THE LAW WHICH UNDERLIES PROTECTIVE COLORATION.

I desire at the outset to point out that my demonstration of the principle of Protective Coloration is not the demonstration of a *theory*, but of an indisputable fact, namely, that if an object be coloured so that its tones constitute a gradation of shading and of colouring counter to the gradation of shading and of colouring which light thrown upon it would produce, such object will appear perfectly flat, retaining its length and breadth, but having lost its appearance of thickness, and when seen against a background of colour and pattern similar to its own will be essentially indistinguishable at a short distance. All persons who have seen the models which illustrate this fact know that they prove it.

Now, if this stands proved, *the fact that a vast majority of the whole Animal Kingdom wear this gradation, developed to an exquisitely minute degree, and are famous for being hard to see in their homes speaks for itself.* It is plain that their colour-gradation can no more escape effacing their look of solidity than the Law of Gravitation can escape drawing a projectile to the earth.

This is so obvious that one hears on all sides expressions of wonder that it was so long unnoticed. I may add that all persons of trained sight, such as artists, perceive it everywhere among wild creatures. Other people supplement their undeveloped sight sense by their other senses, and if they *know* the animal is solid think he *looks* solid. But the time will come when even at zoological gardens, where animals are more or less abnormally environed, people will find a new charm in recognising everywhere this wonderful adjustment of their colouring, and in perceiving its effect.

Let anyone look at a ball, or egg-shaped object, placed anywhere out of doors, and when he has recognised its shading from its light side to its dark, try to so colour it, where it stands, as to obliterate both its shading and its colour-gradation. (The sky-lit side is commonly the bluer). If he succeed, he will find that Nature has swiftly guided him through the same process which has taken her so long on the coats of animals, and that he has given the object the counter-gradation I speak of, and it will have dawned on him that so long as light makes its *one* gradation on objects, there is only the *one* way to neutralise it. In short, I simply prove that this arrangement of animals' colours is what so marvellously effaces them, and leave it to others to discuss the question whether concealment be a benefit to an animal and whether the fact that it is a benefit be the cause of his being concealed.

All who believe in Natural Selection will, of course, feel that this colour law is its work, and since it is so almost universally in use, and accounts, apparently, so almost exhaustively, for all the attributes of graded animal colouring, I believe it will ultimately be recognised as the most wonderful form of Darwin's great Law.

It stands alone in the startling attribute of being the only known or so far conceivable device for making objects in *full light not appear to exist.* This is a distinct plane above even the great beauty of Protective Resemblance, where the deception is of a more material nature, one thing passing itself off for another *thing.* The beautiful sequence of this law, which causes the grading colours to become a picture of the background, I will not force upon those who have not yet digested the first part.

It might be worth pointing out that the old theory that the bellies of fish and tree birds were white to match the sky when seen from below finds itself essentially done away with, since the fishes' or birds' opacity causes even their white to look very dark against an ordinary sky, while this same white proves to work so brilliant a success for the purpose I have shown. All people know the ghostly transparent look of fish in the water. The white bellies of birds do help them to match the *translucent foliage overhead* when seen from below, but the cold sky-holes between the leaves are far too bright. Natural Selection has, of course, surely modified all attributes to suit, not merely main ends, but all minor ones, according to the rank of their importance.

Since publishing my papers in *The Auk* for April and October, 1896, I find that Prof. Poulton perceived years before their appearance the power of a countergrading of light to make the round surface of a pupa appear flat, and in another case the power of light colour in a depression to make the concavity disappear. In both of these cases he perceived the very *Law of Light and Shade* on which the Fact of Protective Coloration rests, and recognised the Fact itself in these instances. In his "Notes in 1886 upon Lepidopterous Larvæ, &c.," read April 6, 1887, he says (*Trans.* Ent. Soc. Lond., 1887, p. 294), "Although the cleft [between the posterior part of the body of the larva of *Rumia crataegata* and the branch] is largely filled up, . . . a considerable furrow remains, but this is not apparent because of the light colour of the fleshy processes, which prevent the attention from being directed to the shadow which would otherwise indicate the position of the groove. The processes, therefore, attain the object of softening the contact between the larva and its food-plant in a two-fold manner, by partially filling up the cleft and by neutralising the shadow in the groove which remains. I have also noticed the processes in the larva of *A. betularia*, and I believe that they are of very general occurrence in *Geometrae.*"

His other case is to be found in his "Notes in 1887 upon Lepidopterous Larvæ, &c.," read October 3, 1888. He says (*Trans.* Ent. Soc. Lond., pp. 595–6), "The most extraordinary thing about this resemblance [of the pupa of *Apatura iris* to a sallow-leaf] was the leaf-like impression of *flatness* conveyed by a pupa which was in reality very far from flat. Thus the length of the pupa was 30·5 mm.; the greatest breadth (dorso-ventral diameter), 11·5 mm.; the greatest thickness (from side to side), 8·5 mm. . . . But exactly in these places, where the obvious thickness would destroy the resemblance to a leaf, the whole effect of the roundness is neutralised by the increasing lightness of these parts—a lightness which is so disposed as to just compensate for the shadow by which alone we judge of the roundness of small objects. (Much larger objects can be judged of by the change of focus, which becomes necessary as their near or distant parts are observed.) In shading the drawing of an object so as to represent roundness, the shade is made to become gradually less and less deep as the tangential planes represented come nearer and nearer to a right angle with the axis of vision. So here, the converse of shading—the whiteness neutralising the shadow which shading is intended to represent—dies off gradually as the [representation of the] mid-rib is approached.

"The whiteness is produced by the relative abundance of white dots and a fine white marking of the surface which is present everywhere, mingled with the green. The effect is, in fact, produced by a process exactly analogous to stippling.

"By this beautiful and simple method a pupa, which is 8·5 mm. from side to side in its thickest part, appears flat and offers the most remarkable resemblance to a leaf which is a small fraction of 1 mm. in thickness."

ABBOTT H. THAYER.

Scarbro, New York.

REPORT OF THE SMITHSONIAN INSTITUTION.

DR. S. P. LANGLEY'S report upon the operations of the Smithsonian Institution for the year ending last June has just reached this country. Many subjects of interest are referred to in the report, but we are only able to mention a few, which will, however, be sufficient to show that the Institution is taking a foremost part in the advancement and diffusion of knowledge among men of all civilised nations.

Hodgkins Fund.—Among the many applications for grants from the Hodgkins fund, it has been found practicable to approve several which conform to the conditions of the bequest. Prof. Wallace C. Sabine, of Harvard University, has received a grant for the aid of his investigations on sound, the particular phase of the problem under investigation being the subject of loudness and interference. This research requires apparatus of special design, part of which is now complete and is satisfactory. Prof. Sabine, who had charge of the design of the new symphony hall in Boston, has for several years given much attention to the problem of architectural acoustics, or the science of sound as applied to buildings. It is expected that his complete report will be of much practical interest in connection with this subject.

Details of the progress of the research mentioned in the last report as conducted by Dr. Victor Schumann, of Leipzig, have been received. The most noteworthy points in the results so far refer, perhaps, to the relation of light and electricity and to the probable insight into the nature of the Röntgen rays to be gained in the course of this investigation.

The investigations of Dr. von Lendenfeld, of the University

of Prague, are still in progress, and it is anticipated that his final report, which is now awaited, may furnish data available for greatly improving the construction of the meteorological kites now in constant use, and thus be the means of adding materially to our knowledge of atmospheric conditions at high altitudes, the practical application of which is of such general interest and usefulness.

The interesting experiments in connection with kites and with air currents at varying altitudes, which have been prosecuted for some time at the Blue Hill Meteorological Observatory by Mr. A. Lawrence Rotch, are still in progress, an additional grant having been approved this year on behalf of Mr. Rotch. It will be remembered that the original grant mentioned was made for the purpose of securing automatic kite records at a height of more than 10,000 feet, an altitude which so lately as four years ago had never been attained. Successive grants have since been made, and the persistence and skill of Mr. Rotch and his assistants have enabled him to surpass his own extraordinary record of 14,000 feet.

FIG. 1.—Diagram illustrating height of packing boxes, resting one upon another, used in transmitting exchanges from the United States to foreign countries during the fiscal year ending June 30, 1901, as compared with the height of the Washington Monument. Height of monument, 555 feet; height of boxes, 2,775 feet.

Dr. Carl Barus, of Brown University, has completed his research on ionised air, and his report is now in course of publication in the Smithsonian Contributions to Knowledge. This research on atmospheric conditions, in investigating the production of nuclei, determining their number per cubic centimetre, their velocity, their association with ionisation, the effect of the presence of the electric field, &c., proves interesting, not only in its own methods and results, but because of its agreement with the data obtained by other investigators from different experiments and theoretically different points of view.

The research of Prof. Louis Bevier, of Rutgers College, in connection with the analysis of vowel sounds, is steadily progressing. During the year detailed studies of several vowel sounds have been made with results which agree well with the conclusions arrived at through an entirely different method by von Helmholtz in his analysis of German vowels. The lower resonance detected in our vowel sounds by Dr. Bevier, and not recorded by von Helmholtz save for "*a*," will later be the subject of detailed discussion which will endeavour to establish and explain these facts.

Dr. Marey, of the French Institute, has received a grant in aid of his experiments on air currents. This research has been materially furthered by the successful application of chrono-photography, a field in which Dr. Marey's experiments have heretofore been noteworthy. By this means it has not only been possible to analyse the movements of waves and currents of liquids which are invisible to the naked eye, but even the displacements of molecules. From reports so far submitted, but as yet necessarily incomplete, it is believed that this research will aid materially in the solution of various problems connected with the mechanics of propulsion in fluids, at the same time rendering service in solving practical questions of ventilation, &c. The reader, if he has not noticed the rare experiment of successful machine flight of heavy bodies through the air, has probably had his attention called at times to the extraordinary difference between the performance of small steam vessels like yachts or tugs, where with equal power one glides through the water almost as though it offered no resistance, while another labours in rolling a formidable wave before it. The same differences occur in still more subtle form in the air. We cannot with the naked eye see separately, in either case, the currents that produce the effect, but by Dr. Marey's ingenious experiments photographic records can be obtained from which the forms which offer the least resistance can be studied.

The experiments of Prof. A. G. Webster, of Clark University, on the propagation, reflection and diffraction of sound, have achieved a result of practical value in the construction of an instrument capable of emitting an accurately measured sound. It is thus possible, in treating persons of defective hearing, to decide with exactness as to the degree of deafness in a subject, and to say if the power of hearing varies at different times. An instrument which furnishes the means of accurately determining these points should prove of value in medical treatment.

Prof. William Hallock, of Columbia University, New York, is conducting a research on the motion of a particle of air under the influence of articulate sound. General investigations allied to this subject, which are carried on in the laboratory of Columbia University, although in no way aided by the Hodgkins fund, have contributed helpfully to a knowledge of the principles underlying these experiments, and especially to certain parts of the investigation referring to the relation between the amplitude of vibration of an air particle and the amplitude of vibration of a film, or dust particle, suspended in the air. Dr. Hallock's research will be continued during the present year, when a final report is expected.

International Exchanges.—The importance of the work accomplished by the International Exchange Service is now well understood among men of science, and the benefits derived from it in the interchange of the publications of the civilised world are appreciated. The liberality of the American people in gratuitously supplying their scientific literature to appreciative students of it, wherever they may be, and the provision for its transmission at the expense of the United States Government and of the Smithsonian Institution jointly, are highly valued in the scientific world.

The term "International Exchanges" is now applied to the mutual exchange between Smithsonian correspondents everywhere of printed books on subjects of interest to the student in any branch of human knowledge.

The field covered by correspondents of the Smithsonian Institution and the contributors and recipients of its exchanges is now represented by one hundred and forty-eight countries, covering every part of the civilised world and extending to several countries where enlightenment has only commenced to manifest itself. In the latter are some of the most appreciative correspondents of the service. Outside the United States the Smithsonian correspondents now number 27,556, and including the United States there is a grand total of 35,705, an aggregate increase of 1754 during the year. The parcels received for transmission in 1900 numbered 121,060 (many of which contained several separate publications), representing an increase over the previous year of 7497 (Fig. 1).

In his last report Dr. Langley presented an account of his visit to London and Berlin during the summer of 1900 for the purpose of impressing upon the British and German Governments the desire of the Institution that they should each establish an international exchange bureau, or at least arrange for the transmission and distribution of exchanges so far as the United States is concerned. This work has been carried on between the United States and Germany and Great Britain from the beginning at the expense of the Institution, which has paid all expenses, even to the employing of a salaried agent in both countries. As yet no definite action has been taken by either Government.

Astrophysical Observatory.—It will be remembered that the observations of last year's eclipse by the Smithsonian expedition raised interesting questions as to the existence of intramercurial planets and as to the nature of the coronal radiations. So far did the interest in these problems extend that it was thought worth while to send an expedition from the Astrophysical Observatory to Sumatra to observe the total eclipse of May 18, 1901, and to repeat and extend the bolometric observations on the coronal radiation and the photographic observations for possible intramercurial planets. Solok, Sumatra, was the point selected for the observations. But, unfortunately, at the time of the eclipse the whole sky, excepting a perfectly clear belt around the horizon, was overcast with a sort of checkerwork of clouds, so thick that the corona could barely be distinguished. During the latter part of totality the very position of the sun was doubtful. Merely to have something to show to prove that the expedition had observed an eclipse, the programme for the intramercurial-planet apparatus was carried through, and the plates were developed. Those exposed in the first half of totality showed the corona faintly, extending out possibly a quarter or half a diameter, and showed the planets Mercury

and Venus. Nothing else could be distinguished, not even the first-magnitude star Aldebaran. The plates exposed during the last half showed even less, as the clouds were then thicker.

The accompanying illustration (Fig. 2) shows the instrument used to obtain the photographs. If the weather had been fine it would have been possible to have obtained photographs which

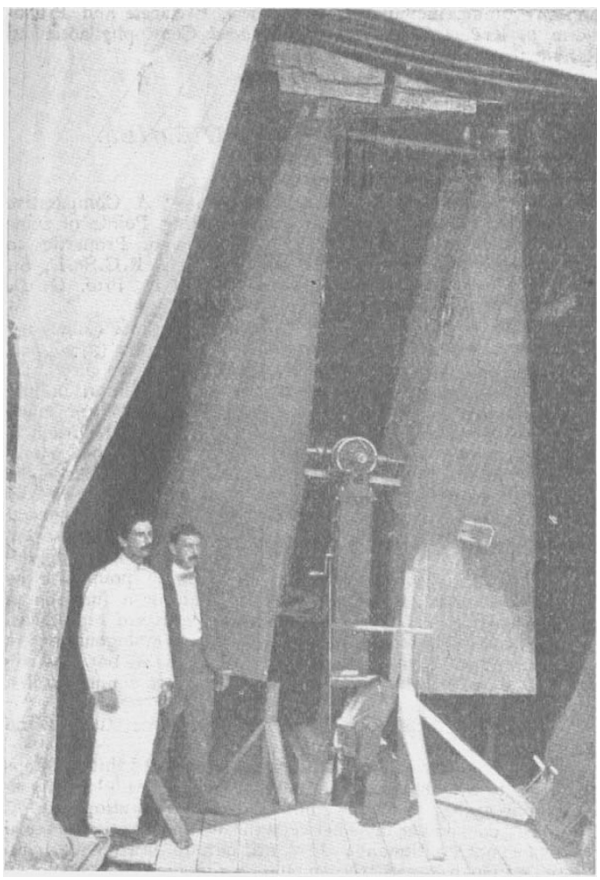

FIG. 2.—The Intra-Mercurial Planet Apparatus of the Smithsonian Institution.

would have decided whether the impressions of the supposed small planets within the orbit of Mercury, which appear upon the photographs of the previous eclipse, represent real bodies or not.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

A FEW particulars of the late Mr. Robert Irvine's bequest for the chair of bacteriology in Edinburgh University are given in the *Lancet*. Certain shares in the Christmas Island Phosphate Co., Ltd., are to form a separate trust to be invested until the property accumulates to the value of 25,000*l.* or 30,000*l.*, when the trustees are to pay the sum over to the Association for the better Endowment of the University of Edinburgh, or to such authorities in connection with the University of Edinburgh as the trustees shall deem expedient, for the purpose of founding a professorship of bacteriology in the University and the equipment of a class-room and laboratory for the teaching of the same, and for conducting original investigation in that subject.

FOLLOWING the example of the London Technical Education Board, the Central Welsh Board has arranged for a conference of science teachers, to be held on Thursday, May 15, at the County Buildings, Festiniog. At the morning meeting, papers will be read by Mr. J. Griffith, on "The Teaching of Science as a Preparation for Industrial Life," and Miss Holmer, on "The Value of Biological Teaching for Girls." At the afternoon meeting, papers will be read by Dr. J. J. Findlay, on "The Correlation of the Teaching of Science and Mathematics in Lower Forms," and Mr. W. Saunders, on "Nature Study as an Introduction to Science Teaching." It is hoped that the conference will assist the development of science teaching in Welsh intermediate and technical schools.

AT the Glasgow meeting of the British Association last year, a committee was appointed in connection with the section of Educational Science to consider the conditions of health essential to the carrying on of the work of instruction in schools. The committee is collecting information and tabulating records with reference to original observations on the periods of day appropriate for different studies, the length of lesson, and the periods of study suitable for children of different ages; anthropometrical and physiological observation forms in use in various schools, with a view to prepare a typical form for general use; anthropometrical and physiological observations recorded in different schools for a series of years on the same children; investigations into the causes of defective eyesight in school children and a definition of the conditions necessary for preserving the sight, and the practical knowledge of hygiene possessed by school teachers. Cooperation in obtaining information on these points is invited. Any facts or references relating to the subjects under consideration should be sent to the chairman, Prof. C. S. Sherrington, F.R.S., or to the secretary, Mr. E. White Wallis, 72 Margaret Street, W.

A NOTABLE event, marking the progress made by agricultural education in the States, will take place on July 7, when the first classes of the Graduate School of Agriculture assemble in the Townshend Hall of the Ohio State University. The Graduate School will provide advanced instruction in agricultural science for teachers and investigators. It meets under the auspices of the Ohio State University (where the movement originated), the Department of Agriculture, and the Association of American Agricultural Colleges and Experiment Stations. The session will last for four weeks, and parallel courses of instruction in animal husbandry, dairying, the culture of field crops and other subjects will be given by a special staff of thirty professors and lecturers, including many of the best-known teachers at the American agricultural colleges. The class-rooms, laboratories and apparatus of the Agricultural College of the Ohio State University will be placed at the disposal of this staff. Typical animals will be provided for demonstration purposes, and lectures will be illustrated by specially prepared specimens and diagrams. Admission to the school is limited to graduates, or to persons specially recommended by college authorities. The fee for instruction is six dollars, and the entire cost of the course, apart from travelling expenses, need not exceed thirty dollars.

SCIENTIFIC SERIALS.

American Journal of Science, April.—On the use of the stereographic projection for geographical maps and sailing charts, by S. L. Penfield. In continuation of previous papers on the same subject, the various modes of stereographic projection are described with photographic illustrations from models, with remarks on the use of the stereographic protractor for measuring distances along great circles, of measuring spherical angles at a given point, together with various applications in navigation.—On the hind limb of Protostega, by S. W. Williston. A description of a hind limb of what is probably *P. gigas*, found in the Kansas chalk two years ago. The specimen had for the most part been washed from its matrix, and the original relations of the bones lost. It is characterised by the femur being much more slender than the specimen described by Case.—The physical effects of contact metamorphism, by Joseph Barrel. Although much has been developed in past years concerning the physical, chemical and mineralogical effects of the metamorphism produced in sedimentary beds by the contact of igneous masses, but little has been said concerning the wholesale liberation of gases from the sediments so affected. The shrinkages of volume, the formation of vein fissures, impregnation deposits, and new intrusion