Correlation between organism size and trophic strategies

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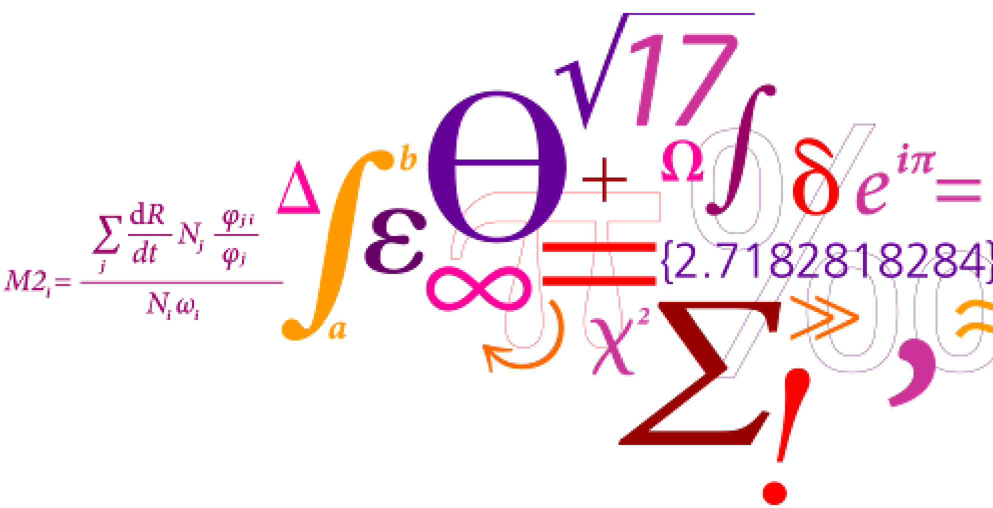

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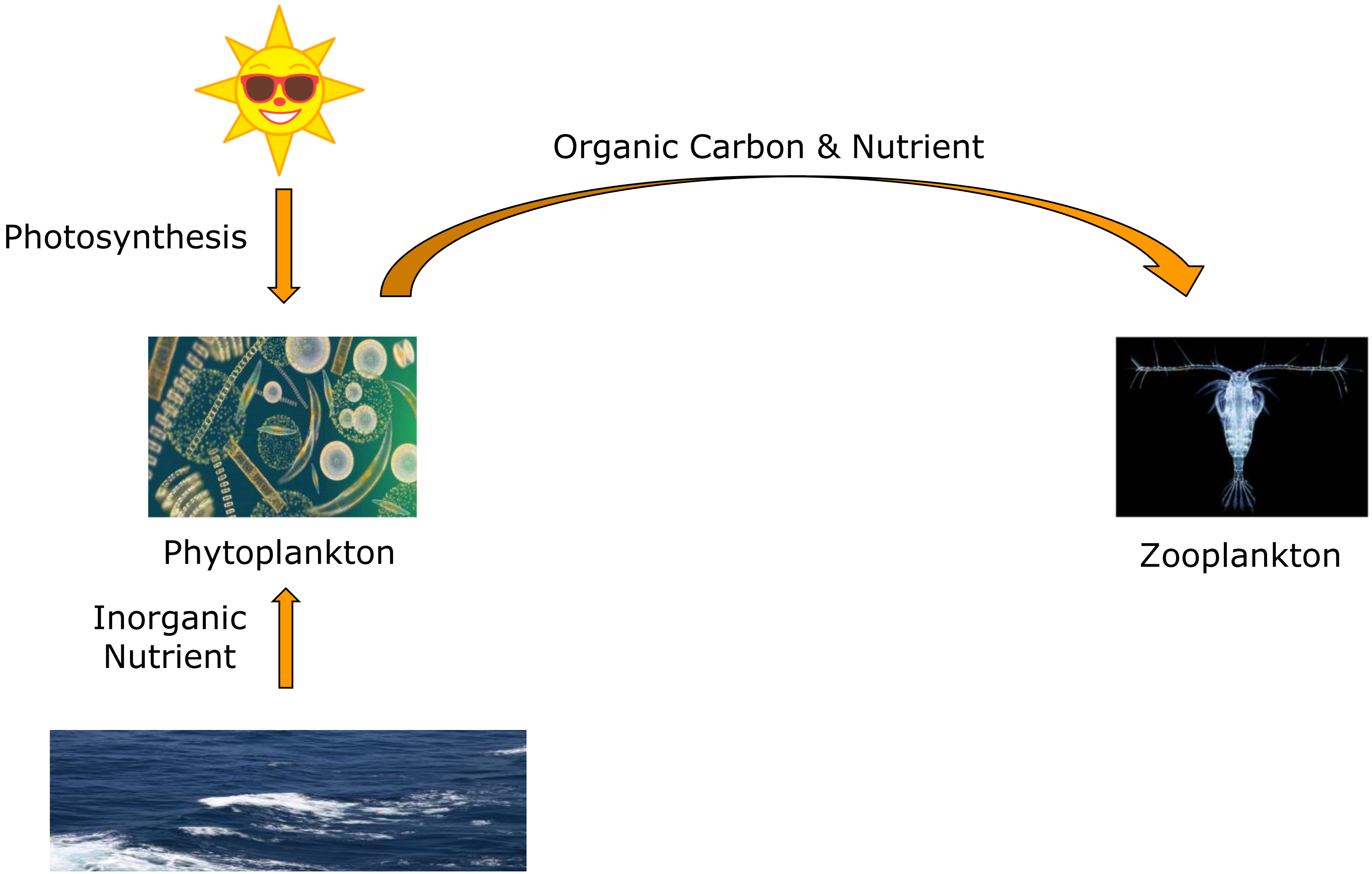
Broad classification:



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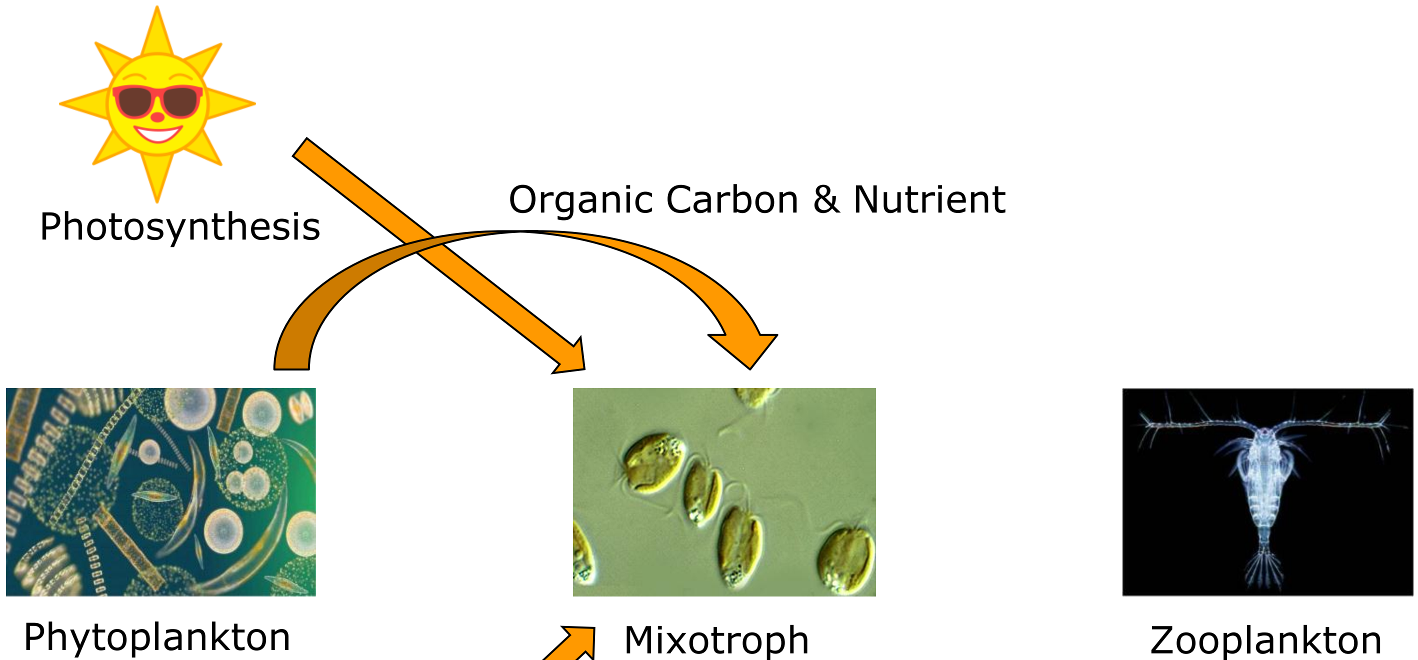
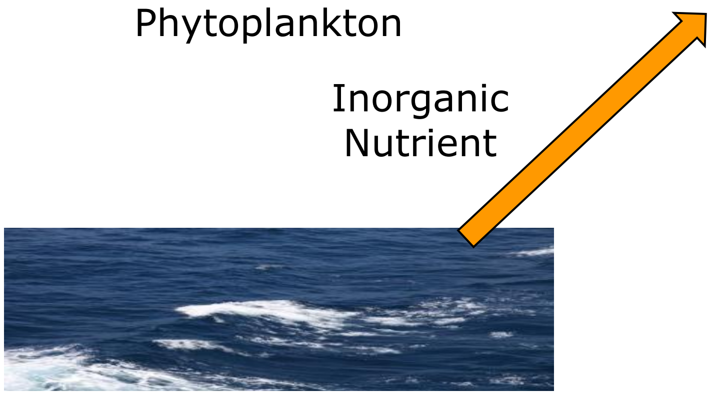
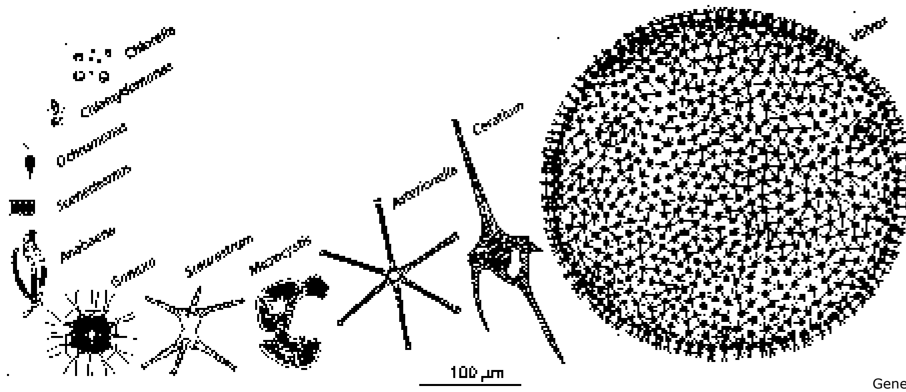




What is/are the factors that determine the trophic strategy of plankton?

Size of organisms



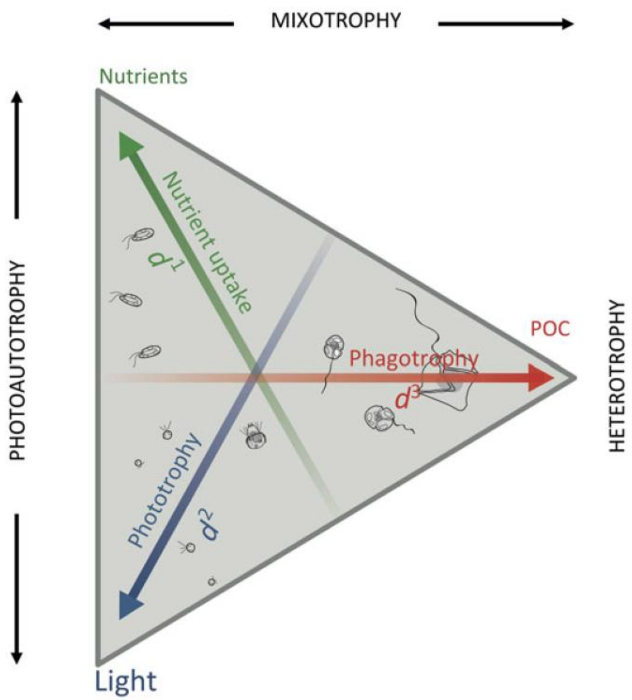
Gene A. Felice

Q1: How the size of an organism affects its trophic strategy?

Q2: How the trophic strategy of an organism of a specific size changes with environmental conditions?

Mathematical model for unicellular organisms

⇨ Trophic strategies are defined by the investments in three resource harvesting traits that leads to the highest growth rate



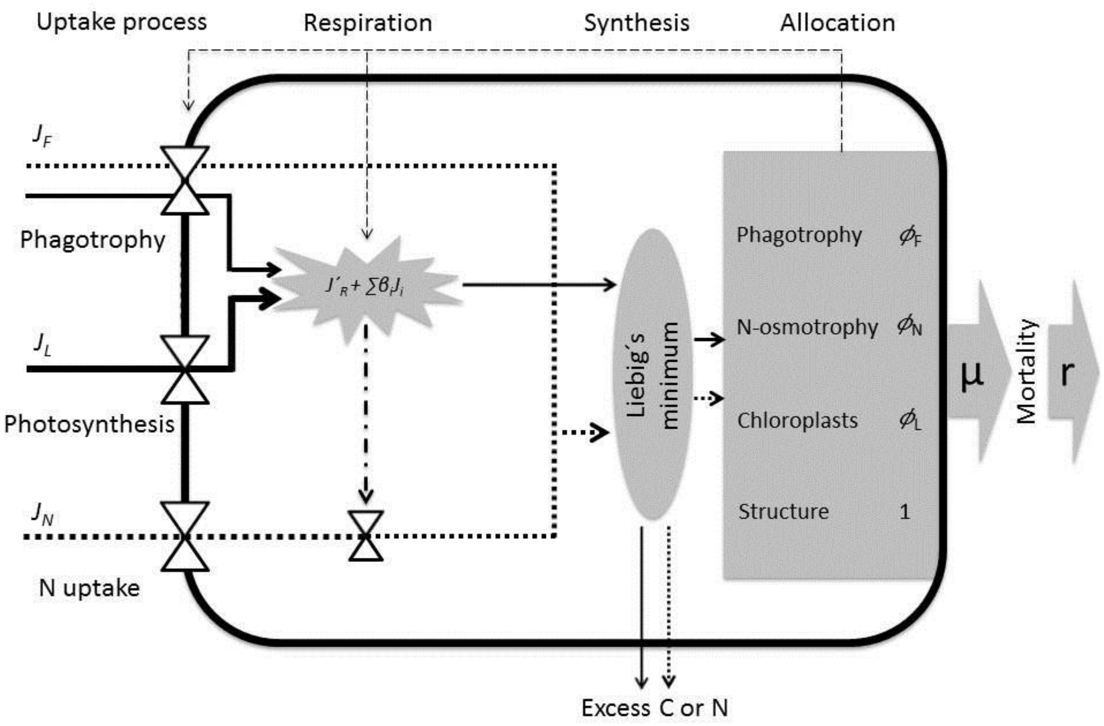
"A specific organisms' trophic strategy is defined as a point within the triangle."..............

Andersen et al. (J. Plank. Res, 2015)

Trade-offs :

1. Investments increase the costs of synthesis and maintanence of organells and structure
2. ∑ (investments)≤1

Schematic representation of the model



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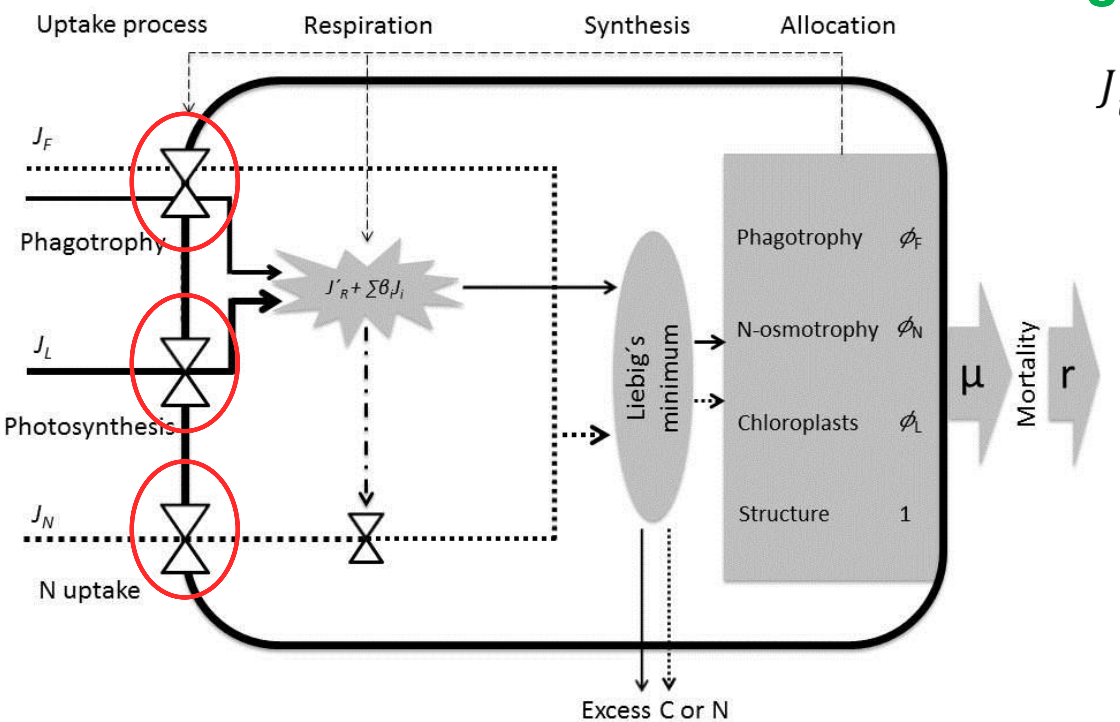

Uptake of resources :

$$J_i = J_{\max.i} \frac{A_i X_i}{A_i X_i + J_{\max.i}} \qquad (i = L, N, F)$$

Max uptake rate

Affinitiy

Size (V μg C) dependence :

$$J_{max.i} = M_i \phi_i V$$

$$A_i = c_i V^{a_i} \frac{\alpha_i \phi_i V}{\alpha_i \phi_i V + c_i V^{a_i}}$$

Affinitiy :

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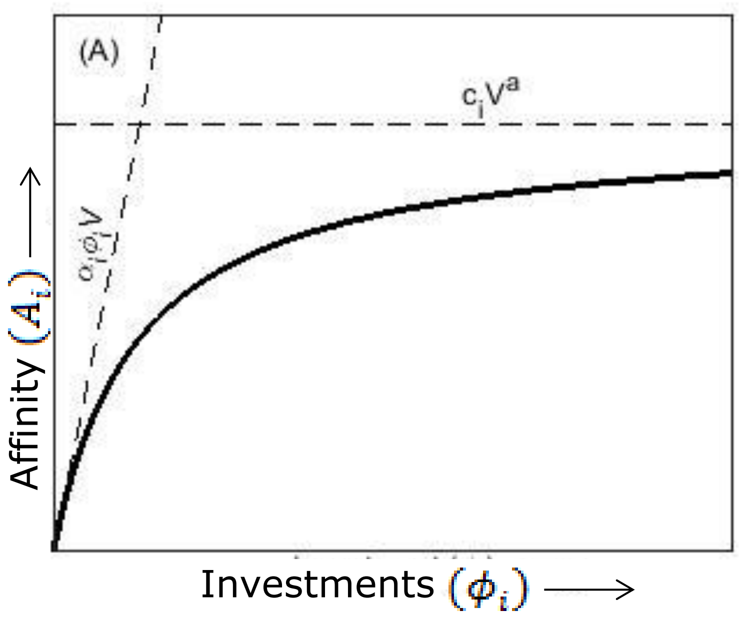

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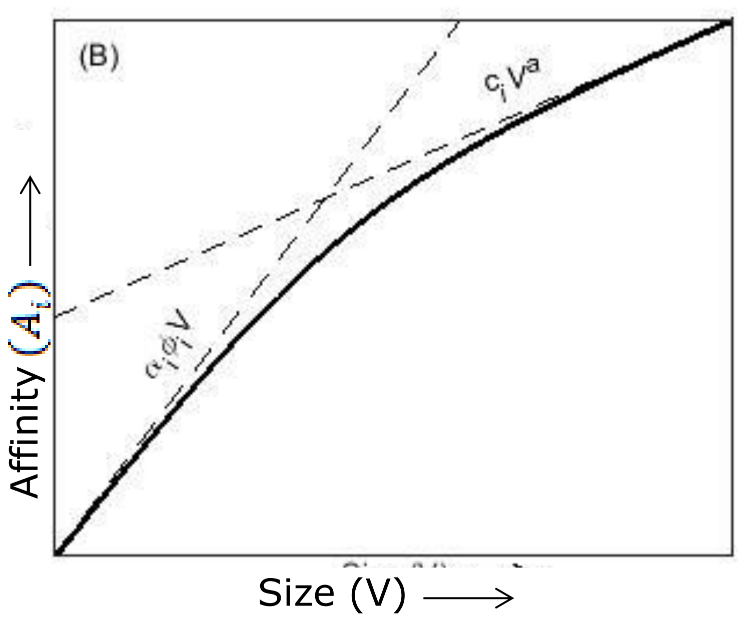

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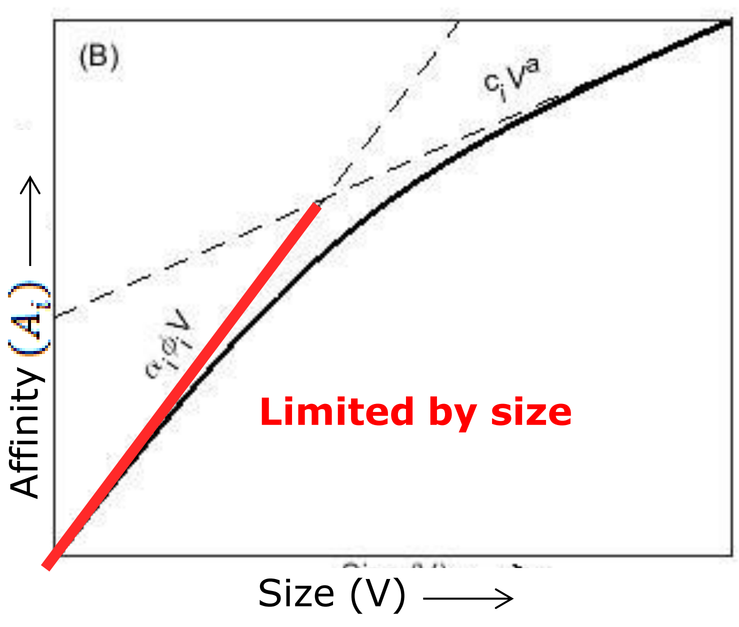

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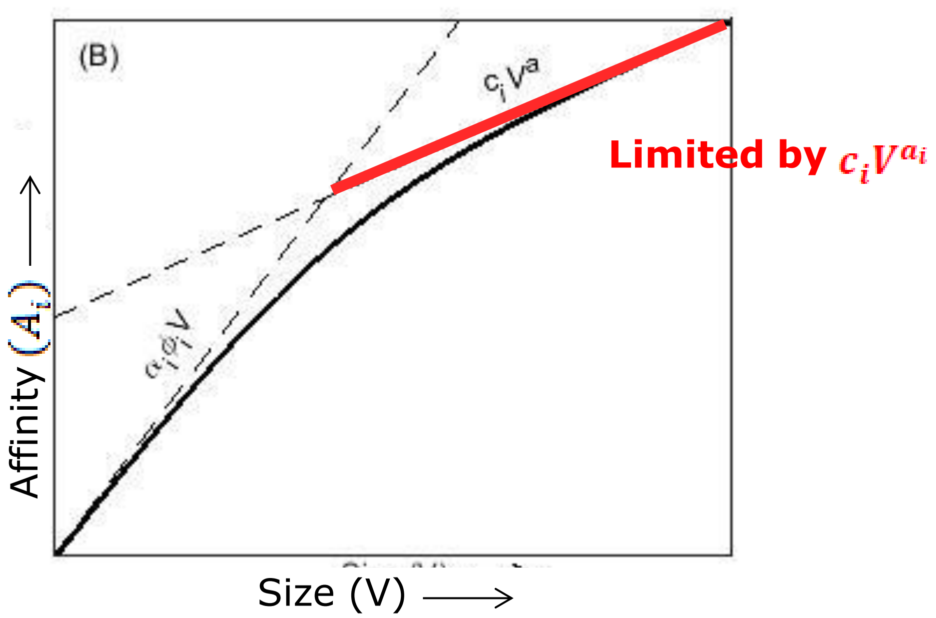
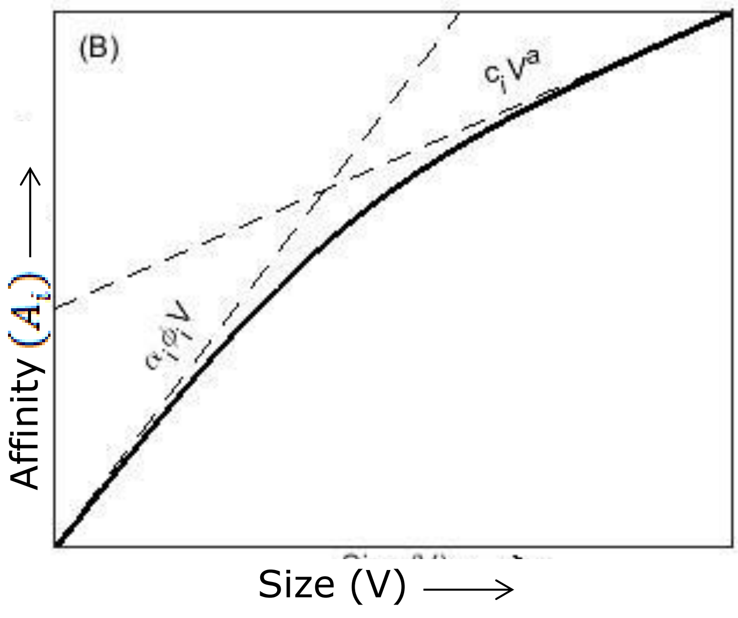
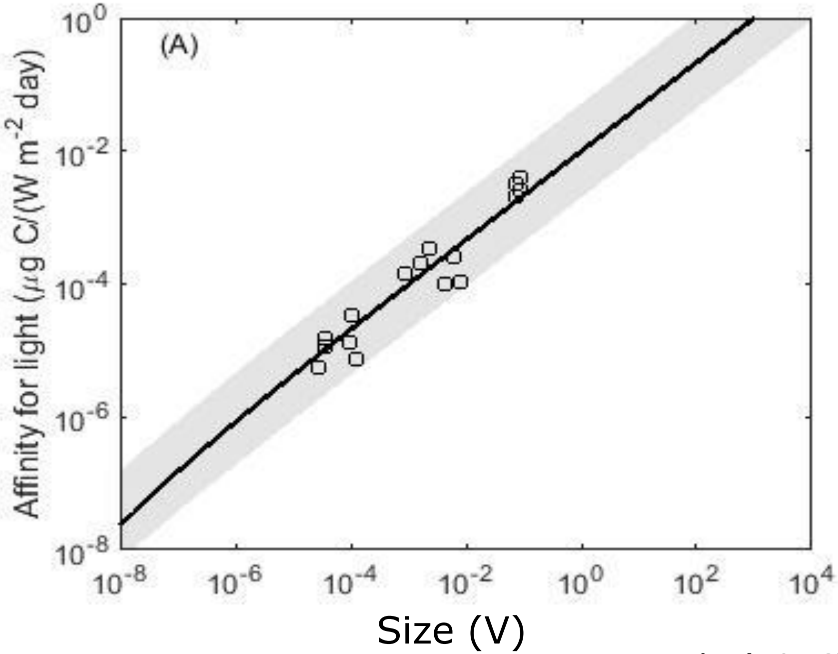


Affinitiy : $A_i = c_i V^{a_i} \frac{\alpha_i \phi_i V}{\alpha_i \phi_i V + c_i V^{a_i}}$

Affinity for light: $A_L = c_L V^{2/3} \frac{\alpha_L \phi_L V}{\alpha_L \phi_L V + c_L V^{2/3}}$





Taguchi (1976)

Affinitiy :

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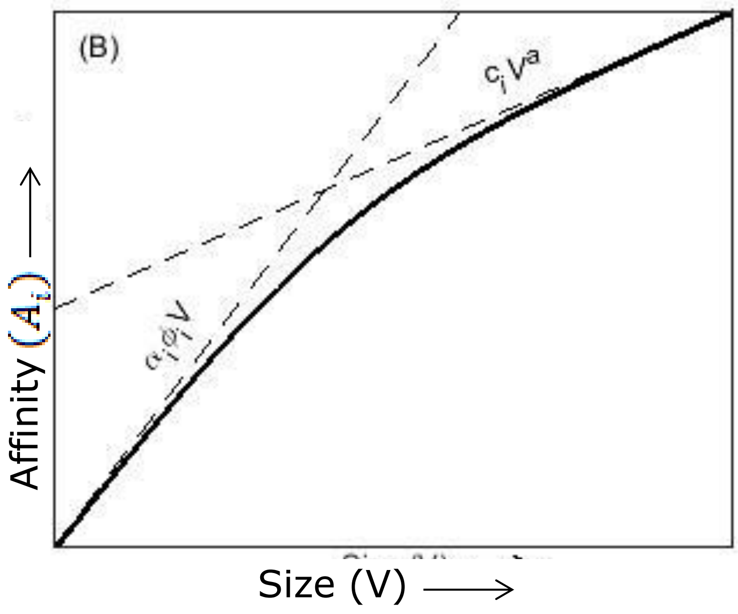

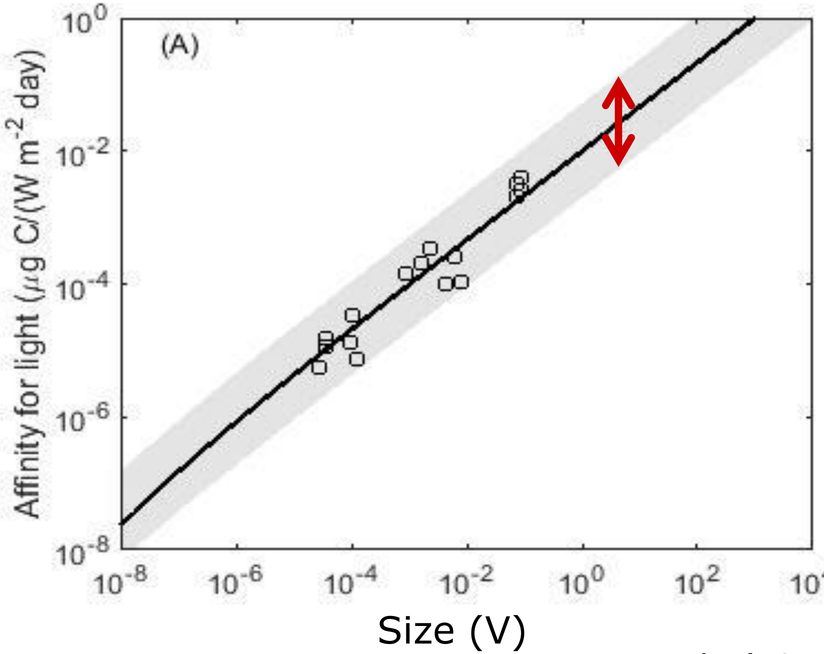

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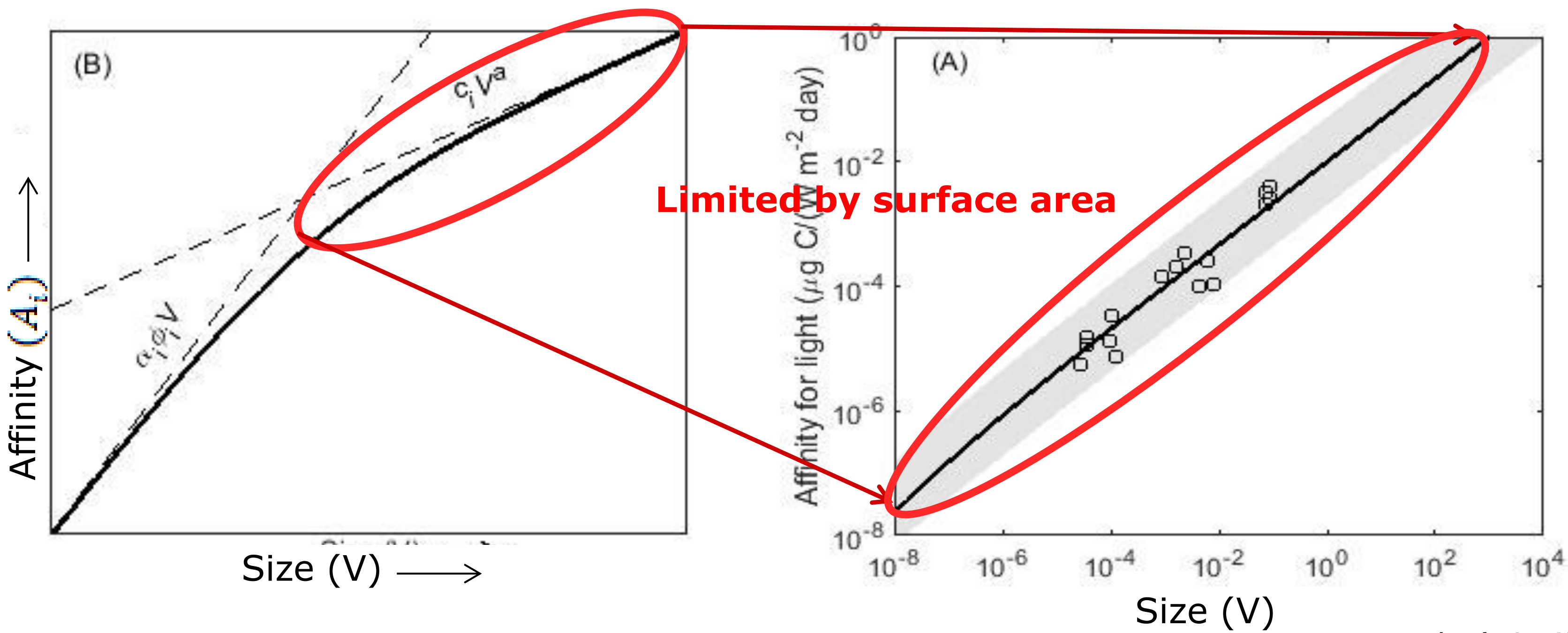

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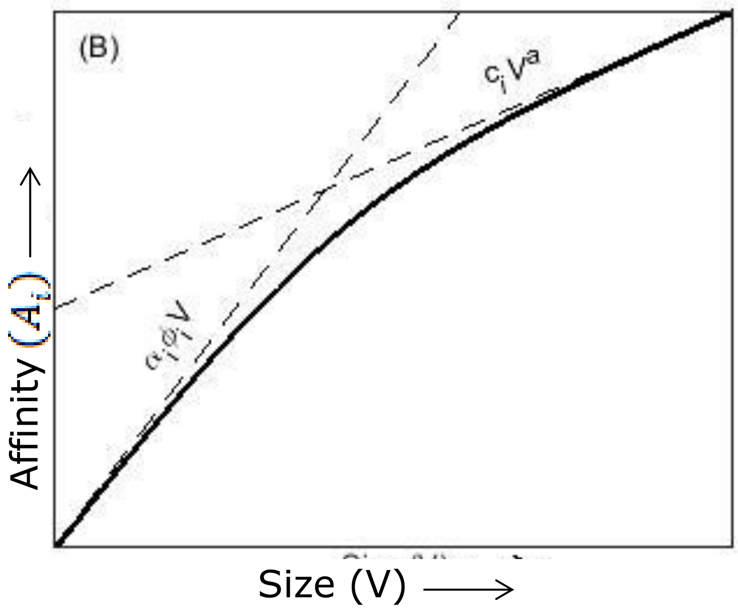

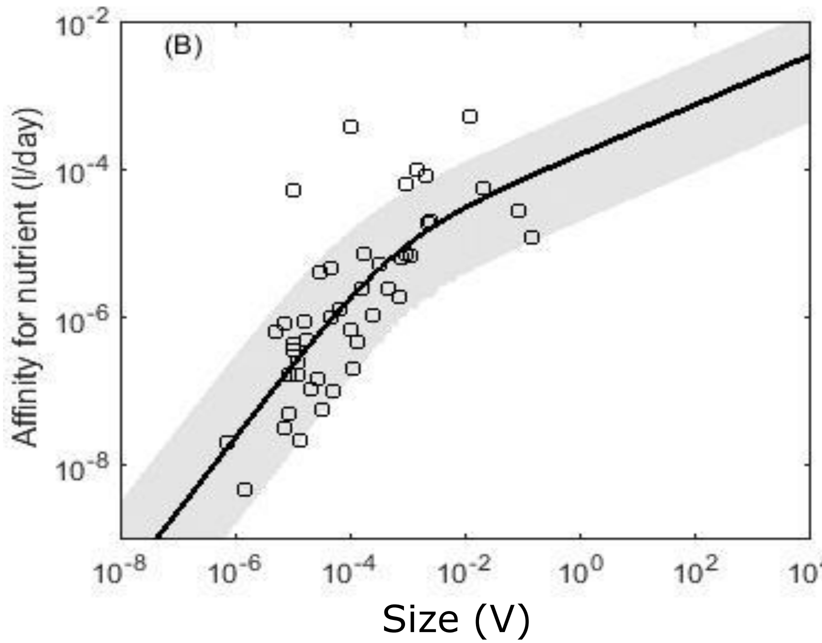

Edwards et al. (2012)

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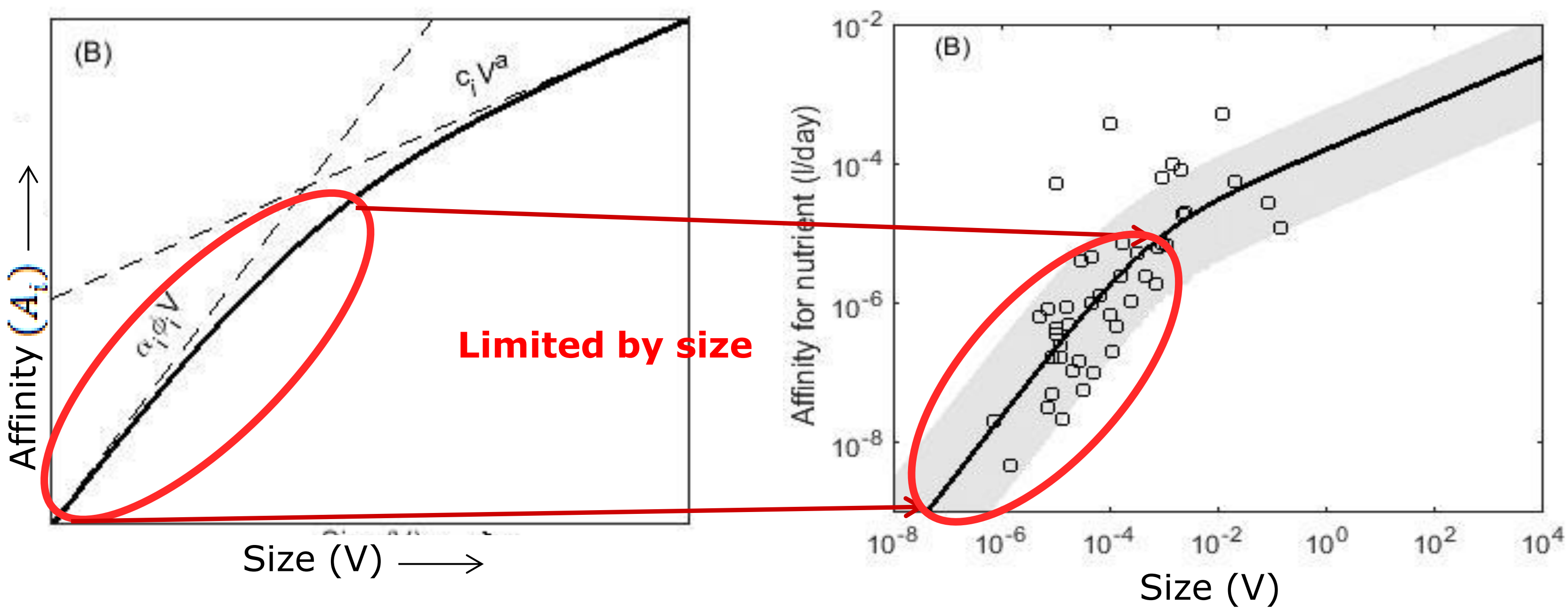

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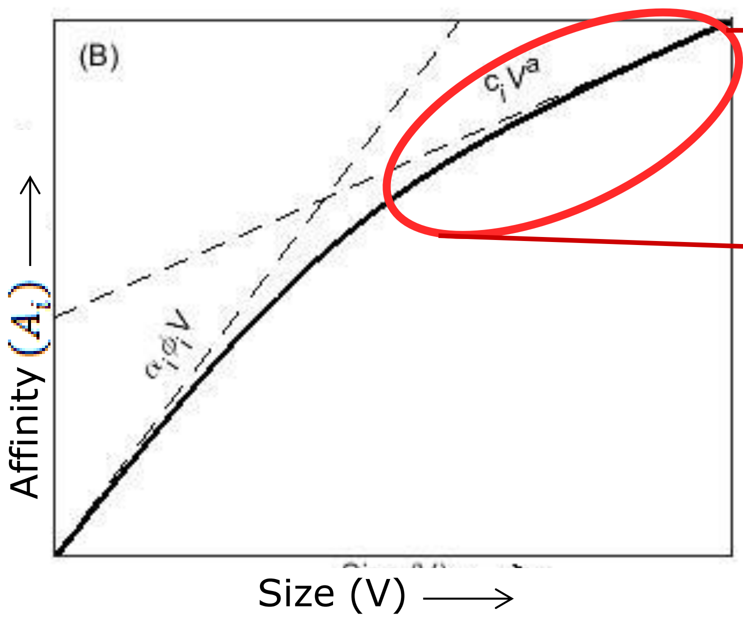

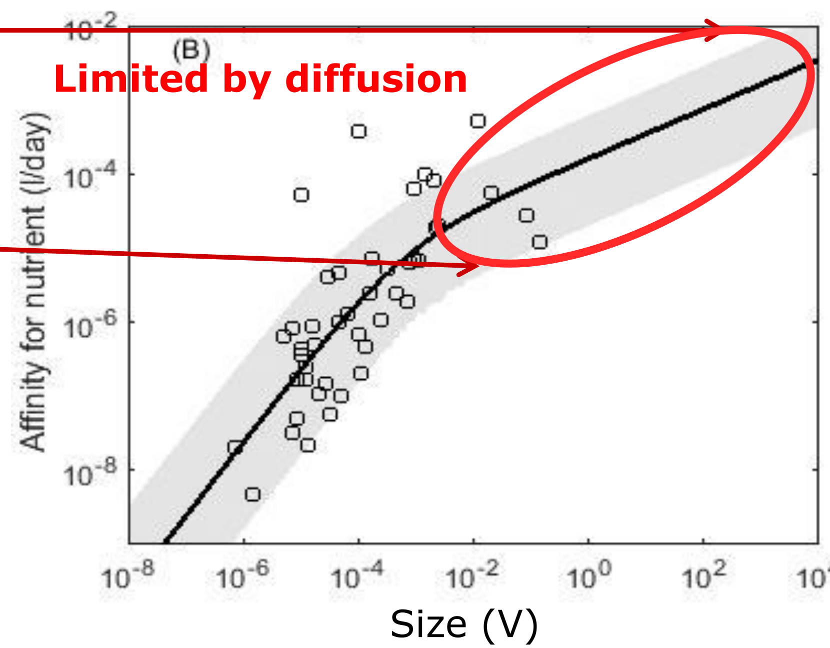

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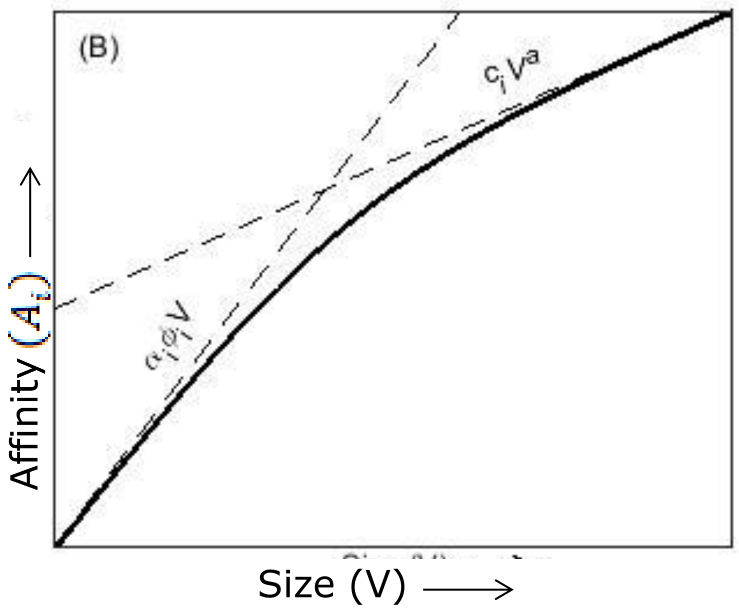
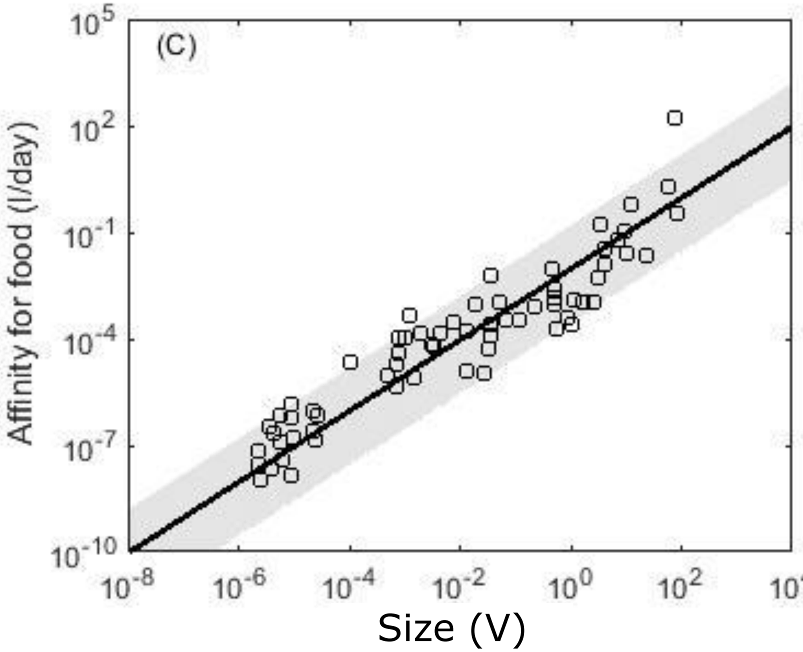
Affinitiy : $$A_i = c_i V^{a_i} \frac{\alpha_i \phi_i V}{\alpha_i \phi_i V + c_i V^{a_i}}$$

Affinity for food: $$A_F = c_F V \frac{\alpha_F \phi_F V}{\alpha_F \phi_F V + c_F V}$$





Kiørboe (2011)

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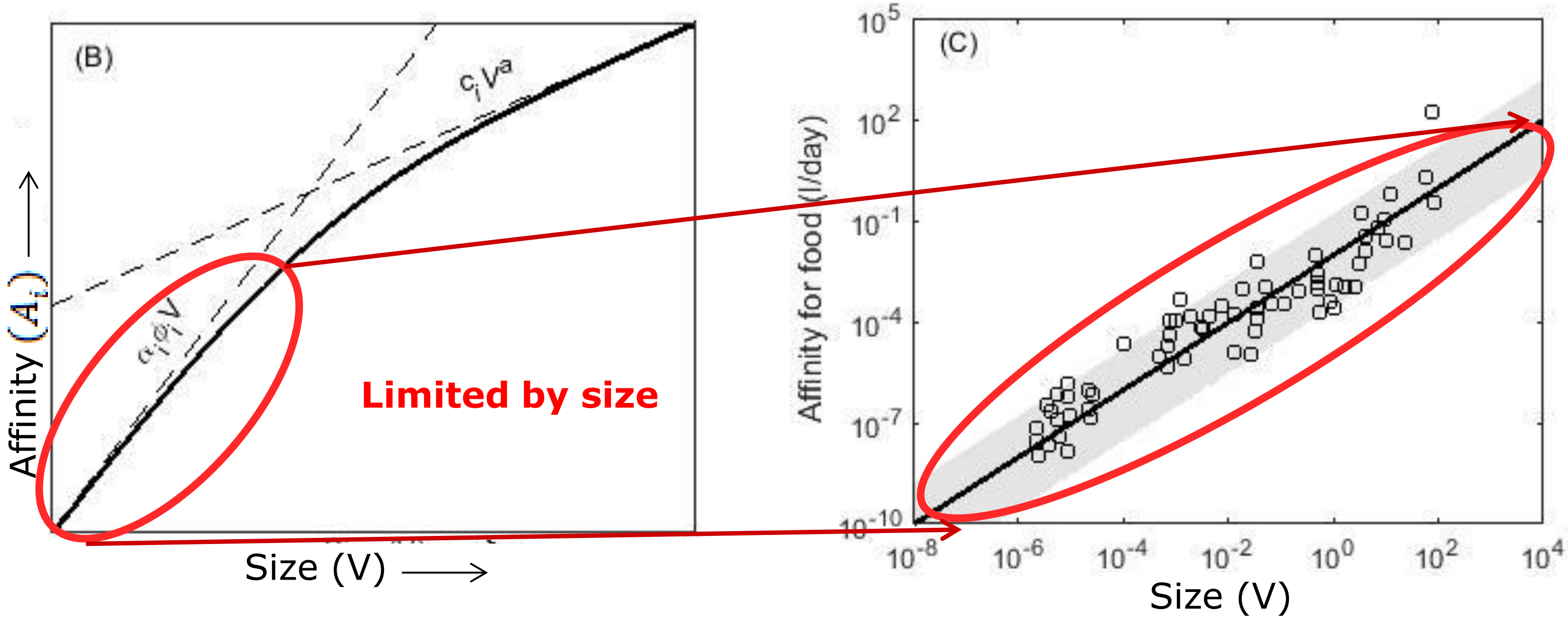
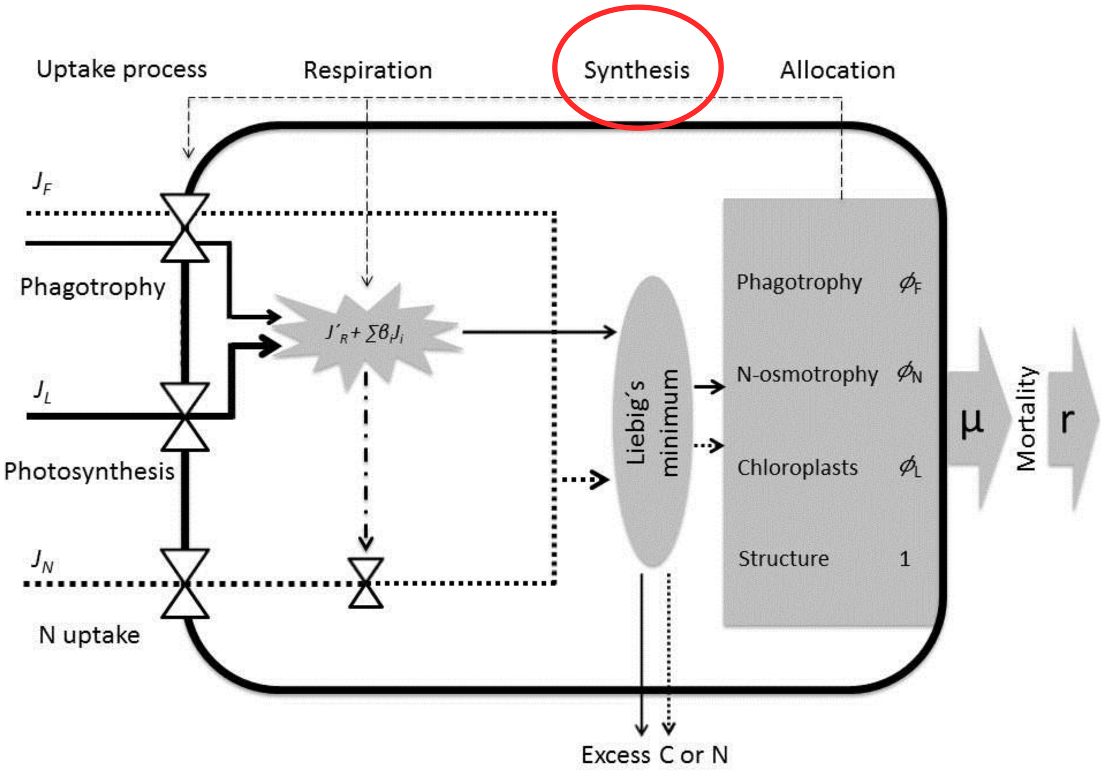


Kiørboe (2011)

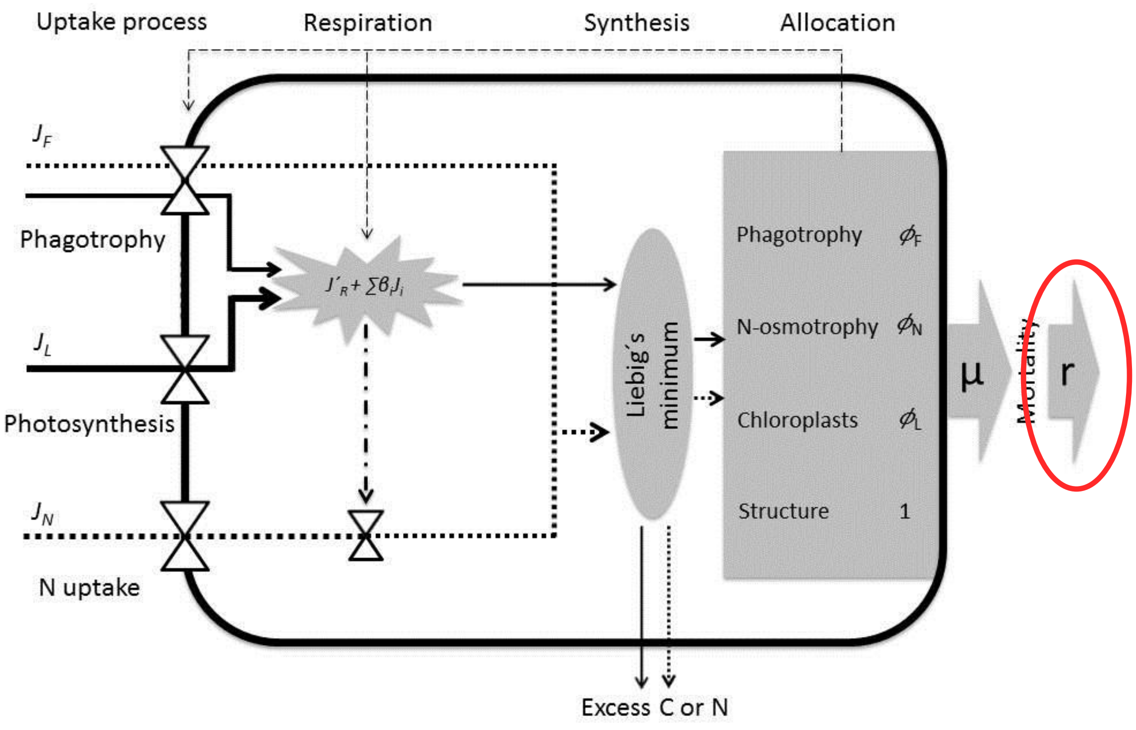
Schematic representation of the model



Final rate of biomass synthesis

$$J_{tot} = \min[J_L - \beta_L J_L - J_R + J_F - \beta_F J_F - \beta_N \rho J_N,\ c_{CN} \rho J_N + J_F]$$

Schematic representation of the model

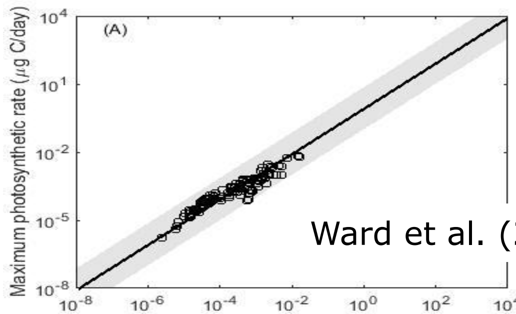


Final growth rate :

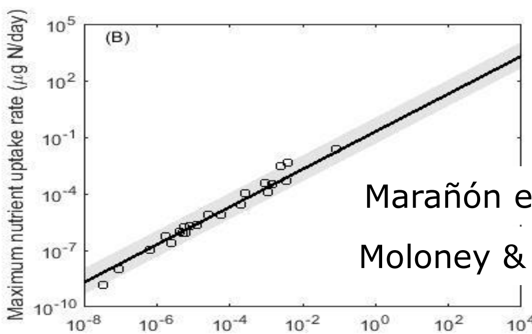
$$g = \frac{J_{tot}}{V(1 + \phi_L + \phi_N + \phi_F)} - mV^{-1/4}$$

Calibration of other parameters

Max uptake rates

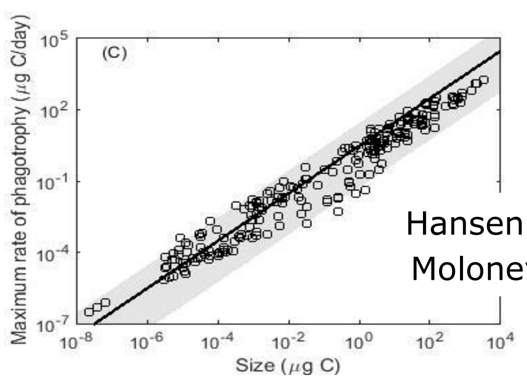


Ward et al. (2012)



Marañón et al. (2013)

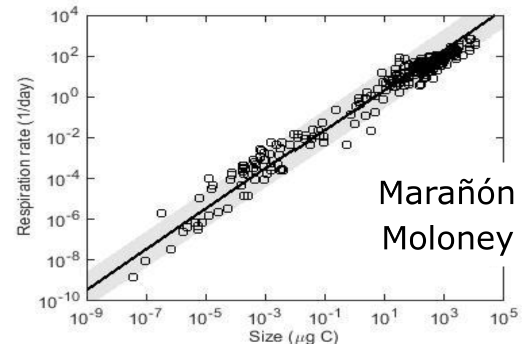
Moloney & Field (1989)



Hansen et al. (1997)

Moloney & Field (1989)

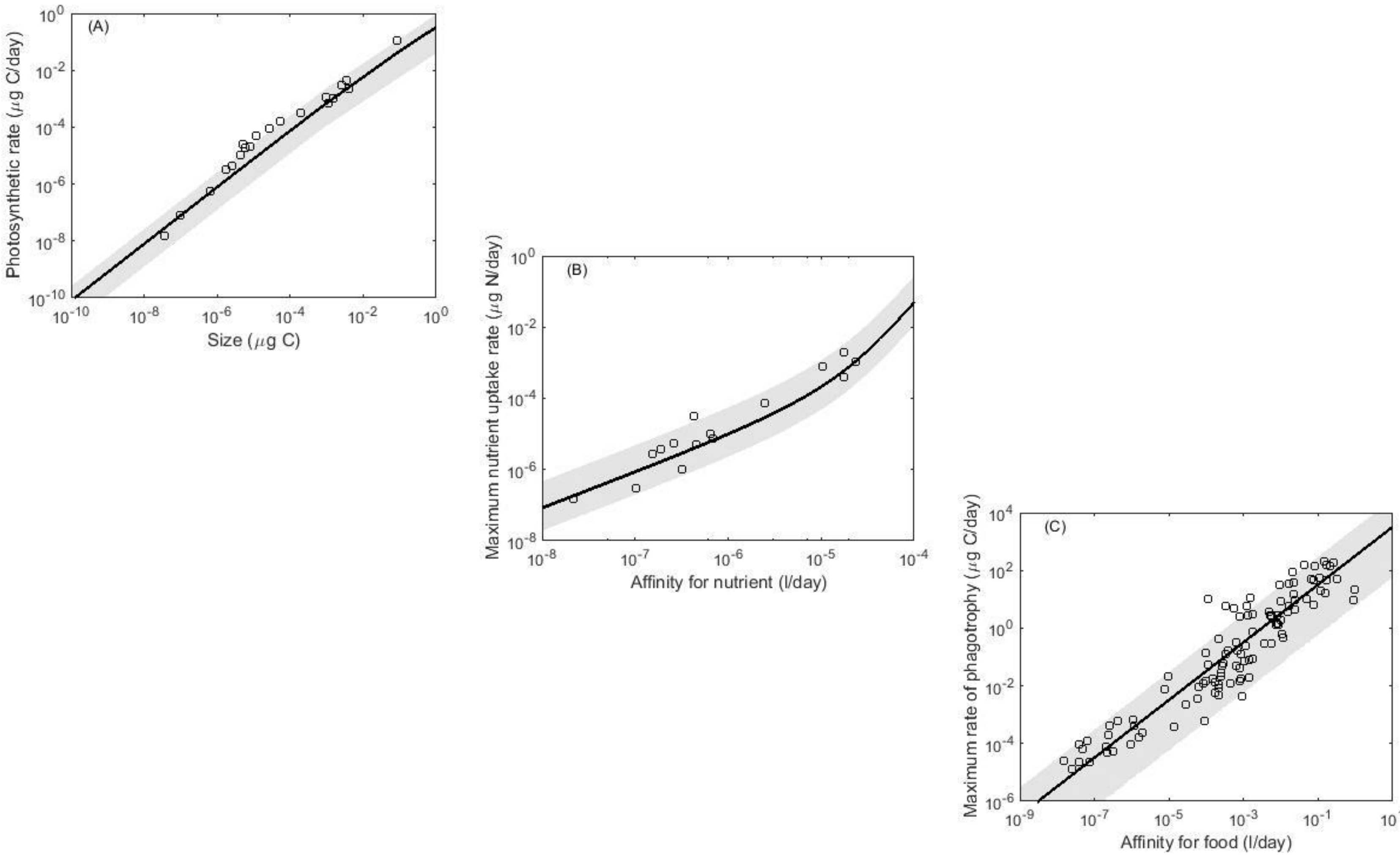
Respiration rate



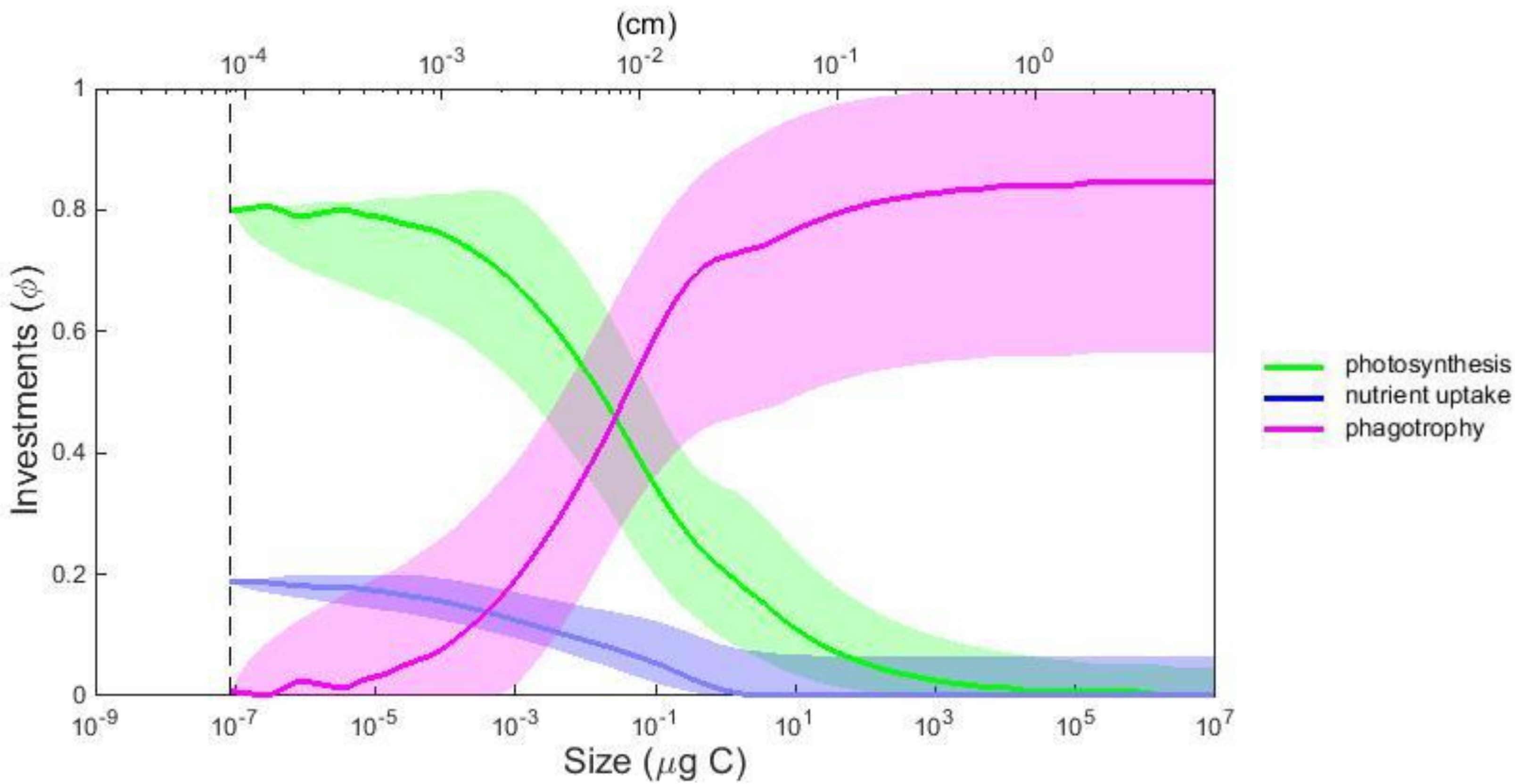
Marañón et al. (2013)

Moloney & Field (1989)

Validation of calibrated parameters



Optimal investments and trophic strategies



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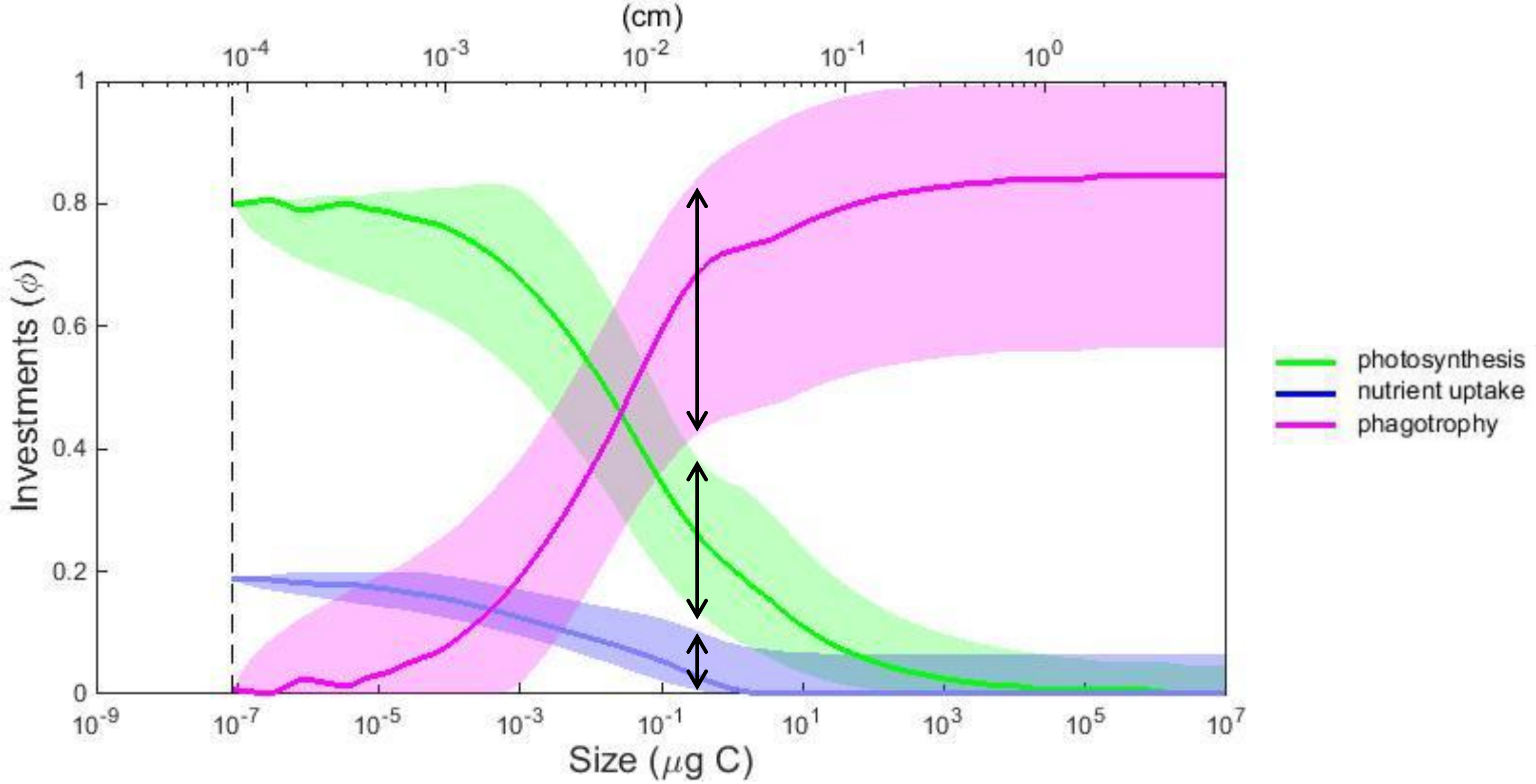
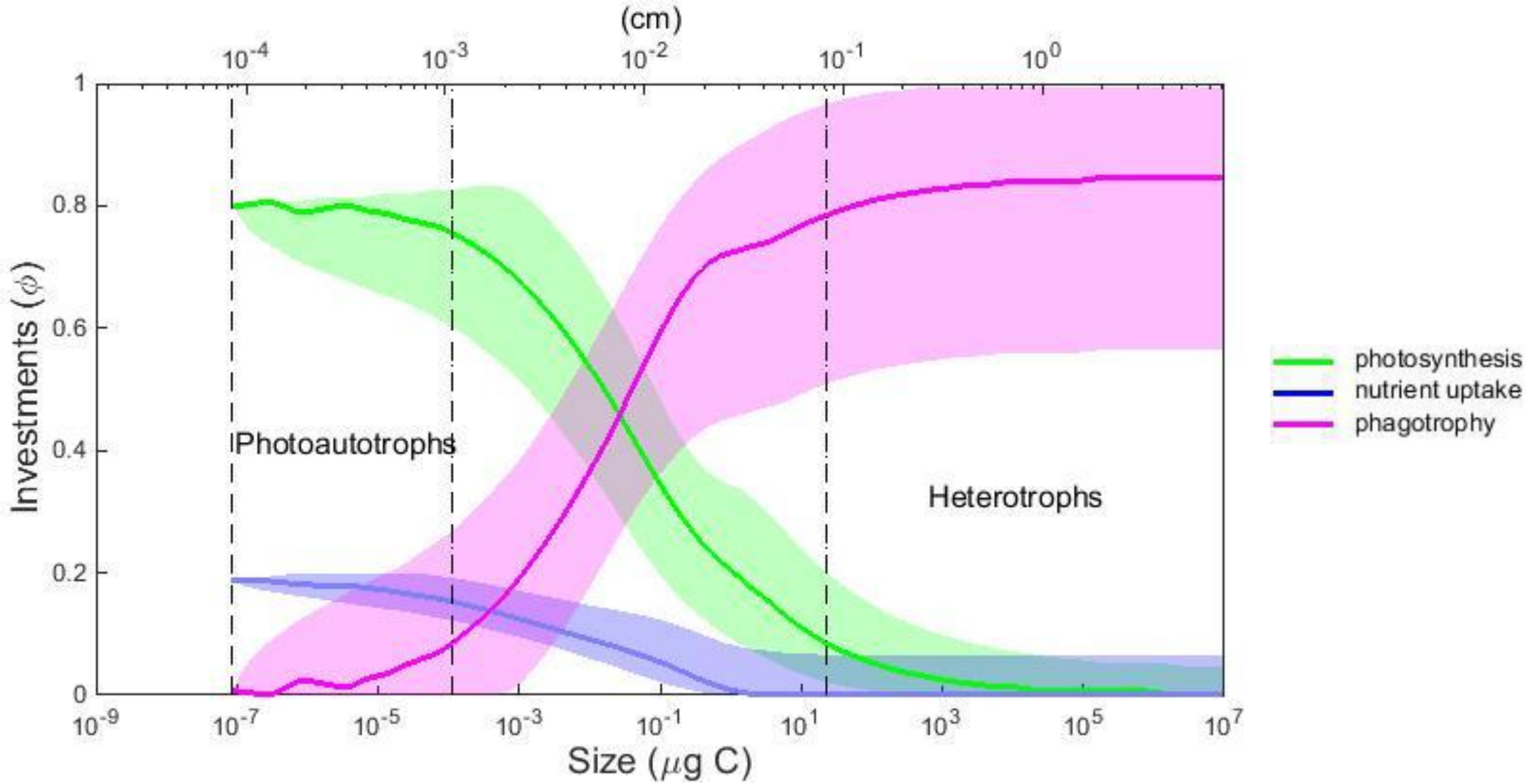


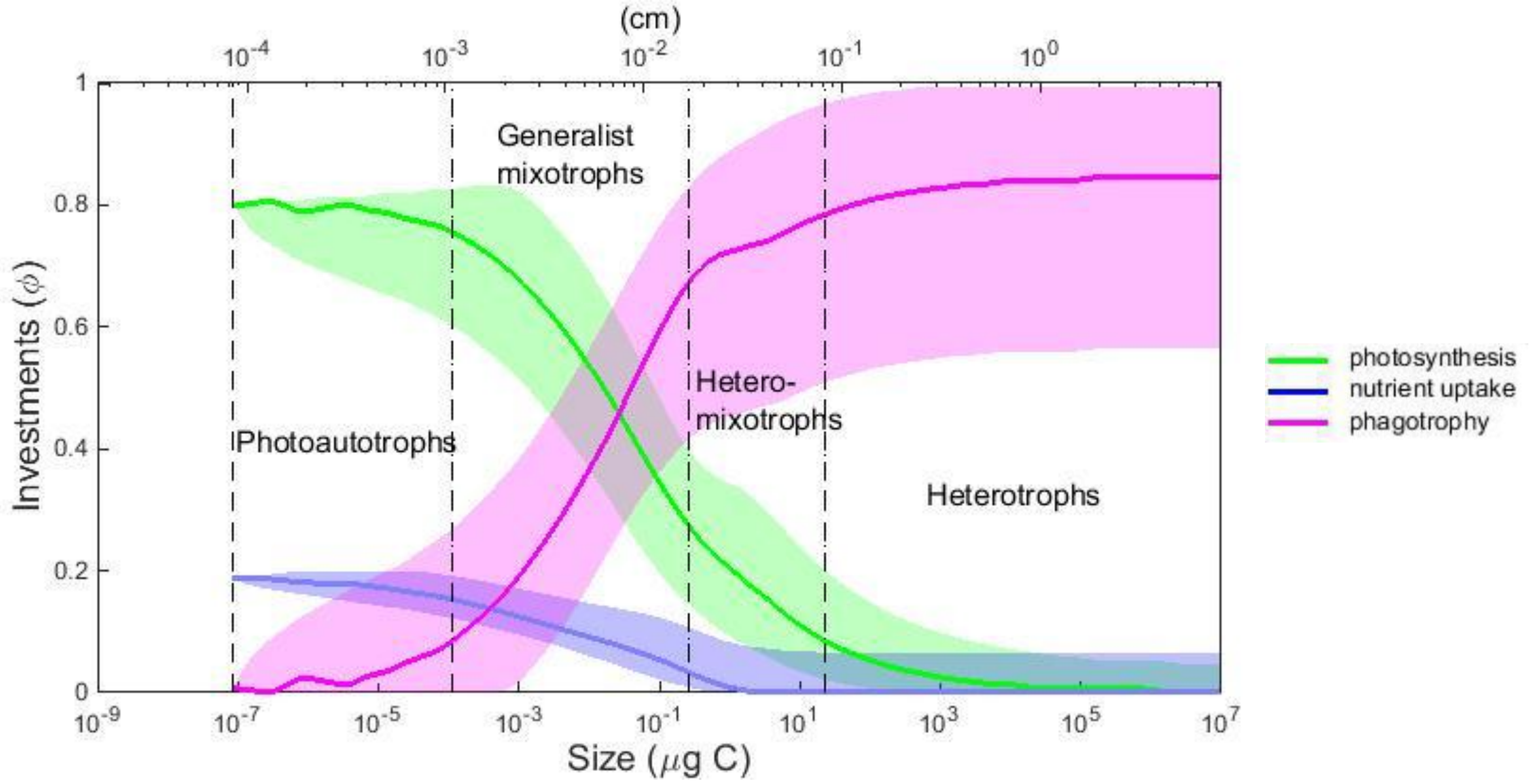
➡ Different possible strategies that keep the growth rate very close to the optimal one

Optimal investments and trophic strategies



Relative investment in phagotrophy compared to investment in photosynthesis

Optimal investments and trophic strategies

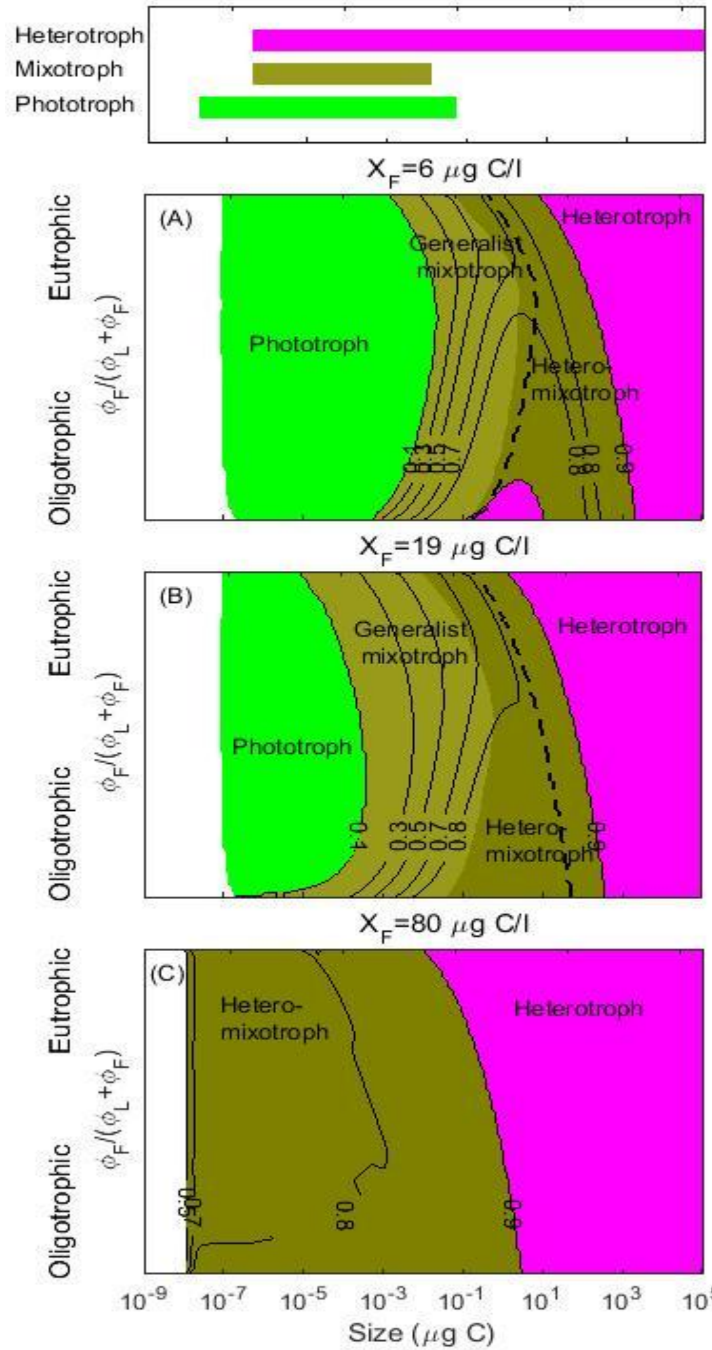


➡ Relative investment in phagotrophy compared to investment in nutrient uptake

Conclusions:

- The transition from photoautotrophy to heterotrophy emerges as a consequence of how benefits of investments in different resource harvesting strategies change with size.
- Among the mixotrophs a pattern of two types emerges: generalist mixotrophs invest in all three different resource uptake strategies and hetero-mixotrophs only invest in photosynthesis and phagotrophy.
- Generalist mixotrophs are relatively smaller compared to the hetero-mixotrophs.

Trophic strategies at different environmental conditions



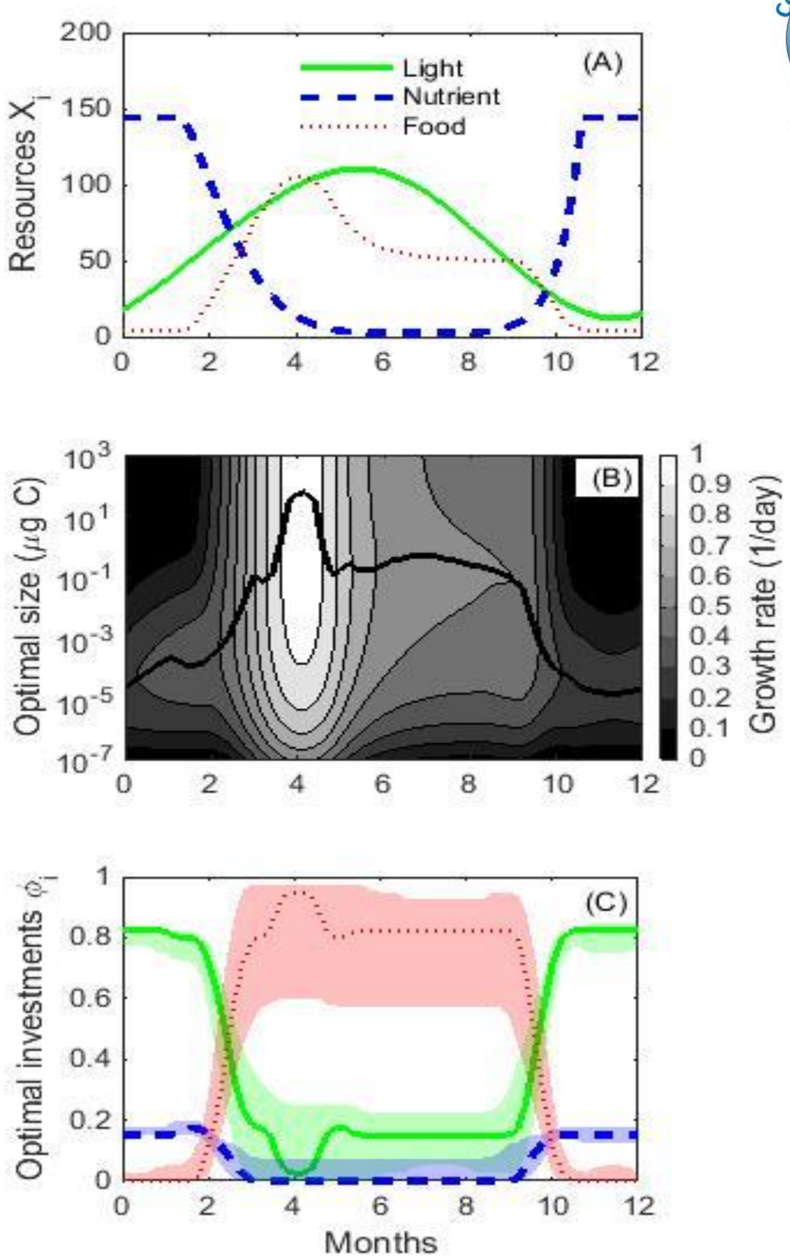
Conclusions:

- Mixotrophy is an optimal strategy for a large size range of organisms under oligotrophic conditions

- Generalist mixotrophs occur under most conditions, whereas hetero-mixotrophs occur mostly under nutrient limited and high light conditions.

- Bottom-up processes dominate the selection for trophic strategy, while top-down processes are more important for size-selection.

Seasonal succession of trophic strategies



Acknowledgment :

This research work was supported by the HC Ørsted COFUND Postdoc Fellowship provided to Subhendu Chakraborty by the Technical University of Denmark

Thank you for your attention!

Some more results:

All fluxes and growth rate