

LIVING WITH OTHERS: POPULATIONS AND COMMUNITIES

DKN

What behaviors do microbial communities engage in?

Why are microbes where they are?

What structures microbial communities?

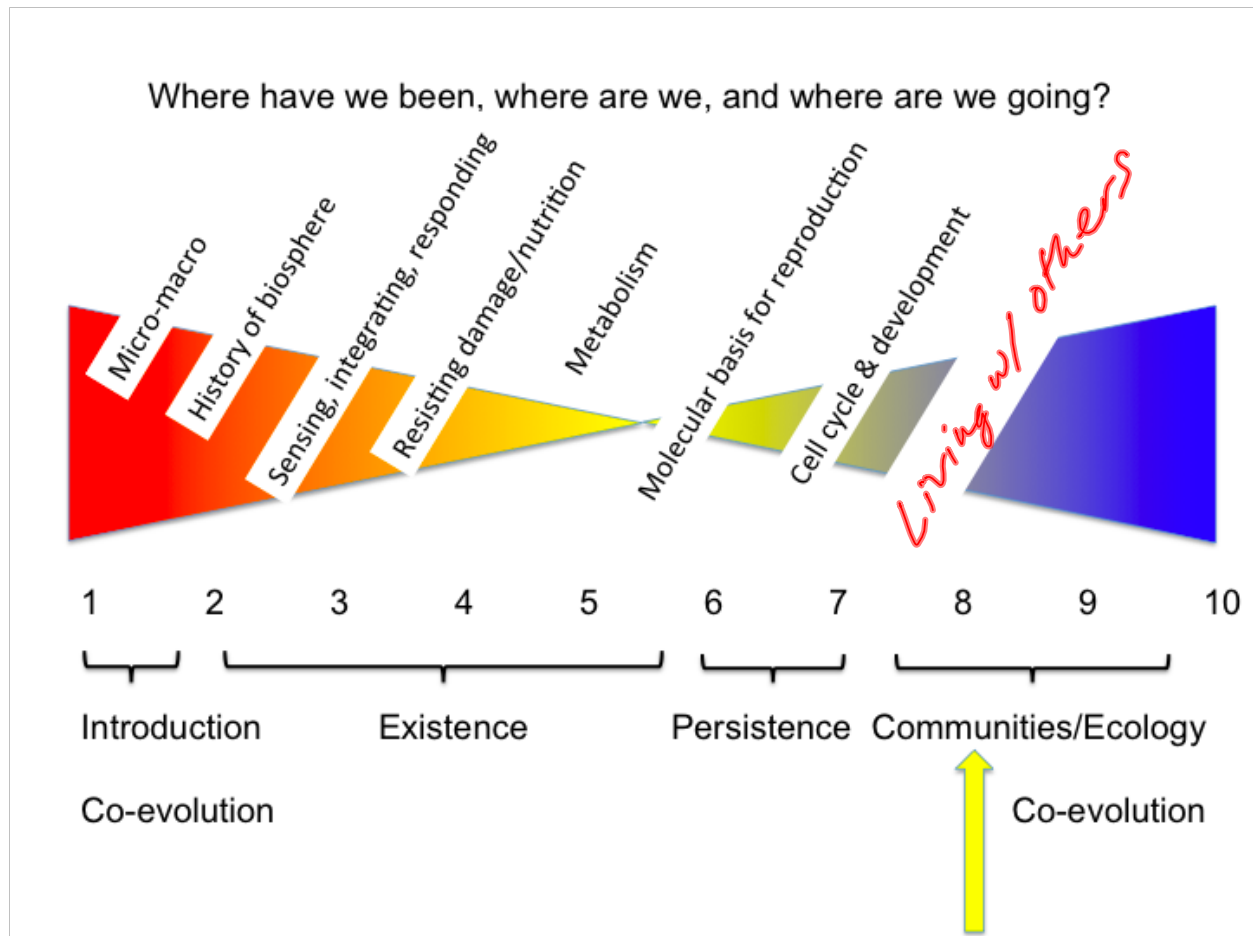
Break

MMN

What processes contribute to diversity in the biosphere?

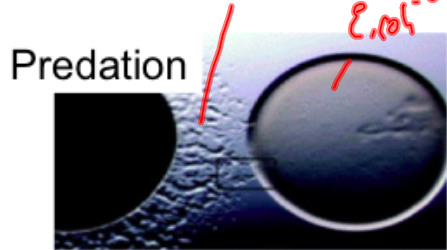
- How do keystone species structure the environment?
- How does allelopathy structure communities?
- What are the mechanisms underlying cooperation?

iClicker quizzes

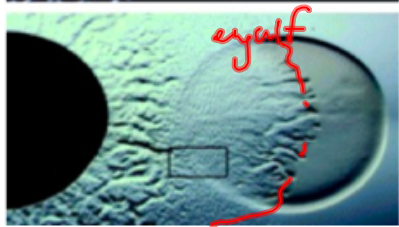


What behaviors do microbial communities
engage in?

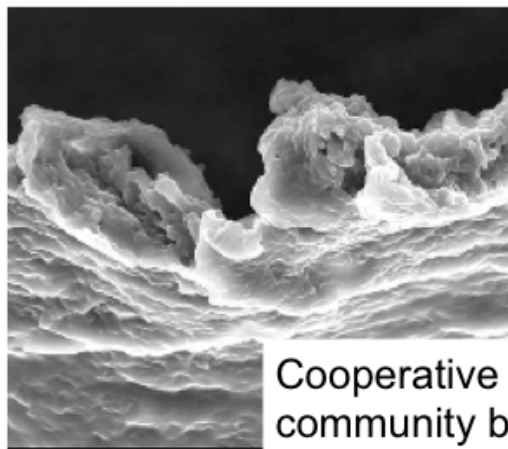
myxco → traveling waves



E. coli

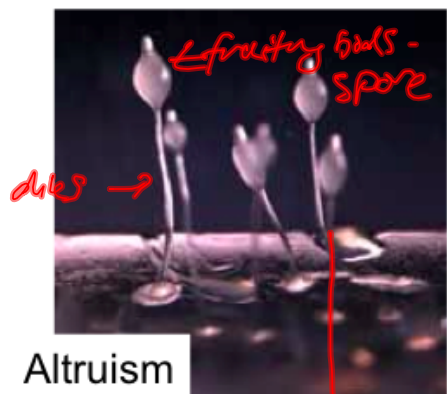


self



Biofilms

Cooperative community building



Altruism

fructifying stalks - spore

does →



fluorescence

Quorum Sensing

→ Virulence factors

→ useful things

ex. Fe-acquisition

Talking & Cheating

↑ siderophore

myxco] "kin selection"

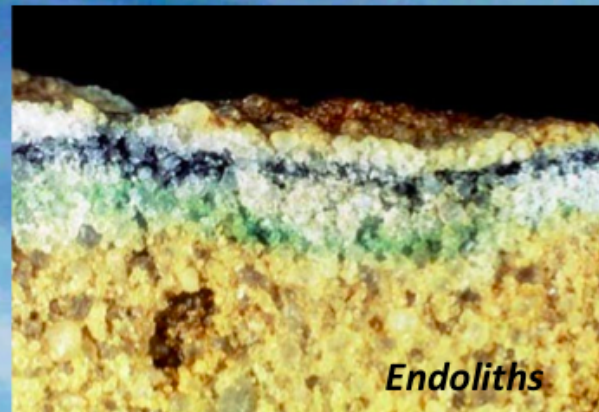
Why are microbes where they are?

"Everything is everywhere, but the environment selects"

Baas Becking, 1934 ("Delft School", Netherlands)

- Example 1: Niche assembly theory
v. dispersal limitation & stochasticity
[biogeography: Antarctica]
- Example 2: Predation [marine viruses]
- Example 3: Competitive exclusion and/or metabolic exchange
[microbial mats]

Example 1 (dispersion)

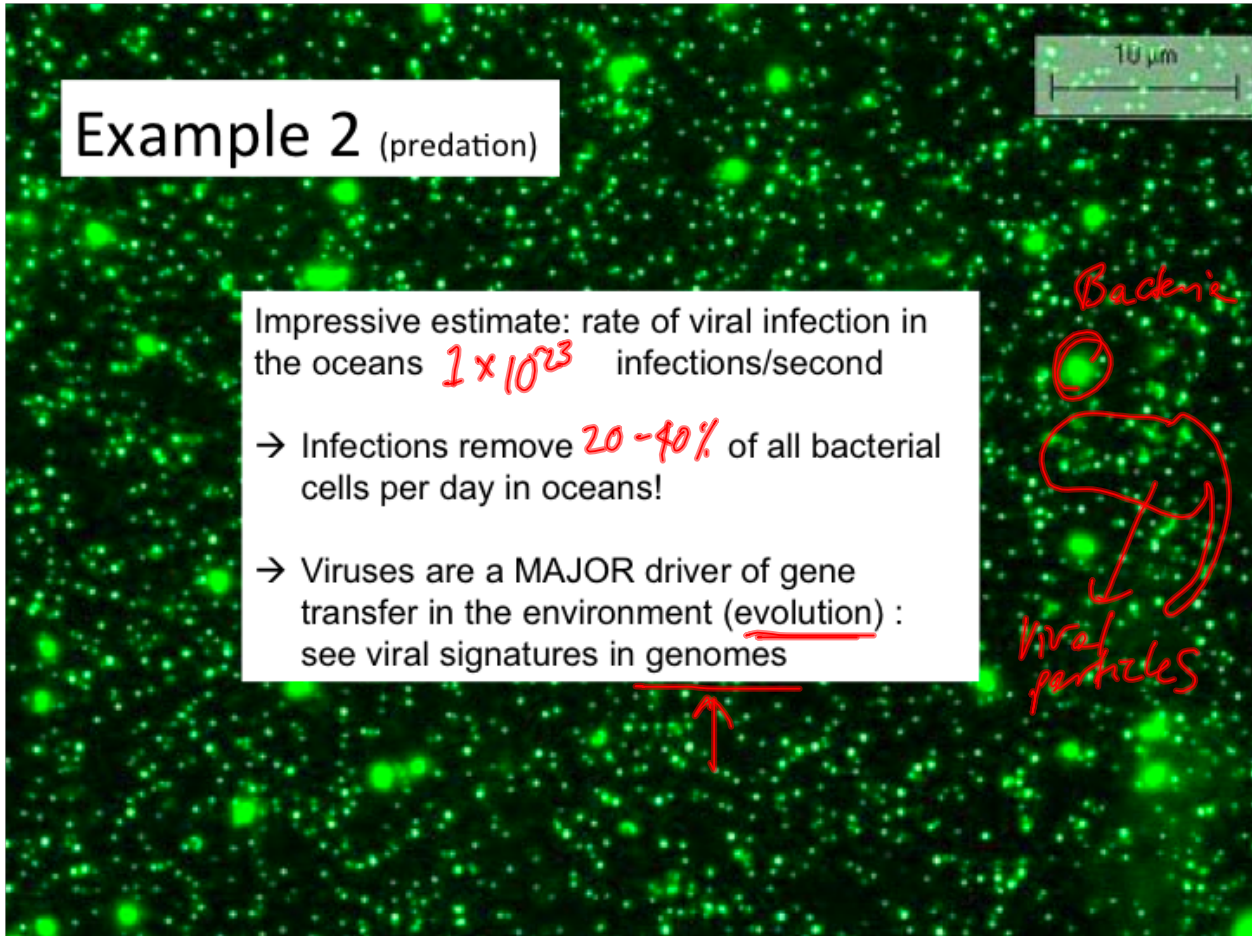
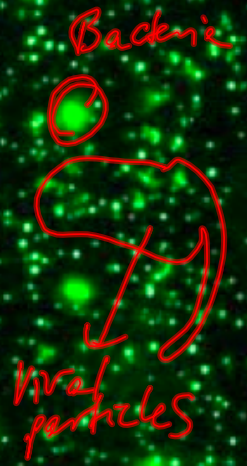
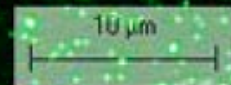


Psychrophiles
Nutrients from aeolian dust

Example 2 (predation)

Impressive estimate: rate of viral infection in the oceans 1×10^{23} infections/second

- Infections remove ~~20~~ 40% of all bacterial cells per day in oceans!
- Viruses are a MAJOR driver of gene transfer in the environment (evolution) : see viral signatures in genomes



Example 3 (competitive exclusion/metabolic exchange)



Yellowstone, Dave Ward

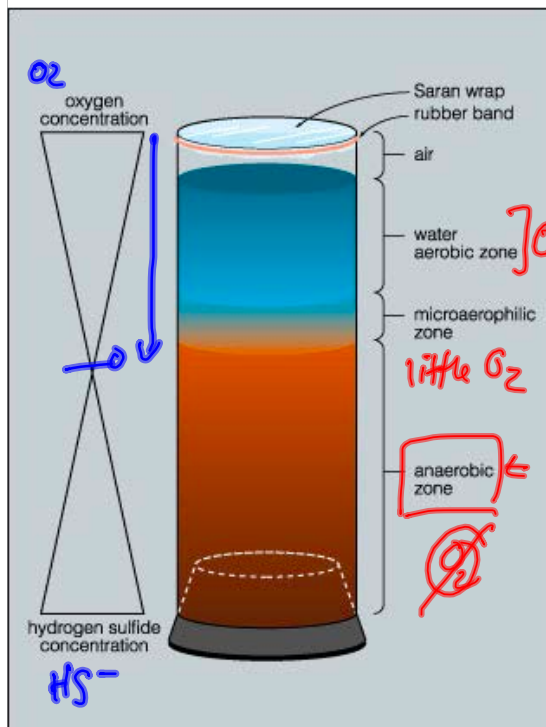
How do microbial communities self organize?

layers



3 Ga
stromatolites

Winogradsky Column:
metabolic stratification
(co-selection by λ , $[O_2]/[HS^-]$)



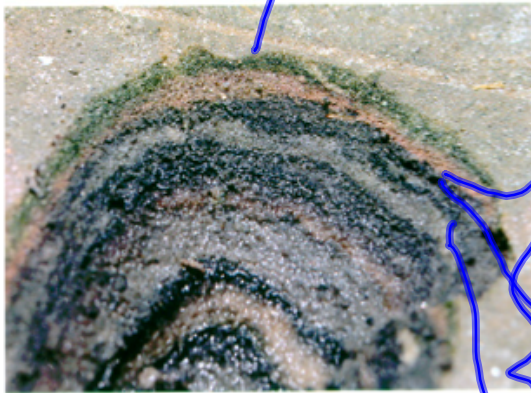
What is the metabolic basis for the layering?

-) Competition for diffusion-limited resources (ex. competitive exclusion)
-) One's waste → another's substrate
-) Dynamic stratifications
→ time & space

Metabolic organization - Sippewissett Salt Marsh

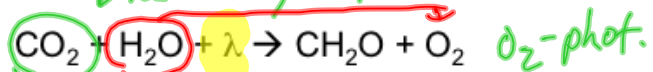
$\bigcirc = e^- \text{ donor}$

$\bigcirc = e^- \text{ acceptor}$

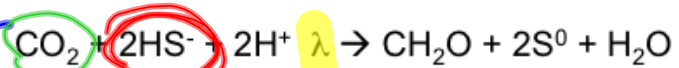


Gold/Green

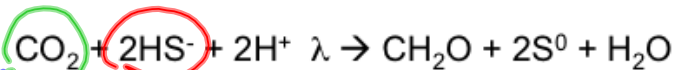
Diatoms, Cyanobacteria



Purple sulfur bacteria

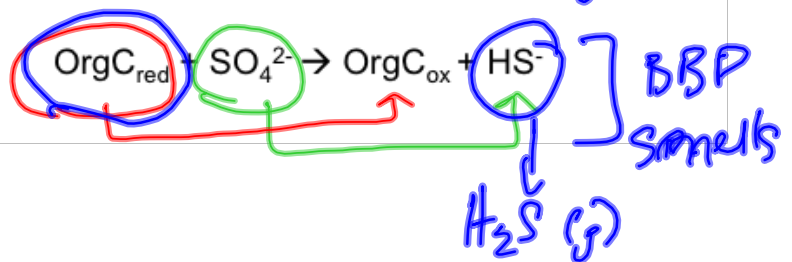


Green sulfur bacteria

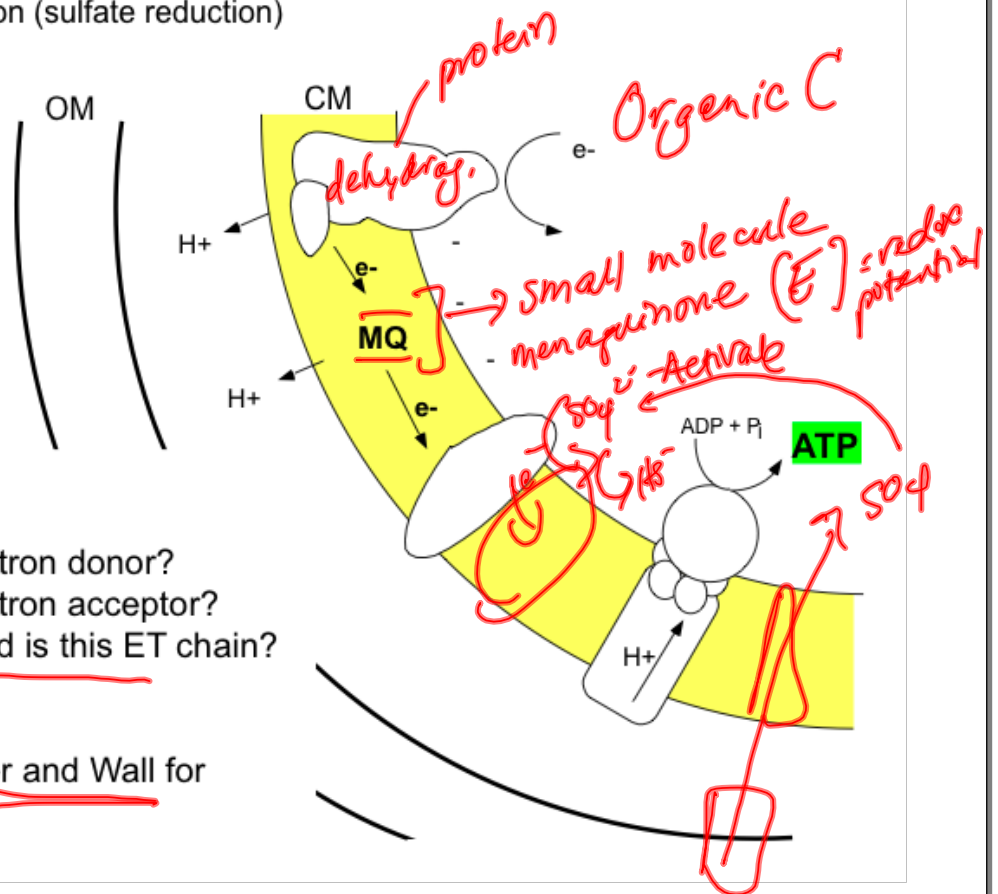


"anoxygenic
photosyn."

Black → Sulfate-reducing bacteria



Anaerobic respiration (sulfate reduction)



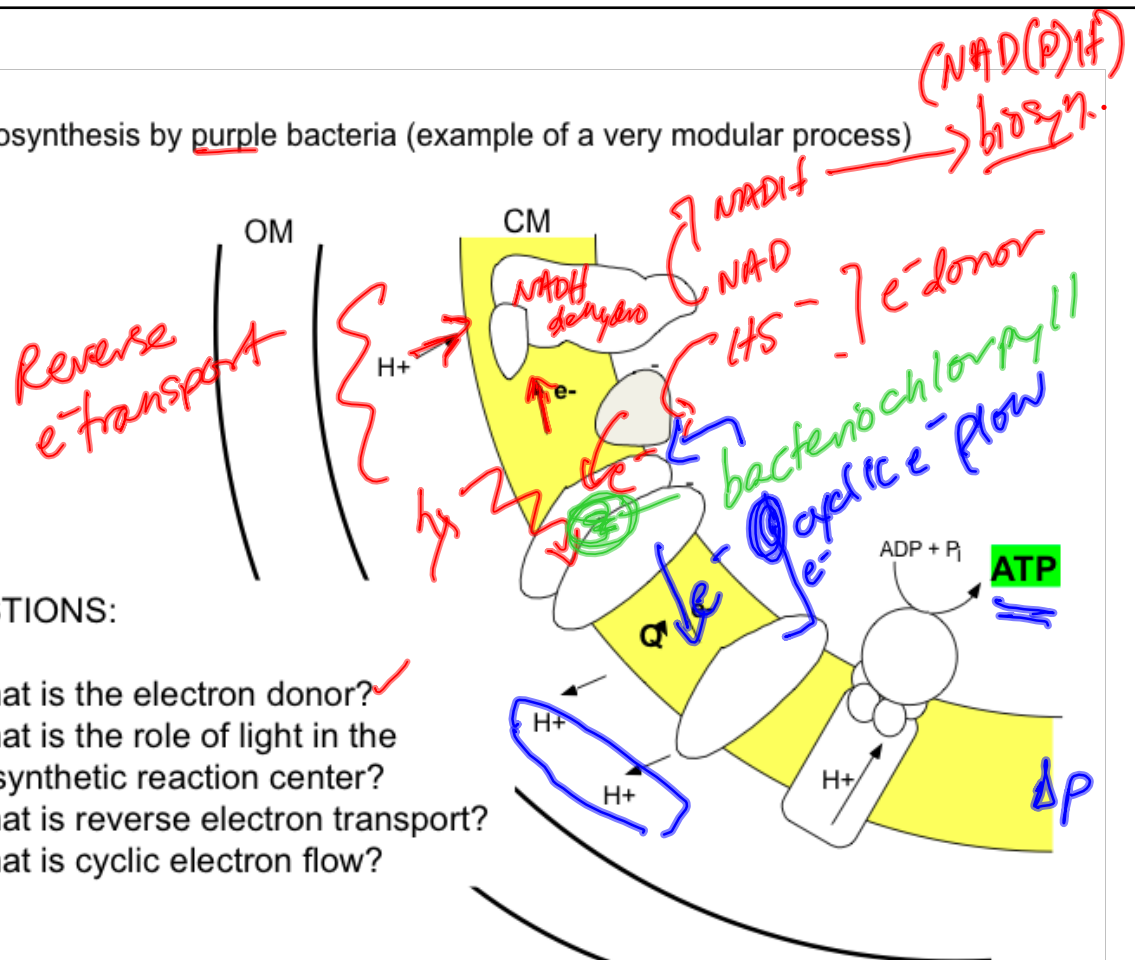
QUESTIONS:

- 1) What is the electron donor?
- 2) What is the electron acceptor?
- 3) How complicated is this ET chain?

very

See article by Keller and Wall for details

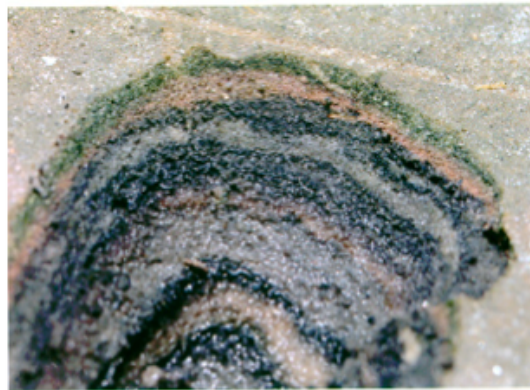
Photosynthesis by purple bacteria (example of a very modular process)



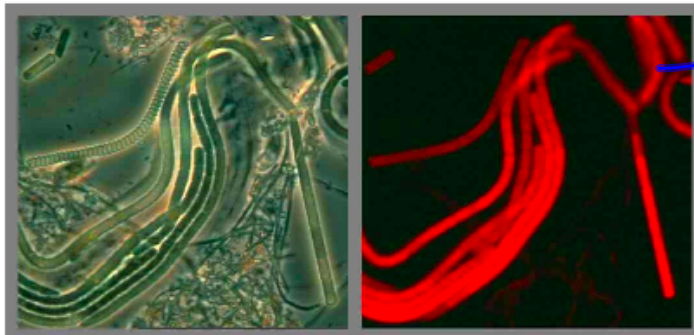
QUESTIONS:

- 1) What is the electron donor? ✓
- 2) What is the role of light in the photosynthetic reaction center?
- 1) What is reverse electron transport?
- 2) What is cyclic electron flow?

What are the biochemical underpinnings
of the layering?

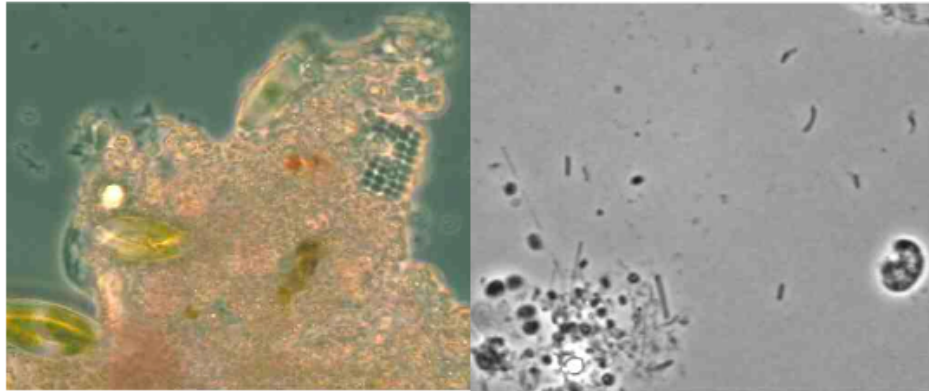


Upper green layer: filamentous cyanobacteria/ red = autofluorescence of light-harvesting pigments

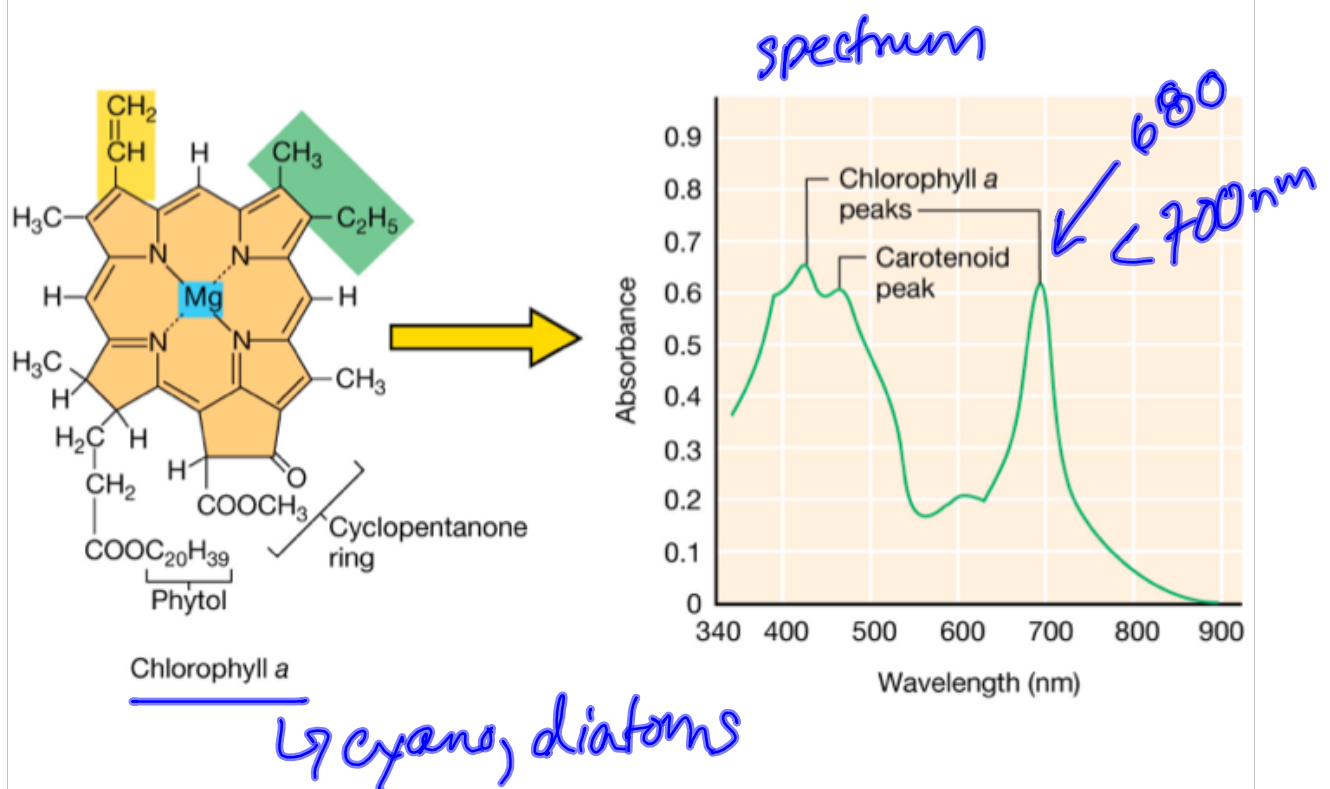


Purple layer: purple sulfur bacteria

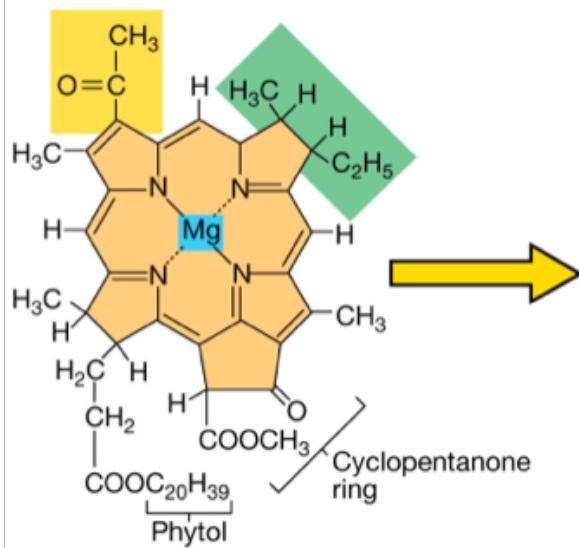
Black layer: sulfate reducers



Biochemical organization – light absorbing pigments in cyanos/diatoms

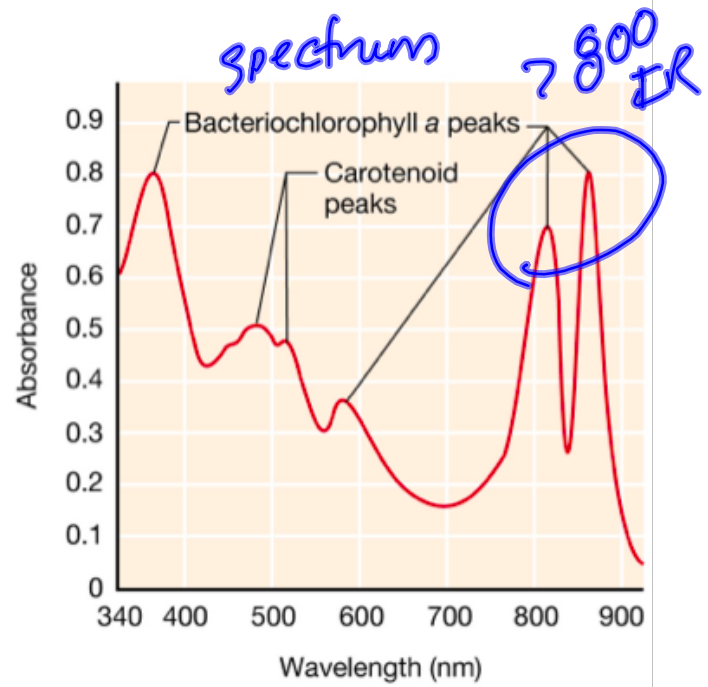


Biochemical organization – light absorbing pigments in purple sulfur bacteria

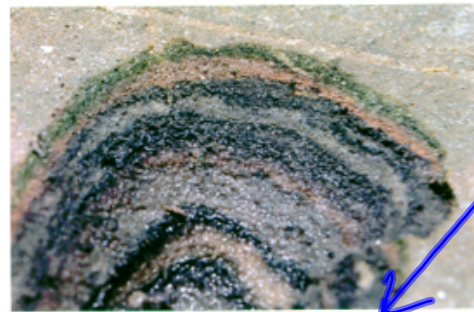
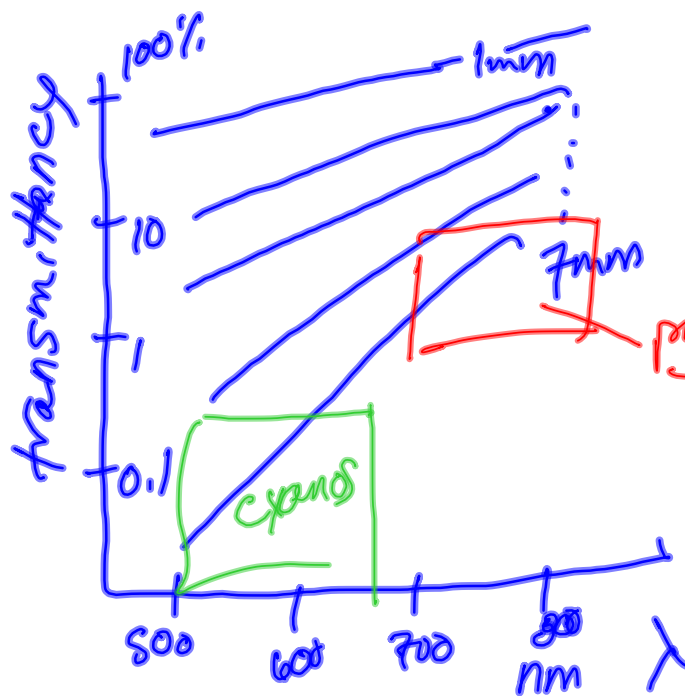


Bacteriochlorophyll a

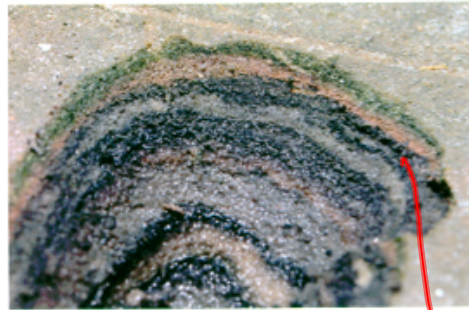
→ purple bacteria



What happens to light in sand?



Differences in sulfide tolerance

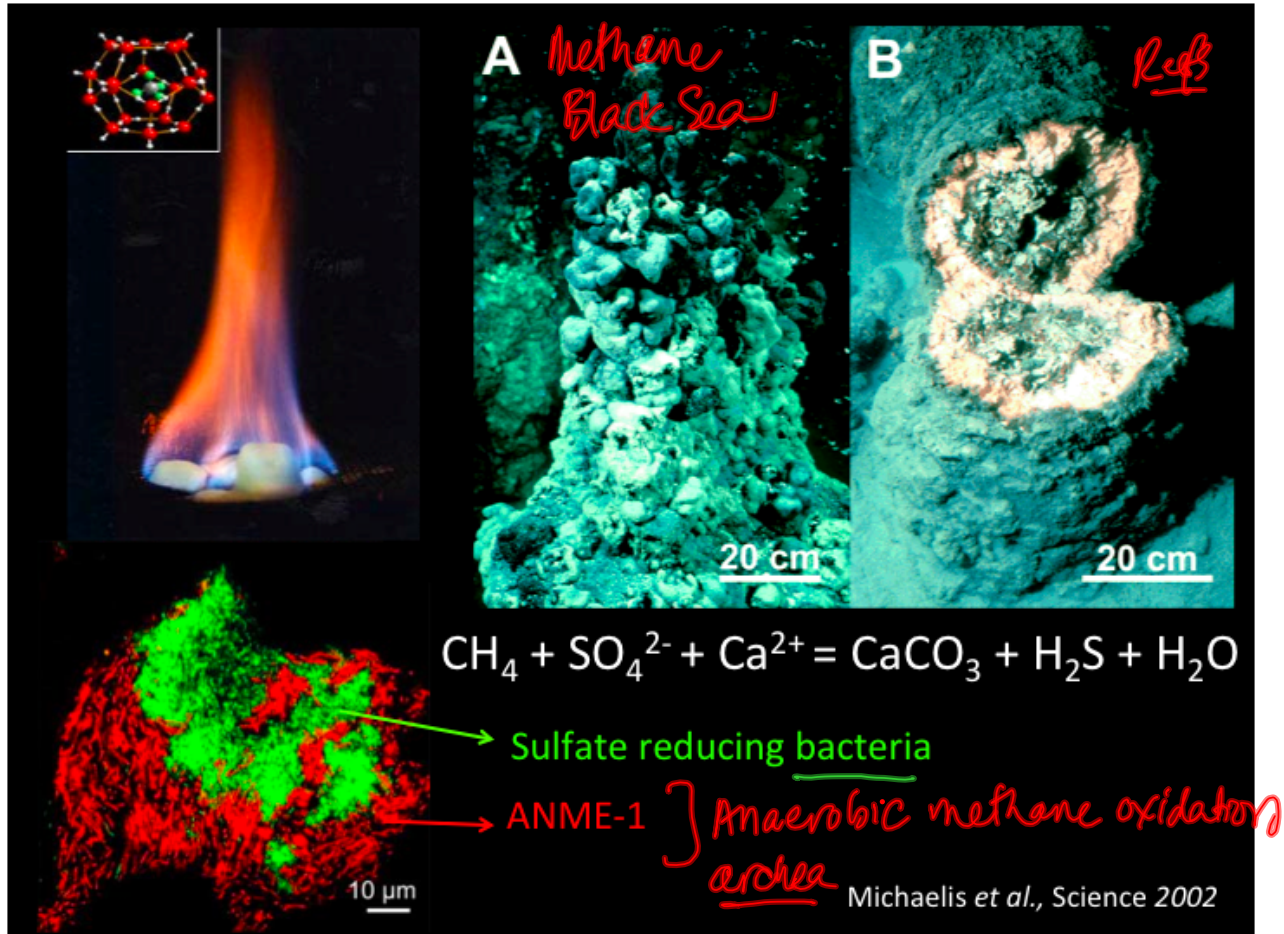


Victoria Orphan
iClicker } nanosIMS

Thermodynamic and kinetic underpinnings

(one cell's waste is another's lunch)

We will work this out mathematically next time



SUMMARY

MICROBES COLLAPSE THE HIERARCHY!



What behaviors do microbial communities engage in?

- *Cooperative, competitive, altruistic, cheating, predatory*
- *They talk to each other*
- *Predatory behaviors (such as viral infection) drive evolution (DNA liberation and uptake)*



Why are microbes where they are?

Ecological theories still in development:

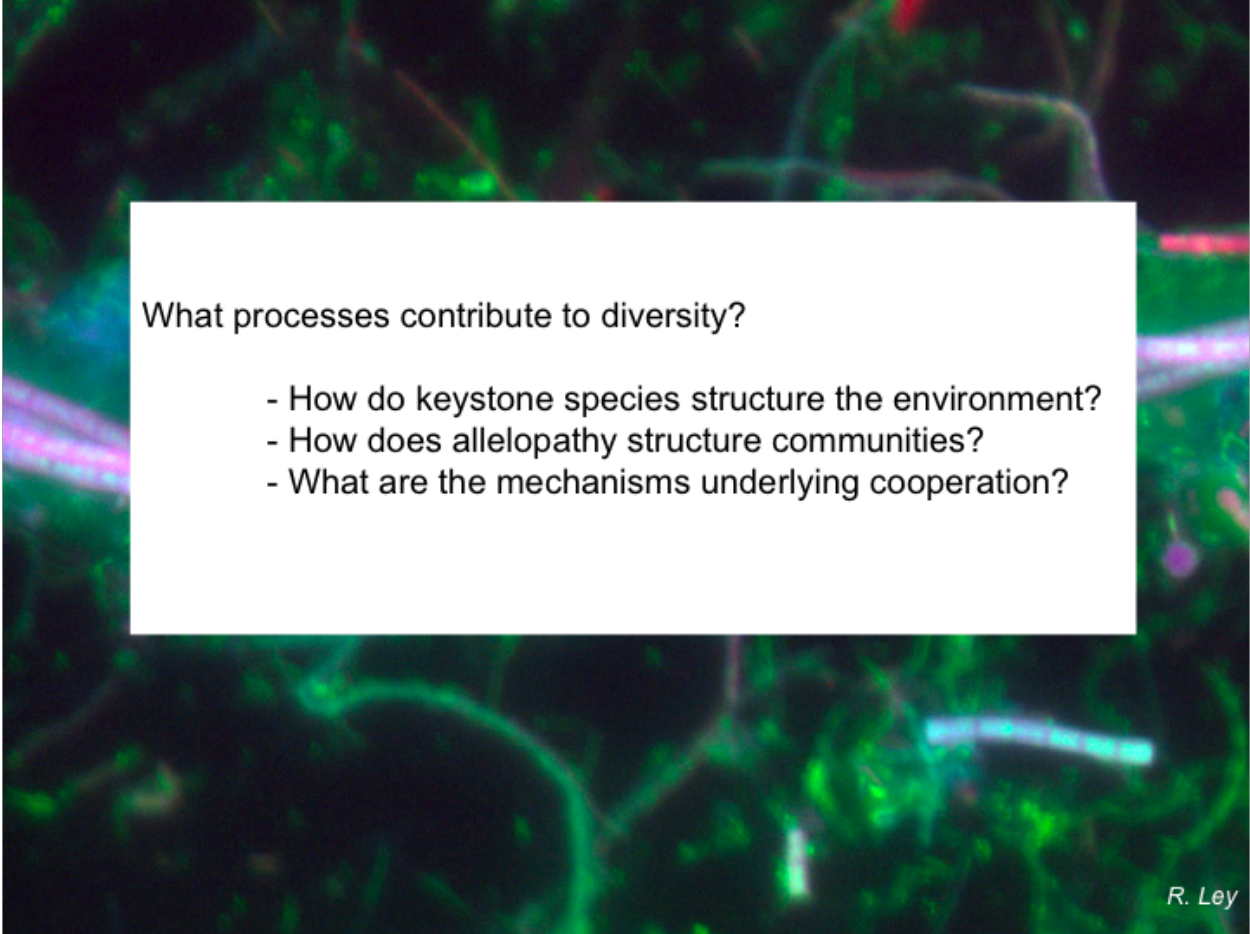
Niche assembly vs. dispersal limitation & stochasticity

What structures microbial communities?

*Metabolism! (Competition for substrates and/or cooperation
★) where one cell's waste becomes another's substrate)*

“If I could do it all over again, and relive my vision in the 21st century, I would be a microbial ecologist. Ten billion bacteria live in a gram of ordinary soil, a mere pinch held between thumb and forefinger. They represent thousands of species, almost none of which are known to science. Into that world I would go with the aid of modern microscopy and molecular analysis. I would cut my way through clonal forests sprawled across grains of sand, travel in an imagined submarine through drops of water proportionately the size of lakes, and track predators and prey in order to discover new life ways and alien food webs. All this, and I need venture no farther than ten paces outside my laboratory building. The jaguars, ants, and orchids would still occupy distant forests in all their splendor, but now they would be joined by an even stranger and vastly more complex living world virtually without end.”

- E.O. Wilson, *The Naturalist*

A fluorescence microscopy image of plant roots, likely from a legume, showing green and red fluorescent signals. The roots are dark, with bright green and red spots indicating specific cellular structures or processes. A white rectangular box is overlaid on the image, containing text.

What processes contribute to diversity?

- How do keystone species structure the environment?
- How does allelopathy structure communities?
- What are the mechanisms underlying cooperation?

R. Ley

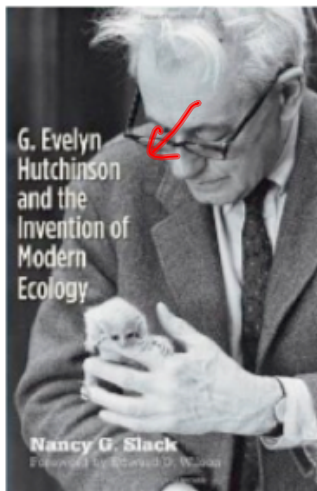
Species interactions: Predation, competition and cooperation

What controls biological diversity in ecosystems?

Diversity – the # of different species in a system
1) species richness – count
2) " evenness – how equal

Niche – how an organism makes a living

A given environment will have a certain diversity, dependent upon the number of niches available in that habitat.



WHAT DETERMINES
DIVERSITY

ND Slack, 2011

Abiotic features affect the number of niches available.

Low



DIVERSITY



High



Within a location, what biotic features determine diversity?

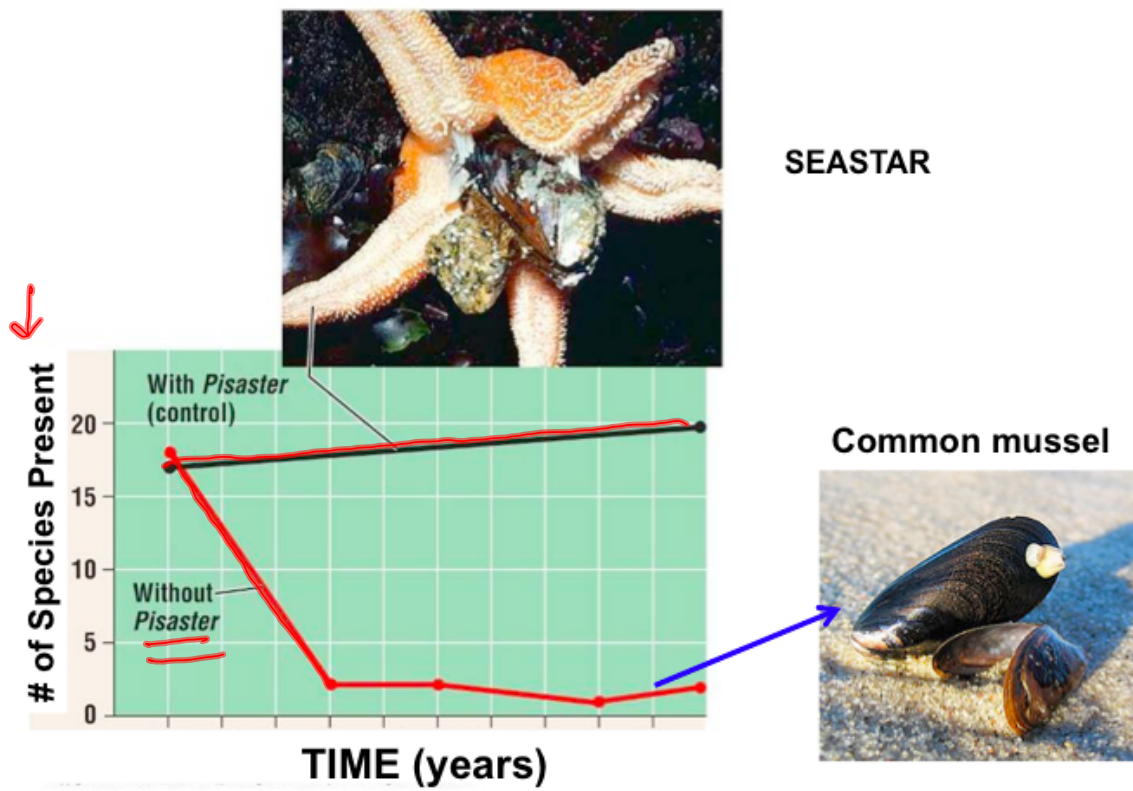
Keystone species = a species that has a disproportionately large effect on its environment relative to its abundance.



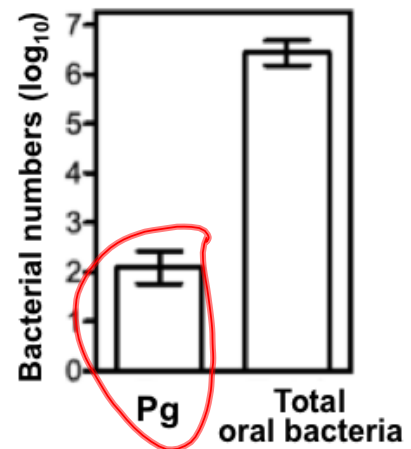
Robert Paine
U Washington

SEASTAR
(*Pisaster*
***ochraceus*)**

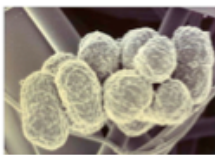




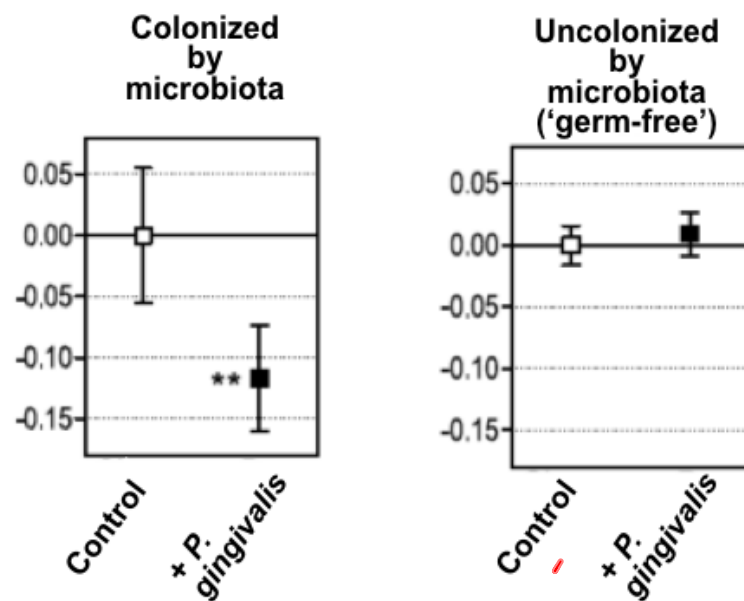
Porphyromonas gingivalis



The bacterium *Porphyromonas gingivalis* is a **keystone species** in the mammalian oral cavity.

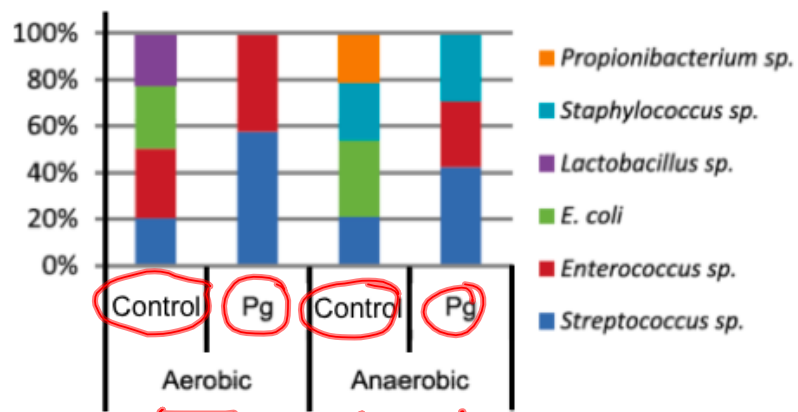


mm change in bone

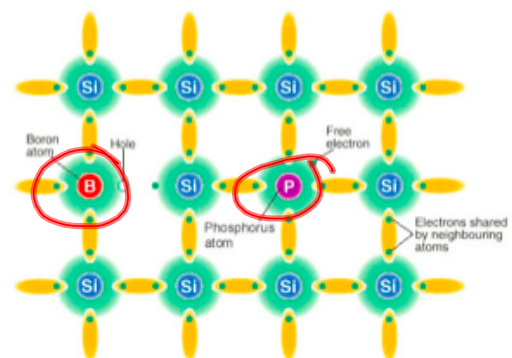
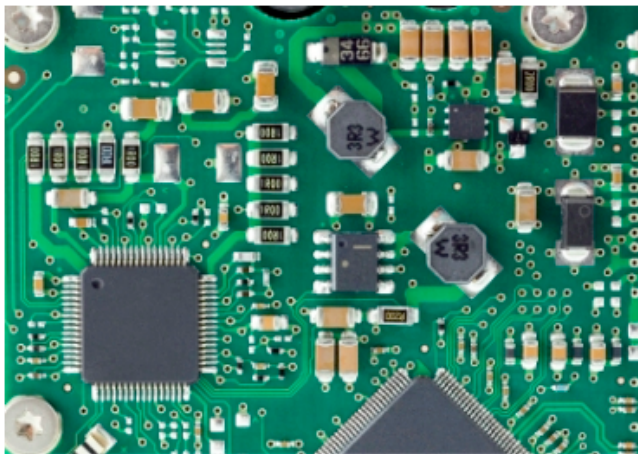


Hajishengallis et al. (2011) *Cell Host & Microbe* 10, 497.

Pg
Δ the composition of a consortium

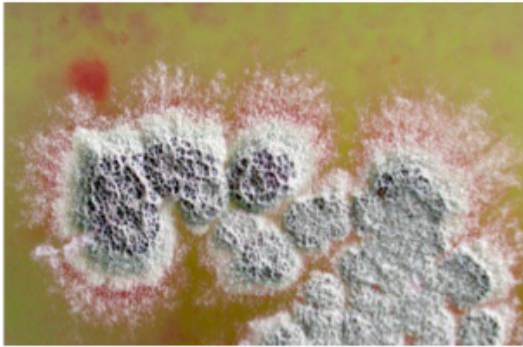


Like the materials used in the doping a semiconductor
(*doping* - the introduction of impurities to change electrical properties)



Allelopathy

— products of biochemical(s) that influence growth, survival, + reproduction of other organisms



Streptomyces coelicolor
(antibiotic undecylprodigiosin)

A strategy in:

competition for space + resources

Creosote bush – desert southwest - selection to minimize competition for water

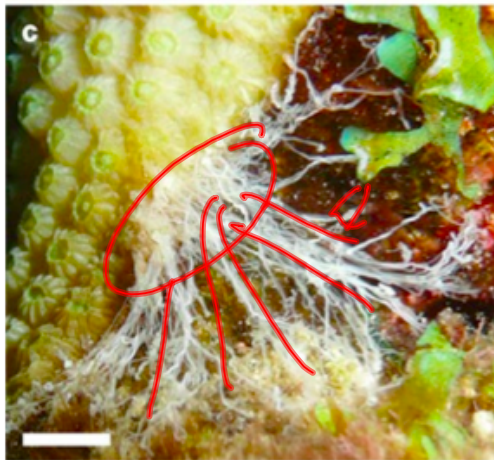
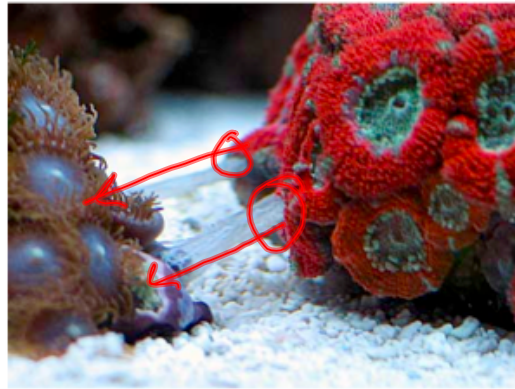


Mature creosote allelopathic toward:

*seedlings
other creosotes*

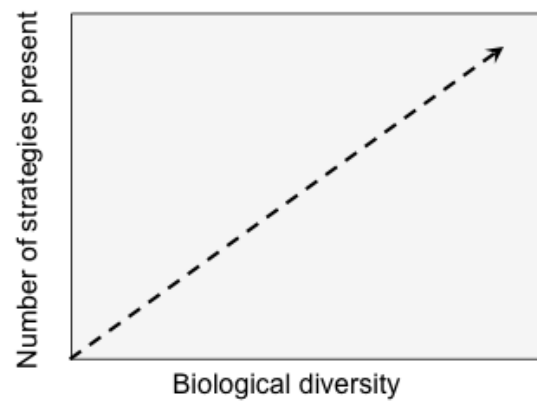
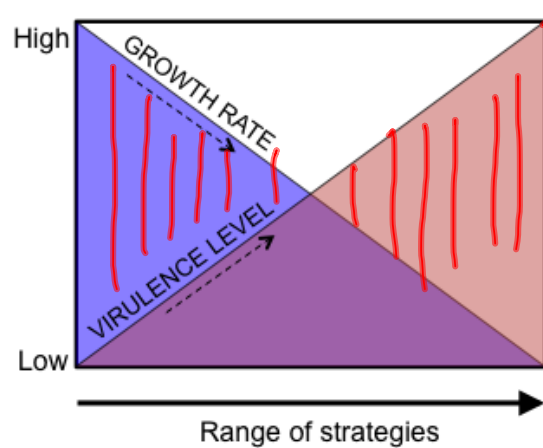


HOW IS THIS DIVERSITY MAINTAINED? –

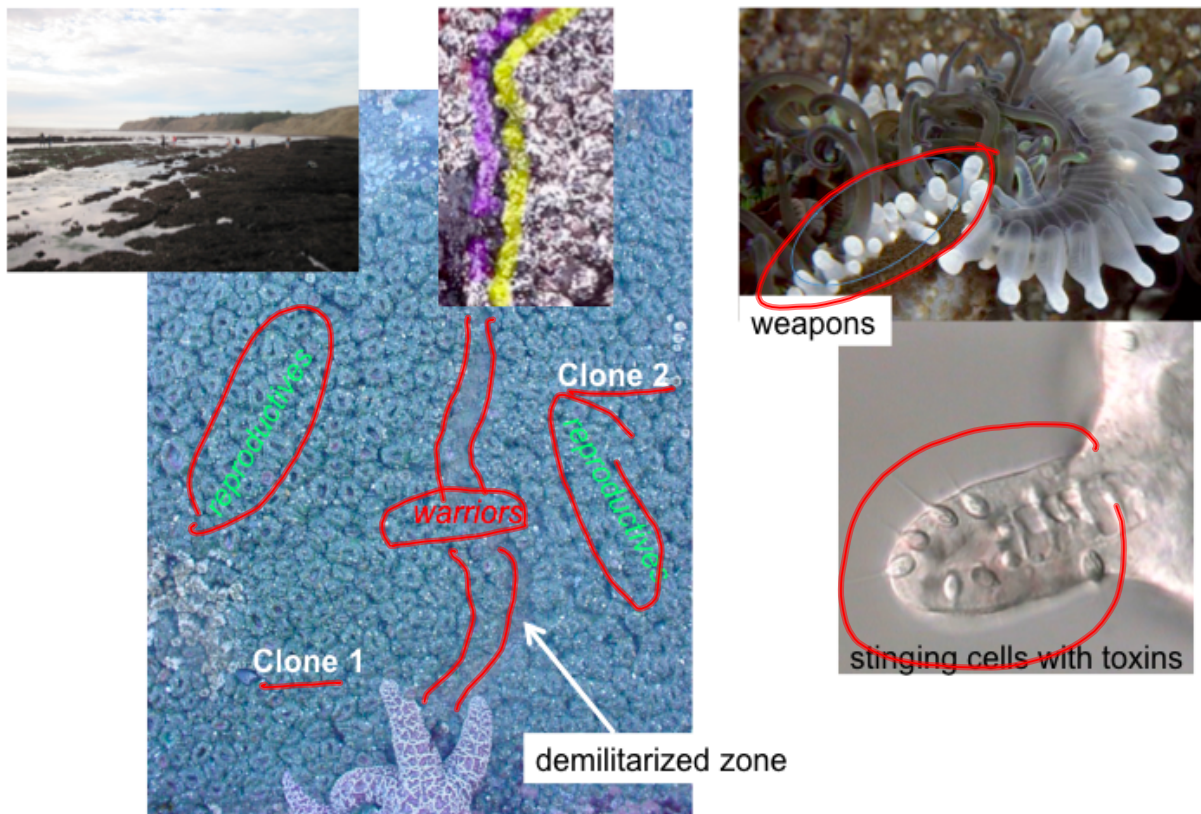


Growth
vs
virulence

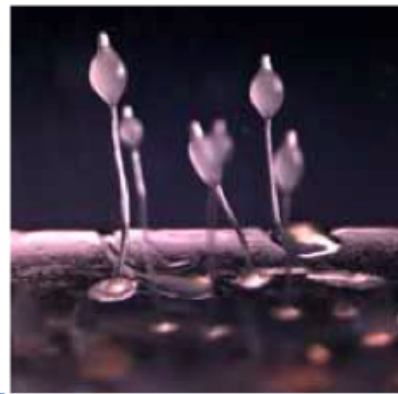
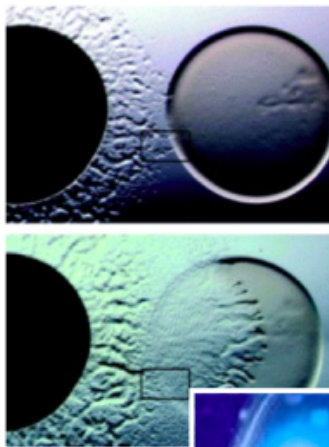
2 activities
- growth (g)
- virulence (v)
inversely related



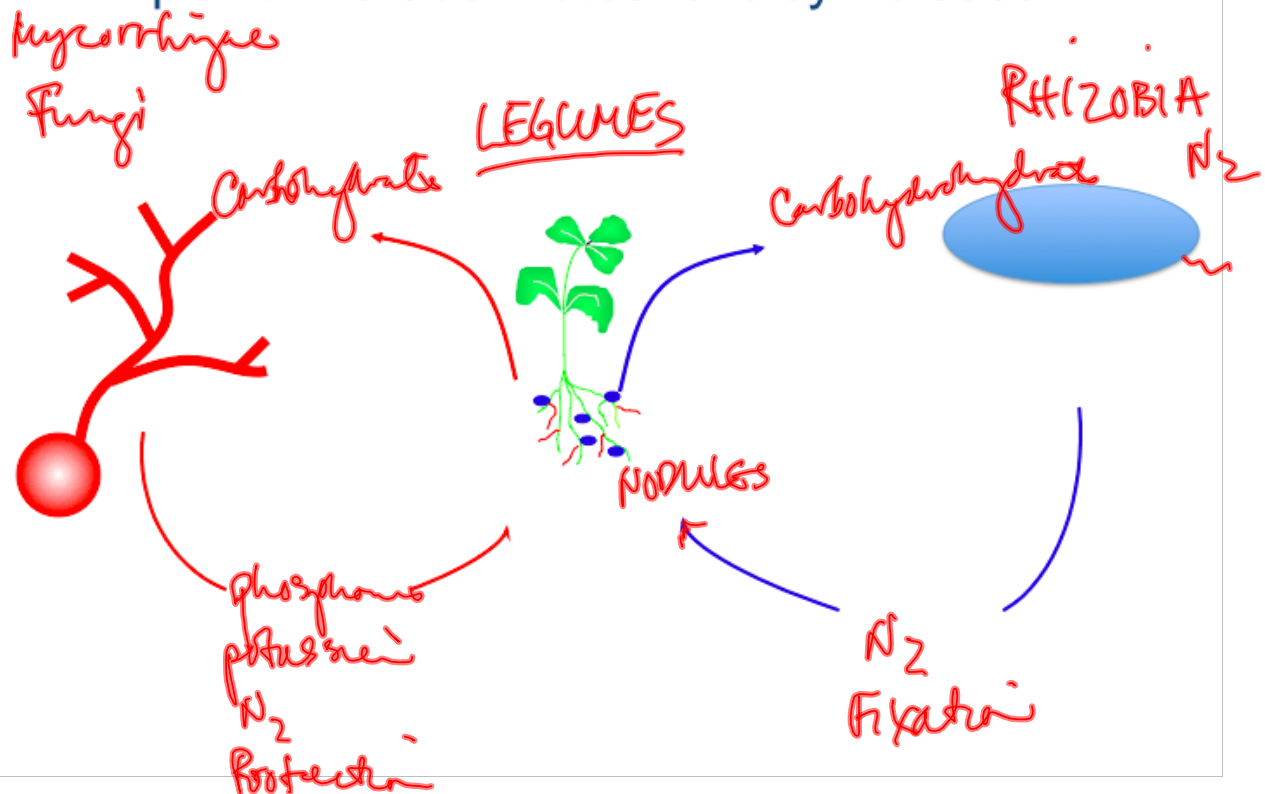
Structuring also occurs among clones of the same species:
e.g., California intertidal anemone



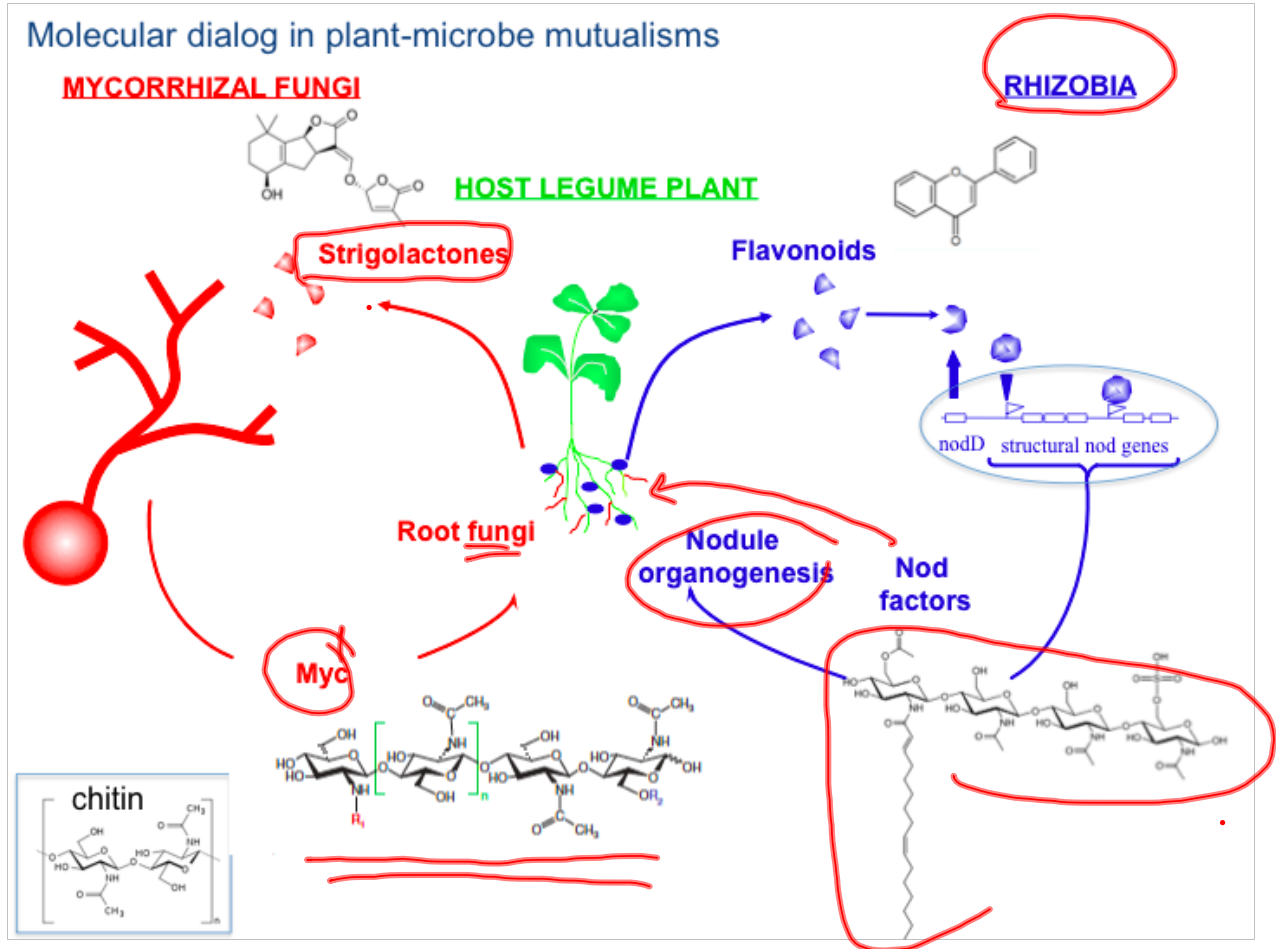
COOPERATION –



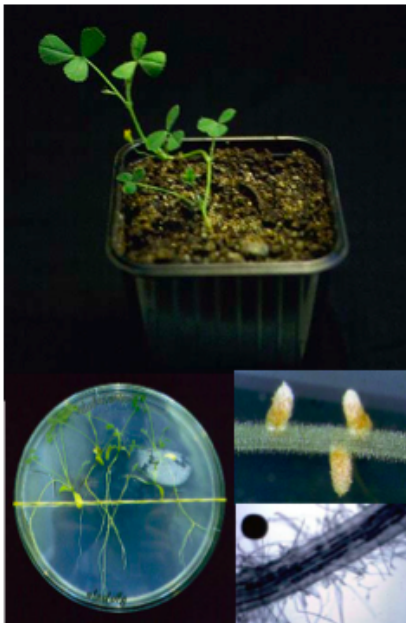
Cooperation - the economics of plant-microbe mutualistic symbioses



Molecular dialog in plant-microbe mutualisms



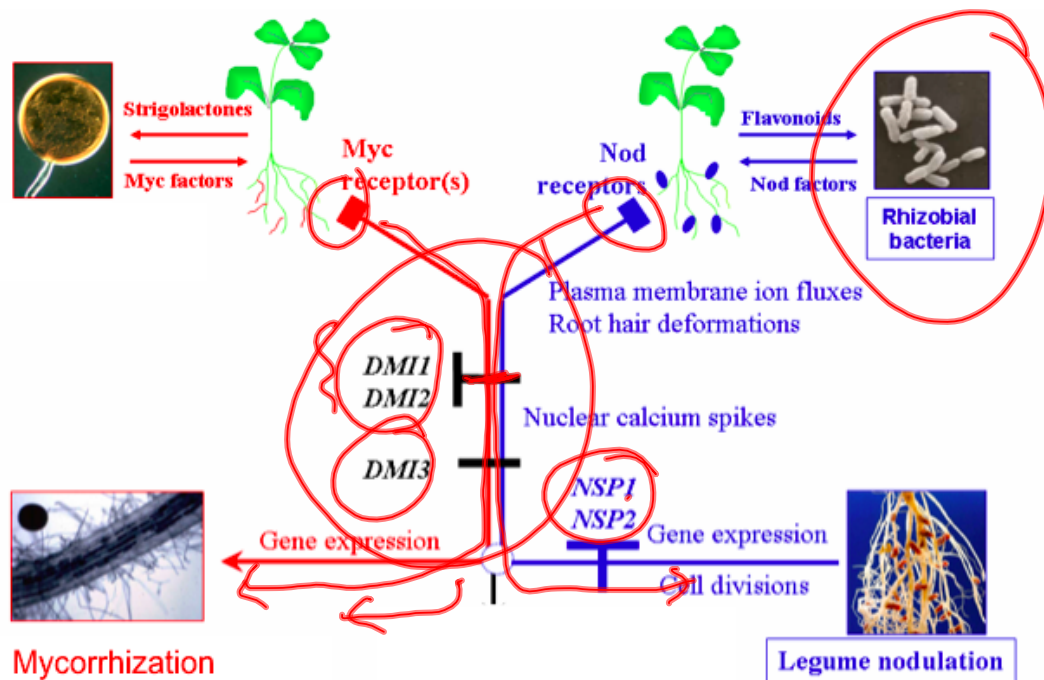
Primary strategies for identifying plant symbiotic genes



- Genes regulated during symbiotic development
- Genes required for nodulation and endomycorrhization
(defined by mutants)

Signaling in plant – microbe symbioses

Fungal and bacterial symbionts share pathways



LIVING WITH OTHERS: POPULATIONS AND COMMUNITIES

DKN

1. Resources (recycling) How does metabolism shape microbial communities?
2. Communication - What non-metabolic processes are also important - chemical communication (b/w different bacteria), viruses...

Break

MMN

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iClicker Quizzes

R. Ley

