Atlee (W. 2)

The Chemical relations of the Human body x x x

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With the respects of the Author

THE CHEMICAL RELATIONS

OF THE

HUMAN BODY

WITH

SURROUNDING AGENTS.

A Lecture Introductory to a Course

ON

MEDICAL CHEMISTRY

IN THE

MEDICAL DEPARTMENT

OF

PENNSYLVANIA COLLEGE,

FOR THE SESSION OF 1845-46,

BY WASHINGTON L. ATLEE, M. D.

PUBLISHED BY THE CLASS.

NOVEMBER, 1845.

PHILADELPHIA:
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1845.

CORRESPONDENCE.

Philadelphia, Nov. 10th, 1844.

Dear Sir:—We have great pleasure in conveying to you the wish expressed by the Class in the Medical Department of Pennsylvania College, to obtain a copy of your instructive introductory lecture for publication, believing as we do, that it contains, in a condensed form, much information useful and interesting to them and us as students of medicine.

With much respect,
We have the honor to be yours, &c.
BENJAMIN F. CHATHAM, New Jersey.
HENRY S. HUBER, Illinois.
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Prof. W. L. Atlee.

No. 3, Colonnade Row,
Philada., Nov. 17th, 1845.

Gentlemen:—Your note, soliciting a copy of my introductory lecture for publication has been received. As you consider it worthy of such distinguished honor, it is at your disposal—although I fear that your kind indulgence has led you to overrate its merits.

That the information it embodies may prove "useful and interesting," is the sincere desire of

Your humble and obedient servant,
WASHINGTON L. ATLEE.

To Messrs. Chatham, Huber, and others, Committee.

INTRODUCTORY.

GENTLEMEN:

The round of events has brought us again together. The circumstances, however, which marked our first interview, widely differ from those which characterize the present. Then, I met you as a stranger, personally unknown to most of you, and—save my warm-hearted and respected friend, the Professor of Surgery—to my colleagues. Thus we met, with mingling hopes and fears for the result of the undertaking, and for the character of our intercourse, to sustain the walls of a new, noble, yet unestablished institution. Now, many of us meet as friends, greeting each other with a hearty welcome, assured that Pennsylvania College is truly the key-stone of an arch, binding the schools together to perpetuate the high medical reputation of Philadelphia, and, by the efforts of a band of brothers, to be made the *fastening-stone* forever. Then, it was the entrance upon the stage as a public teacher, with all the unquiet feelings incident to so responsible and novel a position. Now, the initiation is passed; and, although disquietude may still remain, your familiar and approving countenances infuse a confidence unknown before. Then, I ventured to strike out for myself a new course of teaching, and to hazard the results—convinced that medical schools, generally, failed to give a proper medical bearing to their chemical chair, and that mistaken views, consequent upon the mode of teaching, had been taken by the student, of the utility of this essential part of medical education. Now, after one session of probation—a session marked by the most gratifying results, by repeated assurances of the class of a new interest excited in this study, and by unmistaken evidences of their improvement—I enter upon my duties with the full conviction that the plan is correct, and with an honest endeavor to carry out this plan to the best of my humble abilities.

In my opening lecture of last session, I pointed out to you, in a general way, some of the many relations which chemistry bears to the science of medicine, and attempted to prove that a proper knowledge of chemistry was necessary to the formation of the accomplished physician. I also stated that the principles of the science were common to all its branches, requiring as much attention in the study of medical chemistry as in that of any other form. Consequently, the earliest period of the course was devoted to their consideration, after which the imponderables, the simple bodies, and their combinations, and organic chemistry followed in proper order. No time was spent in exhibiting the chemical character of any substance having no medicinal properties, or no physiological, pathological, or hygienic relations to the animal system. The whole list, however, of chemical elements, and their combinations, with their symbol, equivalent number, and composition, was arranged upon a series of charts, always suspended before you—those substances being marked to which your particular attention was required. The lectures were abundantly illustrated by diagrams and by simple experiments, and the rationale of every chemical process was carefully studied out. To be certain that what I taught was fully comprehended, and in order to secure close attention, the class underwent daily examinations, and the important points of each lecture were thus revived in the most familiar and impressive manner. These were some of the characteristics of the course of last session, the general plan of which will be carried out in this, modifying the details wherever it will be advantageous to the class.

Without further reference to the character of our course, I propose, in continuation of the subject of my first introductory lecture, now to consider the chemical relations of the animal body with some of those agents which are perpetually acting upon it—in order to give you a foretaste of certain parts of our course; to stimulate you to early inquiry in a branch of study so intimately interwoven with every link of organic structure; and to disclose the bold attempt of chemical philosophers to bring vital phenomena within the range of demonstrative science. I would here, however, premise that in stating the chemico-physiological doctrines of the present day, I do not wish to be understood as giving my sanction implicitly to them.

In contemplating these relations, the first necessary inquiry will be into the chemical constitution of the animal body, and that of the agents interested in contributing to the manifold operations of organic life. When this is known, the proportion of the several elements decided, and their respective affinities estimated, the destination of each may be determined; their combination with each other, and their separation, in the functions of nutrition and decay, observed; and the animal organism will be studied with peculiar interest, and viewed as a laboratory of singular and surpassing beauty.

What, then, is the structure of animal fibre? If we examine separately the several parts of the body—the osseous, muscular, nervous, ligamentous, and other tissues—and bring together the elements which chemical analysis has detected in each of them, we will discover that the essential constituents of the human body are Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Sulphur, Iron, Chlorine, Sodium, Calcium, Potassium, Magnesium, and Fluorine—thirteen in number—Carbon, Hydrogen, Oxygen, and Nitrogen being the most important.

Now we all know that matter cannot be annihilated; that its elements cannot be changed one into another; that it cannot, by any process known to man, be created out of that which has no existence; and that the primitive elements of nature must exist forever the same, and as unchangeable as is that Power who first called them into existence, for a wise purpose, to serve in all mundane operations until His mandate shall dissipate them with the same breath that proclaims "time shall be no more." Consequently the body has no power to form an element, or to convert one element into another, or to destroy it. It is manifest, therefore, that these thirteen constituents must be furnished to the system from without; that the various secretions and excretions of the body are formed of the same elements; and that nothing can contribute to the healthy functions of the organs that is devoid of all these constituents. The elements of the body, then, must form a sure index to the chemical character of the food, and alimentary substances, like the contents of an alembic, can be supplied to the body to produce certain results. The elements of nutrition, however, never exist separately as aliment, but are associated under the various forms in which we daily meet with them. Let us refer to them, and see how intimately they correspond with the constituents of our bodies.

According to Liebig, the diet of man consists essentially of two parts—*nitrogenized* and *non-nitrogenized* food, a distinction which is one of his most important generalizations. The former he calls "*the plastic elements of nutrition*," being supposed alone capable of conversion into blood, and of assimilation to the various organs and tissues, and containing a peculiar principle, called *proteine*, essential to existence. The latter he names "*elements of respiration*," because their most obvious and important use is to support respiration and to produce animal heat, not being employed in the formation of blood and the nutrition of the tissues, but equally essential to the continuance of life. Among the nitrogenized principles are vegetable fibrine, vegetable albumen, vegetable caseine, animal flesh, and animal blood. Among the non-nitrogenized principles are fat, starch, gum, sugar, &c.

Although this peculiar principle, proteine, exists in the plastic elements of nutrition, it has no separate and distinct existence, in organic structure, but is associated with mineral and organized substances, constituting fibrine, albumen, and caseine, the so-called proteinaceous or nitrogenous aliments. Proteine consists of carbon, hydrogen, nitrogen, and oxygen. Add sulphur, and we have *Caseine.* Add sulphur and phosphorus, and *Albumen* is the product. Reduce the quantity of sulphur in the albumen, and *Fibrine* is formed: so that proteine is the base of all these alimentary principles.

Caseine is derived from milk, which is composed of caseine, butter, sugar of milk, salts of soda, lime, magnesia, iron, and the chloride of potassium. It also exists in leguminous and oily seeds, and in some of the vegetable juices.

Albumen is found in eggs, the serum of the blood, in flesh, glands, and in the viscera of animals, &c. Besides this, we find in these substances chlorine, potash, soda, lime, magnesia, and their carbonates, phosphates and sulphates. It is likewise found in the cereal grasses, oily seeds, and most of the vegetable juices.

Fibrine constitutes the greater part of the crassamentum of the blood, forms the base of muscular fibre, and exists in some other animal tissues. It is also abundant in the seeds of the cereal grasses, in buckwheat, the juice of grapes, and in the newly-expressed juices of most vegetables.

Pure gluten is also classed, by Pereira, among the vegetable proteinaceous compounds, agreeing with them in composition, and is found in the cereal grains, and several other esculent vegetables.

In this general reference to the analysis of the nitrogenized foods, you perceive the elements are the same as the essential constituents of the human body, with the exception of fluorine, which is not contained in the above list. Pereira is of opinion that if fluorine is a normal constituent of the body, it is introduced into the system in the small portions of the bones of animals occasionally swallowed with their flesh, Berzelius having detected minute quantities of fluoride of calcium in the bones of animals.

Now, proteine is the source of the organic nitrogenized constituents of the body, which are formed from it by the agency of oxygen or of the elements of water, and by resolution into two or more compounds. If, then, proteine be the base of organic structure, it is interesting to inquire after the origin of proteine. Recent researches of chemical philosophers have disclosed the beautiful and important fact that the proteinaceous compounds are alone produced in the vegetable organism, and that the various tissues of the animal body depend for their formation upon these vegetable principles, their development being aided by the action of other chemical agents, and the vital force. How peculiarly interesting is this connection between two of the great kingdoms of nature! How perfectly adapted are the works of creation one to another! In confirmation of the fact that proteine is the base of organic structure, Liebig refers to an egg during the process of incubation: feathers, claws, globules of blood, fibrine, membrane, and cellular tissue, arteries and veins are produced from albumen, a proteinaceous compound, merely by the action of the oxygen of the air.

If, therefore, all the tissues of the body are derived from these compounds of proteine, certain elements must be added to them or taken away. Let us notice a few of the chemical changes occurring in the formation of tissues. The formula for proteine, according to Mulder, is C40, N5, H31, and O12. If, to this formula, we add N, H, and O, or the known compounds of ammonia and water, with oxygen, we produce the gelatinous or membranous tissues. If we merely add H and O, elements furnished by water, with oxygen, we form cartilage. Again, the addition of N, H, and O, or ammonia and O, produces hair; and H and O, or simple water, united with proteine, are the constituents of arterial membrane. Thus:

Gelatinous Tissues.

2 eqs. of Proteine	=80C,	10N,	62H,	24O.
3 " NH^3	-	3,	9,	-
1 " OH	-	-	1,	1
7 " O	-	-	-	7
	—	—	—	—
Gelatinous tissue	=80	13,	72,	32

Chondrine—substance of the cartilages of the ribs.

1 eq. of Proteine	=40C,	5N,	31H,	12O.
4 eqs. OH	-	-	4,	4
2 " O	-	-	-	2
Chondrine	=40,	5,	35,	18

Hair, Horn.

1 eq. of Proteine	=40,	5,	31,	12
1 " NH^3	-	1,	3,	-
3 eqs. O	-	-	-	3
Hair, Horn	=40,	6,	34,	15

Arterial Membrane.

1 eq. of Proteine	=40,	5,	31,	12
2 eqs. OH	-	-	2,	2
Arterial membrane	=40,	5,	33,	14

In all of these changes you observe that one of the elements (carbon) has remained without variation, that an increased quantity of oxygen has been taken up in every instance, and that the hair and gelatinous membranes require an excess of N and H, they being in the proportions to form ammonia.

There is, however, another class of substances, having a wholly different purpose, and yet necessary to the full completion of chemical action in the animal laboratory. I mean the non-nitrogenized foods or elements of respiration, above alluded to, which the school of Giessen says cannot enter into the formation of blood, or into organized or living tissues, but are essential to health and contribute to the formation of fat. Several circumstances have induced recent writers to conclude that the nitrogenized foods were the only ones properly so called, although it does not appear improbable that, under certain circumstances, non-nitrogenized foods may be converted into nitrogenized constituents of the human body. Dr. Ure has shown that when Benzoic acid, a non-nitrogenous substance, is taken into the stomach, it appears in the urine as hippuric acid, a nitrogenous compound. This is supposed to be caused by lactate of urea, which contains the requisite proportion of N. Dr. Pereira, also, has offered some reasonable objections to this view of the case, but the weight of testimony would seem to be in favor of nitrogenized foods being the real pabulum of organized beings.

It is easy to understand how the non-nitrogenized foods contribute to the formation of fat, when we compare the relative proportions of carbon and hydrogen in fat and in some of these foods—for gum, sugar, and starch are supplied with these elements in the very same proportions, and only require the loss of a part of their oxygen to reduce them to fat in the animal body.

Having now alluded to the composition of the animal system and that of the two great classes of nutritive agents, it will be necessary, in order to complete the survey, to refer to the secretions and excretions of the body. This may be considered premature before speaking of the active agents, air and water; but, for the better understanding of the subject, I prefer it.

The organs most interested in the chemico-physiological consideration of the animal body are the liver, the kidneys, and the lungs, and to the products resulting from their action, I shall, upon this occasion, principally confine my attention. As an important general fact, I would premise that the urine is rich in nitrogen, and the bile rich in carbon. According to Demarçay, the chief constituent of bile is a compound of soda with choleic acid—the latter being viewed as the organic portion of the bile, as it is composed of C76, N2, H66, and O22. The most remarkable and characteristic constituents of urine are urea and uric acid. The formula of the latter is C10, N4, H4, and O6; that of the former is C2, N2, H4, and O2. Now these products can be resolved into a variety of compounds, through the intervention of similar elements furnished by agents from without, or by the metamorphosis of tissues within, and many of the phenomena of the animal system depend upon the interchange of these elements. There are many other ingredients in urine, and its analysis by Berzelius proves that it contains nearly all of the constituents of the animal body.

We are now prepared to engage in the consideration of the other external agents, air and water, just alluded to, and which are so much involved in the chemistry of life. Water is so essential to animal life, that the ancients regarded it as the parent of every thing living. When we consider that the human body contains nearly 75 per cent. of its weight of water, we need not be surprised that the vital manifestations must cease without it. Perspiration, secretion, exhalation, and chemical changes are continually making way with the fluids of our bodies, and thus creating unceasing demands for their supply. The system is supplied through drinks, and the moisture of solid nutriment, which contains a large proportion of water, varying from 10 to 85 per cent. Exclusive of the important purposes which water serves to the animal economy—such as repairing the loss of the aqueous portion of the blood, acting as a solvent of alimentary substances, &c.—it can readily be conceived how it may also act the part of a nutritive agent, and assist in the formation of the solid parts of the body. Water is a remarkable combination of two elements, hydrogen and oxygen, which are separated from one another, in numberless processes, in a manner imperceptible to our senses—and as the same elements enter largely into the constitution of all organized bodies, it is not improbable that the elements of water have some important chemical relations in the physiology of nutrition in the animal system. Liebig thinks that all the hydrogen necessary for the formation of an organic compound is supplied to a *plant* by the decomposition of water, and this is confirmed by the researches of M. Payen. If, therefore, water can furnish elements to be assimilated in the lower orders of the organic world, it is fair to infer that it may also subserve a similar purpose in the higher, and contribute to the formation of tissues as well as engage in many of the transformations occurring throughout the animal organism.

Some of the changes which water can effect may be readily understood by examining the composition of uric acid and urea, and perceiving how easily one may be converted into the other. The formulæ of these substances have already been given. Now, in order to reduce uric acid into urea, it will be necessary to subtract 6 equivalents of carbon, and 2 of oxygen, and add 4 of hydrogen—the nitrogen remaining unaffected. Consequently, if we unite with the uric acid 4 equivalents of water, and 6 of oxygen, these 6 eqs. of oxygen, with the 4 in the water, and the 2 in excess in the uric acid, making 12 eqs., will unite with the 6 supernumerary atoms of carbon in the uric acid, and form 6 of carbonic acid, which will be thrown off from the system in the form of gas, while the resulting compound of urea, 2 eqs., will remain, the uric acid having disappeared during the process. Thus:

Conversion of Uric Acid into Urea.

1 eq. uric acid =	10C,	4N,	4H,	6O.
Deduct	6,	-	-	2
	—	—	—	—
	4,	4,	4,	4
Add	-	-	4,	-
	—	—	—	—
2 eqs. of urea =	4,	4,	8,	4

or,

1 eq. uric acid =	10C,	4N,	4H,	6O.
4 eqs. water,	-	-	4	4
6 " oxygen,	-	-	-	6
	—	—	—	—
Total,	10,	4,	8,	16

2 eqs. urea =	4C,	4N,	8H,	4O.
6 " carb. ac.	6,	-	-	12
	—	—	—	—
Total,	10,	4,	8,	16

The conversion of cane sugar, or starch, into sugar of milk or diabetic sugar, depends, also, on the elements of water. The active agent of the gastric juice, and the soda of the blood and bile, are derived from common salt, by means of the same agent: common salt being composed of one equivalent of chlorine and one of sodium, the hydrogen of the water unites with the chlorine forming hydrochloric acid, and the oxygen of the water combines with the sodium, to produce soda. Thus you perceive in how many ways water may be concerned in the changes throughout the system.

In the chemical play between the nutritive elements and the constituents of the body, there is another agent interested in a most important way in almost all of these actions. I allude to the atmosphere. This is composed chiefly of N and O, containing, also, in varying proportions, carbonic acid, aqueous vapour, a trace of ammonia, and carburetted, sulphuretted and phosphuretted hydrogen, in almost inappreciable quantities.* It is, however, the oxygen of the air that is the great agent in most of the chemical phenomena in nature, and takes the chief part in the change of tissues, the production of heat, and various other processes in the animal body. The air is constantly in contact with the skin; is entangled with the saliva, particularly during mastication, and taken into the stomach; but the largest portion gets into the body through the lungs by inspiration—there being thus several ways by which it gets access to the system. The process of respiration, it is well known, never ceases during life, and every moment of our existence is employed in taking in through the lungs the vivifying element of the atmosphere. The quantity of oxygen consumed by an adult is so great as to be almost incredible, but the accurate experiments of Lavoisier, Menzies, and Seguin leave no doubt that a man annually takes into his system about 800 pounds, five times the weight of his own body. When we consider that a still greater amount, in weight, of ingesta is annually consumed, and yet the weight of our bodies is no greater at the end than at the beginning of the year, it appears paradoxical, particularly as the amount of urinary and alvine discharges during the same period will by no means compensate for that taken into the body. What, then, has become of the surplus? Now, this is a most interesting inquiry, and has led to the development of one of those secrets in nature, which, when disclosed, astonish and captivate the mind, and forces it to dwell with peculiar delight upon these revealed phenomena, and to regard, with reverential admiration, that Power and Wisdom which originated and maintains them. What has become of the surplus? It has been carried off by the oxygen. The great amount of oxygen, which enters by the lungs, does not tarry in the system; but, hurrying through its living channels, it seizes the useless molecules of ingesta, which had entered by the stomach, and conveys them from their distant beds in the ultimate fibrils of organic tissue, to make place for fresher and more life-giving atoms, and returning by the passage-way, by which it entered, it empties them into the great reservoir—the atmosphere—to subserve other and equally useful purposes in the lower orders of creation. Thus the body is continually balanced: food enters the stomach, is digested, assimilated, and carried to every part of the body to be converted into organic tissue—but it cannot accumulate; oxygen enters the lungs, is absorbed, and also carried to every part of the body to act upon the already-used particles of this food—and it cannot accumulate; the elements of the former chemically unite with the latter, and both pass out of the system together, leaving it just as they found it, to be followed by their successors in the same round unceasingly, until the vital power yields up the body wholly to their destructive influences.

Let us now inquire what substances are thrown off from the animal body by the process of respiration. Chemists are unanimous in stating that carbonic acid and aqueous vapour are exhaled from the lungs.

* Dumas, Fownes, Gardner.

These are respectively composed of carbon and oxygen, and of hydrogen and oxygen, so that it is plain that carbon and hydrogen are the elements, which, meeting the inspired oxygen, form new compounds with it within the body, and are conveyed again into the exterior world through the lungs. This carbon and hydrogen of the organic tissue, having been removed by the agency of oxygen, must again be replaced by food containing the same elements. Thus it becomes evident that a large portion of the nutritive substances which we consume, goes to sustain the process of respiration, and that the amount of such nutrition must be proportioned to that of the oxygen inspired —else the excess of the "elements of respiration" must produce repletion of the system, or a superabundance of oxygen, a proportionate waste of fibre, and in either case acting injuriously upon the healthy functions.

As oxygen is conveyed to every part of the body, after its introduction into the lungs, it will be satisfactory to allude to the manner of its transportation. Liebig, who has invested chemical physiology with a peculiar charm, by the boldness and beauty of his inductions, assumed that oxygen was conveyed to the capillaries in the arterial blood, combined with iron, as sesqui-oxide—which, there giving up a portion of its oxygen, enters the veins as protoxide. Some late researches of Professor Mulder, however, do not go to sustain these views, and throw much light on the act of change of tissues. He discovered two oxides of proteine, a binoxide and tritoxide, formed by the union of the proteine of the blood and the oxygen of the air during the process of respiration. This oxy-proteine is carried from the lungs to the nutrient capillaries and decomposed, the oxygen carrying off the worn out molecules, and the proteine deposited to supply their place. Either of these hypotheses, explaining the introduction and evolution of the gases, and their transmission to and from the extreme arcs of the circulation, excites our admiration, and if they prove to be true interpretations, the achievements of chemistry will be acknowledged triumphant in unfolding the mysteries of the most recondite processes of the animal economy.

There are some intermediate changes which the combustible elements of the food undergo after their digestion, and before their final elimination, which I have omitted to notice. Until recently, the bile was supposed by many physiologists to be solely excreted; but in a state of health no bile can be detected in the alvine evacuations. It is certainly thrown into the intestinal canal from the ductus communis choledochus, and probably serves some important purpose in digestion, after which its constituents appear to be reabsorbed into the circulation, and entirely disappear in the animal economy yielding up carbon and hydrogen to the oxygen of the arterial blood, to be evolved by the process of respiration. With regard, also, to the use of the fat, we observe that, in a starving man, the fat is absorbed, he continuing to inspire oxygen. Here the food, failing to supply fuel for the lungs, the combustible elements of the body, those of fat being first, are called into requisition. On the other hand, a superabundance of non-nitrogenized food, as compared with the amount of oxygen inspired, favors the deposition of fat—thus the absorption and production of this oleaginous substance are intimately allied to the process of respiration. It is in this way that the non-nitrogenized constituents of food supply the fuel for the system, either directly, or indirectly through the bile and fat, while at the same time the nitrogenized constituents nourish the vital structures.

The carbon and hydrogen of the non-nitrogenized food, therefore, being specially engaged in entering into combination with the inspired oxygen, and the latter, on its part, incessantly busy in carrying off from the system the effete molecules, what is the necessary result if the loss of the latter elements be not renewed? We may stop eating, but we must continue to breathe, and if respiration do not cease while digestion has been suspended, what are the chemical consequences in the animal organism? The oxygen will consume all the combustible materials of the "elements of respiration" first, and then assail the same elements of vital structures, and finally, with insatiate fury, it will attack every part of the body, until resistance to its devastating energy completely ceases. Daily observation proves what chemical physiology teaches. Hybernating animals, certain cases of dysphagia, schirrus of the pylorus, marasmus, and other forms of inanition, unerringly exhibit the destructive influence of oxygen in the rapid emaciation and softening-down of the body. The cause is plain. A candle burns, because the carbon and hydrogen of the tallow unite, during the process, with the oxygen of the air; but the tallow is continually being consumed while combustion goes on, and so long as the supply of the combustible material lasts, light and heat do not disappear—they cease only with the entire consumption of the tallow. So with the animal body. It respires, because the carbon and hydrogen of the non-nitrogenized constituents unite, during the process, with the oxygen of the air; but these elements are continually being consumed while respiration goes on, and so long as their supply lasts, vitality continues—it ceases only with the entire consumption of the combustible materials. Thus oxygen supports life as it does combustion, and yet destroys the body as it consumes oil—it is at once the minister of life and death, now vivifying every fibril of animal tissue, and again, with implacable and relentless power, destroying the beauty and harmony of the whole organism. Life ceases, and oxygen, not cloyed by past excesses, now preying upon dead matter, makes new ravages. It starts other affinities into action—the organic molecules, offering no resistance, are thrown into a chemical ferment—disintegration and decay set in—and every atom of the body is dispersed in another form to continue its ministrations in the organized kingdoms, according to the great designs of creation. How beautiful! that the Spirit, having completed its stewardship, should again return to its Divine Master, yielding up its trust in this earthy tenement, to be divided among the remaining agents agreeably to His Supreme will and direction!

Another circumstance, connected with the chemical combination of oxygen, carbon and hydrogen, is too important to be omitted upon this occasion. It is this: Their union always produces heat. If, therefore, heat is the invariable result of the combustion of carbon and hydrogen, and if these elements are continually uniting with each other, in every point of the nutrient capillaries, then the corollary would follow that heat is generated in the animal system wherever this union takes place. The mind at once appreciates the importance of these facts, and, promptly consenting to the correctness of the conclusion, contemplates, with peculiar satisfaction, this source of animal heat.

That respiration generates heat by a species of combustion, was an opinion first advanced by Mayow, sustained by Black, Lavoisier, Laplace and others, modified by Crawford, and accepted by physiologists, until the more recent experiments of Brodie, Despretz, and Dulong created a doubt of its accuracy, and caused them to refer the phenomenon of animal heat to nervous influence. Liebig, like the advocates of the original theory, associates it with respiration, but, differing from them, maintains that the sole source of animal heat is the mutual action between the elements of the food and the oxygen of the air, conveyed by the blood to every part of the body.

The particles of nutrition, you are well aware, are taken into the circulation, distributed to every part of the system, and becoming incorporated, as constituents, with the animal organism, yield up their carbon and hydrogen, at those distant points, to the oxygen absorbed in the lungs, and brought into immediate contact with them by the arterial canals, producing necessarily an evolution of heat—for whether there be visible combustion of these elements, or a quiet and unseen combination, heat must still be evolved, and the quantity eliminated bears a constant ratio with the amount of material consumed. The correctness of this explanation is sustained by the equable distribution of animal heat throughout the body, and by the effects of climates and seasons upon the temperature and habits of man. The coldest regions of the north, and the burning sun of the equator, although they greatly diversify the face of inanimate nature, affect not the temperature of animal heat. The animal body, it is true, like all matter, must impart heat to surrounding bodies that are colder, and receive it from those which are hotter, and yet the anomaly of maintaining a uniform temperature under the widest range of the thermometer exists without a doubt. This otherwise inexplicable phenomenon is satisfactorily and beautifully accounted for on strictly chemical principles, by the varying quality and quantity of food, and the corresponding amount of oxygen inspired. If this view of animal heat be true, there is much in practical medicine that is involved in the doctrine.

Another interesting inquiry meets us here. The constant combustion of carbon and hydrogen in the bodies of millions of inhabitants and animals for ages, and the innumerable other processes of like character, must tend towards the deterioration of the atmosphere, by consuming its oxygen and replacing it with aqueous vapor and an equal bulk of carbonic acid gas, an agent highly destructive to animal life. Yet notwithstanding all these causes operating incessantly in abstracting the vital air, we see that respiration is not impaired, that animal life continues with undiminished vigor, and that chemical analysis has been incapable of detecting any appreciable variation in the amount of this element, or any other changes in the constitution of the atmosphere. If, therefore, the many processes engaged in the consumption of oxygen and the formation of carbonic acid, do not affect the quantities of these constituents, which appear to stand in some fixed relation to one another, a cause must exist which at the same time that it replaces the one prevents the increase of the other. This cause, whatever it may be, is so intimately associated with the welfare of animal existence, that the physiologist engaged in the study of the human organism, cannot neglect it, notwithstanding his attention is diverted for the time to an inferior order of organized matter. What, then, is the cause of this remarkable uniformity in the composition of the air? It exists in the process of vegetation. The immense beds of vegetation over the globe are vast reservoirs of carbon. A pile of timber, covered with sand, and burned into charcoal, affords sufficient evidence of the great amount of carbon which has been locked up for ages in our forests, and has been annually accumulating. Many earlier generations of vegetable tribes have been swept from the face of the earth unknown to the memory of man, and, being entombed by some powerful natural cause, have likewise carried into its bowels an exhaustless supply of carbon in the form of mineral coal. There are other reservoirs of carbon. The amount that is enclosed in the extensive bodies of carbonated minerals is incalculable. Nor is it woody vegetation alone that contains it—every flower that blooms, from the microscopic corolla to the grandiflores of nature, is rich in carbon. A blade of grass, even, trod upon by man, is a receptacle for this element—for a stack of hay contains nearly half its weight of carbon. Now whence is this carbon derived? From the atmosphere. But the atmosphere contains only one part of carbonic acid in every thousand parts; and is it possible that so small a portion of carbonic acid could have supplied so large an amount of carbon? There is, however, no other source than the air to supply it to vegetation; and as vegetables possess no locomotive power by which they can seek for food, they must depend upon that which is furnished to them by surrounding agents. Consequently the carbon of plants must be derived from the air. This will not appear so improbable if we consider the sum total of carbon existing in the atmosphere. The weight of a column of atmosphere one foot square at the surface of the earth is 2160 pounds. There being one part of carbonic acid for every 1000 parts of air, there must consequently be over 2 pounds of the former to every such column. Now more than one-third of carbonic acid is pure carbon, and if this quantity be multiplied by the number of feet upon the earth's superfices, it is estimated that the amount of carbon at any one time in the atmosphere, notwithstanding its small proportion, exceeds in weight that of all the plants and coal upon the earth! And yet the quantity of carbon escaping into the air from the body of a single adult every year amounts to 300 pounds! After such a calculation, we need not question the source of the carbon of plants, nor, after having thus ascertained its origin and location in the vegetable world, need we any more doubt the cause of the uniform purity of the atmosphere.

It would be interesting to follow up the course of this carbon in all its relations, but as the design of this lecture does not embrace particular details, this, as well as other points, will be more minutely studied hereafter. Permit me, however, to observe that in tracing out the path of carbon, we find it passing from the vegetable kingdom into the bodies of graminivorous animals to aid in forming organic tissues, thence, thus organized, into the various parts of the carnivora, and from these sources collectively it is taken up by omniverous beings, to be returned by these various classes of animals to the atmosphere in the form of carbonic acid, in order that it may become again fixed in the vegetable organism—the point of departure. What an endless round of important purposes belongs to this single element! We now see it modestly engaging in the primary organization of the lowest orders of the organic world, then rising higher and higher through successive steps of animated nature it takes a place in the noblest ranks of creation; and again, as it were purified by fire, it is elevated into the firmament of heaven on the wings of vital air, and re-fitted to begin anew its perpetual office of maintaining the continued existence of both kingdoms of organic nature!

There appears, indeed, an essential connection between carbon and organic life, and the former must have existed before, or have been formed cotemporaneously with the creation of the latter—an opinion which geology itself sustains: for rocks containing carbon do not belong to the first geological periods—periods unknown to fossil remains. The first announcement of the existence of organized matter is at a later period, and by the ascending series of rocks, when we hear of carbon beginning to appear.

I have thus endeavored, gentlemen, to give a cursory view of the recent chemico-physiological doctrines of the organization and functions of the animal system. In a subject embracing so much it is impossible within a single hour to engage in details, no matter how interesting and fascinating they might be:—the pleasure and profit of treating of these minutiæ will be deferred for future and more fitting occasions. In the progress of this lecture, however, you must have observed this remarkable fact: that the food, the water, the air, which enter the animal body, reduced to their ultimate elements and taken collectively, are principally constituted of carbon, hydrogen, nitrogen, and oxygen—that the various portions of this body, subjected to the same methods of analysis, are likewise reducible, in a great measure, to carbon, hydrogen, nitrogen, and oxygen; and that the animal excretions are chiefly composed also of carbon, hydrogen, nitrogen, and oxygen—these elements being associated, under all these circumstances, with variable quantities of other constituents. You must have further observed that the compounds, which contain the carbon and hydrogen of the dead tissues, after having served an important purpose, as constituents of bile, in the animal economy, for the most part pass off by the lungs and skin; those which contain the nitrogen are separated by the kidneys; while oxygen is the active agent in carrying on the process of metamorphosis, and eliminating the remaining elements from the system. Finally, these four elements, which constitute the largest portion of organic nature, exist in great abundance in the atmosphere, and although the proportions of some of them are small, their sum total at any one time, with their unceasing supply, render them amply sufficient for all the wants of the two organized kingdoms of nature.

How beautifully simple is the order of this whole arrangement! a few elements competent to subserve such manifold and apparently opposite purposes! To what simplicity does such a view reduce the complex system of the world, bind down the products of organic Nature under all her different forms, and oblige her to confess her real essence and Divine origin!