Chapter 2
The Benefits of the Soil Food Web

Lecture 6 – Nutrient Cycling

A Healthy Food Web Will:

- Make Nutrients Available at rates plants require (eliminate fertilizer) leading to flavor and nutrition for animals and humans
- Retain Nutrients (stop run-off, leaching)
- Suppress Disease (competition, inhibition, consumption; no more pesticides!)
- Build Soil Structure (reduce water use, increase water holding capacity, increase rooting depth, create aerobic conditions)
- Decompose Toxins

The Ecological Monograph

Ecological Monographs, 55(1), 1985, pp. 119–140

INTERACTIONS OF BACTERIA, FUNGI, AND THEIR NEMATODE GRAZERS: EFFECTS ON NUTRIENT CYCLING AND PLANT GROWTH[1]

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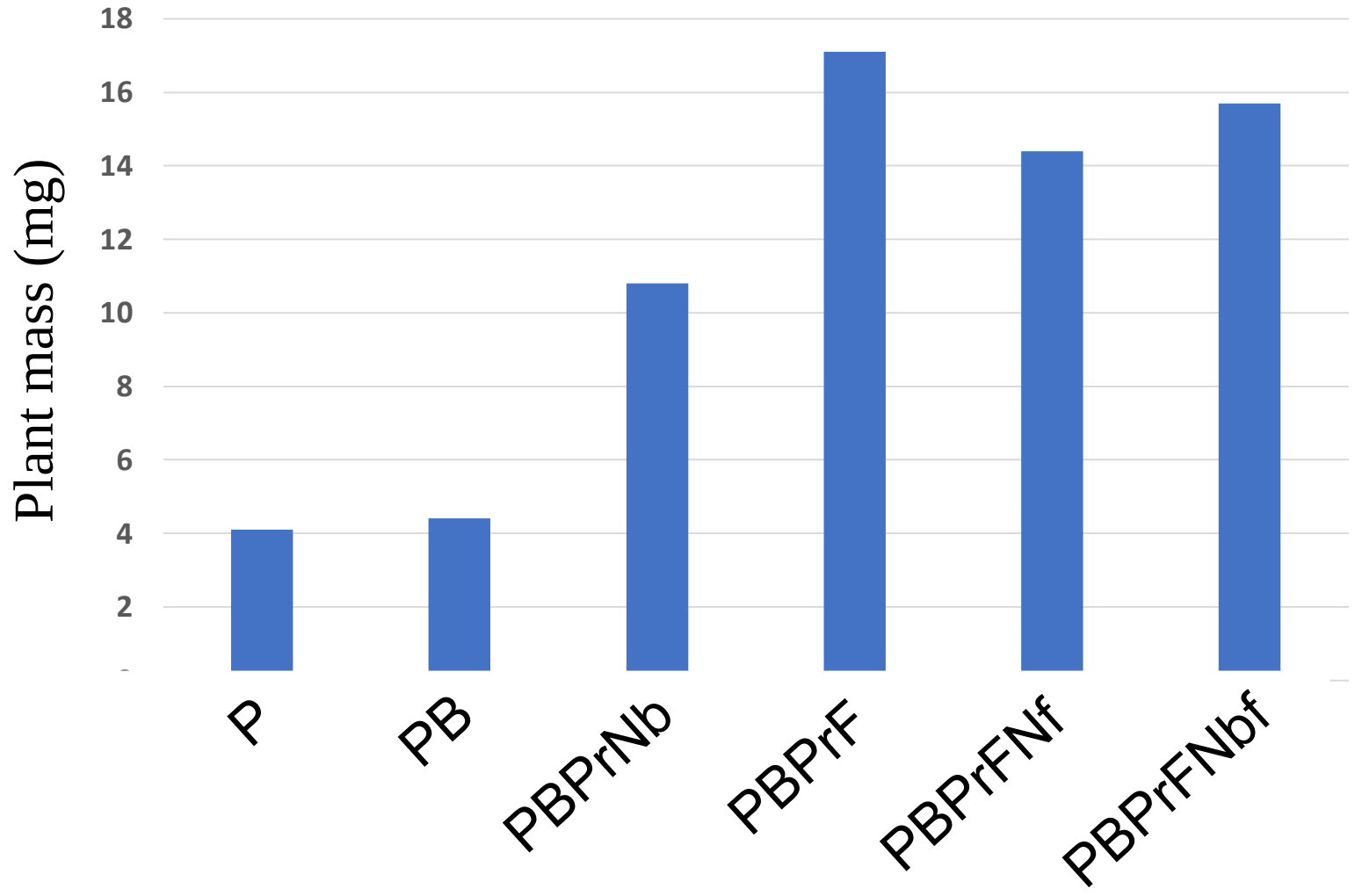
Abstract. The most common system responses attributed to microfloral grazers (protozoa, nematodes, microarthropods) in the literature are increased plant growth, increased N uptake by plants, decreased or increased bacterial populations, increased CO_2 evolution, increased N and P mineralization, and increased substrate utilization. Based on this evidence in the literature, a conceptual model was proposed in which microfloral grazers were considered as separate state variables. To help evaluate the model, the effects of microbivorous nematodes on microbial growth, nutrient cycling, plant growth, and nutrient uptake were examined with reference to activities within and outside of the rhizosphere.

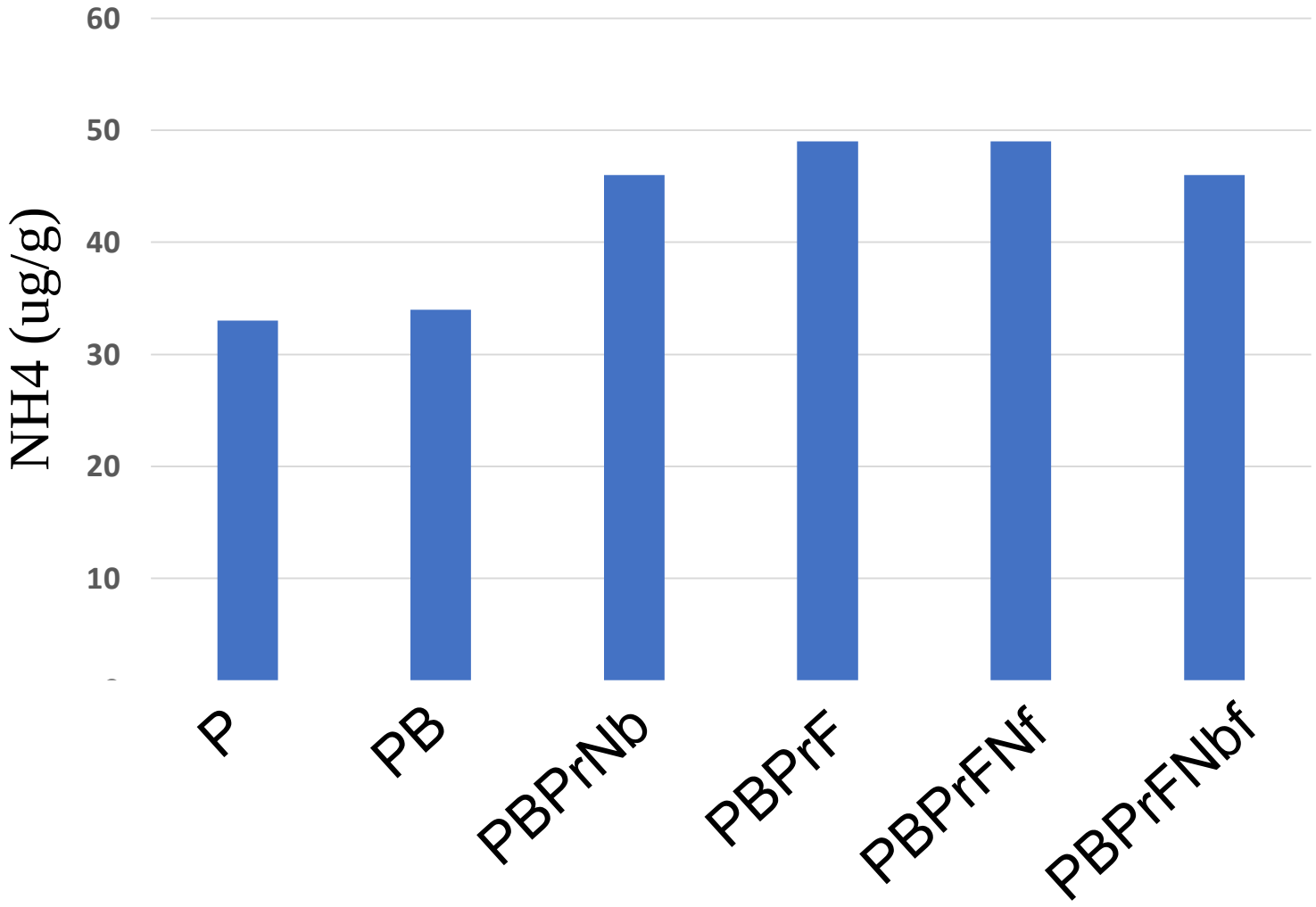
Organism Assemblages

- P = Plant + Sterile Soil
- PB = Plant + Bacteria
- PBF = Plant + Bacteria + Fungi
- PBPrNb = Plant + Bacteria + Protozoa + Bacterial Feeding Nematode
- PBPrFNf = Plant + Bacteria + Protozoa + Fungi + Fungal Feeding Nematode

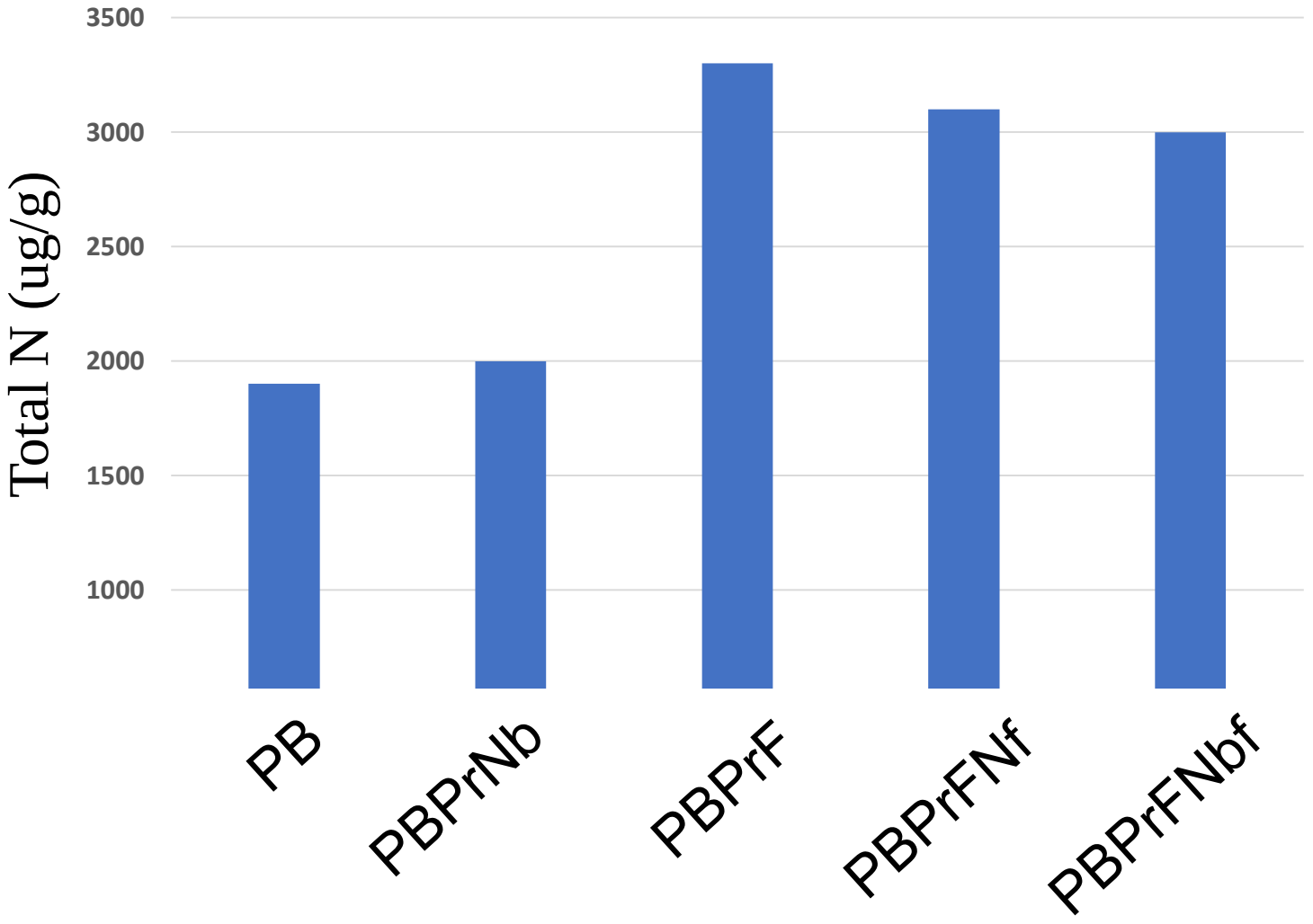
How Biology Affect Plant Growth



How Soil Biology Affects Soil Ammonium Levls



Total Nitrogen Content in Plant Shoots at 80 Days



THE POOP LOOP

Based on information from Dr. Elaine Ingham and Soil Foodweb, Inc.
by Alane O'Reilly Weber, Botanical Art
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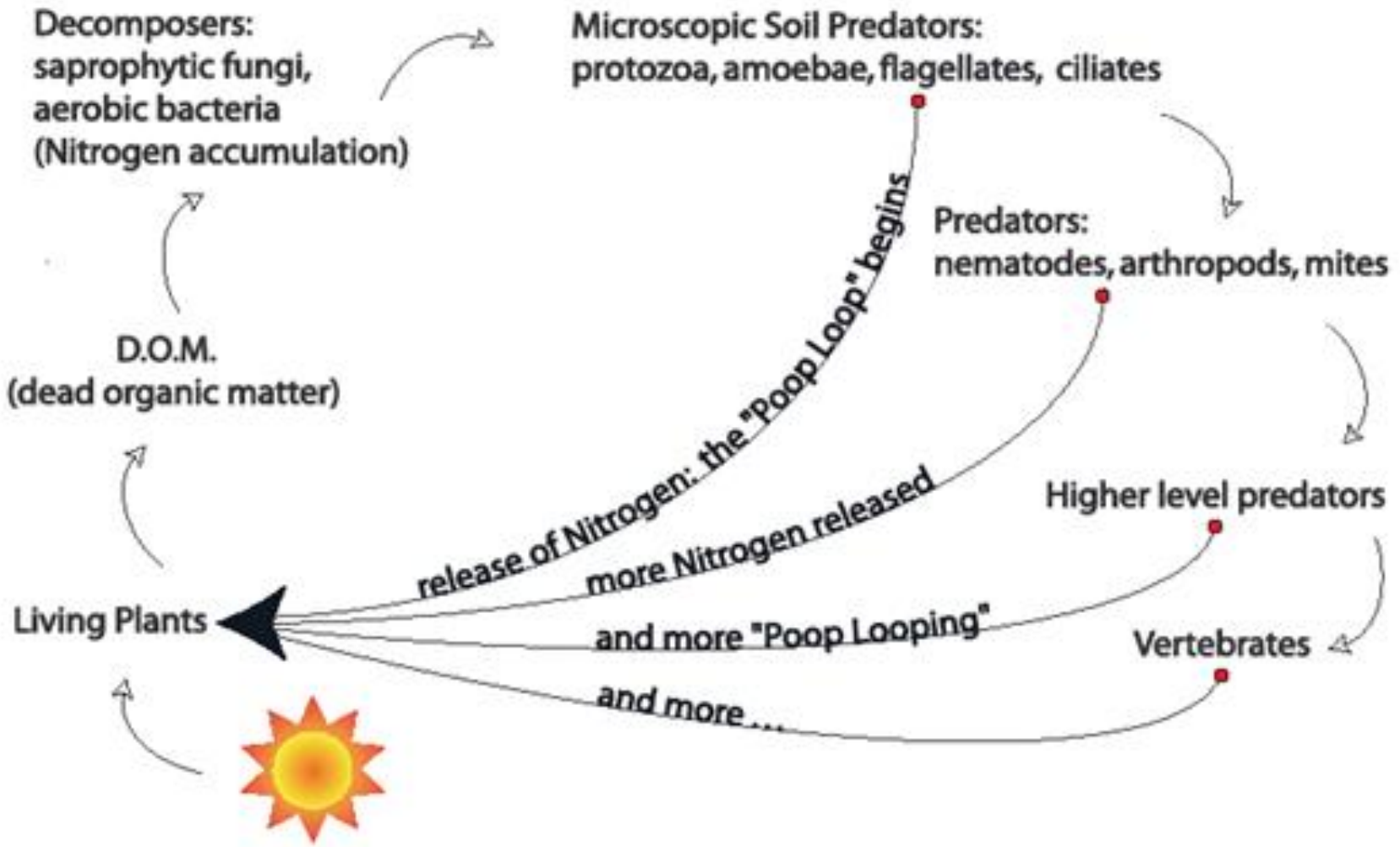



Picture your
favorite plant

Did you remember the roots?

- How important are roots to plants?
- Weeds - only 20% of their energy fixed into roots
- Grasses – up to 60% of their energy fixed into roots
- Vegetables - up to 75% of their energy fixed into roots
- Shrubs, Trees – up to 80% of their energy fixed into roots

Energy going into roots is used to :

1. Build structural roots
   a. Prevent the plant from falling over
   b. Firm anchor in the soil – How deep do roots go?

2. Take up nutrients (lateral roots) only by diffusion, no enzymes to break down organic matter.

3. Make exudates - 50% of energy into roots is released as:

50% of energy into roots is released as exudates!

For a weed that isn't much. But for crop plants, shrubs, and trees, that's huge!

Why dump so much energy into the soil?

What are exudates?

Simple Sugars, Proteins, and Carbohydrates

In human terms, what does that mean?

If I sent you into your kitchen to make something that is mostly sugar, a little protein and some carbohydrate, what am I asking you to make?

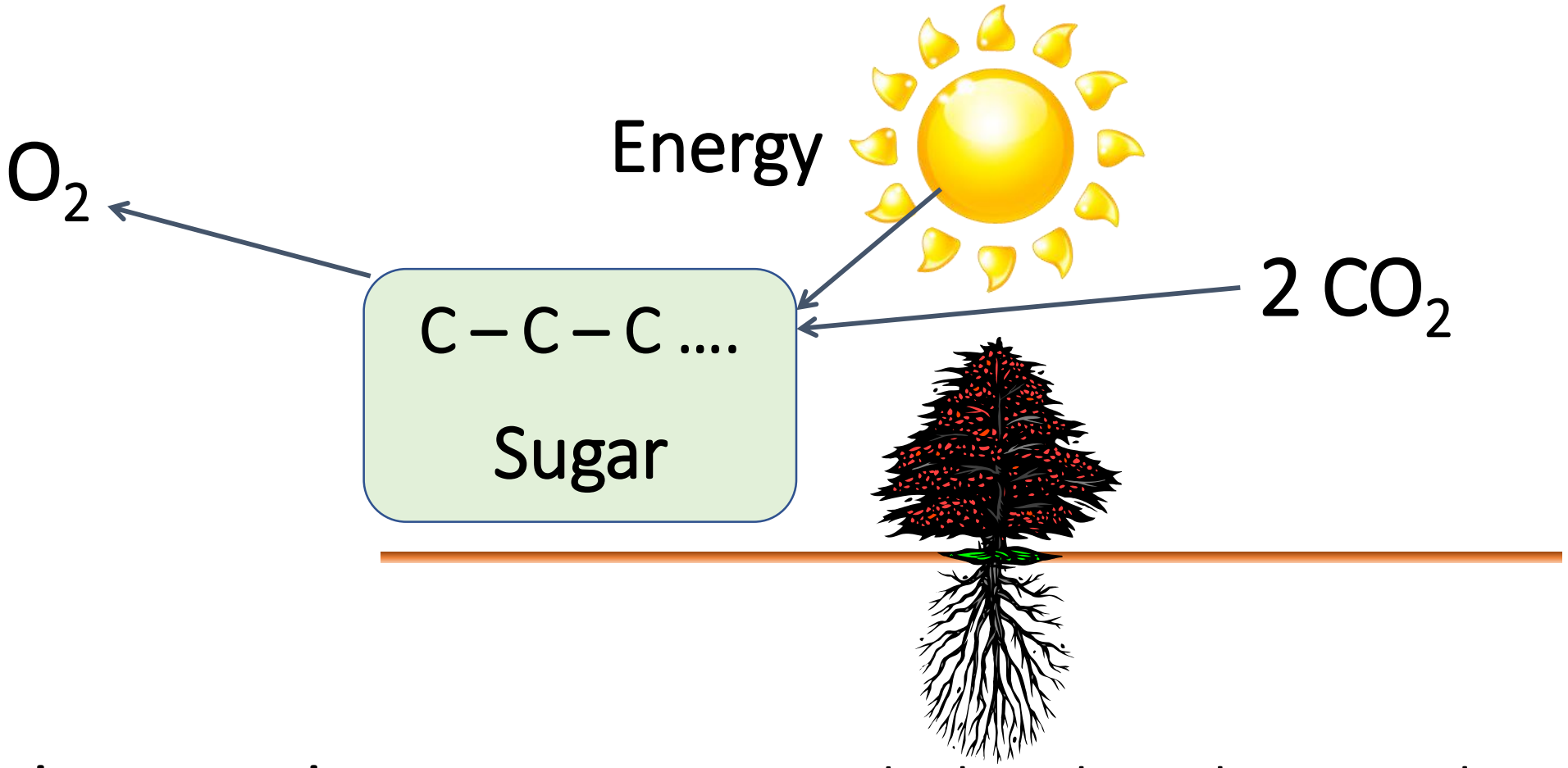
And why would I be releasing those into the soil?

Who do these cakes and cookies feed?

- They feed very specific species or bacteria and fungi that will help the plant gain the nutrients it needs

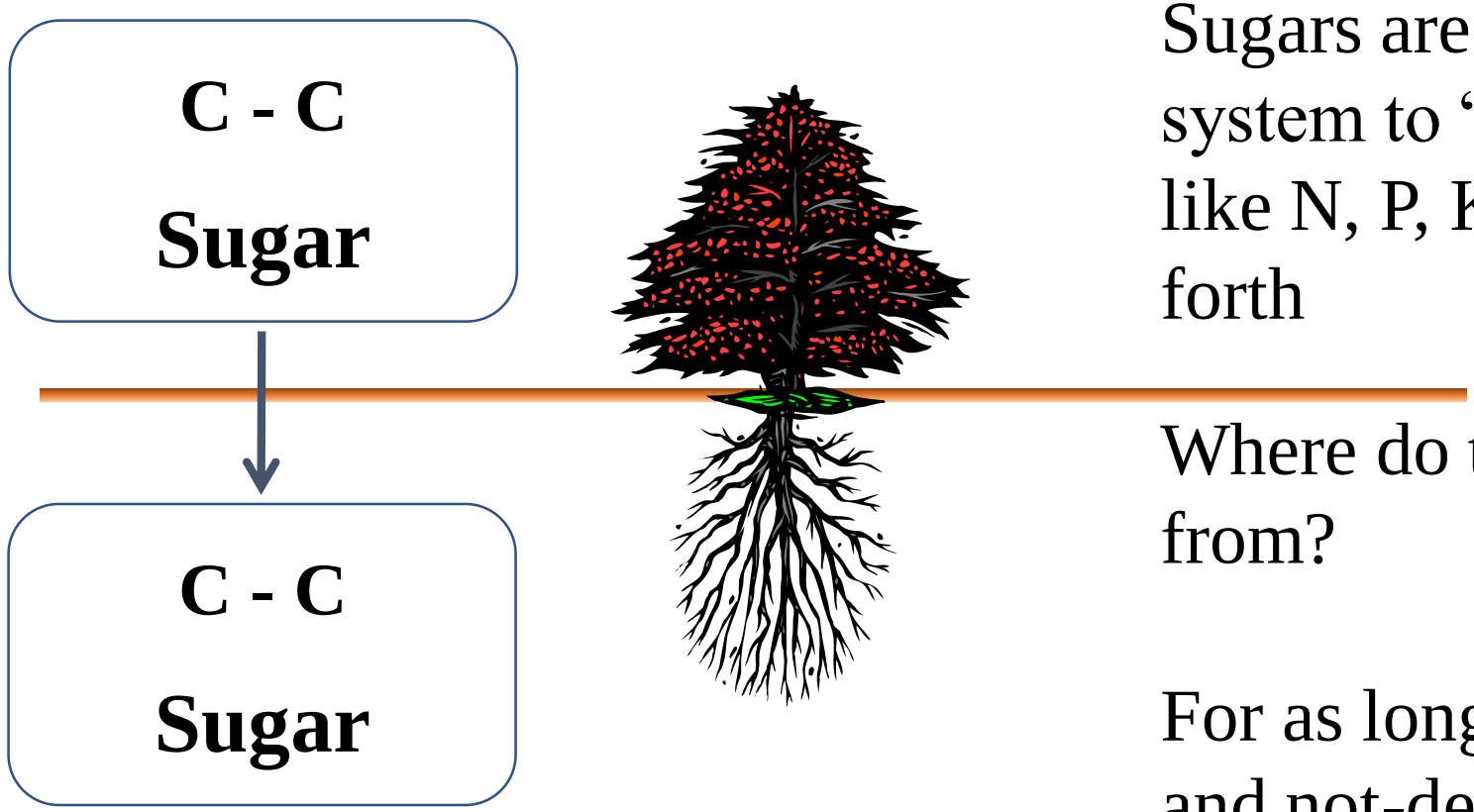
- They will select for the beneficial bacteria and fungi, because if these cakes and cookies fed “bad guys”, the plant would end up dead

Nutrient Uptake



Photosynthesis: Sugar is made by the plant. What does your plant do with sugar?

Nutrient Uptake



Sugars are pumped into the root system to “pick” other nutrients like N, P, K, S, Fe, Co, Ca, and so forth

Where do those nutrients come from?

For as long as that plant is alive and not-decomposed, those nutrients inside the plant are out-of-circulation

The Nutrient Uptake Process

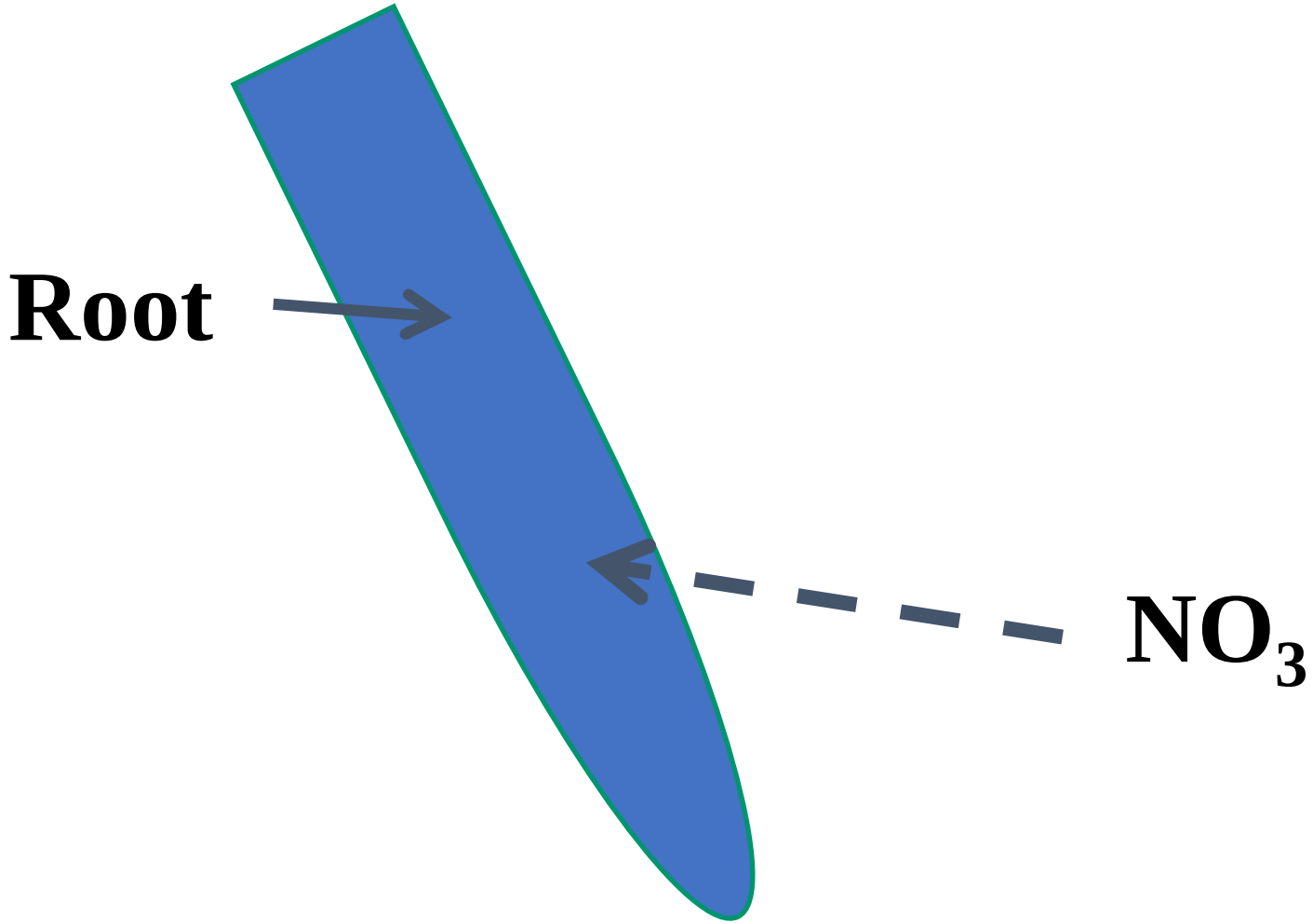
Diffusion: A physical process that refers to the net movement of molecules from a region of high concentration to one of lower concentration.

Active Transport: The movement of ions or molecules across a cell membrane in the direction opposite that of diffusion, that is, from an area of lower concentration to one of higher concentration. Active transport requires the assistance of a type of protein called a carrier protein, using energy supplied by ATP.

Why don’t bacteria and fungi consume all the nutrients on the way to the root?

Nutrient Uptake

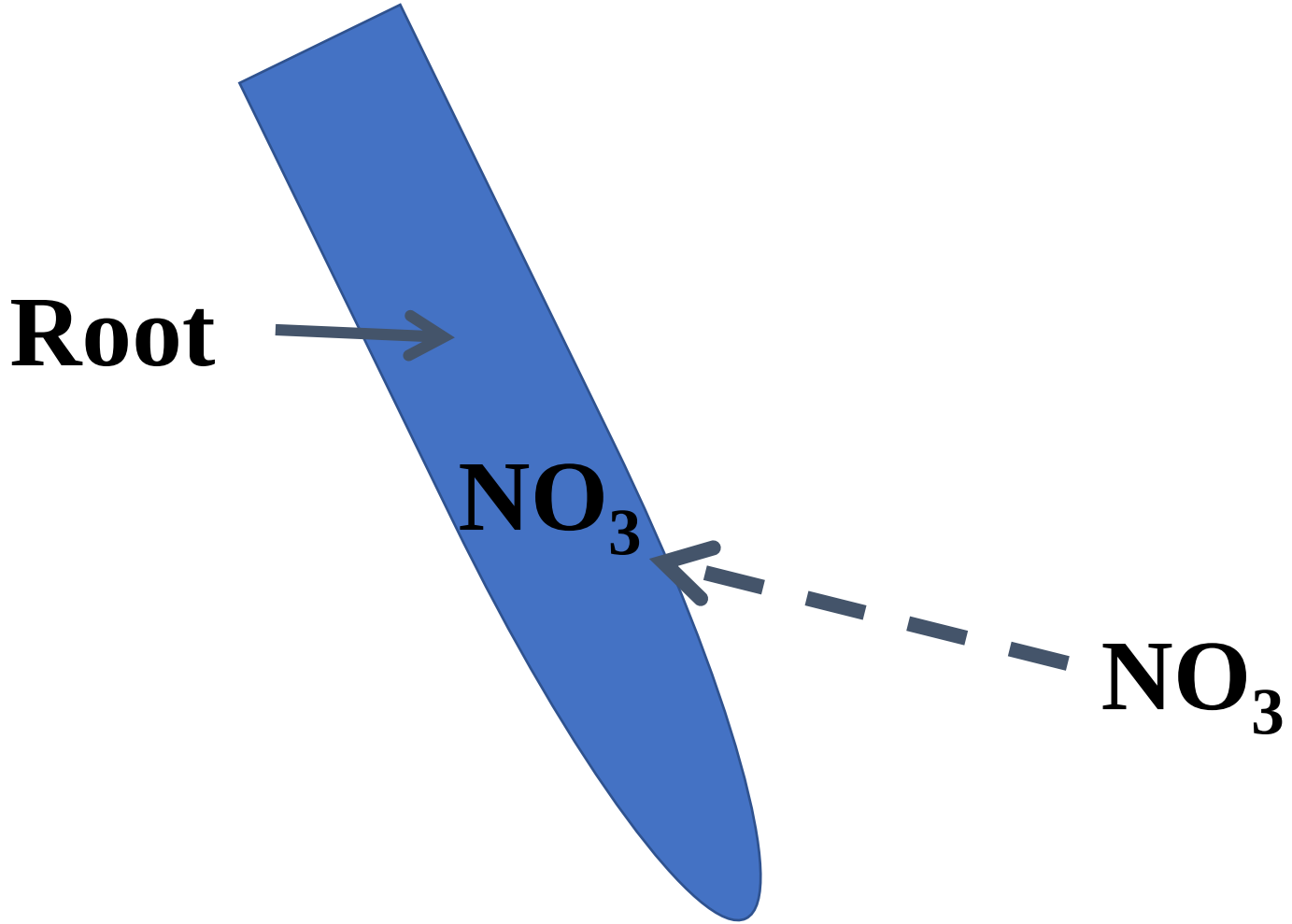
If there is no nitrate in the root, simple diffusion will pull the nutrients into the root so the concentration inside is the same as outside



Nutrient Uptake

If the concentration inside is the same as outside the root, then nitrate stops moving into the root.

To keep the NO3, or NH4, moving into the plant root, something else has to now happen



The Nutrient Uptake Process

With diffusion, what happens if the concentration inside the root and outside the root is the same, but the plant needs more nutrient to keep growing?

What if concentrations outside the root are too high, forcing the plant to take up more than it can tolerate?

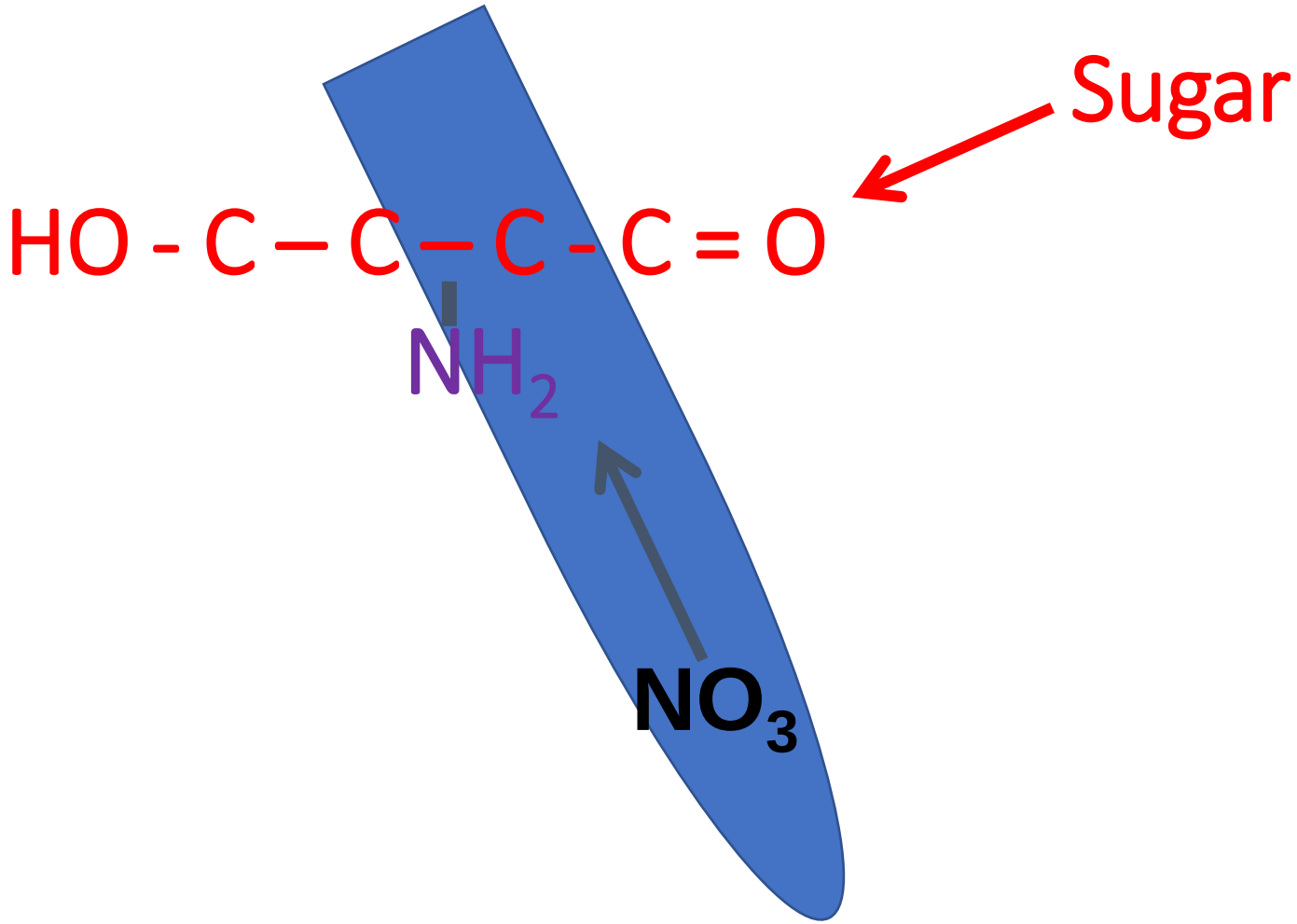
Do we know what the appropriate concentrations should be for all nutrients? How do we test for that? Concentration OUTSIDE the root, or INSIDE? Or in the plant tissues?

What happens if the nutrients outside the plant are too low in concentration to supply what the plant needs? Is there anything that the plant can do?

Nutrient Uptake

NO_3 is converted into NH_2, attached to a carbon chain and the sugar is now an amino acid

Nitrate can now continue to diffuse into the roots



But there is more to consider…

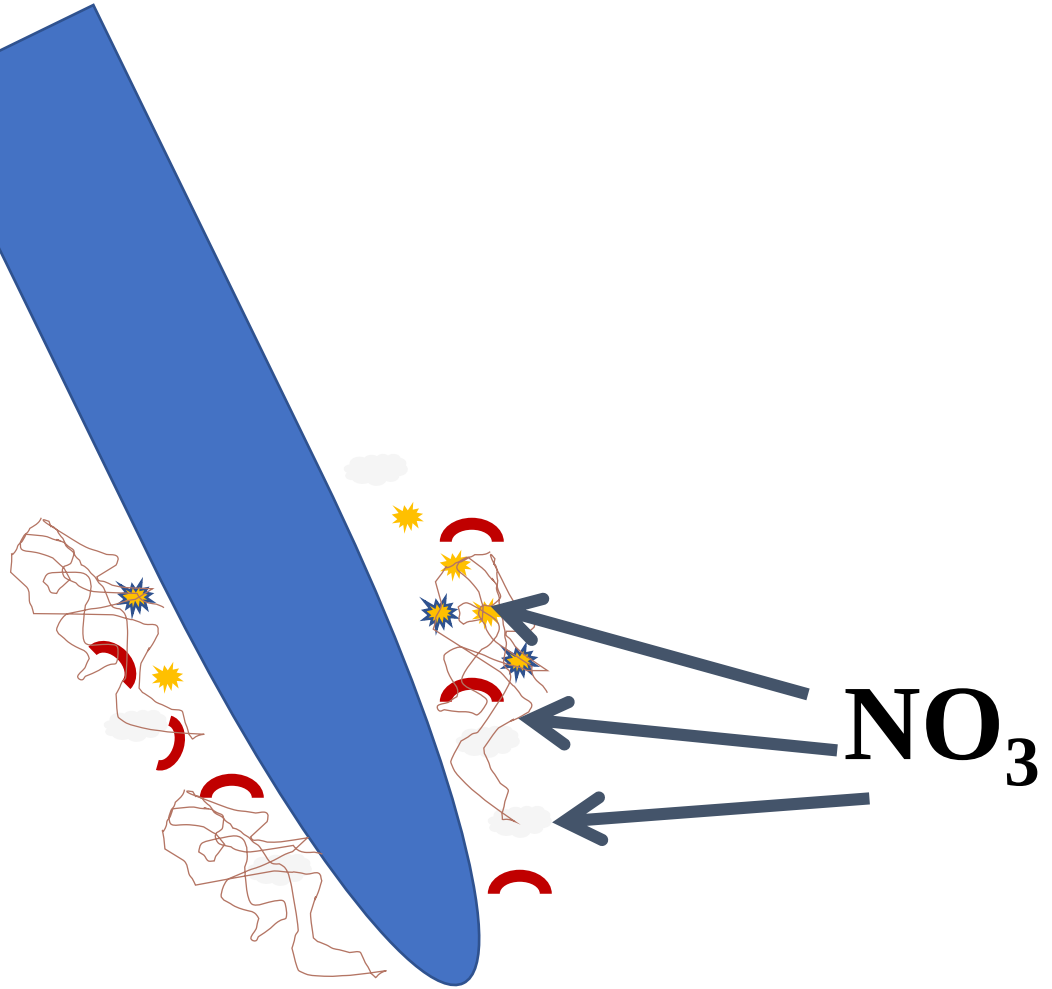
- Plants release exudates into the root zone. Documented by many scientific publications e.g., The Rhizosphere, J. Lynch, 1971
- This feeds an enormous biomass of bacteria and fungi around the roots (E. Paul, Soil Ecology, 1990)
- But exudates from the roots are mostly carbon; the microbes need N, P, K, S, etc.
- Bacteria and fungi intercept any nutrients released by cation exchange, long before the plant can get them

Nutrient Uptake

The 10^{12} bacteria/g and miles of fungal hyphae grab any and all nutrients diffusing to the root

How can the plant get the nutrients it needs?

BUT…..

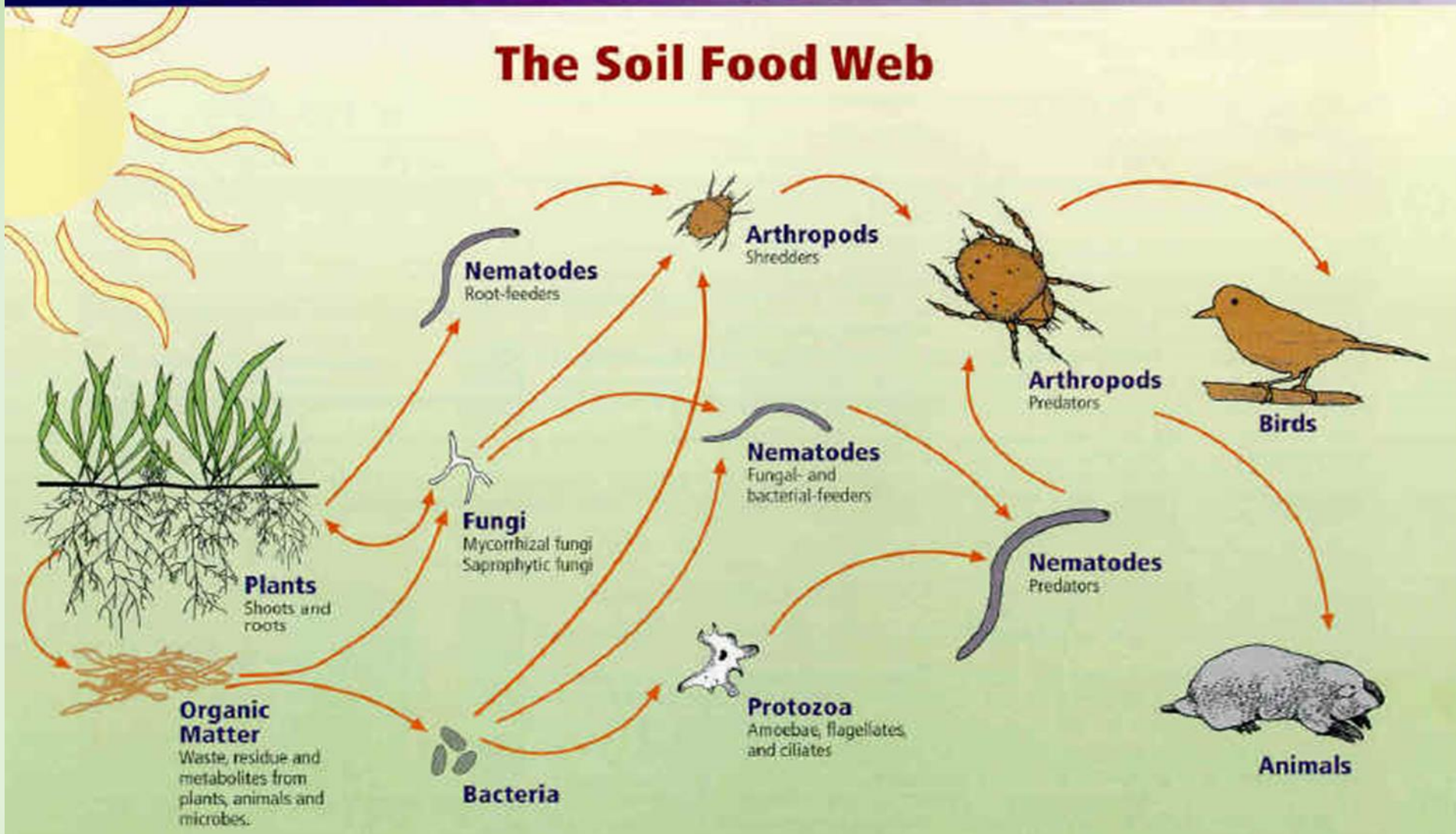


Organisms in soil vs rhizosphere (tomato)

Organism Assays	Ag Soil	Ag Rhizosphere	Healthy Soil	Healthy Rhizosphere
Total Bacteria (µg per g dry soil)	400	1000	350	1000
# of Bacterial species/g soil	5,000	5,000	25,000	75,000
Total Fungi (µg per g dry soil)	5	20	250	300 – 800
# of Fungal species/g soil	500	500	8,000	25,000
VAM colonization	0	0	55%	55%

Predators and Prey

The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

C:N Ratios

Group	C:N
Bacteria	5:1
Fungi	20:1
People	30:1
Green Leaves	30:1
Protozoa	30:1
Nematodes	100:1
Brown plant material	150 – 200:1
Deciduous Wood	300:1
Conifer wood	500:1

Nutrient Cycling (per unit biomass)

Flagellates need	30 C	1 N
1 Bacterium has	5 C	1 N
	25 C	ok

More bacteria needed – how many?

Nutrient Cycling (per unit biomass)

Flagellates need	30 C	1 N
6 Bacterium	30 C	6 N
	C ok	But too much N

- 5 N released for every 6 bacteria consumed
- What form of N? NH_4
- Some Plants need nitrate, some need ammonium, some need a mix of both
- How does the conversion happen?

Is this enough N to grow plants?

- 5 N released for every 6 bacteria consumed
- Each protozoan eats 10,000 bacteria per day, so that's ~8,000 N molecules released per day per protozoan!
- Healthy soils contain 50,000 protozoa per gram
- Protozoa eat 500,000,000 bacteria per gram of soil per day, which releases ~400,000,000 molecules of N per g soil per day
- That's ~7 ng of N per cm^2 surface of root soil per day, and Arabidopsis plants only require 0.2 ng per cm^2 root per day

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