years old with active membership ranging from 600 to over 900, the American, the German, and the Italian in Palermo. Taken with other things, these are signs of a flourishing condition of scientific thought. Possibly the most striking proof of this, so far as mathematics is concerned, is found in the annual quantity of published research which more than doubled during the last thirty years of the century.

No one understands the group of transformations which we call the flight of time, yet it acts unceasingly upon all human possessions. Nor are its invariants known; nor yet can we determine what part of scientific energy is conserved and what part is entropy, or waste. It seems to us now that the few great lines of development that I have so briefly traced do show permanent tendencies of organized knowledge—that in these directions science will at least not retrograde while our civilization endures. Yet it is already evident that the last word has not been spoken in physics, and conceivably the time may come when the names of Helmholtz, Kirchoff, Maxwell and Hertz will be venerated as that of Archimedes now is—hardy pioneers indeed, but no longer in the vanguard. Let me make the trite remark, that the transformations of time work more slowly on the body of treasure that we call pure mathematics than they do upon the far greater and more rapidly growing pile of natural science. The reason is obvious; natural science deals with an infinite number of data, and can never apprehend them all; hence she makes hypotheses serve temporarily. Mathematics does the same, but perfects her products by the progressive exclusion of conflicting data; that is to say, by increasing precision of terms. The Pythagorean theorem concerning the sides of a right triangle will be true longer, in the very nature of things, than Sir George Darwin's magnificent theory of the tides. This which is from one point of view a reproach to pure mathematics, constitutes on the other hand one of its titles to immortality.

That the literature of our science is vast and complicated shows only how many are the things that men have wished to know. More numerous, with every advancing decade, are the questions pressing for solution. It will not be your lot, members of the Sigma Xi, to discover anything so simple, necessary and universally useful as the multiplication table, or the common theorems upon volumes and areas; but you may find something as useful to mankind as Napier's logarithms, which were new only three centuries ago; or some theory as beautiful and perfect as that of elliptic functions applied to plane cubic curves. You may contribute to the labor of other scholars something as helpful as the great "Encyclopaedie" of the mathematical sciences, now almost completed by the untiring labor and devotion of cooperating mathematicians in all lands, but chiefly by Germans. But in whatever large domain or narrow field you may elect to labor, I give you the cheering assurance that there are fruitful discoveries that can be made by every toiler; that to each one who has the *will to know,* will come those rare and golden moments when he shall shout in triumph, with the ancient truth-seeker Archimedes, *Eureka!*

Henry S. White

Vassar College

SEEING YOURSELF SING[1]

It is possible to make vibrations which produce a tone to the ear also produce a picture to the eye—a picture which reveals details of pitch faithfully and far more finely than the ear can hear, and which may, therefore, be

[1] A part of a paper read before the meeting of the National Music Teachers Association in Buffalo, New York, December, 1915.

employed for the objective measurement of pitch and as a guide in training to sing and play in pitch. The singer standing before an instrument sees in clear pictures every pitch movement of the voice as he is singing; he sees exactly how many vibrations per second the vocal organs are producing, and thereby can tell, at the very moment of singing a note, what error is involved, even down to the hundredth of a tone; he can practise before the instrument by the hour with the opportunity of seeing the error in every tone and controlling the voice and the ear by the eye at pleasure; he can study in detail the attack, the sustaining, and the release of a single note; the player of the violin, flute, cornet, or other instrument may treat his instrument in the same way; a person at a distance may connect "long distance" with the tonoscope and project his voice or instrument on this screen hundreds of miles away; a scientist or a musician may take a phonograph record of the tonal effects under observation and ship the cylinder to the laboratory, in which it may be reproduced upon the tonoscope; the student of primitive music can transcribe the phonograph record by this method; the scientist can undertake technical studies on pitch which involve exact measurements and instantaneous recording in actual singing; the student of public speaking can study the inflections of the voice objectively and train for mastery; the teacher of the deaf can place his pupil before the instrument and train him to speak with pleasing inflection of the voice by practising with the aid of the eye.

This array of claims may seem extravagant, but these and many other related achievements are made possible by the development of a ready and accurate method of registering pitch. The instrument which will do this is known as the *tonoscope,* and is now available for use in the studio, having been placed on the market in December, 1915.

THE TONOSCOPE

The tonoscope[2] shown in the accompanying illustration[3] works on the principle of moving pictures, technically known as stroboscopic vision. It converts the sound vibrations into pictures on the screen. The screen, which may be seen through the opening on the front, has eighteen thousand and ninety-five dots so placed

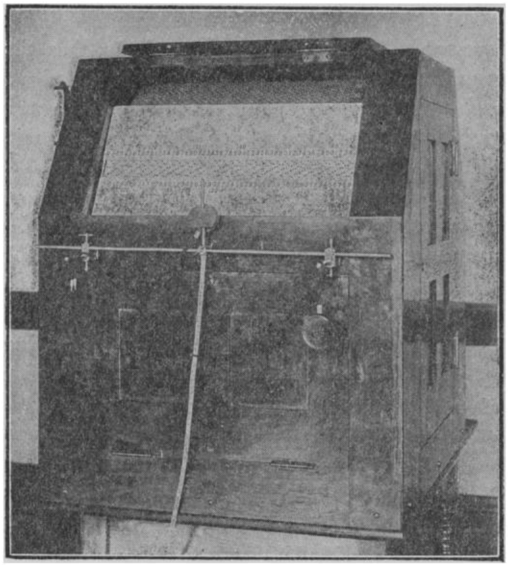

FIG. 1. The Tonoscope.

that, when acted upon by a sensitive light, they arrange themselves in characteristic figure for every possible pitch within the range of the human voice. Each figure points to a number on the screen which indicates the pitch. The dots are arranged into one hundred and ten rows; the first one has one hundred and ten dots, the next one, one hundred and eleven dots, and so on, each successive row having one more dot than the preceding one, up to the last, which has two hundred and nineteen. When the tone is sounded, the row which has the dot frequency that corresponds to the vibration frequency of the tone will stand still, while all

[2] A full account of this instrument by the present writer, and an article by Dr. Walter R. Miles reporting investigations made by means of it, are to be found in the Psychological Monograph No. 69, pp. 1–66, *Psychological Review,* Princeton, N. J.

[3] In this illustration the sensitive flame is energized through a microphone; but ordinarily, simple air transmission to the manometric flame through a speaking tube is used.

other dots move and tend to blur. The row which stands still, therefore, points to a number on the scale which designates the pitch of the tone. The screen contains a sufficient number of rows of dots to cover exactly one octave. Tones above or below this octave are read on this same screen by multiples.

To see the pitch of the tone, one has, therefore, only to see the number of the line that stands still. The tone may be sung or played under natural conditions. Indeed, one may register the tone from any distant point with which there are telephone connections.

The instrument is operated electrically and will run indefinitely without any care or disturbance. This makes the tonoscope a ready and continuously available instrument in the studio or the laboratory. The speed of the revolving screen is controlled by a tuning-fork with which it must keep step, being driven by a synchronous motor.

In other words, we have here an instrument which will transform the vibrations of voice or instrument to visual configurations on a scale that indicates the actual pitch of any note down to an accuracy of a fraction of a vibration—often less than a hundredth of a tone. Indeed, if we are dealing with a note as constant as that of a tuning-fork or a string, the pitch will be recorded accurately in tenths of a vibration, because fractions of vibrations may be read in terms of the number of dots that pass per second in the slowly moving line.

There are various graphic methods of recording pitch in use, but these are entirely too laborious and cumbersome for practical use. The tonoscope furnishes us the first ready and at the same time reliable and accurate means of registering directly the pitch of a tone as sung, spoken, or played with a musical instrument in such form that it can be operated with convenience and safety outside the technical laboratory.

THE SIGNIFICANCE OF THIS INSTRUMENT FOR THE SCIENCE OF TONES

The psychology of music on the sensory side has been studied with fruitful success in recent years. But the motor side of the process—the psychology of tone-production and tone-control—is practically unworked and remains largely in the realm of mystery chiefly for the want of a measuring instrument. The introduction of a ready means of recording, analyzing and projecting sound vibrations before the eye therefore opens up a most wonderful field of research both in pure science and in the art of music.

Up to the present time there has been only one tonoscope available, that in the psychological laboratory of the University of Iowa. This has passed through several stages of improvement during the last fifteen years; and this single instrument in its various stages of development, in the hands of a small group of investigators, has been a valuable aid in the discovery of interesting facts in the psychology of music. The scope of the work which has thus been opened up by investigations already undertaken may be illustrated by the naming of the principal problems which have been investigated up to date, to wit: the comparison of men and women as to ability in singing of true pitch, under a large number of controlled conditions; relative accuracy of pitch within the tonal range, under various conditions; principles involved in the singing of large and small, natural intervals and more artificial intervals; the effect of the strength of the keynote upon the accuracy of reproduction; the effect of the volume of the voice upon the pitch; the variation of pitch with vowel quality or timber; the correlation of ability to sing in pitch with pitch discrimination, tonal memory, tonal imagery, sense of consonance, musical education, and other factors; the establishment of norms for the measurement of ability to sing in pitch; and the study of the effect of training the ear by the aid of the eye. Some of these are reported by Miles in the article referred to above, Psychological Monograph No. 69. The scope of this paper will permit the discussion of only one of these, and for this purpose, the last mentioned may be chosen.

TRAINING THE EAR BY THE AID OF THE EYE

The practical use of the tonoscope in the studio lies in the training of the ear and therefore, indirectly, the control of the voice or instrument by the aid of the eye. On this point we have conducted a number of series of experiments to determine the effectiveness of such training as evidenced, *e. g.*, by the kind, the rate, the degree, and the permanence of the improvement gained by practising with the instrument. The first of these series was begun in 1903; from that time up to the present, experiments in the training of pitch control have been in progress continuously for purposes of developing methods and means and testing results. Laying aside all technical matters and detail, we may glean from these experiments the following points of interest:

Practically all singers—good, bad, or indifferent; trained or untrained; child or adult; professional and non-professional—will improve in pitch control by training with the instrument. He who can not sing a tone may "find" himself by the eye; the average singer is slovenly about pitch until shocked by what he sees in the projected voice; the person who can sing to a high degree of accuracy—say an error of plus or minus one vibration—has abundant room for improvement within a fraction of a vibration, for the more accurately one sings, the finer the instrument registers.

The gain in training by aid of the eye may be attributed in large part to the recognition of certain subjective and objective sources of error which may be eliminated after discovery by the instrument. The ear unchecked is lax in its control of pitch. When the eye reveals an error in pitch, it aids the ear in identifying and making concrete the elements of hearing which had before remained undifferentiated and unrecognized. The seen tone serves both as a whip and as a guide in pitch near the lower limits of the ear, and is, therefore, the best incentive for improvement. Among the objective disturbances are the effect on pitch of the loudness of the keynote heard, the loudness of the note sung, the quality of the tone heard, the quality and register of the tone sung, the vowel of the syllable sung, the duration of the tone, etc. Among the subjective factors the most complicated one is the factor of effort of attention. Ordinarily one sings more accurately when he tries; yet when one comes to a certain stage he will sing better if not conscious of a specific effort to sing in pitch. Fears, theories, anticipations and illusions also modify the pitch. Under certain circumstances accuracy in pitch may be a mark of the general condition of the system.

Training with the eye improves the ability to form concepts of intervals and sing them with increasing accuracy. Who can sing, or knows when he has sung, the chromatic scale or even a single half tone? With the instrument he can place the exact note in tempered scale or in just intonation and study in detail effect after effect and control for mastery with the instrument which registers much finer distinctions than the ear can hear. Here again we have found that there is room for improvement for all. One man who thought he was tone-deaf was trained to sing a tone interval with a high degree of accuracy. One well-known singer was struck with despair when she saw how badly she sang the natural scale.

Training the ear with the eye enhances its ability in voluntary control of the voice as in raising and lowering of the pitch. The improvement in this is astonishingly rapid; and the reason for all this rapid improvement lies in the fact that one sees the tone the moment he sings and hears himself sing it, and can at will identify the direction and exact amount of the error. As has been pointed out, this seeing of the tone serves as a whip and also as a guide to specific effort.

Striking a note may be fractionated, *i. e.*, separated into its parts so that one may study from moment to moment, the attack, the release, and the sustaining (with its various periodic or progressive changes in pitch, both desired and undesired). The instrument enables the singer to take each of these in turn and establish mastery under the criticism and guidance of the eye.

The gain made in singing with the aid of the eye is transferred into auditory and motor control. The improvement which takes place in singing with the instrument is very rapid and one would, therefore, suspect that it would not be permanent. But experiments show that if the training is continued for a few days with the instrument, the gain will be transferred to the ordinary singing without the instrument. This is the most encouraging feature in the process and deserves to be analyzed in great detail for the purpose of a pedagogy of singing; this we are now attempting to do in the laboratory. Such questions as these arise: How is association transferred from the visual to the auditory-motor? What are the common elements in visual and auditory control? How can we isolate each of these factors for the purpose of reduction of error?

This type of training is convenient, inexpensive and rigid. The pupil may be assigned any one of a hundred exercises in pitch training and practise all by himself under correction at every tone production; it may be to reduce a tendency to sharp or flat, to eradicate a tremulo, to gain control of a vibrato, or any other pitch figure the master may set. It gives opportunity for control drill under the severest correction at every stage.

CARL E. SEASHORE
UNIVERSITY OF IOWA

ORVILLE A. DERBY

IN November last the newspapers published a cablegram from Rio de Janeiro announcing the suicide of Orville A. Derby, director of the Brazilian Geological Survey. Letters from mutual friends have now thrown all the light on the subject that we can reasonably expect to get.

Mr. Derby first went to Brazil in 1870 as student assistant of Charles Fred Hartt, who was then professor of geology at Cornell University. He made two other vacation trips to that country, and went to Brazil finally in 1875 to be assistant geologist to the newly established geological survey of the Empire, and lived there the rest of his life. In 1877 the survey was suspended, and Professor Hartt, its director, died at Rio. Mr. Derby was shortly thereafter appointed curator of geology in the National Museum at Rio, and held that position until 1886 when he was put in charge of a newly established geological survey of the state of S. Paulo, a position he held until 1904. In 1907 a new federal survey was provided for under Dr. Miguel Calmon, minister of public works, with Derby as its chief.

The war in Europe disturbed the financial equilibrium of South American countries as well as that of other parts of the world. Brazil was probably obliged to economize wherever it was possible to do so, and this led to the reduction of appropriations for the work of the geological survey to such a point as to destroy the efficiency, and even to threaten the existence of that organization. Probably the necessity for such economies was not apparent to Mr. Derby, and he looked upon them as an attempt to discredit him and the bureau under his direction. In any case he took the matter very much to heart, and his friends find no other reason, or shadow of a reason, for his suicide.

Mr. Derby never married, and he led the solitary life of a recluse and student. He was held in the highest esteem by all who knew him. His whole life was given to the study of the geology of Brazil, and no one, living or dead, knew it as he did, or was more profoundly or more unselfishly interested in it. At the time of his death he had published more than a hundred and twenty-five papers on the geology of Brazil, many of them in the Portuguese language, which he wrote with ease.

His successor as the director of the geological survey of Brazil is Dr. L. F. Gonzaga de Campos, one of the ablest and most trustworthy of the Brazilian geologists, and for many years one of Mr. Derby's most competent assistants.

A fuller account of his life and work will be published in the *Bulletin* of the Geological Society of America.

JOHN C. BRANNER
STANFORD UNIVERSITY, CAL.

PARIS-WASHINGTON LONGITUDE[1]

DIRECTOR B. BAILLAUD, of the Paris Observatory, presented the results of the determina-

[1] Translation from *Comptes Rendus de l'Académie des Sciences*, February 14, 1916.