Chapter 1

Origin of Chordates and Vertebrates

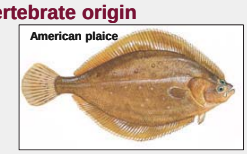
1.1 Introduction

1.2 Relationships between echinoderms, hemichordata and chordata

1.3 Hemichordata

1.4 Phylogeny of Chordata

1.5 Evolutionary scenarios of vertebrate origin



Objectives

- **Origin of vertebrates**
- **Factors associated with Chordate diversity.**
- **Phylogenetic perspective and evolutionary scenarios**

Lacerta agilis **(sand lizard)**

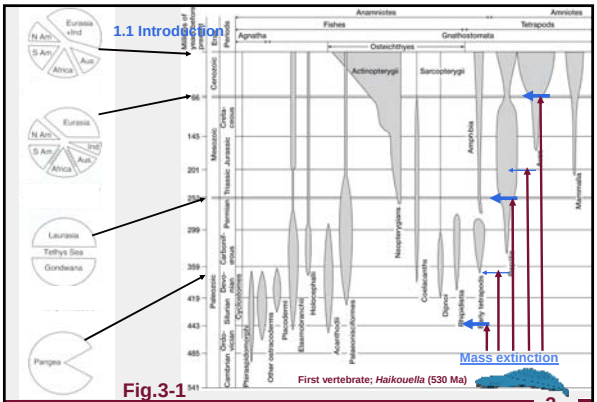
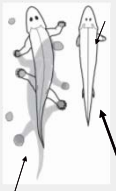


Fig.3-1

Tetrapod origin

Niedzwiedzki et al. 2010. Tetrapod tracks from the early Devonian period of Poland. Nature vol 473: 43-48. (January 7th 2010)



First tetrapods

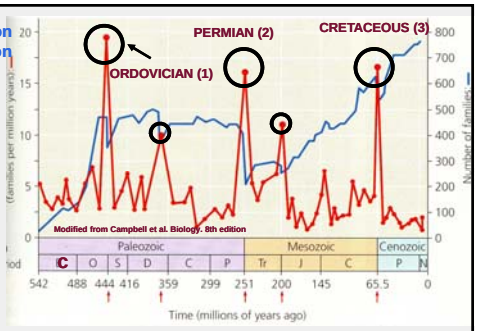
375 Ma

Fish closely related to tetrapods

Panderichthys 385 Ma

Ichthyostega 360 Ma

1.1 Introduction
Mass extinction



- Mass extinctions: 5; with three major ones a short geological time-scale
- Probable causes: 1. Ordovician: intense and sudden _____.

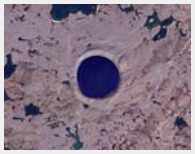
2. Permian: volcanic activity in Siberia; 3. Cretaceous: asteroid impact.

1.1 Introduction

Canadian craters:

- Manicouagan (210 Ma)
  - Asteroid (5 km diam.)
  - Crater 100km Diam. 100 km (62 KM visible)

- Pingualuit (Quebec Crater) (1,4 Ma)
  - Diameter 3,44 km
  - Depth 270m



http://en.wikipedia.org/wiki/List_of_impact_craters_in_North_America#Canada

1.1 Introduction

- Cambrian explosion (542-520Ma): multiplication of life forms in oceans

Key innovations :

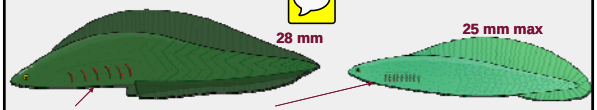
and skeletal body support

1.1 Introduction

Chen, 2009.The sudden appearance of diverse animal body plans during the Cambrian explosion. Int. J. Dev. Biol. 53: 733-751

40 mm max

Haikouella (530 Ma) First vertebrate?



28 mm

25 mm max

Myllokunmingia ou Haikouichthys (530 Ma) Amongst the first vertebrates with a cranium (with auditory and ocular capsules)

1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia

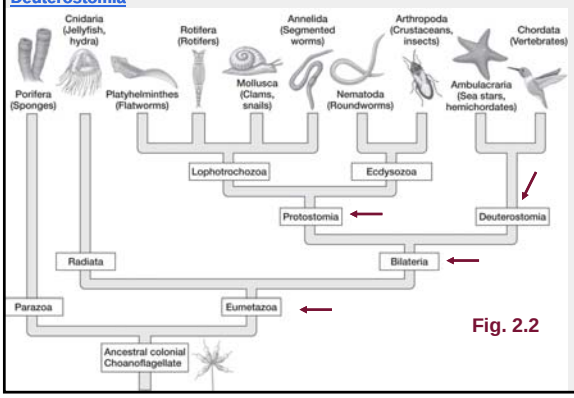


Fig. 2.2

1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia

CLASSIFICATION (Kardong, 2015)

Phylum Ambulacaria
- **Sub-phylum Echinoderms**
- **Sous-phylum Hemichordates***

Phylum Chordates
- **Sous-phylum Cephalochordates***
- **Sous-phylum Urochordates***
- **Sous-phylum Vertebrates**

Traditional view

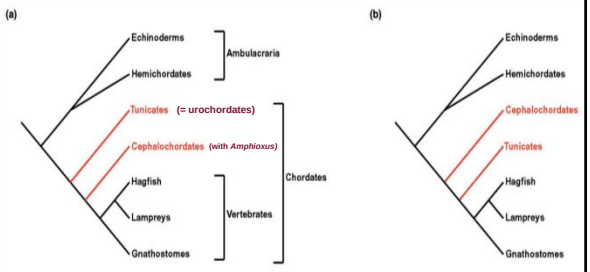
Phylum Chordates
- **Sub-phylum Urochordates***
- **Sub-phylum Cephalochordates***
- **Sub-phylum Vertebrates**

_____ group: group that includes all and only the descendants from a common ancestor (group defined on the basis of derived characters).

*** Protochordates : paraphyletic group (does not include all and only the descendants from a common ancestor).**

(Mainly in chapter 2)

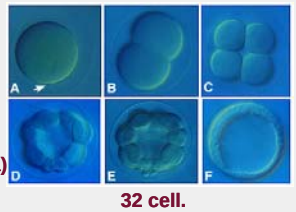
1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia



Schubert et al. 2006. TRENDS in Ecology and Evolution Vol.21 No.5 May 2006

1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia

1 cell. 2 cell. 8 cell.



16 cell. (morula)

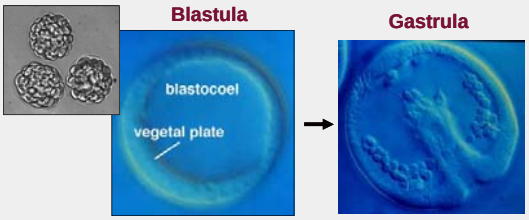
blastula

32 cell.

- **The unicellular _____ becomes a multicellular embryon**
- **Morula-->blastula --> gastrula**

http://worms.zoology.wisc.edu/urchins/SUcleavage_stages.html

1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia



- The blastula (with blastocoel) becomes a gastrula with differentiating tissues [germ layers and body cavity (_____)]

1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia

Protostomes
Molluscs
Annelids
Arthropods

Deutérostomes
Echinoderms
Hemichordates
Chordates

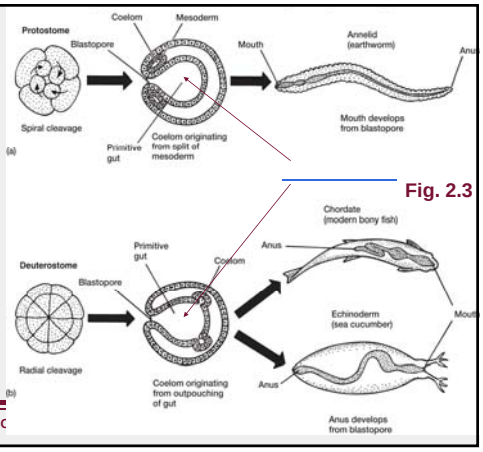


Fig. 2.3

1.2 Relationships between echinoderms, hemicordates et chordates : deuterostomia

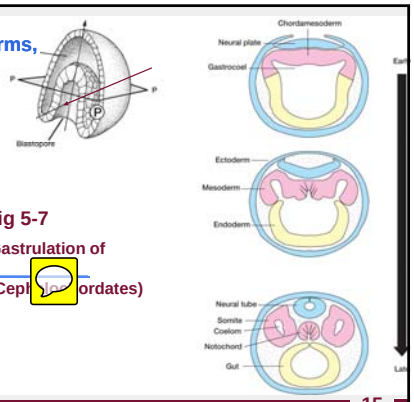
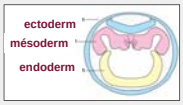


Fig 5-7

- Gastrulation of _____ (Cephalochordates)

1.2 Relationships between echinoderms, hemicordates et chordates : deuterostomia

- **Ectoderm:**
  - _____ of skin and its derivatives
  - Nervous and sensory systems
  - Jaws and teeth
  - Some glands
  - Germ cells
- **Mesoderm**
  - Skeletal and muscular systems
  - Circulatory and lymphatic system
  - Excretory and reproductive systems
  - Dermis of skin
  - Some glands
- **Endoderm**
  - Epithelial lining of digestive tract and associated organs (liver, pancreas)
  - Epithelial lining of respiratory, excretory, and reproductive tracts and ducts
  - Some glands



1.2 Relationships between echinoderms, hemicordates et chordates : Deuterostomia

- **Conclusion**
  - Echinoderms, hemichordata and chordata are deuterostomes. Thus, they share the following derived characters:
    - Radial, _____ cleavage
    - Folds of archenteron forms coelom
    - Anus develops from blastopore

1.3 Hémichordata

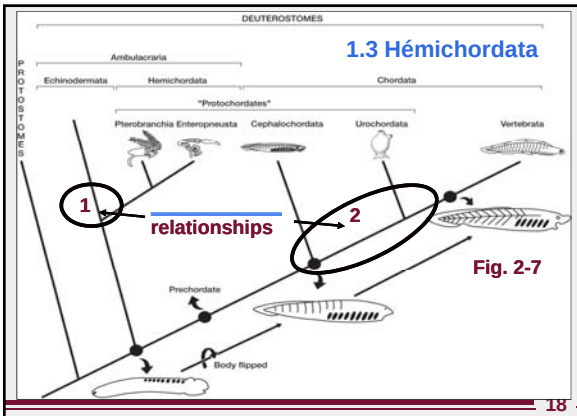
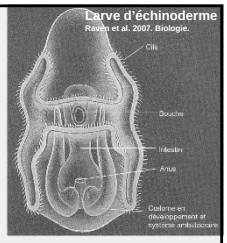


Fig. 2-7

1.3 Hemichordates

ECHINODERMS

- Starfish and other echinoderms are marine animals that are sessile or slow moving.
- Adults have a radial body form but the larvae shows a _____



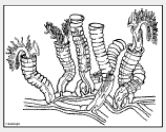
Starfish

Sea urchins

Brittle star

1.3 Hemichordates

Hemicordates (Ptérobranchs): Small colonial animals (first appeared 525 Ma)



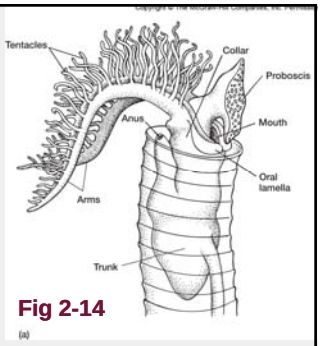


Fig 2-14

Some pharyngeal _____ are present on some species.

1.3 Hemichordates

Hemichordates enteropneusts: pharyngeal or branchial _____ present.

(Acorn worms; 90 species)

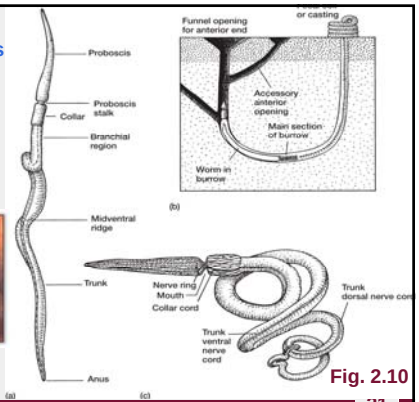


Fig. 2.10

1.3 Hemichordata

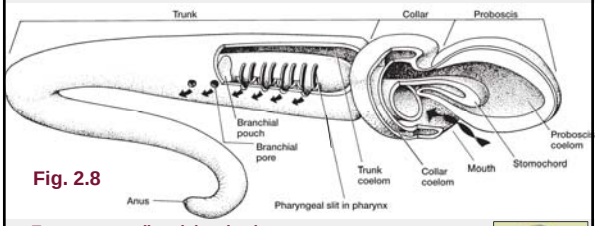
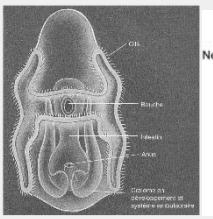


Fig. 2.8

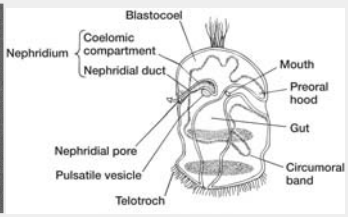
- Enteropneust (hemichordata):
  - _____ is analogous (not homologous) to notochord
  - Pharyngeal (or branchial) slits with pores present.

1.3 Hemichordata

Echinoderm larvae



Hemichordate larvae



- General similarities between the echinoderm larvae and the hemichordate larvae : bilatéral, _____, rows of cilium on surface

1.3 Hemichordata

- _____ fossils
- 505 to 535 Ma
- Small bilateral fossils with external plates imbricated (carbonate de calcium).

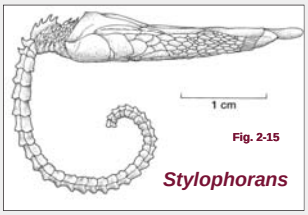


Fig. 2-15

Stylophorans

1.3 Hemichordata

Conclusion:

- Hemicordates and Echinoderms are monophyletic (Ambulacraria) (_____+ larval morphology)
- Pharyngeal slits would be the result of convergence in Hemichordata and Chordata.

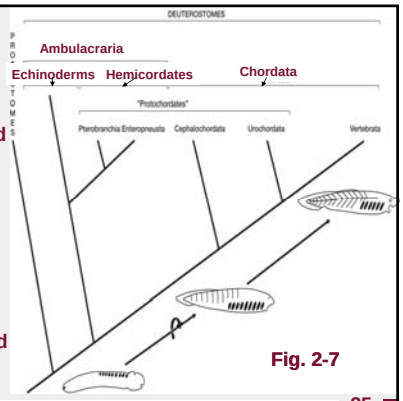
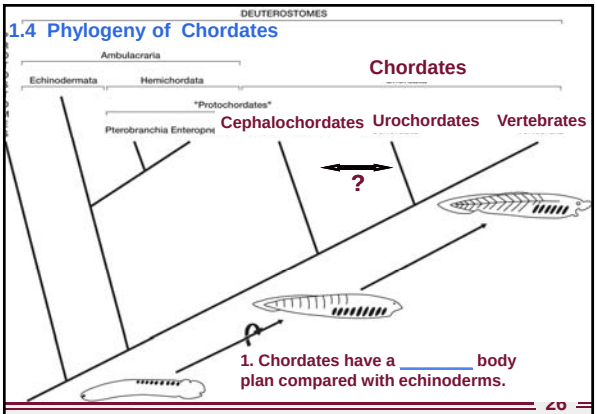


Fig. 2-7

1.4 Phylogeny of Chordates



1. Chordates have a _____ body plan compared with echinoderms.

1.4 Phylogeny of Chordates

Character 1: a _____ body plan
Character 2: notochord
Character 3: dorsal nerve tube (hollow)

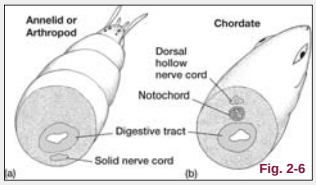


Fig. 2-6

1.4 Phylogeny of Chordates

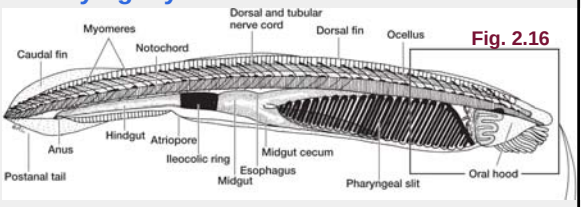
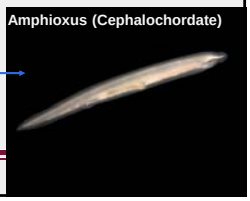


Fig. 2.16

- **Derived characters of Chordates**
  - Char. 4: post-anal tail,
  - Char. 5: metamerisation of body



1.4 Phylogeny of Chordates

Char. 6: _____ (homologous to thyroid gland) (ciliated structure)

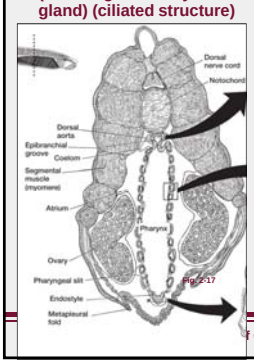
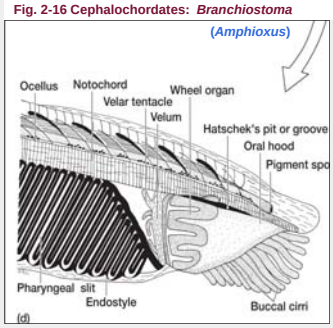


Fig. 2-16 Cephalochordates: *Branchiostoma* (*Amphioxus*)

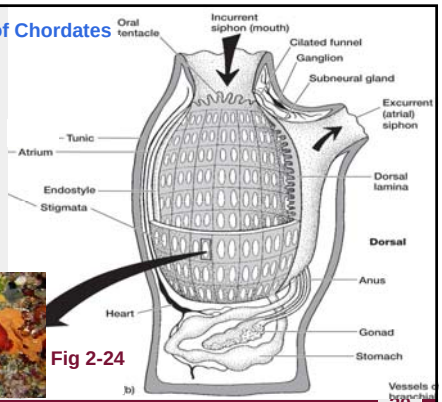


1.4 Phylogeny of Chordates

UROCHORDATES

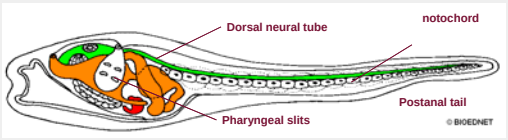
Adult ascidians (_____): sess[illegible]arine found in shallow waters

Fig 2-24



1.4 Phylogeny of Chordates

Presence of metameres (myomeres)
Inversed body plan compared Echin. + Hemich.

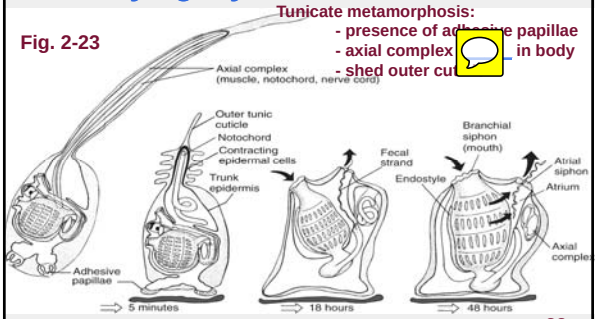


- **Ascidian larva**
  - Tadpole shape and mobile
  - Shows chordates _____ characters.

1.4 Phylogeny of Chordates

Fig. 2-23

Tunicate metamorphosis:
- presence of adhesive papillae
- axial complex _____ in body
- shed outer cu_____



1.4 Phylogeny of Chordates

Two conflicting hypotheses of relationships

- **Cephalochordates (*Amphioxus*) share with vertebrates:**
  - well- defined myomeres (metameres)
  - Glandular intestinal caecum (precursor of _____)
- **Urochordates (Tunicates) share with vertebrates:**
  - Molecular data
  - Migrating cells from the neural crest.

1.4 Phylogeny of Chordates

- _____ originate from the dorsal region of the neural tube of urochordates and vertebrate embryos
- They migrate through the embryo to a predetermined destination.

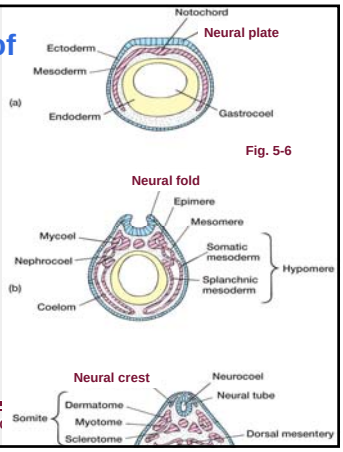
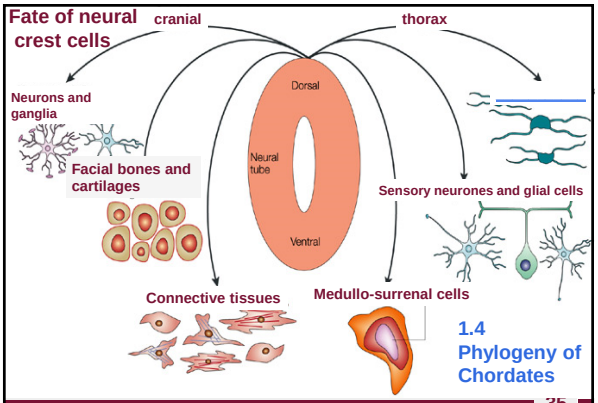


Fig. 5-6

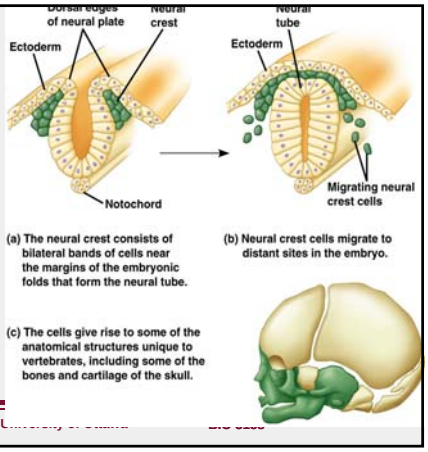


1.4 Phylogeny of Chordates

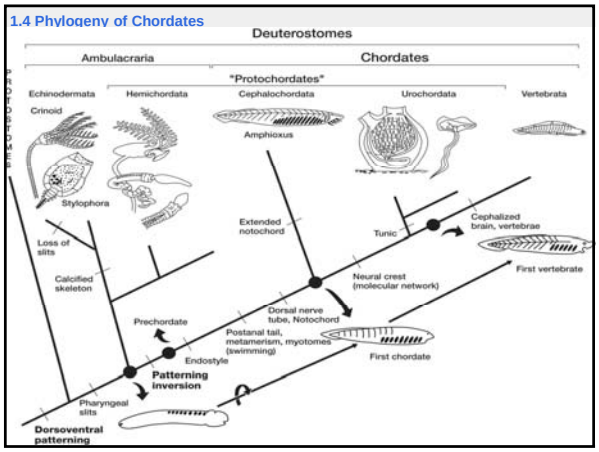
Nature Reviews Genetics 3, 453-461 (June 2002)

1.4 Phylogeny of Chordates

- Example of migrating neural crest cells (NCC)
- In Urochordates, the only NCC identified to date are for the production of _____
- Other types of migrating cells are derived characters of vertebrates

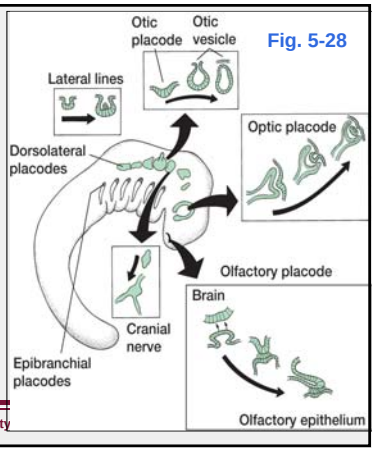


1.4 Phylogeny of Chordates

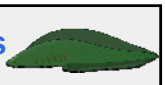


1.4 Phylogeny of Chordates

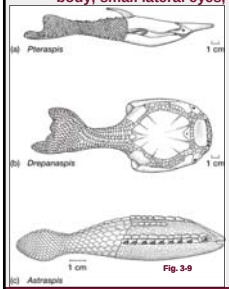
- Ectodermic (derived charact vertebrates):
  - Thickening of surface ectoderm
  - Often linked with cells of the neural crest.
    (will form sensory organs)

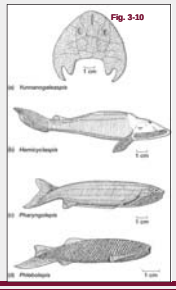


1.4 Phylogeny of Chordates



- First well-known vertebrates fossils (530 Myr)
- Filter-feeding, without jaws, often body shield on anterior part of body, small lateral eyes, lateral stabilizers.



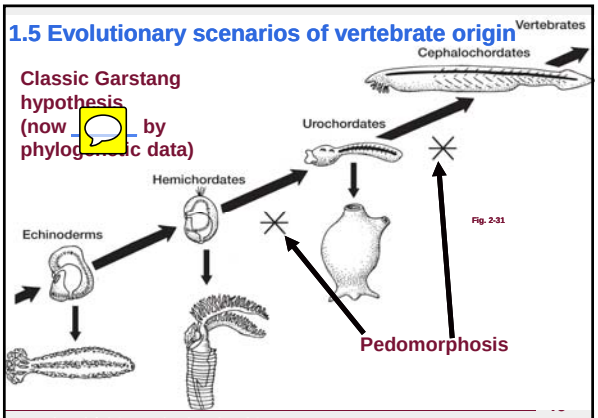


(fossil ja les) vertebra

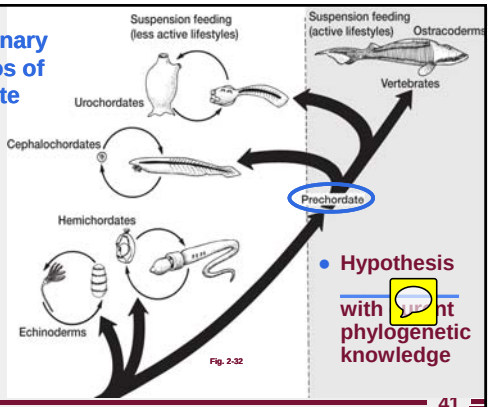
Only living species (Agnathans): lampreys and hagfishes

1.5 Evolutionary scenarios of vertebrate origin

Classic Garstang hypothesis (now _____ by phylog[illegible]c data)



1.5 Evolutionary scenarios of vertebrate origin



- Hypothesis with [illegible]nt phylogenetic knowledge

1.5 Evolutionary scenarios of vertebrate origin

- Origin of vertebrates:
  - Muscular pump requi[illegible] evolution o[illegible] structures:
    - Muscles bands in pharynx
    - Pharynx made of flexible tissues
  - Gill evolution to sustain a more active life-style.
  - Pump has feeding and respiratory functions.