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.

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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 $c^{1}\sharp$. 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.)