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FOSSIL EVIDENCE AND PHYLOGENY: THE AGE OF MAJOR ANGIOSPERM CLADES BASED ON MESOFOSSIL AND MACROFOSSIL EVIDENCE FROM CRETACEOUS DEPOSITS[1]

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The fossil record has played an important role in the history of evolutionary thought, has aided the determination of key relationships through mosaics, and has allowed an assessment of a number of ecological hypotheses. Nonetheless, expectations that it might accurately and precisely mirror the progression of taxa through time seem optimistic in light of the many factors potentially interfering with uniform preservation. In view of these limitations, attempts to use the fossil record to corroborate phylogenetic hypotheses based on extensive comparisons among extant taxa may be misplaced. Instead we suggest a method—minimum age node mapping—for combining reliable fossil evidence with hypotheses of phylogeny. We use this methodology in conjunction with a phylogeny for angiosperms to assess timing in the history of major angiosperm clades. This method places many clades both with and without fossil records in temporal perspective, reveals discrepancies among clades in propensities for preservation, and raises some interesting questions about angiosperm evolution. By providing a context for understanding the gaps in the angiosperm fossil record this technique lends credibility and support to the remainder of the angiosperm record and to its applications in understanding a variety of aspects of angiosperm history. In effect, this methodology empowers the fossil record.

Key words: angiosperms; fossil history; minimum age; node dating.

Recent developments have provided a better understanding of the history, evolution and relationships of (and within) the angiosperms—a set of phenomena that together constitute what Darwin considered to be the intractable ''abominable mystery'' (e.g., Crepet, 2000). This special issue of the *American Journal of Botany* reveals that progress is being made in understanding these problems and that there is imminent hope for more detailed and accurate understanding of these events. It also illustrates that three broad areas in particular have contributed to our improved understanding of angiosperm history and relationships: new data and methods for molecular genetics (Palmer and Zamir, 1982; Matthews and Donoghue, 1999), renewed interest in paleontology (Crane et al., 1989; Crepet and Nixon, 1996; Gandolfo et al., 1998a; Zhou et al., 2001), and new developments in the analysis of phylogenetic relationships (Nixon, 1996, 1999; Goloboff, 1999). There is also an invigorated interest in methods for dating of diversification events (Sanderson et al., 2004). What is distinctive about this moment and also raises the prospect that problems in understanding angiosperm history and relationships will ultimately be resolved is that there is increasing synthesis of these disparate approaches and resultant heightening of insights into the ''abominable mystery.'' This special issue illustrates the momentum of this growing synthesis. Our contribution is intended to provide a perspective on one aspect of the potential importance of paleontological data: timing.

The fossil record, as a body of knowledge that incorporates morphology, biogeography, and ecology in a temporal context, has both informative potential and the capacity to serve as a corroborative mechanism for a variety of hypotheses about evolution, development/homology, relationships, biogeography, and generally about the evolutionary play in the ecological theater (sensu Hutchinson, 1965). In addition, the fossil record, as representative of the history of life, holds the potential for clarifying relationships among extant taxa by revealing extinct mosaic taxa that link modern ones, in addition to providing the *general* pattern of evolution of taxa through time. Historically, and in the context of evolutionary biology, the fossil record has played both informative and corroborative roles and continues to be called upon to do both. However, the advent of modern methodologies for comparative studies of extant taxa invites a reassessment of the primacy and scope of the fossil record in addressing questions of evolution and systematic relationships.

The fossil record post evolutionary theory: utility and limitations in phylogenetic studies—Whereas in a ''pre-evolutionary'' world scientists struggled to understand the meaning of the fossil record and were ultimately informed by it and *post evolutionary-theory* scientists sought fossils to confirm and understand the process of evolutionary change and to clarify relationships among extant taxa, in this genomics era, scientists have an additional tendency to look to the fossil record to confirm increasingly accurate hypotheses of evolutionary relationships based on comparative studies of extant taxa. These relationships have become increasingly clear and accurate through analyses of multiple gene sequences made possible principally through pioneering innovations by, for example, Palmer and Zamir, 1982; Palmer et al., 1983, 1985; Downie and Palmer, 1992, who later, through multi gene analysis, suggested along with others that *Amborella* and Nymphaeales were among basal extant angiosperms (e.g., Parkin-

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accepted 7 September related with the snow plant; (4) R. ellenae could be uniformly . GeneBank accession numbers for fungal mtLSU sequences . ture 63 Source: American Journal of Botany, Vol. 68, No. livebreathelovehiphop.com about/policies/livebreathelovehiphop.com For more information about JSTOR, please contact support@livebreathelovehiphop.com height, and low seed number, pollen volume, and nectar quantity. . flowers of Diamorpha smallii on 7 May .. Rhodora