XV. *New Obſervations upon Vegetation. By Mr.* Muſtel *of the Acad. of Sciences at* Rouen; *tranſlated from the* French.

Read Jan. 14, 1773.

MANY celebrated writers, induced by the analogy, which they obſerved betwixt the vegetable and animal kingdoms, have admitted the circulation of the ſap in the one, in a ſimilar manner to the circulation of the blood in the other.

This important point of vegetable œconomy produced a diverſity of opinions, and has not yet been ſufficiently cleared up.

Dr. Hales, in his Vegetable Staticks, does not ſeem to embrace the ſyſtem of the circulation of the ſap; but he does not prove the contrary *.

* *Il ne prouve pas contre.* This certainly is a miſtake. Dr. Hales, in the IVth Chapter of his *Phyſical Staticks*, not only declares openly againſt the doctrine of the circulation of the ſap, and overturns the arguments alledged in favour of this opinion; but he produces ſeveral new experiments, which prove directly the impoſſibility of ſuch a circulation. (See p. 144, &c.) His reaſons have been thought ſo convincing, that the ſyſtem of the circulation in plants has been ever ſince exploded in England; and that they have had a ſimilar effect abroad, appears from the following quotation from a book of the ingenious Mr. Bonnet, F. R. S. of Geneva, intitled *Recherches ſur l'uſage des feuilles*, printed in 1754, p. 269. " Pour moi, perſuadé de la fauſſeté de " cette opinion (que la ſeve circuloit comme le ſang) par les ex- " périences de M. Hales (Ch. IV.) &c." M. M.

Mr.

Mr. Du-Hamel, in his Phyſiology of Trees, contents himſelf with relating what has been ſaid for or againſt this opinion; but, though he ſufficiently hints that he does not believe it true, he determines nothing about it. The friends of the circulation in plants have never been able to find in them any thing analogous to that powerful organ, which is the promoter of it in animals; for want of ſuch an organ, they were forced to imagine valves and paps in the lymphatick veſſels of plants, by means of which the liquors once introduced into the ſap veſſels were ſuppoſed to be hindered from going back; but, unfortunately, no body has ever been able to diſcover theſe valves and paps, ſo different from the ſimple contrivances, by which nature is uſed to arrive at her ends.

An experiment, which I made, and of which I propoſe giving an account in this paper, throws a great light upon this queſtion, as well as upon ſeveral others; and the concluſions deducible from it appear to me deciſive.

On the 12th of January, I placed ſeveral ſhrubs in pots againſt the windows of my hot-houſe, ſome within the houſe, and others without it. Through holes made for this purpoſe in the panes of glaſs, I paſſed a branch of each of the ſhrubs, ſo that thoſe on the inſide had a branch without, and thoſe on the outſide one within; after this, I took care that the holes ſhould be exactly cloſed and luted. This inverſe experiment, I thought, if followed cloſely, could not fail affording ſufficient points of compariſon, to trace out the differences, by the obſervation of the effects.

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The 20th of January, a week after this diſpoſition, all the branches that were in the hot-houſe began to diſcloſe their buds. In the beginning of February, there appeared leaves, and towards the end of it, ſhoots of a conſiderable length, which preſented the young flowers. A dwarf apple-tree and ſeveral roſe-trees, being ſubmitted to the ſame experiment, ſhewed the ſame appearance then as they commonly put on in May; in ſhort, all the branches which were within the hot-houſe, and conſequently kept in the warm air, were green at the end of February, and had their ſhoots in great forwardneſs. Very different were thoſe parts of the ſame tree, which were without and expoſed to the cold. None of theſe gave the leaſt ſign of vegetation; and the froſt, which was intenſe at that time, broke a roſe pot placed on the outſide, and killed ſome of the branches of that very tree, which, on the inſide, was every day putting forth more and more ſhoots, leaves, and buds, ſo that it was in full vegetation on one ſide, whilſt frozen on the other.

The continuance of the froſt occaſioned no change in any of the internal branches. They all continued in a very briſk and verdant ſtate, as if they did not belong to the tree, which, on the outſide, appeared in the ſtate of the greateſt ſuffering. On the 15th of March, notwithſtanding the ſeverity of the ſeaſon, all was in full bloom. The apple-tree had its root, its ſtem and part of its branches, in the hot-houſe. Theſe branches were covered with leaves and flowers; but the branches of the ſame tree, which were carried to the outſide, and expoſed to the cold air, did not in the leaſt partake

partake of the activity of the reſt, but were abſolutely in the ſame ſtate, which all trees are in during winter. A roſe tree, in the ſame poſition, ſhewed long ſhoots with leaves and buds; it had even ſhot a vigorous branch upon its ſtalk, whilſt a branch which paſſed through, to the outſide, had not begun to produce any thing, but was in the ſame ſtate with other roſe-trees left in the ground. This branch is four lines in diameter, and eighteen inches high.

The roſe-tree on the outſide was in the ſame ſtate; but one of its branches drawn through to the inſide of the hot-houſe, was covered with leaves and roſe-buds. It was not without aſtoniſhment that I ſaw this branch ſhoot as briſkly as the roſe-tree which was in the hot-houſe, whoſe roots and ſtalk, expoſed as they were to the warm air, ought, it ſhould ſeem, to have made it get forwarder than a branch belonging to a tree, whoſe roots, trunk, and all its other branches were at the very time froſt-nipt. Notwithſtanding this, the branch did not ſeem affected by the ſtate of its trunk; but the action of the heat upon it produced the ſame effect as if the whole tree had been in the hot-houſe.

It would be uſeleſs to give an account of the diary I kept throughout the courſe of this intereſting experiment. It may be ſufficient to obſerve, that the walk of nature was uniformly the ſame. The interior branches continued their productions in a regular manner, and the external ones began theirs at the ſame time, and in the ſame manner, as they would have done, had they been left in the ground. The fruits of the in-

terior branches of the apple-tree were, in the beginning of May, of the ſize of nutmegs; whilſt the bloſſoms but juſt began to ſhew themſelves on the branches without. I ſhewed Mr. Du-Tillet, of the Academy of Sciences at Paris, on his paſſage through this town, the effects of my experiments, and likewiſe communicated to him another obſervation, which chance occaſioned, and ought not to be omitted.

I obſerved that three of the flower buds of the apple-tree had been gnawed off by a ſnail in ſuch a manner, that all the petals and ſtamens had diſappeared, being eat up cloſe to the calyx. This not having been entered by the ſnail, the baſis of the piſtillum and the embryo were preſerved.

I took it for granted that theſe flowers would bear nothing; but I was ſoon convinced of my miſtake. Almoſt all of them bore fruit; the apples were perfectly formed, and ſix or ſeven pretty large ones too were ſeen upon each bunch. On the other hand, the ſnail had ſpared ſome other bunches, (doubtleſs becauſe more difficult to be got at;) but out of ten or twelve flowers in each bunch, not above one or two ſhewed any ſigns of fruit. This ſuggeſted to me the idea, that, when the flowers of trees are full blown, the prevention of the natural fall of the petals and ſtamens gives a greater aſſurance of the fructification; and on ſeveral times repeating the following experiment, I convinced myſelf that it did ſo. In imitation of the ſnail, I cut with my ſciſſars the petals of apple, pear, plumb, and cherry bloſſoms, cloſe to the calyx. Almoſt every one of thoſe, which

which were thus cut, ſucceeded, whilſt ſeveral of the neighbouring flowers miſ-carried.

Thus did a ſnail teach me how to render a tree fruitful; nor is it the firſt time that animals have been the inſtructors of mankind. I confeſs, however, that this proceſs is not very practicable in a large orchard: but it might be adopted in an eſpalier; in which one would chuſe to procure a great deal of fruit from trees of the beſt ſort. It may indeed be queſtioned, whether the ſuppreſſion of the ſtamens would not render the fruit barren; and in fact I found, that, though the flowers of the dwarf apple-tree, whoſe petals and ſtamens were eat up by the ſnail, gave me apples equally large and beautiful, and that, when I came to open them, I found the capſules formed as uſual at the center of them; yet they were entirely empty, without the leaſt appearance of a pip. Abſolute fructification conſequently did not take place; ſince botaniſts, with reaſon, call nothing fruit but the ſeed, which contains the germen, which is to perpetuate the ſpecies. All the other parts, being only intended to co-operate in the formation and preſervation of the ſeeds, periſh of courſe, when once the ſeeds are come to maturity and perfection, and the work of nature fulfilled.

Another remarkable thing in theſe apples is, that in the upper part there was found a much deeper cavity than uſual. It was eight or nine lines deep. The orifice of this cavity was bordered by five tubercles, indented and ſomewhat elevated; but there was no veſtige of the calyx, which, it is well known, remains always to the

upper part of apples and pears, and is commonly called the eye.

I now return to my firſt experiment; the conſequences of which, as I have deſcribed them, ſeem to prove,

I. Firſt that the circulation of the ſap does not take place in plants, as the circulation of the blood in animals. This may be deduced from the following obſervations.

The tree in the hot-houſe went through all its changes during the winter, and the branch expoſed to the open air underwent none; conſequently the ſap, which was in action in the root, ſtock, and head, of the tree, did not circulate through the branch without; which had no ſhare in the vegetation of the roots and trunk. It might, indeed, be argued that the cold air, to which this branch was expoſed, ſtopped the circulation, and therefore that the firſt experiment would not be deciſive; but the inverſe of it ſeems fully ſo.

The tree placed on the outſide of the hot-houſe continued, during the whole winter, in the ſtate of numbneſs, natural to all trees, which are expoſed at that ſeaſon; but one of its branches, which was in the hot-houſe, put forth ſucceſſively its buds, leaves, bloſſoms, and fruits. Whilſt therefore the root of the tree, to which this branch belonged, was in the ground ſo frozen, that the pot itſelf, in which it ſtood, was broken by it, whilſt the ſtock and top of the tree were ſo covered over with ice, that many of the branches were killed; this branch alone did not in the leaſt partake of the common ſtate of numbneſs and ſuffering, and was on the contrary in full vegetation.

tion. The ſap in it muſt have been extremely rarefied, and in very quick motion, whilſt that of the tree was greatly condenſed, and in total inaction. How is it poſſible to conceive a circulation of the ſap from ſuch a frozen root and ſtock, to a branch full of vigour, and loaded with leaves and flowers? Surely this experiment muſt appear concluſive againſt the ſyſtem of circulation; ſince in this caſe it could at beſt only be admitted to have taken place in the vegetating branch; and that would very improperly be termed circulation, which ſhould be confined to one limb.

II. This experiment proves, that each part of a tree is furniſhed with a ſufficient quantity of ſap to effect the firſt production of buds, flowers, and fruits. There is little probability that the branch drawn into the hot-houſe ſhould have derived its ſap from the roots of the tree: as they, at that time, lay in a very ſmall quantity of earth, rendered extremely hard and dry by the froſt, they could have but little liquor to ſpare; and even this, conſidering the congealed ſtate of the lymphatick veſſels of the ſtock, could have found no paſſage to the branch. This branch muſt of courſe have been enabled to continue its vegetation by the quantity of ſap with which it was provided, the conſumption of which muſt have been ſupplied at the firſt breaking of the froſt. This truth, now demonſtrable by experience, had been pointed out before by a multiplicity of other facts. Every body may have obſerved that a tree, which has been blown down in autumn, though ſeparated from its trunk, begins the ſame vegetation, that it would have done if it had remained ſtanding.

ing. Its buds open, it bears leaves, and even ſhoots, which ſometimes are very long, and muſt be the effects of the ſap it contained. It is true, indeed, that this appearance does not continue long, becauſe the proviſion of ſap once exhauſted, without being renewed, every thing muſt of neceſſity periſh.

An effect of the like kind often deceives us in trees, that have been newly planted, and in ſcions, which produce flowers and even fruits, without ever having taken root. But in this caſe the ſymptoms, which would ſeem to promiſe life, are on the contrary the forerunners of death; becauſe the leaves, being from their nature the moſt powerful organs of tranſpiration and diſſipation, the graft is the more readily exhauſted, when there is no root to furniſh it with a freſh ſupply of nutritive juices.

III. This experiment proves that it is heat, which unfolds the leaves, and produces the other parts of fructification, in the branch expoſed to its action.

Autumn is the time, in which Nature employs itſelf as it were clandeſtinely, under the cover of the leaves, in forming the buds, which contain the rudiments of the leaves, bloſſoms, and fruits, that are to be produced in the courſe of the ſucceeding ſummer. Theſe buds prepare and work themſelves out, during the winter, under the rough coats, that are deſtined to preſerve them from the injuries of the weather. As ſoon as the warm weather in the ſpring begins to be felt, the buds open, and their coats, which then become uſeleſs, drop off, and give place to the productions, which they

they contained and preſerved. Immediately after this, the bloſſoms, flowers and fruits make their appearance. This is the uſual operation; but in the caſe before us, nature was, as it were, ſurprized by art: what ſhe ſhould not have done till ſpring, ſhe did in the winter, becauſe the heat of the hot-houſe produced that expanſion, which, according to the natural courſe, ought to have been effected by the rays of the ſun darting leſs obliquely than before upon the horizon. There is no doubt but it is to heat, either natural or artificial, that this expanſion is owing; and the experiment proves that it is only in that part of the tree, which is expoſed to the effect of heat, that the ſap, which in every other part remains torpid and inactive, is put into motion, and produces vegetation. From this, it appears that the vegetable œconomy is different from the animal, and that thoſe, who endeavoured to eſtabliſh the circulation in both, carried their analogy too far.

This fact, now eſtabliſhed, furniſhes a good reaſon why in the tapping of the maple and ſugar-birch-trees, ſo much liquor runs out on one ſide, and none at all on the other. It is well known that, if during the time of a froſt, or a ſummer's day, towards noon, you bore a hole on the ſide of the maple-tree expoſed to the ſouth, you will get a great quantity of liquor from it; and that if you bore the north-ſide at the ſame time, you will not get a drop. The cauſe of this evidently appears from what has been ſaid. One likewiſe ſees why trees expoſed to the ſouth loſe a great many of their branches, and ſometimes die altogether, in the courſe of a ſevere winter; whilſt

trees of the ſame ſort, but placed to the north, or in ſome other expoſition, will ſtand the hardeſt froſts. This is particularly remarkable in the ever-greens, whoſe reſinous and oily ſap being liquefied by the heat of the ſun, the tree cannot eſcape ſuffering a great deal, whenever it is ſurprized in that ſtate by the night froſts. Thoſe obſervers, who attend to this, and know how well pines, firs, and bays ſucceed, when planted on the back of mountains expoſed to the north, will take care not to place ſuch kind of trees in a ſouthern aſpect, in hopes of their ſucceeding better by it.

Many other conſequences might be drawn from theſe experiments; but the bounds, I have aſſigned to this paper, do not allow it. I propoſe examining them more at large in a treatiſe upon vegetation, which, I hope, the obſervations and experiments I have made, may render intereſting and uſeful.