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## Multiple origins of Pentacyclic Sympetaly in Dicots

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Sympetaly has long been considered as a major evolutionary innovation during angiosperm evolution. The character occurs in more than one-third of dicots and has been used to define major angiosperm groups. Two primary types of sympetaly, tetracyclic and pentacyclic, were recognized by early workers. Pentacyclic sympetaly was considered heterogeneous and taxa with this condition were treated as members of subclass Dilleniidae in widely accepted classification systems of angiosperm. In contrast, taxa with tetracyclic sympetaly were considered monophyletic and placed in the subclass Asteridae. Ontogenetic studies of corolla morphology revealed two types of sympetaly, early and late, within tetracyclic sympetaly. In order to understand the origin and evolution of sympetaly, the chloroplast encoded *ndhF* gene was sequenced from 220 genera (total 530 kilobases) of sympetalous dicots during last four years. Phylogenetic analyses of *ndhF* data provide three independent origins of the tetracyclic sympetaly, one directly from pentacyclic sympetaly and two others from polypetaly. The former include both early and late sympetaly, while the latter two are only early sympetaly.

**A209***ndhF* gene evolution and the major clades in the sunflower-family

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An extensive sequence comparison of the chloroplast *ndhF* gene from all major clades of the largest flowering plant family (Asteraceae) shows that this gene provides three times more phylogenetic information than *rbcL*. The 5' region (1380 bp) of *ndhF* is very different from the 3' region (955 bp) and is similar to *rbcL* in both the rate and the pattern of sequence change. The bimodal pattern of base substitutions of *ndhF* is particularly advantageous for phylogenetic reconstruction because the conserved and variable segments can be used for ancient and recent groups, respectively. Phylogenetic analyses of 94 *ndhF* sequences identified several major clades in the family: (1) the Calyceraceae is the sister family of Asteraceae; (2) the Barnadesioideae is monophyletic and the sister group to the rest of the family; (3) the Cichorioideae and the two basal tribes Mutisieae and Cardueae are paraphyletic; (4) four tribes of Cichorioideae (Lactuceae, Arctoteae, Liabeae, and Vernoniaceae) form a monophyletic group with the Asteroideae; (5) the monophyletic Asteroideae include three clades.