Primitive Fishes

Origin of fishes

A. From What?
B. When?
C. How?
D. Where?

Fish evolved from primitive Chordates

Phylum Chordata characteristics:

1. Dorsal, hollow nerve chord

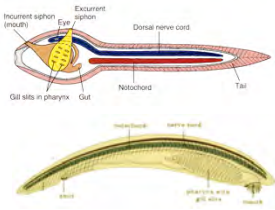
2. Notochord
   - flexible dorsal rod for support
   - present at some stage in all chordates (usually in embryonic development)
   - remnant present in adults of many fishes: sharks, rays, sturgeons

3. Pharyngeal gill slits
   - present in embryos of all vertebrates

Chordate subphyla:

OLD classification
- **Urochordata: tunicates**
- **Cephalochordata: lancelets**
- **Vertebrata: vertebrates**

NEW classification
- **Urochordata: tunicates**
- **Cephalochordata: lancelets**
- **Craniata: craniates**



How did fish evolve?

Neoteny = retention of larval features into the adult stage

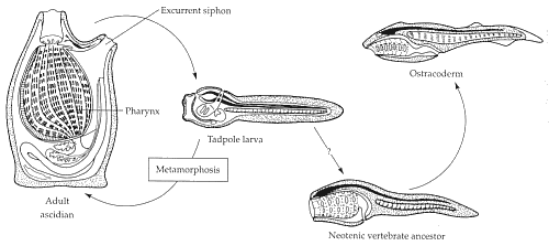
Stages:

1) ancestors (tunicates?) had:
   a) sessile adult stage
   b) free swimming larval stage for dispersal

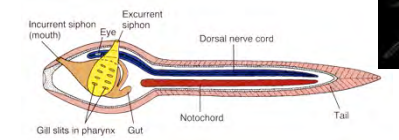
2) larval stage became more active; more vertebrate-like

3) eventually, larvae capable of reproduction evolved (= neoteny)

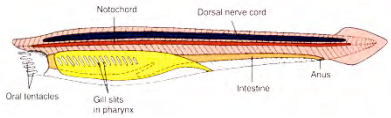
Garstang Hypothesis:
Tunicates gave rise to Cephalochordates (or directly to primitive fishes via neotony (paedogenesis)

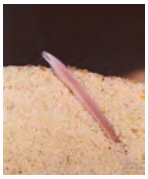


Ascidian “tadpole” larva



Lancelet (adult Cephalochordate)





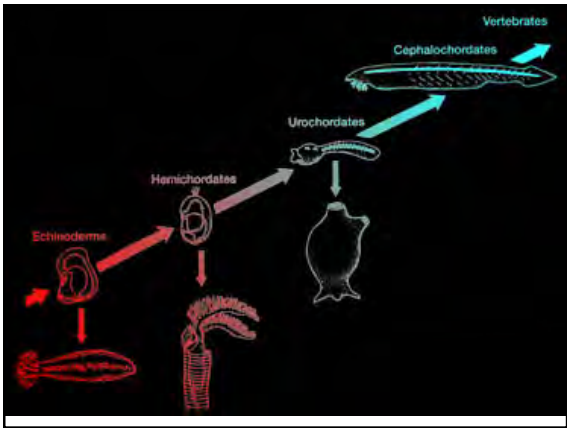
Lancelet (a cephalochordate)

Pharyngeal gill slits — Dorsal hollow nerve cord — Notochord

Ammocoete of lamprey (a fish)

How first fishes may have evolved from primitive chordate ancestors

- first fish
- lancelet
- proto-vertebrate, development of a cranium
- adult with tunicate larval features
- adult tunicate



When did fish first evolve?

- Chordates date from early to mid Cambrian (544 mya)
- first good craniate fossils - late Cambrian/Ordovician (500 mya)
- BUT these first fossil bones were of external armor, characteristic of early jawless fishes (no internal bones)
- so, vertebrates probably originated during the **early Cambrian explosion (600 mya)**

Earliest accepted chordate

Pikaia gracilens - Middle Cambrian Burgess shale

Where did fish evolve?

Generally believed to be in ocean because:

- is the habitat of other chordates
- marine deposits contain most early vertebrate fossils

Characteristics of fishes (& other craniates)

Subphylum **Craniata**

Characteristics:

1. distinct cranium: skull with brain
2. notochord does not extend forward of brain
3. cartilage or bone present
4. brain well developed
5. chambered heart

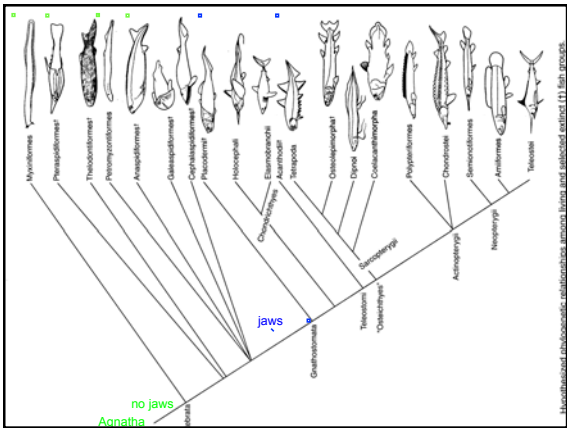
Two **superclasses** within Craniata:

- **Agnatha** – jawless (="no jaw")
- **Gnathostomata** – jawed fishes (="jaw mouth")

only two living groups of Agnathans:

- Myxini (hagfishes)
- Petromyzontida (lampreys)

all other Craniates are Gnathostomes



Jawless Fishes

Subphylum Craniata
Superclass Agnatha
Class Myxini
Order Myxiniformes - hagfish
Class Petromyzontida
Order Petromyzontiformes - lamprey
"Group" Ostracoderms - *Extinct*

1) first jawless fishes were Ostracoderms ("shell skin")
- artificial designation - not a monophyletic group
- **now extinct**

2) two main classes of Ostracoderms:
- Class Cephalaspidomorphi = ancestor to lamprey
- Class Pteraspidomorphi = ancestor to hagfish?

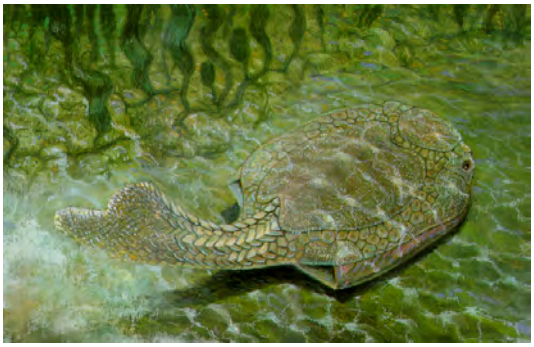
Ostracoderms ("shell skin")

1) Characteristics
   a) first fossils have well developed external bone, no internal bone: Cambrian (500 mya)
   b) dominant for 100 my (gone by 380 mya)
   c) first fossils: marine; later marine and freshwater

2) Features
   a) no jaw, muscular feeding pump (filter feeders)
   b) body armor - true bone
   c) some had paired fin-like appendages, but not true fins with bony support
   d) heterocercal tail

Hemiclaspis, a cephalaspid

Drepanaspis, a heterostracan ostracoderm (about 400 mya)



Phebolepis, a thelodont ostracoderm (about 410 mya)
- small, had scales instead of bony plates

Ostracoderms

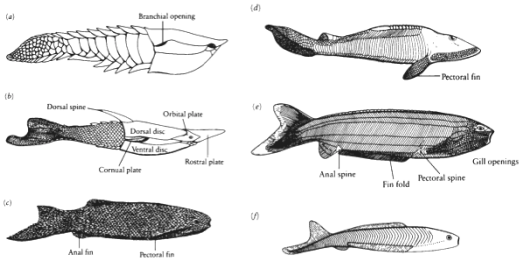
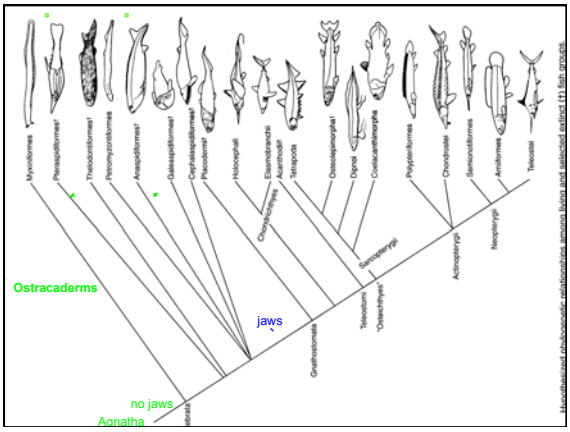


FIGURE 3. Representative ostracoderms. (a) *Anglaspis*; (b) *Pteraspis*; (c) *Phlebolepis*; (d) *Hemicyclaspis*; (e) *Pharyngolepis*; (f) *Jamoytius*. (From Moy-Thomas, J. A. and Miles, R. S., *Palaeozoic Fishes*, 2nd ed., Chapman and Hall, London, 1971. With permission.)



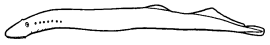
LIVING AGNATHANS:

I. Agnathans (Superclass Agnatha) (jawless fishes)

Hagfishes

Class Myxini (refers to copious amounts of "slime");
Order Myxiniformes

Lampreys



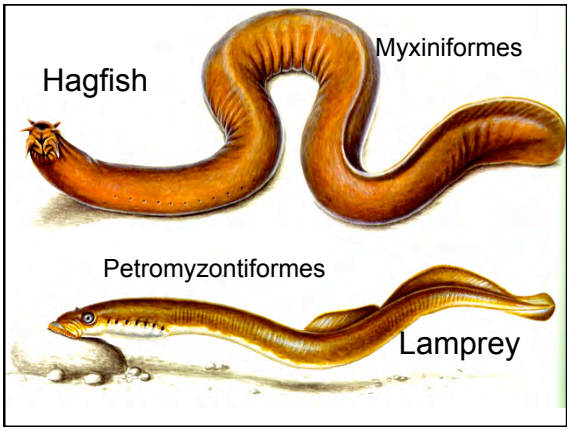
Class Petromyzontida
Order Petromyzontiformes - "stone mouth"

Living Jawless Fishes (Agnathans)

Hagfish - Myxiniformes

First fossils of lampreys and hagfish appeared *after* most modern fishes and even tetrapods

Lamprey - Petromyzontiformes



Characteristics of both hagfish and lampreys

a) jawless

b) single gonad

c) skeleton cartilaginous or fibrous (no vertebrae)

d) no paired fins

e) no body armor

f) single median nostril

g) series of round gill openings, no true gill arches

Comparison of Agnathan characteristics

Character	Ostracoderms	hagfishes	lampreys
mouth	sucking, no teeth	teeth on tongue	teeth on oral disk & tongue
vertebrae	yes	no	no
armor	yes (true bone)	no scales	no scales
paired fins	not true fins	no	no
eyes	yes	rudimentary	yes
mucous	?	copious	no
reproduction	?	direct	larvae

Hagfishes

Myxinidae; ~ 70 spp.

Phylum: Chordata
"Superclass Agnatha"
Class Myxini
Order Myxiniformes

Hagfishes – interesting features

- SLIME! -- a 50 cm hagfish can fill 8 liter bucket in minutes
- scavengers
- ties in knots to feed and rid self of mucus
- degenerate eyes
- teeth only on tongue
- barbels
- cutaneous & gill respiration

Hagfish produce large eggs and are direct developers (no larval phase)

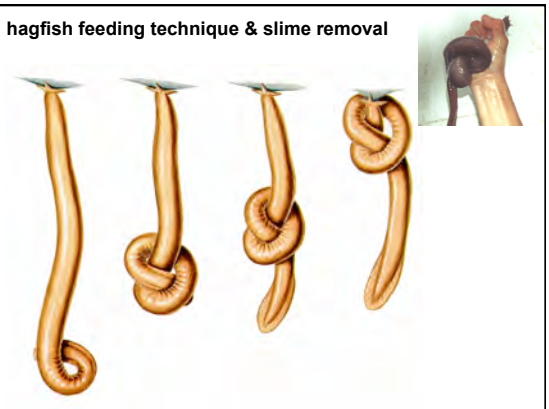
Line of mucous glands along ventral surface

Hagfish mucous is composed of proteins and carbohydrates that bind to water

What is the slime for?

- suffocate prey fishes?
- protection from digestive enzymes?
- discourage other scavengers?
- secure burrow walls?
- defense from predators?

hagfish feeding technique & slime removal



representative species with a great name:

Myxine glutinosa (Atlantic hagfish)

- Myxini = slime
- glutinosa = glutinous or gluey

What can you do with a hagfish?

hagfish are important scavengers

hagfish are food

Lampreys ~ 38 spp.

Phylum: Chordata
"Superclass" Agnatha
Class Petromyzontida
Order: Petromyzontiformes

Hagfishes vs. Lampreys

Similarities:

Character	Hagfishes	Lampreys
notochord	YES	YES
lingual teeth	YES	YES
single nostril	YES	YES
jaws	NO	NO
vertebrae	NO	NO
paired fins	NO	NO
eel-like body	YES	YES

Differences:

Character	Hagfishes	Lampreys
functional eyes	NO	YES
dorsal fins	NO	YES
# semicircular canals	1	2
parasitic	NO	YES

Lamprey – interesting features

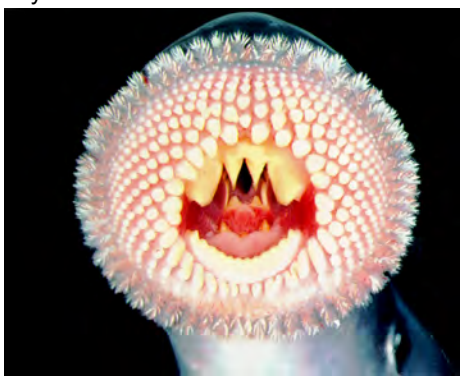
a) oral disk in adults, with horny teeth on disk and tongue

b) two types: freshwater or anadromous

-- anadromous (migratory) and **parasitic**
- larvae stay in streams for 4+ yrs
- adults migrate to ocean or lake, mature and feed (as parasites) for 2 years

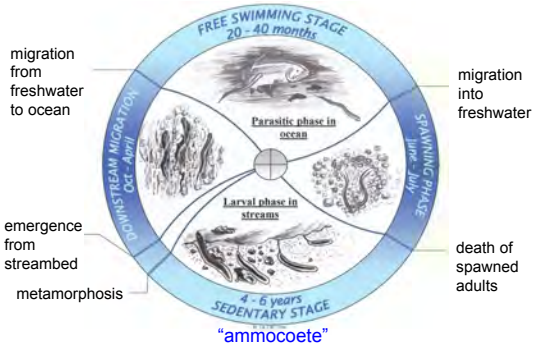
-- freshwater (non-migratory) and **non-parasitic**
- adults also stay in streams
- larval stage 6 yrs
- non-feeding adult for 6 months

lamprey oral disk



lamprey life cycle

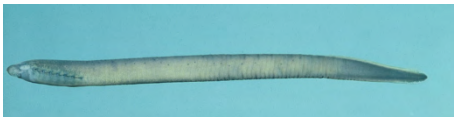
Lampetra tridentata (Pacific lamprey)



"ammocoete"

- convergence with salmon

Larval Lampreys (Ammocoetes)



- no teeth, mouth surrounded by an oral hood
- blind
- filter-feeders that capture particles with mucus
- extended larval period
- like lancelets (Amphioxiforms)

Note: not recognized as lampreys for a long time

Lampetra tridentata (Pacific lamprey)

pit nest

Lampetra tridentata (Pacific lamprey)

spawning act

male squeezes eggs out of female

- isolating mechanism between species pairs? (size differences)
- group spawning in non-parasitic species

http://www.realmonstrosities.com/2013/05/lamprey.html

Ecology: invasion of Great Lakes by a fish parasite:

Petromyzon marinus (sea lamprey)

- invaded Great Lakes
- decimated fish populations
  - up to 56% mortality of lake trout
  - up to 75% mortality of whitefish

Sea Lamprey Control Methods

Migration Barriers & Traps

TFM (Larval Lampricide)

Sterile Males
(bisazir)

Sister species in lampreys:

- parasitic form (large adult)
- free-living form (small adult)

➢ evolved independently many times in different groups of lampreys (parallel evolution)

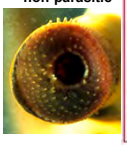
Lampetra aepyptera (least brook lamprey)

Paired (sister) or Satellite Species

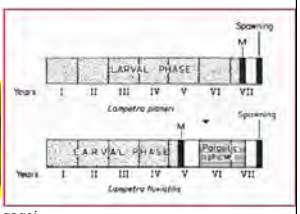
parasitic

Ichthyomyzon castaneus
(chestnut lamprey)

non-parasitic



Ichthyomyzon gagei
(southern brook lamprey)



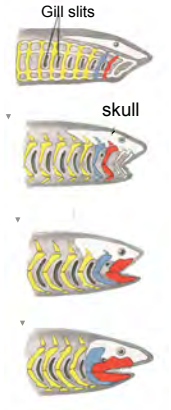
Gnathostomata: jawed fishes

Next big advancement....JAWS

"Perhaps the greatest of all advances in vertebrate history was the development of jaws and the consequent revolution in the mode of life of early fishes"

- Romer 1962

Jaws evolved from modified gill arches



this is still a hypothesis: no intermediate fossils have been found

- red: mandibular arch
  blue: hyoid arch

Gnathostomes diverged from Agnathans soon after fishes first evolved

Evolutionary advantages of jaws:

- manipulate food (e.g., cut, grind, and crush; allows addition of new items to diet)
- use for defense
- manipulate non-food items (aid in nest building)

5 classes of Gnathostomes:

Phylum Chordata
Subphylum Craniata
Subphylum Craniata
Superclass Gnathostomata

extinct	Class Placodermi	"plate skin"
	Class **Chondrichthyes**	"cartilage fish"
extinct	Class Acanthodii	"stout spine"
	Class **Sarcopterygii**	"flesh fin"
	Class **Actinopterygii**	"ray fin"

- **all Gnathostomes are a monophyletic group**
- **all share:**
  - jaws
  - two sets of paired fins
  - three semi-circular canals in their inner ears

Class Acanthodii ("stout spined") spiny sharks

- first jawed fishes in fossil record
- from 450 mya until 280 mya
- first marine, then invaded freshwater

Acanthodi features

- stout median and paired spines (rows down ventral surface)
- cartilaginous skeleton
- large head and large eyes
- small and minnow-like
- ganoid scales
- true teeth on jaws
- strong swimmers: up in water column (pelagic); not benthic like ostracoderms and most placoderms
- unclear if more closely related to modern bony fishes or sharks (but closer to them than placoderms are)

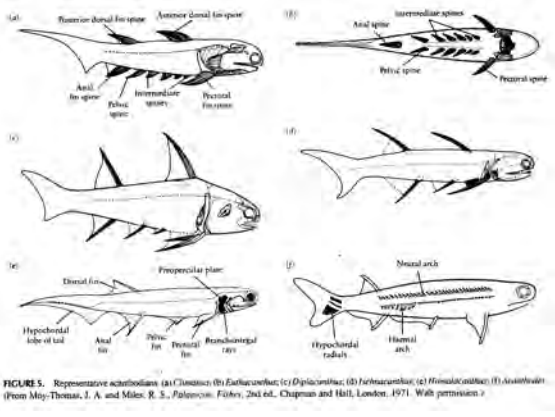


FIGURE 5. Representative acanthodians (a) Climatius; (b) Euthacanthus; (c) Diplacanthus; (d) Ischnacanthus; (e) Homalacanthus; (f) Acanthodes (From Moy-Thomas, J. A. and Miles, R. S., Paleozoic Fishes, 2nd ed., Chapman and Hall, London, 1971. With permission.)

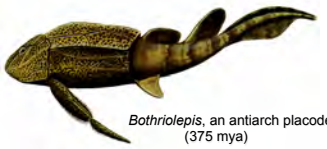
Placodermi (“plate skinned”)

- first fossils from late Silurian (420 mya), dominated in late Devonian (400mya)
- first in marine, then freshwater
- died out 280 mya

arthrodire placoderm
375 mya

Placoderm features

- jaws but no ability to extrude them
- no teeth replacement, and teeth structure different from derived fishes (just bony plates)
- bony armor (plate-like)
- true paired fins, but no anal fin
- some very large (10 m)



Bothriolepis, an antiarch placoderm
(375 mya)

Dunkleosteus, a giant arthrodire placoderm

375 mya, up to 6 m in length