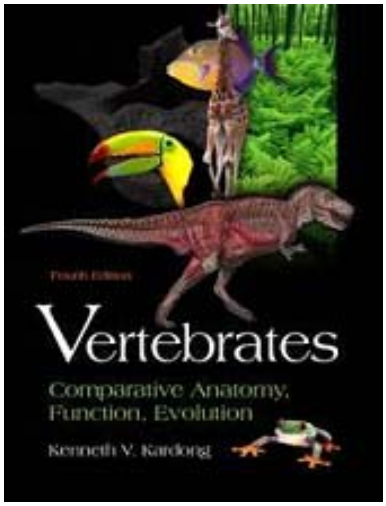


Protochordate Phylogeny

Follow up in Textbook: Chapter 2

A. Objective:

Identify the key characters of representative protochordate animals to complete a character-state table for them. Then use these distinctive features to chart the major evolutionary steps of character changes in protochordate evolution.

B. Textbook Reference:

Pages 20-27 of the Textbook provide a good background for this exercise.

C. Introduction:

First, this exercise is intended to introduce you to the protochordates, informative predecessors to the vertebrates. They carry characteristics that enlighten us to the innovations that preceded vertebrates, mark the way to vertebrates, and in so doing assemble the basic body plan upon which the vertebrates are built.

Second, this exercise gives you practice in using phylogenetic trees by inviting you to plot the first appearance of character transformations along the phylogenetic history leading to vertebrates. Vertebrates, as part of the chordate radiation, did not evolve in one big evolutionary binge. Instead, one step at a time, for the adaptive advantages conferred, characters accumulated. Your task in plotting this history is to marvel at this unfolding of character changes and to think about the advantages of each feature as it entered the ancestral groups to the vertebrates.

D. Preparation & Procedures:

Summary

There is no going back. Life is a one-way street from the past toward the present. The course of evolution from ancestors to descendants, known as **phylogeny**, can be summarized in graphic schemes termed *phylogenetic trees*, or **dendrograms**, which depict the connections between groups in treelike, branched figures. The branch points are the nodes and the distances between the *internodes*. Moving along a branched, one-way

phylogenetic tree, new traits are added, referred to as **derived traits** because they appear later than the earlier primitive or ancestral traits. A taxon is simply a named group of organisms. The assortment of taxa we are interested in examining is our **ingroup**; the **outgroup** is close to but not part of this assortment and is used as a reference. If the outgroup is the taxon most closely related to the group we are interested in it may be called the *sister-group* (see the Textbook Figure 1.26).

It is common today to name the lineage itself of related organisms. A *clade* is such a lineage—all organisms in the lineage plus the single ancestor they all have in common. The dendrogram depicting these clades is a *cladogram*, a hypothesis about the lineages and their evolutionary relationships. Because a clade includes an ancestor and *all* its descendants, and only its descendants, it is *monophyletic*. To discover such monophyletic clades we look for organisms sharing the same derived, homologous traits. Formally, a shared derived trait is a **synapomorphy**, used to diagnose the members of a clade. If we break the criterion of monophyly and lump organisms together with analogous traits, but no immediate common ancestor, then we have formed a *polyphyletic* taxon; if we apply a taxon name to some, but not all descendants of a common ancestor, then we have formed a *paraphyletic taxon*. Both polyphyletic and paraphyletic taxa may be useful, but they are not natural taxa, those that represent actual evolutionary assemblages (see Textbook Figure 1.27).

In this exercise, we will not construct cladograms, a very technical business, but we will work with cladograms already available.

Step 1: Examine Table 1 - Protochordate Character-States. Table 1 is an incomplete character-state table for the major classes of protochordates. Echinoderms are included as the outgroup (a related group used as a reference to determine which character states represent the derived condition). Portions of the table are already completed by denoting the presence of a character with a "1" and an absence with a "0". Complete the remaining cells in Table 1 by examining laboratory specimens to score the remaining characters.

Step 2: Examine Figure 1 - Protochordate Cladogram. This is a phylogenetic tree that includes echinoderms and major protochordate groups. Map the evolutionary changes on this phylogeny by noting where character-states change. This is done by representing character-state transformations with a tic mark along the internode region where these changes first arise. Write a brief description of the character-state change near each tic mark.

E. Synthesis:

1. Mystery Animal: Where would these animals occur in your phylogenetic tree?

What one characteristic of this animal determines where you placed it on the phylogenetic tree?

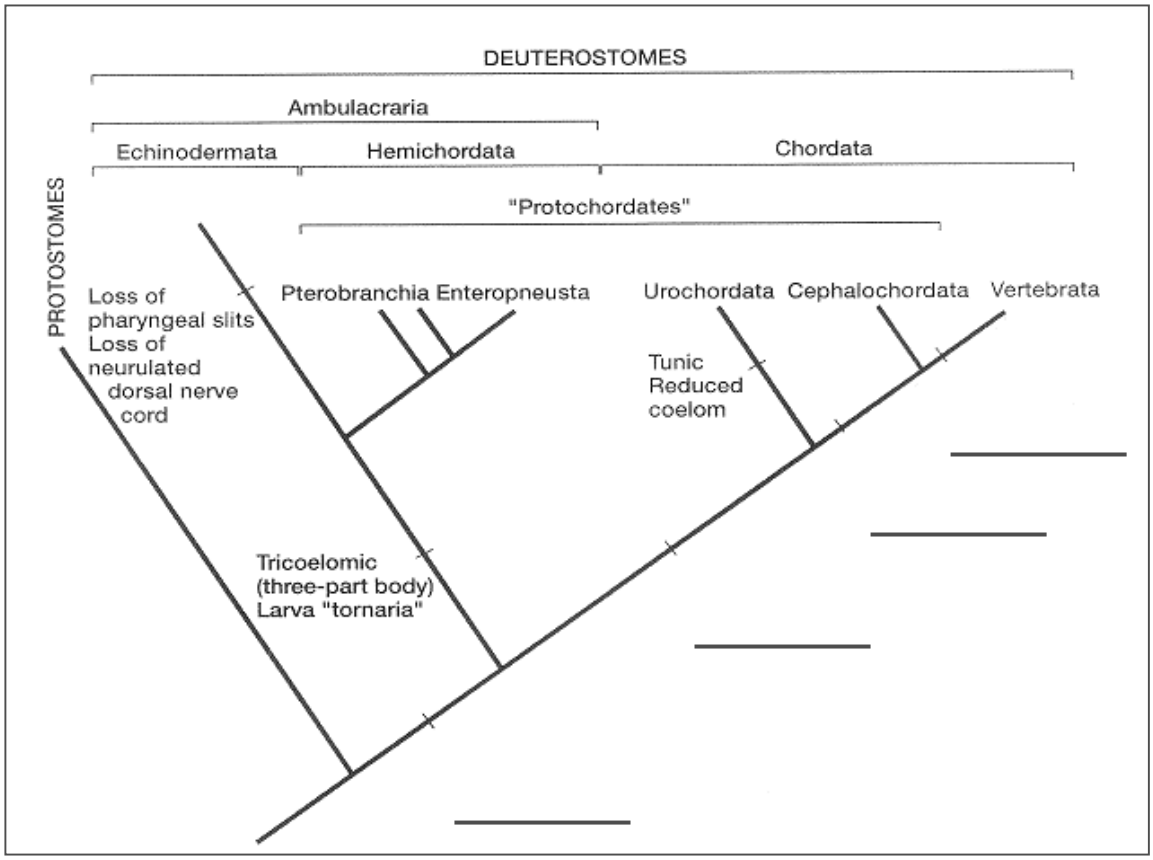
2. Examine your completed phylogenetic tree. In what ways could hemichordates be viewed as intermediates between echinoderms and cephalochordates (chordates)?

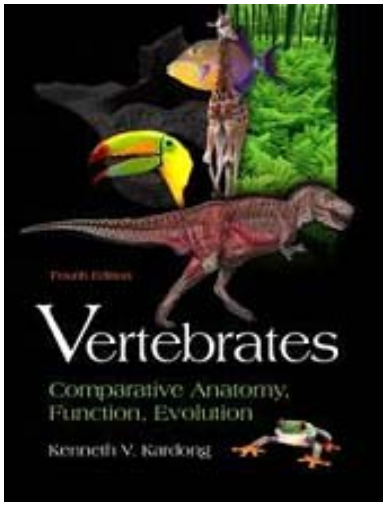
3. What synapomorphies are found in the hemichordate clade?

Table 1 - Protochordate Character-State Table

		Character 1	Character 2	Character 3	Character 4	Character 5	Character 6	Character 7	Character 8	Character 9	Character 10	Character 11
		Notochord	Pharyn-geal slits	Dorsal hollow nerve cord	Post-anal Tail	Myo-meres	Probo-scis, collar, trunk, body plan	Stomo-chord	Tunic	Deuter-ostome	Otolith	Feeding Atrium
1	Echinoderm (Outgroup)	0	0	0	0	0	0	0	0	1	0	0
2	Hemichordata (Enteropneusta) (Acorn Worm)	0	1	0	0	0			0	1	0	0
3	Urochordata (Sea squirt)				1	0	0	0		1		
4	Cephalochordata (Amphioxus)						0	0	0	1	0	
5	Vertebrate (Lamprey)					1	0	0		1	0	0
6	Mystery Animal									1		

0 = absence of a character
1 = presence of a character


DEUTEROSTOMES
Ambulacraria
Echinodermata
Hemichordata
Chordata
"Protochordates"
PROTOSTOMES
Loss of pharyngeal slits
Loss of neurulated dorsal nerve cord
Pterobranchia Enteropneusta
Urochordata
Cephalochordata
Vertebrata
Tunic
Reduced coelom
Tricoelomic (three-part body)
Larva "tornaria"



Instructor's Guide

Protochordate Phylogeny

Follow up in Textbook: Chapter 2

A. Background

This exercise seeks to meet two goals.
First, it is intended to introduce the protochordates, with their wonderful collection of some or all of the chordate characteristics.

Second, it invites students to plot the evolutionary appearance (and loss) of these characters along the route of an "evolving" phylogenetic tree.

This exercise could be inflated into the centerpiece of a vertebrate's course, introducing phylogenetics, its techniques, and consequences. However, we have written it in such a way as to introduce the protochordates and support our efforts of getting students to think about the evolution of characters and their adaptive consequences.

No effort here is made to fully introduce cladistics, as worth a goal as that might be. Obviously, you as the instructor will make the decision as to where you would like this exercise to go in your course. If cladistics is an interest, you might consult: http://www.mhhe.com/biosci/pae/zoology/cladogram/index.mhtml

B. Materials Preparation

Chapter 2, Laboratory Guide (Kardong and Zalisko)
The following specimens will be needed for examination:

1. Sea star, sea urchin, or other representative echinoderm
2. Acorn Worm (Enteropneusta)
3. Adult and Amphioxus (Cephalochordata)

4. Lamprey (Vertebrata)
5. Mystery Animal (any suitable deuterostome, perhaps larval tunicate (Urochordata)
6. a hagfish or other unusual animal that will test the students' analytical skills)

Equipment

1. Microscopes
2. Dissection microscopes
3. blunt probes and dissecting needles
4. gloves
5. Goggles

C. Facilitating Tips

In the Laboratory Dissection Guide, we have written the section on Protochordates in such a way that the **boldface** terms can actually be seen on good slides and whole mounts of the animals (terms in *italics* are more difficult to find and might be available only in specialized material, and so are illustrated in figures). Nevertheless, students will likely require help identifying the characteristics of the animals under study. Encourage them to work in groups to determine a consensus and to complete the character table. With this table in hand, they should plot the points on the phylogeny where character transformations first debut.

D. Assessment - Advice for Evaluating Responses

This exercise is very focused in its purpose. Again, it is NOT intended to be a short course in cladistics. Instead, it is intended to get students thinking about the appearance of new characters and their retention (e.g. vertebrates) or loss (e.g. hemichordates)—the dynamics of evolution.