been transmitted to the Secretaries of the Royal Society, with an occasional expression of opinion as to the merits of the views presented in the several reports.

The next step will be the consideration of these reports and of similar reports from other countries and the formulation of a definite plan by the Provisional International Committee.

In view of the failure of Congress to make an appropriation for carrying on the work in this country, it will be necessary should the Catalogue begin January 1, 1900, to make some special provision. It is hoped that, by the cooperation of universities and libraries in five or six of the large centers, the work can be carried on for one year, and that when the subject is next presented to Congress it will meet with more favorable consideration.

CYRUS ADLER.

SMITHSONIAN INSTITUTION.

A DOUBLE INSTRUMENT AND A DOUBLE METHOD FOR THE MEASUREMENT OF SOUND.

THE work briefly sketched here, at the request of the editor of SCIENCE, was done by the writer in the laboratory of Clark University, and grew out of the suggestion of Professor Webster, that the optical arrangement of Michelson's refractometer, combined with an accoustical method employed by Wien,* might yield a sound-measuring apparatus of great sensitiveness.

RECEIVER.

For this purpose one totally reflecting mirror of the refractometer was made very small and light, and was mounted upon a thin glass plate, which formed a portion of the walls of a spherical, Helmholtz resonator. A pure tone of the same pitch as the resonator causes the interference bands to vibrate with the same frequency. In order to render the maximum displacement visible, the fringes were made vertical, then cut down to a narrow band by a screen with a horizontal slit. This band was viewed by means of a telescope whose object glass was a small lens mounted upon the end of a tuning fork of the same frequency as the source of sound. The fork was driven electrically and the motion of the lens was perpendicular to the narrow band, so that, if the sensitive resonator plate were protected from all sound, the fringes would not be displaced, but the motion of the object glass would stretch out the narrow band into a broad band of vertical fringes. If now a tone were admitted to the resonator the fringes would be simultaneously displaced. In case of the identical agreement of both frequency and phase of the telescope fork with the forced vibration of the resonator plate (excited by the source of sound) the composition of motions would result in a similar band, but one covered with oblique fringes whose slope is a function of the intensity of the sound. Identity of phase is easily realized by making the telescope fork actuate the source of sound; but identity of phase depends upon the distance of the source of sound (as well as upon some elements involved in the mechanical construction of the source of sound, which elements cannot be varied within limits sufficiently wide to compensate for all phase differences depending on various distances of the source), and consequently this identity could be obtained only at particular settings. In a room filled with standing waves from the source, these settings can be found by moving in the three dimensions either the source of sound or receiver. But this adjustment is laborious, and this limitation renders the apparatus unsuited to general investigation. Without such adjustment the composition of the motions of the bright spots in the narrow band gives a set of overlapping ellipses, obscuring the displacement.

* Wied. Ann., 1889, p. 835.

Accordingly the frequency of the lens fork was made slightly different from that of the source, by loading it sufficiently to obtain slow beats. Thus the phases of the one overtook those of the other very slowly, and consequently the interference bands were obtained, sloping first to the right and then after an interval to the left, the changes occurring periodically and following each other as slowly as desired. By means of a suitable eye-piece with divided circle the angle of this slope can be measured, and gives immediately a means of measurement of relative intensities.

CAMERA.

For some work the stroboscopic method of direct observation was replaced by a photographic method by which permanent records of sound disturbances were obtained and intensities determined. In this case the telescope with vibrating eye-piece was replaced by a fixed lens system which focussed a narrow band of fringes upon a sensitive film mounted upon a uniformly revolving cylinder, in a manner similar to that employed by Raps.* The cylinder was driven by a small motor, whose speed was kept constant by Lebedew's† method. Since this photographic record can be made equally well in case of irregular disturbances of the air, the instrument, with the receiving resonator removed from the sensitive plate, affords an unequalled means of studying the physical characters of a great variety of sounds and noises, such as vowel sounds and consonants, the notes of various musical instruments, the calls of birds, the cries of animals, bells, whistles, the din of the streets, the rumble of thunder, etc. The effect of the peculiar note of the sensitive plate may be eliminated by means of differential measures with plates of different natural periods.

* Wied. Ann., 1893, p. 194.

† Wied. Ann., Band 59, s. 118.

SOURCE OF TONE.

For the determination of the instrumental constants, and for fundamental researches in sound, it is essential that the source of sound be pure in tone, constant in intensity, and that its intensity be easily varied within considerable limits. It should also be portable. The following arrangement meets these requirements in a very satisfactory manner. A tuning fork of about the same pitch as the note desired was driven by an electromagnet with a current interrupted by a similar *control* fork, electrically driven by the usual method of self-interruption. The first fork was fastened vertically upon a heavy iron base, and one of its tines was connected to a circular, thin iron plate, of approximately, the same pitch as the fork, by means of a short stiff wire. This plate formed a side of a Helmholtz resonator, constructed to give the note desired and rigidly supported. The motion of the fork tine was in the direction of the wire, *i. e.*, perpendicular to the plane of the plate, so that the vibrations of the fork were communicated to the plate ; thus the air within the source resonator is thrown into forced vibrations of very nearly its own frequency. Accordingly a very small vibration of the fork causes the resonator to emit a very loud tone. Its intensity depends upon the current driving the source fork, and this current is governed by a sliding resistance and shunt. A single storage cell suffices for the loudest tones, and $\frac{1}{50}$ ampere produced a tone loud enough to be heard very distinctly all over a large lecture room (about 14x24 yards). This source was enclosed in a heavy, padded box, so that only the lip of the resonator protruded. Perfect silence could be obtained by simply corking the mouth of the resonator with a rubber stopper, so that a single and definitely located source was obtained, and one which is portable.

Care was taken that no sound should

reach the receiving resonator from the telescope-fork, for it also was carefully boxed. The box was provided with glass windows for the transmission of the beam from the refractometer, which was similarly boxed in such a way that a portion of the receiving resonator protruded and pulsations of sound acted only upon the side of the sensitive plate which faced the mouth of the resonator. The adjusting screws of the refractometer were brought outside the box. The whole was small and portable. Equal care was taken to keep all sounds from motor and cylinder from reaching the receiving resonator, and all these pieces rested upon little piers of soft rubber and tin in layers, this to prevent vibrations from being transmitted through the table and supports. Careful tests were made for immunity from such disturbances.

Results obtained thus far give promise of a high degree of constancy, and of sensitiveness greater than the human ear, *i. e.*, ability to detect both extremely faint sounds, such as escape the sense of hearing, and also the most minute differences in intensity For this reason this instrument may prove useful in the psychological laboratory.

The limits of this sketch allow but an outline of the mathematical theory of the source, and of the receiver, by which the intensity of a tone is reduced to absolute measure. For a measure of intensity can be made independently by each, and one may be used as a check on the other.

ENERGY OF SOURCE.

The energy emitted by the source resonator in sound may be measured in a manner analogous to one employed by Rayleigh* in determining the minimal sound. The rate at which the source fork expends its energy is readily shown to be

$$-\frac{d}{dt}(E_n) = KE_o e^{-Kt_n} = KE_n \text{ per sec.,}$$

* *Phil. Mag.*, 1894, p. 365.

and this energy is constantly supplied by the current driving the fork. But not all this energy is converted into sound. In fact K is composed of three distinct parts :

K_1 peculiar to the fork alone,
K_2 " " " plate "
K_3 " " " resonator "

If the resonator is made very smooth within we may neglect the dissipation of energy in other forms within the resonator and say that the production of tone is due to K_3 for the system. Accordingly the energy of the tone produced is $K_3\, E_s$, when E_s represents the sum of the energy of fork, plate and connection at the time. The energy of fork and connection are approximately

$$E_f = \tfrac{1}{4}\rho l\omega\, \pi^2\, (2\eta)^2\, {}^1/\tau^2 \text{ for fork,}$$
$$E_c = \tfrac{1}{8}\pi^2 M_c\, (2\eta)^2\, {}^1/\tau^2 \text{ `` connection.}$$

The energy of the plate is an infinitesimal of the second order.

Since $2\eta = Ae^{-\frac{1}{2}Kt}$, K can be obtained by noting the time required for the amplitude to fall one-half. The resonator plate is mounted upon a separate ring so that the resonator may be removed without disturbing the plate. Then a differential measure serves to determine K_3. First, K is determined with resonator in place; then the resonator is removed and $K_1 + K_2$ is determined ; thence

$$K_3 = K - (K_1 + K_2) = 2\log_e 2\,({}^1/t_1 - {}^1/t_2).$$

A galvanometer, or millivoltmeter, is interposed in the circuit containing the source forks, so that a few measures, taken through some range of intensities, suffice to calibrate the current in terms of absolute intensity at the mouth of the resonator. From this a simple assumption regarding propagation gives the intensity at any point. Since the intensity can be varied at will, this instrument alone, with the ear for receiver, can be employed for a considerable number of investigations.

ENERGY AT RECEIVER.

The energy of the tone at the mouth of the receiving resonator is proportional to the square of the amplitude of vibration of the sensitive plate. And since this plate carries one of the refractometer mirrors its amplitude can be expressed in terms of wave-lengths of monochromatic (sodium) light. In short, an expression for relative intensity will be:

$$\left(\frac{B \tan a}{w}\right)^2$$

when B is the double amplitude due to the motion of object glass, a is the slope of the fringes due to tone, and w is the width of a double fringe. This relative measure can be reduced to absolute measure in a manner differing from that employed by Wien* only in the fact that the energy of the little mirror is taken account of and the identical resonator in the identical position, but with plate of high pitch, is used to calibrate the sensitive arrangement in absolute units.

This combination of source and receiver seems exceptionally well adapted to the investigation of such problems as the variation of the intensity of sound with distance, the viscosity of the air, sound shadows, reflection of sound from various substances, refraction of sound in various media, the distribution of sound in a room, with the natural pitch and damping (echo) of a room, intensity of the minimum sound audible, test of Weber's Law,† etc.

The elaboration of the instrument has left, thus far, no opportunity for systematic research. Some results of interest have been obtained, such as tests for constancy and sensitiveness, photographs of vowel and other sounds; but these results are fragmentary, and have been of value chiefly to serve the purpose of tests, and of suggestion to further improvements in means or method. In the near future some acoustical problems will be attacked in the laboratory of Clark University, and the results, as well as a fuller account of instruments and method, will be published, it is planned, jointly by Professor Webster and myself.

BENJAMIN F. SHARPE.

GREENWICH, N. Y., June, 1899.

*Wied. Ann., 1889, p. 834.

†Fechner, 'Hauptpuncte der Psychophysik,' p. 185.

NEW YORK STATE SCIENCE TEACHERS ASSOCIATION.

THE third annual meeting was held at the Teachers College of Columbia University, December 29 and 30, 1898, affording to the members of the Association an opportunity to attend most of the meetings of the Society of Naturalists.

Dr. Charles B. Davenport, of Harvard University, read a paper on zoology as a condition for admission to college. He favored the study of animals by the laboratory method as outlined in the Harvard requirements, and thought that too much attention was being given to dissection in most secondary schools. He encouraged the study of economic zoology in a preparatory course, leaving most of the dissection to be done in the college.

The first afternoon was devoted to the report of the Committee of Nine, by Dr. Le Roy C. Cooley, after which the Association attended the annual discussion of the Society of Naturalists on 'Advances in Methods of Teaching.' In the evening the President, Dr. Charles W. Hargitt, delivered the annual address, on 'Science and the New Education,' in which he defined the relation of science to the other elements of the modern curriculum. The address was followed by a most enjoyable reception by the Trustees of Teachers College.

The second day began with four simultaneous section meetings. Section A, Biology, in charge of Dr. Charles L. Bristol,