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Paine



CONTRIBUTIONS IN PHYSIOLOGY BY DR. PAINE.

THE CIRCULATION.

[Continued from vol. 33, page 527.]

To the Editor of the Boston Medical and Surgical Journal.

SIR,—At the close of my last communication, I remarked that, “at another time I will briefly continue this subject, for the purpose of showing that mind is a perfectly distinct essence.” Since then, I have concluded to examine the question in the form of an essay, and will now, with your permission, extend my remarks, as embraced in the foregoing article, upon the subject of the circulation in plants.

Absorption by the roots is considered an inadequate explanation of the circulation of sap among those who advocate the doctrine of capillary attraction; and, if numerical strength were to decide the question, what I am about to say would be a waste of your valuable Journal. To interpret the process in plants, the leaf, or its equivalent, has been taken as especially instrumental; serving either as an exhausting apparatus by evaporation, or under the designation of endosmosis, or contributing its aid by supposed chemical influences, through the operation of light, upon the ascending sap. Some one of these hypotheses is considered an indispensable auxiliary to the doctrine of capillary attraction as applied to the circulation of sap.

An ingenious application of chemical principles has been propounded to satisfy the supposed exigencies of capillary attraction as concerned in the absorption and ascent of sap, and professes to afford the true solution of the downward motion. This hypothesis is also thought to be a new obstacle to the doctrine which ascribes life to a plant, and the dependence of its circulation and unique products upon vital actions. The hypothesis derives, also, no little importance from its application to the circulation of the blood, and the admission that, if it cannot be sustained in respect to plants, it must be equally groundless in regard to animals. The doctrine comes recommended to our attention by its distinguished advocates.

I have already endeavored to show, extensively, the want of all

foundation for the more comprehensive principle set forth by Liebig, that—

“The CAUSE of the state of MOTION is to be found in a series of changes which the food undergoes in the organism, and these are the results of processes of decomposition, to which either the food itself, or the structures formed from it, or parts of organs, are subjected.”

This summary principle, in which oxygen gas figures conspicuously, is the combustive doctrine of life. The projector held it to be applicable to every motion and to all the phenomena of living beings, in health and disease, and even in death. It was also made to explain our very thoughts and passions; these being imputed to the union of oxygen with the combustible elements of the brain.

I cheerfully conceded that—“this summary principle, were it true, would be truly beautiful.” I therefore felt the importance of showing that “it was not only deficient in every necessary element, but was contradicted by all the phenomena of sympathy and by all that is known of pathology and therapeutics; and this, too, according to the author’s own repeated and fullest affirmations and doctrines to the contrary.” This I endeavored to execute particularly in my articles upon Digestion and Animal Heat; and I am thus provided with a vast series of facts in advance, which must be taken in connection with what I may now say of the corollary from the fundamental doctrine. This corollary consists in the application of the general doctrine to the circulation of the sap and the blood. It supposes that the movement of the sap, upward and downward, is generated in the leaf by the action of light in promoting the decomposition of carbonic acid gas. The imperfect ascending fluid is thus converted in the leaf into perfect sap, and the change is supposed to institute a propelling force in the imperfect juice, by which the elaborated sap is driven out of the leaf and through its downward course. The force, generated in the leaf, is also considered, from the motion which ensues in that part, as the most essential cause of the ascent of the sap, or that the fluid is thus *lifted* from the roots to the summit of the most lofty trees.

The same principle is applied to animals. The pulmonary circulation is said to depend upon the union of the oxygen of the air with the carbon of the venous blood, in consequence of which this blood drives the decarbonized into the left auricle. But in the case of the systemic or greater circulation, the order of things is reversed; for here the motion is supposed to be generated by the union of oxygen with the “structures formed out of the food.” The same order of

events obtains in the liver—all referable to “a series of changes which the food undergoes in the organism,” &c.

I shall now limit my remarks to the supposed condition of the circulation in plants; since, if the hypothesis can be contradicted here, it must equally fail, as admitted, in respect to animals; and I shall endeavor to avoid whatever I may have hitherto said. Perhaps, however, it may be well to state the confidence which is entertained in the equal applicability of this theory to plants and animals, and the admission of its necessary failure throughout should it appear defective in relation to either of the organic dominions. This has been forcibly, as well as beautifully and justly, expressed by my learned friend and colleague, Professor Draper, in his able work on the *Organization of Plants*. Thus—

“As we have said, it is the character of a true theory to be applicable to all cases, and to render a clear account of every circumstance that may arise. A true theory is like a window of crystal glass, through which we can see all objects in their proper position, and colors, and relations, no matter whether they are such as are near, or those that are at a distance; no matter whether they are directly before us, or enter only obliquely into the field of view. A fictitious theory is like a Venetian blind, which has to be set in a certain position with respect to the observer, and only shows him objects for which it has been adjusted, and these in an unsatisfactory manner; but if he moves to one side or the other, or endeavors to see objects which are not directly in his way, his view is intercepted, or, perhaps, unless he makes a new adjustment, the light is shut out altogether.”

In the first place, then, it appears to me that the hypothesis contains a fatal element—the prodigious amount of force which is said to be generated in the leaf, as well as the lungs and other soft structures of animals. On *this point* I am bound to abide by the decision of the chemists, who say that such *must* be the consequence of the chemical changes which are supposed to be in progress for the production of motion. As expressed by these philosophers, who designate it as “an *inexpressible force*,” it would be abundantly sufficient for any purposes in artillery or in blasting rocks; and I infer, therefore, would hardly be withstood by the leaf or the lungs.

In the next place, there are many other circumstances attending the circulation of plants, as well as animals, which it would not be easy to interpret by the chemical doctrine, but which are readily explained by the vital. Such, for example, as the remarkable vigor of the circulation in the *acer*

saccharinum before there is a development of the bud. Indeed, the harvest of maple-sugar often takes place in the Northern States while the earth is covered with snow to the depth of many feet. The circulation, too, is most vigorous after frosty nights succeeded by warm mornings; and when the temperature of the air for a night or two rises to some 40° F. the flow of sap is often nearly or quite suspended, but restored in profusion on the return of frost. What in chemistry will explain such a phenomenon? And if it retreat before obstacles of this nature, must it not abandon the whole ground? Nay, how palpable the force of a single fact, when it is considered that the phenomenon is due to the effect of heat as a vital agent on the irritability of vegetable life; and whether operating at the higher and more uniform degrees, or alternating at the freezing point, the exact explanation is involved in the law of vital habit, as set forth in the *Institutes of Medicine* at page 363—370.

Such, mainly, is also true of the vine, which was the subject of many experiments by the celebrated philosopher Dr. Hales, as appear in his *Vegetable Statics*. These experiments are allowed to have been ably and critically conducted, and are standard references. Let us, therefore, interrogate some of these experiments, and see how far they correspond with Nature, or how far they contradict her and bear out the chemist. Now, in some of his experiments there was not only an absence of leaves and buds, but the stump alone was the subject of observation. There was wanting, therefore, the fundamental requisite of the chemist, and, indeed, I may say, what is considered indispensable by all the physical philosophers to the simple doctrine of capillary attraction as it regards the ascent of sap. Take as an example *Exp. xxxvi*. Thus—

“April 6th, at 9, A. M., I cut off a vine on a southern aspect, two feet nine inches from the ground. The remaining stem had no lateral branches. It was seven eighths of an inch in diameter. I fixed on its top the mercurial gage;” of double curve to admit the flow of a few inches of sap.

For several days the mercury was more or less pushed up by the sap, according to the state of the weather.—“April 14th, at 7, A. M., the mercury rose to 20 inches high. At 9, A. M., 22 inches. Fine warm sunshine. Here we see that the warm morning gives a fresh vigor to the sap.”—“April 18th, at 7, A. M., mercury 32 inches high, and would have risen higher if there had been more mercury in the gage. From this time to May 5th, the force gradually decreased [the life of the plant giving way]. On the 18th of April the force of the sap was equal to 36 feet height of water.

“Here,” the Doctor concludes, “the force of the rising sap in the morning is plainly owing to the energy of the root and stem.”

In another and similar experiment, at the same time (“the mercurial gage being fixed near the bottom of a vine) the mercury was raised by the force of the sap 38 inches, equal to 43 feet + 3 inches + $\frac{1}{3}$ height of water; which force is near five times greater than the force of the blood in the great crural artery of a horse; seven times greater than the force of the blood in the like artery of a dog; and eight times greater than the blood’s force in the same artery of a fallow doe”—as ascertained by the rise of the blood in long glass tubes.

In these experiments it is sufficiently manifest that all the physical hypotheses fail, since all of them assume that the leaf or its equivalent is indispensable to the progressive rise of the sap. The result, I say, shows, what the observation of all organic nature teaches, that so important a function as the circulation, and so exceedingly variable as in plants, yet most exactly suited in every species and every individual, but varied in all the species, to the methodical steps in vegetation, is not left to the capricious operation of any chemical or physical agencies, and that a force is established at the very base of a plant, that shall not fail of the exigencies of vegetable life according to its progressive changes. It follows, therefore, that the sap is moved by something peculiar to living beings, and this is called a vital action. The motion which we have seen, however, would prove utterly destructive to the leaf, and even to all delicate branches, without a gradually countervailing intervention of that action, since the subdivision of vessels will not explain the diminution of force. I hence infer, what is denoted by other important facts, that the reduction of force arises, also, from a modified action in the vessels leading to the bud, as well as in the bud, or leaf, itself. Here a new action is set up, and a new motion of the sap begins, which is propagated along its downward course by a universal action of the vascular system, modified in different parts according to the special final causes of each part. Nor is it true, as supposed by one of the ablest chemists of the day, that, “Physiologists have here stepped in with their phantom Vitality, and explained the descent of the elaborated sap on visionary hypotheses, that it was alive, or had obtained some vital qualities.”

There having been no leaves in the foregoing experiments, and, indeed, only a short stump of the vine, the results were not unexpected to the philosopher, who adopts the theory that the circulation of sap is

owing to temperature. But temperature would not always explain the phenomena, capillary attraction was little understood, and chemistry was yet unfledged. Accordingly, as in all cases where genius departs from Nature, even the acute mind of Dr. Hales has a special hypothesis for each apparent difficulty; sometimes borrowing from the theory of the vitalist, and actually raising hypotheses in direct opposition to each other. Take the following examples where the leaves had obtained their full development. Thus—

“ July 4th, at noon, I cut off within three inches of the ground, another vine on the south aspect, and fixed to it a tube seven feet high, and filled it with *water*, which was imbibed by the root the first day, *at the rate of a foot in an hour*, but the next day much more slowly; yet it was continually sinking, so that at noon day I could not see it so much as stationary;” the life of the stump now giving way.

Here are two important facts. There was no apparent upward force, though there may have been some mingling of the sap with the water; and, secondly, the water being vitally adapted to the plant, it was actually carried down to the roots, at the rate of a foot an hour from the tube. There was no chemistry here to effect or in any way influence the descent. The pressure was also slight, and the hypothesis of the laboratory probably scouts the notion of gravity. Besides, I may say, if gravitation effects the descent, it should *prevent* the ascent. This experiment, like the preceding, appears to be decisive against our rival friends, and in a more important aspect; for the *descent* of the sap had been a greater problem to them than its *ascent*. The importance and compass of the proof will be at once perceived. But he who made the experiment, seeing the want of agreement with the preceding, fancied, like a great many other philosophers, that a conflicting fact would justify a special hypothesis. Let us, therefore, hear the Doctor upon this troublesome point. Thus—

“ Now, since the flow of sap ceased at once, as soon as the vine was cut off the stem, the principal cause of its rise must, at the same time, be taken away, viz., the *great perspiration of the leaves*.”

That is the doctrine, along with capillary attraction, of a large section of the physical school. But it arises from a defective observation of facts and from an ignorance of the difference in the physiological condition of the vine before and after leafing. Indeed, how can any *such* distinction be appreciated by those philosophers? In the experiments first recited, the vine was in its budding, and, therefore, bleeding season;

in the present, the leaves had become developed ; and notwithstanding the lifting power ascribed to them by the chemist, and that from the evaporation imputed by others, the circulation is transcendantly greater in the budding season, and Hales might have amputated the largest limb, with all the other leaves remaining, and the same descent of the water would have occurred, and prompted a different hypothesis.

And now contrast the foregoing experiment with his conclusion as expressed in *Exp.* xxxviii. ; the words in Italics being designed by myself to facilitate the hasty reader. It is a hypothesis, directly opposed to the preceding, for the purpose of expounding another fact.

“The sap,” says the Doctor, “begins to rise sooner in the morning in cool weather than after hot days ; the reason of which may be, because in hot weather much being evaporated, it is not *so soon* supplied by the roots as in cool weather, *when less is evaporated.*” In *Exp.* xlvi. he says, “it was found that the trunk and branches of vines were always in an imbibing state *caused* by the *great* perspiration of the leaves, *except in the bleeding season.*” At that season the problem of the stump led him to conclude that “the force of the rising sap is plainly owing to the *energy* of the root and stem.” (See *Exp.* xxxvi.) Will the chemist explain ?

In one of his experiments he attributes an effect to the “sun’s warmth” in making the vessels “*dilate and contract a little.*” This is what he means by “the *energy* of the root and stem.” Had he adhered to that explanation, he would have had no difficult problems to expound, no conflicting experiments, no contradictions of himself. Few philosophers, however, have been as accurate in their experiments, and few better qualified to reason upon facts, than Dr. Hales ; and what may we not, therefore, conclude of the reasoning of those who have assumed spurious inferences in vegetable physiology as a groundwork for the circulation and other organic processes in animals ?

Thus it ever is with all who depart from their main field of operations to build up the difficult parts of other sciences. Hales was a divine, and although adroit in experiments, and better qualified by impartial habits than the chemist, it is no detraction from his (or their) exalted merits to say, that he knew so little of physiology he was incapable of applying or even perceiving the facts which the student of organic nature may readily seize and convert to the philosophy of life, and turn against the conclusions of the original observer.

Am I not, therefore, entitled to conclude, that organic beings are con-

tra-distinguished from inorganic by what is popularly known as life, or vitality, and with the summary remarks of the greatest scientific botanist of the age, of one who has devoted his life to the subject, Professor Lindley of the London University, as expressed in his able analysis of the "First Principles of Botany," that—

1. "The movement of the sap depends upon a vital irritability, and is independent of mechanical causes."

2. "The proximate principles are formed by the vital powers of the plant acting, in conjunction with air and light, upon the fluids contained in its system."

3. "*All the phenomena connected with the growth of plants are caused by an inherent VITAL ACTION.*"

New York, Sept. 25, 1848.