EXPERIMENTS ON COLOR VISION IN MICE IN RELATION TO THE DUPLICITY THEORY.

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With 15 figures in the text.

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Introduction.

The duplicity theory may be said to have originated, in principle, with Max Schultze. He recognized (1866) the two types of retinal sensory cells, rods and cones, in the eyes of many vertebrates, and considered that they probably had different functions in regard to sensitivity to colored and non-colored light. As it is known at present, however, the duplicity theory is chiefly the work of von Kries (1905). By means of a great variety of experiments on the human eye he was able to make a clear statement of the theory. Strictly interpreted, the theory may be stated as follows (von Frisch 1925): "The cones: color sensitive, only slightly adaptable, relatively sensitive to light of long wave length (maximum of brightness of the spectrum in yellow; red appears relatively bright opposite blue); the rods: totally color blind, highly adaptable, relatively sensitive to light of short wave length (maximum of brightness of the spectrum in green; red has no stimulating value and blue is relatively bright)." Most of the evidence on which the theory is based may be found in all textbooks of physiology and needs no repetition here.

Within recent years a rather large literature has grown up on the subject of color vision in animals, and especially in vertebrates. Unfortunately most of the latter are works of psychologists who have been interested not so much in the physiology of vision, in relation to the structure of the retina, as in the sensory factors which may influence the general behavior of the animals. In the case of mammals, with the exception of man, there are very few works on the physiology of vision, as distinct from the psychology. In consequence little attention has been given to the relation between retinal structure and function.

The early researches of Schultze (1866) showed that the proportion of rods and cones in retinae is different in different animals. While in
man, according to this author, both rods and cones are abundant, in the cat and dog there are relatively few cones among the many rods. In other mammals, such as the mouse, guinea pig, and mole, he was unable to find any cones. These observations, and those of later authors, indicate that in general the vertebrates which have their time of activity during daylight have both cones and rods, while those accustomed to night activity have few or no cones among the rods of the retina.

Although, as will be considered later, there have been works on color vision in mammals lacking or having relatively few retinal cones, most of them have led to no definite conclusion as to the ability of coneless specimens to see color. The aim of the present investigations, therefore, was to learn if mice, which are generally considered to have retinas of the all-rod type, can see colors, in the qualitative sense, and in this manner to submit the duplicity theory to a test.

I am happy to express my great appreciation to Professor K. von Frisch for suggesting this work to me and for giving me advice and criticism during the progress of the investigations. Also I owe him thanks for permitting me to work as a guest in his laboratory and for providing me with the apparatus and supplies necessary.

Remarks on the Literature.

It is neither necessary nor advisable to go here into a consideration of the great amount of literature on the duplicity theory and on color vision. Only some of the more outstanding and conclusive works on color vision in mammals, and on rodents in particular, will be mentioned. Only recently von Frisch (1925) gave a comprehensive general review of the works on the subject of the duplicity theory.

Perhaps the most important antagonist of the duplicity theory within late years was von Hess. He was decidedly opposed to any view which credited the fishes and invertebrates with a sense of color: In a review of the subject as late as 1912 he held to this opinion. According to his view the duplicity theory could not hold, for it was known that the lower vertebrates such as fishes have retinas containing both rods and cones. His results, in which it was found that fishes gather in the yellow-green portion of the spectrum, which is the brightest part to the dark adapted or color blind human eye, were construed to signify the animals' seeking of brightness without reference to color as a qualitative factor. However, von Frisch (1925 and previous papers) was foremost in demonstrating that fishes can actually see colors as different in quality from non-colored light, and he was able to show the association of the degree of photo-mechanical adaptation of the retinal elements with the presence or absence of the color sense. This work constituted one of the most important supports of the duplicity theory.