



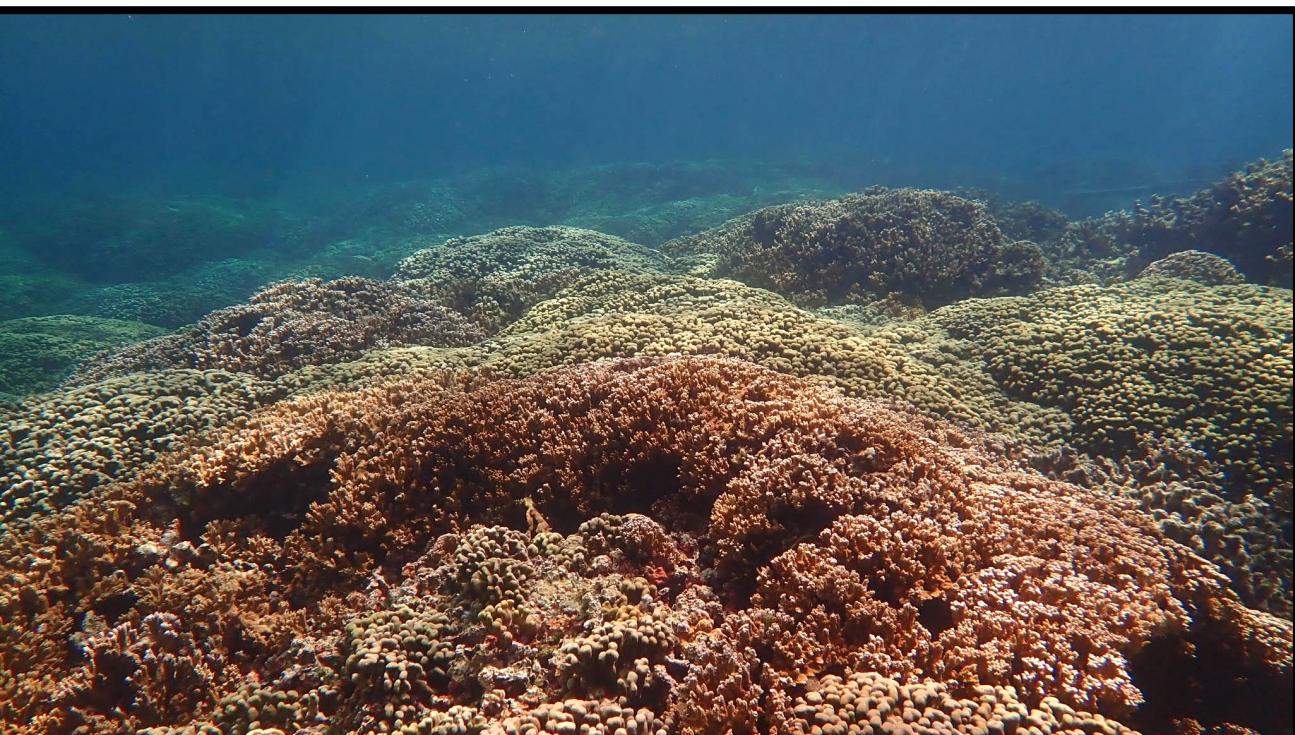
Thermal stress reduces photosynthate metabolism and disrupts nitrogen cycling in coral larvae

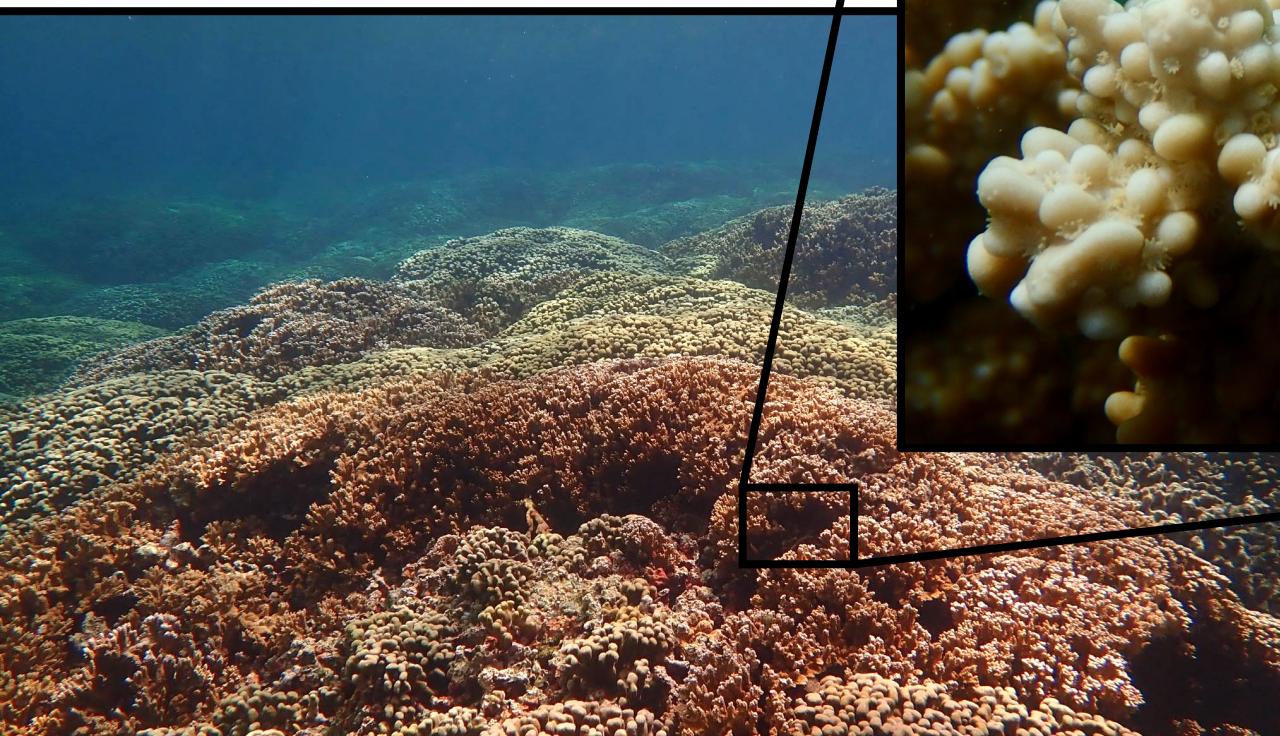
Ariana S. Huffmyer, J Ashey, E Chiles, E Strand, X Su, HM Putnam
University of Rhode Island | University of Washington

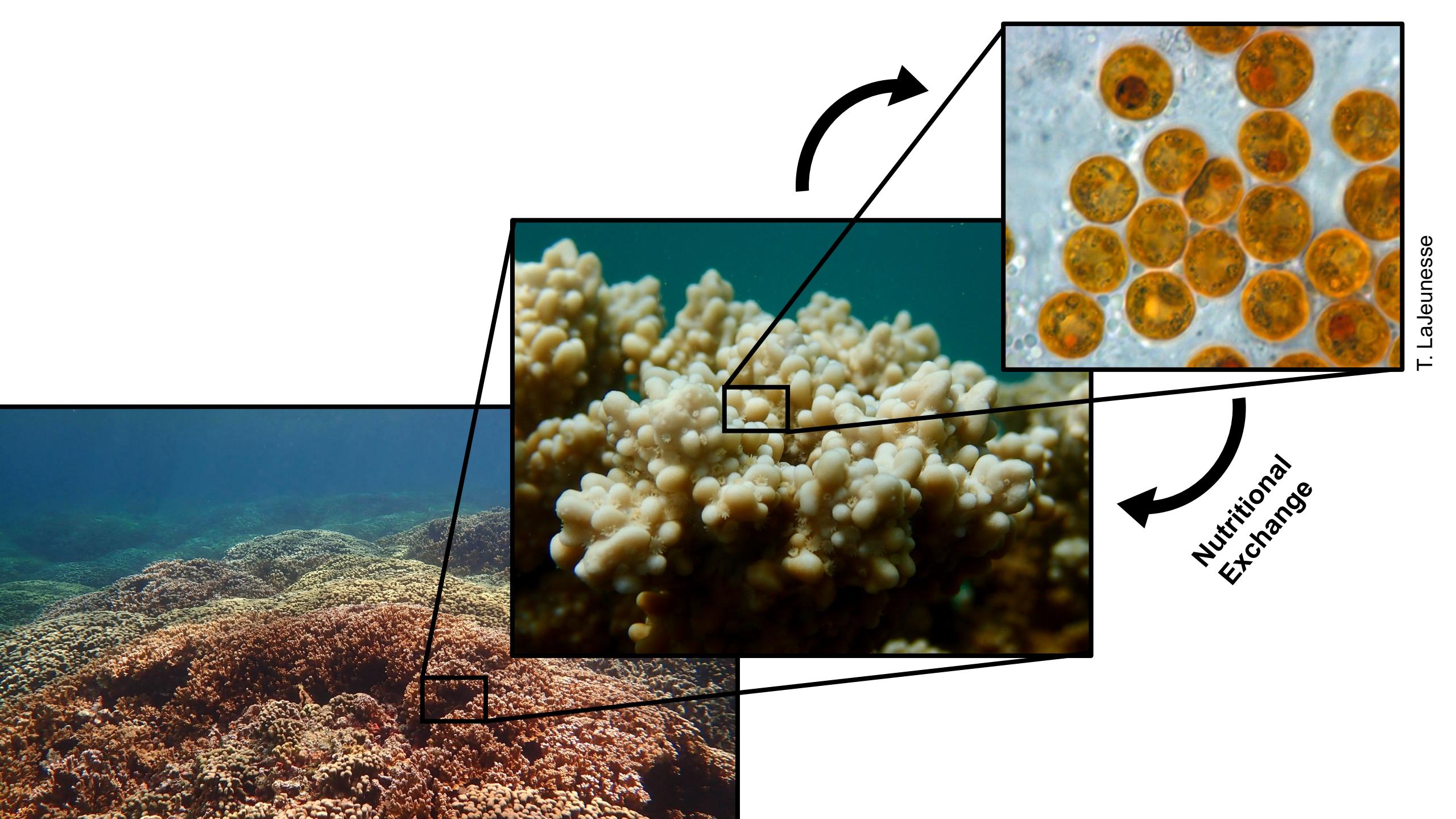
ashuffmyer@uri.edu

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T. LaJeunesse



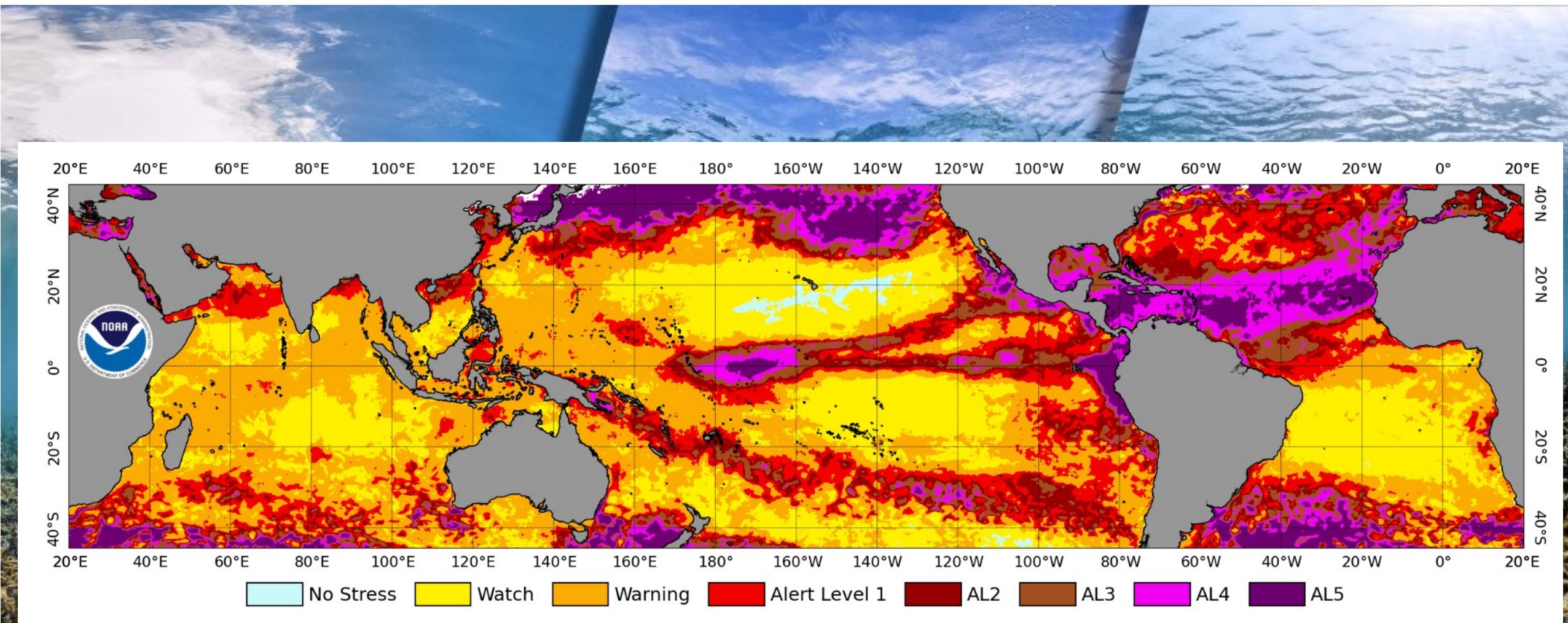
Healthy - Dec 2014



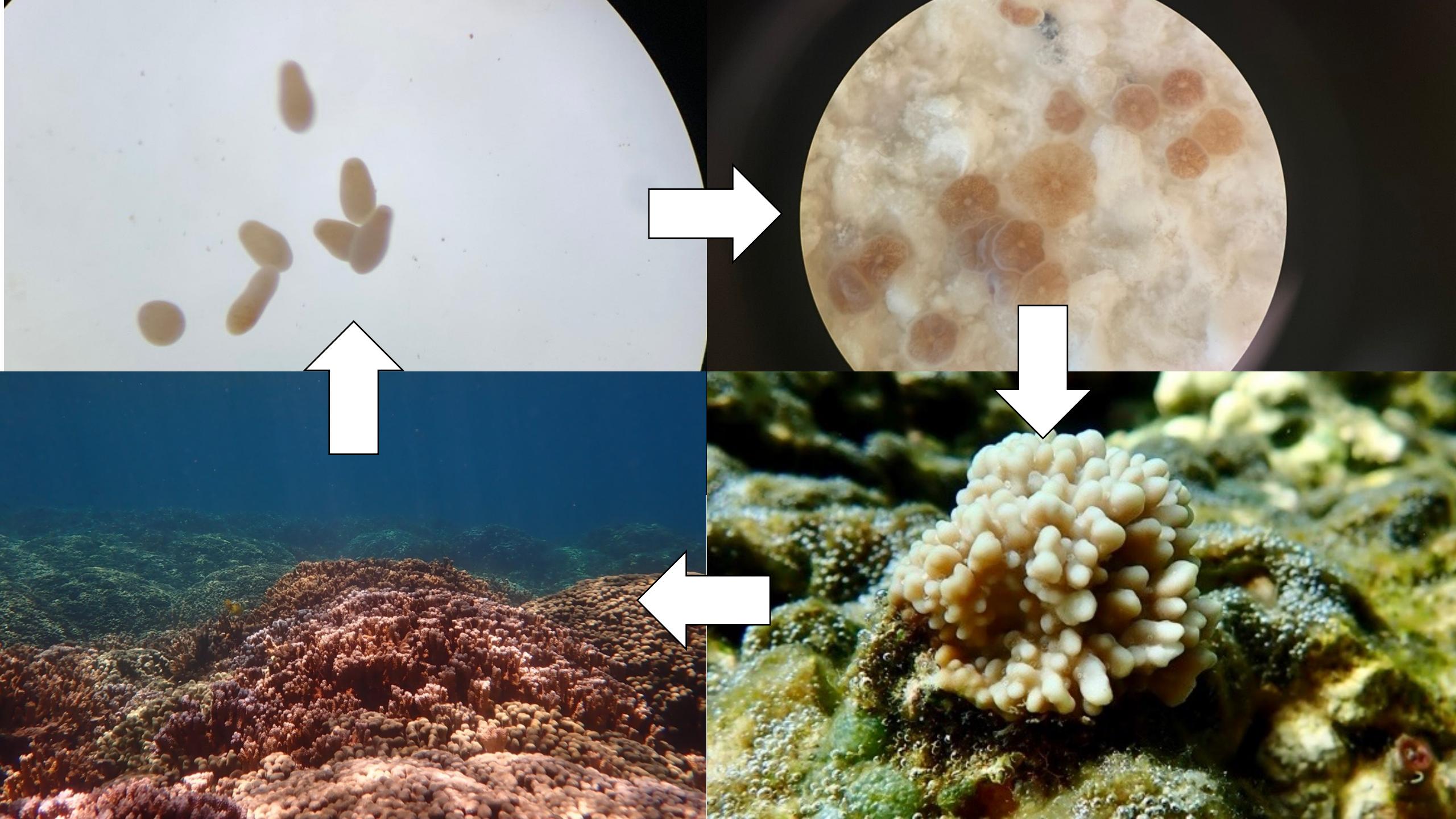
Dying - Feb 2015



Dead - Aug 2015



NOAA Coral Reef Watch

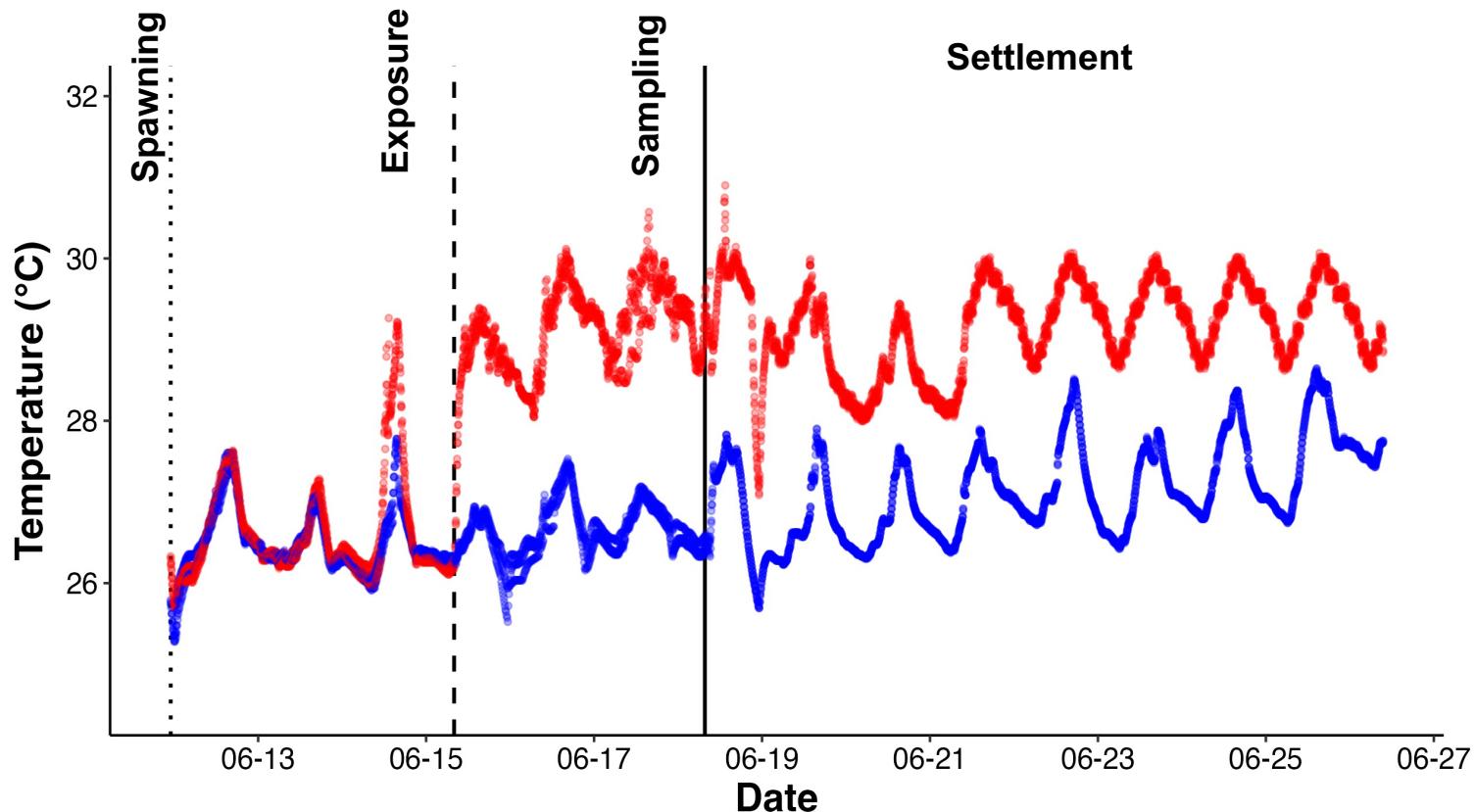




How does thermal stress impact nutritional exchange and metabolism in symbiotic coral larvae?



How does thermal stress impact nutritional exchange and metabolism in symbiotic coral larvae?





No effect of stress on performance and no physiological indications of bleaching, but larvae experienced metabolic depression

No significant difference

Survival
Settlement

Symbiont cell density
Chlorophyll content

Photosynthesis rates



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Survival
Settlement

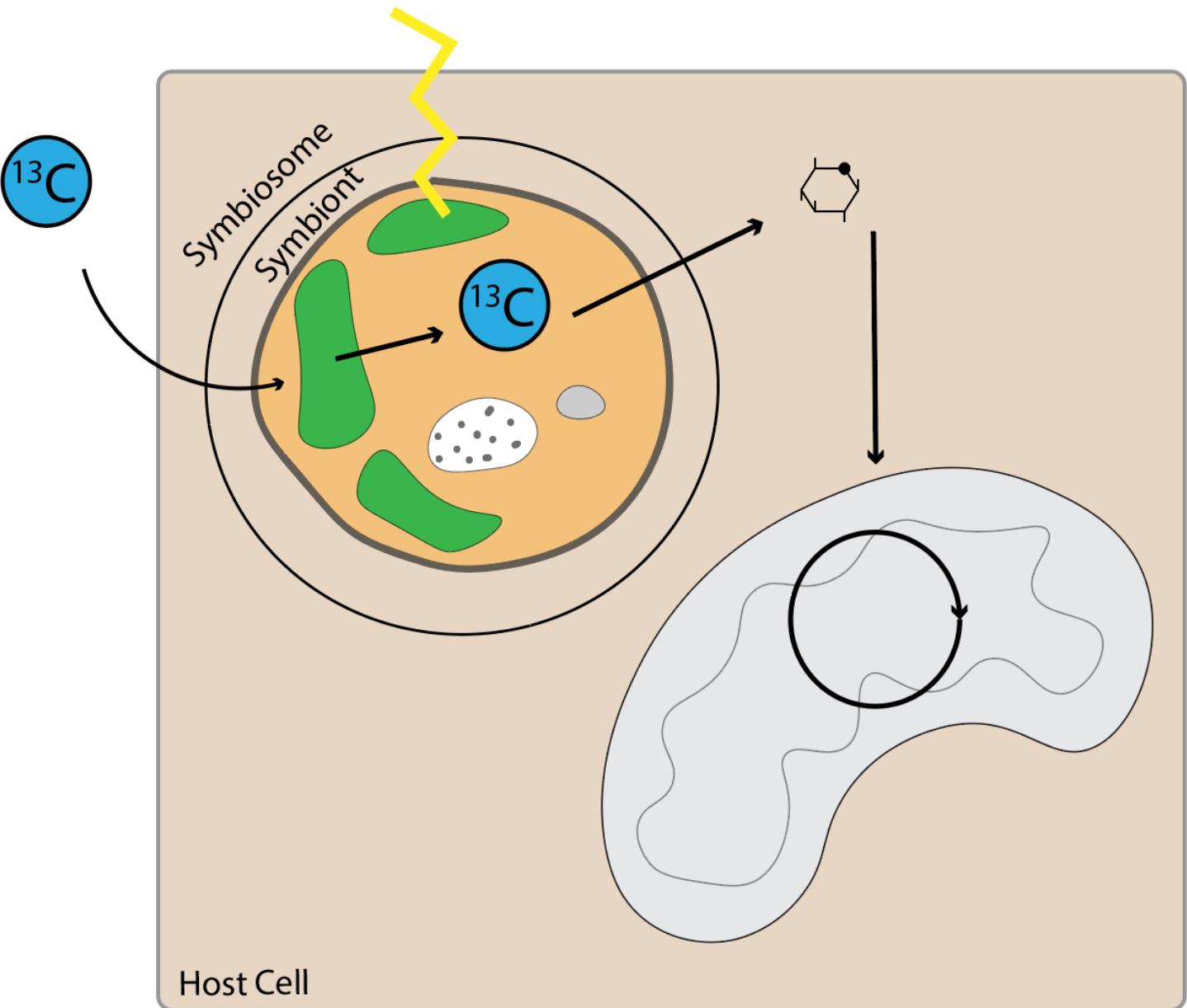
Symbiont cell density
Chlorophyll content

Photosynthesis rates

Significant decrease (18%) in respiration rates under high temperature



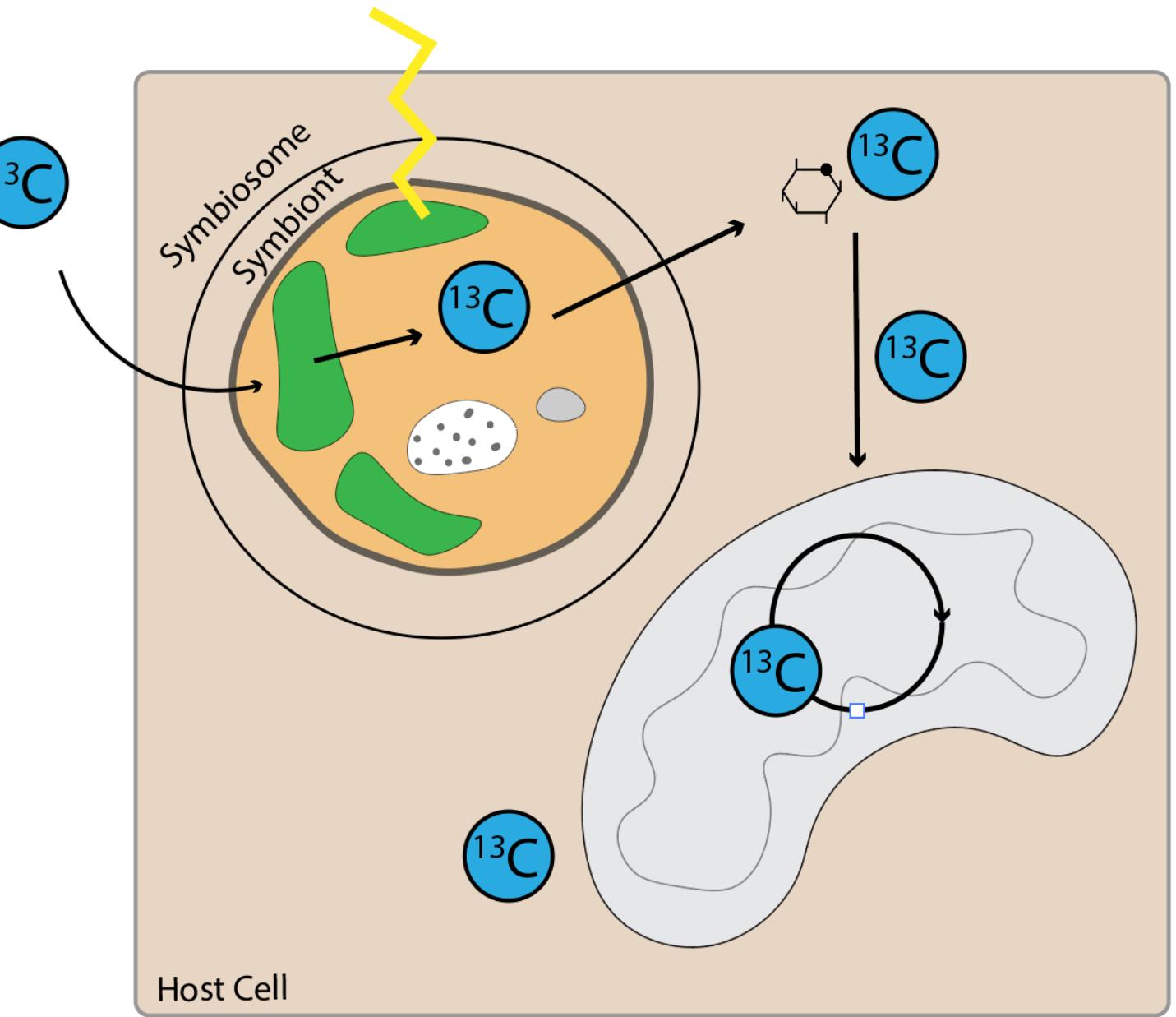
n=6 pools of 300 larvae per temp.
4mM ^{13}C and ^{12}C sodium bicarbonate; 4h
Metabolite extraction from host tissues



Hillyer et al. 2017, 2018
Matthews et al. 2018

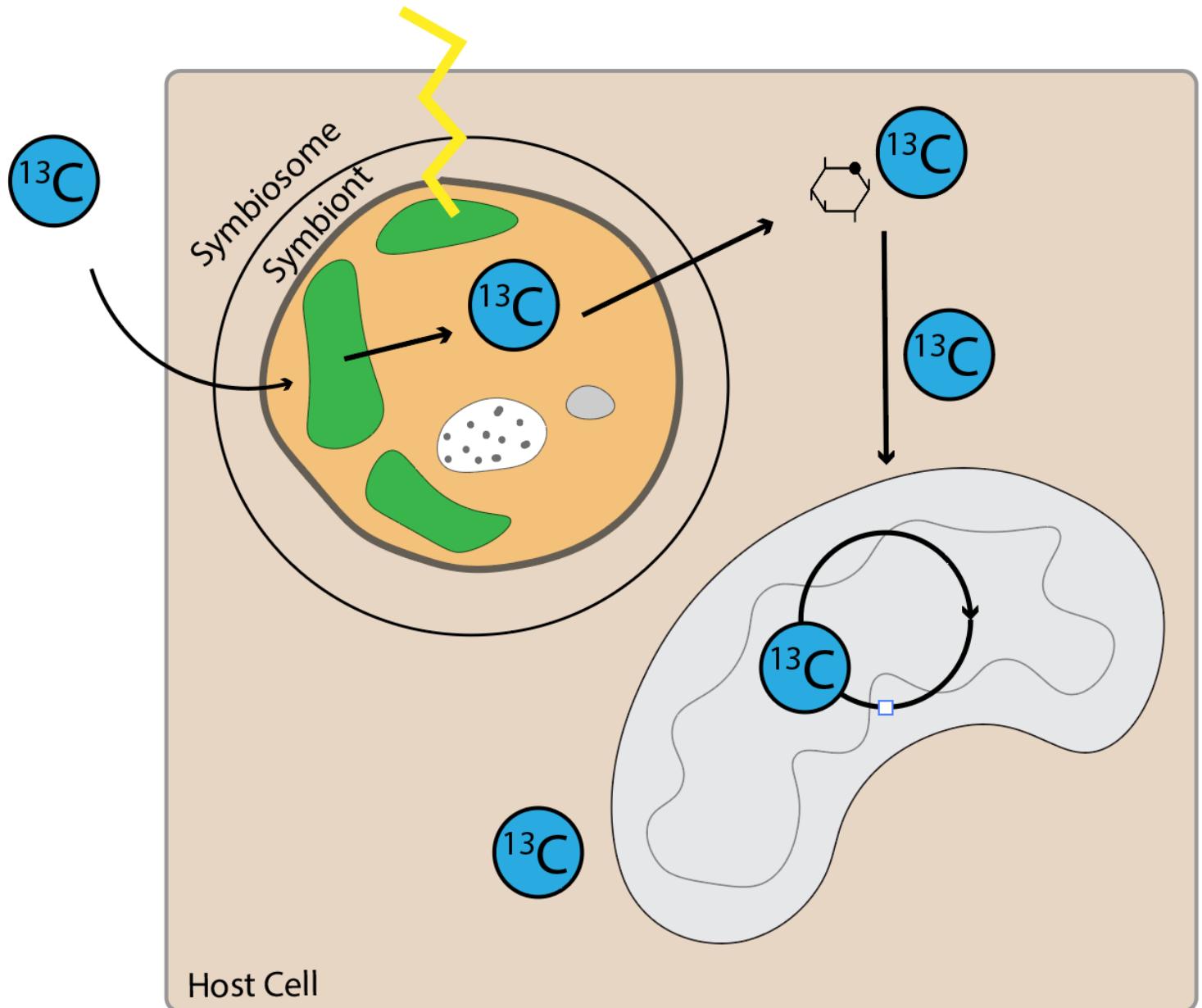


n=6 pools of 300 larvae per temp.
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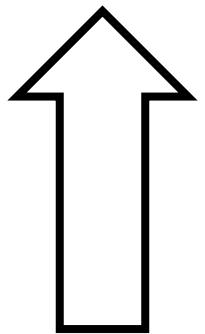


n=6 pools of 300 larvae per temp.
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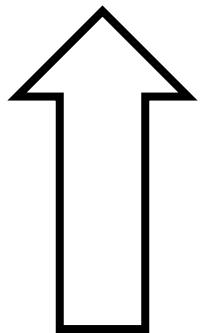
2 sources of information: **metabolite concentration (pool size)** and **^{13}C enrichment**

Metabolic Flux



=

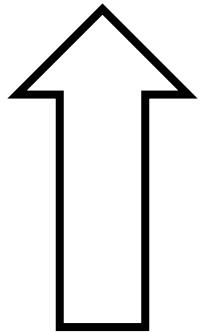
Pool Size



=

^{13}C Enrichment

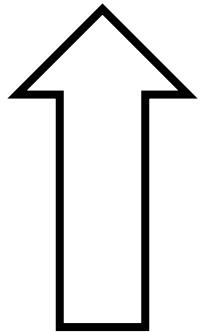
Metabolic Flux



=

Greater metabolite concentration

Pool Size



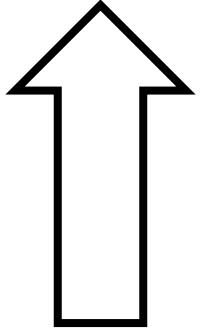
=

Higher metabolite biosynthesis & symbiont-derived C incorporation

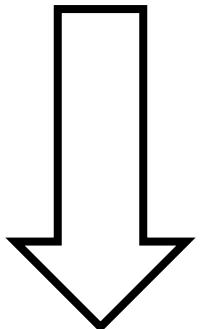
^{13}C Enrichment

We need to know both concentration and biosynthesis to understand metabolic flux.

Metabolic Flux



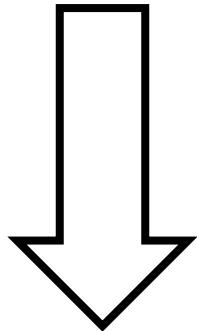
Pool Size



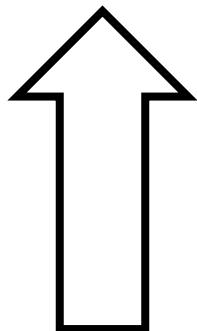
^{13}C Enrichment



Metabolic Flux

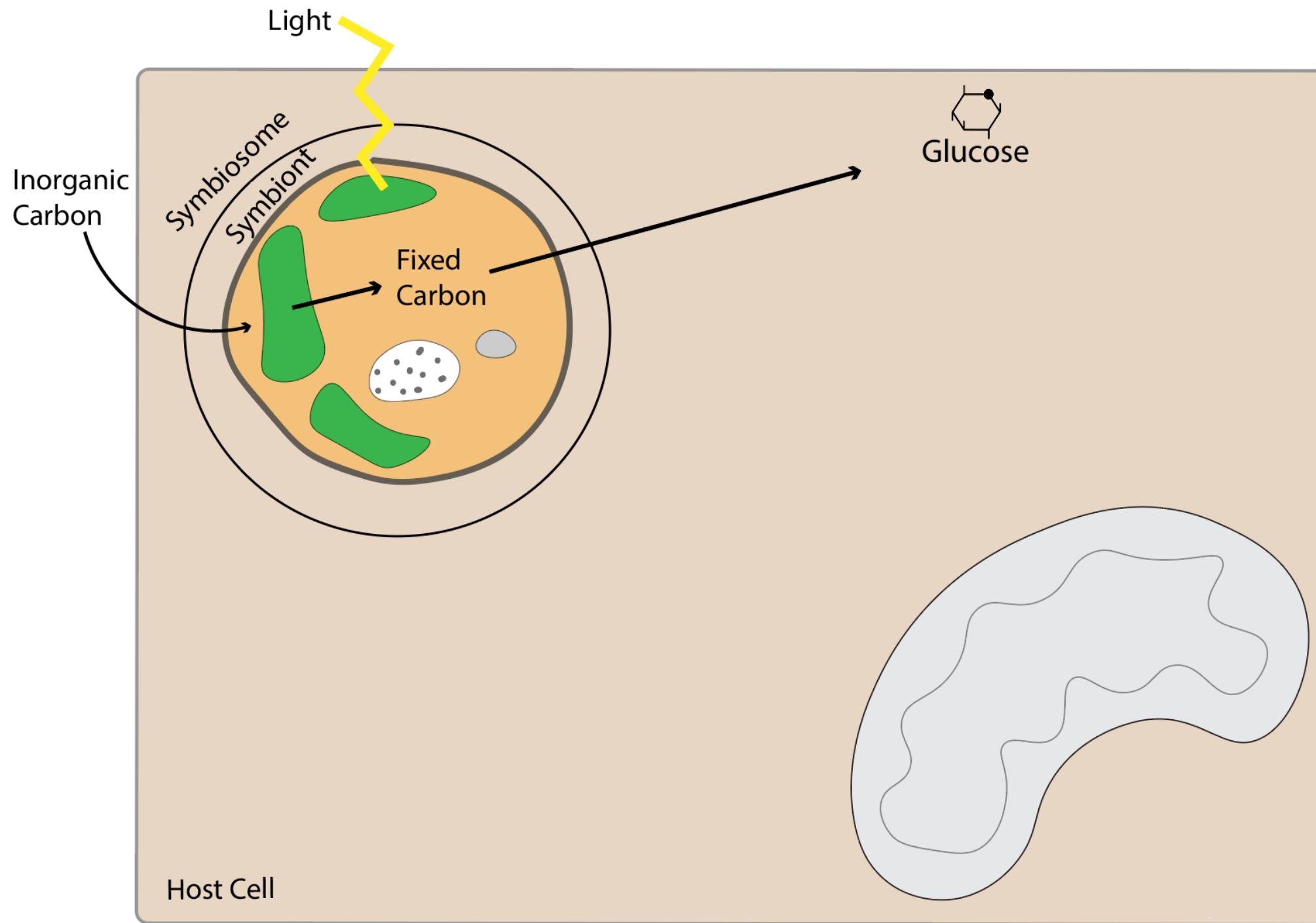


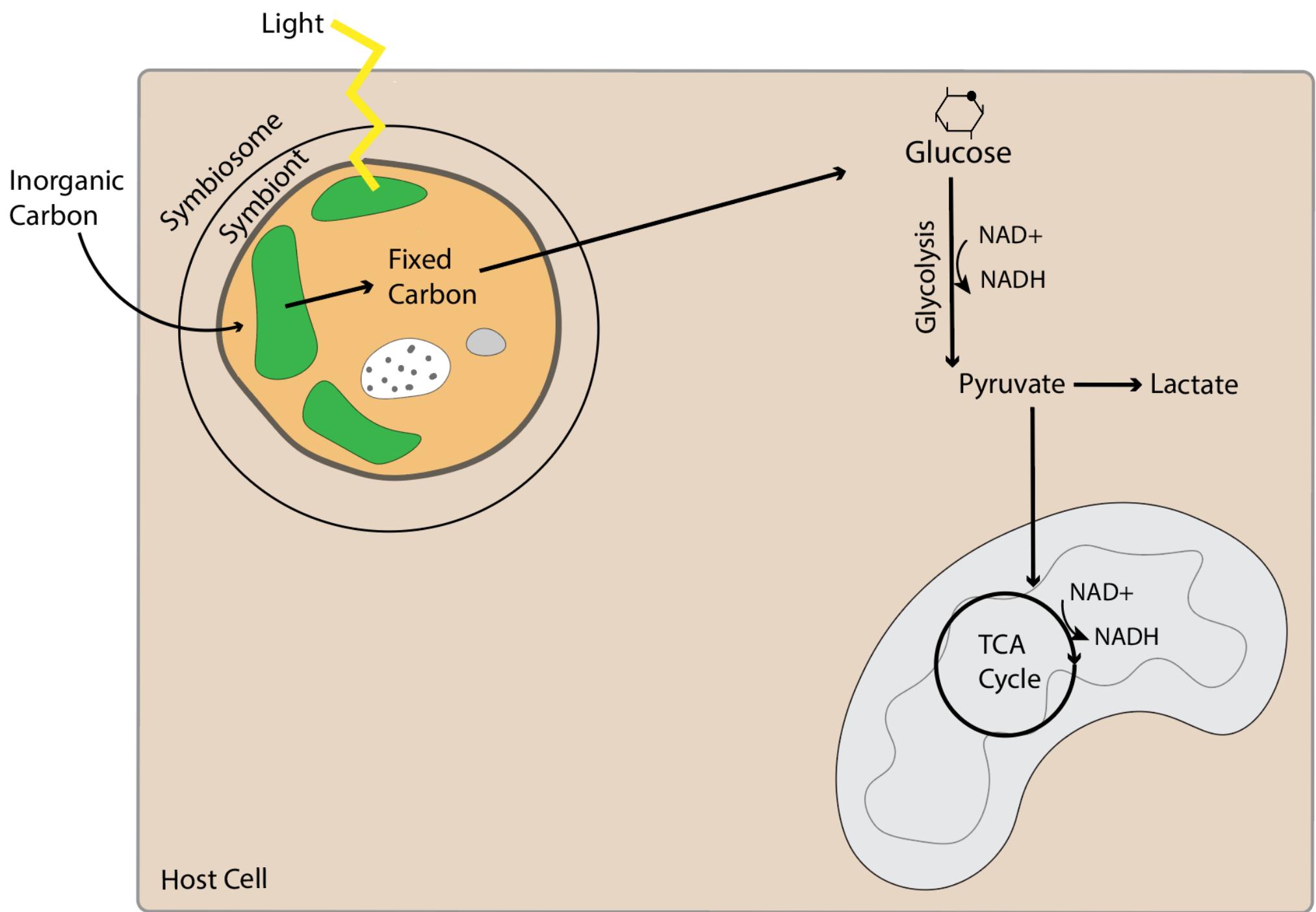
Pool Size

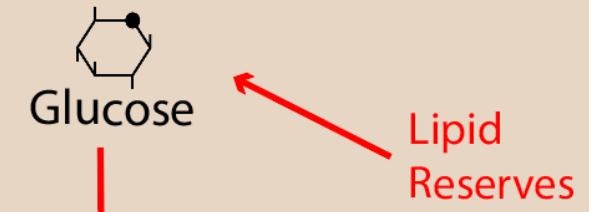
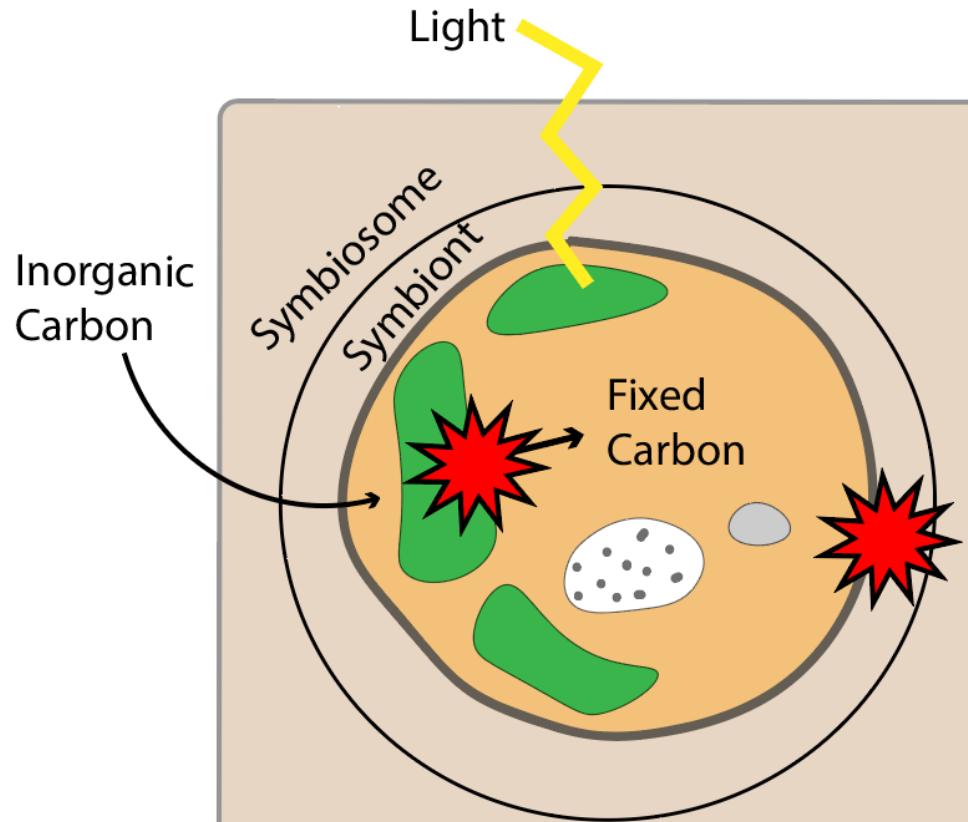


^{13}C Enrichment



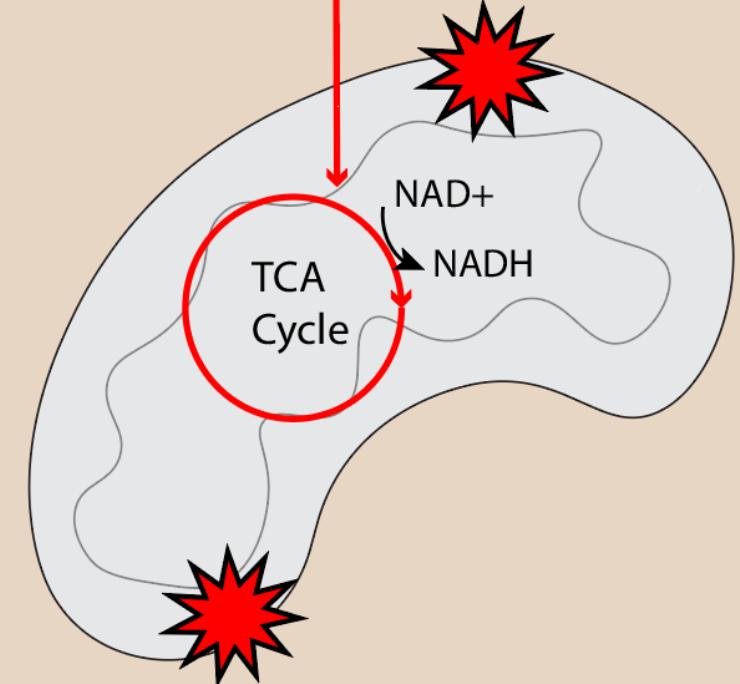






Glycolysis
NAD+
NADH

Pyruvate \longrightarrow Lactate

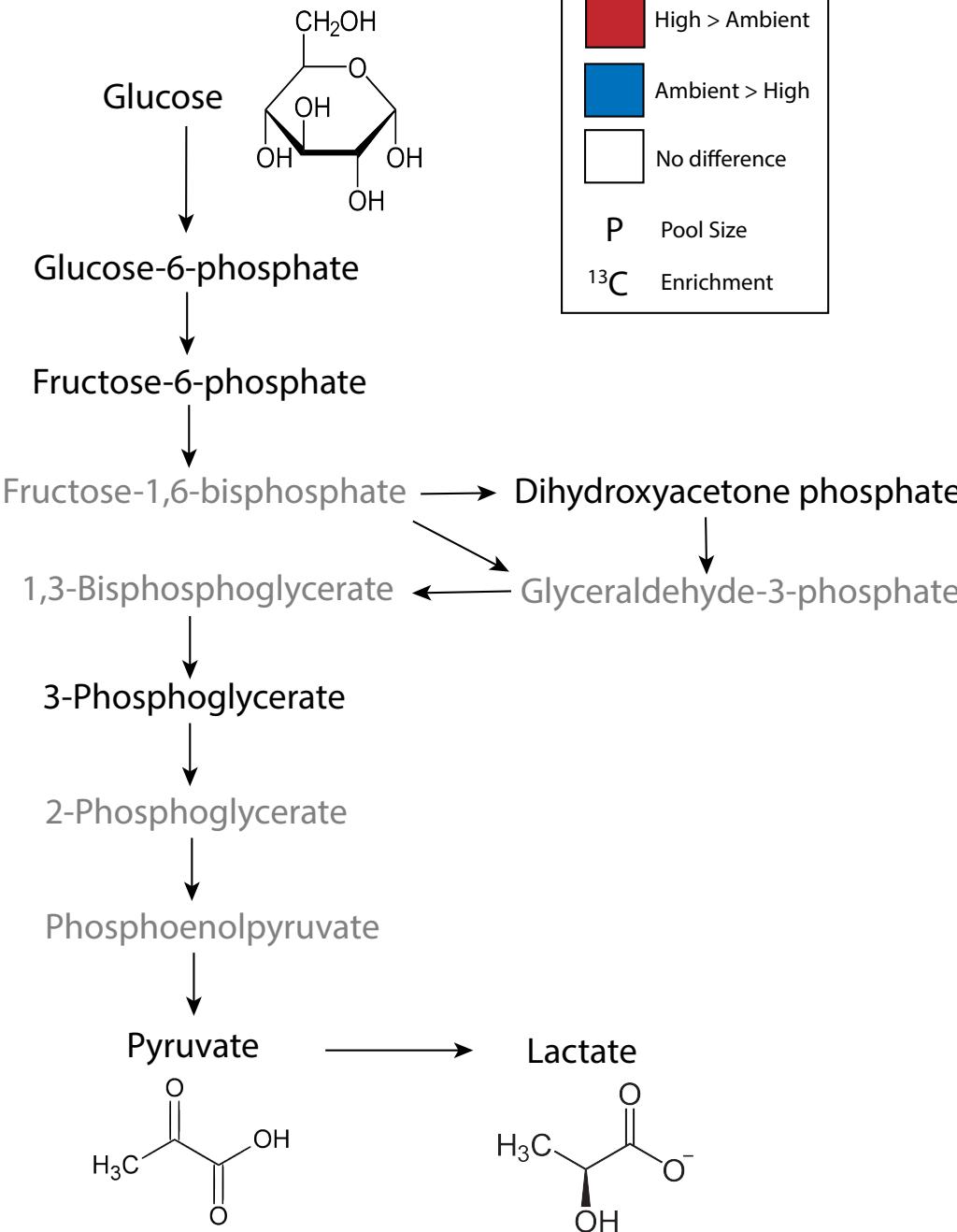


Hillyer et al. 2017
Matthews et al. 2018
Hillyer et al. 2018

Host Cell

Thermal stress reduced central carbon metabolism in coral larvae

Glycolysis



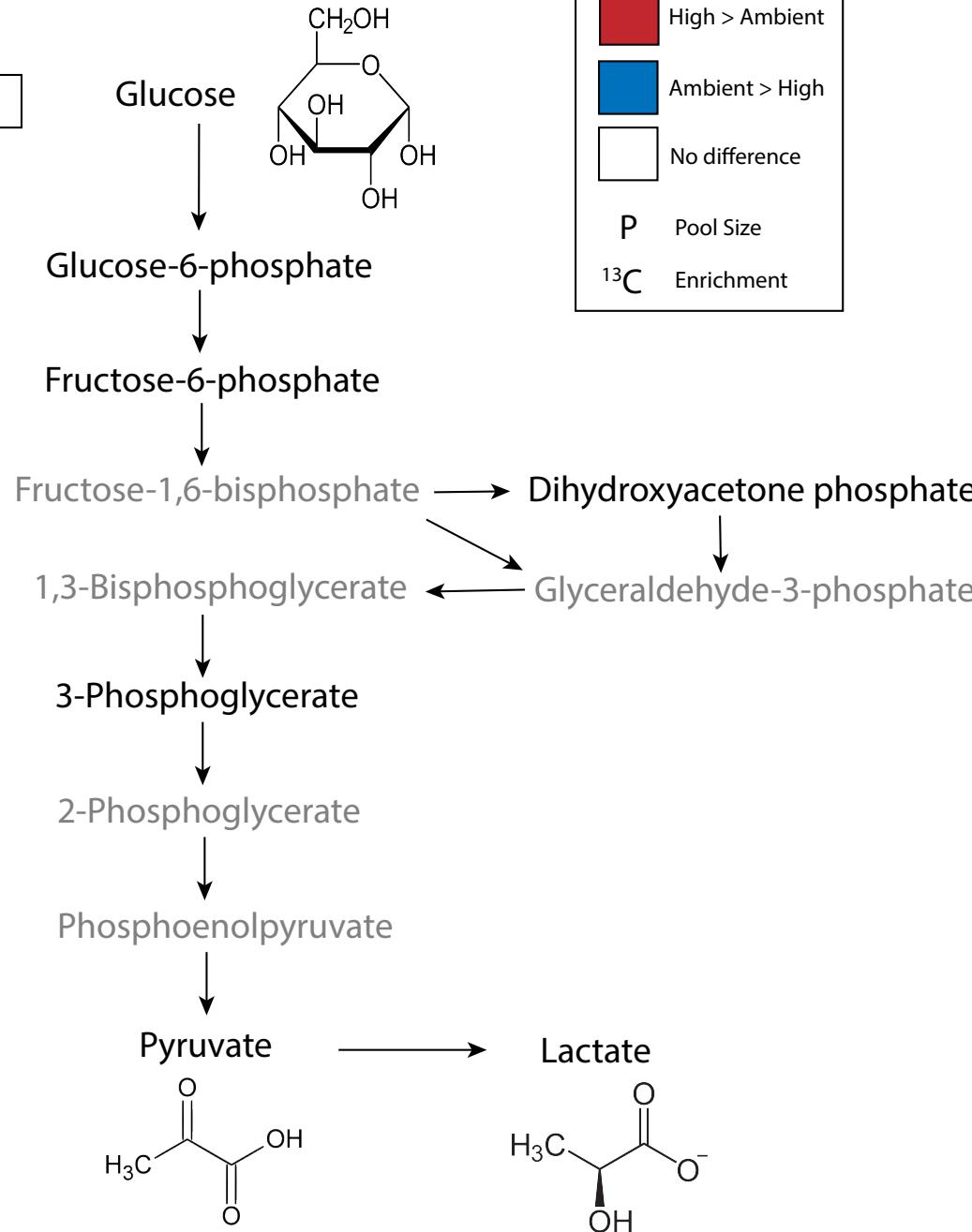
Thermal stress reduced central carbon metabolism in coral larvae

P 10% ^{13}C □

Glycolysis

| | |
|-----------------|----------------|
| | High > Ambient |
| | Ambient > High |
| | No difference |
| P | Pool Size |
| ^{13}C | Enrichment |

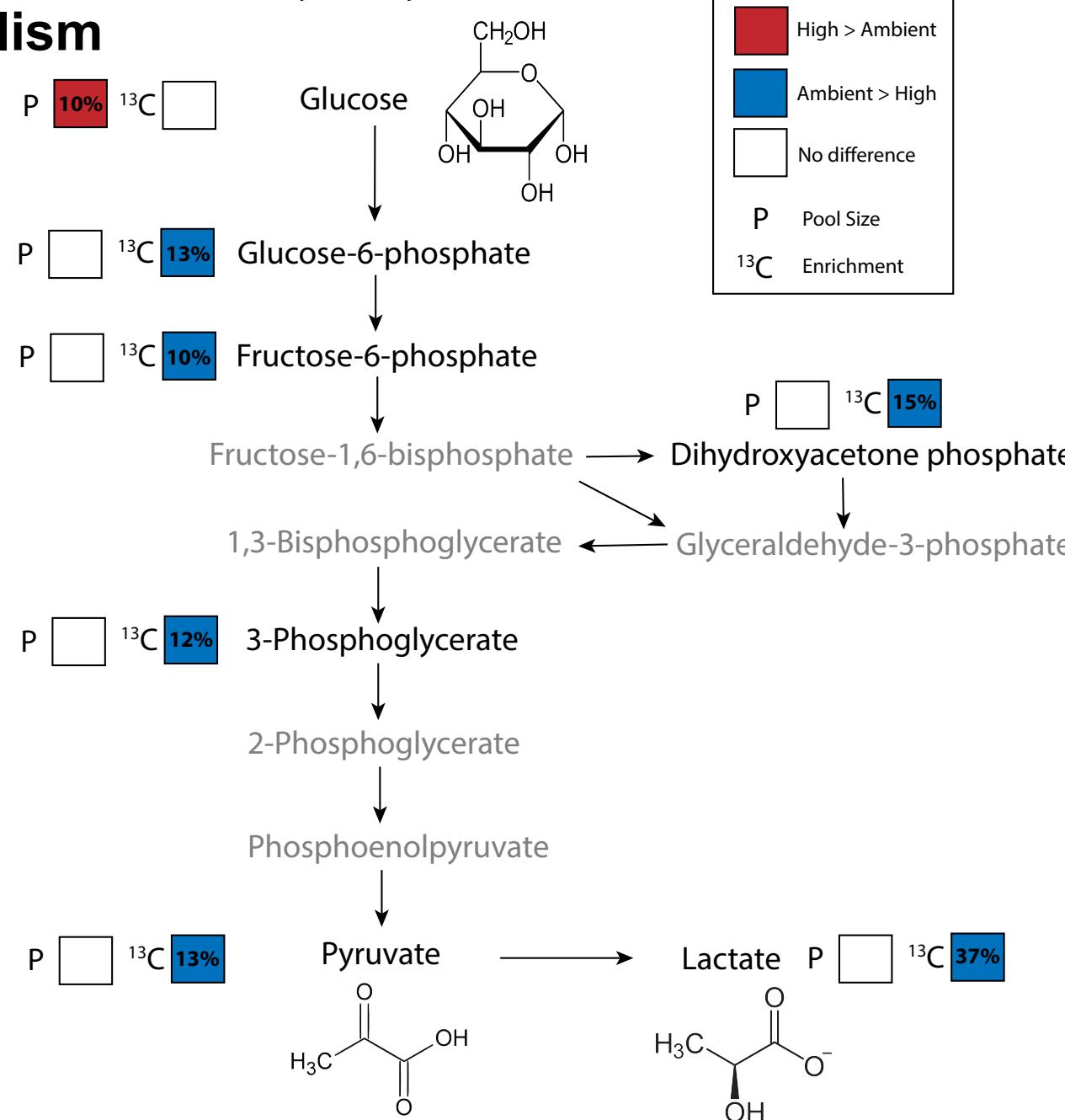
1. Maintained glucose translocation from the symbiont



Thermal stress reduced central carbon metabolism in coral larvae

Glycolysis

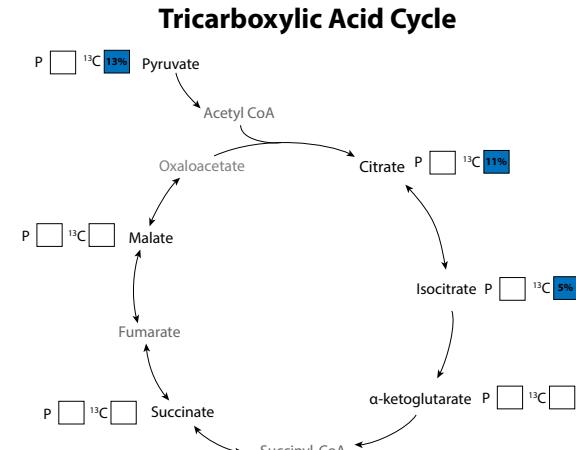
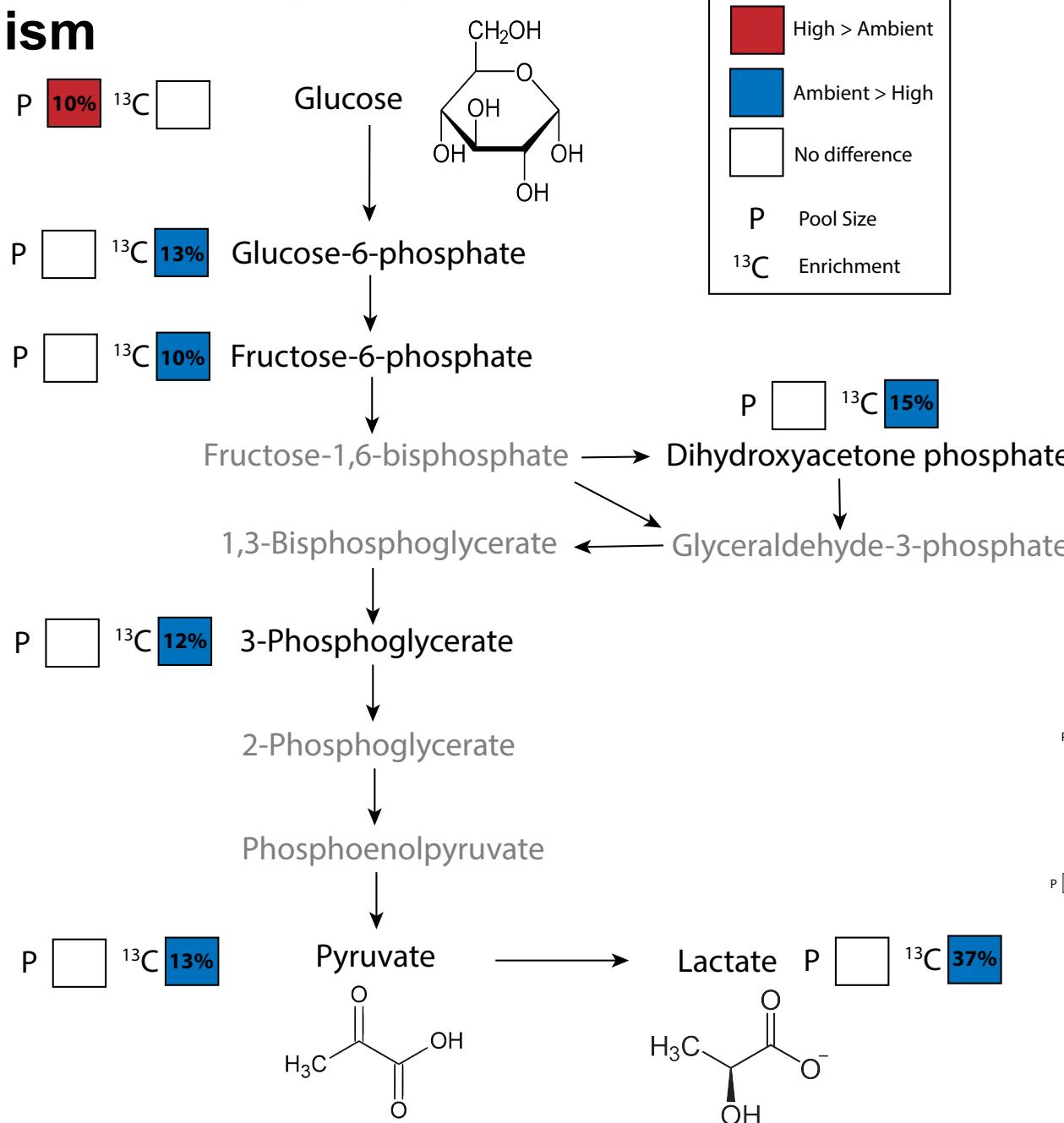
1. Maintained glucose translocation from the symbiont
2. Reduced glycolytic flux
3. Glucose accumulation

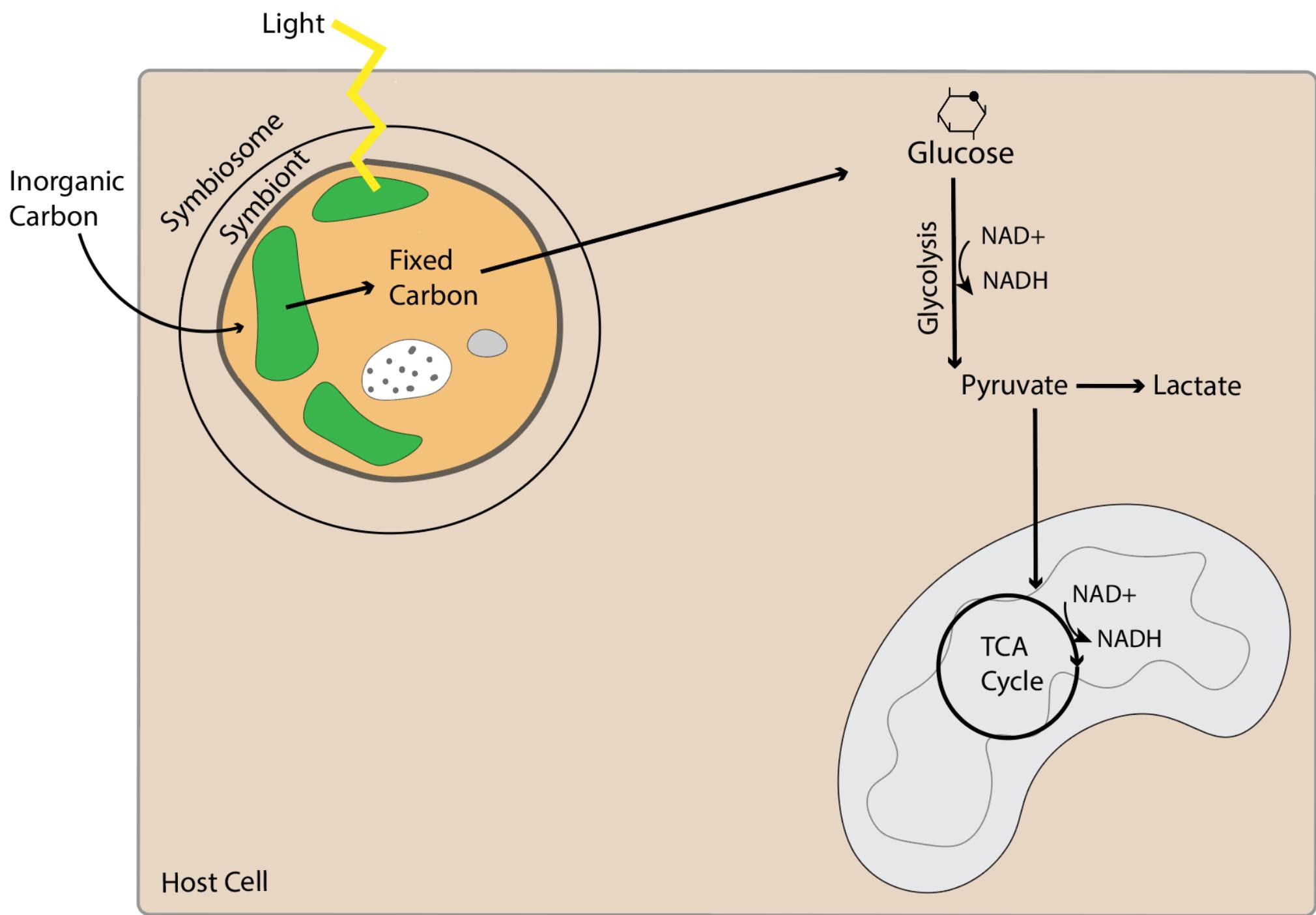


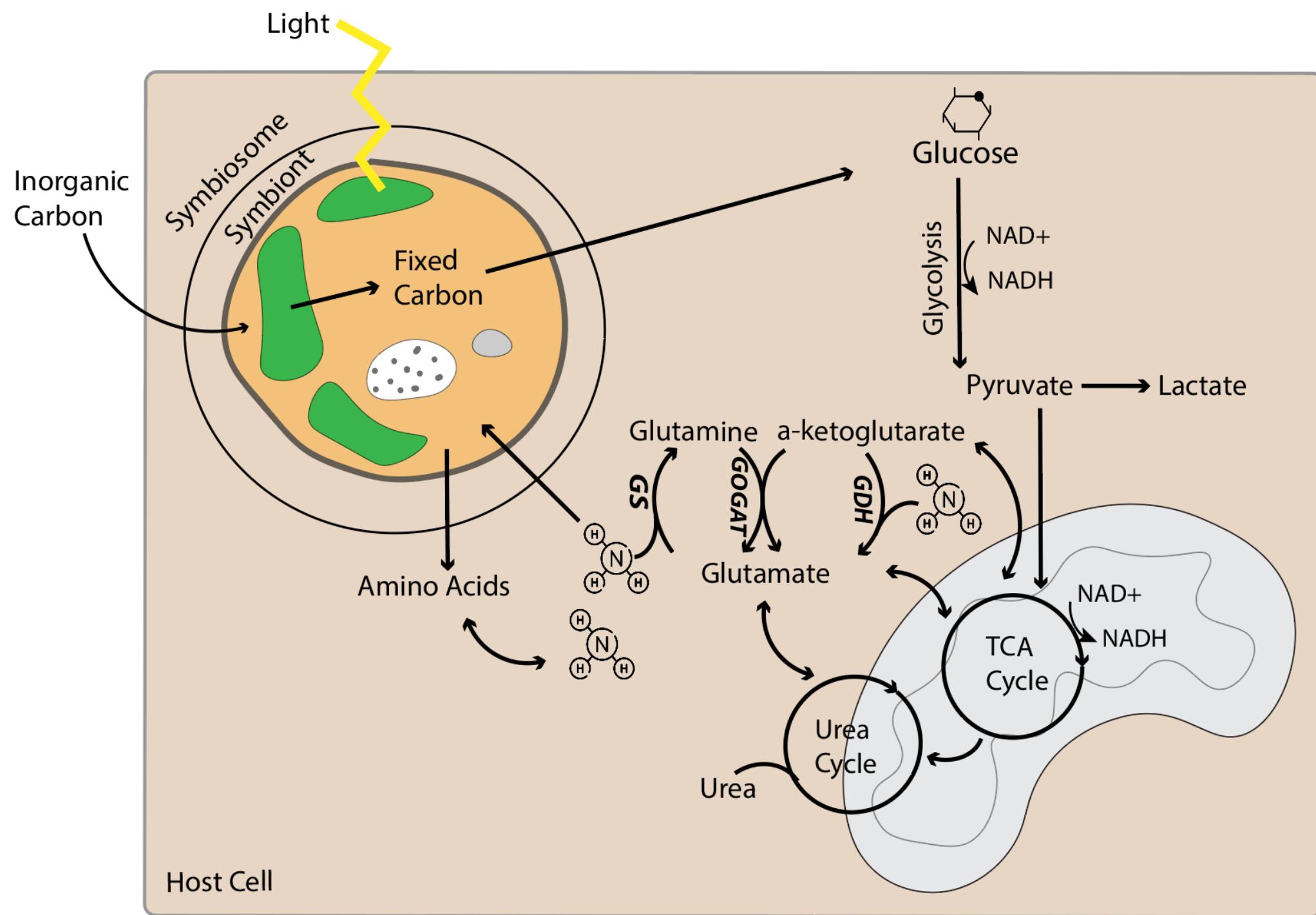
Thermal stress reduced central carbon metabolism in coral larvae

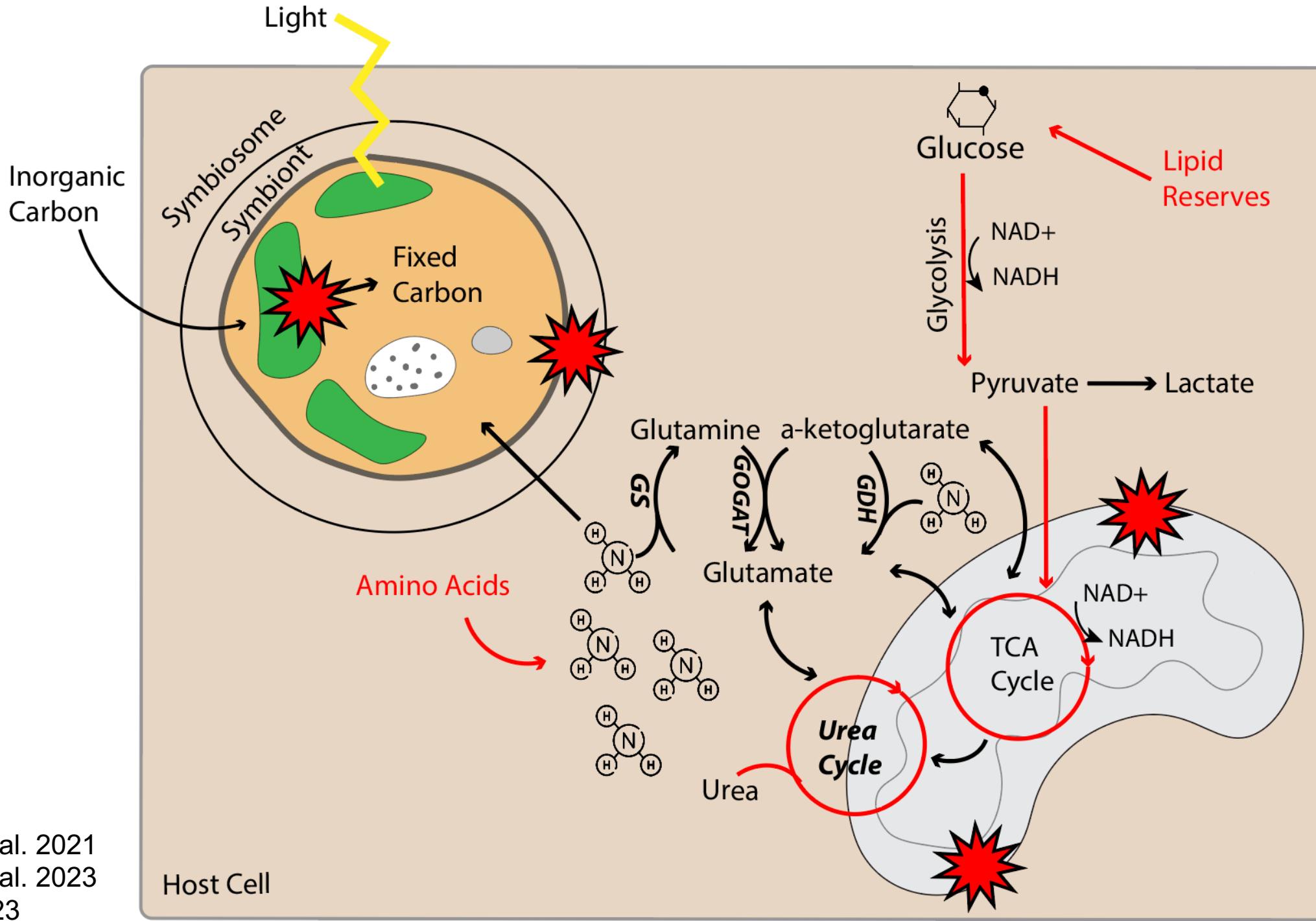
Glycolysis

1. Maintained glucose translocation from the symbiont
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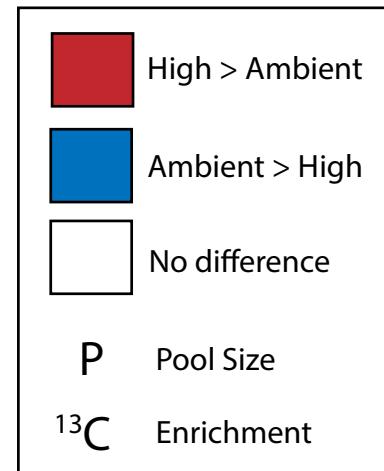
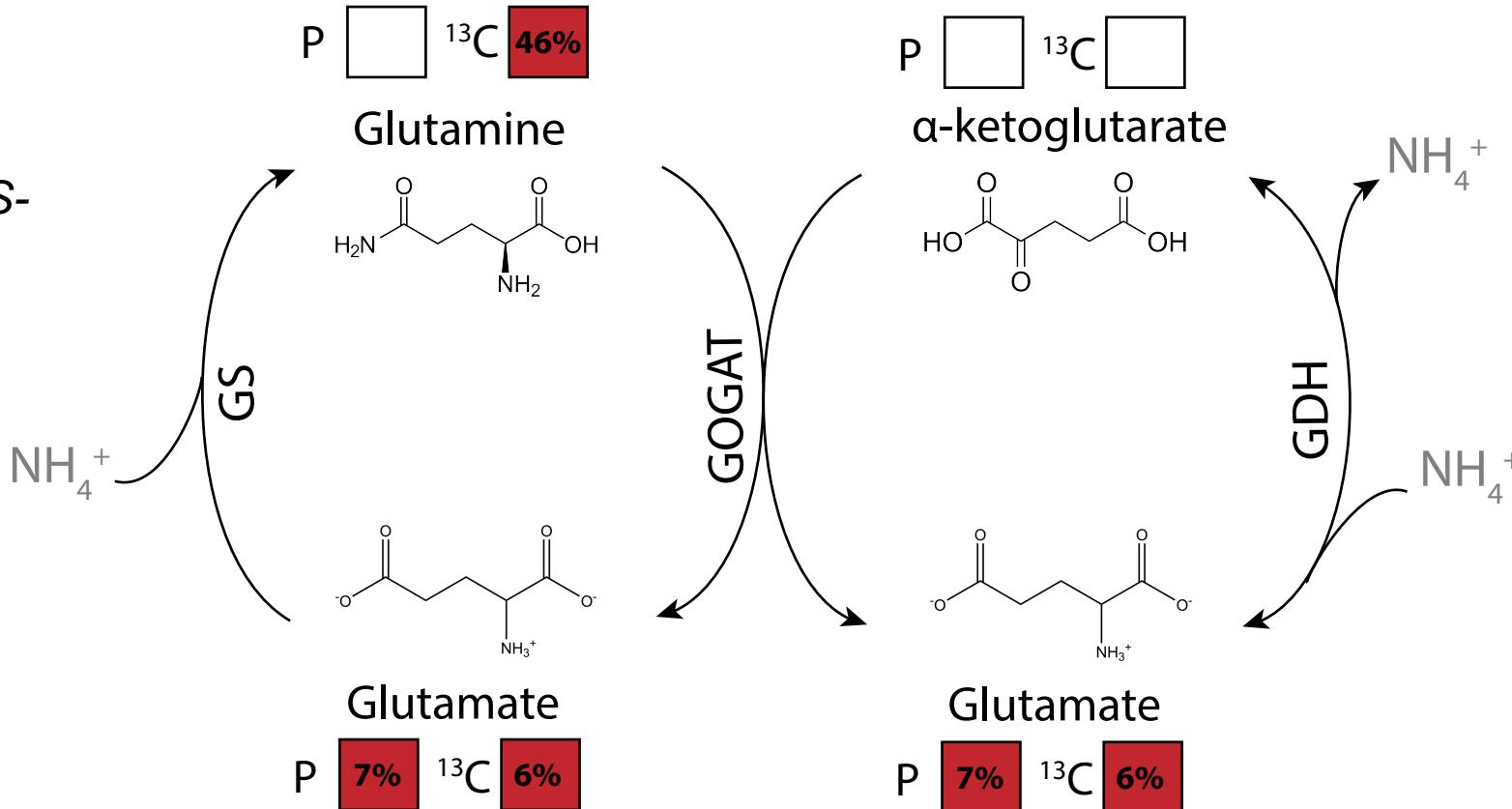


Larvae increased ammonium assimilation under stress

Larvae increased ammonium assimilation under stress

GS-GOGAT

Increased host GS-GOGAT activity under elevated temperature



Larvae increased nitrogen sequestration under stress

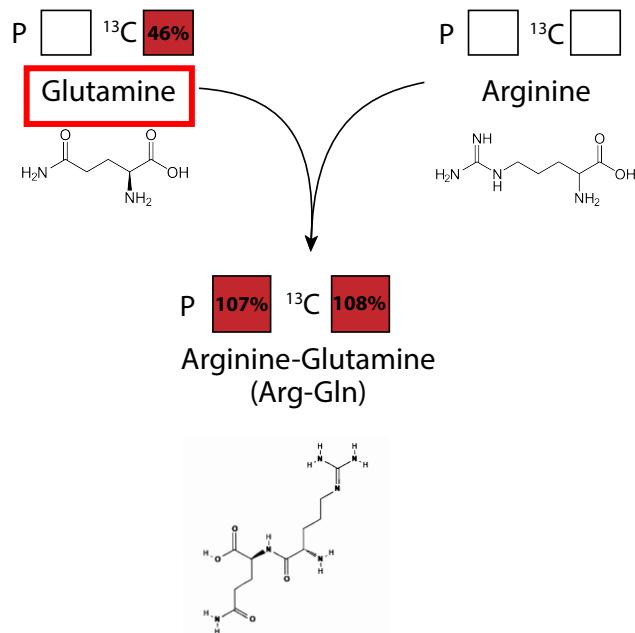
Ammonium is assimilated
via GS-GOGAT pathways....

Larvae increased nitrogen sequestration under stress

Ammonium is assimilated
via GS-GOGAT pathways....


... stored in dipeptides...

Dipeptides



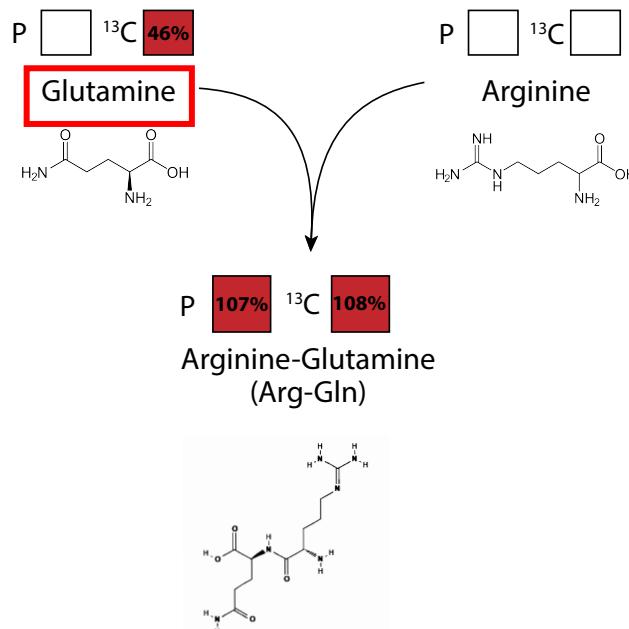
Larvae increased nitrogen sequestration under stress

Ammonium is assimilated via GS-GOGAT pathways....

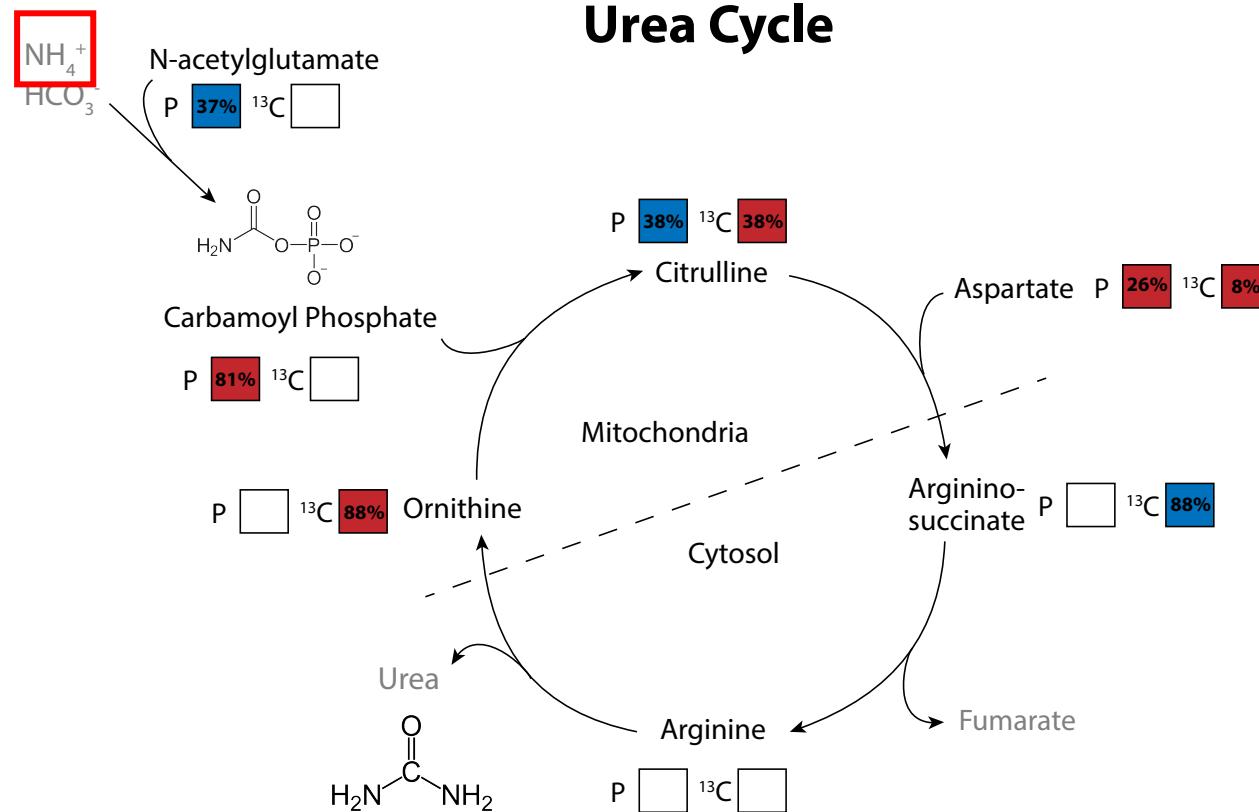
... stored in dipeptides...

... and sequestered by the urea cycle...

Dipeptides



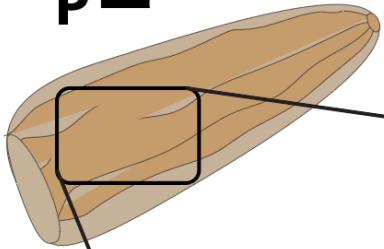
Urea Cycle



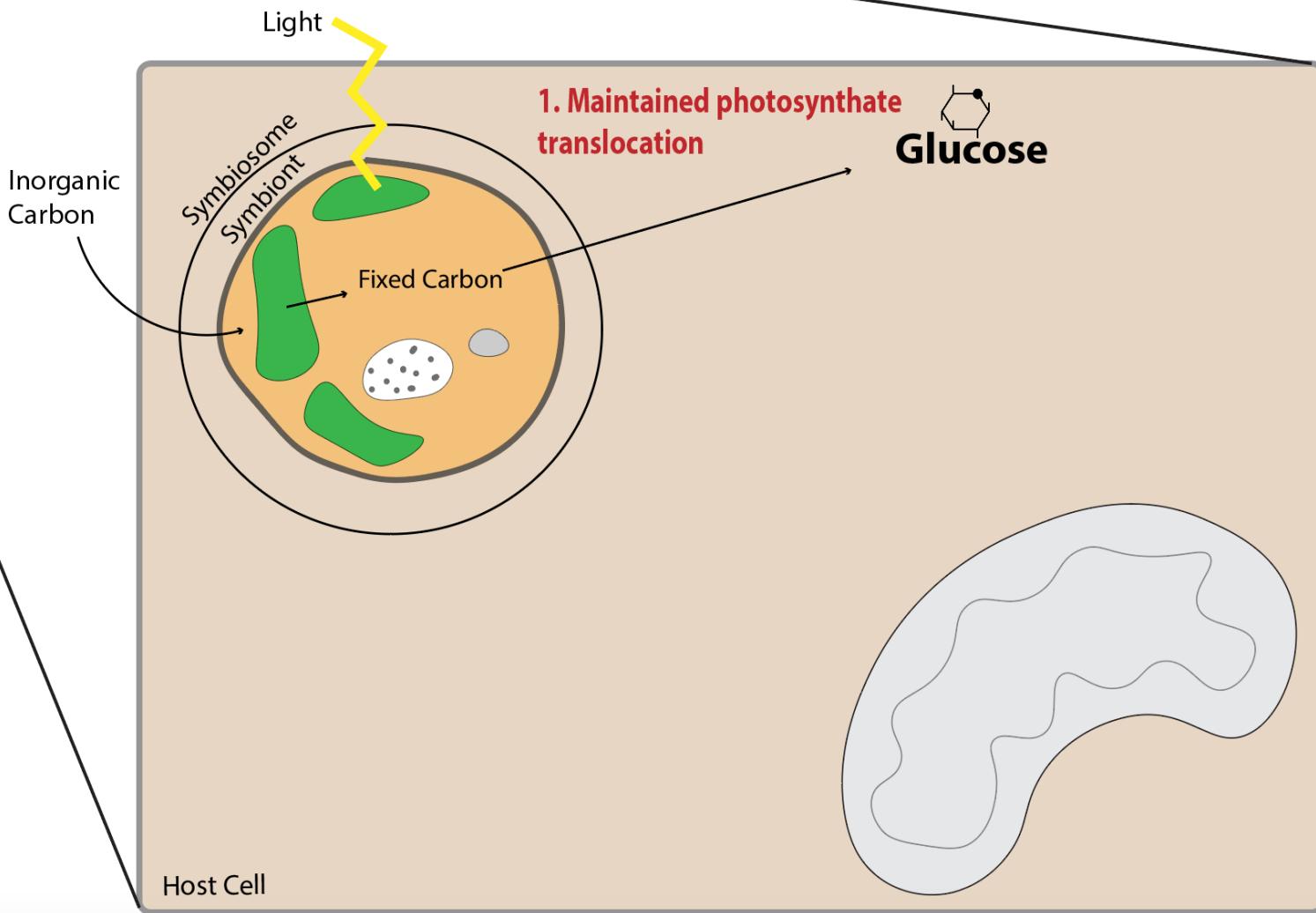
Larvae are susceptible to metabolic stress, but have capacity to maintain symbiosis through nitrogen limitation

Larvae are susceptible to metabolic stress, but have capacity to maintain symbiosis through nitrogen limitation

R ↓
P —

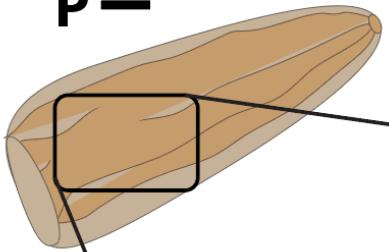


Maintenance of glucose translocation and photosynthetic rates under stress through



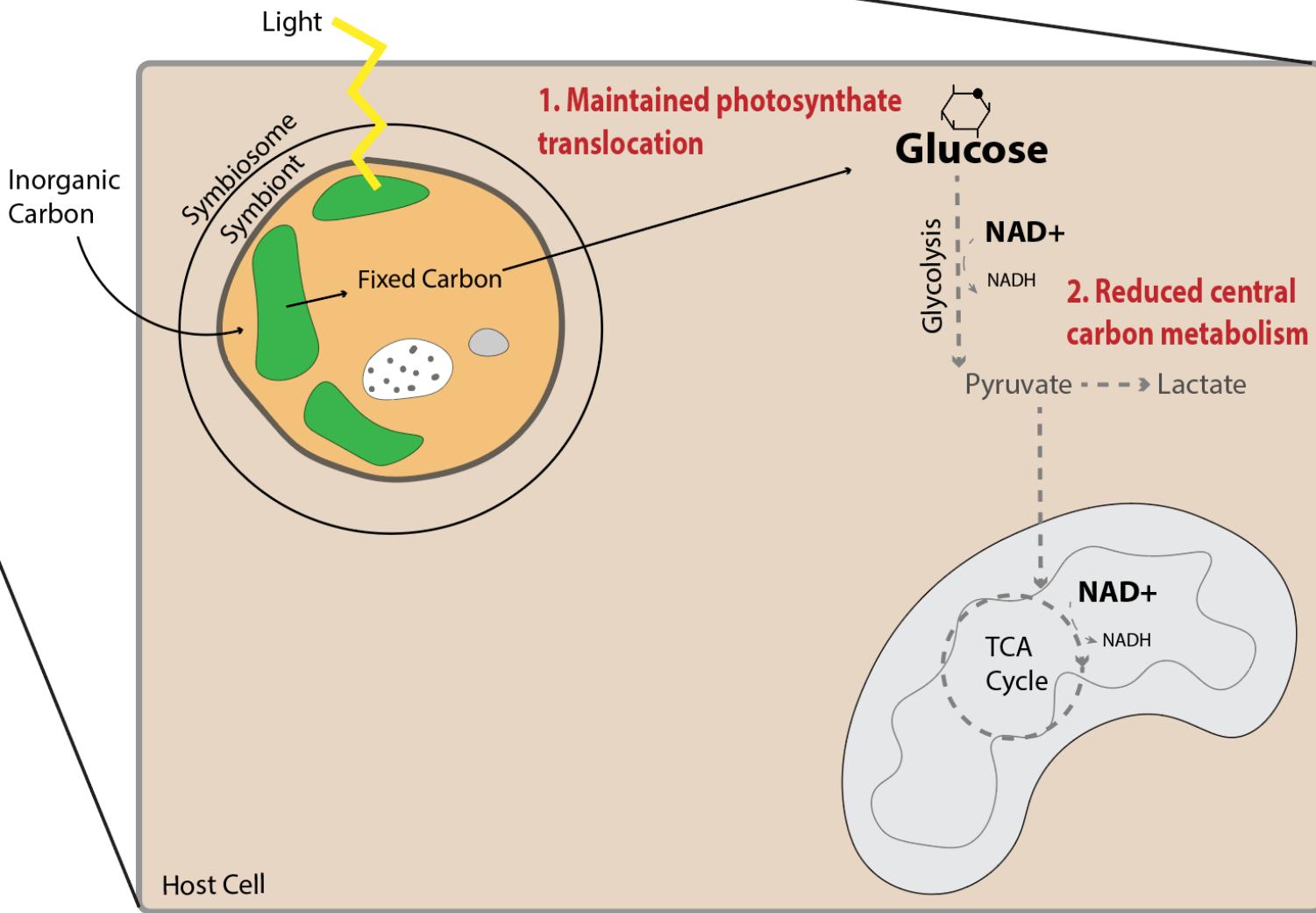
$R \downarrow$
 $P -$

Larvae are susceptible to metabolic stress, but have capacity to maintain symbiosis through nitrogen limitation



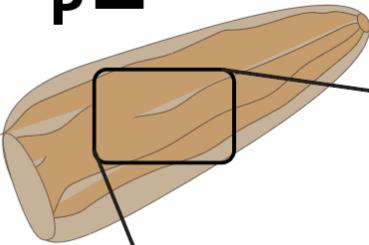
Maintenance of glucose translocation and photosynthetic rates under stress through ...

... reduction of respiratory demand and central metabolism to conserve energy and ...

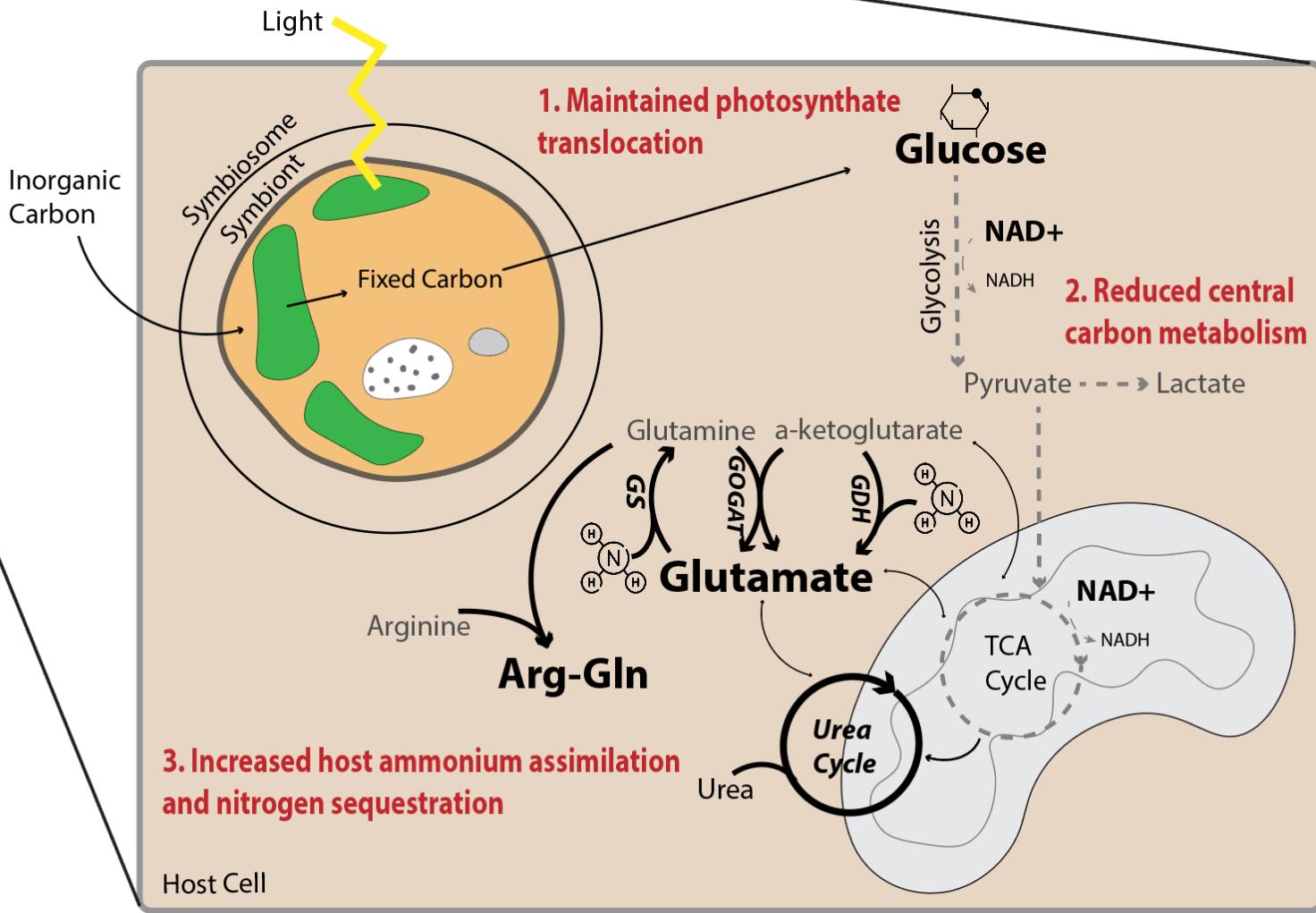


Larvae are susceptible to metabolic stress, but have capacity to maintain symbiosis through nitrogen limitation

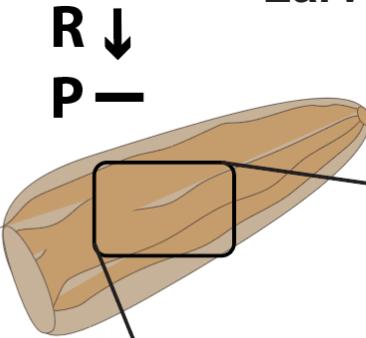
R ↓
P —



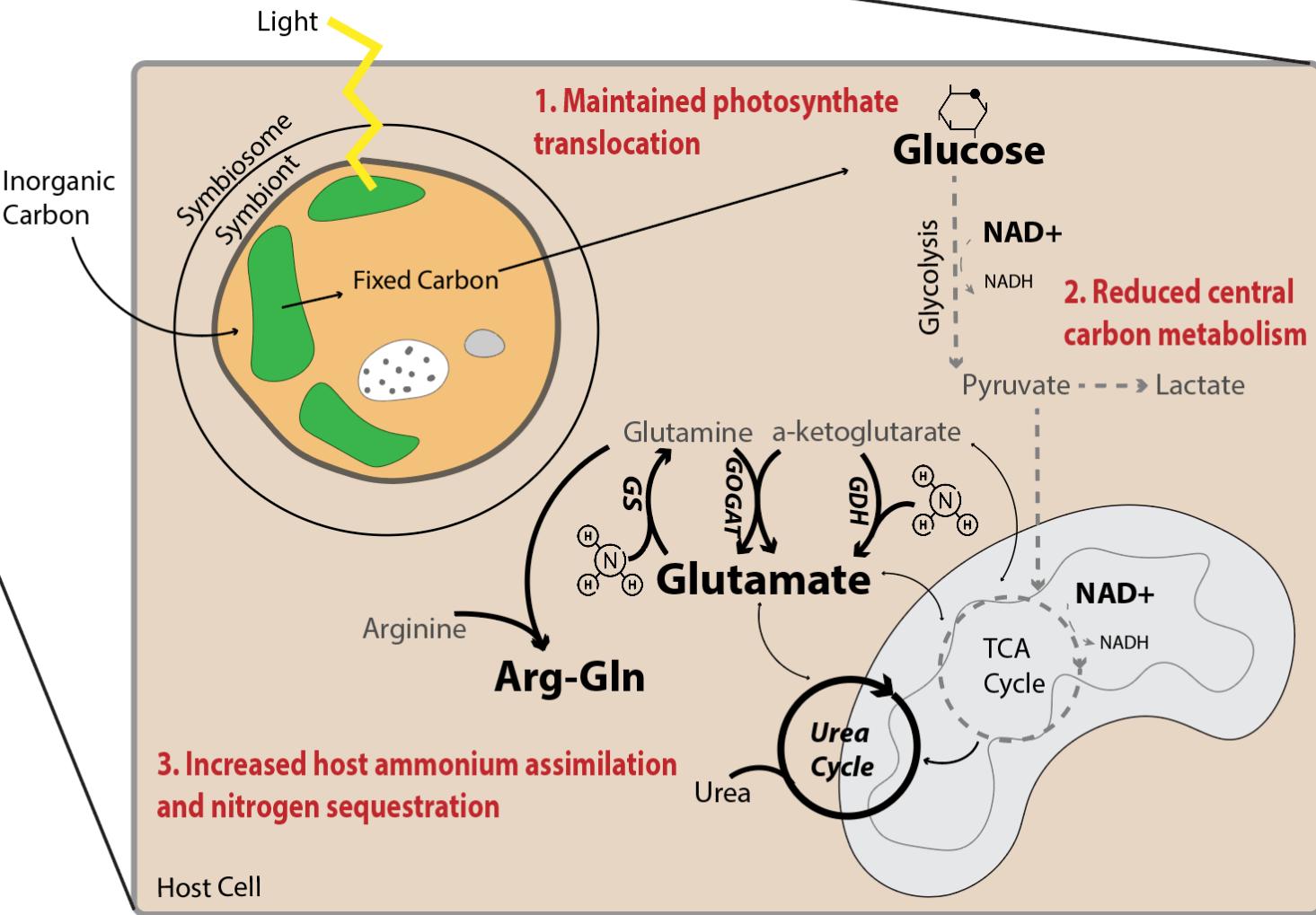
Maintenance of glucose translocation and photosynthetic rates under stress through ...
... reduction of respiratory demand and central metabolism to conserve energy and ...
... upregulation of ammonium assimilation and sequestration to maintain nitrogen limitation.

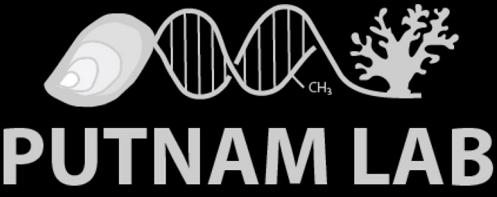


Larvae are susceptible to metabolic stress, but have capacity to maintain symbiosis through nitrogen limitation



Symbiotic nutrition is important for the energetic state of symbiotic coral larvae

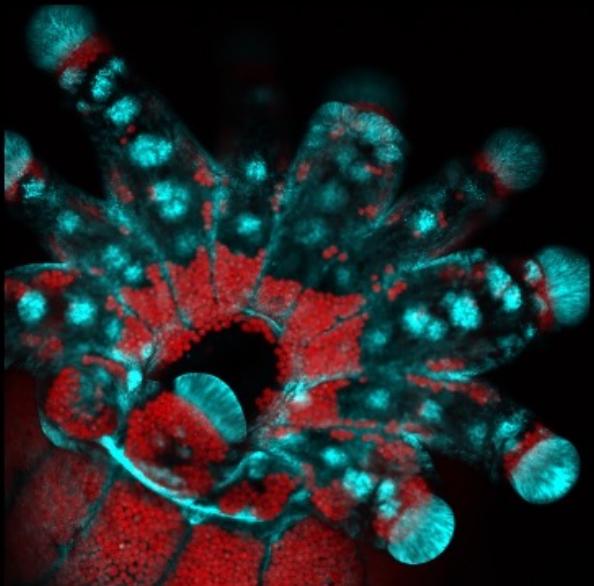




PUTNAM LAB



Early life history coral reef ecophysiology and symbiosis



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- UW eScience Data Science Postdoctoral Fellowship
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- NSF Rules of Life E5 Coral

Collaborators & Coauthors

- Jill Ashley, Emma Strand, Xiaoyang Su, Eric Chiles, Hollie Putnam
- Roberts Lab, University of Washington
- Kevin Wong
- Coral Resilience Lab, Dr. Ford Drury, Hawaii Institute of Marine Biology

Energetic Demand

Energy Reserves

Potential for Symbiotic Nutrition

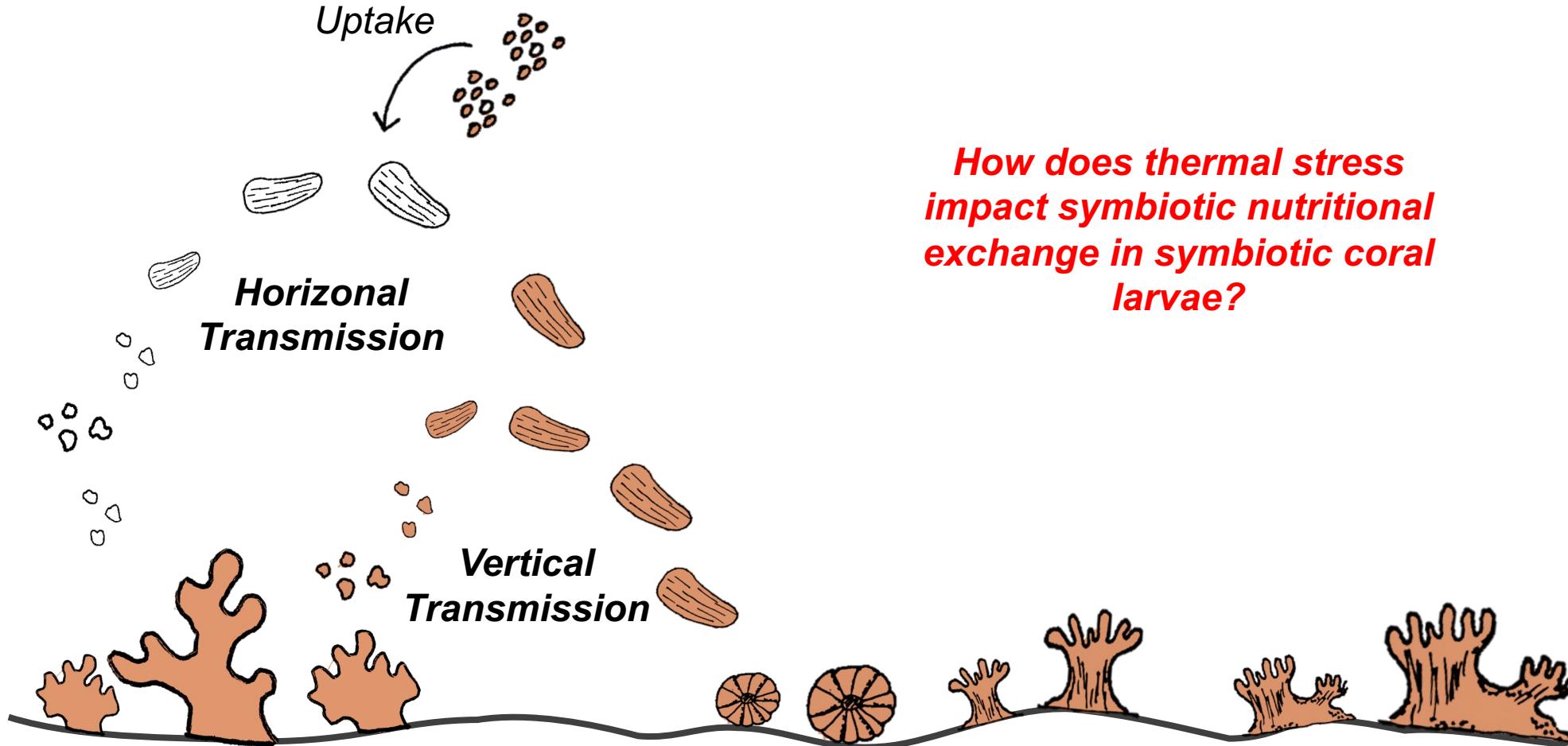
Huffmyer et al. 2023 BioRxiv

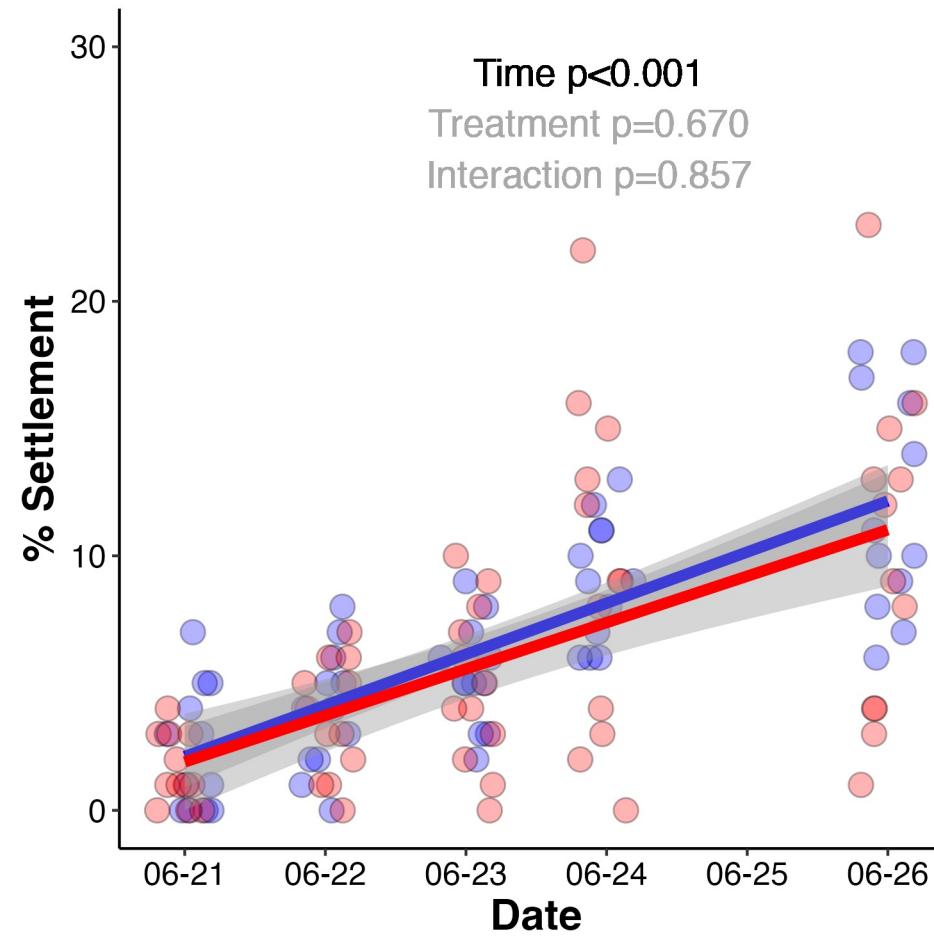
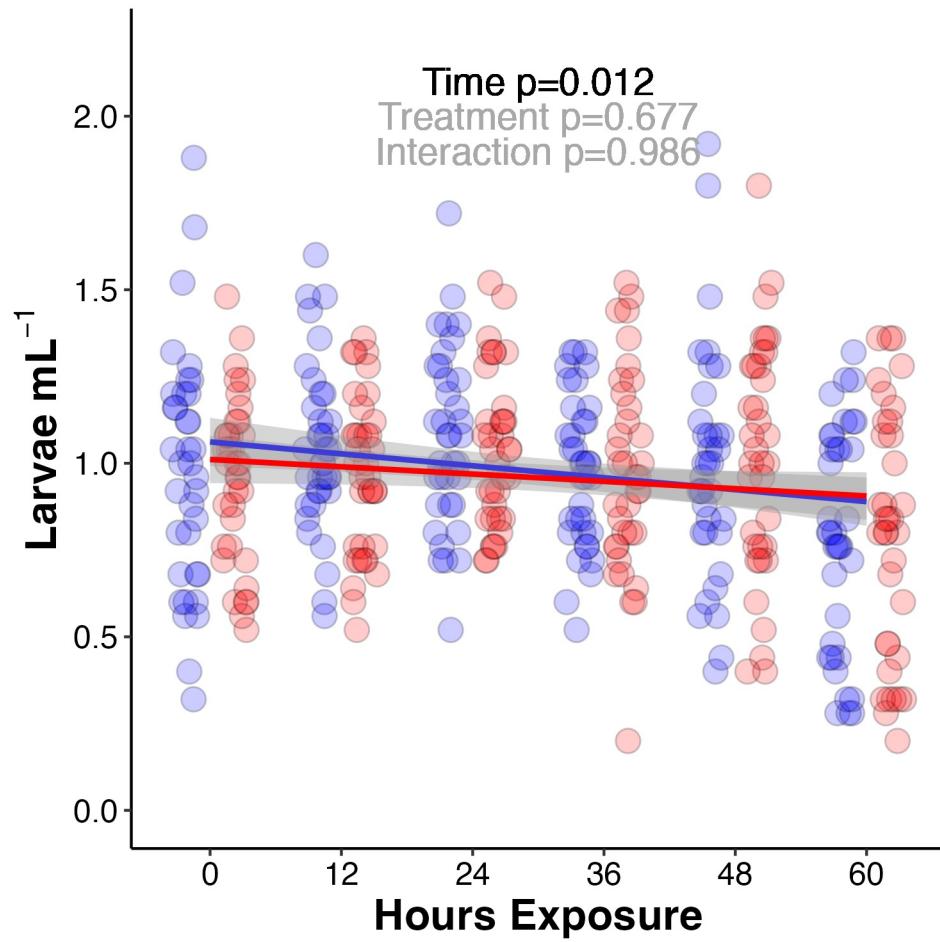
Symbiont
Uptake

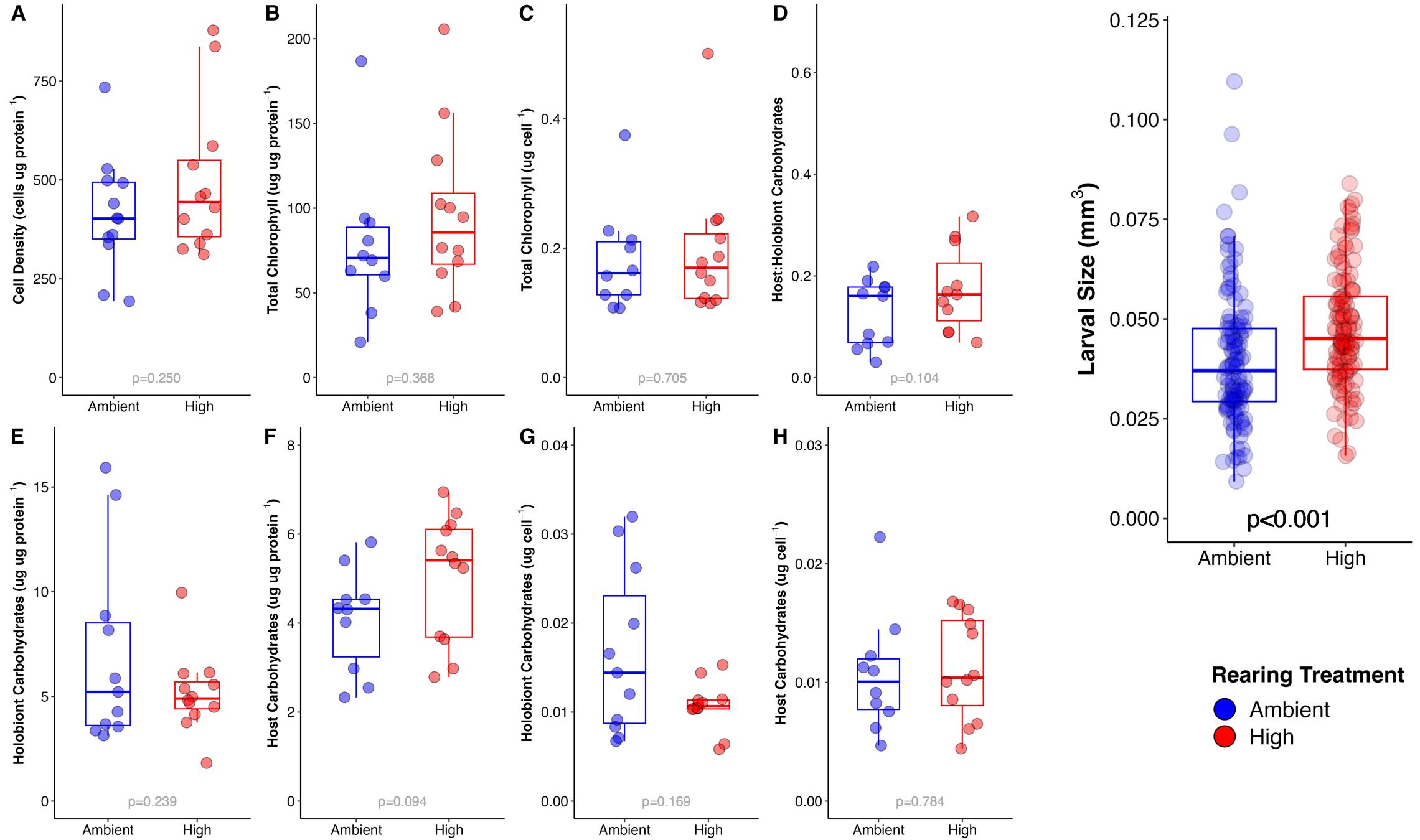
Horizontal
Transmission

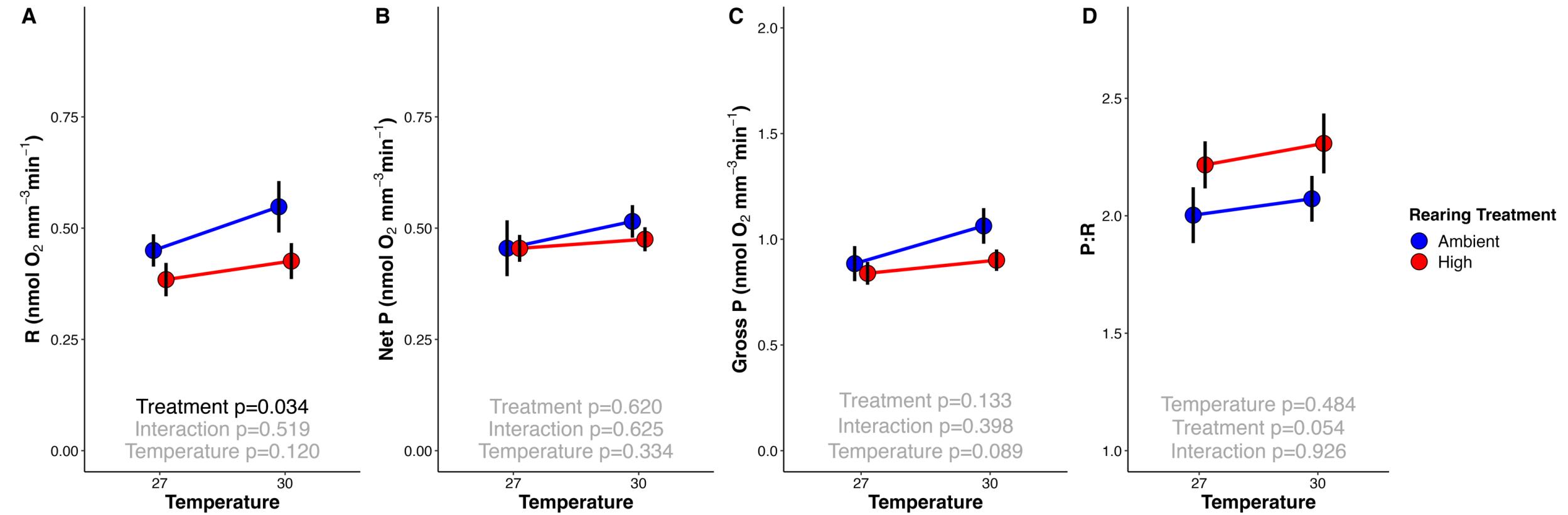
Vertical
Transmission

*How does thermal stress
impact symbiotic nutritional
exchange in symbiotic coral
larvae?*

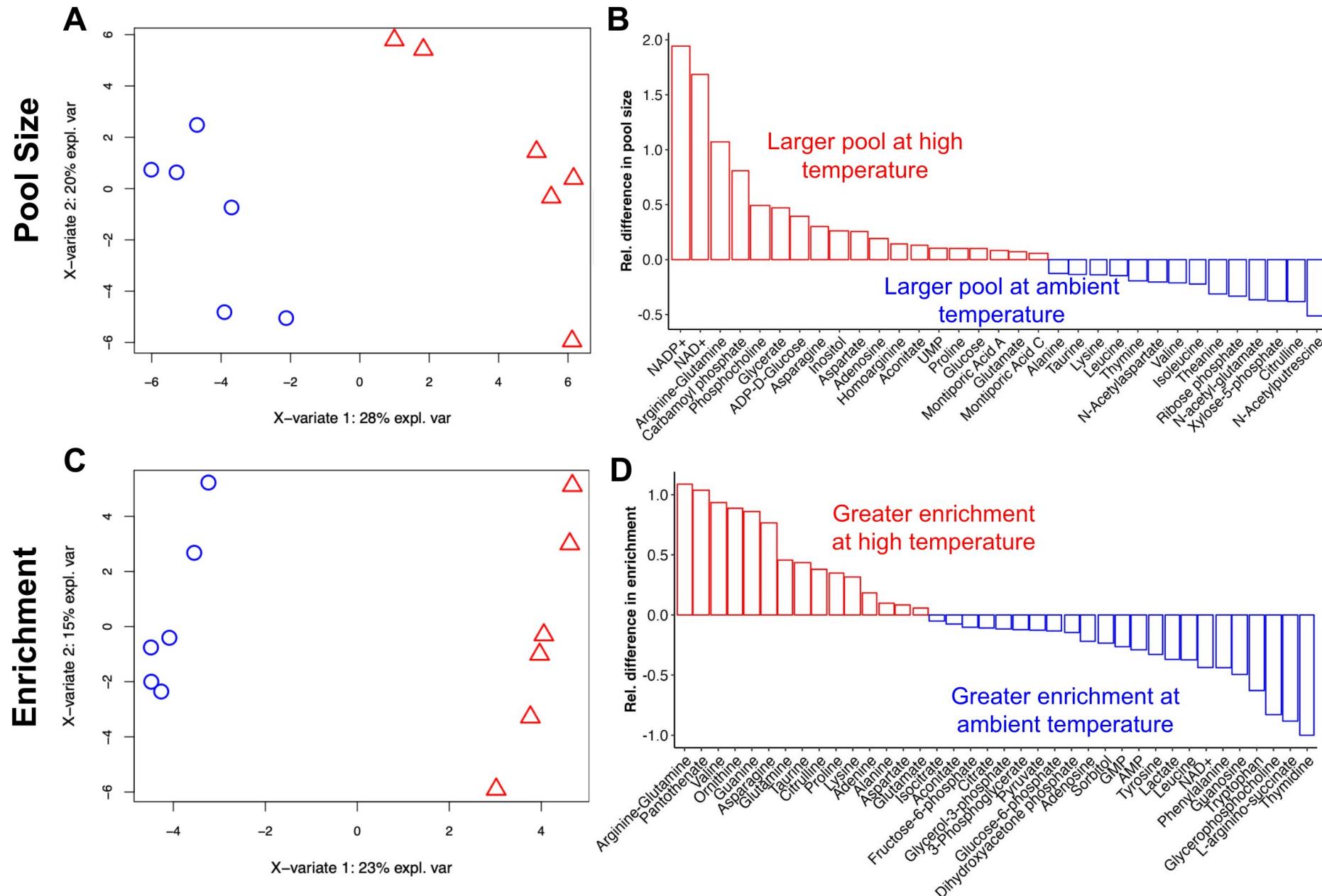




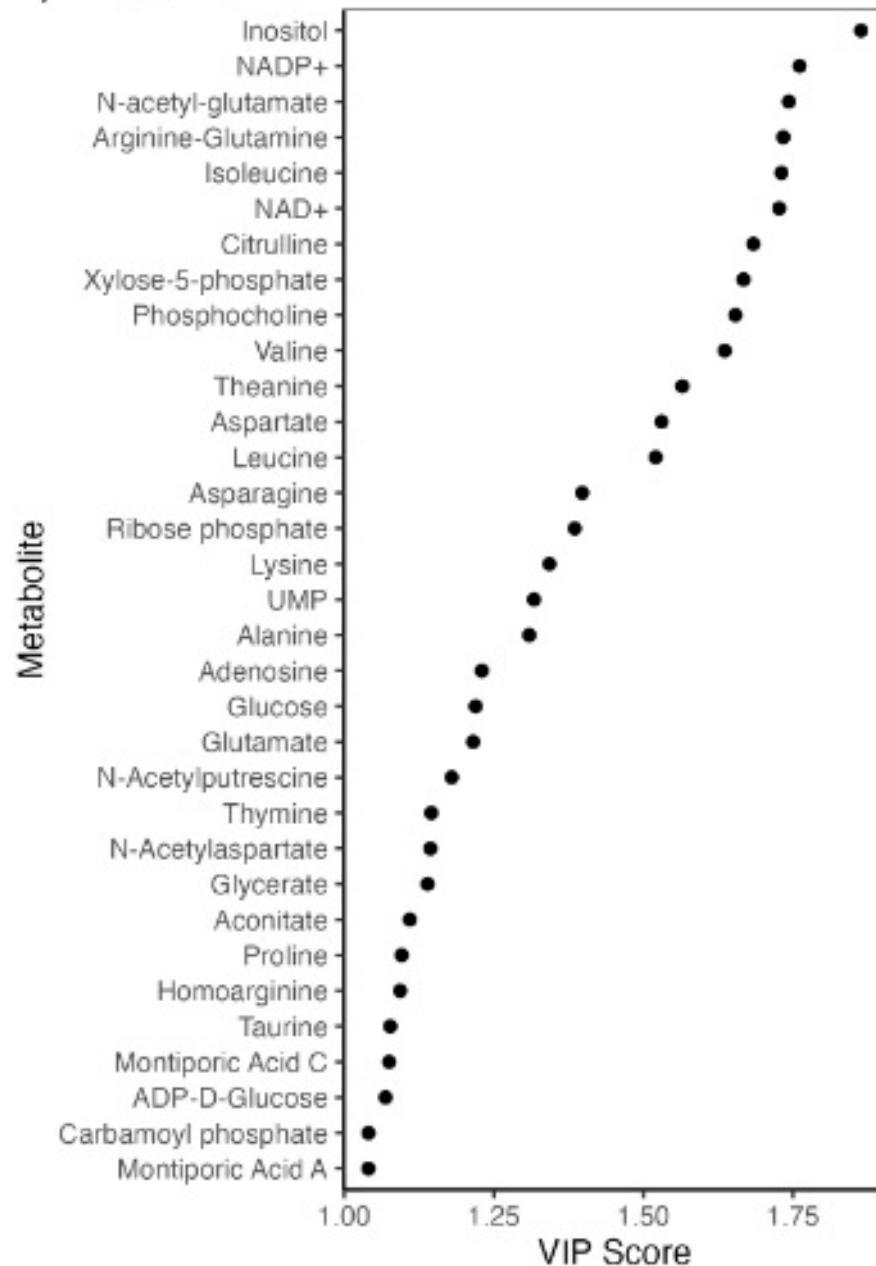




Thermal stress elicits metabolomic response in coral larvae



A) Pool Size VIP



B) Enrichment VIP

