Chapter – 3

ULTRASTRUCTURAL STUDY OF EYE LENS OF SOME VERTEBRATES

INTRODUCTION

The vertebrate eye is the main organ responsible for the physiology of vision which appeared after millennia of evolutionary development. Its main optical component, the lens which transmit and focus light energy on photosensitive transducing inner elements the retina.

The visual process involves three steps: first is the optical stage when an image of the outside world is projected into retina being aided by cornea and lens; second is the transduction stage when the photosensitive visual cells absorb photons and respond by generating electrical signals, and third is the physiological stage when these primary signals are analyzed. Possibly there is a fourth stage that marks the conscious awareness of visual display.

Thus vision is a complex and integrated process of reflection, selective absorption and a psychometric process to see the objects.

The lens is an optically dense, flexible living structure located between the primary fixed refracting surface of the cornea and the retina. The lens has two principle optic properties – transparency and refractive power. The crystalline lens suspended radially from the ciliary body by the Zonular fibers attached on either sides of its equator. (Stafford, 2001)

A capsule called lens capsule encases the cellular elements of the lens. This capsule is highly elastic which is actually a thick basement membrane, secreted by the lens epithelial cells and to which the zonular fibres attaches. The bulk of the lens consists of lens fibers. These are actually vastly elongated lens epithelial cells that have lost their nuclei and many of their organelles. Since they are no longer cells and are of great length they are called lens fibres. Between the capsule and the outer most layers of the lens fibres is a single layer of epithelium cells. Blood vessels, lymphatic, and nerves are not in the lens, which continues to increase in volume, weight and size through out the life (Hogan et al., 1975). The
The eye lens is located just behind the iris. It is held in position by Zonules extending from an encircling ring of muscles. When the ciliary muscle is relaxed, its diameter increases, the Zonules are put under tension and the lens is flattened and when contracted, its diameter is reduced, the Zonular relax and the lens becomes more spherical. This change enables the eye to adjust its focus between far object and near object (Kimbell, 2005).

The eye lens is a transparent tissue that transmits and focuses light on the retina (Fig. 3.1). It is located behind the iris and aqueous humor and is covered by a collagenous capsule. Beneath the anterior surface (outward facing) surface of the capsule is a single layer of epithelial cells that is the major site of metabolic activity in the lens. Epithelial cells migrate from this region towards the lens equator where they differentiate and elongate to form lens fiber cells. As these cells differentiate, they lose their nuclei and organelles. New cells are formed throughout the life, but older cells are not lost as they age. Rather they are compressed in the center (nucleus) of the lens. A large proportion of constituent proteins become more dehydrated and concentrated in older lenses. In order to transmit light properly, fiber cell structural proteins must remain unaltered for decades.

Dioptic apparatus or lens is one of the most important structure associated with the functioning of photoreceptors in both compound and camera type of eyes. The lens of vertebrates performed extensive and varied functions. Despite refractive function they may act as interference filters and may reduce reflection of an undesirable amount of light and also help in selective absorption of light (Bernhard et al., 1965; Sorniya, 1976; Dey 1988).

The crystalline lens of the vertebrate eye is ectodermal in origin is a cellular structure. Initially the posterior cells of the lens vesicle elongate to form the primary lens fibers, later cells multiplies and forms the secondary lens fibers which compresses the old lens materials towards the center. This result in the formation of variable density and refractive index that of the center being higher than that of the periphery (Kulshrestha, 2005).
The lens divides the eyeball into a front compartment filled with watery aqueous humor and a larger more posterior compartment filled with viscous vitreous humor. The lens is divided into two parts: outer cortex and inner nucleus or medulla. Cortex represents a zone of fiber mass of new cells while the nucleus representing the more central and oldest cells of the lens. The function of the lens is to collect and focus light on the retina. According to Campbell (1967), the crystalline lens is a bio-convex, transparent structure, which is enclosed in a highly elastic non-cellular capsule of varying thickness. A single layer epithelium cells below it form the capsule. The substances of the lens are composed of series of ribbon like fibers, which arises from the equatorial region, and are arranged in concentric laminae. The fibrillar cells proceed from the equator towards the center. The thickness of the lens capsule is not uniform: the part covering the posterior surfaces of the lens is uniformly thin, and while the part covering the anterior surface is mostly thicker within a thin central position. The transparent lens possess a regularity of cellular arrangement (Kuck, 1970).

The shapes of the lens are indifferent in different species. In aquatic and nocturnal vertebrates the lens is usually spherical and almost designed to its optical shape (Pumphrey, 1961 and Westheimer and Fuortes, 1972). It is also seen in most fish that the lens is perfectly spherical or slightly flattened and brittle. It is crystalline with high refractive index (Matthiessen, 1882).
have large firm and flattened lenses. In reptiles the lens is soft and small in comparison to the eye. In mammals it is big, ovoid, flattened and soft (Kuck, 1975).

The lens is composed of lenticular fibers. Each fiber may be providing with some side projection called nipples. The shape of the nipple shows variation in different vertebrates. The visual process in all animals is governed by same physical rules for adjustment in a particular ecological niche. The lights activate some photosensitive molecules ultimately leading to image formation. The significant photochemical processes of life depend on a few different pigmented molecules, which absorb radiant energy to initiate vital biochemical and physiological processes (Hoar, 1987).

Scanning electron microscopy performs the ultra structural study of lens of some vertebrates. At least 6 lenses of male adult specimen and 6 lenses of female adult specimen of equal sized are observed for each investigated.

AIMS AND OBJECTIVES

From the review of earlier works, it has been found that ocular structure especially that of the eye lens, exhibits several variations from species to species, and corresponds to habitat and physiological conditions. The ocular refracting structure, which plays extensive and varied roles in the visual system in addition to its normal function of refraction of light.

They regulate the quantity and quality of light entering the retina by acting as interference filters, reducing reflection from the eye surface, helping the reflection of the specific wavelengths from the region behind the receptive cells and assisting in selective light absorption. Eye lens of different vertebrates also shows specialization as well as structural modification in response to photoadaptation. Very few studies have been made on the structure of the lens regarding the variation and specialization in different vertebrates. Moreover different animals adapt to different light conditions.
The aim and objective is to study the ultra structural differences and relation exists among the lens of different vertebrate. In the present studies, the attempt has been made to study the structural variation of the structure of eye lens in certain representation from piscian to mammalian species and analysis of structural transition corresponding to their habitat, physiological events and phylogenetic status.

MATERIALS AND METHODOLOGY

MATERIALS:

The lenses were carefully excised from the eyes of various fresh species collected from different sources. These lenses were fixed for SEM study for observation its structure. Atleast lenses from six individual animals of each sexes and same age are used for investigation.

METHODOLOGY:

Scanning Electron Microscopy:

In the present study “SEM” had been carried out with the electron microscope of Zeol make. The different steps followed for SEM are as follows:

1. Fixation: To fix the tissue in maximum life like condition the lenses were immediately remove from eye of fresh animals and were cut into small pieces. Those were than fixed in 3% glutaraldehyde in 0.1M sodium cocoodylate buffer (Ph 7.2 – 7.4). It was kept there for 3 to 8 hours in approximately 4° C inside an icebox.

2. Putting buffer: After 3 to 8 hour, 0.1M sodium cocoodylate buffer (Ph 7.2 – 7.4) was put drop by drop to cover the tissue completely in the test tube. Here the material can be kept for a minimum of 12 hour to a maximum of 15 days. After putting buffer the material are kept in the refrigerator in below 4° C.
3. **Post Fixation**: Post fixation was done in 1% *Osmium* tetra oxides (OSO₄) prepared in 1.1 sodium cocodylate buffer and *Osmium* tetra oxides. Here the tissue was kept for 15 to 20 mins till the specimen turns black.

4. **Washing**: After the treatment of the tissues with fixative, it were washed in 0.1M sodium cocodylate buffers

5. **Dehydration**: After post fixation and washing dehydration was done by Acetone (Anahar). When Acetone is used as a dehydrating agent, it should be in anhydrous state. Here dry Acetone has been prepared by adding Copper sulphate (CuSO₄) to absolute Acetone. The size of the specimen to be examined was 2 to 3nm. Dehydration was done in gradual steps keeping in each steps for 15 minutes and giving two changes as follows – 30% - 50% - 70% - 80% - 90% - 95% - 100% (Dry Acetone).

6. **Drying or Critical point drying (CPD)**: The drying was done in an organosilicanc compound, for which technique was developed by RISC, NEHU Shillong. The materials were kept for nearly 10 mins where by it was totally dried. Then the samples were kept separately packing them in clean white paper for further observation in SEM.

7. **Metal coating**: The dry specimens are fixed on brass stub by electron conductive paint. They are kept on the specimen stand of ion – sputter and are coated with a thin layer of gold vapour.

8. **Observation on Scanning Electron Microscopy (SEM)**: The specimen coated with gold vapour on the stub is now put inside the specimen chamber. The specimen chamber of the SEM contains a stage capable of easy and quick specimen exchange. The stage can be move in order to select the field of view. The specimen exchange device contains an air lock mechanism. With the help of the three image-forming lenses, the image of the specimen was formed on Fluorescent screen.

9. **Photographic recording**: The electron beam liberates free silver from the silver halide grains of a photographic film and produces a photographic negative of the final electron image. It is recorded in an ORWO-110 black & white film.
During visual display and photographic recording, the maximum intensity of the beam and the length of explosive were controlled.

Later the film was developed and photograph is printed by the usual method

A: EYE LENSES OF FRESHWATER FISHES

Introduction:

The fish eye in spite of being of its gross similarity with the vertebrates is unique owing to its remarkable adaptability. The aquatic medium poses problems in the light reception because of its effects of scattering, depth etc. Even closely related species living under different conditions might have quite different visual adaptation.

Photoreception in aquatic medium depends upon reflection and refraction of light at air-water interface. The cornea is practically useless in the aquatic medium in the fish but effectively compensated by the lens. There are also remarkable retinal adaptation during photopic and scotopic vision. According to Ali and Wagner (1975), the visual strategies employed by fishes in different environments resemble vertebrates in some and differ in others.

The eyes of fishes are housed in a socket like depressions the orbits, on either side of the cranium. The eyeball is elliptical in shape and remains attached to the inner wall of the orbit by six eye muscles and a cartilaginous stalk called optic pedicle. These muscles rotate the eyeball and direct the pupil towards specific objects. The three coats of the eyeball sclerotic, choroids and retina are similar to those of other vertebrates. Eyelids are absent in most fishes. Cornea is transparent and flat and fused with an outer conjunctiva. Choroid is richly vascular and pigmented. In the front part is separated from sclerotic forming a circular curtain like iris around a vertical slit-like large pupil, which cannot be dilated or contracted. The inner most layer or retina consists mainly of elongated receptor cells or rod, which are connected with the fibers of the optic nerves. A
large crystalline lens lies immediately behind pupil and held by a suspensory ligament with ciliary muscles.

The eyes of the fishes are constructed along the general vertebrate plan. They are more or less flattened; fluid filled hollow organ consists of normal complement of six oculomotor muscles. Its wall is composed of three general layers variously modified in different region of the eyeball to perform different function (Munz, 1971).

![Figure 3. A. SEM microphotograph (15KV X 72) of the whole lens of fish showing its spherical shape with distinct cortex (C), medulla (M) and lenticular fibers (F).]

Structurally, fish eyes are superficially quite similar to those of terrestrial vertebrates, although they typically have a short axial length and are nearly hemispherical. The acute shape of the eye depends on the amount and nature of accommodation in the species, since the lens moves within the globe to focus the eye. In fish that do not accommodate, the retinal surface is nearly hemispherical, whereas in fish that do accommodate the eye is asymmetric since the axis along which accommodation occurs, typically the nasal-temporal axis, is considerably longer. In most teleosts the pupil is immobile, but in many elasmobranches the iris is capable of extensive contraction. The eye accommodates by the small
movements of the lens. In teleosts, the lens is pulled backward by a retractor muscle while in elasmobranches; a protractor muscle pulls it forward.

The lens is usually spherical (Fig 3 A 1) and protrudes through the pupil ensuing wide field of view because of the absence of corneal refraction. The lens of fish is almost spherical having two distinct regions: the outer cortex and the inner medulla or nucleus. The lens is enclosed in a capsule with a thin outer epithelial layer. No ringlets are found on the epithelium layer of fish. Beneath the epithelial layer there are multiple layers of lenticular fiber cells, which are the main histological structure.

The eye of the fishes, like those of other more familiar animals, has evolved adaptations responsible for two main visual functions: (1) to collect light and (2) to form a focused image for analysis by the retina. A compartment filled with viscous vitreous humor. The consistency of vitreous humor in different species varies from a liquid to a firm gel (Munz, 1971).

The lens of many fishes contains pigments that filter out ultraviolet radiation, probably improving visual acuity (Kennedy and Milkman, 1956; Denton & Warren, 1957; Motasis, 1957). The lens divides the eyeball into a front compartment filled with watery aqueous humor and a larger more posterior.

The lens of fish is the only refractive element so it is spherical or nearly spherical and crystalline with a high refractive index.

Observation and Results:

1. *Anabas testudineus:*

*Anabas testudineus* belong to the family Anabantidae is a fresh water live fish. It measures about 10 cm. in length and 3.5 cm. in breadth. They are found in wetlands, pits, pools and puddles. It is a carnivore fish feeds on shrimps, ostracods, gastropod shells and young fishes. The body is covered with ctenoid and cycloid scales. The fish possess a well-developed suprabranchial organ, bifid air bladder and accessory respiratory organ. The dorsal and anal fins are long and bear spines. The operculum bears spines. Weberian apparatus are absent. Barbs or barbles are absent. Air bladder is absent. Eye is moderate and visible from underside of the head. The diameter of the eye is 6 to 10 time in head. In rainy
season, at night the fish migrates from pond to pond and while migrating, it walk
on land with the help of operculum and fin spines.

The lens of *A. testudineus* is spherical (Fig. 3.A.1) in shape and off-
white in colour. It is transparent and brittle in nature. Scanning Electron
Microscopy (SEM) micrograph off the whole lens shows two distinct region
outer cortexes and inner deep medulla or nucleus. The lens is enclosed in a
capsule. The outer epithelial layer is thin and distinct. No ringlets are found on
the epithelium layer. Beneath the epithelial layer there are multiple layers of
cortical fiber cells, which are the main histological structure.

![Figure: 3.A.2. SEM microphotograph (15KV X 4000) of lenticular fibers of the lens of *A. testudineus* showing distinct lenticular fibers (F), nipple (Ni), nipples’s head (H), nipple’s stalk (S) and nipple’s projection (P).](image)

Magnified SEM micrograph of the cortex and nucleus shows paralley
arranged lenticular fibers cells, which are uniform in size. These fibers are held
together by linearly arranged finger like projection on either side known as
nipple. The nipples are broad at its apex but narrow at its base with a thin stalk
with which it attached to the fiber. The board apex of the nipple is called the
head. The surfaces of the nipple are rough with some hairy projections. The distance between each nipple is uniform. (Fig. 3.A.2.).

- Width of the lenticular fiber: 8 µm.
- Length of the nipple: 3 µm.
- Diameter of the nipple’s head: 2 µm.
- Length of the stalk: 1 µm.
- Width of the stalk: 1 µm.
- Maximum distance between two nipples: 1.5 µm.
- Minimum distance between two nipples: 0.8 µm.
- Length of the hairy projection of the head: 0.5 µm.

**Figure:** 3.A3. SEM micrograph (15KV X 3000) of the fiber cell of *A. testudineus* showing ball (B), socket (So), gap junction (Gp) and granules (G).

Magnification of the section of the lens shows junctional complex like distinct ball and socket arrangement of the lenticular fibers. The ball consists of a short stalk, which expands to a spherical head embedded in a complementary socket or depression in the adjacent fiber. Junctional complex like ridges and grooves are not seen. Arrangements of interdigitation and gap junction are also seen in the lenticular fibers. Numerous granules are seen in the lens. (Fig. 3.A 3).
Approximate size of the ball ------------1.5 µm in diameter.

Approximate depth of the socket ---- 0.8 µm in diameter.

Distance of the gap junction ---------------0.5µm.

Size of the granules --------------------0.02µm – 0.65µm

2. *Labeo rohita:*

*Labeo rohita* belongs to the family Cyprinidae is a fresh water carp. It is an herbivores bottom feeder and is found in wetlands, river and ponds. The body is covered with large cycloid scales. Fins and operculum are without spines. Bars or barbles are absent. They respire with gills and possess no accessory respiratory system. A peculiar weberian apparatus connecting the ear with the air bladder is present. The eyes are large and are not visible from underside of head, the diameter 4 to 6 times in head.

The lens of *labeo rohita* is also spherical (Fig. 3.A.1) and off white in colour. It is also transparent and brittle in nature. SEM micrograph of the whole lens is same as *A.testudineus*. Magnified micrograph of the lenticular fiber shows that the fibers are not uniform in size . The fibers are held together by invaginated protrusions, the nipples, which are arranged linearly on the either side of the fibers.

![SEM micrograph of the lens of *L.rohita* showing lenticular fiber (F), nipple's stalk (S), nipple's head (H) and nipples (Ni).](image)

**Figure:** 3.A.4. SEM micrograph (15KV X of 4420) of the lens of *L.rohita* showing lenticular fiber (F), nipple’s stalk (S), nipple’s head (H) and nipples (Ni).
The fibers are vertically arranged and the nipples are horizontally arranged on the fibers. The head of the nipple is elongated. The nipples are smooth without any side projection. They are broad, thick and short with equal and even gap between one another. They have a broad head and narrow stalk. (Fig. 3A.4).

Width of the lenticular fibers --------------- 9µm-10µm.
Length of the nipple ----------------------------- 2µm-3µm.
Diameters of the nipple’s head-----------------0.5µm- 1µm.
Length of the nipple’s head---------------------2µm.
Length of the stalk ----------------------------0.3µm.
Width of the stalk-------------------------------1µm.
Maximum distance between two nipples----------0.3µm.
Minimum distance between two nipples----------0.5µm.

Further magnification of the lens shows distinct arrangement of junctional complexes like ball and socket. Distinct very long ridges and grooves are seen. The ridges are linear evagination of the membrane. Irregular interdigitations are also seen. Mounds are small elevation, which are also seen. Ball and socket arrangement alternates with ridges and grooves arrangement in the fiber cells. So both these arrangement are found equally in the fibers, gap junctions are not seen. Few very small granules are seen. (Fig. 3.A.5).

Approximate diameter of the ball ---------------0.5µm.
Approximate depth of the socket ---------------1µm.
Length of lateral flap-------------------------0.3µm.
Width of lateral flap-------------------------0.1µm.
Height of the ridges -------------------------0.4µm - 0.5µm.
Width of the ridges --------------------------1µm-1.5µm.
Size of the mounds--------------------------0.2µm.
Size of the granules-------------------------0.4µm - 0.60µm.
3. Mastacembelus armatus:

*Mastacembelus armatus* belongs to the family Mastacembelidae. They are fresh water herbivores found in wetlands, rivers and ponds. The body is eel-shaped and has series of detached, depressible spines preceding the soft dorsal fins. The anal fin has three spines. Ventral and pectoral fin absent. Air bladder, bars and barbels and weberian apparatus are absent. They have accessory respiratory organs. Eyes are small not visible from underside of head, the diameter 12 to 16 times in head.

The lens of *M. armatus* like other fish is spherical, creamy and very small. The structure of the whole lens is same as other fish. Like other fish the lens consist of two parts the outer cortex and inner medulla or nucleus. SEM micrograph of the lens shows the lenticular fiber cells, which are the main histological structure. The fibers are held together by finger like protrusions called nipples. These nipples are uniform and linearly arranged in the fiber. Enlarge view shows that the nipples are not smooth but possess some short and thick side projection. The nipple is differentiated with round head and slender stalk (Fig. 3.A.6).
Width of the lenticular fiber ---------------------------7μm.
Length of the nipple -----------------------------------17μm.
Diameter of the head of the nipple -------------------15μm.
Length of the stalk ----------------------------------0.5μm.
Width of the stalk--------------------------------------0.5μm.
Maximum distance between two nipples ------------2μm.
Minimum distance between two nipples ------------1μm.
Length of the side projection of the head ---------0.2μm.

Figure: 3. A. 7. SEM micrograph (15KV X 4000) of lenticular fiber of the lens of *M. armatus* showing lenticular fiber (F), nipple's stalk (S), nipple's head (H), nipples (Ni) and nipple's projection (P).

Junctional complexes like distinct ball and socket arrangement are seen. Tongue or ridges are not seen. Mounds are seen. Numerous grooves or depression are present in the lenticular fibers. Few granules are seen which scatters here and there are (Fig.3.A.8).

Approximate size of the ball ------------------------1.5μm.
Approximate depth of the socket ------------------2μm.
Diameter of the mounds --------------------------0.2μm - 0.5μm.
Size of the depression ----------------------------0.1μm.
Size of the granules ---------------------------0.04μm - 0.50μm.
Size of gap junction ---------------------------2μm.
4. *Hilsa ilisha*:

*Hilsa ilisha* belongs to the family Clupeidae is an anadromous fish. They migrate from saline water to fresh water (Brahmaputra river system) during breeding season. They are carnivore fish and live both in saline and freshwater. They are no weberian apparatus and caudal fin is homocercal. Fins and operculum are without spines. Air bladder, barbs and barbies are absent. The eyes are big and prominent and are easily visible, diameters being 5 to 7 times in head. The lenses are collected from the freshwater fishes.

The lens of *H. ilisha* is spherical, (Fig. 3.A.1) transparent and creamy in colour. It is transparent and brittle in nature. The lens is made up of two regions-the outer cortex and inner medulla or nucleus. Like other fish the nucleus and cortex is made up of lenticular fiber cells. SEM study of the lenticular fibers shows that the fibers are not smooth but possess side projection or nipples, which are not uniform, like the other investigated spices. Some of the nipples are elongated and some are very minute. The nipples cannot be differentiated into head and stalk and they does not possess any side projection. In other words the nipples are not prominent. The lenticular fibers show diffraction (Fig. 3.A.9).
**Figure: 3. A. 9.** SEM micrograph (15KV X 1800) of lenticular fiber of the lens of *H.ilihsa* showing lenticular fiber (F) and nipples (Ni).

**Figure: 3.A.10.** SEM microphotograph (20KV X 7200) of the lens of *H.ilihsa* showing ball (B), socket (So), ridges (R), and lateral flap (FL).

Width of the lenticular fibers --------------- 5\(\mu\)m - 7\(\mu\)m.
Length of the nipples ------------------------ 0.2\(\mu\)m-1\(\mu\)m.
Diameter of the nipple’s head -------------- 0.5\(\mu\)m-2\(\mu\)m.
Maximum distance between two nipples------ 0.5\(\mu\)m.
Minimum distance between two nipples------ 0.2\(\mu\)m.
Further magnification of lenticular fibers shows disorganization of the junctional complexes (Fig. 3.A.11). Ball and socket arrangement are not prominent. Mounds are not seen. Ridges and grooves are distinct and prominent. Lateral flaps are prominent (Fig. 3.A.10). Big and distinct gap junctions are seen (Fig. 3.A.11). Granules are absent. (Fig. 3.A.10).

Figure: 3.A.11. SEM microphotograph (15KV X 4800) of the lens of *H.ilihsa* showing disorganization of junctional apparatus like ball (B), socket (So), and prominent gap junction (Gp).

- Approximate size of the ball: 0.2μm.
- Approximate depth of the socket: 0.5μm.
- Height of the ridges: 2μm.
- Width of the ridges: 0.5μm.
- Length of the lateral flaps: 0.7μm.
- Approximate size of the gap junction: 7μm.

5. *Clarias batrachus*:

*Clarias batrachus* belongs to the family Claridae is a fresh water live fish. They are wetland fish found in river and ponds especially in muddy areas. The gill respiration is supplemented by accessory respiratory system so
they can live on land for quite some time. Air bladder is connected with internal ear with weberian ossicles. The body of the fish is scale less with bearing four pairs of sensory barbules. The dorsal and ventral fins are long and are without spines. Pectoral spines are present which can inflict painful wounds. It is a predator fish, which feeds on prawn, insects, crustaceans, etc. The eyes are small and not visible from under side of the head, diameter 10 to 12 times in head. The structure of the whole lens is same as other fish species (Fig. 3.A.1). The lens is made up of two region outer cortex and inner medulla. Both the cortex and medulla is made up of lenticular fibers cells. These fibers are attached together by the nipples. The nipples are distinct and uniform in size. The nipples are differentiated into head and stalk. The nipples are not smooth but possess small fine hair like projection. (Fig. 3.A.12).

Figure: 3. A. 12. SEM micrograph (15KV X 2000) of lenticular fiber of the lens of *C. batrachus* showing lenticular fiber (F), nipple’s stalk(S), nipple’s head (H) and nipples (Ni).

- **Width of the lenticular fibers** = 4.5 μm.
- **Length of the nipples** = 2 μm.
- **Diameter of the head of the nipples** = 1 μm.
- **Length of the stalk** = 0.5 μm.
- **Maximum distance between two nipples** = 2.5 μm.
Minimum distance between two nipples -----------1 μm.
Length of the hairy projection of nipples -----------0.5 μm.

Further magnification of the fibers shows junctional complex like distinct and prominent ball and socket arrangement. The balls are seen with rising apex. Small mounds are also seen. Ridges and grooves are absent. Interdigital flap and gap junction are not seen. Numerous granules are present (Fig. 3.A.12).

![Figure: 3. A.13. SEM microphotograph (15KV X 4400) of the lens of C. batrachus showing ball (B), socket (So), depression (D), mounds(M), granules(G) and nipple’s projection (P).](image)

Approximate diameter of the ball -----------1.5 μm.
Approximate size of the socket -----------2 μm.
Approximate size of the mounds -----------0.5 μm.
Size of the granules -----------0.2 μm - 1 μm.
Size of the depression -----------0.5 μm.

Discussion:

The eye of fish, like those of more familiar animals, has evolved adaptations responsible for two main functions: (1) to collect light and (2) to form a focused image for analysis by the retina. The feature of fish visual system
collection of light and formation of image by the lens is called optics and focusing the image on the retina is called accommodation.

When viewing an extended source, larger fish eyes do not have brighter retinal image resulting from their proportionally larger papillary aperture (Fernald, 1990). Thus it can be suggested investigated piscian species *L.rohita* and *H.iliSha* as it has large eyes has less bright retinal image than *Atestudineus, M.armatus* and *C.batrachus*. Best and brighter image may be found in *M.armatus* and *C.batrachus* that possess small eyes. This indicates an adaptive and functional relationship and significance as the former species shows purely aquatic adaptation where as the latter shows semi-aquatic adaptation (Table.3. A.)

Structurally, fish eyes are superficially quite similar to those of terrestrial vertebrates, although they typically have a short axial and are nearly hemispherical. The optics of animals living under water is different from those of animals living in air in one major respect that in underwater there is no air/cornea interface to provide extra dioptric strength to the eye (Mathiessen, 1880). In all underwater eyes, the refractive power of the cornea is neutralized and the lens needs to be much powerful. In addition lenses of fish must have a short focal length to minimize eye size (Sivak, 1983). Together, these constraints have been met through the evolution of spherical lens, which has a very high refractive power in most fish. All the lenses of the investigated fish species have a spherical shape lens (Fig. 3.A.1) indicates very high refractive power of the lenses.

Since the lens is the only refractive element of fishes so it said to posses a spherical or nearly spherical crystalline lens of high refractive index (Feng et al. 2005). The wavy nature of the lenticular fibers cells of the lens shown in the SEM micrograph of the lenses of the investigated piscian species indicates crystalline nature of the lens. The refractive index is thought to drop continuously and parabolically from the center to the periphery so as to produce a lens with little or no spherical aberration (Mattniessen, 1880). How fish maintain the spherical shape of the embryonic nucleus is unknown.

The lenticular fibers of the lens of all vertebrates filter and regulate the light entering the retina (Berhnard et al., 1965; Fernald, 1990). All the investigated piscian species are fresh water in habitat while *H.iliSha* is an anadromous fish
that migrates from saline water to fresh water for breeding. After investigating the SEM micrograph of the species it is observed that all the species have a well-developed lenticular fiber, the nipples have distinct head and stalk of the lenticular fibers except in *H. ilisha* where stalk is absent (Fig. 3.A.9). The head of the nipple of the lenticular fibers of *H. ilisha* remains embedded on the fibers without a distinct stalk. This may be due to the anadromous habitat of the fish for which adjustment of the lens is required for both saline and fresh water visions as the lenticular fibers filters and regulate the entry of the light to the retina. This suggests some adaptive and functional significance of vision physiology of fish lens. The nipple’s head is spherical in all the investigated pician species except *L. rohita* (Fig. 3.A.4) where it is elongated in shape suggests some functional significance. The size of the lenticular is not same in all the investigated pician species. It is maximum in *L. rohita* and minimum in *C. batrachus* (Chart.3.A.1). The sizes of the fibers are uniform in *A. testudineus, M. armatus* and *C. batrachus* and variable in *L. rohita* and *H. ilisha* (Table.3.A) indicates some phylogenic relationship and functional significance.
The lenticular fibers of the lens bear some finger like side projection called nipples, which regulates the entry of light to the retina (Dey, 1988). The shape and size of the nipples are not same in all the five piscian species. The sizes of the nipples are longest in *A. testudineus* and *L. rohita* and shortest in *H. ilisha* (Chart 3.A.2). Again the sizes of the nipples are uniform through out the fibers in *A. testudineus, M. armatus* and *C. batrachus* while the size is not uniform through out the fibers in *L. rohita* and *H. ilisha* (Table. 3.A) indicates some phylogenic relationship and functional significance.

Again it is observed that all the investigated piscian species (*L. rohita* and *H. ilisha*), which does not posses accessory respiratory system, large eye with variable size of the lenticular fibers and nipple may indicates some phylogenic, physiological and functional relationship and significance among the two species. Moreover it is observe that in those investigated piscian species (*A. testudineus, M. armatus* and *C. batrachus*), which possess accessory respiratory system the size of lenticular fibers and nipples head are uniform. This indicates some phylogenic, physiological and functional relationship and significance among the three species. All these suggest the fact that *A. testudineus, M. armatus* and *C. batrachus* possess a semi-aquatic vision where the lens is adapt for both air and water vision while *L. rohita* and *H. ilisha* possess a purely only aquatic vision where the lens it adapt only for water vision (Table. 3. A)
The investigated specimen where air bladder is present the size of the lenticular fibers are uniform throughout its length while the size is variable in those investigated piscian species where air bladder is absent. This may also indicate some adaptive and functional relationship and significance in vision physiology of fish (Table 3.A).

The maximum and minimum distance of the nipples of the lenticular fiber is not same in all the five-investigated piscian species. The maximum distance between two nipples is highest in *C.batrachus* and lowest in *L.rohita* while the minimum distance is same and highest in *M.armatus* and *C.batrachus* and lowest in *H.ilisha* (Chart 3.A3) These suggest some phylogenetic relationship and functional significance. It also indicates that *M.armatus* and *C.batrachus* evolved from a common ancestor.

![Chart 3.A3. Showing the relation of the distances between the nipples of the lenses in 5 fishes](image)


It is further observed that in *A.testudineus*, *M.armatus* and *C.batrachus* the lenticular fibers of the lens are rough with some hairy side projection while the lenticular fibers of the lens of *L.rohita* and *H.ilisha* are smooth without any side projections. The presence of rough lenticular fibers of the lens indicates that light passes through the lens both in denser and rarer medium while smooth fibers indicates that light passes through the lens only in denser medium (Lythgoe,
This suggests that *A.testudineus*, *M.armatus* and *C.batrachus* possess a semi aquatic mode of vision and *L.rohita* and *H.ilisha* possess a purely aquatic mode of vision. All these again suggest some phylogenetic, physiological and functional significance among the fishes. (Table: 3.A)

The junctional complexes include balls (knob) and sockets arrangement first observed in fiber cells of monkey. They bind fibers firmly together (Dickson and Crock, 1975). Balls and socket arrangement serves to maintain the shape of the lens during focusing movement and minimizes cell slippage (Kuwabara, 1975). Presence of junctional apparatus like ball and socket arrangement in all the investigated piscian species suggests that the shape of the lens is well maintained during focusing movement of the lens and minimized cell slippage in all these piscian species. It also suggests that cellular shape changes mainly in the superficial zone and a little intercellular gliding occurs during focusing (Kuwabara, 1975).

Presence of ball and socket arrangement in the lenticular fibers of all the 5 fishes also indicates that the fibers of the lens are bind firmly (Dickson and Crock, 1975). When investigated the ball and socket arrangement of the five fishes it is seen that the size of ball arrangement (junctional complex) is same in *A.testudineus*, *M.armatus* and *C.batrachus* and the size of socket is same in
Lateral flaps a type of junctional apparatus of the lenticular fibers of the lens is observed only on the SEM micrograph of the lens of *L. rohita* and *H. ilisha* suggests a rotatory kind of intrinsic movement of the lens, which proves an anadromus mode of vision adaptation (Hollenberg et al., 1976). 

*M. armatus* and *C. batrachus* which may indicates same visual physiology and phylogenic significance. (Chart 3.A4). Relation in the size of the ball and socket arrangement of the five investigated pician species (Chart 3.A5) shows that the size of ball and socket arrangement is same and maximum in *M. armatus* and *A. testudineus* and minimum in *H. ilisha*. This suggests some phylogenetic relationship between *M. armatus* and *A. testudineus*. The sizes of ball and socket are smallest in *H. ilisha* (Chart 3.A5) also suggest some phylogenetic and functional significance.

The minimum distance between the nipples of the lenticular fibers of the lens, the length of the stalk and the size of the junctional apparatus like ball and socket is same in *M. armatus* and *C. batrachus* indicates same mode of adaptation that is they live in muddy water suggest same type of vision and also suggests adaptive and functional relationship and significances (Table 3.A).

![Chart: 3.A5 Relation of the sizes of Balls & Socket in 5 Fishes.](image)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. testudineus</td>
<td>B. L. rohita</td>
<td>C. M. armatus</td>
<td>D. H. ilisha</td>
<td>E. C. batrachus</td>
</tr>
</tbody>
</table>

Lateral flaps a type of junctional apparatus of the lenticular fibers of the lens is observed only on the SEM micrograph of the lens of *L. rohita* and *H. ilisha* suggests a rotatory kind of intrinsic movement of the lens, which proves an anadromus mode of vision adaptation (Hollenberg et al., 1976).
Figure: 3. A.14. SEM micrograph (15KV X 4800) of lenticular fiber of the lens of *L.rohita* showing lenticular fiber (F) with irregular interdigitation of lateral flaps (FL).

Junctional apparatus ridges and grooves of the lens of vertebrates prevent lateral sliding movement of the lenticular fibers in accommodating and focusing light by the lens to the retina (Hollenberg *et al.*, 1976). Ridges and grooves are observed only in the SEM micrograph of the lens of *L.rohita* and *H.ilisha* suggest that lateral sliding movement of the lens fibers is well maintained in these two species during accommodation and focusing light while absence of ridges and grooves in the lenticular fibers of the lens of *A.testudineus*, *M.armatus* and *C.batrachus* suggests that lateral movement of the lenticular fibers of the lens is not prevented during accommodation and focusing light by the lens and the eye clearly proves a semi-aquatic mode of visual adaptation (Dickson and Crock, 1975). Further it also suggests that the entry of light through the lens is more controlled by *A.testudineus*, *M.armatus* and *C.batrachus* (semi-aquatic vision) than *L.rohita* and *H.ilisha* (aquatic vision) as lateral sliding movement technique of the lenticular fibers of the lens controls the entry of light to the retina (Kuwabara, 1975).

Mounds or very small globules are another type of junctional apparatus of lens fibers cells was first observed in rabbit lens (Harding and Murphy, 1996). Mounds are observed only in the SEM micrograph of the lens of *L.rohita*, *M.armatus* and *C.batrachus*. The sizes of the mounds are variable in *L.rohita* and Marmatus while it is uniform in *C.batrachus*. It is absent in *A.testudineus* and
H. ilisha suggests some phylogenetic and physiological relationship and significance (Table 3.A).

Gap junction is observed only in the SEM lens micrograph of A. testudineus, M. armatus and H. ilisha implies that the lenticular fibers of the lens in this two species always remain in a metabolically coupled state and facilitates the movement of water, ions and other small metabolites (Goodenough, 1979). Gap junctions may provide a pathway linking epithelial cells directly to the underlying fiber cells (Duncan, 1974; Le and Musil, 2001). Moreover, the size of the observed gap junction in the SEM micrograph of the lens of H. ilisha is larger than A. testudineus and M. armatus indicates that the lens fibers of H. ilisha exist in a state that facilitates better movement of water, ions and other small metabolites (Brown, 1973).

Absence of cytoplasmic apparatus like intermediate filament in all the investigated piscian species proves an accommodating spherical lens of general piscian species (Rafferty and Goossens, 1975). This suggests that fish scatters maximum amount of light and maintains the shape of the fibers and lens.

Numerous spherical bodies of various sizes are observed in the micrograph of the lens of all the investigated piscian species except H. ilisha. The presence of spherical granules indicates that since reflection usually does not take place by the lens, some portion of the light is scattered from the lens to regulate the quantity of light entering the retina (Begum, 2004, 2006, 2007). This suggests that spherical scatters takes place in these fishes but absent in H. ilisha, which may be of its anadromous habitat.

The above discussion indicates that A. testudineus, M. armatus and C. batrachus have a closely related phylogeny or may have evolved from a common ancestor while L. rohita and H. ilisha have evolved from a common ancestor. It also suggests some adaptive and functional significance among A. testudineus, M. armatus and C. batrachus in one hand and L. rohita and H. ilisha on the other hand.
Summary:

1. All together five piscian species are investigated and all these species are of different taxonomic status that is they belong to different families belonging to different habit and habitat.

2. *L.rohita* and *H.ilisha* have a large eye but the eye of *M.armatus* and *C.batrachus* is small while it is moderate in *A.testudineus*. The width of the lenticular fibers, length of the nipples and diameter of the head are uniform in *A.testudineus, M.armatus* and *C.batrachus* while it is variable in *L.rohita* and *H.ilisha*. All the investigated piscian species have well differentiated head and stalk of the lenticular fibers except *H.ilisha* where stalk is undifferentiated. The maximum and minimum distance between the nipples is uniform in all the investigated piscian species and the minimum distance is same in *M.armatus* and *C.batrachus*. Hairy side projection is found only in *A.testudineus, M.armatus* and *C.batrachus* while it is absent in *L.rohita* and *H.ilisha*.

3. Junctional complex like ball and socket arrangement is found in all the investigated piscian species. The size of the ball arrangement is same in *A.testudineus, M.armatus* and *C.batrachus* while the depth of the socket is same in *M.armatus* and *C.batrachus*. Ridges and grooves are present in *L.rohita* and *H.ilisha*. The height and width of the ridges are variable in *L.rohita* but uniform in *H.ilisha*. Ridges and grooves are absent in the rest of the investigated piscian species. Mounds size is variable in *L.rohita* and *M.armatus*, uniform in *C.batrachus* and absent in *A.testudineus* and *H.ilisha*. Depression is found in *M.armatus* and *C.batrachus* and lateral flaps are present only in *H.ilisha* lens.

4. Gap junction is seen only in the lens of *A.testudineus* and *H.ilisha* while it is not seen in the rest of the investigated piscian species. Spherical granules of various sizes are seen in all the investigated piscian species except *H.ilsha*. 


<table>
<thead>
<tr>
<th>Parameter</th>
<th>A. lestu Meadows</th>
<th>I. rohita</th>
<th>M. armatus</th>
<th>H. ilisha</th>
<th>C. batachns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxonomic status</td>
<td>Anabantidae</td>
<td>Cyprinidae</td>
<td>Mastacembidae</td>
<td>Clupeidae</td>
<td>Claridae</td>
</tr>
<tr>
<td>Habitat</td>
<td>Wetlands/ponds/fresh water</td>
<td>Wetland/river/ponds/fresh water</td>
<td>Wetland/ponds/fresh water</td>
<td>Anadromus salmon to fresh water</td>
<td>Wetland/ponds/brackish water</td>
</tr>
<tr>
<td>Food Habit</td>
<td>Carnivore</td>
<td>Herbivore</td>
<td>Herbivore</td>
<td>Carnivore</td>
<td>Carnivore</td>
</tr>
<tr>
<td>Anatomical Peculiarity</td>
<td>Accessory respiratory System present</td>
<td>Accessory respiratory system absent</td>
<td>Accessory respiratory system present</td>
<td>Accessory respiratory system absent</td>
<td>Accessory respiratory system present</td>
</tr>
<tr>
<td>Size and diameter of the eye</td>
<td>Moderate 6 to 10 times in head</td>
<td>large 4 to 6 times in head</td>
<td>small invisible 12 to 16 times in head</td>
<td>large 5 to 7 times in head</td>
<td>small 10 to 12 times in head</td>
</tr>
<tr>
<td>Wt of the lenticular fiber in (µm)</td>
<td>8</td>
<td>9-10</td>
<td>7</td>
<td>5-7</td>
<td>4.5</td>
</tr>
<tr>
<td>L of the nipple (µm)</td>
<td>3</td>
<td>3-2</td>
<td>1.7</td>
<td>1-0.2</td>
<td>2</td>
</tr>
<tr>
<td>L of the stalk of the nipple (µm)</td>
<td>1</td>
<td>0.3</td>
<td>0.5</td>
<td>Absent</td>
<td>0.5</td>
</tr>
<tr>
<td>Diameter of the Nipple's head (µm)</td>
<td>2</td>
<td>1-0.5</td>
<td>1.5</td>
<td>2-0.5</td>
<td>1</td>
</tr>
<tr>
<td>Max. dist. between Two nipples (µm)</td>
<td>1.5</td>
<td>0.3</td>
<td>2</td>
<td>0.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Min. dist. between two Nipples (µm)</td>
<td>0.8</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>L of hairy side projection of head (µm)</td>
<td>0.5</td>
<td>Absent</td>
<td>0.2</td>
<td>Absent</td>
<td>0.5</td>
</tr>
<tr>
<td>Size of the ball (µm)</td>
<td>1.5</td>
<td>0.5</td>
<td>1.5</td>
<td>0.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Depth of the socket (µm)</td>
<td>0.8</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Distance of the gap Junction (µm)</td>
<td>0.5</td>
<td>Absent</td>
<td>2</td>
<td>7</td>
<td>Absent</td>
</tr>
<tr>
<td>Size of granules (µm)</td>
<td>0.02-0.65</td>
<td>0.4-0.60</td>
<td>0.04-0.50</td>
<td>Absent</td>
<td>1-0.2</td>
</tr>
<tr>
<td>Height of ridge (µm)</td>
<td>Absent</td>
<td>0.04-0.5</td>
<td>Absent</td>
<td>2</td>
<td>Absent</td>
</tr>
<tr>
<td>Width of ridges (µm)</td>
<td>Absent</td>
<td>1.5-1</td>
<td>Absent</td>
<td>0.5</td>
<td>Absent</td>
</tr>
<tr>
<td>Size of the mound in diameter (µm)</td>
<td>Absent</td>
<td>0.2</td>
<td>0.2-0.5</td>
<td>Absent</td>
<td>0.5</td>
</tr>
<tr>
<td>Size of the depression</td>
<td>Absent</td>
<td>Absent</td>
<td>0.1µm</td>
<td>Absent</td>
<td>0.5</td>
</tr>
<tr>
<td>Length of the lateral flaps</td>
<td>Absent</td>
<td>0.3</td>
<td>Absent</td>
<td>0.7µm</td>
<td>Absent</td>
</tr>
</tbody>
</table>
Introduction:

The visual process in all animals is governed by same physical rules for adjustment in a particular ecological niche. The light activates some photosensitive molecules ultimately leading to image.

The vertebrate eye is the most highly developed organs of vision in the animal kingdom. These eyes have refractive elements, lens to focus light from an object and form an inverted image on the retinal surface (Wilson, 1972).

The photoreceptor organ of *B. milanosuctus* is two large eyes. Each eye is roughly spherical and protruding lodged inside an orbit in the dorso-lateral side of head protected by eyelids. Six extrinsic muscles control the movement of the eye. Each eye has a thick, pigmented and almost immovable upper eyelid and a thin semi-transparent and freely moveable lower eyelid. From the lower eyelid arises a transparent third eyelid or nictitating membrane, which covers and protects the eye during swimming and keeps it moist in air.

The wall of the eyeball is subdivided into three coats: the sclerotic, choroids and retina. Sclerotic is again divided into inner sclera and outer transparent cornea. Cornea is covered by a thin transparent continuation of skin called conjunctiva. Both the conjunctiva and nictitating membrane is lubricated and kept moist by the secretion of a Harderian gland. Underneath sclerotic is the richly vascular and darkly pigmented circular disc called iris, with a central opening, the pupil, through which light can enter. Pupil can be reduced and increased by circular and radial muscles of iris, which acts like a diaphragm. A large spherical and transparent crystalline lens is present behind the pupil, which is enclosed in a delicate lens capsule. It held in place by suspensory ligaments from ciliary muscles (Kotpal, 2005).

The eye accommodates by the small movement of the lens. Two protractor lentis muscles run on the dorsal and ventral side from the cornea to the ciliary body and suspensory ligaments. The lens is moved forward or backward
by these muscles for accommodation (Pumphery, 1961) It divides the eyeball into a front compartment filled with watery aqueous humor and a larger, more posterior compartment filled with viscous vitreous humor (Munz, 1971).

Observation and Result:

*Bufo malanostictus:*

*B. malanostictus* belongs to the order Anura and family Salientia is a nocturnal animal. The skin of the animal is warty and rough rich in poisonous parotid glands. The animal live in damp places and feeds on earthworms, snails and all sorts of insects. Jaws lack teeth. Eyes are longer and big with well-developed upper eyelids. The eye socket bulge out in the palate region of the mouth. Nictating membrane the third eye lid is present. The diameter of the eye is 5 to 8 times in head.

![Figure: 3.B.1. SEM microphotograph (15KV X 72) of the whole lens of *B. malanostictus* showing its spherical shape with distinct Cortex (C), Medulla (M) and Lenticular fibers (F).](image)

The lens of *B. malanostictus* is spherical, big, solid and colourless and brittle. It is transparent and crystalline in nature. The lens is enclosed in a capsule. Beneath the capsule lies an epithelial layer. Annular pad, which separates the
epithelium and fiber mass topographically, are absent. Like other vertebrates the lens consists of two parts. The inner dens part is called medulla and the less dense part is called cortex. Scanning Electron Micrograph of both medulla and cortex are made up of numerous lenticular fibers, which are the main histological structures (Fig.3.B.1).

Figure: 3. B.2. SEM micrograph (15KV X 2000) of lenticular fiber of the lens of B.malanostictus showing spring like (F) lenticular fiber, (S) nipple’s stalk, (H) nipple’s head (Ni) nipples and (P) Projection.

Magnification of the lens shows that the lenticular fibers are parallel-arranged spring like in appearance. Inter digitations of the fiber cells are well observed. The lenticular fibers are held together by linearly arranged rows of finger like projection called nipples. The nipples are long and rough with side hair like projection. The nipples are broad at the apex and narrow at the base. The base is connected with the fibers with a thin stalk. In B.malanostictus the head of the nipple is elongated. The size and distance between to nipple are not uniform (Fig.3.B.2).

Width of the lenticular fibers. ---------------5μm.
Length of the nipple. ---------------0.5μm-1μm
Diameter of the head------------------0.2μm-0.5μm
Length of the stalk ---------------0.5μm -1μm
Maximum distance between two nipples ------ 1μm- 2μm
Minimum distance between two nipple ----- 0.5μm- 1.5μm.
Length of the hairy projection of head -------- 0.5μm.

Magnification of the section of the lens shows junctional complex like ball and socket arrangement, which are not very prominent (Fig.3.B.3). Ridges and grooves are distinct and prominent. The ridge consists of a linear evagination of the membrane. Numerous irregular interdigitations of ridges with others on adjacent cells are seen (Fig.3.B.3). Mounds are present (Fig.3.B.3). Depressions are also seen in numbers. Numerous granules of various sizes are seen in the SEM micrograph of this lens (Fig. 3.B.3).

Figure: 3. B.3. SEM microphotograph (15KV X 4000) of the lens of *B. malanostictus* showing ball(B), socket(So), depression(D), mounds(M), granules(G), lateral flap(FL) and gap junction(Gp).

Intermediate filaments are seen in the lens fibers. Chain or bead filament with globular particles arranged along a filamentous backbone is seen (Fig. 3.B.4). Tight junction, gap junction and desmosome are also observed.

Approximate size of the ball---------------------0.5μm.
Approximate depth of the socket----------------1.8μm.
Length of the lateral flaps---------------------0.5μm.
Height of the ridges--------------------------0.5μm.
Width of the ridges --------------------------1 μm.
Size of the mounds --------------------------0.2 μm.
Size of the filamentous backbone-- 6 μm in diameter.
Width of the tight junction----------------------0.2 μm.

**Figure:** 3. B.4.SEM microphotograph (20KV X 2200) of the lens of *B. malanostictus* showing (Y) gobular particles, (Z) irregular interdigititation, (Ch) Chain filament and (T) tight junction.

Size of the gap junction----------------------0.5 μm.
Size of the intermediate filament----------- 12 μm.
Size of the depression --------------------- 1 μm.
Size of the granules-----------------------0.02 - 0.75 μm.
Diameter of the globular particles-----------3 μm.

**Discussion:**

The eye of amphibia like fish and other vertebrates is also adapted for two main visual functions: 1. Optics, which is the phenomenon of collecting light and image formation by the lens and 2. Accommodation, which is the focusing of images in the retina (Fernald, 1990). The size of the eye is large indicates that *B. malanostictus* while viewing an extended source they do not have a brighter retinal image resulting from their proportionally larger papillary aperture.
(Fernald, 1988). Instead, because the eye grows in a scaled fashion, the increased light entering the large eye is in focus on a more distant retina, so the light per unit area remains constant.

The lens of *B. malanostictus* is spherical which is similar to fish, which proved to have very high refractive power. Spherical shape of the lens (Fig. 3.B.1) also signifies high dioptric power. Spherical lens can be subject to spherical aberration or any of five other primary aberrations characteristics of optical systems (Fincham, 1959). Of these, only chromatic aberration is a function of the material of the lens itself, while the rest depends on the structure of the lens and the shape of its focusing surface.

Like other terrestrial vertebrates the lens of *B. malanostictus* does not changes its shape for accommodation instead the lens moves within the globe of the eye to accommodate and focus light in the retina. The brittleness and spherical nature of the lens signifies such mode of accommodation (Sivak, 1974). These types of structural modifications are useful for aquatic vision and show some phylogenetic, functional and adaptive relationship with piscian species.

Figure: 3. B.5.SEM microphotograph (20KV X 1100) of the lens of *B. malanostictus* showing spring like cortical fibers.

The lenticular fibers (Fig. 3.B.2) of the lens act as interference filters in the eye. They regulate the entry of light to the retina (Bernhard *et al.*, 1965; Jong, 1982). The lenticular fibers with variable size of the nipples head and stalk prove that the lenticular fibers filter light in two media both air and water which
suggests a semi aquatic mode of vision adaptation (Dey, 1988; Goswami et al., 2000). The fiber cells are spring like in appearance indicates some phylogenetic and functional significances (Fig. 3.B.5).

Moreover the head of the lenticular fibers (Fig. 3.B.2) of the lens are not smooth but possess some hairy side projection. The presence of rough hairy projection of the lenticular fibers indicates that the lens is adapted to passes light through it both in rarer and denser medium (Lythgoe, 1971) which proves a semi-aquatic mode of vision physiology.

Junctional apparatus like ball and socket (Fig. 3.B.3) arrangement are present but not distinct in the microphotograph of *B. malanostictus* lens indicates that the cellular shape of the lens changes during focusing movement and only intercellular gliding occurs during focusing the object to the retina (Kuwabara, 1975). This suggests blurt vision of the animal in rarer medium that is air.

Presences of innumerable and distinct ridges and grooves in the fiber cell of the lens of *B. malanostictus* (Fig. 3.B.3) indicate that lateral sliding movement is prevented among the fibers cells during focusing an object in the retina. This suggests that the lens cells are linked together as a functional unit, which allows some rotatory movement during movement of the lens for movement. This arrangement of junctional apparatus proves mode of vision in rarer medium that is air. This difference mode of vision in rarer medium might indicate a nocturnal behavior.

Many interdigitation of lateral flaps (Fig. 3.B.3) of the fiber cells are observed in the lens of *B. malanostictus*. Interdigitation contributes transport activity of the lens (Kuwabara, 1975). This suggests that the epithelium of the lens is likely to be electrically coupled to the fibers via pathway through the plane of the epithelium, connecting the lens fibers in the bow region (Zelenka, 1978).

Gap junction, is also observed which is a cytoskeleton of the lens (Fig. 3.B.3) proves that a pathway is provided linking epithelial cells directly to the underlying fiber cells (Duncan, 1974). A large number of gap junctions in the fiber cells suggest that the fibers exist in a state that facilitates the movement of
water, ion and other small metabolites (Benedetti et al., 1990; Mathias et al., 1997; Le and Musil, 2001). This proves a purely air vision lens and terrestrial vertebrate characteristic.

Mounds are small elevation is another type of junctional apparatus is observed in the SEM microphotograph of the lens fiber B. mahanostictus (Fig. 3.B.4). Mounds maintain the shape and morphology of the lens during accommodation (Kuwabara, 1975). Mounds are prominent in terrestrial animal, which have air vision. Presence of numerous mounds in the lens of B. mahanostictus suggests that the lens is well adapted for air vision and the shape well maintained during accommodation. This proves that the lens is moved for accommodation, but the shape of the lens is not change during accommodation (Kulshrestha, 2005).

Cytoskeleton of the lens like intermediate filament and chain filament is observed in the lens of B. mahanostictus (Fig. 3.b.5). Intermediate filaments are present in fish, frog, bird and mammalian lenses (Maisel, 1980). Chain filaments consisted of globular particles are found only in frog and chick lens (Bradley et al., 1998). In frog globular particles of chain filaments are arranged along a filamentous backbone. The presence of chain filaments may serve to stabilize the organization of some lens crystallins in a nonrandom form that minimizes disorder in the fiber cell. The intermediate and chain filament correlates the shape of the lens and its accommodative ability. It imparts structural support to the epithelium to maintain the spherical lens shape. This network, attached to the cell membrane, imparts and internal architecture to the fiber cell that minimizes lights scattering, stabilizes the order and distribution of proteins and maintains the shape of the fiber and the lens. The presence of desmosomes in the lens shows (Fig. 3.B.5) an amphibian character (Rafferty and Goosens, 1974, 75, 77 & 78). Numerous granules of various sizes are also seen in the SEM microphotograph of B. mahanostictus (Fig. 3.B.5). The presence of this spherical granules indicate that reflection usually dose not takes place by the lens some portion of the light scattered from the lens to regulate the quantity and quality of the light entering the retina (Miller, 1979). This suggests that the particles may act as spherical scatters in the lens of this species (Goswami et al. 2000).
Summary:

1. The shape of the lens of *B. melanostictus* is round or spherical, transparent and colourless. The lenticular fibers are distinct with interdigitation arrangement. The nipples of the fibers are not smooth but possess hairy side projection. The size of the nipple and the distance between two nipples are not uniform but variable. Nipples are elongated in shape.

2. Junctional complexes like ball and socket arrangement are not clearly seen. Ridges and grooves are present. Interdigitation of the ridges is observed. Numerous mounds are also observed. Many depressions are seen in the fibers cell. Innumerable granules of various sizes are also seen.

3. Cytoskeleton of the fibers like gap junction, intermediate filament, and desmosomes are seen in the micrograph of this lens. Chain filaments with globular particles are also observed which are arranged along a filamentous background. Annular pad are absent.
C: EYE LENSES OF REPTILES

Introduction:

The eye of reptiles shows many specialization and advancements over those of Amphibians in order to function on land. In addition to the usual moveable upper and lower eyelids, there is well-developed third eyelid or nictitating membrane, which slides across the moist cornea. Harderian and lachrymal glands are present, the secretions off which cleanse and lubricate the nictitating membrane and cornea. The eyeball has the usual three layers: choroids, sclerotic and retina. The ciliary body, present at the junction of the sclerotic and cornea, contain well-developed ciliary muscles and ciliary processes forming the suspensory ligament attached to soft tissue around the lens, called annular pad (Kotpal, 2005). Striated intrinsic ciliary muscles are present on the ciliary body for the first time in reptiles (Kulshrestha, 2005). Like other vertebrates the lens of reptiles are transparent, highly refractive structure located between the papillary portion of the iris and the vitreous (Hogan et al., 1975).

Among the reptiles the turtles have the softest and most pliable lenses of all vertebrates. The lenses have a weekly-developed ringwulst and are flattest in land living tortoises and virtually spherical in sea turtles. Crocodile, as nocturnal animals, have more round lenses and a virtual disappearance of the ringwulst (Harding and Murphy, 1996). Lizards have very soft lenses with and extremely thin capsule and relatively thick ringwulst. The lens is flat in diurnal species and nearly spherical in nocturnal species (Kulshrestha, 2005). Accommodation for near object in Reptiles is possible by cilairy muscles and there processes squeezing the periphery of the lens.

Observation and Result:

1. Kachuga sylhentensis:

   *Kachuga sylhentensis* is a reptile belongs to order Chelonia and sub-class Anapsida. It is a fresh water tarrapin commonly known as “Roofed
terrapin" lives in warm deep water. They are commonly found in India and feeds on water plants. It is about 16 to 18 inches long. Body is covered with dorsal carapace and ventral plastron with a short tail. The first three plates of carapace are produced into dorsal median spines. Head, neck and limbs retractile into carapace. Head is triangular in shape with small eyes, which is about 10 to 12 times its head. Each eye has two moveable upper and lower eyelids and a well developed nictitating membrane, which slides across the moist cornea.

Figure: 3.C.1. SEM microphotograph (20KV X 60) of the whole lens of *K. sylhentensis* showing its spherical shape with distinct Cortex (C), Medulla (M) and Lenticular fibers (F).

The lens of *K. sylhentensis* (Fig. 3.C.1) is transparent, soft and creamy in colour. It is spherical and brittle in nature. Like other vertebrates the lens is differentiated into outer cortex and inner medulla or nucleus. Both the cortex and medulla are made up of lenticular fibers of uniform sizes. SEM study of the lenticular fibers shows that the fibers are not smooth but possess side projection or nipples, which binds the lenticular fibers. The nipples are elongated and almost uniform in size. The nipples are differentiated into head and stalk and possess few thick hairy side projections (Fig. 3.C.2).
Figure: 3.C.2. SEM microphotograph (15KV X 3000) of the lens of *K. sylhentensis* showing its lenticular fibers (F), nipples (Ni), nipples head (H), stalk (S) and side projection (P).

Width of the lenticular fibers ----------------------- 4.5 µm.
Length of the nipples -------------------------------- 2.0 µm.
Length of the nipple’s head ------------------------ 1.5 µm.
Diameter of the nipple’s head --------------------- 1 µm.
Length of the stalk ------------------------------- 1 µm.
Width of the stalk -------------------------------- 0.5 µm.
Maximum distance between two nipples ------------- 2 µm.
Minimum distance between two nipples -------------- 0.5 µm.
Length of the hairy projections of head ---------- 0.5 µm.

Further observation of the lenses shows junctional complexes like distinct numerous ball and socket arrangement of the lenticular fibers which are of variable sizes. The balls are embedded in a complementary depression or socket in the adjacent fibers. Big and distinct gap junctions are seen. Ridges are absent. Interdigitations of lateral flaps are distinct. Small mounds are numerous and prominent. Granules are absent. Small grooves are seen (Fig. 3.C.3)

Approximate size of the ball--------------------- 1.5 µm.
Approximate depth of the socket ------------------ 1 µm.
Length of the lateral flaps----------------------- 1 µm.
Size of the gap junction -------------- 2.5μm.
Sizes of the mounds ----------------- 0.1μm.

Figure: 3.C.3 SEM microphotograph (15KV X 3000) of the lens of K. sylhetensis showing its lenticular fibers with distinct ball (B), socket (So), lateral flap (FL), mounds (M) and gap junction (Gp).

2. *Hemidactylus brooki*:

*Hemidactylus brooki* is a reptile belongs to the order Squamata and sub class Lacertilia. It is commonly known as house lizard and is about 10 inches in length. They are pale green in colour and have four limbs. The digits of the limbs are clawed and are provided with adhesive disc underneath which work on vacuum cup principal by which the animal adhere to smooth surface. It is a swift runner and is carnivorous feeding on insects and worms. Eyes are prominent, big and elliptical in shape. Its diameter is about 4 to 6 times in head. Eye lids are well developed and moveable. The lower eyelid is much more moveable than the upper eyelids.

The lens of *H. brooki* is flattened, round and white in colour. It is transparent, soft crystalline and solid structure. The general plane of the whole lens is similar as fish. Higher magnification of SEM micrograph of the lens shows that the lens is made up of lenticular fibers cells which the main
histological structures. The lenticular fibers are not straight but wavy. They are not smooth but possess side projection called nipples. The nipples are of various shapes. Some look like tennis racket and some look like spoon. The nipples can be differentiated into a broad head, a narrow small stalk and a broad base (Fig. 3.C.4). The head of the nipples are not smooth but possess two types of side projection. Some projections are hair like and some are knob like (Fig. 3.C.4). The knobs like projections are almost triangular in shape. The junctions between the stalk and base have epicalyxes like minute structures (Fig. 3.C.4). At high magnification the nipples look like a knob head of a wall pin (Fig. 3.C.5).

Figure: 3.C.4. SEM microphotograph (20KV X 24000) of the lens of *H.brooki* showing its lenticular fibers (F), nipples (Ni) head (H), stalk(S), knob projection (Kp), epicalyx structure (E) and hairy projection (P).

- **Width of the lenticular fibers** = 5µm.
- **Length of the nipples** = 2µm.
- **Diameter of the head of the nipples** = 1.2µm.
- **Length of the stalk of the nipples** = 0.5µm.
- **Width of the stalk** = 0.5µm.
- **Length of the hair like projection of the head** = 0.1µm.
- **Length of the knob like projection** = 2µm.
- **Maximum distance between two nipples** = 1µm.
- **Minimum distance between two nipples** = 0.5µm.
Further observation of the lenses shows junctional complexes like big and prominent ball and socket arrangement. Few surface ridges and grooves are also observed. Here and there minutes mounds are seen. Prominent and numerous interdigitals of lateral flaps are seen. Big gap junctions are distinct. Lens cytoskeletons like beaded filaments are also observed. Granules are absent (Fig. 3.C.6)

Approximate size of the ball -------------------------- 1 μm.
Approximate size of the socket ---------------------- 1.5 μm.
3. *Gecko gecko*:

*Gecko gecko* is reptile belong to the order Squamata and Sub-order Lacertilian. It is a stout body lizard with broad flattened head and stumpy tail. The body is covered with minute granular scales. It has four stout limbs, which have digits. The digits are clawed and the toe possessed adhesive disc or sucker. The animal is carnivorous and catches its prey with long thick, fleshy viscid tongue. Eyes are big and prominent and elliptical in shape. Its diameter is 4 to 5 times in head. Eyelids are absent.

*Figure: 3.C.7 SEM microphotograph (20KV X 78) of the lens of G.gecko showing brittleness of the lenticular fibers (F).*

The lens of *G.gecko* is flattened in shape and is very big in size in comparison to the eye. It is transparent, soft and crystalline in nature. The lenses are round and pale yellow in colour and contain fluorescent materials. The lens is
enclosed in capsule. SEM micrograph of the lens shows two distinct region outer cortex and inner medulla.

Further magnification shows that both the cortex and medulla is made up with parallely arranged lenticular fibers cells, which is the main histological structure of the lens. These cells are almost smooth, uniform in size and wavy in appearance. The lens is brittle in nature (Fig. 3.C.7). The fibers cells are held together by linearly arranged finger like projection on either side known as nipples which are not distinct (Fig. 3.C.8). The nipples of cortexes are short and almost smooth (Fig. 3.C.8). The lenticular fibers of the medulla or nucleus are smooth, broken which appears like a pavement (Fig. 3.C.9).

![SEM microphotograph (20KV X 200) of the lens of G.gecko showing its lenticular fibers (F) and nipples (Ni) of the cortex.](image)

**Figure:** 3.C.8. SEM microphotograph (20KV X 200) of the lens of *G.gecko* showing its lenticular fibers (F) and nipples (Ni) of the cortex.

- Width of the lenticular fiber: 0.5μm - 1μm.
- Length of the nipple: 0.1μm - 1μm.
- Diameter of the nipple: 0.5μm - 1μm.
- Maximum distance between two nipples: 2μm.
- Minimum distance between two nipples: 0.5μm.
Further magnification of the lenticular fibers shows disorganization of junctional complexes. Prominent small ball and socket arrangement are seen only on the fibers of the cortex. This arrangement is not seen in the medulla. Ridges and grooves are numerous and distinct where ridges are clubbed together in parallel clusters and 0.1μm apart. Big lateral flap and prominent interdigital process are present. Small moulds are also seen. Granules are absent (Fig. 3.C.10)

Approximate size of the ball-------------------------- 0.1μm.
Approximate depth of the socket --------------------- 0.1μm.
Approximate size of the mounds --------------------- 0.5μm.
Length of the flaps ------------------------ 9μm -10μm.
Width of the fine particles ---------------0.3μm -0.5μm.
Height of the ridges -------------------- ------------------------0.5μm.
Width of the ridges ------------------ ------------------------3μm.
Size of the groove ------------------ ------------------------1μm-2μm.

Figure: 3.C.11 SEM microphotograph (20KV X 4800) of the lens of G.gecko showing numerous surface ridges (R) and grooves (W).

Discussion:

Like other vertebrates lenses the lenses of reptiles perform twine functions- optics and accommodation. The spherical shape of the lenses of K. sylhetensis indicates aquatic mode of adaptation high refractive power and dioptric vision. This type of lens can be subjected to spherical aberration and changes its shape for accommodation. The flattened shape of the lens of H. brooki and G.gecko indicates terrestrial mode of adaptation and not subjected to spherical aberration (Grusser and Hinstedt, 2003). The lens does not change its shape for accommodation instead the whole eye moves inside the globe to accommodate and focus light in the retina (Sivak, 1983). The lenses of all the three investigated specimens are soft lens, which indicates reptilian characters.

K. sylhetensis has small eyes while H. brooki and G.gecko have big eyes. This suggested that K. sylhetensis eye is well adapted for brighter image under water and short focal length of the lens while H. brooki and G.gecko have well adapted
eye for focusing light and creating brighter images (Femald, 1990; Kulshrestha, 2005).

The SEM micrograph of all the lenses of the entire investigated reptilian species wavy nature of the lenticular fibers, which indicates crystallinity of the lenses. The refractive index is thought to drop continuously and parabolically from the center to the periphery so as to produce a little or no spherical aberration (Mattniessen, 1880; Goswami et al., 2000). One of the major functions of the lenticular fibers of the lens is that it regulates and filters the light entering the retina. After investigating the SEM micrograph of the lenses of the three investigating reptilian species it is seen that the size of the lenticular fibers of K. sylhetensis and H. brooki are uniform while it is variable in G. gecko (Table. 3. 2).

The size of the lenticular fibers is largest in H. brooki and smallest in G. gecko (Chart.3.C1). All these indicate some phylogenetic relationship and functional and adaptive significances. The lenticular fibers have some linearly arranged finger like side projection called nipples, which regulates the entry of light to the retina (Dey, 1988). These nipples are well differentiated into head and stalk in K. sylhetensis and H. brooki while stalk is absent in G. gecko (Table. 3. 2)
The sizes of nipples of the lenticular fibers of the *K. sylhentensis* and *H. brooki* are of the same and uniform but the size is variable and small (Chart 3. C.2) in *G. gecko*. All these indicate some phylogenetic and physiological relationship and significances in vision physiology of reptiles.

The maximum distance between the two nipples is same in *K. sylhentensis* and *G. gecko* and is less in *H. brooki* where as the minimum distance is same in all the three-spices (Table. 3.2). The maximum distance between two
nipples is plotted in a graph against the minimum distance of the nipples of the three investigated reptiles gives a straight line for minimum distance shows the minimum distance is same in all the three reptiles. (Chart.3.C.4). The nipples regulate the entry of the light to the retina (Lythgoe, 1979).

A straight line suggests that the entry of light to the retina is maintained in the same way in all the three investigated reptiles' inspite of being different mode of habitat. (Chart.3.C.4). Again the maximum and minimum distance is same in *H. brooki* and *G. gecko* (Chart.3.C3) signifies same mode of visual adaptation. This also indicates some phylogenetic and physiological significance and relationship among the three species.

The head of the lenticular fibers of *K. sylhentensis* and *H. brooki* is rough and possess some hair like projection. In addition to this hair like projections *H. brooki* lenticular fibers also possess some knob like projections. But the head of the lenticular fibers of *G. gecko* is indifferentiated without any side projection. These again suggest some phylogenetic, physiological and functional significance of vision. Disorganized structure of the fiber cells of *G. gecko* indicates some functional significance in it's vision physiology.
Junctional apparatus of the fibers like ball and socket arrangement are seen in the SEM micrograph of all the three investigated reptilian species. This suggest that the shape of the lens is well maintain and little inter cellular gliding occurs during focusing and minimized cell slippage (Kuwabara, 1975) and also indicates that the lenticular fibers of the lens are binds firmly (Dickson and Crock, 1975).

When the size of the ball is plotted in a graph (Chart.3.C.5) against the size of the socket of the three investigated reptilian species it is seen that the size is biggest in *H. brooki* and smallest in *G. gecko* This suggest that the lens of *G. gecko* have poor vision as its shape is poorly maintain during focusing where as the lens of *H. brooki* is well maintained for proper and efficient vision (Kuwabara, 1975). *K. sylhentensis* ball and socket’s size is in between *G. gecko* and *H. brooki* as it is mainly limited to aquatic vision and not air- vision. All this indicates some phylogenic relationship and significance. In *G. gecko* size of the ball and socket arrangement are same, which suggests some phylogenic significance.

Again when investigated the size of ball and socket arrangement in the three reptilian species (Chart.3.C.6) it is observed that the size of ball in *K. sylhentensis* and the size of socket in *H. brooki* are same.
The size of the socket in *K. sylhentensis* is same with the size of the ball in *H. brookii* may indicate some functional and phylogenetic relationship and significances. It is also seen that the size of the ball and socket arrangement are very small and same in *G. gecko* indicates some functional significance.

Another junctional complex like ridges and grooves are also observed in the SEM micrograph of the lenses *H. brookii* and *G. gecko* (Table 3.2). This proves that lateral sliding movement of the lenticular fibers is preventing during accommodating and focusing light by the lens to the retina (Hollenberg et al., 1976). In *G. gecko* size of ridges and grooves are variable indicates some functional significance. Ridges and groove arrangement are absent in *K. sylhentensis* (Table 3.2) indicates some phylogenetic and adaptive significances.

The sizes of the lateral flaps are variable in *G. gecko* but uniform in *K. sylhentensis* and *H. brookii*. Very large lateral flaps are seen in the micrograph of *G. gecko*. These suggest rotatory kinds of movement of the lens of the three reptilian species (Hollenberg et al., 1976). Numerous interdigitations are observed which proves contribution of transport activity of the lenses and suggest that the epithelium of the lens is likely to be electrically coupled (Dickson and Crock, 1975).
When the sizes of the lateral flaps are compared in the 3 reptiles (Chart 3.C.7) it is observed that the length of the lateral flaps is very long in *G. gecko* and short in *H. brooki* indicates some functional significance.

Mounds another types of junctional apparatus are seen in the SEM micrograph of the lens of *H. brooki* and *G. gecko* and not in *K. sylhentensis*. Mounds maintain the shape of the lens during accommodations that are prominent in terrestrial animals that have air vision (Harding and Murphy, 1996). Absence of mounds in *K. sylhentensis* suggested aquatic mode of adaptation where as *H. brooki* and *G. gecko* possess terrestrial mode of adaptation. Absence of mounds in the lenticular fibers of *K. sylhentensis* also indicates some phylogenic significance.

Gap junctions are observed only in the micrograph of *K. sylhentensis* and *H. brooki* but not in *G. gecko*. This indicates some phylogenic and functional difference and significances among the species and with other vertebrate species.

Cytoplasmic filaments like bead filaments are observed in the fibers of *H. brooki* suggest that and internal order is provided to the fiber cells that may help to maintain cell integrity provide contractile force during lens movement and facilitate transparency of the lens (Feng *et al.*, 2000). It also suggested some phylogenic and functional significance.
Summary:

1. Three reptilian species are investigated and all the three species do not belong to the same taxonomic status. The three species belong to different orders and different habit and habitat.

2. The size of the eye of *K. sylhentensis* is round and small while the size of the eye of *H. brooki* and *G. gecko* are big and elliptical. The lenses of all the three investigated species are not same. In *K. sylhentensis* it is very soft, spherical and creamy. In *H. brooki* it is soft, flattened, round and white in colour and in *G. gecko* it is soft, flattened, round and pale yellow in colour.

3. The sizes of the lenticular fibers are variable in *K. sylhentensis* and *G. gecko* while it is uniform in *H. brooki*. The sizes of the nipples are not same in all the investigated reptilian species. The nipples are differentiated into heads and stalk in *K. sylhentensis* and *H. brooki* but in *G. gecko* it is not differentiated into head and stalk. Minimum distance between the nipples is same in the entire three investigated specimen while the maximum distances is not the same in the entire specimen. Hairs like side projections are present in the nipples of *K. sylhentensis* and *H. brooki* but absent in *G. gecko*. In *H. brooki* in addition to this hair like projection another Knob like projection are present.

4. Ball and Socket arrangement are seen in the entire investigated species but the size is bigger in *H. brooki* and smaller in *G. gecko* among the three. The sizes of the mounds are same in *H. brooki* and *G. gecko* but absent in *K. sylhentensis*.

5. Ridges are present in the *H. brooki* and *G. gecko* but absent in *K. sylhentensis*.

6. Lateral flaps are also seen in three specimen but the sizes are variable in *K. sylhentensis* and *G. gecko* and uniform in *H. brooki*. Also *G. gecko* has very big lateral flaps.

7. Mounds are seen in the micrograph of *H. brooki* and *G. gecko* but absent in *K. sylhentensis*.

8. Gap junctions are seen in *K. sylhentensis* and *H. brooki* but not in *G. gecko*.

9. Bead or chain filaments are observed only in *H. brooki*. 
### Table 3.2: Summary table of the observation of the lens of reptilian species.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>K. sylhetensis</th>
<th>H. brooki</th>
<th>G. gecko</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxonomic status</td>
<td>Chelonia</td>
<td>Squamata</td>
<td>Squamata</td>
</tr>
<tr>
<td>Habitat</td>
<td>Aquatic / fresh</td>
<td>Terrestrial/</td>
<td>Terrestrial/</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>house walls</td>
<td>gardens</td>
</tr>
<tr>
<td>Food habit</td>
<td>Herbivore</td>
<td>Carnivore</td>
<td>Carnivore</td>
</tr>
<tr>
<td>Anatomical peculiarity</td>
<td>Carapace &amp;</td>
<td>Carapace &amp;</td>
<td>Carapace &amp;</td>
</tr>
<tr>
<td></td>
<td>Plastron</td>
<td>Plastron</td>
<td>Plastron</td>
</tr>
<tr>
<td></td>
<td>Present</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td></td>
<td>Scales</td>
<td>scales</td>
<td>scales</td>
</tr>
<tr>
<td></td>
<td>Epidermal</td>
<td>Dermal</td>
<td>Dermal</td>
</tr>
<tr>
<td>Web digits</td>
<td>Padded digits</td>
<td>Padded digits</td>
<td>Padded digits</td>
</tr>
<tr>
<td>Swimmer</td>
<td>Swimmer</td>
<td>creeper</td>
<td>creeper - Runner</td>
</tr>
<tr>
<td>Size &amp; diameter of the eye</td>
<td>Small, 10-12</td>
<td>elongated, big</td>
<td>elongated, big</td>
</tr>
<tr>
<td>The eye</td>
<td>times in head</td>
<td>head</td>
<td>head</td>
</tr>
<tr>
<td>Nature of lenses</td>
<td>Spherical</td>
<td>Flattened</td>
<td>Flattened</td>
</tr>
<tr>
<td>Wt of the lenticular</td>
<td>4.5 - 0.5</td>
<td>5</td>
<td>0.5 - 1</td>
</tr>
<tr>
<td>Fibers in μm</td>
<td>2</td>
<td>2</td>
<td>0.1 - 1</td>
</tr>
<tr>
<td>Lt. of the nipple in μm</td>
<td>1.5</td>
<td>1.2</td>
<td>1.0 - 0.5</td>
</tr>
<tr>
<td>Diameter of the head in μm</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Lt. Of the stalk in μm</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Max. dist between</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Two nipples in μm</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Min. dist between</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Size of the side projection - of head in μm</td>
<td>0.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Size of the ball in μm</td>
<td>1.5</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Depth of the socket in μm</td>
<td>1</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Ht. of the ridges in μm</td>
<td>0.1</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Size of the gap junction in μm</td>
<td>2.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Size of the grooves in μm</td>
<td>-</td>
<td>0.1 - 1</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Size of the mounds in μm</td>
<td>0.1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Lt. of the lateral flags in μm</td>
<td>1</td>
<td>0.1</td>
<td>9 - 10</td>
</tr>
<tr>
<td>Bead filament in μm</td>
<td>-</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
Introduction:

The sense of sight or vision is highly developed in birds in adaptation to the aerial mode of life. Good vision is necessary to cover considerable distance, to find food, to recognize mates, to avoid obstacles, to know when and where to land and so on. According, the eyes are exceptionally well developed and proportionately larger than any other vertebrates. The eyeball is not spherical with a biconvex lens, being flattened anterior-posteriorly. It is somewhat concave in front and convex behind.

Eyebrows or eyelashes are absent in bird’s eyes. The eyelids are conspicuous. The upper eyelid is slightly movable, but the lower eyelid is well developed and more moveable arising upwards to close the eye. The eyelids do not blink, though they are closed in sleep. A semitransparent third eyelid or nictitating membrane is also present forming a fold at the anterior angle of the eye. It can be drawn posteriorly over the surface of the eye with great rapidity. The nictitating membrane serves mainly for cleansing the eye ball, also as a protective covering when the bird are facing or flying against the wind, to reduce the glare of the sunlight during day in nocturnal birds and to shield the eyes of aquatic birds under water (Kulshertha, 2005).

The nictitating membrane is lubricated by the oily secretion of a Harderian gland present in inner angle of the eye. Tear gland or lachrymal glands are also well developed and present below the outer angle of the lower eyelid. Their watery secretion nourishes the non-vascular cornea and washes away dust particles (Kotpal, 2005).

The eyeball is narrow and its wall is made of the usual three layers; the outer sclerotic coat, the middle choroids and inner retina. The sclerotic coat is subdivided into anterior, cornea and the posterior, sclera. Anteriorly, at the junction with cornea, a ring of 10-12 small, overllaping bony sclerotic plates or ossicles strengthens the sclera (Kotpal, 2005).
Beneath the sclerotic wall lays a thin, dark, pigmented and richly vascular membrane the choroids. Anteriorly the choroid forms a circular pigmented diaphragm, the iris pierced by a rounded aperture, the pupil. At the base of the iris, the choroids becomes thickened and radially folded to form the ciliary body, contains well-developed striated ciliary muscles (Kushertha, 2005).

The light sensitive retina lies within the choroids in the posterior region of the eye. The retina consists of nerve fibers and numerous minute rod and cone cells. Two sensitive spots or foveae: the central fovea for monocular vision and temporal fovea for binocular vision are found on the retina (Kushertha, 2005).

A remarkable comb-like structure, the pecten, projects into the cavity of the eye from the region ventral to the blind spot where optics nerve enters the eye ball. It occurs in all birds except Kiwi and found in some reptiles and absent in mammals (Goodenough, 1979).

The lens is suspended behind the iris by suspensory ligaments. It is soft, pliable, crystalline, colourless, transparent and biconvex. Its posterior side is more convex than anterior side. A thin fibrous capsule surrounds the lens.

Observation and Result:

1. *Anas poehiloryncha*:

*A. poehiloryncha* belongs to the order Anseriformes with broad bill and webfeet. It is a water bird with short legs and fleshy tongue. It is a carnivorous bird which feeds on fish, snails etc. The eyes are big and prominent with diameter being 3 to 4 times its head.

The lenses of *A. poehiloryncha* are big, soft, oval and biconvex in shape and creamy in colour. It is transparent and crystalline in nature. Like other vertebrates the lens is enclosed in a capsule and consists of two parts. The outer cortex and the inner dense medulla and is made up of numerous lenticular fibers that are the main histological structures. Further magnification of the lens shows that the lenticular fibers are paralley arranged which are uniform in size. They are wavy in nature. These fibers are held together by invaginated protrusions called nipples, which are arranged horizontally on the either sides of the fibers. The nipples are rough with some hairy projection and are broad and thick and...
elongated with a broad head and narrow stalk. The distance between the two nipples is uniform (Fig.D.1).

![SEM microphotograph](image)

**Figure:** 3.D.1. SEM microphotograph (15KV X 3000) of the lens of *A.poehiloryncha* showing its lenticular fibers (F), nipples (Ni) head (H), stalk(S), hairy projection (P).

- Width of the lenticular fibers $\sim 5 \mu m$
- Length of the nipples $\sim 0.5\mu m - 1.5 \mu m$
- Diameter of the head $\sim 0.5\mu m - 1 \mu m$
- Length of the stalk $\sim 0.2\mu m - 0.5 \mu m$
- Maximum distance between two nipples $\sim 1.5 \mu m$
- Minimum distance between two nipples $\sim 1 \mu m$
- Length of the side projection $\sim 0.5 \mu m$

Further SEM studies of the lens of *A.poehiloryncha* shows some junctional complexes like ball and socket arrangement, ridges and mounds. Ball and socket arrangement are not prominent but ridges are big and prominent. Small mounds are seen. Numerous granules and chain filaments are seen on the lens.
Figure: 3.D.2. SEM microphotograph (15KV X 4000) of the lens of *A. poehiloryncha* showing its lenticular fibers with ball (B), socket (So), mounds (M), ridges (R), gap junction (Gp) and chain filament (Ch).

- Approximate size of the ball: 1 μm.
- Approximate depth of the socket: 1 μm.
- Height of the ridges: 2 μm.
- Width of the ridges: 0.2 μm.
- Size of the mounds: 0.8 μm.
- Size of the gap junction: 1 μm.
- Size of the granules: 0.5 μm.
- Size of the chain filament: 1 μm.

2. *Acridoterif tristis*:

*A. tristis* is a bird belongs to the order Passeriformes is a sad grasshopper hunter. It measures about 22.5 cm in length. *A. tristis* is a perching bird with feet adapted for perching and beaks are adapted for cutting. They are omnivorous birds and feeds on fruits, insects and kitchen scraps. The eyes are prominent and moderate in size with a diameter of 4 to 6 times in head.

The lens of *A. tristis* are big, soft, oval, and flatten and yellowish in colour. Like other vertebrates the lens is transparent and crystalline in nature. The lens is enclosed in a capsule and consisted of to parts cortex and medulla. The arrangements of the lenticular fibers are parallel, wavy and are uniform in size.
The fibers are not smooth but have some side projection called nipples. These nipples are linearly arranged in cluster in *A. tristis*. The nipples bear some hairy side projection (Fig. 3.D.3).

Width of the lenticular fibers: 4µm.
Length of the nipple: 2µm.
Diameter of the head: 1.5µm.
Length of the stalk: 0.5µm.
Maximum distance between to nipples: 2µm.
Minimum distance between to nipples: 1.5µm.

*Figure:* 3.D.3. SEM microphotograph (15KV X 4000) of the lens of *A. tristis* showing its lenticular fibers (F), nipples (Ni), head (H), stalk (S) and hairy projection (P).

Further SEM studies show some junctional complexes like prominent ball and socket, irregular interdigitation and prominent gap junction. Small mounds are seen. The lens is full of numerous granules (Fig. 3.D.4).

Approximate size of the ball: 0.3µm.
Approximate depth of the socket: 0.5µm.
Height of the ridges: 1µm.
Weight of the ridges: 0.1µm.
Length of the lateral flap: 1.5µm.
Size of the mounds: 0.2µm.
Size of the gap junction ................................ 1.5 µm.
Size of the granules ...................................... 0.01 µm.
Size of the chain filament --------------------------- 3 µm.

**Figure:** 3.D.4. SEM microphotograph (15KV X 4000) of the lens of *A. tristis* showing its lenticular fibers with ball (B), socket (So), mounds (M), ridges (R), lateral flap (FL), granules (G), gap junction (Gp) and chain filament (Ch).

**Discussion:**

Like other vertebrates optics and accommodation are the two main visual functions of the eyes of aves. The lens of both the birds are soft, large and oval in size indicates that while viewing extended source they do not have a brighter retinal image instead the increase light entering the eye focus a more distinct image on the retina (Prince, 1956). The lens of *A. poehiloryncha* is biconvex and the lens of *A. tristis* is flattened indicates that the lens changes its shape to accommodate and focus light in the retina which is a typical terrestrial mode of vision but bioconvex lens of *A. poehiloryncha* suggest some phylogenetic and functional significance. Presence of large size eye and lens in both the avian species suggests maximum focal length of the lenses and less refractive power of the lenses during vision physiology (Duke-elder, 1958).
The SEM micrograph of the lenses of both the species shows wavy nature of the lenticular fibers indicates crystalline nature of the lenses (Dey, 1988). The colour of the lens of *A.poehiloryncha* is creamy and that of *A. tristis* is yellow indicates that both the birds lens possesses some fluorescent material of different kind, which suggests some phylogenetic, functional and structural significance.

The lenticular fibers of the lens of both the birds are wavy, which indicates brittleness of the lenses (Dey, 1988). The fiber cells of both the bird are broad (Table 3.3). When further observed it is seen that *A.poehiloryncha* has bigger fiber cells than *A.tristis* (Chart 3.D.1)

The lenticular fibers possess nipples, which are uniform in size in *A.tristis* but variable in *A.poehiloryncha* (Table 3.3). The nipples are well distinguished into prominent head and stalk which are also uniform in sizes in *A.tristis* and variable in *A.poehiloryncha*. All these indicate that the lenticular fibers filters light in two media both air and water in *A.poehiloryncha* and only one medium that is air in *A.tristis*. When the length of the nipples of the two birds are compared (Chart 3.D.2) it is seen that the length of the nipples of *A.poehiloryncha* is bigger than *A.tristis*. This may suggest some phylogenetic and functional significance and relationship.
The head of the lenticular fibers of *A. poehiloryncha* is not smooth but possess some hair like side projection. This indicates that *A. poehiloryncha* have both aquatic and terrestrial mode of vision. Where as the lenticular fibers of *A. tristis* is smooth without any side projection indicates only terrestrial or aerial mode of vision (Lythgoe, 1972).
The maximum and minimum distances between the nipples are not same in both the avian species. It is seen that the maximum distances between two nipples is more in *A.tristis* than in *A.poehiloryncha* and the minimum distances is more in *A.poehiloryncha* than in *A.tristis* (Chart.3.D.3). Again it is observed that the maximum distances between the nipples of *A.poehiloryncha* are same with minimum distances of the nipples of *A.tristis*. All these indicate some phylogenic and functional significance.

Numerous spherical granules are observed in the micrograph of both avian (Table.3.3) species indicates that some portion of the light entering the eye is scattered by the lens to regulate the quantity of light entering the retina (Lythgoe, 1979). This suggests that spherical scatters takes place in the lens of aves (Goswami *et al.* 2000).

Junctional apparatus like ball and socket arrangement are observed in the SEM micrograph of the lens of both the species (Table. 3.3). It is big, prominent and numerous in *A.poehiloryncha* indicates that the shape of the lens is well maintain during focusing movement of the lens and minimized cell slippage and little intercellular gliding occurs during focusing (Kuwabara 1975). This suggests a semi-aquatic mode of vision.
Ball and socket arrangement are small and not distinct in the lens of *A. tristis* indicates the cellular shape of the lens change and cell slippage is not minimized during focusing movement of the lens and more inter cellular gliding occurs during focusing. This suggested an aerial mode of vision (Dickson & Crock, 1975). When the sizes of the ball and socket is compared in the 2 avian species (Chart. 3.D.4) it is observed that the sizes of the ball in both the Aves is of equal in sizes but the sizes of socket is smaller in *A. poehiloryncha* than *A. tristis*. These differences in the arrangement of the ball and socket arrangement in the lens of both the avian species indicate some phylogenetic and functional significance.

Thin prominent ridges and grooves are observed in the fiber cells of the lenses of both the avian species suggest that lateral sliding movement of the lenticular fibers is prevented during accommodation and focusing light by lens to the retina and also indicates that a rotatory movement of the lens occurs during focusing light (Hollenberg *et al.*, 1976). The sizes of the ridges are longer in *A. poehiloryncha* than *A. tristis* (Chart. 3. D.5) indicates some phylogenetic, functional and structural relationship and significance.

![Chart 3. D.5: Showing the Height of the ridges in 2 Aves](image)

Another type of small elevated junctional apparatus called mounds are seen in the SEM micrograph of the lens of both the avian species indicates that the
shape and morphology of the lens is well maintained during accommodation and suggest that the lens is well adapted for air vision.

Gap junctions are observed in both the species of birds providing a pathway linking epithelial cells directly to the underlying fiber cells and facilitating the movement of water, ions, and metabolites (Goodenough, 1979; Le and Musil, 2001). Presence of small gap junctions in *A. poehiloryncha* than *A. tristis* indicates that the fiber lens of the latter remains in a more metabolically coupled state and facilitates better movement of water, ions, and other metabolites (Brown, 1973).

Interdigitation of lateral flaps are observed in the SEM micrograph of the lens of *A. tristis* and not in *A. poehiloryncha* also indicates that the epithelium of the lens of the former bird is likely to be electrically coupled to the fibers via a pathway through the plane of epithelium, connecting the lens fibers in the bow region and facilitating better transport activity of the lens than the lens of the latter bird (Goodenough, 1979). This may be the fact that *A. poehiloryncha* leads both aquatic and air mode of vision and *A. tristis* have only air mode of vision.

Cytoskeleton-like chain filament is observed in the lens of both the species. These filaments serve to stabilize the organization of some lens crystalline in a nonrandom form that minimizes disorder in the fiber cell (Feng et al., 2000). They correlate the shape of the lens and its accommodative ability and impart structural support the epithelium to maintain the shape of the lens. The presence of chain filament suggest an internal architecture of the fiber cell which minimizes light scattering and stabilizes the order and distribution of proteins and maintains the shape of the fiber and lens. Presence of short chain filament in *A. poehiloryncha* and long and thin filament in *A. tristis* suggest also some phylogenetic and functional significance.

Summary:

1. Two avian species of different taxonomic status are investigated. They are *Anas poehiloryncha* belongs to order Anseriformes and *Acriderotif tristis* belongs to order Passeriformes. The former is a water bird while the later is a water bird.
2. *Apoehiloryncha* is a carnivore having board bill, webfeet, short leg and fleshy tongue while *A. tristis* is omnivore with perching feet and cutting beak.

3. The eyes of *Apoehiloryncha* are big, prominent and three to four times in head while the eyes of *A. tristis* are moderate in size and 4 to 6 times in head.

4. The lens of *Apoehiloryncha* is soft, oval, biconvex and creamy in colour while the lens of *A. tristis* is soft, oval, flattened and yellowish in colour.

5. The width of the lenticular fibers of the lens of both the birds is not same but uniform in shape.

6. The nipples are in cluster form in *A. tristis* but not in *Apoehiloryncha*.

7. The nipples are well differentiated into head and stalk in both the avian species.

8. The maximum distance is more and the minimum distance of the nipple is less in *A. tristis* than in *Apoehiloryncha*.

9. The head of the nipples of *Apoehiloryncha* are not smooth but possess few small hairs like projection of same size whereas the head of the nipples of *A. tristis* is smooth without any side projections.

10. Numerous small granules are observed in the lens of both the species.

11. Ball and socket are big and prominent in number in *Apoehiloryncha* while these arrangements are small and not prominent in *A. tristis*.

12. Numerous prominent thin ridges and grooves are seen in both the species but the ridges are longer in *Apoehiloryncha* than *A. tristis*.

13. Small mounds are observed in both the species. Numerous small granules are also seen in both the species but the number is more in *Apoehiloryncha* than *A. tristis*.

14. Gap junctions are seen in both the species but it is indistinct and small in *Apoehiloryncha*.

15. Interdigitation of lateral flaps are observed in *A. tristis* and not in *Apoehiloryncha*.
Table -3 3 Summary table of the lenses of avian species

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A. poehiloryncha</th>
<th>A. tristis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxonomic status</td>
<td>Anseriformes</td>
<td>Passeriformes</td>
</tr>
<tr>
<td>Habitat</td>
<td>aquatic bird</td>
<td>perching bird</td>
</tr>
<tr>
<td>Food habit</td>
<td>Carnivores</td>
<td>Omnivores</td>
</tr>
<tr>
<td>Anatomical</td>
<td>Broad bill</td>
<td>short &amp; sharp bill</td>
</tr>
<tr>
<td>Peculiarity</td>
<td>web feet</td>
<td>perching feet</td>
</tr>
<tr>
<td>Size of eye</td>
<td>Low and short flight</td>
<td>high, long flight</td>
</tr>
<tr>
<td>Shape of the lens</td>
<td>oval, biocconcave &amp; creamy</td>
<td>oval in head flattened &amp; yellow</td>
</tr>
<tr>
<td>Wt. of the lenticular in m</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Lt. of the nipples in m</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>Diameter of the head in m</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Lt. Of the stalk in μm</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Maximum distance between</td>
<td></td>
<td></td>
</tr>
<tr>
<td>two nipples in μm</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>Minimum distance between</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two nipples in μm</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Lt. Of the hairy side projec-</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>tion of the head in μm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of the ball in μm</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Depth of the socket in μm</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Height of ridges in μm</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Wt. of the ridges in μm</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Size of the mounds in μm</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Size of the gap junction in μm</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Lt. Of the lateral flaps in μm</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Size of the chain filament in μm</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Sizes of granules in μm</td>
<td>0.5</td>
<td>0.01</td>
</tr>
</tbody>
</table>
16. Short chain filaments are observed in the micrographed of the lens of *A. poehiloryncha* while long continuous chain filament is observed in the micrographed of the lens of *A. tristis*.

**EYE LENSES OF SOME MAMMALS**

Introduction:

The sense of sight is due to stimulation of the eyes, which lay protected one on either side of head in the skull sockets called orbits which are relatively similar in all vertebrates but the main differences lie in the mechanism of accommodation, structure of lens and retina and method for judging the distance of observed object (Kotpal, 2005). The eyes of all mammals are alike in their main features.

The eyes or eyeball is a hollow, spherical organ of which about four-fifth part remains concealed within its orbit. Six strap-shaped muscles, four rectus muscles and two oblique bring about movements of eye. Each muscle is attached at one end to the eyeball and at the other to the orbit (Kotpal, 2005).

The frontal exposed or visible part of the eyeball is known as cornea. Moveable upper and lower eyelids can close the eye, when required and protect it from dust particles. The stiff hair or eyelashes present on free edges of eyelids also guards the eye against dust particles, rain, sweats and glare. Some mammals possess a transparent nictitating membrane in the anterior corner of eye. It can be drawn across the cornea for cleaning it and for safety from dust particles and water. The nictitating is vestigial in human eye and represented by a pink semilunar mass. Like other vertebrates the wall of eye of mammals is also made up of three layers: an outermost sclerotic, middle choroids and the innermost retina (Kulshertha, 2005).

A crystalline, solid and biconvex lens is present just behind the pupil. It is composed of concentrically arranged layers of transparent fibers enclosed within
a thin transparent elastic lens capsule. It is held in position by suspensory ligaments which are radially arranged fibers connecting the lens capsule with the help of glasses. Among mammals the monotremes have relatively small lenses with perhaps a vestigial ringwulst. The spiny anteater (echidna) has, together with man and the flattest of all lenses. Marsupials have relatively large and thick lenses. Among the placental mammals and diurnal primates have the flattest lenses. In seals and some tooth whales the lens is perfectly spherical and very near so in several aquatic or amphibious mammals and in murid rodents and other small eyed nocturnal lower placentals mammals (Prince, 1956; and Kuwabara, 1975).

The ability to sharply focus or clearly see objects placed at various distances is known as accommodation. The eye of mammals accommodate by changing the shape or curvature of the elastic lens. When the eyes are at the side of the head as in horse, rabbit or rat, each eye covers a different field of vision with no overlapping. This is known as monocular vision. But in man and primates both the eyes face forward, so they do not form two separate images of the same object. But two images are not seen overlapping of their vision As a result the object is seen in three dimensions which also gives a sense of distance of the object in view. This type of vision in which the depth or distance is judged is called binocular or stereoscopic vision (Kotpal, 2005).

Observation:

1. *Pteropus giganteus:*

*Pteropus* belongs to the order Chiroptera and sub-order Megachiroptera. They are aerial in habit and are commonly known as flying fox because of fox like head with large eyes and long snout. Their body measures about 10cm in length and wing known as patagium spread upto 4ft with a short tail. The body is covered with brown fur and claws on first and second digits. Fore limbs is modified into wing like patagium. It is frugivorous and lives on juices of fruits. The eyes are round and big about 3 to 4 times in head.

The lens of *P. giganteus* is transparent, brittle, partially soft and elliptical or oval in shape. The lens is white in colour and enclosed in a capsule. The lens is
characterized by presence of two distinct regions, the central medulla or nucleus and outer cortex.

**Figure: 3.E.1.** SEM microphotograph (20X 44) of the lens of *P. giganteus* showing the hexagonal fibers (cells) (H), belted fibers (cells) (X), cortex (C) and medulla (M)

**Figure: 3.E.2.** SEM microphotograph (20X 44) of the lens of *P. giganteus* showing the lenticular fibers cells (F) without nipples

Elongation of the meridional rows of epithelial layers is seen which results a junta position of the apical surfaces of the anterior epithelium. The cortical fiber cells are elongated hexagonal cells (Fig. 3.E.1) that taper slightly. The hexagonal cells are closely packed cells without nucleus having two long and four short sides. The angles at the junction of the short side are referred as
apexes. Some belt-like cells are also seen in the bow area of the lens (Fig. 3.E.1). The lenticular fiber cells of both the cortex and medulla are wavy and parallel in arrangement. They are attached together by undifferentiated smooth nipples (Fig 3.E.2).

- Width of the lenticular fibers: $8 \mu m$.
- Length of the nipple: $0 \mu m$.

Further observation of the lens shows junctional complexes like ball and socket arrangement, which are not very prominent. Interdigitation of big lateral flaps is also observed in the micrograph of the lens. Ridges and grooves are prominent. Numerous mounds and depression are observed in the lens (Fig 3.E.3). Cytoplasmic structure like gap junction and long continuous intermediate filament are also observed. The lens is packed with minute fine particles (Fig 3.E.4).

![SEM microphotograph (20X1200) of the lens of P. giganteus showing the lenticular fibers ball (B), socket (So), lateral flaps (FL), mounds (M), depression (D), ridges (R) and gap junction (Gp).](image)

- Size of the ball: $1 \mu m$.
- Size of the socket: $2 \mu m$.
- Length of the lateral flap: $12 \mu m$. 

Figure: 3.E.3.
2. *Rattus rattus*:

*Rattus rattus* commonly known as black house rat is a nocturnal mammals belonging to the order Rodentia. They are small gnawing mammals with one pair of long, rootless chisel-like incisors and without canines. They are fossorial in habits and live in holes and burrows in the houses and in cultivated fields and feed on grains. The skin is naked with scales and long snout.

Two small prominent oval eyes are located one on lateral side on the middle of the head. The eyes are small about 8 to 10 times in head. Each eye has moveable upper and lower eyelids bearing very fine eyelashes. Lying in the anterior corner of each eye is a small white nictitating membrane, which can be drawn across the cornea for safety from dust particles. They have monocular vision.
The lens of *Rattus* is transparent, spherical in shape and white in colour. It is transparent and crystalline in nature. The micrograph of the lens shows that both the medulla and cortex are made up of some lenticular fibers. The lenticular fibers are wavy in nature, which indicates brittleness of the lens. The lenticular fibers are attached together by very short nipples. The nipples are short that they look like embedded in the fibers. The nipples are not differentiated into head and stalk. Only head is visible. The head is smooth and without any side projection (Fig. 3.E.5).

![SEM microphotograph (15KV X 4000) of the lens of *Rattus* showing its lenticular fibers (F), nipples (Ni) and head (H).](image)

**Figure:** 3.E.5. SEM microphotograph (15KV X 4000) of the lens of *Rattus* showing its lenticular fibers (F), nipples (Ni) and head (H).

- Width of the lenticular fibers: 2μm.
- Length of the nipple: 0.5μm.
- Diameter of the head: 0.5μm.
- Maximum distance between two nipples: 1μm.
- Minimum distance between two nipples: 0.2μm.

Junctional complexes like ball and socket arrangements are not very prominent. Ball appears flat and elongated in shape. Sockets are also elongated in shape. Prominent surface ridges are observed. Mounds and gobules are very few and are scattered here and there. Interdigitations of small lateral flaps are
observed in the fiber cells. Big gap junctions are observed. Intermediate filaments are also observed. No spherical particles or fine particles are seen in the lens (Fig. 3.E.6).

- Diameter of the ball: 1 µm
- Diameter of the socket: 1 µm
- Height of ridges: 1.5 µm
- Width of ridges: 2.5 µm
- Size of the grooves: 1.5 µm

**Figure: 3.E.6** SEM microphotograph (20X1200) of the lens of *Rattus* showing the lenticular fibers ball (B), socket (So), lateral flaps (FL), mounds (M), depression (D), ridges (R), intermediate filament (Im) and gap junction (Gp).

- Diameter of mounds: 0.2 µm
- Size of the depression: 1 µm
- Length of the lateral flap: 0.1 µm
- Size of the gap junction: 4 µm
- Length of the intermediate filament: 4 µm

4. *Capra hircus aegagrus*:

*Capra hircus aegagrus* is a mammal belonging to the order Artiodactyla. They are herbivorous ruminant mammals who chew their cud. They are even toed
hoofed mammals having an even numbers of toes. Body is covered with hairs with a short tail is short. It lacks incisors and canines in the upper jaws. Stomach is four-chambered.

The eyes are big and prominent. It is elliptical in shape and measures 4 to 5 times in head. It is a diurnal terrestrial mammal. They have monocular vision.

The lens of *C. hircus aegagrus* is biconvex, big and elliptical in shape. It is very soft, transparent and yellowish in colour. Micrograph of the lens shows that the cortex and medulla are composed of parallely arranged lenticular fibers which are of not uniform in sizes. The lenticular fibers are composed of linearly arranged nipples, which are elongated in shape. The nipples are finger like elongated in shape and are not uniform in sizes. The nipples are not prominently differentiated into head and stalk. The head of the nipples are smooth without any side projection. The fibers are wavy in nature (Fig. 3.E.7).

![Figure 3.E.7. SEM microphotograph (15KV X 3000) of the lens of *C. hircus aegagrus* showing its lenticular fibers (F), nipples (Ni) and head (H).](image)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of the lenticular fibers</td>
<td>2 µm - 7 µm</td>
</tr>
<tr>
<td>Length of the nipples</td>
<td>0.2 µm - 0.6 µm</td>
</tr>
<tr>
<td>Diameter of the head</td>
<td>0.1 µm - 0.5 µm</td>
</tr>
<tr>
<td>Length of the stalk</td>
<td>0.5 µm</td>
</tr>
<tr>
<td>Maximum distance between two nipples</td>
<td>1 µm</td>
</tr>
<tr>
<td>Minimum distance between two nipples</td>
<td>0.5 µm</td>
</tr>
</tbody>
</table>
Junctional complexes like ball and socket arrangement are prominent and distinct. Interdigitations of small lateral flaps are seen. Few short ridges are also seen. Some small mounds are also observed in the SEM micrograph of the lenses. Intermediate filament and big gap junctions are also observed.

![SEM microphotograph](image)

**Figure:** 3 E 8.SEM microphotograph (20X4000) of the lens of *C. hircus aegagrus* showing the lenticular fibers ball(B), socket(So), lateral flaps(FL), mounds(M), Grooves(Go), ridges(R), intermediate filament ( Im) and gap junction(Gp).

Approximate diameter of the ball -------------0.05\(\mu\)m.
Approximate diameter of the socket -------------0.5\(\mu\)m.
Height of the ridges -----------------------------1\(\mu\)m.
Depth of the grooves -----------------------------0.5\(\mu\)m.
Length of the lateral flaps ----------------------0.5\(\mu\)m.
Diameter of the mounds ------------------------0.5\(\mu\)m.
Size of the gap junction -----------------------4\(\mu\)m.
Size of the intermediate filament----------------2\(\mu\)m.

**Discussion:**

Like other vertebrates the eye of mammals is adapted for two main visual functions- optics and accommodation (Kotpal, 2005). In mammals lens is located just behind the iris. It is hold in position by Zonules extending from an encircling ring muscles. When this ciliary muscle is released the diameter of the lens
increases which puts the zonules under tension which flattened the lens. When this muscle contracts its diameter is reduced which relax the zonules and the lens become spherical. This change enables the eye to adjust its focus between far objects and near objects (Kimball, 2005). So in mammals the lens moves for accommodation.

The eyes of all the P.gianganteus and Chircus aegagrus are big which resembles a mammalian visual character (Crescitelli, 1972). But the eye of R.rattus is small which indicates a rodent’s character and suggest that the eye probably have no need for active accommodation (S.Duke-Elder, 1958). This also suggests some phylogenetic and adaptive significance. The lenses of all the three species are also large. Presence of large eye and lens suggests maximum focal length of the lenses and less refractive power of the lenses during vision physiology (Fernald, 1988). The lens of P. giganteus and Chircus aegagrus are oval and biconvex in shape indicates that the lens changes its shape and curvature for accommodation and consequently changing its refractivity. This shape of the lens also suggests aerial mode of vision (Jong, 1982). The lens of R.rattus is spherical which indicates a nocturnal mode of vision (Walls, 1942) and some phylogenetic significance. It also suggests that the lens do not changes its shape for accommodation (Bours & Bhrahma, 1996). The lens of all the three investigated species is very soft which indicates pure terrestrial mode of living (Bours & Bhrahma, 1996) and also suggests some physiological and phylogenetic significance. The colour of the lens of P.gianganteus and R.rattus are white or colourless where as the colour of the lens of Chircus aegagrus is yellowish which indicates that the former two mammals are nocturnal and does not promotes visual acuity during day time that is during light vision but promotes night or dark vision while the later one is a diurnal mammal where the colour of the lens acts as a filter to promotes the visual acuity of diurnal light by decreasing the effects of chromatic aberration, minimizing glare resulting from scattered light, and enhance the contrast (Walls ,1942).This also suggests that Capra is a diurnal animals.

The widths of the lenticular fibers of P.gianganteus are very big and uniform. In R.rattus it is uniform and small and in Chircus aegagrus it is big and
not uniform (Table. 3.4) these suggest some phylogenetic, adaptive and functional significance. Uniformity of the size of the lenticular fibers of \emph{P.giganteus} and \emph{R.rattus} also suggest of being nocturnal.

![Chart 3.E.1. Showing the sizes of the lenticular fibers in 3 mammals](image)

When the width of the lenticular fiber of the three mammalian species is compared (chart 3. E.1) it is observed that \emph{P.giganteus} has the broadest fiber while \emph{R.rattus} has the thinnest fibers, which indicates some phylogenetic and adaptive significance.

The lenticular fibers of all the three investigated species are wavy which indicates crystalline nature of the lens (Table. 3.4). The lens regulates the entry of light in the retina with the help of the nipples of the lenticular fibers (Lythgoe, 1979). In \emph{P.giganteus} the nipples are not observed in the fibers which suggest that the lens may not regulate the light entering the retina resulting poor light vision or may have no vision. The nipples of the lenticular fibers of \emph{R.rattus} are very small and remain embedded in the fibers and only the smooth head is distinct. This indicates that the lens is not much efficient to regulate the light entering the retina resulting poor light vision and suggest a nocturnal mode of vision or dark vision. Again the nipples of the fibers of \emph{C.hircus aegagrus} are variable in size.
with stalk and a variable sized head indicates that the lens is well efficient in regulating the light entering the retina. This suggests that *Chircus aegagrus* has well developed light and dark vision. All these also suggest some phylogenic, adaptive and functional significance. Again the nipples of all the investigated mammalian species are smooth without any side projection may
suggest mammalian characteristics. When the sizes of the nipples of the mammals are compared (Chart 3. E.2) it is seen that *Rattus* and *Chircus aegagrus* have almost same sized nipples indicates Phylogenic significances. When the distance between the nipples is compared in the mammalian species it is observed that the maximum distances is same in *Rattus* and *Chircus aegagrus* while the minimum distance is highest in *Chircus aegagrus* (Chart3.E.3).

Junctional apparatus like ball and socket are not prominent in all the three species indicates a mammalian character that the shape of the lens changes during focusing (Kuwabara, 1975). Presences of ball and socket arrangement in all the three mammals (Table. 3.4) suggest that the lenticular fibers are firmly bound together and minimize cell slippage (Hollenberg et al., 1976).

When the size of the ball and socket are compared (Chart3.E.4) in the three mammalian species it is observed that the sizes of ball of *Rattus* and *P.giganteus* is same while the sizes of the socket is highest in *P.giganteus*, which suggests some adaptive, phylogenic and functional relationship.

Again equal size of the ball and socket are observed in *Chircus aegagrus* and is smallest suggests some functional significance.

Dickson and Crock (1975) mentioned that the ridges and grooves arrangement prevents lateral sliding movement of the fiber cells and the lens
during focusing. Presence of prominent ridges and grooves in all three mammalian species indicates that lateral sliding movement of the lens is prevented during focusing (Hollenberg et al., 1976). It also suggests that the lens moves during accommodation. The ridges are thin in *P. giganteus* & *C. hircus aegagrus* but are thick in *R. rattus* (Table. 3.4) indicates some functional significance. Presence of prominent ridges and grooves indicates a mammalian characteristic of vision (Kuwabara, 1975). When the sizes of the height of the ridges are

![Chart 3.6.5. Showing the sizes of the ridges in 3 mammals](chart.png)

plotted in a graph (Chart.3.E.5) it is observed that the ridges of *P. giganteus* are highest while in *C. hircus aegagrus* it is shortest among the three mammals. This may signify some phylogenetic and functional significance.

According to (Hollenberg *et al.*, 1976) interdigitation of lateral flap is responsible for the rotatory kind of intrinsic movement of the lens during accommodation. Presence or lateral flaps in the lenses of all the three mammals indicates that rotatory kinds of intrinsic movement of the lens is well maintain during accommodation and suggests that the shape of the lens change and the lens moves during focusing. It also indicates that the epithelium of the lens is likely to be electrically coupled to the fibers cells (Goodenough, 1979).
When the sizes of the length of the lateral flaps of the 3 mammals are compared (Chart 3.E.6) very long lateral flaps are observed in *P.giganteus* and the lateral flaps of *R.rattus* and *C.hircus aegagrus* are small. This suggests some functional significance in the vision physiology of the animal. Moreover, the lateral flaps of *P.giganteus* are also broad (Table 3.4) indicating some functional and adaptive significances.

Mounds maintain the shape and morphology of the lens during accommodation (Kuwabara, 1975). They are prominent in terrestrial animals (Harding *et al.*, 1996). Presence of mounds in all the mammalian species indicates that the shape of the lenses changes during accommodation with a terrestrial (Ariel) mode of vision and suggests that the lens moves for accommodation (Hollenberg *et al.*, 1976).

Gap junctions are observed in the SEM micrograph of all the three mammalian species suggesting that the lenticular fibers of the lens remain metabolically coupled and facilitate movement of water, ions, and other metabolites which provides a pathway linking epithelial cells directly to the underlying fiber cells (Goodenough, 1979).
Presence of intermediate filament in all the three species suggest that an internal architecture is imparted to the fiber cells that minimizes light scattering and stabilizes the order and distribution of protein which maintain the shape of the fiber cell and the lens (Rafferty and Goosens, 1978).

Some fine particles are observed in the lens of *P. giganteus*, which indicates the presence of some cylindrical scatters (Lythgoe, 1979), which suggest that the visual system of the animal is not acute, and may have poor or no vision.

Summary:

1. All the three investigated mammalian species belong to different orders, having different habit and habitat.
2. The eyes of *P. giganteus* and *C. hircus aegagrus* are big while the eyes of *R. rattus* is small.
3. The eye lenses of *P. giganteus* soft, flat, oval and yellow in colour. It is soft, spherical and white in *R. rattus* and soft, flat, bioconvex and yellow in *C. hircus aegagrus*.
4. The sizes of the lenticular fibers in *P. giganteus* and *R. rattus* are uniform while the former is devoid of nipples and the latter possess small nipples of uniform sizes with uniform sized small head without stalk. The sizes of the lenticular fibers in *C. hircus aegagrus* with variable sized nipples bearing small variable sized head and uniform sized stalk.
5. Maximum distances between two nipples are same in *R. rattus* and *C. hircus aegagrus* while the minimum distance is more in *C. hircus aegagrus*.
6. The sizes of junctional apparatus like ball and socket are uniform in all the three mammalian species.
7. Sizes of ridges and grooves are also uniform in all the three mammalian species.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pteropus giganteus</th>
<th>Rattus rattus</th>
<th>Capra hircus aegagrus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Taxonomic status order</strong></td>
<td>Chirotrem</td>
<td>Rodentin</td>
<td>Artiodactyl</td>
</tr>
<tr>
<td><strong>Habitat</strong></td>
<td>Flying or Arial</td>
<td>Fossorial and Chewing</td>
<td>Curssorial and ruminent</td>
</tr>
<tr>
<td><strong>Food habit</strong></td>
<td>Pugivore</td>
<td>Grannivore</td>
<td>Harvivore</td>
</tr>
<tr>
<td><strong>Anatomical peculiarities</strong></td>
<td>Fox like head with Long snout</td>
<td>Small head with long snout</td>
<td>Head without snout</td>
</tr>
<tr>
<td></td>
<td>Body with Fur.</td>
<td>Body naked</td>
<td>Body with Hair</td>
</tr>
<tr>
<td></td>
<td>Scales absent</td>
<td>Scales in tail</td>
<td>Scales absent</td>
</tr>
<tr>
<td><strong>Patagium present</strong></td>
<td>Claws present</td>
<td>Claws present</td>
<td>Hoof present</td>
</tr>
<tr>
<td><strong>Size &amp; diameter of The eye.</strong></td>
<td>Elongated big 3 - 4 times in Head</td>
<td>elongated, small 8-10 times in head</td>
<td>elongated, big 4-5 times in head</td>
</tr>
<tr>
<td></td>
<td>Nature of lenses</td>
<td>elliptical</td>
<td>Spherical</td>
</tr>
<tr>
<td><strong>Wt. of the lenticular fillers in μm</strong></td>
<td>8</td>
<td>2</td>
<td>7 - 2</td>
</tr>
<tr>
<td><strong>Lt. of the nipple in μm</strong></td>
<td>0</td>
<td>0.5</td>
<td>0.6 - 0.2</td>
</tr>
<tr>
<td><strong>Diameter of the head in μm</strong></td>
<td>0</td>
<td>0.5</td>
<td>0.5 - 0.1</td>
</tr>
<tr>
<td><strong>Lt. Of the stalk in μm</strong></td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Max.dist. between Two nipples in μm</strong></td>
<td>-</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Min.dist. between Two nipples in μm</strong></td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Size of the ball in μm</strong></td>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Depth of the socket in μm</strong></td>
<td>2</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Lt. of the ridges in μm</strong></td>
<td>2</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Wd. of the ridges in μm</strong></td>
<td>-</td>
<td>2.5</td>
<td>-</td>
</tr>
<tr>
<td><strong>Size of the gap junction in μm</strong></td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Size of the grooves in μm</strong></td>
<td>1</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Size of the mounds in μm</strong></td>
<td>0.5</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Lt. of the lateral flaps in μm</strong></td>
<td>12</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Wd. of the lateral flaps in μm</strong></td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Intermediate filament in μm</strong></td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Fine particles in μm</strong></td>
<td>0.3-0.5</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
8. Very thin lateral flaps are observed in the micrograph of the lenses of *Rattus* and *Chircus aegagrus*. While broad and long lateral flaps are observed in the micrograph of the lenses of *P. giganteus*

9. Mounds are observed in the micrograph of the lenses of the three mammalian species.

10. Big gap junctions and long intermediate filament are observed in the micrograph of the lenses of all the three mammalian species.

11. Fine particles are observed in the micrograph of the lens of *P. giganteus*.

**DISCUSSION**

The eye of the vertebrate is the main photoreceptor organ, which enables them to view an object. The eye of vertebrate is camera type with a lens, which focuses images of external objects on the sensitive retina serving as a photographic film. However, the eyes of lower vertebrates (fish and amphibian), which live in water, differ from the eye of higher vertebrates (reptiles, birds and mammals), which live out of water in several respect (Kotpal, 2005).

The shape of the eye is responsible for it’s functioning for viewing and forming images (Kulshrestra, 2005). When viewing an extended source, larger eye do not have brighter retinal image resulting from their proportionally larger papillary apparatus. As the eye grow in a scaled fashion the increased light entering the large eye is in focus on a more distinct retina, so the light per unit area remains constant (Fernald, 1990). Small eye found in many rodents and insectivores probably have no need for active accommodation, the capacity to adjust the optical system for near or distant vision. Accommodation is lacking in primitive animals like primitive fishes, Sphenodon, monotremes, marsupials etc (Duke-Elder, 1958).

*A. testudineus, L. rohita, H. ilisha, B. melanostictus, H. brooki, G. gecko, A. poehleronycha, A. tristis, P. giganteus* and *Chircus aegagrus* possess big eyes (Table .3.5) suggested that they have brighter retinal image but focus a more
distinct image on retina, while *M. marmatus, C. bairachus, K. sylhetensis* and *R. rattus* possess small eyes (Table 3.5) suggested that they have brighter retinal images but focus a less distinct images on the retina. The eyes of the latter animals probably have no need for active accommodation. This suggests that *M. marmatus, C. bairachus, K. sylhetensis* and *R. rattus* are primitive animals as it lacks active accommodation. It indicates some phylogenetic and functional significance. Moreover small eye in *R. rattus* indicates that it is a rodent.

The lens is the only refractive elements of an aquatic eye, present day aquatic species are said to possess a spherical or nearly spherical crystalline lens of high refractive index (Walls, 1942; Pumphrey, 1961; Dey, 1988). The spherical lenses are subjected to spherical aberration and change its shape for accommodation (Sivak, 1984). Among mammals Rodents has spherical lens (Sivak, 1983). The crystalline lens of vertebrate eye is a cellular structure that develops embryologically as a vesicular invagination of the surface ectoderm. Initially the lens vesicle is a hollow sphere formed by a wall of epithelial cells. The cells of the posterior half of the sphere elongate to fill the lumen of the vesicles. The equatorial location of new lens growth and the fact that lens cell must taper anteriorly and posteriorly in order to articulate with the tips of adjacent cells, makes its reasonable to expect the lens to assume more and more elliptical shape as it grows (Scammon and Hesdorffer, 1937; Duke-Elder, 1958; Tripathi and Tripathi, 1983). The lenses of *A. cestudineus, L. robusta, M. marmatus, H. hilisha, C. bairachus, B. malanostictus, K. sylhetensis* and *R. rattus* are spherical (Table. 3.5) suggest that these are primitive animals and the lens is the only refractive element of these animals which are subjected too spherical aberration and the shape of the lenses do not changes for accommodation. While the lens of *H. brooki, G. gecko, A. pochiloryncha, A. tristis, P. giganteus* and *C. hircus aegagrus* the shape of the lenses are oval or flattened in shape (Table. 3.5) suggests that these are modern animals and the lens is not the only refractive elements of these animals and the lens is not subjected to only spherical aberration.

A small lens has a greater depth of focus than a large lens where as in the retina of small lens the visual elements are relatively large (Sivak, 1980). The lenses of *M. marmatus* and *C. bairachus* are small (Table. 3.5) suggests that the
lenses of these two animals has a greater depth of focus with relatively large visual elements in the retina. This indicates some phylogenetic, adaptive and functional significance.

The colour of lens is white in fishes and aquatic vertebrates to regulate and filter the light in dense and rear medium (Femald 1990). The lenses of *A. testudineus*, *L. rohita*, *M. armatus*, *C. batrachus*, and *K. sylhetensis* are white (Table 3.5) suggest of being aquatic in habitat. Lenses are white in nocturnal and aquatic vertebrate (Sivak, 1996). The lenses of *H. brooki*, *P. giganteus* and *R. rattus* are white (Table 3.5) in colour indicates of being nocturnal. Yellow pigments are present in the lens of several diurnal species from widely separated taxa, for example man and other primates, tupias, diurnal squirrels, snakes, geckoes and lampreys. (Walls, 1942) Such yellow lenses probably serve the same purpose as the yellow cornea of some fish and yellow oil droplets in the retinal cone of certain diurnal frog, turtle, lizard and most birds. These intraocular color filters promotes the visual acuity of diurnal animals by decreasing the effects of chromatic aberration, minimizing glare resulting from scattered light, enchaining the contrast (Walls, 1942). This visual physiological phenomenon is perhaps found in *G. gecko*, *A. tristis* and *C. hircus aegagrus* having yellow lenses (Table 3.5). This also suggests some phylogenetic and functional significance. Again the lenses of *H. ilisha* being aquatic and *A. poechiloryncha* being diurnal are creamy indicates some evolutionary and functional significances. The lens of *B. malanosticlus* is colourless may be related to nocturnal and amphibic habit. This also may be of its link between aquatic and terrestrial habitat.

The lenticular fibers are the histological unit of the cell. It acts as an interference filter and regulates the entry of light to the retina (Bernhard et al., 1965; Jong 1982). Among the 14 different investigated vertebrates species it is seen (Chart 3.1) *L. rohita* has the broadest lenticular fiber cells. This suggests that the lens of *L. rohita* best maintain in filtering and regulating the entry of light. The visual physiology is also well maintained in *A. testudineus*, *M. armatus*, *H. ilisha*, *P. giganteus* and *C. hircus aegagrus* who also possess broad lenticular fiber cells. While *R. rattus* and *G. gecko* have the thinnest fiber cells suggest that the lens is not well maintain in regulating and filtering the light entering the retina. The
lenticular fibers of *C.batrachus, B.malanostictus, K.sylhetensis, H.brooki, A.poehiloryncha* and *A.tristis* are almost same in size, in *A.testudineus* and *P.giganteus* the sizes are same and the sizes are same in *M.armatus* and *H.ilisha* (Chart 3.1).

It may indicate same mode of vision physiology among the animals having same size of lenticular fibers. Again it is observed (Table. 3.5) that the size of the lenticular fibers of *A.testudineus, Marmatus, C.batrachus, B.malanostictus, K.sylhetensis, H.brooki, A.poehiloryncha, A.tristis* and *P.giganteus* are uniform in width through the fiber and in *L.rohita, H.ilisha, G.gecko, R.rattus* and *C.hircus aegagrus* the width of the lenticular fibers is not uniform in size. Somewhere the fiber is broad and somewhere it is narrow. This may indicate that the former animal has a common ancestor and the latter another common ancestor.

The lenticular fibers have some finger like side projection called nipples. These nipples bind the fibers firmly and regulate the light entering the retina (Berhnard *et al.*, 1965; Fernald, 1990). In some investigated species the nipples
are distinct and well differentiated into head and stalk and in some there is no differentiation between head and stalk. Again the sizes of the nipples are not same in all the 14 vertebrate species. (Chart. 3.2)

The size is biggest and same in *A.testudineus* and *L.rohita* and smallest in *R.rattus* and *C.hircus aegagrus* while in *P.giganteus* the nipples are not distinct. This indicates some functional significance. Again it is seen that in all the three mammalian species the nipples are either smallest or absent which indicates some phylogenic significances. The sizes of the nipples are same in *C.batrachus, K.sylhetensis, H.brooki* and *A.tristis* may indicate some phylogenic significance. Again the size of the nipples in *M.armatus* and *A.poehiloryncha* are equal indicates some phylogenic relationship and functional significances. Same sizes of nipples are seen in *H.ilisha, B.malanostictus* and *G.gecko* also indicates some
phylogenetic relationship among the three vertebrates. When the maximum and minimum distances between two nipples are measured it is found that the distances are not same in all the 14 vertebrates (Chart.3.3).

When the differences of distance between the two nipples are compared among the 14 vertebrates it is seen that the maximum distances between two nipples are highest in *C. batrachus* and lowest in *L. rohita* may indicates some functional significances. The maximum distances of the nipples are same in *M. armatus, B. malanostictus, K. sylhentensis, G. gecko* and *A. tristis* is same, while it is same in *A. testudineus* and *A. poehiloryncha*. Again the maximum distances between the nipples are same in *H. brooki, R. rattus* and *C. hircus aegagrus*. This may indicates some phylogenetic relationship and functional significances among the species having same maximum distance between the nipples. *P. giganteus* has no nipples also indicates that the entry of the light is not properly regulated by the lens which signifies poor or no vision.
The minimum distance between the 14 vertebrates are also not same. The minimum distance is highest and same in *B. malarostictus* and *A. tristis* and lowest and same in *H. ilisha* and *R. rattus* suggests some functional significance. This distance is same in *M. armatus, C. batrachus, A. poehiloryncha* Again this distance is same in *L. rohita, K. sylhentensis, H. brooki, G. gecko* and *C. hircus aegagrus* may indicates some phylogenic relationship and functional significances among these vertebrates having same minimum distances between the nipples. The distance in *A. testudineus* is not same with the other vertebrates indicates a different phylogeny and functional significances in visual physiology.

The nipples regulate the entry of light by the lenses to the retina (Lythgoe, 1979). In the present investigation it is observed that the head of the nipples of some vertebrate are not smooth and contain some hairy structures. These structures are observed in the micrographs of the lenses of *A. testudineus, M. armatus, C. batrachus, B. malarostictus, K. sylhentensis, H. brooki, A. poehiloryncha* and *A. tristis* (Table. 3.5) indicates some phylogenic and functional significances.

Hairy structures are observed in the nipples head of the fiber cells in the lenses of *A. testudineus, C. batrachus, B. malarostictus, K. sylhentensis, H. brooki, A. poehiloryncha* and *A. tristis* indicates some phylogenic and functional relationships in vision physiology among these vertebrates.

The junctional complexes include balls (knob) and sockets arrangement was first observed in the fiber cells of monkey. The ball consist of a short stalk which expands to form a spherical head embedded in a complementary depression in the adjacent fibers. They bind the fiber cells firmly (Dickson & Crock, 1975). Ball and socket arrangement by minimizing cell slippage maintains the shape of the lens during accommodation and only a little inters cellular gliding occurs during focusing (Kuwabara, 1975). Ball arrangement is more prominent in primitive vertebrates (Rochon-Duvigneaud, 1973). Ball and socket arrangement are different in different animals and may indicates some phylogeny in animal kingdoms (Jong, 1982). It is seen that the size of the ball are not same in all the 14 vertebrates (Chart. 3.4).
The size of the ball is largest and same in *A. testudineus*, *M. aramatus*, *C. batrachus* and *K. sylhentensis* suggest primitive and same phylogeny and indicates the shape of the lens is less changed during accommodation. The sizes of balls are same in *H. brookii*, *A. poehiloryncha*, *P. giganteus* and *R. rattus* suggests same phylogeny and some changes in the shape of the lens during accommodation. Again the shape of the ball is small and of same size in *H. ilisha*, *B. malanostictus* and *C. hircus* suggest same phylogeny and less primitive animals and accommodate by changing the shape of the lens. The size of the ball is smallest in *G. gecko* suggest some phylogenetic and functional significances.

Similarly the depth or sizes of socket are not same in the 14 vertebrates (Chart. 3.5). The size of the socket is largest and same in *M. aramatus*, *C. batrachus* and *P. giganteus* and biggest. The sizes are big in *B. malanostictus* and *H. brookii*. Again the sizes are medium in *A. testudineus*, *L. rohita*, *K. sylhentensis*, *A. poehiloryncha* and *R. rattus* and small in *H. ilisha*, *A. tristis* and *C. hircus*. In *G. gecko* the size is smallest. The sizes are same in *L. rohita*.
K.sylhetensis, A.poehiloryncha and Rattus while H.tilsha, A.tristis and C.hircus aegagrus the sizes is same. This may indicate some phylogenic relationship and functional significance.

Presences of ball and socket arrangement in fiber cells of all the 14 different vertebrates suggest that the fibers cells are bind firmly together (Dickson & Crock, 1975). The shape of the lens is well maintained during accommodation by minimizing cell slippage and occurring only a little intercellular gliding (Kuwabara, 1975). When the relation in sizes of ball and socket arrangements is compared (Chart 3.6.) it is observed that sizes of ball and socket arrangement are smallest in G.gecko.

Equal sizes of ball and socket arrangement are seen in G.gecko, A.poehiloryncha and C.hircus aegagrus. The sizes of the ball of L.rohita and B.malanostictus are equal with the sizes of the socket of H.tilsha, A.tristis and C.hircus aegagrus. The sizes of ball of H.brooki, A.poehiloryncha, P.giganteus
and *R. rattus* are equal with the size of socket of *L. rohita, K. sylhentensis*. Again the size of the ball of *A. testudineus, M. armatus, C. batracJus* and *K. sylhentensis,*

![Chart showing the relation between the sizes of ball & socket in 14 vertebrates.](chart3_6.png)

*A. poehiloryncha* and *R. rattus* are same with the socket of *H. brooki*. All this may indicate some phylogenetic and functional significance. Differences of the description of the junctional apparatus are probably due to species variation, as well as in consistency in identification (Maisel et al., 1999). So far ball and socket arrangement is also reported in the lenses of rabbit, primates, chicken, mouse and even human (Dickson & Crock, 1975). In the adult monkey the diameter of the ball is about 1 μm and the depth of the socket is about 1.5 μm (Kuwabara, 1975).

Ridges and grooves other junctional complexes found in the fiber cells of vertebrates. The ridges consist of a linear evagination of the membrane. In monkey about 1 μm to 3 μm high and 1 μm to 2 μm long (Kuwabara, 1975). Dickson and Crock (1975) indicates that the ridges and grooves prevent lateral sliding movement during accommodation. When observed it is seen that ridges are not present in all 14 vertebrates.
Chart 3.7. Showing the height of the ridges in 14 vertebrates.

They are absent in the lenses of *A. testudineus, M. armatus, C. batrachus* and *K. sylhentensis* (Table 3.5). The heights of the ridges are also not same in all the 14 vertebrates (Chart 3.7). High and same size ridges are seen in *H. ilisha, A. poehiloryncha* and *P. giganteus* while in *A. tristis* and *C. hircus aegagrus* the height is medium and same. Ridges are short and its sizes are same in *L. rohita, B. malanostictus* and *G. gecko* and they are shortest in *H. brooki*.

All these above observation on junctional complexes like ridges may suggest some phylogenetic, adaptive and functional relationship and significances. Presence of ridges in the all the 10 vertebrates except in *A. testudineus, M. armatus, C. batrachus* and *K. sylhentensis* indicates that during accommodation of the eye the lateral sliding movement of the fiber cells of the lens is prevented only in those 10 vertebrates and the lens moves during focusing a image in the retina which is not possible in *A. testudineus, M. armatus, C. batrachus* and *K. sylhentensis*. Again although ridges present they are very thin in *A. tristis, P. giganteus* and *C. hircus aegagrus* indicates some similar visual function in these three vertebrates.
The fiber cells have many interdigitations of lateral flaps (undefined) at the angles of the hexagon and ball and sockets along the long sides, which are observed in the lenses of higher vertebrates (Duncun, 1974). These interdigitation processes maintain the shape of the fiber cells during the rotatory kinds of intrinsic movement of the lens during accommodation (Hollenberg et al., 1976). In the present investigation it is observed that lateral flaps are not observed in all the pician species expect *L.rohita* and *H.ilisha* (Table. 3.5) which suggest some
Mounds are junctional apparatus of the fiber cells of the lenses of vertebrate eyes. They are small elevation about 0.2 μm in diameter in albino mouse. It maintains the shape and morphology of the lenses in vertebrate eyes (Kuwabara, 1975). In the present investigated it is observed that mounds are not present in all the vertebrates. Mounds are not observed in A. testudineus and H. ilisha (Table.3.5). Moreover the sizes of the mounds in all the spices are not same. When the sizes of the mounds of all the species are plotted in a graph (Chart. 3.10) it is seen that the mounds of A. poehiloryncha is largest and K. sylhentensis C. hircus aegagrus is smallest. The sizes of the mounds of M. armatus, C. batruchus, and H. brooki, K. sylhentensis, P. giganteus and C. hircus aegagrus are equal and the sizes of the mounds of L. rohita,
**B. malanostictus** and **A. tristis** and **R. rattus** are same. All these observations indicate some phylogenic and physiological significance.

The plasma membrane of the fiber cells of the lenses usually exists in the form of Gap junctions, which implies that the fiber cells always remain in metabolically, coupled state (Harding *et al.*, 1996). In the present investigation it is observed that the Gap junctions are absent in fishes except **A. testudineus** and **H. iilisha** (Table 3.5). Among the higher vertebrates it is absent in **G. gecko** (Table 3.5). These suggest that the fiber cells of these vertebrates do not always remain in metabolically coupled state. Again it is seen that very big Gap Junctions are observed in the fiber cells of all the mammalian species signifies that the fiber cells of these vertebrates always remain in metabolically coupled state. All these above observations indicate some phylogenic, functional and adaptive relation and significances.

The cytoplasm of the fiber cells of the lenses consists of some granular substances uniformly distributed within the cell (Duncan, 1974; Miller, 1979; Goswami *et al.*, 2000). These granules scatter light from the lens to regulate the quantity of light entering the retina (Lythgoe, 1979 and Begum *et al.*, 2004 and Begum, 2007). These granules are present in all the piscian species except **H. iilisha** (Table 3.5). It is also present in **B. malanostictus**. Among the higher vertebrates it is seen only in the birds and absent in reptiles and mammals. All these signify some phylogenic and functional significance.

Other cytoskeletal elements consist of intermediate filament and chain filament (Bradley *et al.*, 1978 & 1979; Rafferty and Goossens, 1977 & 1978). These filaments are made up of Actin and help to maintain cell integrity, provide contractile force during lens movement and facilitate transparency of the lens (Wanko and Gavin, 1961; Duncan, 1974). Both Intermediate filaments and chain filament are observed in the micrograph of **B. malanostictus** and the three mammalian species **P. giganteus**, **R. rattus** and **C. hircus aegagrus** while chain filaments are observed in **H. brookii**, and both the birds **A. poehiloryncha** and **A. tristis** (Table 3.5). All these indicate some functional and phylogenic significance.
SUMMARY

1. In the present investigation the lenses of fourteen vertebrates of which five piscian species, one amphibian, three reptilian species, two Avian and three Mammalian species of different taxonomic status are investigated.

2. Of all these investigated vertebrate species A.testudineus, L.rohita, M.armatus, H.ilisha and C.batrachus, are aquatic in habitat of which H.ilisha is anadromous fish. B. malanostictus, K. sylhentensis and A. poehiloryncha are amphibious in habitat while Acridoterif tristis and P.giganteus are aerial in habitat and H.brooki, G.gecko, R.rattus and C.hircus aegagrus are terristarial land animals. R.rattus is also a burrowing animal.

3. The food habit of all the investigated vertebrates is not same. L.rohita, M.armatus, K. sylhentensis, R.rattus (grains) and C.hircus aegagrus are herbivore while A.testudineus, H.ilisha, C.batrachus, B.malanostictus, H.brooki, G.gecko and A. poehiloryncha are carnivore animals. A.tristis is omnivore and P.giganteus is frugivore.

4. The sizes of the eyes of all 14 vertebrates are not same. L.rohita, H.ilisha, B. malanostictus, H.brooki, G.gecko, A.poehiloryncha, P.giganteus and Chircus aegagrus have a large eye. M.armatus, C.batrachus K. sylhentensis, and R.rattus have small eye while A.testudineus and A.tristis have moderate sized eye.

5. The shape of the lens of A.testudineus, L.rohita, M. armatus, H.ilisha, C.batrachus, B.malanostictus, K. sylhentensis, and R.rattus is round or spherical. While the shape of the lenses of H.brooki, G.gecko, A.poehiloryncha, A.tristis, P.giganteus and Chircus aegagrus are flattened and ovoid bioconvex.

6. The texture or colors of the lenses of all the 14 investigated vertebrates are also not same. The lenses are colorless in B.malanostictus It is white in color in A.testudineus, L.rohita, C.batrachus, K.sylhentensis, H.brooki, P.giganteus and R.rattus.the and is creamy in color in, M.armatus, H.ilisha and A. poehiloryncha. While it is yellow in color in G.gecko, A. tristis and Chircus aegagrus.
7. The width of the lenticular fibers, length of the nipples and diameter of the head are uniform in *A. testudineus*, *M. armatus* and *C. batrachus*, *K. sylhentensis*, *H. brooki*, *A. poehiloryncha*, and *A. tristis*. While it is variable in *L. rohita*, *H. ilisha*, *B. malanostictus*, *G. gecko* and *C. hircus aegagrus*. The width of the lenticular fiber cells of *R. rattus* are variable but the length of the nipples and diameter of the head are uniform, while the width of the lenticular fibers *P. giganteus* are uniform without bearing any nipples.

8. The nipples of the fibers are not smooth but possess hairy side projection in *A. testudineus*, *M. armatus*, *C. batrachus*, *B. malanostictus*, *K. sylhentensis*, *H. brooki*, *A. poehiloryncha* and *A. tristis*. The nipples are smooth and are without hairy projection in *L. rohita*, *H. ilisha*, *G. gecko*, and same in all the three mammals.

9. Junctional complex like ball and socket arrangement is found in all the 14 investigated species. The size of the ball arrangement is same in *A. testudineus*; *M. armatus* and *C. batrachus*. While sizes of ball are same in *H. brooki*, *A. poehiloryncha*, *P. giganteus* and *R. rattus*. Again the sizes of the ball are same in *L. rohita*, *B. malanostictus* and *K. sylhentensis*. The depth of the socket is same in *M. armatus* *C. batrachus* and *P. giganteus* while it is same in *L. rohita*, *K. sylhentensis*, *A. poehiloryncha* and *R. rattus*. Very small ball and socket are observed in *G. gecko*.

10. Ridges and grooves are also types of junctional apparatus are not seen in the micrograph of all the investigated species. It is absent in *A. testudineus*, *M. armatus*, *C. batrachus* and *K. sylhentensis*. The heights of the ridges are same in *H. ilisha*, *A. poehiloryncha* and *P. giganteus* while it is same in *H. brooki*, *A. tristis* and *C. hircus aegagrus*.

11. Lateral flaps are also seen only in lens *H. ilisha*, *B. malanostictus*, *K. sylhentensis*, *H. brooki*, *G. gecko*, *A. tristis*, *P. giganteus*, *R. rattus* and *C. hircus aegagrus*. Very big lateral flaps are observed in the micrograph of *G. gecko* and *P. giganteus*. 
12. Mounds are very small junctional apparatus observed in the micrograph of the lenses of *L. rohita*, *M. armatus*, *C. batrachus*, *B. melanostictus*, *H. brooki*, *G. gecko*, *A. poehiloryncha*, and *A. tristis*, *P. giganteus*, *R. rattus* and *Chircus aegagrus*.

13. Gap junction is seen in the micrograph of the lenses of *A. testudineus*, *H. tilsha*, *B. melanostictus*, *K. sylhetensis*, *H. brooki*, *A. poehiloryncha*, and *A. tristis*, *P. giganteus*, *R. rattus* and *C. hircus aegagrus* while it is not seen in *L. rohita*, *M. armatus*, *C. batrachus* and *G. gecko*.

14. Spherical granules of various sizes are seen in micrograph of the lenses of *A. testudineus*, *L. rohita*, *M. armatus*, *C. batrachus*, *B. melanostictus*, *A. poehiloryncha* and *A. tristis*. It is absent in all the investigated reptile and mammalian species.

15. Cytoskeleton of the fibers intermediate filament is observed in the micrograph of the lenses *B. melanostictus*, *P. giganteus*, *R. rattus* and *C. hircus aegagrus*.

16. Chain or bead filaments are observed only in the micrograph of the lenses of *B. melanostictus*, *H. brooki*, *A. poehiloryncha* and *A. tristis*.

17. Fine particles are observed only in the micrograph of the lenses of *P. giganteus*.
Table 3.5. Summary table of the observation of the lens structure in 14 vertebrates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pie cies</td>
<td>Pie cies</td>
<td>Pie cies</td>
<td>Pie cies</td>
<td>Am phi lia</td>
<td>Re ptiles</td>
<td>Re ptiles</td>
<td>Re ptiles</td>
<td>Ave s</td>
<td>Ave s</td>
<td>Ma mm als</td>
<td>Ma mm als</td>
<td>Ma mm als</td>
<td></td>
</tr>
<tr>
<td>Taxono mic status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food habit</td>
<td>Car niv ore</td>
<td>Har biv ore</td>
<td>Har biv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Car niv ore</td>
<td>Fug ture</td>
<td>Grin niv ore</td>
<td>Her vory ore</td>
<td></td>
</tr>
<tr>
<td>Sizes of the eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mo der ate</td>
<td>Lar ge</td>
<td>Min ute</td>
<td>Lar ge</td>
<td>Sm all</td>
<td>Lar ge</td>
<td>Sm all</td>
<td>Big</td>
<td>Big</td>
<td>Big</td>
<td>Big</td>
<td>Mo der ate</td>
<td>Big</td>
<td>Sm all</td>
</tr>
<tr>
<td>Wt of the fiber in μm</td>
<td>8</td>
<td>9-10</td>
<td>7</td>
<td>7.5</td>
<td>5-4</td>
<td>5</td>
<td>0.5</td>
<td>4.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Ll of the nipples in μm</td>
<td>3</td>
<td>2-3</td>
<td>1.7</td>
<td>0.2</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
<td>2</td>
<td>0.1</td>
<td>1.5</td>
<td>2</td>
<td>0</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Max Dist. Bet. Nipples</td>
<td>1.5</td>
<td>0.3</td>
<td>2</td>
<td>0.5</td>
<td>2.5</td>
<td>1.2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Min Dist. Bct. Nipples</td>
<td>0.8</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>1</td>
<td>0.5</td>
<td>1.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1.5</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Ll of hairy projection</td>
<td>0.5</td>
<td>0.2</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of the ball</td>
<td>1.5</td>
<td>0.5</td>
<td>1.5</td>
<td>0.2</td>
<td>1.5</td>
<td>0.5</td>
<td>1.5</td>
<td>1</td>
<td>0.1</td>
<td>1</td>
<td>0.3</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Diameter of the socket</td>
<td>0.8</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
<td>1.8</td>
<td>1</td>
<td>1.5</td>
<td>0.1</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Ht. Of the ridges</td>
<td></td>
<td>0.0</td>
<td>4-0.5</td>
<td>2</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wt. Of the ridges</td>
<td></td>
<td>1-1.5</td>
<td>0.5</td>
<td>1</td>
<td>3</td>
<td>0.2</td>
<td>0.1</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Lt. of the lateral flaps</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Diameter of mounds</td>
<td>0</td>
<td>.</td>
<td>0.2</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of the gap junction</td>
<td>0.5</td>
<td>2</td>
<td>7</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of granules</td>
<td>0.0</td>
<td>2</td>
<td>0.6</td>
<td>.</td>
<td>.</td>
<td>0.0</td>
<td>0.4</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of the depression or groove</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>0.1</td>
<td>0.5</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of chain filament</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of intermediate filament</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>1</td>
<td>2</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Sizes of tight junction</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>0.2</td>
</tr>
<tr>
<td>Diameter of gobular particles</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>3</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Lt. of Knob like projection</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>2</td>
</tr>
<tr>
<td>Sizes of bead filament</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>0.5</td>
</tr>
</tbody>
</table>


N.B. All the measurement was done in μm.