

Ocean Acidification and Ocean Biology:



Jim Barry, Monterey Bay Aquarium Research Institute

Ocean Acidification Effects on the West Coast Shellfish Industry, SCCWRPA, 2010



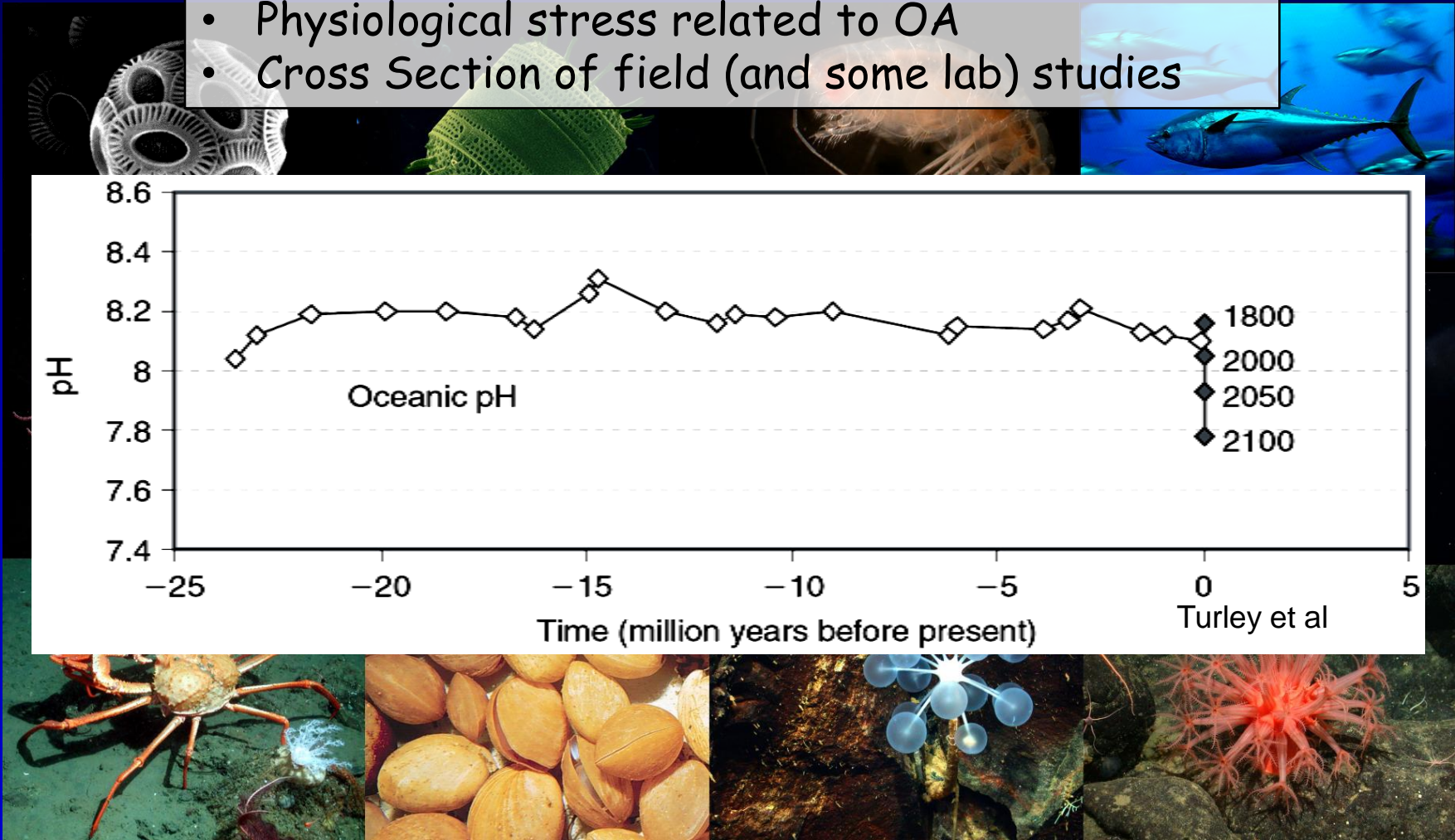
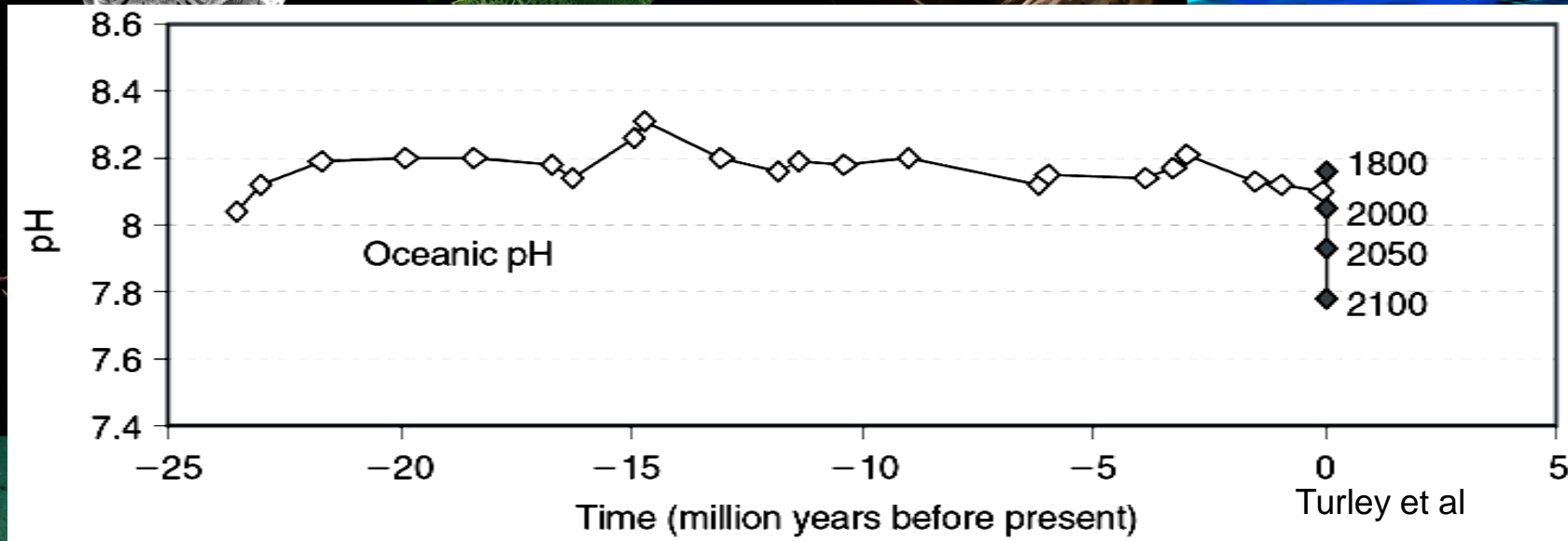
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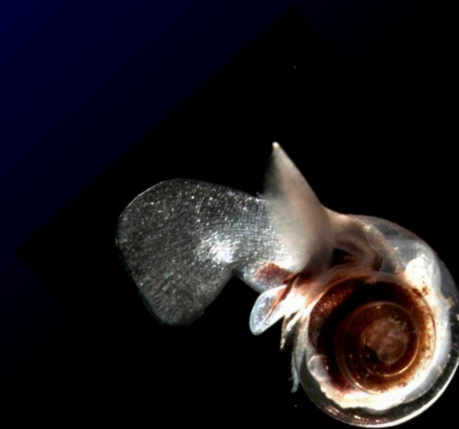
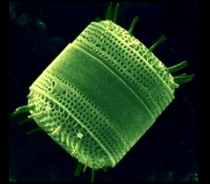
Ocean Acidification Effects on the West Coast Shellfish Industry, SCCWRPA, 2010

- Physiological stress related to OA
- Cross Section of field (and some lab) studies



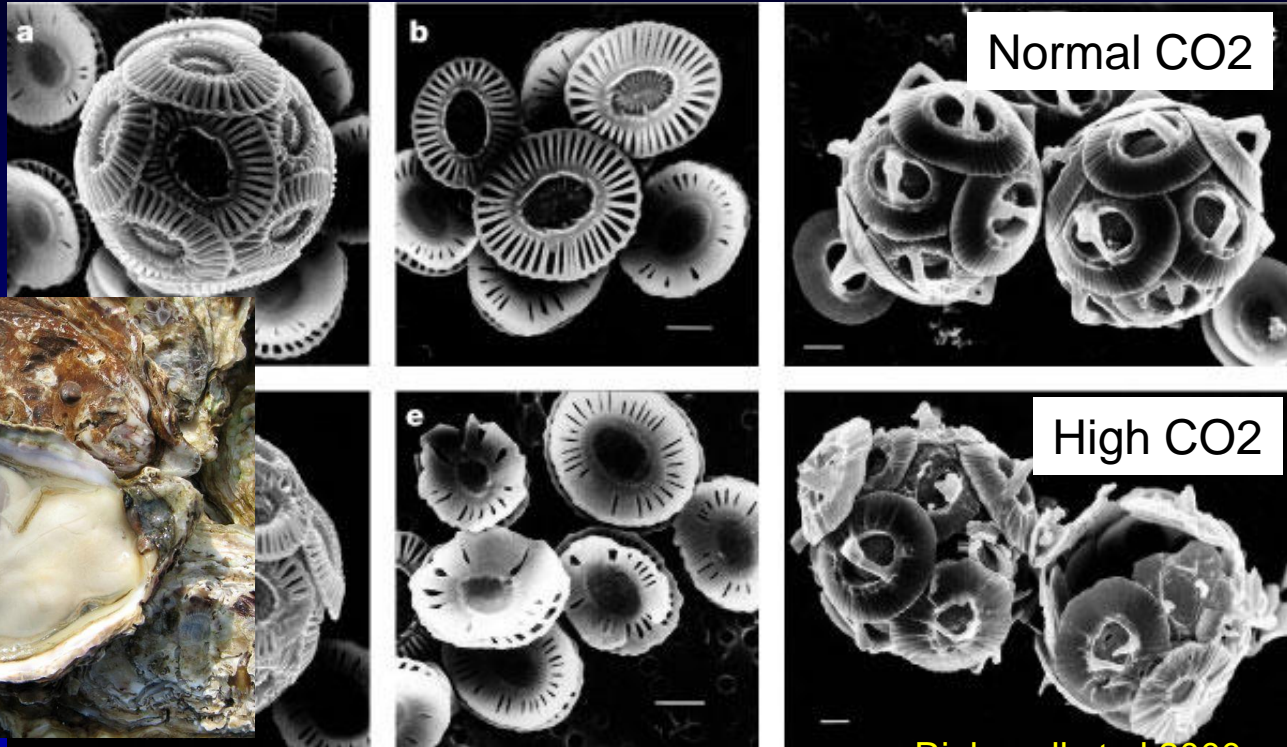
Physiological Effects on Organisms

- *Calcification*
- *Respiratory Stress*
- *Acid-Base Balance / Enzyme Function*
- *Metabolic Depression*



Reduced Calcification

Pteropod

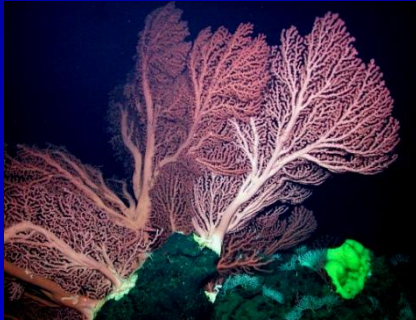


Riebesell et al 2000

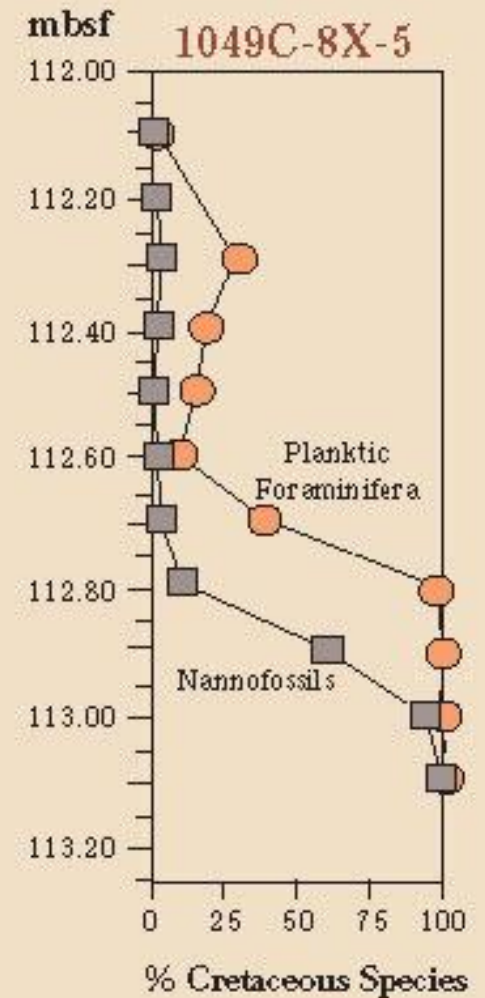
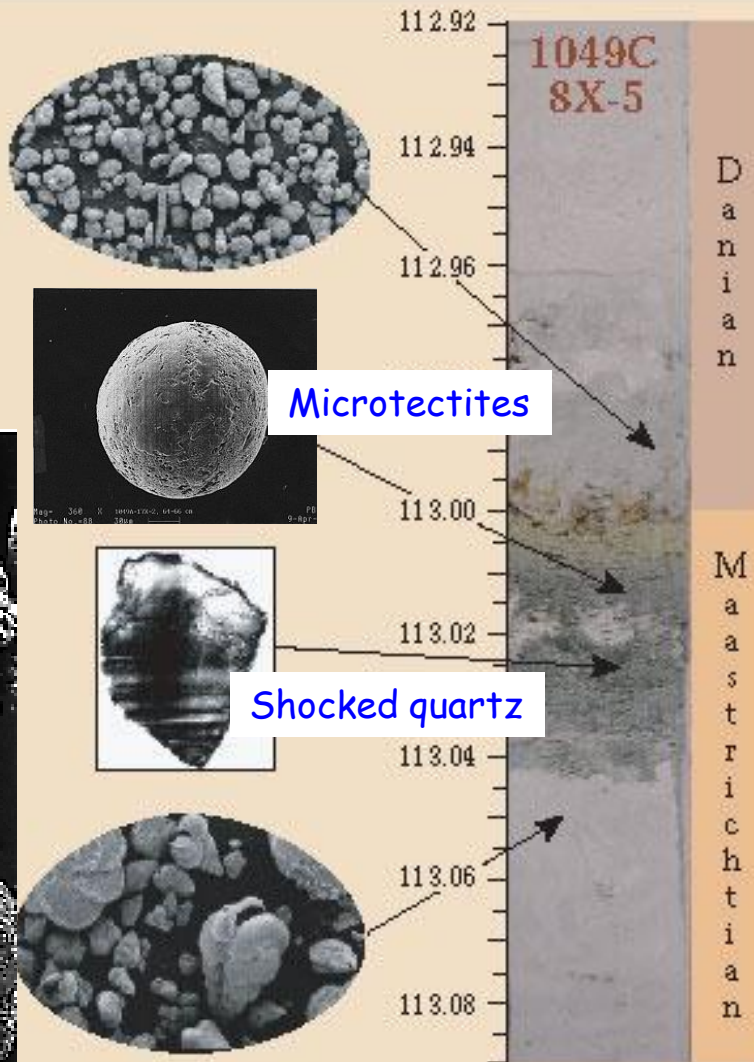
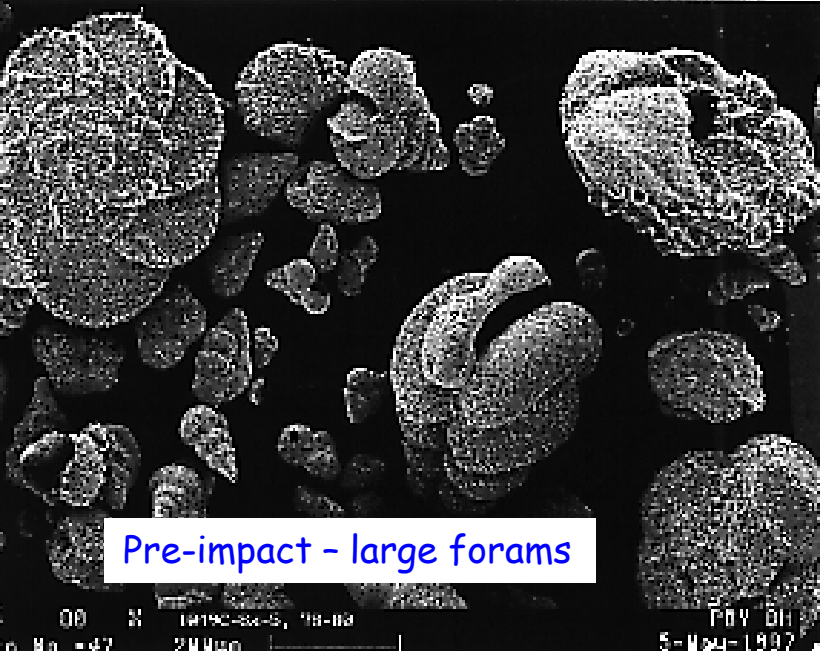
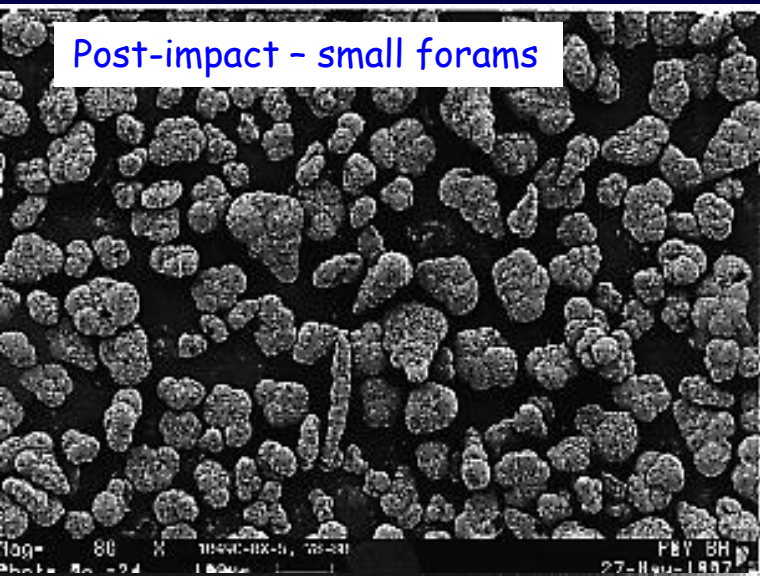
OA may affect calcification in many taxa

- Clams, snails, sea stars, urchins, crabs, shrimps, corals, ...
- Calcareous echinoderms largely absent from naturally high CO₂ sites

Corals,
Echinoderms

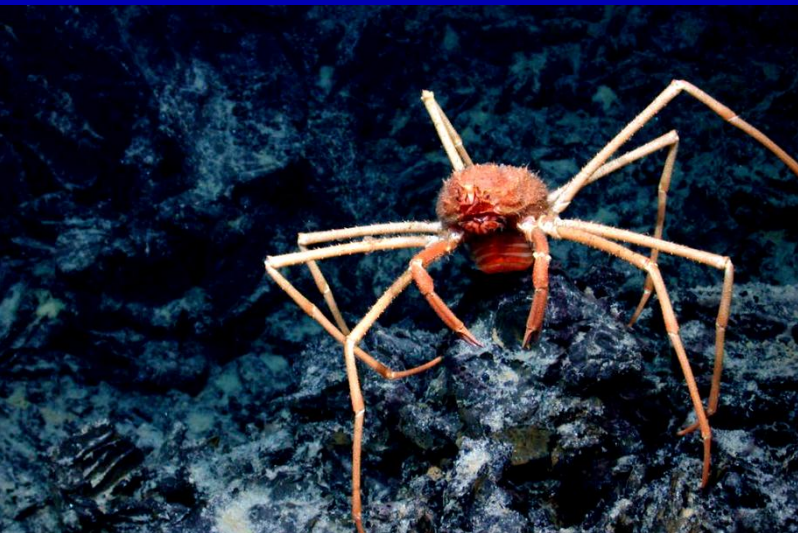
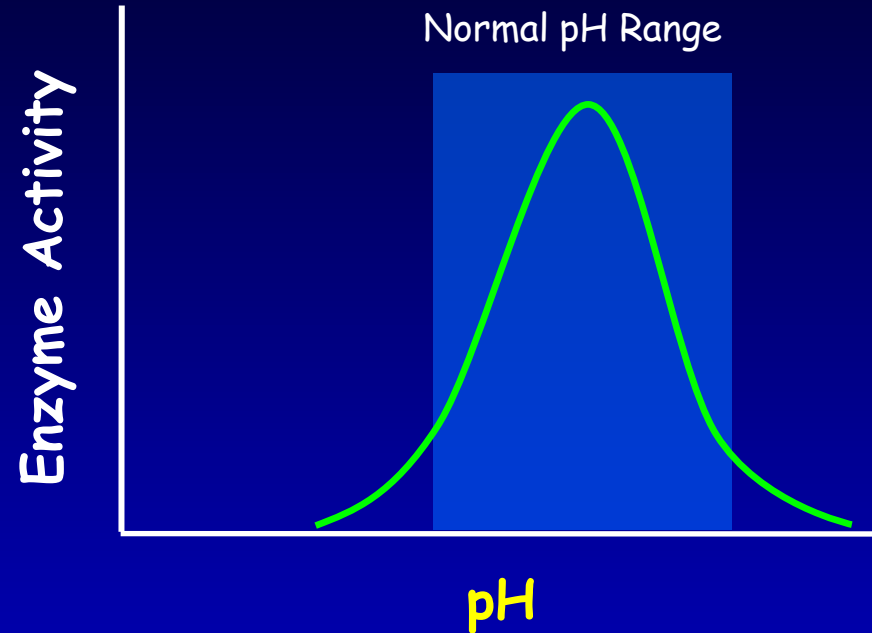


Foraminifera assemblage during the End-Cretaceous extinctions



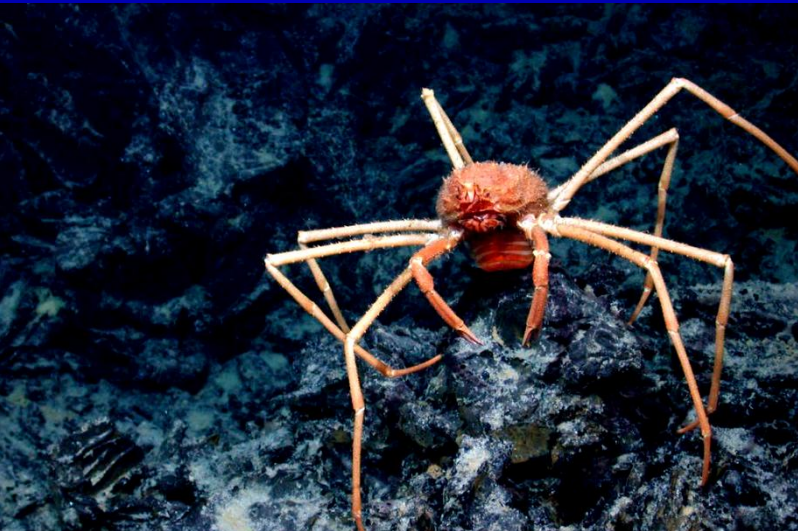
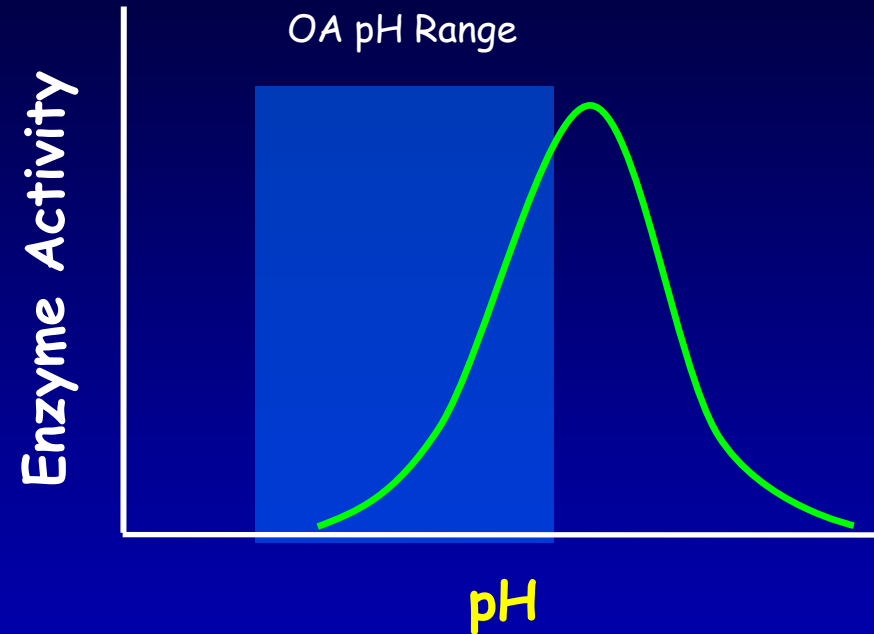
Acidosis and Enzyme Activity

- Enzymes optimized for pH
- Poor ion control can lead to acidosis
- Consequences of $>CO_2$

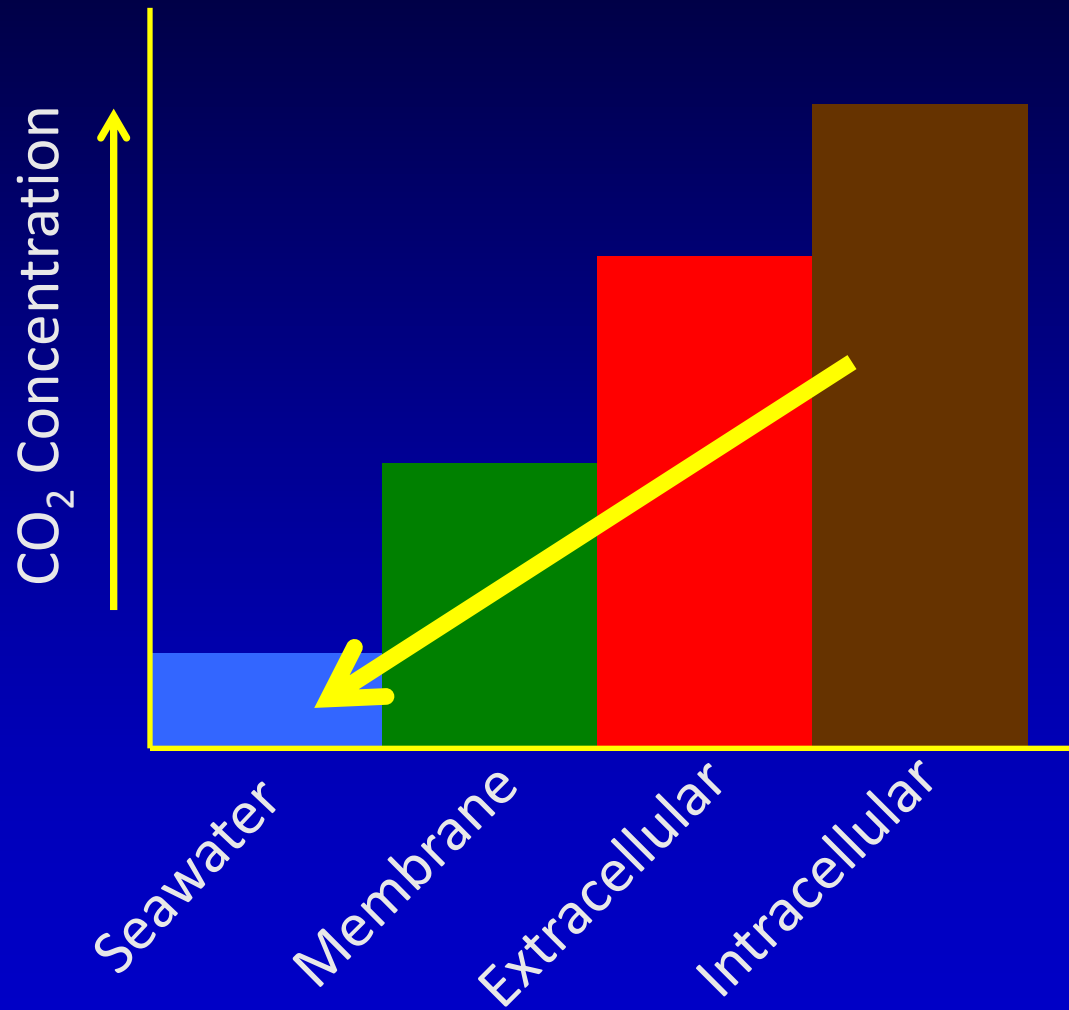


Acidosis and Enzyme Activity

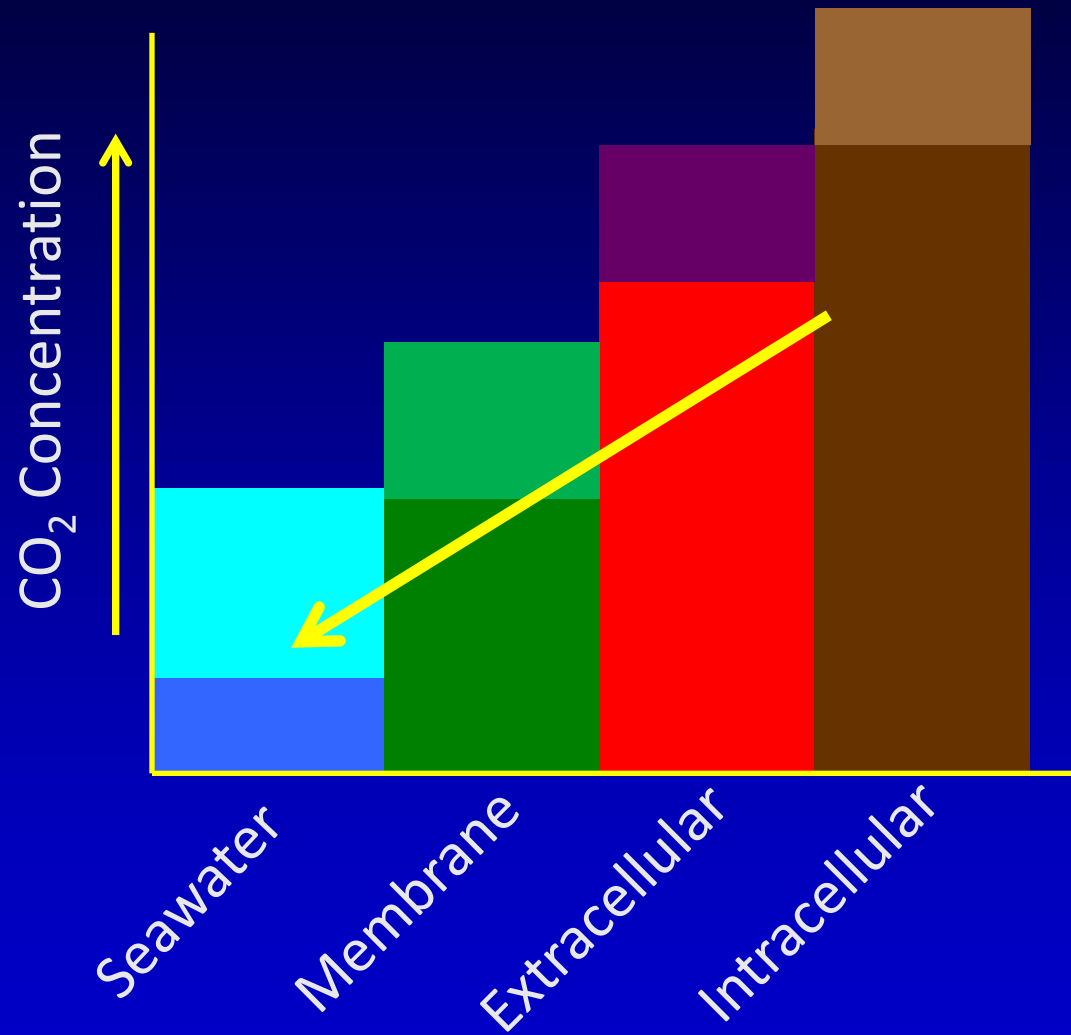
- Enzymes optimized for pH
- Poor ion control can lead to acidosis
- Consequences of $>CO_2$
 - Reduced enzyme activity under $>CO_2$
 - Reduced or inefficient cellular function (e.g. protein synthesis)



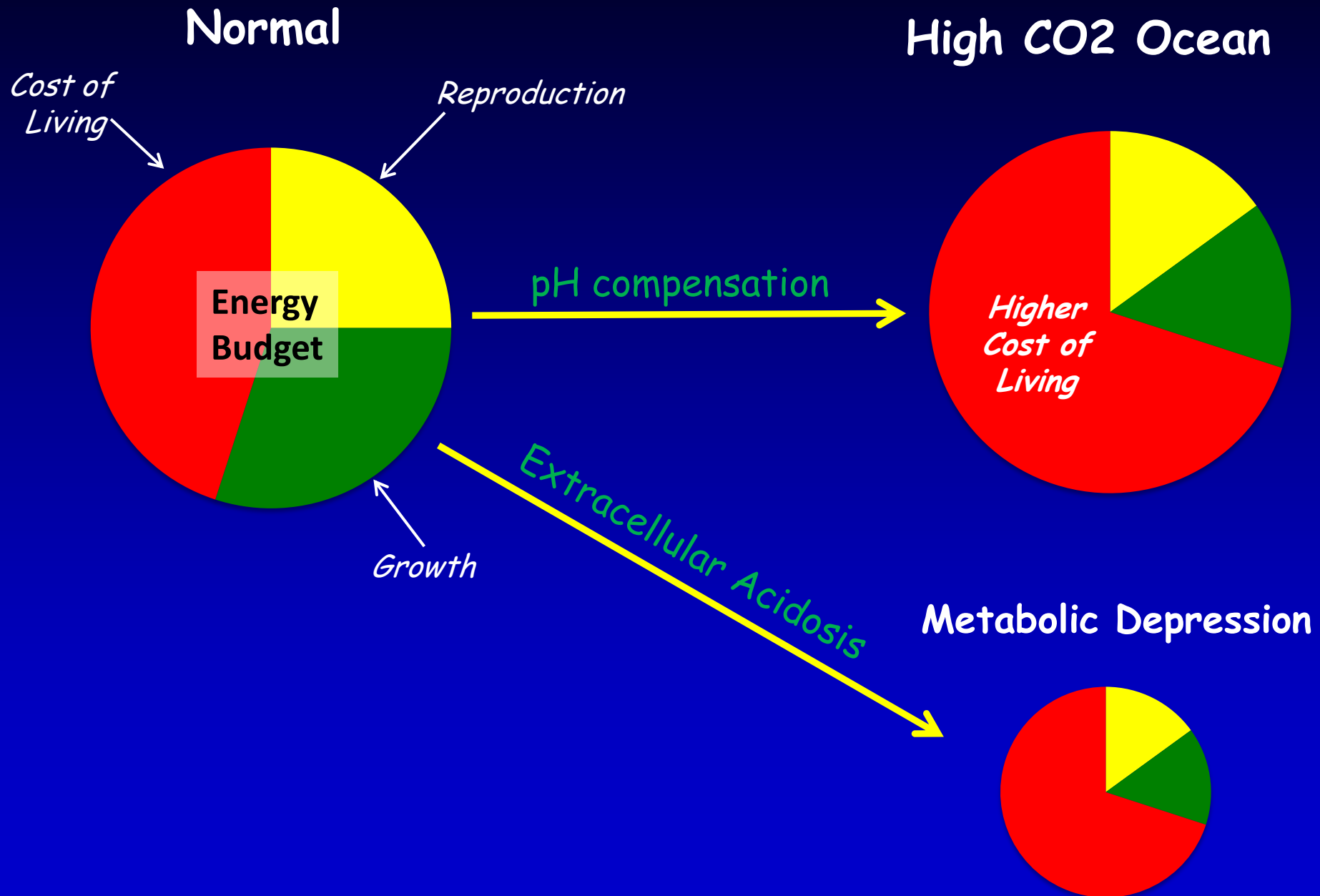
CO₂ Excretion is Diffusive



CO₂ Excretion is Diffusive

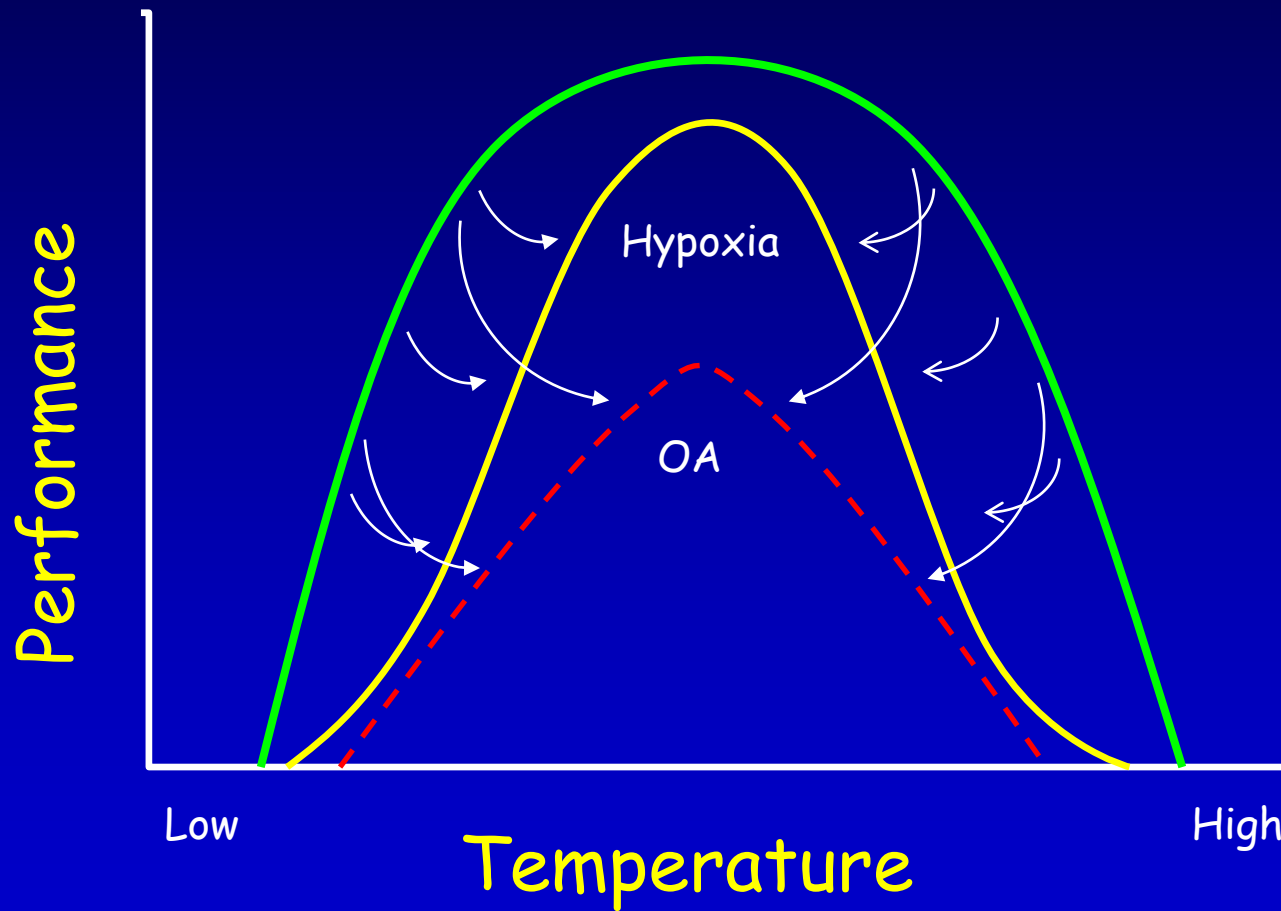


Metabolic Depression Compromises Performance



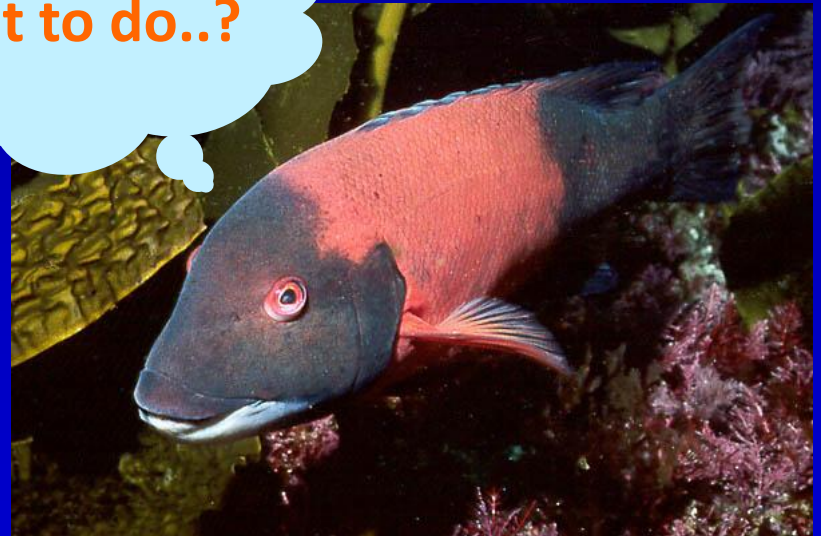
Metabolic Performance Windows

Reduction in performance under multiple stressors



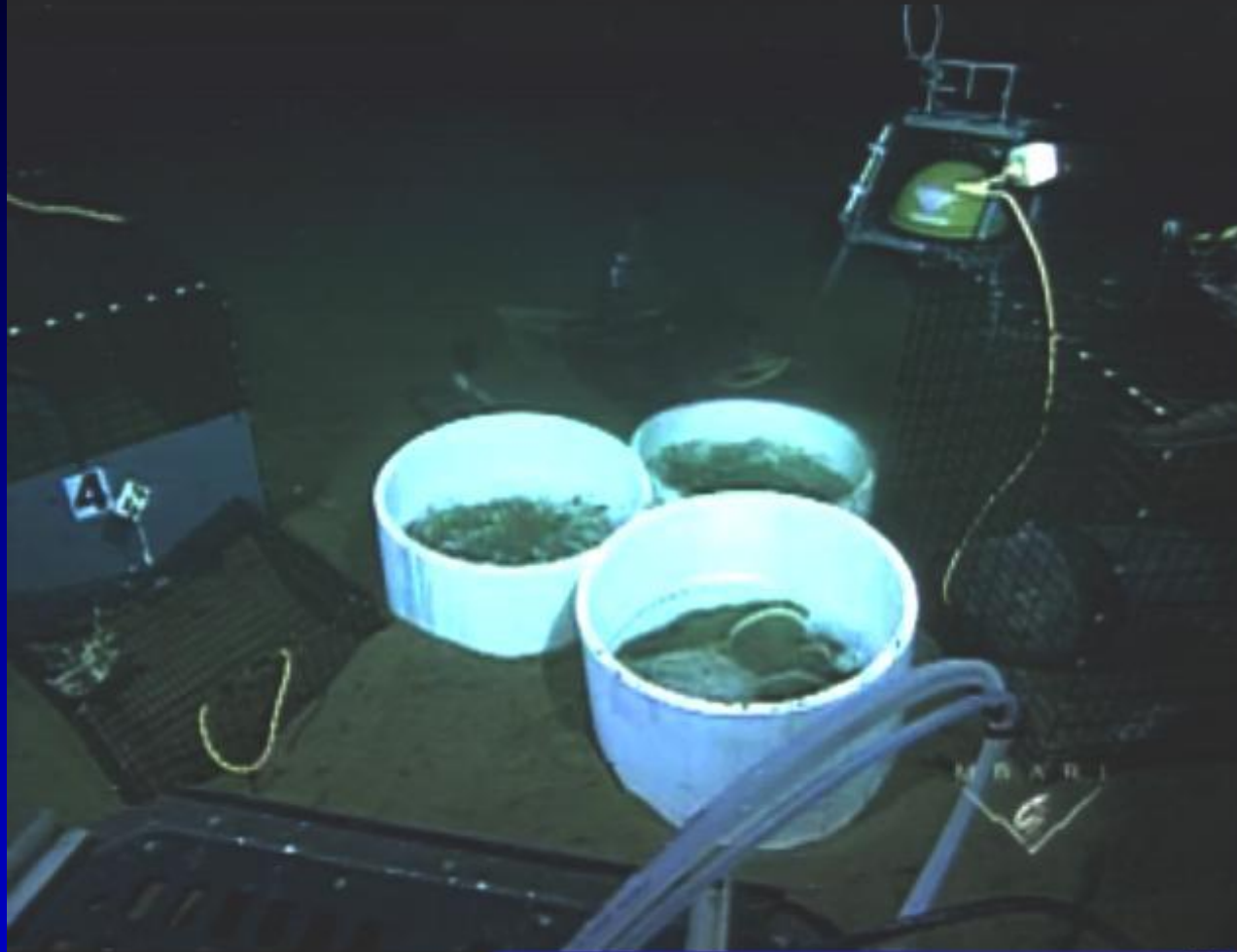
What are the options for organisms faced with environmental stress (e.g. OA)?

- Migration
- Acclimation (tolerance)
- Adaptation (linked to evolutionary history, generation time)
- Extinction



Deep-Sea CO₂ - Release Experiments

- 3600 m (~12,000 ft.)
- Effects of CO₂-rich seawater on animals
- Initial studies of effect of deep-sea CO₂ storage



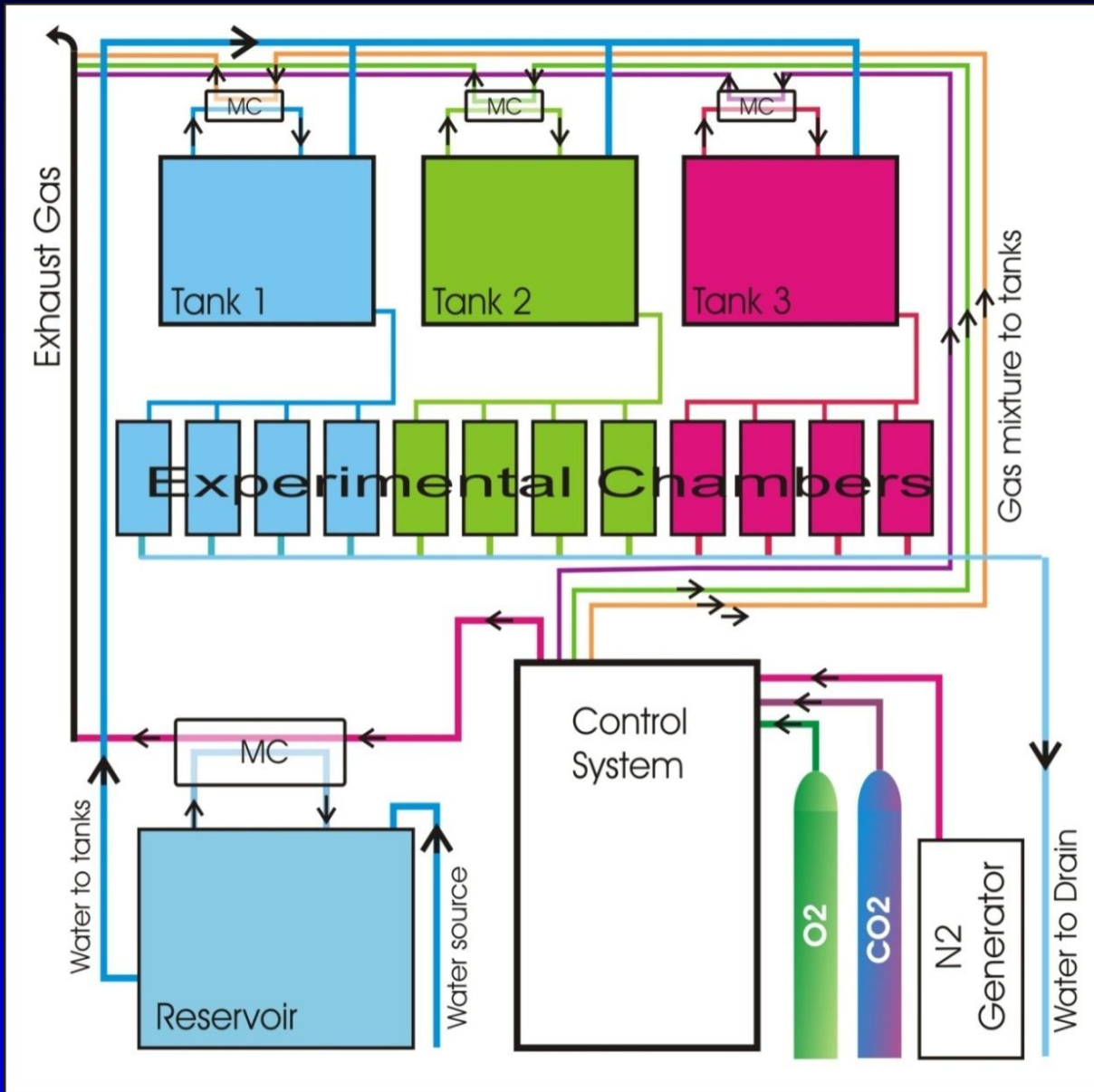
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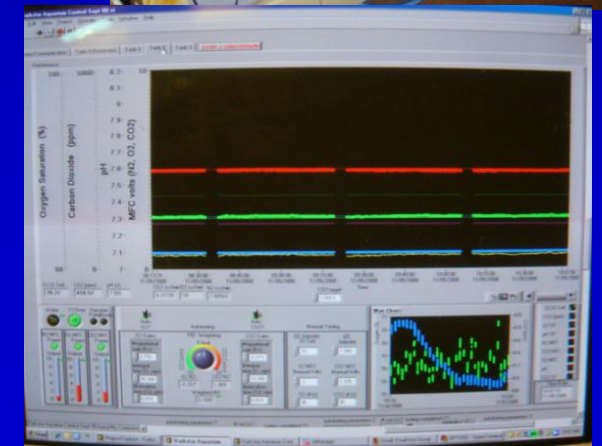
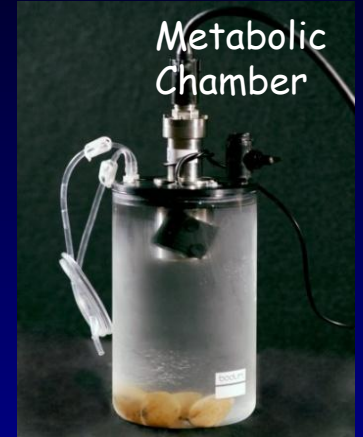
Controlled-Gas Aquarium System for CO₂ Studies



Membrane Contactor



Metabolic Chamber



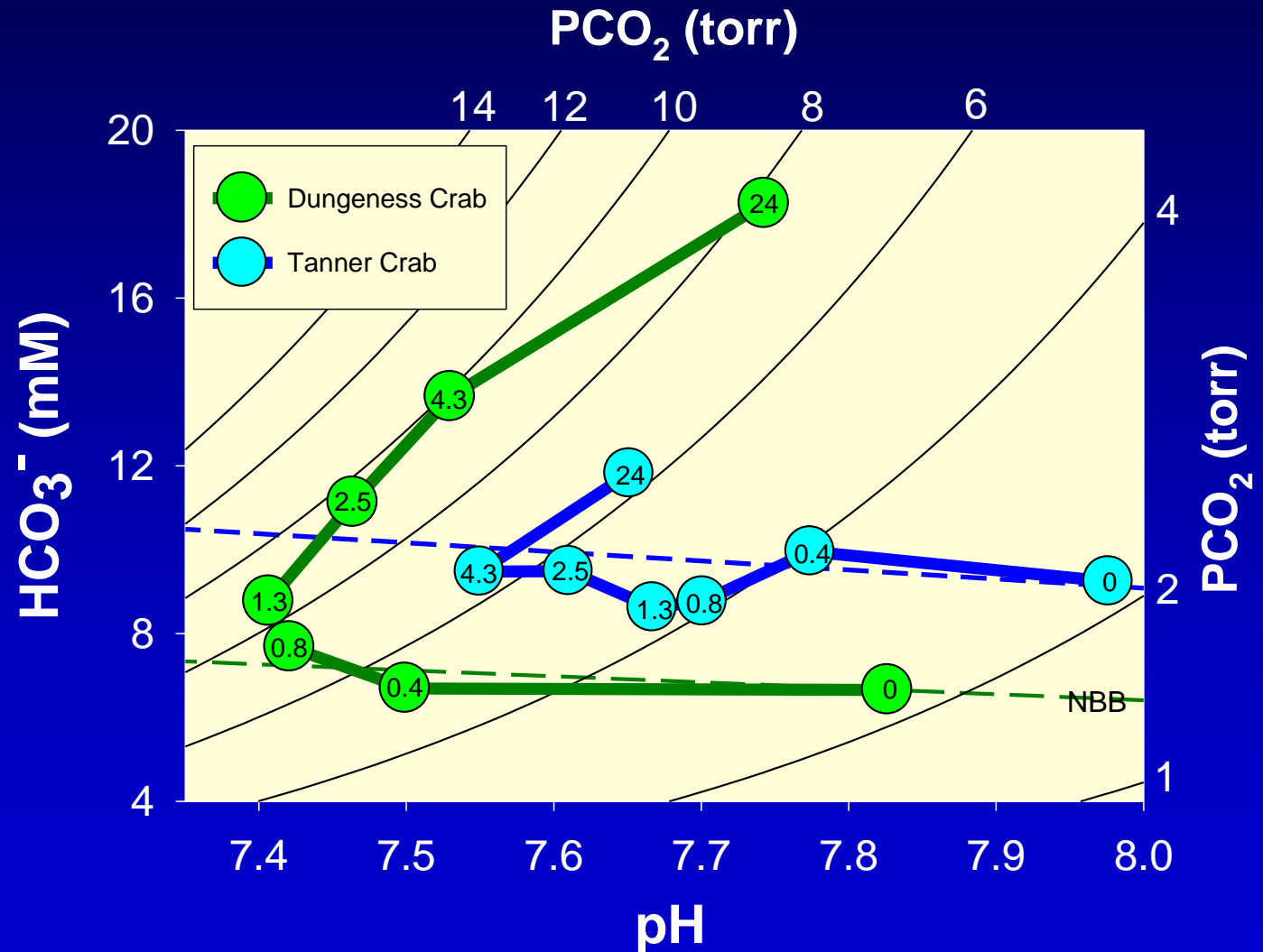
CO₂ tolerance by Decapod Crabs

- How tolerant are shallow and deep-living species of CO₂ stress?
- Does ambient oxygen availability influence CO₂ tolerance?

Tanner Crab (deep-sea)



Dungeness Crab (shallow water)



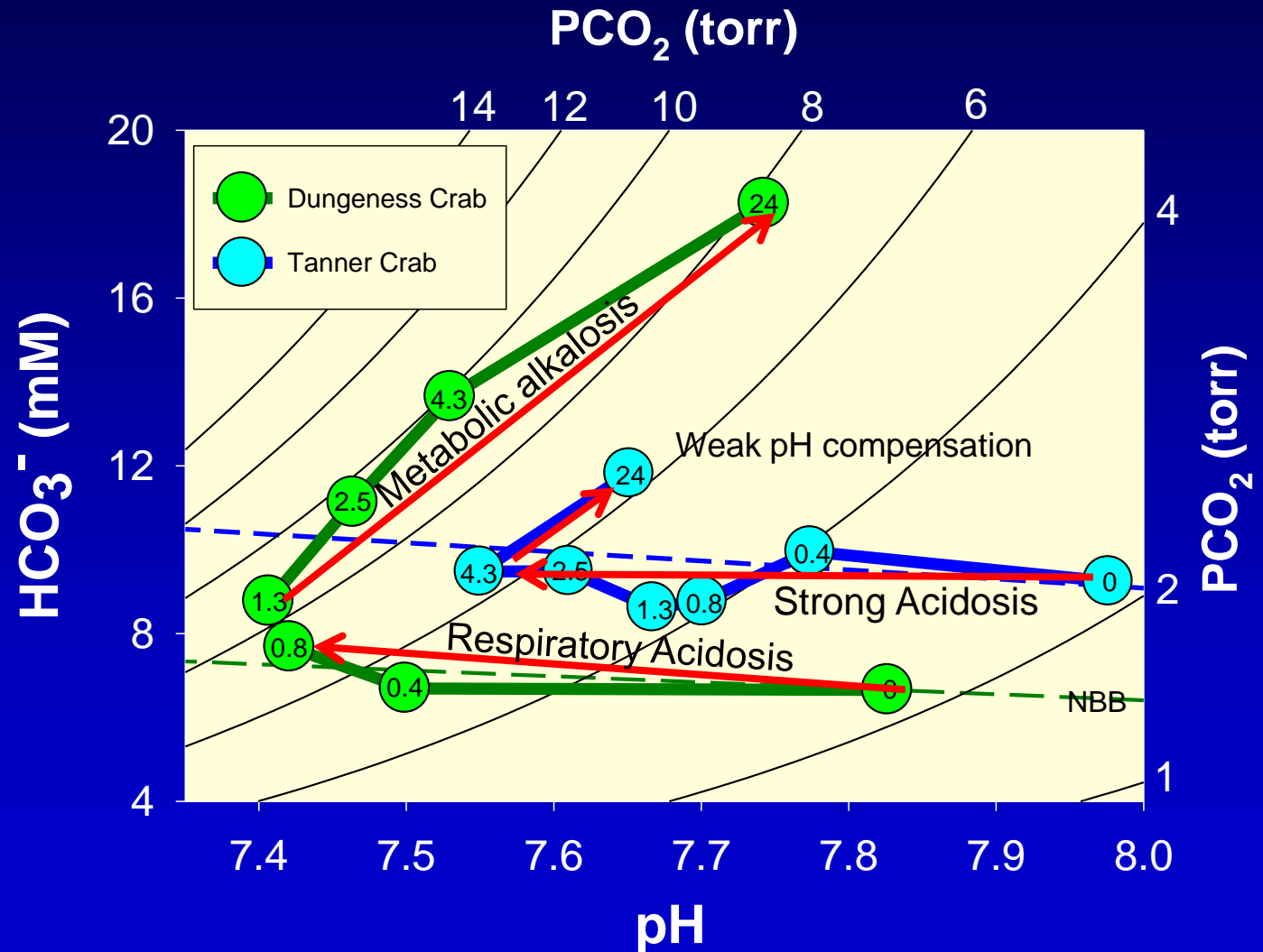
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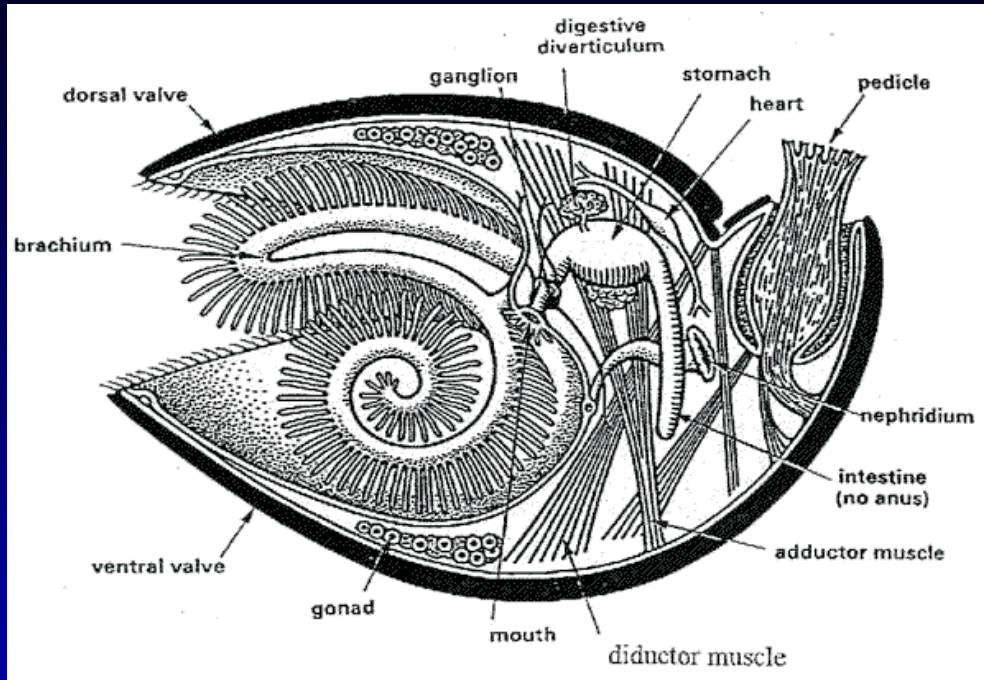
Tanner Crab (deep-sea)



Dungeness Crab (shallow water)



Laqueus californianus



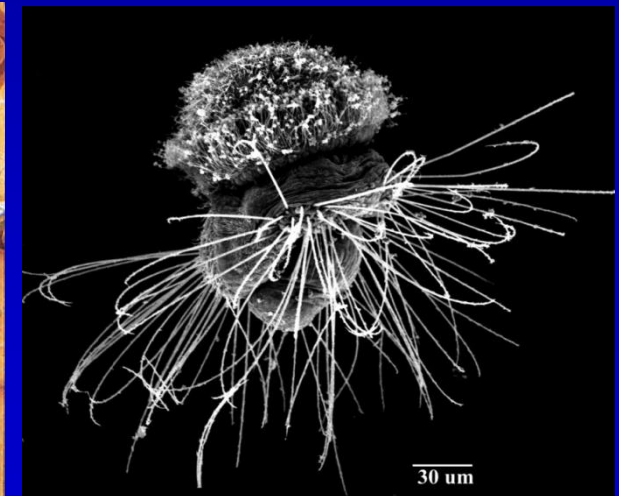
Morphology



Continental Shelf aggregation

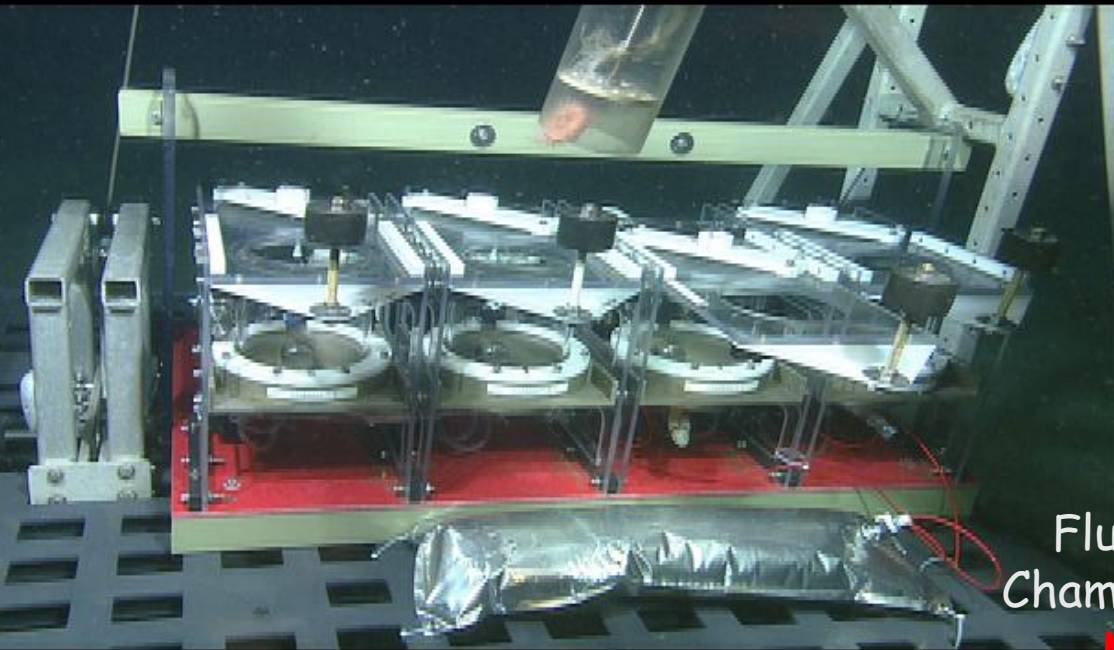


Lophophore



Pennington et al. 1999

Benthic Respiration System for CO₂ studies



4 Chamber system at 600 m in OMZ

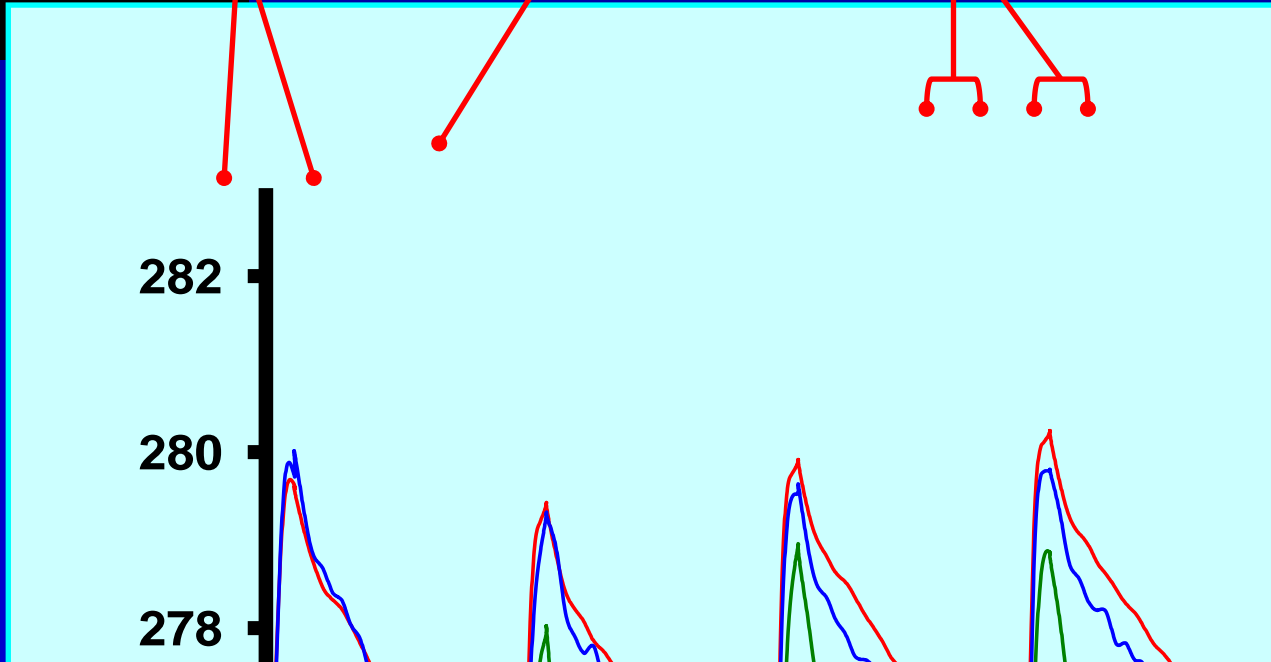
Flush Chambers

Begin Acid Injections

Respiration Rates



Allocentrotus fragilis



Field Mesocosm Studies (mainly planktonic communities)

IFM - GeoMar, Ulf Riebesell team

Svalbard

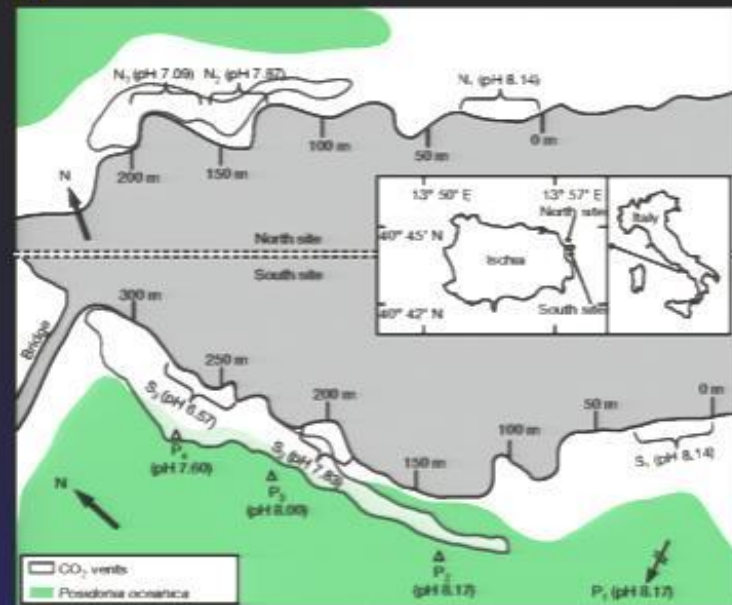
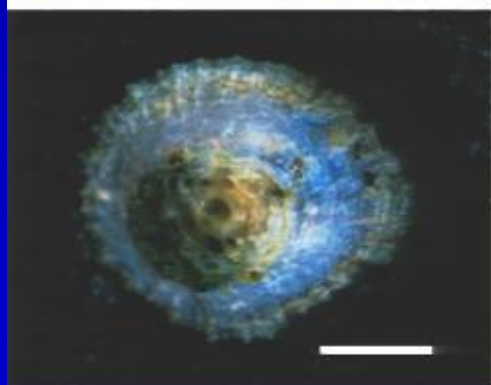
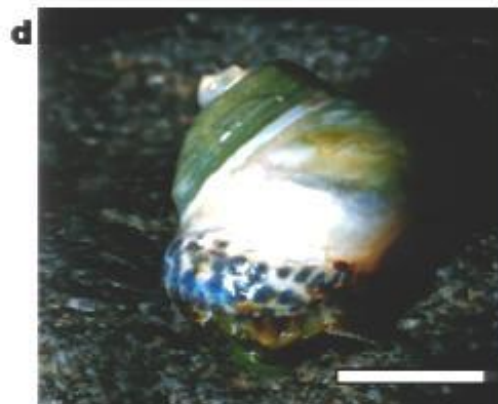
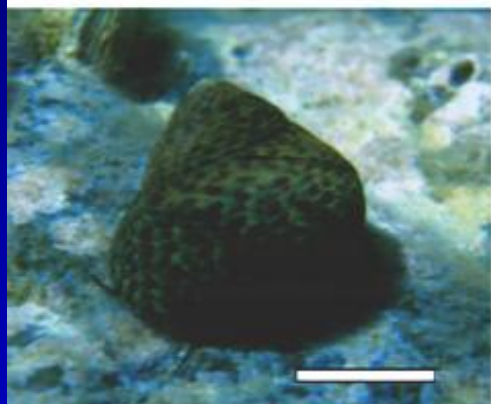
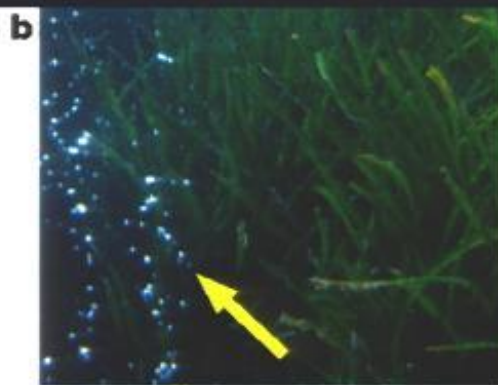


Bergen



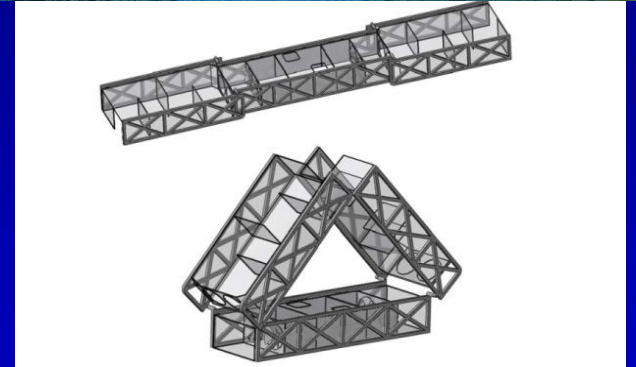
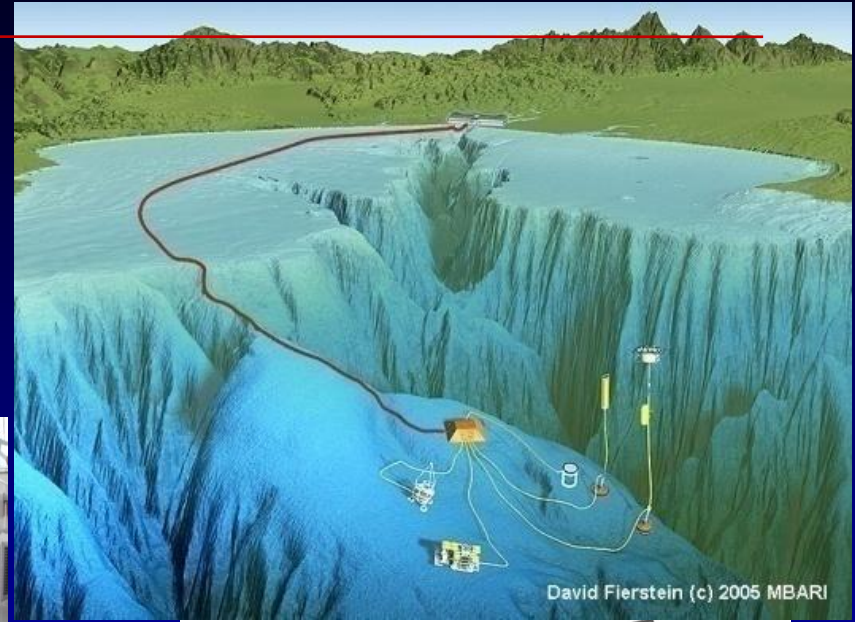
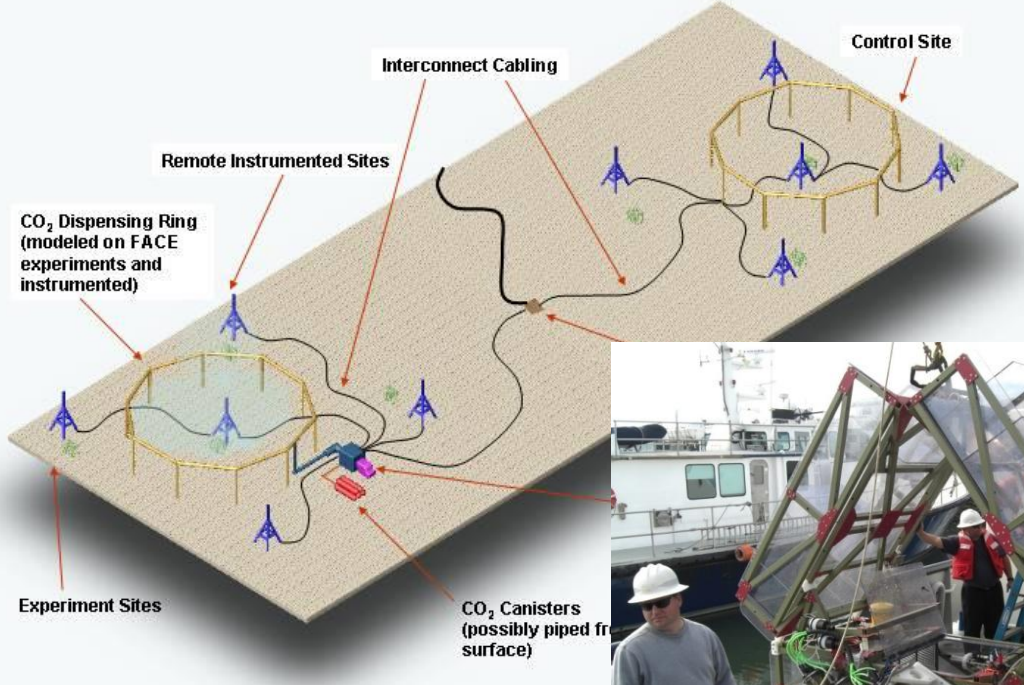
Field Survey of Natural CO₂ Venting Sites in Italy

- Echinoderms conspicuously absent, shell dissolution
- Seagrasses thrive

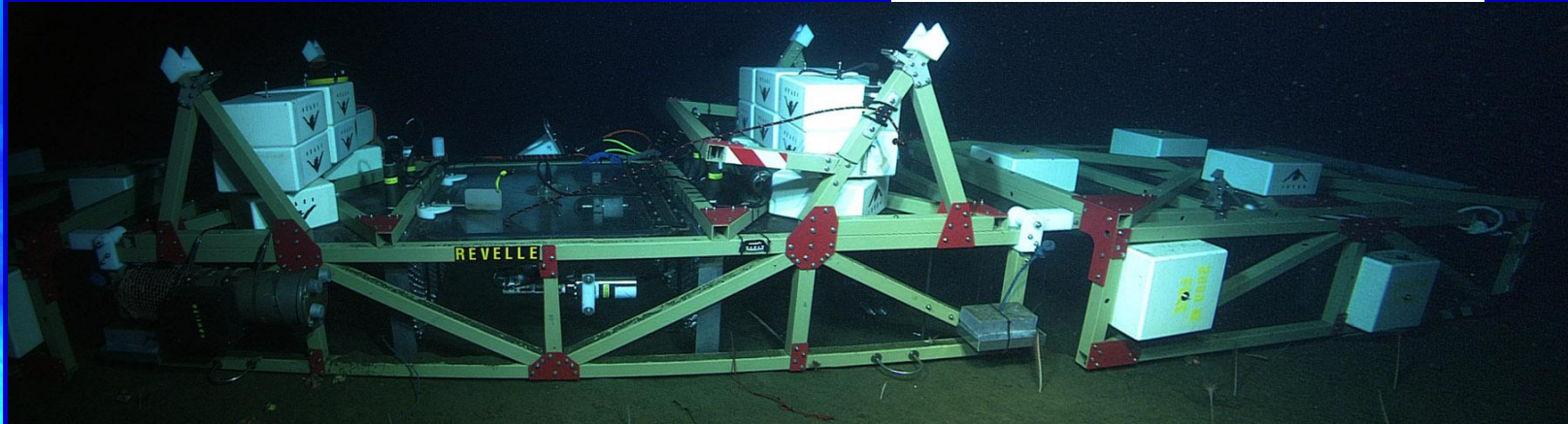
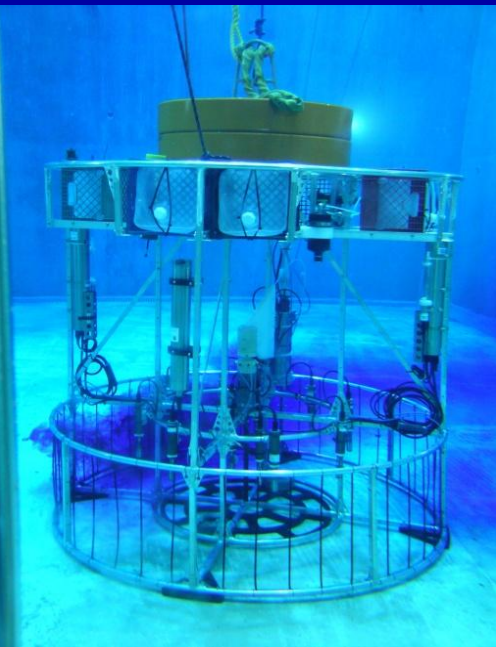


FOCE (Free Ocean CO₂ Enrichment) Technology

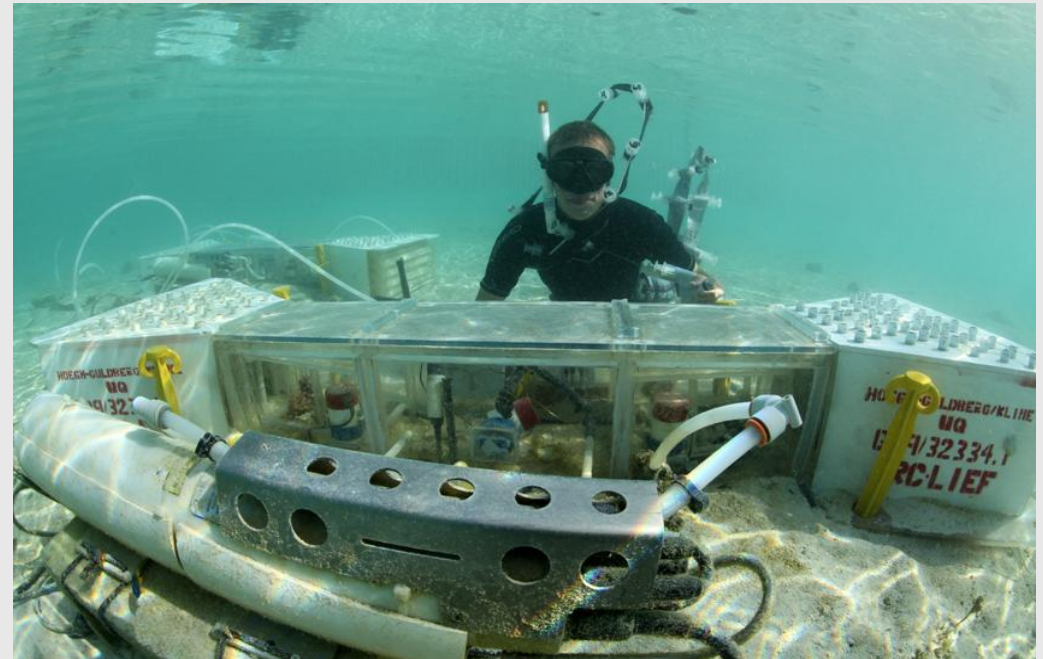
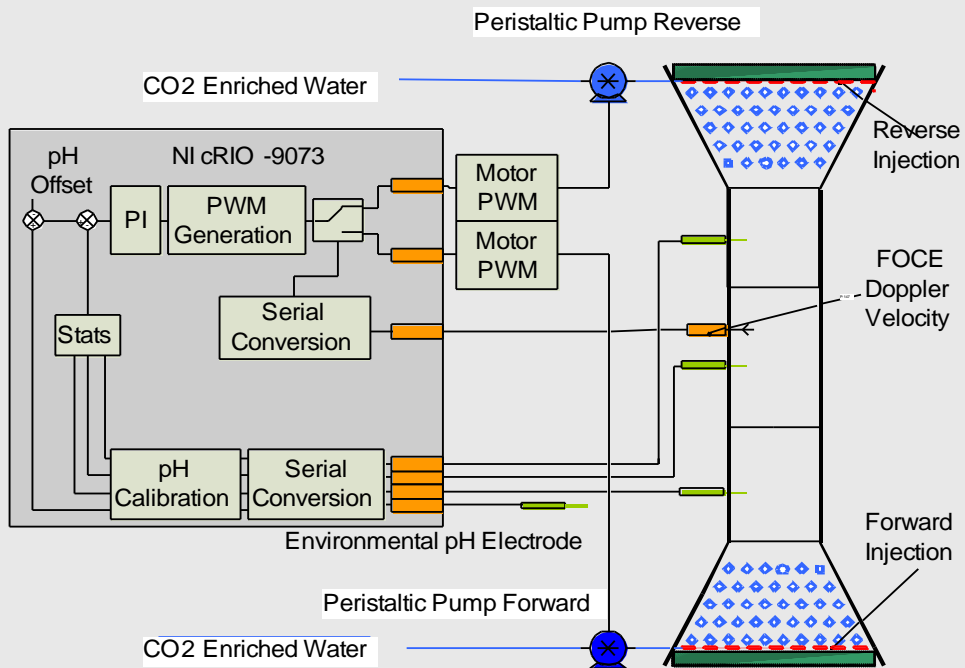
Beyond Climate Cabled Experiment Concept



FOCE prototypes



Modified FOCE at Heron Island, Australia



The Coral Proto - Free Ocean Carbon Enrichment System (CP-FOCE): Engineering and Development

Malcolm Marker¹, D. I. Kline², W. J. Kirkwood³, K. Headley³, P. G. Brewer³, E. T. Peltzer³, T. Miard², A. Chai², M. James¹, K. Schneider⁴, J. Silverman⁵, K. Caldeira⁴, J. R. Koseff⁶, S. Monismith⁶, B. Opdyke⁷, R. Dunbar⁶, R. White¹, S. Dove², O. Hoegh-Guldberg²

Summary

What we know:

- Ocean acidification is ongoing, massive, increasing
- Causes physiological stress for many species
- Can only be mitigated by reduced CO₂ emissions

What we expect:

- Food webs will be affected
- Ecosystem services (e.g. fisheries) will change

What we don't know:

- Capacity for acclimation and adaptation
- Effects on marine communities, ecosystems - tipping points?
 - Coastal vs open ocean systems (i.e. high vs. low natural pH variation)
 - Productivity and Stability of Fisheries

Multiple Stressors

Synergistic effects of warming, acidification, reduced oxygen levels may further impact ocean ecosystems

