# Correlation between organism size and trophic strategies

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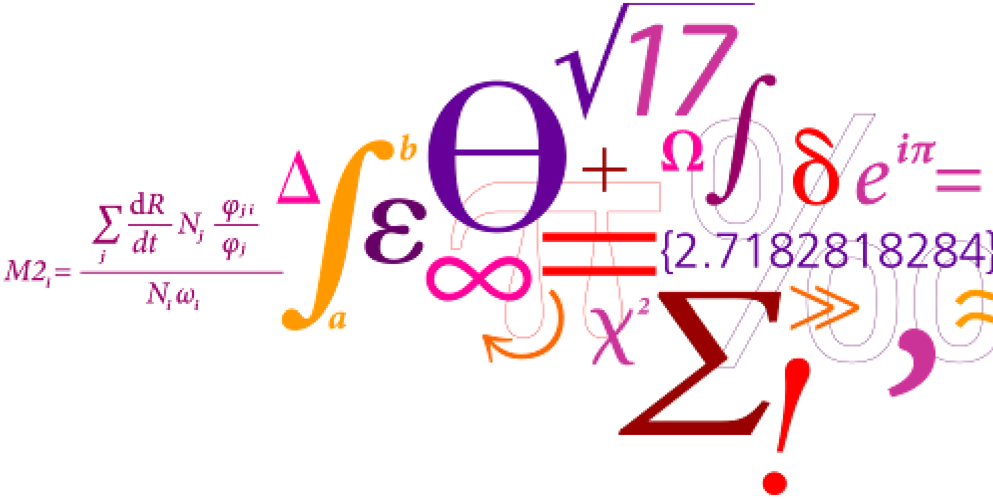
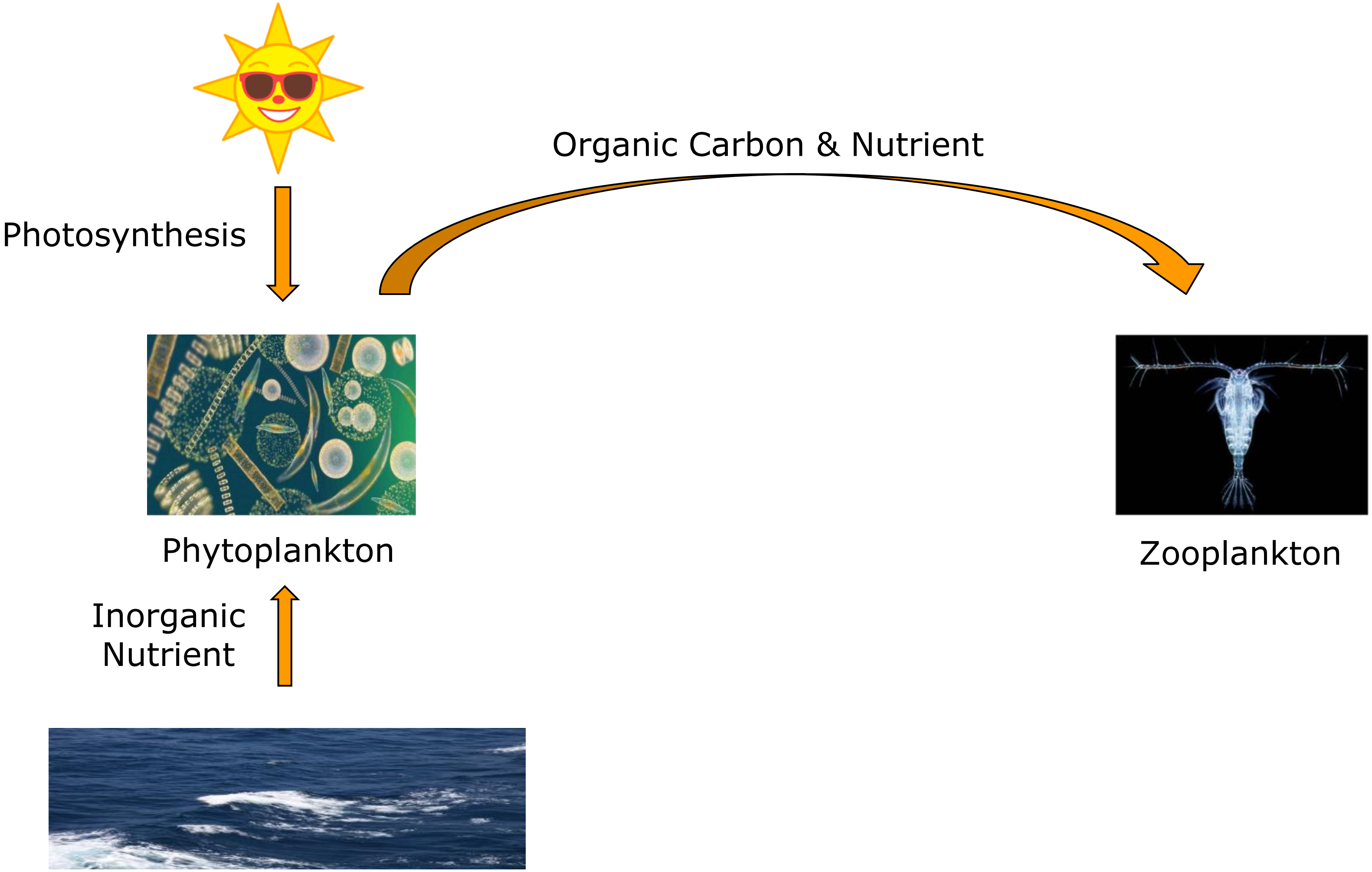


# Broad classification:



Photosynthesis

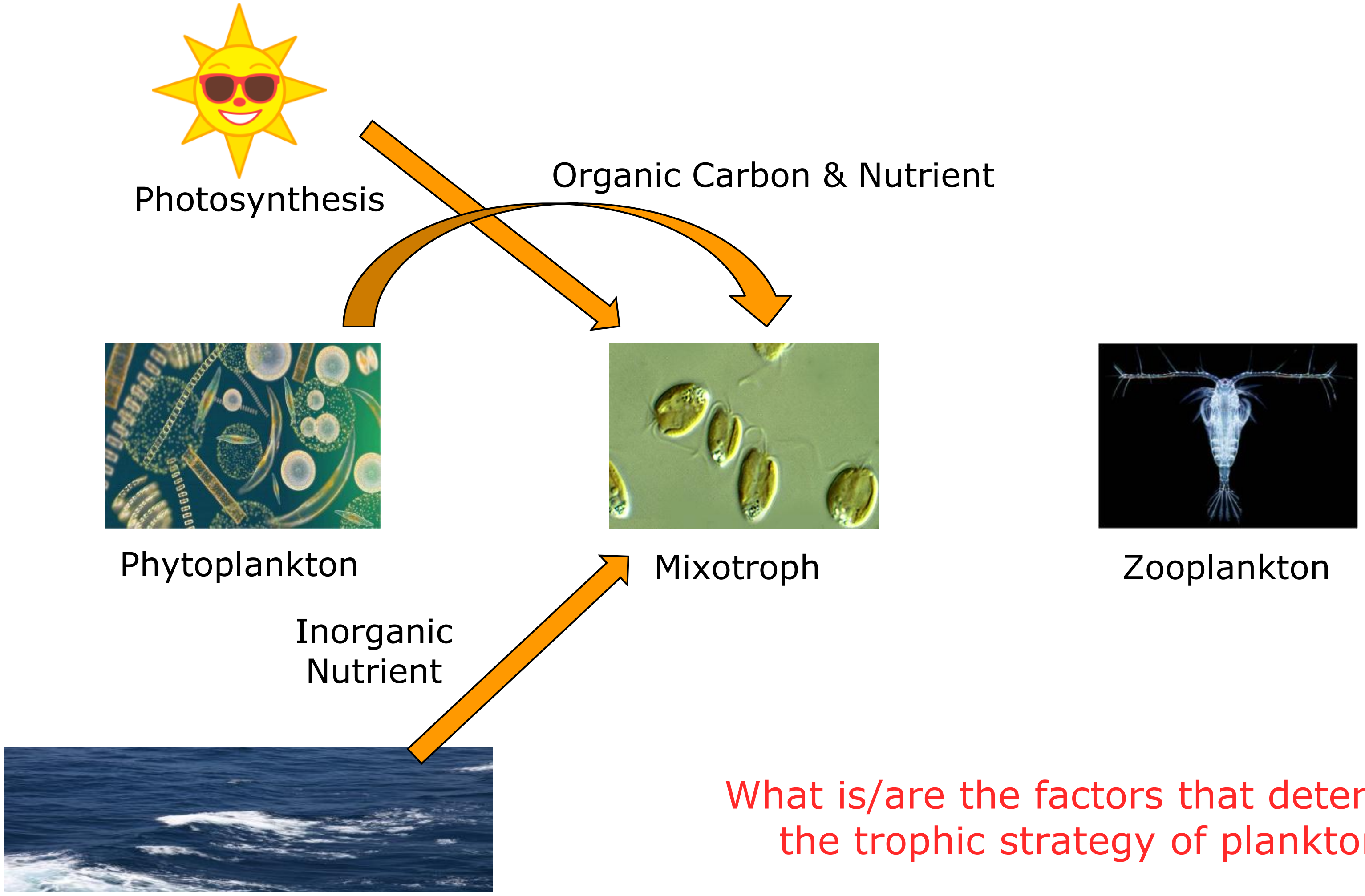
Organic Carbon & Nutrient

Phytoplankton

Zooplankton

Inorganic
Nutrient

# Broad classification:



Photosynthesis

Organic Carbon & Nutrient

Phytoplankton

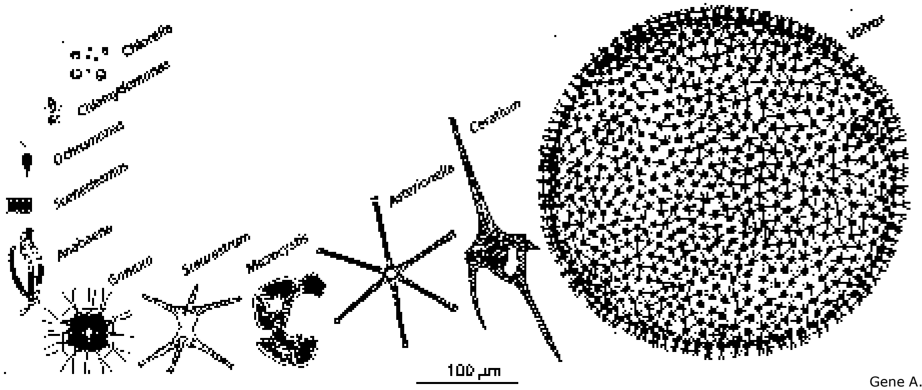
Mixotroph

Zooplankton

Inorganic Nutrient

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

# Size of organisms



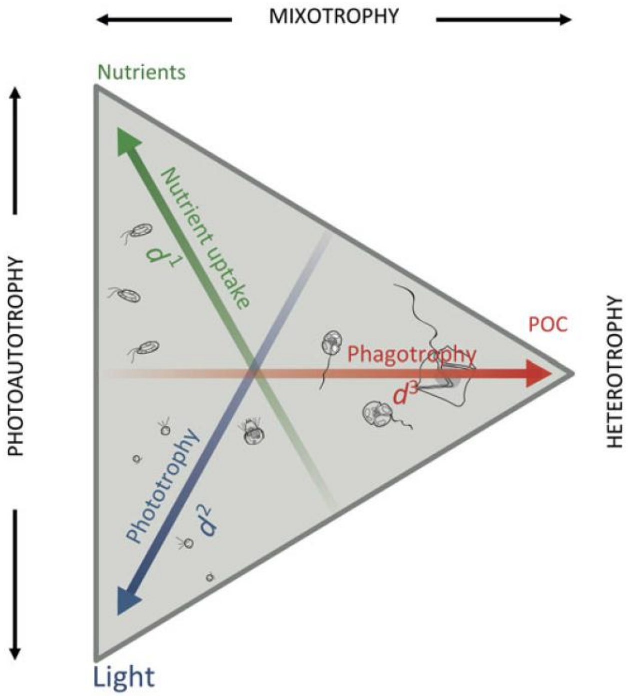
Gene A. Felice

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



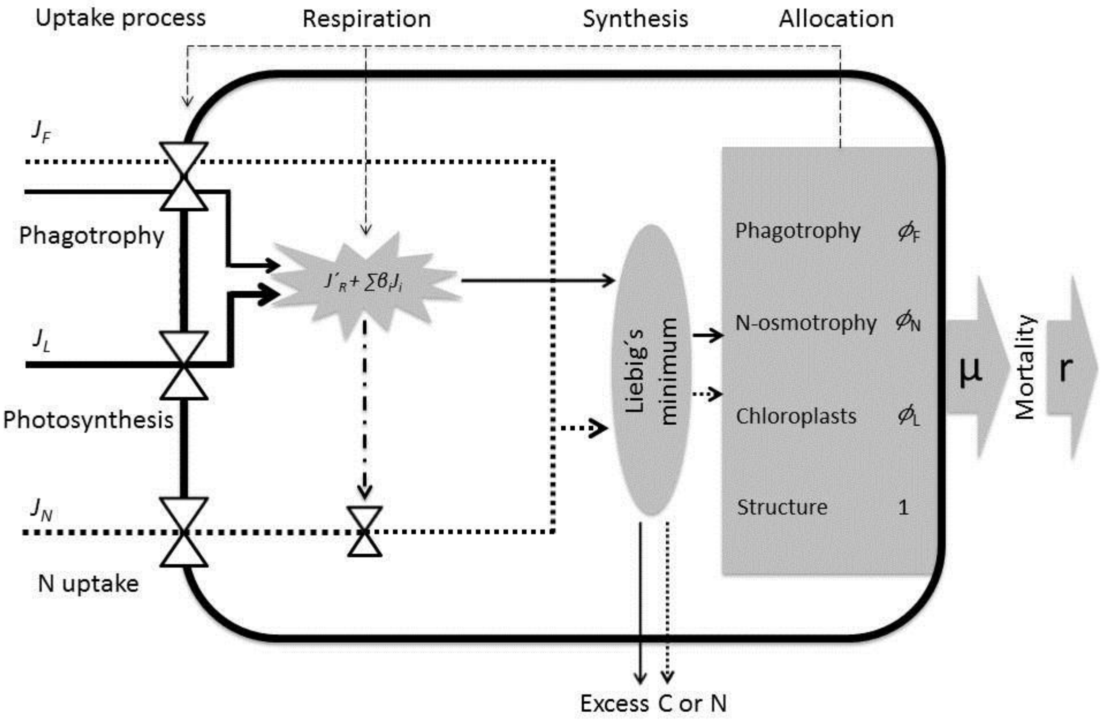
"A specific organisms' trophic strategy is defined as a point within the triangle."…………..

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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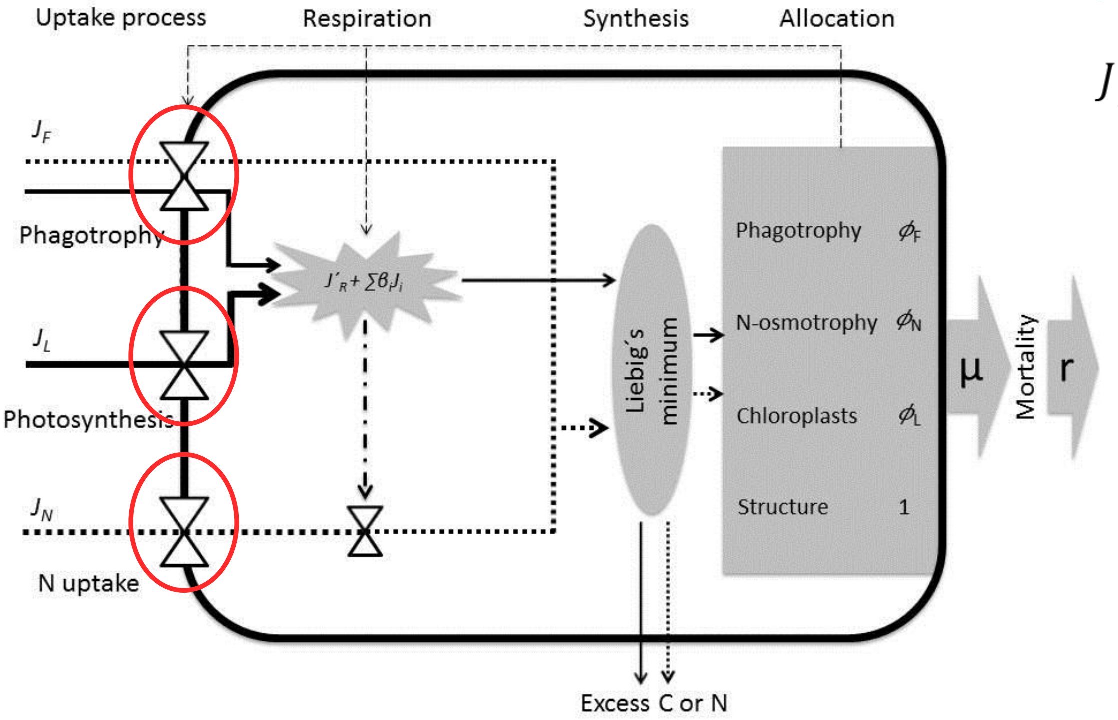


## Uptake of resources :

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

Affinitiy

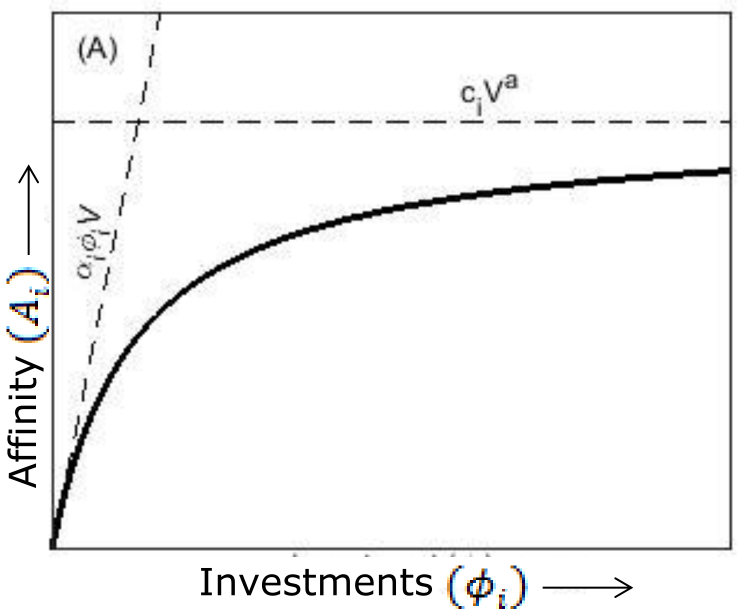
Max uptake rate

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



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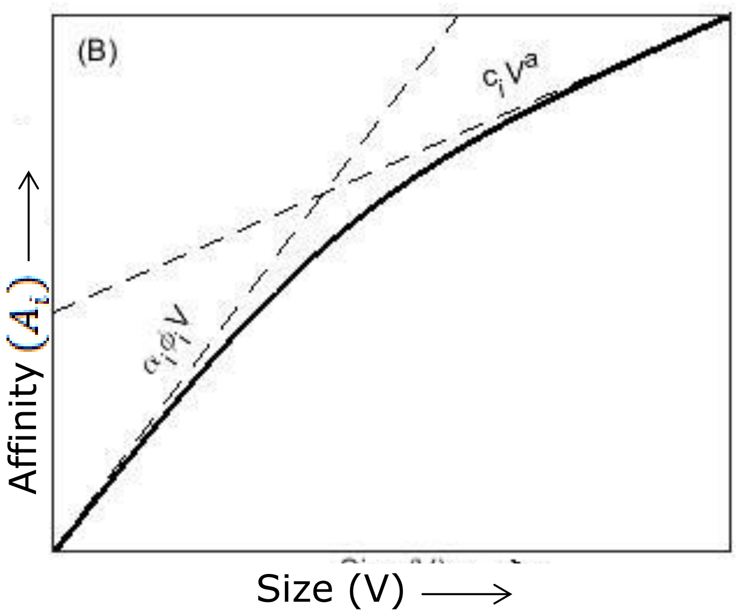
$$A_i = c_i V^{a_i} \frac{\alpha_i \phi_i V}{\alpha_i \phi_i V + c_i V^{a_i}}$$



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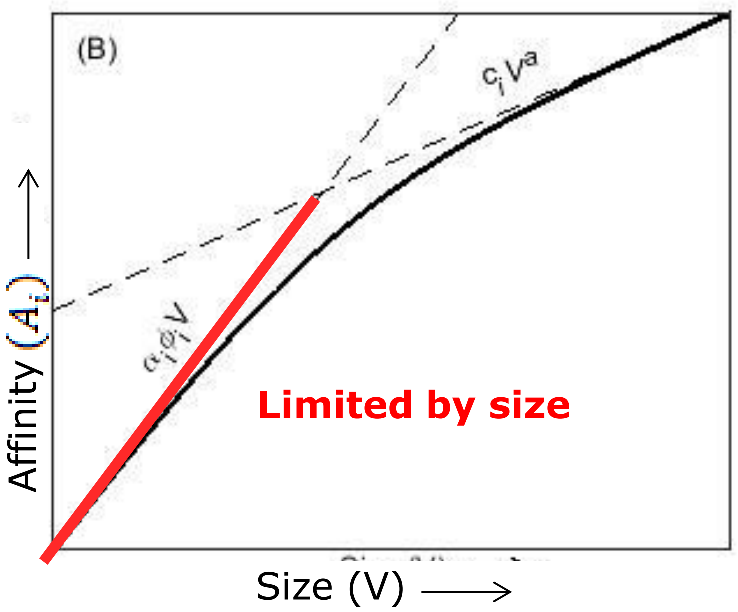

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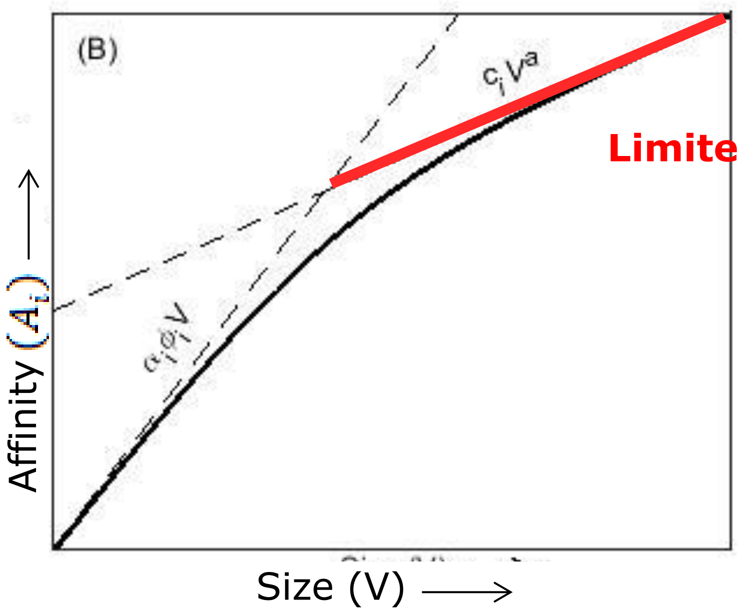
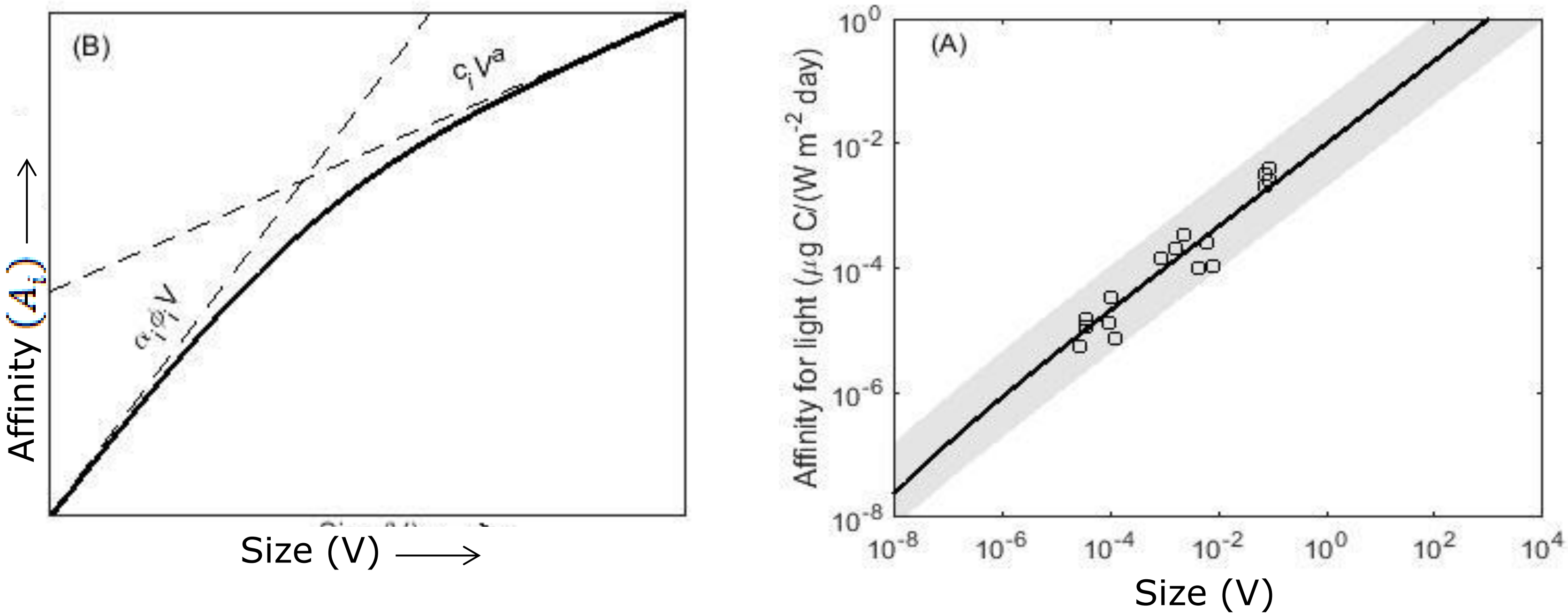


**Limited by $c_i V^{a_i}$**

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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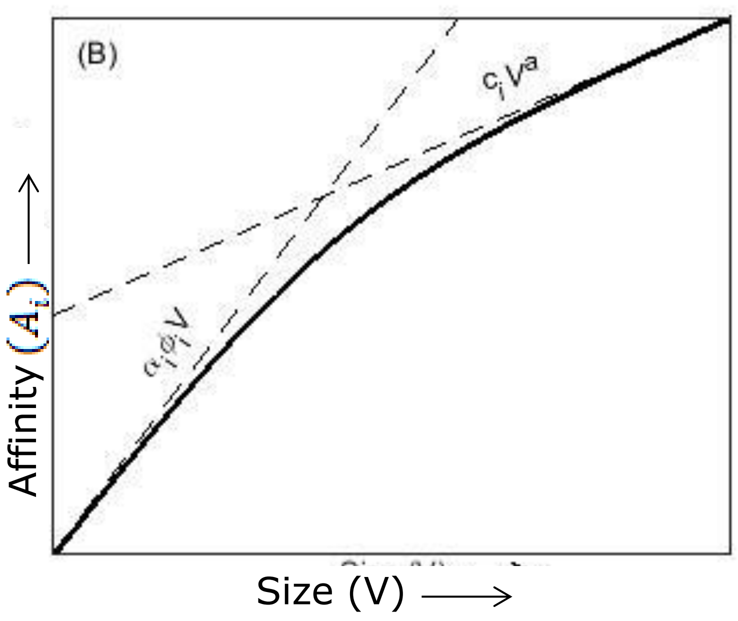

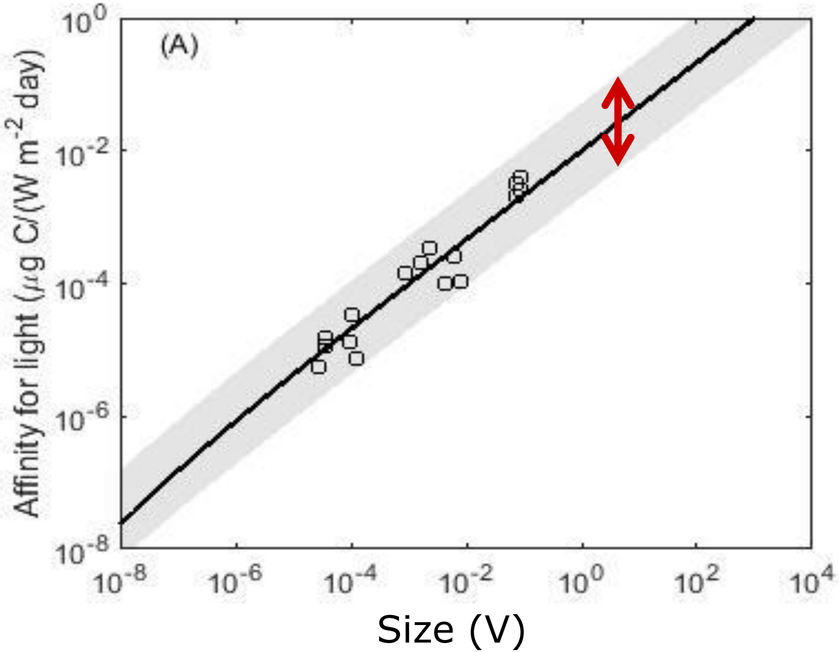

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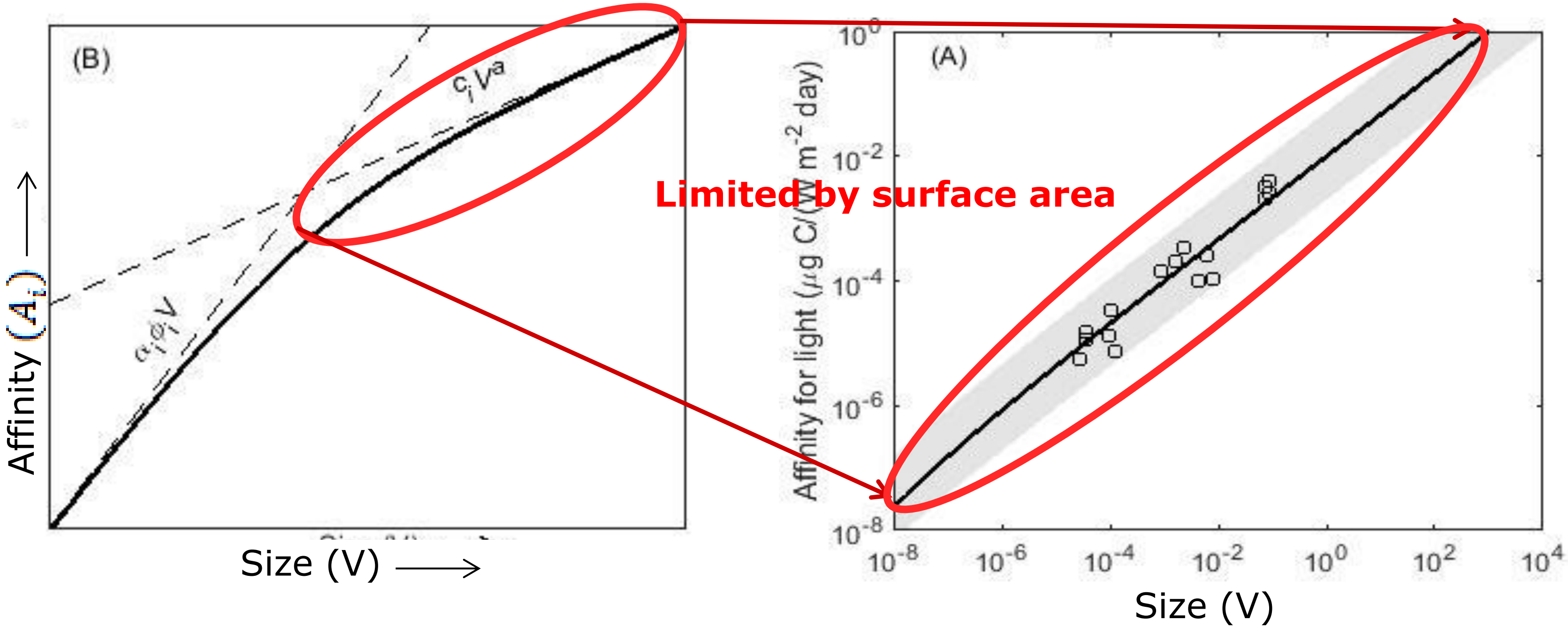
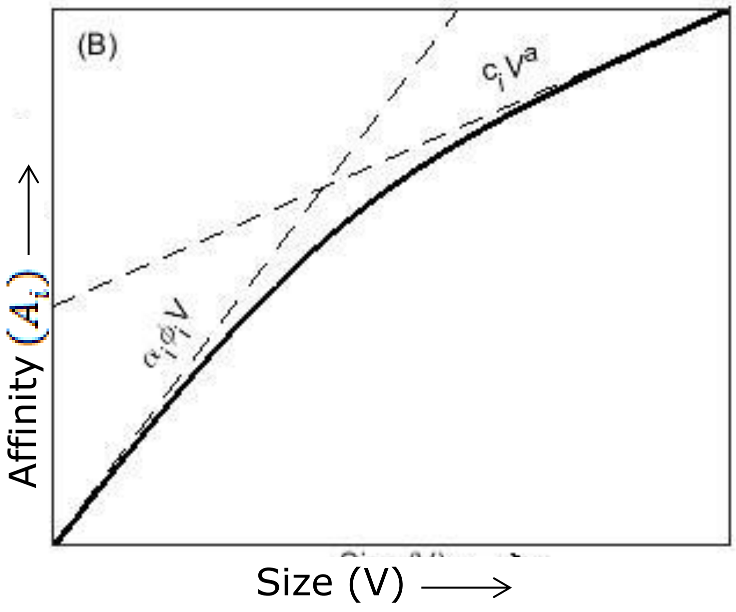


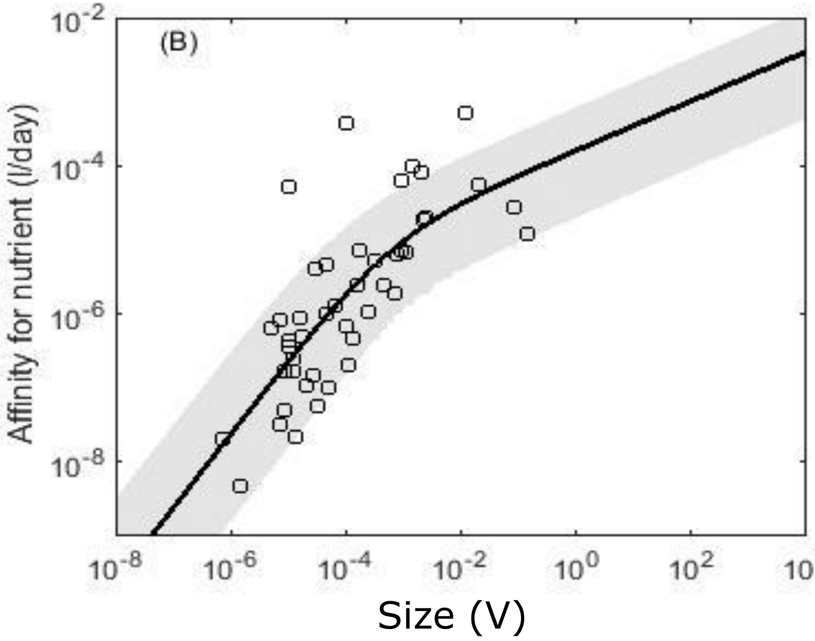
Limited by surface area

Taguchi (1976)

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 nutrient:** $A_N = c_N V^{1/3} \frac{\alpha_N \phi_N V}{\alpha_N \phi_N V + c_N V^{1/3}}$





Edwards et al. (2012)

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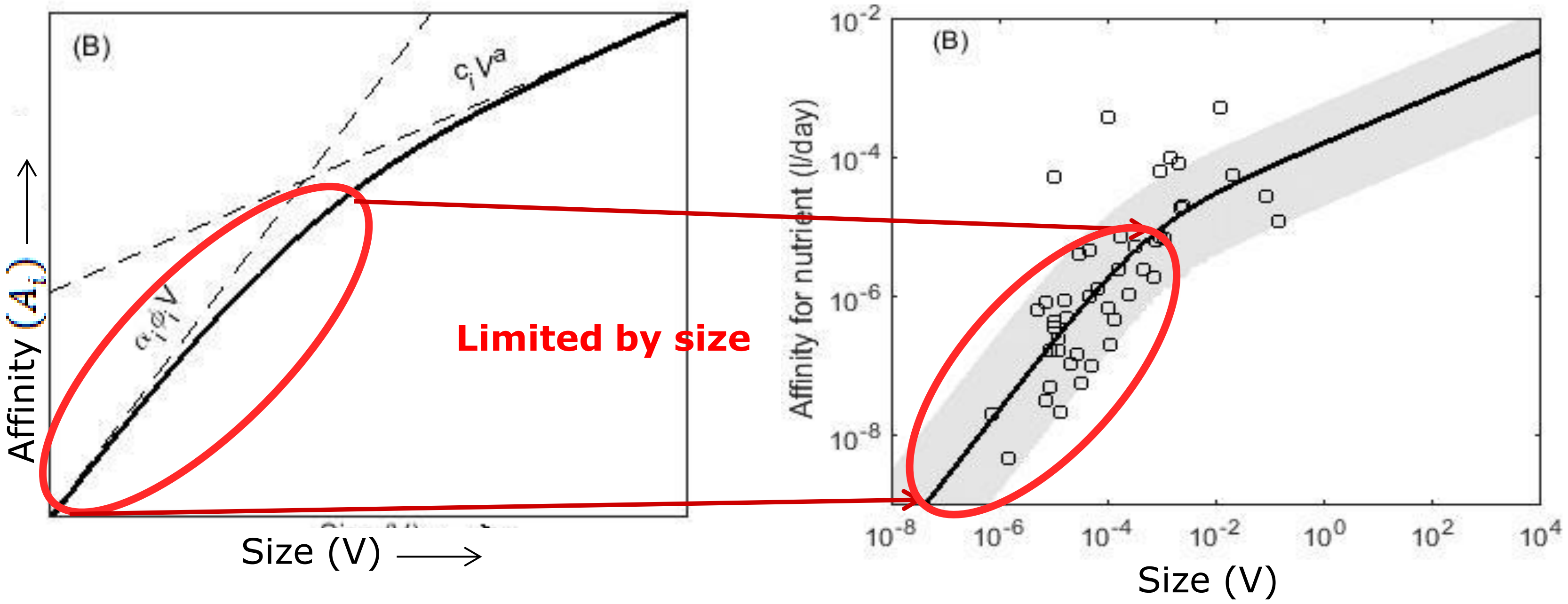
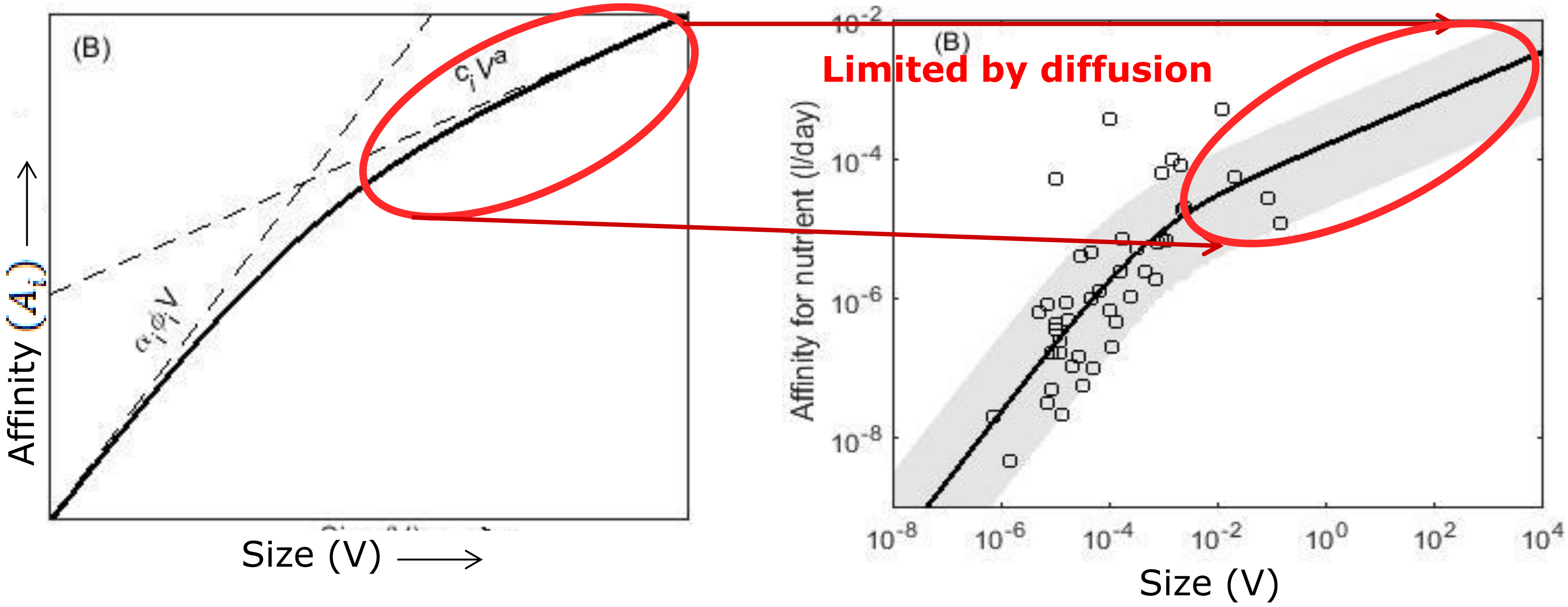


**Limited by size**

Edwards et al. (2012)

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

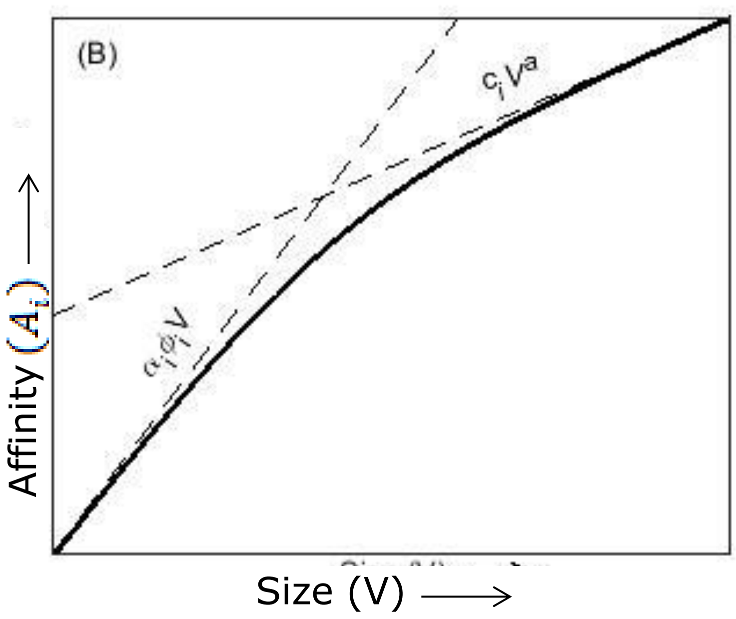
**Affinity for nutrient:** $$A_N = c_N V^{1/3} \frac{\alpha_N \phi_N V}{\alpha_N \phi_N V + c_N V^{1/3}}$$

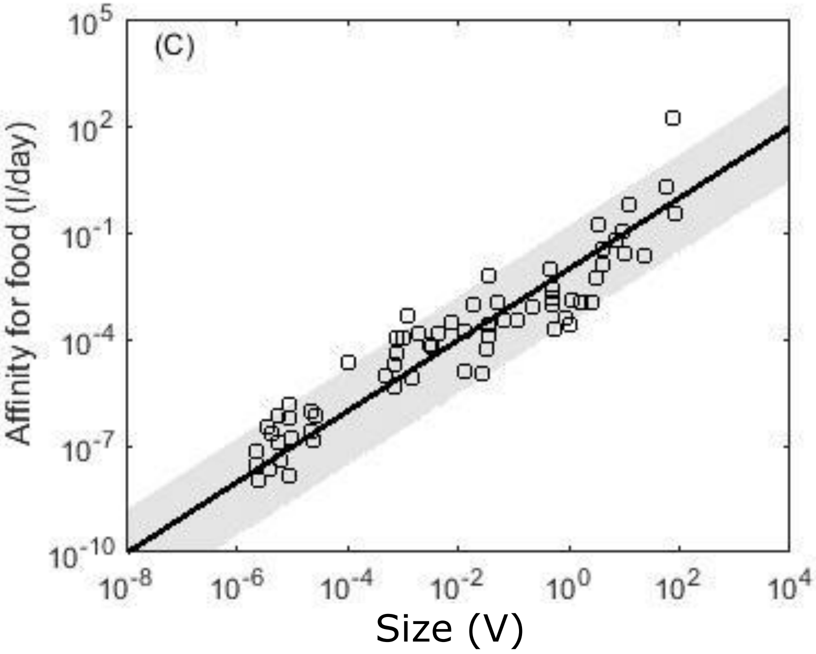


Edwards et al. (2012)

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:** $A_F = c_F V \frac{\alpha_F \phi_F V}{\alpha_F \phi_F V + c_F V}$

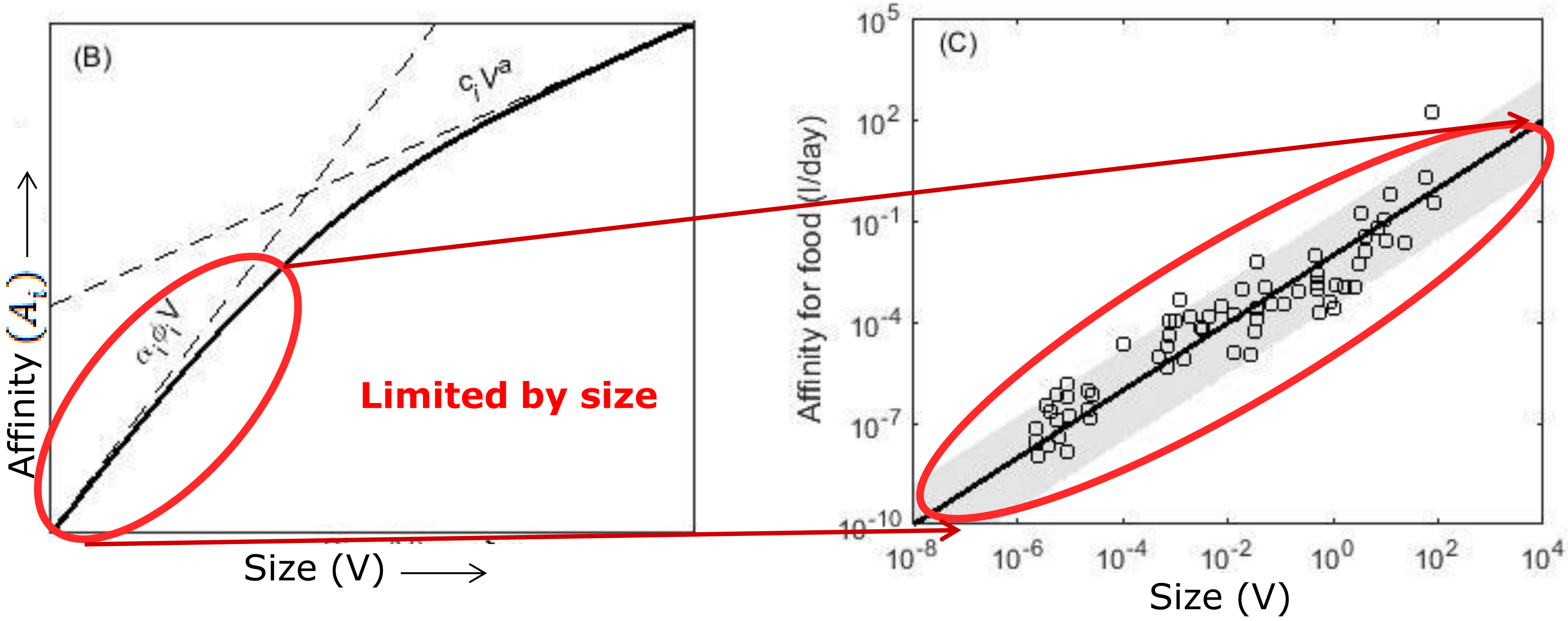




Kiørboe (2011)

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

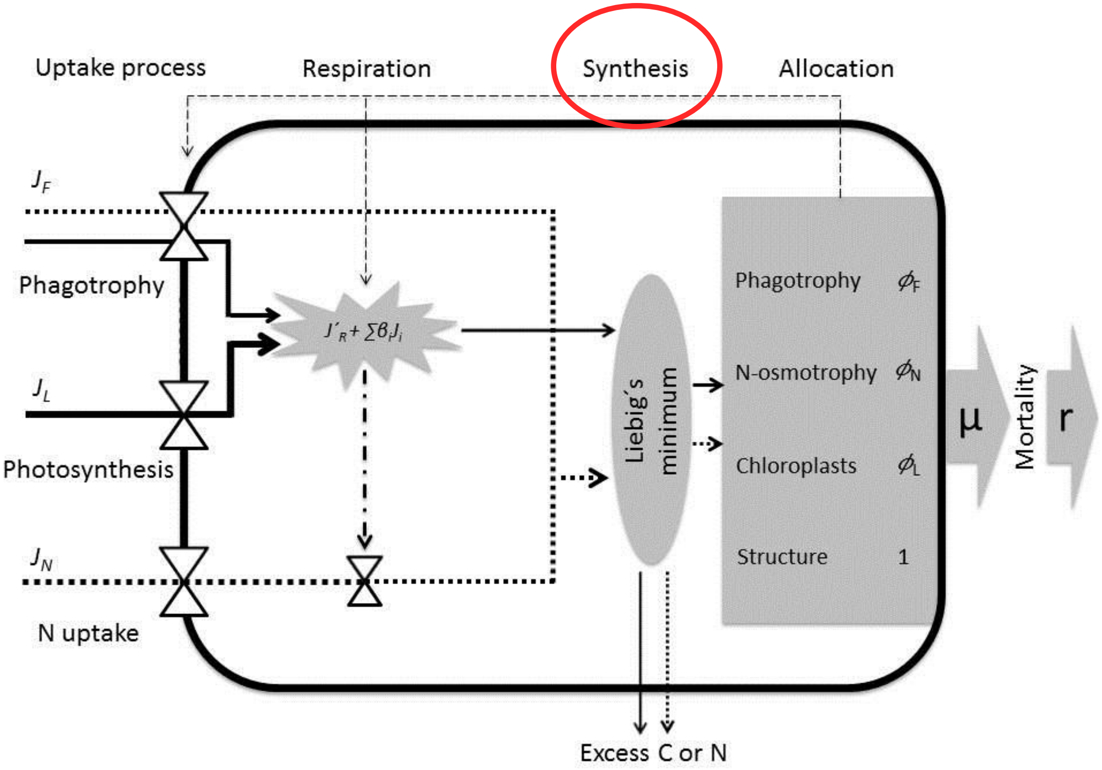
**Affinity for food:** $$A_F = c_F V \frac{\alpha_F \phi_F V}{\alpha_F \phi_F V + c_F V}$$



**Limited by size**

Kiørboe (2011)

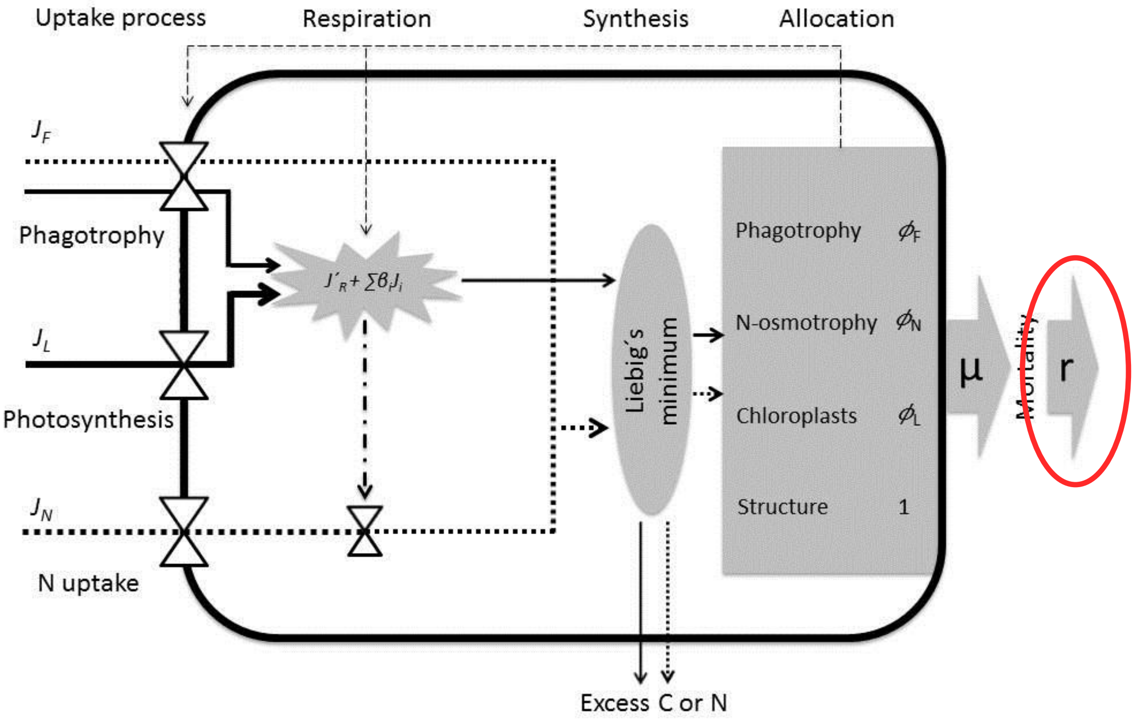
# Schematic representation of the model



**Final rate of biomass synthesis**

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

# Schematic representation of the model

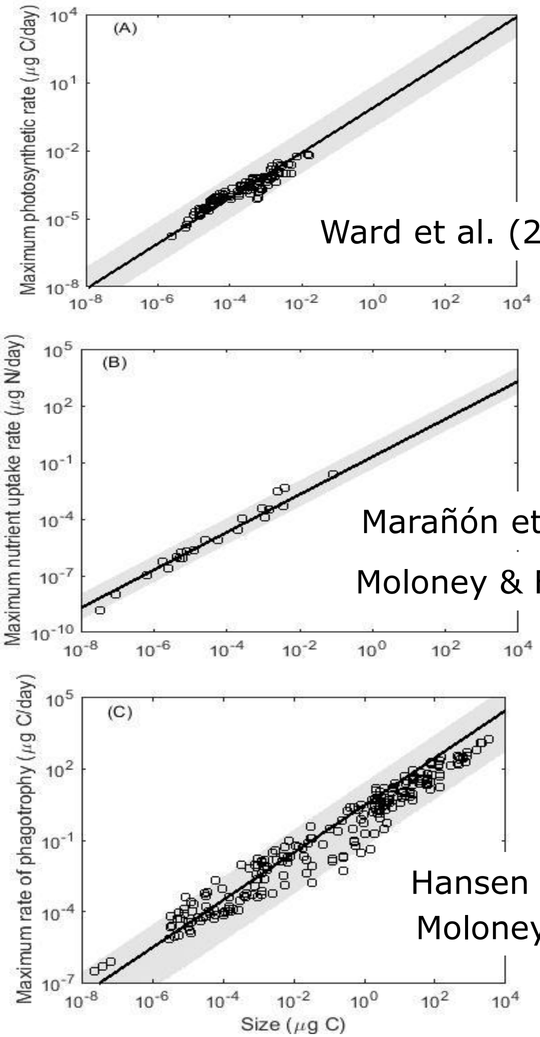


**Final growth rate :**

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

# Calibration of other parameters

## Max uptake rates



Ward et al. (2012)

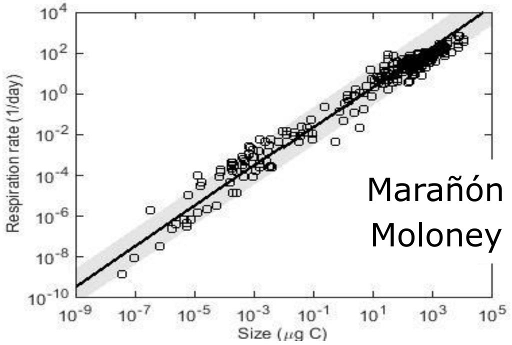
Marañón et al. (2013)

Moloney & Field (1989)

Hansen et al. (1997)

Moloney & Field (1989)

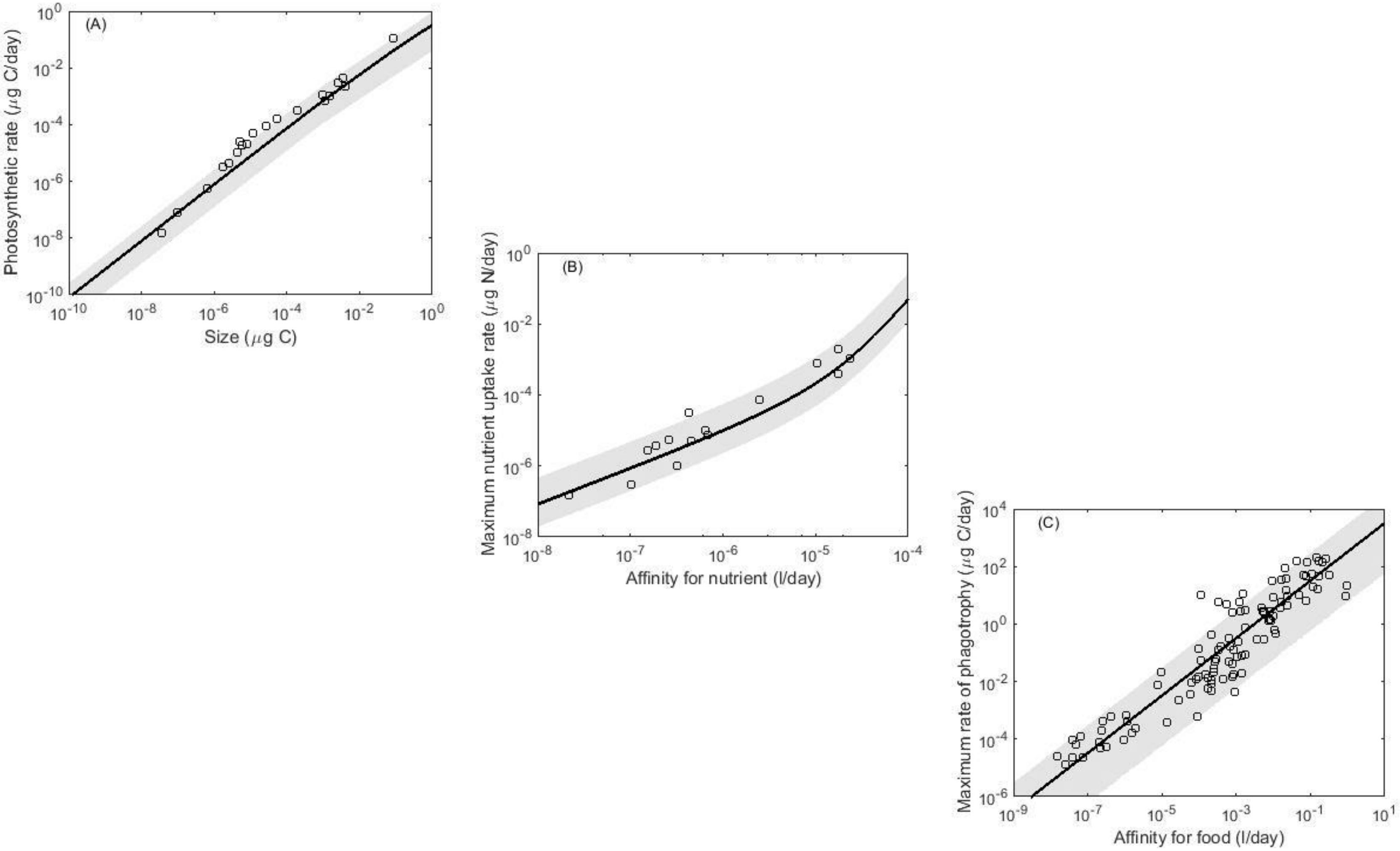
## Respiration rate



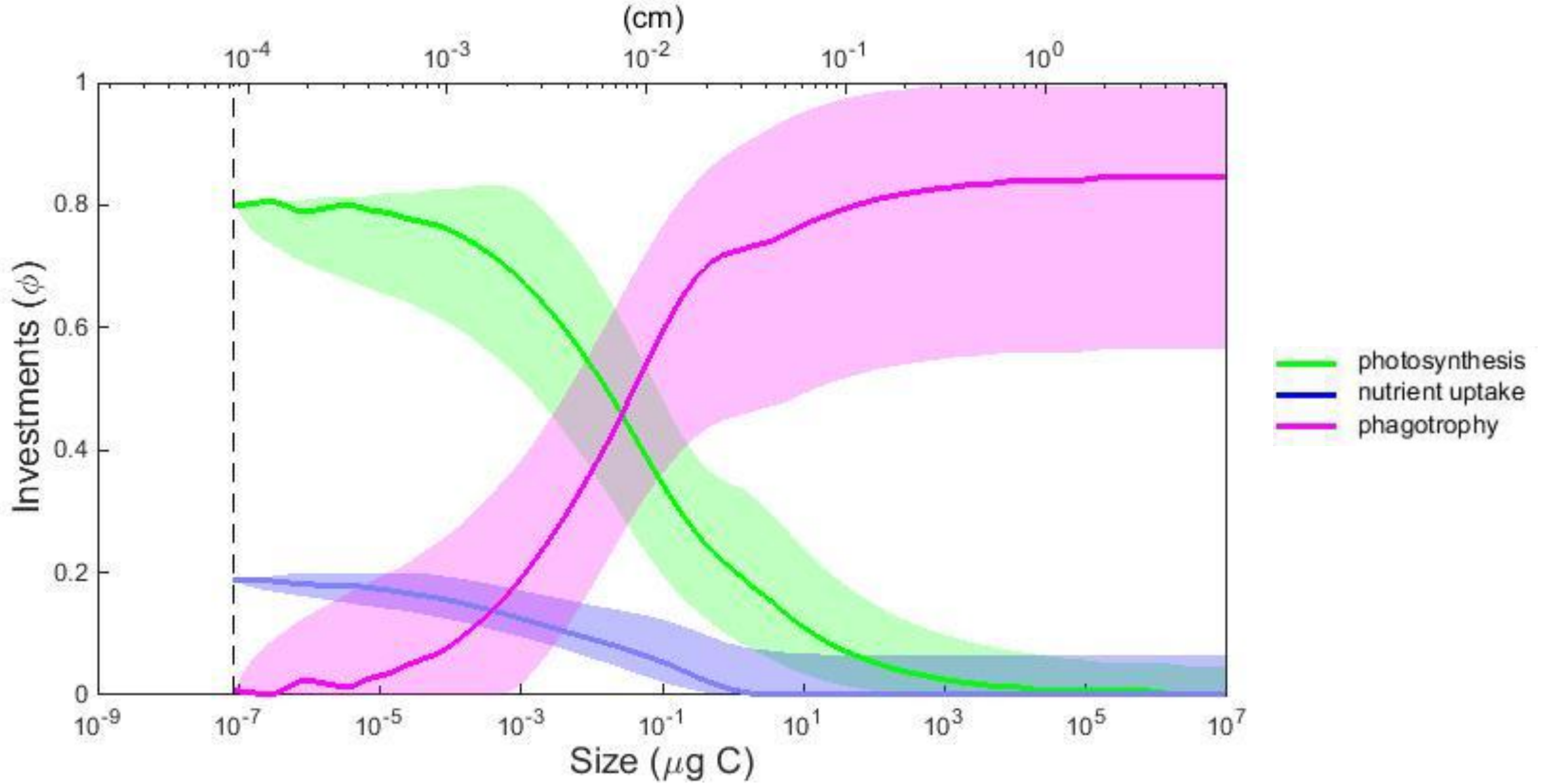
Marañón et al. (2013)

Moloney & Field (1989)

# Validation of calibrated parameters



# Optimal investments and trophic strategies



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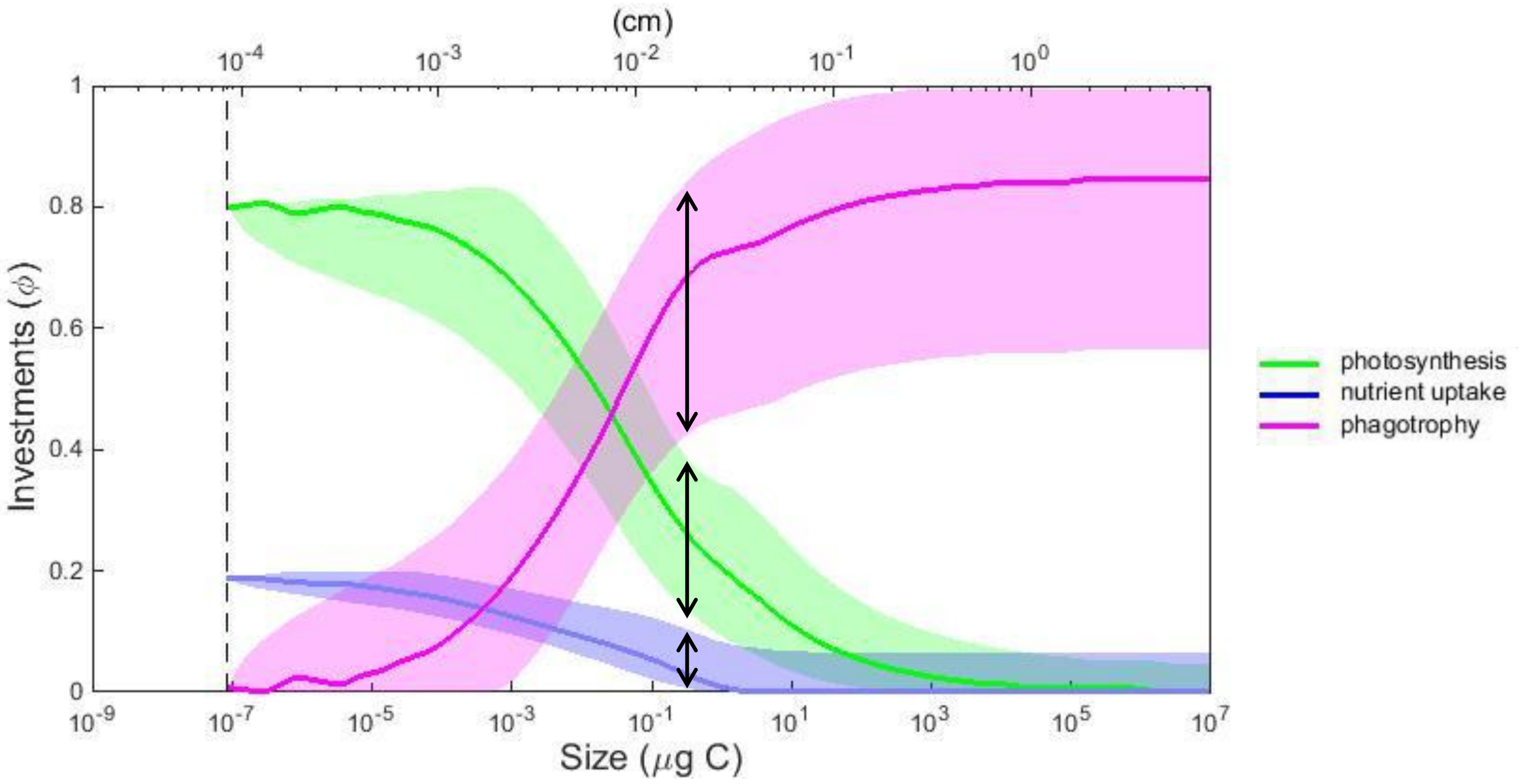
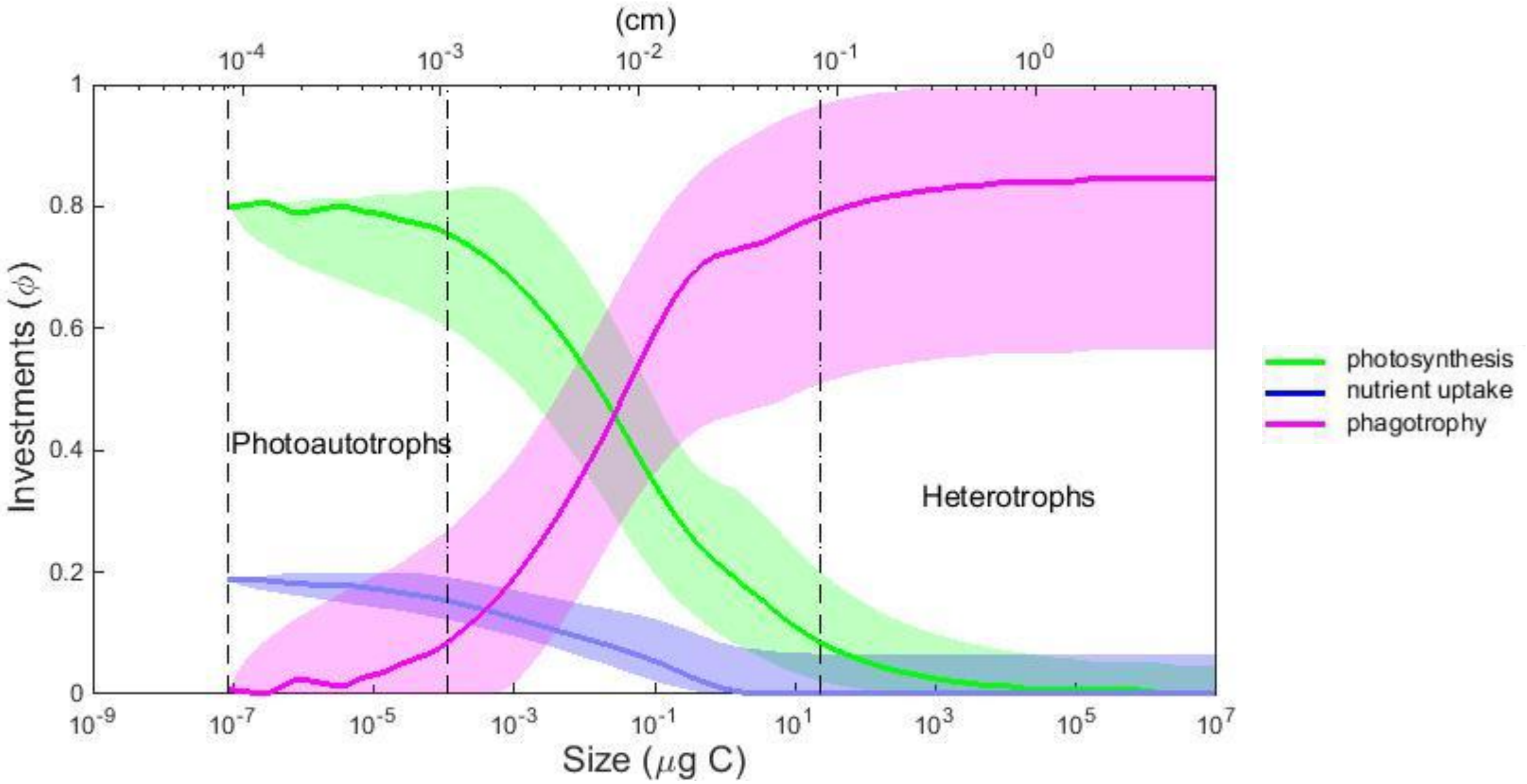


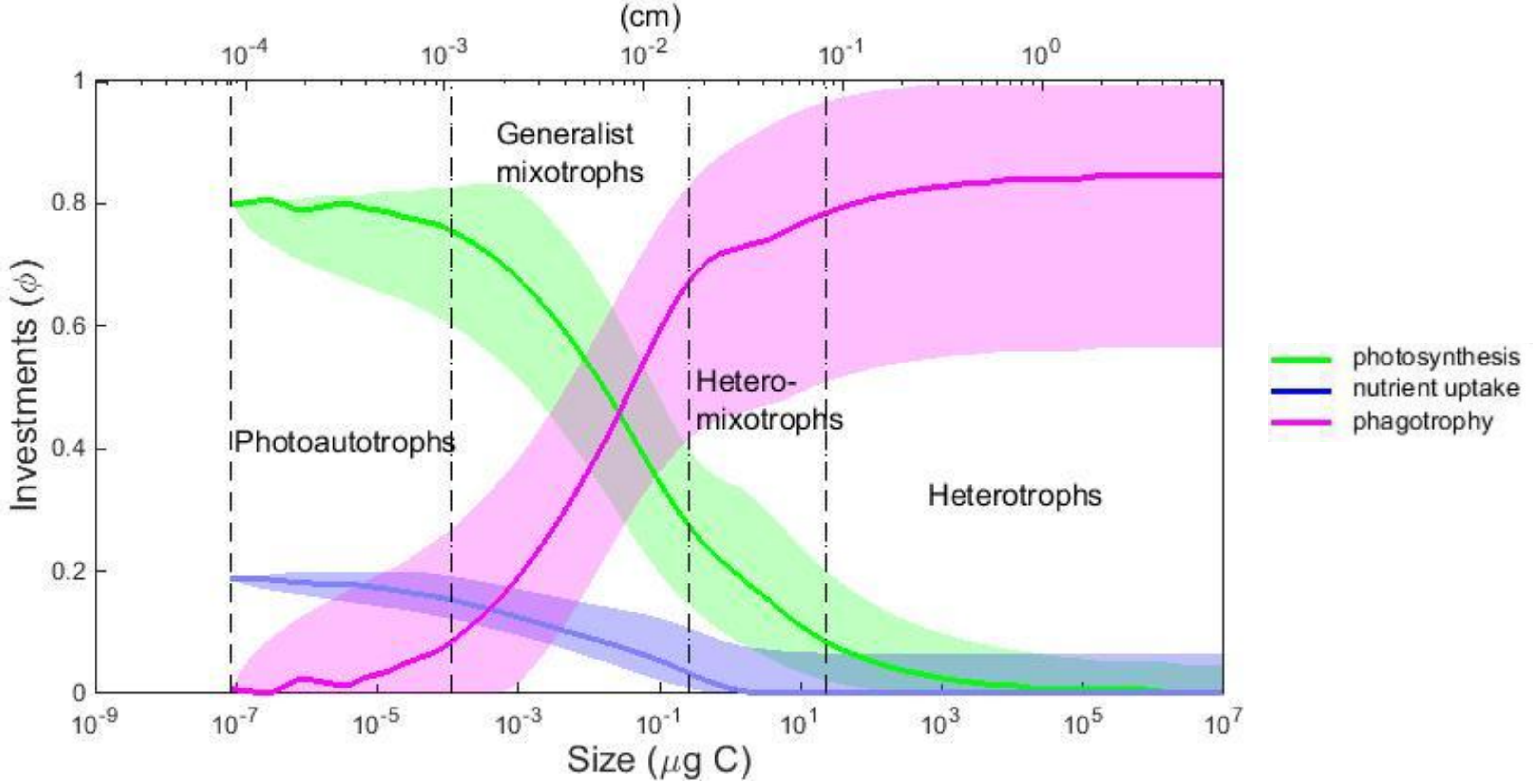
➡ Different possible strategies that keep the growth rate very close to the optimal one

# Optimal investments and trophic strategies



Relative investment in phagotrophy compared to investment in photosynthesis

# Optimal investments and trophic strategies

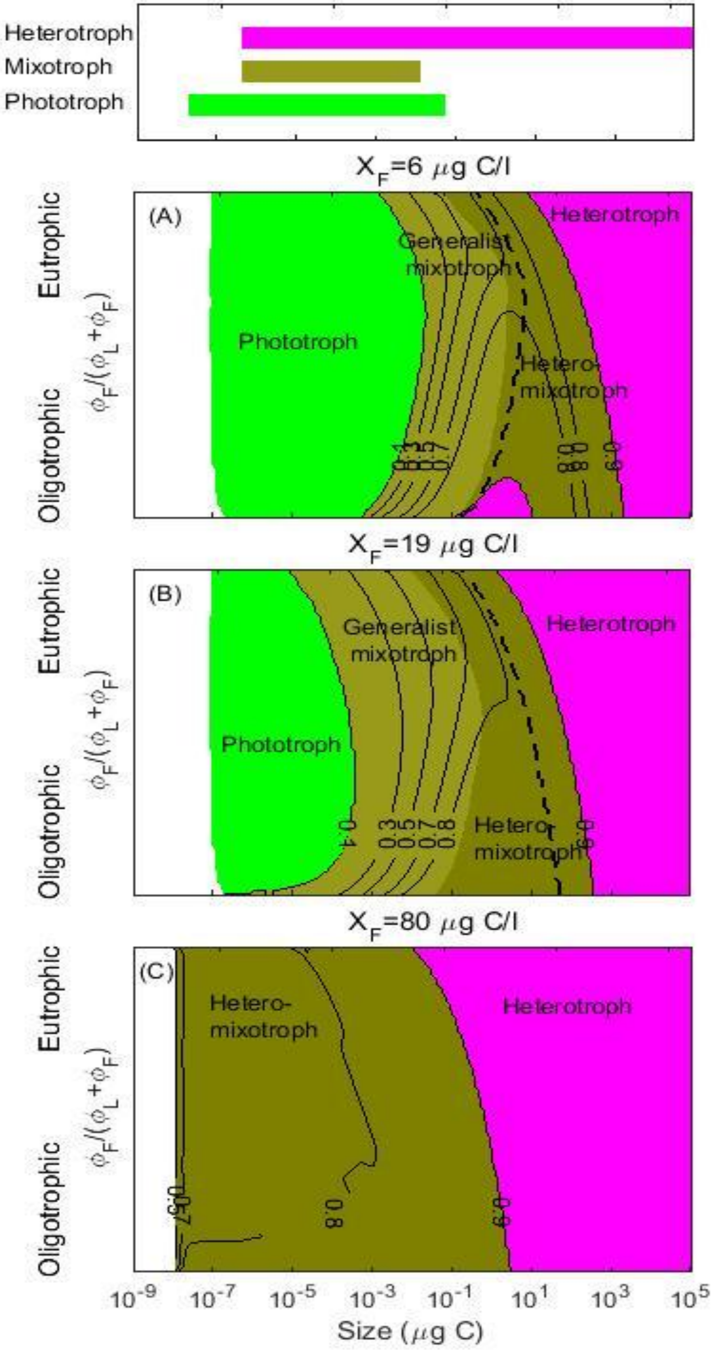


➡ Relative investment in phagotrophy compared to investment in nutrient uptake

# 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



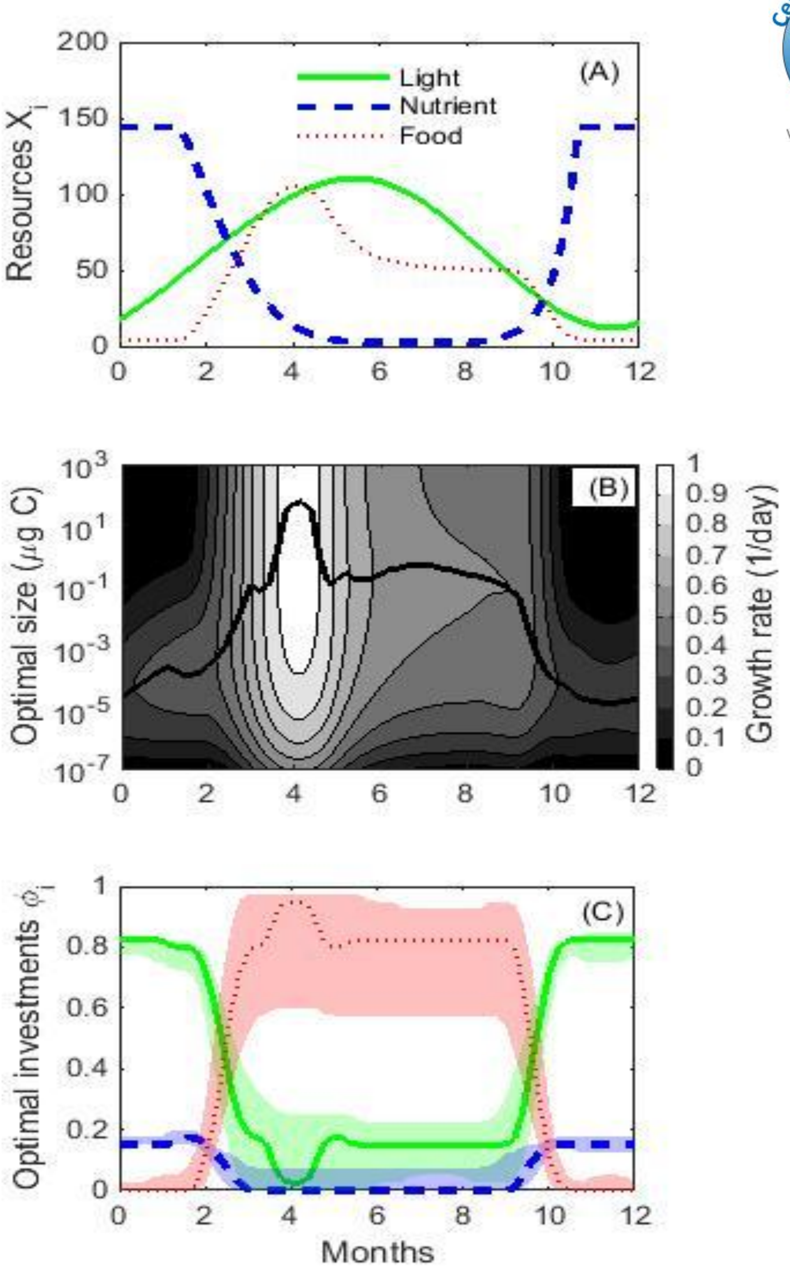
# Conclusions:

- 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



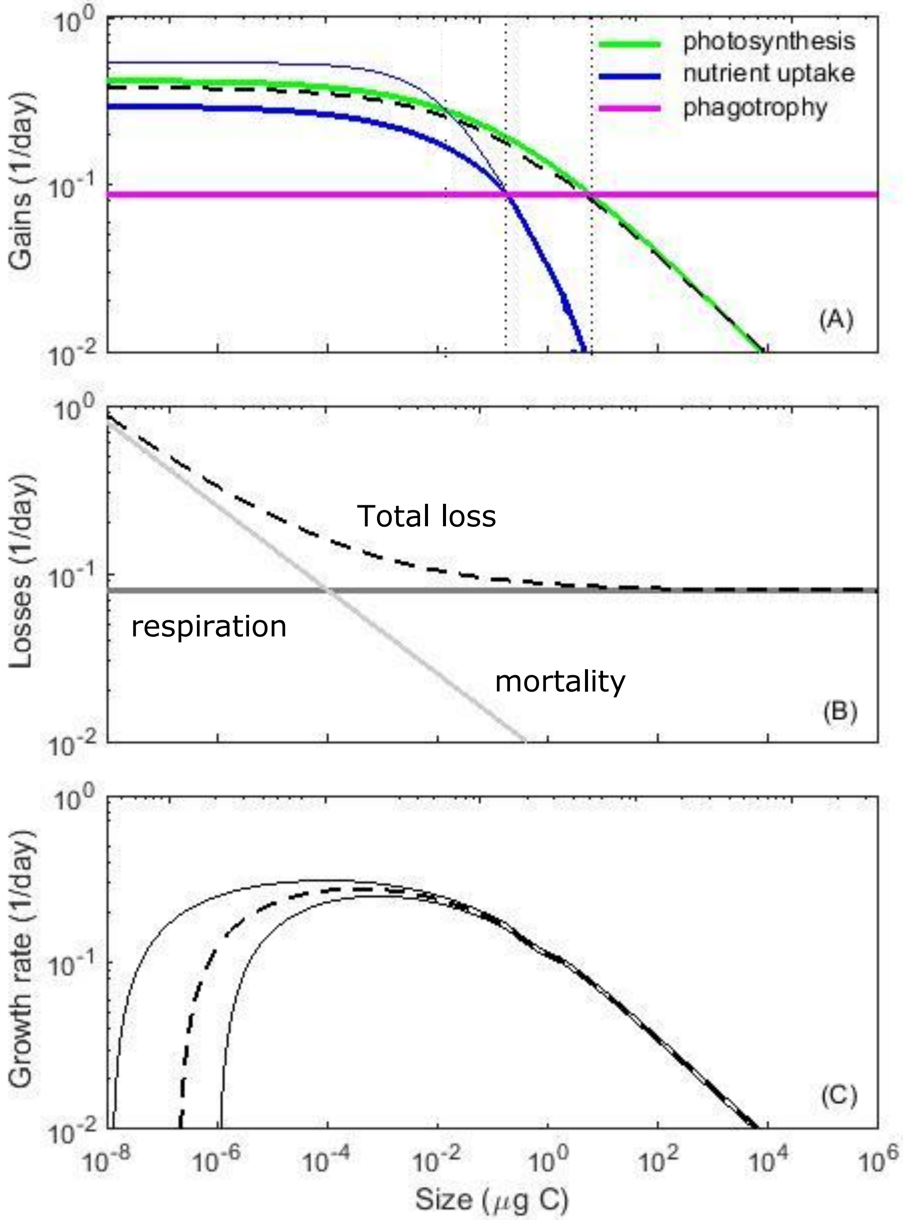
# Acknowledgment :

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**



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