alcohol. The alcohol seems to take out the water very rapidly, probably almost instantaneously, but the alcohol must penetrate or come in contact with all the soil mass.

Before proceeding with the moisture determination the hydrometer is first calibrated. This is accomplished as follows: The specific gravity of pure alcohol, about 96 per cent. by volume, is first ascertained. We will say it is 96 per cent. A volume of 50 cc of this alcohol is carefully measured in the 100 cc cylinder, a 10 cc of water is added to it and the specific gravity is again determined. We will say it is 82 per cent. alcohol. The temperature is also recorded, and the readings are reduced to the same basis, say 20° C. A temperature of 1° makes a difference of about 0.2 per cent. alcohol. For temperatures above 20° C. the corresponding amount is subtracted from the percentage of alcohol indicated, and for temperatures below 20° C. the corresponding amount is added to the percentage of alcohol indicated. When the readings are reduced to the same basis, then the reading of the alcohol which contained the 10 cc of water is subtracted from the reading of the pure alcohol and the difference is divided into the 10 cc of water. This gives the number of cc of water that each degree on the stem is equal to. The standard special hydrometer gives .714 cc of water for each graduation. To find the number of cc of water in the soil sample taken, the difference in specific gravity of the filtrate and the pure alcohol is multiplied by .714.

The general procedure for executing a moisture determination is as follows: Pour 50 cc pure alcohol into the 100 cc cylinder. Add to this alcohol 20 grams of soil whose moisture is to be determined. Disperse the soil by shaking, using one palm as a stopper. Unless a soil is badly puddled and hardened it slacks or crumbles in alcohol. In case of soils which refuse to slack or crumble as in the case of some badly puddled and hardened clays, break them up gently by means of the rod. If clay sticks on the rod, rub latter vigorously on the walls of the cylinder. Soils filter fastest when only shaken and not when dispersed by rubbing. Hard lumps can be gently broken up by a rod without dispersing the soil.

Allow the soil to stand for a minute or two in order that the major portion of soil mass may settle. Then pour supernatant liquid on the filter, allowing filtrate to drain into the 25 cc cylinder which stands in the sand. Only about 12 to 20 cc of filtrate is required. Place hydrometer in the filtrate and take readings. The latter should be taken on straight line to the surface. Take hydrometer out and determine the temperature of the filtrate. Reduce readings to same temperature basis. Subtract reading of filtrate from reading of pure alcohol and multiply differences by .714 or by whatever factor found in calibrating hydrometer, which gives number of cc of water in the sample taken. The percentage of water in the soil is calculated in usual way.

In collecting or preparing a soil sample care must be taken not to puddle it or press it so that the alcohol can penetrate it and slack it easily. Keep the soil as much in its natural crum structure as possible. Care must be taken to rinse vessels with pure alcohol before using.

The waste alcohol can be recovered so it can be used again by treating it with burned lime.

During the process of filtering it is well to cover the funnel to prevent evaporation of the alcohol mixture.

If one has to make many moisture determinations, it would be well to have several cylinders and funnels, so that while one sample is clearing up and being filtered, another is being prepared.

Other forms of alcohol could probably be used equally as effectively as ethyl, but probably this is the most practical.

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SPECIAL ARTICLES

THE ASKENASY DEMONSTRATION OF TRACTION TRANSMITTED THROUGH LIQUID WATER

THAT water and other liquids possess to a great extent the property of cohesion, and that mechanical traction or pull may be transmitted or applied through a mass of liquid in much the same way as through a solid, have long been known, but the experimental demonstration of such transmission still remains outside of the direct experience of most students of natural phenomena. The general concept of taut strands of liquid water and of water masses slightly stretched by traction transmitted through them is familiar enough in the field of plant physiology. Indeed, the molecular phenomena here referred to are so broadly fundamental that they now form the most satisfactory basis for a scientific analysis of the behavior of water and aqueous solutions in ordinary plants. Transmission of traction through liquid water is generally, however, a thing merely to be read about and vaguely, almost mystically, pictured if really envisaged at all. The demonstration of this phenomenon is still regularly omitted from laboratory manuals of plant physiology and general botany, or else the proposed demonstrations are of such nature that they almost always fail, leaving the student to content himself at last with just reading about how such experiments have succeeded in other hands. Text-books of plant physiology are commonly as unsatisfactory in this connection as are the laboratory manuals. It is notable also that physical and physico-chemical treatises generally afford little or no direct help to the perplexed student of this particular corner of the field of molecular physics, while adequate discussion of liquid tension and procedures for its experimental demonstration are not usually included in college and university courses in the physical sciences. Physiology can not here refer to hand-books or courses in the more fundamental fields.

Continuation of such a state of affairs is of course undesirable from the standpoint of plant physiology, since the physical principles here involved constitute a cornerstone in that science. This is true from other standpoints also, for it is not unlikely that the tensile strength of water or that of other liquids may, when more commonly understood and appreciated, become applicable in many fields outside of physiology and in ways as yet unthought of. Capacity to transmit traction is an important characteristic of liquids that has thus far generally escaped conscious appreciation and application in research as well as in the arts and in engineering, although it is known to be inevitably involved in the mechanisms of ordinary plants and may be influential in some hydrodynamic geological processes and in the mechanism of the drying out of some kinds of porous materials. The occurrence of liquid tension in suitable experimental systems and in ordinary plants has been variously demonstrated by a number of experimenters, but the most striking method thus far available for the visual demonstration and study of the transmission of traction through water or aqueous solutions or suspensions is that of Askenasy (1896), which has been modified and improved in detail by Ursprung, Jost and others. In spite of marked improvements, the experiment has remained unsatisfactory, with difficult, awkward or tedious manipulations and uncertain results.

We have been engaged for about a year in further detailed study of this classic experiment, with the hope that additional improvement in technique might at length render it really suitable for elementary lecture and laboratory demonstration and also for the direct utilization of the tensile strength of water in research experimentation wherever this may be desirable. Our attempts have been passably successful, and the phenomena in question can now be readily demonstrated within a few hours, and without undue preliminary work. A brief discussion of our procedure was presented before the physiological section of the Botanical Society of America at its Kansas City meeting in December, 1925, and a description of the method is included, with a diagram, in the new (third) American edition of Palladin's "Plant Physiology" (P. Blakiston's Son and Co., Philadelphia). Still further improvement and simplification, as well as useful applications in research instrumentation, etc., will doubtless be brought forward, but enough has now been accomplished to make possible and feasible the satisfactory introduction of the Askenasy demonstration in laboratory courses or as a lecture experiment in either the physical or physiological sciences.

We shall not describe the experiment in detail in this paper, but we wish to call the attention of science teachers to the pressing need for a more precise and general appreciation of liquid cohesion and its corollaries, particularly the transmission of traction through liquid water as this occurs in ordinary plants. We wish especially to request other experimenters to send to this laboratory information regarding their own experiences with the Askenasy demonstration, whether successful or not. We should like to bring together in a future publication the experiences of all who have been interested in this experiment, with special reference to difficulties and experimental failures as well as successes.

Misunderstanding may exist as to just what constitutes an Askenasy demonstration. A simple form of the apparatus, which cares for all the essentials, consists of a porous porcelain cylinder, closed at one end and attached by a rubber stopper to the upper end of a vertical, small-bore glass tube, a meter or more in length. Tube and cylinder are filled with water without air bubbles of any considerable size, and the lower end of the tube dips into mercury in a reservoir below. Water moves outward and evaporates from the surface of the cylinder but undissolved gas can not enter, for the pores of the cylinder wall are effectively plugged with water, the air-water meniscus within each pore being held fixed by capillary forces capable of withstanding an excess of several atmospheres of external air pressure. Indeed, the entire upper portion of the container that encloses the diminishing water mass (*i.e.*, porcelain cylinder and glass tube) may, for the present purposes, be regarded as practically rigid, like the glass tube of a barometer. Consequently the volume of the water can become adjusted to its diminishing mass only by a rise of the non-rigid boundary between water and mercury at the base of the system. As water continues to evaporate from the water-soaked walls of the cylinder, the water column becomes shorter and the loss is replaced by mercury, which rises in the tube from the reservoir.

At any moment in the progress of the experiment the pressure at any level (calculated as one calculates the pressure in the tube of a barometer and neglecting a very small correction for capillary depression) is the difference between the pressure at the base of the tube and the pressure corresponding to the liquid column extending upward from the base to the level in question. The pressure is thus always least at the top of the system, and greatest at the bottom. At the base of the tube the pressure remains practically unchanged throughout an experiment, being equivalent to the atmospheric pressure acting on the surface of the mercury in the reservoir, increased by a small value to account for the depth of the tube-opening below the mercury surface. But the pressure at any higher level, which is always smaller than that at the base of the tube, becomes still smaller as water lost above is replaced below by the much heavier mercury, and this decrease continues until the mercury-water boundary attains the level in question, after which the pressure in the mercury at that level remains constant with still further elongation of the mercury column. The pressure at the mercury-water boundary becomes continually smaller as this boundary ascends, becoming zero when the column of mercury just balances the opposed external pressure —that is, when the height of the mercury column in the tube just corresponds to the maintained pressure at the base. At this time the pressure at every level in the mercury is positive, being greatest at the bottom and zero at the top of the mercury column, and the pressure at every level in the water is negative, this negative value being of course numerically greatest at the top of the system and zero at the mercury-water boundary. The water is then all in a state of tension; it is taut, like a vertically suspended rope or wire. The water adheres to the nearly rigid glass, rubber and porcelain walls and to the mercury below. As still more water is lost by evaporation from the cylinder and the mercury column continues to elongate upward, the upper portion of this column also passes into a state of tension and we have a demonstration of the transmission of traction through the upper portion of the mercury as well as through all of the water. The taut mercury adheres to the water above and to the very thin water film that intervenes everywhere between mercury and glass and this film adheres to the glass, thus acting as an adhesive cementing mercury and glass together.

The essential pressure relations outlined above may be stated algebraically as follows, all pressure values being expressed as heights of equivalent mercury columns, in centimeters.

$$P = B + b - (H + \frac{h}{13.6} + D)$$

In this expression, P is the pressure at any level in the liquid column, whether in mercury or water. It is clearly negative, and there is tension at the given level, if the expression in the parenthesis is greater than $B + b$. B is the atmospheric pressure on the mercury surface in the reservoir outside of the tube (usually the current barometer reading), while b is the depth to which the tube projects downward into the mercury in the reservoir. H is the vertical length of the mercury column between the base of the tube and the given level, while h is the vertical length of the water column below the given level, between it and the water-mercury boundary below. D is a small value due to capillary depression. (It may be taken as 0.8 cm. for a tube of 1.5 mm. bore.) If the level considered is *below the water-mercury boundary,* then h is zero. If the level considered is *at this boundary,* then h remains zero and H is the total vertical length of the mercury column in the tube, measured from the lower end of the latter. If the given level is *at the top of the system,* then H remains as in the last case and h is the total height of the water column, measured from the water-mercury boundary to the top. To illustrate, if B is 75.5 cm., b is 2 cm., H is 125 cm., h is 20 cm., and D is 0.8 cm., then $P = 75.5 + 2 - (125 + 20 + 0.8) = 77.5 - 145.8 = -68.3$ cm. The negative pressure at the given level, which is 143 cm. above the level of the mercury in the reservoir in this case, is equivalent to 68.3 cm. of a mercury column, or about nine tenths of an atmosphere. This is a measure of the tension or traction at the given level. (It should be noted that the expression "negative pressure" is sometimes erroneously used to denote simply *decreased positive* pressure, a positive pressure lower than that of the surroundings.)

In an experiment of this kind the liquid column in the system eventually breaks in every case, sometimes in the water (in cylinder or tube) and sometimes in the mercury. When rupture of the column occurs before the pressure at the highest point of the system has become negative, then the experiment is a failure in respect to the demonstration of traction and liquid tension (for none is developed in such a case), although it does successfully demonstrate what has been called the "suction power" of evaporation. The suction developed at any level in the system is then equivalent to the (positive) value of P, as found by means of the equation. It is of course greatest at the top of the system.

An experiment to show the "suction power" of evaporation from a fine-pored membrane is regularly performed in laboratory courses in plant physiology and is generally described and figured in the textbooks of that science. The arrangement is essentially like that of the Askenasy experiment. No difficulties are involved and the mercury column gradually elongates and reaches a height of 60 or even 70 cm. in many cases, but (unless proper precautions have been successfully taken to make this really an Askenasy experiment) the liquid column breaks before the pressure at the top has become negative in sign. Every Askenasy experiment demonstrates suction before any tension is developed and it demonstrates both suction (below) and liquid tension (above) when the pressure at the top is negative.

It is this suction experiment that was referred to by Dr. C. A. Arndt (SCIENCE for May 21, 1926, page 527), who seems to have failed to realize that traction and liquid tension can not begin until after the possibilities of ordinary suction have already been exhausted. This author was apparently not dealing with the Askenasy experiment at all. His "superior results" are to be taken as bearing upon the suction experiment only, being consequently just failures for the Askenasy experiment. Without additional data (barometric pressure, length of water column above the mercury in the system, and bore of tube) even the "greatest total height" given, 28 inches, is not in itself evidence of liquid tension, although the smallness of the difference between this value and the normal barometer reading (about 30 inches for Philadelphia) indicates that the pressure in the top of the system was as low as one or two inches of mercury. Shorter mercury columns of ten or twenty inches, such as Dr. Arndt mentions, surely represent failures as far as the demonstration of tension by the Askenasy method is concerned. From Dr. Arndt's printed statement and also from correspondence with him it is clear that the pressure on the surface of the mercury in the reservoir was the current barometric pressure.

Plant physiology requires as careful thinking as do the physical sciences, and students of plant water relations should be led to distinguish clearly between suction and traction. In the case of suction the elongating or moving column of liquid is under the action of two opposing external forces, one larger than the other but both tending to compress the liquid and shorten the column. In the case of traction also there are two external opposing forces, but both tend to overcome the cohesion of the liquid and stretch the column. In the first case the liquid column is slightly compressed, in the other it is slightly stretched (tension). In suction the liquid is *pushed* up and in traction it is *pulled* up. For a demonstration of suction alone it is not necessary to exercise any special care in setting up the apparatus, but special treatment is generally necessary if any tension or traction is to be developed.

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SIMPLE SEISMIC MEASUREMENTS

THE measurement of earthquake acceleration maxima by observation of the fall of vertical columns was proposed more than forty years ago. The condition that a properly directed horizontal acceleration should be sufficient to overturn a simple rectangular parallelopiped was stated by Professor C. D. West as $a = gb/h$, where h is the height and b the breadth of the paralellopiped, and g is the gravitational acceleration. This relation results at once if one equates the inertial moment about a lower edge of the parallelopiped to the gravitational moment about the same edge. By observation after a quake of the status of a number of parallelopipeds having different ratios b/h an estimate of the magnitude of the maximum acceleration was to have been obtained. But upon testing this method by experiment Milne[1] and Omori[2] found West's formula to be inapplicable to earthquake-like accelerations. Discrepancies as high as 35 and 40 per cent., some positive and some negative, were recorded.

There seem to have been two reasons for this disagreement. The acceleration of West's formula—or rather any acceleration in excess of it—although undoubtedly sufficient to *start* the overthrow will not bring it to completion if the duration of the acceleration be too brief. Seismic accelerations are not constant accelerations but are of an alternating nature and may rise to maxima much higher than that expressed by the above equation and yet die away so quickly that the complete overthrow does not take place. On the other hand, the alternating character of the acceleration may in some cases result in the upset of the parallelopiped through the development of resonant oscillations, even though West's acceleration is never attained. In this case the elasticity of the paralellopiped and of its foundation play an important part. These errors, though opposite in sense, can not be expected to annul each other, and a discrepant result, difficult at present to predict, will in general remain.

West's equation, in short, does not apply to the case of an object overturned by an acceleration of alternating or oscillatory character because it was never formulated to fit such conditions. It correctly defines the minimum acceleration, however attained, at which the object will start to turn over. But only for special cases, such as that of a constant acceleration, does the formula state the acceleration competent to complete the overthrow.

The theoretical treatment of an object overthrown by simple harmonic motion does not appear to have been presented. Galitzin dismisses the matter with the observation that the problem offers real difficul-

1 J. Milne, Trans. Seis. Soc. Japan, Vol. 8, 1885.

2 J. Milne and F. Omori, *Seis. Journ.*, Vol. 1, 1893.