of antigen, as it is desirable to wash the amoebae as free as possible from the solid constituents of the culture before extracting.

Test-tube cultures are, of course, more practical than flask cultures for simply maintaining strains of amoebae, since only a few tubes are required. They are also useful for seeding flasks when these are required.

WILLIAM W. FRYE
HENRY E. MELENEY
VANDERBILT UNIVERSITY SCHOOL OF MEDICINE

ON THE REMOVAL OF OXYGEN FROM WATER BY CUT BRANCHES[1]

IT is well known that rooted plants, in water, will remove the dissolved oxygen rapidly, under certain conditions, or not at all, under other conditions. Among the modifying environmental characters are the temperature of the water and the insolation of the shoot. Whether or not rootless shoots, or branches, with leaves, may behave in an analogous way does not appear to be known. The present note indicates that they have the capacity of removing oxygen at least, but whether the rate of such removal can be modified by the factors above mentioned remains to be shown.

In the experiments here summarized the cut ends of leafy branches of a few species of shrubs and trees were kept in distilled water for various lengths of time and the oxygen content of the water was determined at the beginning and at the end of the experimental periods. It was found, in every instance, that the oxygen content of the water was decreased. A similar result was obtained with cut flowers.

As to the effect of the external factors spoken of above, a few experiments appeared to indicate that the temperature of the water had little influence, as opposed to the results with plants having roots. It is possible, however, that the rate of oxygen removal is related to the intensity of the light to which the shoot is exposed. In four experiments, for example, with leafy branches of mulberry the rate of removal was greater during darkness than light.

W. A. CANNON
EDITH A. PURER
STANFORD UNIVERSITY

SPECIAL ARTICLES

MEASUREMENT OF THE VELOCITY OF LIGHT IN A PARTIAL VACUUM[1]

THE plan to measure the velocity of light in a vacuum was proposed in 1929 by the late A. A. Michelson, professor of physics at the University of Chicago and research associate of the Carnegie Institution of Washington. He obtained the funds for the project and lived to see the apparatus installed, but was unable to take part in the measurements, which were carried out by F. G. Pease, of the Mount Wilson Observatory of the Carnegie Institution of Washington, and F. Pearson, of the University of Chicago. The apparatus was installed at Irvine Ranch, near Santa Ana, California; observations were made at intervals during the period from February, 1931, to March, 1933. The method used was that of the rotating mirror, the mirror itself being a cylinder of glass, on the periphery of which 32 equally inclined and optically flat surfaces were ground and figured parallel to the axis. The cylinder was rotated about its axis at a speed such that a beam of light reflected by one surface and traveling a distance of 8 or 10 miles was received and reflected by the next succeeding face of the compound mirror. From the measured speed of rotation of the mirror and the length of path of the beam of light, the velocity of light was readily deduced. The mirror was driven by an airblast regulated by a sensitive, hand-controlled valve; its rotational speed was ascertained stroboscopically by bringing it into coincidence with the vibrations of an electrically driven tuning fork whose frequency was in turn determined stroboscopically by comparison with the period of a gravity pendulum swinging freely under reduced air pressure. The rate of the pendulum was ascertained by flash-box methods in terms of an accurate clock whose rate was determined by comparison with corrected radio time signals from Arlington. For the two optical path lengths of 8 and 10 miles the speeds of the mirror were 730 and 585 rotations per second, respectively. The apparatus was mounted in a tube one mile in length, consisting of 60-foot sections of corrugated steel pipe 36 inches in diameter joined with rubber sleeves, placed on trestles a foot above ground and evacuated to pressures ranging from $\frac{1}{2}$ to 5 mm of mercury. Steel tanks were attached to the ends of the tube; in these the optical parts, consisting of a small diagonal flat, an image-forming concave mirror and two 22-inch optical flats, were installed. Light from an arc lamp, after passing through a collimating lens and slit, was reflected from the upper half of the rotating mirror through an optically plane window in the side of the tube, and after repeated reflections was imaged on one of the large flat mirrors. It was then returned over a path just below the entering path, received on the lower half of the rotating mirror and thence through a small diagonal prism into a micrometer eyepiece. The length of the path followed by the beam of light was ascertained by reference to a base established with extreme care by the U. S. Coast and Geodetic Survey by the side of the pipe line. The ends of the base consisted of two concrete piers with inserted bronze reference plates placed opposite to the 22-inch plane mirrors. Transfer of the positions of these mirrors to the

[1] The study was made with the aid of a grant from the Carnegie Institution of Washington.

[1] Read before the National Academy of Sciences, Cleveland, 1934.

reference plates of the base line was effected by means of an accurate steel straight edge placed in line with and parallel to the mirror faces. The remaining necessary distances between mirrors were measured by steel tapes. Allowance was made for window thickness and air distance from the window to the rotating mirror. The mean paths were 12,811.204 and 15,999.744 meters for the 8- and 10-mile paths, respectively. Fifty-six measures of the base line were made.

The results of the several series of observations are listed in Table I.

TABLE I

Series	Date	Number of determinations	Velocity of light	Average deviation
1– 54	1931—Feb. 19 to July 14 ...	493	299,770	12
1– 56	1932—Mar. 3 to May 13 ...	753.5	780	11
57–104	1932—May 13 to Aug. 4	742	771	9
105–179	1932—Dec. 3 to 1933, Feb. 27	897	775	11
		2,885.5	**299,774**	**11**

The simple mean of the 2,885.5 separate determinations gives for the velocity of light in vacuo 299,774 km/sec. The average deviation (A.D.) given in the table is that of a single series from the mean of the group. A plot of the weighted velocity readings with respect to time shows the following characteristics. The mean velocity for 1931 is 299,770 km/sec. The mean value for the series 14–25 is 299,746 km/sec. while the value for the remainder of the year lies close to 299,775 km/sec. The mean values for the first 56 series of measures for 1932 is 299,780 km/sec. and that for series 57–104, ending in August, 1932, and including approximately the same number of observations, is 299,771 km/sec. If the readings be taken in small groups and the means plotted, the curve through these points starts early in March at 299,784 km/sec., runs slightly above the axis until early in May and then drops to 299,768 km/sec. early in June. Several fluctuations appear in the curve at this time. The curve remains below the axis until observations stopped on August 4. The mean value for 1932–33 is 299,775 km/sec. The curve starts early in December at 299,785 km/sec., crosses the axis about January 1 and reaches a value of 299,765 km/sec. about January 15. It then gradually rises to 299,787 km/sec. late in February. When the velocities were first plotted, each evening's observations were taken as a unit. A curve freely drawn through these points resembled somewhat the tide curve of the water depths at the nearby coast at a lunitidal interval of 10 hours later. To check this apparent relationship sun-moon tide curves were drawn by the U. S. Coast and Geodetic Survey on their tide-predicting machine and careful comparisons were made of the various components of the tide curves with the velocities. The best correlation seemed to be one between velocity and the horizontal component of the tide force perpendicular to the tube, the velocities being high for a strong tide force pulling in a southeasterly direction and low for a northwesterly direction. The dispersion of readings, however, is great, and consequently little weight can be attached to this relation. The same may be said regarding a plot of velocities and moon diameters. Independent plots of both the early 1932 and the 1932–33 observations each show the same feature, namely, that the velocity is high when the diameter is either large or small, suggesting tidal effects. The scattering, however, is large and the results questionable. The formation of the weighted mean curve has, however, eliminated most of the apparent periodic fluctuations. Repeated measures of the base line and checks on the clock rate showed no changes capable of producing the residual differences between the mean curve and the axis. A vibration of the mirror system with a period equal to a fraction of that of the rotating mirror conceivably may have produced the rapid fluctuations observed in the individual readings.

THE LATE A. A. MICHELSON
F. G. PEASE
F. PEARSON

EXPERIMENTAL STIMULATION DEAFNESS

IT has frequently been reported, and also denied, that prolonged exposure of animals to loud tones causes histological damage to the organ of Corti or loss of sensitivity to sounds as judged by conditioned reflexes. Recently the electrical responses of ear and auditory nerve have also been employed in this type of experiment as additional indicators of possible damage.[1] During the past two years, we have exposed five groups of animals (cats and guinea-pigs) to tones of 600, 800 or 2,500 c.p.s. and examined them by one or more of these methods. We believe that our results throw some light on the variability apparent in previous reports.

In testing auditory function of anesthetized animals by the electrical response, we pick up an electrical potential at the round window and observe the amplified electrical waves with a cathode ray oscillograph. The intensity of sound necessary to cause a just-visible deflection is taken as threshold. The sensitivity of normal cats and guinea-pigs determined by this method corresponds quite closely to the normal human audibility curve and is in excellent agreement with our own and with Horton's[2] determinations of the sensitivity of guinea-pigs by the method of conditioned reflexes. This justifies the use of the electrical method in testing auditory function.

[1] E. G. Wever, C. W. Bray and G. P. Horton, "The Problem of Stimulation Deafness as Studied by Auditory Nerve Technique," SCIENCE, 80: 18–19, 1934.

[2] G. P. Horton, "A Quantitative Study of Hearing in the Guinea Pig (Cavia Cobaya)," *Jour. Comp. Psychol.*, 15: 59–73, 1933.