edges of the nebulæ; and the curved and inclined nature of the lines, when compared with those in the comparison spectra, indicate still more clearly relative movements in the nebulæ themselves.

THE RED SPOT ON JUPITER.—In the *Astronomische Nachrichten* (Bd. 158, No. 3786), Mr. A. Stanley Williams gives a discussion of his observations of the red spot on Jupiter during 1901. The planet was badly placed owing to its great southerly declination, but during the summer months the definition was exceptionally good. Tables are given of the times occupied in the transit of the spot over the mean meridian of the disc, measures being taken from both the middle and following end of the marking. The mean rotation period thus determined is 9h. 55m. 40·92s., which is 1·38s. shorter than the value deduced from the observations of the previous year. This shortening of the length of the rotation period has also been noted by several other observers. In appearance the spot was very faint, especially at the preceding end. The following extremity, however, was fairly dark; a distinct though faint reddish tinge was generally noticeable.

Several reductions of measures of the length of the spot are given as evidence in favour of Prof. G. W. Hough's statement that the spot has not materially changed in size during the last twenty years.

THE MEANING OF THE WHITE UNDER SIDES OF ANIMALS.

PROF. E. B. POULTON has sent us the following account of a discovery of great interest to naturalists made by Mr. A. H. Thayer, and a paper in which Mr. Thayer himself describes his observations and conclusions. This paper has been specially revised for publication in NATURE, and with Prof. Poulton's introduction will be welcomed by many observers of nature.

No discovery in the wide field of animal coloration has been received with greater interest than Mr. Abbott H. Thayer's demonstration, by means of models presented to the Natural History Museums of London, Oxford and Cambridge, of the cryptic effect of the gradation of animal tints, from dark on the back to white on the belly. In spite of the intense interest aroused in students of animal life from the side of art as well as from the side of zoological science, the underlying principles have been frequently misunderstood.

Mr. Thayer has seen some of the accounts of his discovery which have appeared in this country, and he feels that the explanation offered has been inadequate and sometimes misleading. He has therefore sent for publication in NATURE a further statement, which may be regarded as an appendix to his original memoirs in *The Auk* for April and October, 1896. In this statement he makes a too generous acknowledgment of my partial discovery of the same principle (unknown to him in 1896) in two isolated cases in 1886 and 1887. I should wish, therefore, to state that I did not discover, and could never have discovered, what it required the eye of an artist to see—viz. the manner in which the total colour-effect of the cold white under side of an animal bathed in shadow and yellow earth reflections matches exactly its earth-brown back bathed in the cold blue-white of the sky. I furthermore failed to see the wide application of that part of the principle which I did discover, and not only failed to see it, but actually applied to the white under sides of animals and the white eggs of certain birds the erroneous interpretation which was then commonly received, the interpretation which Mr. Thayer disposes of so completely in the article printed below.

The following account was drawn up by the present writer for the models presented by Mr. Thayer to the Oxford University Museum. It is believed that the description of the principles concerned may be useful to students in other museums. I should add that Mr. Thayer cordially approves this description of the principles he has discovered:—

"Motlels to show the manner in which wild animals are commonly hidden.

"Made and presented by Abbott H. Thayer, Esq., of Scarbro, N.Y., U.S.A.

"If the two model ducks in this case be looked at from a little distance, the left-hand model will appear almost invisible, transparent and ghost-like, while the right-hand one stands out in startling contrast. The former has a colour arrangement similar to that commonly found among wild animals in nature, while the latter is entirely different.

"There are two quite distinct elements in the concealment of the left-hand model, and of such an animal as a hare or a woodcock. First there is loss of all appearance of *solidity*, secondly there is the harmony with the *colour* of the background.

"We are led to believe that any small object is *solid* and possesses a definite shape solely because of the varying depth of shade on parts of its surface more or less shielded from light. (In the case of a very large object, such as a mountain, the adjustment required when the eye focusses its near and distant parts may also aid the judgment, but this could not apply to anything so small as an animal). Thus an artist can make an object on the flat surface of his canvas appear to stand out as a solid because he paints the shadows as they would be caused by the varying degree of light on the surface of a solid. Mr. Thayer has shown for the first time that the opposite operation is quite possible, viz. that an artist can paint a solid object so as to obliterate the shadows and as a result to remove all appearance of solidity. In the case of an object illuminated, as animals are in nature, by the direct and reflected light of the sky, this is achieved by colouring the object darkest on the top where the light is strongest, gradually less dark on the sides where the light progressively lessens, and white underneath where the light is least, the darkening of the colour corresponding exactly to the strengthening of the illumination. This will be seen at once by turning the handle at the side of the case. The right-hand model is, on the other hand, of uniform colour, and appears far darker on the sides than the back, and darker still, almost dead black, underneath.

"In fact the model which is the same shade of colour all over appears to be a different shade everywhere because of the difference in illumination; while the model which is of a different shade at every level appears to be the same shade all over because the differences of shade exactly counterbalance the differences of illumination.

"Animals in nature are commonly graded in colour like the left-hand model; and Mr. Thayer's discovery of this great and yet simple principle was made because he, as an artist, recognised the ghost-like appearance of wild animals and then set to work to analyse its cause.

"But the obliteration of solidity would not effectually conceal if the *colour* did not harmonise with the environment. The back of the model, and of animals generally, is of the same tint as the brown of the earth bathed in the cold blue-white light of the sky; the under side of the model and the belly of animals is of a cold blue-white bathed in shadow and yellow earth reflections. These two mixtures produce colour effects which are similar to each other and to the mixtures of intermediate components on the sides.

"Hence with *solidity* eliminated and with *colour harmony* between environment and object, the latter appears to be but a part of the former. It is thus possible to explain the concealment of the left-hand model, or of such an animal as the hare crouching motionless on bare earth, or the numerous sand-coloured quadrupeds, birds and reptiles of the desert; but upon the surface of most animals markings are added which suggest the details of a more varied environment, such as that presented by masses of brown leaves, twigs, reeds, grasses, lichen, &c. It is obvious that in an environment full of varied detail a colouring producing a uniform effect would not conceal; hence the markings on the woodcock, ptarmigan, &c. In such cases the animal itself appears to become part of the background while its markings are seen as the details.

"Mr. Thayer has also gained further proof of the accuracy of his interpretation by painting out the gradation of colour on the sides and belly of a stuffed bird, thus extending the colour of the back over all parts of the surface. Although a living bird with its natural colouring would be almost invisible in nature, the painted specimen became extremely conspicuous when placed in the natural attitude and amid natural surroundings.

"It is not too much to assert that the broad fact of the colour gradation on the sides of animals passing into white underneath has now for the first time received its interpretation. "EDWARD B. POULTON.

"Oxford, January 22, 1902."

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