



# *Understanding shifts in symbiotic and physiological state in reef-building corals across developmental and environmental gradients*

**Ariana S. Huffmyer, PhD**

University of Rhode Island | University of Washington

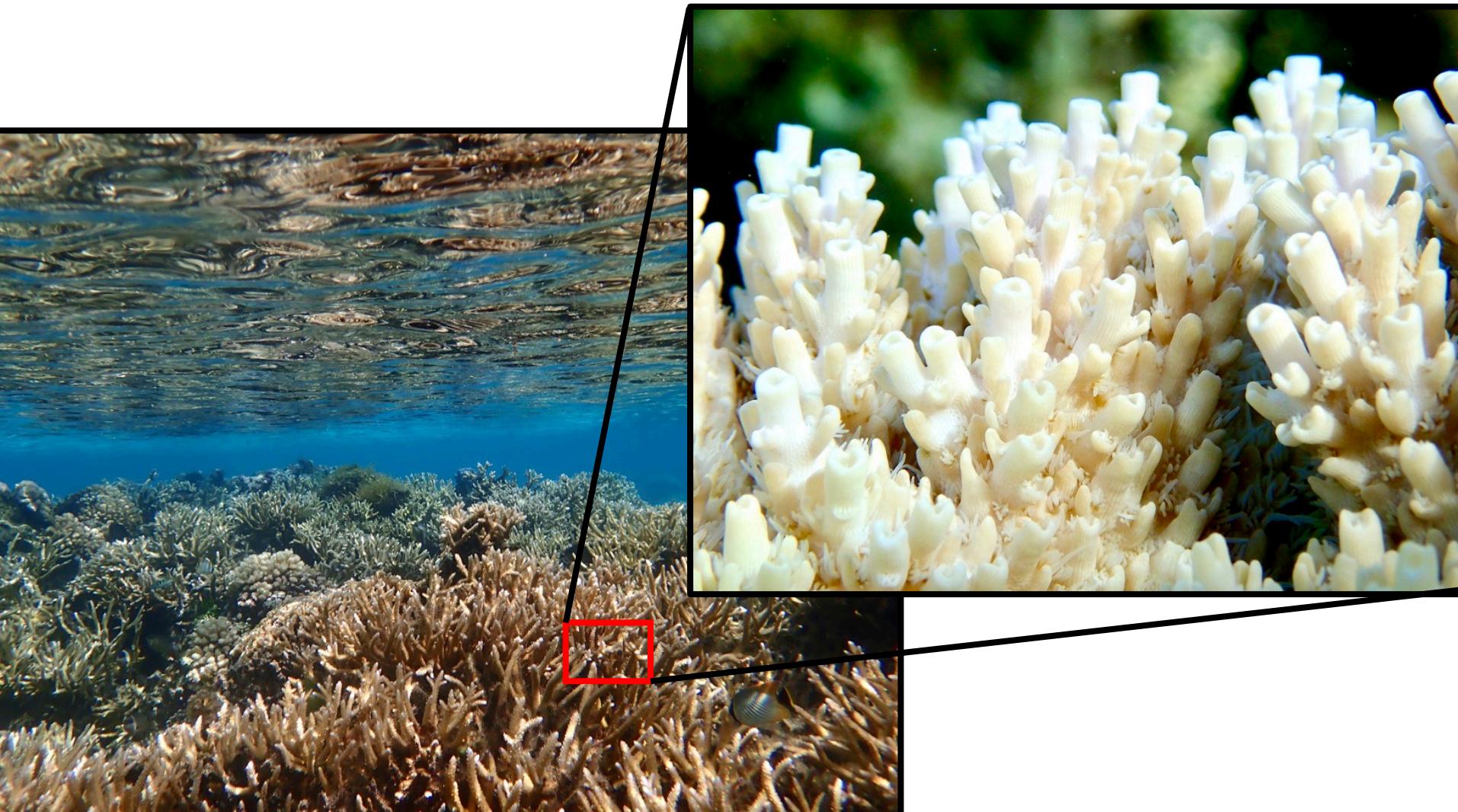
*National Science Foundation Ocean Sciences Postdoctoral Fellow  
University of Washington eScience Data Science Postdoctoral Fellow*

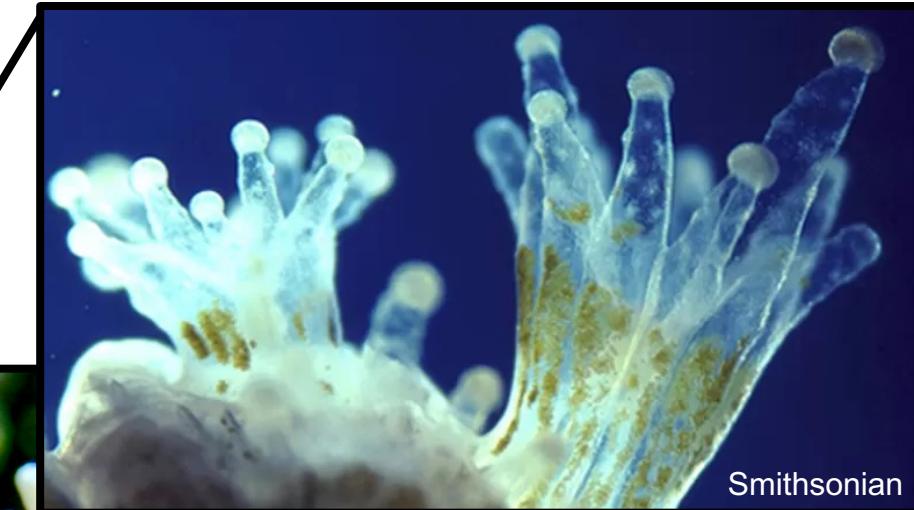
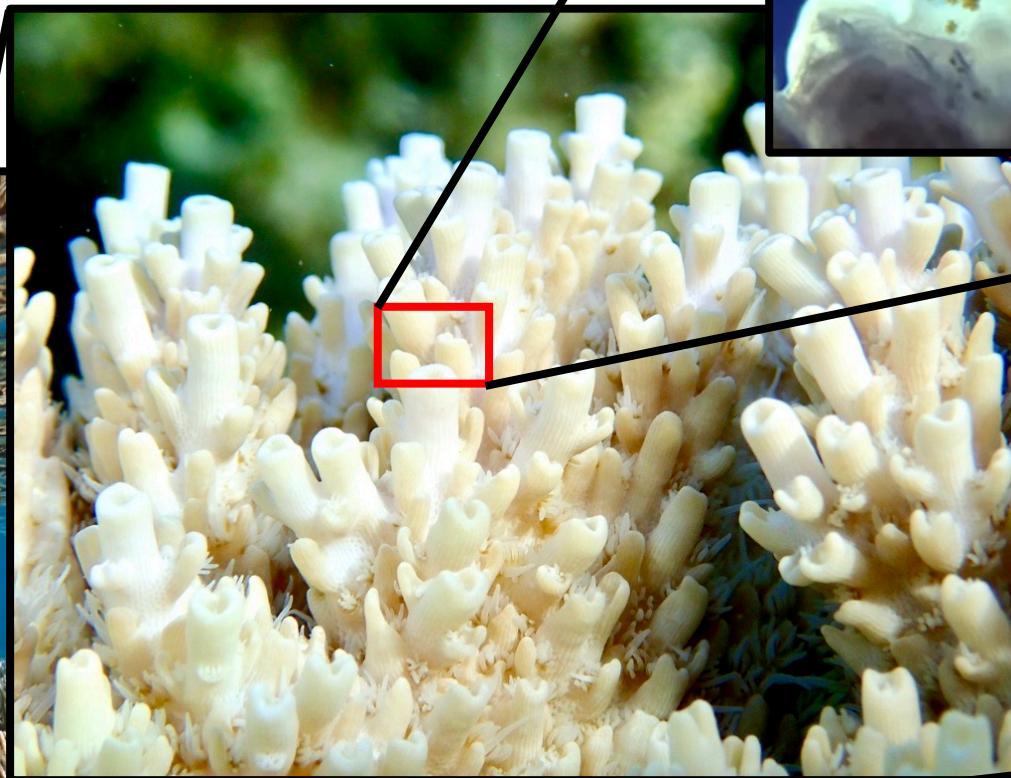
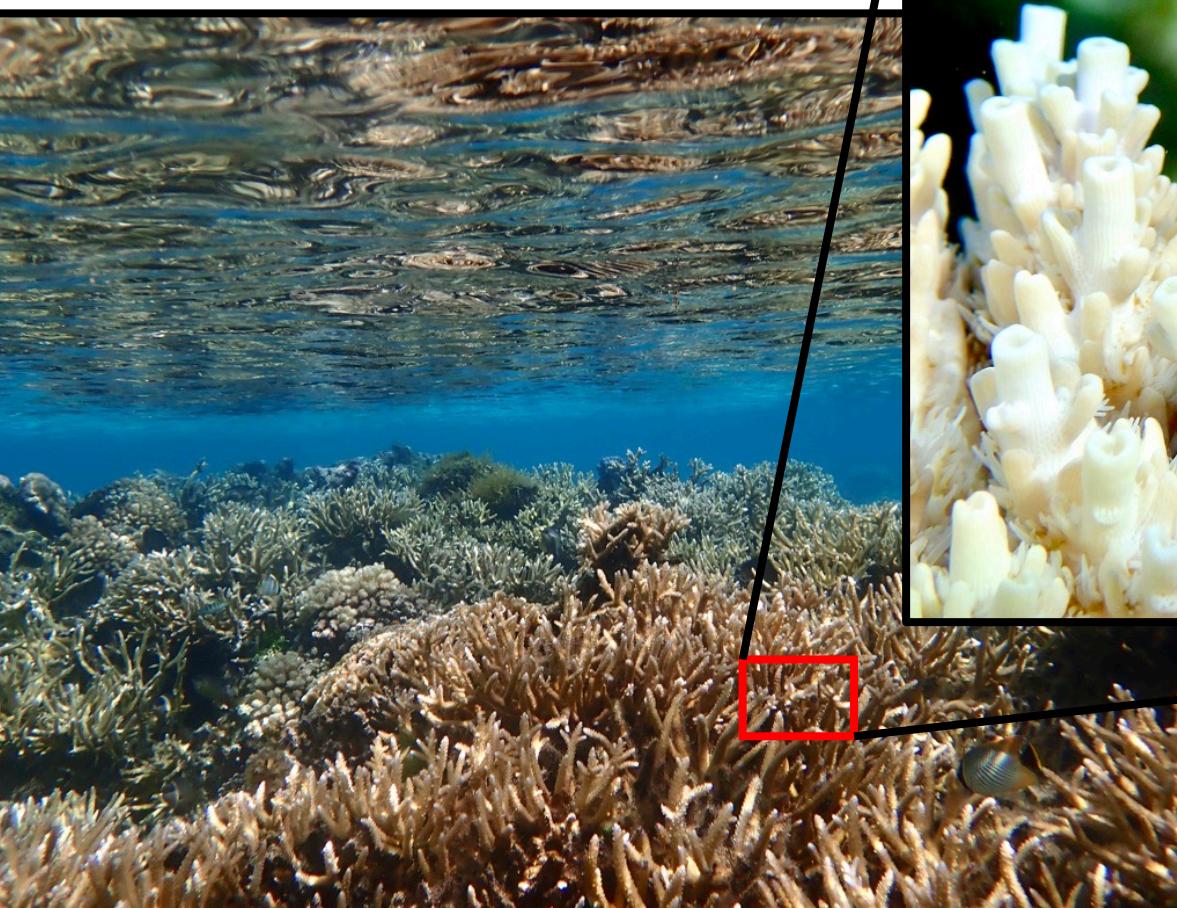
ashuffmyer@uri.edu

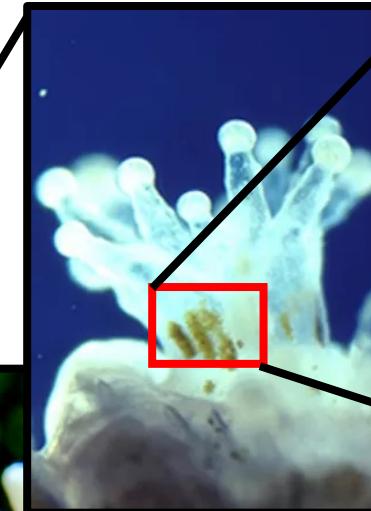
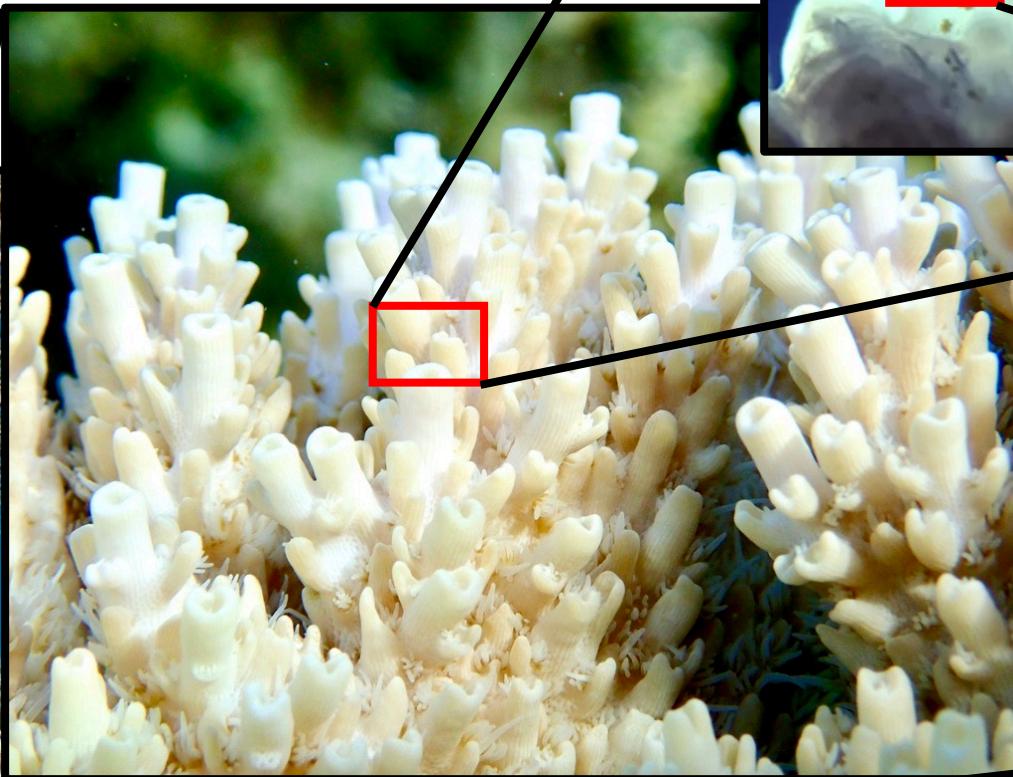
 AHuffmyer

 @Dr\_Cnidariana

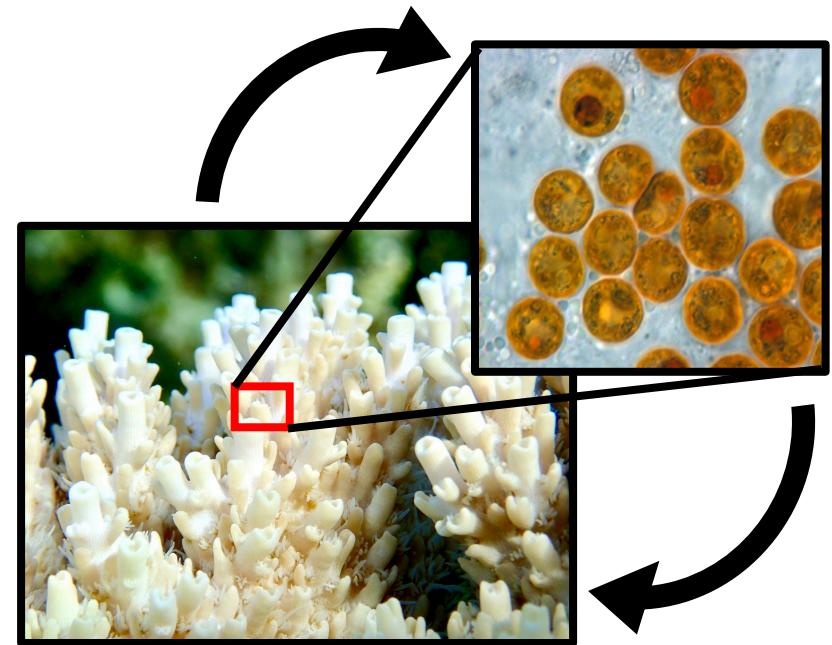
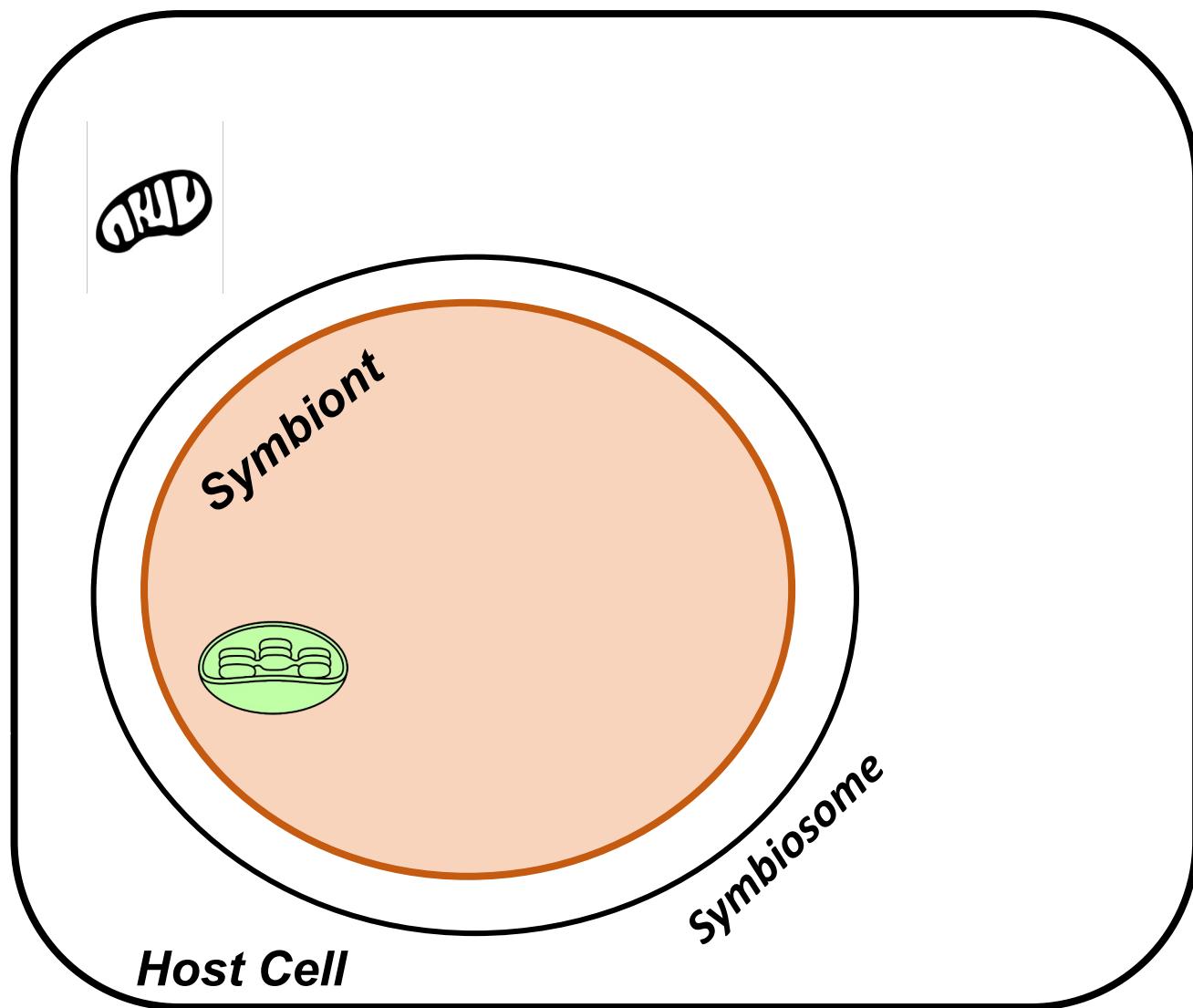




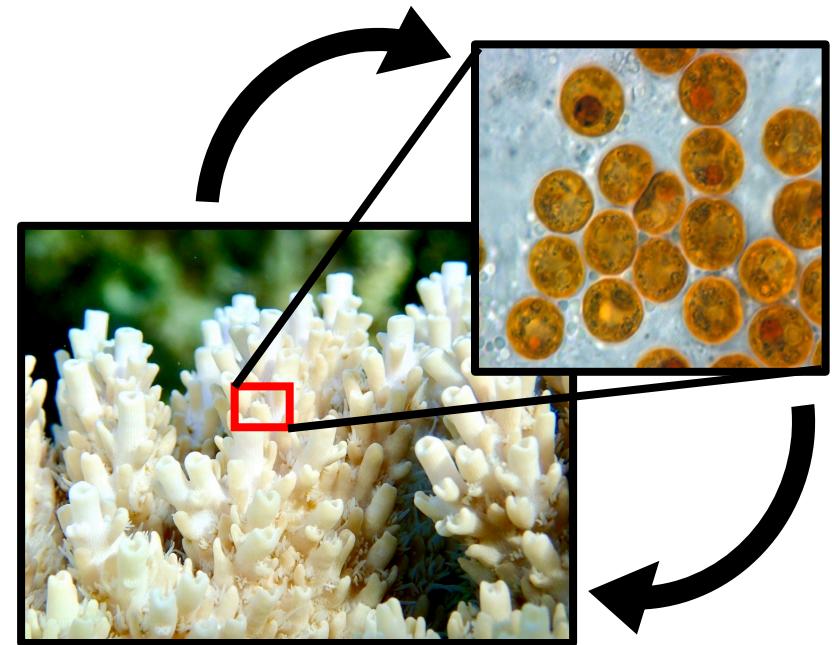
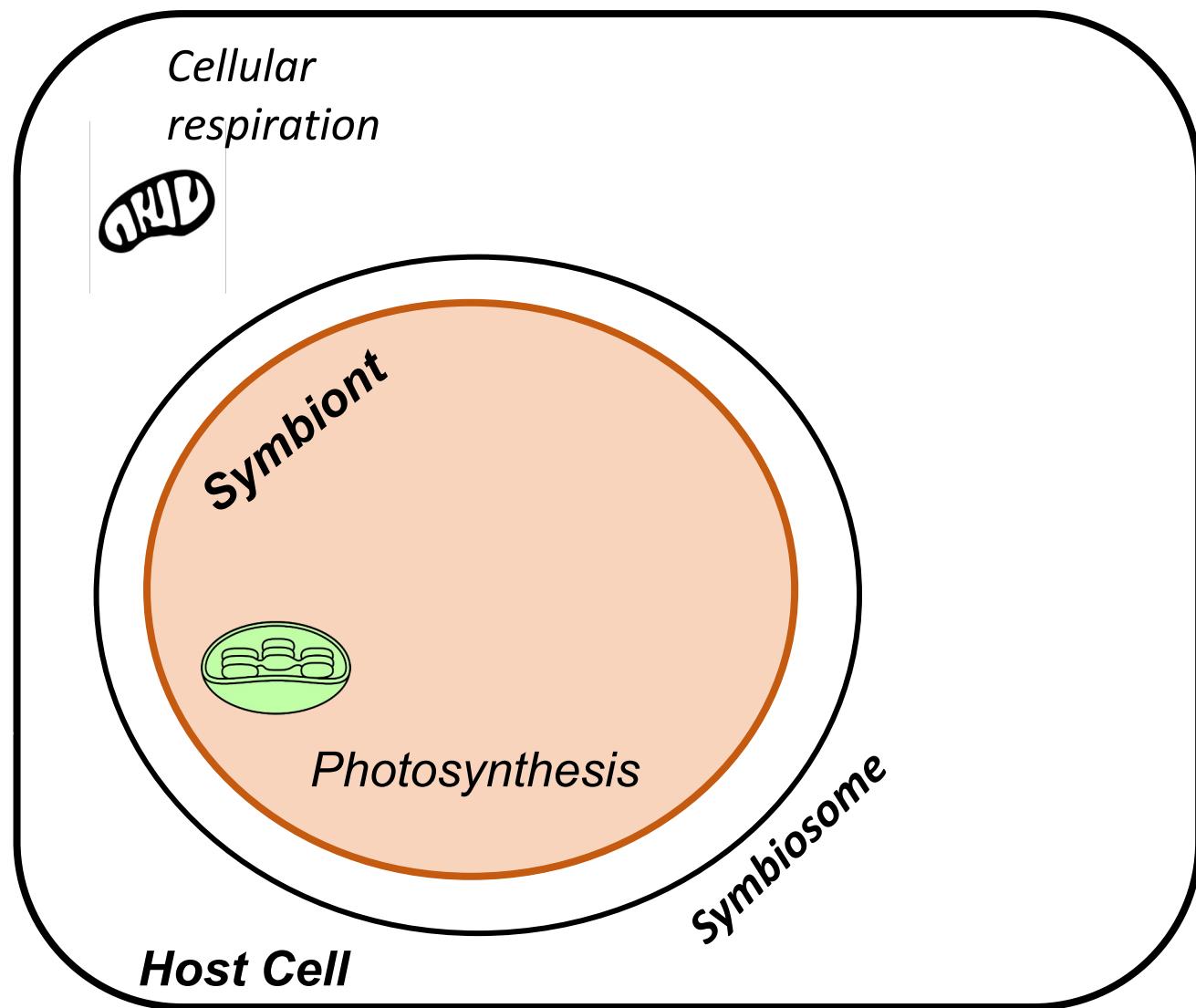




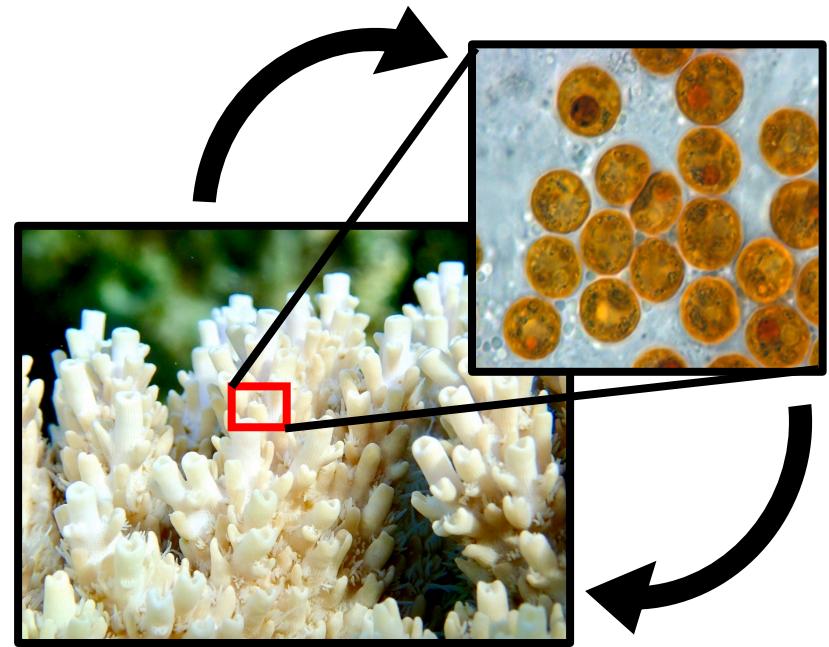
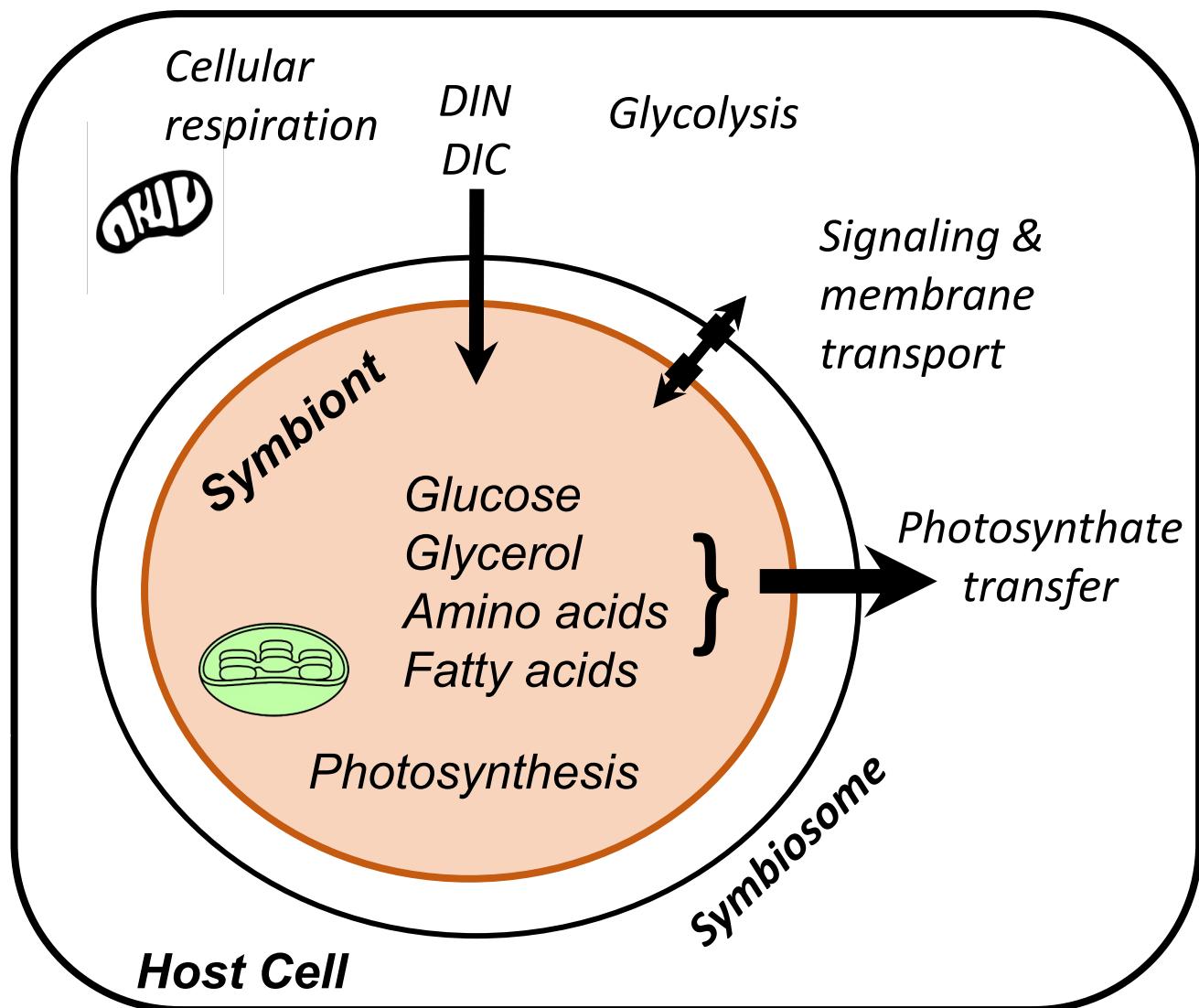
## Coral-Symbiodiniaceae Nutritional Exchange



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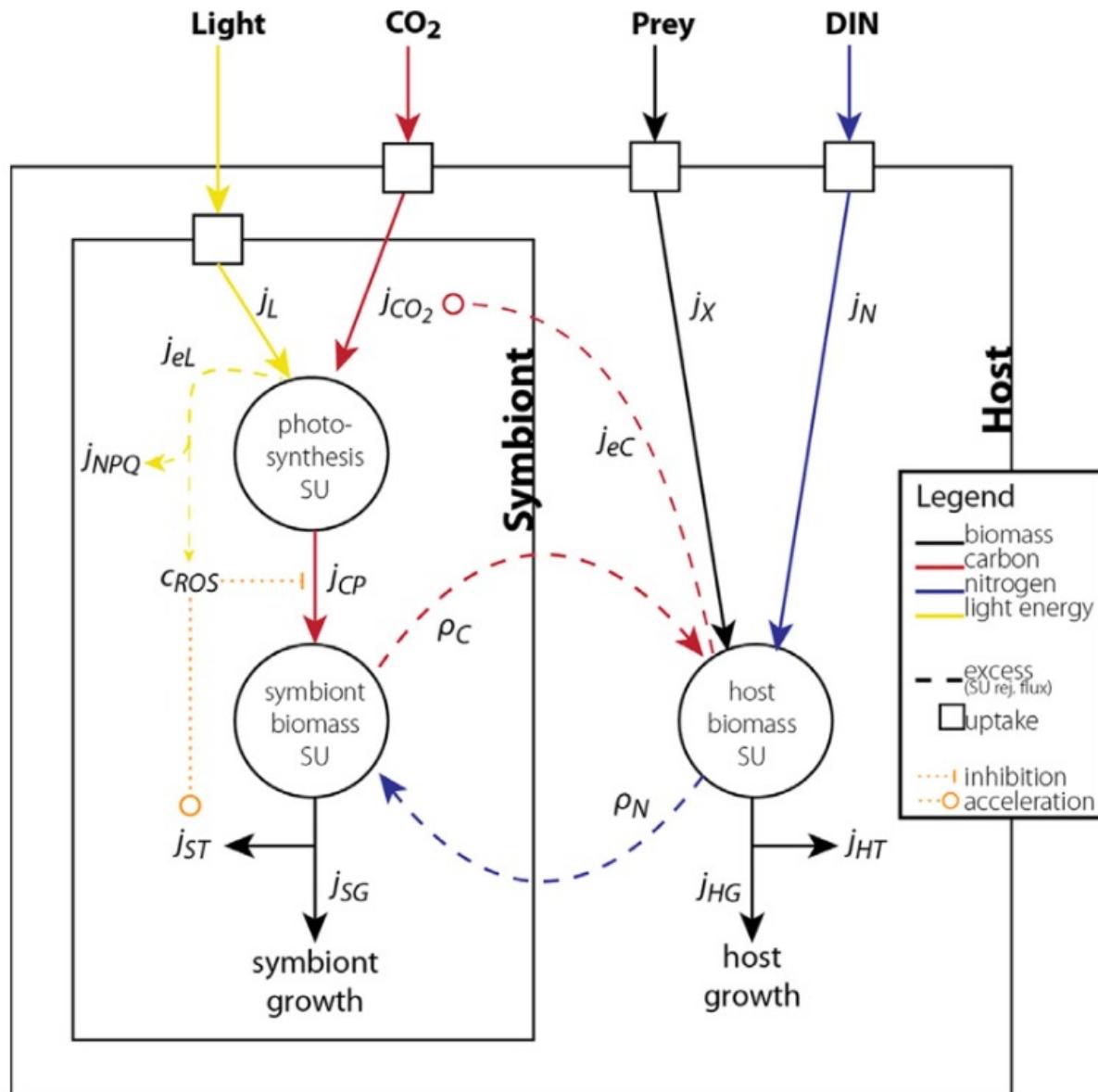


## Coral-Symbiodiniaceae Nutritional Exchange

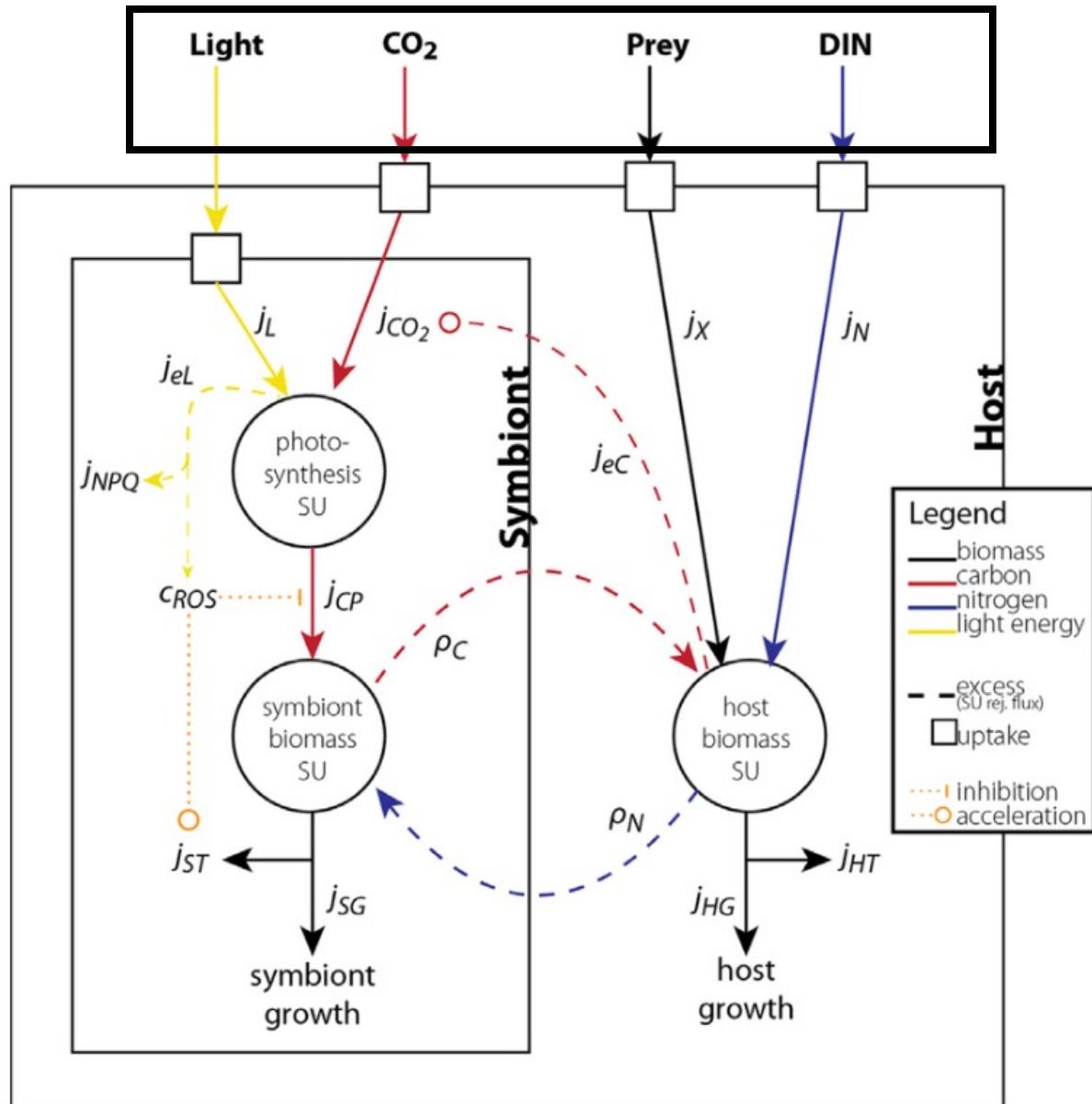




# Environmental variability influences symbiotic and metabolic state



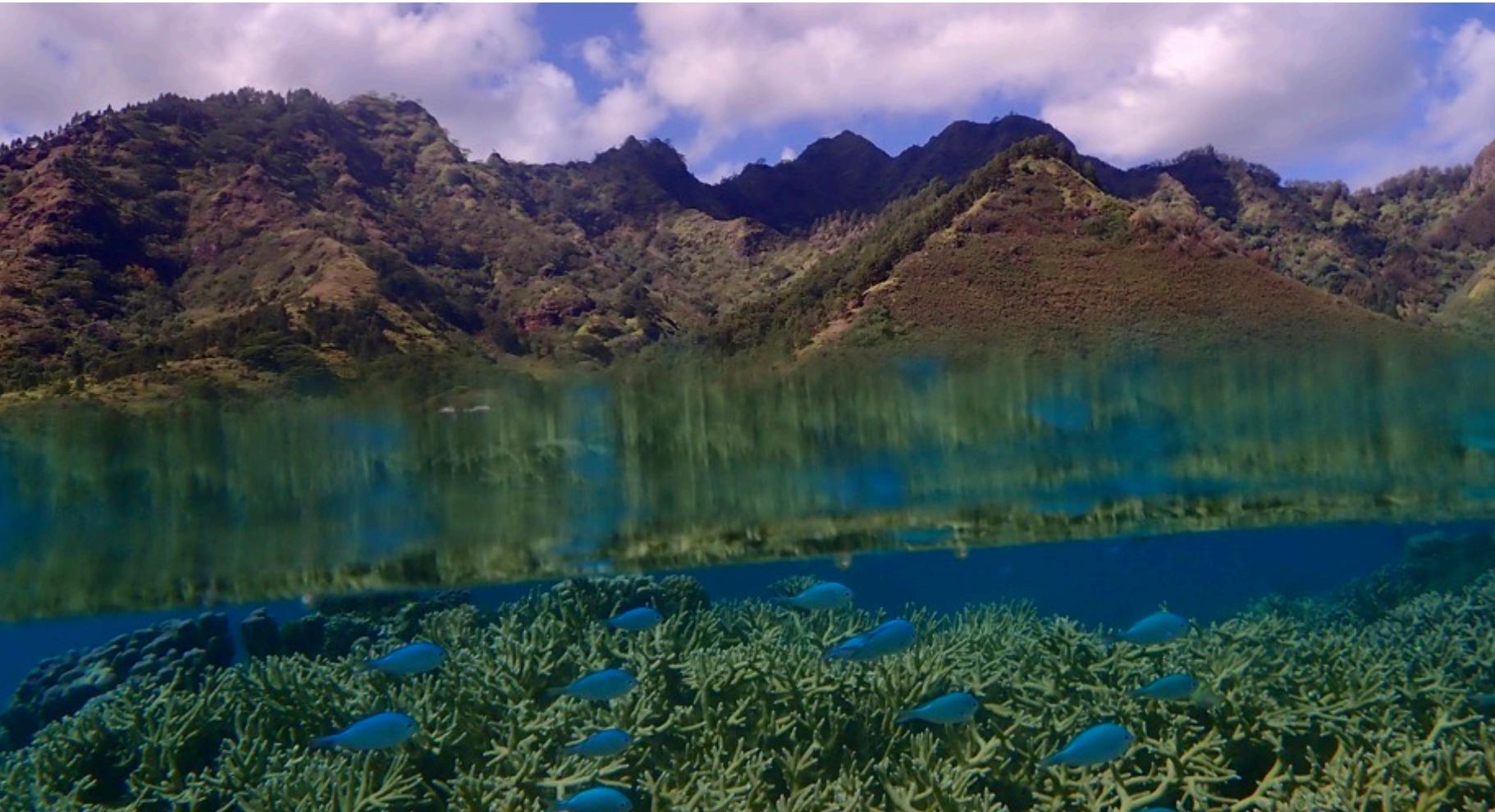
# Environmental variability influences symbiotic and metabolic state



Variability in symbiotic and metabolic state across:

- 1) Environmental gradients
- 2) Developmental gradients

# ***Understanding the Rules of Life: Epigenetics – Predicting phenotypic and eco-evolutionary consequences of environmental-energetic-epigenetic linkages***



## **PI Team:**

Dr. Hollie Putnam  
University of Rhode Island

Dr. Steven Roberts  
University of Washington

Dr. Ross Cunning  
Shedd Aquarium

Dr. Holly Moeller  
Dr. Roger Nisbet  
UC Santa Barbara

Dr. Jose Eirin-Lopez  
Florida International University

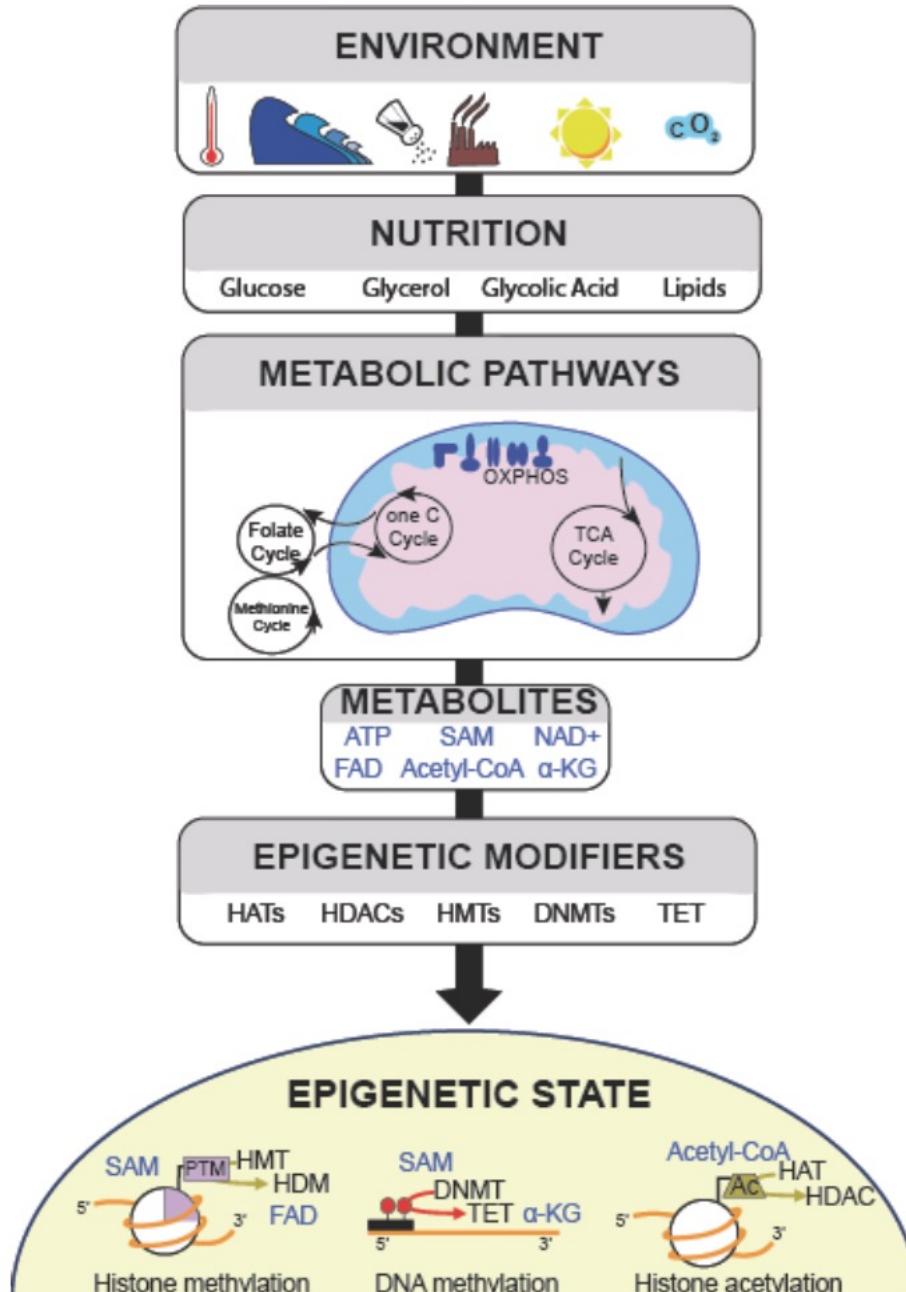
**Website:**  
[e5coral.org](http://e5coral.org)

**Open notebooks:**  
[urol-e5.github.io/](https://urol-e5.github.io/)

**GitHub:**  
[github.com/urol-e5](https://github.com/urol-e5)

# Energetic-Epigenetic Linkages

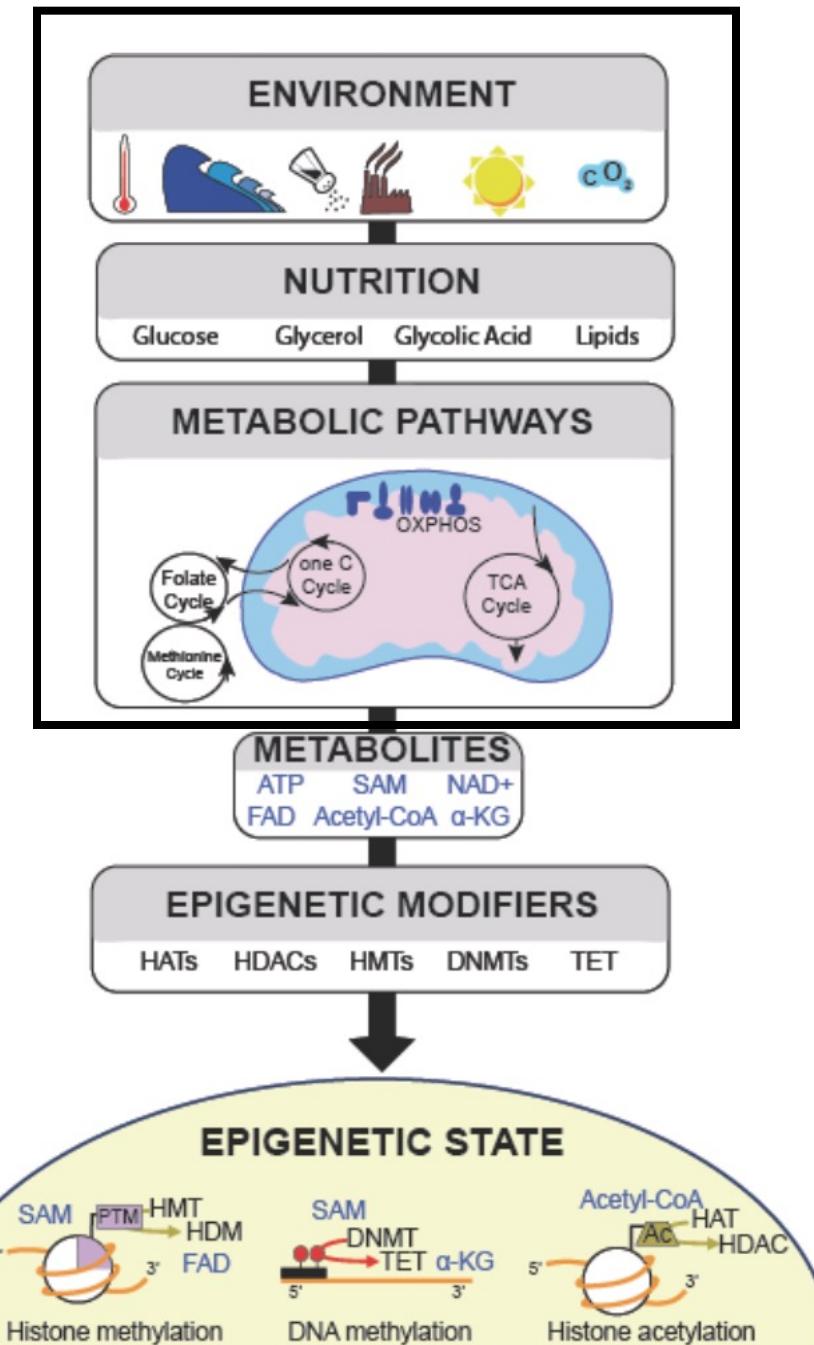
*How does environmental variability influence physiological and metabolic state and what are the consequences for epigenetic state?*

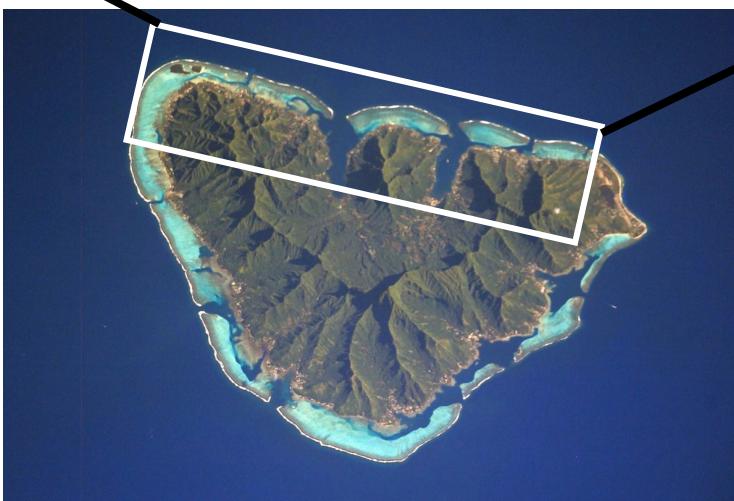
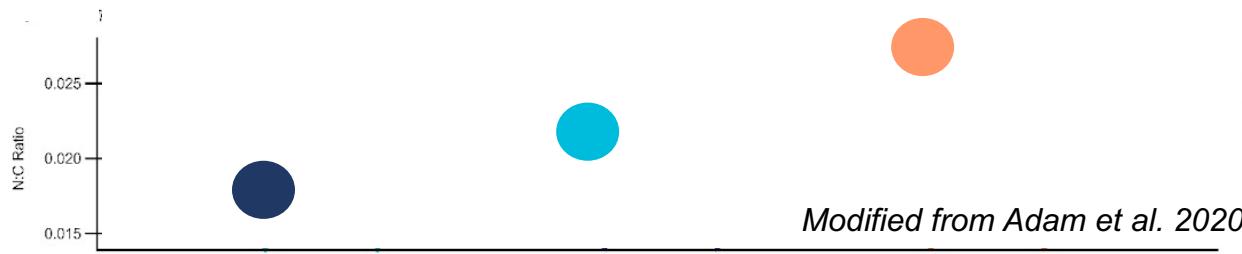


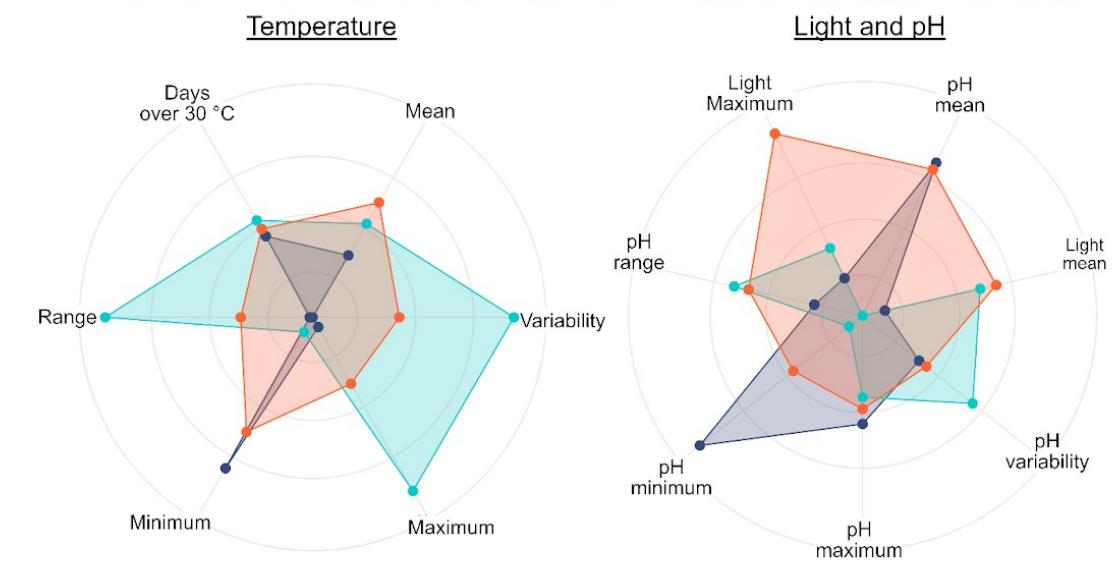
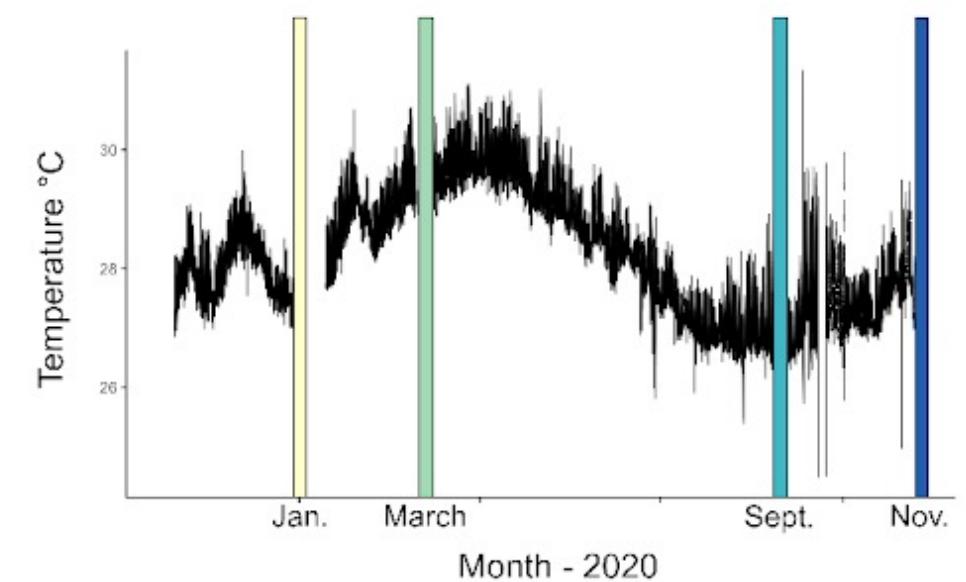
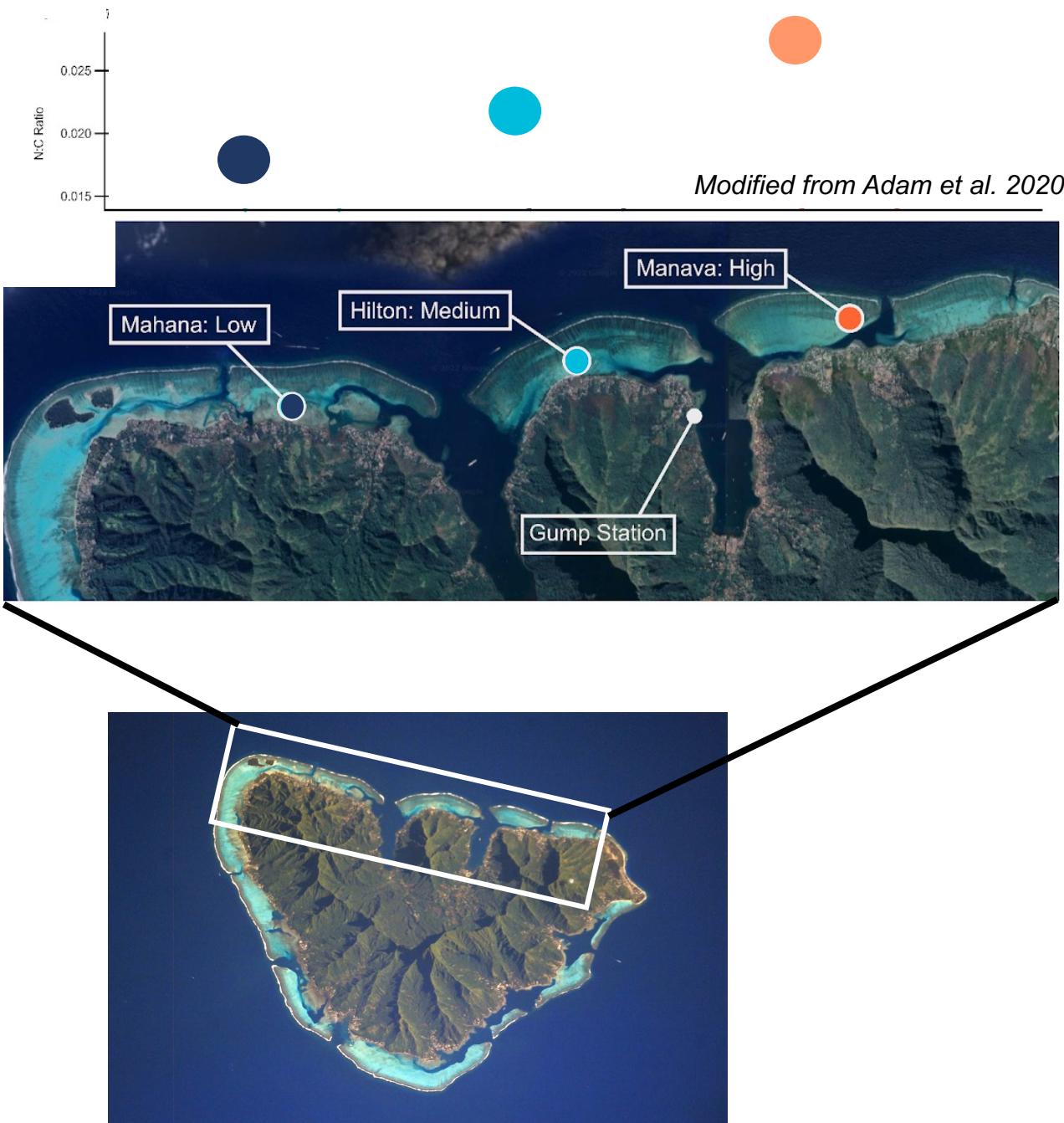
# Energetic-Epigenetic Linkages

*How does environmental variability influence physiological and metabolic state and what are the consequences for epigenetic state?*

*Spatial & seasonal variability*







*Acropora pulchra*



*Pocillopora spp.*



*Porites lutea*



**Host & holobiont physiological variables**

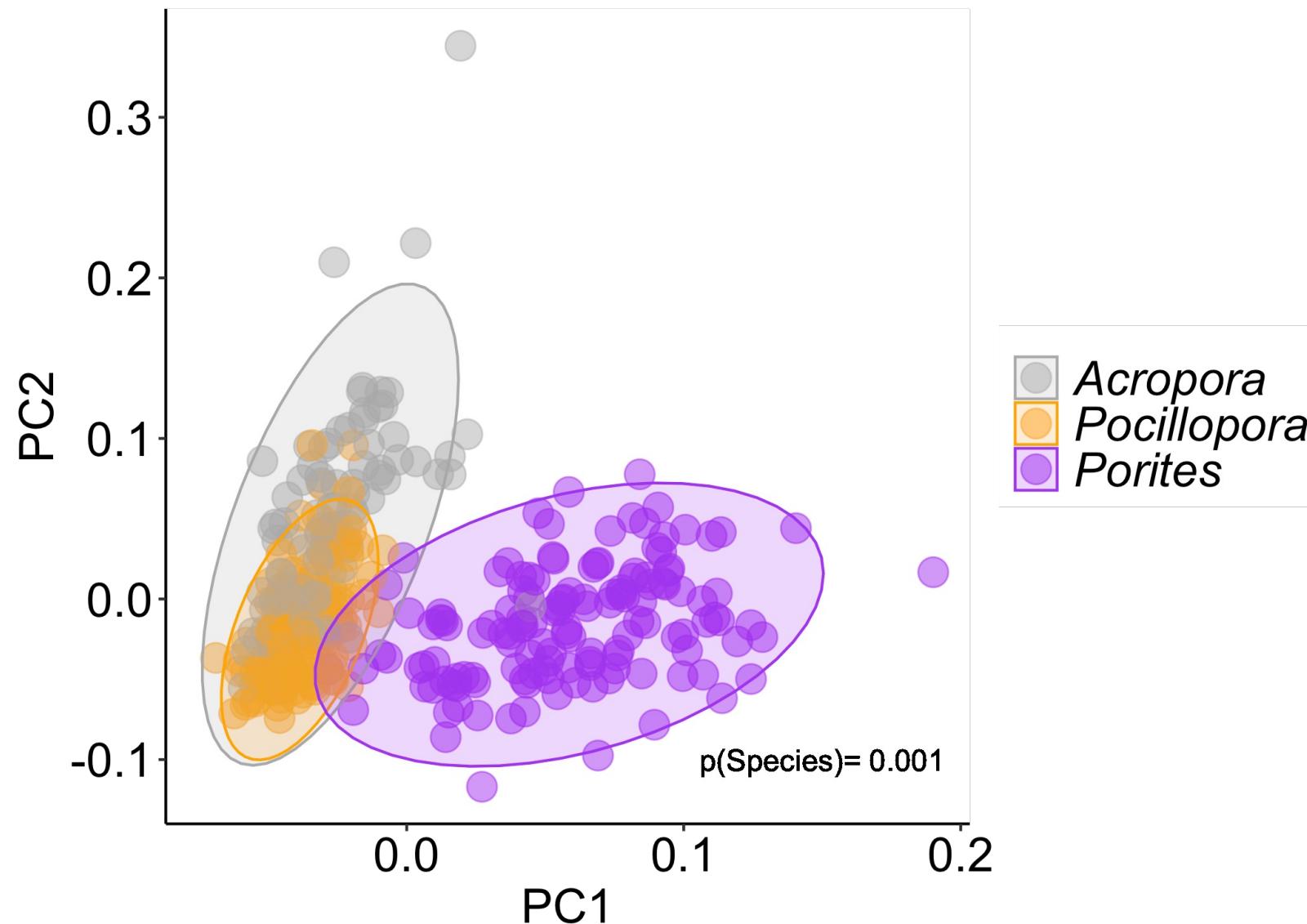
Biomass  
Antioxidant capacity  
Total protein  
Respiration  
Calcification

**Symbiont physiological variables**

Biomass  
Cell density  
Chlorophyll content  
Photosynthesis/PI Curves

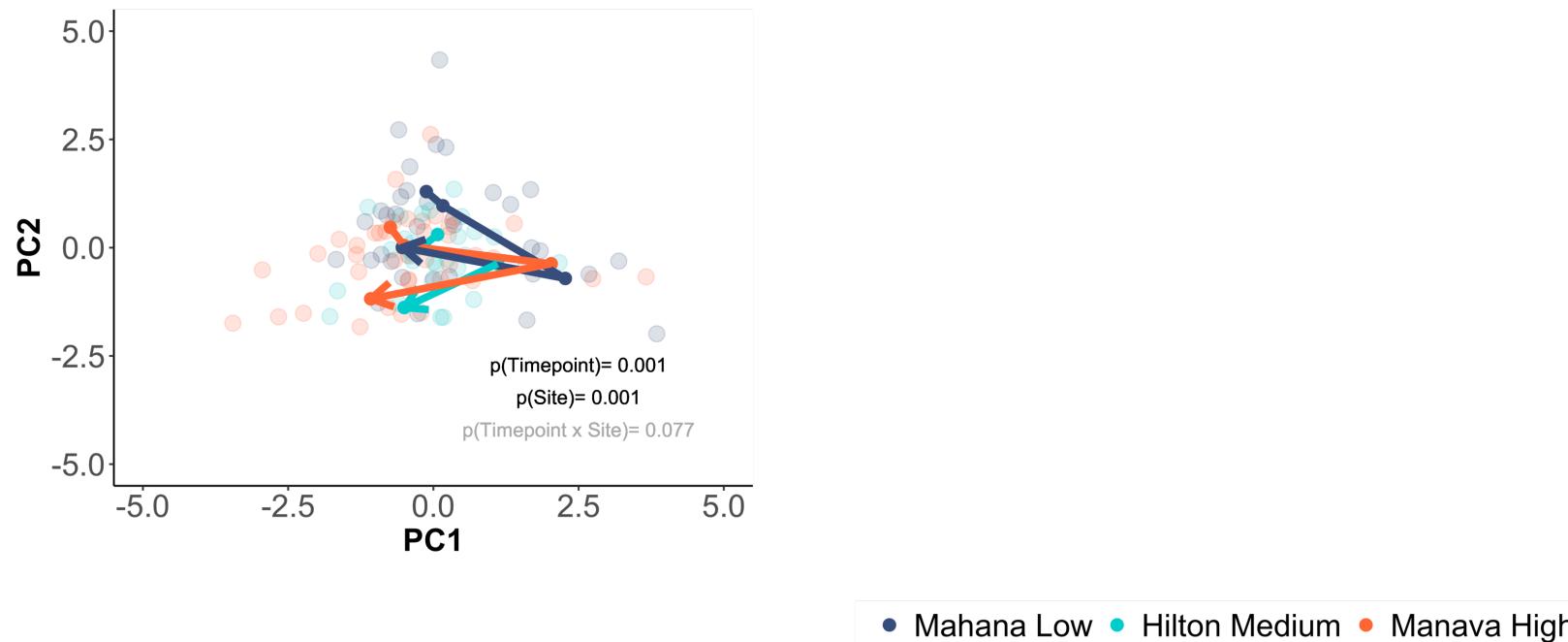
*n=45-50 colonies per species*

# Species-specific physiological states



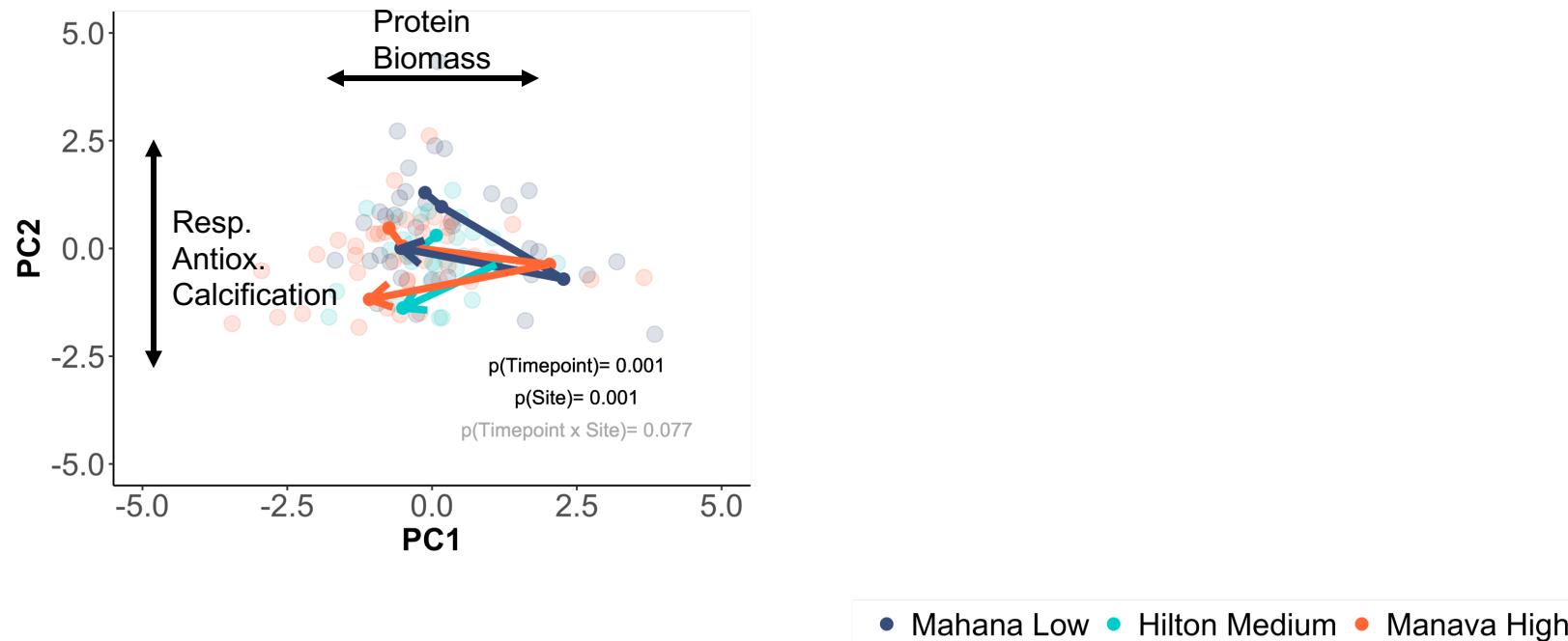
# Shifts in host physiology across space and time

*Acropora*



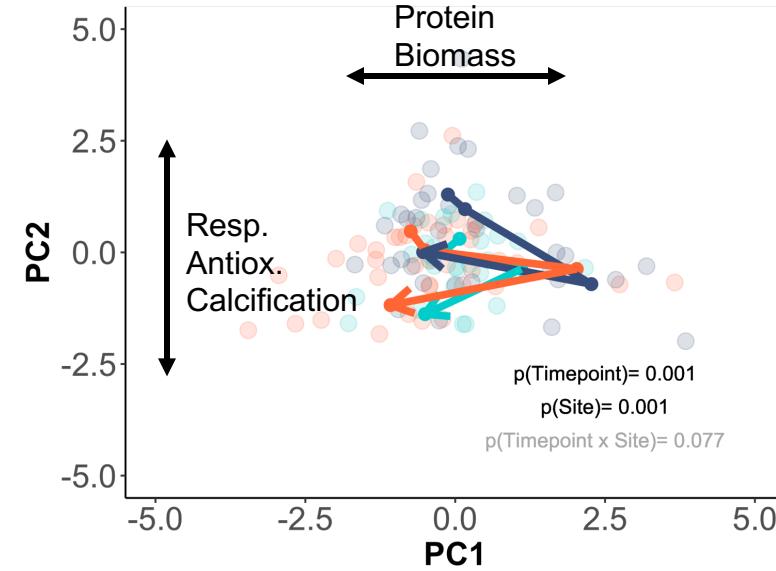
# Shifts in host physiology across space and time

*Acropora*

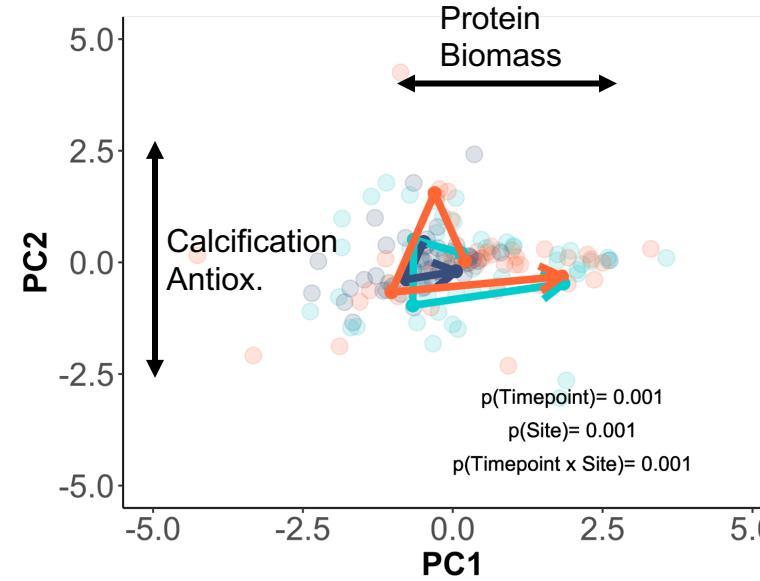


# Shifts in host physiology across space and time

*Acropora*



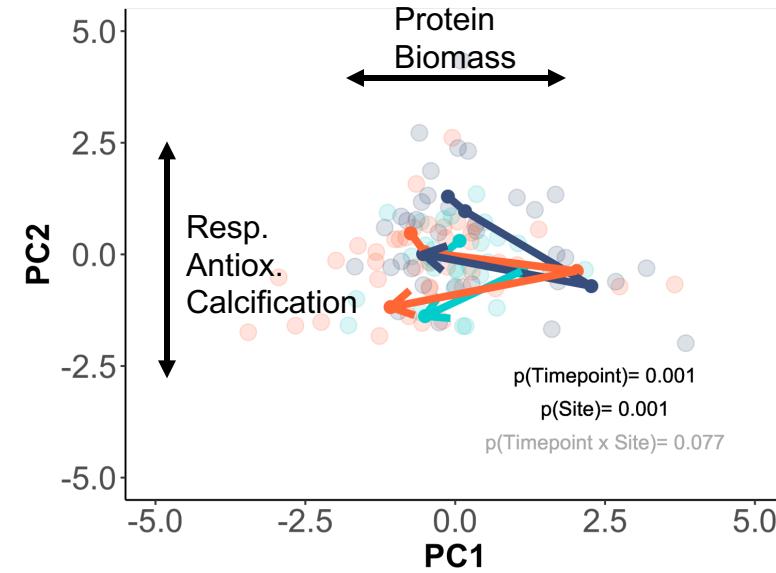
*Pocillopora*



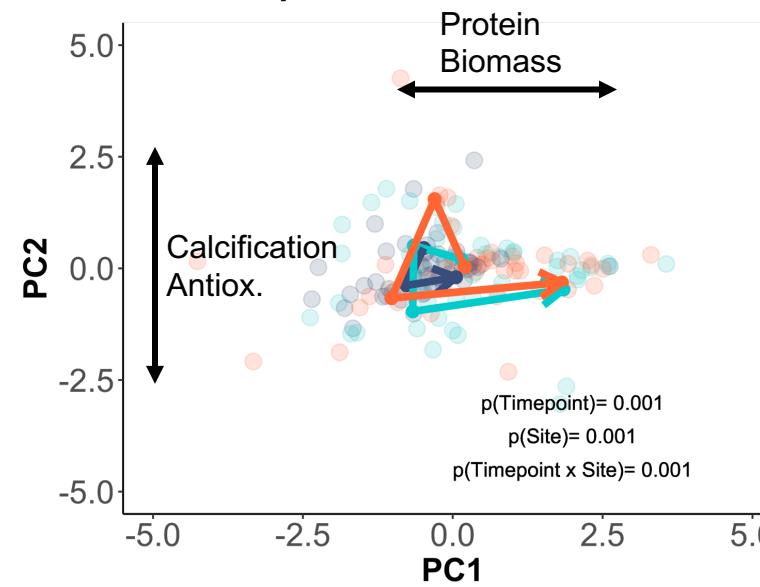
● Mahana Low ● Hilton Medium ● Manava High

# Shifts in host physiology across space and time

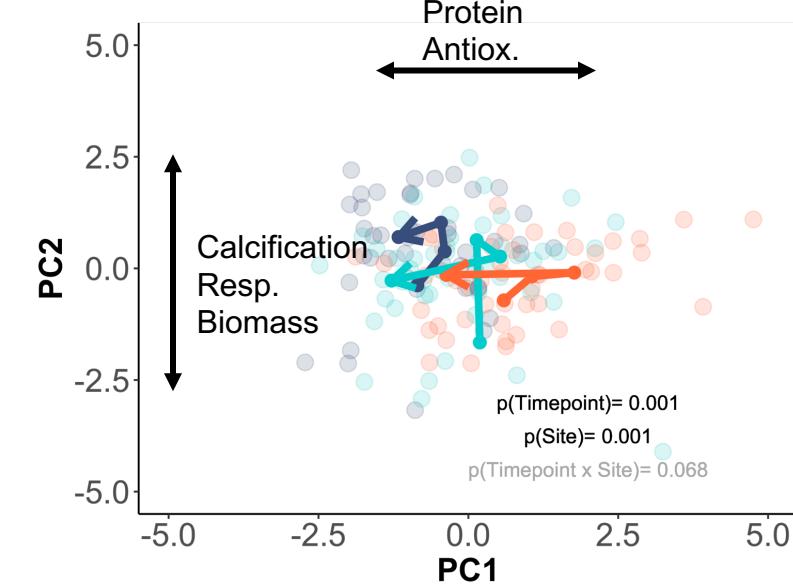
*Acropora*



*Pocillopora*



*Porites*

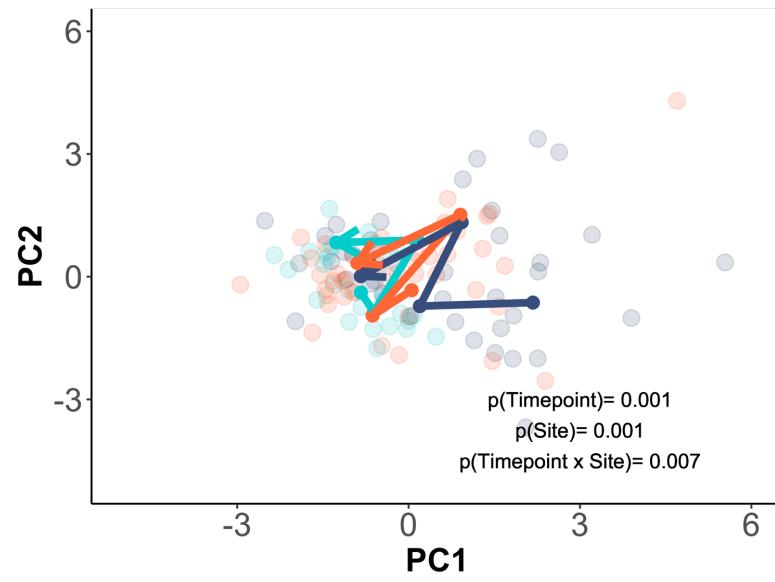


• Mahana Low • Hilton Medium • Manava High

- Species-specific physiological strategies
- Metabolism influenced by spatial variability
- Biomass storage influenced by temporal/seasonal variability

# Shifts in symbiont physiology across space and time

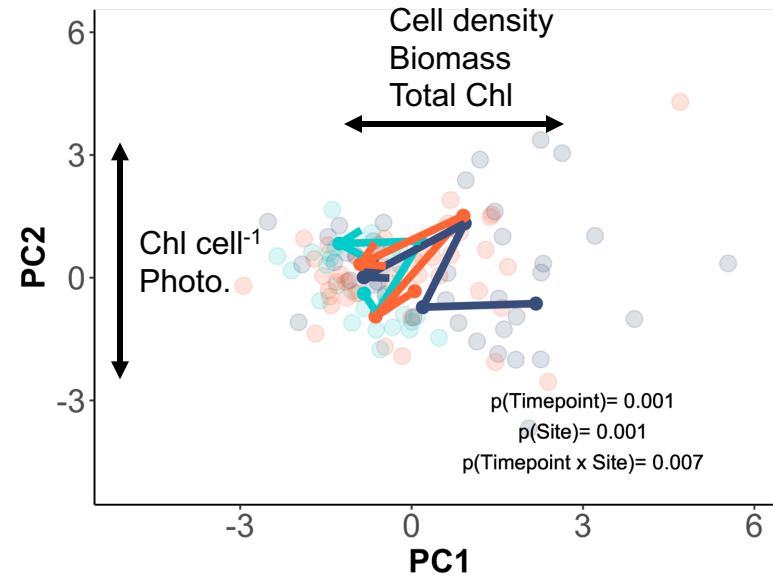
*Acropora*



- Mahana Low • Hilton Medium • Manava High

# Shifts in symbiont physiology across space and time

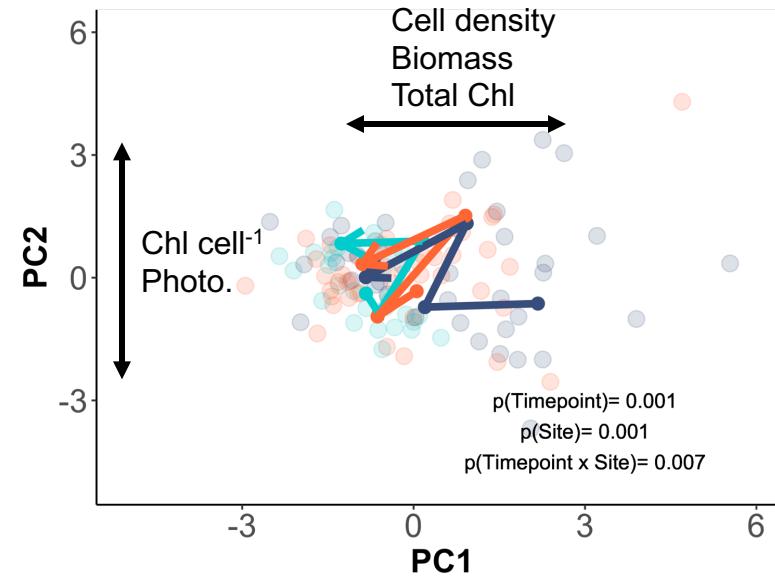
## Acropora



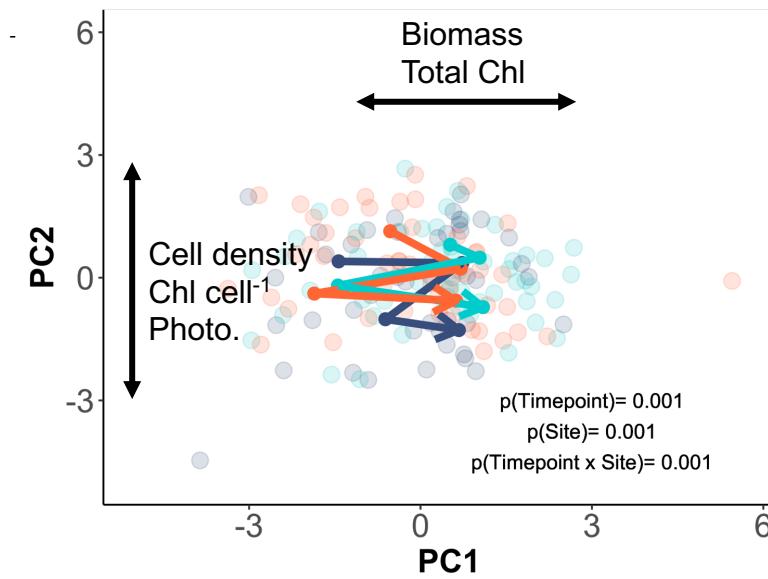
- Mahana Low • Hilton Medium • Manava High

# Shifts in symbiont physiology across space and time

*Acropora*



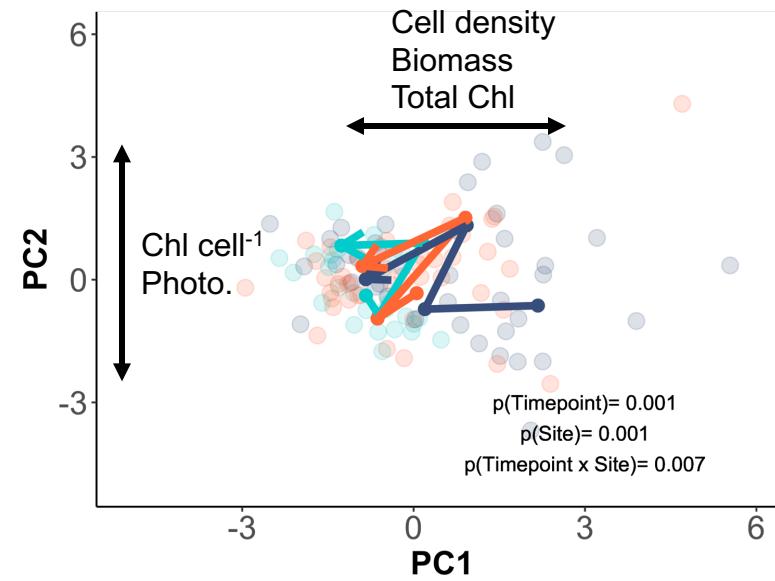
*Pocillopora*



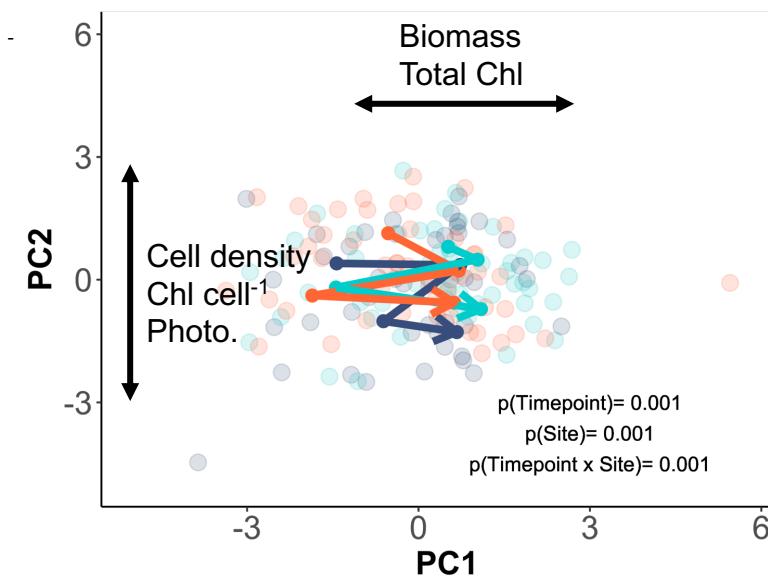
- Mahana Low • Hilton Medium • Manava High

# Shifts in symbiont physiology across space and time

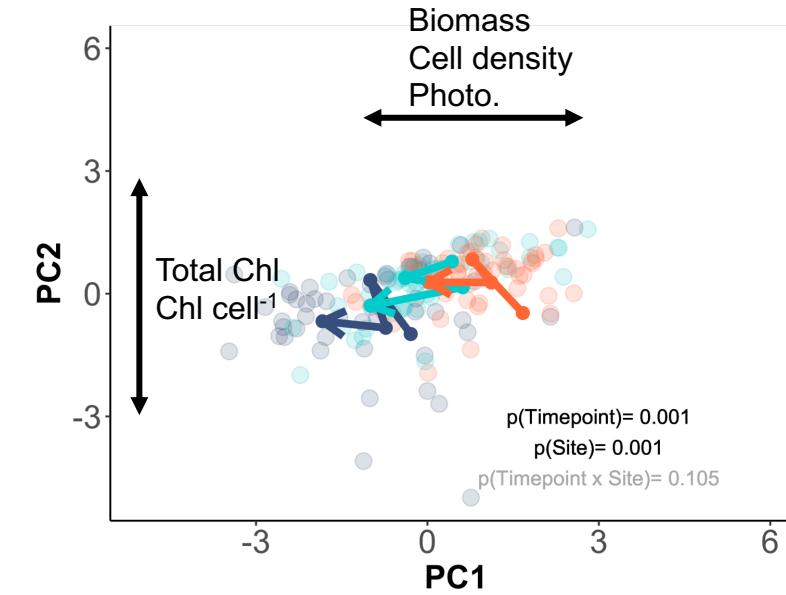
*Acropora*



*Pocillopora*

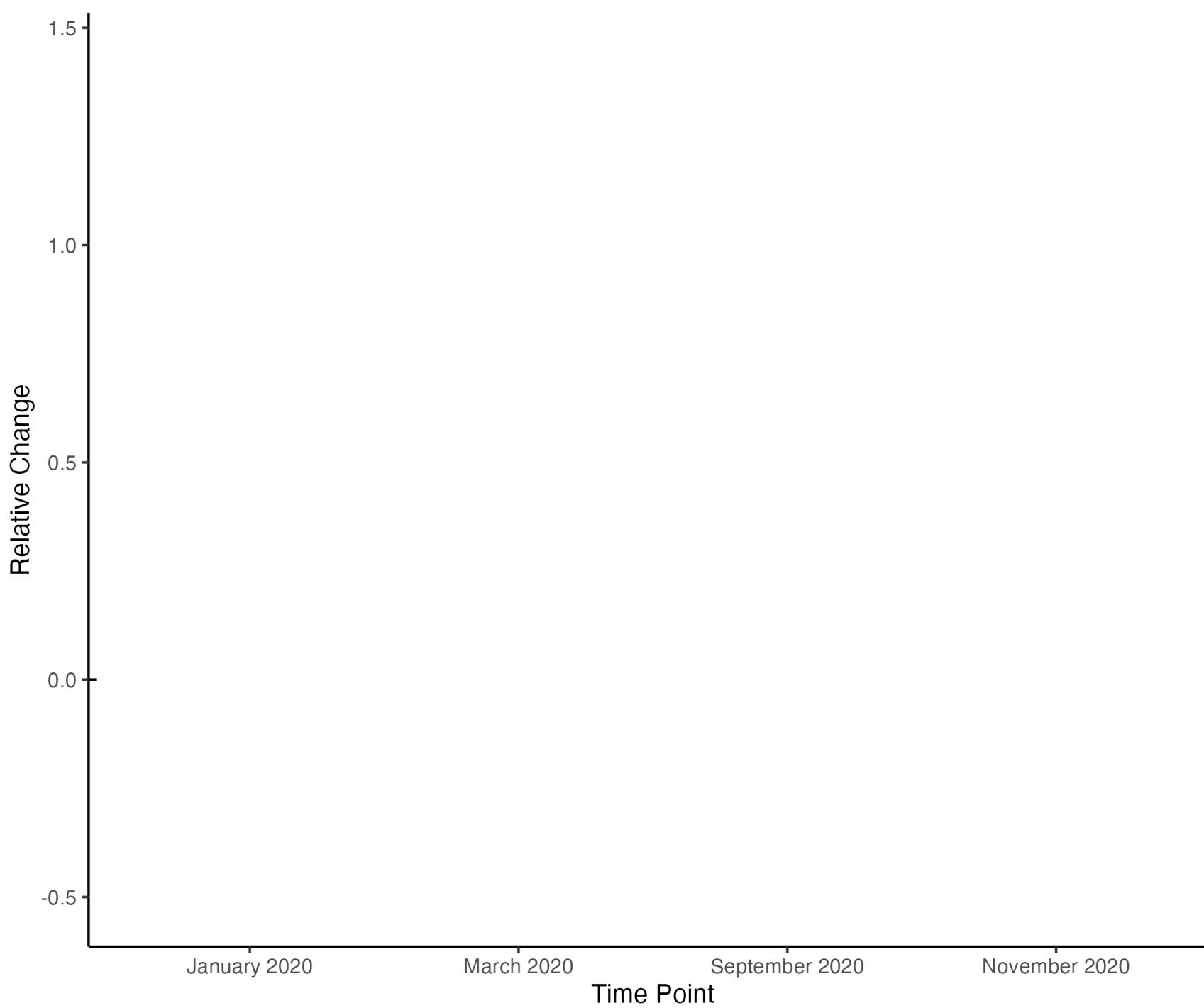


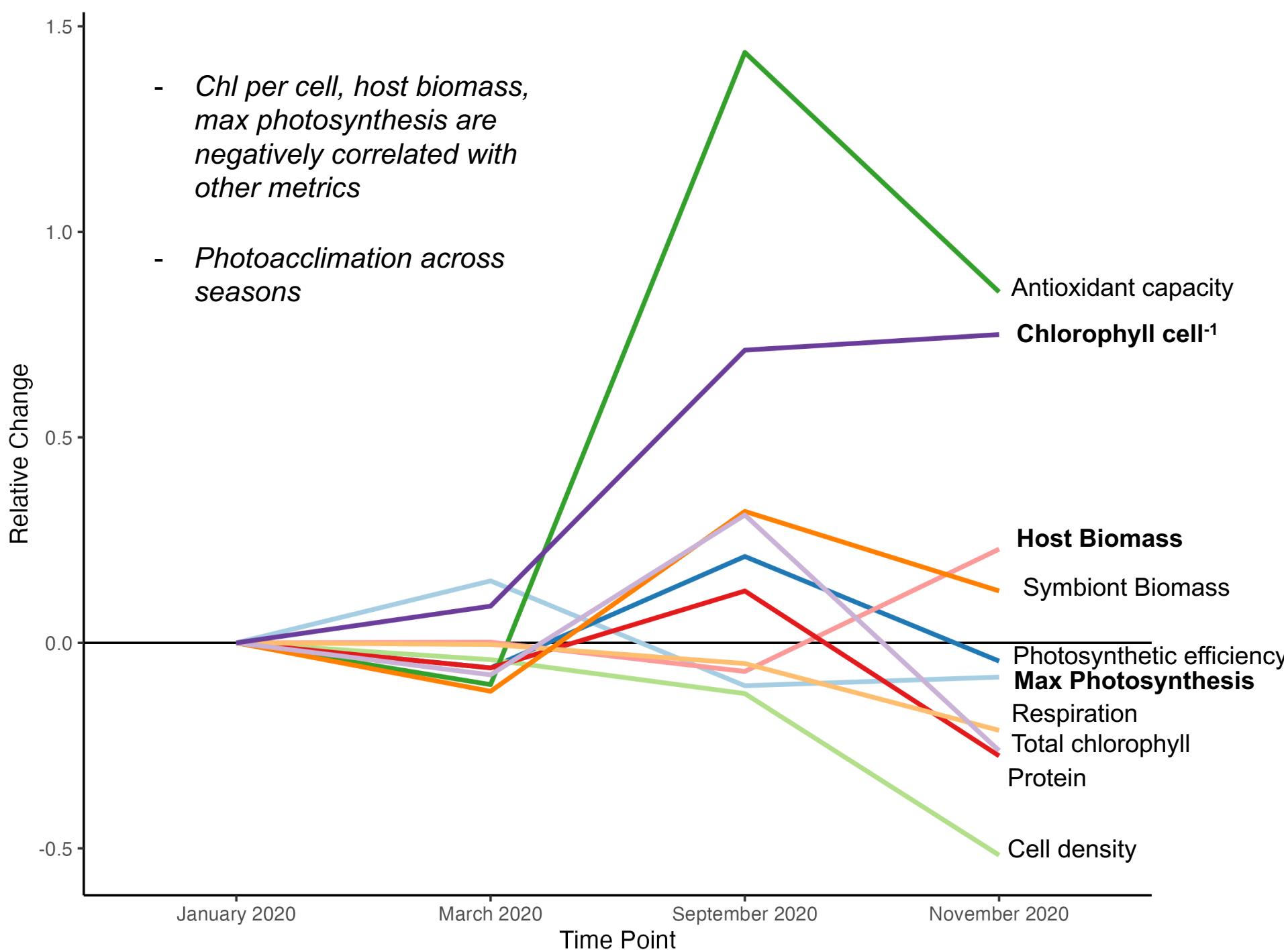
*Porites*

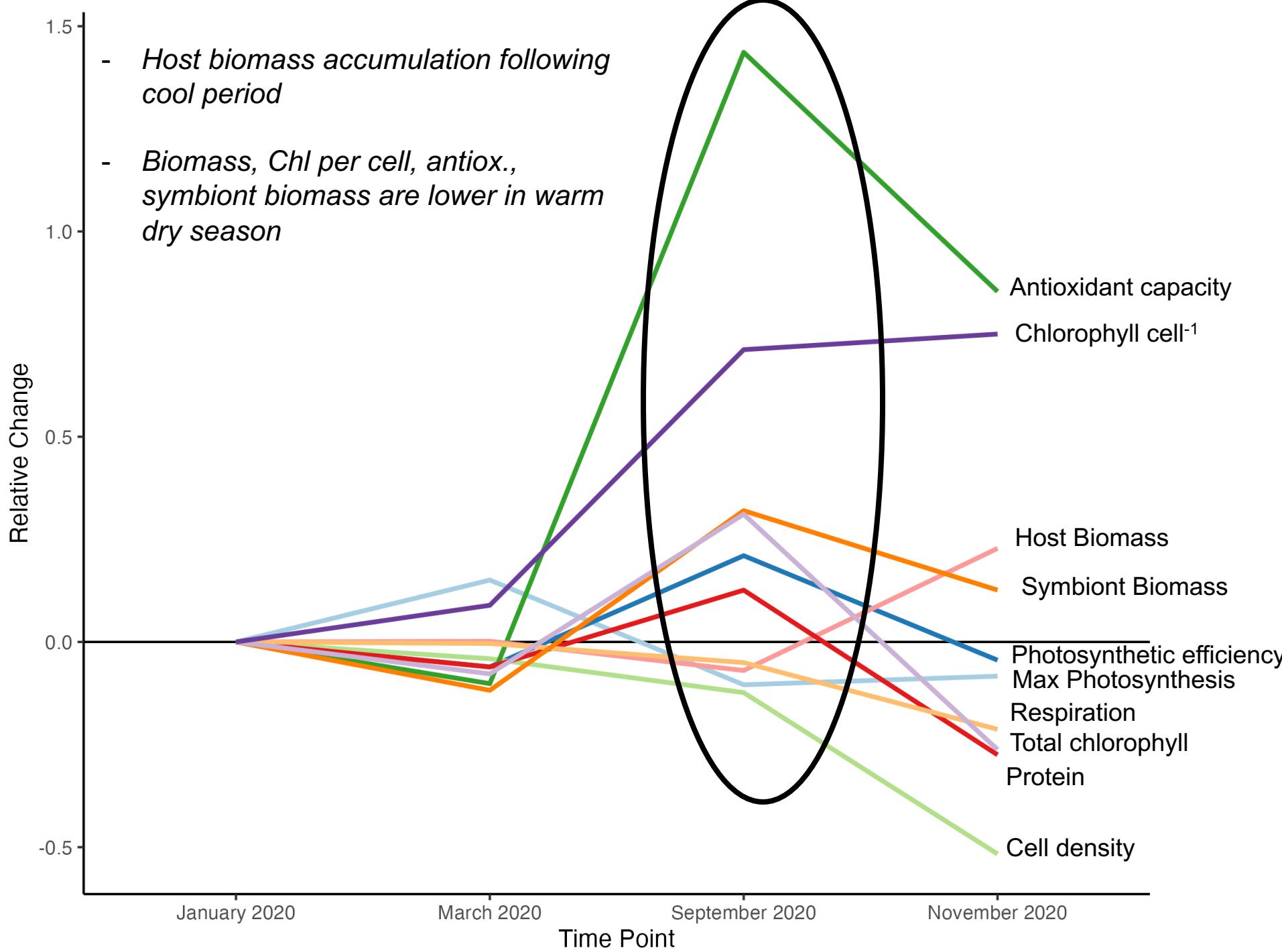


• Mahana Low • Hilton Medium • Manava High

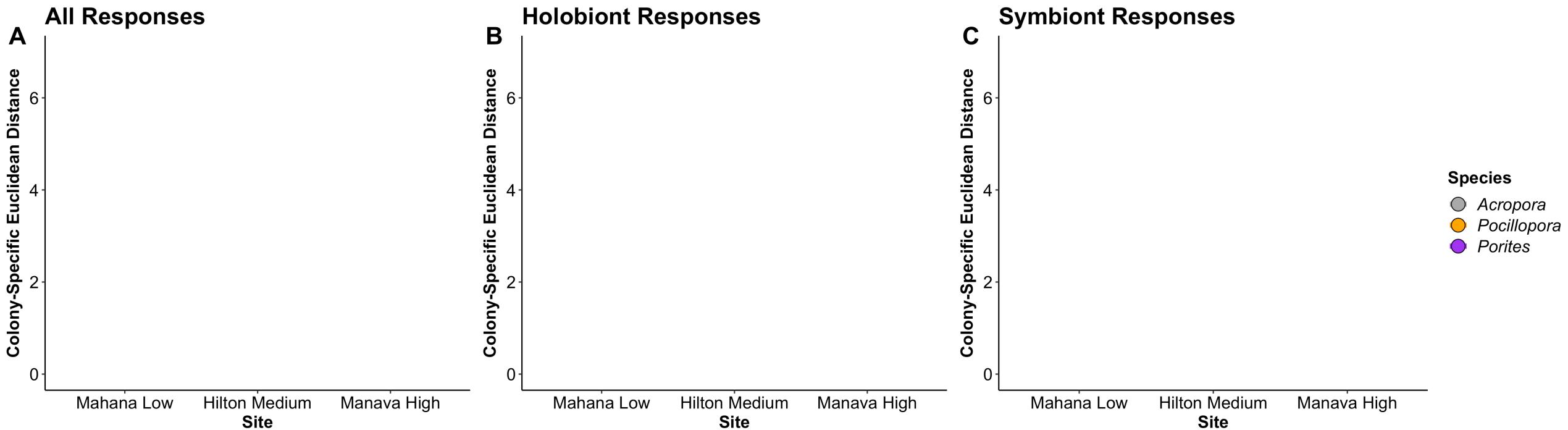
- Photopigments and photosynthesis influenced spatially
- Biomass and population growth influenced seasonally



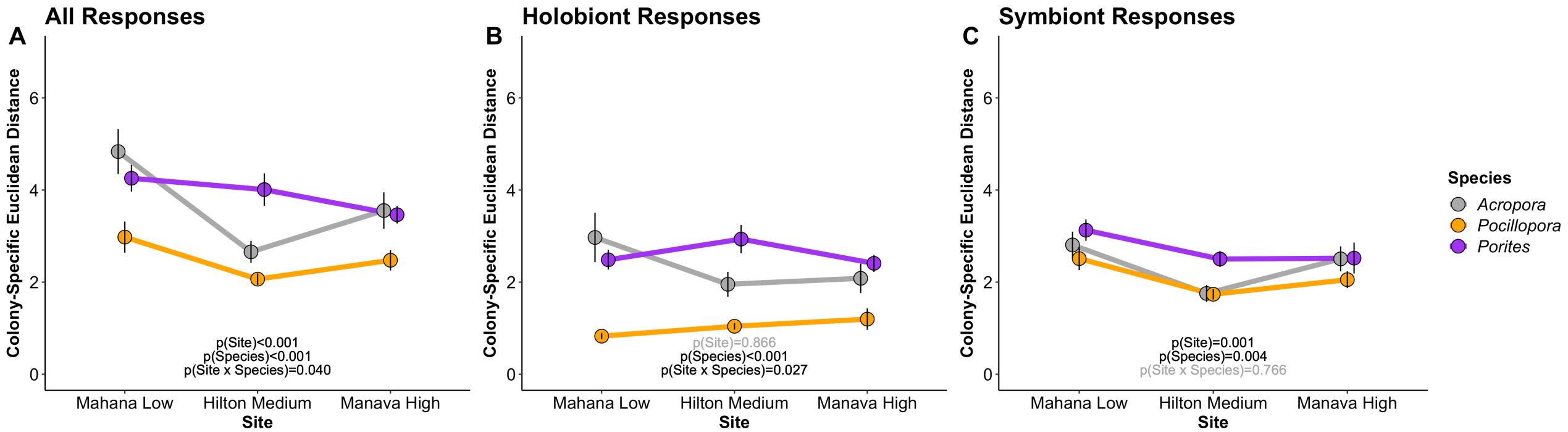


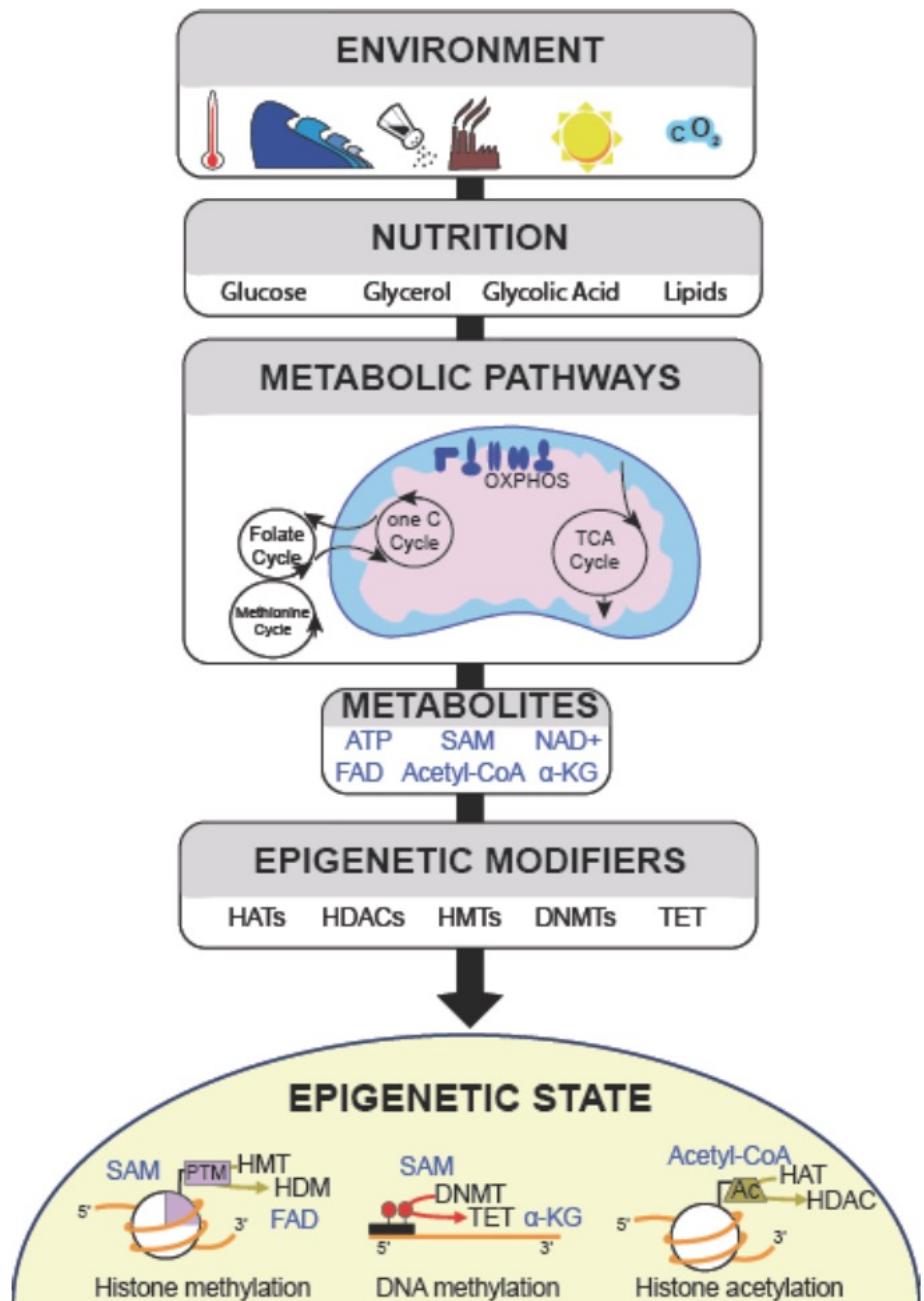


# Species-specific physiological plasticity across environmental gradients

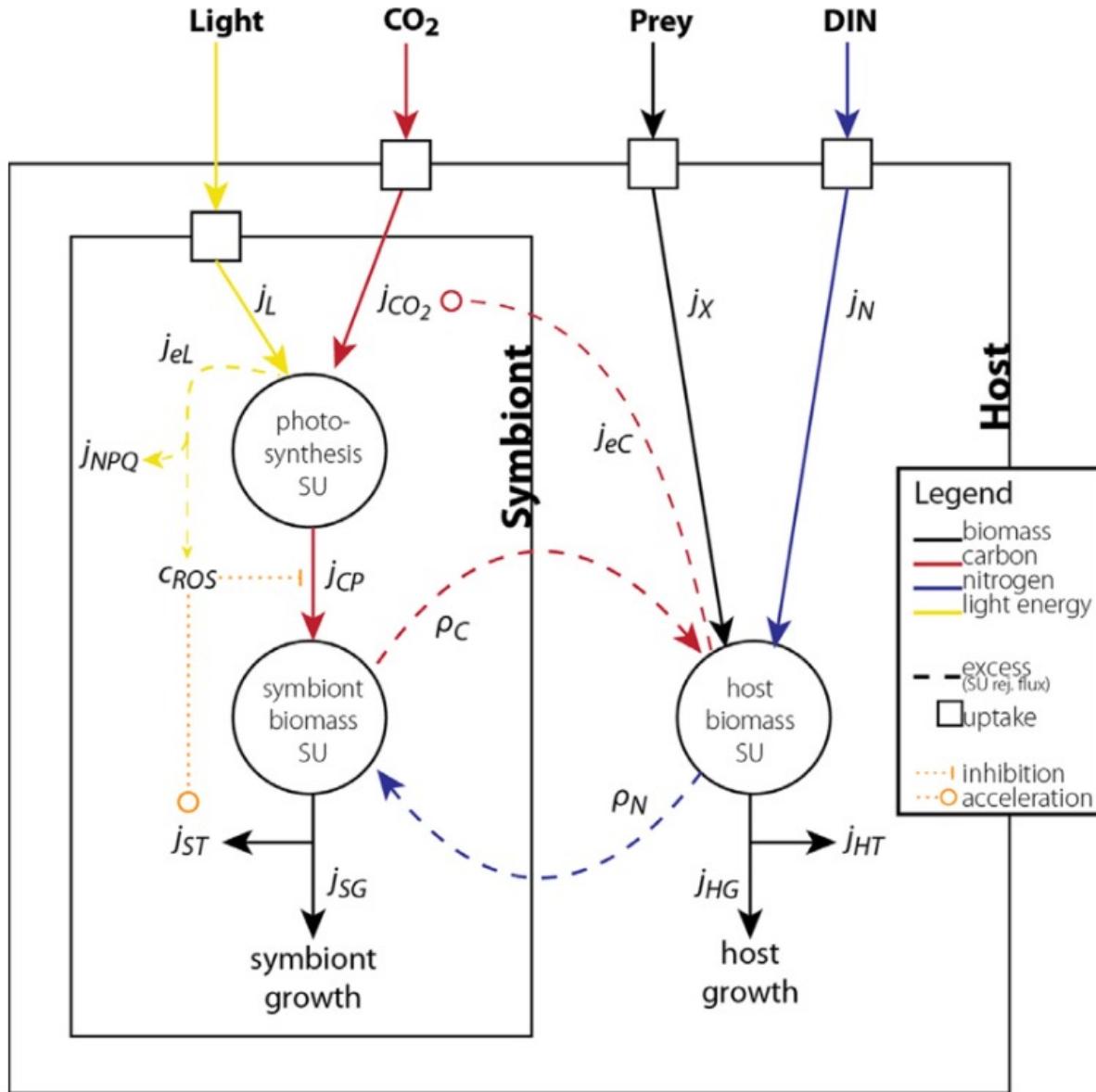


# Species-specific physiological plasticity across environmental gradients

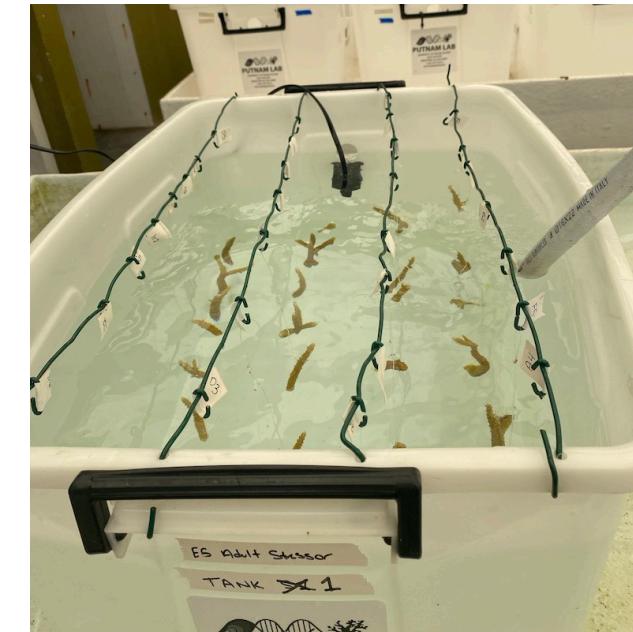
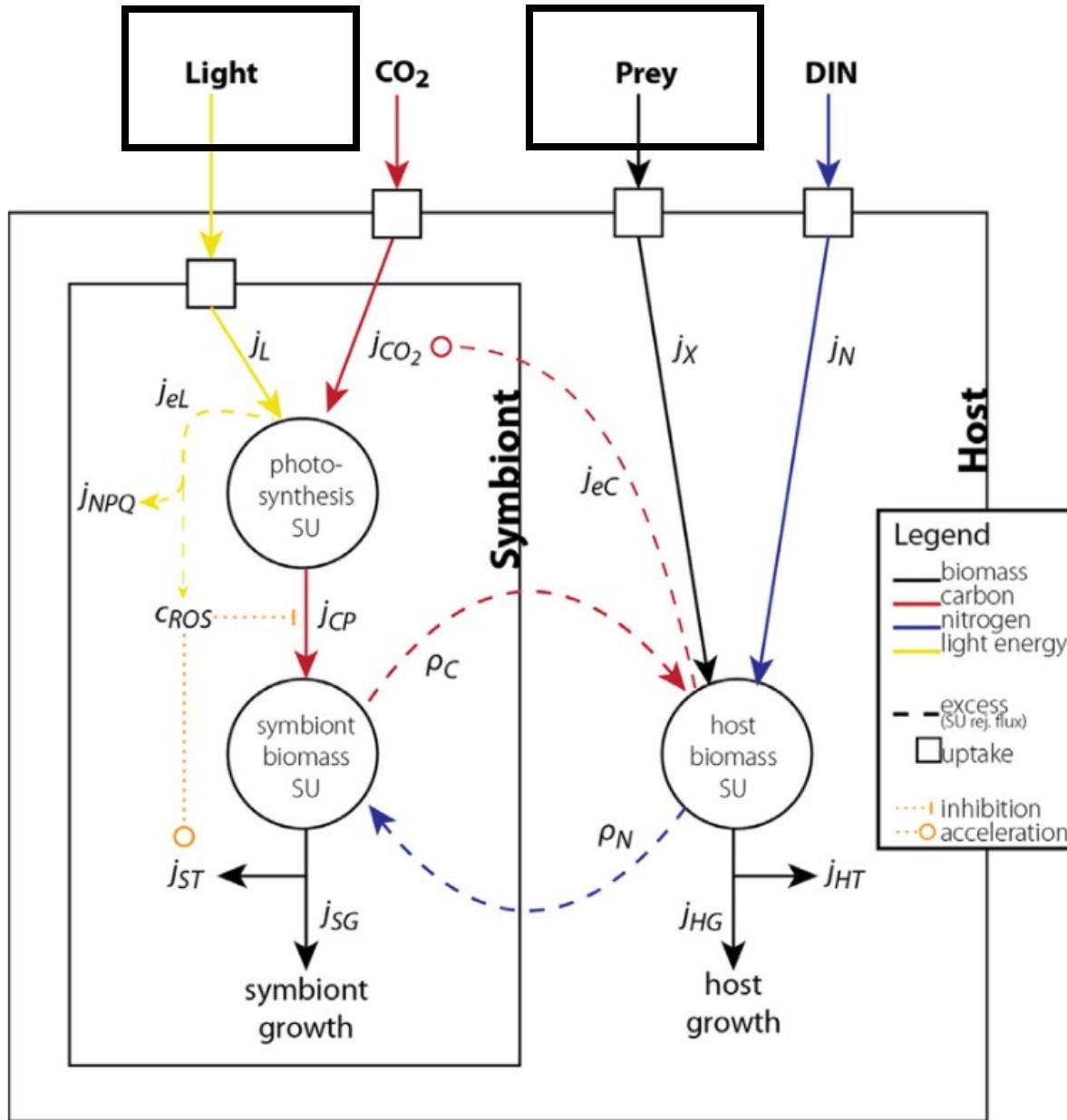




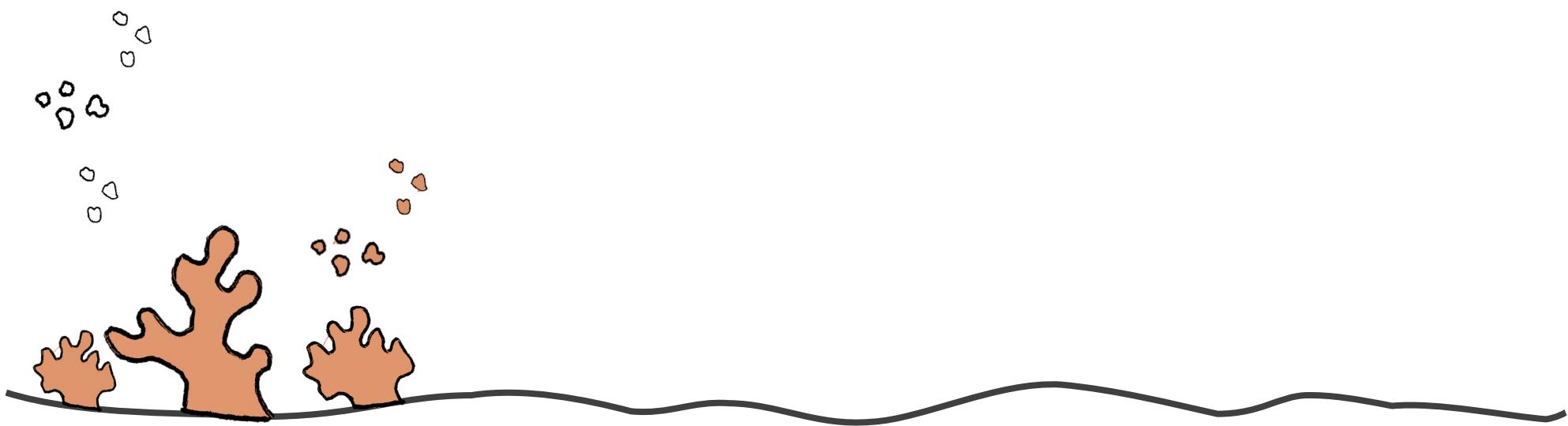
# Manipulating symbiotic and metabolic state to understand energetic-epigenetic linkages

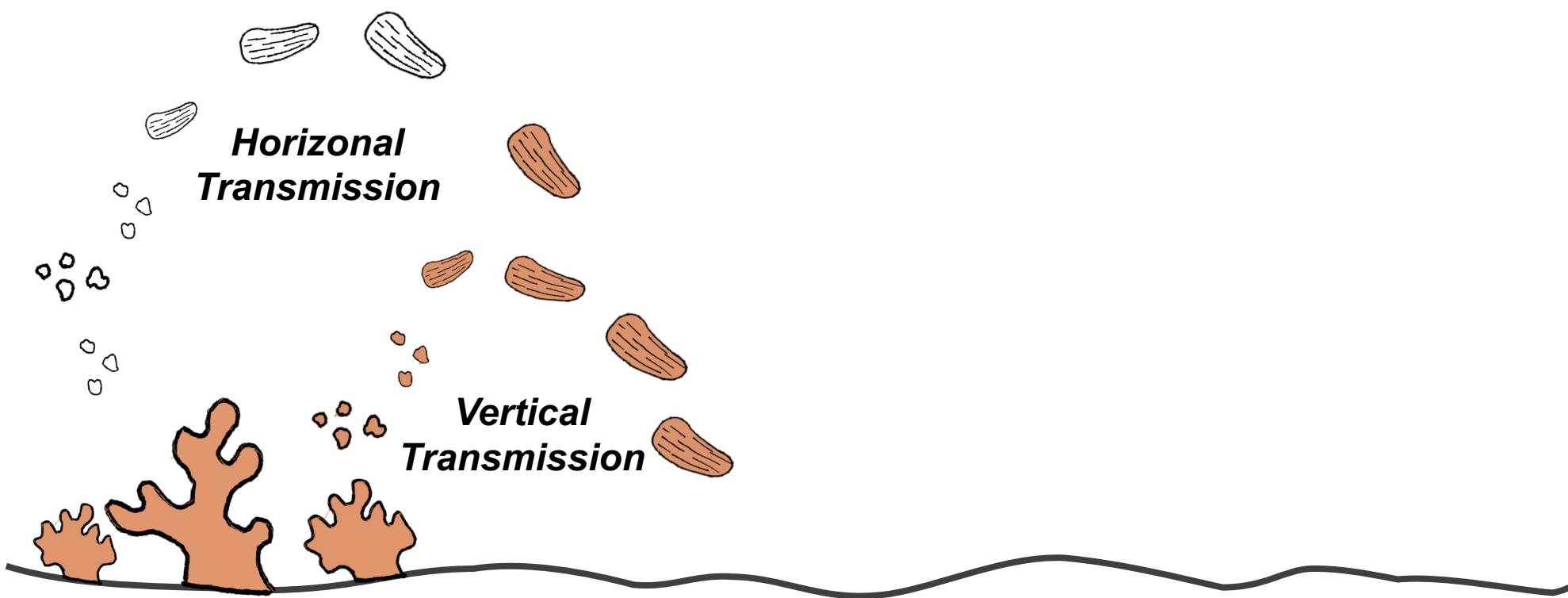


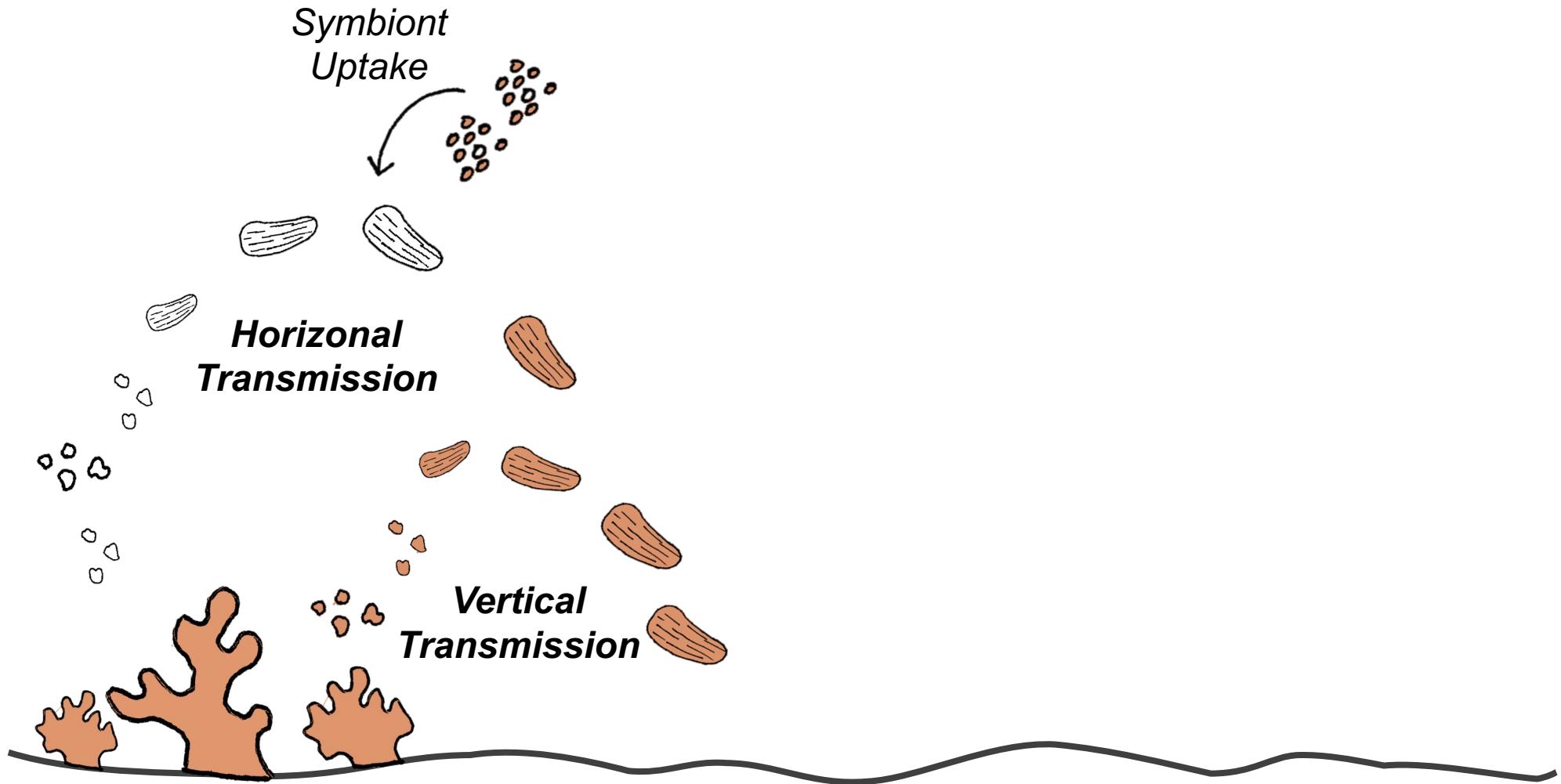
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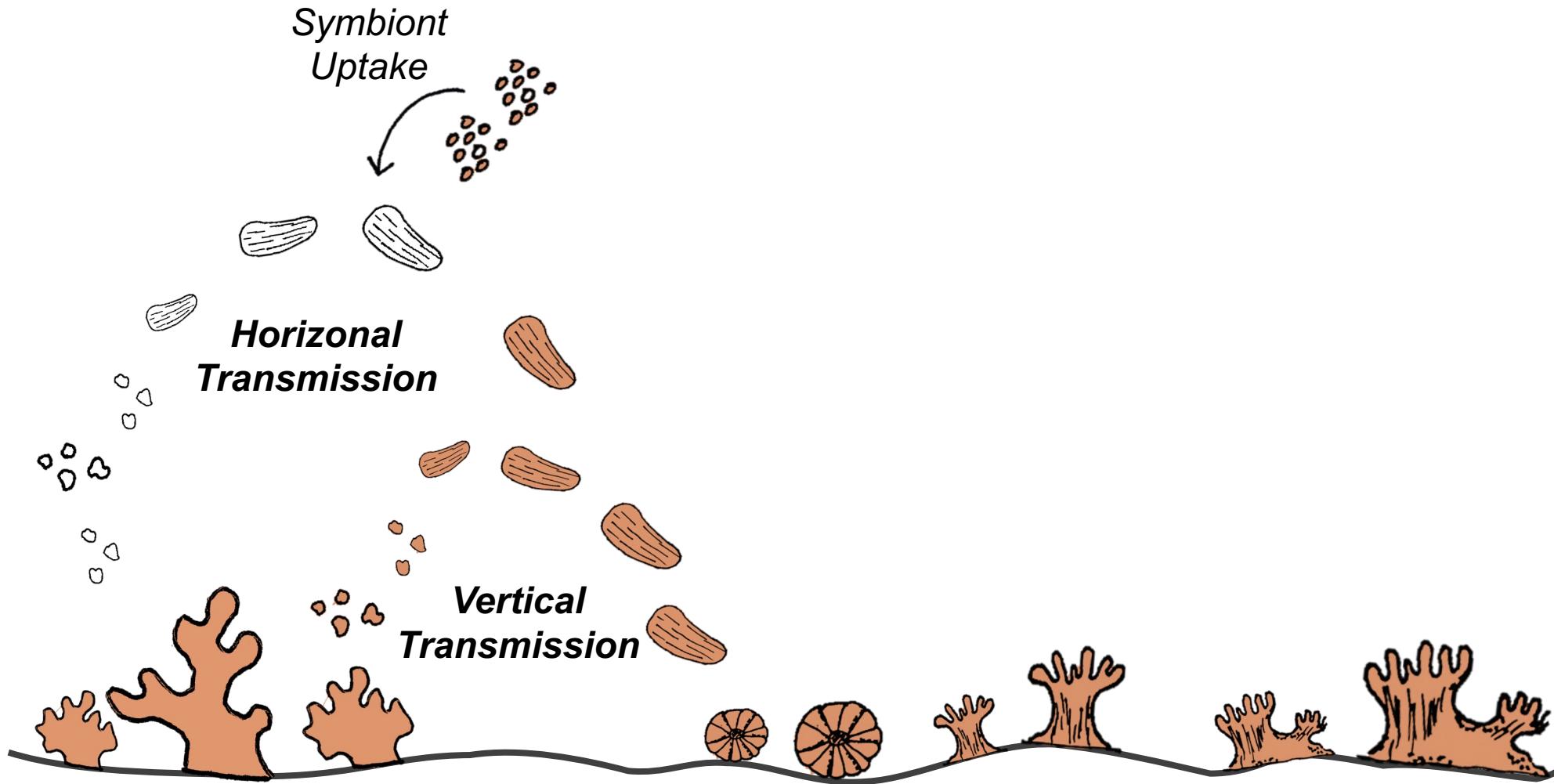




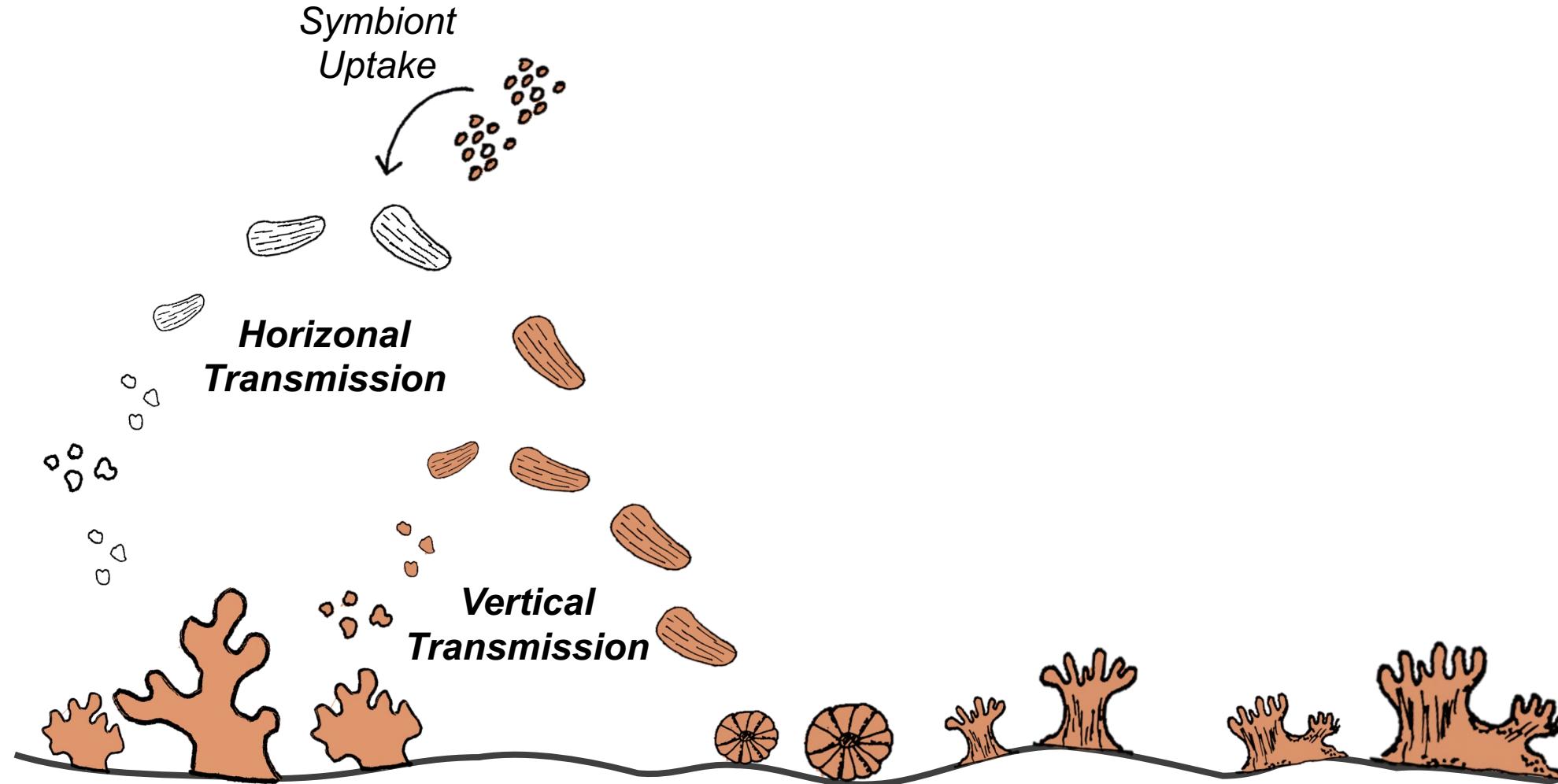




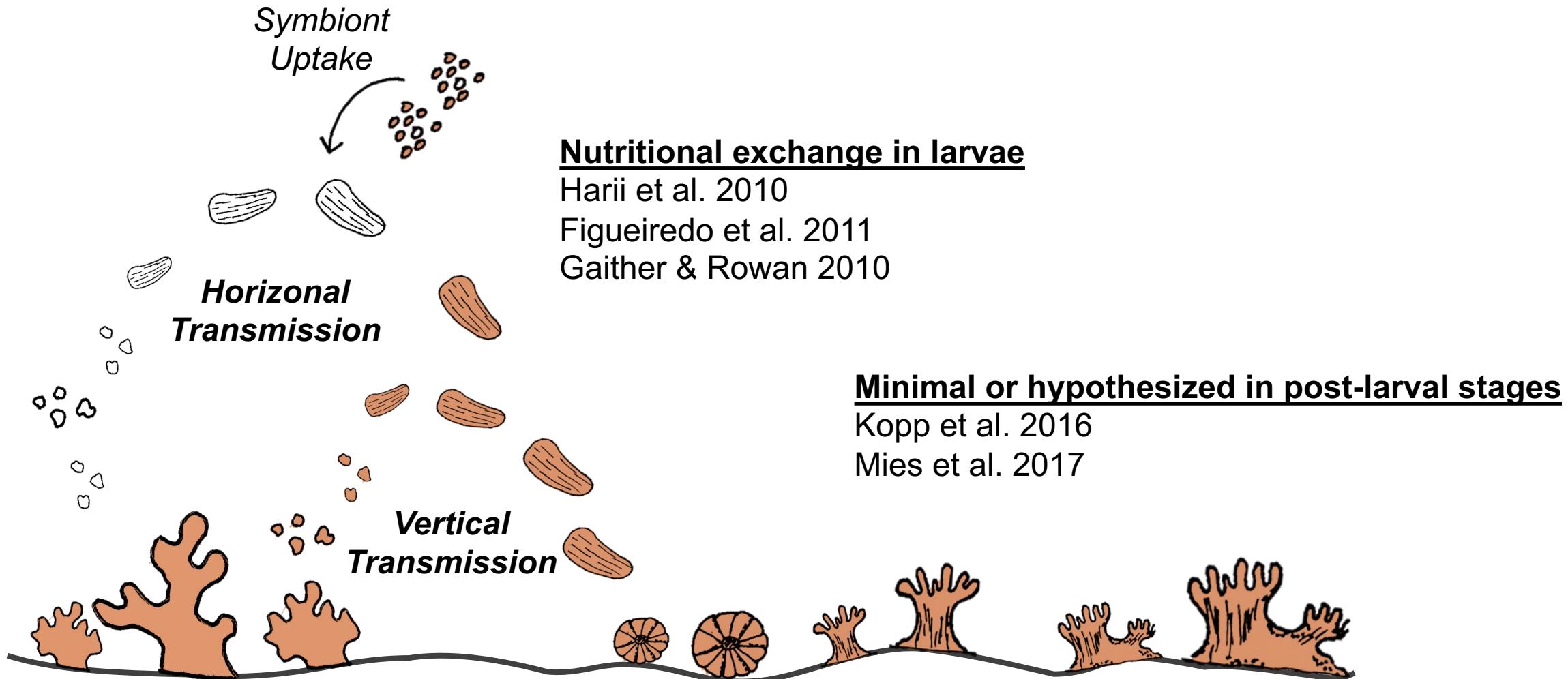




**When does symbiotic nutritional exchange begin during development and how does it impact energetic capacity during recruitment?**

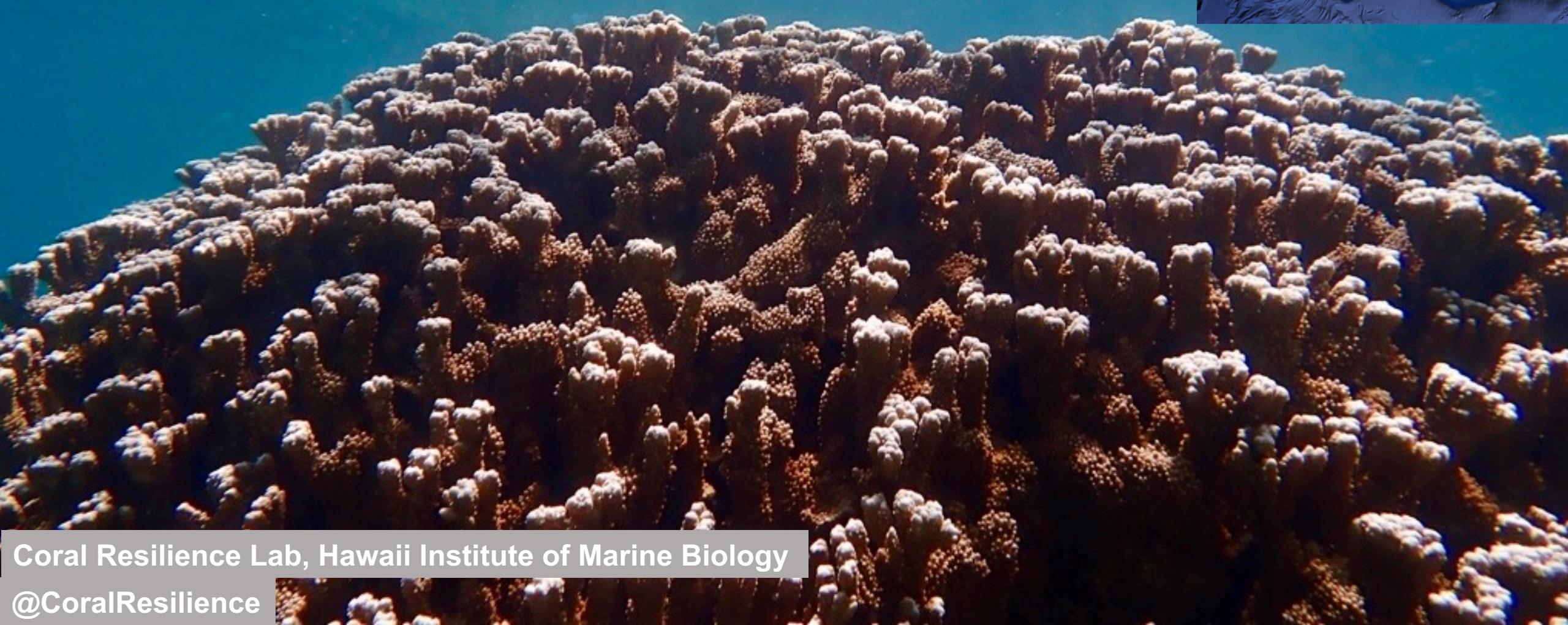


**When does symbiotic nutritional exchange begin during development and how does it impact energetic capacity during recruitment?**



*Montipora capitata*

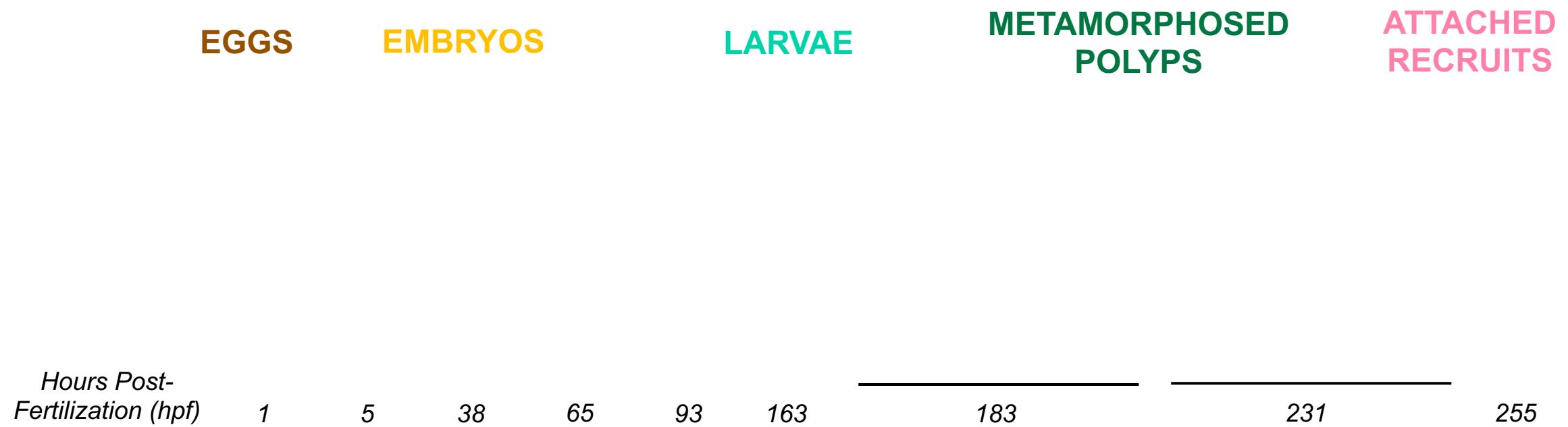
Hermaphroditic broadcast spawner  
Vertical Symbiodiniaceae transmission



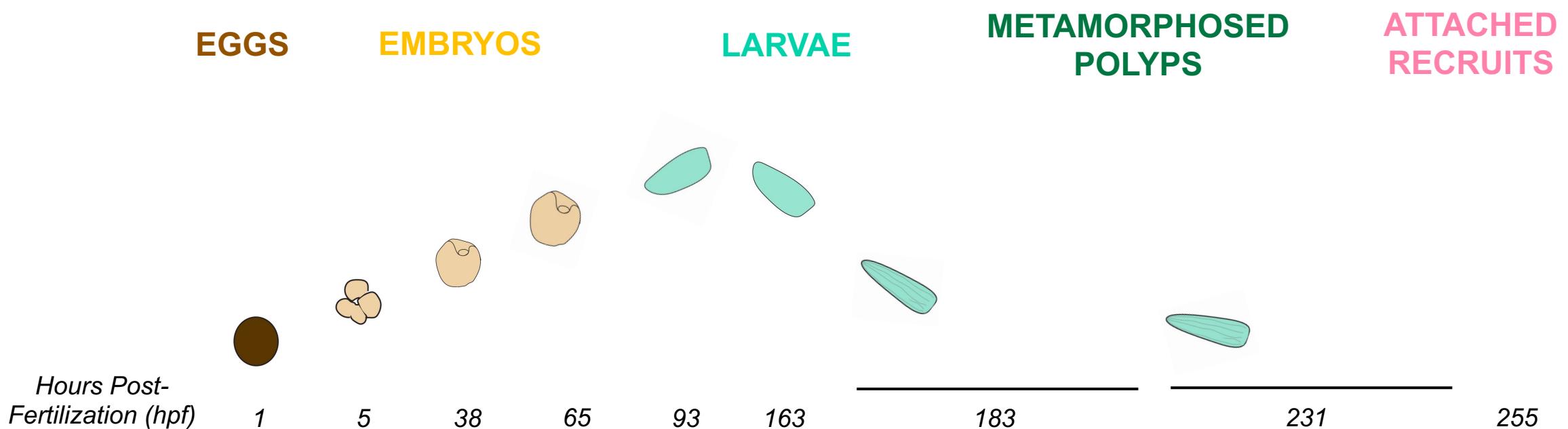
Coral Resilience Lab, Hawaii Institute of Marine Biology

@CoralResilience

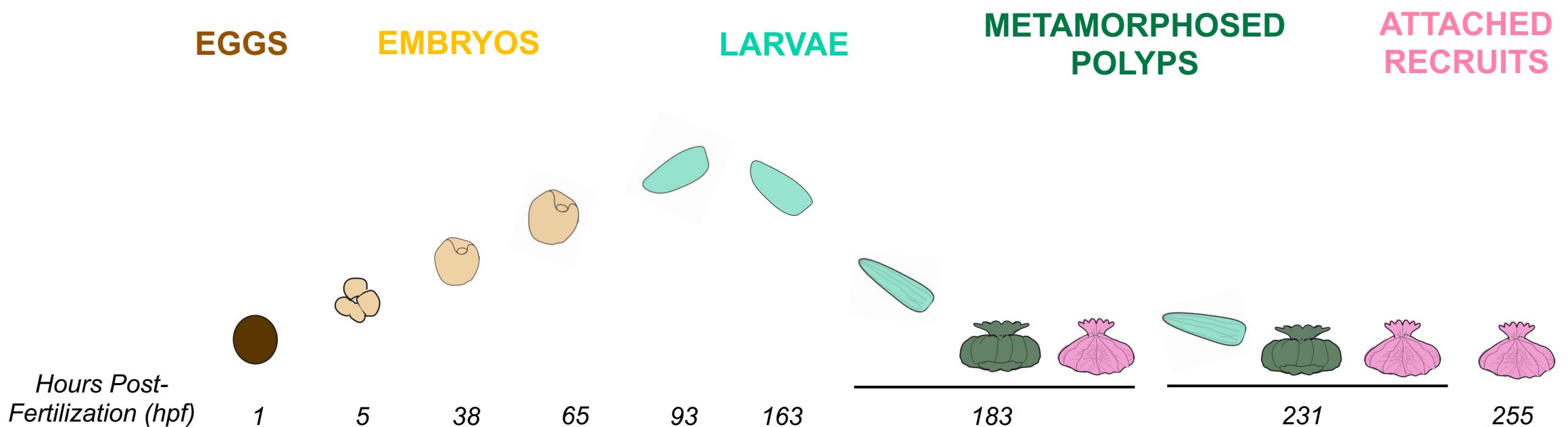
**When does symbiotic nutritional exchange begin during development and how does it impact energetic capacity during recruitment?**



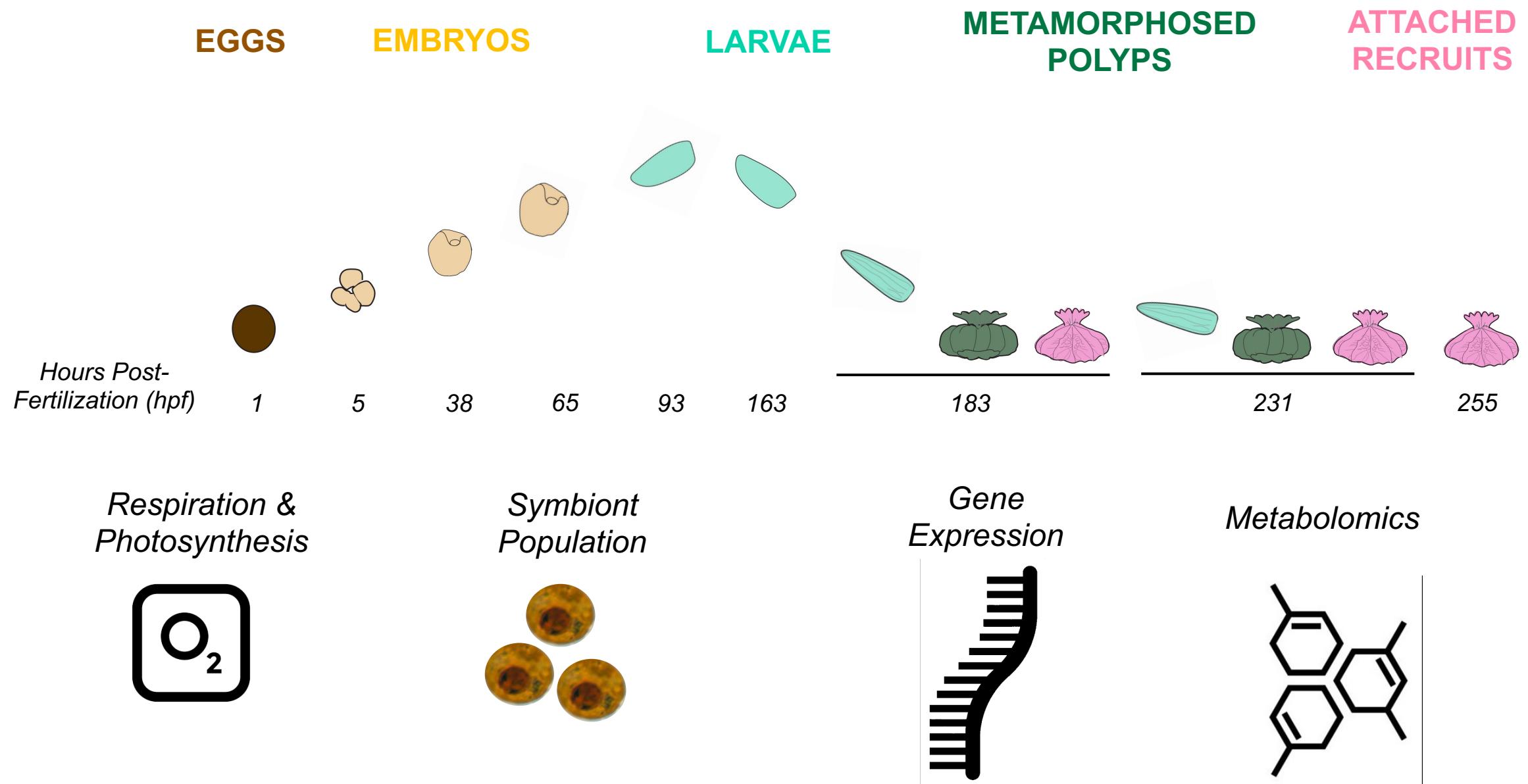
# *When does symbiotic nutritional exchange begin during development and how does it impact energetic capacity during recruitment?*



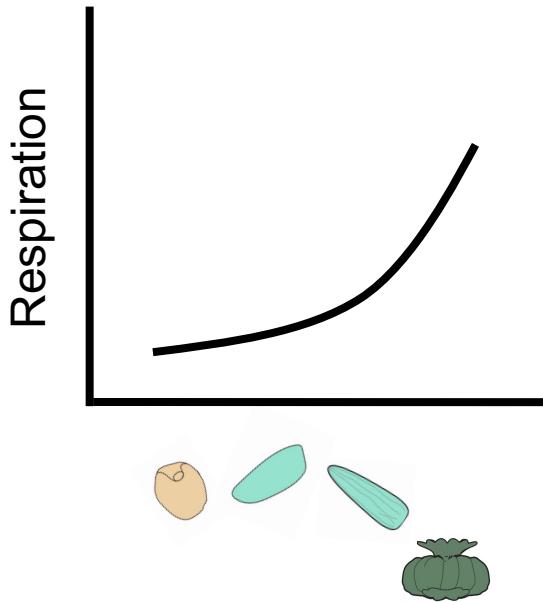
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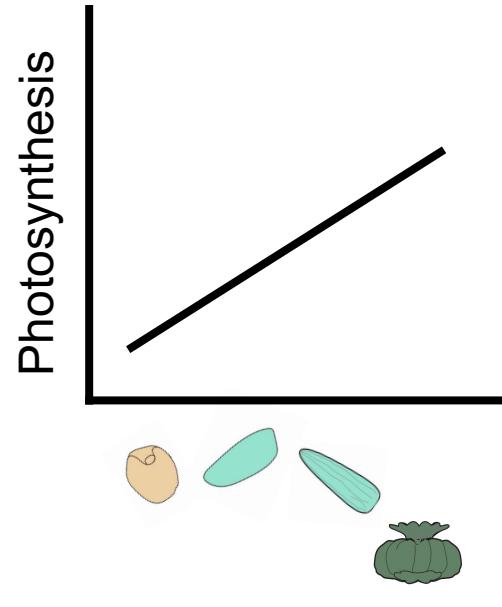
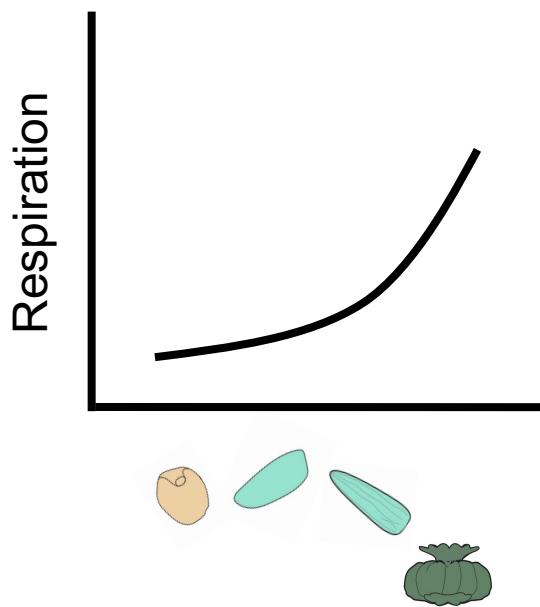


# Metabolism & symbiosis across development

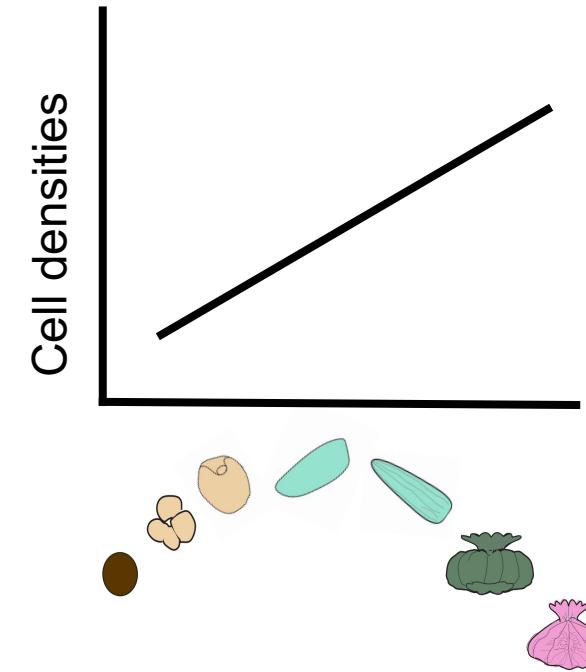
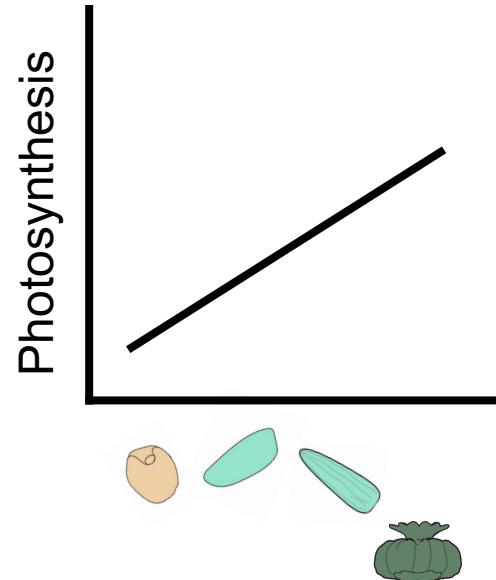
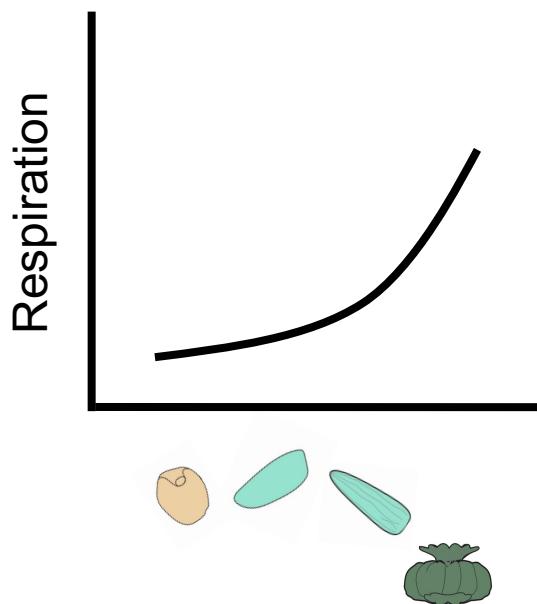


*GLMM p<0.001  
Individual normalized*

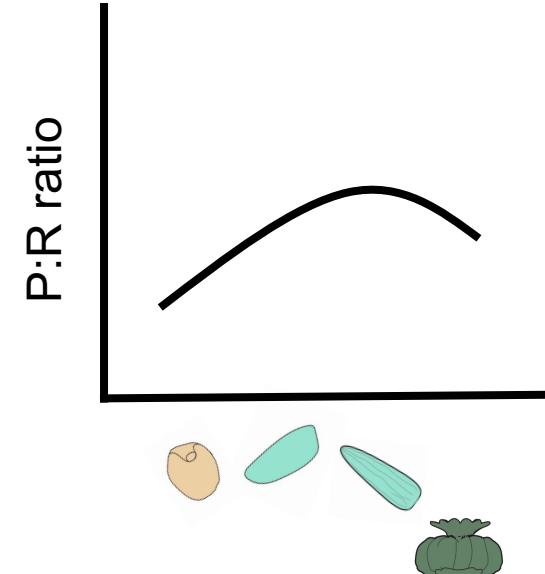
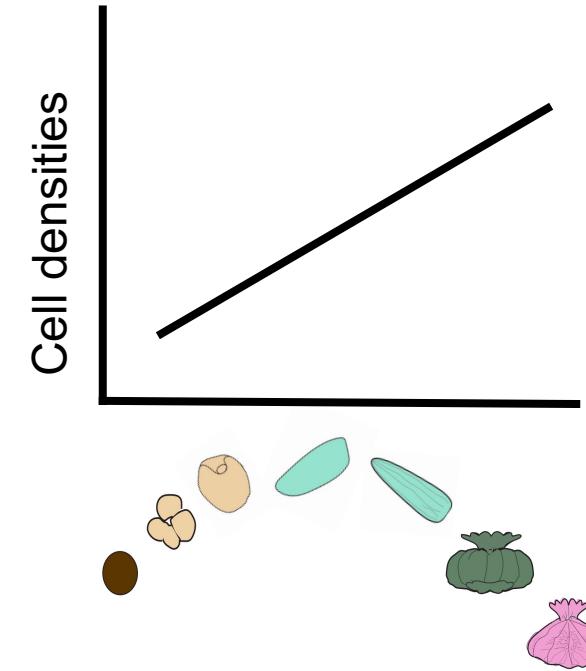
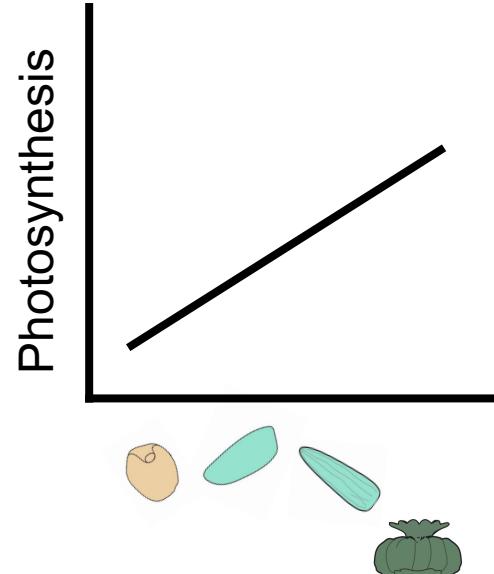
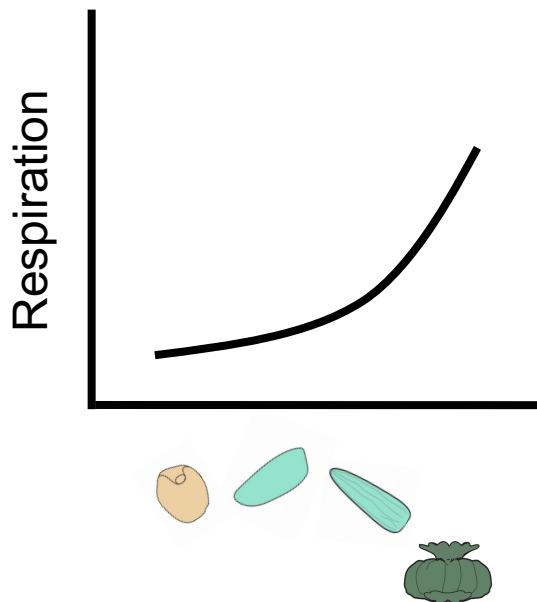
# Metabolism & symbiosis across development



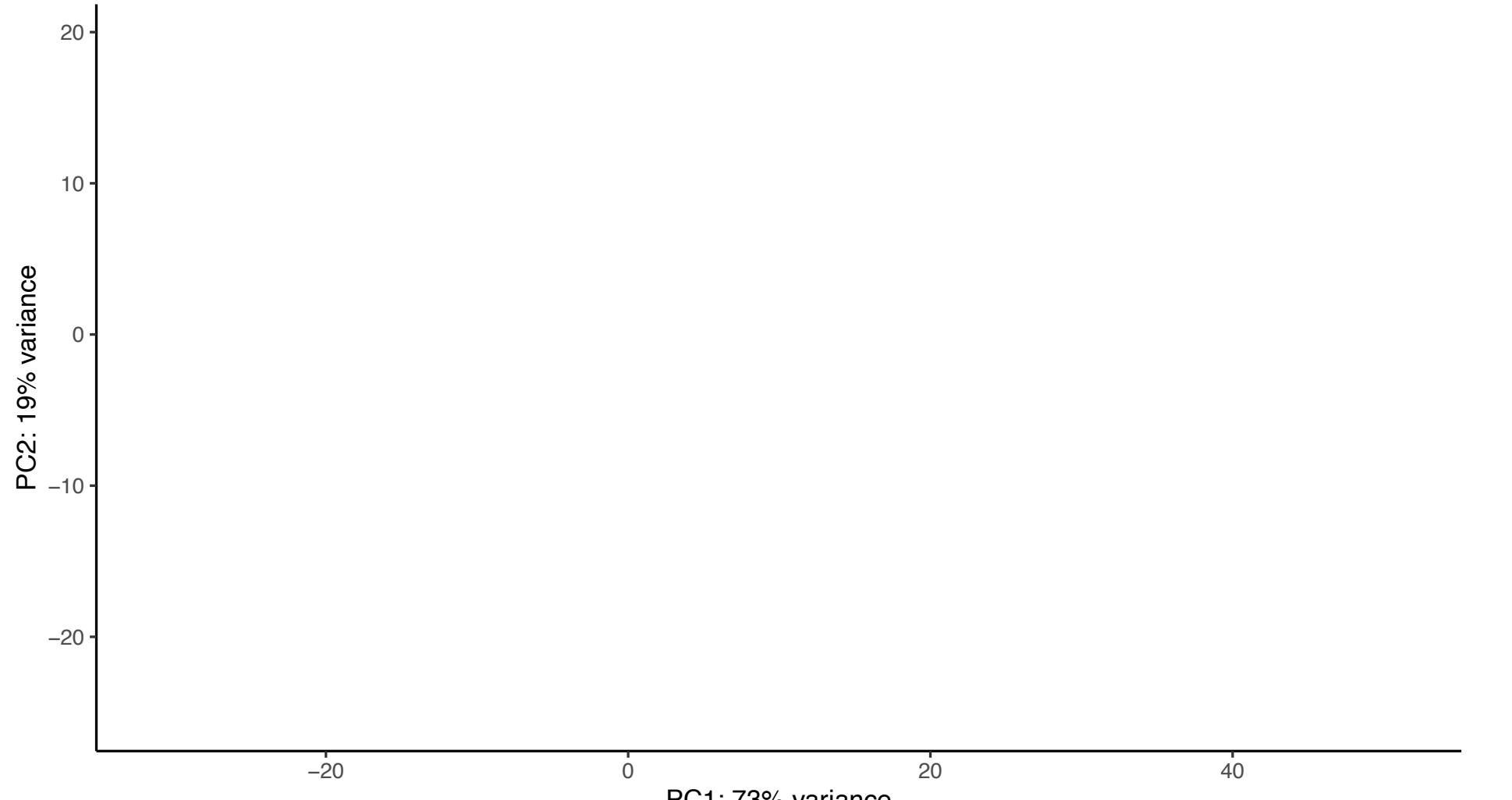
# Metabolism & symbiosis across development



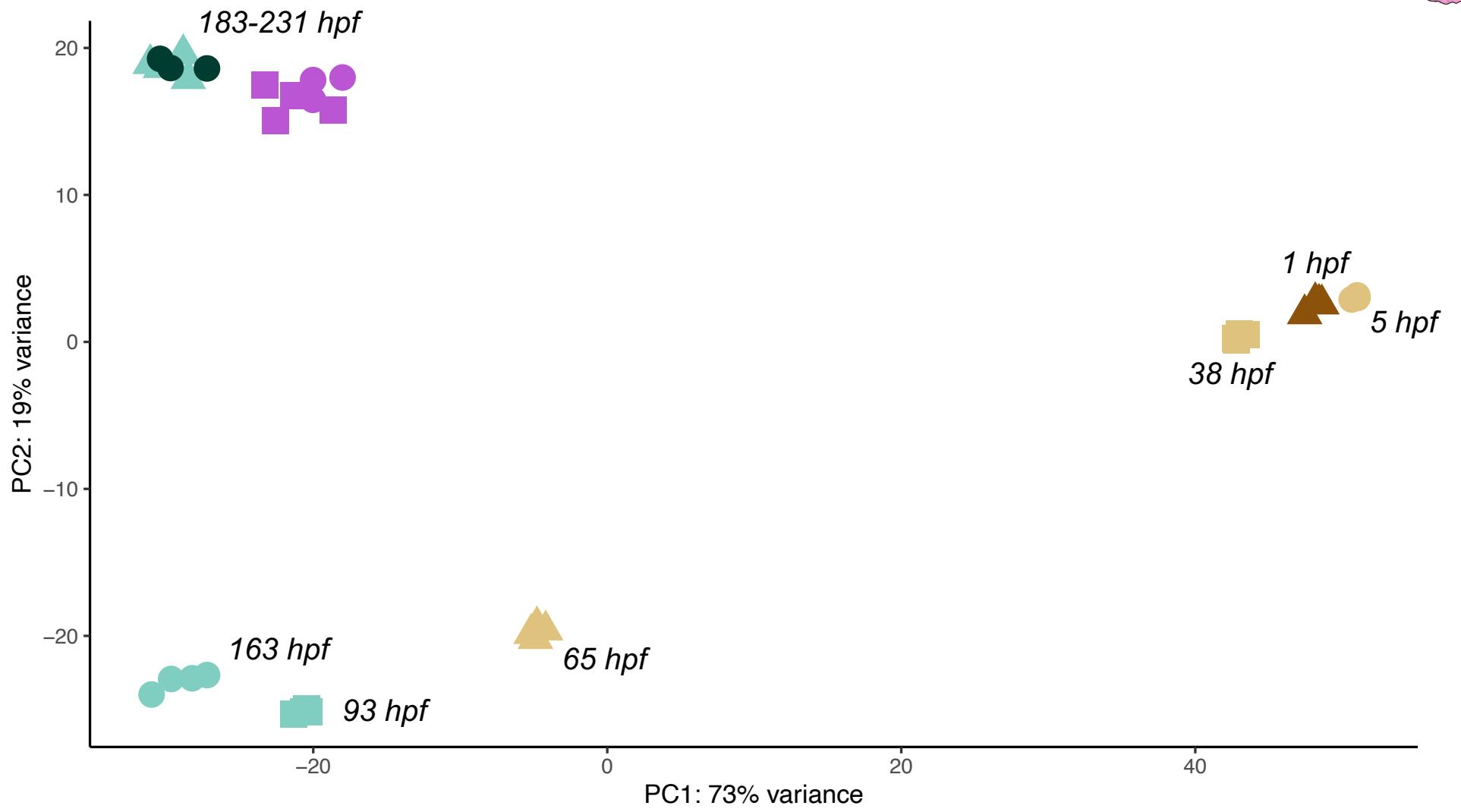
# Metabolism & symbiosis across development



# Distinct gene expression profiles across ontogeny



# Distinct gene expression profiles across ontogeny



TagSeq (Lohman et al. 2016)

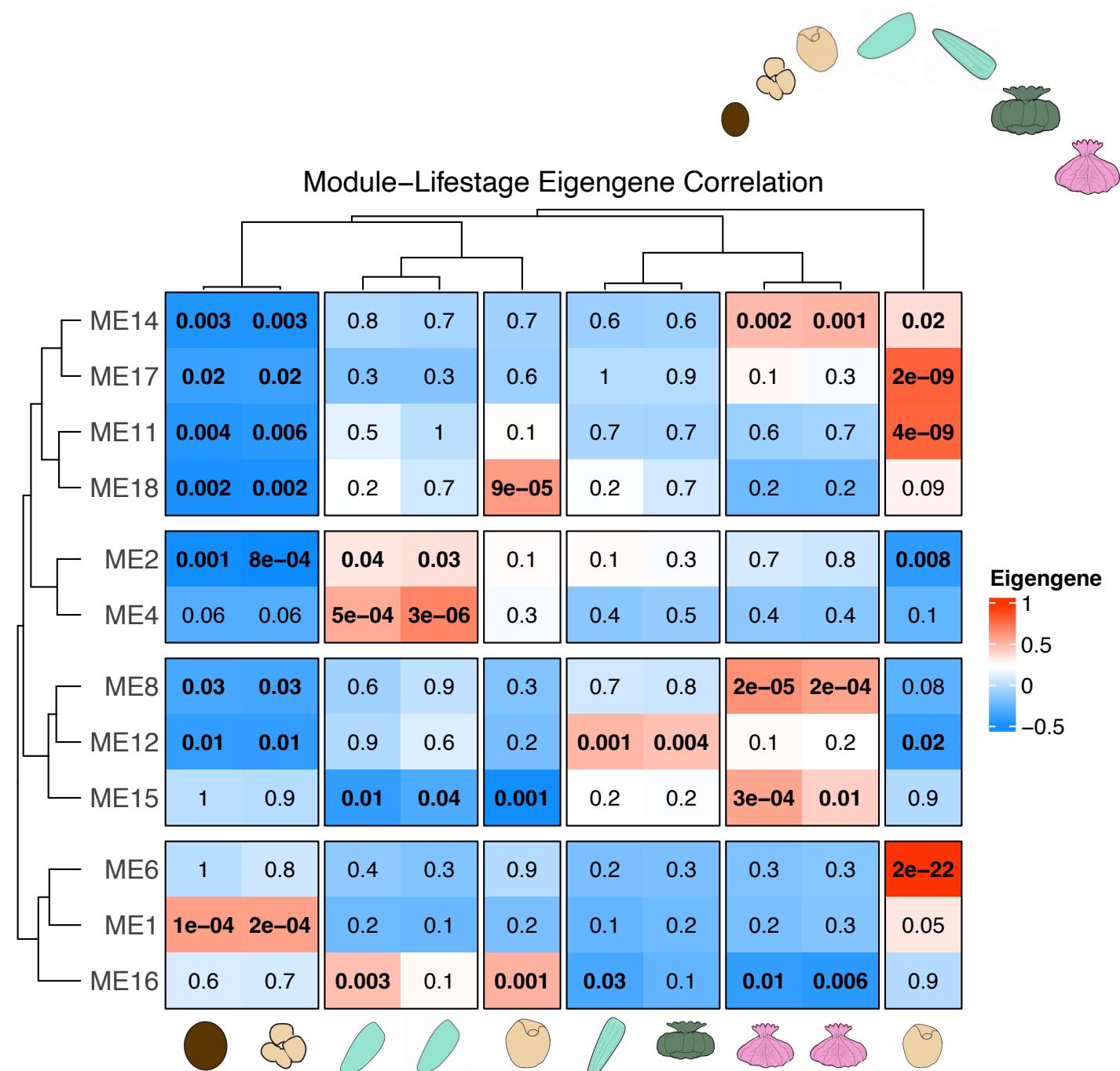
Illumina NovaSeq 100 bp sequencing (UT Austin)

Trimming & QC (FastP); alignment (HISAT2, Stringtie2)

# Distinct gene expression profiles across ontogeny

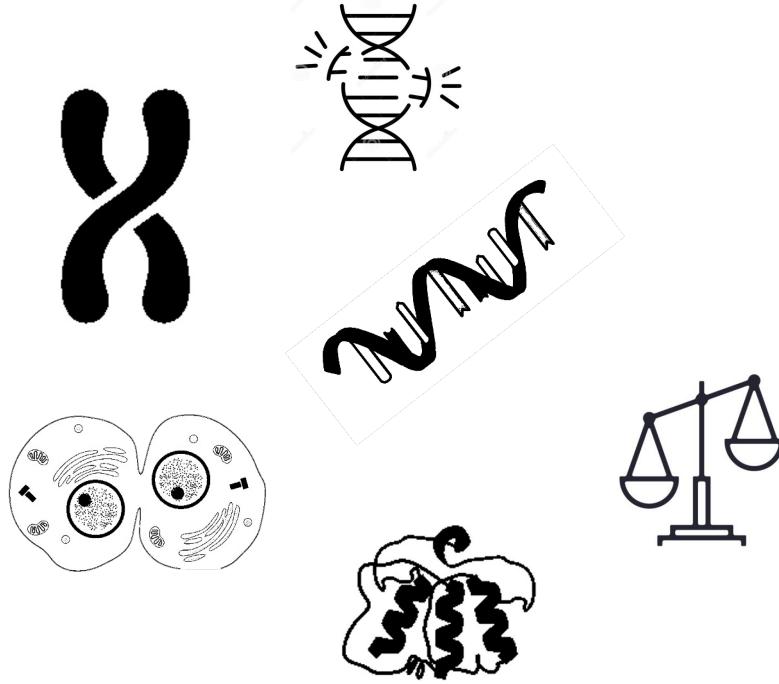
*Weighted gene co-expression network analysis (WGCNA)*

Dynamic tree cut module detection  
GO-Seq functional enrichment  
Filtered FDR<0.05

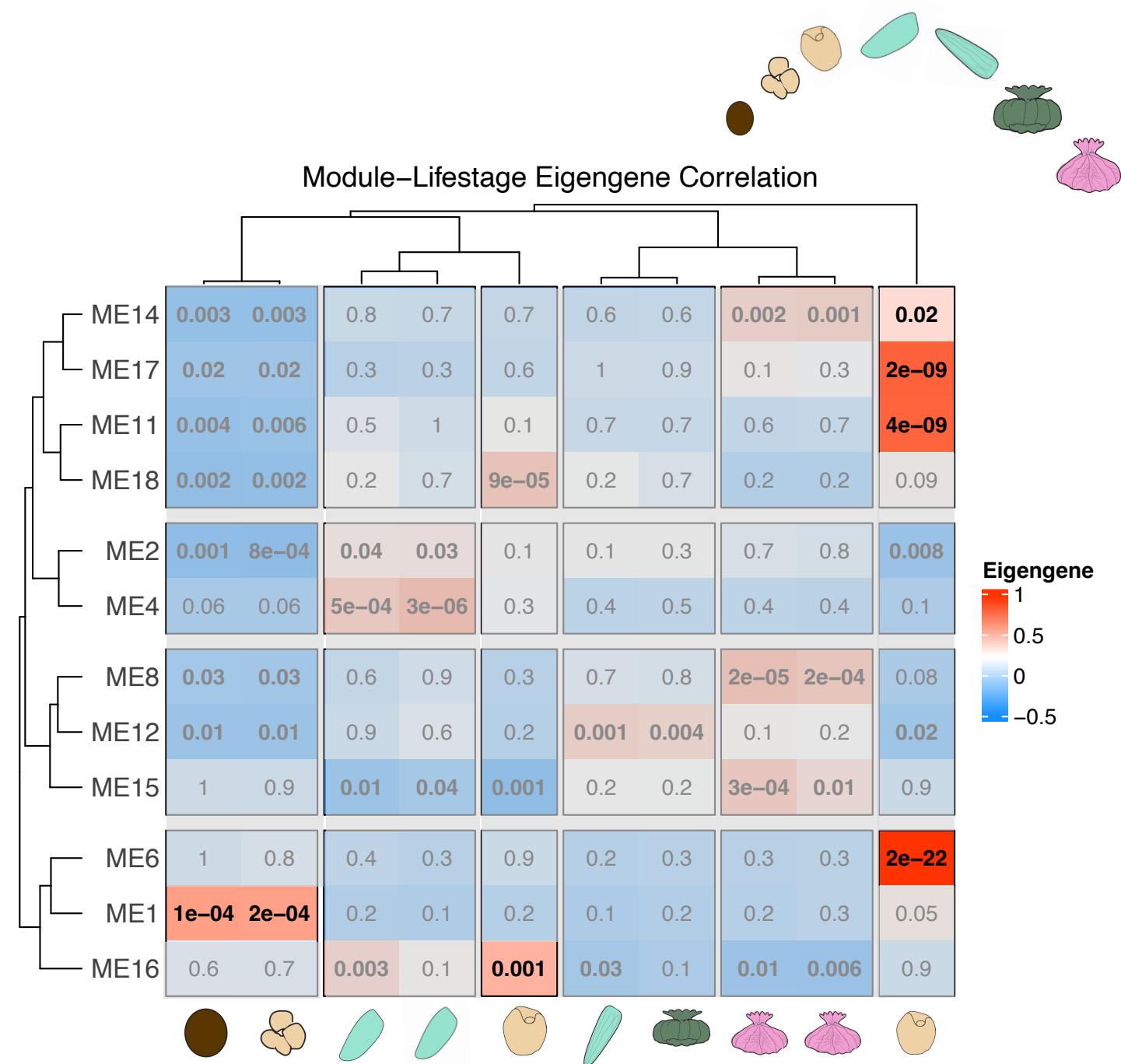


# EGG-EMBRYOS

## 1 hpf - 65 hpf

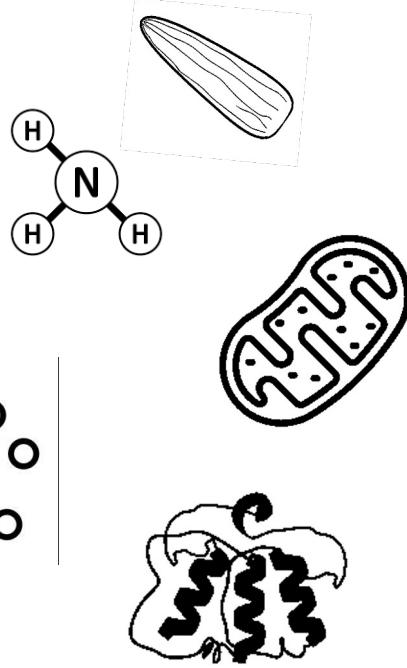
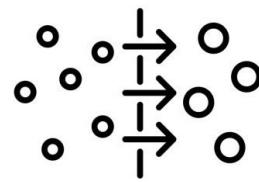


*Cell division, transcription, embryonic development, DNA repair, homeostasis*

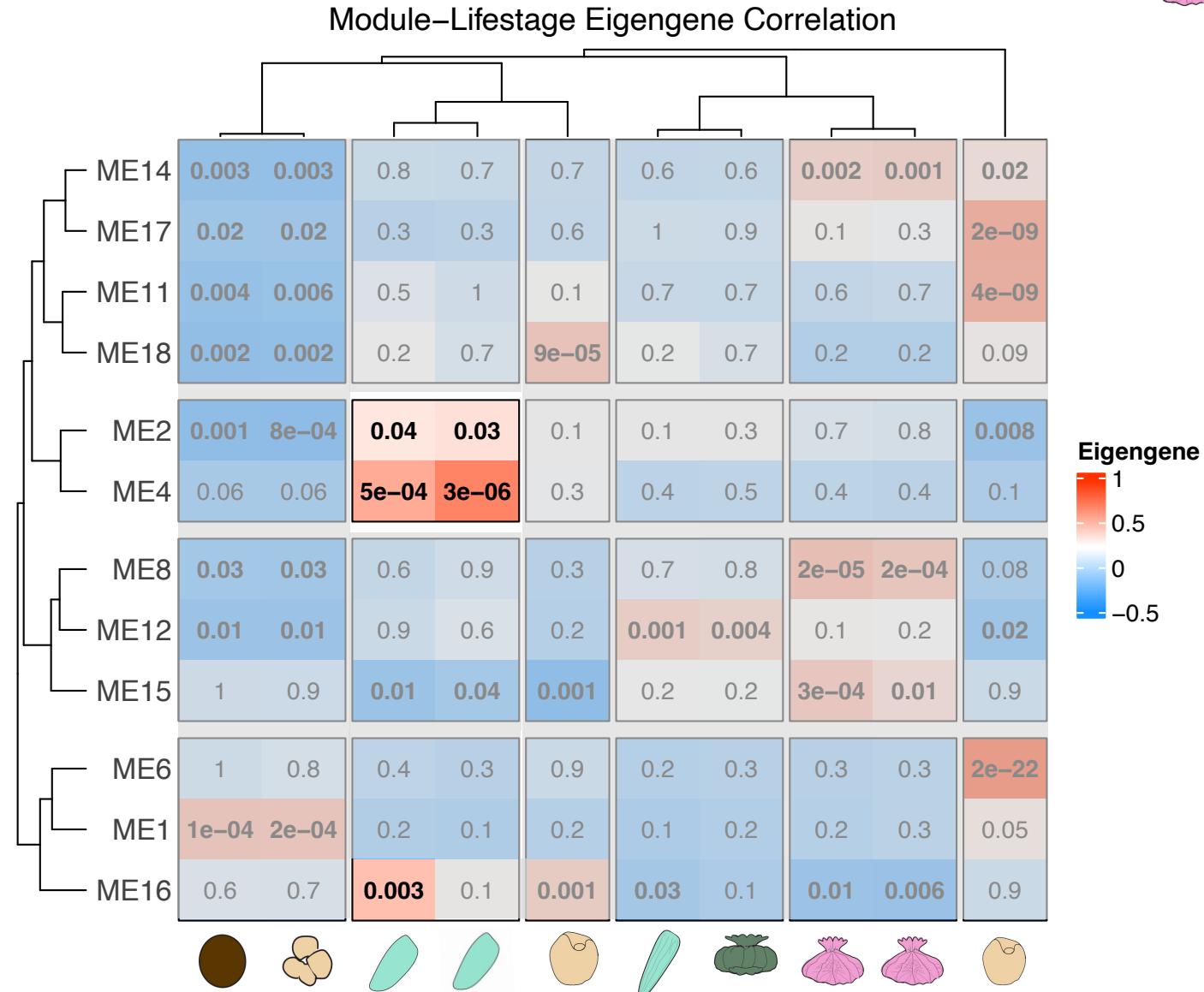


# LARVAE

93 hpf – 163 hpf

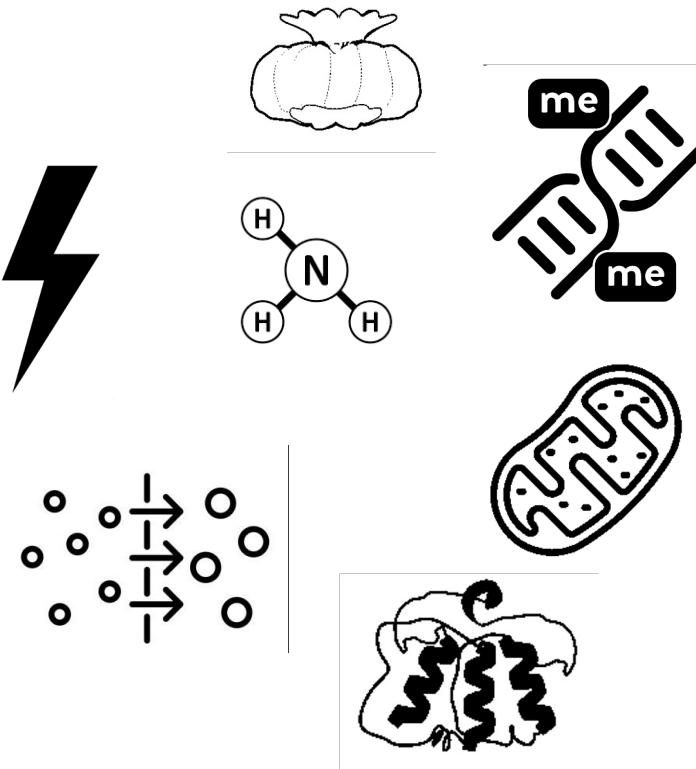


*Nitrogen and carbohydrate metabolism,  
structure development, ion transport*

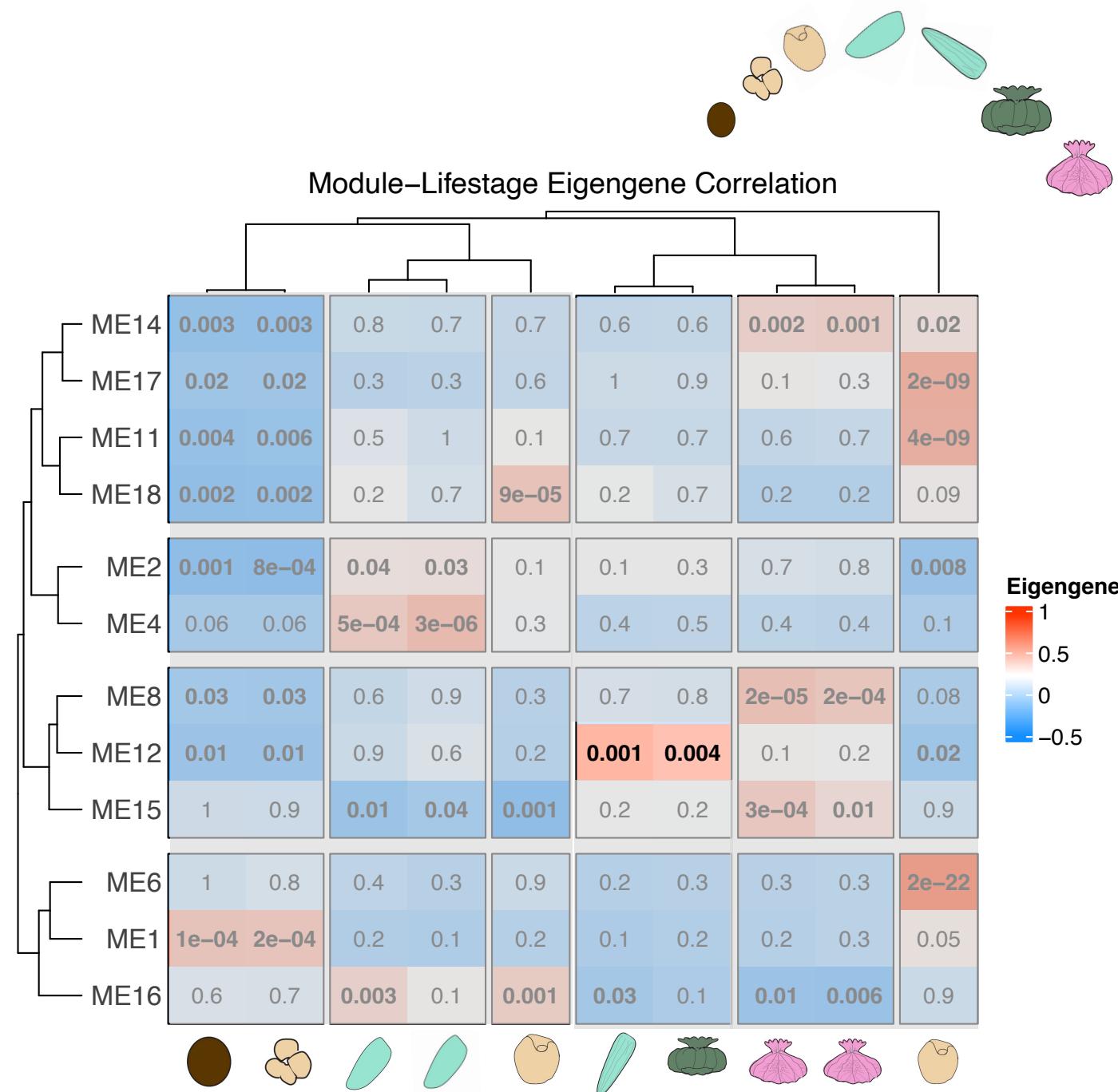


# LARVAE & METAMORPHOSED POLYPS

231 hpf

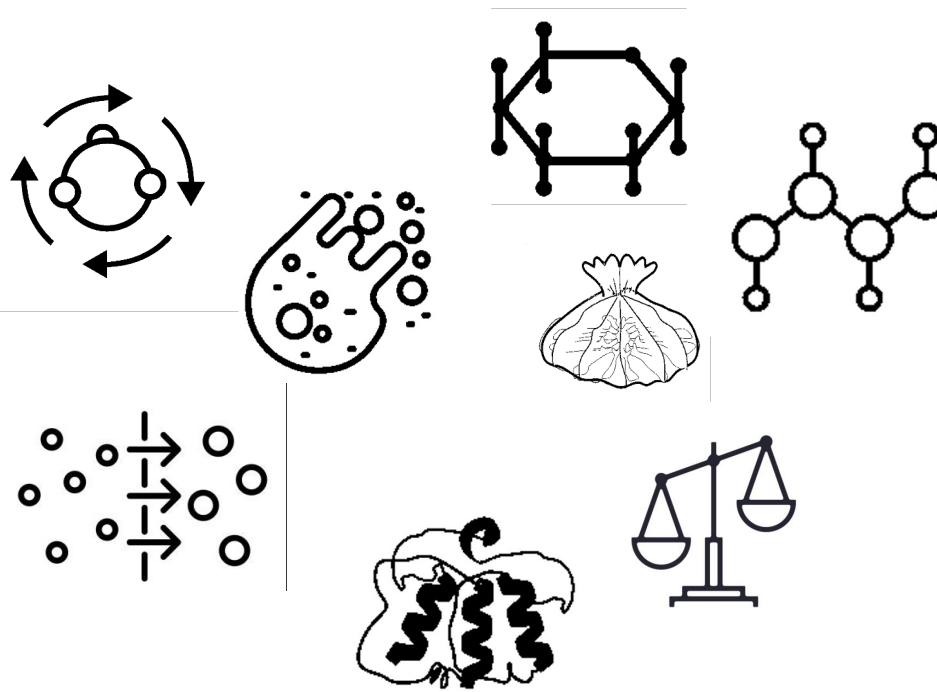


*Nitrogen metabolism, membrane transport, protein transport, metamorphosis, carbohydrate metabolism.*

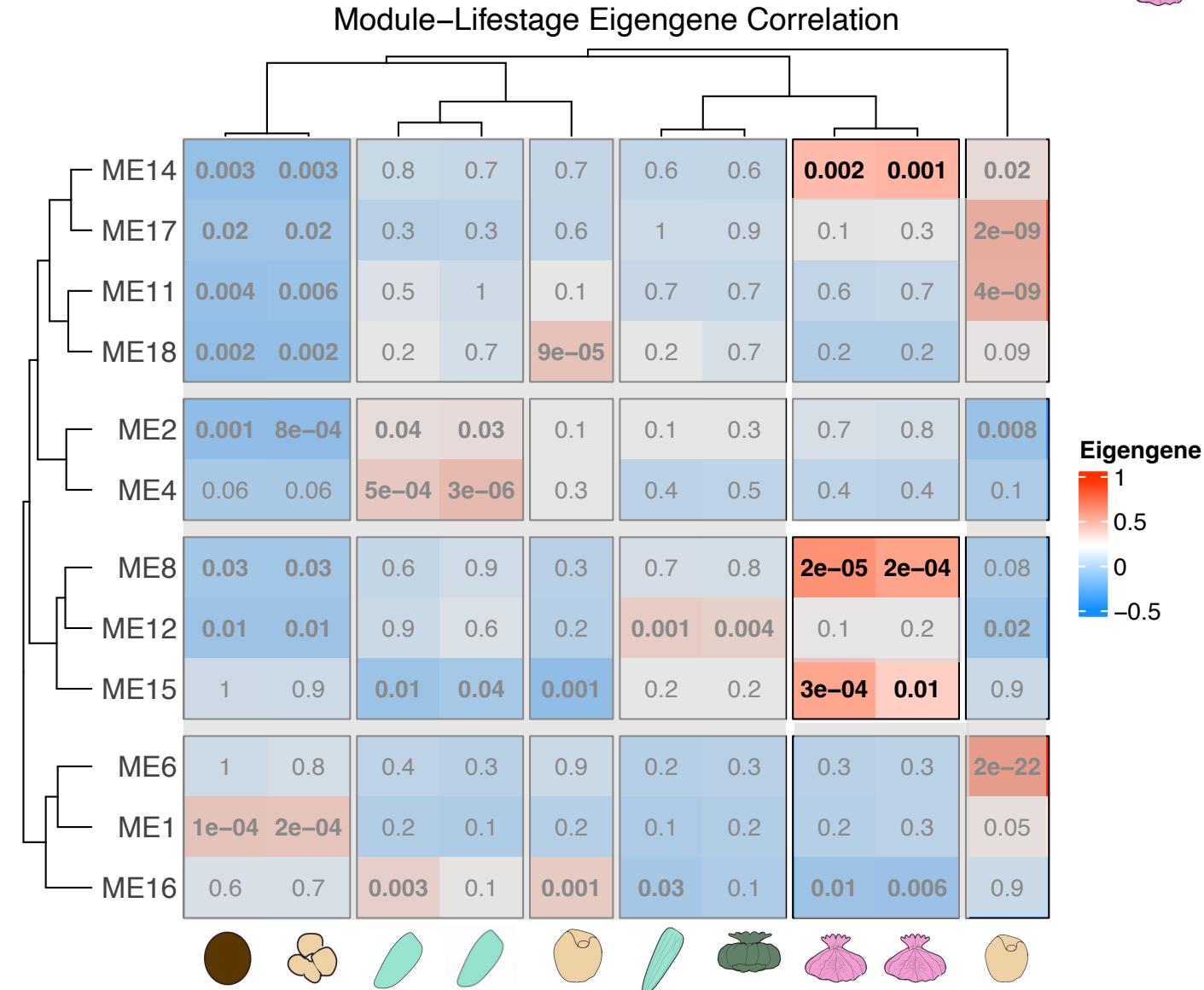


# ATTACHED RECRUITS

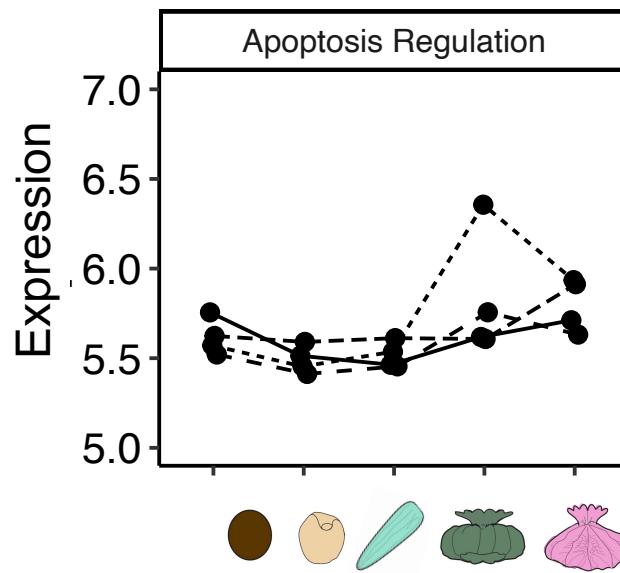
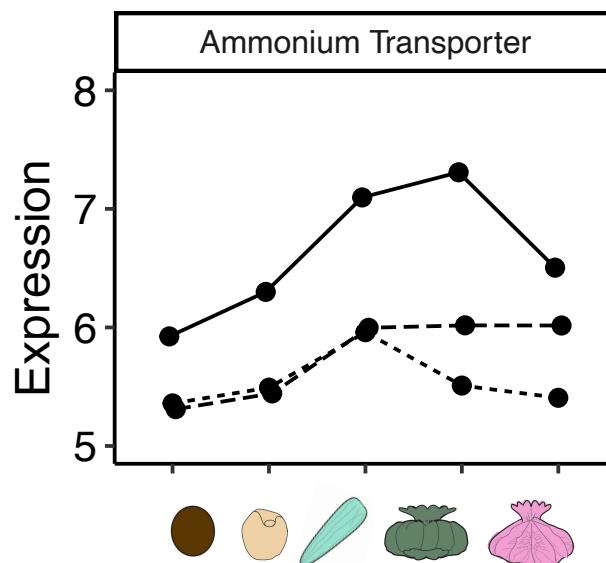
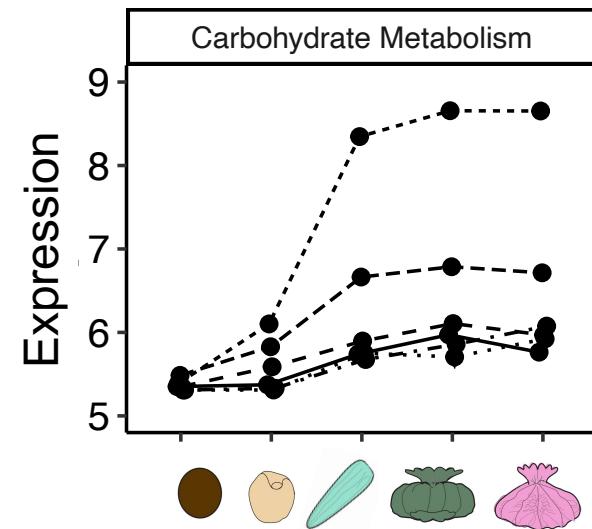
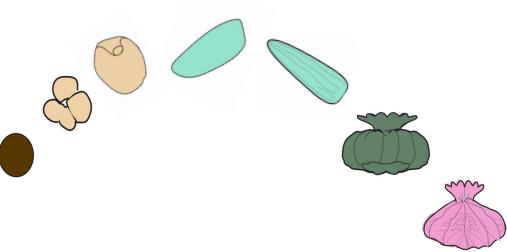
## 183-231 hpf



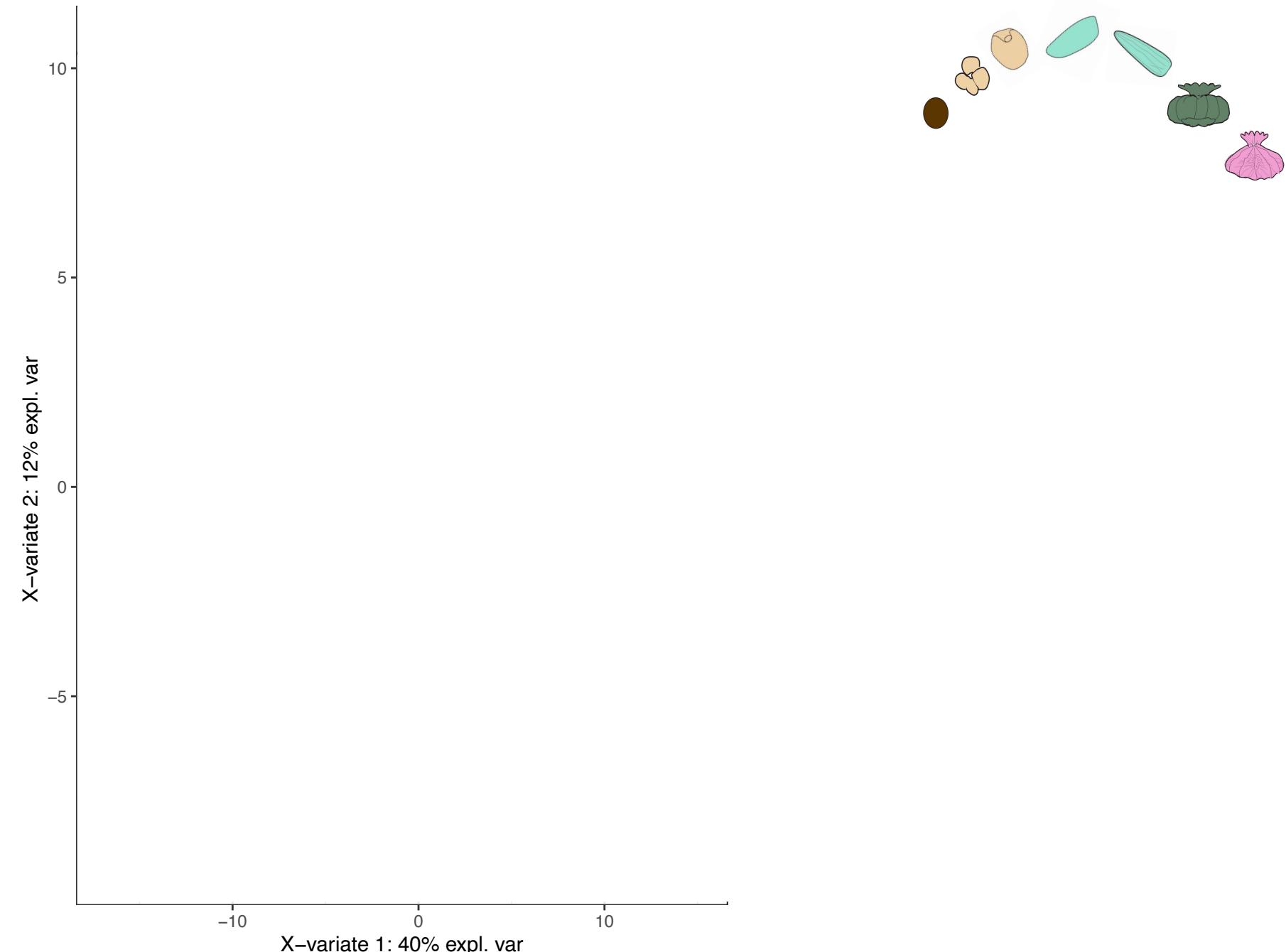
*Cell communication, membrane transport, homeostasis, lipid metabolism, carbohydrate metabolism*



# GENE EXPRESSION SIGNATURES OF SYMBIOSIS



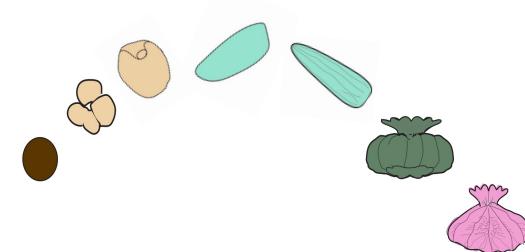
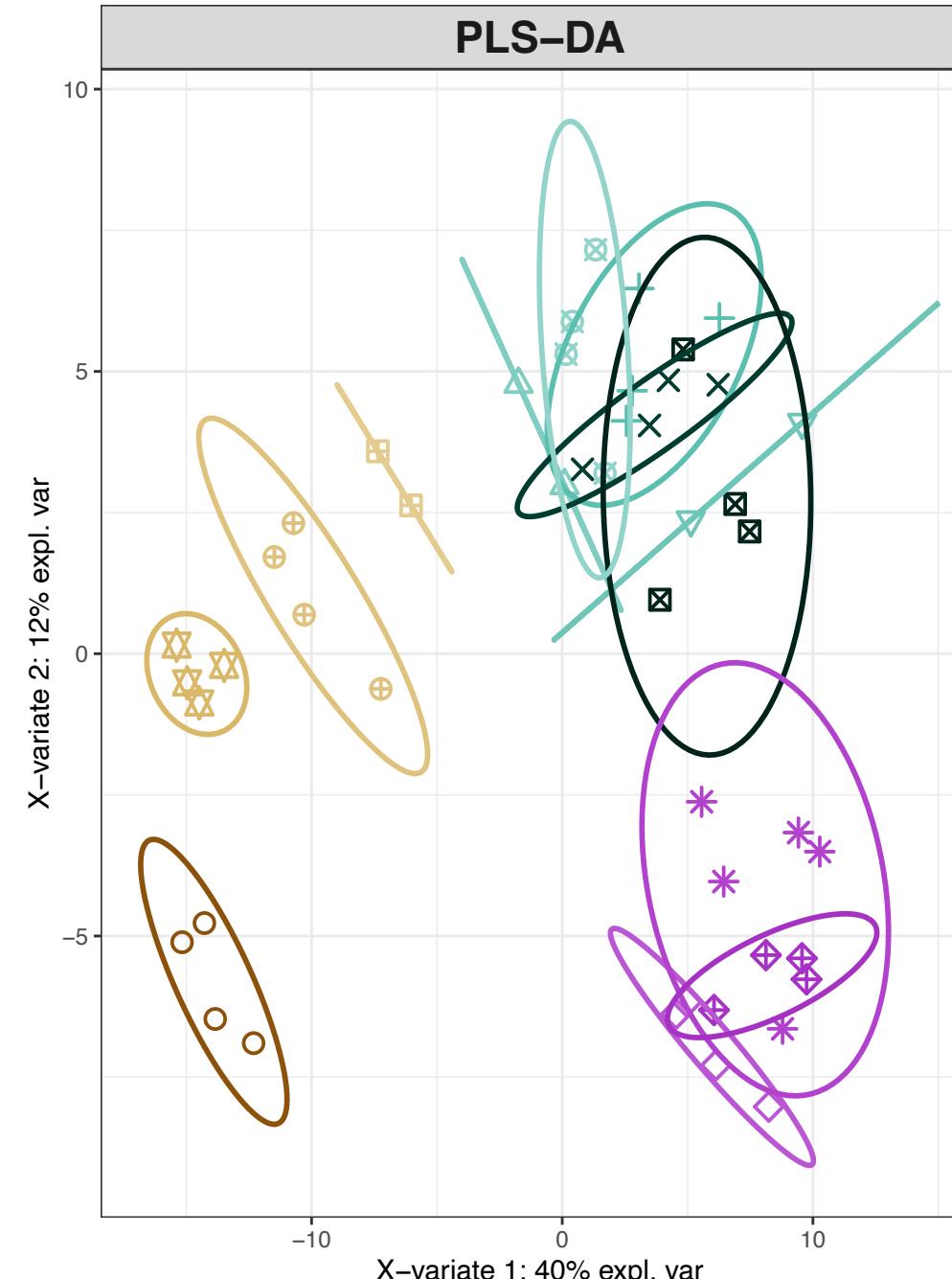
# Distinct metabolomic profiles across ontogeny



Untargeted metabolomics  
LC-MS

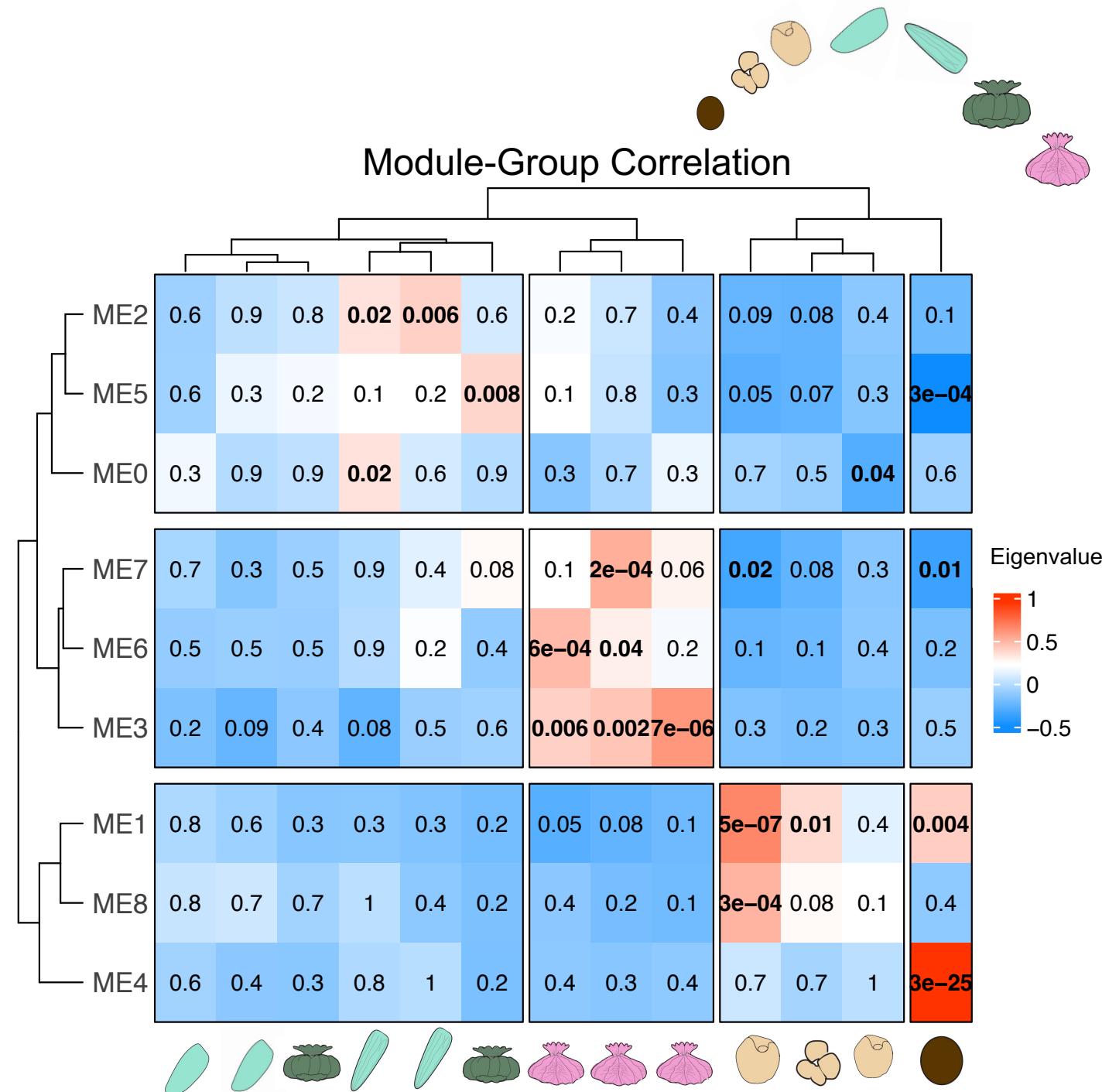
Rutgers Cancer Institute Metabolomics Facility

# Distinct metabolomic profiles across ontogeny



# Distinct metabolomic profiles across ontogeny

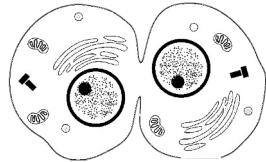
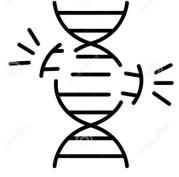
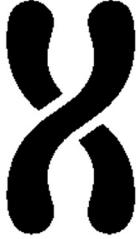
*Weighted correlation network analysis*



blockwiseModules module detection  
Metaboanalyst 5.0 functional enrichment  
Filtered FDR<0.05

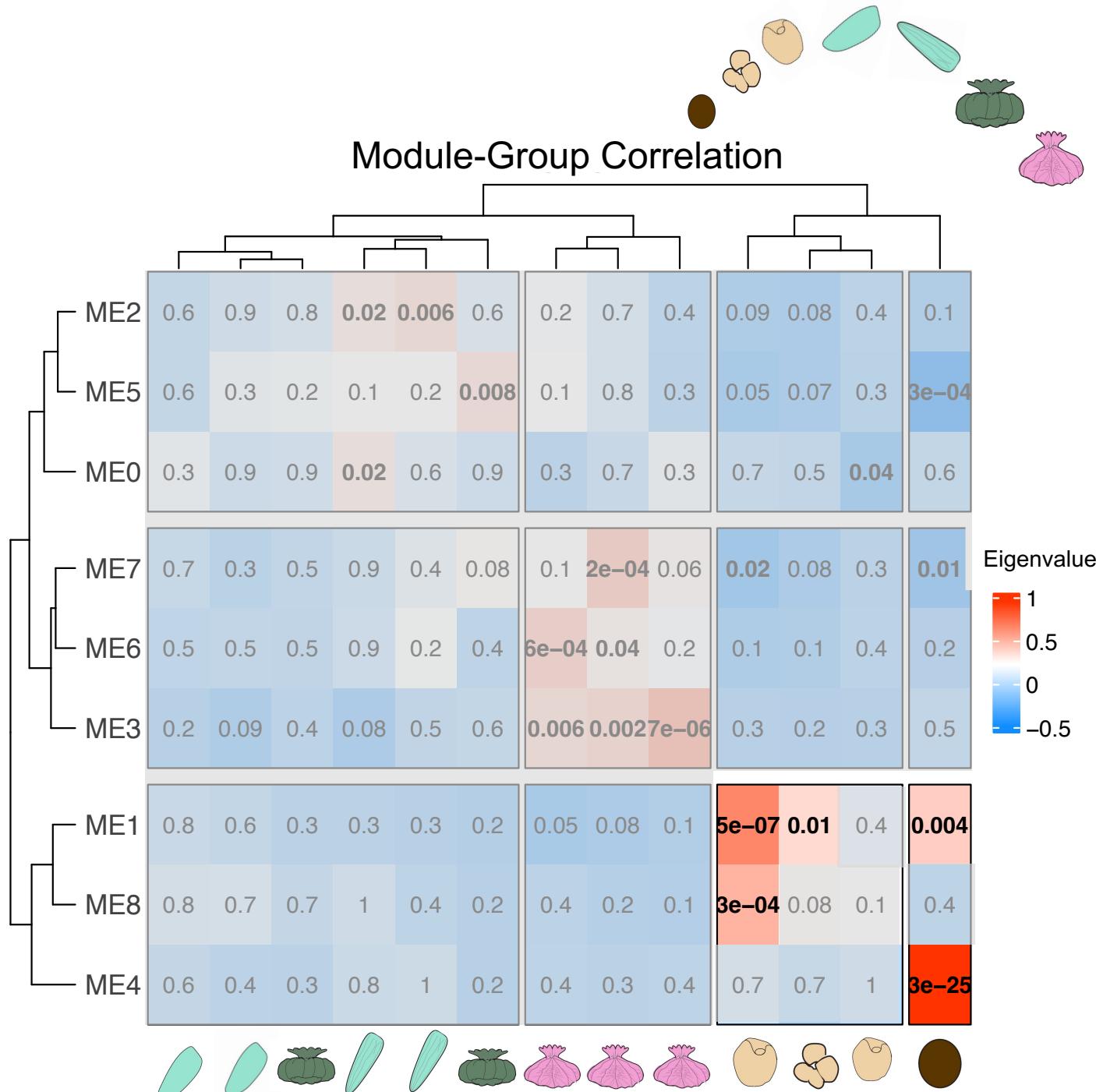
# EGGS & EMBRYOS

# 1 hpf-65 hpf



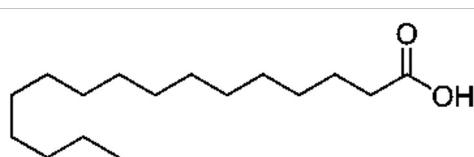
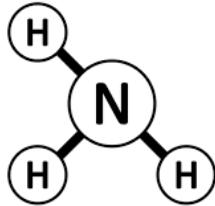
## *Embryonic development*

### *Cell division and differentiation*



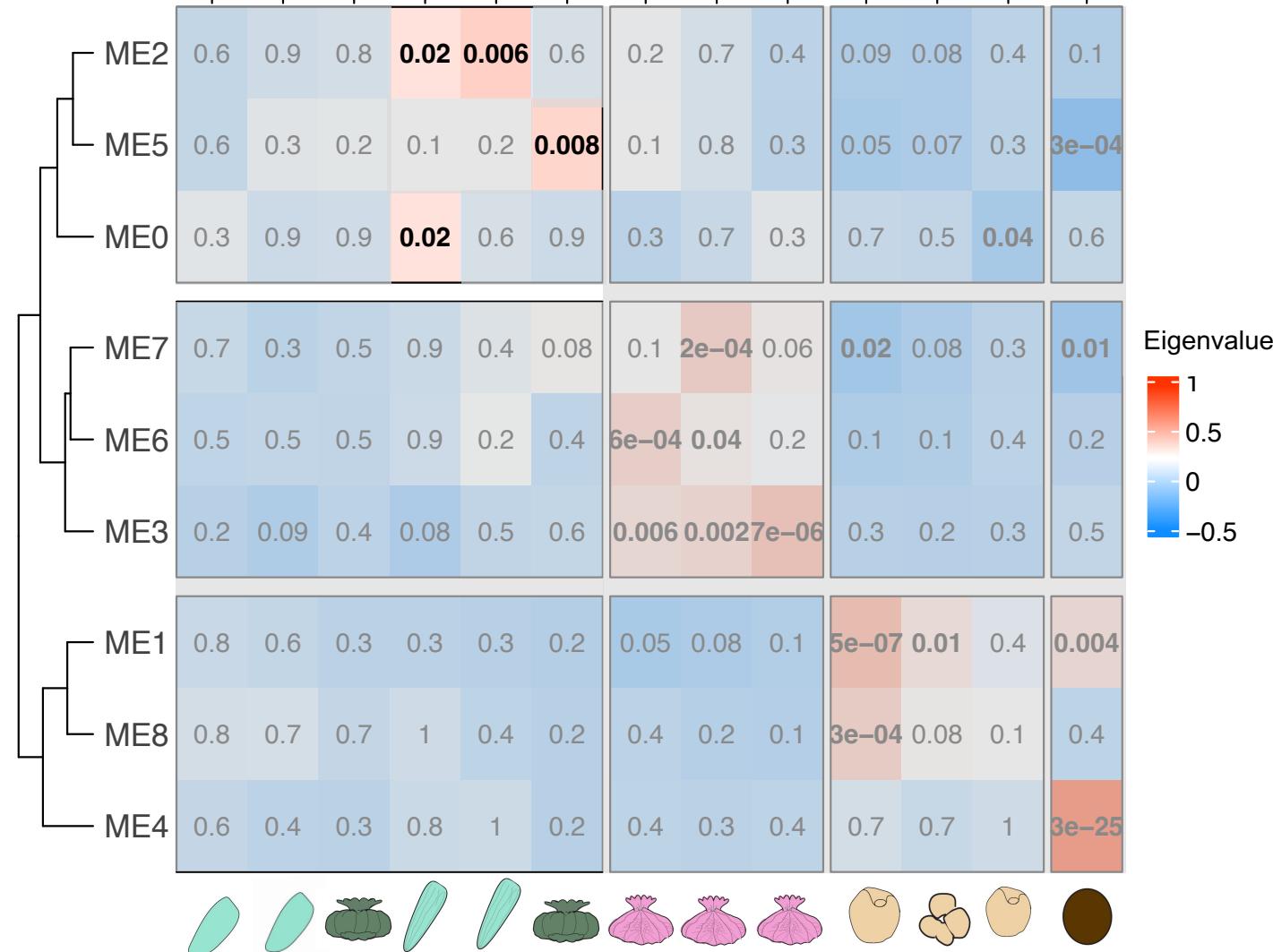
# LARVAE & METAMORPHOSED POLYPS

93 hpf-231 hpf



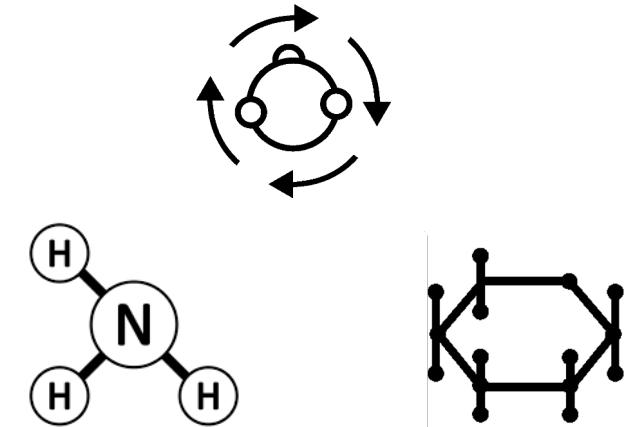
**Nitrogen, protein, fatty acid metabolism**

Module-Group Correlation

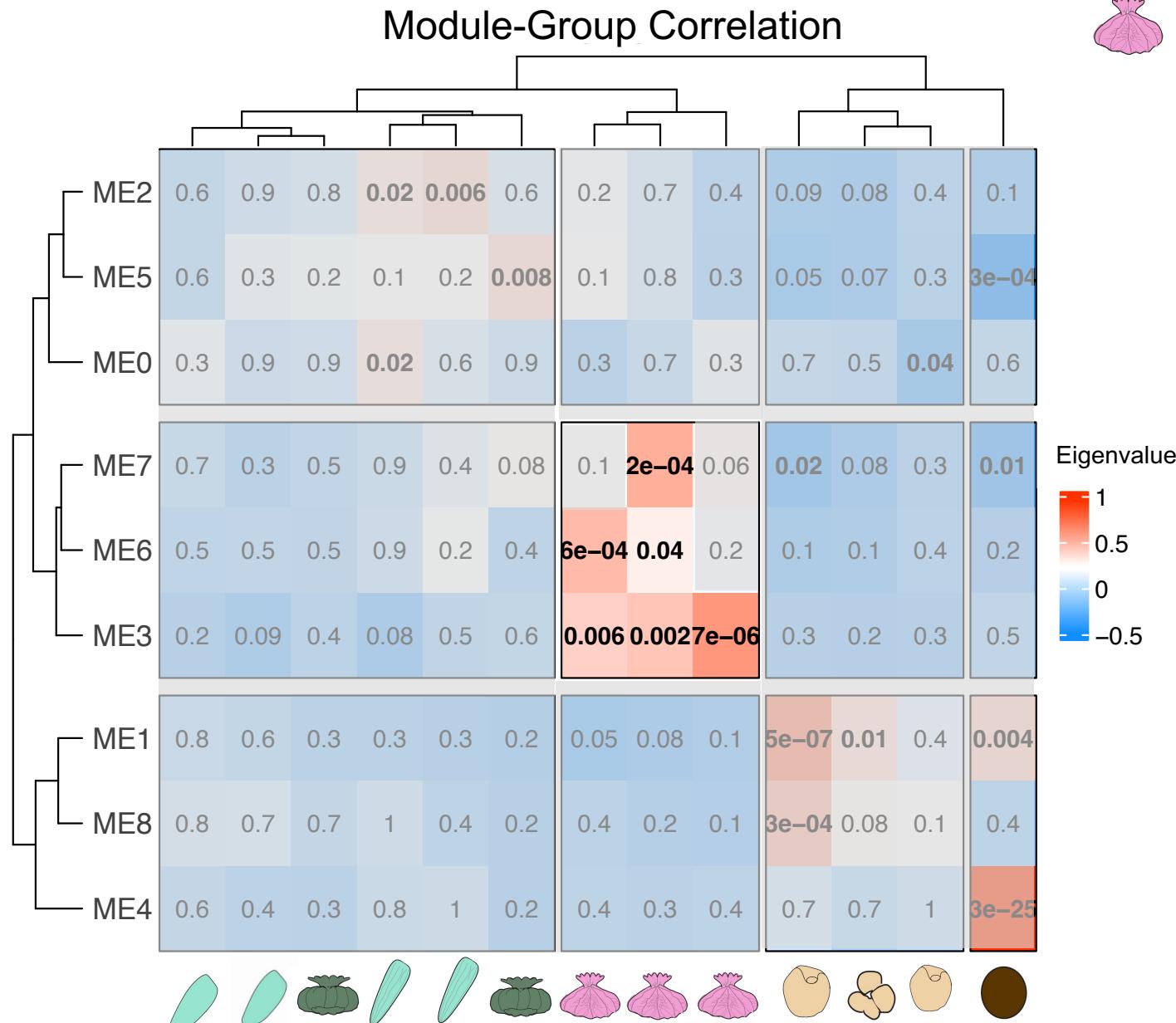


# ATTACHED RECRUITS

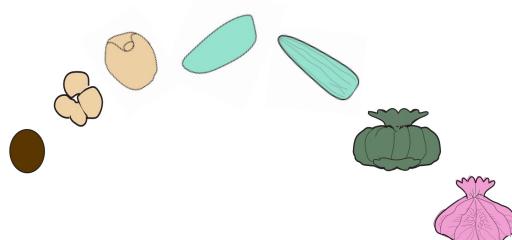
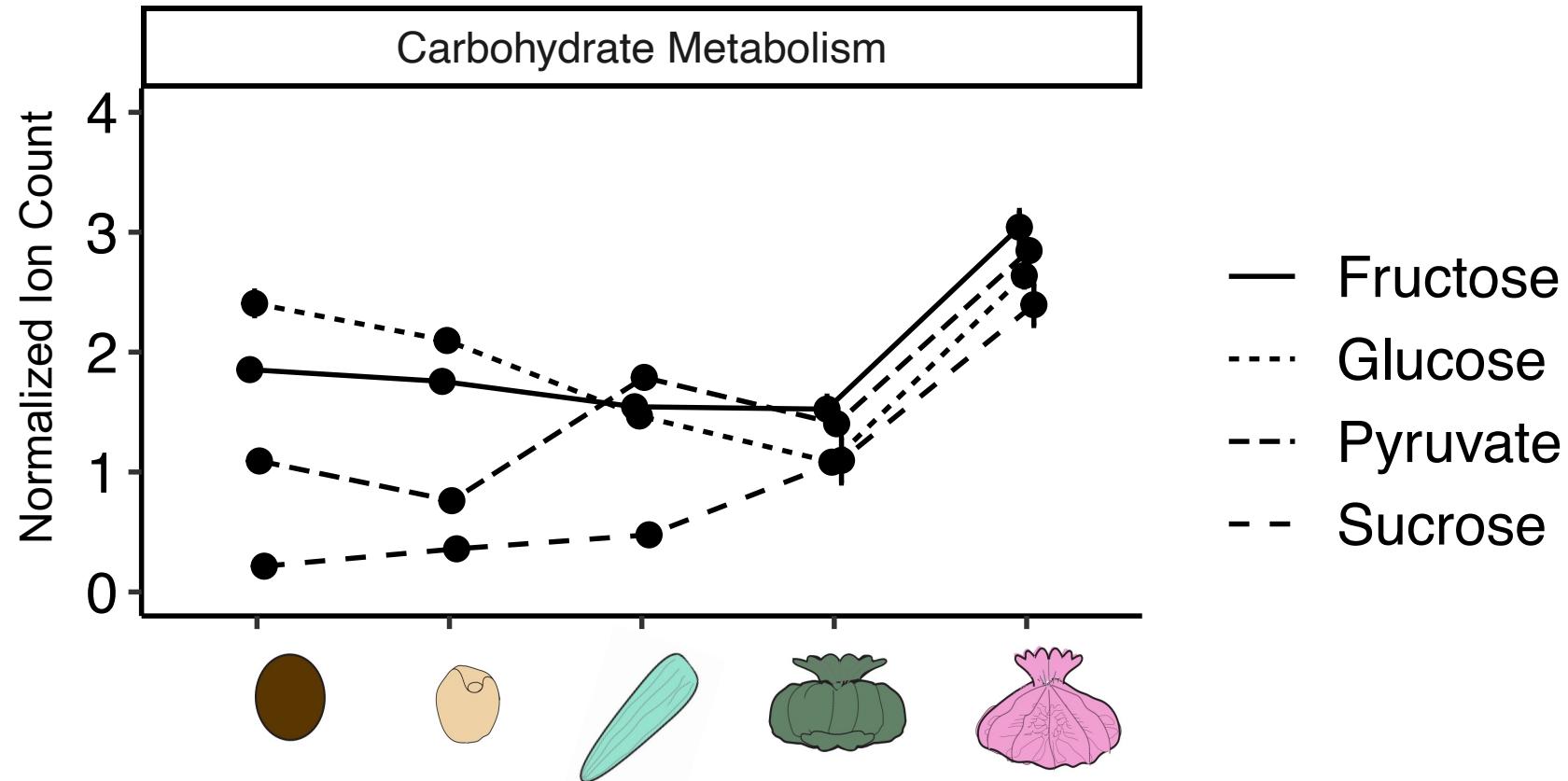
## 183 hpf-255 hpf



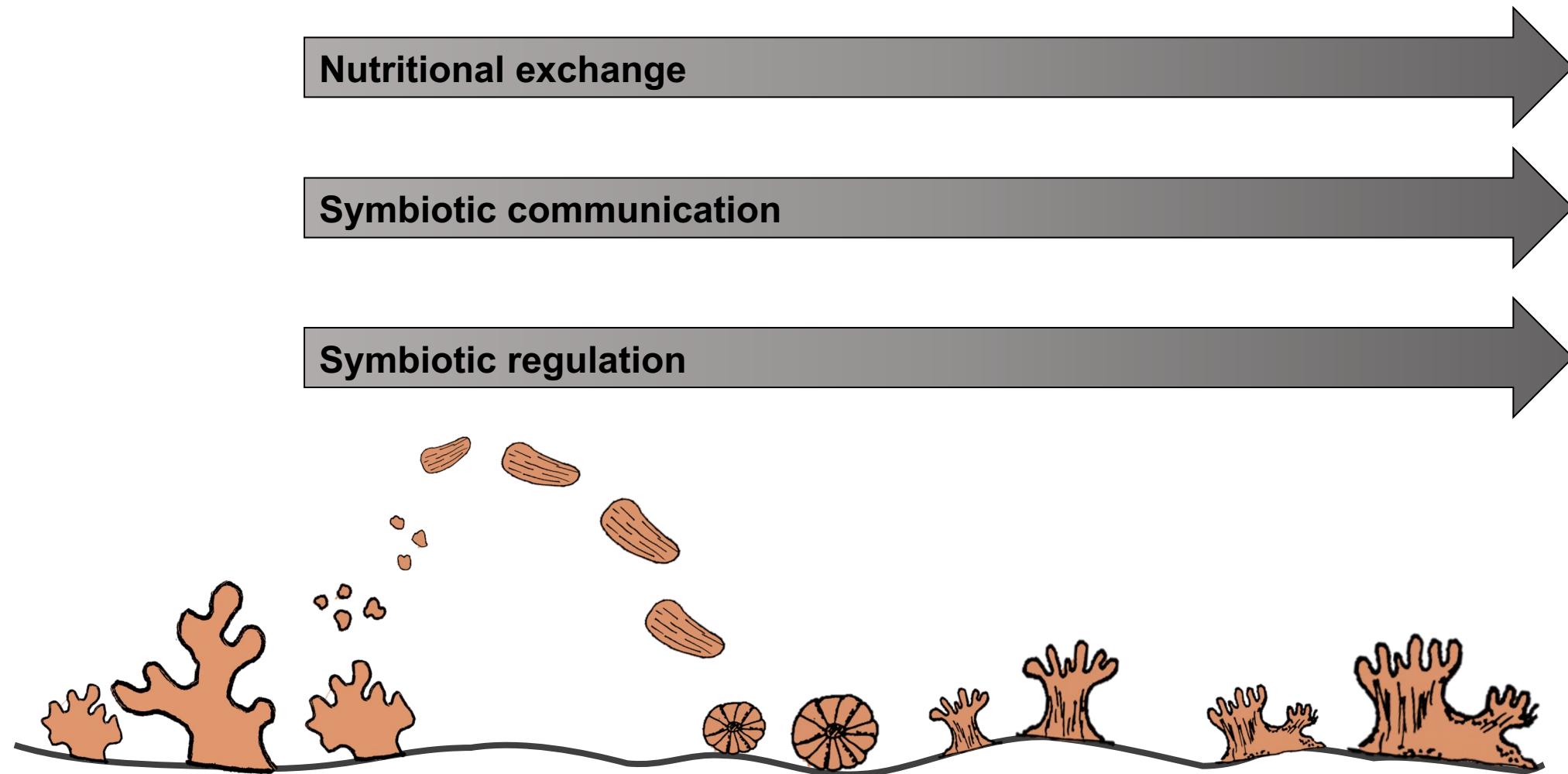
**Nitrogen, carbohydrate metabolism**



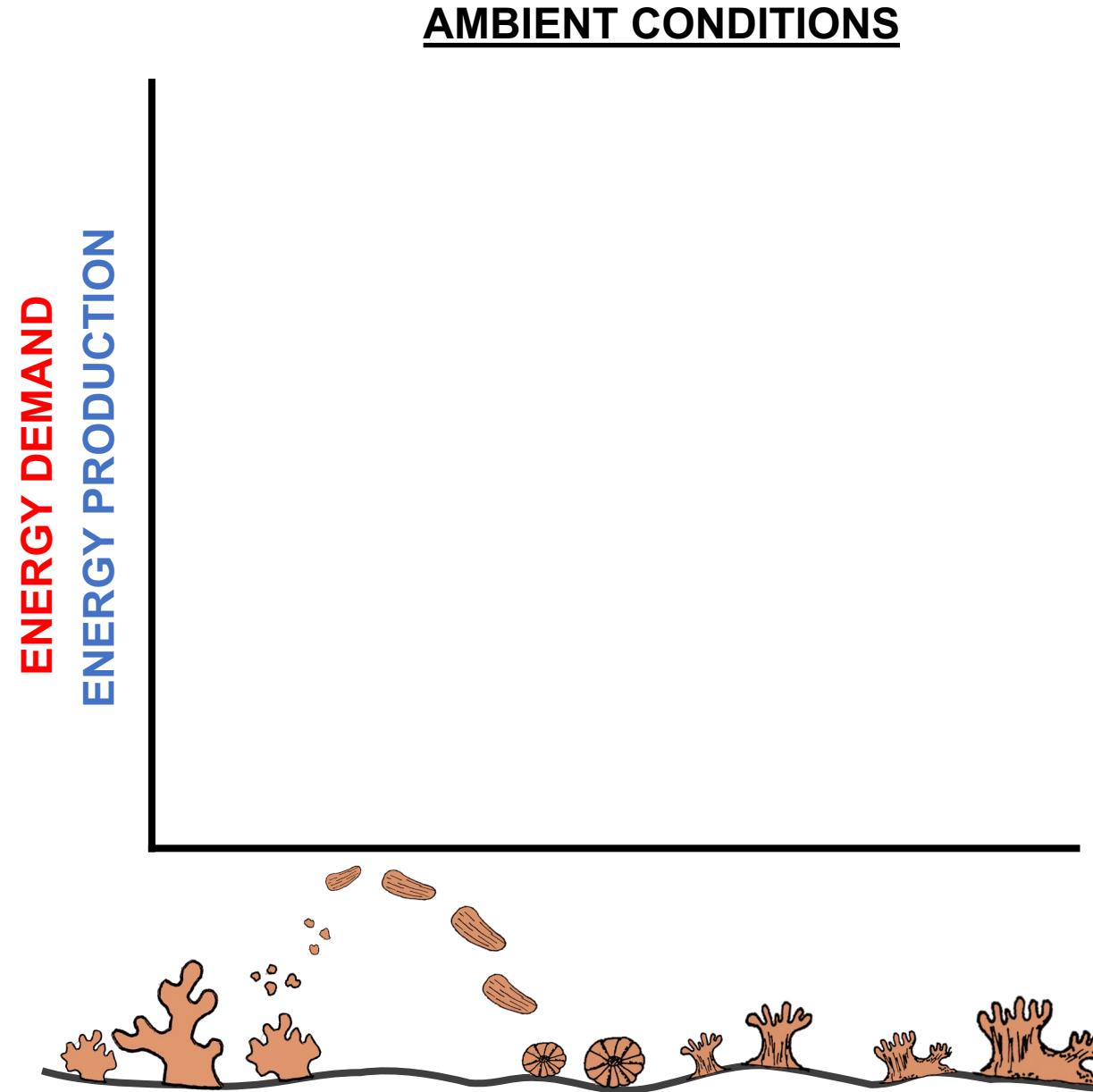
# CARBON METABOLISM



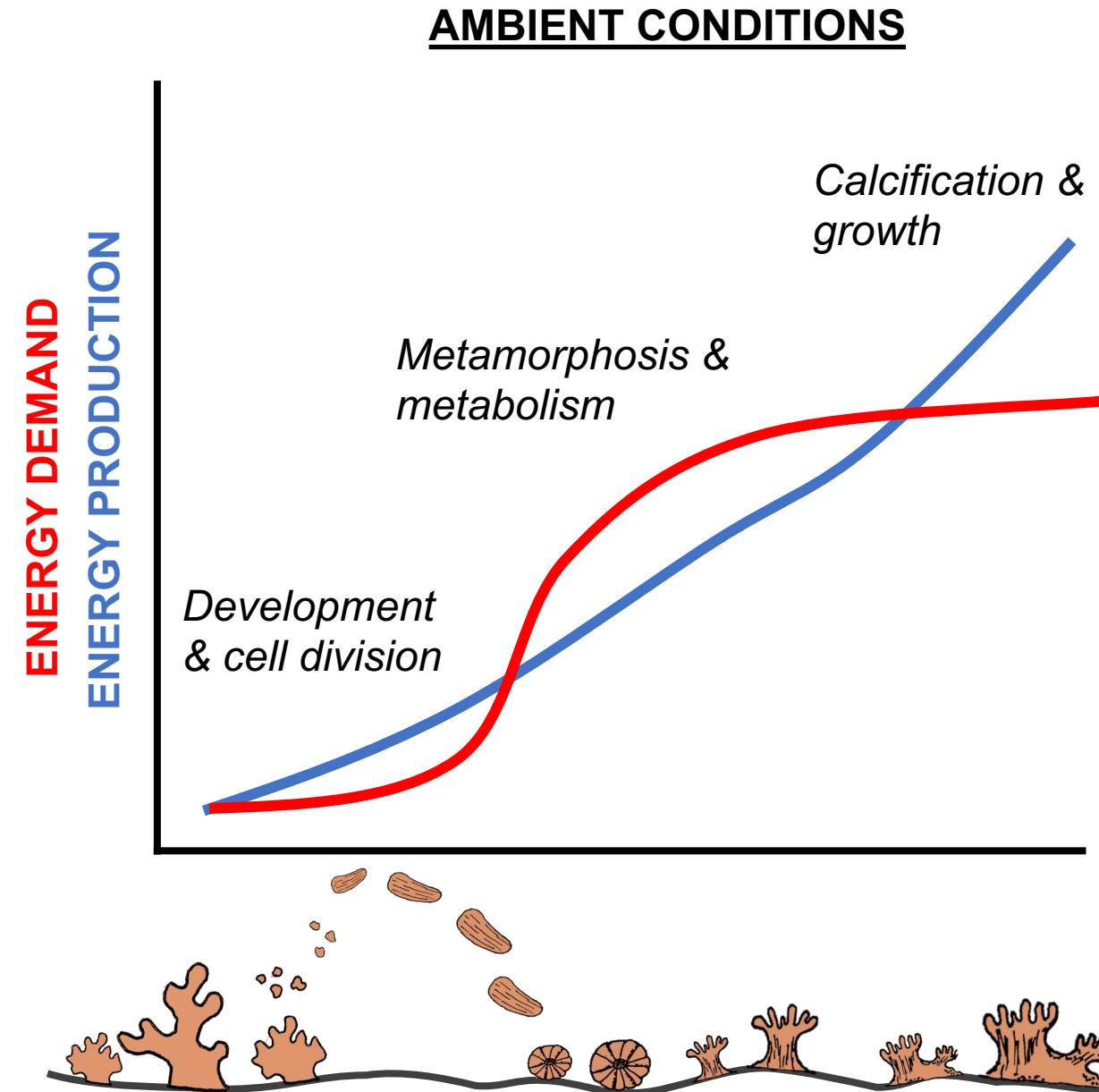
# *Molecular & metabolomic mechanisms of nutritional exchange across a developmental gradient*



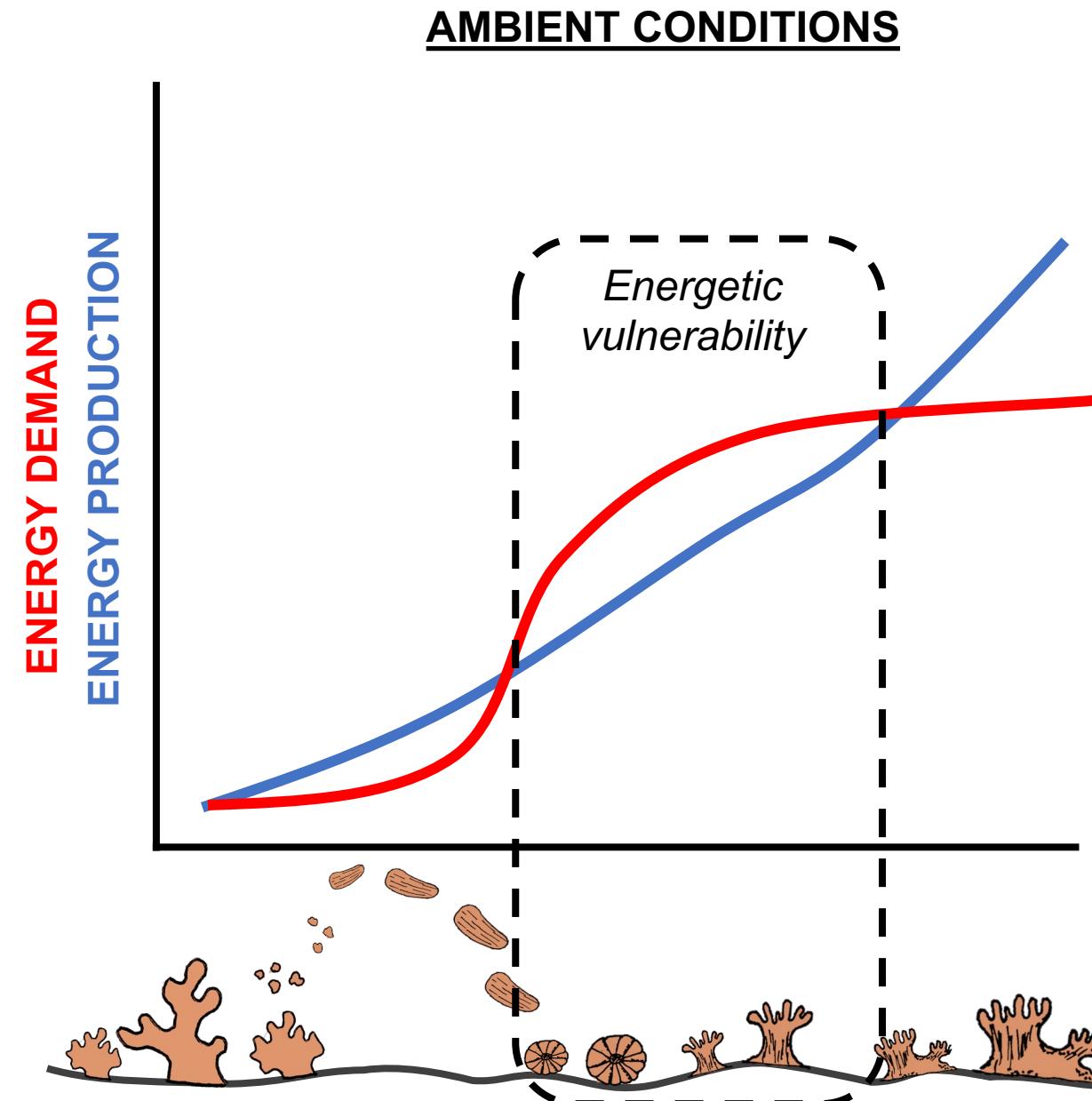
# *How does nutritional exchange impact energetic capacity during recruitment?*



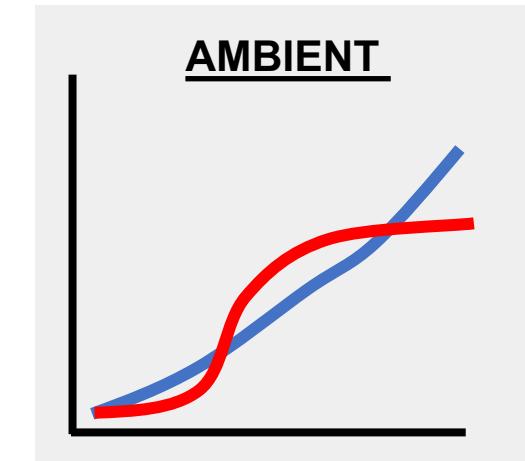
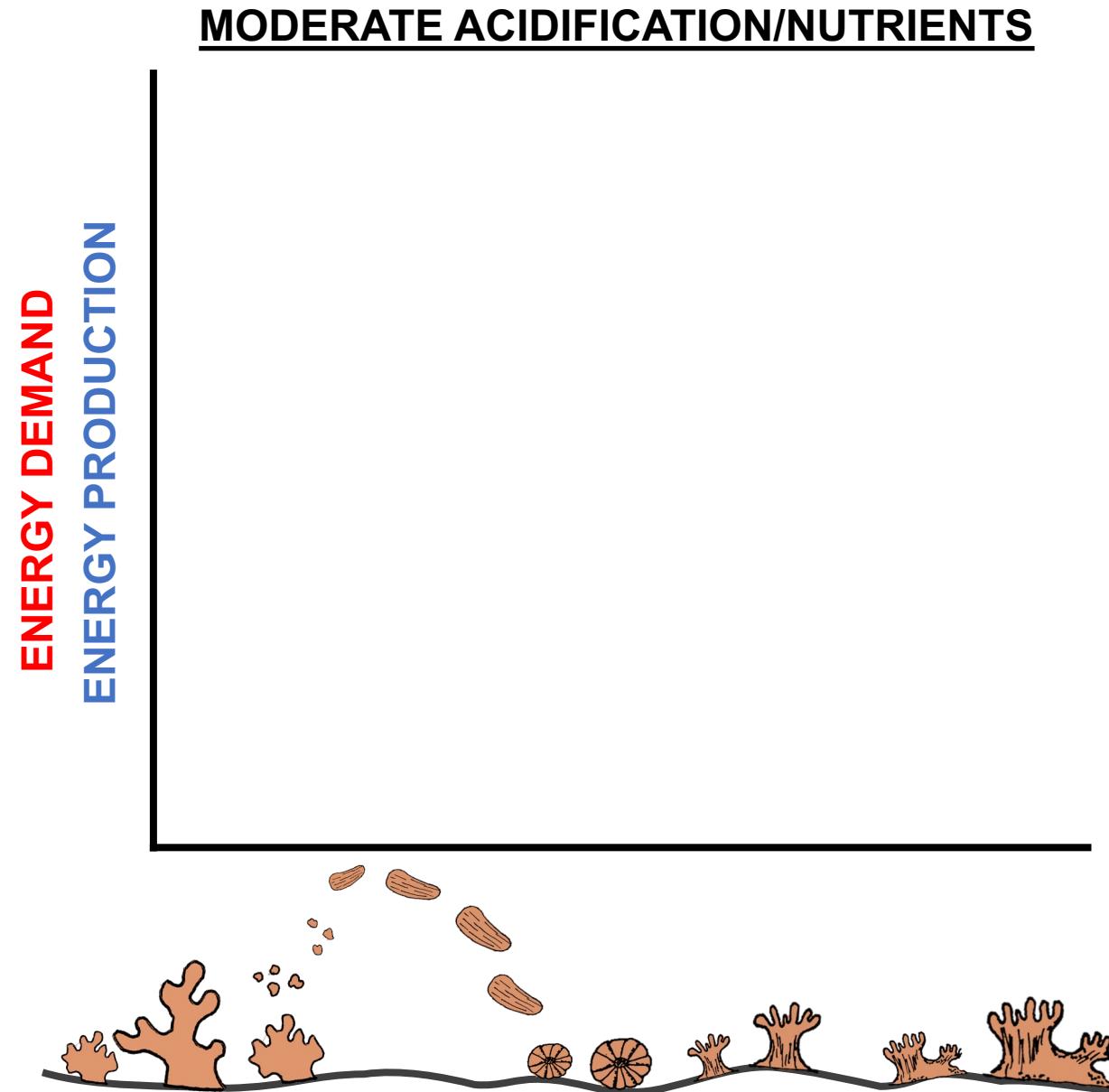
# *How does nutritional exchange impact energetic capacity during recruitment?*



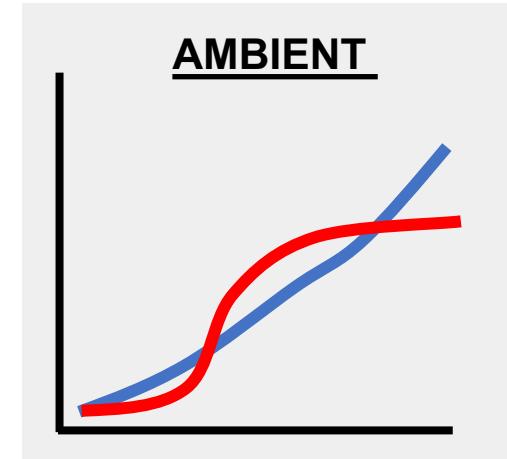
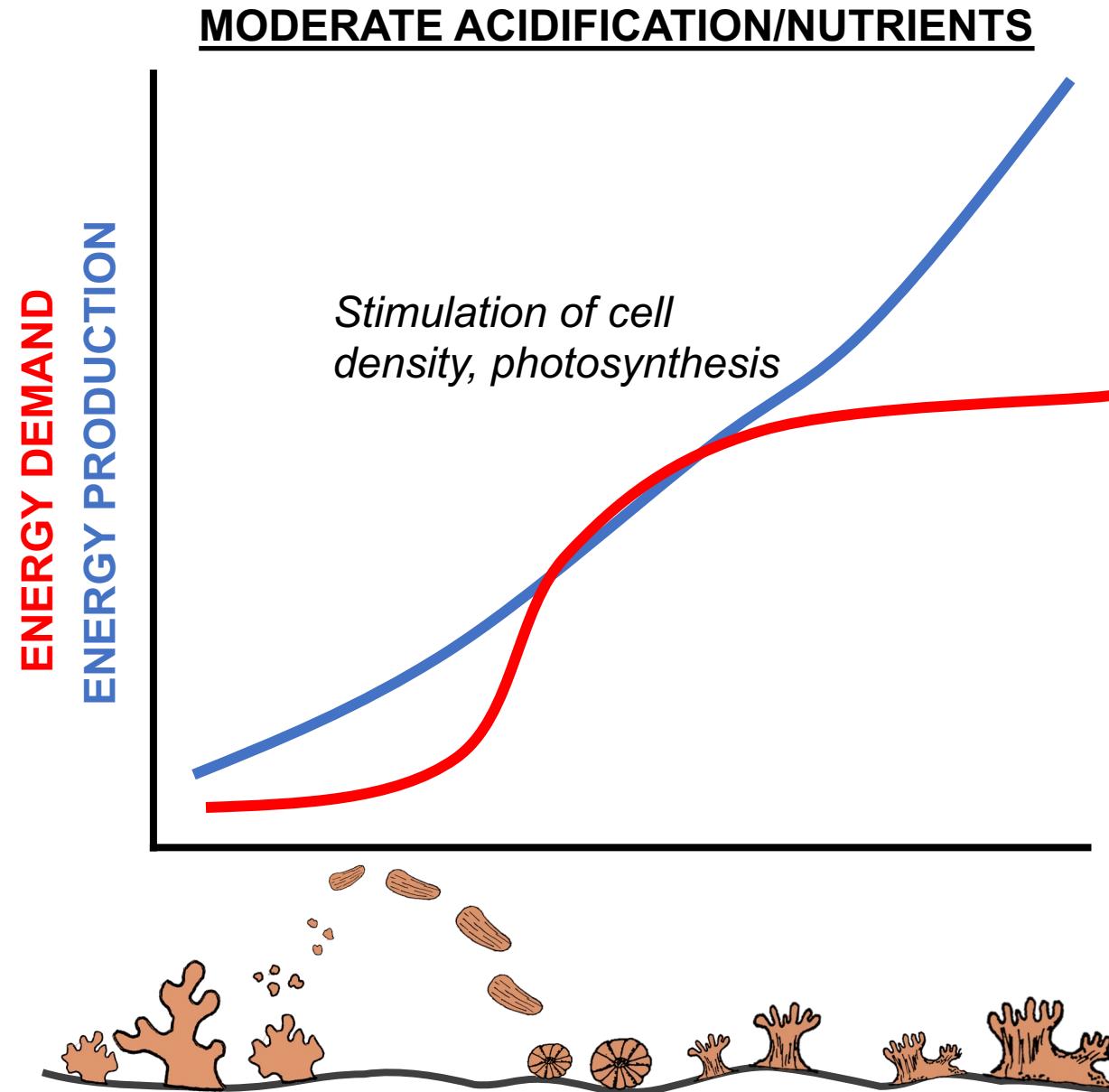
# *How does nutritional exchange impact energetic capacity during recruitment?*



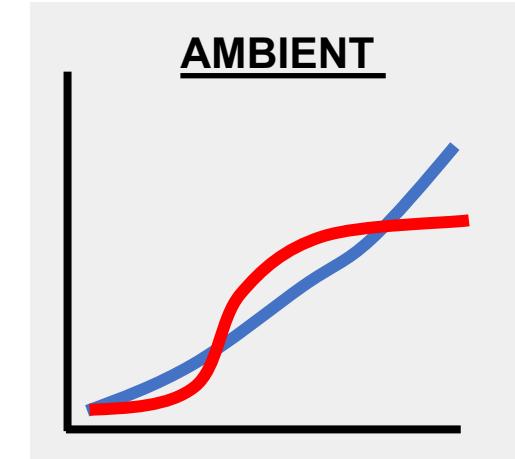
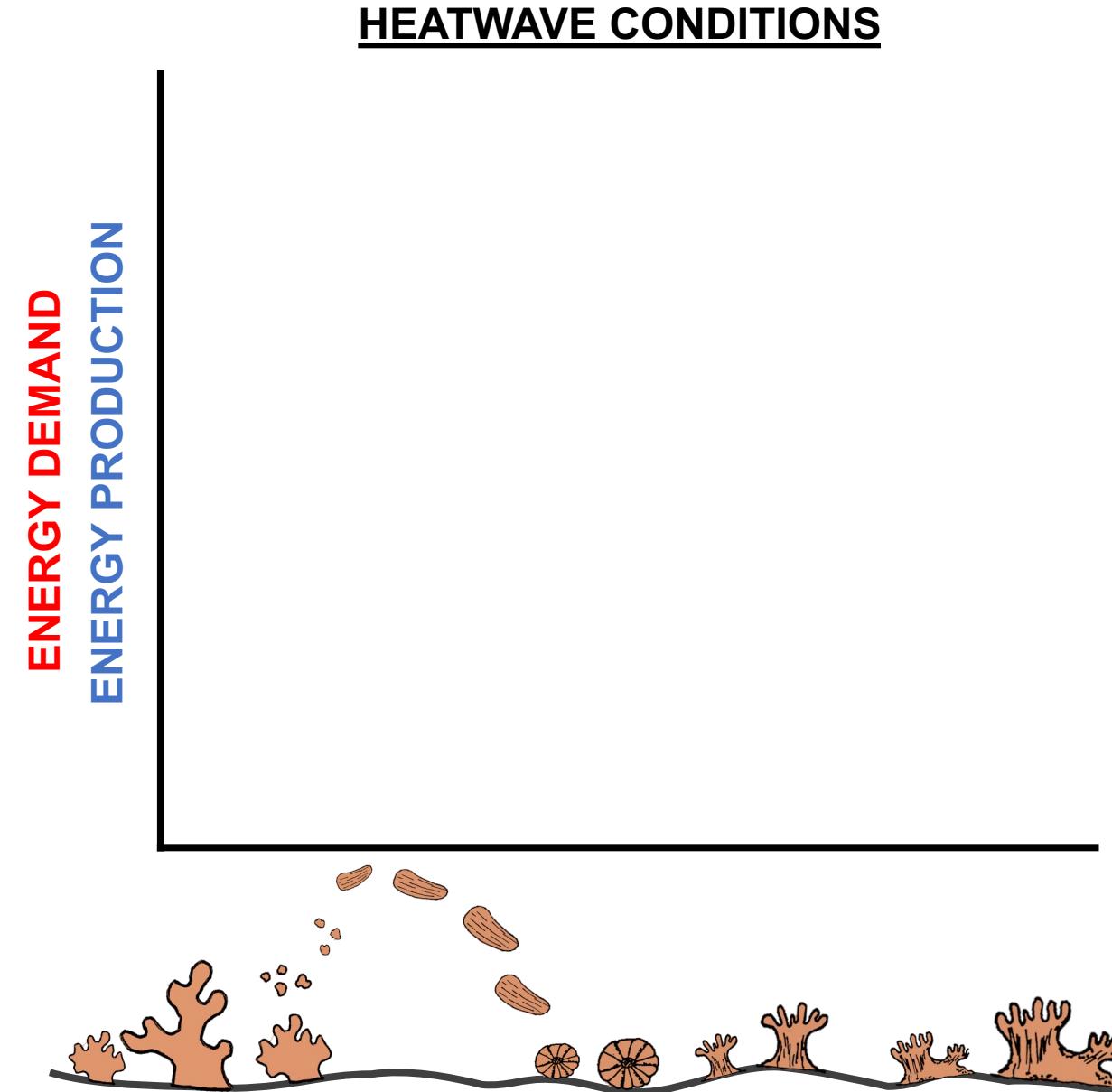
# *How does nutritional exchange impact energetic capacity during recruitment?*



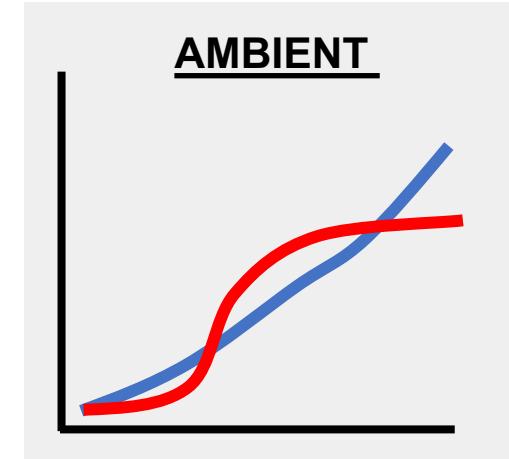
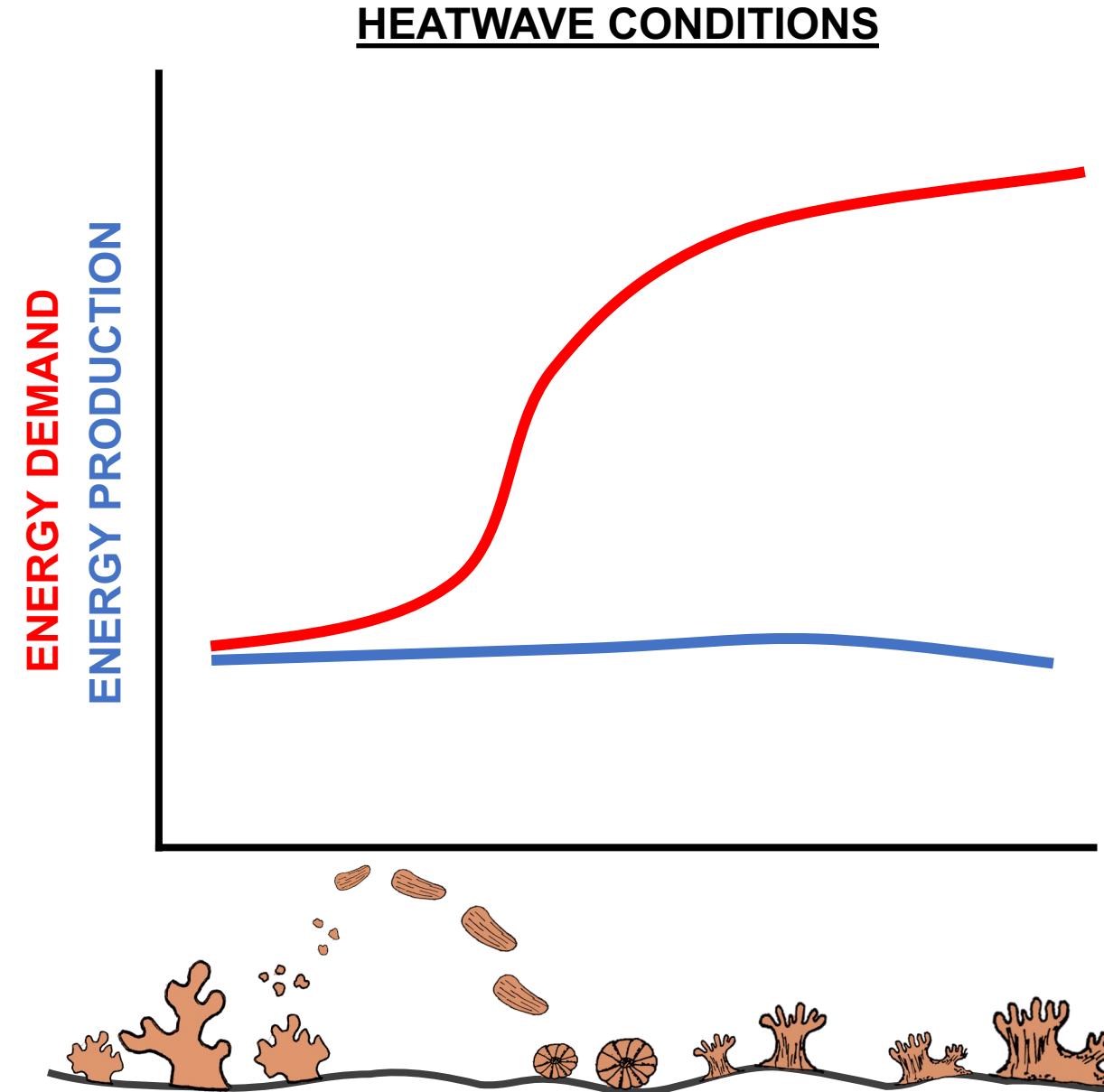
# *How does nutritional exchange impact energetic capacity during recruitment?*



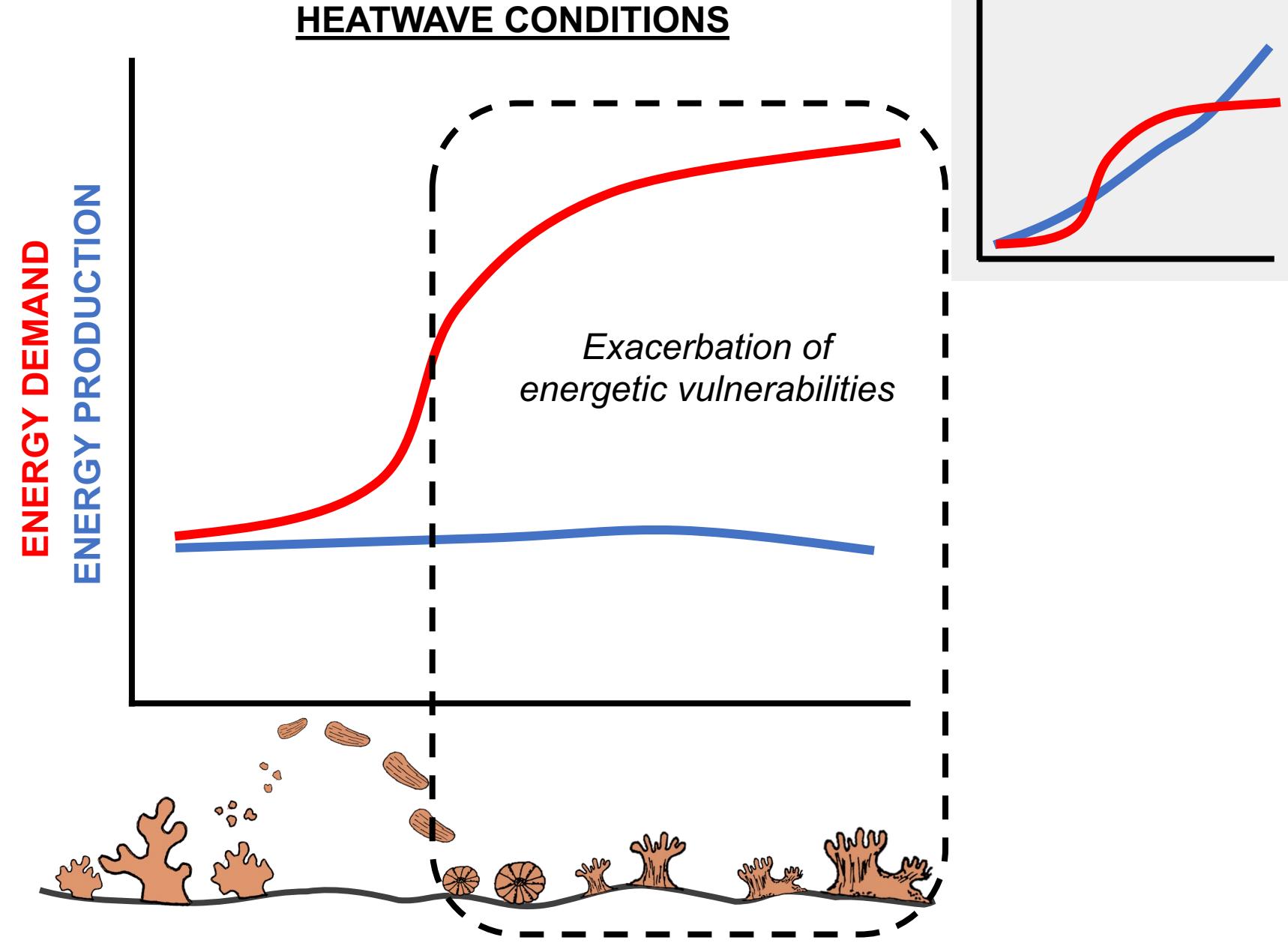
# *How does nutritional exchange impact energetic capacity during recruitment?*



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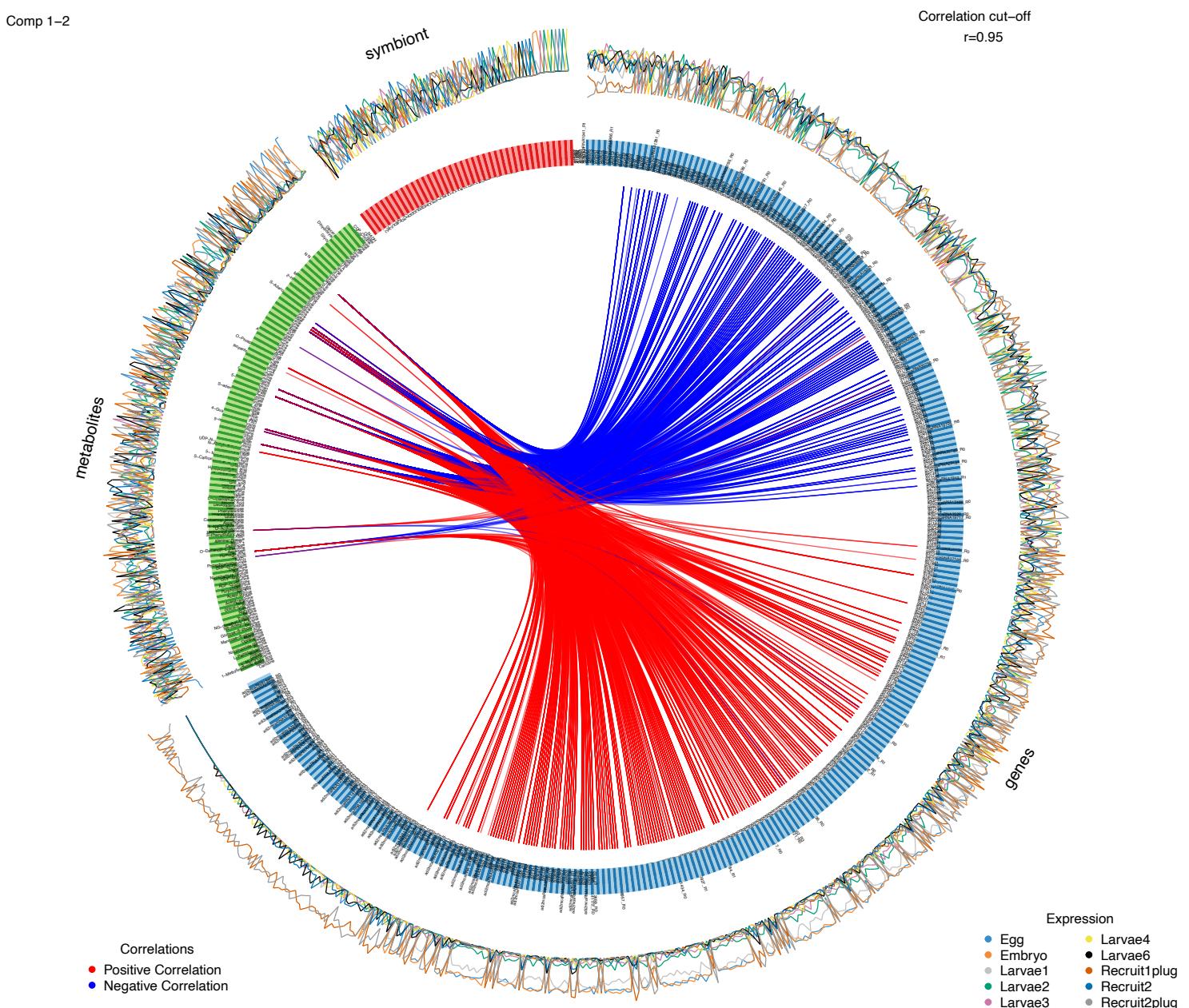


# *Multi-omic integration*

1. Identify holobiont signatures of nutritional transitions

# *Integration of bacterial, symbiont, metabolomic, and gene expression data across developmental time series*

2. Predict nutritional phenotypes under stressful conditions





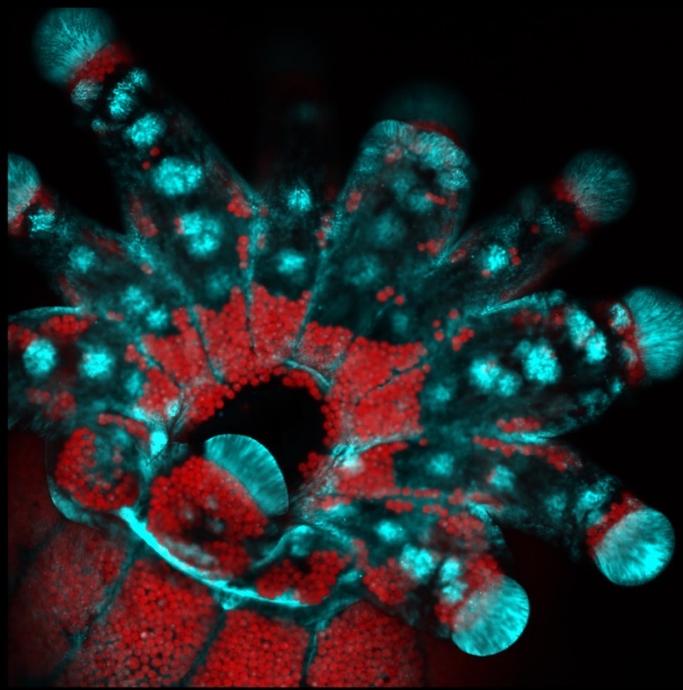
# Symbiotic relationships are dynamic across environmental and developmental gradients



# Thank you! Questions?



*Early life history coral reef ecophysiology and symbiosis*



ashuffmyer@uri.edu



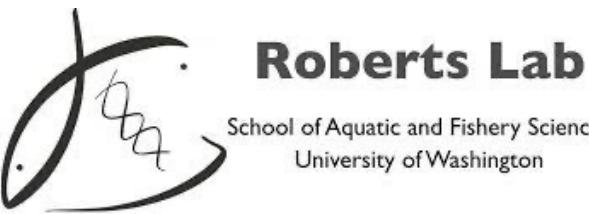
@Dr\_Cnidariana



AHuffmyer



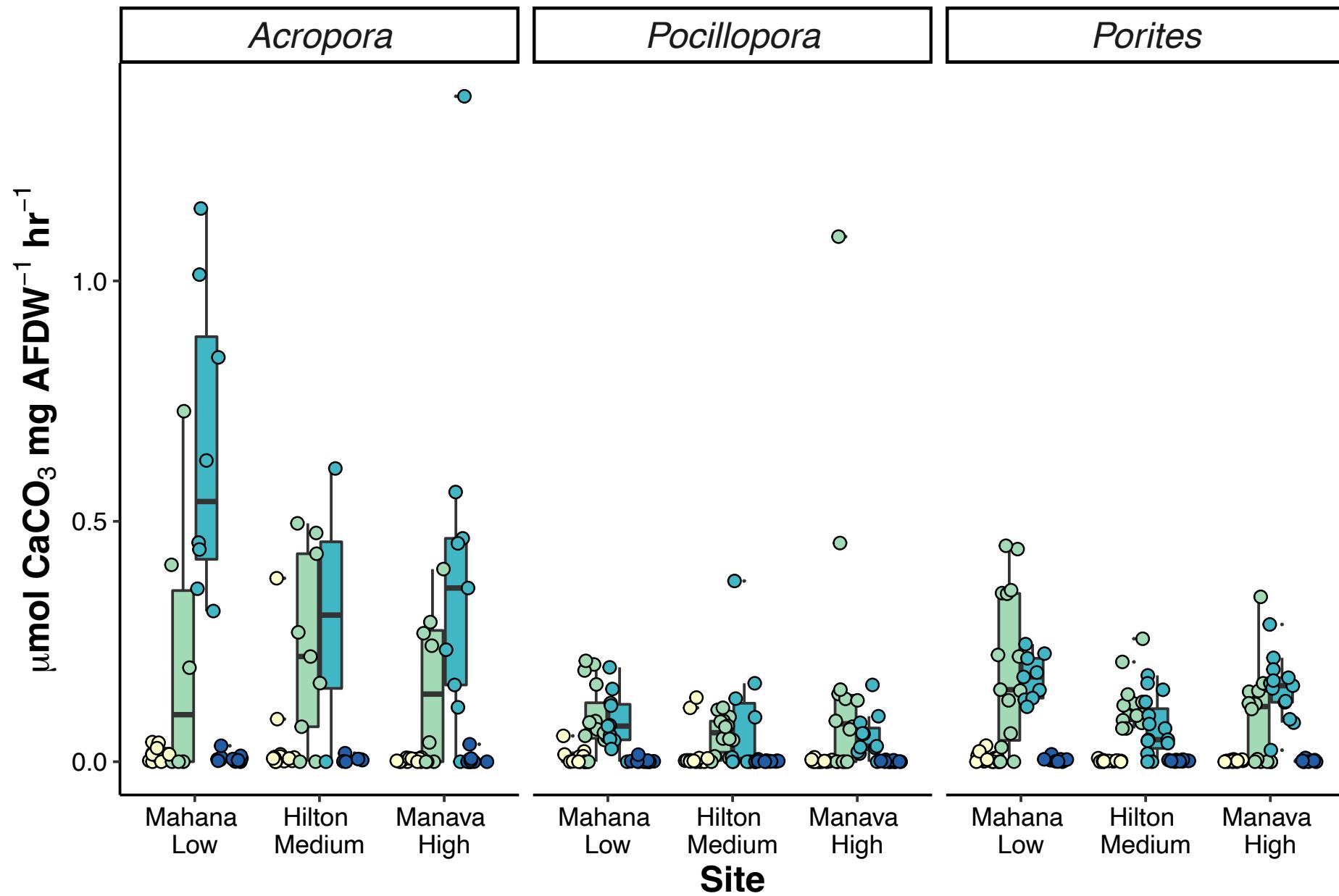
THE  
UNIVERSITY  
OF RHODE ISLAND



UNIVERSITY of WASHINGTON  
eScience Institute

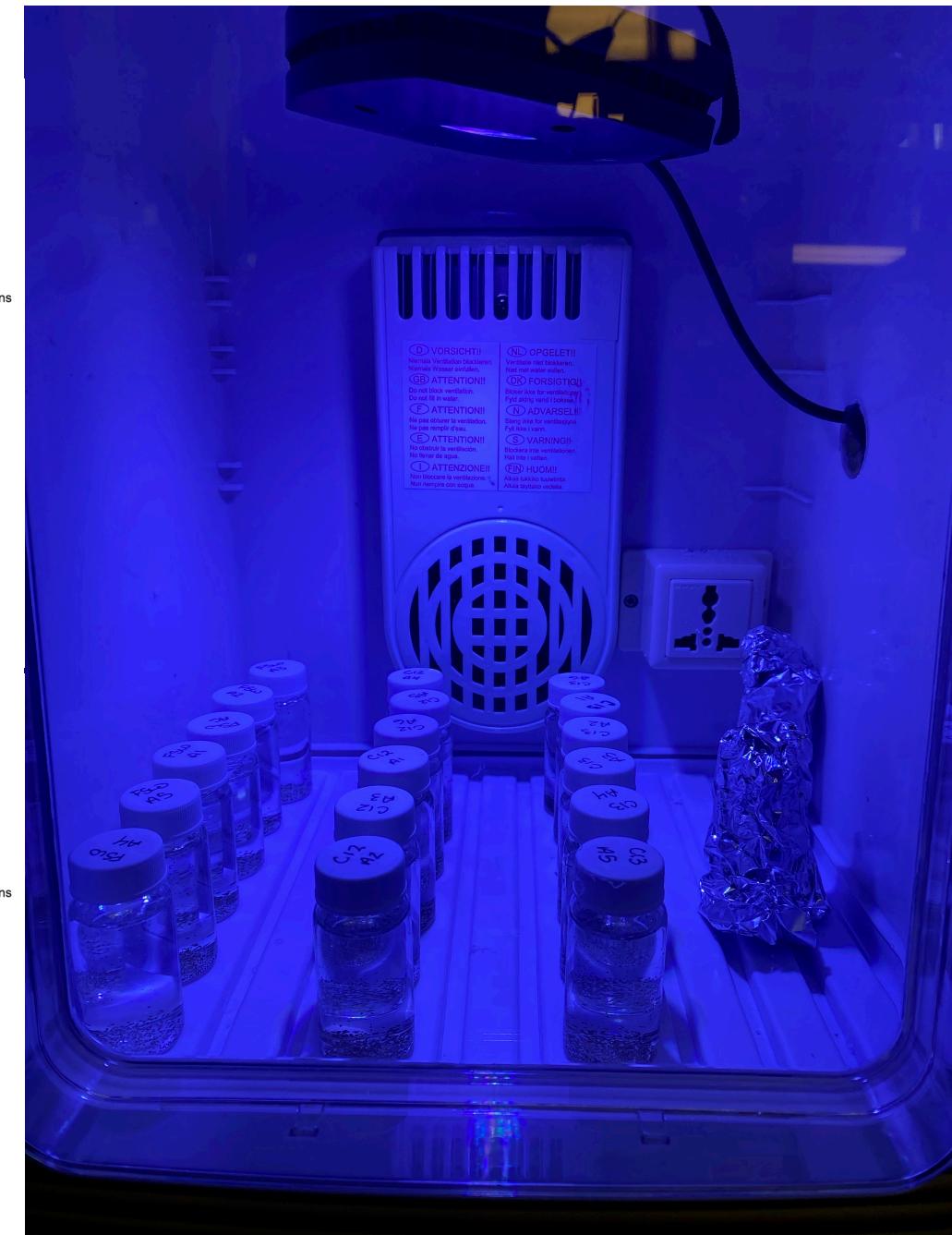
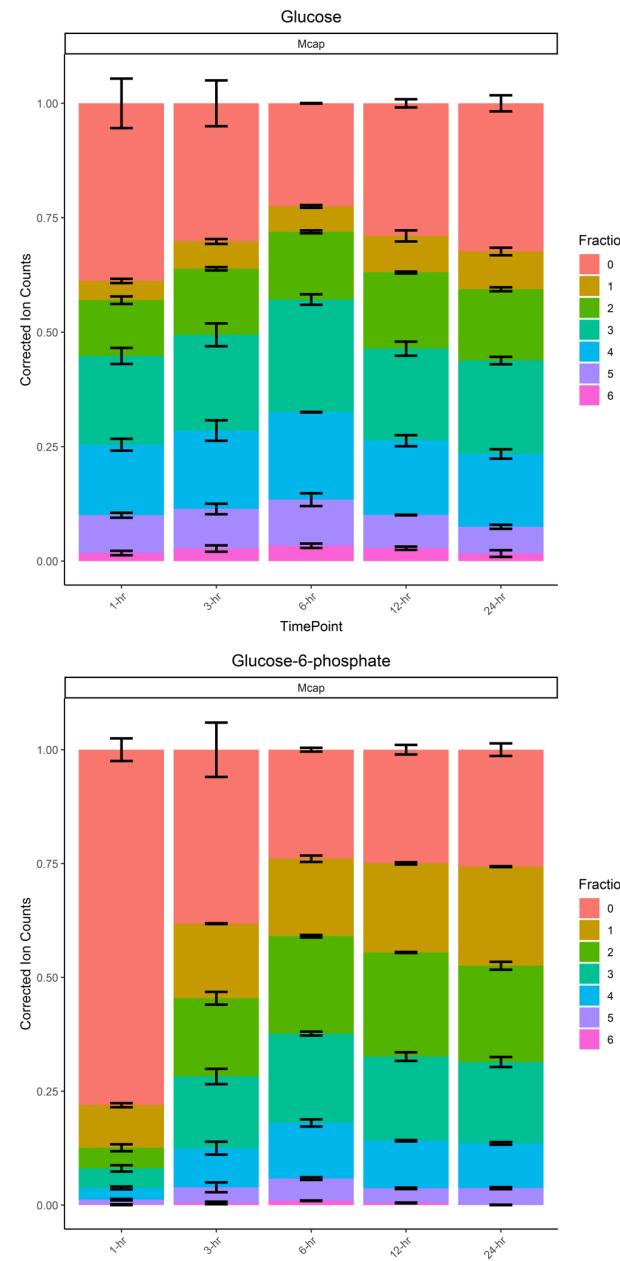


RUTGERS  
THE STATE UNIVERSITY  
OF NEW JERSEY



# Stable isotope metabolomics

*What is the identity and pool size of metabolites translocation from symbiont to host?*



# Stable symbiotic community across ontogeny

# ITS2 Amplicon Sequencing SymPortal profiling (Hume et al. 2019)

