

The Importance of Fossils in Elucidating the Phylogeny And Macroevolution of Foraminifera

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Introduction

Molecular systematics has revolutionized our understanding of where Foraminifera fit on the Tree of Life; however, molecular phylogenies depict crown clades only, and thus cannot evaluate the evolutionary relationships of extinct taxa to modern species. This study summarizes the results of a cladistic analysis of 121 fossil and Recent foraminiferal taxa, including representative species from Paleozoic Lagenina, Paleozoic Fusulinacea, and Mesozoic Involutinina.

Methods

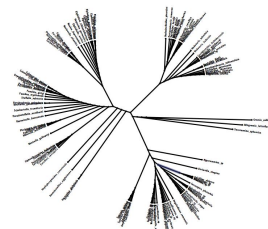
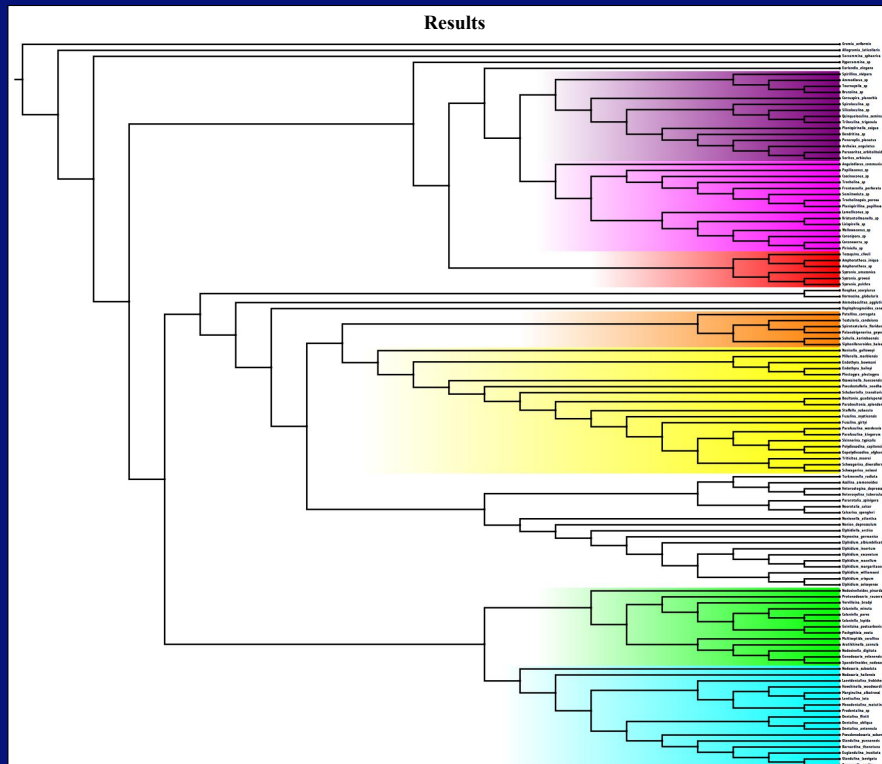
A cladistic analysis of a data matrix comprised of 121 foraminiferal taxa and 170 characters (both binary and multistate) discrete morphological characters was analyzed in TNT (Tree analysis using New Technology) (Goloboff et al. 2003) using the New Technology search option. The search returned retained two trees with a best score of 688 after 15,014,536 rearrangements.

Results

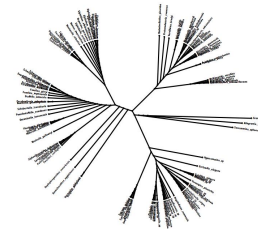
The resulting evolutionary relationships of the fossil foraminiferal groups mentioned above as revealed by this analysis are as follows:

1. **Fusulinacea** (yellow) is a monophyletic clade that branches within the more inclusive clade **Globothalamea** (Node #2) as the sister group to **Textularida** (orange).
2. **Involutinina** (pink) is a monophyletic clade that branches as the sister group to the clade **Tubothalamea** (purple & Node 1).
3. "Lagenina" is a polyphyletic group comprised of:
 - a. A monophyletic clade of two-chambered undivided tubular Paleozoic lagenids (red) that is more closely related to the clade **Tubothalamea** (purple).
 - b. A monophyletic clade of multi-chambered septate Paleozoic "lagenids" (green) that branches as the sister group to the modern multi-chambered lagenids (aqua).
4. The clade **Globothalamea** (Node #2) is the sister group to a more inclusive clade comprised of the multi-chambered Paleozoic "lagenids" (green) + Recent "lagenids" (aqua).

Results



TNT Tree #1



TNT Tree #2

Phylogenetic Nomenclature

Phylogenetic nomenclature defines taxon names in reference to published phylogenies. See the PhyloCode Cantino and de Queiroz (2010) for additional information on phylogenetic nomenclature. Examples of definitions for definiton of foraminiferal clade names are given below.

Foraminifera is the clade originating with the most recent common ancestor of *Marginopora vertebralis* Quoy and Gaimard in de Blainville 1830, and all extant organisms that share a more recent common ancestor with *Marginopora vertebralis* Quoy and Gaimard in de Blainville 1830, than with *Gromia oviformis* Dujardin 1835 or *Filoreta marina* Bass and Cavalier-Smith 2009 or *Haplosporidium nelsoni* (Haskin, Stauber & Mackin 1966) or *Paradinium poucheti* Chatton 1910 or *Plasmiodiophora brassicae* Woronin 1878 or *Eucyrtidium hexastichum* (Haeckel 1887) (Richardson and Lipps In review).

Globothalamea can be defined as: the clade originating with the most recent common ancestor of *Neogloboquadrina dutertrei* (d'Orbigny, 1839) and *Reophax* sp. (GenBank accession: HE998675) as originally depicted on the reference phylogeny of *Foraminifera* in Fig. 1 of Pawlowski et al. (2013).

Tubothalamea can be defined as: the clade originating with the most recent common ancestor of *Marginopora vertebralis* Quoy and Gaimard, 1830, and *Ammodiscus* sp. (GenBank accession: HE998691), as originally depicted on the reference phylogeny of *Foraminifera* in Fig. 1 of Pawlowski et al. (2013).

References Cited

- Cantino, P. D., and K. de Queiroz. 2010. International code of phylogenetic nomenclature. Version 4c. <http://www.ohio.edu/phylocode/index.html>.
- Goloboff, P., J. S. Farris, and K. C. Nixon. 2003. TNT (Tree analysis using New Technology). Published by the authors, Tucumán, Argentina.
- Pawlowski, J., M. Holzmann, and J. Tyszka. 2013. New supraordinal classification of Foraminifera: Molecules meet morphology. *Marine Micropaleontology* 100(1-10).
- Richardson, S. L., and J. H. Lipps. In review. *Foraminifera* d'Orbigny 1826 [S. L. Richardson & J. H. Lipps], converted clade name. In K. de Queiroz, and J. Gauthier, eds. *PhyloCode Companion Volume*. University of California Press, Berkeley, CA.