and they have placed, this year, in the Exhibition of the Imperial Institute a "univalve," or one-lens apparatus, of the third order. Both these lights are on the *feu éclair* system.

Successful as this system appears to be, it should for the present be regarded as on its trial, and as awaiting the collective judgment of mariners on certain points. And meanwhile it should be estimated as supplementing, not displacing, the well-tried forms of apparatus at the disposal of the lighthouse engineer.

A notable adjunct to the new rapidly rotating lights is the mercury-float carriage, by which the effect of weight and friction is largely diminished. Another excellent quality of this arrangement is its suitableness for stations where earthquakes prevail, as it provides an elastic connection between the optical apparatus and the pedestal, instead of the rigid bearings in the older forms of carriage. If the Curaumilla lighthouse in Chili had been fitted with the mercury-float, it is probable that it would not have been wholly ruined by the shock.

(6) The principle of *occultation*—that is, of interrupting the fixed beam of a cylindrical lens of an oil light by a dark shade moving round or over the flame, or in a gas light by cutting off the gas—is acknowledged to be of extreme usefulness, and has been applied to many of the fixed lights of our coasts. It is not that any power is really added to the light, but that the quick alternation of light and dark in various groups or periods imparts a quasi-intensity to the beam, and a valuable set of characteristics for the mariner. The law of contrast has a physiological effect here, as it has in another manner with the *feux éclairs*. It is an extreme example, but it rests on trustworthy evidence, that the occulting light of Ventotene Island, near Naples, which is of the sixth order only, has been seen from a distance of nineteen miles, its normal range being nine miles. Using the words of Cicero with another application, it may be truly said, "Eo magis elucet quo magis occultatur."

Investigations into the amount of light reflected and transmitted by certain kinds of glass—lighthouse glass among the rest—have been most ably conducted by Sir John Conroy, Bart., at Oxford, in 1888. He traversed by newer methods and with surer results the ground of many observers, from Augustin Fresnel to Lord Rayleigh; and he demonstrated that "the values of the transmission-coefficients for light of mean refrangibility show that for 1 centimetre the loss by obstruction amounts to 2·62 per cent. with crown glass, and 1·15 with flint glass." The refractive index of lighthouse glass lying between 1·52 and 1·54, the loss may thus be practically taken as $2\frac{1}{2}$ per cent. for 10 millimetres of thickness.

The intensities of lighthouse apparatus have of late been diligently considered by lighthouse authorities with the view of determining, once for all, the relative values of the six orders of lights, and of the lamps appropriate to them, and also of publishing the results in the Admiralty Light-list. A large amount of uncertainty and misconception seems to have prevailed on this question. M. Allard, in 1876, in a celebrated memoir, gave an elaborate exposition of the whole subject, but his conclusions, always tending to excess, have not been accepted by more recent investigators.

Other estimates, official as well as private, and more or less discordant, have from time to time appeared, both in this country and France. The factors of evaluation, such as radius, lens-surface, vertical section, flame, reduction for losses, &c., have been combined in different ways by different persons, and some of their conclusions must be regarded as merely empirical. But in 1891 and 1892 a serious attempt was made by a committee of the chief engineers of the three Lighthouse Boards to compile an accurate schedule of intensities with photometry as a basis. Taken as a whole, the values arrived at are fairly acceptable, not certainly erring on the side of excess.

But as yet only the lights with oil or gas for illuminants have been determined.

Electricity appears even more difficult to deal with, and no intensities have been assigned officially to any of the electric lights in the British Islands.

Thus it is uncertain whether, for instance, we are to consider the Isle of May as of six millions of candles, or of twenty-six millions, both estimates resting on competent professional authority. The lights on the *feu éclair* system, oil and electric, are obviously less amenable still to formulæ which may give their coefficients of intensity, although French writers do not hesitate to define these, and deduce thirty or forty millions of candles as "ayant la consécration de la pratique."

It is much to be desired that as a sort of sequel to the publication of the intensities of lights—at all events, of the British lights—there should be provided a form for every vessel under the control of the Board of Trade, in which a return should be made of the appearance of every light approached or passed, with statement of the weather, distance, name and character of the light, &c. These returns, duly kept and handed to the Board of Trade on the first opportunity, would gradually constitute an invaluable record of the merits or demerits of our lights, instructive to the engineer, and, through him, beneficial to the mariner. I have repeatedly, but in vain, urged this expedient on the authorities.

The administration of lighthouses in this country has undergone no change in the past decade, nor, indeed, since 1861, when the Royal Commission on Lights recommended that a Central Board should be constituted instead of the quadriform government then, as now, in force, and gave excellent reasons for the recommendation. The further experience of thirty-six years has amply confirmed the earlier conclusions on this subject, and has brought into stronger relief the example of the French Administration. Some slight approach to the desired reconstruction may be indicated in the Report of the Committee of Inquiry on the Mercantile Marine Fund of 1896, paragraph 71, in the following words: "From the evidence brought before us we unanimously recommend the formation of a small committee containing representatives, possessing as far as possible nautical knowledge, of the Trinity House, the Scotch Board and the Irish Board, which should be summoned at least once a year to advise the Board of Trade upon the desirability of all new works, whether in respect of lighthouses, steamers, buoys or signals, together with all renewals, alterations and important repairs."

But however we may regard the system of government of our lighthouses in contrast with the French system, and desire its amelioration, it is impossible to deny that the United Kingdom has during the Victorian era produced men who individually have done fully as much in every part, theoretical and practical, of lighthouse science as have the distinguished men of the sister country. In one group we can point to the names of Faraday, Airy, Thomson and Chance. In another to those of Stevenson, Douglass, Hopkinson and Matthews. In yet another to those of Farrar, Nisbet, Sydney Webb, Trevor, Wharton and Nares.

These men have enriched and illustrated lighthouse mathematics, engineering, optics, mechanics and nautical and general administration, in a manner and with a success to be gratefully remembered in our day, and never to be forgotten in the new developments of the years to come. J. KENWARD.

[*Note.*—I would invite the attention of visitors to the Imperial Institute to the very ingenious and effective illustration of the progress of British coast lights during the past sixty years, by means of two large illuminated maps and a relief plan. This is exhibited by the Trinity House, whose collection of models, lenses, reflectors and burners is also very commendable.—J. K.]

THE LIMITS OF AUDITION.[1]

IN order to be audible, sounds must be restricted to a certain range of pitch. Thus a sound from a hydrogen flame vibrating in a large resonator was inaudible, as being too low in pitch. On the other side, a bird-call, giving about 20,000 vibrations per second, was inaudible, although a sensitive flame readily gave evidence of the vibrations and permitted the wave-length to be measured. Near the limit of hearing the ear is very rapidly fatigued; a sound in the first instance loud enough to be disagreeable, disappearing after a few seconds. A momentary intermission, due, for example, to a rapid passage of the hand past the ear, again allows the sound to be heard.

The magnitude of vibration necessary for audition at a favourable pitch is an important subject for investigation. The earliest estimate is that of Boltzmann. An easy road to a superior limit is to find the amount of energy required to blow a whistle and the distance to which the sound can be heard (*e.g.* one-half a mile). Experiments upon this plan gave for the amplitude 8×10^{-8} cm., a distance which would need to be multiplied 100 times in order to make it visible in any possible microscope. Better results may be obtained by using a

1 Abstract of a lecture delivered at the Royal Institution on April 9, by the Right Hon. Lord Rayleigh, F.R.S

vibrating fork as a source of sound. The energy resident in the fork at any time may be deduced from the amplitude as observed under a microscope. From this the rate at which energy is emitted follows when we know the rate at which the vibrations of the fork die down (say to one-half). In this way the distance of audibility may be reduced to 30 metres, and the results are less liable to be disturbed by atmospheric irregularities. If s be the proportional condensation in the waves which are just capable of exciting audition, the results may be expressed :—

c'	frequency = 256	$s = 6{\cdot}0 \times 10^{-9}$
g'	,, = 384	$s = 4{\cdot}6 \times 10^{-9}$
c''	,, = 512	$s = 4{\cdot}6 \times 10^{-9}$

showing that the ear is capable of recognising vibrations which involve far less changes of pressure than the total pressure outstanding in our highest vacua.

In such experiments the whole energy emitted is very small, and contrasts strangely with the 60 horse-power thrown into the fog-signals of the Trinity House. If we calculate according to the law of inverse squares how far a sound absorbing 60 horse-power should be audible, the answer is 2700 kilometres ! The conclusion plainly follows that there is some important source of loss beyond the mere diffusion over a larger surface. Many years ago Sir George Stokes calculated the effect of radiation upon the propagation of sound. His conclusion may be thus stated. The amplitude of sound propagated in plane waves would fall to half its value in six times the interval of time occupied by a mass of air heated above its surroundings in cooling through half the excess of temperature. There appear to be no data by which the latter interval can be fixed with any approach to precision; but if we take it at one minute, the conclusion is that sound would be propagated for six minutes, or travel over about seventy miles, without very serious loss from this cause.

The real reason for the falling off at great distances is doubtless to be found principally in atmospheric refraction due to variation of temperature, and of wind, with height. In a normal state of things the air is cooler overhead, sound is propagated more slowly, and a wave is tilted up so as to pass over the head of an observer at a distance. [Illustrated by a model.] The theory of these effects has been given by Stokes and Reynolds, and their application to the explanation of the vagaries of fog-signals by Henry. Progress would be promoted by a better knowledge of what is passing in the atmosphere over our heads.

The lecture concluded with an account of the observations of Preyer upon the delicacy of pitch perception, and of the results of Kohlrausch upon the estimation of pitch when the total number of vibrations is small. In illustration of the latter subject an experiment (after Lodge) was shown, in which the sound was due to the oscillating discharge of a Leyden battery through coils of insulated wire. Observation of the spark proved that the total number of (aerial) vibrations was four or five. The effect upon the pitch of moving one of the coils so as to vary the self-induction was very apparent.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

AMONG other bequests, the late Mrs. Muspratt, widow of Dr. Sheridan Muspratt, left by will the sum of 500*l.* to University College, Liverpool.

DR. E. S. MACBRIDE, Fellow of St. John's College, and Demonstrator in Animal Morphology in the University of Cambridge, has been appointed to the newly-founded chair of Zoology in the McGill University, Montreal, Canada.

THE University of Leipzig has conferred the honorary degree of doctor of medicine upon Dr. Simon Schwendener, professor of botany at Berlin ; Dr. W. Hempel, professor of chemistry at Leipzig ; and Dr. W. Hittorf, professor of physics in the Münster Academy. The same University has conferred the honorary degree of doctor of philosophy upon Dr. A. Fick, professor of physiology at Würzburg ; Dr. W. His, professor of anatomy at Leipzig ; and Dr. K. von Leibermeister, professor of anatomy at Tübingen.

WE learn from the *Lancet* that Prof. Engelman, in taking over the late Dr. du Bois Reymond's chair of Physiology at Berlin, is arranging certain changes in the Physiological Institute and its four departments. The first, for microscopical and biological work, will remain under the charge of Prof. Fritsch. Similarly, the second, for chemical physiology, will continue under its present director, Prof. Thierfelder. The third, for special physiology, will be greatly enlarged, and the professor himself will take part in its work in conjunction with the present director, Dr. Immanuel Munk. The fourth department, for physical physiology, will also be largely increased ; it will be called the Department for the Physiology of the Sensory Organs, and will remain under the direction of Prof. König. In addition to extensive new buildings, the supply of apparatus will be largely augmented. The lectures will be given by the professor in a course running through two semesters, but during the last four weeks in the summer Prof. König will lecture on the sensory organs, and during the first four weeks of the winter Prof. Thierfelder will lecture on physiological chemistry.

SCIENTIFIC SERIALS.

American Journal of Science, July.—Pressure coefficient of mercury resistance, by A. de Forest Palmer, jun. By means of Barus's screw compressor, a thread of mercury was subjected to a series of pressures up to 2000 atmospheres. If R is the resistance under any pressure, R_0 that under atmospheric pressure, P the pressure, and β the increment for one atmosphere, then $R = R_0 (1 + \beta P)$. The result of the measurements is that $\beta = -0{\cdot}0000332 - 5 \times 10^{-9}t$. This differs only very slightly from the value obtained by Barus.—An interesting case of contact metamorphism, by H. W. Fairbanks. Black Mountain is the highest peak of the El Paso range, a spur of the Sierra Nevada mountains extending eastwards into the Mojave desert. The mountain owes its name to the dark lava which covers it. The underlying rocks constitute a part of an extensive series of sedimentary beds exposed for many miles along the northern slope of the El Paso range. The strata have been considerably disturbed and faulted, and in one of the cañons have been intruded by two dykes. One of these is 14 feet across, and is a holocrystalline olivine diabase. The adjoining rock has been strikingly metamorphosed. The thickness of the band of altered tufa is about 2 feet where it is best exposed. The light-coloured soft rock has been baked to a dark, hard and very firm one, the slabs of which give forth a ringing sound when struck. The layer is not massive, but breaks up into slate-like slabs. The partings are probably due to contraction on cooling.—The tin deposits of Temescal, South California, by H. W. Fairbanks. The tin deposits lie nearly in the centre of a rudely semicircular area of granite, which is fissured along almost innumerable lines in which a black vein matter is deposited. The veins vary from one-fourth to a few inches in thickness, and consist of tourmaline and quartz, with which the tin ores are loosely associated. They occur in two forms : the common variety is either massive and brownish, or in clear reddish-brown crystals lining cavities ; the less common variety is that of "wood tin," which appears uncrystallised and in the form of thin layers.—Electrosynthesis, by W. G. Mixter. Mixtures of various gases were subjected to a feeble alternate discharge in a special form of eudiometer, in which the terminals consisted of glass surfaces holding water on the other side. Under these circumstances, dry carbonic oxide and oxygen slowly combine. Ethylene and oxygen are partly converted into carbon dioxide and water. Acetylene and oxygen are wholly converted into the same. The molecular changes are analogous to those occurring in synthesis effected by heat or light where combination takes place at a temperature far below that at which the gaseous molecules dissociate.

THE *Rendiconti del Reale Istituto Lombardo*, which is devoted to both literary and scientific subjects, contains in recent numbers the following papers of physical interest :—Prof. Aurelio Mauri (xxx., vii.) describes a new potentiometer, and gives an account of observations of the electromotive forces of Clark's cell, and of a new form of element involving the use of acetate of mercury and acetate of zinc. In the next number (xxx., viii.) he gives tables of the electromotive forces of elements involving various salts. In a later number (xxx., x.) Prof. Paolo Cantoni describes certain phenomena connected with the charging of a condenser, and which on starting or stopping the electromotor give rise to sudden repulsions of the plates from the intervening dielectric, followed by attraction. These phenomena, the author considers, are the outcome of temporary