THE Russian Scientific Expedition to the Amu Daria was to set out on Monday last. The expedition will be commanded by the Grand Duke Nicholas Constantinovitch, assisted by Colonel Stoletoff and Dr. Moreff, secretary. It will include 25 persons, whose work will be divided into four sections:—(1) The Trigonometrical and Topographical. (2) The Meteorological Section, which will construct two stations on the Amu Daria, at one of which hourly observations will be made of all the meteorological phenomena. (3) The Ethnographical Statistical Section. (4) The Natural History Section.

THE meeting of French Astronomers took place last week at the Ministry of Public Instruction, under the presidency of M. Leverrier. It was composed of M. Dumeril, director of the *Enseignement*, the astronomers from Paris, Toulouse, and Marseilles Observatories, and Officers from the General Staff of the Trigonometrical Survey. Four sittings were held, and an account of them will be issued shortly. Steps have been taken for the determination of the latitude of Algiers, by telegraph. M. du Barail, Minister of War, and M. Saget, his Staff-Officer, visited the Observatory last Saturday, in order to see for themselves how the work may be begun without further delay.

THE additions to the Zoological Society's Gardens during the last week include four Bladder-nosed Seals (*Cystophora cristata*) from Greenland, presented by Capt. Alex. Gray; a White-winged Whydah Bird (*Urobrachya albonotus*) from West Africa, presented by Mr. J. Fairchild; a Rose-crested Cockatoo (*Cacatua moluccensis*) from the Moluccas, presented by Mr. H. Baldwin; an Azara's Fox (*Canis azaræ*) from South America; a Snowy Owl (*Nyctea nivea*) from South America; a Green-cheeked Amazon (*Chrysotis viridigenalis*) from Columbia, purchased.

ON THE REFRACTION OF SOUND*

THE principal object of this paper is to show that sound, instead of proceeding along the ground, is lifted or refracted upwards by the atmosphere in direct proportion to the upward diminution of the temperature; and hence to explain several phenomena of sound, and particularly the results of Prof. Tyndall's recent observations off the South Foreland.

The paper commences with the explanation of the effect of wind upon sound, viz., that this effect is due to the lifting of the sound from the ground, and not to its destruction, as is generally supposed. The lifting of the sound is shown to be due to the different velocities with which the air moves at the ground and at an elevation above it. Owing to friction and obstructions the air moves slower below than above, therefore sound moving against the wind moves faster below than above, and the bottom of the sound waves will thus get in advance of the upper part, and the effect of this will be to refract or turn the sound upwards; so that the rays of sound which would otherwise move horizontally along the ground actually move upwards in circular or more hyperbolic paths, and may thus, if there is sufficient distance, pass over the observer's head. This explanation was propounded by Prof. Stokes in 1857, but it was discovered independently by the author.

The paper then contains descriptions of experiments made with a view to establish this explanation.

These experiments were made with an electric ball, over a nearly flat meadow, and again over the same when it was nearly covered with snow, and it was found (as indeed it was expected) that the condition of the surface very materially modified the results in two ways. In the first place, a smooth surface like snow obstructs the wind less than grass, hence over snow the wind has less effect in lifting the sound moving against it than over grass; and it is inferred that a still greater difference would be found to exist in the case of smooth water. In the second place, the ends of the waves of sound travelling along in contact with the rough ground are continually destroyed by the roughness, and the sound from above slowly diverges down to replace that which is destroyed, and this divergence gradually weakens the intensity of the lower parts of the waves, so that, under ordinary circumstances, the sounds which pass above us are more intense than those we hear. The general conclusions drawn from these experiments are:—

1. The velocity of wind over grass differs by $\frac{1}{2}$ at elevations of 1 and 8 feet, and by somewhat less over snow.

2. That when there is no wind, sound proceeding over a rough surface is destroyed at that surface, and is thus less intense below than above; owing to this cause the same sound would be heard at more than double the distance over snow at which it could be heard over grass.

3. That sounds proceeding *with* the wind are brought down to the ground in such a manner as to counterbalance the effect of the rough surface (2), and hence, contrary to the experiments of Delaroche, the range of sound over rough ground is greater with the wind than at right angles to its direction or than when there is no wind. When the wind is very strong it would bring the sound down too fast in its own direction, and then the sound would be heard farthest in some direction inclined to that of the wind though not at right angles.

4. That sounds proceeding against the wind are lifted off the ground, and hence the range is diminished at low elevations. But that the sound is not destroyed and may be heard from positions sufficiently high (or if the source of sound be raised) with even greater distinctness than at the same distances with the wind.

5. In all cases where the sound was lifted there was evidence of diverging rays. Thus although on one occasion the full intensity was lost when standing up at 40 yards the sound could be faintly and discontinuously heard up to 70 yards. And on raising the head the sound did not at once strike the ear with its full intensity nor yet increase quite gradually; but by a series of steps and fluctuations in which the different notes of sound were variously represented, showing that the diverging sound proceeds in rays separated by rays of interference.

On one occasion it was found that with the wind sound could be heard at 360 yards from the bell at all elevations, whereas at right angles it could be only heard for 200 yards standing up, and not so far at the ground; and against the wind it was lost at 30 yards at the ground, at 70 yards standing up, and 160 yards at an elevation of 30 feet, although it could be distinctly heard at this latter point from a few feet higher.

It hence appears that these results agree so well with what might be expected from the theory as to place its truth and completeness beyond question.

The author then goes on to argue from the action of wind upon sound to another phenomenon which admits of a somewhat similar explanation. The effect of wind together with that of a rough surface in lifting the sound may be shown to account for many of the apparently capricious variations in the intensity with which sounds can be heard at different times; and it gives a reason for the custom which prevails of elevating church bells, platforms, &c., where the sounds are intended to be heard at a distance. But it does not explain a fact, which has often been observed, namely, that distant sounds can be heard much better during the night than during the day, and on dull cloudy days better than on bright hot days. This phenomena has engaged the attention of Humboldt, Delaroche, and recently of Prof. Tyndall, who have all assumed that the sound is obstructed or destroyed in the bright hot air, and have suggested causes which they thought might produce this effect. These suggestions are all more or less open to objection, and none of them meet the difficulty that any heterogeneous condition of the air which could obstruct sound must more or less refract or reflect light and so render vision indistinct. In this paper the author gives another explanation, in which he shows how, as in the case of wind, the sound may be lifted and not destroyed.

It is argued that since wind raised the sound simply by causing it to move faster below than above, any other cause which produces such a difference in velocity will lift the sound in the same way. And since the velocity of sound through air increases with the temperature—every degree from 32 to 70 adding 1 foot per second to the velocity—therefore an upward diminution in the temperature of the air must produce a similar effect to that of wind and lift the sound. Whereas Mr. Glaisher has shown by his balloon observations that such a diminution of temperature exists, and further he has shown that when the sun is shining with a clear sky the variation from the surface is 1° for every

* On the Refraction of Sound by the Atmosphere. By Prof. Osborne Reynolds, Owens College, Manchester. Abstract of paper read before the Royal Society April 23.—Communicated by the Author.

100 ft., and that with a cloudy sky it is only half what it is with a clear sky. These results were from the mean of his observations; under exceptional circumstances the variations were both greater and less. It is hence shown that rays of sound otherwise horizontal would be bent upwards in the form of circles, the radii of which with a clear sky are 110,000 ft., and with a cloudy sky 220,000 ft., so that the refraction is double as great on bright hot days as it is when the sky is cloudy, and still more under exceptional circumstances, and comparing day with night.

It is then shown by calculation that the greatest refraction—110,000 ft. radius—is sufficient to render sound from a cliff 235 ft. high inaudible on a ship's deck 20 ft. high at $1\frac{3}{4}$ miles, except such sound as might reach the observer by divergence from the waves above, whereas when the refraction is least—220,000 ft. radius—or where the sky is cloudy, the range would be extended at $2\frac{1}{2}$ miles with a similar extension for the diverging waves. It is hence inferred that the phenomenon which Prof. Tyndall observed on July 3, and other days—namely that when the air was still and the sun was hot he could not hear guns and sounds from the cliffs of South Foreland, 235 ft. high, for more than two miles, whereas when the sky clouded, the range immediately extended to three miles, and as evening approached much farther,—was due, not so much to stoppage or to reflection of the sound by invisible vapour as Prof. Tyndall has supposed, but to the sounds being lifted over his head in the manner described; and that had he been able to ascend 30 ft. up the mast, he might at any time have extended the range of the sound by a quarter of a mile at least. Or had the instruments on the top of the cliff been compared with similar instruments at the bottom, a very marked difference would have been found in the distances at which they could be heard.

It seems that there were instruments at the bottom, and it is singular that throughout his report Prof. Tyndall makes no comment on their performance, unless they were at once found to be so inferior to those at the top that no further notice was taken of them; this seems possible, since beyond mentioning that they were there, Prof. Tyndall throughout his report never refers to them.

It also seems that besides those results of Prof. Tyndall's experiments, there are many other phenomena connected with sound, of which this refraction affords an explanation, such as the very great distances to which the sound of meteors has been heard as well as the distinctness of distant thunder. When near, guns make a louder and more distinctive sound than thunder, although thunder is usually heard to much greater distances. In hilly countries, or under exceptional circumstances, sounds are sometimes heard at surprising distances. When the Naval Review was at Portsmouth, the volleys of artillery were very generally heard in Suffolk, a distance of 150 miles. The explanation being that owing to refraction (as well as to the other causes) it is only under exceptional circumstances that distant sounds originating low down are heard near the ground with anything like their full distinctness, and that any elevation either of the observer or of the source of sound above the intervening ground causes a corresponding increase in the distance at which the sound can be heard.

SCIENTIFIC SERIALS

Memorie della Societa degli Spectroscopisti Italiani, February.—Father Secchi contributes a paper On his Observations of Solar Prominences from April 23 to October 2, 1873. From his tables it appears that the sun was observed on 127 days, when 1,052 prominences were seen, being more than 8 a day, the maximum number visible on any one day was 13, and the minimum 2. The greatest number of prominences over 64″ high occurred in lat. 30° 40′ N. and 20° 30′ S. The greatest number of prominences of all kinds were in lat. 20° 30′ N. and 10° 20′ S. The same author also makes some remarks on the spectroscopic observations of the transit of Venus.

Astronomische Nachrichten, Nos. 1,980–1,981.—These numbers contain a large quantity of observations of positions of the minor planets and comets made in 1873 by Leopold Schulhof. He also gives the positions of more than 100 variable stars, with remarks on a new variable position for 1850, RA 23° 10′ 35″ Dec. – 19° 39′·7. Prof. Peters gives the position of Planet 135, Feb. 18, 1874, at 14h. 37m. 40s., Hamilton College, M.T., RA 11h. 19m. 42·7s. Dec. + 4° 25′ 5″·11 mag. G. Spoerer gives the positions of spots and prominences for February last. J. Palisa gives the position of the planet discovered by him on March 18, 4h. 46m. 39s. RA 12h. 22m. 2·12s. Dec. – 3° 19′ 33″·4.

No. 1,982 contains a long paper On a Method of Computing Absolute Perturbation, being in great measure similar to that of Laplace.

Journal of the Franklin Institute, March.—This number contains an account, by Mr. Crew, of the "prismoidal" one-rail railway (of his invention), of which he has made two years' trial in Alabama, with encouraging results. The cars are kept securely on the prismoidal track by a combination of wheels; a centre one, at either end, on the rail, kept on the track by revolving flanged wheels at either side; and wheels on the sides of the prismoid, with strong wrought-iron bars to the side of the car; these keep the car upright. One proposed application of the system is that of elevated rapid transit by steam through crowded streets in populous cities. As to speed, Mr. Crew thinks even 100 miles an hour would be possible; there is no oscillation through lateral motion.—Mr. Richards continues his Principles of Shop Manipulation for Engineering Apprentices; treating of belts, gearing, hydraulic and pneumatic apparatus as means of transmitting power, and of "machinery of application" of power.—Mr. Isherwood points out a method of ascertaining what portion of the feed-water admitted to a boiler is entrained in the form of spray by the escaping steam.—Details with reference to the Girard Avenue Bridge (which will form the chief entrance to the West Park, at Philadelphia), are furnished by Mr. Hering.—Prof. Thurston claims for Count Rumford a higher place in connection with thermo-dynamics than has hitherto been assigned to him; affirming that he first, and half a century before Joule, determined with almost perfect accuracy the mechanical equivalent of heat, while the sole credit of discovering the true nature of heat is due to him.—We may note, in addition, a paper On Railway Crossings and Turnouts, by Mr. Evans, and one On the Sanitary Care and Utilisation of Refuse in Cities, by Dr. Leas, who describes, more especially, the system followed in Baltimore.

SOCIETIES AND ACADEMIES

London

Royal Society, April 23.—On some points connected with the Circulation of the Blood, arrived at from a study of the Sphygmograph Trace, by A. H. Garrod, B.A., Fellow of St. John's College, Cambridge.

The author commences by giving a table containing a fresh series of measurements of the ratio borne by the cardiosystole * to its component beat in the cardiograph trace. These tend strongly to substantiate the law previously published by him, viz., that the length of the cardiosystole is constant for any given pulse-rate, and that varies as the square root of the length of the pulse-beat only, being found from the equation $xy = 20\sqrt{x}$ when x = the pulse-rate and y = the ratio borne by the cardiosystole to the whole beat.

A similar series of fresh measurements are given in proof of the law previously published by him, that in the sphygmograph trace from the radial artery at the wrist, the length of the sphygmosystole † is constant for any given pulse-rate, but varies as the cube-root of the length of the pulse-beat, it being found from the equation $xy' = 47\sqrt[3]{x}$, where x = the pulse-rate, and y' = the ratio borne by the sphygmosystole to the whole beat.

By measurement of sphygmograph tracings from the carotid in the neck and posterior tibial artery at the ankle, it is then shown that the length of the sphygmograph in those arteries is exactly *the same* as in the radial; so that the above-stated law as to the length of the sphygmosystole in the latter applies to them also, and must therefore equally apply to the pulse in the aorta.

Such being the case, by comparing the equations for finding the length of the cardiosystole with that for finding the aortic sphygmosystole, the relation between the whole cardiac systolic act and the time during which the aortic valve remains open can be estimated with facility; for by subtracting the shorter sphygmosystole from the longer cardiosystole a remainder is obtained which can be nothing else than the expression of the

* The *cardiosystole* is the interval between the commencement of the systole and the closure of the aortic valve in each revolution.

† The *sphygmosystole* is the interval between the opening and closure of the aortic valve in each cardiac revolution.