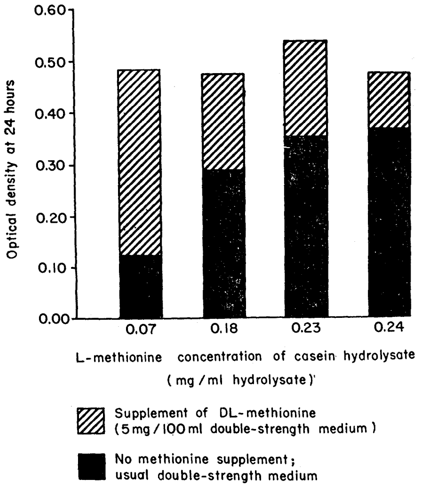

Fig. 1. Effect of methionine supplementation on total growth of *Streptococcus faecalis* 29-21 in folic acid assay medium. (Total growth occurring under conditions represented by 5 ml of double-strength medium and 10 mμg of folic acid, in a total volume of 10 ml.)

et al. (*5*), however, the corresponding values were 0.07, 0.18, 0.24, and 0.23 mg of L-methionine per milliliter of hydrolyzate. The latter data were considered to reflect more nearly the true methionine concentrations than the former, when it was noted that off-colors sometimes resulted in the colorimetric procedure, particularly when certain samples were assayed at high concentrations. A direct relationship existed between methionine concentration of the hydrolyzates and their varying abilities to support the growth of *S. faecalis* (Fig. 1), but even the batch of hydrolyzate with the greatest methionine concentration did not contain enough to permit optimal growth of the organism.

In addition to the strain of *S. faecalis* used in this laboratory, a culture of *S. faecalis* 8043, the strain most commonly employed for folic acid analyses, was also studied. Similar results were obtained with this organism as with *S. faecalis* 29-21—that is, supplements of methionine resulted in improved growth, but the effect of methionine was not as marked as with *S. faecalis* 29-21, for the latter requires about 30 percent more methionine for maximal growth at 24 hours than does *S. faecalis* 8043. Even to meet the requirements of *S. faecalis* 8043 for optimal growth, however, Greenhut *et al.* (*3*) suggest a concentration of 0.25 mg of DL-methionine per assay tube containing 10 ml of single-strength medium. This is, in reality, a requirement of 0.125 mg of L-methionine per tube, since the D-isomer is utilized only slightly, if at all (*6*). With the usual concentration of casein hydrolyzate of 0.5 ml/10 ml single-strength medium, the hydrolyzate must contain 0.25 mg of L-methionine per milliliter of hydrolyzate to provide the requisite amount, yet only two of the four hydrolyzates tested approached this amount. It seems rather noteworthy that the reported (*7*) methionine content of casein of 3.3 g/16 g of nitrogen (equivalent to approximately 3 mg/ml of a 10 percent casein hydrolyzate) exceeds by more than ten times the amount actually found in these hydrolyzates, implying a rather extensive and somewhat variable loss of methionine during hydrolysis. To allow for this, it is now routine in this laboratory to supplement all folic acid assay medium with 5 mg of DL-methionine per 100 ml of double-strength medium.

It has long been recognized that methionine is an amino acid required by many common assay organisms. Thus, a deficiency of this amino acid would adversely affect a number of assays utilizing a variety of test organisms. Correspondence with the manufacturer of the hydrolyzate revealed that no recent changes had been made in the manufacturing process and that the variability observed might be encountered under ordinary manufacturing conditions. The possible inadequacy of the usual amounts of casein hydrolyzate in meeting the amino acid requirements of various organisms should, therefore, be considered as a source of difficulty with microbiological assays.

EILEEN R. BRODOVSKY
MARGARET H. UTLEY
WILLIAM N. PEARSON
Departments of Medicine and Biochemistry, Vanderbilt University School of Medicine, Nashville, Tennessee

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"Root Pressure" in Gymnosperms

Movement of water to the tops of trees 200 or more feet high, in the large quantities which are required for normal growth and to replace losses by transpiration, involves the expenditure of enormous amounts of energy. There are two main theories current today of how this work is accomplished.

The one most widely accepted, the "suction tension theory" of Dixon and Joly (*1*) and of Askenazy (*2*) places the energy expenditure at the surface of the leaf mesophyll cells in the form of heat of vaporization of water; vaporization sets up menisci in the porosities of the cell walls which in turn exert a tension against the water reservoir in the plant; this reservoir is pictured as being continuous through stem and roots with the water of the soil, and held against collapse by adhesion to the rigid framework of the plant's structure and by cohesion within the column. Water is thus *pulled* through the plant by the menisci at the leaf surface. The mechanical processes and structures involved require no active participation of the living protoplasts. Any accident which would break the column would destroy the effectiveness of the system.

Such a system can function only under conditions of (i) active transpiration, (ii) complete freedom from dissolved gases capable of causing cavitation and (iii) complete rigidity (freedom from shocks capable of breaking the adhesion of fluid to wall). Although this theory has a prominent place in present-day textbooks, its inadequacies have been pointed out repeatedly, most recently and forcefully by Scholander (*3*). Greenidge has also reviewed the subject (*4*).

The second theory postulates that energy is expended within the plant, probably in the root tips, endodermis and/or the medullary rays, against pressure gradients, comparable to the water-secreting mechanism of the mammalian kidney tubule which drives water back into the blood after its passive filtration in the glomeruli. Energy for this work would come from respiratory processes and would be independent of the physical phenomenon of transpiration, though affected by temperature, soil moisture, salt levels, carbohydrate availability, and other factors. Its immediate expression is the guttation which occurs from leaves on wet mornings and in the tropics where transpiration is reduced or lacking, and in the well-known exudation from cut stems. It was originally described by Hales (*5*) in 1727 and is commonly designated "root pressure."

Both mechanisms doubtless do operate, each under special conditions. Their relative importance in the water economy of plants is, however, still a subject of debate. Arguments against the importance of root pressure as a factor in sap movement have in general been three.

1) The observed pressures are generally too small to account for movements of water to heights of more than 30 or 40 feet. This argument was seriously weakened by the demonstration by White (*6*) in 1937 of secretion pressures exceeding 6 atm (about 200 feet) in single isolated tomato roots.

2) The amounts of water moved are

too small to account for the volumes involved in the transpiration stream, and root pressure cannot usually be demonstrated in transpiring plants. Although this argument is frequently raised, it is an obvious *non sequitur*. Transpiration, when it does occur, provides a mechanism capable of moving large quantities of water, but this can quite well occur independently of other mechanisms; they are in no way mutually exclusive; and the common methods so far devised for demonstrating root pressure *require* the abolition of the transpiration mechanism during the test. Scholander has recently introduced a method which does permit simultaneous demonstration of the two and has measured them simultaneously in certain vines (*7, 8*).

3) It has been stated, for example by Kramer (*9*), that "A . . . reason for doubting that . . . root pressure phenomena play an essential role in the intake of water, is the fact that it [root pressure] apparently never occurs in Gymnosperms. It would be very surprising if such a process were essential in one group of plants, yet not even occur in another [similar] group." And again, "Root pressure has never been observed in the Gymnosperms, and it is probable that active absorption never occurs in that group" (*9*, p. 790).

This last argument, if based on incontrovertible evidence, would indeed seem to make untenable any idea of root pressure being of general importance in the movement of water to the tops of tall trees.

On a suggestion from Scholander, made during the discussions at the Symposium on the Physiology of Forest Trees at the Cabot Foundation, Harvard Forest, Petersham, Mass. (Apr. 1957), we set out to examine the validity of this argument (*10*). Simple manometers were attached to the roots of three species of Gymnosperms: *Pinus strobus, Picea glauca,* and *Picea rubens* and, for comparison, on three Angiosperms: *Betula lutea, Populus alba,* and *Fraxinus americana.*

The procedure was as follows. Trees of as uniform age and size as possible were chosen, 15 to 20 feet in height, 25 to 40 years old. Roots were traced away from the trunk until branches 0.5 to 1.0 cm in diameter were exposed. These were severed perpendicular to the axis. Since such tissues, in actively transpiring trees, sometimes show negative pressures in the vessels, the roots were left for about 15 minutes to allow any air which might be sucked into the vessels by this negative pressure to come into equilibrium. A second cut was then made about 15 cm acropetal to the first so as to expose a new series of water-filled vessels, now in equilibrium. A rubber hose of suitable diameter was turned back upon itself for a distance of about 2 cm and was then placed on the root by rolling the everted portion on, so that the root tissues were not torn or bruised. A simple manometer of about 0.5 mm internal diameter was then attached to the hose and suitably supported in a vertical position. Readings of the height of fluid in the tubes were recorded at intervals from 11 July to 19 August 1957. It is to be noted that this is the driest part of the year, a season when transpiration is at a maximum and when positive sap flow is least likely to be evident, even in Angiosperms.

Of 51 manometers placed on roots of 17 coniferous trees, 24 (47 percent) showed positive sap flow. In 14 (27 percent) the columns developed were more than 40 cm in height. This was commonly the length of our manometer tubes, and greater heights could be read only by splicing on further tubes. In 13 cases such additional tubes were attached and flows up to 80 cm were recorded. In one case a mercury column was added, using a horizontal "S" connection and a mercury rise of 4 cm, equivalent to about 55 cm of additional water, to a total of about 70 cm, was recorded. In eight cases flow over the top of the manometer occurred and the fluid was lost. In one case a flask was attached and 30 ml of fluid were collected. This was on a red spruce root (*Picea rubens*).

Under comparable conditions, the maximum flows observed from Angiosperm roots were 100 cm (*Betula alba* and *Fraxinus americana*). It is significant that no flow was observed in either Gymnosperms or Angiosperms growing on dry soil, whereas flow was observed in trees growing in moist locations.

From these experiments it is clear that, contrary to previous statements (*8*) active water secretion and "root pressure" *do* exist in Gymnosperms and can be demonstrated in several species under the conditions in which they are demonstrable in Angiosperms. Angiosperms do not, as has sometimes been suggested, occupy a unique position in this respect. The supposed absence of root pressure in Gymnosperms is not a valid argument against the general significance of root pressure in the water economy of plants.

PHILIP R. WHITE, ELEANOR SCHUKER,*
JOHN R. KERN,* FRANCIS H. FULLER†
Roscoe B. Jackson Memorial Laboratory,
Bar Harbor, Maine

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10. The work presented here was carried out as part of the Jackson Laboratory's program of training in research for secondary-school students, during the summer of 1957.

* First-year student, Swarthmore College, Swarthmore, Pa.

† First-year student, Bowdoin College, Brunswick, Me.

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Effect of Transverse Atmospheric Drag on Satellite Orbits

In considering the various factors which influence the orbits of earth satellites, it is obvious that the motion of the earth's atmosphere, rotating with the earth, will tend to deflect the motion of the satellite. An approximate formula may be devised very simply to indicate the maximum perturbation caused by this effect.

When a satellite enters the atmosphere, the relative velocity giving rise to the air resistance, or drag force, is the resultant of the orbital velocity and the rotational velocity of the atmosphere. For any orbit not in the plane of the equator, the drag has a component transverse to the orbital motion, tending to deflect the motion and thus to change the plane of the orbit.

To derive an *approximate* formula for the *maximum change* to be expected, we make two simplifying assumptions: (i) that the plane of the elliptical orbit is parallel to the polar axis of the earth (a polar orbit); (ii) that closest approach (perigee) always occurs at the equator (actually, the position of perigee would change progressively for a polar orbit; for exact calculations suitable averaging factors must be included); (iii) that the satellite is spherical (actually, if it were finned so as to head into the relative wind, or if it tumbled at random, the averaged results would be the same as far as the total orbit change is concerned).

No assumptions need be made with regard to the magnitude of the drag or its dependence on velocity. The ratio of the component of drag, D_t, transverse to the orbit and the component, D_o, parallel to the orbit, will be the same as the ratio of transverse and orbital components of the relative wind velocity, v_e and V_o. That is:

$$D_t/D_o = v_e/V_o, \qquad (1)$$

where v_e is the cross-wind due to the earth's rotation.

On each revolution, the satellite suffers a small change in velocity, ΔV, due to drag (primarily near perigee) and a corresponding change in momentum, ΔMV. ΔV and ΔMV may be separated into components ΔV_o and ΔMV_o parallel