Coral Reefs in a Changing Climate

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Photo: Tim Rock

Coral Reefs in a Changing Climate

- General Coral Biology
- Climate Change and Coral Bleaching
- Framework for Coral Resilience
- Experimental Design

Coral Biology

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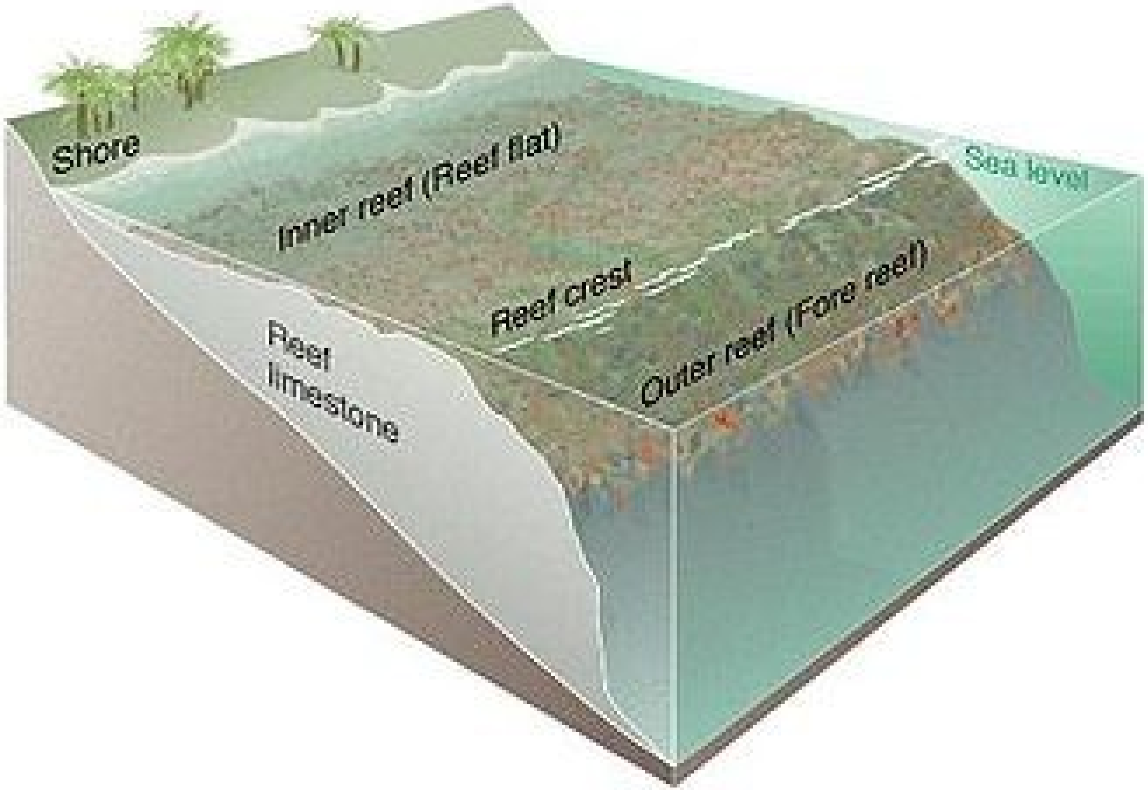
Reef Types on Guam

- Mostly fringing reefs
- Shallow inner reef flats dominat by staghorn corals
- Fore reefs with potentially more diverse communities but often dominated by extensive *Porites rus* colonies



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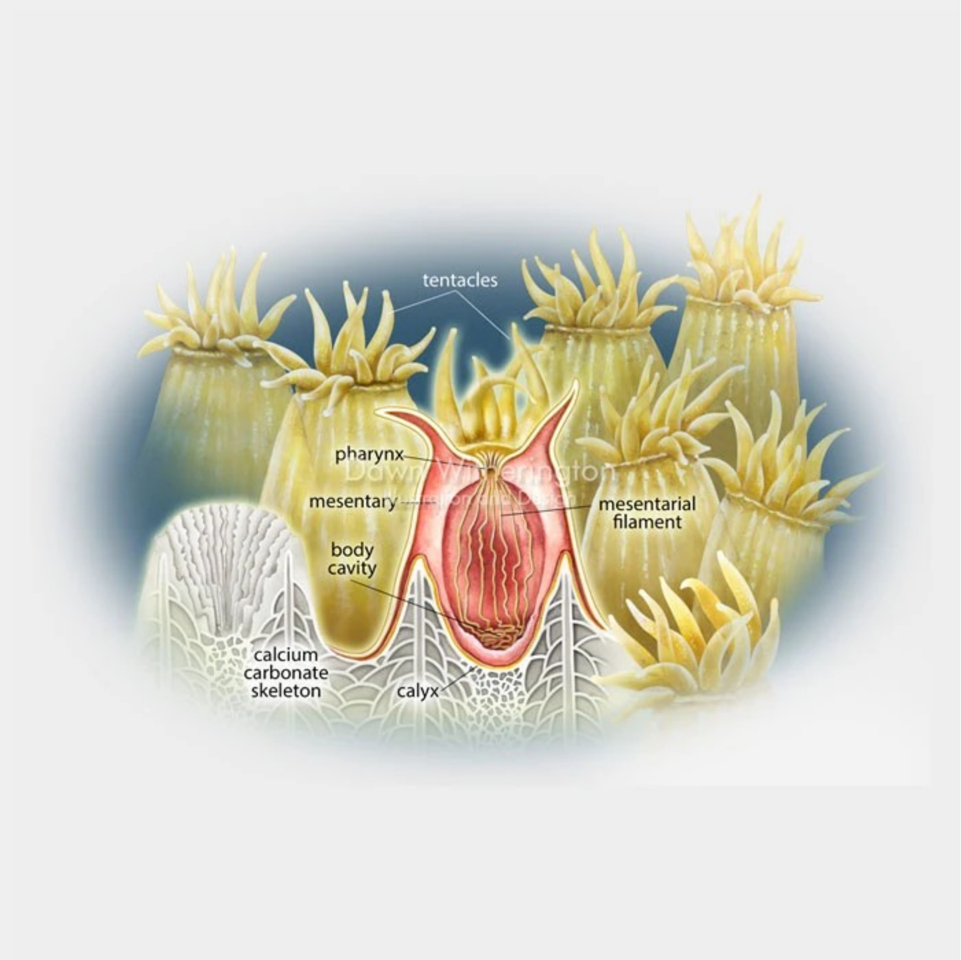
Coral Reefs in a Changing Climate

Corals in the group Scleractinia...

- ...are colonial organisms
- ...may capture food using tentacles with stinging cells similar to jellyfish
- ...often harbor symbionts for photoautotropy (photosynthesis)
- ...deposit extensive calcium carbonate skeletons



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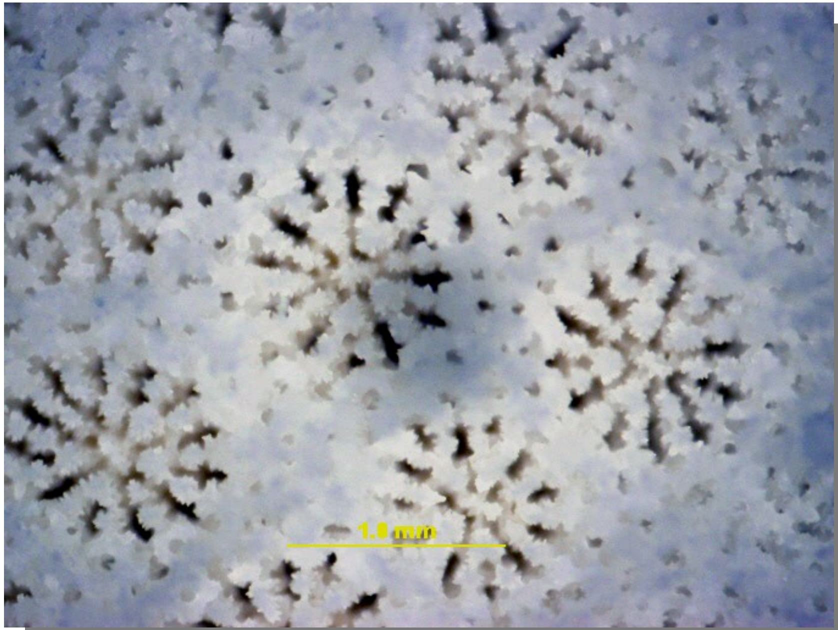
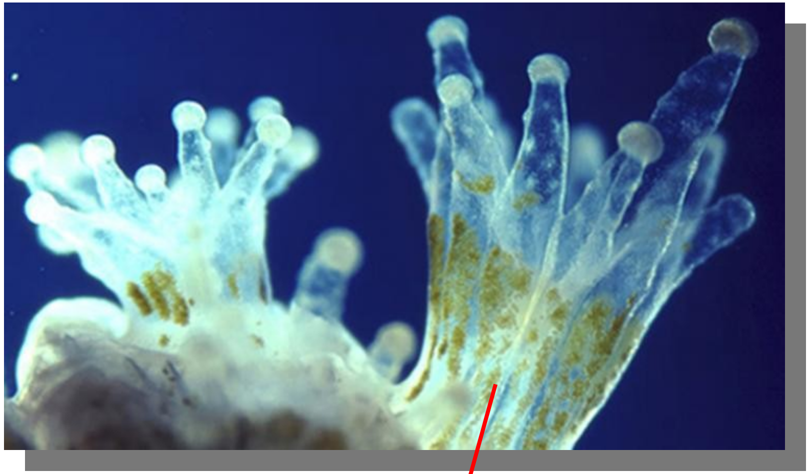
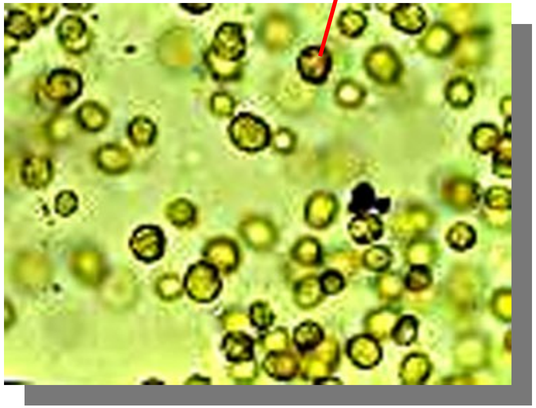


Scleractinia: endosymbiosys

Coral polyp with unicellular photosynthetic dinoflagellates = zooxanthellae

Mutualism: photosynthetically-fixed C is translocated to coral cells and stimulates calcification by utilizing metabolic waste from coral polyp. Algae get light and raw materials for photosynthesis





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- Interaction between CO_2, H_2O, and $CaCO_3$:

  $$\mathbf{CO_2 + H_2O + CaCO_3 \leftrightarrow Ca^{+2} + 2HCO_3^-}$$

- Therefore, the more dissolved CO_2 (i.e., more acidic water…), the more easily water can dissolve $CaCO_3$

A process that removes CO_2 from solution promotes $CaCO_3$ precipitation

Corals remove CO_2 to promote their growth

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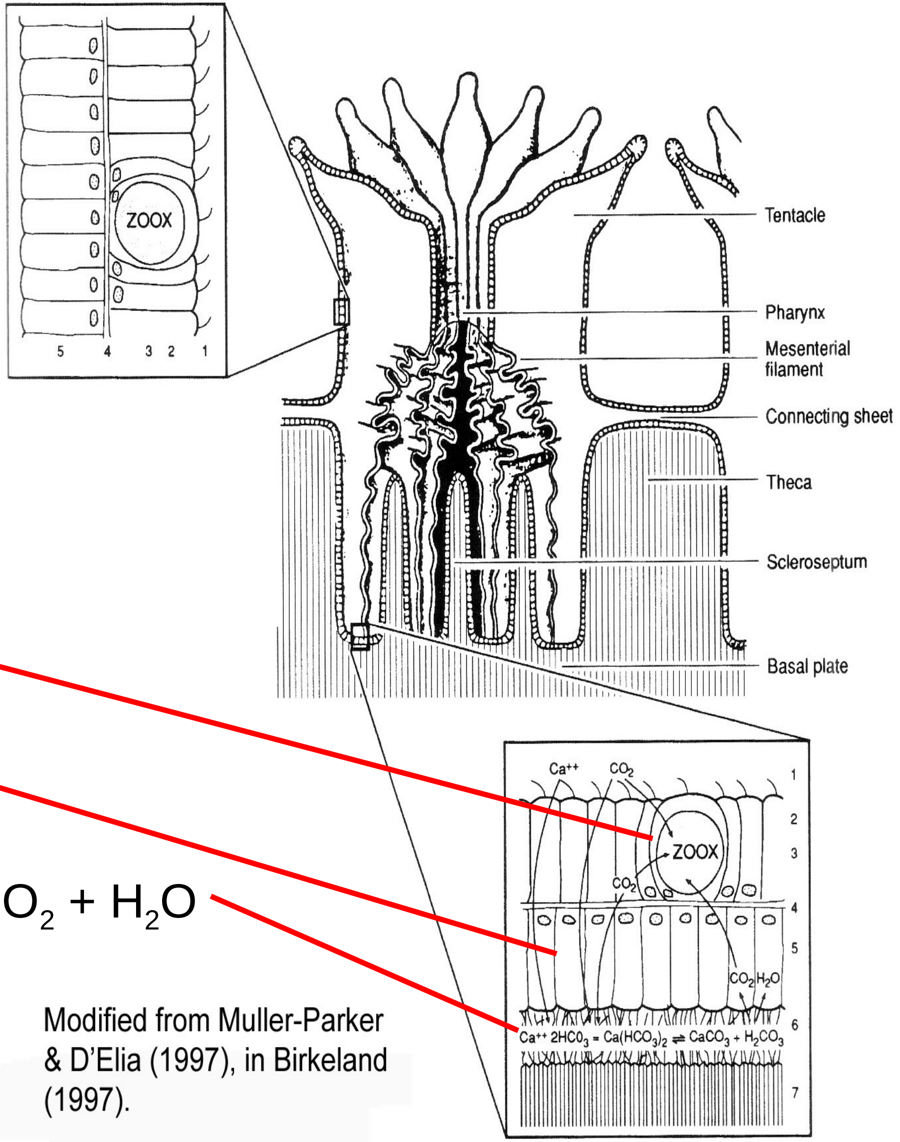

Photosynthesis: $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$

Respiration: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

Calcification: $Ca^{+2} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$

Modified from Muller-Parker & D'Elia (1997), in Birkeland (1997).

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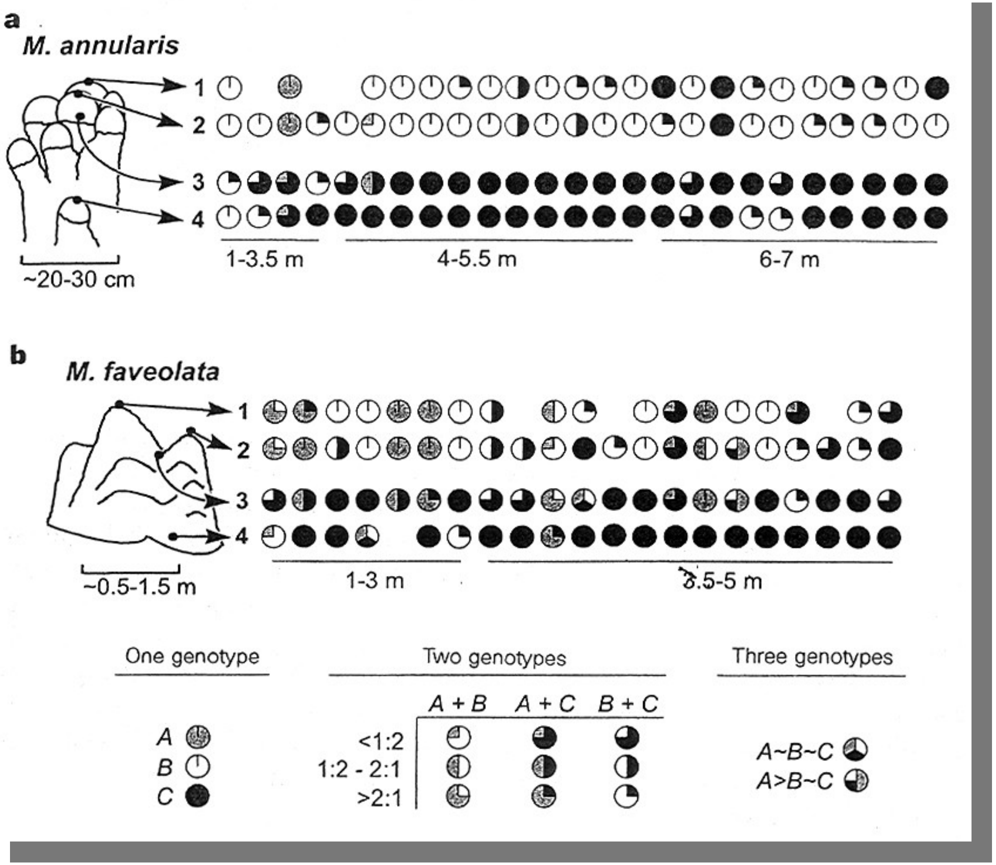
Zooxanthellae are diverse

- Differ in temperature sensitivity
- Complex (>1 species) communities increase resistance/ resilience

Rowan et al. (1997)



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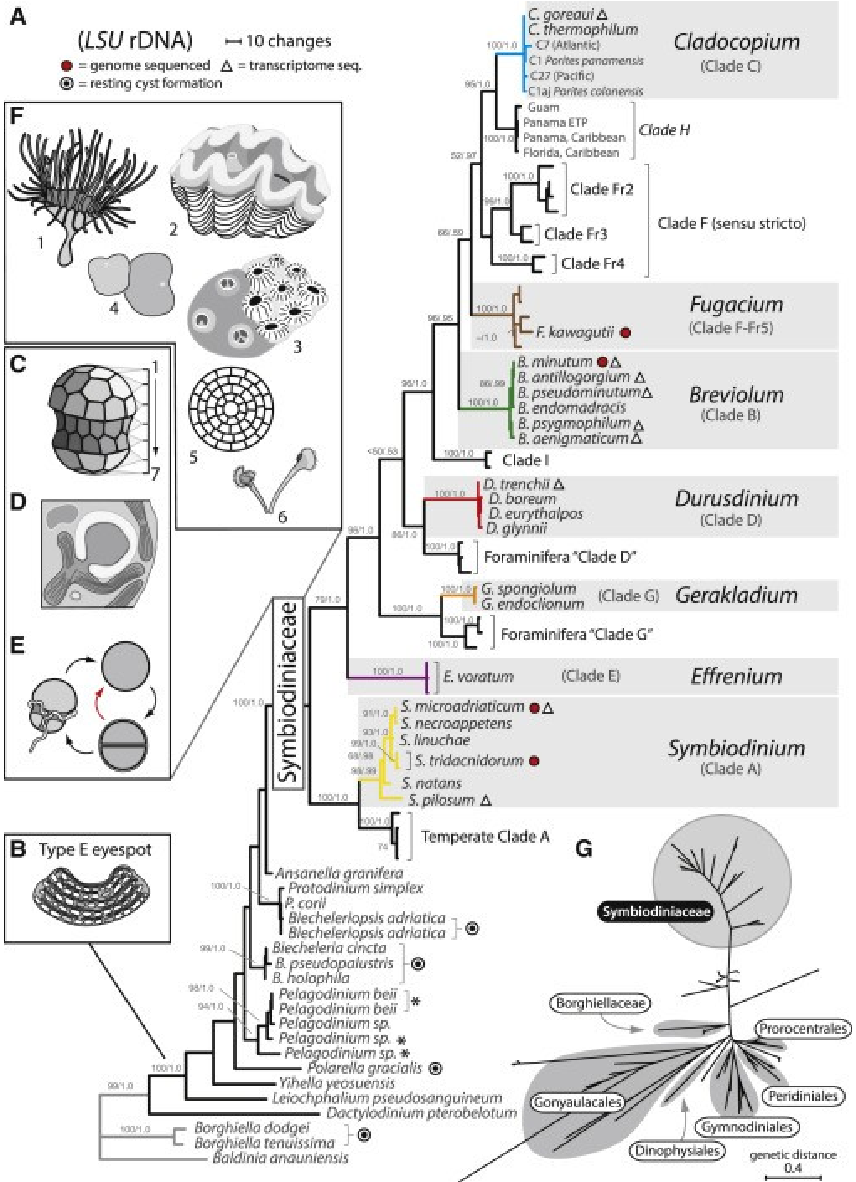
All zooxanthellae used to belong to the genus *Symbiodinium*

- Recent reclassification clarifies diversity and evolutionary relationships
- Guam's corals dominated by clade C, *Cladocopium*
- Clade D, *Durisdinium* less prevalent but this group is known for heat tolerance

LaJeunesse et al. (2018)



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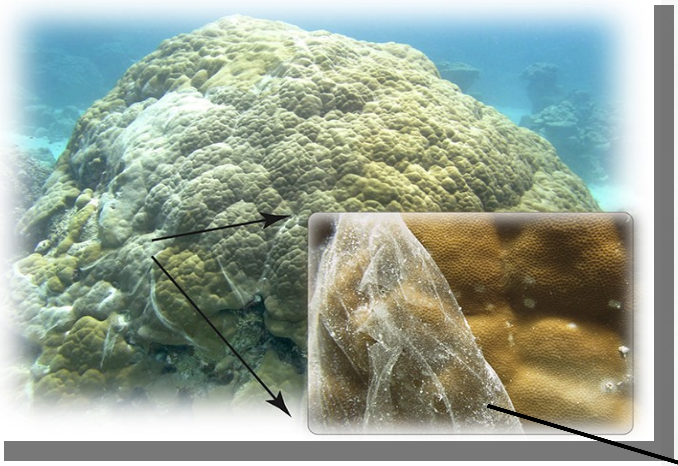

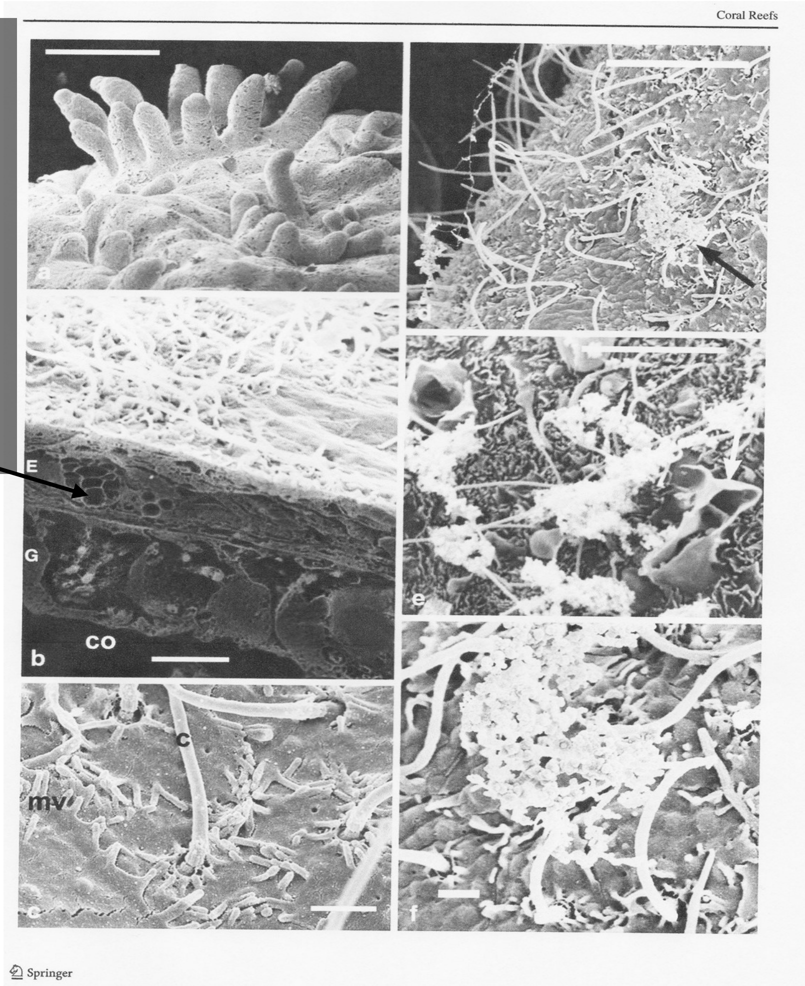

Surface mucous layer (SML)

houses persistent and transient bacterial communities.

Johnston & Rohwer (2007)

Coral Bleaching

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Sea surface temperatures are increasing

- Imposes stress on the coral-zooxanthellae relationship
- Temperature stress leads to active expulsion of zooxanthellae by coral host
- Possible reason: reactive oxygen species as byproduct of photosynthesis

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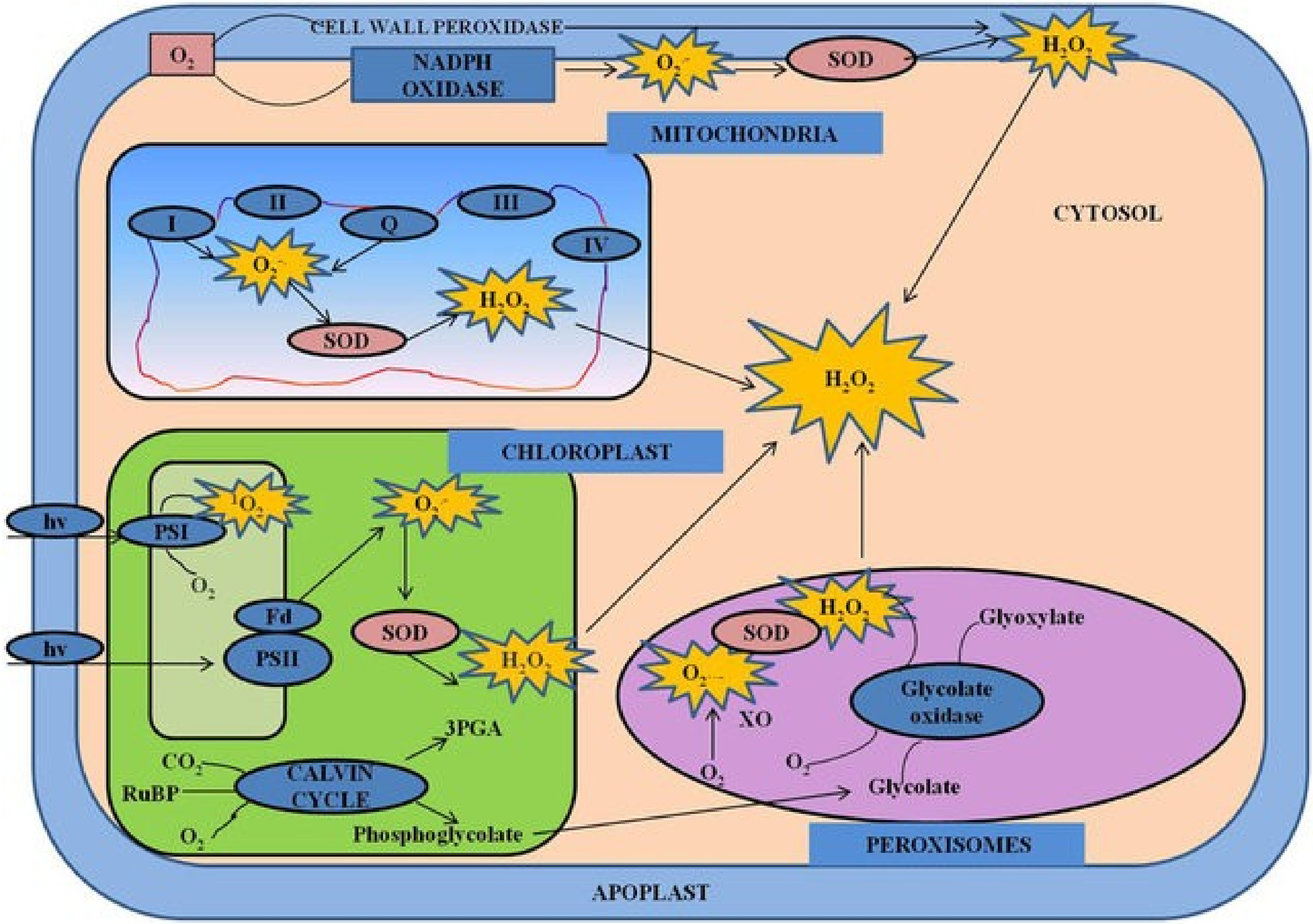

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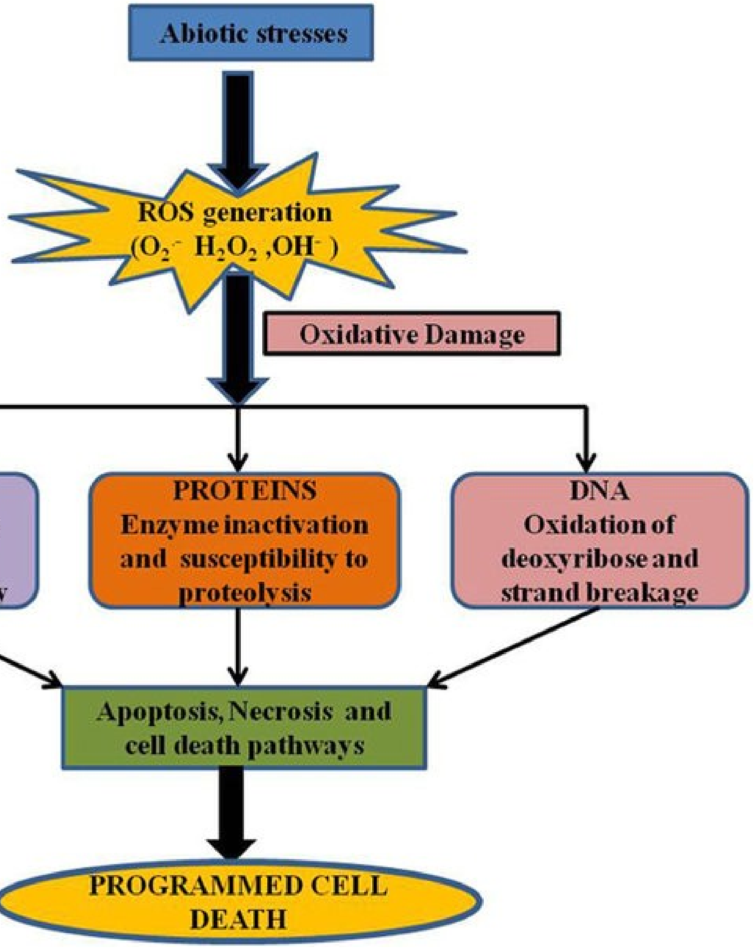

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Coral decline reduces

- biodiversity (eg, fish)
- coastal protection
- overall economic value of reefs (eg, loss in tourism revenue)

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Coral bleaching is increasing in frequency and severity

- Guam already lost about 1/3 of its coral cover starting in 2014
- Increased bleaching frequency limits recover time and reduces resilience

Framework for Coral Resilience

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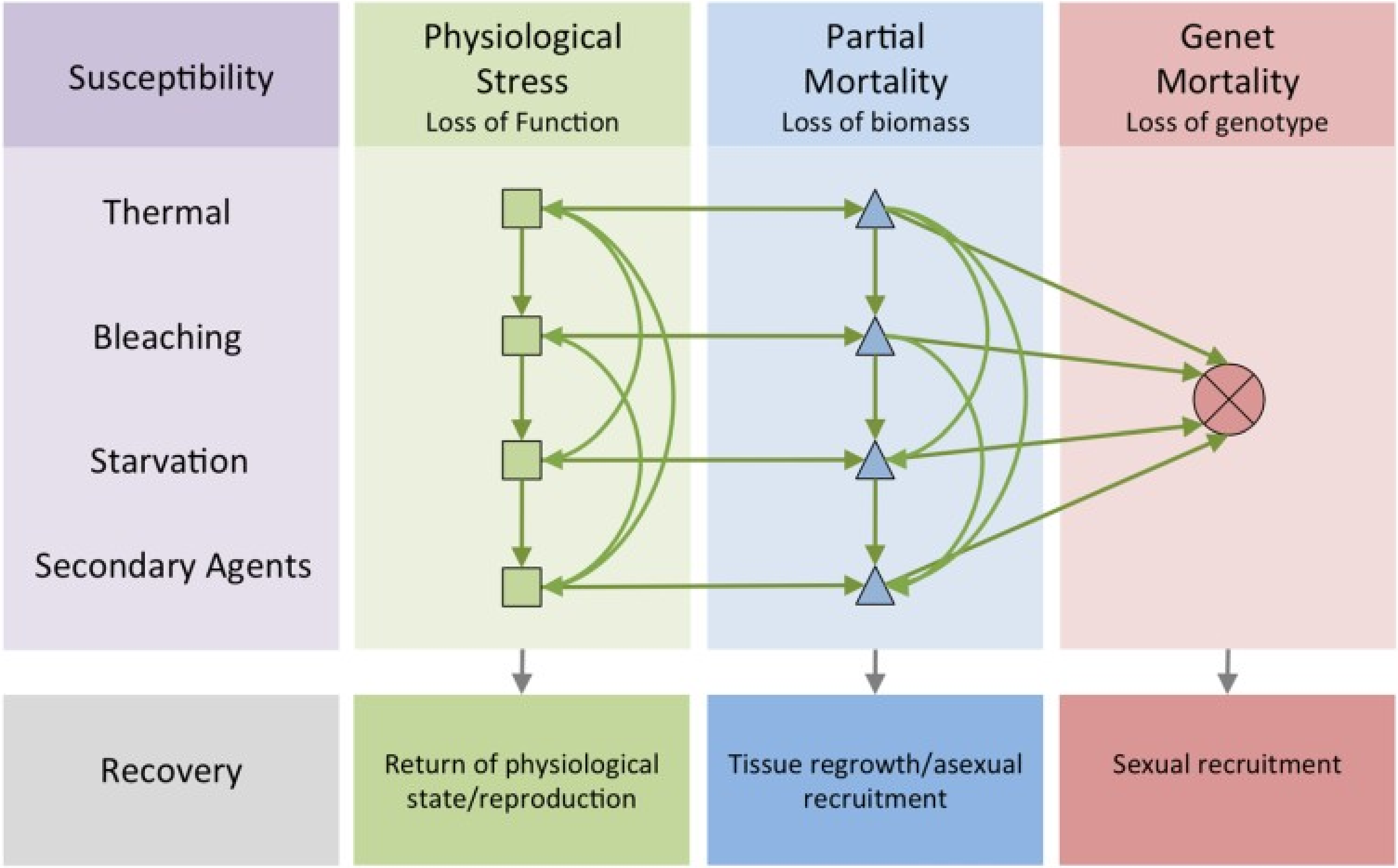
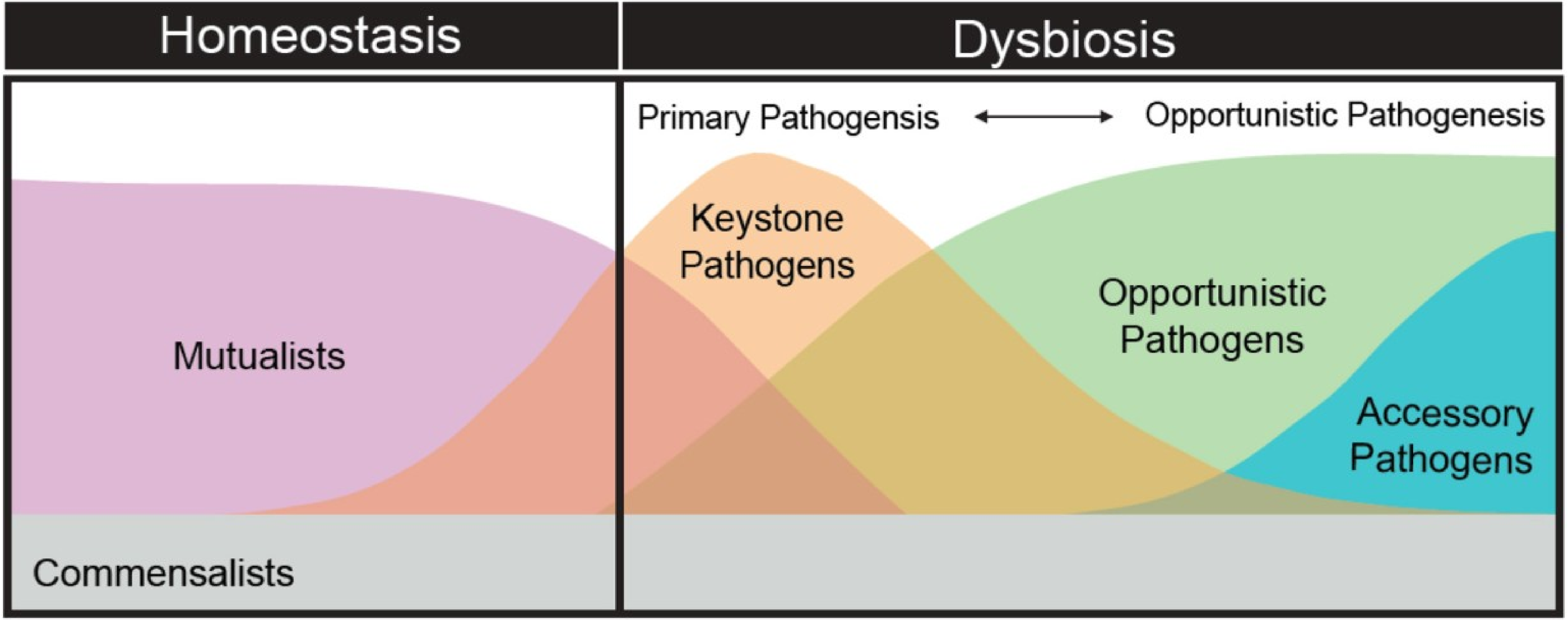
Conceptual model of bleaching responses
(Smith et al. 2013)



Three (3) types of coral (Smith et al. 2013)

- ***Type I:*** large initial response during bleaching that included high bleaching prevalence, high recent mortality, and a large decline in coral cover
- ***Type II:*** high to moderate initial response of bleaching prevalence, followed by delayed recovery of normal coloration, high disease prevalence, high recent mortality, and a large decline in coral cover, and stable or increasing colony abundance
- ***Type III:*** moderate initial response of bleaching prevalence, low to no disease increase after bleaching, low to no increase in recent mortality, low to no decline in coral cover, and stable or increasing colony abundance

Disease progression from a microbiome perspective: homestasis to dybiosis
(Vega-Thurber et al., 2020)



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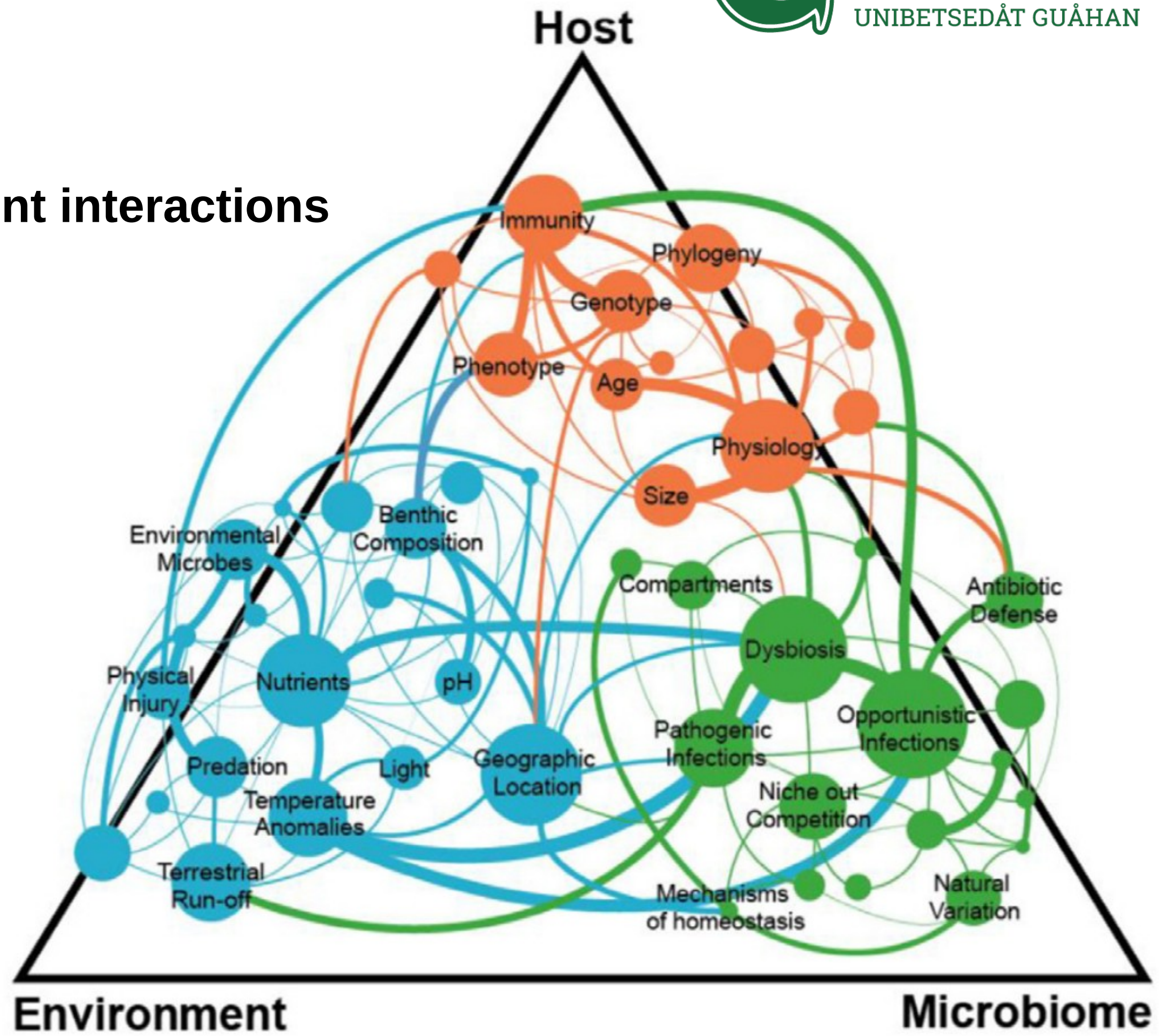
Coral Host – Microbiome – Environment interactions
(Vega-Thurber et al., 2020)



Experimental Design

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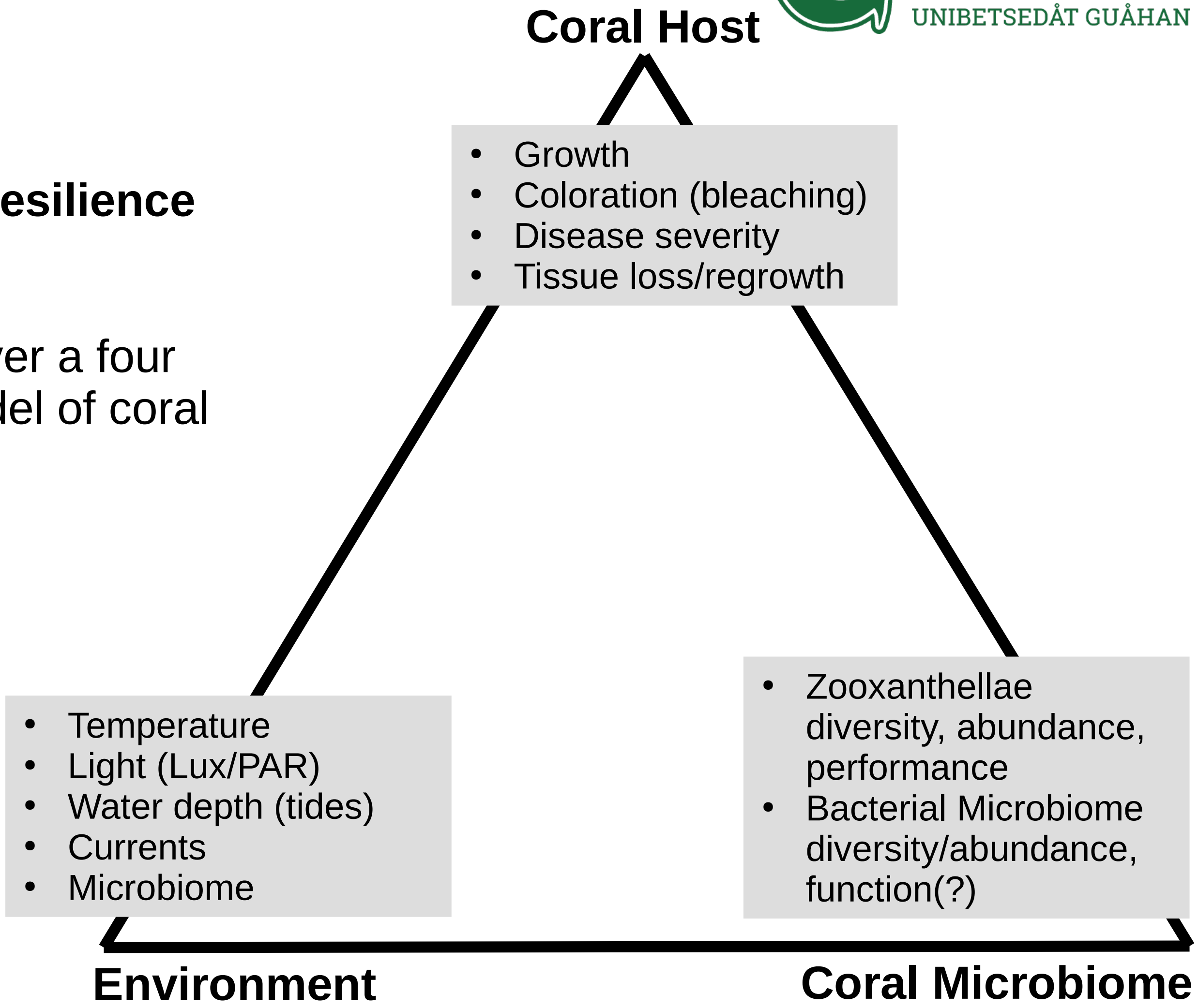
Modified concept for Guam coral resilience research

Data in gray boxes to be collected over a four (4)-year period as foundation for model of coral resilience dynamics



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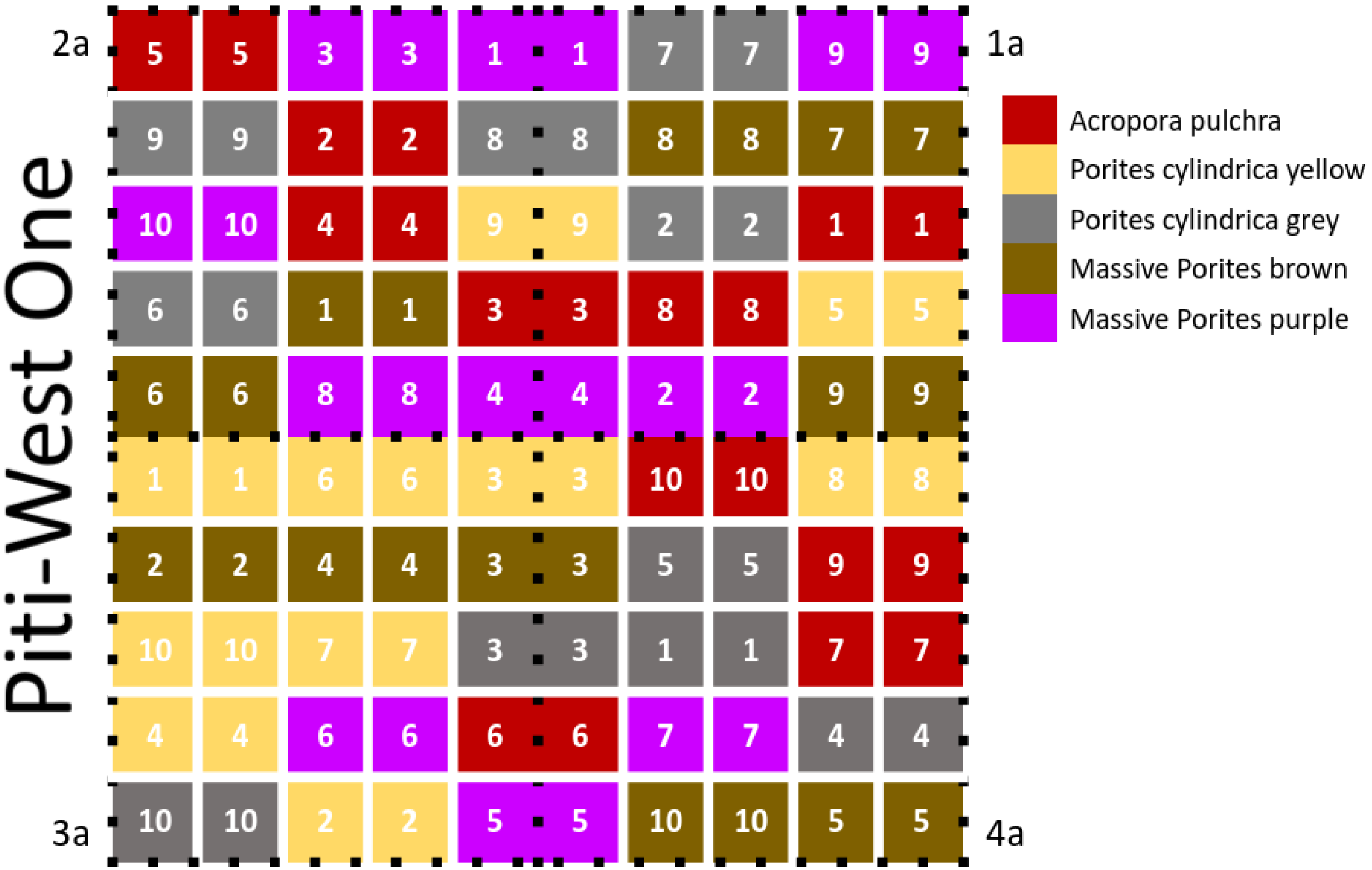
Common Garden Design

Three (3) coral types will be grown in a common environment and their health monitored



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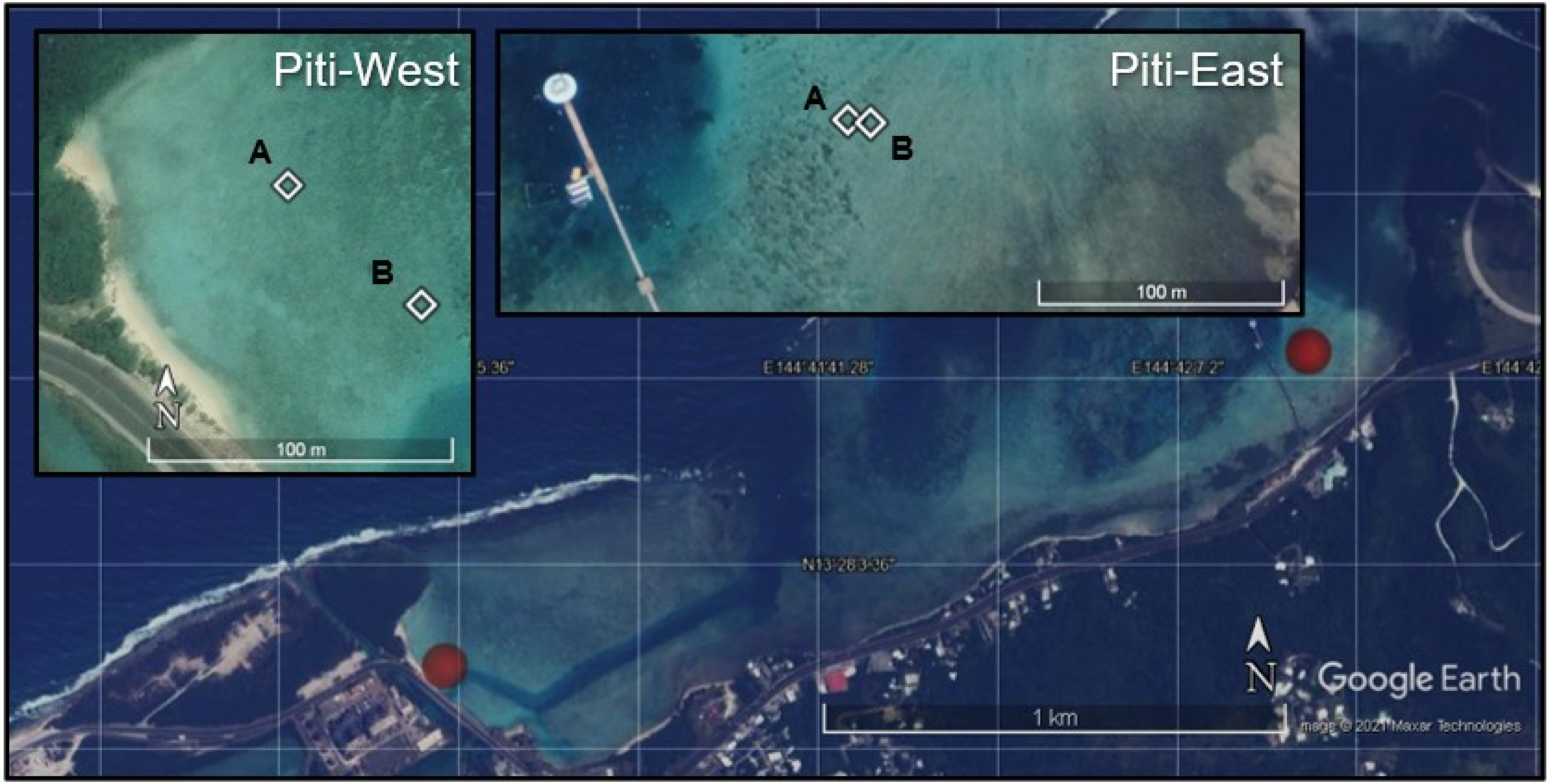
Common Garden Design



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Common Garden Establishment

Donor corals were collected in Luminao and outplanted in late May/ early June 2021

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Common Garden Data Collection

- ***Growth rates*** (infrequent using volume; continuous data)
- ***Bleaching severity*** (monthly or biweekly; categorical and continuous data)
- ***Disease severity*** (monthly or biweekly; categorical data)
- ***Tissue loss/regrowth*** (monthly or biweekly; categorical data)
- ***Microbiome diversity/ abundance*** (quarterly; continuous data)
- ***Environmental data*** (high frequency loggers; continuous)

Site:			**Date:**
Plot:			**Recorder:**
% PM bin: 5 = dead; 4 = 75-99%; 3 = 50-74%; 2 = 25-49%; 1 = 1-24%; 0 = 100% live			
BleachSev: PPL=part pale; PL=whole pale; PBL=part bleach; BL=whole bleach; BLM=bleach mort			
Impacts: WS; BBD; BrB; SEB; GA; CMD; PR; PRD; DMS; DRP; COTS; TP; ALOG; CYA; PR; PD; LTX; PM			
Severity Bin: 0 = healthy; 1=1-10%; 2=11-25%; 3=26-50%; 4=51-75%; 5=76-99%; 6=dead			
Sp Code	**Bleach Bin**	**Impact_Severity Bin**	**Notes**

Coral Reefs in a Changing Climate

What are the traits of corals that will remain resilient in the face of climate change?

Which coral species are likely to be resilient to climate change?

How will Guam's reef ecosystems change over the coming decades?

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