found to be of great service in exploring expeditions, and they are still being used by parties engaged in opening up new pastoral country. Several of the animals have recently been lent to squatters for expeditions to the country on the Western Australian border, the MacDonnell ranges in Central Australia, and elsewhere.

FROM the new issue of Behm and Wagner's "Bevölkerung der Erde," we learn that the present population of the earth is estimated at 1,439 millions as compared with 1,424 millions given in the previous issue. This increase results mainly from the recent censuses which have been taken in several countries. This population is divided among the several continents as follows:—Europe, 312,398,480; Asia, 831,000,000; Africa, 205,219,500; Australia and Polynesia, 4,411,300; America, 86,116,000. This new issue contains the first map we have seen of New Zealand with the recent division into counties, in substitution for the old division into provinces. A census according to counties cannot, however, be taken till 1881. The North Island has thirty-three and the South Island thirty-one counties.

MR. STANFORD has issued a very useful shilling Treaty Map of South-Eastern Europe and Armenia, showing the boundaries of the New Bulgaria and Eastern Roumelia, the accessions to Austria, Russia, Montenegro, Servia, and Roumania, and all the other changes which have been made by the recent Congress. The new features are shown with unmistakable clearness. Mr. Stanford is also preparing a large scale map of Cyprus, showing not only the physical, but also the geological, agricultural, and other features of our latest acquisition.

AN expedition to the mouth of the Yenisei River left St. Petersburg last week. Principally at the instigation of a Moscow commercial firm eight steamers laden with corn, spirits, nitre, and other goods will soon start on the new sea-road to Siberia, their return cargoes consisting of wood and tea.

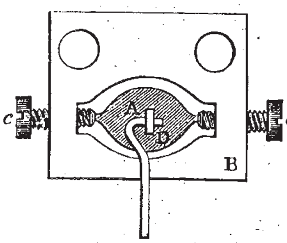
MR. GORDON BENNETT proposes to send the yacht *Dauntless* on a voyage of discovery to the Polar Seas, *viâ* Spitzbergen, in addition to the *Pandora*, which will attempt to reach the Pole by another route.

A METHOD OF RECORDING ARTICULATE VIBRATIONS BY MEANS OF PHOTOGRAPHY[1]

THE object of this paper is to describe a method of obtaining photographs of minute vibrations on a magnified scale.

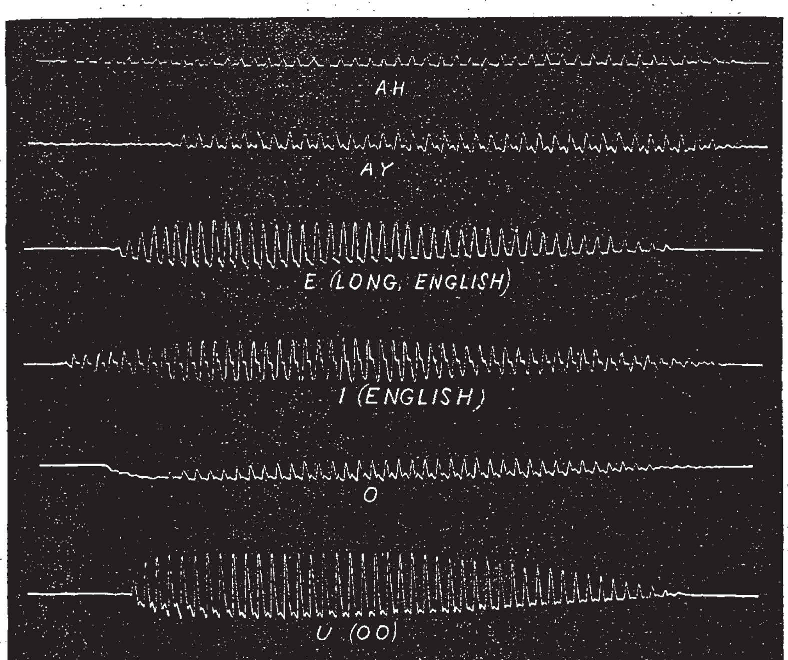
A plane mirror of steel, A, is supported by its axis in the metal frame B. The ends of the axis are conical, and carefully fitted into sockets in the ends of the screws C, C. On the back of the mirror is a slight projection, D, pierced by a small hole.

The vibrating disc, as hitherto employed, is a circular plate of ferrotype iron, 2¾ inches in diameter, screwed to the back of a telephone mouthpiece of the form invented by Prof. John Peirce, and now universally used. From the centre of the back of this disc a stiff steel wire projects, the end of which is bent at a right angle. This wire serves to connect the vibrating disc



Back view of mirror, actual size.

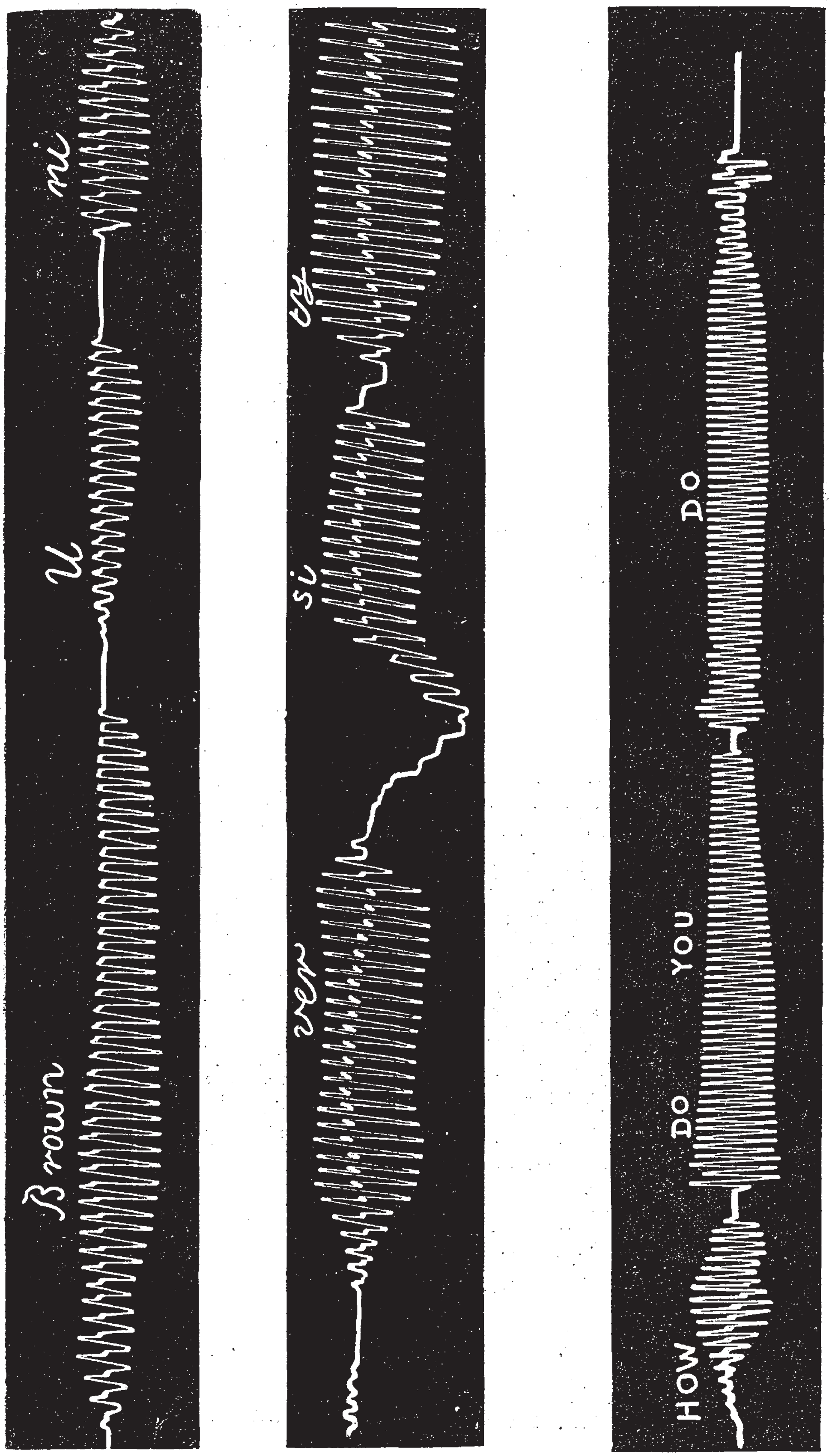
with the mirror by hooking into the hole in D, as represented in



the figure. The mirror frame and the vibrating disc are kept in a fixed relation to each other by a block of hard wood, to which both are firmly screwed. The mirror is set with its axis parallel, and its reflecting surface perpendicular, to the vibrating disc.

A heliostat sends a beam of sunlight horizontally through a small circular opening. This beam passes into a dark closet, and at a distance of several feet from the circular opening falls upon the mirror above described, placed with its axis inclined 45° to the horizon. The rays, reflected vertically downward, pass through a lens at whose focus they form an intensely luminous image of the circular opening.

[1] The text abridged for NATURE by Prof. E. W. Blake, of Brown University, from a paper in the *American Journal* for July. The illustrations (except mirror) from photos supplied by Prof. Blake.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A carriage moving smoothly on four wheels travels beneath the lens at such a distance that the sensitised plate laid upon it comes at the focus for actinic rays. A uniform velocity is given to the carriage by a string fastened to it and passing over a pulley. To this string a lead weight, just sufficient to balance friction, is permanently attached, while a supplemental weight acts at the beginning of motion and is removed just before the sensitised plate reaches the spot of light above described.

The velocity attained by the carriage is determined by placing a sheet of smoked glass upon it and letting it run under a tuning-fork (Ut! 3—512 v. s.) provided with a pointed wire. In every case more than 200 vibrations were counted and measured, and careful comparisons made between the earlier and later ones, so as to be certain of the uniformity of the motion.

From the description it will be evident that when the carriage alone is in motion a straight line will be photographed upon the plate. On speaking into the mouthpiece the disc is set in vibration, each movement causing change of angular position of the mirror, the reflected light moves through twice this angle, and the resulting photograph gives us the combination of its motion with that of the carriage. The carriage should run from *right* to *left*. The negative (examined from the *glass* side), and prints taken from it, then give the syllables in their proper order, and show movements of the disc from the speaker by lines going from the observer. The arrangement of my dark room compelled me to make my carriage move from *left* to *right;* hence, in the figures given, forward positions of the disc are represented by the lower portions of the curves.

The general character of the curves obtained is shown in the accompanying figures, which are the actual size of the originals, except that representing the vowel-sounds, which is about one-half (0·56).

The velocity of the carriage for the vowel-sounds was 21½, for *Brown University*, 40, and for *How do you do*, 14 inches per second.

In the mathematical discussion of these curves the abscissas are measured by the known velocity of the carriage, and serve to determine the *pitch*, the ordinates represent the amplitude of vibration of the centre of the disc, magnified 200 times in the photographs. The reduction of scale makes the magnifying in the woodcuts only 112 times.

The ordinates are not strictly straight lines, but parts of the vertex of a parabola, and closely approximate to circular arcs whose radius is the focal length of the lens employed. In the figures given, the centres of curvature of these arcs is at the right hand.

With an ordinary tone of voice an amplitude of nearly an inch is obtained, implying a movement of the centre of the disc of ·005 inches as determined by actual measurement.

By varying the accelerating weight and its fall, any manageable velocity may be given to the carriage. Each syllable requires for its articulation about one-fourth of a second, hence the plates must be quite long when the velocity is great. I employ plates two feet in length, and find that velocities from 16 to 40 inches per second give good results. The action of the light is, however, inversely as the velocity. To compensate for this, the size of the circular opening admitting the light may be increased. This, of course, causes an enlargement of the luminous image, and apparently involves an injurious widening of the line traced, but, as observed by Dr. Stein in his experiments, the effect of velocity is to narrow the line photographed, since the maximum exposure is in that diameter of the circular image which lies in the line of motion. This is a great advantage, since a variation of velocity in the vibration is marked by the widening of the line, often more clearly than by the form of the curve.

I have employed the ordinary photographic process, not attempting to obtain special sensitiveness. The brightest sunlight is required, a slight haziness interfering seriously with the result. My heliostat employs two reflectors of ordinary looking-glass, and the loss of light is considerable.

Are *all* the audible elements of speech traceable in these records? in other words, is the record complete? I am not prepared as yet to answer this question definitely, but the following experiment leads me to doubt whether an affirmative answer can be given, while at the same time it illustrates in a striking manner the sensitiveness of the ear. The mirror was attached to the disk of a *receiving* telephone and a photograph taken from it while the instrument was talking audibly. The resulting record was almost a smooth line, showing but very slight indications of movement of the mirror. It would therefore appear that there are distinctly audible elements, which are too minute to be recorded by this method. It is to be noted, however, that the width of the line traced where the vibrations are extremely small, is so great as to mask the curvature, so that the experiment just cited is not entirely fair.

The clearness and beauty of the curves obtained can hardly be appreciated without inspection of the originals. Their complexity and variety open a large field for investigation, and they seem to offer the means of analysis of articulate speech.

THE PHONOGRAPH AND VOWEL SOUNDS

I.—The Vowel Sound ō.

In a recent letter to Nature we gave a short account of what we believed to be the existing theories of vowel-sounds. In the present paper we will state the chief results as to the vowel *ō* of our investigations made by means of the phonograph.

The experiments were made as follows:—The vowel under consideration was spoken or sung at a given pitch, determined by a piano, while the barrel of the phonograph was turned at a definite speed, regulated by means of a metronome. The indentations made in the tin-foil were then mechanically transcribed, so as to give curves representing a magnified section of the impressions. The curves were magnified by a system of compound levers, and recorded by an arrangement resembling that of Sir William Thomson's siphon-recorder. The details of the apparatus are described in a paper laid by us before the Royal Society of Edinburgh. The vertical ordinates of the curves drawn in ink, as shown below, are about 400 times larger than the corresponding indentations in the tin-foil, while the longitudinal ordinates are multiplied about seven times. The slowness of the motion by which the transcript was made enabled us to avoid all error due to inertia of the working parts, and the total absence of friction between the marking siphon and the paper allowed the transcript to be made without employing such a pressure on the tin-foil as would sensibly alter the indented curves. This fact was in each case tested by making the phonograph speak the vowel after it had been copied. All transcripts were rejected if the tin-foil did not continue to give the sound clearly after being used to produce these curves.

We employed various sizes of chamber and of mouth-piece, various thicknesses of tin-foil, and various discs as receivers. The curves now given as transcripts were found to be practically independent of variations in all these conditions. We are therefore of opinion that the curves do really represent the motion of an air-particle when the vowel is spoken, and that these curves may be regarded as sufficiently unaffected by any periods of vibration proper to the disc and springs employed, or to the air in the chamber of the mouth-piece, to constitute a true record of the essential parts of the vowel-sounds. This may be inferred from the remarkable constancy in the results obtained, with great variations in the conditions of the experiment, and from the fact that the indentations, after being copied, were in each instance able to give back the vowel-sound distinctly.

Fig. 1 gives a series of curves produced by a single baritone voice singing *ō* on a series of notes ranging from G to *f'*. This series has been selected because the voice was of good quality and considerable range.

After the curves were obtained they were subjected to harmonic analysis. One period was divided into twelve equal parts, and twelve ordinates were drawn and measured at right angles to a line joining two successive maximums or minimums. The numbers so determined enabled us to calculate the amplitudes of the first *six* partial tones.

Table I. gives these amplitudes for the above series of *ō*'s, obtained by analysing one period chosen out of the hundreds of similar periods which were given by each utterance. An examination of the curves and of the table will show that the change in character from note to note is fairly gradual and consistent throughout. The figures are arranged so as to show the absolute pitch of each of the six partial tones.

Voices of very different qualities were tested in the same way throughout the same range or such parts of that range as were within their compass.

Too much space would be taken up if we were to give here all the results obtained. It may be briefly said that the several voices agreed very fairly in respect of the partials composing the vowel at each pitch, that is to say, throughout the range