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Trieste

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ON

THE PRINCIPLE OF VITAL AFFINITY.

PART II.

BY

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FROM THE

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III.—*Observations on the Principle of Vital Affinity, as illustrated by recent discoveries in Organic Chemistry.* By WILLIAM PULTENEY ALISON, M.D., F.R.S.E., *Professor of the Practice of Medicine in the University of Edinburgh.*

(Read 1st and 15th February 1847.)

PART II.

It may be remembered that, in the paper formerly laid before this Society on this subject, I endeavoured to establish the principle still disputed by some physiologists, that the laws which regulate the chemical relations, as well as those which regulate the visible movements of the particles of matter, undergo a certain determinate modification or change in living bodies, which is essential to the commencement and to the maintenance of the organization of those bodies; and farther, that I undertook the task of attempting to deduce, from the numerous but somewhat discordant experiments and observations lately made on the subject, certain inferences which appear to be well ascertained, although not generally admitted, as to the essential nature of this change, *i. e.*, as to laws which regulate those chemical actions which are peculiar to the state of life, and essential to the maintenance of organization, both in vegetables and animals.

In confirmation of my statement of the general principle of Vital Affinity, as distinguished from simply chemical affinities, I have much satisfaction in quoting two sentences from the last edition of LIEBIG'S "Animal Chemistry." Some of the statements of general principles made by this author, seem to me open to objection, and some I do not profess to understand; but the following is simple and precise; and, considering the authority of LIEBIG as a chemist, may, I think, be held nearly decisive as to the soundness of the principle. "A *fundamental error*, committed by some physiologists is, that they suppose the chemical and physical forces alone, or in combination with anatomy, sufficient to explain the phenomena of vitality. It is, indeed, difficult to understand how the chemist, who is intimately acquainted with chemical forces, should recognise in the living body the existence of *new laws*, of new causes, while the physiologist, who is little or not at all familiar with the action and nature of chemical and physical forces, should think himself ready to explain the same processes with the aid of the laws of inorganic nature alone."—*Animal Chemistry* (*third edition*, p. 252.)

The first and most fundamental of these general principles (likewise considered in my former paper) is the power of vegetable life, under the influence of light, to decompose the carbonic acid existing in the atmosphere,—set the oxygen free, fix the carbon, and form with it and the elements of water, starch, sugar, gum, and the analogous compounds. Our knowledge of this power, of the effects which result from it, and of the period when it must have been first exerted on the earth's surface, enables us to assert with confidence, that by means of it, the whole organised creation has been, as DUMAS expresses it, the offspring of the air; and that it was by enabling the rays of the sun to excite this action in certain particles of matter, existing in the atmosphere, but destined to be either the first specimens, or the first germs of vegetable life, that "a beneficent God," to use the striking expression of LAVOISIER, "has strewed the surface of the earth, first with organized structures, and then with sensation and thought."

In proceeding farther to inquire into the laws of Vital Affinity, we must always keep in mind the general arrangement or classification, long ago made by Dr PROUT, of all the organic compounds, of which any organized structures, vegetable or animal, are composed, into three groups or classes, the Saccharine or amylaceous, the Oily, and the Albuminous; and the important observation, I believe first made by him, that the food of most animals contains all these compounds, and that no complex animal structure can be maintained without the concurrence of at least two of these kinds of compounds in its food.

I do not think it is going too far to say that we have now a general knowledge of the laws or conditions under which all these compounds are formed in living bodies, taking the starch formed from carbonic acid and water as the foundation of all. But we perceive farther, that that these laws, *varying* in *different parts of the same structure*, and at *different times in the same parts*, and being of *transient duration* in all, are liable to an *influence of time and of place*, and in animals to a farther influence of mental changes, which is quite analogous to the vital actions, both of muscular and nervous organs, but is strongly contrasted with the uniformity of the laws that determine the changes of inorganic matter. And if this be so, we may assert that considerable progress has been made, both in establishing and in illustrating the doctrine of vital affinity, as a first principle in physiology.

I. The formation of Oil or Fat in living bodies is, perhaps, that part of the chemical processes there carried on, which is now the best understood, and the study of which gives us the clearest insight into the nature of vital affinities. We need not enter into any of the simply *chemical* questions as to the mode of combination of the fatty acids and bases in the different kinds of fat; it is sufficient for our purpose to observe that they are found very generally, though very variously disposed, in almost all vegetables and animals, and even in the earliest stages of their existence; the store of nourishment contained in the seed and in the egg, containing a proportion of fatty matter. And though there is considerable variety in the different kinds of fat or oil, they all differ from the varieties of starch, by having a much smaller proportion of oxygen, and, of course, a larger proportion of carbon and hydrogen. The composition of most fats is stated by Liebig to be $C_{12} H_{10} O_1$; and we have thus, therefore, another compound formed apparently by vital affinity, indicating a peculiar attraction of the two first elements for one another, and a feeble attraction for oxygen. Indeed, in the composition of wax (one of this family of compounds), as stated by MULDER, the proportion of oxygen is only one equivalent to 24 of carbon; in cholesterine, the proportion of carbon to oxygen is stated as high as 36 to 1; and in many volatile oils, no oxygen has been detected.

Supposing such a peculiar affinity to act, there is obviously no difficulty (on looking at the numbers indicating the proportions of the elements) in understanding the formation of these compounds out of starch ($C_{12} H_{10} O_{10}$), just as there is none in understanding the formation of starch or sugar (although by an affinity occurring only in living bodies, and which we regard as vital) from carbonic acid and water ($CO_2 + HO$), in living vegetables, where a continual evolution of oxygen attends the growth; particularly if we suppose that the carbonic acid taken in by the leaves and roots, is carried to, and decomposed in, all parts of the plant; the formation of the fatty compounds, is, no doubt, one of the processes by which the oxygen is set free. But in the case of animals, where (with the exception of some of the infusory tribes) there is no evolution of oxygen, the formation of fat from starch presents a difficulty. Yet the numerous observations and experiments of LIEBIG and of CHEVREUL and MILNE-EDWARDS, leave no room for doubt that various animals, fed chiefly on varieties of starch, or bees fed on sugar, form a much larger quantity of fat, oil, or wax, than they have received mixed with their food, and this when they are exhaling no pure oxygen, but, on the contrary, compounds of hydrogen and carbon with oxygen, viz., water and carbonic acid. Indeed, Dr ROBERT THOMSON having ascertained by repeated experiments, that the quantity of butter yielded by cows bears no fixed proportion to the quantity of oleaginous matter contained in their food, varying indeed from one quarter to nearly the whole of the oleaginous ingesta, thinks himself justified in inferring that "the butter cannot be supplied from the oil of the food." (*On the Food of Animals*, p. 156.)

It is quite certain that in this action, in all animal bodies, the greater part of the oxygen of the starch employed must unite with a portion of its carbon and hydrogen, and pass off in the excretions just noticed, leaving the small remainder of the oxygen in combination with the predominant quantities of carbon and hydrogen.

It appears possible, indeed, that *all* the oxygen which must be separated from starch before it can be converted into fat, may be evolved in combination with part of the carbon and hydrogen of the starch, without any constituent of the air taking any part in the process; but the quantity of fat formed would then be small, and it is also possible that the oxygen of the air may be concerned in the metamorphoses to which starch is liable in a living body; and as we know the importance of oxygen in maintaining (in one way or other) all vital action, the latter supposition is more probable.

If, *e. g.*, we suppose 4 atoms of starch to yield 2 of fat, we must subtract from

	48 C	40 H	40 O
	24 C	20 H	2 O
leaving	24 C	20 H	38 O = 20 HO 9 CO^2 + 15 C;*

so that on this supposition 15 atoms of carbon are set free, and as these do not appear, they must unite with the oxygen of the air, and take the form of carbonic acid; and then the fat which appears, together with the water and carbonic acid thrown off, will account for all the elements concerned in the action. In this process, therefore, supposing the quantities of starch taken in, and of fat formed to be as above, 30 equivalents of oxygen must be absorbed; so that we perceive the use of oxygen in the change, and the necessity of its presence, although the fat formed contains so much less oxygen than the starch.

That this should be the real nature of the change is just what we ought to expect, if, agreeably to the supposition formerly made, the starch taken into the blood of a living animal, is acted on at certain parts of the body by two powers, and divides itself between them, viz., a vital affinity, in which carbon is the chief agent, which leads to the formation of fat, and the simply chemical affinities, exerted chiefly by oxygen (continually taken into the blood), by which, if removed from the living body, we know that it would gradually be resolved into carbonic acid and water. And that this is the real state of the case we are fully assured by a simple but very important observation, viz., attending to the effect of *exercise* on the formation or deposition of fat in the living animal body. As we see by the numbers given above, that a certain amount of oxygen must be absorbed, and a certain quantity of carbonic acid and water, formed by its help, must be excreted, to enable starch to yield oil or fat by the process there represented, we can understand that moderate exercise should favour the change; but when exercise is carried beyond a very moderate extent, we know that the circulation and respiration being much accelerated, and the quantity of oxygen taken into the living blood being much increased, the effect is, to increase the exhalation of carbonic acid and water, and proportionally to diminish the deposition of fat; *i. e.*, to give a preponderance to the simply chemical affinities exerted by the oxygen, over the vital affinity, which would tend to the formation of fat.

From this simple fact we may infer, 1. That the vital affinity by which oil is

* It need hardly be said, that all these numbers are given, not as indicating the exact changes which take place when the organic compounds are formed, but only as illustrating their general nature.

formed from starch, or by which its elements are held together, does not supersede its natural chemical relations, but only adds a new chemical power to those which can operate on it, and allows of a division of the starch between the result of a vital and a simply chemical affinity; and, 2. That the vital action by which fat is formed or maintained, is of no great strength, as compared with the simply chemical affinities to which the same matter is liable; being superseded simply by an increased supply of oxygen. And we cannot doubt that, in this as in other vital chemical processes, the oxygen, although not taken into the organic compound formed, aids its formation materially, by promoting, on the principle of divellent affinity, the other parts of the metamorphoses whereby it is produced. We shall see afterwards the importance of having it established by this simple example, that the oxygen of the air, when taken in full quantity into the blood, is capable of combining, somewhere in the course of the circulation with a part of that carbon and hydrogen, recently absorbed into the blood, which, under a smaller supply of oxygen, would form a living texture; and that the combination of these portions of the ingesta with oxygen, are one source of the excretions.

There are other facts which lead to the same conclusion, as to the affinity by which fat is formed, being more nearly akin than most vital actions to simply chemical affinities; particularly,—

1. The formation of Adipocere, not from starch, but from albumen, after vitality is over, when undergoing decomposition under ground, where there is a full supply of water and but little air, so that the supply of oxygen is less than in ordinary putrefaction, which may be understood thus:—

	C	N	H	O	
	48	6	36	14	= Albumen
Add			12	12	Water
				1	Oxygen
	48	6	48	27	
Subtract	36		30	3	Fat
	12	6	18	24	= Carbonic Acid and Ammonia

which escape, and the attraction of which for each other, no doubt in part determines the result.

2. Again, in the living body, but in a feeble constitution, along with great emaciation, and a deficient supply of oxygen, a morbid deposition of fat sometimes takes place, in circumstances where it could not have been anticipated, but only in particular parts. Some distinct cases of this kind have lately attracted attention, one in the kidneys, in one form of BRIGHT's disease, another in the liver, as in many phthisical cases, and a third in the atheromatous exudations

so common on the arteries. It may be suspected that in these cases the formation of fat is by an affinity hardly more vital than the formation of adipocere,—in both cases the decomposition of albumen to form the fat, being aided by the simply chemical affinities, of carbon for oxygen, and of hydrogen for azote.

3. The same peculiarity of the attractions by which fat is formed in the animal economy may be admitted in explanation of the more general fact, that in a healthy constitution, when more, particularly of amylaceous, food is taken than is required for the nutrition of the more important textures, and when little oxygen is taken in, the excess always tends to the deposition of fat, which implies that a large portion of the oxygen of that food has gone off as carbonic acid and water.

The process of the formation of oil from starch in the animal body, admits of an instructive comparison with the simply chemical one of the formation of alcohol from the same matter,—at least, from a compound fluid of which starch (first converted into sugar by the kind of fermentation formerly mentioned) is the chief constituent, in fermentation; *e. g.*, the changes in the vinous fermentation of grape-sugar, are represented thus,—

$$C_{12} H_{14} O_{14} = 2 (C_4 H_6 O_2) + 4 CO_2 + 2 HO,$$

that is, the elements of grape-sugar resolve themselves into two equivalents of alcohol, four of carbonic acid, and two of water. In this case, as in the formation of fat, the starch or sugar is divided into three parts, water, carbonic acid, and a peculiar compound fluid. In both cases, the oxygen of the air is necessary to the commencement, and probably to the continuance, of the process, although in both, the new compound formed contains less oxygen than the starch or sugar from which it is produced. In both cases, a third body is present, and its influence somehow promotes the process, besides the oxygen and the starch, viz., in the one case, yeast, or some kind of ferment, itself in a state of decomposition, which it imparts, without giving up any part of its substance, to the starch or sugar; in the other case, a living cell, composed of gelatin, which is itself undergoing a simultaneous change, by a living process. In both cases, extension of the change takes place, as from a centre, from this third body, through the fluid in which the change commences. In both cases, the compound formed is not stable; and the portions of the starch which go to form it are destined ultimately to follow the same course as those portions which are resolved into carbonic acid and water. In the one case, the compound formed, $C_4 H_6 O_2$, contains a less proportion of carbon than any of those which we regard as endowed with strictly vital properties; while, in the other, the compound formed, $C_{12} H_{10} O_1$, has the characteristic predominance of carbon. But if we are asked, Why we regard the one as the result of a simply chemical process, and the other of a vital affinity? I apprehend the sufficient answer to be,