Some Account of Professor AMICI's
Discoveries relative to the Motion of the Sap in Plants[1]

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Professor AMICI, in the course of a series of experiments with his newly invented catoptrical microscope, in which he employed only very small and delicate objects, and such as seemed to promise some interesting discovery in respect to their organization, made some very remarkable observations on the motion of the sap in the stonewort plant (*Chara*, Lin.), which he communicated to the public in a short treatise, afterwards inserted in the 18th volume of the Memoirs of the Italian Society.

So long ago as the year 1774, the Abbé Corti had remarked a sort of circulation of the sap in this very simple plant[2]. With the aid of his microscope, Amici has now discovered in it new laws of motion and new organs, which had escaped the observations of Corti, and which throw new light on the physiology of plants in general, and particularly on the much contested porous tubes of Mirbel, and their functions in the economy of plants. Professor Amici's experiments were made from the year 1814 to 1818; they were carefully noted in his journal, and are now fully and circumstantially described in the memoir to which we have alluded. The following is, in substance, the result of his observations.

In all the parts of this plant, in the most delicate fibres of the root, as well as the finest green tendrils of the stem and branches, we may observe a regular circulation of the sap which they contain; while transparent globules of various sizes are constantly and regularly moving in uninterrupted circulation, with a velocity gradually increasing from the centre towards the sides in two opposite alternating streams, up and down, in the two halves or sections of the same simple cylindrical canal or vessel (separated by no partition), which runs lengthwise through the fibres of the plant, but which is interrupted at certain intervals by knots, and closed up by a partition which limits the cyclus. The circulation proceeds thus throughout the whole plant, and in all its fibres, from one knot to another; and in every tract or portion limited, as above described, in itself, and totally independent of the rest.

In general, the motion is perpendicular up and down; in some fibres, however, it is spiral, so that the ascending streams, which were seen at first on the right hand, appear next on the left, and *vice versa*. In the fibres of the root, the circulation is quite simple, as only one single central canal appears; but in the green tendrils of the plant, the great central canal is surrounded by a number of similar small vessels, which have all a similar structure; but in each divided from it by appropriate partitions, so that they may be completely separated from it, each of them having a similar perpendicular or spiral circulation peculiar to itself.

If one of this vessels be slightly tied, or bent in an acute angle, the circulation will be interrupted, as in the case of a natural knot, and will then proceed above and below the ligature or bend, as before, along the whole tract. When restored to its former situation, the original motion will also be renewed, provided the plant has not been essentially injured in that place, or the forced situation has not been too long maintained. The circulation will also continue in the one half of the tract, after the other has been cut off above the ligature.

If one of the vessels be cut through right across, the sap which it contains will not immediately and entirely flow out, but only that of the one half, - the stream, namely, which is flowing towards the

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[1] Translated from Gilbert's *Annalen*.

[2] *Osservazioni microscopiche sulla Tremella e sulla circolazione del fluido in una pianta acquajola, dell'Abate* Bonaventura Corti, *Prof. di Fisica, &c.*, Lucca, 1774, 8vo.

cut, - while the other continues its course. Vinegar deadens the motion, and even prevents the flowing of the sap out of a divided vessel.

The vessels are formed of an exceedingly delicate, smooth, white, transparent membrane, with regular, parallel, greenish stripes, running in a perpendicular or spiral direction, according to the direction in which the sap circulates. Between the stripes of each half of the vessel, that is, between the two streams which run up and down, there is always a smooth interval of the membrane without stripes, of the breadth of five or six, or more stripes. Of these smooth intervals there are two in each vessel, exactly opposite to each other, and of equal breadth; and, between them, the stripes (which, so far as the vessel is perfectly cylindrical, are divided by the intervals into two equal semicircles) are equally distributed.

These stripeless intervals, which exactly intersect the diameter of the circle of the cylindrical vessel, form, as it were, the partition between the two streams; and here there is indeed no motion of the sap globules, or, at most, a very sluggish and interrupted circulation. These stripes, of which above an hundred may be counted in both semicircles of the vessel, are raised and fastened to the internal part of the membrane, and of different compactness and strength. Wherever they appear most compact, thickest, and strongest, and generally in that neighbourhood, and consequently towards the sides of the vessel, we shall always remark the strongest and most rapid motion of the sap globules. These stripes, therefore, have and evident influence on the mode and degree of the circulation.

When magnified 207,025 times[3], these stripes appear to be composed of small green globules, or small bodies of an irregular form, as if strung together like the beads of a rosary. They are distinguished from the sap of globules by their green colour; and they do not mix with them when flowing at the same time out of the divided part of a plant into water.

If the vessel be divided, many of the stripe-globules near the cut will separate from the membrane; those more remote, however, will remain attached to it, and preserve their stripe form, only their direction will undergo some change in consequence of the lost tension, and the stripes will appear bent into various curves, outwards or inwards, and in some places unnaturally approached to, or removed from each other; and in this case, the motion of the sap-globules, so far as it still continues (for we have already observed, that all the sap does not flow out at once), follows this new unnatural direction, and appears to proceed most rapidly in those places where the stripes have accidentally run thickest together.

If the membrane of the vessel be gradually pressed, all these stripe-globules may be forced by degrees in a mass out of the aperture made by the cut; and the membrane will then appear quite smooth, pure white, and transparent as glass. Vinegar causes these globules to come out singly, or in pairs, or several hanging together, like fragments of a chain, and then they appear bound to each other by an extremely delicate membrane.

Now, as the cause of the constant and regular motion of the sap in this plant cannot possibly be ascribed to any of the powers hitherto assumed by vegetable physiologists, - the capillary attraction, the alternate contraction and dilatation, or the irritability of the vessels, because these are evidently quite passive; while, upon the other hand, the symmetrical stripes above described, as composed of small globules, exhibit the most obvious influence, not only on the mode, but even on the degree and reality of the circulation; Amici conceives himself justified in assuming as an hypothesis, that these stripes are to be considered as voltaic piles, and that the motion itself is to be attributed to the influence of galvanic agency; and this hypothesis seems to be supported, on the one hand, by the construction of these stripes, and on the other, by the known fact (although perhaps not yet sufficiently confirmed), that by means of this agent (galvanism) water may be conducted over from the positive to the negative pole, raised, contrary to all the laws of hydraulics, above the level, and brought through the pores of a bladder, which, but for it, are otherwise impermeable.

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[3] 455 times, according to the usual mode of reckoning: Amici gives the magnified superficies, and 455 = $\sqrt{207,025}$. - ED.

It is rather remarkable that another natural philosopher was engaged in these curious and delicate investigations at the same time with Amici, and with the very same plant, and published the result of his observations in the same year. We allude to that eminent German botanist, Dr Martius (at present naturalist to the King of Bavaria in the Brazil), who, in the year 1815, wrote a treatise on the structure and the nature of the *Charæ*, which was read at the Royal Academy at Munich, and printed in the Transactions of the Leopoldine-Carolinian Academy of Naturalists (*Nova Acta Physico-medica*), vol. i. Erlangen, 1818, 4to. Dr Martius investigated the internal organization not only of the *Chara vulgaris* (to which the experiments of Amici were confined), but also of the *Chara flexilis* and *hispida*; and he has communicated his observations very minutely in the memoir to which we have alluded, and to which we must at present refer our readers.

Previous to the experiments of Amici and Martius, Professor Treviranus of Bremen had made similar observations on the motion of the sap in these plants, but without attempting to ascribe it to the same principle which is adopted in Amici's hypothesis[4].

The preceding observations derive still greater importance from the circumstance, that Professor Amici thinks he has discovered a similar organization in various other plants, particularly the *Tropæolum majus* and *Humulus lupulus*, which he examined for the purpose of investigating the porous tubes, discovered by Mirbel, and observed by other vegetable physiologists; and he also thinks himself justified in believing, that the small granular substances which Sprengel found in the cells of some plants, and which frequently exhibit a regular position, are in reality similar stripe-globules, forming a similar galvanic apparatus. It appears to him, therefore, by no means improbable, that the cause of the motion of the sap in all plants may be traced to the same principle and power, although under a variously modified organization.

Amici had been prepossessed against the porous tubes of Mirbel, which he considered as striped vessels, similar to those above described, and the alleged pores he held to be nothing more than symmetrically arranged globules, which, by an optical illusion, had the appearance of being perforated in the centre. Notwithstanding this preconceived opinion, however, and the natural prejudice in favour of his own theory, he became convinced of the contrary, discovered real pores, but found, at the same time, that these vessels were not sap, but really and indisputably air-vessels, - a fact which Link had previously maintained. Professor Amici farther discovered, that the *tubi fibrosi* of this and several other plants, which are their proper sap-vessels, possess similar stripes and globules.

We understand that this ingenious philosopher has also made some very interesting observations respecting the structure and motion of the globules in the bloodvessels of animals, which, we trust, will soon be communicated to the public[5].

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[4] See *Observations on the motion of the granular substance in some* Confervae, *and one* Chara, in Weber's *Contributions to Natural History*, vol. ii. Kiel, 1810, 8vo.

[5] A notice of Amici's discoveries respecting the form of the globules of blood, will be found in the *Edin. Med. Journal*, vol. XV. p. 120. - ED.