# *The Ascent of Water in Trees*: (Second Paper).

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(Abstract.)

The physical conditions in the vessels interpose no obstacle to the exertion of a pumping action on their contents controlled by the medullary ray cells. There are many theoretical ways in which surface tension action could be brought into play in this manner, but no practical proof of the existence of any such action in the wood vessels has as yet been obtained. Similarly, the bleeding of roots and stems affords no absolute proof of the existence of a vital pumping action in them, since all the observed cases can be explained as the result of osmotic action coupled with a reabsorption of the osmotic materials from the ascending stream, and their surface adsorption by the walls of the vessels. Instances are given in which an apparent pumping action proved to be of this character.

Nevertheless, the experiments detailed or quoted in the above paper all tend to show that the continuous ascent of water is only possible in living wood, and that the power of conduction is rapidly lost on death, without any mechanical blocking of the vessels being necessarily responsible for the change. Hence we are forced to conclude that the living cells in tall trees continually restore the conditions for the ascent of water wherever these are affected by the excessive emptying of the vessels, and decrease the resistance to flow, as far as possible, by maintaining continuous water columns in parts at least of the wood. So long as these are present *ab initio*, a pumping action only becomes necessary in trees over 20 to 50 metres in height, but suspended columns cannot be maintained for any length of time in the vessels of tall trees without the aid of the living cells of the wood.

The energy required to pump water upwards in the tallest trees represents only a small fraction of that produced by the daily photosynthetic assimilation, and it is the feeble character and diffuseness of the pumping action which renders it so difficult to demonstrate practically.

Contrary to Strasburger's statement, no vessels appear to run as open channels from end to end of any tree, the longest vessel observed being 564 cm. as measured by the length of stem in which it ran (*Wistaria*). In this plant, however, and others also, owing to the irregular course followed by

the vessels, these are always longer, and sometimes considerably longer, than the piece of stem in which they occur.

Experiments on the suction and exudation of trees at different levels, and upon the influence of the entry of air and water under pressure, showed that no continuous suspended water columns, or high internal tensions, existed in the conducting elements of the trees experimented on (Maple and Poplar) during active transpiration, or, indeed, at any period of the year.

The same was shown by direct measurements of the pressure in intact vessels of *Wistaria* during active transpiration. This fact, coupled with the high total resistance to flow, shows that this resistance is overcome locally from point to point, and not by any enormous tension from above or pressure from below, neither of which exists, nor could be maintained to a sufficient extent to carry on the elevation of water in a tall tree. A high tension from above leads to rapid blocking with air; a high pressure from below leads to great loss by lateral exudation from the vessels.

The apparent differences of osmotic pressure previously observed between leaves at the base and apex of a tall tree are not evidence of the existence of any greater osmotic suction at the higher level, but are the result of the different ages and sizes of the cells, and of the different conditions to which they have been exposed. Equally great differences may exist between leaf-cells at the same level.

The surface adsorption of dissolved solids in the vessels plays a very important part in their function as translocatory channels, causing a delay in the ascent of dissolved solids, such as sugar and salts, and an accumulation of them along the outer walls of the vessels. The latter facilitates their outward diffusion, but at the same time renders the transference of small quantities of material between widely removed organs difficult or impossible.

The tallest trees in Australia do not appreciably exceed 300 feet in height, so that the values previously given for the maximal total resistance to the upward flow of sap in actively transpiring trees must be reduced to between 30 and 50 atmospheres.

In a Maple tree whose younger wood had been killed by formalin the transpiration current turned to the older, partially blocked, but still living wood, and none of Strasburger's experiments show definitely that efficient conduction is possible in the dead wood of tall trees. The ascent of water is, therefore, a vital problem, in so far as it depends upon conditions which hitherto can only be maintained in living wood.