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)

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)
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 Plastraspidomorphi = 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

Drepanaspis, a heterostracan ostracoderm (about 400 mya)

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

Ostracoderms

LIVING AGNATHANS:

I. Agnathans (Superclass Agnatha) (jawless fishes)

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

   Lampreys
   - Class Petromyzontida
     Order Petromyzoniformes - "stone mouth"
Hagfishes
Myxinidae; ~ 70 spp.

Phylum: Chordata
“Superclass Agnatha”
Class Myxini
Order Myxiniformes

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

<table>
<thead>
<tr>
<th>Character</th>
<th>Ostracoderms</th>
<th>Agnathan</th>
<th>Lampreys</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouth</td>
<td>sucking, no</td>
<td>teeth on</td>
<td>teeth on oral disk &amp; tongue</td>
</tr>
<tr>
<td></td>
<td>teeth</td>
<td>tongue</td>
<td></td>
</tr>
<tr>
<td>vertebrae</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>armor</td>
<td>yes (true bone)</td>
<td>no scales</td>
<td>no scales</td>
</tr>
<tr>
<td>paired fins</td>
<td>not true fins</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>eyes</td>
<td>yes</td>
<td>rudimentary</td>
<td>yes</td>
</tr>
<tr>
<td>mucous</td>
<td>?</td>
<td>copious</td>
<td>no</td>
</tr>
<tr>
<td>reproduction</td>
<td>?</td>
<td>direct</td>
<td>larvae</td>
</tr>
</tbody>
</table>

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?

representative species with a great name:
Myxine glutinosa (Atlantic hagfish)
- Myxine = slime
- glutinosa = glutinous or gluey

hagfish feeding technique & slime removal
**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

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**Hagfishes vs. Lampreys**

**Similarities:**

<table>
<thead>
<tr>
<th>Character</th>
<th>Hagfishes</th>
<th>Lampreys</th>
</tr>
</thead>
<tbody>
<tr>
<td>notochord</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>lingual teeth</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>single nostril</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>jaws</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>vertebrae</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>paired fins</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>eel-like body</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

**Differences:**

<table>
<thead>
<tr>
<th>Character</th>
<th>Hagfishes</th>
<th>Lampreys</th>
</tr>
</thead>
<tbody>
<tr>
<td>functional eyes</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>dorsal fins</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td># semicircular canals</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>parasitic</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

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**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

Larval Lampreys (Ammocoetes)

Lampetra tridentata (Pacific lamprey)

Lampetra tridentata (Pacific lamprey)

http://www.realmonstrosities.com/2013/05/lamprey.html
Petromyzon marinus (sea lamprey)

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

Ecology: invasion of Great Lakes by a fish parasite:

Sea Lamprey Control Methods

- TFM (Larval Lampricide)
- Migration Barriers & Traps
- 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)

Paired (sister) or Satellite Species

- Ichthyomyzon gagei (southern brook lamprey)
- Ichthyomyzon casalineus (chestnut lamprey)

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

Gnathostomata: jawed fishes
Jaws evolved from modified gill arches

Gill slits

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
- Superclass Gnathostomata

extinct Class Placodermi "plate skin"
extinct Class Chondrichthyes "cartilage fish"
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)
Placodermi (“plate skinned”)

• First fossils from late Silurian (420 mya), dominated in late Devonian (400 mya)
• First in marine, then freshwater
• Died out 280 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)

Dunkleosteus, a giant arthrodire placoderm

375 mya, up to 6 m in length

Bothriolepis, an antiarch placoderm (375 mya)