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RESEARCH ARTICLE

FOREBRAIN PATTERNS OF CYPRINIDS IN RELATION TO FEEDING HABITS

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ABSTRACT

Forebrain (prosencephalon), comprising of telencephalon and diencephalon is the anterior part of the brain followed by midbrain (mesencephalon), and hindbrain (rhombencephalon). Telencephalon, the most anterior part involves olfactory bulbs (responsible for sense of smell), olfactory tract, and telencephalic hemispheres (cerebrum) while diencephalon, located between telencephalon and the midbrain involves habenula and hypothalamaus. In this study the telencephalic and diencephalic regions are histologically analyzed in two teleosts, *C.auratus* and *B. striata.* In *C.auratus*, the lateral zone of the area dorsalis, Dl region is highly developed and is the primary visual area. In *B.striata*, Dm region is highly developed and is involved in the sense of gustation in feeding. The diencephalic region consists of feeding centers like hypothalamus and habenula. Symmetrical habenula is a special feature of surface dwelling visual feeders like *Carassius auratus* and asymmetrical one isthe feature of bottom dwelling non visual feeders like *Botia striata*.Hypothalamus, involved in hunger and satiety functions as the main feeding centre of vertebrates by the production ofvarious types of peptide factors responsible for either initiating or ceasing food consumption.

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INTRODUCTION

The central nervous system (CNS) in fish, is the primary coordinating and integrating system for body activities and the peripheral nervous system (nerves and neurons) act as the link connecting the CNS to the rest of the body. CNS includes brain and spinal cord and processes sensory information and coordinates motor functions, while the peripheral nervous system transmits this information and motor commands, allowing for sensory input and motor output to and from all body regions. The characteristics of the CNS makes fish an ideal representative for the study of functioning of CNS. The spinal cord of fish is considered as the phylogenetically oldest part of CNS with structural similarity to other vertebrates. The enlarged anterior pole of the spinal cord is brain where all the major vertebrate sensory systems are located. Due to diverse sensory orientation of fishes, brain regions differ greatly in size and form and fishes are the species showing greatest variation of brain anatomy and varied function in all vertebrates (Nieuwenhuys *et al*. 1998).Histological studies in teleosts are vital for understanding their unique brain structure and are increasingly used in neurobiological research due to their conserved genetic programs, offering valuable insights into vertebrate brain evolution. Even though specific structural details of brain anatomy and histology varies across different fish species, number of brain compartments are same. Understanding these anatomical and histological differences across species in fish is crucial for conducting further studies in physiological and immunological studies. Based on anatomical and developmental characteristics, brain is divided into three major regions from rostral to caudal such as forebrain (Prosencephalon), midbrain (Mesencephalon) and hindbrain (Rhombencephalon). Forebrain region includes telencephalon and diencephalon (between brain) and midbrain includes paired optic lobes, in the dorsal area and torus semicircularis and tegmentum in the ventral side. This is followed by the hind brain regions such as cerebellum (corpus cerebelli and valvula cerebelli) and medulla (Northcutt & Davis, 1983). Telencephalon region consists of the olfactory bulb, olfactory tract and telencephalic hemispheres or the cerebrum. Olfactory bulbs, are ventrally attached to the telencephalic hemispheres through the olfactory tract, and dorsally covers diencephalon. Diencephalon consists of Thalamus, Hypothalamus Subthalamus, Epithalamus, and Pretectum (Kotrschal, & Kotrschal, 2020).The olfactory bulb, and olfactory tract constitute the olfactory system in fishes that helps fishes in smelling, a part of forebrain that is extended from telencephalon (Manju *et al*., 2025).Telencephalon evolved from the rostral portion of the embryonic neural tube forms two hemispheres (Meader, 1939). These hemispheres are solid, T-shaped ventricle and separates the two halves by a dorsolateral surface. The olfactory bulbs and telencephalon is bridged by lateral and medial olfactory tracts.

Telencephalon: Telencephalon which is the anterior part of the forebrain are characterized by their everted morphology and consists of two cerebral hemispheres. As in most of vertebrates, telencephalic hemispheres develop by evagination from the lateral walls of the cerebral hemispheres and contains ventricles (Nieuwenhuys, 1982). Hemispheres are solid, and T-shaped ventricle separates the two halves up to the dorso-lateral surface. The cerebral hemispheres are closely attached in the central area while they are either fused or free in lower end. The dorsal part of the telencephalon called pallium and the ventral part, subpallium are located differently than in other vertebrates (de Bruin, 1980). The lateral pallium, considered

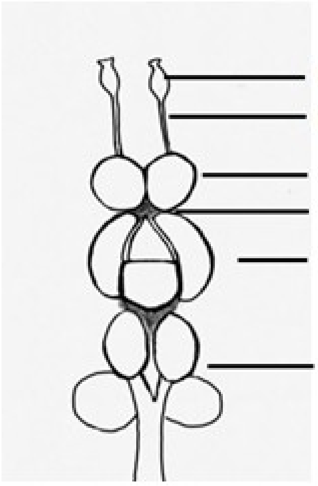

Figure 1. Diagrammatic representation showing the forebrain parts such as olfactory bulb, olfactory tract, telencephalon (cerebrum), diencephalon, midbrain and hindbrain in *C.auratus*

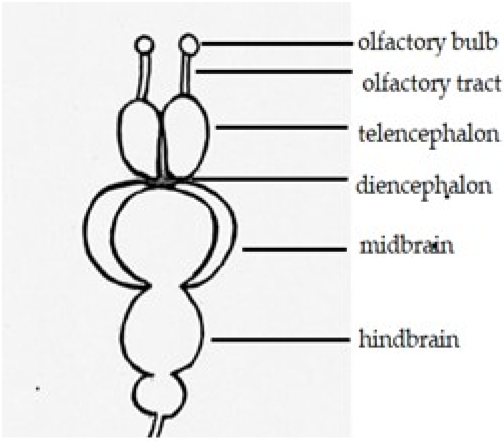

Figure 2. Diagrammatic representation showing the forebrain parts such as olfactory bulb, olfactory tract, telencephalon (cerebrum), diencephalon, midbrain and hindbrain in *B.striata*

homologous to the hippocampus in other vertebrates, is involved in spatial learning and memory in teleosts, while the medial pallium, potentially homologous to the amygdala, is linked to emotional conditioning (Flood *et al*., 1976).The posterior part of the olfactory carrying impulses are attached to the anterior portion of two cerebral hemispheres (telencephalon). In addition to this, secondary olfactory fibers that spreads throughout the entire structure, project its dorsal portion and to the hypothalamic portions. Thus the primary olfactory input is received at the ventral forebrain region or sub pallium (Finger, 1980). The area dorsalis of teleosts consists of a number rostrocuadally oriented longitudinal columns (Northcutt & Davis, 1983). Loci in area dorsalis are connected to specific sensory pathway and the afferents from the olfactory system terminate in a large caudolateral region, Dp, (the posterior zone of D, areadorsalis) and in the central zone subdivision Dm (the medial zone of D). Afferent projections from the diencephalic gustatory nucleus, nucleus lobo bulbaris, have been traced to medial telencephalic regions. Sensory signals from the mechanoreceptive, auditory, lateral line and electro receptive systems also pass through the dorsomedial part of areadorsalis (Striedter, 1991). In this study the focus areas within area dorsalis are dorsomedial areas (Dm) that lies along the rostrocaudal axis of the cell column of medial zone, dorsal and lateral zones (Dd and Dl), overlapping regions along the columns and the central zone (Dc). Anatomical and electrophysiological aspects of the visual telencephalon have been reported in different areas of the area dorsalis, such as Dm, Dd, Dl and Dc (Demski & Beaver, 2001). Areadorsalis also contains anterior commissure, a fibre tract in the brain that facilitates two-way communication between cerebral hemispheres of telencephalon (interhemispheric communication), between telencephalon and diencephalon (thalamus, hypothalamus), as well as within the telencephalon itself (intratelencephalic connections) (Kotrschal, & Kotrschal, 2020). Rakich *et al* (1979) implicated a localized region of the lateral zone of areadorsalis near anterior commissure as an area processing visual information. The fishes that are involved in smell for feeding possess enlarged olfactory lobes. Olfactory lobe consist of olfactory tract and olfactory bulb with secondary olfactory fibers, that project to the sub pallial portion of each hemisphere. The most typical cells of the olfactory bulbs are the mitral cells. The dendrites of these cells are spread to the periphery of the bulb to the entering olfactory fila. The axons of the mitral cells projects to deeper areas of the brain centers. The cerebral hemisphere are of everted type so the membranous ependymal plates expand and cover the dorsal and lateral surfaces and form large basal nuclei. These nuclei are joined by anterior commissure consisting of pallial commissure. These nerve bramches are involved in processing and coordinating sensory and motor information (Flood *et al*., 1976). The telencephalon interacts with hypothalamus, which regulates feeding and reproduction, suggesting a broader role in essential behaviors (Ye *et al*., 2020).

Diencephalon: Diencephalon is a complex brain part found in between the telencephalon rostrally and the mesencephalon caudally. Four major divisions of the diencephalon are the epithalamus, dorsal thalamus, ventral thalamus and hypothalamus. More caudally there is pretectum and, posterior tuberculum (Butler, 2009). The epithalamus is involved in the regulation of circadian rhythm and the modulation of limbic system, hypothalamus and some motor related pathways. The dorsal thalamus, nuclear areas in the diencephalon consists of ascending sensory and motor neurons and send information to the telencephalon, existing as a link between external world and sensory experience. The ventral thalamus found ventral to the dorsal thalamus and act as a relay station of impulses. The hypothalamus consists of preoptic and posterior parts. The areas found rostral to hypothalamus preoptic area consists of parvocellular and the magnocellular preopticnuclei. These are found caudal to the anterior commissure. The posterior hypothalamus consists of large number of nuclear areas. The nuclear areas of this region are connected to pituitary by means of fiber connections as well as hormones. The important connections performed by this area are controlling diurnal rhythms, reproductive behaviors, temperature regulation, feeding, sleeping, drinking, emotional responses etc. Some fishes possess a vascularized structure in the diencephalon called saccusvasculosus, an out pouching of the hypothalamic ventricle (Sueiro *et al*., 2007). The important functions performed by this area are pressure detection, chemosensory, osmoregulatory, ionic transport etc. Though saccusvasculosus occurs in most marine fishes with exceptions, in case freshwater fish, it is absent in cyprinidae (von Mecklenburg, 1974). The hypothalamus and preoptic area are involved in the regulation of internal organ systems. In the present investigation, feeding specific variations in the histology of fore brain focusing telencephalon and diencephalon in two fishes *Carassius auratus* and *Botia striata* are explored.

MATERIALS AND METHODS

Brains were obtained from live fishes, *C.auratus* and *B.Striata*collected from nearby aquariums and anesthetized.The collected brains were fixed in 10% Neutral Buffered formalin to halt tissue degradation and preserve cellular structures. Tissues were dehydrated using increasing concentrations of alcohol. Xylene was used to clear tissue and were embedded in paraffin to provide support for sectioning. The paraffin-embedded brain tissue was cut to serial sections of 8 micrometers (µ) width, using rotary microtome. Deparaffinization or de-waxing in xylene followed by rehydration with different percentages (decreasing) of ethanol was done. To enable staining, tissue was rinsed with water and then double-stained with Hematoxylinthat stains cell nuclei blue followed by Eosin (which stains cytoplasm and connective tissue pink). After staining, the tissue was dehydrated with 100% ethanol and was placed on a microscope slide covered with DPX mounting medium. A special staining method, Cajal's Silver Staining, was performed to reveal more intricate details.

OBSERVATION AND RESULTS

Fore brain morphology: In *C.auratus* the forebrain consists of well-developed telencephalon and diencephalon. The telencephalon consists of well-developed olfactory tract (OFT) with olfactory bulb (OFB) and cerebral hemispheres (CH). The diencephalic area is very prominent. In *Botia striata* the forebrain consists of telencephalon and poorly developed diencephalon. The telencephalon consists of short olfactory tract (OFT) with small olfactory bulb (OFB) and cerebral hemispheres (CH). The diencephalic area is poorly developed.

Histology of Telencephalon in *Carassius auratus:* The telencephalic area are identified as medial (Dm), dorsal (Dd), central (Dc). Posterior (Dp) and lateral (Dl) regions. More recently identified area called ventral (Vv) region is also found in *C.auratus*. In the present study the telencephalic regions were identified according to their number, staining features, and arrangements of the nuclear areas in Cyprinids. The Dm region consists of small, oval shaped cells and are moderately stained. The cells in the Dd are longer, round shaped and undergoes deep staining. The cells of the Dl region are compactly arranged, and small in size. The Dc region occupies largest part and the cells are oval in shape with moderately stained. The Vv region consists of large number of compactly arranged cluster of cells and are deeply stained. The cells of the Ventromedial (Vm) are larger and rounded in shape. These are moderately stained. The posterior (Dp) region consists of round shaped cells. The staining properties in each regions are given in Table 1. The pre optic area consists of deeply stained cells.

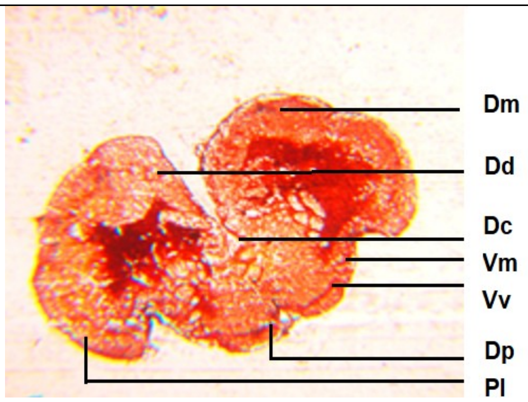

Figure 1. Transverse section of the telencephalon in *C.auratus* showing medial (Dm), dorsal (Dd), central (Dc), posteror (Dp) and postereolateral of pallium, ventromedial (Vm) and ventral (Vv) region

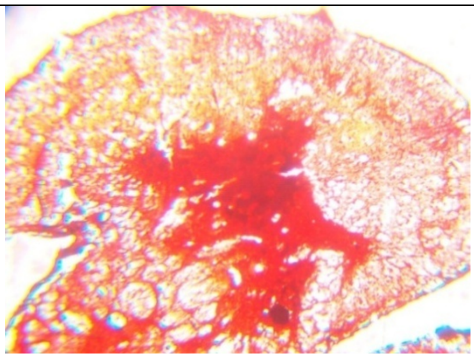

Figure 2. Transverse section of the Dorsal region of the area dorsalis in *C. auratus* *10

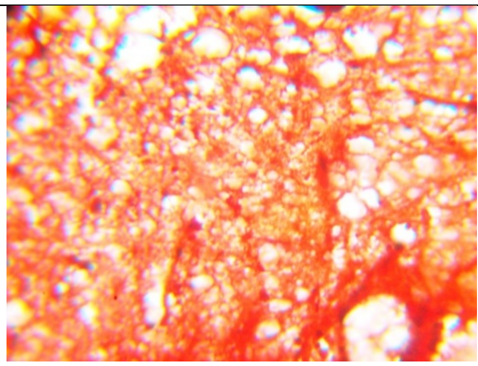

Figure 3. Transverse section of the Medial region of the area dorsalis showing nuclear area in *C. auratus* *40

Table 1. Staining properties of telenceephalic region in *C.auratus* and *B.striata*

Regions of Telecephalom	*C.auratus*	*B.striata*
Medial (Dm)	Moderate	Deep
Dorsal (Dd)	Deep	Moderate
Central (Dc)	Moderate	Deep
Lateral (Dl)	Deep	Deep
Posterior (Dp)	Moderate	Deep
Ventral (Vv)	Deep	Deep
Ventromedial (Vm)	Moderate	Deep

Histology of Diencephalon in *Carassius auratus:* The epithalamic region consists of pineal body and habenula. Habenula is a visual feeding structure present in the diencephalc region and exist in symmetrical form. Visual feeders possess well developed habenula with olfactory structures indicating its significance in vision and olfaction in feeding. The sub-habenular sulcus separate the habenula. The lateral geniculatenucleus (LGN), a clustered neuronal region found in the lateral side of the nucleus corticalis was found larger in size. Dorsolateral side of the sub-habenular sulcus consists of nucleus pretectalis. This region consists of many fibres passing through all areas of the diencephalon. The nucleus corticalis is situated on the dorso lateral side of the nucleus pretectalis. The nucleus pretectalis and corticalis was also well developed. Ventral region of the thalamus is rounded in shape and consists of a nuclear area corpus glomerulosum pars anterior (CGPA). Nucleus pretectalis the nuclear areas similar to corpus glomerulosum pars rotunda (CGPR) of other teleost fishes consists of large cells and is connected with CGPA and the lateral geniculate nucleus. The CGPA is closely connected with nucleus pretectalis consisting of fibers. This region consists of large cluster cells near the optic tectum and is well developed in these species. The nucleus cerebellosis hypothalami is deeply stained. The posterior commissure lies between the diencephalon and mesencephalon.

Histology of Telencephalon in *Botia striata:* The *Botia striata*, bottom dwelling omnivorous feeder possess poorly developed olfactory system indicating their poor role in olfaction. This fish possess well developed barbels in their body indicating that these are very active taste feeder. By the use of gustation, these detect their food. The Dl, Dm, Dp regions are well developed and contains large number of deeply stained cells. The gustatory information is coming from Dm region (Kanwal *et al*., 1988). This information agrees with the findings of *Botia striata*.According to Vargas *et al* (2000) the Dl region is homologus to the tetrapod hippocampus. The hippocampal region is the part of the lymbic system mainly involved in the spatial learning and memory. Highly developed regions of Dl in *B. striata* indicates its role in spatial memory. The Dm consists of clusters of deeply stained cells. The Dd regions cells are small celled and are moderately stained. The Dl zone is largest and are deeply stained cells. The Vv cells are clustered and are deeply stained. The Vm cells are deeply stained and are scattered. The Dc region cells are large and scattered, and are rounded and oval in shape.

Figure 4. Transverse section of the diencephalic area showing habenula (HAB), Nucleus pretectalis (NP), Corpus glomerulosum pars anterior (CGPA), Nucleus isthumus (NI), sulcus medialis (SM), nuclear lateralis thalami (NLT), nuclear thalami posterior (NTP) in *C. arautus* *10

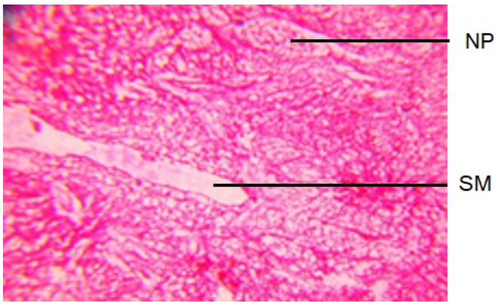

Figure 5. Transverse section of the diencephalic area showing nuclear area in Nucleus pretectalis (NP) and sulcus medialis (SM) in *C. arautus* *40

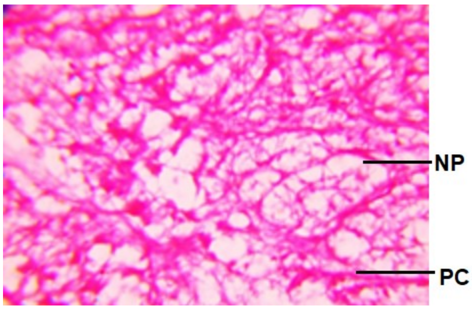

Figure 6. Transverse section of the diencephalic area showing Nucleus pretectalis (NP), and posterior commissure (PC) in C. arautus *40

Histology of Diencephalon in *Botia striata:* A less developed habenula is present indicating low use of vision in their feeding. The asymmetrical habenula are connected by commissural habenularia (COH). The sulcus medians (SM) is very broad and a poorly developed fasciculus retroflexus (RF) is seen. Poorly developed nucleus geniculatus lateralis (LGN) and nucleus pretectalis (NP) is also present. In *B.striata* the corpus glomerulosum pars anterior (CGPA) is not well developed. Corpus glomerulosum pars rotunda consists of network of fibers.

Feeding behavior and Forebrain: In teleost fishes, the forebrain, particularly the telencephalon, plays a crucial role in regulating feeding behavior, alongside other brain regions like the hypothalamus and brainstem. The forebrain integrates sensory information, including olfactory and gustatory inputs, and influences feeding-related neural circuits to control food intake and feeding strategies. In a recent study telencephalon was found to be related to appetite and reproduction (Ye *et al*., 2020). It is particularly important in processing visual inputs and is linked to feeding, defense, schooling, aggression, and reproductive behavior, as well as learning and memory. The main function of this part is the regulation of olfaction as well as mechanoreception and gustation (Hofmann and Meyer, 1993).

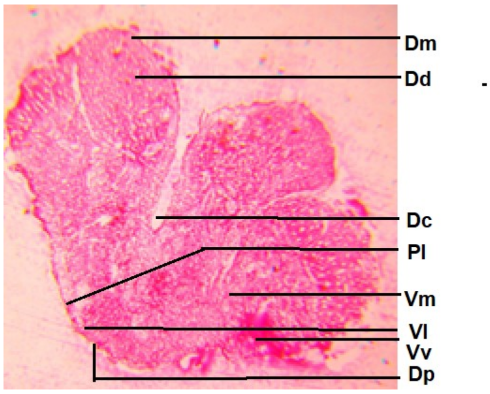

Figure 7. Transverse section of the telencephalon in *B. striata* showing medial (Dm), dorsal (Dd), central (Dc), postereolateral (Pl), posteror (Dp) of pallium, and ventromedial (Vm), lateroventral (Vl) and ventral (Vv) of subpallium region *10

Figure 8. Transverse section of the telencephalon showing olfactory tract (OT) with olfactory bulbs (OB) and dorsal region of the area dorsalis (Dd) in *B. striata* *10

The forebrain, specifically the telencephalon, is involved in processing sensory information related to food, such as smell (olfaction) and taste (gustation). This information is then relayed to other brain areas, like the hypothalamus, to regulate feeding behavior. The hypothalamus acts as a central hub for integrating information from the forebrain and other brain regions, and it plays a key role in regulating appetite and energy balance (Volkoff, 2016). The pallium, a part of the teleost telencephalon, is also considered crucial for higher-order cognitive functions that can be involved in sophisticated feeding behaviors, such as the tool use observed in wrasses (Estienne *et al*., 2024). Previous studies on fishes have found positive correlation between telencephalon size and habitat complexity as well as between olfactory bulb and water turbidity (Huber *et al*., 1997). Environmental factors also significantly influence feeding behavior in fish (Delgado *et al*., 2017). Larger telencephalon is found in Polygamous than monogamoous species (Pollen *et al*., 2007). Wilson & McLaughlin (2010) noticed that foraging behavior in brook trout is related to the specific regions in the brain of fishes. He found that the fish that swim around in the open in search of food have large telencephalon than the fish that sit along the shore line and wait for food to swim by in the water columns. The teleost telencephalon play a key role in processing and co-ordinating sensory and motor information.

Hypothalamic neurocircuits in feeding: Fish feeding behavior is regulated by neural circuits in the forebrain, hypothalamus, and brainstem a part of hindbrain, which coordinate responses to food detection, selection, ingestion, and digestion. Feeding behavior in fish is generally regulated by regions often called feeding centres, and previous experiments in fishes indicates the involvement of hypothalamic area in feeding (Demski, 2012; Peter, 1979). While feeding centres are restricted to hypothalamus in mammals it is seemed to be located in different regions in fish (Cerdá-Reverter &Canosa, 2009). The activities of these feeding centres are influenced by different hormones produced by different brain regions. Secreted by different brain regions, the neurohormones that regulate energy balances have the capacity to

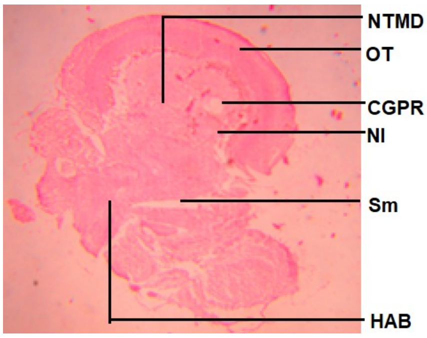

Figure 9. Transverse section of the diencephalic area showing habenular region in B. striata *10

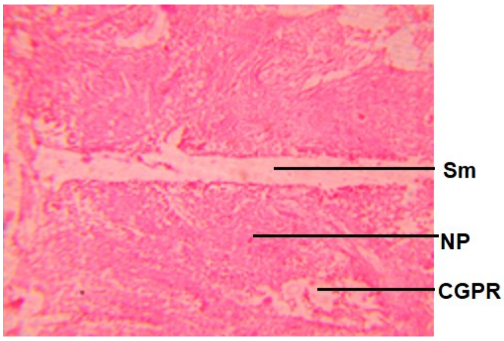

Figure 10. Transverse section of the diencephalic area showing Nuclear areas in B. striata *40

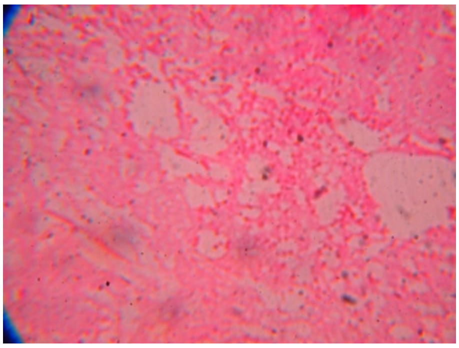

Figure 11. Transverse section of the diencephalic area showing tracts in B. striata *40

either inhibit (anorexigenic factors) or stimulate (orexigenic factors) feeding (Volkoff, 2016). The hypothalamus integrates nutrient and hormonal signals to control appetite via orexigenic and anorexigenic neuropeptides, while the brainstem is vital for fundamental functions like respiration and heart control (Delgado *et al*., 2017).

The hypothalamus contains complex neurocircuits acting as the central regulators of feeding behavior such as food intake and appetite generation. In fish, as in other vertebrates, the hypothalamus is a primary center for regulating feeding behavior. The orexigenic (appetite-stimulating) neurons, co-expressing neuropeptide Y (NPY) and agouti-related protein (AgRP) play a central role in this process. Orexigenic neurons (appetite-stimulating) are located in nucleus lateralis tuberalis (NLTv). These neurons stimulate food intake and are activated during fasting or negative energy balance. Other type is anorexigenic neurons (appetite-inhibiting), co-express proopiomelanocortin (POMC) and cocaine and amphetamine-regulated transcript (CART) (Delgado *et al*., 2017). Levels of nutrients and hormones as well as circadian signals influences the production and release of these peptides. These neurons suppress food intake and are activated in response to food intake and high energy levels. POMC is a precursor to αalphaα-melanocyte-stimulating hormone (αalphaα-MSH), which plays a role in satiety. These two neuronal populations exhibit a push-pull dynamic, where they inhibit each other to precisely regulate feeding behavior. The hypothalamus receives and integrates signals from peripheral organs and nutrient sensors to assess the body's metabolic state. The hypothalamus can sense circulating levels of glucose, fatty acids, and amino acids. These nutrient-sensing systems are crucial for homeostatic control of food intake. The Hormonal signals involved are Ghrelin (GHRL), a "hunger hormone" secreted by the gastrointestinal tract that stimulates NPY/AgRP neurons to promote feeding, Cholecystokinin (CCK), a satiety hormone released from the gut that inhibits food intake, Glucagon-like peptide 1 (GLP-1), a gut-derived hormone that acts as a satiety signal and Leptin. While mammalian leptin inhibits food intake in some fish, the fish-specific actions are still being characterized (Figure 12). Other modulatory factors include stress response and circadian rhythmicity. The hypothalamus-pituitary-interrenal (HPI) axis mediates the stress response, causing the release of hormones like cortisol. Corticotropin-releasing factor (CRF), a stress hormone, can cause anorexia in fish. This integration generates adaptive changes in food intake and energy expenditure during stressful conditions. Hypothalamus coordinates internal circadian clocks, which are synchronized by external cues like light. This enables the fish to anticipate meal times and regulate feeding behavior in accordance with a daily cycle. For example, studies on aquaculture have shown that fish fed on a regular schedule exhibit anticipatory hormonal changes before feeding. (Delgado *et al*., 2017).

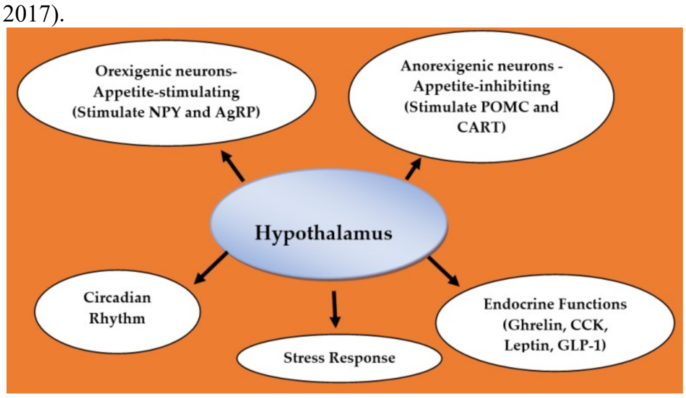

Figure 12. Graphic representation illustrating major functions of hypothalamus related to feeding behavior in fish

In rainbow trout, hypothalamic neuropeptides and serotonergic activity are linked to feeding behavior, with changes in these systems coinciding with feeding times and satiety. Studies have also shown that the diencephalon is sensitive to stress and can influence feeding behavior under certain conditions (Gesto *et al*., 2013).

DISCUSSION

Fish brains, especially those of teleosts (bony fish), show a large diversity in morphology and function. They follow the basic vertebrate brain plan (forebrain, midbrain, and hindbrain) but have unique features like the eversion of the pallial hemispheres. This diversity is linked to their varied lifestyles and sensory specializations (Vernier, 2017).

Telencephalon: The forebrain consists of olfactory bulbs, lobes and cerebral hemispheres. Fishes considered in the present investigation generally comes under omnivorous column feeder and omnivorous bottom feeder. *C.auratus*being an omnivorous column feeder possess well developed olfactory bulbs, and tracts indicating importance of vision in their feeding. But in the case *of B.striata*, the fish possess poorly developed olfactory tracts with olfactory bulbs, showing less significance of olfaction in their feeding. *Carassius auratus* primarily a column feeder is mainly found in surface or column of the aquarium tank. This fish possess well developed Dd and Dm regions with more number of cells. The cells in the Dd region are mainly for vision and Dm is concerned for gustation. Behavioral studies in teleost shows that Dd and Dm regions can discriminate visual evoked potentials after surgical removal of their optic area, indicating that their telencephalic visual areas mediate this function (Ebbesson, 1980).The telencephalon's functional role extends beyond the processing of olfactory information. Visual, mechanoreceptive, gustatory and other modalities are represented in the forebrain. Ablation of the entire telencephalon cause relatively insignificant behavioral patterns, except for those which require an intact olfactory system (Salas *et al*., 1996). Deficits between normal and lesioned fish become apparent only under complex experimental circumstances, i. e., when the fish are required to perform difficult tasks, or are exposed to unfamiliar environments (Hofmann & Meyer, 1993).The lateral zone of area dorsalis (Dl) was identified as the primary visual area in the area dorsalis of the telencephalon of the gold fish, *Carassius auratus*, based on a comparative decrease in bilateral symmetry of cytochroine oxidase (COX) histochemistry. In addition electrophysiological methods were used to verify the visual responsiveness of neurons in this region (Saidel*et al*., 2001).In the present study the Dl region of *Carassius auratus* is well developed indicating the role of vision in feeding.The ventral telencephalon in zebrafish is crucial for social interactions, which can be linked to feeding behavior in some contexts. The telencephalon is also thought to act as a primitive "holding" or attention center, potentially guiding the fish towards or away from food sources (Savage, 1969).

Diencephalon: The four subdivisions of diencephalon such as epithalamus, dorsal thalamus, ventral thalamus and hypothalamus are observed in these Cyprinids. The habenula and pineal body are observed in these fishes. The habenula shows considerable structural variations in column dwelling and bottom dwelling omnivorous feeder. In *Carassius auratus,* the habenula is well developed and symmetrical. This indicates their vision in feeding. The *Botia striata*, bottom dwelling fish possess asymmetrical habenula. Sherly (2002) reported that habenula are well developed in surface dwelling visual feeders than nonvisual feeders. This findings agree with the findings of present investigation.

The habenulae are dorsally connected by commissural habenularis. This tract is well developed in *Botia striata* and also amygdala-habenular tract is found in both fishes. This tract projects olfactory impulses to the habenular nuclei as way stations for feeding refluxes (Lagler *et al*., 1962). The sense of smell play an important role in this fishes for obtaining food. The lateral geniculate nucleus is considered as a part of the dorsal thalamus and is related to vision (Charlton, 1933; Shanklin, 1934). This nucleus is highly developed in column dwelling visual feeders and poorly developed in bottom dwelling taste feeders. Northcutt & Butler (1993) analyzed the pattern of retinofugal projections to nuclei in the diencephalon and to the optic tectum in Clupeaharengus, a Clupeomorph teleost, for comparison with non-teleost achnopterygenns. They observed that most retinal fibers decussate in the optic chiasma and project to nuclei in the pre-optic area, ventral and dorsal thalamus, posterior tuberculum and pretectum as well as to the necessary optic nuclei and optic tectum. Some ipsi lateral projections do not decussate in the optic chiasma, while others decussate and recross via the supra optic and posterior commissures. The pattern of projections is similar to that seen in other actinopterygian fishes with several exceptions.Butler (2000) analyzed the organization and structure of the teleost telencephalon, specifically addressing the apparent contradiction between its topographical (spatial) and topological (continuous) organization i.e. how the teleost telencephalon looks (its topography) and how its parts are interconnected (its topology). The process of eversion of the hemispheres during development in ray-finned fishes was postulated by Holmgren (1922), and Nieuweahuys (1969) that implies reversal of medial-to-lateral topography in the evaginated telencephalon of other vertebrates. In simply everted telencephalons of the developmentally medial (hippocampal) pallium is predicted to be laterally and the lateral (olfactory) pallium medially. In ray-finned fishes with relatively simple cytoarchitecture: Cladistians (bichirs & rope fishes) and Chondrosteans (Strugeons & Paddle fishes) a medially lying site for the major olfactory input supports the simple eversion hypothesis (Northcutt & Bradford, 1980). However, in teleosts, which have more complex cytoarchitecture, the major olfactory target lies in a lateral position (Scalia and Ebbesson, 1971).Northcutt & Braford (1980) in their analysis concluded that the medially lying, predominant olfactory target in the cladistian telencephalon, was the homologue of the more laterally and posteriorly located major olfactory target in teleosts, Dp (the posterior zone of dorsalis). Their eversion-rearrangement hypothesis proposed that the position of the latter was due to secondary migration of the cell group away from medial ependymal surface. They also labeled the predominant olfactory target in sturgeons Dp, even though a large part of it lies in a medial position. Their conclusion that the major olfactory bulb target is homologous across all jawed vertebrates has been widely accepted, even though no evidence of secondary rearrangement of pallial cell masses has been obtained.Braford (1995) has noted similarity between Dm (medial zone of D) in teleosts and the amygdala of tetrapods based on efferent projections to hypothalamus and a topological position only one pallial zone removed from Dp. The amniote suprastriatal pallium including olfactory cortex proper and pallial amygdale is homologous to at least part of Dm. Part of amniote dorsal pallium - anterior dorsal ventricular ridge of reptiles and birds and lateral neocortex of mammals is homologous to the more dorsal part of Dm. Dorsal cortex of reptiles and birds and lateral neocortex of mammals is homologous to the more dorsal part of Dm. The hippocampal pallium in amniotes is homologous to Dp. Saidal & Butler (1996) studied the visual connections of the typical diencephalic nucleus rostro lateralis in *Pantodon buchholzi*. They observed that in *Pantodon*, the nucleus restrolateralis receives an afferent projection from the ventral retina and a bilateral projection from the optic tecta. The circuitry of retina indicates that it is predominantly concerned with processing visual information from the aerial visual field and integrating it with visuomotor activity. The hodology of retinal nucleus suggest that it plays a major role locating prey by simultaneously monitoring aerial and aquatic environments, given its surface-dwelling niche and specialized eye structure. It was demonstrated that this nucleus is an integral component of the visual pathway in *Pantodon buchholzi.*According to Khanna and Singh (1966) *Puntius ticto* and *Channa striatus* possess well developed geniculate nucleus because of their surface dwelling habits. Singh (1971) stated that the nucleus pretectalis and nucleus corticalis were better developed in fishes with large nucleus geniculatus lateralis. This agrees with the observation in *Carassius auratus.* According to Braford & Northcutt (1983) and (Northcutt & Wullimann, 1988), the lateral geniculate nucleus receives retinal input. This indicates the sense of vision is more in surface dwelling *C.auratus* than bottom dwelling *B.striata.* The corpus glomerulosum pars rotunda has been described by Kappers *et al*., (1936). This structure is well developed in *Carassius auratus* and poorly developed in *B. striata.*

CONCLUSION

In fish, the forebrain, specifically the telencephalon and diencephalon, plays a crucial role in feeding behavior. The telencephalon is involved in processing sensory information related to food, learning feeding-related behaviors, and potentially acting as an attention center. Studies in fish have shown that the telencephalon is involved in processing sensory information related to food. For example, in goldfish, the telencephalon is implicated in learning and memory related to food-reinforced behavior. The diencephalon, particularly hypothalamus, is critical for regulating hunger and satiety, and influences feeding motivation. Therefore, disruptions to these forebrain regions can lead to deficits in food-related learning, altered feeding patterns, and changes in the motivation to feed.

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