

# **Ancient Climate Encoded in Molecular Records of C and N Isotope Abundances**

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Climate signatures encoded in the  $^{13}\text{C}$  content of plant biomarkers include the amount and isotopic composition of atmospheric  $\text{CO}_2$  as well as water availability and regulation of vapor exchange. Further,  $\text{C}_3$  and  $\text{C}_4$  plant distributions can follow climatic forcing and ecological shifts between them are readily charted with molecular isotopic analyses. For example, we find  $\delta^{13}\text{C}$  values indicating  $\text{C}_3$  and  $\text{C}_4$  inputs follow aridity signals encoded in the D/H of plant waxes of ancient lake sediments (Olduvai Gorge, Tanzania). These signals also closely follow obliquity variations and are consistent with solar insolation serving as a driver of African Monsoon behavior during the Pliocene. Translating our understanding of the widely varying  $^{13}\text{C}$  signatures in modern  $\text{C}_3$  plants into clear climate signals has proved challenging. Like modern plants, a wide range ( $>10$  permil) in  $^{13}\text{C}$  is observed in ancient terrestrial organic matter and it is difficult to interpret in terms of hydrology or plant physiological traits, as they are both influenced by climate. We present a compilation and analysis of modern  $\text{C}_3$  plant leaf data (see also: Diefendorf, this meeting) and discuss relationships between  $^{13}\text{C}$  abundance and plant biomes as a framework for learning how to interpret past plant signatures and the climatic signals they may encode. Substrate composition, enzymatic fractionation and material flow are important in phototroph nitrogen isotope signatures. Links to climate are indirect for land plants, but can involve soil biogeochemical responses to temperature and water inputs. In algae,  $^{15}\text{N}$  can signify nitrogen fixation by bacteria, including cyanobacteria. Routine isotopic analyses of pigment nitrogen now possible by several research groups are helping to document  $^{15}\text{N}$  patterns in the ancient ocean and opening a path to understand their relationship to past climatic conditions.