SANTA FE INSTITUTE 2023 SUMMER SCHOOL

"Triangulation: merging observations, experiments, and math to understand ecological communities"

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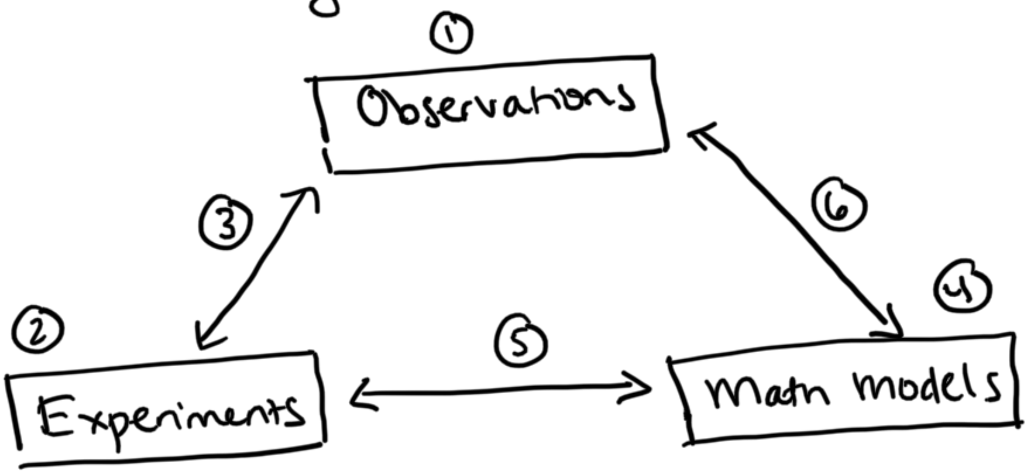
① "Triangulation"



Much of Biology is inspired by observations (1). We often test the hypotheses we generate from obs. with lab or field expts (2), which can motivate new observations (3). However mathematical models (4) can play a critical role, allowing us to integrate and extrapolate from expt and obs data (5, 6), but also generate new hypotheses that we return to field/lab to test.

How I use these triangles:

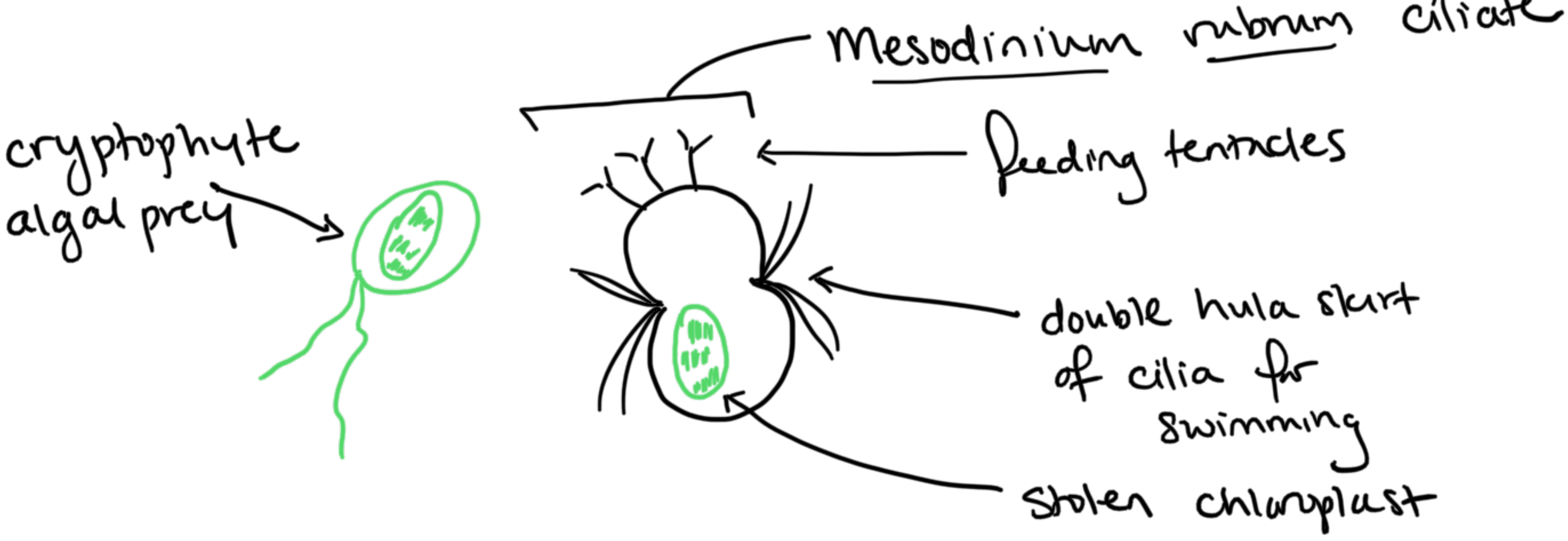
- community ecology: study interactions b/w species, and how these interactions shape the structure and function of the ecosystems that surround, support, and sustain us.
- acquired metabolism: metabolic capabilities that are obtained from another sp. within an organism's lifetime, rather than being encoded in that organism's DNA. E.g., metabolic mutualism, organelle retention...

Today:

Let's work our way around this triangle to show how a mathematical model can help us understand coexistence and population dynamics in the ocean.

② The Observation: Kleptoplasty in ciliates

stealing ↗ ↖ plastid a.k.a. chloroplast



... blooms have been observed in

Mesodinium rubrum blooms [illegible]
coastal oceans all over the world.

⟹ It must be very good at using these stolen organelles!

③ The Experiment: How do stolen chloroplasts work?

We wanted to sequence RNA from cells experiencing different light environments to understand how the stolen chloroplasts are regulated.

But... it was a mess.

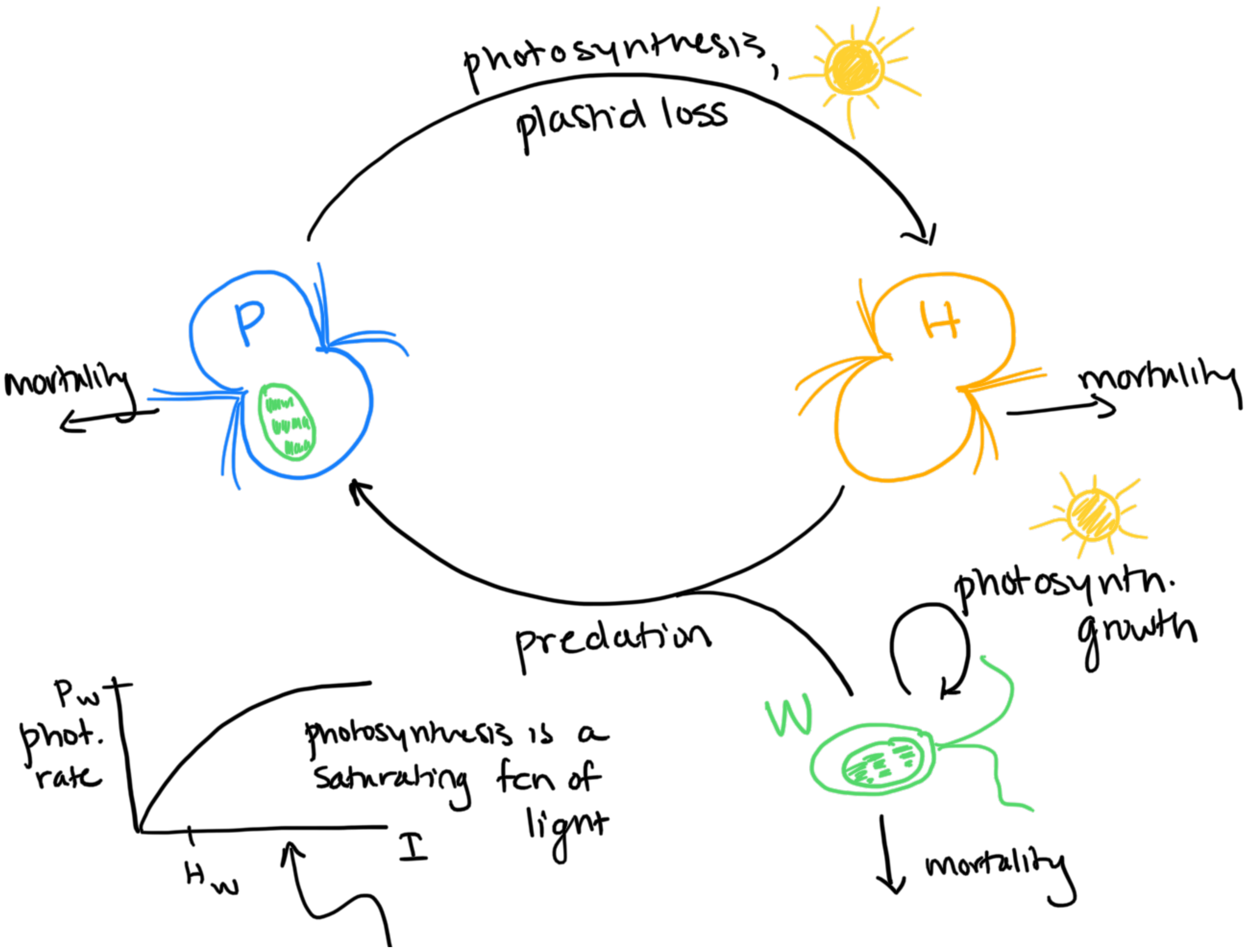
my stressed out postdoc face

Low Light: Prey grew too fast for the ciliates to eat them all. Ciliates got over-crowded and died out.

High Light: Populations of ciliates seemed to be growing really well... but then would die seemingly overnight.

④ The model: A "toy" model for acquired metabolism

* my philosophy: Draw a Diagram ⟶ Verbal Model ⟶ Translate into math *



change in W over time = photosynthesis − mortality − predation

$$\frac{dW}{dt} = \frac{p_W I W}{H_W + I} - m_W W - aWH$$

Change in P over time = plastid gains − plastid loss − mortality

$$\frac{dP}{dt} = aWH - \ell P - m_P P$$

Change in H over time = − predation + plastid loss + photosynth. − mort.

$$\frac{dH}{dt} = -aWH + \ell P + \frac{p_P I P}{H_P + I} - m_H H$$

we assume biomass of organisms absorbs light:

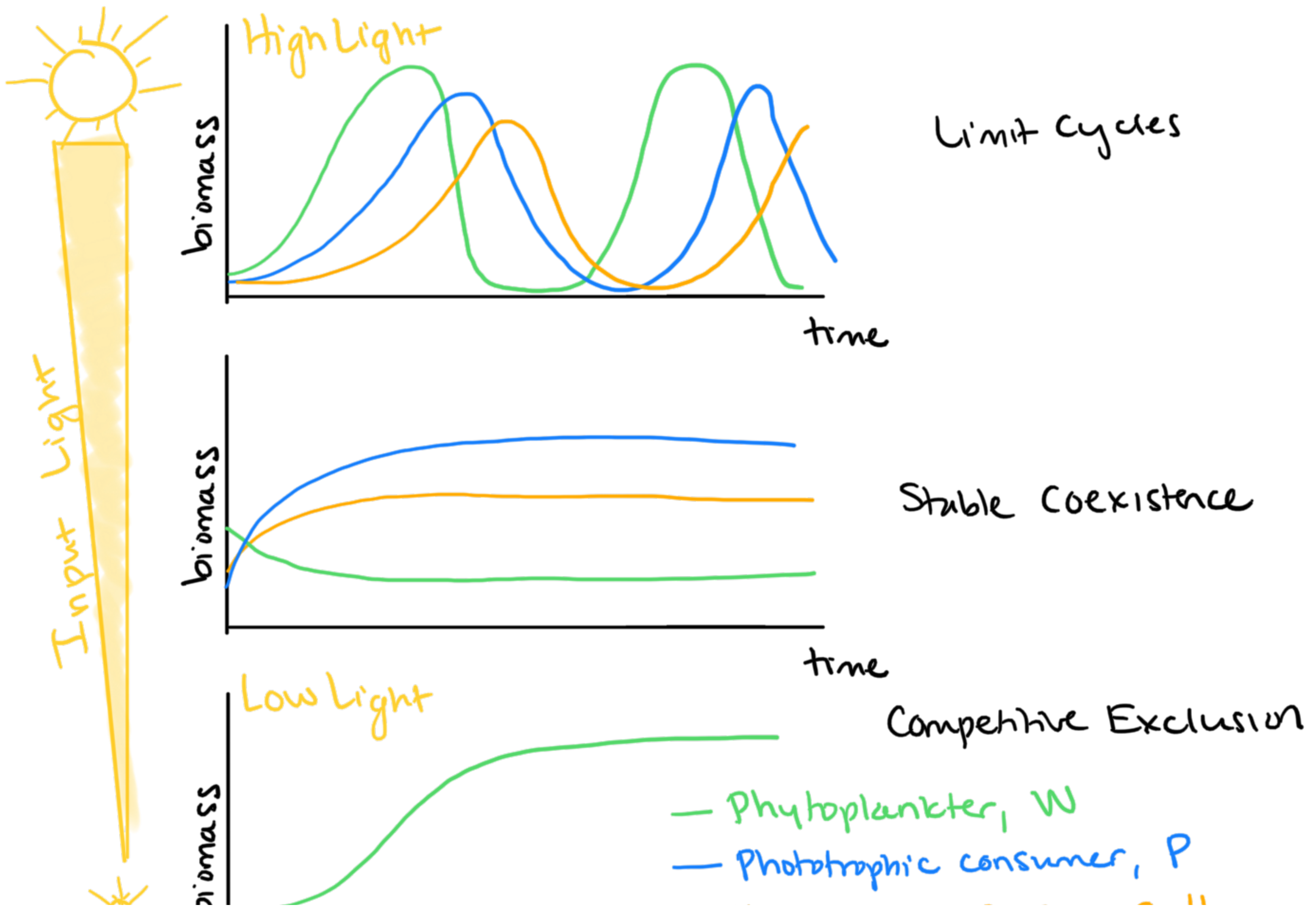
$$I = I_{in} e^{-K}$$

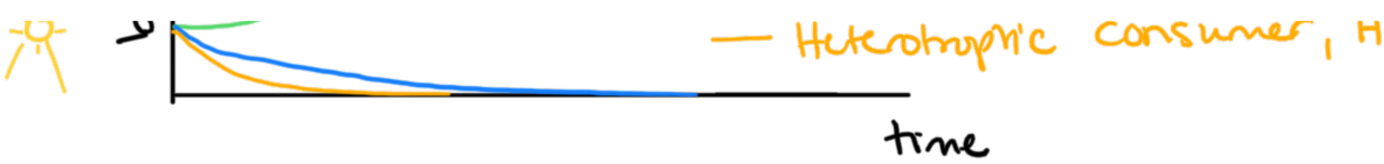
$$K = k_W W + k_P P + k_H H$$

} Lambert-Beer Law

negative feedback: more organisms = less resource. ⟹ could promote stability

The model predicts...





1) what was going on in the lab?
2) what experiment would you do next?

⑤ Closing the loop back to Observations

Recall: Mesodinium rubrum is a bloom-forming species

⟹ model helps us to understand why!
Chloroplasts get a "second life" in their new host, allowing for a second burst of growth.

⑥ Other things we triangulate: (in case you'd like to chat...)