1.89, Environmental Microbiology
Prof. Martin Polz
Lecture 17

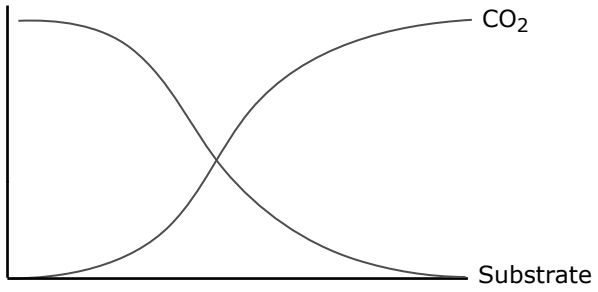
Microbial Activity in the Environment

Relatively easy to get "bulk" rates of transformation of specific chemicals, but the major question is, "who is doing it?"

(1-3) "bulk" methods

1. Radiotracers: Use of radioactive isotopes. For example ^{14}C, ^{35}S, ^{32}P.

   Biodegradation of specific compounds:
   a. Spike labeled compounds into environmental samples. For example: Pesticide: CO_2 evolution → mineralization



   b. Substrate disappear once

   Detection Method: scintillation counters

2. Microelectrodes: Measurement of the concentration of specific chemical species at relevant scales for microorganisms (μm - mm)
   Example: pH, O_2, N_2O, CO_2, H_2, H_2S, CH_4

3. Stable isotopes: example: ^{12}C vs. ^{13}C (1 more neutron, so heavier),
   ^{32}S vs. ^{34}S,
   ^{14}N vs. ^{15}N

   → Isotope fractionation: is often characteristic for a specific type of metabolism | enzymes prefer lighter isotope because heavier isotope has higher activation energy

   → gives record of past biological activity

   → tracer for food web structure

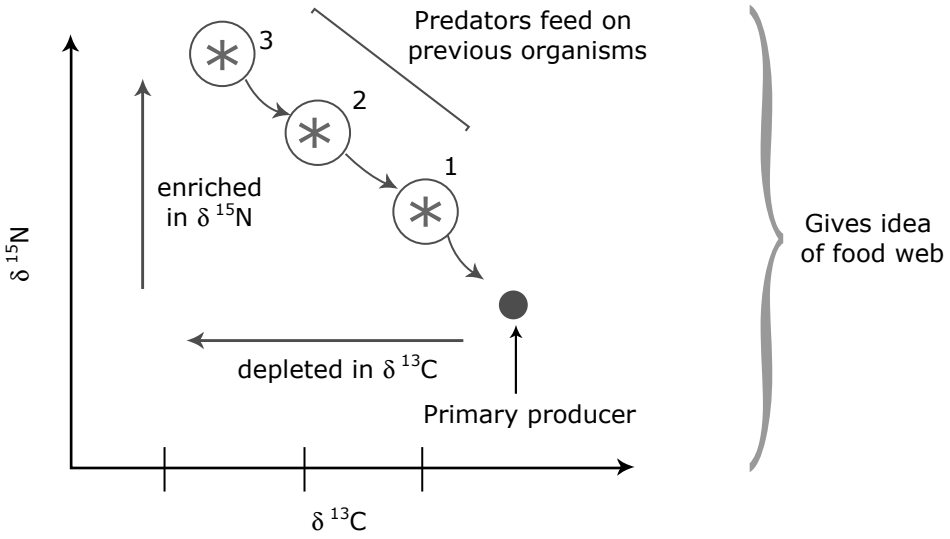
   example: carbon

$$\delta^{13}C = \frac{\left[\left(^{13}C/^{12}C\right)_{sample} - \left(^{13}C/^{12}C\right)_{std.}\right]}{\left(^{13}C/^{12}C\right)_{std.}} \cdot 1000$$

Note: green sulfur bacteria use Reverse TCA cycle, which is why their $\delta^{13}C$ value is different

Heterotrophs are enriched in ^{15}N (~3 pp thousand) and depleted in ^{13}C (~ -2 pp thousand)

Fractionation excrete lighter isotope ^{14}N & keep ^{15}N so that they become heavier



Growth and Biodegradation

- Kinetics
- Tolerance

- Growth rate μ (among of cell increase/time)
  - → in unrestricted environment, could potentially have exponential growth:

$$\frac{dB}{dt} = \mu B$$ (B → biomass)

  - → in practice this is completely unrealistic because <u>one substrate will always limit growth</u>

→ growth rate dependence on limiting substrate

- Monod Equation

$$\mu = \frac{\mu_{max} \cdot [C]}{K_s + [C]}$$

C = substrate
K_s = half-saturation constant

Biomass: $\frac{dB}{dt} = \frac{\mu_{max}\,[C]\,B}{K_s + [C]}$

Limiting cases:

a) $[C] >> K_s \longrightarrow \frac{dB}{dt} = \mu_{max}\,B$

more realistic environmental situation

b) $[C] << K_s$ 1^{st} order Kinetics! $\longrightarrow \frac{dB}{dt} = \frac{\mu_{max}\,[C]\,B}{K_s}$

- Influence on substrate concentration

  → Yield constant (example: glucose Y = 0.5)

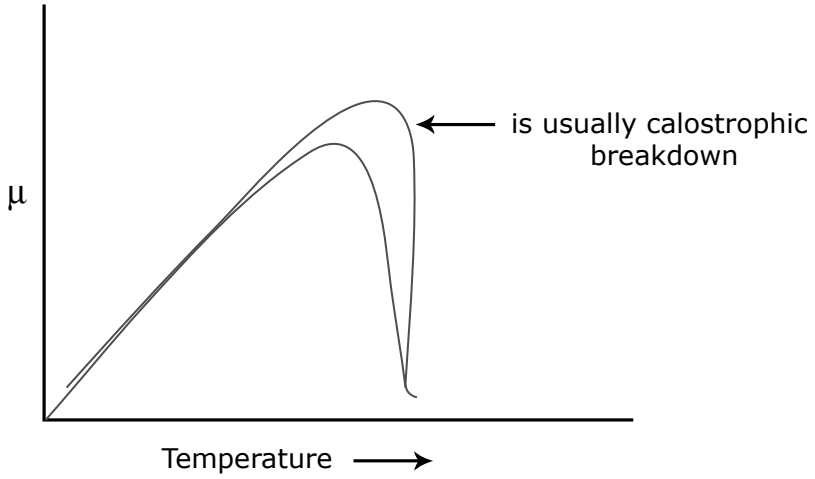
  $$\frac{dC}{dT} = \frac{1}{Y}\left(\frac{\mu_{max}\,[C]\,B}{K_s + [C]}\right)$$

  Need to know: Y (characteristic of a given substrate and type of environment), K_s, μ_{max}, [C], B

  - Y: dependent on substrate and environment type (aerobic or anaerobic?)
  - K_s, μ_{max}: use isolates (can be faulty because lab conditions not representative of environmental conditions). Organisms which easily grow on culture plates are not always representative → in fact, may often be adapted to higher nutrient concentration.
  - [C]: determine analytically
  - B: use techniques: hybridization, QPCR, etc.
  - K_s <u>reveals</u> (not a direct relationship → can serve as an indication for substrate affinity) whether you have an organism adapted to low nutrient concentration (small K_s) or high nutrient concentration (large value for K_s)

    Get these "weeds" in lab

- Tolerance Limits
  Example:



- Temperature: Q_{10} Rule within tolerance limit, there is a ~2–fold increase in activity for each 10^{o}C increase in temperature.

- General tolerance limits for microbial life:

    T: -4^{o}C - ~120^{o}C (eukaryotes have a narrower range than this)
    pH: 0 – 12

    Osmolarity: distilled H_2O – saturated brine solutions (5 M NaCl)