MORPHOLOGY OF THE CHONDOCRANIUM IN THE EMBRYO OF

6.7 mm. LENGTH

1. The Chondrocranium:

(a) Basal plate and the notochord:

The parachordal cartilages form the basal plate of the chondrocranium. Each parachordial is a complete bar or dorso-ventrally flattened plate of cartilage flanking the median notochord and closely appressed to it mesially for the hinder 2/3 of its length. Anteriorly, however, the parachordals diverge away from the notochord leaving a narrow space between them - the basicranial fenestra which is confluent with the hypophysial fenestra.

A little behind the tip of the notochord, both the parachordals are interconnected by a slightly arched bridge or shelf of cartilage known as the pro-otic bridge. This bridge is attached to the dorsal portions of the mesial edge of the parachordals and its slightly concave ventral margin is closely apposed to the dorsal side of the notochord. The ventro-lateral portion of the median edges of the parachordals are free from the notochord and enclose the narrow basicranial fenestra between them in this region. Beyond the pro-otic bridge, in front, the diverging portions of the parachordals border the major portion of the existing hypophysial fenestra from the posterior side and, further on, are prolonged forwards as the parachordal processes
drawn out just to unite with the posterior extremely slender portion of the trebecula, on one side (due to absorption of cartilage). On the other side, the parachordal process stands disconnected and stops short of the posterior projecting stump of the trebecula by a short space, due to the complete absorption of the intervening trabecular portion of the cartilage, initiated for the first time, at this stage. The front portion of these parachordal processes become somewhat depressed and hence lie at a slightly lower level than the rest of the basal plate.

The lateral margin of the parachordal fuses with the ventral wall of the auditory capsule, (thereby completing the floor of the chondrocranium posteriorly in the region of the basal plate) except for a small anterior basicaapsular fenestra, which still persists on the left side and the two posterior basicaapsular foramen for the exit of the glossopharyngeal nerve, one on each side.

Behind the pro-otic bridge, the basal plate exhibits a median convex surface, (hogs-back) flanked by a pair of lateral depressions or fossae, which lodge the saccules of the membranous labyrinth expanding now downwards and inwards. Thus the saccule has a practically complete cartilaginous base now, on each side.

(b) Occipital Region:

In the posterior region of the neurocranium, beyond the posterior limit of the auditory capsule, the parachordals
bear a pair of cartilaginous dorsally diverted processes which are known as the occipital arches. The median cartilaginous wall of the auditory capsule in this region or the septa of the posterior semicircular canal of the auditory capsule, as it may be called, at its hindermost extremity fuses with dorsal end of the occipital arch, on each side, thereby enclosing a space known as the Fissure metotica (jugular foramen) between itself and the auditory capsule, for the exit of the vagus nerve from the brain cavity. Behind the auditory capsule, the occipital arches are never connected with each other medially above the brain; nor is it in any way connected to the tectum synoticum. Thus, an independent occipital arch proper, or a tectum posterior is totally absent. However, the posterior margin of the tectum synoticum projects backwards as a short median knob-like structure dorsally between the anterior portion of the occipital processes. At their hinder ends, the parachordals in this region show a slight dorso-lateral extension on either side of the notochord, which are the fore-runners of the future epichordal commissure fully formed in later stages.

(c) Auditory Region:

The auditory capsules are fully formed at this stage with complete floor, lateral wall and roof. Towards the anterior region, the roof of the auditory capsule ends mesially with a free edge; but posteriorly the roof of both the auditory capsules extends further up to fuse together medially above the brain forming the cartilaginous tectum synoticum. This tectum constitutes the posterior roof of the chondrocranium. Anteriorly the auditory capsules diverge from each other and each of them
gives off a postorbital process which becomes continuous with the posterior extremity of the corresponding taenia marginalis, in front. As in a typical teleost, a medial wall to the auditory capsule is characteristically absent except in the extreme anterior and posterior portions where they are represented by the cartilaginous septa for the anterior and posterior semicircular canals. Thus the cavity of the auditory capsule is freely confluent with the brain cavity. Externally the surface of the auditory capsule exhibits three prominent ridges or rims which reflect the corresponding position of the three semicircular canals. Inside, the cavity of the auditory capsule is crossed by three well-developed cartilaginous septa which clearly separate off the three semicircular canals. Of the three, the septum semicirculare anterius is the shortest and this surrounds only for a short distance the front portion, of the anterior semicircular canal at this stage. The septum semicirculare laterale extends through the whole length of the lateral semicircular canal from just behind its ampulla to a point in the posterior region of the auditory capsule, where the canal itself takes a turn in the mesial direction to join the utriculus of the membranous labyrinth. The third septum semicirculare posterius also extends for almost the entire length of the canal, upto the hindermost limit of the auditory capsule where it dips down to fuse with the dorsal end of the occipital arches, as already described. The utriculus and sacculus are comparatively small and do not reach the wall of the auditory capsule; but the saccule expands downwards and inwards and fits into the corresponding fossa or pit developed in the posterior chordal portion of the parachordals.
(d) **Orbito-temporal Region**:

The orbito-temporal region of the neurocranium stretches between the auditory capsule and the ethmoid region. The floor in this part is formed by the anterior slightly depressed parachordal processes, the rudimentary cartilaginous inter-orbital septum, the paired trabeculae cranii, and more anteriorly the trabecula communis. The paired trabeculae posteriorly fuse with the anterior parachordal processes enclosing between them the hypophysial fenestra. The paired trabeculae, at this stage, are represented by an extremely slender cartilaginous rod between the trabecula communis and the anterior parachordal process on one side only (due to the partial absorption of the cartilage, set in now). On the other side, the absorption of the cartilage in this region is already complete and the trabecula communis and the parachordal stand disconnected by an intervening blank space. As such, the hypophysial fenestra on that side, due to the loss of the lateral wall, becomes freely confluent with the large sphenoid fissure of the orbito-temporal region. The two trabeculae anteriorly beyond the hypophysial fenestra fuse together to form a median plate-like cartilage for the greater part of their length, stretching up to the ethmoid region. Due to the extensive fusion and formation of this trabeculae communis, the hypophysial fenestra is now reduced to smaller dimensions. The hinder part of the trabeculae and the front of the anterior parachordal processes are somewhat depressed, as already mentioned, and hence this region obviously lie at a lower level than the basal plate. This depressed area is of importance, since it is here that the external rectus muscle lodged in the intra-cranial
section of the posterior myodome at this stage, traverses in, from the sphenoid fissure and enters the cranial cavity.

At the hindermost region of the orbito-temporal region, the antero-ventral region of the auditory capsule, origin of the post-orbital process, is connected with the lateral edge of the basal plate by a plate of cartilage known as the lateral commissure enclosing the facial foramen. The facial foramen is bounded behind by the anterior basicapsular commissure and mesially by the anterior portion of the parachordals. The lateral commissure is formed by the fusion of the post-palatine process of the basal plate and the pro-otic process of the anterior-most portion of the auditory capsule (details of the two processes already discussed in the development part).

Located at the outer side, just in front of the auditory capsule, there is a horizontal canal extending between the brain and the lateral commissure known as the trigeminofacialis chamber, whose lateral wall is formed by the afore-said lateral commissure. Medially the dura mater limits this chamber. Thus it is clear that the chamber is an extra-cranial space. The chamber lodges the ganglia of the trigeminal and facial nerves, besides the head-vein and the orbital artery and communicates with the outside by two openings, one of which points anteriorly and the other backwards. The facial foramen constitutes the posterior aperture through which transmits the hyomandibular branch of the facialis nerve (outwards) and the orbital artery and the head vein (inwards). The anterior aperture opens widely into the orbit and through it passes the head-vein, the orbital artery and part of the large gasserian ganglion and the branches
of the trigeminal nerve. The trigemino-facialis chamber is not divided into two portions, - a pars ganglionaris and a pars jugularis - since ossification and formation of the pro-otic bone with its characteristic two lamellae partitioning this chamber has not yet begun at this stage. Due to the conspicuous absence of structures like the pre-facial commissure or a pila antotica or a pila metoptica or even a pre-optic root to the orbital cartilage, each side of the orbito-temporal region is occupied by a large and continuous fenestra known as the sphenoid fissure, through which all the cranial nerves from the olfactory to the trigeminal, the ophthalmic and the anterior retinal artery leave the skull and the pituitary vein and the external rectus eye-muscle enter it.

The lateral wall of the orbito-temporal region are represented by a pair of more or less oval rod-like cartilaginous structures known as the orbital cartilages. Posteriorly they are continuous with the anterior region of the auditory capsules through their post-orbital processes, while in front they converge, as they come forwards, and are continued into the ethmoid region, of course, at a higher level than the post-orbital process. In the ethmoid region, its two prongs, a median sphenoseptal and a lateral sphenethmoid commissures, fuse with the well-developed internasal septum and the lamina orbitonassalis respectively. It is to be mentioned here that the anterior portion of the orbital cartilage in front of the epiphysial bar is slender, while the posterior portion between the epiphysial bar and the auditory capsule is comparatively thicker.
The roof of the chondrocranium in this region is very incompletely chondrified and is solely represented by a dorso-ventrally flattened cartilaginous epiphysial bar, which gets produced laterally into the orbital cartilages, at about their middle. The epiphysial bar is wider in the middle and comparatively narrow laterally at the place of their union with the orbital cartilages.

The orbital cavity or the sphenoid fissure of the two sides in the orbito-temporal region is separated off from one another by a membraneous inter-orbital septum extending between the floor of the brain cavity and the dorsal arched surface of the trabecula communis. At the region of the optic nerves, the inter-orbital septum is ruptured for the passage of the nerves to the opposite sides. In the posterior region where the floor of the brain cavity approximates the floor of the neurocranium, the two blades of the trabecula communis become dorso-ventrally compressed and plate-like expanding laterally and their dorsal fused portion is drawn up into an arched bridge of cartilage connecting them. This bridge of cartilage still posteriorly grows upwards replacing the membraneous septum and terminates just after the divergence of the two limbs of the paired trabeculae, from it. This bridge, in fact, represents a continuation of the dorsal portion of the posterior end of the trabecula communis at this stage. This rudimentary cartilaginous structure marks out the beginning of the well developed cartilaginous inter-orbital septum in later stages, confined to this posterior region of the orbits.

(e) Ethmoid Region:

The trabecula communis is anteriorly continued in-
sensibly into the ethmoid region as an expanded thick plate of cartilage known as the ethmoid plate. There is a well developed cartilaginous inter-nasal septum projecting upwards from the arched dorsal surface of the ethmoid plate, gradually increasing in height towards its posterior region. It is best developed in the region just before it merges into the sphenoseptal commissure, on each side. This posterior portion of the septum develops a concavity dorsally, immediately after which the sphenoseptal commissures, on either side, fuse with it.

The median internasal septum, on either side, lodges the olfactory capsules in which the olfactory organs lie unprotected. Each olfactory capsule is reduced more or less to a pit or the fossa nasalis with a floor formed by the laterally expanded portion of the ethmoid plate, a median wall formed by the internasal septum and a lateral and hind wall formed by the lamina orbitonasalis, where it exists. The lamina orbitonasalis is a laterally compressed cartilaginous plate-like structure rising virtually up to fuse with the sphenethmoid commissure of the orbital cartilage and is connected with the postero-lateral corner of the ethmoid plate, on each side, in a horizontal plane. The structure of this cartilage is different from that of the ethmoid plate in that the former consists of large chondroblasts with little matrix whereas the ethmoid plate is composed of smaller such cells with well developed matrix between them. The roof of the nasal capsule is not in existence except for its hindermost portion where the sphenoseptal commissure forms the dorsal posterior border of the wide foramen olfactorium adehens through which the olfactory nerve, the
orbitonasal vein and the orbitonasal artery, transmitted in from the orbital cavity through the orbital fissure, enter the nasal fossa. Due to a forward shift of the lamina orbitonasalis (consequent on the retrogression of the anterior brain limit), the olfactory nerve becomes correspondingly longer and after leaving the brain cavity through the foramen olfactorium evenhens (membranous aperture) passes actually through the anterior corner of the orbit for a short while, during its transit to the olfactory capsule. In fact, this space of the orbit, through which the nerve appears to pass, limited anteriorly by the foramen olfactorium evenhens and ventrally leading to the orbital cavity by a wide aperture - the orbital fissure of fissura orbitonasalis and located between the hinder margin of the lamina orbitonasalis and the postero-lateral extremity of the ethmoid plate, represents actually the well developed extracranial space - the cavum orbitonasale - of the later stages.

Just in front of the ethmoid plate, an independent small rostral cartilage exists at this stage which is dorsal in position to the ethmoid plate.

(f) Visceral Arches:

At this stage, the chondrocranium is provided with the full compliment of the visceral arch skeleton. All the seven pairs of visceral arches, i.e. the mandibular, the hyoid and the rest five pairs of branchial arches attain complete development and are cartilaginous except for the last one pair, represented by the ceratobranchials only, the middle portion of which has already become bony due to ossification and absorption of the cartilage concerned.
The mandibular arch comprises of a pterygo-quadrate bar in the upper jaw and a Meckel's cartilage in the lower jaw. The pterygo-quadrate, which articulates posteriorly with the Meckel's cartilage, is divisible into two portions, an anterior elongated slender pterygoid section extending forwards and upwards obliquely into the ethmoid region and a posterior broad laterally compressed plate-like quadrate section. Both these limbs together roughly forms the shape of a V. The quadrate section presents an articular and metapterygoid processes, the former proceeding ventrally, at about the point of fusion of the pterygoid and the quadrate portions, to articulate with the posterior part of the Meckel's cartilage and the latter continuing postero-dorsally towards the auditory capsule. The metapterygoid process rests on the antero-dorsal edge of the descending symplectic portion of the hyosymplectic cartilage, receiving support from it and comprises of a diminutive otic process at its narrower hinder portion. This otic process, however, fails to reach the auditory capsule here, as in teleosts in general in such cases.

Anteriorly in the ethmoid region, pterygoid portion lies apposed to the ventro-lateral edge of the ethmoid plate and thus the articulation, in this case, is obviously through a pretty long surface of contact extending posteriorly upto slightly ahead of the point of fusion of the lamina-orbitonasalis with the ethmoid plate. It is of interest to note in this connection that the pterygoid bar, (better known as the palatine section) rather oval in outline in this region of articulation, presents a smooth surface and no traces of any processes or outgrowths such as the rostropalatine or ethmo-
palatine processes for articulation reported in fishes like Salmo, Belone cancilla, Astacambelus etc. are discernible at this stage. Also there is no fusion of cartilages at the place where the two surfaces come into contact. Beyond this place of articulation, the pterygoid bar (the palatine section) proceeds further forwards leaving the ethmoid plate and running sideways and backwards in the form of a curve or loop towards the margin of the snout, where it lies ventral to the olfactory sac.

The quadrate as such is not connected posteriorly with the neurocranium and thus the suspensorium of the pterygo-quadrate is through the intervention of the hyosymplectic cartilage, on which it rests and receives support from beneath. The jaw suspensorium is hence typically of the teleostean methyostylic type. The two Meckels' cartilages are in the form of somewhat curved rods running rather obliquely forwards and are fused with each other at their distal extremities (at the syaphysis) by their median dorsal portions leaving a well marked notch or groove ventrally, suggestive of their point of fusion. Posteriorly each Meckels' cartilage gives out a backwardly directed retro-articular process behind the point of its articulation with the quadrate and a well developed coronoid process slightly ahead of the articulation point towards the front. The Meckels' cartilages at this stage extend far forwards than the ethmoid plate and the pterygo-quadrate bar.

The hyoid arch, on each side, comprises of 4 independent cartilaginous elements known as the hyosymplectic, interhyal cerathyal and the hypohyal. Of these, the hyosymplectic and the short interhyal represents the dorso-lateral elements, while the cerathyal and the median hypohyals constitute the
ventral elements of the hyoid arch. The hyosymplectic consists of a proximal more or less triangular plate-like portion representing the hyomandibular cartilage and a distal slender rod-like tapering portion forming the symplectic cartilage. The hyomandibular is articulated with the ventro-lateral surface of the auditory capsule towards its anterior portion by the broad base, lateral to the head vein and is perforated by a foramen for the transit of the hyomandibular branch of the facial nerve. The symplectic portion is, in fact, a direct extension of the ventral narrower portion of the hyomandibular and dips forwards and downwards underlying the posteroventral margin of the quadrate portion of the pterygoquadrate bar. The interhyal is a small cartilaginous rod which articulates proximally with the postero-ventral region of the hyomandibular portion (where the latter is prolonged further forwards as the symplectic portion) and distally with the postero-dorsal extremity of the large ceratohyal. The ceratohyal assumes the form of a broad elongated cartilage running obliquely forwards and inwards just to articulate medially with the small but independent hypohyal of its side, by a typical "ball-and-socket" articulation. The distal round extremity of the ceratohyal fits into a deep cup-like socket or concavity developed on the ventro-lateral region of proximal end of the hypohyal. The posterior region of the ceratohyal shows a blade-like expansion, steadily increasing in dimensions with the advance in age of the embryo. The two hypohyals of either side meet in the mid-ventral line and remain in close contact; but no fusion between the two occurs at any stage.

A well developed median basihyal projects in front of
the hypohyals. Posteriorly, the narrower and rod-like portion of the basihyal extends backwards dorsal to the median edges of the two hypohyals almost upto their posterior limit. In this region, the posterior extremity of the basihyal and the anterior end of the first median copula overlap each other for a very short distance and are in procartilaginous connexion. Posteriorly the basihyal is also connected to the hypohyals by the intervening zone of procartilage cells. This basihyal is supposed to represent the median element of the hyoid arch and is in the form of a roughly triangular and dorso-ventrally flattened cartilaginous plate, with the broad base directed forwards and the apex backwards in between the two hypohyals. The basihyal forms the anteriormost element of the median copula.

All the branchial arches attain their maximum development and even ossification has started in some of the cartilaginous elements, confined to the posterior region of the splanchnocranium, at this stage. The ossification, however, is seen to spread over the more anterior elements also in due course, in the later stages of the embryos. Pharyngobranchials, as separate elements, are in existence here in the case of the first and second branchial arches only. The first pharyngobranchial makes its belated appearance for the first time at this stage and is in the form a miniature nodule of cartilage, attached to the dorsal end of the anterior bifurcation of the first epibranchial element. The second pharyngobranchial is larger in dimensions and is a somewhat heart-shaped plate of cartilage attached to the extremity of the second epibranchial. The third pharyngobranchial is a large irregular plate of
cartilage stretching medially to the dorsal portions of the third and fourth epibranchials and attached to both of them by their proximal extremity. As such, this last pharyngobranchial obviously represents the fused product of the third and fourth pharyngobranchials. It is of interest to note, in this connection, that at this stage, the two anteriorly directed horns of this pharyngobranchial extend further forwards and come into contact with the posterior margin of the second pharyngobranchial, just in front of them. In fact, the two horns apparently seem to have completely broken off from their parent cartilage and appear as two round nodules of independent cartilages attached to the second pharyngobranchial due to the absorption of the intermediary cartilage consequent on the ossification set in. In the earlier stages they were in perfect cartilaginous continuity with the main structure. Pharyngobranchials are absent in the fifth or the last pair of branchial arches.

The epibranchials are well developed in the first four branchial arches, the third being the smallest. The first epibranchial is the largest and dorsally is bifurcated into two portions by a deep notch or cleft and the first pharyngobranchial gets attached to the terminal portion of the anterior bifurcation, as already specified above. These epibranchials articulate with the corresponding ceratobranchials by their proximal ends.

The ceratobranchials of the first three branchial arches are more or less uniform in size and are slender rod-shaped cartilages running obliquely forwards towards the median line, where they remain attached to the respective hypobranchial
elements. Proximally they are all articulated with the epibranchials concerned. The fourth ceratobranchial is almost of the same size, as the anterior ones, but comparatively thinner and anteriorly it gets directly articulated with the sides of the posterior terminal portion of the diamond shaped short but thick second copula. The fourth hypobranchial is absent. Proximally, however, it is articulated with the corresponding epibranchial. The fifth ceratobranchial is a very slender bar of cartilage. The anterior portions of this last pair of ceratobranchials lie close together in the midventral line; but more posteriorly they diverge away from the middle line towards the margin. No fusion of the anterior part of these ceratobranchials which lie in close association with each other takes place at any stage. Also at this stage, a small terminal rod of cartilage towards the margin is the sole representative of the diverging hinder portion of this last ceratobranchial, since the intermediary portions have already undergone absorption due to the ossification, begun now. The fifth pharyngobranchial, epibranchial and the hypobranchial elements are not developed at any stage. The anterior extremity of the fifth ceratobranchial starts just behind posterior extremity of the second copula.

Thus only the first three branchial arches are provided with the complete set of cartilaginous elements which make up a typical teleostean branchial arch, the fourth one being devoid of the hypobranchials. The fifth arch is represented only by the ceratobranchials at this stage.

The hypobranchials of the first two branchial arches
are closely attached to the sides of the median anterior copula. Still behind, the third pair of hypobranchials about against the sides of both the copulae at their place of junction. These hypobranchials also give out two prominent cartilaginous processes at their place of attachment with the copulae, (one on each side), which project out ventrally along the two sides of the ventral aorta and are of doubtful significance.

The median basibranchials of the branchial arches fuse together in two portions - an anterior longer first copula extending between the first three pairs of branchial arches and a posterior shorter but thicker second copula extending between the third and fourth pair of branchial arches. The anterior portion of the first copula overlap the posterior portion of the basihyal and are in procartilaginous connection with each other; so also the posterior portion and the anterior portion of the second copula at the place of their association.
II) Eye Muscles:

There are two sets of eye-muscles - the two oblique muscles situated anteriorly and the four recti muscles located posteriorly in connection with each of the two eyes.

The oblique muscles are represented by the superior and inferior oblique muscles, both of which arise far anteriorly in the ethmoid region, where the lamina orbitonasalis exists. The superior oblique eye muscle originates from the membranous floor of the brain cavity just median to the sphenoseptal commissure and dorso-lateral to the olfactory nerve emerging into the orbit from the brain cavity. The inferior oblique muscle, however, takes its origin below the olfactory nerve and the orbitonasal artery from the dorso-lateral region of the ethmoid plate in this region. The insertion of these two muscles, is rather close together and in the same region, that of superior oblique muscle being directly dorsal to the plate of origin of the inferior oblique muscle with the olfactory nerve running between them. From the point of origin, both these muscles pass backwards divergingly into the orbit with the orbitonasal artery between them, to get inserted on the dorsal and ventral regions of the anterior portion of the eye. During its course, the superior oblique muscle more posteriorly leaves the membranous floor of the brain cavity and passes just below the orbital cartilage in the dorsal part of the orbit upto its point of insertion on the dorsal region of the eye. The inferior oblique muscle however, passes backwards along the dorso-lateral region of the trabecula communis and further back leaves the trabecula communis and cuts across the lower portion
of the orbit, outwards, median to the anterior rectus muscle. Still posteriorly, it passes obliquely downwards just below the anterior rectus muscle and gets inserted on the ventral region of the eye.

The recti muscles are represented by the anterior, superior, inferior and posterior recti muscles. Of these recti muscles, the superior, the inferior and the anterior recti muscles arise crowded close together from the dura mater forming the brain floor in the region of the mid-brain at about the place of approximation of the brain floor with the floor of the neurocranium. If fact, these muscles originate from the median portion of the brain floor, just adjacent to the internal carotid on each side, in that region. The innermost is the anterior rectus muscle arising from the dura mater next to the internal carotid and dorsal to the efferent pseudobranchial artery. It proceeds forwards just above the trabecula and median to the inferior rectus muscle and further on runs across the orbit obliquely forwards. In the region of the optic nerve, it runs below the nerve and external to the orbitonasal artery. Further forwards, it passes just dorsal to the inferior oblique muscle and gets inserted on the mesial surface of the anterior portion of the eye. It is of interest to mention here that the anterior rectus muscle, at this early stage, does not penetrate the membranous brain floor and extend into the posterior myodome, as in later stages.

The inferior rectus muscle originates just external to the origin of the anterior rectus muscle and runs obliquely downwards and outwards across the orbit, immediately below the
inferior orbital sinus and the ophthalmica magna artery to be inserted on the ventral region of the eye.

The superior rectus muscle is a comparatively slender one arising from the dura mater a little behind the origin of the inferior and anterior recti muscles and just above the anterior parachordal process. From the point of origin, it runs forward along the lateral side of the brain close to the dura mater and dorsal to the main trunk of the trochlear nerve and inferior orbital sinus. Further forward, it leaves the brain floor and runs across the dorsal part of the orbit above the inferior rectus muscle and finally gets inserted on the dorsal region of the eye, running still ahead for some distance, as such, below the orbital cartilage, as a very slender muscle over the eye.

The posterior rectus muscle is very well developed and runs lodged in a prominent posterior myodome as in the case of fishes like Salmo, Clupena, etc. The posterior rectus muscle originates far back from the free ventro-lateral part of the median edge of the parachordals below the prootic bridge and runs forwards through the narrow basi-cranial fenestra on the side of the median notochord, roofed over by the prootic bridge. Further forwards it runs through the posterior narrower extension of the hypophysial fenestra confluent with the basi-cranial fenestra. Thus the posterior portion of the hypophysial fenestra serves for the passage of the external rectus eye-muscle as the posterior myodome in this region. Further forwards, the eye muscle curves over the slightly depressed median edge of the parachordal and runs outwards along the
floor of the skull, (basal plate) lodged in the myodome. The myodome, in this region is limited internally by the dura mater and as such it, strictly speaking, conforms to an extra-cranial space. However, since it is dorsal to the skull floor, it is termed as the intra-cranial section of the posterior myodome. Further forwards, in the anterior region of the Trigemino-facialis' chamber, the muscle lodged in the myodonic space passes just above the lateral commissure. More anteriorly, the eye muscle enters the orbit running laterally to the sub-ocular shelf strictly following the course taken up by the pituitory vein to enter the hypophysial fenestra from the orbit. Within the orbit, the eye-muscle at first passes median to the trigeminal ganglion and the nerves just emerging from it and still forwards it passes dorsal to the common trunk for the maxillary and mandibularis branches to get inserted on the posterior region of the eye-ball.

At this stage the posterior myodome lodging the external recti muscles, thus consists of only two portions - an anterior intra-cranial and a middle intra-mural sections. The last or the sub-cranial section is lacking now.

III) Cranial Nerves:

The olfactory nerve arises from the lower portion of the olfactory lobe on each side, and runs out of the brain cavity through the membranous aperture, foramen olfactorium evenens in the floor of the brain cavity. Outside the brain cavity, it takes a course between the terminal ends of the superior and inferior oblique eye muscles, in the anterior corner of the orbit (cavum orbitonasale). Further forwards,
the olfactory nerve passes through the foramen olfactorium advehens to supply the olfactory organ, located more anteriorly in the olfactory capsule.

The thick optic nerve originates from the ventrolateral region of the diencephalon just behind the epiphysial bar. After leaving the brain cavity, the optic nerves cross each other, rupturing the membranous inter-orbital septum and pass downwards and forwards into the orbits to supply the eyes of the opposite sides. During the course across the orbit, it runs dorsal to the trabecula communis, the anterior rectus muscle and the orbitonasal artery, but ventral to the internal carotid artery.

The oculomotor nerve arises from the ventro-lateral region of the brain at the level of the facial foramen and travels for some distance in the brain cavity medially to the trigemino-facialis chamber. Further on, it emerges out through the membranous wall of the brain cavity into the orbit running just dorsal to the inferior orbital sinus. Almost immediately it gives off a prominent branch which passes forwards and upwards dorsal to the inferior orbital sinus to innervate the superior rectus muscle. The main branch, however, runs forwards and downwards and after a short distance curves down over the inferior orbital sinus to become median to it and in this position between the sinus and the opthalmica magna artery gives of a small branch which runs inwards closely following the orbitonasal artery for a pretty long distance through the orbit to innervate the inferior oblique muscle. Just after this, the main branch of the nerve closely adhering to the median edge of the inferior orbital sinus turns downwards and divides into three
branches. The innermost passes forwards and inwards over the inferior rectus muscle to supply the anterior rectus eye muscle, while the next one passes ventral to the opthalmica magna artery and supplies the inferior rectus muscle. The outermost branch passes on just below the inferior orbital sinus and further on comes to lie between the sinus and the opthalmic magna artery. Still forwards, it curves again round the median edge of this artery and ultimately runs ventrally to it towards the choroid gland along with the artery.

The trochlear nerve arises behind the origin of the oculomotor nerve. It runs forwards within the membranous side wall of the brain cavity for some distance and emerges out into the dorsal portion of the orbit, median to the orbitonasal vein. In the orbit, it runs forwards dorsally for a pretty long distance between the membranous floor of the brain cavity and the dorsal margin of the eye and more anteriorly it comes close to the median edge of the orbitonasal vein. Further on, it curves downwards to become ventral to it and still ahead it leaves the vein and proceeds downwards to innervate the superior oblique muscle at a point directly ventral to the orbital cartilage.

The trigeminal nerve arises from the ventro-lateral region of anterior portion of the hind brain, behind the origin of the trochlear nerve. After its emergence from the membranous wall of the brain cavity, it swells out to form a large gasserian or trigeminal ganglion partly situated in the trigeminofacialis chamber and partly projecting out into the orbit through its anterior wide opening. The opthalmic branch arises from the antero-dorsal portion of the ganglion and proceeds forwards between the posterior part of the orbital cartilage and
the orbitonasal vein, along with the ophthalmic branch of the facial nerve and just median to it, in the dorsal part of the orbit. Further forwards, the ophthalmic branches of both the facial and trigeminal nerves move outwards along the lower edge of the orbital cartilage and in the region of the optic chiasma onwards, they lie external to the orbital cartilage; but below the lateral line sensory canal just external to the orbital cartilage. More anteriorly the ophthalmic branch proceeds forwards dorso-laterally over the orbital cartilage and its median sphenethmoid commissure and continues further, on either side of the rostral cartilage to innervate the anterior region of the snout.

The maxillary and the mandibularis branches of the trigeminal nerve arises from the lower margin of the gasserian ganglion, from its anterior portion, emerging into the orbital cavity through the wide anterior aperture of the trigemino-facialis chamber, as a thick common trunk. It runs forwards and downwards just external to the posterior rectus muscle and internal, to the hyomandibular muscle in this region and further on becomes ventral to the posterior rectus muscle and dorsal to the quadrate, in the lower region of the orbits. In this position, the main trunk divides into an outer mandibular and an inner maxillary branches. The mandibular branch passes on external to the quadrate and downwards into the lower jaw, where it runs just dorsal and to some extent embedded in the thick mandibular muscle of the lower jaw. Still anteriorly the nerve passes through and become median to the muscle. Further on, at the place of articulation of the quadrate with
the neckels cartilage, the mandibular nerve gives off two slender branches, towards the inner and outer sides of the posterior region of the neckels cartilage. Further forwards, the main nerve runs dorsal to the neckels cartilage and at the place where the coronoid process exists, it proceeds down running on the inner side of the neckels cartilage and further, the dentary bone. The maxillary branch runs along the lower portion of the orbit dorsal to the quadrate and still anteriorly below the inferior rectus eye muscle. Further forwards, it runs external to the pterygoid portion of the pterygo-quadrate bar to innervate the region of the upper jaw. During its course, the main maxillary branch divides into smaller branches some of which again fuse and further on divide into smaller branches. However, the inner most slender branch travels up to the ethmoid region, running up lateral to the ethmoid plate and innervates the anterior region of the head. The next one goes to the buccal region as the buccalis branch. The rest of the branches supply the different portions of the upper jaw.

The abducens nerve takes its origin from the ventro-lateral region of the medulla oblongata, far back near to the origin of the auditory nerve and internal to it. It runs forwards and downwards within the cranial cavity ventrally to the medulla and further on passes inwards, immediately dorsal to the parachordal plate, towards its median free edge. More anteriorly just external to the hypophysial fenestra it penetrates into the intracranial section of the posterior myodome to innervate the external rectus muscle lodged in it.

The facial nerve emanates from the ventro-lateral
region of the medulla behind the origin of the trigeminal nerve and swells out to form a large facial or geniculate ganglion. The major part of this ganglion is located in the trigemino-facialis chamber, just behind the gasserian ganglion and to some extent surrounding its posterior portion (the root by which it is connected to the brain). Anteriorly an ophthalmic branch arises from the facial ganglion and passes forwards just external to the ophthalmic branch of the trigeminal nerve, closely following its path right up to olfactory region and further up to the anterior region of head, passing laterally to the rostral cartilage. Further back the facial ganglion gives off a slender palatine branch, running forwards just dorsal to the orbital artery along the membranous mesial wall of the trigemino-facialis chamber and further on just above the lateral commissure, next (externally) to the external rectus muscle lodged in the intracranial section of the posterior myodome. The palatine nerve then follows closely the course taken up by the external rectus eye-muscle and enters the orbit external to the sub-ocular shelf. In the orbit, it runs inwards close to the ventral margin of the post-palatine portion of the lateral commissure. More anteriorly, it runs inwards and downwards and pass between the orbitonasal artery and the efferent pseudobranchial artery innervating the palate. Thus, as in the case of Belone cancila, (Mrs. Das. 1960) a palatine foramen is absent in Tilapia. Posteriorly the thick ramus hyomandibularis emerges out of the ventral portion of the facial ganglion through the posterior opening of the trigemino-facialis chamber, running externally to the orbital artery but internal to the head vein. Then it turns laterally and backwards to pass through the foramen in
the hyomandibular portion of the hyosymplectic cartilage, after
which it runs downwards external to the latter to supply the
opercular region.

The auditory nerve arises from the side of the medulla
oblongata near the origin of the abducens nerve and passing
downwards and inwards between the brain and the internal ear,
it innervates the sensory areas of the membranous labyrinth.

The glossopharyngeal nerve arises well behind the
origin of the auditory nerve and swells out to form a gloss-
opharyngeal ganglion just below the brain and between the utricle
and the forwardly directed saccular extension, within the brain
cavity. Beyond the ganglion, the nerve passes downwards close
to the inner edge of the saccule and emerges out of the brain
cavity through the separate basisacular foramen. Outside the
brain cavity, it comes to be closely attached to the ventral
side of the basal plate, just above the head-vein in this region.
Further on, the nerve pushes inwards between the basal plate
and the head-vein and divides into three branches. The inner
one curves down closely adhering to the median edge of the head-
vein. Still anteriorly, it runs as a thick nerve below the head
vein and external to the first efferent branchial artery. Fur-
ther forwards, it divides into two branches innervating the
first branchial arch. The next or the pseudobranchial branch,
branching off when the main trunk of the nerve passes median
to the head vein, curves downwards and forwards and runs below
the head vein. Further on, it passes ventral to the ramus
hyomandibularis of the facial nerve in the region of the facial
foramen. Then it proceeds down to innervate the pseudobranch
in the region of the lateral commissure. The palatine branch
runs forwards close to the inner border of the head vein and further front, it runs between the head vein and the orbital artery; still ahead in the region of the facial foramen, it runs just dorsal to the orbital artery and internal to the hyomandibular branch of the facial nerve. It innervates the palate region and runs forwards upto the level of the lateral commissure.

The vagus nerve arises behind the origin of the glossopharyngeal nerve from the dorso-lateral portion of the medulla oblongata and passes vertically downwards between the brain and the posterior semicircular canal in this region. It emerges out of the brain cavity through the fissura metotica. Outside the brain cavity it swells out into a large vagus ganglion. Towards the front, the vagus ganglion gives off the branchiolic branches which in the branchial region, passing just external to the head vein downward, finally innervates the second, third and fourth branchial arches. Posteriorly, however, it gives off two branches, a visceralis which runs obliquely downwards and backwards to supply the visceral organs an outer lateralis nerve running backwards along the side of the body.

IV) Main blood vessels of the head region.

(a) Arteries:

The dorsal aorta proceeds forwards below the notochord, in the occipital region, and just at the level of the anterior margin of the jugular foramen, it receives the common trunk formed by the confluence of different branchial arteries from the third and fourth branchial arches. Slightly anterior to this
branchial arch.

The internal carotid then runs forwards and inwards below the anterior part of the parachordals and soon at the level of the lateral commissure gives off an orbitonasal artery. The latter proceeds further on externally to the carotid artery and passes on to the outer side of the anterior parachordal process, where it is dorsal in position to the efferent pseudo-branchial artery. More anteriorly, it continues external to the slender trabecula (on one side only where it exists) and trabecula communis, passing ventral to the ophthalmica magna artery. Further front, the orbitonasal artery passes between the superior and inferior oblique muscles and ultimately it passes through the foramen olfactorium advehens into the olfactory sac. Beyond the origin of the orbitonasal artery, the internal carotid converges, as it passes forward, and enters the anterior portion of the hypophysial fenestra, finding its way through the space, between the median edge of the parachordals and the lower developing parasphenoid bone. Within the hypophysial fenestra, the internal carotid arteries of both the sides proceed forwards close to the median line; but they remain distinct and do not fuse together, as they do in the advanced stages. A little ahead, each carotid gives off a small posterior cerebral artery to the brain and continues forwards to give rise to an optic artery, passing along the optic nerve to the eye, as its arteria centralis retinae. Beyond this artery, the internal carotid gives off a small anterior cerebral artery and runs across the orbit as the retinal artery to supply the anterior region of the eye.

The blood from the pseudobranch is collected by a large
efferent pseudobranchial artery. It arises from the antero-
median portion of the pseudobranch and passes forwards and up-
wards convergingly. Finally it passes below the orbitonasal
artery and further on below the posterior part of the slender
trabecula (on one side only, where it exists) to enter the
hypophysial fenestra. Here the efferent pseudobranchial arteries
of both the sides communicate with each other by an inward
extension from each of the vessels, which fuse together below
the internal carotid arteries. Beyond this transverse connection
each efferent pseudobranchial artery proceeds further as the
ophthalmica magna artery curving over the trabecula and becoming
now dorsal to the orbitonasal artery. Then it runs across the
orbit just below the inferior orbital sinus and dorsal to the
inferior rectus muscle to supply the choroid gland of the eye.

(b) Veins:

An orbitonasal vein originates from each olfactory
sec and runs backwards, external to the olfactory nerve, through
the foramen olfactorium advehens into the anterior portion of
the orbit. In the orbit, it lies immediately below the superior
oblique muscle; but soon comes to run backwards, just median to
the orbital cartilage close to the lateral portion of the brain
floor in this region. Further back, it passes dorsal to the
trochlear nerve and in the region of the epiphysial cartilage,
it receives a small anterior cerebral vein coming from the dor-
sal surface of the brain. Beyond this region, the orbitonasal
vein moves outwards and runs further backwards beneath the
orbital cartilage. After some distance, the orbitonasal vein
again runs inwards towards the median side of the orbital
cartilage and finally joins the superior orbital sinus coming from the dorsal surface of the eye, in its posterior half. The chief vein of the orbit, however, is represented by the large inferior orbital sinus arising from the ventral region of the eye just behind and dorsal to the place where the optic nerve (along with the optic artery) enters the eye. It proceeds obliquely inwards and backwards external to the anterior rectus muscle in this region and still posteriorly it runs just median to the ophthelmica magna artery. Further back, it runs dorsal to the ophthalmica magna artery and the inferior rectus muscle and then proceeds beneath the main branch of the oculomotor nerve. Soon it receives a small but well developed pituitory vein coming from the hypophysis, at the place where the oculomotor nerve just emerges out of the brain cavity, and then passes backwards to join the superior orbital sinus, above the posterior rectus muscle, forming the head-vein. The pituitary vein from its point of origin from the median portion of the inferior orbital sinus runs in the orbit below the brain floor backwards and inwards and comes to lie just median to the posterior rectus muscle lodged in the intra-orbital section of the posterior dura-mater. It actually pushes its way further between the brain and the cartilaginous skull-floor and finally reaches the median hypophysial fenestra below the pituitary body. In the hypophysial fenestra, the pituitary veins of both the sides fuse together and proceed as a common trunk, for a very short distance backwards. Thus the veins of each side communicate by this hypophysial vein which comes off from the part of the head vein representing the remnant of the original
vena capitis medialis at this stage. The head-vein passes backwards and soon receives a large vein from the hyoid arch in the region of the anterior wide aperture of the Trigemino-facialis chamber, just external to the posterior rectus muscle. Further back, it passes through the trigemino-facialis chamber median to the gasserian ganglion and passes ventral to the geniculate ganglion. Ultimately it comes out through the facial foramen, where it runs internal to the hyomandibular muscle and cartilage but external to the hyomandibular branch of the facial nerve. Still posteriorly, the head-vein runs below the auditory capsule. Since this portion of the head-vein, runs internal to the hyomandibular muscle and cartilage, but external to the hyomandibular branch of the facial nerve, it represents the secondary vein. Further back, the head-vein passes internal to the glossopharyngeal and vagus nerves to join the cuvierian duct.