# Plant Carbon Isotope Ecology Across Space and Time

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Foundational work on the meaning of plant carbon isotope values has been ongoing for decades, with models developed for predicted magnitudes of physical and enzyme-derived fractionation [1] for different photosynthetic pathways [2], and the relationship between $\delta^{13}C_{plant}$ and $\delta^{13}C_{atmosphere}$ values [3; $\Delta_{leaf}$ herein]. More recently, meta-analyses of $C_3$ plants [4,5] identified relationships between $\delta^{13}C_{plant}$ or $\Delta_{leaf}$ and mean annual precipitation and temperature (MAP, MAT), altitude, plant-functional type, and latitude. However, most of those relationships are too coarse to be applied quantitatively to the geologic record and much of the work has assumed that biochemistry is more important than evolution and that universal relationships can be derived for all plants that use a given photosynthetic pathway. A number of these foundational assumptions will be tested herein using a series of vignettes that focus on modern isotope ecology of gymnosperms. First, the relationship between $\delta^{13}C_{plant}$ and MAP is investigated using both *Ginkgo biloba* across a wide range of sites globally and using evergreen conifers across a regional precipitation gradient; both types of plants have extenive fossil records and neither follows the "global" meta-relationships between $\delta^{13}C_{plant}$ and MAP, wth Ginkgo exhibiting a weaker response and the conifers a stronger response. Secondly, 63 conifer species (15 genera) grown under the same natural environmental conditions exhibit small ranges (±1‰) between individuals of the same species but a large range of up to 8‰ in their $\Delta_{leaf}$ values between genera. The $\Delta_{leaf}$ differences between genera correlate strongly with phylogenetic distance, indicating that there is an evolutionary component to $\Delta_{leaf}$, and calling into question the assumption of universal relationships. Third, historic records of single species show changes in leaf economics over the period of Industrialization as well as $\delta^{13}C_{plant}$ changes that are of a different magnitude than the Suess effect, suggesting that single species can be used as quantiative recorders of water availability. Thus, interpeting $\delta^{13}C_{plant}$ values in the geologic record accurately requires some understanding of plant identity/evolutionary history.

[1] Farquhar et al. (1989) Ann. Rev. Plant 40:503 [2] Cerling and Harris (1999) Oecologia 120:347 [3] Arens et al. (2000) Paleobio. 26:137 [4] Diefendorf et al. (2010) PNAS 107:5738 [5] Kohn (2010) PNAS 107:19691