Tree figures in texts: A framework for unpacking their educational potential

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Introduction

The difficulties involved in understanding evolutionary reasoning require a systematic and thoughtful approach to the design and implementation of evolution instruction (Alters & Nelson, 2002). Existing instructional approaches tend to focus on students' understanding of natural selection over discussions of historical inference. The interpretation of phylogenetic relationships between taxa as a consequence of descent with modification is an important part of understanding evolution that has not received appropriate attention from educators or educational researchers. Given the increased emphasis on thinking about all biological data in light of its historical context, Hillis and Bull (1991) suggested the extension of Dobzhansky's (1973) statement that "Nothing in biology makes sense except in the light of evolution," to reflect that, "much in evolution makes more sense in the light of phylogeny".

Graphical representations of phylogenetic trees can support students' understanding of the historical relationships between taxa but may also reinforce misconceptions that interfere with the development of an accurate understanding of evolutionary patterns and processes. The development and interpretation of tree figures can be considered from the perspective of social semiotics, that is, how the figures are part of a visual language designed to communicate biological concepts. For students to extract the intended information from figures, they must come to understand some of the norms and structures of the visual language (Pinto & Ametller, 2002). Any combination of misrepresentation or misinterpretation can lead to inefficient or even inappropriate interpretations of the biological messages in tree figures.

Figure 1. Summary of tree figure characterization across five introductory biology texts

Book	Level	Tree Figures	Total Trees	Classification	NOS	Interpretation	Extant	Ancestor	Extinction	Progress
Purves	AP/Undergraduate	34	82	16/18	27/7	23/11	2/29	30/1	3/28	7/24
Campbell	AP/Undergraduate	45	111	24/21	42/3	31/14	2/35	25/12	7/30	11/26
Miller	High School	4	5	1/3	3/1	3/1	0/4	3/1	1/3	3/1
BSCS	High School	3	5	2/1	2/1	0/3	0/3	1/2	1/2	3/0
Holt	High School	10	12	8/2	5/5	5/5	8/1	6/3	7/2	6/4

yes/no

Discussion

This poster presents an exploratory analysis of tree figures in biology textbooks and a framework for characterizing the graphics with respect to several messages about evolution they may communicate. All the tree figures from five introductory texts were collected and scored based on their incorporation of concepts like classification, common ancestry and extinction (See Table 1 and Table 2). The coding scheme was developed and refined iteratively as we attempted to characterize the potential messages about evolution contained in the trees. The framework focuses on the features of the trees that potentially support or interfere with students' development of a robust understanding of descent with modification as a context for understanding biological unity and diversity. While we did not explicitly address many of the superficial characteristics of the representations such as the orientation of the tree, the shapes of the branches or the varied ways that extra-topological information is often layered onto branching diagrams, these factors may also play an important role in how students interpret text figures. These analyses are limited to the information contained in tree figures and their associated figure legends and should not be used to make judgments about the overall approach that any text uses to address evolution.

Our primary purpose was to raise awareness about features of tree representations that may play an important role in how students come to understand evolution. Questions about how students make sense of these figures, and how well the intended conceptual understandings are communicated warrant further study.

Acknowledgments

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Figure 2. An example of a tree incorporating the "nature of science" and "interpretation guidance".

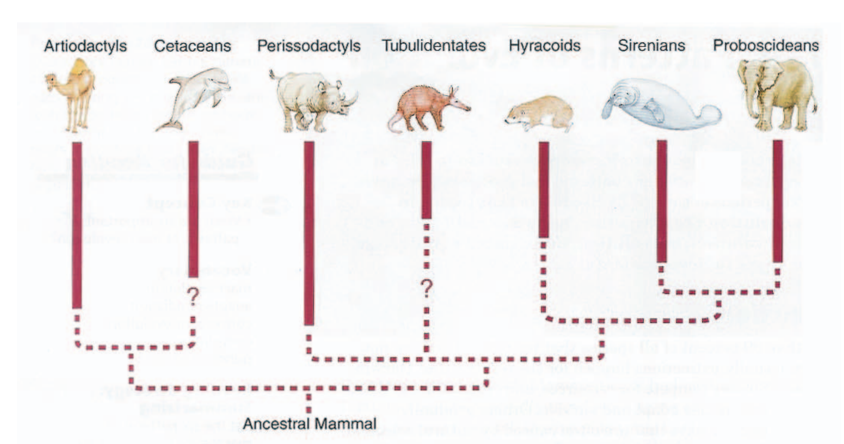

Figure from Miller. This diagram shows part of the adaptive radiation of mammals, emphasizing current hypotheses about how a group of ancestral mammals diversified over millions of years into several related living orders. Note the dotted lines and question marks in this diagram indicate a combination of gaps in the fossil record and uncertainties about the timing of evolutionary branching. **Interpreting Graphics** *According to this diagram, which mammal group is most closely related to elephants?*

Figure 3. An example of a figure "content" that contains information about a general pattern or process but not particular taxa.

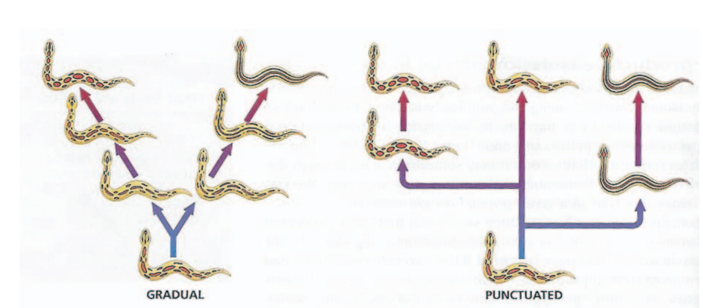

Figure from Holt. In the model of speciation presented on the left, species evolve gradually, at a stable rate. In the punctuated equilibrium model of speciation, illustrated on the right, species arise abruptly and are quite different from the root species. These species then change little over time.

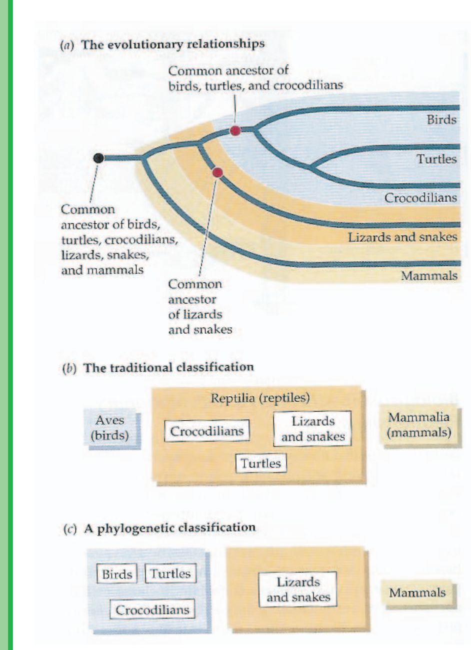

Figure from Purves. Phylogenetic classification based on their evolutionary relationships would group crocodilians and turtles together with birds. The traditional classification unites crocodilians and turtles with lizards and snakes in the paraphyletic taxon Reptile because these animals share many morphological traits.

Figure 4. An example of a tree integrating "classification" with phylogeny and explicitly mentioning a "common ancestor".

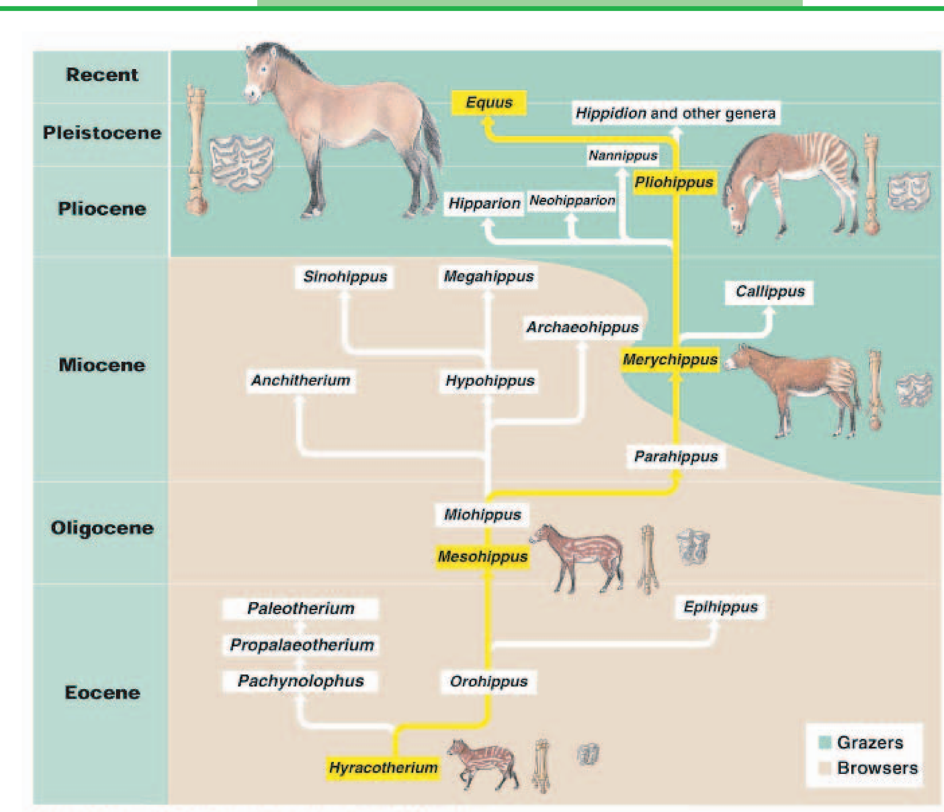

Figure from Campbell. The branched evolution of horses. If we use a yellow highlighter to trace the sequence of fossil horses that are intermediate in form between the modern horse and its Eocene ancestor Hyracotherium, we create the illusion of a progressive trend toward larger size, reduced number of toes, and teeth modified for grazing. In fact, the modern horse (Equus) is the only surviving twig of an evolutionary bush with many divergent trends.

Figure 5. An example of a tree including information about "extinction" and avoiding implying "progress".

Coding Category	Educational Significance
Content Addressed Do the trees contain information about relationships between specific taxa? Do they contain information about general evolutionary processes and patterns? See Figure 6.	While we usually think of trees as ways to represent particular phylogenetic hypotheses, there are a variety of general patterns that can be understood within the context of descent with modification. Students may find it easier to understand concepts like homology, reproductive isolation, and adaptation within a phylogenetic framework.
Classification Do the tree figures make explicit links between classification and phylogenetic relationships? See Figures 1 & 4.	Tree diagrams provide an important opportunity to explicitly display the link between an evolutionary taxonomic scheme and phylogeny. Understanding the nested hierarchy of groups created using this approach to classification can aid in the recognition of patterns of biological unity and diversity.
Nature of Science Do the trees or figure legends include information about the data used to build the tree, state that the tree is a hypothesis, or provide any other indication that the tree the product of scientific reasoning? See Figures 1 & 2.	Too often trees are treated as facts about nature without providing students with any insight into their evidential basis, certainty, or alternative hypotheses. The historical component of evolution research makes it especially important to address the nature of scientific inference building and knowledge claims.
Interpretation Guidance Do the trees or figure legends provide information that supports students' interpretation of the tree diagram? See Figures 1 & 2.	Simply presenting a tree without guidance for making sense of the patterns or relationships it contains is unlikely to help students develop a richer interpretive understanding of trees.
Placement of Extant Taxa Are extant taxa represented as internal nodes in the tree? See Figure 1.	The inclusion of extant taxa internally on a tree could lead to a progressive notion of evolutionary change (ladder of life) and may cause confusion about the differences between shared common ancestry and ancestor-descendent relationships.
Common Ancestor Do the trees or figure legends indicate the presence of any common ancestors? See Figures 1 & 4.	The abstractness of tree representations can make it difficult for students to interpret internal nodes hypothetical common ancestors. Simply labeling the root or some other internal node as a common ancestor can help overcome this issue.
Extinction Do the trees or figure legends address extinct taxa? See Figure 1 & 5.	Extinction plays an essential role in producing the patterns we see in biological taxa. The exclusion of extinction could lead students to beliefs about the persistence of species and progressiveness of change.
Progress Implied Is the tree drawn in a way that evolutionary change could be interpreted as being progressive? See Figures 1 & 5.	This is one of the pernicious misconceptions and misrepresentations in evolutionary biology (Gould, 1995). It is important to be aware of figures that might be interpreted as showing linear progress – particularly toward the evolution of humans.

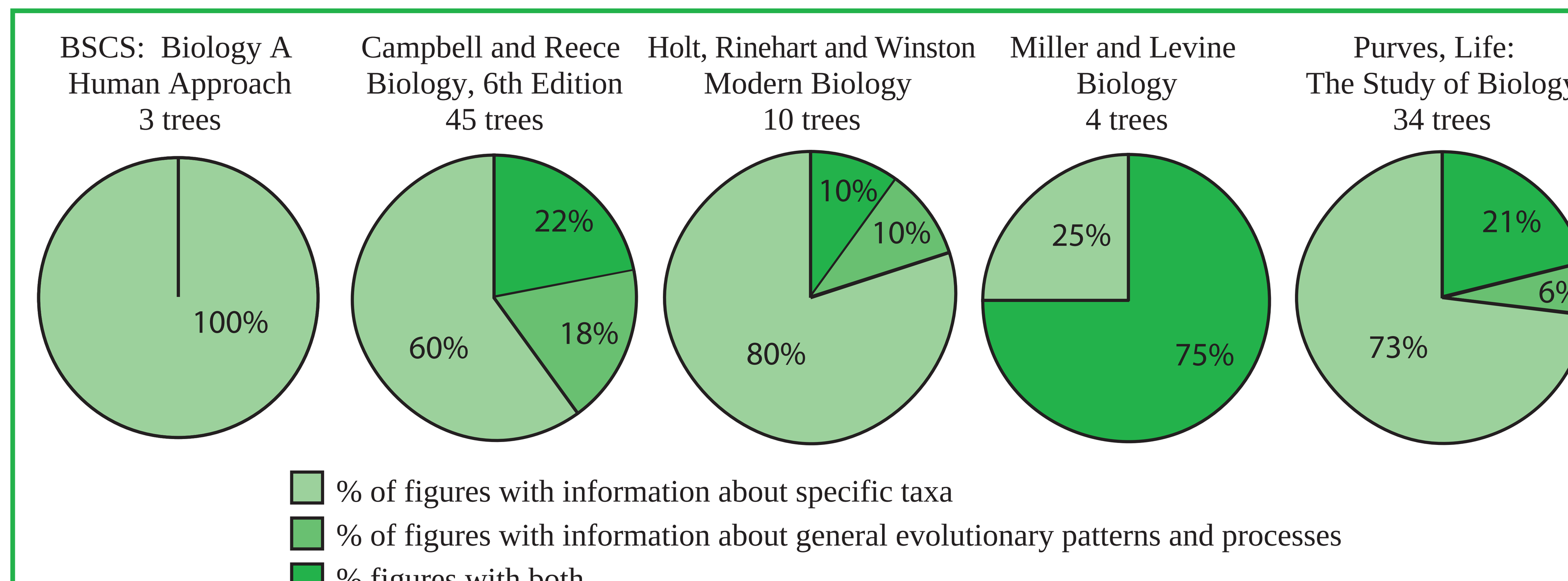

Figure 6. Graphs displaying the content of tree figures across the five texts.

Literature Referenced

- Alters, B. J. and C. E. Nelson. “Perspective: Teaching Evolution in Higher Education.” Evolution 56 (2002): 1891-1901.
- Biology: A Human Approach. Dubuque, Iowa: Kendall/Hunt Publishing, 1997.
- Campbell, Neil, and Jane Reece. Biology. San Francisco: Benjamin-Cummings, 2002.
- Dobzhansky, Theodosius. “Nothing in Biology Makes Sense Except in the Light of Evolution.” American Biology Teacher 35 (1973): 125-129
- Gould, Stephen J. "Ladders and Cones: Constraining Evolution by Canonical Icons" in Silvers, Robert B., ed. Hidden Histories of Science. New York: New York Review of Books, 1995.
- Hillis, D.M. and J.J. Bull. “Of Genes and Genomes.” Science 254 (1991): 528.
- Miller, Kenneth R., and Levine, Joseph. Biology. New Jersey: Pearson, Prentice Hall, 2004.
- Pinto, Roser, and Faume Ametller. “Students’Difficulties in Reading Images. Comparing Results From Four National Research Groups.” International Journal of Science Education 24 (2002): 333-341.
- Purves, William K., et al. Life: The Science of Biology, 6th ed. Massachusetts: Sinaur Assoc., Inc., 2001.
- Standafer, Ellen, ed. Modern Biology. Austin: Holt, Rinehart, and Winston, 1999.