Recent Advances in the Origin and Early Radiation of Vertebrates
G. Arratia, M. V. H. Wilson & R. Cloutier (eds.): pp. 321-343, 12 figs., 4 apps.
 – ISBN 3-89937-052-X

Changing patterns of ontogeny from osteolepiform fish through Permian tetrapods as a guide to the early evolution of land vertebrates

Robert L. Carroll, Catherine Boisvert, John Bolt, David M. Green, Noah Philip, Campbell Rolian, Rainer Schoch & Anna Tarenko

Abstract

Larval stages of both recent and fossil amphibians provide an added dimension – ontogenetic change – that can be used for phylogenetic analysis. This is especially important in regard to the origin and early radiation of tetrapods. A continuous growth series in *Eusthenopteron* shows that a close sister taxon of tetrapods had direct development, without a recognizable larval stage. Gilled larvae of labyrinthodonts are known no earlier than the Upper Carboniferous, although they may have evolved by the Viséan. There is little evidence as to whether the larval stages of temnospondyls and seymouriamorphs evolved from a common ancestry, or by convergence. All lepospondyls show direct development, with even the smallest fossils resembling the adults in body proportions and in possessing highly ossified vertebral centra but lacking external gills. The ancestry of the three "lissamphibian" orders can all be traced to separate Paleozoic lineages, based on both adult anatomy and the pattern of larval development. Frogs and primitive salamanders share similarities with temnospondyls in having gilled larvae, and in the rate and sequence of vertebral development. The sequence of ossification of the skull bones of conservative extant salamanders is identical with that of the early larval stages of the branchiosaur *Apateon*. The adult cranial morphology of extant salamanders could have been achieved by truncation of ossification prior to the appearance of additional skull bones that developed at a later stage in Paleozoic temnospondyls. The ancestors of salamanders may have been facultatively neotenic, with long periods of larval development, but the antecedents of frogs may have gone through a period of direct development before evolving the highly specialized tadpole larvae. Caecilians resemble lepospondyls in the rapidity of vertebral ossification. Most caecilians lose the external gills soon after hatching, which might have been the case in lepospondyls.

Devonian fish and amphibians

Amphibians have long been recognized as transitional forms – broadly intermediate between fish and fully terrestrial tetrapods, the amniotes. Many living amphibians, including the bulk of the more primitive species, depend on standing water for reproduction and go through an aquatic larval stage before metamorphosing into terrestrial adults. Many Paleozoic tetrapods that retain lateral line canals and/or aquatic larvae as well as primitive osteological characters shared with osteolepiform fish, are also referred to as amphibians although their affinities with modern amphibian orders remain contentious.

The biphasic life history of many amphibians reflects their origin from obligatorily aquatic forms, but also makes it possible for them to adapt to divergent habitats and ways of life. Fossils of larvae enable paleontologists to study an essentially embryonic stage in their life history, not available in other vertebrate taxa, that provides additional characters to aid in their classification.

Detailed studies of primitive, Upper Devonian tetrapods by CLACK (2000) and COATES (1996) provide extensive evidence that their closest known sister taxon among fish is the genus *Panderichthys*, but the best known of closely related fish is the tristicopterid *Eusthenopteron* (ANDREWS & WESTOLL 1970, JARVIK 1980). We not only have very detailed knowledge of the osteology of adults of *Eusthenopteron*, but

The whole contribution can be purchased as PDF file.

Availability

Generally all our publications are available as PDF files; full publications as a general rule after the printed version is out of print. If you have questions concerning particular contributions please contact us by e-mail:
pdf@pfeil-verlag.de.

The PDF files are protected by copyright.

The PDF file may be printed for personal use.
The reproduction and dissemination of the content or part of it is permitted.
It is not allowed to transfer the digital personal certificate or the password to other persons.

Prices

Books: Prices are to be found in the catalog.

Articles in journals and single contributions or chapters in books:

10 EURO basic price per order (including the first 10 pages),
and
0.50 EURO per page, beginning with the 11th page.

Page numbers are found in the contents of the publications.

Orders

Use our order form for PDF files or send your order informal per e-mail (pdf@pfeil-verlag.de). The only accepted payment is by credit card. While using the order form for PDF files, your data will be transmitted by secure link (ssl). You also may send the informations informally by e-mail, fax, phone or mail.

Handling

As soon as possible, depending on our business hours and your order, you will receive your PDF file together with the certificate and password by e-mail.
Larger PDF files can be downloaded from our webspace, if necessary.
Your invoice will be sent out by e-mail after we charged your credit card.

To open the encrypted PDF files you have to install your personal certificate after your first order. All PDF files with the same certificate can be opened from that time on.

Dieser Beitrag kann als PDF-Datei erworben werden.

Verfügbarkeit von PDF-Dateien
Prinzipiell sind von allen unseren Publikationen PDF-Dateien erhältlich. Komplette Publikationen in der Regel erst nachdem die gedruckte Version vergriffen ist. Anfragen bezüglich bestimmter Beiträge richten Sie bitte per E-Mail an pdf@pfeil-verlag.de.

Die PDF-Dateien sind urheberrechtlich geschützt.
Ein Ausdruck der PDF-Dateien ist nur für den persönlichen Gebrauch erlaubt.
Die Vervielfältigung von Ausdrucken, erneutes Digitalisieren sowie die Weitergabe von Texten und Abbildungen sind nicht gestattet.
Das persönliche Zertifikat und das Passwort dürfen nicht an Dritte weitergegeben werden.

Preise
Bücher: Die Preise sind dem Katalog zu entnehmen.
Zeitschriftenbeiträge und einzelne Kapitel aus Sammelbänden bzw. Büchern:
10 EURO Grundbetrag pro Bestellung (einschließlich der ersten 10 Seiten),
und
0,50 EURO pro Seite ab der 11. Seite.
Den Umfang der Beiträge entnehmen Sie bitte den Inhaltsverzeichnissen.

Bestellungen
Bestellungen sind mit dem PDF-Bestellformular oder formlos per E-Mail (pdf@pfeil-verlag.de) an uns zu richten. Die Bezahlung ist ausschließlich per Kreditkarte möglich. Bei Verwendung unseres Bestellformulars werden die Kreditkartendaten über eine gesicherte Verbindung (ssl) übermittelt. Sie können die Daten aber auch formlos per E-Mail, Fax, Post oder telefonisch übermitteln.

Abwicklung
So bald wie möglich, aber abhängig von unseren Bürozeiten und der gewünschten Bestellung, schicken wir Ihnen die PDF-Datei(en) zusammen mit Ihrem persönlichen Zertifikat und dem zugehörigem Passwort per E-Mail. Größere Dateien bieten wir Ihnen gegebenenfalls zum Herunterladen an.
Der fällige Betrag wird von Ihrer Kreditkarte abgebucht und Sie erhalten die Rechnung ebenfalls per E-Mail.
Um die verschlüsselten PDF-Dateien öffnen zu können, muss bei der ersten Bestellung das passwortgeschützte persönliches Zertifikat installiert werden, welches anschließend auf dem Rechner verbleibt. Alle mit diesem Zertifikat verschlüsselten Dateien können anschließend auf diesem Rechner geöffnet werden.

This is especially important in regard to the origin and early radiation of tetrapods. A continuous growth series in Eusthenopteron shows that a close sister taxon of tetrapods had direct development, without a recognizable larval stage. Gilled larvae of labyrinthodonts are known no earlier than the Upper Carboniferous, although they may have evolved by the Vis??an.Â Carroll RL, Boisvert C, Bolt J, Green DM, Philip N, Rolian C et al. Changing patterns of ontogeny from osteolepiform fish through Permian tetrapods as a guide to the early evolution of land vertebrates. In Arratia G, Wilson MVH, Cloutier R, editors, Recent Advances in the Origin and Early Radiation of Vertebrates. First ed. Here, the fishâ€“tetrapod transition is represented by the osteolepiform fish Eusthenopteron (3) and the Devonian tetrapod Acanthostega, the best-known early tetrapod (14). Although Panderichthys and Elpistostege are more closely related to tetrapods than Eusthenopteron is (8), we did not have access to any panderichthyid specimens so those taxa were not included.Â In contrast to the â€œtension anteriorly, compression posteriorlyâ€ strain pattern found in the unequivocally aquatic Polypterus and Eusthenopteron, the terrestrial tetrapod Phonerpeton exhibits compression between the frontals and parietals and a possible tension-compression shift denoting complex loading between the postparietals (Fig.