Influence of carbon source on the distribution of carbon isotopes in bacteria

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"*You are what you eat, +1 permil*" is a central principle of carbon isotope systematics that is widely applied to understand trophic ordering. Although based on observations from multicellular organisms that are able to ingest "food", this idea also has been applied to Precambrian ecosystems dominated by unicellular, microbial life, with the suggestion that such systems would develop ordered trophic levels that could be preserved in the sedimentary isotope record [1]. Here we present a survey of several bacterial species grown on a variety of carbon sources to show that the concept of heterotrophic ^{13}C enrichment is not universal. In particular, growth on complex food substrates produces the typical ^{13}C enrichment, yet growth on simple sugars produces ^{13}C depletion – in the same species. These results may be explained because microbes cannot ingest whole, complex foods; *i.e.*, they assimilate small-molecule metabolites. Bacterial carbon isotopic patterns should instead reflect the type of substrate and the entry point of this substrate into central metabolism [2]. In agreement, the intracellular carbon isotope distributions in our experiments – as traced by the $\delta^{13}C$ values of amino acids reflecting different branch points of the intracellular reaction network [2, 3] – change as a function of the primary carbon metabolite. Isotopic patterns of amino acids and lipids in heterotrophs are indistinguishable from autotrophs when the primary food source is fresh photosynthate, *i.e.*, sugar. When acetate is the food source, phytol becomes the most strongly ^{13}C-depleted cellular component and *n*-alkyl lipids have ^{13}C contents equal to biomass. These results can be explained by an isotope flux-balance model initiated with simple stoichiometric relationships and known kinetic isotope effects (ε). Together these observations suggest that organic ^{13}C isotopic patterns in Earth history may primarily reflect the changing nature of carbon inputs to the sedimentary environment.

[1] Logan et al. (1995) *Nature* **376**, 53-56. [2] Hayes (2001) *Rev. Mineral. Geochem.***43**, 225-277. [3] Macko et al. (1987) *Chem. Geol.* **65**, 79-92.