Origem dos Tetrapoda:

A conquista do ambiente terrestre

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Dept. Zoologia IBUSP

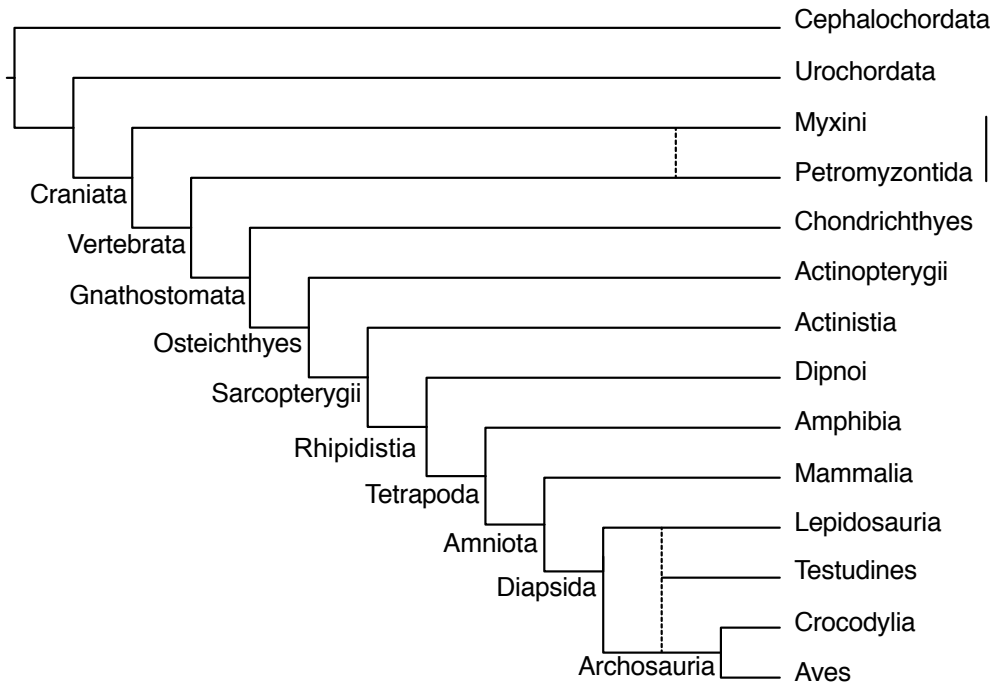
Objetivos da aula

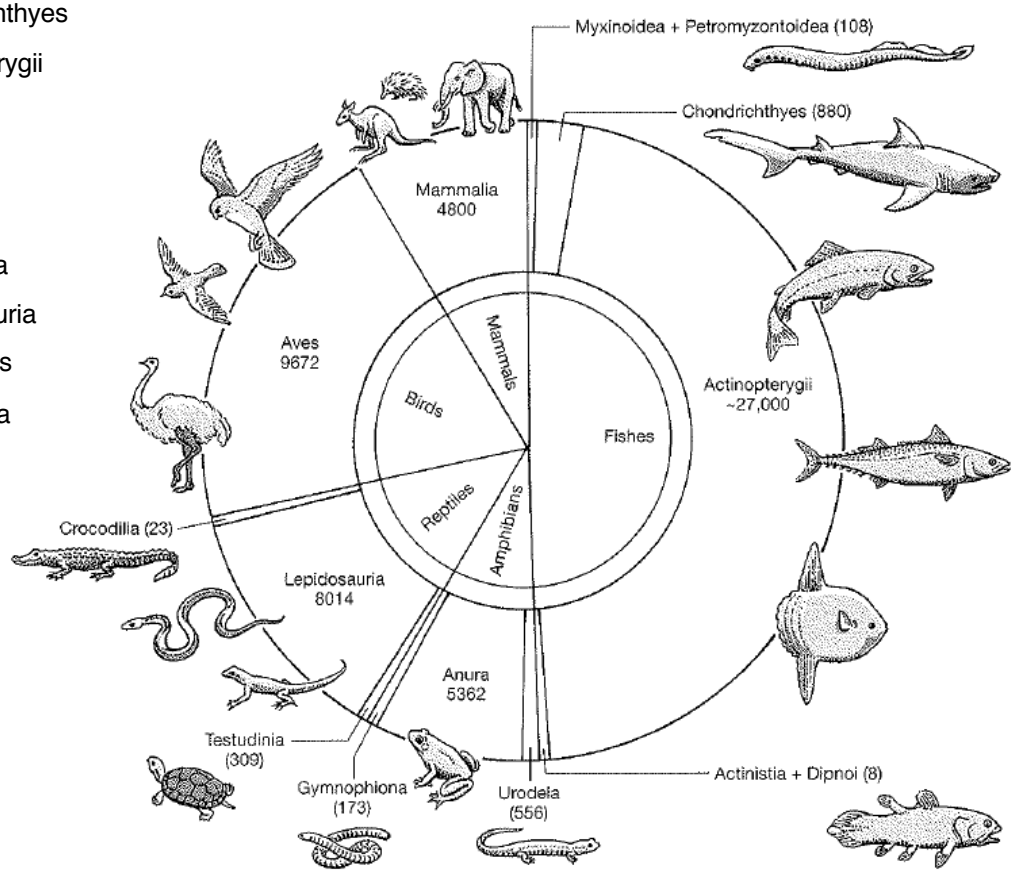
Contexto histórico e ambiental

Principais grupos fósseis transicionais

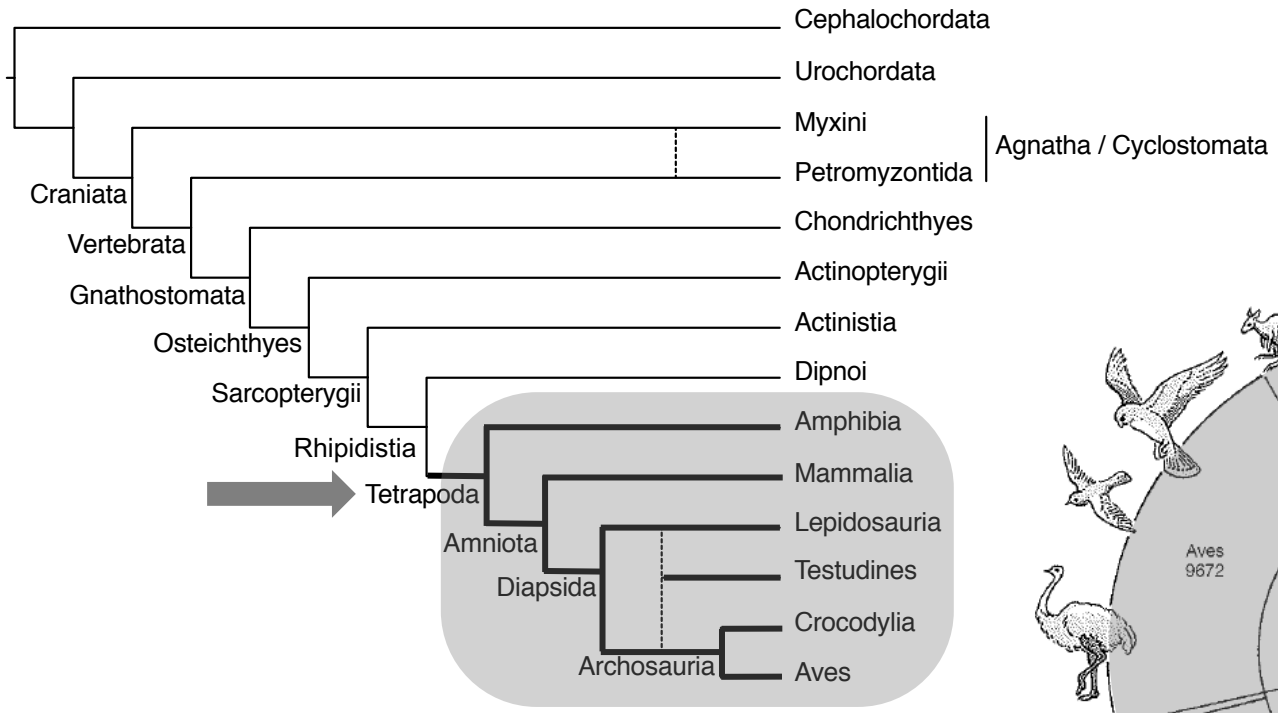
Morfologia e adaptações

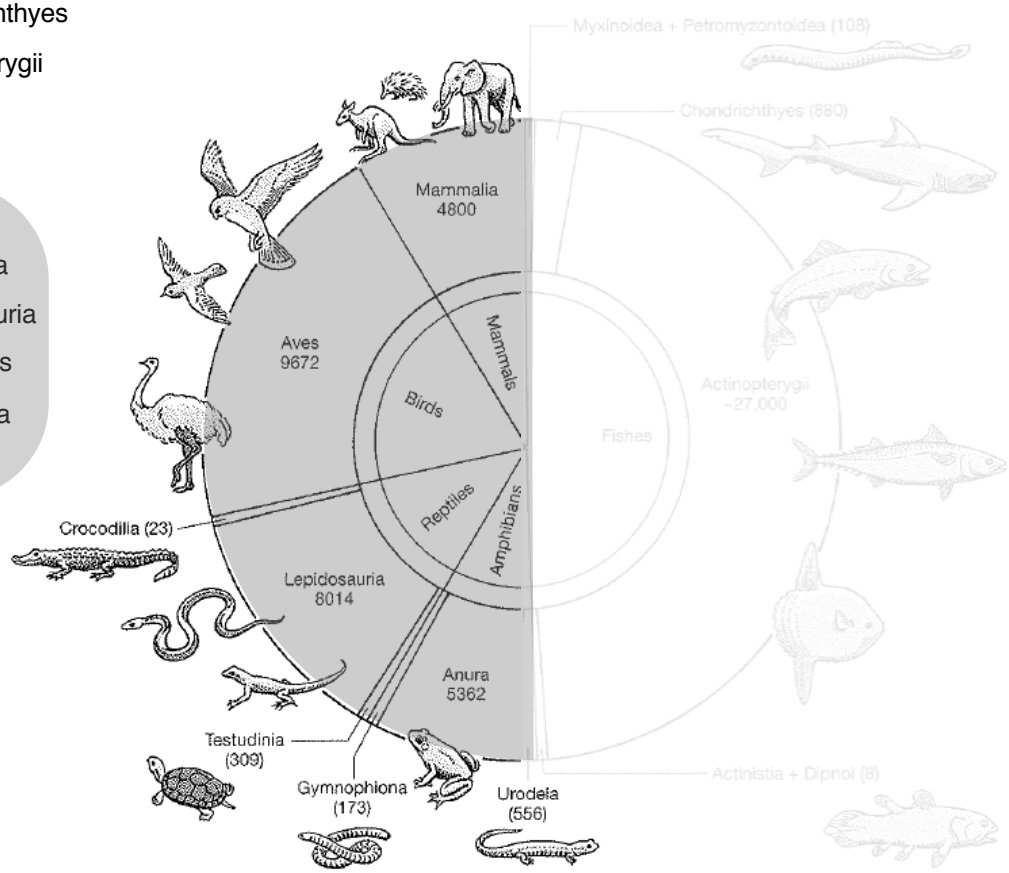
Diversidade de Tetrapoda



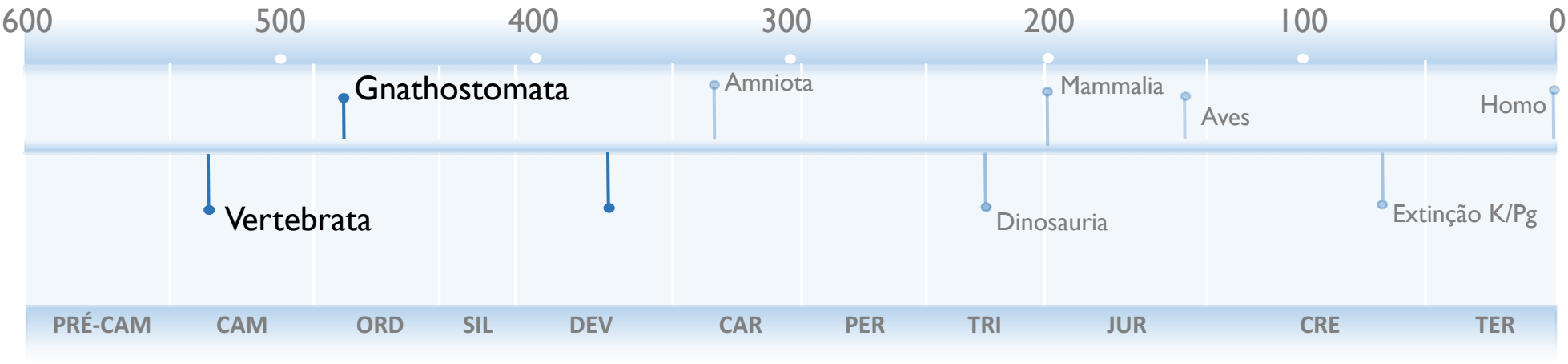


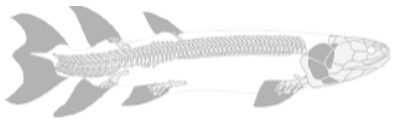
Diversidade de Tetrapoda





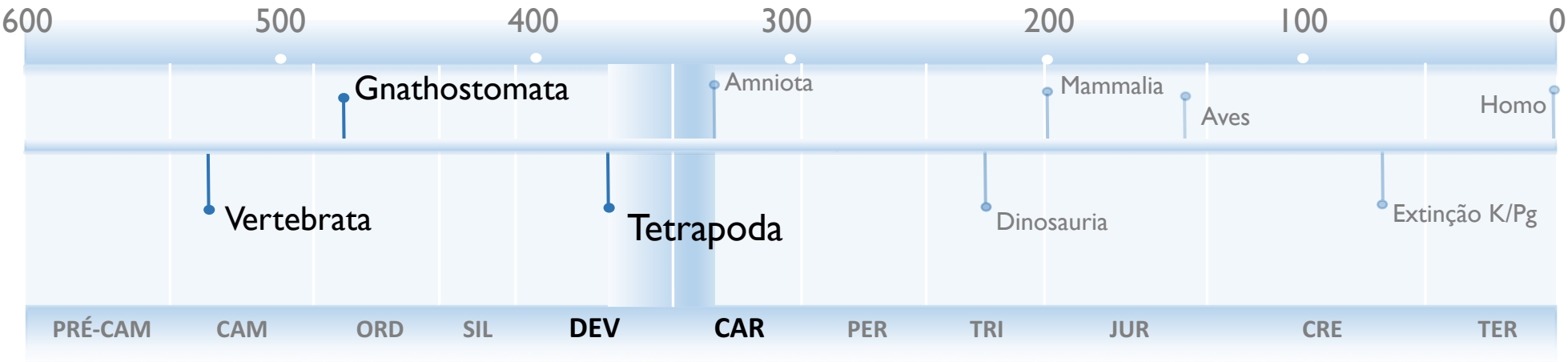
Evolução dos vertebrados e surgimento dos Tetrapoda





Evolução dos vertebrados e surgimento dos Tetrapoda

Períodos DEVONIANO e CARBONÍFERO: **surgimento** e **irradiação**



Transição ao ambiente terrestre

Sustentação e locomoção

- Esqueleto axial e apendicular

Respiração

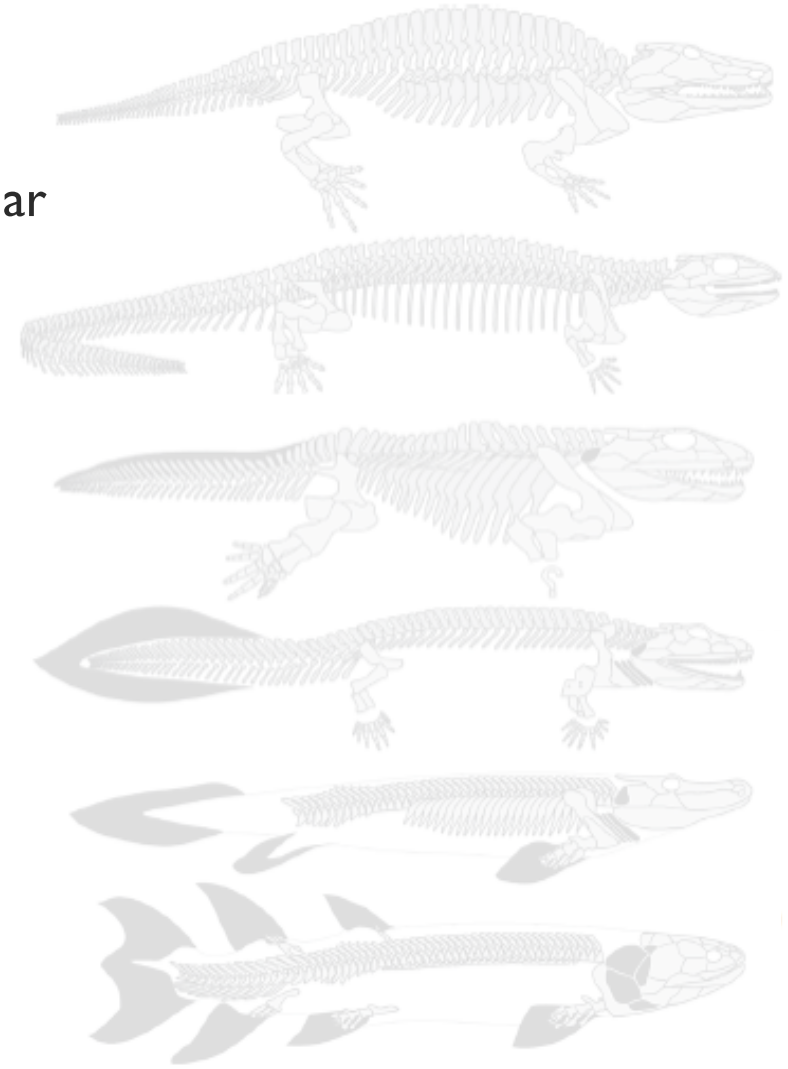
Alimentação

- Crânio e cintura escapular

Excreção, Reprodução

Órgãos sensoriais

- Visão
- Olfação
- Audição



Período Devoniano

Era dos peixes

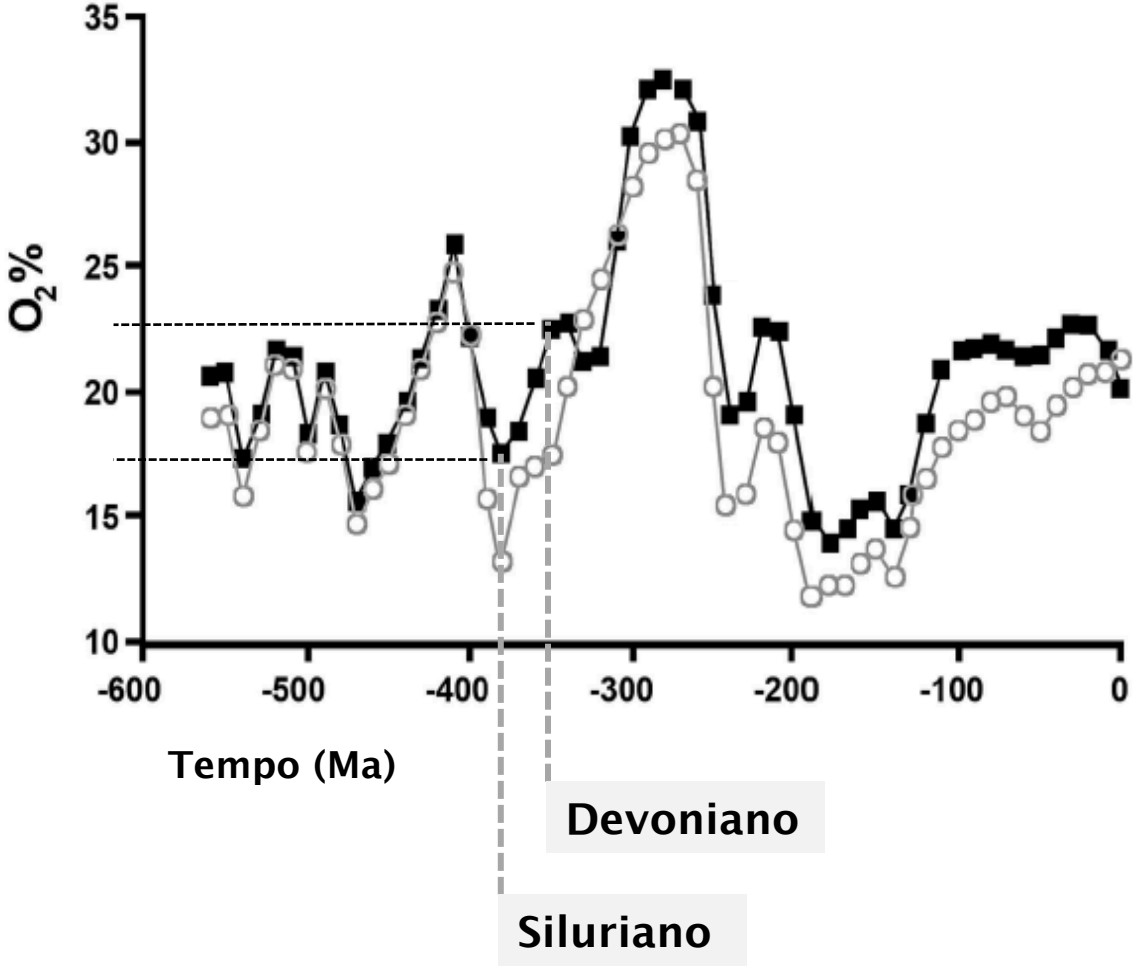
Artrópodes
1os insetos

Expansão de florestas

Gimnospermas

↓ CO_2 ↑ O_2

Variações históricas nas concentrações de O_2



Siluriano

↑ CO_2 ↓ O_2

Ambientes terrestre e aquático

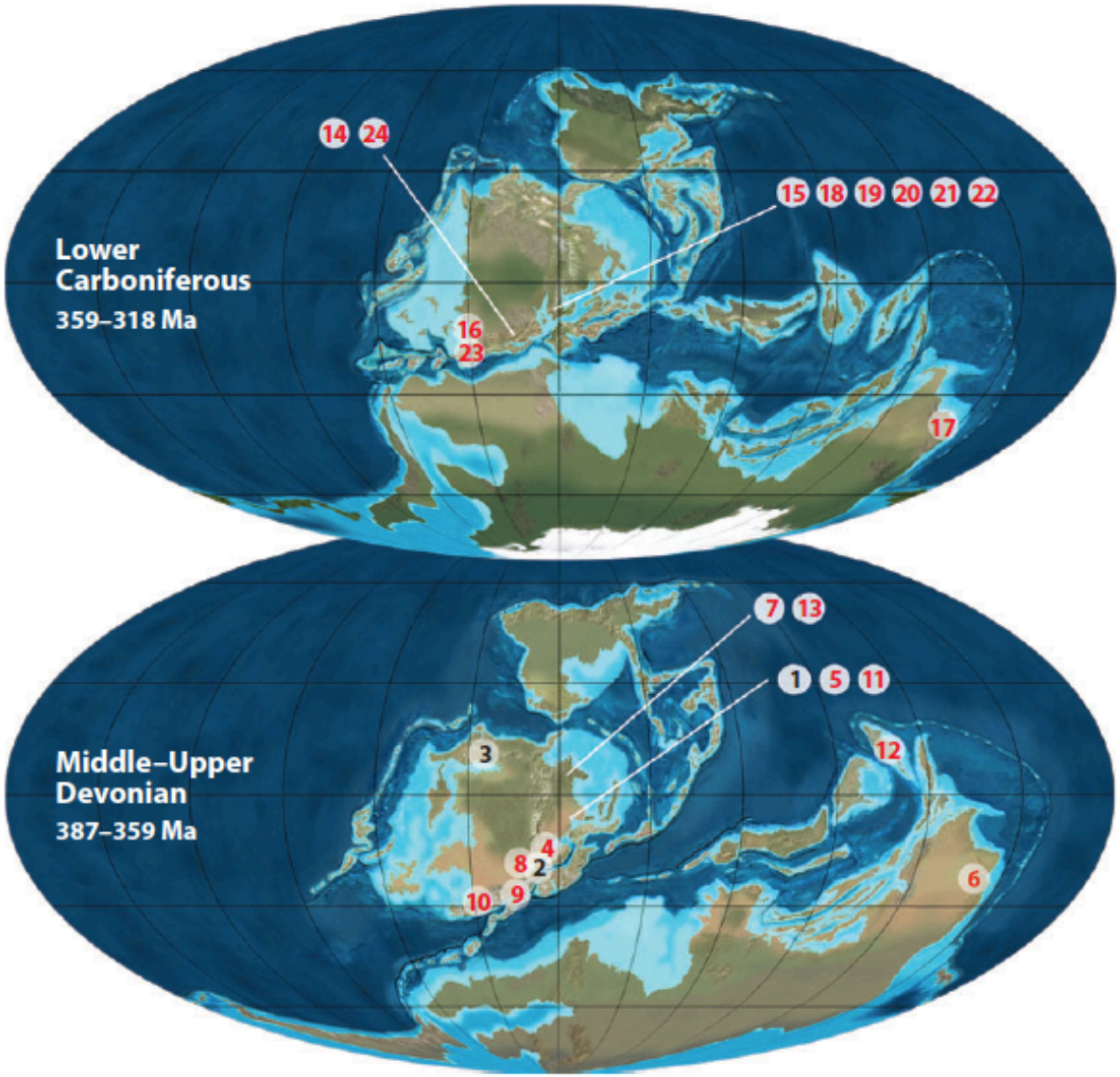
Respiração aérea

Devoniano

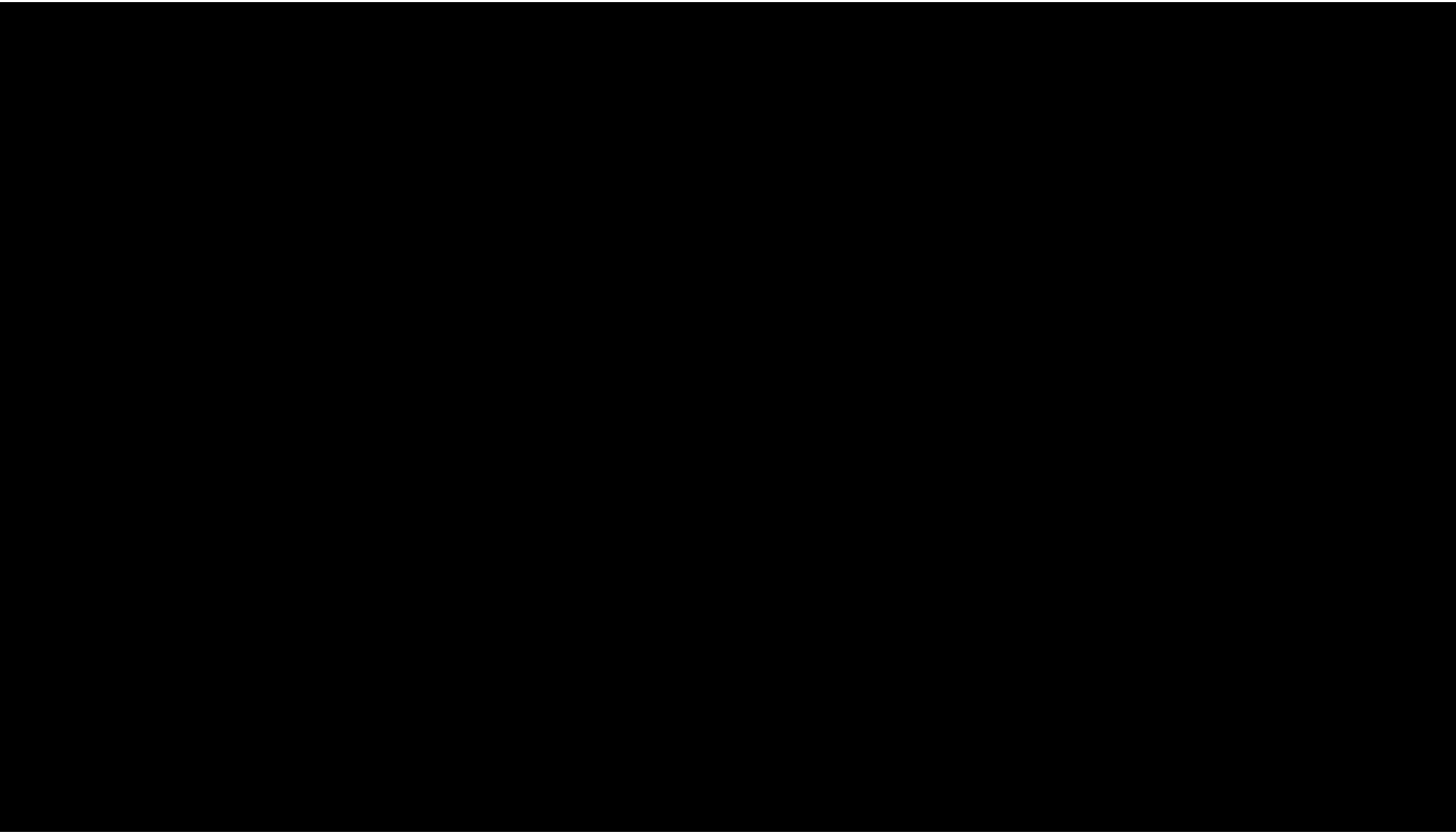
↓ CO_2 ↑ O_2

Adaptado de Ward & Berner (2010)

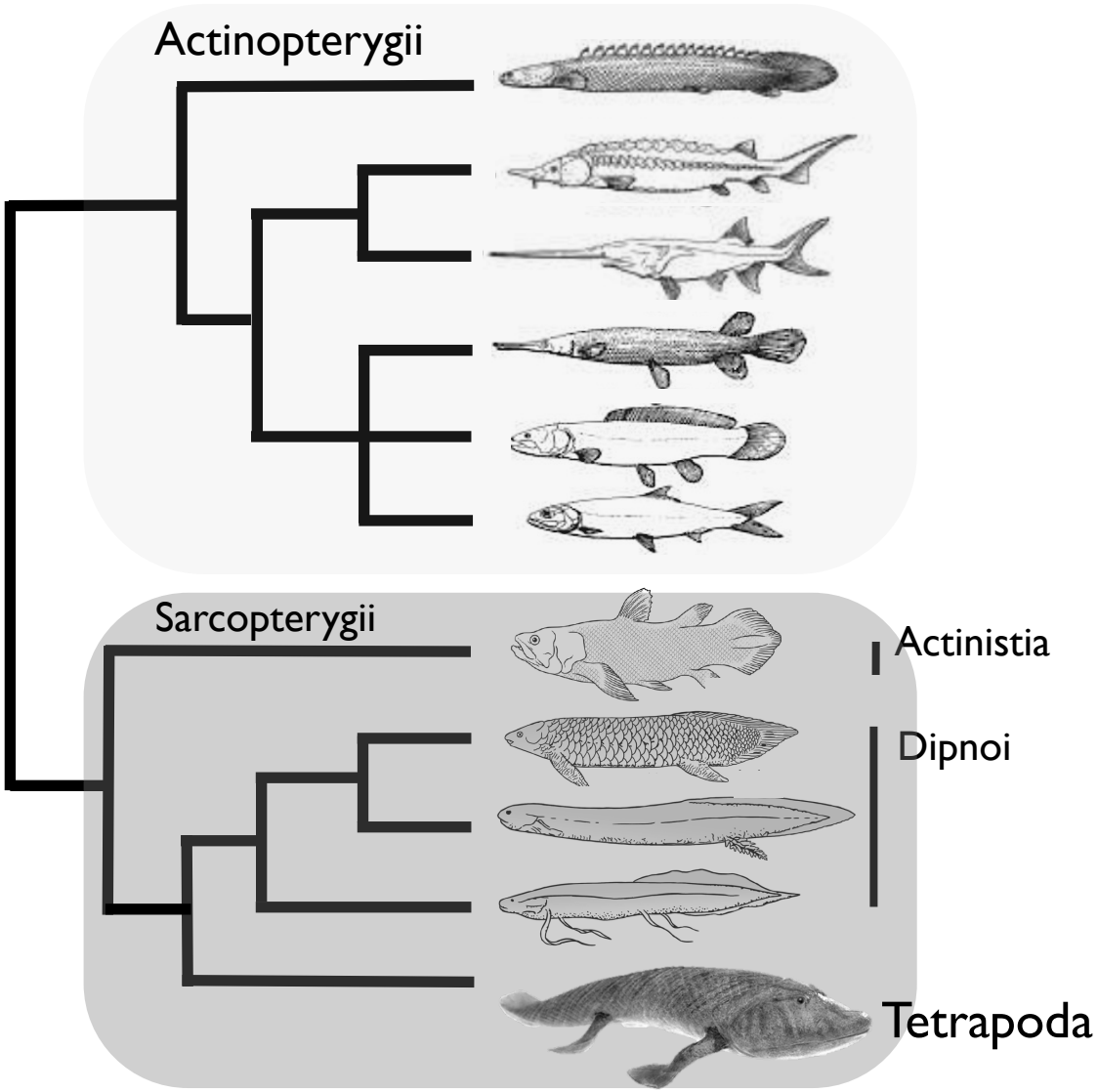
Período Devoniano



Período Devoniano

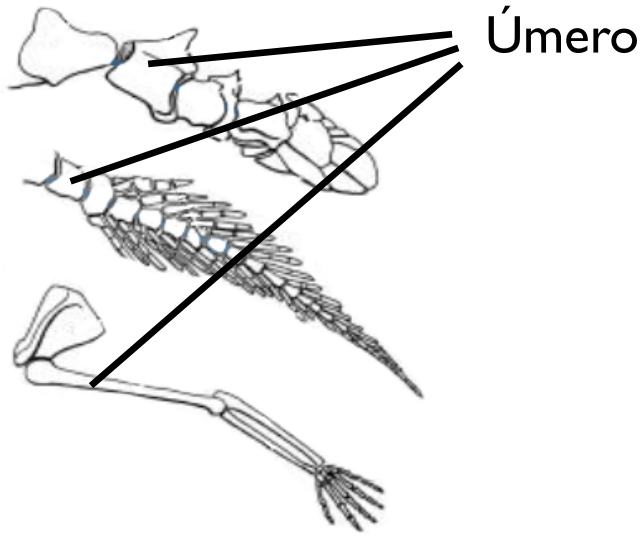


Sarcopterygii

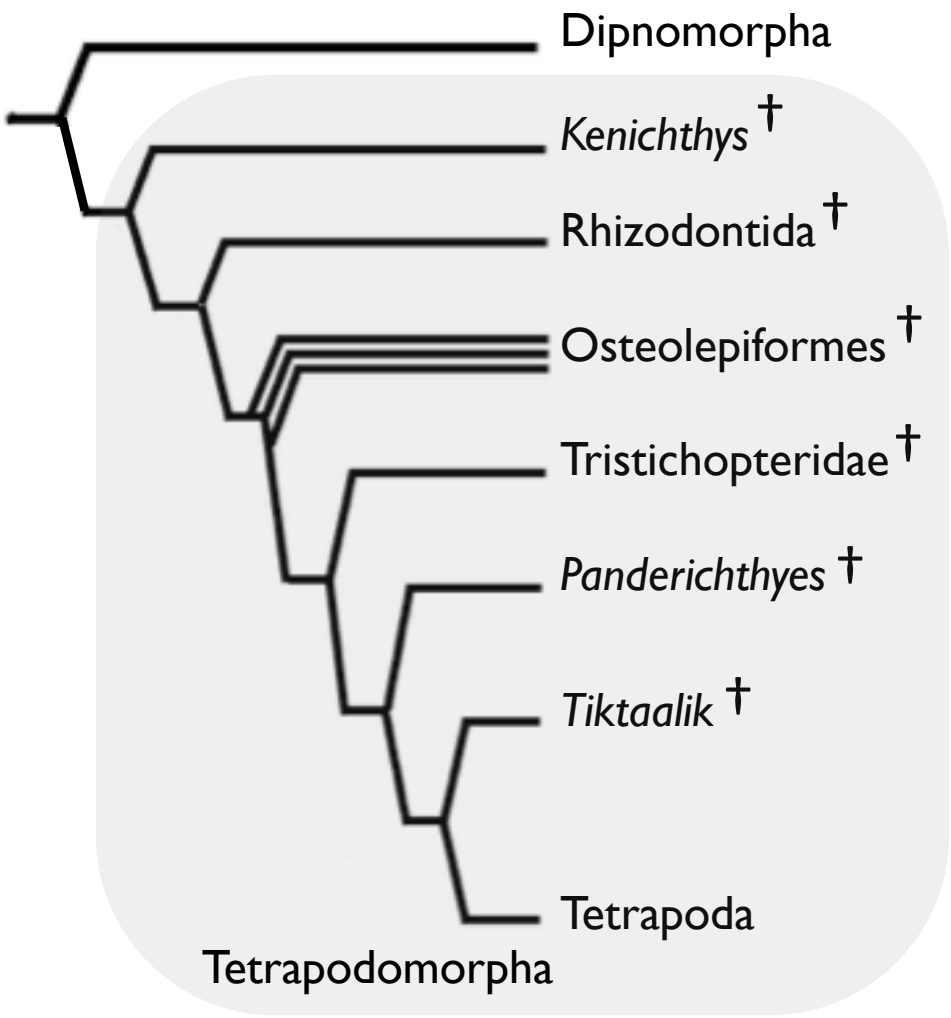


Nadadeiras pares LOBADAS

Articulação MONOBASAL



Rhipidistia



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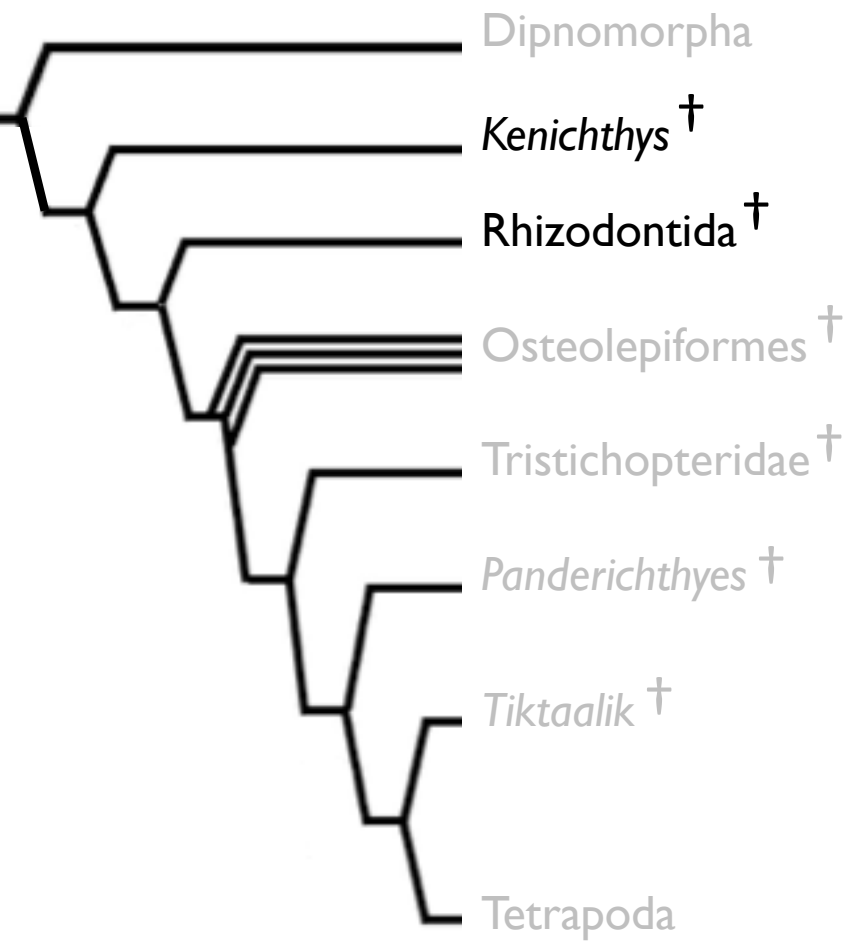

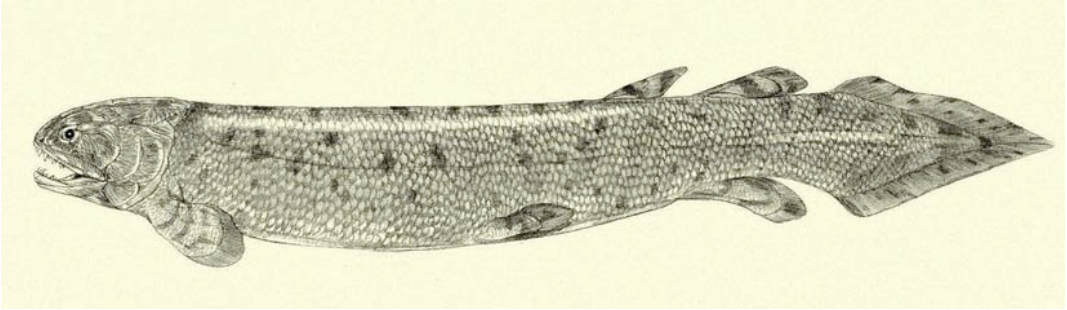

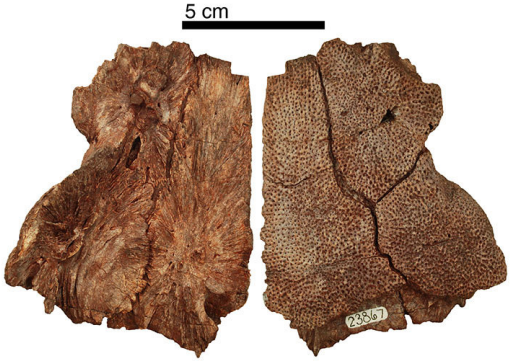

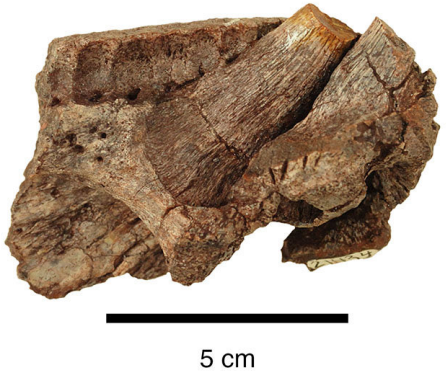

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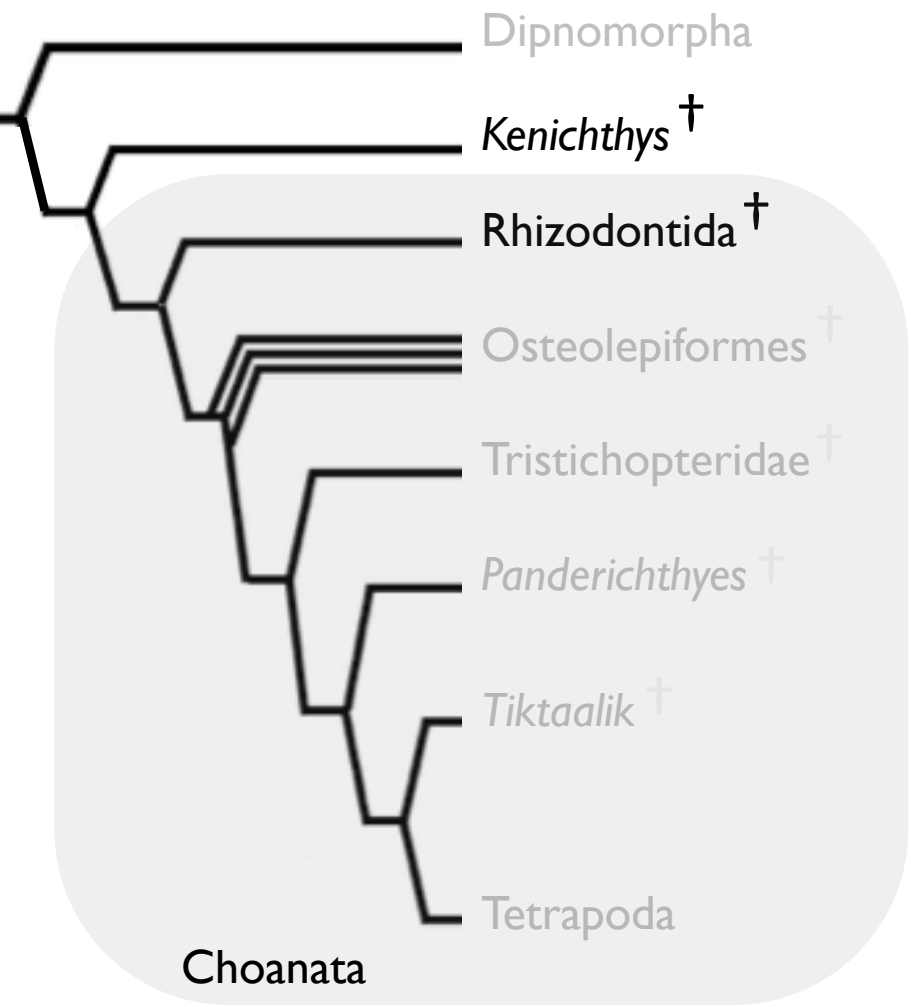
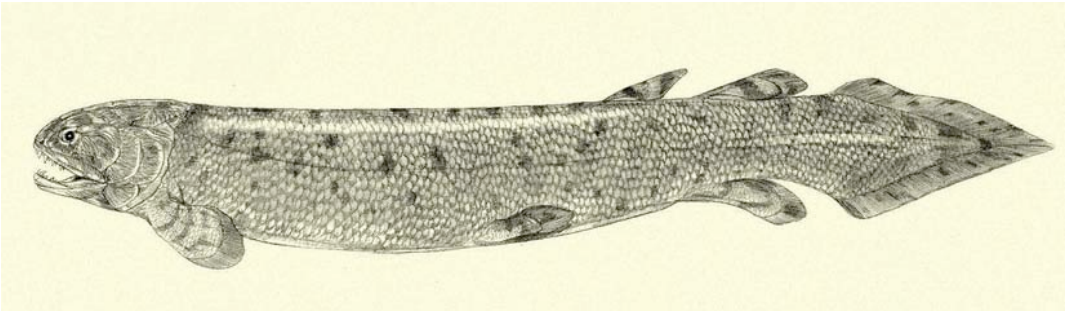


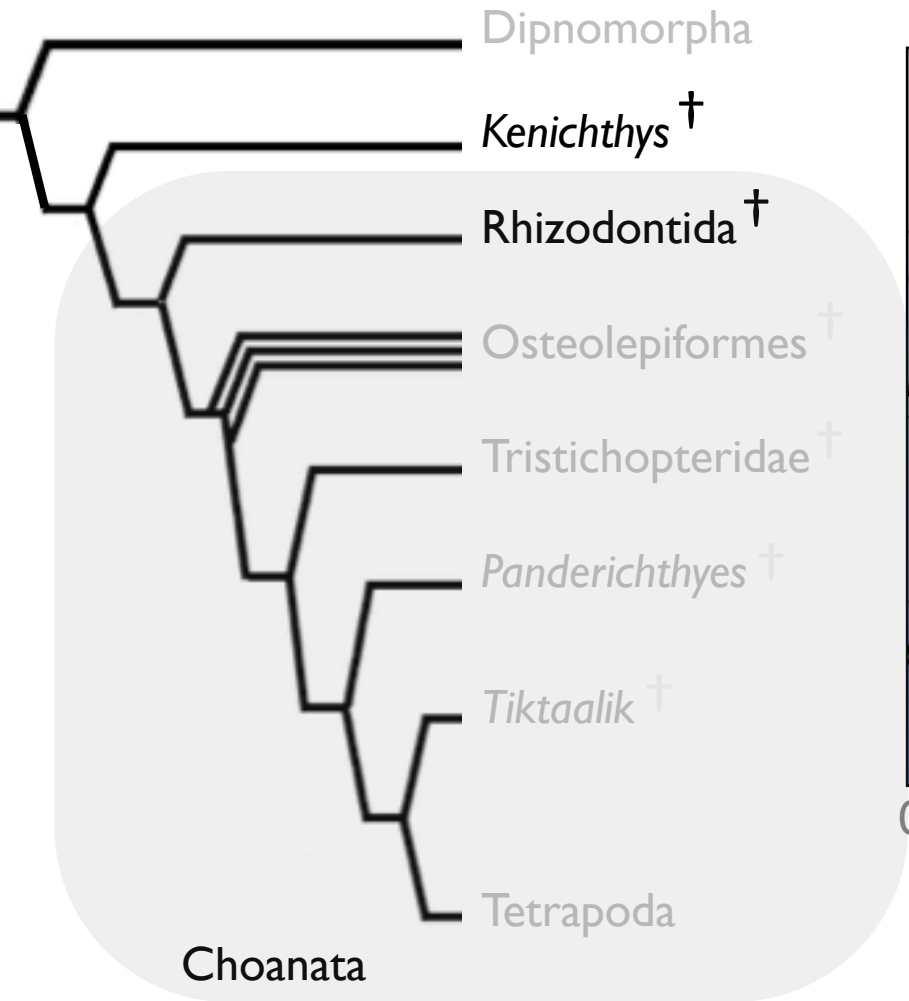


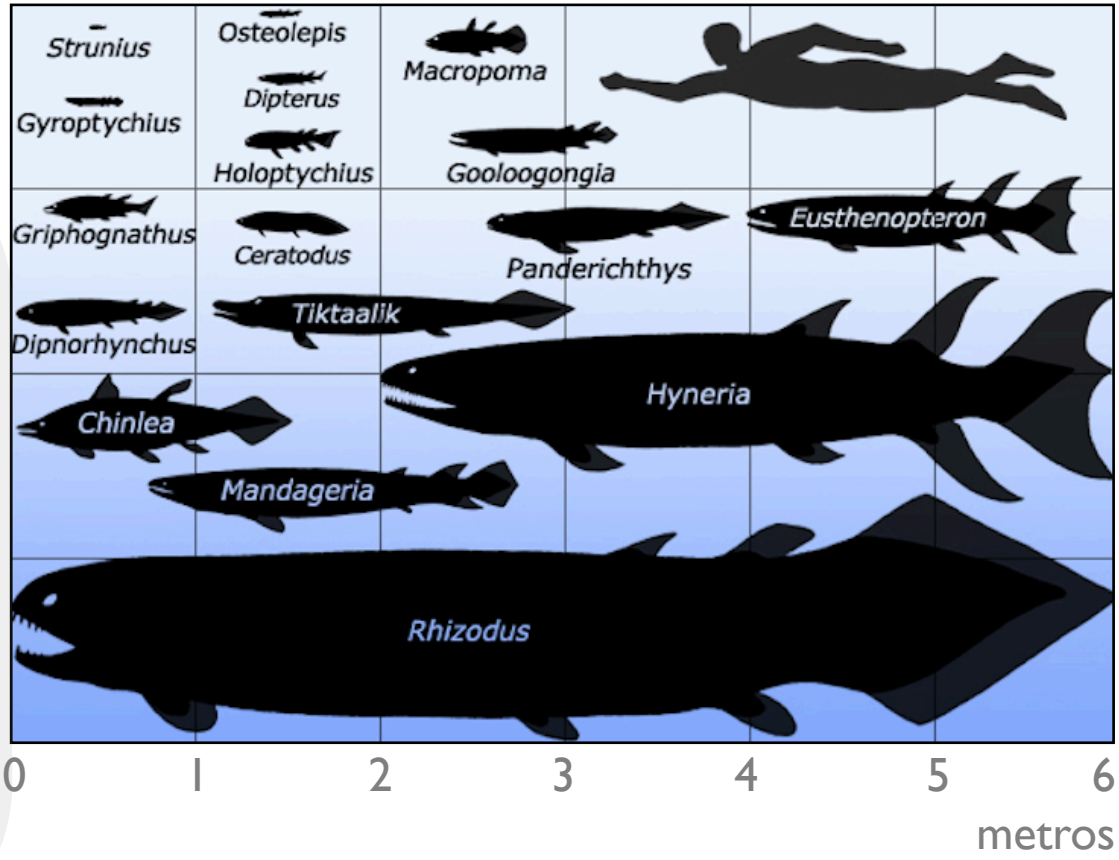
Nadadeiras dorsal e anal mais caudalmente

Nadadeiras peitorais com lepidotríquias não segmentadas e camada superficial de escamas: **resistência**

Presença de coanas

Rhipidistia



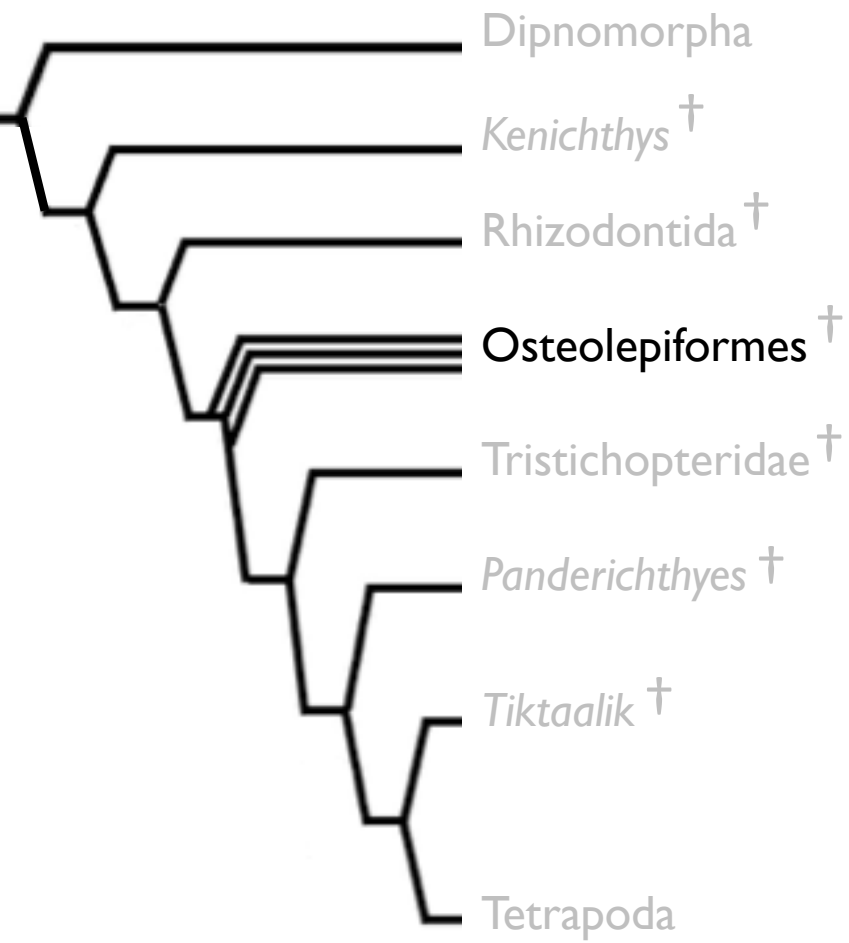


Rhipidistia

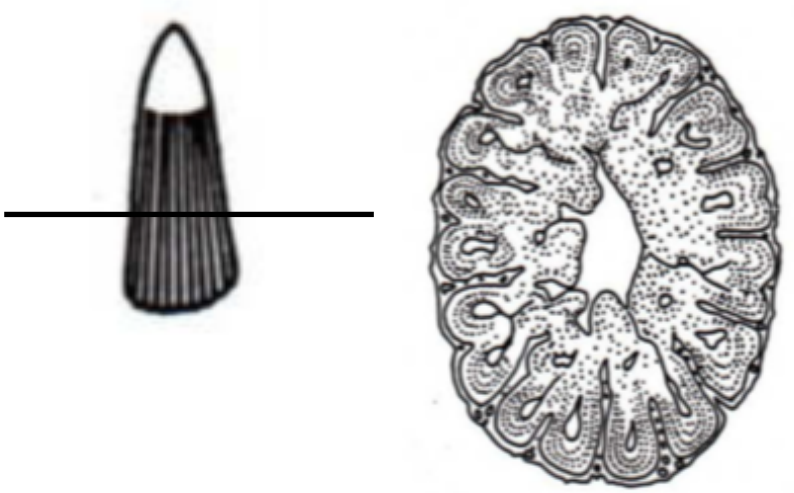
Osteolepiformes †

Osteolepis

Rhipidistia



Dentição labirintodonte



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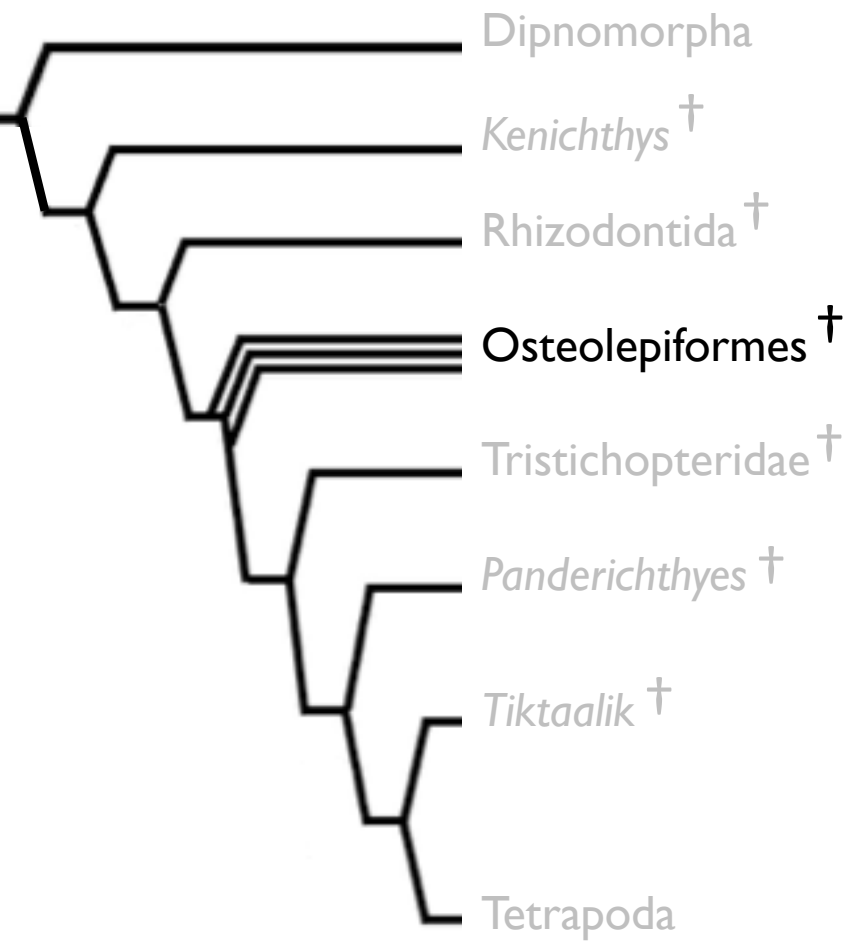
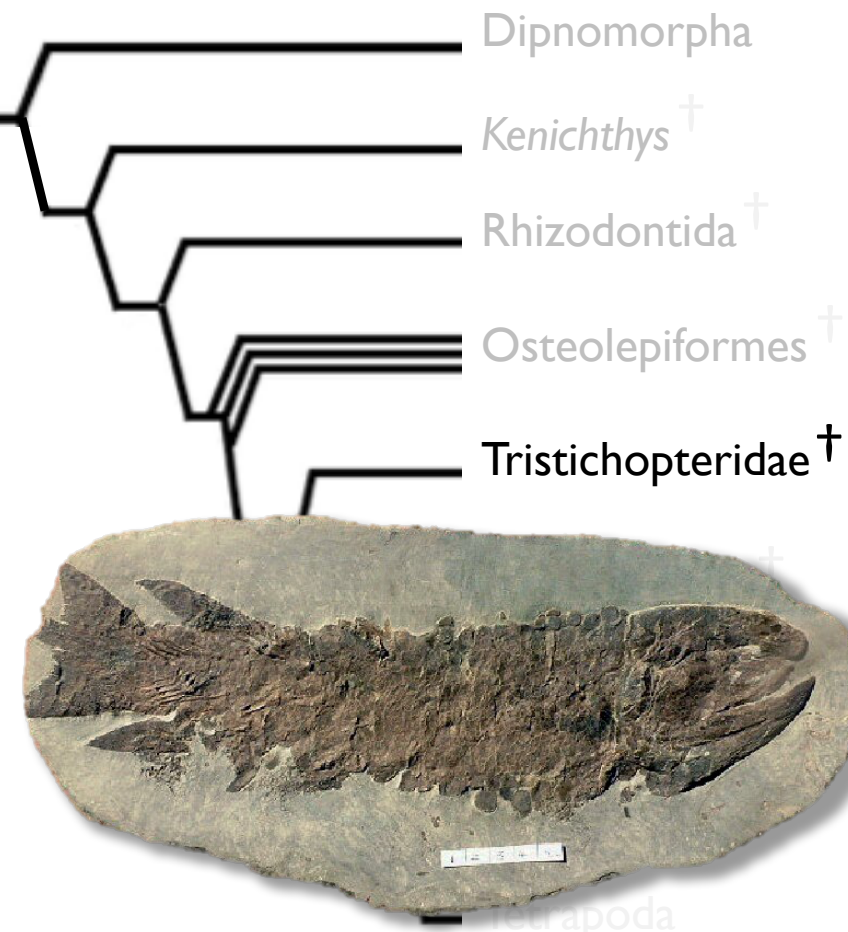


Características mais derivadas das nadadeiras

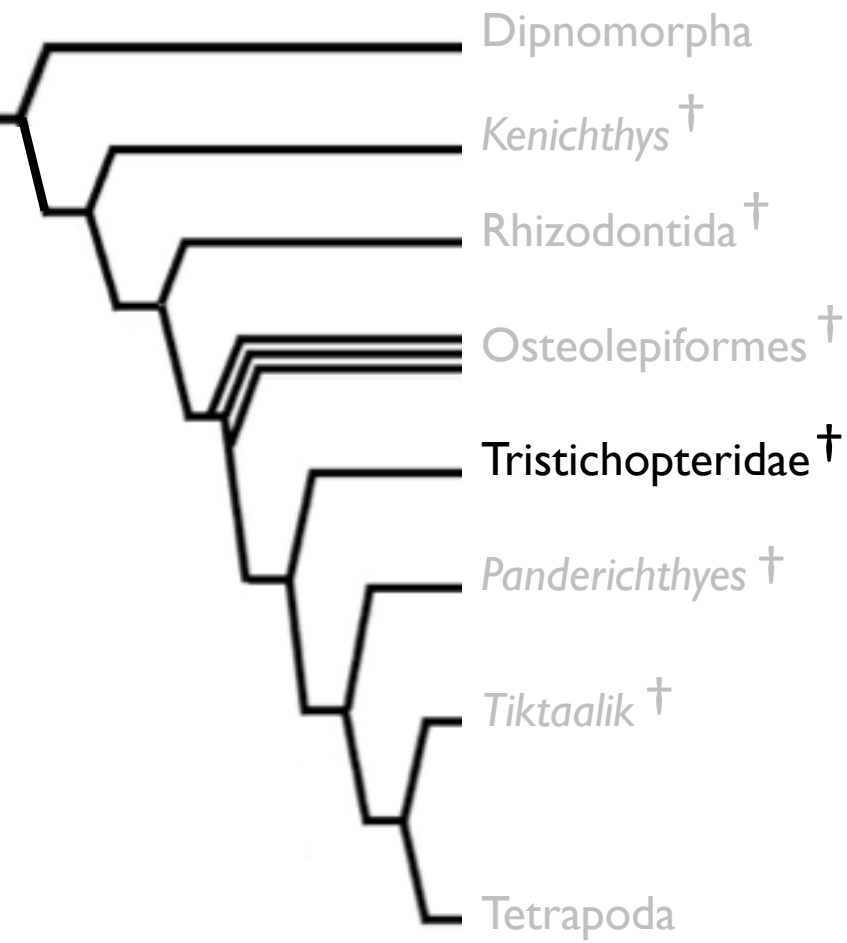
Rhipidistia



Tristichopteridae

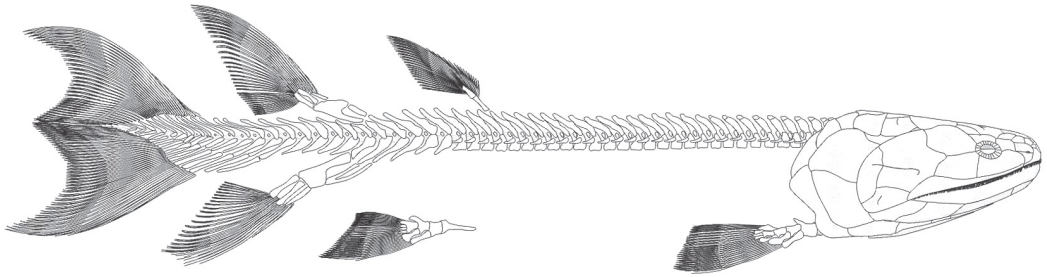
Eusthenopteron

Rhipidistia



Não têm adaptações a águas rasas

Nadadeira caudal trilobada

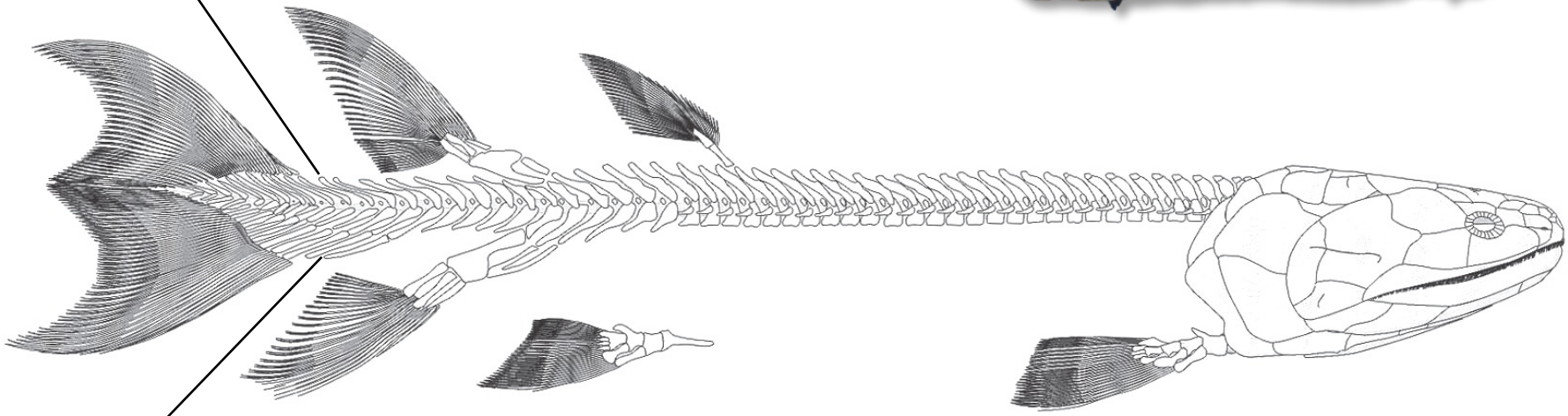


Eusthenopteron

Rhipidistia

Tristichopteridae †

Processos neurais alongados

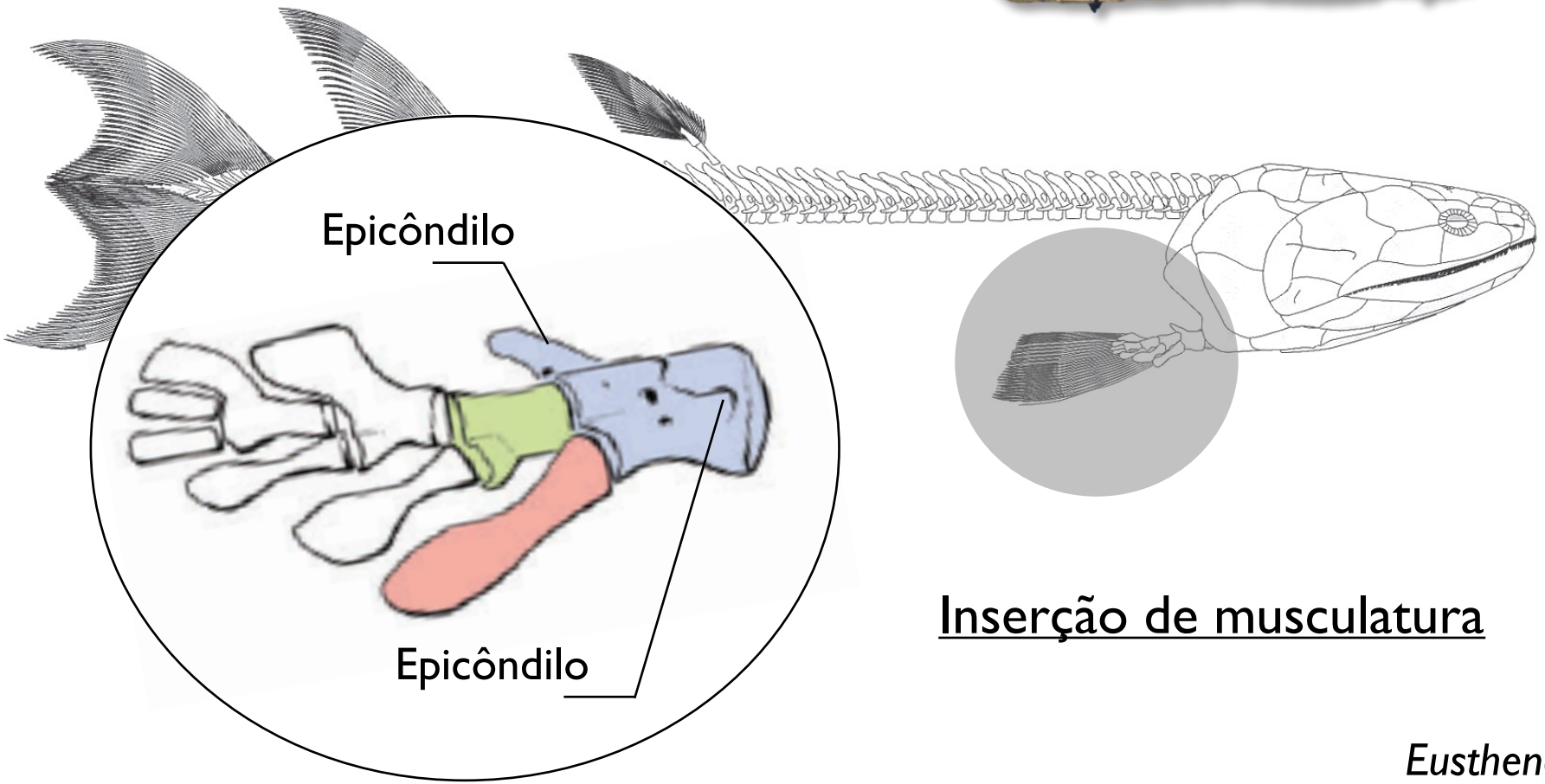


Processos epihemais acessórios

Eusthenopteron

Rhipidistia

Tristichopteridae †



Inserção de musculatura

Eusthenopteron

Rhipidistia

Elpistostegalia

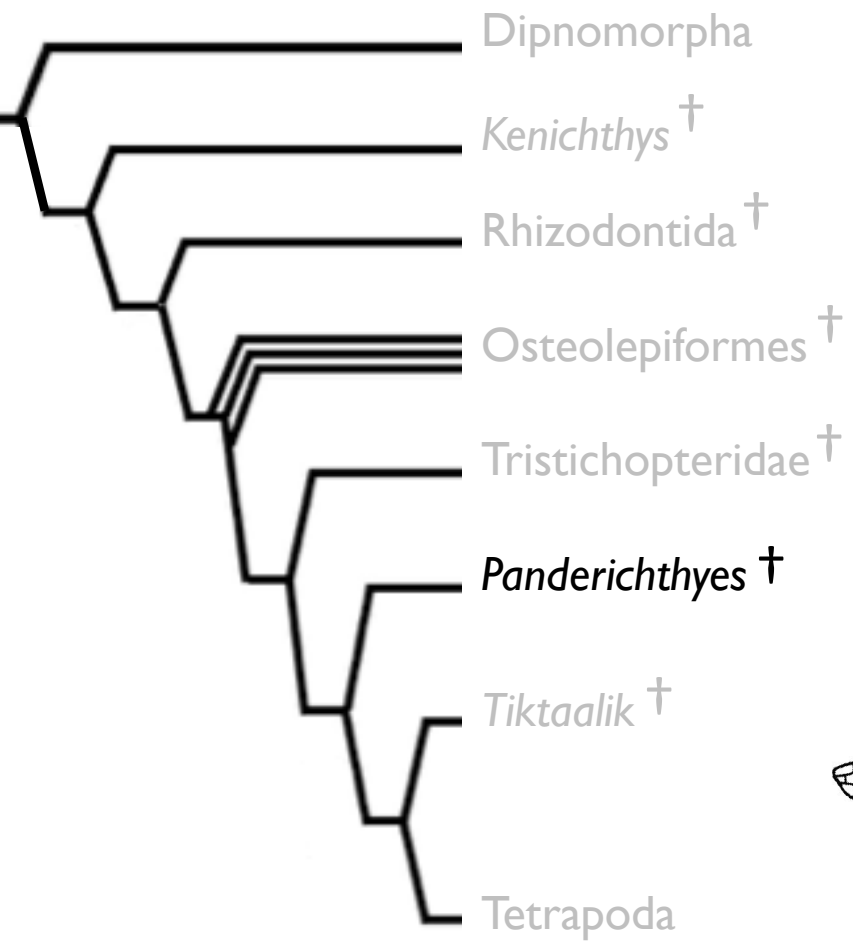
Panderichthyes †

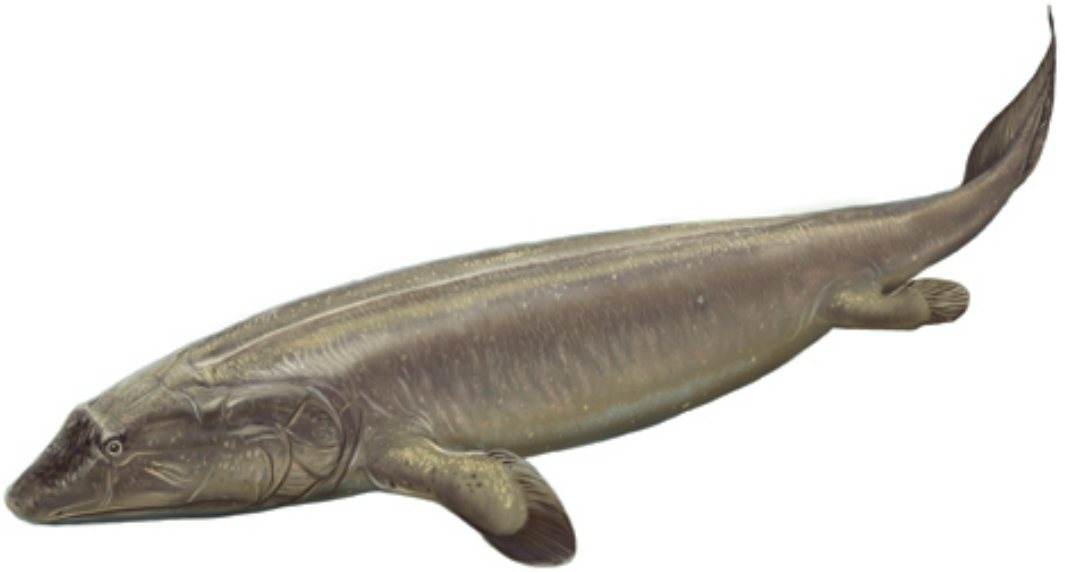
Tiktaalik †

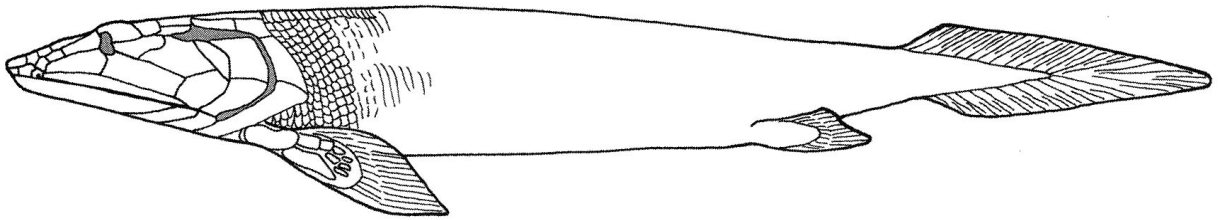
Tetrapoda

Rhipidistia

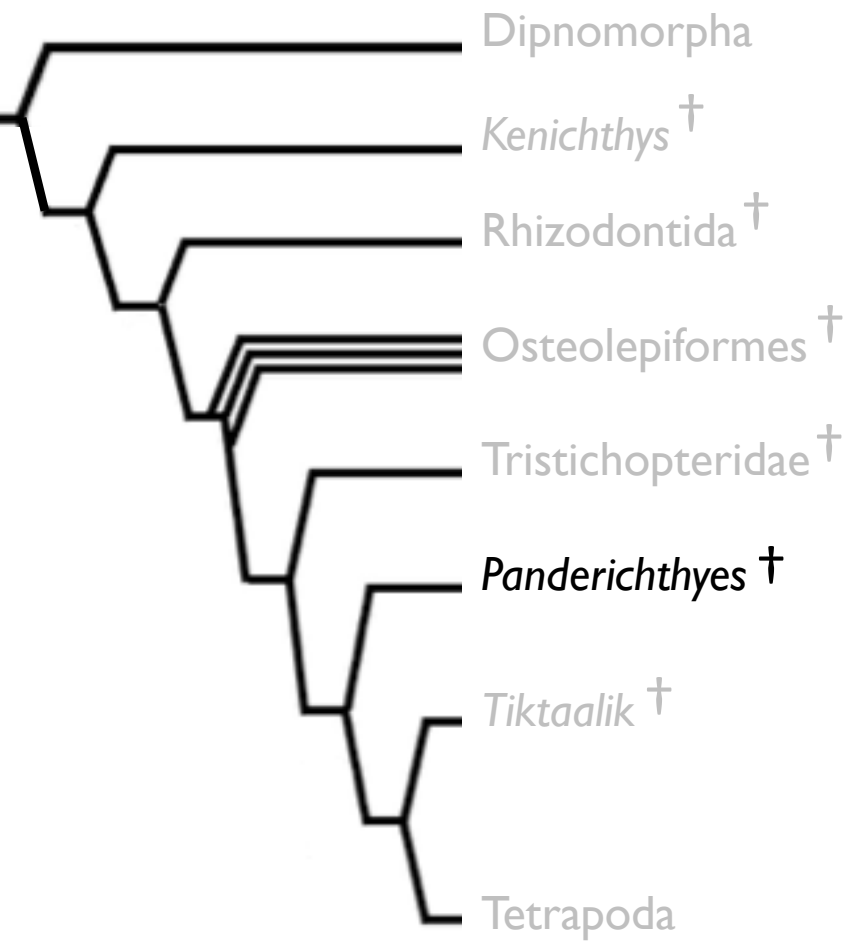
Elpistostegalia



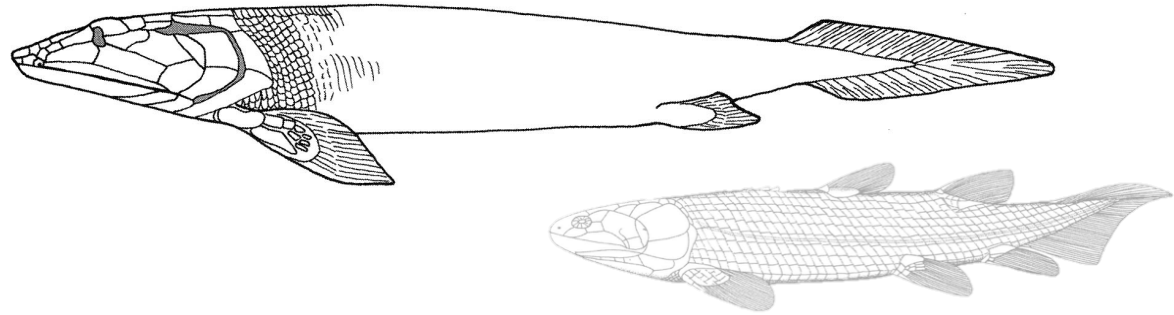




Rhipidistia



Elpistostegalia



Adaptações a águas rasas

Corpo achatado

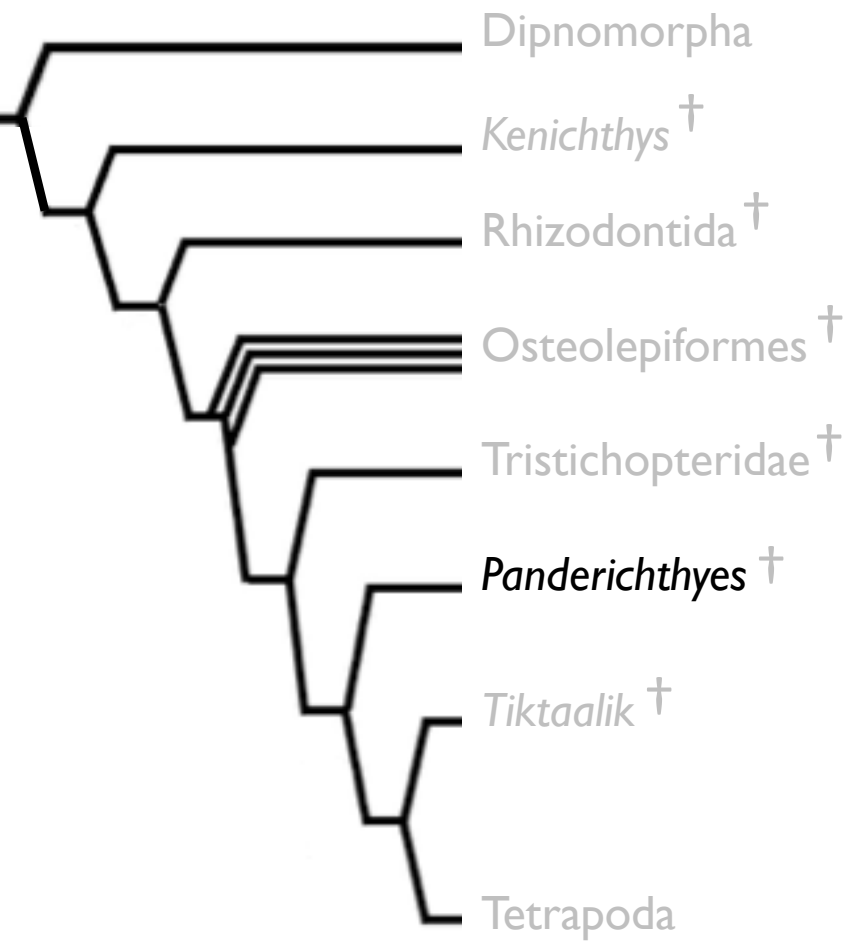
Focinho afilado

Órbitas e narinas dorsalmente no crânio

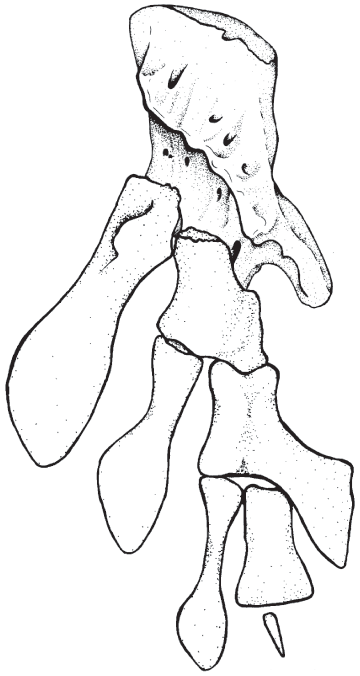
Modificações cranianas

Perda das nadadeiras dorsal e anal

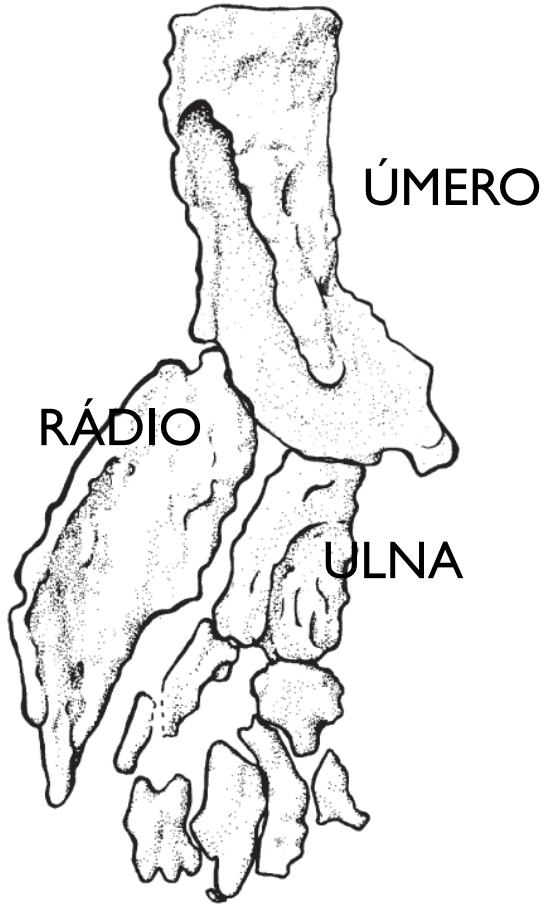
Rhipidistia



Elpistostegalia

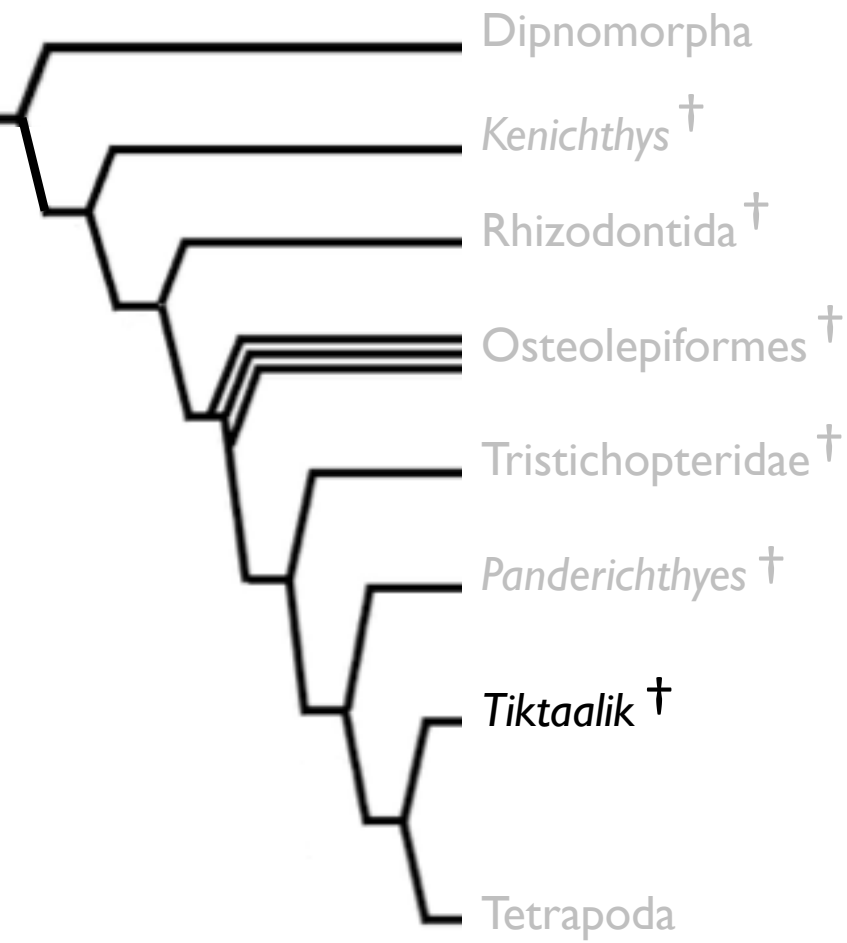


Eusthenopterum



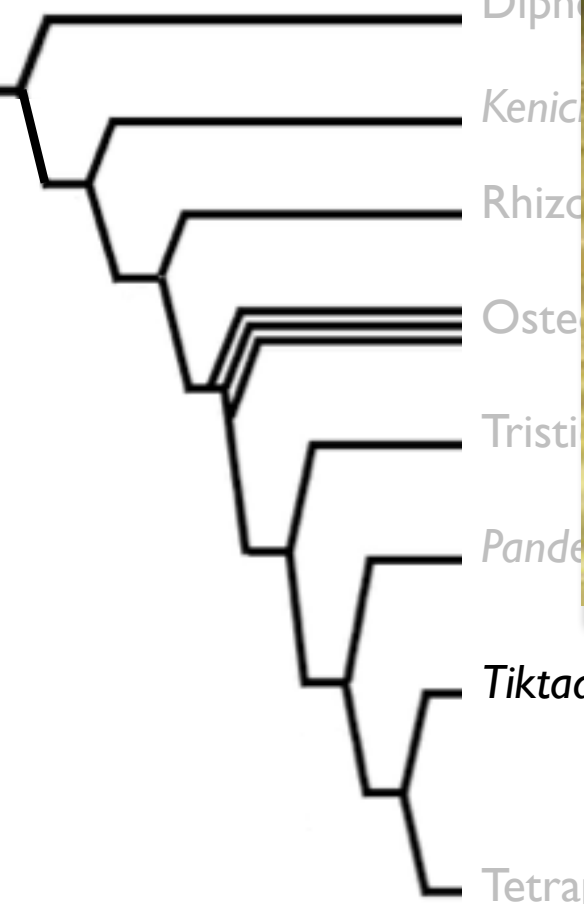
Panderichthyes

Rhipidistia

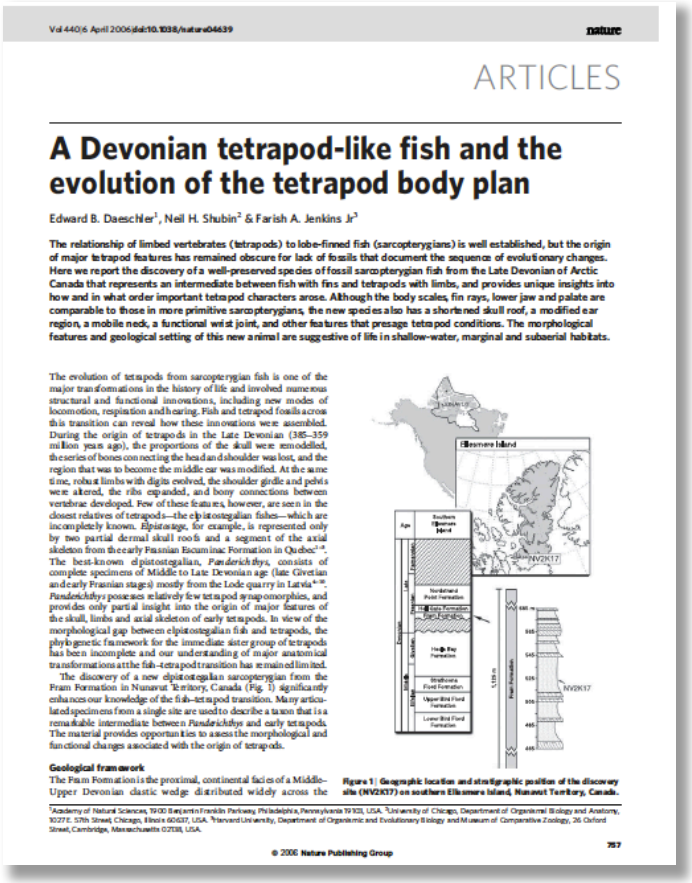


Tiktaalik roseae

Rhipidistia



Tiktaalik roseae



Vol 440|6 April 2006|doi:10.1038/nature04639 nature

ARTICLES

A Devonian tetrapod-like fish and the evolution of the tetrapod body plan

Edward B. Daeschler[1], Neil H. Shubin[2] & Farish A. Jenkins Jr[3]

The relationship of limbed vertebrates (tetrapods) to lobe-finned fish (sarcopterygians) is well established, but the origin of major tetrapod features has remained obscure for lack of fossils that document the sequence of evolutionary changes. Here we report the discovery of a well-preserved species of fossil sarcopterygian fish from the Late Devonian of Arctic Canada that represents an intermediate between fish with fins and tetrapods with limbs, and provides unique insights into how and in what order important tetrapod characters arose. Although the body scales, fin rays, lower jaw and palate are comparable to those in more primitive sarcopterygians, the new species also has a shortened skull roof, a modified ear region, a mobile neck, a functional wrist joint, and other features that presage tetrapod conditions. The morphological features and geological setting of this new animal are suggestive of life in shallow-water, marginal and subaerial habitats.

The evolution of tetrapods from sarcopterygian fish is one of the major transformations in the history of life and involved numerous structural and functional innovations, including new modes of locomotion, respiration and hearing. Fish and tetrapod fossils across this transition can reveal how these innovations were assembled. During the origin of tetrapods in the Late Devonian (385–359 million years ago), the proportions of the skull were remodelled, the series of bones connecting the head and shoulder was lost, and the region that was to become the middle ear was modified. At the same time, robust limbs with digits evolved, the shoulder girdle and pelvis were altered, the ribs expanded, and bony connections between vertebrae developed. Few of these features, however, are seen in the closest relatives of tetrapods—the elpistostegalian fishes—which are incompletely known. *Elpistostege*, for example, is represented only by two partial dermal skull roofs and a segment of the axial skeleton from the early Frasnian Escuminac Formation in Quebec[1–3]. The best-known elpistostegalian, *Panderichthys*, consists of complete specimens of Middle to Late Devonian age (late Givetian and early Frasnian stages) mostly from the Lode quarry in Latvia[4–10]. *Panderichthys* possesses relatively few tetrapod synapomorphies, and provides only partial insight into the origin of major features of the skull, limbs and axial skeleton of early tetrapods. In view of the morphological gap between elpistostegalian fish and tetrapods, the phylogenetic framework for the immediate sister group of tetrapods has been incomplete and our understanding of major anatomical transformations at the fish–tetrapod transition has remained limited.

The discovery of a new elpistostegalian sarcopterygian from the Fram Formation in Nunavut Territory, Canada (Fig. 1) significantly enhances our knowledge of the fish–tetrapod transition. Many articulated specimens from a single site are used to describe a taxon that is a remarkable intermediate between *Panderichthys* and early tetrapods. The material provides opportunities to assess the morphological and functional changes associated with the origin of tetrapods.

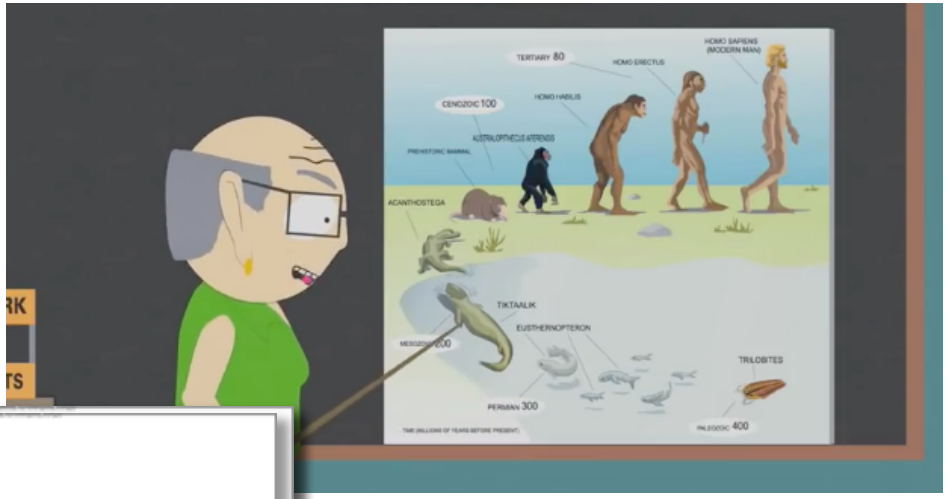
Geological framework

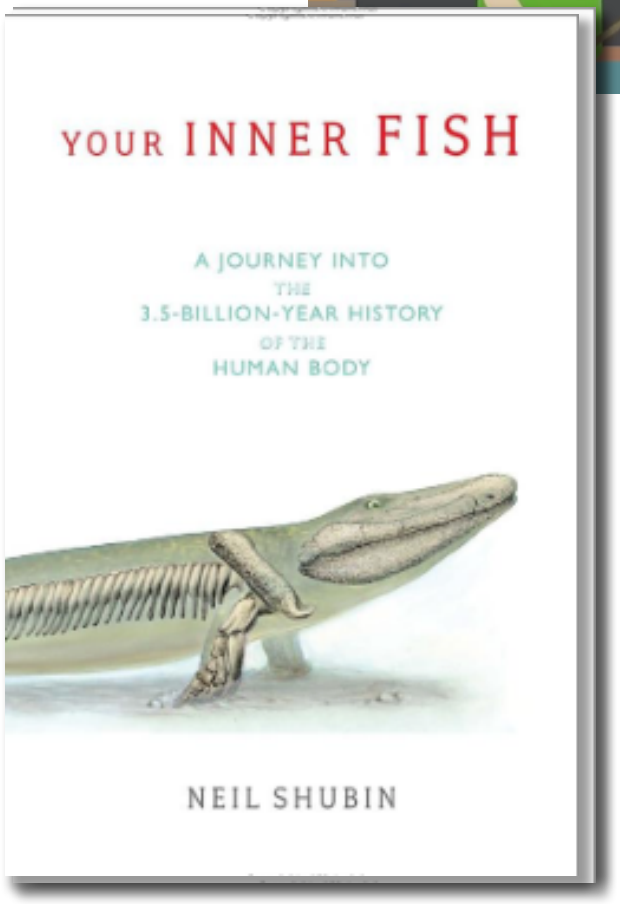
The Fram Formation is the proximal, continental facies of a Middle–Upper Devonian clastic wedge distributed widely across the

Figure 1 | Geographic location and stratigraphic position of the discovery site (NV2K17) on southern Ellesmere Island, Nunavut Territory, Canada.

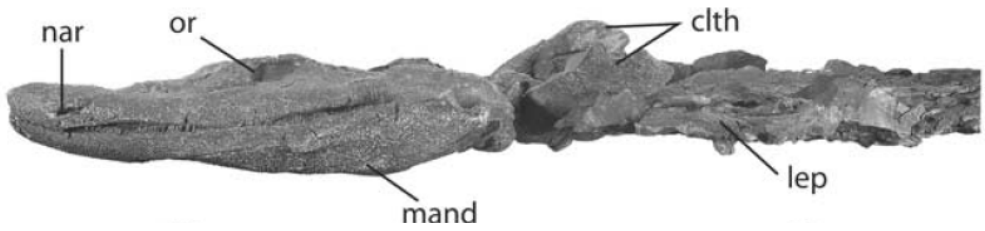
[1]Academy of Natural Sciences, 1900 Benjamin Franklin Parkway, Philadelphia, Pennsylvania 19103, USA, [2]University of Chicago, Department of Organismal Biology and Anatomy, 1027 E. 57th Street, Chicago, Illinois 60637, USA, [3]Harvard University, Department of Organismic and Evolutionary Biology and Museum of Comparative Zoology, 26 Oxford Street, Cambridge, Massachusetts 02138, USA.

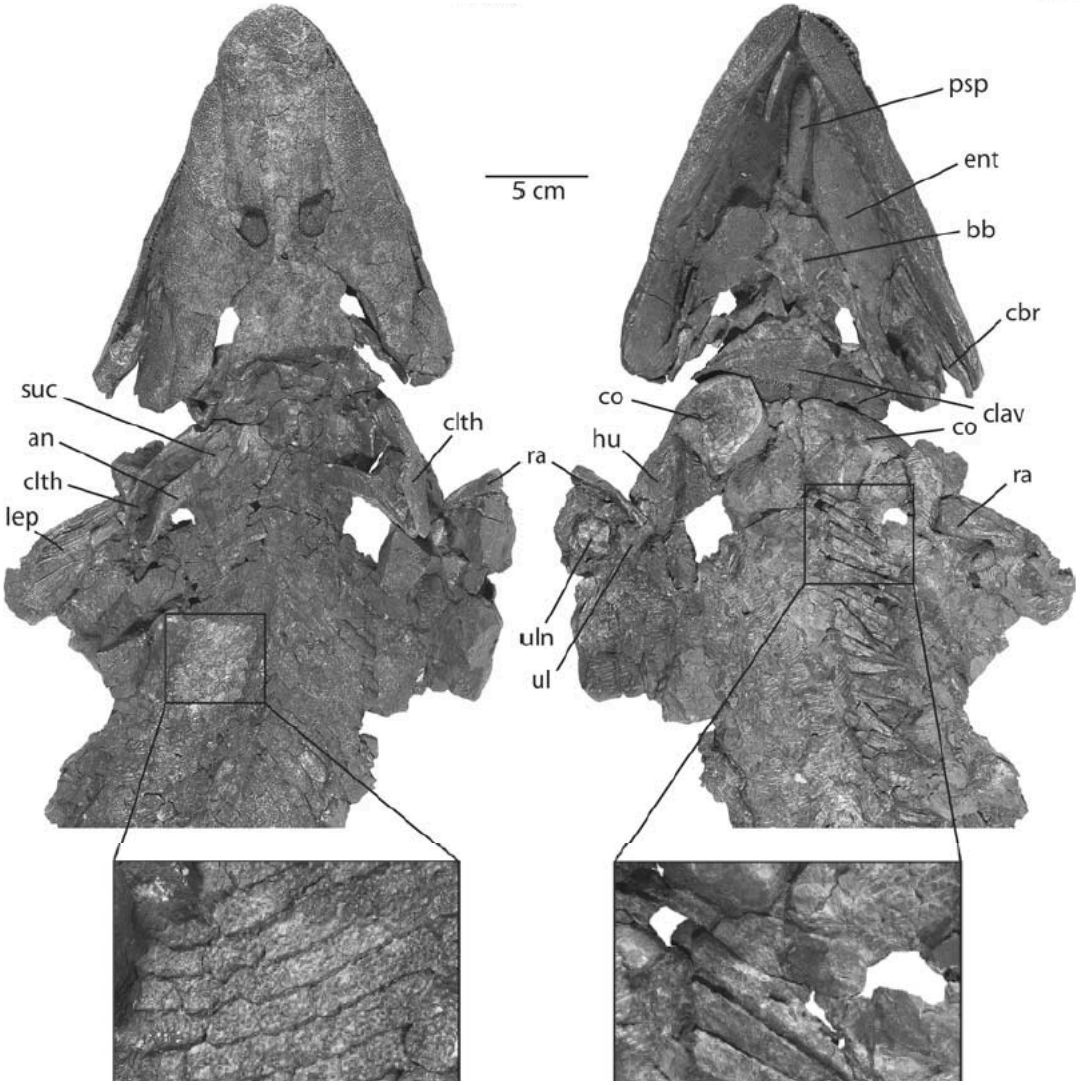
Tiktaalik roseae





Tiktaalik roseae





Morfologia

Corpo e crânio achatados

Focinho longo

Olhos e narinas dorsalmente

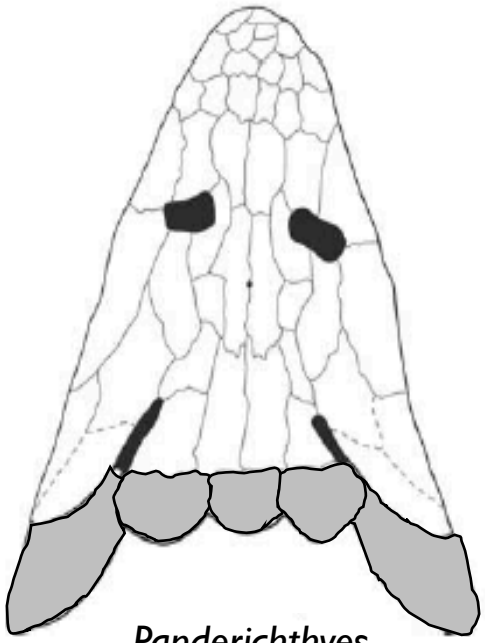
Nadadeiras com lepidotríquia

Perda de ossos cranianos

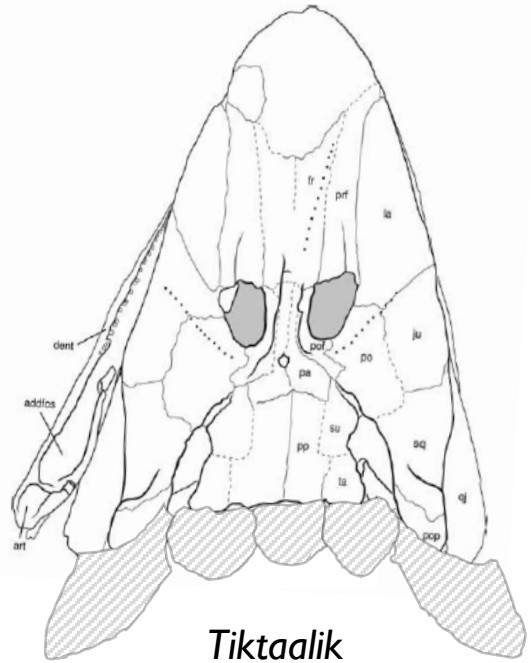
Modificações nas nadadeiras

Tiktaalik roseae

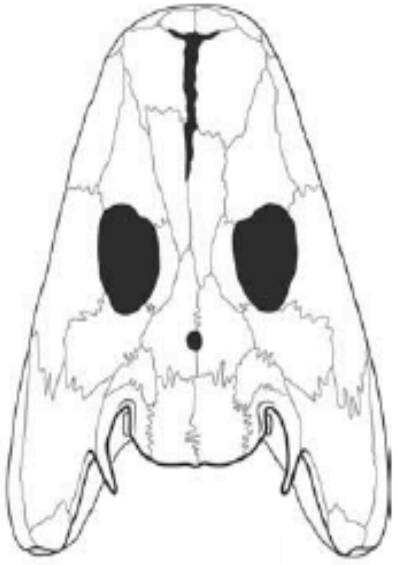
Crânio



Panderichthyes



Tiktaalik



Acanthostega

Perda dos ossos **opercular**, **subopercular** e **extraescapular**

Mobilidade da cabeça

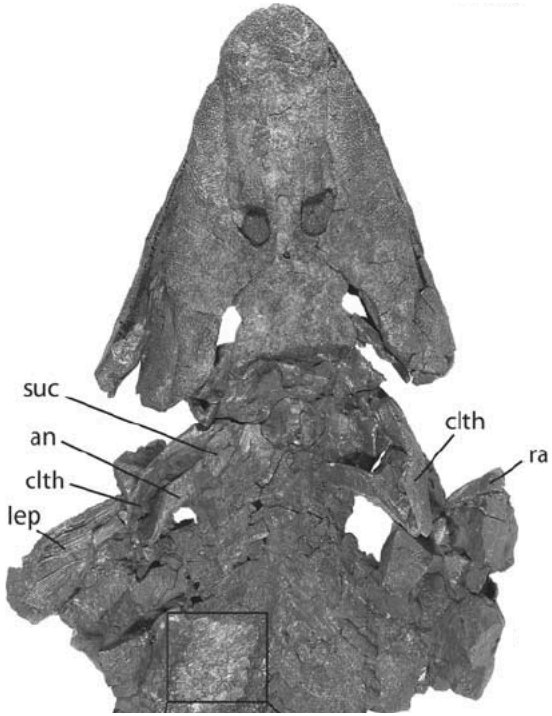
Espaço para inserção de musculatura

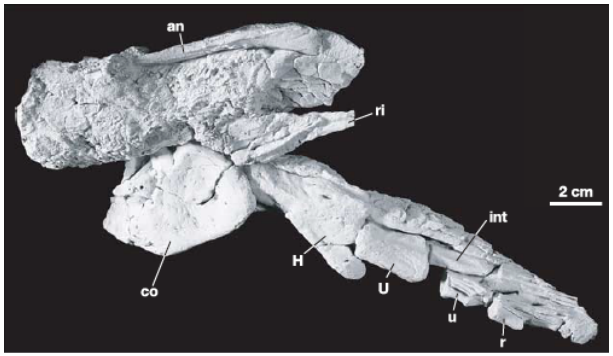
Tiktaalik roseae

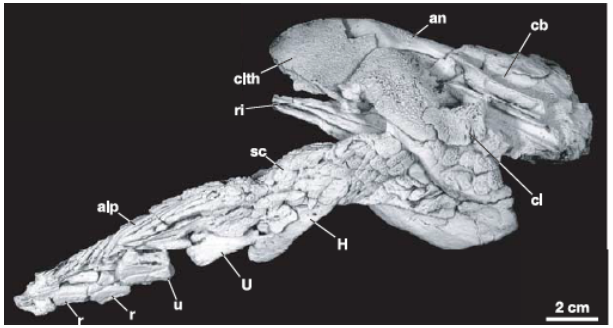
Cintura escapular

Desenvolvimento de elementos endocondrais (escápula e coracóide)

Redução de elementos dérmicos (clavícula, cleithrum, anocleithrum e supracleithrum)

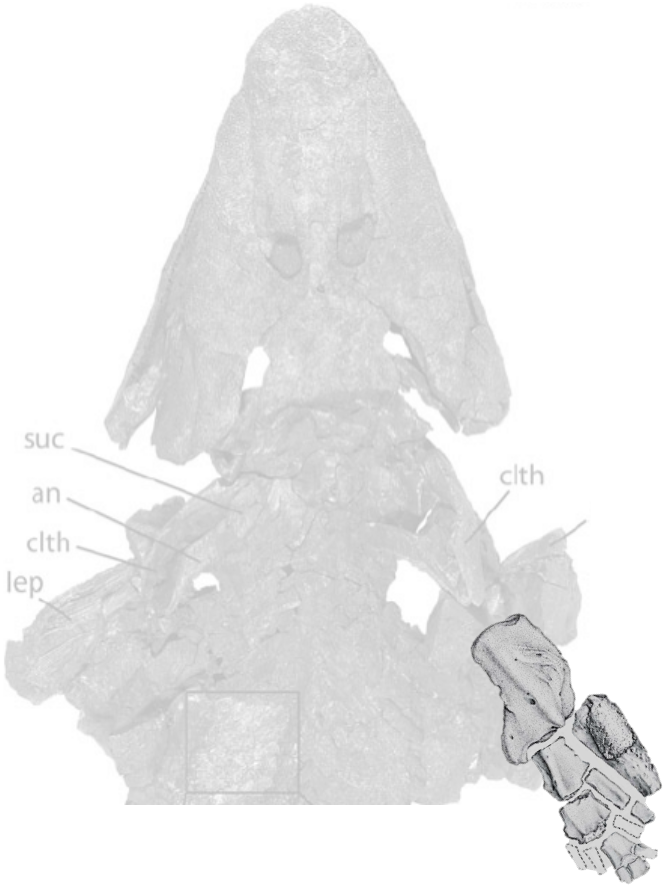




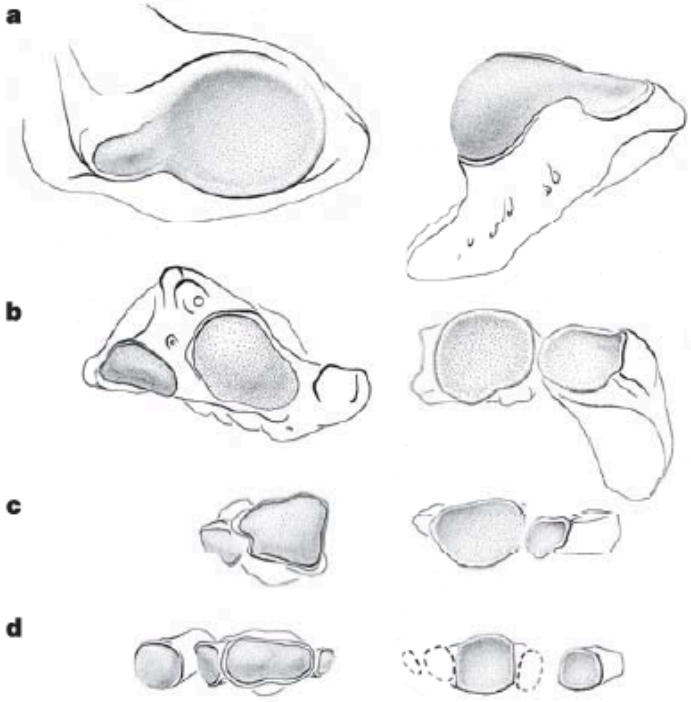


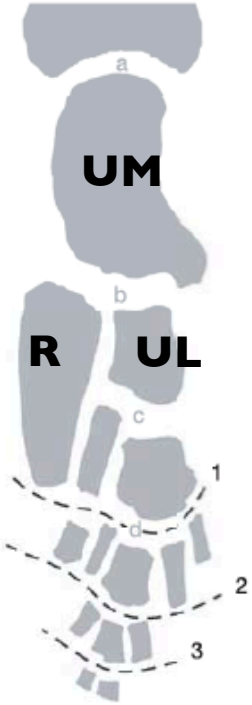
Tiktaalik roseae

Nadadeiras peitorais

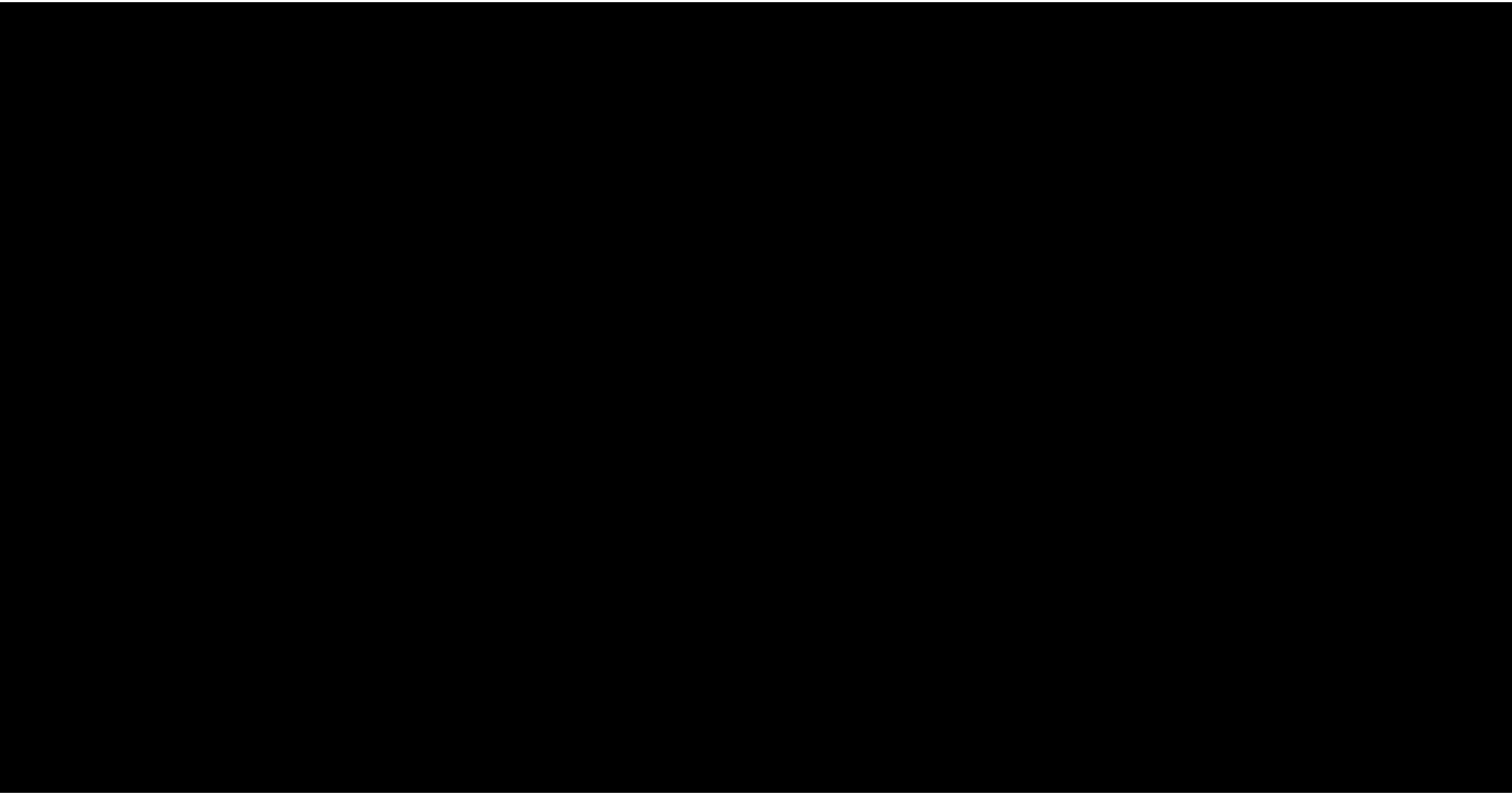


Curvatura das articulações – **mobilidade**



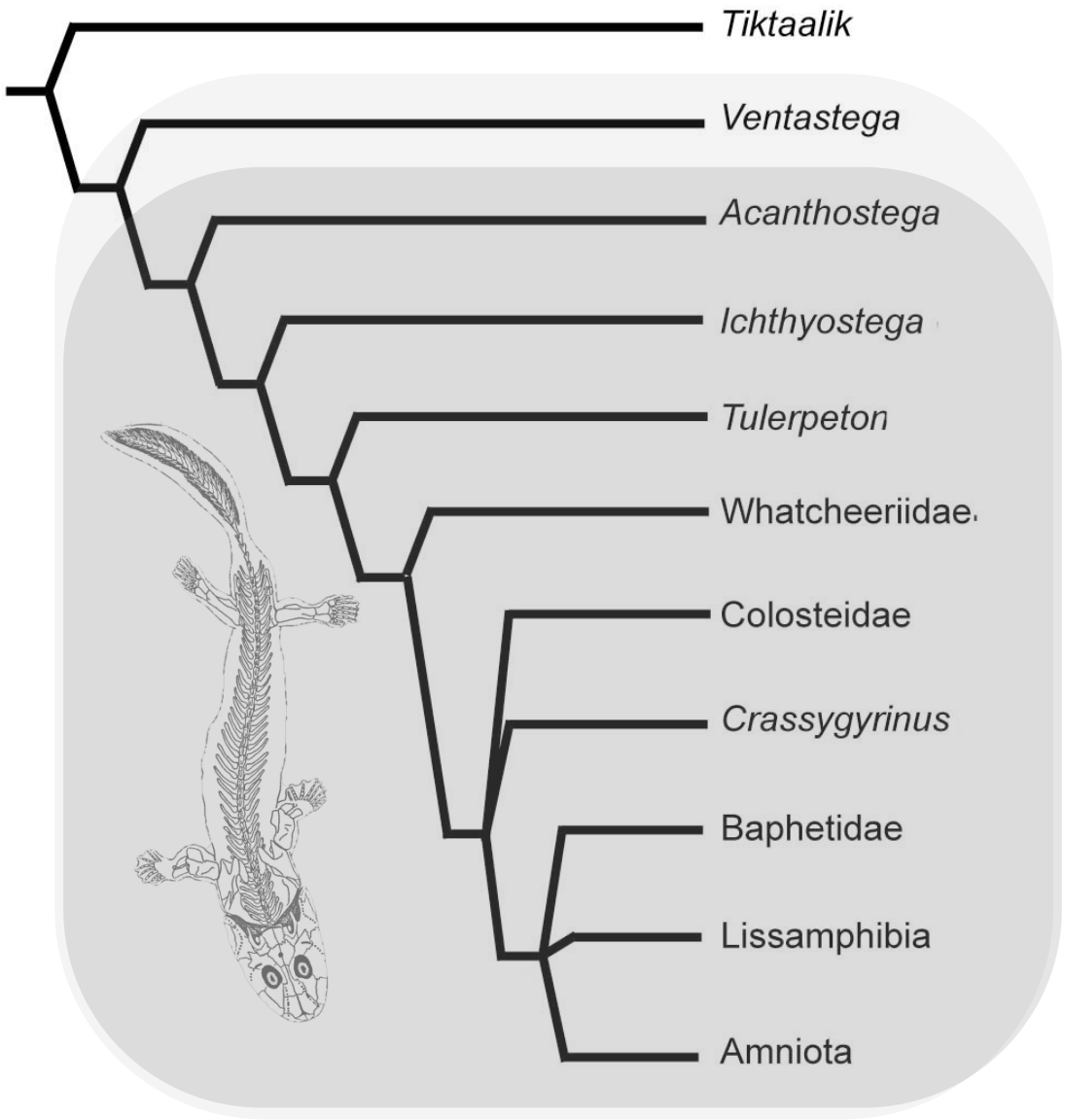


Tiktaalik roseae

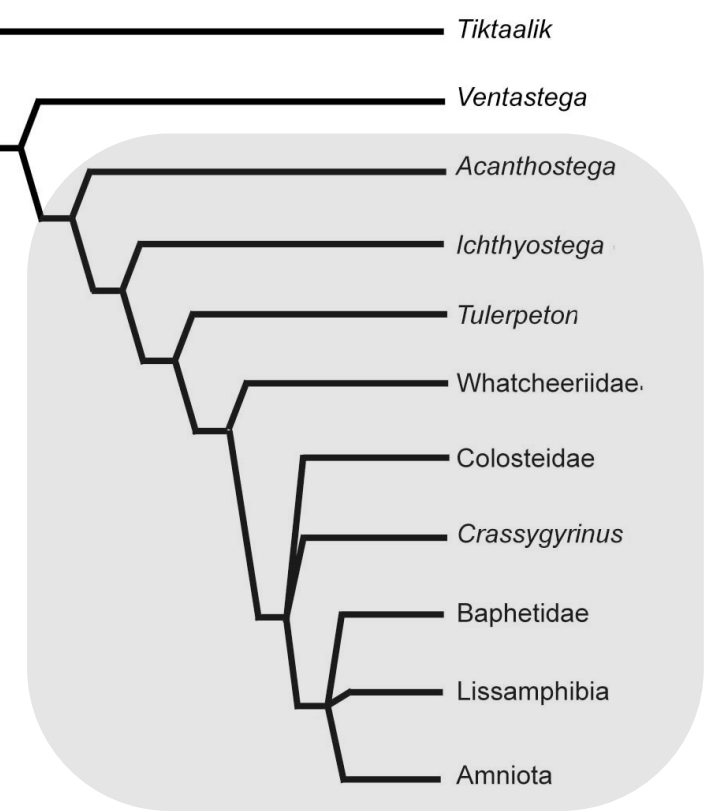


Tetrapoda

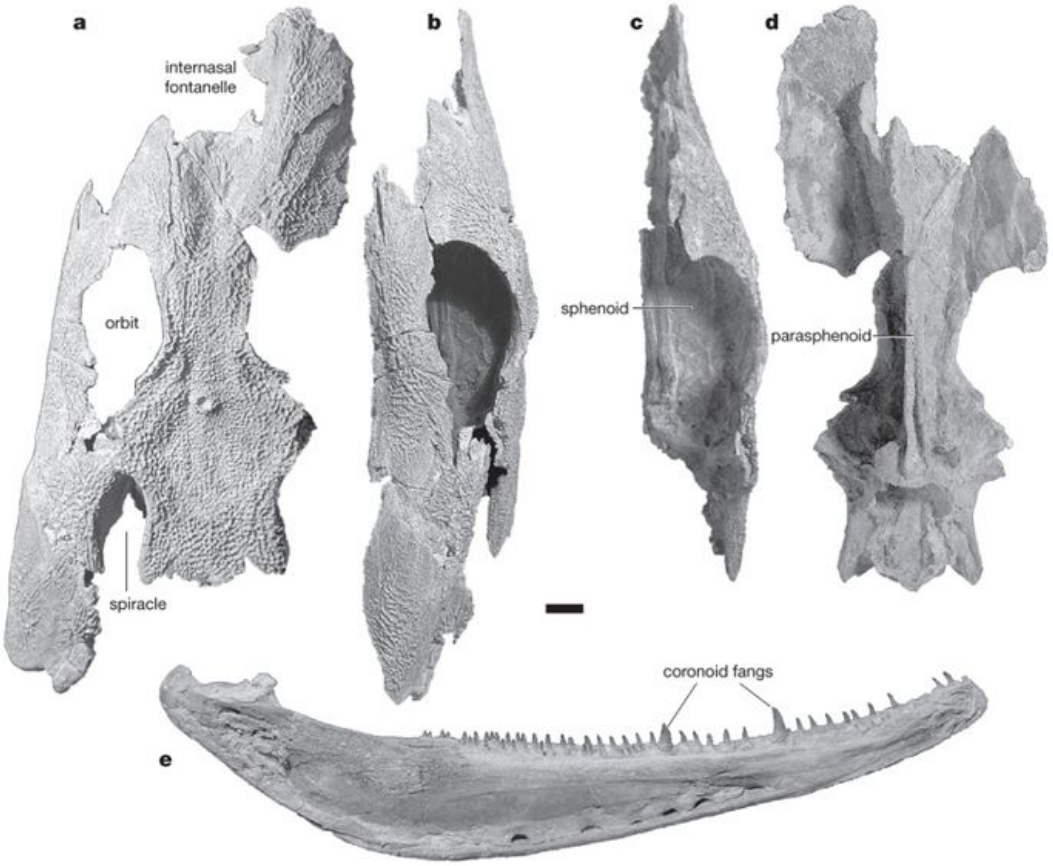

Dipnomorpha
Kenichthys †
Rhizodontida †
Osteolepiformes †
Tristichopteridae †
Panderichthyes †
Tiktaalik †
Tetrapoda


Tiktaalik
Ventastega
Acanthostega
Ichthyostega
Tulerpeton
Whatcheeriidae
Colosteidae
Crassygyrinus
Baphetidae
Lissamphibia
Amniota

Tetrapoda

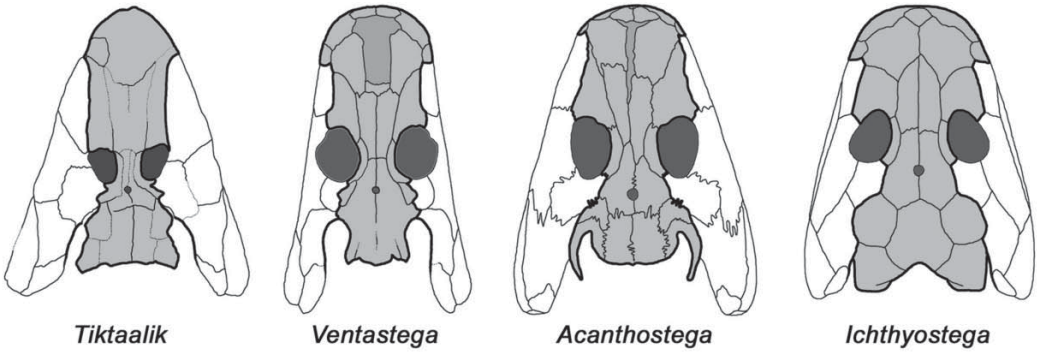


Ventastega



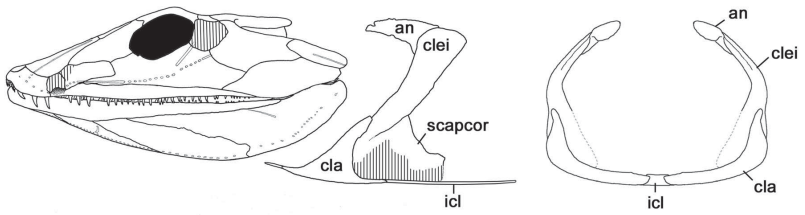
Tetrapoda

Ventastega



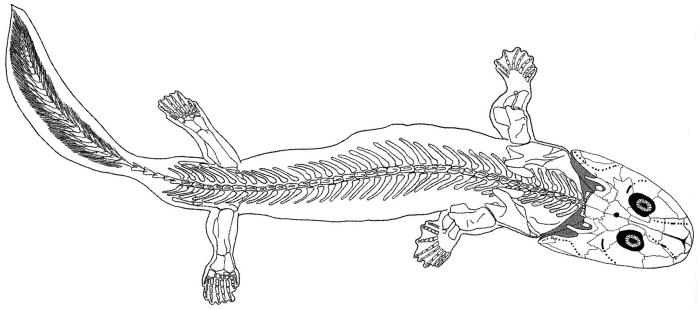
Crânio

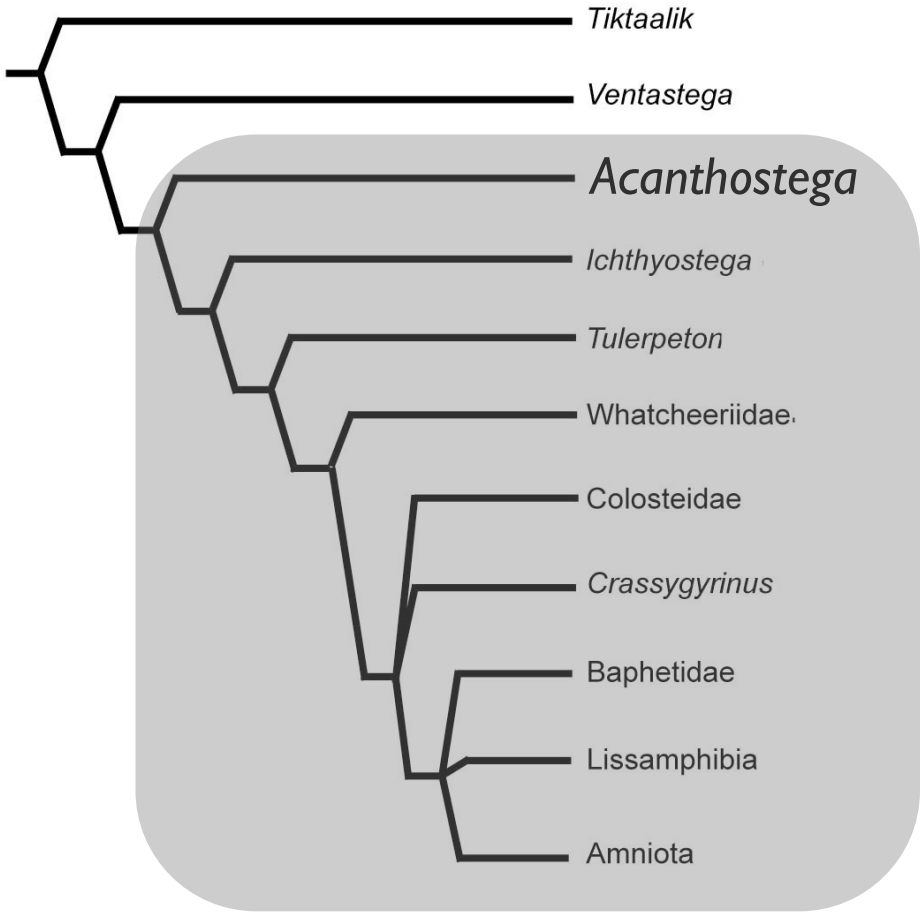
- Ausência dos ossos operculares
- Órbitas mais desenvolvidas



Cintura escapular

- Redução do osso anocleithrum

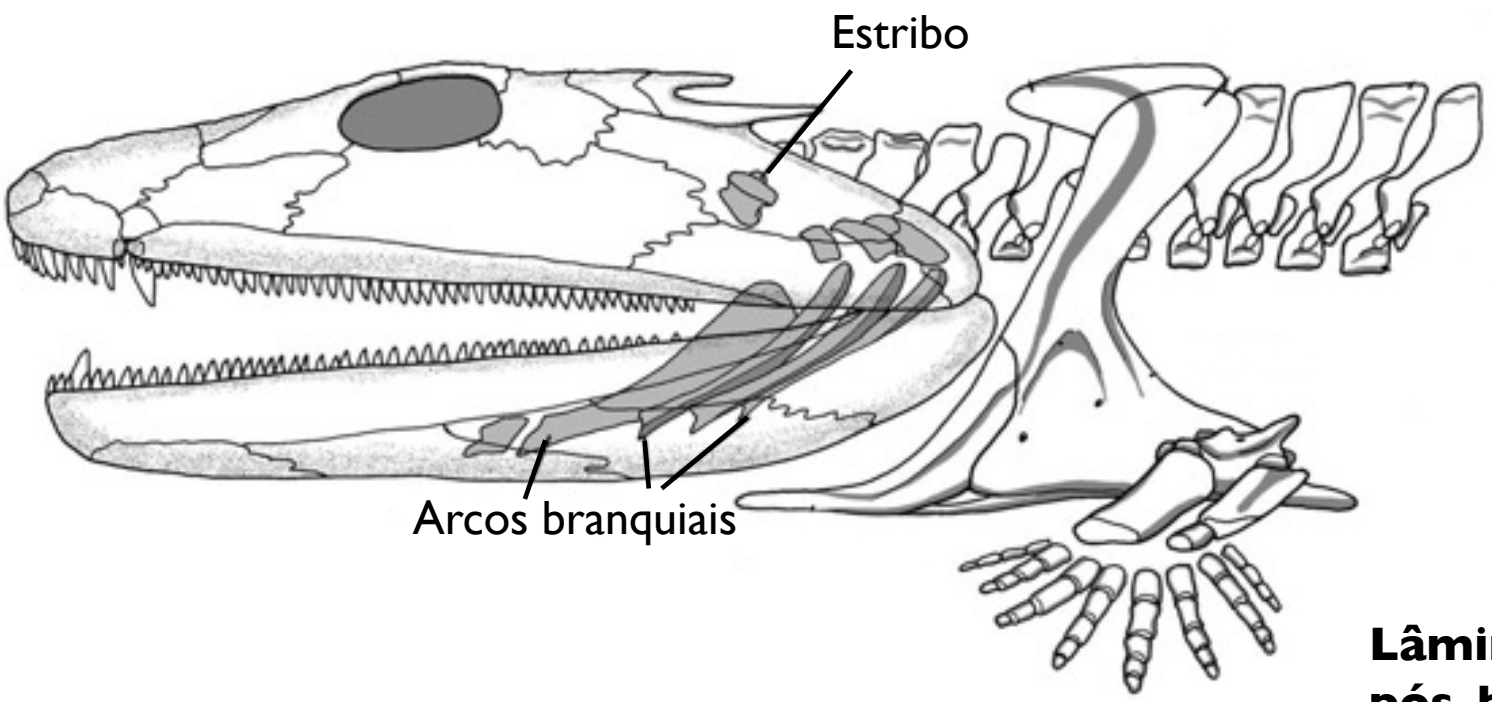


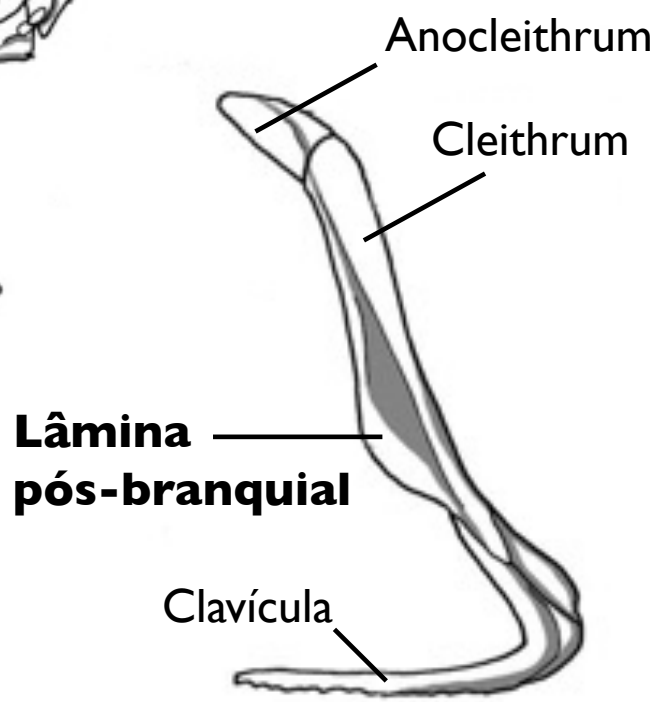


Acanthostega

Primeiro representante Tetrapoda

Acanthostega





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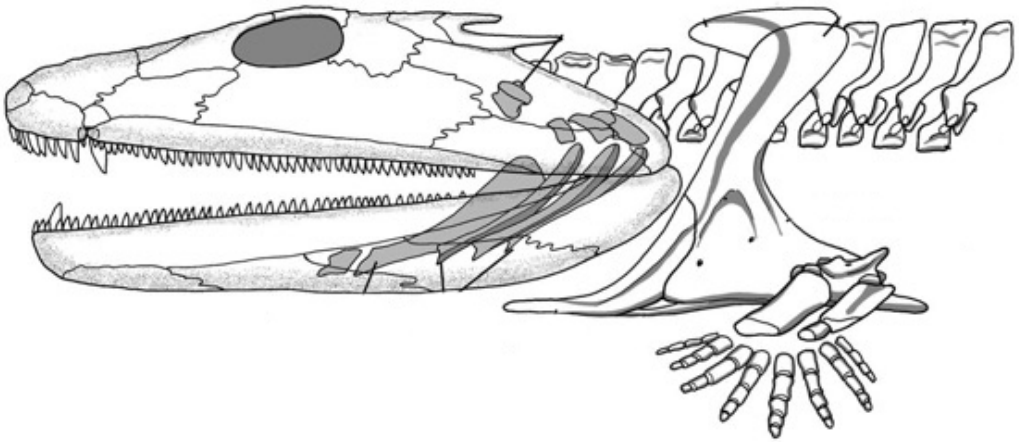
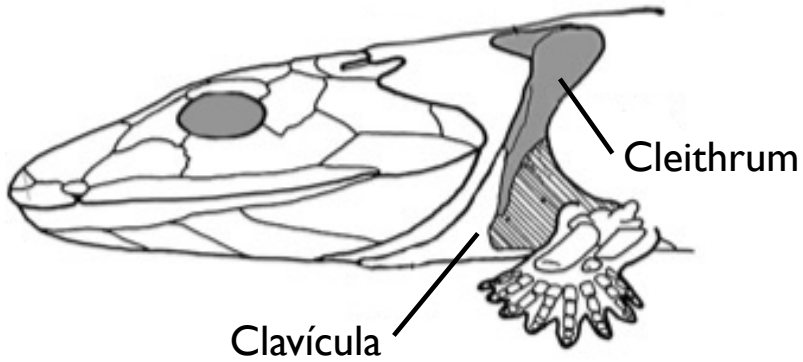
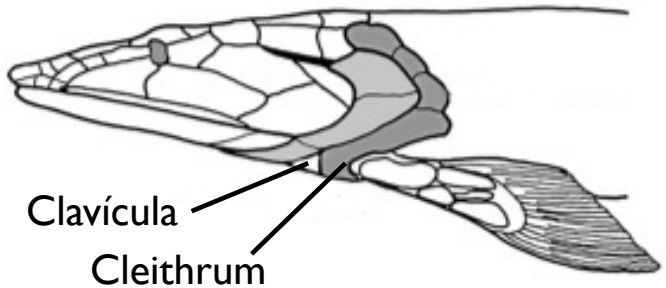
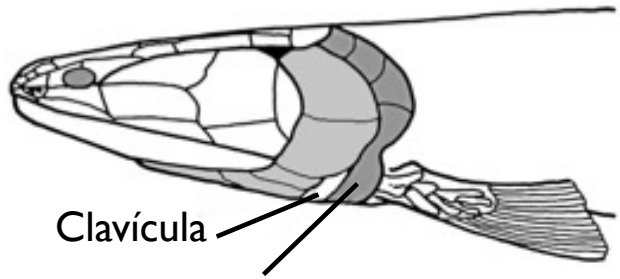




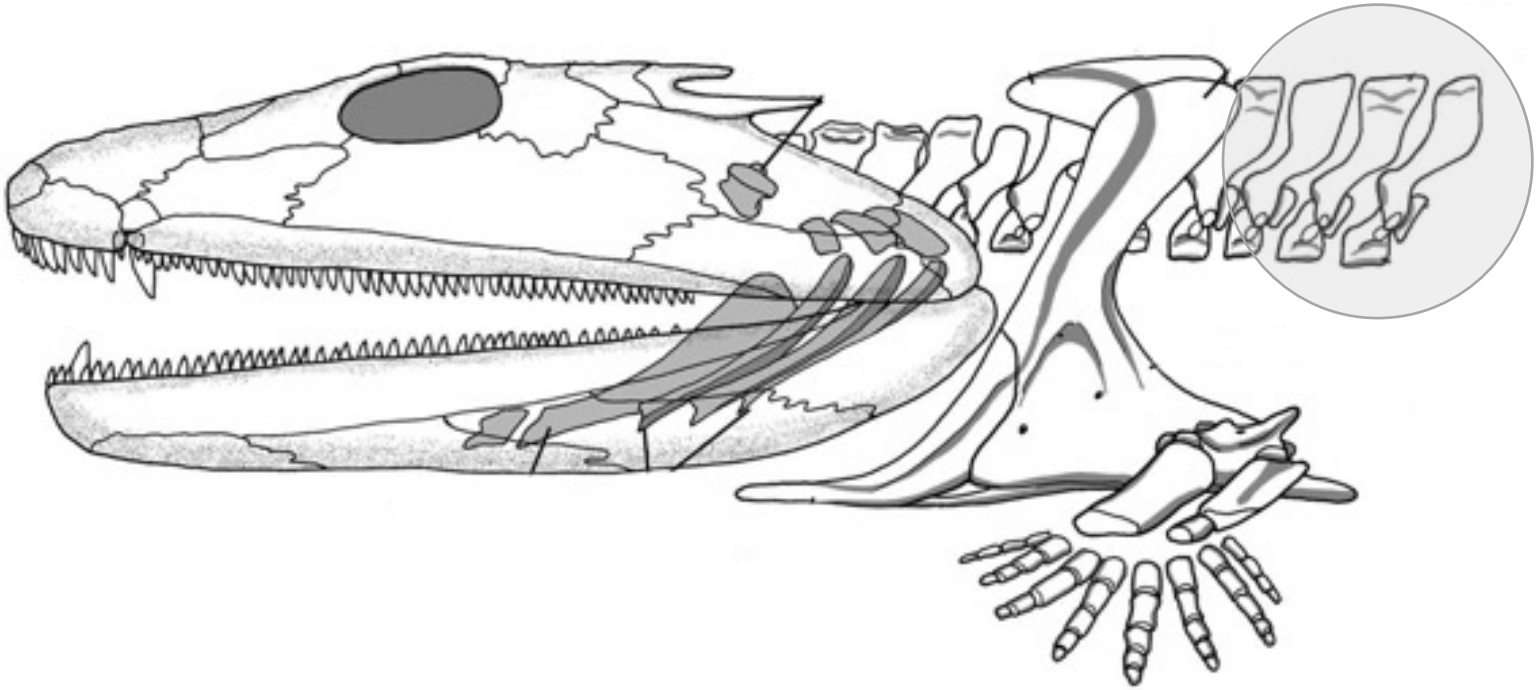


Panderichthyes



Eusthenopterum

Acanthostega



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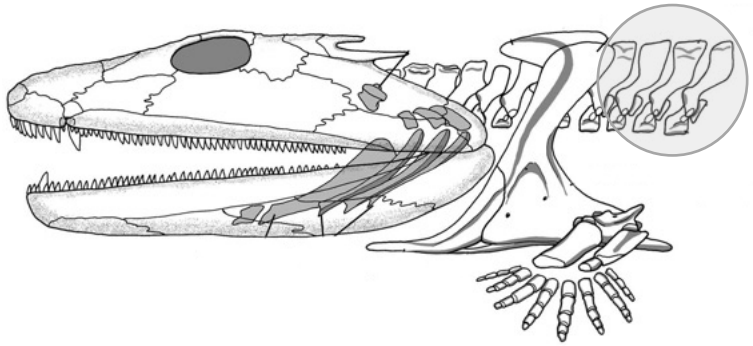

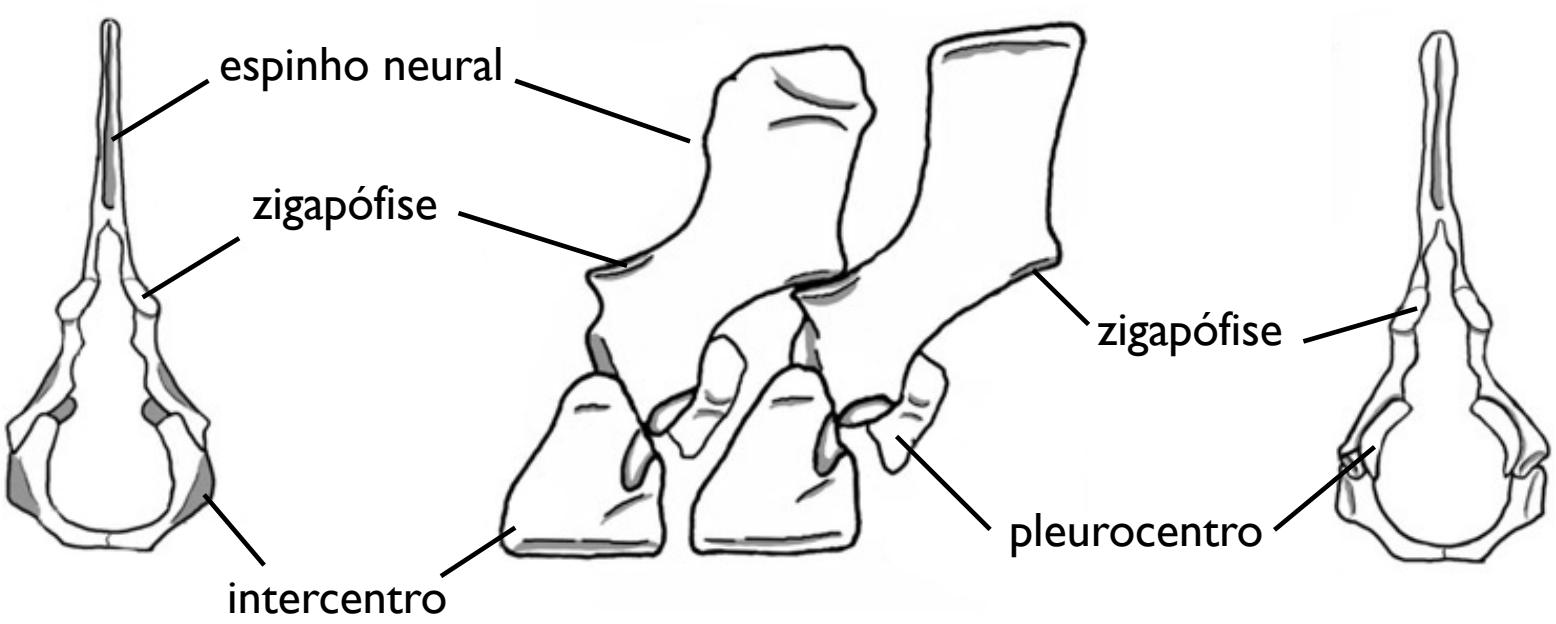

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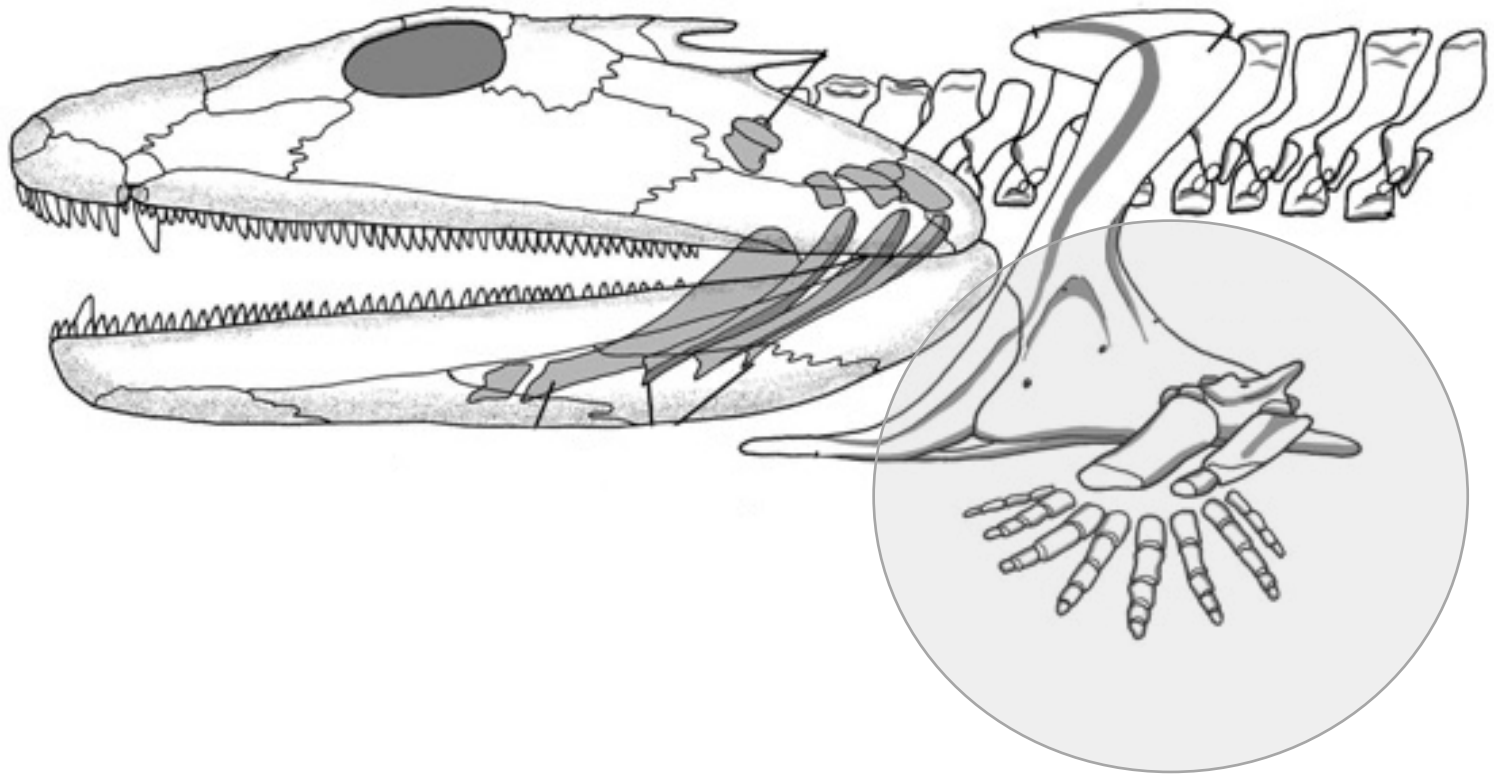
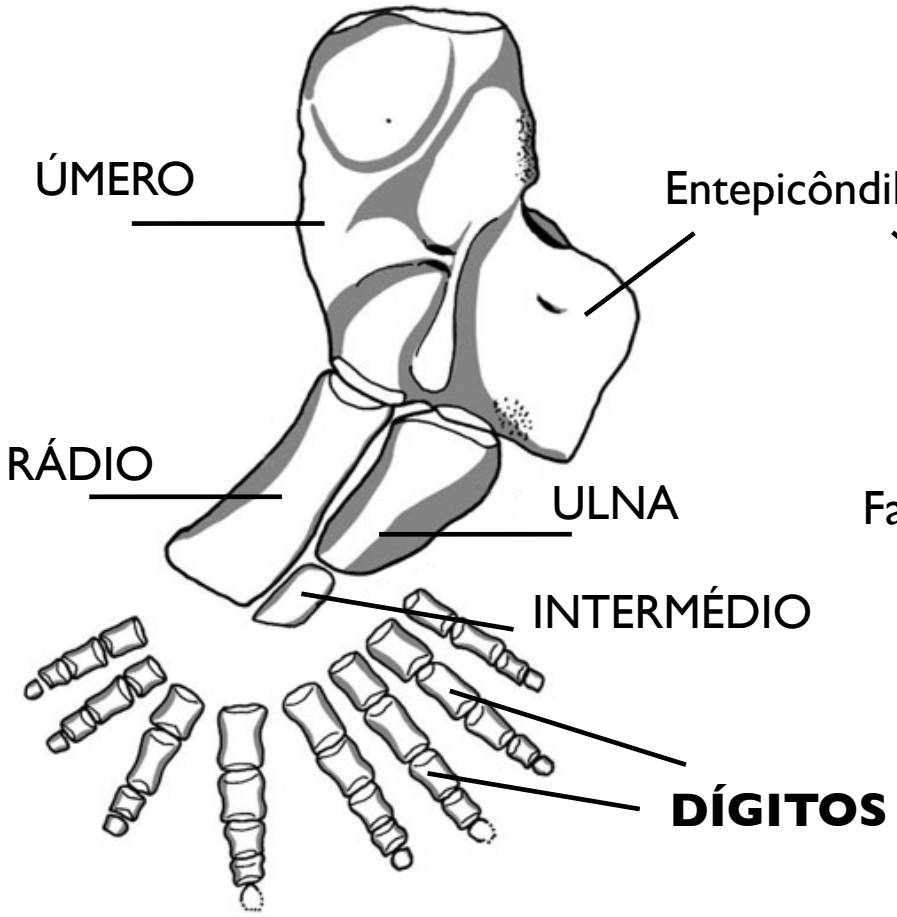
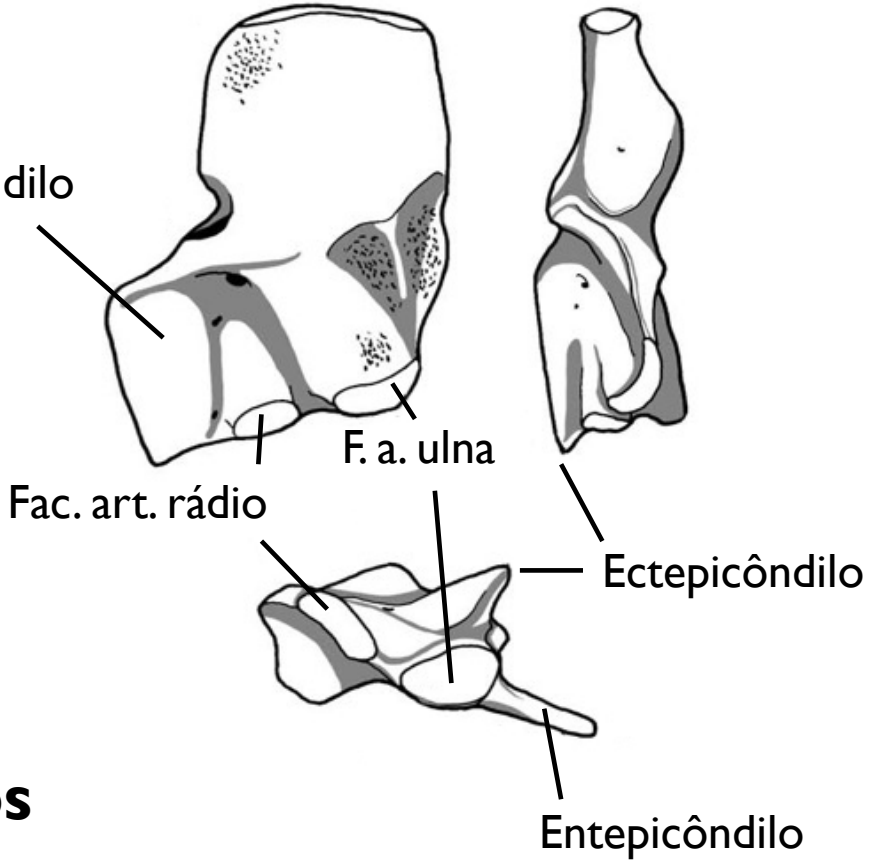


Acanthostega

Membro anterior

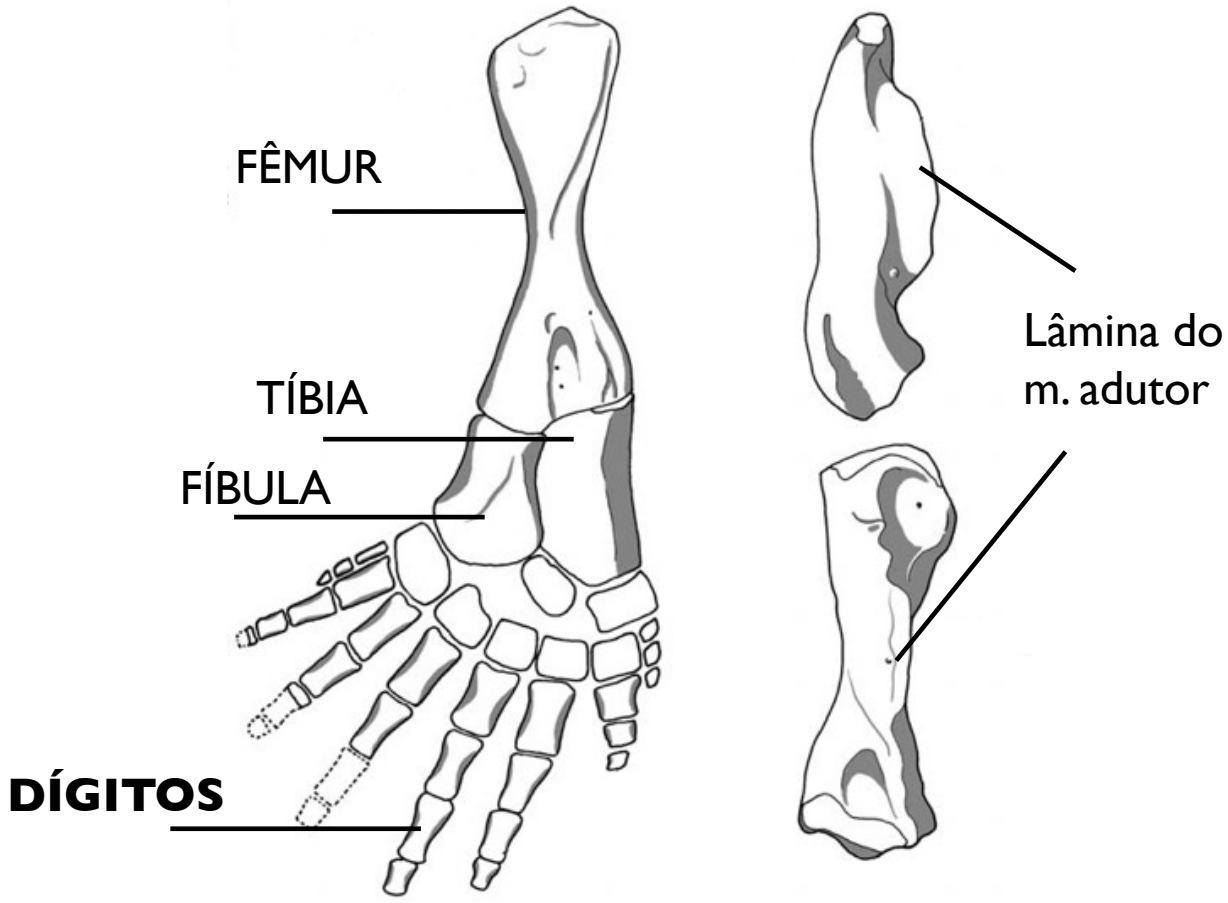


ÚMERO



Acanthostega

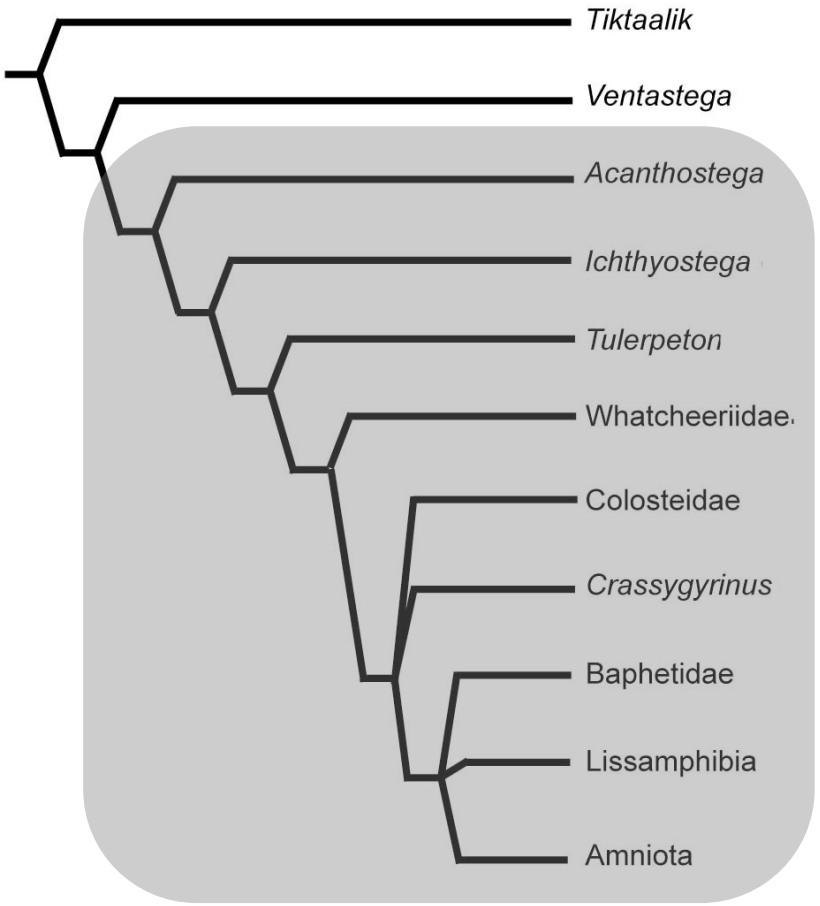
Membro posterior



Acanthostega

Acanthostega

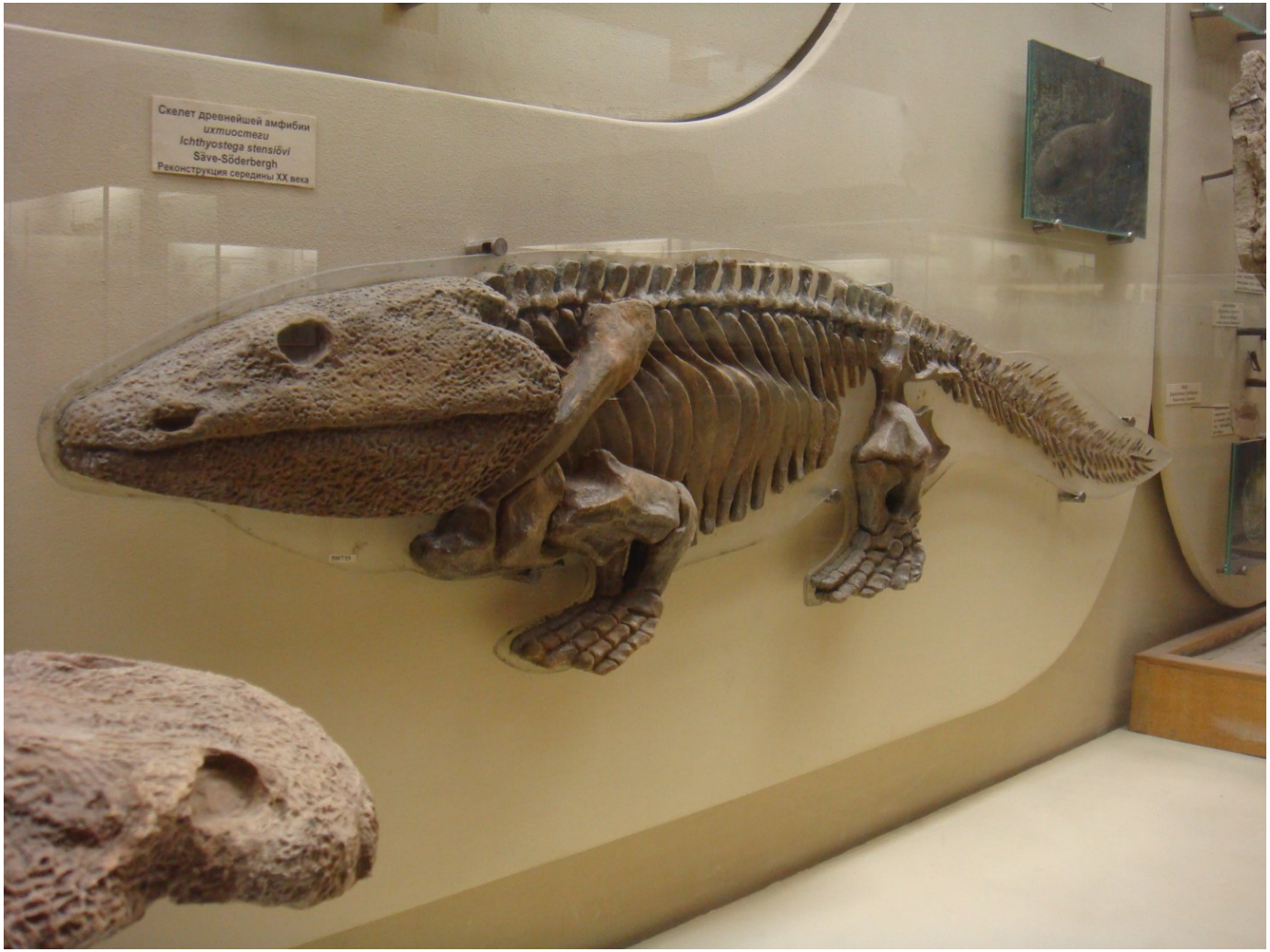
Ichthyostega



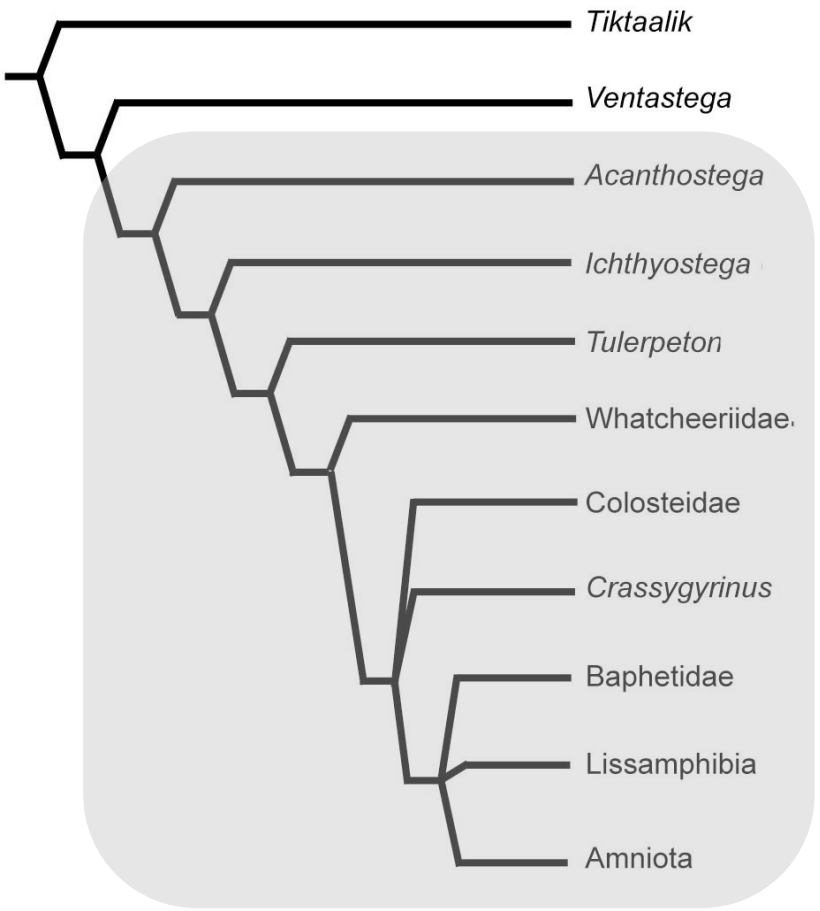
Um dos primeiros fósseis descobertos

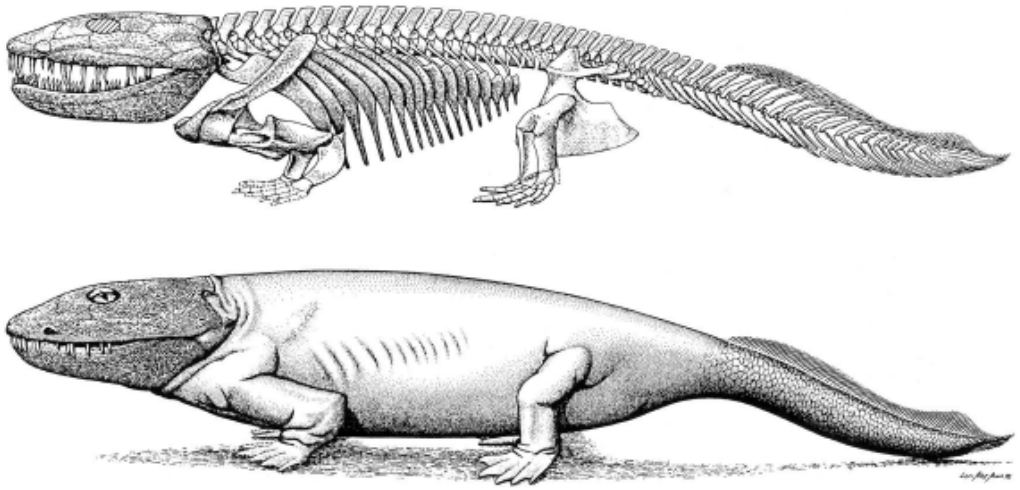
Ichthyostega

Ichthyostega



Ichthyostega

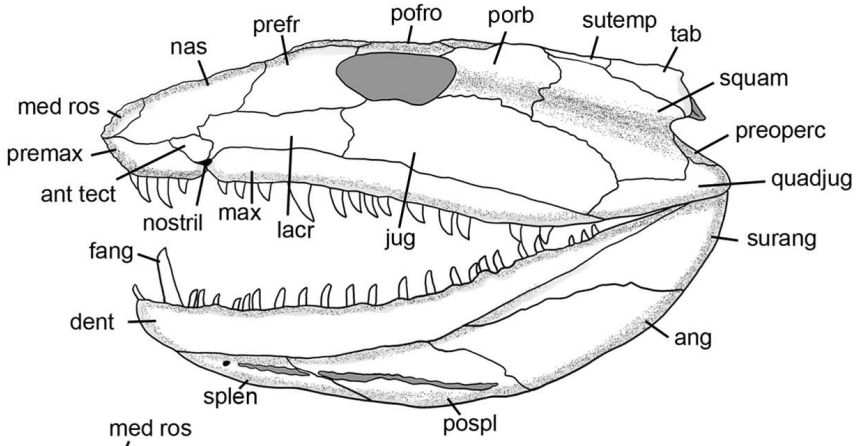


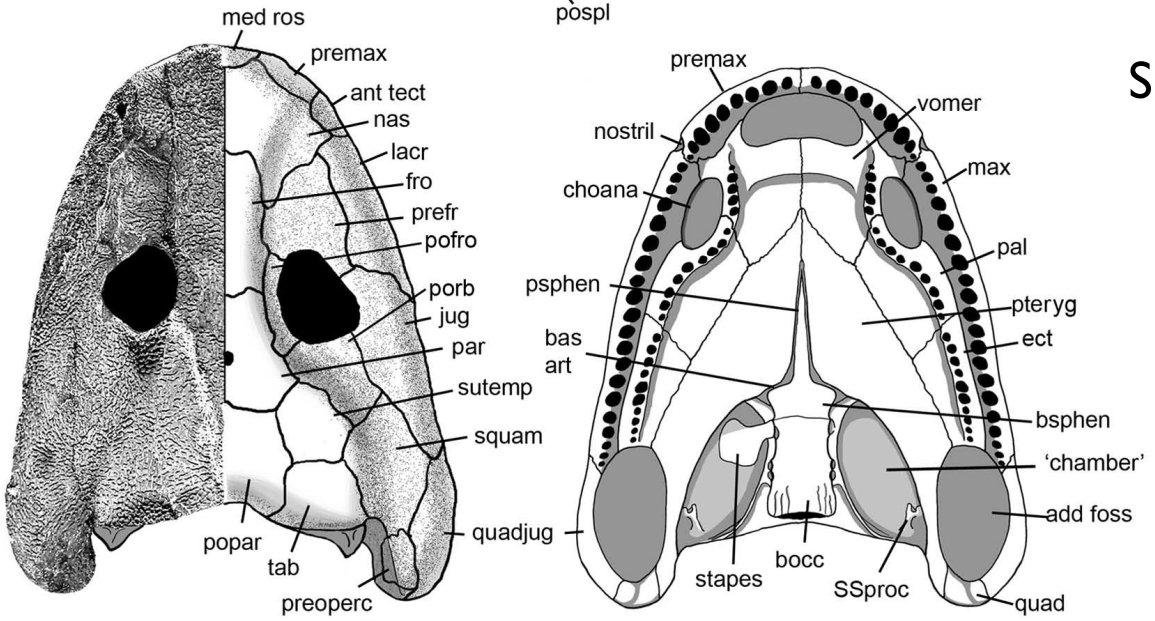


Hábitos semi-aquáticos

Adaptações ao ambiente terrestre

Ichthyostega





Características

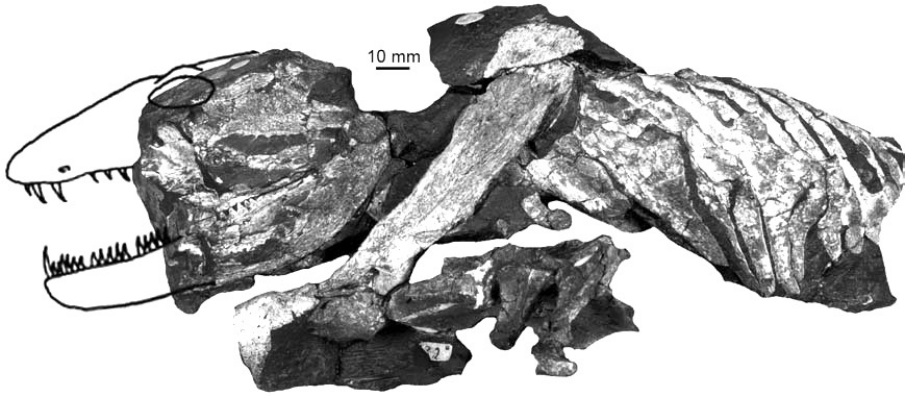
Crânio e mandíbula desenvolvidos

Dentes robustos e curvados

Sistema branquial ossificado

Sistema de linha lateral

Ichthyostega



Costelas desenvolvidas

Sustentação do corpo

Sustentação/proteção de órgãos

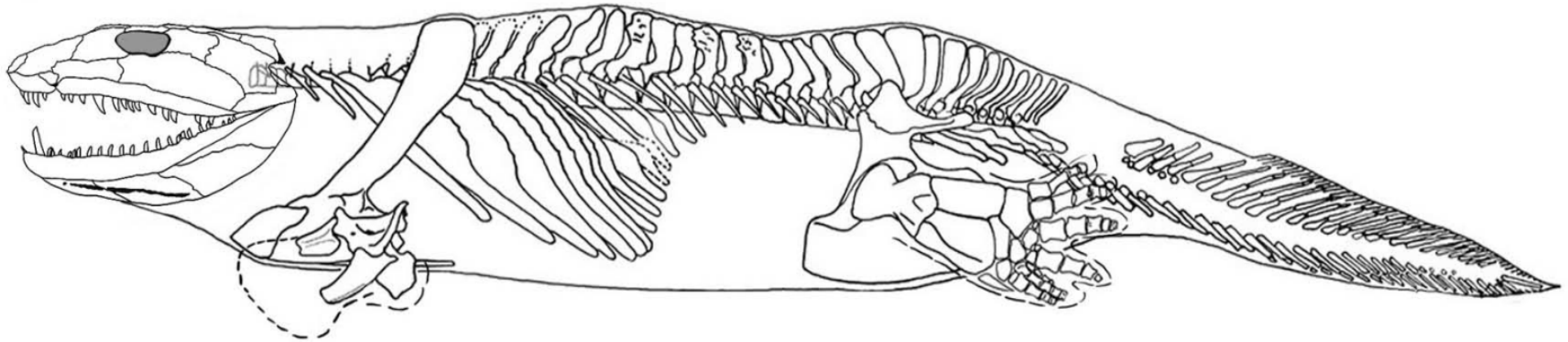
Conflito com locomoção

Vértebras diferenciadas

Regionalização

Diferentes funções e pressões

Musculatura mais complexa



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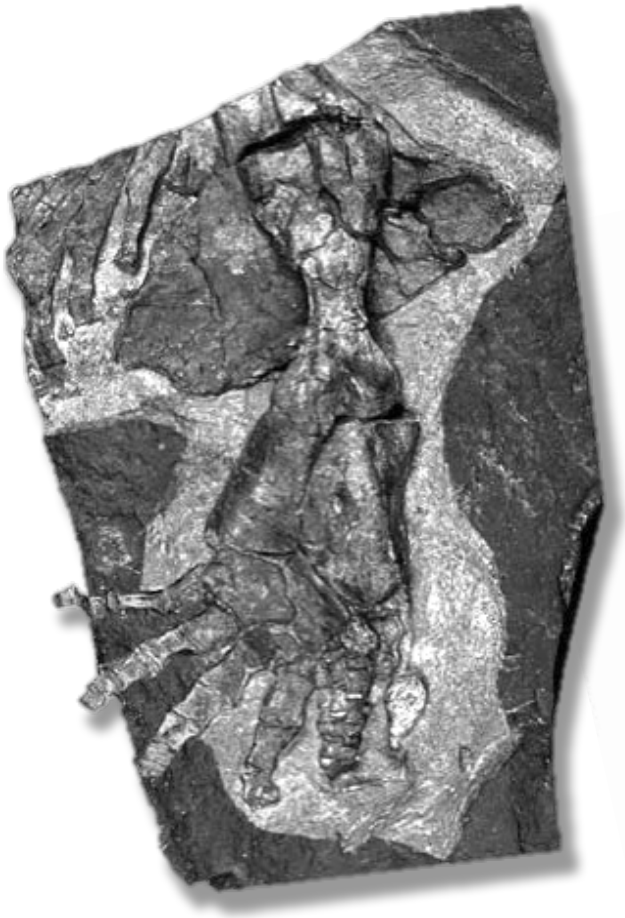
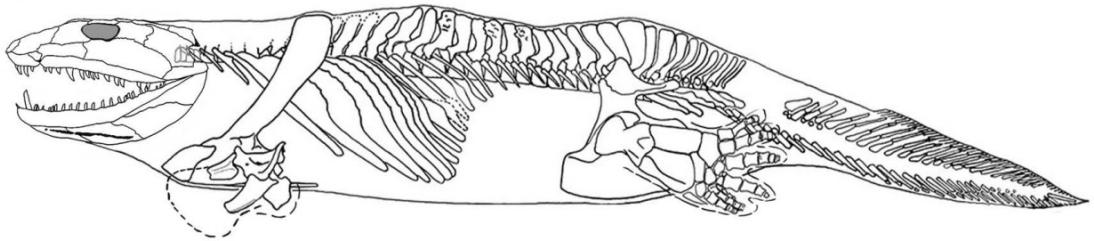
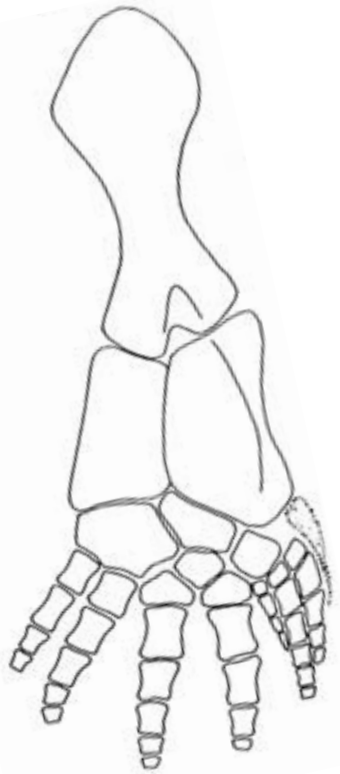






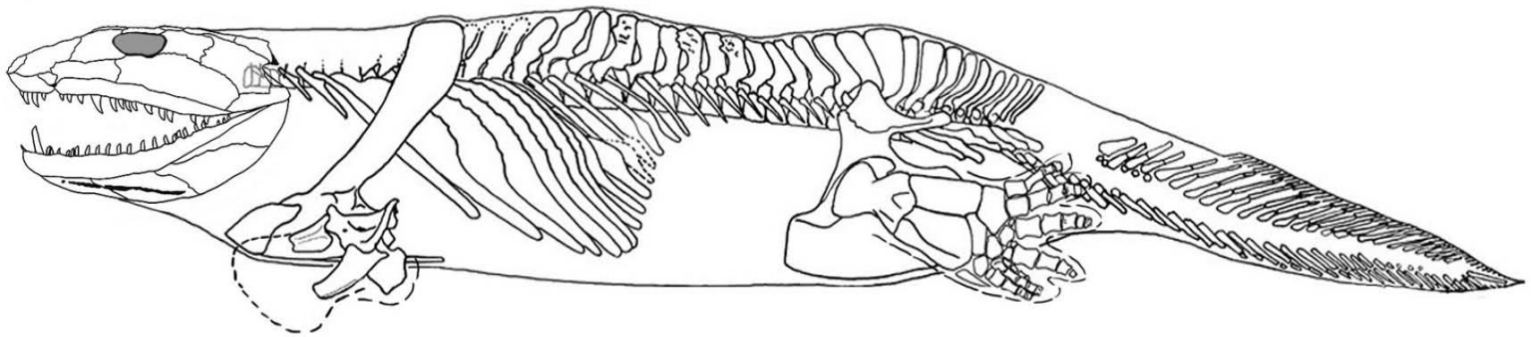
Cinturas escapular e pélvica robustas

Membros robustos

Anteriores pouco conhecidos

7 dígitos

Ichthyostega



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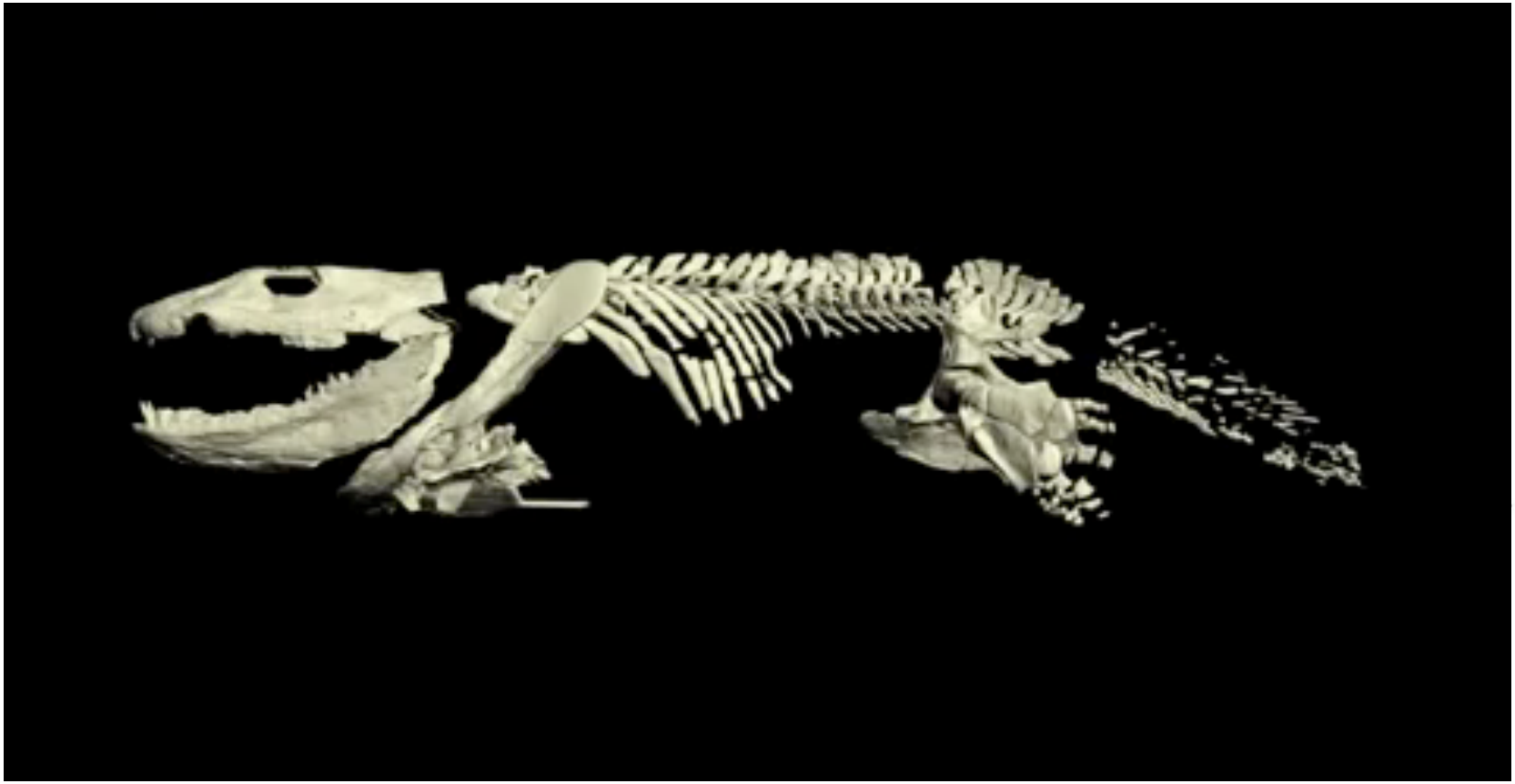
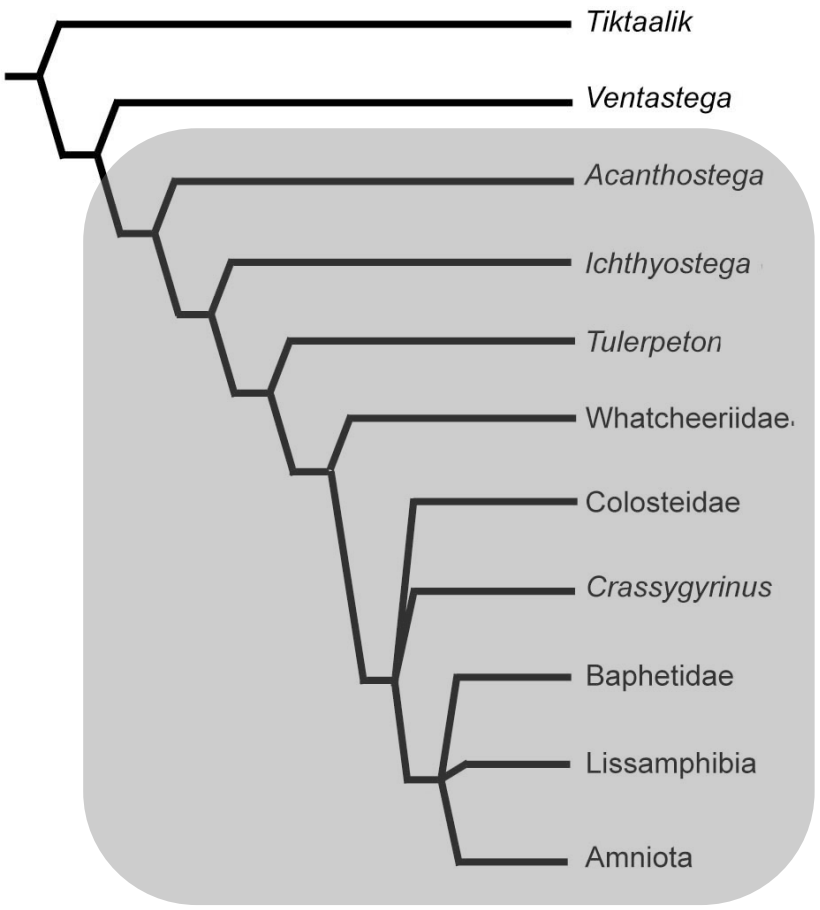
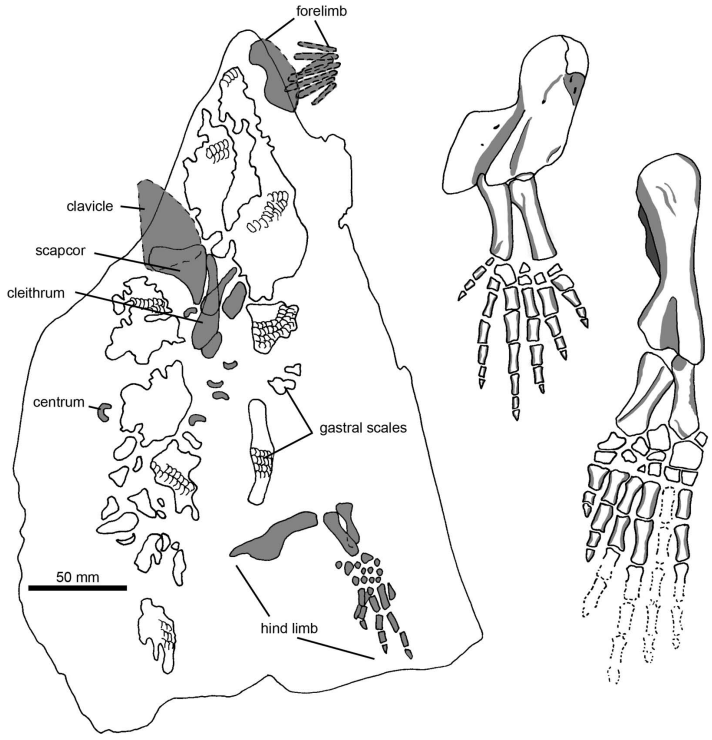


Tulerpeton



Devoniano superior

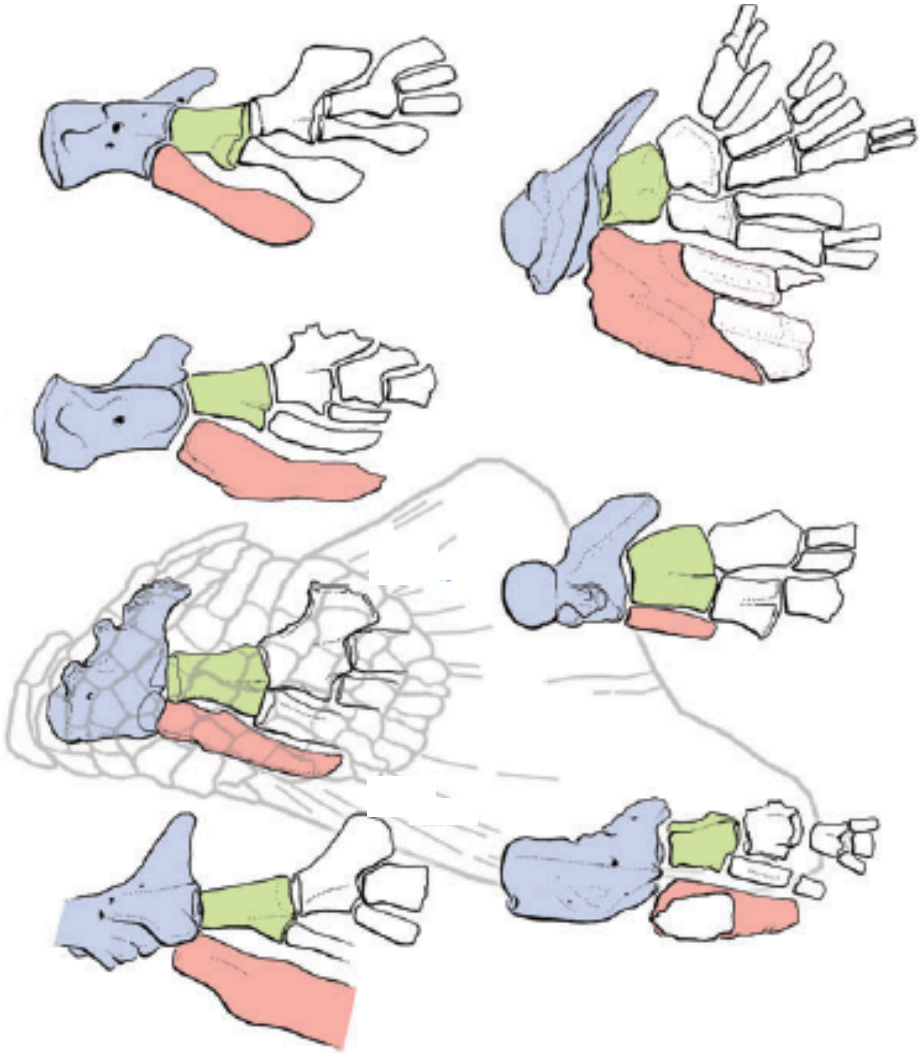
Poucos espécimes



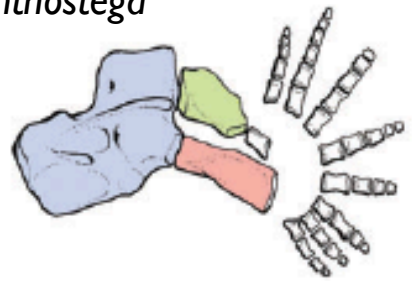
Redução em alguns ossos

Redução do n. de dígitos

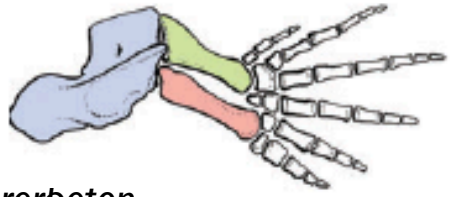
Nadadeiras e membros



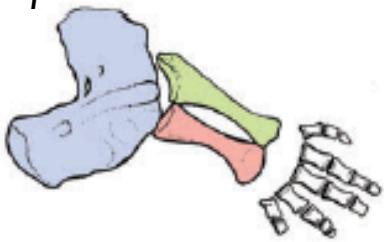
Acanthostega



Tulerpeton



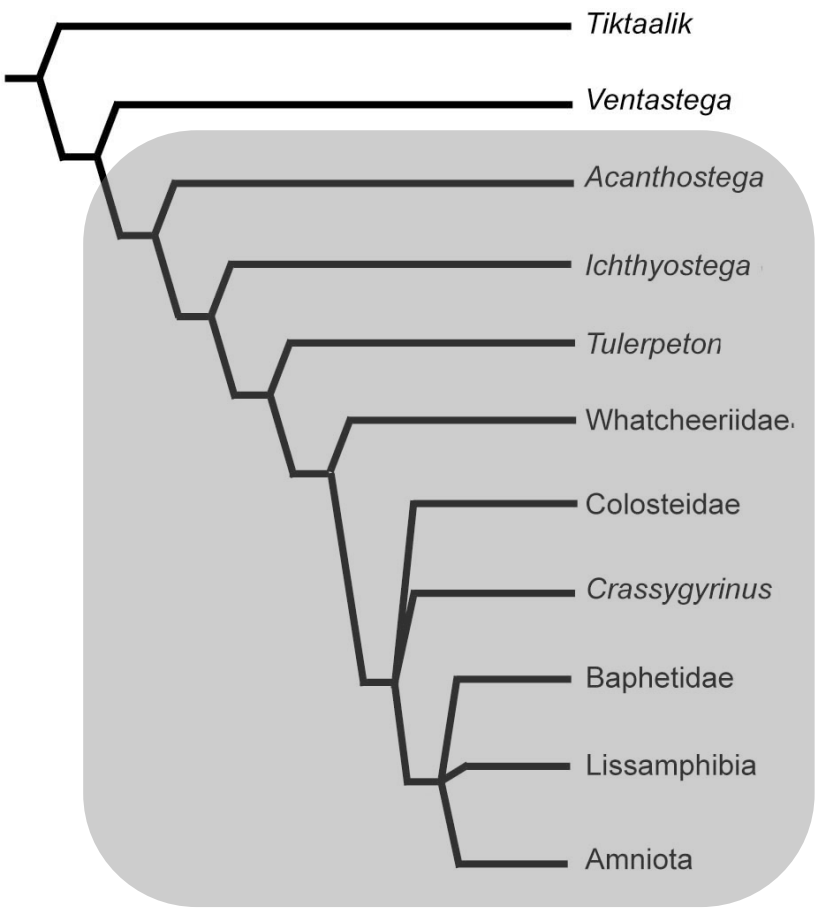
Greererpeton

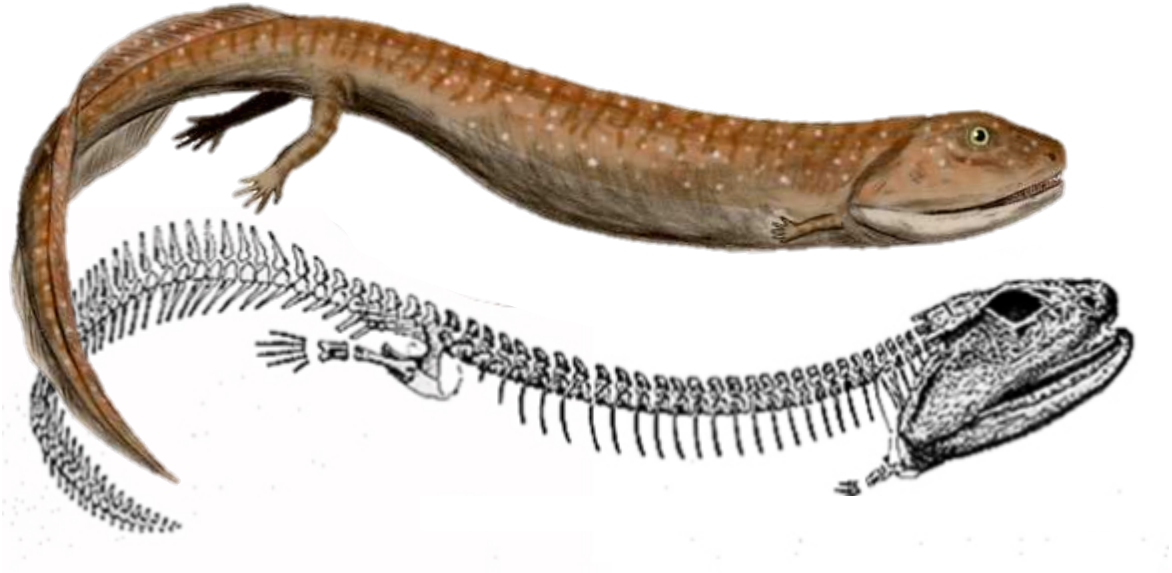


Westlothiana

Adaptado de Coates et al. (2008)

Crassigyrinus

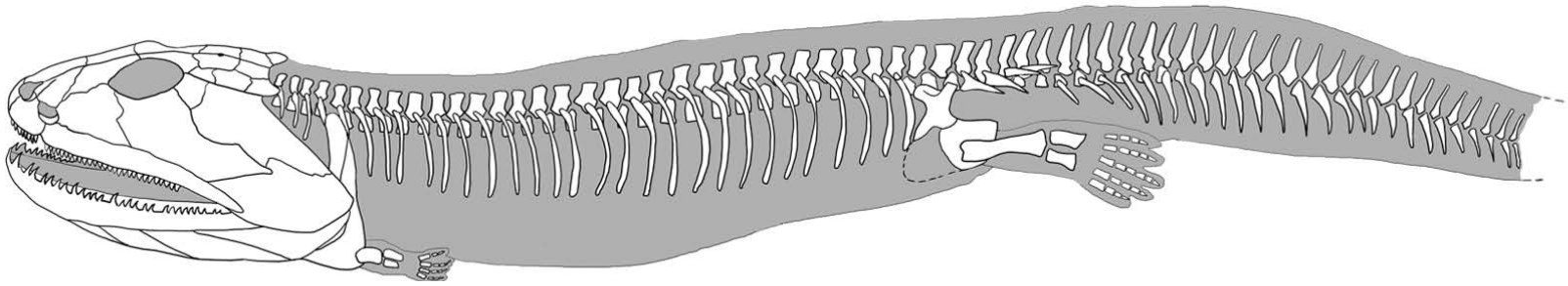


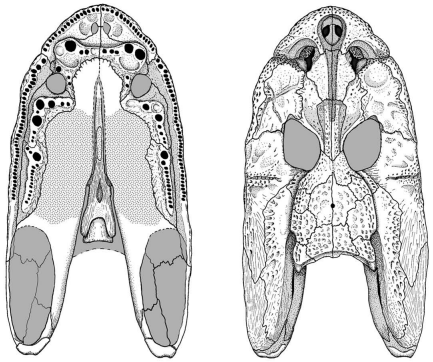


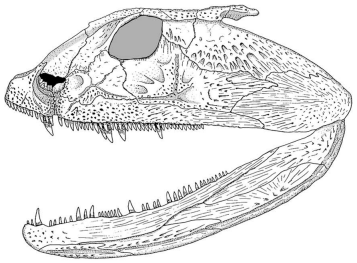
Período Carbonífero

Secundariamente aquático

Crassigyrinus







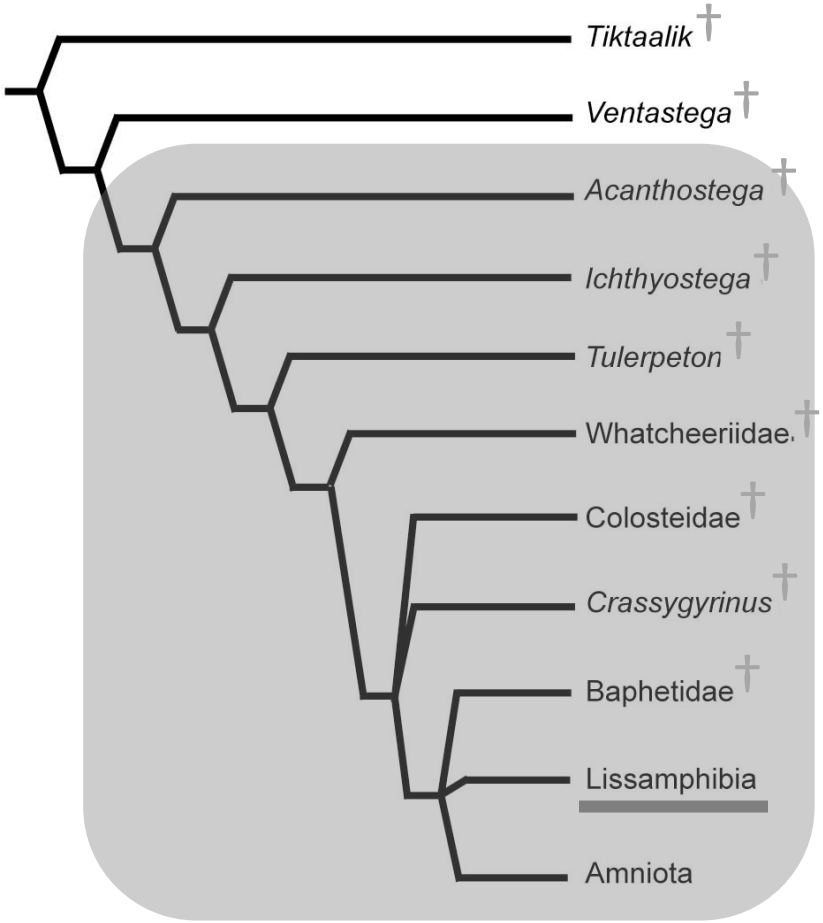
Características

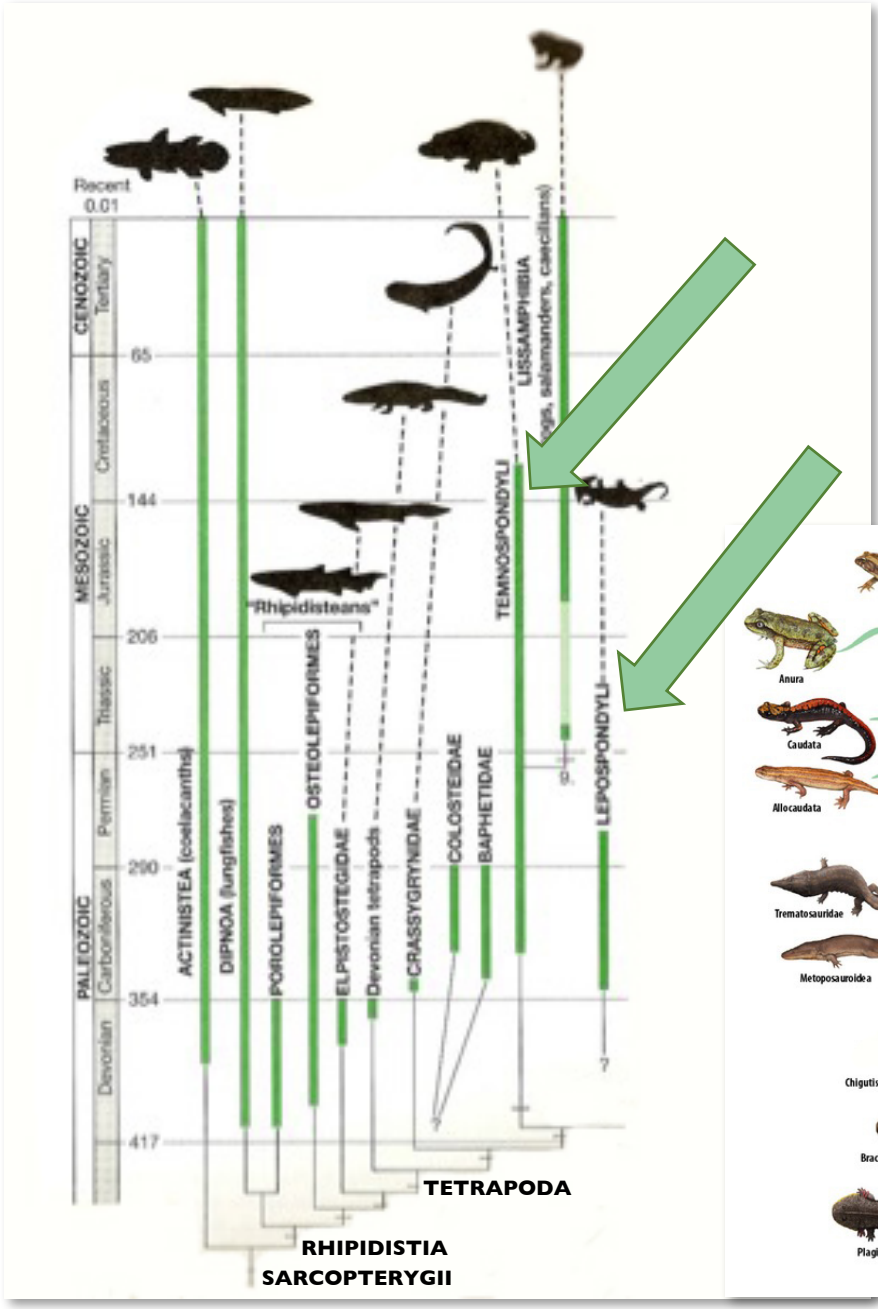
Extrema redução dos membros

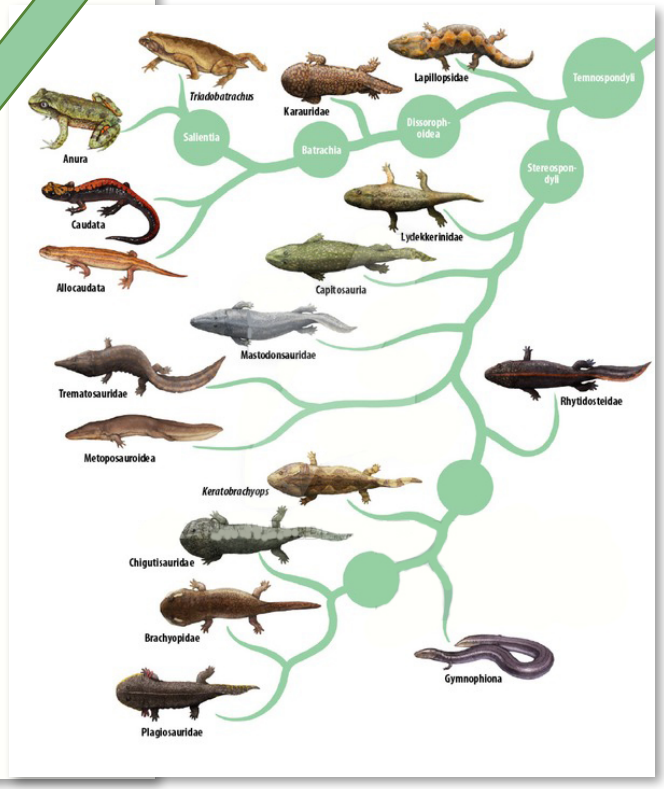
Natação axial

Vértebras simplificadas

Palato semelhante a peixes


Tiktaalik †
Ventastega †
Acanthostega †
Ichthyostega †
Tulerpeton †
Whatcheeriidae †
Colosteidae †
Crassygyrinus †
Baphetidae †
Lissamphibia
Amniota





Lissamphibia

Cecílias, salamandras e sapos

Diferentes hipóteses

Temnospondyli

Lepospondyli

Grupo parafilético