INTRODUCTION
AND HISTORICAL REVIEW

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The study of the development of the skull in bony fishes is bound up with the recognition of two materials: cartilage and bone, of which the skull is mainly composed, and with the theories concerning the relations of these tissues to one another both anatomically and developmentally.

The chondrocranium is composed primarily of a trough of cartilage, the cavity of which is occupied by the brain, and is more or less open at its dorsal surface. There are three pairs of centers of chondrification which transform into cartilaginous material, from posterior to anterior are:

a. A pair of parachordal cartilages, that laying on either side of the notochord.
b. A pair of polar cartilages: which are small rounded centers above the notochord.
c. A pair of trabeculae cranii, that are elongated centers in front of the polar cartilages.

The floor of the cranium begins by an accumulation of mesenchium cells which are derived from the mesoderm in the neighbour hood of the notochord, both on either side of it and anterior to its level. Somewhat about the middle of the floor of the chondrocranium there is a recess in which the infundibulum rests. The part of the floor of the chondrocranium behind this recess is characterized by having the anterior part of the notochord embedded in it. Thus the distinction is made between the posterior region of the chondrocranium known as the chordal and the anterior region known as prechordal.

Gradually, after the formation of the chondrocranium floor, other chondrified centers arise to form its side walls. The primary cranium becomes fused with the cartilaginous sense capsules surrounding and protecting the sense organs. These are the two olfactory capsules anteriorly, and the two auditory (otic) capsules posteriorly. Cartilage also develops in the sclerotic layer of the two eye balls, but it does not fuse with the chondrocranium due to the fact that the eye ball must remain mobile.

The roof of the chondrocranium is formed by the gradual extension of the cartilaginous matter of the occipital arch region giving the (tectum-synoticum) laying between the two auditory capsules. There is a gradual growth of the upper edges of the auditory capsules as well as the orbital carlitages till the roof is finally formed over the brain. This extension between the two auditory capsules is called (tecta-transversalis). There is a vertical cartilage that connects the tectum synoticum with the tecta transversalis which is known as (taenia-tecti-mediate).

In the neurocranium the chordal part generally makes its appearance as a pair of cartilaginous plates known as the parachordal cartilage, lying one on each side of the anterior part of the notochord. The parachordal cartilages were first so called by ***Huxley (1874)***. They are traceable throughout the vertebrate series, as paired cartilages flanking the notochord and obliterating it in the process of their mutual fusion. Since the earliest classical work of ***Stöhr (1882)*** on the craniogenesis of

Salmo salar and *Salmo trutta* and ***Tichomiroff (1885)*** on *Salmo salar,* more publications were added on the study of the teleostean skull.

There are two types of chondrocranium according to the shape of (trabecula cranii); ***Sagemehl (1891)*** stated the primitive "platybasic type of cranium in *Acipenser, Polypterus, Amia, Lepidosteus* as well as in the Siluoidae and Cyprinoidae among the teleostes.

Van Wijhe (1922) distinguished the primitive platybasic type as the trabeculae which are widely separated throughout the orbitotemporal region, the brain extends forward into the ethmoid region and more or less closely approximated to the cranium floor. However, the tropybasic type is distinguished by the fusion of the trabeculae in front of the hypophysis to form a median bar of cartilage, the trabecula communis.

It was pointed out by ***Van Wijhe (1922)*** that as the variation between the two above-mentioned types is concerned not with the basal plate, but with the trabeculae, it would be more appropriate to refer to the two conditions as "platytrabic" and "tropitrabic".

Norman (1926) studied the development of the chondrocranium of the common Eel and found that the neurocranium is of the "tropibasic" type. He denied the presence of rostral or epiphysial cartilages at any developmental stage. He mentioned the prior fusion of the two trabeculae. Furthermore a very small basicranial fenestra is illustrated at early stages, this becomes enlarged and divided into two by a bridge of cartilage. The same author mentioned that the cavity of the auditory capsule has been provided with the lateral and posterior semicircular septa and no medial wall is developed. The base of the capsule is connected from the beginning with the parachordals by a single anterior commissure of cartilage; the posterior commissure, however appears later. Concerning the splanchnocranium, ***Norman (1926)*** stated that the mandibular arch is represented only by its quadrate portion, the hyomandibular is never fused with the auditory capsule or with the quadrate cartilage and the hypohyals are absent.

De Beer (1937) described the development of the skull of some teleostean fish species. In *Acipenser ruthenus* he mentioned a polar cartilage exists in contact with both the parachordal and trabecula cranii of its side. ***De Beer (1937)*** denied the presence of polar cartilage in *Salmo fario*. He described an early cartilage resorption. In *Salmo salar*, the cartilaginous neurocranial base loses its continuity at the level of hypophysial fenestra. As the development proceeds, the resorption of cartilage becomes more pronounced throughout the whole cartilaginous neurocranium. He mentioned that the rudiments of the ceratobranchials are the first structures to appear in the branchial arch skeleton as independent structures; in *Gadus merlangus, Acipenser ruthenus, Salmo fario and Salmo salar*.

Omarkhan (1950) studied the development of chondrocranium of *Notopterus chilala* contrasting with that of *Salmo* and of *Gymnarchus*. He stated that *Notopterus* has no close resemblance to *Gymnarchus* but is more like the generalized Clupieform chondrocranium of *Salmo*. He denied the presence of the myodomes and the interorbital septum.

Srinivasachar (1953) described the chondrocranium of eight stages of *Ophiocephalus gachua*. This investigation could be regarded as a conclusive contribution to our knowledge of the teleostean chondrocranium. He stated that the trabeculae as well as the parachordals have been developed simultaneously but independently. The trabecula communis develops early. The rostral cartilage arises as a small median and independent piece of cartilage developing above the anterior part of the ethmoid region. The same author found that the sphenoseptal commissure is missing. He stated that, the occipital arches is developed in continuation with the parachordals and no tectum posterius. The quadrate is fused with the hyomandibular and the pterygoid process of the palatoquadrate is discontinuous with the quadrate. The prior appearance of ceratobranchials as independent structures in the branchial arch skeleton.

Tewari (1971) studied the development of the chondrocranium of *Rasbora daniconius* (family Cyprinidae) in seven stages ranging between 3.2 mm and 13.5 mm in length. He found that, the cranial floor is of the "platytrabic" type, and the orbital cartilage is in the form of a continuous bar extending from the auditory capsule up to the ethmoid region, on each side, of the neurocranium. He also established that the infrapharyngobranchials of the first four branchial arches are fused together to form a single cartilaginous plane.

Pashine & Marathe (1977) studied the chondrocranium of some stages of *Cyprinus carpio* (family cyprinidae). They showed that the chondrocranium is of the "tropitrabic" type, and the parachordals are connected to the auditory capsules by means of basicapsular and basivestibular commissures. The same authors added that the basihyal and the basibranchials form a common copula which breaks up into two copulae.

Romanov (1978) studied the development of the chondrocranium of *Salmo oncorhynchus* during postembryogenesis using the craniometric method. He noted lengthening of chondrocranial morphogenesis.

Ismail & Elshabka (1982) and Ismail (1984) studied the postembryonic development of the chondrocranium of the buccal and postbuccal stages of the Nile fish *Tilapia galilaea* (= *Sarotherodon galilaeus*). They stated that the chondrocranium of two buccal stages of the cichlid fish *Tilapia galilaeus* (5 mm & 7 mm length), were of tropitrobic type and were found as single, small median rostral cartilage. The orbital cartilages consist of two continuous plates which were connected by an epiphysial bridge and the auditory capsules were open into the cranial cavity. The branchial arches composed of five pairs of incomplete arches in 5 mm stage while the branchial arches were well developed in 9 mm stage. Two madian copulae are present. The neurocranial pharyngobranchial apophysis, which represents a characteristic feature of the cichlid neurocranium with which the upper pharyngeal jaw articulates, develops from the 9 mm stage. They also stated that the absorption of cartilage was observed early at the same stage and becomes more pronounced in the 12 mm stage.

Soni & Shrivastava (1985) Studied the chondrocranium of the teleost fish *Mollienisia sphenops.* They decided that in the early stages the paraphysial bar lies in the anterior portion of the orbitotemporal region and possesses a taenia tecti medialis posterior. In latter stages it shifts posteriorly, to the middle of the orbitotemporal region. Medially it connects the two orbital cartilages half way along their length. The authors therefore consider the paraphysial bar to be the subsequent epiphysial bar. A posterior shift of the paraphysial bar to become the epiphysial bar is peculiar phenomenon seen during the development of the chondrocranium of *Mollienisis sphenops.*

Amer et al., (1987) studied the development of the skull of *Gambusia affinis affinis*. They compared its chondral neurocranium with other bony fishes and stated that the chondral neurocranium is of the "platytrabic" type, the trabeculae become discontinuous with the parachordals at an early stage (8 mm larval stage). An interorbital septum is absent. The epiphysial cartilage is well developed and extends posteriorly as taenia tecti medialis.

Badenhorst (1989), studied the development of the neurocranium of *Merluccius capensis* from the earliest identifiable stage. The anterior mesenchyme gives rise to the rostral carilage, and lamina orbitonasalis and probably also to the planum ethmoidale. There is no true ethmopalatine articulation, only a rostropalatine articulation. The ethmopalatine articulation is represented by the preorbital ligaments. A cartilago supraentethmoidalis develops but no processeus ethmoideus. A preoptic root is absent only a foramen olfactorium advehens is delimited. A lateral commissure and prootic process, and consequently a trigeminofacilis chamber, are absent. Both the audiotry capsules and the occipital arches take part in the development of the tectum synoticum. The tectum posterius does not develop separately, but as a posterior extension of the tectum synoticum. As regards to the viscerocranium, where its development is described from the earliest identifiable stage, the anterior mesenchyme gives rise to the commissura palatoquadrati, the processus pterygoidous and the lamina orbitonasalis. The latter probably represents a suprapharyngopremandibula and processus pterygoideus an infrapharyngopremandibula. A processus basalis absent and the processus oticus represents a processus oticus internus. The hyomandibula consists of epihyal and laterohyal portions. A single suprapharyngobranchial develops, fused on the fourth epibranchial.

Ismail et al. (1990) described the chondrocranium of the 19 mm larval stage of *Gambusia affinis affinis*. They stated that, the resorption of cartilage and its replacement by bone is pronounced along the whole chondrocranium of this stage. The neurocranial base is provided with an interparachordal fenestra which is entirely occupied by the notochord. The auditory capsules are connected dorsally by a tectum synoticum. The palatoquadrate articulates on the ethmoid region of the neurocranium through the developing autopalatine bone. The hyosymplectic cartilage of the hyoid arch articulates by means of two heads with the ventro-lateral aspect of the auditory capsule. Five branchial arches are present. Each of the branchial arches from (I-IV) are complete, while the fifth branchial arch is represented only by a ceratobranchial. Two median copulae are present on which the branchial arches (I-IV) articulate.

Ismail et al. (1991a) studied the morphology of the chondral neurocranium of three late developmental stages of the cyprinid fish "*Cyprinus carpio*". They described a taenia tecti-medialis formed as a backward extension of the epiphysial bridge. Moreover, they added that the chondral neurocranium shows some reduction of its constituents during the late postembryonic development especially in the orbitotemporal and auditory regions, where the resorption of the cartilage and its replacement by bones are remarkable.

Ismail et al. (1991b) studied the postembryonic development of the mandibular and hyoid arches of the splanchnocranium of *Cyprinus carpio* in six developmental stages. They stated that as development proceeds, Meckel's cartilages become separated anteriorly due to cartilage resorption. Posteriorly Meckels' cartilages articulate with their corresponding palatoquadrates. The palatoquadrate articulates with the ethmoid plate by an ethmopalatine articulation. The hyoid arch consists of the hyosymplectic, the interhyal, hypoceratohyal and a single median basihyal. The interhyal appears as an independent structure in the area between the hyosymplectic and hypoceratohyal.

Ismail & Salama (1991) studied the ontogeny of branchial arches of the splanchnocranium in five developmental stages of *Cyprinus carpio* and found that the five branchial arches arise independently. The branchial arches I-III are quite complete. The fourth branchial arch, however; has no hypobranchial and the fifth branchial arch is represented only by the ceratobranchial. The epibranchials are represented by four cartilaginous pieces articulating with their corresponding ceratobranchials and infrapharyngobranchials. The infrapharyngobranchials arise independent of the corresponding epibranchials in the late stages of development.

Abo-Taira et al. (1992) made studies on the ontogeny of the viscerocranium of *Poecilia reticulata*. They showed that there is an independent chondrification of Meckel's cartilage and palatoquadrate. The hyosymplectic originates from two separate centers of chondrification. The interhyal and the basihyal are completely absent. The hypohyal has a separate center of chondrification. The five ceratobranchials have a prior first appearance as compared with the other branchial elements. The two median copulae develop from two separate centres of chondrification. There are three hypobranchials and four epibranchials.

Ismail et al. (1992) studied the development of the hyoid arch of six postembryonic stages of *Gambusia affinis affinis*. They revealed that the different constituents of the hyoid arch are developed as independent structures during ontogeny. In 10 mm stage, absorption of cartilage with replacement by bone is observed at the level of hyosymplectic and ceratohyal.

Abo-Taira et al. (1994) described the neurocranium of three intermediate stages of *Poecilia reticulata* and detected that the ethmoid plate extends as an anterior prolongation of the trabecula communis. The trabeculae cranii as well as the supraorbital cartilage perform cartilage resorption. The prootic process develops from a separate centre of the otic region.

El-Balshy (1995b) studied the development of chondral neurocranium of *Hypophthalmichthys molitrix*. She stated that, the neurocranium is originally represented by the trabeculae cranii, parachordals, auditory capsules and occipital plates. These elements arise quite independent from each other. The lamina orbitonasalis arises, on each side, as an outgrowth from the postero-lateral side of the ethmoid plate. The latter is elevated dorso-medially to form an internasal septum. The taneia marginalis are developed as discontinuous bars of cartilage. Then, they become two continuous bars. Internally, each auditory capsule is provided with three septa: anterior, middle and posterior.

El-Balshy & EL-Hady (1996) studied the postembryonic development of the branchial arches of the teleost *Hypophthalmichthys molitrix* and they revealed the presence of five branchial arches. The anterior three arches are complete, each consisting of a hypobranchial, a ceratobrancial an epibranchial and an infrapharyngobranchial. The 1st and 2nd ceratobranchials develop in continuation with the anterior copula which is in turn continuous with the basihyal of the hyoid arch, the 3rd, 4th, 5th and ceratobranchials develop as independent cartilages.

Riad (1996) studied the development of the neurocranium of the *Xiphophorus helleri* at early stages. She stated that the neurocranium is typically platytrabic and is composed of the floor elements represented by the trabeculae cranii, polar cartilages and parachordals, as well as the auditory capsules, occipital arches and epiphysial bridge.

El-Balshy (1997) studied the ontogeny of the mandibular and hyoid arches of six postembryonic stages of the teleost fish *Hypophthalmichthys molitrix*, she showed that, the palatoquadrate articulates with the ethmoid plate by an ethmopalatine articulation. The paired constituents of the hyoid arch, vis. The hyosymplectics, interhyals and hypoceratohyals are developed as independent structures during ontogeny. The symplectic and the hyomandibular develop as a single structure, so they are known together as the hyosymplectic. The latter articulates posteriorly with the auditory capsule of the neurocranium. The hypohyal and ceratohyal appears as single elements; hypoceratohyal and articulates anteriorly with the median basihyal and posteriorly with the interhyal. The single basihyal arises in continuation with the anterior copula and first & second ceratobranchials of the branchial arches. As development proceeds the basihyal becomes in continuation with the anterior copula only.

El-Balshy (1999) studied the development of the neurocranium in five prenatal stages of the cyprinodont fish *Xiphophorus maculatus*. The author stated that the neurocranium is of the "platytrabic" type, the trabeculae cranii become discontinuous from the parachordals at an early stage (6.5 mm larval stage) as compared with other bony fishes. She denied the presence of an interorbital septum. The cranium is composed of the trabeculae, polar bars, parachordals, the auditory capsules and occipital plates. The former elements originate independently (2.5 mm total length). The epiphysial cartilage is well developed in continuation with the taeniae marginales which are developed as discontinuous bars of cartilage.

El-Balshy (2000a) studied the development of the viscerocranium of four prenatal stages of the cyprinodont fish *Xiphophorus maculatus*. The study has revealed that the mandibular arch, is composed of the palatoquadrate and Meckel's cartilage which appear early during ontogeny as independent structures in procartilaginous state. The palatoquadrate articulates with the ethmoid plate of the chondral neurocranium by an ethmopalatine articulation. Meckels' cartilages at first appear separate anteriorly. Later in 6.5 mm larval stage, they contact each other anteriorly and they articulate with their corresponding palatoquadrate. All elements of the hyoid arch develop as independent structures during ontogeny. The hyomandibular part of the hyosymplectic arises earlier than the symplectic process. The former plays an essential role in jaw suspension, so that *Xiphophorus maculalus* conforms to the hyostylic made of jaw suspension. Five branchial aches were observed. The branchial arches II & III are complete while, the first branchial arch has no infrapharyngobranchial and the fifth branchial arch is represented only by the ceratobranchial. The fourth branchial arch has no hypobranchial. Median copulae are developed during ontogeny as independent structure in a procartilaginous state (3 mm & 4.5 mm total length, respectively).

El-Balshy et al. (2000) described the development of the neurocranium of five buccal stages of *Oreochromis aureus*. The base of the cranium is of "tropitrabic" type. The trabeculae become discontinuous with the parachordals at early stages (6 mm buccal stage) as compared with other bony fishes. In the orbitotemporal region of the neurocranium, the taeniae marginales are developed as discontinuous bars of cartilage and the epiphysial bridge is developed as an independent cartilage. The parachordals are anteriorly separated from each other by the hypophysial fenestra and the anterior end of the notochord. In the middle, they are connected with each other forming the prootic bridge, and posteriorly, they are still separate, on each side, by the notochord.

The review of the above literature shows that the development of the skull in fishes belonging to the family Cyprinidae, has received little attention. Accordingly, the present work has been suggested to fill a noticeable gap in the development of the teleostean skull.

The present study is a new contribution to the knowledge of the teleostean carniogenesis. It deals with the chondrogenesis of a member belongs to family Cyprinidae; *Ctenopharyngodon idella*. This study is based on graphic reconstructions and includes all the accurate details of six developmental stages of *Ctenopharyngodon idella*.