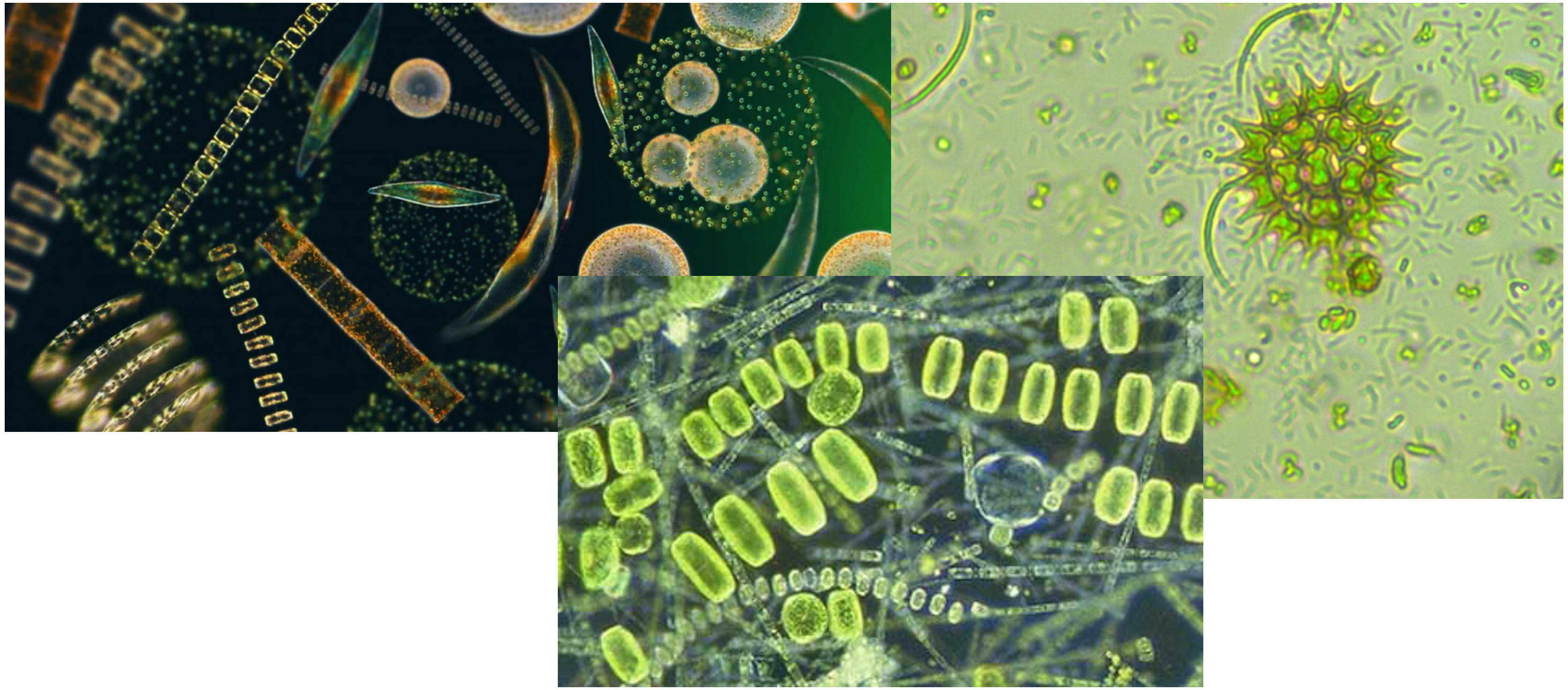
Predicting phytoplankton metabolism from the individual size distribution

Daniel Padfield

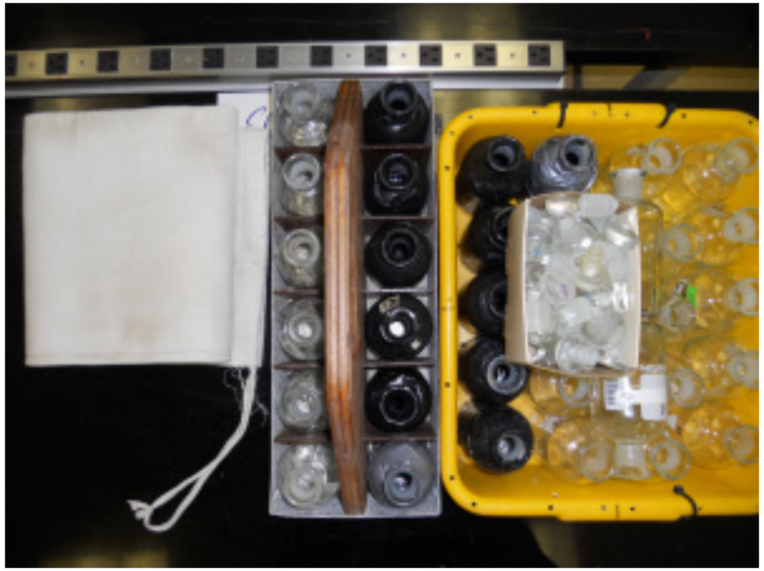
Phytoplankton are key for the carbon cycle

- ~50% of annual carbon fixation
- Fuel entire ocean food webs



Current measurements of metabolism

Bottle incubations – *in vivo*



- Snapshot in time
- Single community
- Control over environmental variables

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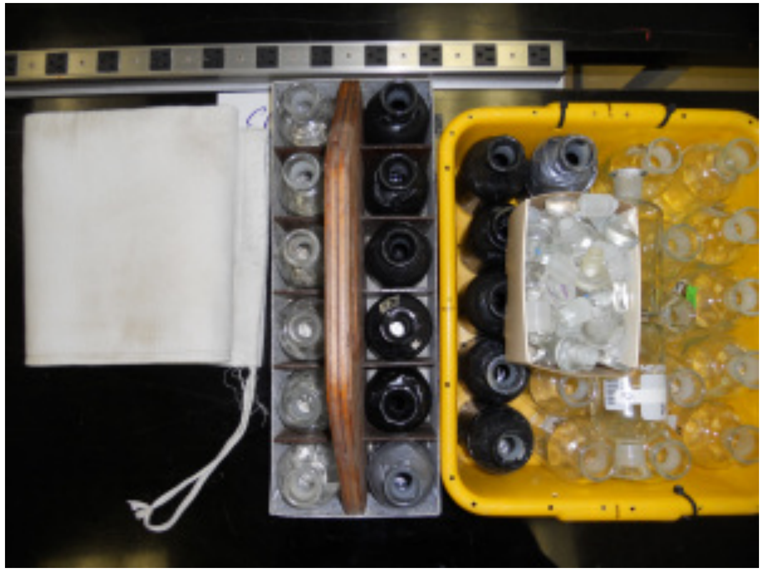


- Snapshot in time
- Single community
- Control over environmental variables

Gas measurements – *in situ*

- Integrates over large areas
- Many communities and many different environmental conditions

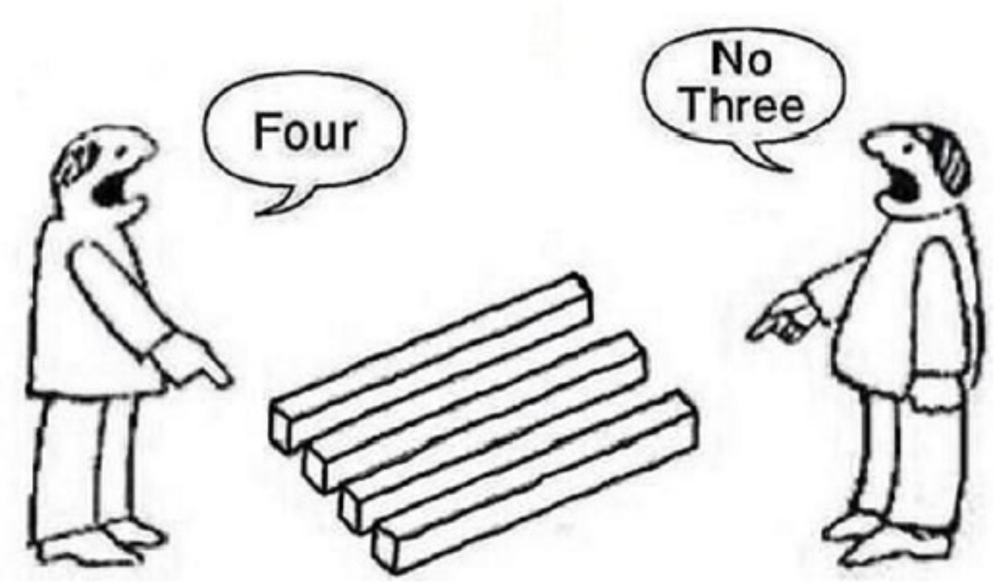
Current measurements of metabolism

Bottle incubations – *in vivo*

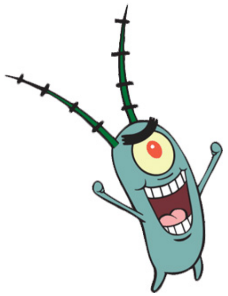
- Most of the open ocean is net heterotrophic

Gas measurements – *in situ*

- Most of the open ocean is net autotrophic



Crash course in metabolic theory



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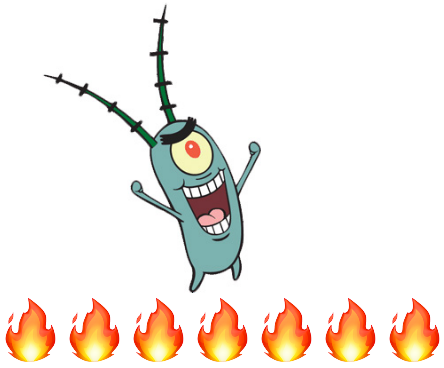
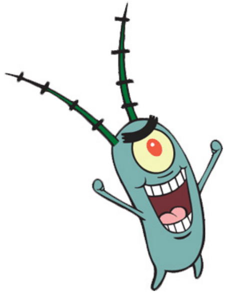


$$e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$

E previously found to be around 0.8 eV for photosynthesis and > 1 for respiration in phytoplankton

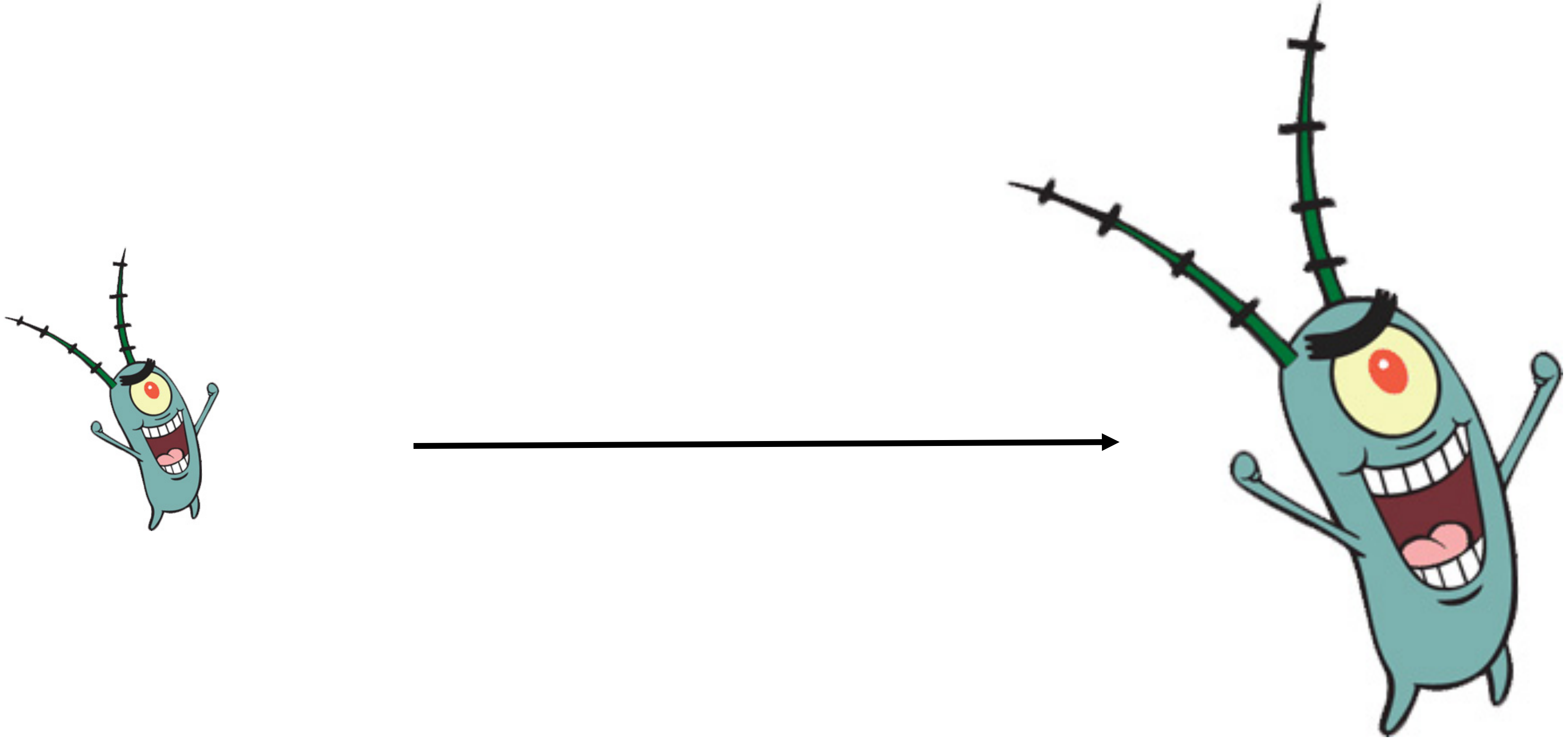
Crash course in metabolic theory



$$m_i^a$$

a previously found to be around 0.75 in most animals, but around 1 for phytoplankton

Crash course in metabolic theory



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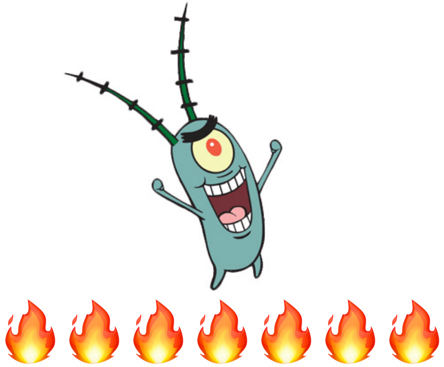

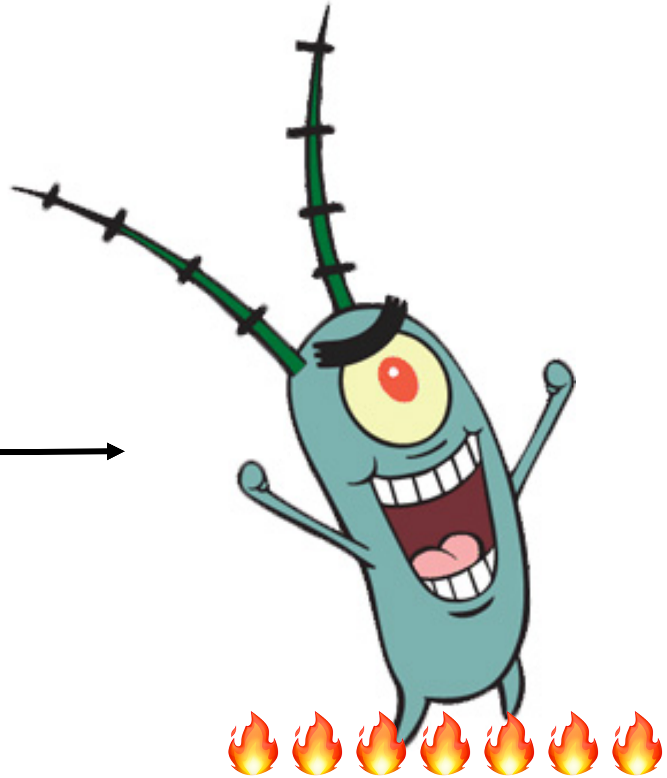

$$b_i(T_c)m_i^a e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$

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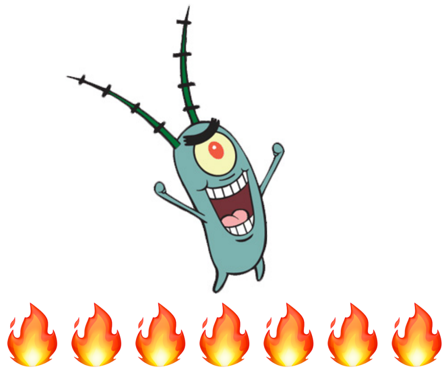

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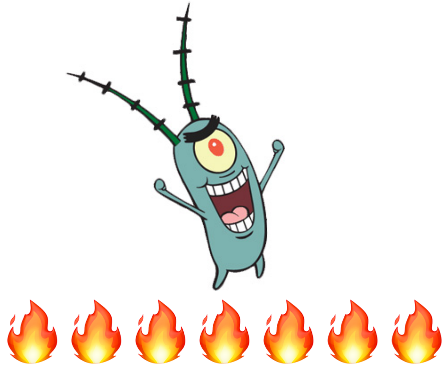
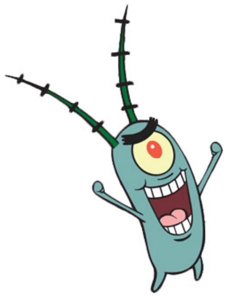
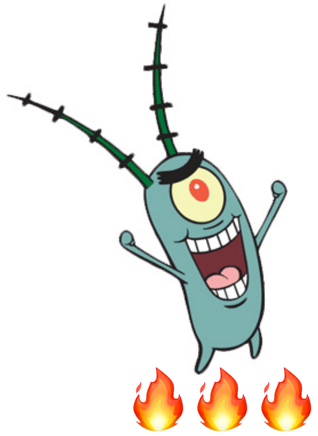
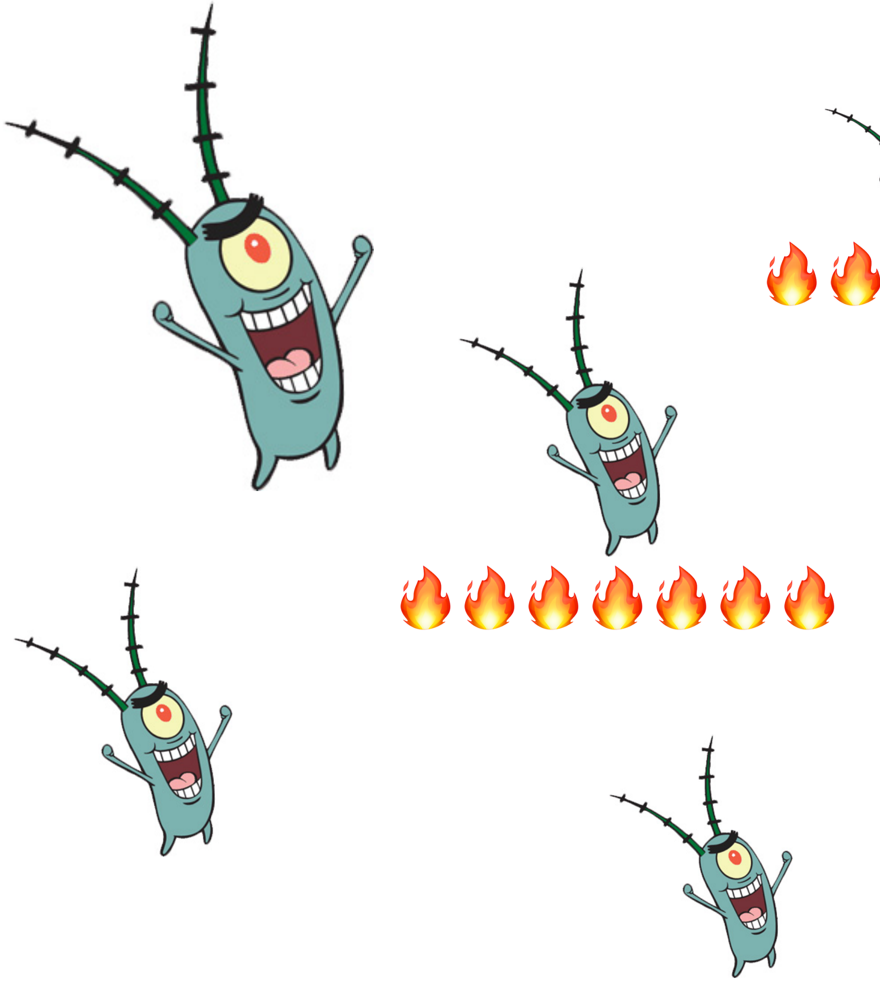


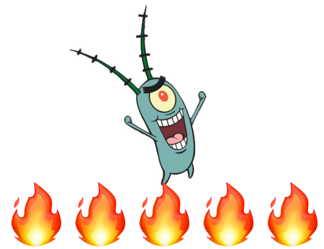


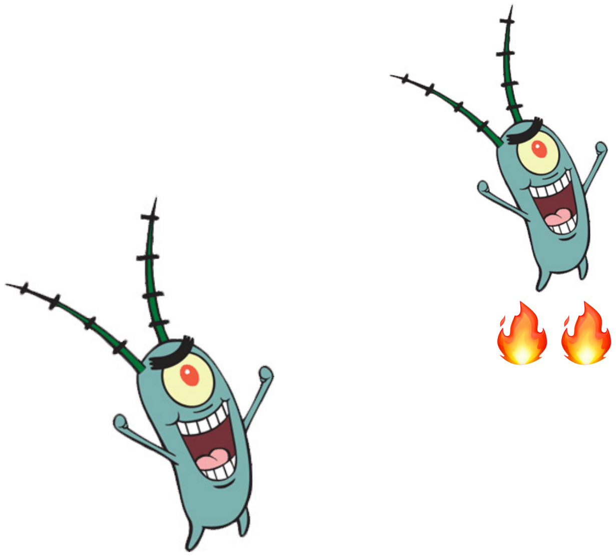


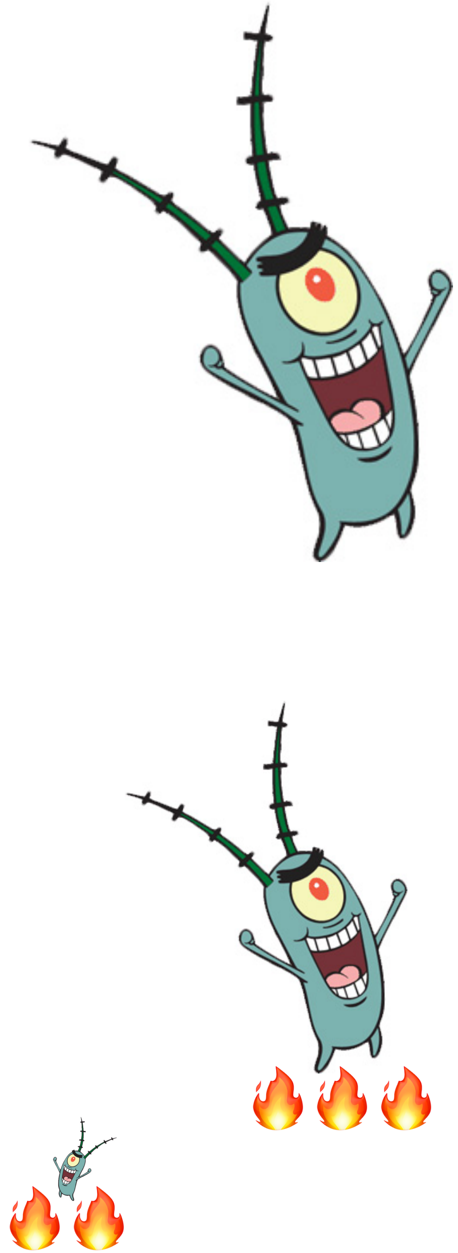
$$\sum_{i=1}^{n_{tot}} b_i(T_c)\, m_i^a e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$

Crash course in metabolic theory









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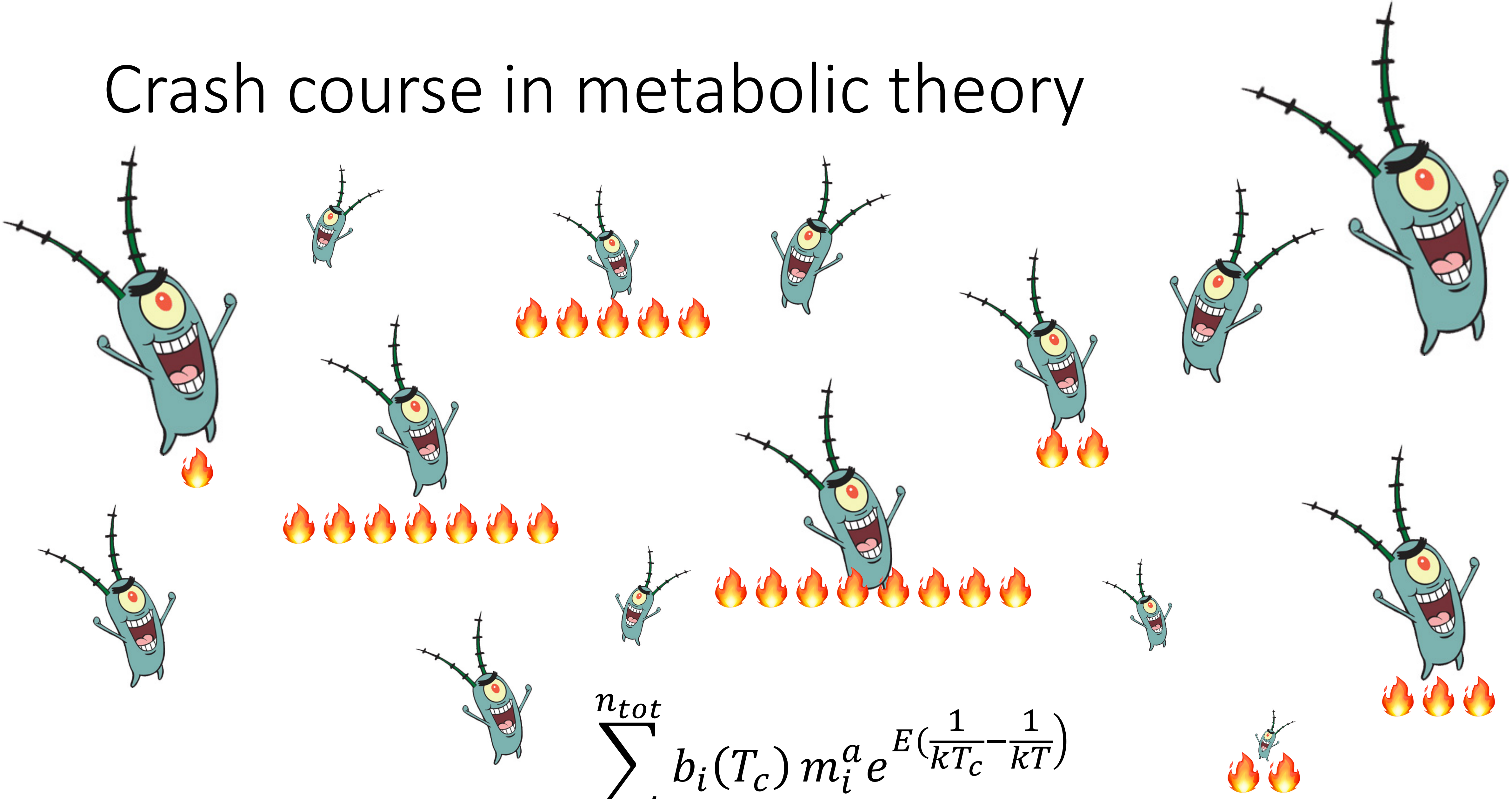

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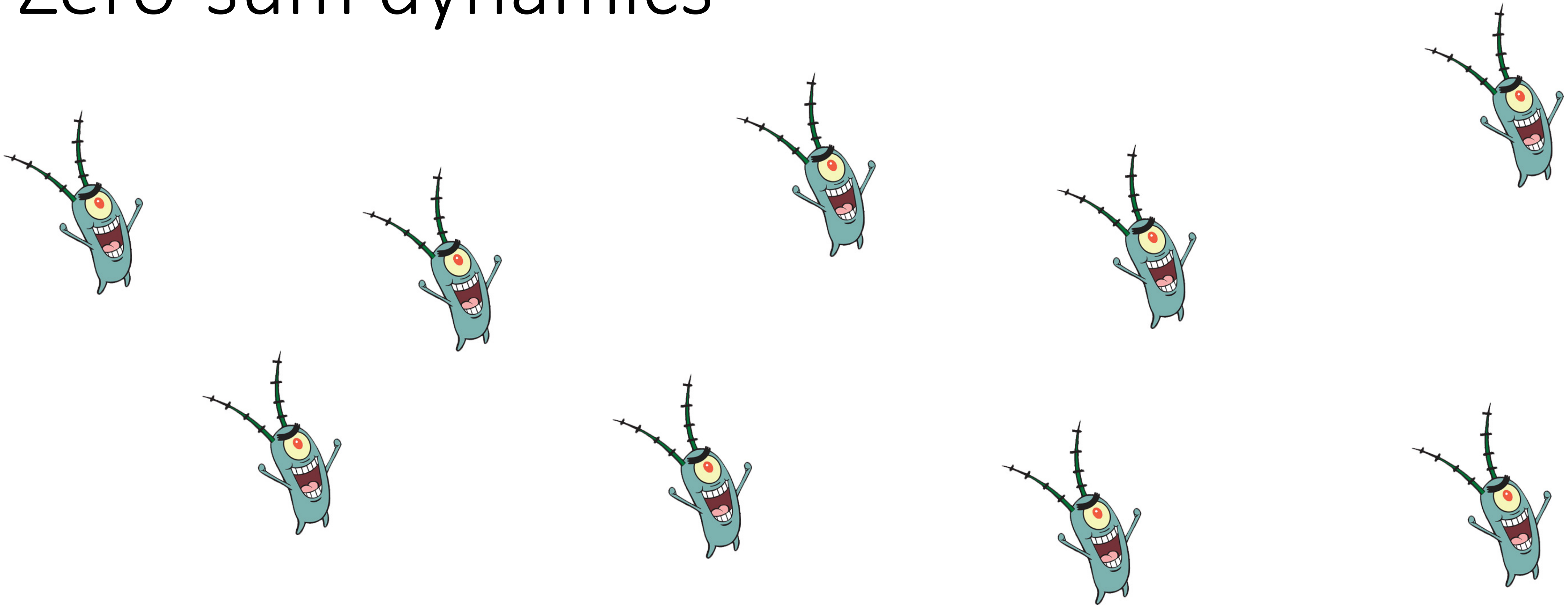
Zero-sum dynamics



$\overline{m_i^a} \uparrow$

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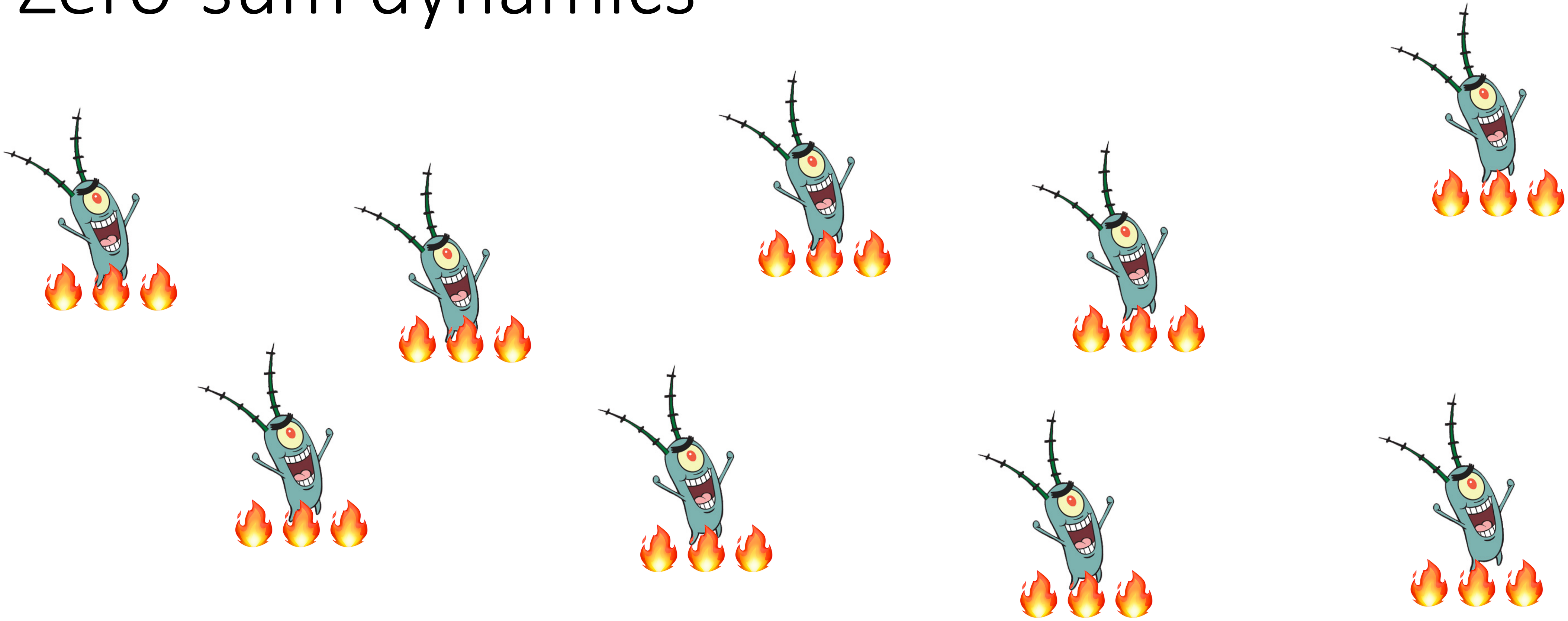

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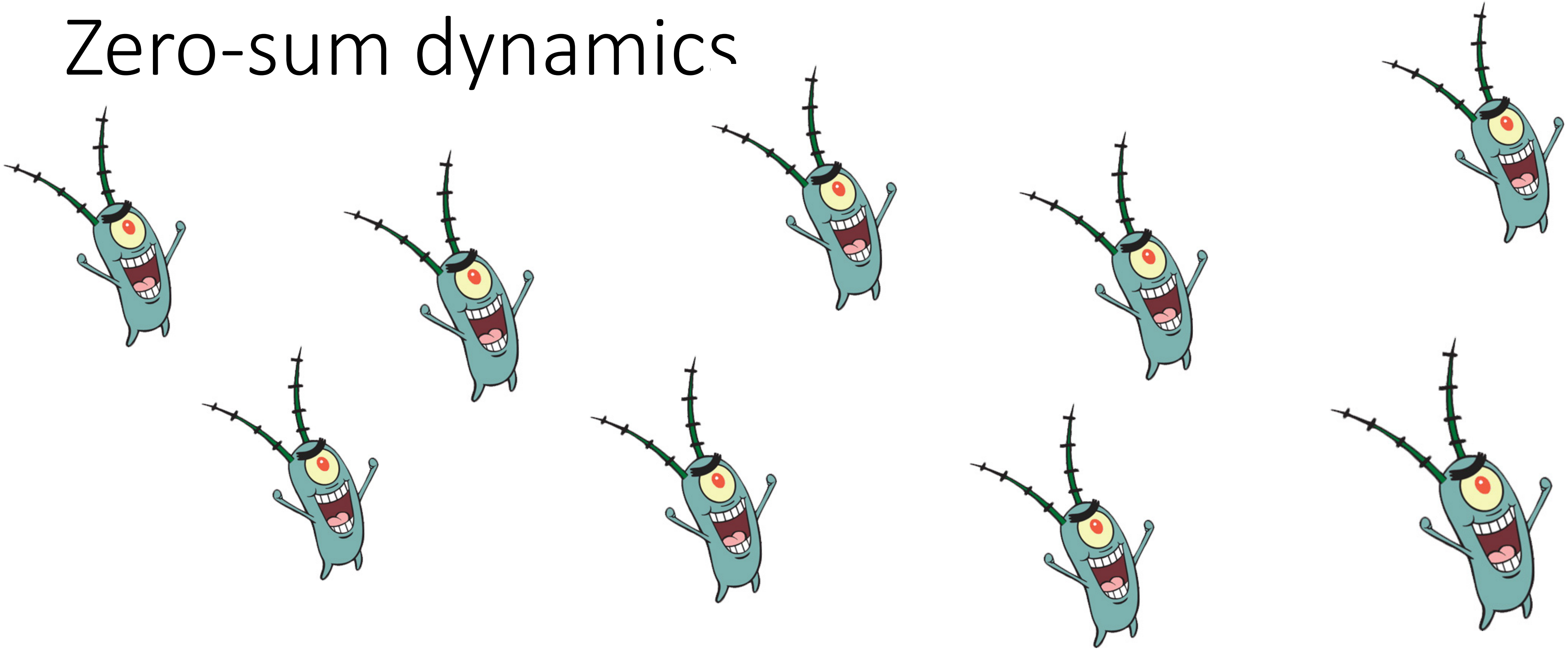

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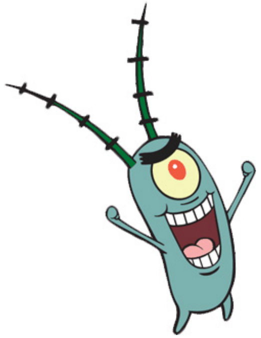

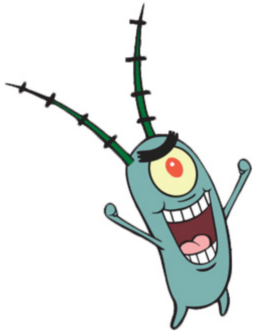

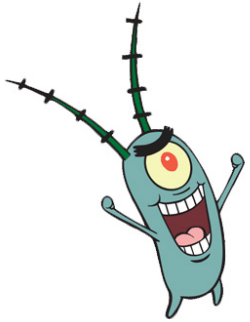

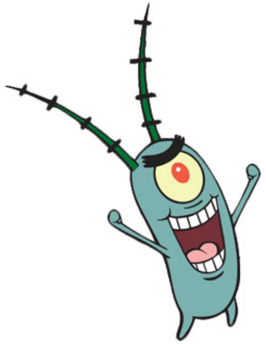

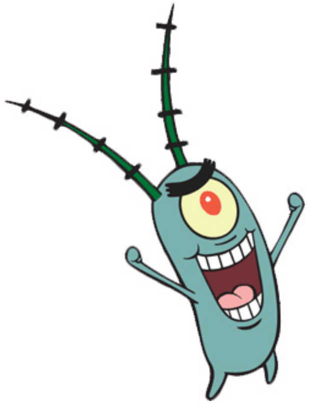

$$\overline{m_i^a} \uparrow \quad n_{tot} \downarrow$$

Predictions

- Can predict metabolism of whole communities from the size- and temperature-dependence of individuals
- Across-communities, there will be a trade off between total abundance and average individual metabolic rate
- Trade offs mean raw metabolism may be stable across communities

Experimental setup

10 years warming : half 4ºC above ambient

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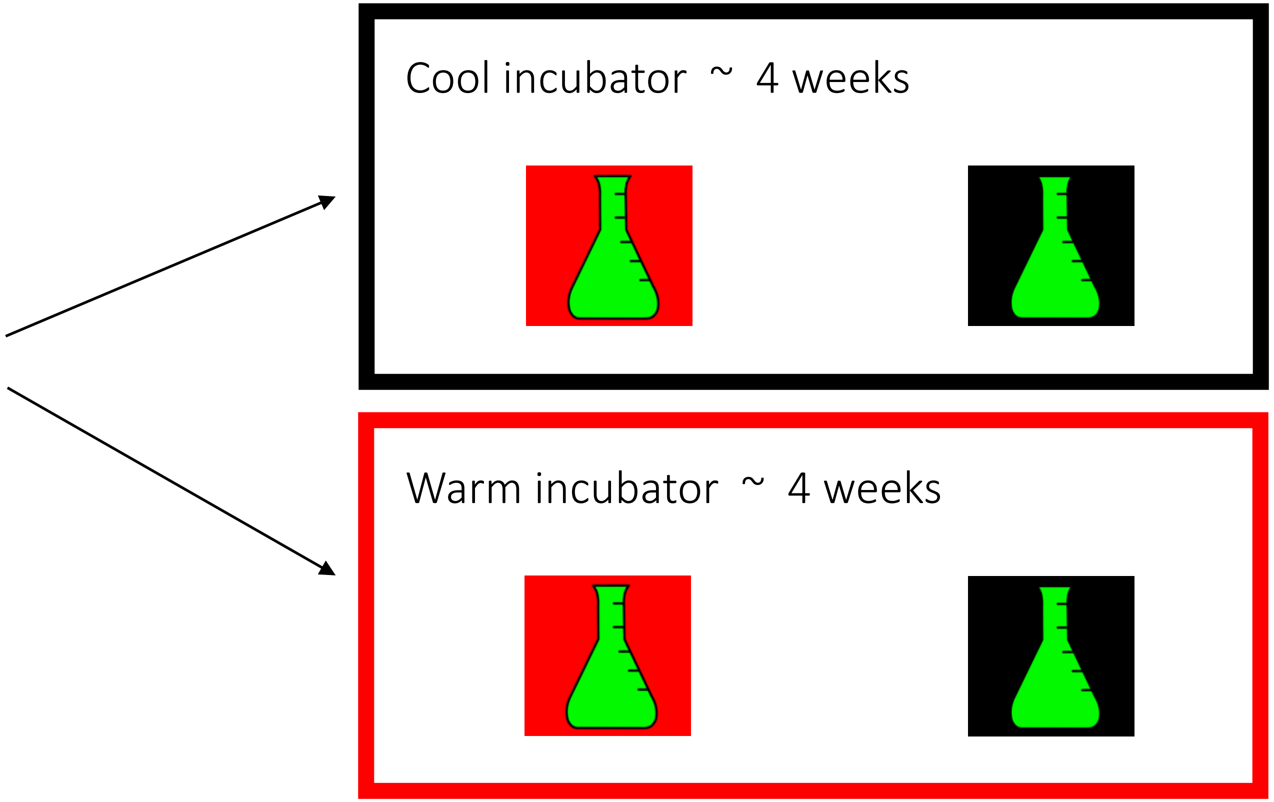
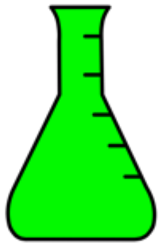
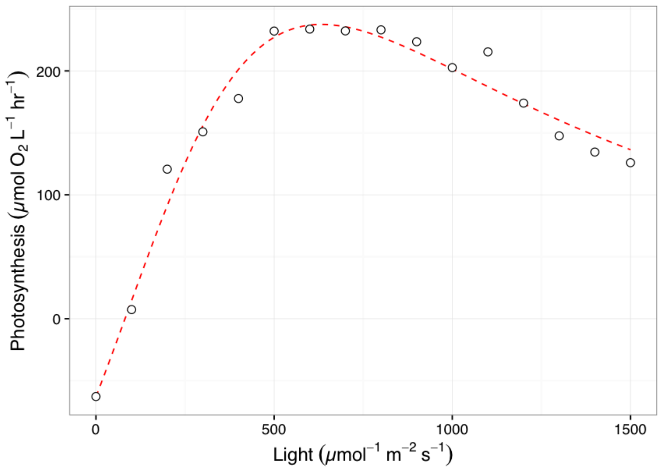
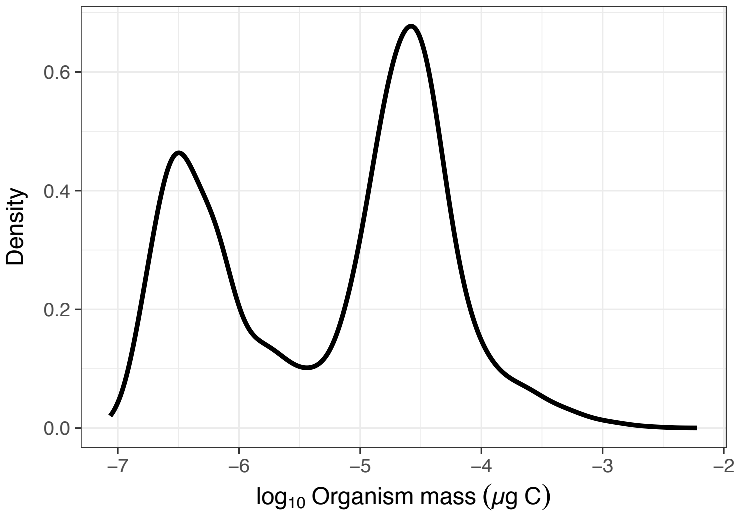
How do the communities and their functioning change in response to long-term and short-term warming



Measurements



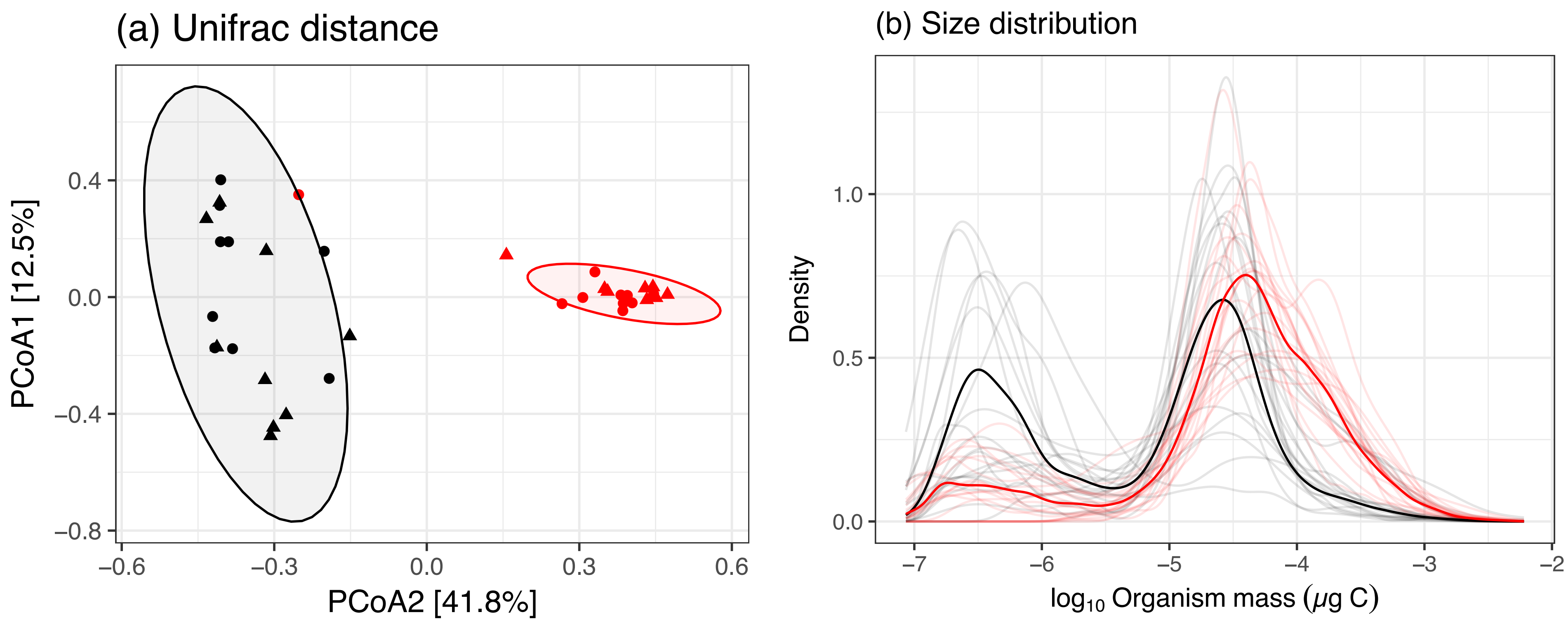




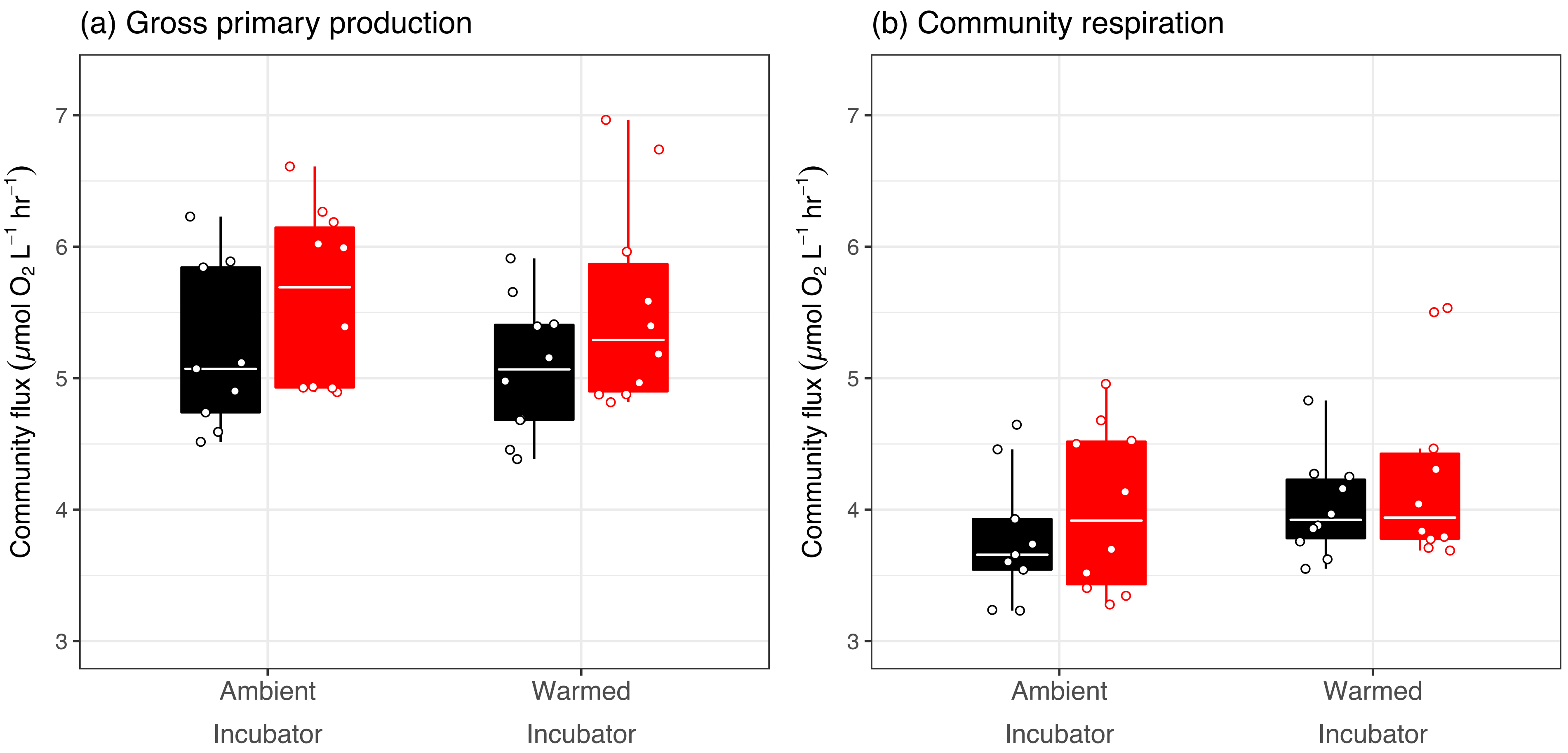
Metabolism @ incubator temperature
1 point for each microcosm

Size distribution
> 300 points per sample!

Long-term warming changes communities



No difference in measured raw metabolism



Model

$$B_j(T) = \sum_{i=1}^{n_{tot}} \underbrace{b_i(T_c)}_{b_i(T_c) \text{ - the individual normalisation constant}} \overbrace{m_i^a}^{a \text{ - how rates change with body size}} \underbrace{e^{E\left(\frac{1}{kT_c} - \frac{1}{kT}\right)}}_{E \text{ - how rates change with temperature}}$$

Model predicts size and temperature-dependence

parameter	**units**	**estimate**	**95% confidence interval**
E_{GPP}	eV	0.741	0.196 - 1.286
E_{CR}	eV	1.417	0.853 - 1.982
α_{GPP}	-	0.887	0.567 - 1.174
α_{CR}	-	1.101	0.743 - 1.412
$\ln GPP(T_c)$	μmol O_2 L^{-1} hr^{-1}	-3.426	-6.335 - -0.989
$\ln CR(T_c)$ **(ambient mesocosm)**	μmol O_2 L^{-1} hr^{-1}	-2.717	-5.943 - -0.150
$\ln CR(T_c)$ **(warm mesocosm)**	μmol O_2 L^{-1} hr^{-1}	-3.110	-6.126 - -0.650

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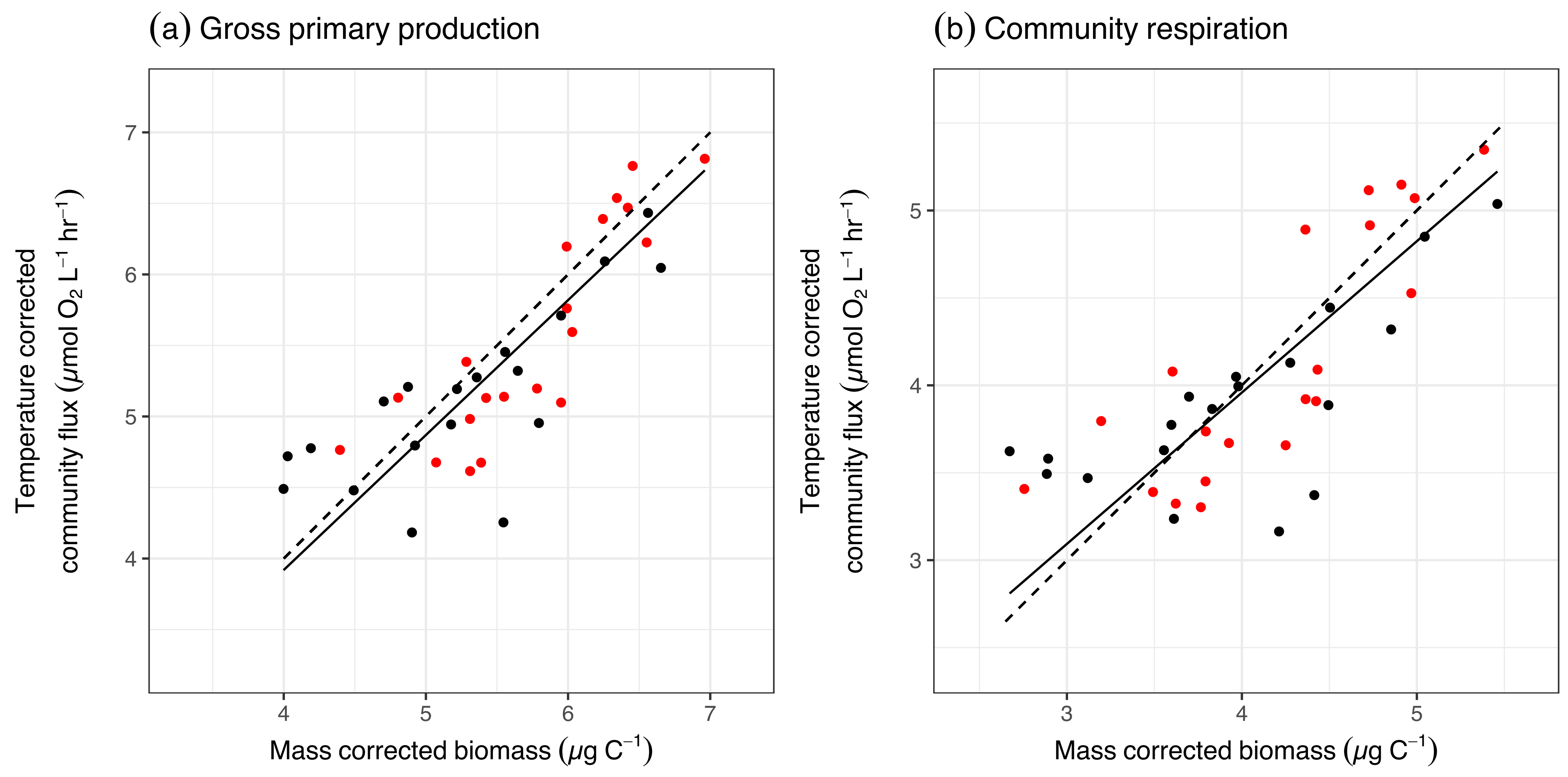
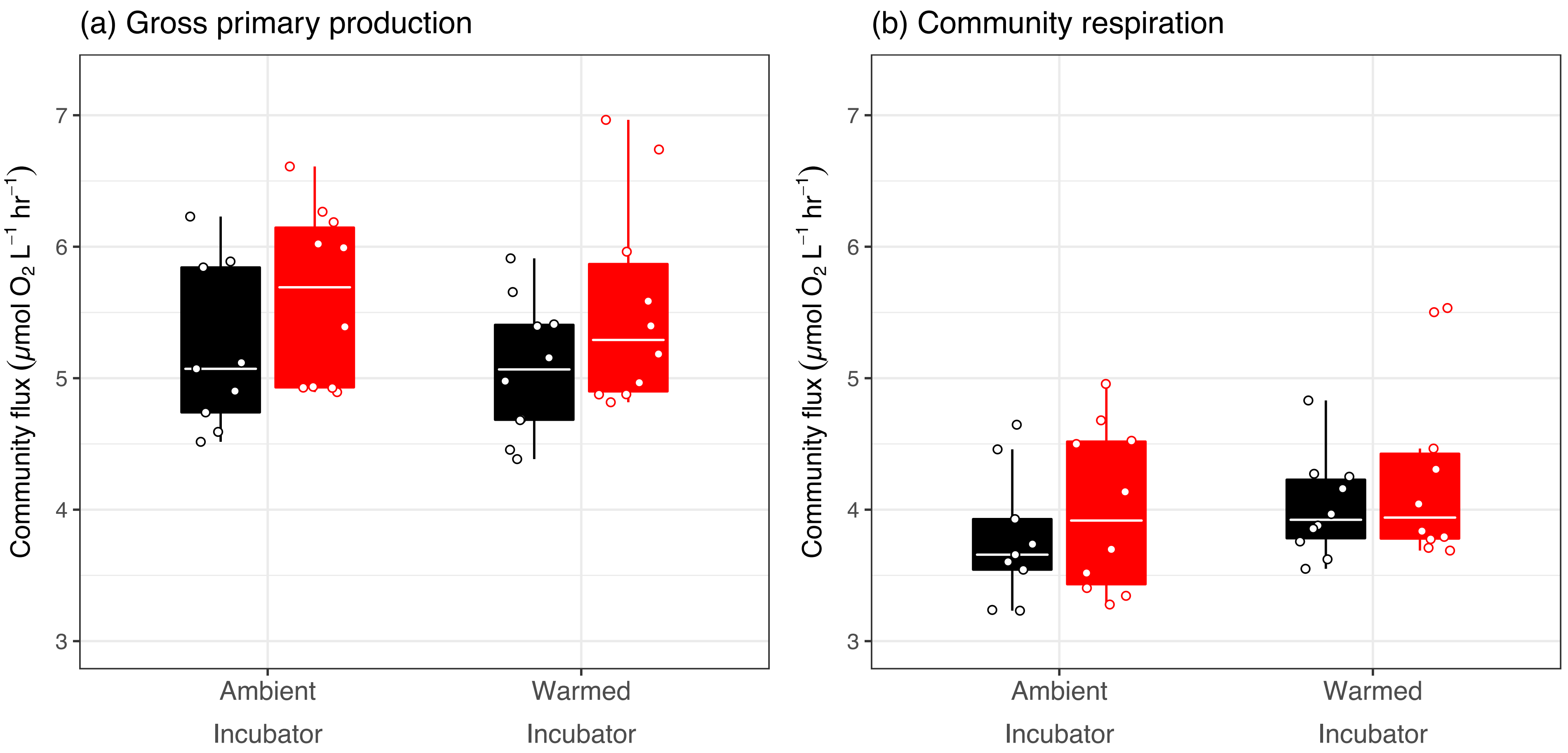
Model does a pretty good job!

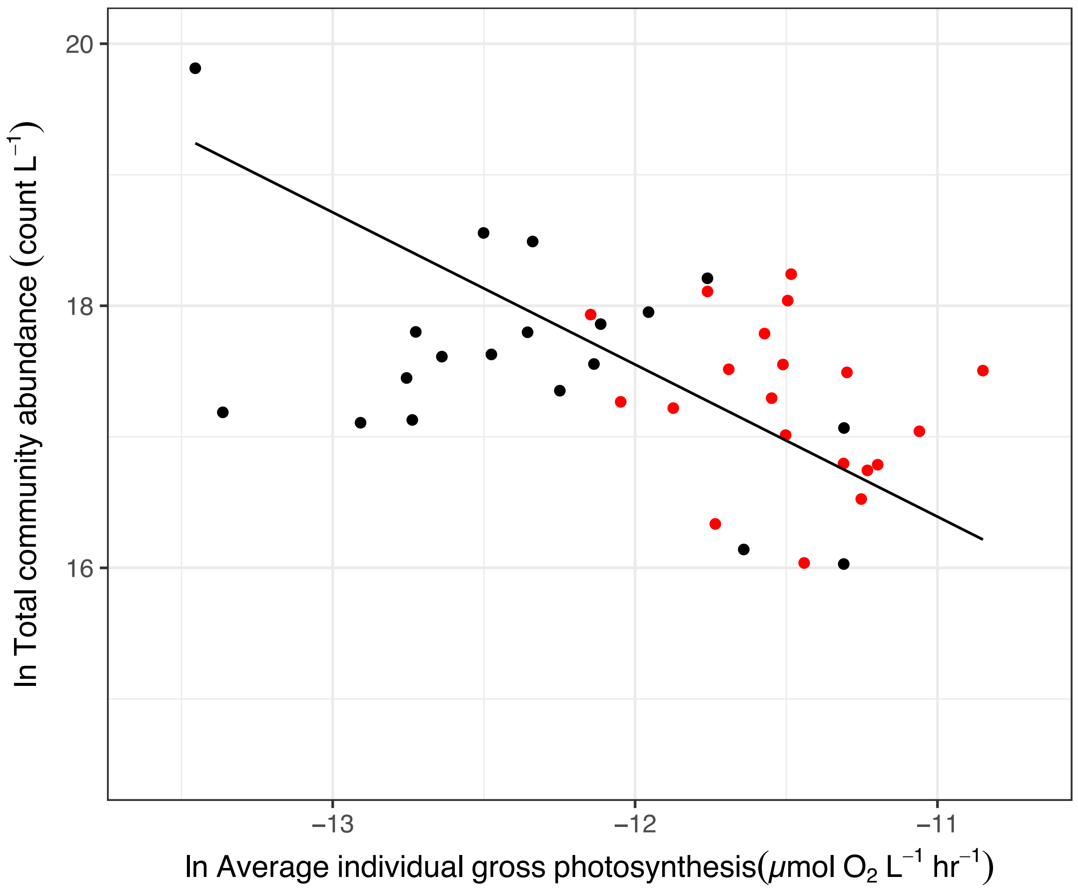


Paradoxical result?



Zero-sum dynamics

$$\overline{m_i^a} \uparrow \quad n_{tot} \downarrow$$



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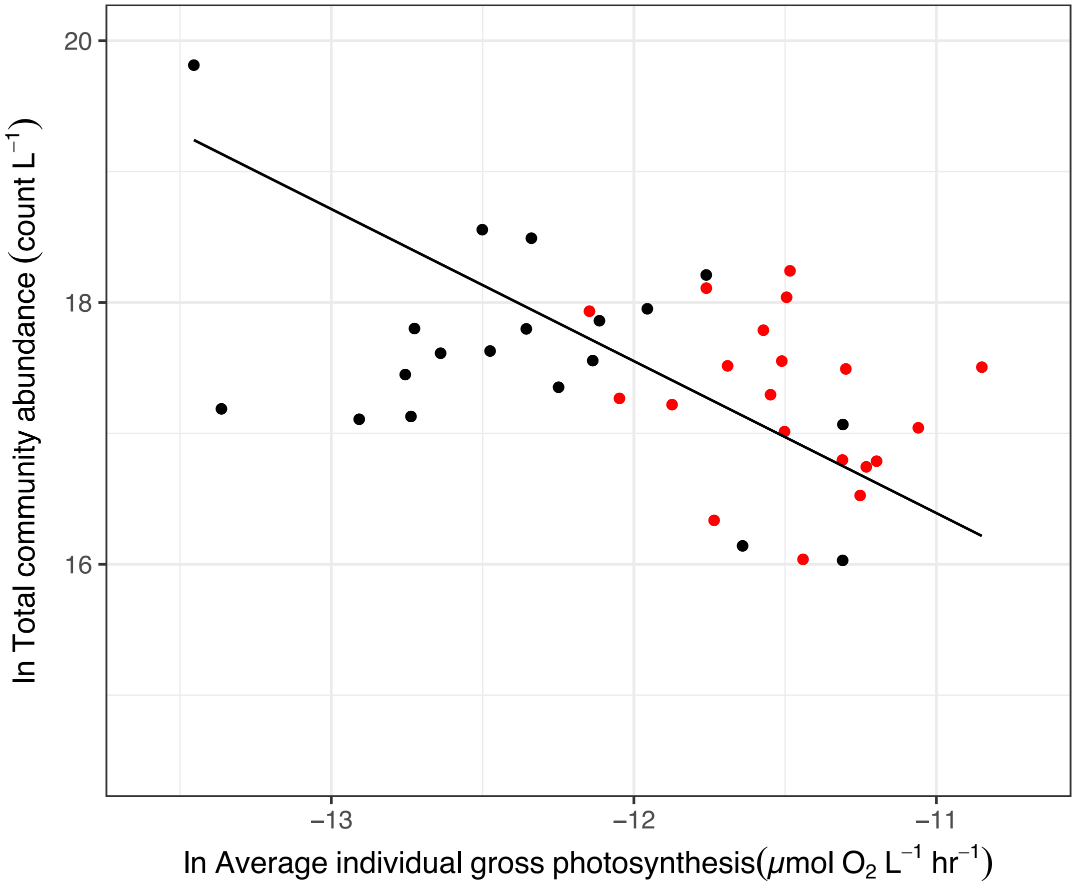
Slope = - 1.16 (95% CI: -1.58 - -0.86)
Not different from -1



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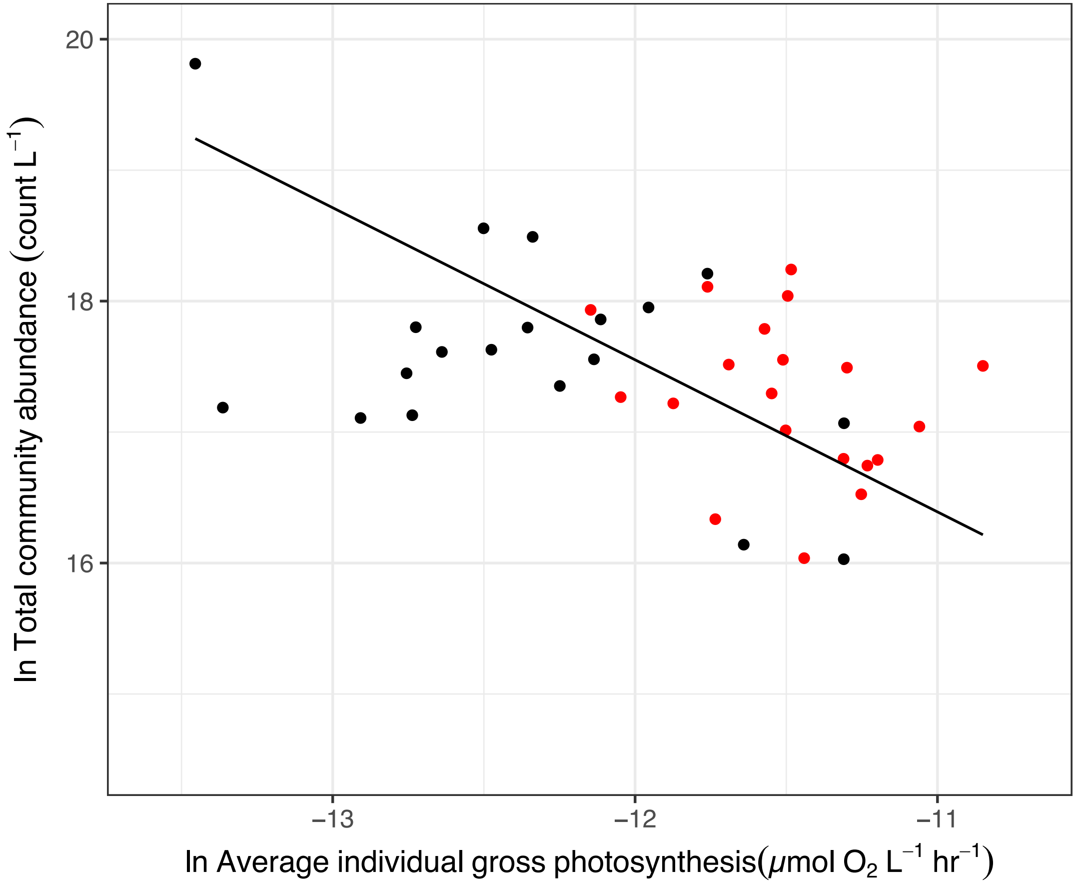
Nutrient concentrations are going to be key for determining response to warming.



Conclusions

- Empirically validated some key assumptions of metabolic theory and zero sum dynamics
- Can potentially estimate metabolism purely from the size distribution of a plankton community!

Thanks for listening!