Systematics of “Fishes”

with an emphasis on African fresh- and brackish water fishes

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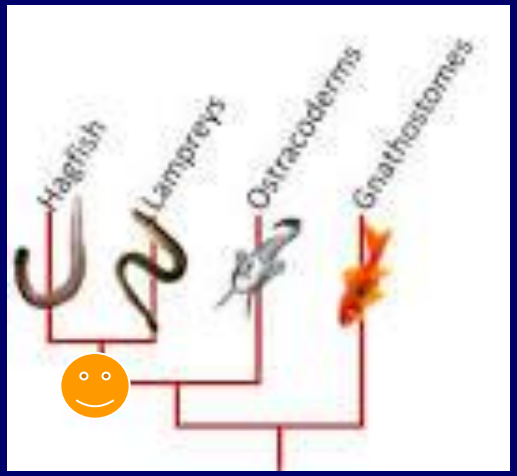
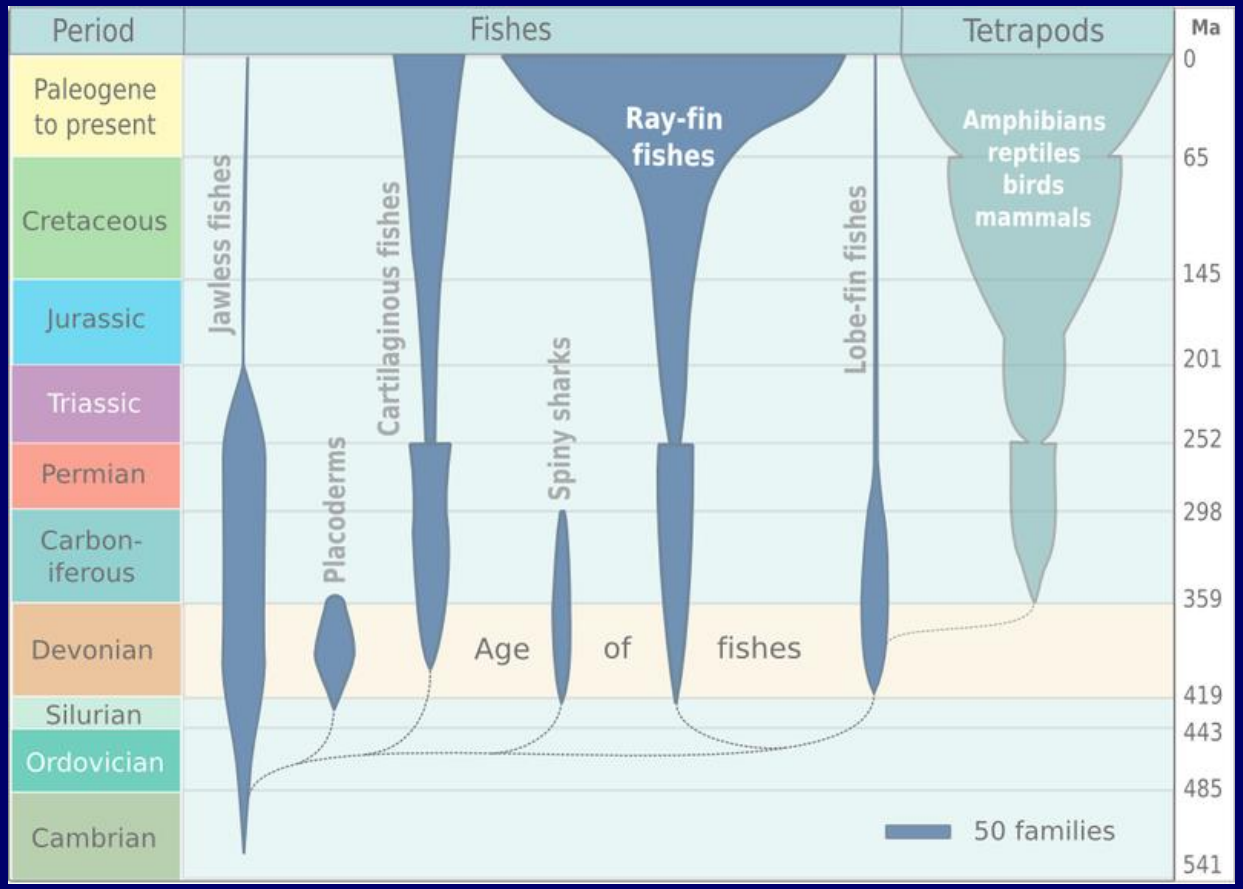
VERTEBRATA:

Craniata = Vertebrata : presence of a skull and vertebral elements

– Agnatha (jawless fish = fossil taxa (Ostracodermi) and Cyclostomata (hagfishes and lampreys)

– Gnathostomata (fishes, amphibians, reptiles, birds, mammals)





CRANIATA = VERTEBRATA

- Important evolutionary innovations:

- Evolution from pre-vertebrate to vertebrate: from system with cilia for food collection to pump-mechanism via:
  - muscles around the pharynx
  - reinforcement of gill arches, first with cartilage

- Further evolution from Agnatha to Gnathostomata: development of jaws and associated muscles

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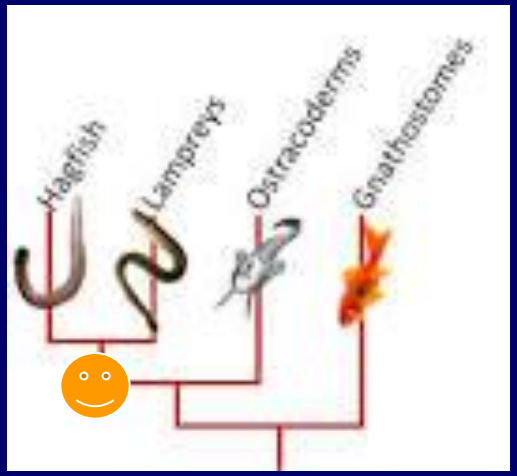
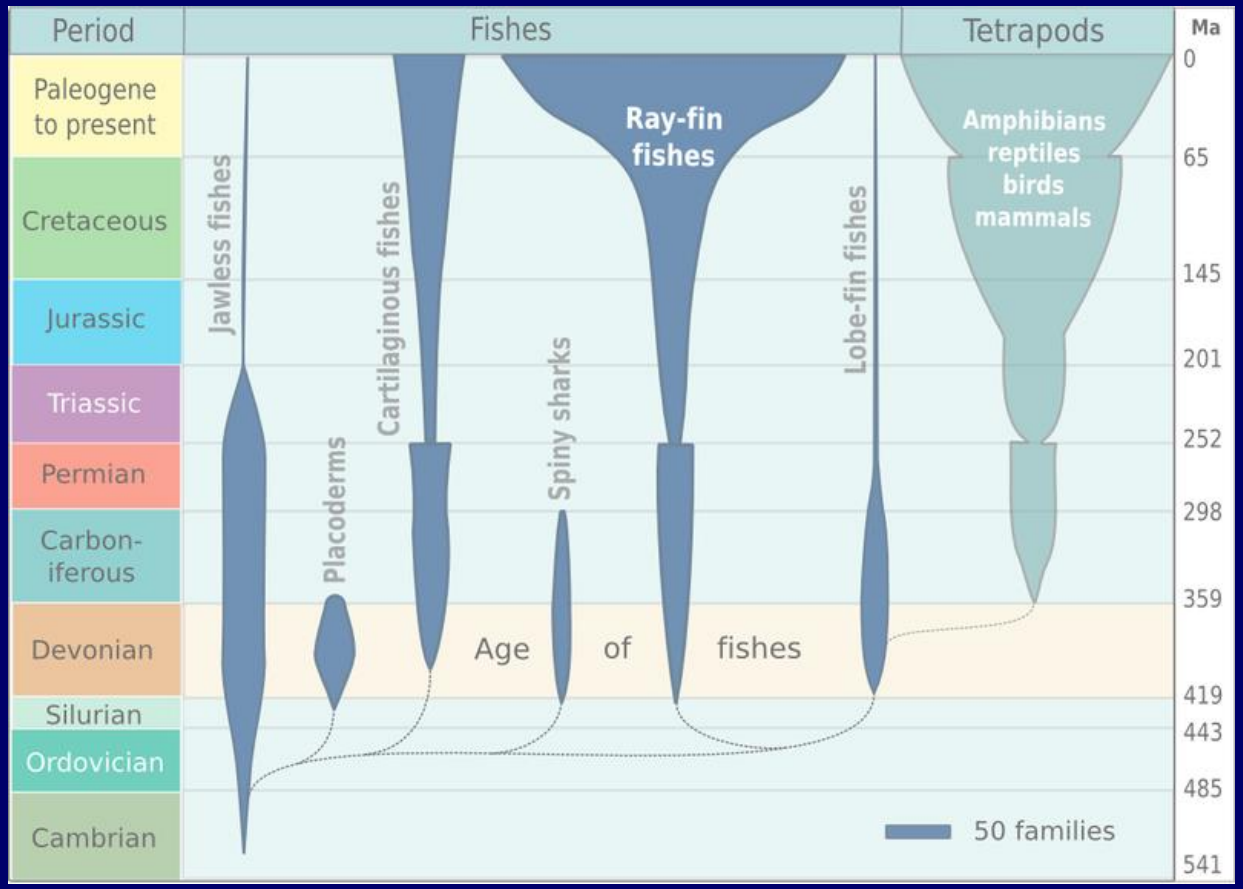
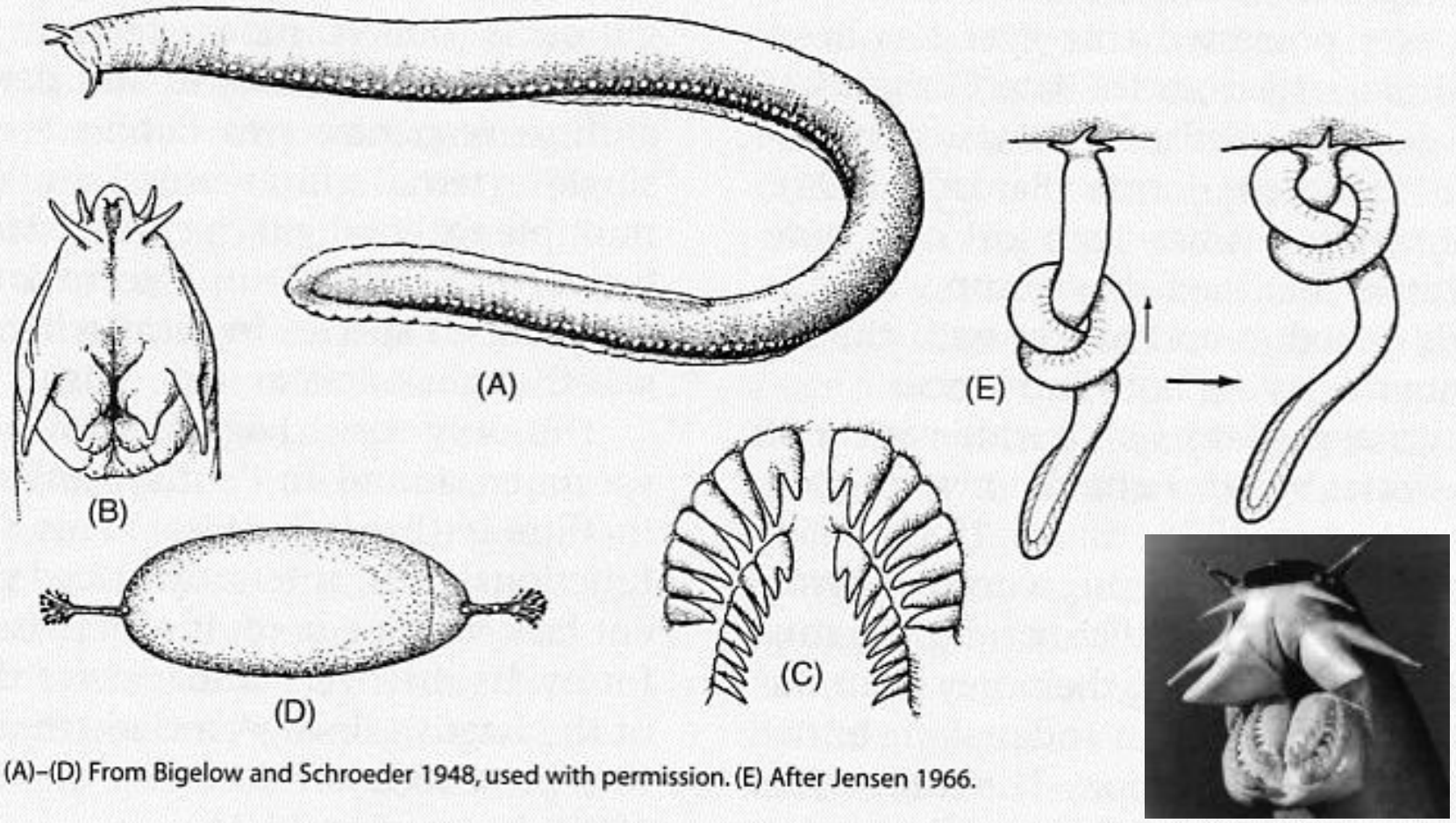




HYPEROTRETI (HAGFISHES): **Characters**



(A)–(D) From Bigelow and Schroeder 1948, used with permission. (E) After Jensen 1966.

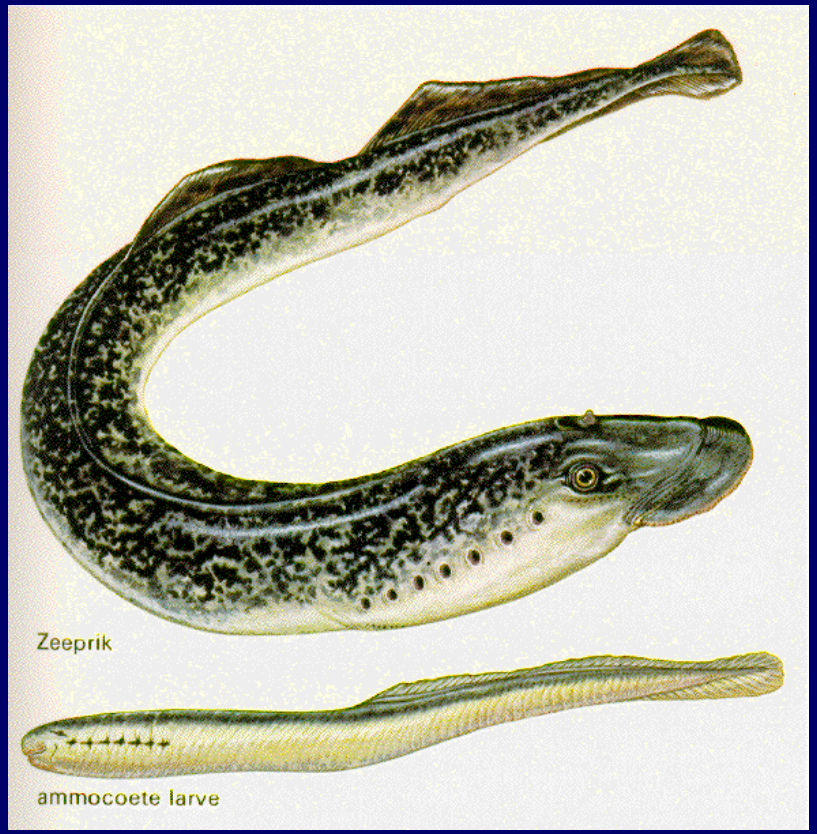
HYPEROTRETI (HAGFISH): **Behaviour**

video

- jawless, degenerated eyes (photoreceptors);
- cartilaginous skeleton, no bony material;
- marine, in temperate and temperate cold zones;
- many live in corridors in the mud or sandy bottom; feeding on invertebrates or carrion-eaters that penetrate in the body of dead or dying sea-animals; use the knot-method;
- ventro-lateral series (70 to 200) of very large mucus glands (specimen of 50 cm, one bucket full in a couple of minutes)

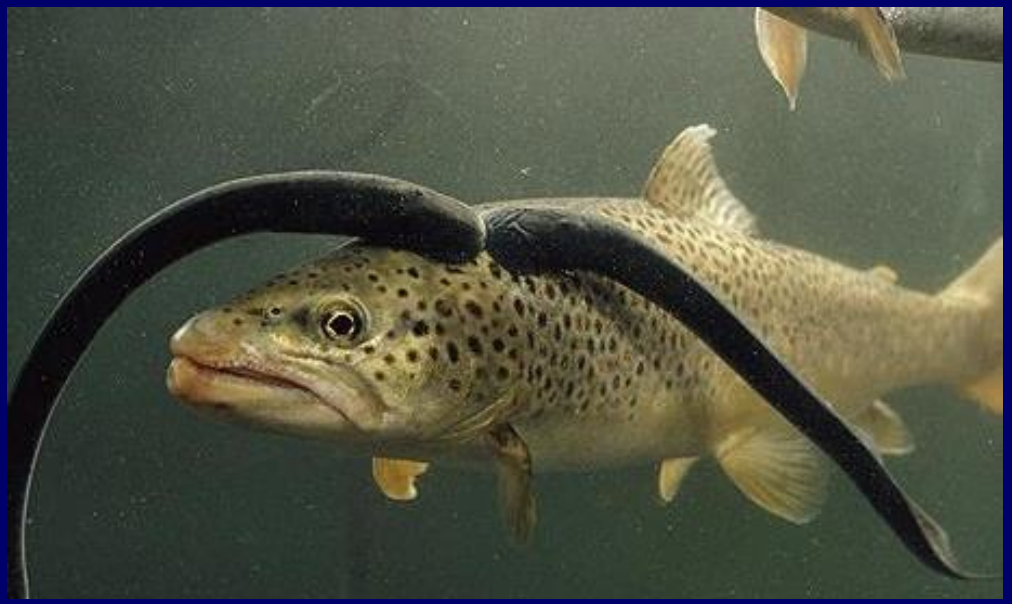
HYPEROARTIA (LAMPREYS): Biology

- Anadromous or freshwater.
- Ammocoete larva, buried half in the mud; largest part of life cycle, 3 to 7 years.
- Important metamorphosis and then migration to the sea for some species.
- Anadromous adults return to river after 1 or 2 years to reproduce and then die.



HYPEROARTIA (LAMPREYS): Biology

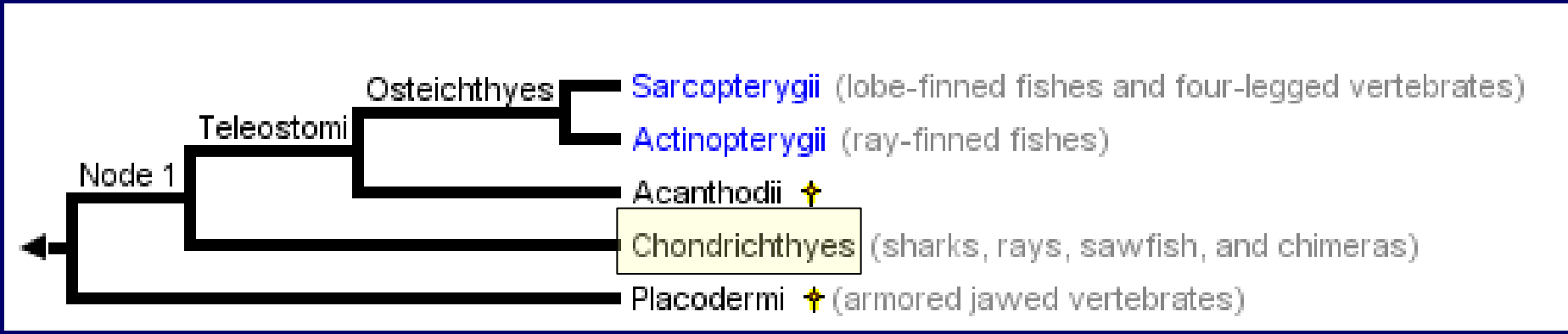
- Many parasitic species:
  - attach to other fish
  - feed on fluids of prey
- Oral sucker disc also helps in upstream migrations, helps in fixing on rocks (*Petromyzon* spp.).
- Non-functional hermaphrodite immature individuals.



GNATHOSTOMATA (Vertebrates with jaws)

“Fishes”: ± 33.300 species
Tetrapods : ± 30.000 species

The development of jaws was probably the largest morphological step forwards for the vertebrates, the development of paired fins is a good second.



Subclass ELASMOBRANCHII: Characters

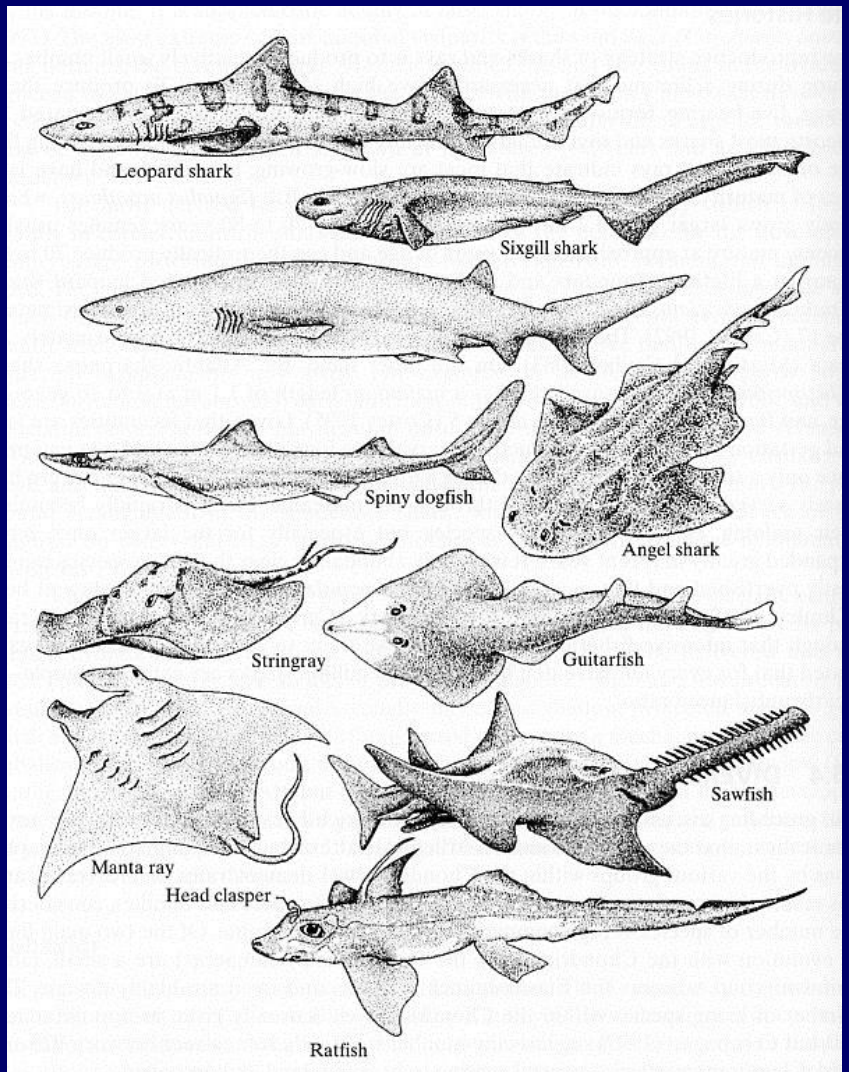


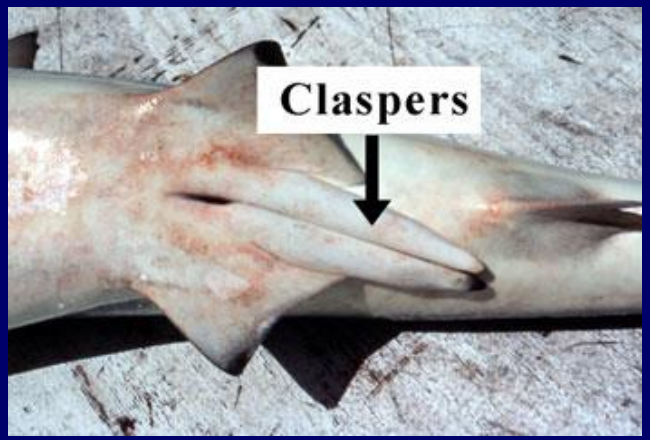
FIGURE 15.3 Representative Chondrichthyes. **Top to bottom:** Carchariniformes: leopard shark *(Triakis semifasciata)*; Hexanchiformes: juvenile sixgill shark (*Hexanchus griseus*); adult sixgill shark; Squatiniformes: angel shark (*Squatina californica*); Squaliformes: spiny dogfish (*Squalus acanthias*); Myliobatiformes: stingray (*Dasyatis* sp.); Rajiformes: guitarfish (*Rhinobatos* sp.); Myliobatiformes: manta (*Manta birostris*); Pristiformes: sawfish *(Pristis perotteti)*; Chimaeriformes: chimaera (*Hydrolagus collei*). From Moyle (1993); © 1993 by Chris Mari Van Dyck.

Class CHONDRICHTHYES (Cartilaginous fishes): Characters

- Cartilaginous skeleton:
  - Often calcified ($CaPO_4$), a.o. vertebrae, but seldom or maybe never ossified;
  - Not well-preserved; hence the origin and relationships are difficult to reconstruct;
  - Reconstruction: based on conserved impression (print), scales and teeth.
- Scales (dermal denticles) and teeth (modified scales) are placoid.
- Teeth not fused to jaws, but fixed with connective tissues; are replaced in series or individually (even each two days in some taxa).

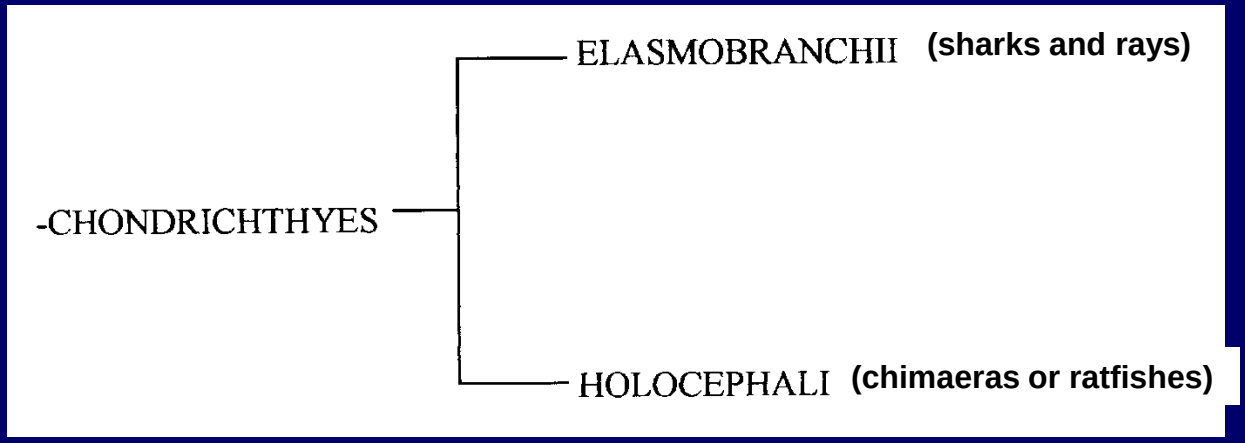
Class CHONDRICHTHYES (Cartilaginous fishes): Characters

- Paired fins supported in the bo**d**y by skeletal girdles.
- No swimbladder, no lungs.
- Intestinal spiral valve.
- Myxopterygia (= pterygopodia, claspers), developed from posterior pars of pelvic fins (metapterygium) in males ⇒ internal fertilisation.
- Oviparous (43 %) with leather-like egg case, ovoviviparous or viviparous (57 %).



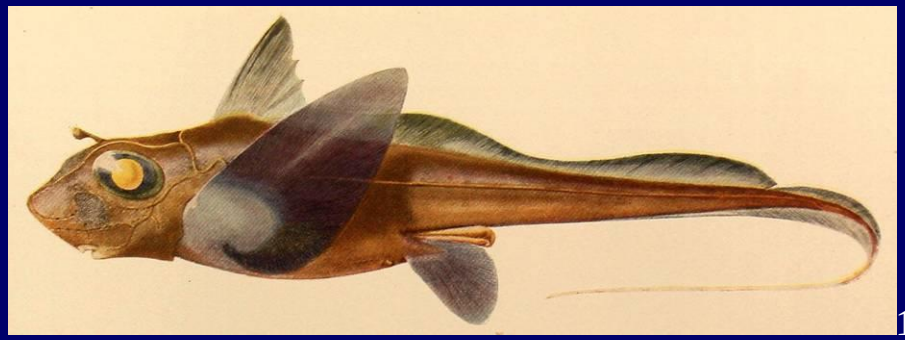
example of egg cases (mermaid purses) of a skate and a shark

Class CHONDRICHTHYES (Cartilaginous fishes): Division



Holocephali

- live in cool and deep marine waters
- feeding on benthic invertebrates



Subclass ELASMOBRANCHII: Characters

- 5 to 7 separate gill clefts, not covered by operculum.
- Spiraculum = modified first gill opening, secondarily lost in some taxa.
- Mostly heterocercal (asymmetrical) caudal fin.
- Nostrils ventrally.
- One cloaca (anal + urogenital opening).
- Mostly 2 dorsal fins, with or without spine.
- Pectoral and pelvic fins with large basis:

Subclass ELASMOBRANCHII: Characters

- Predators, good vision but olfactory senses are more important en better developed; sharks: detection level up to 1 per $25*10^6$ (one drop in an Olympic swimming pool).
- Good mechano-receptorial senses (inner ear and lateral line).
- High electrosensivity: ampullae of Lorenzini, mainly on snout.
- Some taxa, mostly rays have a weak electric organ.
- Relative high brain / body ratio (analysis of stimuli).

Subclass ELASMOBRANCHII: Characters

- Relatively large compared to bony fishes, 50 % of sharks > 1 m.
- Mostly in temperate or tropical waters, rather shallow (continental or insular shelves or slopes), 50 % < 200 m.
- Not really in extreme habitats (temperature, oxygen salinity, turbulence, etc…), but there are some freshwater taxa (migration or fully adapted).
- Large liver (oil) that helps for buoyancy, also cartilage instead of bone.
- Few malignant cancers found (anti-tumor substance in cartilage) and special immunosystem.

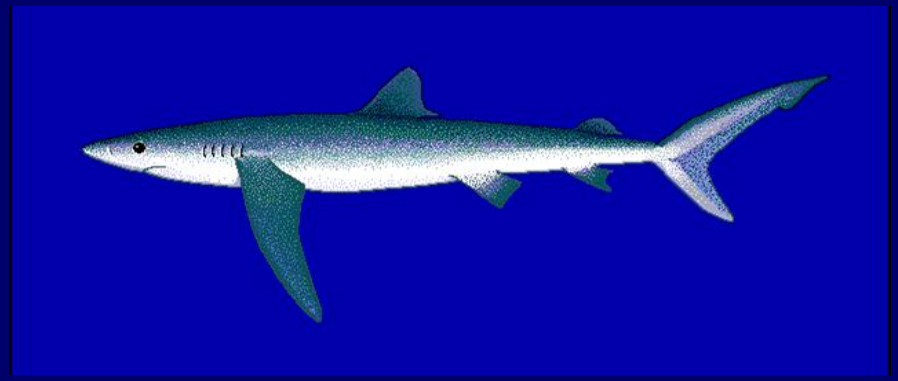
Subclass ELASMOBRANCHII: Characters

- Some sharks migrate over long distances of hundreds or thousands of kilometres.
- Energy savers: low metabolic rate compared to bony fishes (white shark is able to survive on 1 meal every 6 weeks?), slow growth en relatively long life, streamlined, buoyancy, warmth regulation in some body parts (in some groups).
- Large biting force to attack big preys (most bony fishes risk suffocation when biting a prey larger than the mouth opening).
- Not primitive fishes, but have known their own independent specialised evolution (Compagno, 1973 etc…).

Subclass ELASMOBRANCHII: Characters

- Three types of respiration:
  - pump mechanism as in Teleosts;
  - passive ram ventilation by swimming (swimming or suffocating);
  - via spiraculum (many rays).
- Typical K-selected taxa: large, slowly growing, long living, low fecundity, late maturity ⇨ threatened by overfishing.

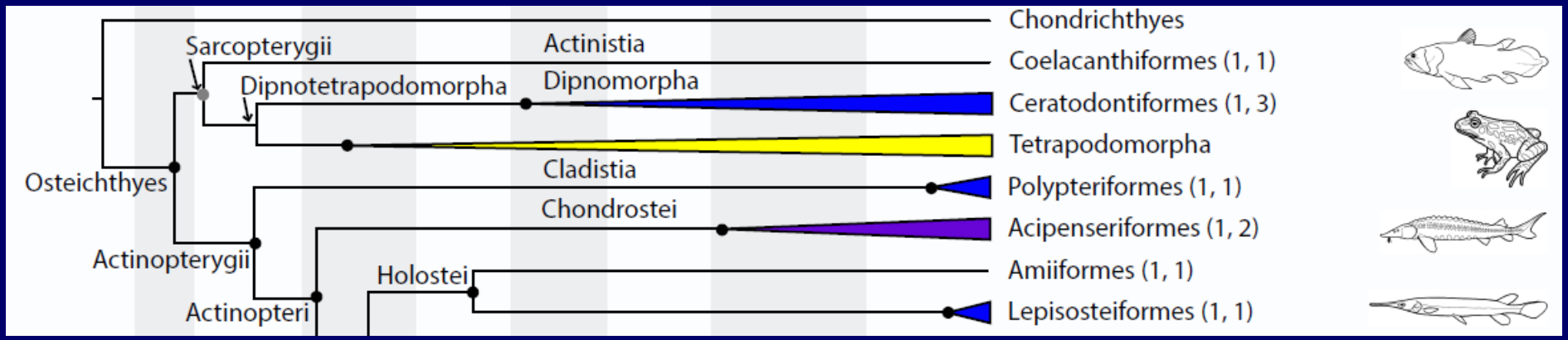
- **SHARKS**
  - gill openings laterally
  - eyes laterally
  - no contact (dorsally) between pectoral girdles
  - pectoral fin not connected to lateral side of head
- **RAYS**
  - gill openings ventrally (except spiracle) as a result of large pectoral fin
  - eyes dorsally
  - pectoral girdles dorsally connected or in contact with vertebral column
  - pectoral fin connected with lateral side of head



[the big white shark]

GNATHOSTOMATA: phylogeny

Euteleostomi:
- Lobe-finned fish (Sarcopterygii)
- Ray-finned fishes (Actinopterygii)



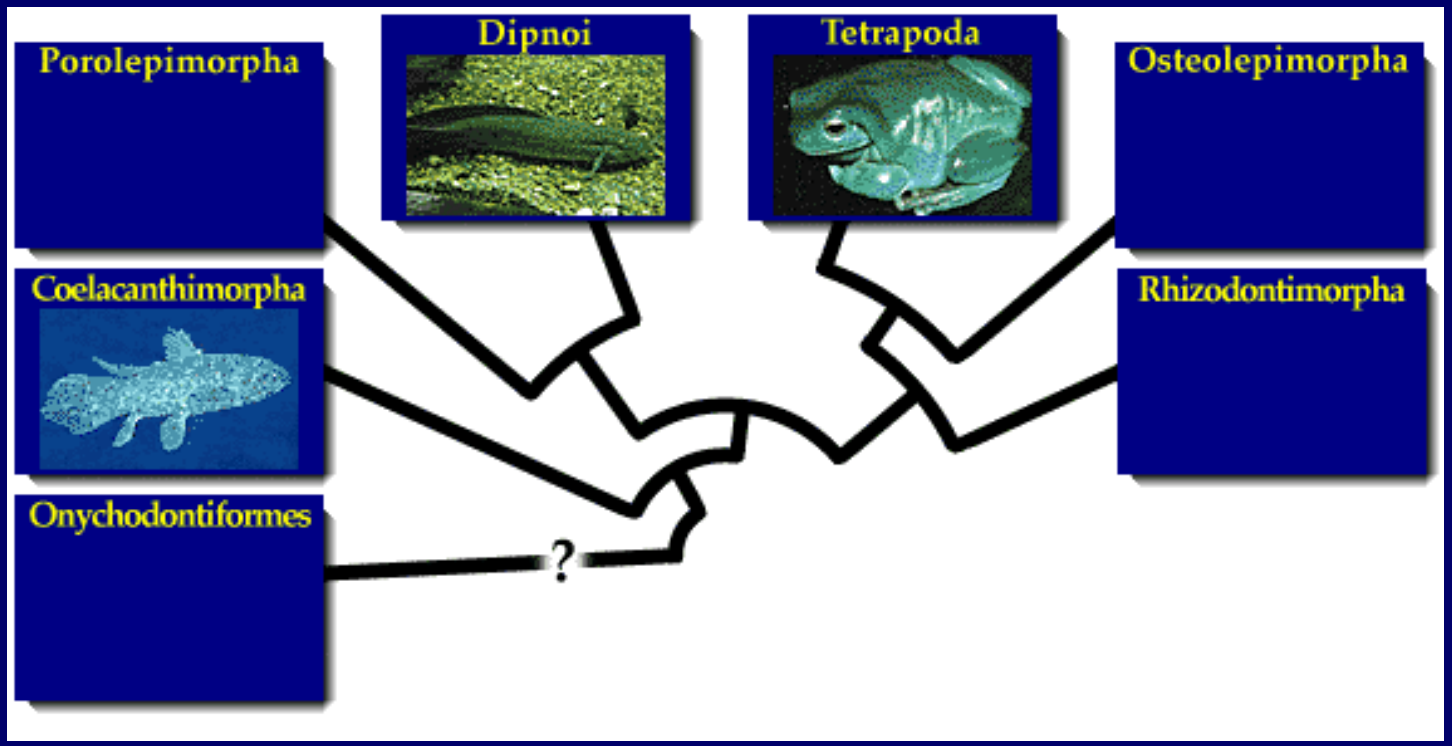
EUTELEOSTOMI (formerly Osteichthyes)

- Skeleton ossified (at least in part).
- Teeth fused to jaws.
- Soft fin rays.
  - dermal in origin (lepidotrichia = modified scales);
  - segmented.
- Gas bladder [swim bladder or functional lung(s)]; the breath came first.
- Intestinal spiral valve only in a few primitive groups.
- Scales with bony layer.

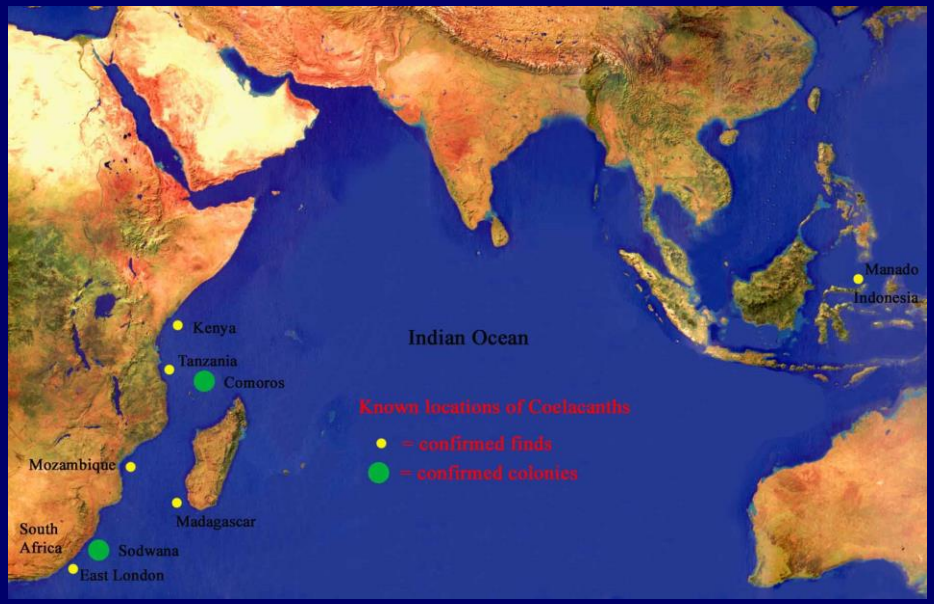
EUTELEOSTOMI (formerly Osteichthyes)

- Heterocercal tail (asymmetrical; primitive taxa).
- One operculum on each side.
- Jaws with dentigerous dentary, premaxilla and maxilla.
- Many characteristics secondary lost in some groups.

Class SARCOPTERYGII: lobe-finned fishes



Subclass COELACANTHIMORPHA



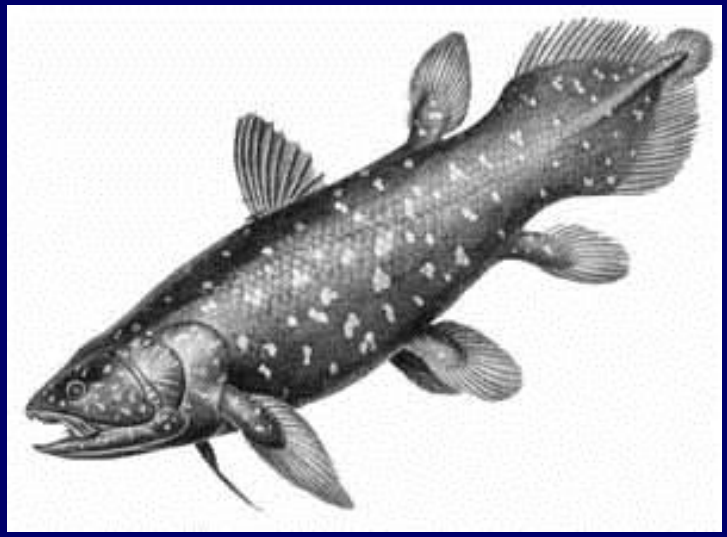
- 1 ordo Coelacanthiformes.
- Many fossils (> 90 species, marine and freshwater).
- 2 living species:
  - First specimen discovered in 1938 off-shore South Africa
    - *Latimeria chalumnae* Smith, 1938
  - Afterwards, centre of distribution are the Comoro Islands
  - In 1998: found off-shore Indonesia
    - *Latimeria menadoensis* Pouyaud *et al.*, 1999 (scientific controversy); difference based on colour, morphology and genetic characteristics
  - Recently off-shore Mozambique and South-Africa, Kenya, Tanzania; northern Tanzania population genetically isolated

COELACANTHIFORMES: *Latimeria chalumnae*

- living fossil
  - Group was considered extinct ($66*10^6$); originated in freshwater.
  - For a long time coelacanth considered as the direct descendant of the fish-like ancestors of the Tetrapoda.
  - Now considered much more distantly related from Tetrapoda than previously thought.
  - Major importance for science ⇨ overfishing?

COELACANTHIFORMES: *Latimeria chalumnae*

- Gas bladder degenerated; and filled with fat (only hydrostatic control)
- Gut with spiral valve
- First dorsal fin with spines
- Ovoviviparous (lecithotrophous)
- very large eggs (8-10 cm)
  - very long incubation period (13 months)
  - young up to 30 cm TL at birth
- During the day in resting caves (150 - 250 m)
- Night predators (200 - 500 m)
- Swim with body obliquely oriented, head down film
- 1.8 m
- 20 (up to 50 ?) years



Subclass DIPNOTETRAPODOMORPHA
Infraclass DIPNOI: Lungfishes

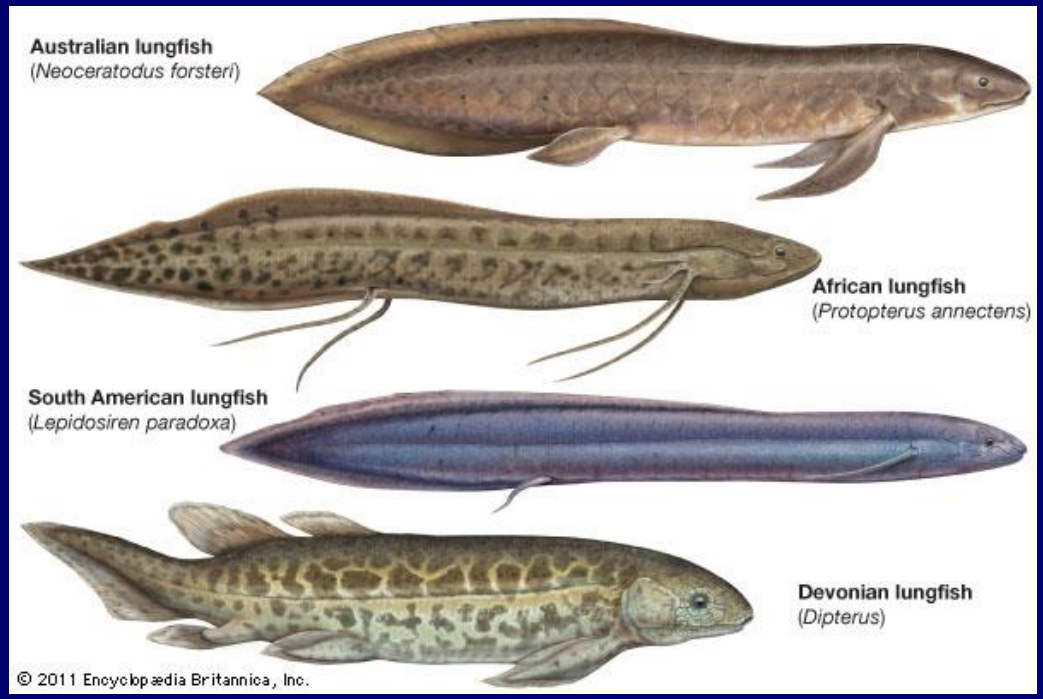
Many fossil ordos on all continents (even Antarctica); origin before split of supercontinent?

Marine origin, one recent ordo.

Massive tooth plates for crushing prey; good fossilization.

Mainly cartilaginous skeleton; evolution from bony to cartilaginous vertebral centra. Caudal fin confluent with dorsal and anal fins.

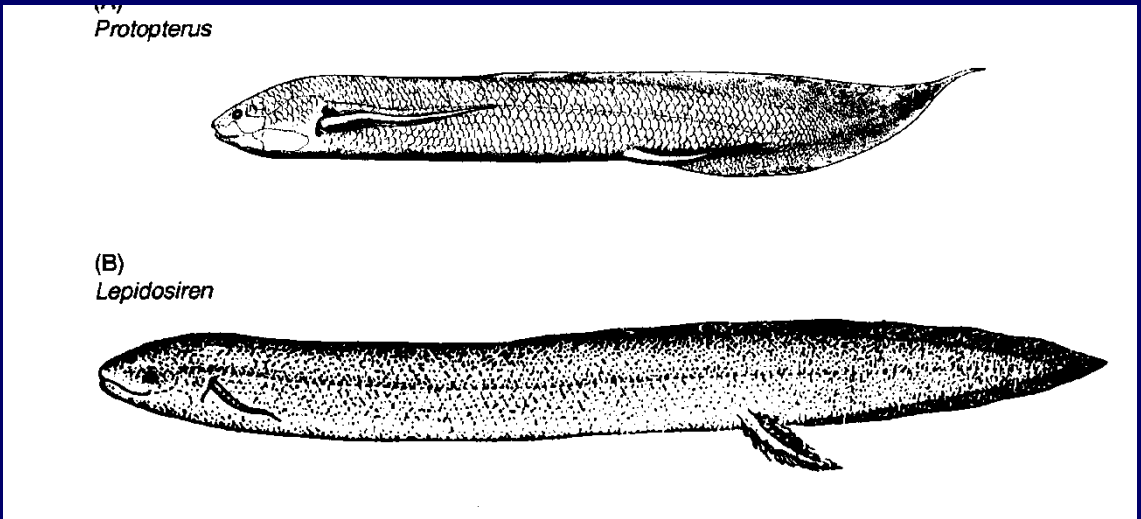
Modern Dipnoi are closest living relatives to tetrapods.



Ordo CERATODONTIFORMES: Ceratodontidae (Australian lungfishes)

- Most primitive group.
- Paired fins (flippers).
- Large cosmoid scales.
- No external gills in larvae.
- No cocoon.
- No parental care.
- Unpaired lung (merely hydrostatic than respiratory organ), facultative airbreathing.
- One species *Neoceratodus forsteri*

Ordo CERATODONTIFORMES



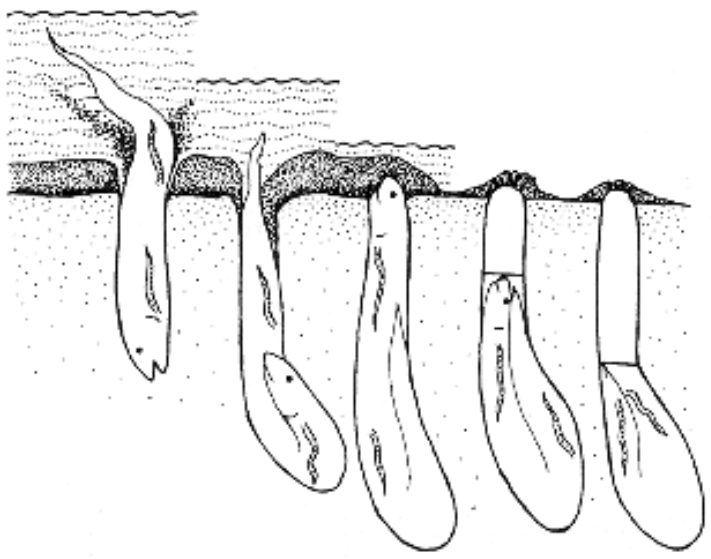
- Anguilliform body, cartilaginous skeleton.
- Paired fins filamentous, without fin rays.
- Small scales.
- Toothplates.

Ordo CERATODONTIFORMES: living lungfishes

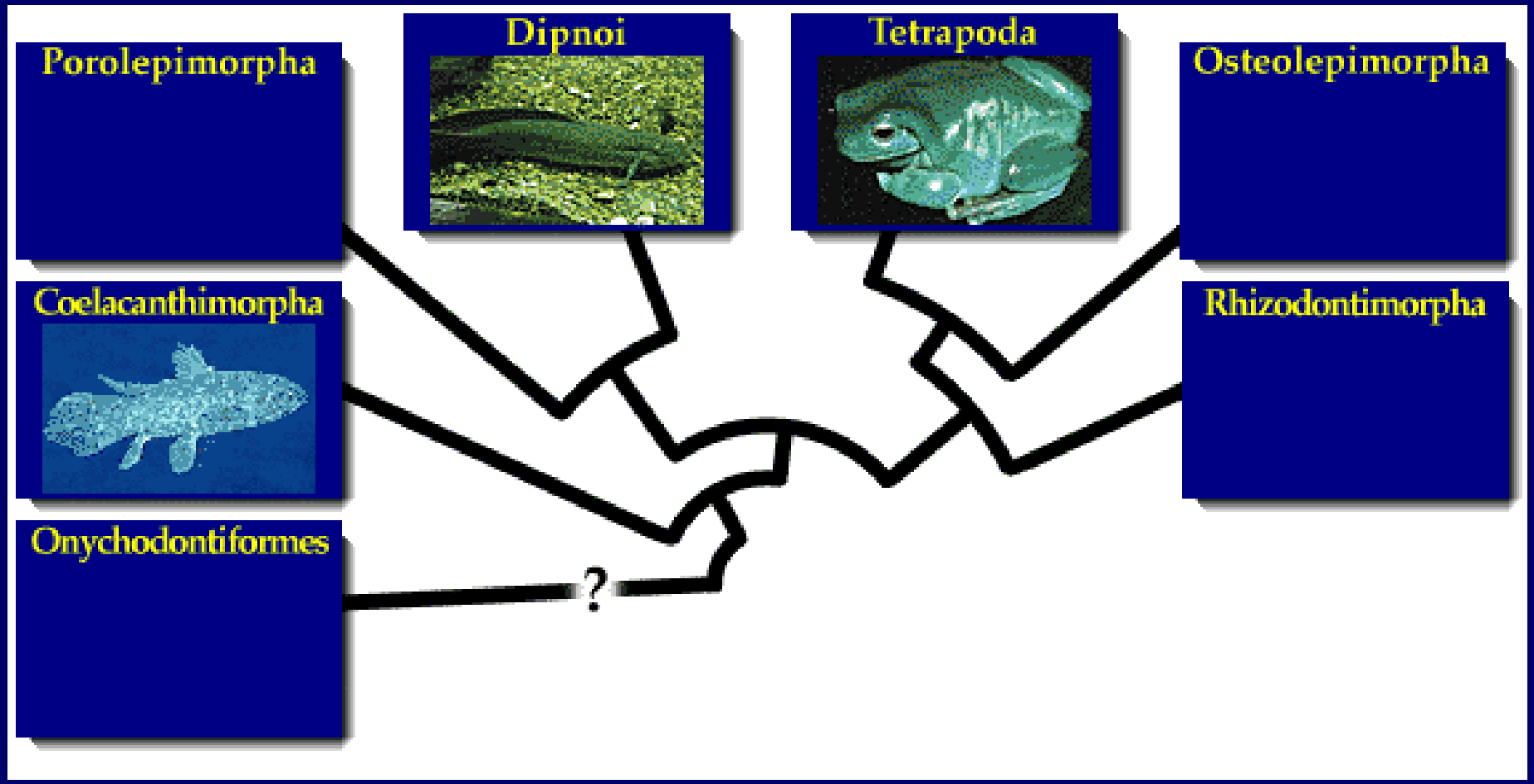
- Paired functional lungs (dorsally with ventral trachea): obligatory air breathing (90 % of O_2 demand uptake via pulmonary route) throughout postjuvenile life
- Also branchial respiration
- Larvae with external gills (misidentified as “amphibians”); sometimes still present in adults
- Adults survive dry season in “cocoon” (extended up to 4 years) (not for all species)
- Up to 1.8 m
- Parental care (presumably male care)
- Freshwater

✓ Lepidosirenidae: South American lungfishes (*Lepidosiren paradoxa*): males develop vascularized filaments during breeding season;

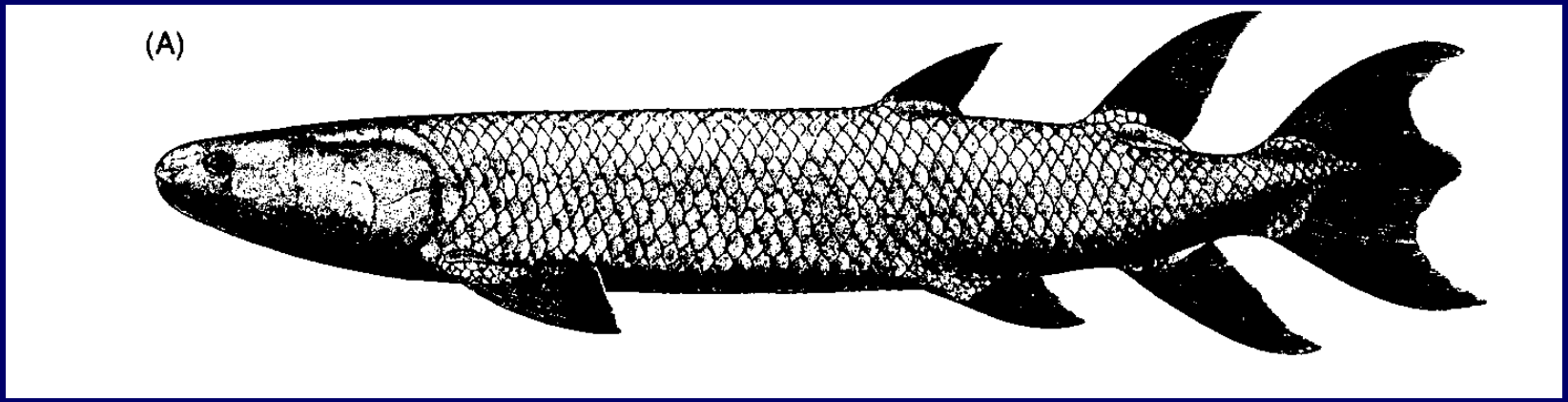
✓ Protopteridae: African lungfishes (*Protopterus* spp.: 4 species): anus asymmetrical position.



As the water level falls lungfish burrow into the bottom mud to form a cocoon and aestivate through the dry season.


Porolepimorpha
Dipnoi
Tetrapoda
Osteolepimorpha
Coelacanthimorpha
Rhizodontimorpha
Onychodontiformes
?

Subclassis OSTEOLEPIDIMORPHA† (RHIPIDISTIA)

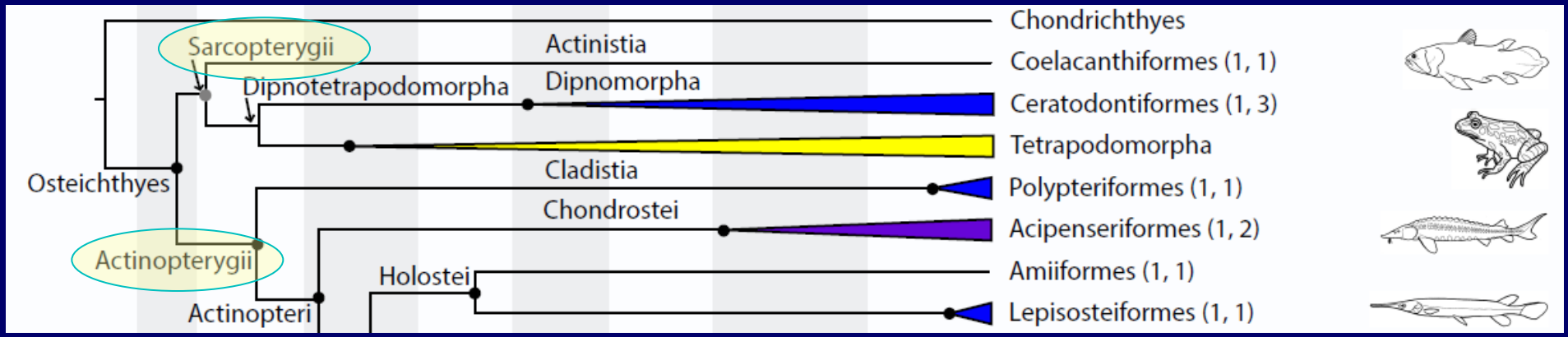


- Large active predators in freshwater: large mouth, symmetrical, large caudal fin, posteriorly placed pelvic and dorsal fins.
- Primarily in shallow, freshwater habitats.
- Middle Devonian up to Lower Permian (380-250.10^6).
- *Eusthenopteron*, one of the best known fossils.
- maximum 4 m.

- Tetrapoda : Middle Devonian (385.10^6) to recent
- extant species:
  - Amphibia: 6.180
  - Amniota
    - Synapsida (a.o. Mammalia): 5.400
    - Reptilia: 17.205
      - Anapsida (a.o. turtles): 285
      - Diapsida
        - » Lepidosauromorpha (lizards; snakes): 7.200
        - » Archosauromorpha (crocodiles; birds): 9.720

GNATHOSTOMATA: Phylogeny

Euteleostomi (formerly Osteichthyes):
- Lobe-finned fish (Sarcopterygii);
- Ray-finned fishes (Actinopterygii).



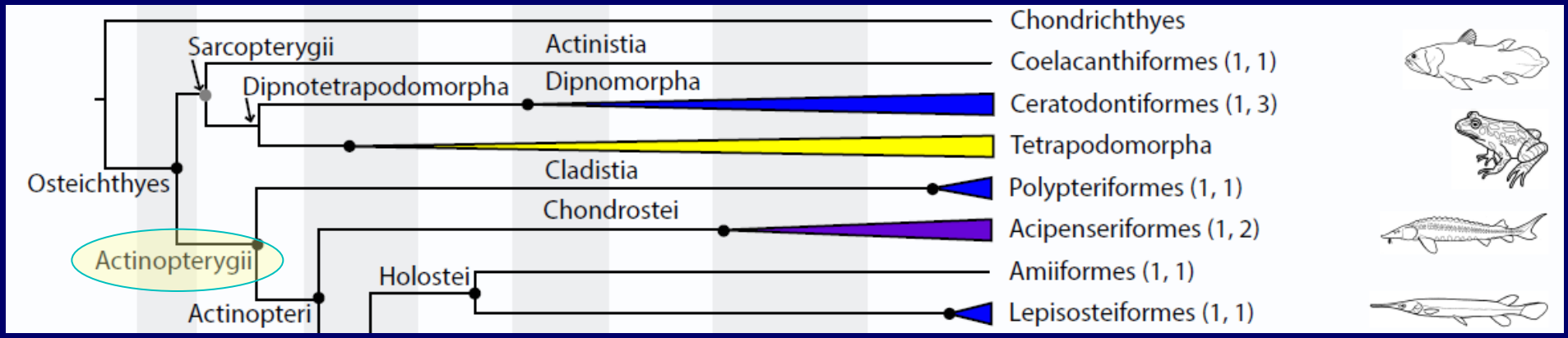
Class ACTINOPTERYGII (ray-finned fishes): Characters

- Trend from thick, stiff ganoid, rhomboid scales with interlocking mechanism to thin, flexible elasmoid (cycloid and ctenoid) scales; sometimes complete reduction.
- Branchiostegal rays usually present.
- External nostrils relative high on head.
- Spiracle (generally) absent.
- About 44 % of species live only or almost only in freshwater.

Class ACTINOPTERYGII (ray-finned fishes): Characters

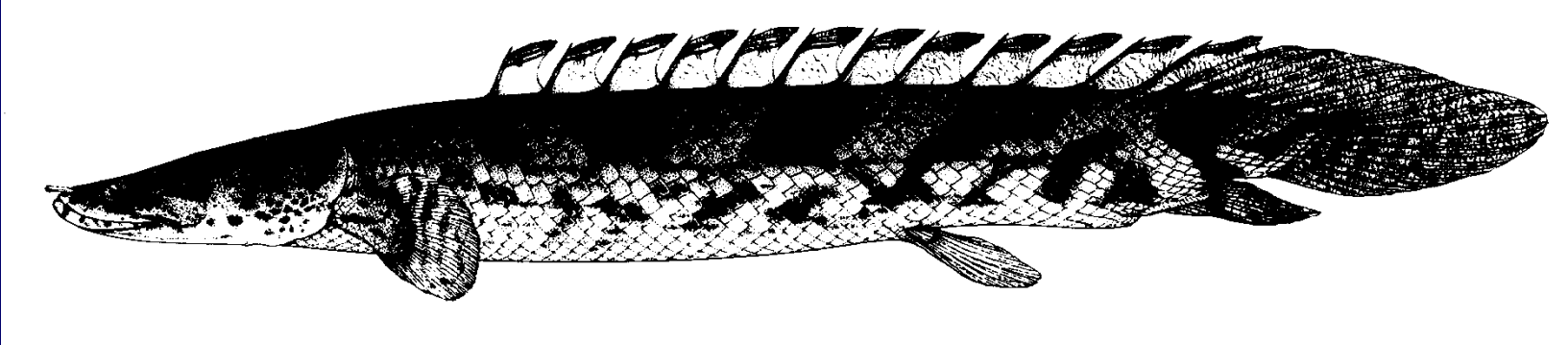
- Trend towards articulation of pectoral fin close to body
  $\Rightarrow$ no lobed fins (exception Polypteriformes)
- Caudal fin from heterocercal to homocercal (more symmetrical).
- All kinds of shifts in cranium elements and muscles.

Class ACTINOPTERYGII



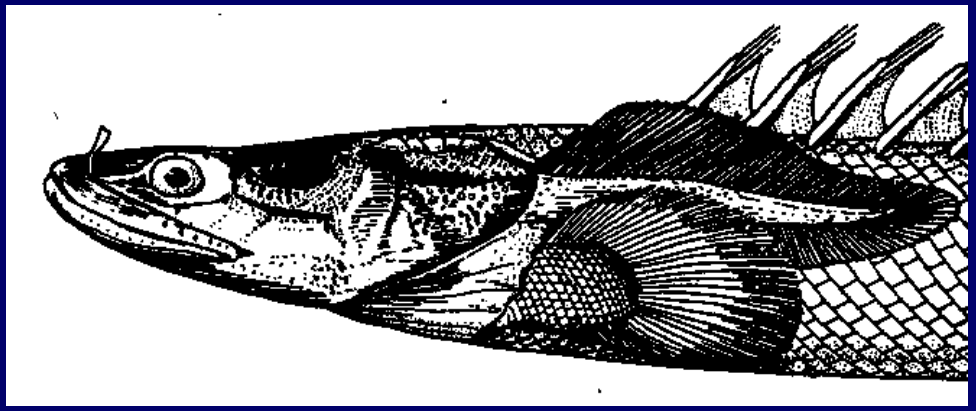
- Cladistia (Polypteriformes, bichirs)
- Chondrostei (Acipenseriformes, sturgeons and paddlefish)
- Holostei
  - Lepisosteiformes (gars)
  - Amiiformes (bowfin)
- Teleostei

Ordo POLYPTERIFORMES



- One family: Polypteridae (bichirs).
- 5 to 18 dorsal finlets, each with a single spine with one or more attached soft rays.
- Caudal fin internally heterocercal, externally symmetrical
- Lobed paired fins (other structure than Sarcopterygii).
- Ganoid, rhomboid scales.
- Spiracle.
- Tubular nostrils.

Ordo POLYPTERIFORMES

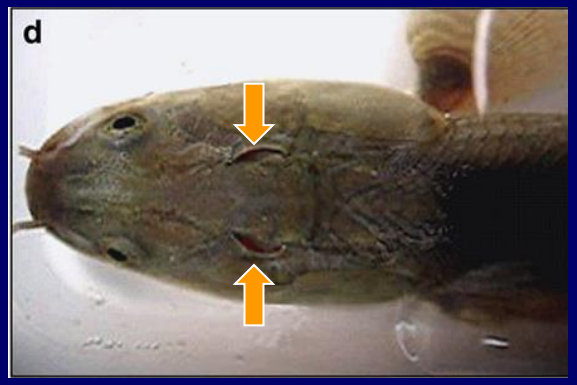


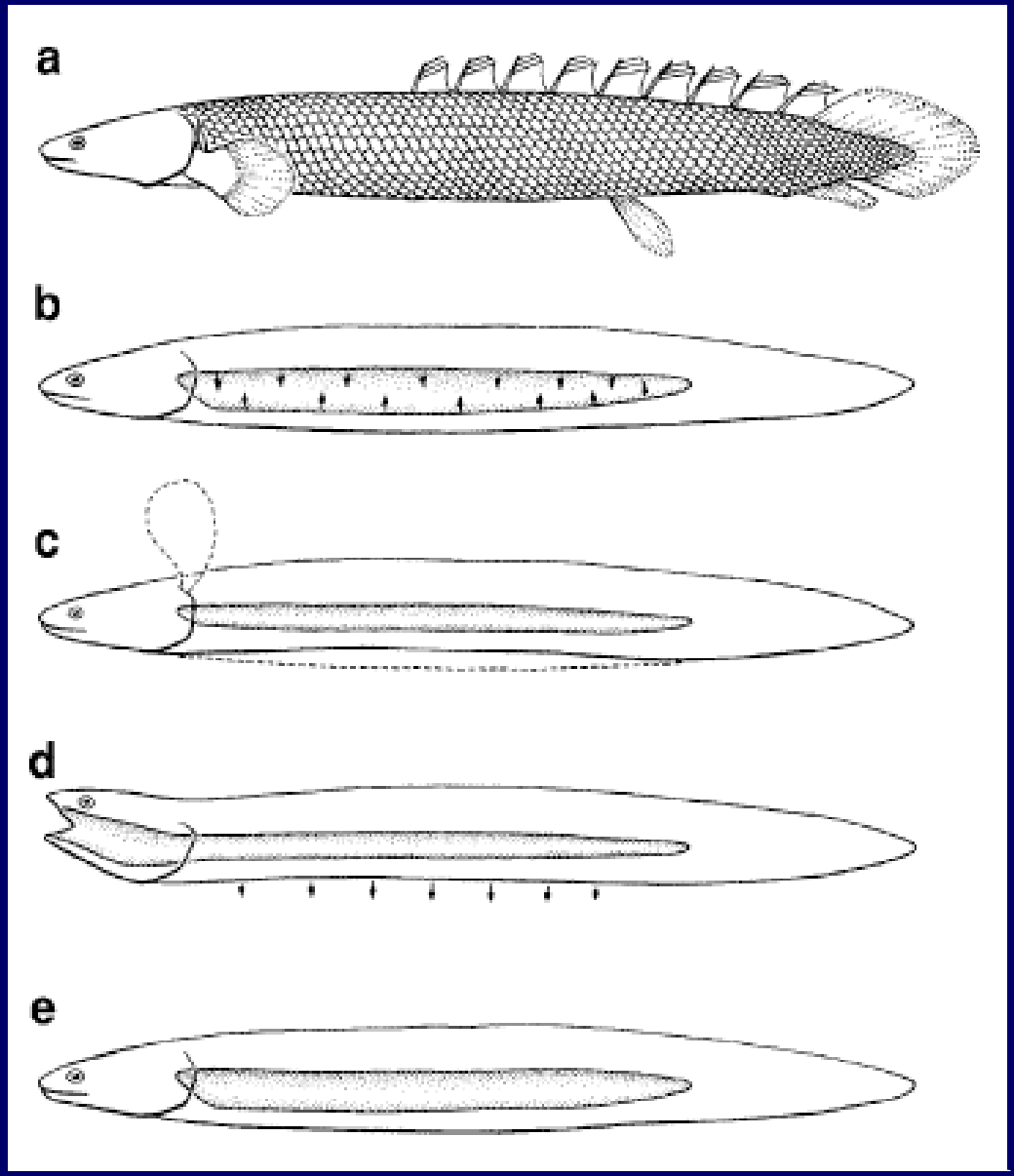
- Larvae with external gills (analogous, not homologous with Dipnoi).
- Primitive paired lungs, ventrally placed, facultative airbreather, obligatory in O_2-poor areas.
- Freshwater Africa.
- Maximal length 90 cm.
- 2 genera *Polypterus* (10 species) and *Erpetoichthys* (1 species).
- Predators.

Ordo POLYPTERIFORMES

Unique recoil aspiration: the use of the elastic energy stored in their integumentary scale jacket during exhalation to power inhalation of atmospheric air.

Figure on the right appears to be partially wrong, because aspiration only via mouth in stressful conditions; normally via spiraculum at the surface of the water by opening a spiracular valve (see below)





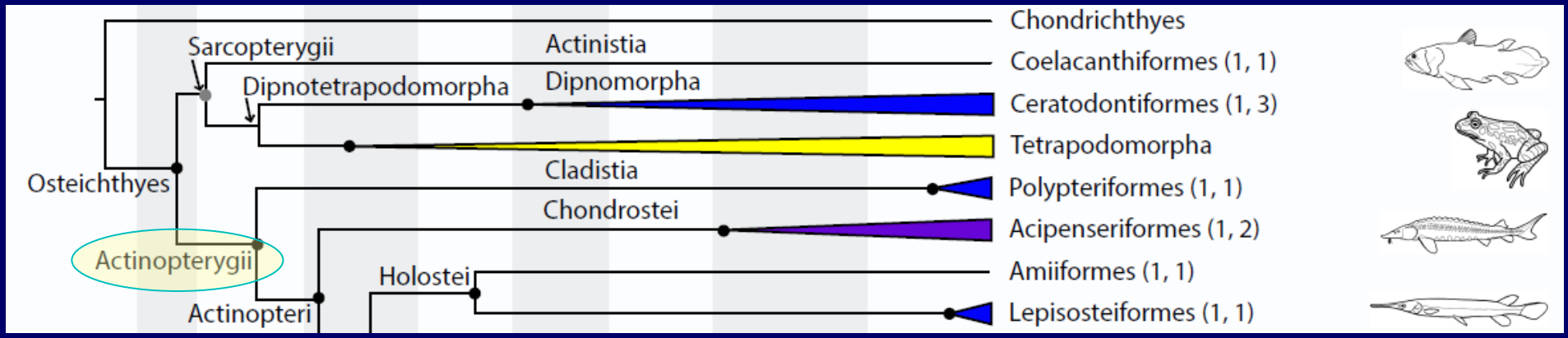
Ordo ACIPENSERIFORMES

- Secondary cartilaginous skeleton.
- Heterocercal caudal.
- Scales reduced.
- Sturgeons and paddlefish.
- Paddlefish (below): 2 living species, freshwater: *Polyodon spathula* in N. America, planktonfeeder, ram ventilation; *Psepherus gladius* in China, piscivorous (possibly recently extinct).

Ordo ACIPENSERIFORMES: Acipenseridae (Sturgeons)

- Mouth inferior and protrusible, four barbels, no teeth in adults.
- Heterocercal caudal fin, five series of bony scutes on body.
- Benthic, anadromous and freshwater species.
- Northern hemisphere (N. America, Europe, Central Asia)
- Contain largest freshwater fish species; *Huso huso* (beluga), up to 6,0 m and > 1000kg.
- Caviar (up to 7 729 700 eggs), female gonads up to 25% of body weight.
- Worldwide decrease because of habitat destruction (spawning places) and overfishing.
- Up to 118 years (late maturity).
- Aquaculture.

Class ACTINOPTERYGII

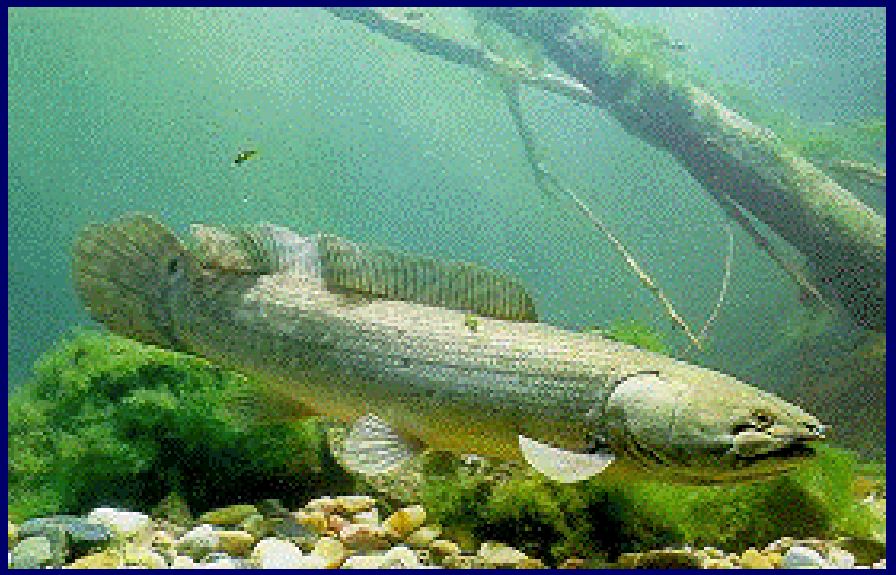


- Cladistia (Polypteriformes, bichirs)
- Chondrostei (Acipenseriformes, sturgeons and paddlefish)
- Holostei
  - Lepisosteiformes (gars)
  - Amiiformes (bowfin)
- Teleostei

Semionotiformes = Lepisosteiformes (gars)

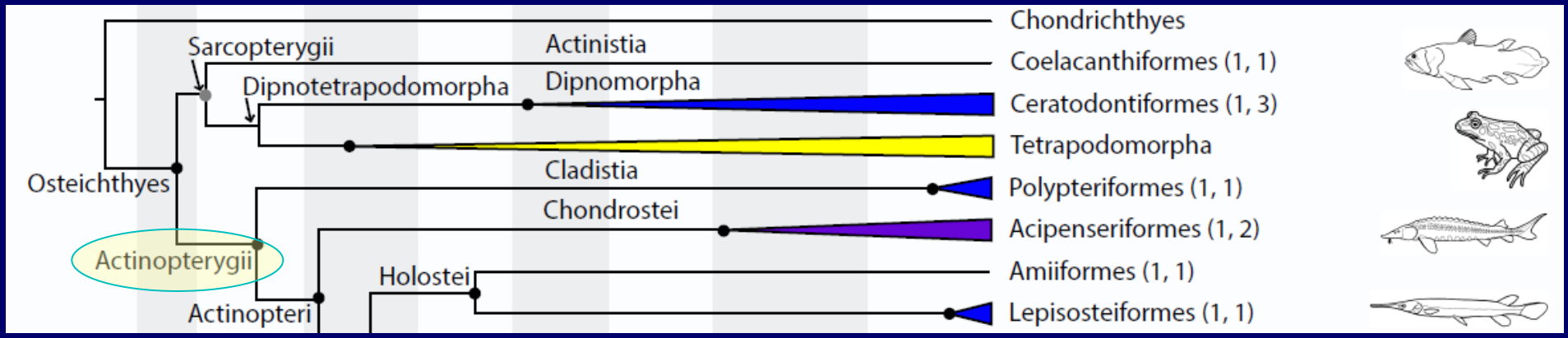
- 1 recent family: Lepisosteidae.
- NoLarge vascularised gasbladder (12 % body volume, hydrostatic control and air breathing).
- Needle-like teeth: predator.
- Modified heavy interlocking ganoid scales (primitive) => heavily armoured fishes.
- Dorsal fin far back.
- Poisonous green eggs
- Mostly freshwater (lenthic habitats), occasionally brackish, rarely marine water.
- North and Central America.

Amiiformes:
1 family: Amiidae (bowfins)



- Many fossils and one living species *Amia calva*.
- Long dorsal fin, undulations used for forwards and backwards swimming.
- Primarily freshwater but also marine fossils / extant species freshwater (eastern N. America).
- Vascularised gas bladder dorsally placed: functions as a lung.

Class ACTINOPTERYGII



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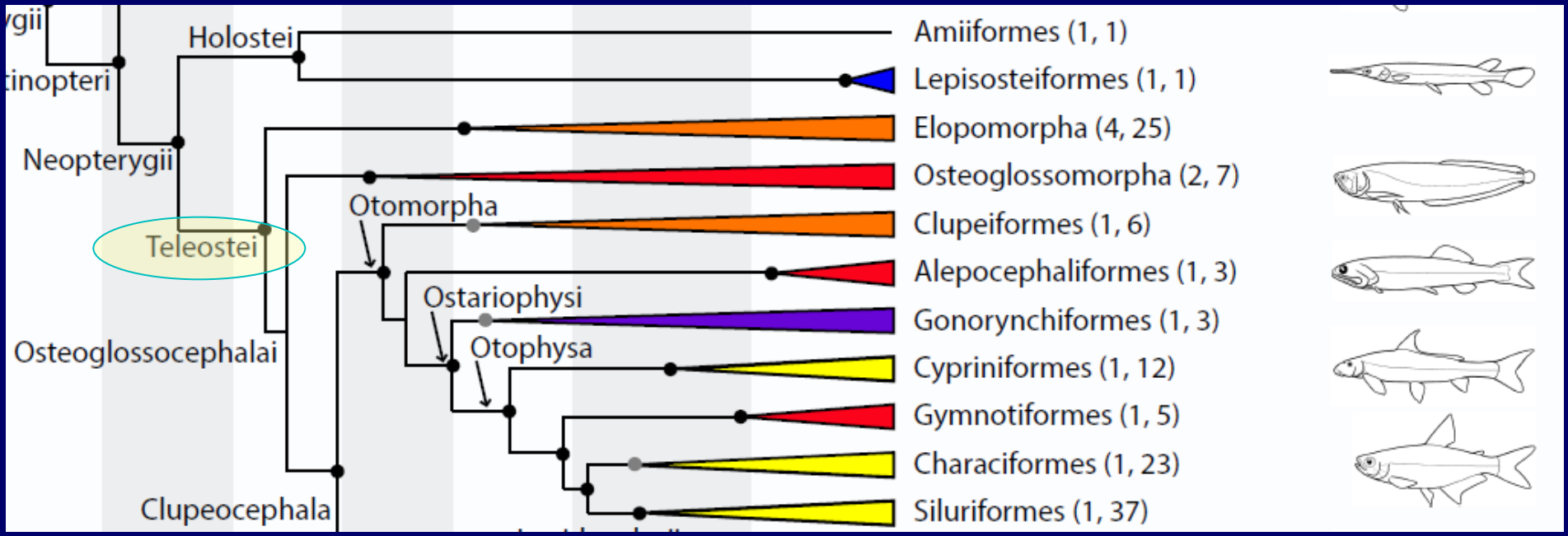
TELEOSTEI


Holostei
Neopterygii
Teleostei
Otomorpha
Ostariophysi
Otophysa
Osteoglossocephalai
Clupeocephala
Amiiformes (1, 1)
Lepisosteiformes (1, 1)
Elopomorpha (4, 25)
Osteoglossomorpha (2, 7)
Clupeiformes (1, 6)
Alepocephaliformes (1, 3)
Gonorynchiformes (1, 3)
Cypriniformes (1, 12)
Gymnotiformes (1, 5)
Characiformes (1, 23)
Siluriformes (1, 37)

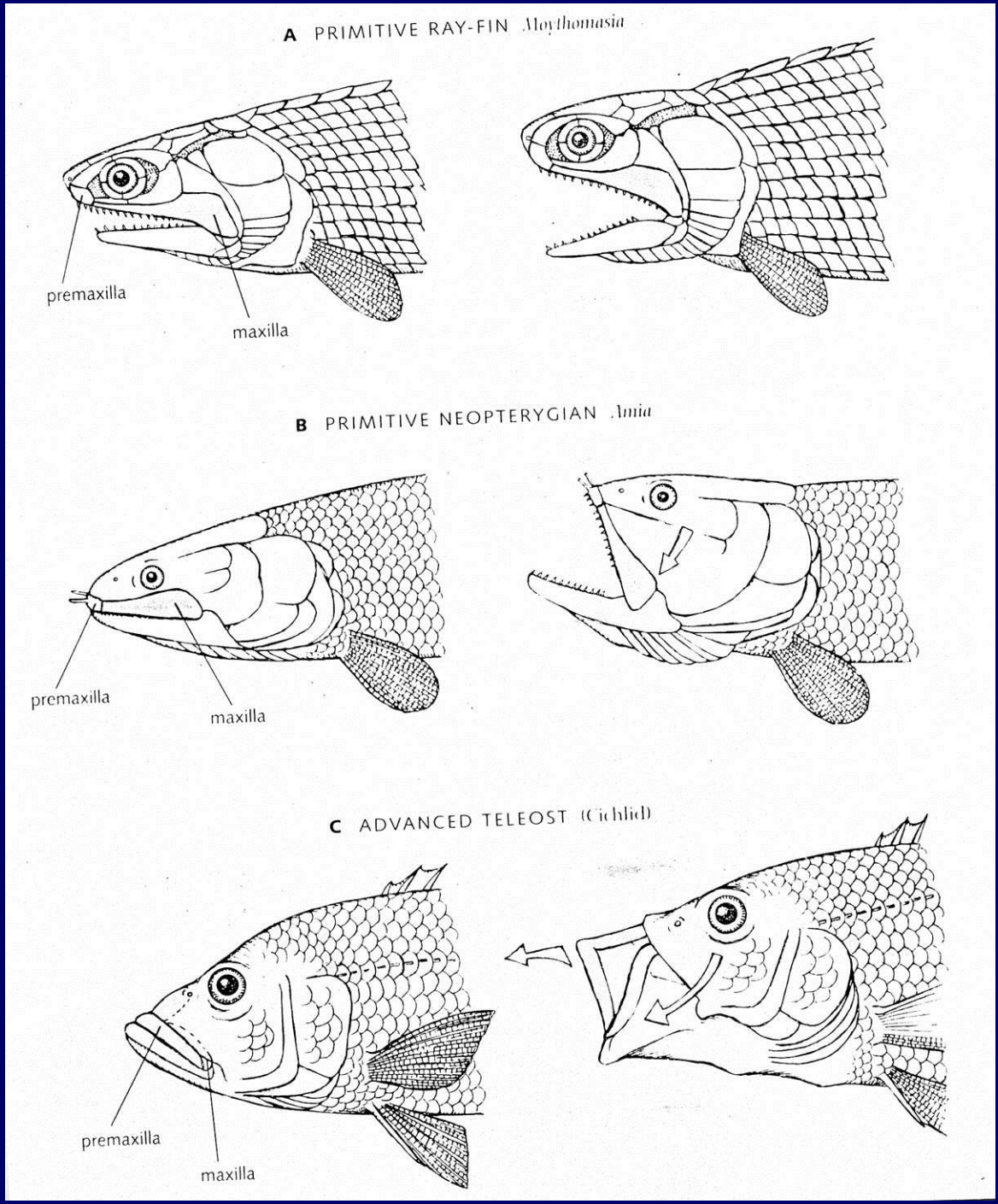
Division TELEOSTEI: characters and trends

- Elasmoid scales.
- Gas bladder reduced to hydrostatic organ, but gets additional functions in some groups.
- Premaxilla becomes most important component of upper jaw.
- Pectoral fins move upwards, pelvic fins move forwards.

Division TELEOSTEI: characters and trends

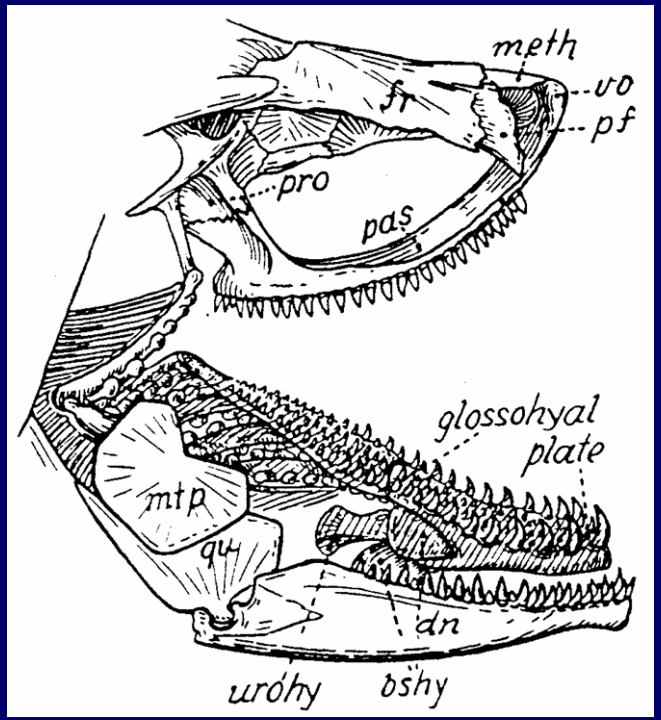
- Almost 30.000 species; why so successful ?
- Increasing mobility:
  - scales become less heavy;
  - all kinds of changes in bony elements;
  - repositioning and functional changes in paired fins;
  - symmetry of caudal fin and changes in its bony elements (stronger fin).
- Diversification in ecological niches:
  - changes in jaw structures;
  - enlargement of mobility and suction capacity via a more protrusible mouth and branchiostegal rays that can sink ventrally;
  - development of pharyngeal jaws.

evolution towards protrusible mouth with moveable premaxilla



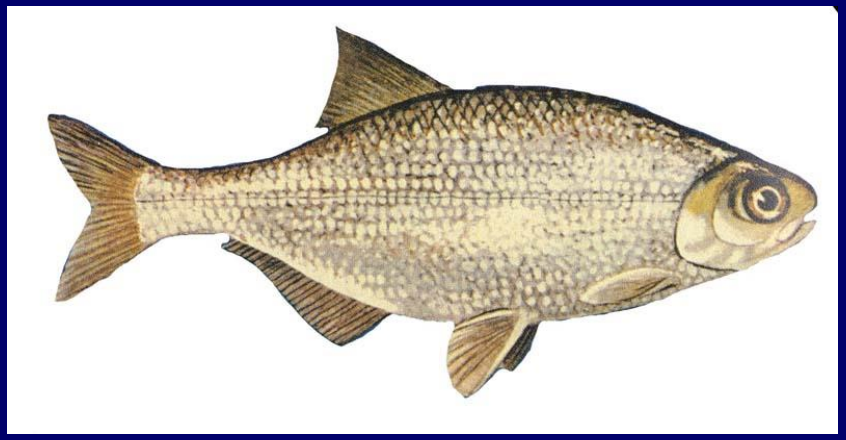
Subdivision OSTEOGLOSSOMORPHA

- Autapomorphies: a.o.
  - Toothplate on tongue: bites against mouth roof that is also provided with teeth.
  - Freshwater.



Hiodon alosoides

Subdivision OSTEOGLOSSOMORPHA

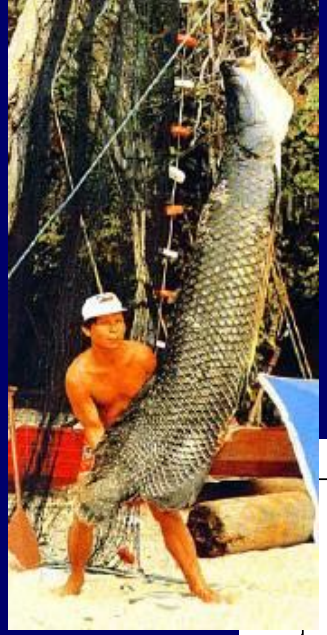


Hiodon tergisus

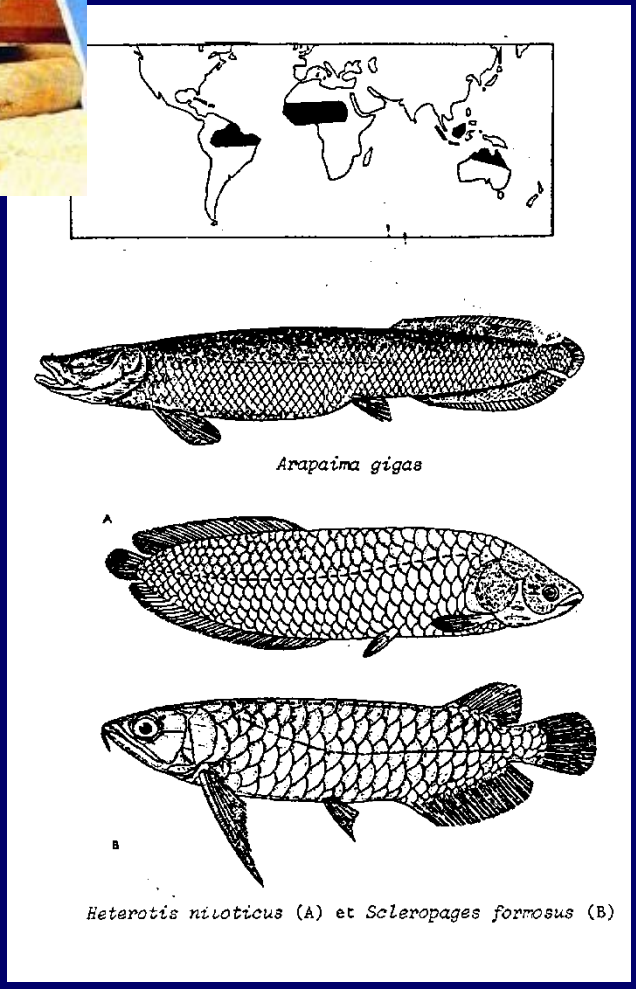
Two extant ordos:

- Hiodontiformes
  - Hiodontidae
    - (mooneyes, 2 species, freshwater, North America)
- Osteoglossiformes (bonytongues)
  - 5 or 6 extant families
  - two large groups:
    - Osteoglossidae and Pantodontidae
    - Notopteridae, Mormyridae and Gymnarchidae

Family OSTEOGLOSSIDAE: Bonytongues

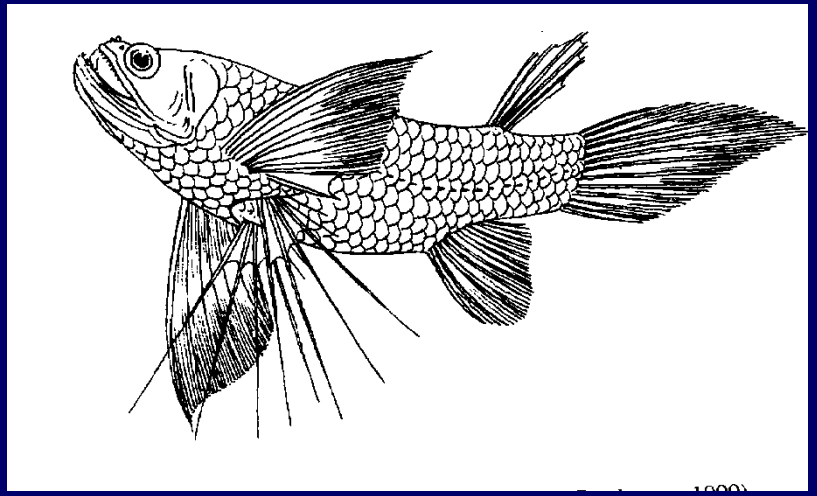


- Freshwater, origin on supercontinent.
- Some are mouthbrooders.
- Can breath air via gas bladder.
- Microphagous, omnivorous to carnivorous.
- Large sculptured scales.
- Some species important in aquaculture.
- N. Australia, New Guinea and S.E. Asia, S. America, Africa
- *Arapaima gigas* (S. America; 2.5 m)
- *Heterotis niloticus* (Africa; 1m):
  - special spiral filter apparatus for food; accumulation (epibranchial organ), originated from upper part of pharynx.

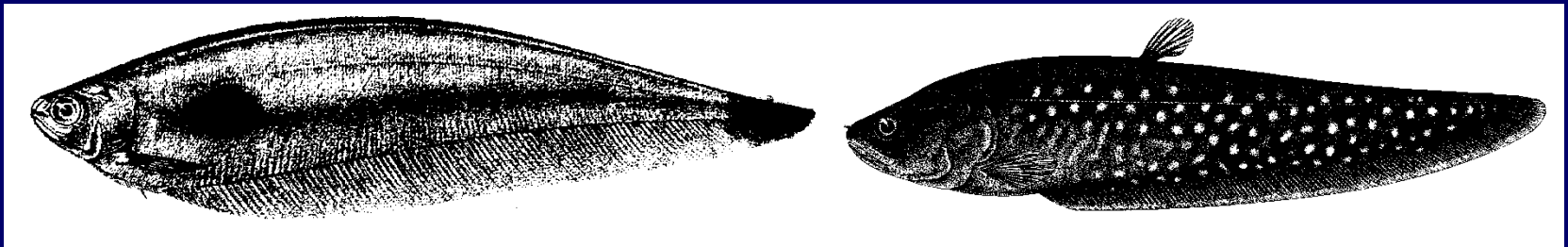


Familie PANTODONTIDAE: Butterflyfish

- one species
- endemic to Africa
- freshwater
- can jump out of the water to avoid predation
- swimbladder can function as accessory respiration organ
- aquarium



Family NOTOPTERIDAE: featherfin or old world knifefishes

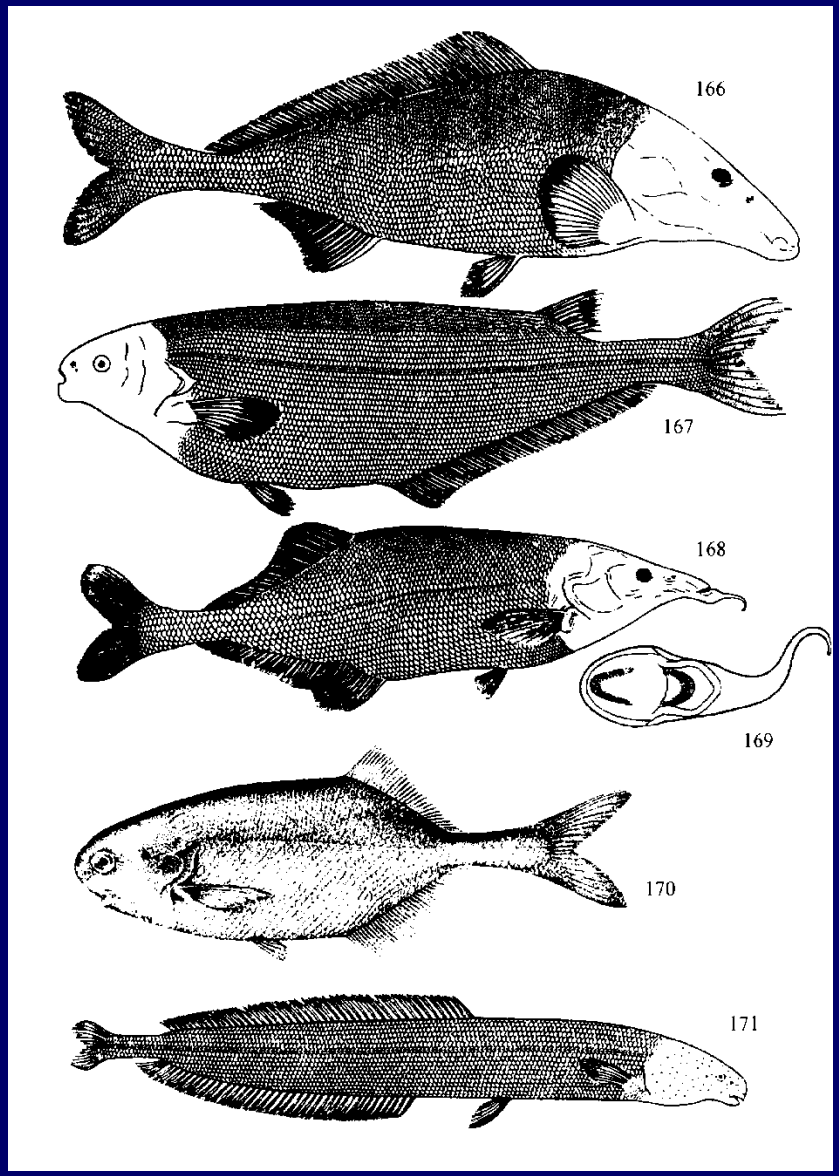


- Africa
  - *Xenomystus* (left): no dorsal fin.
  - *Papyrocranus* (right): dorsal fin present.
- S.E. Asia.
- Freshwater, sometimes brackish.
- Can swim forwards and backwards (anal fin undulations).
- Physostomous, swim bladder also for respiration and sound production, with a forked extension almost up to inner ear.
- Ventral scutes.
- Pelvic fins absent or small.

Family MORMYRIDAE: elephantfishes

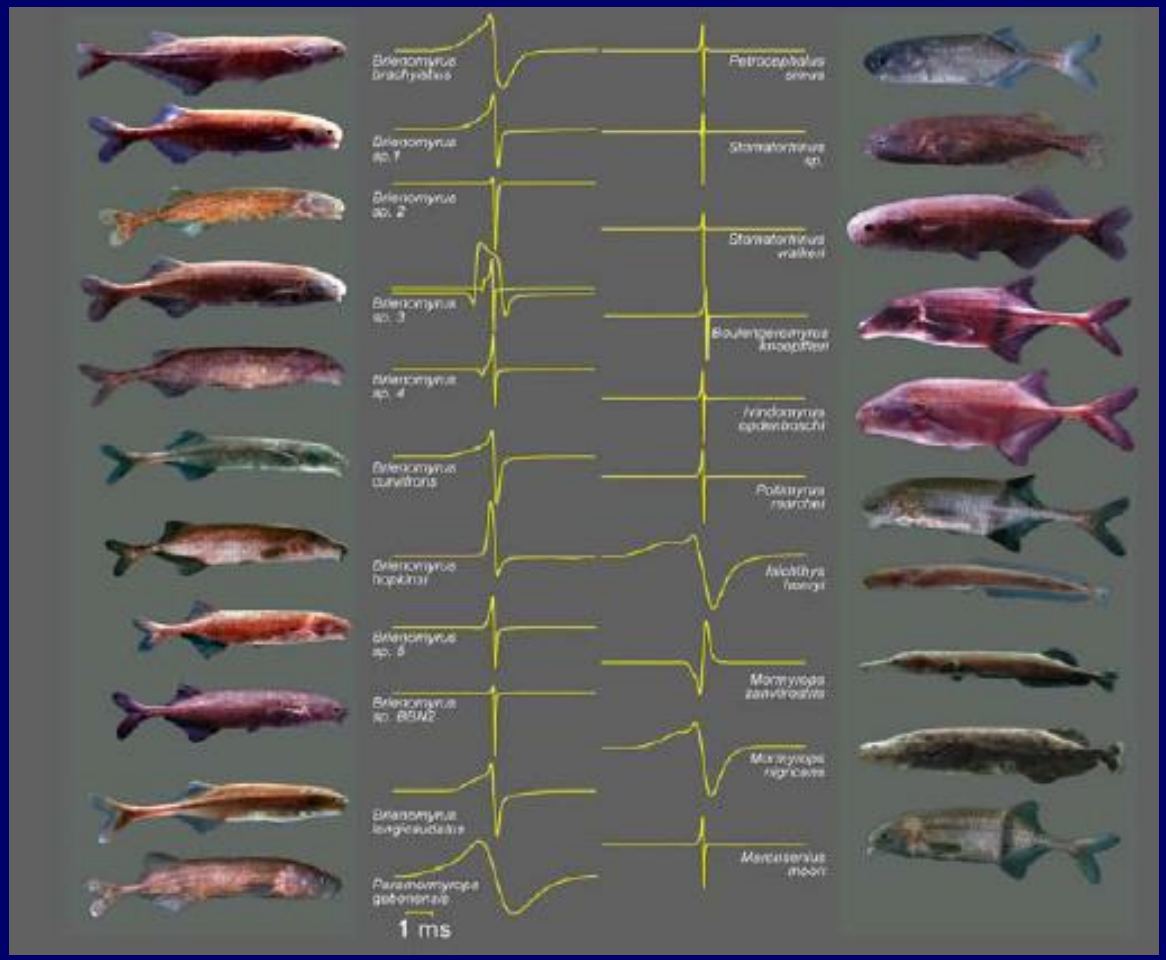
- Endemic to Africa.
- Freshwater.
- Large diversity in shape and species (> 200), from 10 cm to 1.5 m.

Family MORMYRIDAE: Elephantfishes



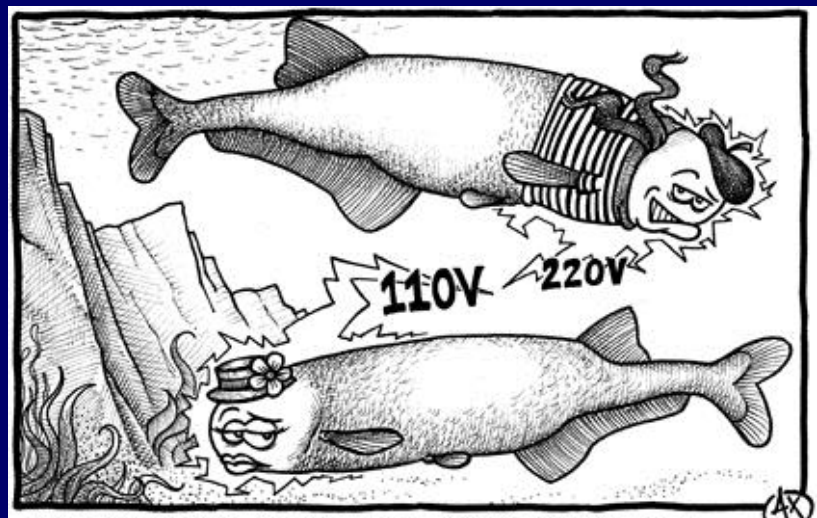
Family MORMYRIDAE: Elephantfishes

- Small eyes covered with skin
- Electric organ in caudal peduncle (muscular) for short electric pulses (EOD)
  - electro-location;
  - communication;
    - often species-specific.
- Receptors (mormyromasts) on body.



Family MORMYRIDAE: Elephantfishes

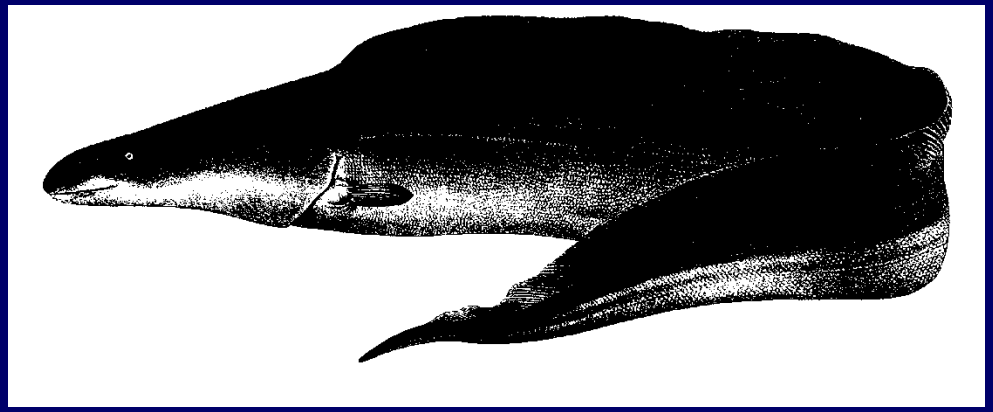
- Very large brain (gigantocerebellum):
  - ratio brain volume / body weight comparable to that of humans;
  - gigantocerebellum (mormyrocerebellum) is neural centre for coordination of electric pulses.
- Swim bladder with intra-cranial extensions.
- Most insectivorous, some piscivorous.



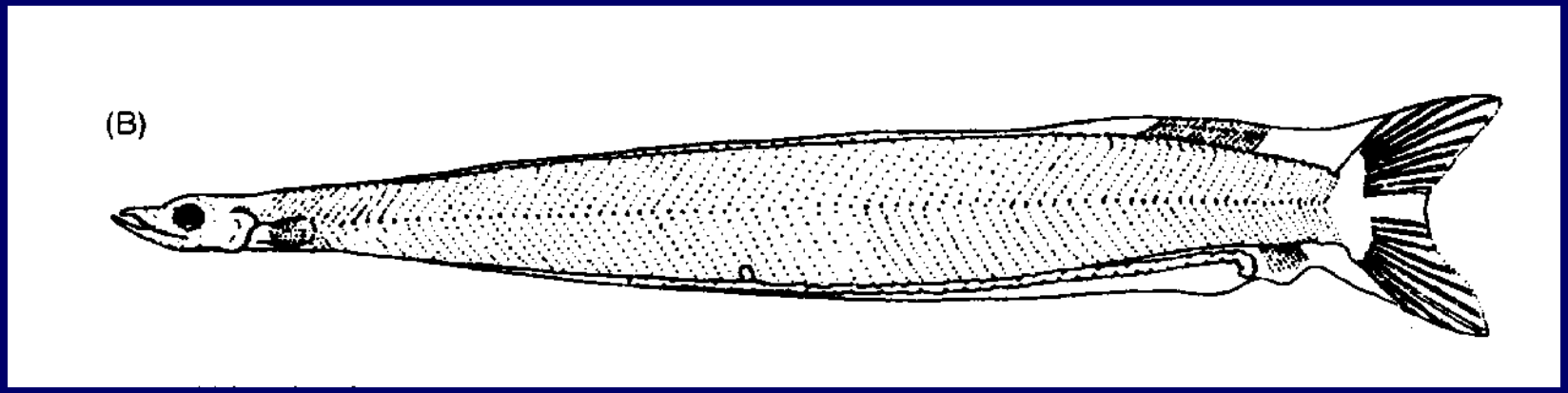
For electric fish Jean-Luc and his girlfriend Daisy, cultural differences often proved difficult to overcome.

Family GYMNARCHIDAE

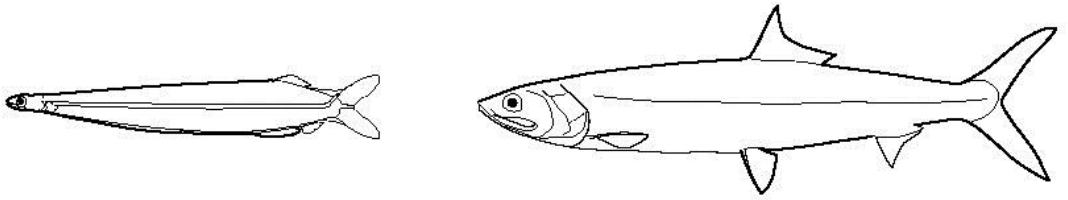
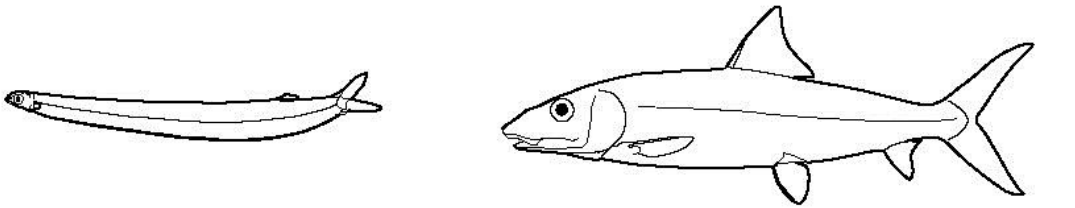
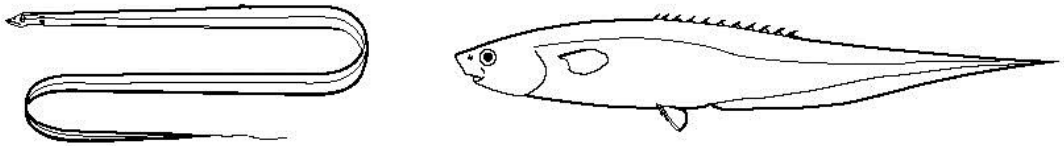
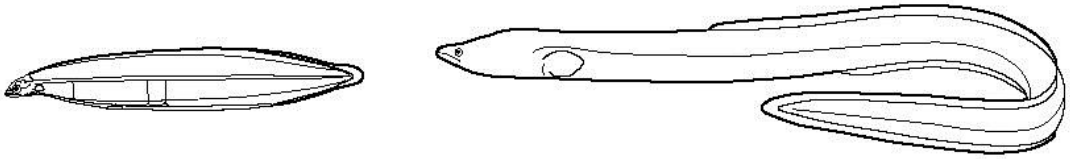
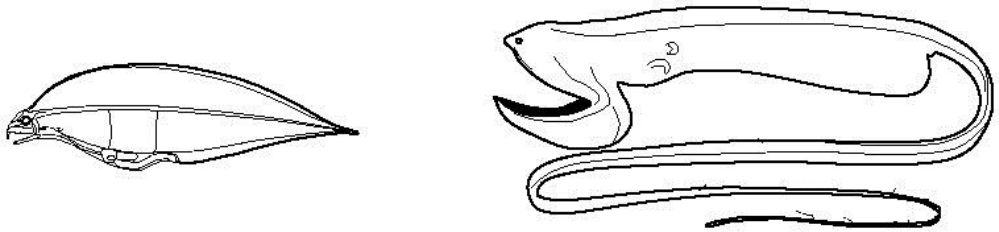
- Closely related to Mormyridae:
  Mormyridae paraphyletic without Gymnarchidae?
- Electric organ.
- Ventral, anal and caudal fins absent.
- Africa, freshwater.
- 1 Genus, 1 species: *Gymnarchus niloticus*
- 1.5 m



Subdivision ELOPOMORPHA



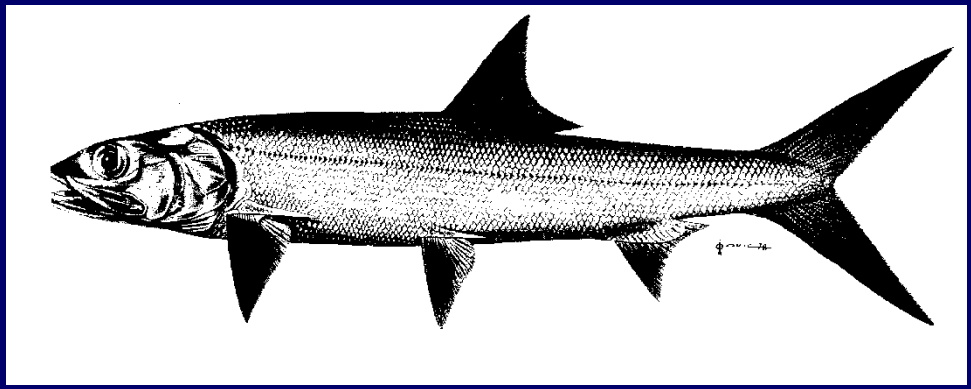
- Autapomorphies: a.o.
  - leptocephalus larva (10 cm to 2m) (up to 2-3 years old):
    - ribbon or leave shaped;
    - transparent (no red blood cells);
    - active food gathering but important part of food supply via absorption of dissolved organic material through skin
    - totally different from adult;
    - during metamorphosis, important reduction in size.

Order	Suborder	
Elopiformes 2 families, 2 genera, 8 spp.		
Albuliformes 3 families, 8 genera, 29 spp.	Albuloidei	
	Notacanthoidei	
Anguilliformes 15 families, 141 genera, 738 spp.		
Saccopharyngiformes 4 families, 5 genera, 26 spp.		

Subdivision ELOPOMORPHA

- Other characters:
  - swimbladder not in contact with inner ear (cf. Clupeomorpha).
- 4 living orders:
  - Elopiformes;
  - Albuliformes;
  - Anguilliformes;
  - Saccopharyngiformes.
- 24 families, 156 genera and 856 species.

Ordo ELOPIFORMES: tenpounders & tarpons



- Small amount of ganoine in scales.
- leptocephalus larvae small (5 cm) with forked tail.
- 2 families: - Elopidae (ladyfish, tenpounders; 1m) and
  - Megalopidae (tarpons: *Megalops atlanticus* 2.4m, 150 kg)
- *Megalops atlanticus* up to 12.10^6 eggs.
- 2 genera, 8 species.
- Mostly marine (occasionally in brackish- and freshwater), tropical and subtropical distribution.

Ordo ALBULIFORMES: Albulidae (bonefishes)

Albula vulpes

- Lower jaw retrognathous.
- Mostly in tropical seas.
- Albuliformes: 3 families, 8 genera and 30 species.

Ordo ANGUILLIFORMES: eels

- Elongate body.
- Pelvic skeleton and fins absent.
- Pectoral girdle and fin midlateral or somewhat higher, absent in some groups.
- Dorsal, caudal and anal fins confluent
- Scales small or absent.
- Mucus production (locomotion; protection against bacterial diseases)
- Leptocephalus larvae with rounded caudal fin, confluent with dorsal and anal fins.
- Small gill slit, no gill rakers.

Ordo ANGUILLIFORMES: eels

- 15 families, ± 738 species (within Teleostei, some 45 other taxa with a anguilliform body through convergence, but without leptocephalus larvae).
- **Anguillidae** (one genus: *Anguilla*; freshwater eels: 15 species):
  - Small cycloid scales.
  - Catadromous: reproduction in sea, *Anguilla anguilla* (European eel) reproduces in Sargasso Sea (migration up to 5600 km) and dies; metamorphosis before entering freshwater; important growth in freshwater (up to 2m).
  - Eel culture: based on culture of leptocephalus larvae.
  - Africa: North Africa (*A. anguilla*) & East Coast only (several species).

Ordo ANGUILLIFORMES: eels

- **Ophichthidae** (snake or worm eels):
- (marine, occasionally freshwater; tropical and warm temperate zones) (± 250 species):
  - 15-49 branchiostegal rays, form basket-likestructure (jugostegalia) in ventral wall of throat.
  - Pectoral fins absent or present.
  - Burrow tail first; tail stiffened and often sharp for rapid burrowing
  - *Ophichthus melanochir* (below); *Myrichthys breviceps* (above).

Ordo SACCOPHARYNGIFORMES: sackpharynx fishes

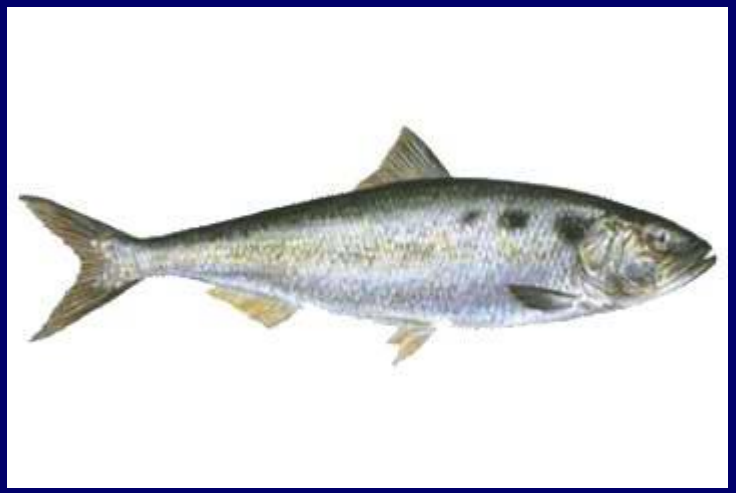
- Highly aberrant: several structures secondary lost (a.o. opercular series; branchiostegal rays, swim bladder, scales, ribs, pelvic fins.
- Very long jaws; mouth large; caudal fin missing or reduced.
- deep sea (tropical and temperate zones).
- 4 families, 5 genera and 28 species.
- **Monognathidae:** long teeth and poisonous gland, unique in fishes.
- *Eurypharynx pelecanoides* (**Eurypharyngidae** – gulper or pelican eels).

Subdivision CLUPEOMORPHA

- Autapomorphies a.o.:
  - Specialised inner ear (utriculus) to swim bladder connection (otophysic connection; paired thin tube-like extensions of swim bladder that enlarge into bullae in skull): increase hearing ability especially for low-frequency sounds such as tail beats of other fishes (3 to 20 Hz); orientation in a school and escape from predators.
- Other characters:
  - Series of ventral scutes (pre- and postpelvic scutes); sometimes also scutes in front of dorsal fin (predorsal scutes).
  - No gular plate.
  - fine gill rakers.
  - Swim bladder connected to gut, stomach or even anus (pneumatic duct).

- 1 living ordo : Clupeiformes: 5 families, 84 genera and 364 species.
- Important for fisheries.

Family CLUPEIDAE: herrings



- Economically important (herrings and sardines).
- Generally marine but some live exclusively in freshwater (*Pellonula*, *Stolothrissa*, *Limnothrissa*); some anadromous; worldwide.
- Pelagic
- No lateral line.
- Teeth small or usually absent.
- Live in schools.
- Planktonivorous (numerous gill rakers) $\Rightarrow$ vertical migrations.
- ± 215 species [*Alosa alosa* (allis shad, upper right); *Sardina pilchardus* (sardine, left)]; most species < 25 cm (60 cm maximal length).

Family ENGRAULIDAE: anchovies

Anchoa mitchilli and *Anchoa hepsetus*

- Economically important (anchovies).
- Mostly marine; occasional freshwater; Atlantic, Indian and Pacific Oceans.
- Generally planctivorous; relatively large mouth because of large maxilla; upper jaw reaching far beyond eye).
- Some species piscivorous.
- 139 species; mostly <20 cm (37 cm maximal length).

Family DENTICIPITIDAE: denticle herrings

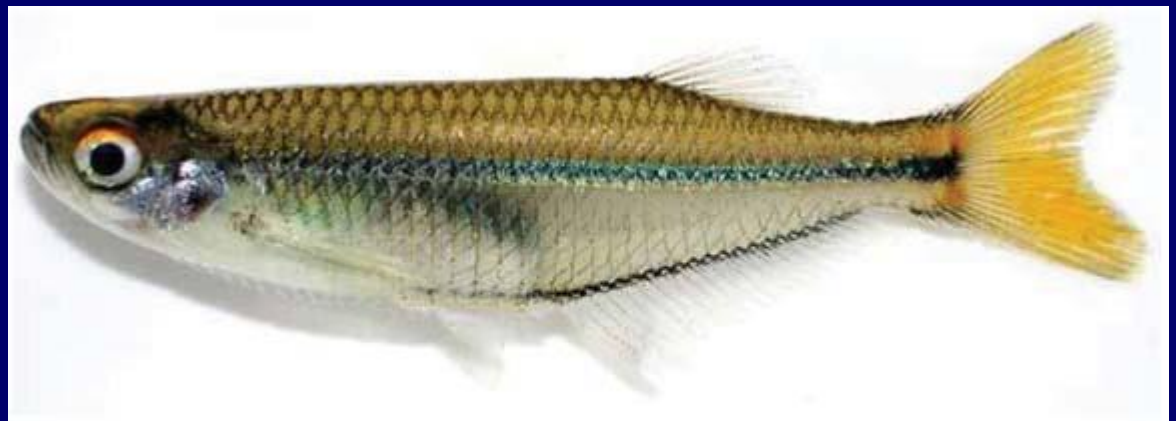
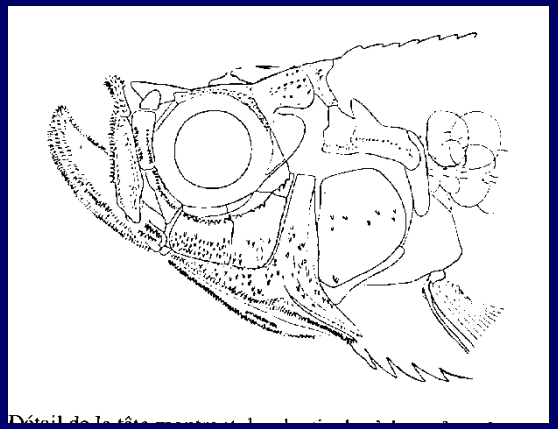


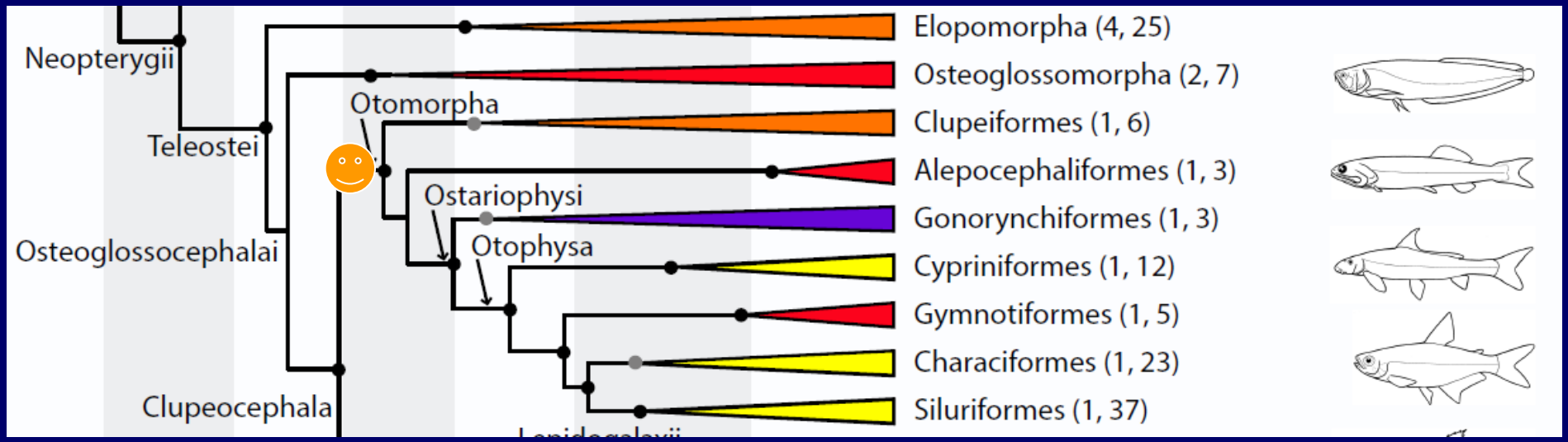
FIGURE 1. Freshly-preserved specimen of *Denticeps clupeoides* (SAIAB 74877; same collection as MZUSP 84776), 42.1 mm S.L. Photo by R. Bills.

- Denticleson dermal skull bones.
- Ventral scutes.
- Freshwater.
- One species: *Denticeps clupeoides.*
- Endemic to Africa: Benin, Nigeria & Cameroon.
- 6 cm.



TELEOSTEI

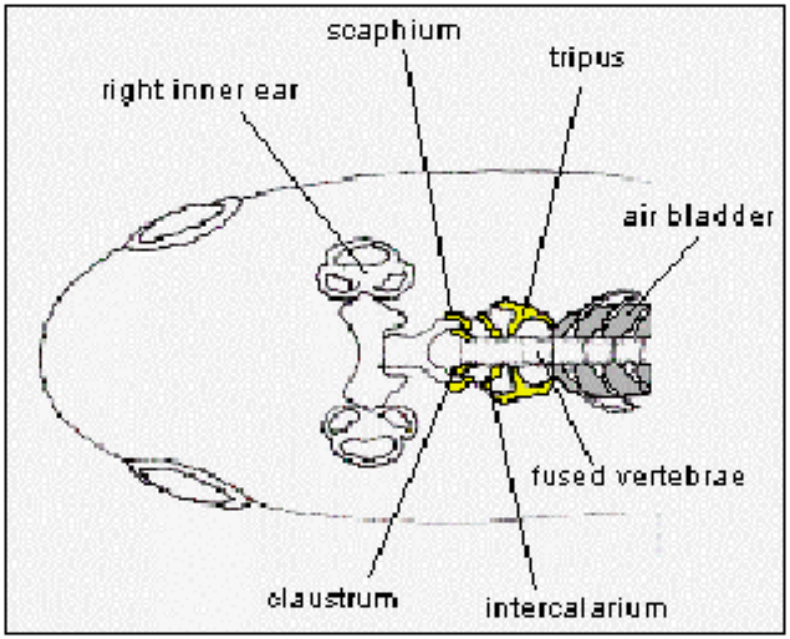
Recently Clupeomorpha (on figure as Clupeiformes) with Ostariophysi as one monophyletic group



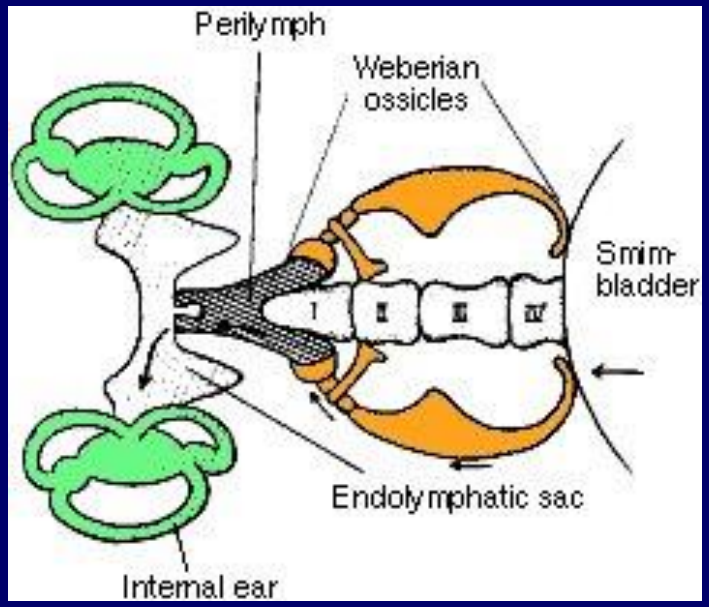
Subdivision OSTARIOPHYSI: characters

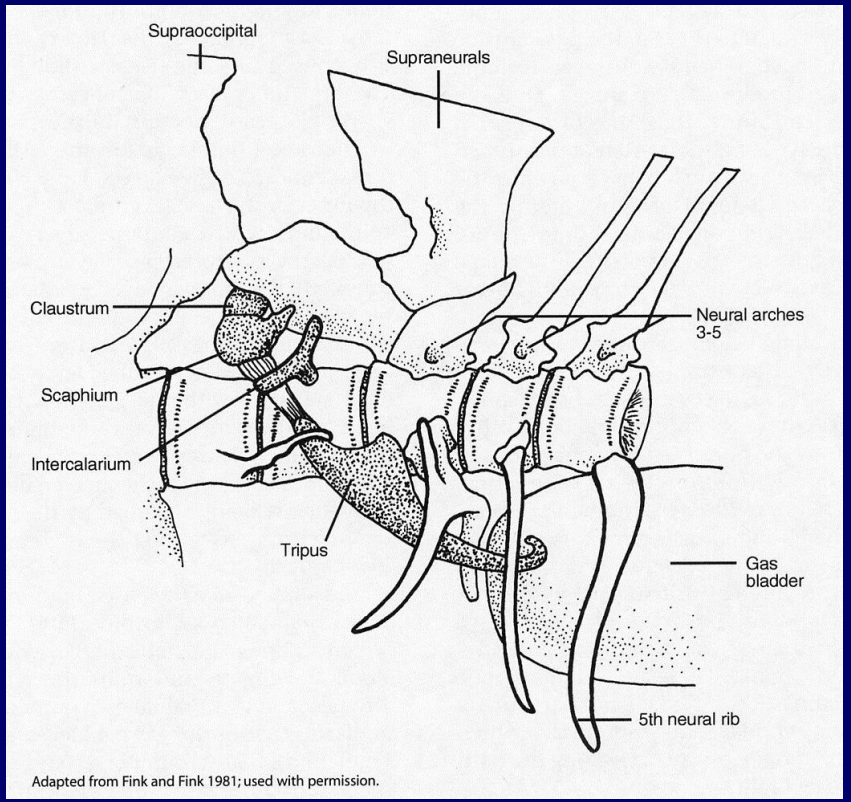
- Autapomorphies a.o.
  - Anterior 4-5 vertebrae with their neural arches, ribs, muscles and ligaments modified to Weberian apparatus (exc. Gonorhynchiformes), connection between swim bladder and inner ear (ostar = small bone; physa = bladder): transmission of sounds.
  - Alarm response (also in a small number of other groups)
    - Epidermal cells produce an alarm substance [Schreckstoff (cf. pheromone)] after injury (lesion, bite, …).
    - Coordinated escape reaction on alarm substance by conspecifics (Schreckreaktion).
    - Some have lost escape response : e.g. Piranhas

Subdivision OSTARIOPHYSI



General scheme of Weberian apparatus for transmitting vibrations from air bladder to ear. Weberian ossicles shown in yellow.





Adapted from Fink and Fink 1981; used with permission.

Subdivision OSTARIOPHYSI: characters

- Other characters:
  - Gas bladder usually constricted and with two chambers.
  - Paired fins still in abdominal position.
  - Upper jaw (premaxilla) becomes protractile in some species.
  - …
- Contains 68 % of all freshwater fishes.
- 5 ordos, ± 68 families, ± 7.931 species of which only ± 123 (<2%) marine [e.g. Ariidae (sea catfishes)].

Subdivision OSTARIOPHYSI: phylogeny

- Five ordos:
  - Gonorynchiformes (Anotophysi);
  - Cypriniformes;
  - Characiformes;
  - Siluriformes;
  - Gymnotiformes.

latter 4 Otophysi.

Ordo GONORHYNCHIFORMES: characters

- Systematic position unclear for a long time: incomplete Weberian apparatus (only first 3 vertebrae and one or more cephalic ribs) (Anotophysi) (secondary loss of swim bladder in some groups?).
- Have alarm response.
- Usually without oral teeth (as in Cypriniformes).
- Epibranchial organ (temporary accumulation, concentration and storage of food particles via gill rakers).
- No adipose fin.
- 4 families with about 37 species.

Ordo GONORHYNCHIFORMES
Family CHANIDAE (milkfishes)

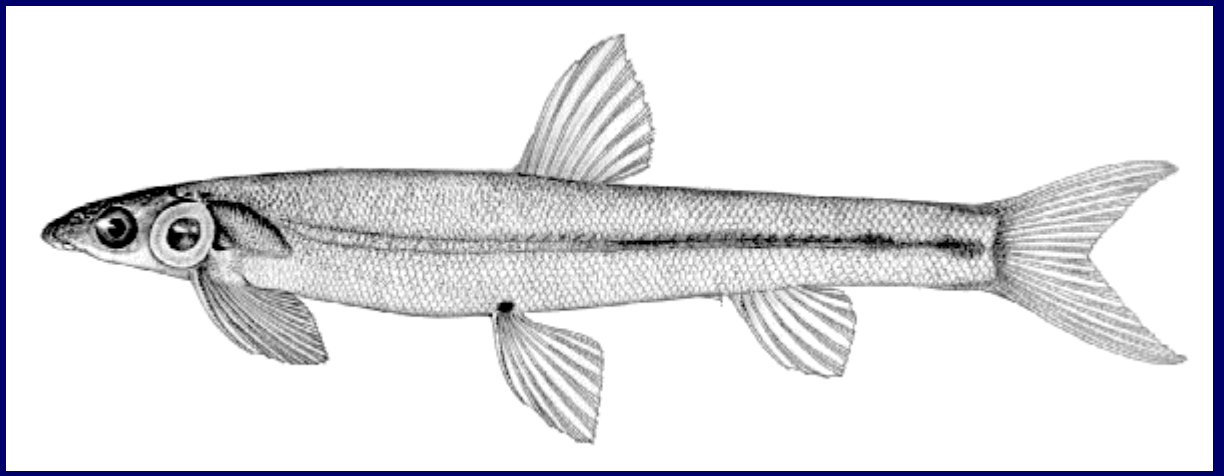
- One species *Chanos chanos.*
- Marine and brackish water (occasionally in freshwater) tropical and subtropical regions.
- Reproduction in ocean, metamorphosis of larvae in brackish water.
- Considerable importance as food fish in region of Pacific and Indian Ocean: Philippines, Indonesia, Taiwan.
- Planktivorous.
- Young reared in brackish water ponds (up to 1.8 m).

Ordo GONORHYNCHIFORMES
Family KNERIIDAE (knerias)

– Freshwater, Africa.
– Small cycloid or no scales.
– Air breathing via swim bladder.
– Some with opercular organ (sucker?, facilating hearing?) in males.
– 30 species; <15 cm.

Kneria auriculata

Kneria polli



Ordo GONORHYNCHIFORMES
Family PHRACTOLAEMIDAE (snake mudheads)

- Freshwater, tropical Africa: Nigeria and Congo basin.
- Swim bladder adapted to air breathing.
- Cycloid scales.
- 1 species: *Phractolaemus ansorgii* (African mudminnow).
- 16 cm.

Ordo CYPRINIFORMES: carps

- Adipose fin absent except in some Cobitidae loaches
- Cycloid scales.
- Upper jaw protractile in most groups (first large group).
- Barbels present or absent.
- 0 to 3 spines in dorsal fin.
- No teeth on the oral jaws.
- Pharyngeal teeth (first large group).
- Freshwater.
- 6 families with ± 3.268 species.
- Largest diversity in Southeast Asia and Africa, absent in South America.
- Popular aquarium fishes.

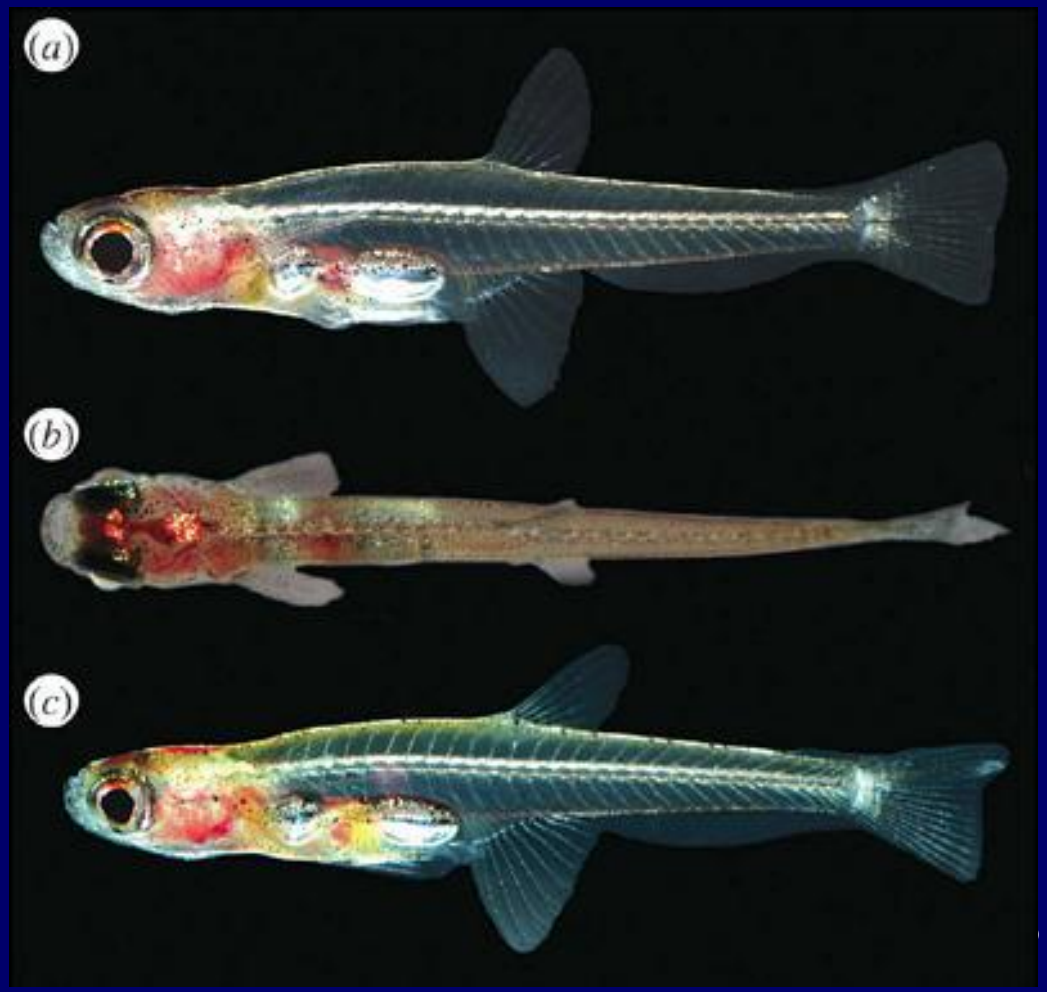
Rasbora heteromorpha
Cyprinidae

Family CYPRINIDAE
(carps, barbels, bream, minnows, ...)

- Pharyngeal teeth in 1 to 3 rows (maximum 8 tooth per row).
- Largest family of fishes (> 2900 species).
- South East Asia, Africa, N.-America and Europe.
- Not in S.-America, ecologically equivalent Characidae.
- Many ecological niches: phytoplanktivorous (e.g. *Pectenocypris balaena*, 212 gill rakers) to piscivorous.
- Polyploidy in some groups (related to size).
- Important in fisheries and fish culture / aquarium fish / science.

Family CYPRINIDAE
(carps, barbels, bream, minnows, ..)

- Smallest freshwater fish *Paedocypris progenetica* (mature female 7,9 mm; max length 10,3 mm).
- Lives in peat swamps in Sumatra.



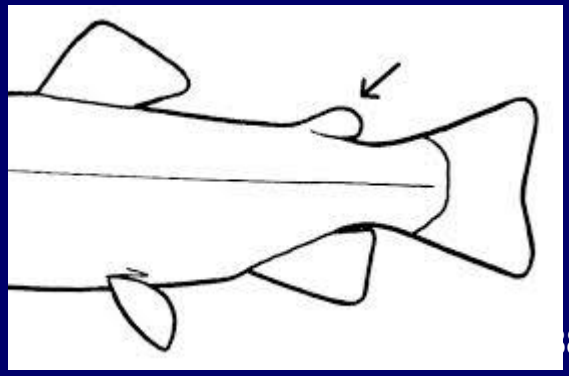
Family CYPRINIDAE

Caecobarbus geertsi, blind cave barb (Mbanza-Ngungu, Lower Congo), Cites II list, IUCN red list, VU

Epalzeorhynchos bicolor, Asia, IUCN red list: 1996 EW; 2011 CE

Ordo CHARACIFORMES (characins): characters

- Adipose fin usually present.
- Mostly cycloid, sometimes ctenoid scales, one species naked in Argentina.
- Mouth not really protractile.
- Edge of upper jaw with premaxilla and maxilla.
- No barbels.
- No spines in dorsal fin.
- Usually strongly developed teeth on jaws (most are carnivores).
- Pharyngeal teeth usually present but less specialised than in Cypriniformes.

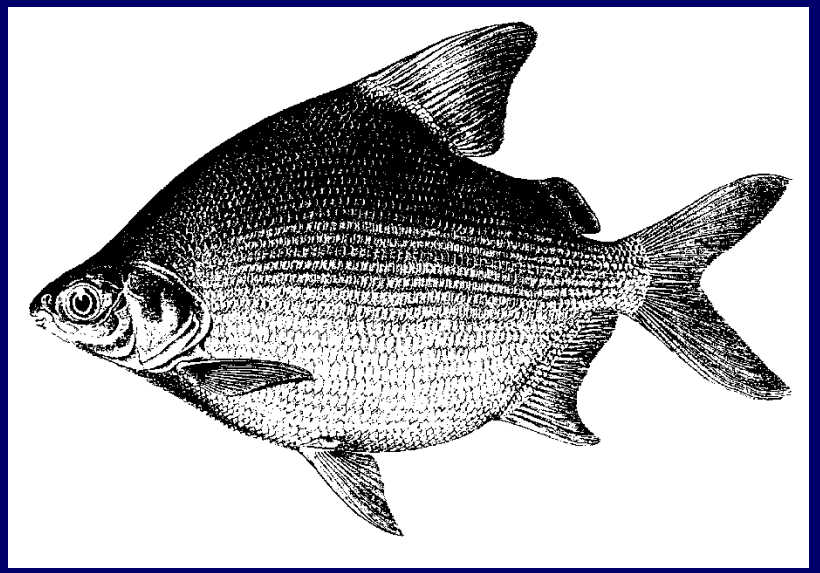


Ordo CHARACIFORMES (characins): characters

- Often living in schools.
- Freshwater.
- 18 families with ± 1.674 species.
- Africa, Central- and South America (largest diversity)? one species in S.W. USA
- Absent in Southeast Asia (ecologically replaced by Cypriniformes).
- Very diverse ordo.
- Some small and beautifully coloured (aquarium fish).
- Some species are important food fish.
- Some families discussed below.

Families: CITHARINIDAE & DISTICHODONTIDAE

- Form monophyletic group, sometimes subfamilies.
- Herbivores (non-protracile upper jaw) and carnivores and fin-eaters (movable upper jaw & body usually elongate).
- Freshwater.
- Max. size: 84 cm.
- ± 98 species.



Citharinus sp. (up)

Phago boulengeri (below)

Family CHARACIDAE (characins)

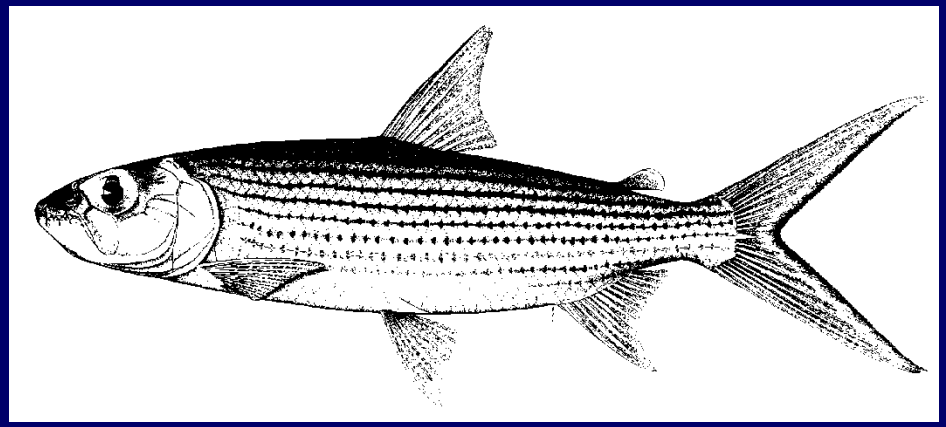
- Often sexual dimorphism in D en A fins.
- Bottom-, midwater-, surface dwellers.
- Variation in tooth shapes.
- Large diversity in body shapes and species (± 962 species).
- *Xenurobrycon* (S. America) (13 mm).
- Freshwater; S.W.-USA, Mexico, Central- and South-America.
- Systematics problematic in many groups.

Cheirodon axelrodi
Nannostomus eques

Family CHARACIDAE: characins

Amazone piranhas (Serrasalminae):
± 80 species:
- predators;
- scale eaters;
- herbivores.

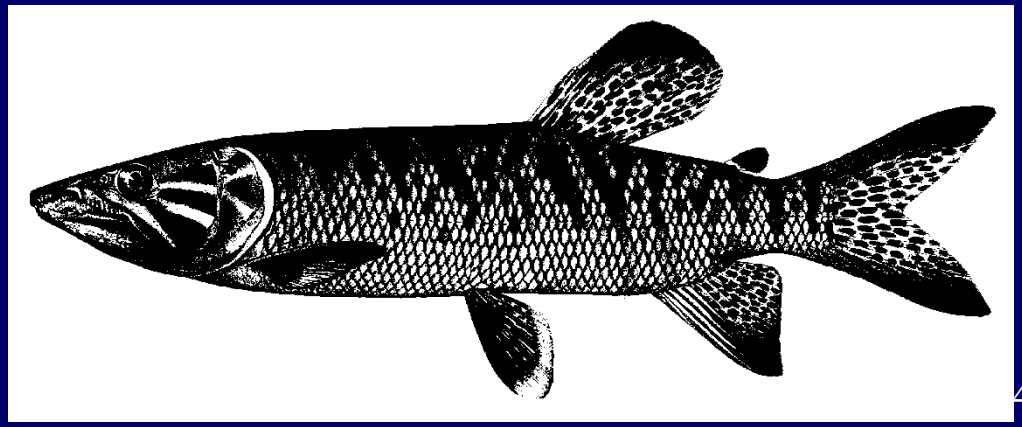
Family ALESTIDAE (African tetras)



- Africa.
- ± 110 species.
- *Hydrocynus goliath*, tiger fish (2 m).

Family HEPSETIDAE (African pikes)

- Elongate pike-like body.
- Large canini like teeth and smaller pointed teeth.
- Eggs laid in a nest of floating foam; adults develop fleshy appendix on both sides of lower jaw in reproductive season; presumably play a role in construction of the foam nest.
- Up to 65 cm.
- Freshwater; Africa.
- Used to be one species
  => now six species

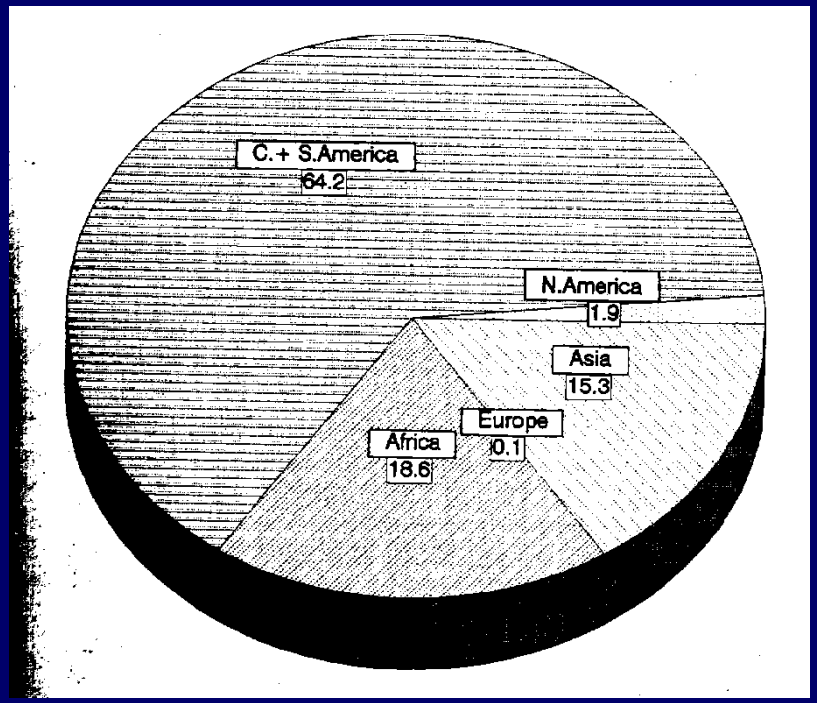


Ordo SILURIFORMES (catfishes)

- No scales:
  - in some families bony plates
- Often spines in fins:
  - dorsal fin;
  - pectoral fins;
  - sometimes spine connected with poisonous gland (*e.g.* Plotosidae).
- No intermuscular bones (⇨ fillets).
- Often adipose fin (sometimes with spine).
- Maximum 4 pairs of barbels (with taste buds; nasal, maxillary; 2 on lower jaw/mandibular barbels).
- Maxilla serves generally only as support for maxillary barbel.
- Teeth (toothplates) on palate.
- Eyes mostly small.

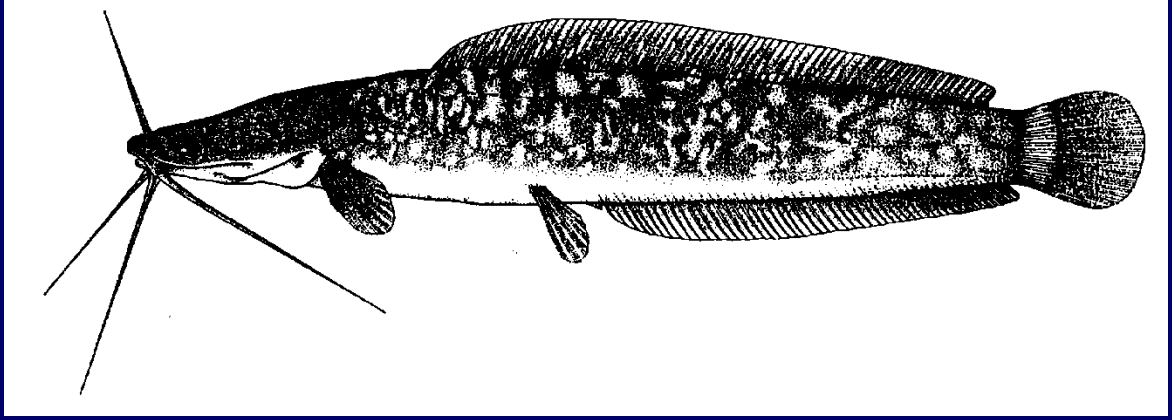
Ordo SILURIFORMES: catfishes

- All continents (fossils on Antarctica).
- Largest species diversity in South America.
- Important diversity in shape and size:
  - Scoloplacidae (S.Am.) 20-30 mm
  - Siluridae (Europe) 5 m
  - Pangasiidae (Southeast Asia) 3 m
- Freshwater; but most Ariidae and Plotosidae are marine.
- Benthic and pelagic groups.
- 32 families with ± 2867 species.
- Systematics often problematic.
- Important food and sports fishes.



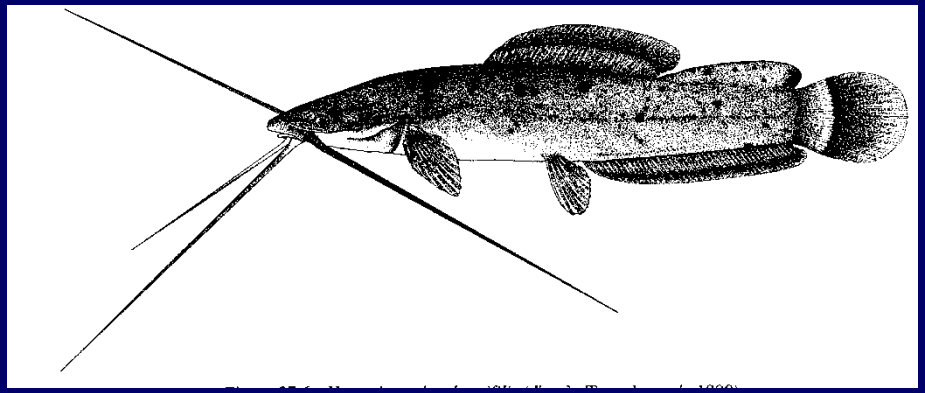
Scoloplacus dicra

Family CLARIIDAE (airbreathing catfishes)

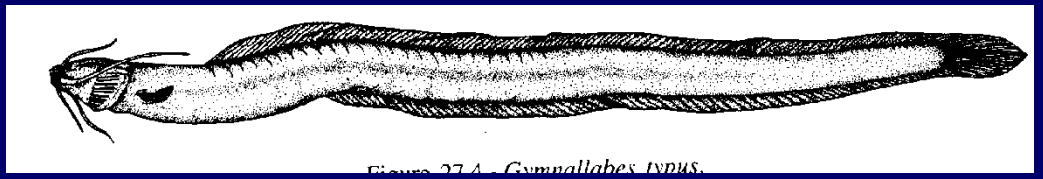


- Air-breathing suprabranchial organ (labyrinth) => derived from gill arches.
- Strong pectoral spines, walking catfish.
- Long dorsal fin with no spine.
- 4 pairs of barbels.
- Benthic.
- Africa (most species), Syria, southern and western Asia.
- Some 90 species.

Family CLARIIDAE (airbreathing catfishes)



- Important variation in shape and size (*Heterobranchus*, above, up to 1.5m; *Gymnallabes*, below, 30 cm).
- Some species can move over land over short distances.
- Economically important both in fisheries and aquaculture.
- Introductions (*Clarias gariepinus*, *C. batrachus*).
- *Channallabes apus* feeds on land.



Family SILURIDAE (sheatfishes)

Kryptopterus bicirrhis, glas catfish

Silurus glanis, European catfish (up to 5 m and 330 kg): economically important in Eastern Europe and Central Asia (aquaculture)

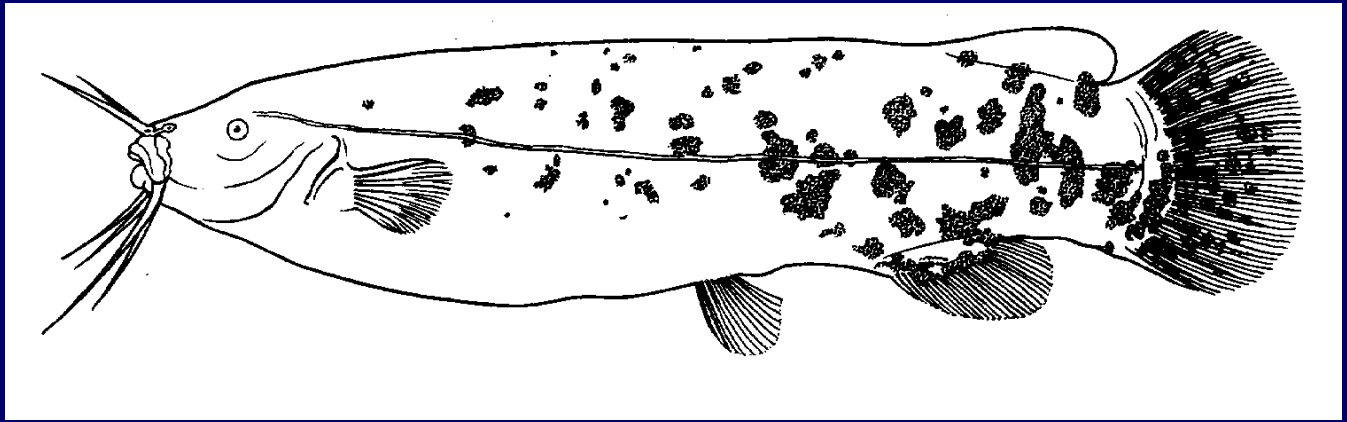
Family SCHILBEIDAE (schilbeid catfishes)

- Usually dorsal fin with spine.
- Usually 4 pairs of barbels.
- Adipose usually present.
- Long anal fin.
- Pelagic catfish.
- Africa and southern Asia.
- Economically important.
- ± 56 species.
- *Pareutropius debauwi*

- *Schilbe intermedius*:

species with or without adipose fin.

Family MALAPTERURIDAE (electric catfishes)



- Electric organ (derived from anterior body musculature), up to 450V.
- No spines.
- Adipose fin (far back), no dorsal fin.
- 3 pairs of barbels.
- Max. size: 1m.
- Africa (a decade ago two species, now 19 species).

Family MOCHOKIDAE (squeakers or upside-down catfishes)

- Strong dorsal and pectoral spines with locking mechanism.
- Adipose fin usually very large.
- Nasal barbels absent, mandibulary barbels usually branched.
- Some species swim on their back.
- Species flock in Lake Tanganyika.
- *Synodontis nigriventris* and *S. angelicus*.

Family MOCHOKIDAE

- *Synodontis multipunctatus*,

cuckoo behaviour (Lake Tanganyika)

Familie LORICARIIDAE

- body with bony plates
- mouth ventral (sucker mouth)
- only (strongly reduced) maxillary barbels
- largest family (684 species)
- Central- and South America
- aquariumfishes
- *Ancistrus sp.*, tentacles, mimicry of larvae ?

Family TRICHOMYCTERIDAE (pensil catfishes or parasitic catfishes)

- 201 species (max size: 23-300 mm).
- Usually no adipose fin,
- Small eyes.
- Many parasitic species:
  - hematophagous;
  - some gill parasites (Vandelliinae).
- May very rarely enter urethra of humans (*Vandellia cirrhosa* = candiru); however certainly not a vertebrate parasite of man; no recent well-documented cases.

Ordo GYMNOTIFORMES (American knifefishes)

- Sistergroup of Siluriformes.
- Anguilliform body.
- Dorsal fin absent.
- Pelvic girdle and fin absent.
- Very long anal fin (forward and backward movements).
- Caudal fin absent or strongly reduced.
- No adipose fin.
- No alarm reaction or substance.
- Electric organ derived from muscle cells (myogenic) or from nerve celles (neurogenic) in Apteronotidae.
- 5 families with ± 173 species.
- Freshwater.
- Central- and South-America.

Family GYMNOTIDAE (nakedback knifefishes): *Gymnotus* (band knifefishes)

- ***Gymnotus*:** weak electric pulses (1V), continuously on high frequency.
- Modified lateral line receives electric pulses.
- Small eyes.
- Central- and South-America (32 species).
- Up to 100 cm. *Gymnotus carapo*

Family Gymnothidae GYMNOTIDAE (nakedback knifefishes) : *Electrophorus* (electric eel)

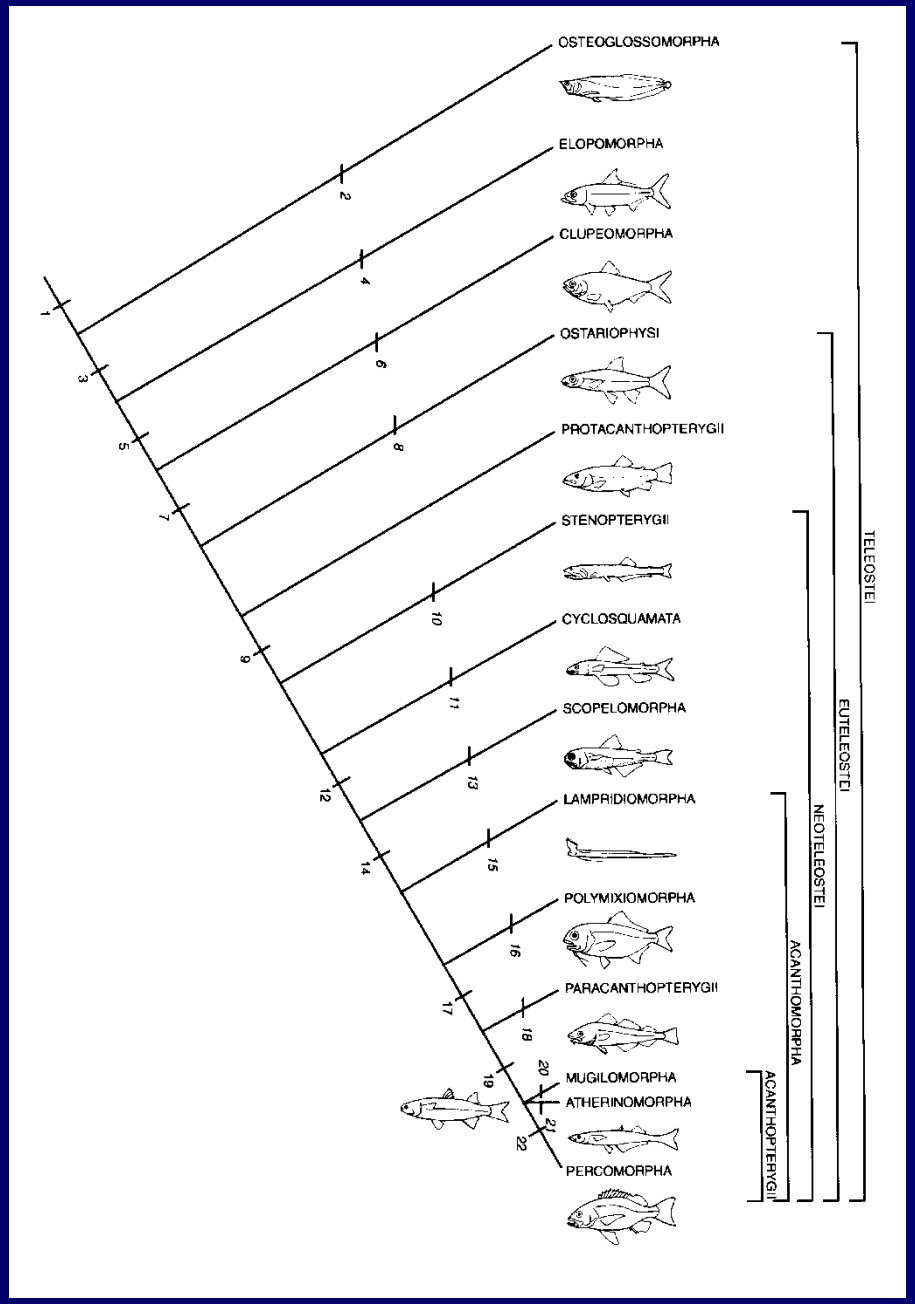
- Large electric organs (half of body muscles); can produce lethal pulses for stunning prey (up to 650 V).
- Two smaller sets of electric organs for electrolocation.
- Air breathing.
- No scales
- Most preys are fish.
- South-America.
- up to 2.2 m TL.
- *Electrophorus electricus*

Protacanthopterygii

then various groups, with many deepwater taxa

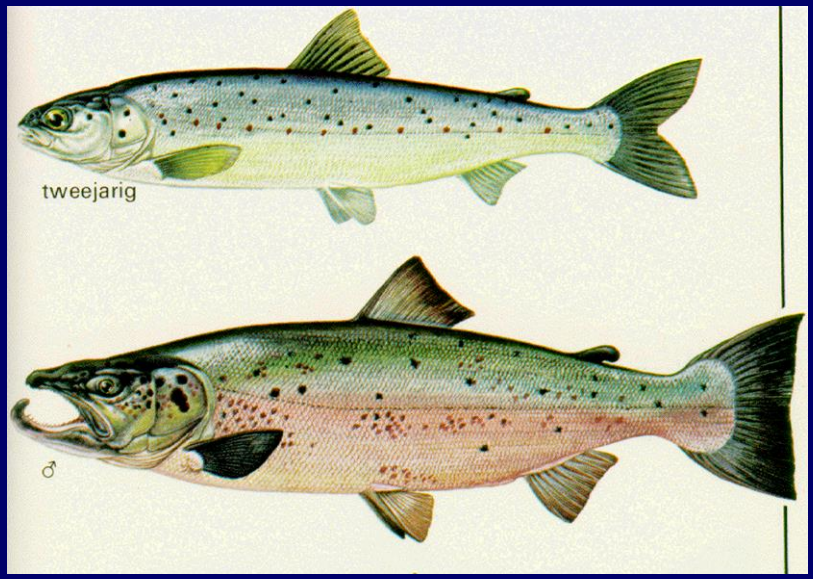
Paracanthopterygii

Acanthopterygii



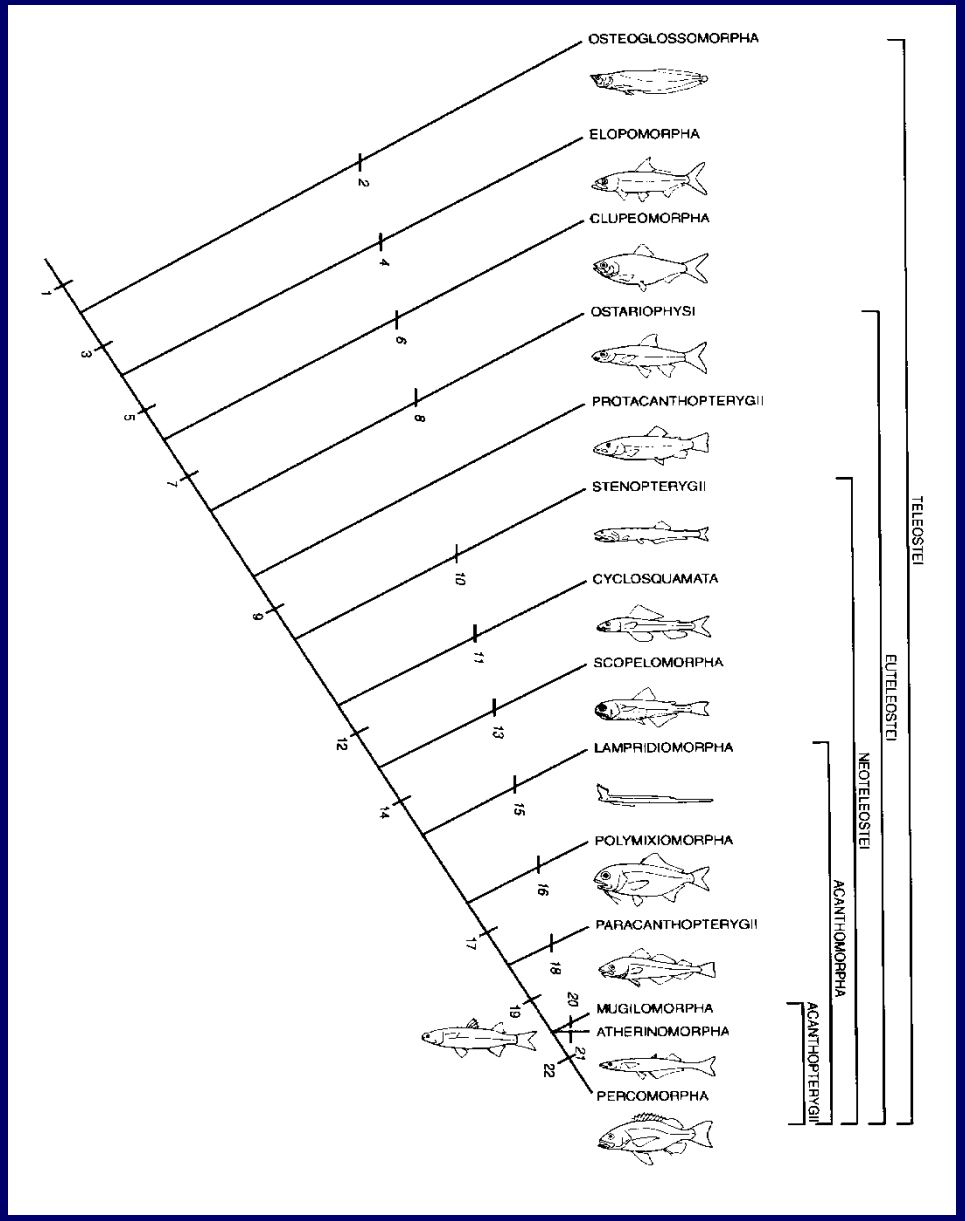
PROTACANTHOPTERYGII: Ordo SALMONIFORMES

- adipose fin
- salmons, trouts, graylings, ... economically very important
- freshwater and anadromous
- northern hemisphere
- Atlantic salmon and European trout in genus *Salmo*, Pacific salmon and trout in *Oncorhynchus*



- **NEOTELEOSTEI**

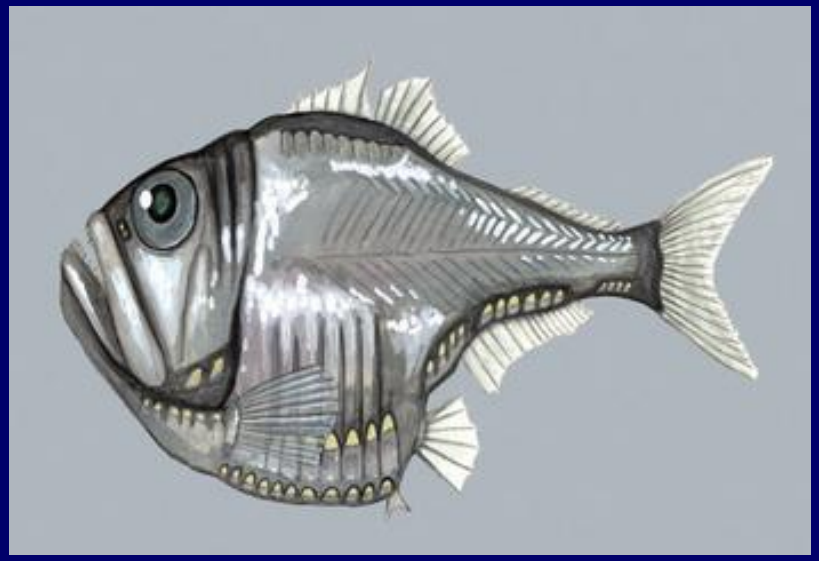
- new classification will gradually replace this one
- various specialized deep sea and pelagic groups, and a few species-rich groups in shallower waters



Characters of deep sea fishes

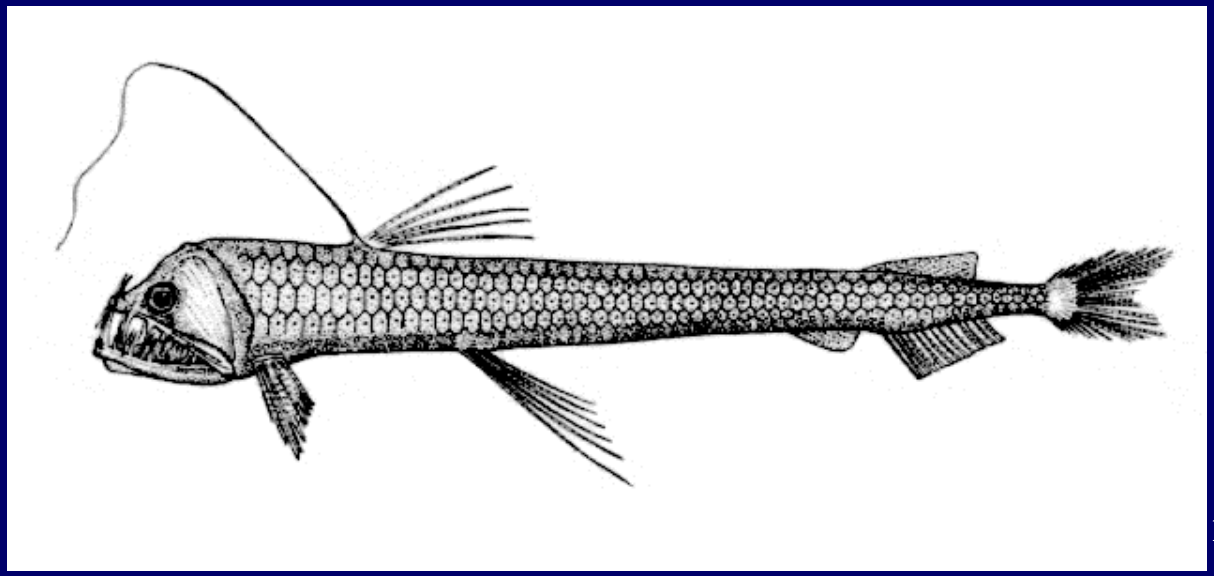
- Adaptation to small amounts of light and food and to low temperature and high pressure in the deep sea.
- Photophores.
- Large expandable mouth provided with dagger-like teeth or some other form of long, sharp dentition.
- Barbels on the chin or modified dorsal spines that are waved in front of prey to lure them.
- Long, thin bones.
- Large tubelar or reduced eyes.
- Resemblances often due to convergence.

Some examples of deep-sea fishes



Argyropelecus aculeatus marine hatchet fish

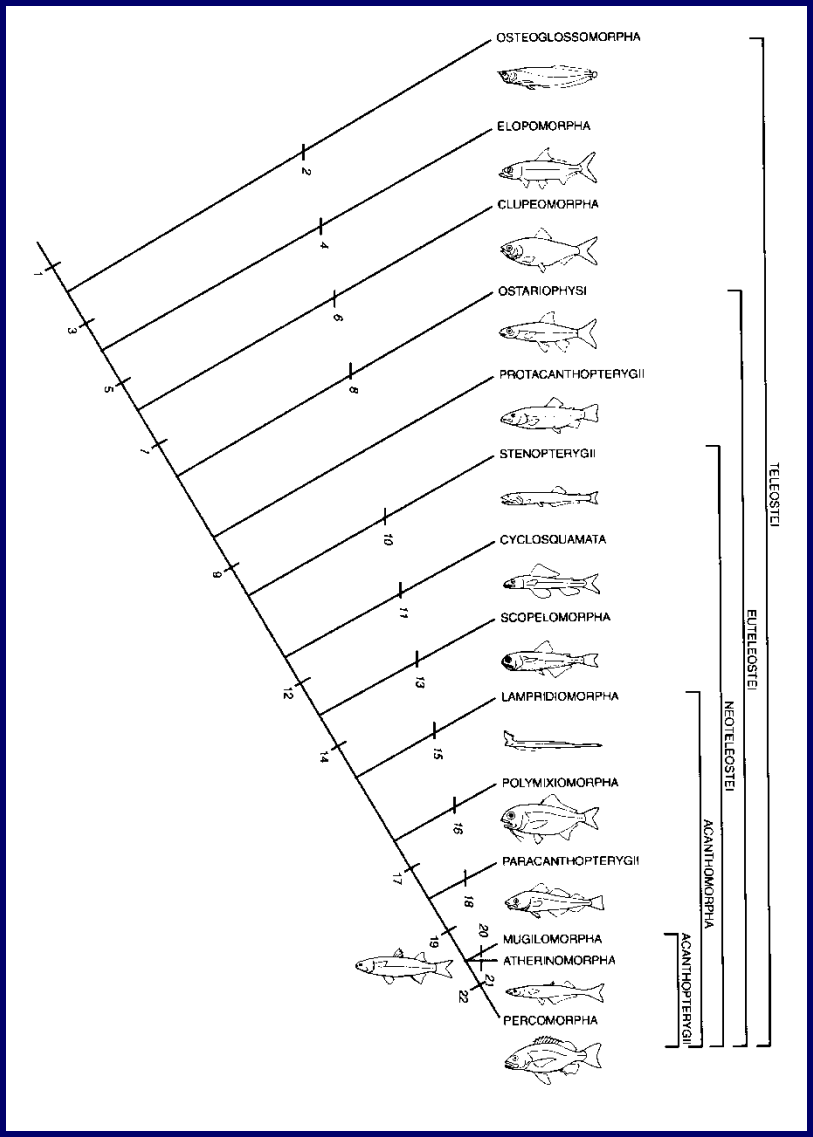
Chauliodus macouni, viper fish



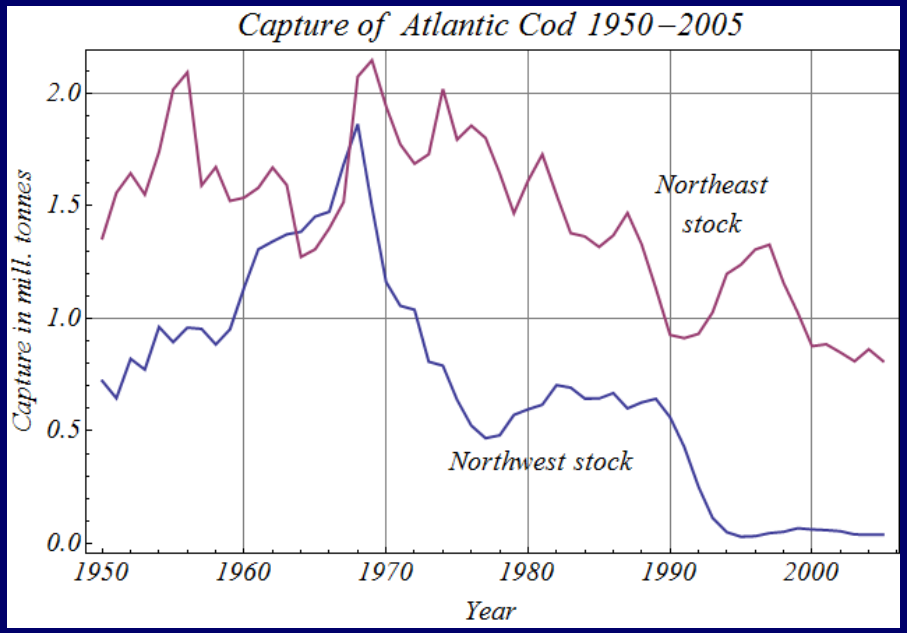
Superordos:

PARACANTHOPTERYGII

+ ACANTHOPTERYGII

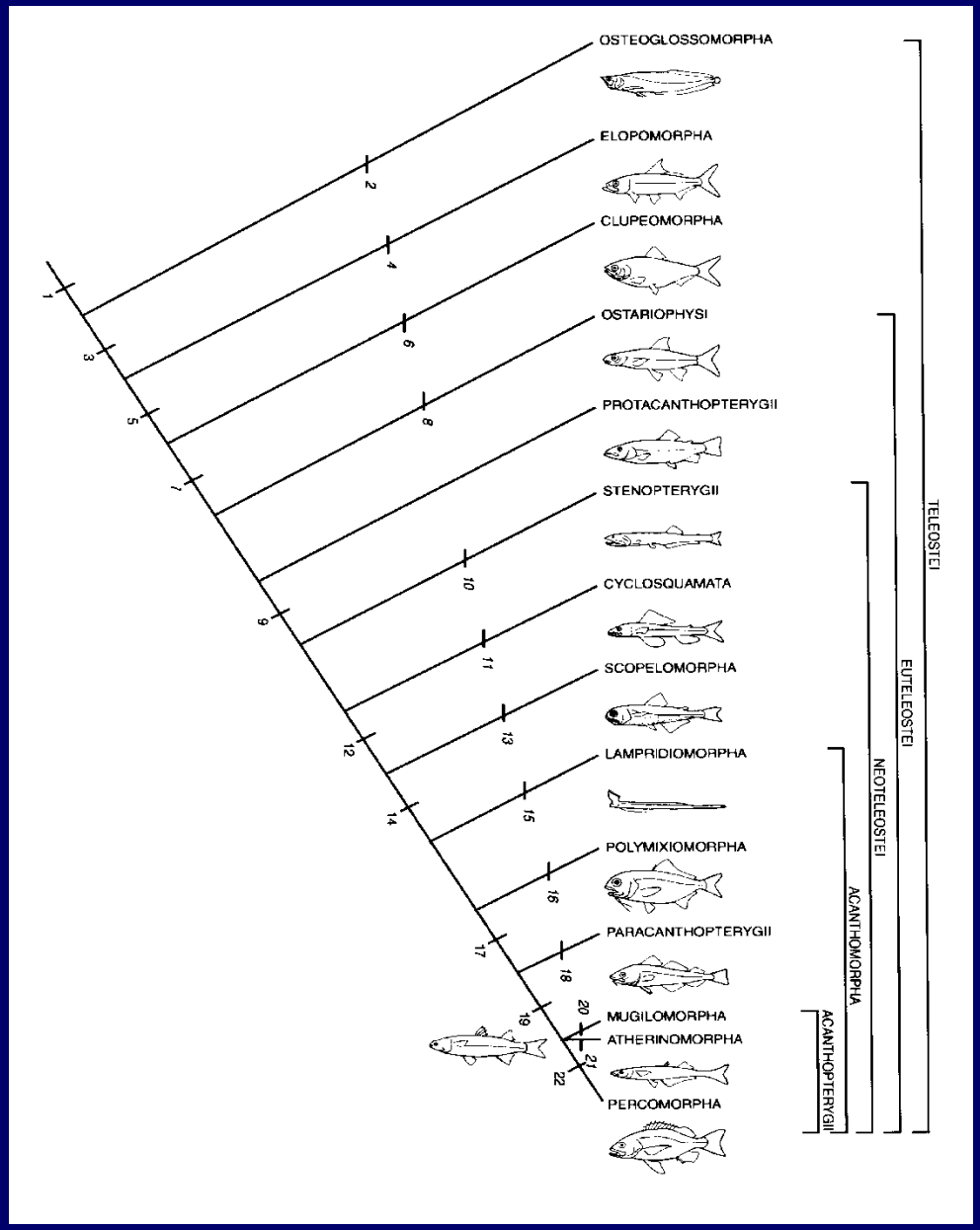


Superordo PARACANTHOPTERYGII
Ordo GADIFORMES



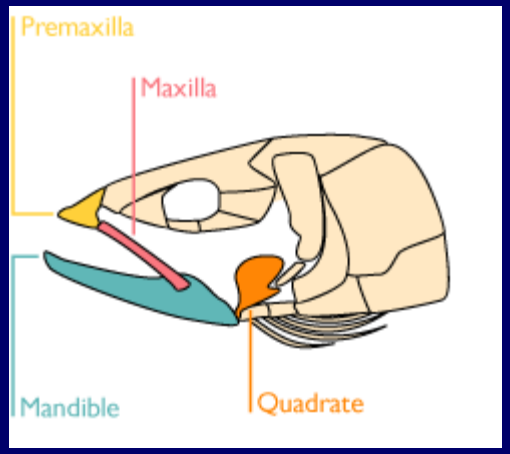
- dorsal fin specialisations (one to three)
- pelvic fin in anterior position
- barbels on chin
- mostly marine
- 9 families with 555 species; some are very important food fish (cod, whiting, hake, …)
- Cod seriously overfished; max. 2 m / 96 kg; 25 jaar, now in North Sea seldom > 10 years and 90 % < 9O cm, < 7 kg

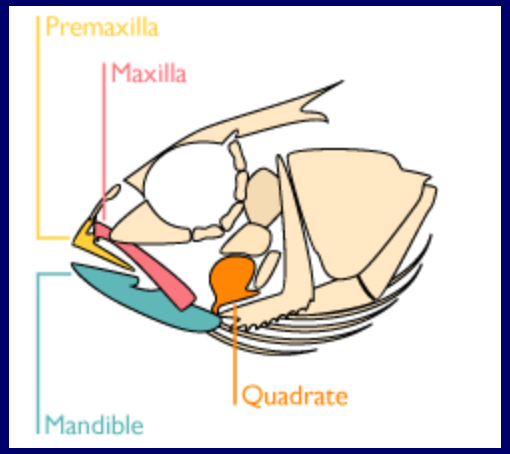
Superordo ACANTHOPTERYGII

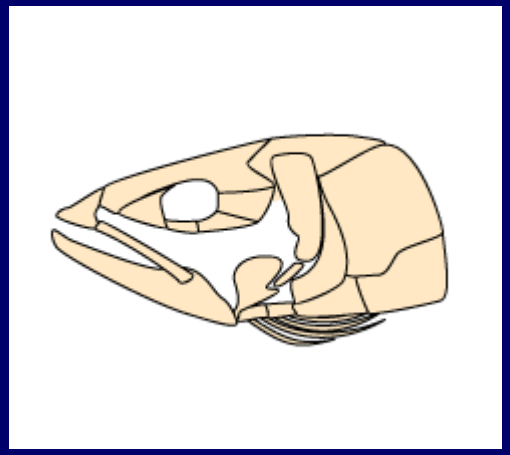


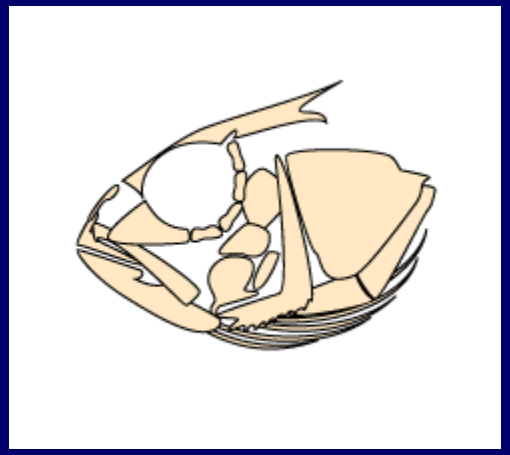
Superordo ACANTHOPTERYGII: characters

- Mobile upper jaw (= ascending process on premaxilla) and protractile mouth (anteriorly and ventrally) (secondary loss possible).
- Maxilla not part of jaw edge.

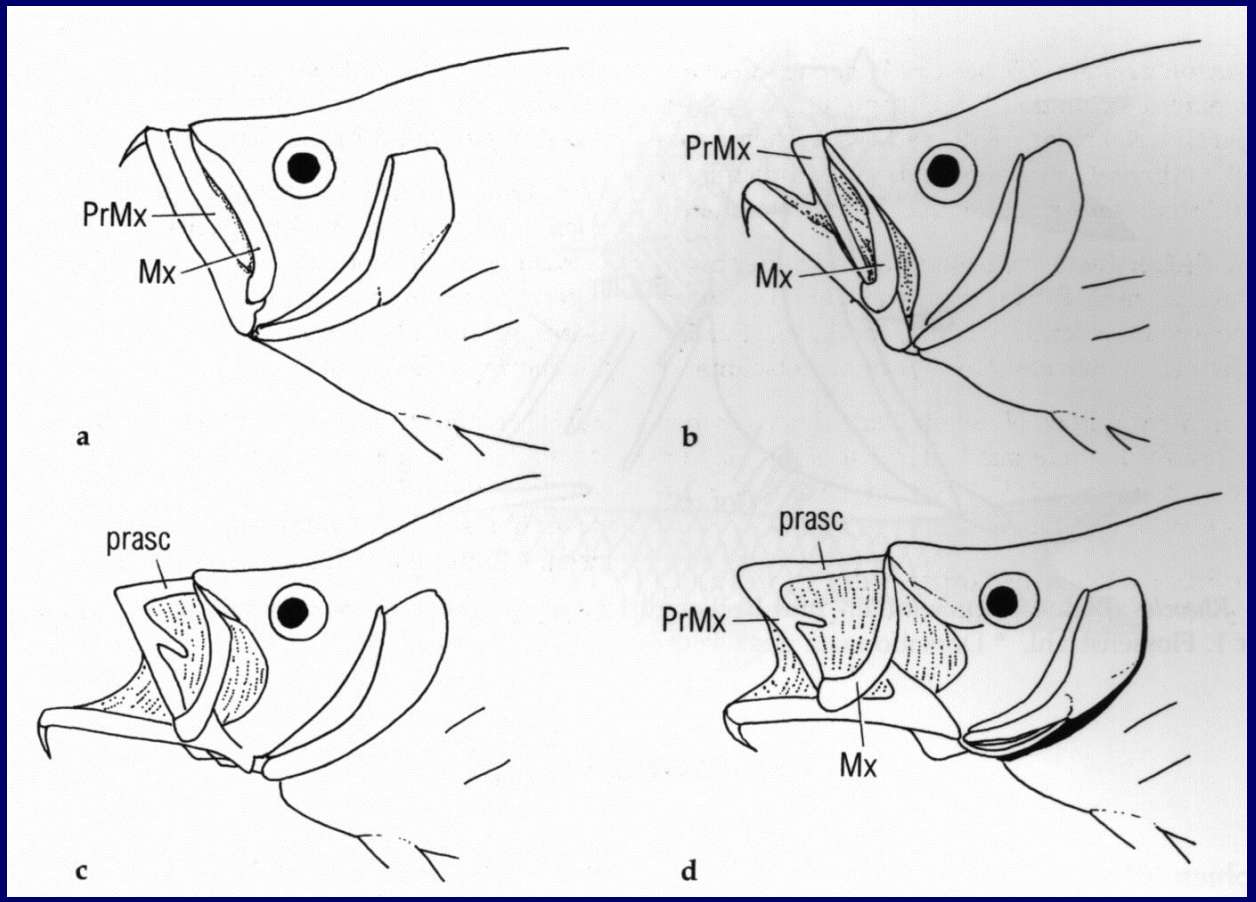








Superordo ACANTHOPTERYGII: characters



Superordo ACANTHOPTERYGII: characters

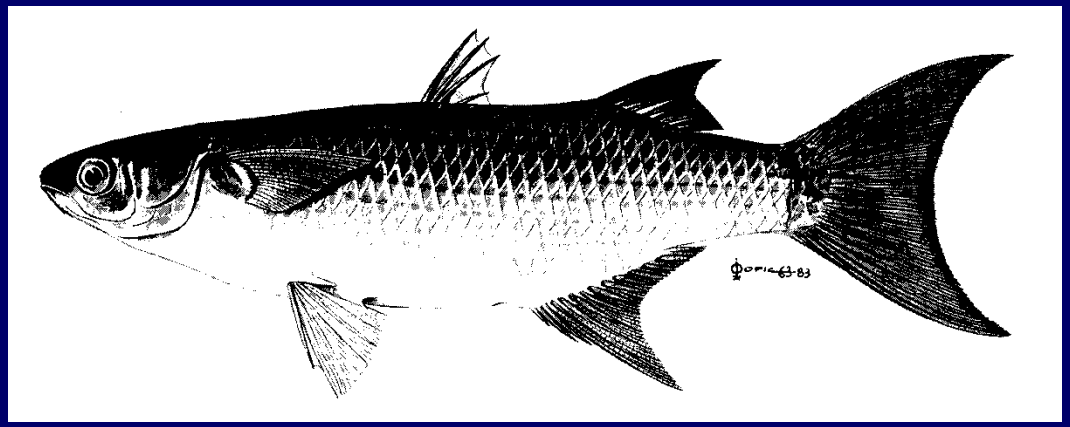
- Pharyngeal teeth highly specialized.
- Often ctenoid scales.
- Physoclistous.
- Two dorsal fins, first one with spines, second with soft fin rays.
- Spines in pelvic and anal fins.
- Pelvic fins in anterior position (1 spine and 5 or less soft fin rays).
- Pectoral fins in lateral position.

Superordo ACANTHOPTERYGII

- 267 families with ± 14.797 species
- 3 Series:
  - **MUGILOMORPHA**: no direct connection between pelvic girdle and cleithrum of pectoral girdle;
  - **ATHERINOMORPHA**: special mechanism for jaw protrusion
  - **PERCOMORPHA**: pelvic girdle attached to pectoral girdle, directly or with a ligament; pelvic fins with one spine and five soft rays.

New insights have lead to a new classification; for the moment we continue with the classification of the textbooks

Series MUGILOMORPHA
Ordo Mugiliformes Fam. Mugilidae (mullets)

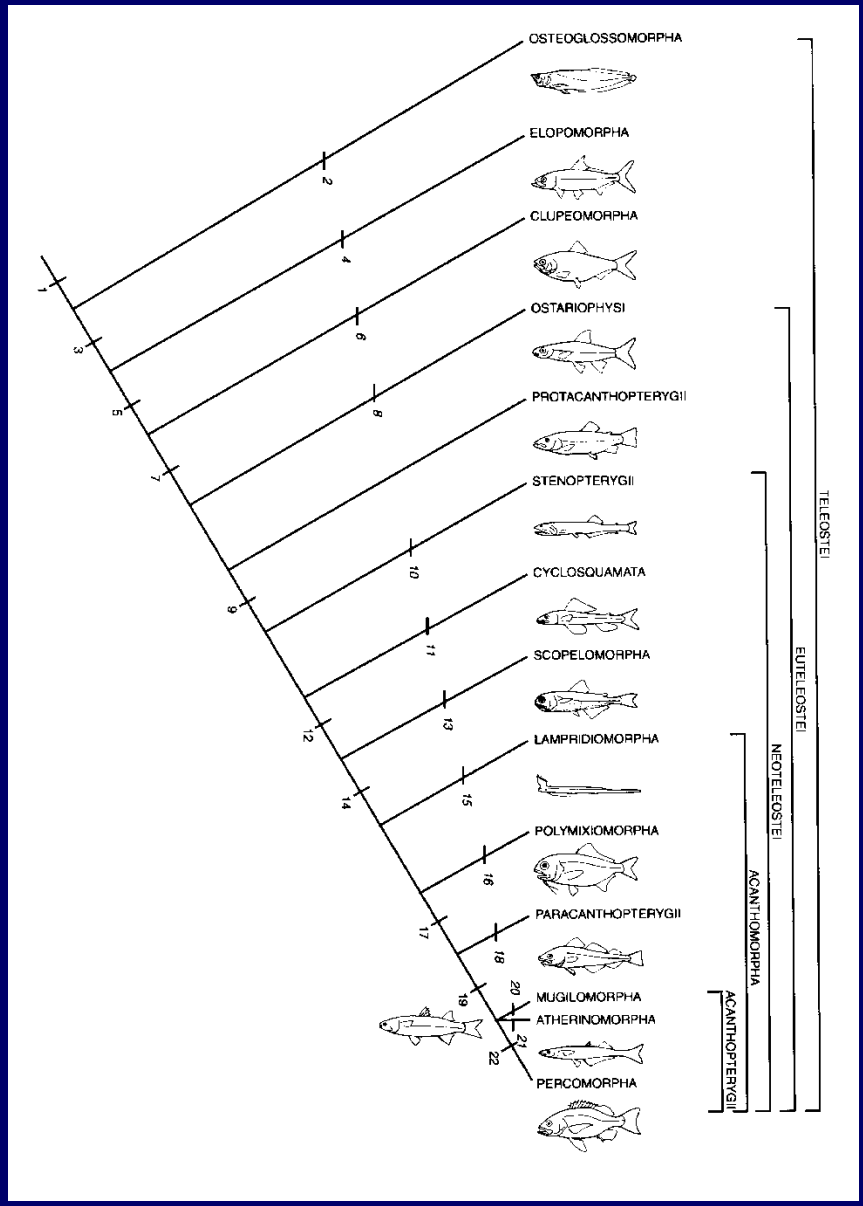


- Economic importance (fisheries and fish culture).
- Detritivorous.
- Coastal areas (marine, brackish water, freshwater).
- Tropical and temperate zones.
- Dorsal fins far from each other, 4 dorsal spines.
- Schooling.

Series ATHERINOMORPHA

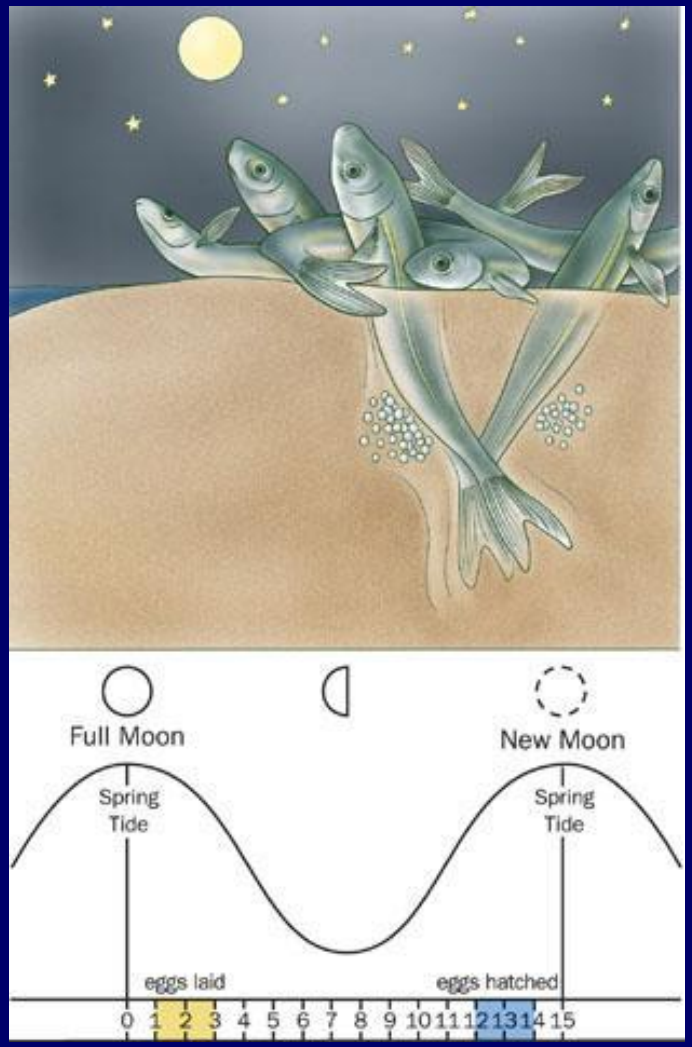
21 synapomorfies a.o.

- All kinds of adaptations for reproduction:
  - internal fertilisation and ovoviviparity;
  - external fertilisation and long development of eggs, eggs with long filaments (adherence to spawning substrate).



Series ATHERINOMORPHA

- Terminal or superior mouth.
- Opercular or preopercular margin without serrations or spines.
- Ctenoid scales still rare.
- Most successful group of surface dwelling fishes, > 85 % fresh or brackish water.
- 3 ordos; ± 1552 spp.
- Atheriniformes, Cyprinodontiformes and Beloniformes.



Atheriniformes

Leuresthes tenuis, Californian grunion

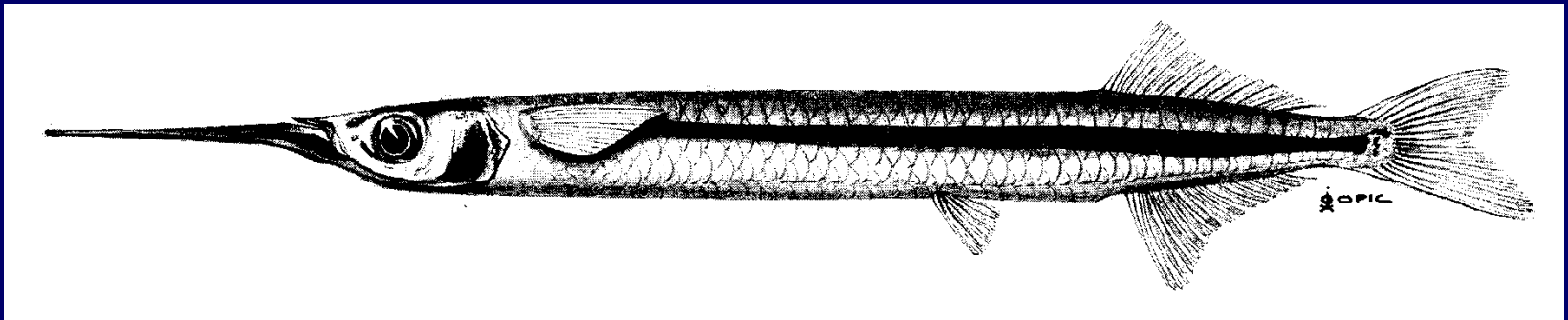
Ordo Beloniformes

- Different sorts of heterochrony (evolutionary change in timing in ontogenetic development) in jaws in various families.
- a.o. medaka *Oryzias*.

Ordo Beloniformes
Fam. Belonidae
(needlefishes)

- Juvenile jaws short and of equal length; during growth lower jaw elongates first (“halfbeak” stage), than upper jaw (“needlenose” stage).
- Fish larvae and copepods (juveniles); fish (adults).
- Green bones (vivianite).
- Marine and freshwater.
- Numerous needle-like teeth.
- 1.5 m.

Ordo Beloniformes
Fam. Hemiramphidae (halfbeaks)



- Lower jaw >> upper jaw.
- Herbivorous (sea grass), freshwater taxa are insectivorous.
- Marine (Atlantic, Indian and Pacific) and freshwater.
- 45 cm.

Ordo Cyprinodontiformes (killifishes)

- Epipelagic.
- Insectivorous (often terrestrial insects).
- Sensorial pores and canals mainly on head (taxonomy).
- Important sexual dimorphism.
- Freshwater (some saline / hypersaline).
- 10 families; ± 1013 spp.
- oviparous, ovoviviparous, exceptionally viviparous (Goodeinae) with some kind of placenta.

Ordo Cyprinodontiformes, Nothobranchiidae

Aphyosemion striatum

- Africa.
- a.o. “annual” fishes; *Notobranchius guentheri*, 4 week life cycle.
- sexual dimorphism in colour pattern.
- *Aphyosemion* (rain forest).

Notobranchius rachovi

Ordo Cyprinodontiformes, Fam. Poeciliidae (livebearers)

Poecilia reticulata

Xiphophorus helleri

- Africa : external fertilisation, oviparous
- southern part of North America to South America:
  - ovoviviparous
  - internal fertilisation (moveable gonopodium: modified anterior anal fin rays)
  - used for musquito control: *Gambusia spp.* (C & S. America)
- *Poecilia formosa* : unisexual species, gynogenesis

Ordo Cyprinodontiformes, Fam. Anablepidae (four-eyed fishes)

- Central and South America.
- Fresh and brackish water.
- Pelvic fins posteriorly placed.
- Sinistral of dextral gonopodium in males and sinistral and dextral females
- a.o. *Anableps sp.* (four-eyed fish), each eye with two pupils.

Ordo Cyprinodontiformes, Fam. Cyprinodontidae (pupfishes)

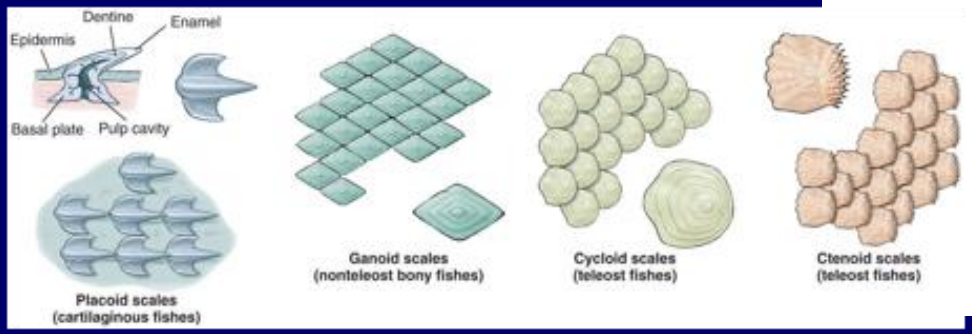
Cyprinodon diabolis

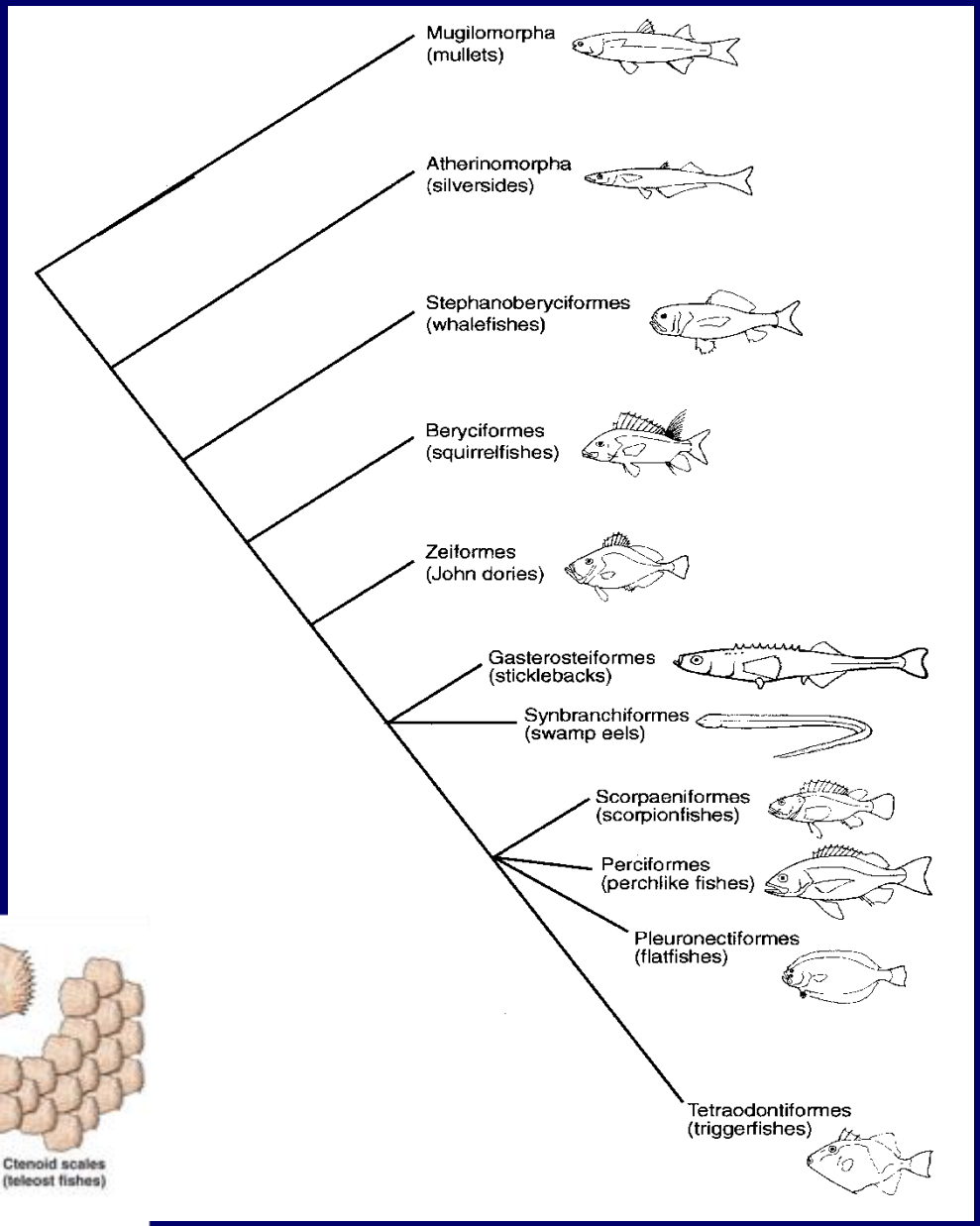
Cotton marsh, Death Valley

- Very disjunct distribution contrasting with monophyly.
- N. and C. America, northern S. America, N. Africa, Mediterranean coastal area.
- Fresh, brackish and sometime coastal marine waters.
- External fertilization.
- *Cyprinodon diabolis* (Devils Hole pupfish), smallest distribution, 20 m^2, 200 – 700 individuals.
- *Cyprinodon salinus*, hypersaline, Death Valley, California (4.6 x sea water, 0 to 40 ° C, daily variation up to 25 °C.

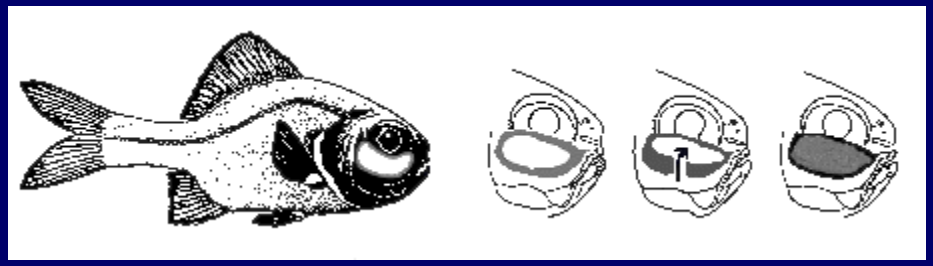
Series PERCOMORPHA

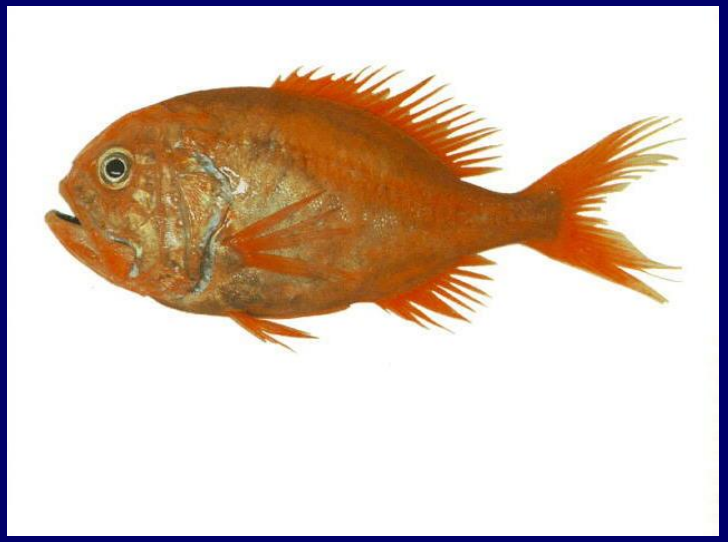
- Protrusible jaws.
- Mostly ctenoid scales.
- Mostly well-developed eyes.
- 9 ordos.
- > 13.173 species.





Ordo BERYCIFORMES

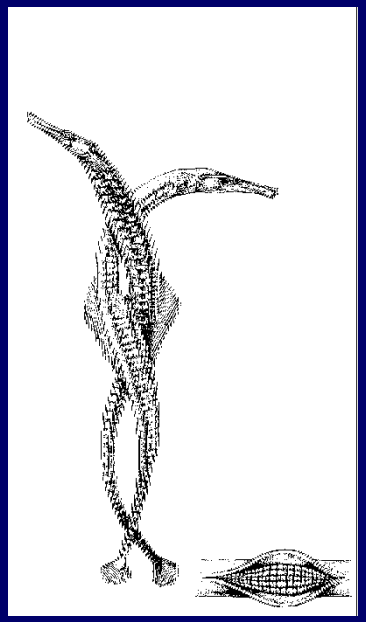




- Marine, some deepsea.
- Sturdy spines on head an operculum.
- Big eyes.
- Anomalopidae (flashlight fishes), subocular organ with symbiotic luminous bacteria, mechanic control via shutter mechanism; video
- *Hoplostethus atlanticus*, orange roughy, economically important but very vulnerable; 800-1500 m, one of most long-living teleosts (150 ?), slowly growing, late maturity, relative few eggs; after 10 years of fisheries already threatened.

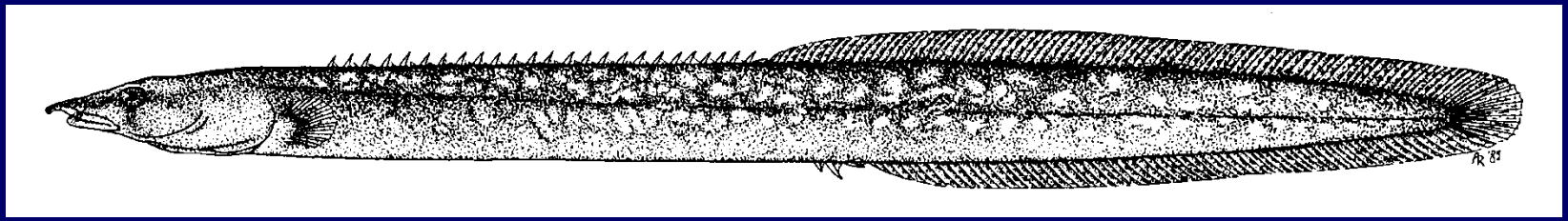
Ordo GASTEROSTEIFORMES
Fam. Syngnathidae (Pipefishes and seahorses)

Phycodurus eques: **seadragon**



- Body elongate and encased in a series of bony rings.
- Pelvic fins absent; other fins can also be absent.
- Males care for the eggs in special area in the undersurface of the trunk or the tail (sometimes pouch).
- Marine and freshwater.
- Usually confined to shallow water.

Ordo SYNBRANCHIFORMES
Fam. Mastacembelidae (spiny eels)

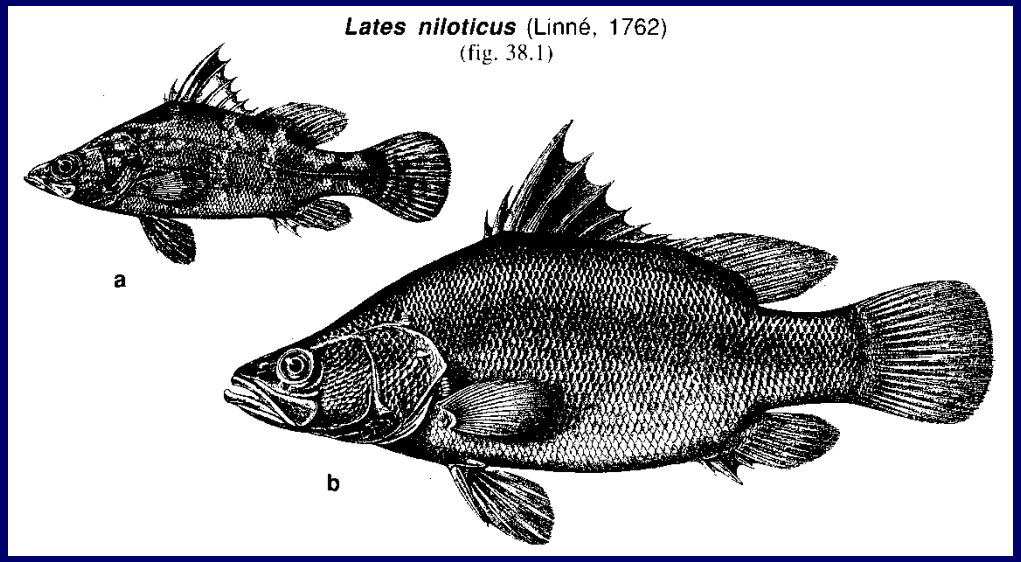


- Anguilliform.
- Spines (9-42).
- Pelvic fins and pelvic girdle absent.
- Fleshy rostral appendage.
- Usually small scales (naked in a few species).
- Freshwater (Africa and Southeast Asia).
- Max size: 0.9 m.

Ordo PERCIFORMES

- used to be largest order in Vertebrata with almost one third of all fishes
- now 62 families with ± 2.248 species
- not monophyletic?

Family Latidae



- Marine, brackish and freshwater.
- *Lates niloticus* (Nile perch) (Africa - freshwater).
- Introduction in Lake Victoria.
- Max size: 1.8 m.

Families Chaetodontidae (butterflyfishes & Pomacanthidae (angelfishes)

Chaetodon auriga

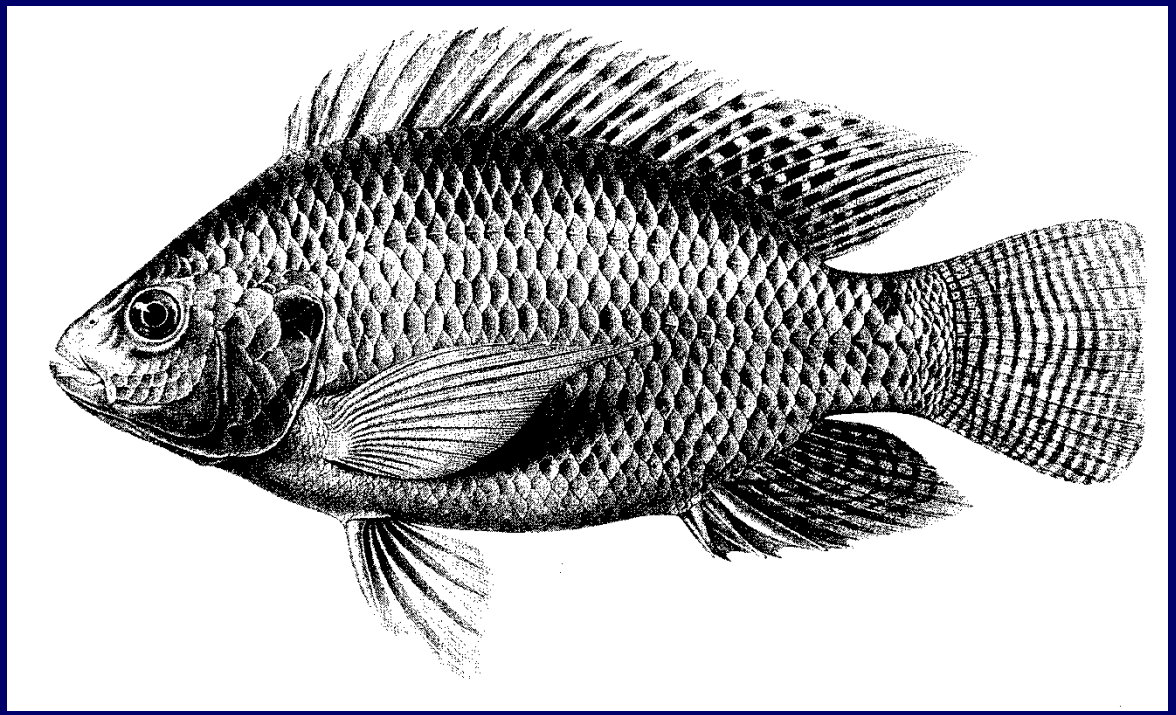
- Marine, coral reef fishes.

Pomacanthus sp.

Family Echeneidae (remoras or sharksuckers)

- Flattened head, prognathous lower jaw.
- Sucker disk (modified spiny dorsal fin).
- 10 - 28 transverse moveable lamina inside a fleshy margin.
- Max size: about 1 m.
- 8 widespread marine species.

Family Cichlidae



- One pair of nostrils.
- Lateral line divided in two parts (upper/lower).
- > 1.350 species (literature) + 1.000.
- Africa (*Oreochromis niloticus*, Nile tilapia) and Madagascar, C. and S. America, southern part of N. America, West Indies, Middle East, coastal India and Sri Lanka.
- Important in fisheries, fish culture and aquarium trade.

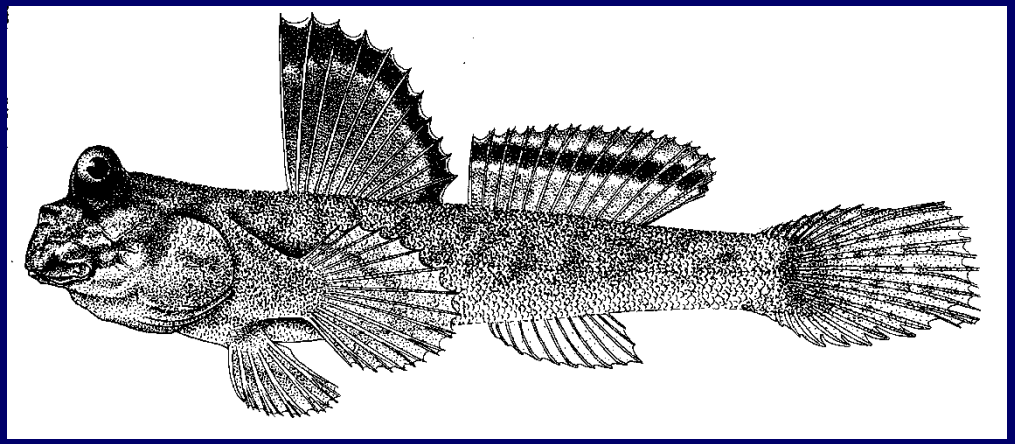
Fam. Cichlidae: trophic specialisations

Fam. Cichlidae: reproductive specialisations

Family Gobiidae (now in Gobiiformes)

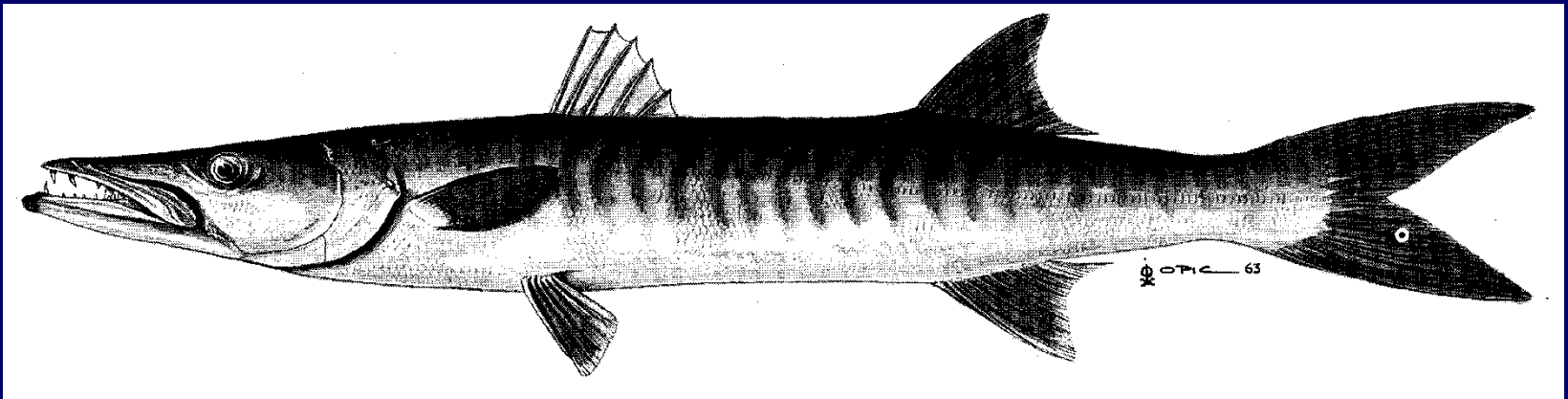
- pelvic fins close to each other, often fused (sucker)
- lateral line system limited to head (taxonomy) (exc. 1 genus)
- swimbladder mostly absent
- mostly marine; some freshwater
- largest family of marine fish (1359 species)
- *Pomatoschistus minutus* - coastal Atlantic Ocean

Family Gobiidae (gobies)



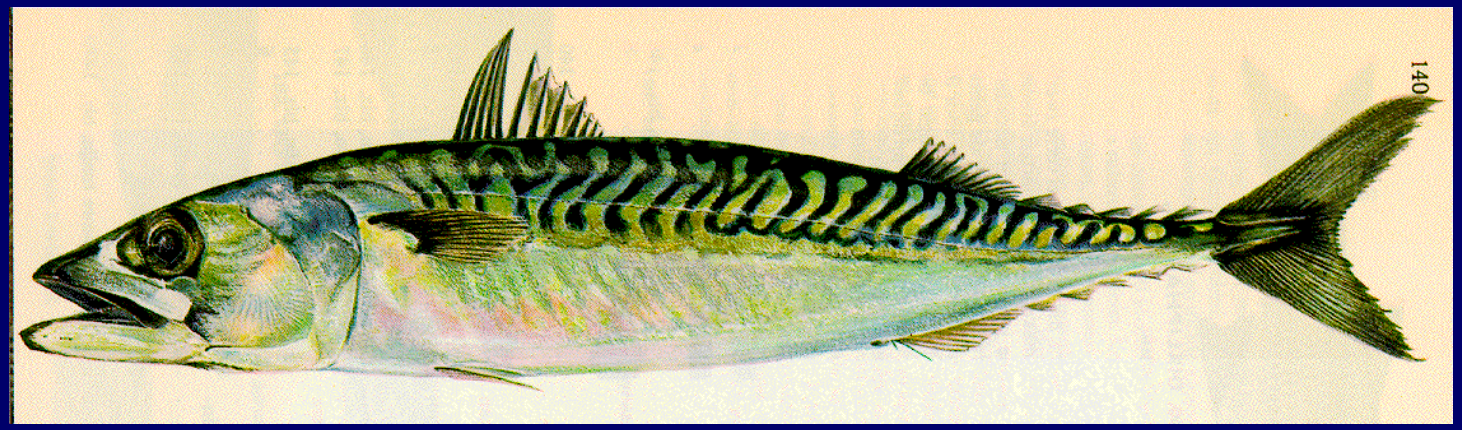
- Mudskippers, mangrovers, East-Atlantic & Indian Ocean coasts.
- Amphibian lifestyle, airbreathing (moistured gills and skin); can climb
- Periscopic eyes well adapted to vision in air.
- Often territorial, dig holes in mud.
- Algae and invertebrates eaters.
- *Periophthalmus barbarus*.

Subordo SCOMBROIDEI



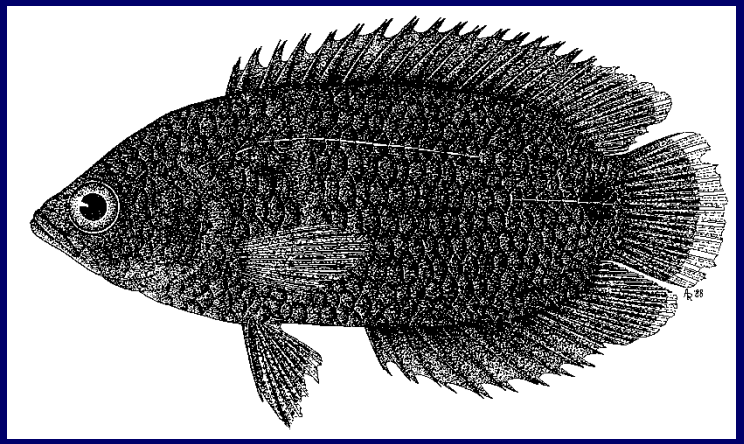
- Fast swimmers; pelagic; schools.
- Sailfish, swordfish, bluefin tuna between 60 - 100 km/h.
- Endothermy or cranial endothermy (brain and eyes) in some groups.
- *Sphyraena afra*, Sphyraenidae (barracudas), tropical and subtropical; some up to 2m.
- Large predators.

Subordo SCOMBROIDEI
Fam. Scombridae (mackerels and tunas)



- Economically important + popular sport fishes.
- Small dorsal finlets posterior to two dorsal fins (depressible into grooves).
- *Scomber scombrus* (mackerel) ± 50cm; Atlantic Ocean.
- *Thunnus thynnus* (tuna) up to 4.2 m, 500 kg.
- Marine (rarely freshwater).
- Pelagic, fast swimming, schools, surface swimmers.

Ordo Anabantiformes



- Suprabranchial organ = auxiliary breathing apparatus allowing to respire aerially and in water.
- In some species floating bubble nest guarded by male.
- Freshwater (Africa & southern Asia).
- a.o. climbing gouramies (Anabantidae) (Africa & Asia), *Ctenopoma sp.*: with two lateral lines and two pair of nostrils (difference with cichlids)

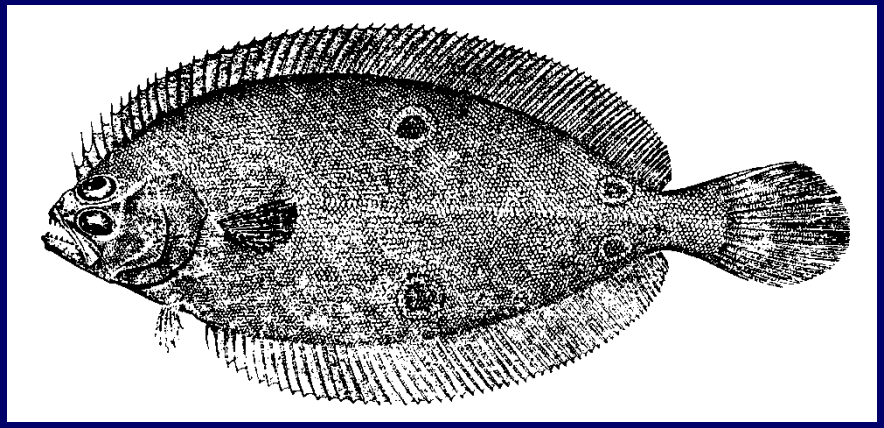
Ordo Anabantiformes

Trichogaster leeri

Betta splendens

Helostoma temmincki

Ordo PLEURONECTIFORMES (flatfishes)

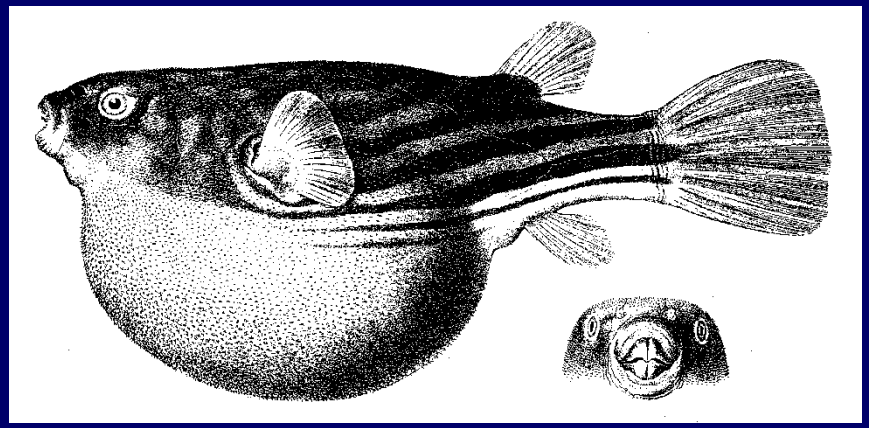


- Larvae bilateral symmetrical; adults asymmetrical (eyed side / blind side).
- Eyes sinistral or dextral, species specific; few species with intra specific variation.
- Benthic, carnivorous, marine (a few freshwater species).
- Swim bladder absent in most adults.
- Important in commercial fisheries and valued as food source.
- *Paralichthys oblongus*, fourspot flounder, Paralichthyidae.

Ordo TETRAODONTIDAE

- A bit a strange order because it harbours families that represent the opposite of most other streamlined and flexible evolved Acantopterygii.
- Slow swimmers, development of defence mechanisms.
- Fusion (maxilla and premaxilla) or loss of many bones on head and body.
- Pelvic fins often absent.
- Produce sound with teeth (jaw teeth or pharyngeal teeth) or with swim bladder (vibrations).
- Skin thick, leather-like covered with modified (spines / bony plates) scales.
- Food: sponges, sea-urchins, corals, invertebrates, plankton.
- Strong tooth-like jaw rims, jaws and muscles.
- Mostly marine.

Fam. Tetraodontidae (puffers)



- Often deadly toxine (tetraodotoxin) especially in viscera (none in the muscles).
- Four fused teeth in jaws (teeth in each jaws fused but separated by a median suture).
- Can inflate body though intake of water or air in ventral part of stomach.
- *Tetraodon* = only freshwater, primarily Congo River & southern Asia.

Family Molidae (ocean sunfishes)

- feeds on jellyfish
- no caudal peduncle nor caudal fin, pseudocaudal made of D & A fin rays
- 3 m long, 4,2 m high and 2300kg, $300*10^6$ eggs (probably most fecund fish)
- number of cartilaginous skeletal elements