Soil Organisms

Diversity	– size, genetics, energy, trophic level, etc…
Biomass	– > 1500 g / meter^2 (fungi)
Number	– 10 to 10^3 earthworms / m^2
	– 10^9 to 10^{10} protozoa / m^2
	– 10^{13} to 10^{14} bacteria / m^2
Distribution	– dry to wet & cold to hot
Roles	– function within the soil environment

Soil Organisms play critical roles in Soil Dynamics

– beneficial, neutral and detrimental

Trophic Levels – primary producers, etc…

Soil Structure

Infiltration/Aeration

Carbon and Nutrient Cycling

Earthworms

Earthwork densities on silty clay loam fields near West Lafayette, Indiana,

- devoted to various agricultural production systems for at least 10 years

Continuous corn, plowed	--10 earthworms per square meter
Continuous corn, no-till	--20 earthworms per square meter
Continuous soybean, plowed	--60 earthworms per square meter
Continuous soybean, no-till	--140 earthworms per square meter
Bluegrass-clover	--400 earthworms per square meter
Dairy pasture, manure	--340 earthworms per square meter
Dairy pasture, manure (heavy)	--1,300 earthworms per square meter

Soil Structure, Infiltration/Aeration and Nutrient Cycling

Soil Structure, Infiltration/Aeration and Nutrient Cycling

TABLE 11.6 Comparative Characteristics of Earthworm Casts and Soils

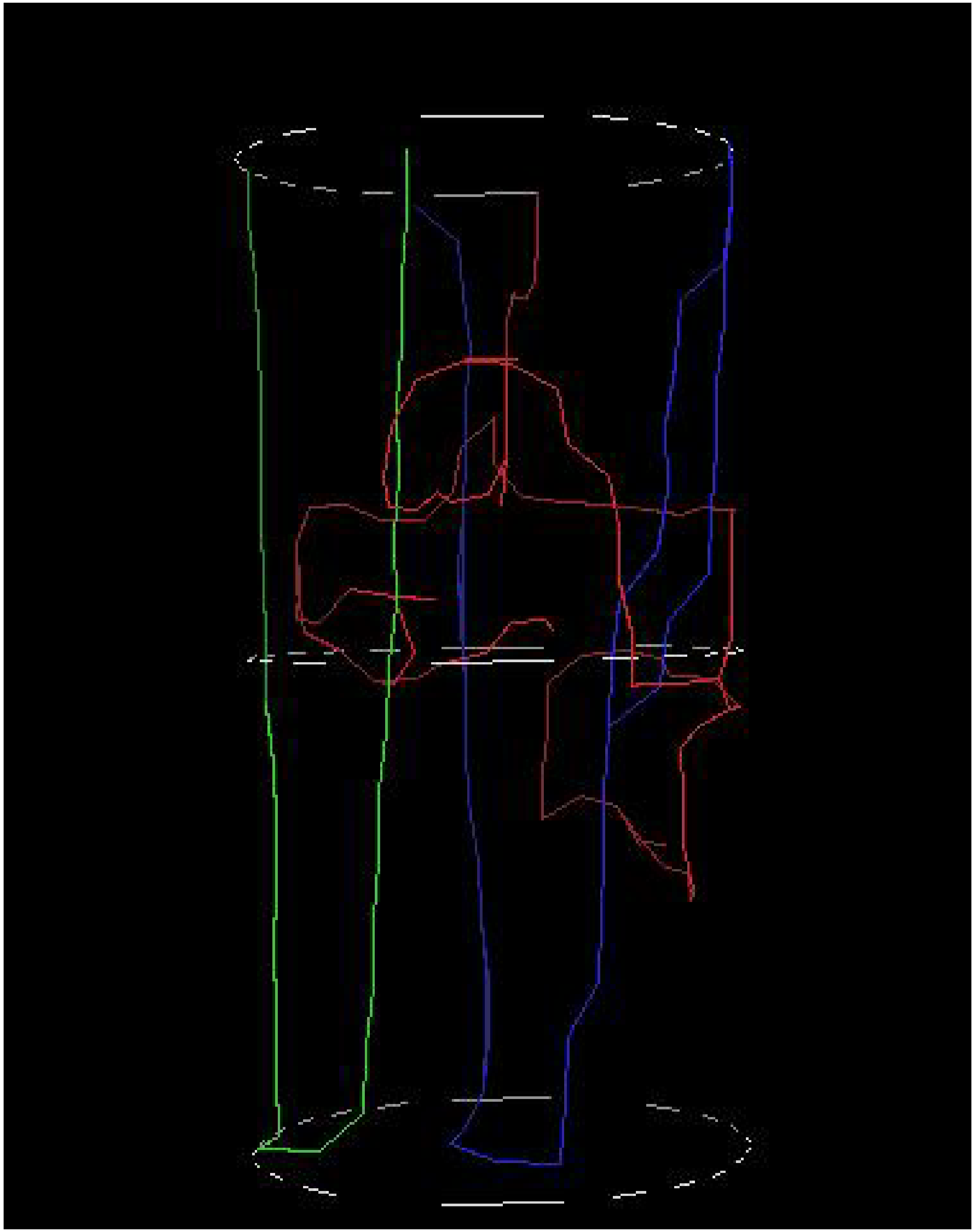
Average of six Nigerian soils.

Characteristic	Earthworm casts	Soils
Silt and clay, %	38.8	22.2
Bulk density, Mg/m^3	1.11	1.28
Structural stability[a]	849	65
Cation exchange capacity, cmol/kg	13.8	3.5
Exchangeable Ca^{2+}, cmol/kg	8.9	2.0
Exchangeable K^+, cmol/kg	0.6	0.2
Soluble P, ppm	17.8	6.1
Total N, %	0.33	0.12

[a] Numbers of raindrops required to destroy structural aggregates.
From de Vleeschauwer and Lal (1981).

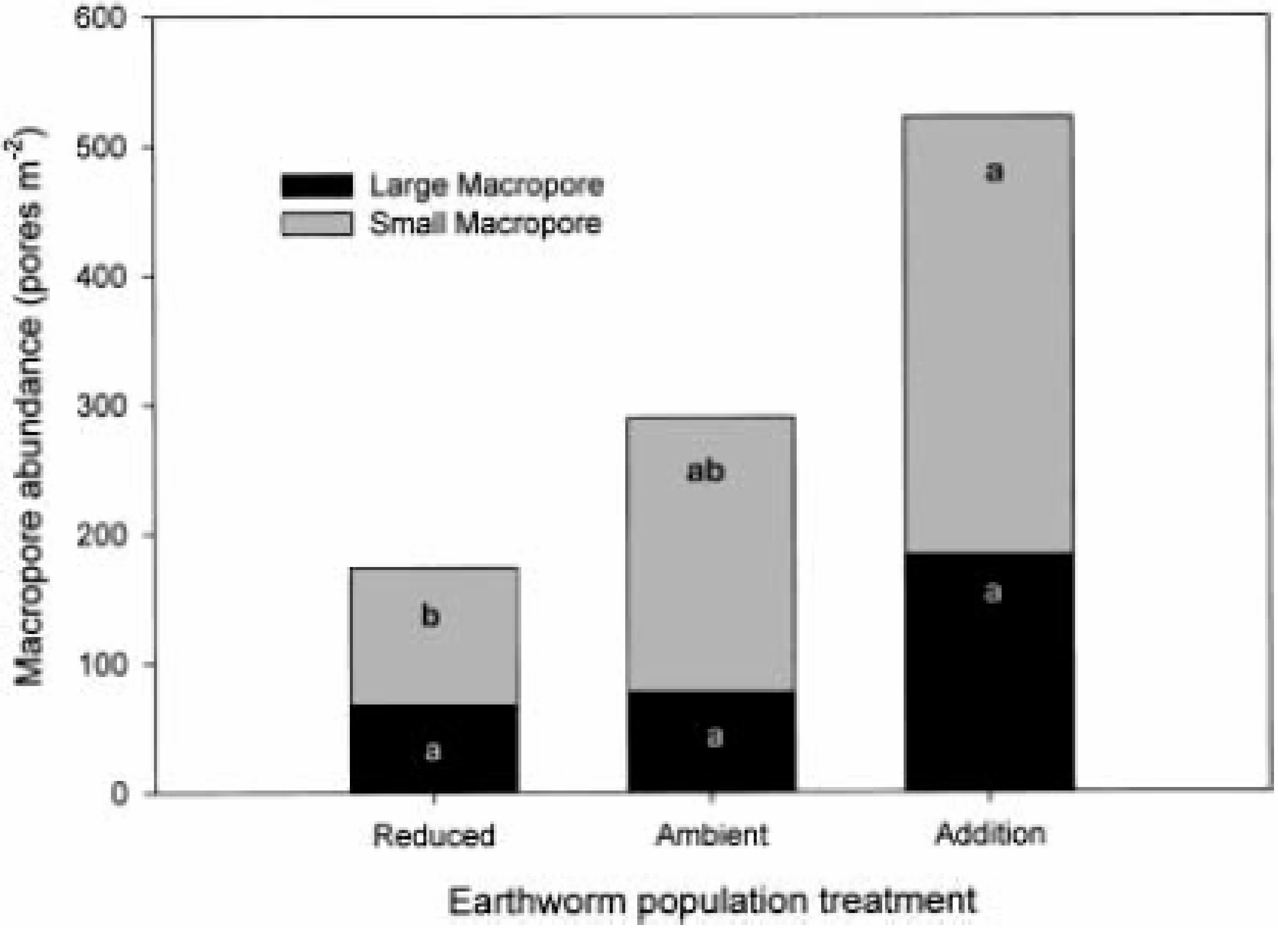
Soil Structure

Charles Darwin conducted an earthworm experiment where he spread chalk over grassy field. Upon returning in 29 years, (yes he was strange, but he was also patient), the worms had piled 6 inches of soil (castings) on top of the chalk line.



Infiltration/Aeration

Simulated earthworm track in a soil column



600
500
400
300
200
100
0
Macropore abundance (pores m-2)
Large Macropore
Small Macropore
b
a
ab
a
a
a
Reduced
Ambient
Addition
Earthworm population treatment

Infiltration/Aeration

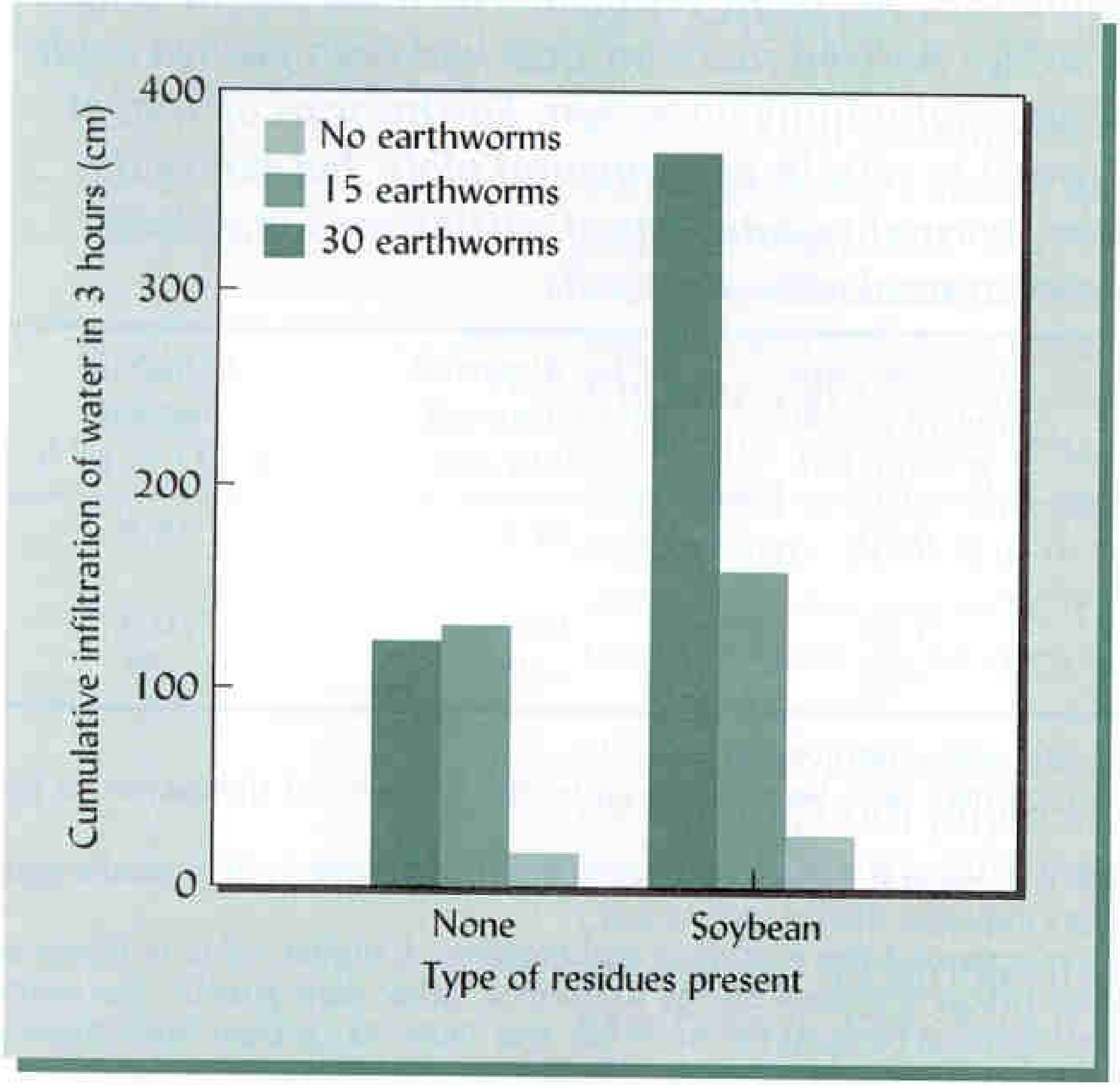


Table 1. Properties of earthworm casts and of soil from cultivated fields.

Compound	Casts	0-6" Soil Depth	8-16" Soil Depth
Total Nitrogen	0.353	0.246	0.081
Organic carbon (%)	5.17	3.35	1.11
Carbon : Nitrogen ratio	14.7	13.8	13.8
Nitrate nitrogen (ppm)	21.9	4.7	1.7
Available phosphorus (ppm)	150.0	20.8	8.3
Exchangeable calcium (ppm)	2,793.0	1,993.0	418.0
Magnesium (ppm)	492.0	162.0	69.0
Potassium (ppm)	358.0	32.0	27.0
Total calcium (%)	1.19	0.88	0.91
Total magnesium (%)	0.545	0.511	0.548
Percent saturation	92.9	71.1	55.5
pH	7.0	6.36	6.05
Moisture equivalent (%)	31.4	27.4	21.1

Source: Lunt, H. A. and G. M. Jacobson, The Chemical Composition of Earthworm Casts. Soil Science, 58:5 (1944).

Another effect on the environment is that the casts are always more neutral (closer to pH 7) then the surrounding soil.

This helps neutralize the acids or alkali that may be present in the soil thereby optimizing the pH for the root development of majority of cultivated plants.

A mucosal substance rich in proteins lines the wall of the burrows. This substance in turn serves as energy source for microbes.

The concentration of nitrifying microbes has been observed to be about 40% higher in the burrows then in the rest of the soil.


Soil Bacteria – Eubacteria **and** Archaebacteria

Requirements of Microbes

Growth usually limited by:

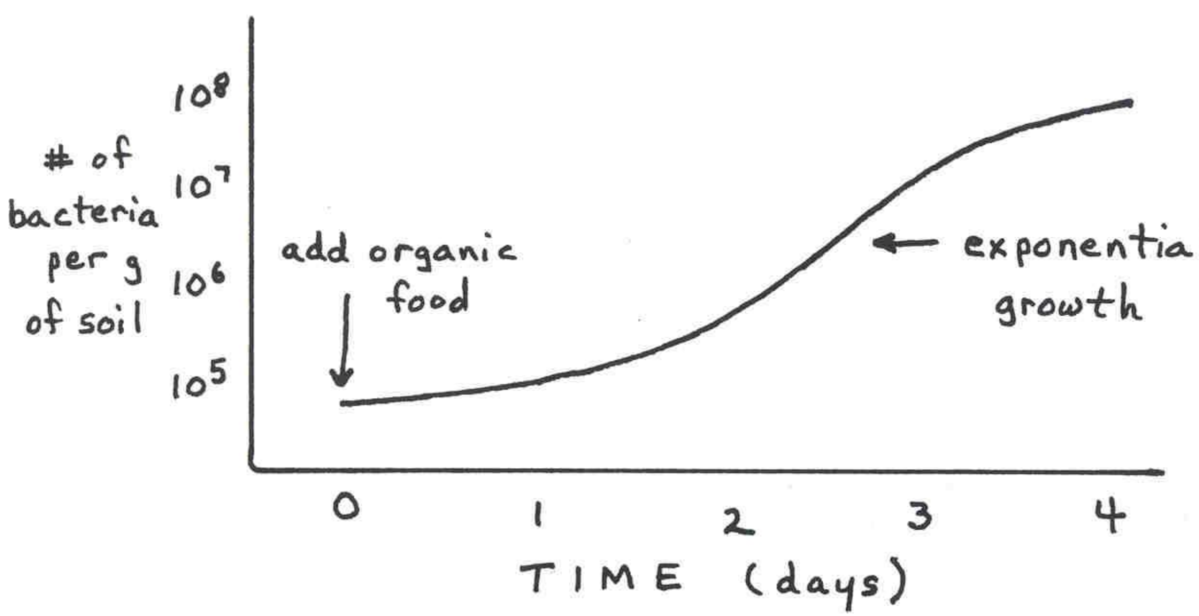
- temperature
- water
- pH
- oxygen
- nutrients (esp. C)

Nutritional Needs -

- usable source of energy
- essential elements

Growth & Survival of Microbes

Growth
- rapid population increase under favorable conditions (temp., moisture, organic food)
- can double cell number in 2-3 hrs
- rapid response to change in conditions:
  - --> multiplication to take advantage of food source
  - --> replacement of one population by another



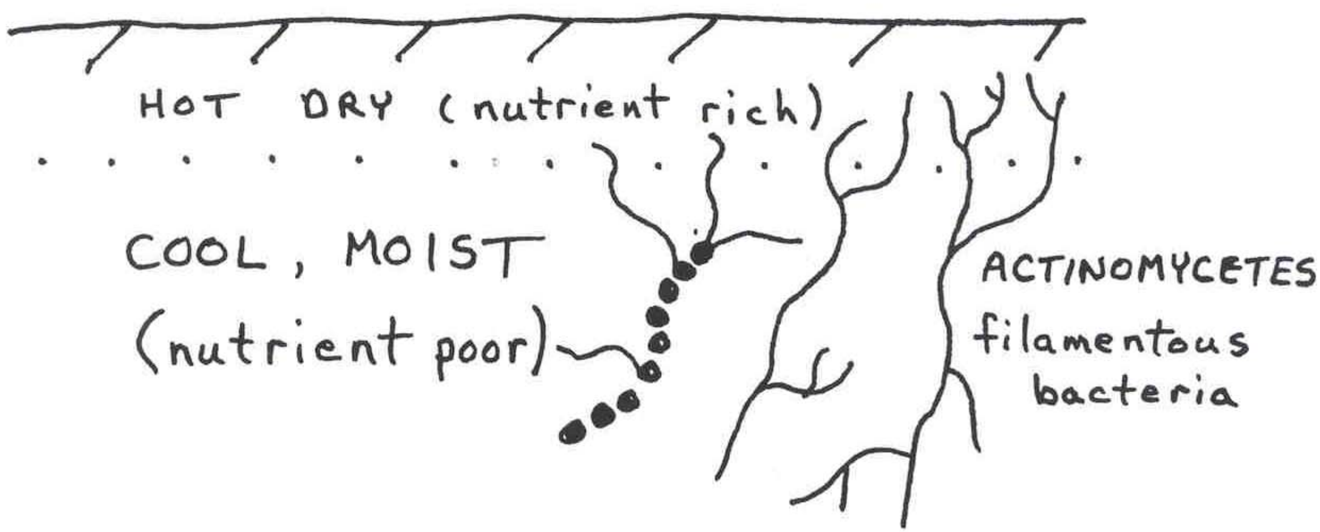
SPREAD - by larger organisms
- by moving air (as dust) or water
- maintaining sterile soil is <u>very</u> difficult.

SURVIVAL - remarkable ability
- soils are <u>usually</u>
  - too dry
  - too cold
  - too hot
  - nutrient deficient
- survival tactics

1. **DORMANCY (inactive, dessicated)**
   --> may be high mortality

2. **Spore formation -**
   - **most fungi, many bacteria**
   - **may survive boiling!**

3. **Filamentous growth habit**
   (fungi, some bacteria)



Constraints and Adaptations

Physical Constraints:

Temperature

$> 35^{O}C$

-Kills less heat-tolerant

-induces spore formation

$\leq 0^{O}C$

-stops microbial growth

WATER

Moderate drought ---> reduces population of rotifers, nematodes, protozoa (all mobile organisms)

Extreme drought ---> fungi and bacteria form spores

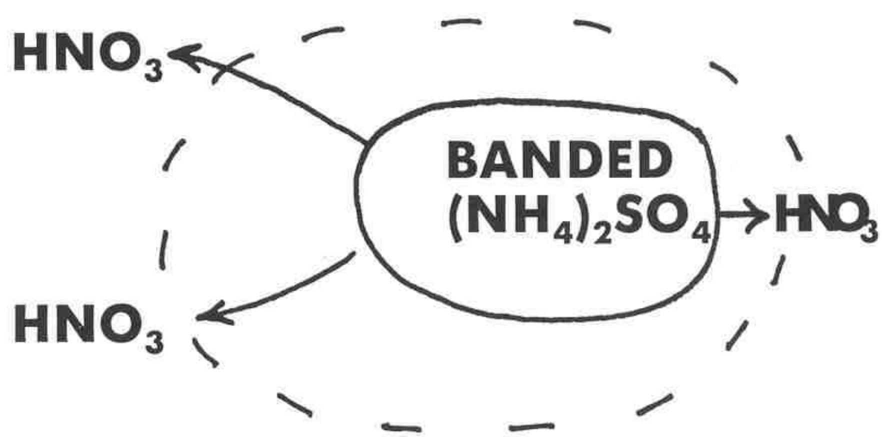
Excess water - aerobic ---> anaerobic organisms.

Chemical Constraints

SOIL ACIDITY

- ---> shortage of Ca
- ---> toxicity of Al or Mn
- ---> species vary in tolerance

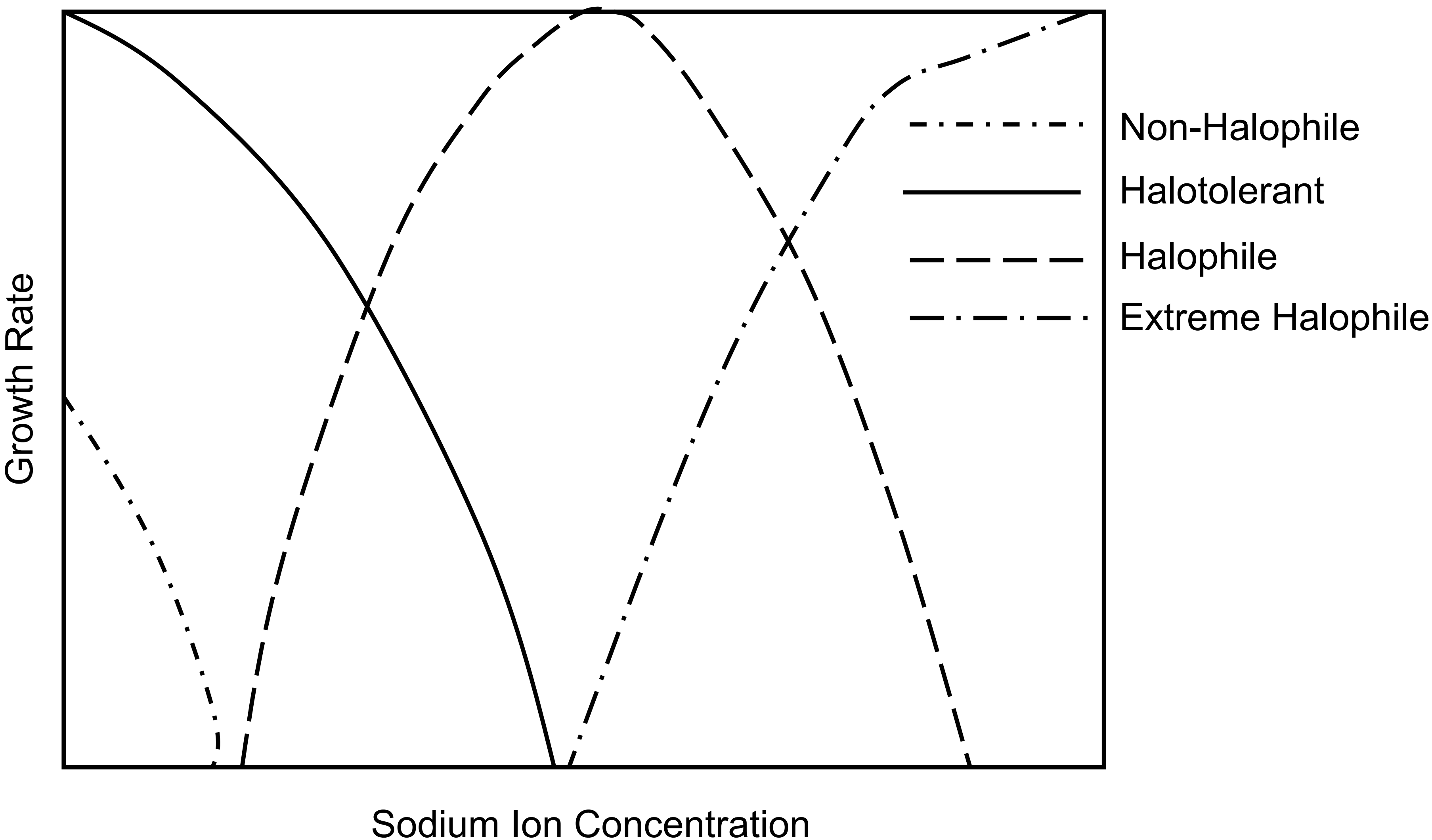
Oxidation reactions are inhibited in acid soils:



Nitrification in band inhibits further nitrification

Soil Salinity

- bacteria are more tolerant than plants



TOXIC METALS (Cu, Cr, As, Hg, etc.)

---> can almost sterilize soils (e.g. acid mine spoils)

---> some microbes are adapted

Nutritional Constraints

Carbon & Nitrogen - most commonly deficient for organotrophic soil microbes
- **usually limiting in useability, not quantity.**

Carbon - **humus breakdown is slow, limits growth**

Nitrogen
- **humus ---> too slow**
- **NH_4^+, NO_3 ---> rapid growth**
- **N_2 gas ---> unusable (Non-fixers)**

C:N Ratio – Rule of Thumb

10:1 average biomass of microorganism

15/20:1 ideal food source

Competitive Advantages

BIOLOGICAL NITROGEN FIXATION

$$N_2 \xrightarrow{\text{nitrogenase}} NH_3 \longrightarrow \text{organic N compounds}$$

- consumes energy
- inhibited by NH_4^+ or NO_3^-
- several bacteria have ability
- most efficient in symbiotic N-fixing bacteria

AUTOTROPHY

phototrophs - energy from sun

lithotrophs - energy from inorganic oxidation

$NH_4^+ \longrightarrow NO_3^-$ $S^{-2} \longrightarrow SO_4^{=}$

avoid competition for limiting organic food.

OPPORTUNISM

- ability to grow rapidly in response to addition of organic material

INHIBITOR PRODUCTION

- bacteria & fungi sometimes release organic inhibitors ---> ANTIBIOTICS

Penicillium (fungus) ---> penicillin
Actinomycete sp. ---> streptomycin,
tetracycline, etc.

SPECIALIZATION

- avoid competition, use C source that others cannot use

WOOD-ROTTING FUNGI & BACTERIA

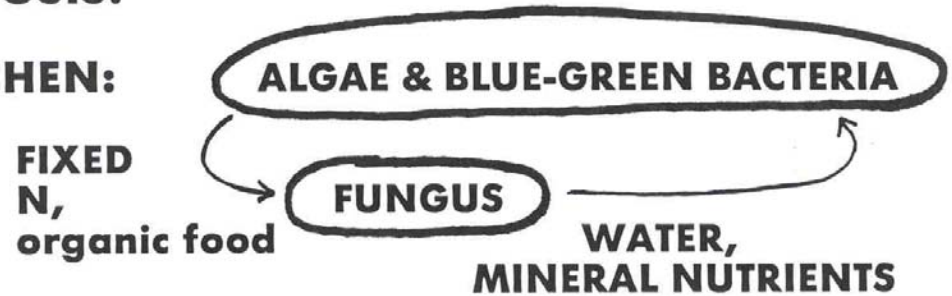
enzymes
cellulose, lignin ---------> energy

plastics, petroleum, pesticides
used by specialized microbes

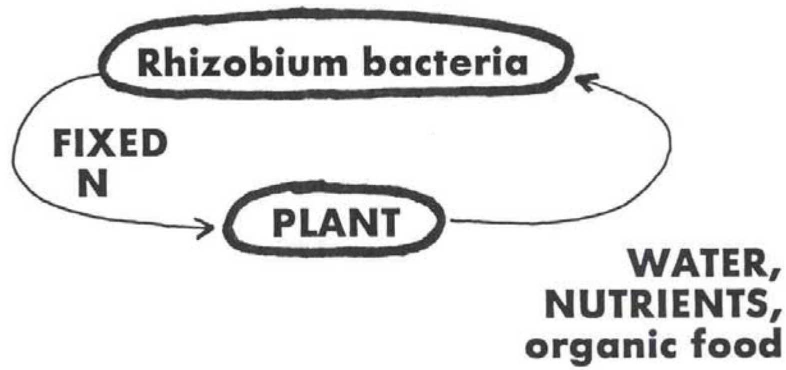
PARASITISM & PREDATION

SYMBIOSIS:

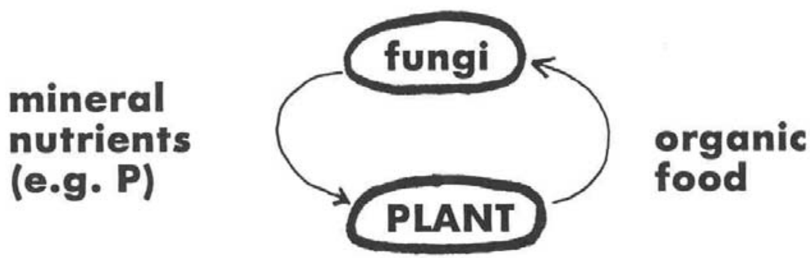
LICHEN:



N_2-FIXING LEGUMES:



MYCORRHIZAE:



MICROBIAL PROCESSES

Decomposition of Organic Matter -

SUBSTRATE
(Mostly plant tissue)

Simple Soluble Cell Components (sugars, organic acids, etc.)

SMALL COMPONENT

rapidly metabolized

CO_2, NH_3, PO_4, etc.

Complex, Less Soluble Macromolecules (Polymers) Peptides, proteins nucleic acids, polysaccharides

LARGE COMPONENT

rate variable

CO_2, NH_3, PO_4, etc.

Most organic matter <u>added</u> to soil (as plant tissue is POLYSACCHARIDES (carbohydrate polymers)