

April 16, 1874.

JOSEPH DALTON HOOKER, C.B., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

- I. "On the Pneumatic Action which accompanies the Articulation of Sounds by the Human Voice, as exhibited by a Recording Instrument." By W. H. BARLOW, F.R.S., V.P.Inst.C.E.
Received February 23, 1874.

All articulated sounds made by the human voice are accompanied by the expulsion of air from the mouth; and in a series of articulated sounds the air is ejected in impulses which vary in quantity and pressure, and in the degree of suddenness with which they commence and terminate.

It appeared to me that it would be interesting and probably useful, as tending to elucidate the process and effects of articulation, to construct an instrument which should record these pneumatic actions by diagrams, in a manner analogous to that in which the indicator-diagram of a steam-engine records the action of the engine.

In considering a suitable form of recording instrument, the conditions to be met were :—first, that the pressures and quantities were very variable, some of them being extremely small; and, secondly, that the impulses and changes of pressure follow each other occasionally with great rapidity.

It was therefore necessary that the moving parts should be very light, and that the movement and marking should be accomplished with as little friction as possible.

The instrument I have constructed consists of a small speaking-trumpet about 4 inches long, having an ordinary mouthpiece connected to a tube $\frac{1}{2}$ an inch in diameter, the other end of which is widened out so as to form an aperture of $2\frac{1}{4}$ inches diameter.

This aperture is covered with a membrane of goldbeater's skin or thin gutta percha.

A spring which carries the marker is made to press against the membrane with a slight initial pressure, to prevent as far as practicable the effects of jar and consequent vibratory action.

A very light arm of aluminium is connected with the spring and holds the marker; and a continuous strip of paper is made to pass under the marker in the same manner as that employed in telegraphy.

The marker consists of a small fine sable brush placed in a light tube of glass $\frac{1}{10}$ of an inch in diameter. The tube is rounded at the lower end, and pierced with a hole about $\frac{1}{20}$ of an inch in diameter. Through this hole the tip of the brush is made to project, and it is fed by colour

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put into the glass tube in which it is held. To provide for the escape of the air passing through the instrument, a small orifice is made in the side of the tube of the speaking-trumpet, so that the pressure exerted upon the membrane and its spring is that due to the difference arising from the quantity of air forced into the trumpet and that which can be delivered through the orifice in a given time.

There being an initial pressure upon the membrane to prevent vibratory action as before described, the strength of the spring and the size of the orifice had to be adjusted, so that while the lightest pressures arising under articulation could be recorded, the greatest pressures should not produce a movement exceeding the limit of the width of the paper.

It will be seen that in this construction of the instrument the sudden application of pressure is as suddenly recorded, subject only to the modifications occasioned by the inertia, momentum, and friction of the parts moved. But the record of the sudden cessation of pressure is further affected by the time required to discharge the air through the escape orifice.

Inasmuch, however, as these several effects are similar under similar circumstances, the same diagram should always be obtained from the same pneumatic action when the instrument is in proper adjustment; and this result is fairly borne out by the experiments.

We are thus enabled to trace to what extent the pneumatic action varies with different articulations; and it will be seen that although there are instances in which considerable differences in sound do not make much variation in the diagram, yet, as a rule, every change of sound or articulation produces a change in the diagram, and that there are pneumatic actions revealed by this instrument which are imperceptible to ordinary observation.

Before referring to the peculiarities of the diagrams, it may be desirable to say a few words on the quantities of air used in articulation.

On reference to medical authorities, it appears that the average quantity of air expelled in one respiration is estimated at 40 cubic inches, and that the total air-space of the lungs is estimated to average 110 cubic inches.

I have ascertained by experiment that a balloon made of goldbeater's skin, whose cubic content when full was 523 cubic inches, was filled with twelve ordinary respirations, or at the rate of about 44 cubic inches for each respiration.

Also that by filling and emptying the lungs as completely as practicable, the 523 cubic inches could be filled with six respirations, or about 88 cubic inches for each respiration.

I also made the following experiment to ascertain the average quantity of air used in pronouncing syllables.

Using the same balloon and speaking into an elastic tube communi-

cating with it, I read from a book until the balloon was filled, taking care to close the elastic tube when it was necessary to take breath.

The results were as follows :—

	Time required.	No. of syllables.	Cubic inches.
	84 seconds	353	523
	84 "	353	523
From another part of the book	90 "	364	523
" "	95 "	364	523
Mean	86 "	359	523

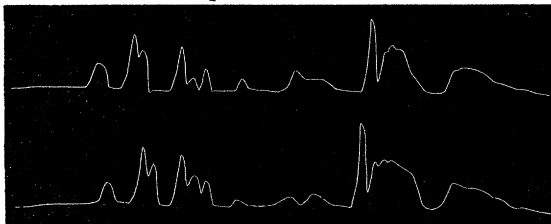
Showing an average of about $1\frac{1}{2}$ cubic inch of air for each syllable, and rather more than four syllables per second, including stops.

Without stops, from five to six syllables can be pronounced in a second.

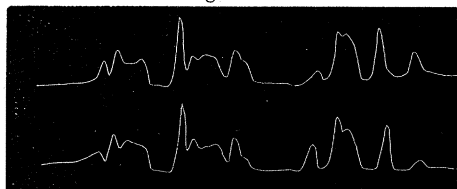
The lungs appear to be capable of exerting considerable pressure in the expulsion of air ; but distinct articulation becomes difficult against a pressure of 2 inches of water, and I could not pronounce any words against a pressure of 4 inches, without considerable exertion.

The following diagrams made by the instrument show the degree of accordence obtained when the same words are repeated by the same speaker:—

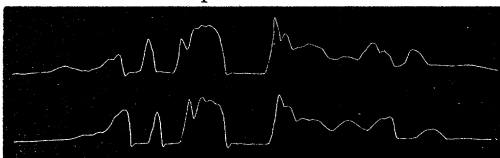
Experimental Tests.



Recording Instrument.



Repetition Trials.



One of the first features manifested in using the instrument is the action produced by the silent discharge of air from the mouth, after a syllable or word or a sentence is pronounced. This silent discharge

appears to depend on the force required in the last syllable, if more than one are consecutively uttered, and is most developed in those syllables terminating with the consonants termed "Explodents," whether with or without the silent vowel E after them.

This effect is exhibited in fig. 1.

Fig. 1.

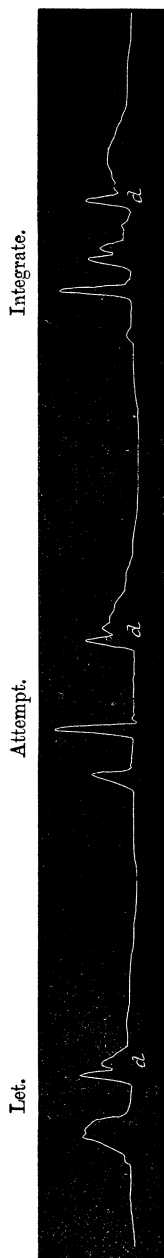


Fig. 2.

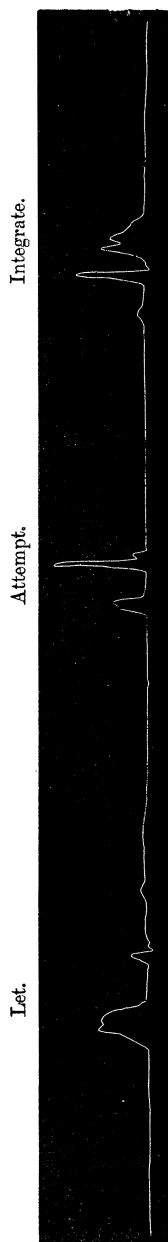
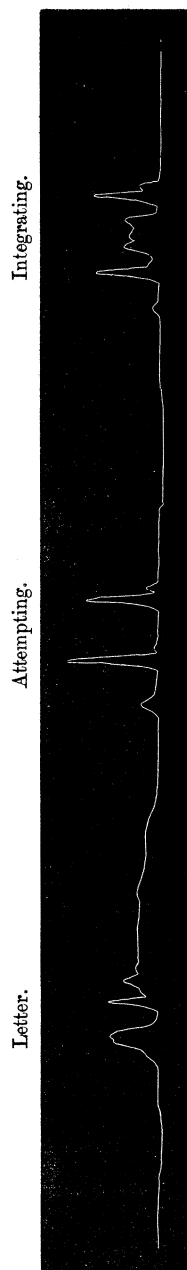


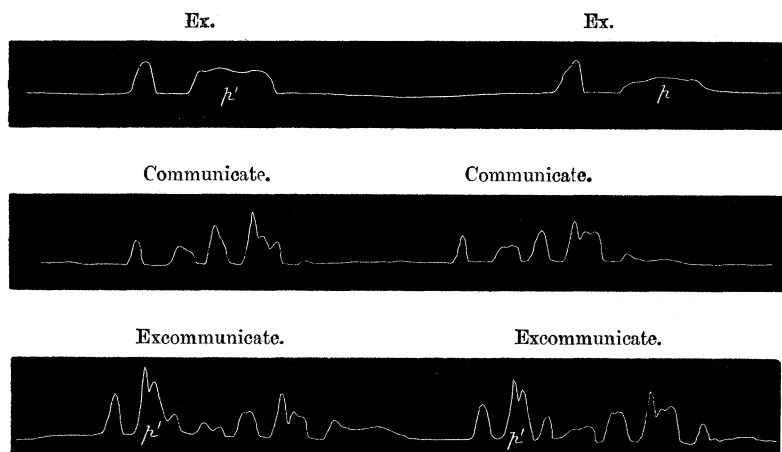
Fig. 3.



In these diagrams the part marked *d* is the silent discharge, and its appearance in the diagram is under the control of the will; for by holding the breath immediately after pronouncing the word, this part of the diagram can be altered and the discharge of air postponed or let off gradually, as exhibited in fig. 2.

If, instead of terminating with the "Explodents," another syllable be added to each word, making them terminate with consonants of softer sound, the air which would have been silently discharged is used to form the syllable added, and the subsequent silent discharge is very much diminished (see fig. 3).

There are other silent or, rather, insensible actions which occur *within* certain words, as is exhibited in the differences between the word "*Excommunicate*" and the syllable "*Ex*" and the word "*Communicate*," pronounced separately.



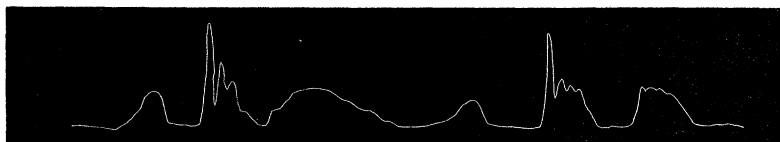
Here it is seen that the part *p*, which is the secondary sound of the syllable "*Ex*," becomes compressed, its length being shortened and its height increased; so that although nearly insensible as regards sound, it becomes developed into the form *p'*, and constitutes the most prominent feature of the diagram when the whole word is pronounced.

Some words are shortened when a syllable is added. This effect is strongly exhibited in the word "*Strengthen*" as compared with "*Strength*." "*Strength*" is, I believe, the only word of one syllable in the English language which contains seven consonants, all of which are pronounced.

The diagrams are as follows :—

Strength.

Strength.



Strengthen.

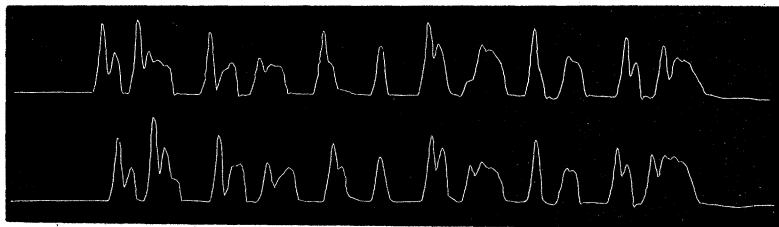
Strengthen.



As a test of the rapidity of action of the instrument, I have used the old nursery words, "*Peter Piper picked a peck of pickled pepper.*"

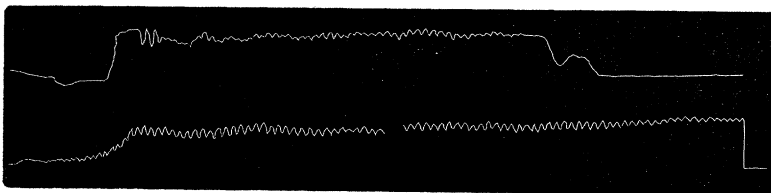
This is said at the rate of six syllables per second; and it will be observed that there are two principal upward and two principal downward movements to many of the syllables, besides other subsidiary actions.

Peter Piper picked a peck of pickled pepper.

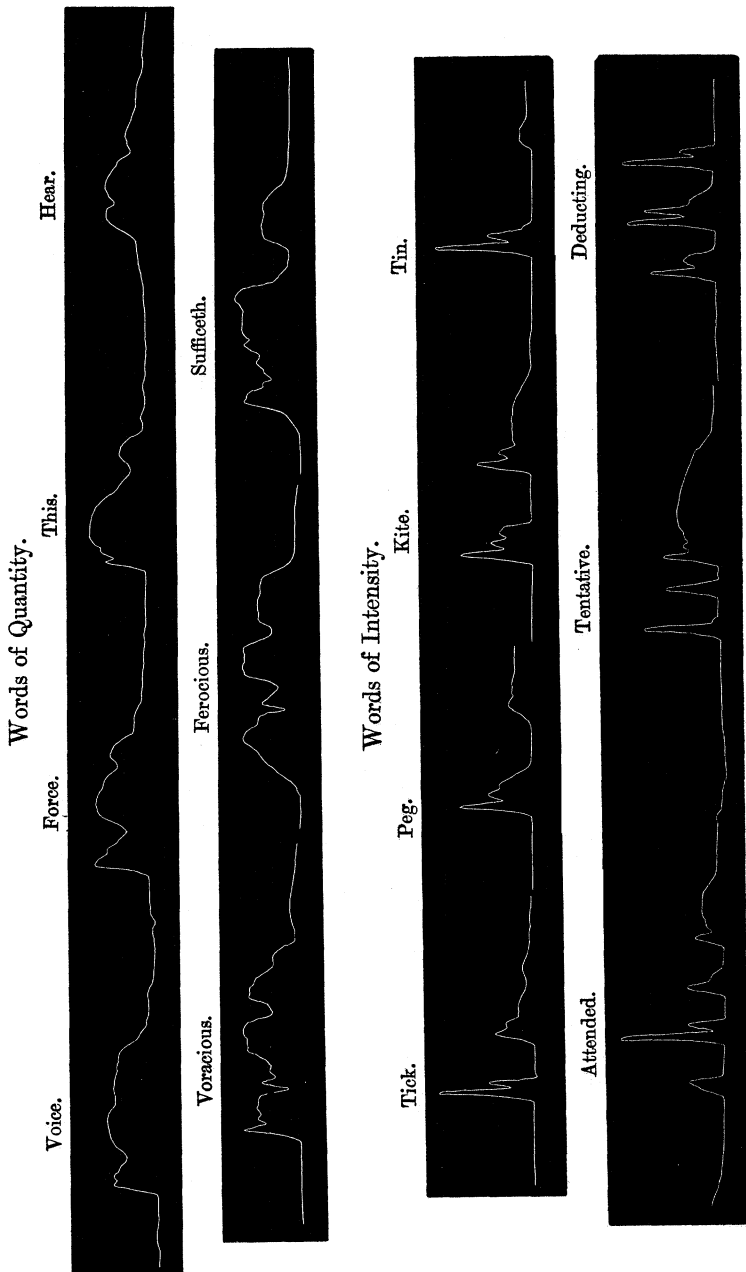


Another curious test is the continuous sound of the rough R.

The upper diagram is pronounced by myself, the lower one by my son.



There is a very marked difference in the quantity of air used and the degree of compression in different words and syllables.



The difference in the action between whispered sounds and those spoken loud is not so great as might have been expected.

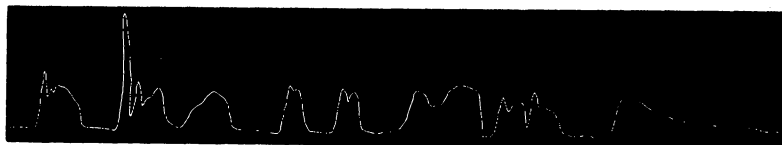
The word used in the four following trials is "*Incomprehensibility*."

The first is whispered faintly,
The second is whispered forcibly,
The third is spoken at the ordinary tone of the voice,
And the fourth is spoken loudly.



In order to show the manner in which the diagrams of words are affected when spoken together, I give four lines from *Hohenlinden* and the words separately.

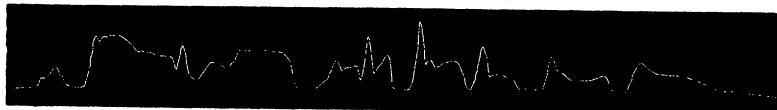
By torch and trumpet fast arrayed,



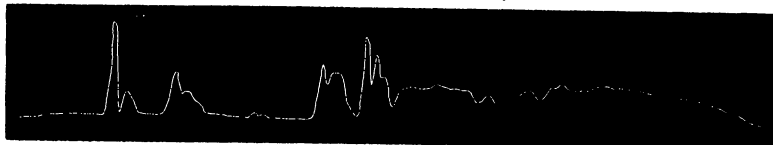
Each Horseman drew his battle blade ;

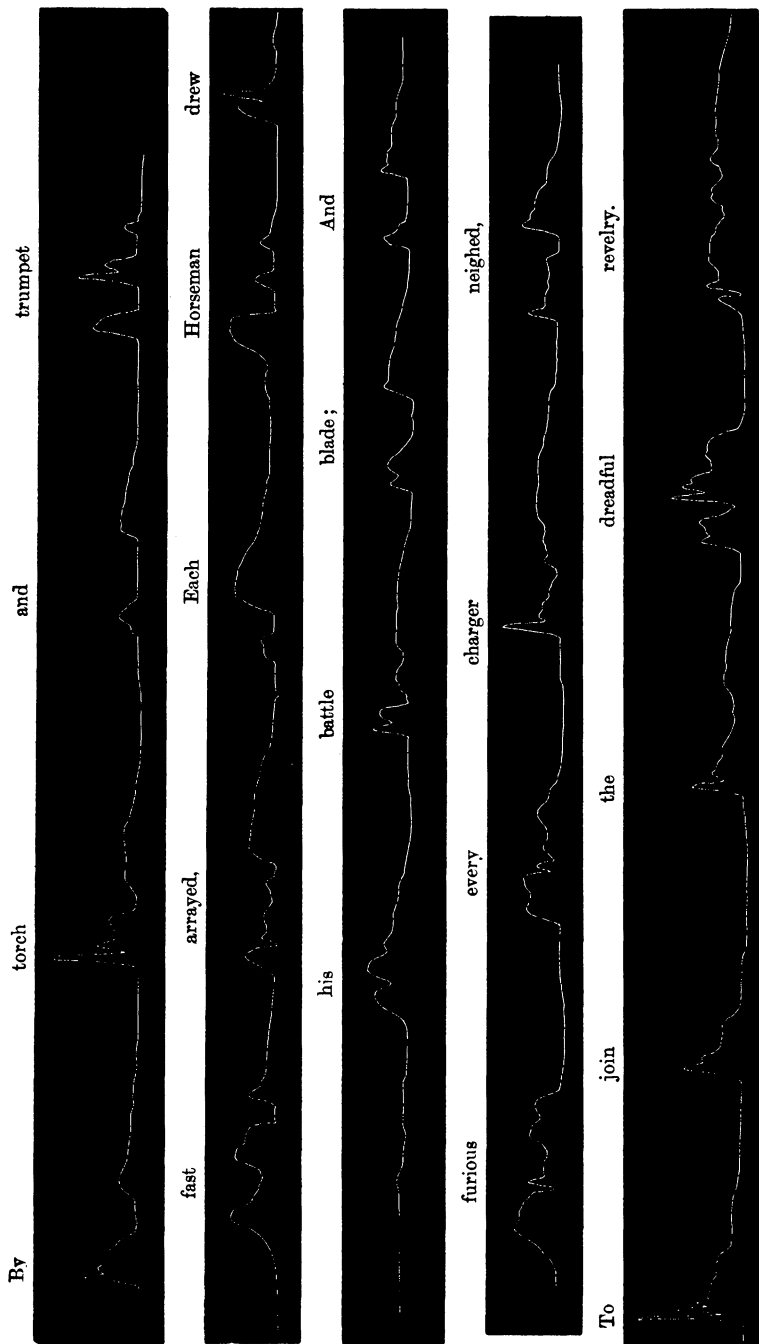


And furious every charger neighed,



To join the dreadful revelry.





It will be observed that the diagrams of the separate words, although they become modified when grouped together, are more or less discernible in the lines continuously spoken; and the similarity of sound at the termination of the first three lines, which constitutes the rhyme of the verse, is represented in the similarity of form, or in the character of the form, of the terminations of the diagrams of these three lines.

The subject might be pursued much further by showing the diagrams of the same words spoken by different individuals, the outlines produced by the words and sentences of other languages, the effect produced by change of accent, &c.

My object, however, has not been to pursue the subject into minute detail, but to show that the articulation of the human voice is accompanied by definite pneumatic actions, and that those actions, many of which are insensible to ordinary observation, are capable of being recorded.

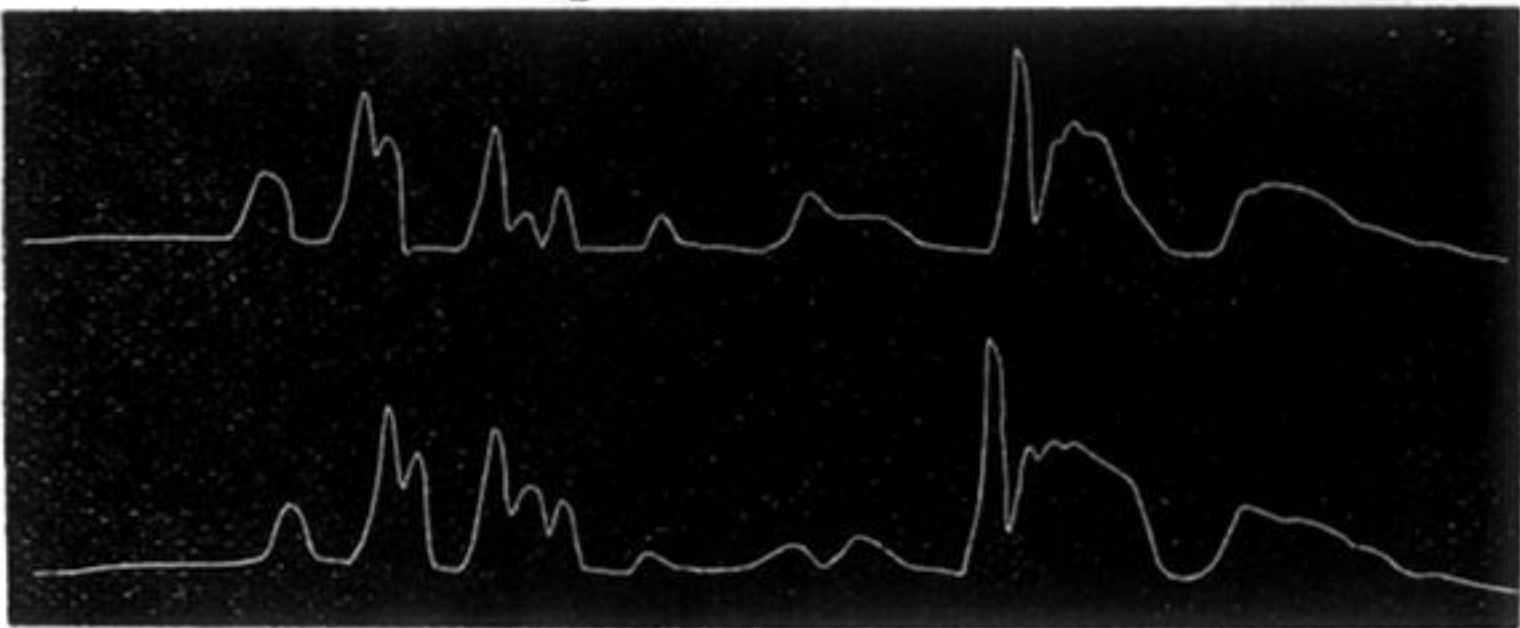
II. "Note on the Periodicity of Rainfall." By J. H. N. HENNESSEY, Esq., F.R.A.S. Communicated by Prof. G. G. STOKES, Sec.R.S. Received February 24, 1874.

1. Interested in the inquiry proposed by Mr. Meldrum, as to whether rainfall varies with the sun-spot area, I examined the register kept at the office of the Superintendent of the Great Trigonometrical Survey of India, and am enabled, through the courtesy of Colonel J. T. Walker, R.E., to communicate the results. These are probably not devoid of peculiar interest, from the abnormal conditions presented by the stations of observation, which are far inland, and on, or adjoining, lofty mountains, as appears from the following brief descriptions.

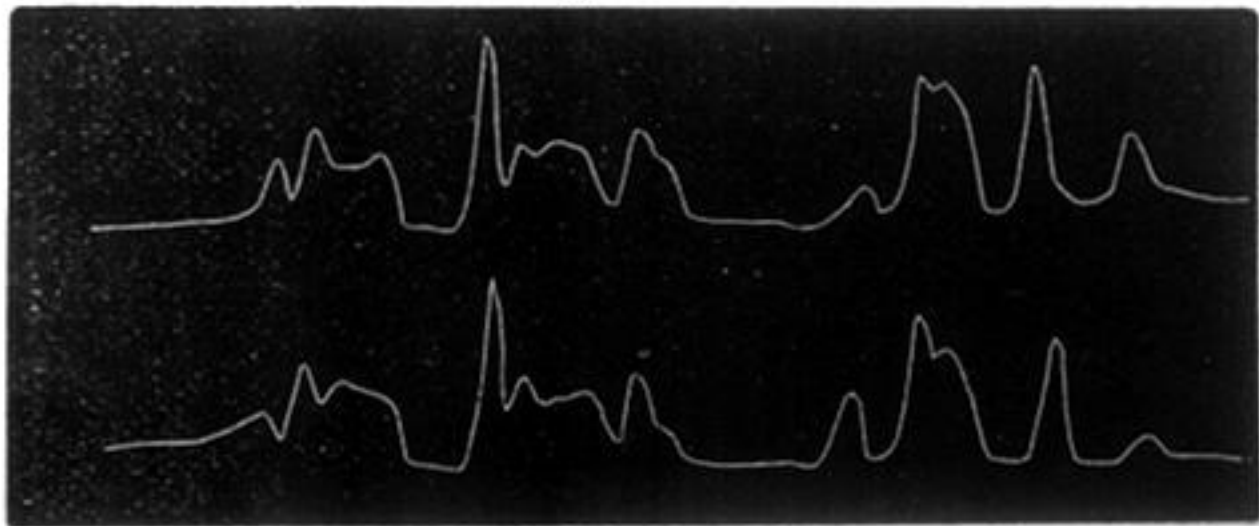
2. Mussoorie station is on the southernmost range of the Himalaya Mountains, lat. N. $30^{\circ} 28'$, long. E. $78^{\circ} 7'$, height 6500 feet; this range rises suddenly and forms the northern boundary of the Dehra Doon (or Dehra valley), which is some 18 miles wide and 40 miles long, and is bounded to the south by the Sewalik range of hills, about 3500 feet high. Dehra station is 2200 feet high, 10 miles south of Mussoorie station, and in the Dehra valley.

3. Owing to the absence of the observers in the winter months from Mussoorie station, the rainfall is not recorded there during that period; this, however, is of little consequence to the inquiry in hand, for the total annual fall occurs almost entirely in June, July, and August. I accordingly give in Table I. the total fall at Mussoorie between May 1 and October 31 of each year; and in order to make these totals comparable at the two stations, if desired, the fall for January, February, March, April, November, and December is excluded from the Dehra totals; this quantity excluded may be set down at some 6 inches, or only

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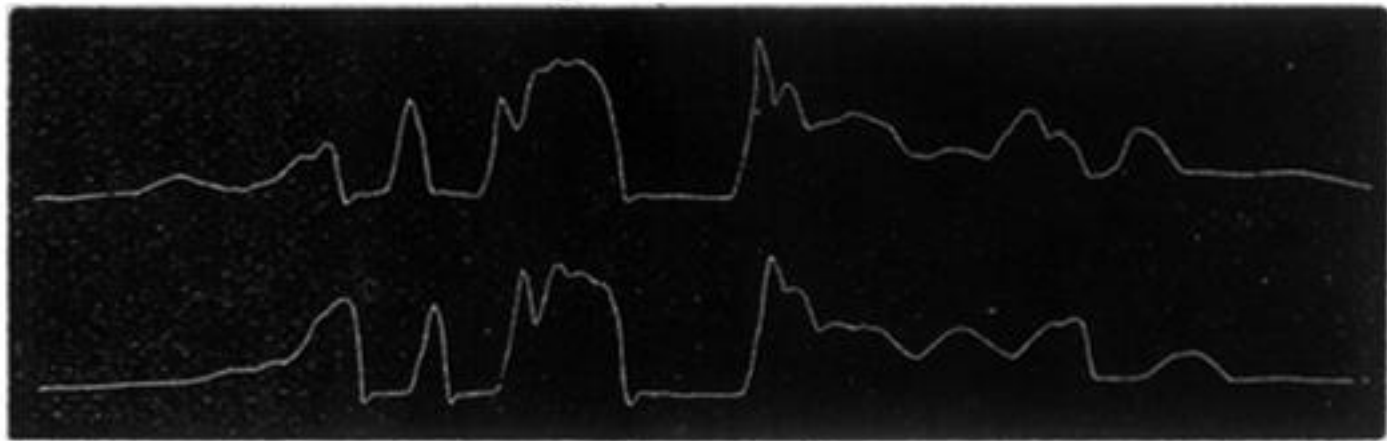


Fig. 1.

Let.

Attempt.

Integrate.

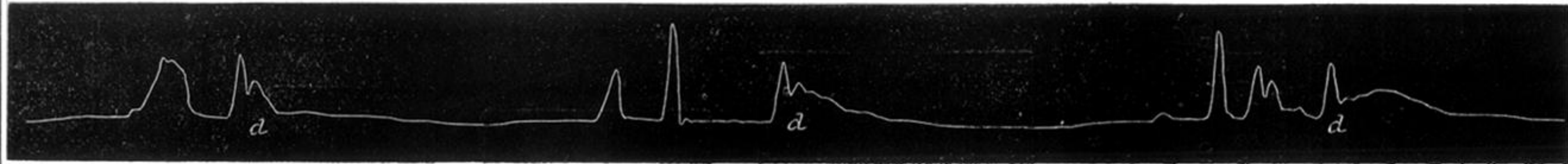


Fig. 2.

Let.

Attempt.

Integrate.

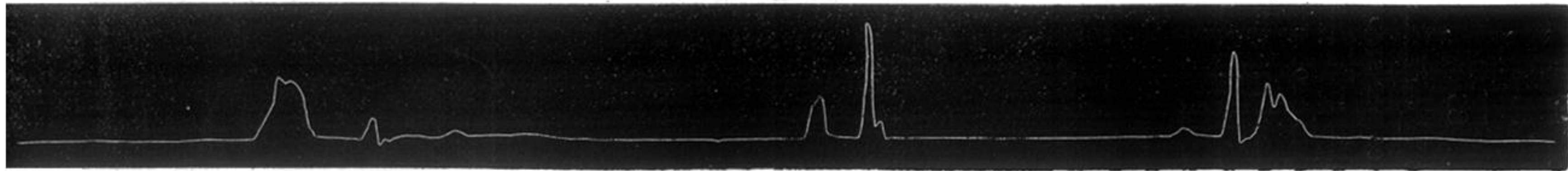
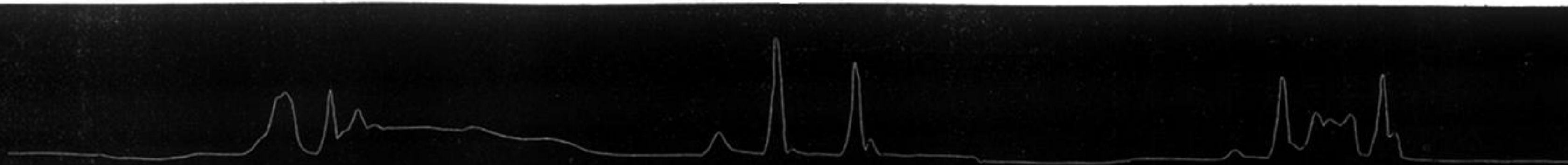


Fig. 3.

Letter.

Attempting.

Integrating.



Ex.

Ex.

μ'

μ

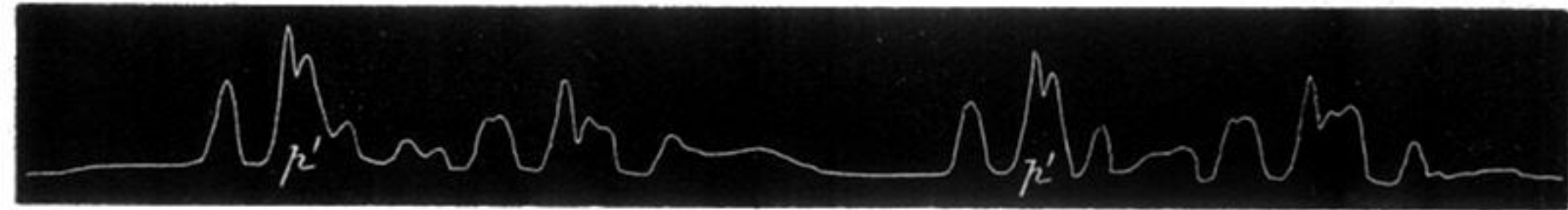
Communicate.

Communicate.



Excommunicate.

Excommunicate.



Strength.

Strength.

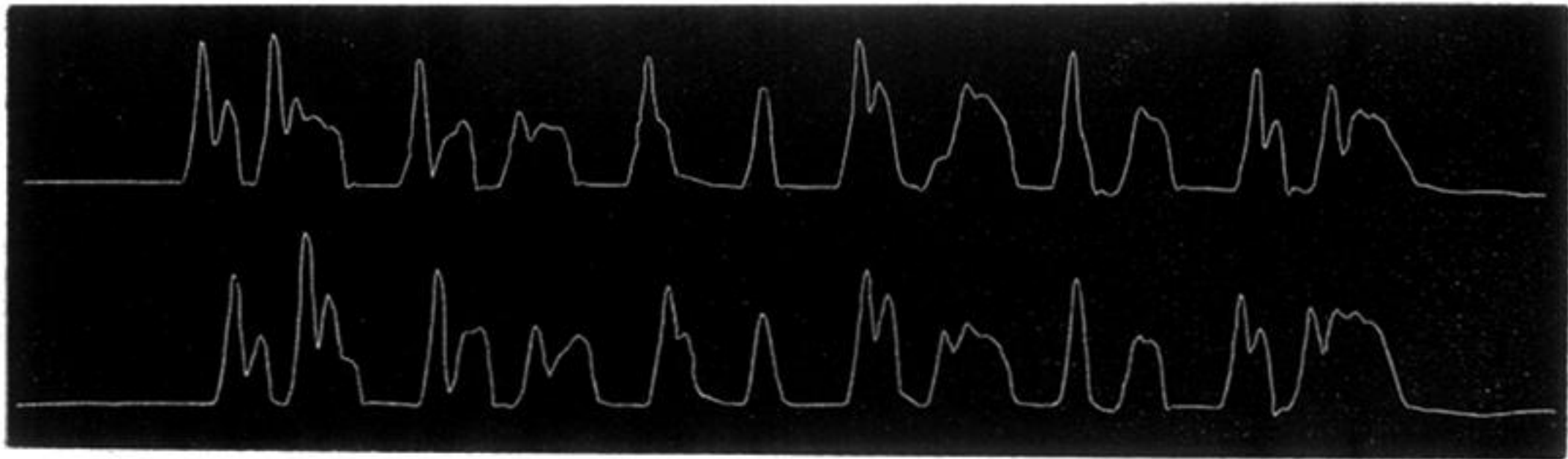


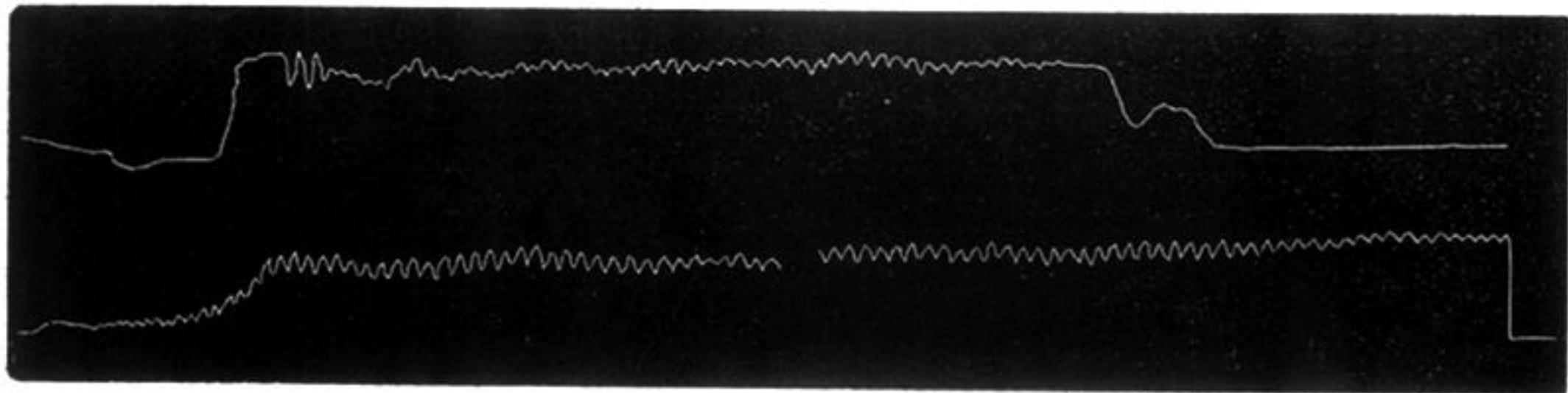
Strengthen.

Strengthen.



Peter Piper picked a peck of pickled pepper.





Words of Quantity.

Voice.

Force.

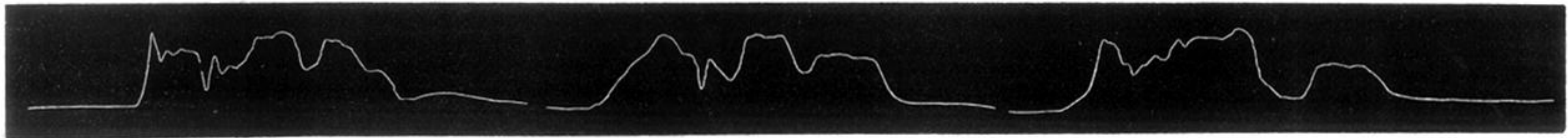
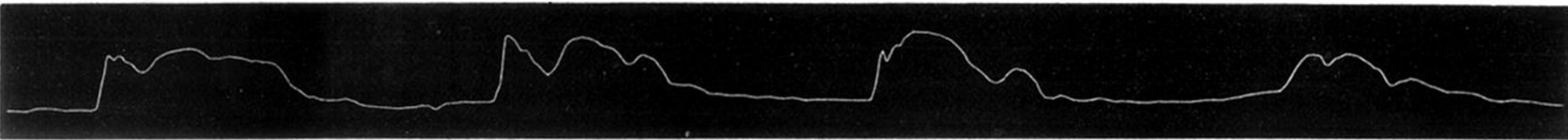
This.

Hear.

Voracious.

Ferocious.

Sufficeth.



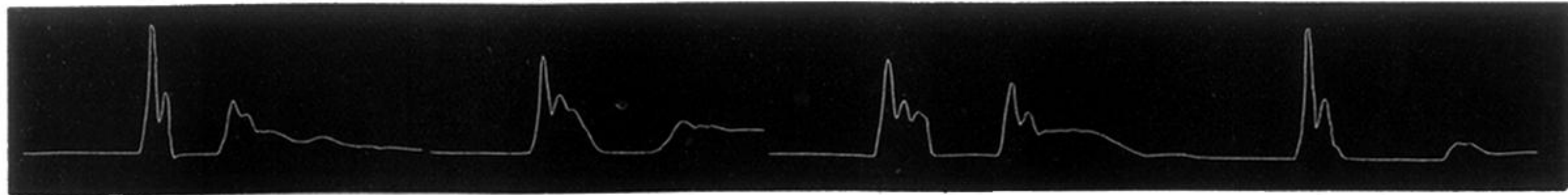
Words of Intensity.

Tick.

Peg.

Kite.

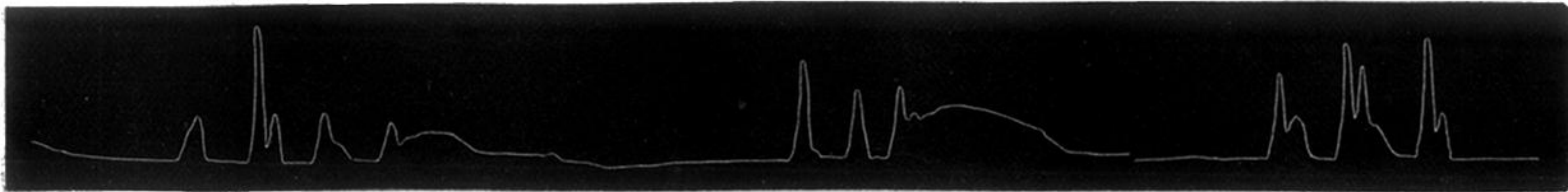
Tin.



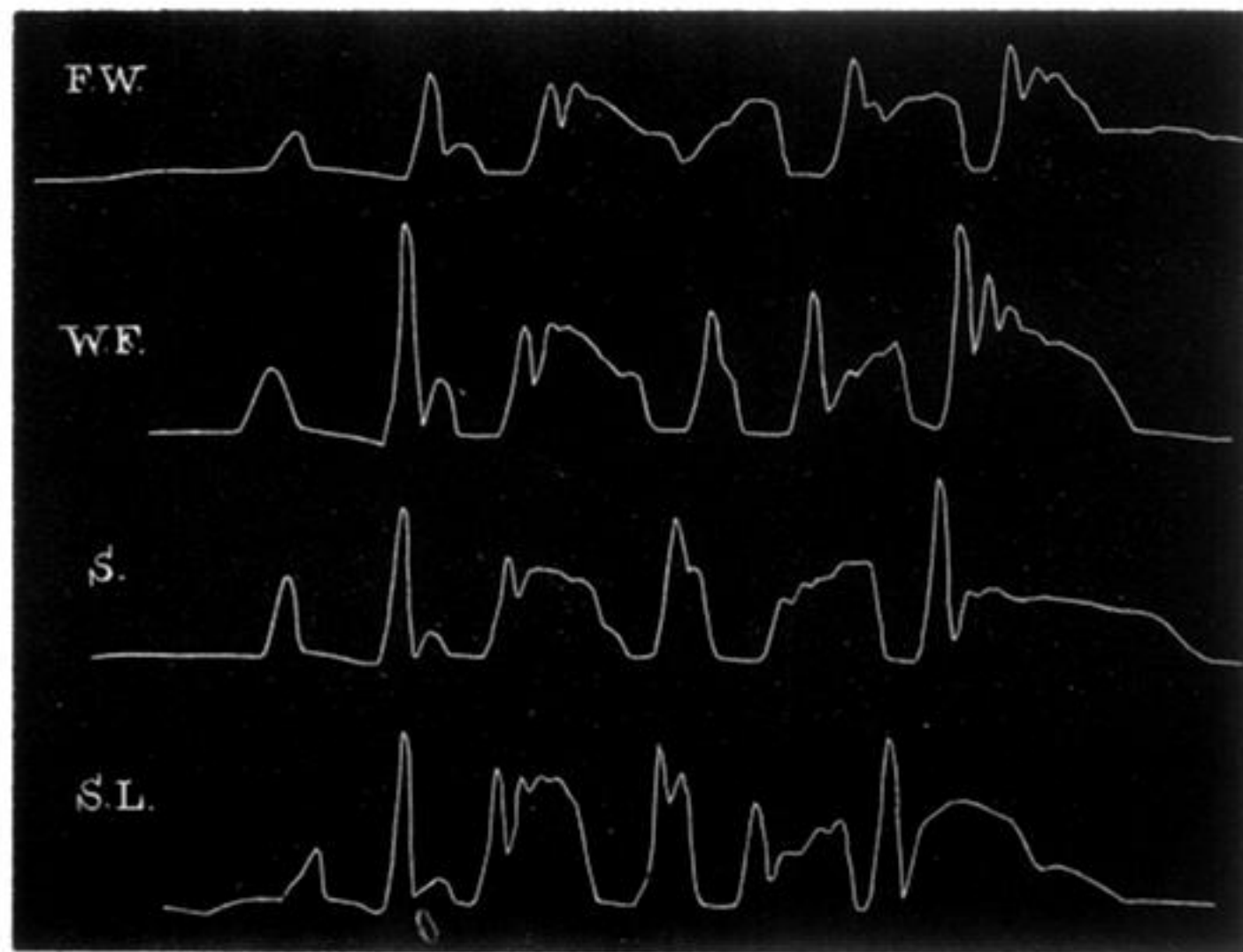
Attended.

Tentative.

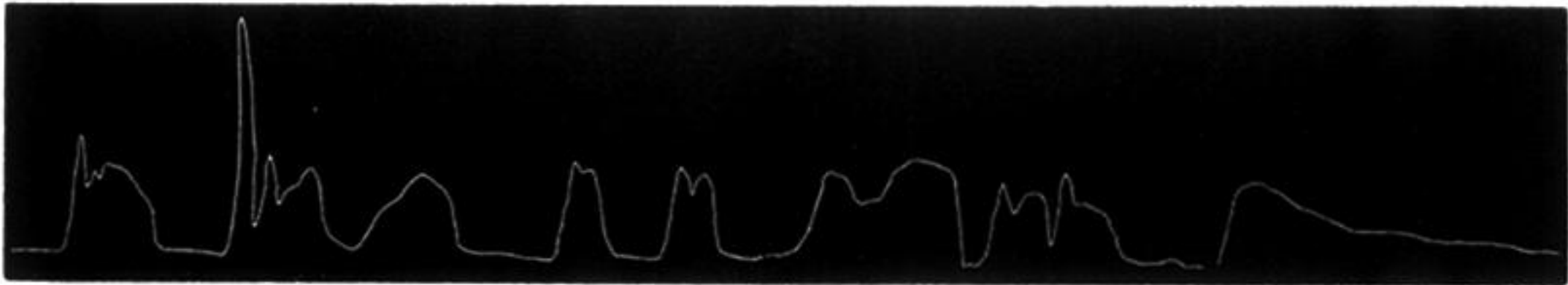
Deducting.



The first is whispered faintly,
The second is whispered forcibly,
The third is spoken at the ordinary tone of the voice,
And the fourth is spoken loudly.



By torch and trumpet fast arrayed,



Each Horseman drew his battle blade ;



And furious every charger neighed,



To join the dreadful revelry.

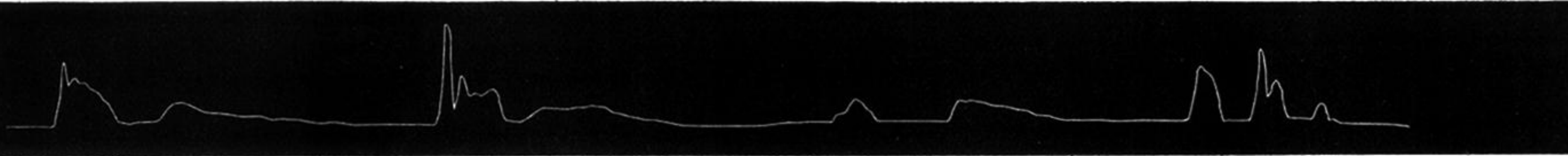


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