is very like that of the medullary portion of the suprarenal capsules (Grandry).

It is difficult to classify organs, of the uses of which physiologists are entirely ignorant; but in structure, the little bodies just described certainly resemble the ductless glands.

CHAPTER XIV.

NUTRITION—ANIMAL HEAT AND FORCE.

Nature of the forces involved in nutrition—Life, as represented in development and nutrition—Substances which pass through the organism—Metabolism—Substances consumed in the organism—Conditions which influence nutrition—Animal heat and force—Estimated quantity of heat produced by the body—Limits of variation in the normal temperature in man—Variations with external temperature—Variations in different parts of the body—Variations at different periods of life etc.—Influence of exercise etc., upon the heat of the body—Influence of the nervous system upon the production of animal heat (heat-centres)—Mechanism of the production of animal heat—Equalization of the animal temperature—Relations of heat to force.

NUTRITION proper, in the light in which it is proposed to consider it in this chapter, is the process by which the physiological wear of the tissues and fluids of the body is compensated by the appropriation of new matter. All of the physiological operations that have thus far been described, including the circulation of the blood, respiration, alimentation, digestion, absorption and secretion, are to be regarded as means directed to a single end; and the great end, to which all of the functions enumerated are subservient, is the general process of nutrition.

The nature of the main forces involved in nutrition, be it in a highly organized part, like the brain or muscles, or in a tissue called extra-vascular, like the cartilages or nails, is unknown. The phenomena attending the general process, however, have been carefully studied, and certain important positive results have been attained; but there is really no more satisfactory explanation of the nature of the causative force of nutrition to be found in the doctrines of to-day than in the speculative theories of the past.

The blood contains all the matters that enter into the composition of the tissues and secretions, either identical with them in form and composition, as is the case in most of the inorganic matters, or in a condition which admits of their transformation into the characteristic constituents of the tissues, as in the organic substances proper. These matters are supplied to the tissues, in the required quantity, through the circulatory apparatus; and oxygen, which is immediately indispensable to all the operations of life, is introduced by respiration. The great nutritive fluid, being constantly drawn upon by the tissues for materials for their regeneration, is kept at the proper standard by the introduction of new matter into the system in alimentation, its elaborate preparation by digestion, and its appropriation by the fluids by absorption. Many of these processes require the action of certain secretions.

The introduction of new matter, so essential to the continuance of the phenomena of life, is demanded, on account of the change of the substance of the tissues into what is called effete matter; and this is discharged from the animal organism, to be appropriated by vegetables and thus maintain the equilibrium between the animal and the vegetable kingdoms.

It is a well established fact that nearly all of the tissues undergo disassimilation, or conversion into effete matter, during their physiological wear in the living organism, while others, like the epidermis and its appendages, are gradually desquamated, and when once formed, do not pass through any farther changes. The whole question of the essence and nature of the nutritive property or force resolves itself into vitality. Life is always attended with what are known as the phenomena of nutrition, and nutrition does not exist except in living organisms. At present, physiologists have been able to define life only by a recital of certain of its invariable and characteristic attendant conditions; and yet there are few if any definitions of life—regarding life as the sum of the phenomena peculiar to living organisms—that are not open to grave objections.

If life be regarded as a principle, it stands in the relation of a cause to the vital phenomena; if it be regarded as the totality of these phenomena, it is an effect.

In the study of the development of a fecundated ovum, life seems to be a principle, giving the property of appropriating matter from without, until the germ becomes changed, from a globule of microscopic size and comparatively simple structure, into a complete organism with highly elaborated parts. This organism has a definite form and size, a definite period of existence, and it produces, at a certain time, generative elements, capable of perpetuating its life in new beings. It may be said that an organism dies physiologically because the vital principle, if such a principle be admitted, has a limited term of existence; but on the other hand, the fully developed living organism, called an animal, presents many distinct parts, each endowed with an independent property called vital, that property recognized by Haller in various tissues, under the name of irritability; and it is the co-ordinated association of these vitalities that constitutes the perfect being. These are more or less distinct; and a sudden and simultaneous arrest of the physiological properties in all the tissues, in what is called death, is not often observed. For example, the nerves may die before the muscles, or the muscles, before the nerves. It is found, also, that physiological properties, apparently lost or destroyed, may be made to return; as in resuscitation after asphyxia or in the restoration of muscular or nervous excitability by injection of blood.

The life of a fecundated ovum is the property which enables it to undergo development when placed under favorable conditions; and by the surrounding conditions, its development may be arrested, suspended or modified. The life of a non-fecundated ovum is like that of any ordinary anatomical element.

The life of an anatomical element or tissue in process of development is the property by virtue of which it arrives at its perfection of organization

and performs certain defined offices, as far as its organization will permit. This can also be destroyed, suspended or modified by surrounding conditions.

The life of a perfected anatomical element or tissue is the property which enables it to regenerate itself and perform it offices, subject, also, to modifications from surrounding conditions.

The life of a perfect animal organism is the sum of the vitalities of its constituent parts; but a being may live with the physiological properties of certain parts abolished or seriously modified, as a man exists and preserves his identity with a limb amputated. Life may continue for a long time without consciousness or with organs paralyzed; but certain functions, such as respiration and circulation, are indispensable to the nutrition of all parts, the properties of the different tissues are speedily lost when these processes are arrested, and the being then ceases to exist.

These considerations make it evident that it is difficult if not impossible to give a single, comprehensive definition of life, a study of the varied phenomena of which constitutes the science of physiology.

The general process of nutrition begins with the introduction of matter from without, called food. It is carried on by the appropriation of this matter by the organism. It is attended with the production of excrementitious matters and the development of certain phenomena that remain to be studied, the most important of which is the production of heat.

The term metabolism, now used by many English writers, seems destined to become generally adopted. It was employed by Schwann to designate a kind of action by cells, resulting in a change in the character of substances brought in contact with them. Modern writers use it as a translation of the German word *Stoffwechsel*. The literal signification of the Greek word μεταβολή is change. As applied to nutritive changes, metabolism is equivalent to assimilation; and as applied to the changes which result in the production of effete matters, it is equivalent to disassimilation, a term much used by the French, and one which well expresses changes that are exactly the opposite of assimilation. The signification of the term metabolism seems likely to be extended so as to include the acts of cells in the production of the constituents of the secretions, a process which it is difficult to express in a single word.

The behavior of various substances in nutrition has already been treated of, to some extent, in connection with alimentation; but certain general relations of nutritive substances to assimilation remain to be considered. It is convenient, as before, to divide these substances into the following classes: 1, Inorganic; 2, organic non-nitrogenized; 3, organic nitrogenized. The excrementitious products constitute a distinct class by themselves.

Substances which pass through the Organism.

All of the inorganic matters taken in with the food pass out of the organism, generally in the form in which they enter, in the fæces, urine and perspiration; but it must not be inferred from this fact that they are not useful as constituent parts of the body. Some of these, such as water and the chlo-

rides, have important uses of a purely physical character. It is necessary, for example, that the blood should contain a certain proportion of sodium chloride, this substance modifying and regulating the processes of absorption and probably of assimilation. In addition, however, the chlorides exist as constituent parts of every tissue and organ of the body, and they are so closely united with the nitrogenized matters that they can not be completely separated without incineration. Those inorganic matters, the uses of which are so important in their passage through the body, are found largely as constituents of the fluids and are less abundant in the solids. They are contained in large proportion, also, in the liquid excretions; and any excess over the quantity actually required by the system is thrown off in this way. Other inorganic matters are specially important as constituent parts of the tissues, and they are more abundant in the solids than in the fluids. Examples of substances of this class are the calcium salts, particularly the phosphates. These are also in a condition of intimate union with organic matters.

If certain simple chemical changes be excepted, such as the decomposition of the bicarbonates, the inorganic constituents of food do not necessarily undergo any modification in digestion. They are generally introduced already in combination with organic matters, and they accompany them in the changes which they pass through in digestion, assimilation by the blood, deposition in the tissues, and the final transformations that result in the various excrementitious products; so that the inorganic salts are found united with the organic matter of the food as it enters the body, and what seem to be the same substances, in connection with the organic excrementitious matters. Between these two conditions, however, are the various operations of assimilation and disassimilation, or metabolism, from which inorganic matters are never absent.

Inorganic Constituents of the Body.—The number of inorganic substances now well established as existing in the human body is about twenty-one; but some are found in small quantities, are not always present and apparently have no very important uses. These will be passed over rapidly, as well as those which are so intimately connected with some important function as to render their full consideration in connection with that function indispensable.

Gases.—The gases (oxygen, hydrogen, nitrogen, carburetted hydrogen and hydrogen monosulphide) exist both in a gaseous state and in solution in some of the fluids of the body. Oxygen plays a most important part in the function of respiration; but the office of the other gases is by no means so essential. Nitrogen seems to be formed by the system in small quantity and is taken up by the blood and exhaled by the lungs, except during inanition, when the blood absorbs a little from the inspired air. It exists in greatest quantity in the intestinal canal. Carburetted hydrogen and hydrogen monosulphide, with pure hydrogen, are found in minute quantities in the expired air and exist in a gaseous state in the alimentary canal. From the offensive nature of the contents of the large intestine, one would suspect the presence of hydrogen monosulphide in considerable quantity; but actual analysis has shown that the gas contained in the stomach and in the small and large in-

testines is composed chiefly of nitrogen, with hydrogen and carburetted hydrogen in about equal proportions (five to eleven parts per hundred), and but a trace of hydrogen monosulphide. With the exception, then, of oxygen and carbon dioxide, the latter being an excretion, the gases do not hold an important place among the constituents of the organism. At all events, their uses, whether they be important or not, are but little understood.

Water.—Water exists in all parts of the body; in the fluids, some of which, as the lachrymal fluid and perspiration, contain little else, and in the hardest structures, as the bones and the enamel of the teeth. In the solids and semi-solids it does not exist as water, but it enters into their composition, assuming the consistence by which the tissues are characterized.

The quantity of water which each organic substance contains is important; and it is provided that this quantity, though indefinite, shall not exceed or fall below certain limits. All organs and tissues must contain a tolerably definite quantity of water to give them proper consistence. The effects of too great a proportion of water in the system are well known to physicians. General muscular debility, loss of appetite, dropsies and various other indications of imperfect nutrition are among the results of such a condition; while a deficiency of water is immediately made known by the sensation of thirst, which leads to its introduction from without.

The fact that water never exists in any of the fluids, semi-solids or solids, without being combined with inorganic salts, especially sodium chloride, is one reason why its proportion in various situations is nearly constant. The presence of these salts influences, in the semi-solids at least, the quantity of water entering into their composition, and consequently it regulates their consistence. The nutrient fluid of the muscles during life contains water with just enough saline matter to preserve the normal consistence of the parts. This action of saline matters is even more apparent in the case of the blood-corpuscles. If pure water be added to the blood, these bodies swell up and are finally dissolved; while on the addition of a strong solution of salt, they lose water and become shrunken and corrugated. Their natural form and consistence can be restored, however, even after they have been completely dried, by adding water containing about the proportion of salt which exists in the blood-plasma. It seems clear, then, that water is a a necessary part of all tissues and is especially important to the proper constitution of organic nitrogenized substances; that it enters into the constitution of these substances, not as pure water, but always in connection with certain inorganic salts; that its proportion is confined within certain limits; and that the quantity in which it exists, in organic nitrogenized substances particularly, is regulated by the quantity of salts which enter, with it, into the constitution of these substances.

The quantities of water which can be driven off by a moderate temperature (212° Fahr., or 100° C.), from the different fluids and tissues of the body, vary of course very considerably according to the consistence of the parts. The following is a list of the quantities in the most important fluids and solids (Robin and Verdeil):

TABLE OF QUANTITIES OF WATER.

	Parts per 1,000.
In the enamel of the teeth	2
In epithelial desquamation	37
In teeth	100
In bones	130
In tendons (Burdach)	500
In articular cartilages	550
In skin (Weinholt)	575
In liver (Frommherz and Gugert)	618
In muscles of man (Bibra)	725
In ligaments (Chevreul)	768
In the blood of man (Becquerel and Rodier)	780
In milk of the human female (Simon)	887
In chyle of man (Rees)	904
In bile	905
In urine	933
In human lymph (Tiedemann and Gmelin)	960
In human saliva (Mitscherlich)	983
In gastric juice	984
In perspiration	986
In tears	990

(Bracket labels: "Solids and semi-solids." for rows from enamel to ligaments; "Liquids." for rows from blood to tears.)

Uses of Water.—After what has been stated with regard to the condition in which water exists in the body, there remains but little to say concerning its uses. As a constituent of organized tissues, it gives to cartilage its elasticity, and to tendons their pliability and toughness; it is necessary to the power of resistance of the bones, and it is essential to the proper consistence of all parts of the body. It also has other important uses, as a solvent. Soluble articles of food are introduced in solution in water. The excrementitious products, which generally are soluble in water, are dissolved by it in the blood, are carried to the organs of excretion, and are discharged in a watery solution from the body.

Origin and Discharge of Water.—It is evident that a great proportion of the water in the organism is introduced from without, in the fluids and in the watery constituents of all kinds of food; but water is also formed in the body by a direct union of oxygen and hydrogen. The evidences of formation of water in the body have already been given, in connection with the question of water considered as a product of excretion, and will be again discussed in treating of the relations of water to the processes of calorification. In the discharge of water by the kidneys and skin, it has long been observed that in point of activity these two emunctories bear a certain relation to each other. When the skin is inactive, as in cold weather, the kidneys discharge a large quantity of water; and when the skin is active, the quantity of water discharged by the kidneys is proportionally diminished.

Sodium Chloride.—Sodium chloride is next in importance, as an inorganic constituent of the organism, to water. It is found in the body at all periods of life, existing even in the ovum. It exists in all the fluids and solids of the body, with the single exception of the enamel of the teeth. The exact quantity in the entire body has never been ascertained; nor, indeed,

has any accurate estimate been made of the quantity contained in the various tissues, for all the chlorides are generally estimated together. It exists in greatest proportion in the fluids, giving to some of them, as the tears and perspiration, a distinctly saline taste. The following table gives the quantities found in some of the most important of the fluids and solids:

TABLE OF QUANTITIES OF CHLORIDES.

	Parts per 1,000.
In blood, human (Lehmann)	4·210
In chyle (Lehmann)	5·310
In lymph (Nasse)	4·120
In milk, human (Lehmann)	0·870
In saliva, human (Lehmann)	1·530
In perspiration, human (mean of three analyses, Piutti)	3·433
In urine (maximum) ⎫	7·280
In urine (mean) .... ⎬ Valentin ⎰	4·610
In urine (minimum) ⎭	2·400
In fæcal matters (Berzelius)	3·010

Uses of Sodium Chloride.—The uses of sodium chloride are undoubtedly important, but are not yet fully understood. While it enters into the composition of the organized solids and semi-solids, as an important and essential constituent, it seems to exercise its chief office in the liquids. It is the sodium chloride particularly which regulates the quantity of water entering into the composition of the blood-corpuscles, thereby preserving their form and consistence; and it seems to perform an analogous office with regard to the other semi-solids of the body. The following brief statement expresses the general uses of this substance in the economy:

"Common salt is intermediate in certain general processes and does not participate by its elements in the formation of organs" (Liebig).

In the first place, the fluids of the body are generally intermediate in their uses, containing nutritious matters, which are destined to be appropriated by the tissues and organs, and excrementitious matters, which are to be separated from the body. In the blood and chyle, sodium chloride is found in greatest abundance. In the nutrition of tissues and organs, sodium chloride is not deposited in any considerable quantity, but it seems to regulate the general process, at least to a certain extent. In all civilized countries salt is used extensively as a condiment, and it undoubtedly facilitates digestion by rendering the food more savory and increasing the flow of the digestive fluids; here, likewise, acting simply as an intermediate agent. There is nothing more general among men and animals than this desire for common salt. In the experiments made by Dailly on sheep and by Boussingault on bullocks, depriving these animals as nearly as possible of common salt for a number of months, the general nutrition was affected without any marked change in special tissues or organs.

It is significant that the quantity of sodium chloride existing in the blood is not subject to variation, but that an excess introduced with the food is thrown off by the kidneys. The quantity in the urine, then, bears a relation to the quantity introduced with food, but the proportion in the blood is nearly

constant. This is another fact in favor of the view that the presence of a definite quantity of common salt in the circulating fluid is essential to normal nutrition.

Origin and Discharge of Sodium Chloride.—Sodium chloride is always introduced with food, in the condition in which it is found in the body. It is contained in the substance of all kinds of food, animal and vegetable; but in the herbivora and in man, this source is not sufficient to supply the wants of the system, and it is introduced, therefore, as salt. The quantity which is discharged from the body has been estimated by Barral to be somewhat less than the quantity introduced, about one-fifth disappearing; but these estimates are not entirely accurate, for the quantity thrown off in the perspiration has never been directly ascertained. It exists in the blood in connection with potassium phosphate, and a certain quantity is lost in a double decomposition which takes place between these two salts, resulting in the formation of potassium chloride and sodium phosphate. It also is supposed to furnish sodium to all the salts which have a sodium base, and a certain quantity, therefore, disappears in this way.

Existing, as it does, in all the solids and fluids of the body, sodium chloride is discharged in all the excretions, being thrown off in the urine, fæces, perspiration and mucus.

Potassium Chloride.—Potassium chloride, although neither so important as sodium chloride nor so generally distributed in the economy, seems to have analogous uses. It is found in the muscles, liver, milk, chyle, blood, mucus, saliva, bile, gastric juice, cephalo-rachidian fluid and urine. It is very soluble, and in these situations it exists in solution in the fluids. Its quantity in the fluids has not been accurately ascertained, as it has generally been estimated in connection with sodium chloride. In the muscles it exists, however, in a larger proportion than common salt. In cow's milk, Berzelius found 1·7 part per 1,000. Pfaff and Schwartz found 1·35 per 1,000 in cow's milk and 0·3 per 1,000 in human milk. Of the uses of this salt, little remains to be said after what has been stated with regard to sodium chloride. The uses of these two salts are probably identical, although sodium chloride, on account of its greater quantity in the fluids and its universal distribution, is by far the more important.

Origin and Discharge of Potassium Chloride.—This substance has two sources; one in the food, existing, as it does, in muscular tissue, milk etc., and the other in a chemical reaction between potassium phosphate and sodium chloride, forming potassium chloride and sodium phosphate. That this decomposition takes place in the body, is evident from the fact that the ingestion of a considerable quantity of common salt has been found, in the sheep, to increase the quantity of potassium chloride in the urine, without having any influence upon the quantity of sodium chloride. Potassium chloride is discharged from the body in the urine and in mucus.

Calcium Phosphate.—This salt is found in all the solids and fluids of the body. As it is always united, in the solids, with organic substances as an important element of constitution, it is hardly second in importance to water.

It differs in its uses so essentially from the chlorides, that they are hardly to be compared. It is insoluble in water, but is held in solution in the fluids of the body by virtue of free carbon dioxide, the bicarbonates and sodium chloride. In the solids and semi-solids, the condition of its existence is the same as that of water; *i. e.* it is incorporated with the organic substance characteristic of the tissue, is one of its essential constituents, and can not be completely separated without incineration. Nothing need be added here with regard to this mode of union in the body, of organic and inorganic substances, after what has been said with regard to water.

The following table gives the relative quantities of calcium phosphate in various situations:

TABLE OF QUANTITIES OF CALCIUM PHOSPHATE.

	Parts per 1,000.
In arterial blood. } Poggiale and Marchal. {	0·79
In venous blood.	0·76
In milk, human (Pfaff and Schwartz)	2·50
In saliva (Wright)	0·60
In urine, proportion to weight of ash (Fleitmann)	25·70
In excrements (Berzelius)	40·00
In bone (Lassaigne)	400·00
In the vertebræ of a rachitic patient (Bostock)	136·00
In teeth of an infant one day old .	510·00
In teeth of the adult	610·00
In teeth, at eighty-one years } Lassaigne. {	660·00
In the enamel of the teeth	885·00

By this table it is seen that calcium phosphate exists in very small quantity in the fluids but is abundant in the solids. In the latter, the quantity is in proportion to the hardness of the structure, the quantity in enamel, for example, being more than twice that in bone. The variations in quantity with age are very considerable. In the teeth of an infant one day old, Lassaigne found 510 parts per 1,000; in the teeth of an adult, 610 parts; and in the teeth of an old man of eighty-one years, 660 parts. This increase in the calcareous constituents of the bones, teeth etc., in old age is very marked; and in extreme old age they are deposited in considerable quantity in situations where there existed but a small proportion in adult life. The system seems to gradually lose the property of appropriating to itself organic matters; and although articles of food may be digested as well as ever, the power of assimilation by the tissues is diminished. The bones become brittle, and fractures, therefore, are common at this period of life, when dislocations are almost unknown. Inasmuch as the efficiency of organs depends mainly upon organic matters, the system actually wears out, and this progressive change finally unfits certain parts for their various offices. An individual, if he escape accidents and die of old age, passes away by a simple wearing out of some essential part or parts of the organism.

Uses of Calcium Phosphate.—This substance, as before remarked, enters largely into the constitution of the solids of the body. In the bones its office is most apparent. Its existence, in suitable proportion, is necessary to the

mechanical uses of these parts, giving them their power of resistance without rendering them too brittle. It is more abundant in the bones of the lower extremities, which have to sustain the weight of the body, than in the upper extremities; and in the ribs, which are elastic rather than resisting, it exists in less quantity than in the bones of the arm.

The necessity of a proper proportion of calcium phosphate in the bones is made evident by cases of disease. In rachitis, where, as is seen by the table, its quantity is very much diminished, the bones being unable to sustain the weight of the body become deformed; and finally, when calcium phosphate is deposited, they retain their distorted shape.

Origin and Discharge of Calcium Phosphate.—The origin of calcium phosphate is exclusively from the external world. It enters into the constitution of food and is discharged in the fæces, urine and other matters thrown off by the body. Its proportion in the urine is very variable.

Calcium Carbonate.—This salt exists in the bones, teeth, cartilage, internal ear, blood, sebaceous matter and sometimes in the urine. It exists as a normal constituent of the urine in some herbivora but not in the carnivora or in man. It is most appropriately considered immediately after calcium phosphate, because it is the salt next in importance in the constitution of the bones and teeth. In these structures it exists intimately combined with the organic matter, under the same conditions as the phosphates, and it has analogous uses. In the fluids it exists in small quantity and is held in solution by virtue of free carbon dioxide and potassium chloride.

Calcium carbonate is the only example of an inorganic salt existing uncombined and in a crystalline form in the body. In the internal ear it is found in this form and has some office connected with audition.

TABLE OF QUANTITIES OF CALCIUM CARBONATE.

	Parts per 1,000.
In bone, human (Berzelius)	113·00
"　"　"　(Marchand)	102·00
"　"　"　(Lassaigne)	76·00
In teeth of an infant one day old .	140·00
In teeth of an adult } Lassaigne. {	100·00
In teeth of an old man, eighty-one years .	10·00
In urine of the horse (Boussingault)	10·82

Origin and Discharge of Calcium Carbonate.—This salt is introduced into the body with food, held in solution in water by the carbon dioxide, which is always present in small quantity. It is also formed in the body, particularly in the herbivora, by a decomposition of the calcium tartrates, malates, citrates and acetates contained in the food. These salts, meeting with carbon dioxide, are decomposed and calcium carbonate is formed. It is probable that in the human subject some of it is changed into calcium phosphate and in this form is discharged in the urine; but it has not been definitely ascertained when and how this change takes place.

Sodium Carbonate.—This salt is found in the blood and saliva, giving to these fluids their alkalinity; in the urine of the human subject when it is