A potometer modified for a double purpose

by

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When plants transpire moisture through their leaves, water is transported from a wet soil upwards through their stems in opposition to the downward pull due to gravity. The force the plants exert in carrying out this process can be used to perform some mechanical work with the apparatus designed for the purpose. The first experiment consists of the customary demonstration of the movement of a thread of water in a capillary tube as a proof of transpiration by plants. The second part is visually more impressive. It consists of the plants energy being used to perform the elevating of a cartesian diver submerged in water contained in a closed vessel.

The density of a colored cartesian diver (secured if necessary from the physics department) is so adjusted, that when placed in a glass jar (25 cm high and 6 cm internal diameter) of water, it will require at least five seconds to sink down to the bottom. This adjustment can be secured after a few trials by dipping the diver alternately in hot and cold water and shaking out any excess of water drawn into it. The jar full of water, is now fitted tightly with a rubber bung (2,5 cm. thick) containing seven holes (3 to 4 mm. in diameter) drilled into it at equal spaces. A length of 6 cm. of a capillary tube (1.5 mm. bore and 22 cm. long) with a greased tap in the middle kept open, is bent at right angles and fitted tightly into one hole on the right. A short glass tube (5 cm.) connected to a rubber tube (4 cm.) is similarly fitted into another hole on the left. While these tubes do not project below the rubber bung, the one on the left is allowed to project 2 cm. above the level of the one on the right.

Five healthy balsam plants, each about a foot high with fifty leaves in all and without buds or flowers are severed at the base an hour after watering them, and the shoots are quickly inserted into each of the five holes previously filled up with water. Time is allowed for the shoots to recover from shock and regain any loss of turgescence. A slightly soft

wax is pressed into each hole round the stem, then a thick layer of the same is applied at the base and on the side of the stem, and pressed to

Fig. 1

stop all possible leaks. This sealing is necessary for the success of the experiments. Some water is poured round the rim of the jar to serve as a seal. The waxed surface is dried by bits of filter paper.

Experiment 1

Keeping the glass tap open, water is poured by a pipette into the tube on the left until it flows out through the capillary tube sweeping out the air in it. Closing the opening of the latter tube by a finger, the other is filled up with water and closed by a glass rod as plug. On removing the finger, the water thread in the capillary tube rapidly moves toward the tap (9 cm. in 4 minutes) as a result of transpiration due to the large number of leaves present. It is better to have file marks on the capillary to observe the rate of movement of the water boundary.

Experiment 2

A rubber tube (25 cm.) is now attached to the capillary tube and held slightly bent upwards. Some water is allowed to collect in this tube by pouring it into the tube on the left. When the latter is full, it is plugged as before. By applying a sucking action through the tube on the right and releasing it, the diver floats up and then sinks down as a result of the change of pressure in the jar. This illustrates the principle on which the cartesian diver functions. The diver is brought up again and left in that position by closing the tap. If within five minutes it does not sink down it may be assumed that leaks in the set-up are absent.

It is now important the diver should be rendered quite sensitive to changes of pressure, if the demonstration is to be finished in a short time. When the diver is at the top, the glass tap is opened very gradually and in stages (intervals ten seconds). As it begins to sink down, the tap is closed quickly, and at the right moment, so that it dives sluggishly and takes 14 seconds to reach the bottom of the jar, showing it has been set properly.

With all the exits closed the cartesian diver now requires only five minutes to rise to the top as a consequence of the pressure in the jar being continuously reduced by the removal of water by the plants. The diver may be brought down again carefully as before and the experiment repeated any number of times, provided there is enough water in the tube on the right.

During the experiment, there should be no trapped air bubbles anywhere from the jar to the tap and particularly in the rubber holes, except in the cartesian diver. When the diver is caught between the plant stems, gentle tapping of the jar will loosen it. Plants other than balsam may also be tried. It is preferable to cut plants under water, less air-locks should be formed in the xylem vessels and retard the movement of water. The experiment should not be performed in direct sunlight, as its heating effect causes the diver to float up due to the expansion of air enclosed in it. The present experiment was performed near a window in the diffused light of a bright day. A gentle breeze assisted in the dispersal of the transpired water vapor. An electric fan may be used for the same purpose in the absence of a breeze.

The wax used in the experiment for sealing off leaks consisted of bee's wax melted with a suitable quantity of castor oil to soften it. The mixture on solidification, was worked by the hands until it attained a homogeneous consistency, and allowed to age for a week before use. Any other wax of medium softness and without action on the plants may also be used.