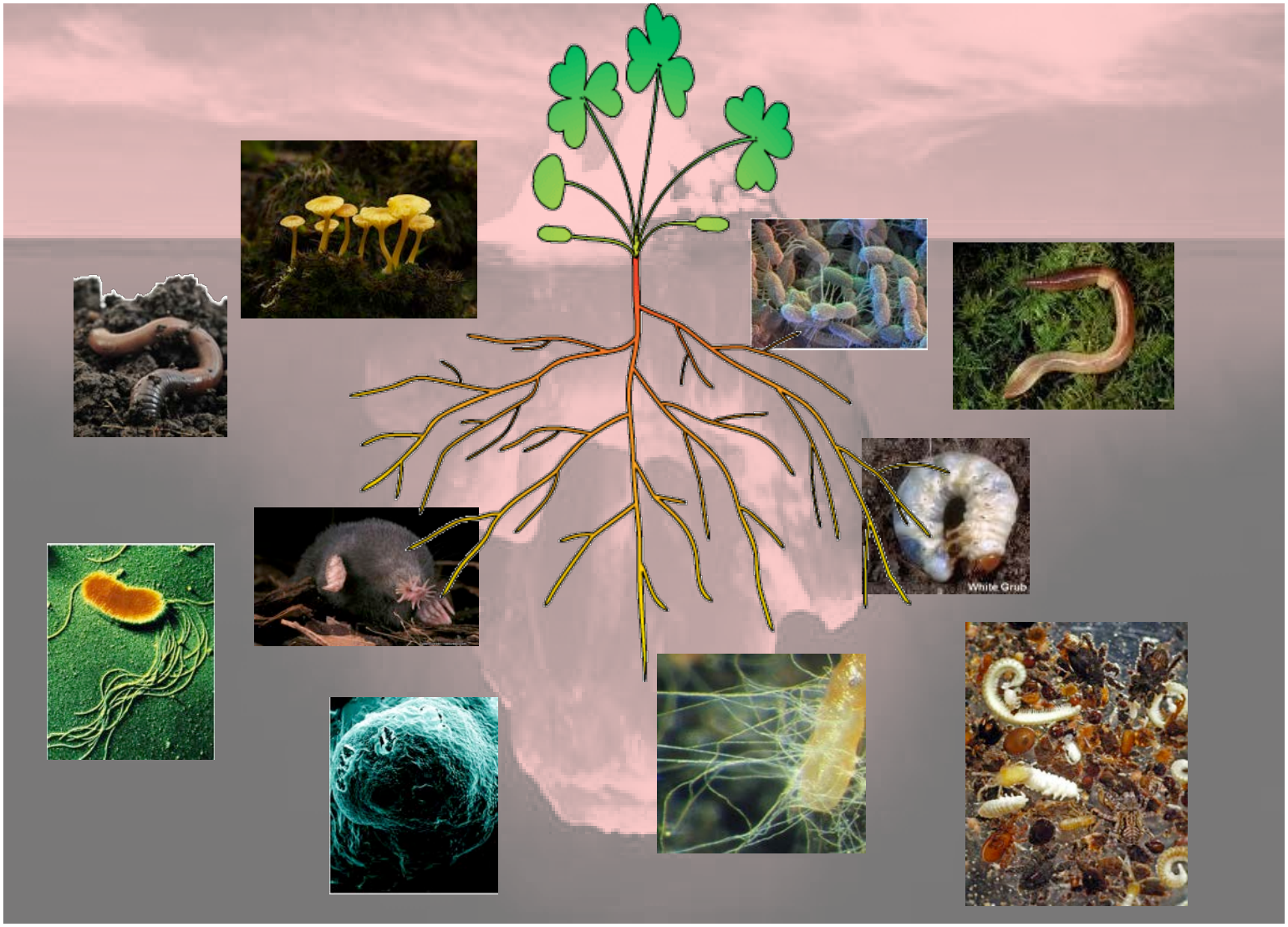
Managing Soil Biology to Increase Agricultural Production and Sustainability

UCDAVIS
AGRICULTURAL
SUSTAINABILITY INSTITUTE

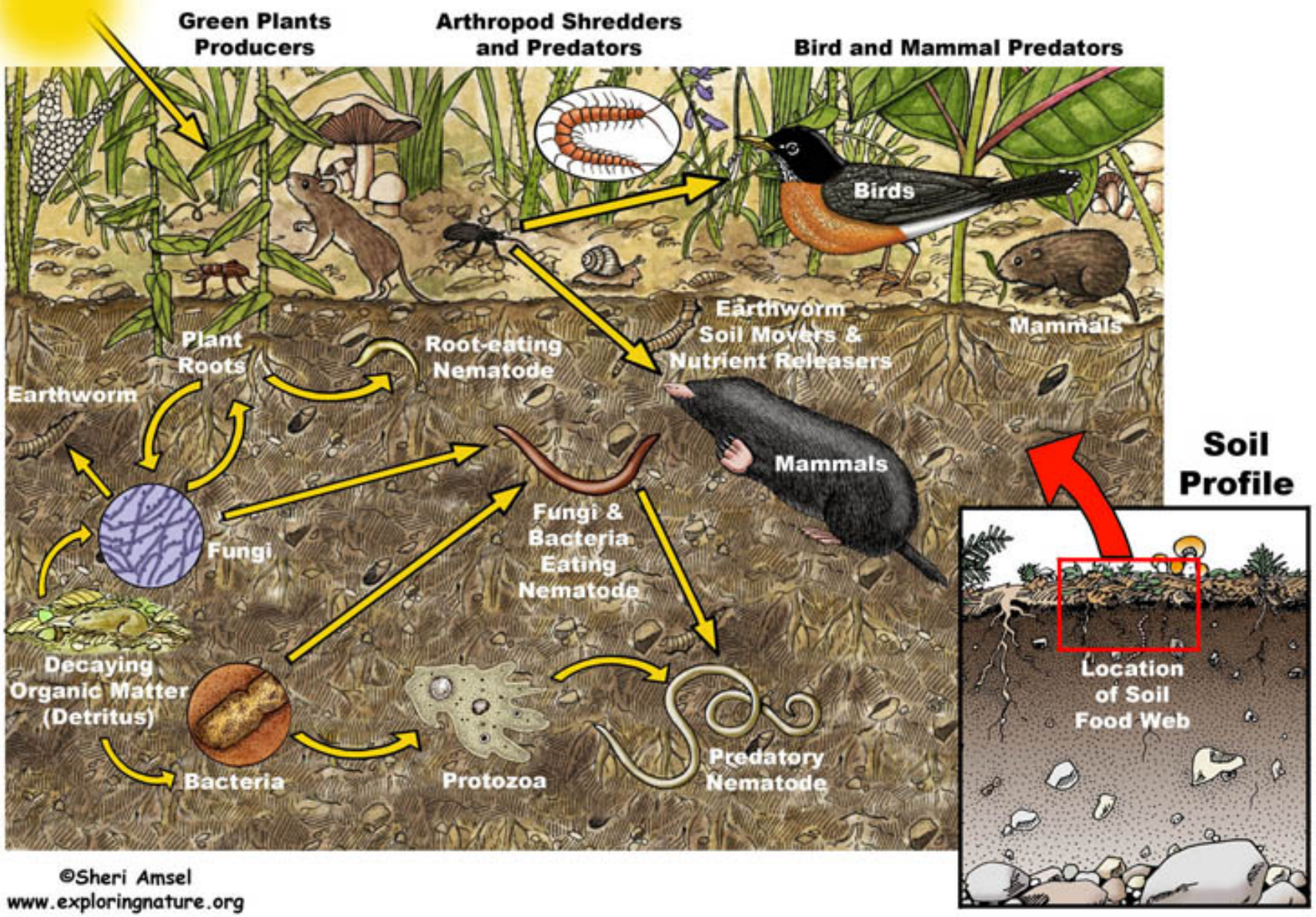
Kate Scow
Dept. of Land, Air & Water Resources
Agricultural Sustainability Institute

Soil biodiversity: like an iceberg…….

… most soil biomass and biodiversity is below the surface

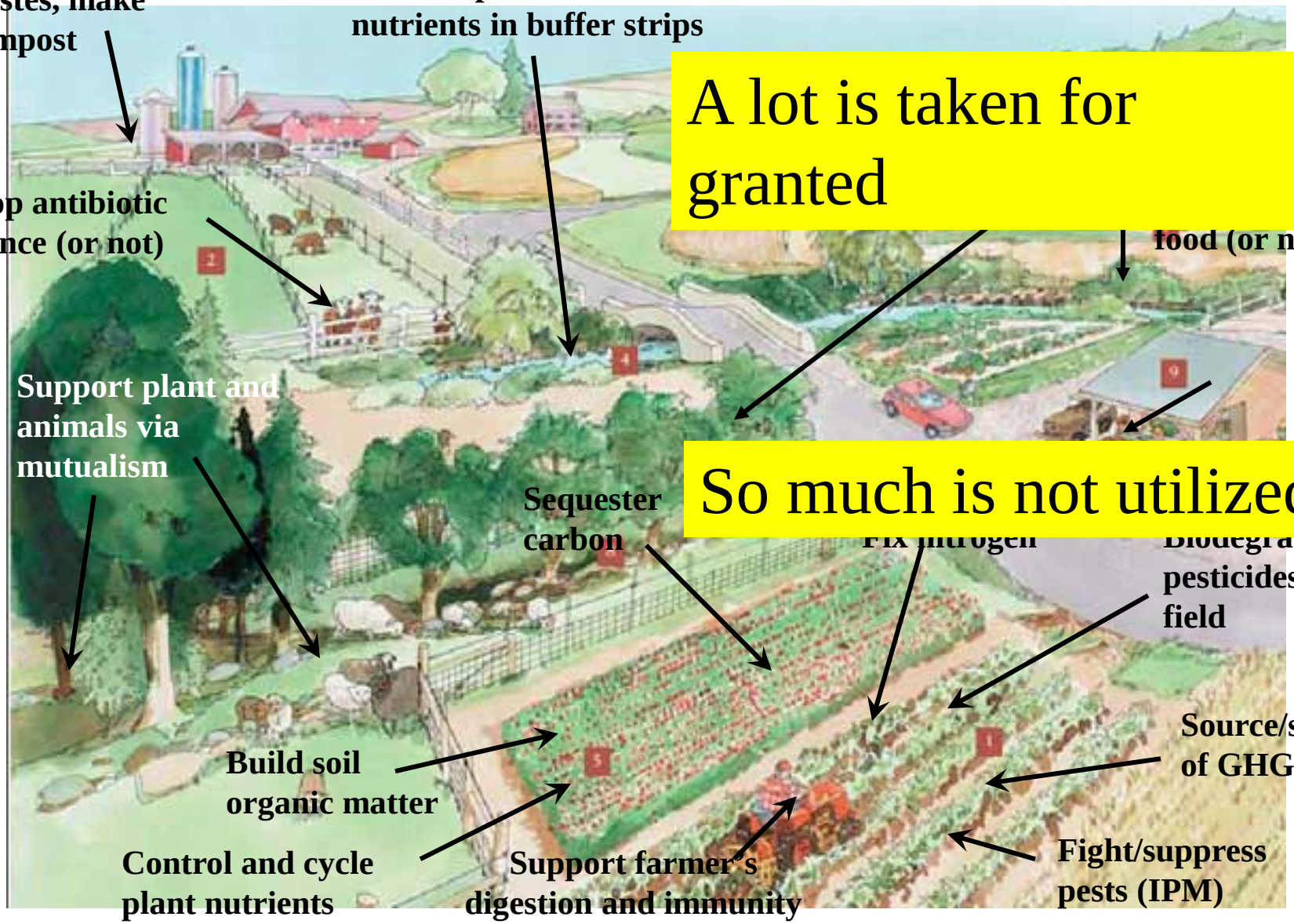


Soil Food Web



Soil biology provides lots of services to agriculture!!

(and disservices)



http://images.google.com/imgres?imgurl=http://www.sare.org/publications/explore/images/scenewide2.jpg

Growing concerns about agricultural systems :

- Decreased resistance and resilience (to disease and stresses)
- Contamination of water from improper use of fertilizers and pesticides
- Increasing resistance of pathogens/pests
- Loss of soil (through erosion) and reduction in quality of soil
- Economic vulnerability due to heavy reliance on external inputs (e.g. fossil fuel)

HOW MODERN AGRICULTURE IS NOT FRIENDLY TO SOIL BIOLOGY

STARVATION We don't feed soil—residue (="trash"??) removed or burned, no carbon inputs (cover crops, compost)

PHYSICAL DISTURBANCE Tillage destroys habitat and breaks apart fungal hyphae

EXPOSURE TO ELEMENTS Soil left bare—hot, dry, carbon loss

TOXINS High concentrations of fertilizers and pesticides

LIMITED PLANT DIVERSITY Monocultures support low soil biodiversity

REMOVE OPPORTUNITIES Fertilizer shuts out symbiotic organisms.

Most agricultural practices are focused on plant (even when involving soil)

- Often target single issues rather than systems oriented
- Address symptoms not underlying cause
- Usually short term perspective (that season)
- May come from consultants who spend little time on farm

How can we benefit more from soil biodiversity?

1. Manipulate conditions to influence native microorganisms ("prebiotics")

and/or

2. Add organisms (often non-native) as inoculants ("probiotics)

Just like in human health applications.

MANAGEMENT to promote native soil microbial communities

Soil Health: Integrating the Biological, Physical & Chemical components of the Soil.

Agroecology is the study of ecological processes that operate in agricultural production systems.

Soil Health Principles:

- Plant Diversity
- Living Roots throughout the year
- Cover the Soil
- Less Disturbance
- Grazing where applicable

Biological
(diverse plants = diverse SFW)

SOIL BIOLOGY DOES NOT EXIST IN A VACUUM

Carbon is the key driver of the soil nutrient-microbial recycling system.

Physical
(soil macro-aggregates)

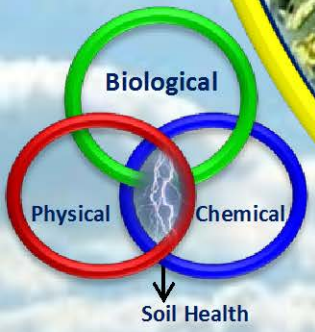
earthworm castings

Chemical
Soil Solution

Top Soil is the Farmers Capital

Plant roots in collaboration with soil organisms build water-stable soil macro-aggregates. These aggregates provide for the optimum physical & chemical conditions required by the plant roots & beneficial soil organisms to thrive.

Carbon is also the key driver for soil moisture holding capacity.



The concept of soil health deals with integrating the biological, physical & chemical components of the soil.

The Soil Food Web (SFW) refers to the collection of micro-organisms and micro-arthropods in the soil that interact directly or indirectly with plants, decompose organic matter, or prey on the organisms that interact with plants.

Soil health, agroecology

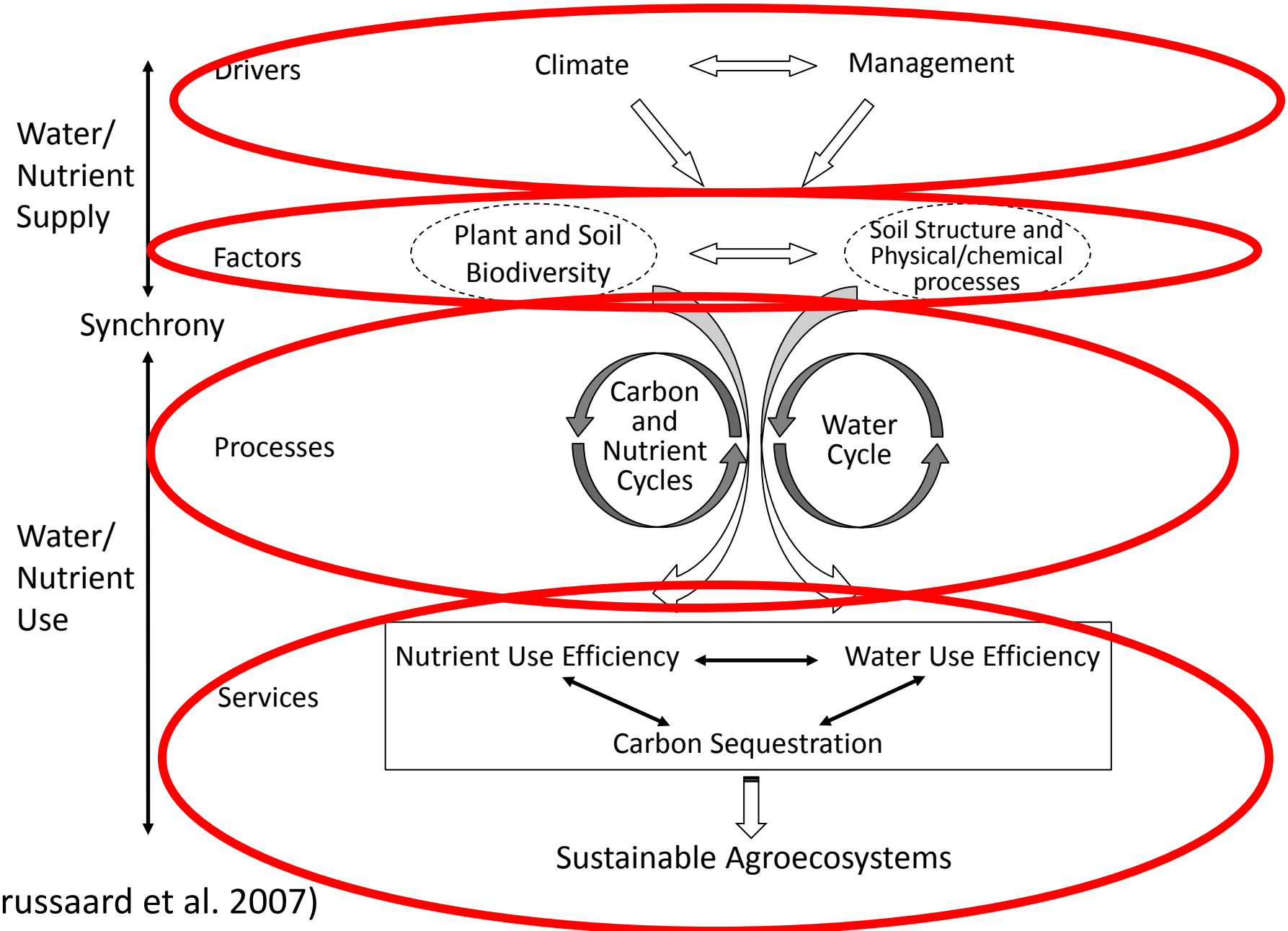
an equal opportunity provider & employer

Ref.: Cornell Soil Health Assessment Training Manual

rudy.garcia.2014

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965

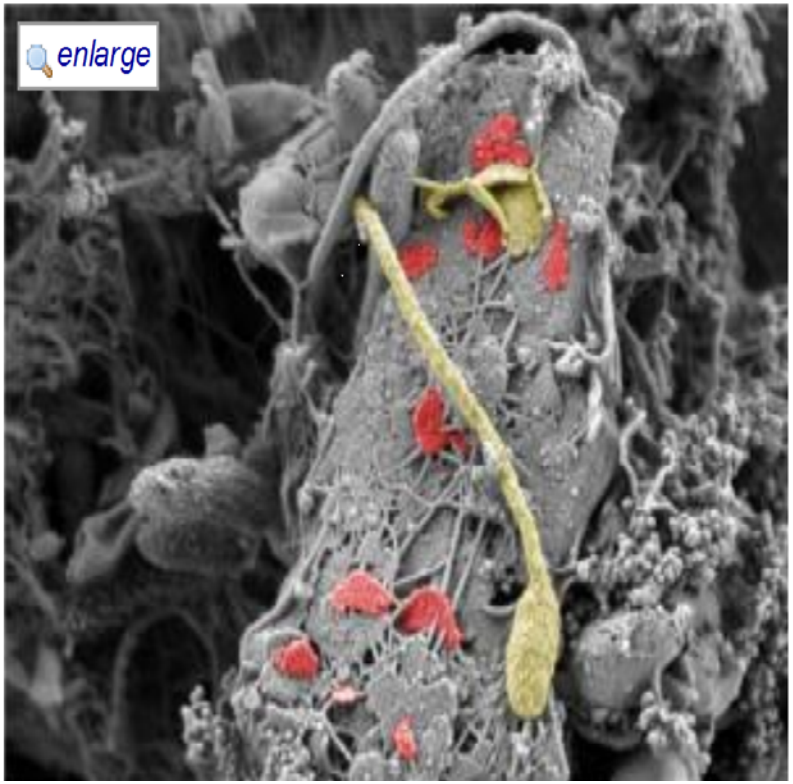
Soil biology is intimately connected to physical environment and chemical processes



(Brussaard et al. 2007)

Fertile Soil Doesn't Fall from the Sky: Contribution of Bacterial Remnants to Soil Fertility Has Been Underestimated Until Now

Dec. 14, 2012 — Remains of dead bacteria have far greater meaning for soils than previously assumed. Around 40 per cent of the microbial biomass is converted to organic soil components,

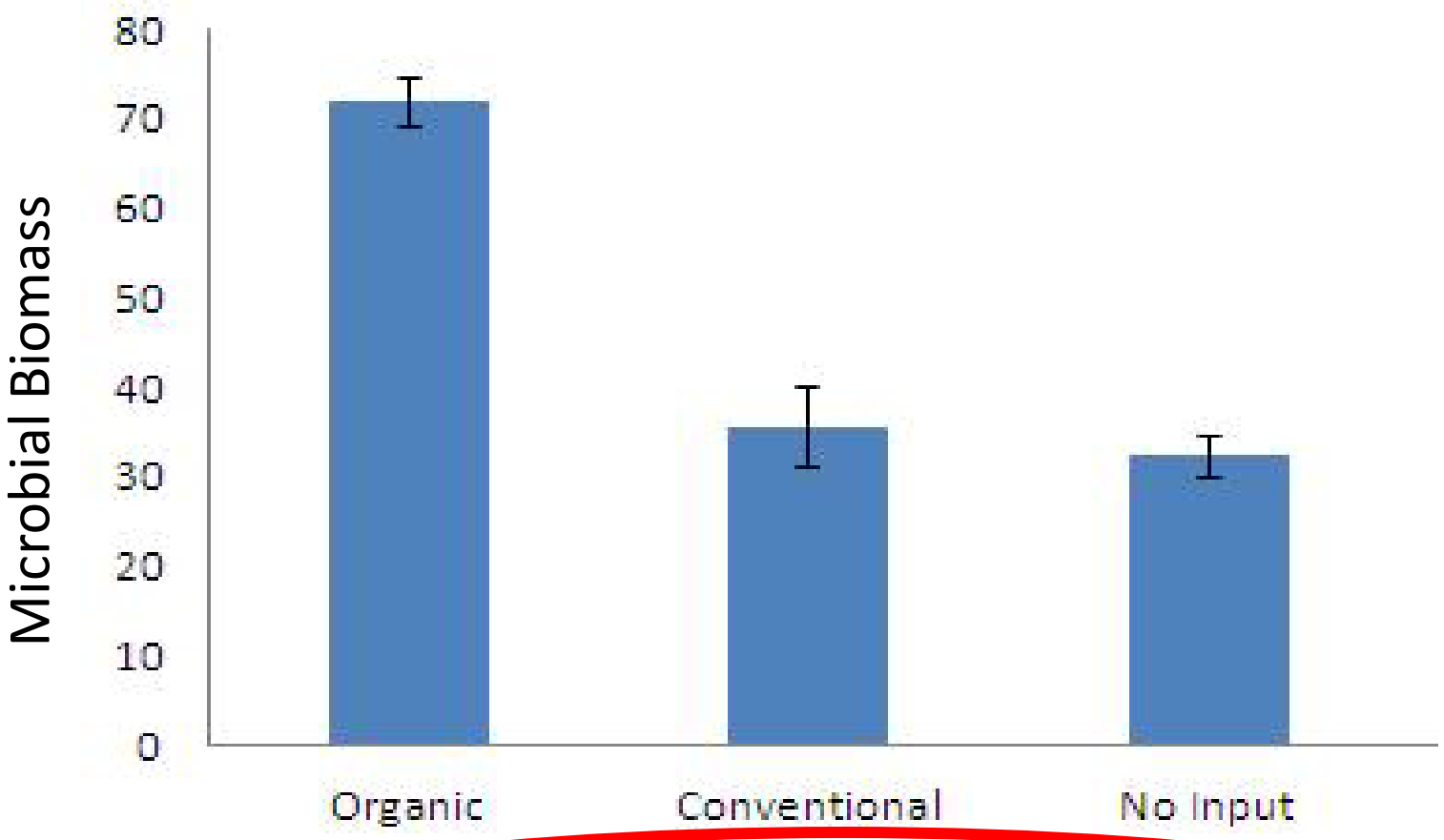


Soil organic matter is formed out of dead microbes

Plant C → microbe C → organic matter C

Miltner et al.. SOM genesis: microbial biomass as a significant source. Biogeochemistry, 2011

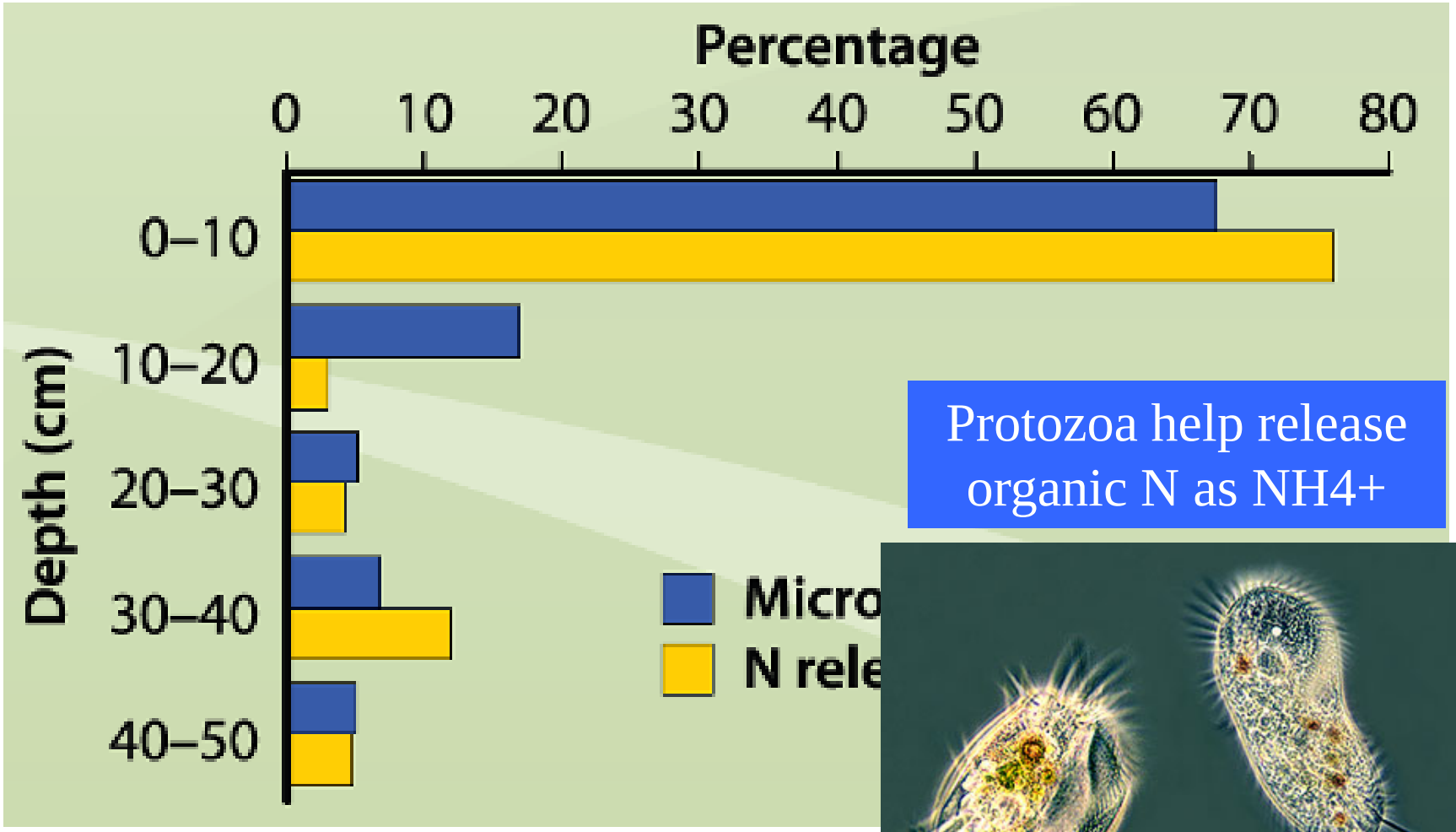
Soil organic matter is correlated to living soil microbial biomass



Soil organic carbon

1.4%	1.0%	0.78%
tomato	tomato	Wheat no fertilizer

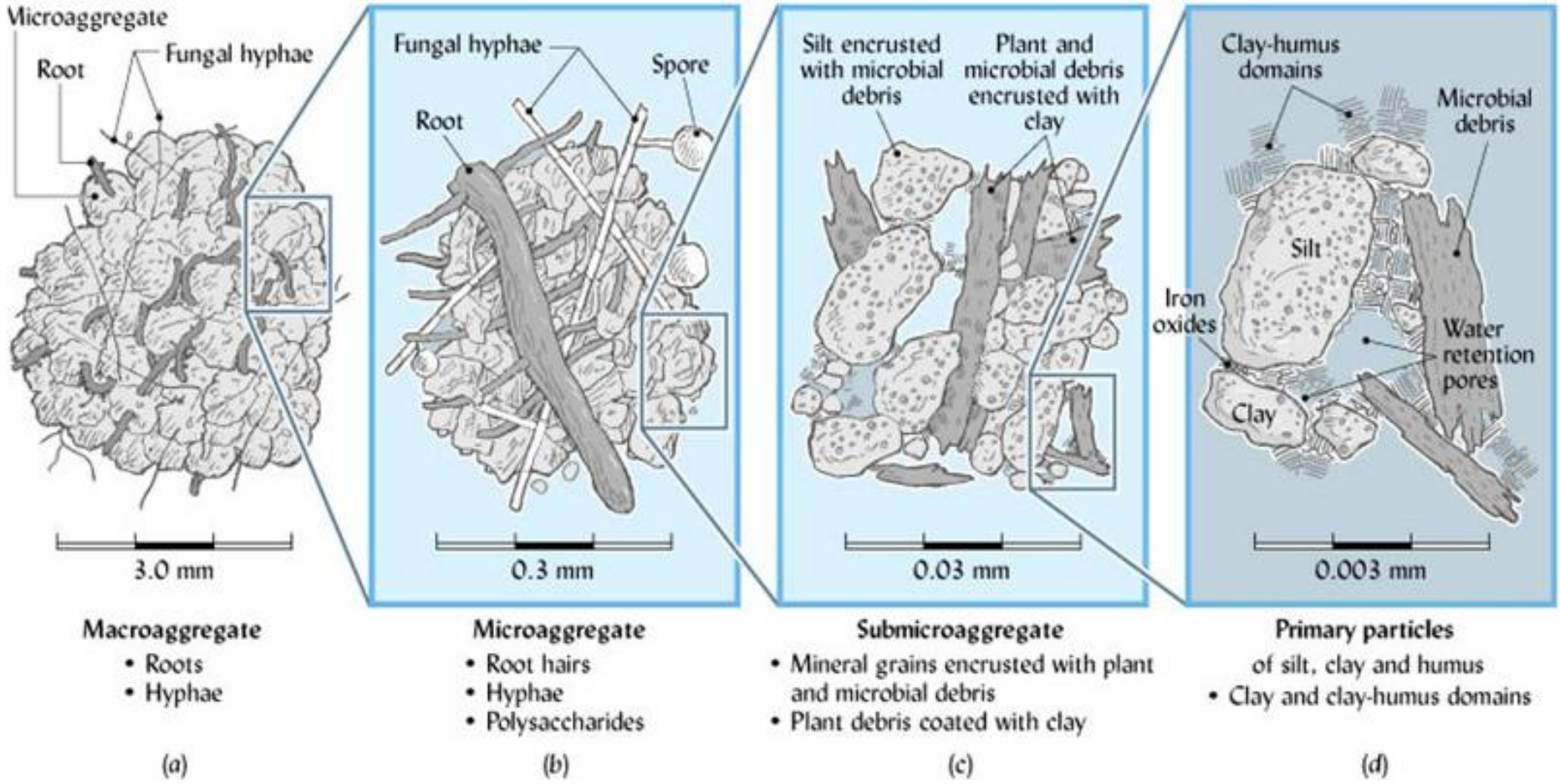
Relationship of microbial biomass nitrogen and plant available nitrogen



Protozoa help release organic N as NH_4^+

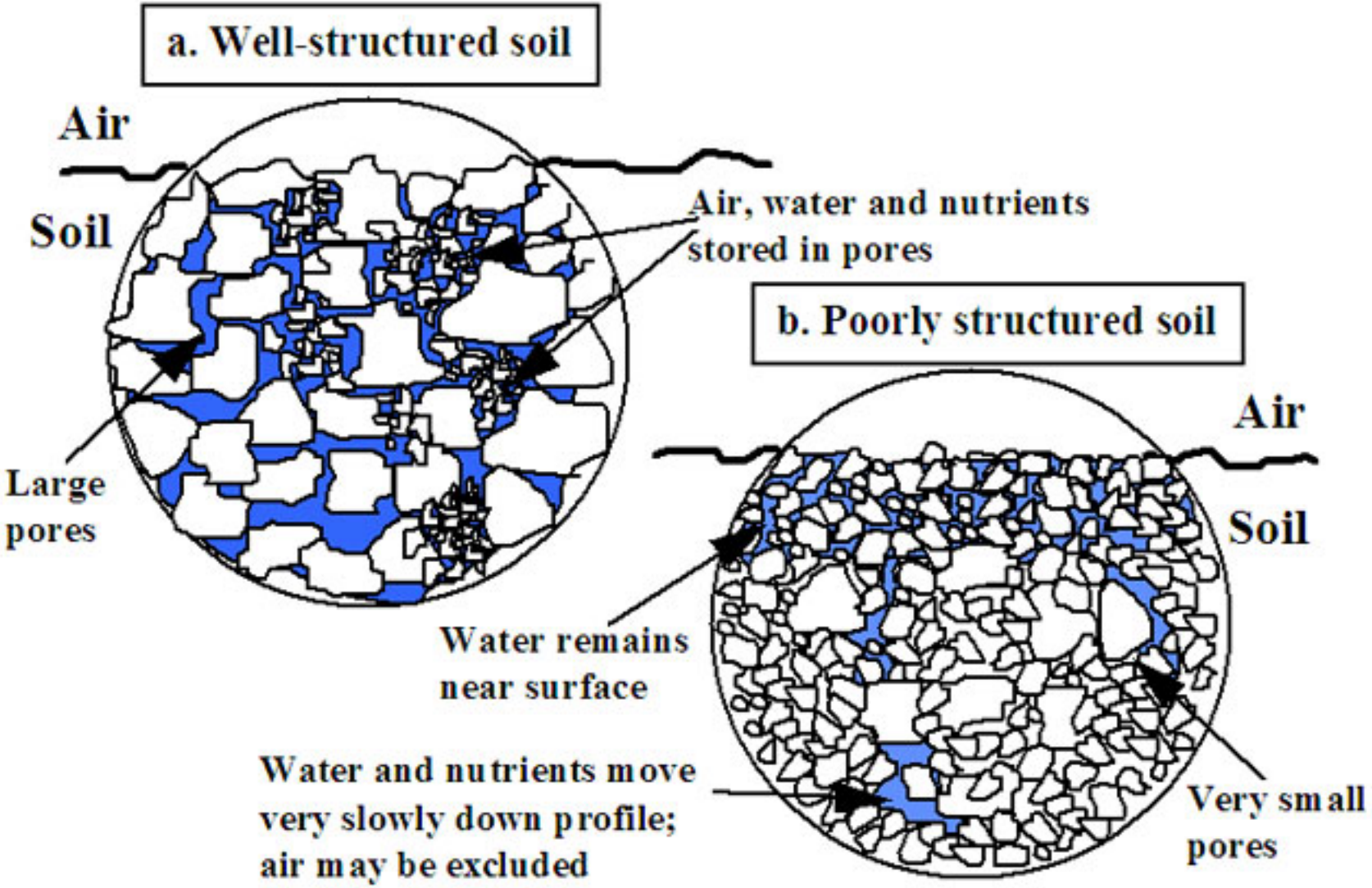
SOIL STRUCTURE

Built by biota (“architects”) out of carbon and minerals



larger <<----------<<----------<<----------smaller

Implications of structure for water movement and gas exchange



Interview with Scott Park—organic vegetable and rice farmer (750 hectares) in California for 25 years

Converted from conventional system (mineral fertilizer, pesticides).

Scott's Philosophy

FEED THEM

GIVE THEM SHELTER

KEEP THEM COVERED

DON'T DISTURB THEM TOO MUCH

DON'T TRY TO DO TOO MUCH

GET OUT OF THEIR WAY (especially later)

Management practices for managing microbes in soil

- Manipulate what they eat: C/N ratio of organics, degradability, physical availability, electron acceptors (e.g. oxygen), other nutrients, specific enzyme co-factors (?)

- Manipulate their environment: water and oxygen content, pH, “architecture”: stratified vs mixed layers in soil

- Inhibit/select for specific microbial groups? *Nitrification inhibitors? Selection through substrates, signaling compounds?*

- Promote symbiotic relationships with plants that short-circuit some of the soil processes providing N

Coupled with new research directions

- High throughput sequencing (e.g. metagenomics) to measure responses and identify **native** organisms involved in desired outcomes
  - Who is there?
  - What do they do?
  - What do they need?

the other approach…..
INOCULATION w/non-native organisms

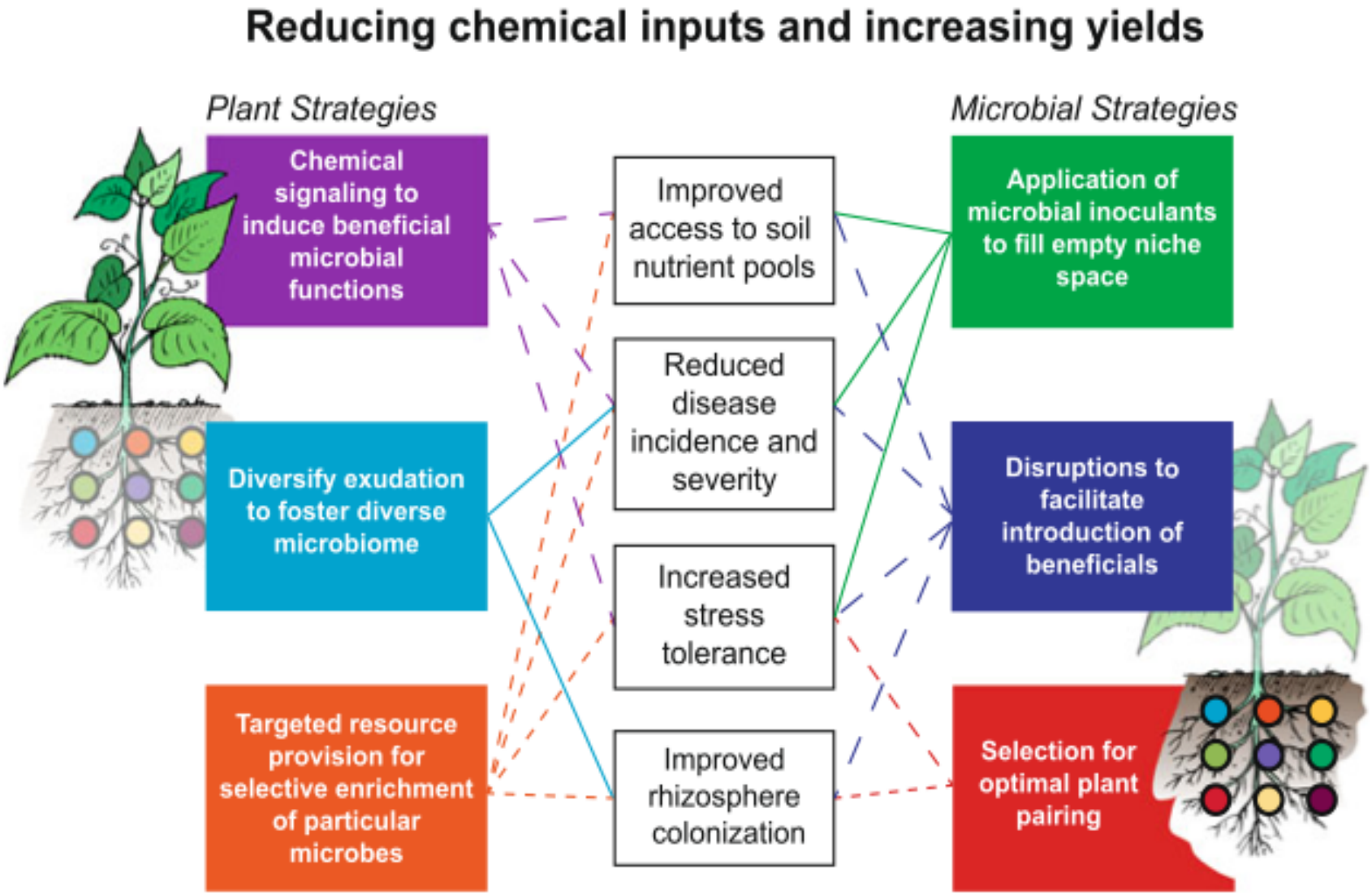
Rising interest in isolating or engineering specific microbes and using as soil inoculants

Major agtech companies jumping into this area

WHY DOES INOCULATION WITH MICROBES OFTEN FAIL?

- Incomplete understanding of abiotic requirements
- Incomplete understanding of biotic requirements – need right partner? Other microbes?
- Environmental conditions not right (no rain, no food, etc.)
- Application method doesn’t get them where they are needed
- Intense predation or competition by residents (e.g., protozoa)
- Inoculum usually commercially produced under optimum conditions for growth—too weak or pampered to survive?

More targeted strategies to increase success of inoculation—focus on plant and microbes, lots of "omics"



Bakker et al., 2012

Soil health/quality is coming back after having lain dormant for 15 to 20 years
NRCS launched initiative in 2012
Many modules, management systems, indices, kits available
Cornell, NRCS,

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

National Soil Health Initiative

The Soil Health Roadmap to Productive, Sustainable Farming in the 21st Century and Beyond

June 4, 2012

NRCS - HELPING PEOPLE HELP THE LAND

NEED TO CONNECT PUBLIC WITH AGRICULTURE'S BELOW GROUND "YIELDS"

State and county fairs give prize for biggest pumpkin…..

How about prize for soil with greatest biomass or biodiversity?

http://www.nytimes.com/2013/05/12/opinion/sunday/the-hidden-world-of-soil-under-our-feet.html?hp&_r=0