

simple costume of the goddesses, passes before the car of Apollo, the god of the sun, while Science observes the phenomenon on the earth and records the results. The legend is the composition of a member of the Academy of Inscriptions. On the obverse of the medal is the following inscription:—

INSTITUT DE FRANCE
ACADÉMIE DES SCIENCES
PASSAGE DE VÉNUS SUR LE SOLEIL
8-9 DECEMBER, 1874.

THE EFFECT OF INAUDIBLE VIBRATIONS UPON SENSITIVE FLAMES

DURING a recent visit to Birmingham my friend and host, Mr. Lawson Tait, showed me some interesting experiments with one of Mr. Galton's whistles, capable of yielding vibrations beyond the limit of hearing. This led to the suggestion of trying a sensitive flame with these whistles, and in fulfilment of my promise to select and send to Mr. Tait a burner sensitive to very high notes, I was yesterday led to make the following experiment, the result of which is, I believe, new, and I think sufficiently interesting to put on record. A sensitive flame was obtained just two feet high when undisturbed, but shrinking down to seven inches under the influence of the feeblest hiss or the clink of two coins. Adjusting the Galton whistle, which Mr. Tait lent me, so as to yield its lowest note, little effect was produced on the flame; a shrill dog-whistle produced a slight forking of the flame, but that was all. Raising the pitch of the Galton whistle, the flame became more and more agitated, until, when I had nearly reached the upper limit of audibility of my left ear, and had gone quite beyond the limit of my right ear, the flame was still more violently affected. Raising the pitch still higher, until I quite ceased to hear any sound, and until several friends could likewise detect no sound, even when close to the whistle, I was astonished to observe the profound effect produced upon the flame. At every inaudible puff of the whistle the flame fell fully sixteen inches, and burst forth into its characteristic roar, at the same time losing its luminosity, and when viewed in a moving mirror, presenting a multitude of ragged images, with torn sides and flickering tongues—indicating a state of rapid, complex, and vigorous vibration.

Nor was this effect sensibly diminished by a distance of some twenty feet from the flame. Placing the flame at one end of the large lecture theatre of this college, and blowing the whistle at the furthest point away, a distance at least of fifty feet and more than thirty feet above the flame, still the effect produced was very pronounced. There can hardly be a more striking experiment. A single silent and gentle puff of air sent from the lips through the whistle, nothing whatever to be heard, and yet fifty feet away an effect produced that might readily be seen by thousands of people.

The extreme smallness of the amount of motion actually concerned in producing this great change in the aspect of the flame is evident. For the inaudible vibrations, having at their origin but a small amplitude, gave rise to a spherical air-wave,¹ which at a radius of fifty feet—and with the vast enfeeblement due to this distance—knocked down a two-foot flame, though the surface acted upon had an area of less than a square inch—for it is only the root of the flame that picks up the wave motion. Of course everything depends upon the delicately-poised state into which the flame has previously to be brought. It then, like a resonant jar, enters into a state of vibration which appears to be synchronous with the note producing the effect. By this means it may be possible, with the aid of a mirror moving at a known speed, to determine the

¹ I have no doubt a similar result would attend an experiment made in the open air, if the air were still enough to allow it to be made.

vibration number of these high notes, and thus with greater exactitude fix the upper limit of hearing.

The flame giving the effect here described was produced by coal gas contained in a holder under a pressure of ten inches of water, and issuing from a steatite jet having a circular orifice 0.04 inch in diameter.¹

W. F. BARRETT

SOUND-VIBRATIONS OF SOAP-FILM MEMBRANES

THE vibration-forms of membranes agitated by their fundamental and upper tones, have usually been studied by means of thin bladder or india-rubber stretched on a ring or frame (see Helmholtz "Sensations of Tone," chaps. iii. and v.; Pisko, "Die Neueren Apparate der Akustik," p. 75). While I was lately trying with Mr. R. Knight the capabilities of various membranes of taking impressions from vocal sounds for phonautographic purposes, the idea occurred of using soap-film. This was at once carried into effect by dipping the end of a lamp-chimney into some soap-solution, strengthened in the usual way with glycerine and a little gelatine. On singing near the open end of the chimney, the series of forms belonging to the various notes became plainly visible, those produced by the upper tones being as it were engine-turned in their complex symmetry, in a way to which the sand-lines on so coarse a material as caoutchouc can bear no comparison. To exhibit these forms at a popular lecture here last night, the light of an oxyhydrogen magic lantern was simply reflected off the vibrating film upon the screen in a disc of some three feet in diameter, so as to show its patterns on a large scale when set in movement by talking, singing, and playing a cornet in its neighbourhood. The effects were of singular clearness and beauty. To lecturers who may use this new and easy means of making the more complex sound-vibrations appreciable by the eye, I would mention that by slightly thinning the soap-solution, and adding a few drops of ammonia, they may obtain a film more free from interference-colours, so as to display the vibration-figures on an almost clear ground. But if this is done, the thicker mixture should be used afterwards, for the gorgeous scenic effect of the masses of prismatic colour whirled hither and thither by the musical vibrations.

EDWARD B. TYLOR

Wellington, Somerset, April 20

THE OTHEOSCOPE²

I COMMUNICATED to the Royal Society in November last, an account of some radiometers which I had made with the object of putting to experimental proof the "molecular pressure" theory of the repulsion resulting from radiation. Continuing these researches I have constructed other instruments, in which a movable fly is caused to rotate by the molecular pressure generated on fixed parts of the apparatus.

In the radiometer, the surface which produces the molecular disturbance is mounted on a fly, and is driven backwards by the excess of pressure between it and the sides of the containing vessel. Regarding the radiometer as a heat-engine, it is seen to be imperfect in many respects. The black or driving surface, corresponding to the heater of the engine, being also part of the moving fly, is restricted as to weight, material, and area of surface. It must be of the lightest possible construction, or

¹ The conditions necessary for obtaining the utmost sensitiveness of the flame are described in an article I published on the subject in the *Popular Science Review* for April, 1867.

² On Repulsion Resulting from Radiation. Preliminary note on the Otheoscope, by William Crookes, F.R.S., &c. Read before the Royal Society, April 26, 1877.

friction will greatly interfere with its movement; it must not expose much surface, or it will be too heavy; and it must be a very bad conductor of heat, so as to retain the excess of pressure on one side. Again, the part corresponding to the cooler of the engine (the side of the glass bulb) admits of but little modification. It must almost necessarily be of glass, by no means the best material for the purpose; it is obliged to be of one particular shape; and it cannot be brought very near the driving surface.

A perfect instrument would be one in which the heater was stationary; it might then be of the most suitable material, of sufficient area of surface, and of the most efficient shape, irrespective of weight. The cooler should be the part which moves; it should be as close as possible to the heater, and of the best size, shape, and weight, for utilising the force impinging on it. By having the driving surface of large size and making it of a good conductor of heat, such as silver, gold, or copper, a very faint amount of incident radiation suffices to produce motion. The black surface acts as if a molecular¹ wind were blowing from it, principally in a direction normal to the surface. This wind blows away whatever easily movable body happens to be in front of it, irrespective of colour, shape, or material; and in its capability of deflection from one surface to another, its arrest by solid bodies, and its tangential action, it behaves in most respects like an actual wind.

Whilst the radiometer admits of but few modifications, such an instrument as the one here sketched out is capable of an almost endless variety of forms; and as it is essentially different in its construction and mode of action to the radiometer, I propose to identify it by a distinctive name, and call it the Otheoscope ($\omega\theta\epsilon\omega$, I propel).

The glass bulb is an essential portion of the machinery of the radiometer, without which the fly would not move; but in the otheoscope the glass vessel simply acts as a preserver of the requisite amount of rarefaction. Carry a radiometer to a point in space where the atmospheric pressure is equal to, say, one millimetre of mercury, and remove the glass bulb; the fly will not move, however strong the incident radiation. But place the otheoscope in the same conditions, and it will move as well without the case as with it. In the preliminary note already referred to,² I described a piece of apparatus by which I was able to measure the thickness of the layer of molecular pressure generated when radiation impinged on a blackened surface at any degree of exhaustion. At the ordinary density of the atmosphere the existence of this molecular disturbance was detected several millimetres off, and its intensity increased largely as the generating surface and movable plate were brought closer together. It would be possible, therefore, to construct an otheoscope in which no rarefaction or containing vessel was necessary, but in which motion would take place in air at the normal density.³ Such a heat-engine would probably work very well in sunlight.

Aided by the mechanical dexterity of my assistant, Mr. C. H. Gimmingham, I have constructed several varieties of otheoscope. These I propose to exhibit at the *soirée* of the Royal Society on Wednesday next, as illustrations of the very beautiful manner in which, at this stage of my investigations, theory and experiment proceed hand in hand, alternately assisting each other, and enlarging our knowledge of those laws of molecular movement which constitute a key to the relations of force and matter.

The following is a list of the otheoscopes I have

¹ *Molecular*, not *molar*. There is no wind in the sense of an actual transference of air from one place to another. This molecular movement may be compared to the movement of the gases when water is decomposed by an electric current. In the water connecting the two poles there is no apparent movement, although eight times as much matter is passing one way as the other.

² *Proc. Royal Soc.*, November 16, 1876, p. 370.

³ Since writing this I have constructed such an instrument. The movement takes place in the way I had anticipated.—*W. C.*, April 26, 1877.

already made, together with some new experimental radiometers, which will be exhibited for the first time on Wednesday:—

1. *Otheoscope*.—A four-armed fly carrying four vanes of thin clear mica is mounted like a radiometer in an exhausted glass bulb. At one side of the bulb a plate of mica blacked on one side is fastened in a vertical plane in such a position that each clear vane in rotating shall pass the plate leaving a space between of about a millimetre. If a candle is brought near, and by means of a shade the light is allowed to fall only on the clear vanes, no motion is produced; but if the light shines on the black plate the fly instantly rotates as if a wind were issuing from this surface, and keeps on moving as long as the light is near.

2. *Otheoscope*.—A four-armed fly carries roasted mica vanes and is mounted in an exhausted glass bulb like a radiometer. Fixed to the side of the bulb are three plates of clear mica equidistant from each other in a vertical plane, but oblique to the axis. A candle brought near the fixed plates generates molecular pressure, which, falling obliquely on the fly, causes it to rotate.

3. *Otheoscope*.—A large horizontal disc, revolving by the molecular disturbance on the surface of inclined metallic vanes, which are blacked on both sides in order to absorb the maximum amount of radiation.

4. *Otheoscope*.—Inclined aluminium vanes driven by the molecular disturbance from the fixed black mica disc below, blowing (so to speak) through them.

5. *Otheoscope*.—A large horizontal coloured disc of roasted mica, driven by inclined aluminium vanes placed underneath it.

6. *Otheoscope*.—A bright aluminium disc cut in segments, and each segment turned at an angle, driven by a similar one below of lampblack silver.

7. *Radiometer*.—A vertical radiometer, made with eight discs of mica blacked on one side, and the whole suspended on a horizontal axis which works in two glass cups. The motion of the radiometer is assisted on each side by driving vanes of aluminium blacked on one side.

8. *Radiometer*.—A vertical turbine radiometer, the oval vanes of roasted mica blacked on one side.

9. *Radiometer*.—A spiral radiometer of roasted mica blacked on the upper side.

10. *Radiometer* of large size, showing great sensitiveness.

11. *Radiometer*.—A two-disc radiometer, the fly carrying roasted mica discs blacked on one side; in front of each blacked surface is fixed a large disc of thin clear mica. The molecular disturbance set up on the black surface, and streaming from it, is reflected in the opposite direction by the clear plate of mica, causing the fly to move abnormally, *i.e.*, the black surface towards the light.

12. *Radiometer*.—A two-disc radiometer, the fly carrying roasted mica discs blacked on one side, similar to No. 11, but with a large clear disc on each side. The molecular disturbance, prevented from being reflected backwards by the second clear disc, is thus caused to expend itself in a vertical plane, the result being a total loss of sensitiveness.

13. *Radiometer*.—A two-disc, cup-shaped, aluminium radiometer, facing opposite ways; both sides bright. Exposed to a standard candle 3.5 inches off, the fly rotates continuously at the rate of one revolution in 3.37 seconds. A screen placed in front of the concave side so as to let the light shine only on the convex surface repels the latter, causing continuous rotation at the rate of one revolution in 75 seconds. When the convex side is screened off, so as to let the light shine only on the concave, continuous rotation is produced at the rate of one revolution in 6.95 seconds, the concave side being apparently attracted. These experiments show that the repulsive action of radiation on the convex side is about equal to the attractive

action of radiation on the concave side, and that the double speed with which the fly moves when no screen is interposed is the sum of the attractive and repulsive actions.

14. *Radiometer*.—A two-disc, cup-shaped, aluminium radiometer, lamp-black on the concave surfaces. In this instrument the usual action of light is reversed, rotation taking place, the bright convex side being repelled, and the black concave attracted. When the light shines only on the bright convex side, no movement is produced, but when it shines on the black concave side, this is attracted, producing rotation.

15.—*Radiometer*.—A cup-shaped radiometer similar to the above, but having the convex surfaces black and the concave bright. Light shining on this instrument causes it to rotate rapidly, the convex black being repelled. No movement is produced on letting the light shine on the bright concave surface, but good rotation is produced when only the black convex surface is illuminated.

16. *Radiometer*.—A multiple-disc, cup-shaped, turbine radiometer, bright on both sides, working by the action of warm water below and the cooling effect of the air above.

17. *Radiometer*.—A four-armed metallic radiometer with deep cups, bright on both sides.

18. *Radiometer*.—A four-armed radiometer, the vanes consisting of mica cups, bright on both sides.

19. *Radiometer*.—A four-armed radiometer having clear mica vanes. The direction of motion being determined by the angle formed by the mica vanes with the inner surface of the glass bulb.

DROUGHTS AND FAMINES IN SOUTHERN INDIA¹

THE paper on this subject, noted below, a copy of which we have just received, will no doubt awaken much interest, not only on account of its scientific bearings but also from its bearings on so very practical a subject as the famines of India. It is most gratifying to see that the subject has been taken up by one who gives evidence on every page of rare capacity as a scientific statistician. There is throughout an absence of straining the facts before him beyond what they may legitimately bear, and a skill in combining them so as to eliminate, as far as possible, what is merely accidental from the results ultimately arrived at in their relation to the sun-spot period.

The data discussed in Dr. Hunter's paper are the amounts of the annual rainfall at Madras from 1813 to 1876, and the relative number of sun-spots from 1810 to 1876. The results of the inquiry are given in the following six propositions :—

1. That no uniform numerical relation can be detected between the relative number of the sun-spots and the actual amount of rainfall.

2. That although no uniform numerical relation can be detected between the relative number of sun-spots and the actual amount of rainfall, yet that the minimum period in the cycle of sun-spots is a period of regularly recurring and strongly marked drought in Southern India.

3. That, apart from any solar theory, an examination of the rain registers shows that a period of deficient rainfall recurs in cycles of eleven years at Madras; that this period consists of the eleventh and second series of years in the cycle; which two series also contain six out of the seven years of minimum sun-spots falling in this century up to 1878.

4. That after the period of minimum rainfall in the eleventh and second series of years in the cycle, the rainfall rises to a maximum in the fifth year; after which it again declines to its minimum period in the eleventh and second years.

5. That, apart from any solar theory, the statistical evidence shows that the cycle of rainfall at Madras has a marked coincidence with a corresponding cycle of sun-spots; that in this cycle of eleven years both the sun-spots and the rainfall reach their minimum in the group consisting of the eleventh, first, and second years; that both the rainfall and the sun-spots then increase till they both reach their maximum in the fifth year, after which they

decline together till both again enter their minimum period in the eleventh, first, and second series of years.

6. That while the statistical evidence discloses a cycle of drought in Southern India, coincident in a marked manner with a corresponding cycle of sun-spots, it also tends to show that the average rainfall of the years of minimum rainfall in the said cycle approaches perilously near to the point of deficiency which causes famine. That the average is, however, above that point; and that, while we have reason to apprehend recurring droughts and frequent famines in these cyclic years of minimum rainfall, the evidence is insufficient to warrant the prediction of a regularly recurring famine.

It will be observed that these results are strongly confirmatory of the general conclusions arrived at by Meldrum and others, who have examined the question from data collected from a large area, and embracing an extended series of years, the only noteworthy point of difference being the larger rainfall of the first year of the cycle, as compared with the eleventh and second years which immediately precede and follow it. It is perhaps only to be looked for that such an anomaly should be met with in dealing with the rainfall of only one place, embracing a period of sixty-four years, seeing that the accidental occurrence of one or two cyclones, accompanied with unusually heavy local rainfall, would be sufficient to produce the anomaly in question. The anomaly would in all likelihood have disappeared if the area of observation had been wider or the time of observation longer. It is scarcely necessary to do more than point out the absolute necessity of establishing physical observatories in order to obtain the data for the investigation of the connection between the state of the sun's surface and the state of terrestrial convection currents, it being only through their cosmical relations that we may reasonably hope to solve many of the more difficult problems of meteorology, some of which lead to intensely practical issues.

OUR ASTRONOMICAL COLUMN

MR. GILL'S EXPEDITION TO ASCENSION.—In an address to the Royal Astronomical Society on April 8, 1857, "On the means which will be available for correcting the measure of the sun's distance during the next twenty-five years," the Astronomer-Royal directed attention to a method of making observations for parallax, not applicable to the planet Venus, but applicable to Mars, namely, by "observing the displacement of Mars in right ascension when he is far east of the meridian, and far west of the meridian, as seen at a single observatory," and he particularised the advantage of this method, and expressed his opinion that it is "the best of all." The observations are not attended with the very great expense which is involved in the efficient observation of a transit of Venus, indeed if made at an established observatory need entail little or no cost; they may be conducted by a single observer or series of observers, in the latter case with a due regard to personal equation, and each observatory co-operating in the work, will furnish a result quite independent of the rest, so that the observer has the satisfaction of knowing that by the method recommended his own observations alone will give a value for the most important unit of measure in astronomy. The Astronomer-Royal confined his remarks to the observation of differences of right ascension, recommending as of the first consequence a firmly-mounted equatorial, and as advantageous though not absolutely necessary the chronographic method of transits first introduced by the American astronomers. The oppositions of Mars in 1860 and 1862 were referred to with regard to their relative advantages for such observations.

Mr. Gill has taken a further and an important step in the direction of utilising observations of Mars for the determination of the solar parallax. Encouraged by Lord Lindsay's liberal offer of the loan of the heliometer employed in the expedition to the Mauritius for the observation of the transit of Venus, Mr. Gill proposes to leave England this month for the island of Ascension, and to apply the heliometric method of measurement of distances instead of observing differences of right ascension, as suggested in the Astronomer-Royal's address, and as was stated

¹ "The Cycle of Drought and Famine in Southern India," by W. W. Hunter, LL.D., Director-General of Statistics to the Government of India.