of the brass tubing forms the well of the tambour, while the long brass tube forms the shaft. The membrane is supplied by a piece of thin rubber dam screwed tightly between the two brass plates. If necessary, a second thickness of rubber dam, with a 1 cm hole pushed through its center by a cork borer may be used as a gasket. A light muscle lever, resting on the dam by means of a small round foot of sheet aluminum, transmits the pulsation to the lever. A light hollow straw bearing a writing tip of celluloid camera film furnishes the best lever.

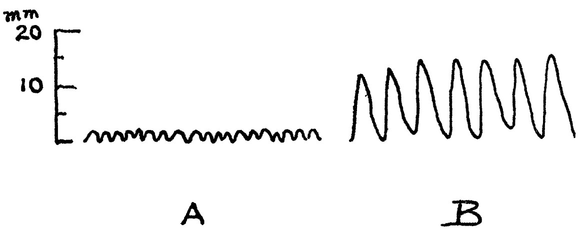


FIG. 4. Mercury manometer tracing (A) and membrane manometer tracing (B) from the abdominal aorta of a rabbit.

The tambour is filled with the anticoagulant solutions by means of a long capillary pipette, inserted through the shaft into the well of the tambour so as to drive out air bubbles.

With such a tambour pulsations 15 mm in amplitude can be obtained from the rabbit's aorta.

### SUMMARY AND CONCLUSIONS

The abdominal aorta of small mammals is easy of access, and this vessel is well suited for the taking of blood pressure tracings having a good amplitude of pulsation.

The construction of a very simply made and satisfactory membrane manometer is described with which tracings of very large pulse amplitude are easily obtained.

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## SPECIAL ARTICLES

### TREE TRUNKS, GROWTH AND REVERSIBLE VARIATIONS IN CIRCUMFERENCE

THE forester bases his conclusions as to growth or production of lumber upon gross measurements compiled from hundreds of trees and is so impressed with individual differences, and with the varying effects of the seasons, that he has but little interest in the changes of the tree from day to day, or, in brief, with its behavior from a physiological viewpoint.

If the production of cellulose, etc., be considered as one of the main interests in forestry, it is obvious that methods similar to those used in the culture and growth of cotton, corn, wheat or flax may be expected to yield results as valuable to forestry as those obtained by making use of the technical results of experimental studies of these great staples.

The botanist, interested in trees as a type of vegetation in which photosynthesis, accumulation of nutritives, conduction of sap and translocation of material and transpiration are carried on in such manner as to afford unexcelled opportunities for study of fundamental problems, has begun to apply exact methods of measurement of the rate, seasonal course and amount of growth in trunks, and to identify the effects of temperature, soil-moisture and other features of the substratum, relative humidity, light intensity, length of season, age, developmental condition, defoliation and other injuries on the activity of growing points and cambial layers.

The size of a tree is an advantageous feature in experimentative manipulation. On the other hand, this massiveness and the term of years requisite for maturity makes it impossible for the geneticist and the physiologist to include hundreds or thousands of individuals in a series, as may be done with corn, wheat or peas. The best procedure is obviously one in which the student, in adherence to a carefully considered program, carries his observations over a term of years on a number of individuals large enough to comprise all developmental stages.

It is in accordance with such a plan that my own studies of tree-growth with the dendrograph include a few seasons' records of trees in about a dozen genera, with attention chiefly concentrated on the Monterey pine (*Pinus radiata*) and the coast redwood (*Sequoia sempervirens*) with an accumulation of continuous records for a total of more than a century, about half of which is of the Monterey pine and including fifteen seasons of redwood.

Of the 29 Monterey pines under observation, the changes in the basal part of tree No. 1 have been recorded for six and one half years, a dendrograph has been attached to its trunk 27 feet from the base since January, 1920, and a similar record of a large root was begun in 1922.

Professor Hirokichi Nakashima has recently published the results of an attempt to find a mathematical expression for growth by a study of a five-year record of a single tree of *Abies Mayriana* in the Botanical Garden at Sapporo, Japan. A Friedrich's Zuwachsautograph was attached to a stem of this Japanese fir, which was about 24.98 mm in diameter at the beginning, and 25.68 mm at the close of the observations. Soil-temperatures and meteorological observations were made in the usual manner. The essential part of the growth-recorder consists of a steel band, 80 centimeters long, with a temperature coefficient of 0.009 per degree C., which encircles the tree so that variations in circumference change the tension on a register lever.

The text and tables of Professor Nakashima's paper[1] amount to about two hundred pages and are illustrated with 26 plates. The summarized conclusions are to the effect that increase in the trunk results either from growth or swelling of the water-conducting tissues; variations in circumference depend closely on transpiration and absorption; increased transpiration without corresponding increase of water intake causes shrinkage; lessened transpiration is followed by swelling of the trunk. The climate of this locality includes a winter with low temperatures, snow and ice, and the year is divided into four periods with respect to the tree; that is, the rest period of winter, the spring transition period, the vegetation or growing period and the autumnal transition period. The author has not availed himself of any short cuts in analyzing his material. The data include figures giving the difference between the circumference each day and on the previous day at 7 o'clock; the difference in circumference between 7 o'clock and 14 o'clock; the difference between the circumference at 24 o'clock and at the corresponding time on the previous day; the difference between the circumference at sunrise and at the previous sunset; the difference between the circumference at sunset and the sunrise of the same day; the differences between daily averages and those of the previous day, which, together with figures as to wind direction, strength, sunshine, cloudiness, relative humidity, precipitation, evaporation, maximum and minimum and average temperatures of the air, the temperature of the soil at 30 centimeters and 120 centimeters, make up 155 pages of tabulated matter.

Precipitation, not the annual total, but the amount during the growing season, May to October, was found to be the determining factor in accretions to the basal part of the trunk, which is to be expressed by the formula, $y = a - b(x + 0.5)^c$, in which $y$ = daily increase of circumference in mm, $x$ = precipitation during the growing season in mm. By substitution, $y = 0.055 - 0.02785(x + 0.5)^{-0.41797}$.

Temperature was the determining factor in the changes of circumference of the trunk in the winter resting period, according to Professor Nakashima's conclusions. $Y$ was taken to express amount of change, $x$ the daily average temperature in the formula $y = a\,10^{-b(2-x)} - 0.2$. By substitution, $y = 0.66359.\,10^{-0.086265(2-x)} - 0.2$.

It is to be noted that these formulae include no physiological terms and recognize in no manner the result of stomatal action or the effect of storage material in the tree. What modifications would be necessary to make these formulae applicable to other individuals in the locality and elsewhere is yet to be seen.

A slight positive correlation between amounts of seasonal growth and rainfall was found by Dr. Shreve[2] in an examination of 125 trees of the Monterey pine, but a negative correlation between growth and rainfall during the season of activity. Advance of temperatures above a certain minimum starts the season's enlargement of the trunk, and reduction of the soil-moisture to something below 10 per cent. brings it to a standstill in mid-summer. It is notable, however, that the terminals begin to elongate earlier and continue to do so after wood-formation in the trunk has ceased, a matter to which G. A. Pearson has recently recalled attention.[3] It may be confidently predicted that the total growth of trees can not be profitably or correctly correlated with the march of any single environic component.

The only generalization as to the amount of growth that can be made upon the basis of the dendrographic records of the Monterey pine is that the thickness of the wood layer formed in any year is closely correlated with the length of the growing season, which obviously involves a complex of agencies. Growth in any case entails a condensation by dehydration of material to proteins and to carbohydrates in every cell preliminary to distention, and any curve fitted to this procedure will necessarily be wide of many available facts.

Increases and decreases in trunks which are not fixed by morphological change have been termed "reversible variations" in my own publications since 1921.[4] These variations depend on expansions and contractions of tracheids and vessels following altered tensions of the cohesive water-column present, and to a minor extent upon the state of hydration of the phloem and cortex. That these variations are not in the first instance an index of the balance between absorption and transpiration is shown by the fact that a contraction of the basal part of a giant redwood 150 feet in height ensues within 15 minutes after the rays of the rising sun strike the summit of the

1 Nakashima, H., "Ueber den Einfluss auf den Stammumfang eines Tannenbaumes," *Journal* of the College of Agriculture, Hokkaido Imp. Univ., Sapporo. Vol. 12, part 2, May, 1924.

2 MacDougal and Shreve, "Growth in trees and massive organs of plants," Publ. 350, Carnegie Institution of Washington, May, 1924.

3 Pearson, G. A., "The growing season of the western yellow pine," *Jour. Agric. Research*, 29, 203, 1925.

4 MacDougal, D. T., "Growth in trees," Publ. 307, Carnegie Institution of Washington, 1921.

crown. Bode[5] has also shown that similar changes follow altered cohesion tensions in small plants. Singular reversals of these alterations have been recorded in the Monterey pine, by which increase in diameter takes place during the daylight period—the usual program of tree cactuses. It is notable that large roots near the base of the trunk of a pine show reversible variations of opposite phase to those in the trunk.[6]

A pine tree dying as a result of complete defoliation in midsummer still carries on transpiration at a lessened rate, but which is sufficient to maintain a cohesive column of upwardly moving water in which daily variations in tension are measurable. Any disturbance of the system would destroy the experiment, but it is highly probable that ascent of sap and reversible variations continue for a time in trees in which every cell is dead. The colloidal masses of dead cells at the terminals are the seat of a minimized transpiration of an amount sufficient to maintain tension on the water-column in wood-cells which are dead when they become conductors. The absorption of water by dead roots is a well-established fact. The conditions described may be taken to illustrate the ascent of sap in trees without the participation of living cells.

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## THE PURIFICATION OF ZIRCONIUM

SALTS of zirconium are used in X-ray crystal analysis as filters for the rays from a Coolidge tube having molybdenum target. This is because of the property, peculiar to zirconium atoms,[1] of transmitting the "Mo alpha" wave lengths very readily, but of being especially opaque to Mo beta and gamma rays. In all zirconium compounds commercially obtainable this property is not as pronounced as it should be, probably because of the presence of some impurity. It therefore seemed worth while to attempt to find a method for separating zirconium from the other elements with which it is naturally associated. The raw material used was zirconium nitrate, because it is water soluble. It was known that the citrate was also water soluble and gave a clear solution with ammonia. It seemed at first that this might serve as a starting point for working out a method of eliminating at least some of the impurities. Contrary to expectations, a precipitate was formed upon adding a limited amount of citric acid to the solution of zirconium nitrate. This precipitate is soluble in an excess of citric acid or in ammonium hydroxide.

It was thought advisable to investigate both the precipitate and the filtrate obtained when a limited amount of citric acid was used. A test was, therefore, made of the absorption of each for the molybdenum alpha and beta X-rays.[2] This test showed at once that the precipitate was a zirconium compound, because it strongly absorbed molybdenum beta wavelengths while it transmitted the molybdenum alpha wave-lengths easily. This is a property of zirconium atoms and is not shown by the atoms of any other element, so that the identification of the precipitate as a zirconium compound was complete. A rough test with the dried filtrate did not show this characteristic X-ray absorption and transmission. It was, therefore, concluded that the filtrate contained either little or no zirconium or a mixture of zirconium and some other elements of such atomic weights as to mask the effect of the zirconium. If the second conclusion is correct, it would be expected from an X-ray standpoint that the impurities which had been concentrated in the filtrate were of higher atomic weight than zirconium.

It was decided to make further experiments with the oxides obtained, first by ignition of zirconium citrate and second by ignition of the part soluble in citric acid. A rough atomic weight determination was made by the writer, by converting the first oxide to chloride and precipitating the chloride with silver nitrate. This gave a value for zirconium equal to 91.09 or .7 lower than that obtained by Venable and Bell.[3] The second oxide treated similarly gave values varying from 92.39 to 92.46. While the latter evidently is mostly zirconia it still contains some impurity of a higher atomic weight.

The observations indicate that a partial separation of zirconium from hafnium might have been effected. It is certain that a single precipitation with citric acid gives a zirconium compound which is much purer than any zirconium salt ever worked with in this laboratory. Further work is being done and a full account of all the experiments will be published in the near future.

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[5] Bode, H. R., "Beiträge zur Dynamik der Wasserbewegung in den Gefässpflanzen," Jahrb. f. Wiss. Bot. 62, 92–127, 1923.

[6] MacDougal, D. T., "Reversible variations in volume, pressure and movement of sap in trees," Publ. 365, Carnegie Institution of Washington, 1925.

[1] A. W. Hull, *Phy. Rev.*, 18, 88, 1921.

[2] These tests were made by Dr. Wheeler P. Davey, of this laboratory.

[3] F. P. Venable and J. M. Bell, *J. A. C. S.*, 39, 1598 (1917).