CHAPTER II

STUDIES ON LIGHT AND DARK ADAPTATIONS
formation (Wigglesworth, 1957). Further, mucopolysaccharides may play role in increasing transparency of lens-cuticle. In this context, it is worth mentioning that during corneal development of vertebrates, rise in transparency of stroma was found to be associated with occurrence of mucopolysaccharides (Anseth and Fransson, 1970).
INTRODUCTION

Vision is a special somatic efferent sense. It is necessary for the eye to be adapted to various stages of illumination for maximum efficiency and a characteristic feature of this adaptation is the movement or migration of screening pigments in the eye.

The visual pigments of all invertebrate, including insects, crustaceans and squids are all rhodopsins. The biological significance of rhodopsin is that they absorb light through the visible spectrum as well as the UV spectrum or range. Lythgoe (1979), showed that the rhodopsin granules prevent reflection of transmitted light. The maximum absorption value of different rhodopsins range from about 345nm (ultra violet) to as high as 610nm (red) (Autrum, 1981; Arikawa, 1999). The absorbing properties of any given rhodopsin are related to the disposition of changed opsin groups around the chromotophore.

The retinal pigment granules (rhodopsin) in the pigment epithelial cells exhibit distinct movement during light and dark adaptation, and thereby help in the process of visual adaptations in various photic levels. Several methods of dark and light adaptations are known- some methods being characteristic of particular groups, although a particular species normally possesses more than one method. According to Lythgoe (1979), the various adaptive methods can be divided into three classes i.e. (i) optical regulation of the light reaching the visual pigment through the pupil (ii) absorption by the visual pigment and (iii) neural processes

The pigment granules as well as the rods and cones themselves, move in response to changes in light intensity in such a way that particular cell type are shielded from unwanted light. These changes are collectively known as
retinomotor or photomechanical movements. The phenomenon of retinomotor movement was first studied separately by Boll (1877) and Kuhne (1877) and has been reviewed by Blaxter (1970). Other notable works are those by Ali (1971), Ali and Wagner (1975), Munz (1971), Walcott (1975), Lythgoe (1979), Ferrero et. al. (1979), Anctil et. al. (1980), Klyne and Ali (1980), Kunz (1980), Fernald (1982, 1988), Kaneko et. al. (1981), Burnside and Nagle (1983), Teranishi et. al. (1983), Weiler and Wagner (1984), kurz-Isler and Wolburg (1986, 1988), Dey et. al. (1994). Both arthropods and vertebrates show several distinctive retinal specializations associated with several daily activity rhythms (Hoars, 1987). Several adaptations for light (photopic) and dark (scotopic) vision are accomplished by changing the intensity of light at the receptor site and the most common feature of light and dark adaptations is change in concentration of visual pigments and modification in neural interaction (Munz, 1971).

Pigment migration has been studied in many invertebrates as well as in all groups of sub-mammalian vertebrates. In arthropods it is more striking in superposition eyes but also occur in apposition eyes. Retinal pigment migration in vertebrate is rapid and pronounced in fishes, frogs and birds but slow and slight in turtles and crocodiles and absent in snakes and mammals. Pigment migration is regulated by hormones in crustacean (Highnam and Hills, 1979), but not well understood in insects and it may depend on nerves (Goldsmith and Bernard, 1974).

The physiological basis of adaptation in the visual system has been studied by Barlow (1972), Pugh (1975), Autrum (1981), Shapley and Enroth-Cugell (1984), Lamb (1981 and 1990), Tamura et. al. (1989, 1991),

In insects, the pigments of the iris move in response to changing photic conditions, and are also otherwise known as screening pigments or accessory pigments. The most widely distributed amongst these pigments are the “ommochromes”. They may be of different types - ommatin, ommin and ommidin being the most important. Ommatin can be further of three types, out of which xanthomatin is the only one found in the eyes, as seen in case of Calliphora and related flies, where it is the principal pigment. Ommin on the other hand is the most widely distributed of the ommochromes in the compound eyes of other insects. It differs from ommatin in respect of a higher molecular weight as well as reduced tendency towards auto-oxidation (Wigglesworth, 1965). Ommidin is closely related to ommin and is chiefly found in the eye of orthopterans. These pigments move in response to changes in light intensity i.e. in relation to light and dark conditions, but other anatomical changes during light and dark adaptations are not similar in all insects.

In the apposition type of compound eyes, the major portion of the retinular cells i.e. up to one-third of its width from the rhabdom, is filled up by elongated large vesicles of the palisade (sacks of endoplasmic reticulum)-the pigment granule occurring between the vesicles of the palisade as well as in the peripheral cell-cytoplasm (Kirschfeld and Franceschini, 1969). In dark-adapted condition, the palisade surrounds the rhabdom, while during light-adapted state, the palisade is reduced to a great extent. In addition the pigment
of the retinula cells move toward the rhabdomeres as seen in Musca (Kirschfeld and Franceschini, 1969).

Light and dark adaptations are associated with the longitudinal movement of pigment granules in the retinula and pigment cells of lepidopteran compound eyes, as also in fireflies, while in the beetles (example, Dytiscus) it results in the movement of some retinula cell bodies (Walcott, 1969). Another interesting feature of light-dark adaptation is the extensive changes in the shape of the cone cells along with their movement with the crystalline tract and rhabdom of the retinula cells - a typical example being seen in hemipterans (Walcott, 1974).

Studies on pigment migration in compound eyes of arthropods started as long back as in 1889 through the pioneering works of Exner (1889), yet the mechanism is still open to conjecture, even though much work is being done in this field. Some prominent workers like Day (1941), have found that in moths subjected to cold, narcosis, CO₂ or even injury, the pigments move and assume a state similar to that of light-adapted condition. Similarly Stavenga (1977) has shown that in praying mantis and katydids, the circadian movement of the pigment is influenced by temperature. He found that a light-adapted state can be achieved during dark via cooling.

In the dragonflies, Austrolestes annulosus and Ischnura heterostecta, pigment migration is associated with pronounced colour changes that resemble that of their epidermal chromatophores (Veron, 1973). During light phase the pigment is concentrated around the base of the crystalline cone as a layer of Tyndall (blue) bodies to produce a bright blue colour, but during dark phase the pigment migrate distally and this disrupts the Tyndall effect, and the eyes
turn grey-brown in colour. Thus, pigment migration and epidermal chromatophores are under similar environmental and physiological control (Veron, 1973).

Other notable works are those by Kitamato et al. 1998; Kelber and Pfaff (1999), Kinoshita et al. (1999), Kinoshita and Arikawa (2000), Hardice (2001), Kelber et al. (2003) etc who have worked on colour vision of honey bees, butterfly, nocturnal hawkmoths and fruitflies. Studies on the reflection of butterflies and bumblebee ommatidia with respect to angular and spectral sensitivity have been carried out by Stavenga (2000a, 2000b, 2003a,b, and 2004) and Skorupski (2007). In crustacean eyes the phenomenon of light and dark adaptation have been studied by Meyer-Rochow (2001), in insects by Meyer-Rochow (1974), Keskinen and Meyer-Rochow (2004), Meyer-Rochow and Mishra (2007), etc. An interesting work has also been done by Lau and Meyer-Rochow (2006) and Lau et al. (2007) on sexual dimorphism of the compound eyes with respect to light and dark adaptation in coleopterans and lepidopteran.

A point to be noted here is that movements of the pigment granules and also the rods and cones are not synchronized, and in some cases either type can occur in the absence of the other. But an unalterable fact is that movements during dark adaptations are much slower, requiring times to the order of an hour to complete (Walcott, 1975).

That these movement must be integrated with the nervous system is an accepted fact, but its mechanism is poorly understood. Kakcheyev (1943) had put forward the hypothesis that dark adaptation is under nervous control. Similarly, Veron (1973) and Dey (1980), have suggested that neurosecretion
and pigment migration are affected by photopic and scotopic states. This has been further confirmed through the works of Deb (1990) and Bendang (1998), who also attributed photopic and scotopic states on the phenomena of neurosecretion and pigment migration in fishes and birds respectively.

It is now known that dark adaptation involves rods and much summation, while light adaptation involves cones and much lesser summation. Moreover, the time taken for the different stages of adaptation is different *i.e.*, the initial stages of adaptation are quite fast (less than one-fifth of a second), while the later stages are less faster. In this regard, Lythgoe (1979) has suggested that perhaps the whole neural organisational changes *i.e.* from light to dark and *vice versa* is accomplished within thirty minutes.

Ali (1964 a), has suggested the possibility of hormones in influencing pigment migration, and Bagnara and Hadley (1969), believed that in all probability it is via intermedin. Other workers like Novales (1959), Van de veerdonk (1962) and Freeman *et. al.* (1968), *etc.* suggested that ions are involved in pigment migration - these (transmembrane) ions acting through intermedin. Thus, Fujii (1969) suggested that both nerves and hormones, either alone or in tandem may be involved in pigment migration.

Different responses induced in the retina by different illuminations are signalled or transmitted to the brain (via the optic nerve) - individual signals from neighbouring cells interacting and adding up, so that their sensitivity is the sum of their respective areas (Pirenne, 1967), but exactly how, is an ongoing area of research (Lythgoe, 1979).

Von Frisch (1911), first reported the role of nervous control of pigment migration in blinded minnows. He showed that the diencephalon was
sensitive to light. Scharrer (1952b) put forward the concept of neurosecretory cells forming a link between the endocrine glands and the nervous system. But reports on the relationship between vision and neurosecretion in insects is scanty. Therefore an attempt has been made to study the effect of light and dark on the neurosecretory system. This is because an accumulation and discharge of secretory materials in the brain (optic lobe) of the two insects in response to light and dark condition is expected.

Another important aspect that has been undertaken is on the role of neurosecretory products. The role of hypothalamic neurosecretion in integrating various physiological events is well-documented (Geris *et al.* 2002; Sharp and Sreekumar, 2002). It is known that biogenic amines are released instantaneously for rapid physiological adaptation to light and dark condition. In addition the role of catecholamines, alkaloids and secondary messenger have been reported to be involved in visual systems (Scheline, 1963; Scott, 1965; Bonner, 1971; Bitensky *et al.* 1973; Robinson *et al.* 1971; Anctil *et al.* 1979; Vander *et al.* 1980; Devries *et al.* 1982; Hasegama and Cahill, 1999; Kato *et al.* 1982; Burnside *et al.* 1982; Allen and Burnside, 1986; Koumenis *et al.* 1995) etc.

Thus the involvement of serotonin or 5-Hydroxytryptamine, cyclic AMP and colchicine in the visual process have been investigated in the present work.

**MATERIALS AND METHODS**

*Adaptation to light and dark conditions:* Two groups of experimental insects, each containing about 20 insects were selected. One group was kept in light
for three hours for light adaptation, while the other group was kept in darkness for the same period for dark adaptation. After the completion of three hours the insects of both the groups, were decapitated and the eyes quickly removed and fixed in alcoholic Bouin’s fluid. The next day the eyes were washed in distilled water, then routine histological preparation were carried out by paraffin embedding method and 8 µ thick sections cut for microscopic preparations and study. The sections were stained in paraldehyde fuchsin-one step tichrome (Gabe, 1966). In the case of the dark adapted eyes, all the preparations were carried out in light-proof vials, since pigment migration might take place when exposed to light (Ali, 1964).

*Effect of light and dark on neurosecretion:* Two groups of insect, each containing about 20 insects were adapted in light and dark for three hours each. After the required period of adaptation, the insects were decapitated immediately and the heads fixed in alcoholic bouin’s fluid and a hole was done on the head for penetration of the fixative and kept for 24 hours. The brain was then taken out and again fixed in the fixative for another 24 hours. Then routine histological preparation were carried out for paraffin embedding method and 8 µ thick sections cut. The sections were stained in Paraldehyde fuchsin- one step tichrome (Gabe, 1966).

*Effect of 5-hydroxy tryptamine, cyclic AMP and colchicine:* Three groups of insects of ten each were adapted in complete darkness for three hours. After three hours, the insect were given topical application of 0.1ml of 5-hydroxytryptamine, cyclic AMP and colchicine respectively. Each of the
drugs were dissolved in insect’s Ringer’s solution. The concentrations of 5-hydroxytryptamine, cyclic AMP were 0.8mM each while the concentration of colchicine was 0.3mM. One hour after topical application of drugs, the eyes were dissected out and fixed in alcoholic Bouin’s fluid. Then routine histological preparations were made and 8 micron thick sections were cut. The sections were stained in paraldehyde fuchsin-one step tichrome (Gabe,1966).

**OBSERVATIONS**

*Adaptation to light and dark conditions:* In the light adapted state, there was radial movement of pigment granules whereas in the dark adapted state, there was peripheral distribution of the pigment granules. However all parts of retina did not respond equally (Photoplates 5-8).

*Effect of light and dark on neurosecretory system:* When both the insects are dark adapted there was a large accumulation of neurosecretory material in the form of compact neurosecretory granules as evident from the positive reaction to Paraldehyde- fuchsin stain (Photoplates 10 & 12). In contrast to this, when the insects were light adapted, it was observed that there is a significant reduction of the neurosecretory material (Photoplates 9 & 11), presumably due to the axonal transport of neurosecretory material. The cytoplasm now appearing lightly stained, and the shape of the cell becoming slightly irregular.

*Effect of 5-hydroxytryptamine, cyclic AMP and colchicine:* Light microscopic studies of paraffin sections of dark-adapted eyes revealed that in all cases, almost complete migration (dispersion) of retinal granules similar to
controlled light adapted eye occurred *i.e.* after treatment with 5-hydroxytryptamine, cyclic AMP and colchicine. There were no marked differences in retinal pigment granule dispersion between groups receiving 5-HT, cAMP and colchicines (Photoplates 13-18).

**Photoplates 5&6**

**Photo plate 5**: T. S. of the light adapted eye of *Pieris brassicae* showing radial distribution of pigment granules (100X).
*Co* (Crystalline cone); *Rh* (Rhabdom)

**Photo plate 6**: T. S. of dark adapted eye of *Pieris brassicae* showing peripheral distribution of pigment granules (100X).
Other details as in photo plate 5.
Photoplates 7&8

**Photo plate 7:**  T. S. of light adapted eye of *Philosamia ricini* showing radial distribution of pigment granules (100X).

**Co** (Crystalline cone);  **Rh** (Rhabdom)

**Photo plate 8:**  T. S. of dark adapted eye of *Philosamia ricini* showing peripheral distribution of pigment granules (100X).

Other details as in photo plate 7.
**Photoplates 9&10**

**Photo plate 9:** T. S. of light adapted brain of *Pieris brassicae* showing reduced neurosecretory content in the neurosecretory cells (100X).

NSC (Neurosecretory cells)

**Photo plate 10:** T. S. of dark adapted brain of *Pieris brassicae* showing large accumulation of neurosecretory material in the form of compact neurosecretory granules in the neurosecretory cells (100X).

Other details as in photo plate 9.
**Photoplates 11&12**

**Photo plate 11**: T. S. of light adapted brain of *Philosamia ricini* showing reduced neurosecretory contents in the neurosecretory cells (100X).
NSC (Neurosecretory cells)

**Photo plate 12**: T. S. of dark adapted brain of *Philosamia ricini* showing large accumulation of neurosecretory materials in the form of compact granules in the neurosecretory cells (100X).
Other details as in photo plate 11.
Photoplates 13, 14 & 15

**Photo plate 13**: T. S. of dark adapted eye of *Pieris brassicae* treated with 5-hydroxytryptamine showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Co (Crystalline cone); Rh (Rhabdom)

**Photo plate 14**: T. S. of dark adapted eye of *Pieris brassicae* treated with cyclic AMP showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Other details as in photo plate 13.

**Photo plate 15**: T. S. of dark adapted eye of *Pieris brassicae* treated with colchicine showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Other details as in photo plate 13.
Photoplates 16,17 &18

**Photo plate 16**: T. S. of dark adapted eye of *Philosamia ricini* treated with 5-hydroxytryptamine showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Co (Crystalline cone); Rh (Rhabdom)

**Photo plate 17**: T. S. of dark adapted eye of *Philosamia ricini* treated with cyclic AMP showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Other details as in photo plate 16.

**Photo plate 18**: T. S. of dark adapted eye of *Philosamia ricini* treated with colchicine showing radial movement of pigment granules similar to that seen in light adapted state (100X).

Other details as in photo plate 16
DISCUSSION

The basic physiology of the photoreceptor system has been adapted in many different ways to varied habits and habitats. Two basic adaptive features being (i) the change in the length and shape of photoreceptors that are brought by changes in the lighting conditions of the environment (Ferrero et. al. 1979) and (ii) the dispersion or concentration of pigment granules (Ali, 1964).

The compound eye which performs well over a wide range of light intensities has several adaptive mechanisms associated with activity during both day and night. These adaptive mechanisms are the primary devices for controlling the amount of illumination which reaches the photosensitive cells. They depend on several photo-mechanical or retinomotor responses involving rapid changes in the pigment distribution, and the action of contractile elements in the lens and in the retina (Hoars, 1987).

Light conditions induce topographical differences within the retina where some type of retinal cells may respond by moving, while some remain in place, even within the same species (Walls, 1942; Tansley, 1965). At night the maximum available light should impinge on the receptors, but where illumination is adequate, another significant problem arises with regard to resolution of pictures because the retinal elements or small groups of cells must be excited separately from different parts of the objects. At night acuity is sacrificed for sensitivity and light is collected from many angles to excite the receptor cells.

Most of the diurnal insects have apposition eyes in which radial movement of pigment granules occurs. On illumination, small pigment granules move towards the rhabdomere, and assemble in the immediate
neighbourhood of the rhabdomere, constituting a longitudinal pupil. The optical formation of this pigment migration and other photochemical effects is presumably to control the amount of light in the photoreceptor organelle \( i.e. \) the rhabdomere.

Pronounced longitudinal pigment migrations are characteristic features of nocturnal or crepuscular species with superposition eye. The superposition eye is common in insects and crustacean that live in dim habitats or lead a nocturnal life (Nilsson, 1989). The clear zone in the superposition eye allows light that enters the eye through many facets to be focused on more or less one single photoreceptor in the retina (Land, 1981; Stavenga, 2006). In this way superposition eyes have the potential to collect more light than apposition eyes without having to sacrifice resolving power.

The pigment granules near the rhabdomere lead to two effects \( v i z \) (i) it tends to increase the refractive index of the surrounding zone (negating or reducing the total internal reflection and intensifying the surrounding) and (ii) absorb a fraction of the light coming from the organelle. According to Stavenga (1974), the rhabdomere acts as an optical wave guide owing to its high refractive index as compared to its surrounding medium. The rhabdomere/organelle propagates a set amount of energy and this is a function of the difference in refractive indices between itself and its surroundings, as also of its physical dimensions and of its physical dimension and wavelength.

But the mechanism by which the pigment granules alter their position in relation to change in the condition of illumination is not clearly understood and a number of suggestions have been put forward. For example Lerner and Takahashi (1956) have discussed the role of ionic exchange between cell
exterior and interior with regard to pigment migration. Ishibashi (1957), Eugenio (1988) and Matthews and Fain (2001) suggested the importance of intracellular calcium ion level in pigment migration and Fain et. al. (2001) reported that change of free Ca^{++} is believed to have a variety of effects in the transduction mechanism. Kinoshita (1963) put forward the view that electro-chemical changes causes melanin migration in fish melanophores; Wiksow and Novales (1969) commented on the role of microtubules in pigment aggregation and dispersion in the scale of fishes.

Pigment migration in the compound eyes of insects is a rapid process. The palisade in *Locusta* requires fifteen minutes of dark adaptation to develop fully (Walcott, 1974). In the cockroach *Periplaneta americana*, where both palisade and pigment granular changes have been observed, anatomical light adaptation requires ten minutes of exposure to light (Butler, 1971).

Adomian and Sjostrand (1975) showed that microtubules must be assembled and disassembled in connections with myoid elongation and contraction. The role of microtubules and microfilaments in retinomotor responses was demonstrated by Warren and Burnside (1978). They found that actin and myosin like-filament are responsible for cone contraction of some marine teleosts. Further the disappearance of the microtubules following colchicine-induced block of cone elongation suggests that microtubules mediate cone elongation through a sliding mechanism. Similarly Anctil et. al. (1979) have shown that rod contraction is mediated by microtubules, but not elongation, and suggested that there may exist inter and intra-specific differences in retinomotor (rods versus cones) mechanisms in lower vertebrates.
Different light conditions induce responses in the retina, which then signals the pattern to the brain via the optic nerve. The signals from the individual rods, cones or retinular cells are not transmitted to the brain in isolation from its neighbour, but the signals from neighbouring visual cells may interact with each other, and may be added up together so that their sensitivity is the sum of their respective areas or, they may inhibit each other (Pirenne, 1967). However, it is likely that the reception of a single photon by a vertebrate rod is potentially enough to trigger a response (Ashmore and Falk, 1976). In this respect Walls (1942) has commented on the confusion surrounding the mechanism that controls photochemical movements.

There are topographical differences within the retina itself, where some types of rods or cones may respond by moving, while others do not move, even within the same species (Walls 1942; Tansley 1965). Munz and McFarland (1977) have reported that some predator fishes have also adapted their cones for low light intensities.

Pigment migration is either controlled by nerves or hormones or both (Fujii, 1969). In this connection, an earlier work by Enami (1955) can be correlated. Enami (1955) proposed a two hormone hypothesis which assumed two antagonistic principles. An example is melanocytes stimulating hormone (MSH) and melanocyte containing hormone (MCH) which are involved in melanin dispersion and concentration. But this hypothesis is not universally accepted, because in fish melanophores MSH is solely responsible for both pigment concentration and dispersion.

Ali (1964a) also suggested that hormones may influence pigment migration. This was based on the fact that when goldfish were dark adapted,
the rods did not move, but the retinal pigment partially expanded. In all probability, intermedin is the actual hypophyseal agent involved in melanophore responses in fishes (Bagnara and Hadley, 1969), though Chavin (1956) emphasised the role of ACTH in melanophore response of fishes.

The role of nervous control of pigment migration was revealed when Von Frisch (1911) reported that the diencephalon of blinded minnows is sensitive to light. Davson (1970) has shown that teleosts possess both nervous as well as hormonal control over their melanophores whereas the former plays the major role. But Osborn (1938) has shown that in catfish both hormonal and nervous factors are equally responsible for pigment dispersion. Works in this regard are those by Day (1941), Fujii (1969), Dey (1980), Deb (1990), Bendang (1998) and Bendang et al. (2004).

Veron (1974) opined that in dragonflies, the eye pigment cells act as independent effectors during proximal migration, but the control of the distal migration appears to be complex. Distal migration is reduced significantly in the eyes, as well as in the chromatophores of decapitated insects. Another observation was that in both the pigment cells of the eyes and the epidermal chromatophores, distal pigment migration occurs at similar rates. Thus, the close relationship between visual adaptation and a neurosecretory mechanism is evident.

That the neurosecretory cells represent a connecting link between the nervous system and the endocrine glands has been proposed by Scharrer (1952b). The neurosecretory cells respond to stimuli despite their glandular activity, i.e. they receive stimuli from the nervous system and transmit it to endocrine glands. Gabe (1966) had also shown that there is a general
relationship between hypothalamo-neurohypophyseal secretion and general adaptation. Ames and Van Dyke (1952) also showed that neurosecretion is elaborate during alarm stimuli. Therefore, it is logical to assume that neurosecretion is involved in the maintenance of equilibrium of an organism with its surroundings via adaptive processes.

The role of hypothalamic neurosecretion in integrating various physiological events is well documented (Geris et al. 2002 and Sharp and Sreekumar 2002), however reports on the relationship between vision and neurosecretion in insects are lacking. In the present experiment, dark-adapted insects showed large accumulation of neurosecretory material, whereas in light-adapted ones, the quantity was distinctly reduced. This may be due to the fact that rate of discharge is slower in dark, while in light, apart from a faster discharge, the production of secretory material is slower. Presumably, during light, axonal transport of neurosecretory material takes place. Thus, accumulation and discharge of the material may be an optical or visual adaption in response to photic and scotopic condition.

There are, generally two types or classes of neurosecretory products viz, (i) neurotransmitters with low molecular weights such as dopamine, 5-Hydroxytraptamine, adrenaline and nor-adrenaline (catecholamines) and (ii) those with relatively high molecular weights such as neuropeptides (biogenic amines). They are responsible for physiological phenomena requiring instantaneous liberation of the neurosecretory products.

In the present experiment the effect of these products have been tested. It has been seen that on application of 5-HT to dark adapted eyes, a reversal to a light-adapted state is seen in both the insects. It can be mentioned that 5-HT
directly affects pigment migration or via release of dopamine. The 5-HT induced dopamine acts as an extracellular messenger to induce a light-adapted cone retinomotor movement (Allen and Burnside, 1986). In this connection, 5-HT has been reported to have melanin aggregating action (Scheline, 1963; Scott, 1965). Moreover, Kato et al. (1982) showed that Ca++ dependent 5-HT stimulated dopamine release a carp retina. Desai (1996) also showed that 5-HT induces alterations in the kidney of the fowl Gallus domesticus.

Another physiological activator i.e. cyclic 3, 5-adenosine monophosphate (cAMP) has been taken up for study in the present work. It is well established that it acts as an intracellular messenger (Robinson et al. 1971), as a regulatory agent in all animals cells (Bonner, 1971), triggers specific responses of the cells (Vander et al. 1980), mimics the effect of intermedin by expanding melanophores (Bagnara and Hadley, 1969). It is also known to play an important role in the visual system. Some notable works are by De Vries et al. (1982) on ground squirrel retinas, Burnside et al. (1982) on photic adaptations of retinomotor movements, Hasegawa and Cahill (1999), on entrainment of retinal photoreceptors, Rey and Burnside (1999) on cone myoid elongation etc. In the present experiment it has been shown that cAMP triggers pigment migration similar to light adapted state when applied to dark-adapted eyes of the two insects.

Apart from this, the effect of colchicine, an alkaloid, has also been tested to see its role in the visual adaptation of the two insects. This has been taken up based on reports of its involvement in the visual adaptational process of other animals. On application of colchicine to dark-adapted eyes of the insects, a reversal to that of a light-adapted state has been observed. This
observation is in consonance with the findings of Miller and Cawthon (1974) who found this same effects in pigment granule movement of *Limulus* retinular cells. Colchicine has been reported to disperse melanosomes of the scales of *Fundulus* (Wikow and Novales, 1969) and also inhibits cone myoid elongation and rod myoid contraction (Anctil et al. 1979).

The rationale behind this is that, the microtubules are important motile processes concerned with intracellular transport in nerve cells, gland secretion and pigment flow of chromatophores (Hoars 1987). Thus Shelanski and Taylor (1968) had concluded that the radially oriented microtubules of retinular cells mediate light and dark induced pigment migration. This was also corroborated by Margulis (1973), who showed that microtubules are dispersed by colchicine. Colchicine specifically binds the tubulin protein of the microtubules subunit (Shelanski and Taylor, 1968).

A photoreceptor is a light trap that converts radiant energy into nerve impulses. The metabolic activity of the photoreceptor cells is due to mitochondria and other associated organelles, which generate chromoproteins and transmitters affecting synapse. The chromoproteins are subject to destruction by light (Young, 1970) and therefore the transmitters must be steadily passed into synaptic vesicles (Hoars, 1987).

Thus, photopic stimulation results in a co-ordinated response of the visual and the neurosecretory systems. In this connections, Buchanan (1957) postulated that since vision is a special exteroceptive sense, it is logical that neurosecretory materials are discharged under the influence of exteroceptive or visual impulses, which are then transported through the hypophyseal portal
system to the interior hypophysis. In the hypophysis this leads to the synthesis and release of anterior lobe hormone (Palay, 1953).