I NOTICE the same phenomenon here, under the sycamore trees, when they are in blossom, which your correspondent Mr. Masheder observed recently under his lime trees, namely, the heads and thoracic segments of severed humble bees lying on the ground, with legs and wings attached, still retaining their vitality in some cases, but without any trace of the abdominal segments, for the sake of whose contents, no doubt, the bees were destroyed. We have no fly-catchers here. I suspect the tom-tits, which are abundant in the vicinity of this wholesale apicide, but I have no direct evidence of their guilt. R. V. D.

Beragh, Co. Tyrone, August 15

Migration of the Wagtail

Apropos of recent letters on this subject in NATURE, permit me to note that on my voyage out to the East Indies in the month of October, 1878, on board the Dutch mail steamer *Celebes*, two wagtails alighted on the ship when not very far north of the equator (the ship's course being then from Aden to Padang in Sumatra). On observing them I pointed them out to a Dutch friend, who at once recognised them as *Kwikstails*. They were rather lively, and did not appear to us to be fatigued; after staying with us for some days they took their departure, but in what direction I had not the satisfaction of observing.

Without affirming positively, I believe the species was the *Motacilla alba*. HENRY FORBES

Sumatra, June

ITALIAN DEEP-SEA EXPLORATION IN THE MEDITERRANEAN

AFTER some delay, beyond our control, the war-steamer of the Italian Royal Navy *Washington*, Capt. G. B. Magnanghi, R.N., left Maddalena on the 2nd inst. on her thallassographic mission. Under the able direction of Capt. Magnaghi, two days were devoted to preliminary dredgings and trawlings in depths from 200 to 1000 metres, principally for testing our apparatus, which works admirably. On the 4th inst. (yesterday afternoon) we did our first deep-sea dredging in 3000 metres; the dredge came up empty, but I had the pleasure of securing, attached to the hempen tangles, a magnificent specimen of that strange blind Crustacean discovered by the *Challenger* in the North Atlantic, and named *Willemœsia leptodactyla;* it is no doubt one of the most characteristic forms of the deep-sea fauna, and its discovery in the Mediterranean is of very great importance and interest, as all students of thalassography will be fully aware, after what Dr. Carpenter has written on the biological conditions of the deeper parts of that sea. Our specimen of *Willemœsia* is slightly smaller than the one dredged by the *Challenger*, and figured in Sir Wyville Thomson's "Atlantic," vol. i. p. 189; but otherwise it differs only in one or two minor details, which may be sexual differences; it was dredged off the west coast of Sardinia.

On account of a slight mishap with our engine we have anchored at Asinara for a couple of days, but shall at once resume our work. HENRY H. GIGLIOLI

Asinara, Sardinia, August 5

KÖNIG'S WAVE-SIREN

EVERY musician is painfully familiar with the fact that two notes nearly, but not quite exactly, in unison with one another, produce, when sounded together, a throbbing sound commonly described as the phenomenon of "*beats.*" In the elementary theory of acoustics the cause of beats is shown to be the mutual *interference* of the two vibrations, one sound interfering with the other and silencing it, when one set of waves is half a vibration behind the other. Just as at certain points on the earth's surface there are no tides when a high tide and a low tide coming from different seas meet, so there is no sound when two sets of sound-waves meet in opposite phases. If the two notes differ just a little in pitch they will alternately reinforce and interfere with one another, and produce the throbbing sound of beats, the number of beats (or maxima of sound) per second being the same as the difference in the number of vibrations per second. If one tone makes m vibrations per second and the other n (a slightly smaller number, being a slightly flatter tone) there will be $m - n$ beats per second heard. If this number be not more than 3 or 4 per second the beats can easily be counted. When they get as rapid as 12 or 14 per second they come too fast to be counted, and are very harsh and grating. They are most disagreeable at about 33 per second; and if yet more rapid, are heard as a harsh, disagreeable, rattling sound quite different from a true note. Imperfect octaves and imperfect twelfths likewise cause beats; in fact there are beats heard for any imperfectly tuned consonance in which the frequency of the higher note is 1, 2, 3, 4, 5, . . . or any integer number of times that of the lower.

But along with the disagreeable and throbbing phenomenon of beats there arises another phenomenon when two notes not in unison with one another are simultaneously sounded. This is a low booming tone, to which musicians give the name of the "grave harmonic." If two stopped organ-pipes are brought to unison, and then one of them is sharpened by gradually pushing in its stopper, the beats are heard first slow, then fast, then unendurably rapid. But when they reach about twenty or thirty per second the low booming note begins, and rises gradually in pitch as the beats become too rapid to be discriminated. When the higher note has reached a point about half-way between unison and the octave note, the beats are practically imperceptible, and from this point the phenomena recur again, but in *inverted order*, the grave harmonic falls in pitch down to a low booming tone, while the beats begin again to be distinguishable, grow harsher, then become slower, until when the interval of the octave is reached they also disappear.

A great controversy with respect to these low tones of the grave harmonics has arisen in recent years, and though it smoulders from month to month, occasionally blazes up into vigorous flame. The controverted question is, What are these grave harmonics, and to what are they due? Also, What becomes of the *beats* when they occur so rapidly that the ear cannot distinguish them? The answer given by Dr. Thomas Young, and by Smith in his "Harmonics" (1749), was that the rapid beats actually passed into the grave harmonic, just as in the generation of any pure tone the separate vibrations (which, when very slow, are heard as separate sounds) blend into one continuous tone whose pitch depends upon their frequency. This view is maintained at the present day with great energy also by the famous acoustician Dr. Rudolph König of Paris. On the other hand, Helmholtz has emphatically maintained that the grave harmonic is not, and cannot be, thus accounted for, and has given very cogent reasons for thinking that it has another explanation; and in this view he is supported by Preyer, Lord Rayleigh, Ellis, Bosanquet, and all the best English physicists. Mere alternations of sound and silence, however rapidly they occur, cannot produce the same effect on the mechanism of the ear as a pure to-and-fro motion of the same periodic frequency. A tuning-fork which vibrates 100 times per second will give out waves which, falling on the ear, push the drumskin in, and draw it back that number of times per second. But a continuous tone interrupted 100 times per second by short periods of silence produces quite a different mechanical action on the mechanism of the ear. The writer of this article once tried to ascertain, by the experiment of rotating a vibrating tuning-fork upon its axis, whether the alternations of sound and silence which are observed as it is rotated would blend into a continuous tone; but no kind of blending took place. Another most conclusive proof that the beats and the beat-tones are distinct phenomena is that at a certain speed both can be heard going on simultaneously. Helmholtz gives to the grave harmonic the name of "*difference-tone*," because its number of vibrations exactly corresponds to the difference between the number of vibrations of the primaries. Two notes whose frequencies are respectively m per second and n per second will give rise to a difference-tone whose frequence is $m-n$ per second, which is, in fact, just the same number as the number of beats between the two. König uses a different name, and agreeably to his (and Young's) theory, calls these notes "*beat-notes*," and classifies them into two sets, *lower* and *upper*, the lower beat-note being that corresponding to the beats between the lower note and the one that is sharper than it, the higher beat-note being that corresponding to the beats between the higher note and the octave of the lower. For example, if the notes c' and d'' are sounded together, their frequencies being in the ratio 8 : 9, there will be heard a beat-note whose frequency is relatively 1, or three octaves below the lower note. If c' and b' (a seventh) are sounded, their frequencies being in the ratio 8 : 15, there will be heard a beat-note of the upper series of relative frequency 1 (being the difference between 15 and 16), or also three octaves below the c'. So also the interval between c' and $\sharp f''$ (the twelfth-tone flattened by about a semitone, so as to make the ratio 8 : 23) will also give a beat-tone of relative frequency 1, being the difference between 23 and 24.

Now on Helmholtz's theory beats can only arise between vibrations so near together on the scale as to act on the same fibre of Corti in the ear (provided the vibrations be pure and free from upper partial tones), and they should therefore be audible not as *two tones* but as fluctuations in loudness of *one* tone. But when c' and d' are sounded we certainly hear *two separate* tones *plus* the low note which we call the grave harmonic. Helmholtz has therefore concluded that another explanation must be sought, and this he finds in a mathematical investigation of the resultant displacements due to super-

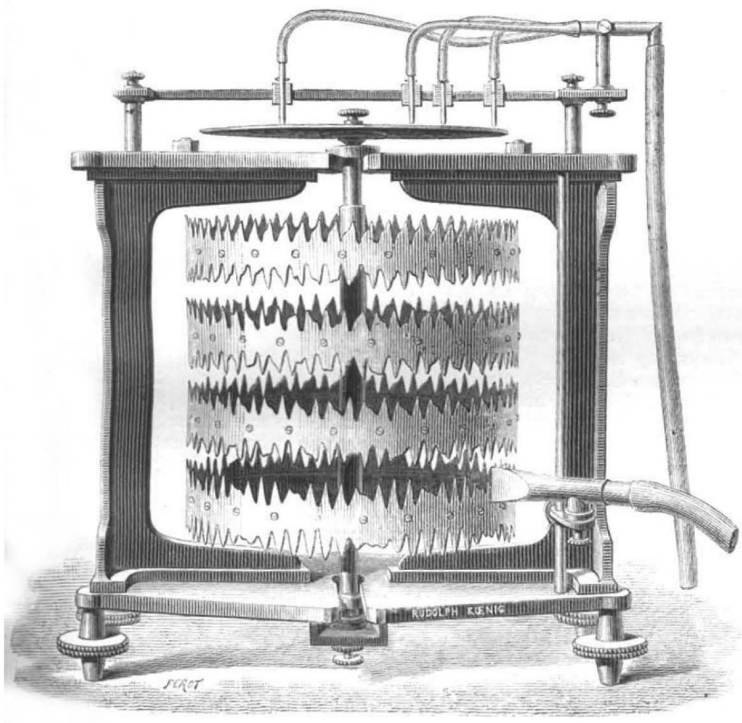

FIG. 1.

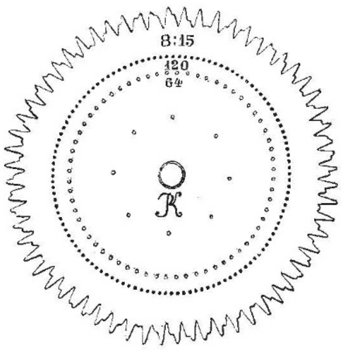

FIG. 2.

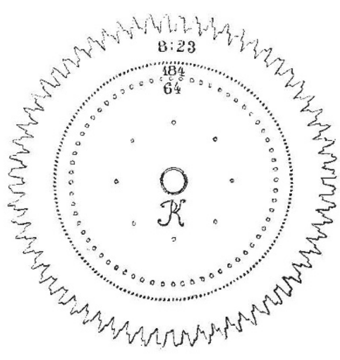

FIG. 3.

posing two tones, on the supposition that the vibrations of the primaries are so large that the moving forces are no longer simply proportional to the displacement, but are influenced by the squares or higher powers of them. He has shown that when this is the case combinational tones *must* arise whose frequencies correspond to the difference in the number of vibrations, and he further conjectures that to the dissymmetry of the drumskin and other vibrating parts of the ear is due the fact that the *squares* of the displacements can thus affect the resultant vibration. If so, all the combinational tones other than those of mistuned unisons must really arise in the ear itself and be *subjective* in character, as indeed Mr. Bosanquet, who has lately studied the matter most carefully, roundly declares.

Dr. König, however, undaunted by Helmholtz's reasonings, has returned to the contest with new weapons. He has repeated all his former experiments with new tuning-forks specially made of massive form, so as to be yet more perfect in tone, and finds his observations on beat-tones confirmed. He has further constructed a new instrument, the *wave-siren*, with which to establish his doctrine that *beats*, when too rapid to be heard separately, blend into a *beat-note*. In this instrument vibrations are set up in the air by blowing through a slit against the edges of a notched disk or rim which rotates rapidly upon an axis. In 1872 Dr. König constructed sirens on this principle, the indentations at the edges of the disks being simple harmonic curves, or "wave-forms," which therefore gave rise to simple tones. In the new wave-siren (Fig. 1) the indentations are determined in the following manner :—Two simple vibrations whose ratio is known are mechanically compounded together by machinery, and a resultant curve is obtained which *exactly* corresponds on a large scale to the resultant motion of the air when the two notes having this interval are sounded together. This compound curve is then set off very exactly round the periphery of a metal disk, and cut out in the metal with the utmost nicety. Fig. 2 shows the form of the curve (set out on the edge of a *flat* disk) for the interval of the seventh, the ratio being 8 : 15. When this disk is rotated rapidly, and wind is blown through a flat nozzle held with its opening radially at the edge, two notes are heard giving this exact interval. *If the vibration is slow, beats are heard : if the vibration be rapid, the beat-note is heard.* In order to compare these notes the more accurately with a true combinational tone, the same disk is pierced by three concentric rings of holes, one with 64, another with 120, giving the ratio 8 : 15, and another, with 8 holes only, corresponding to the number of beats between 120 and the octave of the 64 set (128), that is to say, to the upper beat-note of the interval 8 : 15. When air is blown through the rings of 64 and 120 holes in the rotating siren-disk, exactly the same notes and same beats or beat-notes are produced as by the wave-curve at the edge. Here there can surely be no partial tones present to complicate the phenomenon. For greater convenience in comparing several combinations, the wave-forms are cut upon cylindrical rims mounted upon one axis as in the first figure, a flat disk pierced with holes being added above for comparison. In every case slow rotation gives beats, and rapid rotation the beat-note exactly as König's theory requires.

It remains yet to be seen what answer Helmholtz and the mathematical acousticians will give to the challenge thrown down by König in this beautiful and ingenious piece of mechanism. Meantime we may mention that Mr. Bosanquet of Oxford has just been examining the very same question, though by different means. He finds that all König's higher beat-tones can be accounted for by the assumption that the terms of higher orders become important in the mechanism of the ear when the displacements are considerable, and that therefore "by transformation" in this sense the variations of maximum displacement in the resultant wave give rise to to-and-fro vibrations of simple form having the same frequency as these variations, and therefore evoke *in the ear* a note whose frequency is the same as the number of beats. He is also positive that such tones exist only in the ear, and are inaudible in resonators. Lastly, he has satisfied himself that in all the cases of beats between mistuned consonances in which the higher note is (nearly) 2, 3, 4, . . . &c., times as rapid as the lower, *the beat consists of variations of intensity of the* lower *of the two primary tones.*

S. P. T.

HYDRODYNAMIC ANALOGIES TO ELECTRICITY AND MAGNETISM

FROM a scientific and purely theoretical point of view there is no object in the whole of the Electrical Exhibition at Paris of greater interest than the remarkable collection of apparatus exhibited by Dr. C. A. Bjerknes of Christiania, and intended to show the fundamental phenomena of electricity and magnetism by the analogous ones of hydrodynamics. I will try to give a clear account of these experiments and the apparatus employed; but no description can convey any idea of the wonderful beauty of the actual experiments, whilst the mechanism itself is also of most exquisite construction. Every result which is thus shown by experiment had been previously predicted by Prof. Bjerknes as the result of his mathematical investigations.

It has long been known that if a tuning-fork be struck and held near to a light object like a balloon it attracts it. This is an old experiment, and the theory of it has been worked out more than once. Among others Sir William Thomson gave the theory in the *Philosophical Magazine* in 1867. In general words the explanation is that the air in the neighbourhood of the tuning-fork is rarefied by the agitation which it experiences. Consequently the pressure of the air is greater as the distance from the tuning-fork increases. Thus the pressure on the far side of the balloon is greater than that on the near side, and the balloon is attracted.

Dr. Bjerknes has followed out the theory of this action until he has succeeded in illustrating most of the fundamental phenomena of electricity and magnetism. He causes vibrations to take place in a trough of water about six inches deep. He uses a pair of cylinders fitted with pistons which are moved in and out by a gearing which regulates the length of stroke and also gives great rapidity. These cylinders simply act alternately as air-compressers and expanders, and they can be arranged so that both compress and both expand the air simultaneously, or in such a way that the one expands while the other compresses the air, and *vice versâ.* These cylinders are connected by thin india-rubber tubing and fine metal pipes to the various instruments. A very simple experiment consists in communicating pulsations to a pair of tambours, and observing their mutual actions. They consist each of a ring of metal faced at both sides with india-rubber and connected by a tube with the air-cylinders. One of them is held in the hand; the other is mounted in the water in a manner which leaves it free to move. It is then found that if the pulsations are of the same kind, *i.e.* if both expand and both contract simultaneously, there is attraction. But if one expands while the other contracts, and *vice versâ,* there is repulsion. In fact the phenomenon is the opposite of magnetical and electrical phenomena, for here like poles attract, and unlike poles repel.

Instead of having the pulsation of a drum we may use the oscillation of a sphere; and Dr. Bjerknes has mounted a beautiful piece of apparatus by which the compressions and expansions of air are used to cause a sphere to oscillate in the water. But in this case it must be noticed that opposite sides of the sphere are in opposite phases. In fact the sphere might be expected to act like a magnet; and so it does. If two oscillating spheres be brought near each other, then, if they are both moving to and from each other at the same time, there is attraction; but if one of them be turned round, so that both spheres move in the same direction in their oscillations, then there is repulsion. If one of these spheres be mounted so as to be free to move about a vertical axis, it is found that when a second oscillating sphere is brought near to it, the one which is free turns round its axis and sets itself so that both spheres in their oscillations are approaching each other or receding simultaneously. Two oscillating spheres, mounted at the extremities of an arm, with freedom to move, behave with respect to another oscillating sphere exactly like a magnet in the neighbourhood of another magnetic pole. I believe that these directive effects are perfectly new, both theoretically and experimentally. The professor mounts his rod with a sphere at each end in two ways: (1) so that the oscillations are along the arm, and (2) so that they are perpendicular. In all cases they behave as if each sphere was a little magnet with its axis lying along the direction of oscillation.

Dr. Bjerknes looks upon the water in his trough as being the analogue of Faraday's medium; and he looks upon these attractions and repulsions as being due, not to the action of one body on the other, but to the mutual action of one body and the water in contact with it. Viewed in this light, his first experiment is equivalent to saying that if a vibrating or oscillating body have its motions in the same direction as the water, the body moves away from the centre of disturbance, but if in the opposite direction, towards it. This idea gives us the analogy of dia- and para-magnetism. If, in the neighbourhood of a vibrating drum, we have a cork ball, retained under the water by a thread, the oscillations of the cork are greater than those of the water in contact with it, owing to its small mass, and are consequently *relatively* in the same direction. Accordingly we have repulsion,