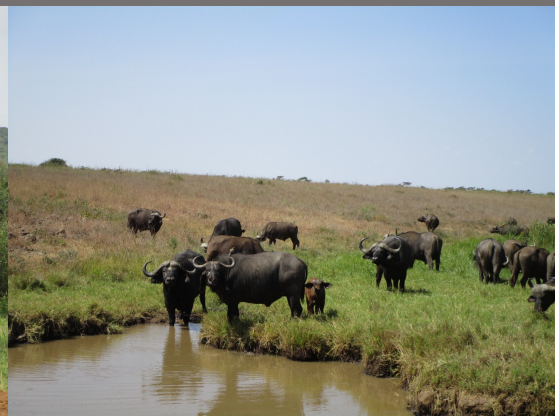


Consumer Oxygen

Elemental Ecology



Where does the oxygen in animal tissues come from?

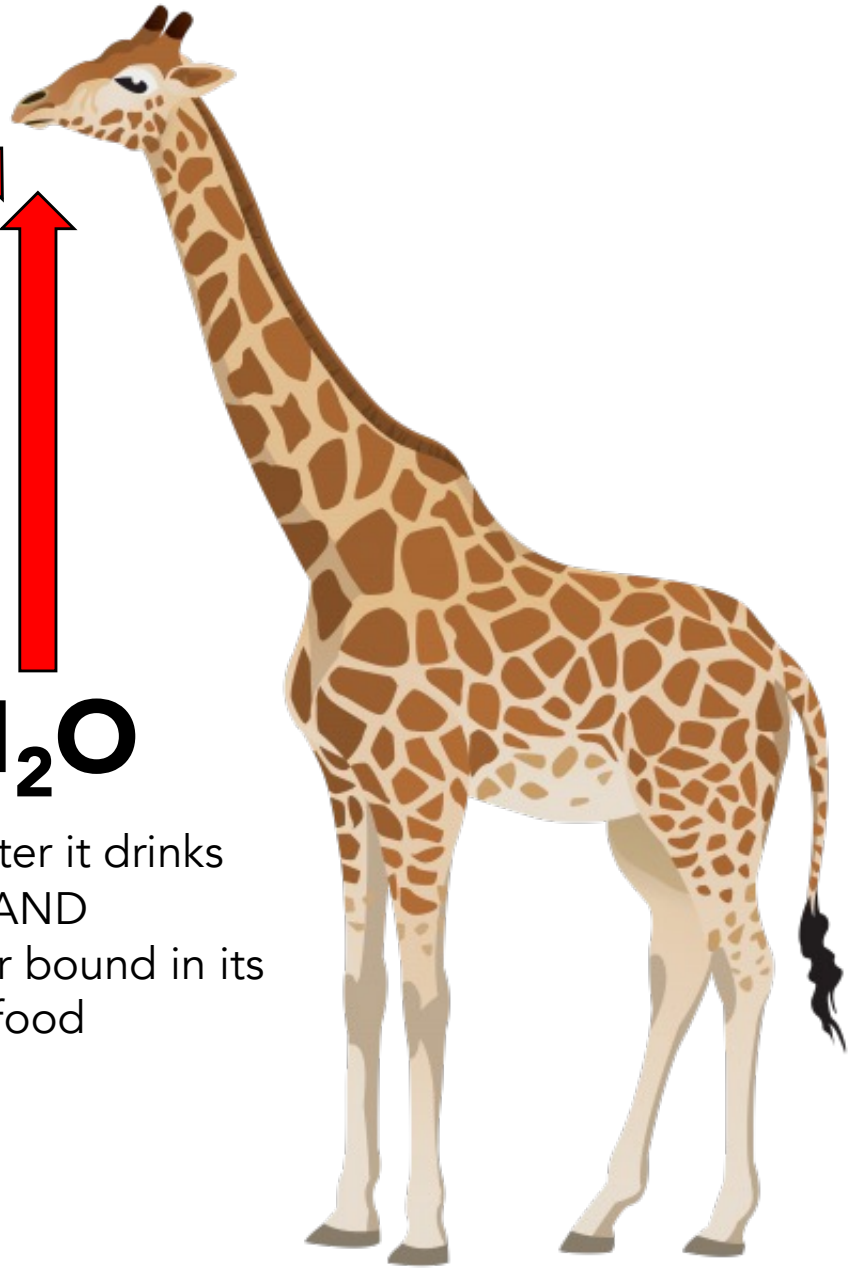
The oxygen it breathes O_2

$C_6H_{12}O_6$

The food it eats

H_2O

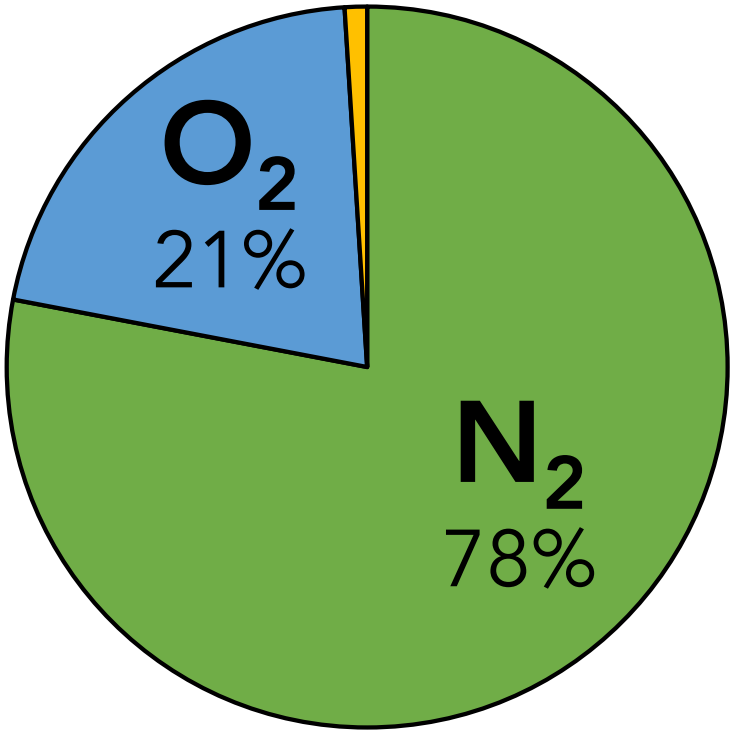
The water it drinks
AND
The water bound in its food



Where does the oxygen in animal tissues come from?

relatively constant concentration since land plants evolved

Relatively constant $\delta^{18}O$ of 23‰



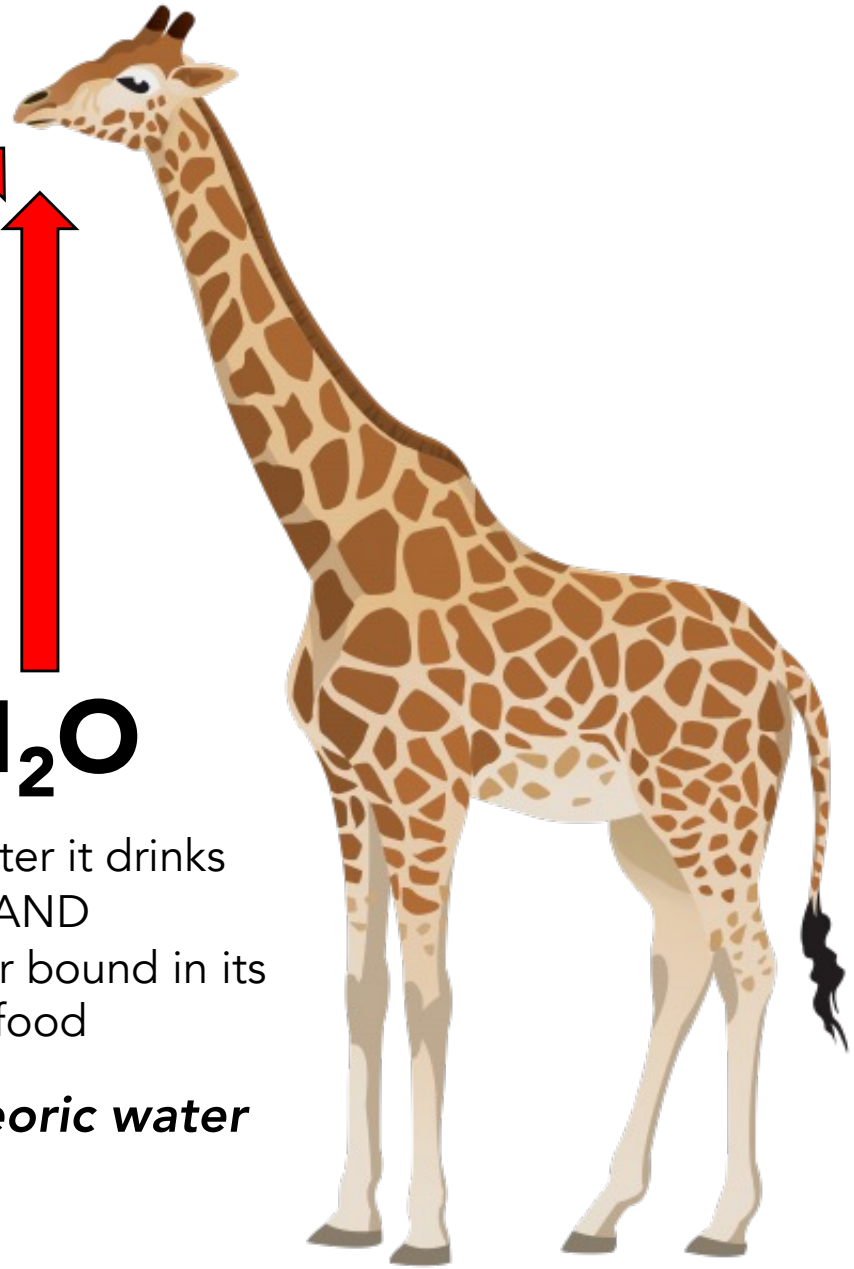
$C_6H_{12}O_6$

The food it eats

H_2O

The water it drinks
AND
The water bound in its food

~ meteoric water

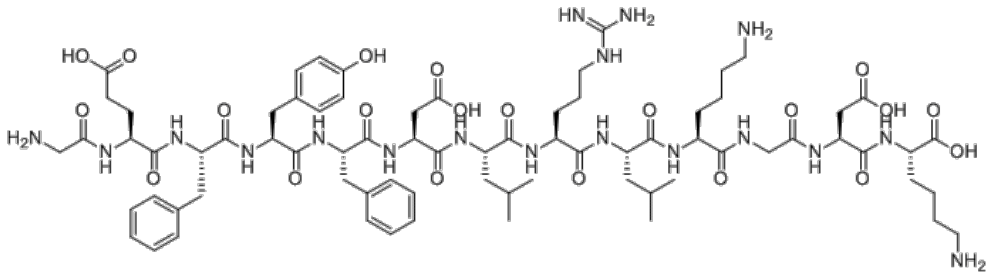


Bone Composition

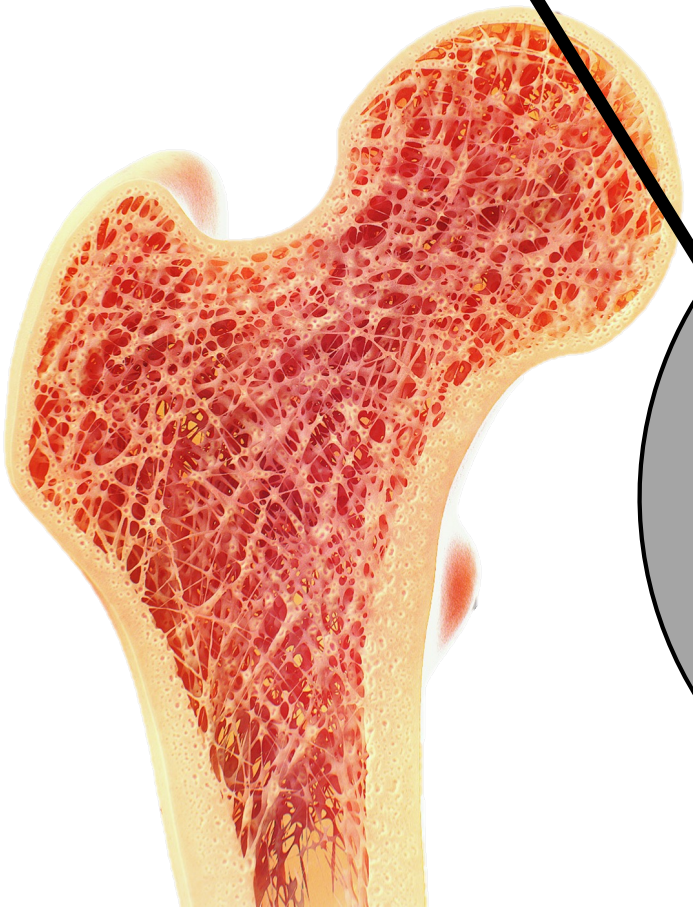
Phosphate Oxygen
PO_4

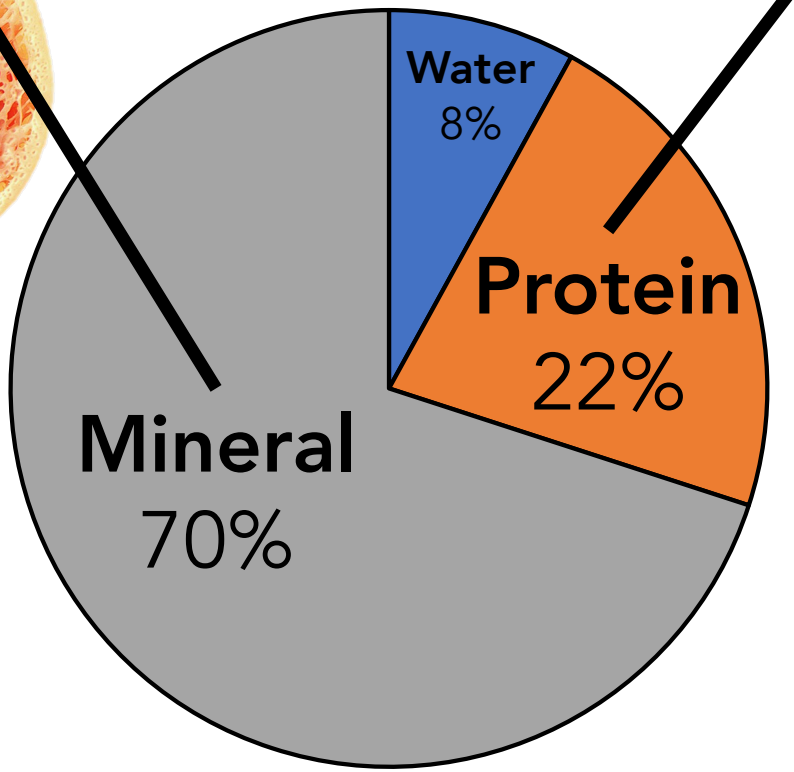
Carbonate Oxygen
CO_3

Hydroxyapatite
$Ca_{10}(PO_4,CO_3)_6(OH,CO_3)_2$



Collagen





Tooth Composition

Hydroxyapatite

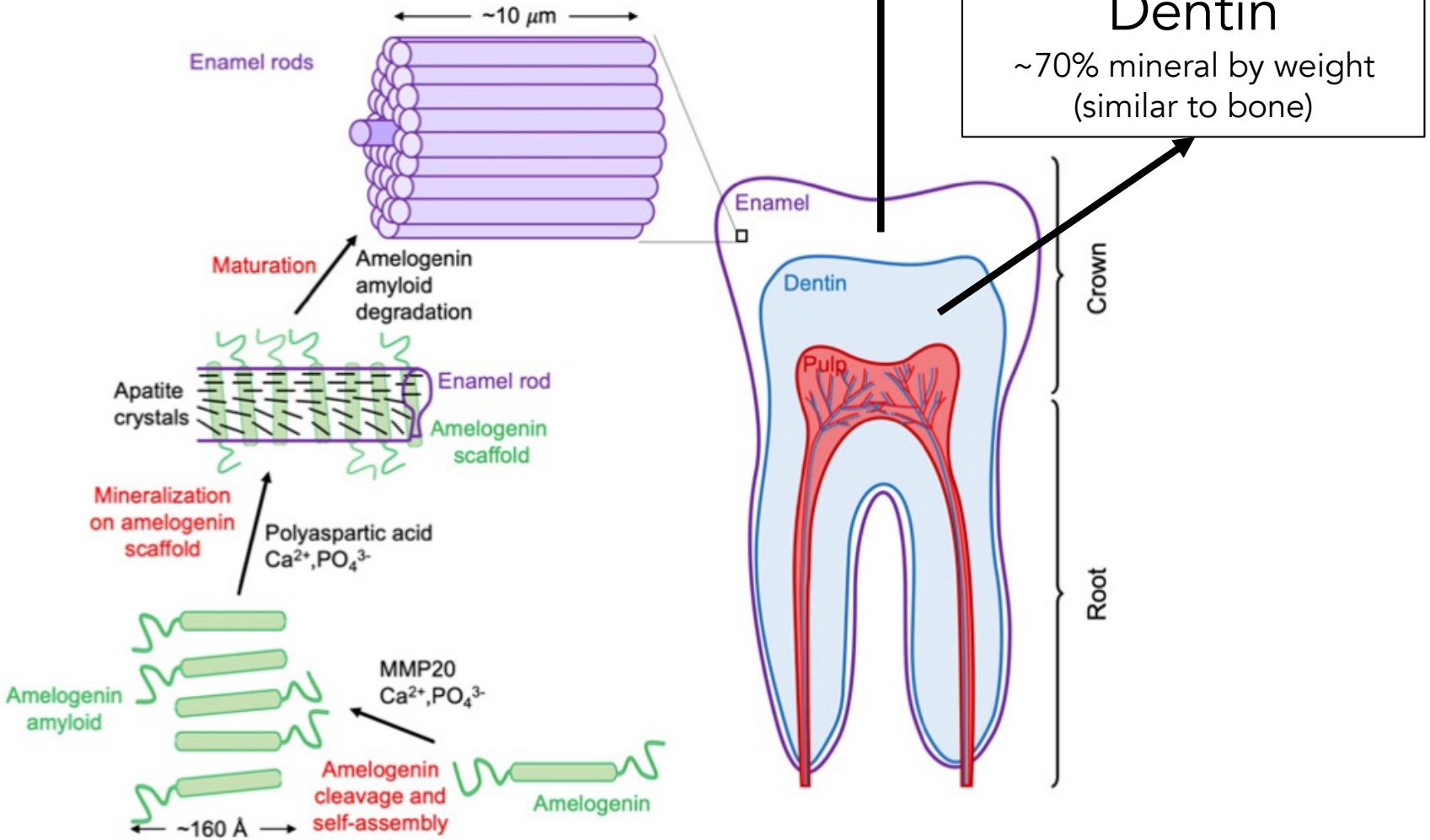
$Ca_{10}(PO_4,CO_3)6(OH,CO_3)_2$

Enamel

>95% mineral by weight

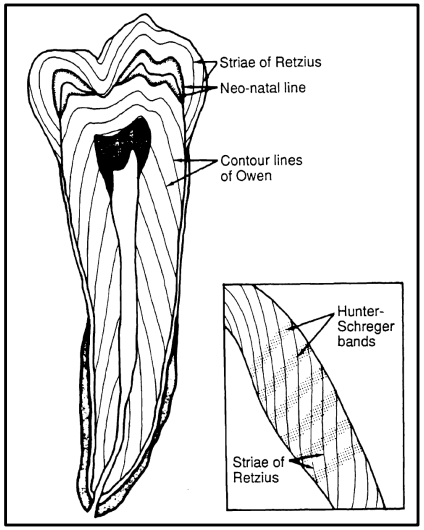
Dentin

~70% mineral by weight
(similar to bone)



Welborn 2020

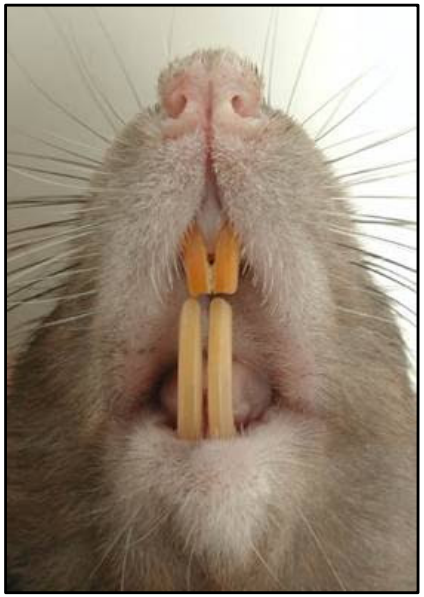
Teeth grow by accretion



Most tooth growth occurs early on in an animal's life

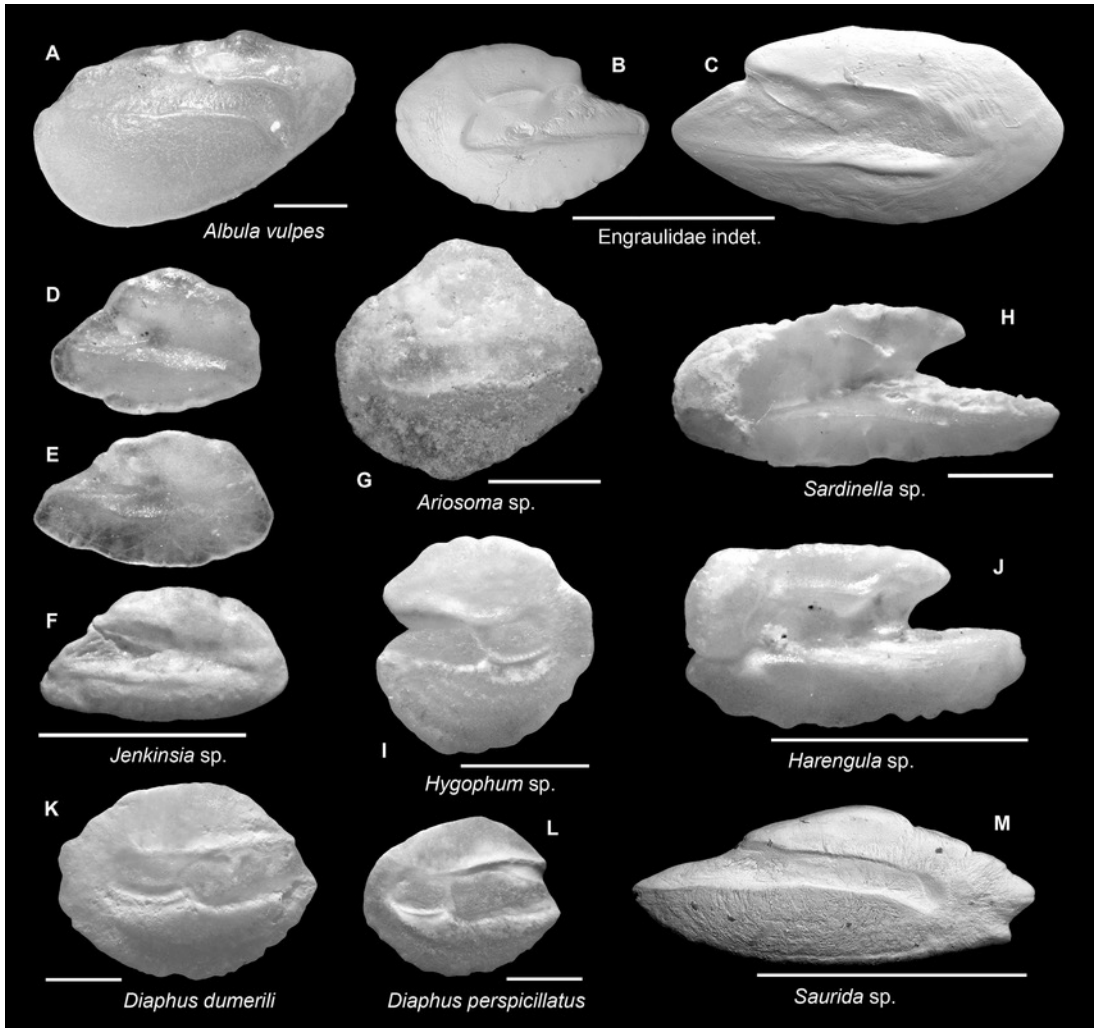
But…

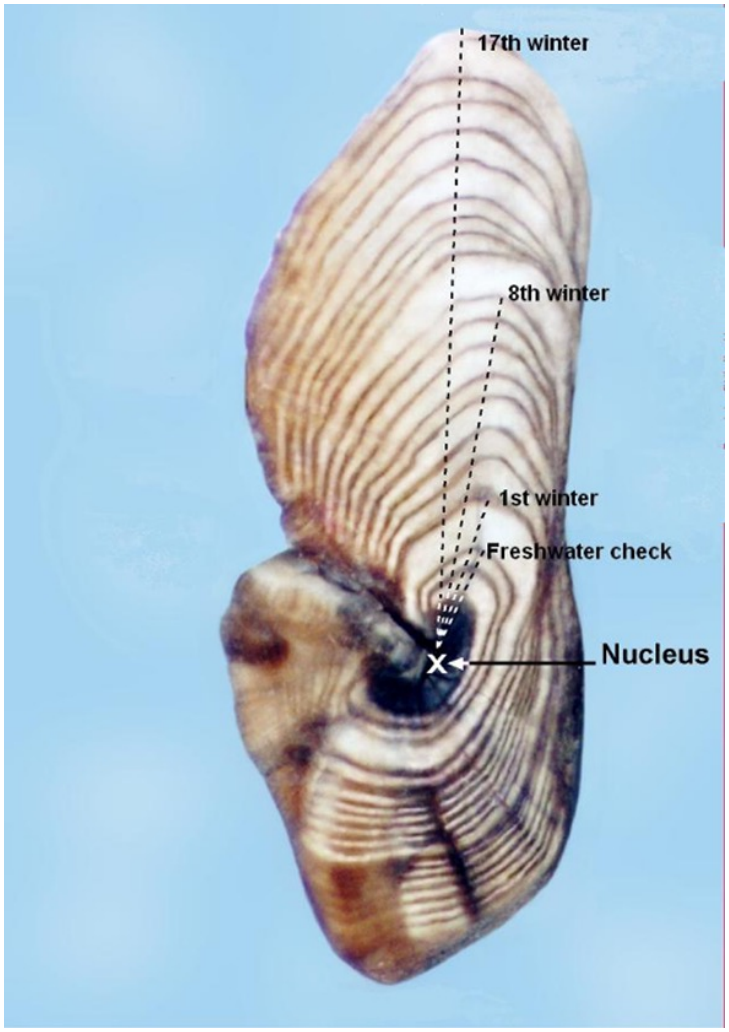
Some animals have continuously-growing teeth (e.g., elephants, rodents)



Some animals have continuous tooth replacement (e.g., fish, amphibians, and reptiles)

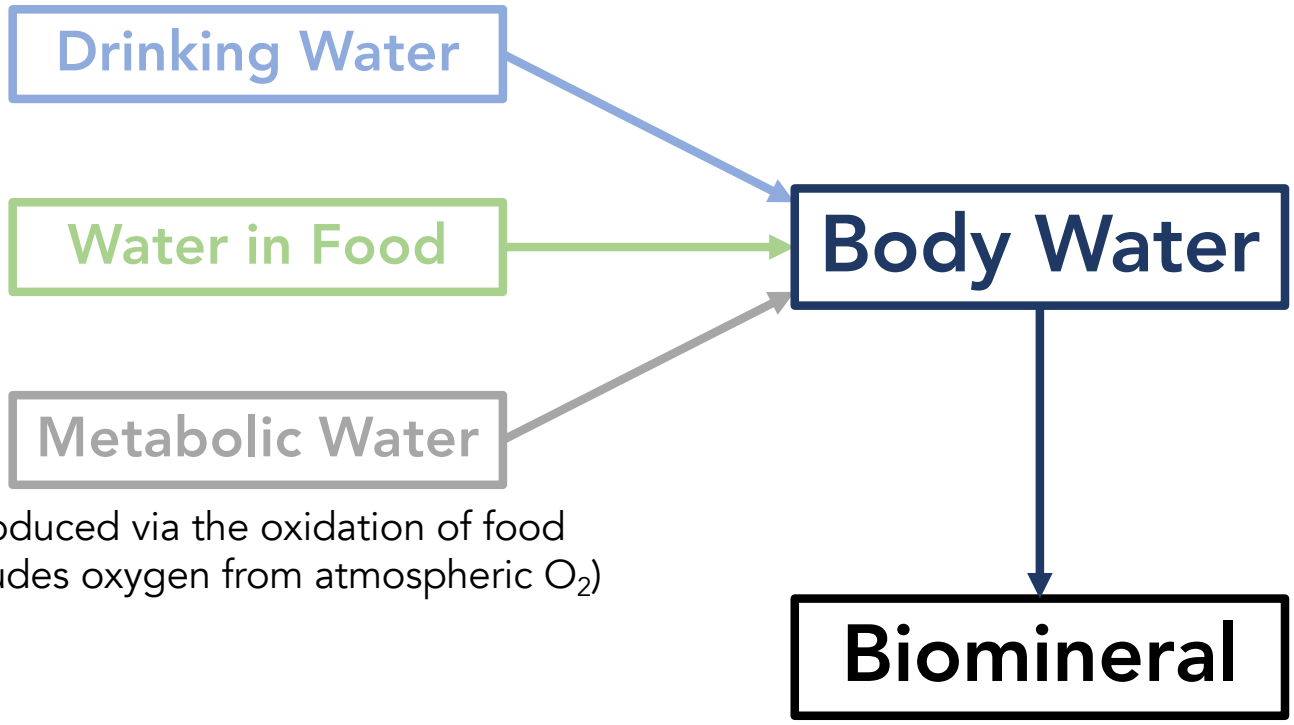
Fish otoliths also grow by accretion





Inorganic $\delta^{18}O$ Assumptions

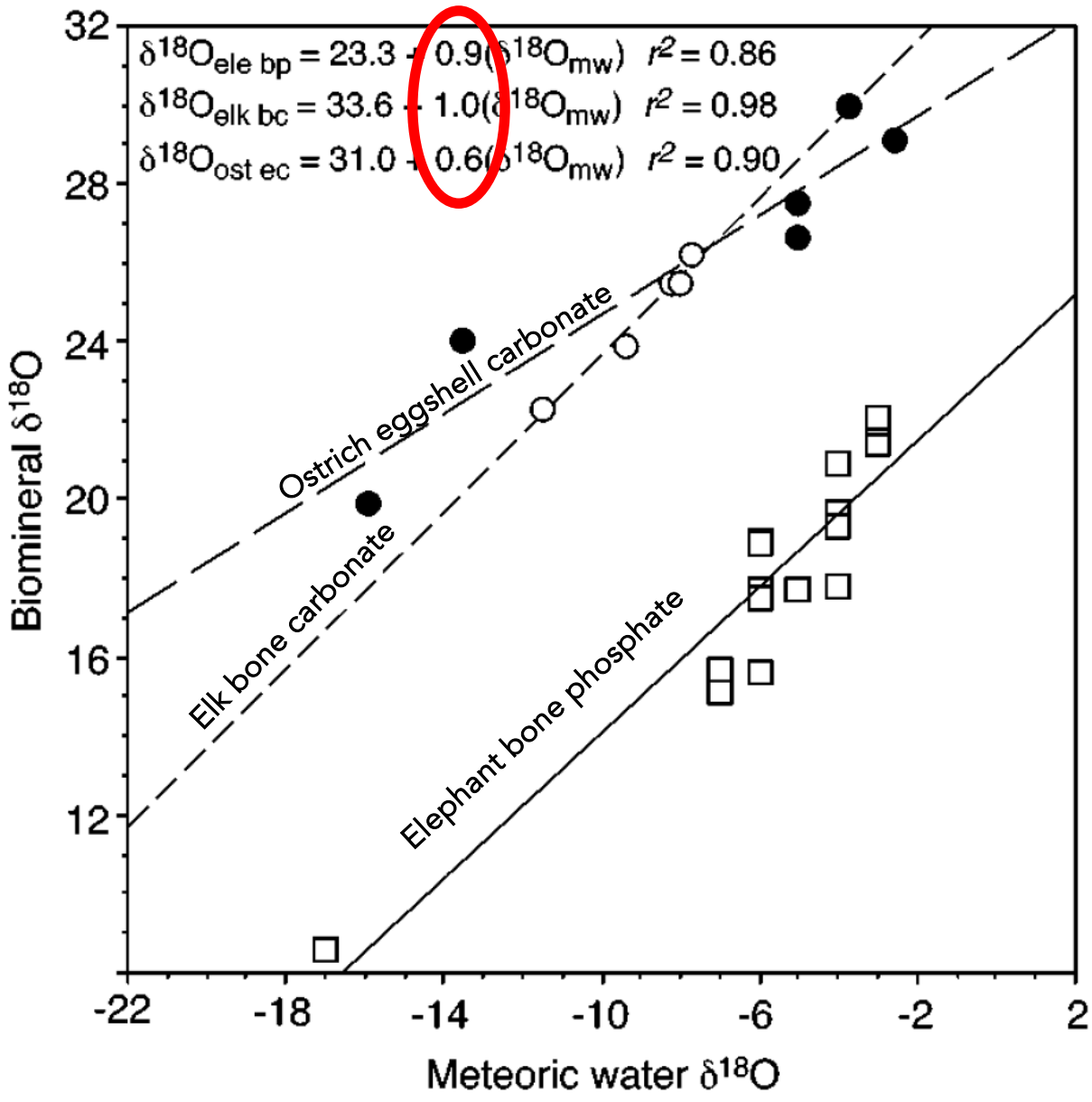
Biogenically produced minerals are in *isotopic equilibrium* with body water



Produced via the oxidation of food (includes oxygen from atmospheric O_2)

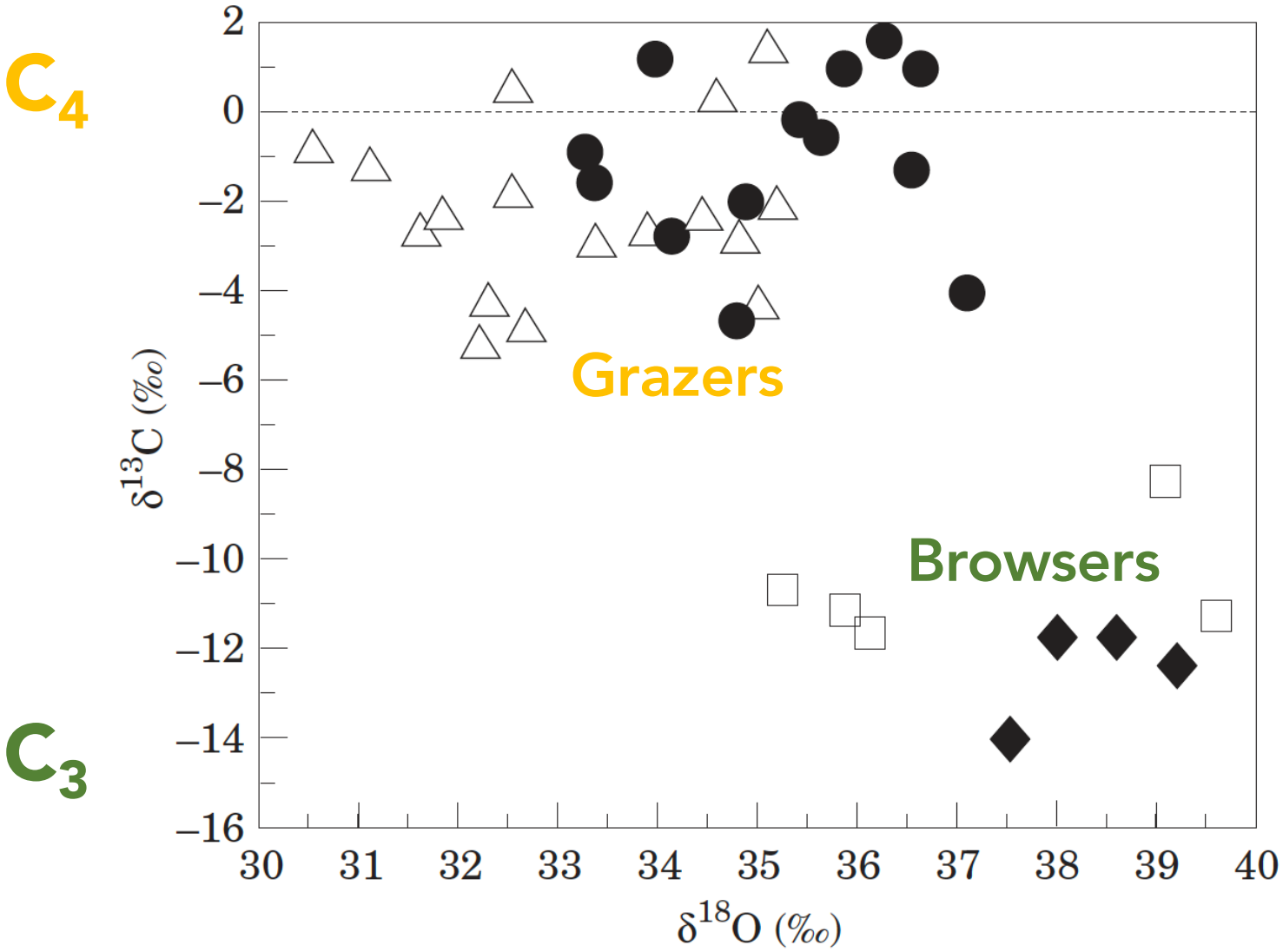
The $\delta^{18}O$ of body water and the **temperature** (mainly a concern for ectotherms) influence biomineral $\delta^{18}O$

Biogenic phosphate and carbonate $\delta^{18}O$ values are strongly correlated with meteoric water $\delta^{18}O$ values



Koch 1998

Diet and physiology impact consumer inorganic $\delta^{18}O$ values

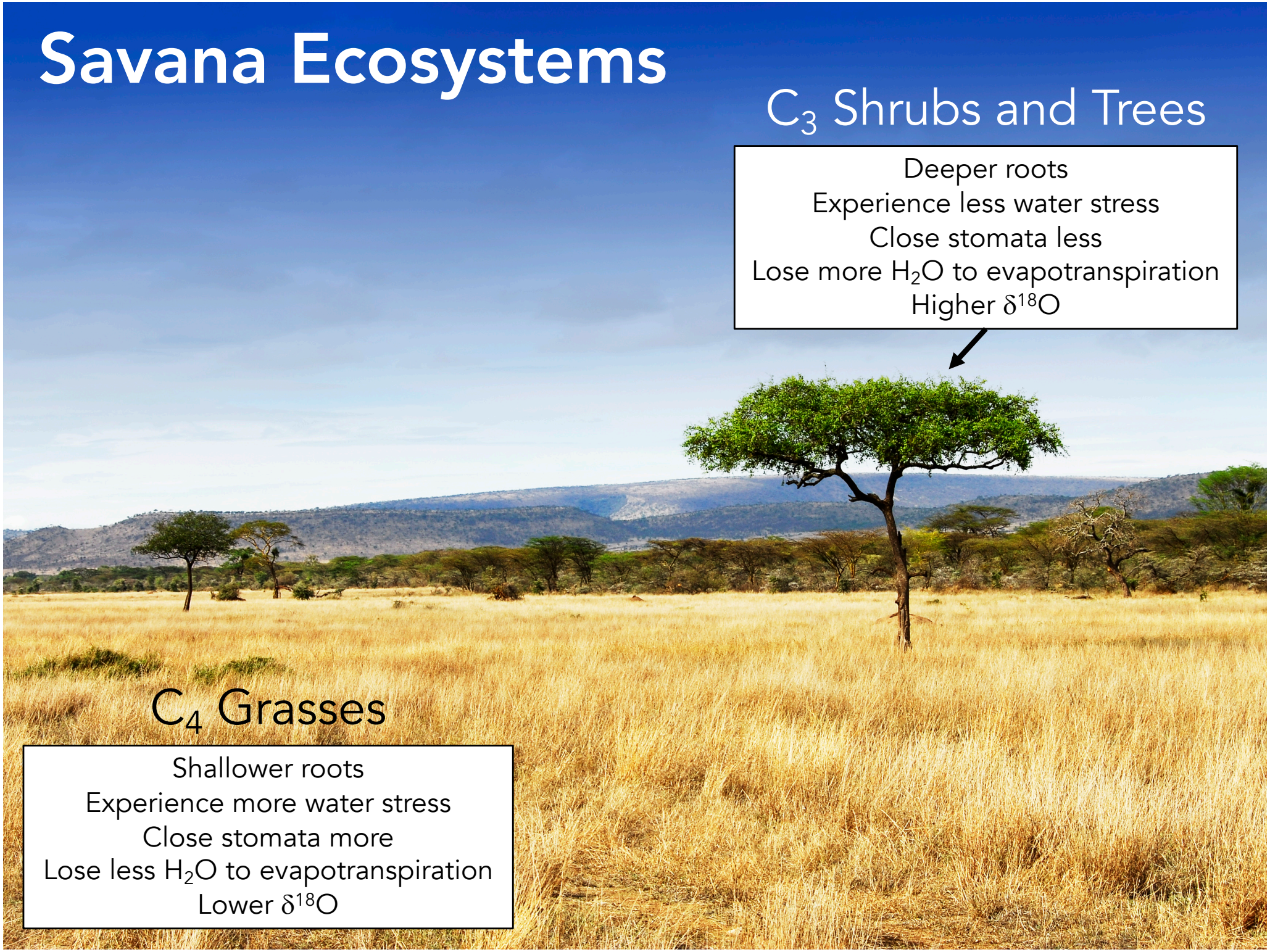


Sponheimer and Lee-Thorp 1999

Savana Ecosystems

C_3 Shrubs and Trees

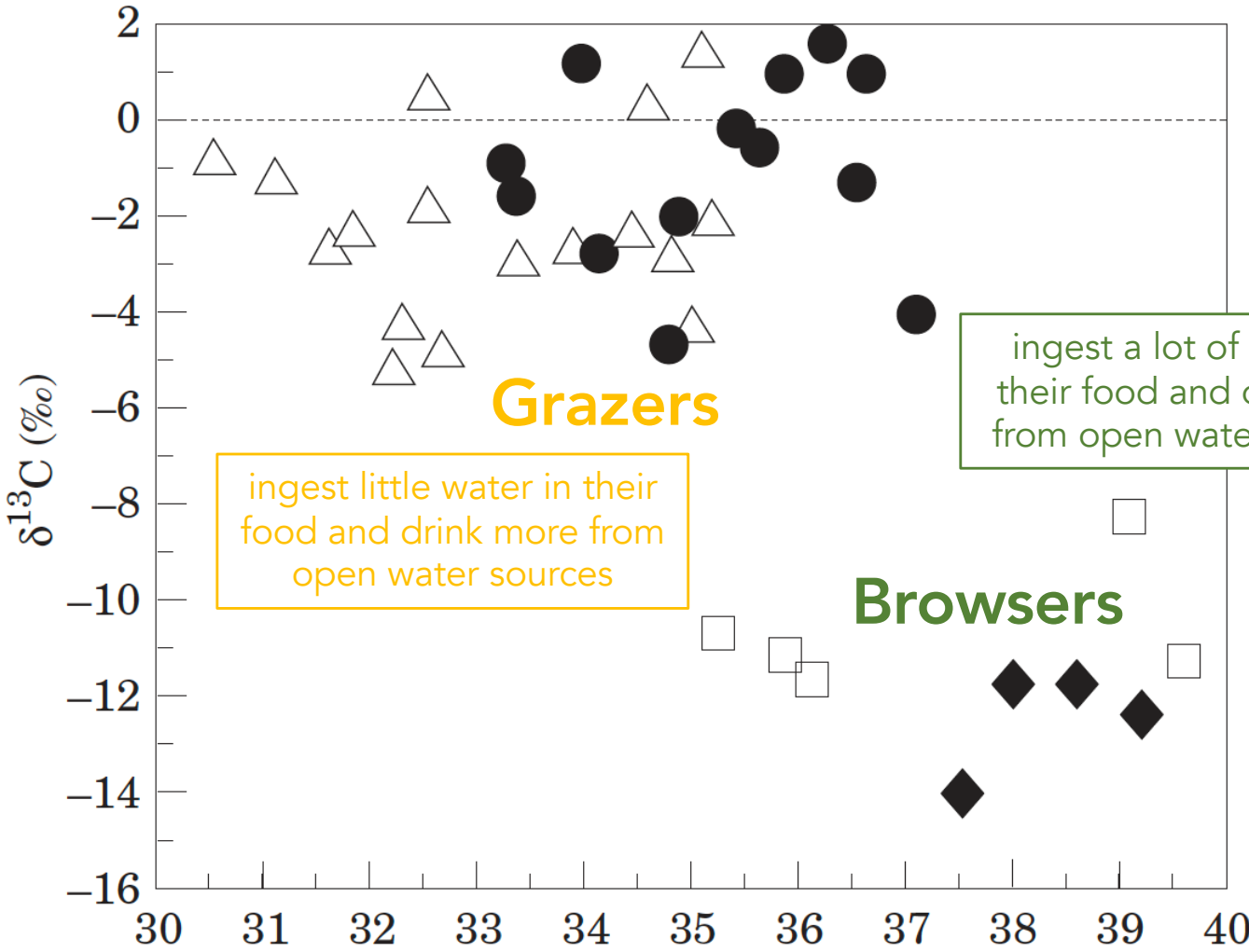
Deeper roots
Experience less water stress
Close stomata less
Lose more H_2O to evapotranspiration
Higher $\delta^{18}O$



C_4 Grasses

Shallower roots
Experience more water stress
Close stomata more
Lose less H_2O to evapotranspiration
Lower $\delta^{18}O$

Diet and physiology impact consumer $\delta^{18}O$ values

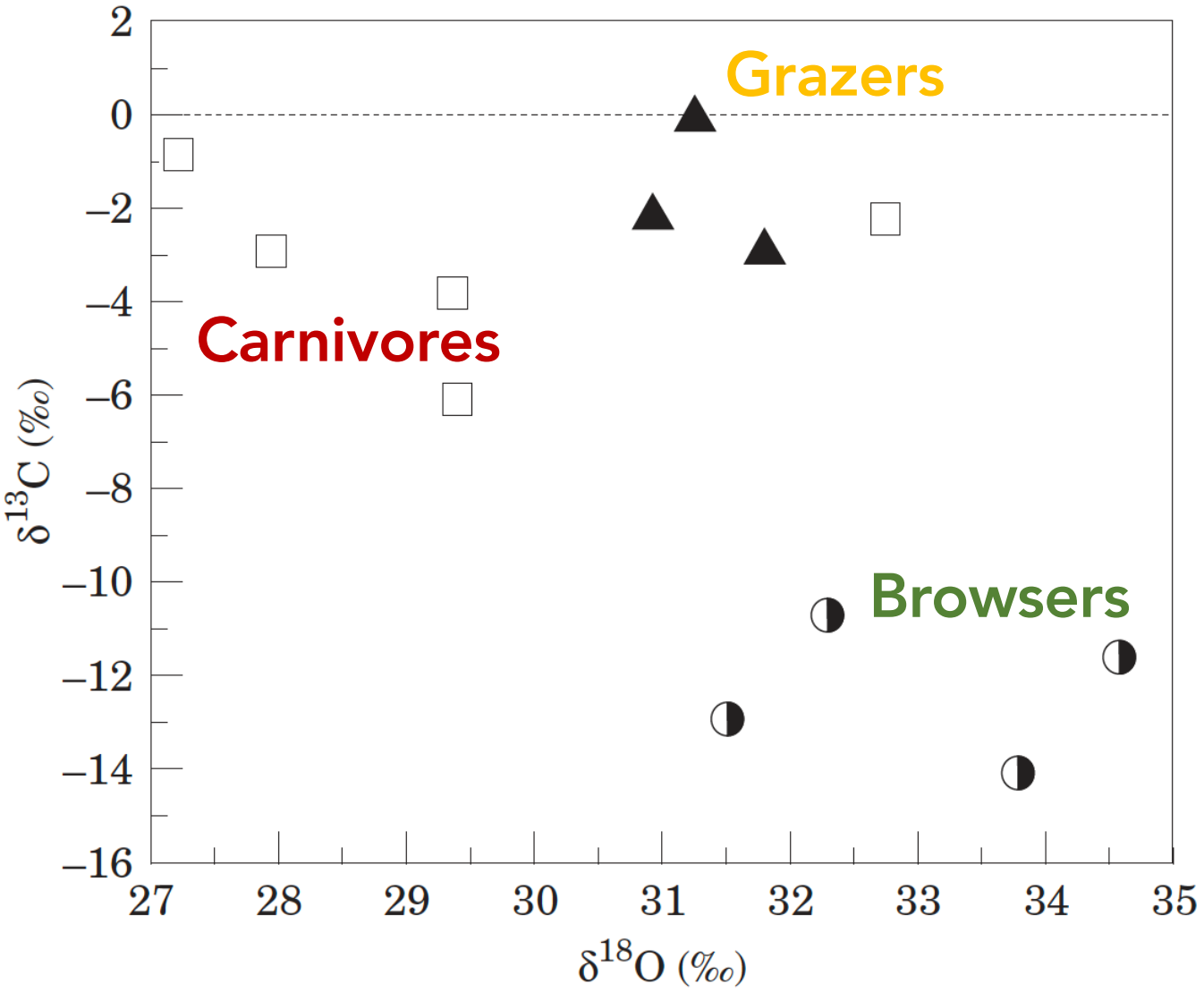


C_4 grasses have lower $\delta^{18}O$ values

C_3 shrubs and trees have higher $\delta^{18}O$ values

Sponheimer and Lee-Thorp 1999

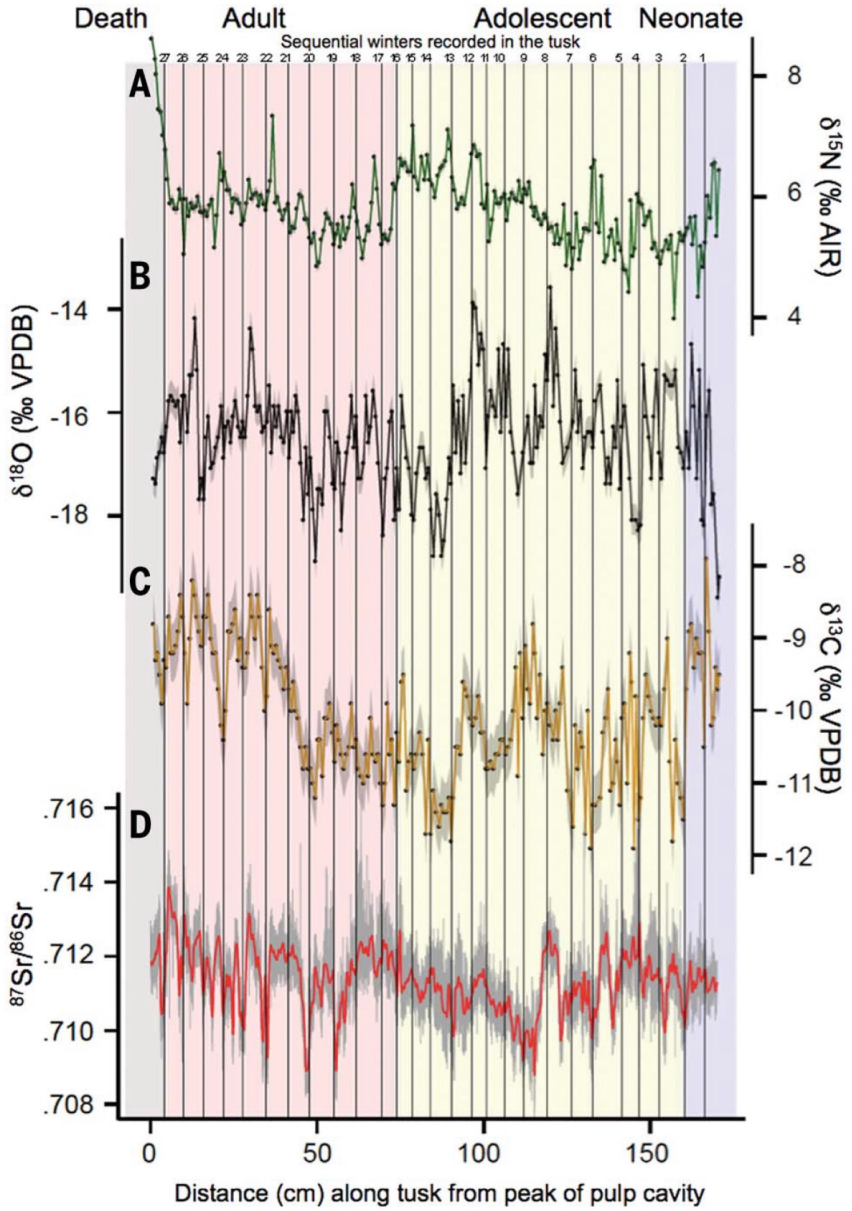
Diet and physiology impact consumer $\delta^{18}O$ values



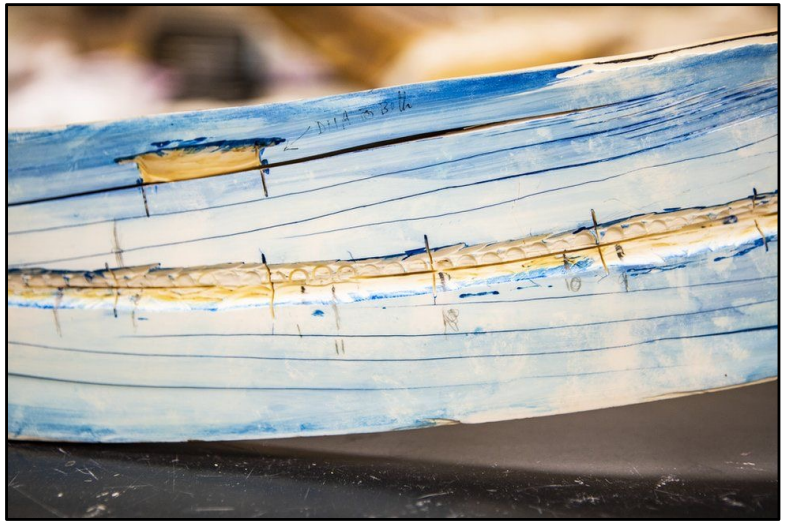
Sponheimer and Lee-Thorp 1999

$^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values tell a story about the movement patterns of a Woolly Mammoth that lived 17,100 years ago

enamel



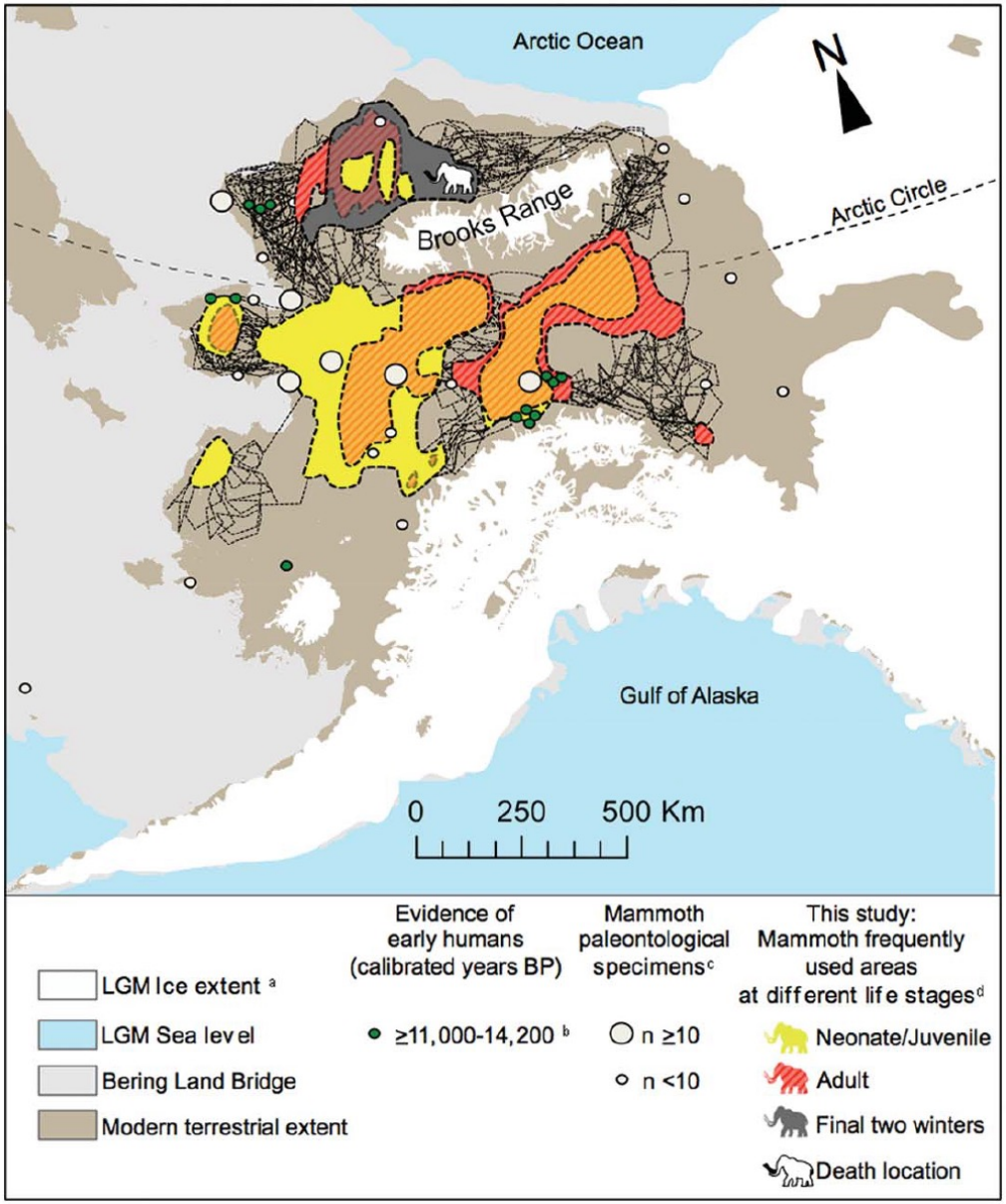
dentin collagen



1.7 m long tusk
from a
28-year-old male

Wooller et al. 2021

~340,000 $^{87}Sr/^{86}Sr$ measurements and ~1,500 $\delta^{18}O$ measurements mapped onto isoscapes of Alaska and Canada



Wooller et al. 2021

$\delta^{18}O$ records as climate proxies

The $\delta^{18}O$ values of minerals precipitated in water (e.g., calcite, aragonite) are dependent on temperature and the $\delta^{18}O$ value of dissolved CO_2

$$T\,(°C) = 16.5 - 4.3(\delta^{18}O_{calcite} - \delta^{18}O_{water}) + 0.14(\delta^{18}O_{calcite} - \delta^{18}O_{water})^2$$

Physiology (e.g., growth rate) can also impact the $\delta^{18}O$ values of biogenically produced minerals (geologists refer to these impacts as "vital effects")

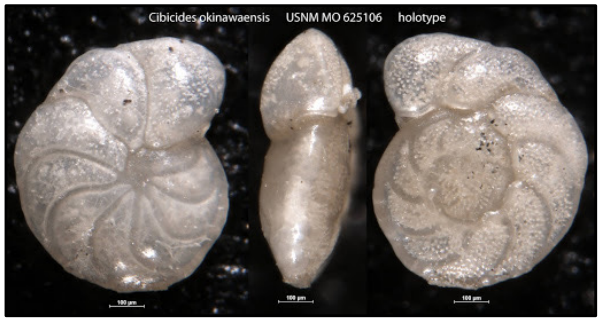
Epstein et al. 1953

$\delta^{18}O$ records as climate proxies

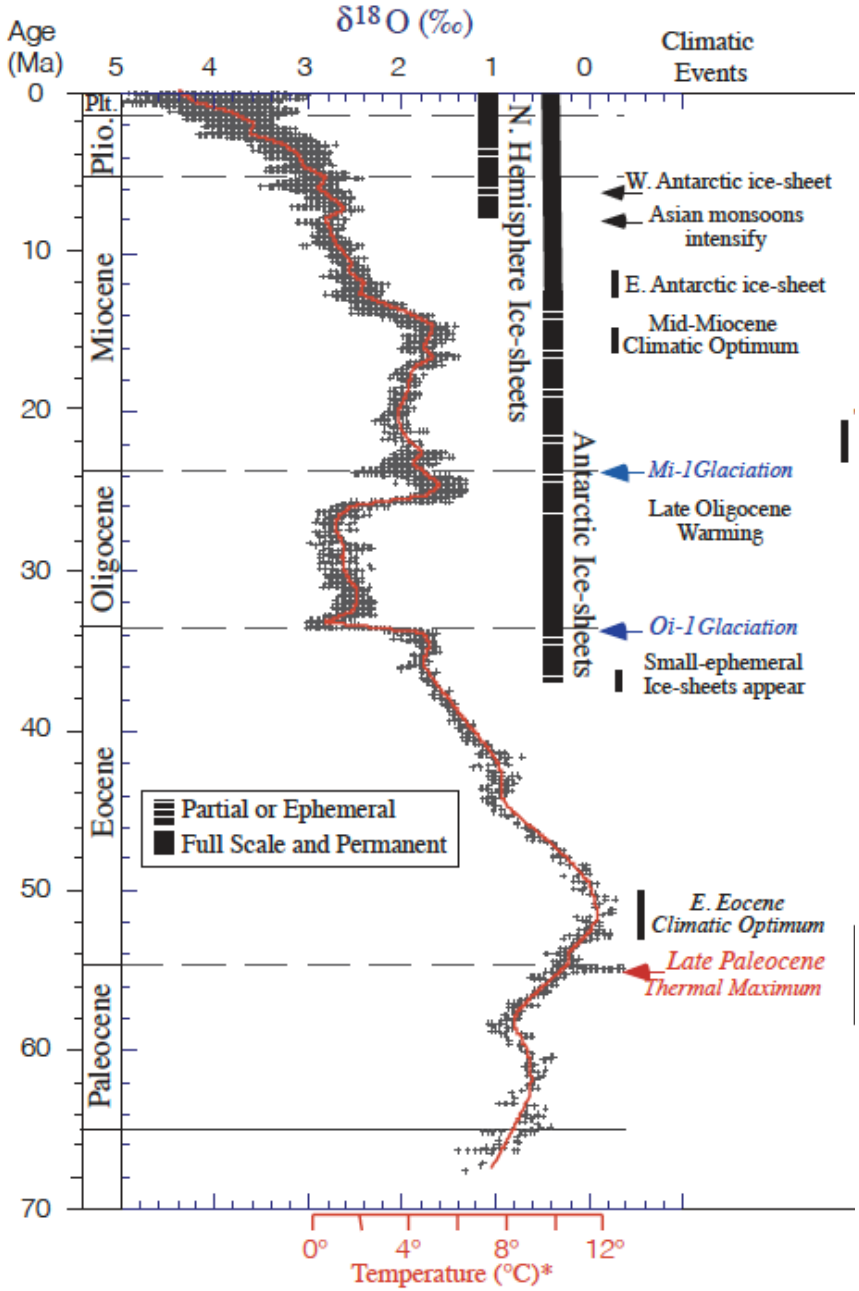
Foraminifera

most are benthic and heterotrophic

typically have shells made of calcium carbonate ($CaCO_3$)

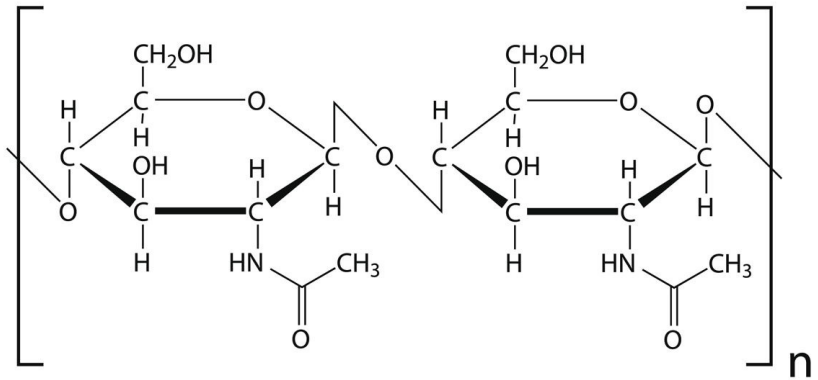


decreasing $\delta^{18}O$ values indicate increasing temperature

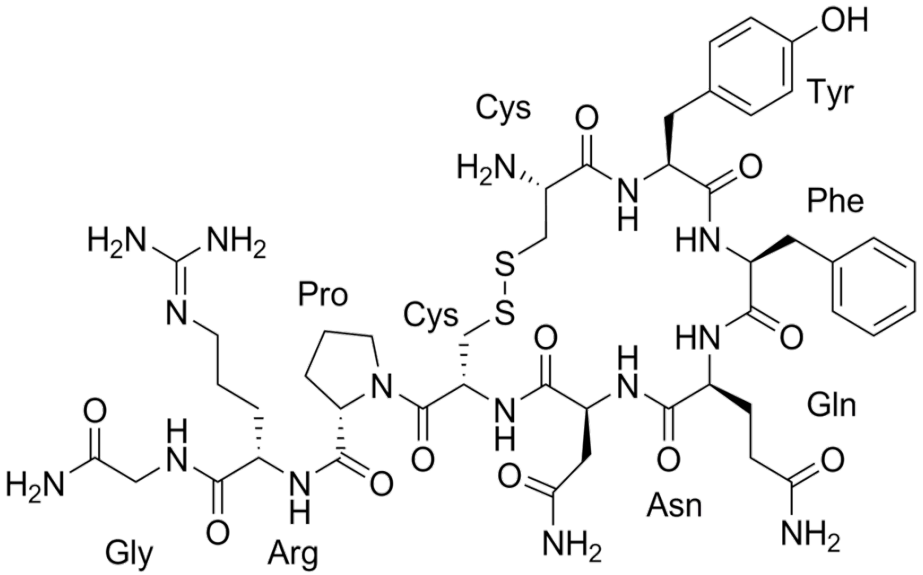


Zachos et al. 2001

Oxygen in organic tissues



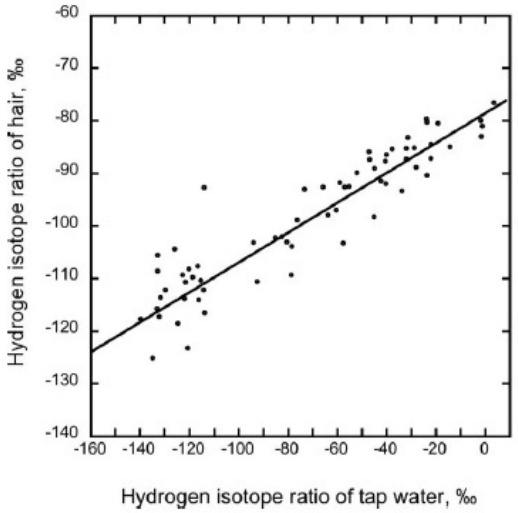
Chitin

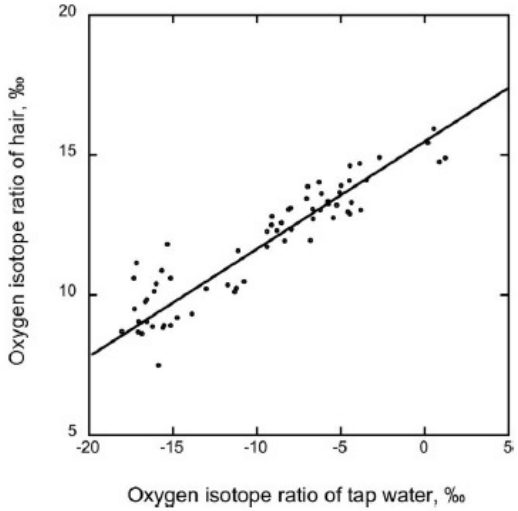


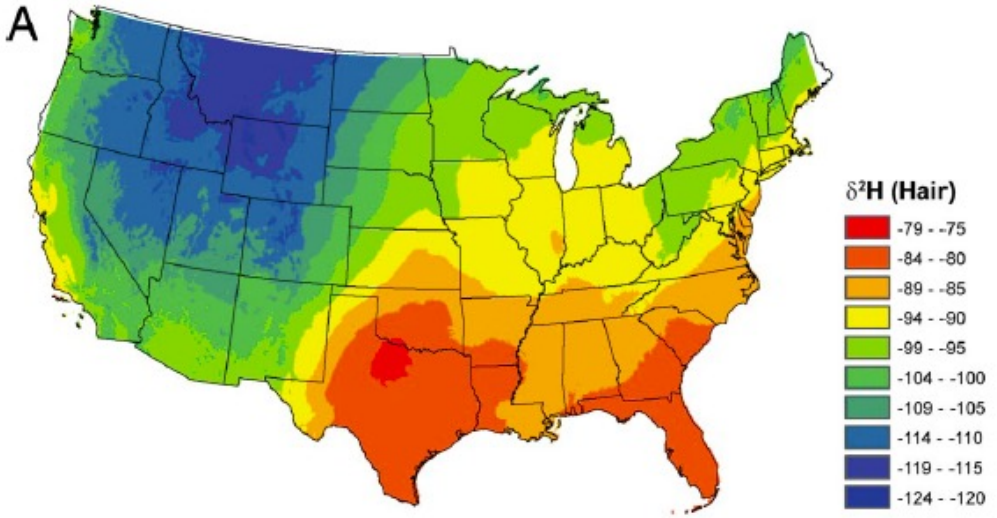
Protein

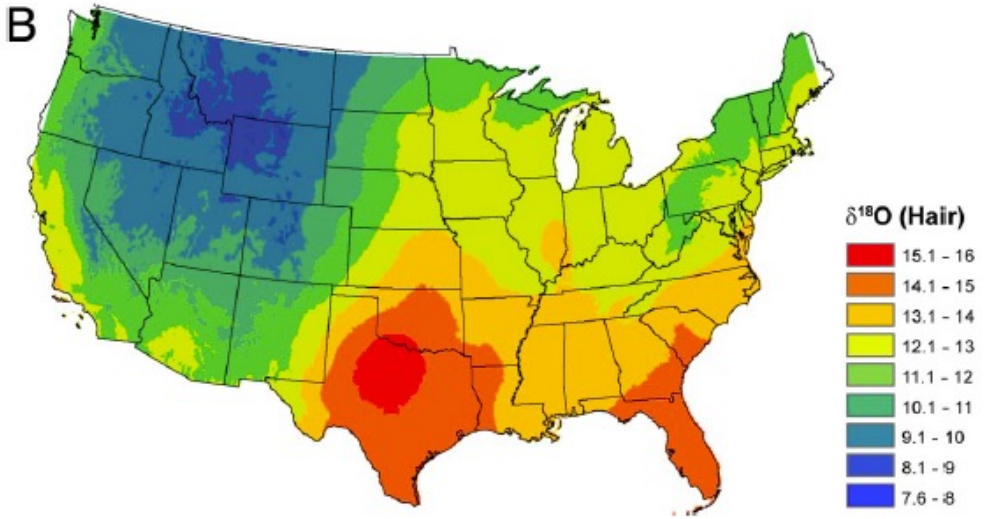
δ^2H and $\delta^{18}O$ in Human Hair

This study found 35% of oxygen in hair derived from local drinking water



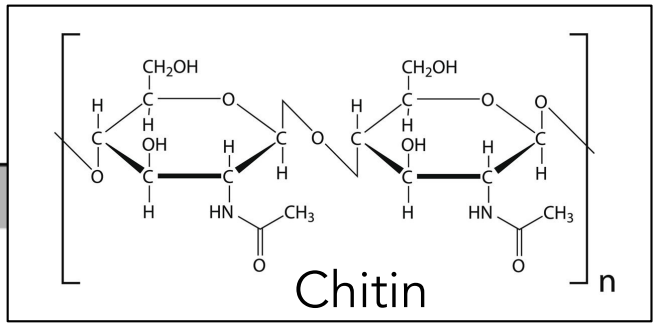


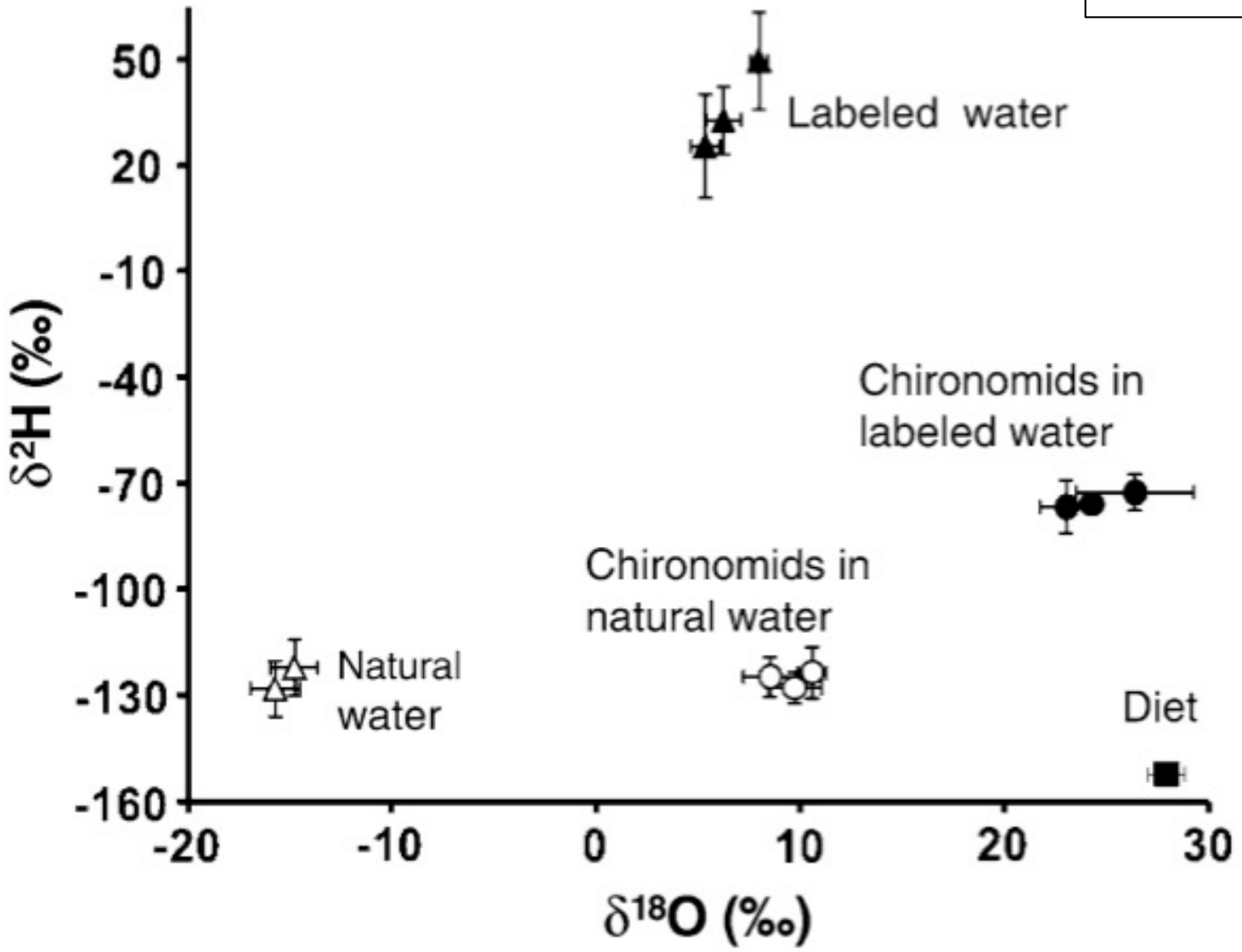




Ehleringer et al. 2008

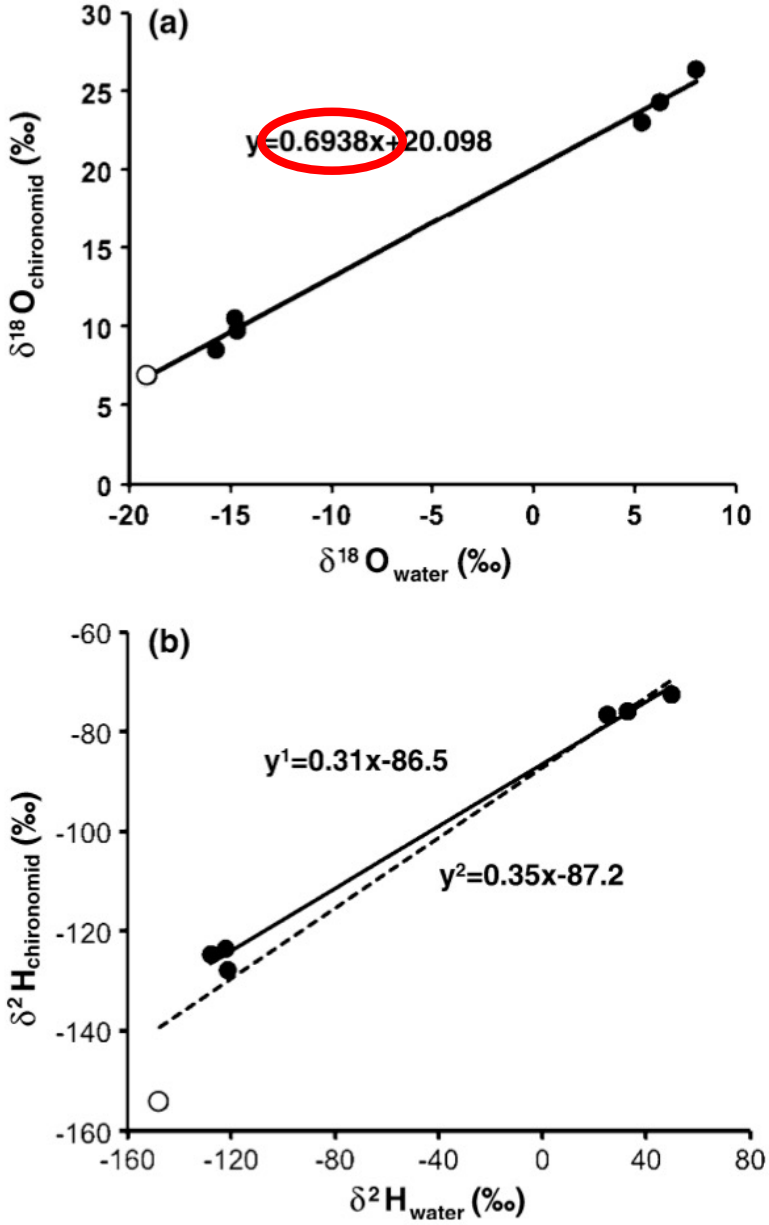
Oecologia (2009) 160:225–233
DOI 10.1007/s00442-009-1303-3





Wang et al. 2009

Estimated that nearly 70% of oxygen in chironomid chitin came from environmental water



Wang et al. 2009

Organic $\delta^{18}O$ Assumptions

$$\delta^{18}O_C = \underbrace{(\delta^{18}O_D + \varepsilon_D)(1 - p)}_{\text{Routing of dietary macromolecules}} + \underbrace{(\delta^{18}O_W + \varepsilon_W)p}_{\text{\textit{De novo} synthesis of tissue macromolecules}}$$

We are ignoring atmospheric O_2 contributions…