

DISTINCTIVE SKULL CHARACTERS IN SPECIES
OF THE GENUS *AMBYSTOMA**

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INTRODUCTION

The skulls of amphibia in the order Caudata show interesting modifications and differ much from one another, but all agree in the following respects: (1) absence of the quadratojugals; (2) a parallel relation of the palatines or vomeropalatines with the axis of the cranium; and (3) the large size of the parasphenoid.

The separation of the frontal and parietal bones and the occurrence of paired orbito-sphenoids are characteristic.

Lower types such as *Necturus*, *Siren*, *Proteus*, and *Amphiuma*, have a long, narrow type of skull which throughout life remains in much the same condition as that of a tadpole or larval salamander. Internal to the membrane bones the roof and floor of the cranial vault are formed of fibrous tissue and not of well developed cartilage. The epi-otic regions of the skull are ossified, forming large bones external to and distinct from the exoccipitals. The *Stegocephalia* are the only other amphibia which have these elements separately ossified. Nasals are sometimes present, sometimes absent. Teeth are usually borne on the vomers, premaxillae, pterygoids, dentaries, and angulosplenials. The suspensorium is directed forward.

Higher types of amphibia, such as the salamanders, have broad, wide skulls. In these the suspensorium is found projecting nearly at right angles to the cranium, instead of being forwardly directed. The maxillae are usually well developed, and the premaxillae are completely ankylosed together. There are no palatines. In the otic region the prootics are found distinct from the exoccipitals, and the latter are ossified continuously with the epi-otics and opisthotics.

Of the family *Ambystomidae*, Cope (1887) says: "The *Ambystomidae* are of particular interest in the Urodela as furnishing connecting links between the ordinary types of the order and those larger species which we suppose to be characteristic of former periods of the earth's history. It also furnishes us with transitional conditions

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of characters which have been regarded as indicating very diverse origin and nature." The species are mostly of large size, and probably confined to North America with the exception of a species in India.

A rather large series of characters restricts the family. The ethmoid bone is lacking. There is a fusion of vomer and palatine to form the vomero-palatine. The palatine portion is a pointed process which projects laterally from the parasphenoid. The orbito-sphenoid is separated from the prootic by a tough, membraneous wall. The internal wall of the vestibule is ossified. There are conspicuous pre-frontals and pterygoids present, and the premaxillae are fully developed. Dentigerous plates are lacking on the parasphenoids.

This paper involves a comparative study of the skulls of six species in the genus *Ambystoma*. Distinctive characters are analyzed in terms of the factors affecting developmental mechanics. The significance of the genus and the importance of a comparative skull study are also discussed.

The entire genus numbers eleven species. The names of these, and their distribution, are listed below, after Stejneger and Barbour (1923).

Name	Range
<i>A. annulatum</i> Cope—Arkansas.	
<i>A. cingulatum</i> Cope—South Carolina to north; Florida and Alabama.	
<i>A. decorticatum</i> Cope—Coastal region of south; Alaska and British Columbia.	
<i>A. jeffersonianum</i> Green—Canada (to Hudson Bay) and New England, south to Virginia, Illinois, and Arkansas.	
<i>A. macrodactylum</i> Baird—Northern California, to British Columbia, Idaho, and Montana; probably to and in Iowa.	
<i>A. maculatum</i> Shaw—Nova Scotia west to Wisconsin, southward to Georgia and Texas.	
<i>A. microstomum</i> Cope—South Carolina to Texas; north to Ohio, Illinois, and possibly Canada.	
<i>A. opacum</i> Gravenhorst—Massachusetts to Florida; west to Louisiana and Texas, Mississippi basin north to Arkansas, Missouri, Indiana, and Illinois.	
<i>A. paroticum</i> Baird—Northern California, to British Columbia, Vancouver Island.	
<i>A. talpoideum</i> Holbrook—South Atlantic and Gulf States, Louisiana to Illinois.	
<i>A. tigrinum</i> Green—Widely distributed over almost all United States, each of the Cascade Range and Sierra Nevada, and extending southward over the northern portion of the Mexican plateau.	

Ambystoma texanum, formerly listed as a separate species, is now considered as identical with *A. microstomum*. The names *Siredon*, *Axolotl*, *S. pisciformis* and *S. mexicanus* are still used for denoting the persistent larval condition of *A. tigrinum*.

OSTEOLOGY OF *AMBYSTOMA OPACUM*

The description which follows will answer in general for any of the species as far as identification of the bony elements is concerned. It is chosen because it represents a sort of intermediate type, having neither an excessively broad brain case, nor one especially elongate.

The Dorsal View of the Skull

The skull (fig. 1) presents a series of smooth, graceful arcs and curves which immediately suggest a symmetry of the whole. Considering the various paired elements, this symmetry is more apparent than real. The antero-lateral part of the skull describes a partial ellipse, the anterior part of which is formed by the premaxillae (pm) meeting together in the midline and articulating with the maxillae (m) laterally and posteriorly. These bones extend the arc to about half the linear dimension of the skull, which is slightly longer than it is wide. Along the mid-dorsal plane the premaxillae also send up large, blade-like frontal processes (fpm) which are closely approximated anteriorly, but diverge slightly in the posterior direction. Laterally they overlap the nasals (n), and posteriorly the frontals (f). It is a general rule that the anterior bone overlaps the element posterior to it. The maxillae, near their junction with the premaxillae, send up an ascending ramus (ar) which articulates with the prefrontals (pf) laterally. The nasolacrimal duct bears a relation to it medially and posteriorly (nld). The external nares (nc), oval in shape, are immediately back of the premaxillae and originally are covered by membrane and a nasal roof cartilage. A small bony element, the septomaxillary (sm) is found in the nasal capsule near the ramus of the maxilla. It is irregular in shape and bent upon itself medially, where it faces the naso-lacrimal duct. A foramen is usually evident in the bone. Primarily it serves for the origin of the muscle dilator naris accessorius. In the Urodela it is found to be an ossification of the cartilage in the posterior wall of the nasal cavity. The work of Lepage (1928) indicates "a chondral origin for the septum." Gaupp considered the homology of the bone in anurans, urodeles, and sauropsida as settled.

The nasals (n) are thin plates of bone, irregular in contour but approximating a wedge. Each bone presents a straight margin toward the nasal process of the premaxilla; a slightly concave margin toward the external nares; and a somewhat convex lateral border which articulates with the prefrontal and is extended posteriorly to articulate with the frontal.

