

ECOSYSTEMS BIOLOGY – GLOBAL ISSUES

DKN

How have microbes impacted large scale biogeochemical cycles?

How does microbial metabolism change the game so dramatically?

How could microbes impact future global climate change?

Break – short movie

MMN – A case study

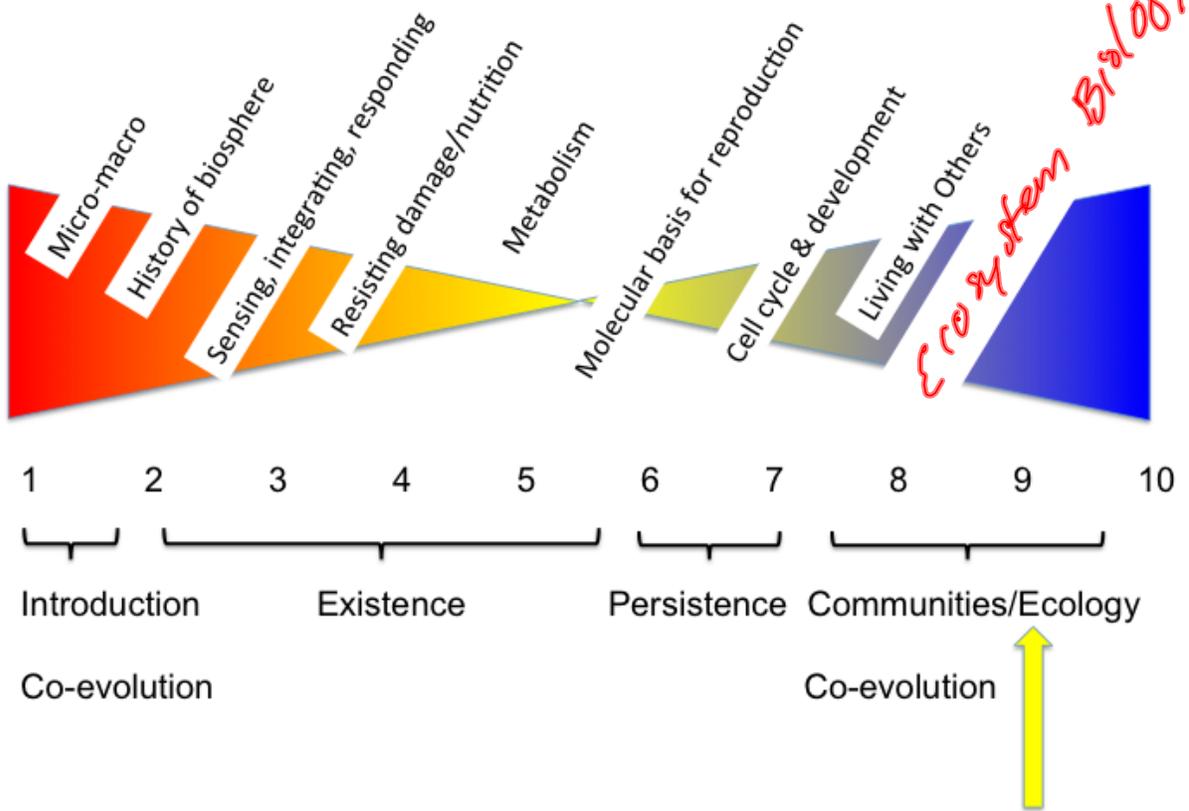
What are the constraints on the form, function and distribution of coral reefs?

How are global, anthropogenic environmental changes affecting the health of the world's coral reef habitats?

3 iClicker quizzes



Where have we been, where are we, and where are we going?

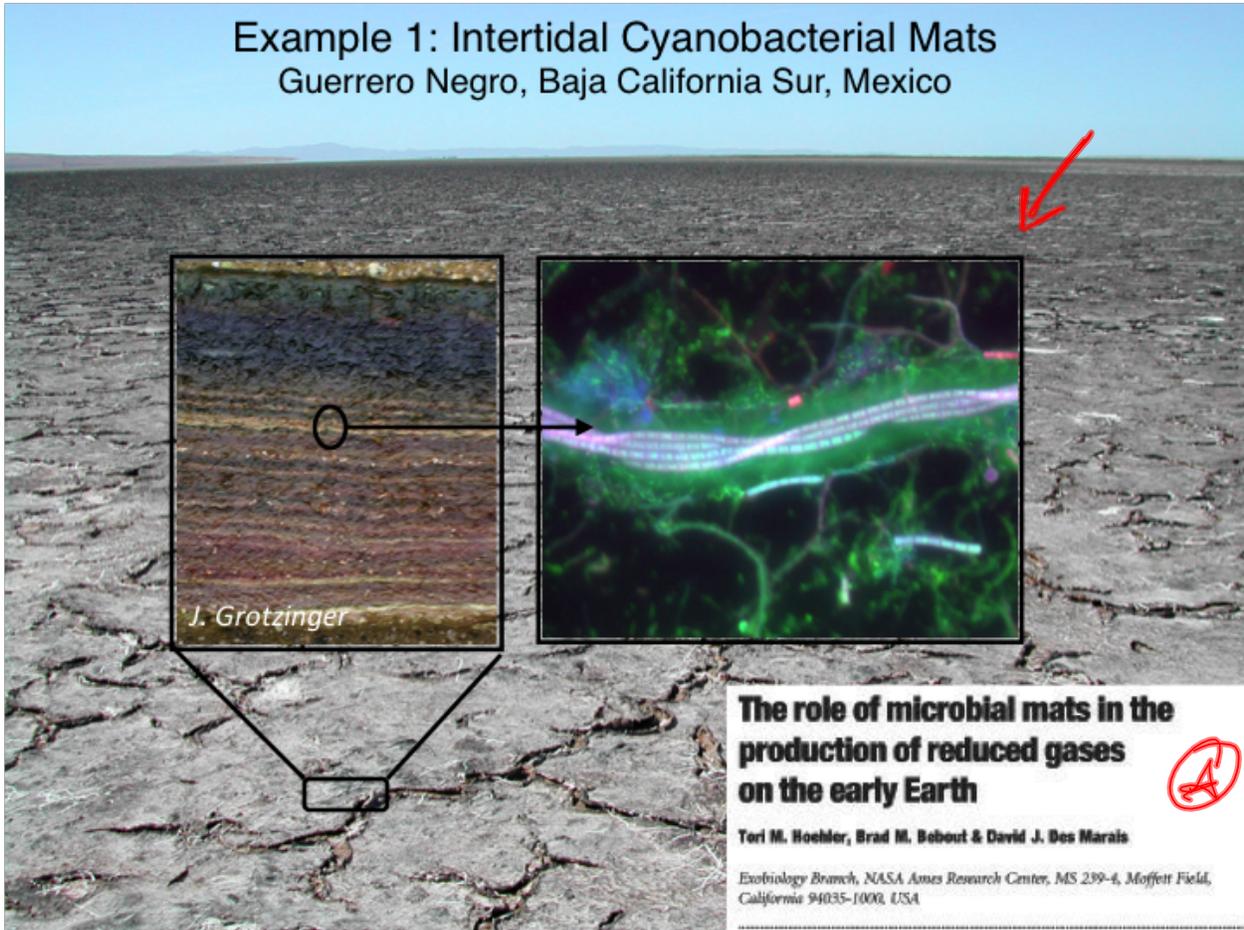


How have microbes impacted large scale biogeochemical cycles?



- Example 1 – Microbial mats and the atmosphere
- Example 2 – Evolution of photosynthesis and ore deposits
- Example 3 – The biological pump in the oceans sequesters carbon (which affects our atmosphere)

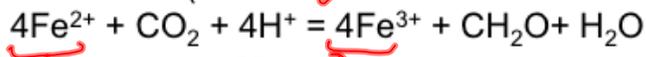
Example 1: Intertidal Cyanobacterial Mats Guerrero Negro, Baja California Sur, Mexico



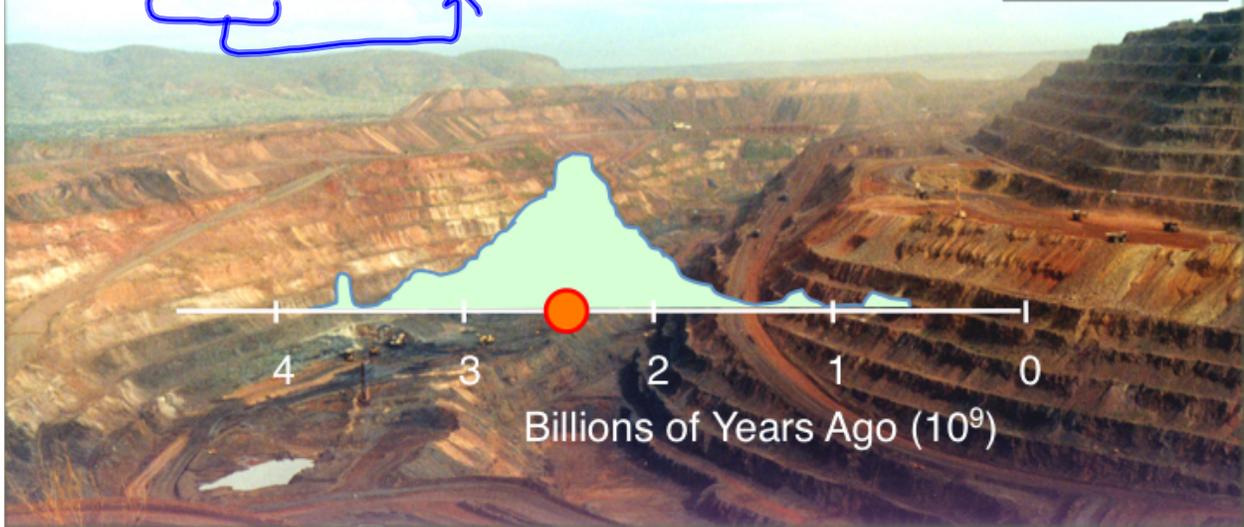
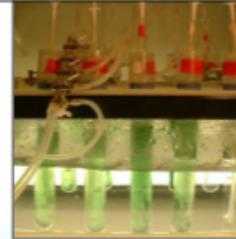
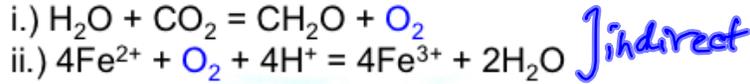
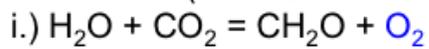
Example 2: Banded Iron Formations

direct

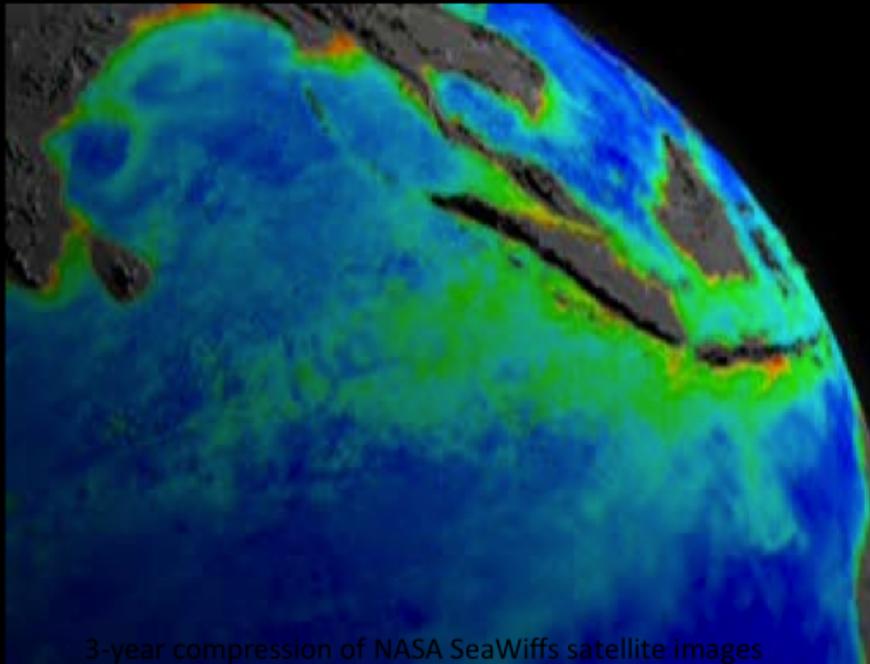
Scenario 1 (*anoxygenic photosynthesis*):



Scenario 2 (*oxygenic photosynthesis*):

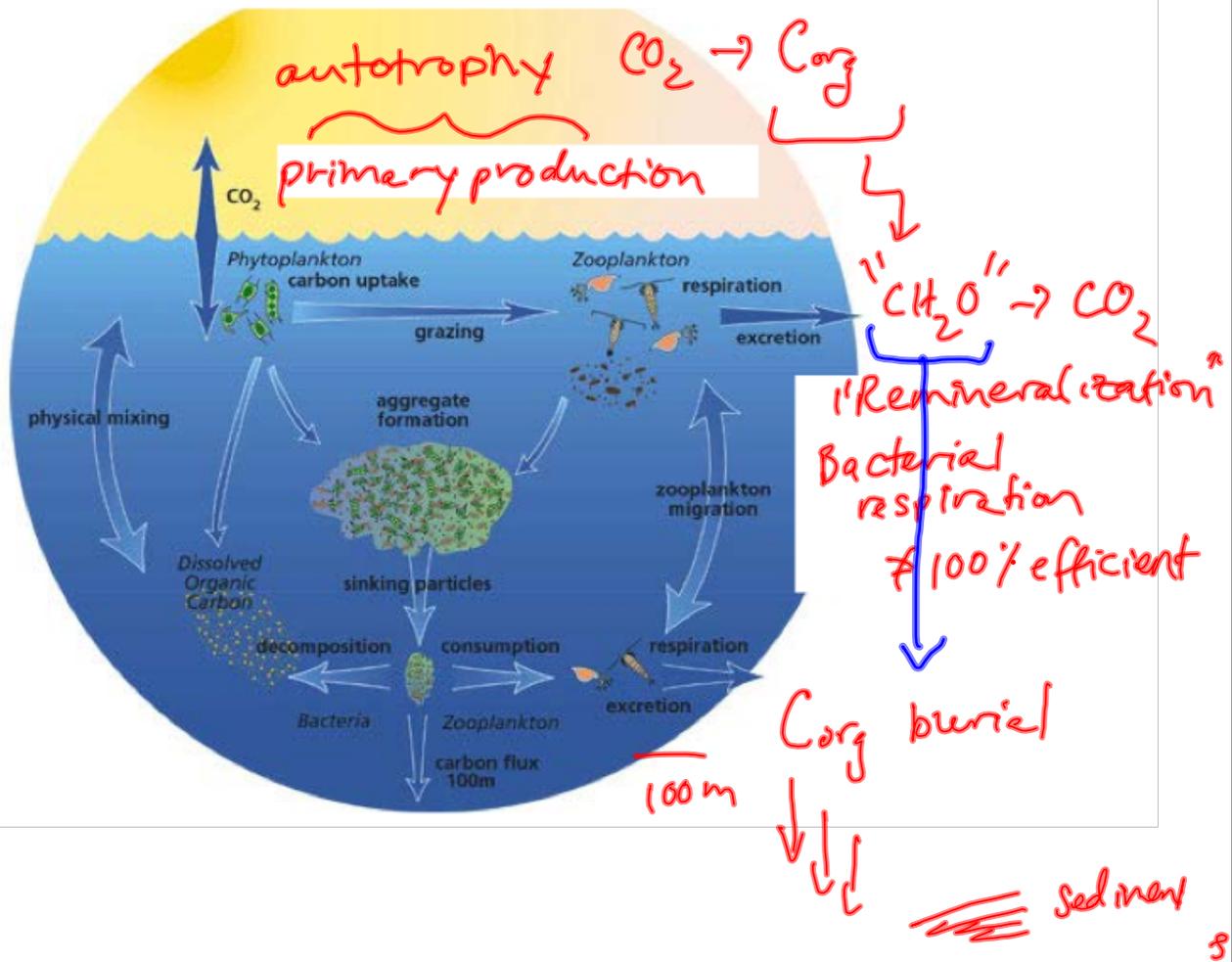


Example 3: atmospheric O₂ produced (and maintained at high levels) by marine phytoplankton and the “biological pump”



3-year compression of NASA SeaWiifs satellite images

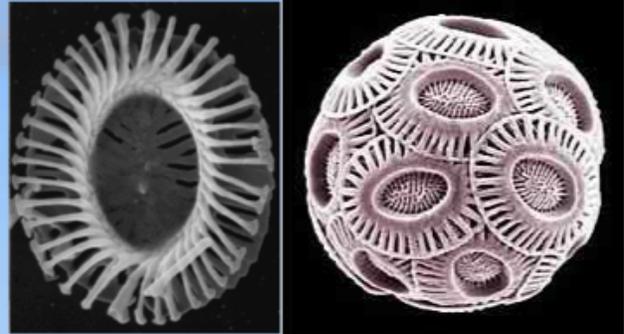
What is the BIOLOGICAL PUMP?



phytoplankton

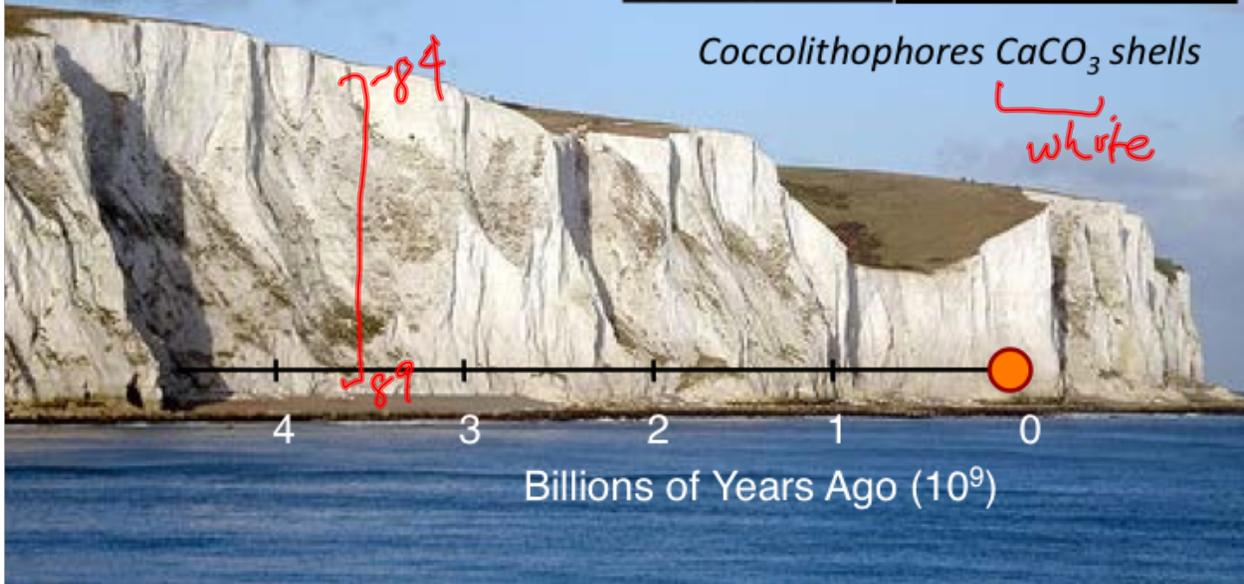
Example of the biological pump
when dinosaurs roamed the Earth
(Late Cretaceous, ~89 Ma)

White Cliffs Dover, UK



Coccolithophores CaCO_3 shells

white



How does microbial metabolism change
the game so dramatically?

(a.k.a. thermodynamic and kinetic underpinnings)

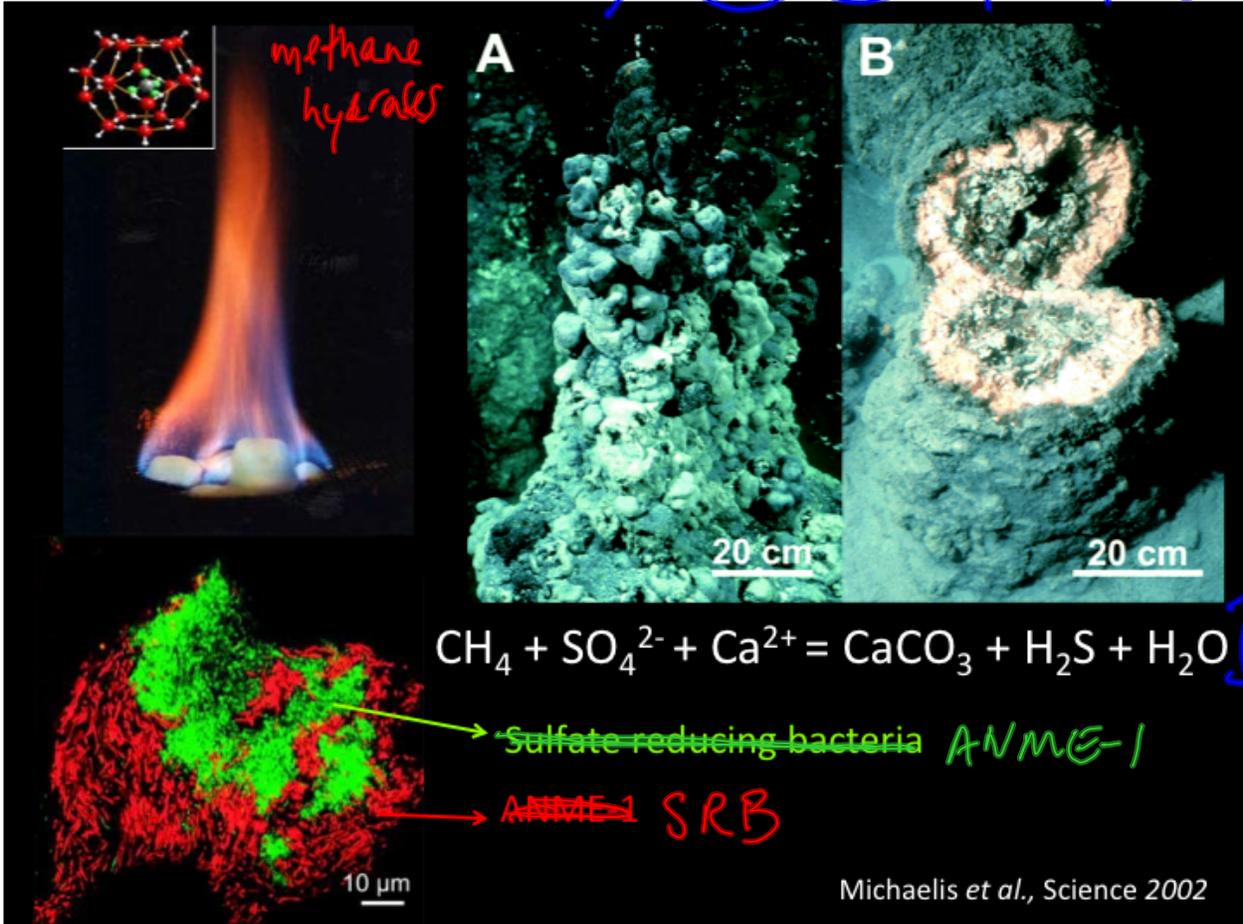


Example: AOM – primary production in the dark

} chemoautotrophy

- 90% methane (greenhouse gas) originating from marine sediments is oxidized by AOM
- CaCO_3 reef formation bottom of Black Sea

Reefs CaCO₃



methane hydrates

A

B

20 cm

20 cm

$CH_4 + SO_4^{2-} + Ca^{2+} = CaCO_3 + H_2S + H_2O$

Sulfate-reducing bacteria ANME-1

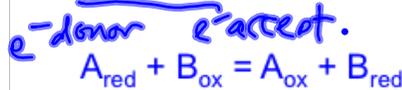
~~ANME-1~~ SRB

10 μm

Michaelis et al., Science 2002

REVIEW

Catabolic redox reaction:



$$\Delta G = -nF\Delta E \text{ (kJ)}$$

n = number of e⁻ transferred

F = Faraday constant

ΔE = difference in redox potential

e- donor (A_{red})? e- acpt (B_{ox})?

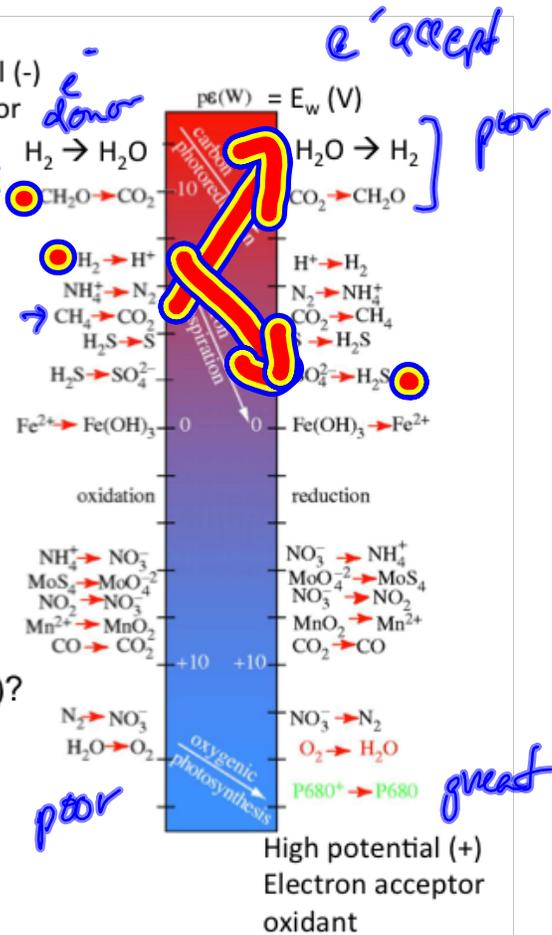
AOM:



Sulfate reduction:



Low potential (-)
 Electron donor
 reductant



Calculating Gibbs Free Energy from the Mass Law

Generic reaction: $A + 3B \rightarrow C + D + 4E$

Env. conditions!

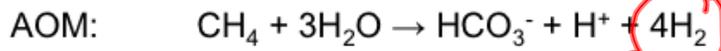
$\Delta G = \Delta G^\circ + 2.3RT \log \frac{[C][D][E]^4}{[A][B]^3}$

stand. cond 1M (under ΔG°)

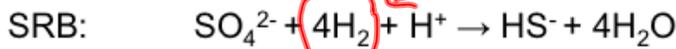
pure solids, liquids = 1 (A)

Specific case of H₂-exchange:

an example



ΔG°	ΔG
+	-



-	-
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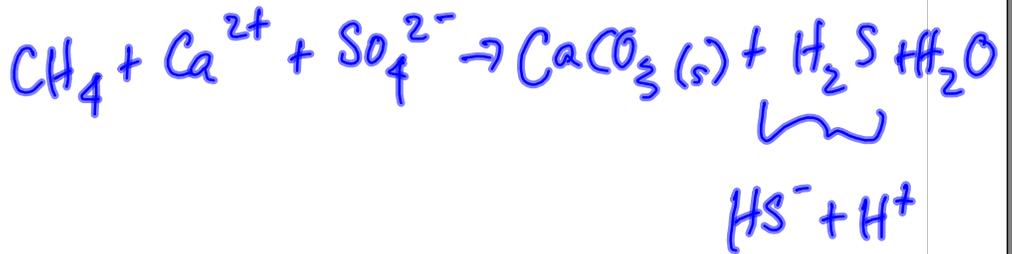
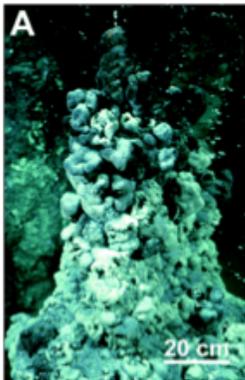
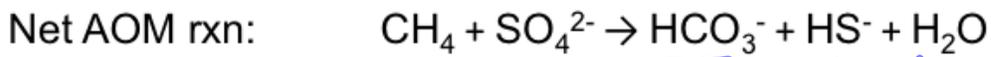


favorable

$\Delta G = \Delta G^\circ + 2.3RT \log \frac{[HCO_3^-][H^+][H_2]^4}{[CH_4]}$

→ Drive AOM rxn forward by SRB consuming H₂ (or other intermediate)

How does this promote reef formation?



How could microbes impact future global climate change?

- Example 1 – Marine iron fertilization experiments
- Example 2 – GAIA and the CLAW hypothesis
- Example 3 – CO₂ and warming of the permafrost

Example 1: Iron fertilization experiments (Boyd et al, 2007)

- Natural
nutrient upwelling zones, aeolian dust
- Man-made (targetting HNLC regions)

High Nutrient Low Chlorophyll
→ missing trace metals (e.g. Fe)
→ cofactors in essential enzymes

- Potential impact for climate?

↑ phytoplankton growth
 $CO_2 \rightarrow C_{org}$
↳ draw down $AtmCO_2$

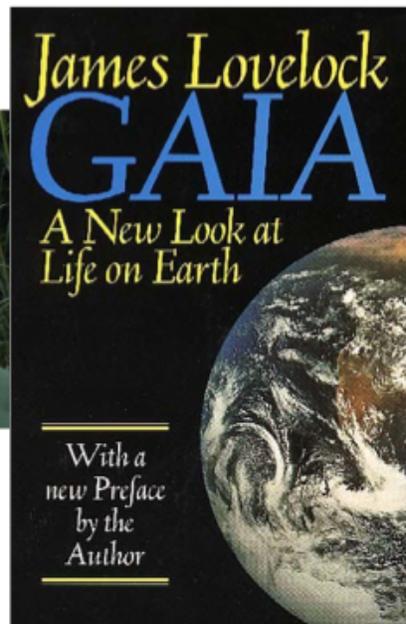
→ But is it so simple? How else can phytoplankton affect climate?

Southern Ocean (HNLC)



Example 2: The GAIA hypothesis: Earth is like an organism,
which maintains planetary homeostasis

A revolutionary, but controversial idea



Oxford University Press, Oxford, 1979

CLAW hypothesis

R.J. **C**harlson

J.E. **L**ovelock

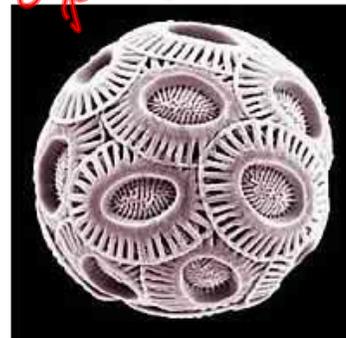
M.O. **A**ndreae

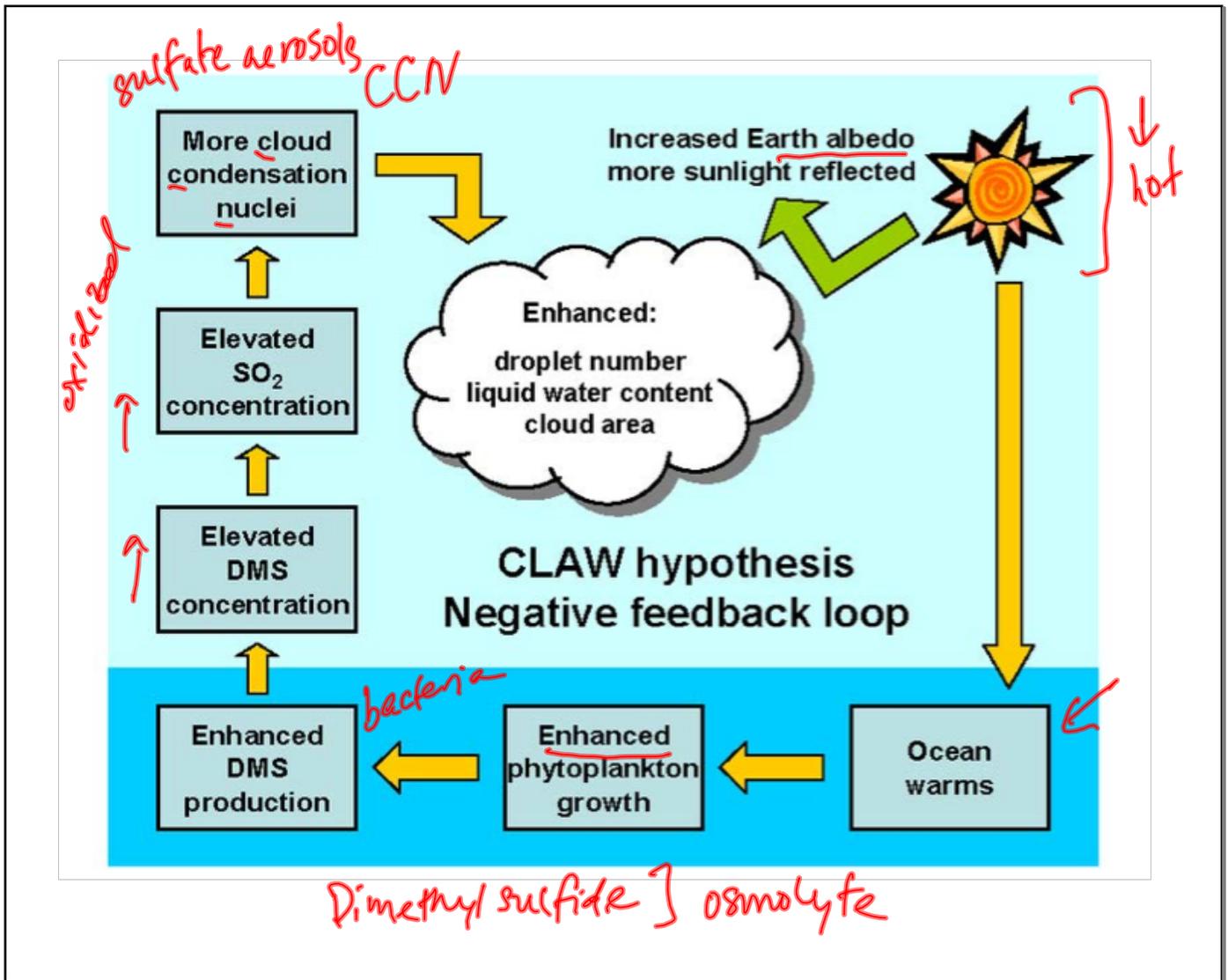
S.G. **W**arren

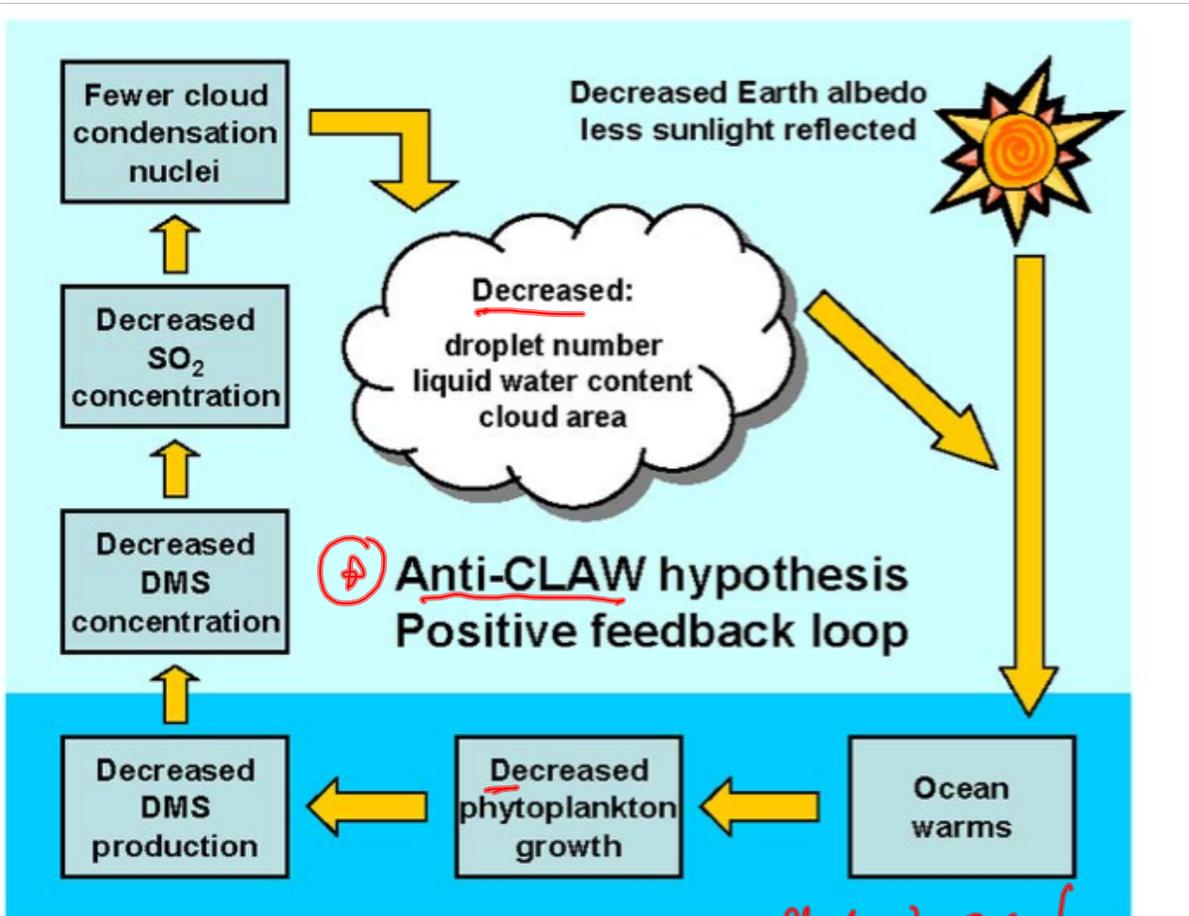
Oceanic phytoplankton,
atmospheric sulphur,
cloud albedo and climate
Nature 1987



phytoplankton





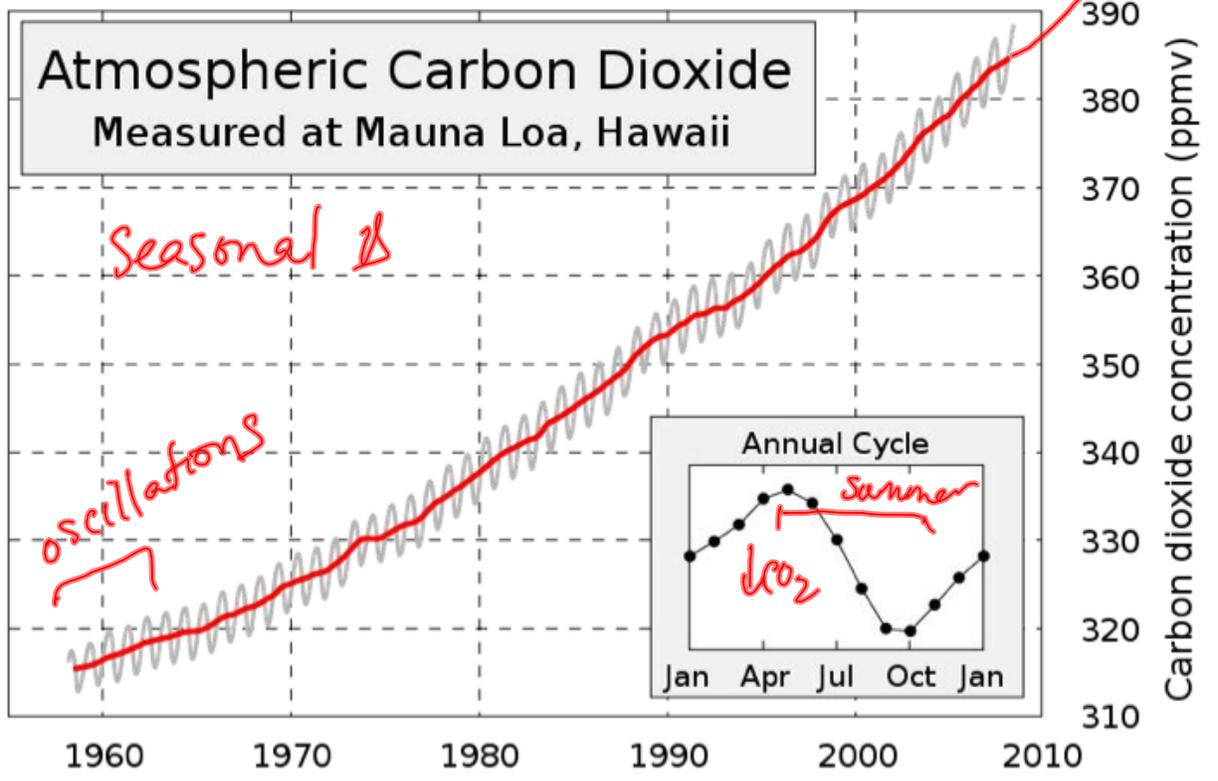


effect physical processes

Homework

→ The take-home message is that complex feedback loops are at play that complicate our ability to predict!

Example 3: Rising atmospheric CO₂, The Keeling Curve



Arctic

Permafrost

What do you think will happen when permafrost at high latitudes warms?



Respiration \rightarrow $\text{CH}_2\text{O} \rightarrow \text{CO}_2$ CH_4 } greenhouse gases
(+) feedback

ECOSYSTEMS BIOLOGY – GLOBAL ISSUES

How have microbes impacted large scale biogeochemical cycles?

The have shaped all aspects of the planet throughout Earth history, from the atmosphere to the oceans to the lithosphere.

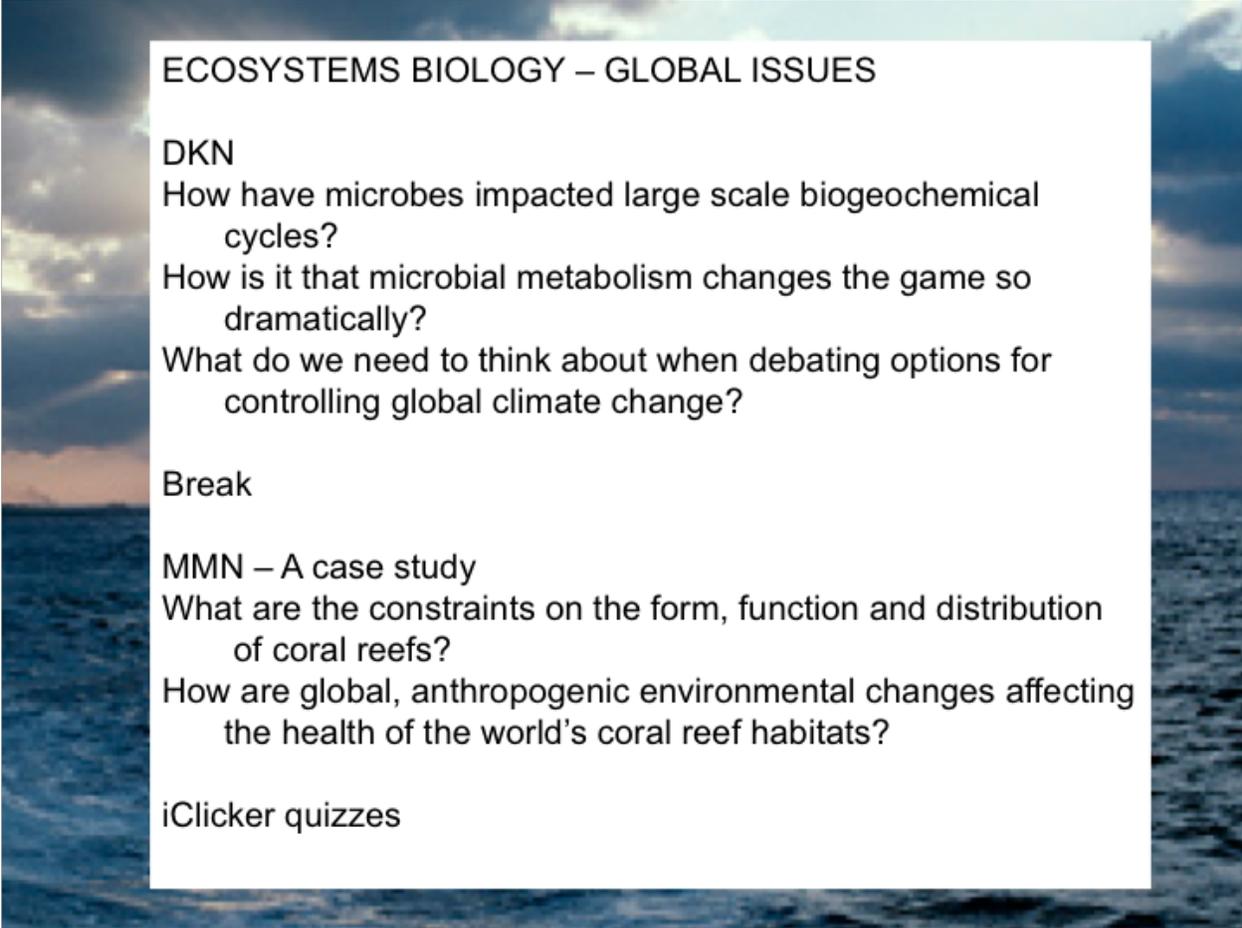
How is it that microbial metabolism changes the game so dramatically?

By altering local conditions such that processes become favorable that otherwise would not be (either thermodynamically or kinetically). ✓

What do we need to think about when debating options for controlling global climate change?

Biogeochemical cycles are highly complex and difficult to predict without knowing all the feedback-loops! "Geoengineering" is a VERY DANGEROUS GAME. Our understanding of these systems isn't good enough yet to roll the dice.

Handwritten red annotations: a bracket on the right side of the text, and three circles containing the letter 'A' stacked vertically.



ECOSYSTEMS BIOLOGY – GLOBAL ISSUES

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What do we need to think about when debating options for controlling global climate change?

Break

MMN – A case study

What are the constraints on the form, function and distribution of coral reefs?

How are global, anthropogenic environmental changes affecting the health of the world's coral reef habitats?

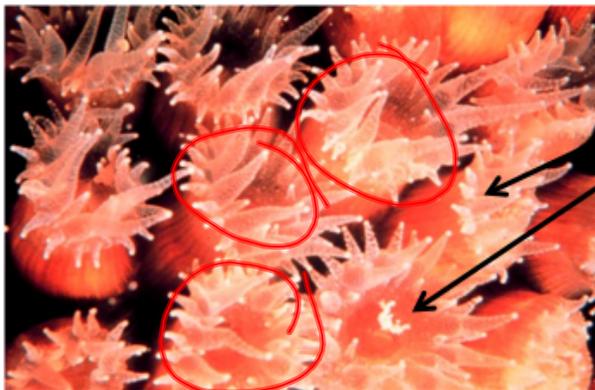
iClicker quizzes

One system dramatically affected
by anthropogenic activity



Coral reefs

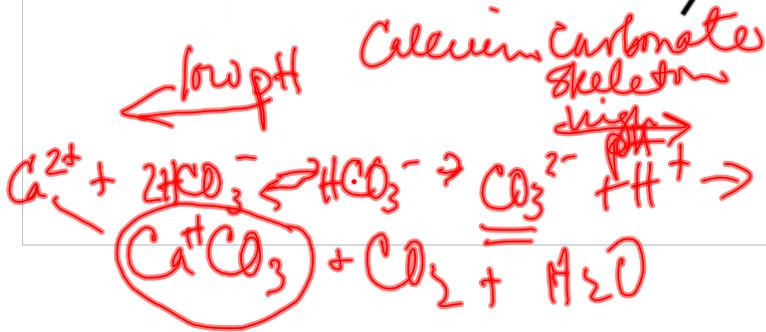
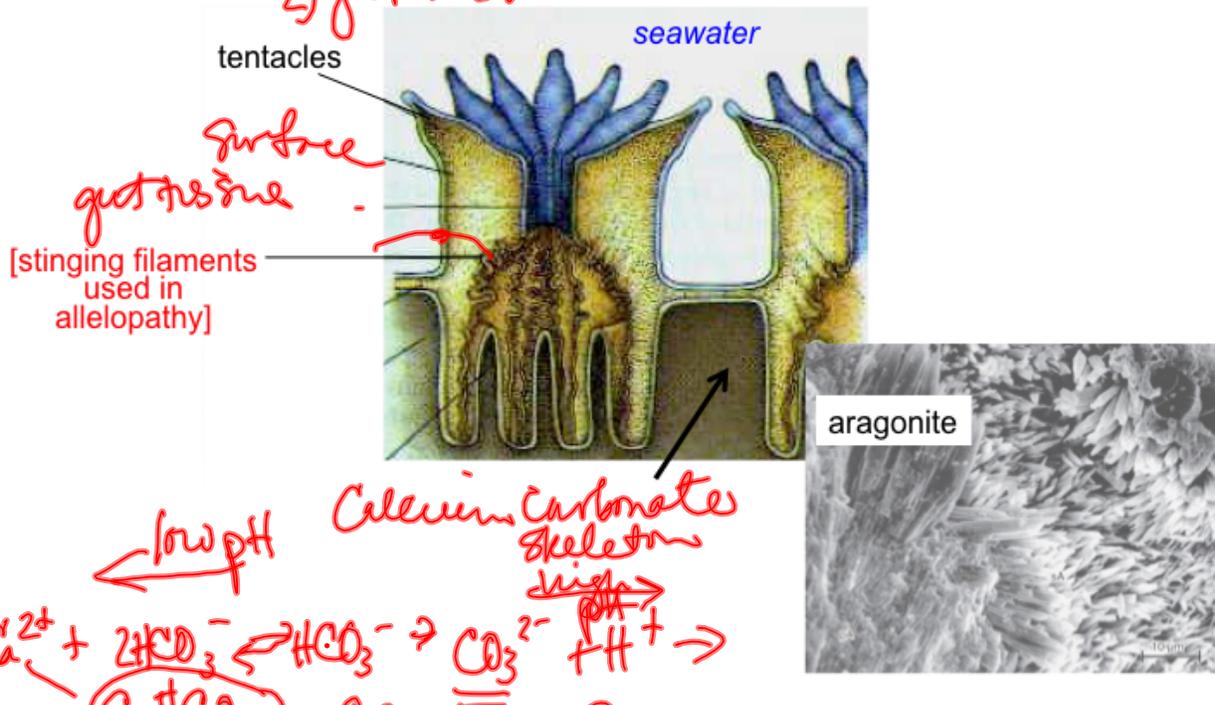
Colony



clone
asexual reproduction!

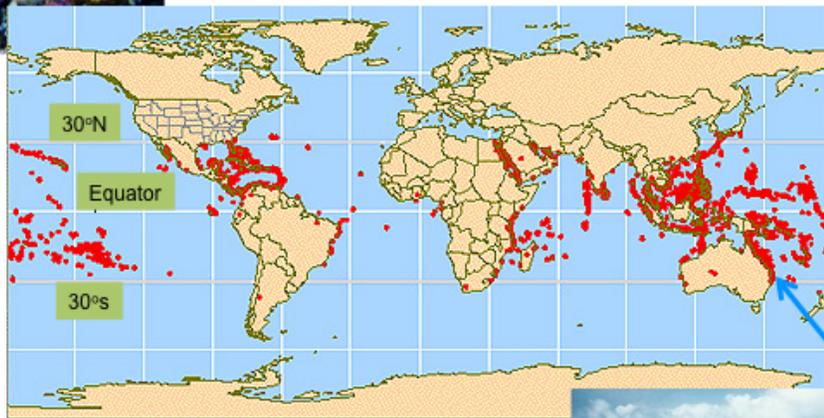
[also sexual
reproduction]

Coral – solitary or colonial animals with 2 tissue layers
 1) surface interfaces w/ environmental
 secretes exo skeleton
 2) gut tissue





Coral reefs
restricted - 30°N + 30°S



Great barrier reef
2600 km



Largest single structure made from living organisms



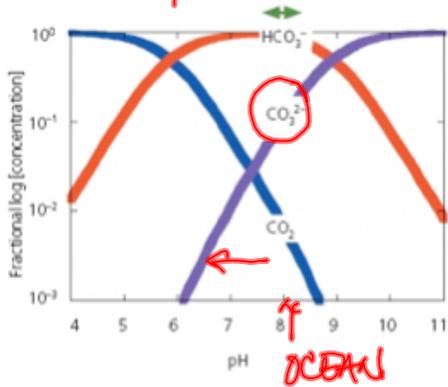
Some non-reef-building corals of
Southern California



1cm

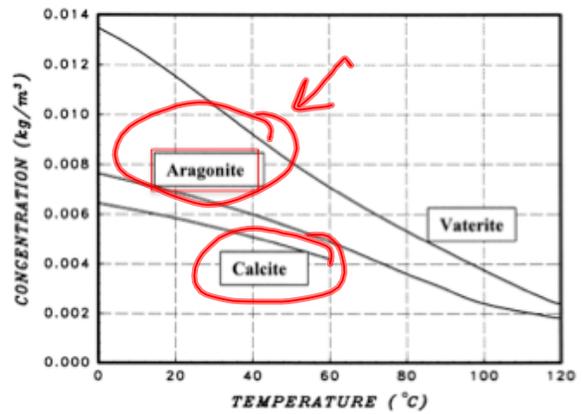
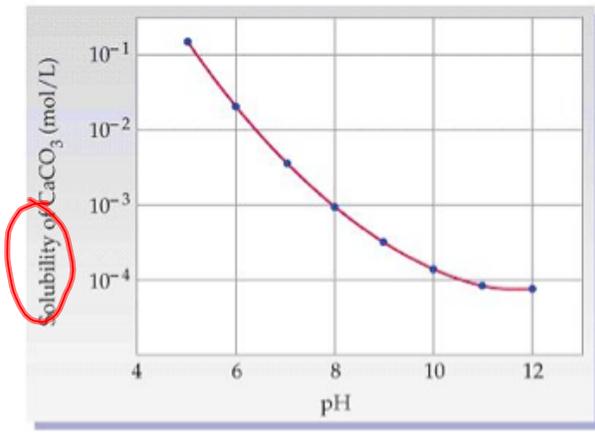
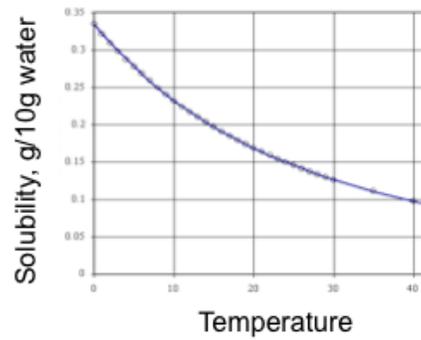


pH



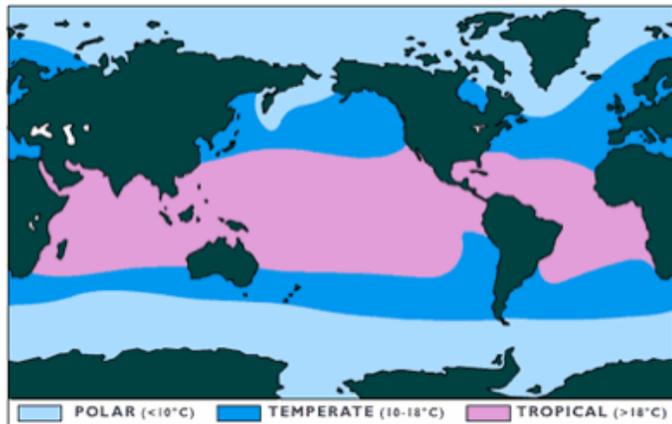
TEMPERATURE

CO₂ solubility in water

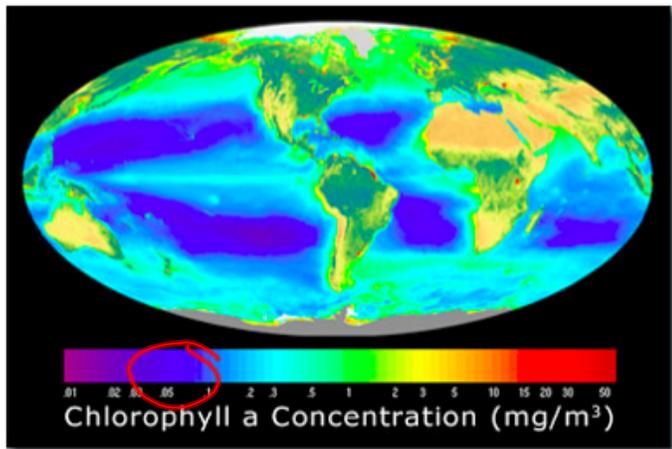


PRODUCTIVITY

-  High
-  High
-  Low
-  High
-  High



NUTRIENT CONIC.
CHLOROPHYLL

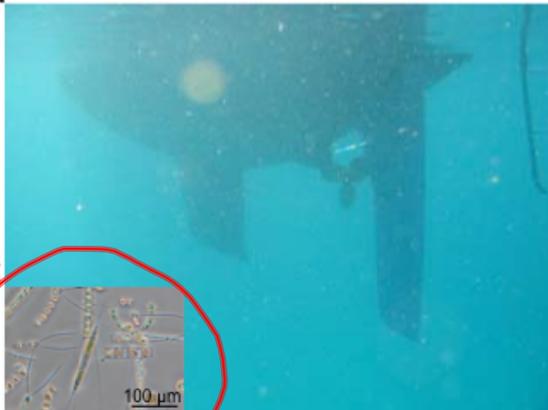




*"The [tropical] ocean is a desert, with it's life underground,
And a perfect disguise above."
{America, 'Horse with No Name'}*

Tropical waters are clear due to lack of nutrients, low numbers of small plants and animals.

Low visibility in temperate waters is due to high nutrient levels supporting large number of small plants/ animals.





So...the tropical regions are 'deserts', yet...

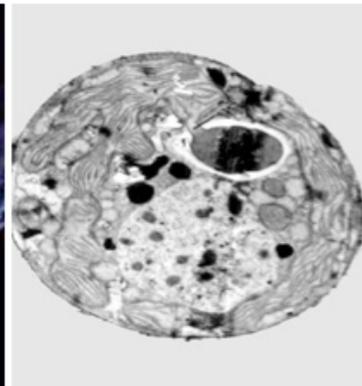
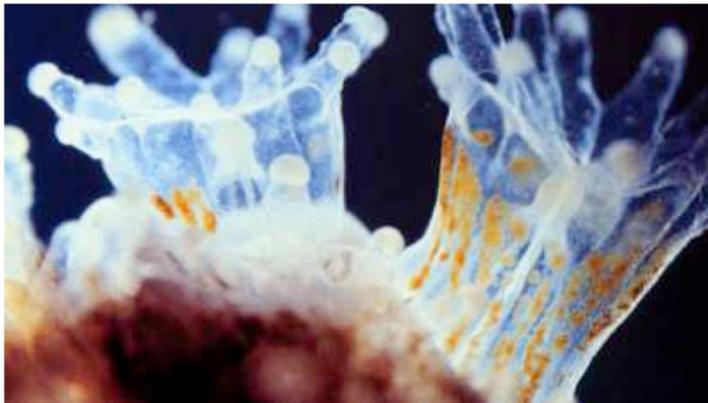
Coral reefs that are restricted to these tropical regions.

highly diverse
Complex 3-D structure

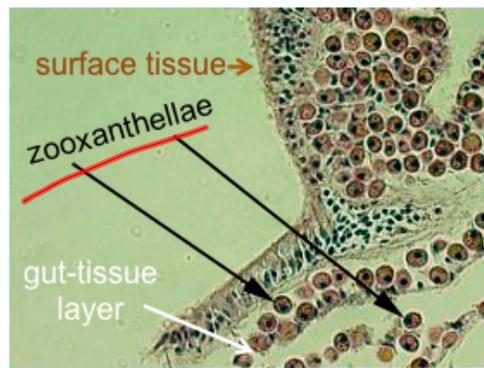
- 1) 0.01% of EARTH'S surface
- 2) 1/4 of all ocean species live w/ coral reefs

How?

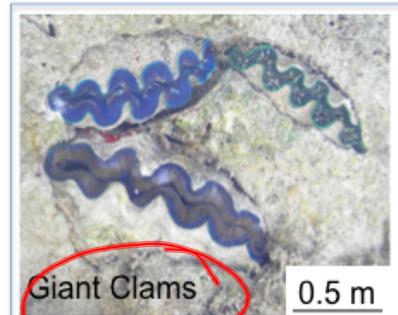
Coral - Zooxanthellae

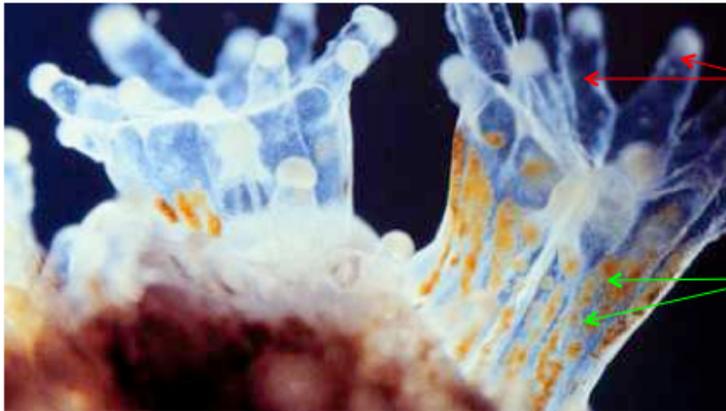


Zoox =
unicellular
algae
gut tissue



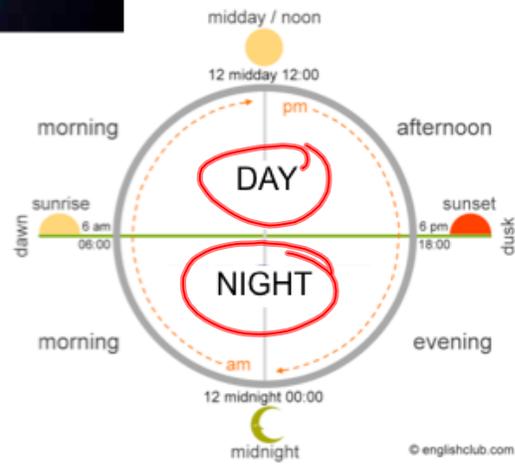
photosynthetic





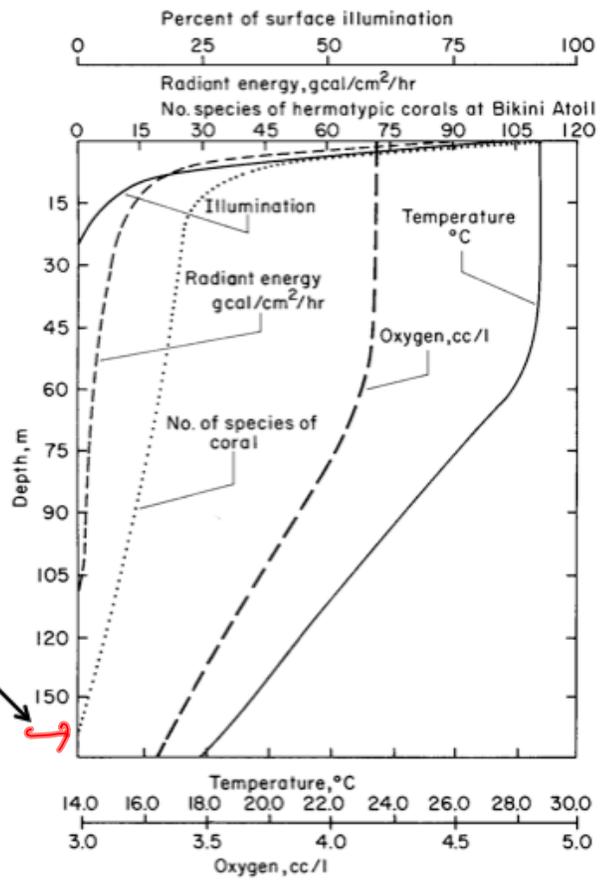
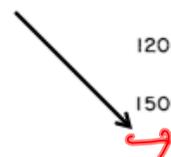
Prey capture

LIGHT CAPTURE
(symbiosis)



*h_v absorption
restricts
depth of corals*

*photosynthetic
compensation
depth*



Destruction of the coral reefs



Southeast Asia

Overfishing -
Destructive fishing methods

Destruction of
coastline



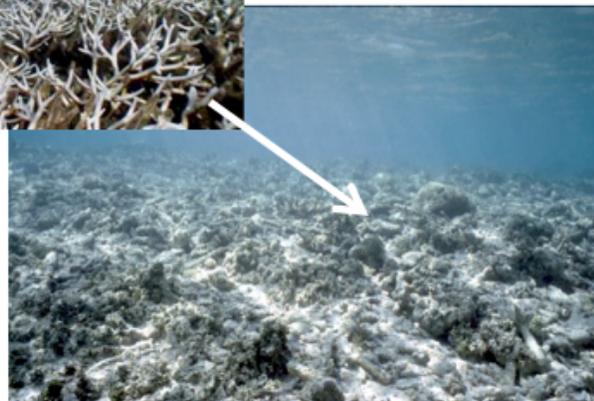
Chitales, Yucatan Peninsula,
Mexico





healthy

coral bleaching



dead

Coral Bleaching – loss of pigmentation of the corals

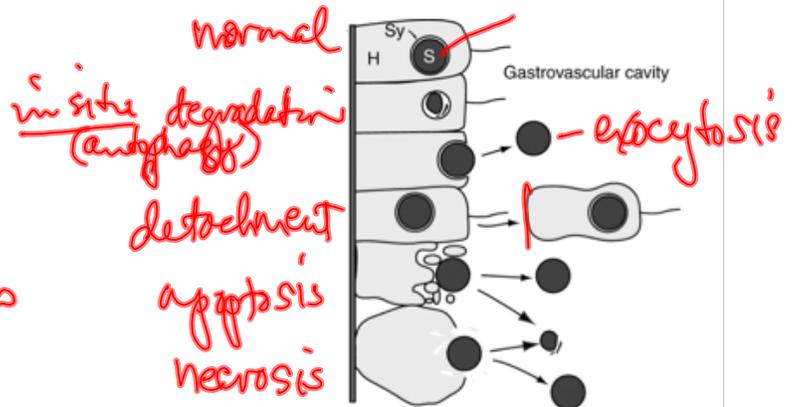
Proximate cause – *loss of symbiosis*

since 1970 ~ 30%



How & why?

5 types of cellular mechanisms

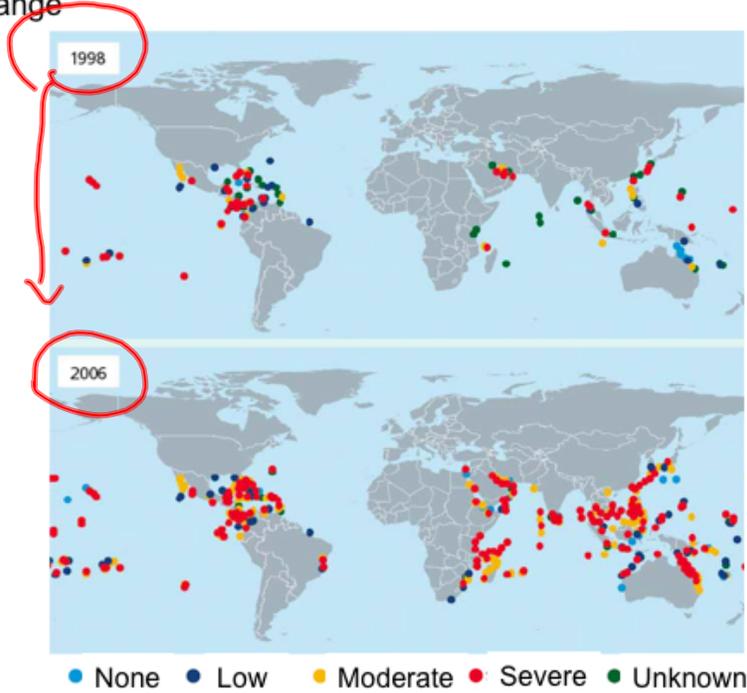


Movie on

- 1) global temperature change
- 2) ocean acidification –

OVER YOUR LIFETIME

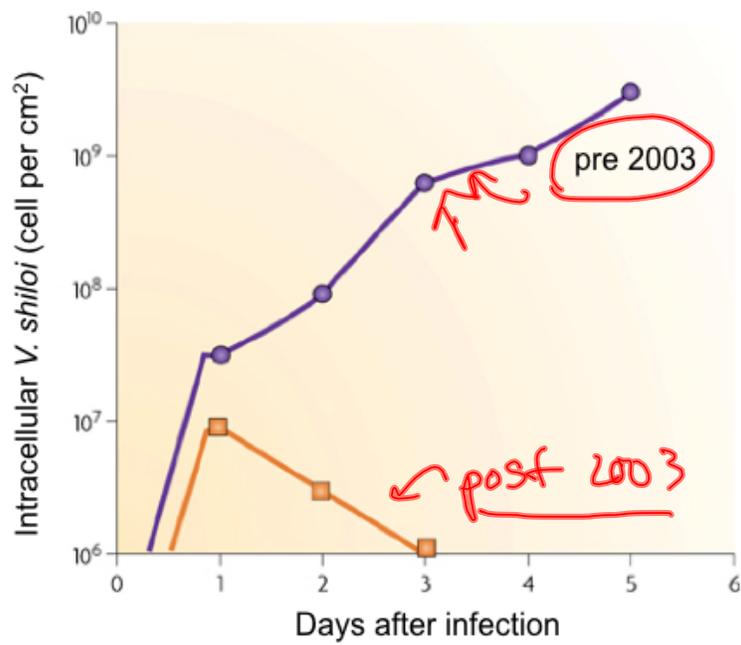
NO TIME FOR RECOVERY



← low pH high pH →

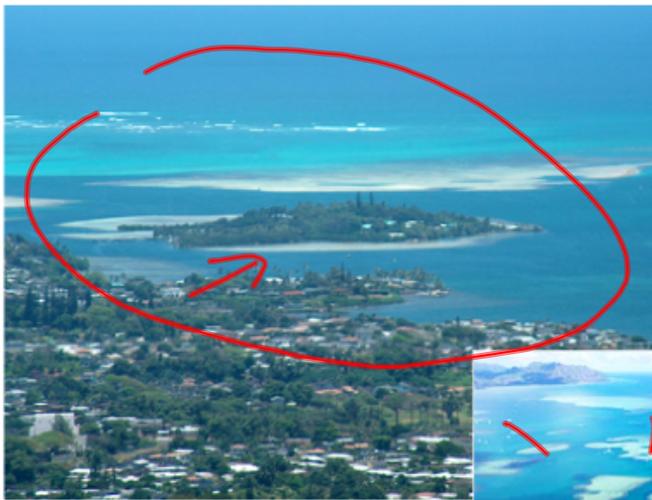


Marine bacteria going to the dark side with higher temperatures.



Occurrence of *Vibrio shiloi* in coral tissues.

THERE'S HOPE - ACT NOW!



Coconut Island – O'ahu, Hawaii
[Moko o'lo'e]



ECOSYSTEMS BIOLOGY – GLOBAL ISSUES

MMN – A case study

What are the constraints on the form, function and distribution of coral reefs?

Coral reefs are ecosystems in which corals are the major physical and biological elements. Reef-building corals are colonial animals with calcium carbonate exoskeletons. These reefs support much of the ocean's diversity.

Coral reefs are restricted to the tropics and subtropics, areas of low nutrients. They are able to live in such environments because they form a symbiotic relationship with photosynthetic, unicellular algae.

How are global, anthropogenic environmental changes affecting the health of the world's coral reef habitats?

Global climate change and ocean acidification severely threaten the world's coral reefs.

iClicker quizzes

This Thursday - Exam 2 Q's will be handed out

Next week - we will hold a review session (time TBD → we will announce next class)

Ⓐ Send us specific questions for the review. It will not be a lecture.

Email!