ON THE SPECTRAL CHARACTERISTICS OF PROTECTIVE COLORATION

THE following note is of the nature of a preliminary report on some investigations made last summer at Woods Hole. In this investigation an answer was sought to the following specific question: Is the color of a protectively colored animal spectrally similar or dissimilar to the color of the background which it matches?

The significance of the question lies in the light it can throw on the nature of color vision in animals. Take, for instance, the color of the frog—his head and back so closely resembling the slime of stagnant pools that it is difficult to detect him. If, in the first place, this color is adaptive, if the resemblance really helps to conceal the frog either from prey or enemies; and if in addition it can be shown that the frog's green and the green of the slime are, spectrally considered, different mixtures, it follows that the organisms from which the frog is concealed have color vision which in this respect at least agrees with our own. Color, as a natural fact, is not a physical but a psychological entity and a knowledge of facts like this is a knowledge of the *experience* of other organisms. There are those among biologists who deny the existence of adaptations in the sense of directed evolutionary responses by an organism to an environment. It is perhaps not out of place to note that such a denial is here beside the point. All that is really postulated in the case of the frog is that green frogs are safer from enemies or more dangerous to their prey than red frogs would be, so that while the language here implies a particular point of view the conclusions are largely independent of the biological philosophy which may have directed the work.

One obvious difficulty presents itself. We may be confident that cases of adaptive coloring exist but it is difficult to establish the adaptive nature of any particular case. Undoubtedly some cases of close color resemblance are accidental, in the sense of being unrelated to the external life of the organisms, so that it is only by multiplying instances that any general probability can be established. Again, while material of a general sort is available in large quantity, the number of clear cut types is much smaller. The exclusion of material rests upon various grounds, among which may be mentioned:

(*a*) The adaptation is to a very generalized background, and is usually accomplished by similarity of *pattern* as much as by hue. Thus the plumage of the quail and the markings of the garter snake serve admirably to conceal them in natural surroundings, but it is hard to pick out a pair of specific color matches. These cases, which are very numerous, can now be studied in the light of the knowledge of camouflage obtained during the war and some work of this kind has, I believe, been done. This work, which requires special training of the kind possessed by painters, seems capable of yielding very valuable information, but the results would be pertinent to the present inquiry only in so far as they might help to establish more generally the fact of the existence of color adaptations.

(*b*) The pair of colors is such as to offer little variety of possible composition. Reds and blues cannot be synthetized in as many ways as greens and yellows, so that the matches of these colors will necessarily show only minute spectral differences.

From this it follows that the most suitable material is furnished by color matches with a solid green or yellow background. The cases which were found most suitable were those of animals colored green to match the leaves and grass in which they lived. Such cases are very numerous among reptiles and insects and are particularly good instances because the green of chlorophyll has well marked spectral characteristics, being relatively deficient in the blue-green. On the other hand, many green insects assimilate directly in the epidermis the chlorophyll of the leaves on which they feed. Thus the katydid and the tomato worm are colored with actual chlorophyll. For such cases there would necessarily be no spectral difference and there is moreover not the same presumptive evidence of color adaptation. There remain, however, a large number of instances of which a few were studied.

The method of study adopted was by the use of color filters. These were used either (1) by illuminating the animal on its background with white light and viewing through the filter; or (2) by illuminating with the light trans-

mitted through filter. For the cases studied the two methods are equivalent, the first being suited to the study of organisms in their out of doors environment, and the second being on the whole more convenient in the laboratory. The two methods are not in all cases equivalent, as will be noted later.

The filters used were an improvised set made by fixing out and washing ordinary photographic plates and dipping them in dyes. These were made before going to Woods Hole and all dyes of the rather meagre stock available were tried out. These included some pre-war specimens of commercial "Diamond Dyes" and it is perhaps unfortunate that some of the most useful filters were made from these dyes of unknown composition. The most important filter is, however, Brilliant Green (Gruebler). Used in combination with Diamond Orange this transmits deep red and the blue end of the green. Seen through this combination foliage appears brownish red, whereas most artificial green pigments appear more intensely green. Used with Diamond Turkey Red the same general effect is produced, the obliterated portions of the spectrum being somewhat wider so that the greens appear bluer and the reds purer. Used with Diamond Olive Green, foliage appears straw color. Brilliant Green and eosin transmits only red and blue.

The most characteristic phenomena are shown by the common grass snake (*Liopeltis Vernalis*). The use of this animal, a specimen of which was secured early in the investigation, was suggested by the late Dr. George Lefevre, and saved much time which might otherwise have been spent in search for suitable material. This is to the eye so good a match for the grass which it inhabits that it is hard to discover the snake even when the observer is looking directly at it. When viewed through any of the filter combinations mentioned above the contrast is vivid and startling. The snake appears a vivid green, or, in the case of the eosin combination, deep blue—in absolute contrast to the red or yellow grass. A photograph, which can not here be reproduced, exhibits this contrast, the panchromatic plates used being more sensitive to the red than to the green, so that the snake appears darker; but no photograph can reproduce the violence of the color contrast. The green of frogs is of a similar character. Certain grasshoppers (*e.g. Melanoplus femur-rubrum*) have in their coloring a green that is spectrally different from leaf and grass greens, also the green of the so-called Florida chameleon (*Anolis Carolinensis*). This last changes from green to brown, but the coloring is not clearly adaptive.

These scattering observations and a few others were all that the time permitted last summer. While not sufficient to warrant definite conclusions they indicate clearly that color vision similar to human exists lower in the phylogenetic scale. It is hoped that next summer will furnish instances sufficiently numerous to settle this point definitely. In addition, many interesting lines of development open up, some of which will now be indicated.

Color is, as remarked above, not a physical but a psychological entity. To be green is to appear green to some percipient and it is the visual experience of this percipient that alone can explain the color in the sense in which we here use the word "explain". To make this sense clear it may be noted that though we may or may not have an explanation of the absorption spectrum of chlorophyll or hemoglobin, such an explanation would not touch the problem of the greenness of grass or the redness of blood. This being understood, the question arises: For what percipients does the color of a given organism exist? Now according as it can be shown to exist for the organism itself or for its environmental enemies or prey, we are led to biological implications of quite different kinds. In the first case we would be led to consider the evolutionary development of the adaptation as guided from without by natural selection or some similar process, whereas in the second case we are led to think of an evolutionary process self contained within the organism. These two points of view divide evolutionary speculation into two classes which we may call the peripheral and central types and the class of facts which these investigations open up seems suited to throw light on this very fundamental question. Keeping this philosophical problem in mind, let us enumerate some definite questions of fact which need to be settled.

(1) Just how low in the scale of organisms does color vision exist? The snakes and lizards have vertebrate enemies from which protection is needed. Most insects have birds to fear, so

that the few instances here studied give information only about the vertebrate eye. Cases of coloration among marine organisms are known which indicate color vision in anthropods, and the current explanation of the colors of flowers presupposes an ability of insects to discriminate color, but more information on this point is needed.

(2) Some animals have variable color and some at least of these make their own color response to visual stimuli. The most conspicuous example is the flat-fish. The very thorough studies of Mast and others establish the fact that this sees color, but no tests have been made to see whether, for instance, a red-green combination would be matched by its subjective equivalent, yellow. Here we have an animal which can actually be put through the same kind of psychological test that is applied to men. We ask it in effect, "What does this look like to you?" and tests can be made for after-image colors, contrast illusions, etc. Such tests seem likely to throw more light on color vision in animals than any other line that is now open. In this connection a point of technique in the use of color filters should be noted. It was said above that it is a matter of indifference whether the grass snake is illuminated with white light and viewed through the filter, or illuminated with the filtered light. This is true for an animal of fixed color, but it will be readily seen that the experience of the snake is different in the two cases, for in the second case it shares with the observer the color contrast produced. As a matter of fact the snake manifested no uneasiness at being thus rendered so startlingly conspicuous, indicating that color experience does not form a part of his ordinary response, though this can hardly be affirmed definitely on the basis of a single uncontrolled observation. In the case of an animal like the flat-fish, however, it is clear that the two methods of observation would lead to quite different results, for in the second case the fish would respond so as to make the contrast disappear as far as possible.

(3) Does color perception imply color *vision, i.e.,* are eyes essential to the process of color response? The question may seem absurd, but cases are cited in the literature of larvae forming chrysalides matching a background in which blinding the larvae did not alter the response. It may be that the underlying photochemical processes are here generalized in the skin instead of being confined to a specific end-organ. This would place color response on the same footing with most others, but the present meagre indications of fact must be widely corroborated and extended before any conclusions can be drawn.

(4) Do animals with dichromatic color vision exist? Is, for instance, the brilliant plumage of the cardinal really a contrast to the surrounding foliage for the eyes that are most concerned with finding him?

The writer hopes during the next and succeeding summers to continue work on some of the problems here raised.

This work was rendered possible by the generosity of the Nela Research Laboratories of the General Electric Company, who defrayed the expenses of the work at Woods Hole. To a physicist venturing into foreign fields the biologists there were most generous in their advice and encouragement. To Dr. Ralph S. Lillie in particular my thanks are due for his unfailing interest and helpful suggestions.

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FEBRUARY 28, 1923

LONGEVITY IN THE SOUTHERN STATES

THE federal statistics of 1920 are very important because they afford the first satisfactory opportunity of estimating longevity in the southern states. It is true that southern states were added to the registration area for deaths a few years before 1920, but as population statistics are collected only at decennial intervals the year 1920 is the first year at which both mortality and population statistics of the southern states are directly available.

As the negro has so often been referred to as the most disturbing factor in the progress of this country the results of an investigation into the relative longevity of southern states whose populations include such large numbers of negroes should be of considerable interest and importance. The writer believes that the general feeling among those interested in the problem has been similar to his own that such results would prove alarming. If so, the results