TREE CIRCULATION WITH SIPHONING

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ABSTRACT
A proposed modification of an existing circulation model for trees [1] is offered to account for the case where a branch has a downward slope. The original circulation scheme consists of side by side vertical xylem and phloem tubes, connected with short horizontal tubes at top and bottom, where water enters at the bottom by osmosis and exits at the top by evaporation. Both vertical tubes have dissolved molecules but there are significantly fewer per unit volume in the xylem. Consequently, there is a pressure gradient in the bottom tube which drives the circulation: xylem up and phloem down. When a branch slopes downward the tube structure is altered here such that two back to front siphons can keep the flow operating.

Keywords: Tree circulation, siphoning

1. Introduction

Inside a tree the movement of fluids cannot be observed directly, which allows the imagination to take control over how it should operate, from a physical science point of view. It is hard enough to comprehend when the trunk and all branches have an upward directional component counter to that of the acceleration of gravity. How does such a tree get water to rise from the roots to the leaves? Somehow the trees have solved that problem. But then there are trees with one or more branches sloping downward from the upright trunk, or they might start up then bend down. How does the circulation work in that case?

A tree circulation system has been proposed before [1], called evapero-osmotic, to explain the flow of fluids in a tree involving pairs of idealized xylem and phloem tubes connected at the top and bottom, forming a circuit. Water enters at the bottom by osmosis and exits from the top by evaporation. Dissolved molecules, imitating that created in nature by leaves, makes the density of the phloem fluid greater than that of the xylem, which has a larger amount of pure water per unit volume. It is the pressure difference between the xylem and phloem fluids at the bottom of the circuit that drives the circulation: xylem up and phloem down. If everything else stays constant, the closer the two vertical tubes are to each other, the stronger the driving force is. Water passes in, through, and out of the system but the dissolved substance does not go away.

This conceptual circulation is not like any of those to be found in the existing literature that aim to explain how plants cause fluids to move internally. Actually there is only one long standing theory in the botany field to account for the upward transport of water inside trees and it is based on the xylem tubes exclusively, evaporation from the leaves, and the cohesion force between neighboring water molecules.

What follows is an attempt to explain how the presently modified circulation model (Figure 2) can be adapted to the case of a tree with a downward sloping portion of a branch. Adding the concept of siphoning is the technique used. It is not obvious a priori that this theoretical method could be carried out in practice. In fact, the original evapero-osmotic arrangement (Figure 1) has not yet been done under laboratory conditions to the best of my knowledge.

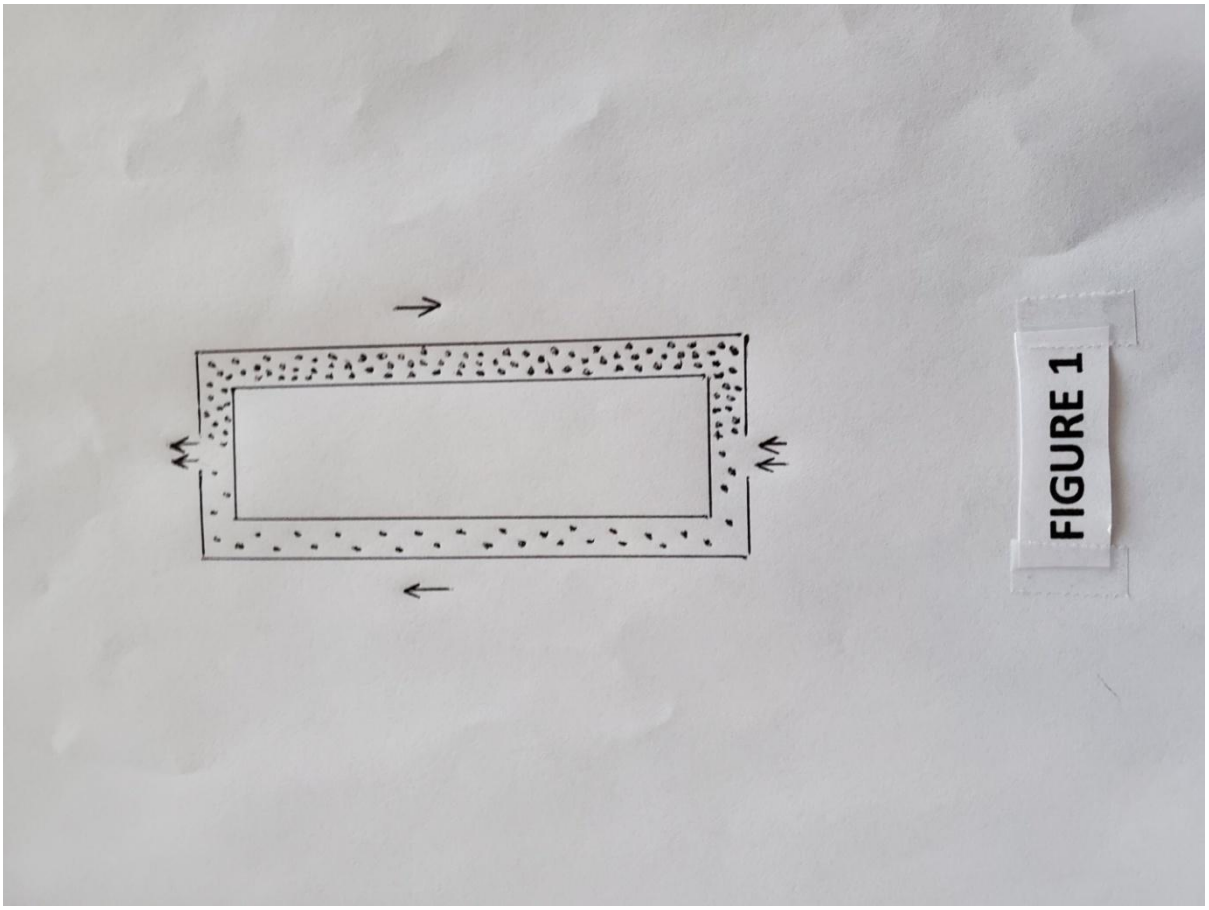

Figure 1

Schematic tree circulation element with upward xylem flow, downward phloem flow, and intake and exit flows at top and bottom. Dots indicate dissolved molecules in the water.

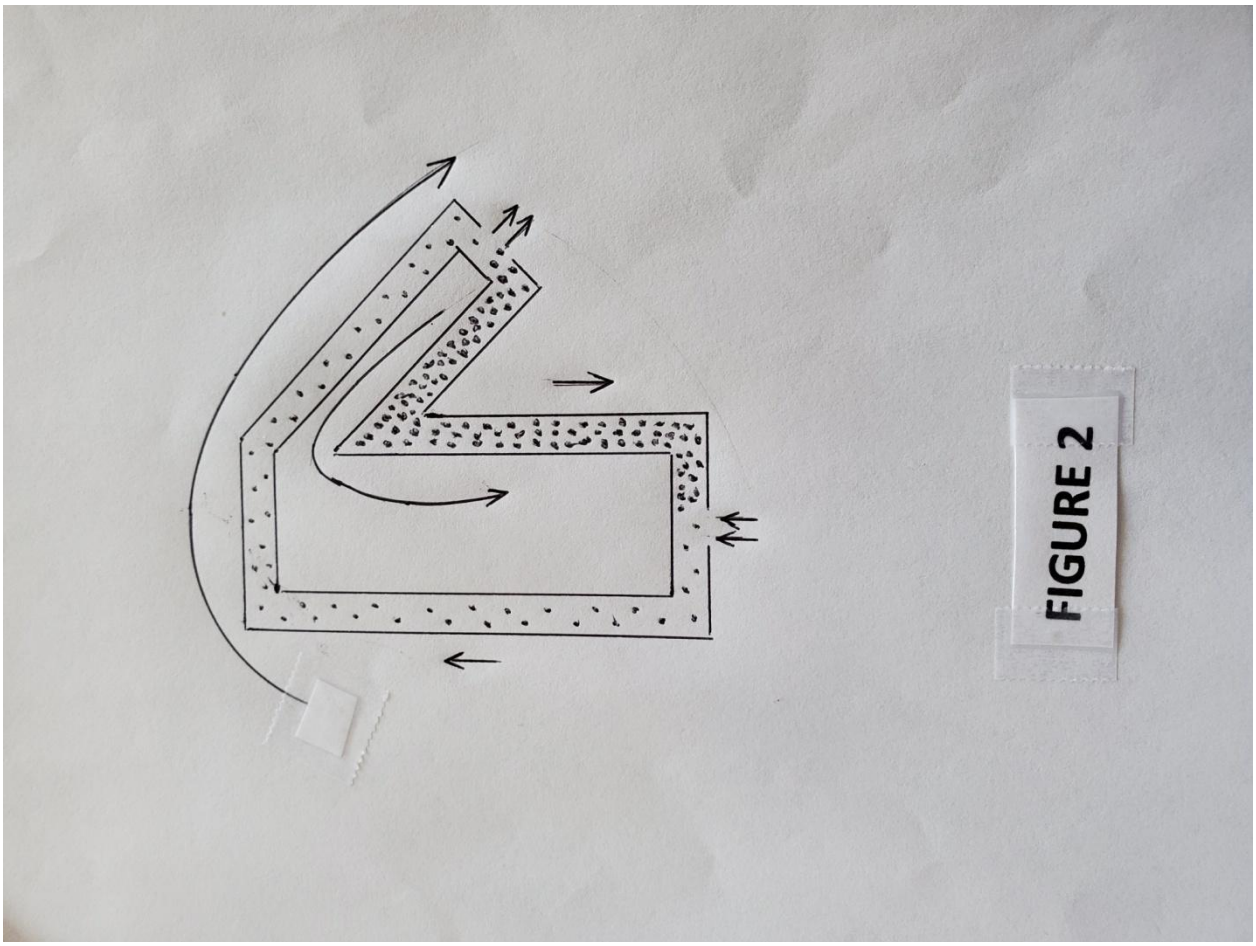

Figure 2
Modified schematic circulation element applied to a trunk with a downward sloping branch. Two curved lines show the siphons and their sense of flow.

2. Mechanism

Given the circulation of Figure 1, which makes common sense, because the more dense fluid goes down in the phloem and the less dense fluid goes up in the xylem. However, a dilemma presents itself when considering the configuration in Figure 2. It occurs that inside the downward slanting branch the lighter fluid must go down and the heavier fluid must go up. How could that situation be sustained? Then the working of the siphon comes to mind as a possible way to get around this potential intellectual difficulty. This new idea does not come directly from Figure 1, which has no siphons.

Figure 2 contains two siphons front to back, so to speak, as indicated by the curved lines. They act together to make the circulation go as shown. It may be necessary initially to prime the circulation to get it started.

3. Discussion

The mechanism discussed above does not come very close to what occurs in a fairly comprehensive review of the siphon [2], which includes a history of the subject, the two main theories of how the siphon works, experimental support to compare with those theories, and various applications. In particular, the review contains no circulation system that has two siphons. On the other hand, the

physics and mathematical methods in the review do not exclude the possibility of the present model existing on scientific grounds.

One piece of the circulation in Figure 2 is not part of a siphon, on the lower left half side, but it is pulled up by one siphon near the top and pushed to the left by the other siphon. If all the parameters are adjusted appropriately, the circulation should continue and not come to a halt.

4. Conclusion

A theoretical circulation of fluid inside a downward sloping branch of an upright tree trunk is proposed by modifying an existing model consisting of pairs of side by side vertical tubes connected by much shorter horizontal tubes above and below that allow water in at the bottom (osmosis) and out at the top (evaporation). In the tube of upward flow (xylem) there is a smaller amount of dissolved molecules per unit volume than in the tube of downward flow (phloem), causing the circulation by a pressure gradient in the bottom tube. Within the trunk and downward sloping branch the tube structure is altered such that there are two siphons back to front which should maintain the flow once it is started.

References

[1] Kenyon, K. E. (2007) Evapero-osmotic circulation. Phys. Essays, **20**, 127-130.

[2] Wikipedia (2020) Siphon.