Phylogeny Exhibits and Understanding Geological Time

Jeff Dodick and Miri Aharonson, The Hebrew University of Jerusalem

Understanding the Tree of Life Conference, Carnegie Museum of Natural History (August, 2010)

Introduction: As a graphical representation, a phylogenetic tree can be deconstructed into two elements: an *evolutionary vector* which represents evolutionary change amongst the represented taxa and a *time vector* which represents the temporal relationships amongst the represented taxa. Often amongst subjects who have little experience with understanding phylogenetic trees the evolutionary vector is often read across the tips of the tree (i.e. along its terminal taxa) while ignoring the common ancestry represented by the branching patterns of the tree. We believe that this is due to the fact that such novice subjects conflate the vector of time with the evolutionary vector, possibly because most phylogenetic trees, as hypotheses of relationships, do not explicitly add the dimension of time. Thus, in this research we hypothesize that people who understand the true direction of the vector of time will better understand phylogenetic trees (and avoid reading its relationships strictly along the terminal taxa).

Method: Our research used in depth semi-structured interviews in which the subjects interpret visual representations of evolution including the Hominid and *Drosophilae* phylogenetic diagrams from the ***Virus and Whale*** exhibit (Diamond et. al., 2002). The former diagram tests what we call a *familiar scenario*[1] with *extant* organisms; the latter tests the understanding of an *unfamiliar scenario* with *extant* organisms. The latter phylogeny also permits us to test such phylogenies with an external absolute time line (based on biogeography). The Hominid tree was exposed to the students in its original tree form; the *Drosophilae* tree was exposed in both its original "fan" form as well as a reconstructed ladder form. A third phylogeny, representing dinosaur relationships, tests the understanding of a *familiar scenario* with *extinct* organisms; it is based on the UCMP dinosaur exhibit and was exposed to the subjects in its original ladder form.

Our research sample consists of adults (N=15) and children (N=15). "Children" are defined as being between ages 13-18. Research shows that children below the age of 13 do not understand terms such as century, or generation so it is unlikely that they would be appropriate for this research (Dodick and Orion, 2003). Adults are defined as subjects who have finished secondary school and thus possibly have encountered phylogeny in either the secondary or tertiary level of education. (Phylogeny is not a regular part of the middle or high school curricula in Israel).

During our interviews we asked the following types of questions with each of the trees:

1. How do subjects understand the temporal nature of local branching events?
2. How do subjects understand the evolutionary relationships amongst taxa (based on local branching events)?
3. How do the subjects understand the temporal vector of the phylogenetic tree?

In the case of the first two questions the answers were coded based on 7 conceptual categories (such as reference to evolution, visual elements of the tree, and specific branching events). Based on theses 7 categories it was possible to classify the answers into 3 levels of evolutionary and 3

[1] By familiar we mean scenarios involving organisms that subjects would probably recognize. We do not mean that the subject would be expected to have a detailed understanding of the phylogeny.

levels of non-evolutionary thinking. These levels of evolutionary / non-evolutionary thinking were correlated with the results of the third question.

Results: Most of the subjects (irrespective of age and education) do not correctly identify the correct direction of the vector of time in phylogenetic trees; this vector is identified as flowing the terminal taxa of the tree (tip reading). Factors influencing the subjects' understanding include structural and visual elements, such as the length of the branches and the visual appearance of the terminal taxa. These visible elements of the tree are conflated with the subjects (often) naïve understanding of evolutionary processes.

Nonetheless there were strong overall correlations between the subjects' understanding of the temporal vector of time in phylogentic trees and their evolutionary thinking in three of the four trees tested. This confirms our original hypothesis. Added support is provided by the fact that overall scores for the sample in terms of evolutionary thinking were significantly better ($p<.05$ based on the Wilcoxon signed rank test) when a timeline was explicitly present in the *Drosophilae* "fan" tree.

Conclusions and Implications: There appears to be a strong correlation between understanding the direction of the vector of time and the ability to correctly explain specific evolutionary problems as represented in phylogenetic diagrams. Possibly this is connected to the fact that the subjects intuitively understand the importance of the common ancestors in the diagram. This causes them to pay attention to the deep structure of the tree while ignoring the extraneous clues along the tips of the tree. We thus suggest that in order to make them more understandable, phylogenetic trees should include explicit temporal information (if possible) and/or understandable visual indications of common ancestry; such visual clues would prompt museum visitors into a deeper search of such trees providing greater understanding. In the classroom soliciting students temporal understanding of such trees might serve as a quick indicator of some of their evolutionary misconceptions.**References**

Diamond, J. et. al. 2002. *Virus and the Whale: Exploring Evolution in Creatures Small and Large*. Arlington, VA: NSTA Press.

Dodick, J. T., and Orion, N. 2003. Cognitive factors affecting student understanding of geological time. *Journal of Research in Science Teaching*, 40 (4), 415-442.