HEALTHY PLANTS GROW IN HEALTHY SOILS

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GAIA THEORY

In 1979- James Lovelock PhD published the book: A New Look at Life on Earth.

He proposed an idea that he hoped would facilitate the task of converting destructive human activities into constructive and cooperative human behaviour.

The idea that both the living (biotic) and non-living (abiotic) parts of the Earth are interconnected in intricate ways, so all ecosystems can function together harmoniously.

SO WHY DO WE TREAT SOIL LIKE DIRT?

A dust storm at the Denver Airport that grounded airplanes

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Desertification- not just in Africa

SOIL ORGANIC C: FEEDING THE SOIL TO FEED THE PLANTS

Increasing water holding capacity

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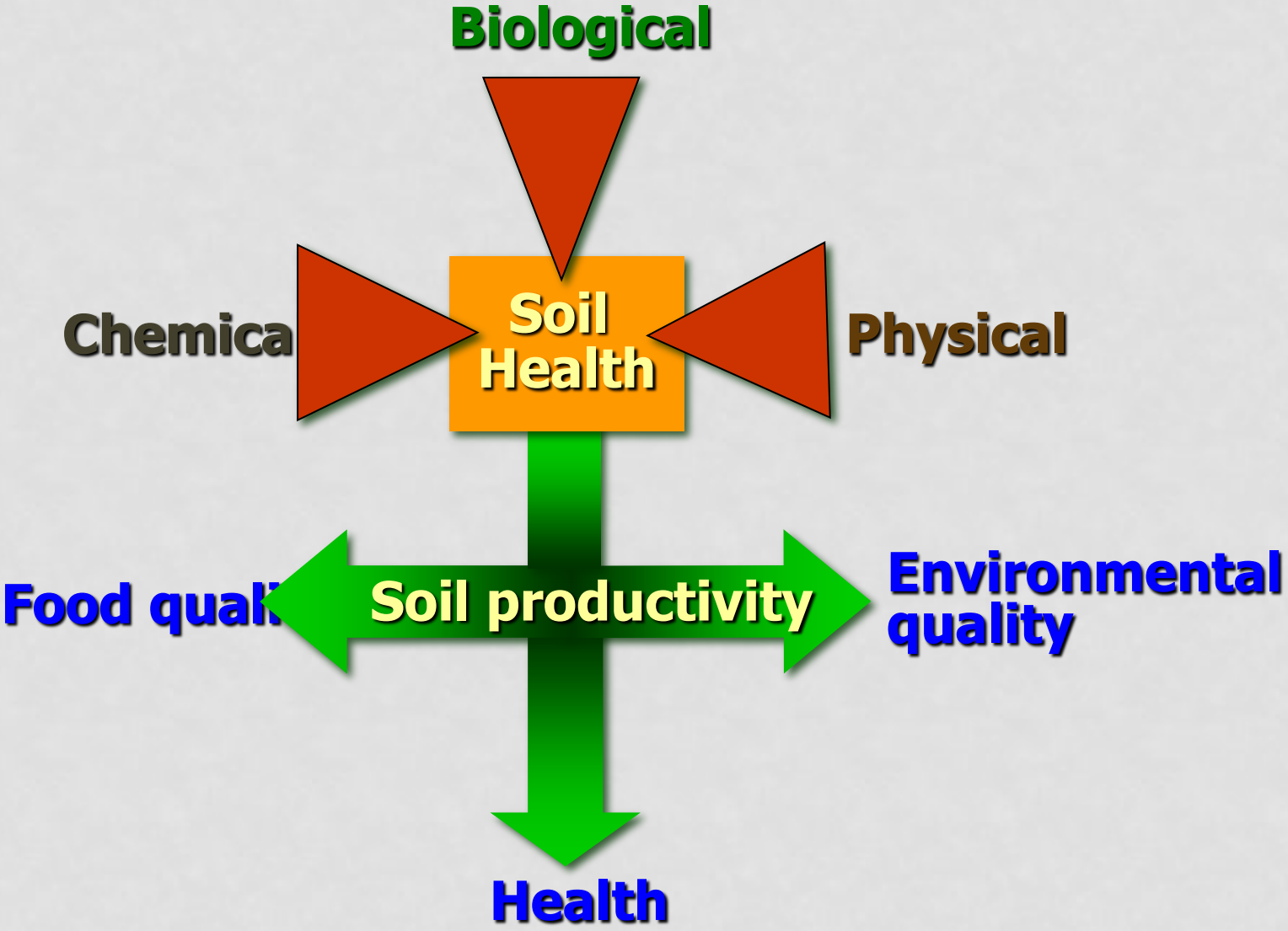
USING A PELLETIZED COMPOST PRODUCT FROM ROYAL ORGANICS TO INCREASE WATER NUTRIENT HOLDING CAPACITY AND SOM


Biological
Chemica
Soil Health
Physical
Food quali
Soil productivity
Environmental quality
Health

WHAT CHARACTERISES A HEALTHY SOIL?

The soil is alive, well and the plants are thriving

- Good soil structure
- Large number of functioning soil services
  - ✧Limited soil erosion
  - ✧Increased nutrient cycling
  - ✧Nutrient availability and recycling
  - ✧Water holding capacity, filtering
  - ✧Biodegrading toxic compounds
- Diversity of soil organisms
- Healthy nutrient dense plants

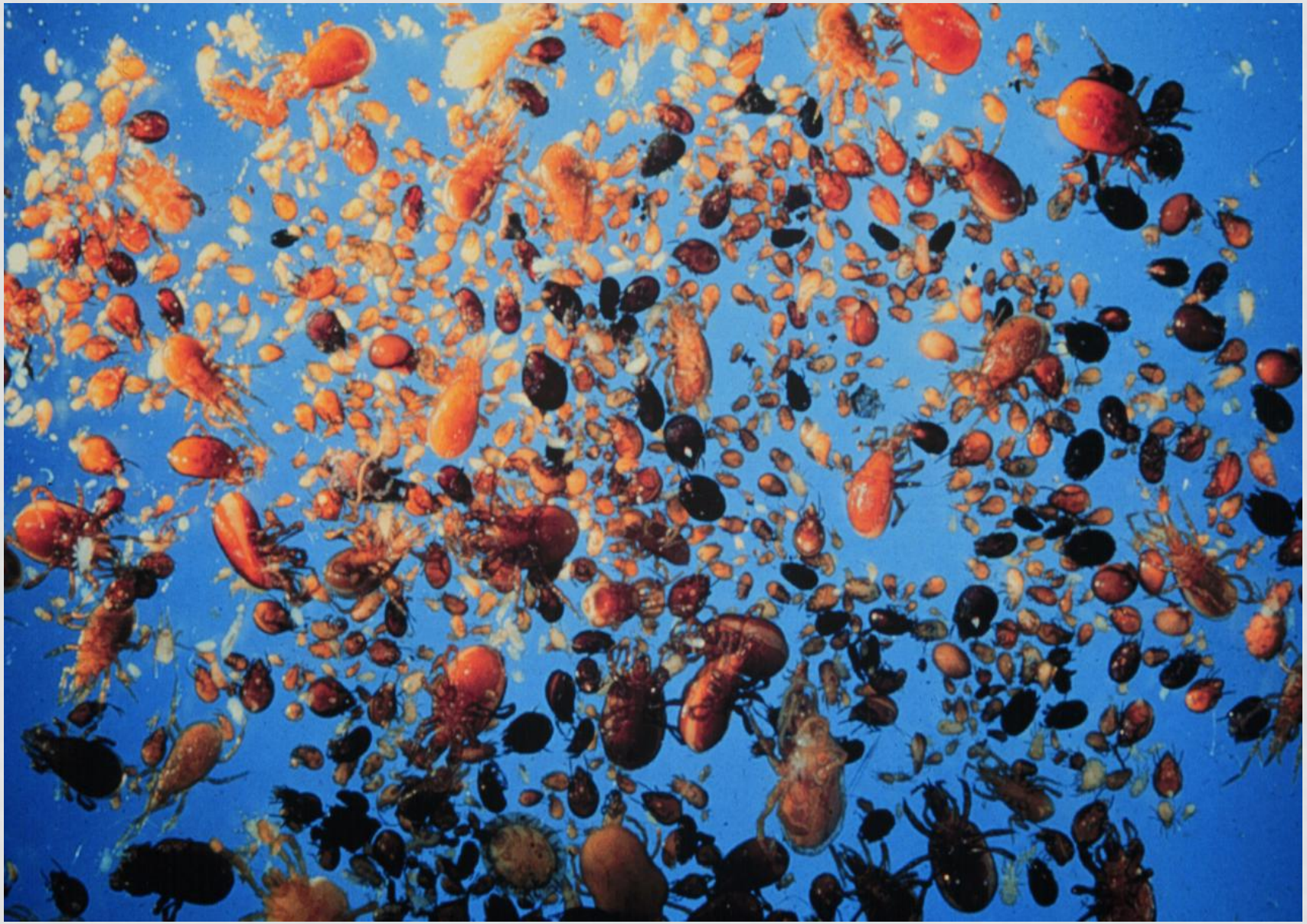
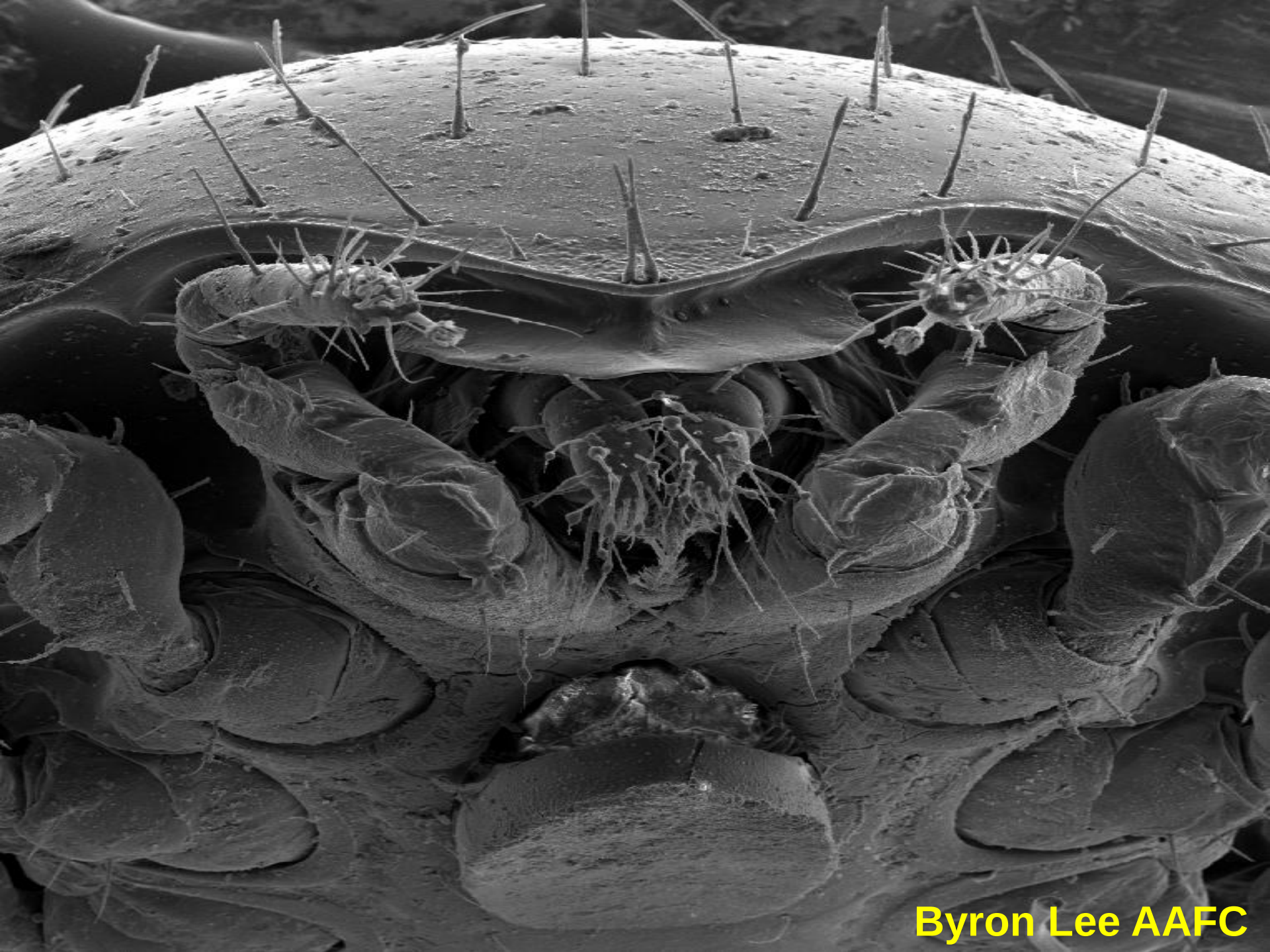


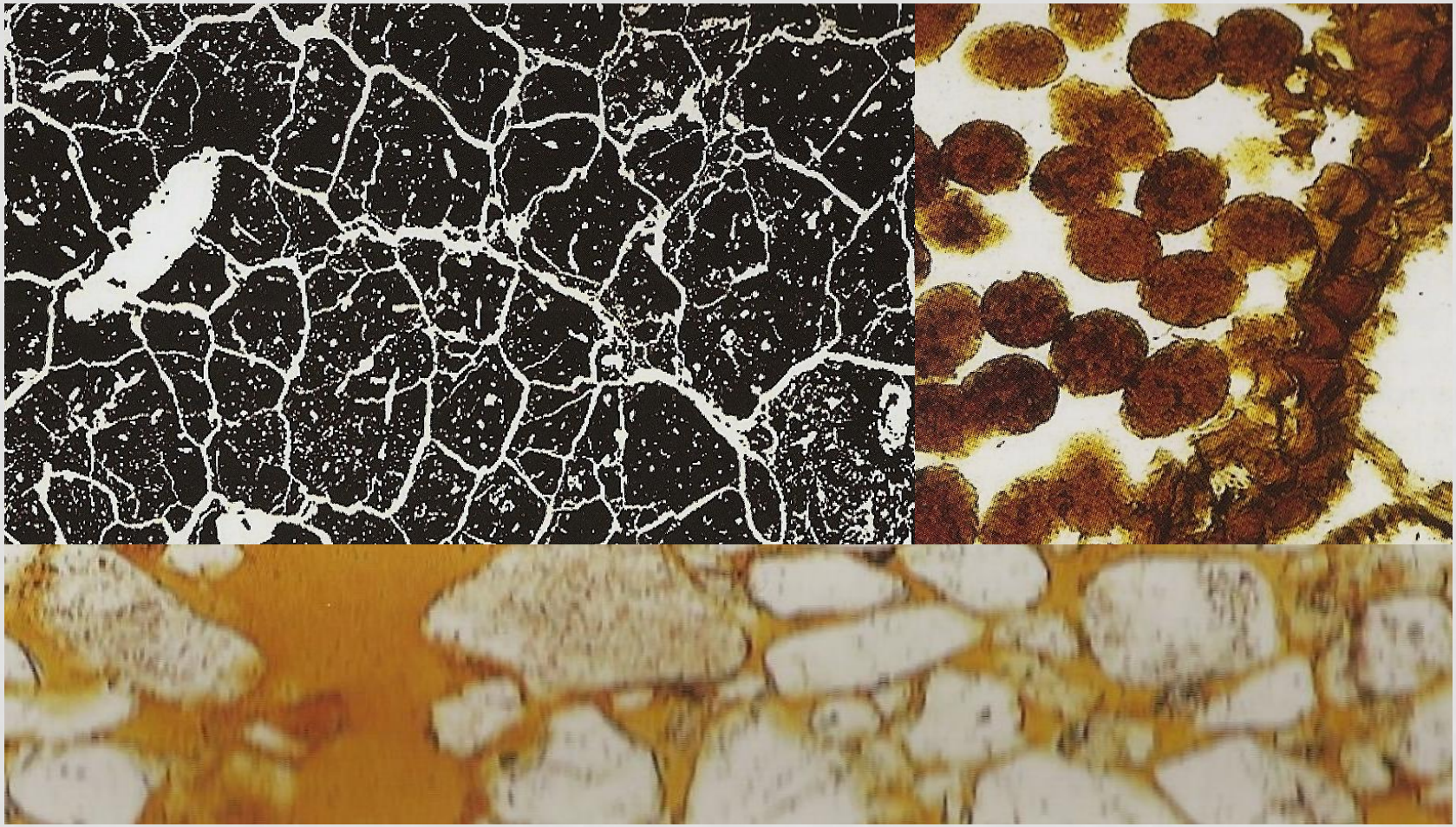
Photo by V. Behan-Pelletier AAFC


Byron Lee AAFC

WHAT CHARACTERISES A HEALTHY SOIL?

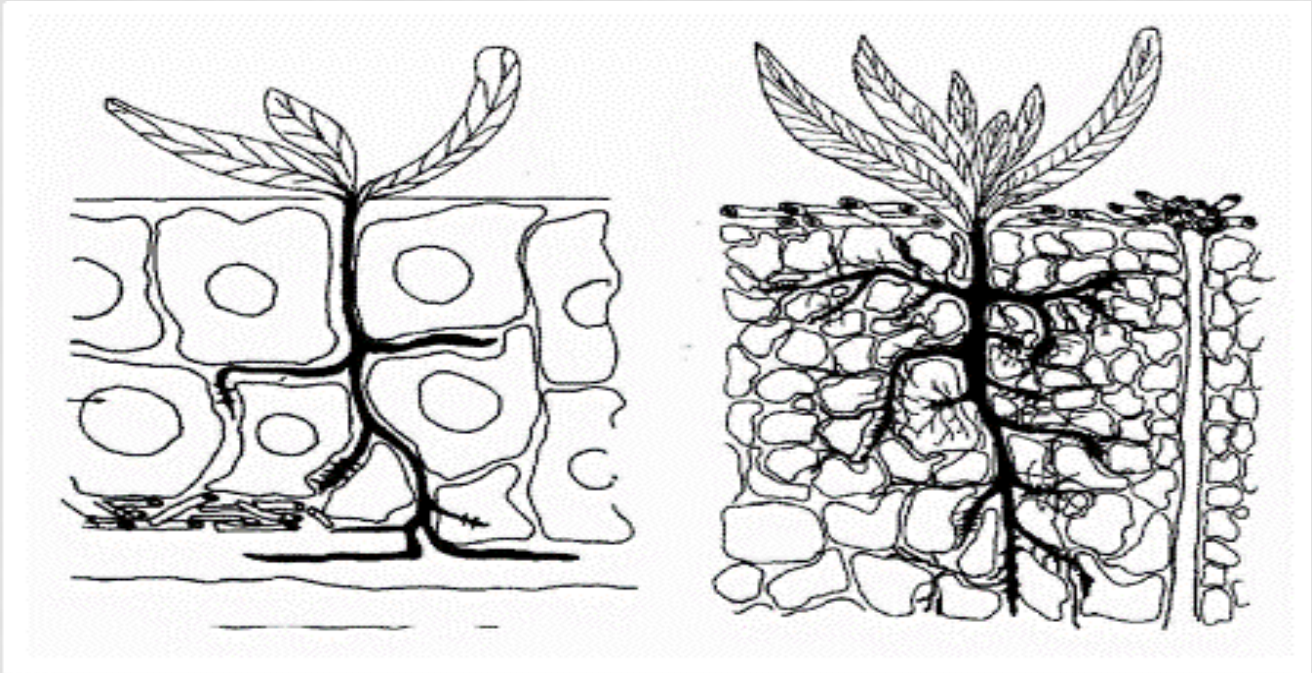
- Good soil structure- the shape, size and arrangement of soil particles, and clusters or aggregates of soil particles.
  - The shape size distribution and arrangement of soil pores affects the storage and movement of water, gases, and solutes, predator prey relationships.
  - Larger pores spaces support more biochemical reactions
- Just like any great city the infrastructure and access to services often determines the productivity, health and profitability of the population.

CONTINUOUS SOIL PORE NETWORKS



European Encyclopedia of Soil Biodiversity

Soil structure determines root depth and architecture and predator/prey relationships. In turn, roots modify the soil structure improving predator/prey relationships and nutrient availability to the plants. Roots can also create nutrient depleted zones very quickly in poorly structured soil.



FROM: BAYERISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT (LFL)

BUILDING SOIL STRUCTURE= BUILDING THE HABITAT

- No Tillage and/or pasture and forages allow the soil biota to build soil infrastructure- homes linked by a huge soil pore network.
- Diverse crop rotation- feeds the diversity belowground maintaining soil ecosystem functions and services. That means we have improved infrastructure, info exchange and a carbon trading network (mycorrhizae).
- More quality SOM combined with improved infrastructure means more water holding and exchange capacity, and improved water use efficiency – Better and more efficient soil ecosystem services

OLD ROOT CHANNELS AND EARTHWORMS

- Accessing nutrients in the subsoil is easier with better soil structure
- Between 20 and 40% of roots in field grown crops access subsoil through earthworm and old root channel freeways.
- Deep roots capture leached nutrients that can supply as much as 30% of their N for growth

TOP SOIL FLOWING THROUGH A NIGHT CRAWLER BURROW IN THE SUB SOIL, AND A ROOT FOLLOWING IT DOWN.

MORE ON ROOTS

- Former root channels are pathways for water and air infiltration, and new root growth.

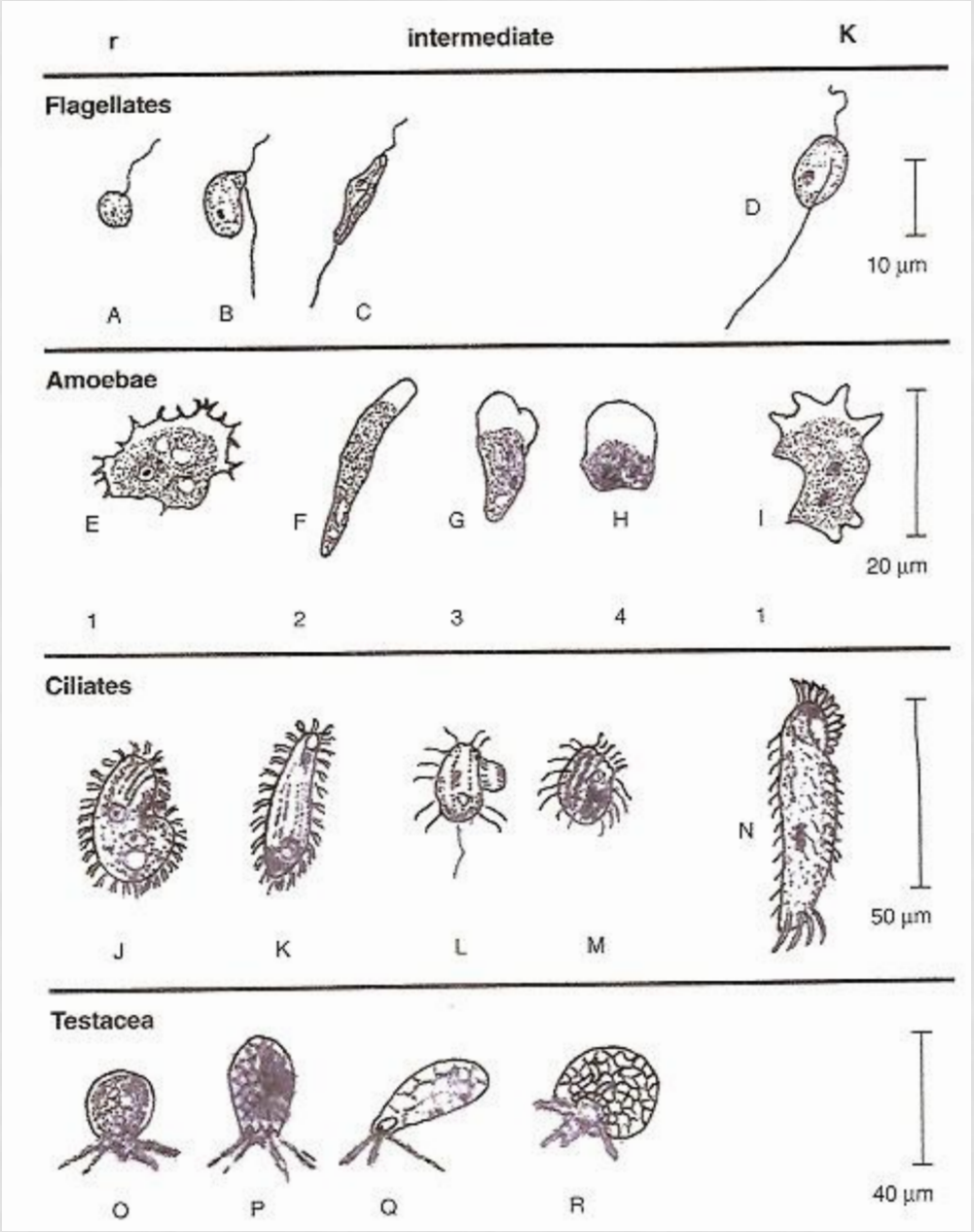
- Roots that grow in preexisting root channels, in fractures, or along aggregate faces may facilitate use of preferentially flowing water, and also allow deeper vertical rooting to find the wetter subsoils.

SD Logsdon 2013

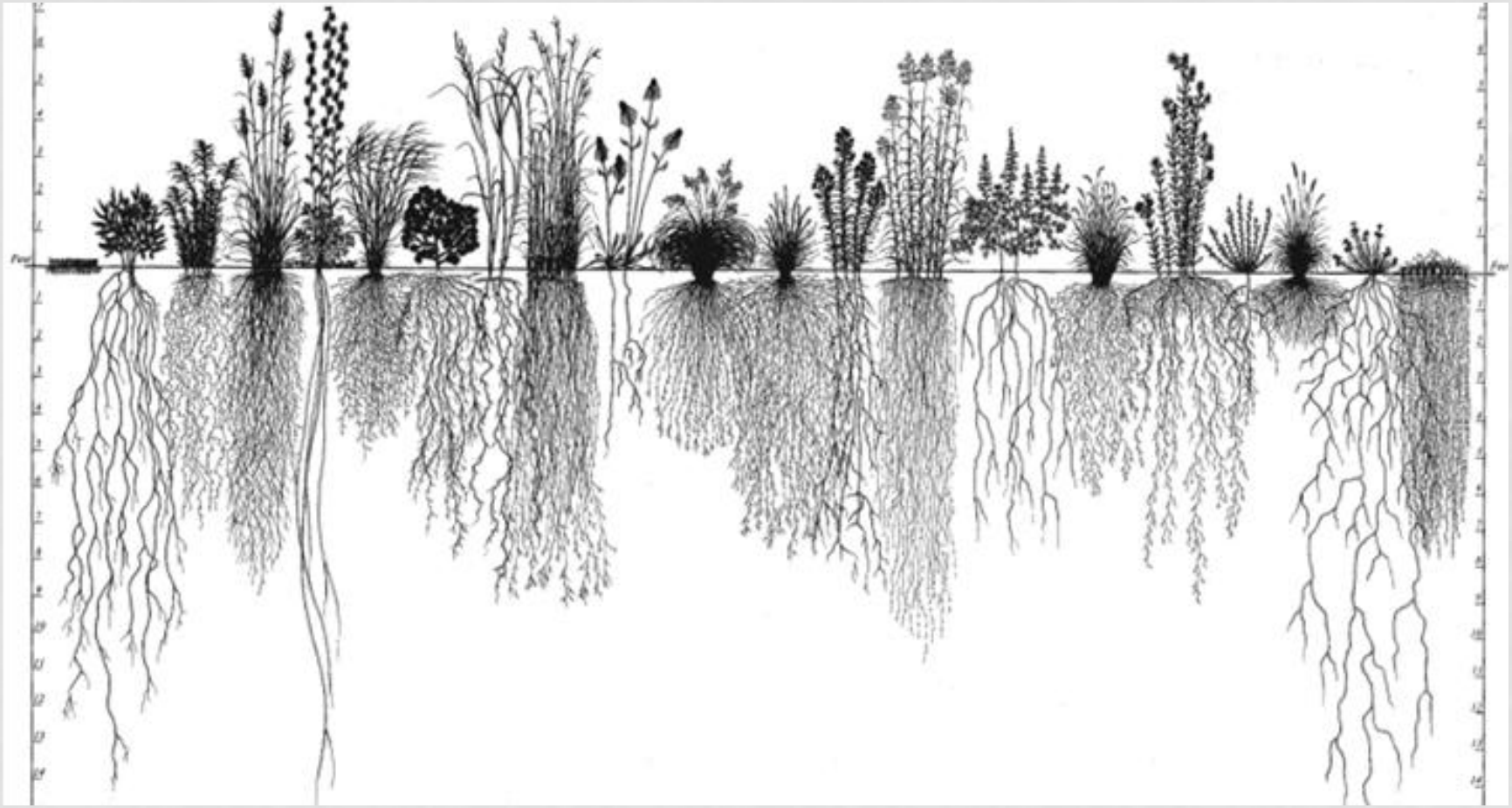
IF YOU BUILD IT……..

PROTOZOA

- Increase N min by up to 45%
- Voracious eaters of bacteria
- Rely on water films and pores



CREATING A ROOT CANOPY



Aboveground diversity is a mirror for belowground diversity

EVIDENCE FOR WHY WE SHOULD PUT AT LEAST 2 PLANTS IN A COVER CROP
TURNIP JULY 31

OILSEED RADISH JULY 31

COCKTAIL JULY 31

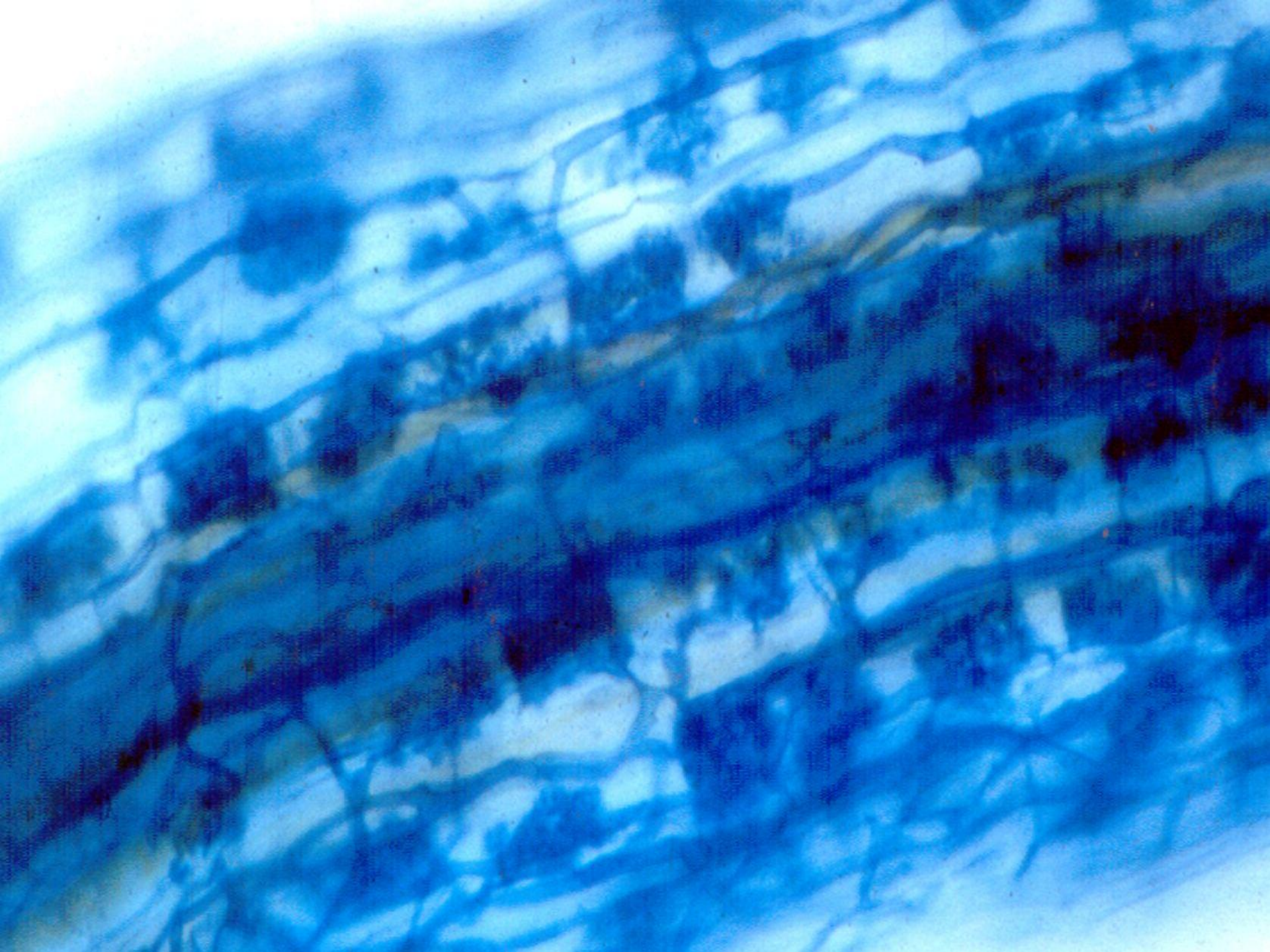

Faba Bean


Persian Clover


Sunn Hemp


Wooly Pod Vetch

INTERMINGLING OF ROOTS



SD LOGSDON (2013): ROOT EFFECTS ON SOIL PROPERTIES AND PROCESSES

- Roots perform vital functions:
  - Uptake of water
  - Uptake of nutrients
  - Holding the plant in place
  - Influence soil structure
    - Make aggregates smaller when growing in larger aggregates
    - Make aggregates bigger when growing in smaller aggregates

Sunflower rooting depth reached 1.88 m (6.2 ft) at the beginning of disk flowering and 2.02 m (6.6 ft) m at the completion of disk flowering (Jaffar et al., 1993). Use sunflowers in the mix to tap the subsoil, and they will feed and water the neighbors. Check out all the bees.

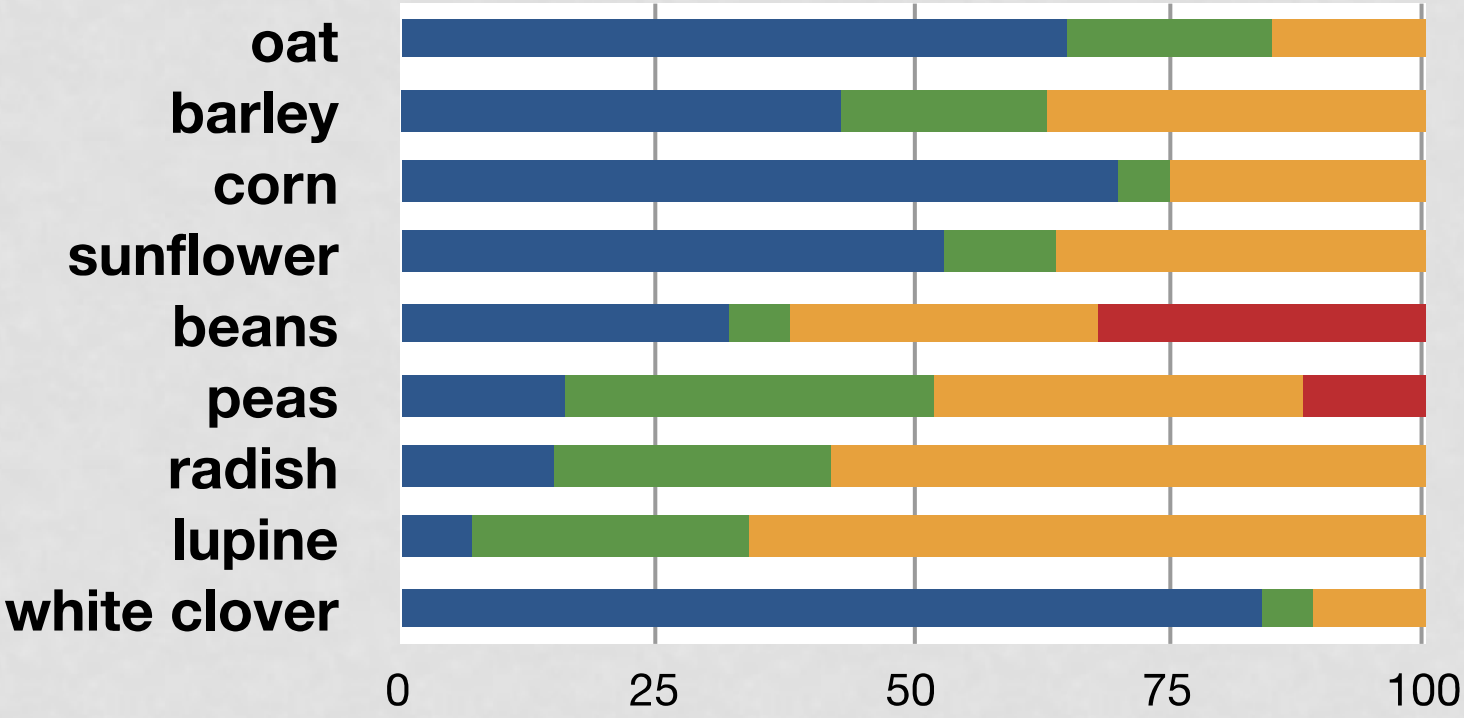
- Human-driven ecosystem simplification has highlighted questions about how the number of species in an ecosystem influences its function (Tilman et al. 2006), this includes crop and forage systems.

- The diversity in root systems alone will stabilze an ecosystem and insure that there is always something for the soil biota to feed on.

SOIL FOOD WEBS

- Soil food webs are mainly based on three primary carbon (C) sources: root exudates, litter or residues, and soil organic matter (SOM). These C sources vary in their availability and accessibility to soil organisms, and can thus, increase the C flow and biodiversity within the food web.

The percentage of N in the roots as nitrate (blue), amino acids (green), amides (yellow) and ureides (red). These compounds leak from the roots as exudates and are part of the plant's signature to create a unique rhizosphere.



JS Pate 1972

WEEDS VS NATIVES

- Cheat grass or Downy Brome (*Bromus tectorum*), Japanese Brome (*Bromus japonicus*), and dandelion (*Taraxacum officinale*) all produce root exudates that inhibit bacterial nitrification (stop the conversion of NH_4 to NO_3).
- Native grasses such as *Stipa comata* (Needle and thread grass) have exudates that promote nitrification.
- John Neal, Can J Bot. 1976

SOIL FOOD WEBS

- Soil Carbon from roots is retained and forms more stable soil aggregates than shoot derived C (Gale et al. 2000)
- Roots normally account form only 10-20% of the total plant weight
- Contribute 12% of soil organic C, 31% soluble organic C, and 52% of the microbial biomass C (Liang et al. 2002)

Looking closer to the ground we can see that some soil animal has been busy

Counting piles of earthworm castings (poop) and middens is an easy way to assess soil health.

Or just count the number of earthworms.

SOIL FOOD WEBS

- The amount of carbon from corn roots and corn root exudates can be as much at 1.5-3.5 times higher than the organic C contribution from corn stover (Allmaras et al. 2004; Wilts et al. 2004)

- Increasing the amount of carbon exuded from the roots drove the microbes to release more extracellular enzymes to breakdown the organic N accelerating the turn over of organic N (Phillips et al. 2011, Ecol. Lett. 14:187-194).

NUTRITION AND CROPPING

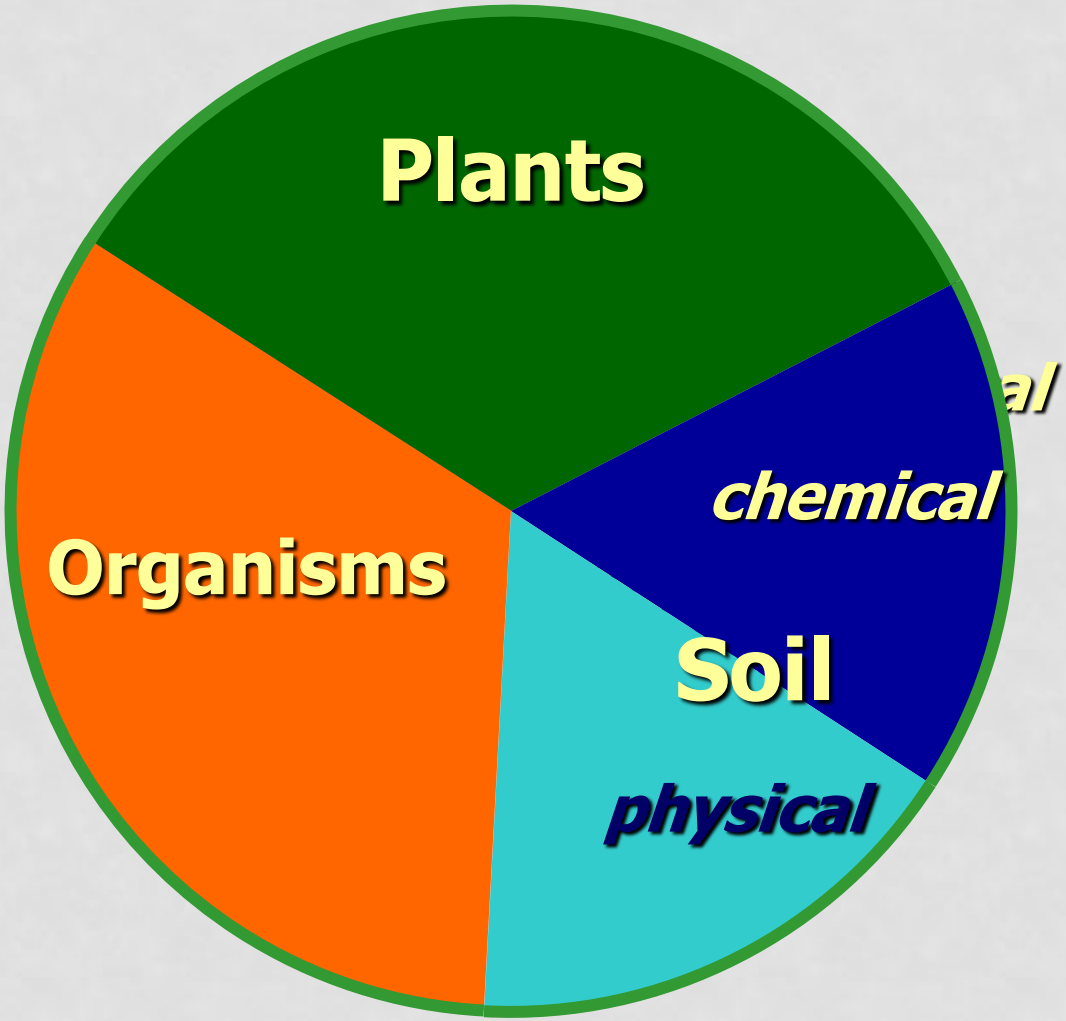
- Chlorophyll content is critical for conversion of essential amino acids to vitamins.
- Mycorrhizal fungi increase chlorophyll content and photosynthesis, and P, Ca, B, Zn and Cu uptake in plants.
- Plants take-up mineralised N, S, and P more efficiently and effectively

1 Pea, Hairy Vetch, Oat
2 Sun Hemp, Sorghum-sudan grass, Buckwheat
3 Cowpea, Sorghum-sudan grass
4 Lentil, Buckwheat
5 Lentil, Phacelia
6 Faba bean, Pea, Oat
7 Crimson clover, Oat
8 Persian clover, Oat
9 Sub clover, Sorghum-sudan grass, Buckwheat
10 Woollypod Vetch, Oat
11 Chickling Vetch, Oilseed Radish, Oat
12 Crimson clover, Chicory, Oat
13 White Lupin, Pea, Oat
14 Oilseed Radish, Hairy Vetch
15 Chicory, Hairy Vetch

Lethbridge wheat yield (kg/ha) CDC Teal HRSW the year after the cover crop (8 inches of spring rainfall)

CC Mix	Mean ± SD
1	(65 bu/acre) 4403±848 High (Mn, P, Zn, Mg, S)
2	(62 bu/ac) 4159± 367
3	(62 bu/ac) 4158 ±329
4	(66 bu/ac) 4428 ±312
5	(61 bu/ac) 4134 ± 354 Highest Fe content
6	(67 bu/ac) 4543 ±453 Highest mineral density except Fe
7	(65 bu/ac) 4371 ± 494 High (K, S, Mg)
8	(57 bu/ac) 3853 ± 502
9	(60 bu/ac) 4049 ± 608
10	(58 bu/ac) 3893 ± 423
11	(61 bu/ac) 4129 ± 672
12	(59 bu/ac) 4000 ± 776 High (P, Mg, K)
13	(61 bu/ac) 4028 ± 356 High (P, S, Ca)
14	(65 bu/ac) 4378 ± 583 High S
15	(37 bu/ac) 2483 ± 1820

Rhizosphere

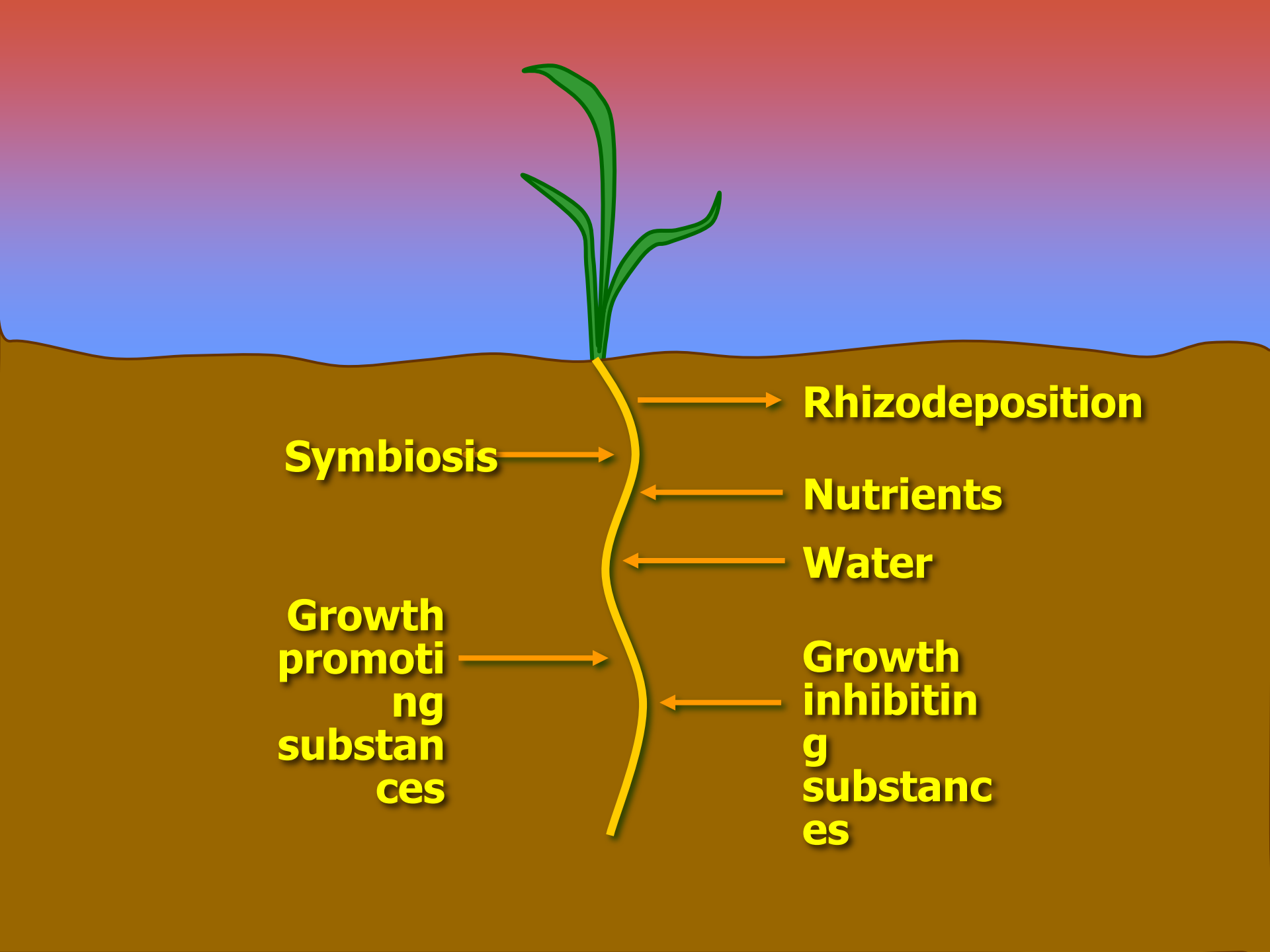


PLANTS SOIL AND SOIL ORGANISMS

Each plant species or crop species modifies the soil and soil organisms in ways that can benefit, inhibit or have no affect on the establishment and growth of the subsequent crop.

We can use these processes to manage crops, weeds, diseases to increase soil and plant health and productivity, and animal and human wellness.

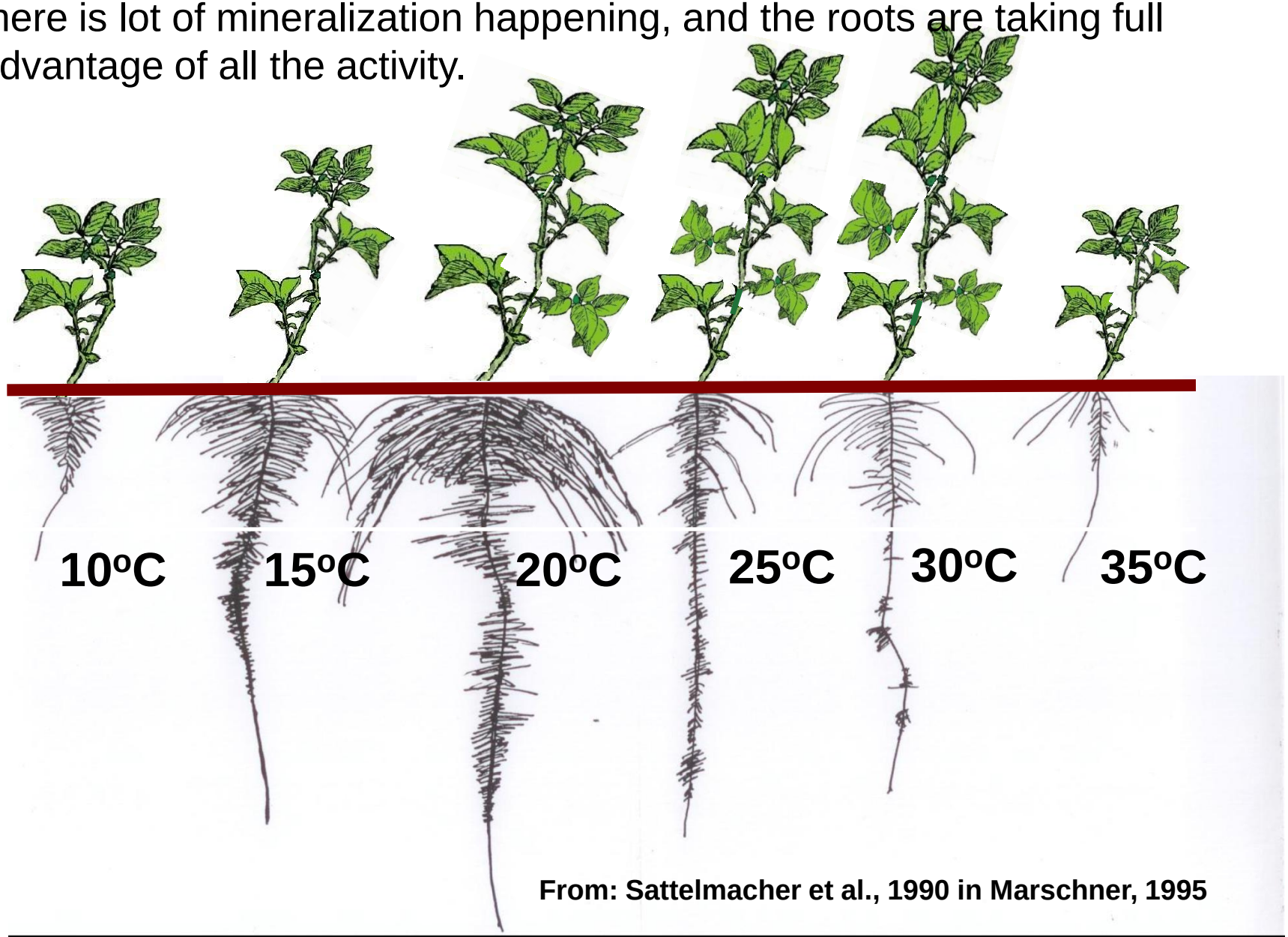
The Rhizosphere Effect…….


Rhizodeposition
Symbiosis
Nutrients
Water
Growth promoting substances
Growth inhibiting substances

THE RHIZOSPHERE IS THE MOST BIOLOGICALLY ACTIVE PART OF THE SOIL

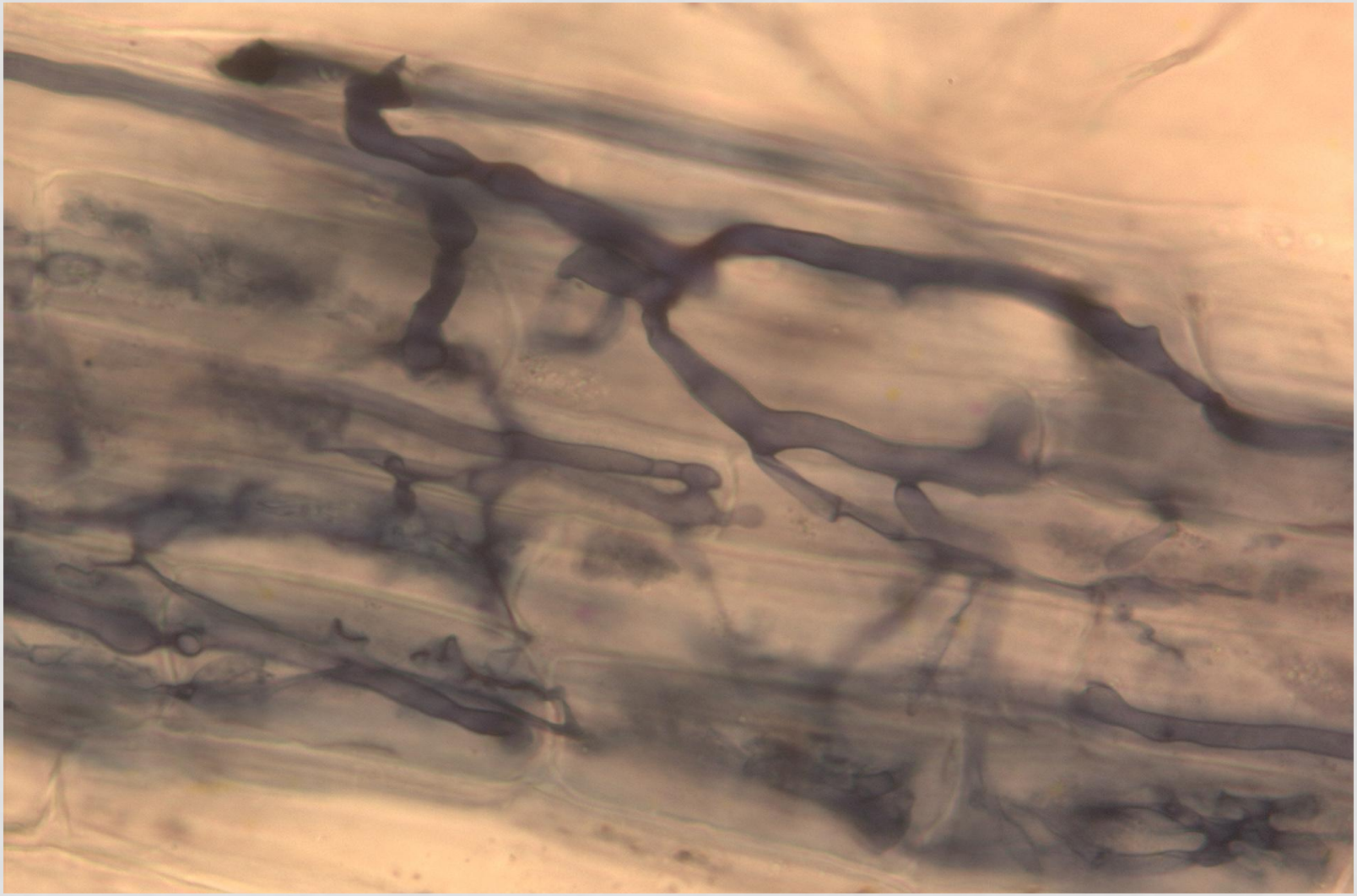
- In a model grassland system it was recently shown that increasing plant diversity enhances CO2 assimilation by surrounding plants. This in turn increased the amount of C allocated to the roots and mycorrhizal fungi, which is a key mechanism driving carbon sequestration in soil.
- These effects, however, were due to the presence of legumes in high-diversity mixtures, rather than to diversity per se (Gerlinde De Deyn et al. 2009, Journal of Ecology 97: 864-75).

At a soil temperature of 20°C or 68°F most organisms have fully functional populations and may be actively reproducing, which means there is lot of mineralization happening, and the roots are taking full advantage of all the activity.



From: Sattelmacher et al., 1990 in Marschner, 1995

Mycorrhizas-the underground network



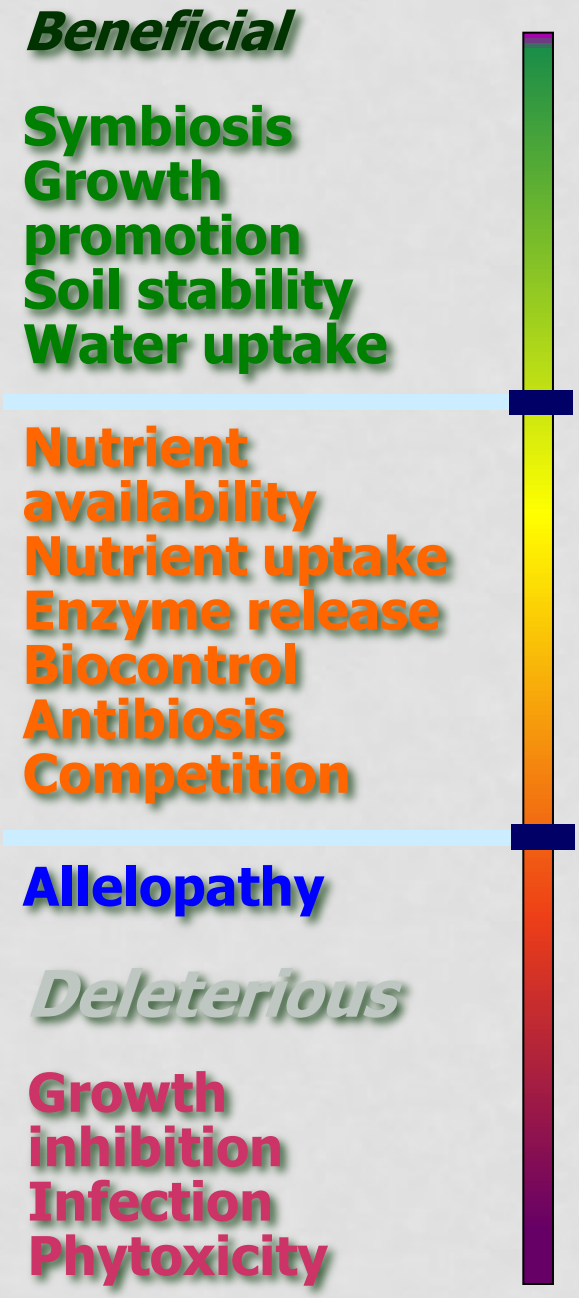
At optimum soil temperature we have high speed transport

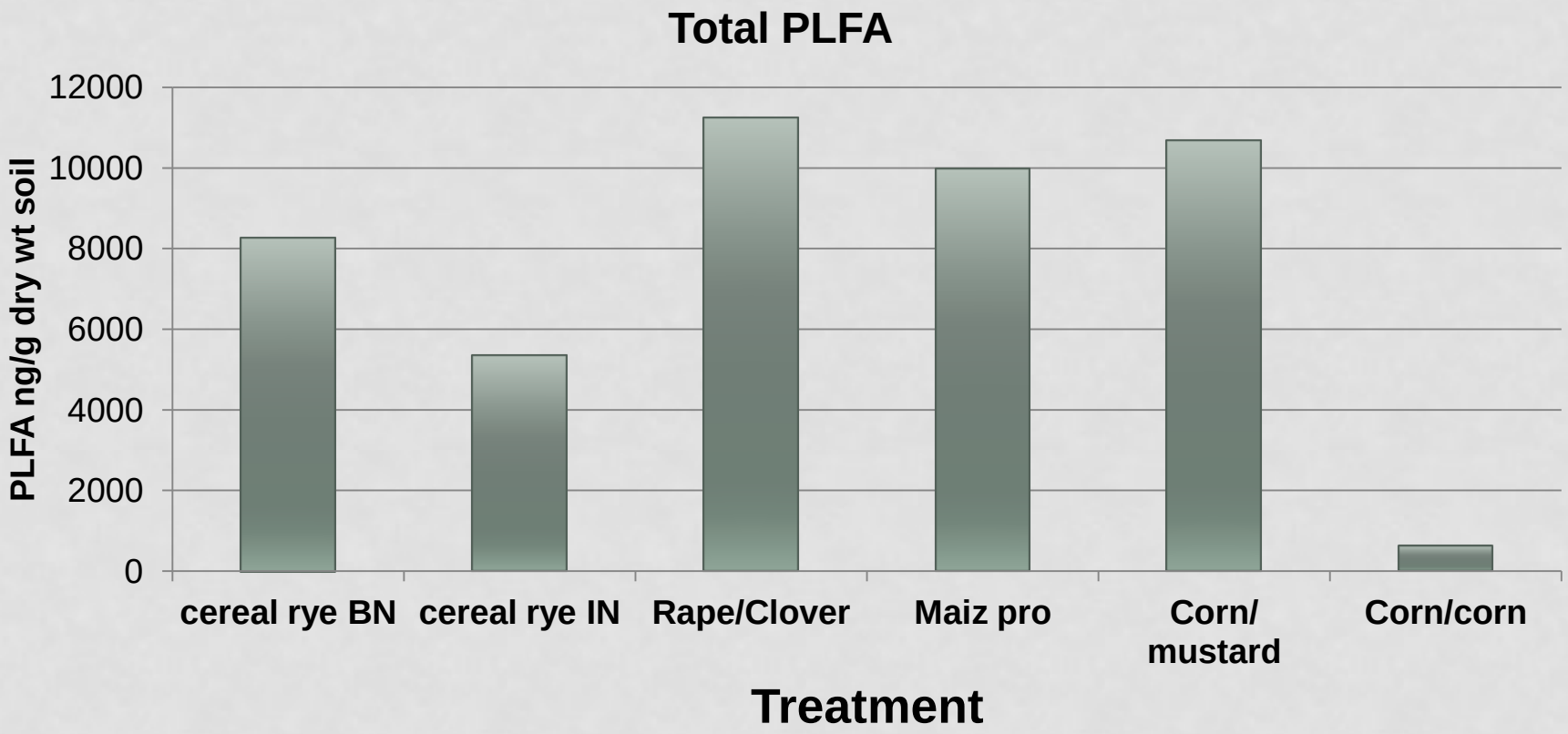
PLANTS AND NUTRIENT UPTAKE

- Plants species differ in abilities to acquire nutrients, each may have a different strategy
  - Exudation of P mobilizing carboxylates
  - Fe- and other micronutrient (Zn)- chelating phytosiderphores (may depend on pH).
  - Mycorrhizas or other symbionts
  - A combination of all of the above

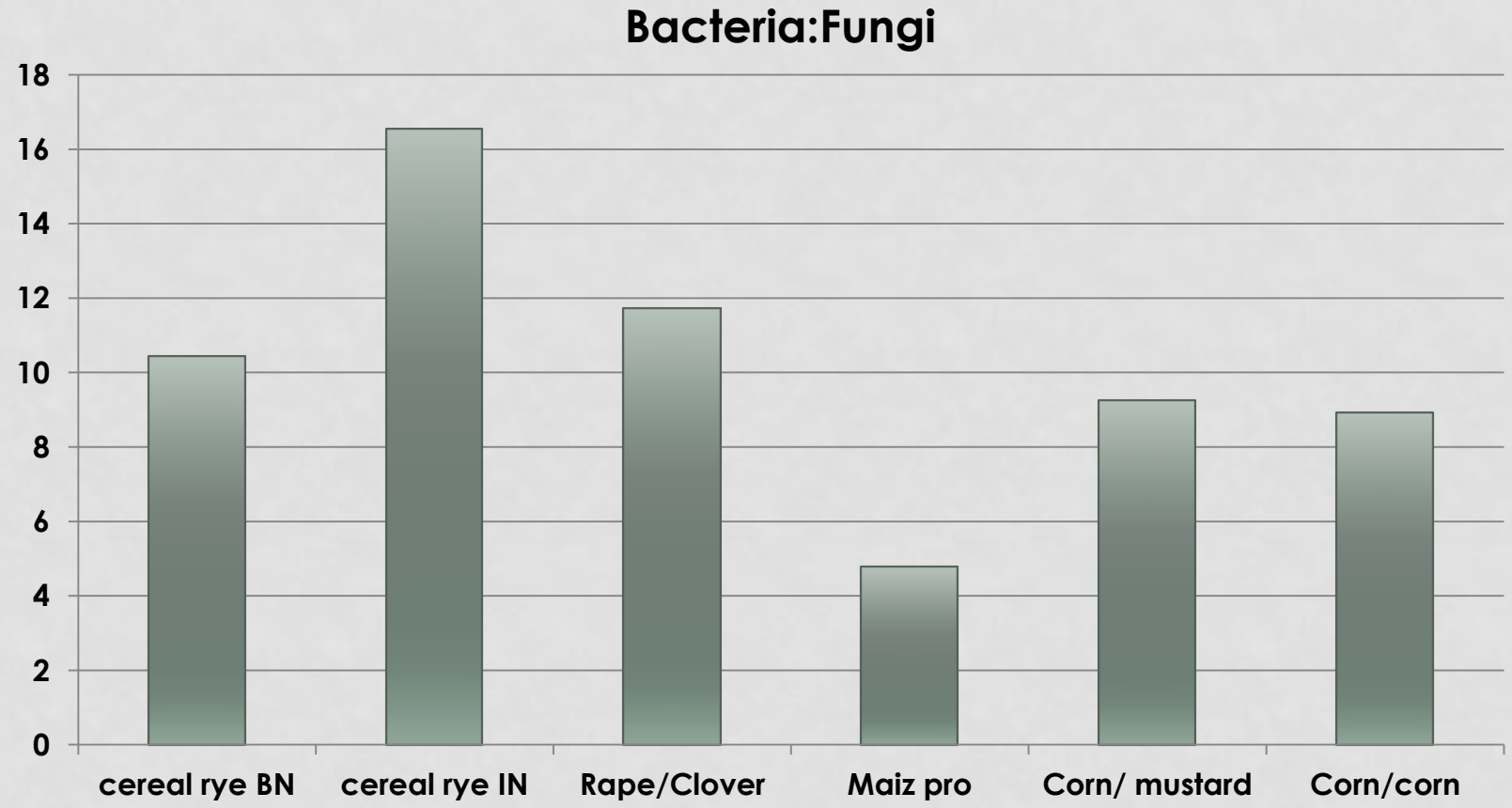
    - So why is biodiversity important?

Rhizosphere interactions and processes

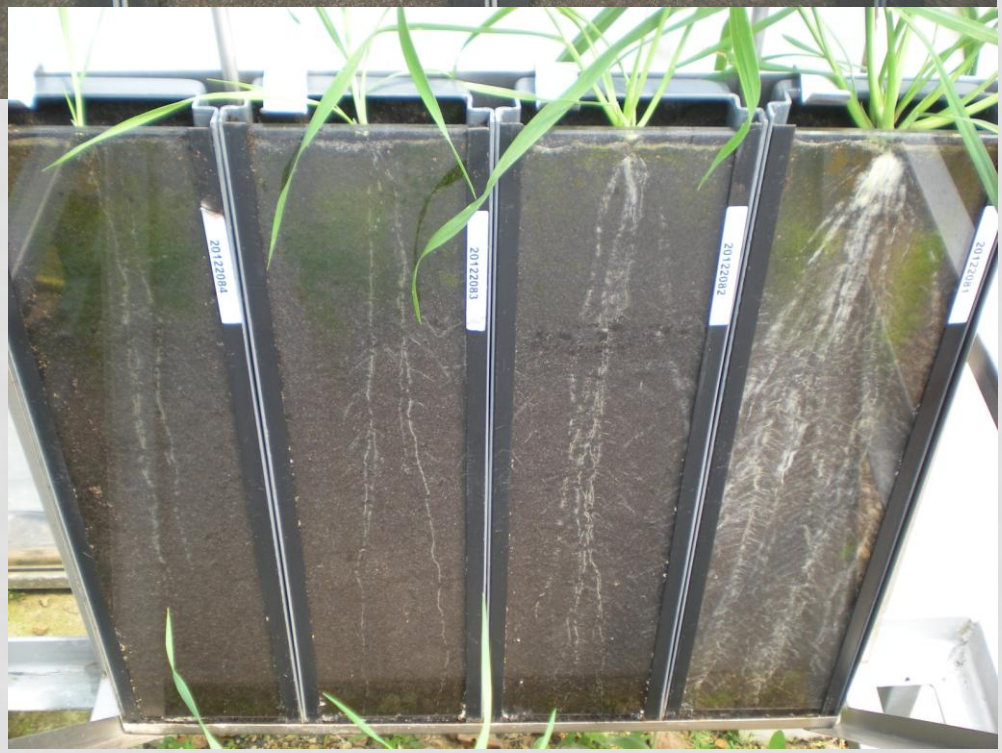




Total PLFA indicates is a measure of the total amount of living biomass in the soil sample.



Bacteria to fungi ratio- somewhere around 8-10 is ideal. Higher indicates a system that is strongly based on bacterial decomposition and nutrient cycling. Bacteria cycle nutrients faster than fungi – fungi hold the N longer with less leaching. Below 6 the fungi are likely tying up the nutrients, or the soils have higher organic matter with no disturbance and the fungi are busy breaking down woody residues.



Generally speaking plants that have more roots also have greater productivity and yield better, and more surface area means more nutrient uptaks.

Rooting trials at DSV seed in Asendorf, Germany.

HISTORICALLY SPEAKING

- When yield became a critical factor cereals became the dominant crop…..
- When cereals were made a staple food there was a decrease in the nutritional quality of the diet
- Major cereal grains lack the essential vitamins and minerals, and have lower protein quality compared with pulses (food legumes).

WHAT ABOUT FOOD QUALITY?

Agriculture has not held nutrient output as an explicit goal of its production systems.

The mean nutrient content of wheat grain (mg/kg) from organic and low-input rotations, analysed by ICP, n = 4, ± s.e., p<0.05.

Rotation	P	Ca	Zn	Cu	Mg	K
1 Organic	267 ± 24	2730 ± 240	43.2 ± 4	3.9 ± 1.0	1080 ± 60	2040 ± 90
2 Low input	198 ± 17	2400 ± 270	29.7 ± 3	1.89 ± 0.48	990 ± 60	1830 ± 90
3 Organic	246 ± 20	2520 ± 180	38.1 ± 1	2.91 ± 0.69	1110 ± 30	1920 ± 90
4 Low input	237 ± 20	2520 ± 120	37.2 ± 2	2.67 ± 0.36	1110 ± 14	1980 ± 90
5 Organic	270 ± 17	3330 ± 180	44.7 ± 2	2.73 ± 0.60	1020 ± 30	2310 ± 60
6 Low input	264 ± 20	3540 ± 270	42.9 ± 4	2.76 ± 0.27	1020 ± 30	2340 ± 150
7 Wheat	249 ± 16	3060 ± 210	40.2 ± 3	2.94 ± 0.36	1020 ± 30	2160 ± 60

TALKING ABOUT N AND WHEAT

- The more N available to wheat……
  - More protein in the grain
  - Fewer essential amino acids such as Lysine (which is essential for human health).
  - Fewer carbohydrates that can be used in the conversion to Vitamin C
- Use of ammonia sulphate increases the Thiamine content

Daily Express UK. 14th. Feb 2005.

Healthy bread that could save your life

Loaf fights cancer and helps heart

By **Sarah Westcott**

THE first "superbread" that could help beat cancer and protect the heart hits the shelves today.

The new loaf is enriched with the mineral selenium following claims that British consumption of the essential micro-nutrient has fallen to "worryingly" low levels.

Scientists have proved that selenium can reduce breast cancer by up to 80 per cent and regulate blood pressure, yet it is one of the human nutrients in greatest shortage.

Now Waitrose is launching the selenium-enriched bread, the latest in a growing breed of pharmaceutical foods to be offered to health-conscious consumers. Britons can already buy Intelligent Eating eggs, which contain healthy fatty acid and even crisps containing the natural anti-depressant St John's Wort.

Other "pharma-foods" available in supermarkets are Tropicana orange juice enriched with calcium, probiotic drinks which claim to maintain a healthy gut and spreads containing plant substances which inhibit cholesterol.

A Waitrose spokeswoman said: "Selenium is crucial to our diet for the function of a strong immune system but our current consumption is relatively poor due to the lack of it in British soil.

"Our bread suppliers have worked very closely with farmers to develop a natural way of putting this trace element back into the soil just as mother nature intended. As a result, the wheat from this reinvigorated soil is then harvested and used to bake naturally-enriched selenium loaves. British consumption of selenium is at a worryingly low level. However, consuming two to four slices of selenium-enriched bread each day would ensure a good intake of this essential micro-nutrient as part of a healthier diet."

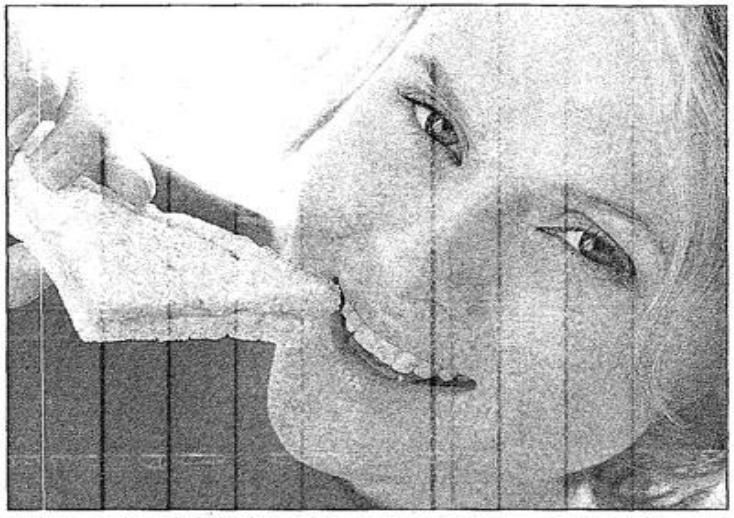
The Food Standards Agency has warned the average dietary intake of selenium has plummeted to half of what it was 20 years ago in the UK due to a steady depletion of the mineral in British soil.

Scientists at the University of Liverpool last year discovered that an increase in selenium intake improves immune function while many studies since the 1970s have shown that there is an inverse relationship between selenium intake and cancer mortality.

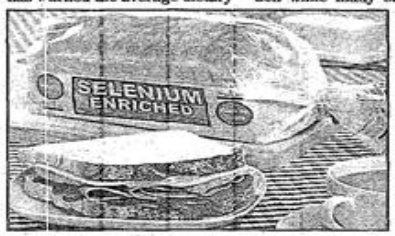
Studies have indicated that selenium can also fight the development of advanced prostate cancer.

A trial in the US found those receiving selenium showed 50 per cent lower total cancer mortality and 37 per cent lower total cancer incidence, with 63 per cent fewer cancers of the prostate and 58 per cent fewer cancers of the colon.

Food agency researcher John Arthur said: "The low concentration of selenium in an enriched loaf gives a lot of safety to consumers as toxic consumption of pill supplements could be achieved with just 20 pills, while the equivalent intake could only be achieved by eating nearly 13 loaves in a day."



CRUMBS! A loaf enriched with the mineral selenium could bring many health benefits



UPPER CRUST: Two to four slices daily could ensure the right intake of the micro-nutrient, Waitrose claim, and scientists agree

Male motorists are

Ladies desperate

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Healthy Soil for a Healthy World