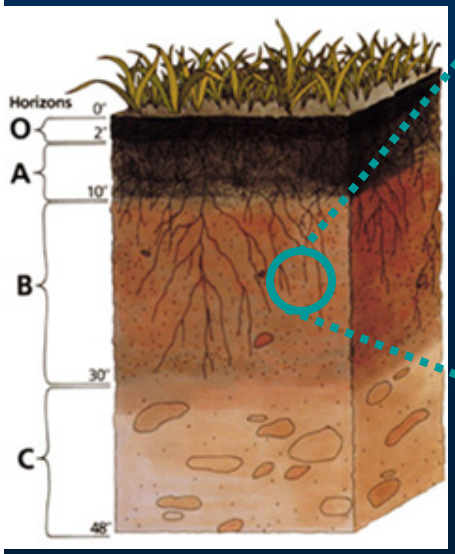
# Life in the Soil



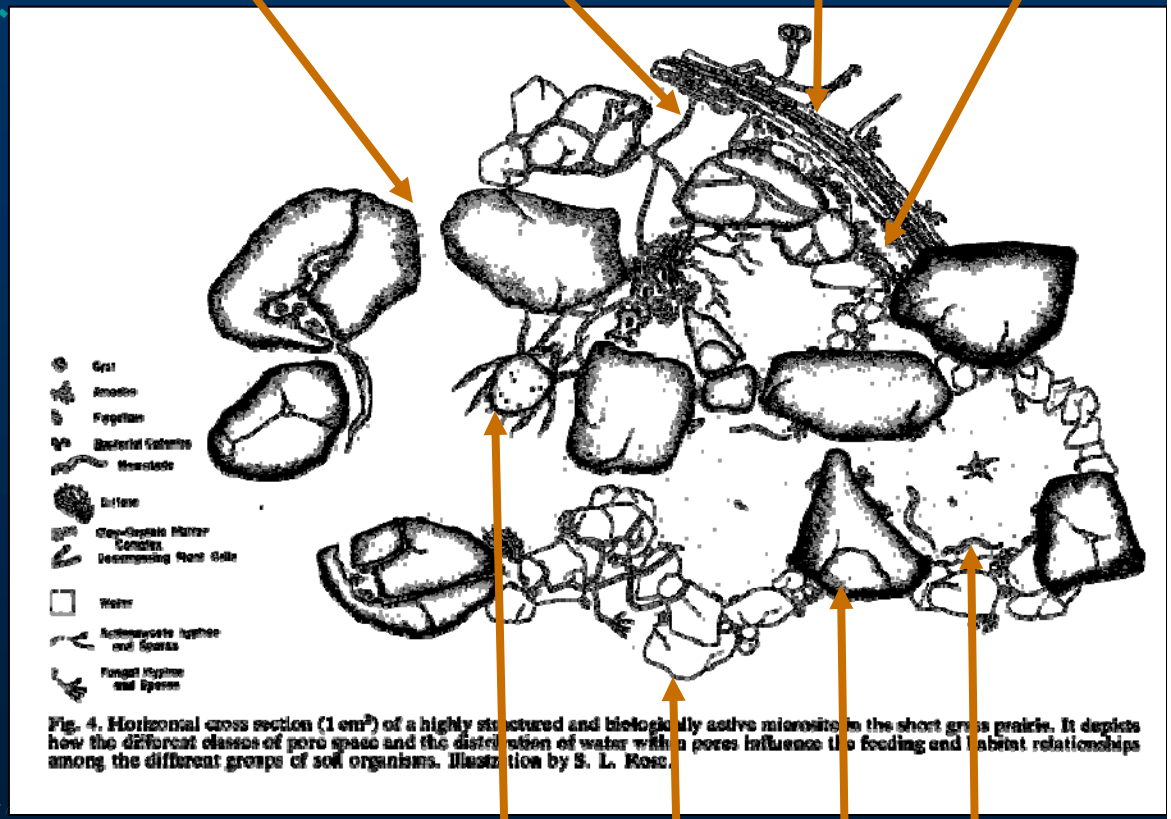




Fig. 4. Horizontal cross section (1 cm²) of a highly structured and biologically active microsite in the short grass prairie. It depicts how the different classes of pore space and the distribution of water within pores influence the feeding and habitat relationships among the different groups of soil organisms. Illustration by S. L. Rose.

http://archive.niees.ac.uk/talks/egenomics_2006/kowalchuk.ppt

Productivity depends on soil microbes

**Table 1. Essential nutrient elements showing element, symbol and primary forms used by plants.**

| Element | Symbol | Primary Forms Used by Plants |
|---|---|---|
| NON-MINERAL ELEMENTS | | |
| Carbon | C | $CO_2$ (g) |
| Hydrogen | H | $H_2O$ (l), $H^+$ |
| Oxygen | O | $H_2O$ (l), $O_2$(g) |
| MINERAL ELEMENTS | | |
| Major Nutrients | | |
| Nitrogen | N | $NH_4^+$, $NO_3^-$ |
| Phosphorous | P | $HPO_4^{2-}$, $H_2PO_4^-$ |
| Potassium | K | $K^+$ |
| Secondary Nutrients | | |
| Calcium | Ca | $Ca^{2+}$ |
| Magnesium | Mg | $Mg^{2+}$ |
| Sulfur | S | $SO_4^{2-}$ |
| Micronutrients | | |
| Iron | Fe | $Fe^{3+}$, $Fe^{2+}$ |
| Manganese | Mn | $Mn^{2+}$ |
| Zinc | Zn | $Zn^{2+}$ |
| Copper | Cu | $Cu^{2+}$ |
| Boron | B | $B(OH)_3^\circ$ (Boric acid) |
| Molybdenum | Mo | $MoO_4^{2-}$ |
| Chlorine | Cl | $Cl^-$ |

Decomposition depends on soil microbes

**Plants require at least 16 elements for normal growth and for completion of their life cycle.**

**Those used in the largest amounts, carbon, hydrogen and oxygen, are non-mineral elements supplied by air and water.**

**The other 13 elements are taken up by plants only in mineral form *from the soil* or must be added as fertilizers.**

Minerals must be available , continuously, and in balanced proportions to support photosynthesis and other metabolic processes of plants.

If **any one** of these essential elements is missing, plant productivity will be limited or will cease entirely.

**Principle of limiting factors**:
The level of production can be no greater than that allowed by the most limiting of the essential plant growth factors.

Applies in both cropping systems and in natural ecosystems.

Common limiting factors:

N,P,K: Primary nutrients - plants need relatively large amounts. Frequently supplied in fertilizers.

Ca, Mg, S: Secondary nutrients - required in smaller amounts

Plants absorb the essential elements through their root systems or their leaves in various forms. In general, the soil contains large amounts of all the elements, but only a very small percentage of these total amounts are actually **plant-available**.

For example, the actual total iron content of a soil may exceed 50,000 parts per million (ppm), however the portion available to plants may be less than 5 ppm.

The availability of nutrients to plants is determined by:

--the form and chemical properties of the element
--the soil pH
--interactions with soil colloids
--soil physical conditions such as aeration, compaction, temperature, and moisture --
***microbial activity***

Carbon cycle
Nitrogen cycle
Sulfur cycle
Phosphorus availability
Iron availability
Etc.

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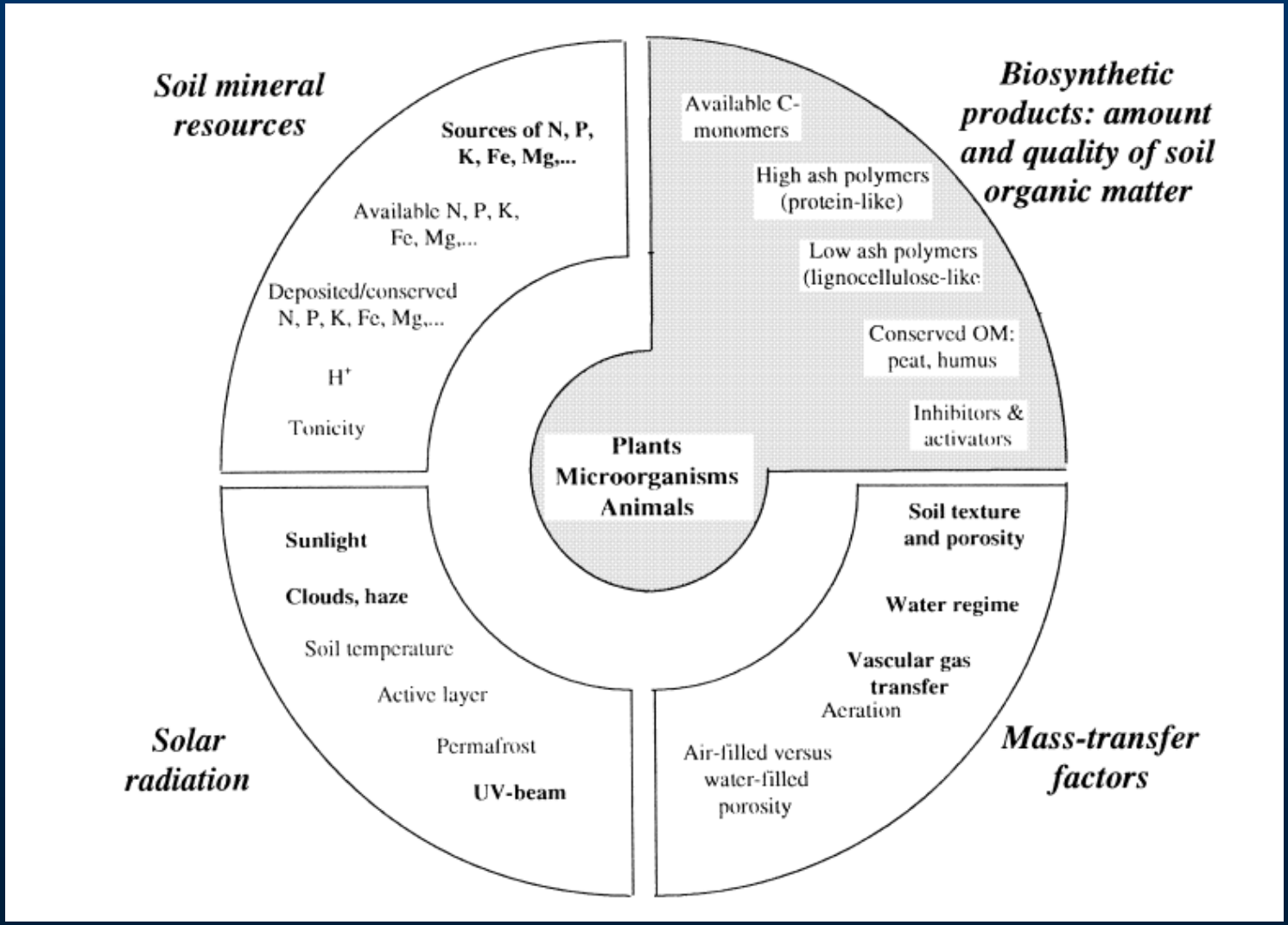
Two perspectives on soil microbial communities:

1. Systems view (nutrient cycling as a whole)

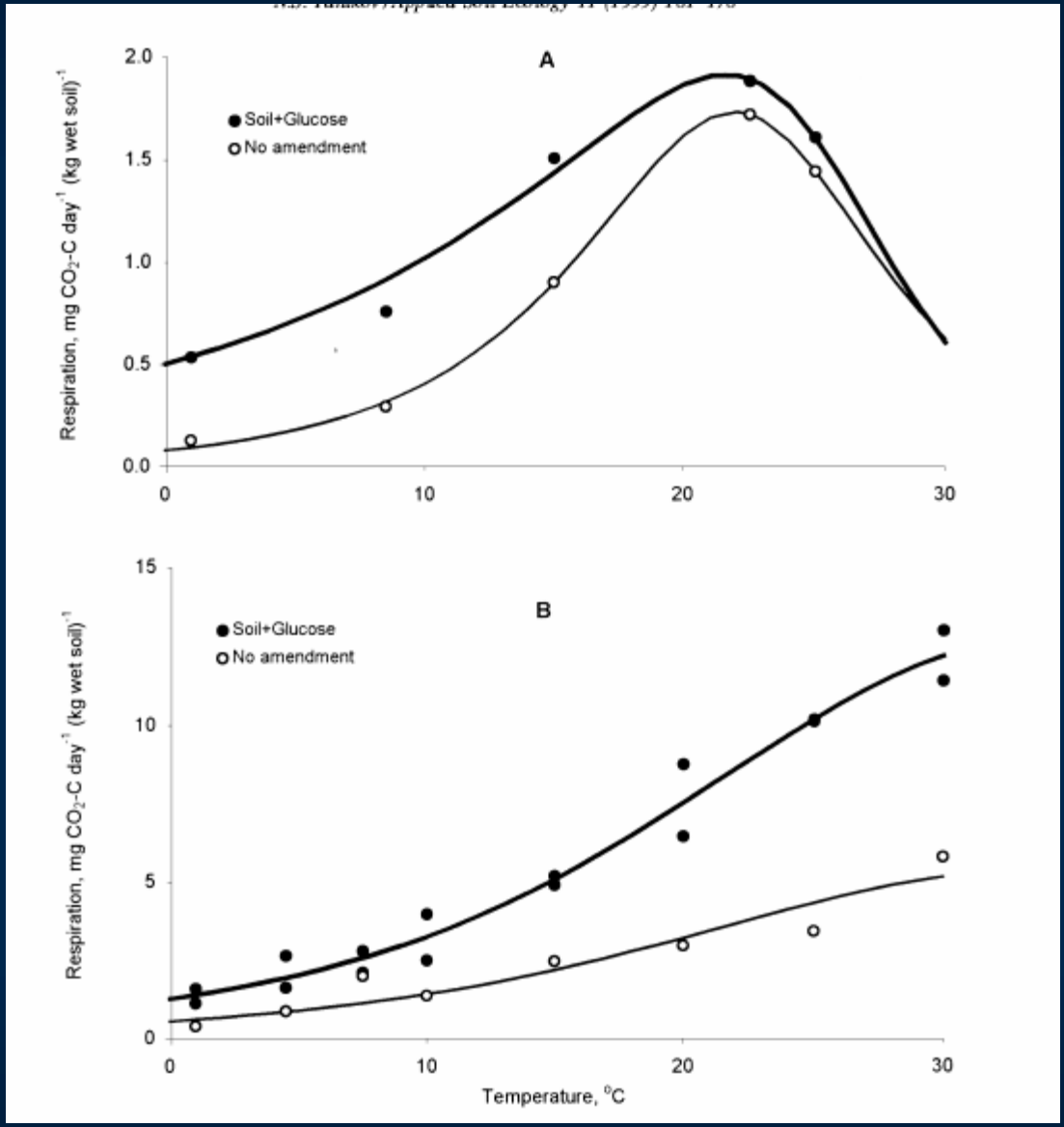
2. Single-process view (suppressive soil due to single antibiotic)

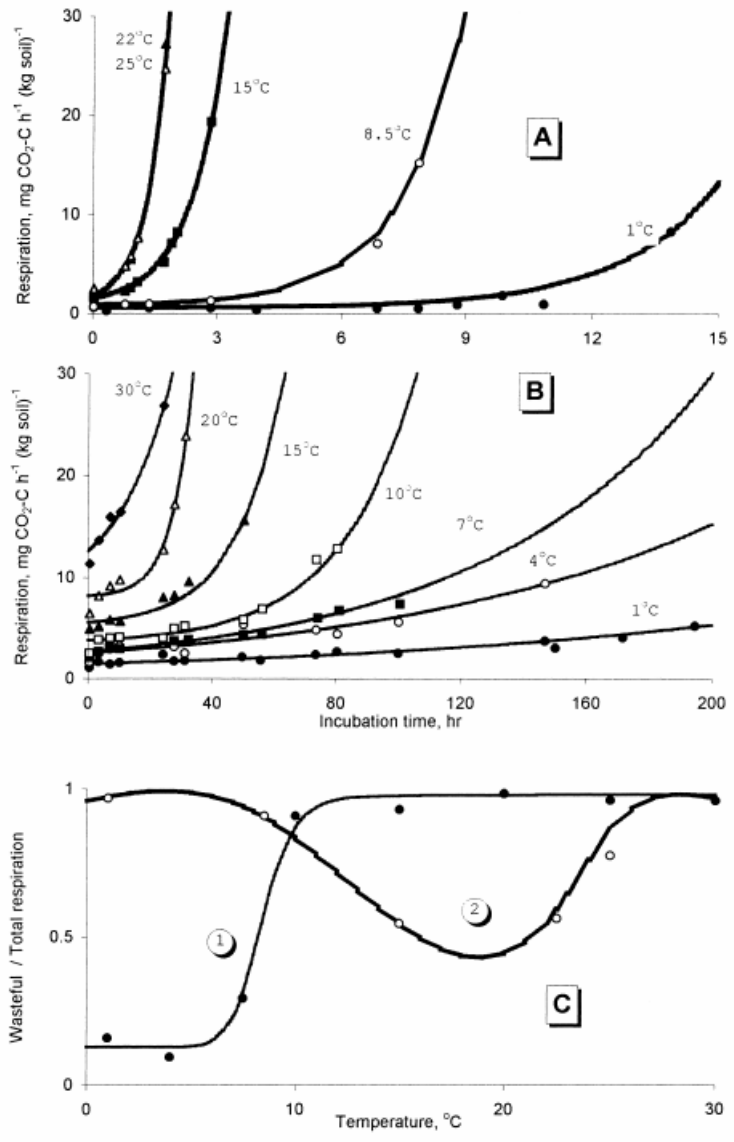
Both are important!

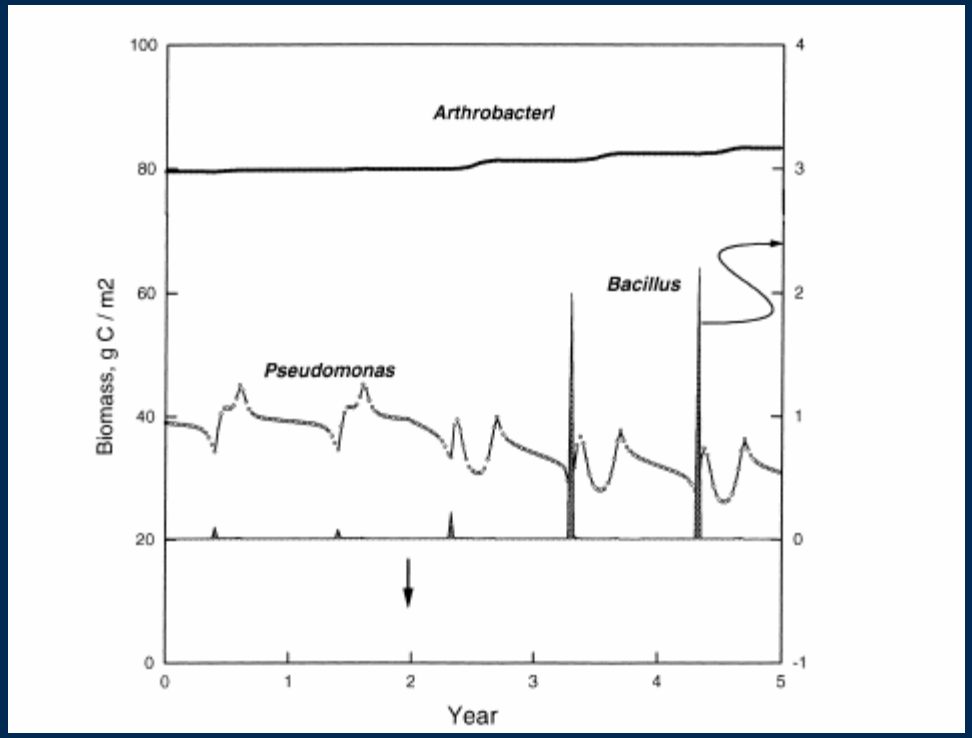
# Environmental factors affecting soil communities

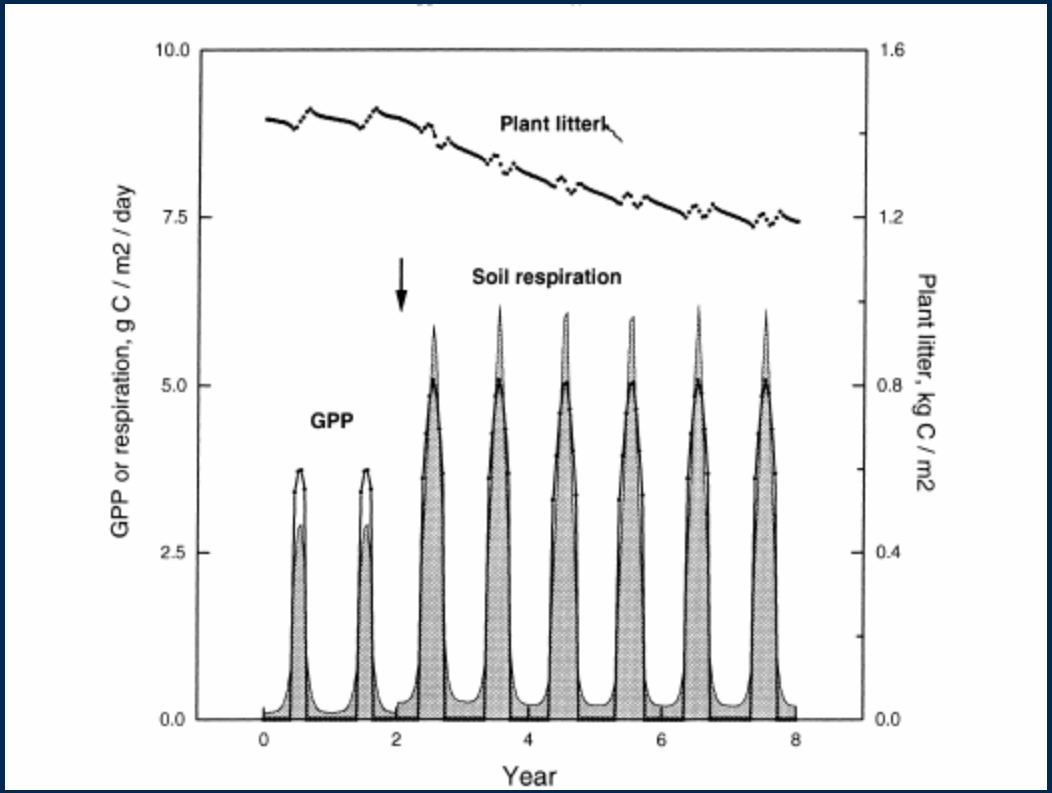


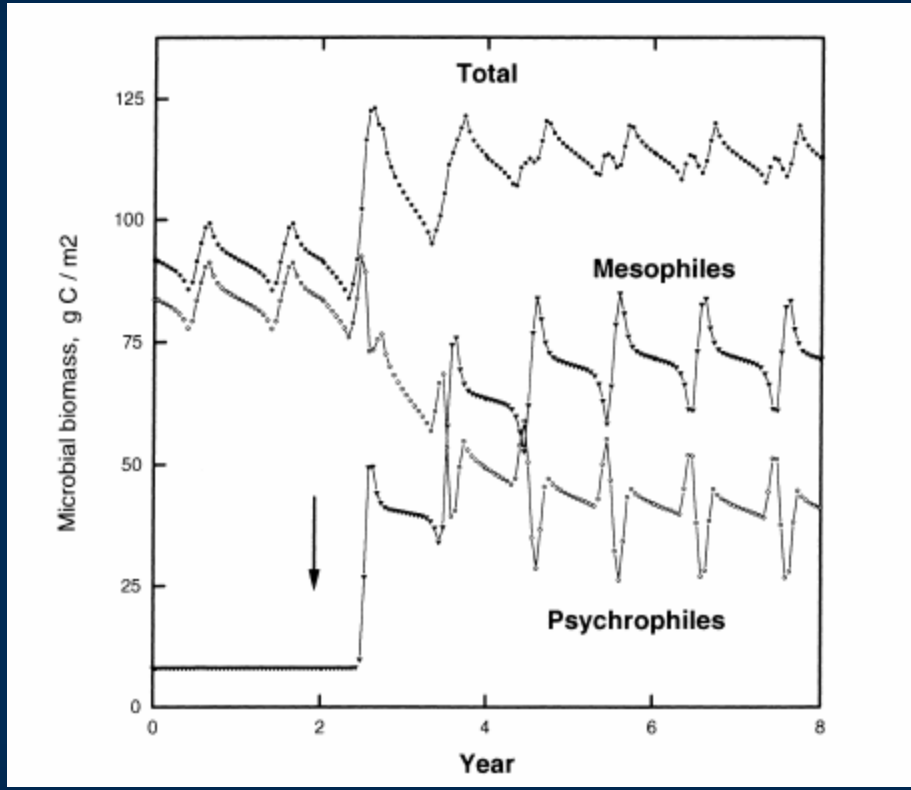

N.S. Panikov / Applied Soil Ecology 11 (1999) 161–176

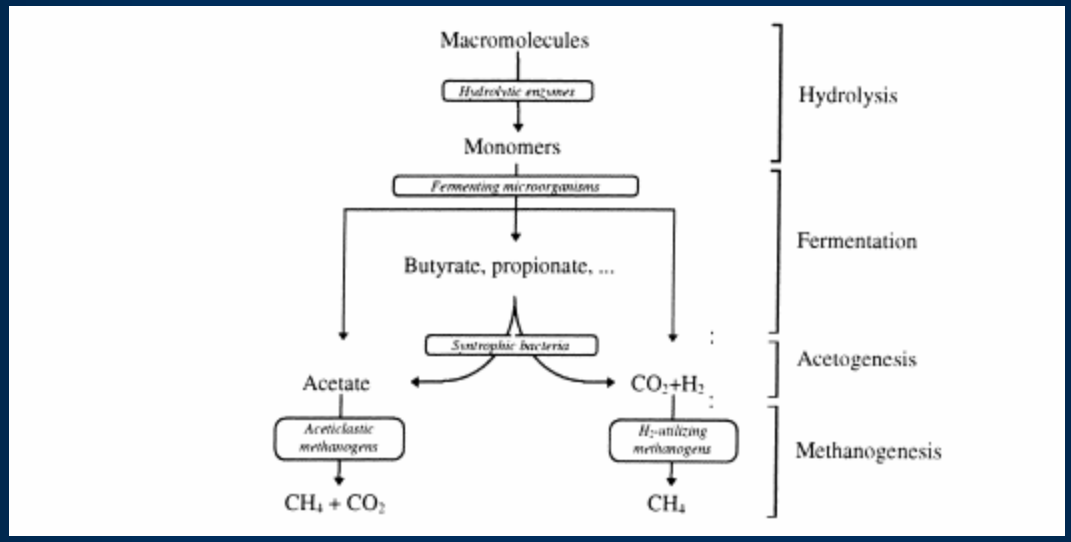

A
Soil+Glucose
No amendment
Respiration, mg $CO_2$-C $day^{-1}$ (kg wet soil)$^{-1}$
2.0
1.5
1.0
0.5
0.0
0
10
20
30
B
Soil+Glucose
No amendment
Respiration, mg $CO_2$-C $day^{-1}$ (kg wet soil)$^{-1}$
15
10
5
0
0
10
20
30
Temperature, °C


Respiration, mg $CO_2$-C $h^{-1}$ (kg soil)$^{-1}$
22°C
25°C
15°C
8.5°C
1°C
A
30°C
20°C
15°C
10°C
7°C
4°C
1°C
B
Incubation time, hr
Wasteful / Total respiration
1
2
C
Temperature, °C


Arthrobacterl
Bacillus
Pseudomonas
Biomass, g C / m2
Year
100
80
60
40
20
0
4
3
2
1
0
-1
0
1
2
3
4
5


10.0
7.5
5.0
2.5
0.0
1.6
1.2
0.8
0.4
0.0
Plant litter
Soil respiration
GPP
GPP or respiration, g C / m2 / day
Plant litter, kg C / m2
0
2
4
6
8
Year


Total
Mesophiles
Psychrophiles
Microbial biomass, g C / m2
Year
0
25
50
75
100
125
0
2
4
6
8

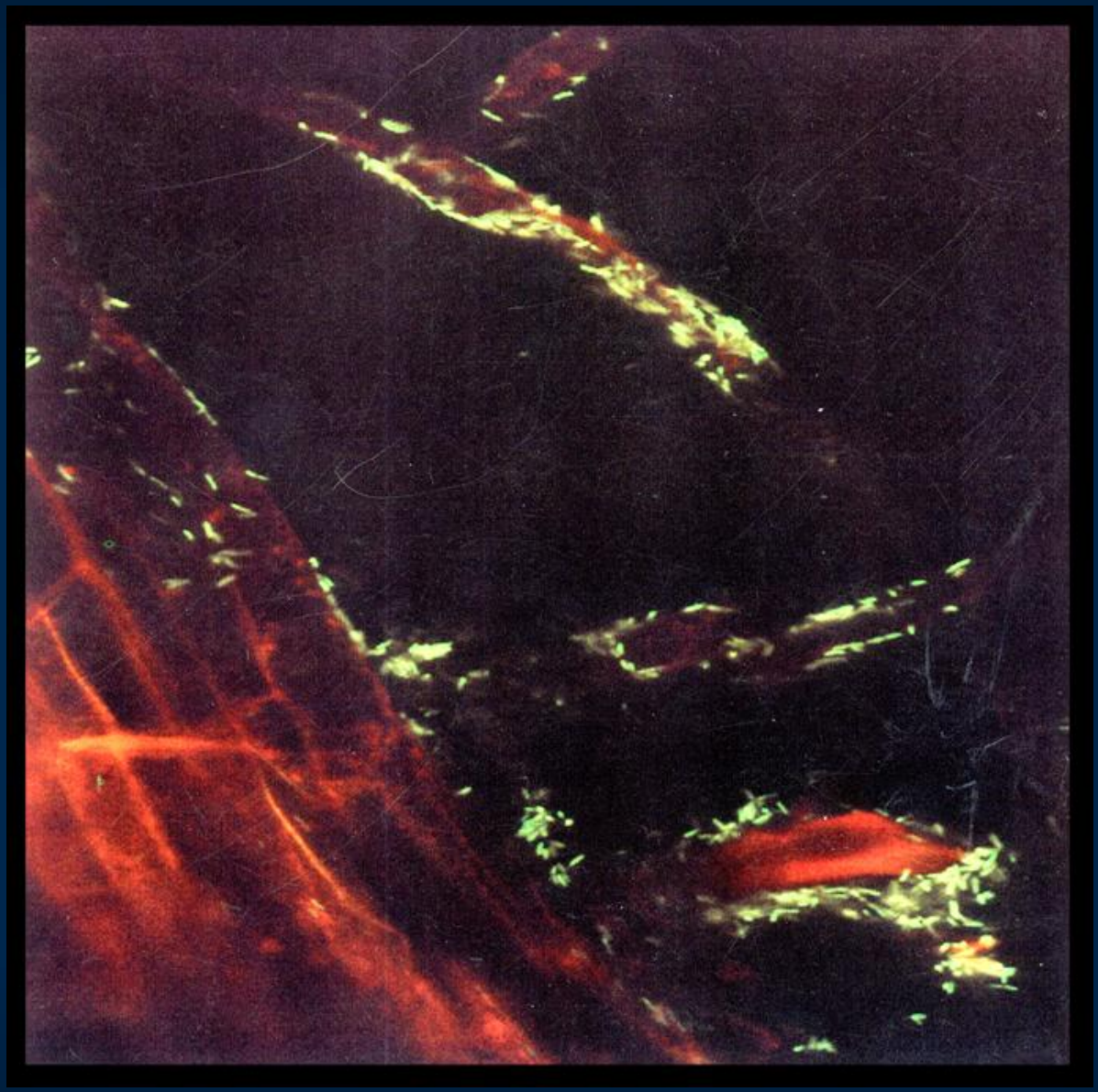

Macromolecules
Hydrolytic enzymes
Monomers
Fermenting microorganisms
Butyrate, propionate, ...
Syntrophic bacteria
Acetate
$CO_2+H_2$
Aceticlastic methanogens
$H_2$-utilizing methanogens
$CH_4 + CO_2$
$CH_4$
Hydrolysis
Fermentation
Acetogenesis
Methanogenesis

# Suppressive soils

Fluorescent pseudomonads suppress *Fusarium oxysporum* (Fusarium wilt of many plants); iron competition, ISR, and direct inhibition of fungal growth

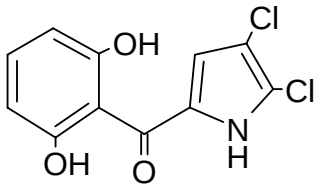
Fluorescent pseudomonads suppress *Gaeumannomyces graminis* var. *tritici* (take all of wheat) – 2,4-DAPG

*Trichoderma* inhibits *Rhizoctonia solani* root rots - parasitism



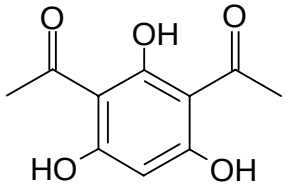
# Biological control of *Pythium* damping-off of cotton by *Pseudomonas fluorescens*

# Known *interacting* antibiotics produced by *Pseudomonas*



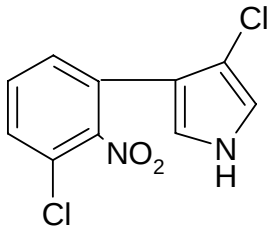

**Pyoluteorin (PLT)**

Oomycete pathogens – *P. ultimum*




**2,4-diacetylphloroglucinol (2,4-DAPG)**

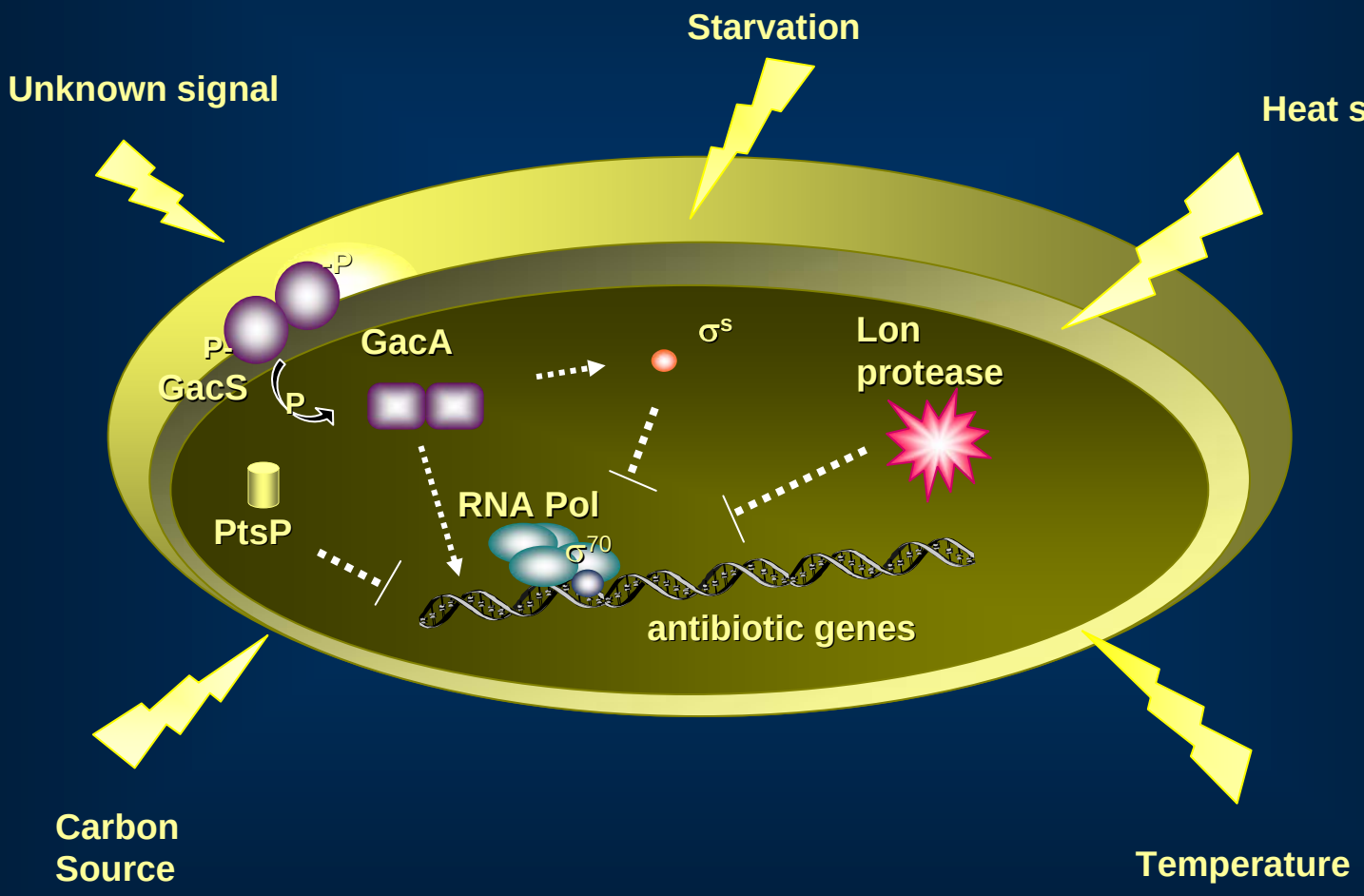
Broad spectrum: *Fusarium*, *Gaeumannomyces*, etc.



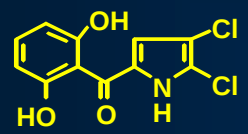

**Pyrrolnitrin (PRN)**

*Rhizoctonia*, *Pyrenophora*, *Sclerotinia*

# Factors known to influence antibiotic biosynthetic gene transcription in *Pseudomonas*

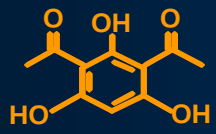


# Antibiotic interaction in *Pseudomonas* cultures

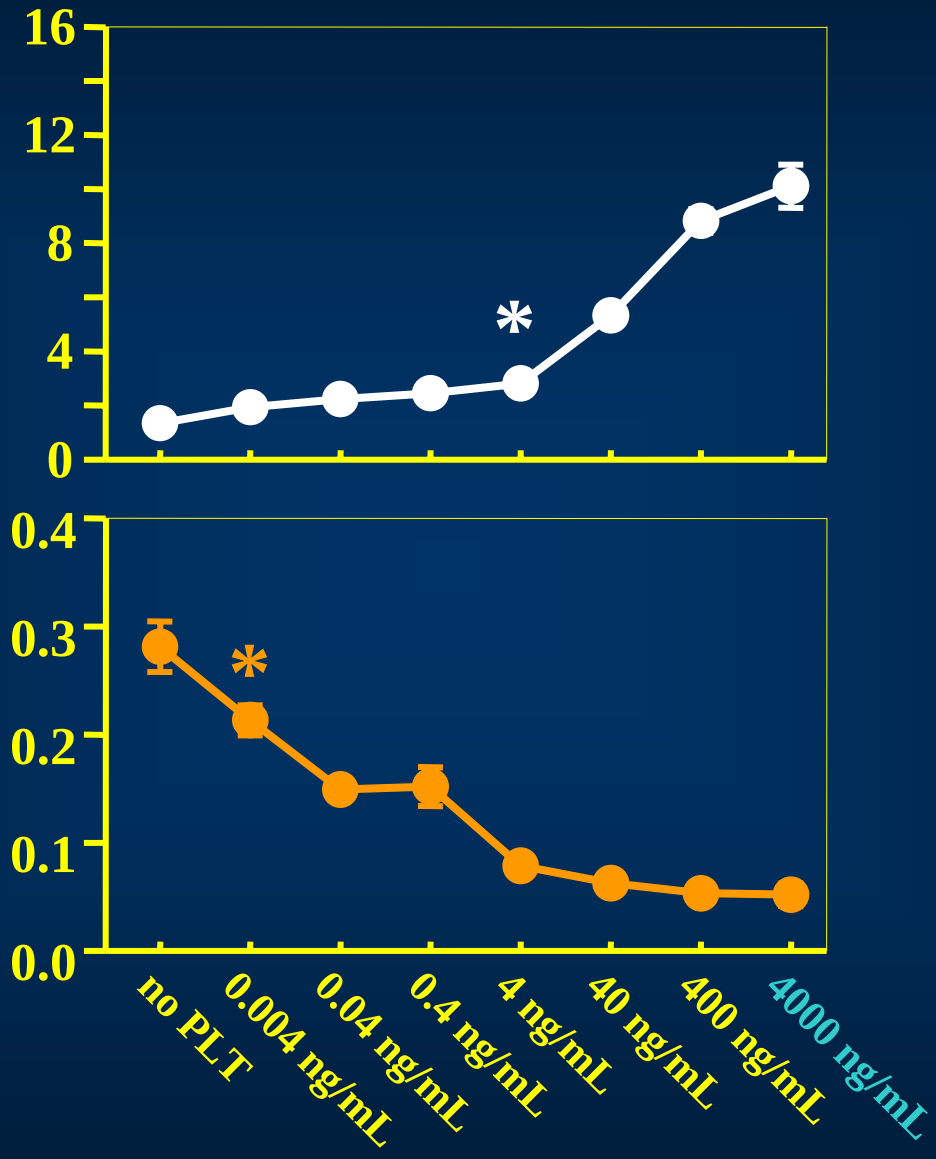


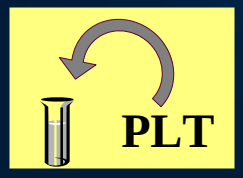

**PLT**

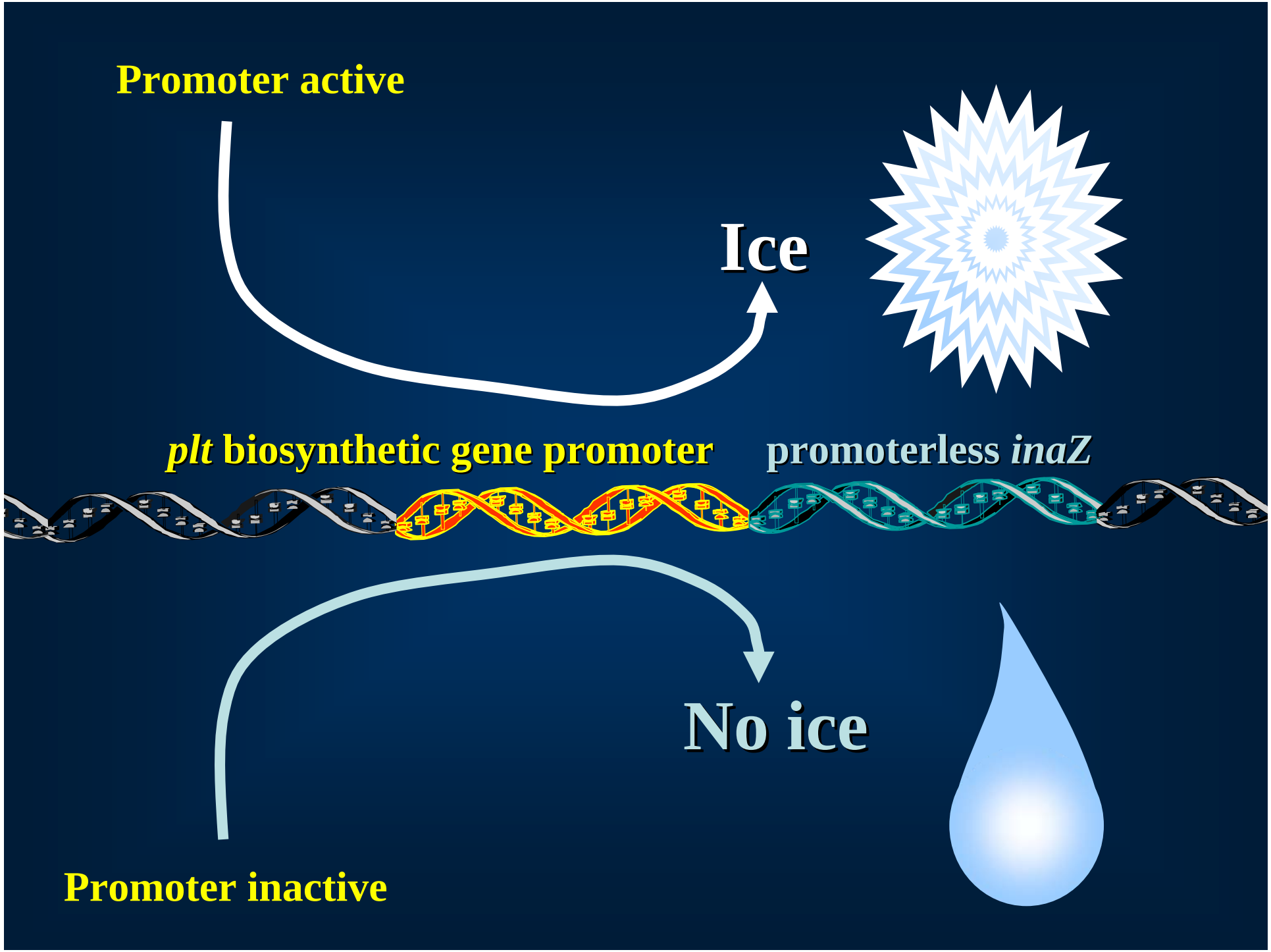
**(μg/mL)**



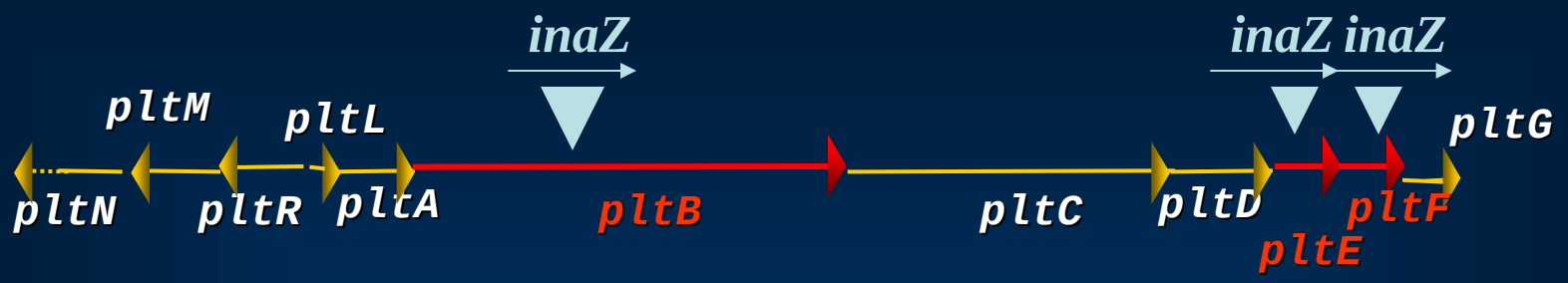

**2,4-DAPG**
**(μg/mL)**

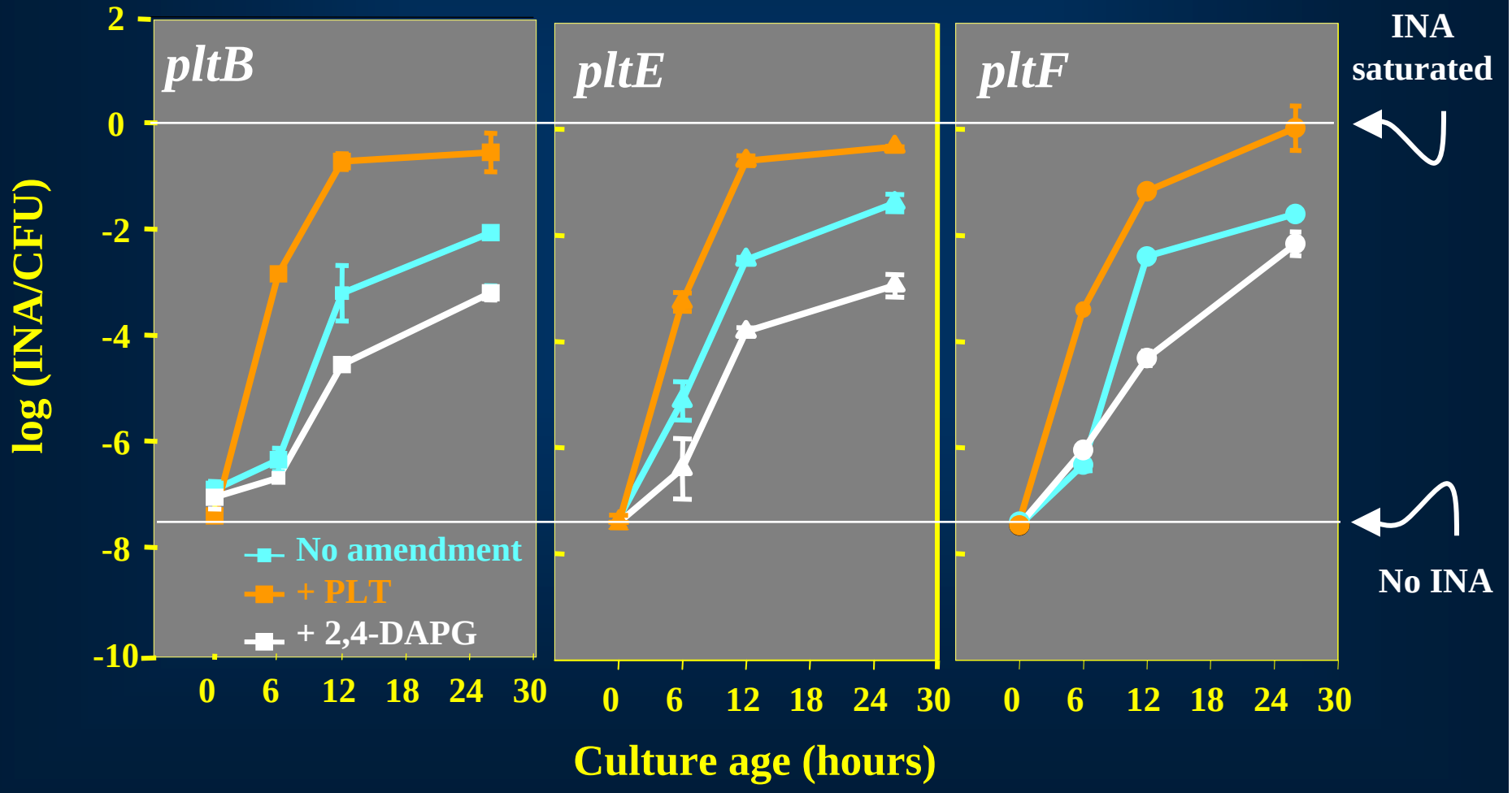


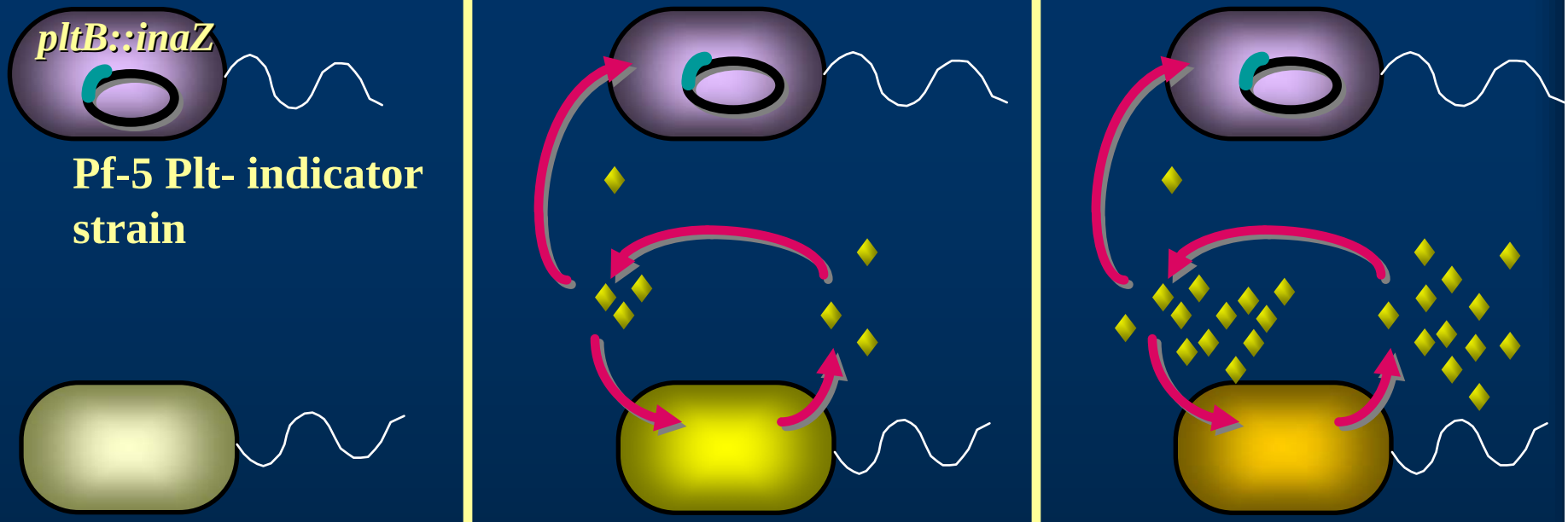

Promoter active
Ice
*plt* biosynthetic gene promoter
promoterless *inaZ*
No ice
Promoter inactive

# PLT and 2,4-DAPG effects on PLT occur at transcriptional level

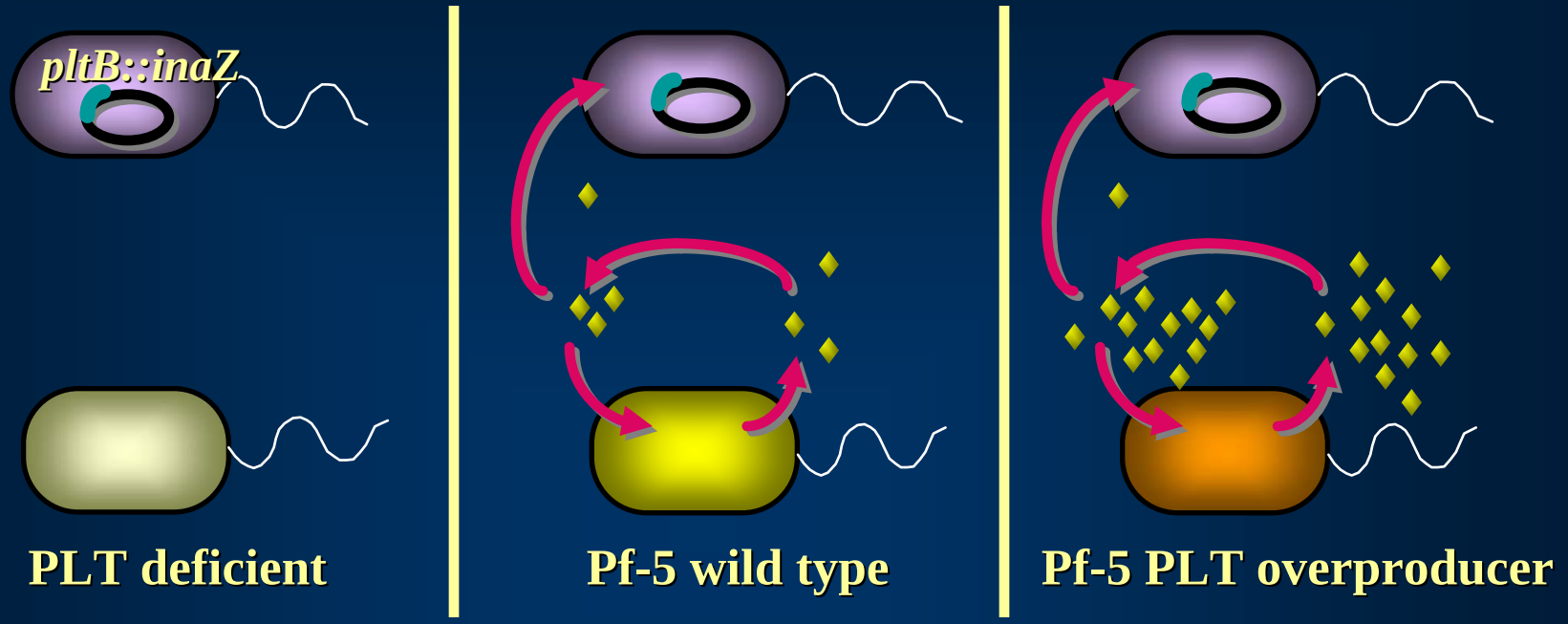


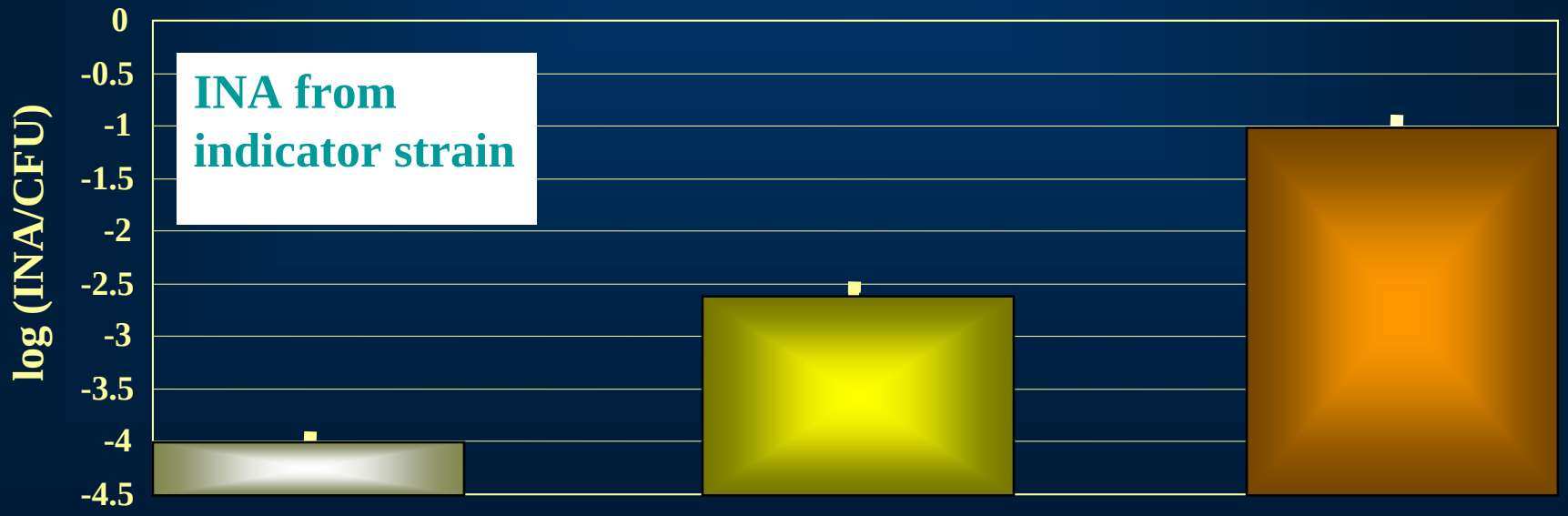



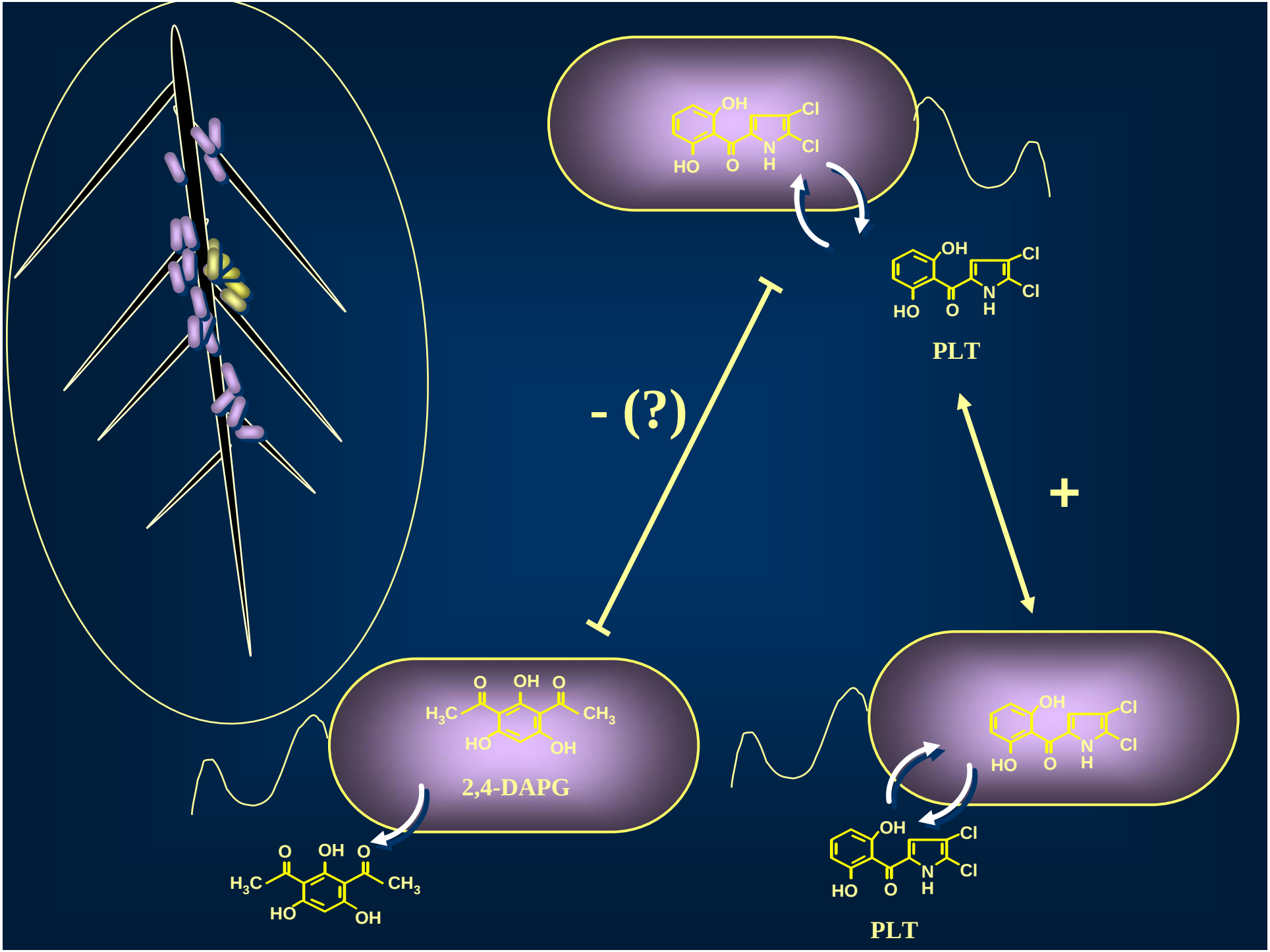
# Cross-feeding used to assess PLT autoinduction on germinating cucumber seeds in soil

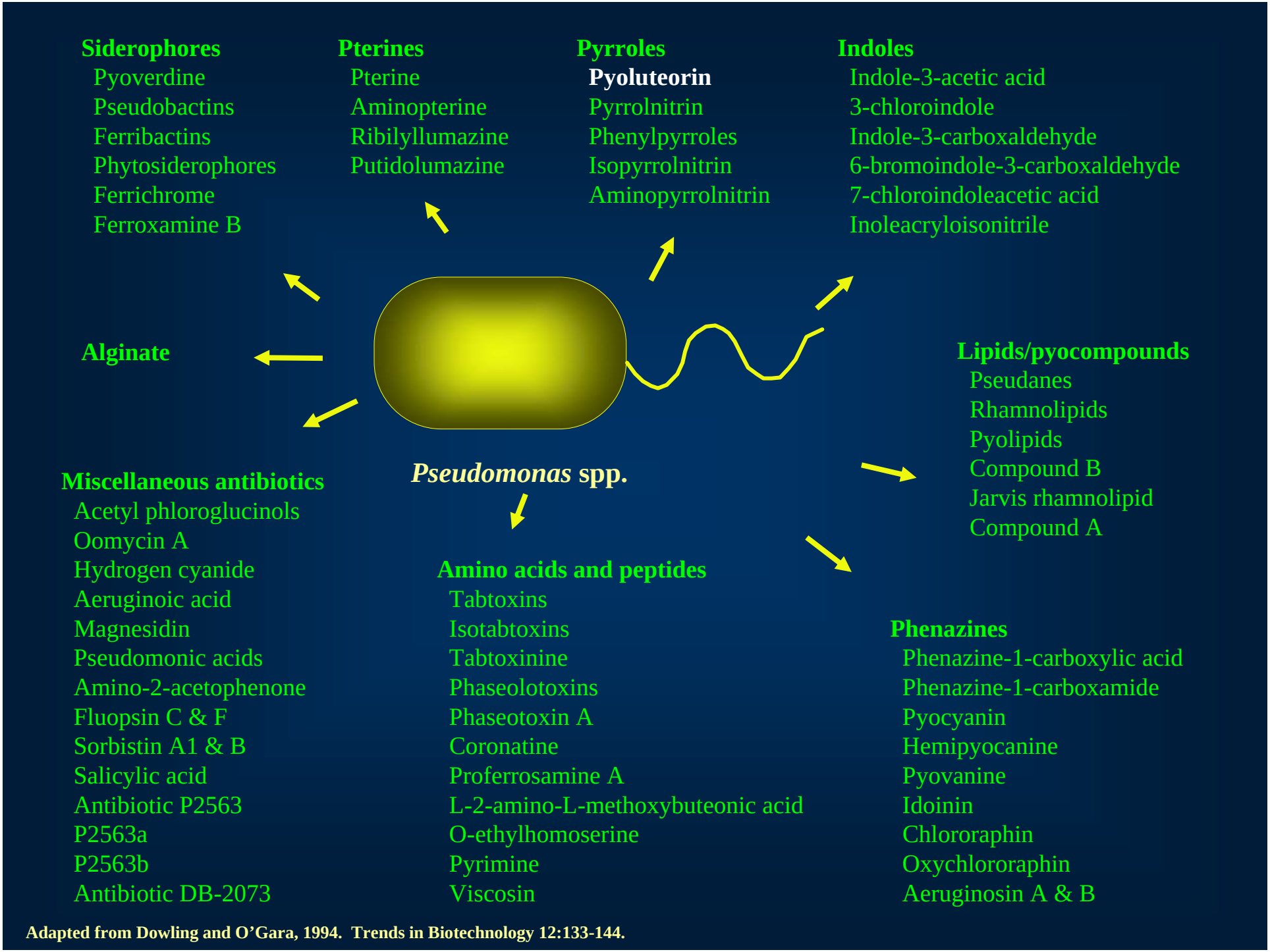


# Autoinduction occurs in the rhizosphere of cucumber

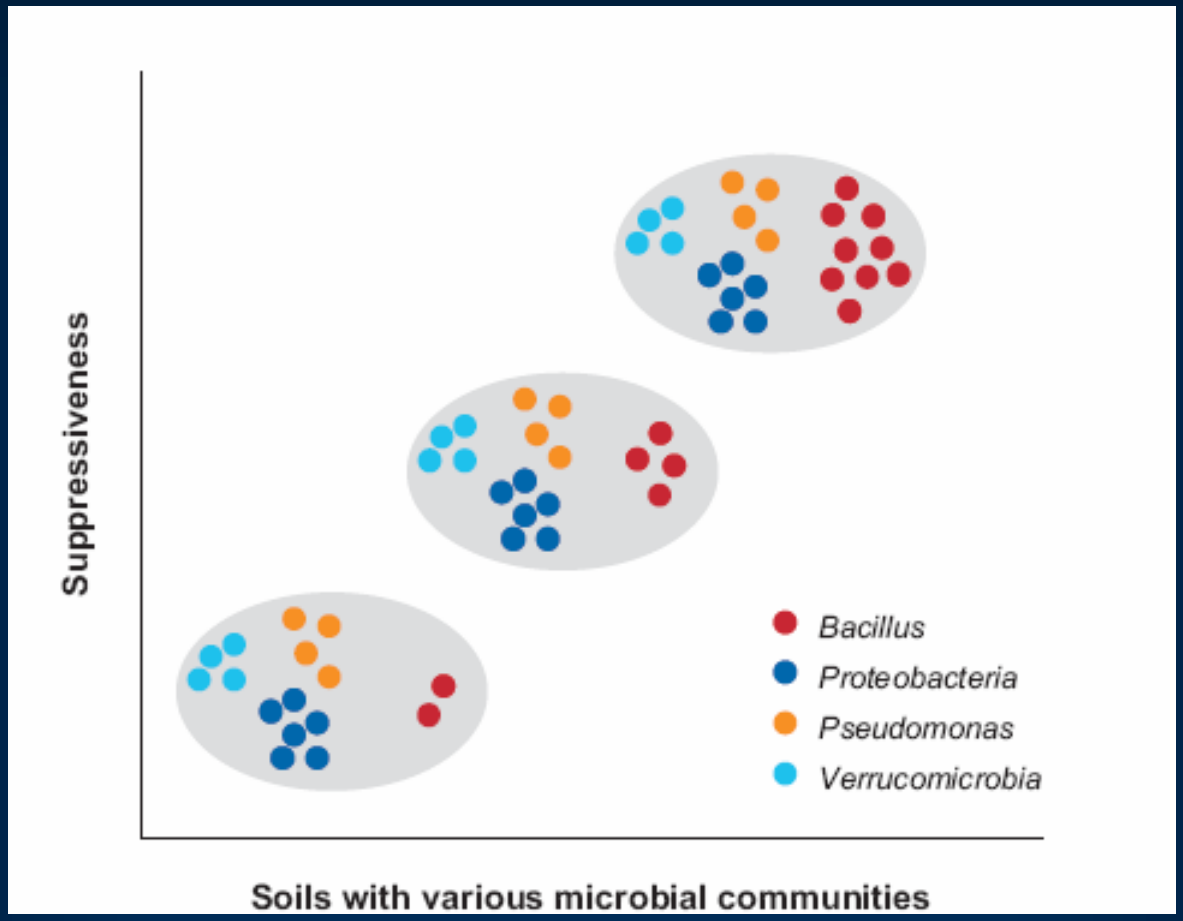



PLT
- (?)
+
2,4-DAPG
PLT




**Adapted from Dowling and O'Gara, 1994. Trends in Biotechnology 12:133-144.**




Identifying Microorganisms Involved in Specific Pathogen Suppression in Soil

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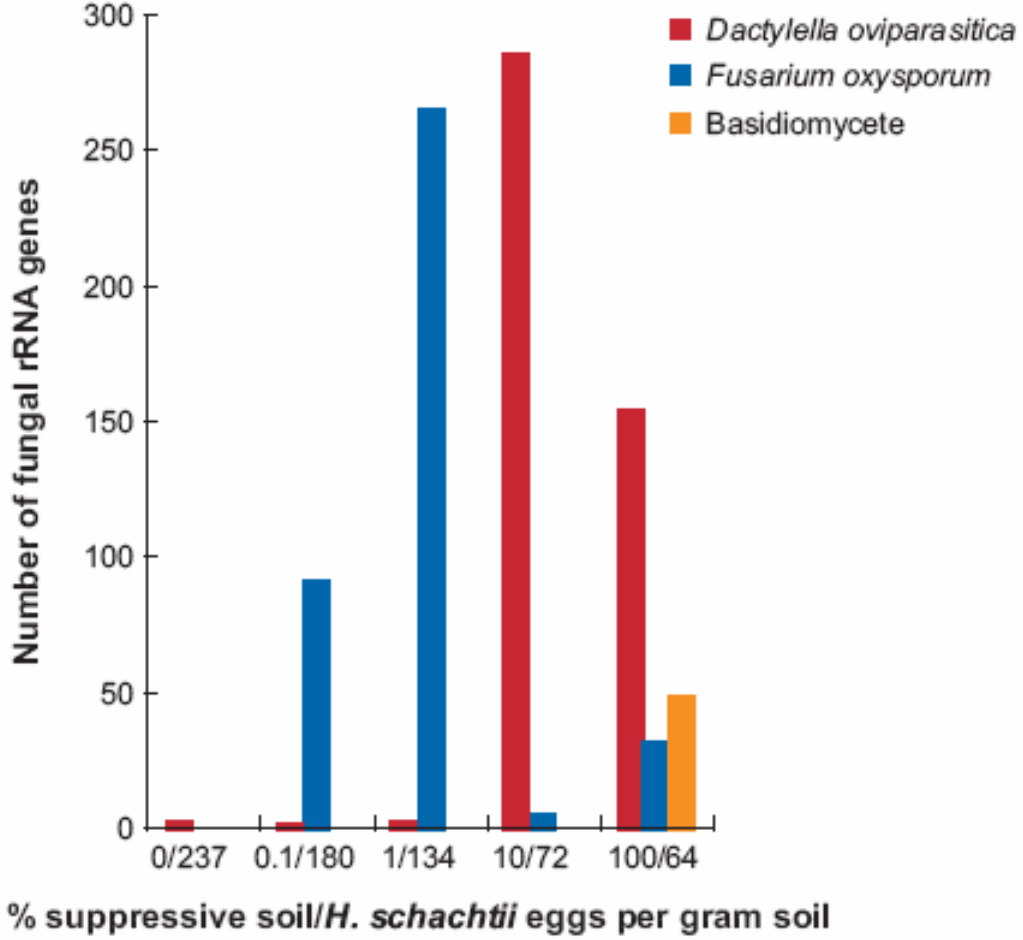
300
250
200
150
100
50
0
Number of fungal rRNA genes
Dactylella oviparasitica
Fusarium oxysporum
Basidiomycete
0/237
0.1/180
1/134
10/72
100/64
% suppressive soil/H. schachtii eggs per gram soil