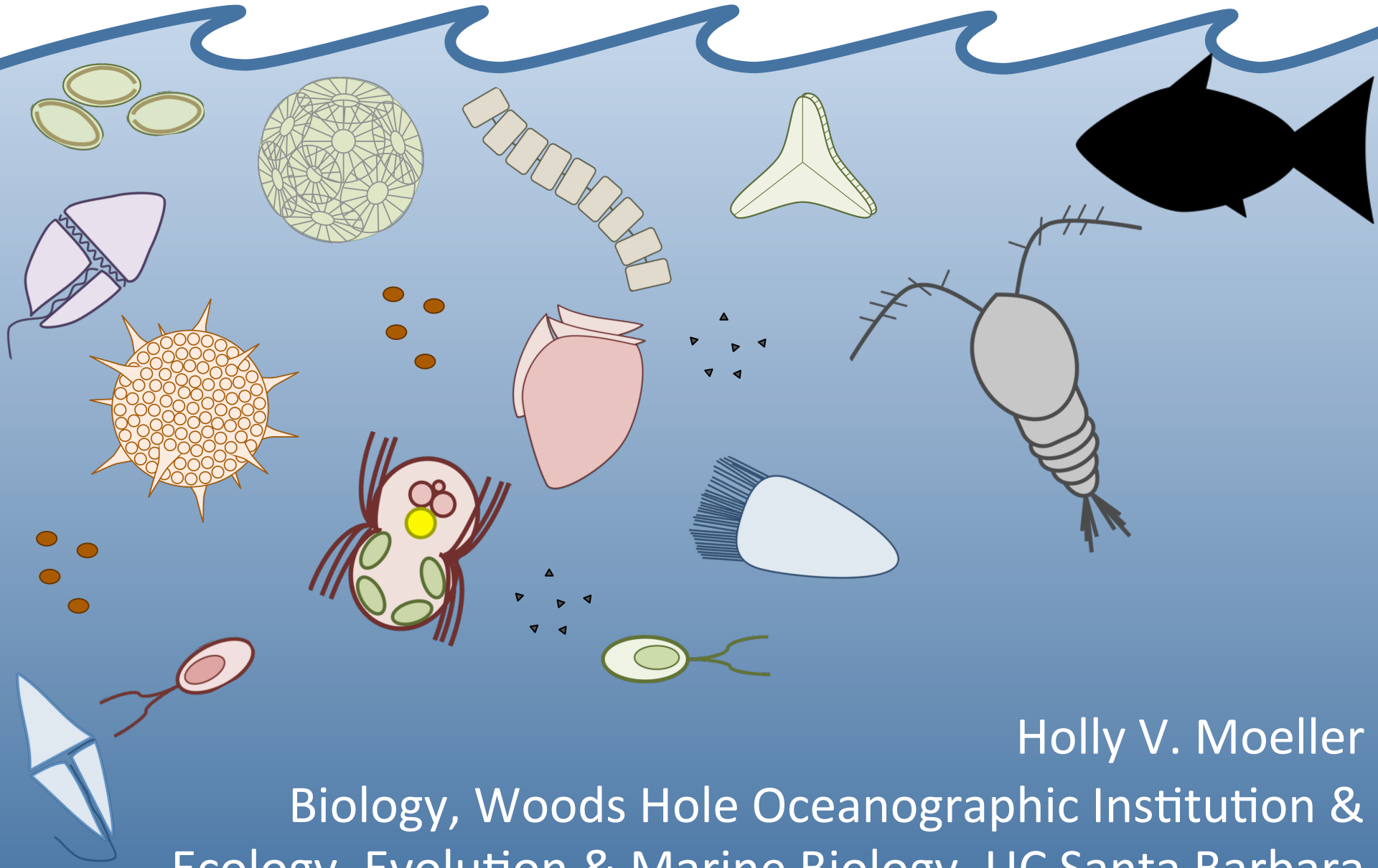
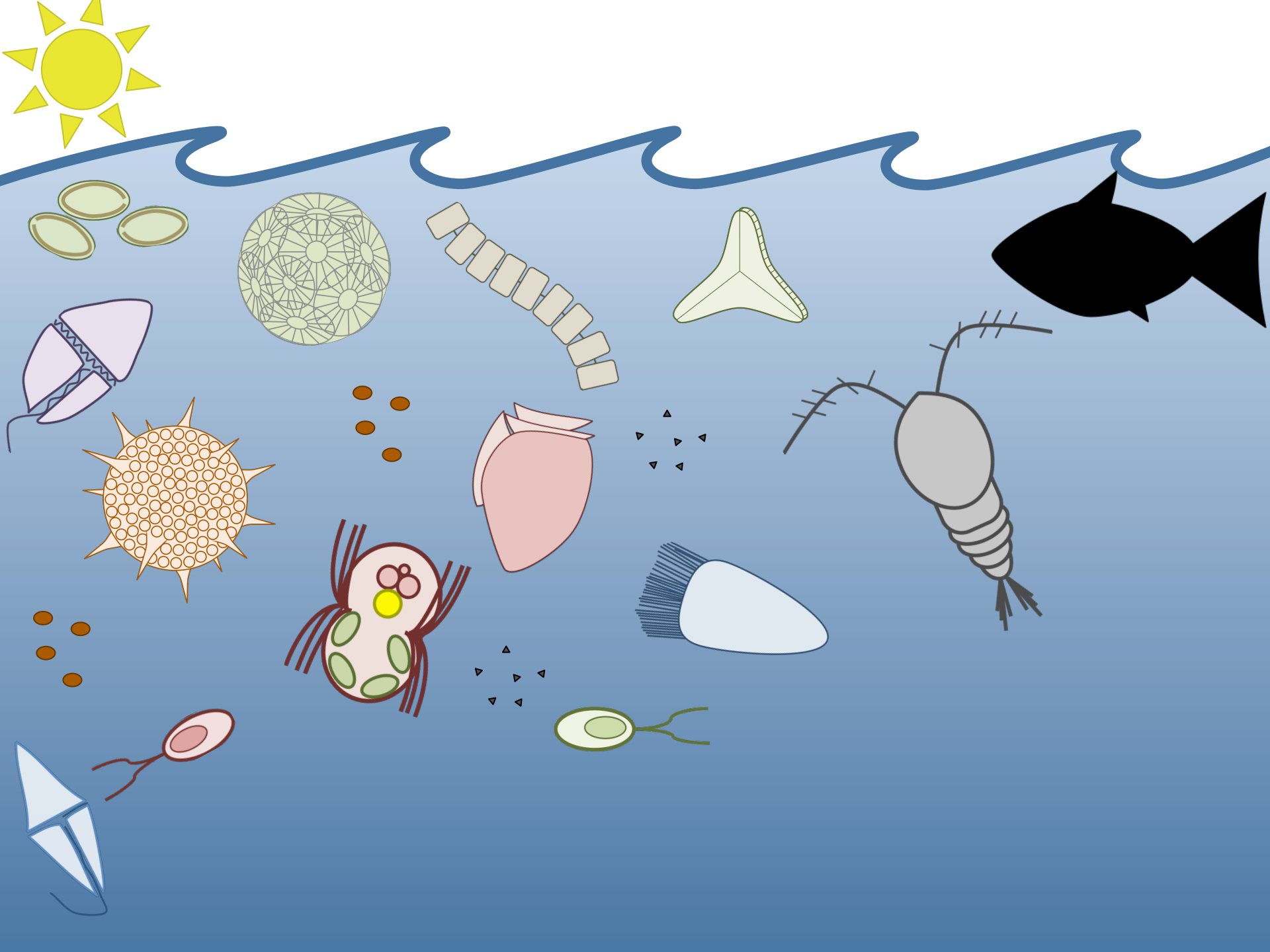
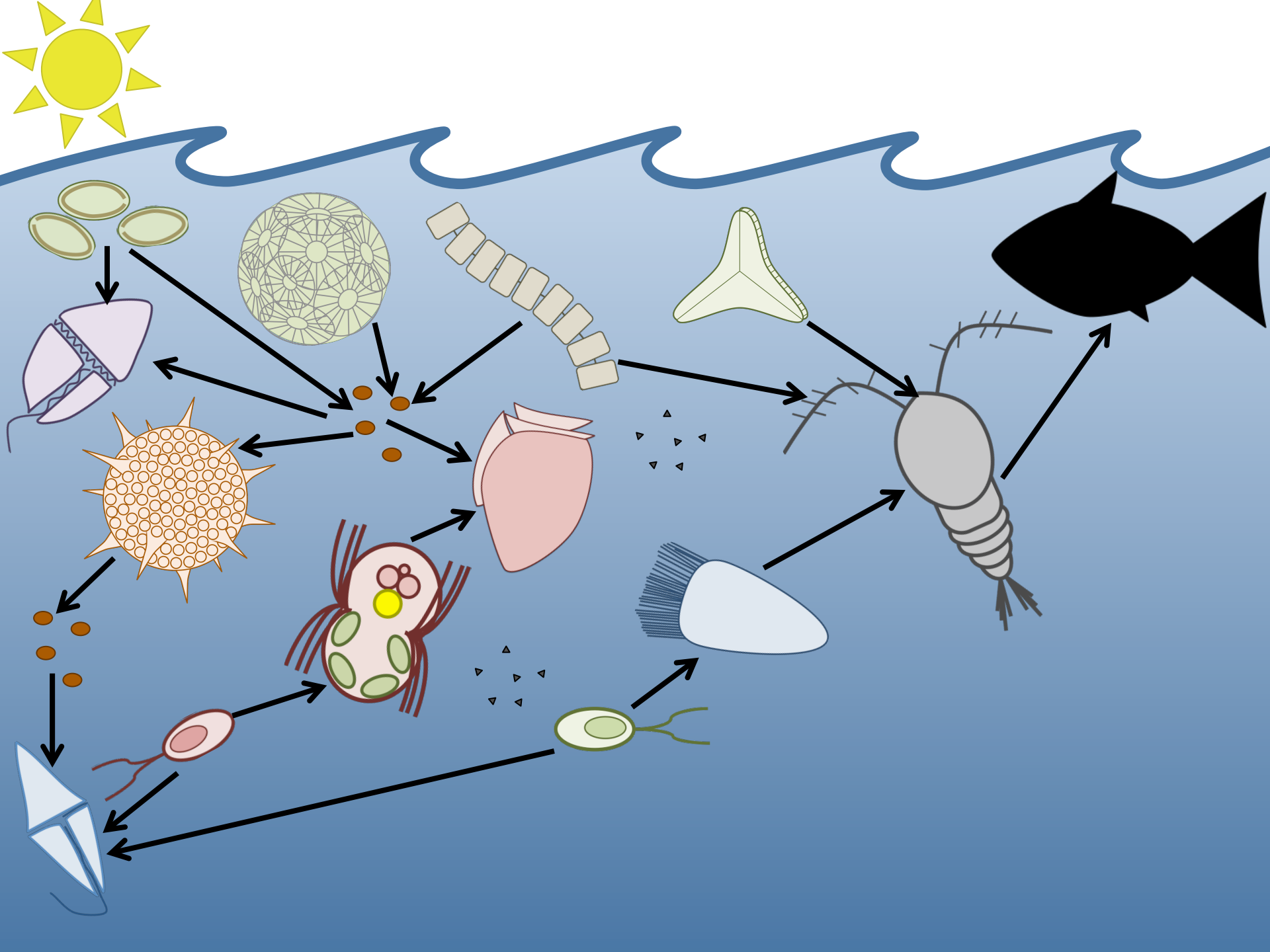
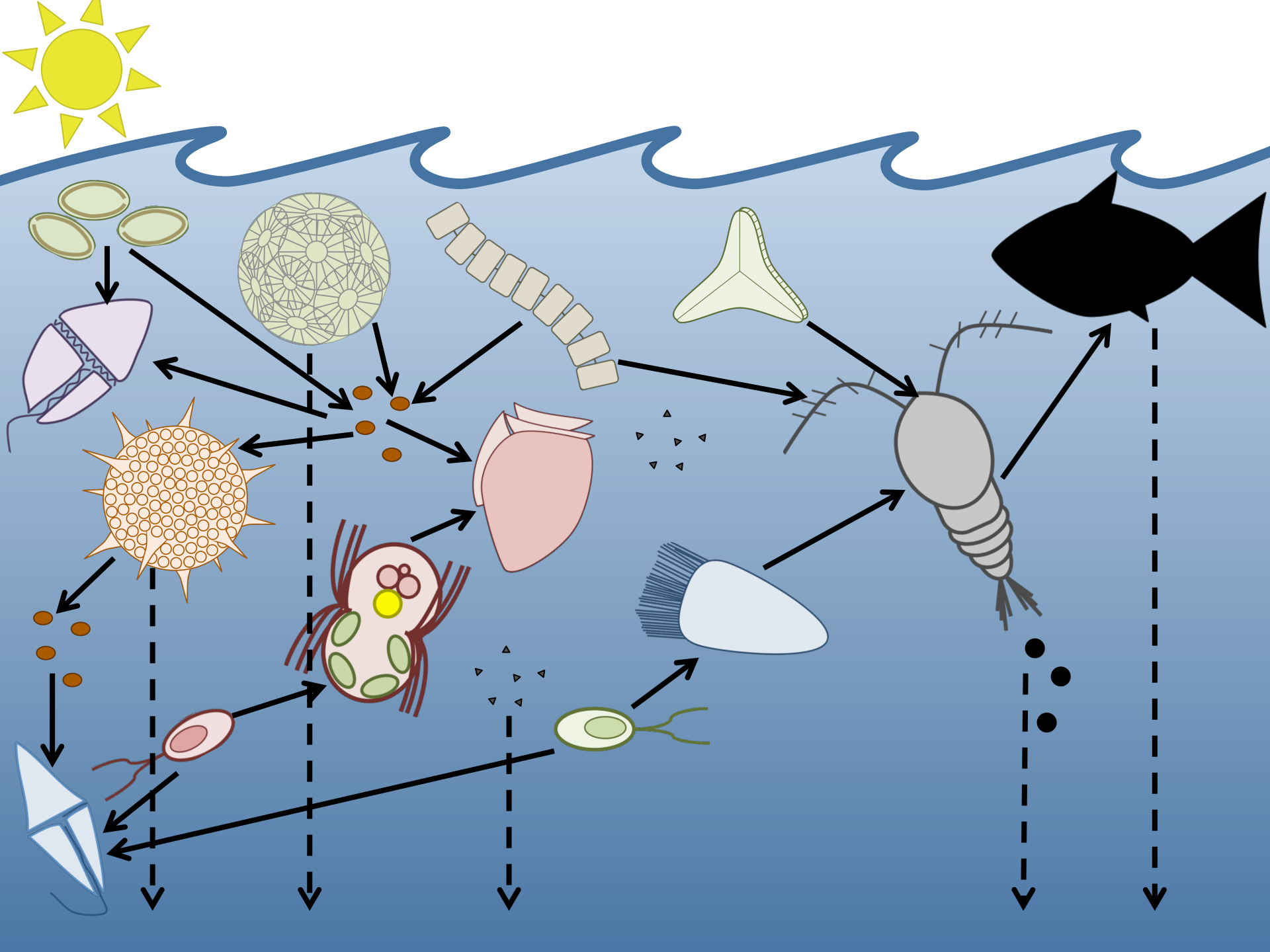
Mixotrophic Modulators of the Biological Pump



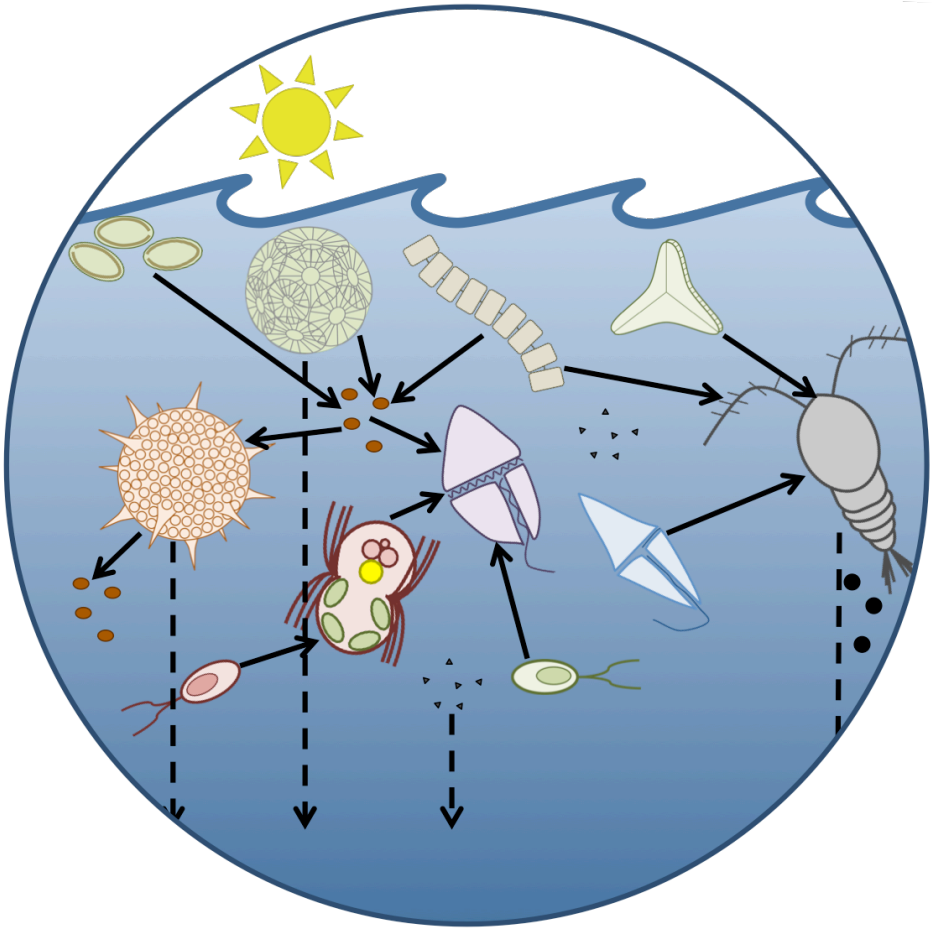
Holly V. Moeller
Biology, Woods Hole Oceanographic Institution &
Ecology, Evolution & Marine Biology, UC Santa Barbara



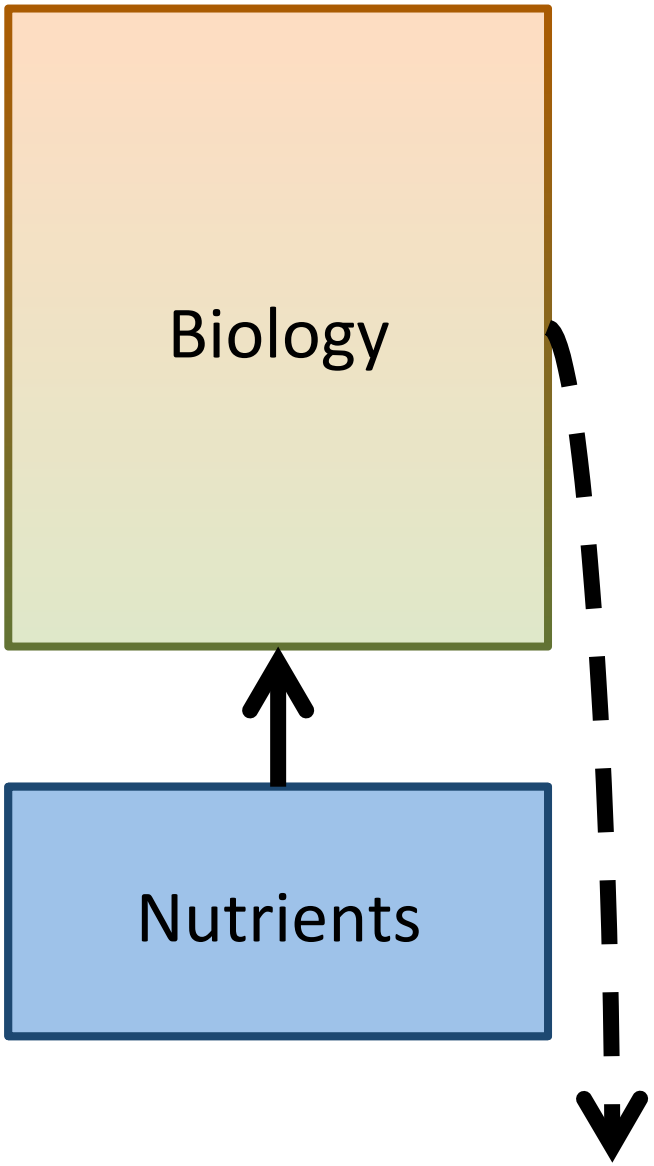




How complicated should we get?



vs.



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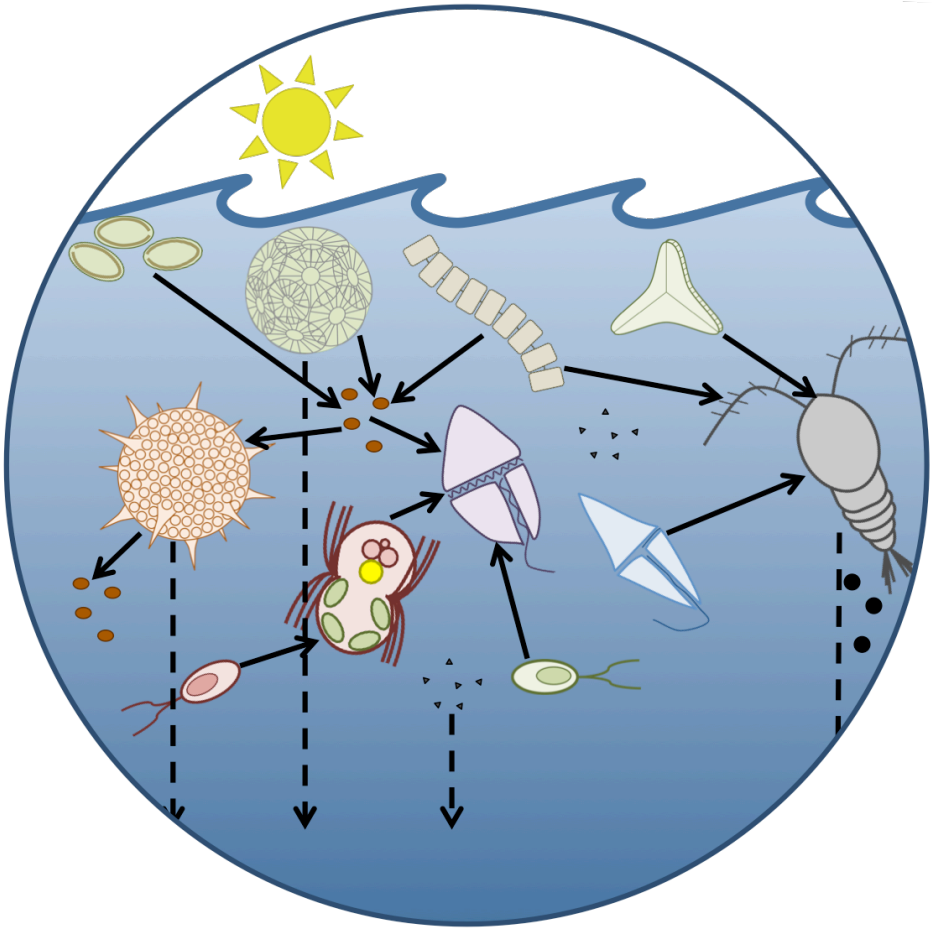

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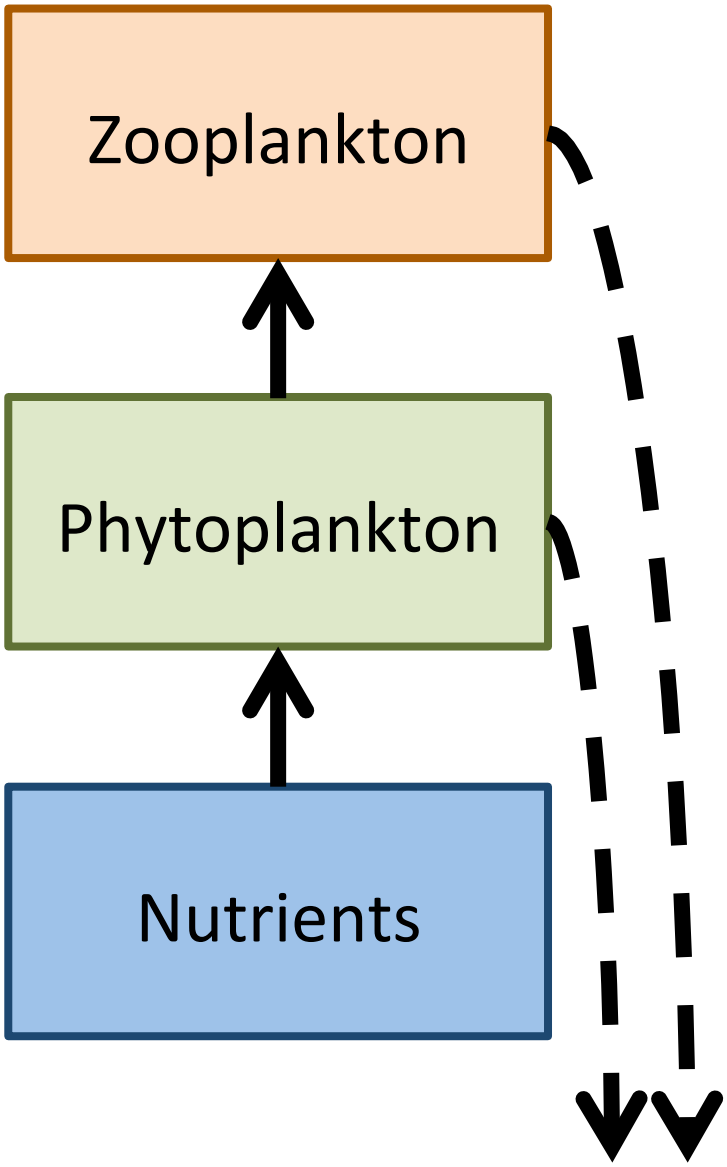

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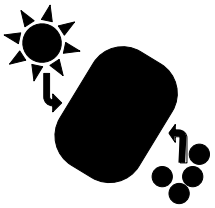
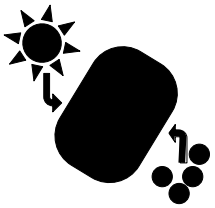


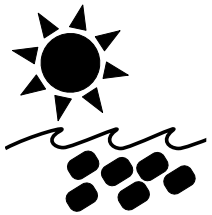
What is a mixotroph?

Mixotrophic Modulators of the Biological Pump



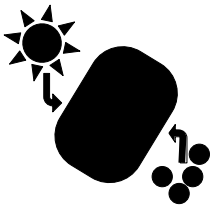
What is a mixotroph?

Impacts on the Biological Pump



How mixotrophs modulate primary productivity

Mixotrophic Modulators of the Biological Pump



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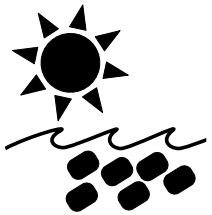
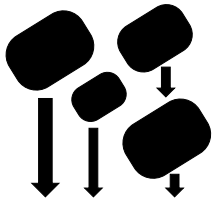


How mixotrophs modulate primary productivity



How mixotrophs modulate particle flux

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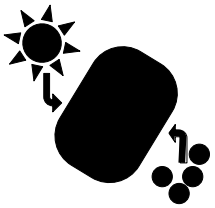

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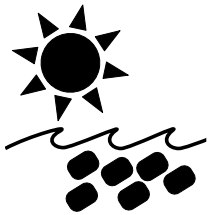

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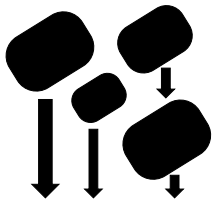

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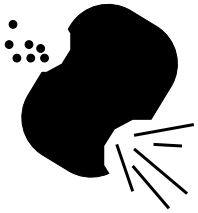
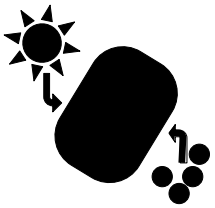


How mixotrophs modulate remineralization rates

Mixotrophic Modulators of the Biological Pump



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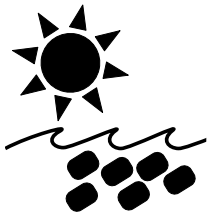

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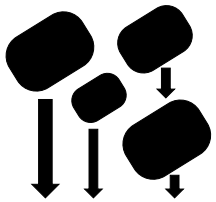

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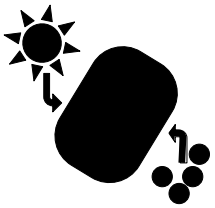
Where and when should mixotrophs matter?

Mixotrophic Modulators of the Biological Pump



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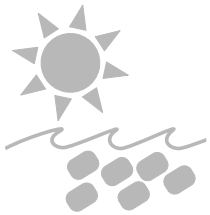

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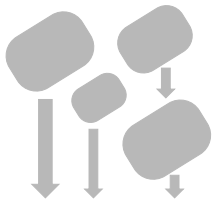
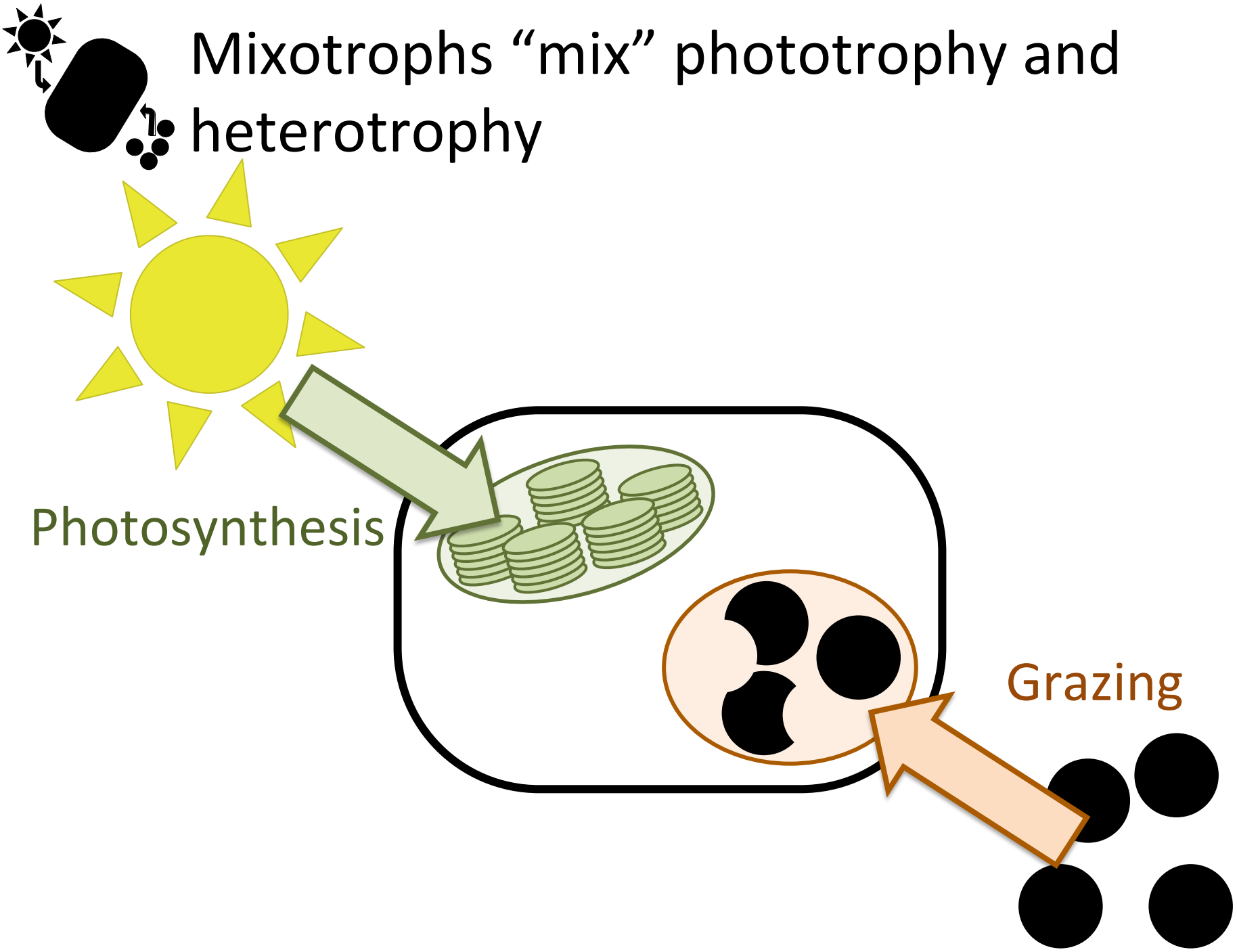


How mixotrophs modulate particle flux

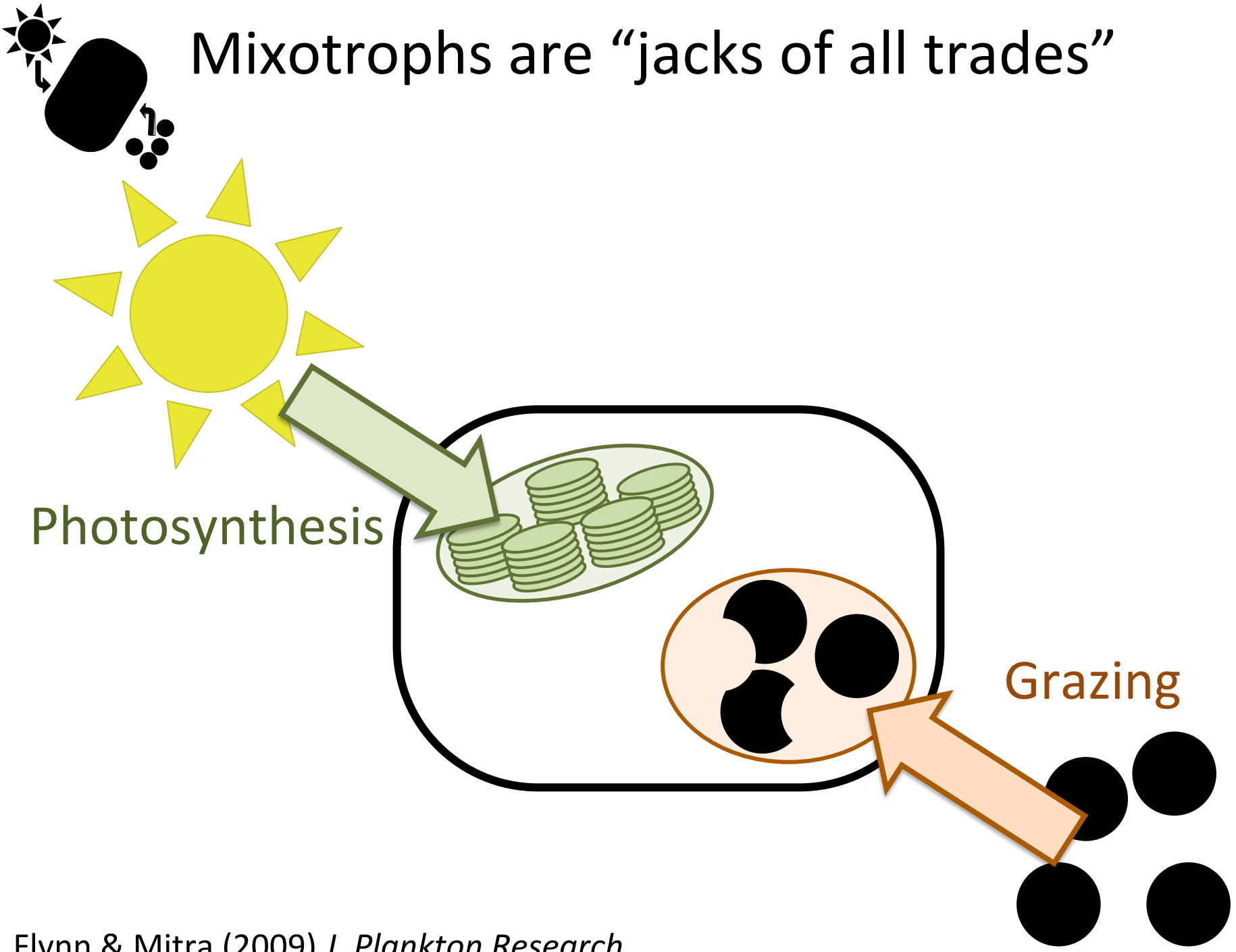
How mixotrophs modulate remineralization rates

Where and when should mixotrophs matter?

Mixotrophs “mix” phototrophy and heterotrophy



Mixotrophs are “jacks of all trades”



Flynn & Mitra (2009) *J. Plankton Research*

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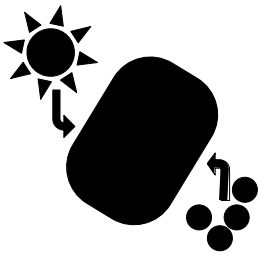
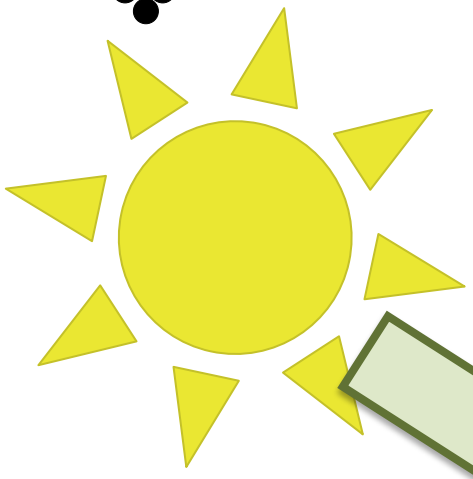
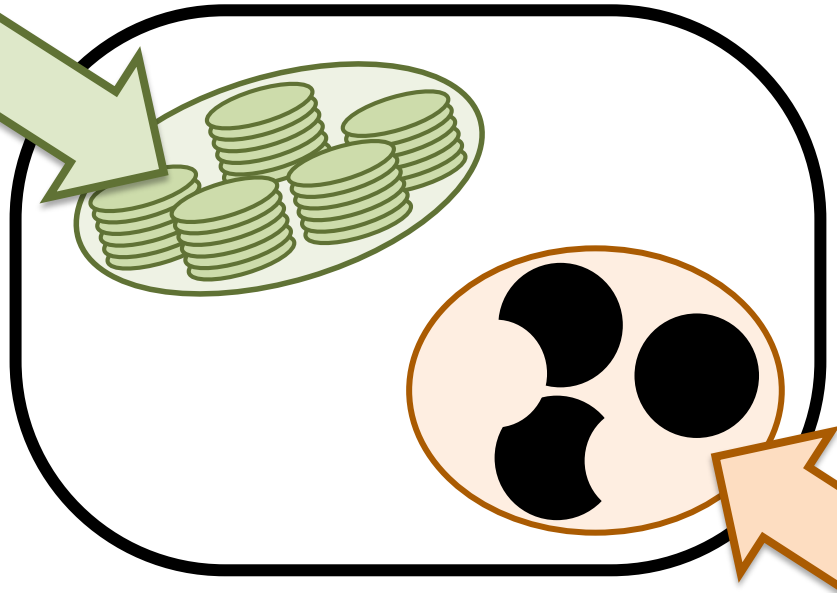


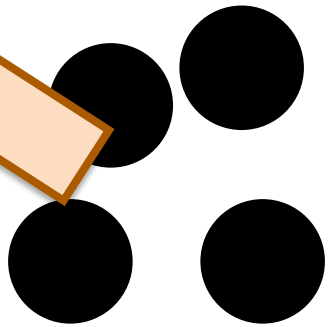


Photosynthesis

Carbon source when prey is limiting



Grazing



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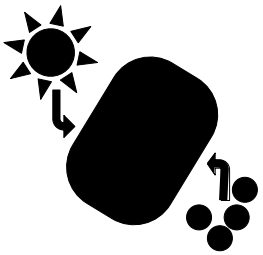

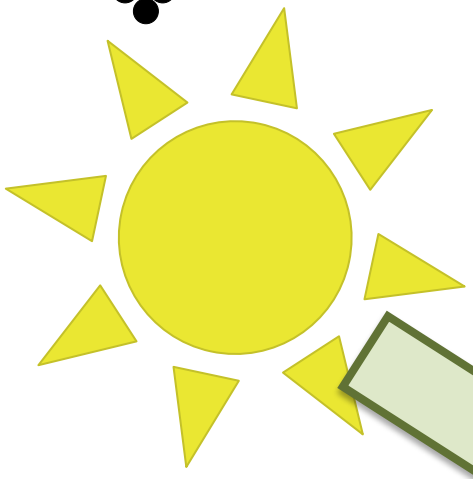

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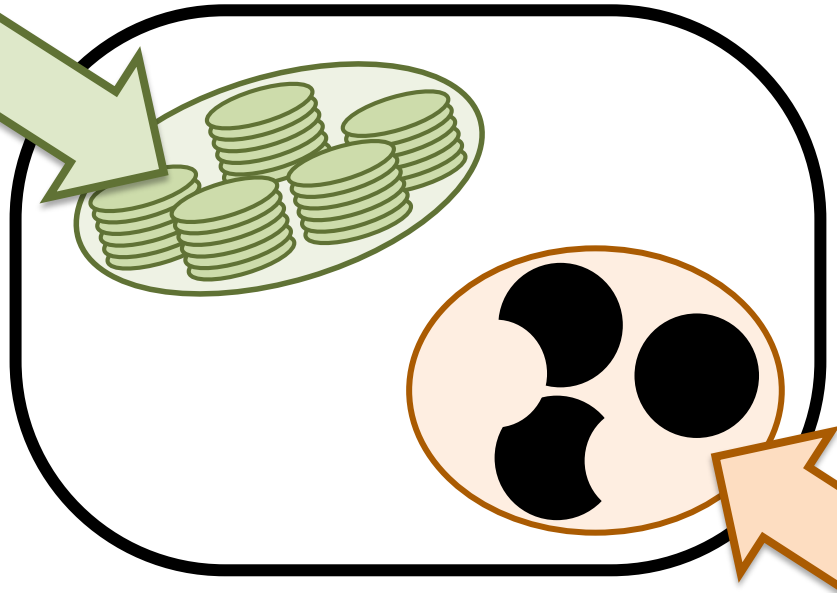
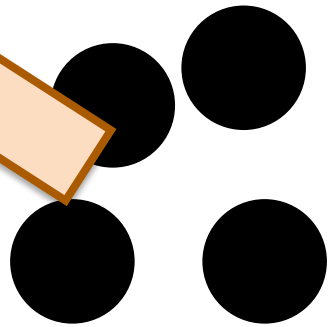


Nutrient source when nutrients are limiting

Grazing



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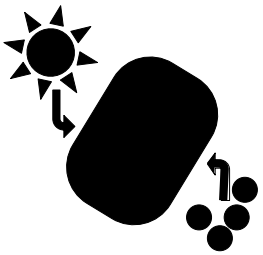
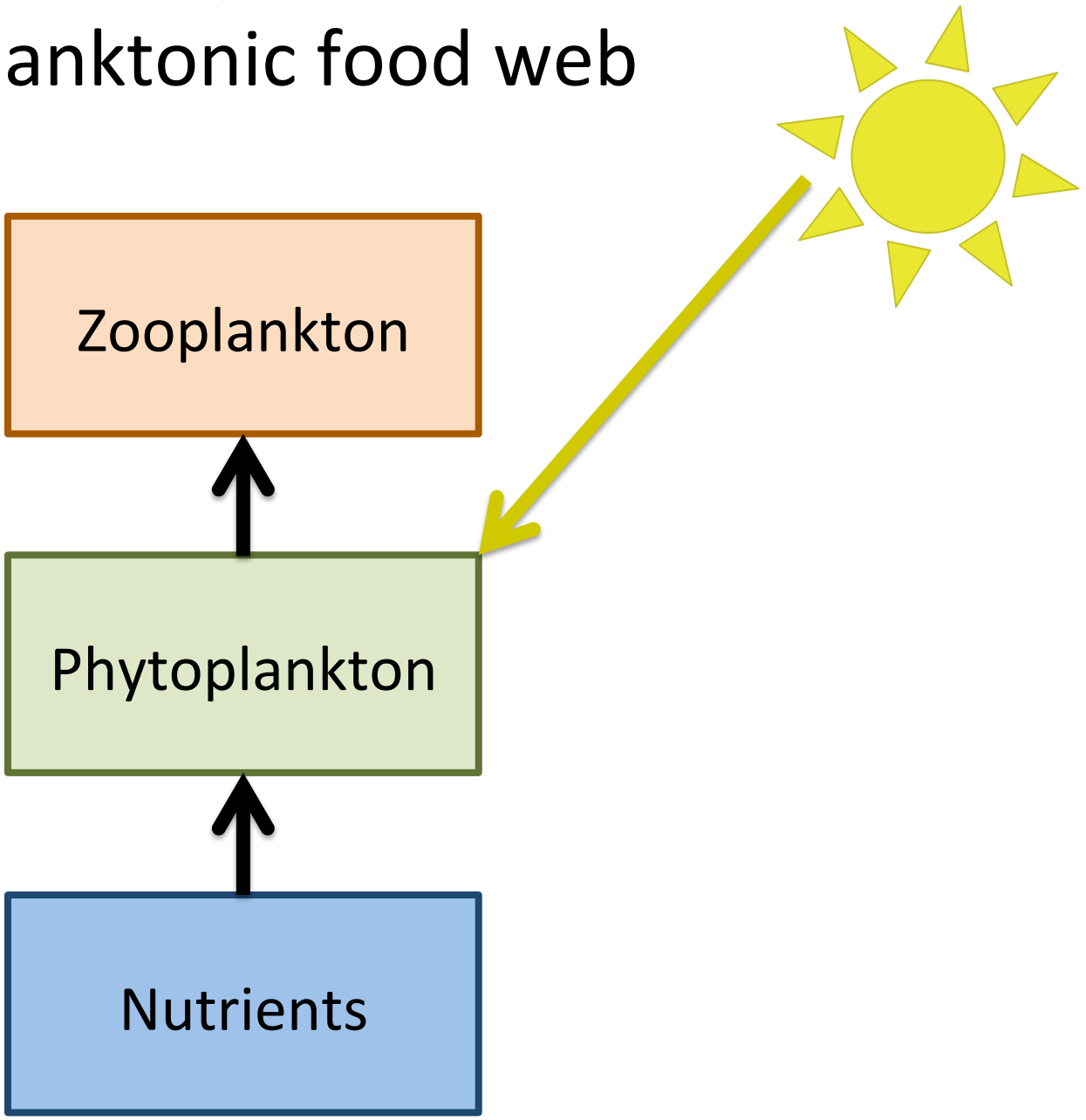


Mixotrophs can “short-circuit” the planktonic food web



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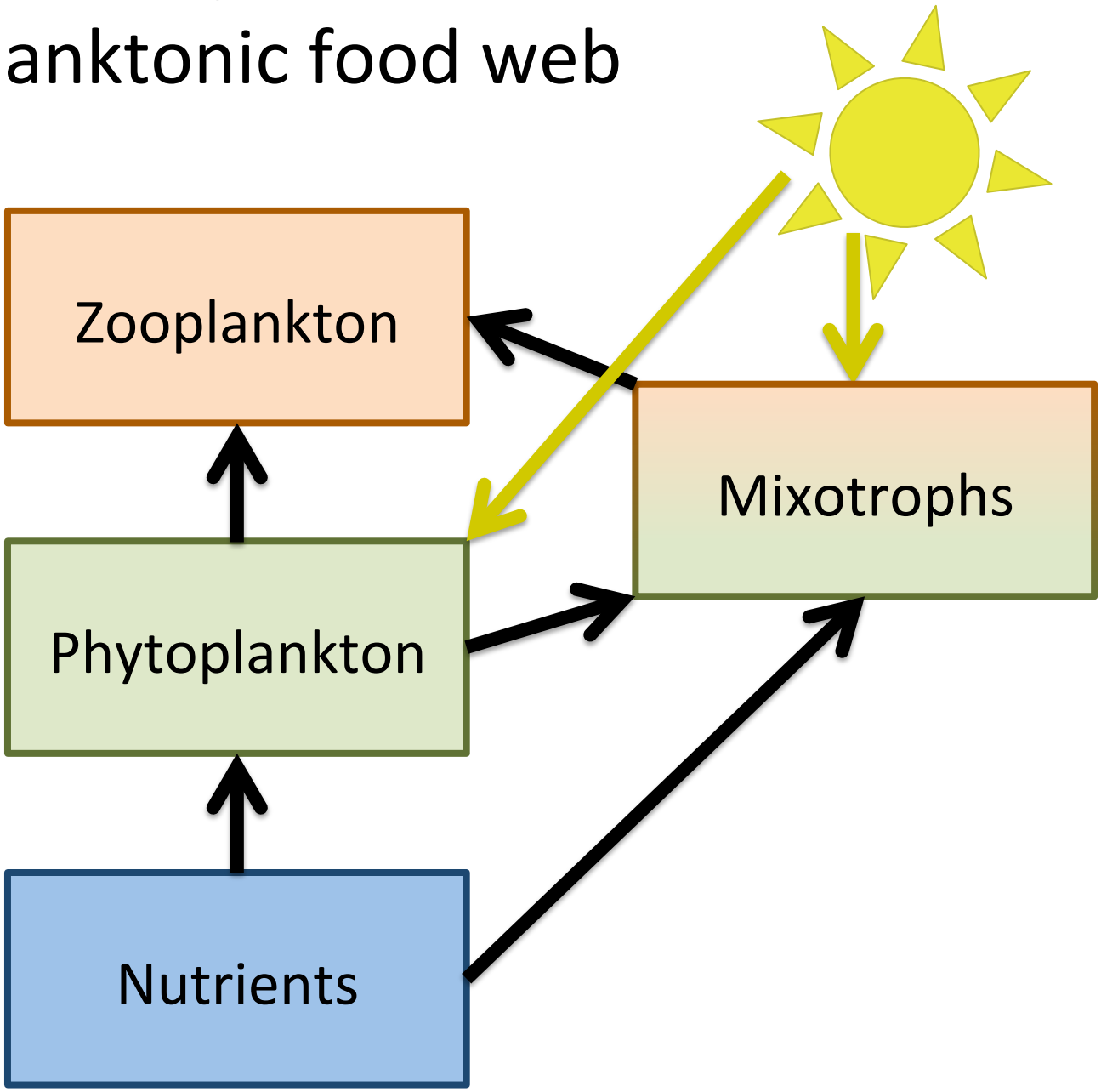

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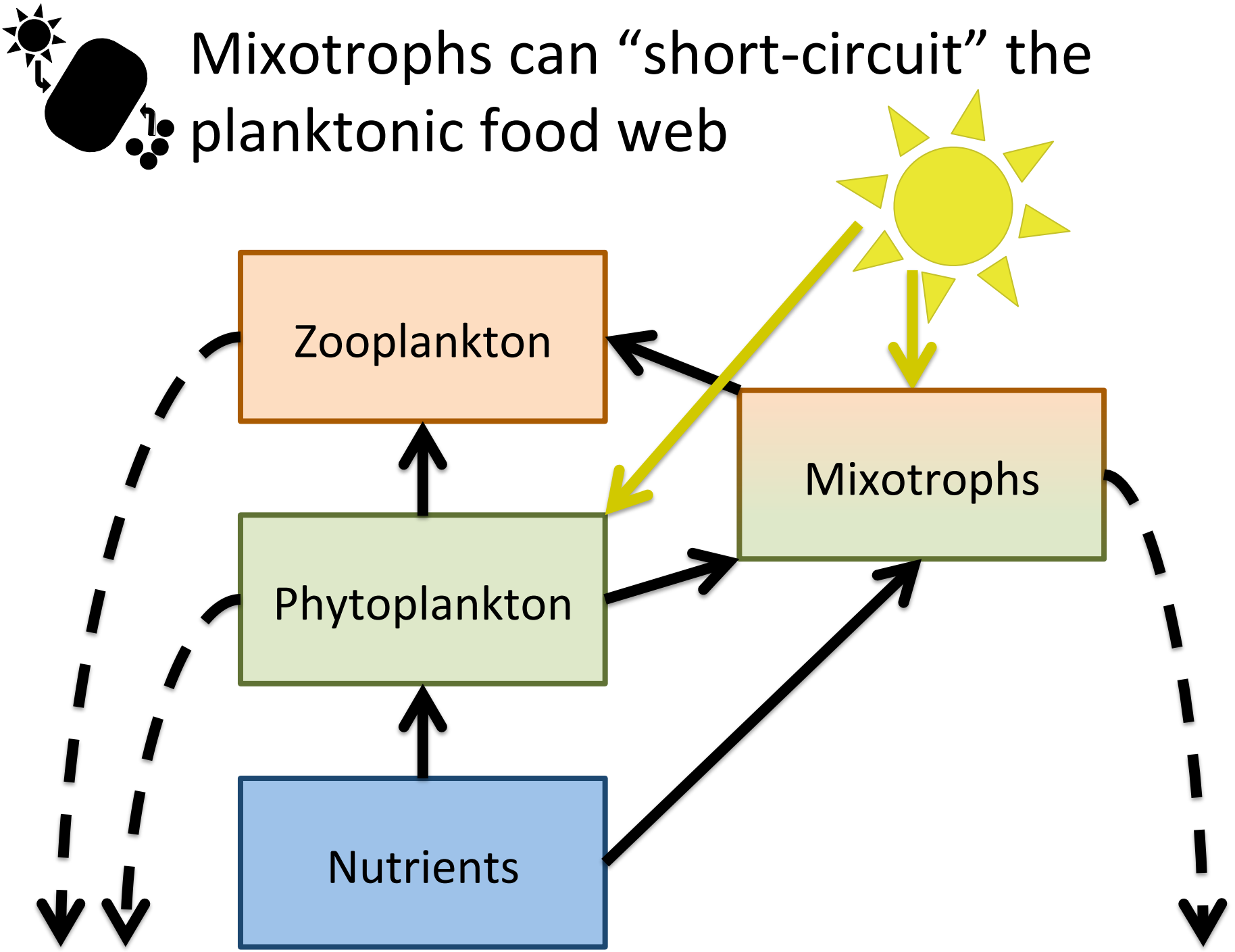
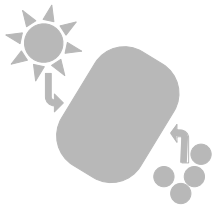
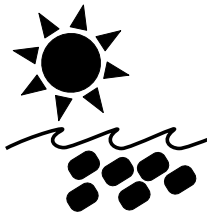


Mixotrophic Modulators of the Biological Pump

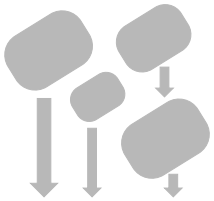


What is a mixotroph?

Impacts on the Biological Pump



How mixotrophs modulate primary productivity



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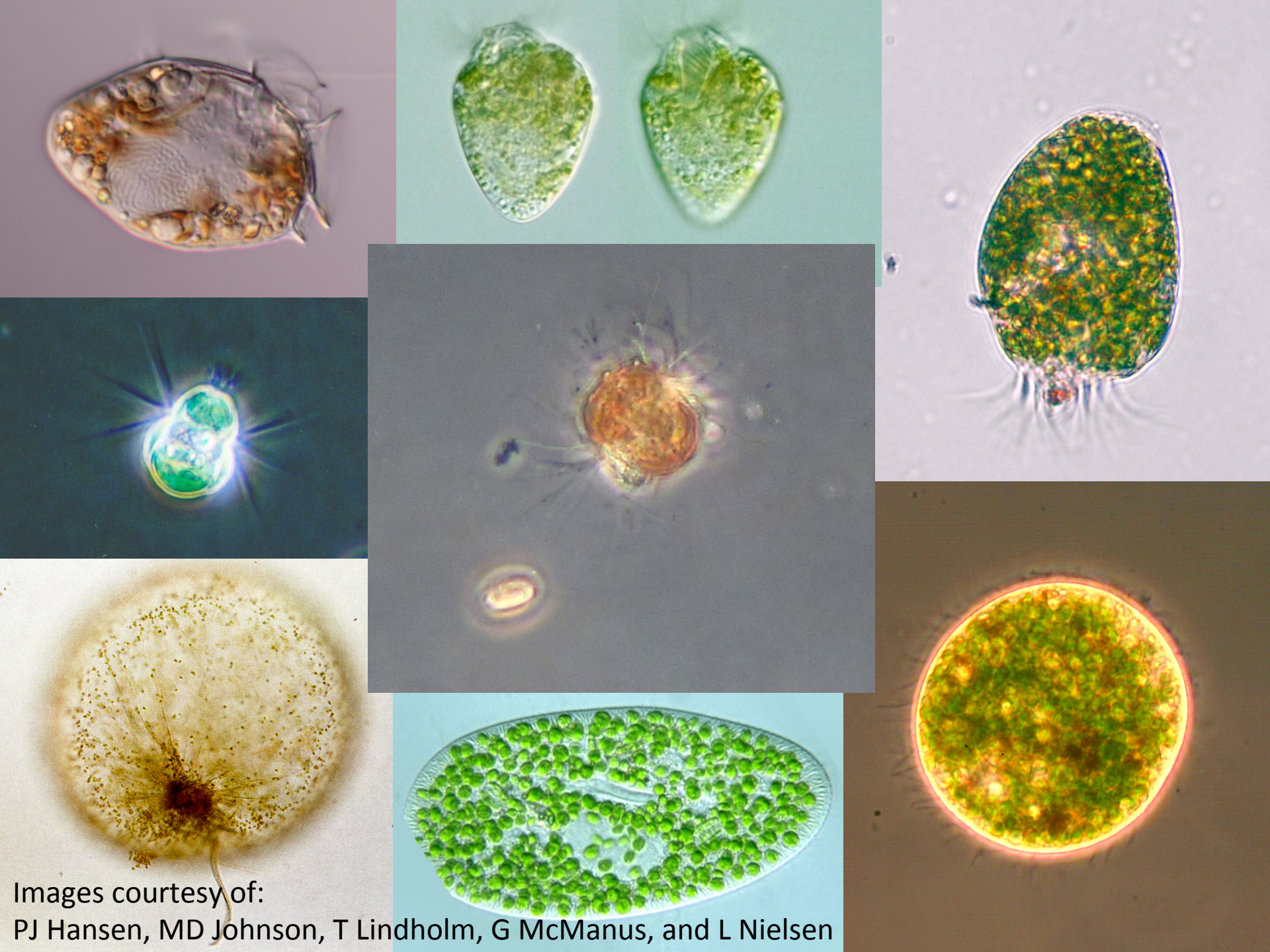
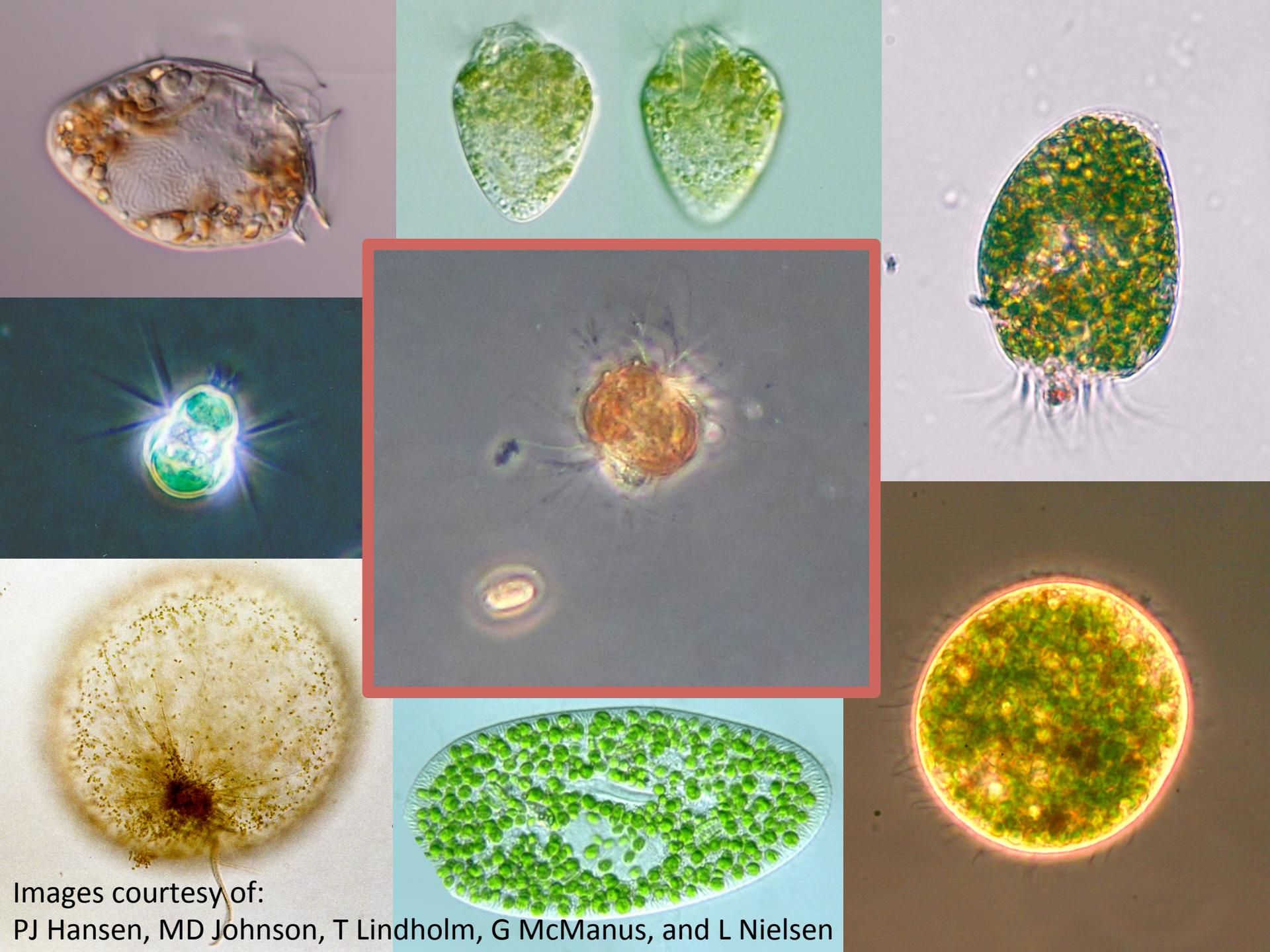
Where and when should mixotrophs matter?



Images courtesy of:
PJ Hansen, MD Johnson, T Lindholm, G McManus, and L Nielsen



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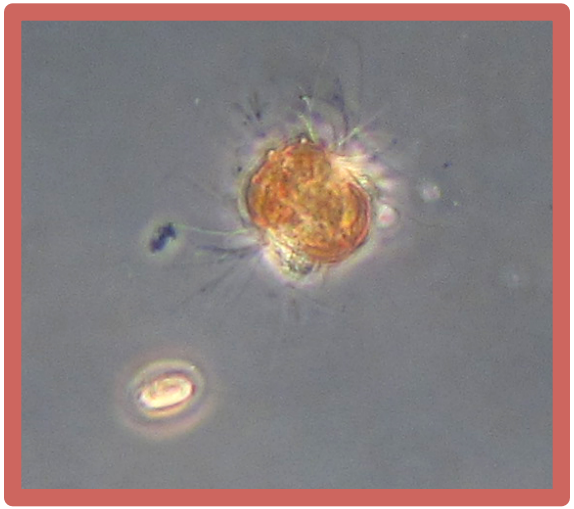
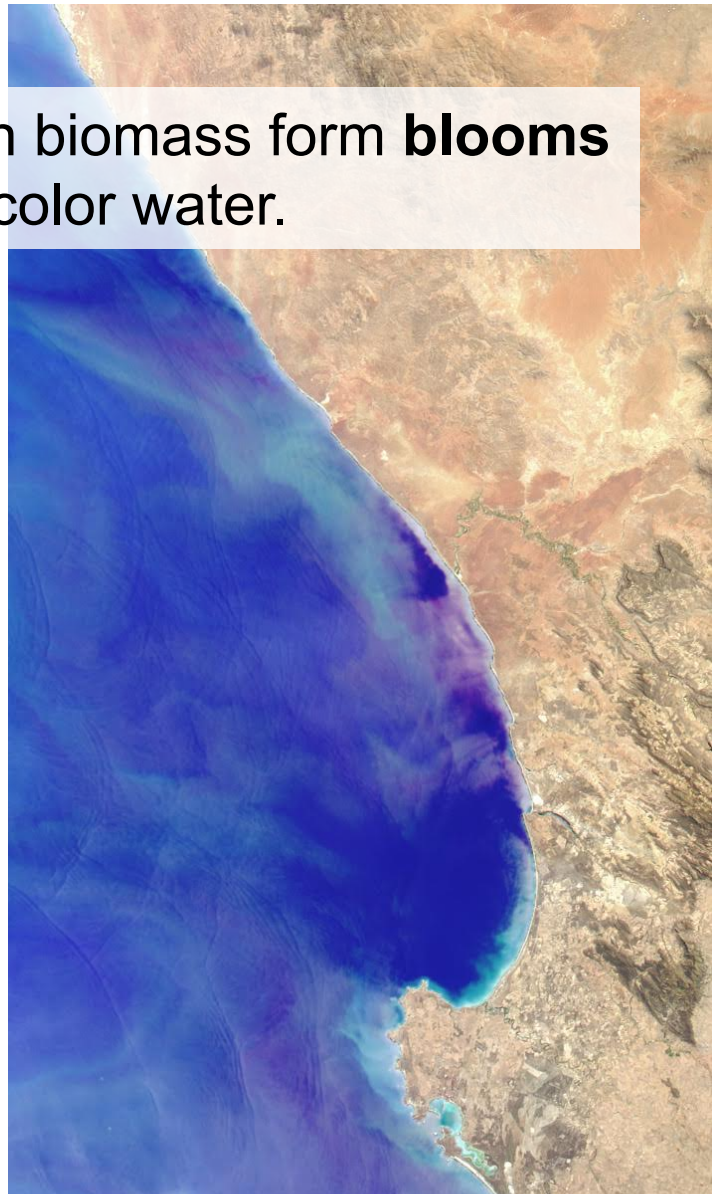
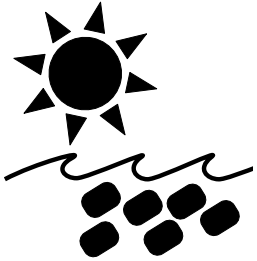


Rapid increases in biomass form **blooms** dense enough to color water.

APL-UW



NASA MODIS



A model of acquired phototrophy

Moeller et al. (2016) *Ecology Letters*

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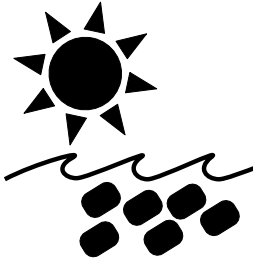

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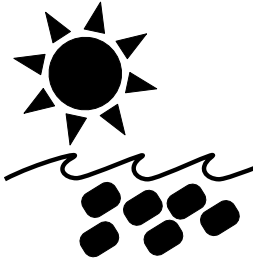

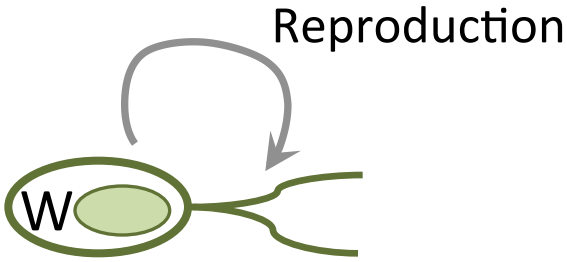

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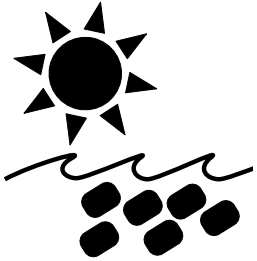

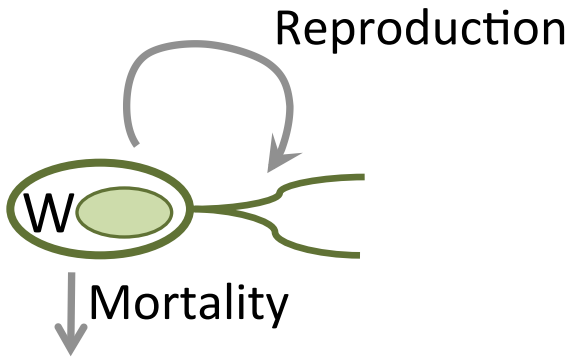

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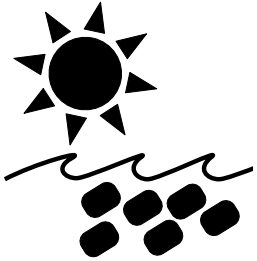

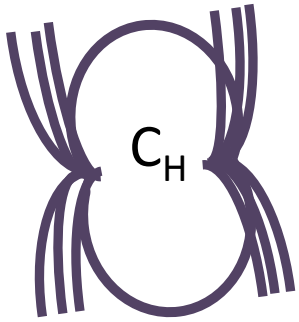

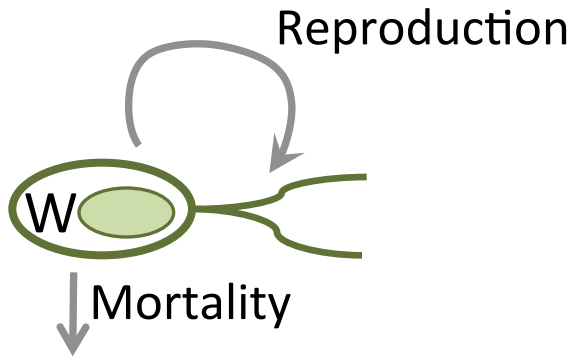

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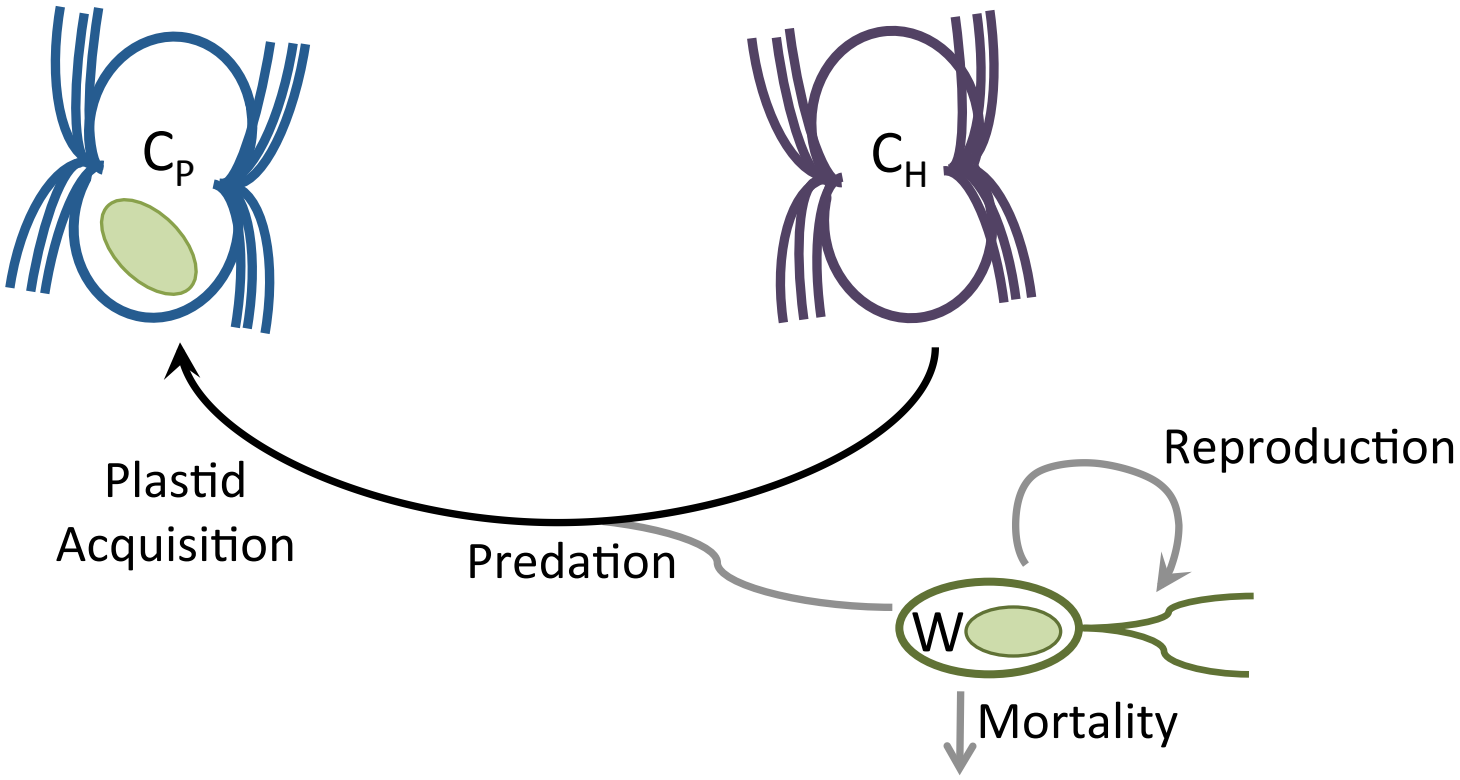
A model of acquired phototrophy



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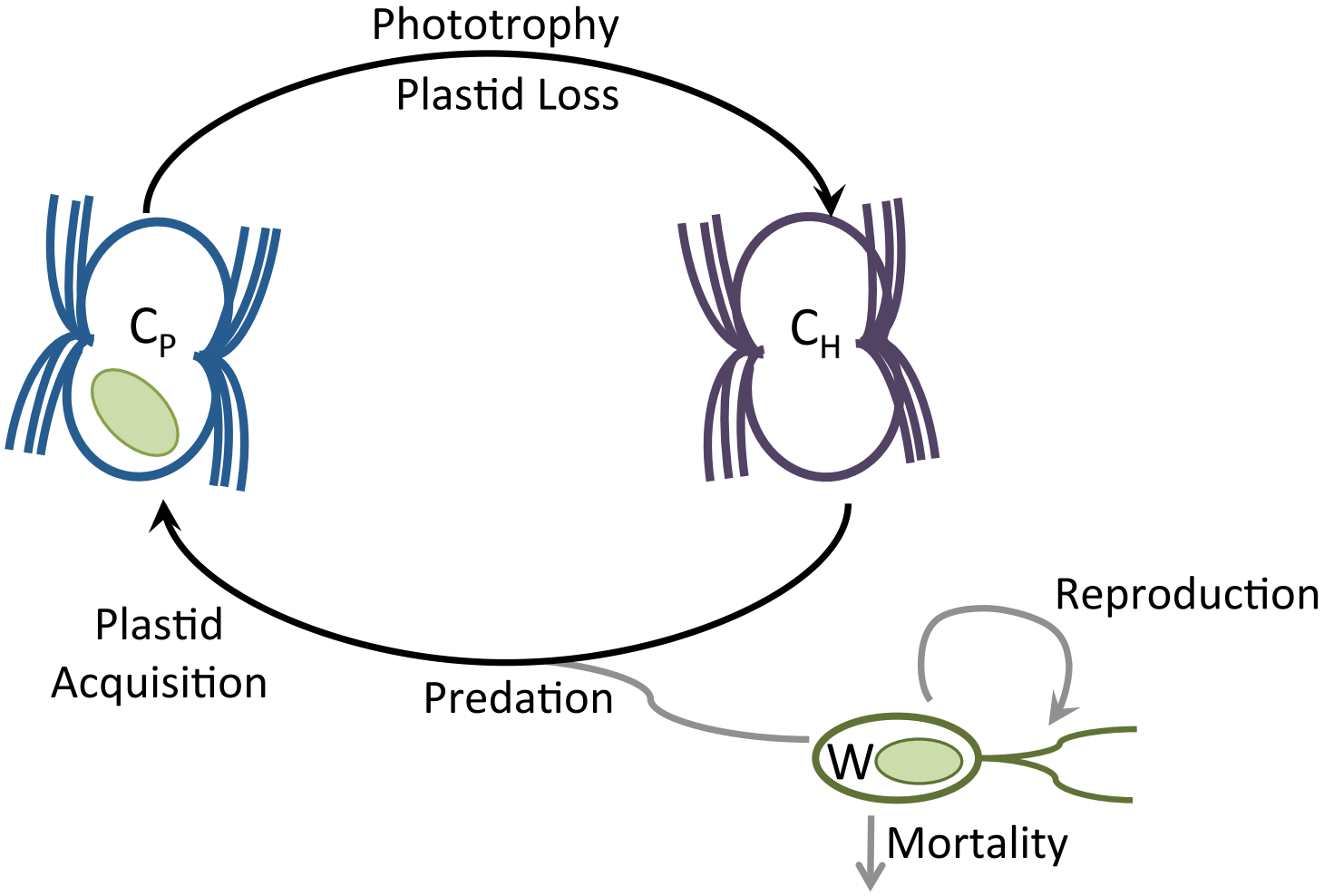

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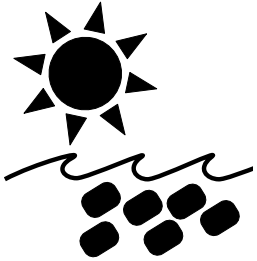

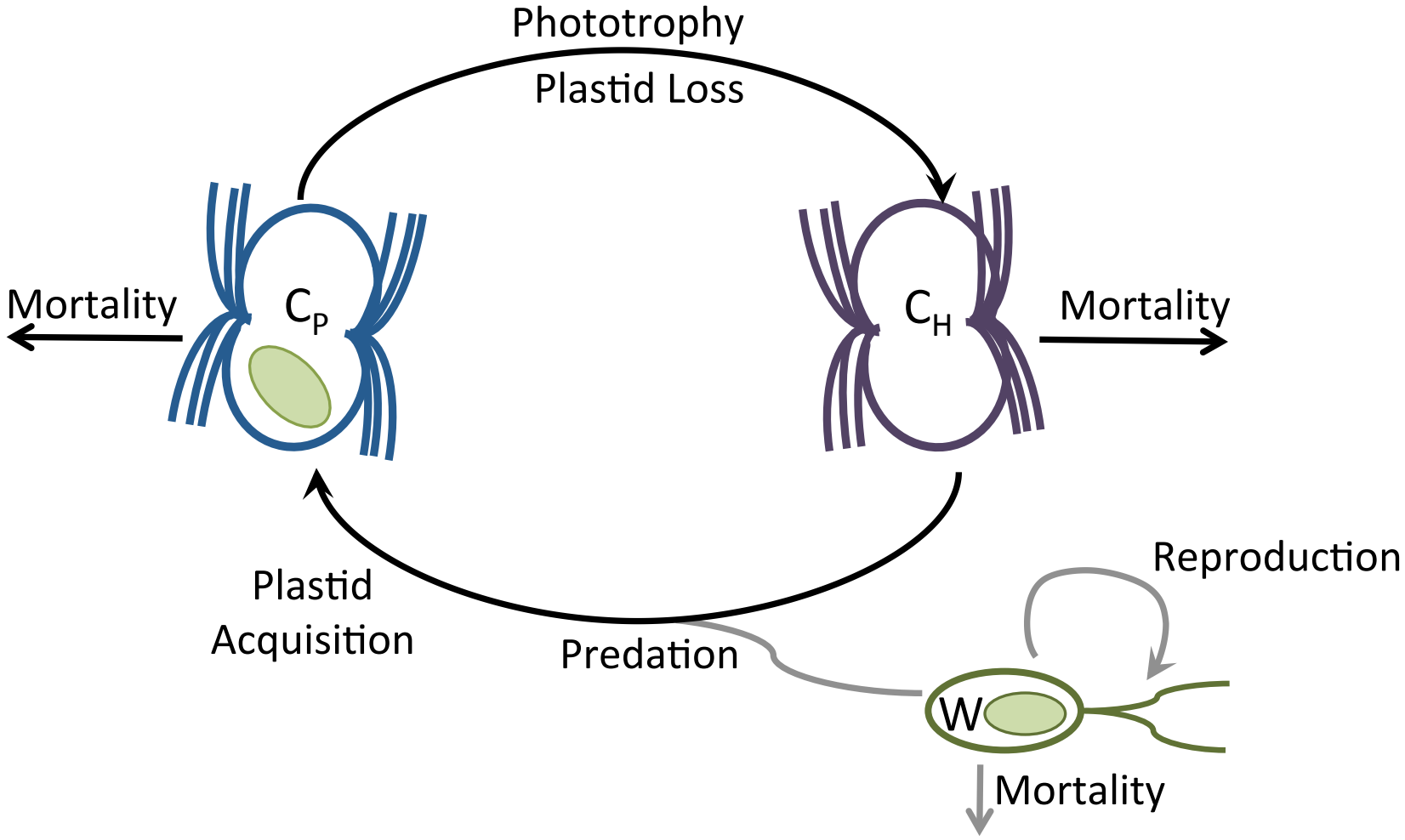

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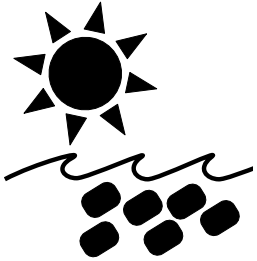

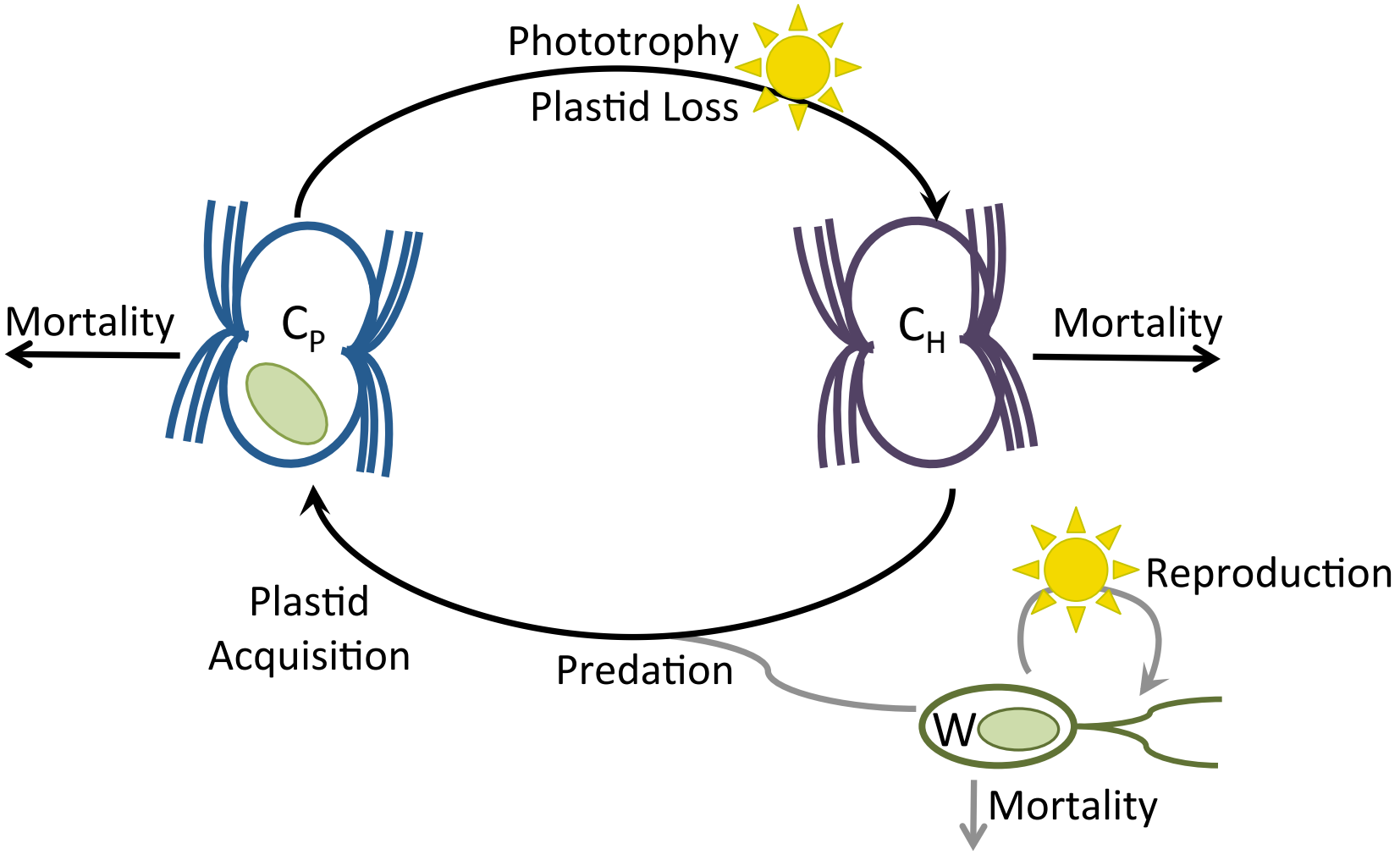

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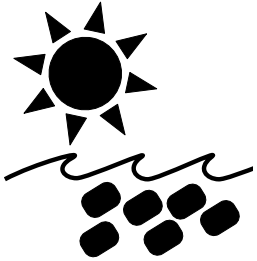

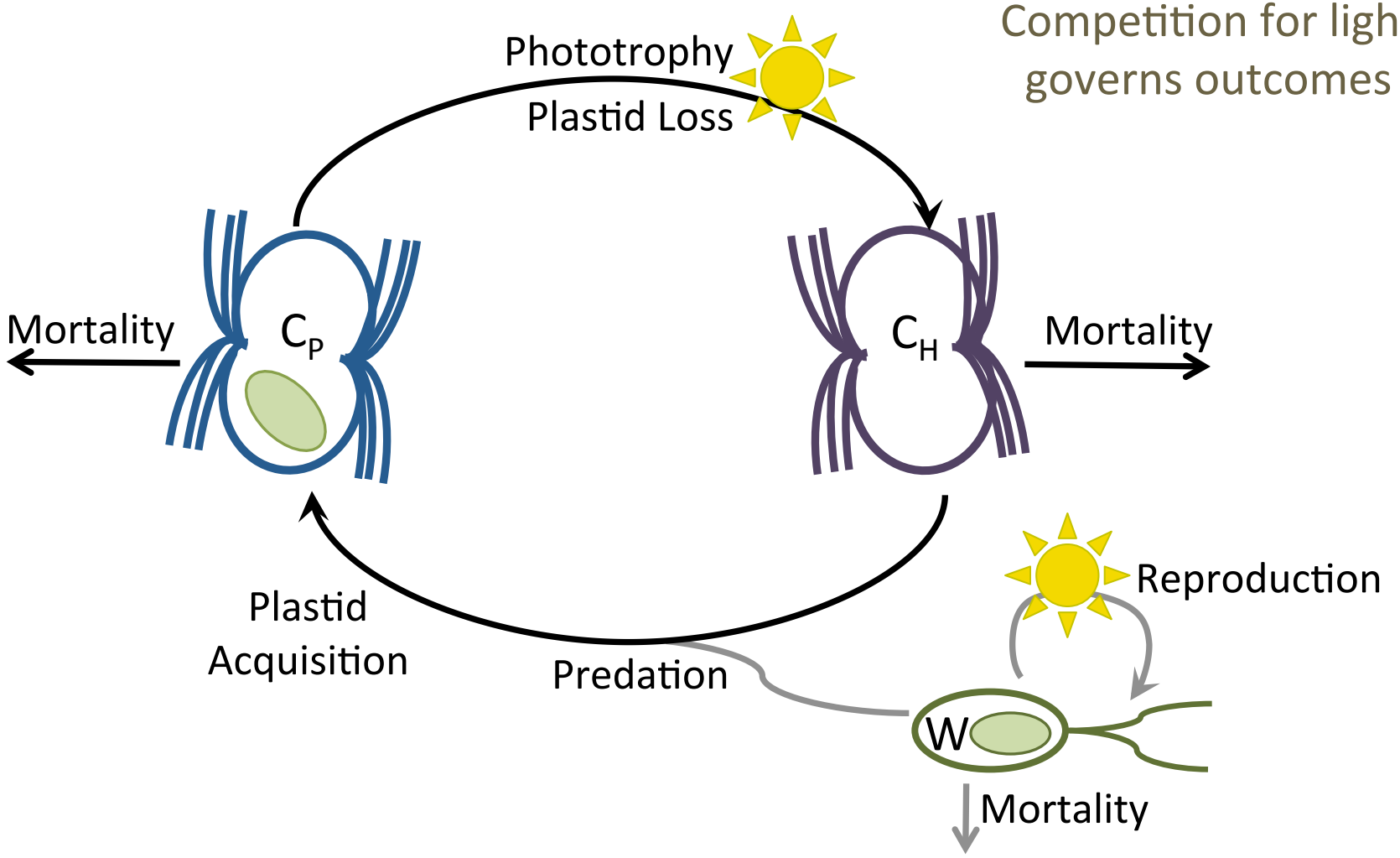

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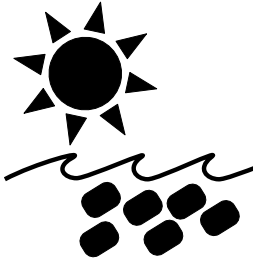
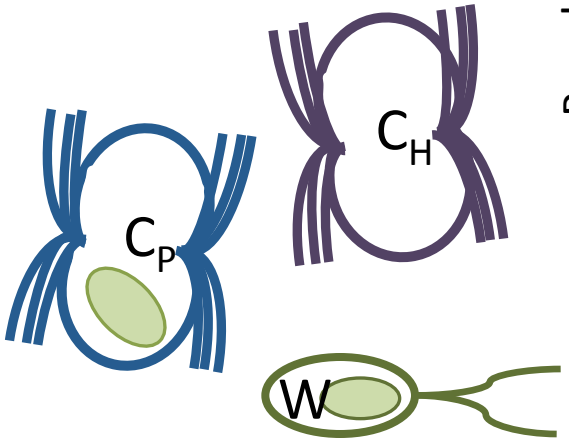
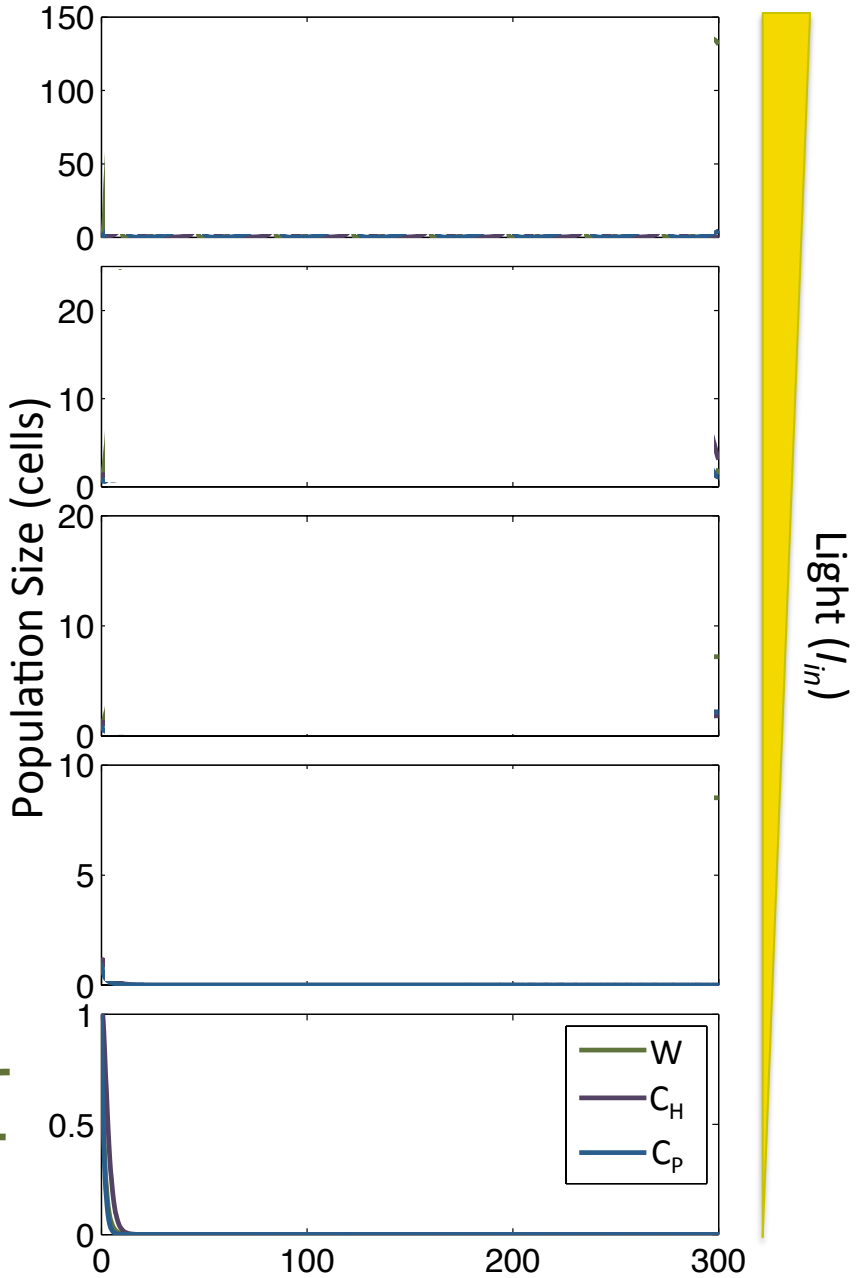
Dynamics depend upon light







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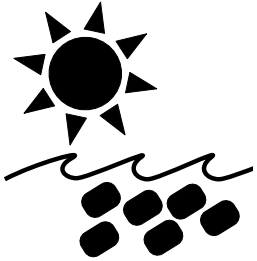

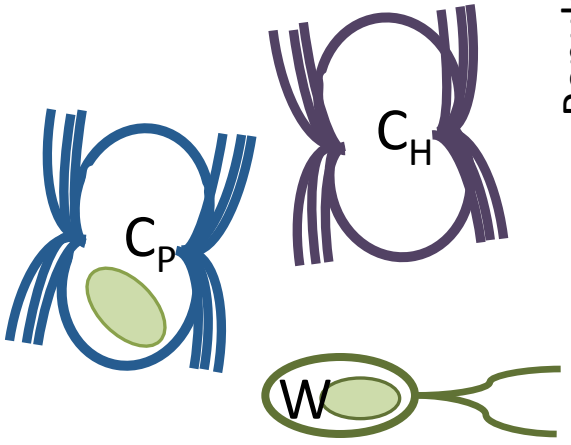

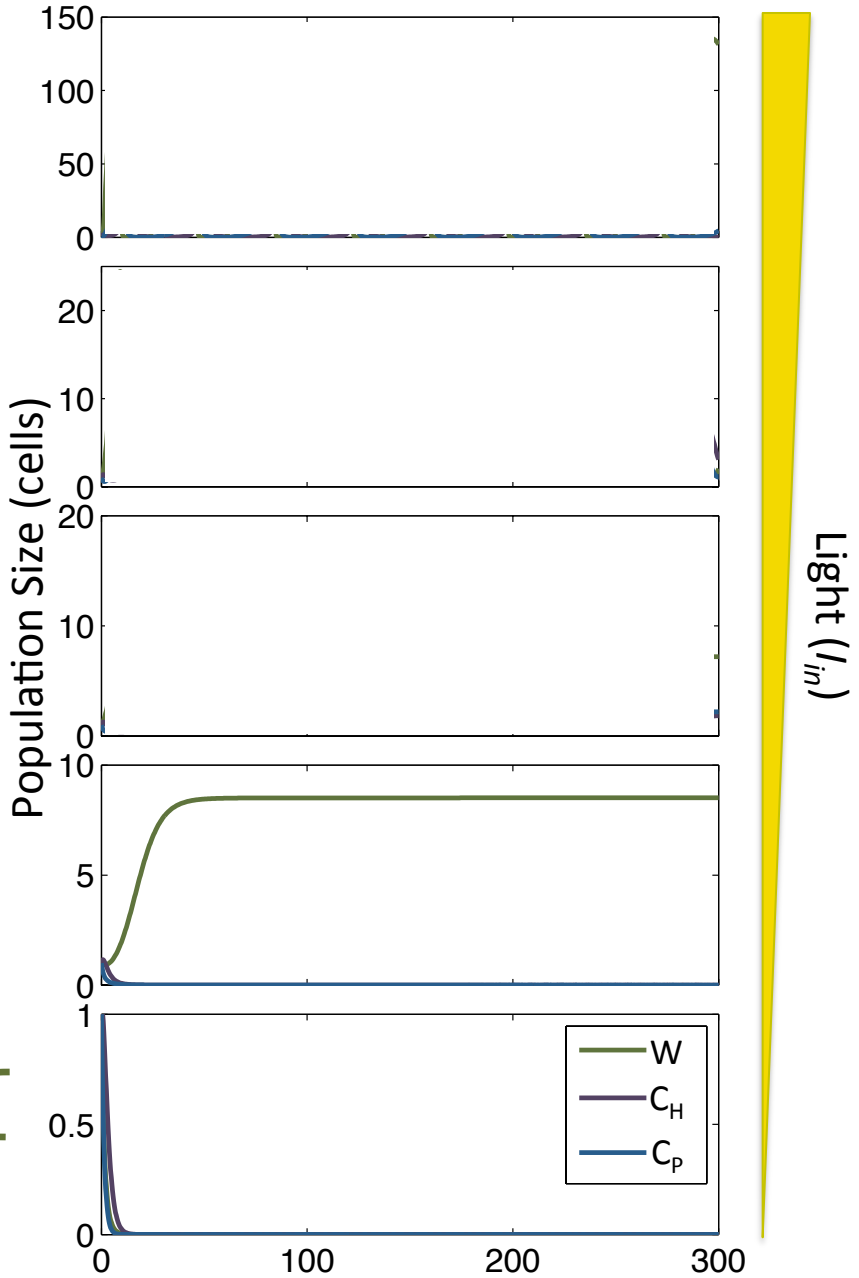

Moeller et al. (2016)

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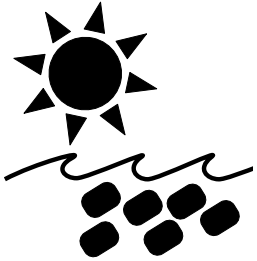

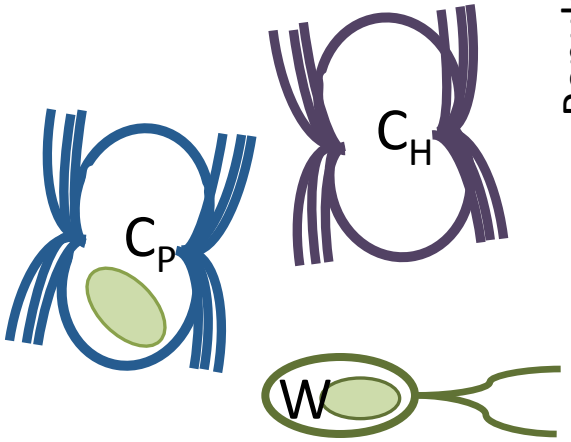

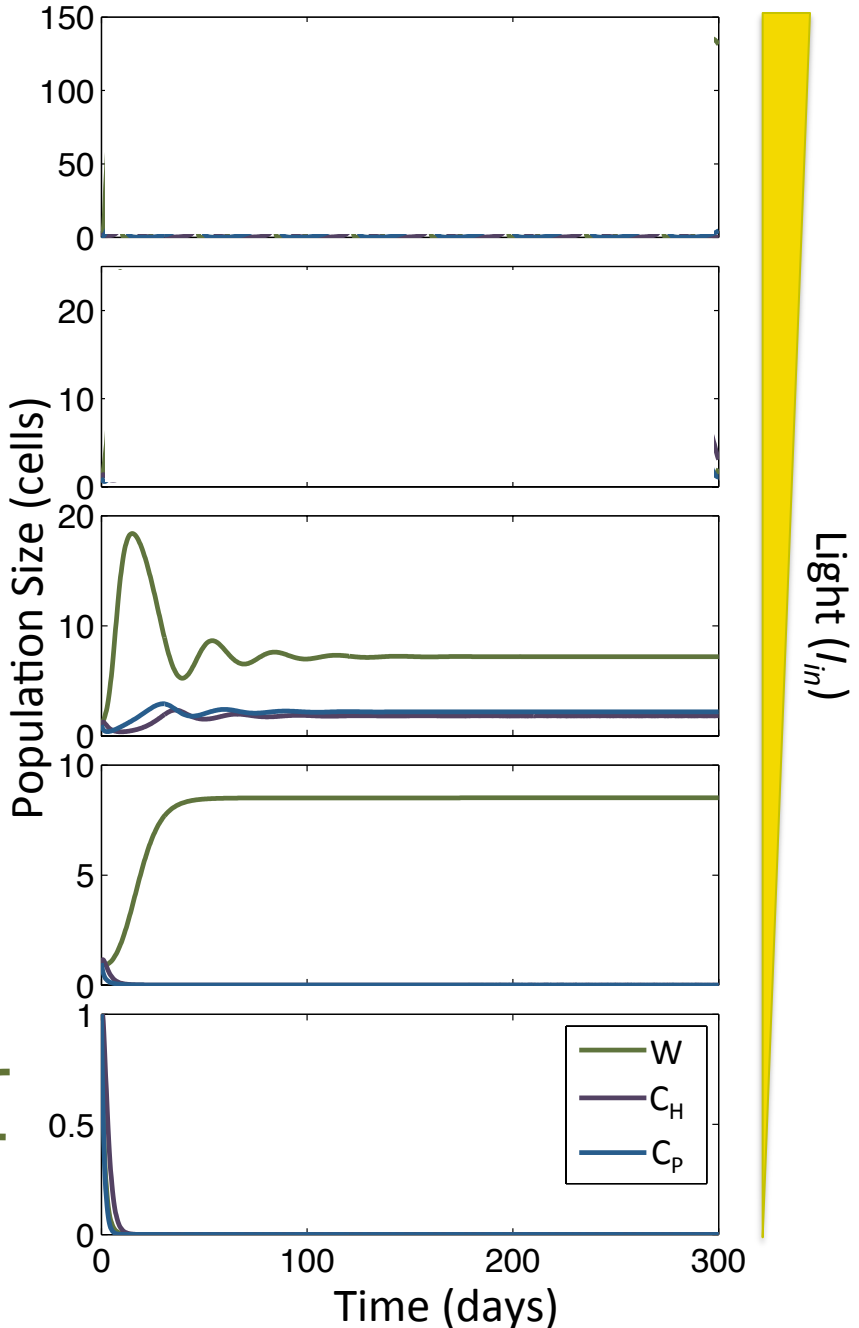

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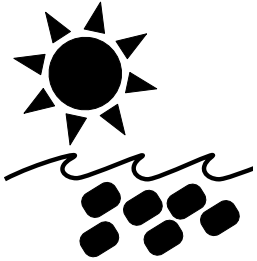

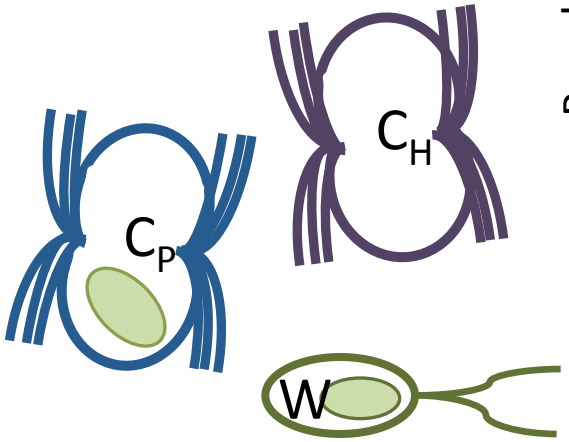

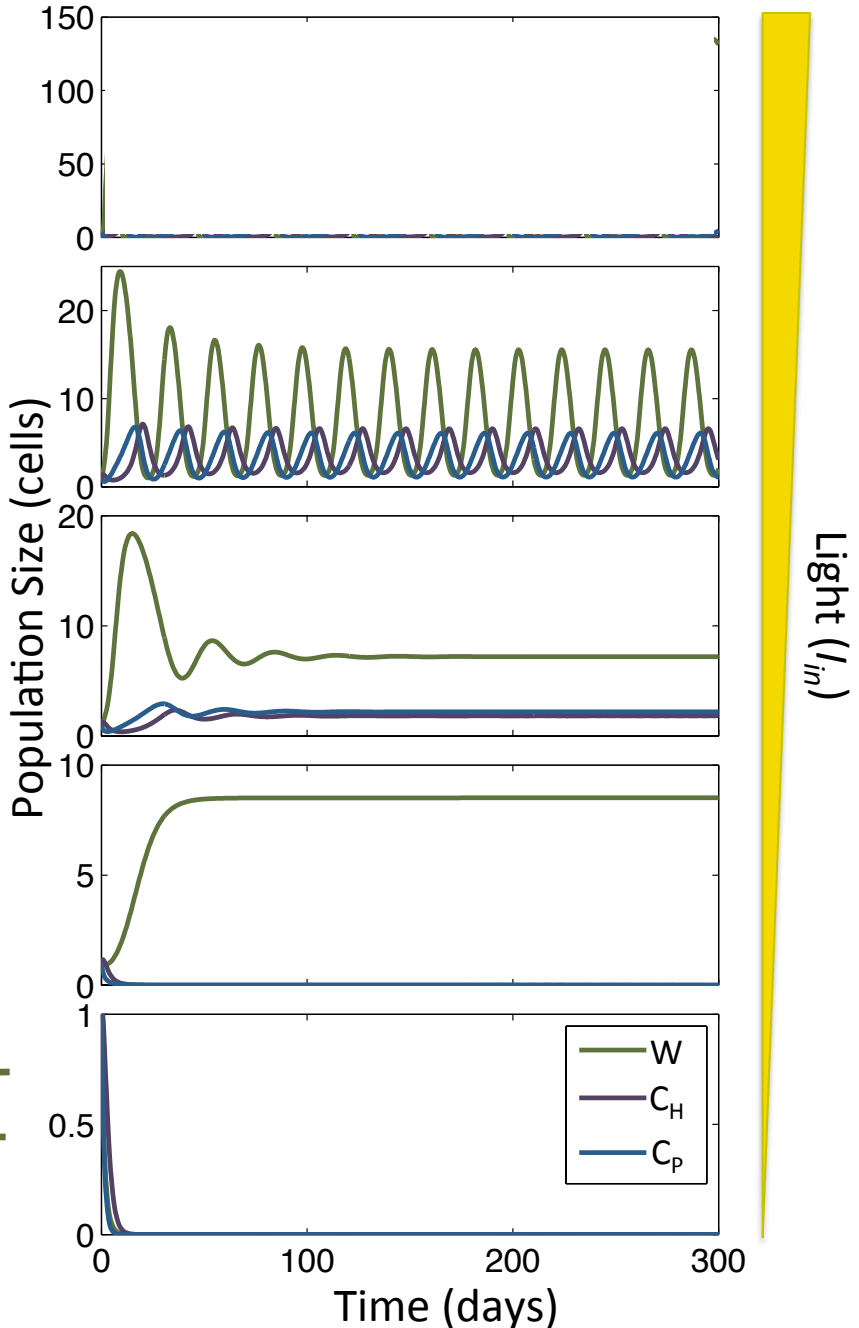

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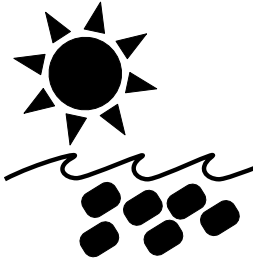
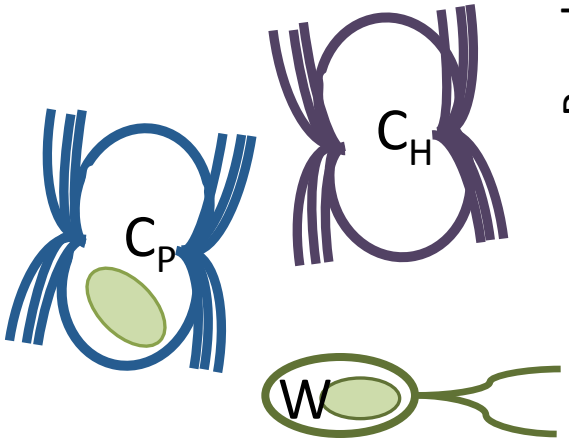
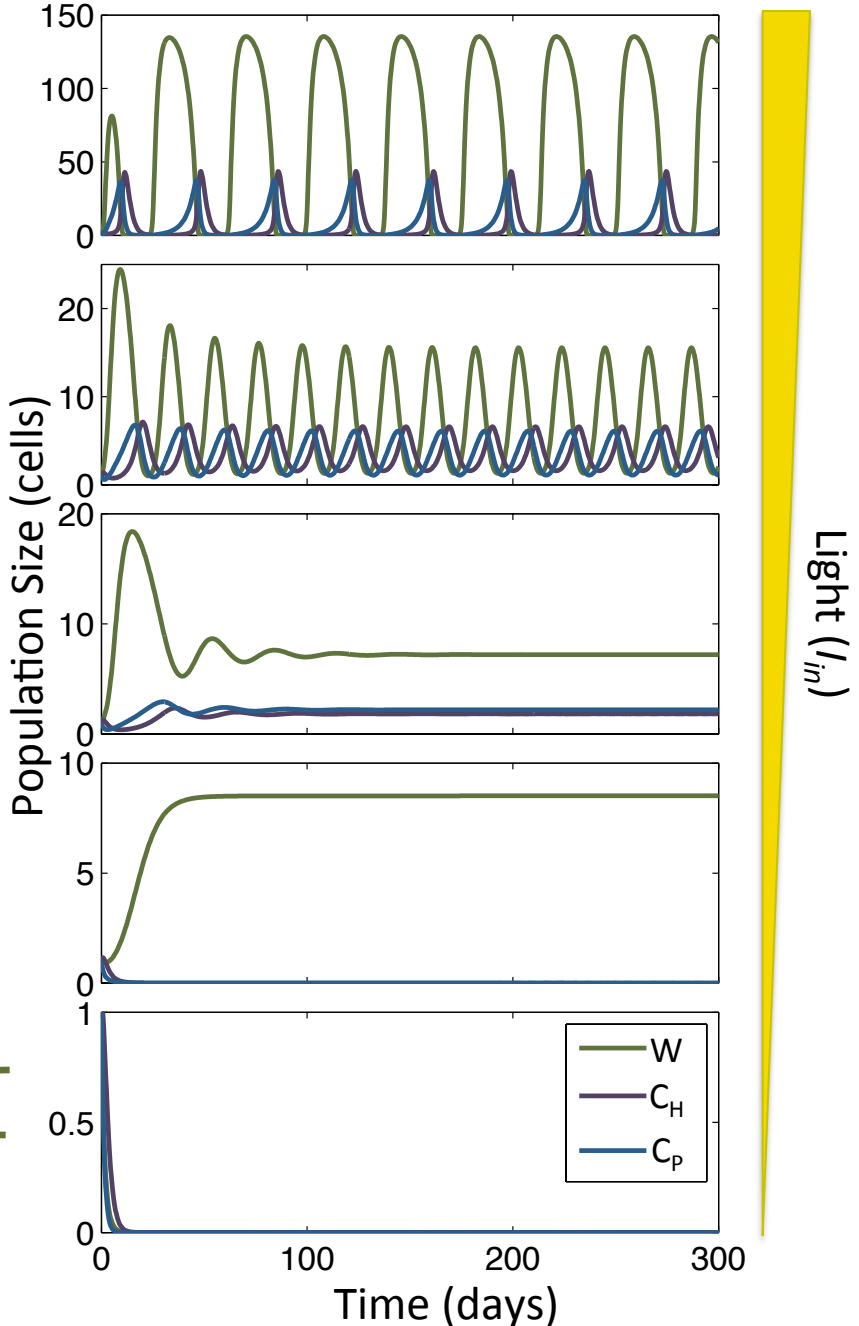
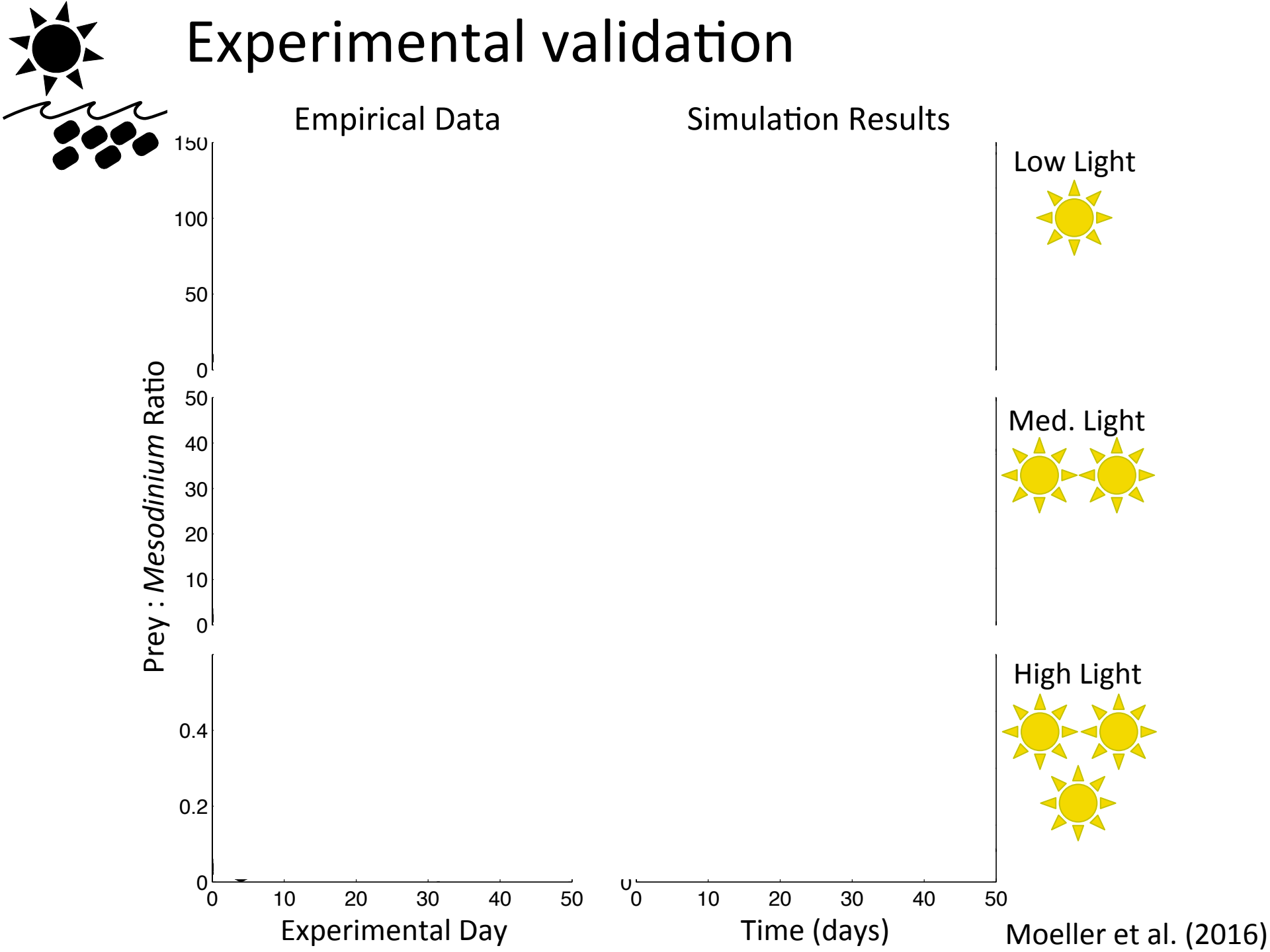






Moeller et al. (2016)

Experimental validation



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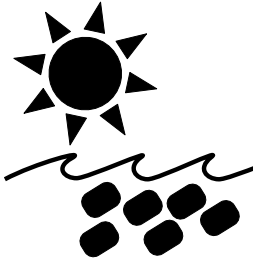

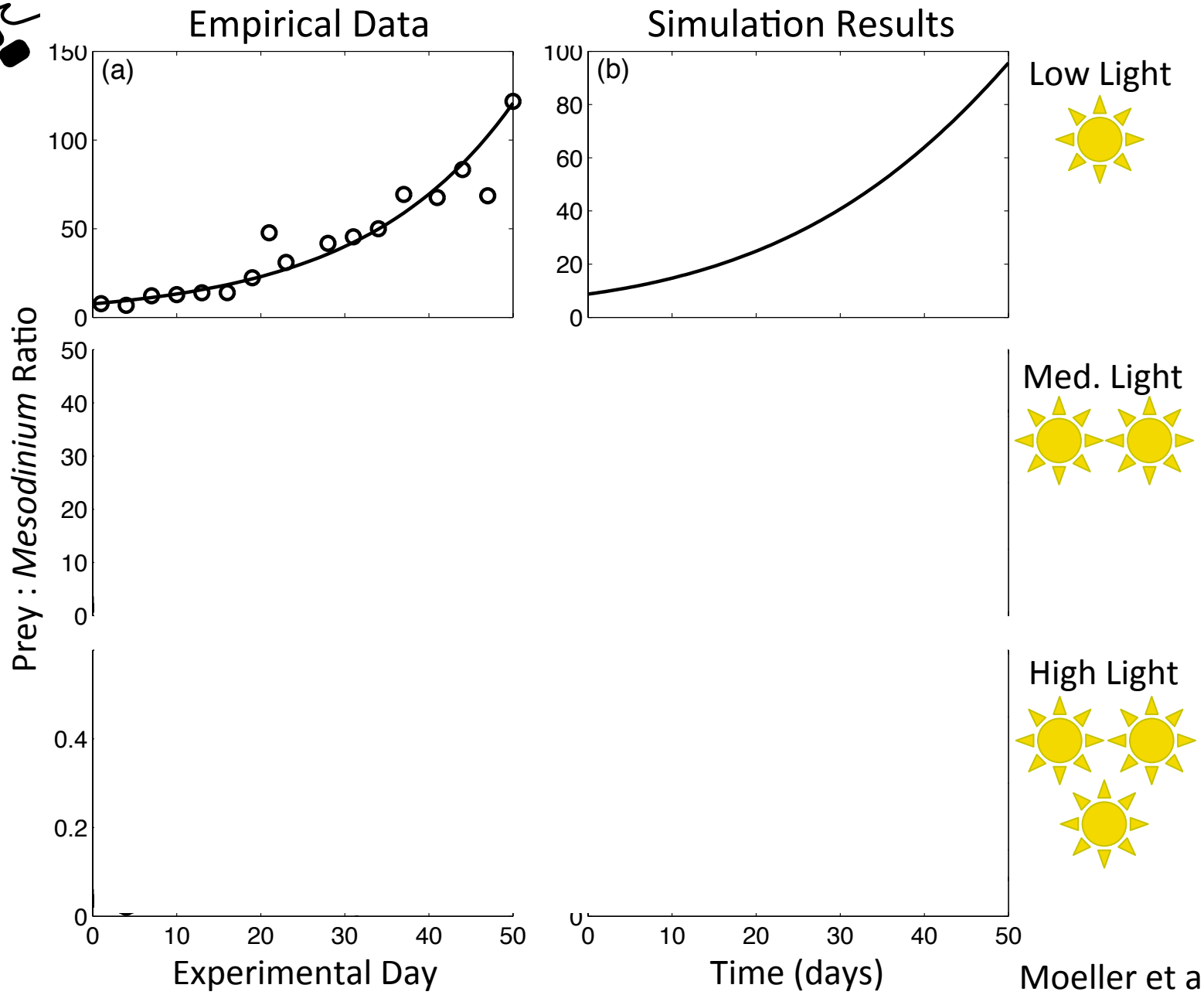

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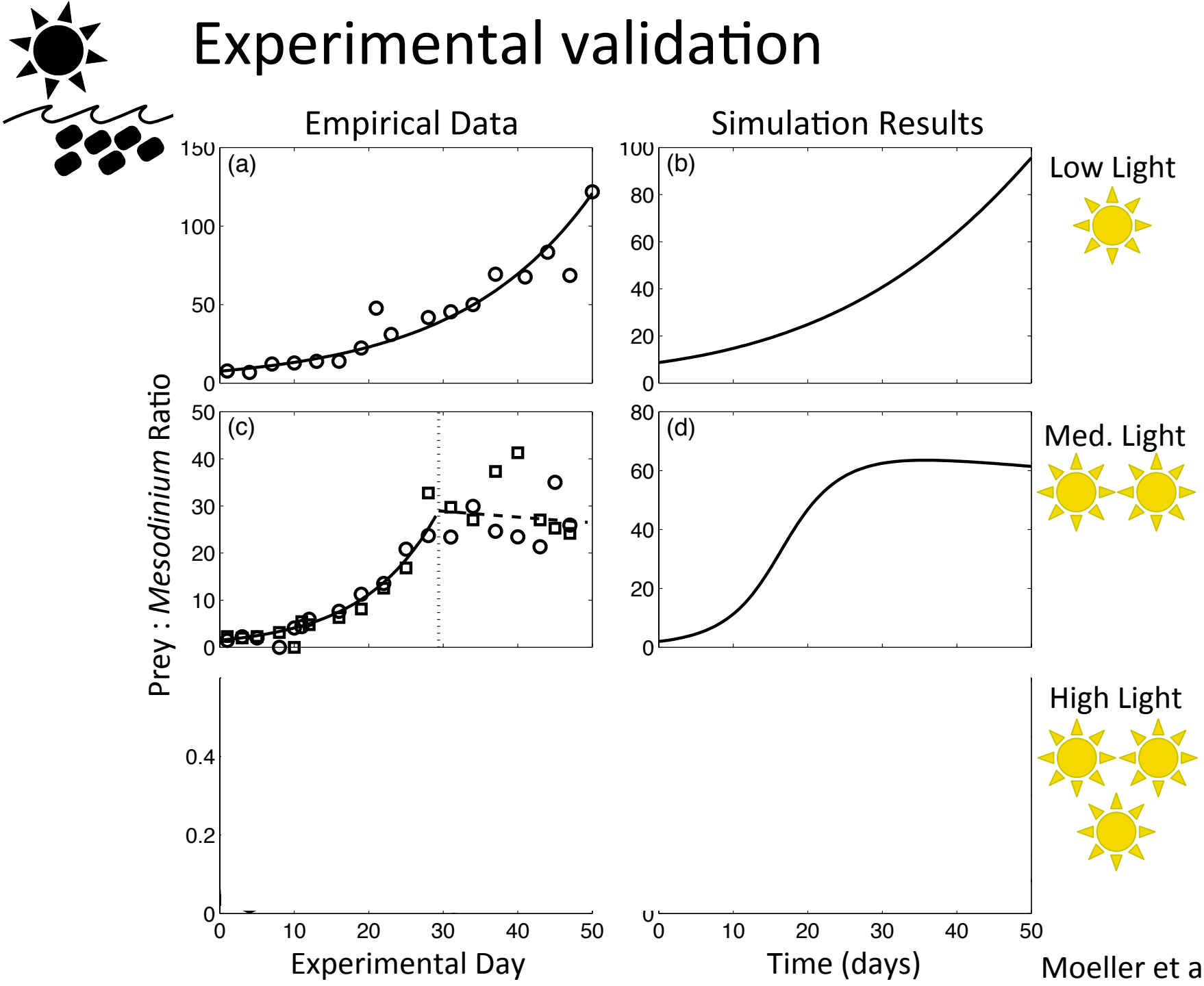

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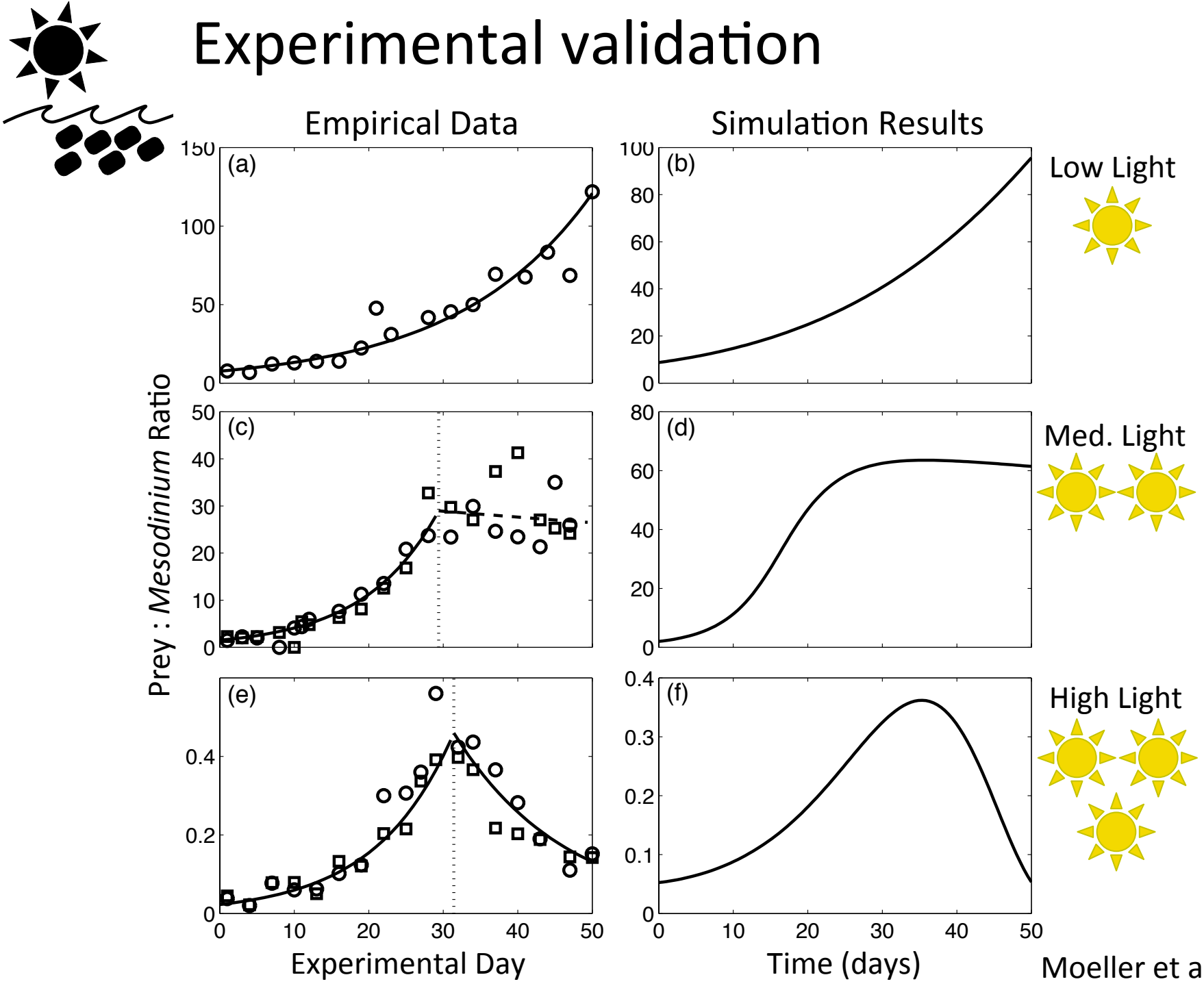
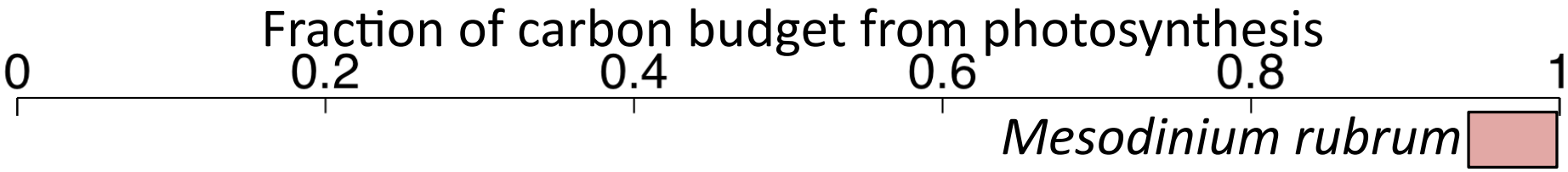


Moeller et al. (2016)

Acquired phototrophs vary in carbon budget



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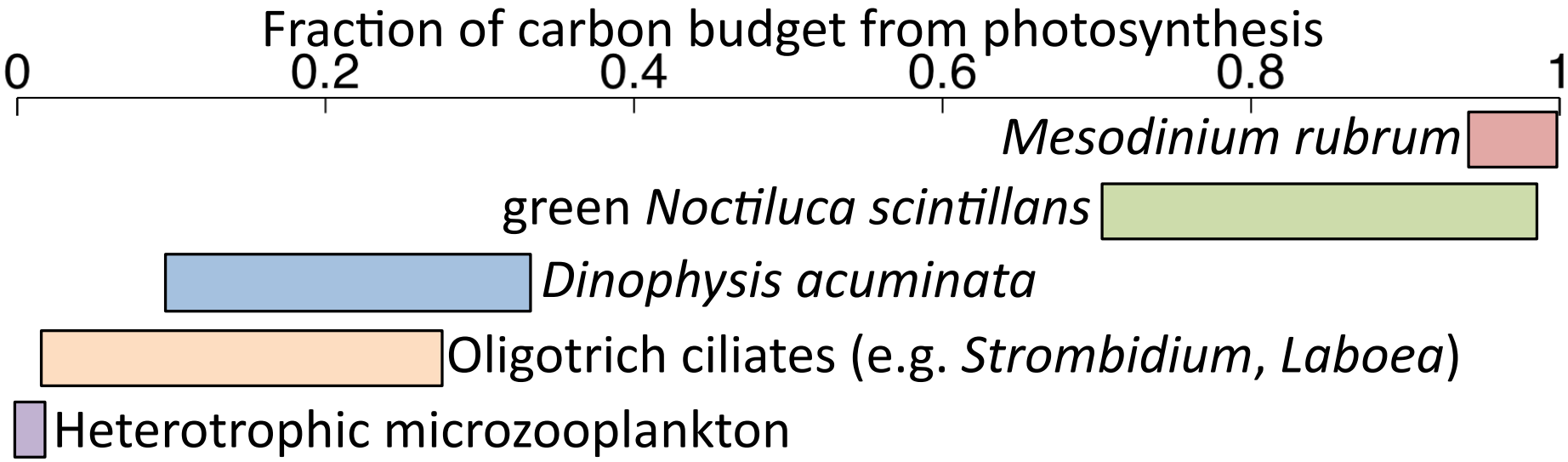

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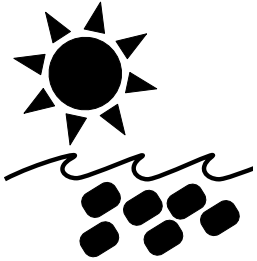

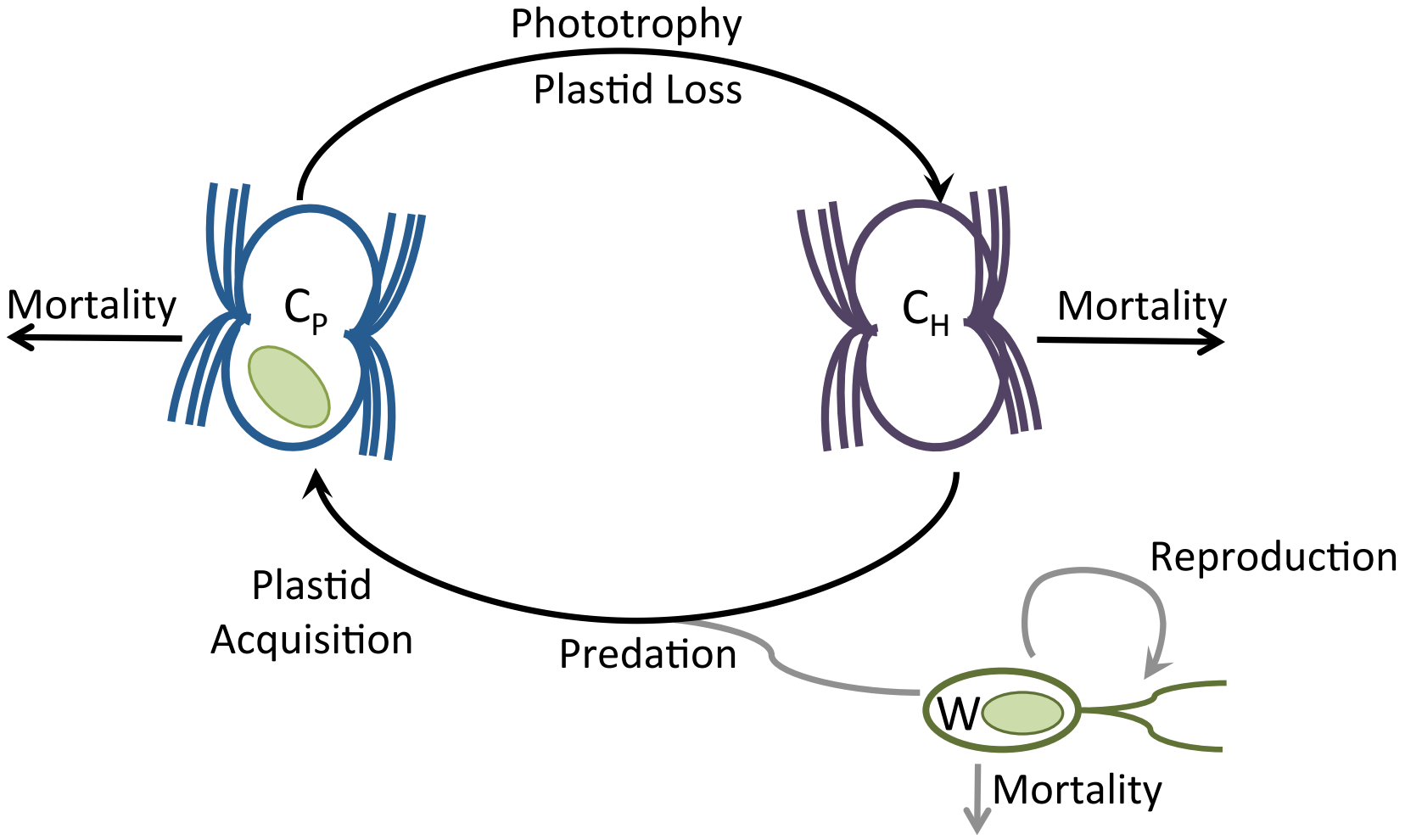

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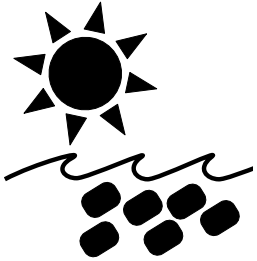

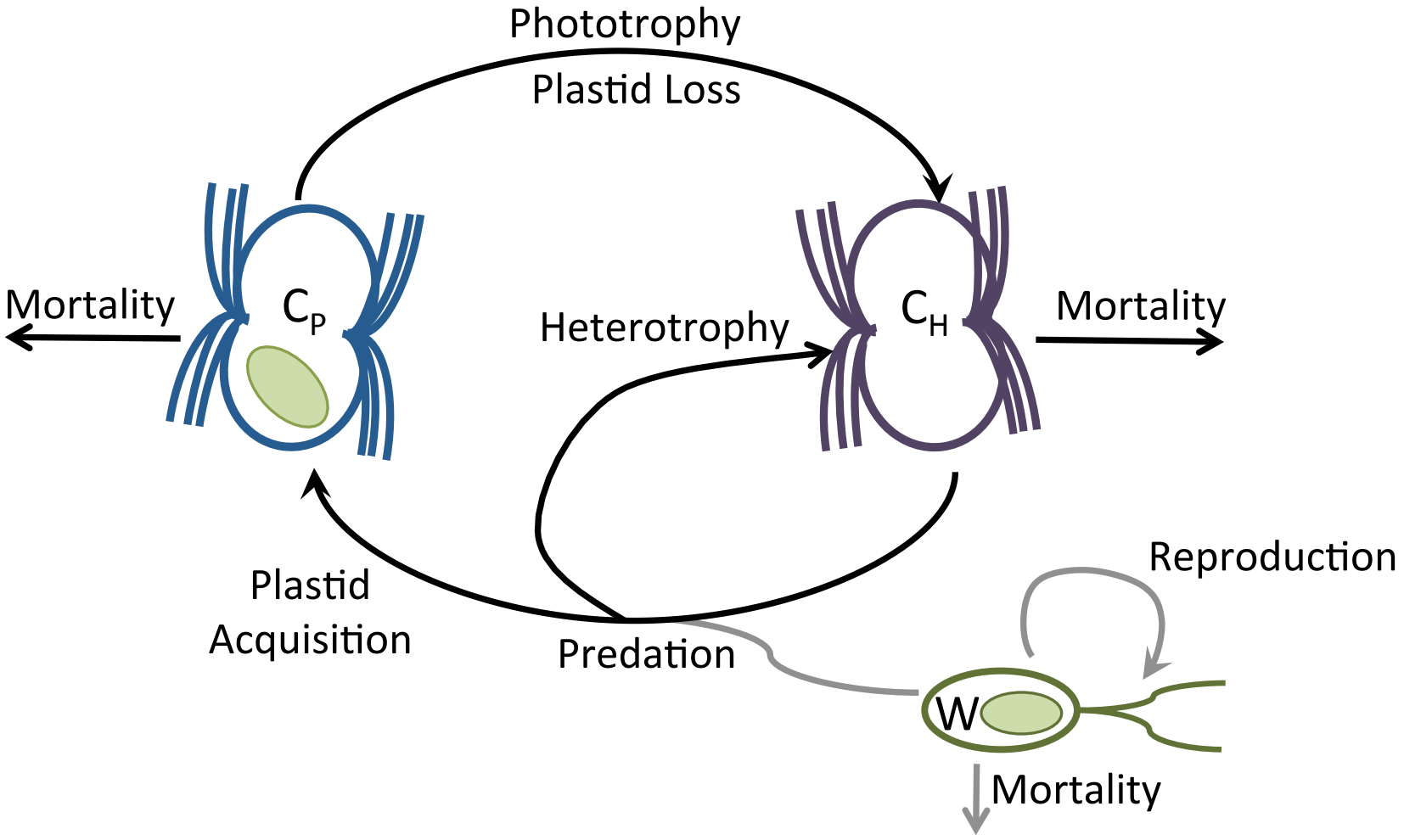

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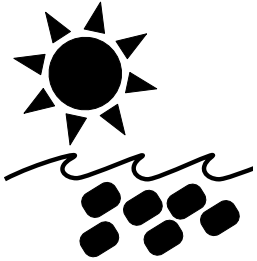

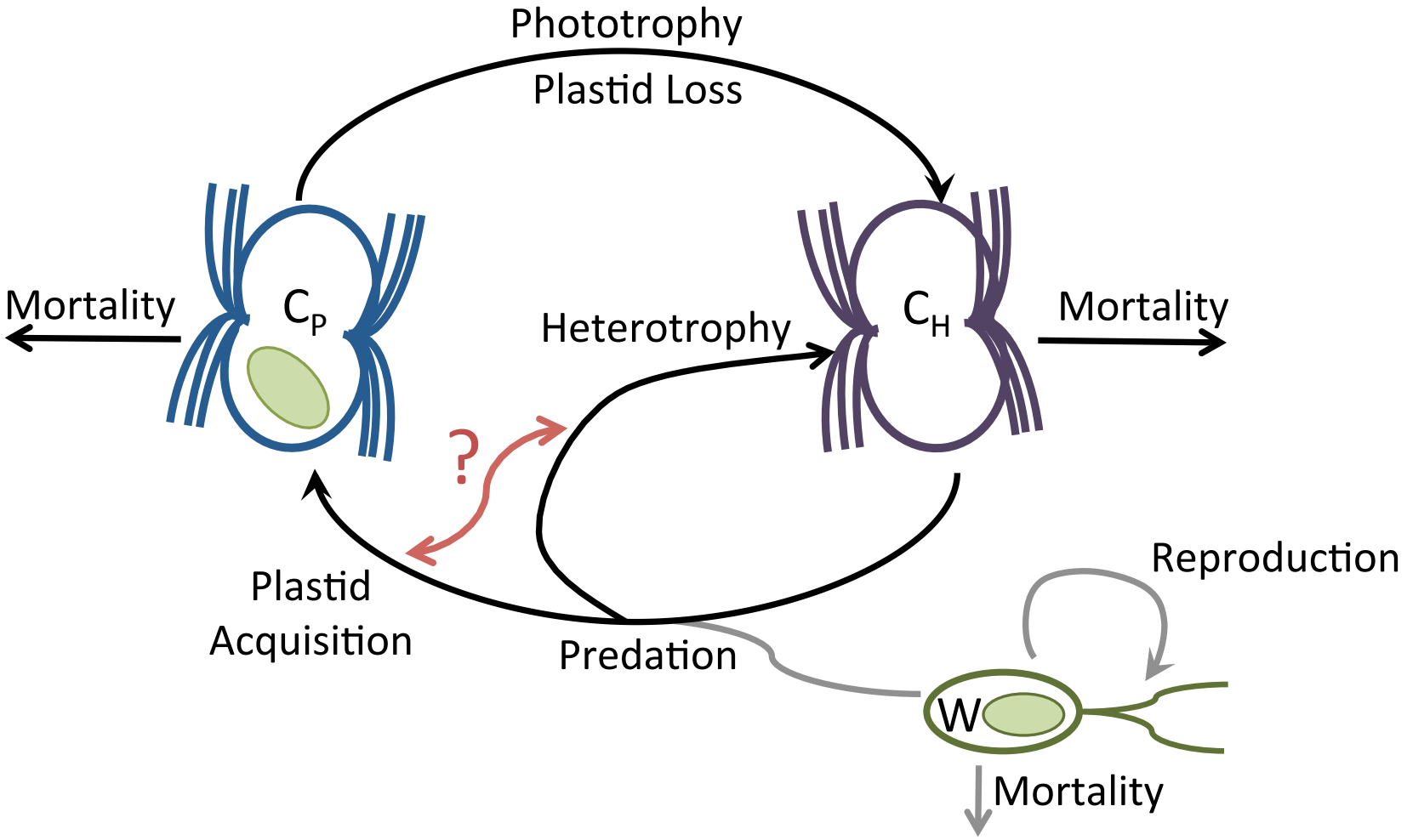

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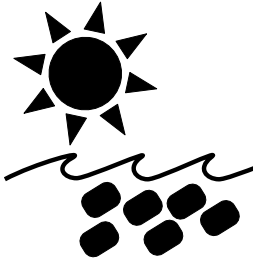

Phototrophy

Plastid Loss

Mortality

C_P

Heterotrophy

C_H

Mortality

?

n

Predation

Reproduction

W

Mortality

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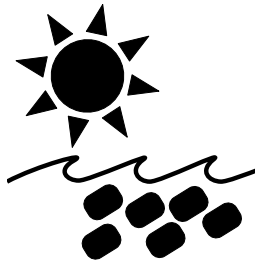
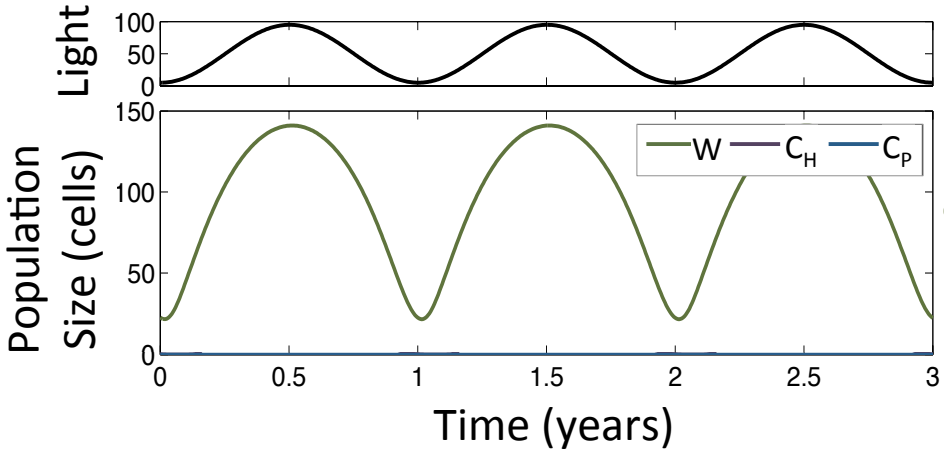
Force the model with annual light cycles





Prey only

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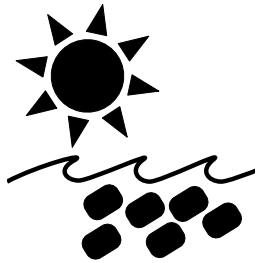
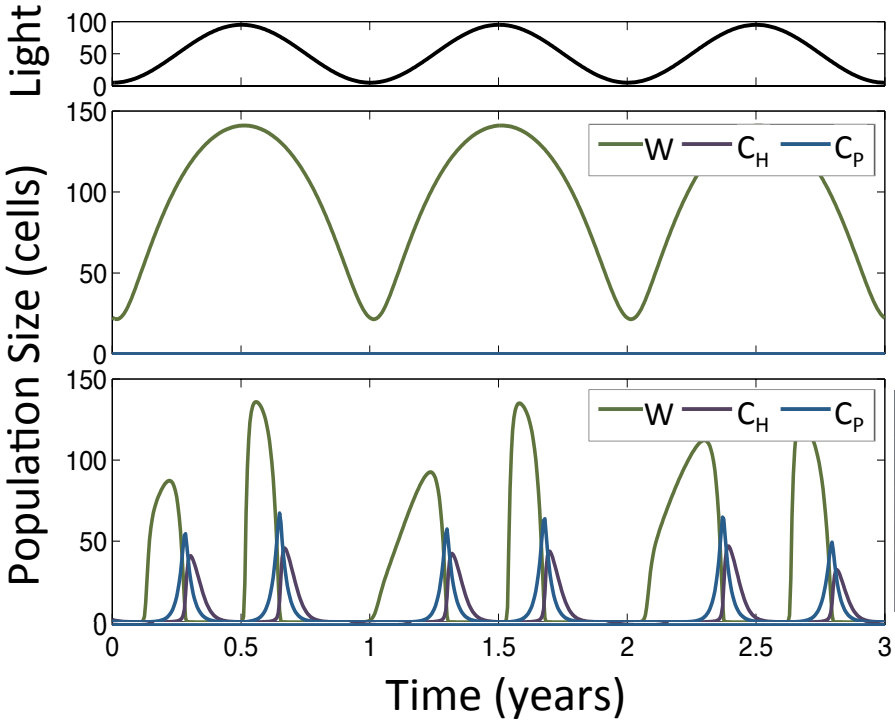
Blooms depend on degree of mixotrophy





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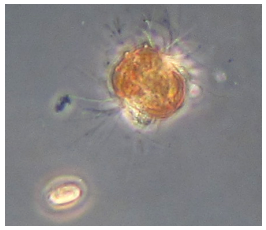

Strict acquired phototroph
(e.g., *Mesodinium rubrum*)
(image by H. Moeller)

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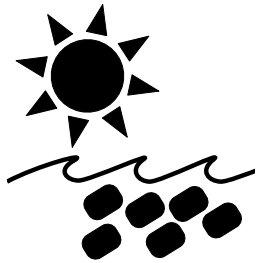
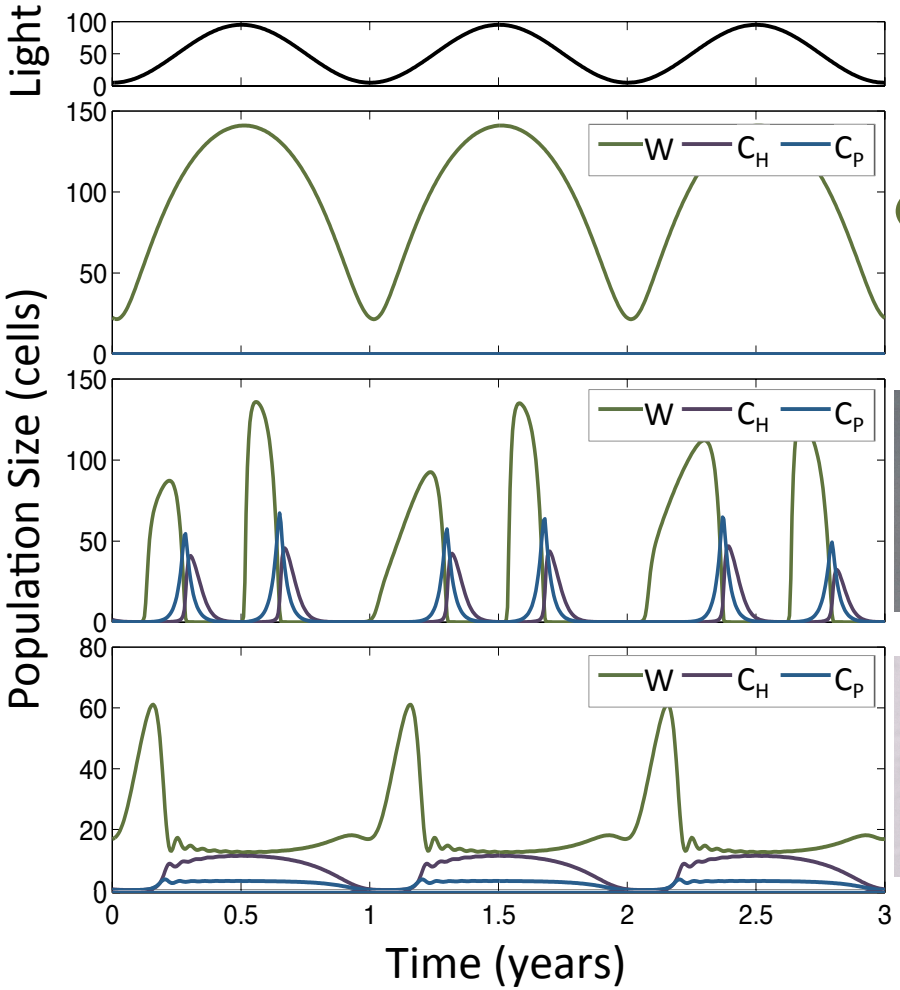
Blooms depend on degree of mixotrophy





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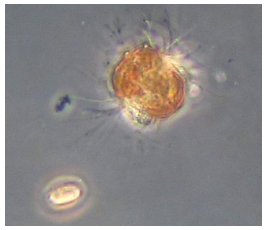

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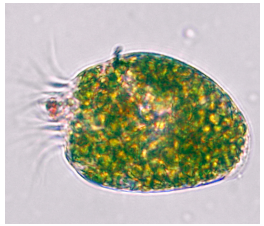
(e.g., *Mesodinium rubrum*)
(image by H. Moeller)



Mixotrophic acquired phototroph
(e.g., *Strombidium*)
(image courtesy of G. McManus)

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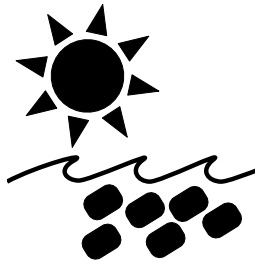
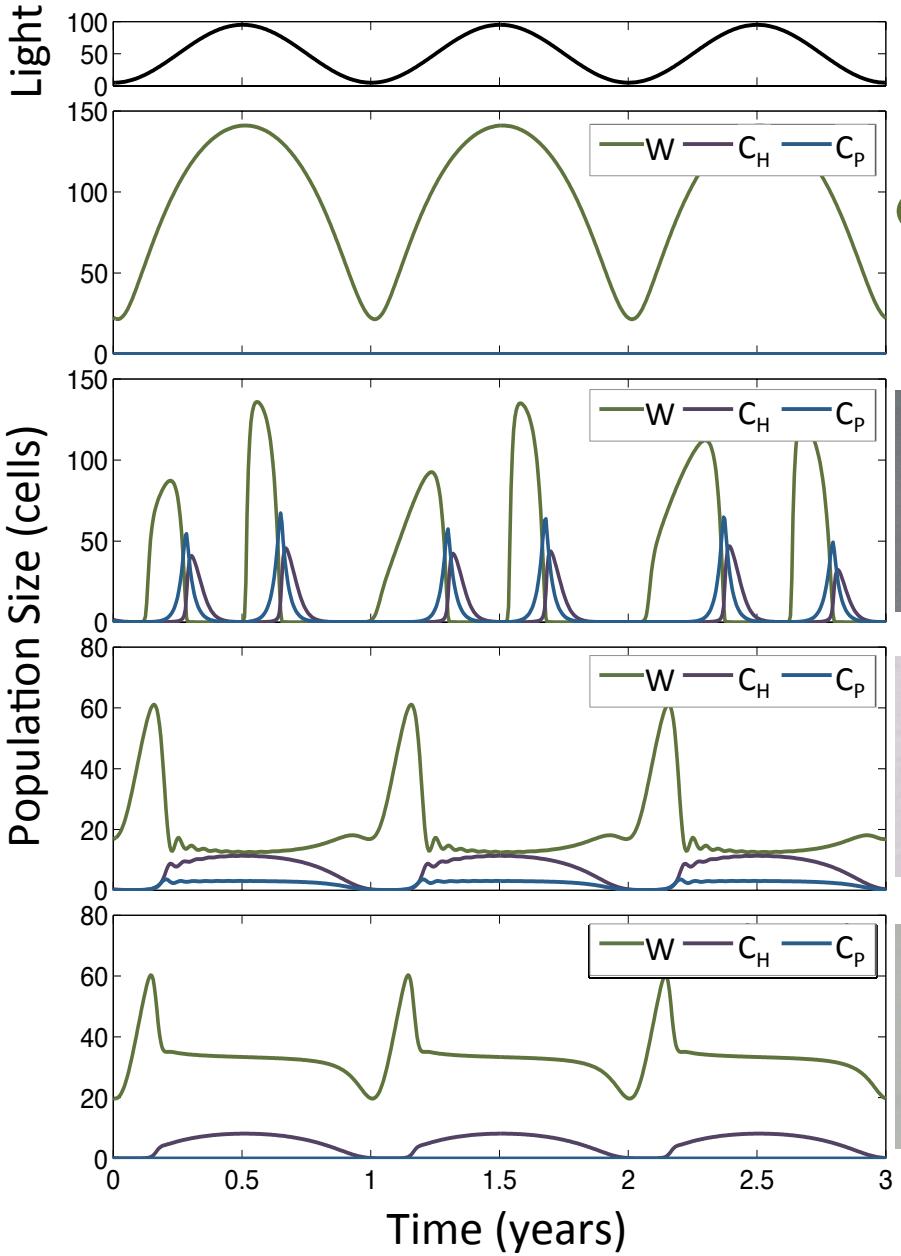
Blooms depend on degree of mixotrophy





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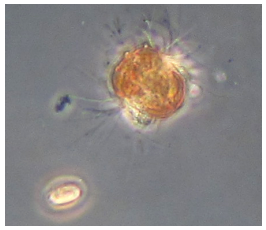
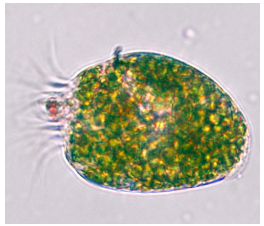


Strict acquired phototroph
(e.g., *Mesodinium rubrum*)
(image by H. Moeller)



Mixotrophic acquired phototroph
(e.g., *Strombidium*)
(image courtesy of G. McManus)

Strict heterotroph
(e.g., *Protoperidinium*)
(image by M. Johnson)

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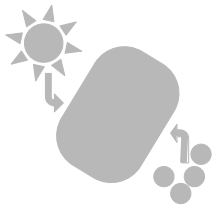
Mixotrophic Modulators of the Biological Pump



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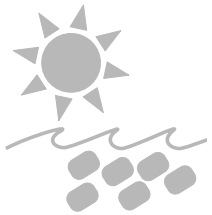
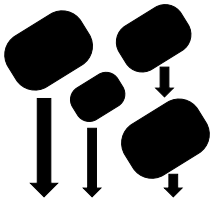
Impacts on the Biological Pump



How mixotrophs modulate primary productivity

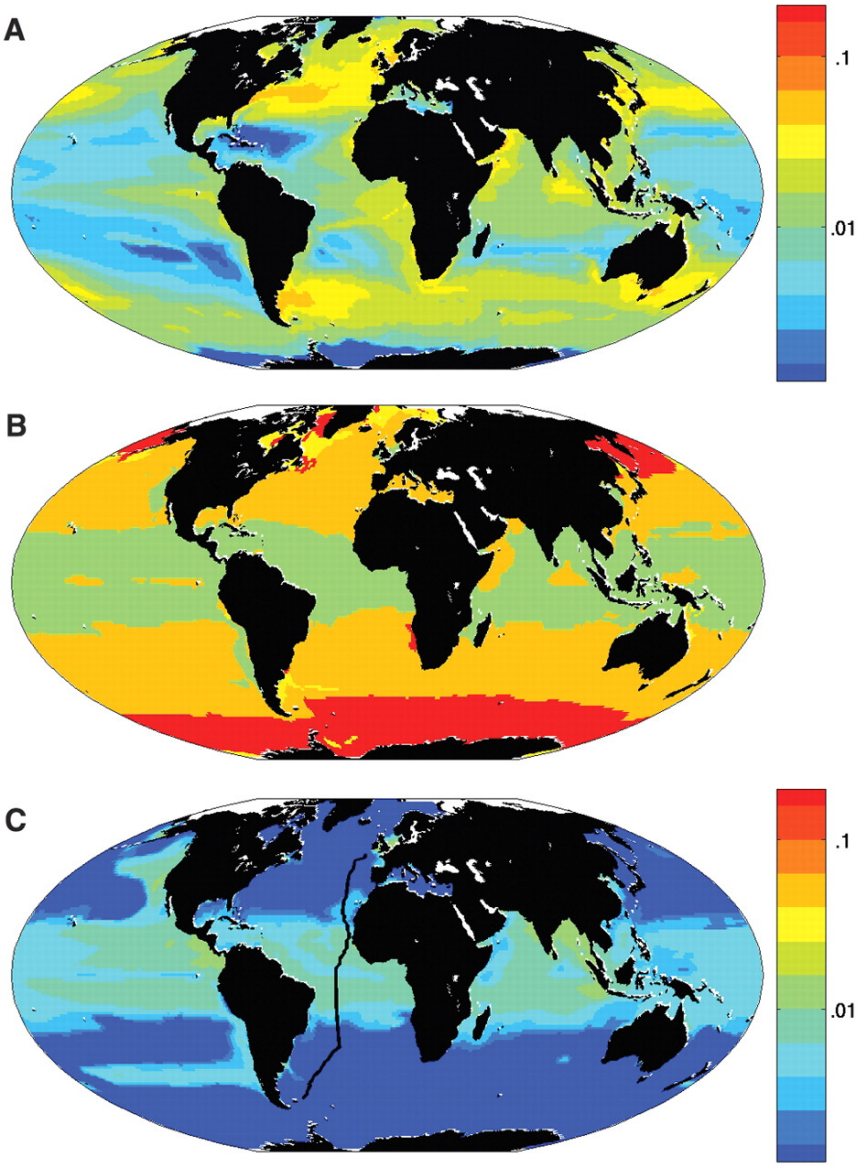


How mixotrophs modulate particle flux

How mixotrophs modulate remineralization rates

Where and when should mixotrophs matter?

Modeling mixotrophy at the global scale



Follows et al. (2007) *Science*

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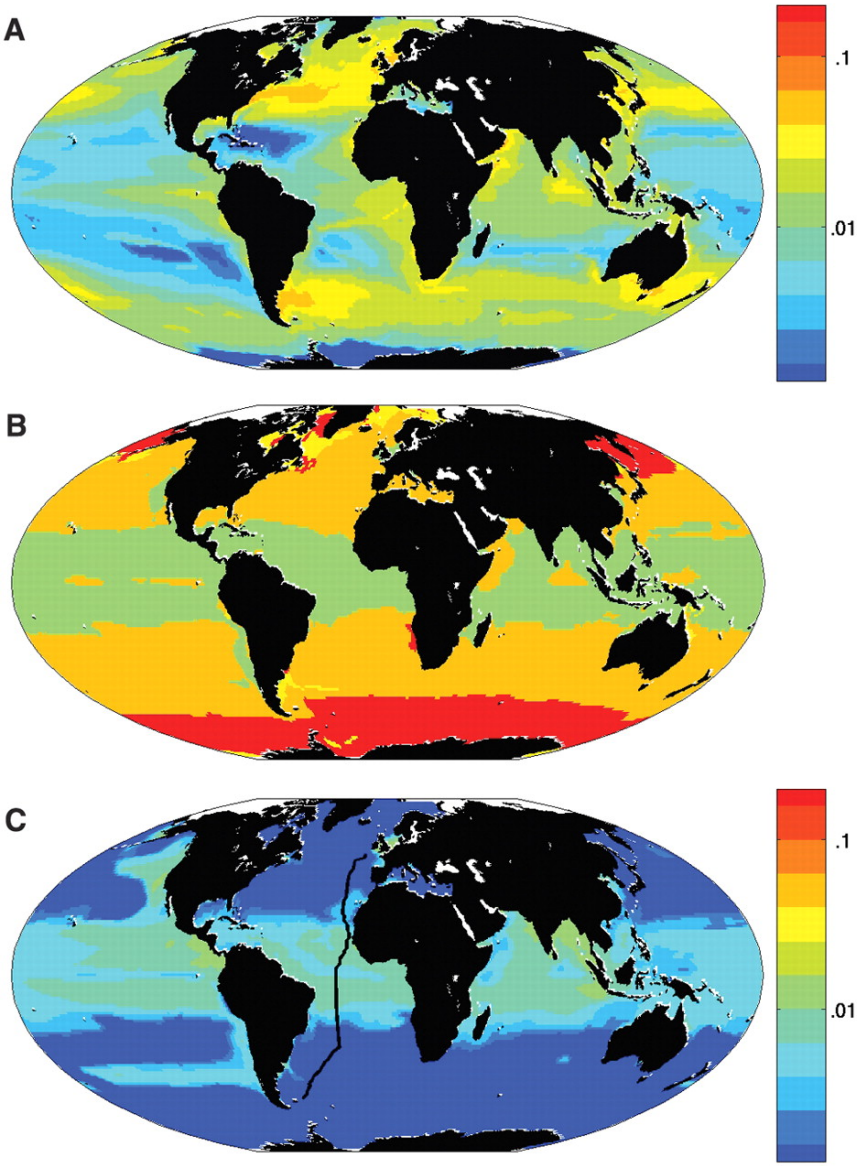

A trait-based approach to modeling marine plankton

Follows et al. (2007) *Science*

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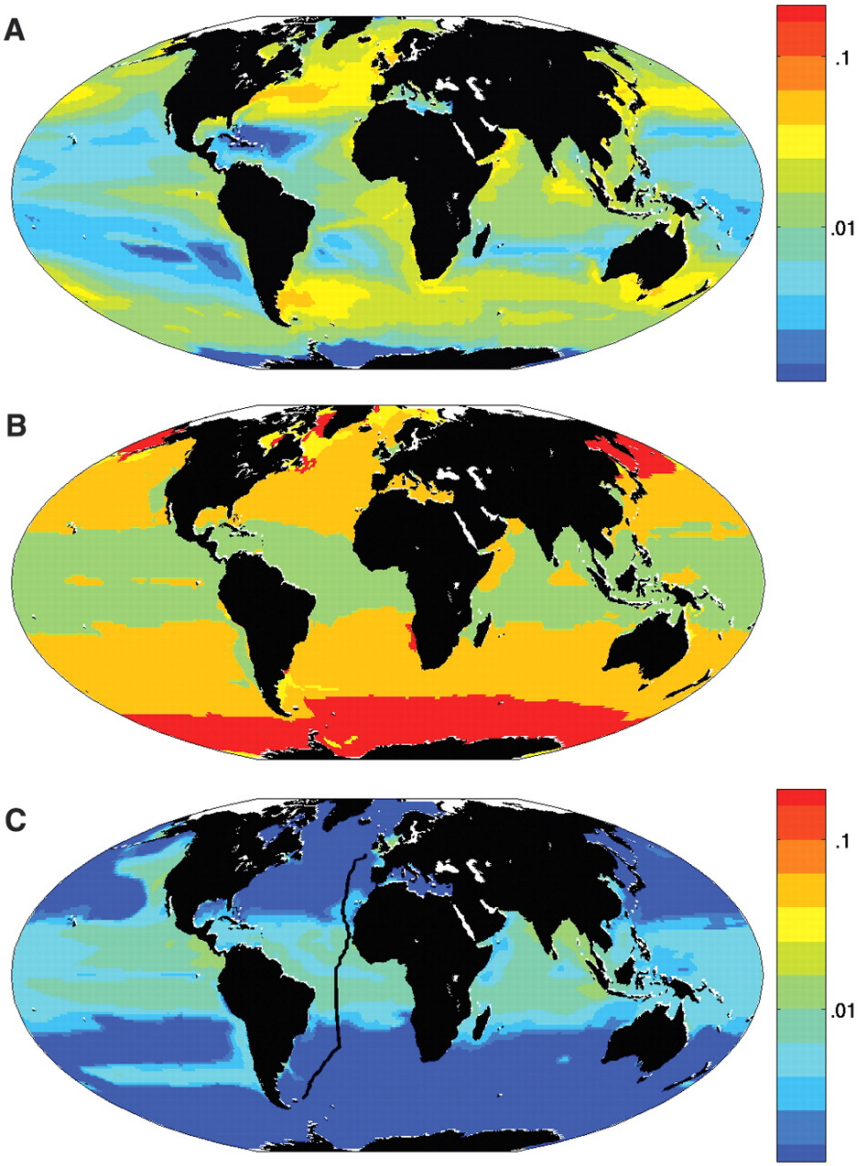

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- size
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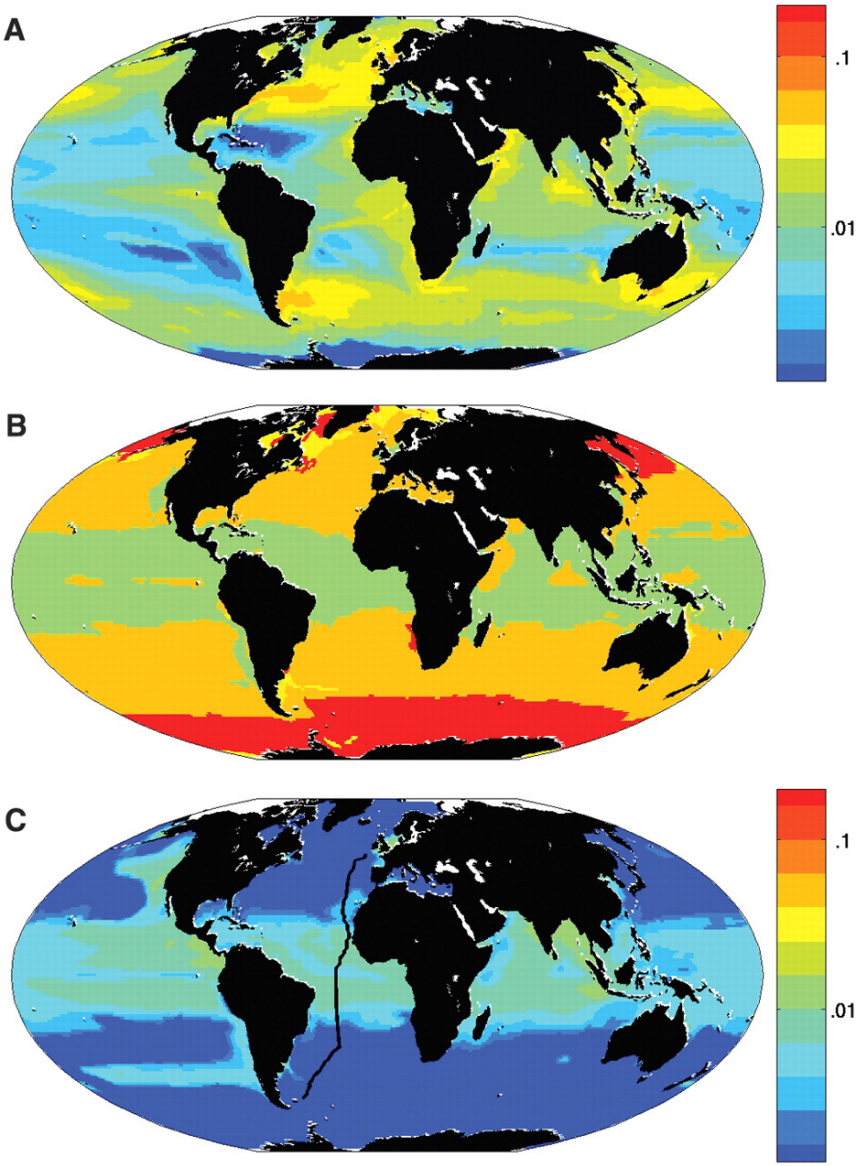

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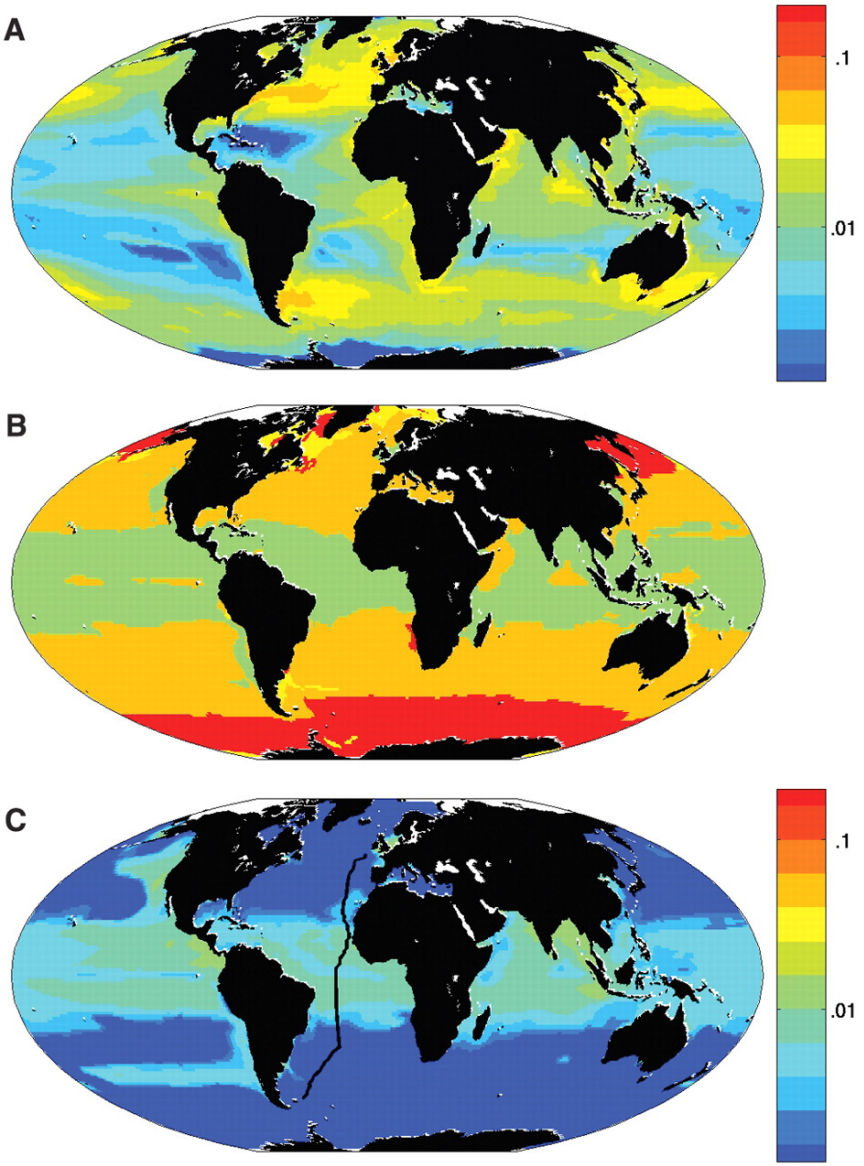

A trait-based approach to modeling marine plankton

- size
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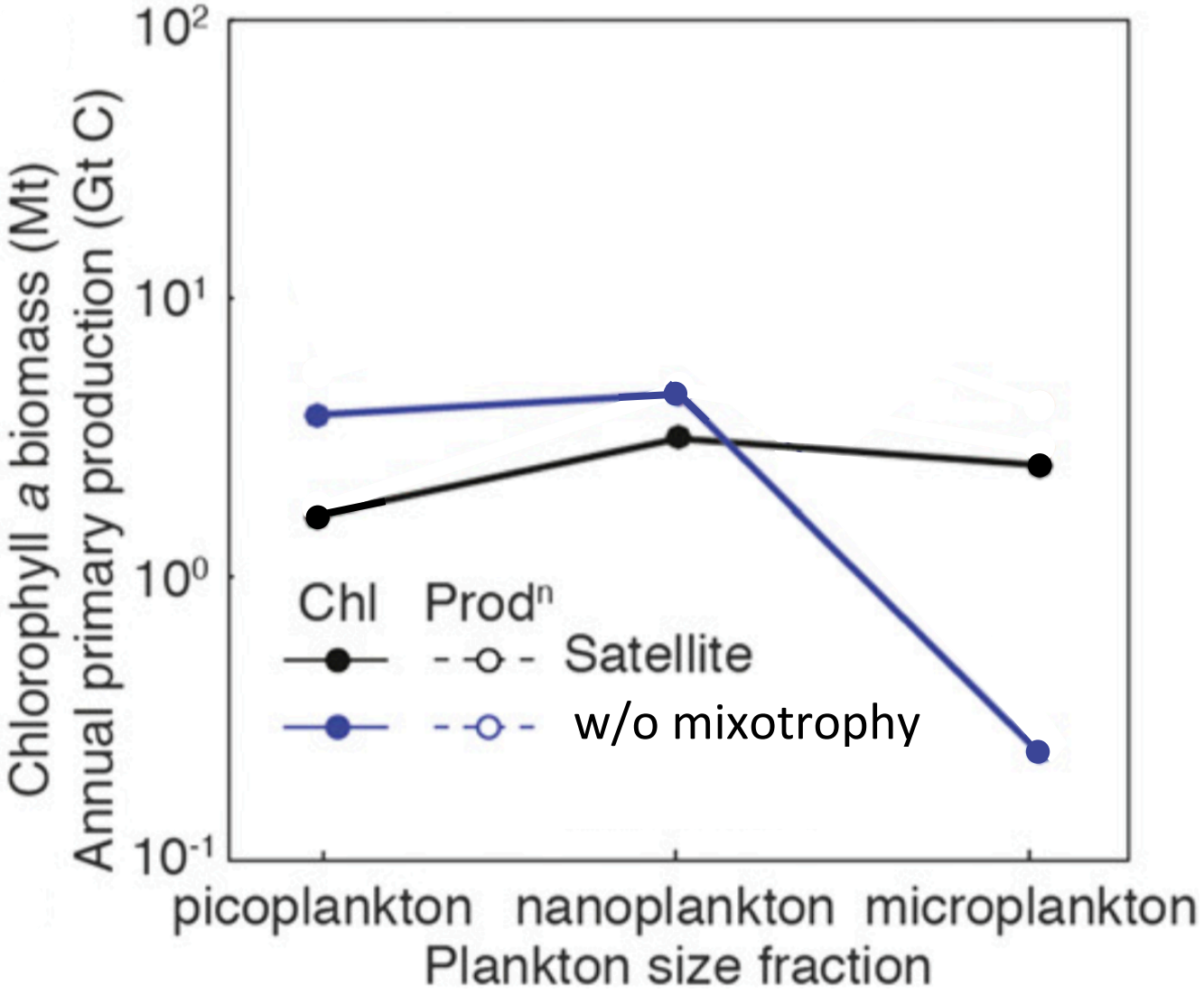
Seed with organisms randomly assigned traits

Observe emergent patterns

Follows et al. (2007) *Science*

Allowing for mixotrophy increases mean particle size



Ward and Follows (2016) *PNAS*

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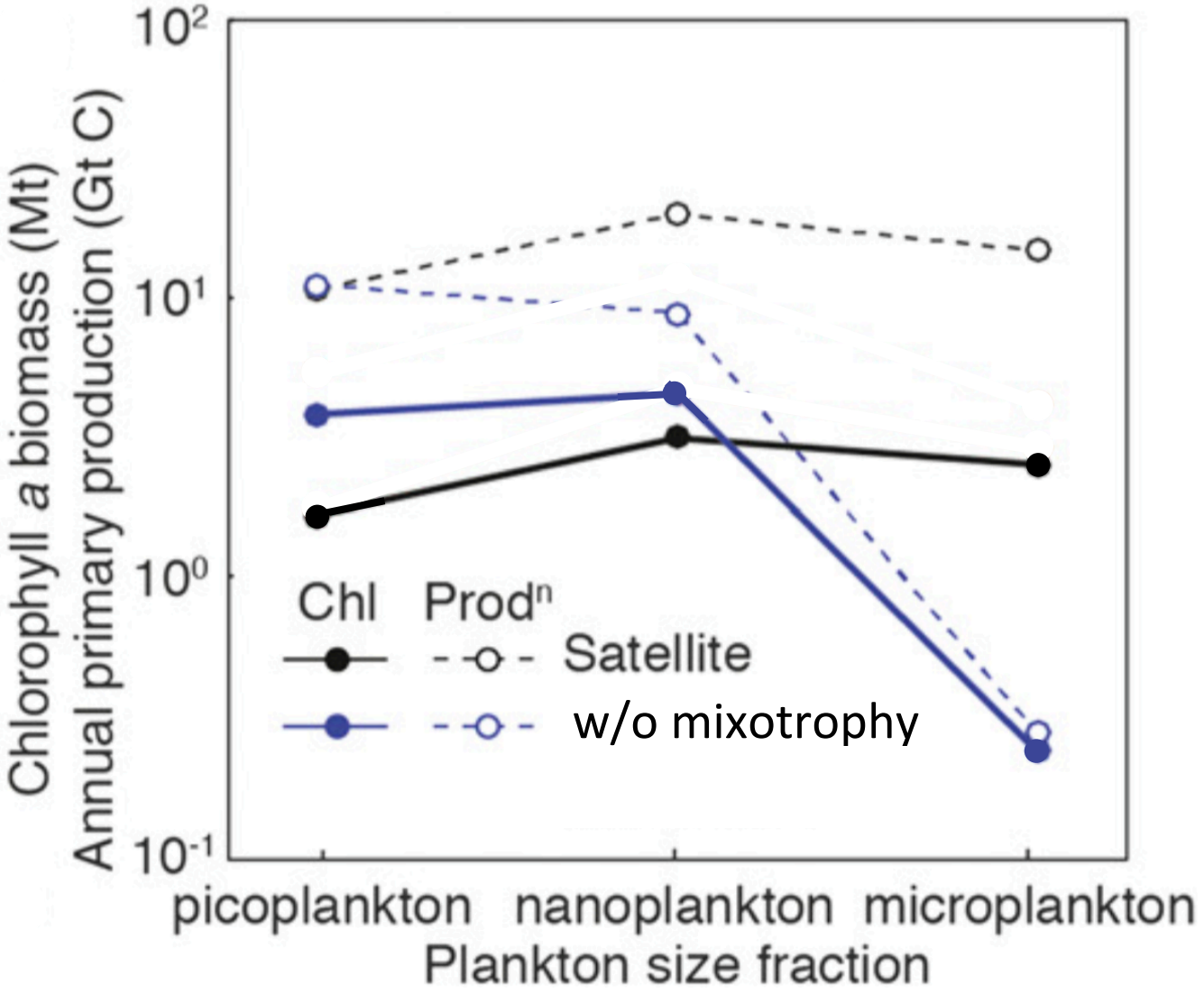

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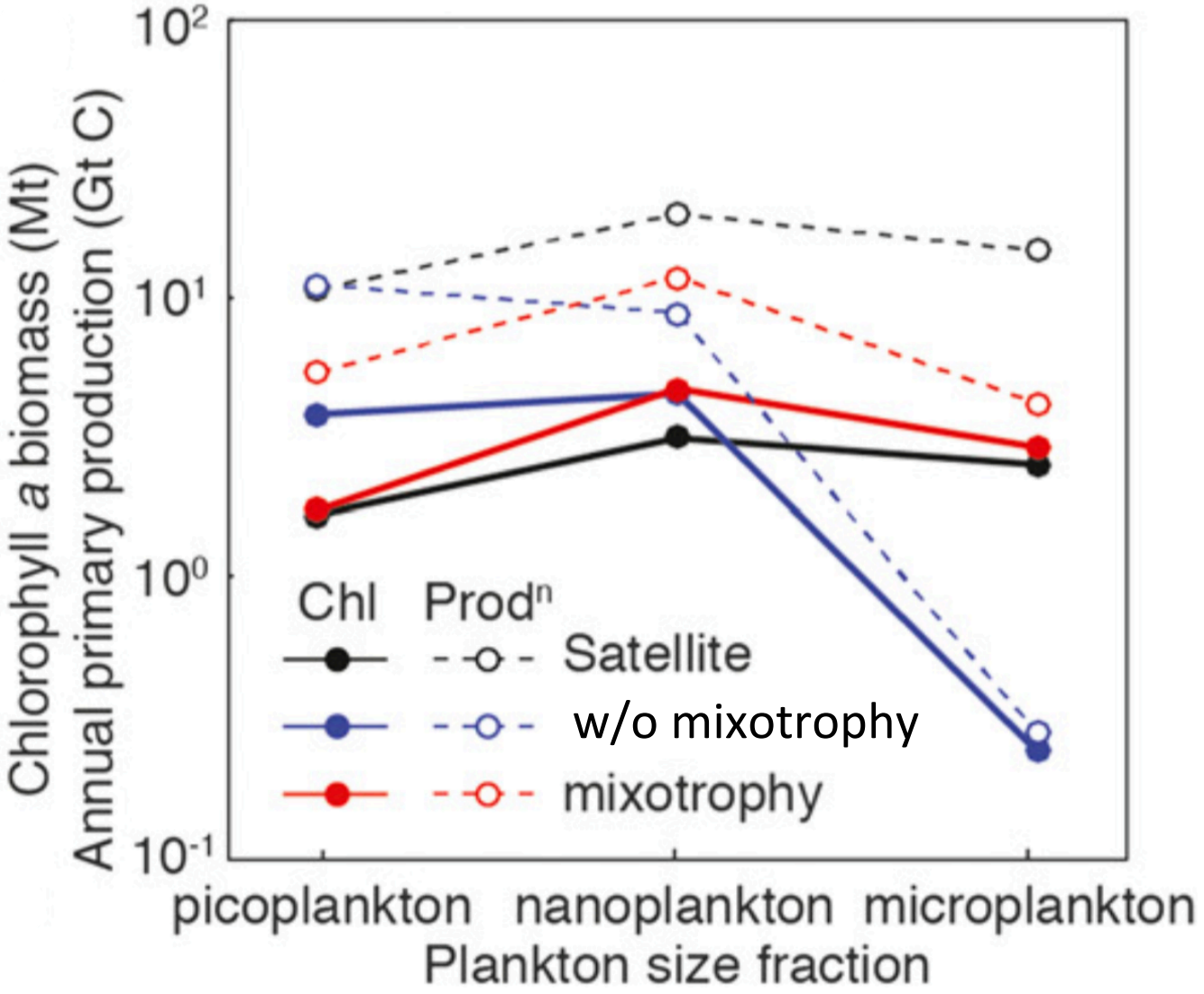

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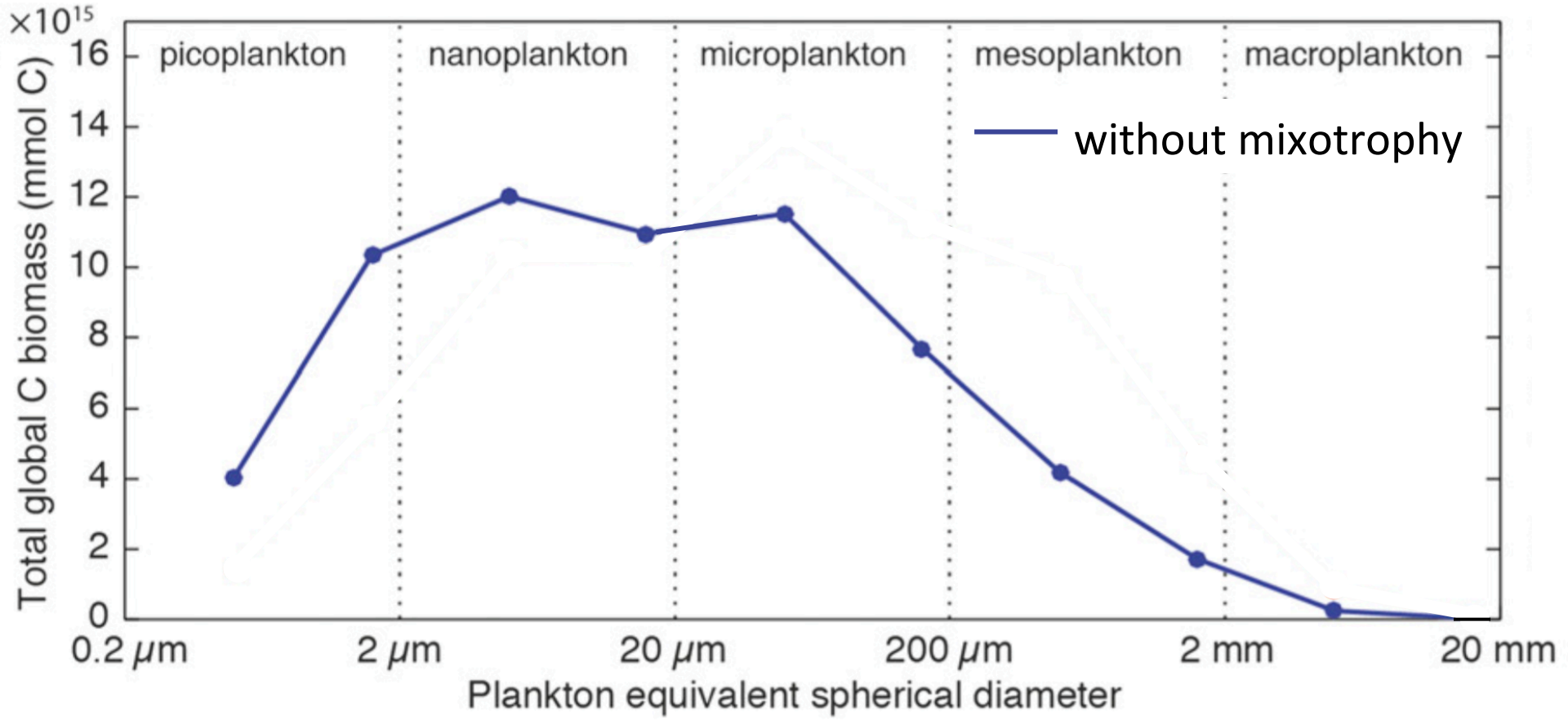

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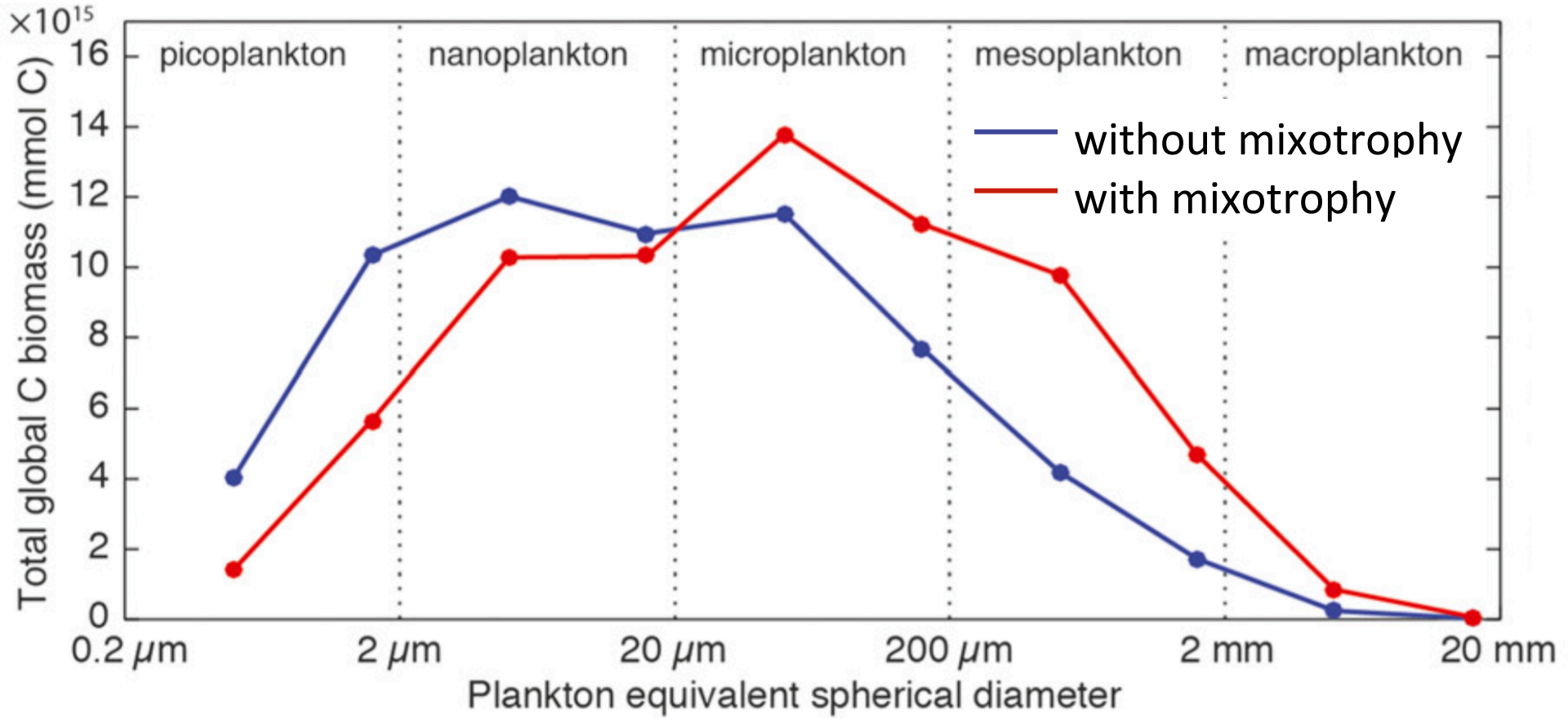

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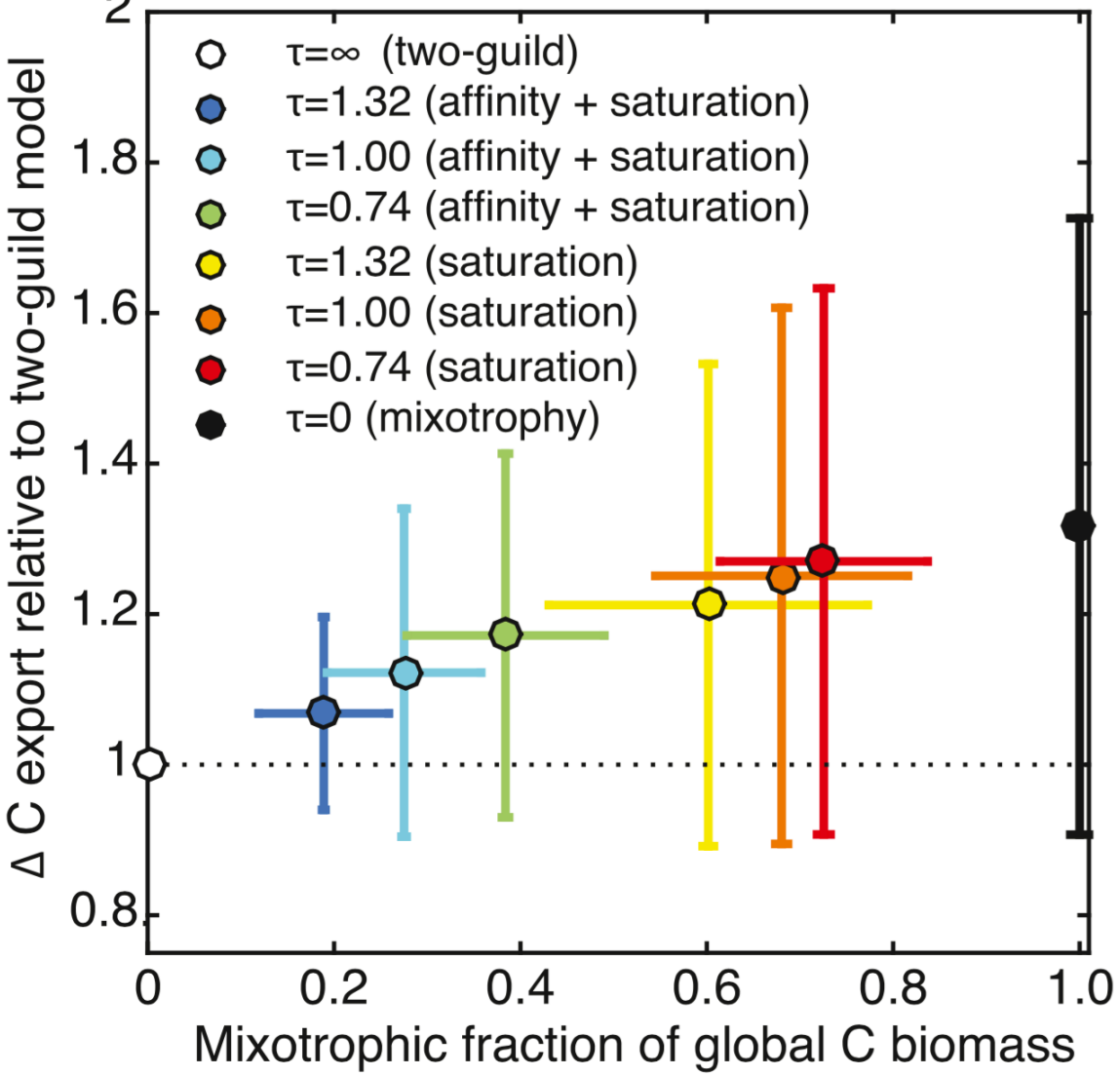
Allowing for mixotrophy increases mean particle size, increasing C export



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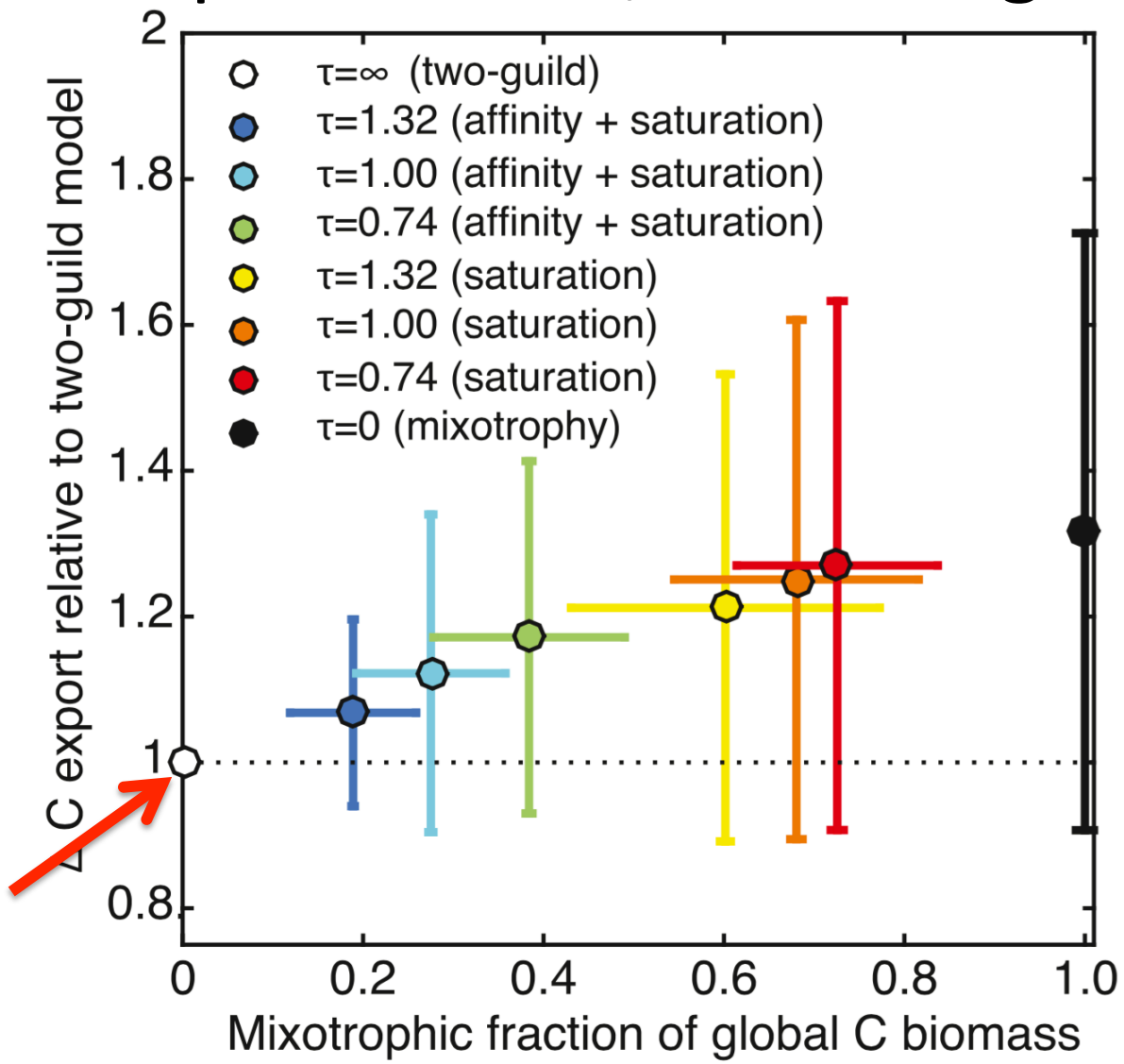

without mixotrophy

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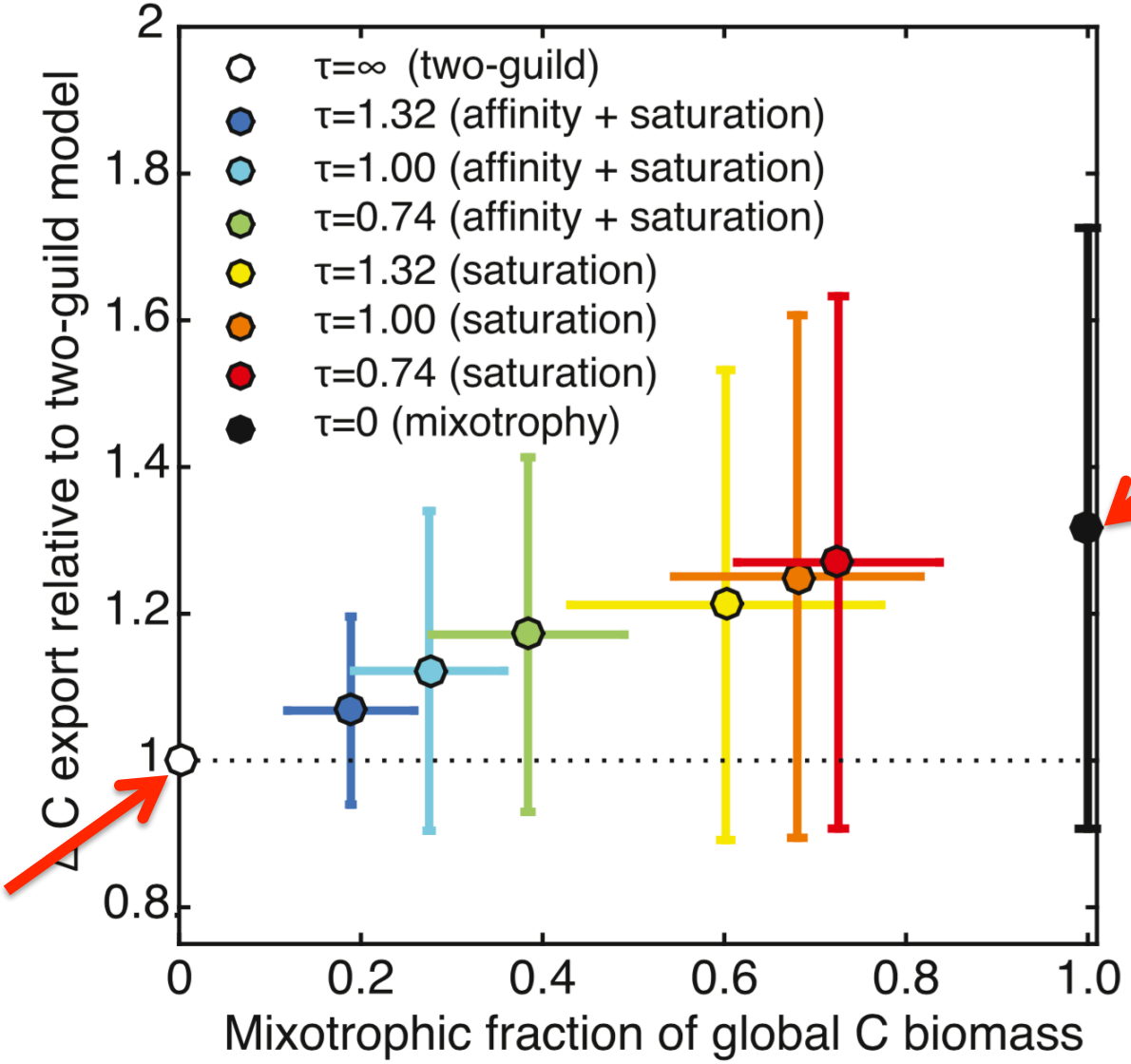

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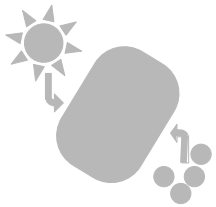

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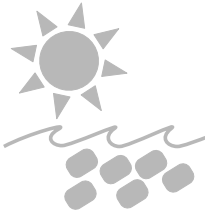
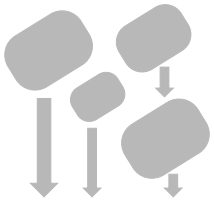
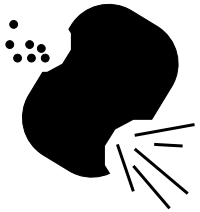


How mixotrophs modulate primary productivity



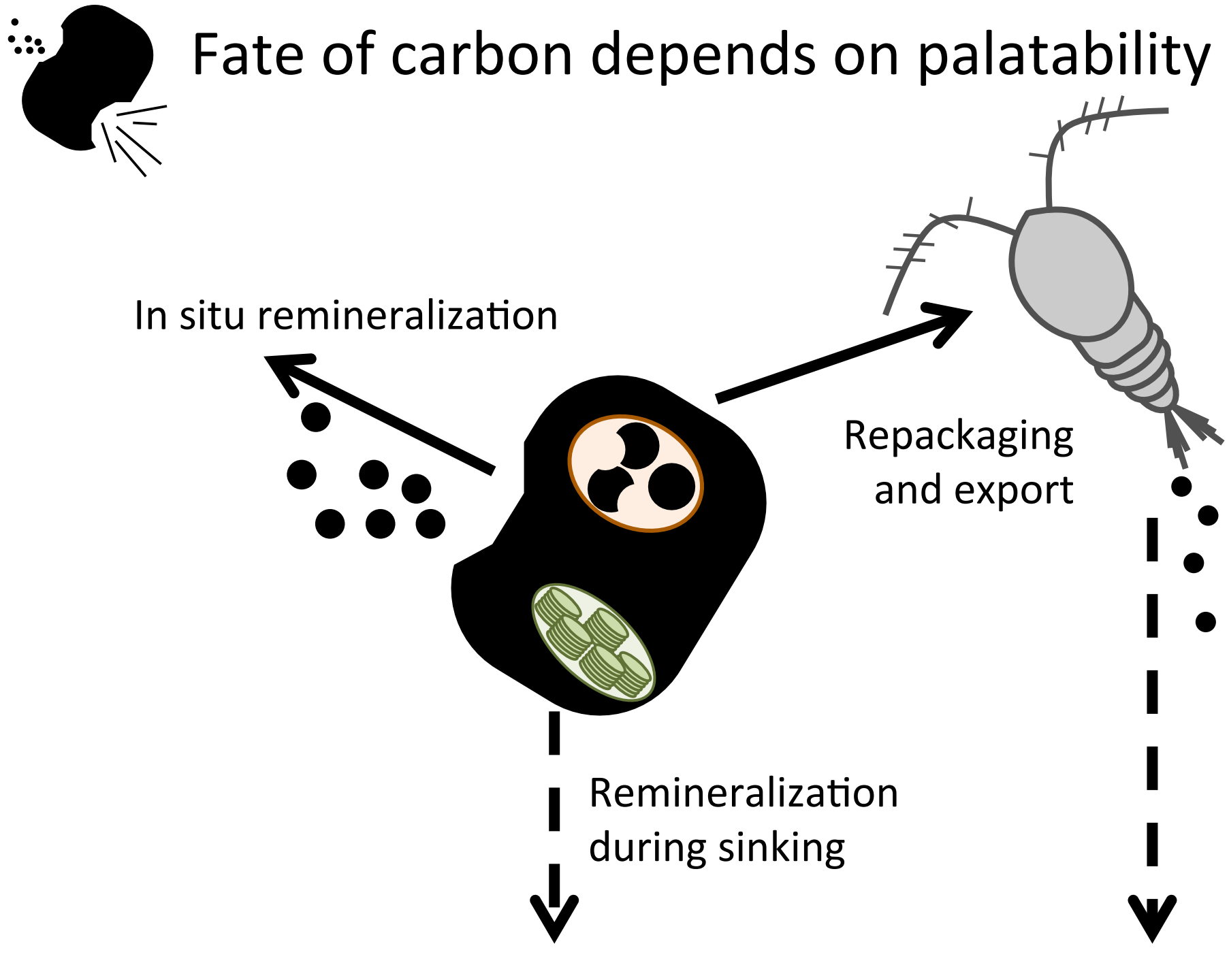
How mixotrophs modulate particle flux



How mixotrophs modulate remineralization rates

Where and when should mixotrophs matter?

Fate of carbon depends on palatability



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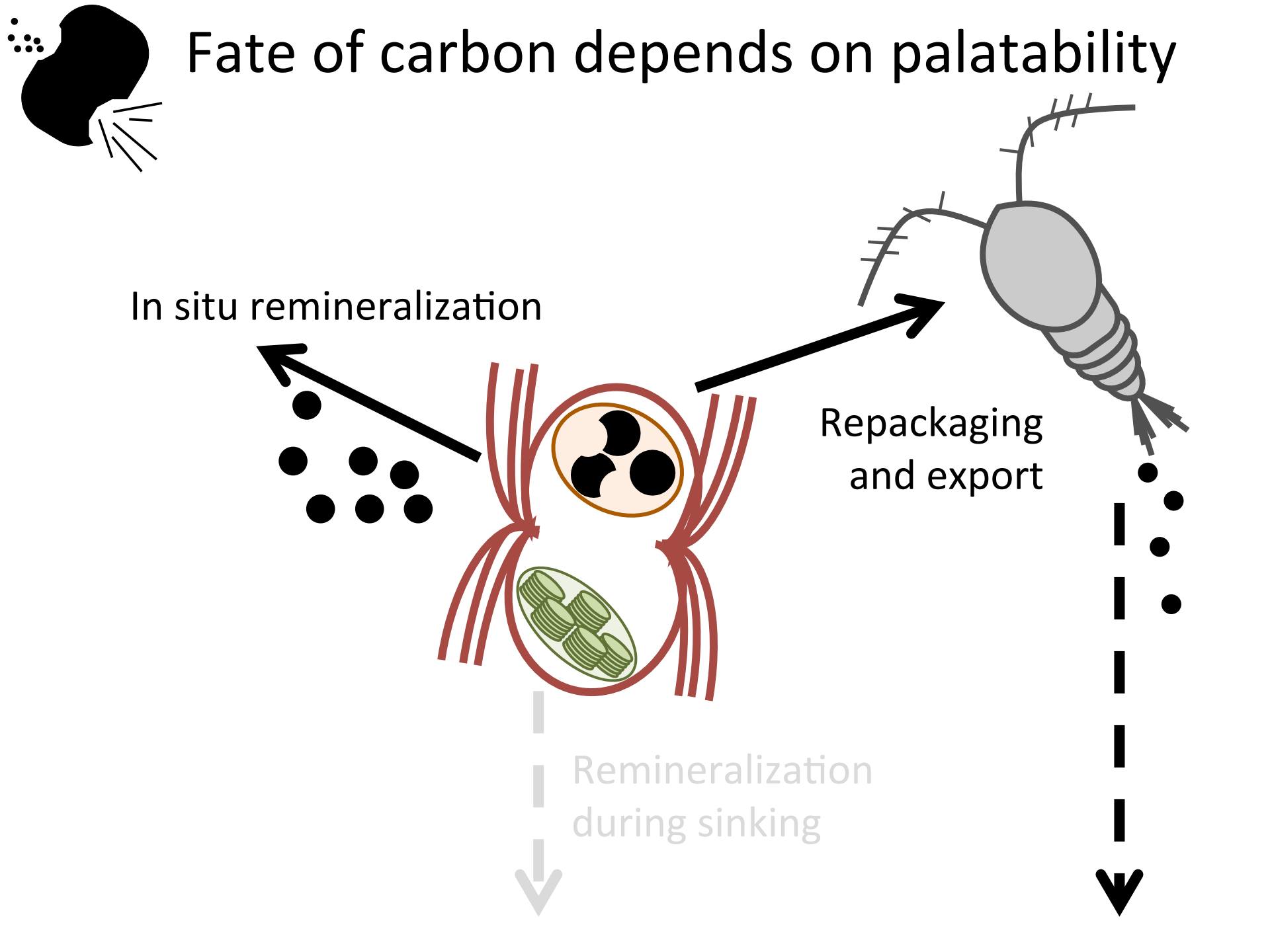

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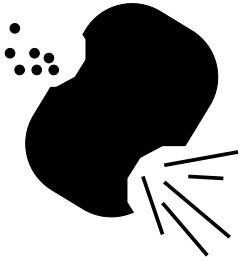

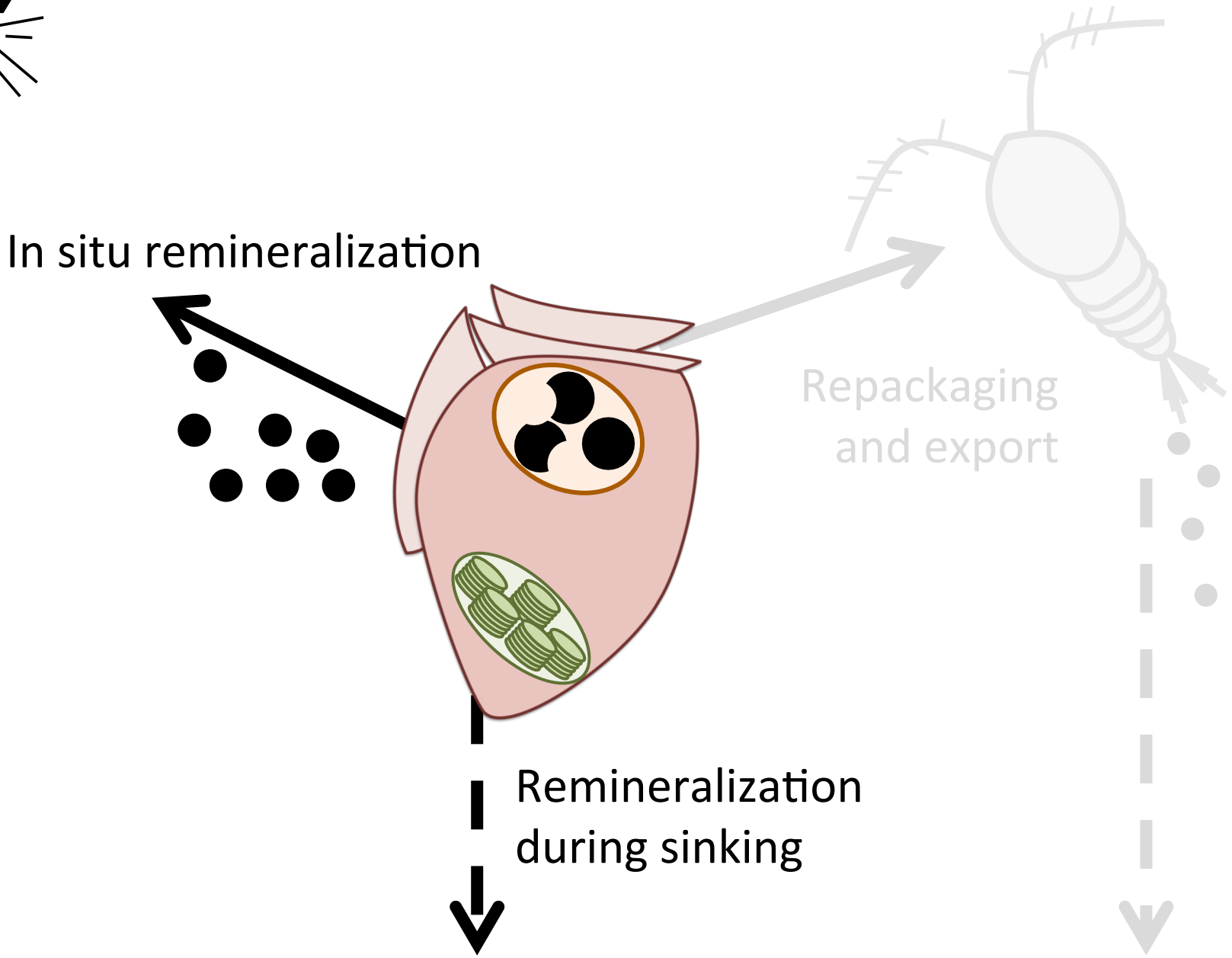

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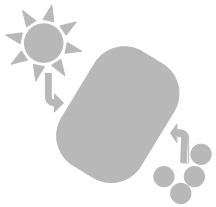

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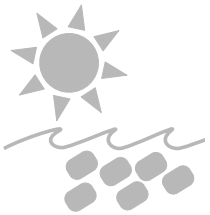

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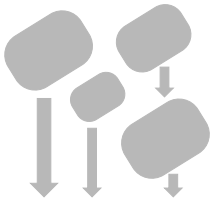

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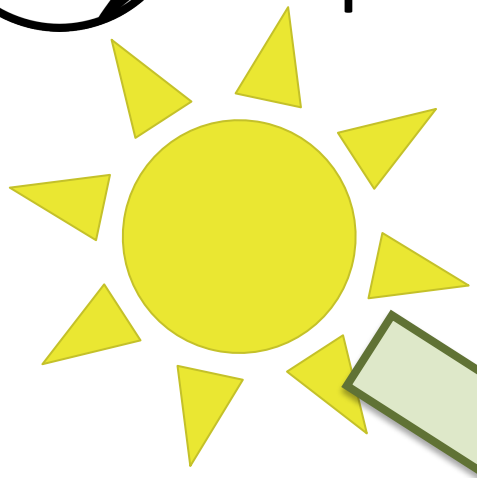
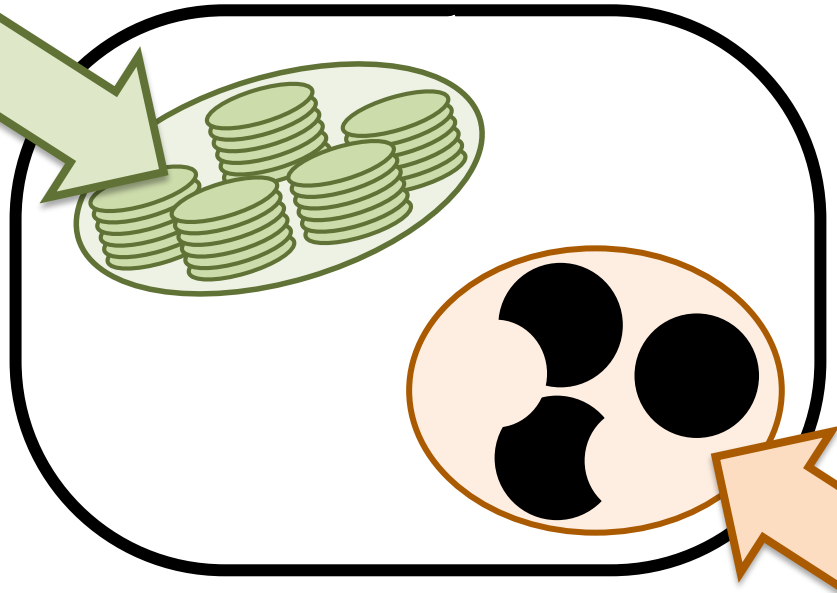
Where and when should mixotrophs matter?

The mixotroph advantage: Should these "superbugs" be universally dominant?



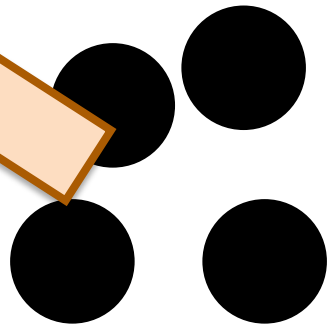
Photosynthesis

Carbon source when prey is limiting



Nutrient source when nutrients are limiting

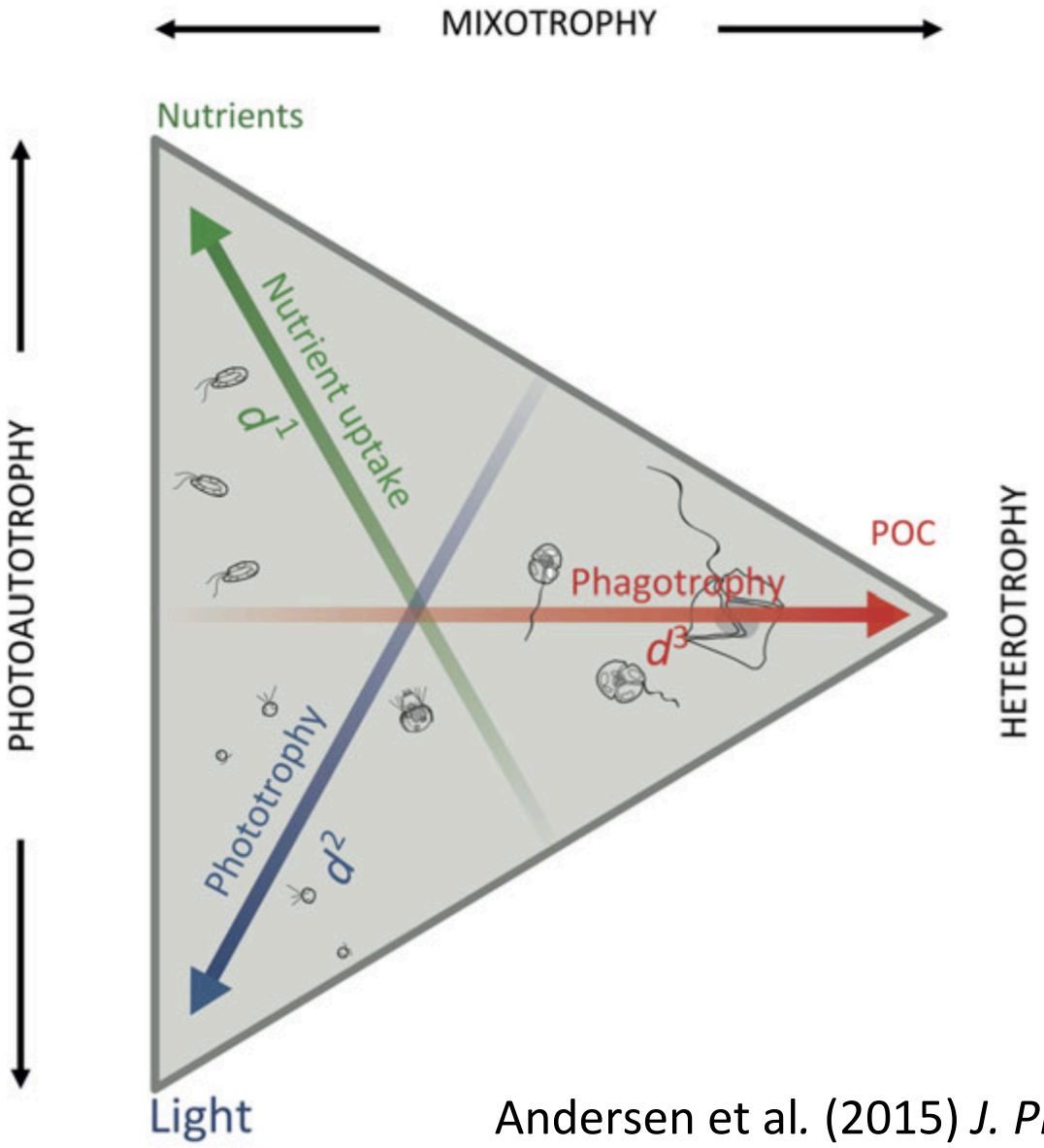
Grazing



Tittel et al. (2003) *PNAS*

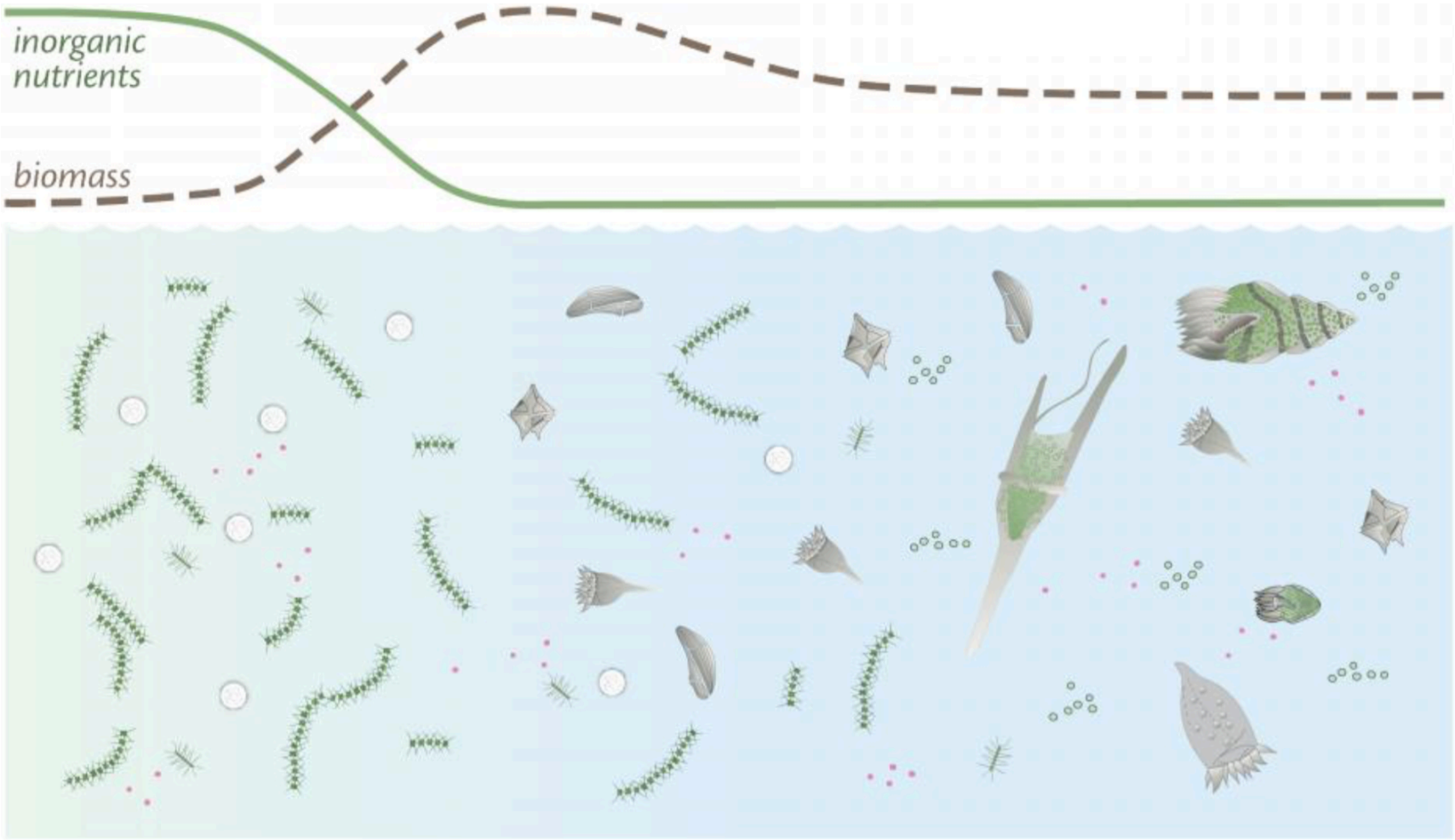
Flynn & Mitra (2009) *J. Plankton Research*

Key: Quantifying tradeoffs in resource acquisition strategies



Andersen et al. (2015) *J. Plankton Research*

Mixotrophs have an advantage in low-nutrient, “mature” regimes



Mitra et al. (2014) *Biogeosciences*

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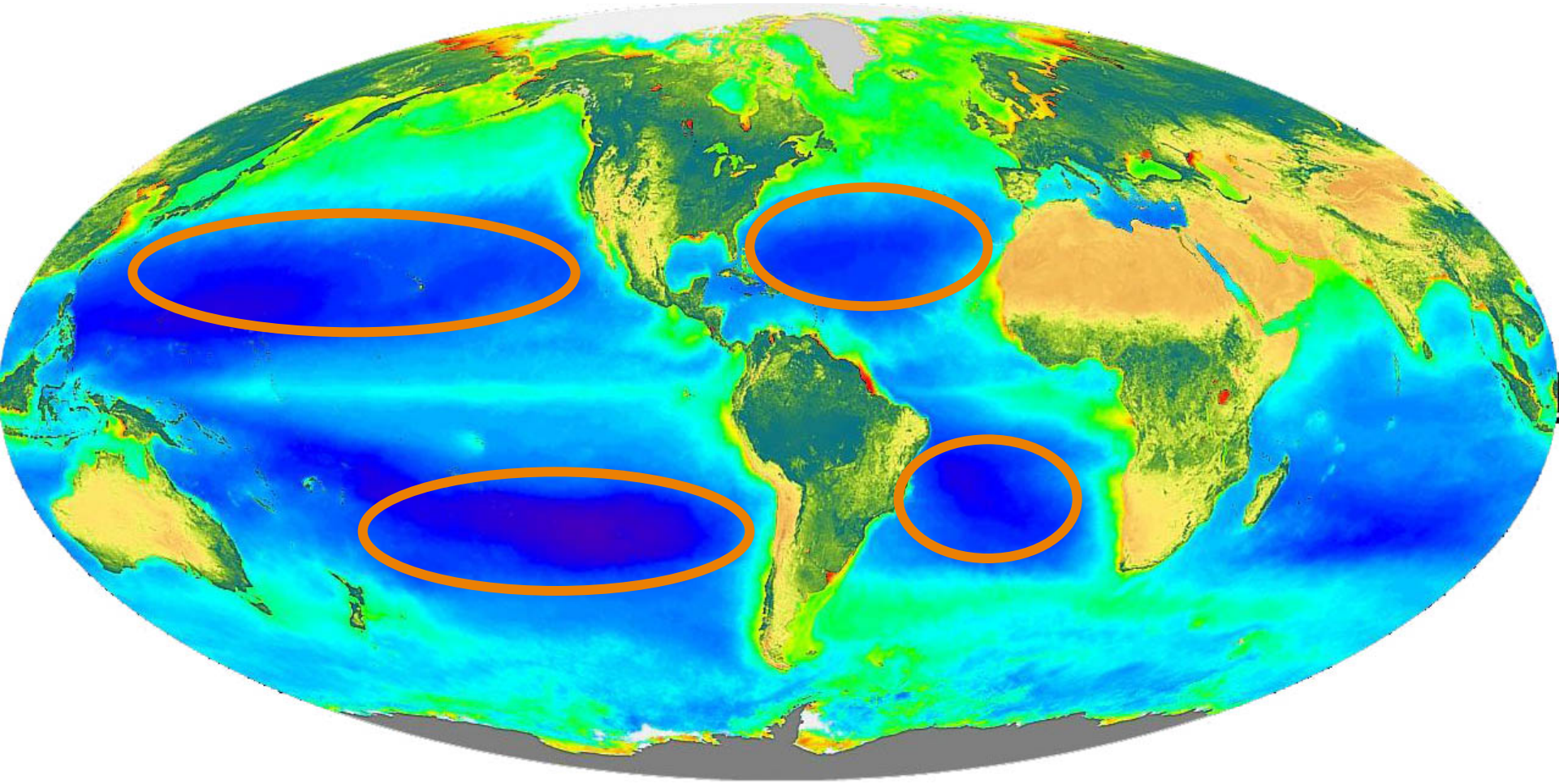

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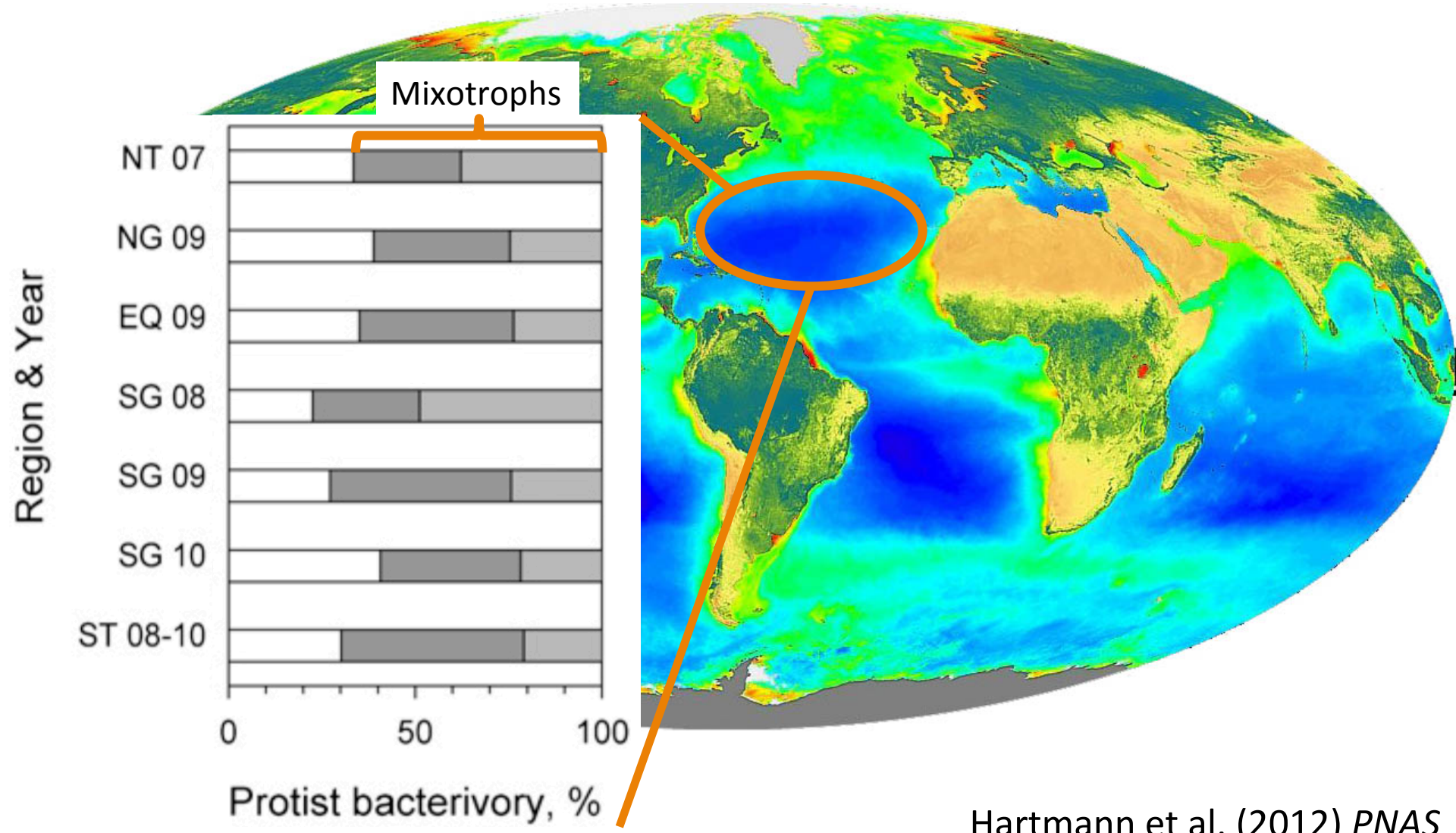

Hartmann et al. (2012) *PNAS*

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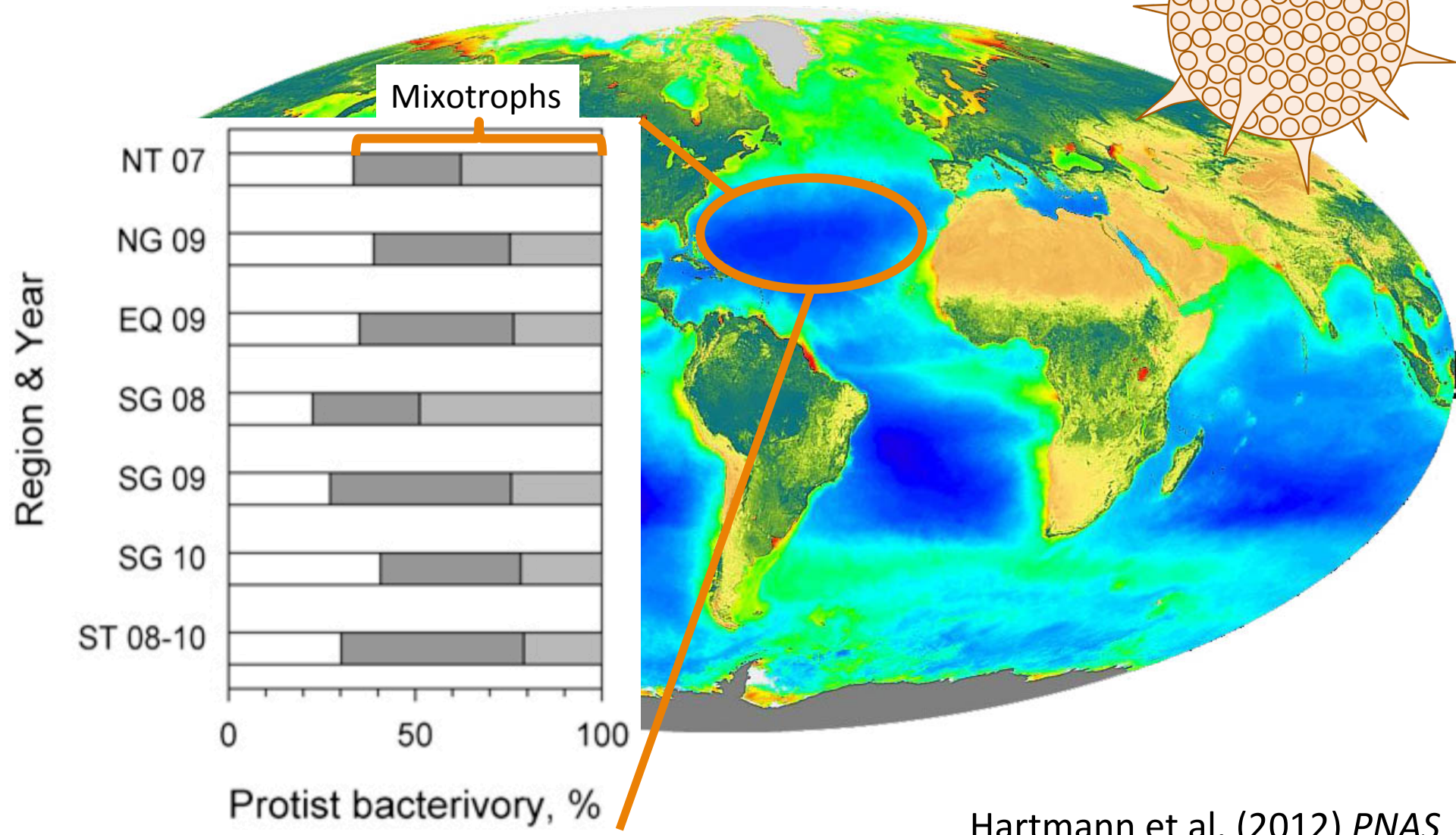

Hartmann et al. (2012) *PNAS*

Oligotrophic gyres are also expanding and warming

Polovina et al. (2008) *Geophys. Res. Lett.*

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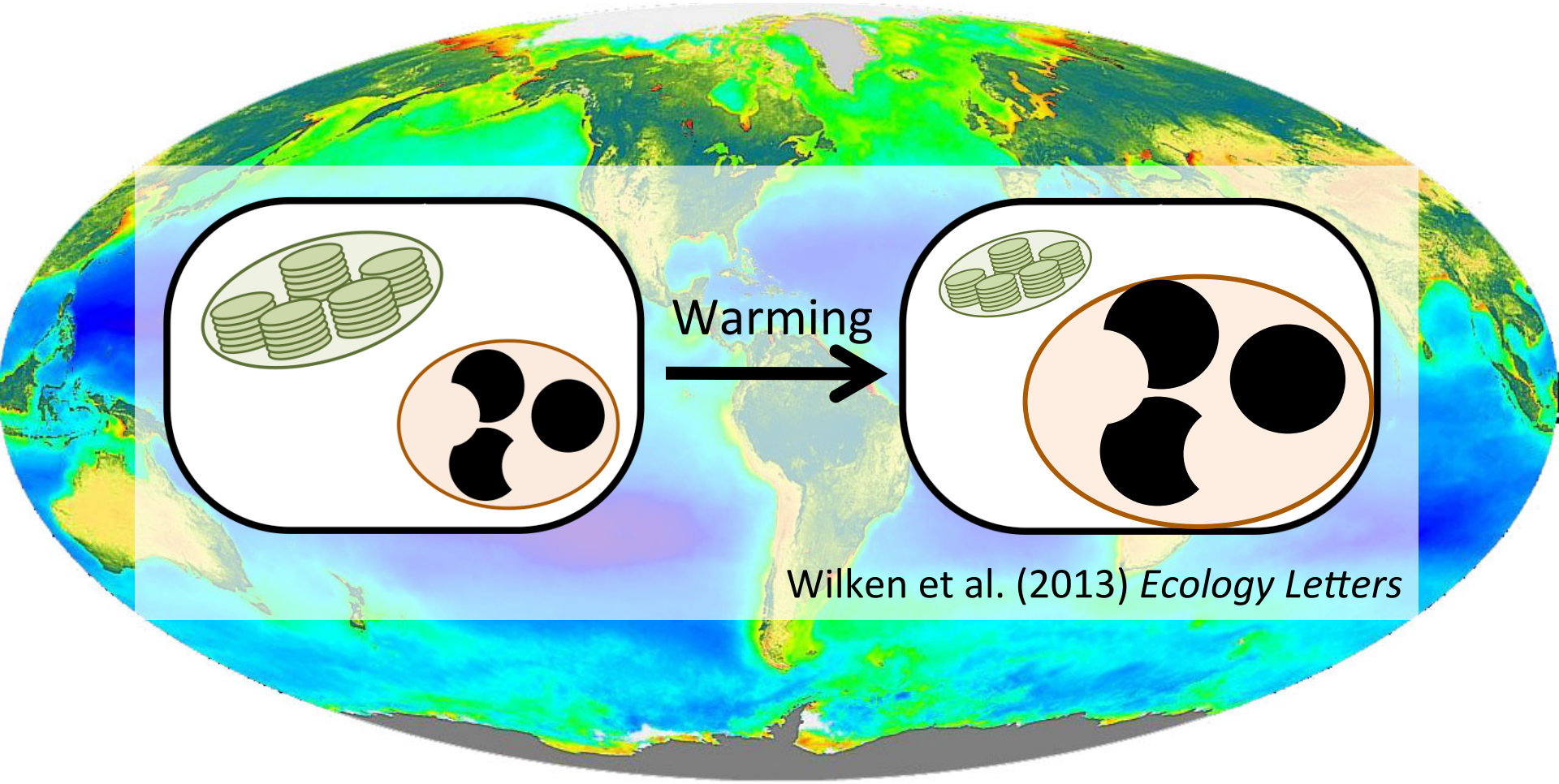

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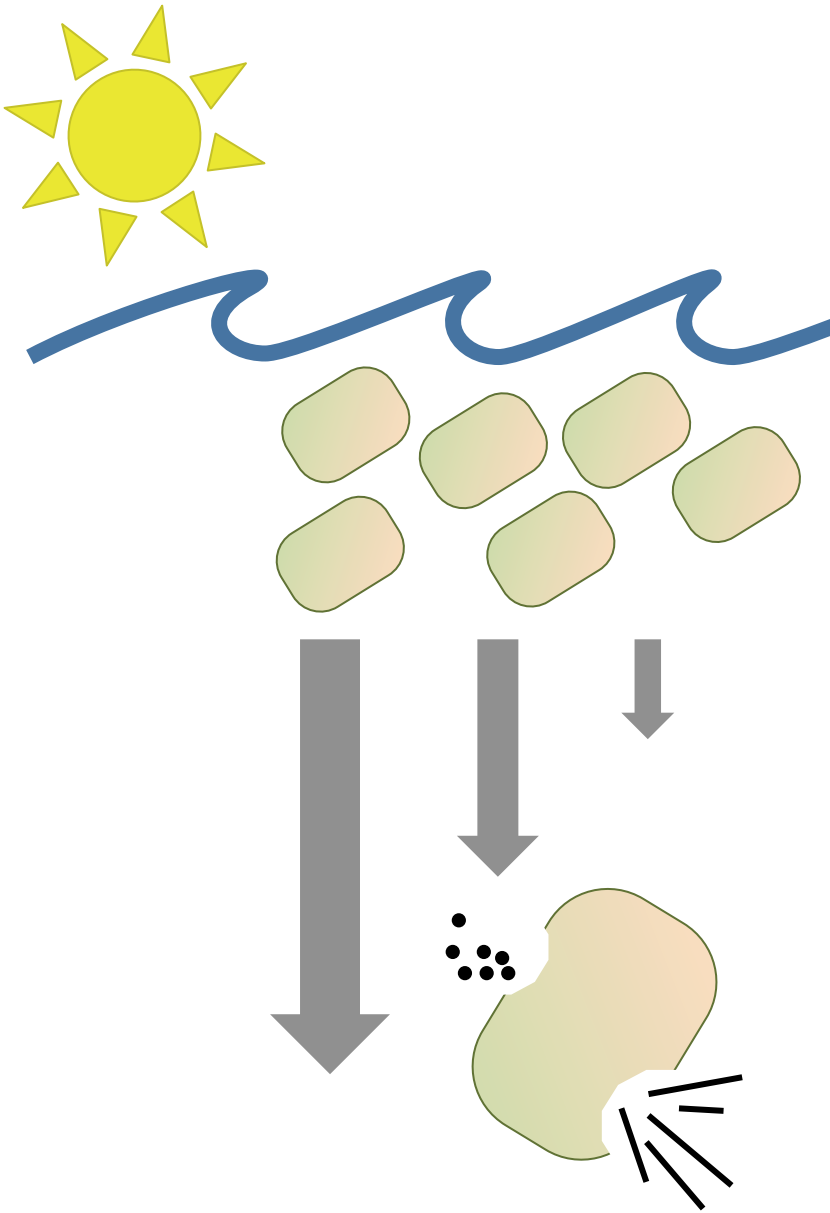
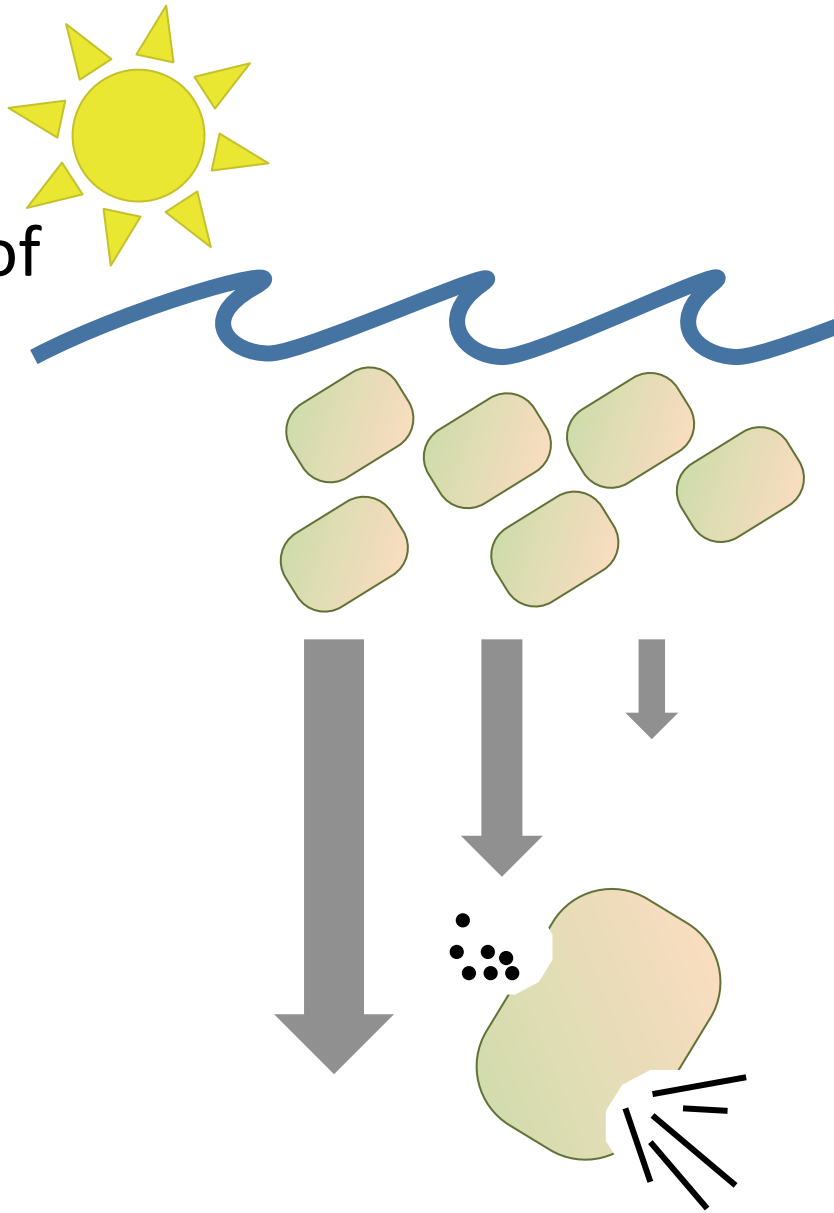
Moving forward with mixotrophy



holly@whoi.edu

Moving forward with mixotrophy

1. Mixotrophy affects the amount of primary production



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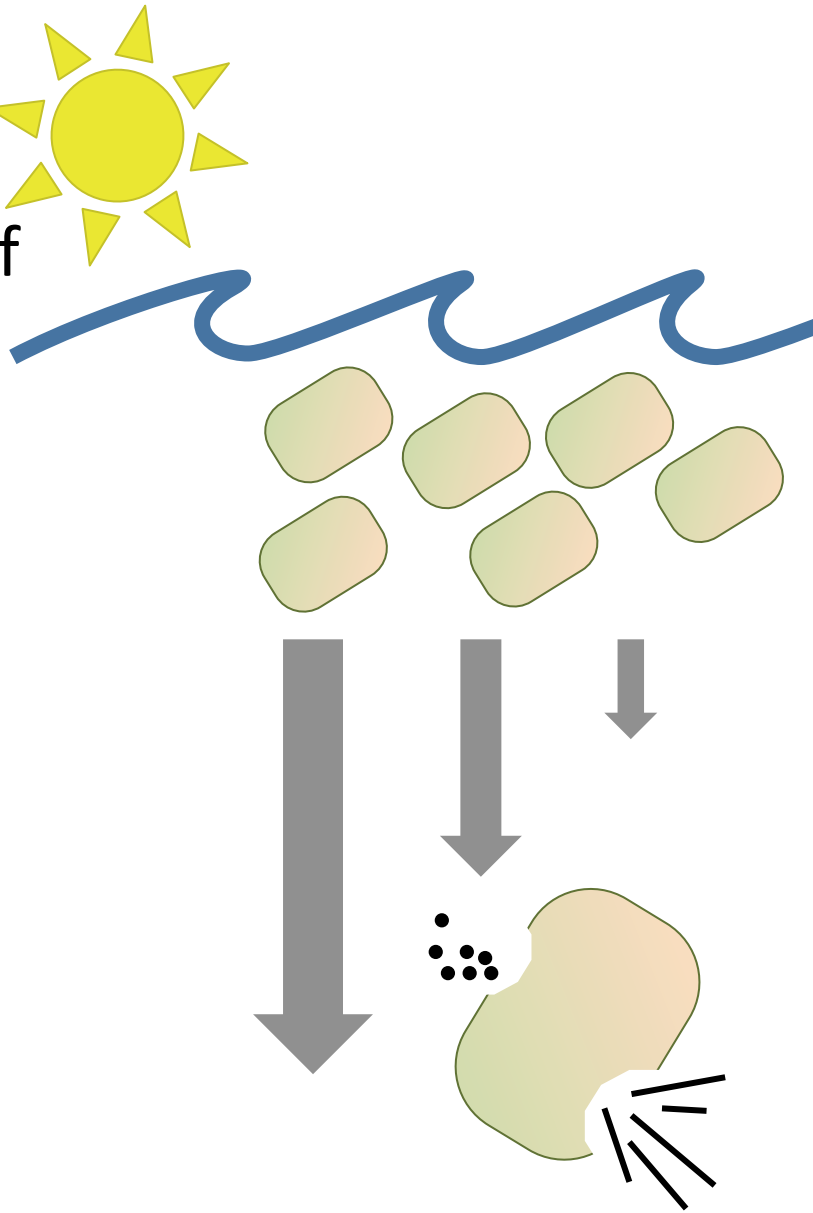
    - Allows extra carbon fixation



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Moving forward with mixotrophy

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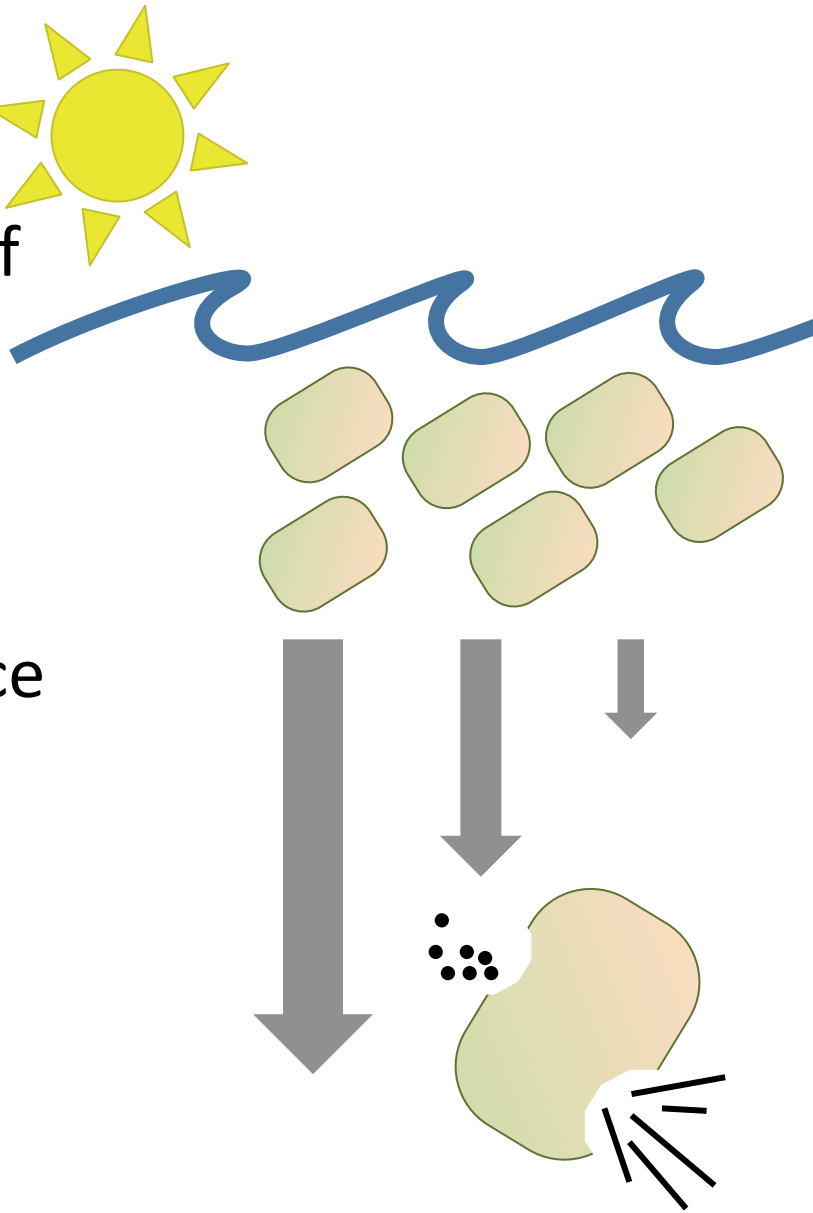
    - Provides a “short-circuit” in remineralization at the surface



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Moving forward with mixotrophy

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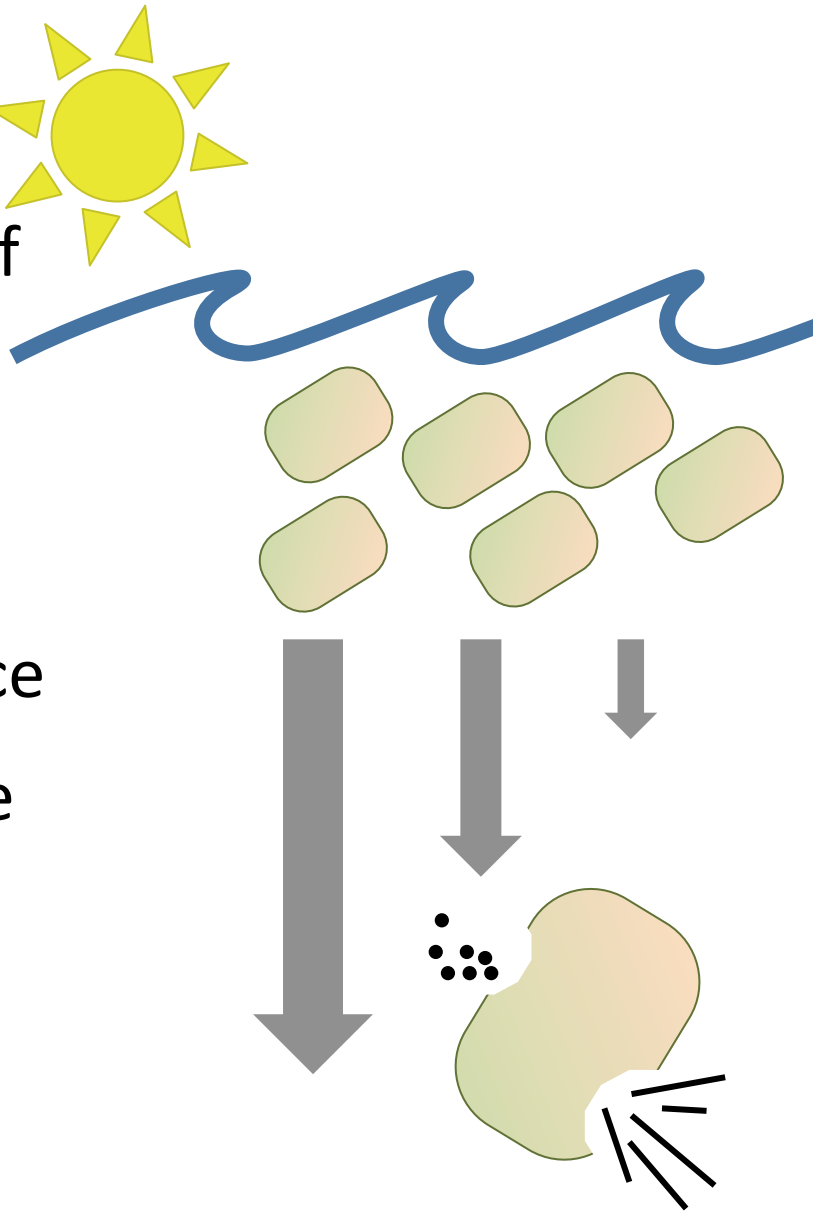
2. Density and palatability affect the fate of this organic C



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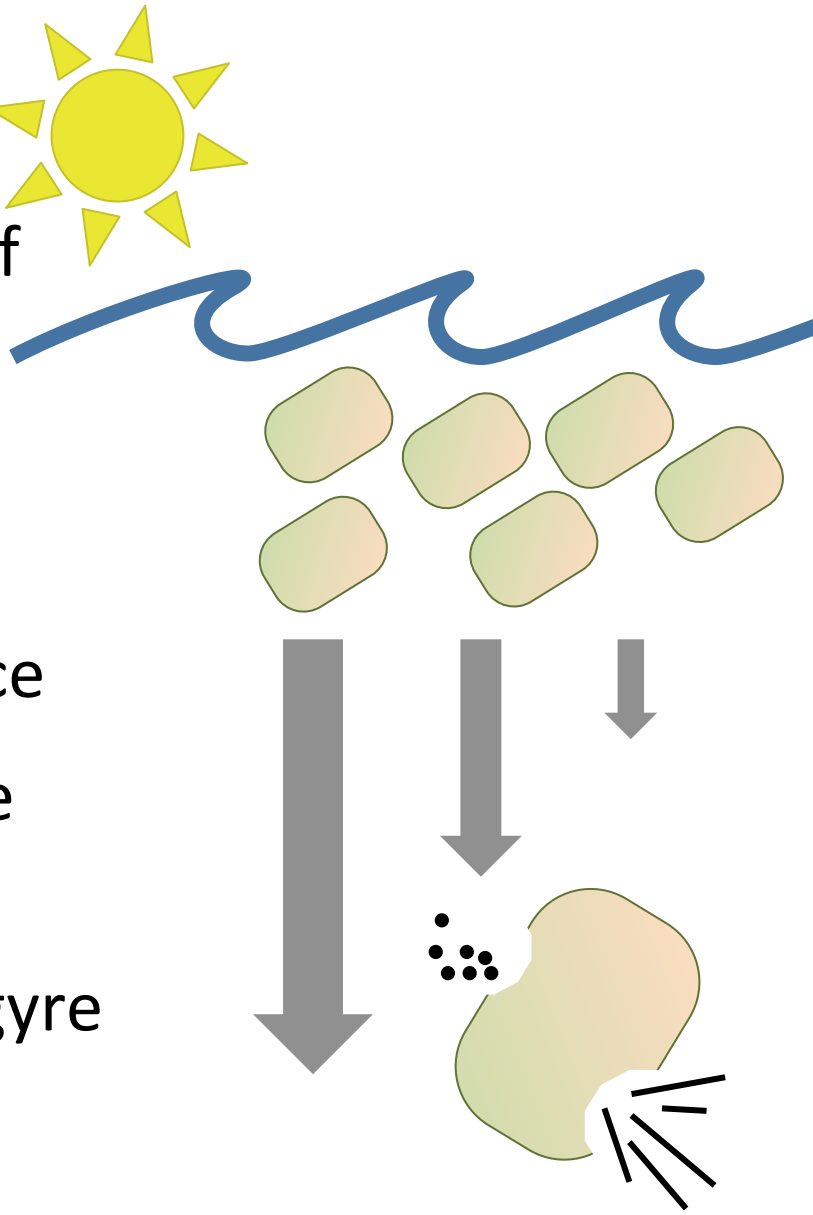
3. Focused studies on oligotrophic gyre communities can provide climatically relevant insight



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