

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

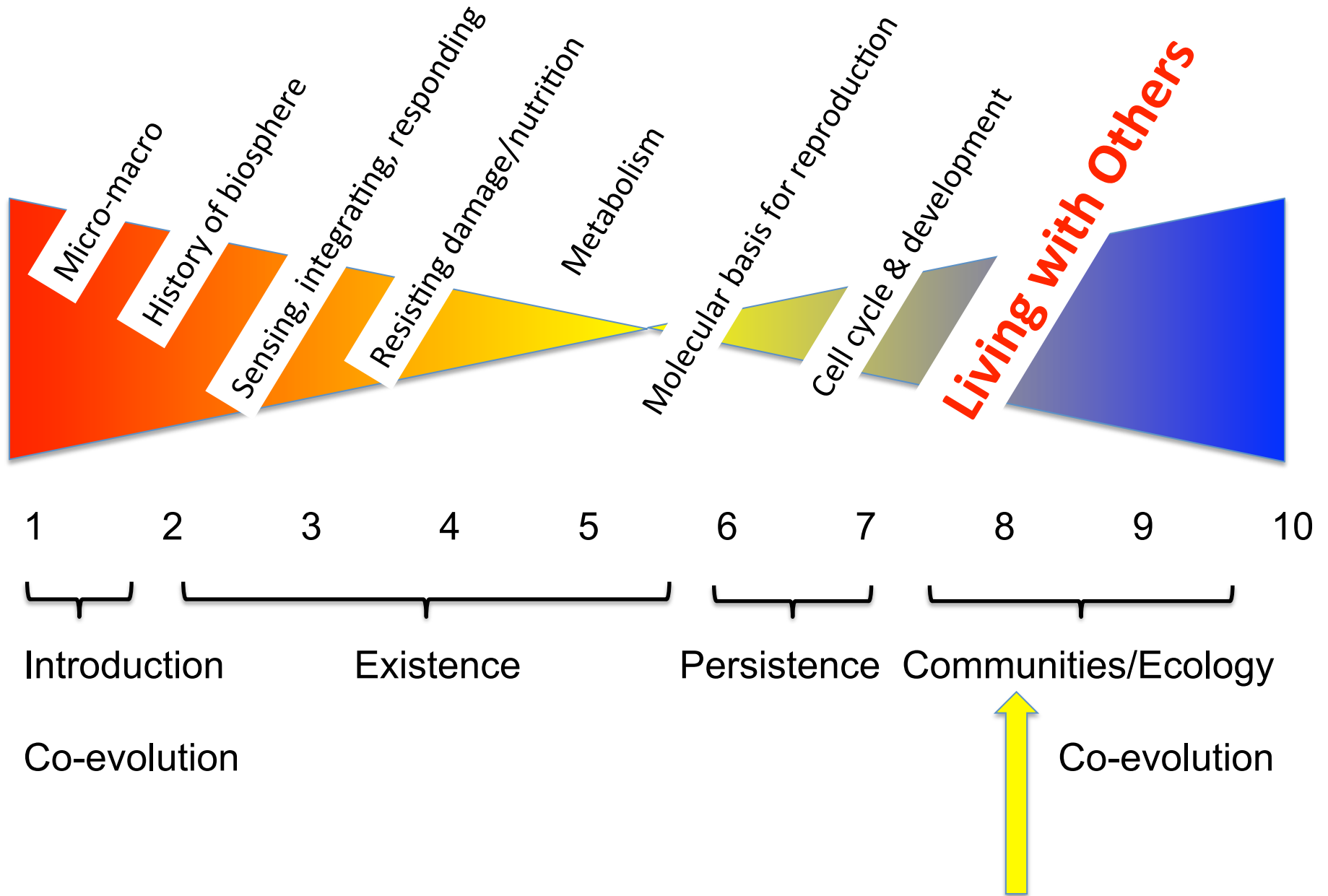
MMN

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?

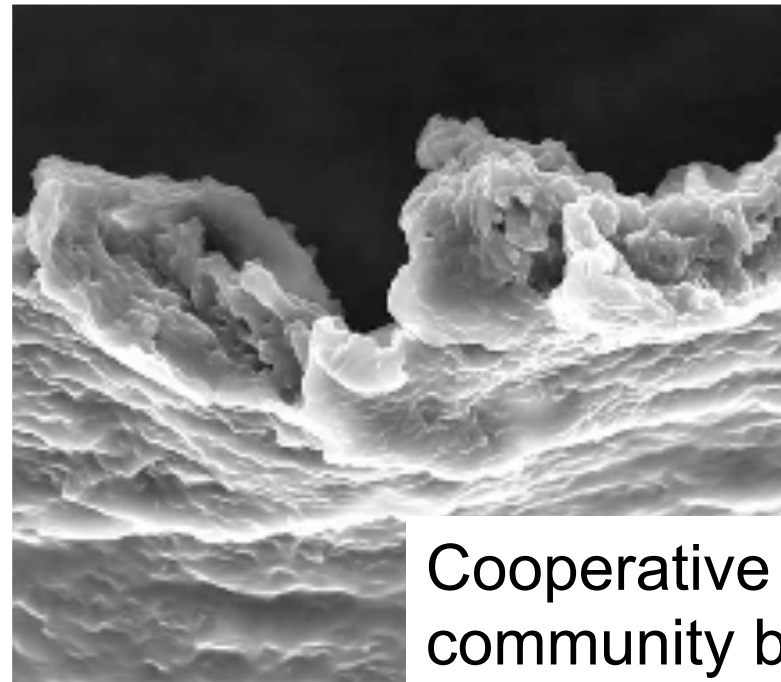
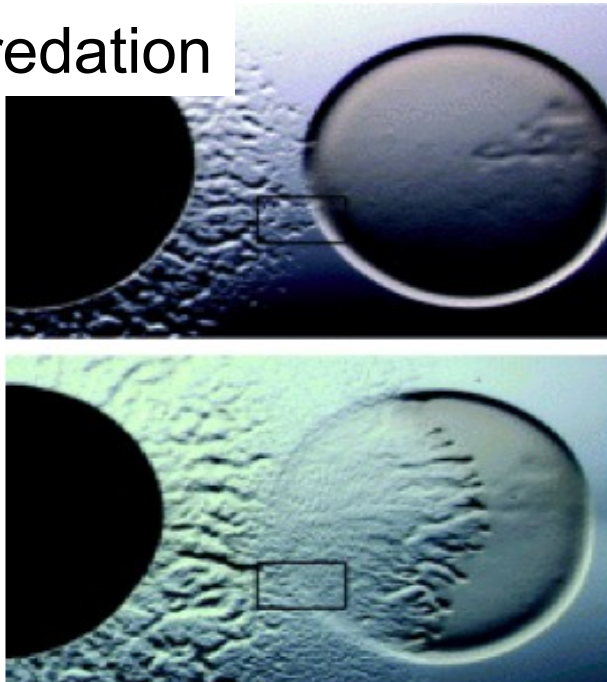
iClicker quizzes

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

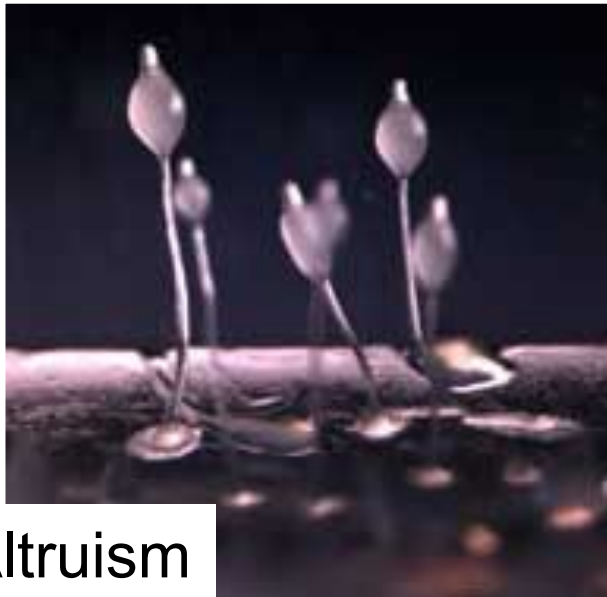


What behaviors do microbial communities engage in?

Predation



Cooperative
community building



Altruism



Talking & Cheating

QS
→ Virulence
Factors

→ Useful
Factors
(Fe acquisition)

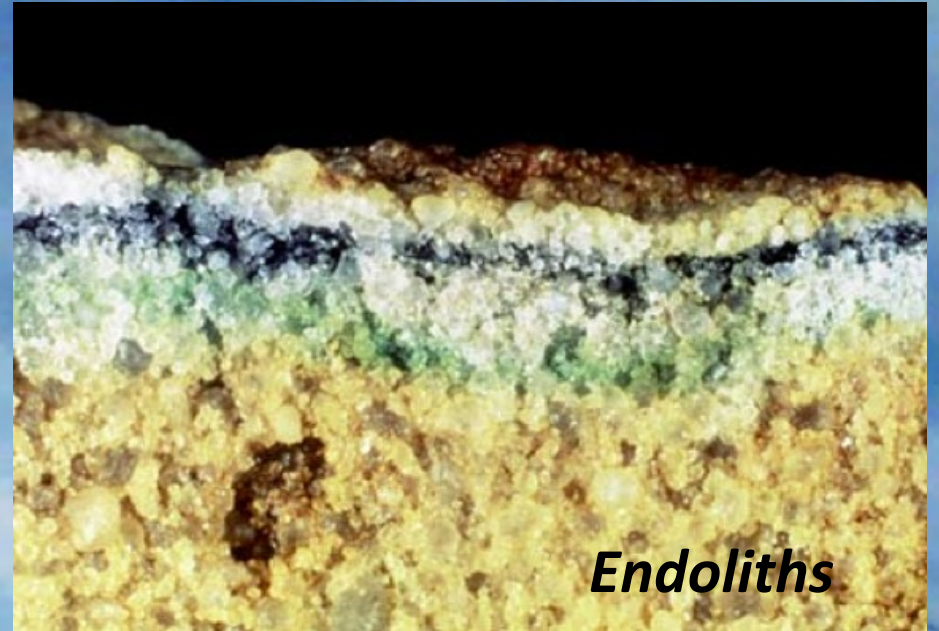
Why are microbes where they are?

“Everything is everywhere, but the environment selects”

Baas Becking, 1934

- 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]

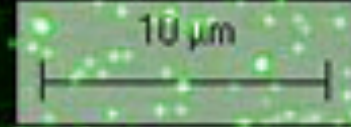
Example 1 (dispersion)



Endoliths

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)



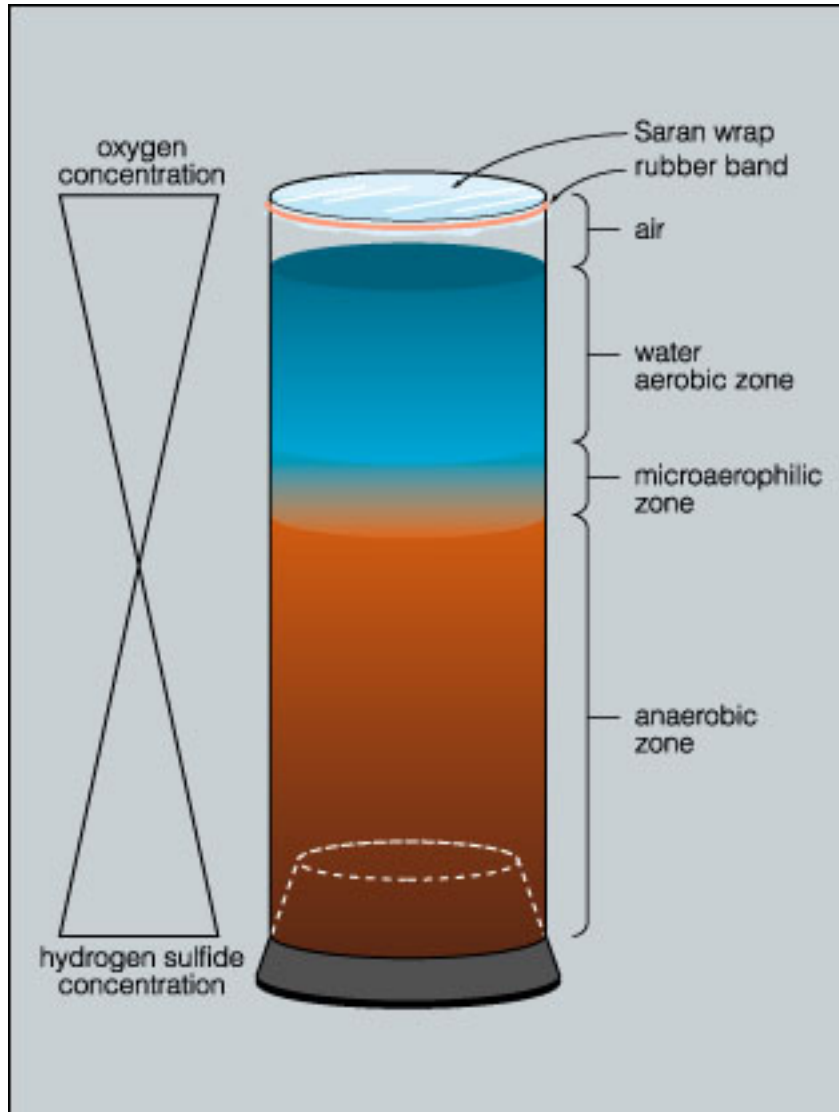
Yellowstone, Dave Ward

How do microbial communities self organize?

Layered communities



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



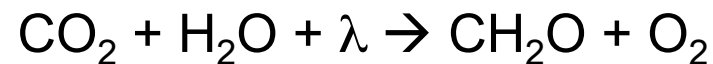
What is the metabolic basis for the layering?

- Competition for resources (diffusion limitation)
- One cell's waste is another's lunch
- Dynamics (diurnal cycles)

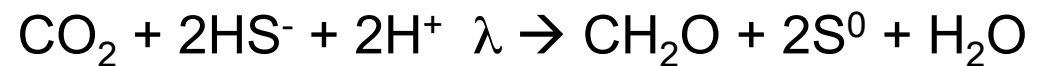
Metabolic organization - Sippewissett Salt Marsh



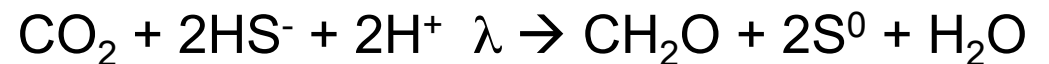
Diatoms, cyanos



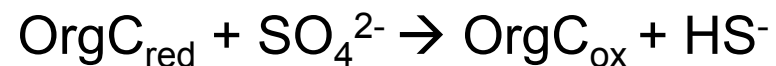
Purple sulfur bacteria



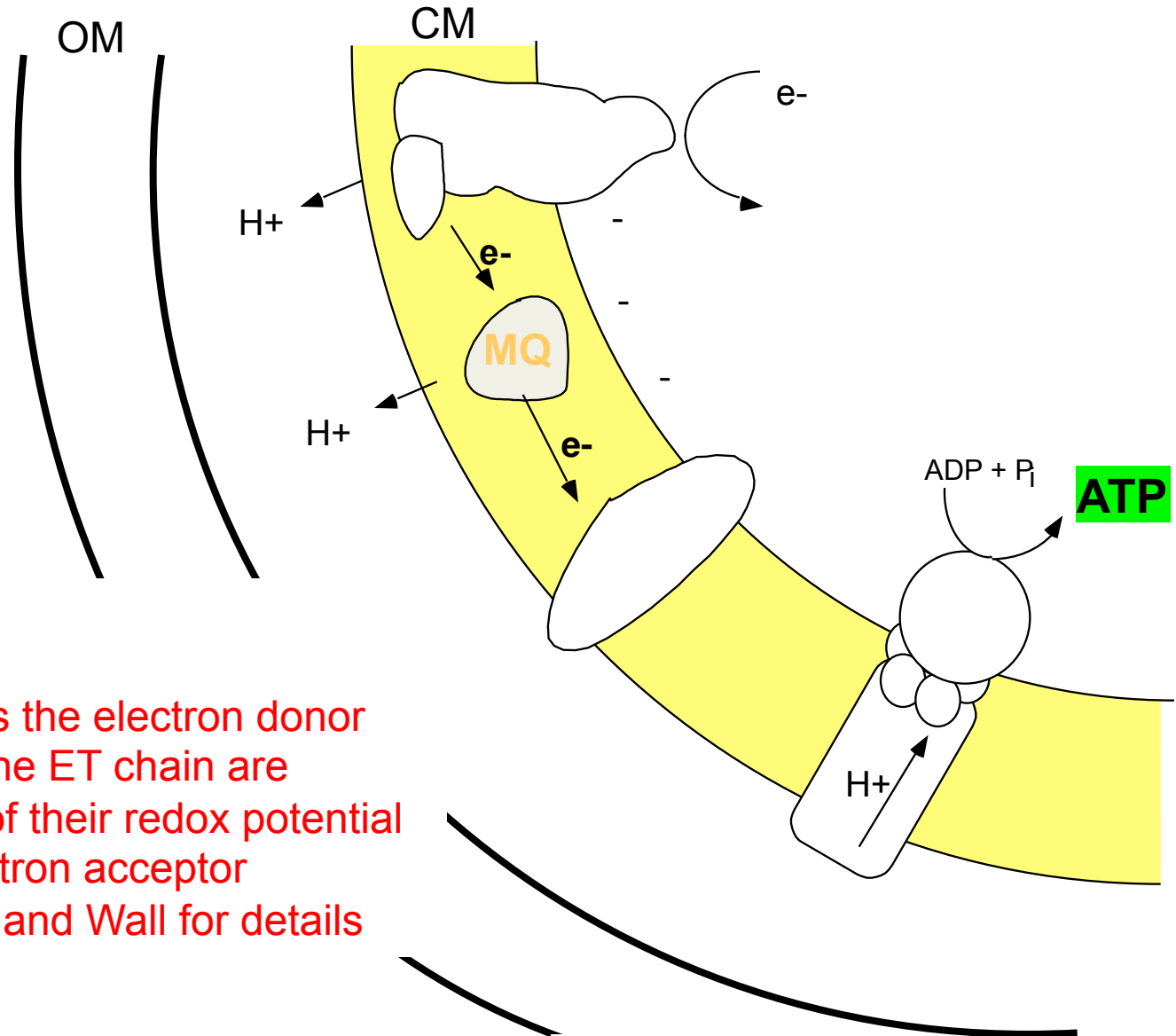
Green sulfur bacteria



Sulfate reducers



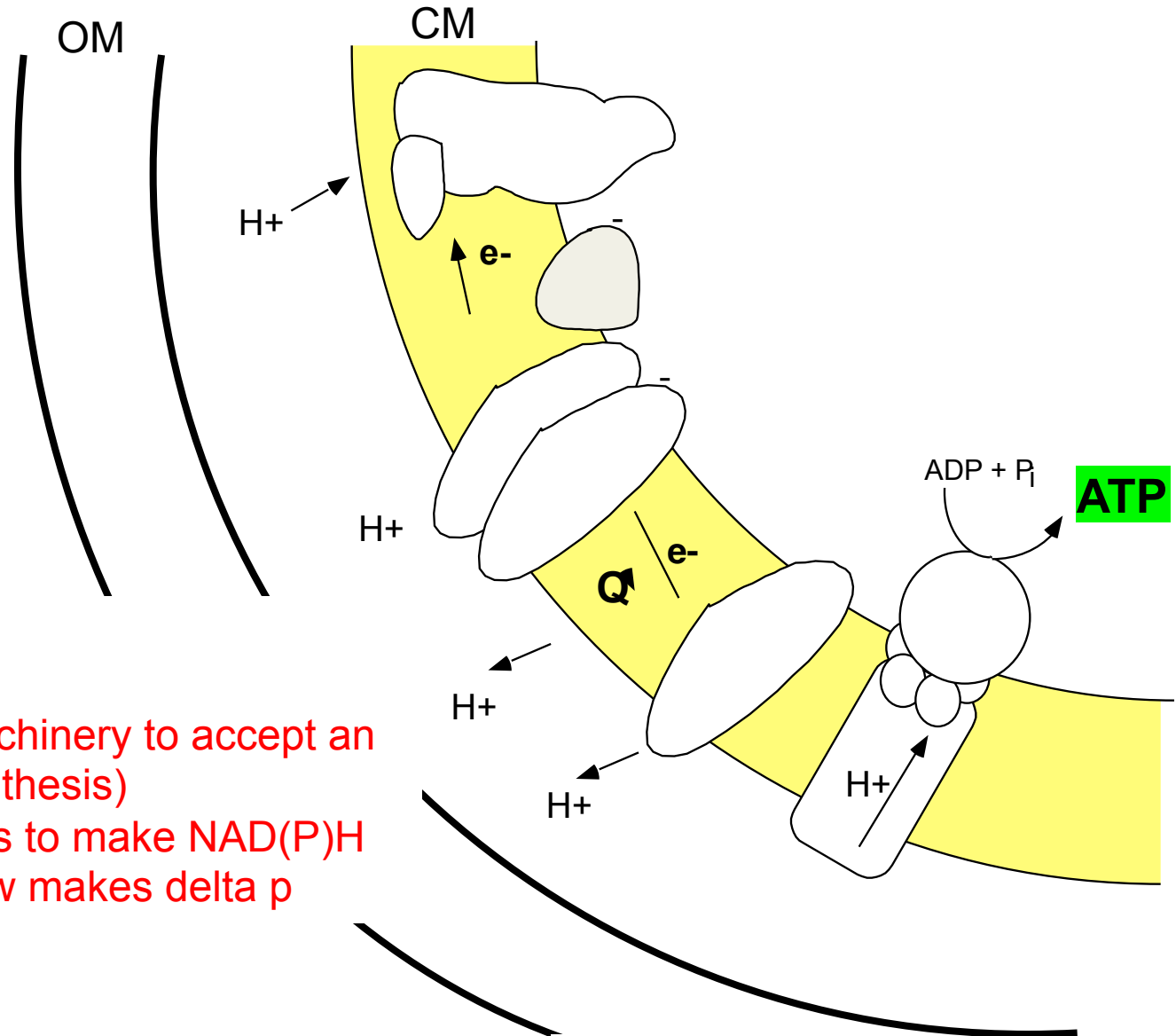
Anaerobic respiration (sulfate reduction)



KEY points:

- 1) Organic carbon is the electron donor
 - 2) Components of the ET chain are optimized in terms of their redox potential
 - 3) Sulfate is the electron acceptor
- See article by Keller and Wall for details

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



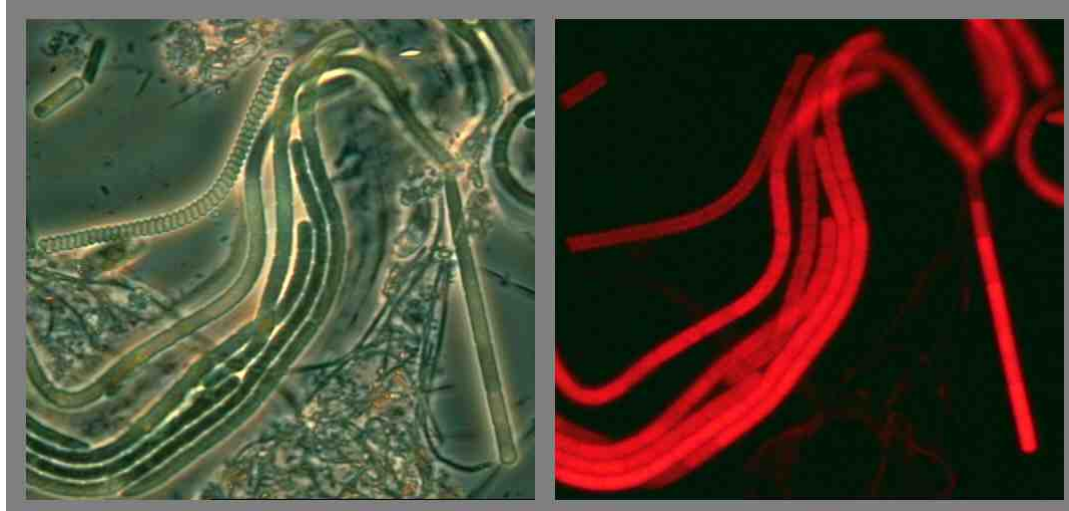
KEY points:

- 1) Light activates machinery to accept an electron (photosynthesis)
- 2) Reverse ET occurs to make NAD(P)H
- 3) Cyclic electron flow makes Δp

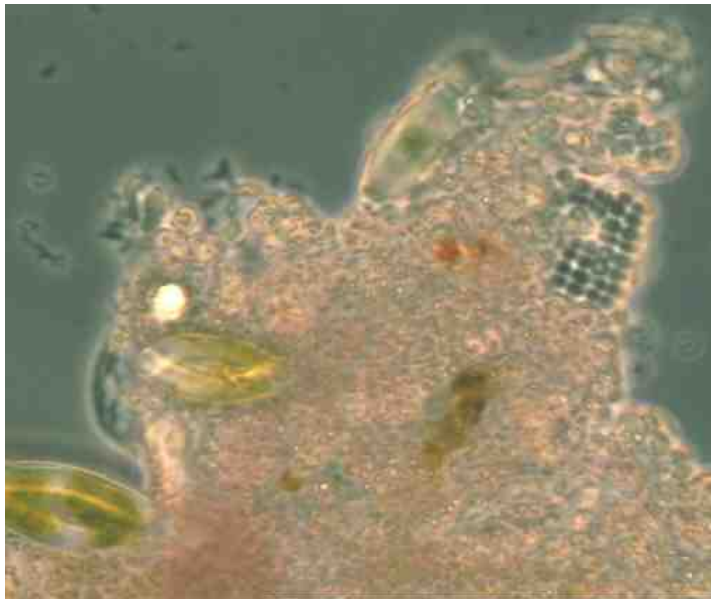
What are the biochemical underpinnings of the layering?



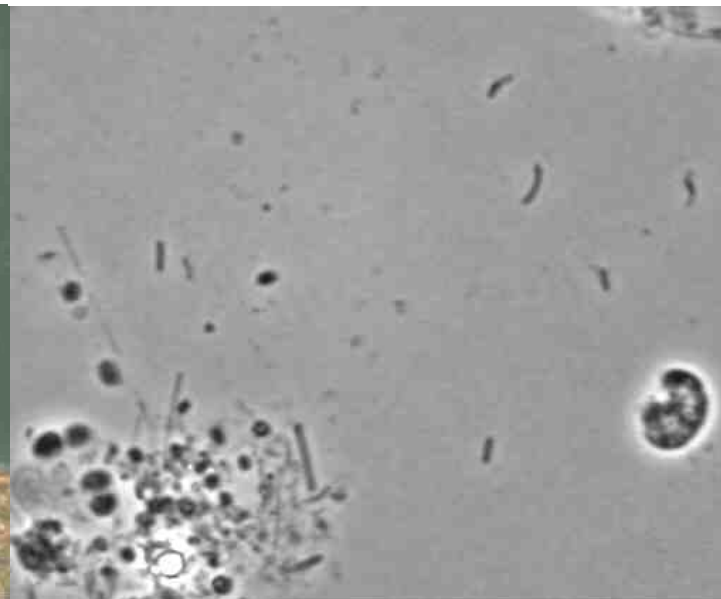
Upper green layer: filamentous cyanobacteria/ red = autofluorescence of light-harvesting pigments



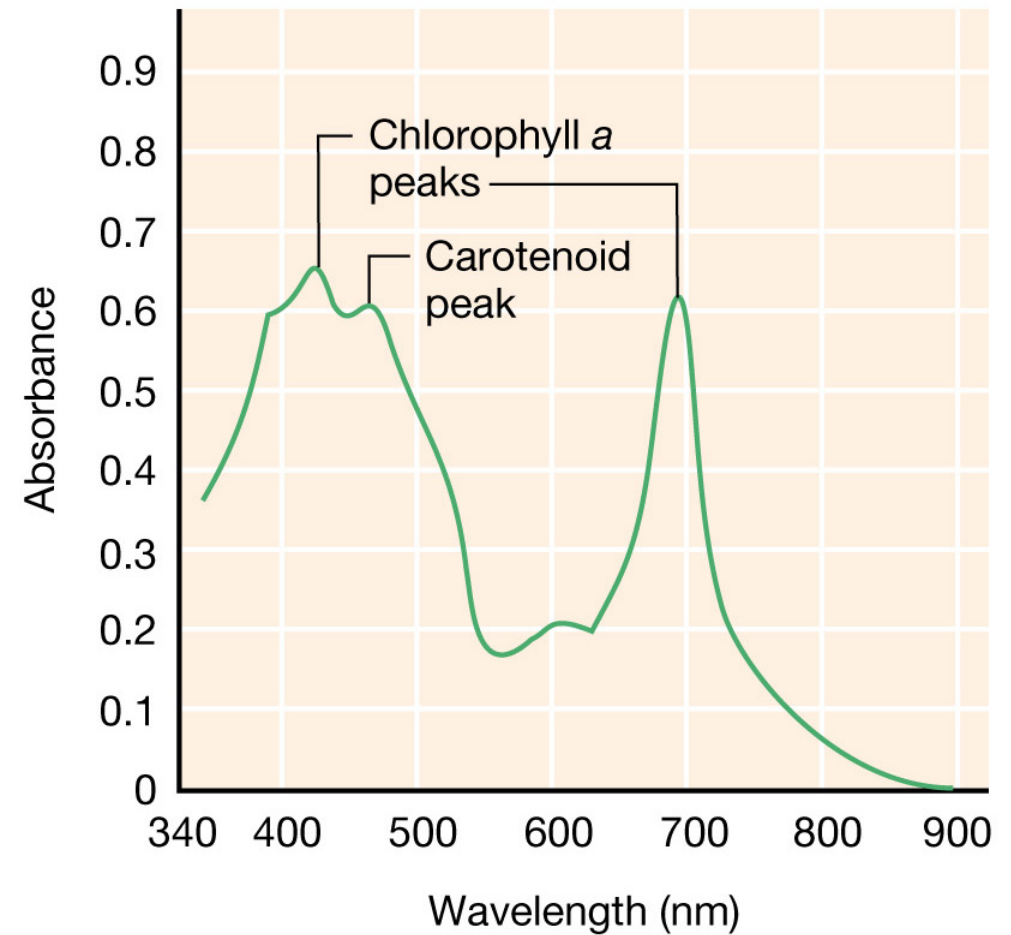
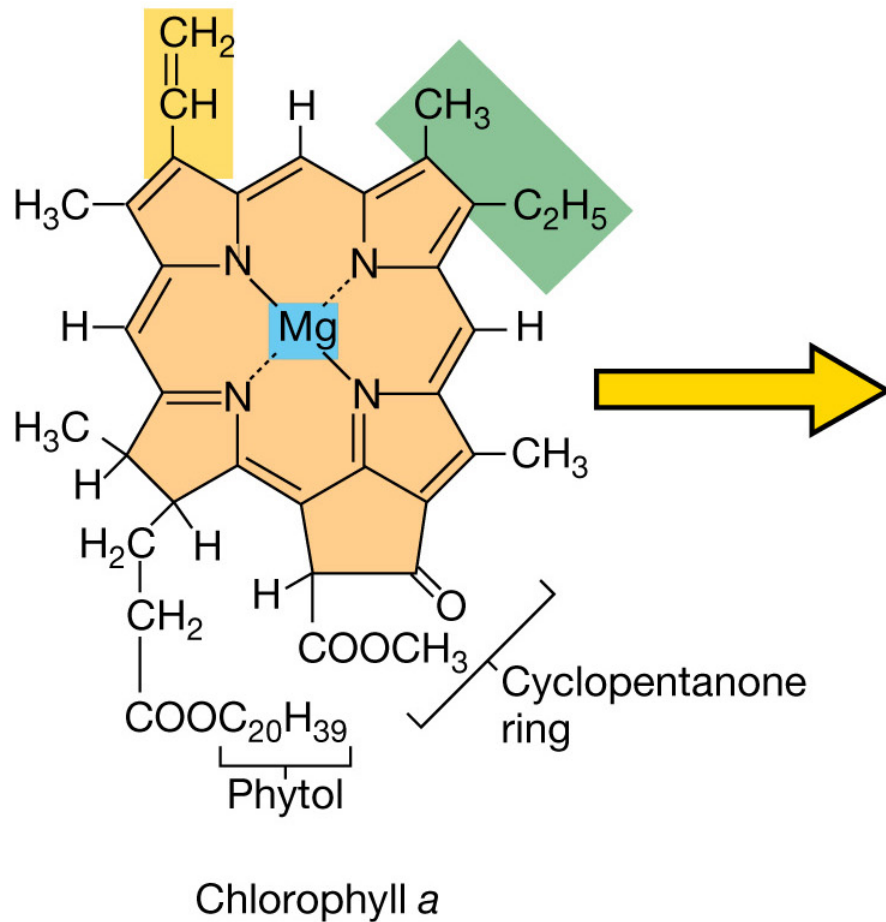
Purple layer: purple sulfur bacteria



Black layer: sulfate reducers

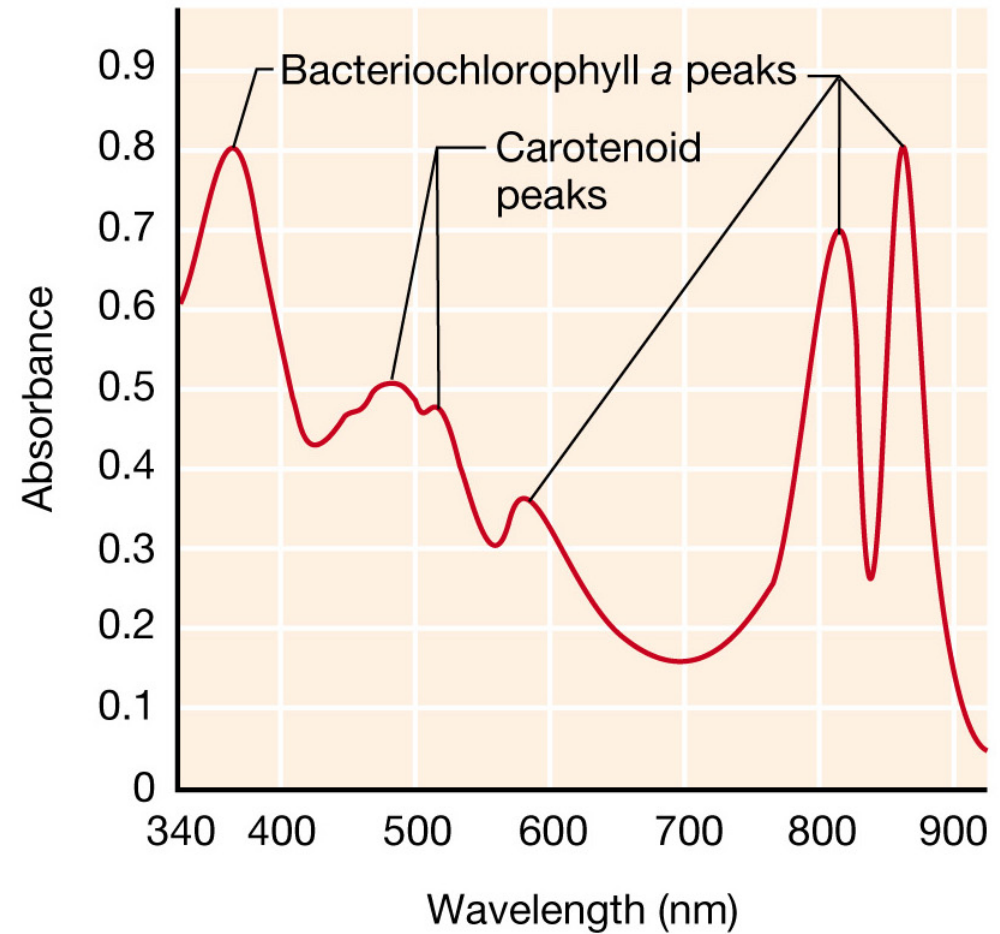
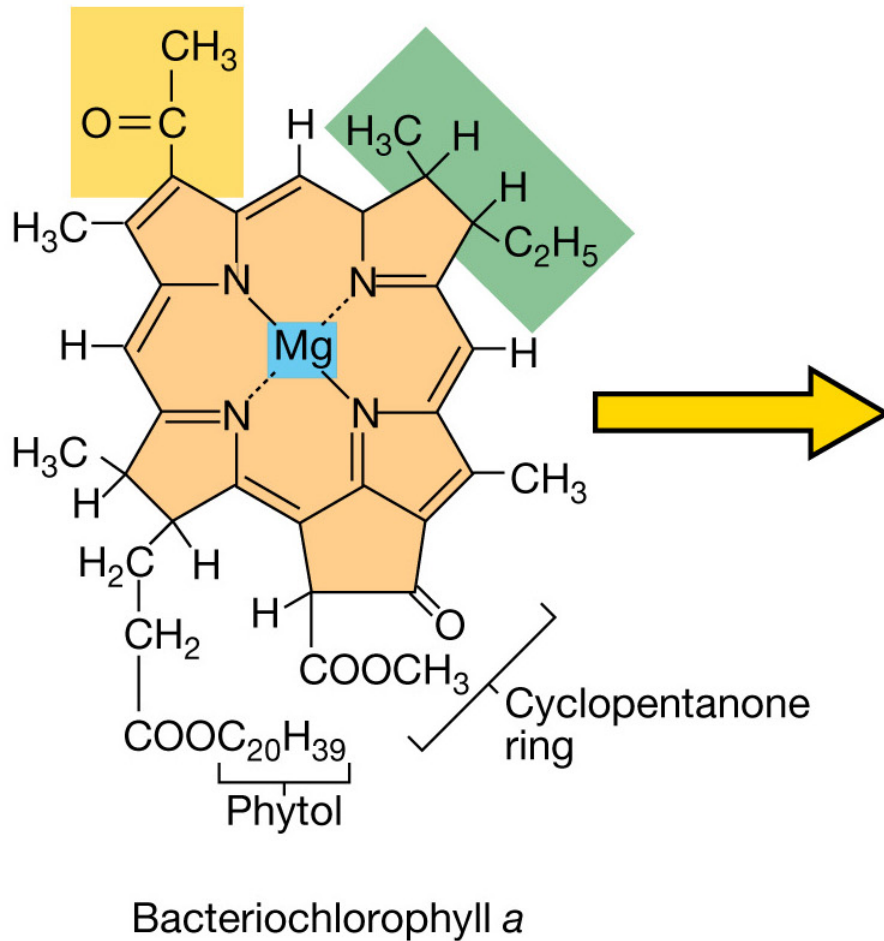


Biochemical organization – light absorbing pigments in cyanos/diatoms



Spectra for Chlorophyll *a* (Cyanos, Diatoms)

Biochemical organization – light absorbing pigments in purple sulfur bacteria



Spectra for Bacteriochlorophyll *a* (Purples)

What happens to light in sand?

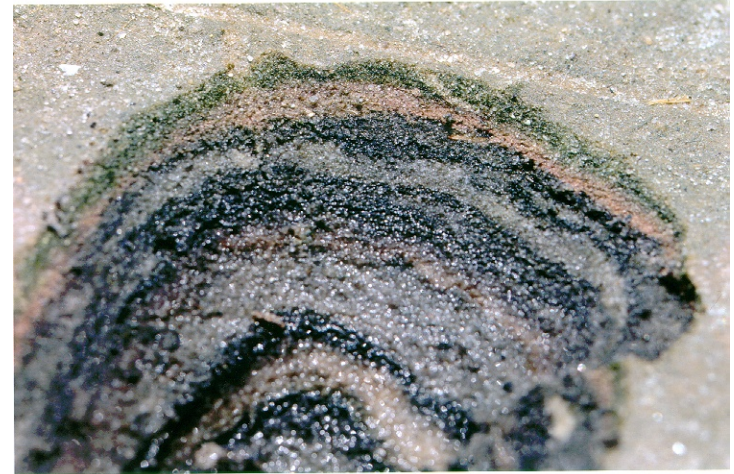


Draw out transmittancy of radation of different wavelengths through sand

TAKE HOME POINTS:

- Shorter wavelengths don't transmit very deeply
- Only longer (IR) wavelengths get down below a couple mm depth
- The photosynthetic machinery in the different phototrophs is optimized to absorb maximally in different regions, that coincide with where light of those wavelengths penetrate

Differences in sulfide tolerance

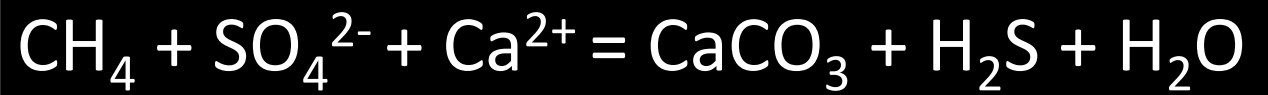
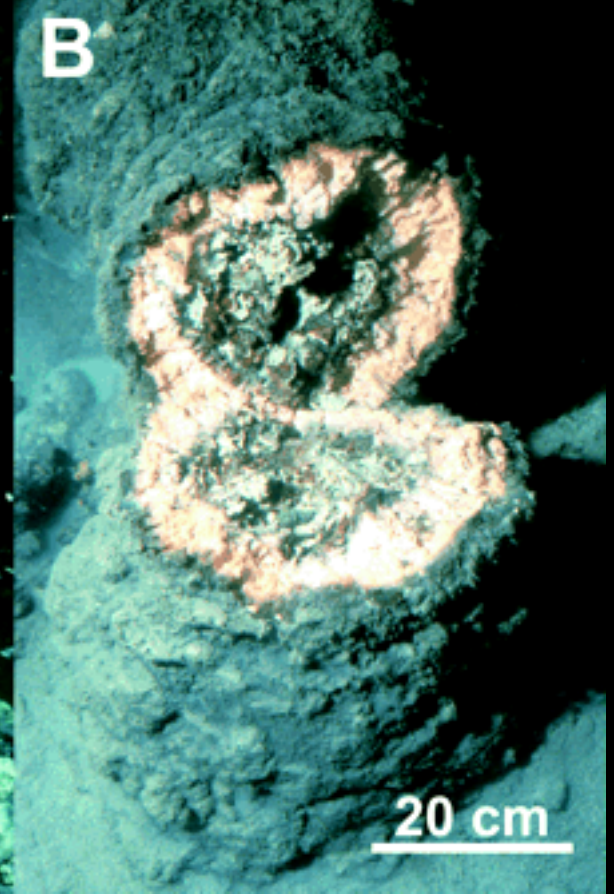


- Draw out specific growth rate curve vs. sulfide concentration

Thermodynamic and kinetic underpinnings

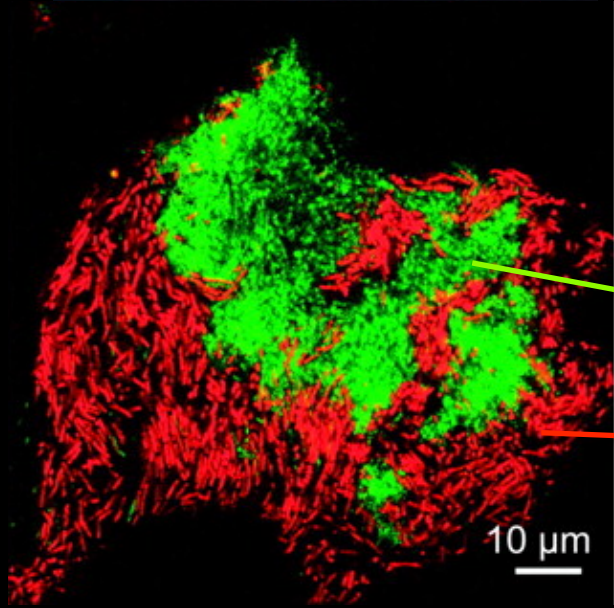
(one cell's waste is another's lunch)

We will work this out mathematically next time

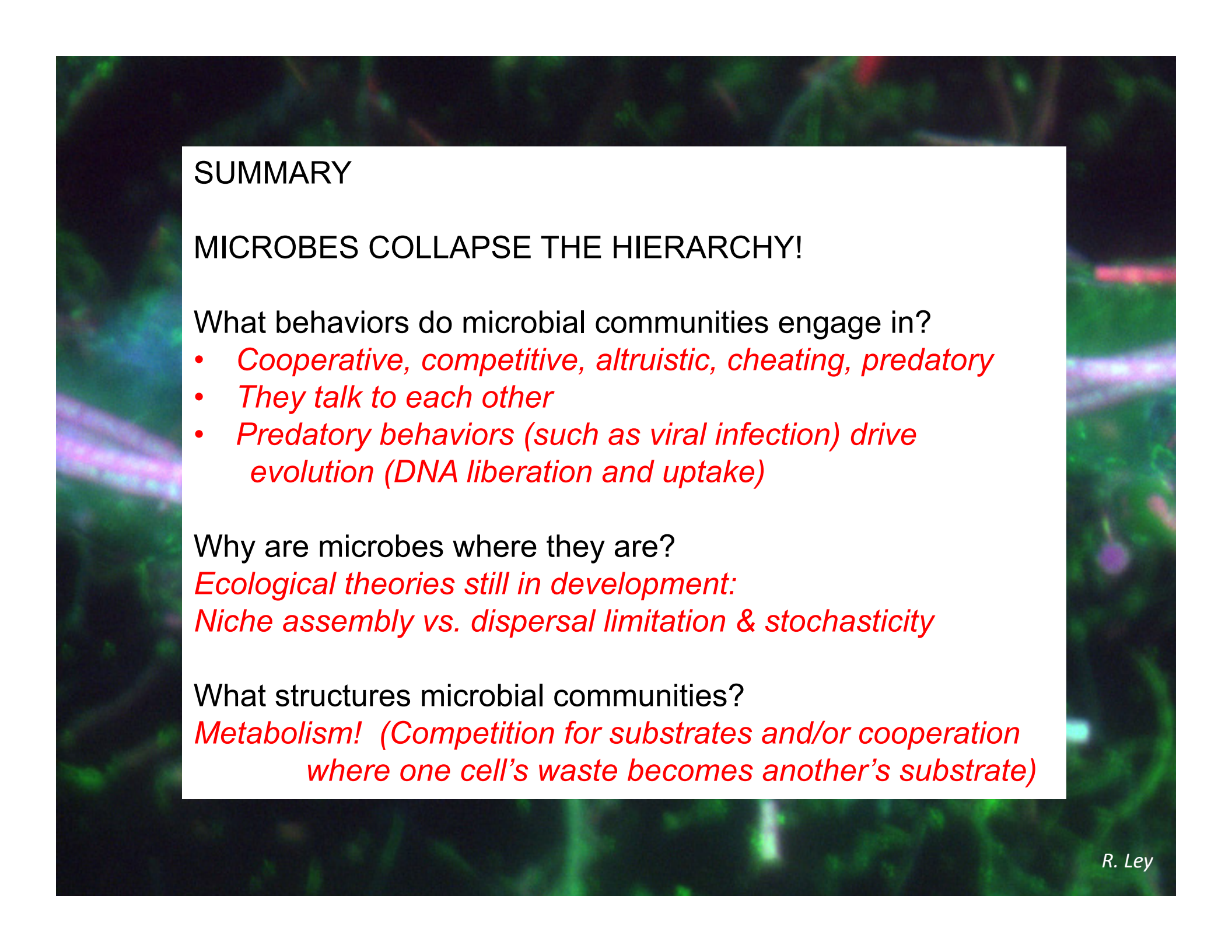


Sulfate reducing bacteria

ANME-1



Michaelis *et al.*, Science 2002



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:

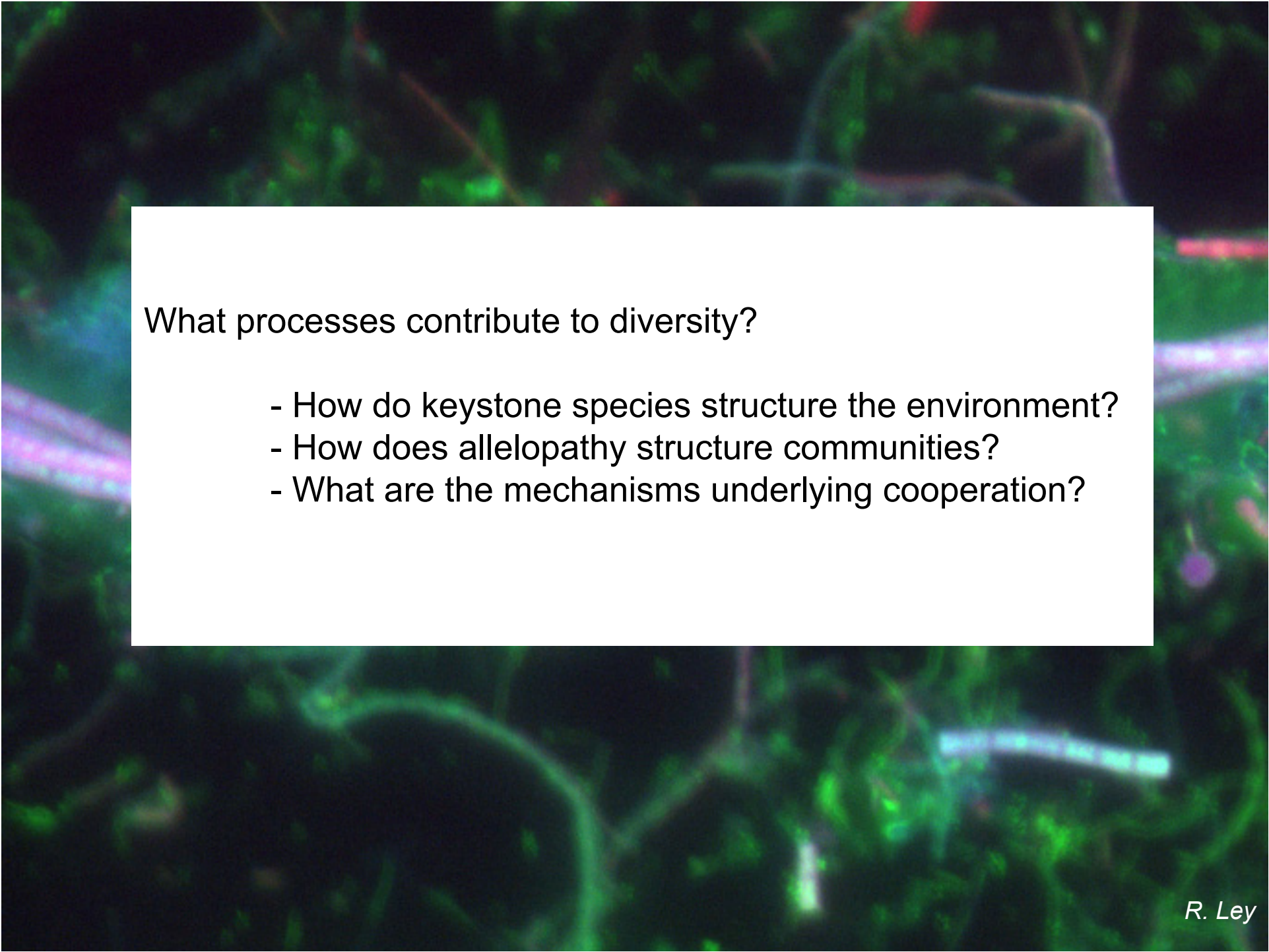
Niche assembly vs. dispersal limitation & stochasticity

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*



What processes contribute to diversity?

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

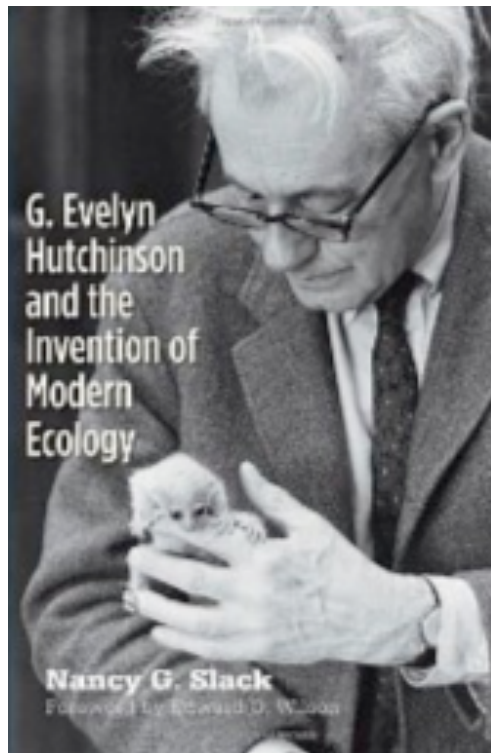
Species interactions: Predation, competition and cooperation

What controls biological diversity in ecosystems?

Diversity – the number of different species in a system

2 components: *Species richness* – simple count of the species
Species evenness – how equal the abundance

Niche – how an organism makes a living (relative to others)



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

ECOLOGICAL ELEMENTS THAT DETERMINE DIVERSITY
IN LIGHT OF COMPETITIVE EXCLUSION?

ND Slack, 2011

Abiotic features affect the number of niches available.

low
↓
DIVERSITY
↓
high



Antarctic



Dead Sea Israel



Great Barrier Reef - Australia



Rainforest - Borneo

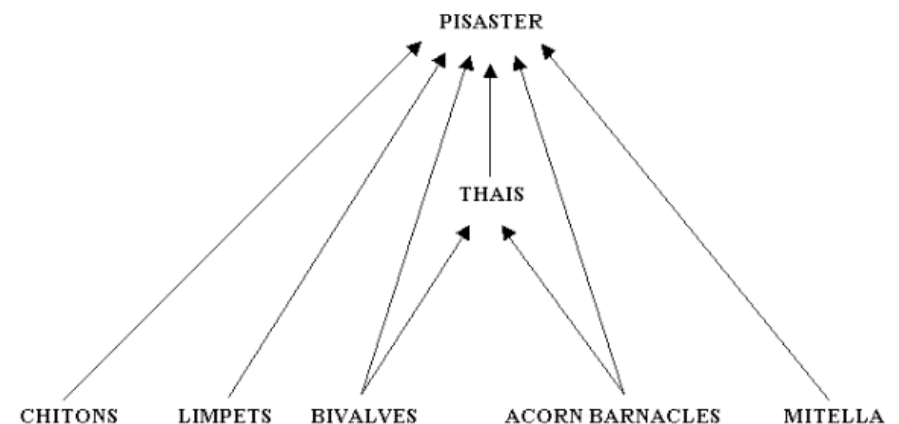
Within a location, what biotic features determine diversity?

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



Robert Paine
U Washington

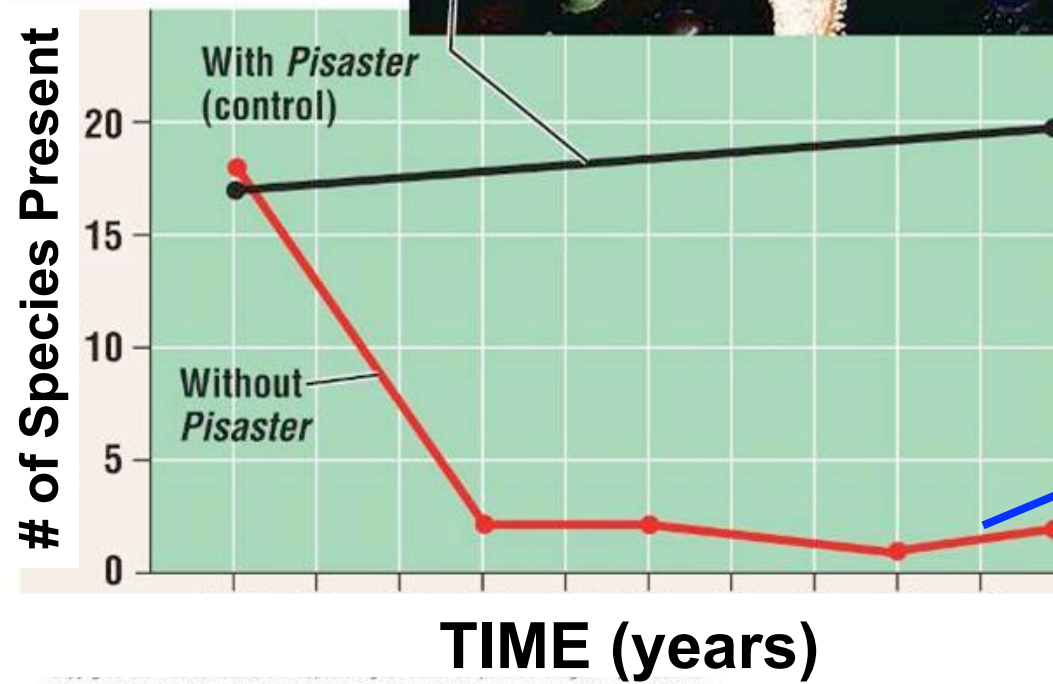
SEASTAR
(*Pisaster*
***ochraceus*)**



Removal of the keystone species dramatically alters the ecology.



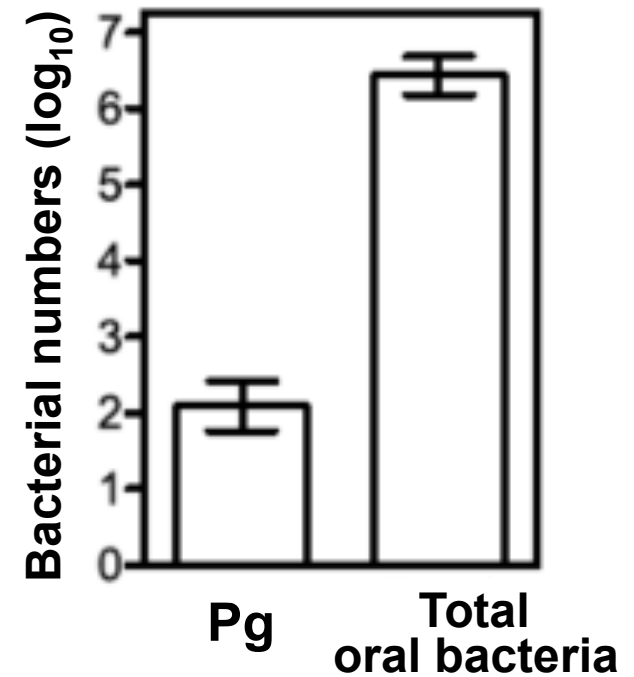
SEASTAR



Common mussel



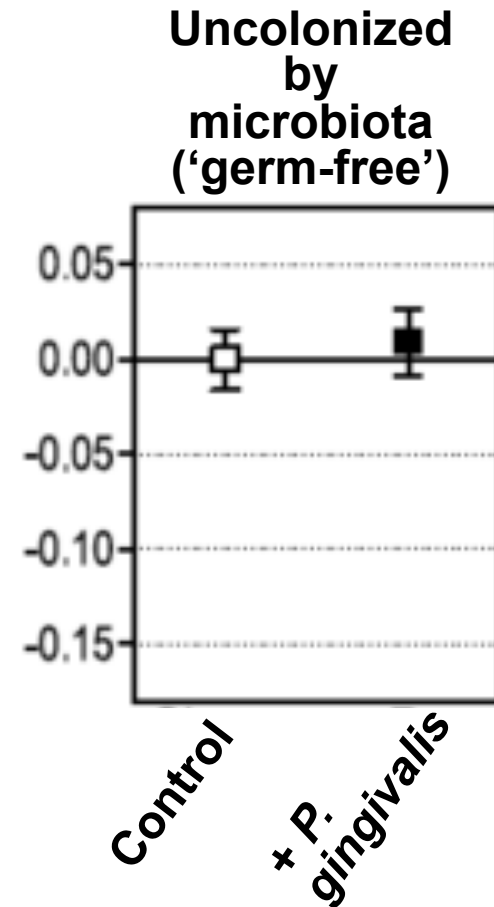
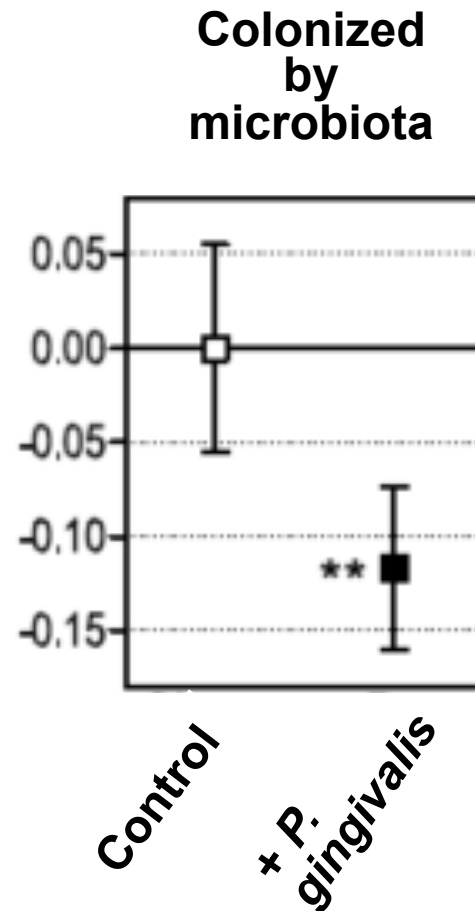
The bacterium *Porphyromonas gingivalis* is a **keystone species** in the mammalian oral cavity.



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



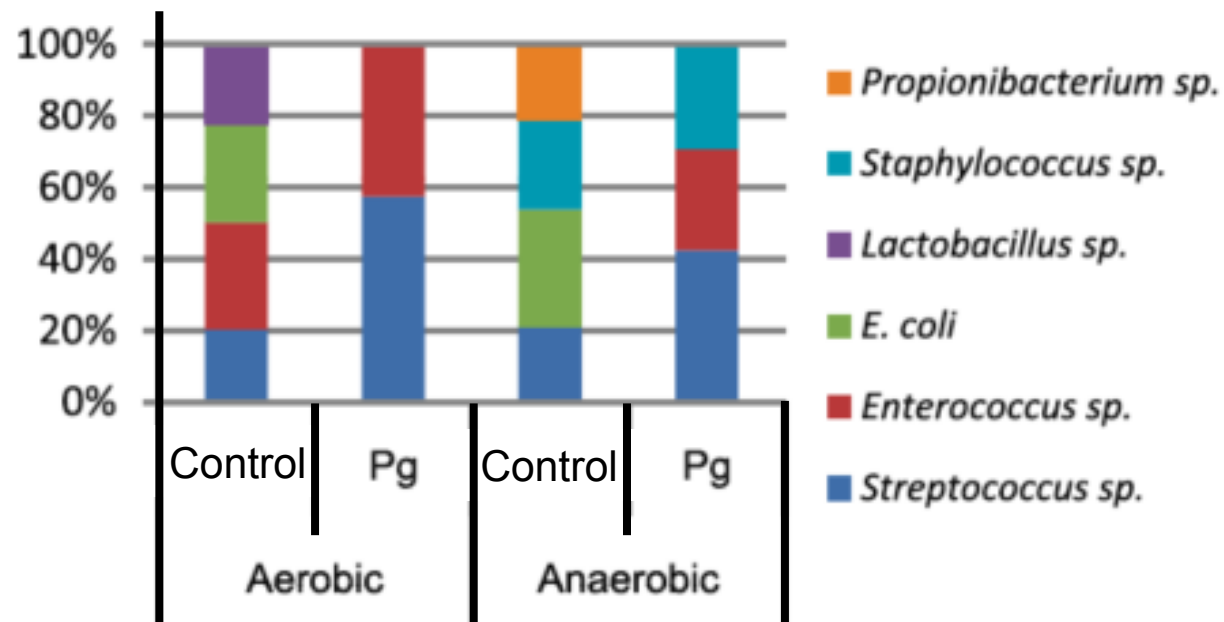
mm change in bone



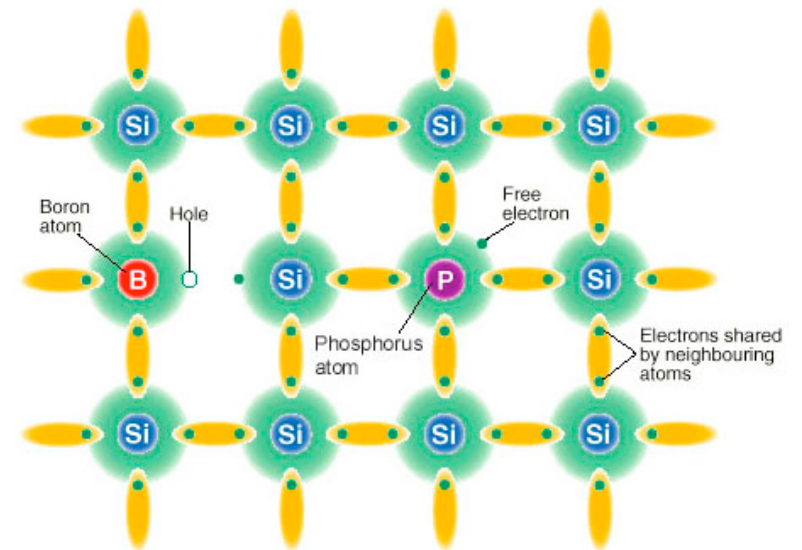
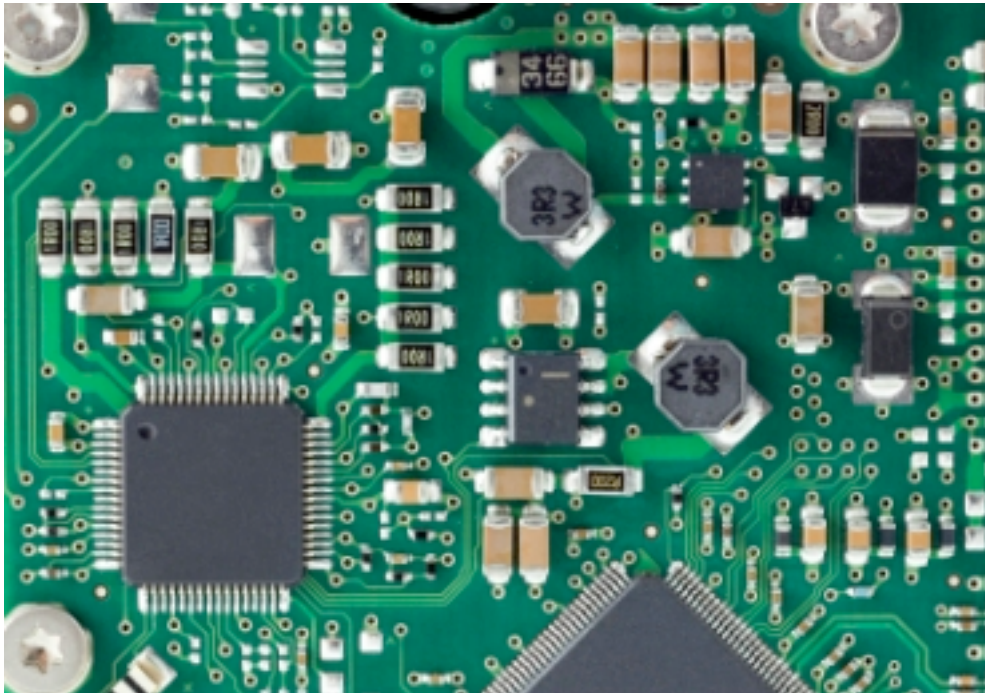
P. gingivalis in low abundance causes bone loss (through inflammation), but only when oral microbiota are present.

The presence of the keystone species, *Porphyromonas gingivalis*:

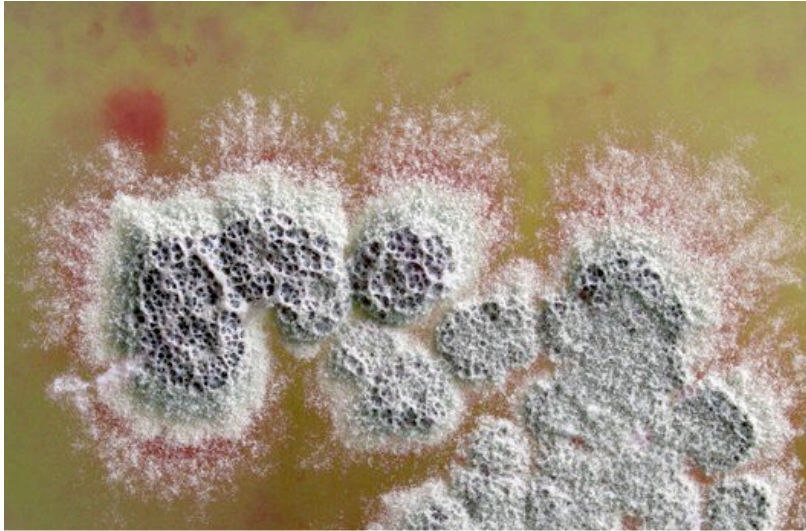
- 1) changes the composition of the a culture-grown consortium;
- 2) change dependent on oxygenation.



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



Allelopathy – production of biochemical(s) that influence the growth, survival, and reproduction of other organisms.



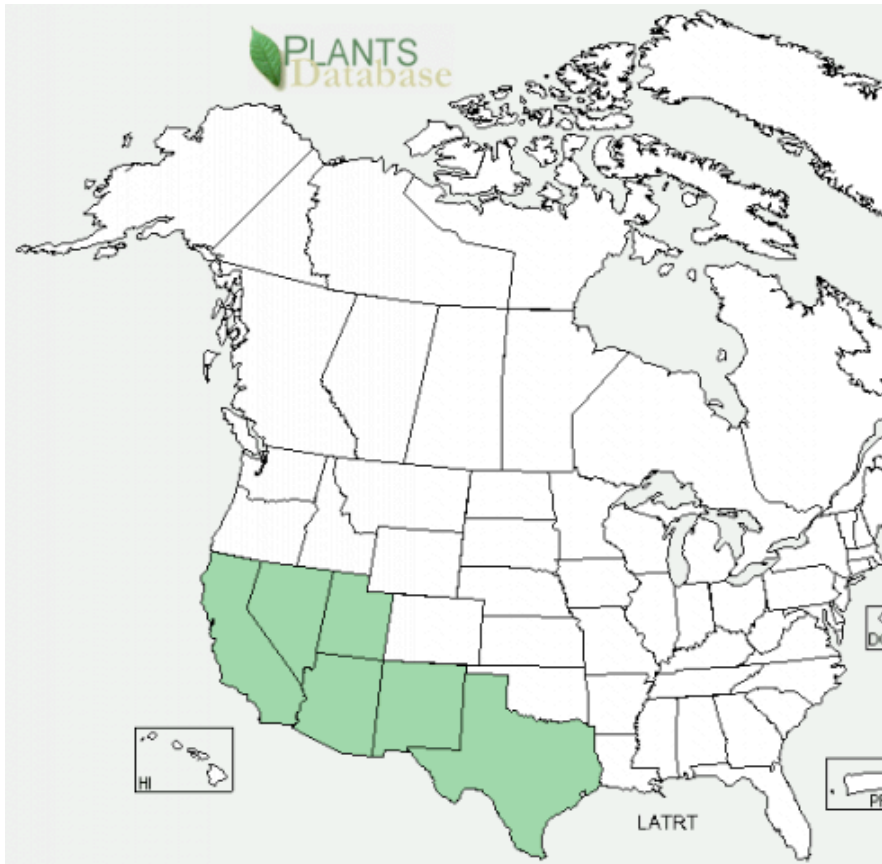
Streptomyces coelicolor
(antibiotic undecylprodigiosin)

A strategy in:

Competition for space and resources in sessile (non-moving organisms) –

e.g., plants, reef animals

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



Mature creosote allelopathic toward:
their own seedlings
other creosote plants

You've heard about asexually reproducing colonial animals. They are very good competitors for space because they can grow out without requiring intervening stages of sexual reproduction and recruitment.



HOW IS THIS DIVERSITY MAINTAINED? – also a kind of allelopathy



Organisms put energy into 2 activities:

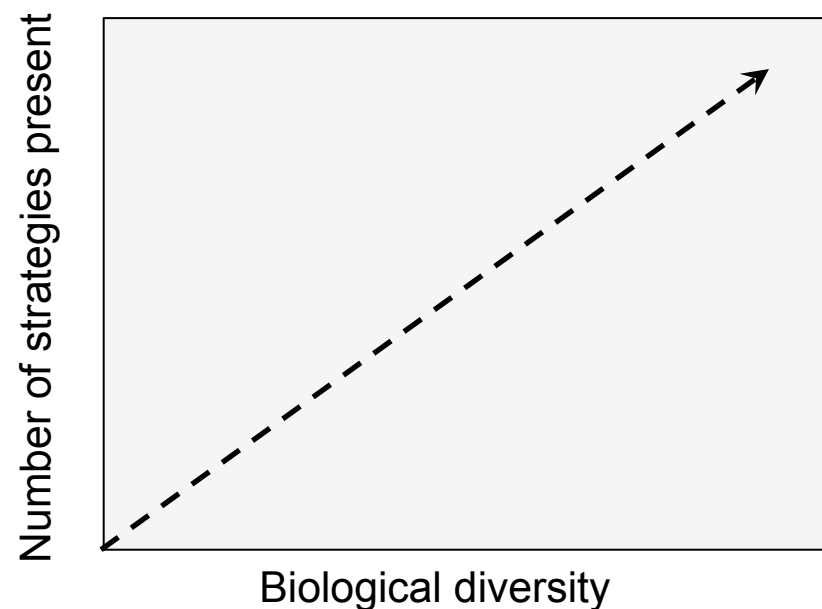
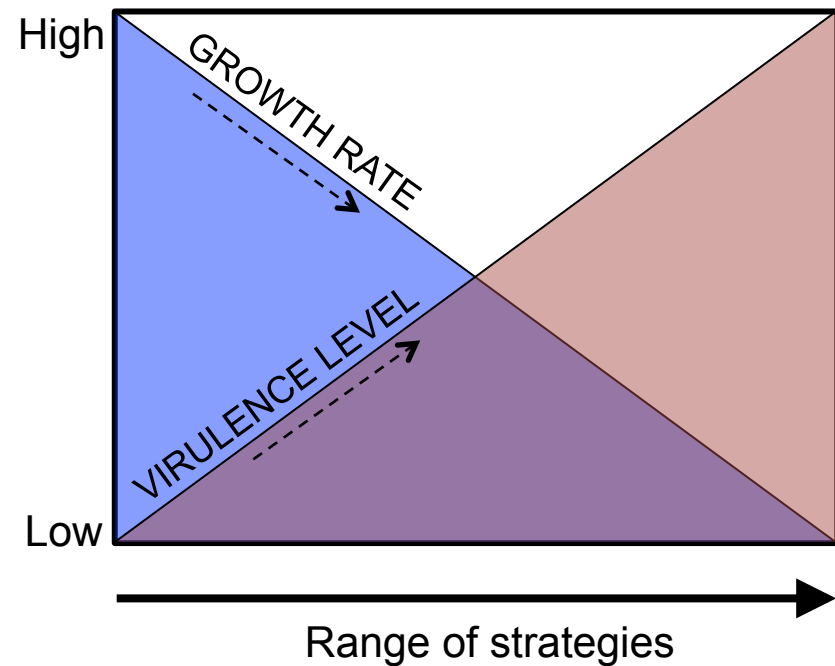
- growth (G)
- virulence (V)

(a) These activities are inversely related
i.e., $(G) \times (V) = \text{constant}$

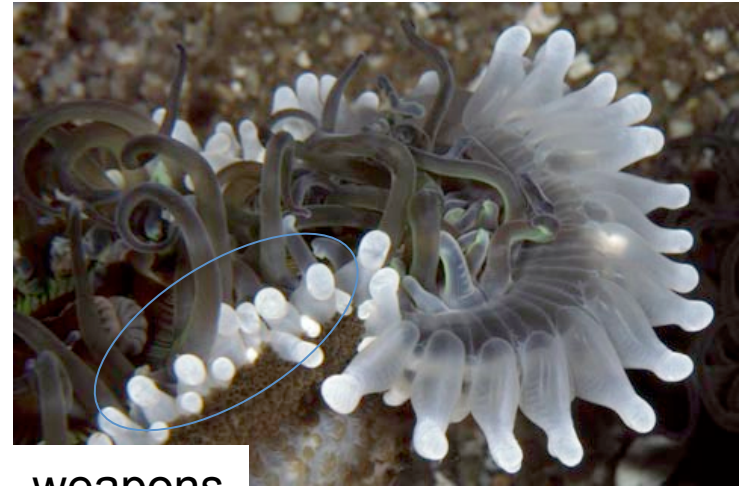
(b) Each possible pairing of G and V
is a *strategy*

(c) To maintain a high diversity,
many strategies must be present
in a habitat

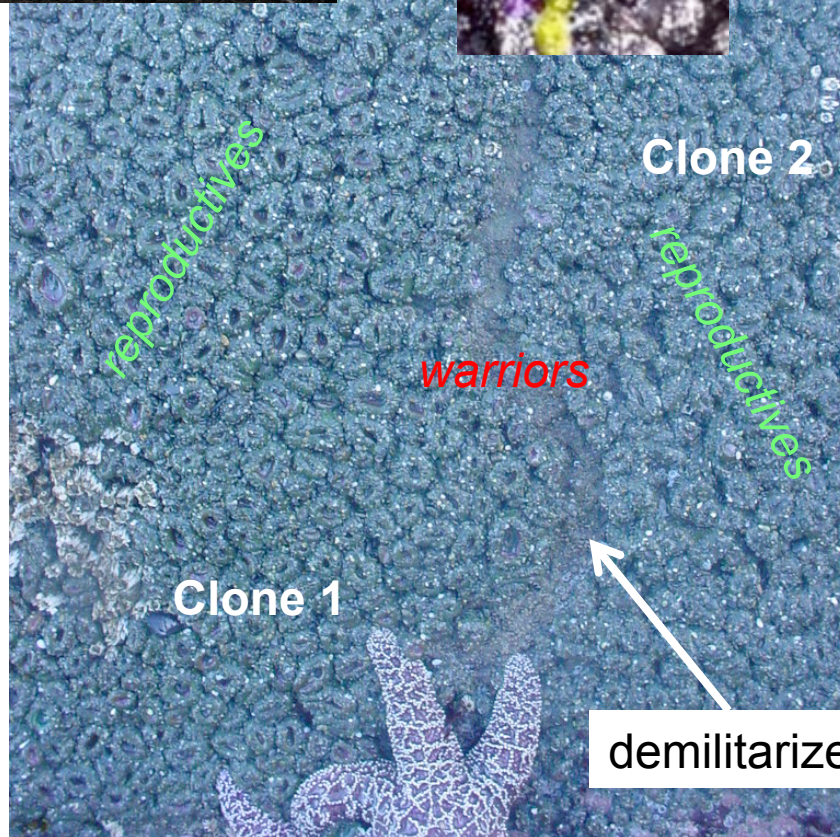
Diversity on the reef is maintained
by balance of strategies between
slow growth/high virulence and fast
growth/low virulence



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

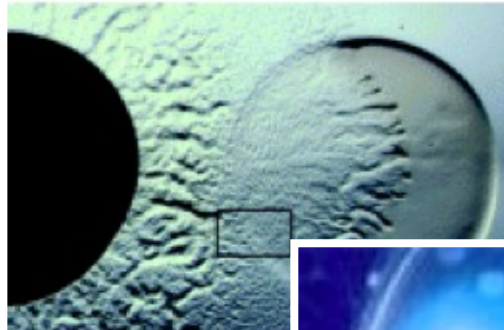
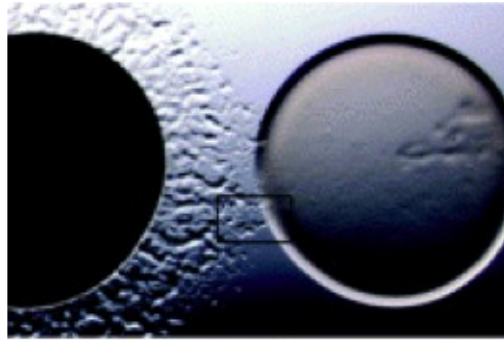


weapons



stinging cells with toxins

COOPERATION – working together to increase fitness

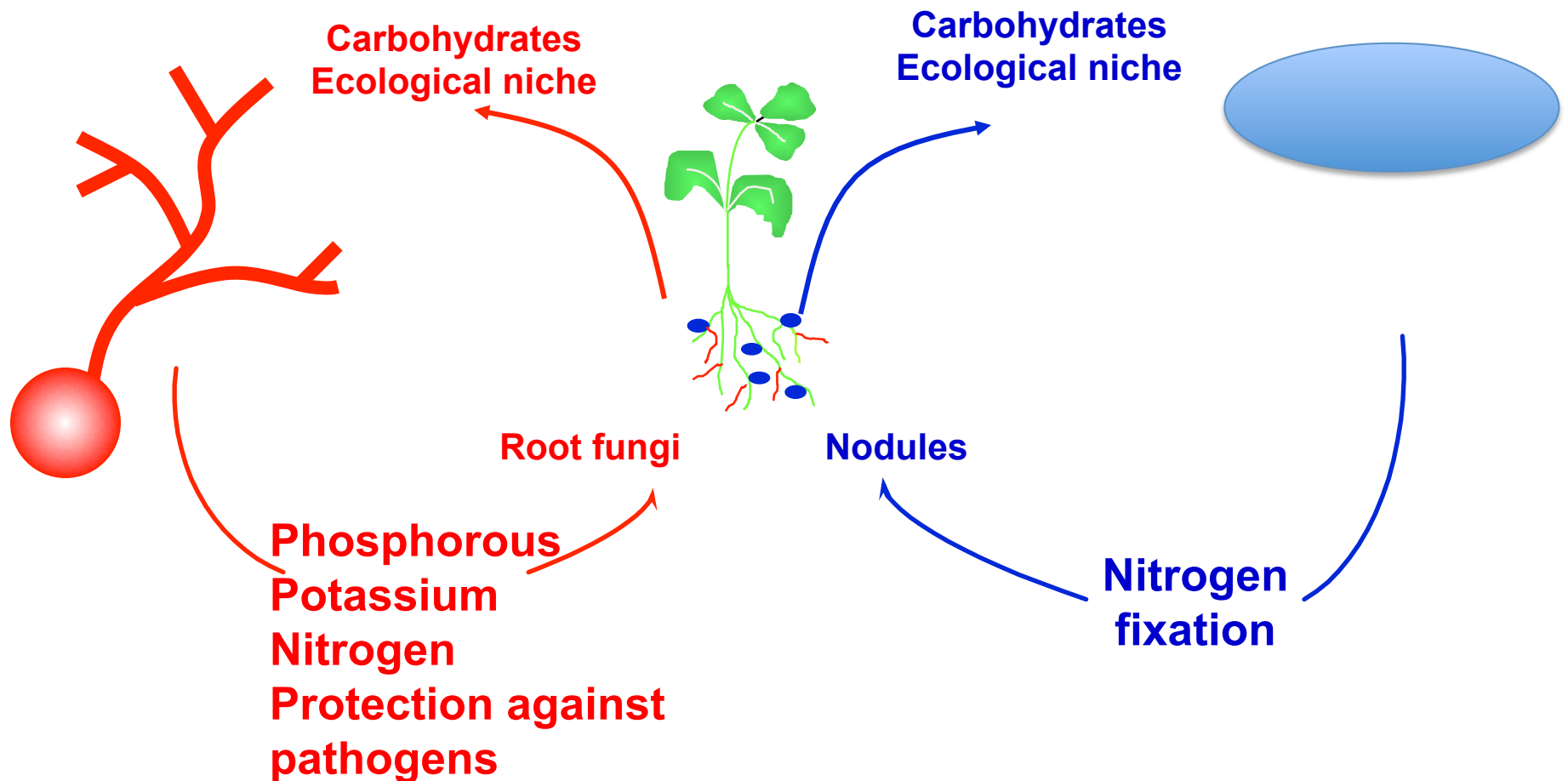


Cooperation - the economics of plant-microbe mutualistic symbioses

MYCORRHIZAL FUNGI

HOST LEGUME PLANT

RHIZOBIA



MYCORRHIZAL FUNGI

RHIZOBIA

HOST LEGUME PLANT

Strigolactones

Flavonoids

Root fungi

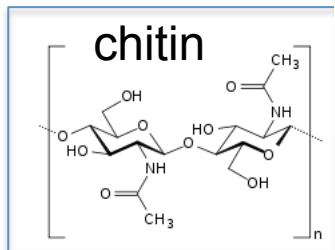
Nodule organogenesis

Nod factors

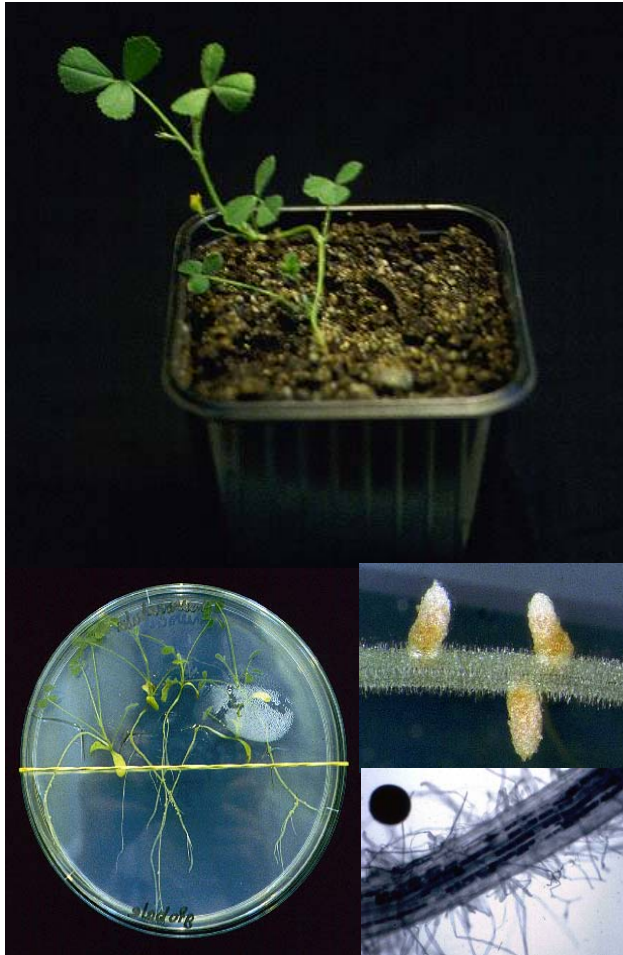
nodD structural nod genes

chitin

Myc

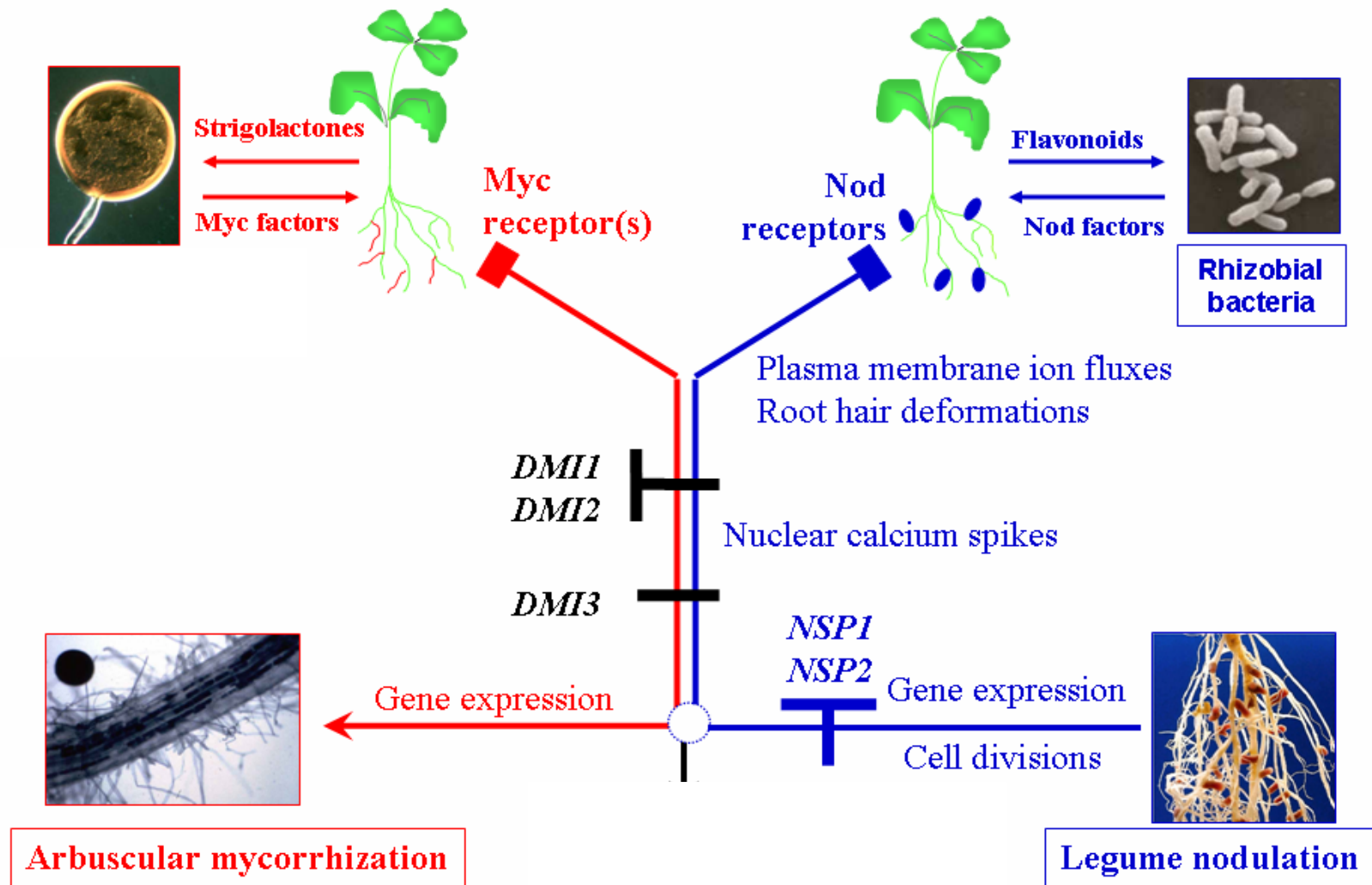


Primary strategies for identifying plant symbiotic genes



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

Signaling in plant – microbe symbioses



LIVING WITH OTHERS: POPULATIONS AND COMMUNITIES

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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