setting up of an area of maximum pressure upon the underside of the ogival head. This gives rise to a resultant disturbing couple, which, by reason of the symmetry of the surface, has its axis parallel to the horizontal principal axis at the C.G., and this axis is directed rightwards. Since this disturbing couple has its axis at right angles to the axis of angular momentum, *i.e.* to the axis of figure, it causes a precessional motion of the axis in the plane of its own axis and of the axis of figure, so that this axis begins to turn itself slightly to the right of the trajectory, the rifling being taken to be right-handed. This action is a very small one, because the couple producing it is very small compared with the couple which is equivalent to the total angular momentum. The axes of angular momentum and of angular velocity being initially coincident with the axis of figure, while the axis of the disturbing couple is at right angles to it and parallel to one of the principal axes at the C.G., this couple has no effect upon the magnitude of either the angular momentum or the rotational velocity. It alters only the orientation of the axis of angular momentum, and leaves it coincident with the axis of figure.

Now this deflection of the axis to the right causes the left side of the head of the shot to experience a greater normal pressure than the right, and so gives rise to a second disturbing couple, of small magnitude relatively to the whole angular momentum, about an axis parallel to a principal axis at the C.G. and directed downwards, very nearly, if not exactly, in the vertical plane through the axis of the shot. The effect of this is to bring about a precessional motion of the axis in this plane, directed downwards, so that the nose of the shot begins to dip towards the tangent to the trajectory. This couple has, otherwise, exactly the same effects on the motion of the axis as the other one, and since both couples are very small in comparison with the total angular momentum, it is permissible to combine their effects after considering them separately. It thus appears that the axis acquires a small precessional motion about the tangent to the trajectory, and that the excess of pressure upon the left of the head will cause the trajectory itself to be bent to the right, bringing about the well-known rightward drift of the shot. If the rifling be left-handed the shot will drift to the left, but the nose of the shot will, as before, dip towards the trajectory.

Any device that throws the C.G. well towards the base of the shot will have the effect of adding to the magnitude of the first of the above two couples. A smaller deviation of the axis from the trajectory will then afford a larger disturbing couple, and the rightward precessional motion will be more quickly established. In consequence of this the rightward drift will be diminished. A long, hollow bullet of thin steel, the rear half having a smaller diameter than the front half, and this rear half being filled with lead, and also coated exteriorly with lead so as to take the rifling, may, on this theory, be expected to have less drift than the ordinary bullet, whereas a bullet weighted towards the head would have more.

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The Problem of the Random Path.

THE following illustration of Prof. Karl Pearson's "Random Path" problem may be of interest.

Mr. Kipling in his story, "The Strange Ride of Morrowbie Jukes," gives the following directions for finding the safe path across a quicksand, which directions are supposed to have been found by the hero of the story in the coat of an earlier victim:—

"Four out from crow-clump; three left; nine out; two right; three back; two left; fourteen out; two left; seven out; one left; nine back; two right; six back; four right; seven back."

These numbers were probably taken at random, and it will be noted that seventy-five paces are taken, and the final position is only seven paces from the original position.

This is a rather curious confirmation of Lord Rayleigh's solution of the problem.

REGINALD A. FESSENDEN.

SPEECH CURVES.[1]

DR. SCRIPTURE since 1901 has worked with zeal and energy at experimental phonetics, and he has published several valuable papers, as well as a large volume treating generally of the subject. The work has been carried on with the aid of the Carnegie Institution of Washington at Yale, Munich, Berlin, and Zurich. It has been an expensive research, as in addition to costly apparatus a staff of clerks was required for computation. A perusal of this monograph proves that Dr. Scripture has shown great ingenuity in the construction of recorders and in overcoming technical difficulties that can be fully appreciated only by those who have made excursions into this field of research. His experimental method has been to transcribe on smoked paper the curves of speech both from the gramophone of Berliner and the phonograph of Edison.

On the disc of the gramophone the curves produced by sound vibrations are not indentations in the bottom of a groove or furrow, as in the tracing on a phonograph cylinder, but they are horizontal, as if they were drawn on the plane of a sheet of paper. Further, it is interesting to note that in the gramophone record the depth of the groove is constant, whereas in that of the phonograph the downward movement of the recording disc bearing the cutting tool is diminished, in consequence of increasing resistance, in comparison with the upward movement. Each instrument has its own peculiar quality of tone, and, except in very fine modern instruments, natural sounds are more or less falsified. This falsification Dr. Scripture shows is due to a distortion of the waves by the bending of the diaphragm, and not to nodal vibrations such as occur on Chladni's plates. His best tracings were taken from gramophone records, by using either a simple or a compound lever, which at one end travelled slowly over the record, and at the other recorded the waves on a moving strip of smoked paper.

There is no special novelty in this method except that it has been applied to the gramophone, and that the mechanical arrangements have been of the finest quality. It gives one a notion of the delicacy of the method when it is stated that 1 mm. of the tracing = 0·0004 sec. The vertical magnification by the use of a simple lever was 300 times, but Dr. Scripture adds:—"The future of the method lies in the development of a compound lever." Great care was taken to identify any portion of the record on the smoked paper with the corresponding part of the surface of the gramophone plate. This was accomplished by a very ingenious device. The reproduction of the curves for printing was done by etching on zinc. An example of a tracing of the sounds of an orchestra is shown in Fig. 1, and the following is Dr. Scripture's description:—

"The curve in Fig. 32 [Fig. 1] is from the record of a note from an orchestra. The most prominent vibration is one whose wave-length is 3 mm. = 0·0012 sec., that is, about the note $g^{2}\sharp$. Another prominent feature is the grouping of these vibrations in threes, indicating a tone with a period of 9 mm. = 0·0036 sec., or a note about $^{1}\sharp$. There is one which reinforces every sixth vibration of the high note and another that coincides approximately with every ninth; the former would correspond to $c^{0}\sharp$, the latter to $g^{-2}\sharp$. The combination of all these notes—each comprising a fundamental with overtones—produces a very complicated curve. From such vibrations, however, the ear can pick out not only the component notes, but also the characteristic tones of the piano, violin, &c." (p. 33).

[1] "Researches in Experimental Phonetics: the Study of Speech Curves." By Dr. E. W. Scripture. Pp. 204. (Washington, D.C.: Published by the Carnegie Institute of Washington, 1906.)

In a similar manner Dr. Scripture gives a careful description of a large number of tracings of noises, whistling, various musical instruments, and human speech.

We now approach the most difficult part of the investigation, namely, the analysis of the curves produced by human speech. Dr. Scripture's plan has been to analyse carefully portions of actual speeches,

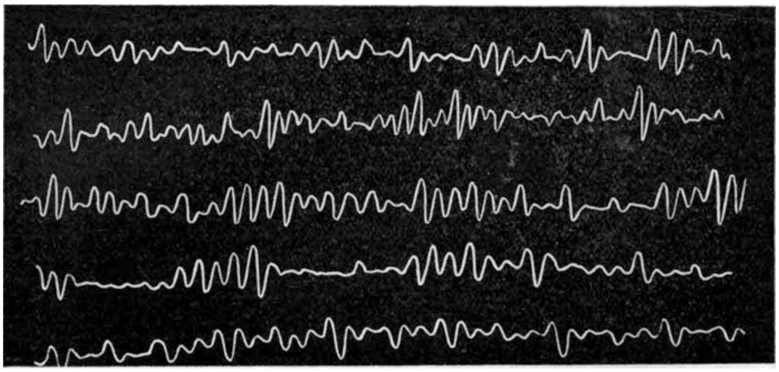

FIG. 1.—Record of a note from an orchestra.

as, for example, that of Chauncey M. Depew on "Forefather's day," when he says "Without regard to race or creed I can," &c.; or from "Cock Robin," "With my little eye I saw him die," &c.; or Joseph Jefferson's speech in proposing Rip Van Winkle's toast, "Come, Rip, what do you say to a glass? That's fine schnapps." As an example, take a small portion of the latter speech :—

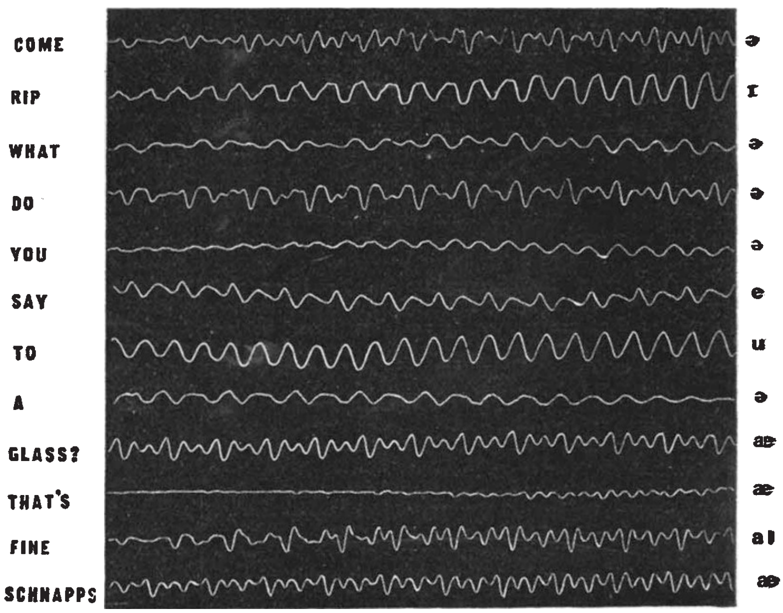

FIG. 2.—Curves showing waves from various vowels spoken by Joseph Jefferson in "Rip Van Winkle's Toast."

Each line contains only a few waves out of the curve for a vowel, and Dr. Scripture gives a careful analysis. It would have been better, I think, if Dr. Scripture, with his fine appliances, had given us an exhaustive examination of each vowel, not as it occurs in such a speech as we are considering, but by itself. The vowels here examined are "American vowels." Would it not have been better to have obtained first-rate gramophone records of clearly sounded vowels, and then to have reproduced the curves of these sounds? However, there can be no doubt Dr. Scripture's analysis teaches us a great deal. One would have expected that the wave forms in a vowel tone would have had the same form or shape for a short time, but it would appear that this is not so.

"So much has been said," writes Dr. Scripture, "of the complexity and the variability of the speech curves that the impression may have been produced that they are hopelessly irregular. This is not true. They are as irregular as the leaves of a tree; no two are alike, yet the individuals of a variety resemble one another, and differ from other varieties" (p. 49). . . . "As already pointed out, no two waves of a vowel are alike; the differences are often so great that we may be sure that one part sounds utterly different from another, although the ear apparently gets only a single general impression" (p. 53).

Dr. Scripture then devised a method "whereby the ear can be enabled to hear the sound of each wave separately." A special apparatus was constructed by which a single selected wave was many times repeated on a strip of zinc, then etched, and then transferred to the gramophone disc. The group of waves reproduced the sound represented by these exactly similar waves, and the ear was appealed to as to the resemblance of the sound to any particular vowel. This is quite a novel method of investigation, and suggests further experimental work. It shows the possibility of transferring any set of curves to a gramophone plate and then listening to the sound and comparing it with other sounds. The writer of this notice, by another method, has obtained many curves of vowels, and he cannot altogether bear out the statement of Dr. Scripture that all the waves differ from each other. At the beginning of a vowel tone, and towards its close, the waves may differ, although of the same general type, but in the middle of the tracing, when the vowel tone is clear and distinct to the ear, the waves appear to be the same in form.

In the analysis of speech curves, Dr. Scripture attaches importance to what may be termed the melody of speech. We have "melody" when sounds of different pitch are heard after one another.

"The study of melody is the study of the fluctuations of the pitch of the tone from the glottal lips. Each explosion, puff, or vibration from the glottis arouses a vibrating movement that shows itself in the speech curve as a group of vibrations; this we have called a 'wave-group' or a 'wave.' A 'wave' thus means the whole complicated group of vibrations resulting from a single glottal movement. The study of melody has to do with these waves or wave-groups."

By a special method Dr. Scripture plots a melody curve from a transcribed record, showing, for example, the curve when "Oh" is uttered "sorrowfully," or "admiringly," or "questioningly," &c. He works out the "melody curves" in Depew's speech, and then writes the melody in musical notation. With regard to the emphasis of speech as indicating the emotional condition of the speaker's mind, we must, however, take into account not only melody, or the sequence of tones of different pitch, but also the intensity, the passing from *diminuendo* to *crescendo*, or *vice versa*. Dr. Scripture has not attributed sufficient importance to this element in the analysis. The amplitudes of the wave forms increase or diminish according to the intensity.

Dr. Scripture expounds the principles of harmonic and inharmonic analysis in two chapters at great length and with much clearness. Nowhere have I met with a fuller exposition of Fourier's theorem and its application to acoustical problems. He does not hold, however, that a vowel curve is produced by combining simple sinusoid vibrations in a harmonic series, and he concludes that

"the sounds from the musical instruments are presumably produced in this way, but we dare not assume that the vowels are so produced until the fact has been proven" (p. 78).

He shows how to separate, by the rules of Hermann, harmonic and inharmonic sinusoids from the mixed results of a harmonic analysis. How is one vowel distinguished from another? Are the differences due to the presence of certain tones of definite pitch, as held by both Helmholtz and Hermann? If so, are we to hold with Helmholtz that these tones are harmonic overtones of the glottal tone or that they are inharmonic to it, as stated by Hermann? Dr. Scripture holds that Hermann has completely disproved the theory of Helmholtz. After discussing the method of analysis with frictional sinusoids, as distinguished from simple sinusoids, he states:—

"The vibrations of the voice in speech are . . . composed exclusively of frictional sinusoids and not of simple sinusoids, as has hitherto been assumed. Can a method of analysis into frictional sinusoids be found? Does an analysis into simple sinusoids give false results for the vowel curves?" (p. 101).

He answers the question thus:—

"The treatment of the curves by simple harmonic analysis—the only method that has hitherto been tried—furnishes results that are so wrong as to be utterly misleading when used to indicate the manner in which the vibrations were produced."

I observe that Dr. Scripture states that Prof. Weber, of the Swiss Polytechnicum, along with Schneebeli, was the first to apply the Fourierian analysis to a vowel curve, but he does not give the date when this was done. We must not forget that such an analysis was made by Fleeming Jenkin and Ewing in 1878 ("On the Harmonic Analysis of certain Vowel Sounds," *Trans. Roy. Soc. Edin.*, vol. xxviii., p. 745).

As to the mode of production of vowel tones, Dr. Scripture discards the views of Wheatstone, Grassmann, and Helmholtz that the glottal lips vibrate after the manner of strings or the borders of a membrane on each side of a narrow opening, and he fully adopts the "puff" theory of Willis and Hermann, according to which

"the glottis emits a series of more or less sharp puffs; each puff, striking a vocal cavity, produces a vibration whose period is that of the cavity; a single wave-group shows the sum of these vibrations from all the cavities; the periods of these vibrations may stand in any relation to the interval at which the puffs come, that is, to the fundamental."

There can be little doubt that, at all events in his later days, Helmholtz saw the analogy between the action of the glottis and the "puffing" sounds of a syren, but he undoubtedly held that the overtones were harmonics of the glottal tone. Hermann, however, has conclusively shown that at least some of the tones of the cavities may be inharmonic to the glottal tone, and Dr. Scripture supports this view by many ingenious experiments. His description, however, of the glottis is not either anatomically or physiologically quite satisfactory. It is not in accordance with anatomical detail to write, "Each glottal lip consists mainly of a mass of muscle supported at the ends and along the lateral side," or that "the two masses of muscle close the air passage," or that the air from the trachea "bursts the muscles apart." The glottis is a much more delicate structure than these words would imply. It contains much elastic tissue at the borders which come together, according to the "puff" theory, and the muscular structures are devoted to placing strains on this tissue and to separating or approximating the lips of the glottis. Dr. Scripture's view is that

"the effect of each puff on each element of the vocal cavity is double: first, to arouse in it a vibration of a period depending on the cavity; second, to force on it a vibration of the same period as that of the set of puffs."

The glottal puff produces a frictional sinusoid with large amplitude and a very large coefficient of friction, and the cavity vibrations are also of the frictional sinusoid form. This may explain the failure of a simple harmonic analysis to reveal the real elements of the vowel curve.

In chapter ix. Dr. Scripture gives his views as to the action of the organ of Corti in relation to wave analysis, and he conjectures that portions of it are affected by "groups of stimuli," when complex wave forms reach it. This does not seem very conclusive, and in my judgment the theory of Helmholtz, by which he explained the action of the organ by adopting the principle of resonance, still holds the field.

Dr. Scripture has also attempted a synthesis of vibrations by ingenious mechanisms, by which he obtained curves somewhat similar to speech curves. There is no doubt a great future for this line of experimental research. After fully worked out examples of vowel analysis, with all arithmetical details, Dr. Scripture appends to the end of the monograph a number of elaborate schedules to assist in the Fourierian analysis, namely, schedules of 12 ordinates, 24 ordinates, 36 ordinates, and 72 ordinates. The preparation of these schedules was a very laborious task, and the work will be much appreciated.

We congratulate Dr. Scripture on the production of a splendid monograph. It might have been improved by fuller bibliographical details, and perhaps by a more adequate recognition of the work of others.

JOHN G. MCKENDRICK.

AGRICULTURAL EDUCATION AND RESEARCH.[1]

ONE of the functions of the Board of Agriculture is the administration of a Treasury grant for the purposes of agricultural education, and though the total distributed is not large it has been a potent factor in stimulating the development of the higher forms of agricultural education during the last fifteen years. It is certain that many of the county councils

[1] The Annual Report of the Board of Agriculture and Fisheries on the Distribution of Grants for Agricultural Education and Research in the Year 1905–6.