A close-up photograph of dark brown, rich soil. The soil has a crumbly texture with visible organic matter, including small twigs and roots. The lighting is natural, highlighting the texture and color of the earth.

“Carbonomics”

The Wonderful Economy of the Soil

Farming Background

- No-tilling for 30 years
- 1/2 dryland 1/2 irrigated
- Corn – Beans – Cereal rotation
- Added rye, triticale, oats, barley, vetch, sunflowers, buckwheat



Farming Background

- Cover crops for 10 years
- Green Cover Seed started in 2009





SOIL HEALTH
— INSTITUTE —

LIVING SOIL
THE SERIES

"Not only for our generation but for future generations."

—Keith Berns, Nebraska Farmer

LIVING SOIL

THE SOIL HEALTH INSTITUTE PRESENTS **LIVING SOIL** A DOCUMENTARY FILM BY TINY ATTIC PRODUCTIONS, LLC

DIRECTED BY **CHELSEA WRIGHT** PRODUCED BY **CHELSEA WRIGHT & JOSH WRIGHT**

EXECUTIVE PRODUCERS **DR. WAYNE HONEYCUTT DR. STEVEN SHAFER SHELDON JONES BYRON RATH**

CINEMATOGRAPHER & EDITOR **CHELSEA WRIGHT**

ADDITIONAL CINEMATOGRAPHY **KEVIN MATHEIN**

DIKING OPERATION **BEN HARRIS**

SOUND RECORDING **TIM PILCHER**

ADDITIONAL SOUND RECORDING **JOSH WRIGHT & HALEY MYERS**

SOUND DESIGN **TIM PILCHER CHELSEA WRIGHT JOSH WRIGHT**

TECHNICAL ADVISER **DR. ROB MYERS**

LEGAL **JOSH OXENHANDLER**

ORIGINAL SCORE **HALEY MYERS & TIM PILCHER**

A DOCUMENTARY SHOWCASING INNOVATIVE FARMERS WHO ENRICH THEIR SOILS TO ENHANCE LIFE ON EARTH.

SPECIAL THANKS TO

THE BERNS FAMILY THE DESUTTER FAMILY

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE

U.S. DEPARTMENT OF AGRICULTURE AGRICULTURAL RESEARCH SERVICE

THE MARYLAND DEPARTMENT OF AGRICULTURE BOXCAR FILMS

LIVINGSOILFILM.COM





Carbonomics\$ – The Wonderful Economy of the Soil



Carbonomic\$ – The Wonderful Economy of the Soil

7 Keys To A Healthy Economy

- Supply (Producers/Sellers)
- Demand (Consumers/Buyers)
- Currency
- Capital
- Energy and Resources
- Infrastructure
- Defense and Protection

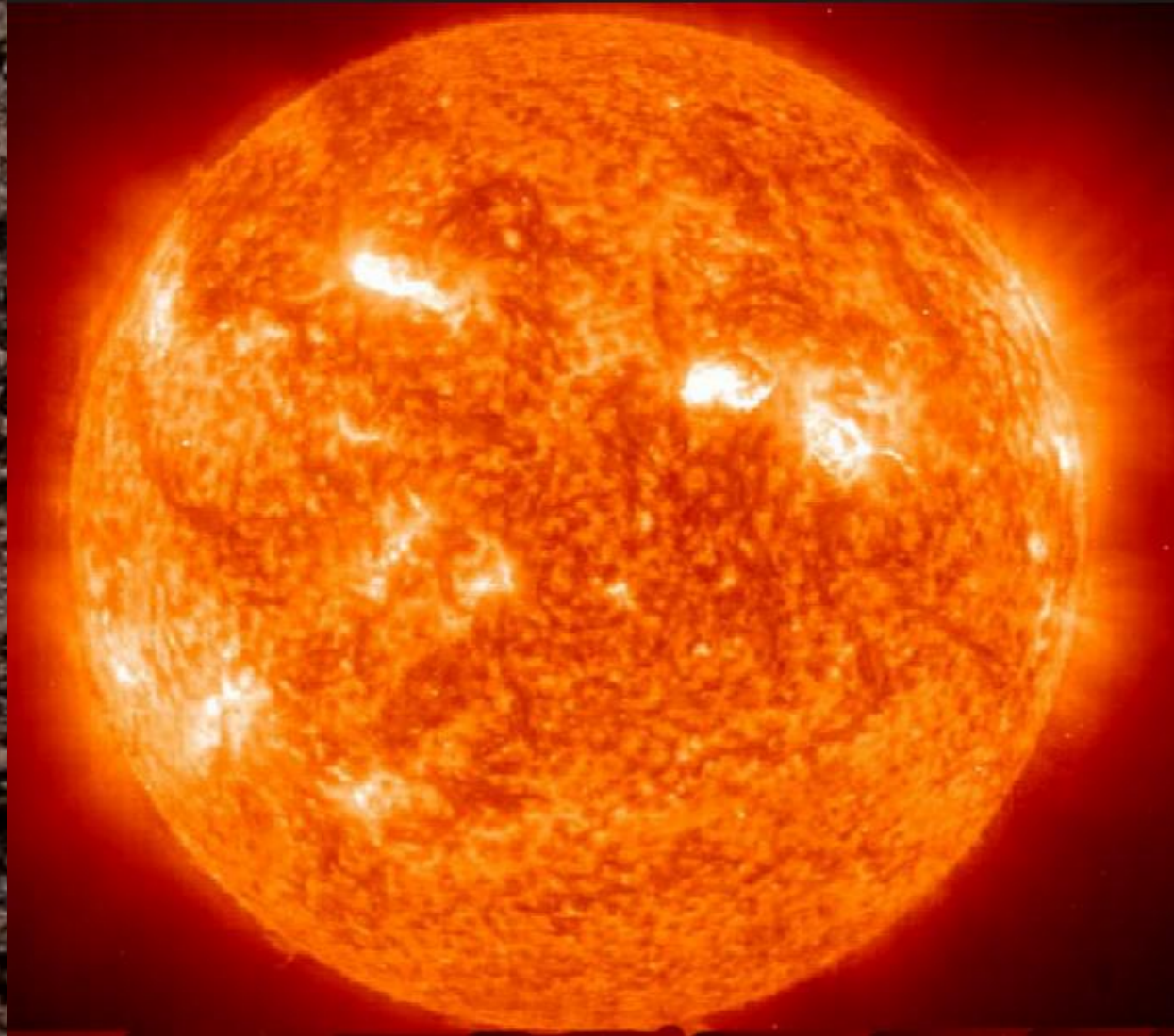


7 Keys To A Healthy SOIL!

- Supply (Producers/Sellers)
- Demand (Consumers/Buyers)
- Currency
- Capital
- Energy and Resources
- Infrastructure
- Defense and Protection



The Soil Economy



The Soil Economy

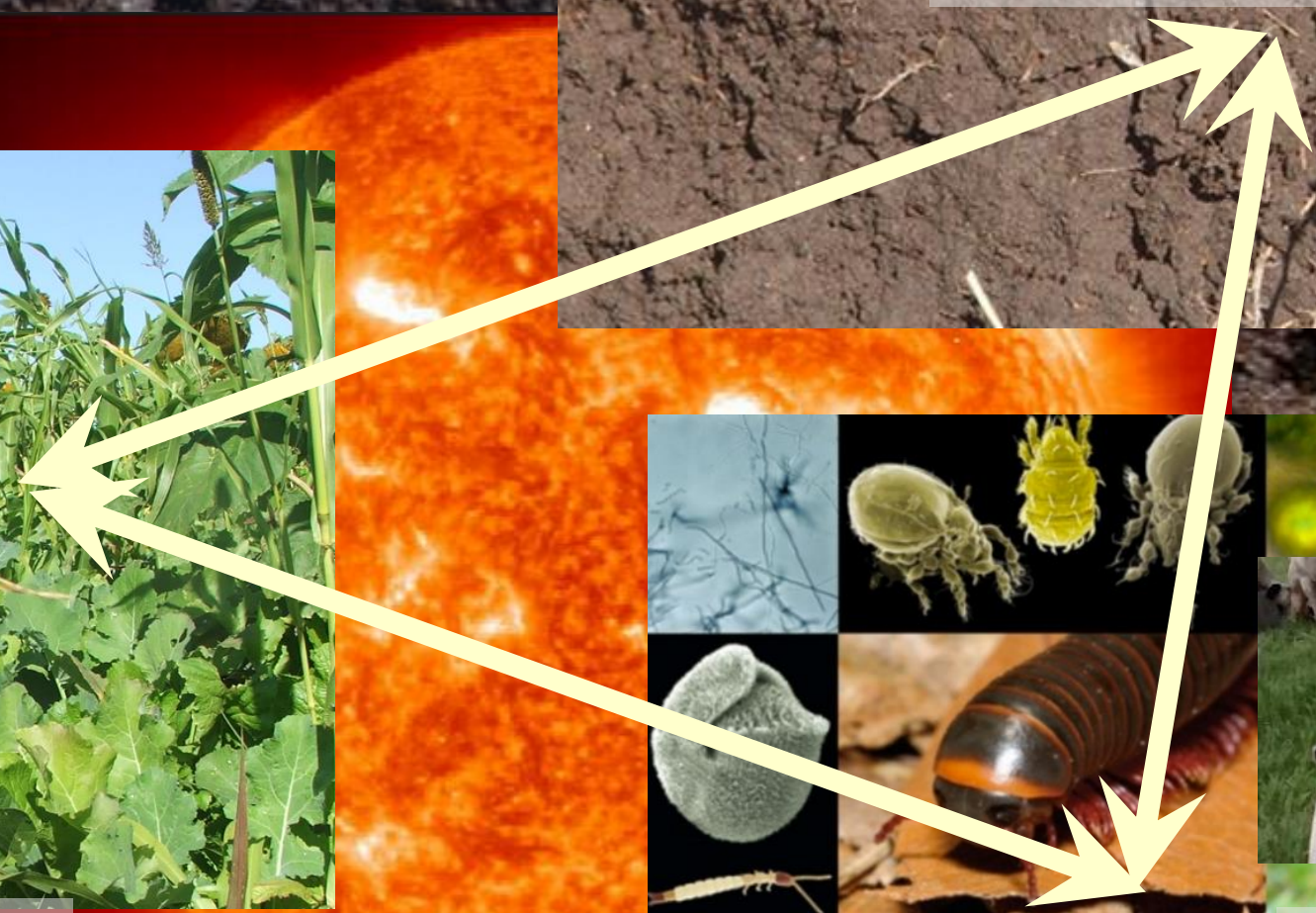
Soil



Plants

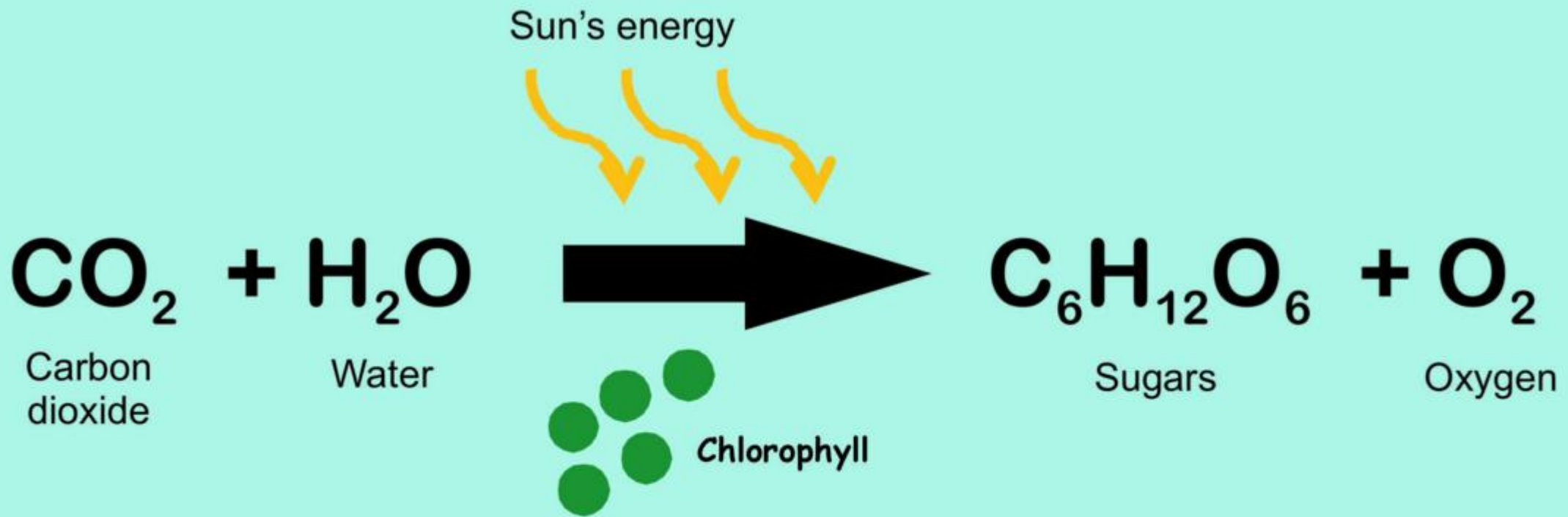


Animals



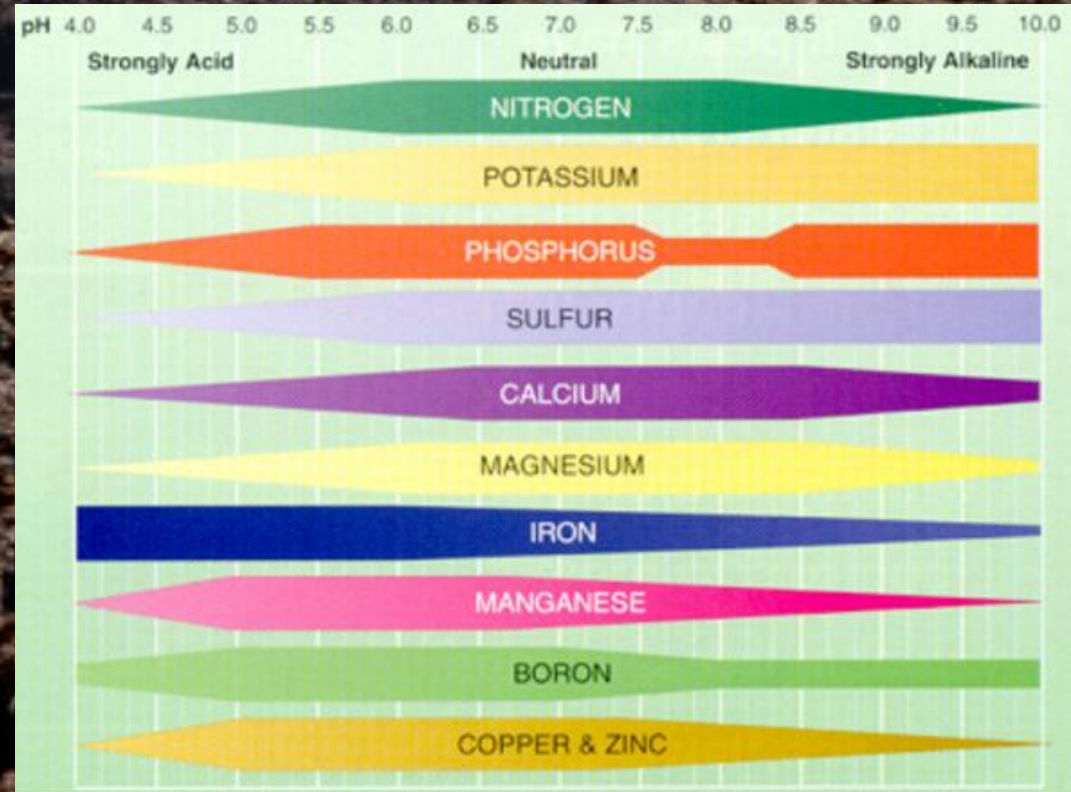
Supply (Producers/Sellers)

- Plants – Producing Carbon



Supply (Producers/Sellers)

- Soil – Provides Nutrients (Minerals)
- Soil – Provides Habitat for Roots and Biology
- Soil – Provides Water storage



Keys To A Healthy **SOIL!**

Supply (Producers/Sellers)

- Soil Biota – Producing Nutrients (Fixation) (Cycling) (Availability)
- Soil Biota – Providing Defense and Protection



Demand (Consumers/Buyers)

- Plants – Need Nutrients and Water
- Plants – Need Services (Protection, Support, etc...)



Demand (Consumers/Buyers)

- Soil– Needs Carbon
- Soil– Needs Services (Protection, etc...)



Demand (Consumers/Buyers)

- Soil Biota – Needs Food and Habitat



Producers –(Sellers) Consumers (Buyers)

- In a strong human economy, one of the leading indicators is low unemployment rate, where most people are both consumers AND producers and are actively engaged in making a contribution to the system.



Producers –(Sellers) Consumers (Buyers)

- The soil economy is strongest when plants, soil, and animals are ALL producing and consuming.
- Diversity is very important.



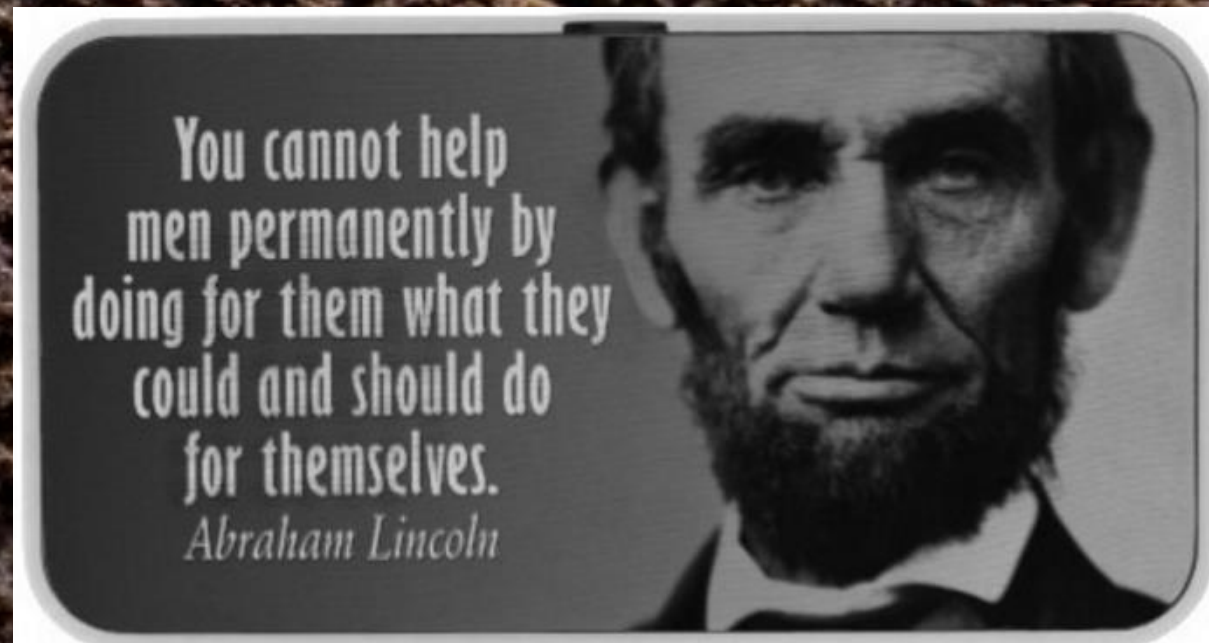
Agricultural Welfare

- When we externally provide the plant with everything that it needs from the outside, we weaken the economy.
 - Fertility inputs
 - Crop protection inputs



Agricultural Welfare

- When we externally provide the plant with everything that it needs from the outside, we weaken the economy.
 - Fertility inputs
 - Crop protection inputs



We need to allow the system to work the way it was created to work!

Soil



Plants



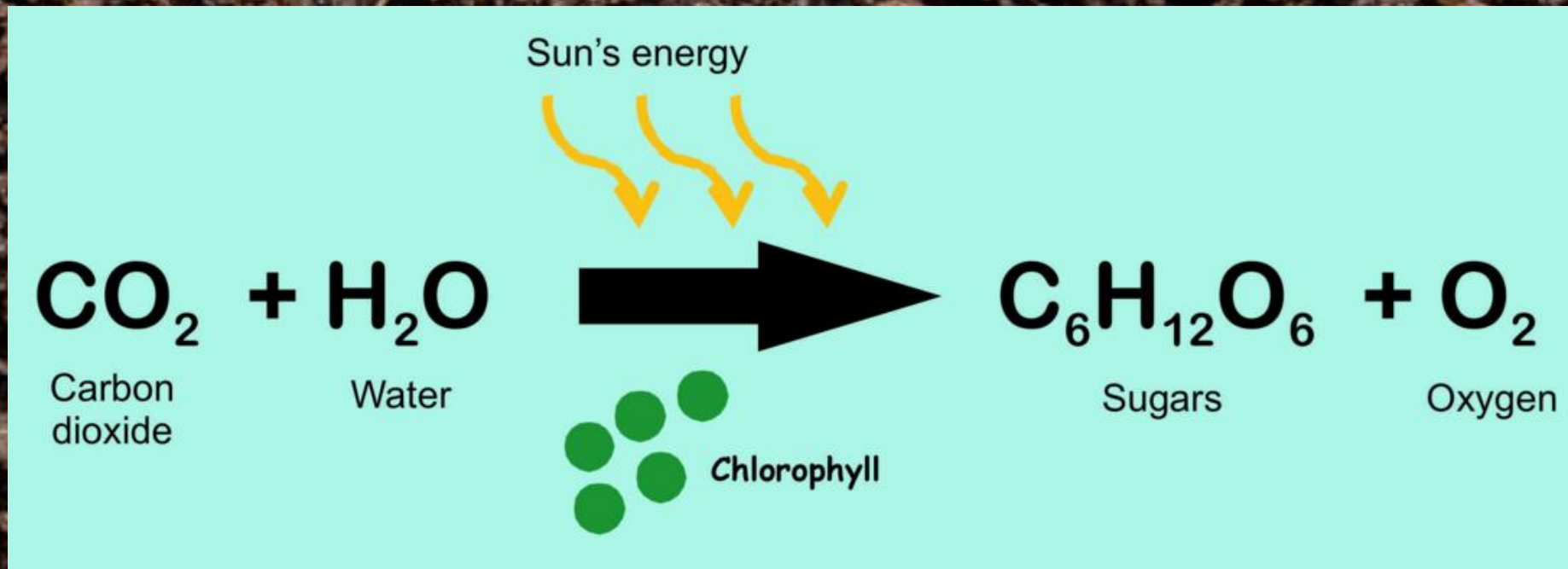
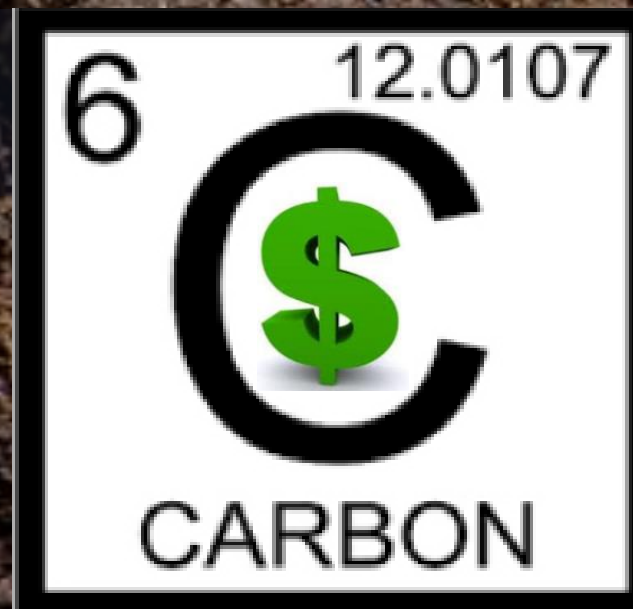
Currency

- Currency is important because it allows goods and services to be exchanged more efficiently



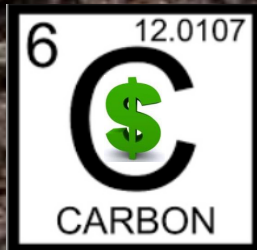
Currency

- In the plant economy, the currency is Carbon



Carbon Currency

- Currency (Carbon) is important because it allows goods and services to be exchanged more efficiently with the soil economy.



Carbon Payments

Root Exudates

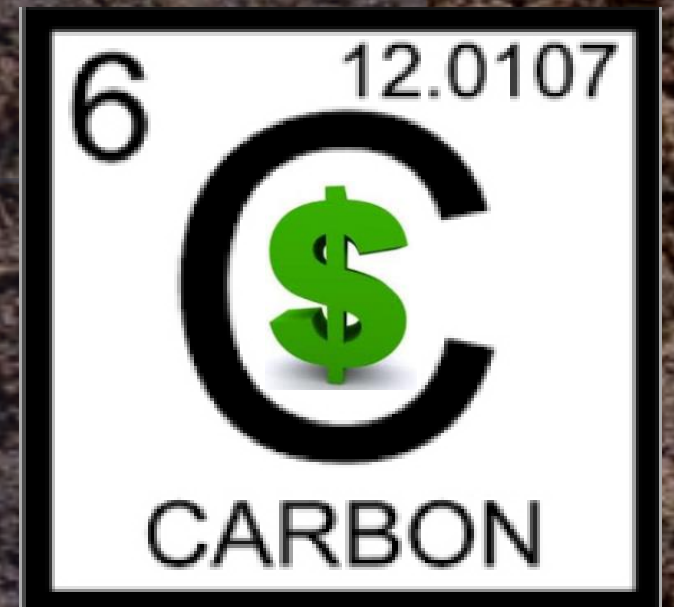
Plant Services

Sourcing, Delivery, Protection



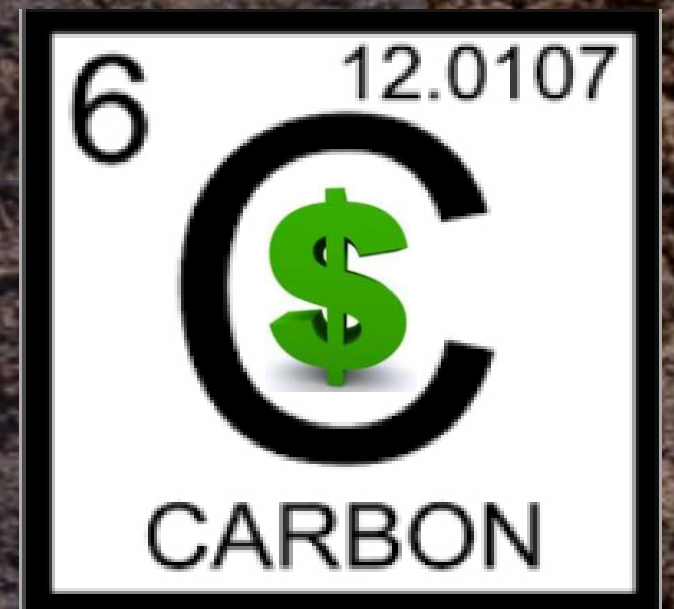
Importance of Carbon

- Carbon is essential to all life
- People are 19% carbon
- Carbon can form over 10 million compounds
- Carbon is the *most important* but *most overlooked* of all plant nutrients
- Carbon is the main food source for soil biology



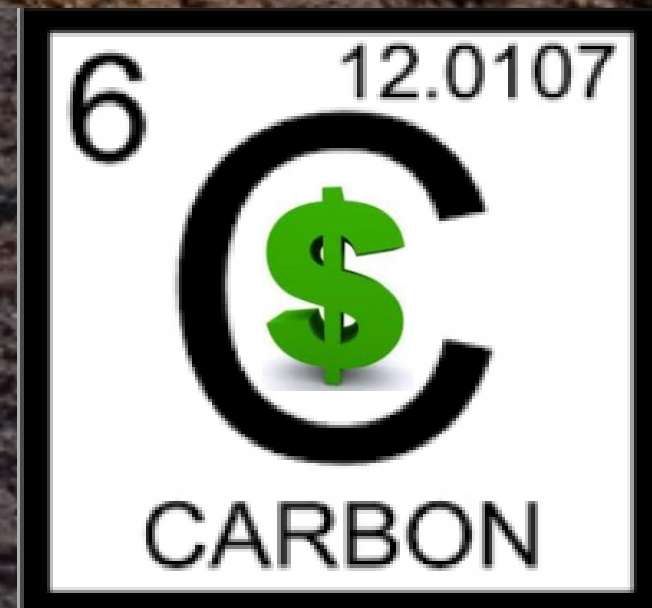
Increased Soil Carbon Currency

- Normalizes soil pH
- Increases CEC
- Increases availability of P, Ca, K, S, Zn, Fe, Mo, B
- Reduces availability of Na and Al



Carbon Currency

- Carbon can be:
 - collected (photosynthesis)
 - spent (traded to soil organisms)
 - saved (soil organic matter)
 - desired by all members of the economy



Carbon Currency

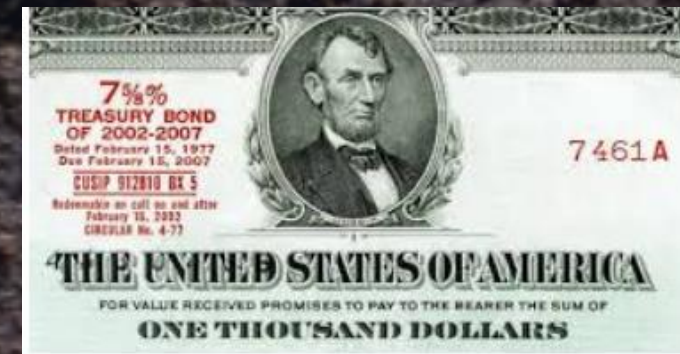
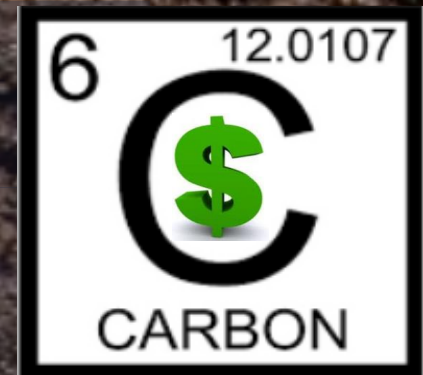
- Carbon has different states

- Gas – CO₂



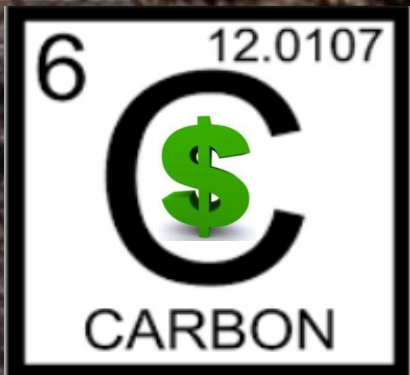
- Liquid – in plants and soils

- Solid – in living organisms and Organic Matter



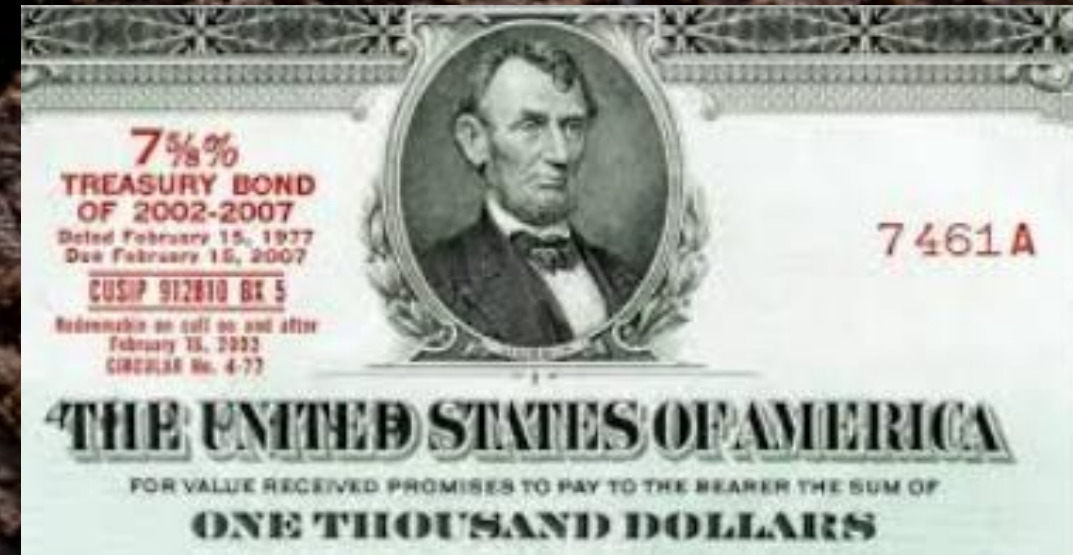
Carbon Currency

- Carbon has different states
 - Gas – CO₂
 - Liquid – in plants and soils
 - Solid – in living organisms and Organic Matter



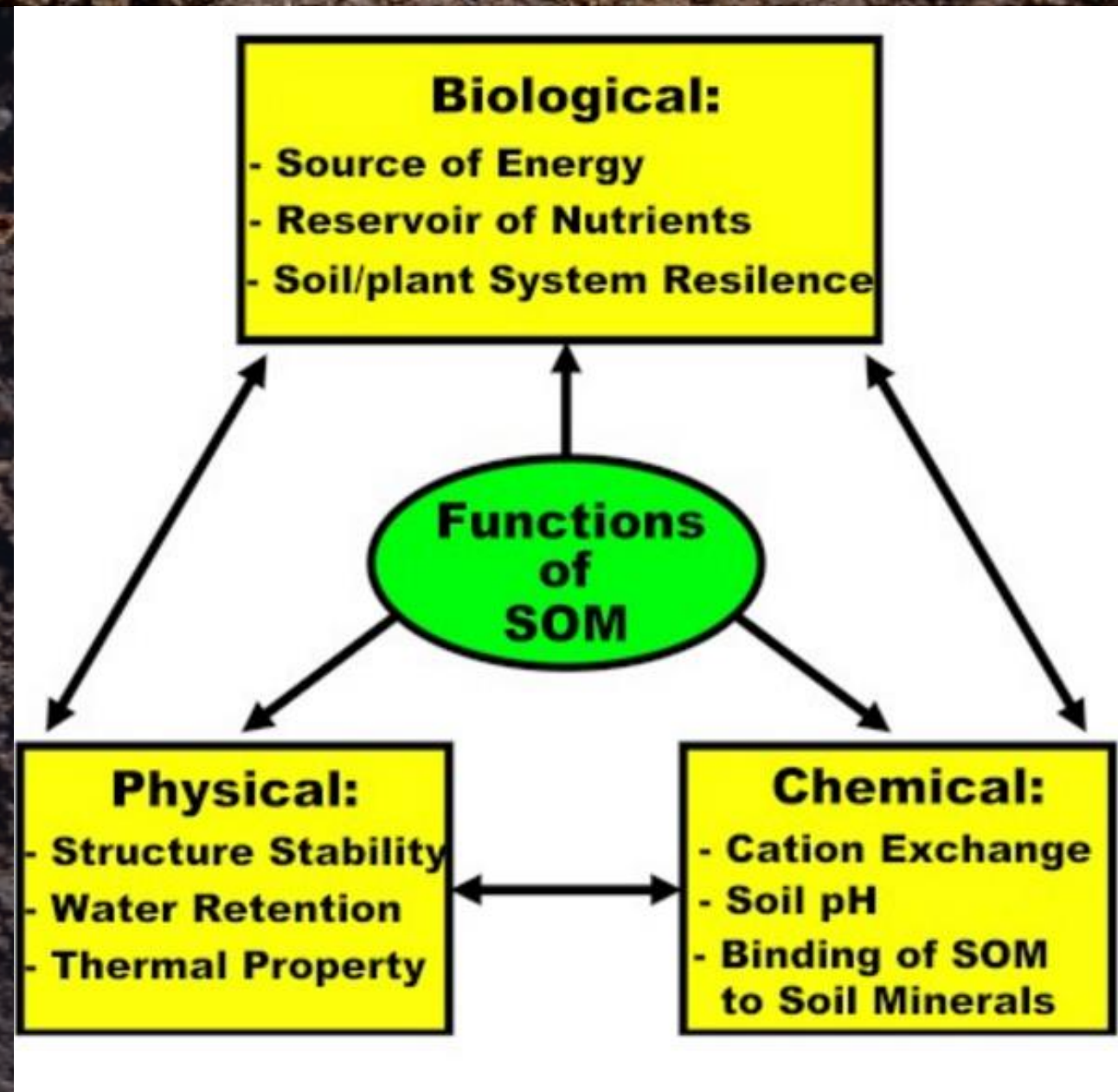
Capital

- Accumulated (stored or saved) currency
- Needed for Growth and Stability



Soil Carbon Capital

- Organic Matter and Humus
- Accumulated (stored or saved) carbon currency
- Needed for Growth and Stability



Benefits of Soil Organic Matter

Jennifer Moore-Kucera NRCS Linking Soil Biology To Soil Health

Food & habitat
for soil organisms

Increased
microbial activity,
decomposition,
mineralization

Increased microbial
biomass, competition
& antagonism against
plant pests

Increased
infiltration and
water-holding
capacity



Protect surface
from solar energy
and raindrops

Increased CEC &
adsorption of
organic
compounds

Buffers
temperature
extremes

Increased supply
of micro- and
macro-nutrients

Increased
aggregate stability,
macroporosity

Capital Rich Economies



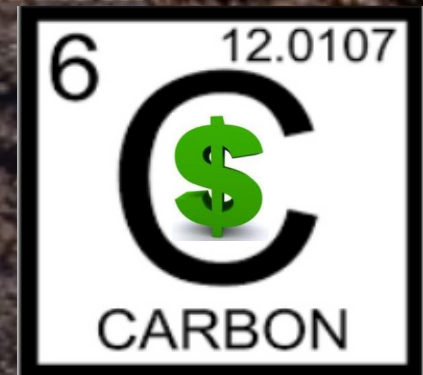
High Organic Matter Soils

- Productive
- Stable
- Resilient
- Efficient

- Productive
- Stable
- Resilient
- Efficient

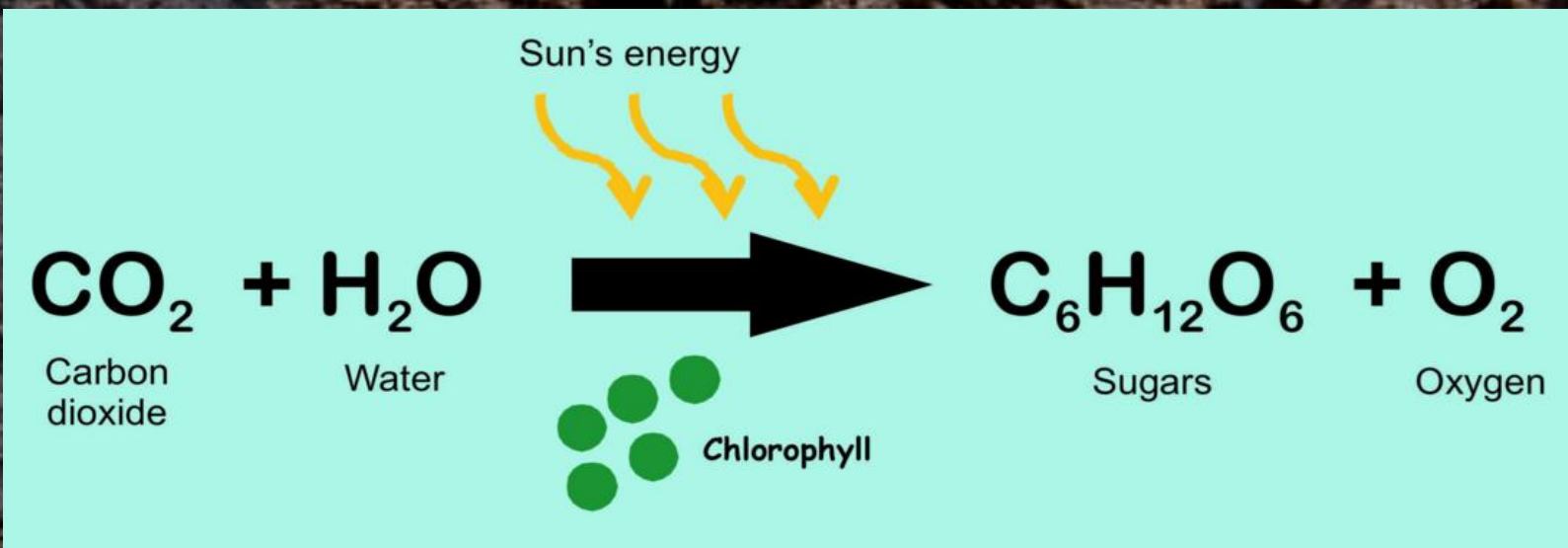
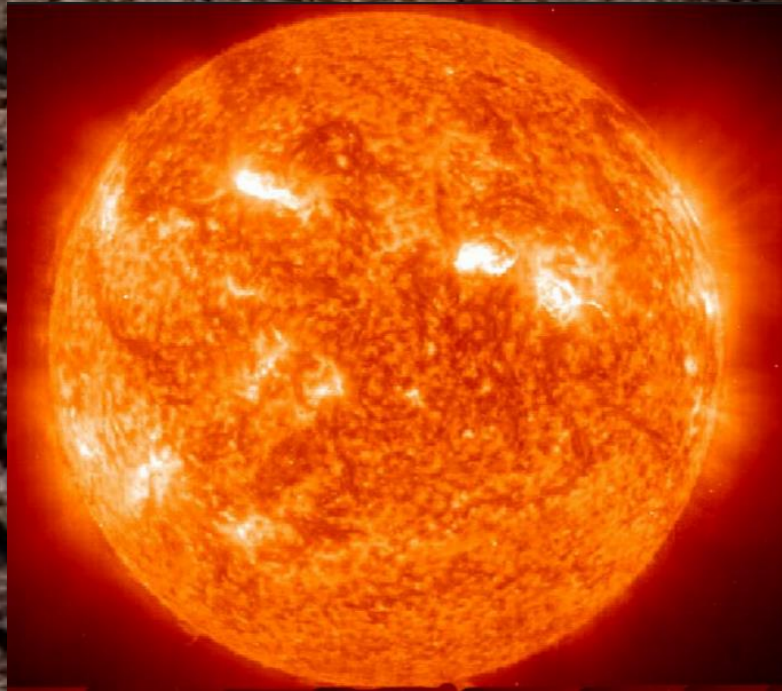
Carbon Capital

- Capital (Savings) can't be increased without an excess of cash income
- Soil Organic Matter can't be increased without an excess of soil carbon currency
- Soil Carbon can't be increased in most rotations without the use of cover crops



Energy and Resources

- Plant economy energy comes from the sun



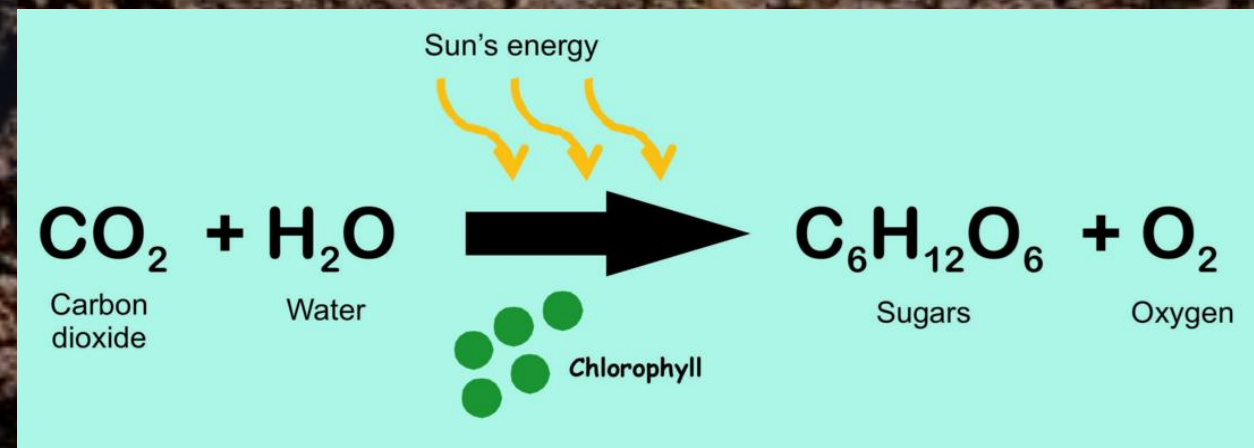
Energy and Resources

- Plant economy energy comes from the sun
- Plant solar collectors (seeds) are MUCH cheaper and easier to install than man-made solar panels!



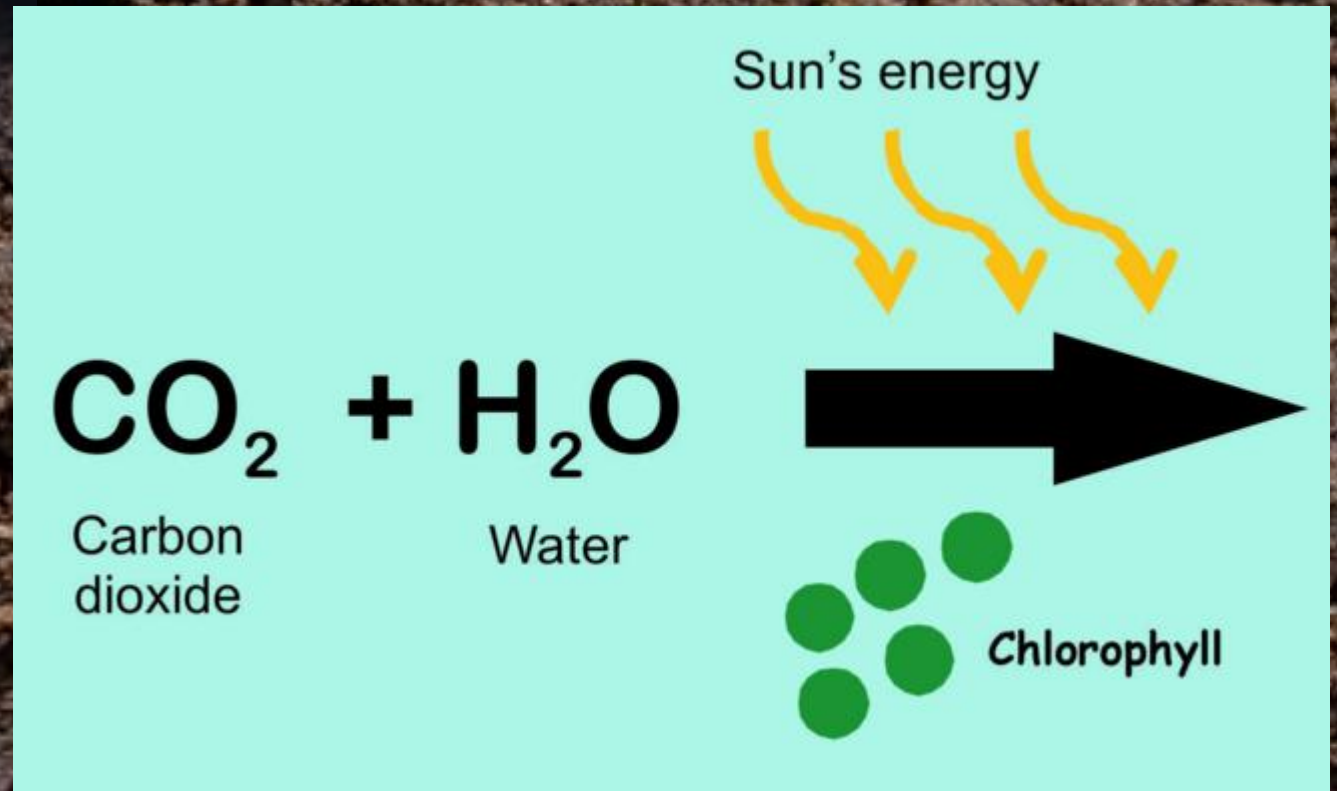
Energy and Resources

- Plant economy energy comes from the sun
- Plant solar collectors (seeds) are MUCH cheaper than man-made solar panels!
- A healthy soil economy should not need significant purchased energy inputs



Energy and Resources

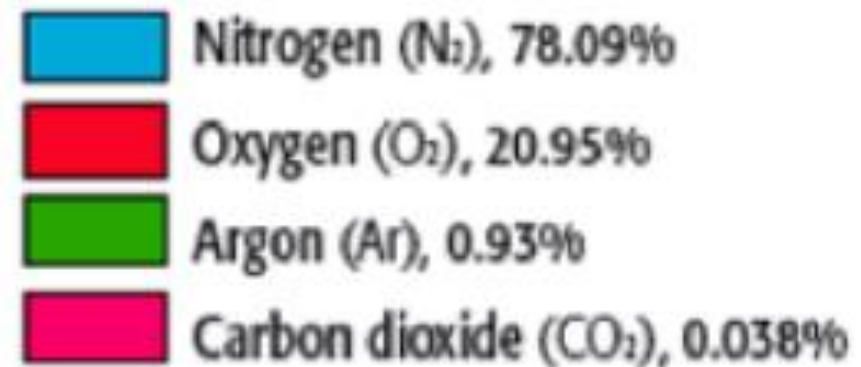
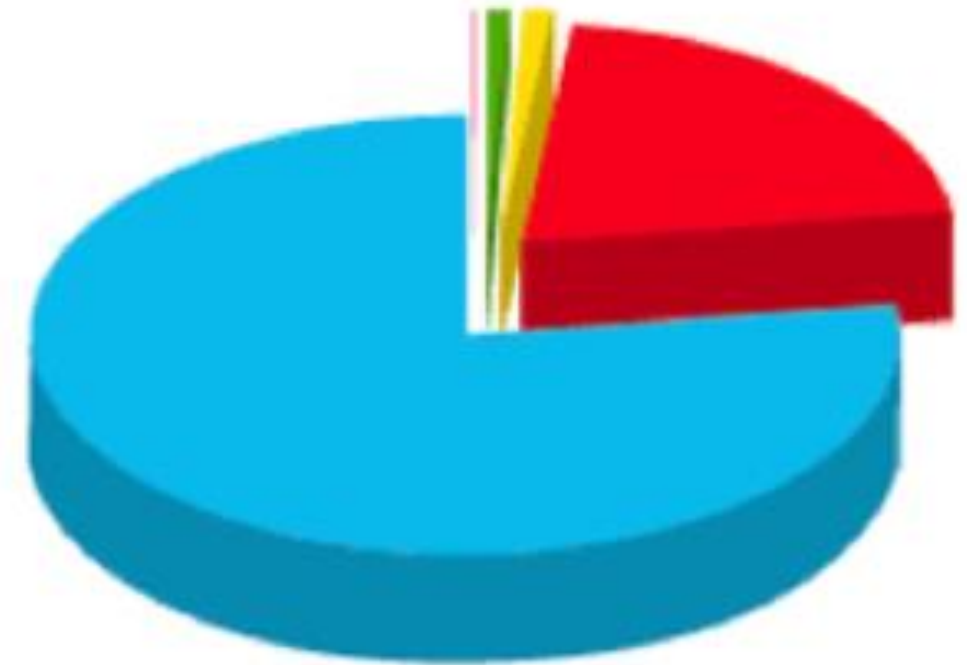
- Plant economy resources
- #1 is CARBON



Energy and Resources

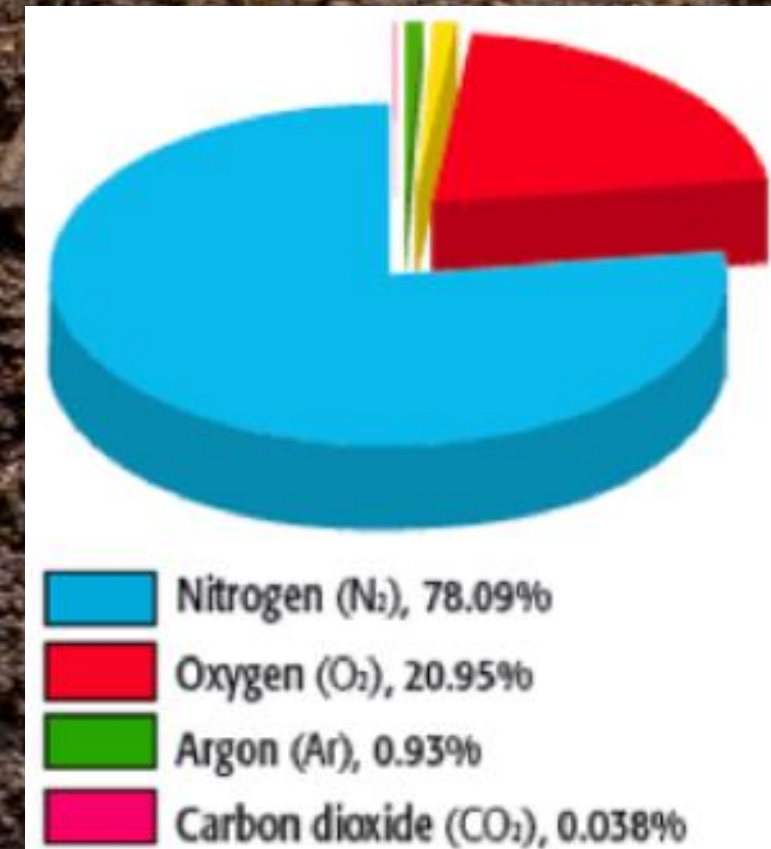
- Plant economy resources
- #1 is CARBON
- #2 is NITROGEN

Atmospheric composition



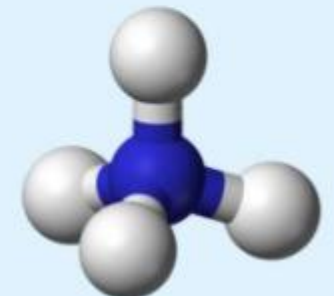
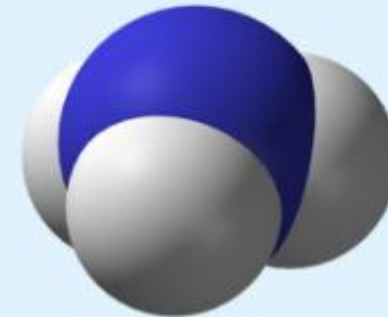
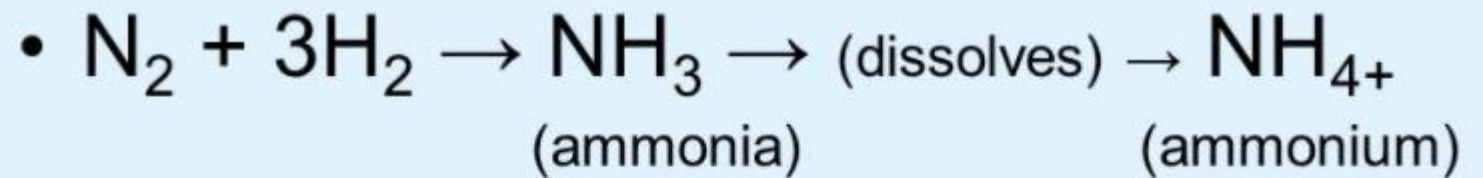
Energy and Resources

- Plant economy resources
- #1 is CARBON
- #2 is NITROGEN



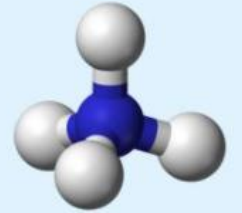
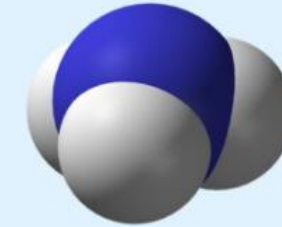
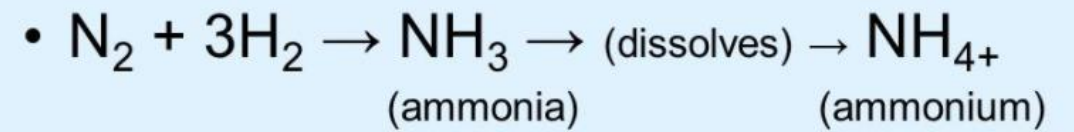
Energy and Resources

- Nitrogen gets “fixed” or made plant available when combined with hydrogen or oxygen



Energy and Resources

- Nitrogen gets “fixed” or made plant available when combined with hydrogen or oxygen
- Very energy intensive process



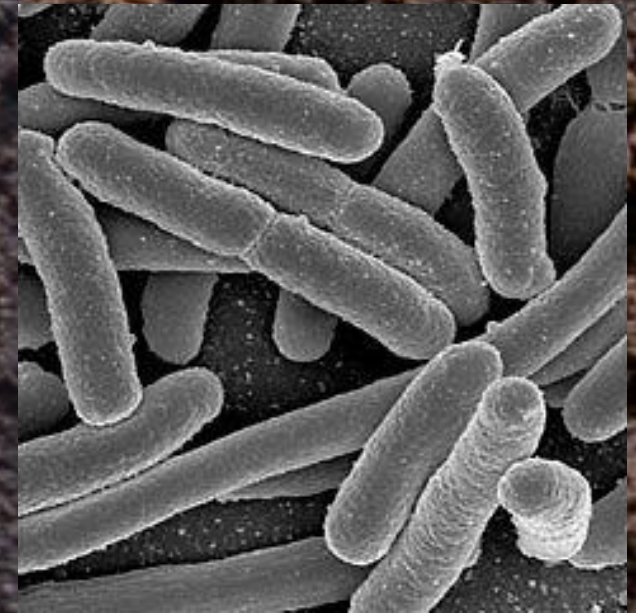
Energy and Resources



Rhizobia Bacteria

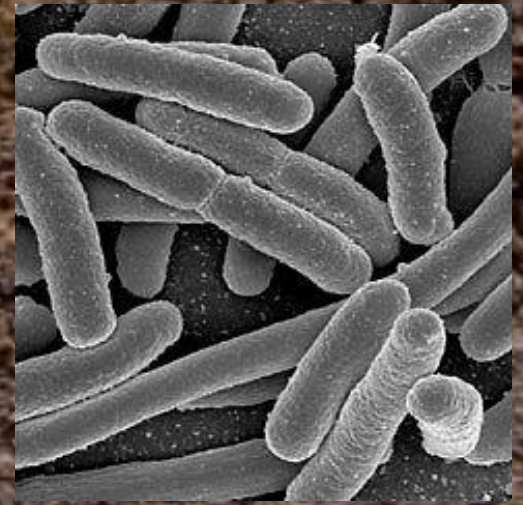
Nitrogen Factories

- Azospirillum
- Azotobacter
- Not limited to legumes



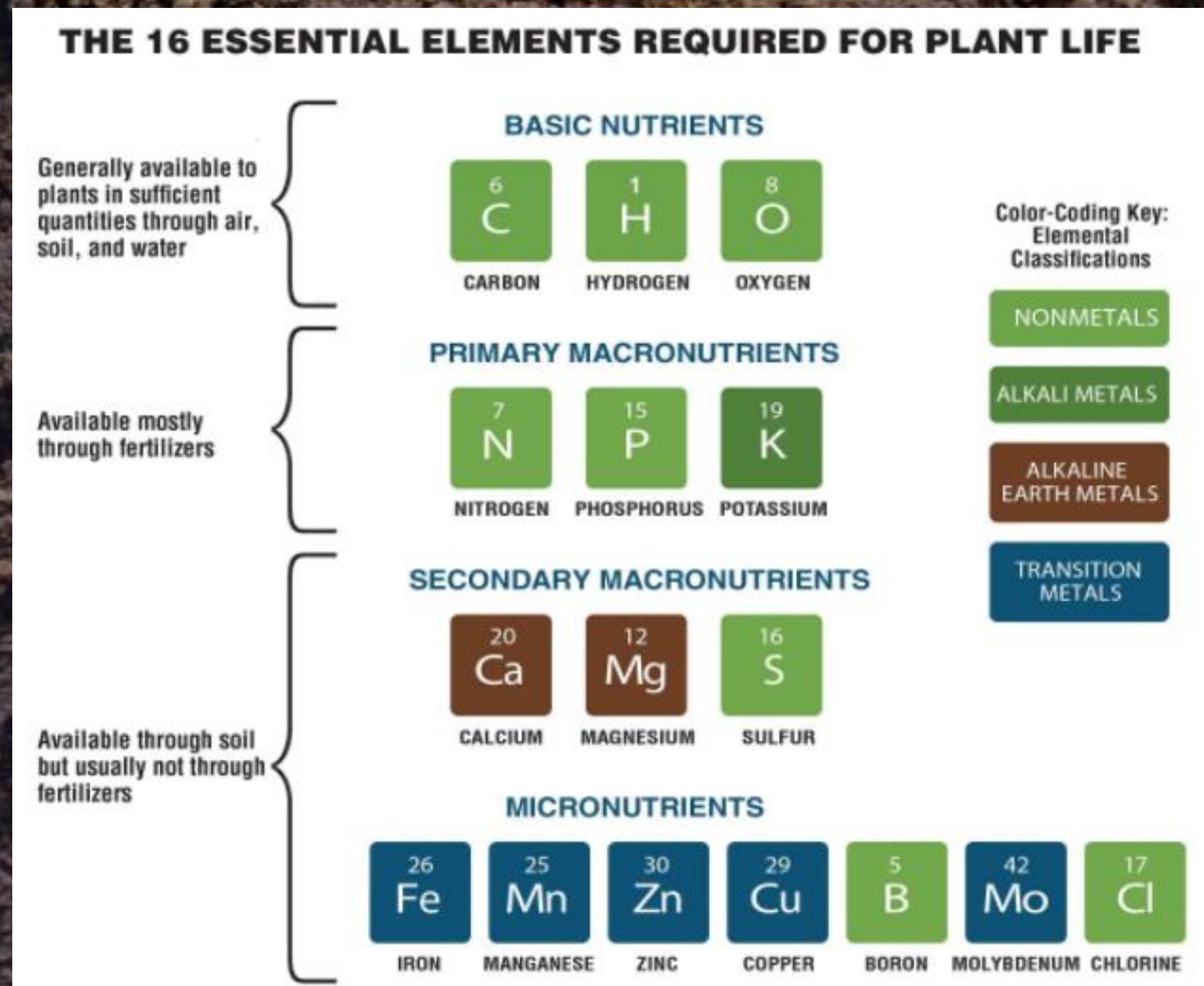
Nitrogen Factories

- Azospirillum
- Azotobacter
- Rhizobia
- Must associate with a plant
- “Trade” nitrogen to the plant for carbon
- Will not happen if excess N is in the soil



Energy and Resources

- Plant economy resources
- #1 is CARBON
- #2 is NITROGEN
- Other mineral resources



Energy and Resources

- Plant economy resources
 - #1 is CARBON
 - #2 is NITROGEN
- Other mineral resources
- Employ tiny miners to extract the nutrients from the soil.

Mycorrhizal Fungi run the Largest Mining Operation in the World

Up to 85% of plants depend on fungi to survive. Plants and fungi depend on each other for nutrient cycling and water absorption

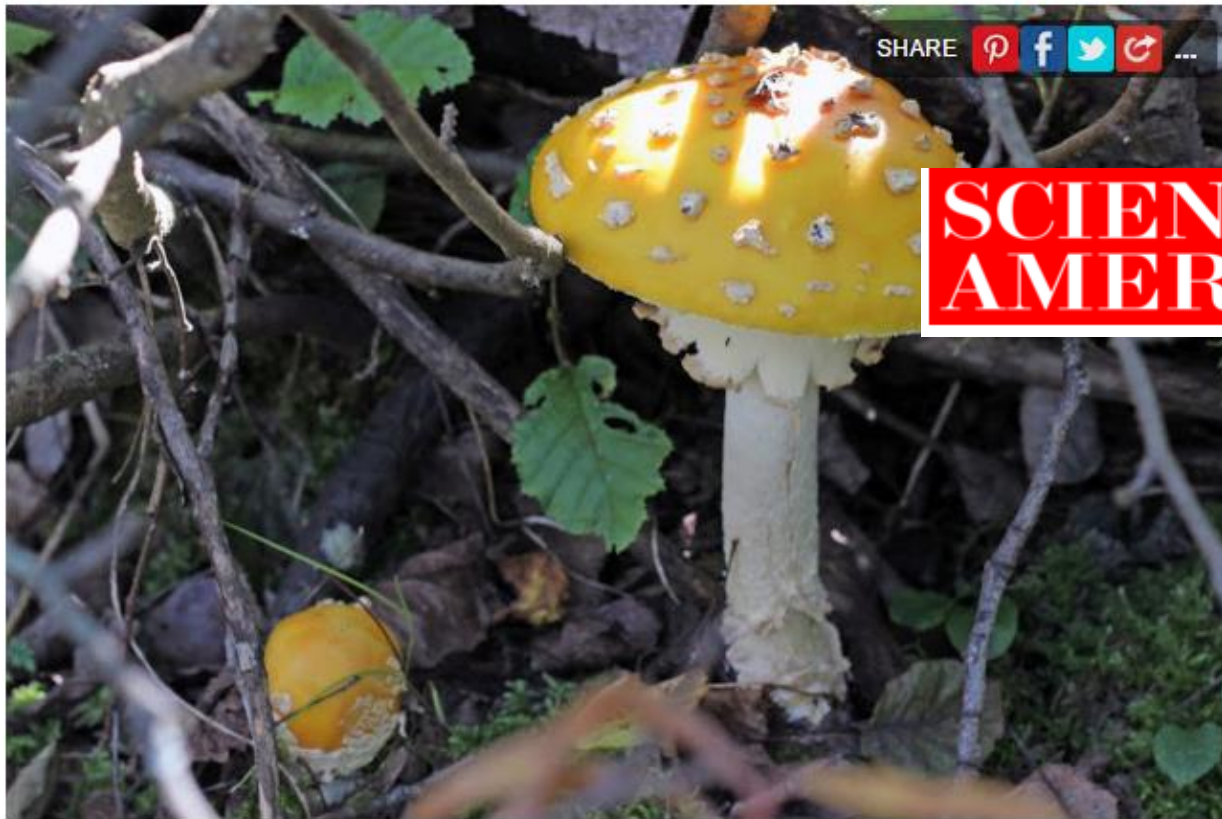


Photo: Amanita gemmata by Courtney Celley; US Fish & Wildlife Service

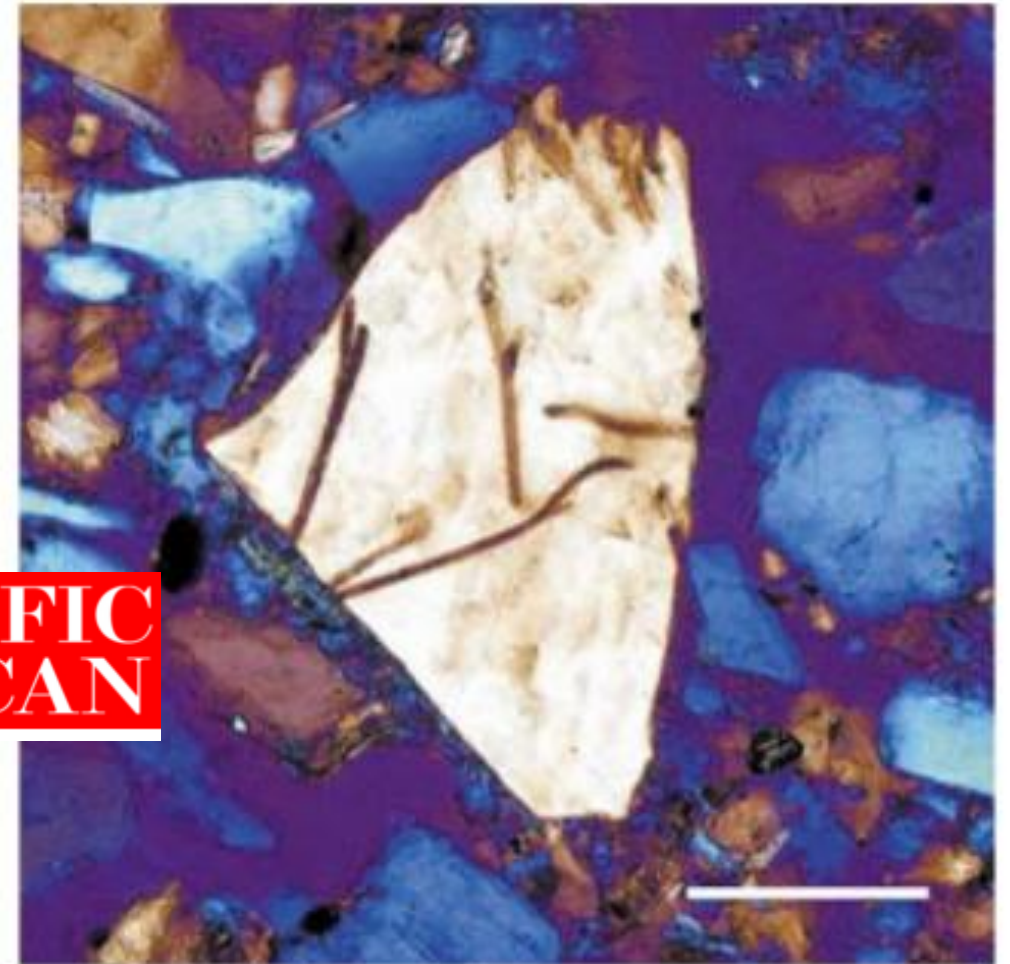
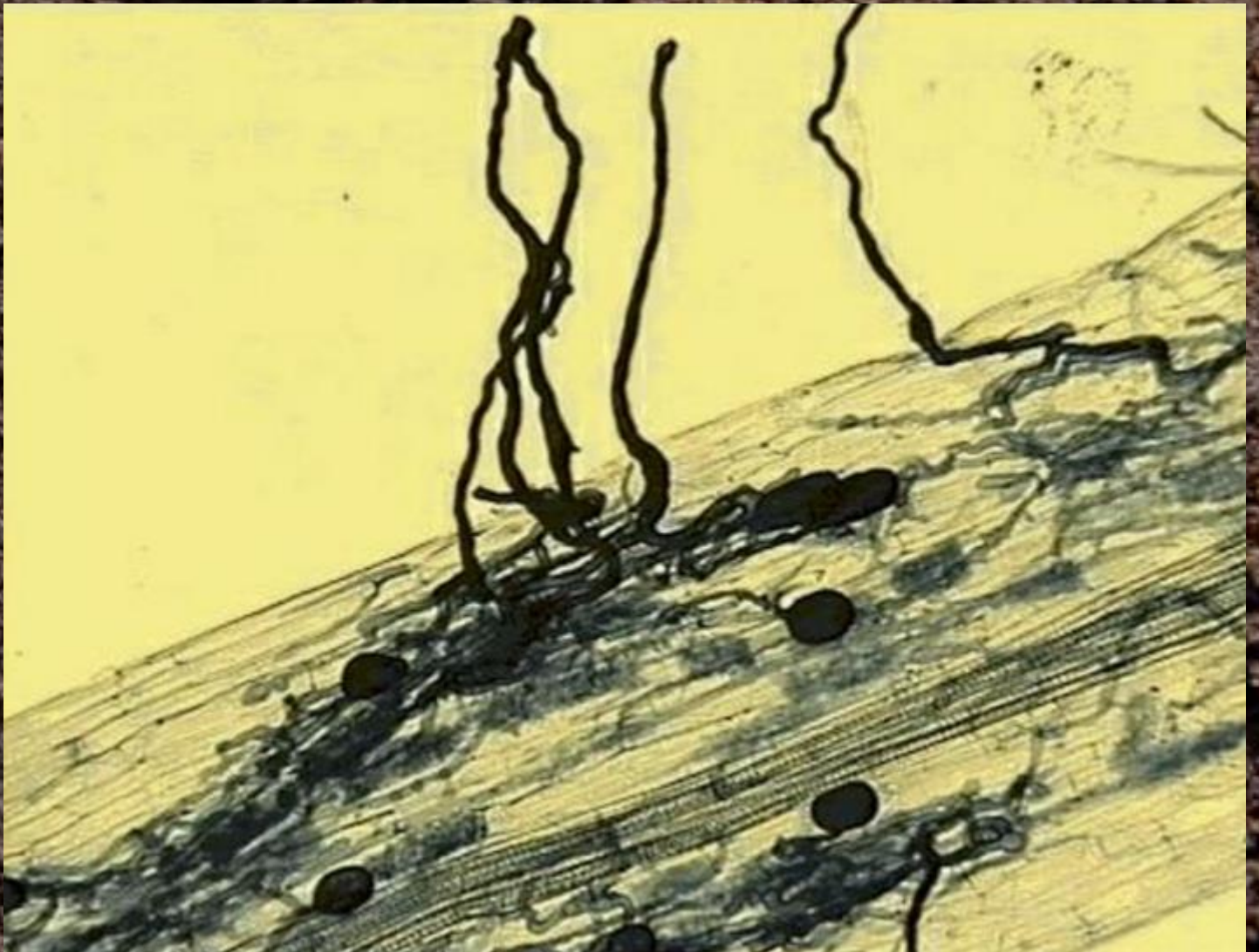


Image: Landeveert 2001

Thin-section micrograph of a tunneled feldspar
Scale bar = 100 micrometers

Arbuscular Mycorrhizal Fungi



Mineral Resources

- Mycorrhizal fungi mine the soils not only for the basic nutrients like nitrogen, phosphorus, etc, but also those hard to come by trace elements (Zinc, Copper, Manganese, etc) which plants need for strong immune system health and survival.... Oddly enough many soils are rich in important nutrients, but they are often locked up in a physical form which makes them unavailable to most plants.

(Source: Scientific American - Jennifer Frazer)

infrastructure

noun | in·fra·struc·ture | \ˈin-frə-ˌstrək-chər, -(.)frä-ˌ\

Simple Definition of INFRASTRUCTURE

Popularity: Top 20% of words

: the basic equipment and structures (such as roads and bridges) that are needed for a country, region, or organization to function properly

- **Transportation**
- **Communication**
- **Economies will be severely crippled or limited when these are lacking or disrupted (war strategies)**

infrastructure

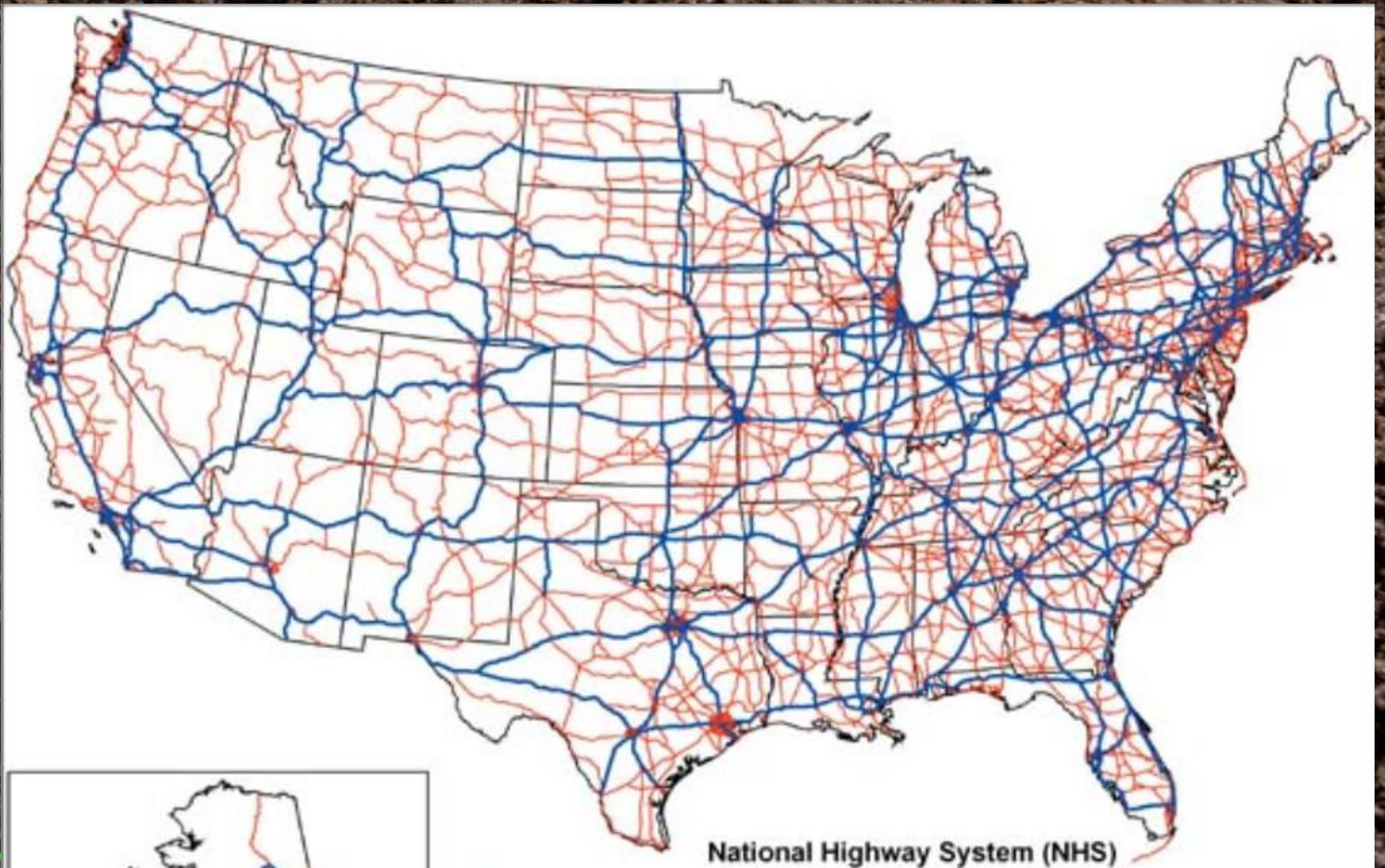




Infrastructure

Carbonomics\$ – The Wonderful Economy of the Soil

Keys To A Healthy **SOIL!**



National Highway System (NHS)

Carb

**NON-MYCORRHIZAL
ROOTS**



**ROOTS WITH
MYCORRHIZAL FUNGI**



Mycorrhizal fungi transports:

- Phosphorus – one of the hardest to access
- Nitrogen, Potassium, Calcium, Magnesium, Iron
- Zinc, Boron, Manganese and Copper.
- In dry times they help transport and supply water.



Transportation Infrastructure

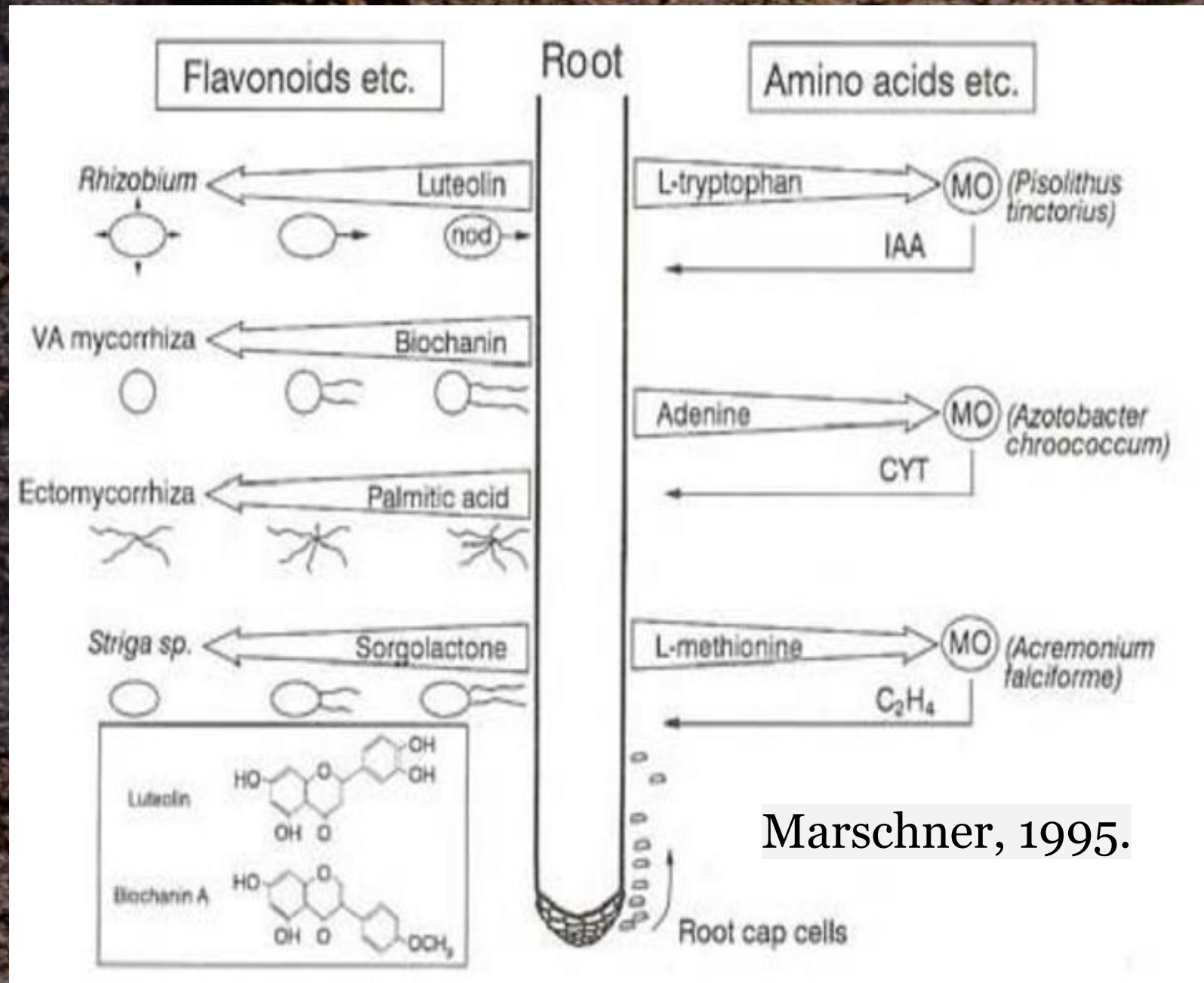
Earth worms
help transport:

- Water
- Oxygen
- Surface carbon (residue)
- Other biota



Communication Infrastructure

Plants use liquid carbon root exudates to communicate to soil biota what they need



Marschner, 1995.

Communication Infrastructure

Plants use liquid carbon root exudates to communicate to soil biota what they need

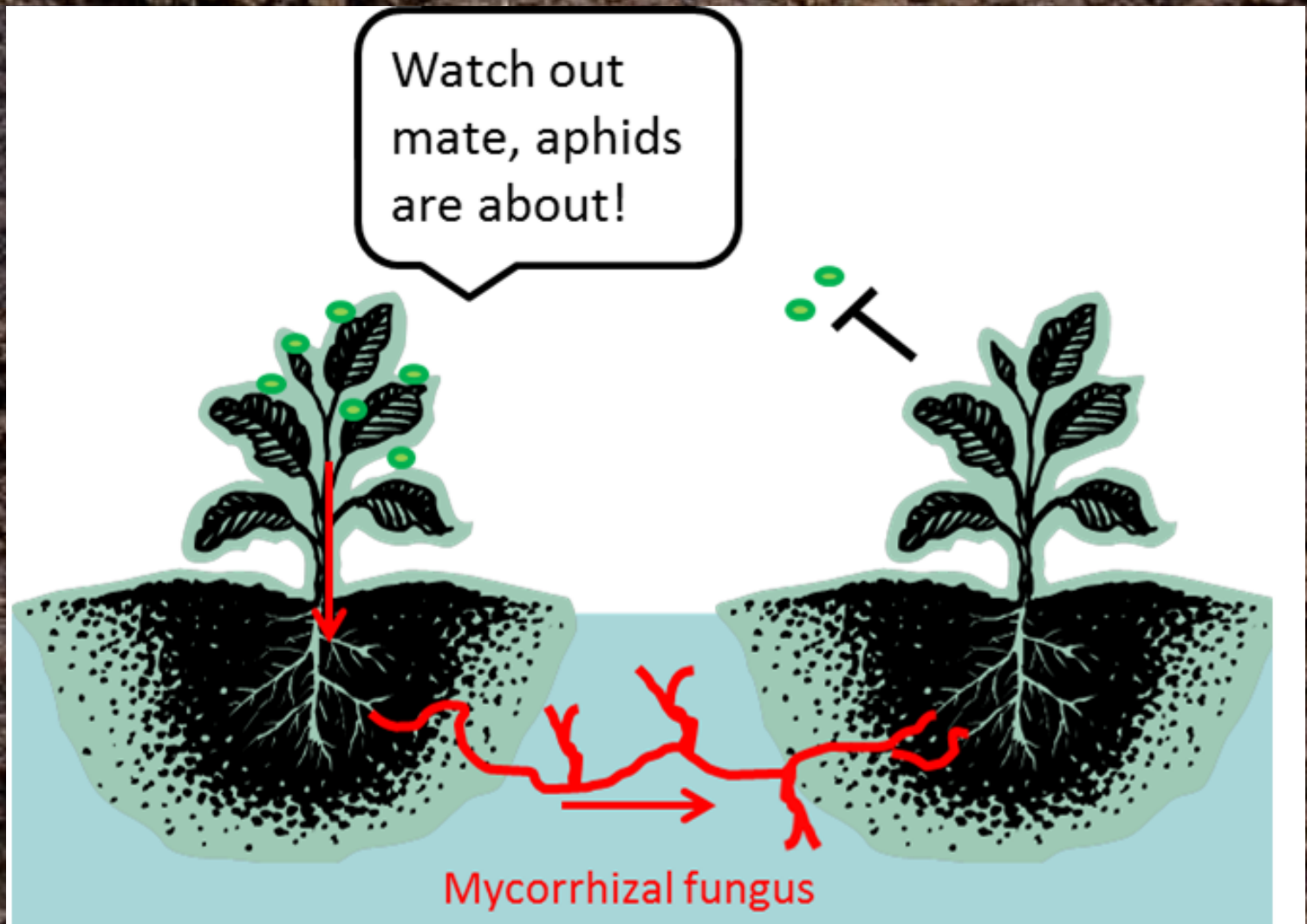


Carbon Compounds

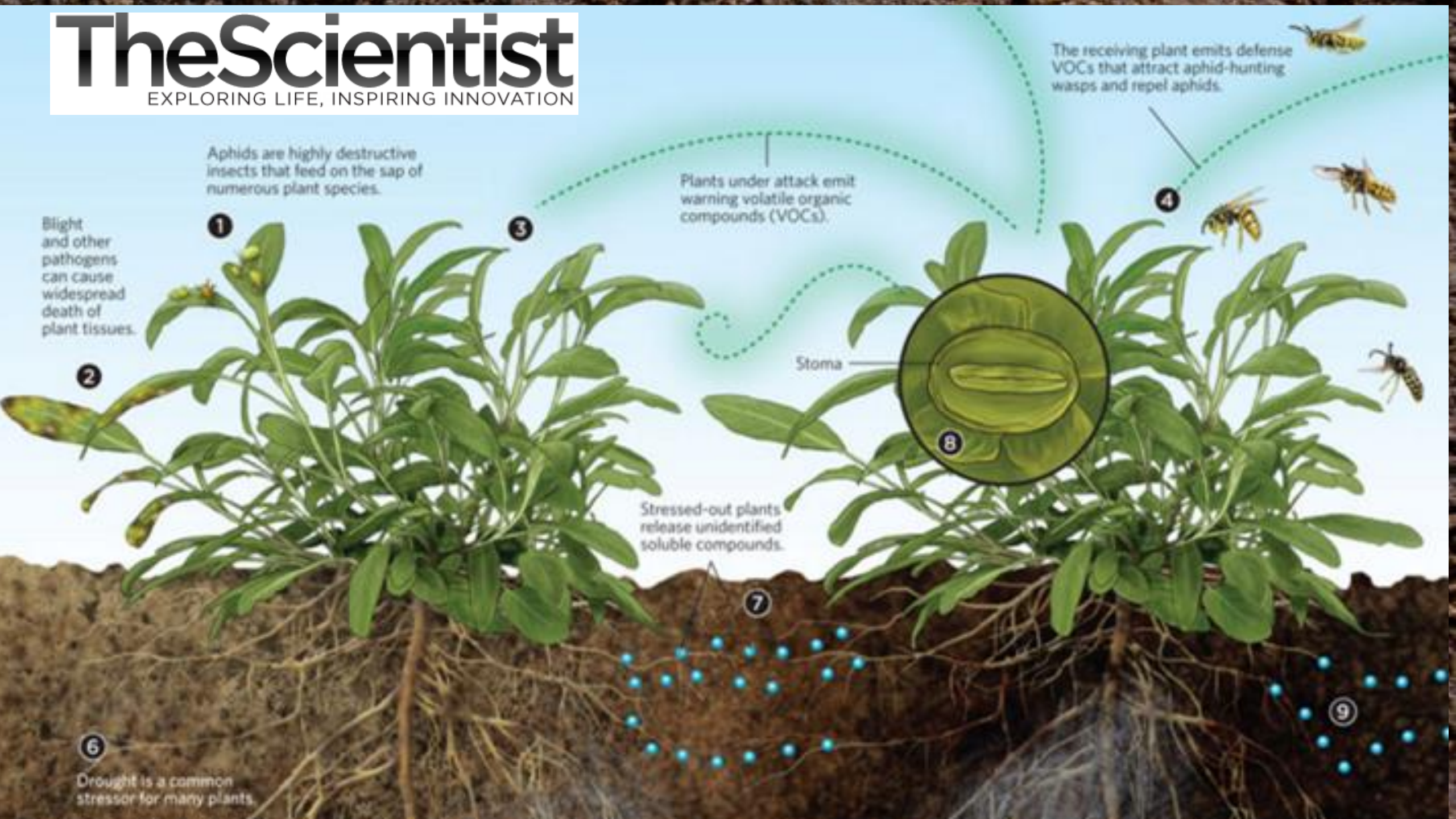
- Carbohydrates
- Sugars
- Proteins
- Fats
- Lipids
- Oils

Communication Infrastructure

Mycorrhizal networks interconnect root systems and allow plants to communicate threats through chemical signaling



When aphids infect the plant on the left a signal travels to through the mycorrhizal network warning other (uninfected) plants that aphids are nearby. This induces defence responses that include the production of methyl salicylate, which repels the aphids and attracts the parasitoid wasp (an aphid predator).



Defense and Protection

The plant/soil economy needs protected from:

- Water (too much or too little)
- Wind
- Heat
- Cold
- Compaction
- Weeds
- Insects
- Diseases



Defense and Protection

The first line of defense is soil armor (cover)

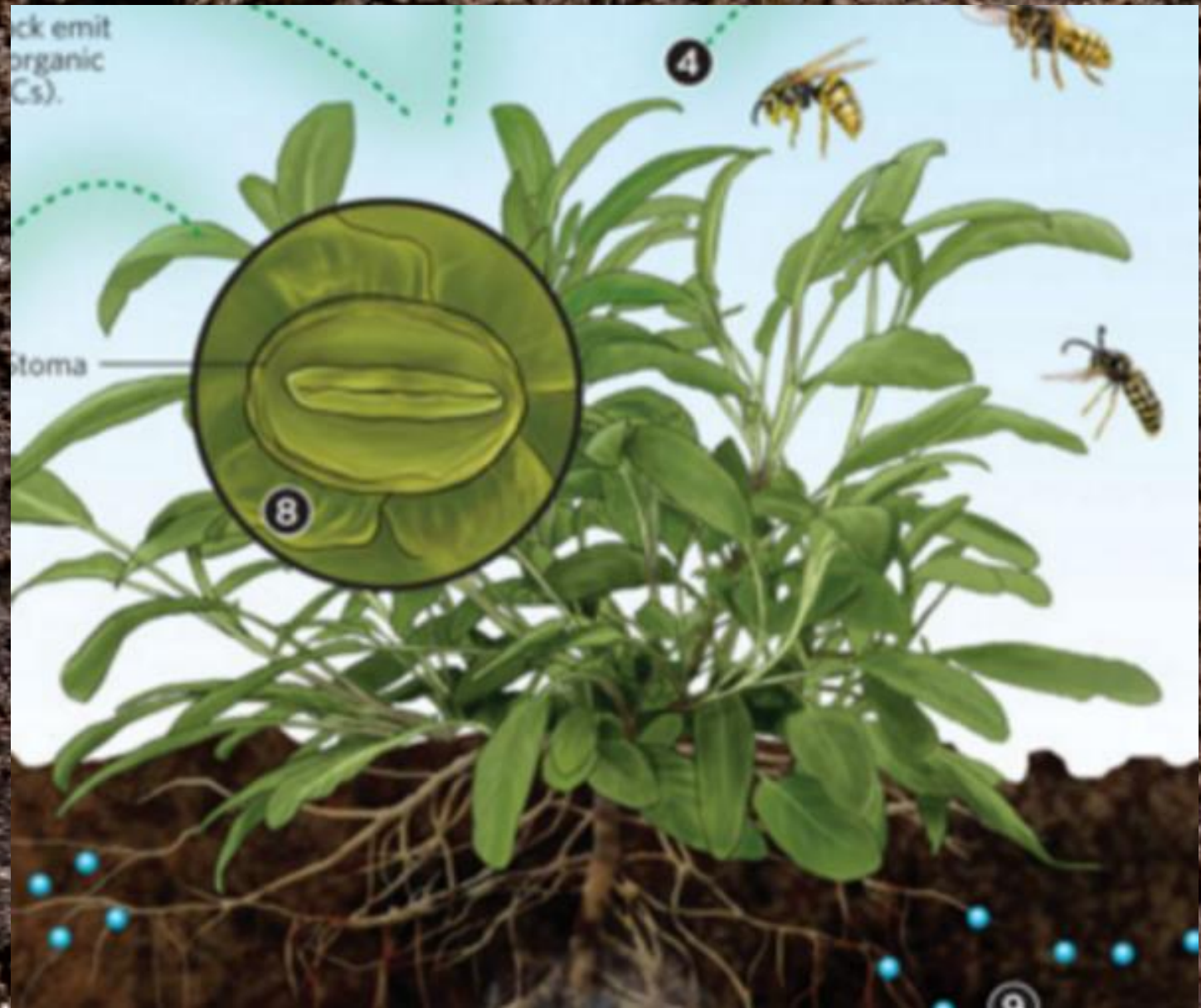
Almost all advantages of the No-tillage system come from the permanent cover of the soil, and only few from not tilling the soil.

We should always aim at full soil cover.

Rolf Derpsch

Defense and Protection

The second line of defense is plant signaling - plants signaling each other and signaling insects and soil organisms to assist in defense



Defense and Protection



*This Rock Cress plant infected with the pathogen *Pseudomonas syringae* shows typical yellowing and disease symptoms.*

Photo by Thimmaraju Rudrappa

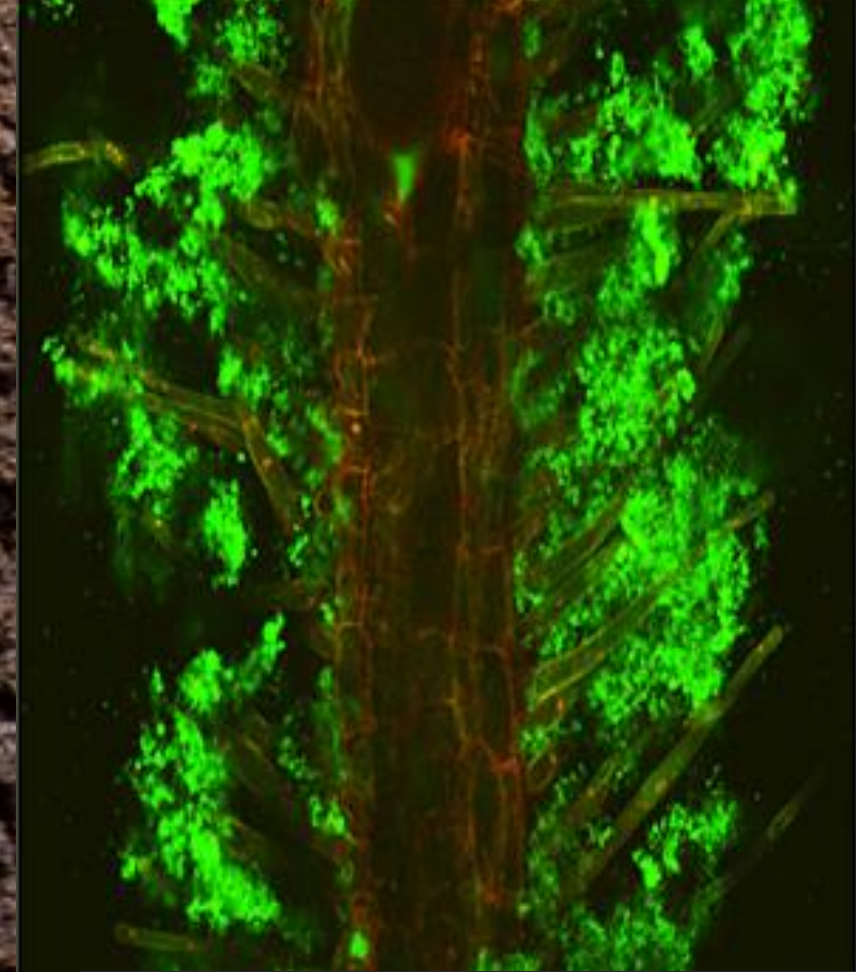


*This plant's roots were treated with the beneficial bacterium *Bacillus subtilis*.*

Photo by Thimmaraju Rudrappa



UNIVERSITY *of* DELAWARE



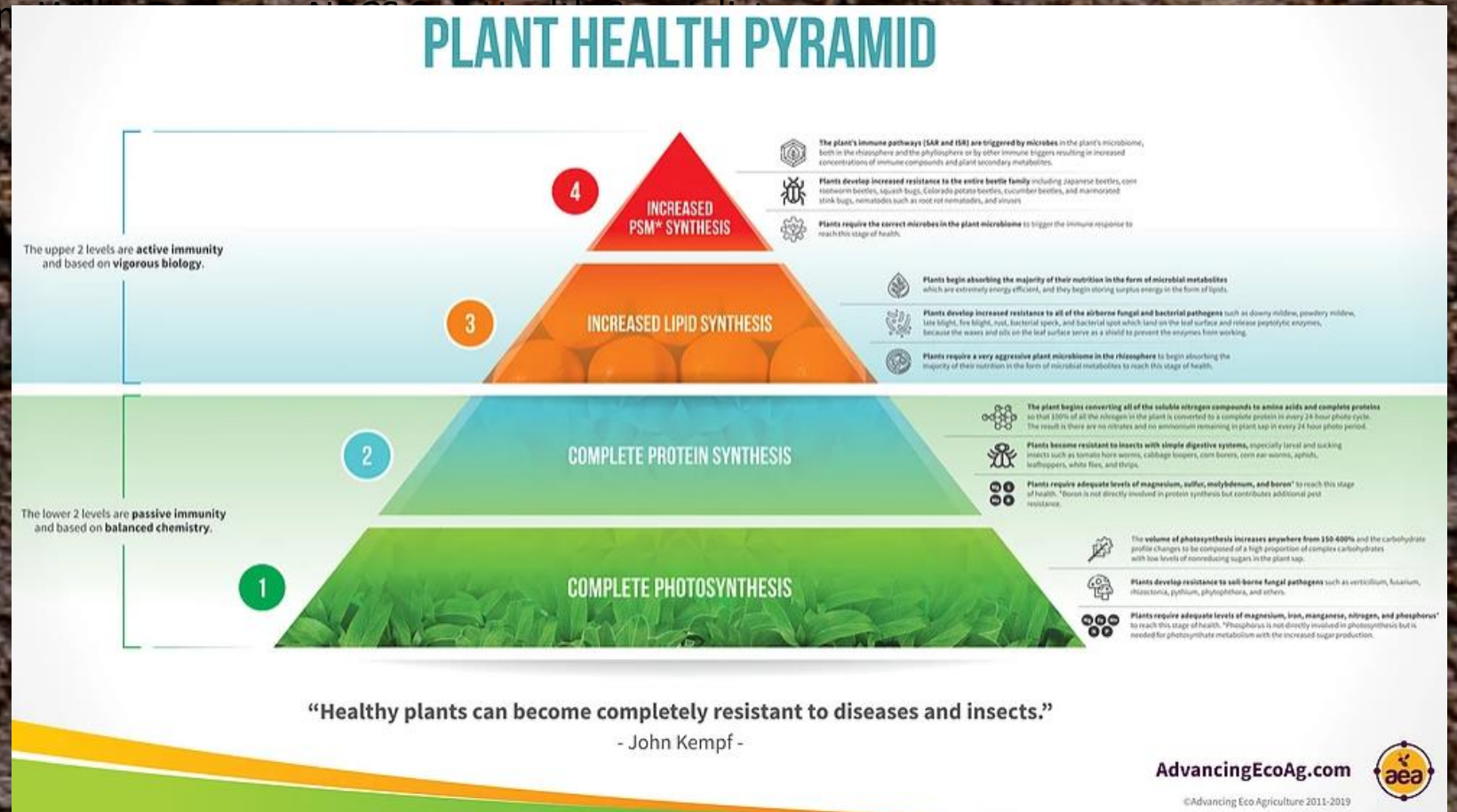
*The green represents the beneficial bacterium *Bacillus subtilis*, which has formed a biofilm on the Rock Cress root surface.*

Photo by Thimmaraju Rudrappa

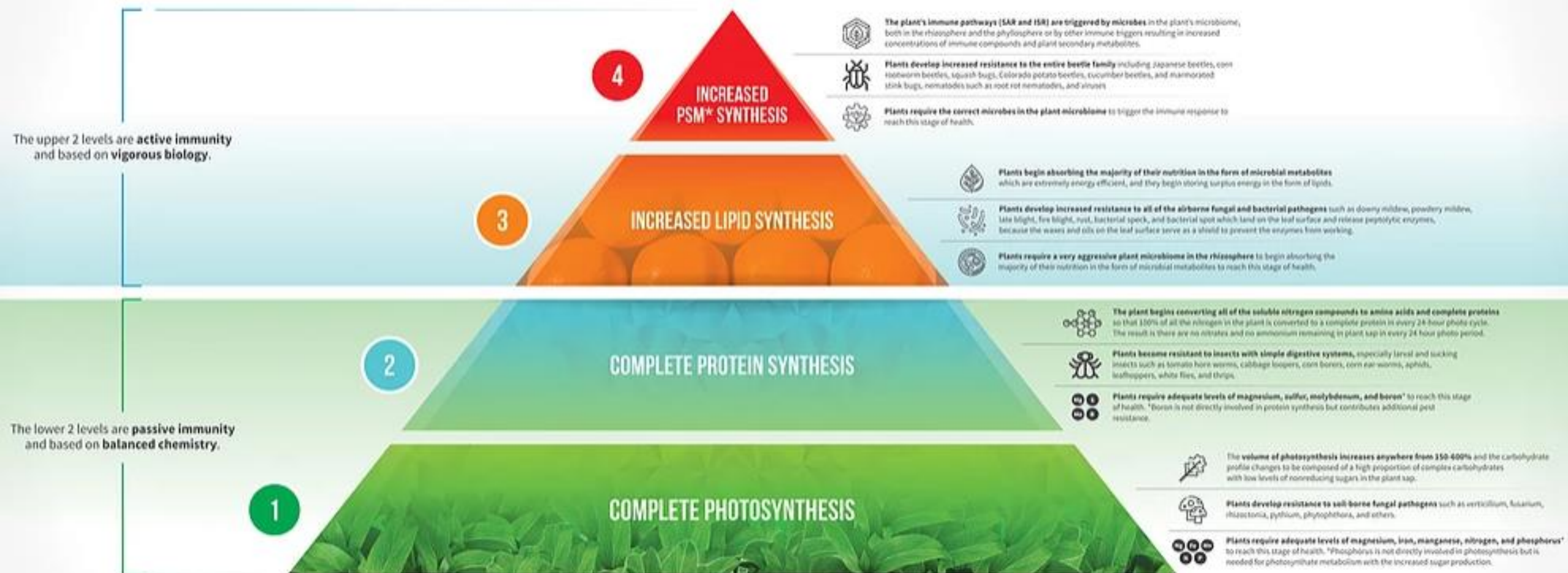
Defense and Protection

The third line of defense is healthy plants producing complex compounds which give natural resistance

From



PLANT HEALTH PYRAMID

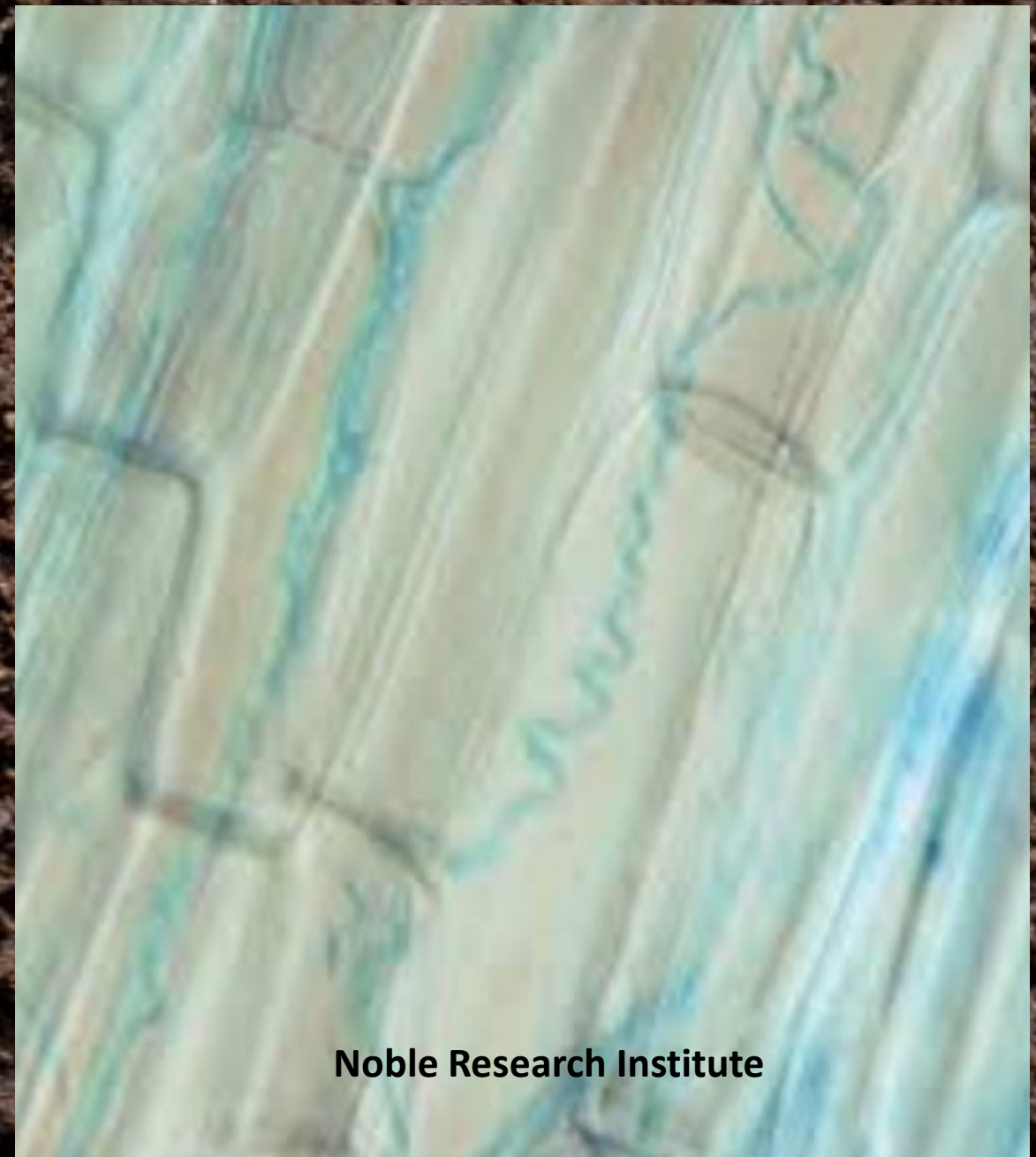


“Healthy plants can become completely resistant to diseases and insects.”

- John Kempf -

Defense and Protection

The fourth line of defense is symbiotic relationships between plants and organisms such as endophyte fungus



Noble Research Institute

Defense and Protection

- The fifth line of defense is Diversity - of plants, roots, types, seasons, insects, biota
- Most attackers will focus on only one or two things



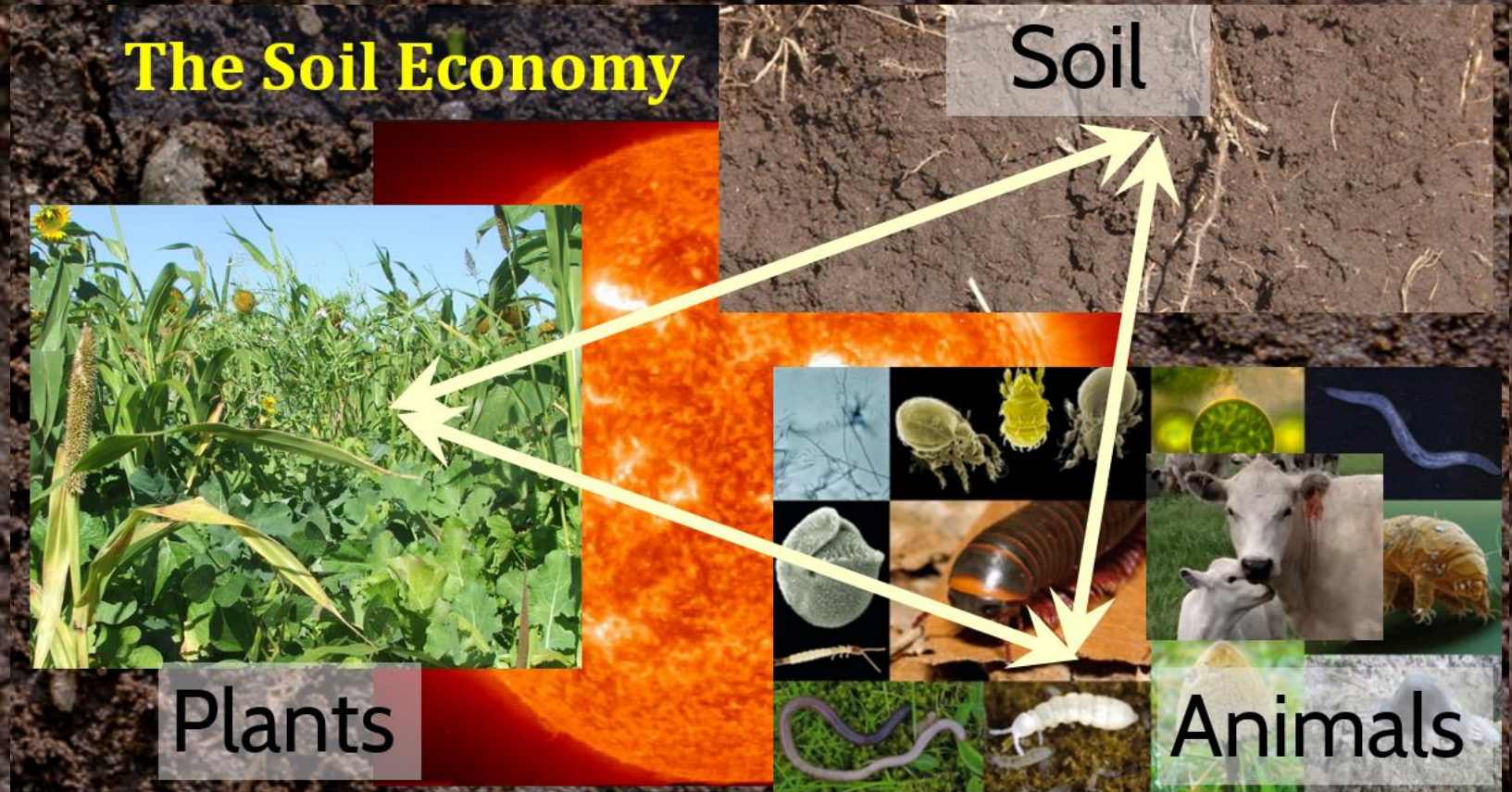
Keys To A Healthy SOIL!

- Supply (Producers/Sellers)
- Demand (Consumers/Buyers)
- Currency
- Capital
- Energy and Resources
- Infrastructure
- Defense and Protection



Eight Take-Away Points

1. Economies are intricately interconnected and interdependent



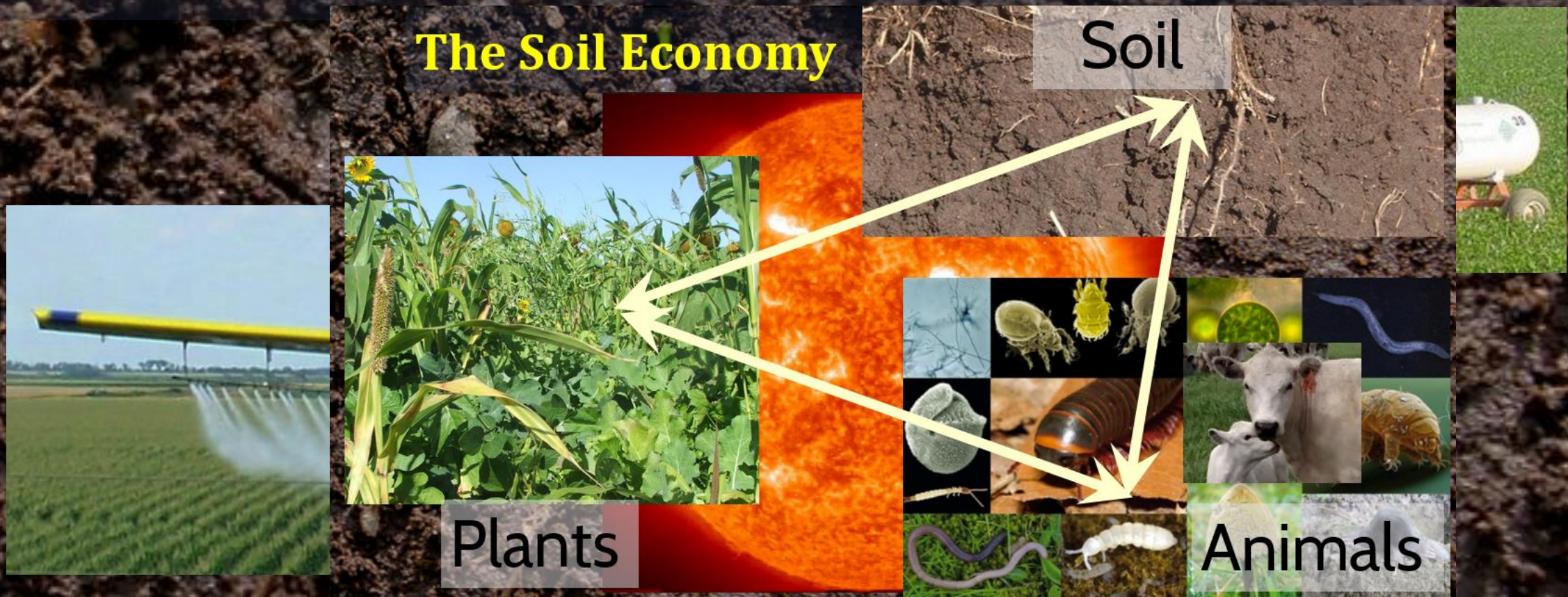
Eight Take-Away Points

2. Reduce the amount of welfare you are giving your economy - get everyone working!



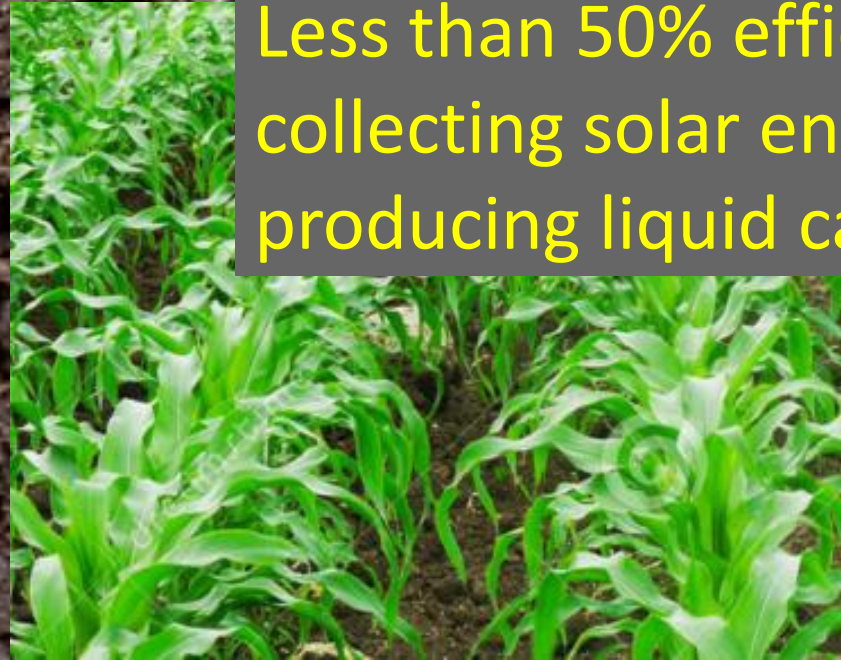
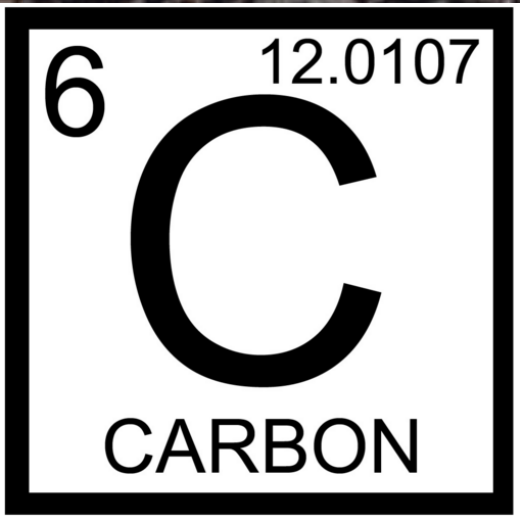
Eight Take-Away Points

2. Reduce the amount of welfare you are giving your economy - get everyone working!

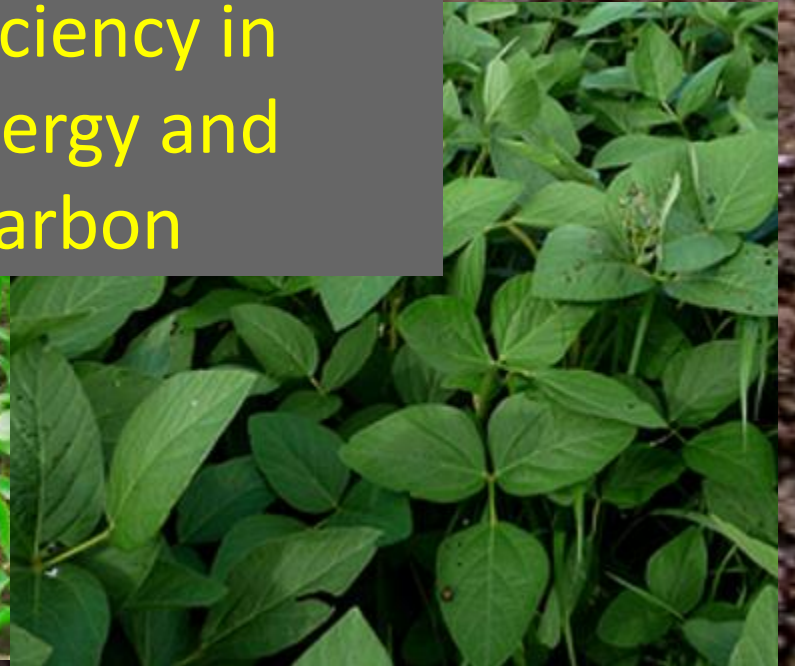


Eight Take-Away Points

3. Increase your “cash flow” of carbon currency

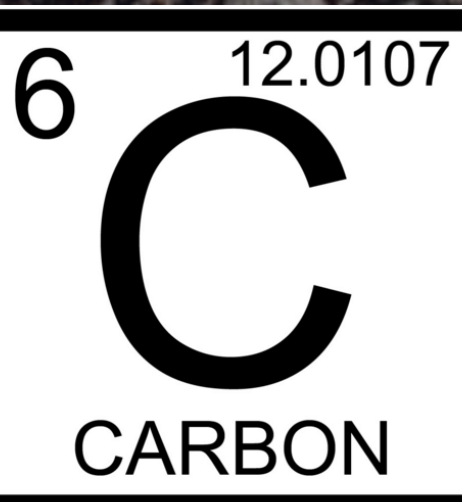


Less than 50% efficiency in collecting solar energy and producing liquid carbon



Eight Take-Away Points

3. Increase your “cash flow” of carbon currency



Less than 50% efficiency in collecting solar energy and producing liquid carbon



Eight Take-Away Points

4. Make capital investments of long term carbon (organic matter) and don't sell off investments



Eight Take-Away Points

4. Make capital investments of long term carbon (organic matter) and don't sell off investments



Keys To A Healthy **SOIL!**

Eight Take-Away Points

5. Take advantage of free tiny workers

- Manufacturing
- Mining
- Transportation
- Communication
- Protection

Biological Diversity



Eight Take-Away Points

6. Build and do not destroy infrastructure - you will really see your economy grow!



Eight Take-Away Points

6. Build and do not destroy infrastructure - you will really see your economy grow!



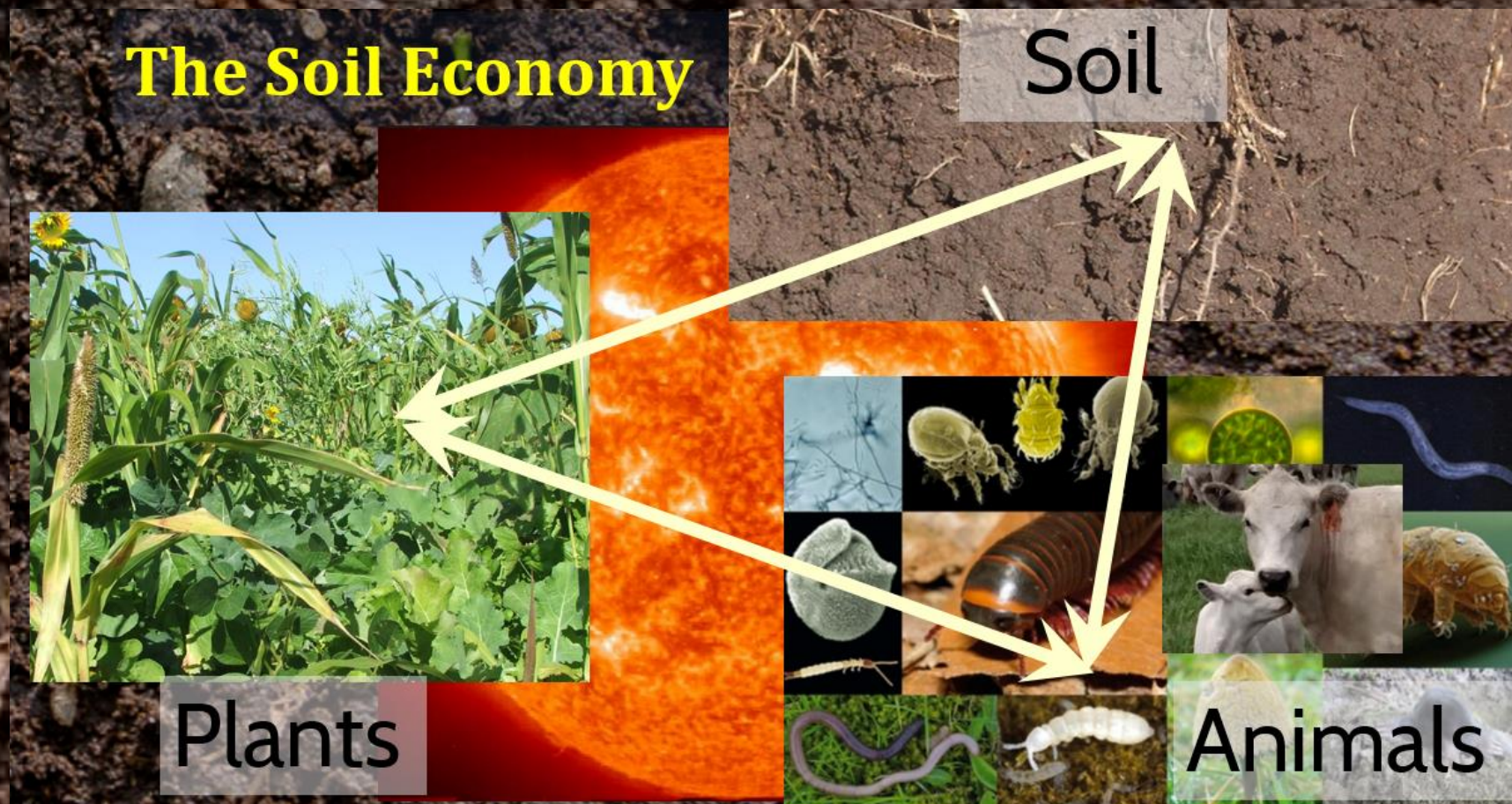
Eight Take-Away Points

7. Protect your economy with soil armor



Eight Take-Away Points

8. Diversity is so very important for a healthy economy - plants, roots, and soil animals





Carbonomic\$ – The Wonderful Economy of the Soil



GREENCOVER

COVER CROPS SEED FORAGES

Soil Health Education & Resource Guide 5th Edition

Email: keith@greencoverseed.com



Featuring articles by

Gabe Brown, Rolf Derpsch, Dwayne Beck, Jay Fuhrer, Allen Williams, Ray Archuleta, Christine Jones, Wendy Taheri, Jonathan Lundgren, Dale Strickler, and more

Table of Contents

2	Purpose Of This Guide
3	Our Mission, Values, and History
4	Ten Years of Soil Health
5	Introduction to Regenerative Agriculture
6-10	Principles of Soil Health
11	Why Cover Crop?
12-13	Ecosystem Services from Living Plants
14-24	Soil Health in Practice
14	<i>Poly Cropping with Multiple Cash Crops</i>
15	<i>Cereals Back in the Rotation</i>
16	<i>Spring Green Manure</i>
16	<i>Cover Cropping After Hail Damage</i>
17	<i>Summer Fallow Replacement Cover Crops</i>
18	<i>Annual Seedings</i>
25	<i>Interseeding into Cool Season Perennials</i>
26	<i>Interseeding into Warm Season Perennials</i>
27	<i>Wildlife</i>
28	<i>Rental of Cover Crop Forages</i>
28	<i>Milpa Gardens</i>
29	Quorum Sensing in the Soil Microbiome
30-31	Nitrogen: The Double-Edged Sword
32-33	Soil Biology
34-35	SmartMix Calculator
36-39	Livestock and Grazing
40-41	Insects and Pollinators
42-43	Legumes
44-47	Grasses
48-49	Brassicas
50-51	Other Broadleaves
52-53	Perennials
54-56	Cover Crop Mixes
57	Cover Crops and Resistant Weeds
58	Herbicide Carryover
59	Cover Crops and Moisture Use
60-63	Green Cover Seed: Built to Serve You
60	<i>The Crew</i>
61	<i>Shipping</i>
63	<i>Facilities</i>

See back cover for contact information

Cover photo by Sandy McDougall. Blooming in all of its glory, this part of a Green Cover Seed molluscicide mix. Assigned for Ecological Resilience

