The olfactory apparatus of *M. armatus* is present at the dorso-lateral side of the head (Fig. 3a**).** The tube shaped paired anterior nostrils are present at the apical extremities of elongated snout and are well connected to slightly elliptical posterior nostrils acts as gateway of water ventilation (Fig. 3a and 3b). Ovoid paired posterior nostrils are present at the anterior edge of eyes (Fig. 3b). Anterior nostrils are devoid of nasal flaps but possesses irregular boundary (Fig. 3c). Posterior nostrils are possesses thin skinny covering that does not encircled the posterior nostrils completely (Fig. 3d). The olfactory apparatus is comprises of olfactory chamber, olfactory rosette, single accessory nasal sac (*viz*., lacrimal sac), paired nerve tracts, olfactory bulb and brain (Figs. 4a and 4b). Paired olfactory rosettes are present at both sides of the snout in between anterior and posterior nostrils (Figs. 2a and 2b). The olfactory rosette is encapsulated within keratin rich olfactory chamber, from the floor of which multiple lamellae are arises (Figs. 4a and 4b). Multiple variable sized olfactory lamellas are caudally arranged on either side of medial olfactory raphae (Figs. 4a and 4b). External surface topography of olfactory rosette denotes ridges of lamellae with depressed structure of olfactory nasal cavities (Fig. 4b).The numbers of lamellae per olfactory rosette are approx 38 - 42. Single accessory nasal sac is identified and is well associated with basal region of each olfactory rosette (Fig. 4b). From the caudal region of each sided rosette, slender nerve tracts are arises and are travelled a distance of 1.2 cm long separately and then joined together to form

fork appearance but each remain their single entity and well connected with the olfactory bulb of the brain (Fig. 4b).

Surface topography of single lamellae denotes patchy arrangement pattern of both sensory and nonsensory components within the olfactory neuroepithelium (Fig. 5a). Distinct zonations are restricted in few region of olfactory epithelium of *M. armatus* for sensory and nonsensory cellular components (Fig. 5b). Density of nonsensory cilia is greater than sensory cilia at the lateral part of the olfactory lamella (Fig. 5b). Mucin droplets are clearly marked over the non sensory epithelial cell (Fig. 5a). Non-sensory areas of neuroepithelium are covered by dense population of ciliated cellular components (Fig. 5a). In between sensory components nonsensory supporting cells are arranged (Fig. 5c). The olfactory knobs of different sensory cells are evident from surface area of the olfactory neuroepithelium (Fig. 5b). Tuft of 5-6 cilia at the apical margin of ciliated olfactory knobs are well demarcated (Fig. 5b). Slightly ruptured area of olfactory neuroepithelium clearly denotes the distinct arrangement pattern of intact cellular components of neuroepithelium (Fig. 5c). Perikaryons of different sensory cells are present at different depth of olfactory neuroepithelium (Fig. 5c).

Microanatomically, the olfactory rosette of *M. armatus* is a multilamellar in structure and variable nauroepithelial components are arranged in pseudostratified form**.** In between parallel layers of neuroepithelium a distinct

zone *viz*., lamina propia is present within single lamella of olfactory rosette (Fig. 6). The thickness of olfactory neuroepithelium of a single lamella ranges from approx 40 µm to 50 µm. Morphologically, different types of cells are evident withinthe neuroepithelium of *M. armatus viz*., sensory receptor cell, supporting cell, basal cell, mucus secreting cell, rodlet cell, *etc*. (Fig. 6). Sensory receptor cells are deviates from supporting cell of the neuroepithelium by their oval to cylinder shaped deeply stained nucleus (Fig. 6). Perikaryons of the sensory receptor cells are arranged at the different depth of the olfactory neuroepithelium (Fig. 6). The receptor cells are extended their dendritic processes towards the free end of the nasal cavity and axonal parts are travelled across the epithelium toward the central core of the neuroepithelium. Three distinct types of sensory cells are evident in the olfactory neroepithelium of the *M. armatus*. *viz;* the ciliated sensory receptor cell, microvillous sensory receptor cell and crypt cell. Length of the dendron of ciliated sensory receptor cell is longer than the other type of sensory receptor cells (Fig. 6). Terminal ends of the sensory cells bear swollen structure *i.e.* the olfactory knob towards nasal cavity (Fig. 6a). The apical part of olfactory sensory knob bears cilia (Fig. 6a**).** Columnar supporting cells are arranged in between the sensory receptor cell (Fig. 6). Nucleus of the supporting cell is almost round in shape with lightly stained cytoplasm (Fig. 6). Basal cells are small polygonal cell and are arranged at the basal lamina of the olfactory epithelium (Fig. 6). Middle portion of parallel arranged olfactory neuroepithelium of single olfactory lamella that

underlying beneath the basal lamina is characterized with connective tissue with blood vessels, blood cell, collagen, fibroblast cell, axonal bundles, *etc*.

Sensory cellular components and non sensory cellular components are arranged in a pseudostratified form within the olfactory neuroepithelium of *M. armatus*. A clear distinct boundary line is identified that deviates the sensory zone from non sensory zone (Fig. 7). In the sensory zone, the sensory component possesses apical projections in their sensory knob with either cilia or microvilli (Fig. 8b) whereas in non sensory zone only the flattened apical surfaces with microridges like projections are evident (Fig. 8a).Ciliated sensory receptor cells (cSRC) are frequently distributed within the olfactory neuroepithelium of *M. armatus* (Fig. 9a).Under transmission electron microscope the apical extensions of the sensory receptor cell that form swollen out growth are very much prominent (Fig. 9a). Knob like swollen extensions of these cell's dendritic processes bears 3 to 4 cilia at their proximities. Each cilium possesses a long slender process bearing axial filament, basal plate and basal body (Fig. 9b). At the basal part of basal body, circular centriole is marked (Fig. 9b).The microtubule of the each cilium of the sensory receptor cell follows the (9+2) orientation pattern (Fig. 10b). Any types of rootlets are neither documented in the basal body of each sensory cilium (Fig. 10b). Cytoplasm of ciliated sensory receptor cell is granular in structure. Apical cytoplasmic part of sensory receptor cell dendron bears slender mitochondria (mi). Spindle shaped perikaryon of

ciliated sensory receptor cell is present at the middle of the olfactory neuroepithelium (Fig. 9c). Heterochromatin and euchromatin materials are distinguished in the nuclear part of parikaryon with maximum peripheral distribution of heterochromatin. The peripheral part of the nuclear region shows cisternae of endoplasmic reticulum with attached ribosome (Fig. 9c). The Golgi complex with prominent cis and trans axis are observed under transmission electron microscope (Fig. 9c). Mitochondria (Mi) with cristae at their inner membrane are clearly demarcated under high resolution electron microscope (Fig. 9c).

Microvillous sensory receptor cells (mSRC) is the another receptor cells that also forming the basic structural components of sensory neuroepithelium.These types of receptor cells are also bears *i.e.*, the dendron, the perikaryon and long axonal processes. Microvillous sensory receptor cells are distinguished from others types of sensory receptor cell by their variable apical extension. Apical extensions towards nasal cavity of these types of cell bear several fingers like projections *i.e.*, the microvilli (Fig. 11a). Lengths of these microvilli are 01nm to 02nm. The length of the dendritic process of microvillous sensory receptor cell is comparatively shorter than the ciliated sensory receptor cell. Cytoplasm of these types of cells is granular in structure that comprises of spherical nucleus, large number of mitochondria, secretary granules and neurofilaments (Fig. 11c). Mitochondria with variable morph are viewed at perinuclear part of

the dendritic processes (Fig. 11b). In the nuclear region distribution of heterochromatin material is less than euchromatin (Fig. 11c). Perikaryons of microvillus sensory receptor cell are located at the middle of the neuroepithelium. The Golgi complex is also demarcated (Fig. 11c). Variable secretary vesicle (diameter: 10nm-15nm) are frequently observed at the perinuclear cytoplasm (Fig. 11c).

Crypt cells are observed at the apical part of the olfactory neuroepithelium of *M. armatus* (Fig. 12). These cells are ovoid or pear-shaped structure (Fig. 12). The crypt cell possesses two distinct morphological parts *viz.*, the perikaryon and axon. The length of the dendron of the crypt cell is very short (Fig. 12). The apical tip of the perikaryon in crypt cell is equipped with microvilli and sunken cilia (Fig. 12). Crypt cell has a prominent apical invagination. The bottom and lateral parts of the invagination shows sunken cilia (Fig. 12). The basal body of these cilia is not well marked in *M. armatus*. Microvilli are present around the cilia on the apical rim of the crypt cell (Fig. 12). Like other type of sensory receptor cells *i.e.*, ciliated sensory receptor cell and microvillous sensory receptor cell, a large number of vesicles are associated with the axis of neurofilaments of *M. armatus* (Fig. 12).

Round to oval shaped, polygonal cells are arranged at the basal region of the olfactory neuroepithelium above the basal lamina (Fig. 13). Nucleuses of these cells are very much prominent with chromatinised nuclear part that deviate them

into two distinct types *viz.,* electron dense and electron lucent basal cell type. The cytoplasm of the basal cells are possesses various cell organelles like mitochondria, vacuole, endoplasmic reticulum, free ribosome, granular particles, *etc.* (Fig. 13). Developmental stages of different sensory receptor cell from basal cell lines are clearly demarcated under transmission electron microscope. Variable differentiating stages of immature sensory cells are noticed that leads to others sensory cell types (Figs. 14 and 15).

Another group of cells that are arranged within pseudostratified columnar epithelium in between the sensory receptor cells, named as supporting cell. Cytoplasm is distinct from the sensory receptor cell and electron lucent in nature (Fig. 16). Nucleuses of these cells are present at the middle layer of the epithelium and below the ciliated sensory cell perikaryon(Fig. 6). Apical extremities of these cells bears small irregular ciliary protrusion, separated the dendrites of all typed of sensory receptor cells from each other (Fig. 16). Basal body of the cilium is distinct (Fig. 16). Flattened apical extremities towards the nasal cavity of the olfactory chamber are the identifying characteristics of these cells (Fig.16). Secretary supporting cell are noticed in the principal nasal cavity in between the sensory receptor cell (Fig. 6). Secretary granules along with numerous mitochondria are aggregated at the upper region of the supporting cell (Fig. 16). Maximum cytoplasmic area of these supporting cells is occupied by nucleus (Fig. 16). Nuclear part is not prominently marked with clear zonations

of euchromatin and heterochromatin part (Fig.16). The apical area of perinuclear region is marked with frequently arranged mitochondrial structure (Fig.16). The shape of the non sensory ciliated cell is more or less columnar in structure with flattened cylindrical apical portion (Fig. 6). Theextension ofapical epithelial region, are arouse to form flattened apical portion (Fig. 17). The apical ends of these cells are sometimes dome- shaped and protrude into the lumen so that they may envelop the olfactory knobs (Fig. 17). The cytoplasm is less granular than ciliated supporting cell (Fig. 6). The secretary granules that fill the perinuclear region are now large and electron dense (Fig. 17). Oval shaped nucleus is lodged at the middle portion of these types of supporting cell. The cytoplasm bears striated rootlets (Fig. 17). Goblet cells, containing large round mucous granules, were present in maximum areas of the olfactory epithelium but most abundant in the nonsensory region of the olfactory epithelium (Fig. 18). These cells are either electron dense or electron lucent and immature cells are present at the upper middle part of the olfactory epithelium towards nasal cavity (Fig. 18). Mature goblet cells are shifted towards the apical part of the epithelium (Fig. 18). Small nuclear elements are present at the basal part of this cell where as maximum part of the cytoplasm covered by mucous droplets (Fig. 18). The particular non sensory cell components that arepresent within the apical extremitiesof neuroepithelium. But their apical boundary that emerged out to release secretory product at the external medium are not so prominent in this micrograph. Rodlet cells are the enigmatic cell exclusive to

fish including this specimen. Few numbers of club shaped cells are present in the olfactory neuroepithelium of *M. armatus*. Morphologically these cells are different from other cell types by their peculiar double membrane cell coat and internal cytoplasm containing rodlet and rodlet vesicles (Fig. 19). The mature rodlet cells are marked with rodlet core that are emerged out from the rodlet sac towards the apical extremities of the nasal cavity (Fig. 19). At the apical part of rodlet cell shows cytoplasmic protrusion (Fig. 19). The nucleus is lodged at the basal part of the cell extremities (Fig. 19). Organelles like endoplasmic reticulum, Golgi bodies, mitochondrial labyrinth, secretary granules, *etc*. are arranged at the periphery of the cell border (Fig. 19). The thickness of the rodlet capsule is approx. 0.5µm thickness (Fig. 19).

In the central core area of the olfactory neuroepithelium of *M. armatus* is distinctly characterized with large number of axons that are aggregated to form bundle like structure (Fig. 20). These axons are usually unmyelinated in nature (Fig. 20). In transverse section each axons are roughly round or circular in appearance (Fig. 20). Microtubules (average diameter: 20 nm) are clearly observed and are uniformly distributed within the axonal processes (Fig. 20). However, the number of axons in each axonal bundle is variable (Fig. 20). Adjacent to the periphery of these unmyelinated axonal bundles, Schwann cell is observed (Fig. 20). In the fila olfactoria region of the olfactory neuroepithelium of *M. armatus* is frequently occupied by variable extra cellular

matrix and one of the important components of them is collagen fiber (Fig. 21). The collagen fibers are thread shaped structure with average diameter of about 1.0nm -1.5nm (Fig. 21). The transverse view of the fiber denotes that each fiber is made up of bundle of fibrils and runs parallel to each other (Fig. 21). Fibrils are very connected to each other and are located adjacent to fibroblast cell (Fig. 21). Another important type of cell that marked in this region is fibroblast cell and is characterized by large nuclear part than its less cytoplasmic area with pesudopodia like cytoplasmic extremities (Fig. 22). Elliptical nucleus is present at the central part of the cell (Fig. 22). Heterochromatin and euchromatin materials of the nucleus are distinctly well distributed within the nucleus (Fig. 22). Beneath the basal cell line the areas are marked with different cellular components *viz*., collagen fiber, fibroblast cell, blood cell, blood ribosome, *etc.* is well marked at the perinuclear area of the cytoplasm (Fig. 23). Collagen granules are scattered at the peripheral part of the fibroblast cell (Fig. 23). Blood vessels are thin walled roughly circular in structure (Fig. 23). The perivascular cells are resting on the basal lamina of the blood vessels which is supported by loose network of reticular fibers (Fig. 23). Nucleus of the perivascular cell is flattened and extends its tail like extensions at the basal portion of the cell (Fig. 23). Erythrocytes are chromatinised structures and are present within the blood vessels (Fig. 23).

The olfactory neuroepithelium of *M. armatus* is comprises of different sensory and nonsensory epithelial components. Immunocytochemical observations reveals that specific morphological types of olfactory sensory receptor neuron *viz.*, ciliated sensory receptor neurons are marked against specific Gαolf antisera (Fig. 24a). The ciliated sensory receptor neurons whose nuclei located at the lower region of the olfactory neuroepithelium were marked by Gαolf antisera (Fig. 24a).The ciliary part of the ciliated olfactory receptor neurons were labeled strongly than the other part *viz.*, perikaryon or axons of the ciliated olfactory receptor neuron (Fig. 24b). The axonal part of the ciliated olfactory receptor neurons that were accumulated in the fila olfactoria region were also positively marked against Gαolf antisera (Fig. 24c). The nuclear element of the sensory receptor neuron within the neuroepithelium of *M. armatus* shows distinct condensation mode of variable differentiating stages (Fig. 25a). Condensing chromatin granules marked with acridine orange fluorochrome are frequently observed within the olfactory neuroepithelium (Fig. 25b). At the basal region of the olfactory neuroepithelium condensed chromatin riched basal cells are marked (Fig. 25b). Numbers of condensed chromatin richen cells are gradually decreased in Fig. 25a than Fig. 25b.

During the ultrastructural analysis of the olfactory neuroepithelium of *M. armatus,* elemental analysis of the neuroepithelium was simultaneously performed. In olfactory neuroepithelium of *M. armatus,* maximum number of

sensory receptor cell is ciliated sensory receptor cell (cSRC). The dendritic process of cSRC in *M. armatus* is consists of variable number of sensory cilia having (9+0) arrangement of microtubules. The perikaryon of cOSRN is characteristically associated with chromatinised nucleus, rough endoplasmic reticulum, Golgi bodies, lysosomes, mitochondria, *etc.* (Fig. 27a, 27b)**.** Under TEM EDAX at the perinuclear area of the cSRC shows accumulation of different metals *viz*., Cu, Pb, Cd, Ni, *etc*. at a different proportion (Table: I). The maximum accumulated metal is Cd with 10.93% of mass percentage (Table: II). At the same time the ultrastructural features of cSRC was simultaneously observed and denotes sparely granulated nucleus, dilated ER, increase number of lysosome (Fig. 28a), increased gap between adjacent tubules (Fig. 29a and 29b), distorted mitochondria with dialated inner membrane are marked (30a and 30b). Perinuclear region of cSRC are also marked with multivesicular bodies with numerous rough endoplasmic reticulum and variable mitochondria with distinct cristae structure (Fig. 31).