FURTHER EXPERIMENTS WITH THE GRAMOPHONE.

IN NATURE of April 15 I described a number of experiments with the gramophone. Since then I have continued to work on this interesting subject, and have at last succeeded in transcribing the vibrations of tones or chords as these are produced by the gramophone; that is to say, during the time that the sounds are given forth. The method is illustrated in the figure accompanying this paper (Fig. 1), and I also give several illustrations of the tracing so obtained. The sounds of the gramophone are carried by a tin tube from the end of the arm of the instrument to which the horn or trumpet-resonator is attached, to a sensitive microphone. The microphone used was made by Herr Müller-Uri, of Brunswick, and was intended to be used in the experiment of the singing-arc flame and also for a loud-speaking telephone. In the circuit of the microphone I have five or six dry cells giving a current of about five volts. In the same circuit is the recorder, which is a very small electromagnet having a marker attached to the keeper.

In early experiments I used a large electromagnet acting on a spring that carried a marker, but such an arrangement only recorded notes or chords, as regards intensity, but without showing the constituent vibrations. It was not quick enough. Accordingly I adopted a small electromagnetic arrangement, like a "Deprez-signal," known to physiologists; but, taking a hint from the use of elasticity in the construction of the reproducer of the gramophone and improved phonograph, I arranged thin india-rubber bands so as to hold the keeper of the tiny electromagnet about one or two millimetres from the small soft iron cores, and so placed that the keeper was kept in equilibrium between two forces, at the distance I have mentioned. I found that with this arrangement, when the gramophone was played, the electromagnetic recorder gave forth the tune with perfect accuracy, and when one touched the keeper it could be felt thrilling on the finger.

The electromagnetic recorder acted like a little telephone. After many contrivances, I found the best method was to place the recorder on the well-known

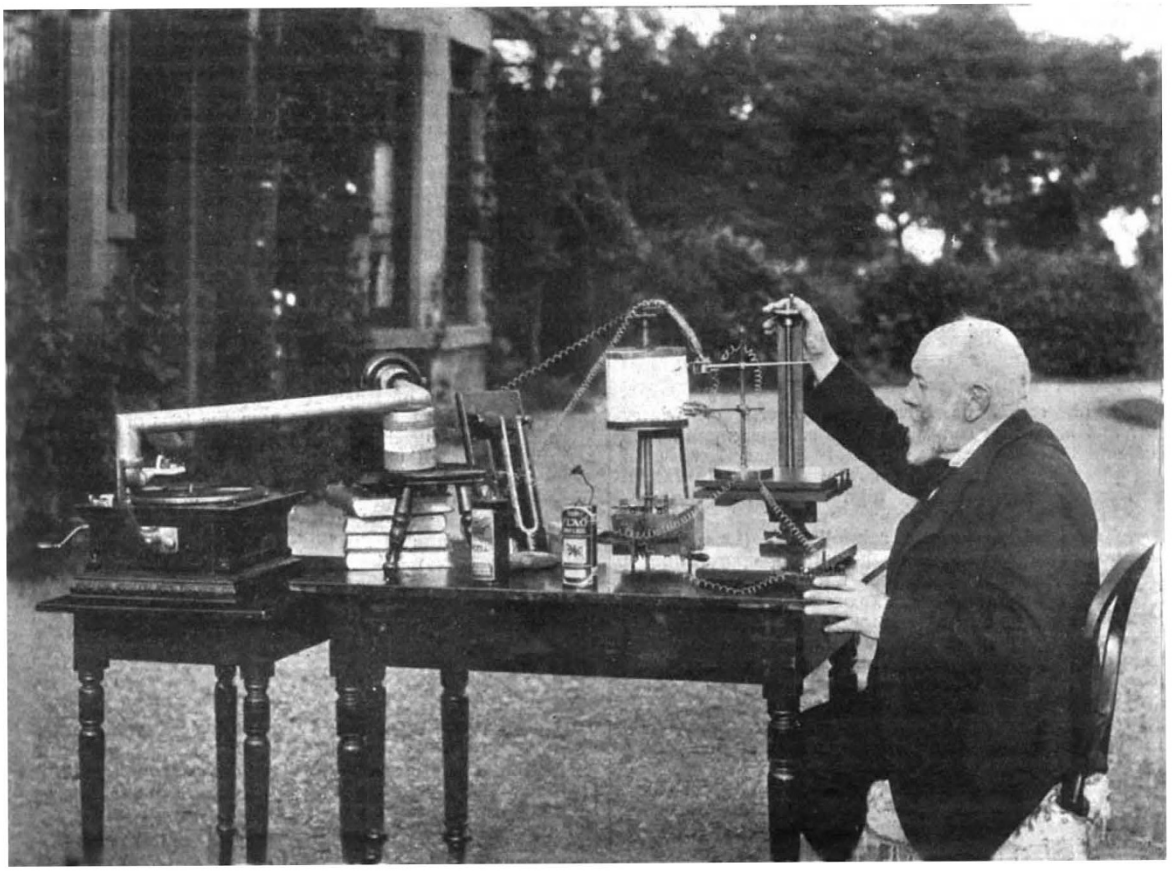

FIG. 1.—Arrangement of apparatus. Gramophone to the left. Observe the tin tube carrying the sound waves to the microphone. The operator is on the right controlling the movable stage. The upper electromagnetic marker adjusted to the cylinder (revolving drum) registers the vibrations of the 1/100th per second tuning fork seen in the middle of the table. The lower electromagnetic marker writes the vibrations of the sound waves as these act on the microphone. While it is registering the lower marker gives forth the sounds played by the gramophone.

Cambridge platform-stand, which can be moved up or down by a finely cut strong screw (see Fig. 1). On the platform I placed a device of my own, by which I could adjust the marker on the smoked paper with great nicety. On the same platform, as shown in the illustration, I placed an electromagnetic recorder controlled by a 100 vib. tuning fork, so as to register on the tracing 1/100ths of a second. The drum used was an old-fashioned Hawksley drum, well known to physiologists, and it rotated at a speed that gave 12 inches per second. The paper was smoked in the usual way over a camphor flame, and, after the tracing was taken, it was fixed by clear shellac varnish. The tracings shown are from slightly enlarged photographs of a portion of each tracing, and

the length of each line, from side to side, represents in time 0·3 second. Short descriptions of the tracings are printed below the figures.

The experiment was performed thus:—After carefully adusting the markers on the smoked paper, the cylinder was allowed to rotate until it reached its maximum uniform speed. By closing a key, a time record was taken. Then the gramophone was started; the sound waves acted on the microphone, and the little electromagnetic marker began to sing or play; finally, by having my right hand at the top of the screw, as shown in the figure, I was able slowly to raise the platform, carrying the recorder, so as to describe a long spiral line, about 135 feet in length, from the bottom to the top of the cylinder. On reaching the top, the experiment came to an end. To secure good results, great care had to be taken to secure nicety of adjustment. It must be explained that in the tracings so taken the recorder traverses 12 inches per second. The waves in my tracings are thus compressed laterally. To obtain waves at the speed of the gramophone, I had a wooden cylinder made which was attached to the circular plate of another gramophone, and having a circumference such that the recorder traversed from 21 to 24 inches per second. The two gramophones, one to play, the other to carry the wooden drum, were driven at the same speed. Tracings were thus obtained similar to the indentations or waves on the gramophone record. Trouble arose, however, from the oscillations of the gramophone plate (one of the conditions of the success of the gramophone, in which all the arrangements are more or less mobile), but this difficulty was easily surmounted. Finally, I found that with my arrangement it was not necessary to use the gramophone, as it was easy to record the vibrations of a human voice by causing the singer or speaker to sing or speak direct to the microphone. The arrangement is an excellent phonautograph. About five minutes are occupied in taking a tracing, the average length of which is 135 feet.

An inspection of these tracings shows the wonderful variety of pressures pouring in upon the ear as we listen to music. Three or four or more notes differ-

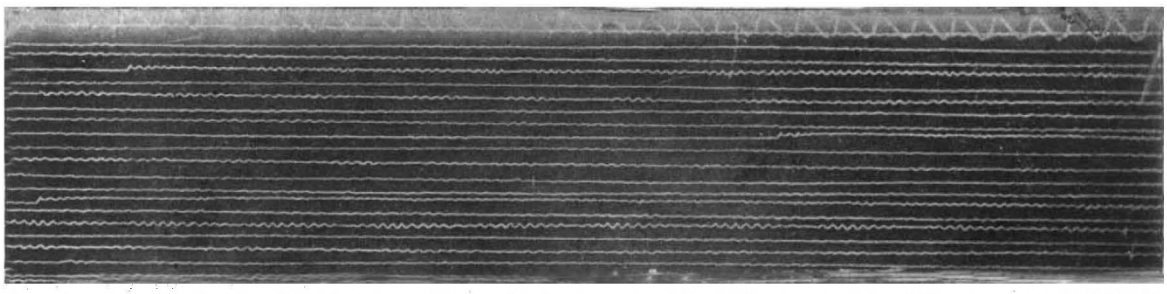

FIG. 2.—Small portion of tracing of the Westminster chimes. The tracing begins at the left-hand corner at the bottom, runs along the line to the right, then is continued in the next line above, again at the lower left-hand corner, and so on. The length of time represented by the length of one line from left to right is about one-third of a second. The tracings of the 1/100th of a second are seen at the top. The tracing is from the portion of the record giving the strokes of twelve o'clock. Near the top little groups of waves indicate the beats, &c., after the last stroke.

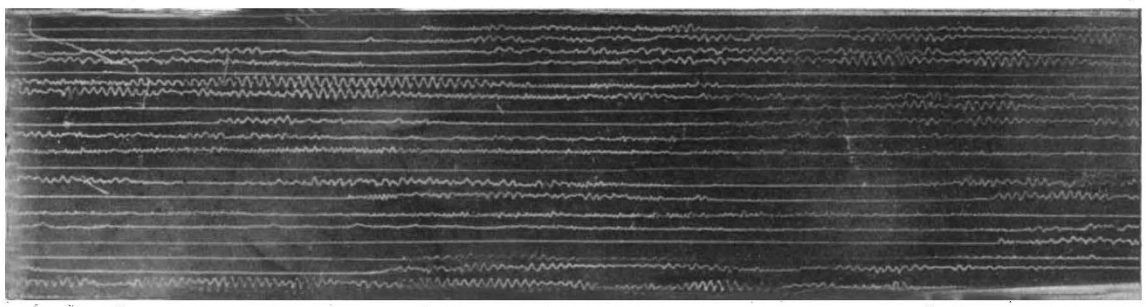

FIG. 3.—Small portion of tracing of a number of male voices singing the "Soldiers' Chorus" from *Faust*. From the La Scala Theatre, Milan. The time relations, &c., are the same as in Fig. 2. Observe the complicated form of the curves.

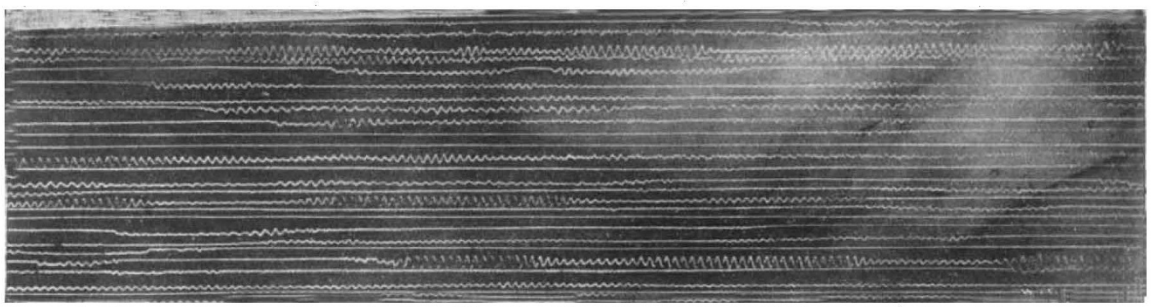

FIG. 4.—Small portion of a tracing giving the vibrations of the voice of Signor Caruso in singing "Spirito Gentile." Time relations, &c., same as in Fig. 2. Observe the crescendo and diminuendo of certain notes, the high pitch of others, and the regularity in form of the waves.

ing in pitch may affect the ear in a second of time. From ten to twenty vibrations, falling on the ear at a certain rate, are sufficient to arouse the sense of pitch of a tone of that frequency. It would seem that with notes of low pitch, within limits, fewer vibrations are required to enable the ear to appreciate pitch, and the opposite holds good with notes of high pitch. This corresponds with the fact that differences of pitch are difficult to detect both in the upper and the lower limits of the scale of audibility, whereas a skilled ear in the middle ranges of the scale can appreciate a difference of one sixty-fourth of a semitone. The tracings also indicate approximately the pitch of any note registered. Suppose three small waves correspond to the wave of the one-hundredth of a second, then the pitch of the note will be about three hundred per second, or (taking the middle *c* at 256) a little below *f*. The highest pitch I have mentioned is *g*″, or more than 1500 vibs. per second, in the "Bell Song," Lakmé (Delebes), by Madame Tetrazzini. I have also observed that the tracings show intervals in which there is a straight line, with no vibrations. If those intervals are very short, then the interval may not be appreciated by the ear, even with the most careful attention. In all the tracings the wave form is compound, not only owing to the existence of overtones, but also because the voice is usually accompanied by an instrument, the piano, or an orchestra. I took one tracing of voice-tones (a bass voice) with no accompaniment.

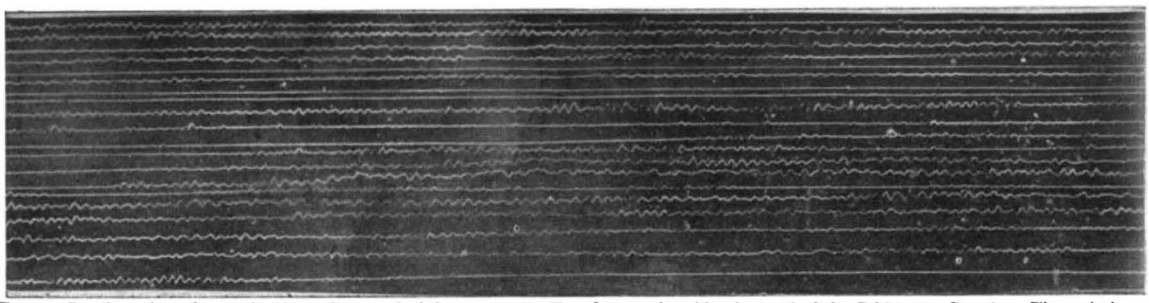

FIG. 5.—Small portion of a tracing from the record of the overture to *Tannhäuser* played by the band of the Coldstream Guards. Time relations, &c., as in Fig. 2. Observe the variations in pitch as indicated by the number of waves in a short period, and the irregularity in form of the waves.

The most complex waves are those produced by the blending of many voices or by an orchestra (see Figs. 3 and 5). Here again there arises a curious consideration. Suppose that in an orchestral piece all the instruments do not *attack* at the same instant, or if one lingers after the rest the fraction of a second, in both cases the wave form and the tracing picture in general will be affected. If the want of coincidence passes beyond a limit, which it is difficult to define, a musical ear finds the result defective, although one can scarcely tell why. Nothing has excited more in my mind a feeling of wonder at the powers of the ear than the inspection of these tracings. Is there a damping mechanism, or is a damping mechanism necessary? May it not be, after all, that our perceptions of musical tones, as in a musical composition, are the result of different *modes* of stimulating the ends of the cochlear nerves? May not innumerable varieties of pressures act on the nerve-endings, possibly as a whole, and send corresponding impulses to the brain? I confess that in the face of these tracings I find it more difficult to realise an analysis in the cochlea; but if not there, where does it take place? That there is an analysis when we make an effort of attention there can be no doubt.[1]

JOHN G. MCKENDRICK.

[1] I have to thank Prof. Noël Paton, of Glasgow, and Prof. MacWilliam, of Aberdeen, for the loan of some portions of the apparatus.

PEAT IN NORTH AMERICA.

FOR many years peat was looked on as a source of fuel in poor countries only, where communications were undeveloped, and where cottagers extracted it by their personal labour for use in their own household fires. To this day, the economist will probably find that this is the best and most practical treatment of a peat-bog. It becomes idle in such cases to speak of relative calorific values, and to point out that, even under present conditions of transport, coal would form a more effective fuel. Where the right of digging peat over a certain area is included in the rent of a small holding, this peat is dug at odd but suitable times, when the crofter or his family might otherwise have remained idle. The cost of labour thus becomes insignificant, especially where creels are used for transport; and even the horse or ass must be fed, whether or no he is engaged in drawing the red cart along the ridges between cut-away boglands, or down the grooved hillside from the high-level deposit on the plateau.

But from time to time capitalists have turned longing eyes towards these stores of carbonaceous matter, and have sought to get rid of the 80 or 90 per cent. of water in the peat, and to produce a fuel economically capable of transport. Others have proposed to produce gas at the bog itself; while others, often with marked success, have manufactured moss-litter for use as an absorbent bedding for city stables and dairy barns.

The various uses of peat have now attracted attention even on the North American continent. Messrs. E. S. Bastin and C. A. Davis have provided an introductory manual on the subject in their description of "The Peat Deposits of Maine" (Bulletin No. 376 of the United States Geological Survey, 1909, pp. 128). They acknowledge that they have been preceded by Mr. Erik Nyström's treatise on "Peat and Lignite: their Manufacture in Europe," issued a year previously by the Canadian Department of Mines. Messrs. Nyström and Anrep have now also published the results of their "Investigation of the Peat Bogs and Peat Industry of Canada, during the Season 1908–9" (Bulletin No. 1, Department of Mines, Canada, 1909, pp. 25).

The deposits in Maine are at present so little utilised that Messrs. Bastin and Davis direct attention to the various ways in which peat has become profitable elsewhere, and, we must admit, to the various ways in which it has been worked without profit to anyone except the makers of machinery. The buildings and heaps of scrap-iron lying derelict beside the bogs of Europe have not yet served to warn those who are fascinated by some fancy process, put before them under seductive influences in the glamour of a well-lit exhibition. The authors of the United States bulletin have no false enthusiasms, and they lay proper stress