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Rayleigh, John. “On the determination of absolute pitch by the common harmonium.“ Nature 19, no. 482 (1879): S. 275-276.

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observation and principles which have worked like a master-key in opening to our understanding the meaning of this wonderful region. Without those methods and principles it would have been of comparatively little utility to attempt to solve the problems of such a region. Those whose privilege it has been to carry them into practice will ever be glad to acknowledge how great is their indebtedness.

INCLINATION OF THE AXES OF CYCLONES AND ANTICYCLONES

I HAVE during the last seven years endeavoured, though apparently without much effect, to direct the attention of meteorologists to a law which I conceive to be of very high importance in relation to the theory of the movements of the atmosphere. The law to which I refer is this:—The movements of the upper-currents prove that the axis of a progressive cyclonic circulation is commonly inclined, so that the extremity nearest to the earth's surface is considerably in advance of that in the higher regions of the atmosphere. A barometric minimum consequently occurs at any locality on the earth's surface some hours before the corresponding minimum in the higher regions passes over the same spot ("Laws of the Winds Prevailing in Western Europe," pp. 156 to 162, 1872; *Meteorological Magazine*, vol. x. pp. 92 to 93, 1875; *Quarterly Journal of the Meteorological Society*, October, 1877, pp. 440 to 445). I have also pointed out that the axis of an anticyclonic circulation has, at least in some instances, a similar inclination; a point which will be discussed more fully in a future paper.

I hope that the results, strongly confirmatory of this law, which Prof. Loomis has recently derived from his examination of the wind and barometer reports from Mount Washington, Mount Mitchell, and Pike's Peak, will attract more attention than my own deductions from upper-current observations have done. In his tenth paper of "Contributions to Meteorology" (*American Journal of Science and Arts*, January, 1879), Prof. Loomis shows that with very few exceptions the barometric minima occur at the base of a mountain considerably earlier than at the summit, the retardation amounting to about one hour for an elevation of from 900 to 1,300 feet, and that the maxima appear to follow the same law.

Other points of agreement between the results of cloud observations in Europe, and those obtained from the reports of the mountain observatories in America, seem to me to be of great interest. I would especially call attention to the substantial coincidence of these results as regards, first, the rarity of easterly upper-currents, as compared with easterly surface-winds; and secondly, the higher, and also less variable, value of the angle made by the northerly, than that made by the westerly upper-currents, with the direction of the centre of lowest pressure at the earth's surface. W. CLEMENT LEY

BARTOLOMEO GASTALDI

SINCE the last anniversary of the Geological Society many distinguished men among its members, both in this and foreign countries, have been removed by death. We regret to have to add to the sad list the name of Prof. Gastaldi, the well-known head of the Italian Geological Survey.

Bartolomeo Gastaldi was born at Turin, in the year 1818, and was originally destined by his father for a legal career; his fondness for geological studies, however, proved too strong to be repressed, and he was eventually entered as a student at the École des Mines at Paris. Here, and throughout his subsequent career, he enjoyed the friendship of Quintino Sella, who afterwards became so distinguished alike in Italian scientific and political circles.

Gastaldi had reached the age of twenty-eight before his first scientific memoir was published, and his earliest essays in this direction were devoted to anatomical and palæontological questions. Before long, however, he seems to have discovered that the true bent of his genius was towards physical geology. In his studies in this department of science he was greatly aided by his powers as a pedestrian, and he soon made himself familiar with all the southern spurs of the Alpine chain. In company with his friend Sella he founded the Italian Alpine Club, of which he was the second president.

He succeeded Sella as Professor of Geology at the Engineering School of Turin, and subsequently became Professor also at the University. During the later years of his life the work of the Geological Survey, of which he was made director by the Italian Government, occupied much of his attention, and to his energy and capacity much of the success which has already attended that important work is due.

No less than thirty papers on various branches of geological science have proceeded from Gastaldi's pen. He was an advocate, during his later years, of extreme views upon glacial subjects, and many of the views which he propounded on this and on other questions of Alpine geology have not been generally accepted by the geologists of other countries. In some of his speculations, indeed, his boldness seems to have outrun his caution. Those who had the happiness of a personal acquaintanceship with Gastaldi describe him as a most sanguine and earnest student and a warm-hearted friend.

Prof. Gastaldi was a Corresponding Member of the Geological Society of London, and received similar honours from the academies of many other foreign countries. In Turin, where he spent the greater part of his life, and where he occupied the position of a Common Councillor, he was very greatly respected and beloved; this fact is testified to by the circumstance that at his funeral more than three thousand people followed his remains to the cemetery.

ON THE DETERMINATION OF ABSOLUTE PITCH BY THE COMMON HARMONIUM[1]

THE methods described depend upon the principle that the absolute frequencies of vibration of two musical notes can be deduced from the *interval* between them, *i.e.*, the *ratio* of their frequencies, and the number of beats which they occasion in a given time when sounded together. For example, if x and y denote the frequencies of two notes whose interval is an equal temperament major third, we know that $y = 1{\cdot}25992\,x$. At the same time the number of beats heard in a second, depending upon the deviation of the third from true intonation, is $4y - 5x$. In the case of the harmonium these beats are readily counted with the aid of a resonator tuned to the common over-tone, and thus are obtained two equations from which the absolute values of x and y may be found by the simplest arithmetic.

Of course, in practice, the truth of an equal temperament third could not be taken for granted, but the difficulty thence arising would be easily met by including in the counting all the three major thirds which together make up an octave. Suppose, for example, that the frequencies of c, e, $g\sharp$, c' are respectively $x, y, z, 2x$, and that the beats per second between x and y are a, between y and z are b, and between z and $2x$ are c. Then,

$$4y - 5x = a,$$
$$4z - 5y = b,$$
$$8x - 5z = c,$$

from which

$$x = \tfrac{1}{3}(25a + 20b + 16c),$$
$$y = \tfrac{1}{3}(32a + 25b + 20c),$$
$$z = \tfrac{1}{3}(40a + 32b + 25c).$$

[1] Abstract of a paper read before the Musical Association, December 2, 1878, by Lord Rayleigh, F.R.S.

In the above statements the octave $c-c'$ is for simplicity supposed to be true. The actual error could be readily allowed for, if required; but in practice it is not necessary to use c' at all, inasmuch as the third set of beats can be counted equally well between $g\sharp$ and c.

Although at first sight the method just sketched looks satisfactory, it is not practical in the case of the harmonium, in consequence of the pitch of the various notes not being sufficiently constant for the purpose, even when the blowing is carefully conducted with the aid of a pressure-gauge. A small variation in the absolute pitch of a chord when sounded under slightly varying pressures, would not be of much importance, but the slightest change of *interval* is fatal to the success of the method, and such a change actually occurs.

In order, therefore, to apply the fundamental principle with success, it is necessary to be able to check the accuracy of the interval which is supposed to be known, at the same time that the beats are being counted. If the interval be a major tone (9 : 8), its exactness is proved by the absence of beats between the ninth component of the lower, and the eighth component of the higher note, and a counting of the beats between the tenth component of the lower and the ninth of the higher note completes the necessary data for determining the absolute pitch.

The equal temperament whole tone (1·12246) is intermediate between the minor tone (1·11111) and the major tone (1·12500), but lies much nearer to the latter. Regarded as a disturbed major tone, it gives slow beats, and regarded as a disturbed minor tone it gives comparatively quick ones. Both sets of beats can be heard at the same time, and when counted give the means of calculating the absolute pitch of both notes. If x and y be the frequencies of the two notes, a and b the frequencies of the slow and quick beats respectively,

$$\begin{aligned} 9x - 8y &= a \\ 9y - 10x &= b, \end{aligned}$$

whence

$$\begin{aligned} x &= 9a + 8b \\ y &= 10a + 9b. \end{aligned}$$

The application of this method in no way assumes the truth of the equal temperament whole tone, and in fact it is advantageous to flatten the interval somewhat by loading the upper reed with a minute fragment of soft wax, so as to make it lie more nearly midway between the major and the minor tone. In this way the rapidity of the quicker beats is diminished, which facilitates the counting.

It is impossible, of course, for the same observer to count both sets of beats, and the counting of even one set without the aid of resonators would present difficulties to most unpractised persons. Great assistance may be obtained by the choice of a suitable position. A room in which a pure tone is sounded is traversed by surfaces at which the intensity of sound is very much reduced in consequence of the superposition of vibrations reflected from the walls and ceiling. By choosing as the place of observation a position where the intensity of the beats which are not to be counted is a minimum, and with the aid of a resonator tuned to the pitch of the beats which are to be counted, the listener is able to work with ease and certainty.

The course of an experiment is then as follows:—The notes C and D are sounded, and the listeners begin counting the beats at a given signal, whose pitch is about d'' and e'' respectively. At the expiration of a measured interval of time a second signal is given, and the number of both sets of beats is recorded.

In my experiments the interval of time was ten minutes (in one case eleven minutes), and the rapidity of the beats was about four a second. The listeners counted up to ten only, after each set of ten making a stroke with a pencil on a piece of paper. The number of strokes was afterwards counted, multiplied by ten, and added to the number which the listener was saying at the instant of the second signal. The following are the details of the actual observations:—

September 16, 1878.—Period of observation ten minutes. Numbers of beats 2392 and 2341.

$$a = \frac{2392}{600},\ b = \frac{2341}{600},\ \text{giving } x = \frac{9\times 2392 + 8\times 2341}{600} = 67\cdot09,$$

for the frequency of the lower note C.

September 17.—Period of observation ten minutes.

$$a = \frac{2423}{600},\ b = \frac{2302}{600},\ \text{giving } x = 67\cdot04.$$

September 18.—Period of observation ten minutes.

$$a = \frac{2476}{600},\ b = \frac{2261}{600},\ \text{giving } x = 67\cdot29.$$

September 19.—Period of observation eleven minutes.

$$a = \frac{2663}{600},\ b = \frac{2547}{600},\ \text{giving } x = 67\cdot19.$$

The discrepancies are hardly greater than may be attributed to errors in giving the signals, by which the intervals may have been unduly lengthened or shortened by about a second. On each day after the counting of the beats between C and D, the harmonium was compared with a Kœnig fork whose nominal frequency was 64. In order to obviate any objection arising from a mutual influence of the notes of the harmonium, *both* C and D were sounded at the same time as the fork. The beats between C and the fork were counted for about ninety seconds, during which time the fork was not bowed. In this way the pitch of the fork came out on the four days respectively as 64·06, 64·07, 64·17, 63·98, that is somewhat sharper than its nominal pitch, a result in agreement with that obtained by other methods.

The object of the experiments referred to was rather to prove the practicability of a method so unusually independent of special apparatus, than to obtain a result competing in point of accuracy with those of Prof. Macleod and other experimenters on this subject. Nevertheless it is believed that very accurate results might be obtained by the introduction of certain modifications. Ten minutes is near the limit of time over which beats can be conveniently counted by a single listener, but experiment proved that it is perfectly possible for one listener to relieve another without any break in the regularity of the counting. Even without an extension of time a more accurate result would be obtained if the listeners were able to fix the time for themselves, as they might do for example if they could conveniently observe the swinging of a clock pendulum. In this way the error in the time interval might be reduced to $\frac{1}{4}$ second, which would amount to but one part in 2400 in the case of a ten minutes' observation. In consequence, however, of the imperfect constancy of the pitch of the harmonium notes, even when the blower is assisted by a pressure-gauge, further attempts at accuracy would be useless unless the comparison with the fork were simultaneous with the other observations. In that case the result would be entirely independent of variations in the harmonium notes, and no difficulty would be experienced in carrying out the method excepting the necessity for more observers.

THE FISSURES OF THE CEREBRAL HEMISPHERES IN UNGULATA

AN important memoir by Dr. Krueg on the cerebral hemispheres of Ungulata has recently appeared in the *Zeitsch. wiss. Zool.* After a review of the previous papers that have appeared on this subject—but few in number—Dr. Krueg describes his method of investigation.