

**STUDIES ON  
CERTAIN PHYSIOLOGICAL AND  
Biochemical Aspects of Vision In Some  
Arthropods**

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" STUDIES ON CERTAIN PHYSIOLOGICAL AND BIOCHEMICAL  
ASPECTS OF VISION IN SOME ARTHROPODS" submitted  
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Philosophy of the North-Eastern Hill University,  
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## GENERAL INTRODUCTION

In the simplest way of definition, vision is a physiological phenomenon by means of which an organism sees the objects around it. Since, vision is a photo-physiological phenomenon, the two most important factors involved in the process are, (1) light and (2) photoreceptor, the organ, which is capable of absorbing light.

The electromagnetic radiation reaching the surface of the earth includes X-rays, ultra-violet, visible and infra-red light, micro-waves and radio-waves. The radiation travels in the form of quanta of energy. The energy is determined by the wave-length; the smaller the wave-length, the greater the energy ( Dethier, 1963 ).

Of the total radiant energy spectrum, only a very small segment, which is termed as visible light can be detected by organisms. The visible spectrum lies between about 300 to 800 m $\mu$ , although ultra-violet wave-lengths down to about 210 m $\mu$  can be detected by some organisms. (Dethier, 1963 ).

To receive the radiant energy of this narrow band of the spectrum, the prime requisite for an organism is the visual pigments present in the photoreceptor organ. In the animal kingdom, there is a variety of photoreceptor organs. The most primitive type of photoreceptor is the eyemspot of Euglena, which is capable of detecting only the presence or absence of light. In metazoans, there are more complex receptor organs or eyes, which are capable of forming some type of

image on the photoreceptive surface.

The most highly developed organs of vision in the animal kingdom are the vertebrate eyes and the eyes of cephalopod molluscs. These eyes have the refractive element, lens to focus light from an object, and it forms an inverted image on the retinal surface.

Among the photoreceptor organs of animals, the compound eye of arthropods has attracted many of the vision physiologists because of its unique structural organisation. Compound eyes of arthropods are image - forming eyes. They are capable of determining the plane of polarized light, and the animals can use such information for orientation or directed locomotion.

The compound eye consists of a number of structural and functional units, known as ommatidia. The number of ommatidia varies in different species. As for example, the worker of the ant, Ponera punctatissima has only one ommatidium, whereas in some Odonata the number is between 10,000 and 28,000 or more ( Wolken, 1968 ).

An ommatidium consists of a corneal lens, a crystalline cone and retinula cells. The cornea is a transparent area of the cuticle and it forms the facet or lens of an ommatidium. It is more or less bi-convex and is cast off during each act of ecdysis ( Imms, 1957 ).

Beneath the cornea is the transparent body known as crystalline cone.

Immediately behind the crystalline cone are the sensory elements or the retinula cells. The number of retinula cell is not constant in all species. In many ommatidia, the number of retinula cell is eight, e.g. Apis. In certain cases, the number is reduced to six or seven. In certain moths, the retinula cell are ten to twelve in number ( Imms, 1957 ). Crustacean Ommatidia are also similar ( Waterman, 1961 ). The retinula cells collectively secrete an internal " light-trapping " rod-like structure known as rhabdom. The portion of the rhabdom, contributed by each retinula cell is known as rhabdomere. The rhabdomere is analogous in function to the retinal rod outer segment of the vertebrate eye ( Wolken, 1968 ).

In addition to these structures, the ommatidia of compound eyes contain a number of pigment cells. Surrounding the crystalline cone and corneagen layer are present a layer of densely pigmented cells, known as Primary iris cells. Primary iris cells and the retinula cells in turn are surrounded by a second group of elongated pigment cells, known as secondary iris cells. These pigment cells serve to isolate one ommatidium from the next.

The arrangement of these various components of the Ommatidium, however is not constant in all forms. Exner( 1891 ) has described two distinct types of compound eyes in arthropod, on the basis of difference in their anatomy. They are the apposition and superposition eyes.

The apposition type of compound eyes are characteristic of diurnal insects. Among the crustaceans, this type of eye is found in diurnal, terrestrial and littoral forms. In apposition eye, which is also known as photopic eye, the rhabdom is long and thin, and it lies directly beneath or against the crystalline cone. A double-layered sheath of pigment cells surround each ommatidium, and thus it is optically isolated from its neighbour. Light falling upon the lens of an ommatidium can only reach the rhabdomeres of that ommatidium. During light-dark adaptation, there is little or no longitudinal migration of the screening pigments. But in some cases there is radial movement of the screening pigments around the rhabdom due to the change in condition of illumination ( Walcot, 1974 )

Superposition or scotopic eyes are those in which short and broad rhabdom lies some distance away from the crystalline cone. A marked longitudinal migration of the screening pigments during light - dark adaptation is a characteristic feature of this type of eye. During a condition of bright illumination, the pigment granules migrate inwards and extend the full length of the ommatidium. At dark, however, the pigments move upward and condense distally between the crystalline cones. The superposition eyes are found in nocturnal or crepuscular species ( Dethies, 1963 ).

To explain the functioning of the compound eye of arthropods, Johannes Muller (1826) formulated the classical theory

known as "mosaic theory". According to the theory, each ommatium receives light from its own lens. Light falling on the lense of one ommatidium cannot reach the adjacent one because of the presence of pigment-sheath. Thus, an image of the limited part of the visual field is produced by each ommatidium and the entire eye forms the image from the "reports" from individual ommatidium.

Since the time of Muler's "mosaic theory" (Muller, 1826), the compound eyes of arthropods have been extensively studied by different groups of authors from various disciplines to explain the mechanisms involved in photoreception in this group of animals. But, in spite of a large amount of work on the compound eyes, it seems that much research still remains before one can completely understand how compound eyes perform this complicated visual phenomenon.

It is seen from a review of previous works on the subject, that there is a need for some more information on certain aspects of arthropod vision.

To give an example, the lens, which covers the ommatidium of a compound eye is modified cuticle. It is well known that the nature of the cuticle of insects and other arthropods varies in different regions of the body, which perform various types of functions (Richards, 1972). It is also evident that the chemical nature of cuticles involved in various functions may vary (Wigglesworth, 1952). Since lens performs a special optical function of conducting light rays to the rhabdomes, besides playing a general defensive role, it is

expected that the lens -cuticle may differ in chemical nature and ultra-structure from the cuticle covering other parts of the body. But the chemical composition of the lens in relation to its special function has not been studied in detail. In the similar way, there are many other aspects in this field of research, worth-studying.

The migration of the screening pigments, for example, is one such area, which needs further investigations. The movement of pigment granules in the compound eyes during light-dark adaptation has been described by Exner(1899,1891) and has been reviewed by Parker(1932) and Turala(1954). Since that time, extensive amount of works have been performed on the subject. But inspite of that, we do not have a clear idea regarding the mechanism which controls the migration of the screening pigments. However, the phenomenon is more or less clearly understood in crustaceans (Fingerman 1959), but there is little information on the physiological control mechanism of eye-pigments migration in insects.

Another interesting aspect of arthropod vision is the fluorescence of the compound eyes. Many authors have detected fluorescence in the compound eyes in vivo (Hess 1920; Mercker 1929; Kay 1969). It has been observed that the compound eyes on irradiation with ultraviolet light in a darkened room give a blue or blue-green fluorescence. Hess( 1920) has suggested that the U.V. sensitivity of the compound eye may be due to the fluorescence

set up in various tissues of the eye. This suggestion however, has been rejected by Walther and Dodt (1959) and Goldsmith (1961 a). Since that time, a great amount of controversy centres around the subject.

Another very important area, where there is a lacuna in our knowledge is the enzymology of the compound eyes. It is well established that certain enzymes, especially, adenosine triphosphatases (ATPases) are intimately associated with the process of photoreception (Langer, 1963, Drujan and Ali 1972) but in spite of an extensive investigation on the activity of this enzyme in the photoreceptors of various vertebrates and invertebrates, there is very little information regarding the study of ATPase system from the compound eyes of arthropods.

Keeping all these in view, certain histochemical, biochemical and physiological studies have been performed on the compound eyes of some arthropods.

The animals which have been chosen for the present study are the house-fly, Musca domestica (Insecta); the honey-bee Apis-Cerana indica (insecta); the fresh-water prawn, Macrobrachium birmancium (Crustacea); and the marine prawn, Metapinneus sp. (Crustacea).

The aim of this research programme is to gather some more informations regarding certain physiological and biochemical aspects of vision in arthropods, with the available facilities.