Chapter-3

Observations
Plate-1: Lateral view of head of *C. carpio*

- ANT. NAS. OP. - Anterior nasal opening
- Eye - Eye
- NAS. FLAP - Nasal Flap
- POST. NAS. OP. - Posterior nasal opening
- RIM - Rim

Plate-2: Dissection of the head of *C. carpio* from lateral side to show rosette insitu

- ROS. - Rosette
- RPH. - Raphe
Histological Observations of the Olfactory Organ of *Cyprinus carpio* Linnaeus

*C. carpio* bears a pair of olfactory chambers (OLF. CHAM.) lying on the dorso-lateral surface of the head and are more close to the eye-orbit than the snout (Plate-1, Fig.-1A). The olfactory chambers are oval in shape and get surrounded by integumental formation, which forms an upwardly and forwardly erected nasal flap (NAS. FLAP, Plate-1, 2; Figs.-1A, 1B). It is dipped into the olfactory cavity by its ventral extension, dividing it transversely in the anterior and posterior chambers (Figs. 1A, 1B, 1C). The olfactory chamber is communicated outside by a pair of nasal openings which lie close to each other. The nasal flap acts as partition in between them (apertures). The nasal openings allow most of the part of the olfactory chamber exposed to water except that covered by the integumental borders of nasal flap. The rosette can be seen easily through the posterior nasal opening (POS. NAS. OP., Figs. 1A, 1B, 1C).

The olfactory rosette (ROS.) is oval shaped and occupies the entire olfactory chamber (Fig. 1D). It has a ventral convex and dorsal concave surface with large number of closely set lamellae (LAM., Fig. 1D). A leaf shaped thick raphe (RPH.) divides the olfactory rosette in ethmoidal and lacrimal halves and extends antero-posteriorly of the rosette. (Plate-2, Fig. 1D) In the extreme periphery of the lacrimal half, the olfactory epithelium remains lamellaeless (LAM. LESS. AREA) forming a pocket like structure which probably be understood as rudimentary accessory sac (Fig. 1D). This may help in retaining water during the course of its transportation from the olfactory chamber.
Fig. 1A: Diagram of the lateral view of the head of *C. carpio*.

Fig. 1B: Diagram of the olfactory chamber to show nasal flap and posterior nasal opening in *C. carpio*.

Fig. 1C: Diagram after removing the nasal flap to show the position of anterior nasal opening and RIM in *C. carpio*.

Fig. 1D: Diagramatic sketch of the rosette of *C. carpio*.

Fig. 1E: A set of 1 - 18 lamellae from one half of the rosette of *C. carpio*.

ANT : Anterior
ANT. NAS. OP : Anterior nasal opening
CEH. CH : Central Channel
ETH. H. : Ethmoidal half
EY. : Eye
INT. LAM. SP : Inter lamellar space
LAC. H. : Lacrymal half.
LAM. : Lamella
LAM. LESS AREA : Lamellaeless - Area
LING. P. : Linguiform Process
NAS. FLAP : Nasal flap
OLF. CHAM. : Olfactory chamber
PER. CH. : Peripheral Channel
Fig. - 1
Fig. -2 : Diagram of the dissection of the head of *C. cupio* from dorsal side to show the relationship of brain with rosette.

CE. : Cerebellum
EY. : Eye
OLF. BL : Olfactory bulb
OLF. LO : Olfactory lob
OLF. TR. : Olfactory tract
OP. LO : Optic lob
ROS. : Rosette
Each half of the rosette is further divided into peripheral and central channels due to presence of linguiform process of all the lamellae in an antero-posteriorly progressing manner. The linguiform processes (LING.P.) form a curtain like separation in between the channels of each half of the rosette (Fig.-1D). The raphe is richly supplied with chromatophores but in other regions of rosette they are scattered rarely.

The lamellae (LAM., Fig.-1E) are leaf shaped structures lying attached on either sides of the raphe (Fig.-1D, Plates-3, 4). They are possessing ventral convex and dorsal flat surface. The former is attached with the wall of olfactory chamber where as latter is free and maintain interlamallar spaces (INT.LAM.SP., W.OLF.CHAM.,Plate-5) among them. The proximal end (PRO.E.) of each lamellae is narrow and attached with the raphe while the distal end (DIS.E.) is broad and attached with olfactory chamber (Plates-3, 4, 5). The linguiform process is present in the middle of each lamellae and are arranged in an antero-posterior ascending series. In few posterior lamellae its growth exceeds beyond the distal end of the lamellae (Fig.-1E, Plates-6-18). The chromatophores are present on the linguiform process (Fig.-1E).

The brain and its cranial connections are exposed after dissecting the fish from dorsal side and removing the frontal and partials. The olfactory bulbs (OLF.B.) are conspicuous and bulbous structures, against the convex surface of the olfactory rosette. It receives the olfactory nerve fibres from the rosette and joins the hemisphere of forebrain by a thick olfactory tract (OLF.TR.). The
Plate-19: The distal end of lamella showing terminal bud formation, trifurcation ad bifurcation.
A. Terminal bud formation

B. Trifurcation series

C. Bifurcation series

Plate-19
Plate-3: Horizontal section of complete rosette of *C. carpio* showing the lamellar arrangement in relation to raphe and with olfactory chamber. The distal end of lamella makes a continuous series forming a peripheral channel for water circulation. Central channel is on both sides of the raphe for water circulation. Magnification 50X.

- ANT. E. - Anterior end
- DIS.E. LAM. - Distal end of lamella
- INT.LAM.SP. - Inter lamellar space
- MID.LAM. - Middle lamella
- POST.E. - Posterior end
- POST.LAM. - Posterior lamella
- PRO.E.LAM. - Proximal end of lamella
- RPH. - Raphe
- SMSA. - Sub mucosa

Plate-4: Transverse section T.S. of lamellae of *C. carpio* showing emergence of raphe and lamellar attachment with olfactory wall.

- BIF. - Bifurcation
- DIS.E. LAM. - Distal end of lamella
- MSA. - Mucosa
- PRO.E.LAM. - Proximal end of lamella
- RPH. - Raphe
- SMSA. - Submucosa
- W. OLF. CHAM. - Wall of olfactory chamber
Plate-5: Horizontal section of rosette of C. carpio showing one half of lamellar arrangement with raphe and with olfactory chamber. Peripheral goblet cell are seen occupying whole of the lamellar surface except few intervening supporting cells and receptors. Connective tissue, blood and nervous supply is through submucusa of raphe to the submucosa of lamella. Magnification 100 X.

ARE. - Areolae
BM. - Basal membrane
DIS.E. LAM. - Distal end of lamella
GC. - Goblet cell
INT.LAM.SP. - Inter lamellar space
MSA. - Mucosa
RPH. - Raphe
W. OLF. CHAM. - Wall of olfactory chamber

Plate-6: Magnified horizontal section passing through the raphae of C. carpio showing the regular emergence of lamella along with connective tissue, fibres blood and nervous entering in submucosa of lamella. Magnification 450 X.

BCP. - Blood capillaries
CONN. TIS. FIB. - Connective tissue fibres
FIB. - Fibroblast
GC. - Goblet cell
GC.TH. - Goblet cell theca
HIS. - Histocytes
OCl. - Olfactory cilia
RPH. - Raphe
Plate-7: Horizontal section through the rosette of *C. carpio* showing the sequential arrangement of initial, middle and hinder lamellae. Goblet cell activity is clearly visible in middle and hinder lamellae with the presence of crypts of different sizes at variable depths of olfactory mucosa. Magnification 50 X.

DIS.E. LAM. - Distal end of lamella
HIN.LAM - Hinder lamella
INI.LAM. - Initial lamella
INT.LAM.SP. - Inter lamellar space
MID.LAM. - Middle lamella
PRO.E.LAM. - Proximal end of lamella
W.OLF.CHAM. - Wall of olfactory chamber

Plate-8: Horizontal section of rosette of *C. carpio* showing middle and hinder lamellae with tremendous activity of goblet cells along with other microformations on the lamellar surface. Magnification 100 X.

CRY. - Crypts
HIL.ELE. - Hillock Elevation
HIN.LAM - Hinder lamella
MID.LAM. - Middle lamella
olfactory lobes (OLF.L.) are considerably developed but are smaller than the optic lobes (OPT.L., Fig.-2).

The olfactory rosette (ROS.) of *C. carpio* is oval shaped and is thrown out in number of ventro-dorsally projected folds or lamellae (Fig. 1D, Plates3,4). They are attached on either sides of the raphe, (APH.) which is a median thickening of the olfactory floor dividing it into two equal halves (Fig.1D, Plates-2, 4, 5, 6, 10). All the lamellae are free on the dorsal surface and maintain inter lamellar spaces (INT. LAM. SP.) in between them (Fig.1D, Plates-3, 4, 5, 7, 8, 12). Each lamella is made up of a central core or submucosa, lining on its both sides by the cellular component of mucosa (MSA, Plates-3-7,9,11,12). The mucosa is composed of pseudo-stratified columnar and ciliated epithelium which is abundantly supplied with the mucous secretory goblet cells (GC., Plates-5,6,8-12). The basement membrane (BM) stands as partition in between the submucosa and mucosa (Plate-10). The peripheral surface of the lamellae is provided with number of microformations which are due to the flow of basal cells and bursting of goblet cells at different levels of the olfactory epithelium (Plates-9,10). They may be in the form of the hillock elevations (HIL. ELE.), straight projections, bifurcations (BIF.) and trifurcations (TRI., Plates-8, 17, 18). The grouping of the goblet cells and their fusion causes the interuption of the olfactory epithelium leading to the formation of depressions, flask, funnel, tubular and rounded vocuoles like crypts (CRY. Plates-14-17). The goblet cells burst on the surface in groups, forming crypts like structures on the periphery of lamellae through which receptors are projecting their olfactory cilia (OCI.) to the interlamellar space.
Plate-9: Magnified section of terminal end of lamella of C. carpio showing presence of goblet cells, ciliated supporting cells, rod shaped and spindle shaped receptor cells. Magnification 450 X.

- BC.Z. Basal zone
- DIS.E. LAM. Distal end of lamella
- GC.TH. Goblet cell theca
- MU. Mucous
- NU.GC. Nucleus of goblet cell
- RR. Rod shaped receptor
- SC. Supporting cell
- SMSA. Sub mucosa
- SR. Spindle shaped receptor

Plate-10: Transverse section of C. carpio passing through raphe zone exclusively, showing nonreceptor zone with goblet cells and nonciliated supporting cells on the peripheral margin. Submucosa of raphe is supplied with dense connective tissue fibres, blood supply histocytes, fibroblasts and mast cells. Magnification 450 X.

- BCP. Blood capillaries
- BM. Basal membrane
- CONN. TIS.FIB. Connective tissue fibres
- FOL.OLF. Folium olfactorium
- GC.B. Goblet cell blast
- GC.TH. Goblet cell theca
- SC. Supporting cell
The crypts or opening of the goblet cells with their sensory cilia, projecting out to the inter lamellar space, gives an impression of "Olfactory Crypts", embedded deep in the olfactory epithelium (Plates-15, 16). The division of the central core or submucosa is seen only in bifurcations and trifurcations but in other micro formation it does not send its offshoots (Plates-17, 18, 20). The formation of secondary lamellae is not observed in C. carpio and microformations leads to increase the sensory surface of the olfactory lamella. Only the anterior most lamellae have their proximal and middle lamellar surface uniform (Plates-11-12) but others are richly supplied with crypts and microformations (Plates-8, 15-18). The "Cell Ball" (C. BALL, Plate-13) formation is also observed, which are arranged against the distal tip of anterior lamella.

The cellular contents of the olfactory epithelium of C. Carpio can be identified as : supporting or sustentacular cells, receptor cells, goblet cells and basal cells. The connective tissue of submucosa and raphae is richly supplied with branched fibroblasts, histocytes and basal cells.

**Supporting cells:**

The supporting cells (SC.) of C. caripo are subjected to a process of continuous transformation into mucous secretary goblet cells, therefore, whole of the peripheral surface of the lamella is lined by goblet cells with few intervening supporting cells (Plates-5, 9-11, 13).

The nonciliated supporting cells are present in proximal and intervening region of lamellae adjacent to raphe. These cells have elongated cell body with oval nucleus. The chromatin material is dust like and uniformly distributed in karyoplasm. The outer or distal limb
is elongated, extending up to the peripheral surface of the lamella. The ciliated supporting cells have long cilia projected into the interlamellar spaces showing their unidirectional movement (Plate-6, 11). The distal or outer limb of the ciliated supporting cell contains homogenous cytoplasm in the distal regions of lamella. The proximal limb is inconspicuous and difficult to trace among the other cellular contents lying beneath these cells. The ciliated supporting cells are also present in crypts or opening of goblet cells among the primary neurons (Plates-9, 10).

The ciliated supporting cells in the middle and distal regions of the lamella are comparatively broad and columnar in shape with a slightly convex distal end which projects cilia in the interlamellar spaces. They bear rounded or oval nuclei with a nucleolus and faintly visible chromatin material. The nuclei of these cells are larger than the receptor cells and take darker stain as compared to primary supporting cells. The outer distal limbs of secondary ciliated supporting cells are thick and filled with fibrilar cytoplasm. The ciliation is thick and prominent, projecting into the interlamellar space. The ciliated supporting cells may undergo a process of transformation into the goblet cell and transitional stages of these cells can easily be seen in the olfactory epithelium of C. carpio. Some ciliated cells are also seen discharging the mucous into the interlamellar space at certain places.

**Receptor Cells:**

The receptor cells are supplied throughout the olfactory epithelium of C. carpio irrespective of their restriction in any particular region of the lamellae. But, however, they are concentrated in crypts
and in the middle region of all the lamellae. They can be classified into three types: Primary neurons (PN.); spindle shaped receptors (SR.) and rod shaped receptors (RR.).

The primary neurons (PN.) are confined in the crypts (Plates-14-16) and in the proximal region of lamellae among the nonciliated supporting cells. They bear a rounded nucleus (NU. PN.) which send a fibrillar dendrite (DN. PN.) to the peripheral surface. The dendrite is darkly stained. These receptor cells are situated close to the basement membrane (BM.) as they usually lie in the interuptions caused by the bursting of goblet cells (GC.B.) in the form of crypts. The terminal end of primary neurons either bear cilia or protrude as such in the lumen of crypts which are communicated with interlamellar spaces by their openings. In this manner olfactory cilia (OCI., Plate-11) or protruding end of dendrite remain in contact with the water current passing through the interlamellar spaces of the lamella. The independent identity of the axon of these receptors are not very commonly traced out due to their insignificant length but, however, at the places of thick olfactory epithelium their clear demarcation can be seen.

The spindle shaped receptor (SR.) bears elongated and oval nucleus (NU.SR.) with long dendrite (DN. SR.). The axonal end is also considerably long and can be easily traced out in thick regions of olfactory epithelium. Their occurrence is comparatively rare in the olfactory epithelium of C. carpio but, however, they can be observed among the ciliated supporting cells in thick olfactory epithelium (Plates-9, 11, 12, 14). They are not present among the marginal goblet cells or in the crypts or opening of the goblet cells.
Plate-11: Magnified section of initial lamella of *C. carpio* showing uniform mucosa and submucosa. Goblet cell occupy most of the peripheral zone along with ciliated and non-ciliated supporting cell and also with intervening rich supply of rod and spindle shaped receptors. Magnification 750X.

BCP. - Blood capillaries
BC.Z. - Basal zone
DN.R.R. - Dendrite of rod shaped receptor
GC. - Goblet cell
GC.TH. - Goblet cell theca
PIG. - Pigment cell
RR. - Rod shaped receptor
SC. - Supporting cell
SMSA. - Sub mucosa
SR. - Spindle shaped receptor

Plate-12: Magnified section of initial most lamella of *C. carpio* showing comparatively lesser goblet cell activity, intervening supporting cells, rod and spindle shaped receptors and thick basal zone. Magnification 450X.

BCP. - Blood capillaries
GC.TH. - Goblet cell theca
INT.LAM.SP. - Inter lamellar space
MSA. - Mucosa
RR. - Rod shaped receptor
SC. - Supporting cell
SMSA. - Sub mucosa
SR. - Spindle shaped receptor
The rod shaped receptor cells (RR.) are commonly observed in the middle and distal regions of the olfactory epithelium of a lamella. Their dendrites (DN. RR.) are thick and rod shaped, extending either in between the theca of two marginal goblet cells or traversing singly or in groups through the empty theca of a goblet cell (Plates-9, 11, 12, 14, 16). The dendrite terminates distally in the form of expanded tip which bears minute cilia (OCl.) projecting in interlamellar space. The rod shaped receptor bears darkly staining narrow and elongated nucleus (NU.RR.). The axon is elongated, extending upto basal zone (BC.Z.) where they join to form folium olfactorium (FOL. OLF.).

The olfactory vesicles are observed in the terminal ends of the dendrite of rod and spindle shaped receptor cells in C. carpio. The spindle shaped receptor cells bear rounded vesicle while the terminal end of the dendrites of rod shaped receptor cells end terminally in the form of expanded tip forming olfactory vesicle of variable shapes. They are projected in the interlamellar spaces either by olfactory cilia or micro villi or both.

The presence of primary neuron in crypts and the projection of their cilia or protruding ends in theca (TH.) gives a shape of deeply embedded "Olfactory crypt" which can be commonly observed in the olfactory epithelium of C. carpio. (Plates-8, 10, 15, 16). The dendrites of rod shaped receptor cells also show their rare aggregation in the form of an "Olfactory crypt" on the uniform surface of the olfactory lamellae. The synaptic contacts in between any two receptor cells have not been observed any where in the olfactory epithelium of C. carpio and independant identity of each receptor cell is maintained. The
Plate-13: Magnified section of distal end of lamella of *C. carpio* showing full formation of terminal bud possessing all cellular elements of the lamella. magnification 450 X.

TER. BUD - Terminal bud

Plate-14: Magnified section of middle lamellae of *C. carpio* showing tremendous activity of goblet cell which become grouped and regrouped and collectively burst out to form big vacuole like structure and also exerting pressure on underlying zone forcing them to migrate in any direction leading to the formation of surface elevation, crypts of different shapes and sizes which possess the primary neurons in groups or in solitary states. Magnification 750X.

GC. - Goblet cell
PN. - Primary neuron
RR. - Rod shaped receptor
SMSA. - Sub mucosa
SR. - Spindle shaped receptor
Plate-15: Magnified section of hinder lamellia of *C. carpio* depicting total breaking down of peripheral surface of mucosa in the form of crypts of different shapes and sizes accommodating large number of primary neurons which protrudes their dendritic end in their lumen. Rod and spindle shaped receptor cells are present on general surface, sending their dendrite or olfactory vesicle or olfactory cilia in the inter lamellar space spaces. Magnification 750 X.

Plate-16: Magnified section of hinder lamellia of *C. carpio* showing tremendous muciferous activity with the result of formation of different types of crypts. Due to the bursting of goblet cells there occurs migration of basal cells to the peripheral surface. Magnification 750 X.
axons of all the receptor cells extend proximally and join folium olfactorium along basement membrane (Plate-10).

**Goblet Cells:**

These are the dominating cellular components of the olfactory epithelium of *C. carpio*. They can be easily distinguished into two types: (1) Marginal goblet (MG.) cells, (2) Migratory goblet cells (MIG.). The former are transformed by secondary supporting cells whereas later are the result of the specific basal cells lying in the proximal and intervening regions of the lamella adjacent to the raphe.

The marginal goblet cells are seen arranged serially throughout the peripheral surface of the lamella. They are provided with a cup shaped spacious theca (GC. Th.), which is filled with pale droplets of mucigen. The nuclear (NU.GC.) contents are very much compressed and pushed downwardly, leaving a small amount of darkly staining cytoplasm around the nucleus. The nucleus and cytoplasmic contents take a triangular shape in which nucleolus and chromatin material is not visible due to the high degree of compression. A stem like proximal limb connects the goblet cell with the basal zone (BC.Z.). The rod shaped receptors either lie in between the theca of these cells or traverse through the empty theca. The marginal goblet cells are produced continuously with the result of transformation of positively muciferous supporting cells with the age of the fish (Plates-8, 11, 12).

The migratory goblet cells (MIG.) originate from the muciferous basal cells which are concentrated in the proximal or intervening region of the lamellae adjacent to the raphe. They are shapeless and usually show rounded structure and remain in wandering tendency from deeper zones to peripheral zone of the olfactory epithelium.
Generally number of newly formed migratory goblet cells are grouped and fused in the form of complicated vacuole like structure, which gradually grows in size and ultimately burst out (GC. B.) from the peripheral surface of the lamella, discharging their mucous content in the inter lamelar space (Plates-9, 10, 14). This leads to the formation of crypts like formation which may be in the form of depression, flask, funnel and tubular deepenings (Plates-15, 16). Due to the migratory process of these goblet cells, the olfactory epithelium is affected greatly causing the displacement of basal cells. This results the flow of basal cells in any direction which may lead to the formation of hillock elevation, straight projection, bifurcation and trifurcations from the general surface of the olfactory epithelium (Plates-13, 17, 18).

The grouping and fusion of the goblet cells at some places cause perfect interruption of the olfactory epithelium. Formation of crypts and microformations amount peculiar findings of this study as nowhere this phenomenon is noticed in the olfactory epithelium of the fishes studied so far.

**Basal Cells:**

The basal cells (BC.) can be distinguished in number of forms lying irregularly above basement membrane. The rounded forms of these cells are provided with darkly staining oval nucleus (NU.BC.) with a clear centrally placed nucleolus and uniformly distributed chromatin material in karyoplasm. The rounded basal cell can be observed anywhere in the olfactory epithelium. They are found distributed even in the extreme peripheral zone among the dendrites of receptors and distal limbs of the supporting cells. Their aggregation in groups can be commonly observed in the olfactory epithelium of *C.*
Plate-17: Vertical section of trifided lamella of *C. carpio* showing all three lobes along with corner crypts, peripheral goblets, rod shaped receptors, spindle receptors and accumulation of primary neurons in corner and other crypts. Submucosa is sending its offshoots in all the three lobes making them a complete lamella form. Magnification 750X.

Plate-18: Vertical section of terminal end of initial lamella of *C. carpio* showing bifurcation with no crypts but theca of goblet cell occupy the periphery of supporting zone which possess intervening ciliated, nonciliated supporting cells, rod and spindle shaped receptors. Submucosa is sending its offshoot in these two lobes. Magnification 450 X.
which may be the initial preparation, leading to microformations in the surface of lamella. The larger form of the basal cell is observed uniformly distributed above the basement membrane in proximal and intervening regions of the olfactory epithelium of anterior lamellae. These are filled with highly muciferous cytoplasm which push the nuclear and cytoplasmic content to the extreme inner side, to give rise to migratory goblet cell. These basal cells are migratory form and show their shifting from proximal zone to the peripheral zone, giving rise to the crypts and microformations.

Fibroblast cells and irregular lymphoid cells can also be observed in the basal zone.

Central Core or submucosa:

The central core or submucosa (SMSA.) is lined on either side by the basement membrane. It is made up of dense collagen fibre connective tissues (CONN. IS. FIB.), which lies entangled in matrix. The presence of branched fibroblasts, histocytes, basal cells, and pigment cells are also noticed in the sub mucosa of C. carpio. Only folium olfactorium fibres run along the basement membrane and which join the nonmedullated nerve fibres (NMN.FIB.) at raphe. The blood supply is in form of finer blood capillaries (BCP.) and blood sinus passes through raphe. Thick collagen bundles are lying in the central core which entangles branched pigment cells. The connective tissue lying in submucosa is compact and no areolae are seen. It is in continuation with the submucosa of raphe. Thick collagen fibres provide strength to the lamellae forming a turgor like structure. The branching of submucosa is observed at the terminal bifurcation and
Raphe:

The raphe is nonciliated, non sensory and median thickening of olfactory floor, which allow the attachment of all the lamellae on its either sides. It is composed of a spacious central core or submucosa with dense collagen fibres. basal cells, fibroblasts (FIB) and histocytes (HIC.) cells submerged in the thick matrix. Two rounded areolae (ARE.) and central blood sinus are seen in the submucosa of the raphe of C. carpio. Non-medullated nerve fibres (NMN.FIB.) extend along the basement membrane and join the folium olfactorium coming from lamellar regions. The mucosa (MSA.) of raphe is made up of cuboidal epithelium, consisting of cuboidal supporting cells, marginal goblet cells and basal cells. The margin of the raphe is totally occupied by the cupshaped theca of the goblet cells (GC.TH.), which is outwardly or distally covered by mucous sheath, secreted by these cells. Below the goblet cells lie one or two layers thick cuboidal cells whose distal processes extend up to the distal surface of the raphe. They have rounded, darkly staining nuclei. The basal zone is three to five layers thick, lying in regular rows just above the basement membrane. The submucosa and mucosa of the raphe is in continuation with the lamellae. The nervous and nutritional supply in the lamellae is through the raphe.

Ecological Coefficient:-

It is calculated by two methods: first by taking the length as parameter of mesencephalon and telencephalon; second by measuring the areas of two retinas and both the rosettes. By comparing the former and
later parameters, the effectiveness of the olfactory and optic faculties can be assessed approximately from the anatomical point of view.

Five fishes of different sizes ranging from 113mm to 210mm are selected for calculating the ecological coefficient. It is observed that the length of the brain and the number of lamellae increases successively with the size of the fish.

The areas of two retinae and both the rosettes are measured by Teichmann (1954) method and further modified by Rahmani and khan (1981). It is observed that the former ranges from 114.36mm² to 226.08mm² and that of later from 265.50mm² to 650.24mm² (Table-1). Though the areas of both the rosettes are found to be higher than the retinae but the value of later is of considerable significance and cannot be ignored. Considering the above values, it shows that C. carpio bears both olfactory and optic faculties better developed and, therefore, it can be identified as eye-nose fish and can be denominated as mesosmatic. In the natural habitat, the fish uses both the faculties with equal capability. This can increase the general efficiency of the fish and therefore, C. carpio is considered as most active exotic carp of fresh waters.

**Route of water circulation through the olfactory chamber of C. carpio:**

The posterior nasal opening is a wide aperture covering most of the area of the olfactory chamber and allowing exposure of the posterior part of the olfactory rosette to the external medium. Therefore, in C. carpio the olfactory epithelium remains in a constant touch with the water (similar to the gills).

In addition to it, the forward movement of the fish and synchronously the unidirectional beating of the cilia of the olfactory
epithelium, causes the entry of water current through anterior nasal opening to the central part of the outer concave surface of rosette. From here it is directed to the central and peripheral channels, leading to its ultimate expulsion from the posterior nasal opening. The forwardly directed nasal flap deflects the water current to the anterior nasal opening. During the course of circulation, water passes through the interlamellar spaces and lamellae are bathed properly.

The fish in motionless condition enjoys a constant contact of the olfactory lamellae with water through the posterior nasal opening but during forward movement, the current of water enters through the anterior nasal opening and is virtually expelled out from the posterior.

The olfactory epithelium of *C. carpio* is intensively mucous secretory and it is observed that foreign materials are trapped from the water current by the mucous at certain places in the interlamellar spaces. This may be a device for removing the unwanted foreign material from the water circulating over the olfactory rosette through the outgoing water current. This device can be compared with mucous secretion of the nasal epithelium of mammals which makes the air dust free before its intake in the alveoli.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Total length (mm)</th>
<th>Number of lamellae Rosette</th>
<th>Total length of brain (mm)</th>
<th>Length of mesencephalon (mm)</th>
<th>Length of telencephalon (mm)</th>
<th>Ecological coefficient (through lobes of brain) Length of telencephalon x 100</th>
<th>Length of mesencephalon</th>
<th>Retinal area of both eyes (mm²)</th>
<th>Olfactory area of both rosettes (mm²)</th>
<th>Ecological coefficient (through rosettes) Olfactory area x Length of mesencephalon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>113</td>
<td>23 Right 24 Left</td>
<td>5.70</td>
<td>2.29</td>
<td>1.58</td>
<td>68.09</td>
<td>114.36</td>
<td>265.50</td>
<td>127.16</td>
<td>280.24</td>
</tr>
<tr>
<td>2.</td>
<td>145</td>
<td>30 Right 30 Left</td>
<td>8.19</td>
<td>3.27</td>
<td>1.98</td>
<td>60.55</td>
<td>156.00</td>
<td>585.62</td>
<td>226.08</td>
<td>601.44</td>
</tr>
<tr>
<td>3.</td>
<td>165</td>
<td>32 Right 32 Left</td>
<td>8.77</td>
<td>3.74</td>
<td>2.57</td>
<td>68.71</td>
<td>226.08</td>
<td>650.24</td>
<td>287.08</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>185</td>
<td>34 Right 33 Left</td>
<td>10.53</td>
<td>3.86</td>
<td>2.57</td>
<td>66.58</td>
<td></td>
<td></td>
<td>260.64</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>210</td>
<td>36 Right 36 Left</td>
<td>11.21</td>
<td>4.09</td>
<td>2.92</td>
<td>71.39</td>
<td></td>
<td></td>
<td>287.08</td>
<td></td>
</tr>
</tbody>
</table>
Histochemical observations of *Cyprinus carpio*

Histochemical descriptions are meant for explaining correct morphological concepts of biological systems. In the present study, attempt has been made to demonstrate the histochemical localization of acid phosphatase, alkaline phosphatase, lipid, glycogen and acid mucopoly saccharides in the olfactory epithelium of *Cyprinus carpio.*

**Acid Phosphatase:**

The enzyme histochemical reactions have been treated as a link between morphology and biochemistry. An attempt has been made in the present study for the histochemical demonstration of acid phosphatase in the olfactory epithelium of *Cyprinus carpio.*

Acid phosphatase has been regarded as marker enzyme for lysosome. Recent evidence shows that acid phosphatase has not been restricted to lysosomal fraction but is also formed in golgi cisternae, and specialized region of endoplasmic reticulum as "GERL" (Farquhar et al. 1974).

In the acid phosphatase preparation of olfactory epithelium of *Cyprinus carpio,* all the cellular components are showing positive reactions. The localization of acid phosphatase in the olfactory epithelium was considered as one of the confirmatory indices for the identification of neurosecretory functions (Barymann and Zelforsch, 1949). Baronyi (1966) reported that acid phosphatase plays a role in the process of catabolism.

The synaptic junction shows low intensity reaction for acid phosphatase. This may be attributed to the fact, that, the animals
were collected in winter when most of the metabolic activities slows down.

The axon shows moderate acid phosphatase activity in the olfactory epithelium of *Cyprinus carpio*. This may be due to uncoupling of phosphorylation followed by cells during the olfaction.

Increase in the activity of acid phosphotase in the primary neurons or receptors cells, spindle and rod shaped receptor cells, secondary neurons, columnar supporting cells and goblet cells of olfactory epithelium is due to more hydrolytic enzymes which are concerned with the lysosomes. Increased activity of acid phosphatase in spindle shaped neurons of *Cyprinus carpio* is correlated with increased catabolic activity and their sudden increase in the activity suggests a metabolic readjustment.

The lysosomal enzymes are associated with degradative processes and their higher activities are often correlated with greater turnover of molecules (Allison, 1953) (Table-1)

**Alkaline Phosphatase:**

Alkaline phosphatase activity in *C. carpio* occur in the basal cells in a relatively high degree. The intense activity is seen in the aggregation of these cells at interlamellar levels and at the base of the olfactory epithelium in the distal region of the growing lamellae.

The spindle shaped neurons displayed a moderate reaction along the nuclear membrane while primary neurons rod shaped receptors and synaptic junction are also stained brownish black, indicating the low concentration or mild enzyme activity (Table-2). The columnar supporting cells and goblet cells show negative response with stain (Table-2).
The difference in the alkaline phosphatase level in the primary neurons, spindic and rod shaped receptor cells, synaptic junction, columnar supporting cells, basal cells and goblet cells may be related to the differential rate of substrate hydrolysis and transfer of metabolites across the olfaction site. High activity in the basal cell may be linked to considerable demand of the metabolites to mobilize and transfer large amount of energy rich precursors. (Table-2). The low concentration of the enzyme may be due to lesser demand and transfer of metabolites.

**Glycogen:**

Metabolic contribution of carbohydrate metabolism is often reflected in alterations in the glycogen, the major carbohydrate reserve. Hence the study is initiated to note the variation in the glycogen content during olfaction.

Occurrence of glycogen in the olfactory epithelia show a seat of intense biological activity and glycogen as a readily available source of energy will be required to support the sense of olfaction.

For localization of glycogen in *C. carpio* the rosette were fixed in appropriate fixative. 8μm thick section were processed and Best Caramine technique were used for demonstration.

The observations (Table-3) reveal that heavy deposits of glycogen occur in the columnar supporting cells around the distal limb and basal cell. Heavy reserves also occur in the goblet cells. It is also found in the present study that synaptic junction showed moderate deposition which denotes that glycogen were utilized rapidly for the supply of energy in sense of olfaction.
The decline in the glycogen content is greater in the primary neurons, spindle and rod shaped receptor cells. This could be due to their utilization in olfaction, fuel energy production and their probable contribution to the protein build up in the neurons. According to Tate and Winter (1962) the depletion in the glycogen is due to its transformation into protein and lipid.

Heavy deposits of glycogen in the columnar cells, basal cells and goblet cells indicate utilization of this polysachharides during olfaction (Table -3).

**Acid Mucopolysaccharides**:

The mucous secreting goblet cells of olfactory epithelia of *C. carpio* retain a brilliant bluish green stain with Alcian blue which demonstrates the intense deposition of mucopolysaccharides whereas in the distal limbs of the columnar supporting cells and in some basal cells mild stain is seen. Except these components of the olfactory epithelia, non of the other cellular components showed any reaction with the Alcian blue. So it has been assumed that the goblet cells are reservoir of mucopolysaccharides whereas its activity in columnar supporting cell and some basal cells indicate that these are in muciferous position and ultimately convert into goblet cells to compensate the enhanced mucous activity in the olfactory epithelium (Table 4).

The excessive mucous is meant for lubricating the delicate olfactory epithelial surface as well as to protect it with the damaging effect of constantly circulating water current with different degree of striking pressure. It is also meant for entangling foreign bodies and
isolating them from circulating water current and ultimately removing such unwanted mass through outgoing water current.

Acid mucopolysaccharides are complex carbohydrates characterised by the presence of a hyaluronic acid along with a N-acetyl hexosamine, stable and resistant to chemical hydrolysis and therefore, they are found at places where strength and chemical resistance is required (Sinha et al., 1978).

Hyaluronic acid, a biologically important acid mucopolysaccharide found in many animal tissues, act as a barrier to fluid diffusion and prevent the leakage of material and impulse across the cell membrane. The acid mucopolysaccharides is also utilised rapidly for the supply of energy. The functional role of acid mucopolysaccharides seems to aid in binding with calcium ion in C. carpio and fulfilling the requirement of energy consumed during receptory process through odorant.

Thus, acid mucopolysaccharides detected in olfactory epithelia play an important role in olfaction by acting as selective ion barrier and by initiating impulse due to depolarization of the membrane.

Lipids:

Lipids are present in high concentrations in the distal tips of columnar supporting cells of olfactory epithelium C. carpio. Comparatively moderate quantities also occur in the mucin granules of goblet cells, cytoplasm around nuclei of primary neurons, dendrites of primary neurons, synaptic junctions between primary and secondary neurons and proximal limb of columnar supporting cells. Mild concentration of lipids are also present in the nuclear
membranes of various cell types, cytoplasm of basal cells, cilia of columnar supporting cells and axons of secondary neurons (Table-5).

**Meta cromasia:**

*Metacromasia in C. curpio* is demonstrated in the proximal part of the dendrites of primary neurons, synaptic junction between primary and secondary neurons and the cytoplasm around the nuclei of primary and secondary neurons. A comparative milder reaction is observed in the goblet cell, axon of secondary neuron, proximal limb of columnar supporting cell and basal cell (Table-6).
Table 1: Showing Histochemical demonstration of Acid phosphatase employed by Pearse 1968, and the reaction obtained in various cellular components of olfactory epithelium of *Cyprinus carpio*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Cryostate</td>
<td>Modified Lead nitrate method PROCESSED AS RECOMMENDED by TAKEUCHI AND TANOUÉ AS GIVEN BY PEARSE, 1968.</td>
<td>(i) Primary neurons</td>
<td>+++</td>
</tr>
<tr>
<td>Phosphatase</td>
<td></td>
<td></td>
<td>(ii) Spindle shaped receptors cells</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Rod shaped receptors cells</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Synaptic junction</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Columnar supporting cell</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vi) Basal cell</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vii) Goblet cell</td>
<td>++</td>
</tr>
</tbody>
</table>

**Remarks**

+++ High activity
++ Moderate activity
+ Low activity

Absence of any activity
**Table-2:** Showing the demonstration of *Alkaline phosphatase* activity employed by Pearse 1968, and the reaction obtained in various cellular components of olfactory epithelium of *Cyprinus carpio*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline</td>
<td>Cryostat</td>
<td>Calcium Cobalt method</td>
<td>(i) Primary neurons</td>
<td>±</td>
<td>+++ High activity</td>
</tr>
<tr>
<td>Phosphatase</td>
<td></td>
<td>[after GOMORI, as given by Pearse 1968]</td>
<td>(ii) Spindle shaped</td>
<td>±</td>
<td>++ Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>receptors cells</td>
<td>(iii) Rod shaped</td>
<td>±</td>
<td>± Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>receptors cells</td>
<td>Synaptic junction</td>
<td>±</td>
<td>± Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Columnar</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>supporting cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Basal cell</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Goblet cell</td>
<td>±</td>
<td></td>
</tr>
</tbody>
</table>
Table-3: Showing the histochemical localization of **Glycogen** in olfactory epithelium of *Cyprinus carpio*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycogen</td>
<td>Microtomy</td>
<td>Periodic Acid-Schiff technique and Best Carmine stain</td>
<td>(i) Primary neurons</td>
<td></td>
<td>High activity</td>
</tr>
<tr>
<td></td>
<td>8µm</td>
<td></td>
<td>(ii) Spindle shaped receptors cells</td>
<td></td>
<td>Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Rod shaped receptors cells</td>
<td></td>
<td>Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Synaptic junction</td>
<td></td>
<td>Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Columnar supporting cell</td>
<td>++ (Distal limb)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vi) Basal cell</td>
<td>+++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vii) Goblet cell</td>
<td>+++</td>
<td></td>
</tr>
</tbody>
</table>
Table-4: Showing the histochemical localization of *Acid mucopolysaccharide* in the various cellular components of olfactory epithelium of *Cyprinus carpio* (employed by Pearse, 1968).

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid mucopolysaccharides</td>
<td>Microtomy</td>
<td>Alcianblue method [after STEEDMAN, vide PEARSE, 1968]. Deposition showed the bluish green stain with Alcian Blue</td>
<td>(i) Primary neurons</td>
<td><strong>+++</strong></td>
<td>High activity</td>
</tr>
<tr>
<td></td>
<td>(8μm)</td>
<td></td>
<td>(ii) Spindle shaped receptors cells</td>
<td><strong>++</strong></td>
<td>Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Rod shaped receptors cells</td>
<td><strong>+</strong></td>
<td>Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Synaptic junction</td>
<td></td>
<td>Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Columnar supporting cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vi) Basal cell</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vii) Goblet cell</td>
<td><strong>+++</strong></td>
<td></td>
</tr>
<tr>
<td>ENZYME</td>
<td>SECTION</td>
<td>TECHNIQUE</td>
<td>CELLULAR COMPONENT</td>
<td>NATURE OF REACTION</td>
<td>REMARKS</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>-----------</td>
<td>-------------------</td>
<td>--------------------</td>
<td>---------</td>
</tr>
<tr>
<td>LIPID</td>
<td>Microtomy (8µm)</td>
<td>Sudan Black B method (after MANNUS VIDE PEARSE, 1968)</td>
<td>(i) Primary neurons</td>
<td>++ (Cytoplasm around nucleus and dendrites)</td>
<td>+++ High activity</td>
</tr>
<tr>
<td></td>
<td>Temporary mount</td>
<td></td>
<td>(iii) Spindle shaped receptors cells</td>
<td></td>
<td>+++ Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iiii) Rod shaped receptors cells</td>
<td></td>
<td>+ Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Synaptic junction</td>
<td></td>
<td>Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Columnar supporting cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vi) Basal cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vii) Goblet cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Table-6**: Showing histochemical localization of metacromasia in the olfactory epithelium of *Cyprinus carpio*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacromasia</td>
<td>Microtomy</td>
<td>Toulidine Blue method (after KRAMER and</td>
<td>(i) Primary neurons</td>
<td>+++ (Proximal part of</td>
<td>+++ High activity</td>
</tr>
<tr>
<td></td>
<td>(8μm)</td>
<td>WINDRUM, as given by PEARSE, 1968)</td>
<td>(ii) Spindle shaped</td>
<td>dendrites)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>receptors cells</td>
<td>(-cytoplasm around</td>
<td>(+) Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>nucleus)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-axon)</td>
<td>(-) Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Rod shaped</td>
<td>(-cytoplasm around</td>
<td>Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>receptors cells</td>
<td>nucleus)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-axon)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Synaptic junction</td>
<td>(-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Columnar supporting</td>
<td>(+ (proximal limb))</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vi) Basal cell</td>
<td>(+ (proximal limb))</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(vii) Goblet cell</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ANT. NAS. OP. - Anterior nasal opening
Eye - Eye
NAS. FLAP - Nasal flap
POST. NAS. OP. - Posterior nasal opening

Plate-2: Dissection of the head of *B. bagarius* from lateral side to show rosette in situ

ROS. - Rosette
RPH. - Raphe
VEN. LAT. ACC. - Ventro lateral accessory nasal sac
NAS. SAC
Histological Observations of The Olfactory Organ
of Bagarius bagarius

B. bagarius bears a pair of olfactory chambers on the dorsal
surface of the head, lying close to the snout and away from the eye
orbit (Fig.-1A, Plates-1,2). They are ventilated outside by a pair of
openings which can be named as anterior and posterior nasal
openings which can be named as anterior and oposterior nasal
openings (ANT. NAS. OP. and POST. NAS. OP.) with regards to their
respective position. The anterior nasal opening is tubular over hanging
on the upper lip, while, posterior is valvular and flush with surface of
the head (Figs.-1A, Plate-1, 2). The later is in the form of an oblique
furrow surrounded by the loose cresentric area of the integument and
is made of anterior and posterior lips of the skin (ANT. LIP and POST.
LIP, Fig.-38D). The former gets expanded over the later giving a shape
of valve to the posterior nasal opening which regulates the entry and
exit of water current through the olfactory chamber (OLF.CHAM.).
Anterior to the posterior nasal opening lies a nasal barble (NAS. BAR.,
Fig. 1A, Plate-1), whose movement causes effective variation in the
volume of the olfactory chambers. It is (olfactory chamber) enormously
developed with a leaf shaped appearance, accommodating the rosette
(ROS.) and the accessory nasal sac (VEN.LAT.ACC.NAS.SAC., Plate-2).
The olfactory rosette is leaf shaped elongated structure having
anterior broad and posterior narrow ends (Fig.-1B) It consists of thick
olfactory epithelium and give rise to numerous lamellae (LAM.),
attached on either sides of the raphe (RPH., Fig.-1B, C) The rosette is
almost flat and is attached with the floor of the olfactory chamber by

61
Fig. 1 A  Diagram of the lateral view of the head of *B. bagarius*.

Fig. 1 B  Diagramatic sketch of the right rosette of *B. bagarius*.

Fig. 1 C  A set of 1 - 32 lamellae from one half of the rosette of *B. bagarius*.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANT. NAS. OP</td>
<td>Anterior national opening</td>
</tr>
<tr>
<td>ANT. NAS. TUBE</td>
<td>Anterior nasal tube</td>
</tr>
<tr>
<td>LAM.</td>
<td>Lamellae</td>
</tr>
<tr>
<td>LING. P.</td>
<td>Linguiform process</td>
</tr>
<tr>
<td>NAS. BARBLE</td>
<td>Nasal barble</td>
</tr>
<tr>
<td>OLF. CHAM</td>
<td>Olfactory Chamber</td>
</tr>
<tr>
<td>POS. NAS.OP</td>
<td>Posterior nasal opening</td>
</tr>
<tr>
<td>ROS.</td>
<td>Rosette.</td>
</tr>
<tr>
<td>RPH</td>
<td>Raphe</td>
</tr>
</tbody>
</table>
Fig. - 1
Fig. 2: Diagram of the dissection of the head of *B. bagarius* from dorsal side to show the relationship of brain with the rosette.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE.</td>
<td>Cerebellum</td>
</tr>
<tr>
<td>EY.</td>
<td>Eye</td>
</tr>
<tr>
<td>OLF. BL.</td>
<td>Olfactory bulb</td>
</tr>
<tr>
<td>OLF. LO.</td>
<td>Olfactory lobe</td>
</tr>
<tr>
<td>OLF. TR.</td>
<td>Olfactory tract</td>
</tr>
<tr>
<td>ROS.</td>
<td>Rosette</td>
</tr>
<tr>
<td>VEN. LAT.</td>
<td>Ventro lateral Accessory</td>
</tr>
<tr>
<td>ACC. SAC</td>
<td>Nasal sacs</td>
</tr>
</tbody>
</table>
fibrous connective tissue. The peripheral and central channels are present in each halves of the rosette and continuous anteroposteriorly ascending series of linguiform process (LING.P.) stand as partition in between them. The posterior extremity of the olfactory rosette is narrow and lamellaeless (LAM.LESS) where the accessory sac opens by an independent aperture.

The lamellae (LAM.) of *B. bagarius* are short and broad which are attached proximally with the raphe and distally with the wall of the olfactory chamber (W.OLC.CHAM., Figs.-1B, Plates-3, 4, 5). Their dorsal surface is free and maintains inter-lamellar space (INT. LAM. SP., Plates-3,4,5) in between them. The dorsal medial surface of each lamella is projected out in the form of a thumb like linguiform process, arranged in an anteroposteriorly ascending manner, which forms curtain like separation in the centre of each half of the rosette.

After removing the median ethmoid, lateral ethmoid and frontals from the dorsal side of the head, the brain and its relation to the olfactory rosette become clearly exposed. The olfactory bulbs (OLF. BL.) are situated close to the postero-ventral surface of the rosette and receive the nerve fibres from each lamella. The olfactory bulbs are anteriorly broad and become narrow posteriorly which are joined with telencephalon by thick olfactory tracts (OLF. TR., Fig.-2). The olfactory lobe (OLF.L.) is better developed as compared to the optic lobe (OP.L.). The size of brain and its lobes are found increasing successively with respect to the size of the fish (Table-7).

Olfactory epithelium forms the outlining of olfactory chamber and is thrown into the number of lamellae which are attached on either sides of the raphe (RPH., Plates-3, 4). It is a median antero-
Plate-3: Horizontal section rosette of *B. bagarius* showing lamellar arrangement with respect to aphe and olfactory chamber. The ventro lateral accessory nasal sac is also shown in relation to rosette. Magnification 50X.

- **DIS.E. LAM.** - Distal end of lamella
- **INT.LAM.SP.** - Inter lamellarspace
- **PRO.E.LAM.** - Proximal end of lamella
- **RPH.** - Raphe
- **W. OLF. CHAM.** - Wall of olfactory chamber
- **VEN.LAT.ACC.NAS.SAC** - Ventro lateral accessory nasal sac

Plate-4: Magnified section of rosette of *B. bagarius* showing supply of connective tissue, blood capillaries, nervous elements from submucosa of raphe to submucosa of lamellae. Magnification 100X.

- **BCP.** - Blood capillaries
- **CONN. TIS. FIB.** - Connective tissue fibres
- **HIN. LAM.** - Hinder lamella
- **INT. LAM. SP.** - Inter lamellar space
- **INI. LAM.** - Initial lamella
- **MID. LAM.** - Middle lamella
- **MIN. LAM.** - Minor lamella
- **MSA.** - Mucosa
- **NMN. FIB.** - Non medullated nerve fibre
- **RPH.** - Raphe
A section of rosette of *B. bagarius* showing one half of lamellar arrangement with olfactory chamber of raphe along with demarcation of distal, middle and proximal end of lamella. Magnification 100 X.

**Plate-6:** Magnified section of proximal end of initial lamella of *B. bagarius* showing compact submucosa, mucosa, thick basal zone, ciliated and nonciliated supporting cells, independent spindle shaped receptor and primary neurons. Synaptic contact in between these receptors is occasionally visible which is indicated by arrow. Magnification 450 X.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIS.E. LAM.</td>
<td>Distal end of lamella</td>
</tr>
<tr>
<td>INT.LAM.SP.</td>
<td>Inter lamellar space</td>
</tr>
<tr>
<td>MSA.</td>
<td>Mucosa</td>
</tr>
<tr>
<td>PRO.E.LAM.</td>
<td>Proximal end of lamella</td>
</tr>
<tr>
<td>RPH.</td>
<td>Raphe</td>
</tr>
<tr>
<td>SMSA.</td>
<td>Sub mucosa</td>
</tr>
<tr>
<td>W.OLF.CHAM.</td>
<td>Wall of olfactory chamber</td>
</tr>
<tr>
<td>BCP.</td>
<td>Blood capillaries</td>
</tr>
<tr>
<td>CONN. TIS.FIB.</td>
<td>Connective tissue fibres</td>
</tr>
<tr>
<td>FOL.OLF.</td>
<td>Folium olfactorium</td>
</tr>
<tr>
<td>PN.</td>
<td>Primary neuron</td>
</tr>
<tr>
<td>SC.</td>
<td>Supporting cell</td>
</tr>
<tr>
<td>SR.</td>
<td>Spindle shaped receptor</td>
</tr>
<tr>
<td>SYN.</td>
<td>Synapse</td>
</tr>
</tbody>
</table>
posterior thickening of the olfactory epithelium, dividing the rosette into two clear halves. The olfactory lamellae are encapsulated by the ventro-lateral expansion of the olfactory epithelium (W. OLF. CHAM, Plates-3,4,5) but their dorsal and outer ends remain free, maintaining interlamellar space (INT. LAM. SP., Plates.-3,4,5) inbetween them. Each lamella is made up of central core or submucosa (SMSA.) which is an extension of the tissue underlying the ventral wall of the olfactory chamber. The central core or submucosa is lined by the cellular component of the olfactory epithelium or mucosa (MSA.) on either sides so that a lamella is virtually supported by two layers of sensory epithelium (Plates-4,5,12) From histological point of view, all the lamellae of a rosette can be divided in three groups: initial; middle and hinder (Plate-4). The cellular organization of these three division of lamellae varies greatly.

The initial lamellae are having compact cellular organization. The central core or submucosa and epithelial cellular lining are well built, giving the impression of youngest lamellae of the rosette. They bear short, narrow structure with mucous secretory goblet cell on the extreme tip. Submucosa is comparatively narrow having rich blood and connective tissue supply (Plates-6,12)

The middle lamellae contain elongated body with distal end lined by indifferent epithelium which is richly supplied with large flask shaped mucous secretory goblet cells. The submucosa is well built in the proximal and middle part but detached from the basement membrane in an irregular manner in the distal region of these lamellae (Plates-10, 11).
A. Stages depicting emergence of minor lamella from mother lamella by the process of outpushing of submucosa and mucosa of mother lamella.

B. Lateral bud showing detachment from the mother lamella and gradually elongating to join distal end of recipient lamella to enhance the growth of later.

C. The distal end of lamella discharging "cell ball" by gradual constriction of underlying region. It later joins to the subsequent lamella and contributes lamellar contents to the recipient lamella.

Plate-19
Plate-7: Section passing through old and worn out set of posterior lamellae of *B. bagarius* showing abnormal elongation, widening, curving, fragmenting, crypting, swellings and other mucosal surface specification. Magnification 100 X.

Plate-8: Magnified section of *B. bagarius* passing through the curving, crypting, broadening, capillary accumulation, goblet cell activity and formation of different deepenings in the form of crypts accommodating primary neurons send their dendritic end to the respective lumens. Magnification 450 X.
The hinder ones are old and worn out set of lamellae with enormously enlarged submucosa which has fragments of blood capillaries and loose collagen connective tissue (Plate-7). They are broad and short, lined with nonciliated cuboidal supporting cells (SC.) and mucous secretary goblet cells (GC.) throughout their surface. The receptor cells are distributed upto the middle of each hinder lamellae, though they are less in number (Plate-9).

The curved (CUR. LAM., Plate-12 ) and minor lamella (MIN. LAM., Plates-13,14,19A) can be observed in the middle and initial lamellae respectively. The formation of minor lamella takes place in the proximal end of the lamella, forming its minor offshoot which remains attached with it. The curving is noticed in the distal end of the initial lamella, where the whole of distal tip becomes curved in the form of 'U' shaped structure.

The distal tips of the middle and hinder lamellae undergoes the process of discharging their lamellar contents in the form of "Cell balls" (C. BALL) which contains all the contents of the olfactory epithelium (Plates-15,19B). They get discharged from the distal tips by gradual constriction (CONS., Plate-15,19B) of the underlying region of the lamella. The "Cell Balls" are arranged against the distal end of the lamellae in a regular manner, showing their gradual disintegration. Thus, this may be probably assumed that they might be supplying their cellular contents as nutrients to the other part of the olfactory rosette (Plate-19C).

The bud formation is observed in the hinder lamellae, which originate from the lateral surface of the distal end. This bud contains living contents of the olfactory epithelium and shows gradual
region of hinder lamellae of *B. bagarius* showing the presence of goblet cells, swelling in submucosa with rich concentration of blood capillary, connective tissue fibre and other cellular elements of submucosa. Primary neurons are richly supplied and spindle shaped receptors are also visible.

Magnification 750 X.

CONN. TIS. FIB. - Connective tissue fibres
FOL. OLF. - Folium olfactorium
GC. - Goblet cell
MSA. - Mucosa
PN. - Primary neuron
SMSA. - Sub mucosa
SR. - Spindle shaped receptor

Plate-10: Magnified section through distal and proximal end of the lamellae of *B. bagarius* showing attachment with the peripheral wall of the olfactory chamber with clear cut submucosa differentiation in between proximal and distal zones of lamella. Magnification 750 X.

BC.Z. - Basal zone
DIS.E. LAM. - Distal end of lamella
GC. - Goblet cell
PRO.E.LAM. - Proximal end of lamella
SC. - Supporting cell
SR. - Spindle shaped receptor
Plate-11: Magnified section passing exclusively through distal zone of lamella of *B. bagarius* showing broad, loosely arranged submucosa, fragment of connective tissue fibres, blood capillaries and other submucosa elements. Goblet cells with prominent theca depicting mucous discharging activity. Primary neurons and spindle shaped receptors are also visible. Magnification 750 X.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCP.</td>
<td>Blood capillaries</td>
</tr>
<tr>
<td>CONN. TIS.FIB.</td>
<td>Connective tissue fibres</td>
</tr>
<tr>
<td>GC.</td>
<td>Goblet cell</td>
</tr>
<tr>
<td>MU.</td>
<td>Mucous</td>
</tr>
<tr>
<td>PN.</td>
<td>Primary neuron</td>
</tr>
<tr>
<td>SMSA.</td>
<td>Sub mucosa</td>
</tr>
</tbody>
</table>

Plate-12: Transverse section of the one half of the rosette of *B. bagarius* passing through the region of initial lamellae. The curved distal end of the lamella and swellings of submucosa are also visible. Magnification 100 X.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONN. TIS.FIB.</td>
<td>Connective tissue fibres</td>
</tr>
<tr>
<td>CUR. LAM.</td>
<td>Curved lamella</td>
</tr>
<tr>
<td>DIS.E. LAM.</td>
<td>Distal end of lamella</td>
</tr>
<tr>
<td>INT.LAM.SP.</td>
<td>Inter lamellar space</td>
</tr>
<tr>
<td>MSA.</td>
<td>Mucosa</td>
</tr>
<tr>
<td>NMN.FIB.</td>
<td>Non medullated nerve fibre</td>
</tr>
<tr>
<td>PRO.E.LAM.</td>
<td>Proximal end of lamella</td>
</tr>
<tr>
<td>RPH.</td>
<td>Raphe</td>
</tr>
</tbody>
</table>
attachment on the adjacent lamella after being detached from the mother lamella (MOT. LAM.). In this process the recipient lamella (REC. LAM.) and the bud elongate (ELO.BUD) gradually to join each other and ultimately the later becomes fixed on the former. This cause immediate enlargement of recipient lamella with the result of the addition of the content of olfactory epithelium in the form of bud (Plates-16, 19B)

The submucosa swells abnormally in the initial and recipient lamellae, which are in the process of curving and attachment with the bud respectively (Plates-12, 16). This may be due to the accumulation of basal cells, connective tissue, blood capillaries and other epithelial contents required for elongation of lamella for attachment with the bud or curving.

On the basis of distribution of supporting and sensory cells, the lamella of *B. bagarius* can be divided in following zones:

*Proximal zone*: It extends on either sides of raphe upto the middle region of the olfactory rosette. The anterior and middle lamellae of this region have columnar ciliated epithelium with rich supply of receptor cells. This region is devoid of mucous secretory goblet cells.

*Distal Zone*: The distal zone of the lamella is composed of non-ciliated columnar supporting cells (S.C.). This zone is nonciliated but mucous secretory goblet cells (G.C.) are richly present. The central core of this region is supplied with pigment cells.

The following cell types may be identified in the olfactory epithelium of *B. bagarius*: Supporting or sustentacular cells, receptor cells; goblet cells and basal cells. The cellular components and their nuclei are arranged in the series from inner (or basal) to outer (or
peripheral) margins in the following manner. The innermost position next to basement membrane (BM.) is occupied by the basal cells (BC.) having rounded or irregular nucleus. These are followed by the nuclei of spindle shaped receptor cells (SR.) and then nuclei of supporting cells. Peripheral or outer zone is filled with the distal end of the supporting cells and dendrites of the receptor cells. The goblet cells are confined in the hinder lamellae or in the distal end of all lamellae intermingled with supporting cells.

Supporting cells:

They are columnar and cuboidal, arranged perpendicular to the central core of the lamella and contributes in the formation of greater bulk of the olfactory epithelium. These cells can be distinguished in following types: ciliated supporting cells; nonciliated supporting cells and transitionary supporting cells.

Ciliated supporting cells (Cl. SC.) are tall and richly ciliated. They are confined in the proximal and middle region of the initial and middle lamellae. The arrangement of these cells in the olfactory epithelium is very compact and no intercellular spaces can be seen among them. The columnar cells are made of proximal or inner limb and distal or outer limb. The later is broad and elongated, extending upto the peripheral surface of the lamella while the former is short, inconspicuous and extends upto the basement membrane. The cytoplasm of these cells frequently show granulated appearance and granules tend to become concentrated at the distal tip. The distal end of ciliated supporting cells bear cilia (OCI) which project into the interlamellar spaces. The spherical or oval nucleus of the ciliated supporting cell (NU.SC.) lies in the proximal part of inner limb. A
centrally situated nucleolus is clearly visible and chromatin material is evenly distributed in karyoplasm. The nucleus of ciliated supporting cells takes sharp stain of haematoxylin.

Nonciliated supporting cells (NCI. SC.) are confined in the distal regions of the initial and middle lamellae but the epithelium of hinder ones is mainly made up of these cells. They are short columnar and nonciliated provided with oval nucleus. The distal or outer limb is short, broad and terminates in the peripheral surface of the lamella by an expanded tip. The proximal or inner limb is inconspicuous but distal or outer end is prominent and broad. The nucleus lies somewhere in the proximal or inner side of the cell. The nuclei of these cells lie at different levels of the epithelium with clear nucleous and a uniform distribution of chromatin material.

The olfactory epithelium of hinder lamellae is mainly constituted of nonciliated cuboidal supporting cells. They are made up of short and broad distal limb and bears darkly staining rounded nucleus. The cuboidal supporting cells are compactly arranged along the peripheral surface of the mucosa which provide insulation to the dendrite of spindle shaped receptor cells (DN.SR.) The centrally placed nucleolus and chromatin material are clearly visible in the nucleus of cuboidal supporting cells.

Some of the nonciliated supporting cells are positively muciferous and are denominated as transitionary supporting cells (T. SC.) The distal or outer limb of these cells become ovoid pushing the cytoplasmic and nuclear content towards the proximal or inner side. The cytoplasmic and nuclear contents remain compressed while the distal part gradually filled with the mucin forming contents.
Receptor cells:

The receptor cells are confined in the proximal and middle part of all the lamellae, however, they are highly concentrated in the middle regions. The distal regions of all the lamellae show complete absence of the receptor cells. The receptor cells are interspersed among the ciliated columnar and nonciliated cuboidal supporting cells. Their grouping in the form of olfactory bud is not observed in the olfactory epithelium of *B. bagarius*. The receptor cells have slender body with scanty cytoplasm, surrounding the elongated oval nucleus. It takes good stain of haemotoxylin but slightly lighter than the nuclei of the surrounding supporting cells. Nucleus and chromatin material are clearly visible in the nuclei of receptor cells. These cells are situated deep in the olfactory epithelium and send their elongated dendrite to the peripheral surface of the lamella. The dendrites can easily be identified from the distal ends of supporting cells due to their filamentous nature. The olfactory cilia (OCI.) are seen projecting out from the distal tip of dendrite of receptor cells and they are longer than the cilia of supporting cells. It is difficult to trace the axonal end of receptor cells but careful staining and sectioning of material reveal few of them very clear. The axonal end of all the receptors meet along the basement membrane to form folium olfactorium (FOL.OLF.) which ultimately join nonmedullated nerve fibres (NMN.FIB.) passing through the raphe (Plates-6,9,10).

In *B. bagarius* two types of receptor cells are found, namely. Primary neurons and spindle shaped receptors. The distribution of these receptor cells varies in different regions of the lamella. The
Plate-13: Vertical section of colon of *B. hograrius* showing emergence of basal minor lamella from mother lamella and bifurcation of submucosa is visible, which is indicated by arrow. Magnification 450 X.

- **INT.LAM.SP.** - Inter lamellar space
- **MIN.LAM.** - Minor lamella
- **MSA.** - Mucosa
- **SMSA.** - Sub mucosa
- **UN.CRY.** - Unexposed crypt

Plate-14: Vertical section of rosette of *B. hograrius* showing the growth of minor lamella and unexposed crypts formed by the fusion of mucosa of mother and minor lamella. Submucosal division is indicated by arrow. Magnification 450 X.

- **MIN.LAM.** - Minor Lamella
- **MOT.LAM.** - Mother lamella
- **SMSA.** - Sub mucosa
- **UN.CRY.** - Unexposed crypt
Plate-15: Transverse section of one half of the rosette of B. bagarius passing through hinder lamella and showing a stage of discharge of cell ball by the process of gradual constriction of underlying region. Magnification 450 X.

- C.BALL. - Cell ball
- CONS. - Constriction
- DET.C.BALL - Detached cell ball
- INT.LAM.SP. - Inter lamellar space
- GC. - Goblet cell

Plate-16: Vertical section of B. bagarius showing joining of cell ball with recipient lamella after getting detached from mother lamella. Junctional morphogenetic activity is clearly visible. Magnification 450 X.

- ELO.BUD. - Elongated bud
- FU.LAM. - Fused lamella
- INT.LAM.SP. - Inter lamellar space
- MSA. - Mucosa
- MU. - Mucous
- REC.LAM. - Recipient lamella
- SMSA. - Sub mucosa
spindle shaped receptors and primary neurons also forms synapse, which can be easily seen in the mucosal zone. (Plates-6,9,10).

**Goblet cells:**

The mucous secretory goblet cells (GC.) are confined in the distal region of the initial and middle lamellae (Plates-10,11,15,16), but can be encountered any where in hinder ones (Plate-9). The proximal and middle regions of initial and middle lamellae are devoid of the mucous secretory goblet cells. A fully developed goblet cell bears an apical end, filled with pale mucigen droplets and slender basal end containing compressed nucleus and small amount of deeply stained cytoplasm. The apical part of these cells has an expanded cup called theca, which is filled with secretory droplet. It becomes empty after discharging the mucous contents in the interlamellar spaces. The proximal or inner limb is stem like extending upto the basement membrane (BM.). It is hard to observe the presence of nucleous and chromatin material in nucleus due to high degree of compression.

The goblet cells can be identified as: megagoblet cells (MG.) and microgoblet cells (MIG) in the olfactory epithelium of *B. bagarius*. The former are larger and flask shaped and are formed by the transformation of the nonciliated columnar supporting cells. The nuclear and cytoplasmic contents are pushed in the form of triangular darkly stained mass (NU. MG.) situated proximally in the cell body. They generally lie on the peripheral margin of lamella either filled with mucous or empty theca (TH. GC.) after its dischargement.

The microgoblet cells in *B. bagarius* are transformed from the cuboidal supporting cells of hinder lamellae. The are present on the peripheral or outer surface of the olfactory epithelium and generally
bears an outwardly projected beak like structure. They are having nearly oval theca and compressed nuclear body. They are frequently seen in the hinder lamellae and discharged part of the lamellar contents (cell ball and bud, C. Ball and Bud, Plates-15,16,19B,C).

**Basal cells:**

They are rounded with irregular branching processes. Each cell has rounded, irregular and darkly staining nucleus with faintly visible and chromatin material. The cytoplasm form a thin border around the nucleus. The basal cells (BC,) are sparse and scanty in the proximal and middle regions of the initial and middle lamellae and are arranged in a single row (Plates-6,10). In the distal region of all lamellae and in hinder ones, these cells are irregularly arranged forming three to four rows of basal cells just above the basement membrane (Plate-11). Their rich aggregation can be observed in cell ball (C. Ball, Plate-15) and bud (BUD, Plate-16) forming lamellae. The basal cells show their specific migratory tendency towards the formations of the cell ball and bud. At the places of above formations, they are seen line up and take position in the preparations for their eventual transformation and migration.

**Central core or submucose:**

The central core or submucosa (SMSA). is lined on either sides by a well defined basement membrane (BM). It is filled with collagen of connective tissue (CONN. TISS. FIB.) and long areolae (ARE., (Plate-4) are present in between the facia of collagen connective tissue (Plates-4,6,10). In the distal region of the lamellae the aerolar connective tissue is converted into dense connective tissue in which no areolae are observed (Plate-10). The submucosa of the hinder lamellae
becomes enormously enlarged causign damage to the connective tissue fibre and blood capillaries (BCP, Plates-4, 9). The fibroblast cells (Fib., Plate-9) are commonly observed in the central core of the distal regions of the initial and middle lamellae and in the hinder lamellae their rich supply is noticed. The histocytes (HIS.) and basal cells (BC.) can be observed in the connective tissue. Branched pigment cell (PIG. C. Plates-8,17,18) are seen in the submucosa of middle and hinder lamella, which are confined in the middle and distal regions of these lamella. The blood capillaries (BCP., Plates-4,8,9,17,18) transverse through the central core and at certain places their swellings (SWE., Plate-8,9,10) can be observed. The nonmedullated nerve fibres (NMN. Fib., Plate-4) extend through the central core along the basement membrane. The central core of all the lamellae is in continuation the central core the raphe and all the vascular, nervous and cellular supply is passed to the lamellae through it (Plates-4,5,9,10,11).

The raphe:

The raphe (RPH.) is made up of simple columnar epithelium which lies on either sides of the well demarcated basement membrane (Pltes-4,5,12,13) cells bear darkly stained nucleus (NU. SC.), situated just above the basement membrane in a uniform level. The elongated peripheral surface of the olfactory epithelium of raphe and cytoplasm of columnar cells is homogeneous. No other cellular component is seen in the olfactory epithelium of raphe of B. bagarius. The central core of submucosa of the raphe is spacious and is filled with connective tissue (CONN. TIS.). The nonmedullated nerve fibres (NMN. FIB., Plate-4.) are observed below the basement membrane
Plate-17: Section passing through the ventrolateral accessory nasal sac of *B. bagarius* showing thick basal zone, wavy supporting zone, hillock elevation and depression with prominent goblet cell activity. Elastic connective tissue fibres are also seen traversing through the submucosa of sac. Magnification 450 X.

BM. - Basal membrane  
CONN. TIS. FIB. - Connective tissue fibres  
GC. - Goblet cell  
PIG. - Pigment cell  
SAC.SP. - Sac Space  
SC.Z. - Supporting zone  
VEN.LAT.ACC.NAS.SAC - Ventrolateral accessory nasal sac

Plate-18: Magnified section of olfactory epithelium of ventrolateral accessory nasal sac of *B. bagarius* showing abnormally broad, thick submucosa with dense elastic connective tissue supply, pigment cell, blood capillary system, and all other prominent cellular elements of submucosa. Supporting zone is more pronounced showing prominent hillock elevation and depressions with prominent goblet cell activity. Magnification 750 X.

BCP. - Blood capillaries  
BM. - Basal membrane  
CONN. TIS. FIB. - Connective tissue fibres  
DEP. - Depression  
GC. - Goblet cell  
HIL.LE. - Hillock elevation  
MSA. - Mucosa  
PIG. - Pigment cell  
SMSA. - Sub mucosa
their direction of supply can be seen in the raphe of *B. bagarius*. The fibroblasts (FIB.), histocytes (HIS.) and basal cells (BC.) are rarely seen in the connective tissue of raphe.

**Accessory nasal sac:**

The ventrolateral accessory sac of *B. bagarius* is made up of non-ciliated cuboidal epithelium. The epithelial lining of the sac is wavy and shows hillock elevations (HIL.ELE.) and depression (DIP., Plates-17,18). It consists of cuboidal supporting (SC.) cells, rounded goblet cells (GC.) and basal cells (BC.).

The cuboidal cells are situated in the periphery with darkly stained oval nucleus. They can be seen in two or three rows in elevated regions of the epithelium. The goblet cells are rounded, neckless and found embedded in the peripheral epithelial surface. They can also be observed with empty theca after discharging their mucous contents. They can also be seen in two or three rows in regions of elevations. The basal cells lie in three or four rows just above the basement membrane. In the elevations, basal cells are accumulate in large number and show their migratory tendency towards the periphery.

The wavy basement membrane lies just below the basal cells and is followed by elastic connective tissue. The elastic fibres are loosely cemented with matrix and are also followed by thin collagen fibres. The fibroblasts and basal cells can also be observed within the elastic and collagen connective tissue fibres. Blood capillaries and nonmedullated nerve fibres are present in the connective tissue of the accessory sac of *B. bagarius* (Plate-17,18).
In a normal condition, the cuboidal epithelial and basal cells are accumulated in 9 - 11 layers (Palte-17). The elastin fibres and basement membrane is wavy, however, in a distended condition the accessory sac consists of 2-3 layers of basal cells. The basement membrane and elastic fibers are stretched in distended condition (Plate-18).

Ecological co-efficient:

The usual methods are employed to calculate the ecological co-efficient in fishes varying from 140mm to 270mm in total length. The length of brain and number of lamellae undergo considerable increase with respect to the size of the fish (Table-7). The size of mesencephalon ranges from 1.98mm to 2.44mm in length where as the telencephalon varies from 2.13mm to 2.96mm (Table-7).

The areas of both retinæ and those of rosette of both the sides are calculated by Teichmann (1954) method and is further modified by Rahmani and Khan (1981). It is found that former ranges from 14.12mm$^2$ to 39.24mm$^2$ and that of later from 167.54mm$^2$ to 485.90mm$^2$ (Table-7). The area of both the rosettes is higher where as the retinal area is insignificant showing thereby feebly developed optic faculty. The olfactory centre in the brain also adds further weightage to the efficiency of the olfactory faculty. *B. bagarius* is, therefore, be placed under "nose-fish" category, were the olfactory faculty plays its significant role in the habit of the fish, such as location of food and fright reactions etc. *B. bagarius* is a nocturnal fish and lives in dark places which supports the findings that the fish under observations
needs a better developed olfactory faculty rather than retinal (optic faculty).

The route of water circulation through the olfactory chamber of *B. bagarius*:

The movement of nasal barbie (NAS. BAR.) and pumping activity of the ventro-lateral accessory nasal sac, synchronously with the unidirectional beating of cilia conduct the water current through the anterior tubular nasal opening over the anterior most part of the olfactory rosette. From there the water current is directed to the central and peripheral channels of the olfactory chamber. The channels are converged posteriorly (Fig.-1B) in a narrow lamellae-less region of the olfactory rosette which is communicated by an aperture to the accessory sac, resulting the water current to the sac after crossing the entire distance of the rosette. In this course of circulation, water travels through the interlamellar spaces and each lamella is properly bathed. The compression of accessory sac causes the exit of water current from the posterior nasal opening. Valvular arrangement of posterior nasal opening can only allow the exit of water current, demonstrating unidirectional flow of water through the olfactory chamber.

The continuous and gradual flow of water through the olfactory chamber from anterior to posterior nasal opening is a regular feature in *B. bagarius*, but during forward movement it becomes more rapid. The slow passage of water current through the olfactory chamber maintains a regularity with opercular movements. This indicates that respiratory movements also help to transport water through the olfactory chamber.
Plate-1: Lateral view of head of *T. mossambica*

ANT. NAS. OP. - Anterior nasal opening
POST. NSA. OP. - Posterior nasal opening

Plate-2: Dissection of the head of *T. mossambica* form lateral side to show rosette insitu.

ETH.ACC. NAS.SC. - Ethmoidal accessory nasal sac
ROS. - Rosette
LAC.ACC.NAS.SAC. - Lacrymal accessory nasal sac
The Olfactory organ in *Tilapia mossambica* are comprised of a pair of olfactory chambers (Olf. Ch AM.) lying dorsally on the snout, anterior to and about at the level of the eyes (Plate-1, Fig.-1A). Each olfactory chamber bears a small circular anterior and an oval posterior nasal opening (ANT. NAS. OP., POS. NAS. OP, Fig.-1A,B,C, Plate-1). The later is wide and more prominent. The olfactory chamber is somewhat quadrangular in shape, floored with the rosette (ROS.), which is having less pronounced olfactory lamellae (LAM. Fig-1B,C). The posterior nasal opening is placed higher as compared to the anterior. The later is rimmed (RIM) and non tubular, whereas, the former is having a loose fold of integument, converying half of the opening and acts as a valve. The separate openings of ethmoidal and lacrymal accessory nasal sacs (ETH. ACC. NAS. SAC., LAC. ACC. NAS. SAC.) (Fig.-1C, Plate-2) are present just below the posterior nasal opening, which allow the water circulation in both the sacs through olfactory chamber.

The area surrounding the olfactory chamber is provided with numerous chromatophores. It is occupied by a quadrangular olfactory rosette which can easily be visualized after removing the surrounding integument (Plate-2). The olfactory rosette is devoid of raphe (RPH.) and provided with fewer lamellae ranging from 7-10. The arrangement of lamellae presents a rough appearance of lotus petals, emerging out from one point and expanding at the other. The lamellae in *Tilapia mossambica* are of different type i.e. they do not have their separate formation but they are in the form of thickening, attached with the
Fig. 1A  Diagram of the lateral view of the head of *T. mossambica*

Fig. 1B  Diagram of the olfactory chamber to show the position of anterior and posterior nasal opening in *T. mossambica*.

Fig. 1C  Diagramatic sketch of the olfactory chamber of *T. mossambica* to show the position of ethmoidal and lacrymal accessory nasal sacs. Arrows indicating the entry and exist of water through nasal openings and its course of circulation within the olfactory chamber.

Fig. 1D  A set of 1 - 10 lamellae from a rosette of *T. mossambica*

ANT. NAS. OP. : Anterior nasal opening
ETH. ACC. NAS. SAC : Ethmoidal accessory nasal sac.
EY. : Eye
INTEG. : Integument
LAC. ACC. NAS. SAC : Lacrymal accessory nasal sac.
LAM. : Lamellae
LAM. LESS AREA : Lamellaeless area
OP. ETH. ACC. : Opening of ethmoidal accessory nasal sac.
NAS. SAC
OP. LAC. ACC. : Opening of lacrymal accessory nasal sac.
NAS. SAC
POS. NAS. OP. : Posterior nasal opening.
RIM : RIM
Diagram of the dissection of head of *T. mossambica*
from dorsal side to show the relationship of brain
with the rosette.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE.</td>
<td>Cerebellum</td>
</tr>
<tr>
<td>OLF. BL</td>
<td>Olfactory Bulb</td>
</tr>
<tr>
<td>OLF. LO</td>
<td>Olfactory lobe</td>
</tr>
<tr>
<td>OLF. TR</td>
<td>Olfactory Tract</td>
</tr>
<tr>
<td>OP. L</td>
<td>Optic lobe</td>
</tr>
<tr>
<td>ROS.</td>
<td>Rosette</td>
</tr>
</tbody>
</table>
Fig. - 2
floor of olfactory chamber. The number of lamellae shows an increasing trend with the growth of the fish. The linguiform processes are wanting in it. The lamellae are arranged almost parallel to the body axis (Fig.-1B, C, Plate 2).

*T. mossambica* possesses a pair of well developed accessory nasal sac, associated with each olfactory chamber. The sacs are situated in relation to ethmoid and lacrymal bones, consequently, they are named as ethmoidal and lacrymal accessory nasal sac respectively. The opening of the former is visible in the intact fish through the posterior nasal opening (Plate-2). It is oval in shape. The wall of the sac is extremely thin and flexible. The opening of lacrymal sac is partly visible through the posterior nasal opening. It is smaller as compared to the opening of ethmoidal sac.

When the mouth is tightly closed, the opening of ethmoidal sac becomes slit like and it remains in its maximum expansion. When it is opened but the premaxilla in not extended, this opening remains slit like. However, when the premaxilla is protruded out and its extremely long ascending processes is extended rostrally, the opening of the ethmoidal sac becomes stretched and its volume is effected with the elevation of ethmoid. During this protrusion, the lacrymal sac is stretched extremely but narrows in its size causing expulsion of water into the olfactory chamber from both the sacs.

Careful removal of the long ascending process of the premaxilla, nasal, frontal and the muscles from the dorsal side, expose the olfactory nerve (OLF.N.) and the brain. The olfactory bulbs (OLF.B.) are small and attached to the forebrain. Therefore, they are sessile type. The olfactory lobes (OLF.L.) are larger and closely attached with
Plate-3: Transverse section passing through the olfactory chamber of *T. mossambica* depicting lamellar arrangement, interrelation with ethmoidal and lacrymal accessory nasal sacs along with the visibility of crypts, cuneiform, filiform, fungiform and other elevations. Magnification 50 X.

**DIS.E. LAM.** - Distal end of lamella  
**ETH.ACC. NAS.SC.** - Ethmoidal accessory nasal sac  
**LAC.ACC.NAS.SAC.** - Lacrymal accessory nasal sac  
**MSA.** - Mucosa  
**PRO.E.LAM.** - Proximal end of lamella  
**SMSA.** - Sub mucosa  

Plate-4: Transverse section passing through olfactory rosette of *T. mossambica* showing lamellar arrangement and other microformations. Magnification 100 X.

**ARE.** - Areolae  
**BCP.** - Blood capillaries  
**BM.** - Basal membrane  
**BC.Z.** - Basal zone  
**CONN. TIS.FIB.** - Connective tissue fibres  
**CRY.** - Crypts  
**CUN.** - Cuneiform  
**DEP.** - Depression  
**ELE.** - Elevation  
**FIL.** - Filiform  
**FUN.** - Fungiform  
**HIN.LAM** - Hinder lamella  
**INI.LAM.** - Initial lamella  
**MID.LAM.** - Middle lamella  
**MSA.** - Mucosa  
**SC.Z.** - Supporting zone  
**SMSA.** - Sub mucosa  
**W.OLF.CHAM.** - Wall of olfactory chamber
the bulbs. Behind the telencephalon lies the mesencephalon which
mainly consists of large optic lobes (OP. LO., Fig.-2).

The olfactory rosette (ROS.) of *Tilapia mossambica* is
quadrangular in shape which bears lamellae (LAM.) in the form of
thickenings, coming out from the olfactory epithelium. The rosette is
devoid of raphe and its endings are free from the lamellar thickenings.
The arrangement of olfactory lamellae in the central part of the rosette
gives a rough impression of petals of lotus (Fig.-1B, C). All the lamellae
are attached with the floor of olfactory epithelium with their ventral
surface and remain projected in the olfactory chamber through their
dorsal surface. The lamellae are separated from each other by well
defined interlamellar spaces (INT. LAM. SP.) whereas their distal and
proximal ends remain attached with the rosette (Plates-3,4). The
lamellae are constituted of central core or submucosa (SMSA.) lined
on both the sides by cellular components of mucosa (MSA.). The
mucosa is mainly constituted of ciliated columnar epithelium and
abundantly supplied with basal cells (BC.). The basement membrane
(BM.) stands as partition in between submucosa and mucosa. The
mucosal zone exhibits great variation in its thickening in all the
lamellae and possesses some peculiar microformations which are due
to the flow of basal cells in different patterns. This flow causes the
displacement of other cellular components and subsequently leads in
the formation of cuneiform (CUN.), filiform (FIL.) and fungiform (FUN.)
mucosal surface which is supposed to increase the olfactory area.
With the result of these formations, there appears depressions (DIP.),
elevations (ELE.) and crypts (CRY.) of different shapes and sizes
(Plates-3,4,5,6,7,8).
Plate-5: Magnified section of olfactory lamella of *T. mosambica* demonstrating the grouping of primary neurons in crypts, grouping of rod shaped receptors in depression forming olfactory receptive point, migratory basal cell groups showing offshoots to submucosa in the direction of microformations. Submucosa with dense connective tissue fibres, folium olfactorium, histocytes, mast cells, fibroblasts, areolae and grouping of transforming basal cells can be easily visible. Magnification 750X.

ARE. - Areolae
BM. - Basal membrane
BC.Z. - Basal zone
CRY. - Crypts
DN. P.N. - Dendrite of primary neuron
DN.R.R. - Dendrite of rod shaped receptor
FOL.OLF. - Folium olfactorium
FIB. - Fibroblast
GC. - Goblet cell
GR.PN. - Group of primary neurons
HIS. - Histocytes
MIG.GC. - Migratory goblet cell
MC. - Mast cell
NU.RR. - Nucleus of rod shaped receptor
RR. - Rod Shaped Receptor
SC.Z. - Supporting zone
SMSA. - Sub mucosa

Plate-6: Magnified section of *T. mosambica* passing through the different types of crypts with the accumulation of primary neurons and their dendritic extension to the lumen of crypt. Olfactory cilia of rod shaped receptor is also visible projecting into the interlamellar space. Transitionary basal cells in the preparation of their migration leading to subjective formation for the increase of receptive surface. Magnification 750X.

ARE. - Areolae
BC.Z. - Basal zone
FIB. - Fibroblast
HIS. - Histocytes
INT.LAM.SP. - Inter lamellar space
MIG.GC. - Migratory goblet cell
MSA. - Mucosa
OCI. - Olfactory cilia
SMSA. - Sub mucosa
VAC. - Vacuole
different patterns in the surface of lamella causes the formation of "Crypts" (CRY.) of different shapes and sizes which are sunken in the lamellar surface at different depths. Such formations are richly supplied with primary neurons which, projecting their dendrites into the lumen interlamellar spaces (Plates-5, 6, 7). The minor lamella (MIN. LAM) are also observed but they are present in the interlamellar spaces of middle lamellae (MID. LAM.), formed of only mucosal cellular components. The microformations are richly visible in the middle and hinder lamellae whereas initial ones do not exhibit such features. It is commonly observed that the lamellae are subjected to the activity of basal cells which may push the mucosa in the form of bulging (Plate-4) at any place and giving the shape of transitionary epithelium, which may proceed in the direction forming microformations. The olfactory epithelium also discharges or extrudes its cells in groups or in solitary condition which can be observed in the interlamellar spaces. The broadening of submucosa is very prominent in the hinder lamellae and it widens at the expanse of mucosa, causing the reduction of later to a thin zone (Plate 3, 4). From the submucosal point of view, the lamellae can be divided into three categories: (i) initial lamellae, (ii) middle lamellae and (iii) hinder lamellae.

The initial lamellae (INI. LAM.) are well composed having their terminal ends pointed whereas narrow at the base and broader in the middle part. These lamellae are provided with well built mucosa, made up of columnar ciliated supporting cells (SC.) and compactly built submucosa (Plates-4,9,11).
Plate 7 and 8:

Magnified section of hinder lamellae of *T. mossambica* showing crypts, filiform, fungiform, cuneiform shapes along with transitionary basal zone. Submucosa contains blood, connective tissue, nervous, fibroblast, histocyte and mast cell supply. Grouping of rod shaped receptor cells in these said elevations is clearly visible. Magnification 750 X.
The middle lamellae are comparatively broader, having widening in the submucosa but not at the expanse of mucosal zone which remains well formed and shows scattered fibroblasts (FIB.) histocytes, (HIS.) and dense matrix entangled with connective tissue fibres (CONN. TIS.FIB., Plate-4).

The hinder lamellae are provided with enormously developed submucosa which causes the reduction in the thickening of mucosal zone. With the result of widening of submucosa, areolae (ARE.) appear due to the rare distribution of connective tissue fibres and other cells in the zone. The basement membrane (BM.) is pushed to the periphery. These are old and worn out lamellae which have attained full size (Plates-1, 7, 8).

The cellular components in *T. mossambica* may be identified as supporting cells, receptor cells, goblet cells and basal cells. The submucosa is supplied with connective tissue fibres, fibroblasts, histocytes, basal and pigment cells (P.I.G.C.).

**Supporting Cells:**

The supporting cells (SC.) of *T. mossambica* are subjected to great variation because of the enormous production of basal cells (BC.) and their subsequent migration in different patterns showing changes in mucosal region (Plates-5,6).

The supporting cells are ciliated and present in well composed initial lamellae. In the middle and proximal parts, these cells are having elongated body with oval nucleus which bear one or two nucleolus. The chromatin material is visible and distributed in karyoplasm. The outer or distal limbs are elongated, extending upto the peripheral surface of the lamellae which bear cilia. The cilia (Cl.) of
supporting cells are considerably long, projected in interlamellar spaces and showing a trend of directional movement, depending upon the pressure of water coming out from both the accessory nasal sacs. The outer or distal limb of the supporting cell contains homogenous and eosinophilic cytoplasm. The inner or proximal limb is inconspicuous and difficult to trace among the other cellular components, lying beneath these cells.

With the result of great variation in mucosal surface, the supporting cells are affected and exhibit variation in their shape and occurrence. The mucosa may be affected either by enormous broadening of submucosal zone or by the movement of basal cells. In the former case, the supporting cell becomes oval and short with almost oval nucleus and invisible chromatin material. These cells become inconspicuously ciliated and bear short outer or distal limb. In the zone of micro formations where tremendous migration of basal cells is observed, the supporting cells cannot be clearly identified from migratory basal cells and receptor cells. Such zones which may be either in the form of elevations or depressions, the supporting cells are of the size of basal cells or may be in the formative stage, leading to microformations of different patterns (Plates-5,6,7,8). The indifferent epithelium where basal cells migrate in different patterns, is supposed as the transitionary phase and receptor cells can only be identified because of clear dendrites and axons, extending in their respective direction in the mucosal zone.

**Receptor cells:**

The receptor cells are observed throughout the epithelium of *T. mossambica* irrespective of their restriction in any particular region of
the lamella. However, they are concentrated in the mucosal deepenings and olfactory crypts, formed for the purpose of increasing the olfactory surface area. Such deepenings are alternated by elevations in the shape of cuneiform, filiform, fungiform, and simple elevations which are richly supplied with elongated bodied receptors known as rod shaped receptor cells. The receptor cells in *T. mossombica* can be identified as primary neurons and rod shaped receptors.

The primary neurons are confined in the crypts of different patterns and rarely observed in the mucosa of middle and hinder lamellae but absent in initial ones which are having well composed mucosal zone (Plats-5,6,11,14). They bear rounded nucleus (NU.PN.) and send fibrilar dendrites (DN.PN.) to the peripheral surface. The dendrite is darkly stained and bears some form of cilia (CL.) on its terminal end which project in the opening of different patterns. These receptor cells are situated away from the basement membrane roughly in the middle of mucosa or sometimes situated terminally in the mucosal zone. With the result of migration of basal cells, the primary neurons are pushed at different levels in the uniform or ununiform mucosa but the identity of dendritic extension is clearly visible because it acquires a dark stain. The trace of axon is visible but not as clearly as that of dendrite because in the lower region cellular components are compactly packed. The terminal tip of the dendrite is visible in the form of dark stained spot, the receptor vesicle, bearing olfactory villi or olfactory cilia (OCL.).

The rod shaped receptor cells (RR.) are common in occurrence in the well composed mucosa of all the lamellae and specially in the
zones where olfactory epithelium is activated to give rise to deepenings and elevations of different patterns (Plates-5,6,7,8,9,11). They are present almost in the middle lower zone of mucosa and possesses oval, darkly stained nucleus (NU.RR.) with conspicuous dendritic (DN.RR.) extension towards the interlamellar spaces. The terminal tips of dendrites bear some form of cilia, projected in the interlamellar spaces. The axonal extensions of these rod shaped receptor cells can be clearly traced out. These receptors are present almost at the level below the zone of supporting cells, thereby having less elongated axons which sometimes give the appearance that the rod shaped receptors are directly coming out from folium olfactorium (FOL.OLF).

The synaptic (SYN.) contact between any two receptor cells has not been observed anywhere in the olfactory epithelium of T. mossambica and independent identify of each type of receptor cell is maintained in both solitary and aggregatory arrangement. The axons of all the receptor cells extend proximally and join folium olfactorium along the basement membrane.

**Goblet cells:**

The goblet cells (GC.) are rare in occurrence and occasionally observed in different zones of mucosal layer. They can be rarely seen at any level of mucosa and originate from the basal zone due to muciferous activity of basal cells. The mucous cells are richly supplied in the epithelium of accessory nasal sacs (ACC. NAS. SAC., Plates-12,13). Because of rare occurrence of goblet cells, very little muciferous activity is observed in the olfactory rosette of T. mossambica. The observation of goblet cells at different levels in the mucosa from basal to supporting zone, demonstrates that the muciferous basal cells are
created in the basal zone which migrate up to the peripheral region for the discharge of their mucous into the interlamellar space. The goblet cells possess rounded to elongated body. They gradually grow in size and exhibit muciferous activity as they come to peripheral surface, where the terminal tips of theca of goblet cells project in the interlamellar spaces for easy discharge of the mucous. The goblet cell bears round to elongate theca (GC.TH.) with triangular nucleus, which can be deeply stained with haemotoxylin and shows its inconspicuous stalk up to the basement membrane. The chromatin material and nucleus is not visible. Though the muciferous activity is very restricted in *T. mossambica* because of rare occurrence of goblet cells, however, deposition of mucous in the histological sections in present investigation has been observed on the peripheral surface of the lamellae.

**Basal cells:**

The basai cells (BC.) can be distinguished in a number of forms, lying regularly or irregularly above the basement membrane and contributing a major part of the mucosa. Each basal cell is provided with a darkly stained oval nucleus (NU.BC.) with centrally placed nucleolus and uniformly distributed chromatin material. The basal cells can be seen both in mucosa and submucosa and can be identified by their rounded shape and darkly stained nuclei. In some zones of mucosa the basal cells exhibit a tremendous tendency of migration, leading to different patterns of elevations and deepenings. Both these shapes are accumulated result of the large production of basal cells due to cell division and their subsequent flow in any direction, resulting unmanageable aggregation of mucosa which can
Plate-9: Magnified section of proximal end of 1st lamella of *T. mossambica* showing a uniform surface with dense distribution of basal cells, ciliated and nonciliated supporting cells, rod shaped receptor cell, basement membrane, folium olfactorium and all elements of submucosa is clearly visible. Magnification 750 X.

BC.Z. - Basal zone
FOL.OLF. - Folium olfactorium
PRO.E.LAM. - Proximal end of lamella
RR. - Rod shaped receptor
SC.Z. - Supporting zone
SMSA. - Sub mucosa

Plate-10: Magnified demonstration of submucosa of olfacotry chamber of *T. mossambica* showing stellate type of chromatophores, blood capillaries, collagen connective tissue fibres, histocytes, fibroblasts, mast cells, arcolae, nervous supply and lymphocytes. Magnification 750 X.

HIS. - Histocytes
PIG. - Pigment cell
SMSA. - Sub mucosa
be named as indifferent or transitionary mucosa. (Plates-5,6,7,8,14) Such transitionary or indifferent mucosa becomes regularised in its form after taking the shape of deepenings and elevations. The former may be in the form of flask, vacuole, funnel, tubule etc., whereas the later in the shape of cuneiform, filiform, fungiform simple and major elevations. In such places submucosa becomes more activated and plays its role in supplying nutritional contents through blood circulation, so as to nourish the large production of basal cells and their flow properly. The purpose of increase of olfactory surface in different patterns may be served successfully for the proper discharge of olfactory and other functions related to olfactory epithelium.

The flow of basal cells occurs in well fed lamellae and as soon as the flow is started or prior to initiation of flow, the mucosal surface acquires the form of transitionary epithelium which in due course of time converted into formations described earlier. It is rarely observed that minor lamella is also a result of the flow of basal cells from the olfactory epithelium which is devoid of central core or submucosa. The minor lamella is compactly formed and it is the outpushing of mucosal zone. During the course of flow of basal cells and the formation of deepenings and elevations, the basal cells are extruded out in the interlamellar spaces which may be washed away with circulatory water current.

**Central core or submucosa:**

The central core or submucosa (SMSA.) is greatly varied in its composition and widening in different lamella of *T. mossamabica*. The submucosa does not extend in microformations and elevations because these are solely made up of mucosal cellular components.
Plate-11: Magnified section of distal narrow end of lamellae of *T. mossambica* showing vacuole like crypt, narrow submucosa with narrow basal and supporting zone. Rod shaped receptors are present at free surface while primary neurons are accumulated in crypts at deeper zone of mucosa. Magnification 450 X.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC.Z.</td>
<td>Basal zone</td>
</tr>
<tr>
<td>CRY.</td>
<td>Crypts</td>
</tr>
<tr>
<td>DIS.E. LAM.</td>
<td>Distal end of lamella</td>
</tr>
<tr>
<td>SC.Z.</td>
<td>Supporting zone</td>
</tr>
<tr>
<td>SMSA.</td>
<td>Sub mucosa</td>
</tr>
</tbody>
</table>

Plate-12: Magnified section passing through lacrimal accessory nasal sac of *T. mossambica* showing narrow submucosa with thickly distributed elastic connective tissue fibres. Mucous filled beaked goblet cells, cuboidal supporting cells and basal cells are distributed in thin zones. Sac space is also visible. Magnification 750 X.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAC.ACC.NAS.SAC.</td>
<td>lacrimal accessory nasal sac</td>
</tr>
<tr>
<td>SMSA.</td>
<td>Sub mucosa</td>
</tr>
</tbody>
</table>
Plate-13: Magnified section passing through ethmoidal sac of *T. mossambica* showing hillock elevation, mucous filled goblet cells, cuboidal supporting cells, thick basal zone and submucosa with elastic connective tissue and other cellular contents are clearly visible. Magnification 750 X.

ELS.CONN. TIS. - Elastic connective tissue  
DN. RR. - Dendrite of rod shaped receptor  
GC. - Goblet cell  
HIL. ELE. - Hillock Elevation  
SMSA. - Sub mucosa

Plate-14: Magnified section of rosette of *T. mossambica* passing through the proximal region depicting crypt and deeper vacuole like microformation with cuneiform, filiform and fungiform formations with the grouping of primary neurons sending their dendrites in crypts and vacuole lumen for olfactory reception. In other parts rare occurrence of goblet cells and rod shaped receptors are visible. In funiform, fungiform and cuneiform forms rod shaped receptors, ciliated and non ciliated supporting cells, mass of basal cells in basal zone are visible. Structure of submucosa and mucosa with their connective tissue fibres, fibroblasts, mast cells, histocytes is clearly demonstrated.

CRY. - Crypts  
SMSA. - Sub mucosa  
VAC. - Vacuole
The matrix of submucosa is formed by connective tissue fibres (CONN.TIS.FIB.) with dense supply of fibroblasts (FIB.), histocytes (HIS.) mast cells (MC.) arcoia (ARE.) and basal cells (Plates-5,6,7,8,10,14). The pigment cells (PIG.) are concentrated in the olfactory rosette at the point of emergence of olfactory lamella and the surrounding of blood sinuses (Plate-14). The nonmedullated nerve fibres (NMN.FIB.) run below the basement membrane which join medullated nerve fibre bundles (MN.FIB.) at the point of emergence of lamella in the olfactory rosette. Branched fibroblasts and shapeless histocytes are common in occurrence in the submucosa. In the initial lamellae, the submucosa is supplied with connective tissue fibres, having properly distributed fibroblasts, histocytes and basal cells (Plte-4,9). As we proceed to hinder region of the rosette, the submucosa grows abnormally, pushing the mucosa to a thin layer (Plates-7,8). In such cases connective tissue fibres becomes irregularly distributed having a rich supply of fibroblasts, histocytes and basal cells. Areolae are present in broadest submucosa. The blood capillaries (BCP.) and nonmedullated nerve fibre bundles are observed in the submucosa of all the lamellae. The connective tissue fibres provide support to the lamellae. Specific turgor formation for strengthening the lamellae, is not observed in *T. mossambica*.

**Accessory nasal sacs:**

The ethmoidal and lacrymal accessory nasal sacs of *T. mossambica* are made up of nonciliated cuboidal epithelium (Plates-13,14). The epithelial lining of the sacs is wavy and shows elevations and depressions (Plate-13). It is constituted of cuboidal supporting cells, rounded goblet cells and basal cells.
The cuboidal cells are situated in the periphery with darkly stained oval nuclei. They can be seen in two or three rows in elevated regions of the epithelium. The goblet cells are rounded, neckless and found embedded in the peripheral epithelial surface. They can also be observed with empty theca after discharging their mucous. The goblet cells may also be present in two or three rows in the regions of elevations. The basal cells are lying in three or four rows just above the basement membrane. In elevations, the basal cells are accumulated in large number, showing their migratory tendency towards the periphery (Plate-13).

The wavy basement membrane lies just below the basal cells. The connective tissue fibres are loosely arranged in the submucosa. The fibroblasts and basal cells are intermingled with connective tissue fibres. The blood capillaries are also present in the submucosa of accessory nasal sacs.

The number of sac layer varies with the distension of accessory sac. In normal condition, the cuboidal epithelial and basal cells are accumulated in seven to eight layers. The connective tissue fibres and basement membrane are wavy (Plate-13), however, in distended condition the accessory sac consists of 2-3 layers of basal cells and the basement membrane and connective tissue fibres are stretched (Plate-14). Both the ethmoidal and lacorymal accessory nasal sacs exhibit similar histological picture in the present investigation.

**Ecological Coefficient:**

The ecological coefficient in *T. mossambica* measuring from 115 to 176 mm total length, was calculated by two methods:
(i) by taking the length of mesencephalon and telecephalon as parameter and
(ii) by measuring the areas of two retinae and both the rosettes.

By comparing the former with that of latter, the effectiveness of optic and olfactory faculties can approximately be assessed.

By comparing the former with that of later, the effectiveness of optic and olfactory faculties can approximately be assessed. The length of mesencephalon and telencephalon varies from 2.936 to 3.510mm and 2.053 to 2.340mm respectively, showing the ecological coefficient range from 65.847 to 69.925% (Table-7)

From the area point of view, both the rosette varies from 39-934 to 70-113mm² whereas those of two retinae ranges from 72.827 to 80.206% (Table-7).

The results thus obtained show that *T. mossambica* is a microsmatic fish because it possesses tremendously developed optic faculty as compared to that of olfactory faculty which is very much regressed. This suits to its highly predaceous habit, preying on fishes half of its size. In this action *T. mossambica* visually target the fish and capture the same as its prey.

**Route of water circulation through the olfactory chamber of T. mossambica:**

The fish exhibits a characteristic of continuous protruding and retracting its jaw apparatus during normal swimming and feeding conditions. The above action, in addition to forward movement of fish, causes the entry of water through anterior nasal opening. The water circulates in the olfactory chamber freely, as its major part is
lamellaeless and whatever the lamellae present are the simple thickenings of the floor of olfactory chamber. It is connected with the ethmoidal and lacrymal accessory nasal sacs by well defined openings. Immediately after reaching into the olfactory chamber through anterior nasal opening, water takes its route to both the accessory nasal sacs through their separate openings. When the mouth is closed, jaws are retracted causing the reduction in the volume of accessory nasal sacs and olfactory chamber. This leads to the expulsion of water from posterior nasal opening. The valve condition of posterior nasal opening demonstrates unidirectional flow of water from anterior to posterior nasal opening (Fig. 1A, B, C).
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Total length (mm)</th>
<th>Number of lamellae Rosette</th>
<th>Total length of brain (mm)</th>
<th>Length of mesencephalon (mm)</th>
<th>Length of telencephalon (mm)</th>
<th>Ecological coefficient (through lobes of brain) Length of telecephalon x 100 Length of mesencephalon</th>
<th>Retinal area of both eyes (mm²)</th>
<th>Olfactory area of both rosette (mm²)</th>
<th>Ecological coefficient (through area) Olfactory area x 100 Retinal area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>115</td>
<td>7</td>
<td>7</td>
<td>8.775</td>
<td>2.936</td>
<td>2.053</td>
<td>69.925</td>
<td>54.834</td>
<td>39.934</td>
</tr>
<tr>
<td>2.</td>
<td>127</td>
<td>7</td>
<td>8</td>
<td>9.243</td>
<td>3.159</td>
<td>2.094</td>
<td>66.286</td>
<td>58.647</td>
<td>44.237</td>
</tr>
<tr>
<td>3.</td>
<td>133</td>
<td>8</td>
<td>8</td>
<td>9.594</td>
<td>3.217</td>
<td>2.117</td>
<td>65.847</td>
<td>61.524</td>
<td>49.346</td>
</tr>
<tr>
<td>4.</td>
<td>142</td>
<td>8</td>
<td>8</td>
<td>10.620</td>
<td>3.274</td>
<td>2.223</td>
<td>67.898</td>
<td>70.986</td>
<td>55.053</td>
</tr>
<tr>
<td>5.</td>
<td>176</td>
<td>10</td>
<td>9</td>
<td>11.700</td>
<td>3.510</td>
<td>2.340</td>
<td>66.666</td>
<td>90.832</td>
<td>70.113</td>
</tr>
</tbody>
</table>
Histochemical observations of olfactory epithelium of *Tilapia mossambica*.

**Acid Phosphatase:**

The acid phosphatase activity in *Tilapia mossambica* is relatively high degree along cell and nuclear membrane of various types. It is specifically more in the dendrites of primary neurons, distal extremity of columnar supporting cells. It is also observed in cytoplasm and some granules present in cytoplasm which acquires dominant stain. These granules which are probably lysosomes, that are supposed as the pooling cell organelles of hydrolytic enzyme in *T. mossambica*. These granules (Pysosomes) make available the metabolite to the cell concern for the production of energy and elsewhile utilization of metabolites for the other requirement of cells such as growth, repair and resistance to fight against infection.

*Tilapia mossambica* is an exotic fish and is subjected to number of climatic variations in the route of its adaptability for acclimatization in a particular captive environment. The lysosomes contains hydrolytic enzymes, whose marker is acid phosphatase and therefore it reveals intense activity in cell sites (Table-1). For confirming this concept, acid phosphatase activity in *T. mossambica* is higher in columnar supporting cells, dendrites, olfactory cilia and in some basal cells who are in active mitotic division in the preparation of their route either for their transformation in some other cell type or for fulfilling the requirement of olfactory epithelium under the conditions of injuries and creation of microformations (Table-1).
Alkaline Phosphatase:

Alkaline phosphatase is seen remarkable higher in basal zone and at interlamellar level. The activity in basal cells present in submucosa or central core is also higher in *T. mossambica*. The alkaline phosphatase is a supporting precursor for acid phosphatase in the process of providing metabolite to the cell for the purpose of their utilization under the influence of acid phosphatase. *T. mossambica* is a raphelless fish and fewer lamellae are seen originating from peripheral wall of olfactory chamber and conversing to the central. This indicate that lamellae in the centre region of rosette are in growing phase and activity of alkaline phosphatase in such tips is intense. These tips are having indifferent olfactory mucosa, where few receptors and goblet cells can only be identified. The lymph space at the emergence of lamellae through peripheral olfactory wall also contain dense connective tissue system. In such tissues basal cell, fibroblasts and other cells related with supporting and nutrition also show alkaline phosphatase activity. In the region of lamellae through which nerve are innervated and pass to the ultimate regions through folium olfactorium and non medulated nerve fibres also show aggregation of some cells where in alkaline phosphatase activity is visible (Table-2).

Glycogen: -

It is a general concept that glycogen is a reserve potential energy, which after converting into glucose (passing through a metabolic cycle) release chemical energy required for the building of ATP. The cell structure in the olfactory epithelium of *T. mussambica* which are engaged in greater activity shows high degree of localisation
of glycogen. The supporting cells with their cilia and nucleus shows abundant localization of glycogen. The primary neurons as compared to rod shaped receptor cells shows dominant glycogen activity. The glycogen deposition in the basal cells lying exactly along the basement membrane is greater, which is supposed as their preparation in the process of forming other cell type for the growth of lamella and in the increase of olfactory reception surface. This takes place by the way of rapid mitotic division in such cells which requires energy and is obtained by reserve glycogen.

Goblet cells are the unicellular gland which are constantly discharging mucous content for protecting the olfactory mucosa from soft and other damages of circulating water current. These cells are short lived but subjected to higher metabolic activity. The secretory content is also constituted of major bulk of glycogen reserve (Table-3).

**Acid Mucopolysaccharides:**

The localization of acid mucopolysaccharides is restricted to the goblet cell as it is the main content in the constitution of mucin in *T. mossambica*. However, its demonstration also occur in some other cell types in supporting and basal zones. This indicate that muciferous activity are gradually cultivating in basal and supporting cells which may ultimately grow to full grown goblet cell. Thus, cells exhibiting the demonstration of acid mucopolysaccharides in basal and supporting zone are identified as transitional basal and supporting cells which are in the process of their conversion to goblet cells (Table-4).

**Lipid:**

Lipid localization in *T. mossambica* is conducted in an usual manner. It is observed that the distal tip of the lamella has moderate
concentration of lipid in their supporting cells but in proximal zone of lamellae, the concentration of lipid in supporting cells increases in greater degree. Remarkable observation in this regard is that, the lipid core is at high degree in the basal cell above the basement membrane but in such cells where mitotic activity is reported the lipid core is in negative degree. At the point of convergence of all the lamella in centre, adipose tissues are visible which has got high conc. of lipid deposition. In receptor cell and dendrite projections lipid conc. is moderate, but where the axons join to folium olfactorium, concentration is intense (Table 5).

**Metacromasia:**

The olfactory epithelium of *T. mossambica* exhibit positive metacromasia demonstration in all the cellular extension of all mucosal elements. It is demonstrated in axon and dendrite, including folium olfactorium and non medulated nerve fibre bundle present in the central girdle of *T. mossambica*. The stock of mucous secretory goblet cells also reveals feeble reaction of this histochemical contents. The limbs of different type of receptor cells, supporting cells, basal cells demonstrates moderate degree of localization. Its representation in cytoplasm indicates the granulation in it. Peripheral surface of entire lamella react negatively in response to toluidine blue (Table -6).
Table-1: Showing histochemical distribution of Acid Phosphatase employed by Pearse 1968, and the reaction obtained in various cellular components of olfactory epithelium of Tilapia mossambica.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Phosphatase</td>
<td>Cryostate</td>
<td>Modified Lead nitrate method</td>
<td>(i) Primary neurons</td>
<td>+++ (dendrite)</td>
<td>+++=High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processed as recommended by TAKEUCHI and TANOUE as given by Pearse, 1968.</td>
<td>(ii) Rod shaped receptors cells</td>
<td>++</td>
<td>+= Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Columnar supporting cell</td>
<td>++(distal limb)</td>
<td>+= Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>++(cilia)</td>
<td>-= Absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Basal cell</td>
<td>+++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Goblet cell</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>
Table-2: Showing the demonstration of **Alkaline phosphatase** employed by Pearse 1968, and the reaction obtained in various cellular components of olfactory epithelium of *Tilapia mossambica*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALKALINE PHOSPHATE</td>
<td>Cryostate</td>
<td>Calcium-Cobalt method</td>
<td>(i) Primary neurons</td>
<td>+</td>
<td>+++=High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(After GOMORI, as given</td>
<td>(ii) Rod shaped receptor cells</td>
<td>+</td>
<td>++= Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by PEARSE, 1968).</td>
<td>(iii) Columnar supporting cell</td>
<td>-</td>
<td>+ = Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Goblet cell</td>
<td>-</td>
<td>- = absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Basal cell</td>
<td>+++ (basal zone, sub mucosa and connective tissue)</td>
<td></td>
</tr>
</tbody>
</table>
Table-3: Showing the histochemical location of *Glycogen* in olfactory epithelium of *Tilapia mossambica*

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycogen</td>
<td>Microtomy, 8 ( \mu m )</td>
<td>Periodic Acid Schiff technique and Best Carmine stain</td>
<td>(i) Primary neurons</td>
<td>+++</td>
<td>+++ = High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) Rod shaped receptor cells</td>
<td>++</td>
<td>+++ = Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Columnar supporting cell</td>
<td>+++ (Cilia, nucleus)</td>
<td>+ = Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Goblet cell</td>
<td>+++</td>
<td>- = absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Basal cell</td>
<td>++ (Basal Zone)</td>
<td></td>
</tr>
</tbody>
</table>
Table-4: Showing the histochemical localization of *Acid mucopolysaccharides* in the various cellular components of olfactory epithelium of *Tilapia mosambica*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid mucopolysaccharides</td>
<td>Microtomy 8μ</td>
<td>Alcianblue method [after STEEDMAN, vide PEARSE, 1968]. Deposition showing the Bluishgreen stains with Alcian Blue.</td>
<td>(i) Primary neurons</td>
<td>-</td>
<td>+++=High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) Rod shaped receptor cells</td>
<td>-</td>
<td>+++= Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Columnar supporting cell</td>
<td>++</td>
<td>+ = Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Goblet cell</td>
<td>+++</td>
<td>- = absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Basal cell</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>
Table-5: Showing histochemical technique for demonstration of lipid in the olfactory epithelium of *Tilapia mosambica*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIPID</td>
<td>Microtomy (temporary mount) 6μm</td>
<td>Sudan Black B method (after Mc MANUS Vide PEARSE, 1968)</td>
<td>(i) Primary neurons</td>
<td>++ (dendrite)</td>
<td>+++=High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+++ (axon joining folium olfactorium)</td>
<td>++= Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) Rod shaped receptor cells</td>
<td>++ (dendrite)</td>
<td>+ = Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Columnar supporting cell</td>
<td>+++(proximal limb)</td>
<td>- = absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>++ (distal limb)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Goblet cell</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Basal cell</td>
<td>+++</td>
<td></td>
</tr>
</tbody>
</table>
Table-6: Showing histochemical demonstration of *metachromasia* employed by Pearse 1968, and the reaction obtained in various cellular components of olfactory epithelium of *Tilapia mossambica*.

<table>
<thead>
<tr>
<th>ENZYME</th>
<th>SECTION</th>
<th>TECHNIQUE</th>
<th>CELLULAR COMPONENT</th>
<th>NATURE OF REACTION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacromasia</td>
<td>Microtomy (6 to 8μm)</td>
<td>Toulidine Blue method (after KRAMER and WINDRUM, as given by PEARSE 1968)</td>
<td>(i) Primary neurons</td>
<td>++</td>
<td>+++=High activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ii) Rod shaped receptor cells</td>
<td>++</td>
<td>++= Moderate activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iii) Columnar supporting cell</td>
<td>++</td>
<td>+ = Low activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(iv) Goblet cell</td>
<td>+</td>
<td>- = absence of any activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(v) Basal cell</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>