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Development of the median fins of the North American paddlefish (*Polyodon spathula*), and a reevaluation of the lateral fin-fold hypothesis

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Abstract

To understand more about the structure of median fins of "lower actinopterygians" (that is, actinopterygians outside of Neopterygii), we investigated development of median fins in the North American paddlefish, *Polyodon spathula* (Acipenseriformes: Polyodontidae). We observed that dorsal and ventral median fin-folds form during the embryonic period, and are well-developed by hatching (stage 36). Fin-webs of both the dorsal median fin-fold and ventral median fin-fold greatly narrow at the posterior tip of the body, so that the notochordal axis reaches the most caudal point of the body. The three median fins (dorsal, anal and caudal) differentiate rapidly from the median fin-folds during the yolk-sac larval period (stages 36 to 46). The order of differentiation is dorsal, anal and caudal, which reflects the general gradient of development from anterior to posterior. Myotomes extend first into middle portions of dorsal and anal fins. Cartilage condensations that will form radial elements and bundles of actinotrichia that will contribute to fin-rays also develop first in the middle portions of these fins. Radial skeletal elements of dorsal and anal fins differentiate in this order: middle radials, proximal radials, and finally distal radials. Juveniles have only slightly fewer radials in the dorsal and anal fins than do adults. Thus, fin endoskeletons are essentially fixed by metamorphosis, that is, about 39 days old, when fin shapes approximate those of adults, and adult coloration and feeding mode are achieved.

Pectoral and pelvic fins of *Polyodon* share a skeletal design (based on radial elements) with dorsal and anal fins. In contrast, the endoskeleton and exoskeleton of the caudal fin differ from those of the dorsal, anal and paired fins. Unlike other fins, myotomal extensions do not contribute to either the epichordal or hypochordal lobes of the caudal fin. Dorsally, the epichordal lobe develops from a portion of the dorsal median fin-fold, and its endoskeleton consists of a series of supraneural elements and neural arches; in contrast, such elements do not participate in formation or support of the dorsal fin. Fulcra form along the leading edge of both the epichordal and hypochordal lobes of the caudal fin; in contrast, fulcra are absent from dorsal, anal and paired fins. Ventrally, the hypochordal lobe forms from a portion of the ventral median fin-fold, and its endoskeleton consists chiefly of a series of hypural bones that is serially homologous with hemal arches and spines; in contrast, such elements do not participate in formation or support of the anal fin. The caudal fin also has a few so-called distal caudal radials of uncertain homology.

A small preanal portion of the ventral median fin-fold persists between the anus and yolk-sac throughout the yolk-sac larval period. Neither myotomes nor cartilage condensations contribute to this preanal fin, and it is lost during further development. Pelvic fin-buds develop later (stage 38) than do median fins (<stage 36). Median fin-folds are never continuous with the pelvic fin buds. A wide stretch of flank separates the pelvic and pectoral fin-buds, with no trace of a continuous fin-fold between them.

For more than a century, the structure and development of fins of Acipenseriformes have been studied by authors primarily interested in evolution of gnathostome fins. Fins of Acipenseriformes and other gnathostomes have been interpreted through many hypothetical (that is, non-empirical) models, which now are entrenched in the literature. We reevaluate some of the conclusions and extrapolations of these models, and concepts related to the lateral fin-fold hypothesis. We find little developmental or phylogenetic support for most of these ideas, and urge a retreat from such idealistic morphology.

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