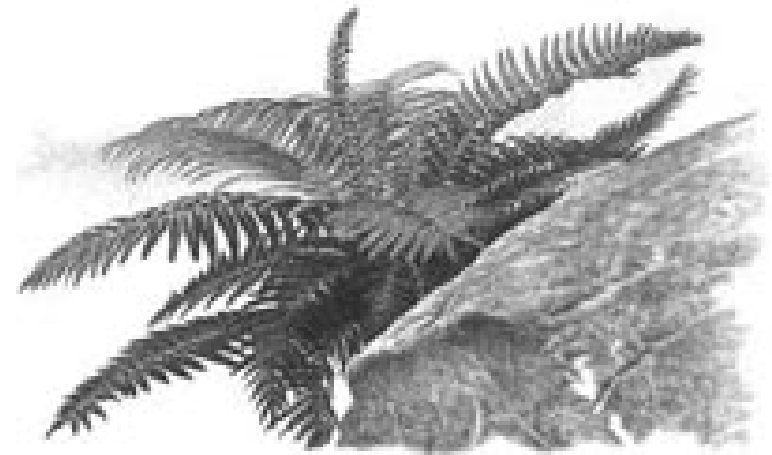


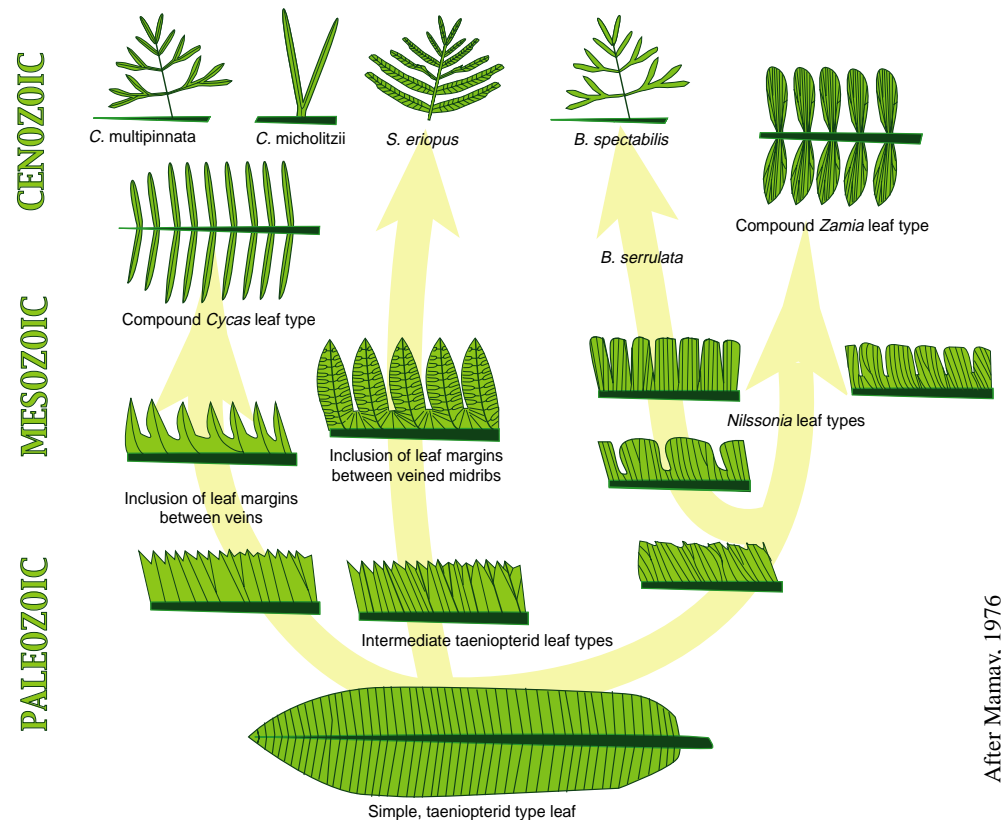
Permian Cycadales

Taeniopteris, (middle ground of painting below) and other early tree-fern like plants, possessed simple leaves, bore small seeds along their edges near the base. *Taeniopteris* is associated with fossil reproductive material (seed bearing leaves) given the name *Crossozamia*; these fossils resemble the modern day reproductive megasporophylls of the genus *Cycas*, although they are more highly divided. A reduction in leaf size and the number of seeds could conceivably replicate the loose, open cone of this modern cycad. From the many variations of seed leaves, simple and compound vegetative leaves it is apparent that even in the Permian period early cycads and cycad-like plants were a very diverse group. For example, in *Yuania chinensis*, from the Lower Permian of China the lower pinnae were reduced to thornlike structures similar to the prickles of the rachis of modern day *Cycas*.



John Sibbick

The chart at right illustrates how compound leaves could be derived from a simple tree-fern-like leaf. *Stangeria*, *Bowenia*, and the multipinnate forms of *Cycas* have been added to show how cycads continue to adapt, developing more efficient leaf designs. Not shown are *Macrozamia stenomera*, *M. diplomera*, and others, and the newly discovered genus *Chigua* that also have developed multipinnate leaves. Such a leaf architecture increases the amount of photosynthetic surface of a leaf, while keeping wind loading to a minimum. Damage from insects would also be reduced. Since cycads produce new leaves no more than once or twice a year on average, they need to protect this major metabolic investment from damage.



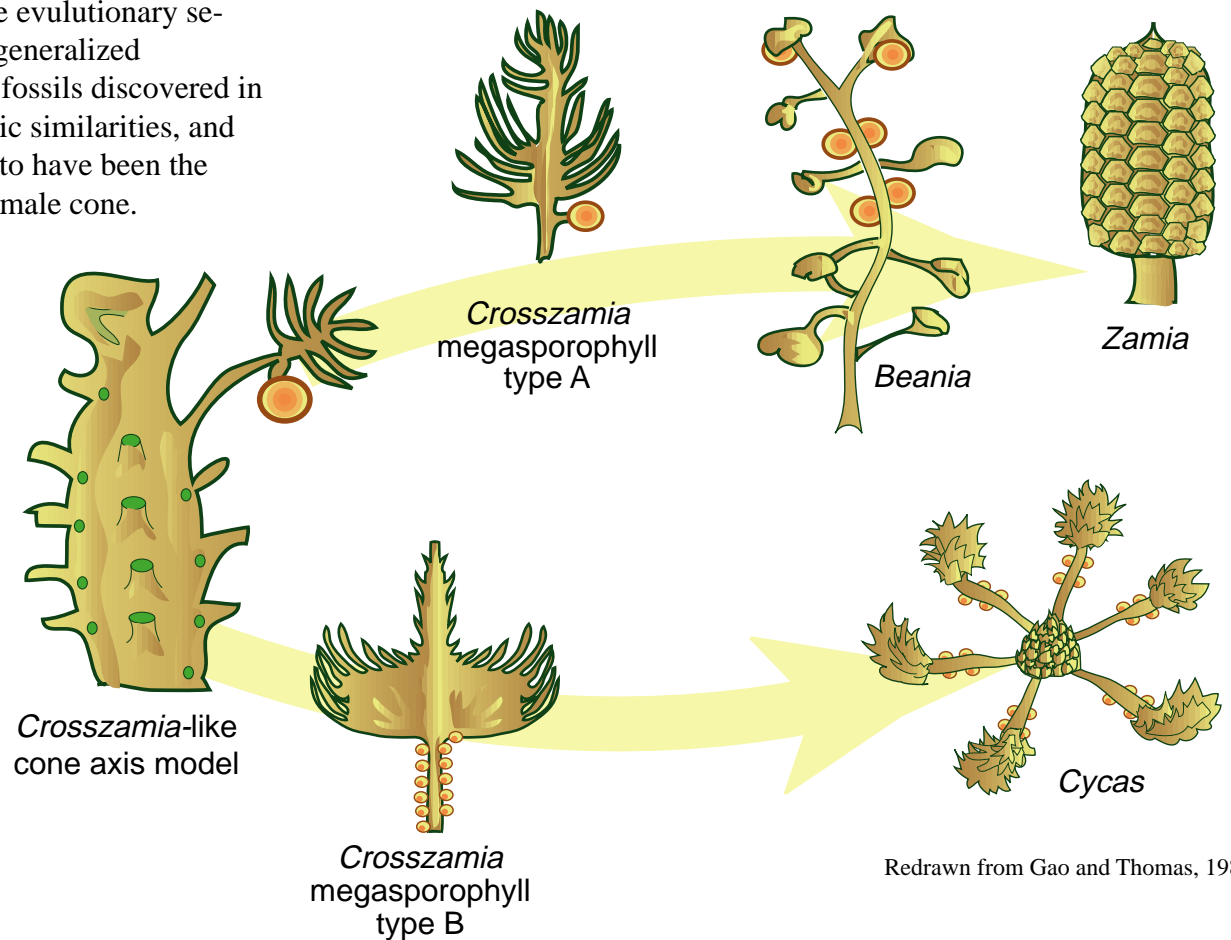
Douglas Henderson

After Mamay, 1976

Several fossils from the Late Permian resemble male cycad-like cones, with twin spines on the cone scales like *Macrozamia*. Certainly, the male cone of *Beania* is very similar in appearance to modern cycad cones, even if the female cone is very open and elongated. If these fossils are truly of cycad cones, and not the fossilized impressions of club moss stems, they suggest that cycad structures were evolving at different rates. Although leaves initially remained primitive, reproductive structures were adopting more modern and efficient structural designs. The chart below shows a possible evolutionary sequence of cycad megasporophylls from a generalized *Crosszamia* cone axis design. *Crosszamia* fossils discovered in China, France and Sweden have many basic similarities, and yet are variable enough in construction as to have been the precursors to both the *Cycas* and *Zamia* female cone.

Modern cycads are very dependent on specific insects to pollinate their cones, and there's no reason to believe this wasn't also the case in the past. There may even have been co-evolution of these seed bearing structures and their pollinators. Cycad cones signal that they are ready to release pollen, or to be pollinated by broadcasting attractive odors and also distinctive heat signatures for those insects capable of sensing infrared radiation. Cone shapes were probably driven by how well they attracted and allowed access to specific pollinating insects. Afterwards, the cone had to become a protective shield for the developing seeds. Once mature, the cone had yet

another function, to attract yet more co-agents, animals drawn by the fleshy seed coverings that would strip off this inhibiting coating and then transport the seeds away from the parent plant so that they might find a lucky spot to germinate. Over the millions of years that cycads have existed, these co-agents could have been insects, dinosaurs, pterosaurs, birds, various mammals, perhaps even fruit bats, who would find the open cone of *Cycas* an especially easy target.



Redrawn from Gao and Thomas, 1989

Possible evolution of *Cycas* and *Zamia*-like female cones from variations of a *Crosszamia*-type cone axis. Type A and Type B refer to two different fossil variations. There was much variation in *Crosszamia* megasporophyll design.