



## **The emergence of modern type rain forests and mangroves and their traces in the palaeobotanical record during the Late Cretaceous and early Tertiary**

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The origin of modern rain forests is still very poorly known. This ecosystem could have potentially fully evolved only after the development of relatively high numbers of flowering plant families adapted to rain forest conditions. During the early phase of angiosperm evolution in the early Cretaceous the palaeo-equatorial region was located in a seasonally dry climatic belt, so that during this phase, flowering plants often show adaptations to drought, rather than to continuously wet climate conditions. Therefore it is not surprising that except for the Nymphaeales, the most basal members of extant angiosperm families have members that do not necessarily occur in the continuously wet tropics today.

However, during the late Early Cretaceous several clades emerged that later would give rise to families that are typically found today mostly in (shady) moist places in warmer regions. This is especially seen among the monocotyledons, a group of the mesangiosperms, that developed in many cases large leaves often with very specific venation patterns that make these leaves very unique and well recognizable. Especially members of three groups are here of interest: the arum family (Araceae), the palms (Arecaceae) and the Ginger and allies (Zingiberales). The earliest fossil of Araceae are restricted to low latitudes during the lower Cretaceous. Arecaceae and Zingiberales do not appear in the fossil record before the early late Cretaceous and occur at mid latitudes.

During the Late Cretaceous, Araceae are represented at mid latitudes by non-tropical early diverging members and at low latitudes by derived rainforest members. Palms became widespread during the Late Cretaceous and also *Nypa*, a typical element of tropical to subtropical mangrove environments evolved during this time period. During the Paleocene Arecaceae appear to be restricted to lower latitudes as well as Zingiberales. All three groups are again widespread during the Eocene, reaching higher latitudes and probably diversifying at mid latitudes. Later on, they slowly became restricted to lower latitudes as seen today. This fluctuation appears to be linked to climate change and are still reflected by the regional diversity of these groups, which reflect rather well rain forest evolution. When tracing the fossil record of rain forest plants we clearly see a pattern that suggests the onset of this type of environment during the late Late Cretaceous and spread during the early Tertiary with phases of retreat during the Oligocene and from the mid-Miocene onwards.