Synopsis of Vertebrate Evolution
Agnathans & Gnathostomes

BIO308/508 Comparative Anatomy
Early agnathans (jawless vertebrates)
Hagfish from the Cretaceous Tethys Sea and a reconciliation of the morphological–molecular conflict in early vertebrate phylogeny

Tetsuto Miyashita, Michael I. Coates, Robert Farrar, Peter Larson, Philip L. Manning, Ray A. Wogelius, Nicholas P. Edward, Jennifer Ansell, Uwe Bergmann, A. Richard Palmer, and Philip I. Currie

Current Phylogeny

Current Phylogeny

Updated Cyclistone Hypothesis

Hagfish and lampreys (cyclostomes) represent the only living lineages of jawless vertebrates (or agnathans). (1) Cyclostomes are generally considered primitive morphologically with respect to jawed vertebrates (gnathostomes) (1, 2). However, controversy is still lacking about cyclostome relationships. None of the traits proposed to unite hagfish and lampreys sets them apart clearly from extinct lineages of jawless vertebrates (3, 4). Furthermore, characters distribute asymmetrically. Hagfish have fewer traits than lampreys in common with gnathostomes, and are characterized by rudimentary state or absence of otherwise plesiovertebrate traits such as electrosensors or tangibods (3, 5). Thus, resolving the cyclostome relationships holds direct implications for defining the vertebrate crown group, and for defining the origin and early radiation of gnathostomes. Detailed morphological analysis of hagfish and lampreys is required to clarify the relationships among these two groups. Although trunk morphology has been extensively described in hagfish and lampreys, no consensus exists among different studies or authors about which characters are specific to hagfish or lampreys, or even which characters are homologous. The need for a comprehensive morphological analysis in hagfish and lampreys is becoming evident as new fossil hagfish and lampreys are being discovered in the Cretaceous Tethys Sea. Hagfish and lampreys are the only living lineages of jawless vertebrates, and their relationships with gnathostomes are of fundamental importance in understanding the evolution of vertebrates. The relationships among hagfish and lampreys are still controversial, and the morphological analysis of these two groups is required to clarify their relationships with gnathostomes. The relationships among hagfish and lampreys are also important for understanding the evolution of vertebrates, as hagfish and lampreys represent the only living lineages of jawless vertebrates. The relationships among hagfish and lampreys are still controversial, and the morphological analysis of these two groups is required to clarify their relationships with gnathostomes. The relationships among hagfish and lampreys are also important for understanding the evolution of vertebrates, as hagfish and lampreys represent the only living lineages of jawless vertebrates.
Lamprey
Hagfish
Major Groups of Gnathostomes
Caudal fins

Hypocercal Caudal fin
Pharyngolepis
median dorsal scutes

external branchial openings
pectoral spine
paired fins
anal fin
anal spine

Caudal skeleton of Polyodon (heterocercal)
Notochord
Hypurals
Fin rays (cut)
Centrum

Caudal skeleton of Amia (abbreviated heterocercal)
Hypurals
Fin rays (cut)
Centrum

Caudal skeleton of Elops (homocercal)
Epural
Uroneural
Centrum

Caudal skeleton of Latimeria (diphycercal)
Epural
Uroneural
Centrum

Row of trunk scutes
Dorsal fin
Anal fin
Heterocercal caudal fin
Pelvic fin
Pectoral fin
Barbels
Nares
Acipenser

reduced heterocercal tail

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