**Overview:**

- Bacterial immobilization or remineralization of N.
- Competition between bacteria and phytoplankton for DIN.
- Experimentally examine how dissolved organic carbon (DOC) affects the competition between bacteria and phytoplankton for limiting nutrients.
- Demonstrate use of microcosms to study microbial dynamics.
- Analysis of time-series and predator-prey dynamics.
The microbial loop is a conceptualization by which DOM can be routed into the classic food chain via bacteria and their grazers.

- **DOM:** Dissolved organic matter
- **P:** Phytoplankton
- **Z:** Zooplankton
- **F:** Fish
- **B:** Bacteria
- **nF:** Nanoflagellates
- **C:** Ciliates
Primary flow of C and N into *aquatic* food webs

Energy and mass enter the base of the food web via phytoplankton or bacteria.

Depending on the C:N composition of DOM, bacteria and phytoplankton can be in competition for DIN (and P).

Organisms with the higher surface area to volume will win.
**Carbon and Nitrogen Balances**

- **Bacteria**
  - Consume DOM
  - Use DON over DIN
  - Either excrete or consume DIN

- **Effect of C:N ratio of DOM on DIN uptake or excretion**

  ![Diagram](image)

  - $r_U$: Rate of DOC uptake ($\mu$mol C l$^{-1}$ d$^{-1}$)
  - $r_E$: Rate of DIN excretion ($\mu$mol N l$^{-1}$ d$^{-1}$)
  - $\rho_B$: C:N Ratio of bacteria (atomic)
  - $\rho_D$: C:N Ratio of DOM (atomic)

  Bacterial N requirement: $\varepsilon_r u \frac{1}{\rho_B}$

  N associated with DOM uptake: $r_U \frac{1}{\rho_D}$

  Rate of DIN excretion: $r_E = r_U \left( \frac{1}{\rho_D} - \frac{\varepsilon}{\rho_B} \right)$
Phytoplankton-Bacteria Competition

- Consider aggregated conceptualization of lower trophic levels.
- If the C:N ratio of DOM is high, then bacteria will utilize DIN.
- Bacteria should out compete phytoplankton for DIN. Why?
- Dynamics of food web should be dependent on DOM composition

Paradox: why do phytoplankton excrete DOM?
Value of Time Series Data

• In order to understand ecosystem function, causal relationships need to be determined between organisms and nutrients.

• "Snap shots" can not provide this information. Systems must be followed over time.

• Basic understanding obtained from observations can be used to build models.

• New time series data can be used to test models.
Example: Mesocosm Experiment

- **Additions:**
  - NO$_3$ (5 $\mu$M), PO$_4$ (0.5 $\mu$M), Si (7 $\mu$M)
  - Leaf litter leachate (300 $\mu$M DOC)

- **Treatments:**
  - Control: Bag A
  - Organic Matter: Bag B
  - Daily Nutrients: Bag C
  - DOM + Nutrients: Bag D

- **Samples Taken:**
  - NO$_3$, NH$_4$, PO$_4$, Si, O$_2$ DIC
  - PAR
  - POC, PON, DOC, DON
  - Chl a
  - PP ($^{14}$C and O$_2$ incubations)
  - Bacterial No. and productivity
  - Phyto- and zooplankton counts
  - DI$^{13}$C, DO$^{13}$C, DO$^{15}$N
  - Size fractionated $\delta^{13}$C and $\delta^{15}$N
Mesocosm Food Web Model

- Aggregated, coupled C and N model
- Emphasis on OM processing
- Holling type II and III growth kinetics

- State Eqns: 10
  - Auto. C, N
  - Osomo. C, N
  - Hetero. C, N
  - Detritus C
  - Detritus N
  - DIN N
  - DOM-L C
  - DOM-L N
  - DOM-R C
  - DOM-R N

- Parameters
  - 29 Kinetic
  - 10 Initial cond.
Experimental Setup

• Collect Woods Hole seawater into two 20 l carboys
• Prepare two treatments:

<table>
<thead>
<tr>
<th></th>
<th>Treatment A</th>
<th>Treatment B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>0 µM</td>
<td>75 µM (450 µM C)</td>
</tr>
<tr>
<td>NO$_3^-$</td>
<td>36 µM</td>
<td>36 µM</td>
</tr>
<tr>
<td>SiO$_3$</td>
<td>52 µM</td>
<td>52 µM</td>
</tr>
<tr>
<td>PO$_4$</td>
<td>2.3 µM</td>
<td>2.3 µM</td>
</tr>
</tbody>
</table>

• Measure the following constituents over the 7 day incubation
  • DOC (1 person)
  • NO$_3^-$ (1)
  • NH$_4^+$ (1)
  • PO$_4^{3-}$ (1)
  • Chlorophyll a (by fluorescence and extraction) (1)
  • Bacteria abundances (DAPI) (1)
  • Phosphatase (2)
  • Bacterial production (2)

What will happen in Treatment A versus Treatment B?
Work clean, as sea water is readily contaminated by hands, etc.