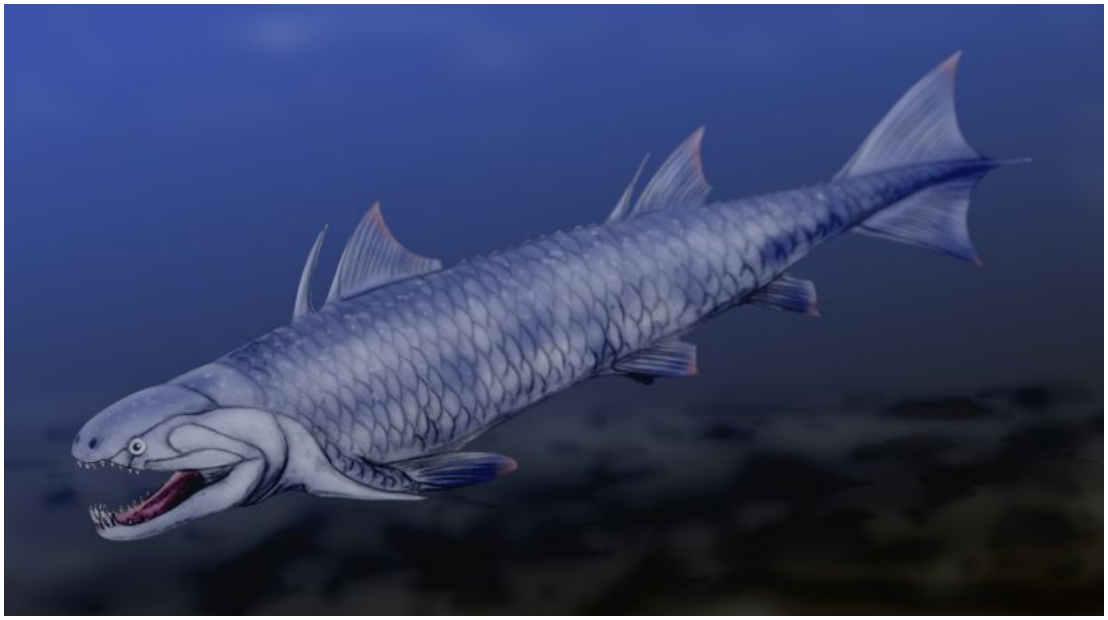
Actinopterygii

Peces con aleta radiada

Curso Paleontología de Vertebrados 2018

¿Cuál es morfológicamente más derivado?



¿Qué es un actinopterigio?

Polypteriformes

Bichires – *Polypterus*
Erpetoichthys

Chondrostei

Esturiones – *Acipenser*
Huso
Pseudosaphirhynchus
Scaphirhynchus

Peces espátula – *Polyodon*
Psephurus

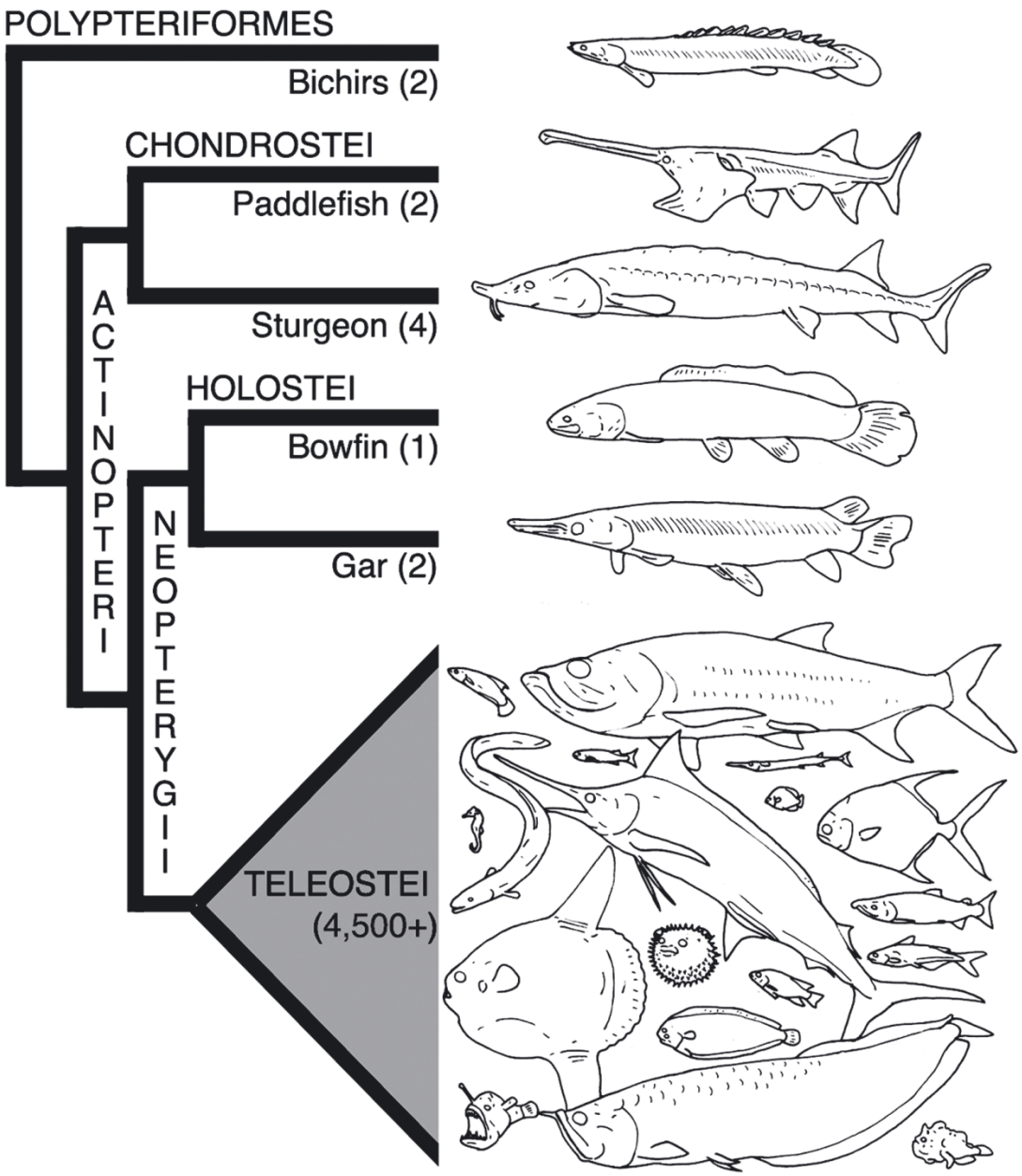
Holostei

Bowfin – *Amia*

Gar o pejelagarto – *Lepisosteus*
Atractosteus

Actinopterigios recientes

(Número de géneros)



Cladistia: Polypteriformes

Bichires

2 géneros, 10 especies
Humedales de África tropical y el Nilo.

Espiráculos, pulmones, placas gulares.

Polypterus

Erpetoichthys

Larva de *Polypterus*

Pulmones de *Polypterus*

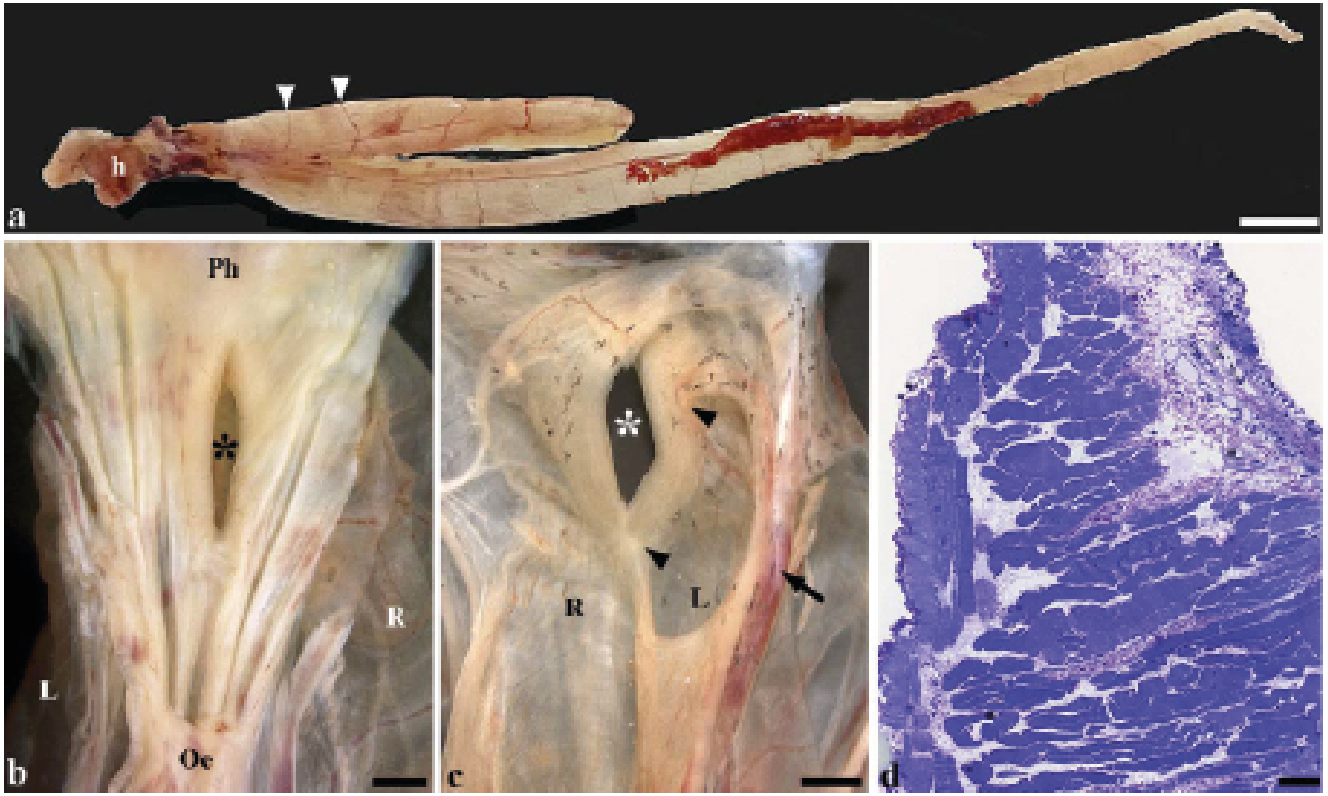
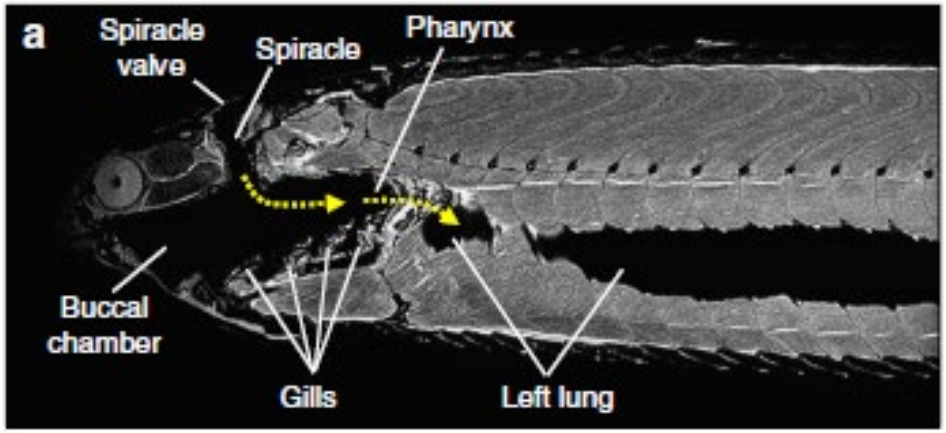
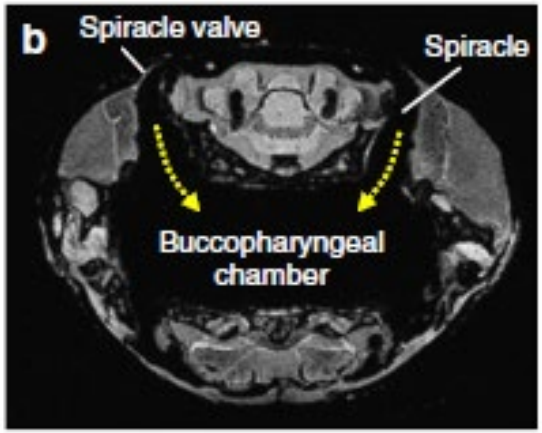
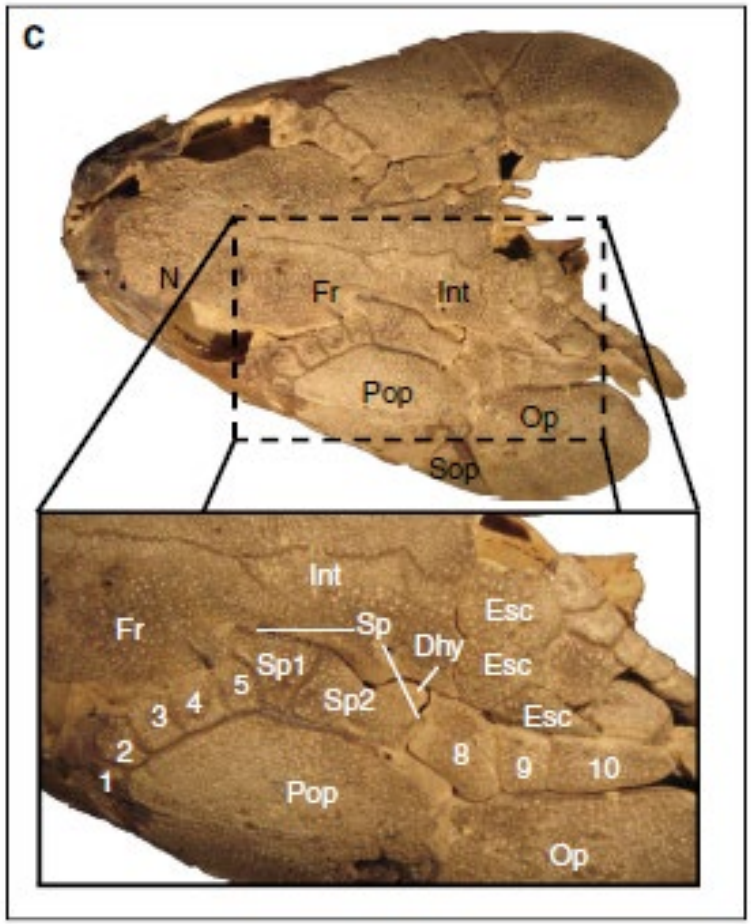


FIGURE 1 (a) Polypterus senegalus Ventral view of the lung. The right lobe is much longer than the left one. Note the presence of parallel, transversely arranged arterial branches (arrowheads). h, heart. (b) Erpetoichthys calabaricus. The dorsal wall of pharynx (Ph) and oesophagus (Oe) is opened. The pharyngeal communication with the lung is a ventral, slit-like opening (asterisk) with slightly thickened borders. The left (L) and right (R) lungs locate ventrally. (c) Polypterus senegalus Ventral view. The dissection has eliminated the ventral wall of the left (L) and right (R) lobes. The pharyngeal aperture (asterisk) shows thick lips. The communication between lobes is a rounded orifice deviated to the left. Note that the dorsal side of this orifice (arrowheads) is formed by the left rim of the pharyngeal aperture. Arrow indicates ventral pulmonary vessel. (d) Erpetoichthys calabaricus. Semi-thin section. Toluidine bue. The muscle component of the lip of the pharyngeal aperture is depicted. The amount of muscle decreases toward the lung wall (upper portion of the panel). Note different muscle bundle orientations. Scale bars: (a) 2 cm; (b) 0.5 cm; (c) 0.5 cm; (d) 50 1 m







- Espiráculos: respiración aérea

Graham 2014

Caminando como *Polypterus*

Chondrostei

Acipenseriformes (Cretácico Tardío –)

Endoesqueleto **cartilaginoso**

Perdida de **centro vertebral**

Intestino con **válvula espiral**

Formas fósiles con hueso datan Jurásico-Cretácico

Acipenser

Polyodon

Esqueleto Cartilaginoso

Protrusión mandíbula

¿Qué es un actinopterigio?

Linnaeus

Systema Naturae 1758

IV PISCES.

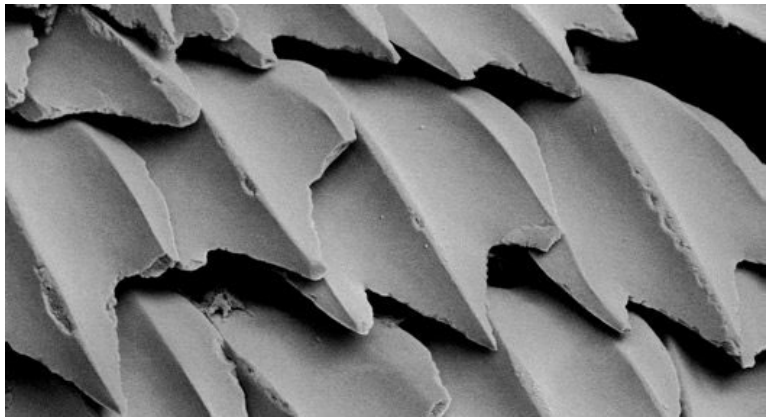
Corpus apodum, pinnis veris instructum, nudum, vel squamosum.

PLAGIURI. *Cauda* horizontalis.	Thrichechus.	*Dentes* in utraque maxilla. *Dorsum* impenne.	Manatus f. *Vacca mar.*
	Catodon.	*Dentes* in inferiore maxilla. *Dorsum* impenne.	Cot. Fistula in rostro *Art.* Cete *Clus.*
	Monodon.	*Dens* in superiore max. 1, *Dorsum* impenne.	Monoceros. *Unicornu.*
	Balæna.	*Dentes* in sup. max. cornei. *Dorsum* sæpius impenne.	B. Groenland. B. Finfisch. B. Maxill. inf. latiore. *Art.*
	Delphinus.	*Dentes* in utraque maxilla. *Dorsum* pinnatum.	Orcha. Delphinus. Phocæna.
CHONDROPTERYGII. *Pinnæ* cartilagineæ.	Raja.	*Foramina* branch. utrinq. 5. *Corpus* depressum.	Raja clav. asp. lævi. &c. Squatino-Raja. Altavela. Pastinaca mar. Aquila. Torpedo. Bos *Vet.*
	Squalus.	*Foram.* branch. utrinq. 5. *Corpus* oblongum.	Lamia. Galeus. Carulus. Vulpes mar. Zygæna. Squatina. Centrine. Pristis.
	Acipenser.	*Foram.* branch. utrinq. 1. *Os* edentul. tubulatum.	Sturio. Huso. *Ichthyocolla.*
	Petromyzon.	*Foram.* branch. utrinq. 7. *Corpus* bipenne.	Enneophthalmus. Lampetra. Mustela.

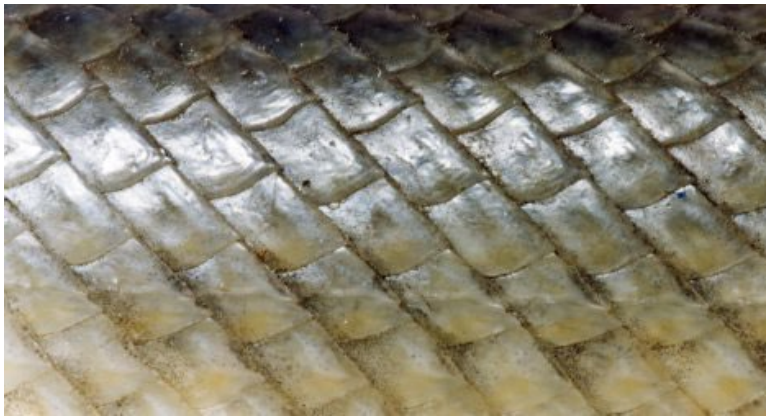
BRANCHIOSTEGI. *Pinnæ* offic. carentes. *Branch.* oss. & membran.	Lophius.	
	Cyclopterus.	
	Ostracion.	
	Balistes.	
ACANTHOPTERYGII. *Pinnæ* osseæ, quarum quædam aculeatæ.	Gasterosteus.	
	Zeus.	
	Cottus.	
	Trigla.	
	Trachinus.	
	Perca.	
	Sparus.	
	Labrus.	
	Mugil.	
	Scomber.	
	Xiphias.	
	Gobius.	
MALACOPTERYGII. *Pinnæ* osseæ, quæ omnes molles.		Gymnotus.
		Muræna.
		Blennus.
		Gadus.
		Pleuronectes.
		Ammodytes.
		Coryphæna.
		Echeneis.
		Esox.
		Salmo.
		Osmerus.
		Coregonus.
		Clupea.
		Cyprinus.
		Cobitus.
		Syngnathus.

Paleontología - Louis Agassiz

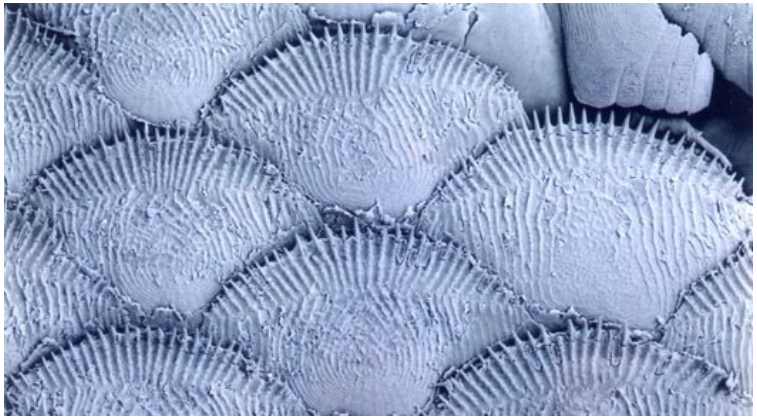
Recherches sur les poisson fossiles (1833-44)



"**Placoidei**" Escama placoide



"**Ganoidei**" Escama ganoide



"**Ctenoidei**" Escama ctenoide

"**Cycloidei**" Escama cicloide

Agassiz “Ganoidei”

Esturiones
Gar – Pejelagarto
Bichires
Peces pulmonados
Peces gato

Anatomía Comparada - Johannes Müller

Teleostei – Holostei – Chondrostei – Dipnoi - Cyclostomi

(1844-1845)

Dipnoi

Holostei

Chondrostei

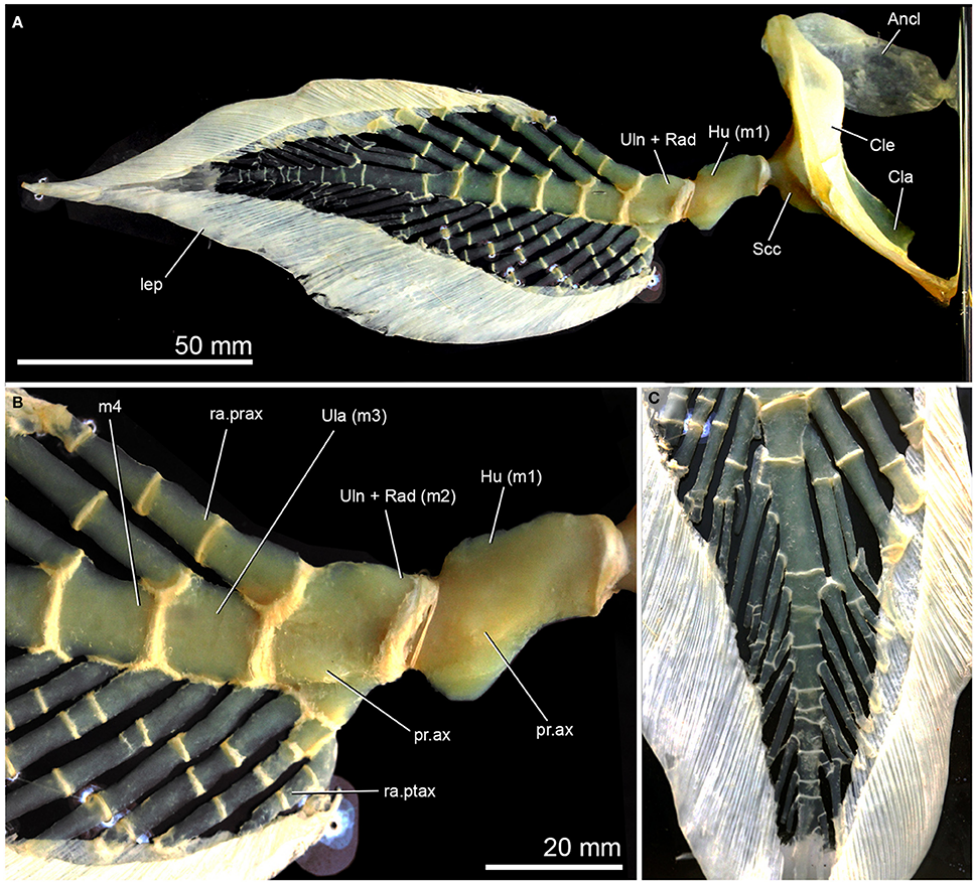
Teleostei

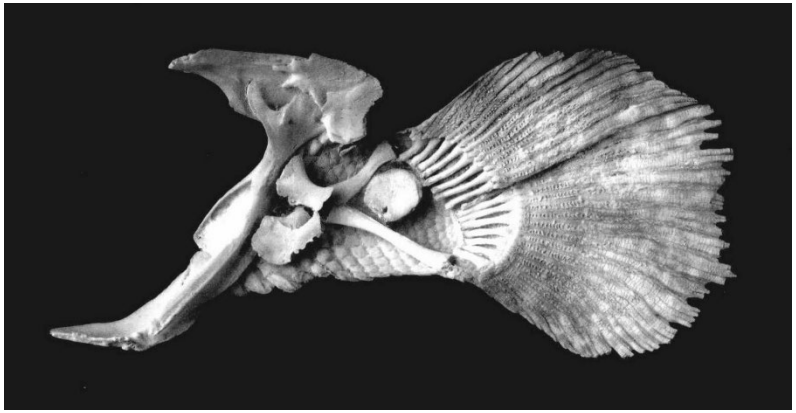
Actinopterygii - Edward Drinker Cope

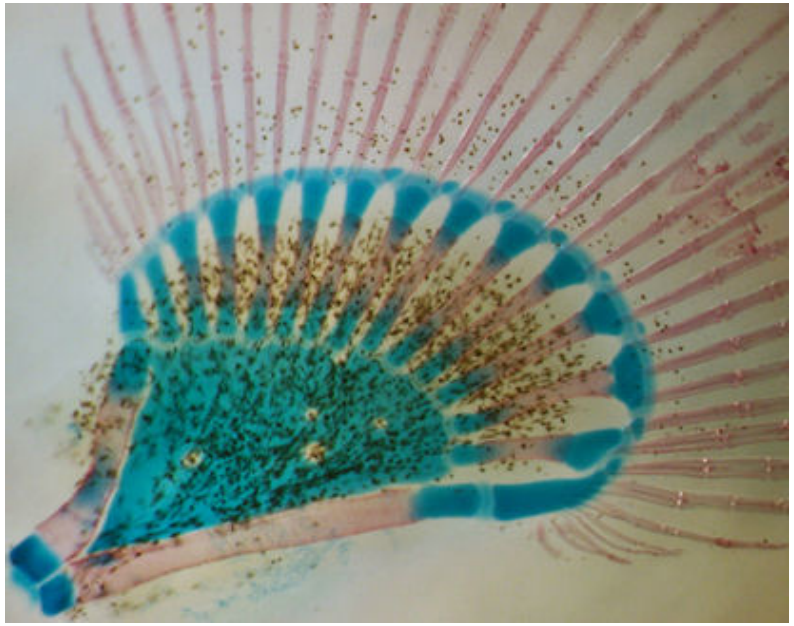
Transformación del “Archipterygium” de Gegenbauer (1871)

Dipnoi

Polypterus

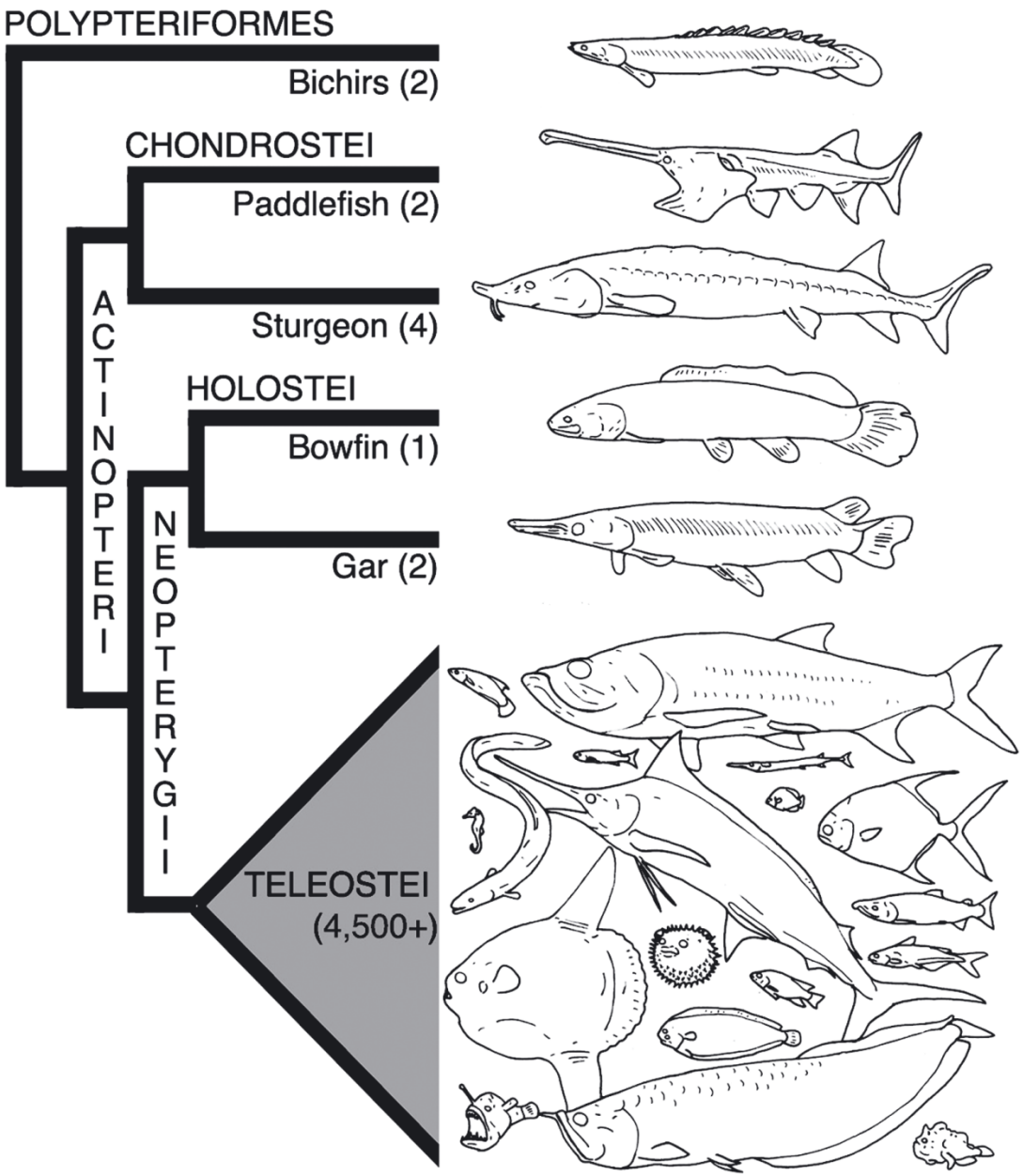






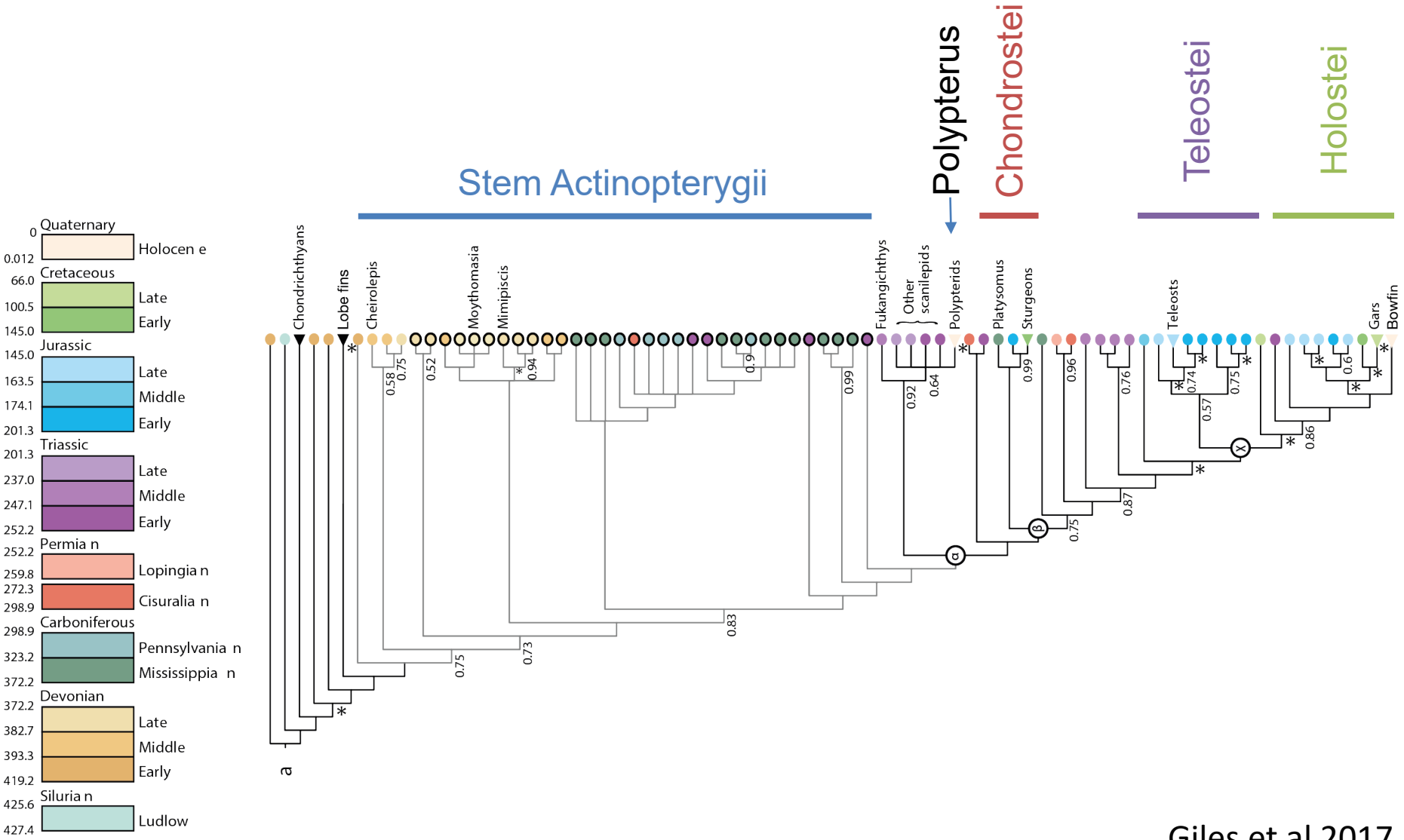
Actinopterigios recientes

(Número de géneros)



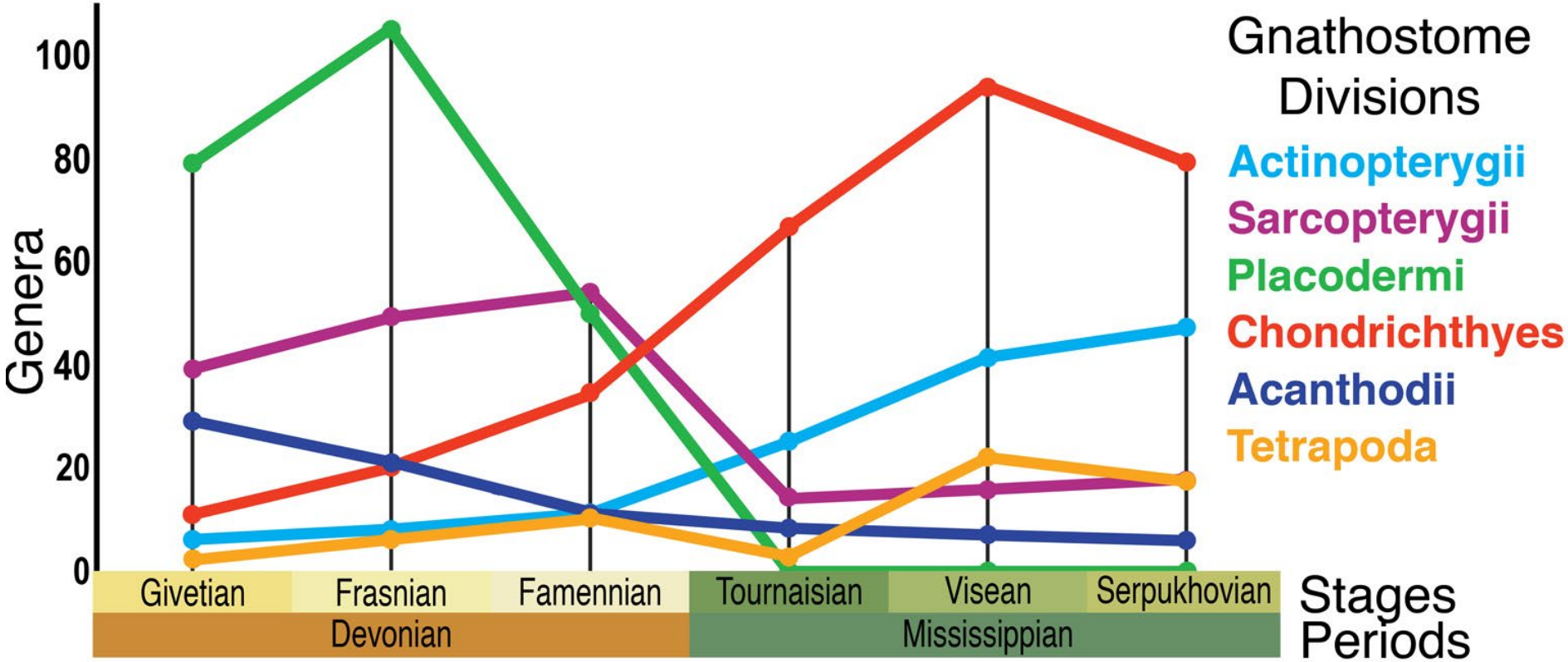
Grande 2010

Filogenia Actinopterygii



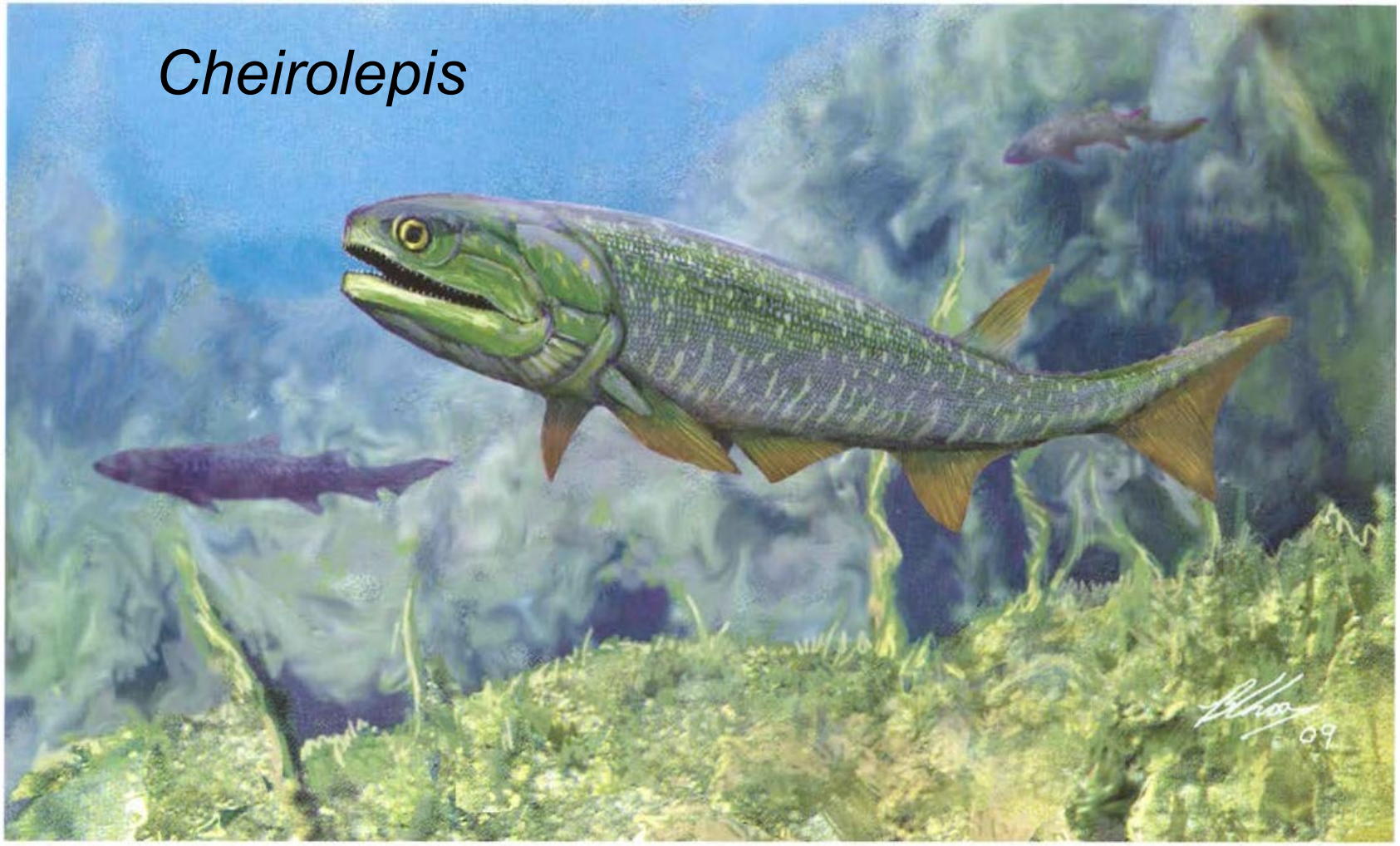
Giles et al 2017

Mesozoico
Actinopterygii / Chondrichthyes



Sallan 2012

Origen Actinopterigios



Long 2011

†*Cheirolepis* Agassiz, 1835

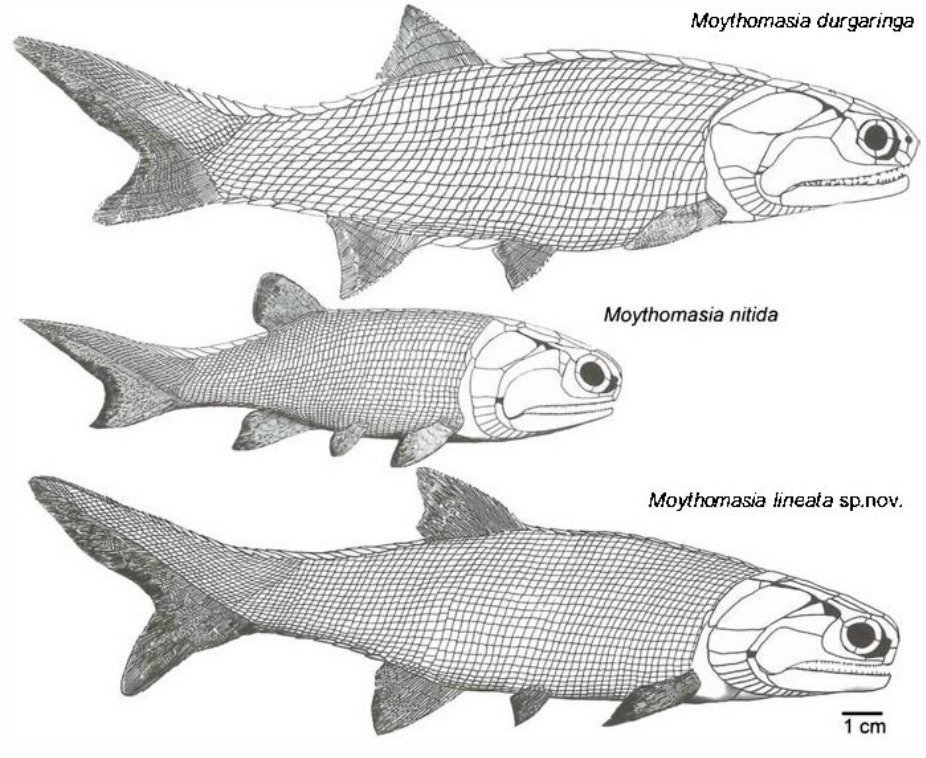
Primer indiscutible actinopterigio

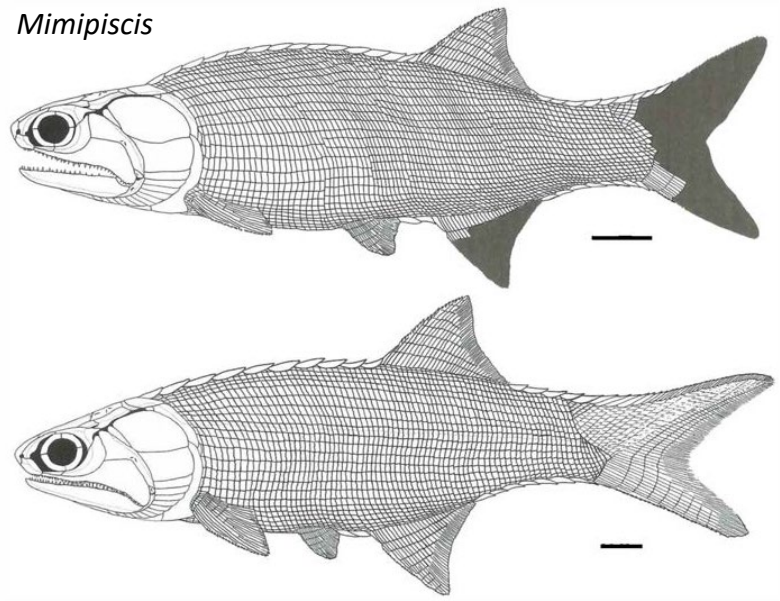
- Devónico Medio-Tardío

  Norteamérica y Europa

Long 2011

Actinopterigios tempranos



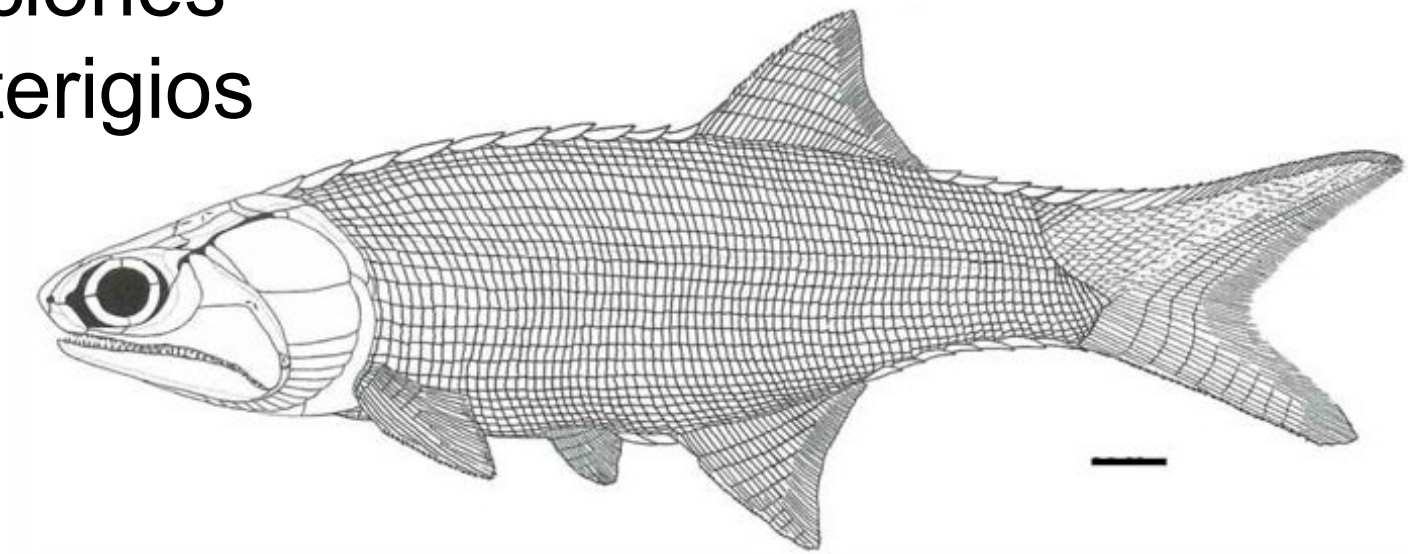


Grupo relativamente homogéneo morfológicamente

Choo 2011, 2015

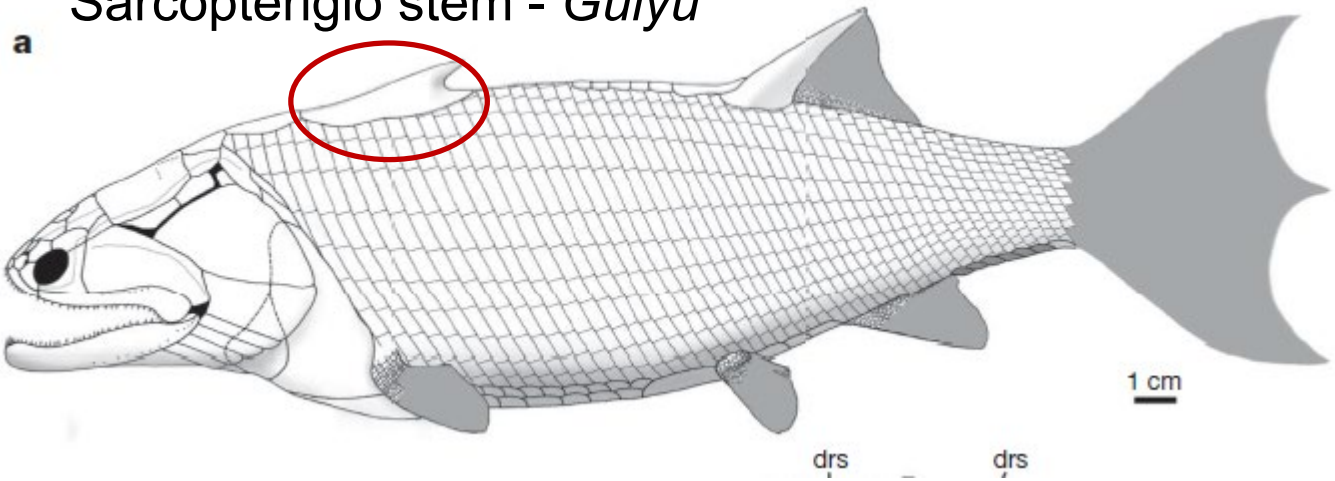
Innovaciones Actinopterigios

Actinopterigio stem - *Mimipiscis*



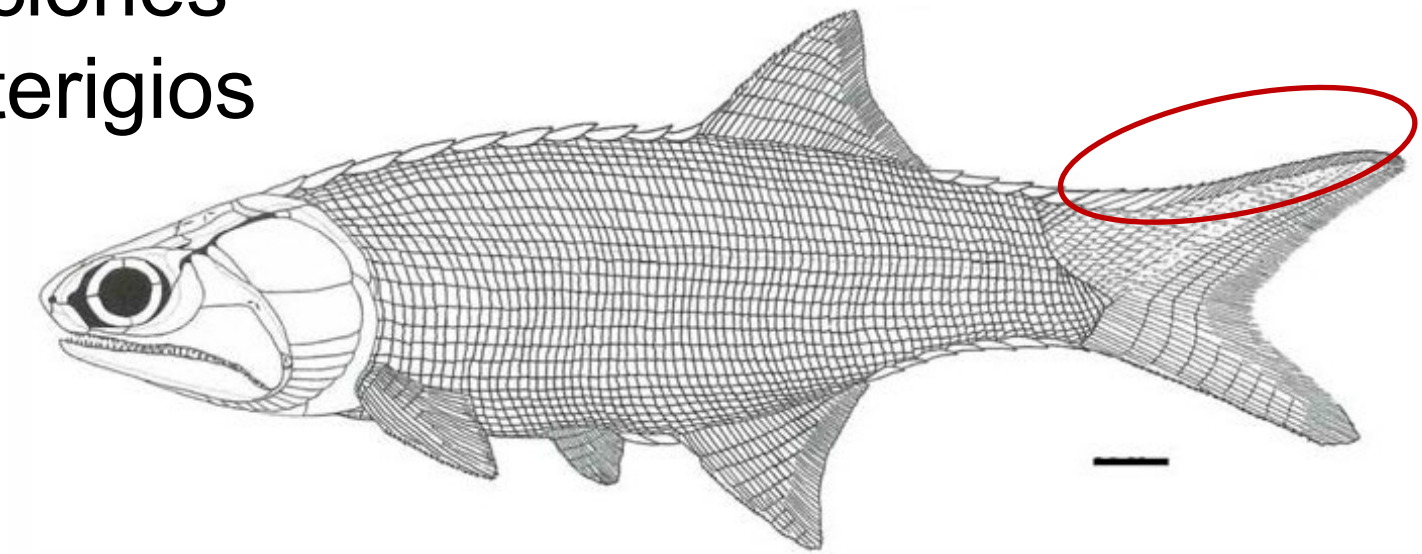
1 aleta dorsal (en vez de dos)

Sarcopterigio stem - *Guiyu*



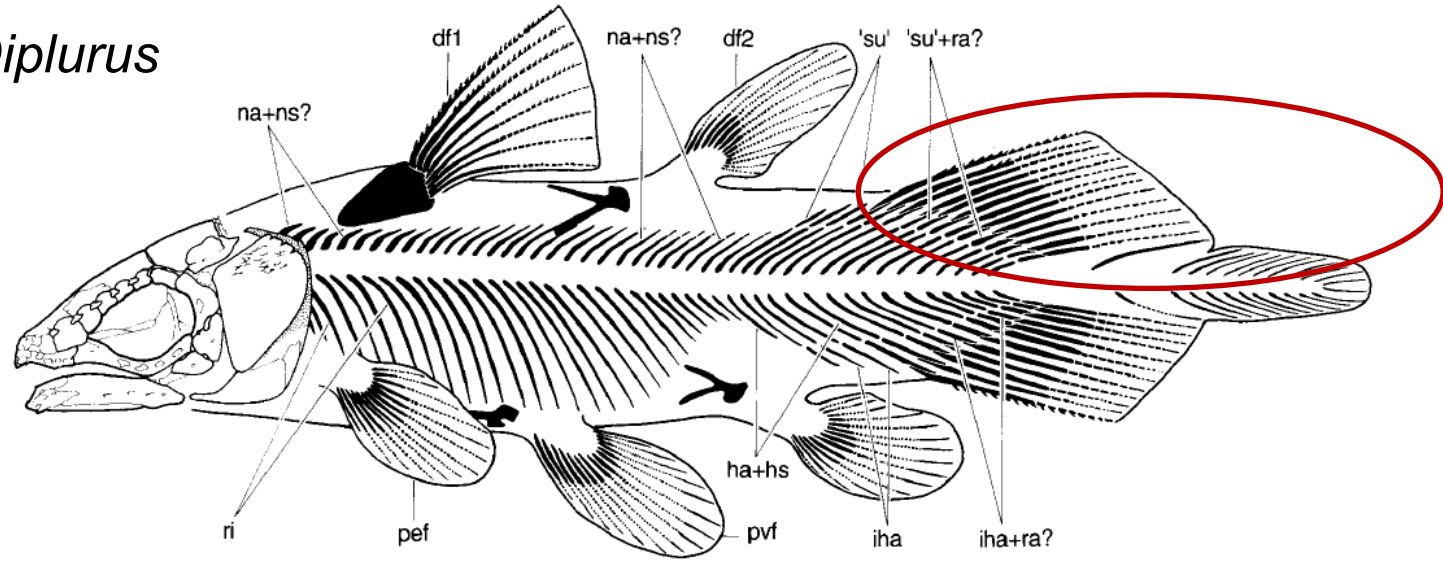
Innovaciones Actinopterigios

Actinopterigio stem - *Mimipiscis*



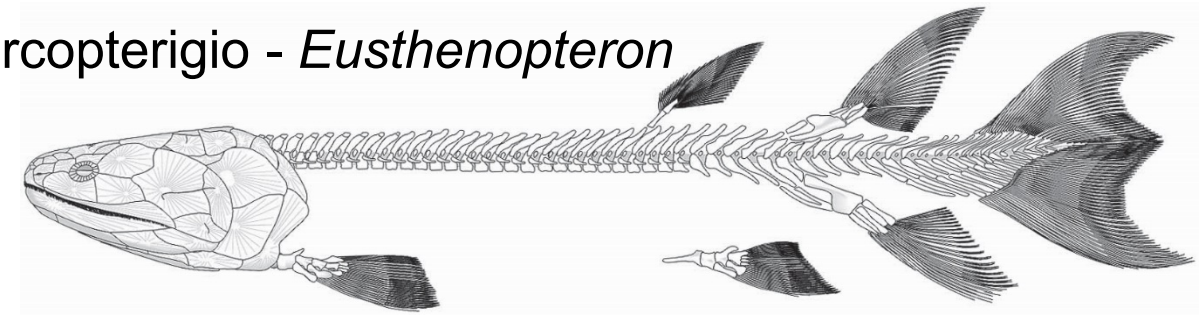
Perdida de rayos óseos epicordales en la aleta caudal

Actinistia - *Diplurus*

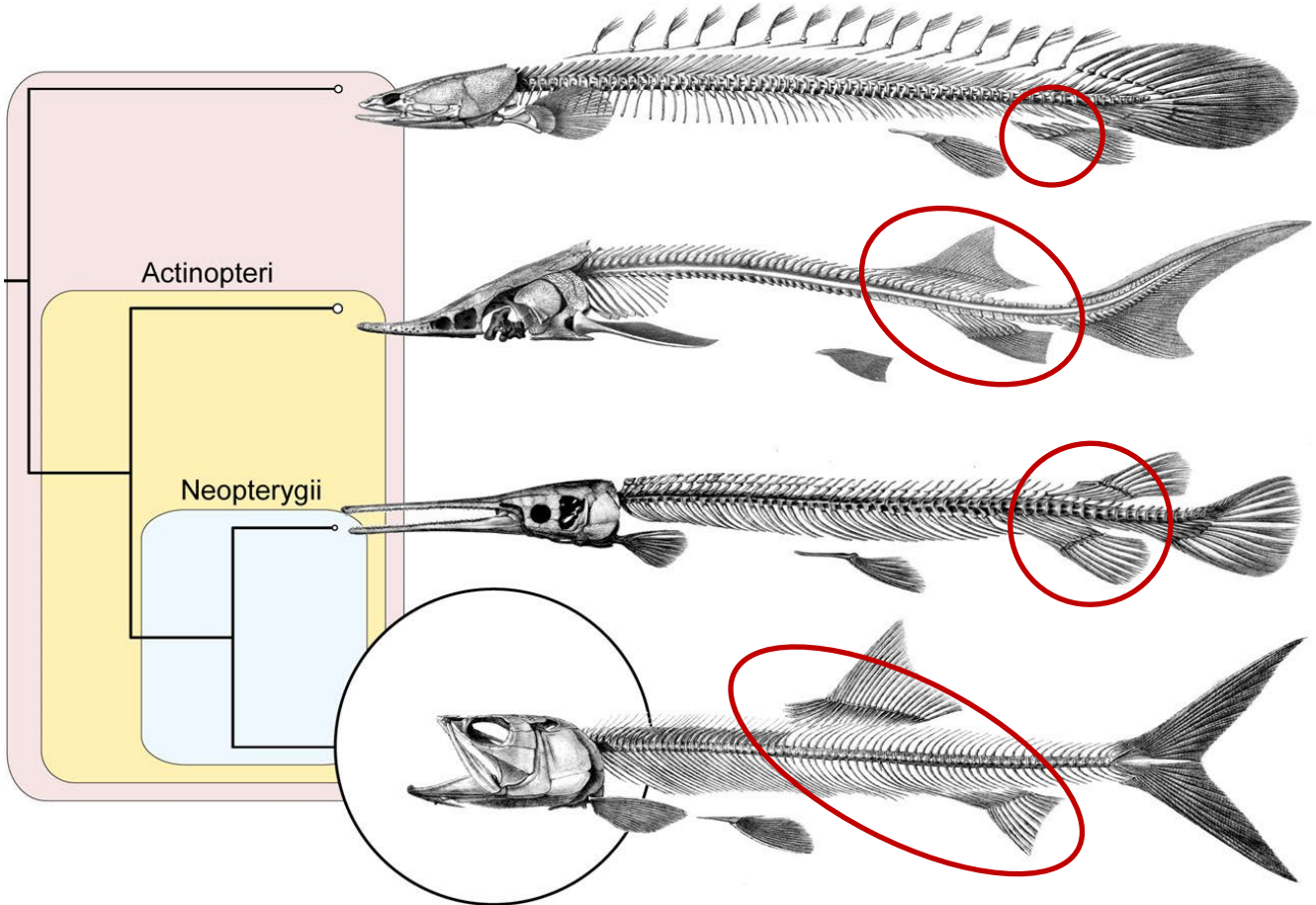


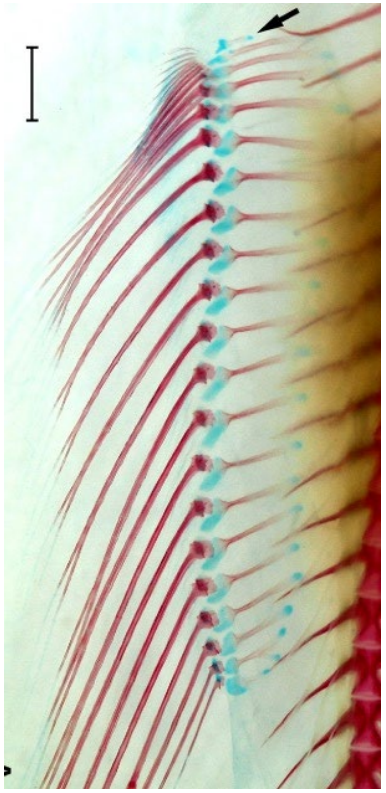
Innovaciones Actinopterigios

Sarcopterigio - *Eusthenopteron*



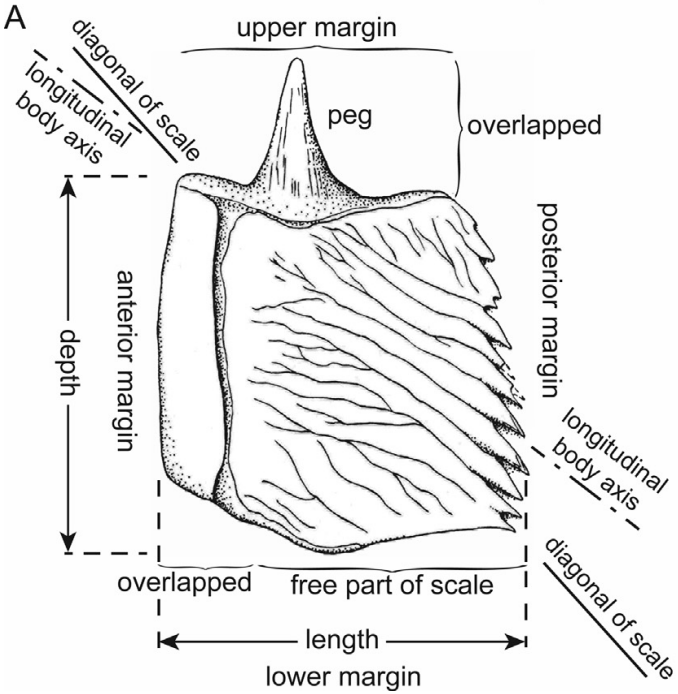
Aletas **anal** y **dorsal** reforzadas con **radiales** delgados y paralelos

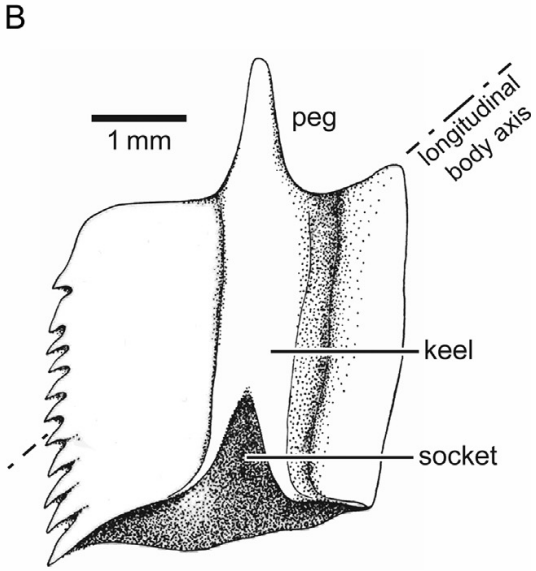




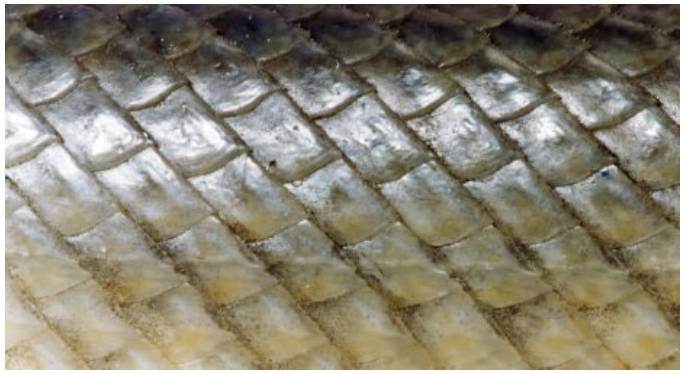
Innovaciones Actinopterigios

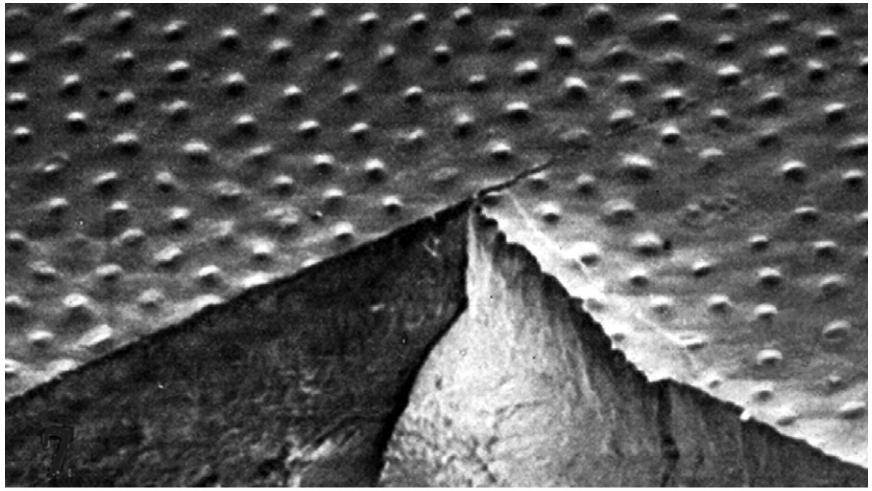
Escama Ganoidea





Articulación entre escamas

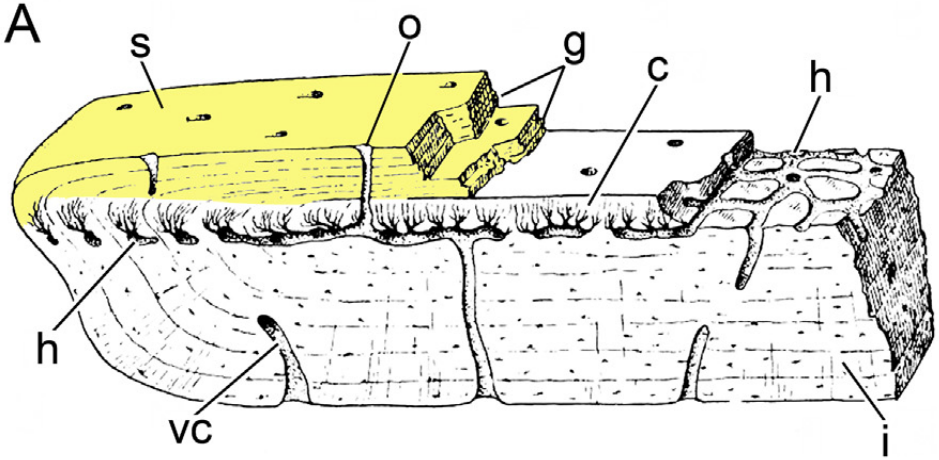




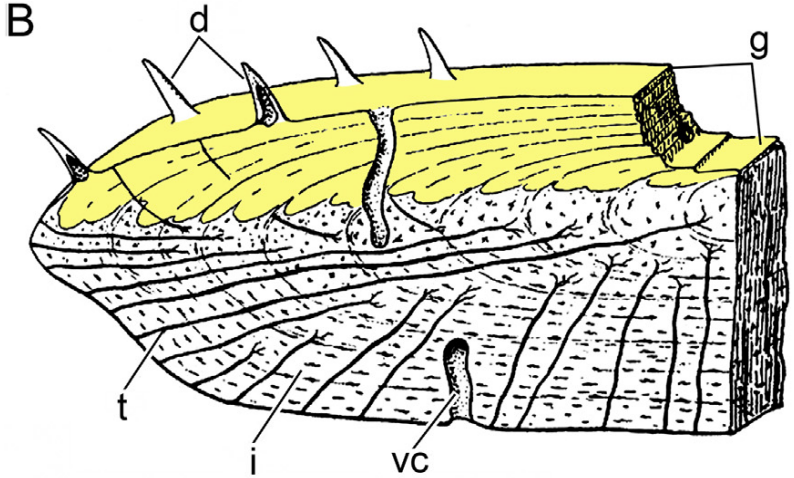
Schultze 2016

Tipos de escama en actinopterigios

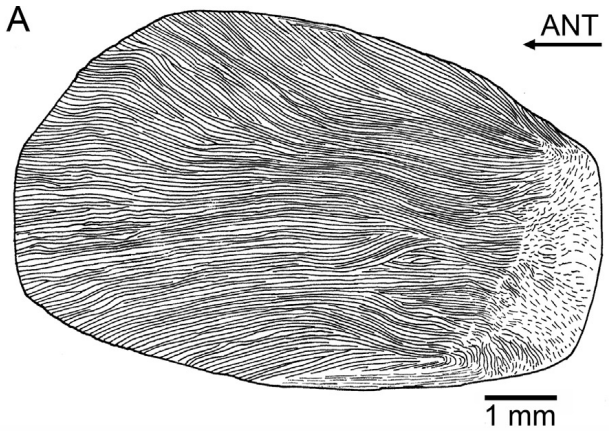
Escama ganoide y elamoide

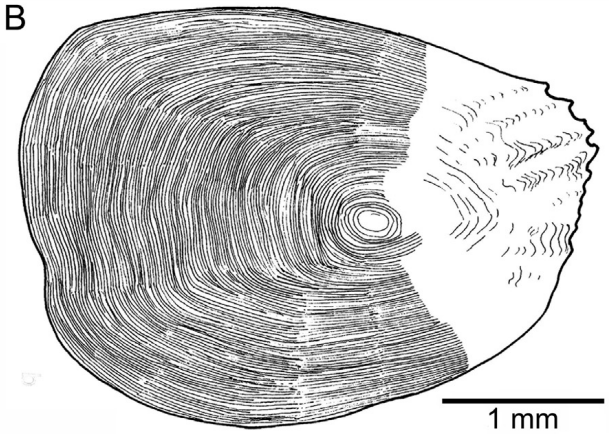


Actinopterigio basal paleoniscoídeo



Lepisosteus osseus





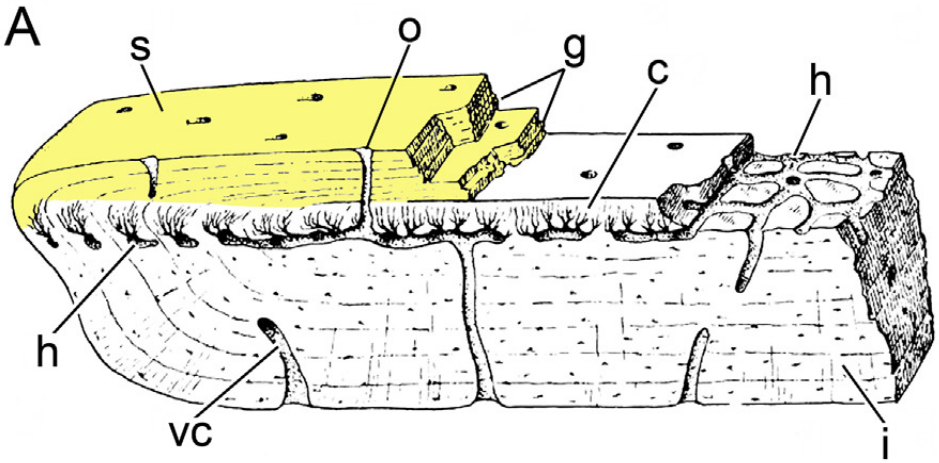
g = ganoína
c = cavidad vascular
d = dentículos
i = isopedina o capa de hueso interna

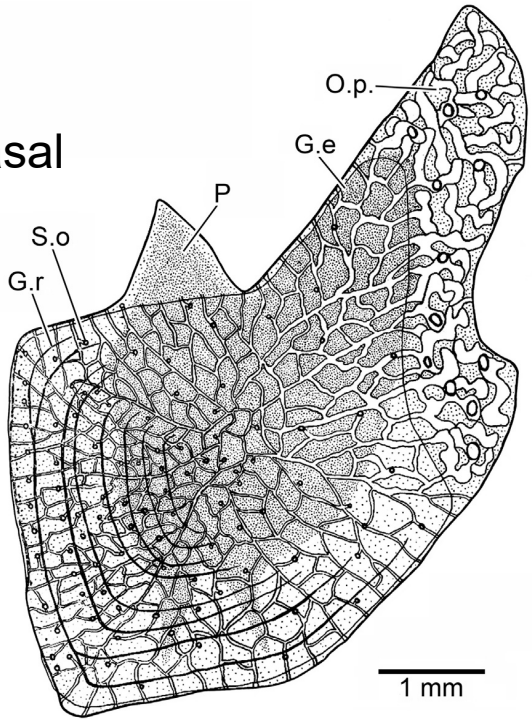
Schultze 2016

Escamas

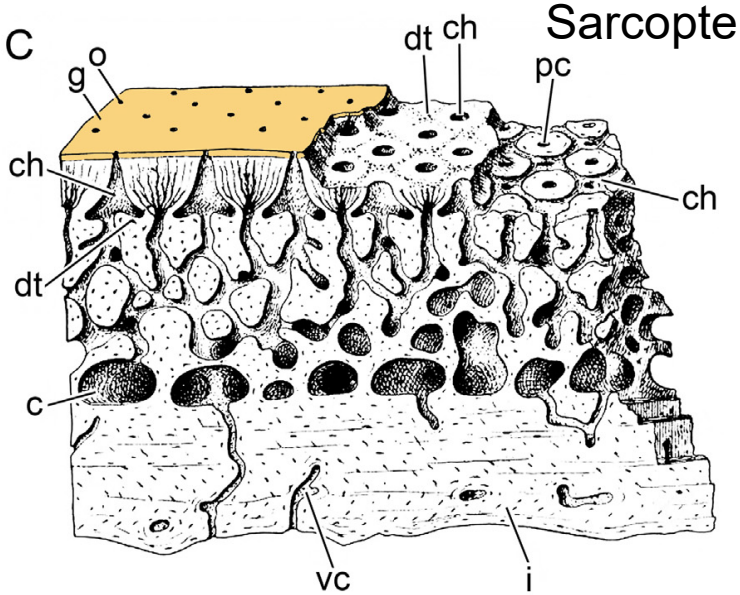
actinopterigios vs sarcopterigios

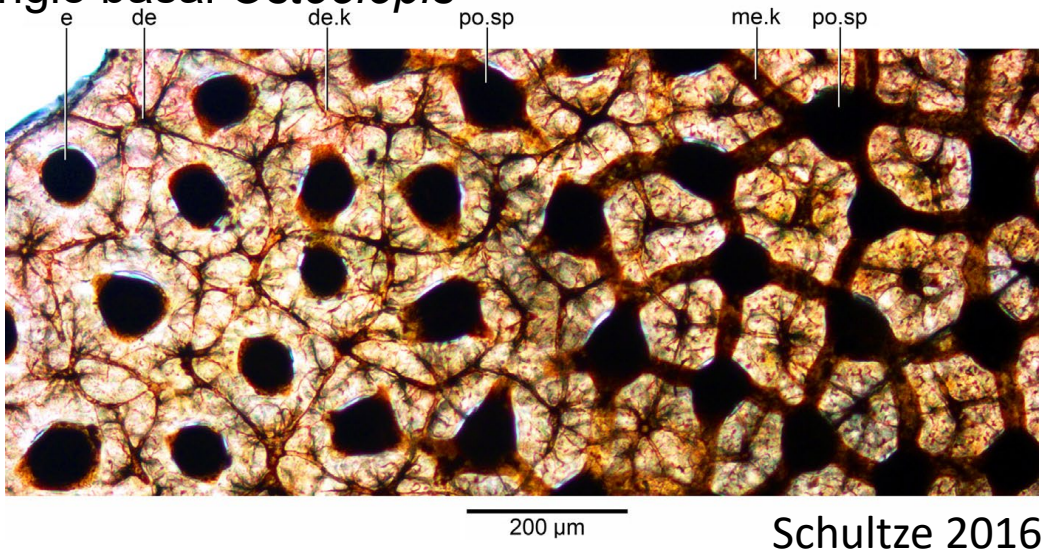
Actinopterigio basal paleoniscoídeo





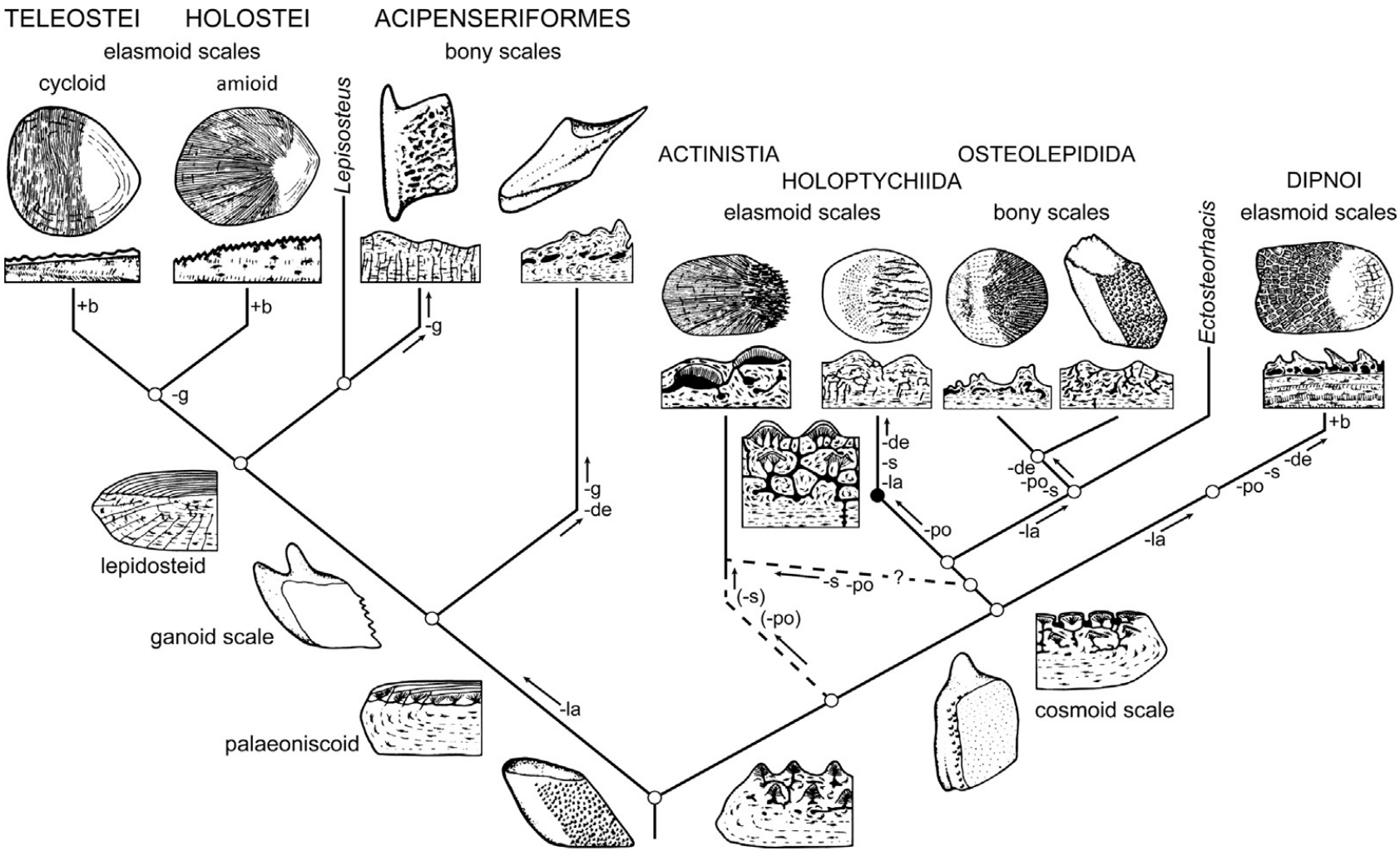
Sarcopterigio basal *Osteolepis*





Schultze 2016

Evolución de las escamas en osteíctios



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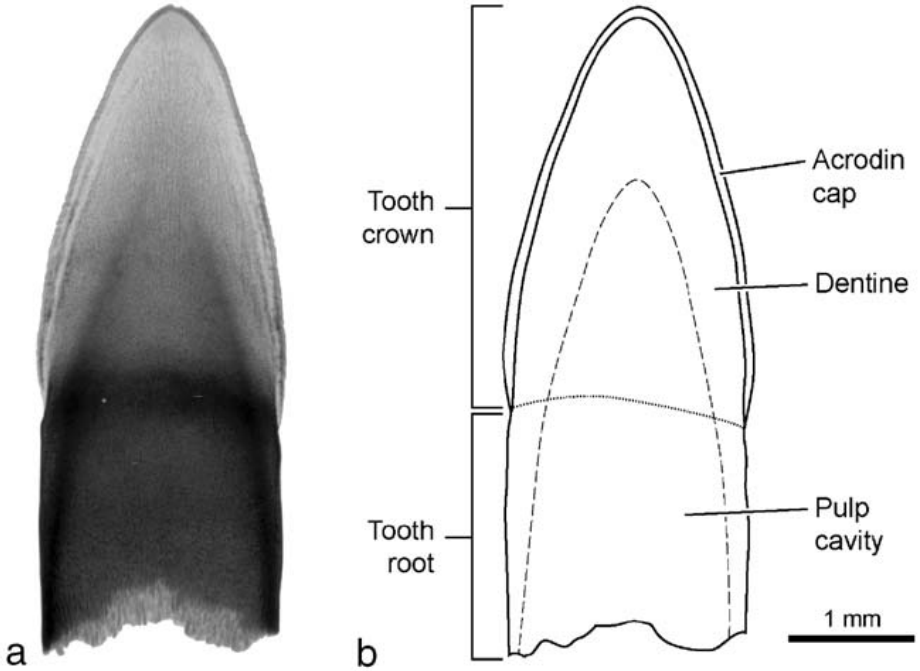
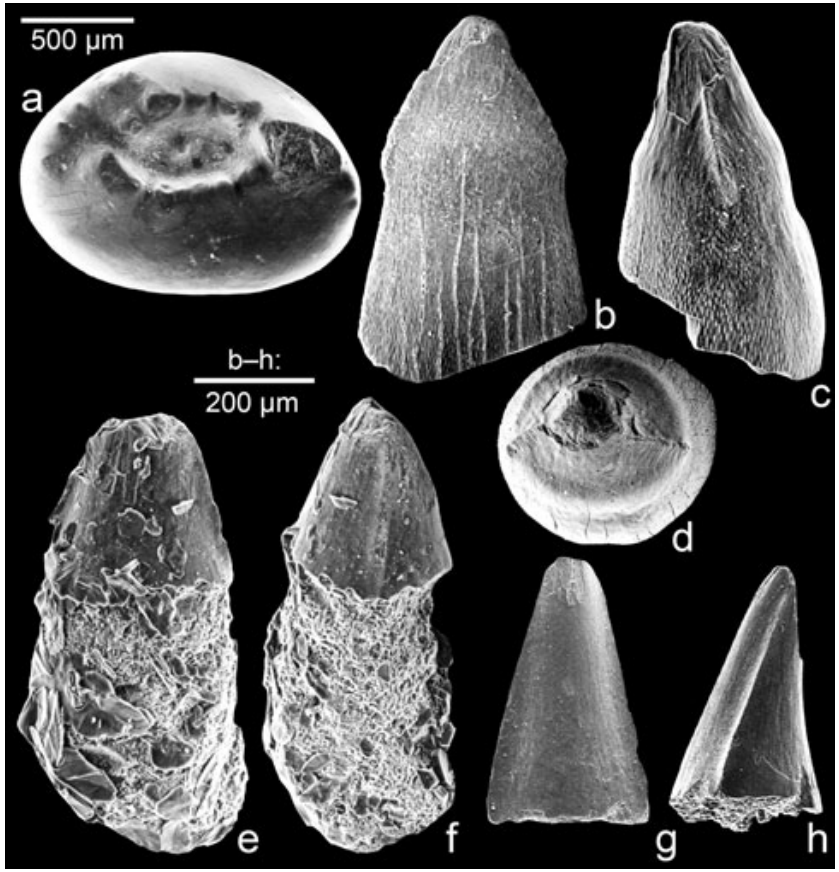
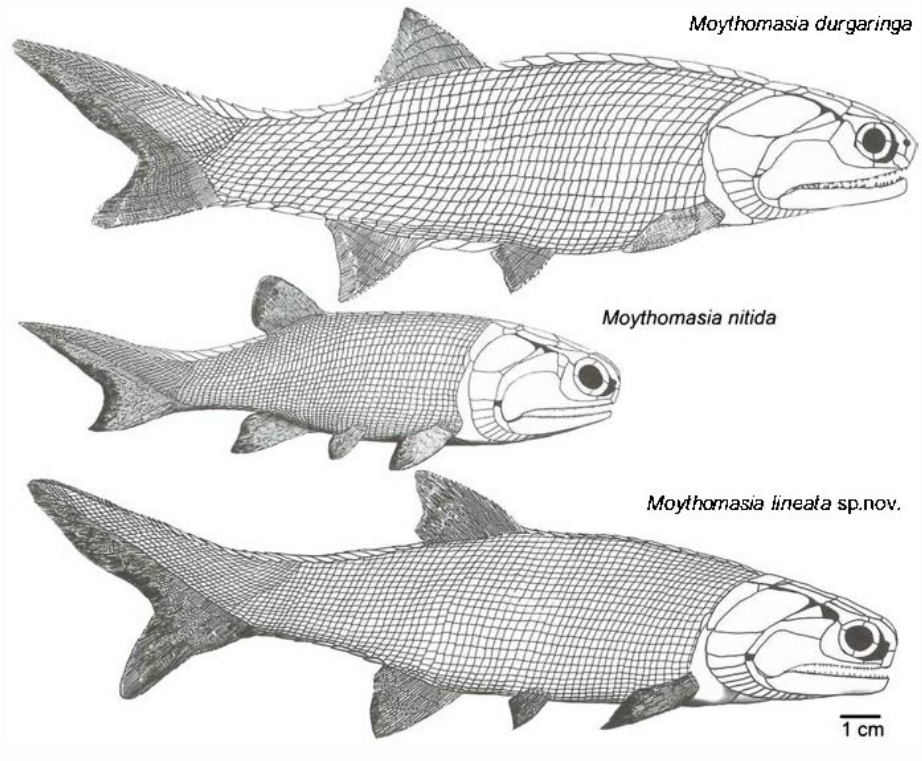
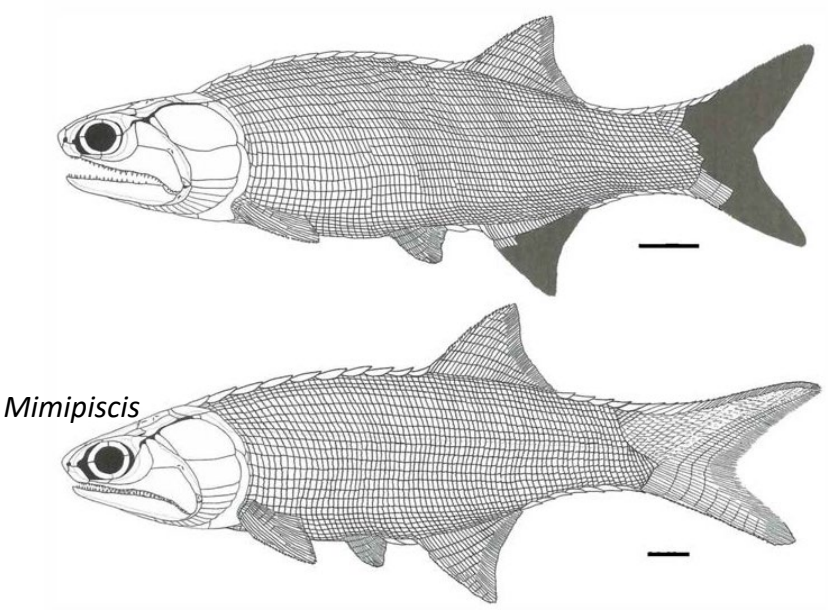
Innovaciones Actinopterigios

Cubierta de acrodina en dientes









Grupo relativamente homogéneo morfológicamente

Tendencias en el linaje:

- **Acortamiento** de la **boca**
- **Aumento** del tamaño de los huesos **operculares**
- **Estabilización** del techo del **cráneo** por grandes huesos (huesos parietal y postparietal)
- Cambio de **escamación** micromerica a **rómbica**

Carbonífero-Pérmico

Paleonisciformes, Paleoniscoideos y Condrósteos

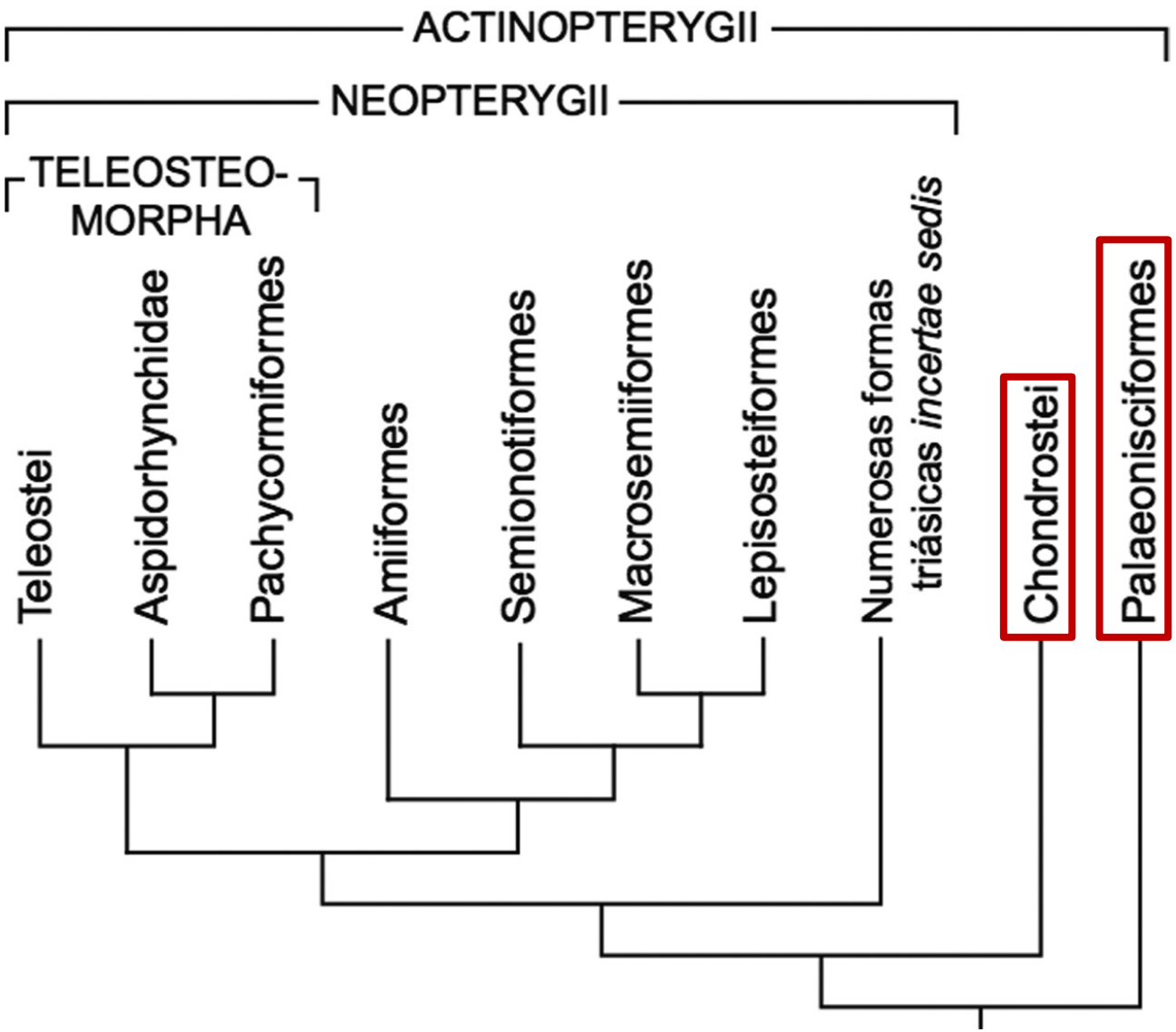


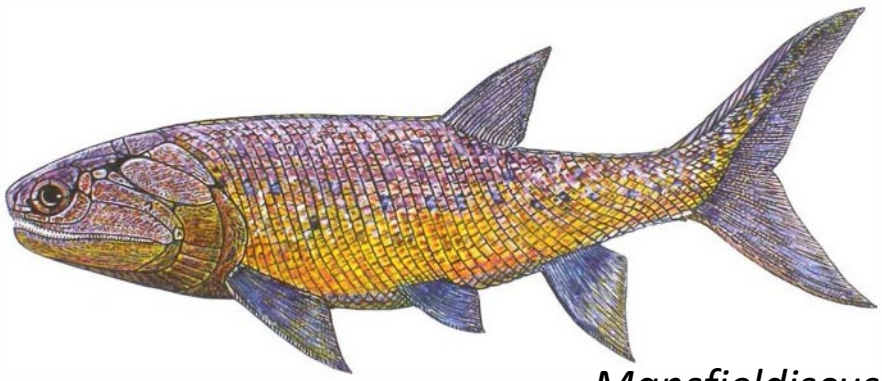
FIGURA 2. Hipótesis abreviada de las relaciones filogenéticas de ciertos clados de Actinopterygii basada en Arratia (2001), Grande (2010) y Betancur-R. *et al.* (2013). Los polypteriformes no fueron incorporados en la ilustración.

†Palaeonisciformes

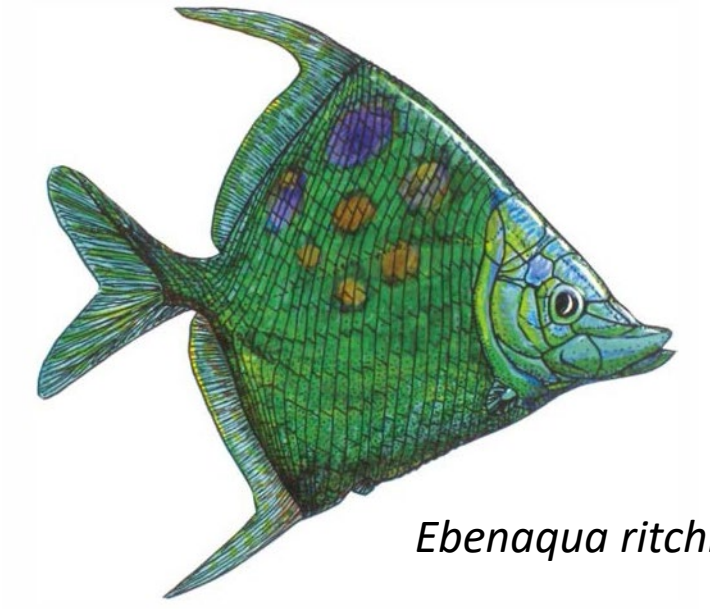
Devónico-Triásico

Grupo heterogéneo

Más de 17 familias



Mansfieldiscus



Ebenaqua ritchiei

En formas avanzadas:

- **Aumento** en **articulaciones** al interior del **cráneo**
- **Órbitas** mas **posteriores**
- Aleta **caudal** heterocerca **reducida**

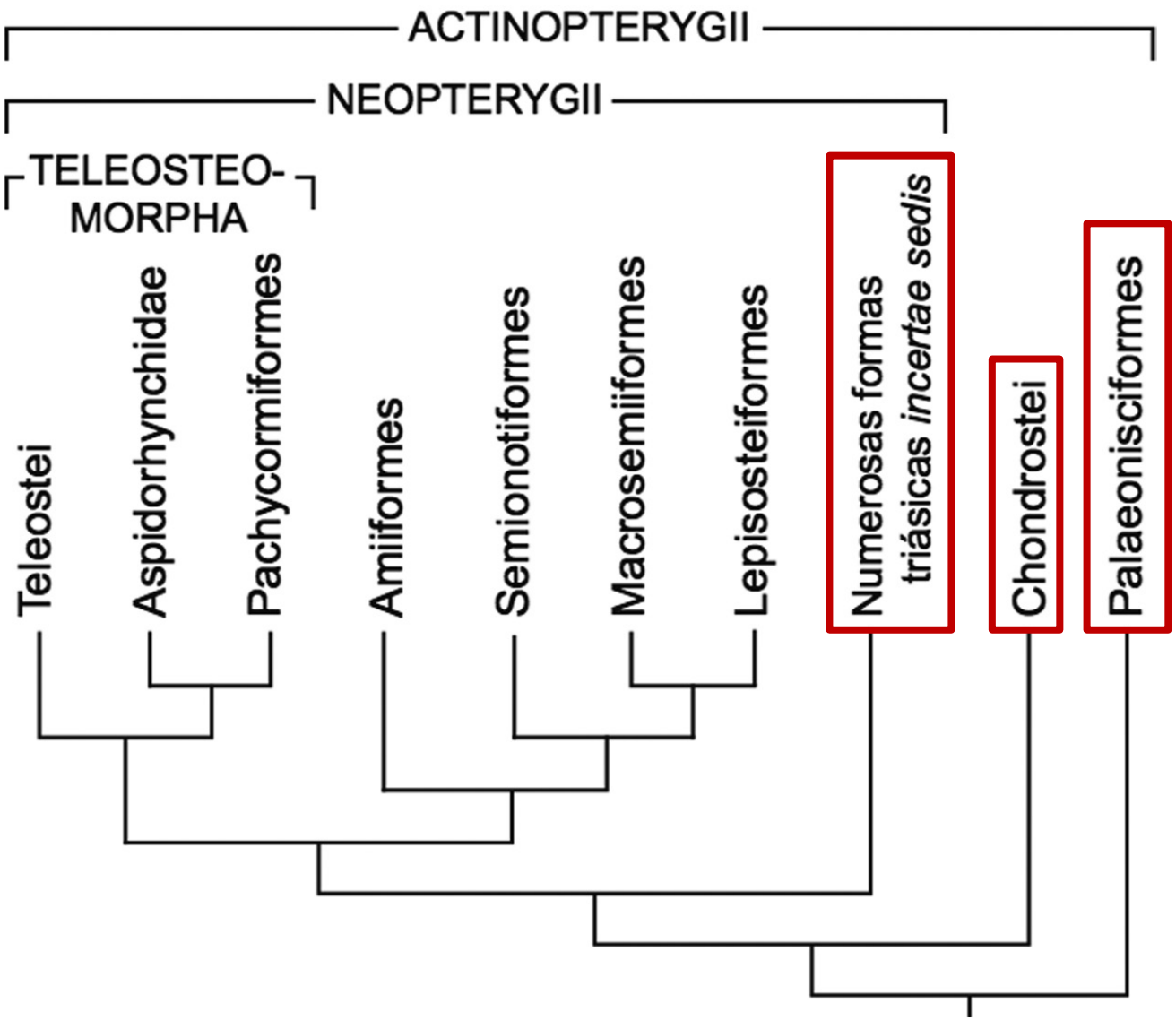


FIGURA 2. Hipótesis abreviada de las relaciones filogenéticas de ciertos clados de Actinopterygii basada en Arratia (2001), Grande (2010) y Betancur-R. *et al.* (2013). Los polypteriformes no fueron incorporados en la ilustración.

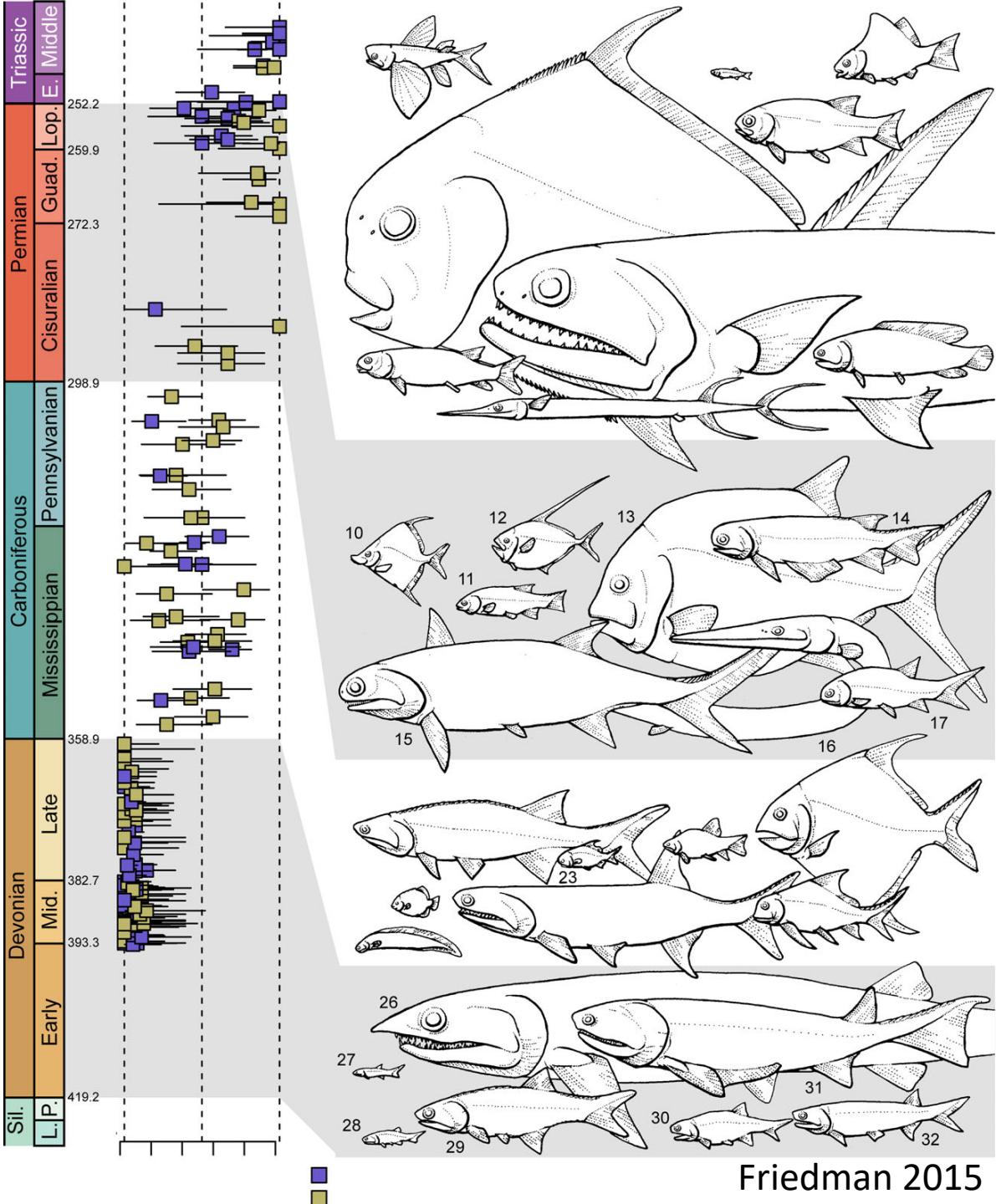
Diversificación de formas

Devónico-Jurásico

"Paleoniscoideos"

†Cheirolepiformes
†Guildayichthyiformes
†Luganoiiformes
†Perleidiformes
†Phanerorhynchiformes
†Pholidopleuriformes
†Ptycholepiformes
†Saurichthyiformes
†Tarrasiiformes

Aun no bien resueltos



Friedman 2015

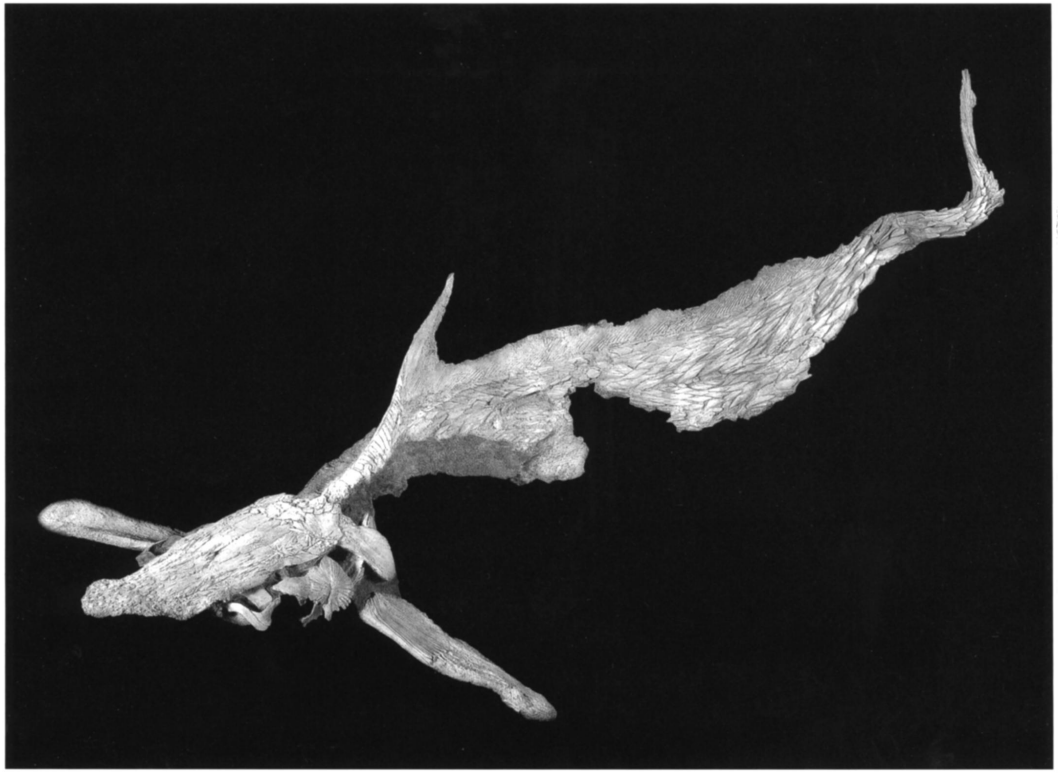
Tendencias en “Paleoniscoideos” a Neopterygii

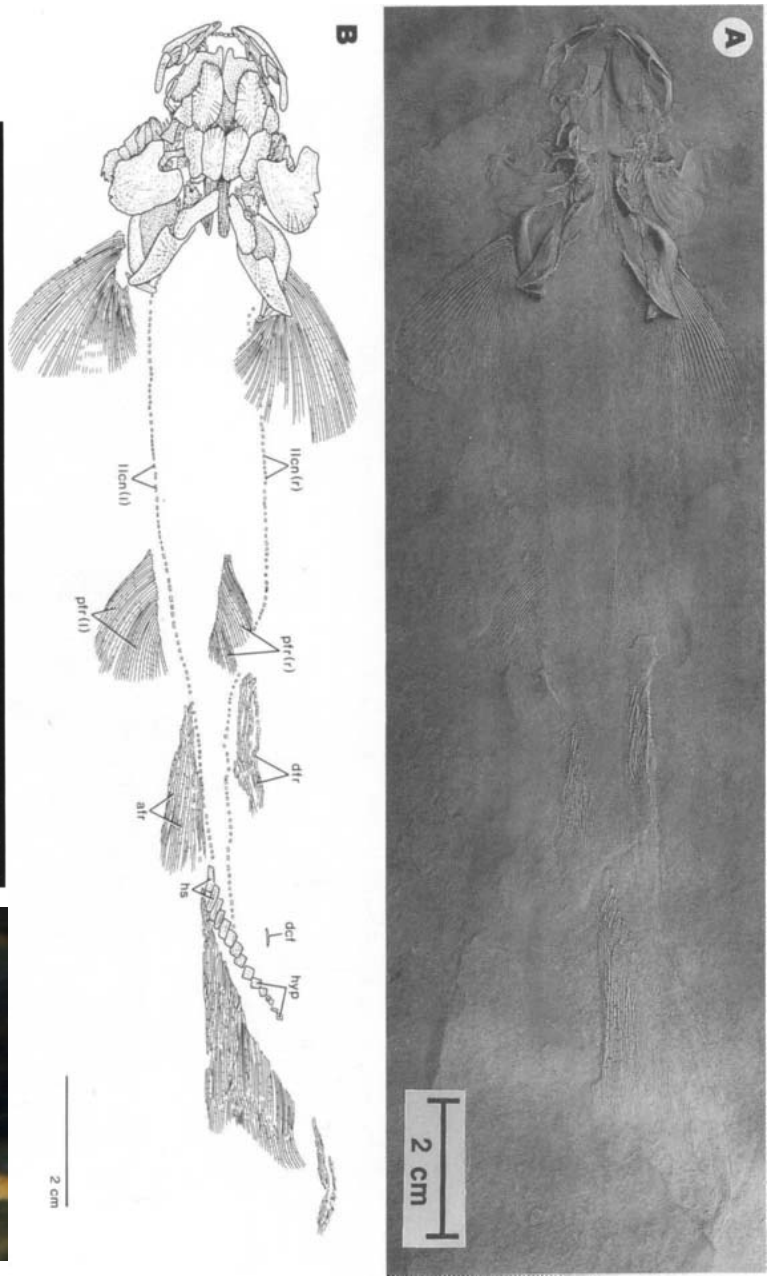
→ **Escamas** cambian de pesadas, gruesas y en forma de diamante a **delgadas**, **livianas** y **circulares**.

→ Incremento en la **osificación** de la **columna vertebral**

→ Aumento en la **movilidad** de la **mandíbula**

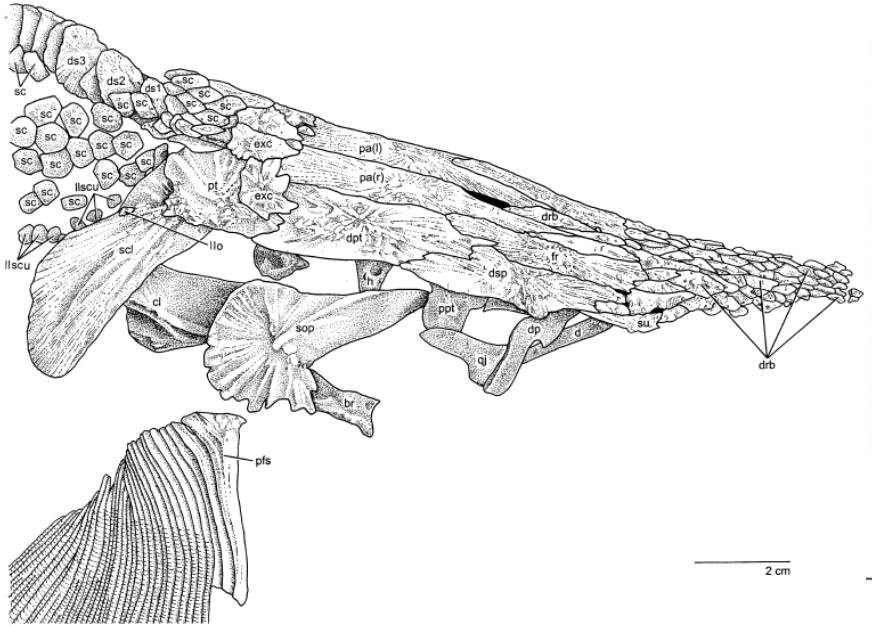
Chondrostei

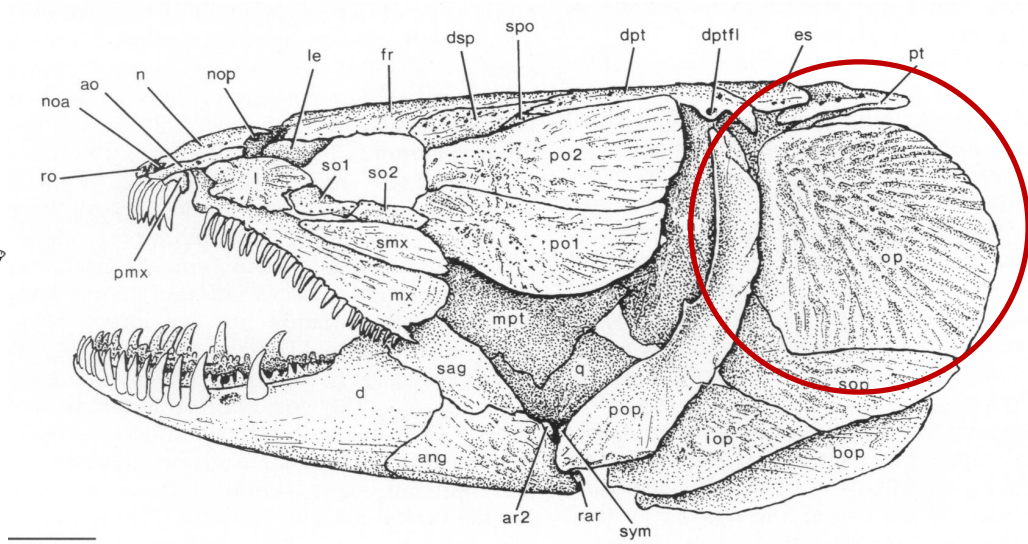




Innovaciones Chondrostei

Reducción y Pérdida del opérculo
Reducción de la escamación
Reducción de la mineralización ósea

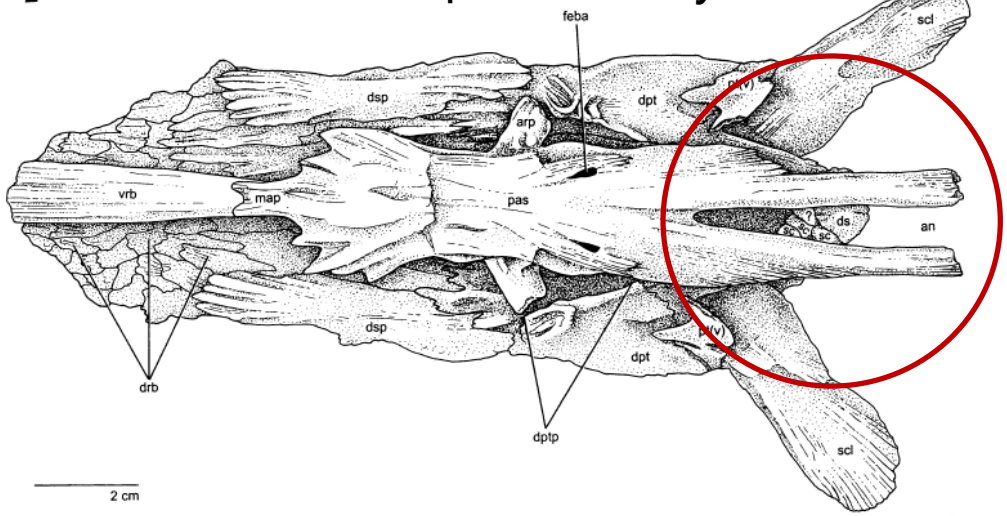




Grande & Hilton 2006

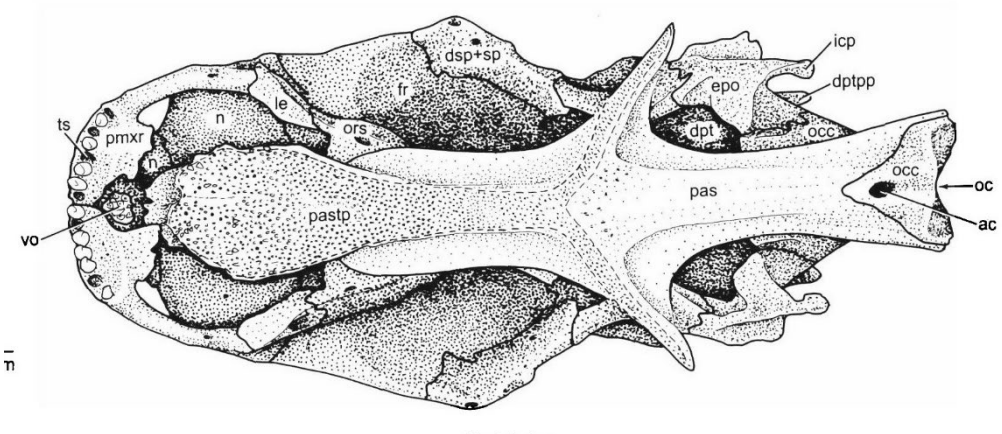
Innovaciones Chondrostei

Chondrostei - †*Psammorhynchus*

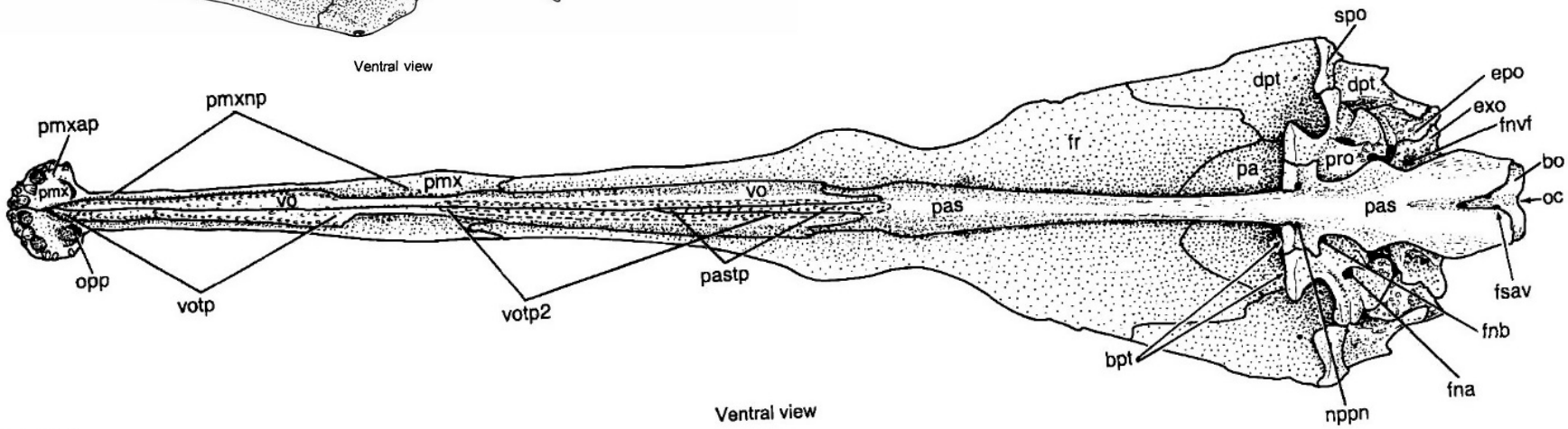


Parasfenoides elongado posteriormente

Cladistia - *Polypterus*

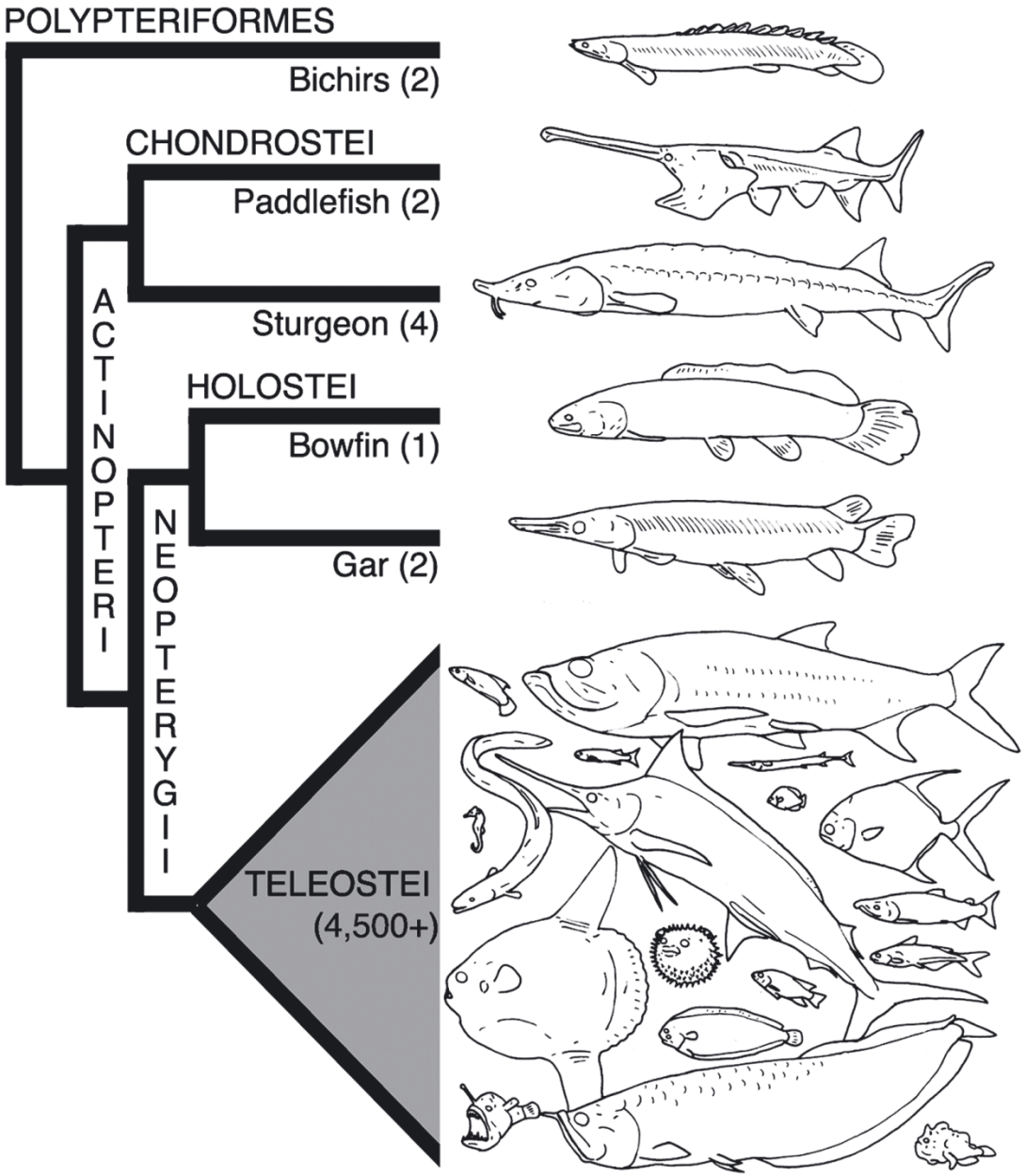


Holostei - *Lepisosteus*



Triásico-Jurásico

Neopterygii: Holostei y Teleostei

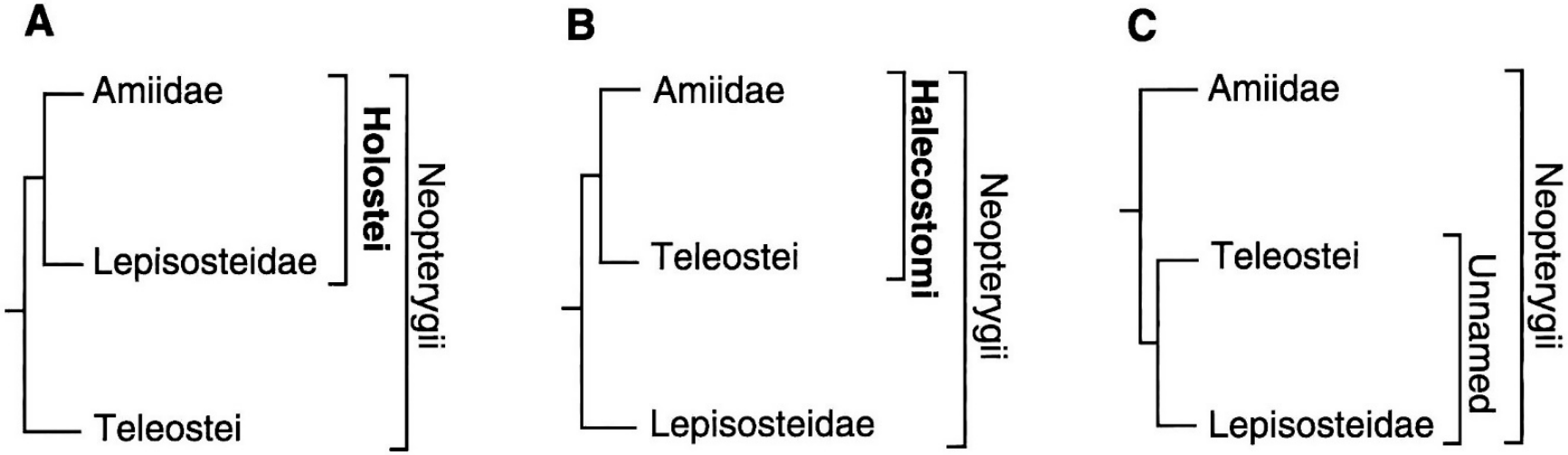


Neopterygii

"Nueva aleta"

Holostei + Teleostei

Controversia Gar-Amia-Teleostei



after Huxley, 1861
Regan, 1923
Goodrich, 1930
Romer, 1945,1966
Jarvik, 1959,1980
Andrews et al.,1967
McAllister, 1968
Nelson, 1969
Jollie, 1984
Olsen and McCune, 1991
Normark et al., 1991
Lecointre et al., 1994
Venkatesh et al., 1999
Inoue et al., 2002

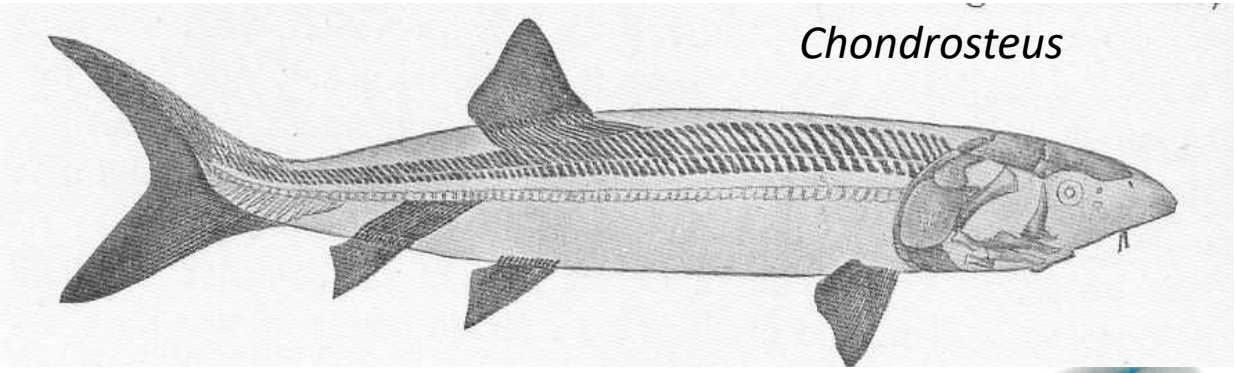
after Gardiner, 1960
Patterson, 1973
Wiley, 1976
Nelson, 1976, 1984, 1994
Bartram, 1977
Rosen et al., 1981
Lauder & Liem, 1983
Wiley & Schultz, 1984
Gardner, 1984
Nolf, 1985
Verran, 1988
Gardner et al., 1996
Liem et al., 2001

after Olsen, 1984

Grande 2010

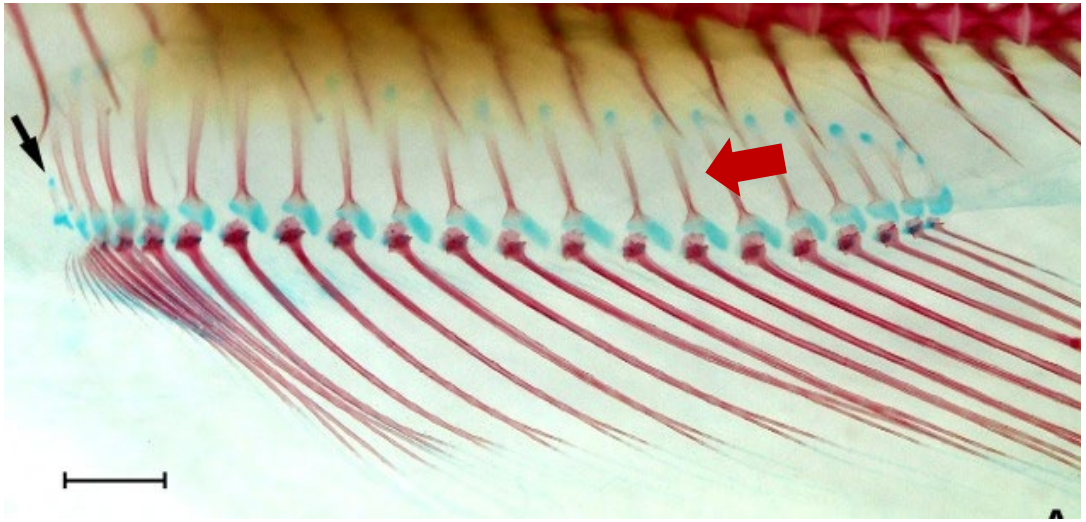
Neopterygii

"Nueva aleta"



1:1 rayo óseo / pterigioforo

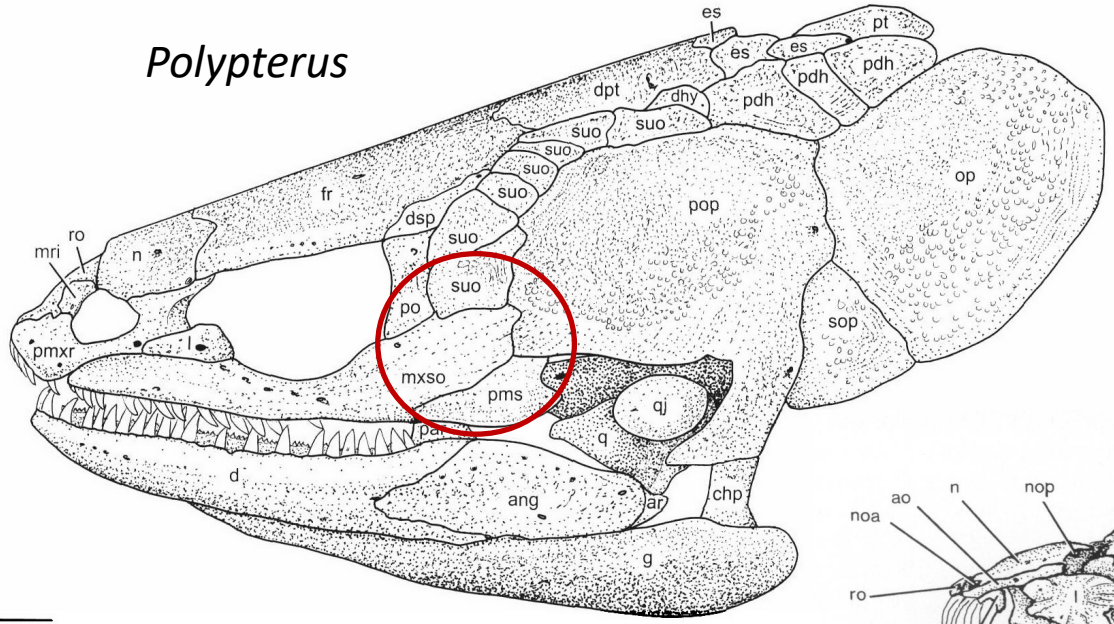
Polyodon spathula



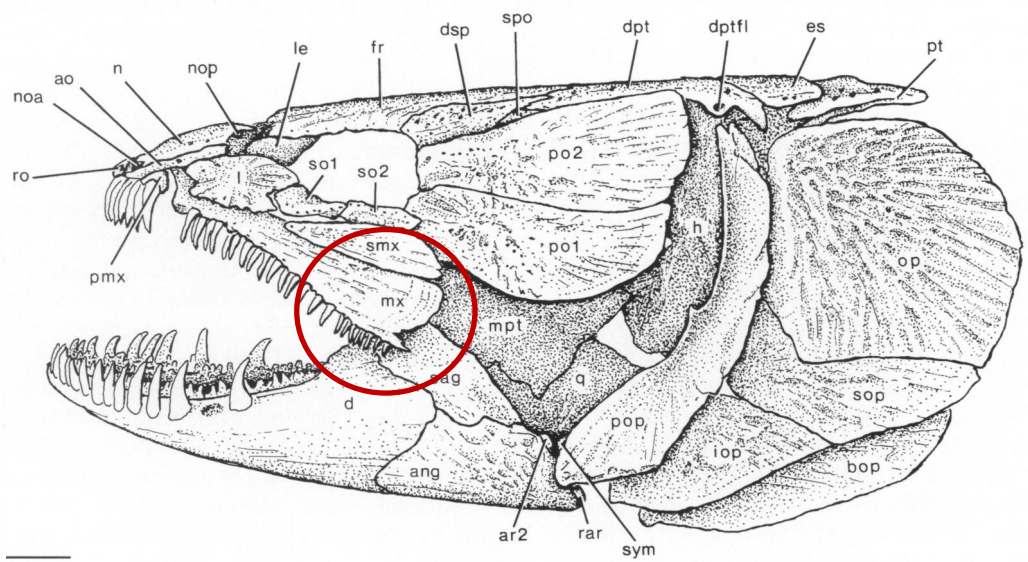
Aleta anal pez neopterigio

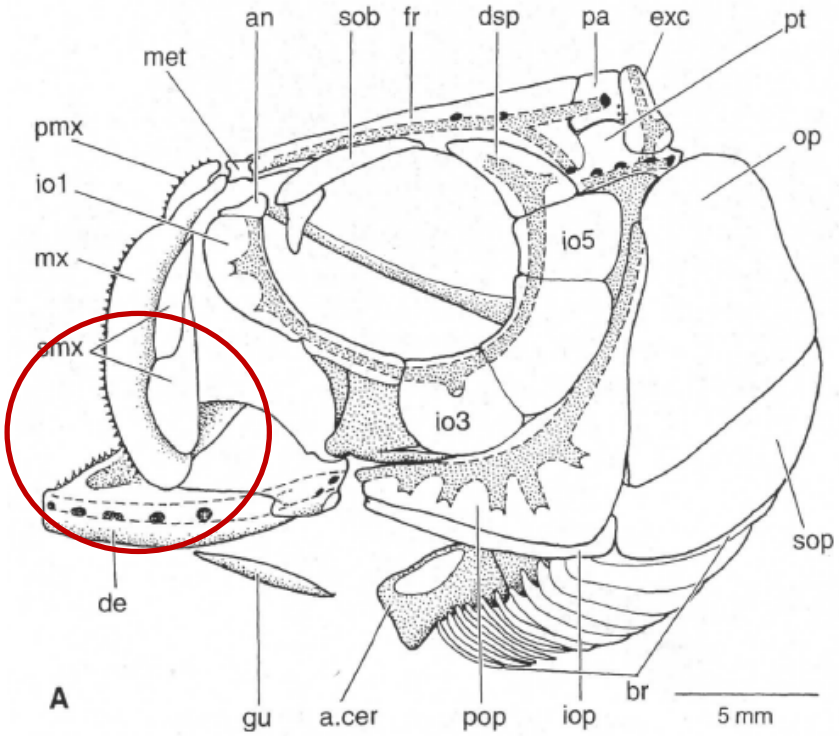
Innovaciones Neopterygii

Polypterus



Amia





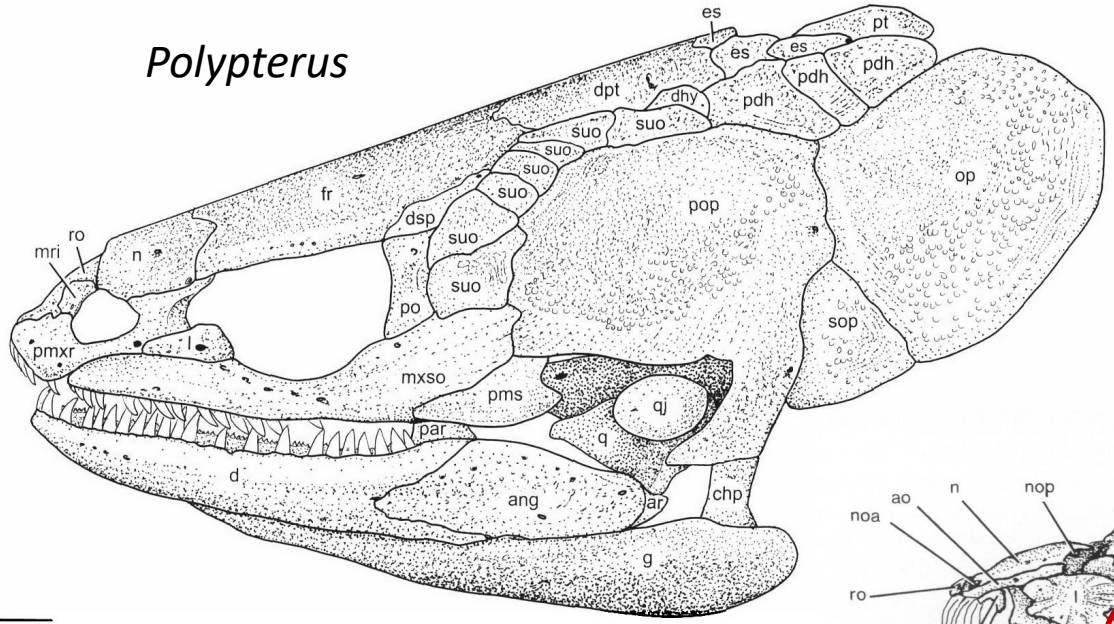
Pérdida articulación posterior maxila (mx)

Basal teleost

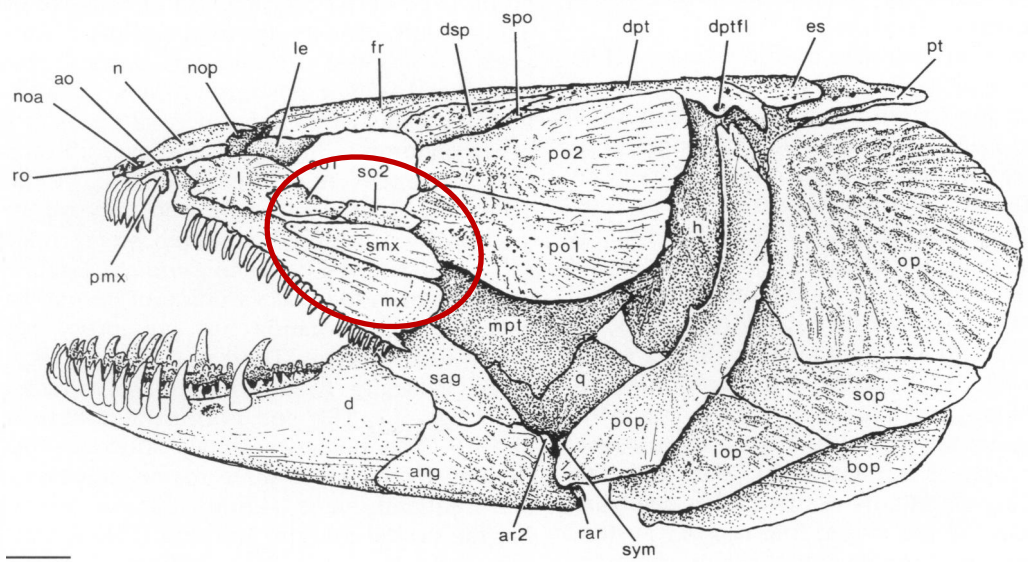
Grande 2010

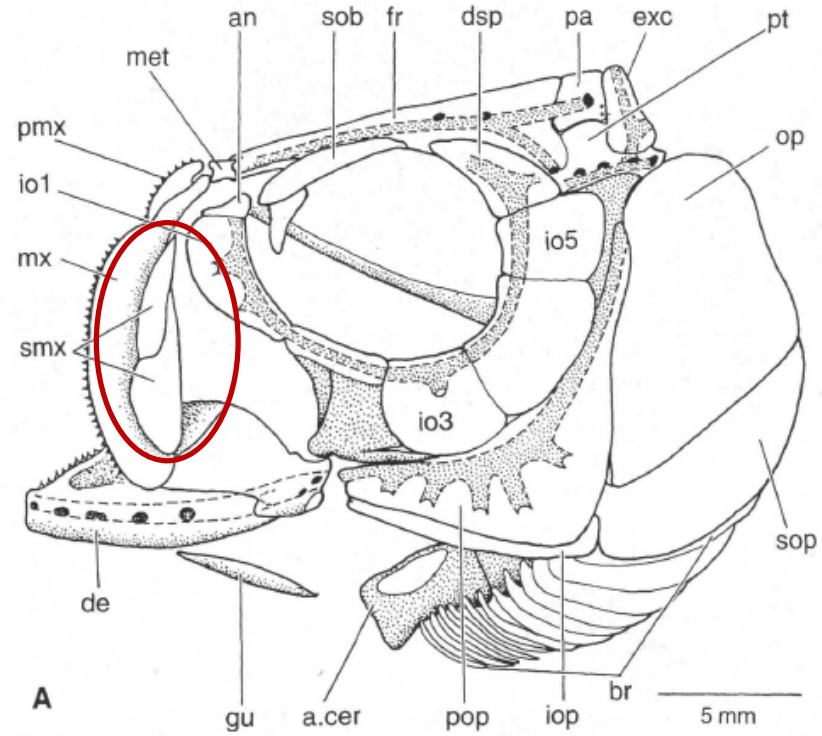
Innovaciones Neopterygii

Polypterus



Amia





Supramaxilar (smx)

Basal teleost

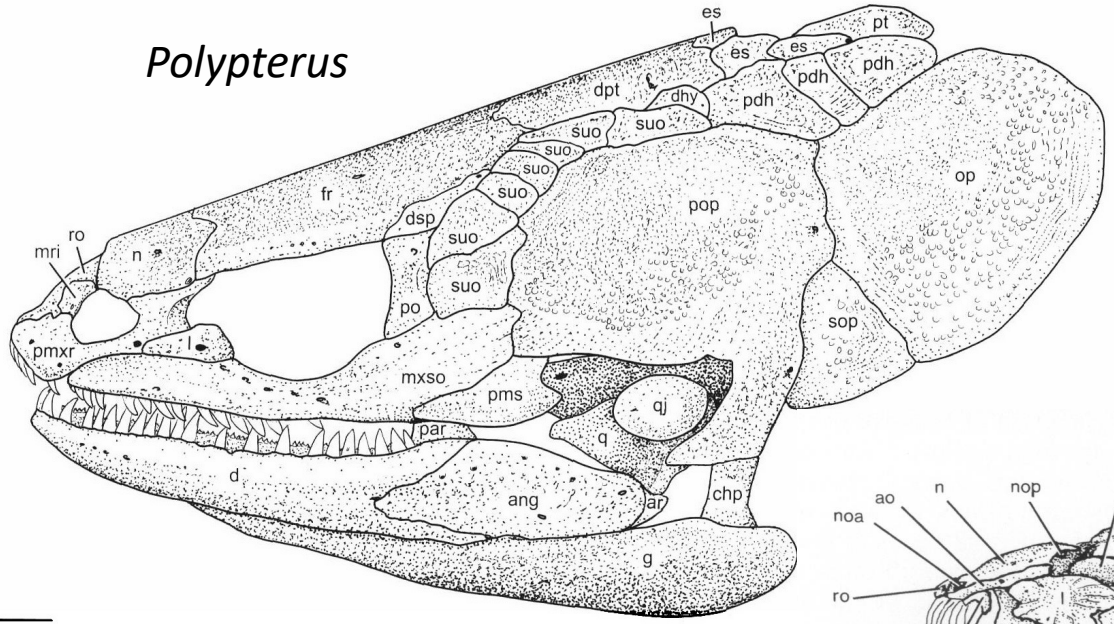
Grande 2010

Alimentación *Polypterus*

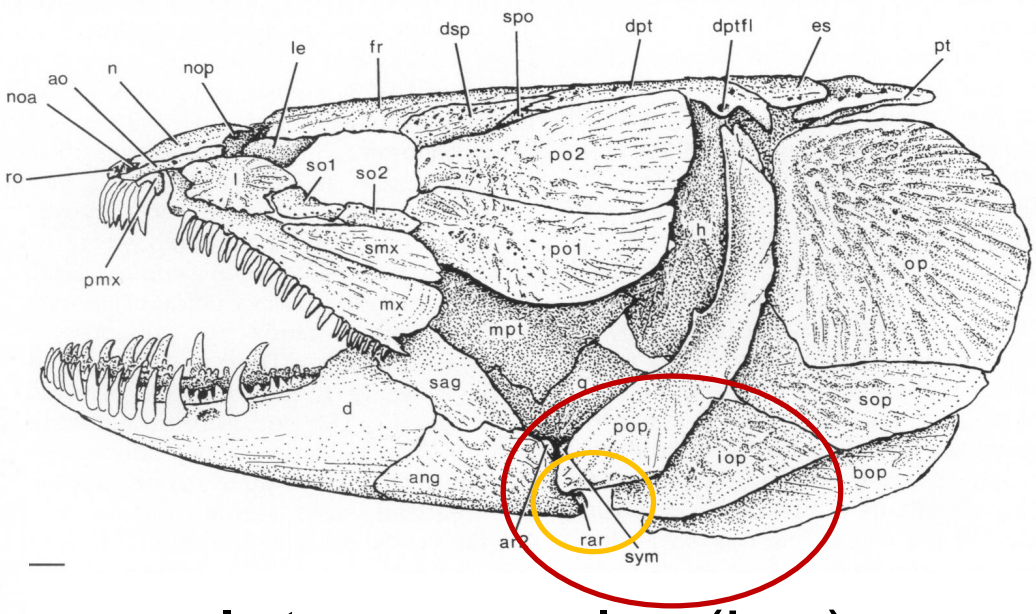
Protrusión Mandíbula

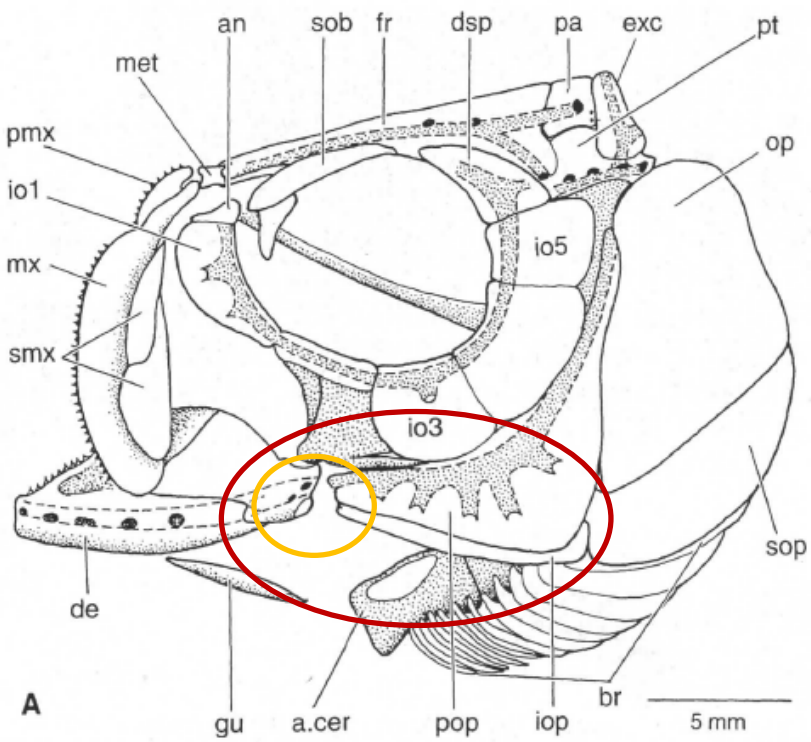
Innovaciones Neopterygii

Polypterus



Amia





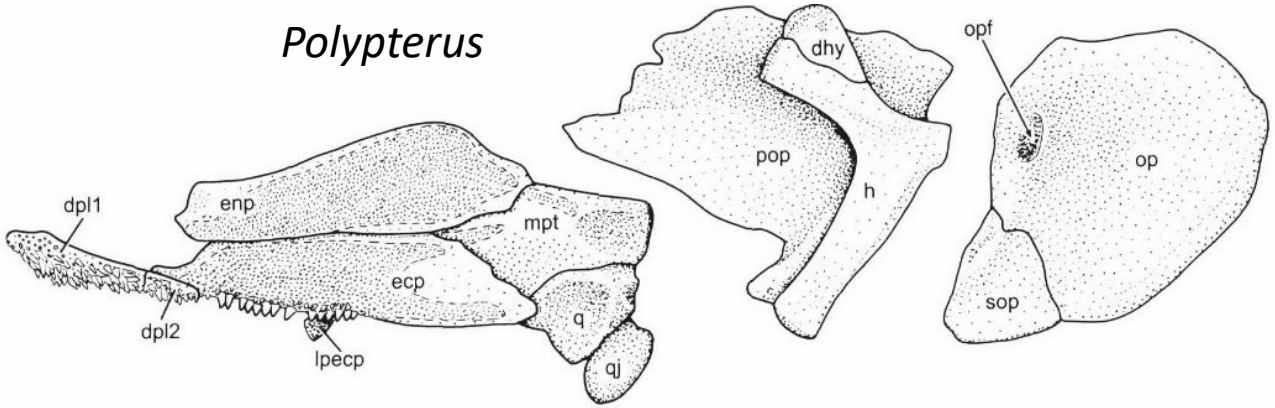
Interopercular (iop)
Unión opérculo-retroarticular

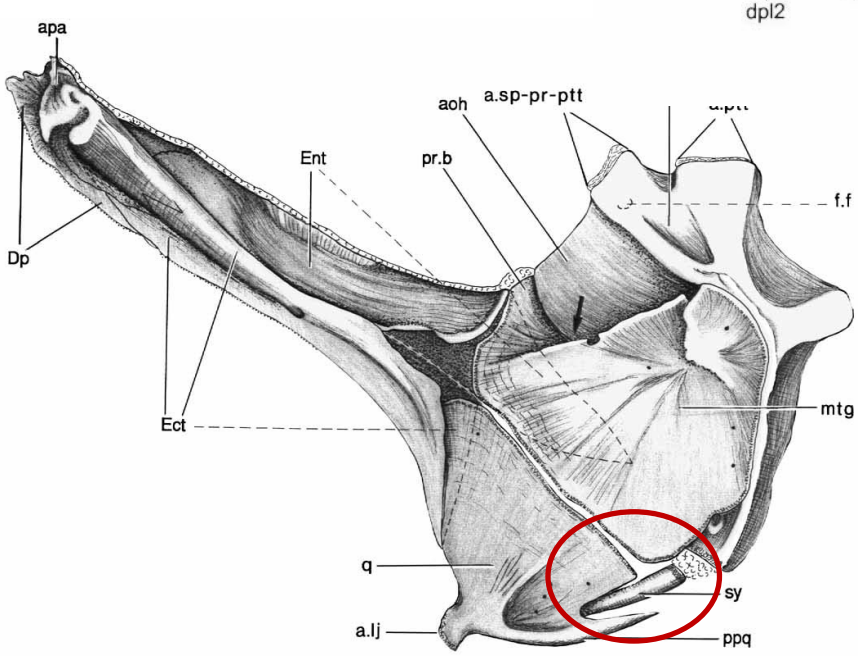
Basal teleost

Grande 2010

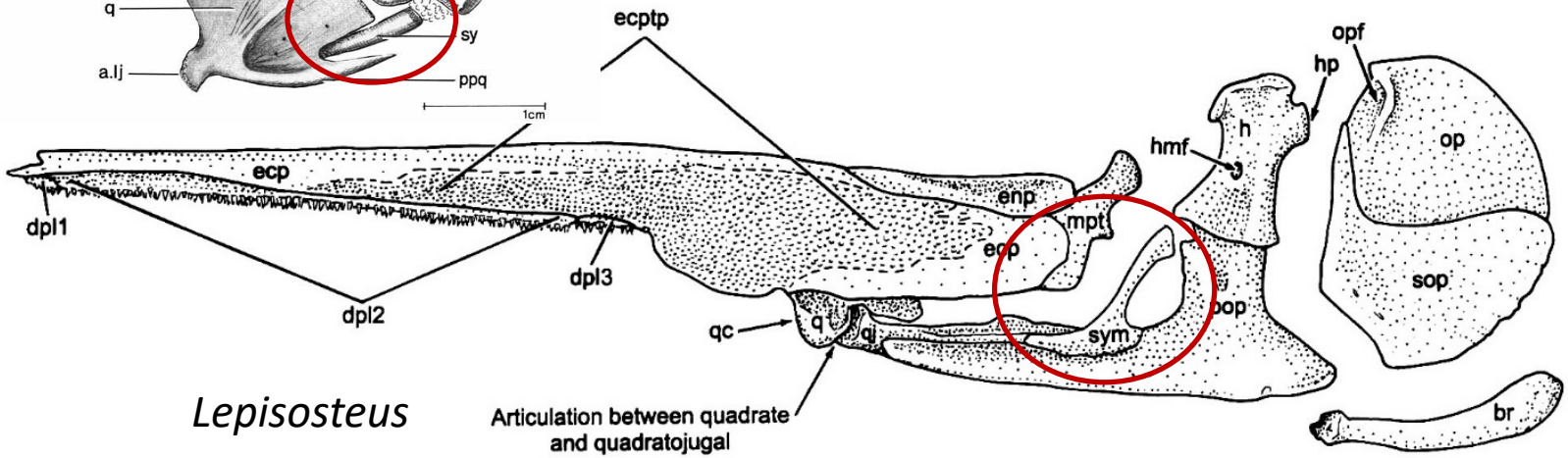
Innovaciones Neopterygii

Polypterus





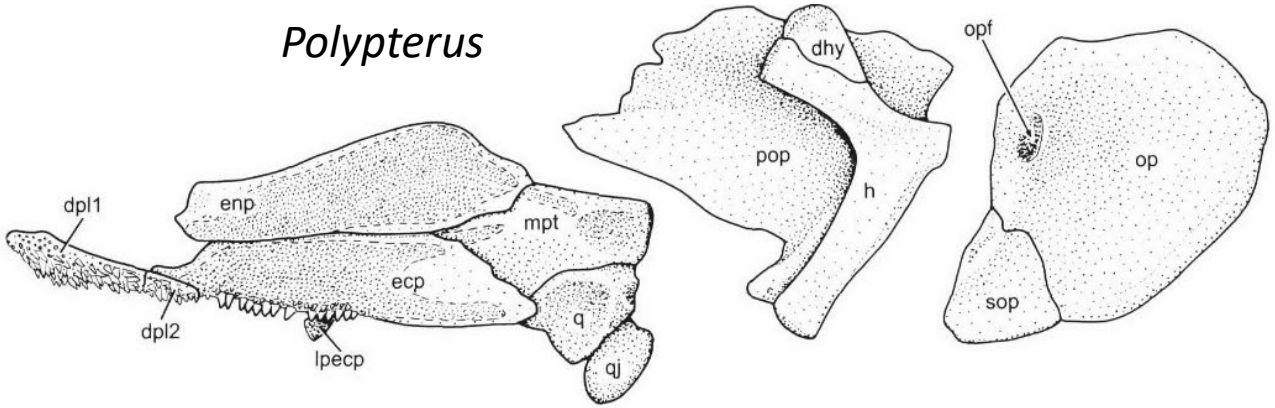
Simpléctico y formación del suspensorium

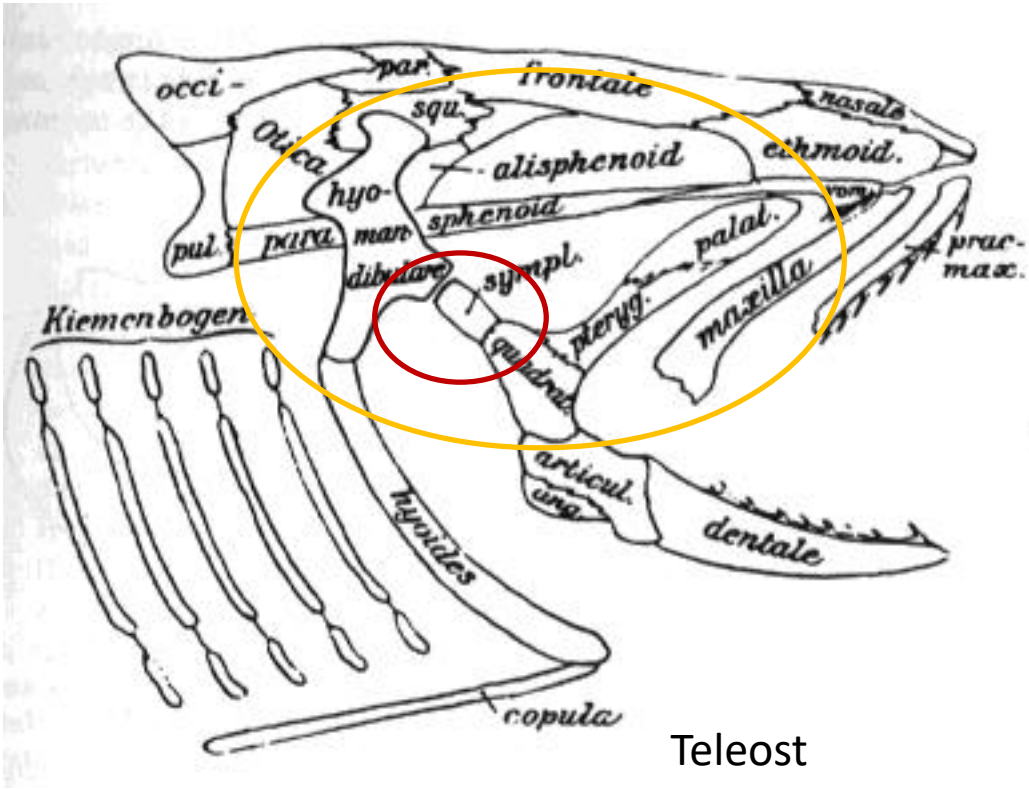


Lepisosteus

Grande 2010

Innovaciones Neopterygii





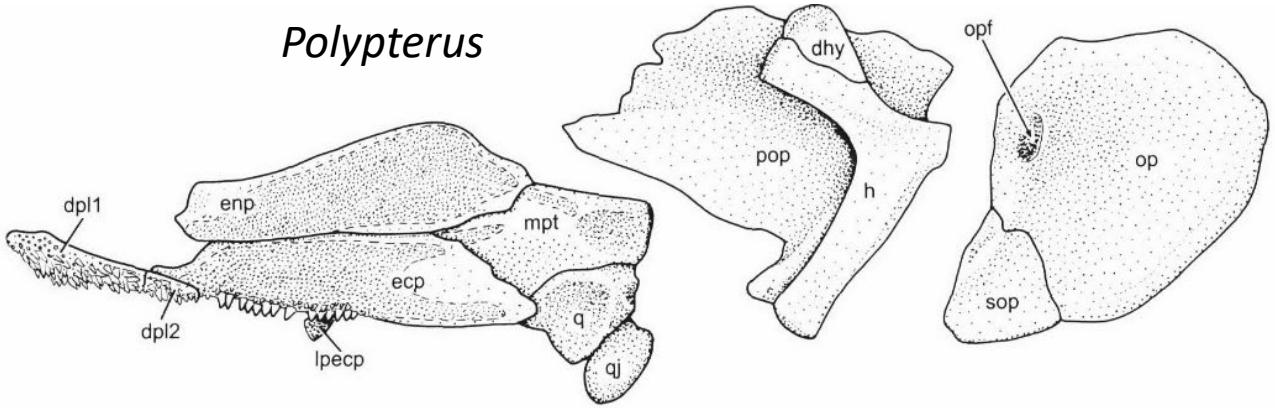
Teleost

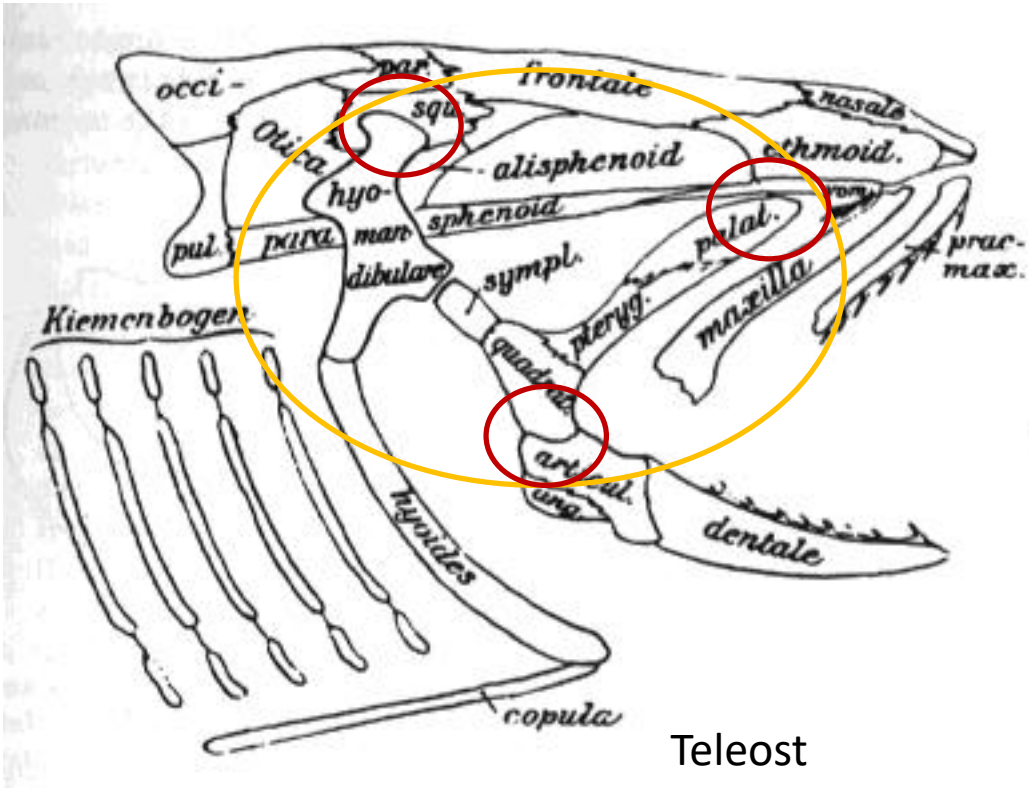
Simpléctico y formación del suspensorium

Grande 2010

Innovaciones Neopterygii

Polypterus





Teleost

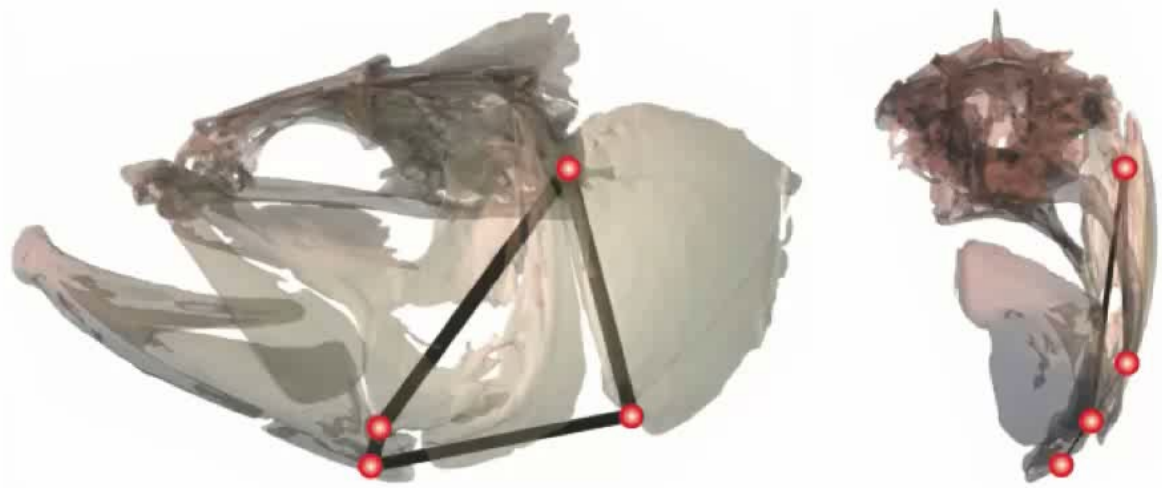
Simpléctico y formación del suspensorium

Grande 2010

4-bar linkage model

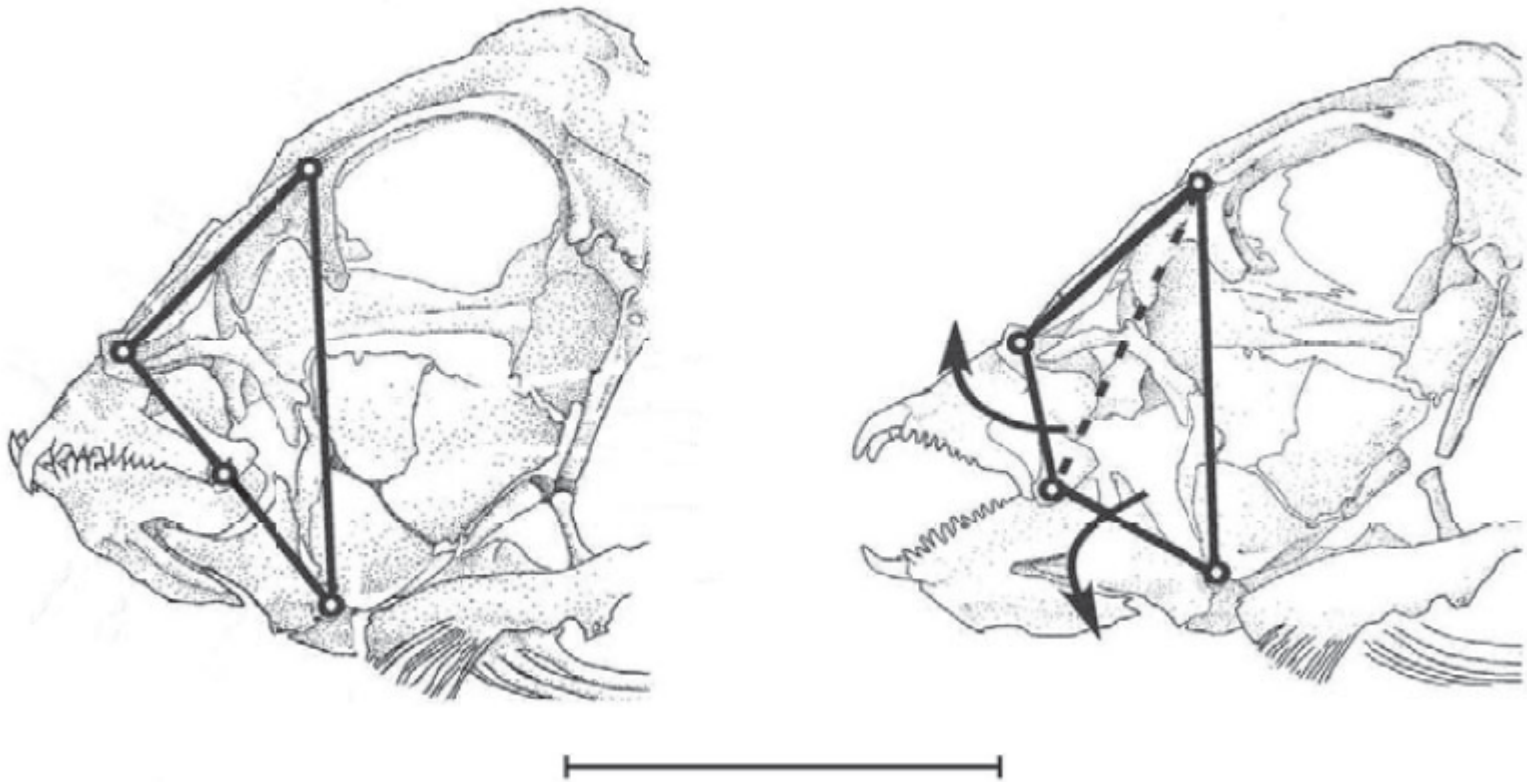
Kinematics of jaw movement

Animations of 4-bar models fit to the opercular mechanism of largemouth bass



From: Olsen, AM, Camp, AL, & Brainerd, EL (2017). The opercular mouth-opening mechanism of largemouth bass functions as a 3D four-bar linkage with three degrees of freedom

Otro diagrama

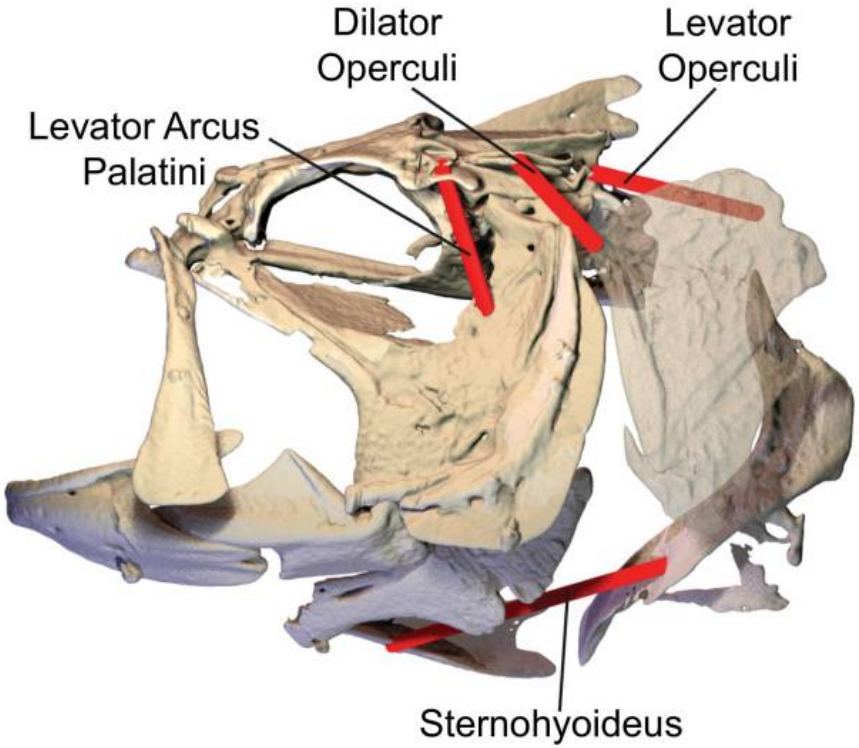


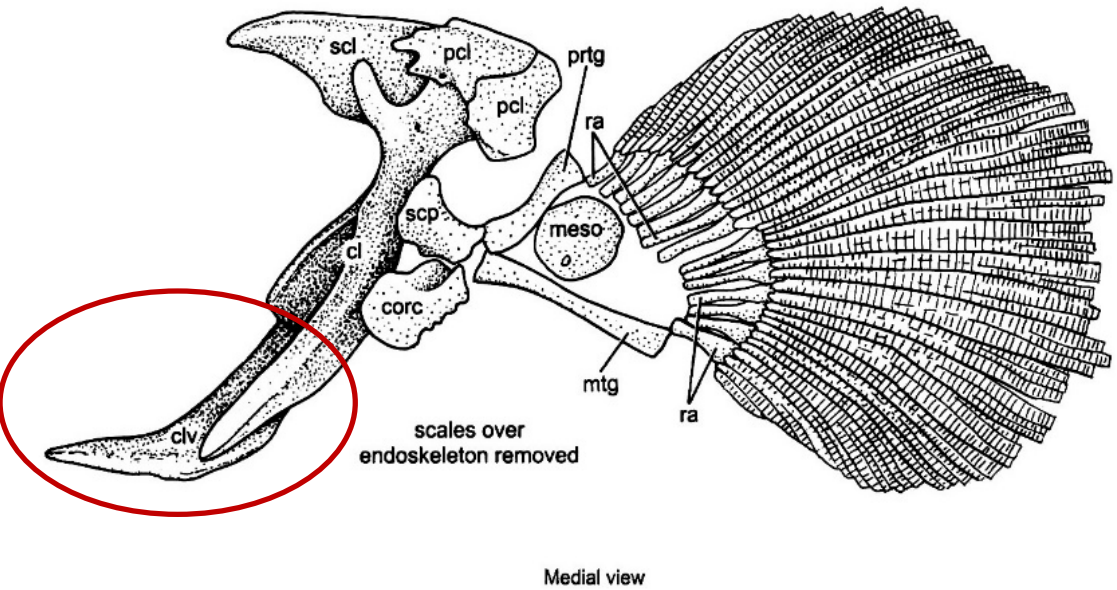
Wainwright 2008

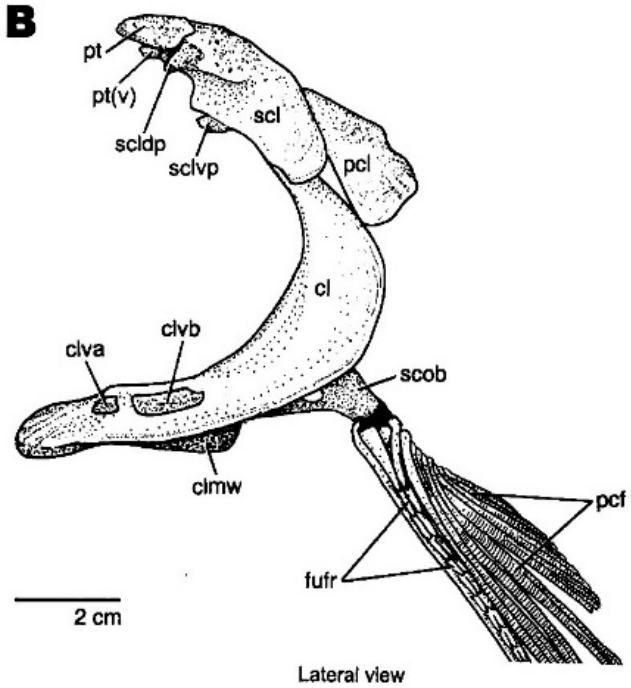
Alimentación por Succión

Innovaciones Neopterygii

Pérdida de la clavicula y extensión del cleithrum



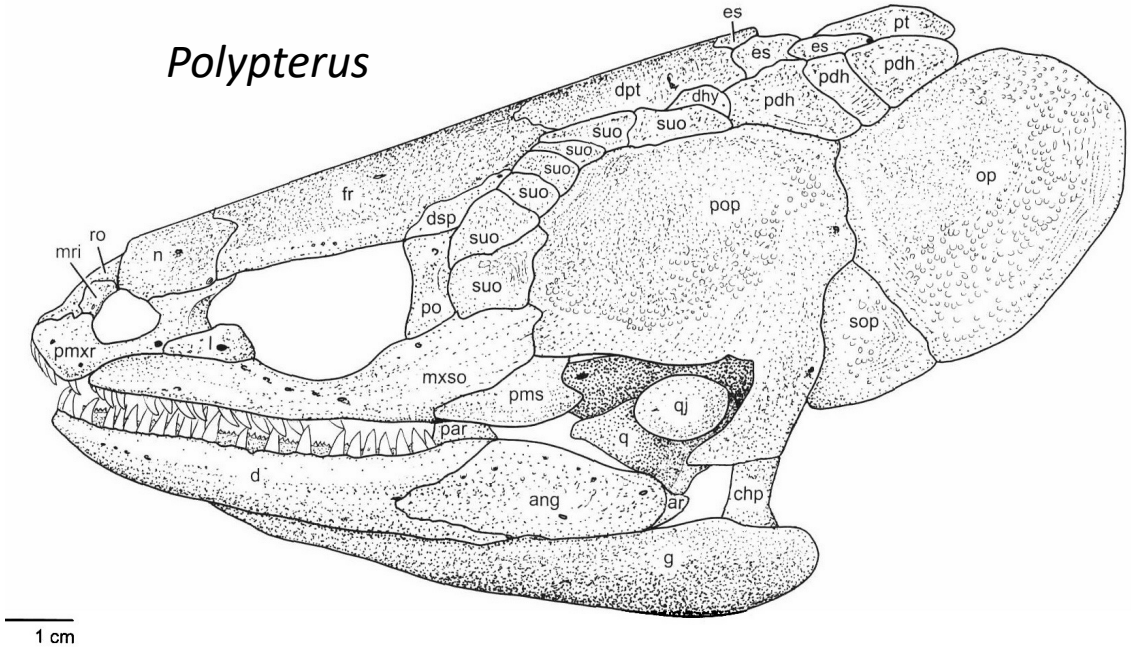


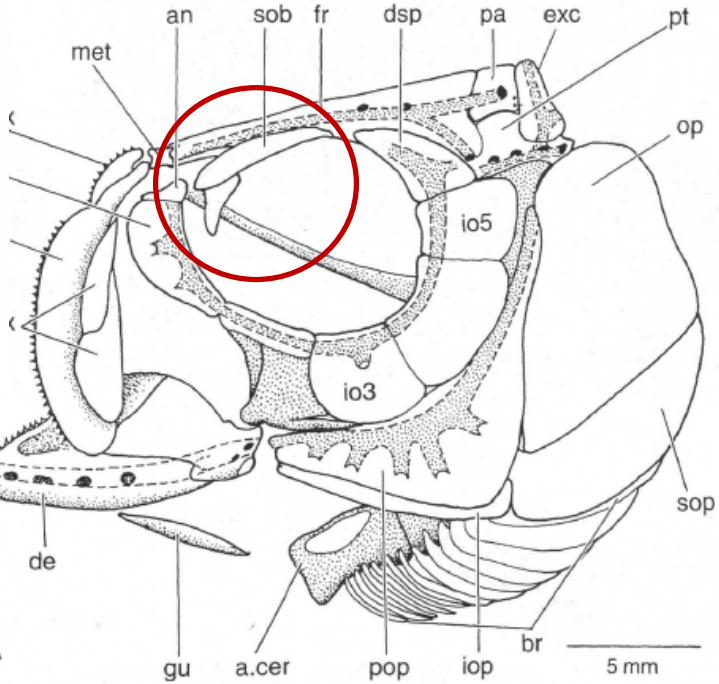


Camp 2015; Grande 2010

Innovaciones Neopterygii

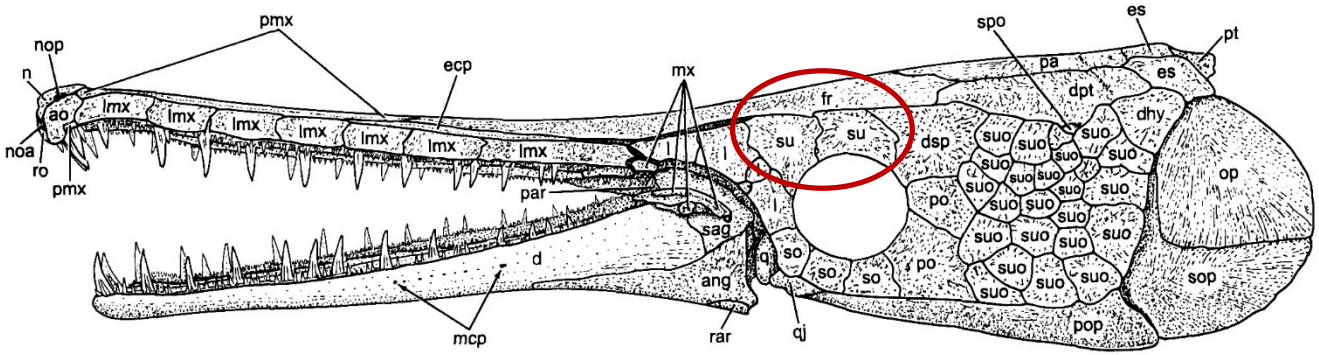
Polypterus





Basal teleost

Supraorbitales (su/sob)



Lepisosteus

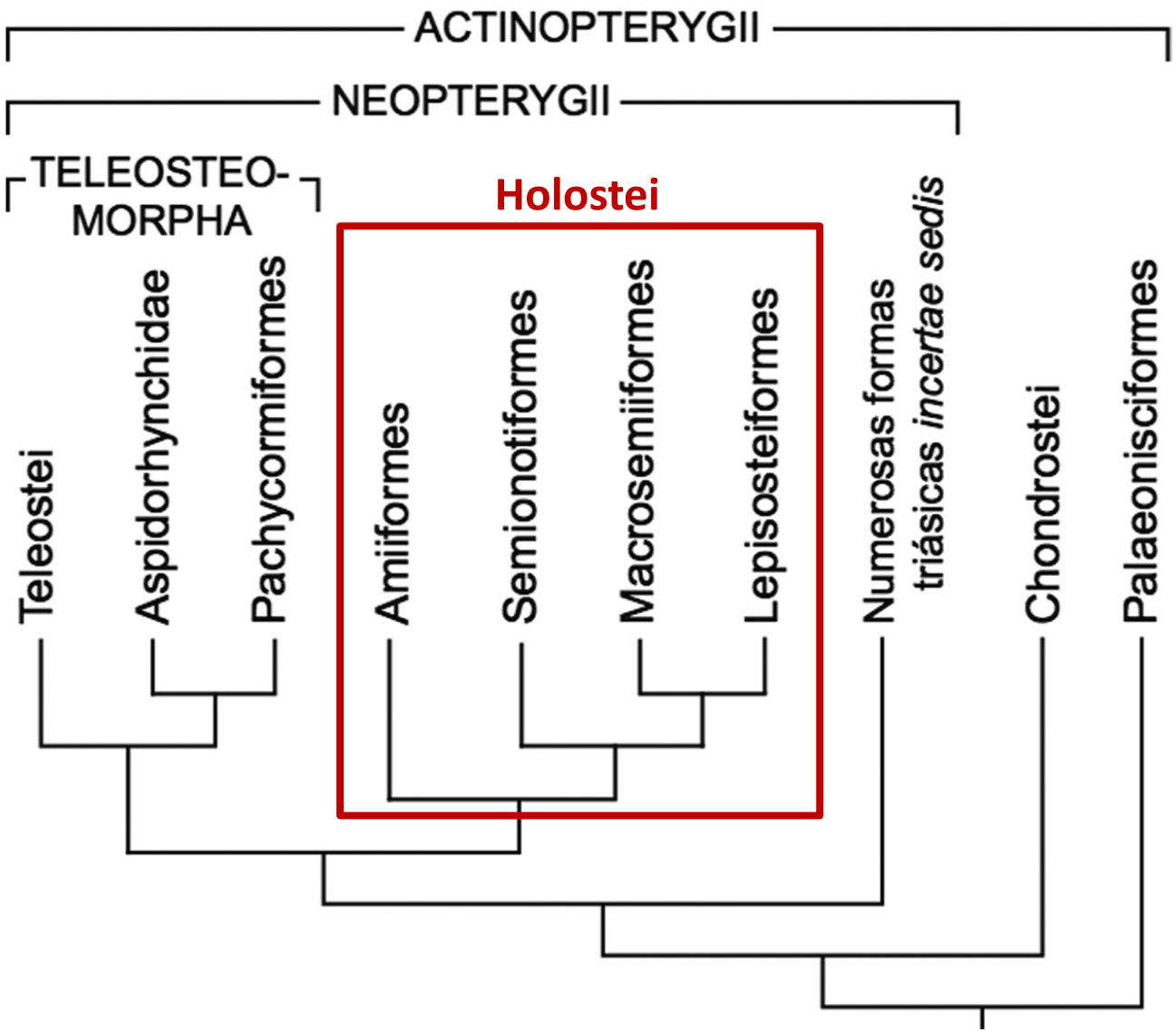


FIGURA 2. Hipótesis abreviada de las relaciones filogenéticas de ciertos clados de Actinopterygii basada en Arratia (2001), Grande (2010) y Betancur-R. *et al.* (2013). Los polypteriformes no fueron incorporados en la ilustración.

Holostei (Triásico-)

Amiiformes (Jurásico-)

Amia calva

Dulceacuícola de Norteamérica.

(Cretácico-) Lepisosteiformes

”Pejelagartos” 2 géneros; 7 spp.

Dulceacuícolas de Norteamérica.

Amia calva

Lepisosteus

†Semionotiformes

Late Triassic – Early Cretaceous

Marinos y dulceacuícolas
Europa y Norteamérica

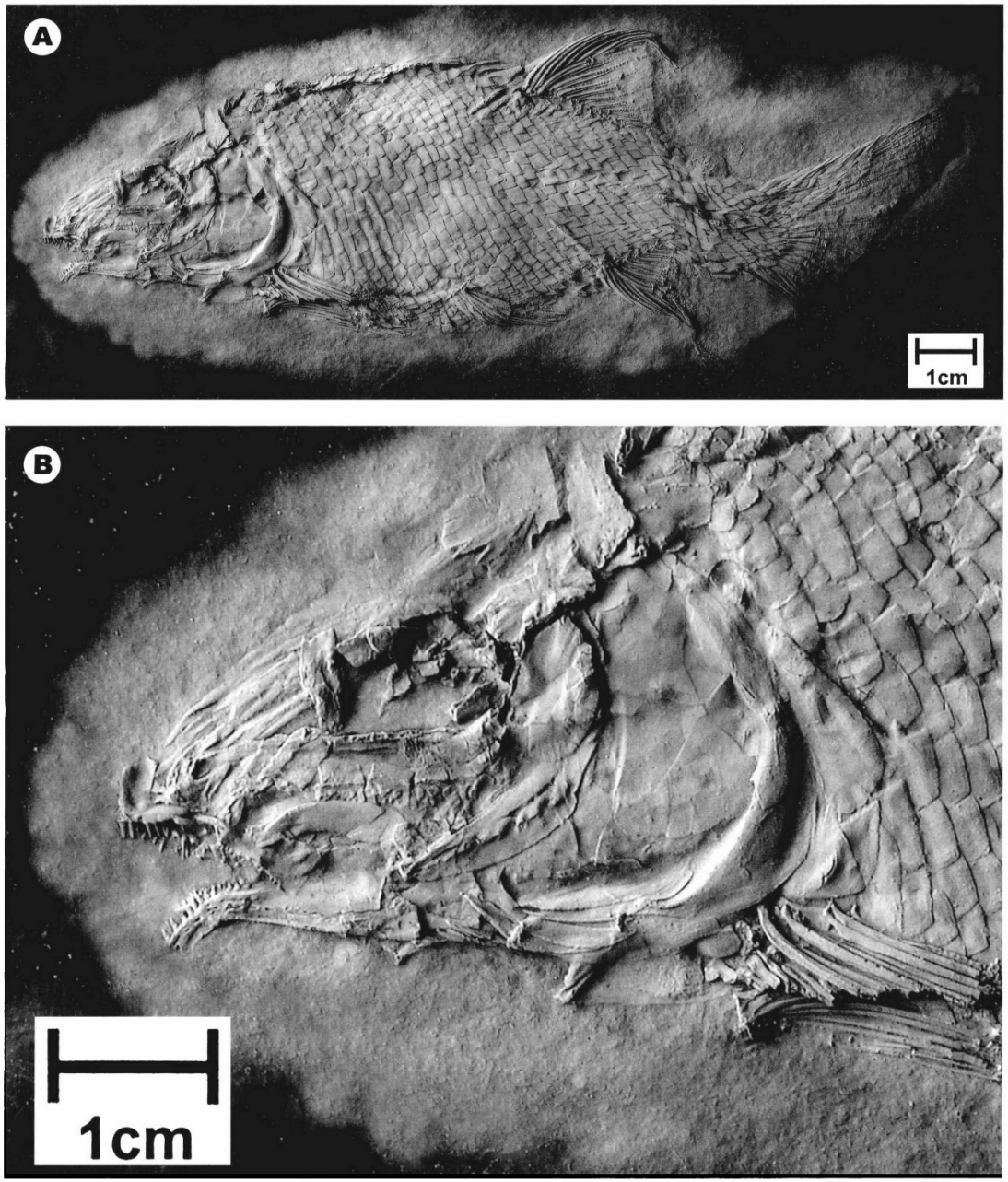
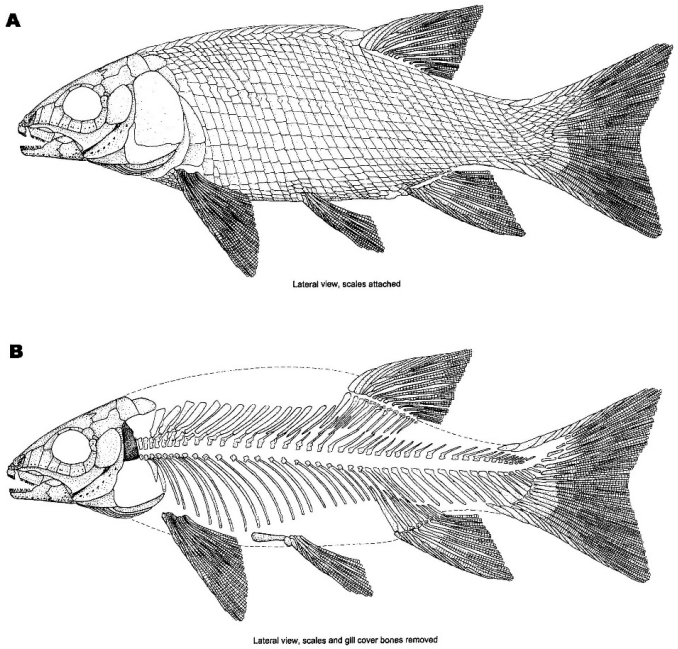
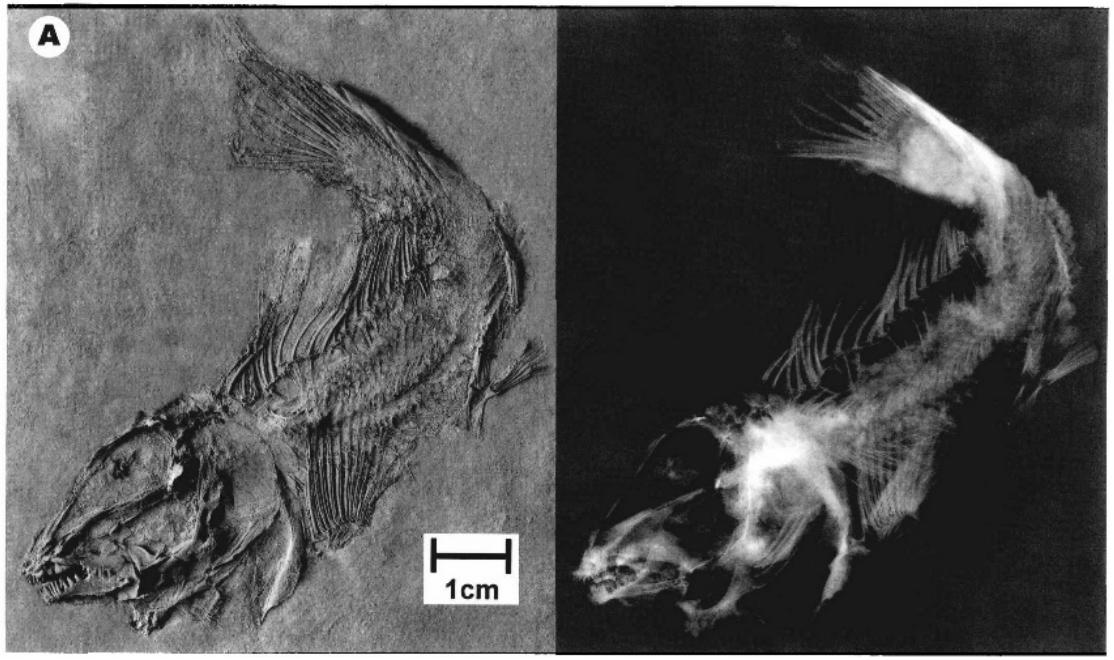


FIGURE 531. †*Semionotus elegans* (Newberry, 1888) *sensu* the †"*Semionotus elegans* species group" of Olsen and McCune (1991) (†Semionotiformes: †Semionotidae) used here for outgroup comparison in analysis of Lepisosteiformes and ingroup comparison for analysis of Neopterygii. From the Lower Jurassic freshwater deposits of the Boonton Formation of the Newark Supergroup, New Jersey. **A)** Black latex rubber peel of specimen YPM 6567 (150 mm SL) coated with ammonium chloride. **B)** Close-up of head region from **A**.



Grande 2010



†Macrosemiiformes

Late Triassic – Early Cretaceous

Marinos de arrecife
Europa y Norteamérica

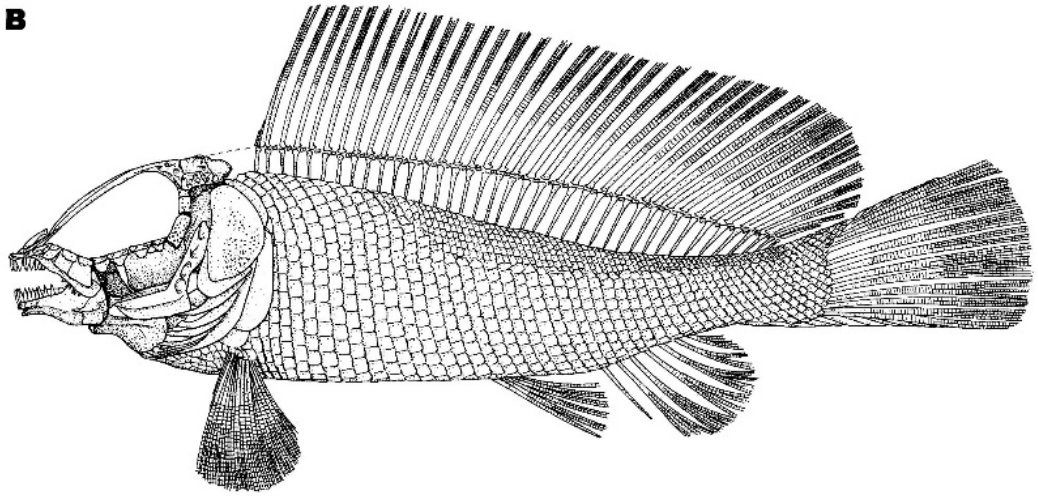
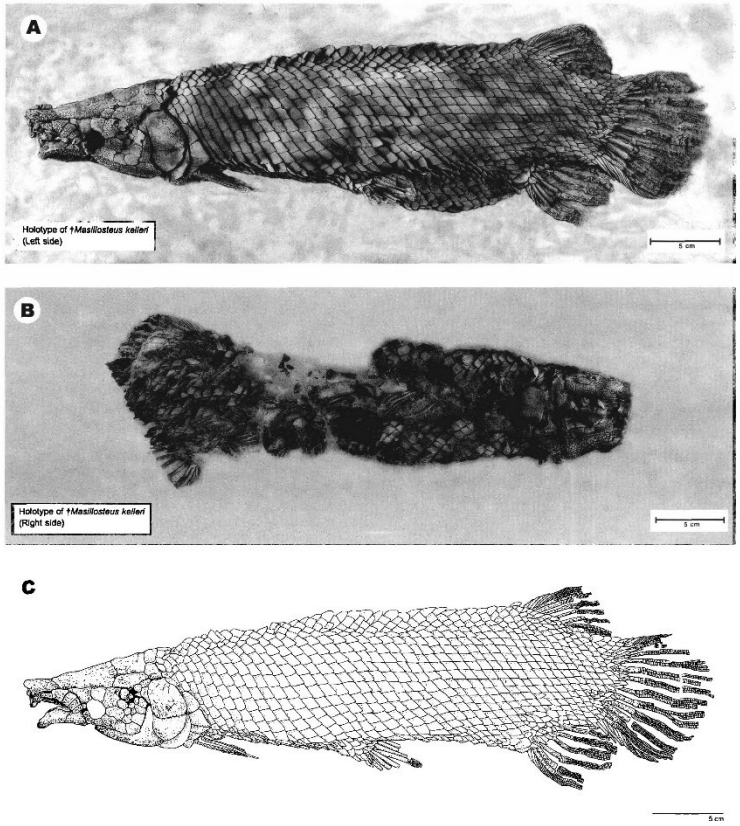


FIGURE 534. †*Macrosemius rostratus* Agassiz, 1844 (†Macrosemiiformes: †Macrosemiidae) used here for outgroup comparison in analysis of Lepisosteiformes and ingroup comparison for analysis of Neopterygii. From the Upper Jurassic marine deposits of the Solnhofen Limestone, Germany. Anterior facing left. **A)** Well preserved acid-transfer prepared specimen (BMNH 37094; 105 mm SL); photograph of ammonium chloride coated specimen (left) and print of radiograph (right). **B)** Line drawing reconstruction of complete individual, mostly after Bartram (1977:fig. 1).

Grande 2010

Lepisosteiformes
Early Cretaceous - Recent

Dulceacuícolas



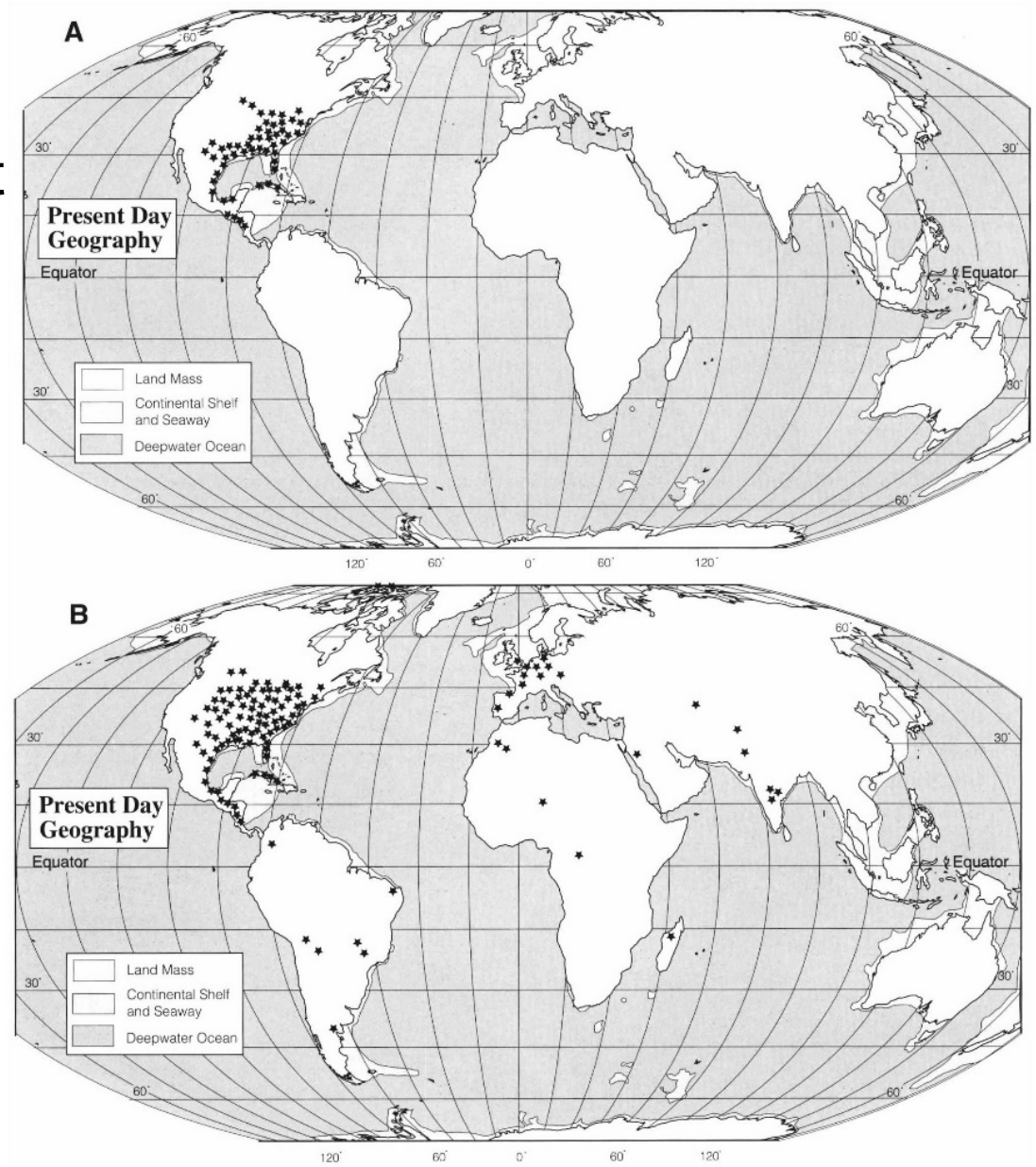


FIGURE 552. Distribution maps of known Lepisosteiformes discussed in this monograph. Base map (equal area projection) is of present-day geography and was modified after Scotese and Golonka (1992). Stars indicate general localities and geographic range of occurrence. **A)** Extant species only. **B)** Extant range plus fossil occurrences.

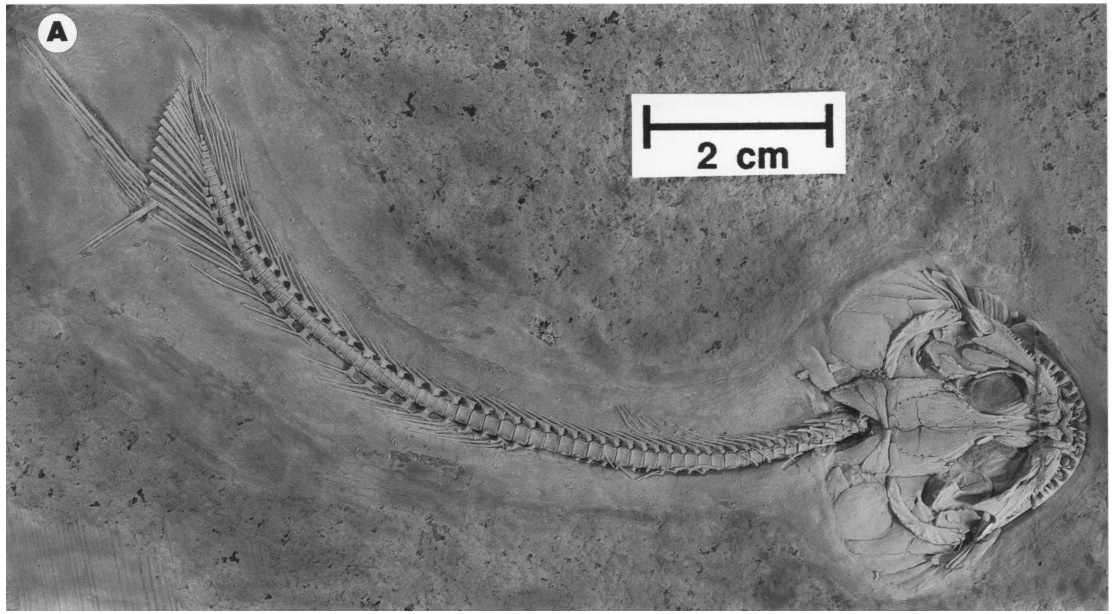
Grande 2010

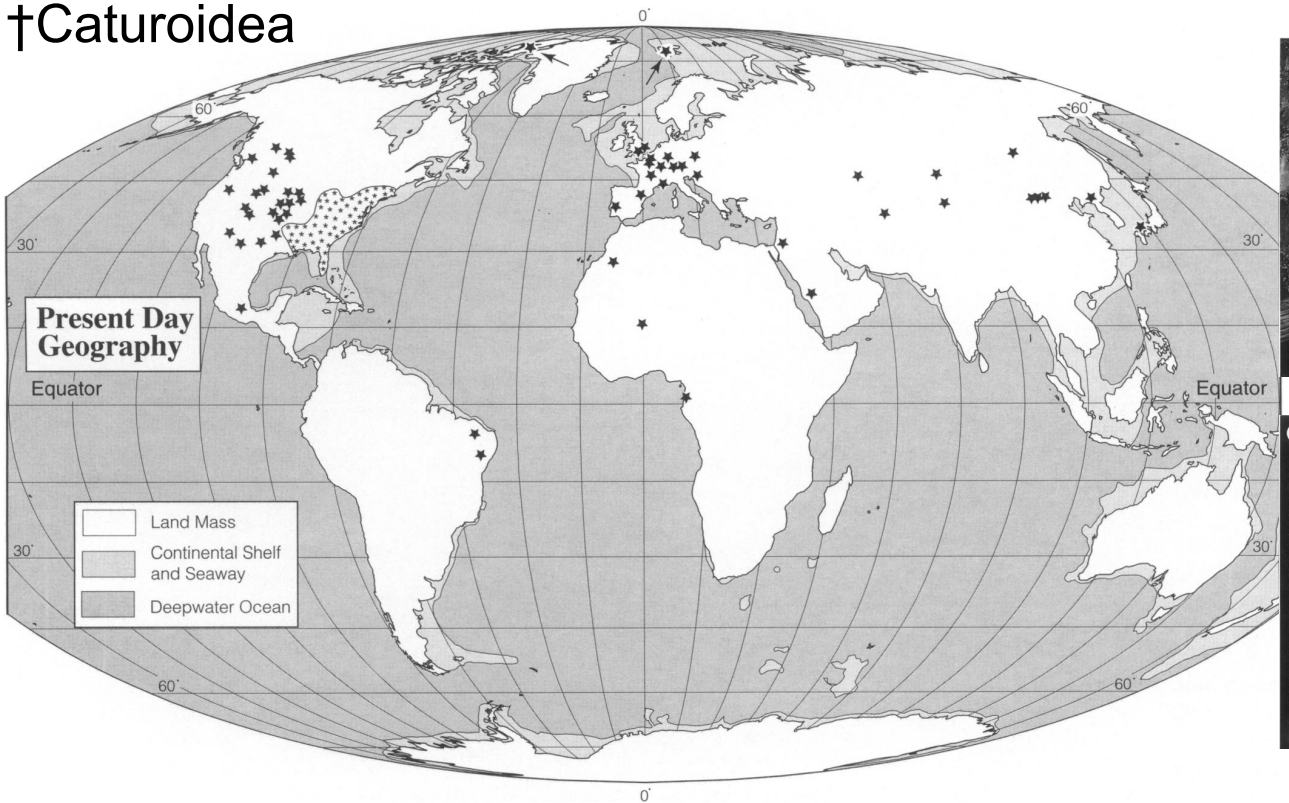
Halecomorphi o Amiiformes

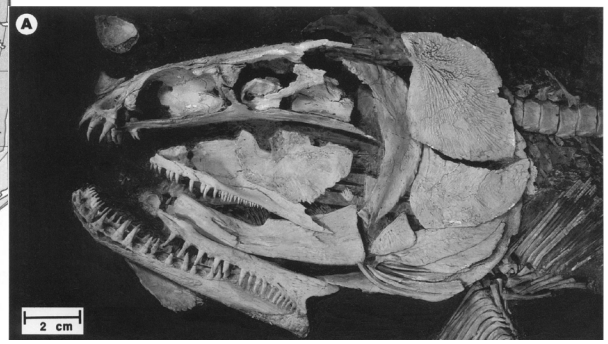
Mid Triassic - Recent

Marinos y Dulceacuícolas

Amiidae
†Parasemionotiformes
†Ionoscopiformes
†Caturoidea

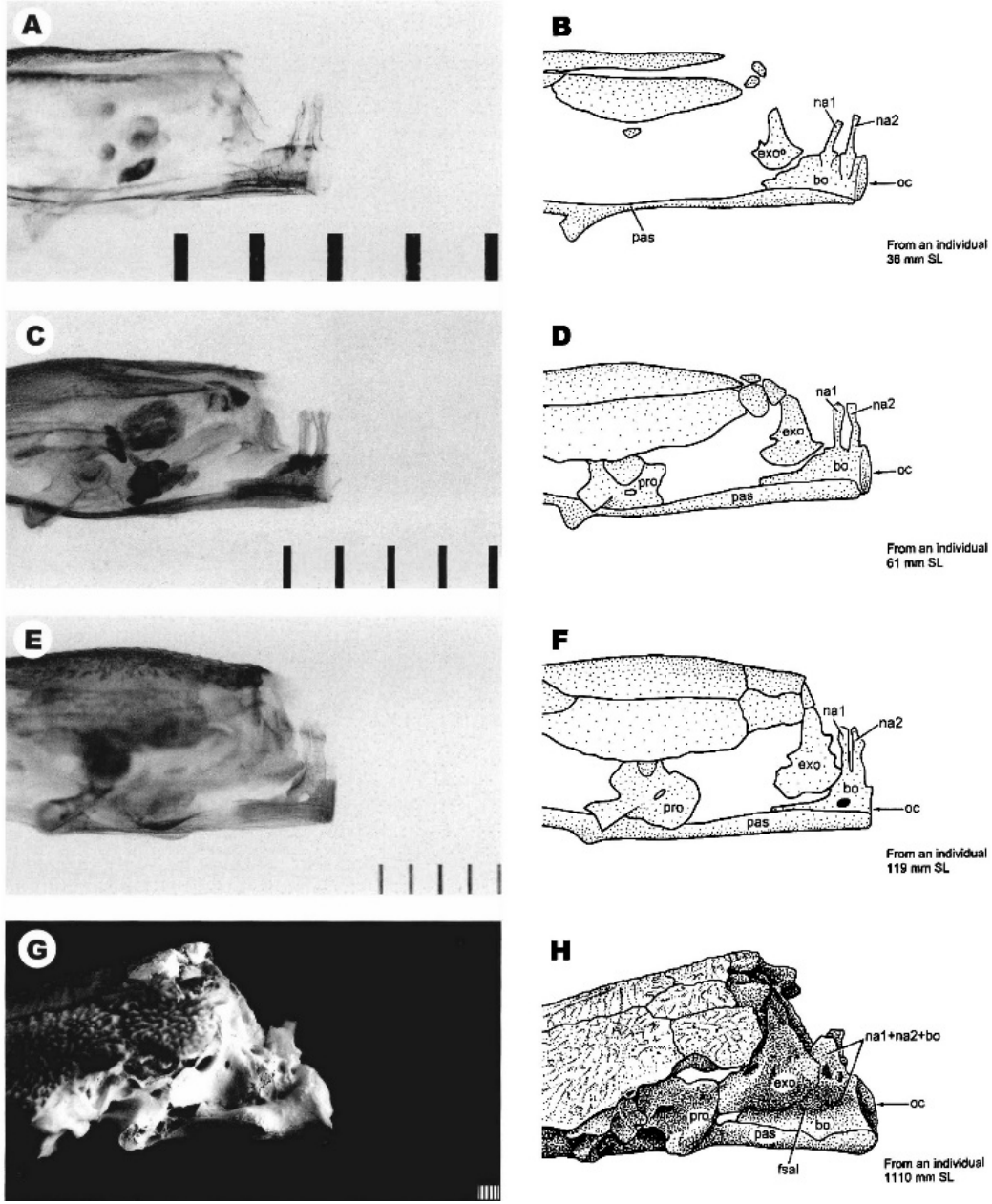






Grande 2010

Holósteo (*Atractosteus*)

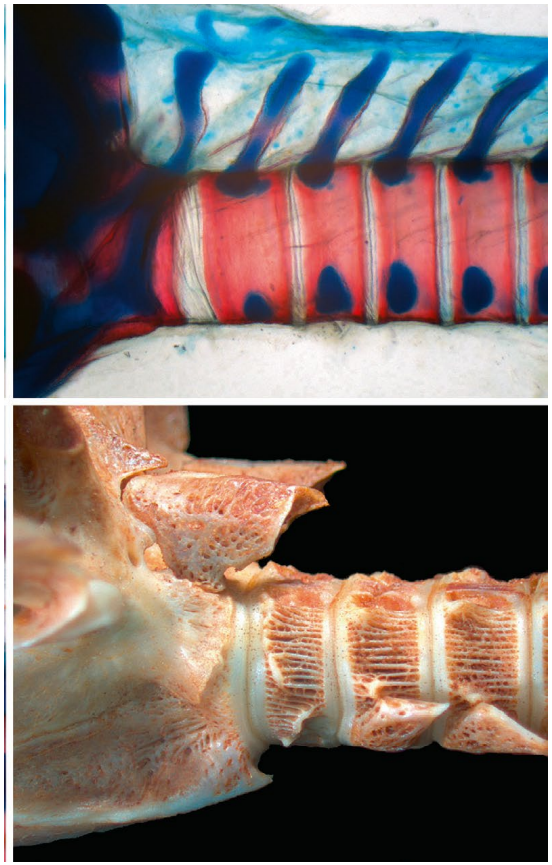


Holostei

"Todo hueso"

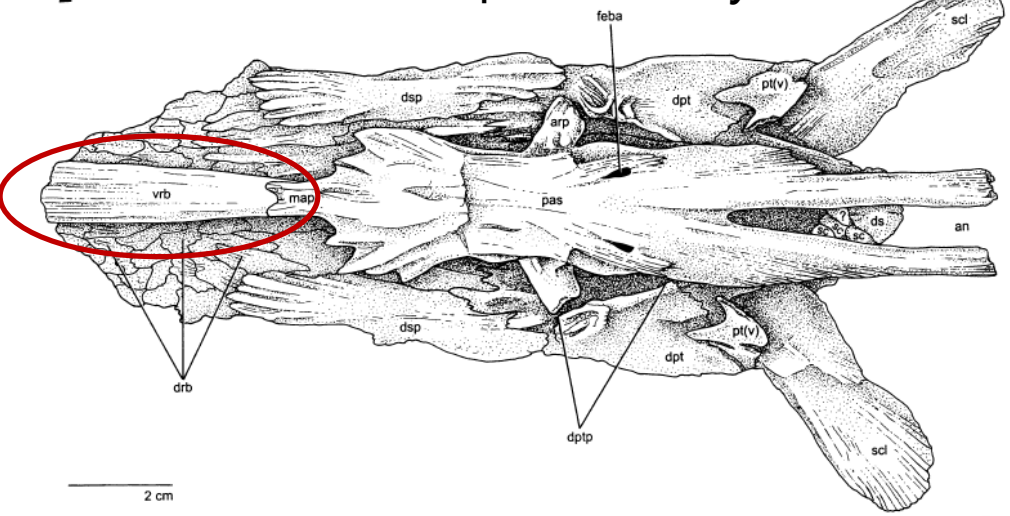
Fusión de las primeras dos vértebras con cóndilo occipital

Teleósteo (*Elops*)



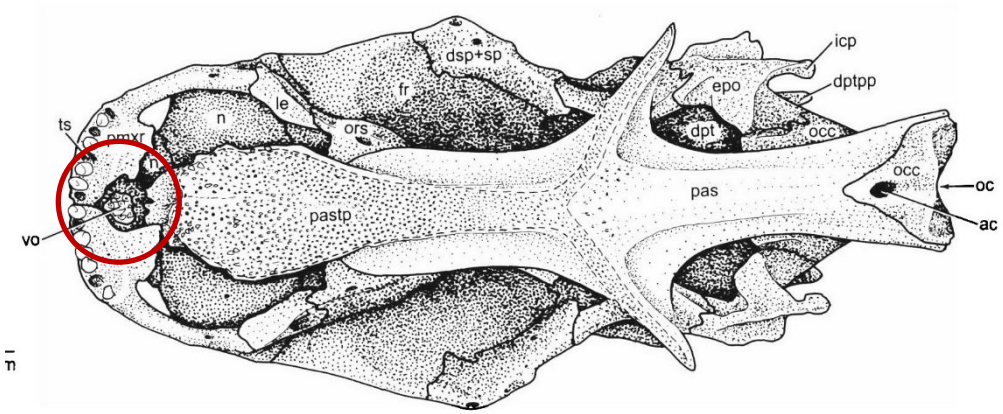
Innovaciones Holostei

Chondrostei - †*Psammorhynchus*

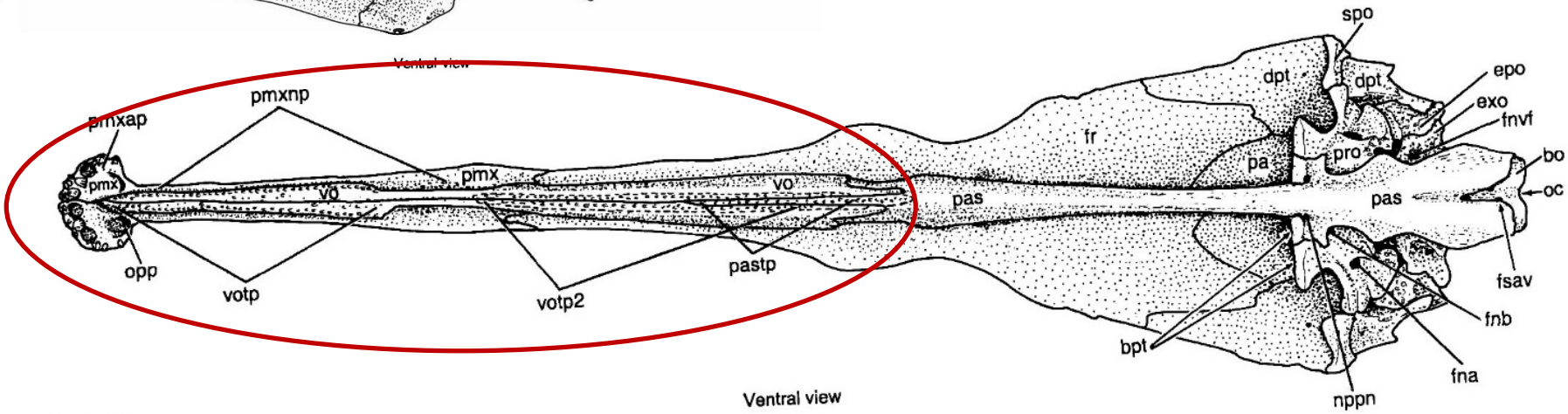


Vómer pareado

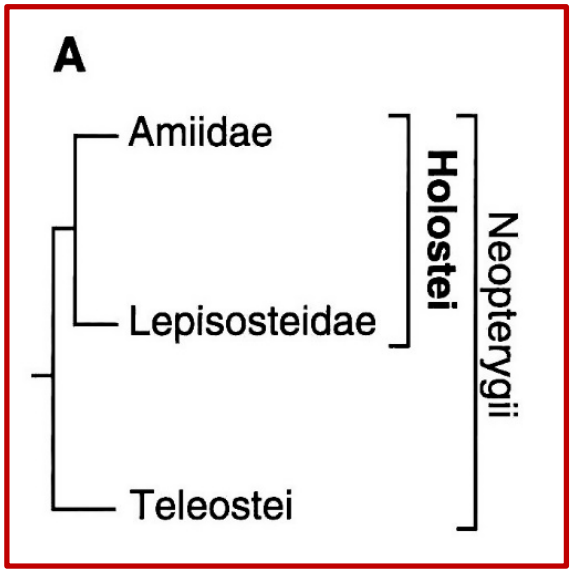
Cladistia - *Polypterus*



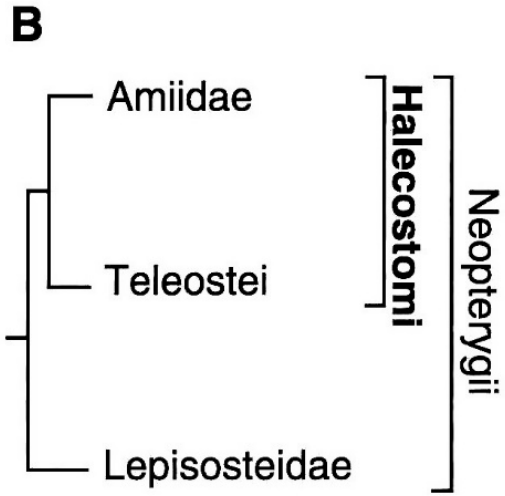
Holostei - *Lepisosteus*



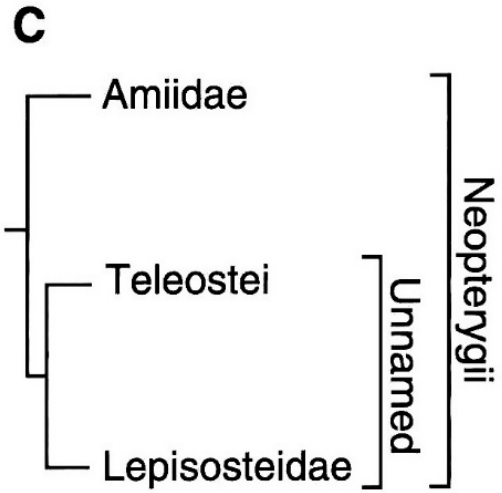
Controversia Gar-Amia-Teleostei



after Huxley, 1861
Regan, 1923
Goodrich, 1930
Romer, 1945,1966
Jarvik, 1959,1980
Andrews et al.,1967
McAllister, 1968
Nelson, 1969
Jollie, 1984
Olsen and McCune, 1991
Normark et al., 1991
Lecointre et al., 1994
Venkatesh et al., 1999
Inoue et al., 2002



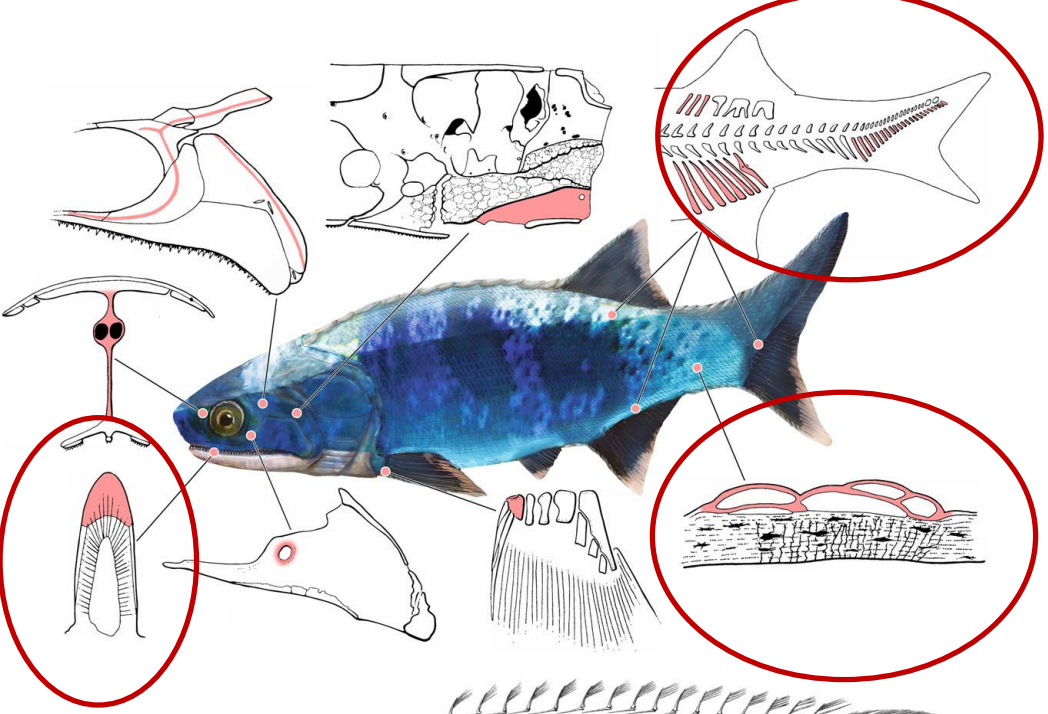
after Gardiner, 1960
Patterson, 1973
Wiley, 1976
Nelson, 1976, 1984, 1994
Bartram, 1977
Rosen et al., 1981
Lauder & Liem, 1983
Wiley & Schultz, 1984
Gardner, 1984
Nolf, 1985
Verran, 1988
Gardner et al., 1996
Liem et al., 2001



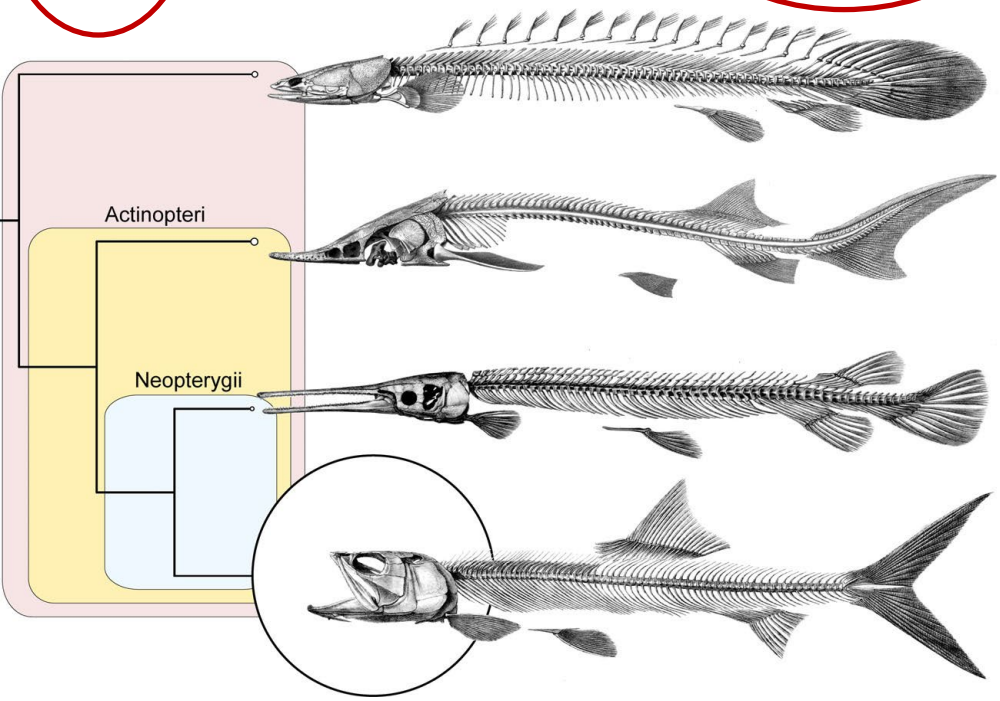
after Olsen, 1984

Consenso
Morfología / Molecular

Síntesis

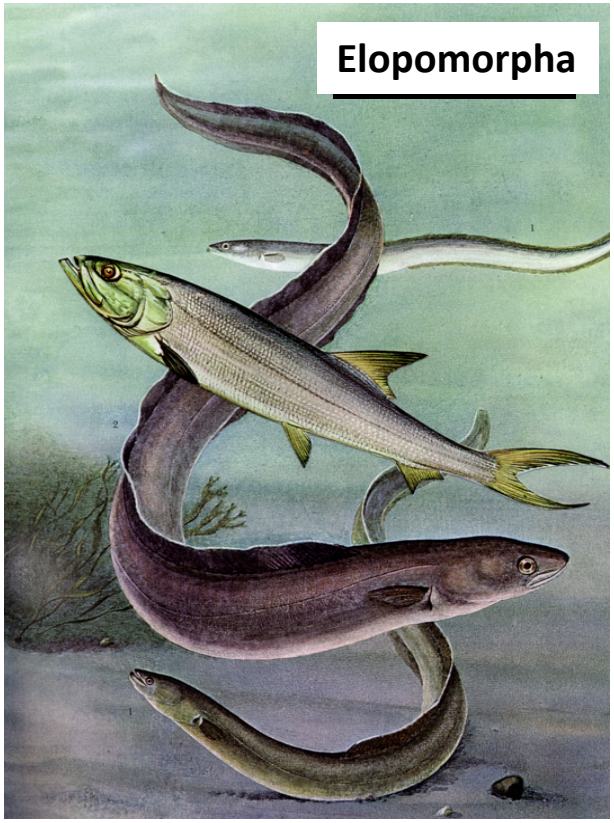


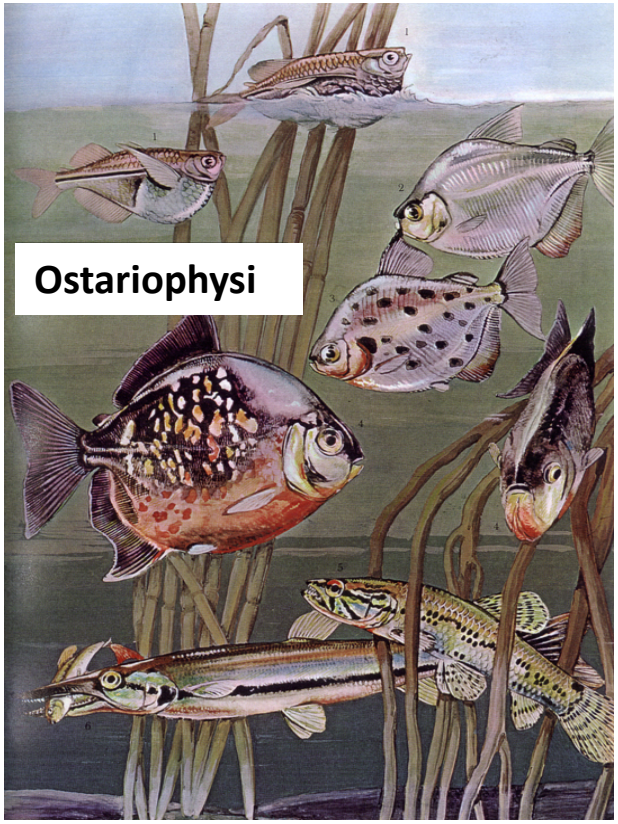
Actinopterygii:
-Aleta dorsal única
-Aleta caudal sin rayos epicordales (Aleta heterocerca)
-Radiales en aletas impares
-Ganoina y acrodina

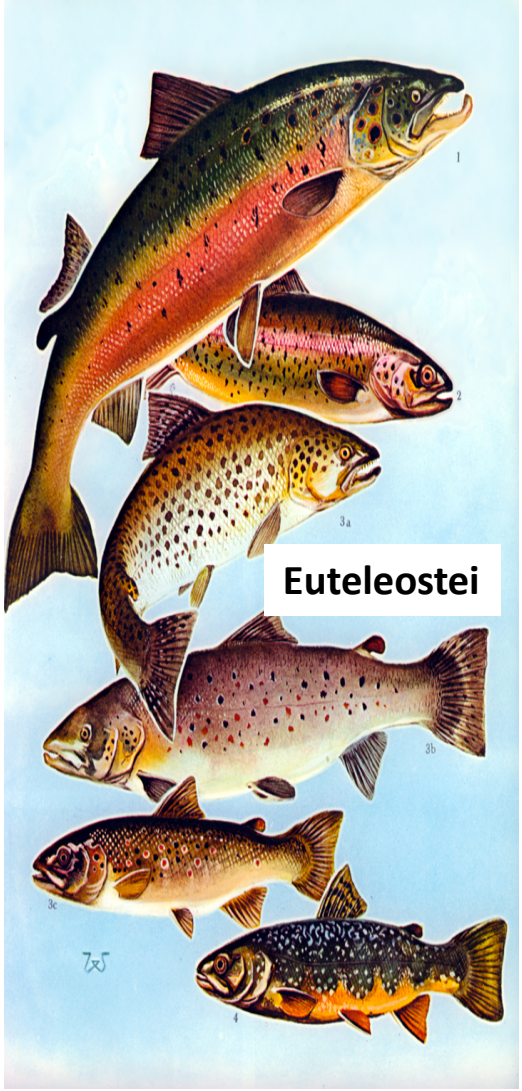


Chondrostei:
Esqueleto desmineralizado

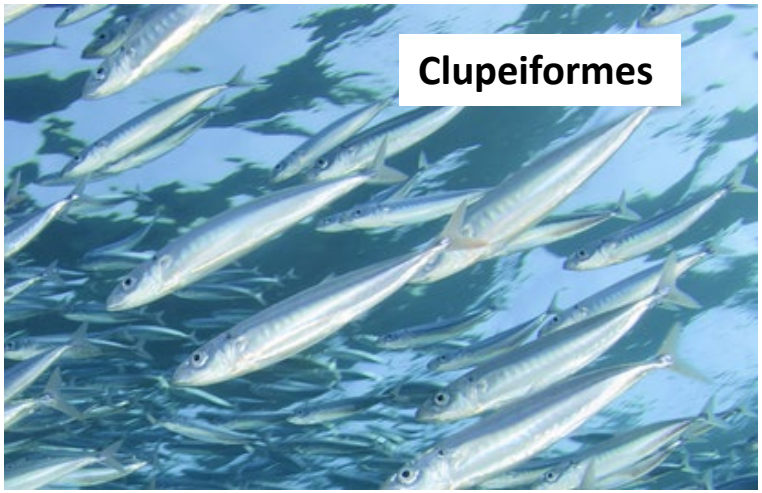
Neopterygii:
Alimentación por succión

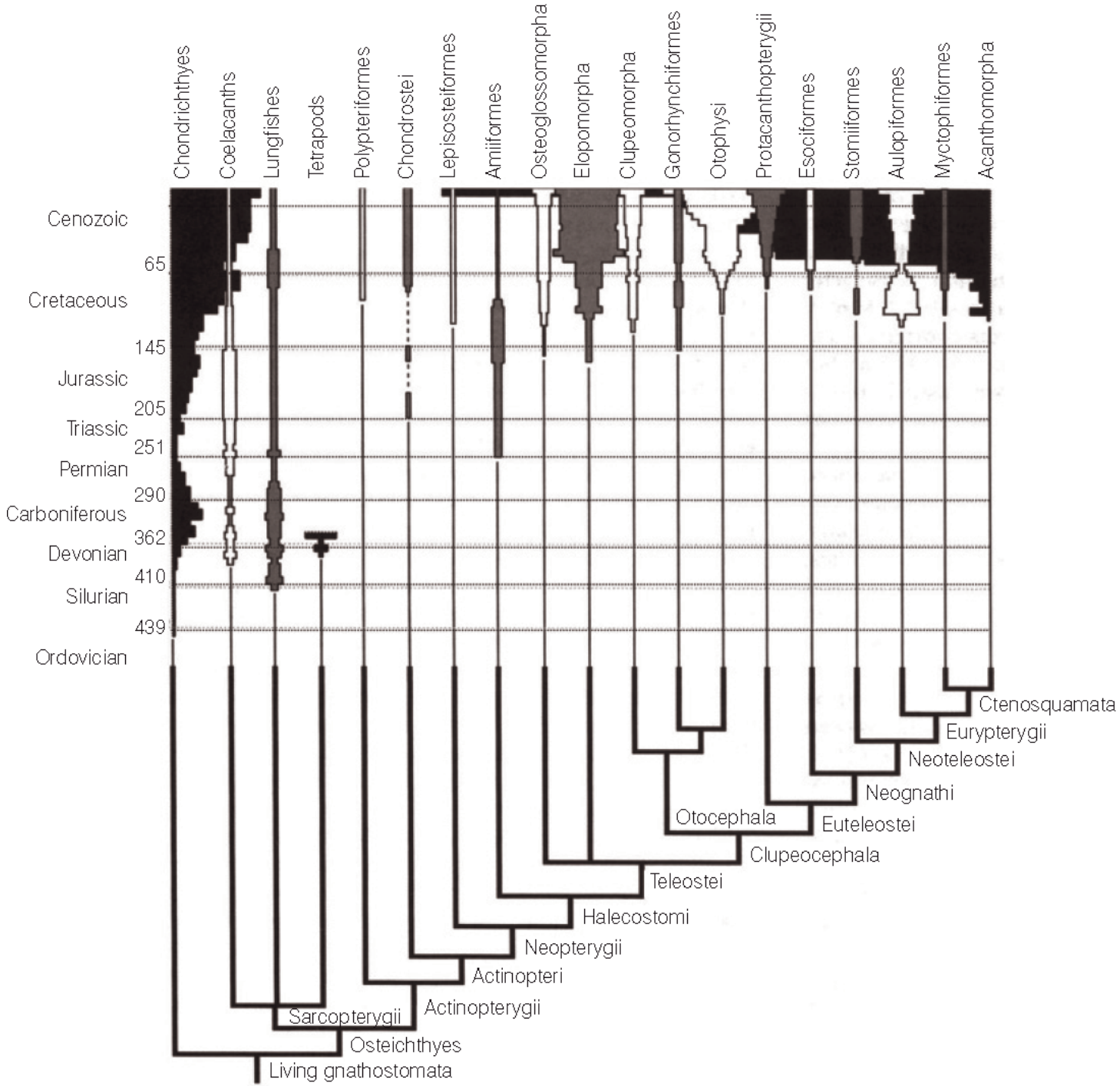






Teleósteos corona




Chondrichthyes
Coelacanths
Lungfishes
Tetrapods
Polypteriformes
Chondrostei
Lepisosteiformes
Amiiformes
Osteoglossomorpha
Elopomorpha
Clupeomorpha
Gonorhynchiformes
Otophysi
Protacanthopterygii
Esociformes
Stomiiformes
Aulopiformes
Myctophiformes
Acanthomorpha
Cenozoic
65
Cretaceous
145
Jurassic
205
Triassic
251
Permian
290
Carboniferous
362
Devonian
410
Silurian
439
Ordovician
Ctenosquamata
Eurypterygii
Neoteleostei
Neognathi
Euteleostei
Otocephala
Clupeocephala
Teleostei
Halecostomi
Neopterygii
Actinopteri
Actinopterygii
Sarcopterygii
Osteichthyes
Living gnathostomata

Bibliografia sugerida

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- Long, J. (2011) *The rise of fishes*. 2 ed.
- Helfman, Collette, Facey & Bowen (2009) *The diversity of fishes.* 2 ed.
- Arratia (2015) *Complexities of early Teleostei and the evolution of particular morphological structures through time. Copeia* 103(4), 999-1025

Actinopterygii

Peces con aleta radiada

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Biología Molecular, Celular y Neurociencias

Univ. de Chile

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Curso Paleontología de Vertebrados. Enero 2016

Teleostei

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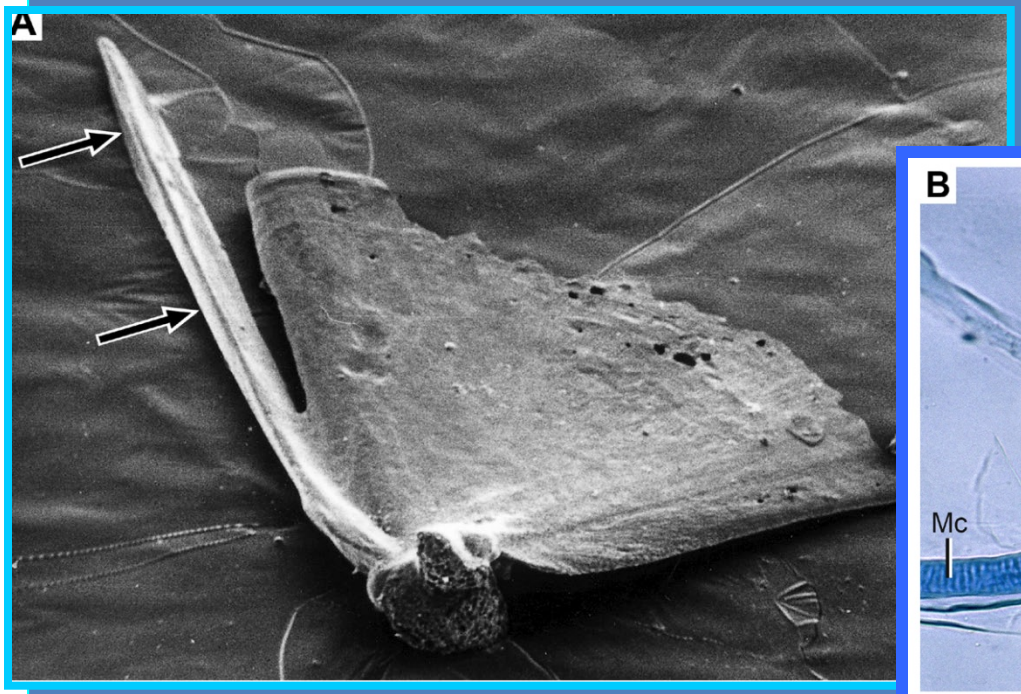
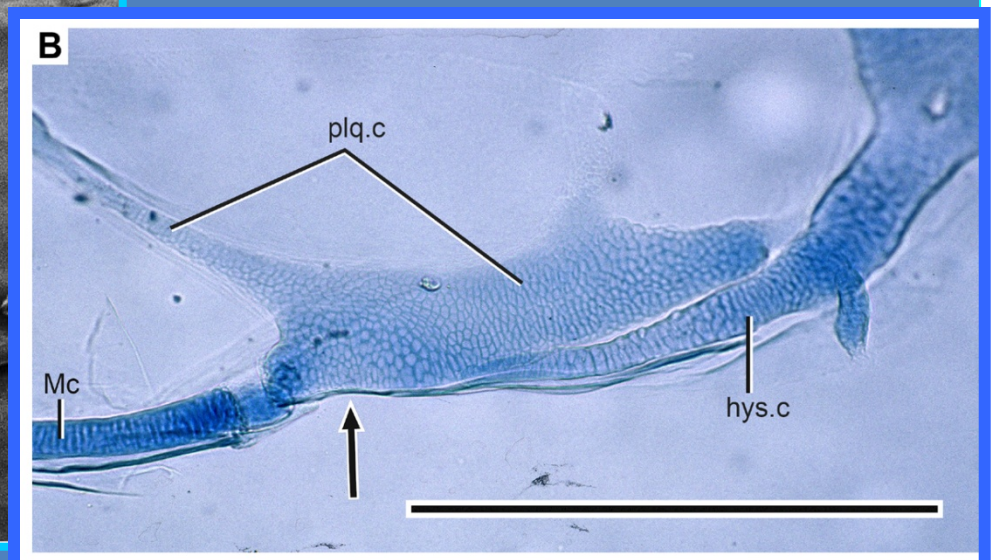
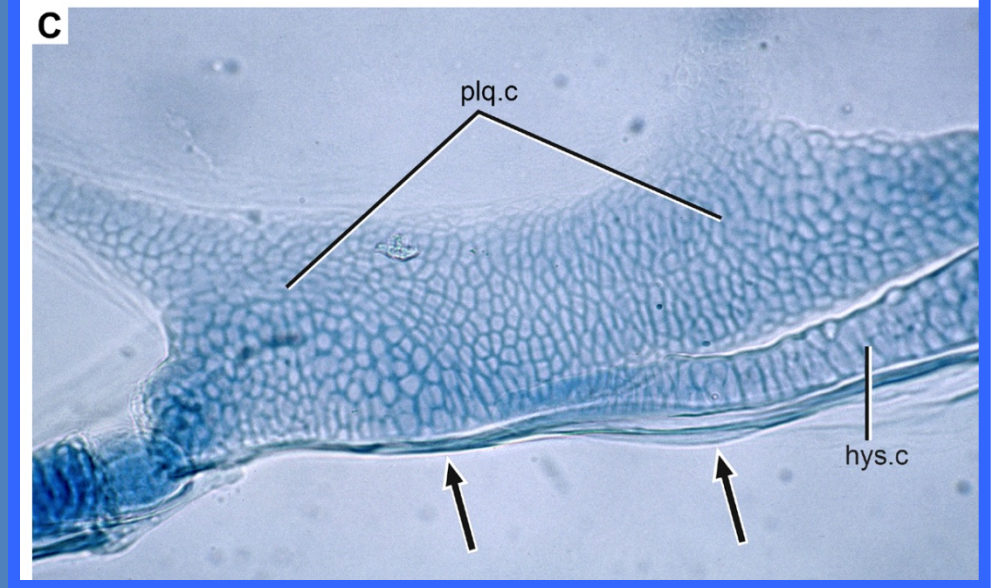
nicump@gmail.com

Curso Paleontología de Vertebrados. Abril 2016







El proceso posteroventral (puntas de flechas) del hueso quadrado es una osificación membranosa en cambio la parte posterior del palatocuadrado (*pars quadrata*) es condral.