Proceedings of the Iowa Academy of Science

Volume 6 | Annual Issue Article 5

1898

The Color of Deep-Sea Animals

C. C. Nutting

be seen that we, too, were foundation builders, that upon our work has risen a temple of science commensurate in usefulness, beneficence and inspiration, with the imperial destiny of our river-bordered state.

THE COLOR OF DEEP-SEA ANIMALS.

BY C. C. NUTTING.

The purpose of this paper is to explain the phenomena of bright colors among marine animals living in the sea beyond the depths to which sunlight can be supposed to penetrate to such an extent as to render bright colors visible. Although there are doubtless actinic effects of sunlight at considerable depths, we are safe, I think, in saying that colors cannot be clearly distinguished at a depth greater than 100 fathoms. Photographic experiments show that the "extreme limit of effect of the sun's rays on sensitive plates is at a depth of 250 metres," or less than 125 fathoms. As to the facts concerning coloration of deep-sea animals—and the deep sea may be considered from our standpoint as any depth below 100 fathoms—all our information leads to the conclusion that the phenomena of bright colors are present in all groups. The main sources from which I have drawn this conclusion are the "Challenger" Reports and Narrative, "The Three Cruises of the Blake," by Alexander Agassiz, and my own observations, most of which are recorded in my narrative of the "Bahama Expedition" sent out by the State University of Iowa. Professor Mosely, of the Challenger staff, says:*

"Peculiar coloring matters giving absorption spectra have now been found to exist in all the seven groups of the animal kingdom. The echinodermata and cœlenterata appear to be the groups which are most prolific in such coloring matter. Pentocrinin and antedonin seem to be widely diffused in immense quantities through the tissues of the crinoids in which they occur; and the echinoderms generally seem to be characterized by the presence of evenly diffused, abundant and

*Quarterly Journal of Microscopical Science, xvii, p. 1.

readily soluble pigments." Again he says "the same coloring matters exist in deep-sea animals which are found in shallow water forms."

Alexander Agassiz says that there are many "vividly colored bathyssal animals belonging to all the classes of the animal kingdom and possessing nearly all the hues found in types living in littoral waters."* He notices the scarcity of blue color, however, having found it only in an encrusting sponge and blue crustacean eggs. The following statements are important: "There is apparently in the abysses of the sea the same adaptation to the surroundings as upon the littoral zone. We meet with highly colored ophiurians within masses of sponges themselves brilliantly colored at a depth of more than 150 fathoms." "While we recognize the predominance of tints of white, pink, red, scarlet, orange, violet, purple, green, yellow and allied colors in deep-water types, the variety of coloring among them is quite as striking as that of better known marine animals." "There is as great a diversity in color in the reds, oranges, greens, yellows and scarlets of the deep-water starfishes and ophiurians as there is in those of our rocky or sandy shores.

"Among the abyssal invertebrates living in commensalism the adaptations to surroundings is fully as marked as in shallow water. I may mention especially the many species of ophiurians attached to variously colored gorgonians, branching corals and stems of *Pentacrinus* scarcely to be distinguished from the part to which they cling, so completely has their pattern of coloration become identified with it. There is a similar agreement in coloration in annelids when commensal upon starfishes, mollusca, actiniæ or sponges, and with crustacea and actiniæ parasitic upon corals, gorgoniansor mollusks. The number of species of crustaceans * * * colored a brilliant scarlet is quite large." "Large masses of brilliant orange-yellow or brownish-pink sponges are constantly dredged."

The results of my own observations fully confirm the above statements of Agassiz.

Among the crustacea we found that a bright scarlet was very common, while the remaining species were generally either green or pale colored. One remarkable exception was a bright blue *Solenolambrus*. The echinoderms were particularly striking in their colors. Yellow and purple comatulidæ

* "Three Cruises of the Blake," Vol. I, pp. 310 and 311.

abounded in deep water near Havana. One ophiurian was brown, conspicuously marked with white, others were marked with purple and deep violet. The simple-armed basketfish were bright yellow, or bright yellow barred with brown, or deep orange and rich chocolate. A *Luidia* was a rich chocolate with conspicuous white spines. Among the sea urchins may be noted a *Coelopleurus* with crimson and white spines, a *Salenia* with vermilion and white barred spines, an *Aspidodiadema* with spines banded with purplish velvet and white, a very brilliant *Coeloplourus* with spines barred carmine and white and a test with alternating chocolate and orange zones, an *Echinus* with a beautiful green test ornamented with white diamond-shaped patterns. The cœlenterates tell the same story; gorgonidae of brilliant crimson, orange, yellow and scarlet, corals red and pink and rose color and bright yellow plumularian hydroids.

The following general statements seem to me to be justified concerning the coloration of the animals of the deep sea:

First.—The coloration is fully as brilliant as in shallow water, although perhaps not so varied.

Second —The reds, orange, yellows, violet, purple, green and white predominate.

Third.—The colors, when they occur at all, are apt to be in solid masses in striking contrast, or the whole animal is of a uniform brilliant coloration. Fine patterns are very scarce and nature seems to have used a large brush in adorning her children of the depths.

Fourth.—There is a conspicuous absence of blue color among all groups. But two exceptions, a sponge and crab, have been noted.

A brief reference to the physical conditions of the deep sea is necessary to the proper understanding of the discussion in the latter part of this paper.* These conditions are:

First.—Great pressure, which of course increases with the depth. At a depth of 1,000 fathoms, the pressure is one ton to the square inch, a pressure 120 times greater than that to which we are subjected; while at 3,000 fathoms, the pressure is equal to that of 400 atmospheres Curiously enough, this enormous pressure does not seem to greatly affect the animals subjected to it. The bodies of many of them are composed

* Most of the data in this paper concerning physical conditions are taken from "The Three Cruises of the Blake," Agassiz, chapter xiii.

largely of water, which is nearly incompressible, while many invertebrates possess abundant skeletal tissues of limestone usually permeated by profusely branching canals containing watery fluid (echinoderms, corals, etc), or consisting of small particles or spicules, embedded in a watery coenasarc (alcyonaria, sponges), or with an external chitinous investment (crustacea).

When fishes are brought up from great depths their tissues almost fall apart, on account of the release of pressure; the swim-bladder projects from the mouth and the eyes are greatly protruded.

Second.—Deep-sea animals are subjected to a comparatively uniform low temperature. This temperature is between 38 degrees and the freezing point at all places below 150 fathoms. As we near the poles this low temperature approaches, and finally reaches, the surface.

Third.—Absence of wave novements. In many places, however, there is a steady mass-movement of the water in the shape of currents.

Fourth.—Practical absence of sunlight. By this I mean that the light penetrating to a depth below 100 fathoms can not be regarded as sufficient to enable such eyes as ours, and probably all eyes, to distinguish between colors.*

Fifth.—The presence in many places of animals giving forth phosphorescent light. This being an important phenomenon for our purpose, I have gathered together considerable evidence to show the extent to which this light-emitting power prevails among abyssal forms. It seems that phosphorescent light is found among the following groups of deep-sea animals: *Fishes*, along the lateral organs or on the head. *Salpa;* the Blake expedition secured specimens which were several yards in length and highly phosphorescent. Many *crustaceans*, *cephalopods*. Among the Challenger material were specimens having very efficient phosphorescent organs on the lower surface, and not only was the light emitted, but lenses were found for concentrating the light as does a bull's eye lantern.† *Ophiurians*, *Pennatulidæ*, which are described as

* Professor Verrill, however, maintains that a pale green light penetrates even to great depths. (See report of Commissioner of Fish and Fisheries, 1882, pp. 1054-1056.) This point will be discussed later.

† These remarkable structures were described before the zoological section of the A. A. A. S. at the Detroit meeting by Prof. William E. Hoyle, in a paper that was not published.

being brilliantly phosphorescent, *Gorgonidæ*, *Antipathidæ*, *Hydroida* and many *jelly-fishes*. Among the *Protzoa*, the noctiluca is perhaps the most widely diffused and numerically the greatest of all.

It should be remembered in this connection that it is altogether probable that the phosphorescence of deep-water forms, even where present, is only exceptionally discovered. While dredging operations are under way the work is usually done by daylight and the specimens are sorted and cared for as quickly as possible, only a small portion from considerable depths being alive when brought to the surface, and only a fraction of these being kept alive for nocturnal observations.

Under these circumstances, the occurrence of phosphorescence would be, as I have said, only exceptionally noted, even were it abundantly present in the forms studied. When we consider the above list of phosphorescent forms that have been recorded in spite of the conditions just referred to, it will be conceded that the actual amount of this light must be far greater than the face of the record shows.

It is well to bear in mind also, in this connection, that many of these phosphorescent forms, especially among the fixed cœlenterates, are aggregated together in masses on the sea bottom: No one can have had much experience in dredging in rich localities without noticing this. Agassiz speaks of "forests of gorgonians which become luminous by disturbances due to currents or other movements," * and I have frequently been surprised, when dredging on the Pourtales Plateau, at the immense quantities of echinoderms and cœlenterates secured at a single haul, indicating a profusion of life on definite areas of the sea bottom.

Taking the above facts into consideration, it is safe to say that phosphorescent light is a very characteristic and widely spread phenomenon which must enter into our discussion of the physical features of the deep sea.

It now becomes necessary to consider very briefly the nature and extent of organs for the perception of light and color with which the dwellers of the deep sea are endowed.

On this point Agassiz has the following statement: †

"We should not forget on the one hand that blind crustacea and other marine invertebrates without eyes, or with rudimentary organs of vision, have been dredged from a depth of

* "Three Cruises of the Blake," p. 308.
† "Three Cruises of the Blake," p. 307.

less than 200 fathoms, and, on the other, that the fauna as a whole is not blind as in caves, but that by far the majority of animals living at a depth of about 2,000 fathoms have eyes either like their allies in shallower water, or else rudimentary, or sometimes very large, as in the huge eyes developed out of all proportion in some of the abyssal crustacea and fishes; and undoubtedly adapted to make the most of the little light existing in deep water."

Verrill bears practically the same testimony:*

"That light of some kind and in considerable amount actually exists at depths below 2,000 fathoms may be regarded as certain. This is shown by the presence of well-developed eyes in most of the fishes, all of the cephalopods, most of the decapod crustacea and in some species of other groups. In many of these animals the eyes are relatively larger than in the allied shallow water species." This author thinks that the rudimentary eyes in many gastropods are due to burrowing habits.

It may be said in general that a greater proportion of eyes in abyssal regions are either rudimentary or wanting, on the one hand, or unusually large and effective, on the other, than in shallow water.

We now come to the main purpose of this paper—the attempt to explain the phenomena of coloration among animals of the deep sea. The theories heretofore advanced may be briefly summarized as:

First.—The vain and impotent conclusion that this profusion of color is meaningless. Beddard frankly makes the following statement:† "The inevitable conclusion, therefore, from these facts appears to be that the brilliant and varied colorations of deep-sea animals are totally devoid of meaning; they cannot be of advantage for protective purposes, or as warning colors, for the single and sufficient reason that they are invisible."

This sort of unconditional surrender is unworthy of the scientific spirit of the age. Beddard, however, it must be remembered, delights in finding evidence whereby he can throw discredit on the Neo-Darwinian school. It would have been much more to the point had he contented himself with saying that the utility of these colors had not as yet been explained.

* Report of Commission of Fish and Fisheries, 1882, p. 1054.
† Animal Coloration, p 37.

Second.—The green-light theory of Verrill. This is an attempt to explain brilliant coloration as protective.* He says in effect that sunlight penetrates to even the greatest depths and that only green rays reach those regions. He calls attention to the fact that the reds are the predominant, conspicuous colors in deep-sea forms and concludes that in a green light red would be invisible and thus the color would be protective.

Two objections present themselves to this theory. In the first place, it is incredible that a sufficient amount of sunlight penetrates to great depths to render protective coloration necessary.

Agassiz, whose knowledge of the deep sea is unsurpassed, says:†

"We may imagine a reddish, yellow twilight at a depth of about fifty fathoms, passing into a darker region near the 100 fathom line; and finally, at 200 fathoms, a district where the light is possibly that of a brilliant star-light night."

Now, when we remember how little of color can be seen in the most brilliant moonlight, and how soon all colors but white, if that be a color, are rendered undistinguishable at the approach of dusk in the evening, it becomes evident that our credulity cannot meet the requirement of this theory, *i. e.*, that green rays penetrate even to 2,000 fathoms or more in such quantities that protective coloration is needed. Again, even if it should prove that light does thus penetrate, animals would be equally well protected by neutral tints without the lavish expenditure of pigment which is so conspicuous among deep-sea forms.

The third and last theory regards the presence of bright colors and of functional eyes in so many groups as conclusive evidence that light is present in the abysses of the ocean, but considers that the widely diffused phosphorescent light, and not sunlight, is the aid to vision. This theory was adopted by Dr. W. B. Carpenter and Sir Wyville Thomson, and is the view which the present writer regards as the most reasonable.

Let us briefly recapitulate the facts which are important in this discussion:

I. *As to coloration of deep-sea animals.*

(a) Brilliant colors are common in all groups.

* Report of Commission of Fish and Fisheries, 1882, p. 1054, et seq.
† "Three Cruises of the Blake," p. 305.

(b) Reds, yellows and greens predominate.
(c) These colors are in masses, usually in striking contrast.
(d) Commensal associations of similarly and brilliantly colored animals are frequent.

II. *As to physical conditions:*
(a) Great pressure.
(b) Uniform low temperature.
(c) Practical absence of sunlight.
(d) Aggregation of animals in limited areas.
(e) A considerable amount of organic matter near the bottom.

III. *As to visual organs among deep-sea animals:*
(a) They are possessed by a majority of animals that normally possess them in shallow water.
(b) They are often of great size among deep-sea forms.
(c) They are often, on the other hand, either rudimentary or aborted.

IV. *As to phosphorescent light:*
(a) It is found among practically all classes of deep-sea forms.
(b) It is often of remarkable brilliancy. I, myself, have seen it so brilliant, on the surface of course, that ordinary print could be read from the deck of a vessel.
(c) It is possessed by animals that are known to be aggregated in immense quantities at certain spots at the sea bottom.
(d) It has the remarkable actinic property of rendering particularly conspicuous the reds, yellows and greens.*

Here, then, it would seem that we have a light that would render the characteristic colors of deep-sea animals, *i. e.*, the reds, yellows and greens, conspicuous, and no less nor more explicable than similar colors among their shallow-water relatives. In many cases they are doubtless to be regarded as warning coloration, as in the sea urchins, whose sharp spines are frequently banded with brilliantly contrasted red and

*Mosely found that the phosphorescent light emitted by certain marine forms consisted of red, yellow and green rays only, and adds: "Hence, were the light in the deep sea derived from this source, in the absence of blue and violet, only red, yellow and green colors could be effective." (Quoted from Agassiz' "Three Cruises of the Blake," p. 310.)

white. This may also be true of bright red gorgonians, pennatulidæ and sponges, with their glassy spicules, and red corals, with their very large nematocysts.

The various cases of commensal association, such as the ophiurians, resembling the brilliant gorgonians upon which they climb, would thus be readily explained as instances of protective resemblance.* Among the crustacea the numerous cases of bright red, red and white or green coloration may be possibly capable of explanation along the lines of directive coloration, whereby the individual may recognize its own species, and thus the meeting of the sexes be facilitated. It must be remembered that many deep-sea crustaceans have excellent eyes. In short, these brilliant colors in all groups can, according to this theory, be explained by reference to the same laws that prevail on land or in shallow water.

Beddard regards as a fatal objection to this theory the fact that the eyes of many deep-sea dwellers are apparently now in the process of degradation. But the same thing is found among the mud-dwelling mollusca and the sponge-inhabiting crustacea, such as *Alpheus* in shallow water. Mud and sponges are also found in deep water and have their inhabitants as well. Again there are doubtless vast areas in which the phosphorescence is exceedingly feeble or entirely wanting, and yet they are not necessarily or even probably tenantless. In such places the possessors of eyes would find them worse than useless and gradual atrophy would ensue. I must confess to an utter inability to see the force of Beddard's so-called "fatal objection."

A side-light is thrown on our discussion by some of the well known facts concerning cave fauna. These facts are:

First.—Cave animals are almost universally colorless, or at least are not brightly colored.

Second.—I have been unable to find any record of phosphorescence among cave animals.

Third.—Blind animals are common in cave fauna.

Fourth.—No cave animals, so far as I know, are characterized by greatly enlarged eyes.

It would thus seem that the absence of phosphorescence in

*Beddard explains such cases by saying that the parasite actually assimilates and deposits in its own skin the pigments of the host. (Loc. Cit., p. 38.) When we consider that the colors of the gorgonians are in the hard and jagged *spicules alone* we cannot withhold our sympathy from the ophiurian, which has either to eat such unattractive fare or in some way to absorb it through the skin.

caves has rendered both brilliant colors and large eyes useless, and thus both have been rigidly suppressed.

The presence of phosphorescence in so many animals which are supposed to be sightless, *e. g.*, pennatulids, gorgonians and hydroids, is hard to explain.* Indeed, it is not properly within the scope of this paper to explain it. A suggestion occurs to me, however, that may be worth noting. These animals feed, for the most part, on minute crustacea and on protozoa. Most crustacea, and more particularly *their embryos*, have functional eyes. *May they not be attracted by light*, as is the case with shallow-water forms? The protozoa are generally without distinct organs of vision, but many of them are, nevertheless, apparently attracted by light. If this is true, we have a reason for phosphorescence among the fixed cœlenterates. It attracts the prey. This, to my mind, is more plausible than the theory that it is a protective contrivance.

We may thus imagine the bottom of the sea to be for the most part dark, but with limited areas where are congregated phosphorescent animals that give forth sufficient illumination to render striking colors, particularly red, yellow and green, distinctly visible, enabling them to play the same role that they do in shallow water, and bringing them within the province of the same laws.

NOTES ON THE HEMIPTERA OF NORTHWESTERN IOWA.

BY HERBERT OSBORN.

From the difference in geological and floral conditions of the northwestern part of the state, we might naturally expect a somewhat interesting insect fauna. Occasional specimens of species, rare or unknown in the central part of the state, have come to hand and, especially in Hemiptera, have served to strengthen a desire to investigate more thoroughly the fauna in this order. Many of these additions have been due to the

* Verrill thinks that phosphorescence in these cases is of value in warning away enemies from the nettling cells. I have been unable to find nematocysts among the gorgonidæ and have never seen them mentioned as found among pennatulids. They are seldom of large size among the hydroids.