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The growth of abstract science in this country is perhaps no better illustrated than by the advance which has been made of late years in the various departments of mathematics. It is only a few years since Prof. Peirce was about the only person in the United States who held a position among the original mathematicians of the world, while to-day there are in this country a number of persons whose writings are destined to rank among the classics, and a journal of mathematics of the highest rank is published under the auspices of the Johns Hopkins University and sustained almost entirely by American contributors. Among the best of the abstract writers referred to is Mr. William Ferrel, who has been hitherto best known by his tidal researches, but is now engaged in investigations on the mathematical principles of meteorology. His latest work, just published by the Coast Survey, is now before us, and although nominally consisting only of researches on Cyclones, Waterspouts and Tornadoes, is in reality a valuable contribution to the theory of storms in general.

The Board of Directors of the Ohio Mechanics' Institute have organized a "*Department of Science and Arts*" for the purpose of increasing the usefulness of the Institution. A Section of Mechanics and Engineering under the chairmanship of Professor H. T. Eddy, and one of Chemistry under Professor F. W. Clark, have been arranged. Meetings for the public discussion of scientific subjects will be held once a month, and various other arrangements are in progress which will contribute to the success of the present attempt to provide increased facilities for technical and scientific education for the youths of Cincinnati.

SCIENTIFIC SOCIETIES OF WASHINGTON.

THE BIOLOGICAL SOCIETY, WASHINGTON.—Since our last report the following papers have been read: "Roan Mountain, North Carolina, and its Flora," by Prof. J. W. Chickering, Jr.; "Notes on the Flowering of *Solanum rostratum* and Cassia chamaecrista, with illustrations," by Prof. J. E. Todd; "A Critical Review of Günther's Ichthyology," by Prof. Theodore Gill; "On the Mortality of Marine Animals in the Gulf of Mexico," by Mr. Ernst Ingersoll: "A Statistical View of the Flora of the District of Columbia," by Prof. Lester F. Ward. It is to be regretted that the absence of our Washington correspondent from the meetings deprives us of abstracts of these valuable papers.

THE ANTHROPOLOGICAL SOCIETY.—The Constitution of this society, now in its third year, makes it obligatory upon the President to prepare at the commencement of each year, a summary of the transactions of the organization during the past year. At the close of the first year, the President overlooked this fact, but made ample amends at the commencement of the third year by preparing a pamphlet containing both annual addresses, and copious abstracts of all the papers that had ever been read.

Since our last report, the following papers have been read: "The Savage Mind in the Presence of Civilization," by Prof. Otis T. Mason; "Prehistoric Trephining," by Dr. Robert Fletcher; "Some Superstitions of the Sioux Indians," by Dr. H. Yaddow; "The Chief's Son and the Thunders: An Omaha Myth," by Rev. J. Owen Dorsey.

The design of the first named paper was two-fold: first, to show that the presence of other peoples better furnished and skilled in some respect had always operated as a stimulus in the onward march of civilization; and second to draw attention to the fact that in the treatment of the Indians, Chinese, and Negroes, the phenomena of the past history of civilization were being re-presented. The two latter papers were recitals of exceedingly interesting Indian myths, Dr. Fletcher, who is associated with Dr. Billings in publishing "Index Medicus," having collected all that could be gathered on the subject of prehistoric-trephining, from two years reading, gave an elaborate summary of his investigations.

THE PHILOSOPHICAL SOCIETY OF WASHINGTON.—THE SPECTROPHONE.—At the 198th meeting of the Philosophical Society of Washington, Prof. Alexander Graham Bell communicated the announcement of his discovery of the Spectrophone, the latest outgrowth of the Photophone.

In a paper read before the American Association for the Advancement of Science, in which he announced the discovery of the photophone, Mr. Bell ventured the prediction that probably all matter would be found to posses sonorous properties of the same nature as those manifested by the discs used in that instrument. More recent investigations in Europe with gases and liquids have fully verified this prediction. Any liquid or gas placed in a test tube and exposed to the action of a beam of light condensed upon it by a lens can be made, by means of an interrupter, to emit musical tones. This has been shown by Prof. Tyndall in his memoir, to the Royal Society, on Radiant Heat. Some substances thus emit feeble sounds, others stronger ones. Iodine vapor, Nitrogen Oxide and Bromine give very loud sounds. It is found that those substances which emit loud sounds are those which absorb heat in a high degree, and among these lamp-black is especially remarkable. It has been questioned whether such sounds are provoked by the luminous rays or by the dark ones. M. Mercadier expressed the belief that the inciting rays are the red and dark ones. This led Mr. Bell, with the assistance of Mr. Sumner Taintor, to experiment with the sonorous properties of Carbon Disulphide, actuated by the light of the Spectrum.

When lamp-black is exposed to the action of the light of the spectrum it is found to give a sonorous response to all of its rays as far as the middle of the violet, and perhaps beyond. The intensity of the sound, however, varies remarkably in different parts of the spectrum. Taking the rays successively from different parts, from the violet towards the red, the sounds begin very feebly and increase in intensity, reaching a maximum in the ultra red. Beyond that point they suddenly cease. The increase of intensity is very gradual, the decrease very sudden.

Other substances have been experimented with, and while exhibiting similar properties, each has a range of its own. Porous and fibrous substances give loud sounds. Thus, common wool or worsted are found to be very sonorous, but the sounds are obtained wholly from the visible parts of the spectrum and have the maximum intensity in the green. In all substances tried success has resulted, but nearly all have a very short range.

In experimenting with more homogeneous substances of simpler constitution, still more definite results are obtained. The rays of the spectrum are passed through sulphuric ether. Outside of the ultra red is a very narrow band which cause sounds while the other parts fail to produce them. Hydrogen peroxide gives sounds at several places wholly within the visible parts of the spectrum, and these places are found to coincide with the positions of the known absorption bands of that substance. The same is found to be true of Nitrogen Oxide and a solution of Ammonia, Sulphate of Copper, and many other substances. The general law deduced is that *sounds are produced in any substance by the rays which it absorbs.*

Thus a kind of spectrum analysis can be obtained through the intermediation of sound. The principal value of the spectrophone, Mr. Bell believes, will be found in the investigation of absorption bands in the ultra red part of the spectrum.

Mr. William B. Taylor inquired whether the sounds observed from the two absorption bands of ammonia, sulphate of copper, were octaves. Mr. Bell replied that this question had not as yet been investigated.

Mr. G. Brown Goode read portions of a paper on the sword-fish and its allies, which paper will be published in full in the next annual report of the U. S. Fish Commission.

ON THE MODERN DEVELOPMENT OF FARADAY'S CONCEPTION OF ELECTRICITY.*

By Professor Helmholtz.

The majority of Faraday's own researches were connected, directly or indirectly, with questions regarding the nature of electricity, and his most important and most renowned discoveries lay in this field. The facts which he has found are universally known. Nevertheless, the fundamental conceptions by which Faraday has been led to these much-admired discoveries have not been received with much consideration. His principal aim was to express in his new conceptions only facts, with the least possible use of hypothetical substances and forces. This was really a progress in general scientific method, destined to purify science from the last remnants of metaphysics. Now that the mathematical interpretations of Faraday's conceptions regarding the nature of electric and magnetic force has been given by Clerk Maxwell, we see how great a degree of exactness and precision was really hidden behind his words, which to his contemporaries appeared so vague or obscure; and it is astonishing in the highest to see what a large number of general theories the methodical deduction of which requires the highest powers of mathematical analysis, he has found by a kind of intuition, with the security of instinct, without the help of a single mathematical formula.

The electrical researches of Faraday, although embracing a great number of apparently minute and disconnected questions, all of which he has treated with the same careful attention and conscientiousness, are really always aiming at two fundamental problems of natural philosophy, the one more regarding the nature of physical forces, or of forces working at a distance; the other, in the same way, regarding chemical forces, or those which act from molecule to molecule, and the relation between these and the first.

The great fundamental problem which Faraday called up anew for discussion was the existence of forces working directly at a distance without any intervening medium. During the last and the beginning of the present century the model after the likeness of which nearly all physical theories had been formed was the force of gravitation acting between the sun, the planets, and their satellites. It is known how, with much caution and even reluctance, Sir Isaac Newton himself proposed his grand hypothesis, which was destined to become the first great and imposing example, illustrating the power of true scientific method.

But then came Oerstedt's discovery of the motions of magnets under the influence of electric currents. The force acting in these phenemena had a new and very singular character. It seemed as if it would drive a single isolated pole of a magnet in a circle around the wire conducting the current, on and on without end, never coming to rest. Faraday saw that a motion of this kind could not be prodaced by any force of attraction or repulsion, working from point to point. If the current is able to increase the velocity of the magnet, the magnet must react on the current. So he made the experiment, and discovered induced currents; he traced them out through all the various conditions under which they ought to appear. He concluded that somewhere in a part of the space traversed by magnetic force there exists a peculiar state of tension, and that every change of this tension produces electromotive force. This unknown hypothetical state he called provisionally the electrotonic state, and he was occupied for years and years in finding out what was this electrotonic state. He discovered at first, in 1838, the dielectric polarisation of electric insulators, subject to electric forces. Such bodies show, under the influence of electric forces, phenomena perfectly analogous to those exhibited by soft iron under the influence of the magnetic force. Eleven years later, in 1849, he was able to demonstrate that all ponderable matter is magnetized under the influence of sufficiently intense magnetic force, and at the same time he discovered the phenomena of diamagnetism, which indicated that even space, devoid of all ponderable matter, is magnetizable; and now with quite a wonderful sagacity and intellectual precision Faraday performed in his brain the work of a great mathematician without using a single mathematical formula. He saw with his mind's eye that by these systems of tensions and pressures produced by the dielectric and magnetic polarisation of space which surrounds electrified bodies, magnets or wires conducting electric currents, all the phenomena of electro-static, magnetic, electro-magnetic attraction, repulsion, and induction could be explained, without referring at all to forces acting directly at a distance. This was the part of his path where so few could follow him; perhaps a Clerk Maxwell, a second man of the same power and independence of intellect, was necessary to reconstruct in the normal methods of science the great building, the plan of which Faraday had conceived in his mind and attempted to make visible to his contemporaries.

Nevertheless the adherents of direct action at a distance have not yet ceased to search for solutions of the

* The Faraday Lecture, delivered before the Fellows of the Chemical Society in the Theatre of the Royal Institution, on Tuesday, April 5th, 1881, by Professor Helmholtz. Abstract revised by the author.