored up in the body is consumed, when there is a deficiency in any of the constituents of food, as well as that which is taken into the alimentary canal. It is rendered probable, indeed, by the few experiments that have been made upon the subject, that obesity increases the power of resistance to inanition. At all events, in starvation, the fatty constituents of the body are the first to be consumed, and they almost entirely disappear before death. Sugar is never deposited in any part of the organism, and it is merely a temporary constituent of the blood. If the sugars and fats have, in certain regards, similar relations to nutrition, and if, in addition to the mechanical uses of fat, it may be retained in the organism for use under extraordinary conditions, it becomes important to ascertain the mechanism of its production and deposition.

The production of fatty matter by certain insects, in excess of the fat supplied with the food, was established long ago by the researches of Huber;

and analogous observations have been made upon birds and mammals, by Boussingault. Under certain conditions more fat exists in the bodies of animals than can be accounted for by the total quantity of fat taken as food added to the fat existing at birth. In experiments with reference to the influence of different kinds of food upon the development of fat, it has been ascertained that fat can be produced in animals upon a regimen sufficiently nitrogenized but deprived of fatty matters; but the fact should be recognized that “the nutriment which produces the most rapid and pronounced fattening is precisely that which joins to the proper proportion of albuminoid substances the greatest proportion of fatty matters” (Boussingault).

There can be no doubt with regard to the formation of fat in the organism from albuminoid matters. Where an excess of such matters is taken as food, it is probable that the albuminoid substance is decomposed, and that a part of it is either deposited as fat or is oxidized into carbon dioxide and water, and a part is discharged from the body in the form of urea.

Theoretical considerations point to starch and sugar as the constituents of food most easily convertible into fat, as they contain the same elements, though in different proportions; and it is more than probable that this view is correct. It is said that in sugar-growing sections, during the time of grinding the cane, the laborers become excessively fat, from eating large quantities of saccharine matter; and although there are no exact scientific observations upon this point, the fact is generally admitted by physiologists. Again, it has been frequently a matter of individual experience that sugar and starch are favorable to the deposition of fat, especially when there is a constitutional tendency to obesity. Carbohydrates added in quantity to a nitrogenized diet favor the formation of fat. The fat may be formed from the carbohydrates either directly (Lawes and Gilbert) or indirectly. If formed indirectly, it is probable that the carbohydrates are oxidized into carbon dioxide and water, and that this saves, to a certain extent, destruction of albuminoids. The albuminoids are split up into fats, which are deposited in the body, and into urea.

Fatty degeneration occurs in tissues during certain retrograde processes. The muscular fibres of the uterus, during the involution of this organ after parturition, become filled with fatty granulations. Long disuse of any part will produce such changes in its power of appropriating nitrogenized matter for its regeneration, that it soon becomes atrophied and altered. A portion of the nitrogenized constituents of the tissue, under these conditions, is changed into fatty matter. The fat is here inert, and it takes the place of the substance that gives to the part its characteristic properties. These changes are observed in muscles and nerves that have been long disused or paralyzed. If the change be not too extensive, the fat may be made to disappear and the part will return to its normal constitution, under appropriate exercise; but frequently the alteration has proceeded so far as to be irremediable and permanent.

It is difficult to explain the tendency to obesity observed in some individuals, which is very often hereditary. Such persons will become fat upon



a comparatively low diet, while others deposit but little adipose matter, even when the regimen is abundant. It is to be noted, however, that the former are generally addicted to the use of starchy, saccharine and fatty articles of food, while the latter consume a greater proportion of nitrogenized matter. It is not an uncommon remark that the habit of taking large quantities of liquids favors the formation of fat; but it is not easy to find any scientific basis for such an opinion. The formation of fat by any particular organ or organs in the body has not been determined.

*Condition under which Fat exists in the Organism.*—It is said that fat, combined with phosphorus, is united with nitrogenized matter in the substance of the nervous tissue; but its condition here is not well understood. A small quantity of fat is contained in the blood-corpuscles and is held in solution in the bile; but with these exceptions, fat always exists in the body isolated and uncombined with nitrogenized matter, in the form of granules or globules and of adipose tissue. The three varieties of fat (stearine, palmitine and oleine) are here combined in different proportions, which is the cause of the differences in its consistence in different situations.

*Physiological Anatomy of Adipose Tissue.*—Adipose tissue is found in abundance in the interstices of the subcutaneous areolar tissue, where it is sometimes known as the panniculus adiposus. It is not, however, to be confounded with the so-called cellular or areolar tissue, and is simply associated with it without being one of its essential parts; for the areolar tissue is abundant in certain situations, as the eyelids and scrotum, where there is no adipose matter, and adipose tissue exists sometimes, as in the marrow of the bones, without any areolar tissue.

Adipose tissue is widely distributed in the body and has important mechanical uses. Its anatomical element is a rounded or ovoid vesicle,  $\frac{1}{800}$  to  $\frac{1}{500}$  of an inch (30 to 80  $\mu$ ) in diameter, composed of a delicate, structureless membrane,  $\frac{1}{25000}$  of an inch (1  $\mu$ ) thick, enclosing fluid contents. The membrane sometimes presents a small nucleus attached to its inner surface. The contents of the vesicles are a minute quantity of an albuminoid fluid moistening the internal surface of the membrane, and a mixture of oleine, palmitine and stearine, nearly liquid at the temperature of the body but becoming harder on cooling. Little rosettes of acicular crystals of palmitine are frequently observed in the fat-vesicles at a low temperature. The quantity of fat in a man of ordinary development equals about one-twentieth of the weight of the body (Carpenter). The adipose vesicles are collected into little lobules,  $\frac{1}{25}$  to  $\frac{1}{4}$  of an inch (1 to 6 mm.) in diameter, which are surrounded by a rather wide net-work of capillary blood-vessels. Close examination of these vessels shows that they frequently surround individual fat-cells, in the form of single loops. There is no distribution of nerves or lymphatics to the elements of adipose tissue.

*Conditions which influence Nutrition.*—Physiologists know more concerning the conditions that influence the general process of nutrition than about the nature of the process itself. It will be seen, for example, in studying the nervous system, that there are nerves which regulate, to a certain extent,

the nutritive forces. This does not imply that nutrition is effected through the influence of the nerves, but it is the fact that certain nerves, by regulating the supply of blood, and perhaps by other influences, are capable of modifying the nutrition of parts to a very considerable extent.

As regards the influence of exercise upon the development of parts, it has been shown that this is not only desirable but indispensable; and the proper performance of the offices of nearly all parts involves the action of the nervous system. It is true that the separate parts of the organism and the organism as a whole have a limited existence; but it is not true that the change of nitrogenized substances into effete matters—a process that is increased in activity by physiological exercise—consumes, so to speak, a definite amount of the limited life of the parts. Physiological exercise increases disassimilation, but it also increases the activity of nutrition and favors development. It is often said that bodily or mental effort is made always at the expense of a definite amount of vitality and matter consumed. This is partly true, but mainly false. Work involves change into effete matter; but when restricted within physiological limits, it engenders a corresponding activity of nutrition, assuming, of course, that the supply from without be sufficient. Other things being equal, a man would live longer under a system of physiological exercise of every part than if he made the least effort possible. It is, indeed, only by such use of parts, that they can undergo proper development and become the seat of normal nutrition. Notwithstanding all these facts, life is self-limited. Organic substances are constantly undergoing transformation. In the living body, their metabolism is unceasing; and after they are removed from what are termed vital conditions, they change, first losing excitability, and afterward decomposing into matters which, like the products of their disassimilation, are destined to be appropriated by the vegetable kingdom. Nutrition sufficient to supply the physiological decay of parts can not continue indefinitely. The forces in the fecundated ovum lead it through a process of development that requires, in the human subject, more than twenty years for its completion; and when development ceases, no one can say why it becomes arrested, nor can any sufficient reason be given why, with an adequate and appropriate supply of material, a man should not grow indefinitely. When the being is fully developed, and during what is known as adult life, the supply seems to be about equal to the waste; but after this, nutrition gradually becomes deficient, and the deposition of new matter in progressive old age becomes more and more inadequate to supply the place of the nitrogenized substance. There may be at this time, as an exception, a considerable deposition of fat; but the nitrogenized matter is always deficient, and the proportion of inorganic matter combined with it is increased.

There can be little if any doubt that the properties which involve the regeneration or nutrition of parts reside in the organic nitrogenized substance, the inorganic matter being passive, or having purely physical uses. If, therefore, as age advances, the organic matter be gradually losing the power of completely regenerating its substance, and if its proportion be progressively diminishing while the inorganic matter is increasing in quantity,