ANIMAL CHEMISTRY.

MEMOIR

OF

THE AUTHOR.

Justus Liebig, Professor Ordinarius in the University of Giessen, Grand-duchy of Hesse-Darmstadt, was born at Darmstadt, on the 8th of May, 1803. His father, who was a merchant, indulged the predilection of his son for natural philosophy, and, after having acquired a scientific education in the Gymnasium (Latin school) of Darmstadt, he became an apprentice in a Dispensary in 1818, where he passed two years in practical preparation for his future pursuits. From 1819 to 1822 he studied in Bonn and Erlangen, where Goldfuss, Bischoff, Kastner, and others, were his teachers. Honored now by the Grand-duke of Darmstadt with a salary which enabled him to travel, he went to Paris, where he remained till 1824.

were perceptible, partly, also, because a true basis on which it should be founded was wanting.

To this design of recreating, as it were, Organic Chemistry, in his native country, Liebig was always faithful; and, though he no longer stands alone as a distinguished promoter of that department, yet no one can overlook the influence he has had upon his colleagues and pupils. This influence operates in Germany and England to urge on the science, in France more to moderate its progress; that is, to keep theory within its proper limits. The consequence has been, that, whereas, before, many chemical students repaired to the laboratories of Paris, the young chemists of all nations are now assembled in the little town of Giessen, to profit by the instructions of this great master. In the present year there are around him one hundred and thirty-five foreigners. The British chemists are looking with eagerness to Germany; and to undervalue German Chemistry, at the present day, would be ridiculed even in France. We know very well that Dr. Liebig has not produced this effect

TO

THE BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

At the meeting of the British Association in Glasgow, in 1840, I had the honor to present the first part of a report on the then present state of Organic Chemistry, in which I endeavoured to develope the doctrines of this science in their bearing on Agriculture and Physiology.

It affords me now much gratification to be able to communicate to the meeting of the Association for the present year the second part of my labors; in which I have attempted to trace the application of Organic Chemistry to Animal Physiology and Pathology.

In the present work, an extensive series of phenomena have been treated in their chemical relations; and, although it would be presumptuous to consider the questions here raised as being definitely resolved, yet those who are branches of medicine, and his intimate acquaintance with the German language, — all these, taken together, are the best securities that the translation is such as to convey the exact sense of the original; securities, such as are not often united in the same individual.

It is my intention to follow this second part with a third, the completion of which, however, cannot be looked for before the lapse of two years. This third part will contain an investigation of the food of man and animals, the analysis of all articles of diet, and the study of the changes which the raw food undergoes in its preparation; as, for example, in fermentation (bread), baking, roasting, boiling, &c. Already, it is true, many analyses have been made for the proposed work; but the number of objects of investigation is exceedingly large; and, in order to determine with accuracy the absolute value of seed, or of flour, or of a species of fodder, &c., as food, the ultimate analysis alone is not sufficient; there are required comparative investigations, which present very great difficulties.

DR. JUSTUS LIEBIG.

GIESSEN, 3*d June*, 1842.

PREFACE.

By the application to Chemistry of the methods which had for centuries been followed by philosophers in ascertaining the causes of natural phenomena in physics, — by the observation of weight and measure, — Lavoisier laid the foundation of a new science, which, having been cultivated by a host of distinguished men, has, in a singularly short period, reached a high degree of perfection.

It was the investigation and determination of all the conditions which are essential to an observation or an experiment, and the discovery of the true principles of scientific research, that protected chemists from error, and conducted them, by a way equally simple and secure, to discoveries which have shed a brilliant light on those natural phenomena which were previously the most obscure and incomprehensible.

The most useful applications to the arts, to industry, and to all branches of knowledge related to chemistry, sprung from the laws thus of fresh points of departure for researches, render physiology more extensive, but neither more profound nor more solid.

No one will venture to maintain that the knowledge of the forms and of the phenomena of motion in organized beings is either unnecessary or unprofitable. On the contrary, this knowledge must be considered as altogether indispensable to that of the vital processes. But it embraces only one class of the conditions necessary for the acquisition of that knowledge, and is not of itself sufficient to enable us to attain it.

The study of the uses and functions of the different organs, and of their mutual connexion in the animal body, was formerly the chief object of physiological researches; but lately this study has fallen into the background. The greater part of all the modern discoveries has served to enrich comparative anatomy far more than physiology.

These researches have yielded the most valuable results in relation to the recognition of the dissimilar forms and conditions to be found in the healthy and in the diseased organism; but they have yielded no conclusions calculated to give us a more profound insight into the essence of the vital processes.

The most exact anatomical knowledge of the conclusions, could not be received as expressions of the truth.

How clear are now to us the relations of the different articles of food to the objects which they serve in the body, since organic chemistry has applied to the investigation her *quantitative method* of research!

When a lean goose, weighing 4 lbs., gains, in thirty-six days, during which it has been fed with 24 lbs. of maize, 5 lbs. in weight, and yields $3\frac{1}{2}$ lbs. of pure fat, this fat cannot have been contained in the food, ready formed, because maize does not contain the thousandth part of its weight of fat, or of any substance resembling fat.* And when a certain number

---

* Dumas and Payen have recently stated, that they obtained from maize 9 per cent. of yellow oil, and maintain that the source of the fat in the above and in analogous cases is the fatty matter in the food.* Mr. A. A. Hayes, whose chemical science and practical skill are so well known and acknowledged in this country, has devoted much attention to the examination of the varieties of maize, and has kindly favored the editor with the following results and observations. — *W.*

"The fact is, both Liebig and Dumas are right, if the expression in Liebig's work has a general meaning. The proportion of oil in maize varies with the varieties and seasons. In no instance has so much as $\frac{9}{100}$ been obtained from our grain. I think Dumas has overestimated the proportion, from the fact that alcohol extracts from the maize other principles which are united with the oil. The weight of a bushel of sound maize is nearly 54 avoirdupois pounds. In the manufactories of spirits

* See Comptes Rendus des Séances de l'Académie des Sciences, October and November, 1842.

of bees, the weight of which is exactly known, being fed with pure honey, devoid of wax,

---

and oil, I found a mean produce of oil to be 9 gallons from 45 bushels; 45 × 54 = 2430 lbs.; and the gallon of oil, reckoned at 8 lbs. × 9 = 72 lbs. = to nearly 3 per cent. This will be the full quantity for the Indian corn of our northern sections of country. The color is accidental; white corn gives a colorless oil, and the darker colored varieties a more highly colored oil. There is a variety of maize, which is known as the 'Tuscarora corn,' and highly valued as an article of human food, which contains NO oil. Another variety, much cultivated in our Southern States, contains a very small proportion only. The native maize of the Rocky Mountains, from which our varieties have been obtained by cultivation, closely resembles, in proportion of oil and other constituents, the 'flat southern' and western corn, the great staple article of food for a portion of the population and for animals. Rice and rye both contain oil, and the proportions vary with the seasons, as in the case of Indian corn. The Indian corn offers an interesting instance of the union, in one grain, of matters which are quite distinct in properties and unequal in value as articles of food. I have elsewhere shown, that, by applying chemical reagents to the sections of kernels, we can point out the precise place where each substance reposes, and the relative proportions, by bulk, of each. In the central soft part, and surrounding the germ, is the albuminous matter, the phosphate and peroxide of iron. The starch in a state of purity occupies another place apart from the ferruginous salt, and its position and quantity mark the variety of corn. The oil saturates a compound substance and woody fibre, giving a translucent appearance to the grain. The chemical examination of a large number of specimens of varieties, including nearly all found on this continent, has established the fact of the perfect individuality of the several constituents which the grain contains. If, however, the grain is not of mature growth, a blending of parts becomes evident; the ferruginous constituent is mixed throughout with the starch, and the phosphates are not found in the same parts as when the grain is mature. During the maturation of the grain, we can easily trace the conversion of one organic matter into another; as the changes advance, the inorganic elements, which were before mixed throughout the others, assume their proper places. *No Indian corn has yet been found* yield one part of wax for every twenty parts of honey consumed, without any change being perceptible in their health or in their weight, it is impossible any longer to entertain a doubt

---

destitute of phosphoric acid and peroxide of iron. When the kernel germinates, the inorganic matters move with the radicle and plumula; the plant at one stage of growth absorbs from the soil additional proportions of these substances, to supply the increased demand in the grain. Experiments have been made to ascertain if the phosphates and oxide of iron are really as essential to the growth of the plant, as they are to the existence of the grain. Specimens of Indian corn (maize) and rye were steeped in solutions of copper, which removed the iron, and substituted copper as phosphate of copper; these were planted on different soils, under the care of different persons, and carefully attended. The plants were vigorous for some time, but, before fructification took place, disease was apparent and the vegetating power was lost. The nutritive and fattening powers of this grain have long been acknowledged, but its value as an article of food for man is a subject on which minds differ. The digestive organs of man and of some animals cannot render the whole of this grain capable of assimilation. Even when quite finely ground, horses do not digest the parts saturated with oil, while swine and fowls subsist and fatten on it. After the fine flour has been fermented so as to form a spongy bread, or before the grain has ripened, its constituents are digested by man. In the fattening of swine and fowls, the largest increase of fat is produced by those grains and nuts which contain the most oil. Swine eagerly select, from the produce of forest-trees, those nuts which contain most oil; and if they are deprived of food which does not contain oil ready formed, the diminished production of fat and its altered quality are plainly perceptible. In the statements of Dr. Liebig I think there is a well grounded reliance on facts; but the remarks above, and the case supposed at page 83, would be a better illustration of the formation of tissues and fat, with a slight alteration in the elements of the food. The fact, however, that there is a variety of maize containing *no oil* is indisputable, *and this forms a favorite and nutritious food for man and animals.*"

PART III.

APPENDIX.

because the animal body can produce within itself that source of motion, which is indispensable to the vital process.

Assimilation, or the process of formation and growth, — in other words, the passage of matter from a state of motion to that of rest, — goes on in the same way in animals and in vegetables. In both, the same cause determines the increase of mass. This constitutes the true vegetative life, which is carried on without consciousness.

The activity of vegetative life manifests itself, in vegetables, with the aid of external influences; in animals, by means of influences produced within their organism. Digestion, circulation, secretion, are no doubt under the influence of the nervous system; but the force which gives to the germ, the leaf, and the radical fibres of the vegetable the same wonderful properties, is the same as that residing in the secreting membranes and glands of animals, and which enables every animal organ to perform its own proper function. It is only the source of motion that differs in the two great classes of organized beings.

While the organs of the vital motions are never wanting in the lowest orders of animals, as in the impregnated germ of the ovum, in which they are developed first of all, we find, in the higher orders of animals, peculiar organs of feeling and sensation, of consciousness and of a higher intellectual existence.

Pathology informs us, that the true vegetative life is in no way dependent on the presence of this apparatus;

that the process of nutrition proceeds in those parts of the body where the nerves of sensation and voluntary motion are paralyzed, exactly in the same way as in other parts where these nerves are in the normal condition ; and, on the other hand, that the most energetic volition is incapable of exerting any influence on the contractions of the heart, on the motion of the intestines, or on the processes of secretion.

The higher phenomena of mental existence cannot, in the present state of science, be referred to their proximate, and still less to their ultimate causes. We only know of them, that they exist ; we ascribe them to an immaterial agency, and that, in so far as its manifestations are connected with matter, an agency entirely distinct from the vital force, with which it has nothing in common.

It cannot be denied, that this peculiar force exercises a certain influence on the activity of vegetative life, just as other immaterial agents, such as Light, Heat, Electricity, and Magnetism do ; but this influence is not of a determinative kind, and manifests itself only as an acceleration, a retarding, or a disturbance of the process of vegetative life. In a manner exactly analogous, the vegetative life reacts on the conscious mental existence.

There are thus two forces, which are found in activity together ; but consciousness and intellect may be absent in animals as they are in living vegetables, without their vitality being otherwise affected than by the want of a peculiar source of increased energy or of disturbance. Except in regard to this, all the vital chemical processes go on precisely in the same way in man and in the lower animals.

The efforts of philosophers, constantly renewed, to penetrate the relations of the soul to animal life, have all along retarded the progress of physiology. In this attempt men left the province of philosophical research for that of fancy; physiologists, carried away by imagination, were far from being acquainted with the laws of purely animal life. None of them had a clear conception of the process of development and nutrition, or of the true cause of death. They professed to explain the most obscure psychological phenomena, and yet they were unable to say what fever is, and in what way quinine acts in curing it.

For the purpose of investigating the laws of vital motion in the animal body, only one condition, namely, the knowledge of the apparatus which serves for its production, was ascertained; but the substance of the organs, the changes which food undergoes in the living body, its transformation into portions of organs, and its re-conversion into lifeless compounds, the share which the atmosphere takes in the processes of vitality; all these foundations for future conclusions were still wanting.

What has the soul, what have consciousness and intellect, to do with the development of the human fœtus, or the fœtus in a fowl's egg? not more, surely, than with the development of the seeds of a plant. Let us first endeavor to refer to their ultimate causes thought, every sensation, is accompanied by a change in the composition of the substance of the brain.

In order to keep up the phenomena of life in animals, certain matters are required, parts of organisms, which we call nourishment. In consequence of a series of alterations, they serve either for the increase of the mass (*nutrition*), or for the supply of the matter consumed (*reproduction*), or, finally, for the production of force.

II. If the first condition of animal life be the assimilation of what is commonly called nourishment, the second is a continual absorption of oxygen from the atmosphere.

Viewed as an object of scientific research, animal life exhibits itself in a series of phenomena, the connexion and recurrence of which are determined by the changes which the food and the oxygen absorbed from the atmosphere undergo in the organism under the influence of the vital force.

All vital activity arises from the mutual action of the oxygen of the atmosphere and the elements of the food.

In the processes of nutrition and reproduction, we perceive the passage of matter from the state of motion to that of rest (static equilibrium) ; under the influence of the nervous system, this matter enters again into a state of motion. The ultimate causes of these different conditions of the vital force are chemical forces.

The cause of the state of rest is a resistance, deterthat, in the same individual, the quantity of nourishment required must vary with the force and number of the respirations.

A child, in whom the organs of respiration are naturally in a state of great activity, requires food oftener, and in greater proportion to its bulk, than an adult, and bears hunger less easily. A bird, deprived of food, dies on the third day, while a serpent, which, if kept under a bell-jar, hardly consumes in an hour so much oxygen as that we can detect the carbonic acid produced, can live without food three months and longer.

The number of respirations is smaller in a state of rest than during exercise or work. The quantity of food necessary in both conditions must vary in the same ratio.

An excess of food is incompatible with deficiency in respired oxygen, that is, with deficient exercise ; just as violent exercise, which implies an increased supply of food, is incompatible with weak digestive organs. In either case the health suffers.

But the quantity of oxygen which an animal takes up by the lungs, depends not only on the number of respirations ; it is also affected by the temperature and density of the atmosphere.

The capacity of the chest in an animal is a constant quantity. At every respiration a quantity of air enters, the volume of which may be considered as uniform ; but its weight, and that of the oxygen it contains, is not constant. Air is expanded by heat, and contracted by cold, and equal volumes of hot and cold air contain unequal weights of oxygen. In summer air contains aqueous vapor, in winter it is dry ; the space occupied moderation in eating, and men can bear hunger for a long time under the equator; but cold and hunger united very soon exhaust the body.

The mutual action between the elements of the food and the oxygen conveyed by the circulation of the blood to every part of the body is **THE SOURCE OF ANIMAL HEAT.**

III. All living creatures, whose existence depends on the absorption of oxygen, possess within themselves a source of heat independent of surrounding objects.

This truth applies to all animals, and extends, besides, to the germination of seeds, to the flowering of plants, and to the maturation of fruits.

It is only in those parts of the body to which arterial blood, and with it the oxygen absorbed in respiration, is conveyed, that heat is produced. Hair, wool, or feathers do not possess an elevated temperature.

This high temperature of the animal body, or, as it may be called, disengagement of heat, is uniformly and under all circumstances the result of the combination of a combustible substance with oxygen.

In whatever way carbon may combine with oxygen, the act of combination cannot take place without the disengagement of heat. It is a matter of indifference whether the combination take place rapidly or slowly, at a high or at a low temperature; the amount of heat liberated is a constant quantity.

The carbon of the food, which is converted into carthe Esquimaux cannot expire more carbon and hydrogen than he takes into the system as food, unless in a state of disease or of starvation. Let us examine these states a little more closely.

The Englishman in Jamaica sees with regret the disappearance of his appetite, previously a source of frequently recurring enjoyment; and he succeeds, by the use of cayenne pepper and the most powerful stimulants, in enabling himself to take as much food as he was accustomed to eat at home. But the whole of the carbon thus introduced into the system is not consumed; the temperature of the air is too high, and the oppressive heat does not allow him to increase the number of respirations by active exercise, and thus to proportion the waste to the amount of food taken; disease of some kind, therefore, ensues.

On the other hand, England sends her sick, whose diseased digestive organs have in a greater or less degree lost the power of bringing the food into that state in which it is best adapted for oxidation, and therefore furnish less resistance to the oxidizing agency of the atmosphere than is required in their native climate, to southern regions, where the amount of inspired oxygen is diminished in so great a proportion; and the result, an improvement in the health, is obvious. The diseased organs of digestion have sufficient power to place the diminished amount of food in equilibrium with the inspired oxygen; in the colder climate, the organs of respiration themselves would have been consumed in degree of exercise, as in labor or exertion of any kind, on the temperature of the air, and finally, on the presence or absence of water. Through the skin and lungs there escapes a certain quantity of water, and as the presence of water is essential to the continuance of the vital motions, its dissipation hastens death. Cases have occurred, in which a full supply of water being accessible to the sufferer, death has not occurred till after the lapse of twenty days. In one case, life was sustained in this way for the period of sixty days.

In all chronic diseases death is produced by the same cause, namely, the chemical action of the atmosphere. When those substances are wanting, whose function in the organism is to support the process of respiration; when the diseased organs are incapable of performing their proper function of producing these substances; when they have lost the power of transforming the food into that shape in which it may, by entering into combination with the oxygen of the air, protect the system from its influence, then, the substance of the organs themselves, the fat of the body, the substance of the muscles, the nerves, and the brain, are unavoidably consumed.*

The true cause of death in these cases is the respiratory process, that is, the action of the atmosphere.

A deficiency of food, and a want of power to convert the food into a part of the organism, are both,

* For an account of what really takes place in this process, I refer to the considerations on the means by which the change of matter is effected in the body of the carnivora, which will be found further on.

and of the par vagum. The respiratory motions continue for a time, but the oxygen does not meet with those substances with which, in the normal state, it would have combined; because the paralyzed viscera will no longer furnish them. The singular idea, that the nerves produce animal heat, has obviously arisen from the notion, that the inspired oxygen combines with carbon, in the blood itself; in which case the temperature of the body, in the above experiments, certainly, ought not to have sunk. But, as we shall afterwards see, there cannot be a more erroneous conception than this.

As, by the division of the pneumogastric nerves, the motion of the stomach and the secretion of the gastric juice are arrested, and an immediate check is thus given to the process of digestion, so the paralysis of the organs of vital motion in the abdominal viscera affects the process of respiration. These processes are most intimately connected; and every disturbance of the nervous system or of the nerves of digestion reacts visibly on the process of respiration.

The observation has been made, that heat is produced by the contraction of the muscles, just as in a piece of caoutchouc, which, when rapidly drawn out, forcibly contracts again, with disengagement of heat. Some have gone so far as to ascribe a part of the animal heat to the mechanical motions of the body, as if these motions could exist without an expenditure of force consumed in producing them; how then, we may ask, is this force produced?

By the combustion of carbon, by the solution of a metal in an acid, by the combination of the two electricities, positive and negative, by the absorption of light, and even by the rubbing of two solid bodies together with a certain degree of rapidity, heat may be produced.

By a number of causes, in appearance entirely distinct, we can thus produce one and the same effect. In combustion and in the production of galvanic electricity we have a change of condition in material particles; when heat is produced by the absorption of light or by friction, we have the conversion of one kind of motion into another, which affects our senses differently. In all such cases we have a something given, which merely takes another form; in all we have a force and its effect. By means of the fire which heats the boiler of a steam-engine we can produce every kind of motion, and by a certain amount of motion we can produce fire.

When we rub a piece of sugar briskly on an iron grater, it undergoes, at the surfaces of contact, the same change as if exposed to heat; and two pieces of ice, when rubbed together, melt at the point of contact.

Let us remember, that the most distinguished authorities in physics consider the phenomena of heat as phenomena of motion, because the very conception of the *creation* of matter, even though imponderable, is absolutely irreconcilable with its production by mechanical causes, such as friction or motion.

But, admitting all the influence which electric or magnetic disturbances in the animal body can have on the functions of its organs, still the ultimate cause of all these forces is a change of condition in material particles, which may be expressed by the conversion, within a certain time, of the elements of the food into oxidized products. Such of these elements as do not undergo this process of slow combustion, are given off unburned or incombustible in the excrements.

Now, it is absolutely impossible that a given amount of carbon or hydrogen, whatever different forms they may assume in the progress of the combustion, can produce more heat than if directly burned in atmospheric air or in oxygen gas.

When we kindle a fire under a steam-engine, and employ the power obtained to produce heat by friction, it is impossible that the heat thus obtained can ever be greater than that which was required to heat the boiler; and if we use the galvanic current to produce heat, the amount of heat obtained is never, in any circumstances, greater than we might have by the combustion of the zinc which has been dissolved in the acid.

The contraction of muscles produces heat; but the force necessary for the contraction has manifested itself through the organs of motion, in which it has been excited by chemical changes. The ultimate cause of the heat produced is, therefore, to be found in these chemical changes.

By dissolving a metal in an acid, we produce an electrical current; this current, if passed through a wire, converts the wire into a magnet, by means of from 32° to 195563·3°; or to cause 67·9 lbs. of water at 32° to boil; or to heat 184·3 lbs. of water to 98·3° (the temperature of the human body); or to convert into vapor 11·4 lbs. of water at 98·3°.

If we now assume, that the quantity of water vaporized through the skin and lungs in 24 hours amounts to 48 oz. (3 lbs.), then there will remain, after deducting the necessary amount of heat, 144137·7 * degrees of heat, which are dissipated by radiation, by heating the expired air, and in the excrementitious matters.

In this calculation, no account has been taken of the heat evolved by the hydrogen of the food, during its conversion into water by oxidation within the body. But if we consider, that the specific heat of the bones, of fat, and of the organs generally, is far less than that of water, and that consequently they require, in order to be heated to 98·3°, much less heat than an equal weight of water, no doubt can be entertained, that when all the concomitant circumstances are included in the calculation, the heat evolved in the process of combustion, to which the food is subjected in the body, is amply sufficient to explain the constant temperature of the body, as well as the evaporation from the skin and lungs.

VI. All experiments hitherto made on the quantity of oxygen which an animal consumes in a given time, and also the conclusions deduced from them as to the

* In the above, the latent heat of vapor at 212° is taken, according to Despretz, at 955.8.

been equally unsatisfactory. Animals have been allowed to respire in close chambers surrounded with cold water; the increase of temperature in the water has been measured by the thermometer, and the quantity of oxygen consumed has been calculated from the analysis of the air before and after the experiment. In experiments thus conducted, it has been found that the animal lost about $\frac{1}{10}$ more heat than corresponded to the oxygen consumed; and had the windpipe of the animal been tied, the strange result would have been obtained of a rise in the temperature of the water without any consumption of oxygen. The animal was at the temperature of 98° or 99°, and the water, in the experiments of Despretz, was at 47·5°. Such experiments consequently prove, that when a great difference exists between the temperature of the animal body and that of the surrounding medium, and when no motion is allowed, more heat is given off than corresponds to the oxygen consumed. In equal times, with free and unimpeded motion, a much larger quantity of oxygen would be consumed without a perceptible increase in the amount of heat lost. The cause of these phenomena is obvious. They appear naturally both in man and animals at certain seasons of the year, and we say in such cases that we are freezing, or experience the sensation of cold. It is plain, that if we were to clothe a man in a metallic dress, and tie up his hands and feet, the loss of heat, for the same consumption of oxygen, would be far greater than if we were to wrap him up in fur and woollen cloth. Nay, in the latter case, we

The second principal ingredient of the blood is contained in the serum, and gives to this liquid all the properties of the white of eggs, with which it is identical. When heated, it coagulates into a white elastic mass, and the coagulating substance is called *albumen.*

Fibrine and albumen, the chief ingredients of blood, contain, in all, seven chemical elements, among which nitrogen, phosphorus, and sulphur are found. They contain also the earth of bones. The serum retains in solution sea salt and other salts of potash and soda, in which the acids are carbonic, phosphoric, and sulphuric acids. The globules of the blood contain fibrine and albumen, along with a red coloring matter, in which iron is a constant element. Besides these, the blood contains certain fatty bodies in small quantity, which differ from ordinary fats in several of their properties.

Chemical analysis has led to the remarkable result, that fibrine and albumen contain the same organic elements united in the same proportion, so that two analyses, the one of fibrine and the other of albumen, do not differ more than two analyses of fibrine or two of albumen respectively do, in the composition of 100 parts.

In these two ingredients of blood the particles are arranged in a different order, as is shown by the difference of their external properties; but in chemical composition, in the ultimate proportion of the organic elements, they are identical.

This conclusion has lately been beautifully confirmed by a distinguished physiologist (Dénis), who has succeeded in converting fibrine into albumen, that is, in giving it the solubility, and coagulability by heat, which characterize the white of egg.*

---

* This remarkable experiment was first performed by M. Prosper Dénis; but as it confirms, in an unexpected and very interesting manner, the conclusion drawn by Professor Liebig from the researches of Mulder, and from those made at Giessen; namely, the identity of the organic part of vegetable fibrine, albumen, and caseine with that of animal fibrine, albumen, and caseine; and as M. Dumas has made a claim to this discovery, as being previously well known to the French chemists, it appears advisable to mention a few circumstances connected with the history of these researches.

The opinions of Liebig on this subject were not only detailed in his lectures in the winter session of 1840-41, but communicated to Müller, Wagner, and Tiedemann, and also among others to M. Marignac of Geneva, a friend of M. Dumas, who shortly after returned from Giessen to Paris, viz., in February, 1841.

In the mean time, M. Dénis, having made his curious researches, found, that they were not received as they ought to have been by the Parisian chemists. On the contrary, he was laughed at for his *facts!* He then applied to Liebig, who, at once, caused his experiments to be repeated, and confirmed his conclusions. To those who know the care with which every new observation is protected in Paris, there can be no stronger proof that no other French chemist had any idea of the truth as it now appears, otherwise it would have been announced and the date taken.

In a work published by Dumas and Boussingault, on the composition of the air, in the spring of 1841, the ideas in regard to the cause of the uniform amount of oxygen in the atmosphere, are those previously published in Liebig's Organic Chemistry applied to Agriculture, published in 1840.

Further, M. Dumas, in a lecture published by him in the end of August, 1841, consequently long after the views of Liebig were known in Paris, put forth views, coinciding with those of Liebig in regard to the nutrition of animals, and the composition of the azotized vegetable nutritious compounds, without the slightest acknowledgment.

The researches which led to these views were not Parisian; for M. Dumas had never made researches on vegetable fibrine, albumen, and caseine; while the researches of Boussingault led to the conclusion, that these substances differed in composition from the constituents of blood. Now, during the two preceding years, Mulder had

Fibrine and albumen, besides having the same composition, agree also in this, that both dissolve in con-

---

published his admirable papers, while Liebig and his pupils at Giessen had confirmed and extended the conclusions of Mulder, and Liebig himself had made the important deductions on which the present work is founded, and had, as we have seen, publicly taught them in the winter of 1840 – 41.

It is impossible to speak too highly of the labors of Boussingault, and accordingly, Liebig, in the present volume, has availed himself of them, with the fullest acknowledgment. It is only to be regretted that that eminent chemist, in the work already mentioned, published along with Dumas, should not have done the same justice to his distinguished German contemporary.

Finally, on a careful review of the above facts, it cannot be doubted, that, as in the case of the Agricultural Chemistry, our author was the first to advance those views, founded as well on the experiments of others as on his own, which have for the first time given a consistent shape to Physiological Chemistry. These views being once published, nothing is easier than to attach a meaning to older observations and remarks, which even their authors had allowed to fall into oblivion from not perceiving their true bearing; and every great advance in science is sure to draw on its author similar charges of plagiarism. The voice of posterity, however, never fails to declare itself in favor of the true discoverer, and Liebig will not lose the honor to which he is so justly entitled.

The conduct of the French chemists in regard to the observations of Dénis, is a clear proof, that, previous to the time when Liebig's views reached Paris, they had not formed any distinct opinions on these important points. In fact, it is universally known, that during that period, M. Dumas, who now steps forward to claim a share in discoveries, the value of which he, along with all chemists, now fully appreciates, was occupied with researches, interesting indeed, but of far less value and importance, on his favorite theory of substitutions. Indeed, up to the publication of the paper on air, with M. Boussingault, in 1841, M. Dumas had not appeared at all in the interesting field now in question; whereas, previous to that period, the views of Liebig were matured.

We could easily prove, by the internal evidences of M. Dumas's writings, that his views are borrowed from Liebig; as, for example, his formula for fibrine and albumen, the origin of which was unknown to him. But we have done enough to show how groundless is the charge of plagiarism against Liebig.

centrated muriatic acid, yielding a solution of an intense purple color. This solution, whether made with fibrine or albumen, has the very same reactions with all substances yet tried.

Both albumen and fibrine, in the process of nutrition, are capable of being converted into muscular fibre, and muscular fibre is capable of being reconverted into blood. These facts have long been established by physiologists, and chemistry has merely proved, that these metamorphoses can be accomplished under the influence of a certain force, without the aid of a third substance, or of its elements, and without the addition of any foreign element, or the separation of any element previously present in these substances.

If we now compare the composition of all organized parts with that of fibrine and albumen, the following relations present themselves: —

All parts of the animal body which have a decided shape, which form parts of organs, contain nitrogen. No part of an organ which possesses motion and life is destitute of nitrogen; all of them contain likewise carbon and the elements of water; the latter, however, in no case in the proportion to form water.

The chief ingredients of the blood contain nearly 17 per cent. of nitrogen, and no part of an organ contains less than 17 per cent. of nitrogen. (7)*

The most convincing experiments and observations have proved, that the animal body is absolutely incapa-

* See Note XXVII.

ble of producing an elementary body, such as carbon or nitrogen, out of substances which do not contain it; and it obviously follows, that all kinds of food fit for the production either of blood, or of cellular tissue, membranes, skin, hair, muscular fibre, &c., must contain a certain amount of nitrogen, because that element is essential to the composition of the above-named organs; because the organs cannot create it from the other elements presented to them; and, finally, because no nitrogen is absorbed from the atmosphere in the vital process.

The substance of the brain and nerves contains a large quantity of albumen, and, in addition to this, two peculiar fatty acids, distinguished from other fats by containing phosphorus (phosphoric acid?). One of these contains nitrogen (Frémy).

Finally, water and common fat are those ingredients of the body which are destitute of nitrogen. Both are amorphous or unorganized, and only so far take part in the vital process as that their presence is required for the due performance of the vital functions. The inorganic constituents of the body are, iron, lime, magnesia, common salt, and the alkalies.

IX. The nutritive process in the carnivora is seen in its simplest form. This class of animals lives on the blood and flesh of the graminivora; but this blood and flesh is, in all its properties, identical with their own. Neither chemical nor physiological differences can be discovered.

constituents. Animals cannot be fed on matters destitute of these nitrogenized constituents.

These important products of vegetation are especially abundant in the seeds of the different kinds of grain, and of pease, beans, and lentils; in the roots and the juices of what are commonly called vegetables. They exist, however, in all plants, without exception, and in every part of plants in larger or smaller quantity.

These nitrogenized forms of nutriment in the vegetable kingdom may be reduced to three substances, which are easily distinguished by their external characters. Two of them are soluble in water, the third is insoluble.

When the newly-expressed juices of vegetables are allowed to stand, a separation takes place in a few minutes. A gelatinous precipitate, commonly of a green tinge, is deposited, and this, when acted on by liquids which remove the coloring matter, leaves a grayish white substance, well known to druggists as the deposit from vegetable juices. This is one of the nitrogenized compounds which serves for the nutrition of animals, and has been named *vegetable fibrine*. The juice of grapes is especially rich in this constituent, but it is most abundant in the seeds of wheat, and of the cerealia generally. It may be obtained from wheat flour by a mechanical operation, and in a state of tolerable purity; it is then called *gluten*, but the glutinous property be longs, not to vegetable fibrine, but to a foreign sub stance, present in small quantity, which is not found in the other cerealia.

The method by which it is obtained sufficiently proves that it is insoluble in water ; although we cannot doubt that it was originally dissolved in the vegetable juice, from which it afterwards separated, exactly as fibrine does from blood.

The second nitrogenized compound remains dissolved in the juice after the separation of the fibrine. It does not separate from the juice at the ordinary temperature, but is instantly coagulated when the liquid containing it is heated to the boiling point.

When the clarified juice of nutritious vegetables, such as cauliflower, asparagus, mangel-wurtzel, or turnips, is made to boil, a coagulum is formed, which it is absolutely impossible to distinguish from the substance which separates as a coagulum, when the serum of blood or the white of an egg, diluted with water, are heated to the boiling point. This is *vegetable albumen.* It is found in the greatest abundance in certain seeds, in nuts, almonds, and others, in which the starch of the gramineæ is replaced by oil.

The third nitrogenized constituent of the vegetable food of animals is *vegetable caseine.* It is chiefly found in the seeds of pease, beans, lentils, and similar leguminous seeds. Like vegetable albumen, it is soluble in water, but differs from it in this, that its solution is not coagulated by heat. When the solution is heated or evaporated, a skin forms on its surface, and the addition of an acid causes a coagulum, just as in animal milk.

These three nitrogenized compounds, vegetable fibrine, albumen, and caseine, are the true nitrogenized constituents of the food of graminivorous animals ; all other nitrogenized compounds, occurring in plants, are either rejected by animals, as in the case of the characteristic principles of poisonous and medicinal plants, or else they occur in the food in such very small proportion, that they cannot possibly contribute to the increase of mass in the animal body.

The chemical analysis of these three substances has led to the very interesting result that they contain the same organic elements, united in the same proportion by weight; and, what is still more remarkable, that they are identical in composition with the chief constituents of blood, animal fibrine, and albumen. They all three dissolve in concentrated muriatic acid with the same deep purple color, and even in their physical characters, animal fibrine and albumen are in no respect different from vegetable fibrine and albumen. It is especially to be noticed, that, by the phrase, identity of composition, we do not here imply mere similarity, but that even in regard to the presence and relative amount of sulphur, phosphorus, and phosphate of lime, no difference can be observed. (8)

How beautifully and admirably simple, with the aid of these discoveries, appears the process of nutrition in animals, the formation of their organs, in which vitality chiefly resides! Those vegetable principles, which in animals are used to form blood, contain the chief constituents of blood, fibrine, and albumen, ready formed, as far as regards their composition. All plants, besides, contain a certain quantity of iron, which reappears in the coloring matter of the blood. Vegetable fibrine and animal fibrine, vegetable albumen and animal albumen, hardly differ, even in form; if these principles be wanting in the food, the nutrition of the animal is arrested; and when they are present, the graminivorous animal obtains in its food the very same principles on the presence of which the nutrition of the carnivora entirely depends.

Vegetables produce in their organism the blood of all animals, for the carnivora, in consuming the blood and flesh of the graminivora, consume, strictly speaking, only the vegetable principles which have served for the nutrition of the latter. Vegetable fibrine and albumen take the same form in the stomach of the graminivorous animal as animal fibrine and albumen do in that of the carnivorous animal.

From what has been said it follows, that the development of the animal organism and its growth are dependent on the reception of certain principles identical with the chief constituents of blood.

In this sense we may say, that the animal organism gives to blood only its form; that it is incapable of creating blood out of other substances which do not already contain the chief constituents of that fluid. We cannot, indeed, maintain, that the animal organism has no power to form other compounds, for we know that it is capable of producing an extensive series of compounds, differing in composition from the chief constituents of blood; but these last, which form the starting point of the series, it cannot produce.

The animal organism is a higher kind of vegetable, the development of which begins with those substances, with the production of which the life of an ordinary vegetable ends. As soon as the latter has borne seed, it dies, or a period of its life comes to a termination.

In that endless series of compounds, which begins with carbonic acid, ammonia, and water, the sources of the nutrition of vegetables, and includes the most complex constituents of the animal brain, there is no blank, no interruption. The first substance capable of affording nutriment to animals is the last product of the creative energy of vegetables.

The substance of cellular tissue and of membranes, of the brain and nerves, these the vegetable cannot produce.

The seemingly miraculous in the productive agency of vegetables disappears in a great degree, when we reflect that the production of the constituents of blood cannot appear more surprising than the occurrence of the fat of beef and mutton in cocoa beans, of human fat in olive oil, of the principal ingredient of butter in palm oil, and of horse fat and train oil in certain oily seeds.

X. While the preceding considerations leave little or no doubt as to the way in which the increase of mass in an animal, that is, its growth, is carried on, there is yet to be resolved a most important question, namely, that of the function performed in the animal system by substances containing no nitrogen, such as sugar, starch, gum, pectine, &c.

The most extensive class of animals, the graminivora, cannot live without these substances; their food must contain a certain amount of one or more of them, and if these compounds are not supplied, death quickly ensues.

This important inquiry extends also to the constituents of the food of carnivorous animals in the earliest periods of life; for this food also contains substances, which are not necessary for their support in the adult state.

The nutrition of the young of carnivora is obviously accomplished by means similar to those by which the graminivora are nourished; their development is dependent on the supply of a fluid, which the body of the mother secretes in the shape of milk.

Milk contains only one nitrogenized constituent, known under the name of *caseine*; besides this, its chief ingredients are butter (fat), and sugar of milk.

The blood of the young animal, its muscular fibre, cellular tissue, nervous matter, and bones, must have derived their origin from the nitrogenized constituent of milk, the caseine; for butter and sugar of milk contain no nitrogen.

Now, the analysis of caseine has led to the result, which, after the details given in the last section, can hardly excite surprise, that this substance also is identical in composition with the chief constituents of blood, fibrine and albumen. Nay, more, a comparison of its properties with those of vegetable caseine has shown that these two substances are identical in all their properties; insomuch, that certain plants, such as peas, beans, and lentils, are capable of producing the same substance which is formed from the blood of the mother, and employed in yielding the blood of the young animal. (9)

The young animal, therefore, receives, in the form of caseine, which is distinguished from fibrine and albumen by its great solubility, and by not coagulating when heated, the chief constituent of the mother's blood. To convert caseine into blood no foreign substance is required, and in the conversion of the mother's blood into caseine, no elements of the constituents of the blood have been separated. When chemically examined, caseine is found to contain a much larger proportion of the earth of bones than blood does, and that in a very soluble form, capable of reaching every part of the body. Thus, even in the earliest period of its life, the development of the organs, in which vitality resides, is, in the carnivorous animal, dependent on the supply of a substance, identical in organic composition with the chief constituents of its blood.

What, then, is the use of the butter and the sugar of milk? How does it happen that these substances are indispensable to life?

Butter and sugar of milk contain no fixed bases, no soda or potash. Sugar of milk has a composition closely allied to that of the other kinds of sugar, of starch, and of gum; all of them contain carbon and the elements of water, the latter precisely in the proportion to form water.

There is added, therefore, by means of these compounds, to the nitrogenized constituents of food, a certain amount of carbon, or, as in the case of butter, of carbon and hydrogen; that is, an excess of elements, which cannot possibly be employed in the production of blood, because the nitrogenized substances contained in the food already contain exactly the amount of carbon which is required for the production of fibrine and albumen.

The following considerations will show that hardly a doubt can be entertained, that this excess of carbon alone, or of carbon and hydrogen, is expended in the production of animal heat, and serves to protect the organism from the action of the atmospheric oxygen.

XI. In order to obtain a clearer insight into the nature of the nutritive process in both the great classes of animals, let us first consider the changes which the food of the carnivora undergoes in their organism.

If we give to an adult serpent, or boa constrictor, a goat, a rabbit, or a bird, we find that the hair, hoofs, horns, feathers, or bones of these animals, are expelled from the body apparently unchanged. They have retained their natural form and aspect, but have become brittle, because of all their component parts they have lost only that one which was capable of solution, namely, the gelatine. Fæces, properly so called, do not occur in serpents any more than in carnivorous birds.

We find, moreover, that, when the serpent has regained its original weight, every other part of its prey, the flesh, the blood, the brain, and nerves, in short, every thing, has disappeared.

The only excrement, strictly speaking, is a substance expelled by the urinary passage. When dry, it is pure white, like chalk; it contains much nitrogen, and a small quantity of carbonate and phosphate of lime mixed with the mass.

This excrement is urate of ammonia, a chemical compound, in which the nitrogen bears to the carbon the same proportion as in bicarbonate of ammonia. For every equivalent of nitrogen it contains two equivalents of carbon.

But muscular fibre, blood, membranes, and skin, contain four times as much carbon for the same amount of nitrogen, or eight equivalents to one; and if we add to this the carbon of the fat and nervous substance, it is obvious that the serpent has consumed, for every equivalent of nitrogen, much more than eight equivalents of carbon.

If now we assume, that the urate of ammonia contains all the nitrogen of the animal consumed, then at least six equivalents of carbon, which were in combination with this nitrogen, must have been given out in a different form from the two equivalents which are found in the urate of ammonia.

Now we know, with perfect certainty, that this carbon has been given out through the skin and lungs, which could only take place in the form of an oxidized product.

The excrements of a buzzard which had been fed with beef, when taken out of the rectum, consisted, according to L. Gmelin and Tiedemann, of urate of ammonia. In like manner, the fæces in lions and tigers are scanty and dry, consisting chiefly of bone earth, with mere traces of compounds containing carbon; but their urine contains, not urate of ammonia, but urea, a compound in which carbon and nitrogen are to each other in the same ratio as in *neutral* carbonate of ammonia.

Assuming that their food (flesh, &c.) contains carbon and nitrogen in the ratio of eight equivalents to one, we find these elements in their urine in the ratio of one equivalent to one; a smaller proportion of carbon, therefore, than in serpents, in which respiration is so much less active.

The whole of the carbon and hydrogen which the food of these animals contained, beyond the amount which we find in their excrements, has disappeared, in the process of respiration, as carbonic acid and water.

Had the animal food been burned in a furnace, the change produced in it would only have differed in the form of combination assumed by the nitrogen from that which it underwent in the body of the animal. The nitrogen would have appeared, with part of the carbon and hydrogen, as carbonate of ammonia, while the rest of the carbon and hydrogen would have formed carbonic acid and water. The incombustible parts would have taken the form of ashes, and any part of the carbon unconsumed from a deficiency of oxygen, would have appeared as soot, or lampblack. Now the solid blood; out of the newly-formed blood those parts of organs which have undergone metamorphoses are reproduced. The carbon and nitrogen of the food thus become constituent parts of organs.

Exactly as much carbon and nitrogen is supplied to the organs by the blood, that is, ultimately, by the food, as they have lost by the transformations attending the exercise of their functions.

What, then, it may be asked, becomes of the new compounds produced by the transformations of the organs, of the muscles, of the membranes and cellular tissue, of the nerves, and brain?

These new compounds cannot, owing to their solubility, remain in the situation where they are formed, for a well-known force, namely, the circulation of the blood, opposes itself to this.

By the expansion of the heart, an organ in which two systems of tubes meet, which are ramified in a most minute network of vessels through all parts of the body, there is produced a vacuum, the immediate effect of which is, that all fluids which can penetrate into these vessels are urged with great force towards one side of the heart by the external pressure of the atmosphere. This motion is powerfully assisted by the contraction of the heart, alternating with its expansion, and caused by a force independent of the atmospheric pressure.

In a word, the heart is a forcing pump, which sends arterial blood into all parts of the body; and also a suction pump, by means of which all fluids of whatever strictly speaking, the carbon of the compounds formed in the metamorphoses of living tissues that serves for the production of animal heat.

The food of the carnivora is converted into blood, which is destined for the reproduction of organized tissues; and by means of the circulation a current of oxygen is conveyed to every part of the body. The globules of the blood, which in themselves can be shown to take no share in the nutritive process, serve to transport the oxygen, which they give up in their passage through the capillary vessels. Here the current of oxygen meets with the compounds produced by the transformation of the tissues, and combines with their carbon to form carbonic acid, with their hydrogen to form water. Every portion of these substances which escapes this process of oxidation is sent back into the circulation in the form of the bile, which by degrees completely disappears.

In the carnivora the bile contains the carbon of the metamorphosed tissues; this carbon disappears in the animal body, and the bile likewise disappears in the vital process. Its carbon and hydrogen are given out through the skin and lungs as carbonic acid and water; and hence it is obvious, that the elements of the bile serve for respiration and for the production of animal heat. Every part of the food of carnivorous animals is capable of forming blood; their excrements, excluding the urine, contain only inorganic substances, such as phosphate of lime; and the small quantity of organic matter which is found mixed with these is derived from excretions, the use of which is to promote their passage through the intestines, such as mucus. These excrements contain no bile and no soda; for water extracts from them no trace of any substance resembling bile, and yet bile is very soluble in water, and mixes with it in every proportion.

Physiologists can entertain no doubt as to the origin of the constituent parts of the urine and of the bile. When, from deprivation of food, the stomach contracts itself so as to resemble a portion of intestine, the gall-bladder, for want of the motion which the full stomach gives to it, cannot pour out the bile it contains; hence in animals starved to death we find the gall-bladder distended and full. The secretion of bile and of urine goes on during the winter sleep of hybernating animals; and we know that the urine of dogs, fed for three weeks exclusively on pure sugar, contains as much of the most highly nitrogenized constituent, urea, as in the normal condition. (Marchaud. Erdmann's Journal für praktische Chemie, XIV. p. 495.)

Differences in the quantity of urea secreted in these and similar experiments are explained by the condition of the animal in regard to the amount of the natural motions permitted. Every motion increases the amount of organized tissue which undergoes metamorphosis. Thus, after a walk, the secretion of urine in man is invariably increased.

The urine of the mammalia, of birds, and of amphibia, contains uric acid or urea; and the excrements of the mollusca, and of insects, as of cantharides and of the butterfly of the silkworm, contain urate of ammonia. This constant occurrence of one or two nitrogenized compounds in the excretions of animals, while so great a difference exists in their food, clearly proves that these compounds proceed from one and the same source.

As little doubt can be entertained in regard to the function of the bile in the vital process. When we consider, that the acetate of potash, given in enema, or simply as a bath for the feet, renders the urine strongly alkaline (Rehberger in Tiedemann's Zeitschrift für Physiologie, II. 149), and that the change which the acetic acid here undergoes cannot be conceived without the addition of oxygen, it is obvious, that the soluble constituents of the bile, prone to change in a high degree as we know them to be, and which, as already stated, cannot be employed in the production of blood, must, when returned through the intestines into the circulation, in like manner yield to the influence of the oxygen which they meet. The bile is a compound of soda, the elements of which, with the exception of the soda, disappear in the body of a carnivorous animal.

In the opinion of many of the most distinguished physiologists, the bile is intended solely to be excreted; and nothing is more certain, than that a substance containing so very small a proportion of nitrogen can have no share in the process of nutrition or reproduction of organized tissue. But quantitative physiology must at once and decidedly reject the opinion, that the bile serves no purpose in the economy, and is incapable of further change.

No part of any organized structure contains soda; only in the serum of the blood, in the fat of the brain, and in the bile, do we meet with that alkali. When the compounds of soda in the blood are converted into muscular fibre, membrane, or cellular tissue, the soda they contain must enter into new combinations. The blood which is transformed into organized tissue gives up its soda to the compounds formed by the metamorphoses of the previously existing tissues. In the bile we find one of these compounds of soda.

Were the bile intended merely for excretion, we should find it, more or less altered, and also the soda it contains, in the solid excrements. But, with the exception of common salt, and of sulphate of soda, which occur in all the animal fluids, only mere traces of soda are to be found in the fæces. The soda of the bile, therefore, at all events, must have returned from the intestinal canal into the organism, and the same must be true of the organic matters which were in combination with it.

According to the observations of physiologists, a man secretes daily from 17 to 24 oz. of bile; a large dog, 36 oz.; a horse, 37 lbs. (Burdach's Physiologie, V. p. 260.) But the fæces of a man do not on an average weigh more than 5½ oz.; and those of a horse 28½ lbs., of which 21 lbs. are water, and 7½ lbs. dry fæces. (Boussingault.) The latter yield to alcohol only $\frac{1}{20}$th part of their weight of soluble matter.

If we assume the bile to contain 90 per cent. of water, a horse secretes daily 592 oz. of bile, containing 59·2 oz. of solid matter; while 7½ lbs. or 120 oz. of dried excrement yield only 6 oz. of matter soluble in alcohol, which might possibly be bile. But this matter is not bile; when the alcohol is dissipated by evaporation, there remains a soft, unctuous mass, altogether insoluble in water, and which, when incinerated, leaves no alkaline ashes, no soda. (10)

During the digestive process, therefore, the soda of the bile, and, along with it, all the soluble parts of that fluid, are returned into the circulation. This soda reappears in the newly formed blood, and, finally, we find it in the urine in the form of phosphate, carbonate, and hippurate of soda. Berzelius found in 1,000 parts of fresh human fæces only nine parts of a substance similar to bile; 5 ounces, therefore, would contain only 21.6 grains of dried bile, equivalent to 216 grains of fresh bile. But a man secretes daily from 9,640 to 11,520 grains of fluid bile, that is, from 45 to 56 times as much as can be detected in the matters discharged by the intestinal canal.

Whatever opinion we may entertain of the accuracy of the physiological experiments, in regard to the quantity of bile secreted by the different classes of animals; thus much is certain, that even the maximum of the supposed secretion, in man and in the horse, does not contain as much carbon as is given out in respiration. With all the fat which is mixed with it, or enters into its composition, dried bile does not contain more than

69 per cent. of carbon. Consequently, if a horse secretes 37 lbs. of bile, this quantity will contain only 40.848 ounces of carbon. But the horse expires daily nearly twice as much in the form of carbonic acid. A precisely similar proportion holds good in man.

Along with the matter destined for the formation or reproduction of organs, the circulation conveys oxygen to all parts of the body. Now, into whatever combination the oxygen may enter in the blood, it must be held as certain, that such of the constituents of blood as are employed for reproduction, are not materially altered by it. In muscular fibre we find fibrine, with all the properties it had in venous blood; the albumen in the blood does not combine with oxygen. The oxygen may possibly serve to convert into the gaseous state some unknown constituent of the blood; but those well-known constituents which are employed in reproduction, cannot be destined to support the respiratory process; none of their properties can justify such an opinion.

Without attempting in this place to exhaust the whole question of the share taken by the bile in the vital operations, it follows, as has been observed, from the simple comparison of those parts of the food of the carnivora which are capable of assimilation, with the ultimate products into which it is converted, that all the carbon of the food, except that portion which is found in the urine, is given out as carbonic acid.

But this carbon was ultimately derived from the substance of the metamorphosed tissues; and this being admitted, the question of the necessity of substances containing much carbon and no nitrogen in the food of the young of the carnivora, and in that of the graminivora, is resolved in a strikingly simple manner.

XII. It cannot be disputed, that in an adult carnivorous animal, which neither gains nor loses weight, perceptibly, from day to day, its nourishment, the waste of organized tissue, and its consumption of oxygen, stand to each other in a well-defined and fixed relation.

The carbon of the carbonic acid given off, with that of the urine ; the nitrogen of the urine, and the hydrogen given off as ammonia and water ; these elements, taken together, must be exactly equal in weight to the carbon, nitrogen, and hydrogen of the metamorphosed tissues, and since these last are exactly replaced by the food, to the carbon, nitrogen, and hydrogen of the food. Were this not the case, the weight of the animal could not possibly remain unchanged.

But, in the young of the carnivora, the weight does not remain unchanged ; on the contrary, it increases from day to day by an appreciable quantity.

This fact presupposes, that the assimilative process in the young animal is more energetic, more intense, than the process of transformation in the existing tissues. If both processes were equally active, the weight of the body could not increase ; and were the waste by transformation greater, the weight of the body would decrease.

Now, the circulation in the young animal is not weaker, but, on the contrary, more rapid ; the respirations are more frequent; and, for equal bulks, the consumption of oxygen must be greater rather than smaller in the young than in the adult animal. But, since the metamorphosis of organized parts goes on more slowly, there would ensue a deficiency of those substances, the carbon and hydrogen of which are adapted for combination with oxygen; because, in the carnivora, it is the new compounds, produced by the metamorphosis of organized parts, which nature has destined to furnish the necessary resistance to the action of the oxygen, and to produce animal heat. What is wanting for these purposes, an infinite wisdom has supplied to the young animal in its natural food.

The carbon and hydrogen of butter, and the carbon of the sugar of milk, no part of either of which can yield blood, fibrine, or albumen, are destined for the support of the respiratory process, at an age when a greater resistance is opposed to the metamorphosis of existing organisms; or, in other words, to the production of compounds, which in the adult state are produced in quantity amply sufficient for the purpose of respiration.

The young animal receives the constituents of its blood in the caseine of the milk. A metamorphosis of existing organs goes on, for bile and urine are secreted; the matter of the metamorphosed parts is given off in the form of urine, of carbonic acid, and of water; but the butter and sugar of milk also disappear; they cannot be detected in the fæces.

The butter and sugar of milk are given out in the sugar by very different means. This change occurs in the process of germination, as in malting, and it is easily accomplished by the action of acids. The metamorphosis of starch into sugar depends simply, as is proved by analysis, on the addition of the elements of water.(12) All the carbon of the starch is found in the sugar ; none of its elements have been separated, and, except the elements of water, no foreign element has been added to it in this transformation.

In many, especially in pulpy fruits, which when unripe are sour and rough to the taste, but when ripe are sweet, as, for example, in apples and pears, the sugar is produced from the starch which the unripe fruit contains.

If we rub unripe apples or pears on a grater to a pulp, and wash this with cold water on a fine sieve, the turbid liquid, which passes through, deposits a very fine flour of starch, of which not even a trace can be detected in the ripe fruit. Many varieties become sweet while yet on the tree ; these are the summer or early apples and pears. Others, again, become sweet only after having been kept for a certain period after gathering. The after-ripening, as this change is called, is a purely chemical process, entirely independent of the vitality of the plant. When vegetation ceases, the fruit is capable of reproducing the species, that is, the kernel, stone, or true seed is fully ripe, but the fleshy covering from this period is subjected to the action of the atmosphere. Like all substances in a state of eremacausis, or decay, it absorbs oxygen, and gives off a certain quantity of carbonic acid gas.

In the same way as the starch in putrefying paste, in which it is in contact with decaying gluten, is converted into sugar, the starch in the above-named fruits, in a state of decay, or eremacausis, is transformed into grape sugar. The more starch the unripe fruit contains, the sweeter does it become when ripe.

A close connexion thus exists between sugar and starch. By means of a variety of chemical actions, which exert no other influence on the elements of starch than that of changing the direction of their mutual attraction, we can convert starch into sugar, but it is always grape sugar.

Sugar of milk in many respects resembles starch; (13) it is, by itself, incapable of the vinous fermentation, but it acquires the property of resolving itself into alcohol and carbonic acid when it is exposed to heat in contact with a substance in the state of fermentation (such as putrefying cheese in milk). In this case, it is first converted into grape sugar; and it undergoes the same transformation, when it is kept in contact with acids, — with sulphuric acid, for example, — at the ordinary temperature.

Gum has the same composition in 100 parts as cane-sugar. (14) It is distinguished from the different varieties of sugar by its not possessing the property of being resolved into alcohol and carbonic acid by the process of putrefaction. When placed in contact with fermenting substances, it undergoes no appreciable change, whence quantity of phosphoric acid which on these suppositions would exist in the urine is not so small as not to be easily detected by analysis in the daily secretion of urine (3 lbs. according to Boussingault); for it would amount to 0·8 per cent. But, as above stated, most observers have been unable to detect phosphoric acid in the urine of the horse.

Hence it is obvious, that the phosphoric acid, which, in consequence of the metamorphosis of tissues is produced in the form of soluble alkaline phosphates, must reënter the circulation in this class of animals. It is there employed in forming brain and nervous matter, to which it is essential, and also, no doubt, in contributing to the supply of the earthy part of the bones. It is probable, however, that the greater part of the earth of bones is obtained by the direct assimilation of phosphate of lime, while the soluble phosphates are better adapted for the production of nervous matter.

In the graminivora, therefore, whose food contains so small a proportion of phosphorus or of phosphates, the organism collects all the soluble phosphates produced by the metamorphosis of tissues and employs them for the development of the bones and of the phosphorized constituents of the brain; the organs of excretion do not separate these salts from the blood. The phosphoric acid which, by the change of matter, is separated in the uncombined state, is not expelled from the body as phosphate of soda; but we find it in the solid excrements in the form of insoluble earthy phosphates."

entertain a doubt that such food, in its various forms of starch, sugar, &c., is closely connected with the production of fat.

In the natural course of scientific research, we draw conclusions from the food in regard to the tissues or substances formed from it; from the nitrogenized constituents of plants we draw certain inferences as to the nitrogenized constituents of the blood; and it is quite in accordance with this, the natural method, that we should seek to establish the relations of those parts of our food which are devoid of nitrogen and those parts of the body which contain none of that element. It is impossible to overlook the very intimate connexion between them.

If we compare the composition of sugar of milk, of starch, and of the other varieties of sugar, with that of mutton and beef suet, and of human fat, we find that in all of them the proportion of carbon to hydrogen is the same, and that they only differ in that of oxygen.

According to the analyses of Chevreul, mutton fat, human fat, and hog's lard contain 79 per cent. of carbon to 11·1, 11·4, and 11·7 per cent. of hydrogen respectively. (16)

Starch contains	44·91 carbon	to 6·11	hydrogen.
Gum and sugar	42·58 ——	to 6·37	ditto. (17)

It is obvious that these numbers, representing the relative proportions of carbon and hydrogen in starch, gum, and sugar, are in the same ratio as the carbon and hydrogen in the different kinds of fat; for

$$44{\cdot}91 : 6{\cdot}11 = 79 : 10{\cdot}75$$
$$42{\cdot}58 : 6{\cdot}37 = 79 : 11{\cdot}82$$

there must be separated 90, 100, and 110 equivalents of oxygen from these compounds respectively.

There is, therefore, but one way in which the formation of fat in the animal body is possible, and this is absolutely the same in which its formation in plants takes place; it is a separation of oxygen from the elements of the food.

The carbon which we find deposited in the seeds and fruits of vegetables, in the form of oil and fat, was previously a constituent of the atmosphere, and was absorbed by the plant as carbonic acid. Its conversion into fat was accomplished under the influence of light, by the vital force of the vegetable; and the greater part of the oxygen of this carbonic acid was returned to the atmosphere as oxygen gas.*

In contradistinction to this phenomenon of vitality in plants, we know that the animal system absorbs oxygen from the atmosphere, and that this oxygen is again given out in combination with carbon or hydrogen; we know, that in the formation of carbonic acid and water, the heat necessary to sustain the constant temperature of the body is produced, and that a process of oxidation is the only source of animal heat.

Whether fat be formed by the decomposition of fibrine and albumen, the chief constituents of blood, or by that of starch, sugar, or gum, this decomposition must be accompanied by the separation of oxygen from the elements of these compounds. But this oxygen is

---

* See Appendix, Note 19, on the formation of wax and honey by the bee.

not given out in the free state, because it meets in the organism with substances possessing the property of entering into combination with it. In fact, it is given out in the same forms as that which is absorbed from the atmosphere by the skin and lungs.

It is easy to see, from the above considerations, that a very remarkable connexion exists between the formation of fat and the respiratory process.

XVII. The abnormal condition, which causes the deposit of fat in the animal body, depends, as was formerly stated, on a disproportion between the quantity of carbon in the food and that of oxygen absorbed by the skin and lungs. In the normal condition, the quantity of carbon given out is exactly equal to that which is taken in the food, and the body acquires no increase of weight from the accumulation of substances containing much carbon and no nitrogen.

If we increase the supply of highly carbonized food, then the normal state can only be preserved on the condition that, by exercise and labor, the waste of the body is increased, and the supply of oxygen augmented in the same proportion.

The production of fat is always a consequence of a deficient supply of oxygen, for oxygen is absolutely indispensable for the dissipation of the excess of carbon in the food. This excess of carbon, deposited in the form of fat, is never seen in the Bedouin or in the Arab of the desert, who exhibits with pride to the traveller his lean, muscular, sinewy limbs, altogether free from

According to the ordinary view, 12 equivalents of carbonic acid separate from 3 of sugar, yielding 6 of alcohol, — that is, exactly the same amount of these products as if two thirds of the sugar had yielded oxygen to the remaining third, so as completely to oxidize its elements.

$$C_{36}H_{36}O_{36} = C_{24}H_{36}O_{12} + 12CO_2.^*$$

By a comparison of these two methods of representing the same change, it will easily be seen, that the division or splitting of a compound like sugar into carbonic acid, on the one hand, and a compound containing little oxygen, on the other, is, in its results, perfectly equivalent to a separation of oxygen from a certain portion of the compound and the oxidation or combustion of another portion of it at the expense of this oxygen.

It is well known that the temperature of a fermenting liquid rises; and if we assume that a hogshead of wort, holding 1,200 litres = 2,400 lbs., French weight, contains 16 per cent. of sugar, in all 384 lbs., then, during the fermentation of this sugar, an amount of heat must be generated equal to that which would be produced by the combustion of 51 lbs. of carbon.

This is equal to a quantity of heat, by which every pound of the liquid might be heated by 298·9°; that is, supposing the decomposition of the sugar to occur in a period of time too short to be measured. This is well known not to be the case; the fermentation lasts five or six days, and each pound of liquid receives the 297·9

* For an explanation of the formulæ and equations employed, see the Introduction to the Appendix.

degrees of heat during a period of 120 hours. In each hour there is, therefore, set free an amount of heat capable of raising the temperature of each pound of liquid 2·4 degree; a rise of temperature which is very powerfully counteracted by external cooling and by the vaporization of alcohol and water.

The formation of fat, like other analogous phenomena, in which oxygen is separated in the form of carbonic acid, is consequently accompanied by a disengagement of heat. This change supplies to the animal body a certain proportion of the oxygen indispensable to the vital processes; and this especially in those cases in which the oxygen absorbed by the skin and lungs is not sufficient to convert into carbonic acid the whole of the carbon adapted for this combination.

This excess of carbon, as it cannot be employed to form a part of any organ, is deposited in the cellular tissue in the form of tallow or oil.

At every period of animal life, when there occurs a disproportion between the carbon of the food and the inspired oxygen, the latter being deficient, fat must be formed. Oxygen separates from existing compounds, and this oxygen is given out as carbonic acid or water. The heat generated in the formation of these two products contributes to keep up the temperature of the body. Every pound of carbon which obtains the oxygen necessary to convert it into carbonic acid from substances which thereby pass into fat, must disengage as much heat as would raise the temperature of 200 lbs. of water by 70°, — that is, from 32° to 102°.

In other diseases, as for example, in inflammation of the liver, we find the blood loaded with fat and oil; and in the composition of the bile there is nothing at all inconsistent with the supposition, that some of its constituents may be transformed into fat.

XVIII. According to what has been laid down in the preceding pages, the substances of which the food of man is composed may be divided into two classes; into *nitrogenized* and *non-nitrogenized*. The former are capable of conversion into blood; the latter incapable of this transformation.

Out of those substances which are adapted to the formation of blood are formed all the organized tissues. The other class of substances, in the normal state of health, serve to support the process of respiration. The former may be called the *plastic elements of nutrition*; the latter, *elements of respiration*.

Among the former we reckon —

Vegetable fibrine.
Vegetable albumen.
Vegetable caseine.
Animal flesh.
Animal blood.

Among the elements of respiration in our food, are —

Fat.	Pectine.
Starch.	Bassorine.
Gum.	Wine.
Cane sugar.	Beer.
Grape sugar.	Spirits.
Sugar of milk.	

XIX. The most recent and exact researches have established as a universal fact, to which nothing yet known is opposed, that the nitrogenized constituents of vegetable food have a composition identical with that of the constituents of the blood.

No nitrogenized compound, the composition of which differs from that of fibrine, albumen, and caseine, is capable of supporting the vital process in animals.

The animal organism unquestionably possesses the power of forming, from the constituents of its blood, the substance of its membranes and cellular tissue, of the nerves and brain, of the organic part of cartilages and bones. But the blood must be supplied to it ready formed in every thing but its form, — that is, in its chemical composition. If this be not done, a period is rapidly put to the formation of blood, and consequently to life.

This consideration enables us easily to explain how it happens, that the tissues yielding gelatine or chondrine, as, for example, the gelatine of skin or of bones, are not adapted for the support of the vital process; for their composition is different from that of fibrine or albumen. It is obvious, that this means nothing more than that those parts of the animal organism which form the blood, do not possess the power of effecting a transformation in the arrangement of the elements of gelatine, or of those tissues which contain it. The gelatinous tissues, the gelatine of the bones, the membranes, the cells, and the skin, suffer, in the animal body, under the influence of oxygen and moisture, a progressive alteraare affected by a change of the health, then, even should the power of forming blood remain the same, the organic force by which the constituents of the blood are transformed into cellular tissue and membranes must necessarily be enfeebled by sickness. In the sick man, the intensity of the vital force, its power to produce metamorphoses, must be diminished as well in the stomach as in all other parts of the body. In this condition, the uniform experience of practical physicians shows, that gelatinous matters in a dissolved state, exercise a most decided influence on the state of the health. Given in a form adapted for assimilation, they serve to husband the vital force, just as may be done, in the case of the stomach, by due preparation of the food in general. Brittleness in the bones of graminivorous animals is clearly owing to a weakness in those parts of the organism, whose function it is to convert the constituents of the blood into cellular tissue and membrane ; and, if we can trust to the reports of physicians who have resided in the East, the Turkish women, in their diet of rice, and in the frequent use of enemata of strong soup, have united the conditions necessary for the formation both of cellular tissue and of fat.

PART II.

THE

METAMORPHOSIS OF TISSUES.

9

compounds assume the same arrangement when acted on by potash at a high temperature.

All the organic nitrogenized constituents of the body, how different soever they may be in composition, are derived from proteine. They are formed from it, by the addition or subtraction of the elements of water or of oxygen, and by resolution into two or more compounds.

5. This proposition must be received as an undeniable truth, when we reflect on the development of the young animal in the egg of a fowl. The egg can be shown to contain no nitrogenized compound except albumen. The albumen of the yolk is identical with that of the white; (23) the yolk contains, besides, only a yellow fat, in which cholesterine and iron may be detected. Yet we see, in the process of incubation, during which no food and no foreign matter, except the oxygen of the air, is introduced, or can take part in the development of the animal, that out of the albumen, feathers, claws, globules of the blood, fibrine, membrane and cellular tissue, arteries, and veins, are produced. The fat of the yolk may have contributed, to a certain extent, to the formation of the nerves and brain; but the carbon of this fat cannot have been employed to produce the organized tissues in which vitality resides, because the albumen of the white and of the yolk already contains, for the quantity of nitrogen present, exactly the proportion of carbon required for the formation of these tissues.

6. The true starting-point for all the tissues is, con-

sequently, albumen ; all nitrogenized articles of food, whether derived from the animal or from the vegetable kingdom, are converted into albumen before they can take part in the process of nutrition.

All the food consumed by an animal becomes in the stomach soluble, and capable of entering into the circulation. In the process by which this solution is effected, only one fluid, besides the oxygen of the air, takes a part ; it is that which is secreted by the lining membrane of the stomach.

The most decisive experiments of physiologists have shown, that the process of chymification is independent of the vital force ; that it takes place in virtue of a purely chemical action, exactly similar to those processes of decomposition or transformation which are known as putrefaction, fermentation, or decay (eremacausis).

7. When expressed in the simplest form, fermentation, or putrefaction, may be described as a process of transformation, — that is, a new arrangement of the elementary particles, or atoms, of a compound, yielding two or more new groups or compounds, and caused by contact with other substances, the elementary particles of which are themselves in a state of transformation or decomposition. It is a communication, or an imparting of a state of motion, which the atoms of a body in a state of motion are capable of producing in other bodies, whose elementary particles are held together only by a feeble attraction.

8. Thus the clear gastric juice contains a substance in a state of transformation, by the contact of which

and thus reach the lungs, where they are exhaled; but the presence of membranes offers not the slightest obstacle to their passing directly into the cavity of the chest. It is, in fact, difficult to suppose that the absorbents and lymphatics have any peculiar tendency to absorb air, nitrogen, or hydrogen, and convey these gases into the circulation, since the intestines, the stomach, and all spaces in the body not filled with solid or liquid matters, contain gases, which only quit their position when their volume exceeds a certain point, and which, consequently, are not absorbed. More especially in reference to nitrogen, we must suppose that it is removed from the stomach by some more direct means, and not by the blood, which fluid must already, in passing through the lungs, have become saturated with that gas, that is, must have absorbed a quantity of it, proportioned to its solvent power, like any other liquid. By the respiratory motions all the gases which fill the otherwise empty spaces of the body are urged towards the chest; for by the motion of the diaphragm and the expansion of the chest a partial vacuum is produced, in consequence of which air is forced into the chest from all sides by the atmospheric pressure. The equilibrium is, no doubt, restored, for the most part, through the windpipe, but all the gases in the body must, nevertheless, receive an impulse towards the chest. In birds and tortoises these arrangements are reversed. If we assume that a man introduces into the stomach in each minute only $\frac{1}{8}$th of a cubic inch of air with the saliva, this makes in eighteen hours 135 cubic inches; and if accomplished in the stomach, acts on the food. The insoluble matters become soluble, — they are digested.

It is certainly remarkable, that hard-boiled white of egg or fibrine, when rendered soluble by certain liquids, by organic acids, or weak alkaline solutions, retain all their properties except the solid form (cohesion) without the slightest change. Their elementary molecules, without doubt, assume a new arrangement; they do not, however, separate into two or more groups, but remain united together.

The very same thing occurs in the digestive process; in the normal state, the food only undergoes a change in its state of cohesion, becoming fluid without any other change of properties.

The greatest obstacle to forming a clear conception of the nature of the digestive process, which is here reckoned among those chemical metamorphoses which have been called fermentation and putrefaction, consists in our involuntary recollection of the phenomena which accompany the fermentation of sugar and of animal substances (putrefaction), which phenomena we naturally associate with any similar change; but there are numberless cases in which a complete chemical metamorphosis of the elements of a compound occurs without the smallest disengagement of gas, and it is chiefly these which must be borne in mind, if we would acquire a clear and accurate idea of the chemical notion or conception of the digestive process.

All substances which can arrest the phenomena of fermentation and putrefaction in liquids, also arrest diis formed, also, from albumen, which contains only half as much phosphorus as fibrine.

Every attempt to give the true absolute amount of the atoms in fibrine and albumen in a rational formula, in which the sulphur and phosphorus are taken, not in fractions, but in entire equivalents, must be fruitless, because we are absolutely unable to determine with perfect accuracy the exceedingly minute quantities of sulphur and phosphorus in such compounds; and because a variation in the sulphur or phosphorus, smaller in extent than the usual limit of errors of observation, will affect the number of atoms of carbon, hydrogen, or oxygen to the extent of 10 atoms or more.

We must be careful not to deceive ourselves in our expectations of what chemical analysis can do. We know, with certainty, that the numbers representing the relative proportions of the organic elements are the same in albumen and fibrine, and hence we conclude that they have the same composition. This conclusion is not affected by the fact, that we do not know the absolute number of the atoms of their elements, which have united to form the compound atom.

15. A formula for proteine is nothing more than the nearest and most exact expression in equivalents, of the result of the best analyses; it is a fact established so far, free from doubt, and this alone is, for the present, valuable to us.

If we reflect, that from the albumen and fibrine of the body all the other tissues are derived, it is perfectly clear, that this can only occur in two ways. Either certain elements have been added to, or removed from, their constituent parts.

If we now, for example, look for an analytical expression of the composition of cellular tissue, of the tissues yielding gelatine, of tendons, of hair, of horn, &c., in which the number of atoms of carbon is made invariably the same as in albumen and fibrine, we can then see, at the first glance, in what way the proportion of the other elements has been altered ; but this includes all that physiology requires in order to obtain an insight into the true nature of the formative and nutritive processes in the animal body.

From the researches of Mulder and Scherer we obtain the following empirical formulæ : —

Composition of organic tissues.

Albumen	$C_{48}N_6H_{36}O_{14} + P + S$*
Fibrine	$C_{48}N_6H_{36}O_{14} + P + 2S$
Caseine	$C_{48}N_6H_{36}O_{14} + S$
Gelatinous tissues, tendons . . .	$C_{48}N_{7.5}H_{41}O_{18}$
Chondrine	$C_{48}N_6H_{40}O_{20}$
Hair, horn	$C_{48}N_7H_{39}O_{17}$
Arterial membrane	$C_{48}N_6H_{38}O_{16}$

The composition of these formulæ shows, that when proteine passes into chondrine (the substance of the cartilages of the ribs), the elements of water, with oxygen, have been added to it ; while in the formation of the serous membranes, nitrogen also has entered into combination.

If we represent the formula of proteine, $C_{48}N_6H_{36}O_{14}$

* The quantities of sulphur and phosphorus here expressed by S and P are not equivalents, but only give the relative proportions of these two elements to each other, as found by analysis.

by Pr, then nitrogen, hydrogen, and oxygen have been added to it in the form of known compounds, and in the following proportions, in forming the gelatinous tissues, hair, horn, arterial membrane, &c.

	Proteine.	Ammonia.	Water.	Oxygen.
Fibrine, Albumen	Pr			
Arterial membrane . . .	Pr		+ 2HO	
Chondrine	Pr		+ 4HO	+ 2O.
Hair, horn	Pr	+ NH_3	. . .	+ 3O.
Gelatinous tissues . . .	2Pr	+ $3NH_3$	+ HO	+ 7O.*

16. From this general statement it appears, that all the tissues of the body contain, for the same amount of carbon, more oxygen than the constituents of blood. During their formation, oxygen, either from the atmosphere or from the elements of water, has been added to the elements of proteine. In hair and gelatinous membrane we observe, further, an excess of nitrogen and hydrogen, and that in the proportions to form ammonia.

Chemists are not yet agreed on the question, in what manner the elements of sulphate of potash are arranged; it would therefore be going too far, were they to pronounce arterial membrane a hydrate of proteine, chondrine a hydrated oxide of proteine, and hair and membranes compounds of ammonia with oxides of proteine.

The above formulæ express with precision the differences of composition in the chief constituents of the animal body; they show, that for the same amount of carbon the proportion of the other elements varies, and how much more oxygen or nitrogen one compound contains than another.

---

* See Note XXVII.

17. By means of these formulæ we can trace the production of the different compounds from the constituents of blood; but the explanation of their production may take two forms, and we have to decide which of these comes nearest to the truth.

For the same amount of carbon, membranes and the tissues which yield gelatine contain more nitrogen, oxygen, and hydrogen, than proteine. It is conceivable, that they are formed from albumen by the addition of oxygen, of the elements of water, and of those of ammonia, accompanied by the separation of sulphur and phosphorus; at all events, their composition is entirely different from that of the chief constituents of blood.

The action of caustic alkalies on the tissues yielding gelatine shows, distinctly, that they no longer contain proteine; that substance cannot in any way be obtained from them; and all the products formed by the action of alkalies on them differ entirely from those produced by the compounds of proteine in the same circumstances. Whether proteine exist, ready formed, in fibrine, albumen, and caseine, or not, it is certain that their elements, under the influence of the alkali, arrange themselves so as to form proteine; but this property is wanting in the elements of the tissues which yield gelatine.

The other, and perhaps the more probable explanation of the production of these tissues from proteine, is that which makes it dependent on a separation of carbon.

If we assume the nitrogen of proteine to remain entire in the gelatinous tissue, then the composition of the latter, calculated on 6 equivalents of nitrogen, might be represented by the formula, $C_{38}N_6H_{32}O_{14}$. This formula approaches most closely to the analysis of Scherer, although it is not an exact expression of his results. A formula corresponding more perfectly to the analyses, is $C_{32}N_5H_{27}O_{12}$; or, calculated according to Mulder's analysis, $C_{54}N_9H_{42}O_{20}$. *

According to the first formula, carbon and hydrogen have been separated; according to the two last, a certain proportion of all the elements has been removed.

18. We must admit, as the most important result of the study of the composition of gelatinous tissue, and as a point undeniably established, that, although formed from compounds of proteine, it no longer belongs to the series of the compounds of proteine. Its chemical characters and composition justify this conclusion.

No fact is as yet opposed to the law, deduced from observation, that nature has exclusively destined compounds of proteine for the production of blood.

No substance analogous to the tissues yielding gelatine is found in vegetables. The gelatinous substance is not a compound of proteine; it contains no sulphur, no phosphorus, and it contains more nitrogen or less carbon than proteine. The compounds of proteine, under the influence of the vital energy of the organs which form the blood, assume a new form, but are not altered in composition; while these organs, as far as our expe-

* The formula $C_{52}N_8H_{40}O_{20}$, adopted by Mulder, gives, when reduced to 100 parts, too little nitrogen to be considered an exact expression of his analyses.

rience reaches, do not possess the power of producing compounds of proteine, by virtue of any influence, out of substances which contain no proteine. Animals which were fed exclusively with gelatine, the most highly nitrogenized element of the food of carnivora, died with the symptoms of starvation ; in short, the gelatinous tissues are incapable of conversion into blood.

But there is no doubt that these tissues are formed from the constituents of the blood ; and we can hardly avoid entertaining the supposition, that the fibrine of venous blood, in becoming arterial fibrine, passes through the first stage of conversion into gelatinous tissue. We cannot, with much probability, ascribe to membranes and tendons the power of forming themselves out of matters brought by the blood ; for how could any matter become a portion of cellular tissue, for example, by virtue of a force which has as yet no organ ? An already existing cell may possess the power of reproducing or of multiplying itself, but in both cases the presence of a substance identical in composition with cellular tissue is essential. Such matters are formed in the organism, and nothing can be better fitted for their production than the substance of the cells and membranes which exist in animal food, and become soluble in the stomach during digestion, or which are taken by man in a soluble form.

19. In the following pages I offer to the reader an attempt to develope analytically the principal metamorphoses which occur in the animal body ; and, to preclude all misapprehension, I do this with a distinct pro-

test against all conclusions and deductions which may now or at any subsequent period be derived from it in opposition to the views developed in the preceding part of this work, with which it has no manner of connexion. The results here to be described have surprised me no less than they will others, and have excited in my mind the same doubts as others will conceive; but they are not the creations of fancy, and I give them because I entertain the deep conviction, that the method which has led to them is the only one by which we can hope to acquire insight into the nature of the organic processes.

The numberless qualitative investigations of animal matters which are made are equally worthless for physiology and for chemistry, so long as they are not instituted with a well-defined object, or to answer a question clearly put.

If we take the letters of a sentence which we wish to decipher, and place them in a line, we advance not a step towards the discovery of their meaning. To resolve an enigma, we must have a perfectly clear conception of the problem. There are many ways to the highest pinnacle of a mountain; but those only can hope to reach it who keep the summit constantly in view. All our labor and all our efforts, if we strive to attain it through a morass, only serve to cover us more completely with mud; our progress is impeded by difficulties of our own creation, and at last even the greatest strength must give way when so absurdly wasted.

20. If it be true, that all parts of the body are formed and developed from the blood or the constituents of

the blood, that the existing organs at every moment of life are transformed into new compounds under the influence of the oxygen introduced in the blood, then the animal secretions must of necessity contain the products of the metamorphosis of the tissues.

21. If it be further true, that the urine contains those products of metamorphosis which contain the most nitrogen, and the bile those which are richest in carbon, from all the tissues which in the vital process have been transformed into unorganized compounds, it is clear that the elements of the bile and of the urine, added together, must be equal, in the relative proportion of these elements to the composition of the blood.

22. The organs are formed from the blood, and contain the elements of the blood; they become transformed into new compounds, with the addition only of oxygen and of water. Hence, the relative proportion of carbon and nitrogen must be the same as in the blood.

If then we subtract from the composition of blood the elements of the urine, then the remainder, deducting the oxygen and water which have been added, must give the composition of the bile.

Or if from the elements of the blood, we subtract the elements of the bile, the remainder must give the composition of urate of ammonia, or of urea and carbonic acid.

It will surely appear remarkable, that this manner of viewing the subject has led to the true formula of bile, or, to speak more accurately, to the most correct emmust include the analytical expression of these modes of decomposition; in other words, that it must enable us to show that the composition of the products derived from it is related, in a clear and simple manner, to the composition of the acid itself. This is the only satisfactory test of a formula; and the analytical expression thus obtained, loses nothing of its truth or value, if it should appear, as the researches of BERZELIUS seem to show, that choleic and choloidic acids are mixtures of different compounds; for the relative proportions of the elements cannot in any way be altered by this circumstance.

25. In order to develope the metamorphoses which choleic acid suffers under the influence of acids and alkalies, the following formula alone can be adopted as the empirical expression of the results of its analysis.

Formula of choleic acid: $C_{76}N_2H_{66}O_{22}$. (29)

I repeat, that this formula may express the composition of one, or of two or more compounds; no matter of how many compounds the so-called choleic acid may be made up, the above formula represents the relative proportions of all their elements taken together.

If now we subtract from the elements of choleic acid, the products formed by the action of muriatic acid, namely, ammonia and taurine, we obtain the empirical formula of choloidic acid. Thus; from the

Formula of choleic acid		$C_{76}N_2H_{66}O_{22}$
subtract—		
1 atom taurine . . .	$C_4NH_7O_{10}$	$\left.\right\} = C_4N_2H_{10}O_{10}$
1 eq. ammonia . . .	NH_3	
There remains the formula of choloidic acid		$= C_{72}H_{56}O_{12}$ (30)

quantity of water consumed by different animals in a given time.

When uric acid is subjected to the action of oxygen, it is first resolved, as is well known, into alloxan and urea. (32) A new supply of oxygen acting on the alloxan causes it to resolve itself either into oxalic acid and urea, into oxaluric and parabanic acids, (33) or into carbonic acid and urea.

31. In the so-called mulberry calculi we find oxalate of lime, in other calculi urate of ammonia, and always in persons, in whom, from want of exercise and labor, or from other causes, the supply of oxygen has been diminished. Calculi containing uric acid or oxalic acid are never found in phthisical patients; and it is a common occurrence in France, among patients suffering from calculous complaints, that when they go to the country, where they take more exercise, the compounds of uric acid, which were deposited in the bladder during their residence in town, are succeeded by oxalates (mulberry calculus), in consequence of the increased supply of oxygen With a still greater supply of oxygen they would have yielded, in healthy subjects, only the last product of the oxidation of uric acid, namely, carbonic acid and urea.

An erroneous interpretation of the undeniable fact, that all substances incapable of further use in the organism, are separated by the kidneys and expelled from the body in the urine, altered or unaltered, has led practical medical men to the idea, that the food, and especially nitrogenized food, may have a direct influence on the formation of urinary calculi. There are no reasons which support this opinion, while those opposed to it are innumerable. It is possible that there may be taken, in the food, a number of matters changed by the culinary art, which, as being no longer adapted to the formation of blood, are expelled in the urine, more or less altered by the respiratory process. But roasting and boiling alter in no way the composition of animal food. (34)

Boiled and roasted flesh is converted at once into blood ; while the uric acid and urea are derived from the metamorphosed tissues. The quantity of these products increases with the rapidity of transformation in a given time, but bears no proportion to the amount of food taken in the same period. In a starving man, who is any way compelled to undergo severe and continued exertion, more urea is secreted than in the most highly fed individual, if in a state of rest. In fevers and during rapid emaciation the urine contains more urea than in the state of health. (Prout.)

32. In the same way, therefore, as the hippuric acid, present in the urine of the horse when at rest, is converted into benzoate of ammonia and carbonic acid as soon as the animal is compelled to labor, so the uric acid disappears in the urine of man, when he receives, through the skin and lungs, a quantity of oxygen sufficient to oxidize the products of the transformation of the tissues. The use of wine and fat, which are only

but if we assume the formula to be correct, it then appears, from the statement just given, that the elements of two atoms of proteine, *plus* the nitrogenized products of the transformation of a third atom of proteine (uric acid and urea) and water; or three atoms of proteine, *minus* the elements of a compound containing no nitrogen, which actually occurs as one of the products of the transformation of choleic acid, yield in both cases a formula closely approaching to the composition of gelatinous tissues. We must, however, attach to such formulæ, and to the considerations arising from them, no more importance than justly belongs to them. I would constantly remind the reader, that their use is to serve as points of connexion, which may enable us to acquire more accurate views as to the production and decomposition of those compounds which form the animal tissues. They are the first attempts to discover the path which we must follow in order to attain the object of our researches; and this object, the goal we strive to reach, is, and must be, attainable.

The experience of all those, who have occupied themselves with researches into natural phenomena leads to this general result, that these phenomena are caused, or produced, by means far more simple than was previously supposed, or than we even now imagine; and it is precisely their simplicity, which should most powerfully excite our wonder and admiration.

Gelatinous tissue is formed from blood, from compounds of proteine. It may be produced by the addition, to the elements of proteine, of allantoine and water, or of water, urea, and uric acid ; or by the separation from the elements of proteine of a compound containing no nitrogen. The solution of such problems becomes less difficult, when the problem to be solved, the question to be answered, is matured and clearly put. Every experimental decision of any such question in the negative forms the starting-point of a new question, the solution of which, when obtained, is the necessary consequence of our having put the first question.

39. In the foregoing sections, no other constituent of the bile, besides choleic acid, has been brought into the calculation ; because it alone is known with certainty to contain nitrogen. Now, if it be admitted that its nitrogen is derived from the metamorphosed tissues, it is not improbable that the carbon, and other elements which it contains, are derived from the same source.

There cannot be the smallest doubt, that in the carnivora, the constituents of the urine and the bile are derived from the transformation of compounds of proteine; for, except fat, they consume no food but such as contains proteine, or has been formed from that substance. Their food is identical with their blood; and it is a matter of indifference which of the two we select as the starting-point of the chemical development of the vital metamorphoses.

There can be no greater contradiction, with regard to the nutritive process, than to suppose that the nitrogen of the food can pass into the urine as urea, without having previously become part of an organized tissue; for albumen, the only constituent of blood, which, from its amount, ought to be taken into consideration, suffers not the slightest change in passing through the liver or kidneys; we find it in every part of the body with the same appearance and the same properties. These organs cannot be adapted for the alteration or decomposition of the substance from which all the other organs of the body are to be formed.

40. From the characters of chyle and lymph, it appears with certainty, that the soluble parts of the food or of the chyme acquire the form of albumen. Hard-boiled white of egg, boiled or coagulated fibrine, which have again become soluble in the stomach, but have lost their coagulability by the action of air or heat, recover these properties by degrees. In the chyle, the acid reaction of the chyme has already passed into the weak alkaline reaction of the blood; and the chyle, when, after passing through the mesenteric glands, it has reached the thoracic duct, contains albumen coagulable by heat; and, when left to itself, deposits fibrine. All the compounds of proteine, absorbed during the passage of the chyme through the intestinal canal, take the form of albumen, which, as the results of incubation in the fowl's egg testify, contains the fundamental elements of all organized tissues, with the exception of iron, which is obtained from other sources.

Practical medicine has long ago answered the question, what becomes in man of the compounds of proteine taken in excess, what change is undergone by the superabundant nitrogenized food? The blood-vessels are distended with excess of blood, the other vessels cretions in the limbs or in the bladder are utterly unknown.

42. That which must be viewed as an undeniable truth in regard to the origin of the bile, or, more accurately speaking, of choleic acid in the carnivora, cannot hold in regard to all the constituents of the bile secreted by the liver in the herbivora, for with the enormous quantity of bile produced, for example, by the liver of an ox, it is absolutely impossible to suppose, that all its carbon is derived from the metamorphosed tissues.

Assuming the 59 oz. of dry bile (from 37 lbs. of fresh bile secreted by an ox) to contain the same percentage of nitrogen as choleic acid (3·85 per cent.), this would amount to nearly 2¼ oz. of nitrogen; and if this nitrogen proceed from metamorphosed tissues, then, if all the carbon of these tissues passed into the bile, it would yield, at the utmost, a quantity of bile corresponding to 7·15 oz. of carbon. This is, however, far below the quantity which, according to observation, is secreted in this class of animals.

43. Other substances, besides compounds of proteine, must inevitably take part in the formation of bile in the organism of the herbivora; and these substances can only be the non-nitrogenized constituents of their food.

44. The sugar of bile of Gmelin (picromel or biline of Berzelius), which Berzelius considers as the chief constituent of bile, while Demarçay assigns that place essentially to choleic acid, burns, when heated in the

air, like resin, yields ammoniacal products, and, when treated with acids, yields taurine and the products of the decomposition of *choleic acid*; when acted on by alkalies, it yields ammonia and *cholic acid*. At all events, the sugar of bile contains nitrogen, and much less oxygen than starch or sugar, but more oxygen than the oily acids. When, in the metamorphosis of sugar of bile or choleic acid by alkalies, we cause the separation of the nitrogen, we obtain a crystallized acid, very similar to the oily acids (cholic acid), and capable of forming with bases salts, which have the general characters of soaps. Nay, we may even consider the chief constituents of the bile, sugar of bile and choleic acid, as compounds of oily acids with organic oxides, like the fat oils, and only differing from these in containing no oxide of glycerule. Choleic acid, for example, may be viewed as a compound of choloidic acid with allantoine and water:

Choloidic acid.		Allantoine.		Water.		Choleic acid.
$C_{72}H_{56}O_{12}$	+	$C_4N_2H_3O_3$	+	H_7O_7	=	$C_{76}N_2H_{66}O_{22}$

Or, as a compound of cholic acid, urea, and water:

Cholic acid.		Urea.		Water.		Choleic acid.
$C_{74}H_{60}O_{18}$	+	$C_2N_2H_4O_2$	+	H_2O_2	=	$C_{76}N_2H_{66}O_{22}$

45. If, in point of fact, as can hardly be doubted, the elements of such substances as starch, sugar, &c., take part in the production of bile in the organism of the herbivora, there is nothing opposed to such a view in the composition of the chief constituents of bile, as far as our knowledge at present extends.

If starch be the chief agent in this process, it can happen in no other way but this, — that, as when it passes into fat, a certain quantity of oxygen is separated from the elements of the starch, which, for the same amount of carbon (for 72 atoms), contains five times as much oxygen as choloidic acid.

Without the separation of oxygen from the elements of starch, it is impossible to conceive its conversion into bile; and this separation being admitted, its conversion into a compound, intermediate in composition between starch and fat, offers no difficulty.

46. Not to render these considerations a mere idle play with formulæ, and not to lose sight of our chief object, we observe, therefore, that the consideration of the quantitative proportion of the bile secreted in the herbivora leads to the following conclusions: —

The chief constituents of the bile of the herbivora contain nitrogen, and this nitrogen is derived from compounds of proteine.

The bile of this class of animals contains more carbon than corresponds to the quantity of nitrogenized food taken, or to the portion of tissue, that has undergone metamorphosis in the vital process.

A part of this carbon must, therefore, be derived from the non-nitrogenized parts of the food (starch, sugar, &c.); and in order to be converted into a nitrogenized constituent of bile, a part of the elements of these bodies must necessarily have combined with a nitrogenized compound derived from a compound of proteine.

In reference to this conclusion, it is quite indifferent

The transformation of the compounds of proteine present in the body is effected by means of the oxygen conveyed by the arterial blood; and if the elements of starch, rendered soluble in the stomach, and thus carried to every part, enter into the newly formed compounds, we have the chief constituents of the animal secretions and excretions; carbonic acid, the excretion of the lungs, urea and carbonate of ammonia, excreted by the kidneys, and choleic acid, secreted by the liver.

Nothing, therefore, in the chemical composition of those matters, which may be supposed to take a share in these metamorphoses, is opposed to the supposition, that a part of the carbon of the non-azotized food enters into the composition of the bile.

51. Fat, in the animal body, disappears when the supply of oxygen is abundant. When that supply is deficient, choleic acid may be converted into hippuric acid, lithofellic acid, (37) and water. Lithofellic acid is known to be the chief constituent of the bezoar stones, which occur in certain herbivorous animals:

$$\left.\begin{array}{ll}\text{2 at. choleic acid} & C_{76}N_2H_{66}O_{22} \\ \text{10 at. oxygen . . .} & O_{10} \\ \hline & C_{76}N_2H_{66}O_{32}\end{array}\right\} = \left\{\begin{array}{ll}\text{2 at. hip. acid} & C_{36}N_2H_{16}O_{10} \\ \text{1 at. lith. acid} & C_{40}H_{36}O_8 \\ \text{14 at. water . .} & H_{14}O_{14} \\ \hline & C_{76}N_2H_{66}O_{32}\end{array}\right.$$

52. For the production of bile in the animal body a certain quantity of soda is, in all circumstances, necessary; without the presence of a compound of sodium no bile can be formed. In the absence of soda, the metamorphosis of the tissues composed of proteine can yield only fat and urea. If we suppose fat to be com-

56. The comparison of the amount of carbon in the bile secreted by an herbivorous animal, with the quantity of carbon of its tissues, or of the nitrogenized constituents of its food, which, in consequence of the constant transformations, may pass into bile, indicates, as we have just seen, a great difference.

The carbon of the bile secreted amounts, at least, to more than five times the quantity of that which could reach the liver in consequence of the change of matter in the body, either from the metamorphosed tissues or from the nitrogenized constituents of the food ; and we may regard as well founded the supposition, that the non-azotized constituents of the food take a decided share in the production of bile in the herbivora ; for neither experience nor observation contradicts this opinion.

57. We have given, in the foregoing paragraphs, the analytical proof, that the nitrogenized products of the transformation of bile, namely, taurine and ammonia, may be formed from all the constituents of the urine, with the exception of urea, — that is, from hippuric acid, uric acid, and allantoine ; and when we bear in mind that, by the mere separation of oxygen and the elements of water, choloidic acid may be formed from starch ; —

on the human body. Two or three drachms, in crystals, had no injurious action on rabbits to which it was given. In man, a large dose appeared to act only on the kidneys. In certain diseases of the liver, alloxan would very probably be found a most powerful remedy. — *J. L.*

From 6 at. starch	$= 6\ (C_{12}H_{10}O_{10}) =$	$C_{72}H_{60}O_{60}$
Subtract 44 at. oxygen, 4 at. water	$=$	$H_4\ O_{48}$
Remains choloidic acid	. . . . . $=$	$C_{72}H_{56}O_{12}$; —

that, finally, choloidic acid, ammonia, and taurine, if added together, contain the elements of choleic acid ;—

1 at. choloidic acid	$=$	$C_{72}\ H_{56}O_{12}$
1 at. taurine . . .	$=$	$C_4\ N\ H_7\ O_{10}$
1 at. ammonia . .	$=$	$N\ H_3$
1 at. choleic acid .	$=$	$C_{76}N_2\ H_{66}O_{22}$; —

if all this be considered, every doubt as to the possibility of these changes is removed.

58. Chemical analysis and the study of the living animal body mutually support each other ; and both lead to the conclusion, that a certain portion of the carbon of the non-azotized constituents of food (of starch, &c., the elements of respiration) is secreted by the liver in the form of bile ; and further, that the nitrogenized products of the transformation of tissues in the herbivora do not, as in the carnivora, reach the kidneys immediately or directly, but that, before their expulsion from the body in the form of urine, they take a share in certain other processes, especially in the formation of the bile.

They are conveyed to the liver with the non-azotized constituents of the food ; they are returned to the circulation in the form of bile, and are not expelled by the kidneys till they have thus served for the production of the most important of the substances employed in respiration.

59. When the urine is left to itself, the urea which

same products by the action of acids and of alkalies. This, however, is contrary to experience.

Thus, even if we could convert allantoine, or uric acid and urea, into taurine and ammonia, out of the body, we should acquire no additional insight into the true theory of the formation of bile, just because the preëxistence of ammonia and taurine in the bile must be doubted, and because we have no reason to believe that urea or allantoine, as such, are employed by the organism in the production of bile. We can prove that their elements serve this purpose, but we are utterly ignorant how these elements enter into these combinations, or what is the chemical character of the nitrogenized compound which unites with the elements of starch to form bile, or rather choleic acid.

61. Choleic acid may be formed from the elements of starch with those of uric acid and urea, or of allantoine, or of uric acid, or of alloxan, or of oxalic acid and ammonia, or of hippuric acid. The possibility of its being produced from so great a variety of nitrogenized compounds is sufficient to show, that all the nitrogenized products of the metamorphosis of the tissues may be employed in the formation of bile, while we cannot tell in what precise way they are so employed.

By the action of caustic alkalies allantoine may be resolved into oxalic acid and ammonia; the same products are obtained when oxamide is acted on by the same reagents. Yet we cannot, from the similarity of the products, conclude that these two compounds have a similar constitution. In like manner the nature of condition of their existence, because it is only as the result of the change of matter in the body, that those substances can be formed, which are destined to enter into combination with the oxygen of the air; and in this sense we may say, that the non-azotized constituents of the food of the herbivora impede the change of matter, or retard it, and render unnecessary, at all events, so rapid a process as occurs in the carnivora.

67. The quantity of azotized matter, proportionally so small, which the herbivora require to support their vital functions, is closely connected with the power possessed by the non-azotized parts of their food to act as means of supporting the respiratory process; and this consideration seems to render it not improbable, that the necessity for more complex organs of digestion in the herbivora is rather owing to the difficulty of rendering soluble and available for the vital processes certain non-azotized compounds (gum? amylaceous fibre?) than to any thing in the change or transformation of vegetable fibrine, albumen, and caseine into blood; since, for this latter purpose, the less complex digestive apparatus of the carnivora is amply sufficient.

68. If, in man, when fed on a mixed diet, starch perform a similar part to that which it plays in the body of the herbivora; if it be assumed, that the elements of starch are equally necessary to the formation of the bile in man as in these animals; then it follows, that a part of the azotized products of the transformation of the tissues in the human body, before they are expelled through the bladder, returns into the circulation from

pears from the preceding considerations to be derived from the elements of the non-azotized food. But its formation is impossible without the addition of an azotized body, for the bile is a compound of nitrogen. All varieties of bile yet examined yield, when subjected to dry distillation, ammonia and other nitrogenized products. Taurine and ammonia may easily be extracted from ox bile ; and the only reason why we cannot positively prove that the same products may be obtained from the bile of other animals is this, that it is not easy to procure, in the case of many of these animals, a sufficient quantity of bile for the experiment.

Now, whether the nitrogenized compound which unites with the elements of starch to form bile be derived from the food, or from the substance of the metamorphosed tissues, the conclusion, that its presence is an essential condition for the secretion of bile, cannot be considered doubtful.

Since the herbivora obtain in their food only such nitrogenized compounds as are identical in composition with the constituents of their blood, it is at all events clear, that the nitrogenized compound which enters into the composition of the bile, is derived from a compound of proteine. It is either formed in consequence of a change which the compounds of proteine in the food have undergone, or it is produced from the blood, or from the substance of the tissues, by the act of their metamorphosis.

73. If the conclusion be accurate, that nitrogenized compounds, whether derived from the blood or from

the food, take a decided share in the formation of the secretions, and particularly of the bile, then it is plain, that the organism must possess the power of causing foreign matters, which are neither parts nor constituents of the organs in which vital activity resides, to serve for certain vital processes. All nitrogenized substances capable of being rendered soluble, without exception, when introduced into the organs of circulation or of digestion, must, if their composition be adapted for such purposes, be employed by the organism in the same manner as the nitrogenized products which are formed in the act of metamorphosis of tissues.

We are acquainted with a multitude of substances, which exercise a most marked influence on the act of transformation, as well as on the nutritive process, while their elements take no share in the resulting changes. These are uniformly substances, the particles of which are in a certain state of motion or of decomposition, which state is communicated to all such parts of the organism as are capable of undergoing a similar transformation.

74. Medicinal and poisonous substances form a second and most extensive class of compounds, the elements of which are capable of taking a direct or an indirect share in the processes of secretion and of transformation. These may be subdivided into three great orders; the first (which includes the metallic poisons) consists of substances which enter into chemical combination with certain parts or constituents of the body, while the vital force is insufficient to destroy

the growth or reproduction of organs, combines with the substance of the living parts, and produces, by its union with their elements, the act of transformation which we have called the change of matter.

78. It is obvious, that all compounds, of whatever kind, which are present in the capillaries, whether separated there, or introduced by endosmosis (B) or imbibition, if not altogether incapable of uniting with oxygen, must, when in contact with the arterialized globules, the carriers of oxygen, be affected exactly in the same way as the solids forming part of living organs. These compounds, or their elements, will enter into combination with oxygen, and in this case there will either be no change of matter, or that change will exhibit itself in another form, yielding products of a different kind.

79. The conception, then, of a change in the two qualities of the blood above alluded to, by means of a foreign body contained in the blood or introduced into the circulation (a medicinal agent), presupposes two kinds of operation.

Assuming, that the remedy cannot enter into any such chemical union with the constituents of the blood as puts an end to the vital activity; assuming, further, that it is not in a condition of transformation capable of being communicated to the constituents of the blood or of the organs, and of continuing in them; assuming, lastly, that it is incapable, by its contact with the living parts, of putting a stop to the change of matter, the transformation of their elements; then, in order to discover the modus operandi of this class of medicinal agents, as a product of the vital process. On the other hand, a non-azotized medicinal agent, in so far as its action affects the secretions, must be capable of performing in the animal body the same part as that which we have ascribed, in the formation of the bile, to the non-azotized elements of food.

Thus, if we suppose that the elements of hippuric or uric acids are derived from the substance of the organs in which vitality resides; that, as products of the transformation of these organs, they lose the vital character, without losing the capacity of undergoing changes under the influence of the inspired oxygen, or of the apparatus of secretion; we can hardly doubt that similar nitrogenized compounds, products of the vital process in plants, when introduced into the animal body, may be employed by the organism exactly in the same way as the nitrogenized products of the metamorphosis of the animal tissues themselves. If hippuric and uric acids, or any of their elements, can take a share, for example, in the formation and supply of bile, we must allow the same power to other analogous nitrogenized compounds.

We shall never, certainly, be able to discover how men were led to the use of the hot infusion of the leaves of a certain shrub (tea), or of a decoction of certain roasted seeds (coffee). Some cause there must be, which would explain how the practice has become a necessary of life to whole nations. But it is surely still more remarkable, that the beneficial effects of both plants on the health must be ascribed to one and the same substance, the presence of which in two vegetamatter, in the proportion of 90 parts by weight of the former to 10 of the latter. If we suppose these 10 parts by weight of solid matter to be choleic acid, with 3·87 per cent. of nitrogen, then 100 parts of fresh bile will contain 0·171 parts of nitrogen in the shape of taurine. Now this quantity is contained in 0·6 parts of caffeine; or $2\frac{8}{10}$ths grains of caffeine can give to an ounce of bile the nitrogen it contains in the form of taurine. If an infusion of tea contain no more than the $\frac{1}{10}$th of a grain of caffeine, still, if it contribute in point of fact to the formation of bile, the action, even of such a quantity, cannot be looked upon as a nullity. Neither can it be denied, that, in the case of an excess of non-azotized food and a deficiency of motion, which is required to cause the change of matter in the tissues, and thus to yield the nitrogenized product which enters into the composition of the bile; that in such a condition, the health may be benefited by the use of compounds which are capable of supplying the place of the nitrogenized product produced in the healthy state of the body, and essential to the production of an important element of respiration. In a chemical sense, —and it is this alone which the preceding remarks are intended to show,—caffeine or theine, asparagine, and theobromine, are, in virtue of their composition, better adapted to this purpose, than all other nitrogenized vegetable principles. The action of these substances, in ordinary circumstances, is not obvious, but it unquestionably exists.

88. With respect to the action of the other nitro-

also on a certain quality of the substance of the brain, spinal marrow, and nerves ; insomuch, that all the manifestations of the life or vital energy of these modifications of nervous matter, which are recognised as the phenomena of motion, sensation, or feeling, assume another form as soon as their composition is altered. The animal organism has produced the brain and nerves out of compounds furnished to it by vegetables ; it is the constituents of the food of the animal, which, in consequence of a series of changes, have assumed the properties and the structure which we find in the brain and nerves.

89. If it must be admitted as an undeniable truth, that the substance of the brain and nerves is produced from the elements of vegetable albumen, fibrine, and caseine, either alone, or with the aid of the elements of non-azotized food, or of the fat formed from the latter, there is nothing absurd in the opinion, that other constituents of vegetables, intermediate in composition between the fats and the compounds of proteine, may be applied in the organism to the same purpose.

90. According to the researches of Fremy, the chief constituent of the fat found in the brain is a compound of soda with a peculiar acid, the ***cerebric acid***, which contains, in 100 parts,

Carbon,	66·7
Hydrogen,	10·6
Nitrogen,	2·3
Phosphorus,	0·9
Oxygen,	19·5

It is easy to see that the composition of cerebric acid matter, their action on the healthy as well as the diseased organism admits of a surprisingly simple explanation. If we are not tempted to deny, that the chief constituent of soup may be applied to a purpose corresponding to its composition in the human body, or that the organic constituent of bones may be so employed in the body of the dog, although that substance (gelatine in both cases) is absolutely incapable of yielding blood; if, therefore, nitrogenized compounds, totally different from the compounds of proteine, may be employed for purposes corresponding to their composition; we may thence conclude that a product of vegetable life, also different from proteine, but similar to a constituent of the animal body, may be employed by the organism in the same way and for the same purpose as the natural product, originally formed by the vital energy of the animal organs, and that, indeed, from a vegetable substance.

The time is not long gone by, when we had not the very slightest conception of the cause of the various effects of opium, and when the action of cinchona bark was shrouded in incomprehensible obscurity. Now that we know that these effects are caused by crystallizable compounds, which differ as much in composition as in their action on the system; now that we know the substances to which the medicinal or poisonous energy must be ascribed, it would argue only want of sense to consider the action of these substances inexplicable; and to do so, as many have done, because they act in very minute doses, is as unreasonable as it would be to judge of the sharpness of a razor by its weight.

93. It would serve no purpose to give these considerations a greater extension at present. However hypothetical they may appear, they only deserve attention in so far as they point out the way which chemistry pursues, and which she ought not to quit, if she would really be of service to physiology and pathology. The combinations of the chemist relate to the change of matter, forwards and backwards, to the conversion of food into the various tissues and secretions, and to their metamorphosis into lifeless compounds; his investigations ought to tell us what has taken place and what can take place in the body. It is singular that we find medicinal agencies all dependent on certain matters, which differ in composition; and if, by the introduction of a substance, certain abnormal conditions are rendered normal, it will be impossible to reject the opinion, that this phenomenon depends on a change in the composition of the constituents of the diseased organism, a change in which the elements of the remedy take a share; a share similar to that which the vegetable elements of food have taken in the formation of fat, of membranes, of the saliva, of the seminal fluid, &c. Their carbon, hydrogen, or nitrogen, or whatever else belongs to their composition, are derived from the vegetable organism; and, after all, the action and effects of quinine, morphia, and the vegetable poisons in general, are no hypotheses.

94. Thus, as we may say, in a certain sense, of caffeine, or theine and asparagine, &c., as well as of

the non-azotized elements of food, that they are food for the liver, since they contain the elements, by the presence of which that organ is enabled to perform its functions, so we may consider these nitrogenized compounds, so remarkable for their action on the brain and on the substance of the organs of motion, as elements of food for the organs as yet unknown, which are destined for the metamorphosis of the constituents of the blood into nervous substance and brain. Such organs there must be in the animal body, and if, in the diseased state, an abnormal process of production or transformation of the constituents of cerebral and nervous matter has been established ; if, in the organs intended for this purpose, the power of forming that matter out of the constituents of blood, or the power of resisting an abnormal degree of activity in its decomposition or transformation, has been diminished ; then, in a chemical sense, there is no objection to the opinion, that substances of a composition analogous to that of nervous and cerebral matter, and, consequently, adapted to form that matter, may be employed, instead of the substances produced from the blood, either to furnish the necessary resistance, or to restore the normal condition.

95. Some physiologists and chemists have expressed doubts of the peculiar and distinct character of cerebric acid, a substance which, from its amount of carbon and hydrogen, and from its external characters, resembles a nitrogenized fatty acid. But a nitrogenized fat, having an acid character, is, in fact, no anomaly. Hippuric

acid is in many of its characters very similar to the fatty acids, but is essentially distinguished from them by containing nitrogen. The organic constituents of bile resemble the acid resins in physical characters, and yet contain nitrogen. The organic alkalies are intermediate in their physical characters between the fats and resins, and they all contain nitrogen. A nitrogenized fatty acid is as little improbable as the existence of a nitrogenized resin with the characters of a base.

96. An accurate investigation would probably discover differences in the composition of the brain, spinal marrow, and nerves. According to the observations of Valentin, the quality of the cerebral and nervous substance is very rapidly altered from the period of death, and very uncommon precautions would be required for the separation of foreign matters, not properly belonging to the substance of the spinal marrow or brain. But, however difficult it may appear, the investigation seems yet to be practicable. We know, in the mean time, that all experience is against the notion of a large amount of carbon and hydrogen in the substance of the brain. The absence of nitrogen as an element of the cerebral and nervous matter, appears, at all events, improbable. This substance, moreover, cannot be classed with ordinary fats, because we find the cerebric acid combined with soda, whereas, all fats are compounds of fatty acids with oxide of glycerule. In regard to the phosphorus of the brain, we can only guess as to the form in which the phosphorus exists. Walchner observed recently, that bubbles of spontane-

PART III.

THE

PHENOMENA OF MOTION

IN THE

ANIMAL ORGANISM.

essence of natural phenomena are recognisable, not by abstraction, but only by comparative observations.

If the vital phenomena be considered as manifestations of a peculiar force, then the effects of this force must be regulated by certain laws, which laws may be investigated; and these laws must be in harmony with the universal laws of resistance and motion, which preserve in their courses the worlds of our own and other systems, and which also determine changes of form and structure in material bodies; altogether independent of the matter in which vital activity appears to reside, or of the form in which vitality is manifested.

The vital force in a living animal tissue appears as a cause of growth in the mass, and of resistance to those external agencies which tend to alter the form, structure, and composition of the substance of the tissue in which the vital energy resides.

This force further manifests itself as a cause of motion and of change in the form and structure of material substances, by the disturbance and abolition of the state of rest in which those chemical forces exist, by which the elements of the compounds conveyed to the living tissues, in the form of food, are held together.

The vital force causes a decomposition of the constituents of food, and destroys the force of attraction which is continually exerted between their molecules; it alters the direction of the chemical forces in such wise, that the elements of the constituents of food arrange themselves in another form, and combine to produce new compounds, either identical in composition with the living tissues, or differing from them ; it further changes the direction and force of the attraction of cohesion, destroys the cohesion of the nutritious compounds, and forces the new compounds to assume forms altogether different from those which are the result of the attraction of cohesion when acting freely, that is, without resistance.

The vital force is also manifested as a force of attraction, inasmuch as the new compound produced by the change of form and structure in the food, when it has a composition identical with that of the living tissue, becomes a part of that tissue.

Those newly-formed compounds, whose composition differs from that of the living tissue, are removed from the situation in which they are formed, and, in the shape of certain secretions, being carried to other parts of the body, undergo in contact with these a series of analogous changes.

The vital force is manifested in the form of resistance, inasmuch as by its presence in the living tissues, their elements acquire the power of withstanding the disturbance and change in their form and composition, which external agencies tend to produce ; a power which, simply as chemical compounds, they do not possess.

As in the case of other forces, the conception of an unequal intensity of the vital force comprehends not only an unequal capacity for growth in the mass, and an unequal power of overcoming chemical resistance, but also an inequality in the amount of that resistance which the senses when the stone, for example, rests upon a table, the particles of which oppose a resistance to the manifestation of its gravitation. The force of gravity, however, is constantly present, and manifests itself as a pressure on the supporting body ; but the stone remains at rest ; it has no motion. The manifestation of its gravity in the state of rest, we call its weight.

That which prevents the stone from falling is a resistance produced by the force of attraction, by which the particles of the wood cohere together ; a mass of water would not prevent the fall of the stone.

If the force which impelled the mass of the stone towards the centre of the earth were greater than the force of cohesion in the particles of the wood, the latter would be overcome ; it would be unable to prevent the fall of the stone.

When we remove the support, and with it the force which has prevented the manifestation of the force of gravity, the latter at once appears as the cause of change of place in the stone, which acquires motion, or falls. Resistance is invariably the result of a force in action.

According as the stone is allowed to fall during a longer or shorter time, it acquires properties which it had not while at rest ; it acquires, for example, the power of overcoming more feeble or more powerful obstacles, or that of communicating motion to bodies in a state of rest.

If it fall from a certain height it makes a permanent impression on the spot on which it falls ; if it fall from a

Every force, therefore, exhibits itself in matter either in the form of resistance to external causes of motion, or of change in form and structure; or as a moving force when no resistance is opposed to it; or, finally, in overcoming resistance.

One and the same force communicates motion and destroys motion; the former, when its manifestations are opposed by no resistance; the latter, when it puts a stop to the manifestation of some other cause of motion, or of change in form and structure. Equilibrium or rest is that state of activity in which one force or momentum of motion is destroyed by an opposite force or momentum of motion.

We observe both these manifestations of activity in that force which gives to the living tissues their peculiar properties.

The vital force appears as a moving force or cause of motion when it overcomes the chemical forces (cohesion and affinity) which act between the constituents of food, and when it changes the position or place in which their elements occur; it is manifested as a cause of motion in overcoming the chemical attraction of the constituents of food, and is, further, the cause which compels them to combine in a new arrangement, and to assume new forms.

It is plain, that a part of the animal body possessed of vitality, which has, therefore, the power of overcoming resistance, and of giving motion to the elementary particles of the food, by means of the vital force manifested in itself, must have a momentum of motion, which is nothing else than the measure of the resulting motion or change in form and structure.

We know that this momentum of motion in the vital force, residing in a living part, may be employed in giving motion to bodies at rest (that is, in causing decomposition, or overcoming resistance), and, if the vital force is analogous in its manifestations to other forces, this momentum of motion must be capable of being conveyed or communicated by matters, which in themselves do not destroy its effect by an opposite manifestation of force.

Motion, by whatever cause produced, cannot in itself be annihilated; it may, indeed, become inappreciable to the senses, but, even when arrested by resistance (by the manifestation of an opposite force), its effect is not annihilated. The falling stone, by means of the amount of motion acquired in its descent, produces an effect when it reaches the table. The impression made on the wood, the velocity communicated by its parts to those of the wood, — all this is its effect.

If we transfer the conceptions of motion, equilibrium, and resistance, to the chemical forces, which, in their modus operandi, approach to the vital force infinitely nearer than gravitation does, we know with the utmost certainty, that they are active only in the case of immediate contact. We know, also, that the unequal capacity of chemical compounds to offer reimpeded by other forces, a blow, or mechanical friction, or the contact of a substance, the particles of which are in a state of motion (decomposition, transformation), or any external cause, whose activity is added to the stronger attraction of the elementary particles in another direction, may suffice to give the preponderance to this stronger attraction, to overcome the vis inertiæ, to alter the form and structure of the compound, which are the result of foreign causes, and to produce the resolution of the compound into one or more new compounds with altered properties.

Transformations, or, as they may be called, phenomena of motion, in compounds of this class, may be effected by means of the free and available chemical force of another chemical compound, and that without its manifestation being enfeebled or arrested by resistance. Thus the equilibrium in the attraction between the elements of cane-sugar is destroyed by contact with a very small quantity of sulphuric acid, and it is converted into grape-sugar. In the same way we see the elements of starch, under the same influence, arrange themselves with those of water in a new form, while the sulphuric acid, which has served to produce these transformations, loses nothing of its chemical character. In regard to other substances on which it acts, it remains as active as before, exactly as if it had exerted no sort of influence on the cane-sugar or starch.

In contradistinction to the manifestations of the so-called mechanical forces, we have recognised in the chemical forces causes of motion and of change in form and structure, without any observable exhaustion of the force by which these phenomena are produced; but the origin of the continued manifestation of activity remains still the same; it is the absence of an opposite force (a resistance) capable of neutralizing it, or bringing it into the state of equilibrium.

As the manifestations of chemical forces (the momentum of force in a chemical compound) seem to depend on a certain order in which the elementary particles are united together, so experience tells us, that the vital phenomena are inseparable from matter; that the manifestations of the vital force in a living part are determined by a certain form of that part, and by a certain arrangement of its elementary particles. If we destroy the form, or alter the composition, of the organ, all manifestations of vitality disappear.

There is nothing to prevent us from considering the vital force as a peculiar property, which is possessed by certain material bodies, and becomes sensible when their elementary particles are combined in a certain arrangement or form.

This supposition takes from the vital phenomena nothing of their wonderful peculiarity; it may therefore be considered as a resting-point, from which an investigation into these phenomena, and the laws which regulate them, may be commenced; exactly as we consider the properties and laws of light to be dependent on a certain luminiferous matter, or ether, which has no further connexion with the laws ascertained by investigation.

Considered under this form, the vital force unites in its manifestations all the peculiarities of chemical forces, and of the not less wonderful cause, which we regard as the ultimate origin of the electrical phenomena.

The vital force does not act, like the force of gravitation or the magnetic force, at infinite distances, but, like chemical forces, it is active only in the case of immediate contact. It becomes sensible by means of an aggregation of material particles.

A living part acquires, on the above supposition, the capacity of offering and of overcoming resistance, by the combination of its elementary particles in a certain form; and, as long as its form and composition are not destroyed by opposing forces, it must retain its energy uninterrupted and unimpaired.

When, by the act of manifestation of this energy in a living part, the elements of the food are made to unite in the same form and structure as the living organ possesses, then these elements acquire the same powers. By this combination, the vital force inherent in them is enabled to manifest itself freely, and may be applied in the same way as that of the previously existing tissue.

If, now, we bear in mind, that all matters which serve as food to living organisms are compounds of two or more elements, which are kept together by certain chemical forces; if we reflect that in the act of manifestation of force in a living tissue, the elements of the food are made to combine in a new order; — it is quite certain that the momentum of force or of motion in the vital force was more powerful than the chemical attraction existing between the elements of the food.*

The chemical force which kept the elements together acted as a resistance, which was overcome by the active vital force.

Had both forces been equal, no kind of sensible effect would have ensued. Had the chemical force been the stronger, the living part would have undergone a change.

If we now suppose that a certain amount of vital force must have been expended in bringing to an equilibrium the chemical force, there must still remain an excess of force, by which the decomposition was effected. This excess constitutes the momentum of force in the living part, by means of which the change was produced; by means of this excess the part acquires a permanent power of causing further decompositions, and of retaining its condition, form, and structure, in opposition to external agencies.

We may imagine this excess to be removed, and employed in some other form. This would not of it-

* The hands of a man, who raises, with a rope and simple pulley, 30 lbs. to the height of 100 feet, pass over a space of 100 feet, while his muscular energy furnishes the equilibrium to a pressure of 30 lbs. Were the force which the man could exert not greater than would suffice to keep in equilibrium a pressure of 30 lbs., he would be unable to raise the weight to the height mentioned.

self endanger the existence of the living part, because the opposing forces would be left in equilibrio ; but, by the removal of the excess of force, the part would lose its capacity of growth, its power to cause further decompositions, and its ability to resist external causes of change. If, in this state of equilibrium, oxygen (a chemical agent) should be brought in contact with it, then there would be no resistance to the tendency of the oxygen to combine with some element of the living part, because its power of resistance has been taken away by some other application of its excess of vital force. According to the amount of oxygen brought to it, a certain proportion of the living part would lose its condition of vitality, and take the form of a chemical combination, having a composition different from that of the living tissue. In a word, there would occur a change in the properties of the living compound, or what we have called a change of matter.

If we reflect, that the capacity of growth or increase of mass in plants is almost unlimited ; that a hundred twigs from a willow tree, if placed in the soil, become a hundred trees ; we can hardly entertain a doubt, that, with the combination of the elements of the food of the plant so as to form a part of it, a fresh momentum of force is added in the newly formed part to the previously existing momentum in the plant; insomuch, that, with the increase of mass, the sum of vital force is augmented.

According to the amount of available vital force, the products formed by its activity from the food are varied. The composition of the buds, of the radical fibres, of the leaf, of the flower, and of the fruit, are very different one from the other; and the chemical force by which their elements are held together is very different in each of these cases.

Of the non-azotized constituents of plants we may assert, that no part of the momentum of force is expended in maintaining their form and structure, when their elements have once combined in that order in which they become parts of organs endued with vitality.

Very different is the character of the azotized vegetable principles; for, when separated from the plant, they pass, as is commonly said, spontaneously, into fermentation and putrefaction. The cause of this decomposition or transformation of their elements is the chemical action which the oxygen of the atmosphere exercises on one of their constituents. Now we know, that, as long as the plant exhibits the phenomena of life, oxygen gas is given off from its surface; that this oxygen is altogether without action on the constituents of the living plant, for which, in other circumstances, it has the strongest attraction. It is obvious, therefore, that a certain amount of vital force must be expended, partly to retain the elements of the complex azotized principles in the form, order, and structure which belong to them; and partly as a means of resistance against the incessant tendency of the oxygen of the atmosphere to act on their elements, as well as against but both of these manifestations are confined within certain limits.

We observe in animals, that the conversion of food into blood, and the contact of the blood with the living tissues, are determined by a mechanical force, whose manifestation proceeds from distinct organs, and is effected by a distinct system of organs, possessing the property of communicating and extending the motion which they receive. We find the power of the animal to change its place, and to produce mechanical effects by means of its limbs, dependent on a second similar system of organs or apparatus. Both of these systems of apparatus, as well as the phenomena of motion proceeding from them, are wanting in plants.

In order to form a clear conception of the origin and source of the mechanical motions in the animal body, it may be advantageous to reflect on the modus operandi of other forces, which in their manifestations are most closely allied to the vital force.

When a number of plates of zinc and copper, arranged in a certain order, are brought into contact with an acid, and when the extremities of the apparatus are joined by means of a metallic wire, a chemical action begins at the surface of the plates of zinc, and the wire, in consequence of this action, acquires the most singular and wonderful properties.

The wire appears as the carrier or conductor of a force, which may be conducted and communicated through it in every direction with amazing velocity.

It is the conductor or propagator of an uninterrupted series of manifestations of activity.

Such a propagation of motion is inconceivable, if in the wire there were a resistance to be overcome; for every resistance would convert a part of the moving force into a force at rest.

When the wire is divided in the middle, and its continuity interrupted, the propagation of force ceases, and we observe, that in this case the action between the zinc and the acid is immediately stopped.

If the communication be restored, the action which had disappeared, reappears with all its original energy.

By means of the force present in the wire, we can produce the most varied effects; we can overcome all kinds of resistance, raise weights, set ships in motion, &c. And, what is still more remarkable, the wire acts as a hollow tube, in which a current of chemical force circulates freely and without hinderance.

Those properties which, when firmly attached to certain bodies, we call the strongest and most energetic affinities, we find, to all appearance, free and uncombined in the wire. We can transport them from the wire to other bodies, and thereby give to them an affinity (a power of entering into combination) which in themselves they do not possess. According to the amount of force circulating in the wire, we are able by means of it to decompose compounds, the elements of which have the strongest attraction for each other. Yet the substance of the wire takes not the smallest share in all these manifestations of force ; it is merely the conductor of force.

We observe, further, in this wire, phenomena of attraction and repulsion, which we must ascribe to the disturbance of the equilibrium in the electric or magnetic force ; and when this equilibrium is restored, the restoration is accompanied by the development of light and heat, its never-failing companions.

All these remarkable phenomena are produced by the chemical action which the zinc and the acid exert on each other ; they are accompanied by a change in form and structure, which both undergo.

The acid loses its chemical character; the zinc enters into combination with it. The manifestations of force produced in the wire are the immediate consequence of the change in the properties of the acid and the metal.

One particle of acid after another loses its peculiar chemical character ; and we perceive that in the same proportion the wire acquires a chemical, mechanical, galvanic, or magnetic force, whatever name be given to it. According to the number of acid particles which in a given time undergo this change, that is, according to the surface of the zinc, the wire receives a greater or less amount of these forces.

The continuance of the current of force depends on the duration of the chemical action ; and the duration of the latter is most closely connected with the carrying away, by conduction, of the force.

produce mechanical effects, and which, when transferred to other bodies, communicates to them all those properties, the ultimate cause of which is the chemical force itself; for these bodies acquire the power of causing decompositions and combinations, such as, without a supply of force through the conductor, they could not effect.

If we employ these well-known facts as means to assist us in investigating the ultimate cause of the mechanical effects in the animal organism, observation teaches us, that the motion of the blood and of the other animal fluids proceeds from distinct organs, which, as in the case of the heart and intestines, do not generate the moving power in themselves, but receive it from other quarters.

We know with certainty that the nerves are the conductors and propagators of mechanical effects; we know, that by means of them motion is propagated in all directions. For each motion we recognise a separate nerve, a peculiar conductor, with the conducting power of which, or with its interruption, the propagation of motion is affected or destroyed.

By means of the nerves all the parts of the body, all the limbs, receive the moving force which is indispensable to their functions, to change of place, to the production of mechanical effects. Where nerves are not found, motion does not occur. The excess of force generated in one place is conducted to other parts by the nerves. The force which one organ cannot produce in itself is conveyed to it from other quarters; and the vital force which is wanting to it, in order to furnish resistance to external causes of disturbance, it receives in the form of excess from another organ, an excess which that organ cannot consume in itself.

We observe further, that the voluntary and involuntary motions, in other words, all mechanical effects in the animal organism, are accompanied by, nay, are dependent on, a peculiar change of form and structure in the substance of certain living parts, the increase or diminution of which change stands in the very closest relation to the measures of motion, or the amount of force consumed in the motions performed.

As an immediate effect of the manifestation of mechanical force, we see, that a part of the muscular substance loses its vital properties, its character of life; that this portion separates from the living part, and loses its capacity of growth and its power of resistance. We find that this change of properties is accompanied by the entrance of a foreign body (oxygen) into the composition of the muscular fibre (just as the acid lost its chemical character by combining with zinc); and all experience proves, that this conversion of living muscular fibre into compounds destitute of vitality is accelerated or retarded, according to the amount of force employed to produce motion. Nay, it may safely be affirmed, that they are mutually proportional; that a rapid transformation of muscular fibre, or, as it may be called, a rapid change of matter, determines a greater amount of mechanical force; and conversely, that a greater amount of mechanical motion (of mechanical force expended in motion) determines a more rapid change of matter.

From this decided relation between the change of matter in the animal body and the force consumed in mechanical motion, no other conclusion can be drawn than this, that the active or available vital force in certain living parts is the cause of the mechanical phenomena in the animal organism.

The moving force certainly proceeds from living parts; these parts possessed a momentum of force or of motion, which they lost in proportion as other parts acquired a momentum of force or of motion; they lose their capacity of growth, and their power to resist external causes of change. It is obvious that the ultimate cause, the vital force, from which they acquired those properties, has served for the production of mechanical force, that is, has been expended in the shape of motion.

How, indeed, could we conceive, that a living part should lose the condition of life, should become incapable of resisting the action of the oxygen conveyed to it by the arterial blood, and should be deprived of the power to overcome chemical resistance, unless the momentum of the vital force, which had given to it all these properties, had been expended for other purposes?

By the power of the conductors, the nerves, to to that of oxygen, the manifestation of which must be considered as dependent on the vital force.

In chemical language, to annihilate the chemical action of oxygen, means, to present to it substances, or parts of organs, which are capable of combining with it.

The action of oxygen (affinity) is either neutralized by means of the elements of organized parts, which combine with it (after the free vital force has been conducted away), or else the organ presents to it the products of other organs, or certain matters formed from the elements of the food, by the vital activity of certain systems of apparatus.

It is only the muscular system which, in this sense, produces in itself a resistance to the chemical action of oxygen, and neutralizes it completely.

The substance of cellular tissue, of membranes, and of the skin, the minutest particles of which are not in immediate contact with arterial blood (with oxygen), are not destined to undergo this change of matter. Whatever changes they may undergo in the vital process, affect, in all cases, only their surface.

The gelatinous tissues, mucous membranes, tendons, &c., are not designed to produce mechanical force; they contain in their substance no conductors of mechanical effects. But the muscular system is interwoven with innumerable nerves. The substance of the uterus is in no respect different in chemical composition from the other muscles; but it is not adapted to the change of matter, to the production of force, and conhas been expended in producing mechanical effects. For the waste of matter, in consequence of motion and laborious exertion, is extremely various in different individuals.

If we reflect, that the slightest motion of a finger consumes force ; that in consequence of the force expended, a corresponding portion of muscle diminishes in volume ; it is obvious, that an *equilibrium between supply and waste of matter* (in living tissues) can only occur when the portion separated or expelled in a lifeless form is, at the same instant in which it loses its vital condition, restored in another part.

The capacity of growth or increase in mass depends on the momentum of force belonging to each part ; and must be capable of continued manifestation (if there be a sufficient supply of nourishment), as long as it does not lose this momentum, by expending it, for example, in producing motion.

In all circumstances, the growth itself is restricted to the time ; that is to say, it cannot be unlimited in a limited time.

A living part cannot increase in volume at the same moment in which a portion of it loses the vital condition, and is expelled from the organ in the form of a lifeless compound ; on the contrary, its volume must diminish.

The continued application of the momentum of force in living tissues to mechanical effects determines, therefore, a continued separation of matter ; and only from consider with what infinite wisdom the Creator has divided the means by which animals and plants are qualified for their functions, for their peculiar vital manifestations.

The living part of a plant acquires the whole force and direction of its vital energy from the absence of all conductors of force. By this means the leaf is enabled to overcome the strongest chemical attractions, to decompose carbonic acid, and to assimilate the elements of its nourishment.

In the flower alone does a process similar to the change of matter in the animal body occur. There, phenomena of motion appear ; but the mechanical effects are not propagated to a distance, owing to the absence of conductors of force.

The same vital force, which we recognise in the plant as an almost unlimited capacity of growth, is converted in the animal body into moving power (into a current of vital force) ; and a most wonderful and wise economy has destined for the nourishment of the animal only such compounds as have a composition identical with that of the organs which generate force, that is, with the muscular tissue. The expenditure of force which the living parts of animals require, in order to reproduce themselves from the blood ; the resistance of the chemical force which has to be overcome in the azotized constituents of food by the vital agency of the organs destined to convert them into blood ; these are as nothing compared to the force with which the elements of those of the food, has lost its condition of life, and has been expelled in combination with oxygen.

The one individual, which, being exposed to the lower temperature, consumed more food, has also absorbed more oxygen ; a greater quantity of the constituents of its body has been separated in combination with oxygen ; and, in consequence of this combination with oxygen, a greater amount of heat has been liberated, by which means the heat abstracted has been restored, and the proper temperature of the body kept up.

Consequently, by the abstraction of heat, provided there be a full supply of food and free access of oxygen, the change of matter must be accelerated ; and, along with the augmented transformation, in a given time, of living tissues, a greater amount of vital force must be rendered available for mechanical purposes.

With the external cooling, the respiratory motions become stronger ; in a lower temperature more oxygen is conveyed to the blood ; the waste of matter increases, and, if the supply be not kept in equilibrium with this waste, by means of food, the temperature of the body gradually sinks.

But, in a given time, an unlimited supply of oxygen cannot be introduced into the body ; only a certain amount of living tissue can lose the state of life, and only a limited amount of vital force can be manifested in mechanical phenomena. It is only, therefore, when the cooling, the generation of force, and the absorption bear a fixed relation to the amount of oxygen which can be absorbed in a given time by the animal body.

The quantities of oxygen which a whale and a carrier's horse can inspire in a given time are very unequal. The temperature, as well as the quantity of oxygen, is much greater in the horse.

The force exerted by a whale, when struck with the harpoon, his body being supported by the surrounding medium, and the force exerted by a carrier's horse, which carries its own weight and a heavy burden for eight or ten hours, must both bear the same ratio to the oxygen consumed. If we take into consideration the time during which the force is manifested, it is obvious that the amount of force developed by the horse is far greater than in the case of the whale.

In climbing high mountains, where, in consequence of the respiration of a highly rarefied atmosphere, much less oxygen is conveyed to the blood, in equal times, than in valleys or at the level of the sea, the change of matter diminishes in the same ratio, and with it the amount of force available for mechanical purposes. For the most part, drowsiness and want of force for mechanical exertions come on; after twenty or thirty steps, fatigue compels us to a fresh accumulation of force by means of rest (absorption of oxygen without waste of force in voluntary motions).

By the absorption of oxygen into the substance of living tissues, these lose their condition of life, and are separated as lifeless, unorganized compounds; but the pounds formed by the change of matter, or that of the substance of living tissues, they (the elements of alcohol) could not combine with oxygen in the body.

It is, consequently, obvious, that by the use of alcohol a limit must rapidly be put to the change of matter in certain parts of the body. The oxygen of the arterial blood, which, in the absence of alcohol, would have combined with the matter of the tissues, or with that formed by the metamorphosis of these tissues, now combines with the elements of alcohol. The arterial blood becomes venous, without the substance of the muscles having taken any share in the transformation.

Now, we observe, that the development of heat in the body, after the use of wine, increases rather than diminishes, without the manifestation of a corresponding amount of mechanical force.

A moderate quantity of wine, in women and children unaccustomed to its use, produces, on the contrary, a diminution of the force necessary for voluntary motions. Weariness, feebleness in the limbs, and drowsiness plainly show that the force available for mechanical purposes, in other words, the change of matter, has been diminished.

A diminution of the conducting power of the nerves of voluntary motion may doubtless take a certain share in producing these symptoms; but this must be altogether without influence on the sum of available force.

What the conductors of voluntary motion cannot carry away for effects of force, must be taken up by the part, although a certain momentum of motion be expended in keeping up the circulation, will not be separated and expelled from the body.

With the return of the higher temperature, the capacity of growth increases in the same ratio, and the motion of the blood increases with the absorption of oxygen. Many of these animals become emaciated during the winter sleep, others not till after awaking from it.

In hybernating animals, the active force of the living parts is exclusively devoted, during hybernation, to the support of the involuntary motions. The expenditure of force in voluntary motion is entirely suppressed.

In contradistinction to these phenomena, we know, that, in the case of excess of motion and exertion, the active force in living parts may be exclusively and entirely consumed in producing voluntary mechanical effects, in such wise that no force shall remain available for the involuntary motions. A stag may be hunted to death; but this cannot occur without the metamorphosis of all the living parts of its muscular system, and its flesh becomes uneatable. The condition of metamorphosis, into which it has been brought by an enormous consumption both of force and of oxygen, continues when all phenomena of motion have ceased. In the living tissues, all the resistance offered by the vital force to external agencies of change is entirely destroyed.

But, however closely the conditions of the producat once recognised in the complete supply of the matter consumed. In old age more is wasted; in childhood more is supplied than wasted.

The force available for mechanical purposes in an adult man is reckoned, in mechanics, equal to ⅕th of his own weight, which he can move during eight hours, with a velocity of five feet in two seconds.

If the weight of a man be 150 lbs., his force is equal to a weight of 30 lbs. carried by him to a distance of 72,000 feet. For every second his momentum of force is $= 30 \times 2 \cdot 5 = 75$ lbs.; and for the whole day's work, his momentum of motion is $= 30 \times 72,000 = 2,160,000$.

By the restoration of the original weight of his body, the man collects again a sum of force which allows him, next day, to produce, without exhaustion, the same amount of mechanical effects.

This supply of force is furnished in a seven hours' sleep.

In manufactories of rolled iron it frequently happens that the pressure of the engine, going at its ordinary rate, is not sufficient to force a rod of iron of a certain thickness to pass below the cylinders. The workman, in this case, allows the whole force of the steam to act on the revolving wheel, and not until this has acquired a great velocity does he bring the rod under the rollers; when it is instantly flattened with great ease into a plate, while the wheel gradually loses the velocity it had acquired. What the wheel gained in velocity, the rium during sleep = 100 = 17 waking hours = 7 hours of sleep, we obtain the following proportions. The mechanical effects are to those in the shape of formation of new parts :

In the adult man	= 100 : 100		
In the infant . .	= 25 : 250	(24 : 286)	
In the old man .	= 125 : 50	(118 : 43)	

Or the increase of mass to the diminution of waste :

In the adult man	= 100 : 100	
In the infant . .	= 100 : 10	(9)
In the old man .	= 100 : 250	(274)

It is consequently clear, that, if the old man performs an amount of work proportional to the sleeping hours of the adult, the waste will be greater than the supply ; that is, his body will rapidly decrease in weight, if he carry 15 lbs. to the distance of 72,000 feet with a velocity of 2½ feet in the second ; but he will be able, without injury, to carry 6 lbs. to the same distance.

In the infant the increase is to the decrease as 10 to 1, and consequently, if we in his case increase the expenditure of force in mechanical effects to ten times its proper amount, there will thus be established only an equilibrium between waste and supply. The child, indeed, will not grow ; but neither will it lose weight.

If, in the adult man, the consumption of force for mechanical purposes in 24 hours be augmented beyond the amount restorable in seven hours of sleep, then, if the equilibrium is to be restored, less force, in the same proportion, must be expended in mechanical effects in the next 24 hours. If this be not done, the mass of the body decreases, and the state characteristic of old age more or less decidedly supervenes.

With every hour of sleep the sum of available force increases in the old man, or approaches the state of equilibrium between waste and supply which exists in the adult.

It is further evident, that, if a part of the force which is available for mechanical purposes, without disturbing the equilibrium, should not be consumed in moving the limbs, in raising weights, or in other labor, it will be available for involuntary motions. If the motion of the heart, of the fluids, and of the intestines (the circulation of the blood and digestion) be accelerated in proportion to the amount of force not consumed in voluntary motions, the weight of the body will neither increase nor diminish in 24 hours. The body, therefore, can only increase in mass, if the force accumulated during sleep, and available for mechanical purposes, is employed neither for voluntary nor for involuntary motions.

The numerical values above given for the expenditure of force in the human body refer, as has been expressly stated, only to a given, uniform temperature. In a different temperature, and with deficient nourishment, all these proportions must be changed.

If we surround a part of the body with ice or snow, while other parts are left in the natural state, there occurs, more or less quickly, in consequence of the loss of heat, an accelerated change of matter in the cooled part.

The resistance of the living tissues to the action of oxygen is weaker at the cooled part than in the other parts; and this, in its effects, is equivalent to an increase of resistance in these other parts.

The momentum of force of the vitality in the parts which are not cooled is expended, as before, in mechanical motion; but the whole action of the inspired oxygen is exerted on the cooled part.

If we imagine an iron cylinder, into which we admit steam under a certain pressure, then, if the force with which the particles of the iron cohere be equal to the force which tends to separate them, an equilibrium will result; that is, the whole effect of the steam will be neutralized by the resistance. But, if one of the sides of the cylinder be movable, a piston-rod, for example, and offer to the pressure of the steam a less resistance than other parts, the whole force will be expended in moving this one side, — that is, in raising the piston-rod. If we do not introduce fresh steam (fresh force), an equilibrium will soon be established. The piston-rod resists a certain force without moving, but is raised by an increased pressure. When this excess of force has been consumed in motion, it cannot be raised higher; but, if new vapor be continually admitted, the rod will continue to move.

In the cooled part of the body, the living tissues offer a less resistance to the chemical action of the inspired oxygen; the power of the oxygen to unite with the elements of the tissues is, at this part, exalted. When the part has once lost its condition of life, resistance entirely ceases; and, in consequence of the combination of the oxygen with the elements of the metamorphosed tissues, a greater amount of heat is liberated.

For a given amount of oxygen, the heat produced is, in all cases, exactly the same. In the cooled part, the change of matter, and with it the disengagement of heat, increases; while in the other parts the change of matter and liberation of heat decrease. But, when the cooled part, by the union of oxygen with the elements of the metamorphosed tissues, has recovered its original temperature, the resistance of its living particles to the oxygen conveyed to them again increases, and, as the resistance of other parts is now diminished, a more rapid change of matter now occurs in them, their temperature rises, and along with this, if the cause of the change of matter continue to operate, a larger amount of vital force becomes available for mechanical purposes.

Let us now suppose that heat is abstracted from the whole surface of the body; in this case the whole action of the oxygen will be directed to the skin, and in a short time the change of matter must increase throughout the body. Fat, and all such matters as are capable of combining with the oxygen, which is brought to them in larger quantity than usual, will be expelled from the body in the form of oxidized compounds.

III.

THEORY OF DISEASE.

Every substance or matter, every chemical or mechanical agency, which changes or disturbs the restoration of the equilibrium between the manifestations of the causes of waste and supply, in such a way as to add its action to the causes of waste, is called *a cause of disease*. *Disease* occurs when the sum of vital force, which tends to neutralize all causes of disturbance (in other words, when the resistance offered by the vital force), is weaker than the acting cause of disturbance.

Death is that condition in which all resistance on the part of the vital force entirely ceases. So long as this condition is not established, the living tissues continue to offer resistance.

To the observer, the action of a cause of disease exhibits itself in the disturbance of the proportion between waste and supply which is proper to each period of life. In medicine, every abnormal condition of supply or of waste, in all parts or in a single part of the body, is called disease.

It is evident that one and the same cause of disease will produce in the organism very different effects, according to the period of life; and that a certain amount of disturbance, which produces disease in the adult state, may be without influence in childhood or in old age. A cause of disease may, when it is added to the cause of waste in old age, produce death (annihilate all resistance on the part of the vital force); while in the adult state it may produce only a disproportion between supply and waste; and in infancy, only an equilibrium between supply and waste (the abstract state of health).

A cause of disease which strengthens the causes of supply, either directly, or indirectly by weakening the action of the causes of waste, destroys, in the child and in the adult, the relative normal state of health; while in old age it merely brings the waste and supply into equilibrium.

A child, lightly clothed, can bear cooling by a low external temperature without injury to health; the force available for mechanical purposes and the temperature of its body increase with the change of matter which follows the cooling; while a high temperature, which impedes the change of matter, is followed by disease.

On the other hand, we see, in hospitals and charitable institutions (in Brussels, for example) in which old people spend the last years of life, when the temperature of the dormitory, in winter, sinks two or three by the vital force. These methods, the result of ages of experience, are such that the most perfect theory could hardly have pointed them out more acutely or more justly than has been done by the observation of sagacious practitioners. They diminish, by blood-letting, the number of the carriers of oxygen (the globules), and by this means the condition of change of matter; they exclude from the food all such matters as are capable of conversion into blood; they give chiefly or entirely non-azotized food, which supports the respiratory process, as well as fruit and vegetables, which contain the alkalies necessary for the secretions.

If they succeed, by these means, in diminishing the action of the oxygen in the blood on the diseased part, so far that the vital force of the latter, its resistance, in the smallest degree overcomes the chemical action; and if they accomplish this without arresting the functions of the other organs, then restoration to health is certain.

To the method of cure adopted in such cases, if employed with sagacity and acute observation, there is added, as we may call it, an ally on the side of the diseased organ, and this is the vital force of the healthy parts. For, when blood is abstracted, the external causes of change are diminished also in them, and their vital force, formerly neutralized by these causes, now obtains the preponderance. The change of matter, indeed, is diminished throughout the body, and with it the phenomena of motion; but the sum of all resisting powers, taken together, increases in proportion as the amount of oxygen acting on them in the blood is diminished. In the sensation of *hunger*, this resistance, in a certain sense, makes itself known; and the preponderating vital force exhibits itself, in many patients, when hunger is felt, in the form of an abnormal growth, or an abnormal metamorphosis of certain parts of organs. *Sympathy* is the transference of diminished resistance from one part, not exactly to the next, but to more distant organs, when the functions of both mutually influence each other. When the action of the diseased organ is connected with that of another; when, for example, the one no longer produces the matters necessary to the performance of the functions of the other, — then the diseased condition is transferred, but only apparently, to the latter.

In regard to the nature and essence of the vital force, we can hardly deceive ourselves, when we reflect that it behaves, in all its manifestations, exactly like other natural forces; that it is devoid of consciousness or of volition, and is subject to the action of a blister.

The nerves, which accomplish the voluntary and involuntary motions in the body, are, according to the preceding exposition, not the producers, but only the conductors of the vital force; they propagate motion, and behave towards other causes of motion, which in their manifestations are analogous to the vital force, towards a current of electricity, for example, in a precisely analogous manner. They permit the current to traverse them, and present, as conductors of electricity, all the phenomena which they exhibit as conductors of the vital force. In the present state of our knowledge, no one, probably, will imagine that electricity is to be considered as the cause of the phenomena of motion in the body ; but still, the medicinal action of electricity, as well as that of a magnet, which, when placed in contact with the body, produces a current of electricity, cannot be denied. For to the existing force of motion or of disturbance there is added, in the electrical current, a new cause of motion and of change in form and structure, which cannot be considered as altogether inefficient.

Practical medicine, in many diseases, makes use of cold in a highly rational manner, as a means of exalting and accelerating, in an unwonted degree, the change of matter. This occurs especially in certain morbid conditions in the substance of the centre of the apparatus of motion ; when a glowing heat and a rapid current of blood towards the head point out an abnormal metamorphosis of the brain. When this condition continues beyond a certain time, experience teaches that all motions in the body cease. If the change of matter be chiefly confined to the brain, then the change of matter, the generation of force, diminishes in all other parts. By surrounding the head with ice, the temperature is lowered, but the cause of the liberation of heat continues ; the metamorphosis, which decides the issue of the disease, is limited to a short period. We must not forget that the ice melts and absorbs heat from the disamount of steam generated, and its tension increase) with the temperature in the fireplace, which depends on the supply of coals and of air. There are in these engines other arrangements, all intended for regulation. When the tension of steam in the boiler rises beyond a certain point, the passages for admission of air close themselves; the combustion is retarded, the supply of force (of steam) is diminished. When the engine goes slower, more steam is admitted to the cylinder, its tension diminishes, the air passages are opened, and the cause of disengagement of heat (or production of force) increases. Another arrangement supplies the fireplace incessantly with coals in proportion as they are wanted.

If we now lower the temperature at any part of the boiler, the tension within is diminished; this is immediately seen in the regulators of force, which act precisely as if we had removed from the boiler a certain quantity of steam (force). The regulator and the air passages open, and the machine supplies itself with more coals.

The body, in regard to the production of heat and of force, acts just like one of these machines. With the lowering of the external temperature, the respirations become deeper and more frequent; oxygen is supplied in greater quantity and of greater density; the change of matter is increased; and more food must be supplied, if the temperature of the body is to remain unchanged.

Whatever change the other constituents of the blood undergo in the lungs, thus much is certain, that the globules of venous blood experience a change of color, and that this change depends on the action of oxygen.

Now we observe that the globules of arterial blood retain their color in the larger vessels, and lose it only during their passage through the capillaries. All those constituents of venous blood, which are capable of combining with oxygen, take up a corresponding quantity of it in the lungs. Experiments made with arterial serum have shown, that, when in contact with oxygen, it does not diminish the volume of that gas. Venous blood, in contact with oxygen, is reddened, while oxygen is absorbed; and a corresponding quantity of carbonic acid is formed.

It is evident that the change of color in the venous globules depends on the combination of some one of their elements with oxygen; and that this absorption of oxygen is attended with the separation of a certain quantity of carbonic acid gas.

This carbonic acid is not separated from the serum; for the serum does not possess the property, when in contact with oxygen, of giving off carbonic acid. On the contrary, when separated from the globules, it absorbs from half its volume to an equal volume of carbonic acid, and, at ordinary temperatures, is not saturated with that gas. (See the article "Blut" in the "Handwörterbuch der Chemie von Poggendorff, Wöhler, und Liebig," p. 877.)

pended, otherwise than in the formation of carbonic acid, the amount of this latter gas expired will correspond exactly with that which has been formed; less, however, will be given out after the use of fat and of still wines, than after champagne.

According to the views now developed, the globules of arterial blood, in their passage through the capillaries, yield oxygen to certain constituents of the body. A small portion of this oxygen serves to produce the change of matter, and determines the separation of living parts and their conversion into lifeless compounds, as well as the formation of the secretions and excretions. The greater part, however, of the oxygen is employed in converting into oxidized compounds the newly formed substances, which no longer form part of the living tissues.

In their return towards the heart, the globules which have lost their oxygen combine with carbonic acid, producing venous blood; and, when they reach the lungs, an exchange takes place between this carbonic acid and the oxygen of the atmosphere.*

---

* Since the publication of the first edition of this work, the following conclusions, from some researches by MM. Andral and Gavarret, have been published in the *Comptes rendus des Séances de l'Académie des Sciences* for January 16th, 1843. They tend to confirm the theory of the formation of carbonic acid in the system, and not in the lungs.

"1st. The quantity of carbonic acid exhaled by the lungs in a given time differs according to age, sex, and constitution, in different persons.

"2d. At all ages between eight years and the most advanced, there

The organic compound of iron, which exists in venous blood, recovers in the lungs the oxygen it has lost, and, in consequence of this absorption of oxygen, the carbonic acid in combination with it is separated.

All the compounds present in venous blood, which have an attraction for oxygen, are converted, in the lungs, like the globules, into more highly oxidized compounds; a certain amount of carbonic acid is formed, of which a part always remains dissolved in the serum of the blood.

---

is a difference in the quantities exhaled by males and females. Between the ages of sixteen and forty, man exhales about twice as much as woman.

"3d. In man, the quantity exhaled increases regularly from eight to thirty years of age, increasing very suddenly at puberty. After the age of thirty, it commences decreasing, till the extreme *of life*, when the exhalation is no more than at ten years of age.

"4th. In woman, however, there is a marked exception after the age of puberty, till which period she follows the same law as man. As soon as the catamenia appear, the exhalation of carbonic acid no longer increases; and, while the menstrual periods maintain their regularity, this exhalation is only a little more than in infancy. As soon, however, as the menses are suppressed, the increase of exhalation is very remarkable; but, as old age comes on, woman again follows the same rule as man.

"5th. During pregnancy the exhalation of carbonic acid by woman is increased.

"6th. In both sexes, and at all ages, the quantity of carbonic acid exhaled by the lungs is greater in proportion to the strength of the constitution, and the development of the muscular system."

The experiments, from which the above conclusions were drawn, were carefully performed at the same hour of the day, between one and two o'clock, and at a regular time after the subjects had eaten. — *W.*

The quantity of carbonic acid dissolved, or of that combined with soda, must be equal in venous and arterial blood, since both have the same temperature; but arterial blood, when drawn, must, after a short time, contain a larger quantity of carbonic acid than venous blood, because the oxygen of the globules is expended in producing that compound.

Hence, in the animal organism, two processes of oxidation are going on; one in the lungs, the other in the capillaries. By means of the former, in spite of the degree of cooling, and of the increased evaporation which takes place there, the constant temperature of the lungs is kept up; while the heat of the rest of the body is supplied by the latter.

A man, who expires daily 13·9 oz. of carbon in the form of carbonic acid, consumes, in 24 hours, 37 oz. of oxygen, which occupy a space equal to 807 litres = 51,648 cubic inches (Hessian).

If we reckon 18 respirations to a minute, we have, in 24 hours, 25,920 respirations; and, consequently, in each respiration, there are taken into the blood $\frac{51648}{25920}$ = 1·99 cubic inch of oxygen.

In one minute, therefore, there are added to the constituents of the blood $18 \times 1{\cdot}99 = 35{\cdot}8$ cubic inches of oxygen, which, at the ordinary temperature, weigh rather less than 12 grains (12·2 Eng.).

If we now assume, that in one minute 10 lbs. of blood pass through the lungs (Müller, Physiologie, vol. i. p. 345), and that this quantity of blood measures 320 of the blood. It does not exclude the opinion, that carbonic acid may reach the lungs in other ways ; that certain other constituents of the blood may give rise to the formation of carbonic acid in the lungs. But all this has no connexion with that vital process by which the heat necessary for the support of life is generated in every part of the body. Now it is this alone which, for the present, can be considered as the object truly worthy of investigation. It is not, indeed, uninteresting to inquire, why dark blood becomes florid by the action of nitre, common salt, &c. ; but this question has no relation to the natural respiratory process.

The frightful effects of sulphuretted hydrogen, and of prussic acid, which, when inspired, put a stop to all the phenomena of motion in a few seconds, are explained in a natural manner by the well-known action of these compounds on those of iron, when alkalies are present ; and free alkali is never absent in the blood.

Let us suppose that the globules lose their property of absorbing oxygen, and of afterwards giving up this oxygen and carrying off the resulting carbonic acid ; such a hypothetical state of disease must instantly become perceptible in the temperature and other vital phenomena of the body. The change of matter will be arrested, while the vital motions will not be instantly stopped.

The conductors of force, the nerves, will convey, as before, to the heart and intestines the power necessary for their functions. This power they will receive

APPENDIX;

CONTAINING

THE ANALYTICAL EVIDENCE

REFERRED TO IN THE SECTIONS IN WHICH ARE DESCRIBED THE

CHEMICAL PROCESSES OF RESPIRATION,

OF

NUTRITION,

AND OF THE

METAMORPHOSIS OF TISSUES.

23

= 12·478; N a weight of nitrogen = 177·04; and, lastly, O a weight of oxygen = 100.

The formula of proteine, $C_{48}N_6H_{36}O_{14}$, expresses, therefore,

48 times	76·437 =	3668·98	carbon.
6 times	177·040 =	1062·24	nitrogen.
36 times	12·478 =	449·21	hydrogen.
14 times	100·000 =	1400·00	oxygen.
The sum gives a weight of		6580·43	proteine.

Therefore, —

			In 100 parts.
In 6580·43	parts of proteine are contained	3668·98 carbon	55·756
In 6580·43	ditto	1062·24 nitrogen	16·142
In 6580·43	ditto	449·21 hydrogen	6·827
In 6580·43	ditto	1400·00 oxygen	21·275
			100·000

The actual results of the analysis, reduced to 100 parts, when compared with the above numbers, will show how far the assumed formula is correct; or, supposing the formula ascertained, they will show the degree of accuracy displayed by the experimenter. Thus the proportions in 100 parts, calculated from the formula, furnish an important check to the operator; and, conversely, the formula calculated from his results, when compared with other known formulæ, supplies a test of his accuracy, or of the purity of the substance analyzed.

NOTE I. P. 12.

CONSUMPTION OF OXYGEN BY AN ADULT. *a*

An Adult Man

According to	consumes of oxygen in 24 hours		produces of carbonic acid in 24 hours		Carbon contained in the carbonic acid.	
	cubic in.	grains.	cubic in.	grains.	grains.	
Lavoisier and Seguin	46,037	15,661	14,930	8,584	2,820	French.
Menzies	51,480	17,625				English.
Davy	45,504	15,751	31,680	17,811	4,853	do.
Allen and Pepys	39,600	13,464	39,600	18,612	5,148	do.†

a Gmelin, — Brande's Manual, p. 1198.

---

† The experiments of Despretz (for which, see Thomson's "Animal Chemistry," Edinburgh, 1843, p. 635) lead to the conclusion, that about 1-10th of the oxygen gas absorbed combines with hydrogen and forms water, and that 9-10ths of it go to the formation of carbonic acid gas. If this estimate be true, we must, in order to get the true volume of oxygen gas abstracted from air during respiration, augment the volume of carbonic acid gas evolved by 1-10th. This would make the average quantity of oxygen abstracted from the air inspired amount to 4·092 per cent.

Dr. Thomson examined the air from his lungs on ten consecutive days, between eleven and twelve o'clock each day, and has given the following table of the results.

	Carbonic acid gas.
1st day	4·64 per cent.
2d "	4·70 "
3d "	6·07 "
4th "	3·27 "
5th "	5·26 "
6th "	2·05 "
7th "	2·39 "
8th "	3·85 "
9th "	3·05 "
10th "	7·16 "

The mean of the whole was 4·24 per cent. He has also given the

NOTE II. P. 13.

COMPOSITION OF DRY BLOOD (See Note 28).

	In 100 parts.	In 4·8 lbs. Hessian = 36,864 grains.
Carbon	51·96	19154·5
Hydrogen	7·25	2672·7
Nitrogen	15·07	5555·4
Oxygen	21·30	7852·0
Ashes	4·42	1629·4
	100.00	36864·0

Grains.		Grains.		
19154·5 carbon	form, with	50539·5	oxygen,	carbonic acid.
2672·7 hydrogen	do.	21415·8	do.	water.
	Sum =	71955·3	do.	
Deduct oxygen present in blood	=	7852·0	do.	
	Remain	64103·3	grains of oxygen, required	

for the complete combustion of 4·8 lbs. of dry blood. †

---

results of the examination of the air from the lungs of ten individuals, the average being 4·16 per cent. of carbonic acid gas. Dr. Prout found that the proportion of carbonic acid expired is different at different periods of the day, being at its maximum nearly about noon, and at its minimum about midnight. It further appears, from his trials, that the quantity begins to increase nearly at twilight. The mean of Dr. Prout's trials was 3·45 per cent. The mean of Mr. Coathupe's trials, continued for a week, was 4·02 per cent. ‡

According to Mr. Coathupe, if the population of Great Britain, Ireland, Scotland, and Wales be 26,500,000, (excluding the army and navy,) as quoted in Thomson's *British Annual*, 1839, we have no less than 10,342,957,234 cubic feet of carbonic acid gas, or 147,072 tons of carbon, as the present year's residuum from the respiration of the human beings now existing within the circumscribed boundaries of Great Britain and Ireland. — *Mech. Mag.*, XXXI., 454.

† Or 63685·6, H = 12·478 and C = 76·437.

MM. Macaire and Marcet analyzed dried arterial and venous

‡ Thomson's *Animal Chemistry*, Edin., 1843, p. 614.

3. Calculation,

with the help of the preceding data, of the amount of carbon expired by an adult man. The following results are deduced from observations made (see table) on the average daily consumption of food, by from 27 to 30 soldiers in barracks for a month, or by 855 men for one day. The food, consisting of bread, potatoes, meat, lentils, pease, beans, &c., was weighed with the utmost exactness, every day during a month (including even pepper, salt, and butter); and each article of food was separately subjected to ultimate analysis. The only exceptions, among the men, to the uniform allowance of food, were three soldiers of the guard, who, in addition to the daily allowance of 2 lbs. of bread, received, during each of the periods allotted for the pay of the troops, 2½ lbs. extra; and one drummer, who, in the same period, left 2½ lbs. unconsumed. According to an approximate report by the sergeant-major, each soldier consumes daily, on an average, out of barracks, 3 oz. of sausage, ¾ oz. of butter, ½ pint of beer, and $\frac{1}{10}$ pint of brandy; the carbon of which articles amounts to more than double that of the fæces and urine taken together. In the soldier, the fæces amount daily, on an average, to 5½ oz.; they contain 75 per cent. of water, and the dry residue contains 45·24 per cent. of carbon, and 13·15 per cent. of ashes. 100 parts of fresh fæces consequently contain 11·31 per cent. of carbon, very nearly the same proportion as in fresh meat. In the calculation, the carbon of the fæces and of the urine has been assumed as equal to that of the green vegetables and of the food (sausages, butter, beer, &c.) consumed in the alehouse.

From the observations, as recorded in the table, the following conclusions are deduced.

Flesh. — Meat devoid of fat, if reckoned at 74 per cent. water, and 26 per cent. dry matter, contains in 100 parts very nearly 13·6 parts of carbon. Ordinary meat contains both fat and cellular tissue, which together amount to ⅐th of the weight of the meat as bought from the butcher. The number of ounces consumed (by 855 men) was 4,448, consisting, therefore, of

3812·5 oz. of flesh, free from fat, containing of		carbon	518·5 oz.
635·5 oz. of fat and cellular tissue,		ditto	449·0 oz.
4448·0 oz.		In all, carbon	967·5 oz.

With the bones, the meat, as purchased, contains 29 per cent. of fixed matter; 4,448 oz. of flesh, therefore, contain 448 oz. of dry bones. These have not been included in the calculation, although, when boiled, they yield from 8 to 10 per cent. of gelatine, which is taken as food in the soup.

Fat. — The amount of fat consumed was 56 oz.; which, the carbon being calculated at 80 per cent., contain in all 44·8 oz. of carbon.

Lentils, pease, and beans. — There were consumed 53·5 oz. of lentils, 185·5 oz. of pease, and 218 oz. † of beans. Assuming the average amount of carbon in these vegetables to be 37 per cent., the total quantity of carbon consumed in this form was 169·1 oz.

Potatoes. — 100 parts of fresh potatoes contain 12·2 parts of carbon. In the 15,876 oz. of potatoes consumed, therefore, the amount of carbon was 1936·87 oz.

Bread. — 855 men eat daily 855 times 32 oz., besides

† According to the table, 222 oz.

TABLE II. — Note IV., page 14. *a.* †

FOOD CONSUMED BY A HORSE IN TWENTY-FOUR HOURS.

Articles of food.	Weight in the fresh state.	Weight in the dry state.	Carbon.	Hydro-gen.	Oxy-gen.	Nitro-gen.	Salts and earthy matters.
Hay	7500	6465	2961·0	323·2	2502·0	97·0	581·8
Oats	2270	1927	977·0	123·3	707·2	42·4	77·1
Water	16000	—	—	—	—	—	13·3
Total	25770	8392	3938·0	446·5	3209·2	139·4	672·2

EXCRETIONS OF A HORSE IN TWENTY-FOUR HOURS.

Excretions.	Weight in the fresh state.	Weight in the dry state.	Carbon.	Hydro-gen.	Oxy-gen.	Nitro-gen.	Salts and earthy mat-ters.
Urine	1330	302	108·7	11·5	34·1	37·8	109·9
Excrements	14250	3525	1364·4	179·8	1328·9	77·6	574·6
Total	15580	3827	1473·1	191·3	1363·0	115·4	684·5
Total from the previous part of this Table.	25770	8392	3938·0	446·5	3209·2	139·4	672·2
Difference	10190	4565	2464·9	255·2	1846·2	24·0	12·3
+ or —	—	—	—	—	—	—	+

a Boussingault, Ann. de Ch. et de Phys., LXX. 136. The weights in this table are given in grammes. 1 gramme = 15·44 grains Troy, very nearly.

† The discrepancy between the results of Table II. and those given

NOTE VI. P. 34.

The prisoners in the House of Arrest at Giessen receive daily 1½ lb. of bread (24 oz.), which contain 7¼ oz. of carbon. They receive, besides, 1 lb. of soup daily, and, on each alternate day, 1 lb. of potatoes.

1½ lb. of bread contains . .	7·25 oz.	of carbon.
1 lb. of soup contains . .	0·75	ditto.
½ lb. of potatoes contains . .	1·00	ditto.
Total . .	9·00	ditto.†

NOTE VII. P. 42.

COMPOSITION OF THE FIBRINE AND ALBUMEN OF BLOOD, *a*.

	Albumen from Serum of Blood.			Fibrine.		
	Scherer.*			Scherer.*		Mulder.
	I.	II.	III.	I.	II.	III.
Carbon . .	53·850	55·461	56·097	53·671	54·454	54·56
Hydrogen .	6·983	7·201	6·880	6·878	7·069	6·90
Nitrogen .	15·673	15·673	15·681	15·763	15·762	15·72
Oxygen, Sulphur, Phosphorus	23·494	21·655	22·342	23·688	22·715	22·82

a Annalen der Chem. und Pharm., XXVIII., 74., and XL., 33, 36.

For additional analyses of animal fibrine and albumen, see Note XXVII., which also contains analyses of the various animal tissues.

† At page 34 the carbon contained in the daily food of these prisoners is calculated at 8½ oz., and the Appendix in the original makes the number also 8·5, apparently by an error in adding up the above numbers, which yield the sum of 9 oz. Possibly there may be an error in excess in the proportion of carbon calculated for the soup, which, in that case, ought to be 0·25 oz. — *G.*

NOTE VIII. P. 47.

COMPOSITION OF VEGETABLE FIBRINE, VEGETABLE ALBUMEN, VEGETABLE CASEINE, AND VEGETABLE GLUTEN.

	Vegetable Fibrine.				Gluten. As obtained from wheat flour.	
	Scherer.*a			Jones.*b	Marcet.c	Boussingault.
	I.	II.	III.	IV.	I.	II.
Carbon	53·064	54·603	54·617	53·83	55·7	53·5
Hydrogen	7·132	7 302	7·491	7·02	14·5	15·0
Nitrogen	15·359	15·809	15·809	15 58	7·8	7·0
Oxygen, Sulphur, Phosphorus	24·445	22·285	22·083	23·56	22·0	24·5

a Ann. der Chem. und Pharm., XL., 7.
b Ibid., XL., 65.
c L. Gmelin's Theor. Chemie, II., 1092.

Vegetable Albumen. *a*

	From Rye. Jones.*	From Wheat. Jones.*	From Gluten. Varrentrapp & Will.*	From Almonds. Jones.*
Carbon	54·74	55·01	54·85	57·03
Hydrogen	7·77	7·23	6·98	7·53
Nitrogen	15·85	15·92	15·88	13·48
Oxygen, Sulphur, Phosphorus	21·64	21·84	22·39	21·96

	Boussingault.	Varrentrapp and Will.*
Carbon	52·7	——
Hydrogen	6·9	——
Nitrogen	18·4	15·70
Oxygen, &c.	22·0	——

a Ann. der Chem. und Pharm., XL., 66, and XXXIX., 291.

	Mulder.[a]
Carbon	54·96
Hydrogen	7·15
Nitrogen	15·80
Oxygen	21·73
Sulphur	0·36

[a] For the analysis of vegetable caseine, see the preceding note.

NOTE X. P. 63.

AMOUNT OF MATTER SOLUBLE IN ALCOHOL IN THE SOLID EXCREMENTS OF THE HORSE AND COW. (WILL.*)

18·3 grammes of dried horse-dung lost, by the action of alcohol, 0.995 gramme. The residue, when dry, had the appearance of sawdust, after it has been deprived, by boiling, of all soluble matter.

14·98 grammes of dry cow-dung lost, by the same treatment, 0·625 gramme.

NOTE XI. P. 68.

COMPOSITION OF STARCH.[a]

	Calculated $C_{12} H_{10} O_{10}$.	Strecker.* From Pease.	From Lentils.	From Beans.	From Buckwheat.
Carbon	44·91	44·33	44·46	44·16	44·23
Hydrogen	6·11	6·57	6·54	6·69	6·40
Oxygen	48·98	49·09	49·00	49·15	49·37

Analysis of Hay.

100 parts of hay, dried in the air, contain 86 of dry matter.
14 of water.

100

100 parts of hay, dried at 212°, = 116·2 parts dried in air, contain

Carbon	45·8
Hydrogen	5·0
Oxygen	38·7
Nitrogen	1·5
Ashes	9·0
	100·0
	16·2 water.
	116·2 hay dried in the air.

100·0 of hay, dried at the ordinary temperature, contain 1·29 of nitrogen.

240 oz. of such hay = 15 lbs. contain	3·096 oz. of nitrogen.	
72 oz. of oats = 4½ lbs. contain	1·344	ditto.
Total	4·440	

NOTE XVI. (a.) P. 74.

AMOUNT OF CARBON IN FLESH AND IN STARCH.

100 parts of starch contain 44 of carbon; therefore, 64 oz. (4 lbs.) contain 28·16 oz. of carbon.

100 parts of fresh meat contain 13·6 of carbon (see Note III.); hence 240 oz. (15 lbs.) contain 32·64 oz. of carbon. †

† By an error in calculation in the original, the amount of carbon in 15 lbs. of meat is stated to be 27·64 oz. It follows that the carbon of 4 lbs. of starch is not equal, as stated in the text, to that of 15 lbs. of flesh, but to that of 13 lbs. This difference, however, is not sufficient to affect the argument at p. 74. — *G.*

NOTE XVI. (b.) P. 81.

COMPOSITION OF

	Hog's lard.	Mutton fat. Chevreul. a	Human fat.
Carbon . .	79·098	78·996	79·000
Hydrogen . .	11·146	11·700	11·416
Oxygen . .	9·756	9·304	9·584

a Recherches Chim. sur les corps gras. Paris. 1823.

NOTE XVII. P. 81.

COMPOSITION OF CANE SUGAR.

According to

	Berzelius.	Prout.	W. Crum.	Liebig.*	Gay-Lussac & Thénard.	Calculated $C_{12}H_{11}O_{11}$.
Carbon	42·225	42·86	42·14	42·301	42·47	42·58
Hydrogen	6·600	6·35	6·42	6·384	6·90	6·37
Oxygen	51·175	50·79	51·44	51·315	50·63	51·05

For the composition of gum and of starch, see Notes (14) and (11).

NOTE XVIII. P. 82.

COMPOSITION OF CHOLESTERINE.

According to

	Chevreul. a	Couerbe. b	Marchand.	Calculated $C_{36}H_{32}O$.
Carbon	85·095	84·895	84·90	84·641
Hydrogen	11·880	12·099	12·00	12·282
Oxygen	3·025	3·006	3·10	3·077

a Recherches sur les corps gras, p. 185.
b Ann. de Ch. et de Phys., LVI., 164.

really nourishment for bees, they ought to be able to support life on it, mixed with water.

Bees never build honeycomb unless they have a queen, or are provided with young out which of they can educate a queen. But, if bees be shut up in a hive without a queen, and fed with honey, we can perceive in forty-eight hours that they have laminæ of wax on their scales, and that some have even separated. The building of cells is, therefore, voluntary, and dependent on certain conditions; but the oozing of wax is involuntary.

One might suppose that a large proportion of these laminæ must be lost, since the bees may allow them to fall off, out of the hive as well as in it; but the Creator has wisely provided against such a loss. If we give to bees engaged in building cells honey in a flat dish, and cover the dish with perforated paper, that the bees may not be entangled in the honey, we shall find, after a day, that the honey has disappeared, and that a large number of laminæ are lying on the paper. It would appear as if the bees, which had carried off the honey, had let fall the scales; but it is not so. For, if above the paper we lay two small rods, and on these a board, overhanging the dish on every side, so that the bees can creep under the board and obtain the honey, we shall find next day the honey gone, but no laminæ on the paper; while laminæ will be found in abundance on the board above. The bees, therefore, which go for and bring the honey, do not let fall the laminæ of wax, but only those bees which remain hanging to the top of the hive. Repeated experiments of this kind have convinced me that the bees, as soon as their laminæ of wax are mature, return to the hive

On the 5th of September I stupefied the bees, by means of puff-ball, and counted them. Their number was 2,765, and they weighed 10 oz. I next weighed the hive, the combs of which were well filled with honey, but the cells not yet closed; noted the weight, and then allowed the honey to be carried off by a strong swarm of bees. This was completely effected in a few hours. I now weighed it a second time, and found it 12 oz. lighter; consequently the bees still had in the hive 12 [17?] oz. of the 29 oz. of honey given to them. I next extracted the combs, and found that their weight was $\frac{5}{8}$ of an ounce. I then placed the bees in another box, provided with empty combs, and fed them with the same honey as before. In the first few days they lost daily rather more than 1 oz. in weight, and afterwards half an ounce daily, which was owing to the circumstance, that, from the digestion of so much honey, their intestinal canal was loaded with excrements; for 1,170 bees, in autumn, when they have been but a short time confined to the hive, weigh 4 oz.; consequently 2,765 bees should weigh 9 oz. But they actually weighed 10 oz., and therefore had within them 1 oz. of excrement, for their honey bladders were empty. During the night the weight of the box did not diminish at all, because the small quantity of honey the bees had deposited in the cells, having already the proper consistence, could not lose weight by evaporation, and because the bees could not then get rid of their excrements. For this reason, the loss of weight occurred always during the day.

If, then, the bees, in seven days, required $3\frac{1}{2}$ oz. of honey to support and nourish their bodies, they must have consumed $13\frac{1}{2}$ oz. of honey in forming $\frac{5}{8}$ of an ounce of wax; and consequently, to form 1 lb. of wax, 20 lbs. of honey are required. This is the reason why the strongest swarms, in the best honey seasons, when other hives, that have no occasion to build, often gain in one day 3 or 4 lbs. in weight, hardly become heavier, although their activity is boundless. All that they gain is expended in making wax. This is a hint for those who keep bees, to limit the building of comb. Cnauf has already recommended this, although he was not acquainted with the true relations of the subject. From 1 oz. of wax, bees can build cells enough to contain 1 lb. of honey.

100 laminæ of wax weigh 0·024 gramme (rather more than $\frac{1}{3}$ of a grain); consequently, 1 kilogramme (= 15,360 grains) will contain 4,166,666 laminæ. Hence, $\frac{5}{8}$ of an ounce will contain 81,367 laminæ. Now this quantity was produced by 2,765 bees in six days; so that the bee requires for the formation of its 8 laminæ (one crop) about thirty-eight hours, which agrees very well with my observations.

The laminæ, when formed, are as white as bleached wax. The cells, also, at first, are quite white, but they are colored yellow by the honey, and still more by the pollen. When the cold weather comes on, the bees retire to the hive under the honey, and live on the stock they have accumulated.

P. 54. Many believe that bees are hybernating animals; but this opinion is quite erroneous. They are lively throughout the winter; and the hive is always warm, in consequence of the heat which they generate. The more numerous the bees in a hive, the more heat is developed; and hence strong hives can resist the most in-

NOTE XXI. (a.) P. 100.

COMPOSITION OF HYDRATED CYANURIC ACID, OF HYDRATED CYANIC ACID, AND OF CYAMELIDE, IN 100 PARTS, ACCORDING TO THE ANALYSIS OF

	Wöhler and Liebig.* a Cyanuric acid, cyanic acid, cyamelide.
Carbon	28·19
Hydrogen	2·30
Nitrogen	32·63
Oxygen	36·87

a Poggendorff's Annalen, XX., 375 et seq.

NOTE XXI. (b.) P. 100.

COMPOSITION OF ALDEHYDE, METALDEHYDE, AND ELALDEHYDE. a

	Aldehyde. Liebig.*	Metaldehyde. Fehling.*	Elaldehyde.		Calculated $C_4 H_4 O_2$.
Carbon	55·024	54·511	54·620	54·467	55·024
Hydrogen	8·983	9·054	9·248	9·075	8·983
Oxygen	35·993	36·435	36·132	36·458	35·993

a Ann. der Pharm., XIV., 142, and XXVII., 319.

NOTE XXII. P. 101.

COMPOSITION OF PROTEINE.

	From the crystalline lens.	From albumen. Scherer.* a	From fibrine.
Carbon . .	55·300	55·160	54·848
Hydrogen .	6·940	7·055	6·959
Nitrogen .	16·216	15·966	15·847
Oxygen .	21·544	21·819	22·346

	Scherer.* *a* From hair.		From horn.		Calculated $C_{48} H_{36} N_6 O_{14}$.
Carbon	54·746	55·150	55·408	54·291	55·756
Hydrogen	7·129	7·197	7·238	7·082	6·826
Nitrogen	15·727	15·727	15·593	15·593	16·142
Oxygen	22·398	21·926	21·761	23·034	21·276

a Ann. der Chem. und Pharm., XL., 43.

	From vegetable albumen.	From fibrine.	From albumen.	From cheese.
	Mulder. *a*			
Carbon . .	54·99	55·44	55·30	55·159
Hydrogen .	6·87	6·95	6·94	7·176
Nitrogen .	15·66	16·05	16·02	15·857
Oxygen .	22·48	21·56	21·74	21·808

a Ann. der Pharm., XXVIII., 75.

NOTE XXIII. P. 103.

COMPOSITION OF THE ALBUMEN OF THE YOLK AND OF THE WHITE OF THE EGG. *a*

	From the yolk. Jones.* I.	II.	From the white. Scherer *
Carbon	53·72	53·45	55·000
Hydrogen	7·55	7·66	7·073
Nitrogen	13·60	13·34	15·920
Oxygen, Sulphur, Phosphorus	25·13	25·55	22·007

a Ann. der Chem. und Pharm., XL, 36; ibid. 67.

NOTE XXIV. P. 107.

COMPOSITION OF LACTIC ACID.

	$C_6H_5O_5$.
Carbon	44·92
Hydrogen	6·11
Oxygen	48·97

NOTE XXVIII. P. 127.

According to the analyses of Playfair and Boeckmann,

0·452 parts of dry muscular flesh gave 0·836 of carbonic acid.
0·407 . . . . 0·279 of water. [of water.
0·242 . . . . 0·450 of carbonic acid and 0·164
0·191 . . . . 0·360 . . . 0·130
0·305 of dried blood gave 0·575 of carbonic acid and 0·202 of water.
0·214 . . . . 0·402 . . . . . 0·138
1·471 of dried blood, when calcined, left 0·065 of ashes = 4·42 per cent.
The dried flesh was found to contain of ashes 4·23 per cent.
The nitrogen was found to be to the carbon as 1 to 8 in equivalents.

Hence, —

	Flesh (beef).		Ox-blood.		Blood.
	Playfair.	Boeckmann.	Playfair.	Boeckmann.	Mean of 2 analyses.
Carbon	51·83	51·89	51·95	51·96	51·96
Hydrogen	7·57	7·59	7·17	7·33	7·25
Nitrogen	15·01	15·05	15·07	15·08	15·07
Oxygen	21·37	21·24	21·39	21·21	21·30
Ashes	4·23	4·23	4·42	4·42	4·42

Deducting the ashes or inorganic matter, the composition of the organic part is,

Carbon . .	54·12	54·18	54·19	54·20
Hydrogen .	7·89	7·93	7·48	7·65
Nitrogen . .	15·67	15·71	15·72	15·73
Oxygen . .	22·32	22·18	22·31	22·12

This corresponds to the formula

C_{48}	54·81
H_{39}	6·91
N_{6}	15·87
O_{15}	22·41

An excellent method of detecting the presence of cystic oxide in calculi or gravel is the following.

The calculus is dissolved in a strong solution of caustic potash, and to the solution is added so much of a solution of acetate of lead, that all the oxide of lead is retained in solution. When this mixture is boiled, there is formed a black precipitate of sulphuret of lead, which gives to the liquid the aspect of ink. Abundance of ammonia is also disengaged; and the alkaline fluid is found to contain, among other products, oxalic acid.

NOTE XXXIII. P. 131.

COMPOSITION OF OXALIC, OXALURIC, AND PARABANIC ACIDS.

1. Oxalic Acid (hydrated).

	Gay-Lussac & Thénard.	Berthollet.	Calculated $C_2 O_3 + HO$.
Carbon	26·566	25·13	27·04
Hydrogen	2·745	3·09	2·21
Oxygen	70·689	71·78	70·75

2. Oxaluric Acid. a

	Wöhler and Liebig.*		Calculated $C_6 H_4 N_2 O_8$.
Carbon	27·600	27·318	27·59
Hydrogen	3·122	3·072	3·00
Nitrogen	21·218	21·218	21·29
Oxygen	48·060	48·392	48·12

a Ann. der Pharm., XXVI., 589.

3. Parabanic Acid. a

	Wöhler and Liebig.*		
Carbon	31·95	31·940	31,91
Hydrogen	2·09	1·876	1·73
Nitrogen	24·66	24·650	24·62
Oxygen	41·30	41·534	41·74 †

a Ann. der Pharm., XXVI., 286. † Calculated $C_3 H_1 N_1 O_3$.

NOTE XXXIV. P. 132.

COMPOSITION OF ROASTED FLESH.

(1.) 0.307 of flesh gave 0·584 of carbonic acid and 0·206 of water.
(2.) 0·255 do. 0·485 do. 0·181 do.
(3.) 0·179 do. 0·340 do. 0·125 do.

Hence, —

	Flesh of roedeer (1).	Flesh of beef (2).	Flesh of veal (3).
	Boeckmann.*	Playfair.*	
Carbon	52·60	52·590	52·52
Hydrogen	7·45	7·886	7·87
Nitrogen	15·23	15·214	14·70
Oxygen / Ashes	24·72	24·310	24·91

NOTE XXXV. P. 135.

The formula $C_{108} H_{84} N_{18} O_{40}$, or $C_{54} H_{42} N_{9} O_{20}$, gives, when reduced to 100 parts,

C_{54}	50·07
H_{42}	6·35
N_{9}	19·32
O_{20}	24·26

Compare this with the composition of gelatine, as given in Note (27).

NOTE XXXVII. P. 146.

COMPOSITION OF LITHOFELLIC ACID. a

	Ettling and Will.*			Wöhler.	Calculated $C_{40} H_{36} O_{8}$
Carbon	71·19	70·80	70·23	70·83	70·99
Hydrogen	10·85	10·78	10·95	10·60	10·44
Oxygen	17·96	18·42	18·92	18·57	18·57

a Ann. der Chem. und Pharm., XXXIX., 242, XLI., 154.

NOTE XLI. P. 168.

COMPOSITION OF MORPHIA. a

	Liebig.*	Regnault.		Calculated $C_{35} H_{20} NO_6$.
Carbon	72·340	72·87	72·41	72·27
Hydrogen	6·366	6·86	6·84	6·73
Nitrogen	4·995	5·01	5·01	4·78
Oxygen	16·299	15·26	15·74	16·22

a Ann. der Pharm., XXVI., 23.

NOTE XLII. P. 168.

COMPOSITION OF CAFFEINE, THEINE, GUARANINE, THEOBROMINE, AND ASPARAGINE.

	Caffeine. a Pfaff and Liebig.*	Théine. b Jobst.	Guaranine. c Martius.	Calculated $C_8 H_5 N_2 O_2$.
Carbon . .	49·77	50·101	49·679	49·798
Hydrogen .	5·33	5·214	5·139	5·082
Nitrogen . .	28·78	29·009	29·180	28·832
Oxygen . .	16·12	15·676	16·002	16·288

a Ann. der Pharm., I., 17.
b Do. XXV., 63.
c Do. XXVI., 95.

Guaranine is the name given to the crystallized principle of the *guarana officinalis*, till it was shown to be identical with caffeine and théine, as the above analyses demonstrate.

COMPOSITION OF THEOBROMINE. a

	Woskresensky.			Calculated $C_9 H_5 N_3 O_2$.
Carbon	47·21	46·97	46·71	46·44
Hydrogen	4·53	4·61	4·52	4·21
Nitrogen	35·38	35·38	35·38	35·84
Oxygen	12·88	13·04	13·39	13·51

a Ann. der Chem. und Pharm., XLI., 125.

COMPOSITION OF ASPARAGINE. *a*

	Liebig.*	Calculated $C_8 H_8 N_2 O_6 + 2 HO$.
Carbon	32·351	32·35
Hydrogen	6·844	6·60
Nitrogen	18·734	18·73
Oxygen	42·021	42·32

a Ann. der Pharm., VII., 146.

NOTE XLIII. P. 143, 167.

ON THE CONVERSION OF BENZOIC ACID INTO HIPPURIC ACID. †

By Wilhelm Keller.

(From the Annalen der Chemie und Pharmacie.)

So early as in the edition of Berzelius's "Lehrbuch der Chemie," published in 1831, Professor Wöhler had expressed the opinion, that benzoic acid, during digestion, was probably converted into hippuric acid. This opinion was founded on an experiment which he had made on the passage of benzoic acid into the urine. He found in the urine of a dog, which had eaten half a drachm of benzoic

† To the evidence produced by A. Ure, of the conversion of benzoic acid into hippuric acid in the human body, M. Keller has added some very decisive proofs, which I append to this work on account of their physiological importance. The experiments of M. Keller were made in the laboratory of Professor Wöhler, at Göttingen; and they place beyond all doubt the fact that a non-azotized substance taken in the food can take a share, by means of its elements, in the act of transformation of the animal tissues, and in the formation of a secretion. This fact throws a clear light on the mode of action of the greater number of remedies; and, if the influence of caffeine on the formation of urea or uric acid should admit of being demonstrated in a similar way, we shall then possess the key to the action of quinine and of the other vegetable alkalies. — *J. L.*

acid with his food, an acid crystallizing in needle-shaped prisms, which had the general properties of benzoic acid, and which he then took for benzoic acid. (Tiedemann's Zeitschrift für Physiologie, i. 142.) These crystals were obviously hippuric acid, as plainly appears from the statements, that they had the aspect of nitre, and, when sublimed, left a residue of carbon. But at that time hippuric acid was not yet discovered; and it is well known, that, till 1829, when these acids were first distinguished from each other by Liebig, it was uniformly confounded with benzoic acid.

The recently published statement of A. Ure, that he actually found hippuric acid in the urine of a patient who had taken benzoic acid, recalled this relation, so remarkable in a physiological point of view, and induced me to undertake the following experiments, which, at the suggestion of Professor Wöhler, I made on myself. The supposed conversion of benzoic acid into hippuric acid has, by these experiments, been unequivocally established.

I took, in the evening, before bedtime, about thirty-two grains of pure benzoic acid in syrup. During the night I perspired strongly, which was probably an effect of the acid, as in general I am with great difficulty made to transpire profusely. I could perceive no other effect, even when, next day, I took the same dose three times; indeed, even the perspiration did not again occur.

The urine passed in the morning had an uncommonly strong acid reaction, even after it had been evaporated, and had stood for twelve hours. It deposited only the usual sediment of earthy salts. But when it was mixed with muriatic acid, and allowed to stand, there were formed in it long, prismatic, brownish crystals, in great quantity, which, even in this state, could not be taken for benzoic acid. Another portion, evaporated to the consistence of syrup, formed, when mixed with muriatic acid, a magma of crystalline scales. The crystalline mass was pressed, dissolved in hot water, treated with animal charcoal, and recrystallized. By this means the acid was obtained in colorless prisms, an inch in length.

These crystals were pure hippuric acid. When heated, they melted easily; and, when exposed to a still stronger heat, the mass was carbonized, with a smell of oil of bitter almonds, while benzoic acid sublimed. To remove all doubts, I determined the proportion of carbon in the crystals, which I found to be 60·4 per cent. Crystallized hippuric acid, according to the formula $C_{18} H_8 NO_5 + HO$, contains 60·73 per cent. of carbon; crystallized benzoic acid, on the other hand, contains 69·10 per cent. of carbon.

As long as I continued to take benzoic acid, I was able easily to obtain hippuric acid in large quantity from the urine; and since the benzoic acid seems so devoid of any injurious effect on the health, it would be easy in this way to supply one's self with large quantities of hippuric acid. It would only be necessary to engage a person to continue for some weeks this new species of manufacture.

It was of importance to examine the urine which contained hippuric acid, in reference to the two normal chief constituents, urea and uric acid. Both were contained in it, and apparently in the same proportion as in the normal urine.

The inspissated urine, after the hippuric acid had been separated by the muriatic acid, yielded, on the addition of

NOTE (B.) P. 165.

ENDOSMOSE AND EXOSMOSE.

If we place the lower end of an open tube, which has been covered with a thin membrane, such as a piece of moistened bladder, in a vessel of water, and pour a solution of sugar into the tube, the water from the vessel will shortly be found to pass into the tube, and the column of liquid will increase in height. At the same time, the water in the vessel will become slightly sweet; a small quantity of syrup having passed through the pores of the bladder into the water without, while a much larger portion of water has entered the tube. The water will continue to enter the tube, and the syrup to leave it, until the two liquids are nearly of the same density. A solution of gum, salt, or other substances may be employed instead of sugar. If two solutions be employed, as, for instance, sugar or gum within the tube, and potash or soda without, a circulation will in like manner take place. Instead of animal membrane, any vegetable matter with fine pores, such as a thin piece of wood, or any porous mineral substance, may be substituted without affecting the result. Dutrochet, the discoverer of these phenomena, gave the name of *Endosmose* to the inward, and that of *Exosmose* to the outward movement. He supposed them to be due to two opposite currents of electricity.—Dutrochet's hypothesis has not been confirmed. It does not constantly happen that the denser fluid attracts more of the thinner than the latter does of the former; in the case of gases, especially, the contrary is seen to be sometimes the case.

INDEX.

A.

C.

F.

I.

J.

K.

L.

M.

Q.

T.

Y.