Factors Affecting Photosynthesis

- Temperature
  - Eppley (1972)
- Light
  - Sverdrup’s Critical Depth Model
- Nutrients
  - Limitations
  - Uptake Kinetics
Temperature

• The oceans vary much less than the land does, both seasonally and daily
• Increased temperature decreases viscosity, so you sink
• Organisms grow faster, die younger as temperature increases
• In general, warm water species are smaller and have more extensions
• Eppley (1972) plotted species growth vs. temp.

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$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{10/(T_2-T_1)}$$
Temperature & Phytoplankton
Eppley Equation:

\[ V_{\text{max}} = 0.85 \times e^{(0.063 \times T)} \]

This means that with nothing but a thermometer you can predict the maximum growth rate for any algae!

Note: this was updated by Bissinger et al. 2008, L&O 53: 487-493, but the general concept is still valid.
Photosynthesis & Temperature

**Remember:** in the laboratory, we can measure photosynthesis versus irradiance (PvsE) and calculate $E_k$, $P_{\text{max}}$, and alpha.

If we take this idea and go to the field, a vertical profile of photosynthesis in the ocean is essentially a PvsE curve, where you are measuring photosynthesis versus depth, and irradiance changes with depth.
When we measure in the field, we call $P_{\text{max}}$, maximum photosynthesis, $P_{\text{opt}}$ to distinguish it from a lab experiment.

For both lab and field experiments we often divide $P$ by biomass (chlorophyll) so that the value is not changing simply because we have more or less biomass. This is $P^B_{\text{max}}$ (lab) and $P^B_{\text{opt}}$ (field).
$P_{B_{opt}}$ & Temperature
Fig. 7. Measured (●; ±SD) and modeled (——; Eq. 11) median value of the photoadaptive parameter, $P^B_\text{opt}$, as a function of sea surface temperature. Dashed curve indicates the theoretical maximum specific growth rate ($\mu; \text{d}^{-1}$) of photoautotrophic unicellular algae described by Eppley (1972), which is used in a variety of productivity models (e.g. Balch and Byrne 1994; Antoine et al. 1996).
Mini-Summary

- Biological rates (including photosynthesis) generally increase with increasing temperature.

- We can model photosynthesis versus irradiance in field data by plotting $P_B$ versus optical depth (light levels).

- $P_{B\text{ opt}}$ increases with increasing temperature, until the temperature gets too high.
Compensation Depth

Positive Net Production

Positive Net Respiration
Sverdrup’s Critical Depth Model:

“…there must be a critical depth such that blooming can occur only if the mixed layer is less than the critical value.”

Assumptions:

• Constant mixing, uniform phytoplankton
• NO Grazers!
• Nutrients are not limiting
• The compensation depth is known
• Production is directly controlled by light and is linear
Critical Depth

Given the previous assumptions, the Critical Depth \( (Z_{cr}) \) can be approximated by:

\[
\frac{Z_{cr}}{(1-e^{-k \cdot Z_{cr}})} = \frac{E_o}{(E_c \times k)}
\]

This says that so long as the average depth of the mixed layer is shallower than the compensation depth, you get a bloom.
Alternative Explanations

**a) Critical Depth Hypothesis**
- Phytoplankton decreasing
- Convective mixed-layer deepening
- Critical mixing depth is reached, and a bloom is initiated

**b) Critical Turbulence Hypothesis**
- Phytoplankton decreasing
- Convective mixed-layer deepening
- Surface phytoplankton accumulate when cell division outpaces turbulent transport to depth
- Grazing quickly removes phytoplankton below the turbulent layer
- Convective mixing ends, a net positive heat flux into the ocean begins, and a bloom is initiated

**c) Disturbance-Recovery Hypothesis**
- Autumn decreases in cell division, overgrazing, and dilution caused by mixed-layer deepening deplete grazer populations
- By early winter, the impacts on grazers exceed light-driven decreases in cell division, and a bloom is initiated; mixed-layer phytoplankton stocks increase, but concentrations remain low owing to continued dilution by convective mixing
- Once the mixed layer stops deepening, phytoplankton and grazer concentrations rise in parallel; ecosystem feedbacks and light-driven increases in division rate maintain growth-loss imbalance and allow blooming during the spring stratification period