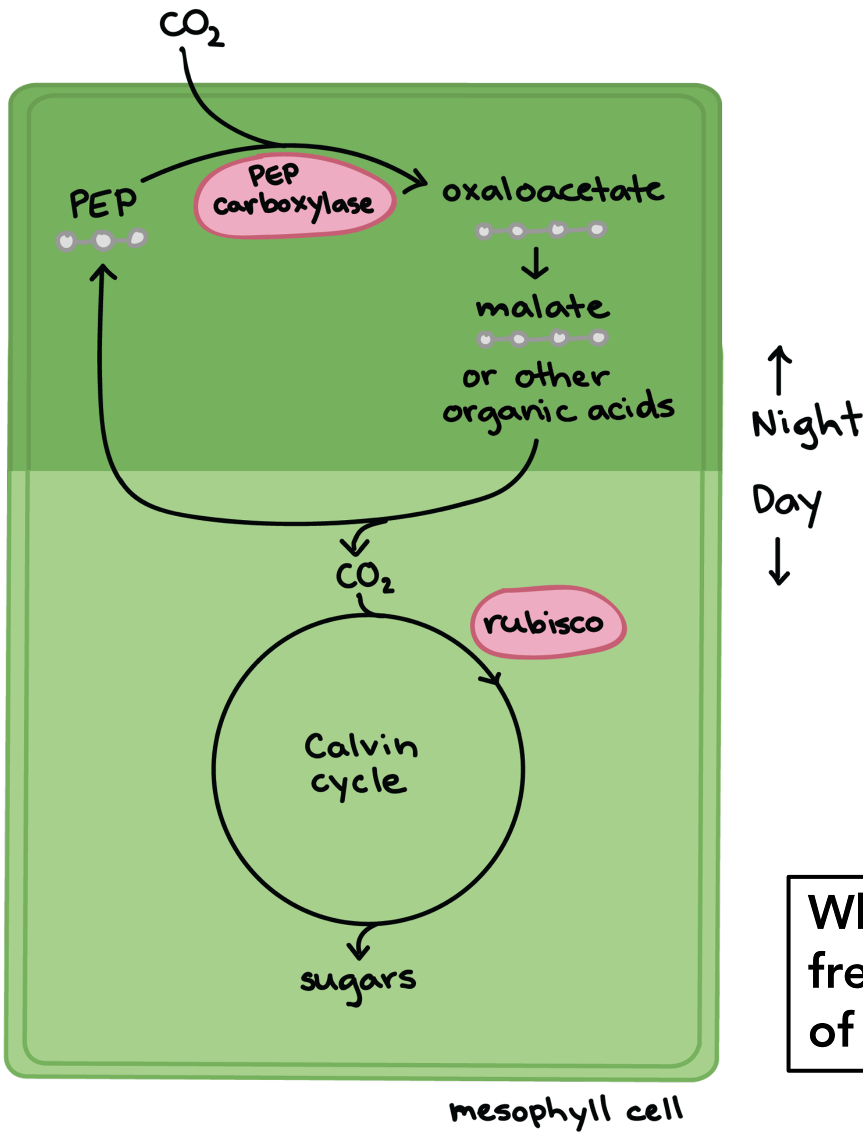
Primary Producer Carbon

Elemental Ecology

Week Three

CAM Photosynthesis



Crassulacean Acid Metabolism (CAM)

Typically, CAM plants open their stomata during the night and fix CO_2 using PEP carboxylase. Then they close their stomata during the day and decarboxylate 4-carbon sugars to produce CO_2, which is subsequently fixed by Rubisco.

However, some CAM plants open their stomata during the day and use Rubisco to fix CO_2 directly.

Which enzyme is a CAM plant using more frequently to fix CO_2 if it has a $\delta^{13}C$ value of -13‰? What about -20‰?

CAM Photosynthesis

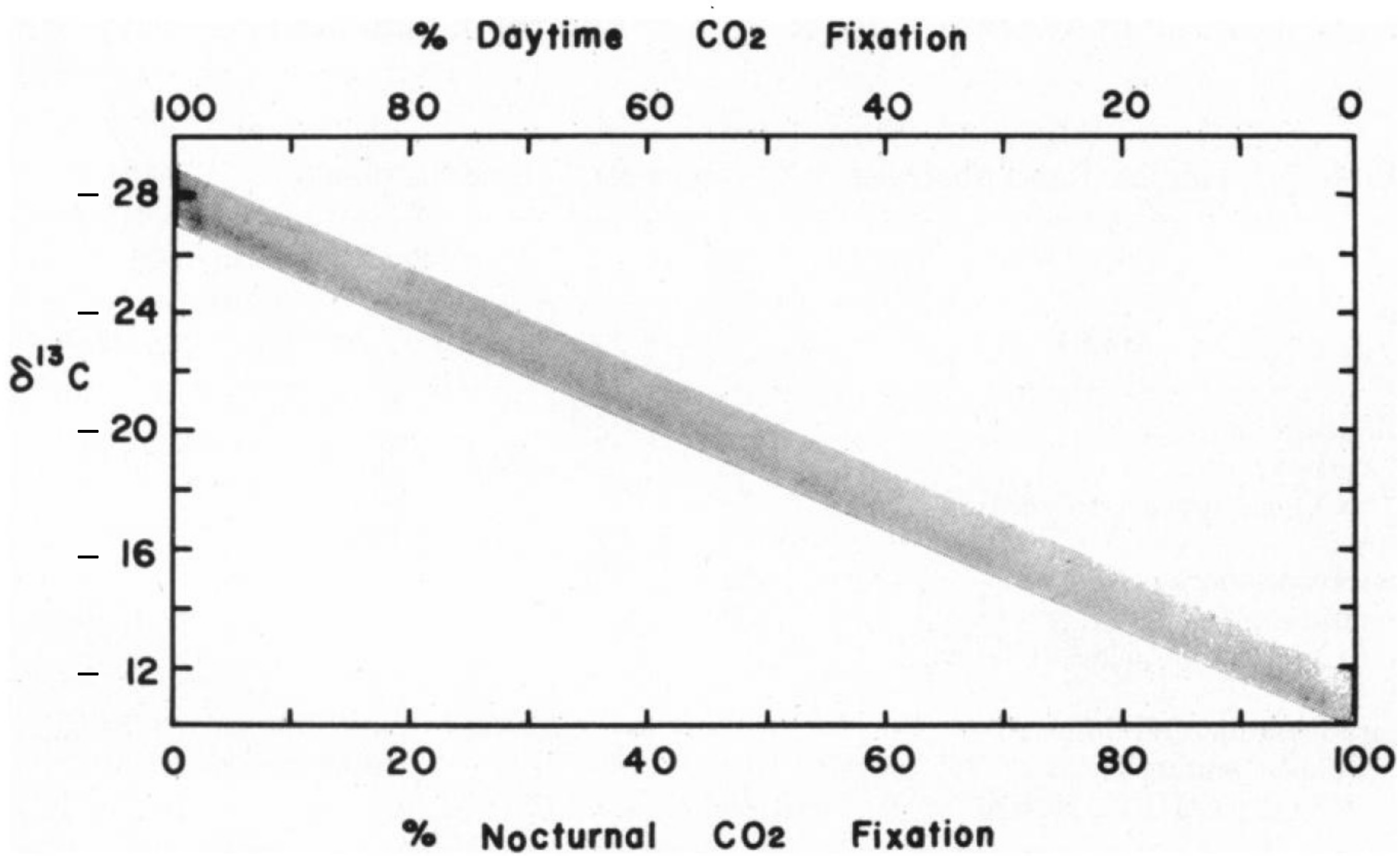


Figure 4. Predicted $\delta^{13}C$ value for CAM plants as a function of the proportions of CO_2 fixed at night and during the day.

O'Leary 1988

Terrestrial Plant $\delta^{13}C$ Summary

What variable is the biggest determinant of $\delta^{13}C$ values in C_3 plants?

c_i / c_a ratio

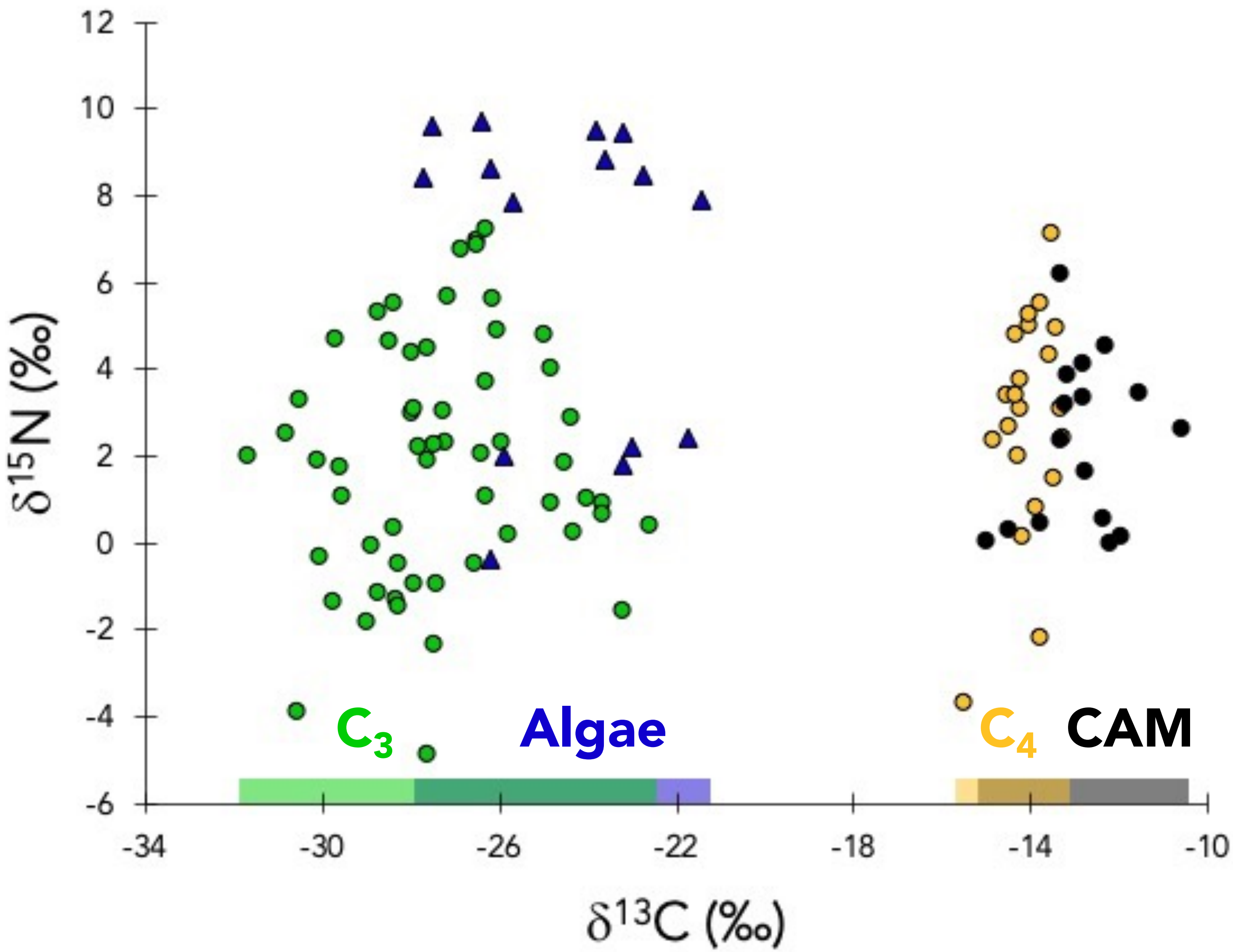
How about in C_4 plants?

ϕ (bundle sheath cell "leakiness" factor)

CAM plants?

Relative proportion of daytime vs. nighttime CO_2 fixation

New Mexican Primary Producers



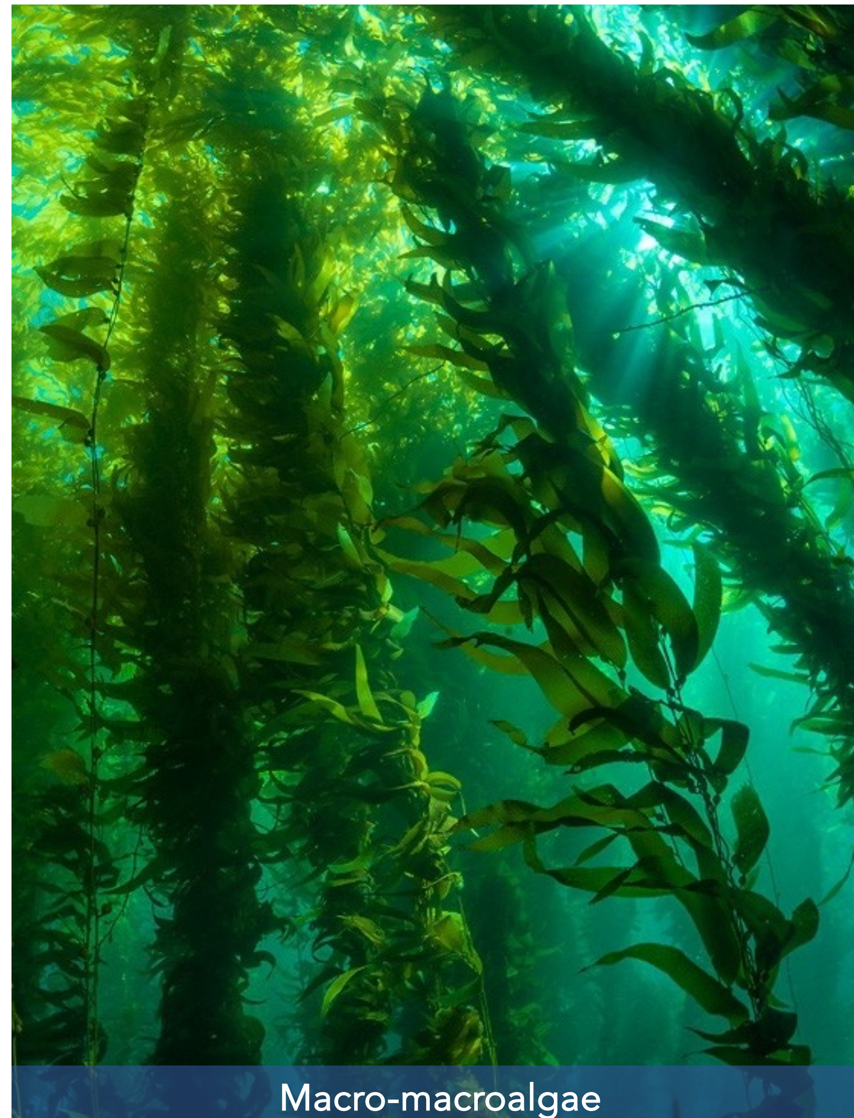
Aquatic Photosynthesis

Macroalgae

Cyanobacteria

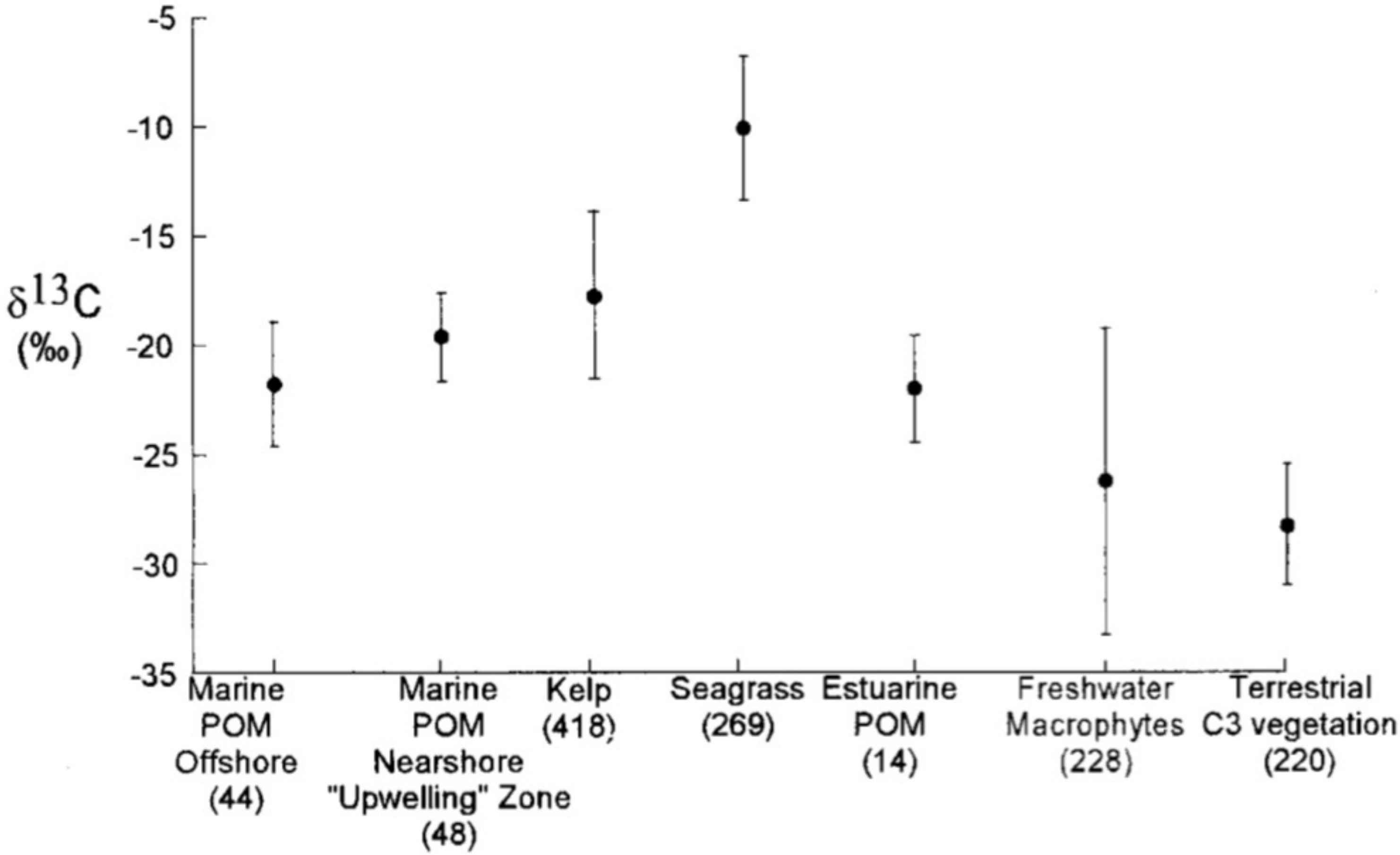
Microalgae

Seagrass (a C_4 plant!)



Macro-macroalgae

$\delta^{13}C$ values vary among aquatic primary producers



Different aquatic primary producers have different $\delta^{13}C$ values due
To physiological and environmental conditions

Clementz and Koch 2001

Aquatic Photosynthesis

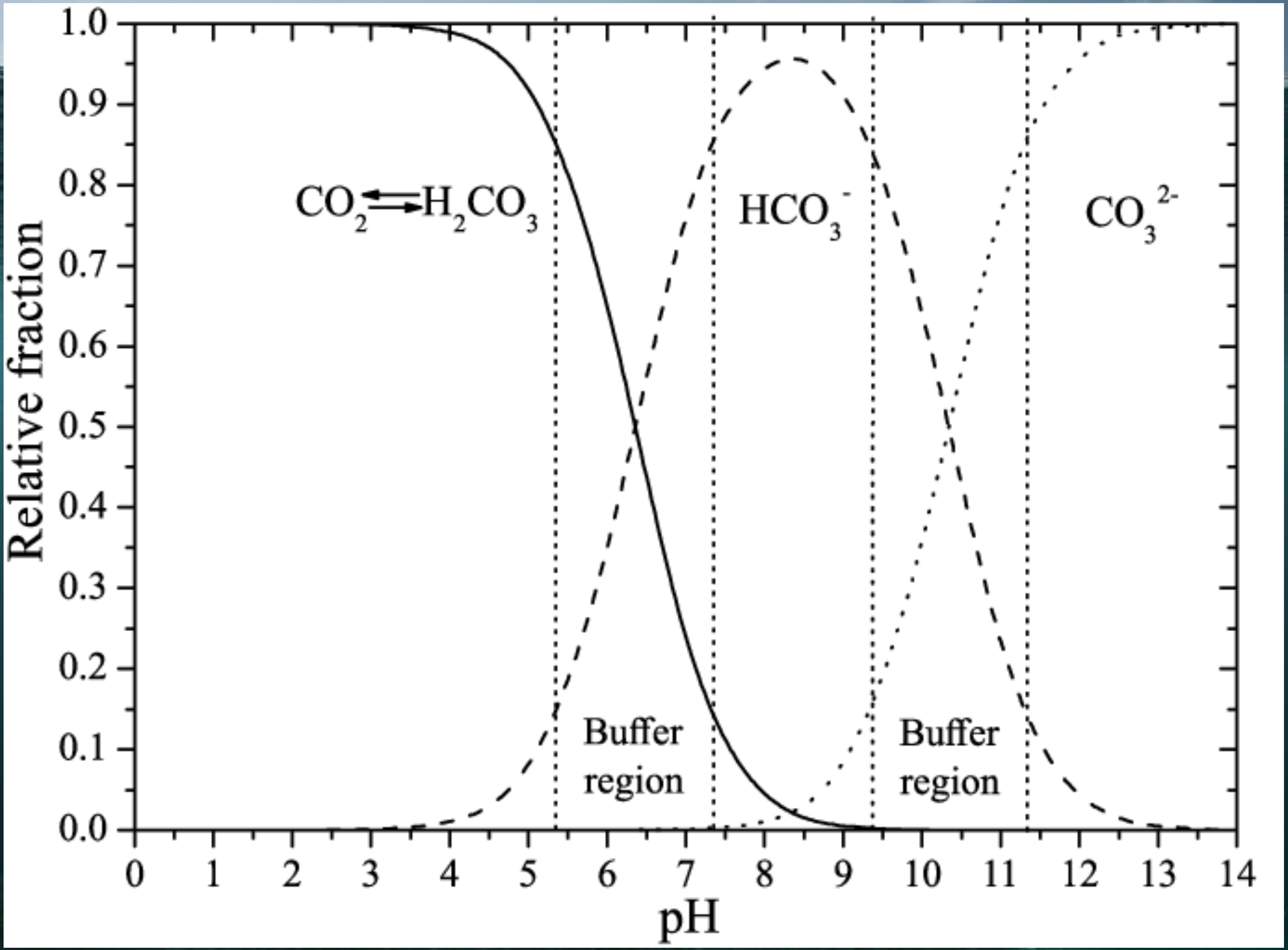
Inorganic carbon is fixed by photosynthetic organisms

There are different types of inorganic carbon in water

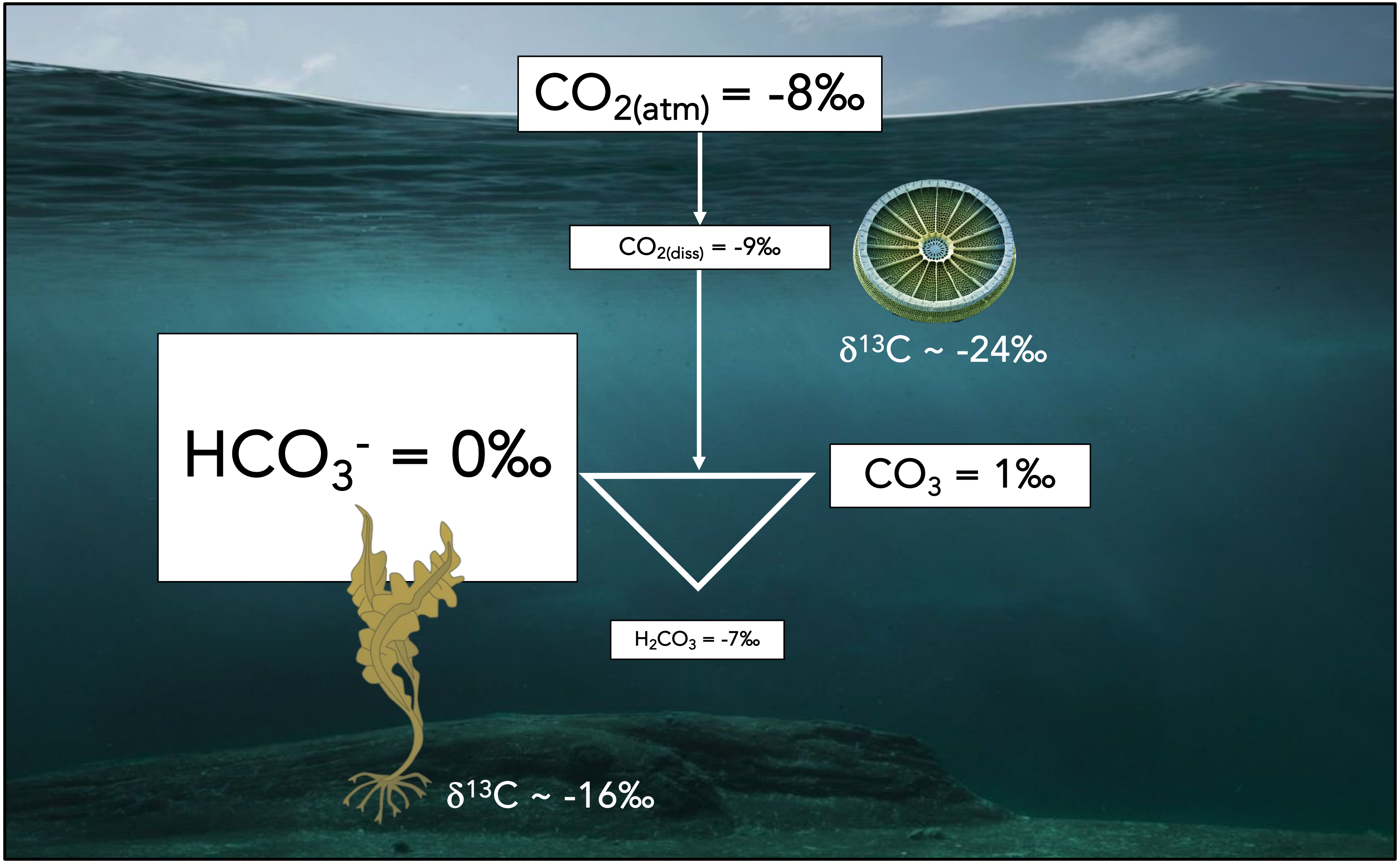
The $\delta^{13}C$ values of aquatic primary producers vary across space and time due to the following factors:

- → types and concentrations of inorganic carbon sources
- → carbon concentrating mechanisms
- → primary producer growth rate
- → primary producer cell size and geometry
- → temperature
- → water velocity and water mixing

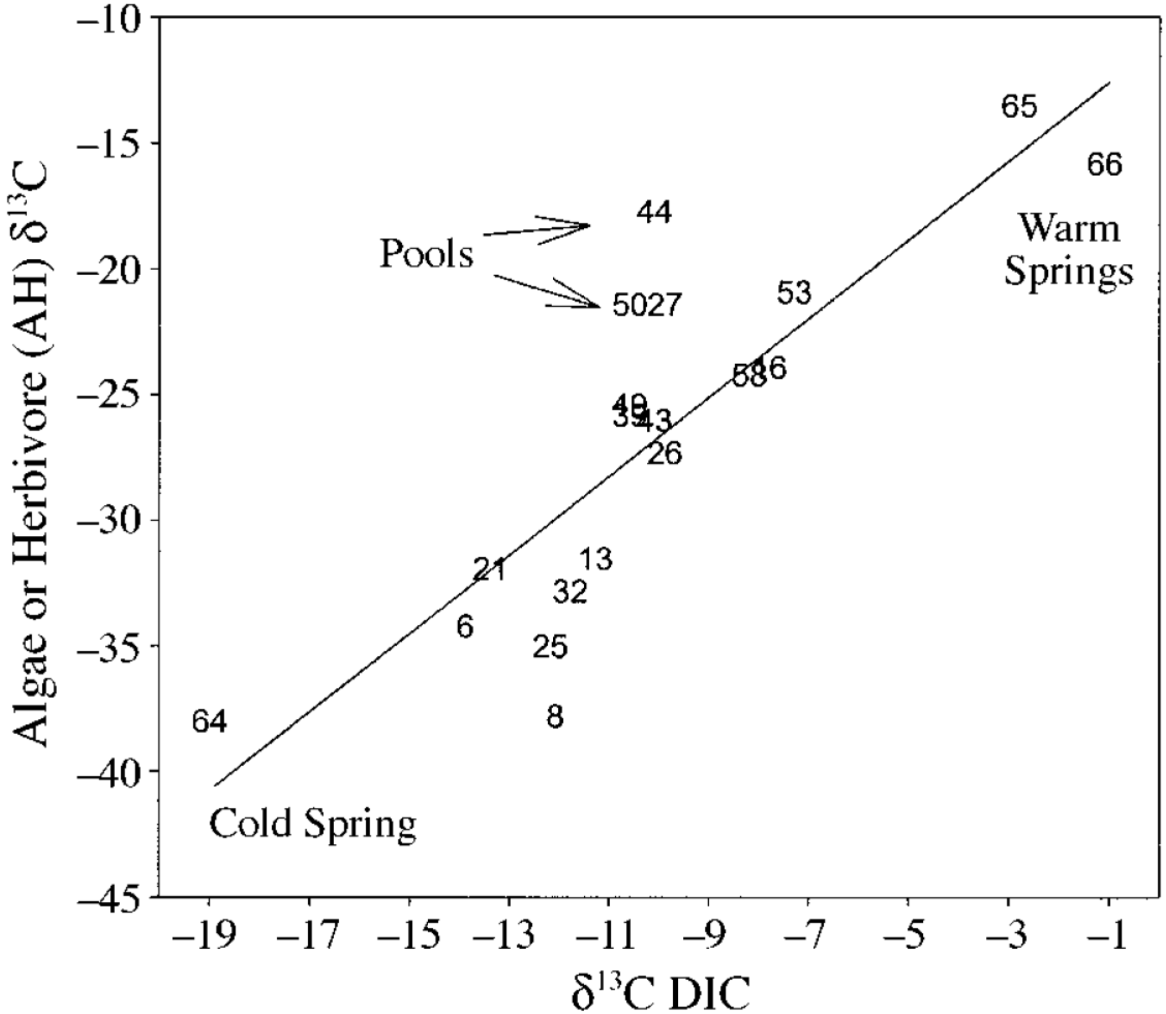
Aquatic Inorganic Carbon Sources



Aquatic Inorganic Carbon Sources



Aquatic Inorganic Carbon Sources



DIC $\delta^{13}C$ values influence algal $\delta^{13}C$ values in streams

Finlay 2001

Growth Rate

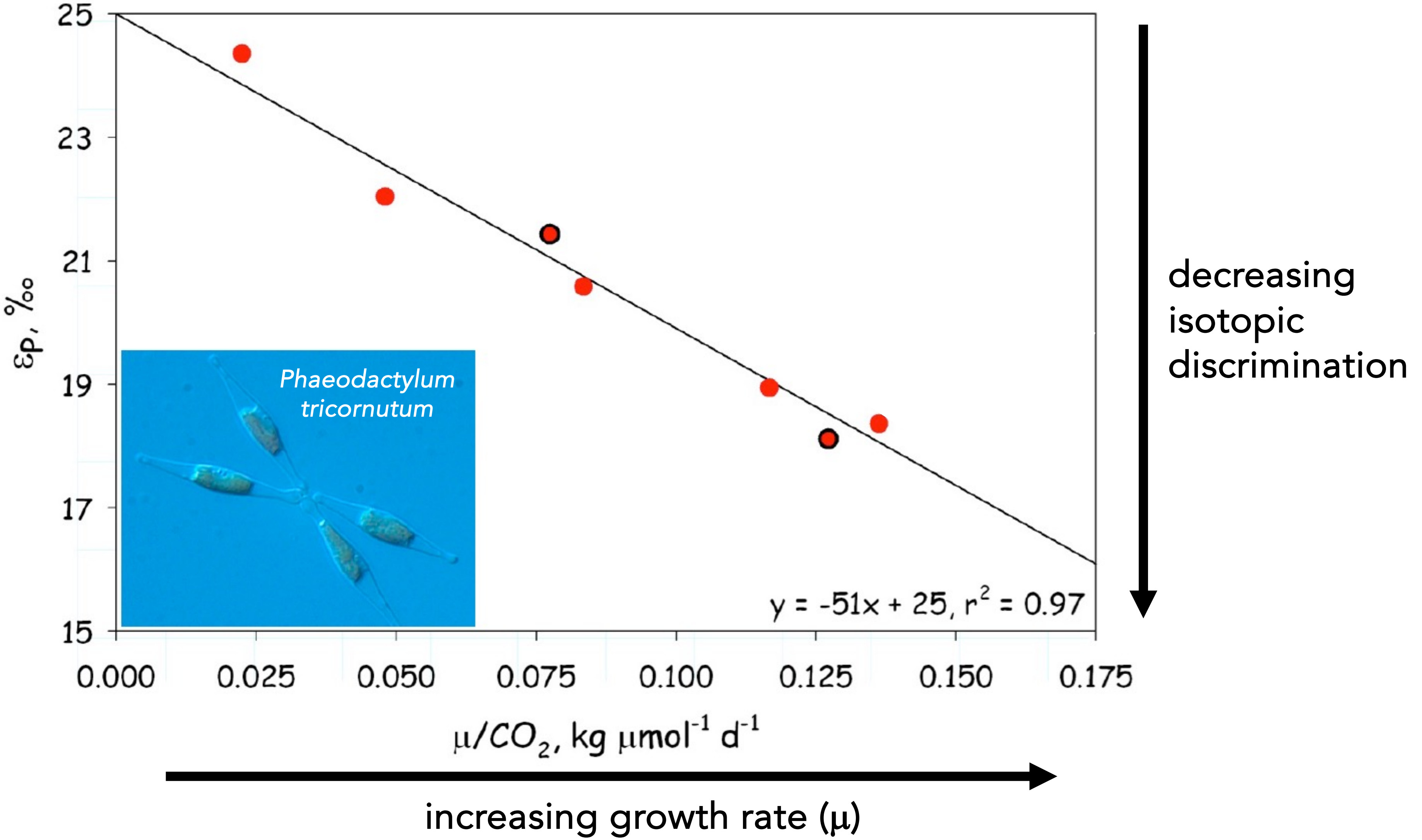
Growth rate is proportional to the net flux of CO_2 into the cell

$\uparrow$ growth rate leads to $\downarrow \Delta^{13}C$

$\downarrow \Delta^{13}C = \uparrow \delta^{13}C$

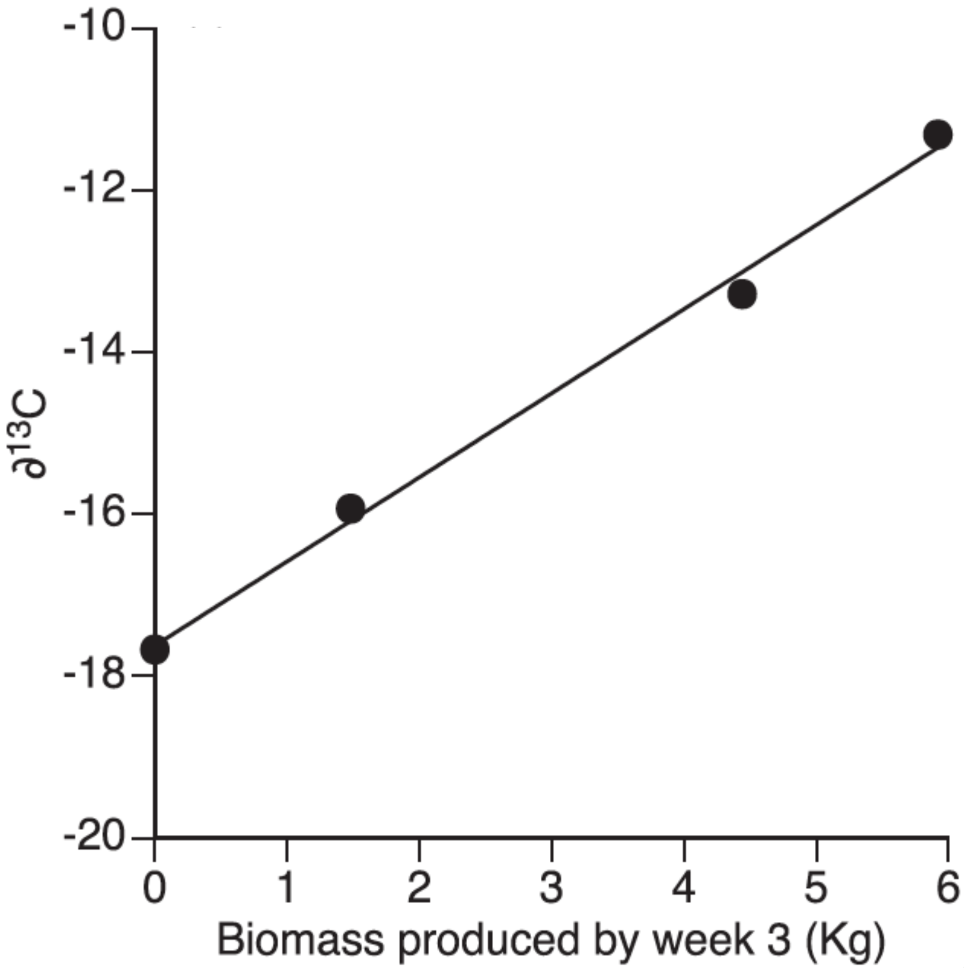
As algal growth rates increase, the organisms essentially become less 'picky' and discriminate against $^{13}CO_2$ less

Growth Rate



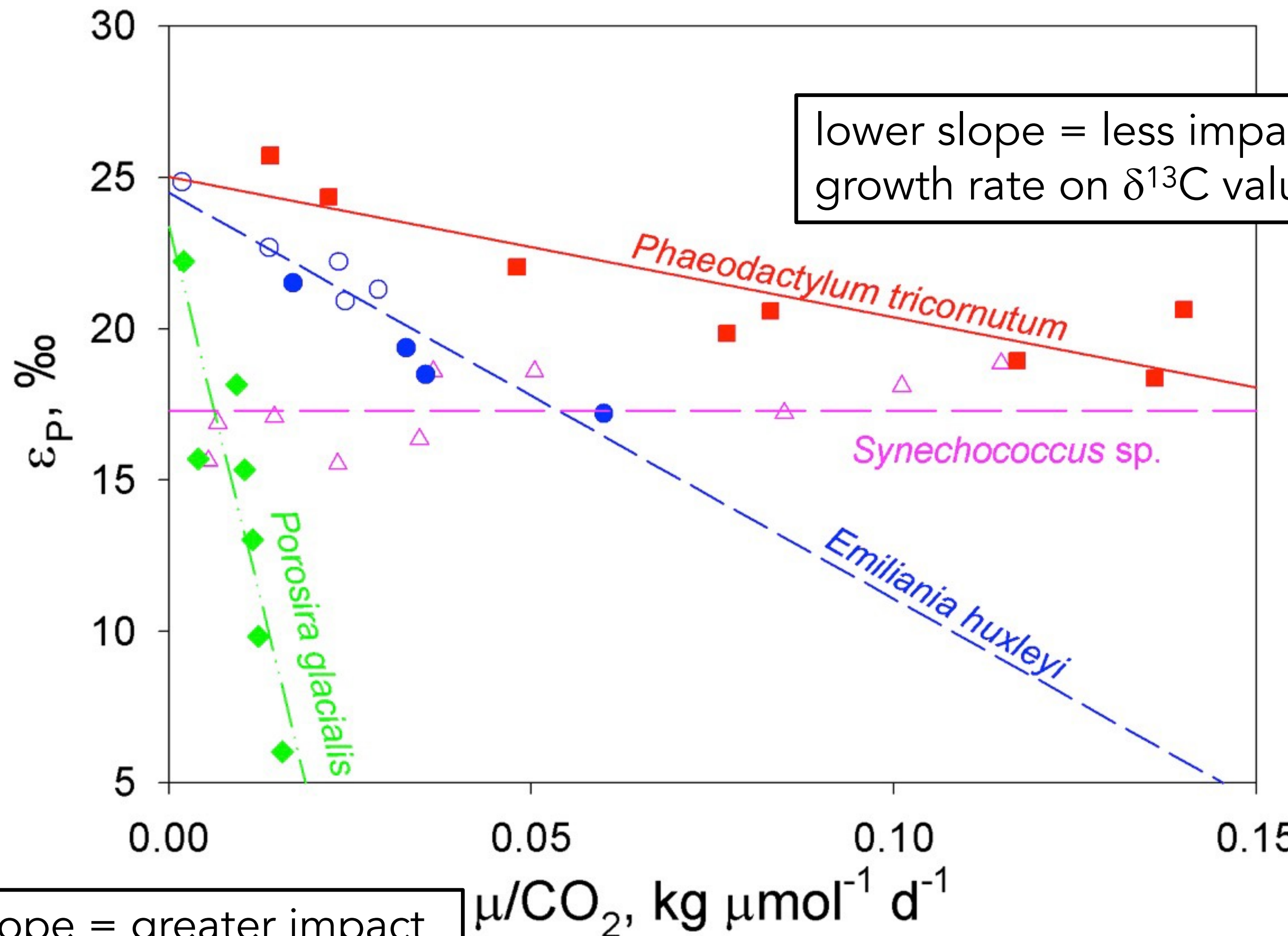
Laws et al. 1995

Growth Rate



Fox 2013

Algal Cell Size and Geometry

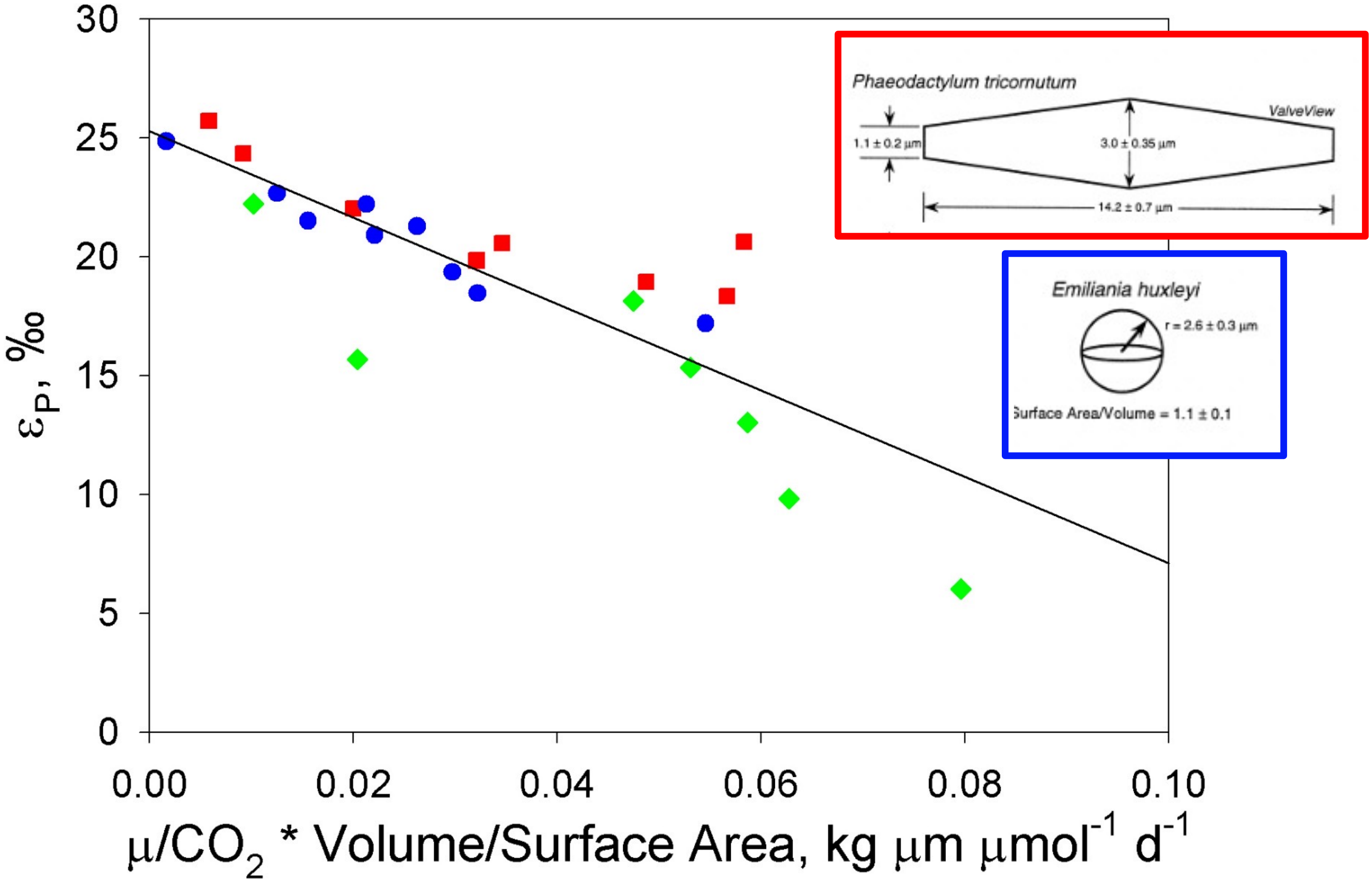


lower slope = less impact of growth rate on $\delta^{13}C$ values

greater slope = greater impact of growth rate on $\delta^{13}C$ values

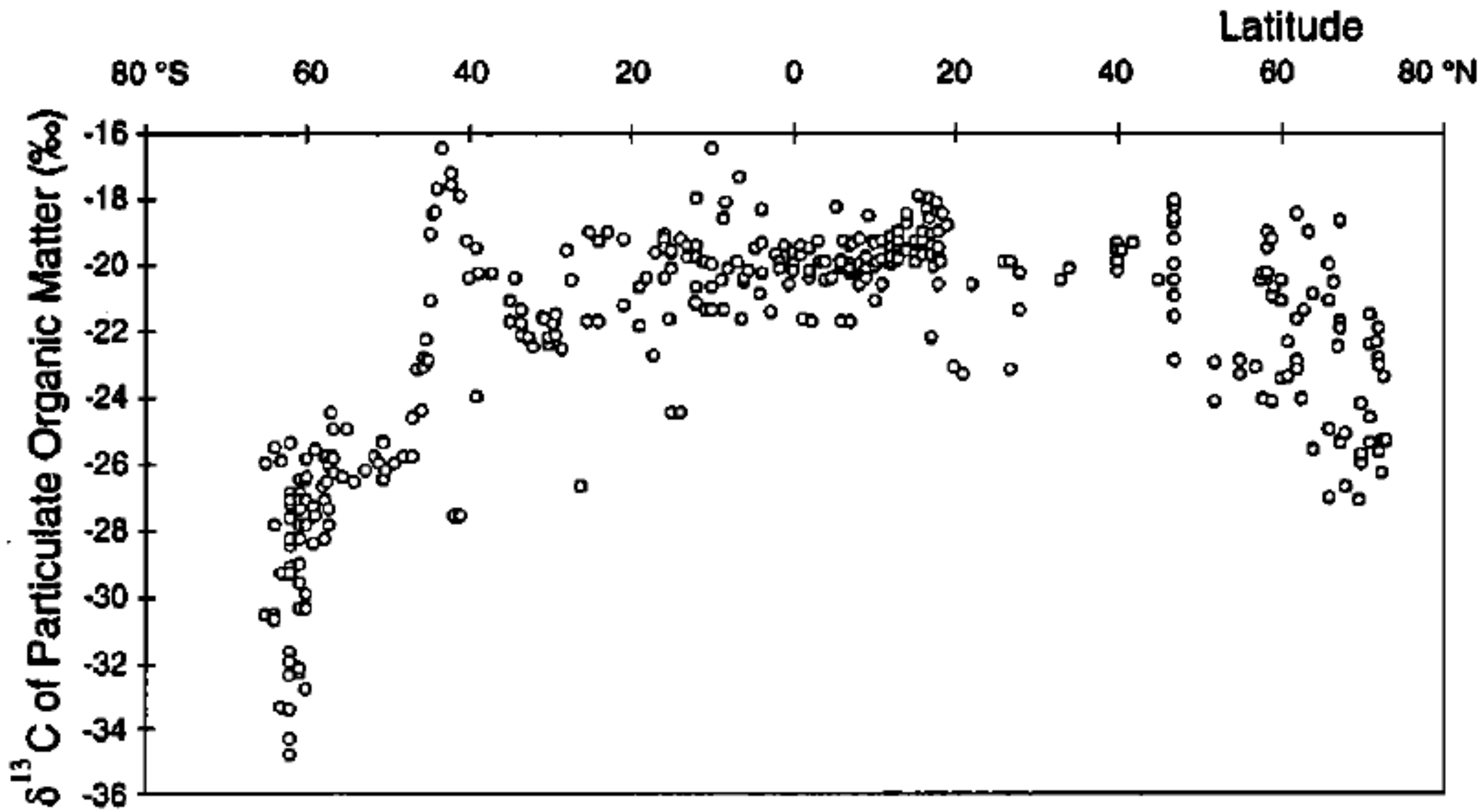
Popp et al. 1998

Algal Cell Size and Geometry



Popp et al. 1998

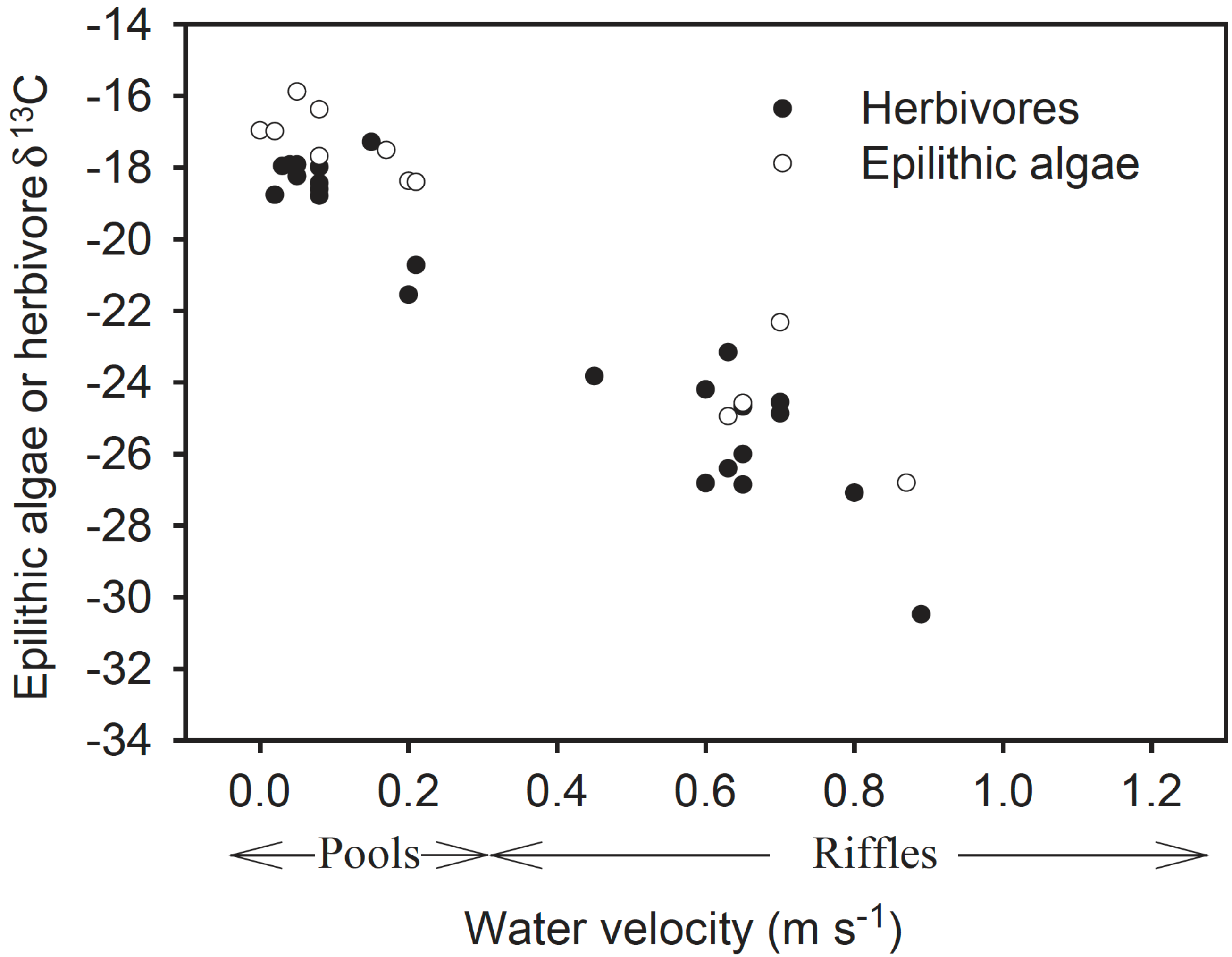
Temperature



decreasing temperature leads to increasing isotopic fractionation and lower $\delta^{13}C$ values

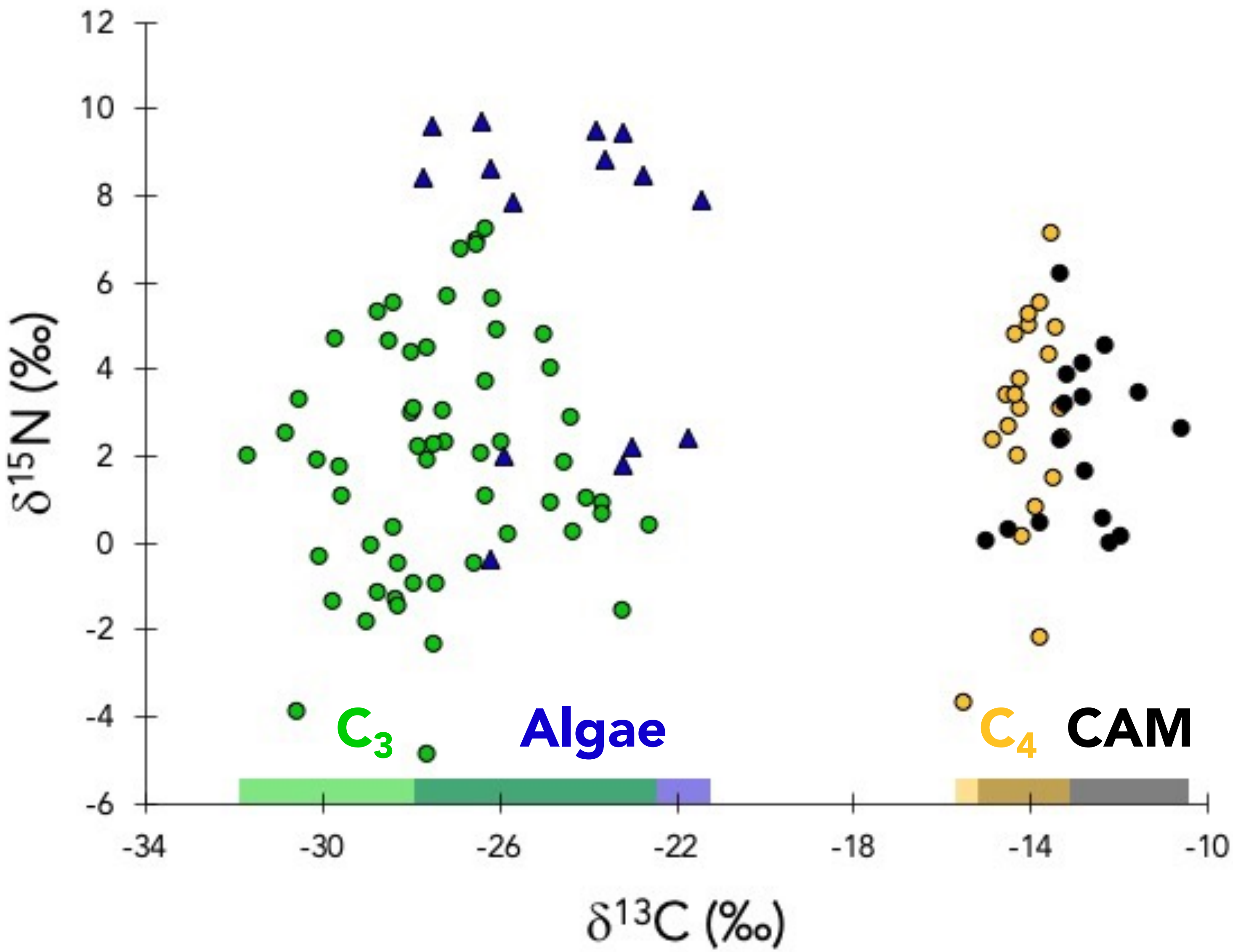
Goericke and Fry 1994

Increasing water velocity decreases algal $\delta^{13}C$ values in streams and rivers



Finlay et al. 2002

New Mexican Primary Producers



Additional slides…

Aquatic Algal Photosynthesis

equilibrium dissolution of CO_2 into water
$\varepsilon = 1.1‰$

$$\Delta^{13}C = e_s + a_l + [b - e_s - a_l](c_i / c_e)$$

diffusion of CO_2 in water
$\varepsilon = 0.7‰$

CO_2 fixation by Rubisco
$\varepsilon = 27.0‰$

Aquatic Algal Photosynthesis

Assuming algal growth rate (μ) is proportional to net cellular CO_2 flux…

$$\mu = K_1 c_e - K_2 c_i$$

$$c_i = (K_1 c_e - \mu)/K_2$$

$$\mathbf{\Delta^{13}C = e_s + a_l + [b - e_s - a_l]((K_1 c_e - \mu)/K_2 / c_e)}$$

What do you think contributes the most to variation in $\Delta^{13}C$ in algae?