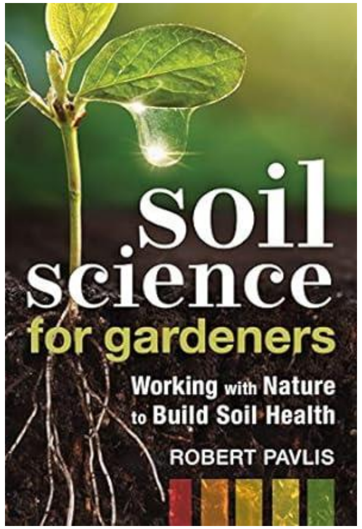
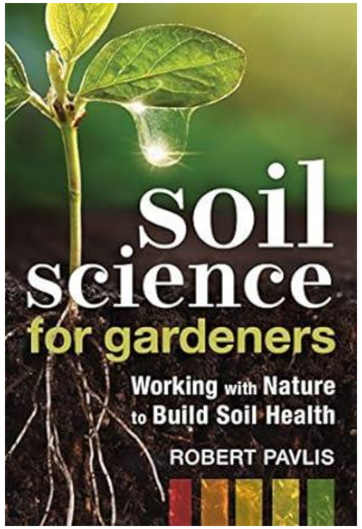
Soil Health, Naturally

INTRODUCTION



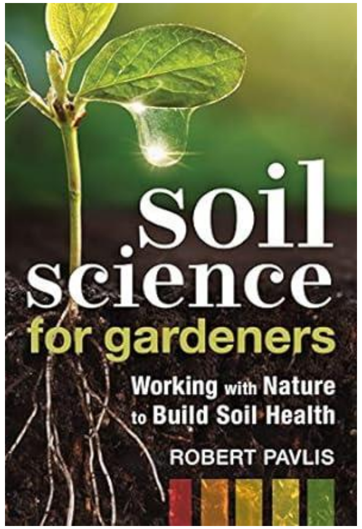
Understanding Soil Health for Plant Success



What's wrong with my plants, there are 4 problem areas:

Light
Water
Pest & Disease
Soil

In a pinch of soil there are billions of living organisms representing many thousands of different species. They are growing, breathing, and reproducing. Some attack plants while others form partnerships
and defend.
Roamers case the soil and collect nutrients and deliver them to the plant roots, spoon feeding the plants. All this mysterious activity can not be see by the naked eye. The numbers are vast and the microbe societies are very complex.



What's wrong with my plants, there are 4 problem areas:

Growing plants is easy if you understand the soil below. It acts as an anchor, feeds them and provides air and water. If you create a healthy soil you can grow anything suitable to the climate.

The goals lined out in this book are:

1. The role soil plays
2. Understanding what goes on in the soil and how if effects the plants

Defining Soil Health depends on what eco-entity is your focus. For example:

A farmer would define soil by yield production
A climate scientist might define by how much sequestered carbon is in the soil
A microbiologist by microbial populations and diversity

This book will defines a healthy soil as:

- One that grows a wide range of plants
- Has good aggregation and supports a
- Has a high number of diverse microbes

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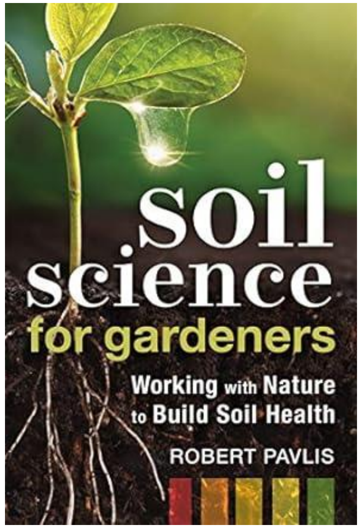


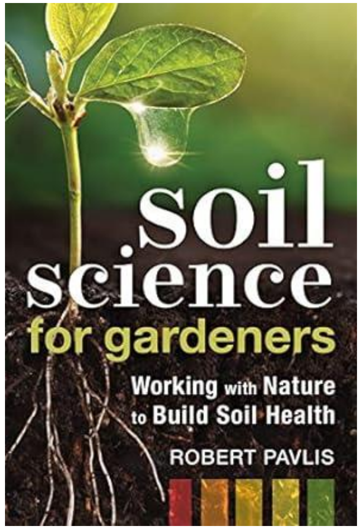
Terminology

Organic is used too frequently to mean several different things leading to all kinds of misunderstandings. This book will use the chemist's definition of organic and the term certified organic when referring to organic agriculture.

Organic soil definition by trade:
Gardner's-soil that has been treated organically following certain organic certification rules
Soil Scientists-soil created by layering of plant material instead of the degradation of rocks. Typically contains more than 20% organic matter, and peat bogs and marshes are a prime example. This book uses the Soil Science definition as a basis.

Fertilizer-Any material added to the soil with the primary purpose of supplying at least ONE plant nutrient.

Synthetic fertilizers are referred to as man made.
Organic fertilizers are from natural products



Soil Amendments

Soil amendments are added to the soil with the purpose to change the physical properties water retention, permeability, drainage and pH changes.
Some amendments have a duel purpose, changing both physical and nutrients such as compost it provides nutrients and changes the physical properties.

Organic Matter

Organisms in the soil are classified as flora(plants) and fauna(animals). Organic matter refers to dead material such as wood chips and manure or highly decomposed such as compost or humus.

Microbes

On the top tier these microorganisms are easy to separate and they decrease in size the differences between plant and animal is muddied because some have characteristics of both.
This book references these organisms as microbe and microorganisms.

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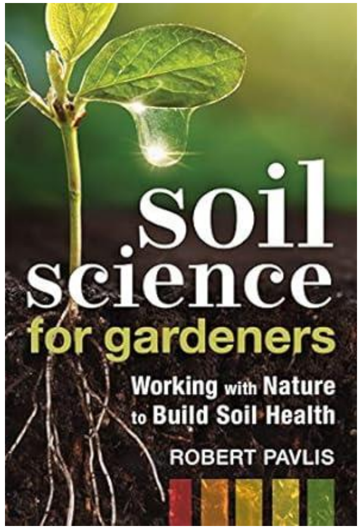
Chapter 1 Soil Basics



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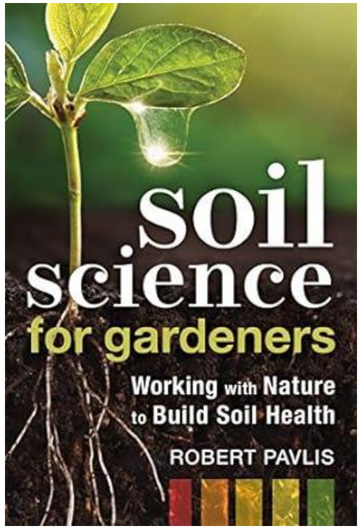

Defining soil is difficult

According to the Soil Science Academy of America

"Soil is the top layer of the Earth's surface that generally consists of loose rock and mineral particles mixed with dead organic matter." One thing to note, this definition does NOT include

the many different organisms that live in the soil.

MYTH- Soil is alive

Soil is NOT alive, it does not eat or breathe. When referring to a "living soil" they are actually referring to a Soil Ecosystem that consist of soil and all the living organisms in and on it.

It has life and supports life and has life in it BUT even it is not alive.

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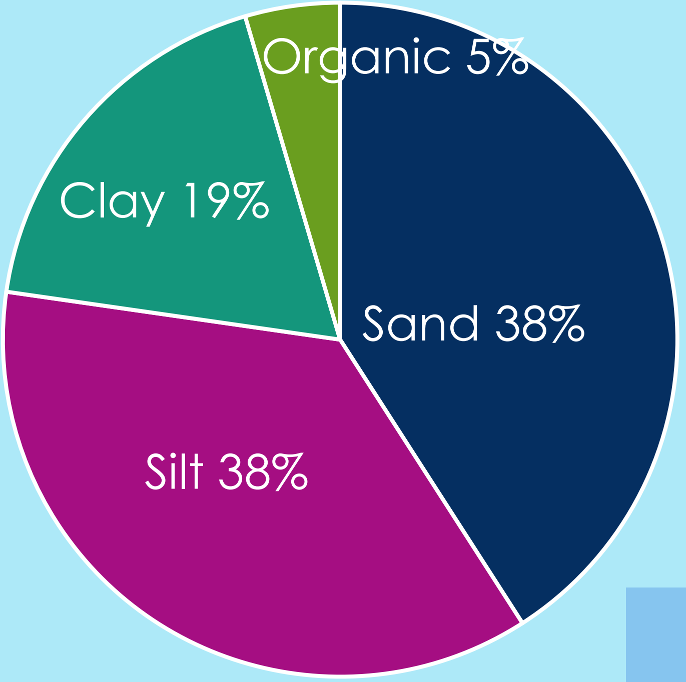
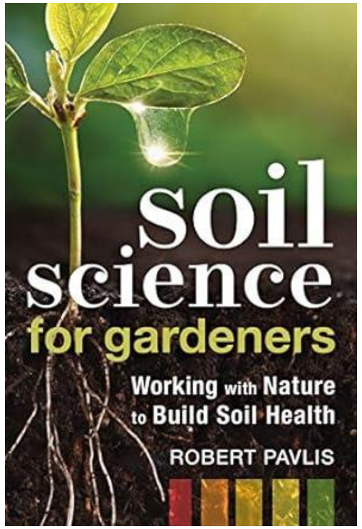
Ideal Soil/Composition



Components of ideal soil



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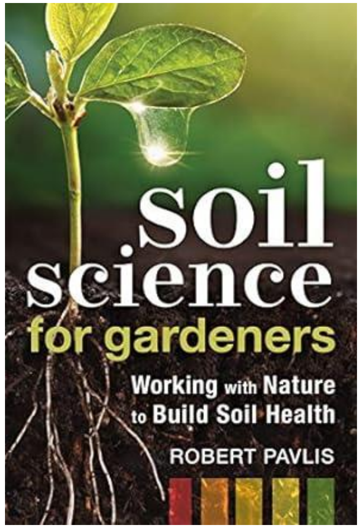
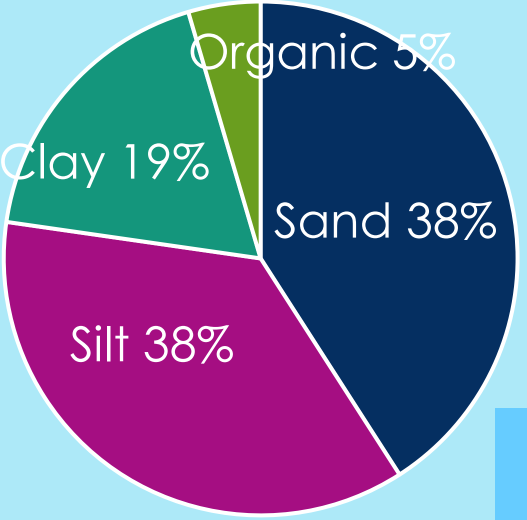


Ideal Soil



Although, the OM is only 5% it is extremely important for providing soil it's physical and chemical characteristics.
It is rare to have soil with these ratios, and impractical to convert soil to these ratios. Many plants are adaptable and grow in a variety of soil composition.
With the largest majority of the soil being sand, silt and clay it is by large to vast to change. However, if you can change the OM percent and even by 1% it can have a significant effect.
When soil ratios deviate from ideal, the more issues you will have with your soil.

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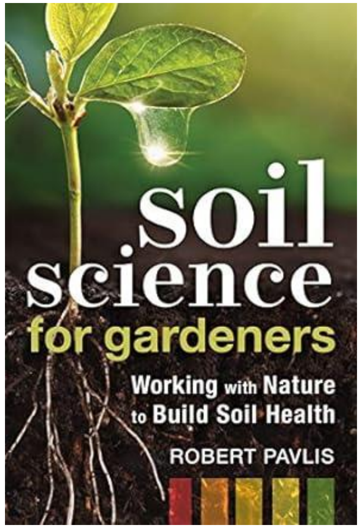


Soil Origin

Soil starts as large rock formations. Over time, broken into smaller and smaller pieces through the action of three types of weathering

PHYSICAL

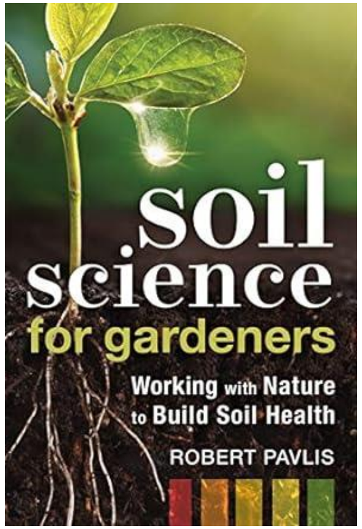
Physical factors such as wind, rain, snow, and temperature with the freeze and thaw cycle starts the erosion process allowing colonization develop.

CHEMICAL

Reactions with atmospheric gasses like oxygen, carbon and sulfur starts the rock decaying cycle that forms a thin organic layer over the rocks.

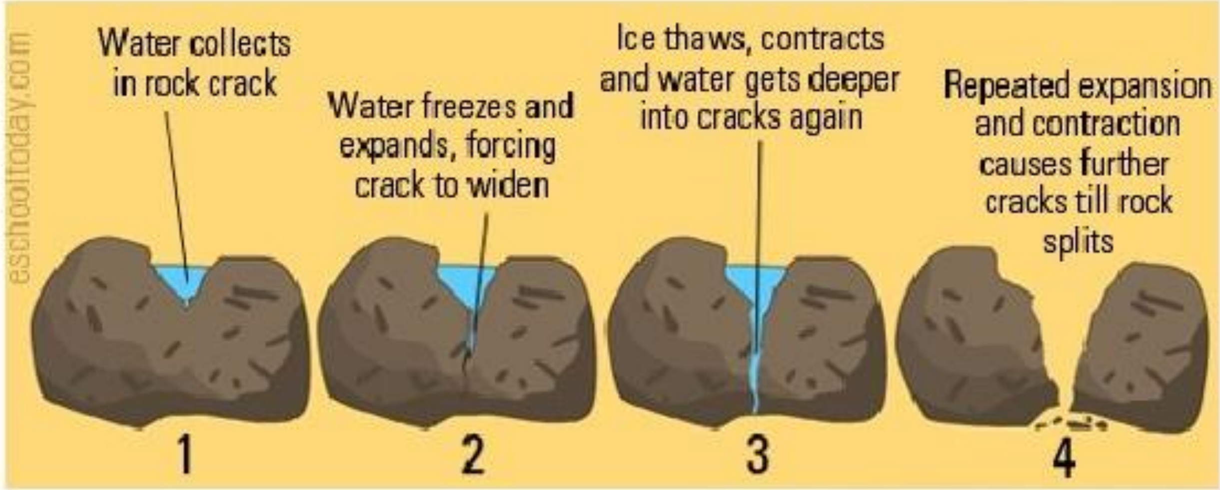
BIOLOGICAL

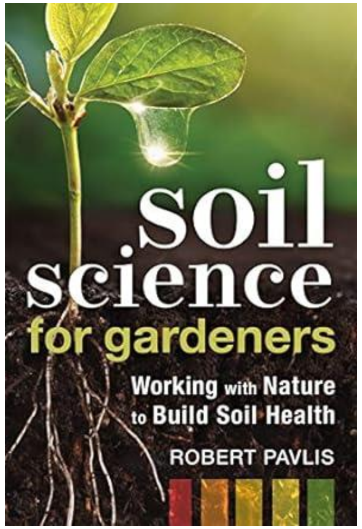
From the parent rock material, by the interaction of climate and soil vegetation begin forming. After thousands of years what once started as rock has converted into different types of soils.



Physical Weathering

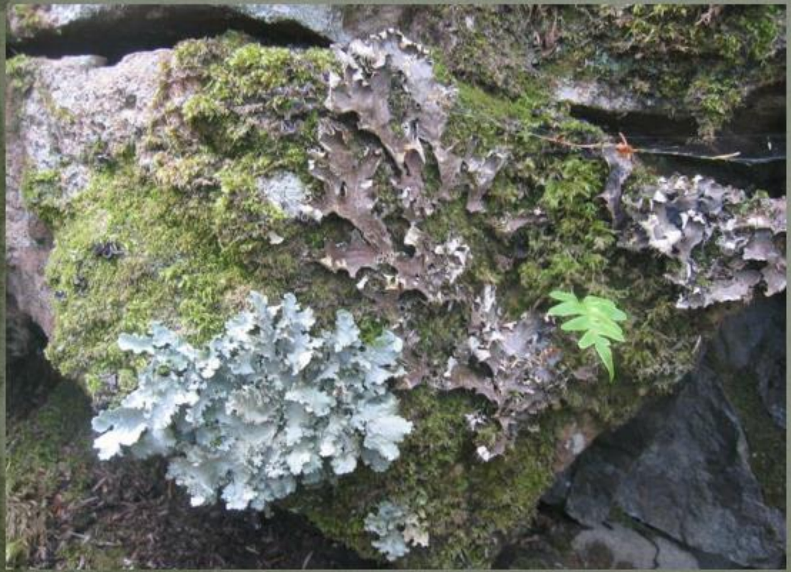
The process that breaks down rock into smaller pieces.





Chemical Weathering types

- Living Organisms
  - Plants that grow on or in rocks produce a weak acid that chemically break down rock
    - Example: Lichens and mosses



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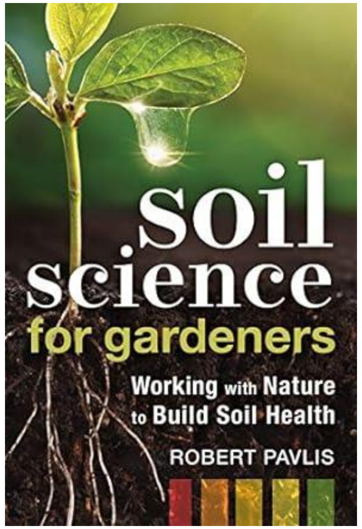
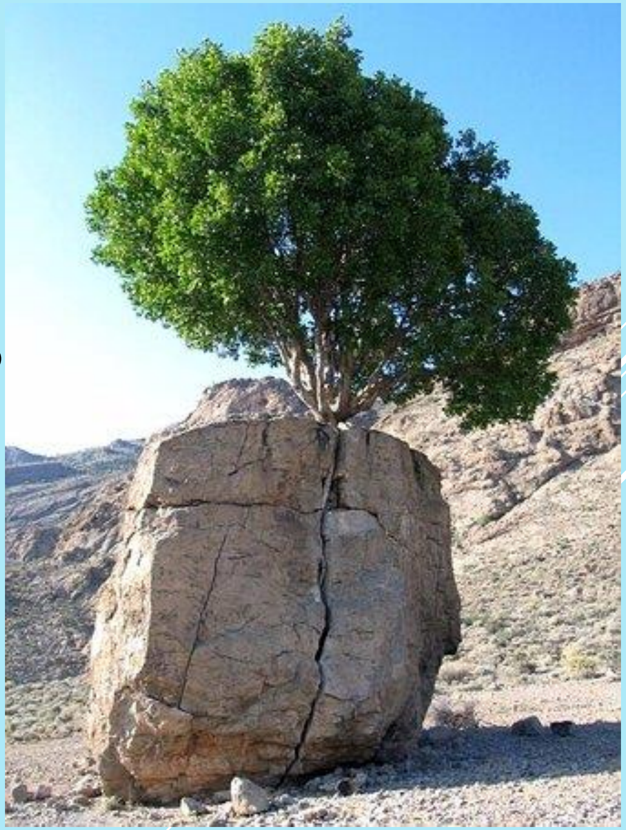


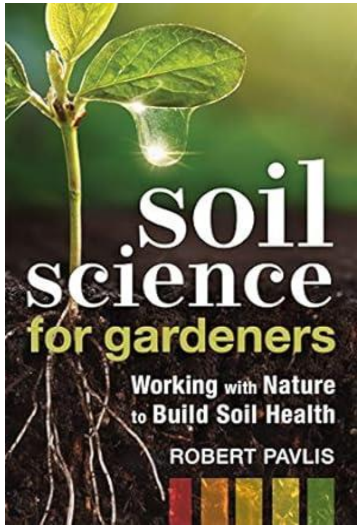
Animal Action
Burrowing animals e.g. rats, ants, snakes, dig out

Plant Action
Plant roots break up rocks when growing between rock joints

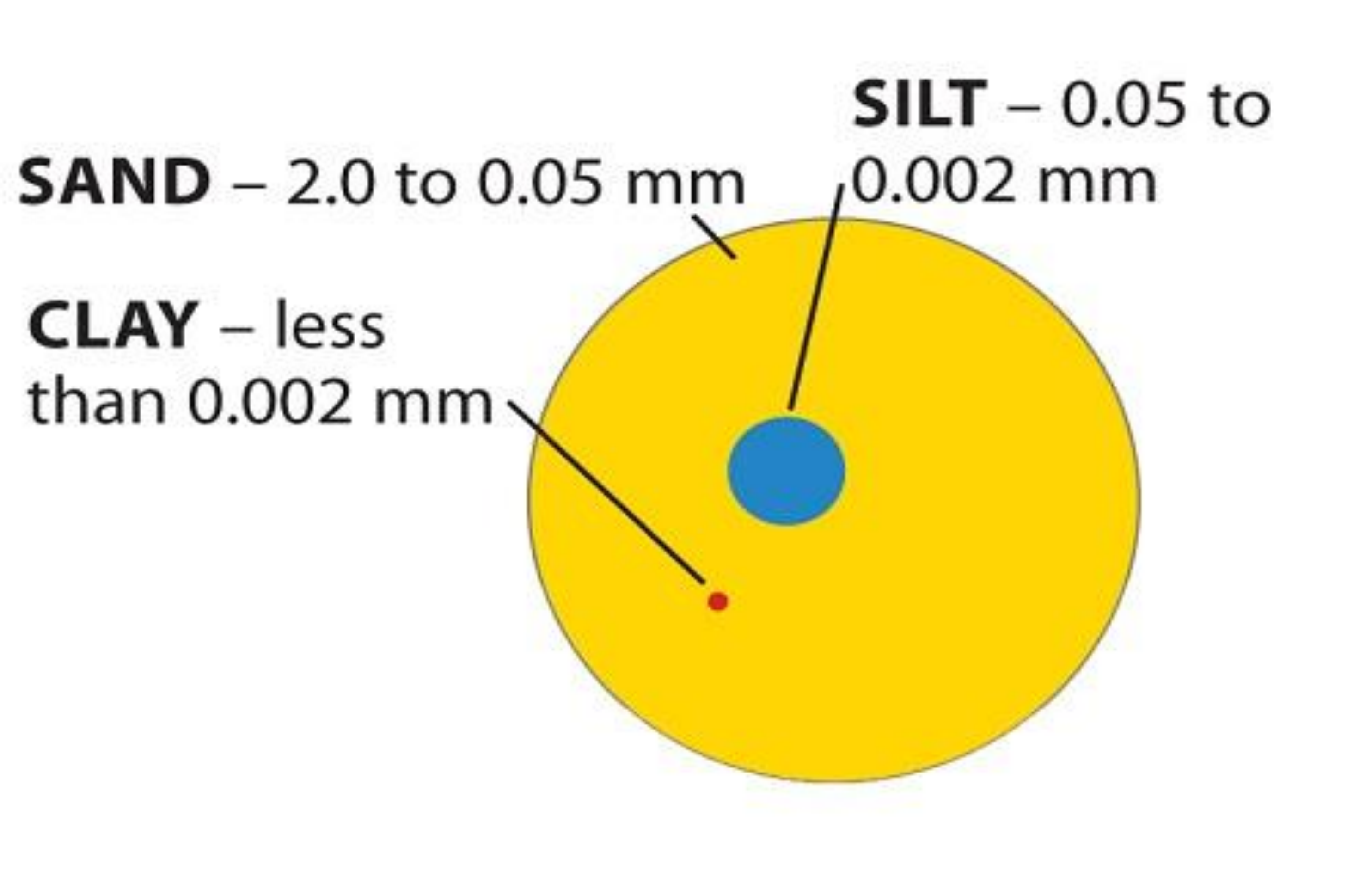


Human Action
Any type of construction, leads to rock breakdown

Granite, sandstone and shale result in acidic soil and limestone and basalt contain calcium and magnesium resultingin alkaline soil.



Soil Particle Size



Soil Types & Characteristics

SAND

- Dry, light soil and gritty, rough to the touch
- Has **larger soil particle size** and lots of air spaces
- Easy to work and good to work with
- Free draining, tends to lose nutrients easily
- Usually deficient in plant food and humus
- It is mostly acidic

SILT

- Medium in size
- Has **medium soil particles** and adequate air space
- Smooth and slippery, flour like texture
- Non-sticky
- Very often rich in humus and nutrients
- Medium drainage ability
- Medium water holding capacity

Soil Types & Characteristics

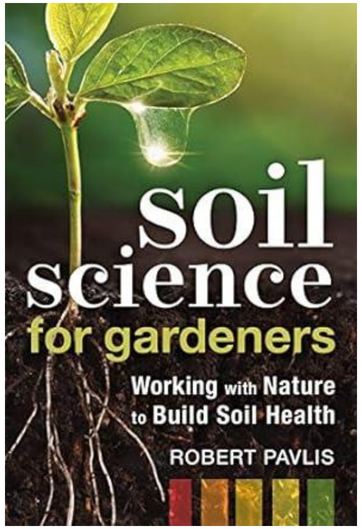
CLAY

- Heavy, sticky when moist, compacted, and hard when dry
- Has **smaller soil particles** and smaller air space
- Does not drain easily
- Difficult to work with when wet
- Very often deficient in humus but rich in nutrients
- Tends to be alkaline

  Great for growing plants that need a lot of water

LOAM

- Darker and rich in organic matter
- **Mixture of sandy, clay, and silt soil particles**
- Fairly easy to work
- Drought resistant because of water-holding capacity
- Ideal for growing crops and other plants
- Can hold up nutrients, making soil



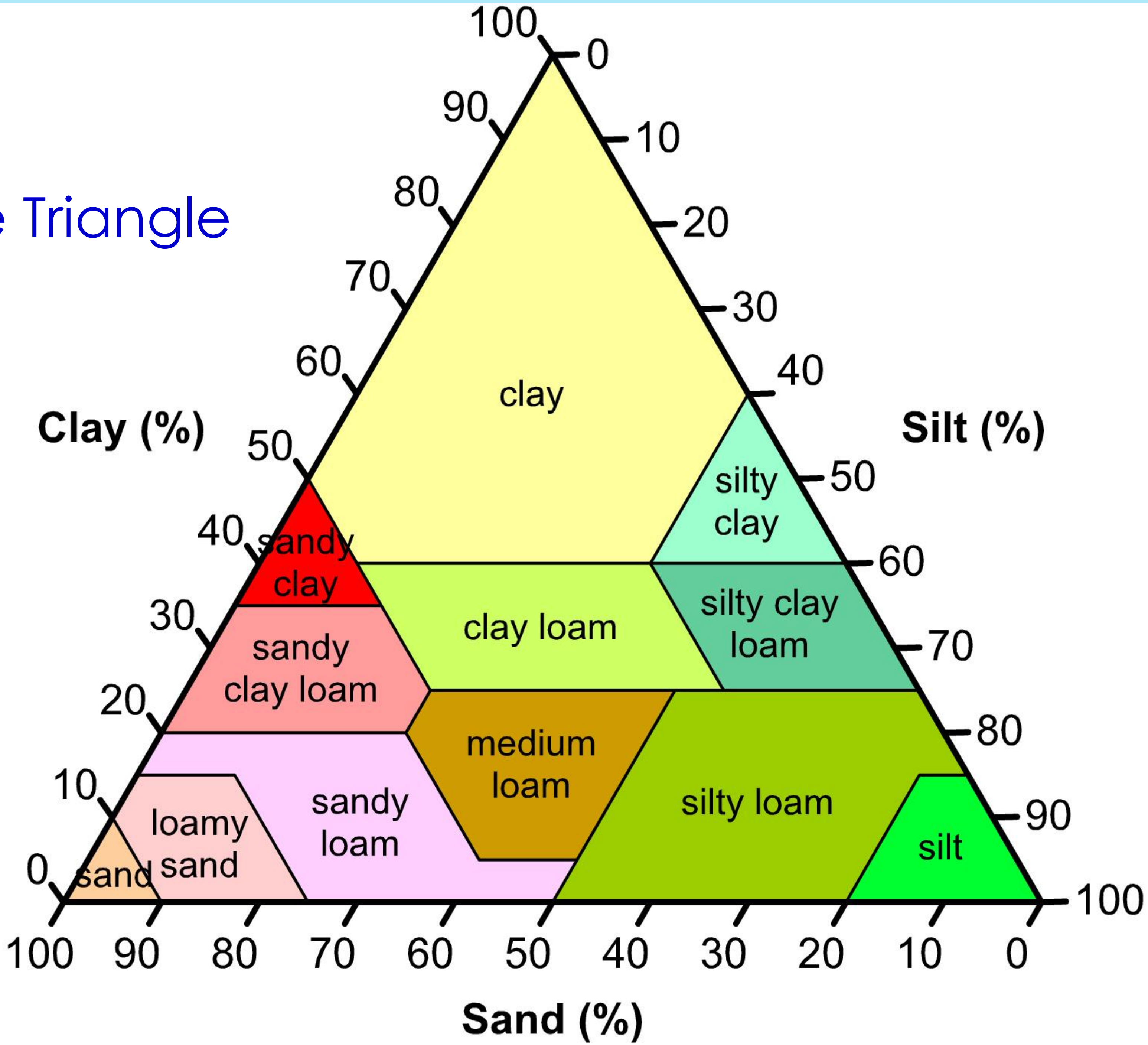
Soil Texture

Sand, silt and clay are particles that most often occur together. Scientist use the term soil texture to describe the ratio of sand, silt and clay in a given sample.

Ideal soil which is 38% sand, 38% silt, and 19% clay and 5 OM is referred to as a loam.
If the clay amount is larger, it is a clay loam. A very sandy soil with some clay and silt is a sandy loam

Knowing each soil texture is very important because each will function differently. The soil texture triangle is very helpful in determining the physical and chemical properties of your soil.

Soil Texture Triangle



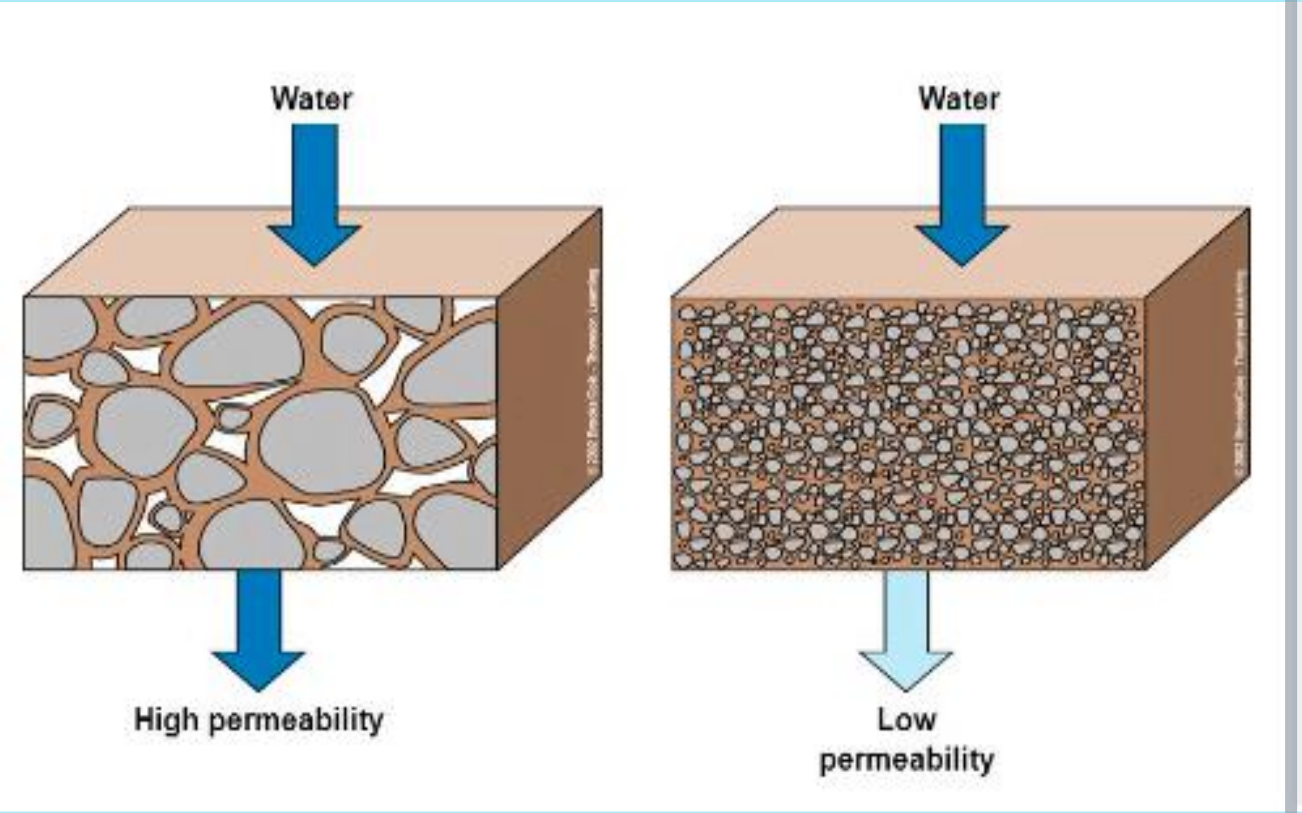
Clay

Loam

Silt

Sand

The Importance of Particle Size

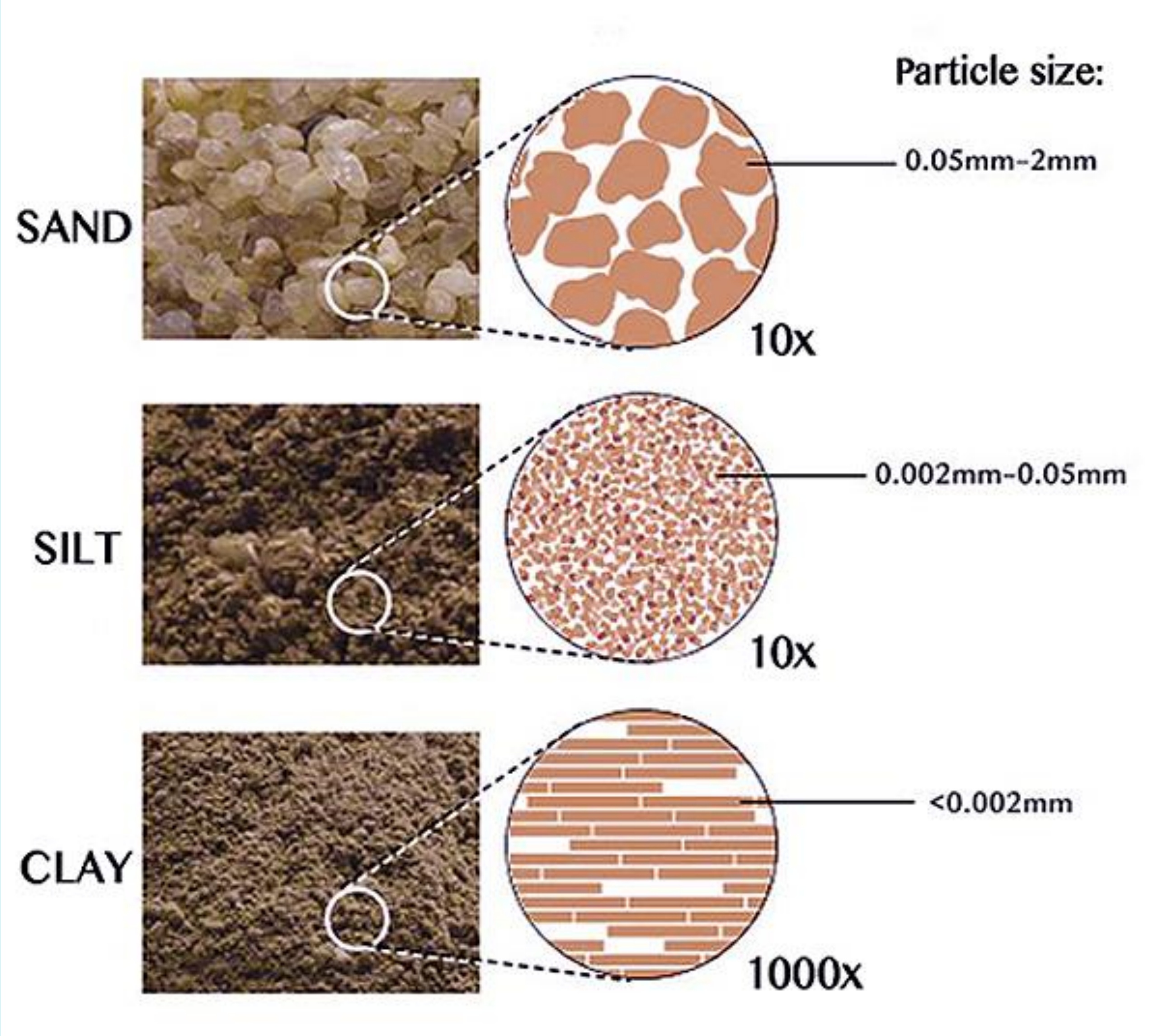


Soil Permeability

Permeability is the rate water flows through the soil.

% Water retention is how much water is trapped by the soil and how much by unit volume the soil can hold is influenced by the texture, clay minerals, organic content, particles and soil structure. Sandy soils are highly permeable where water can easily and quickly move through the soil profile. Clay soils, due to a smaller particle size have less room for water movement resulting in low permeability.

Particle Size & Porosity



Porosity:
Determines the total amount of water a material will hold. Dependent on the number and the size of the pores in the soil. These factors also affect the permeability of the soil.

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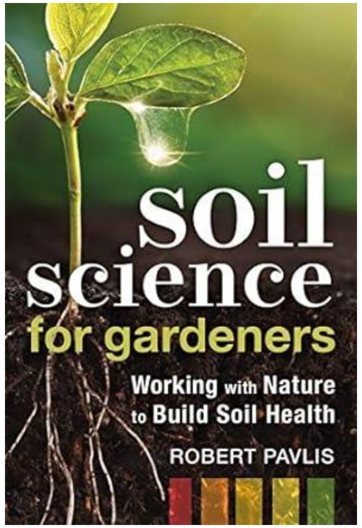

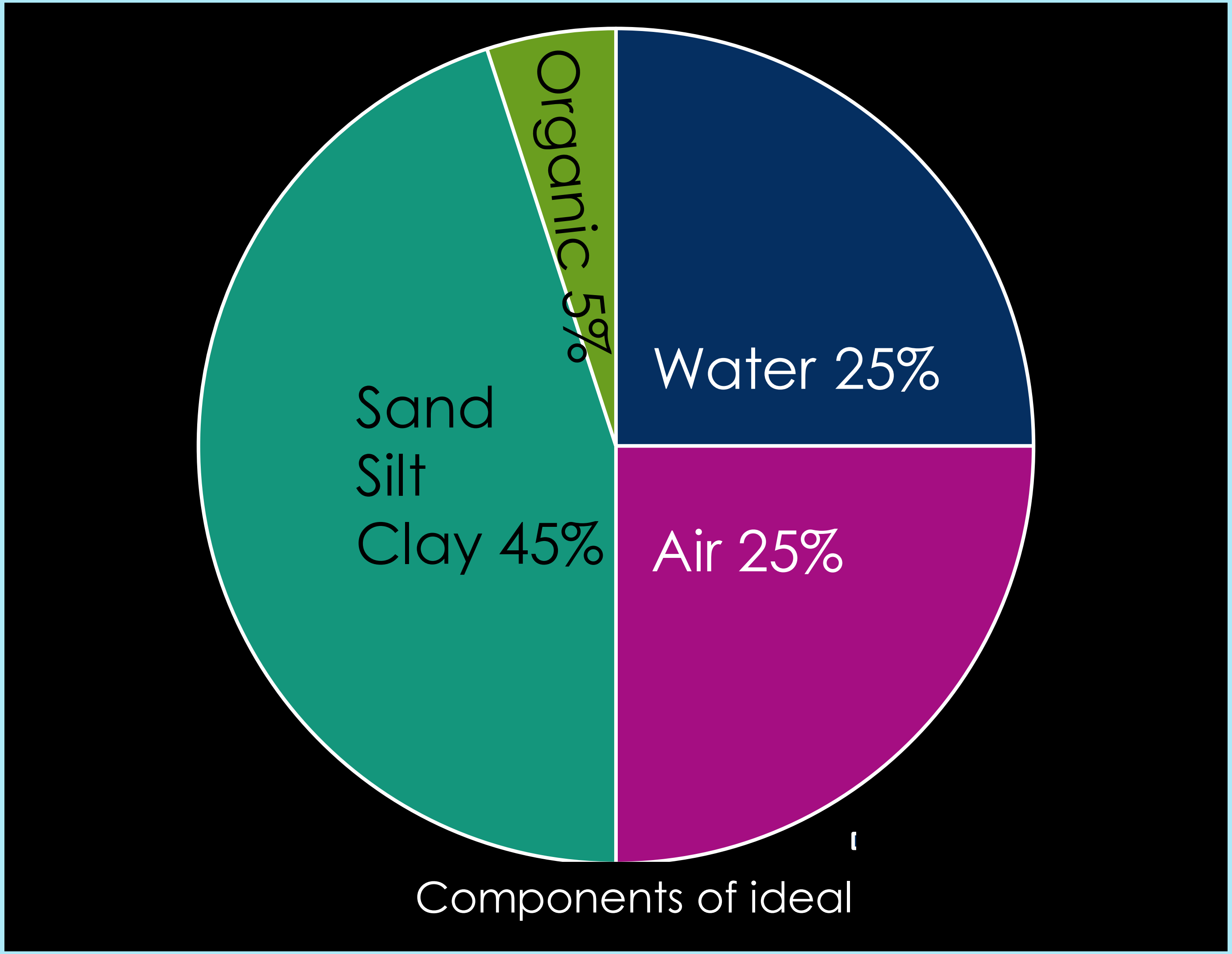

Evaporation-At the soil surface, water turns to water vapor that releases into the air.
The process continues drawing water to the surface by capillary action, slowly drying the soil

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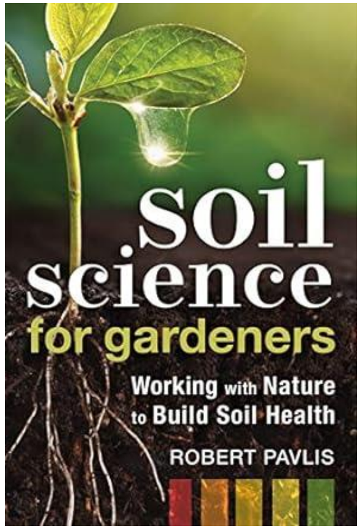
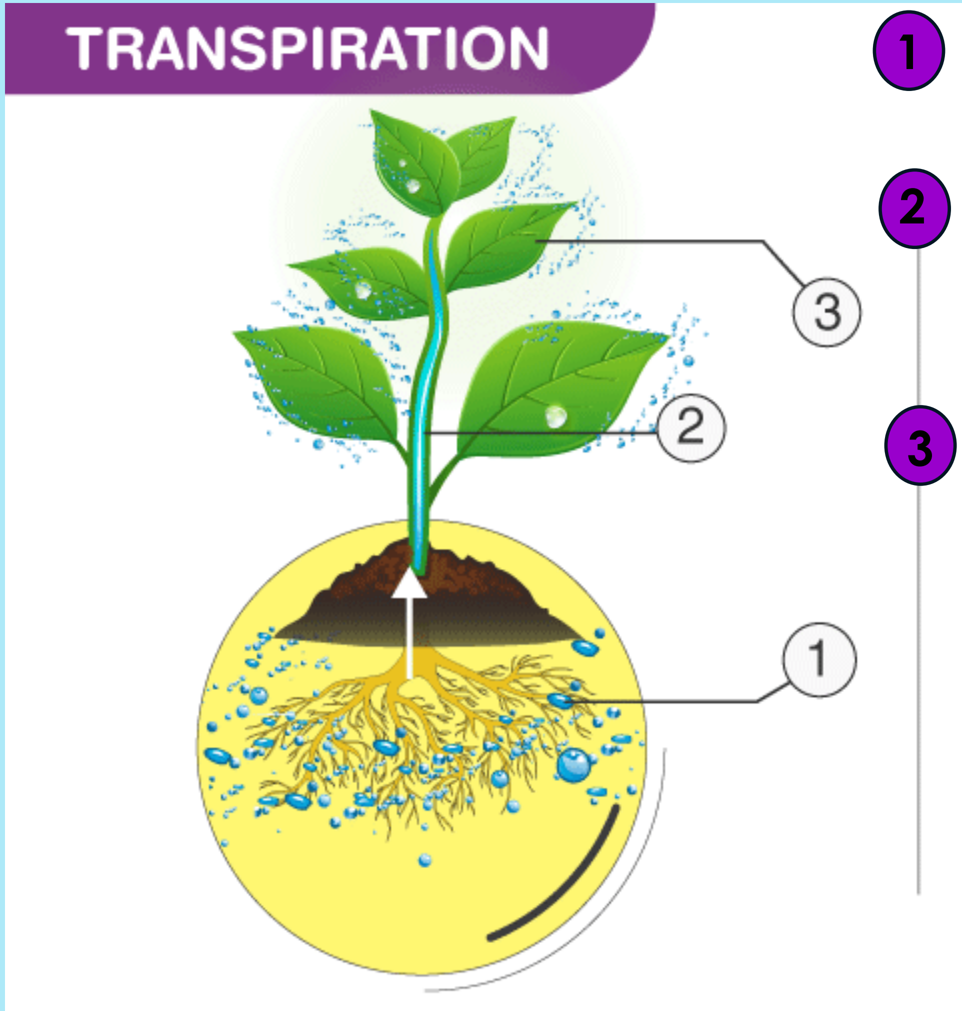




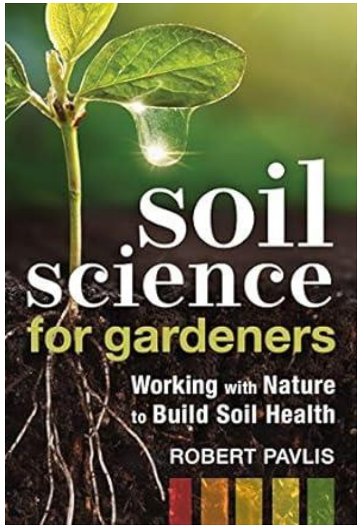
1. Plant roots constantly absorb water through the root hairs

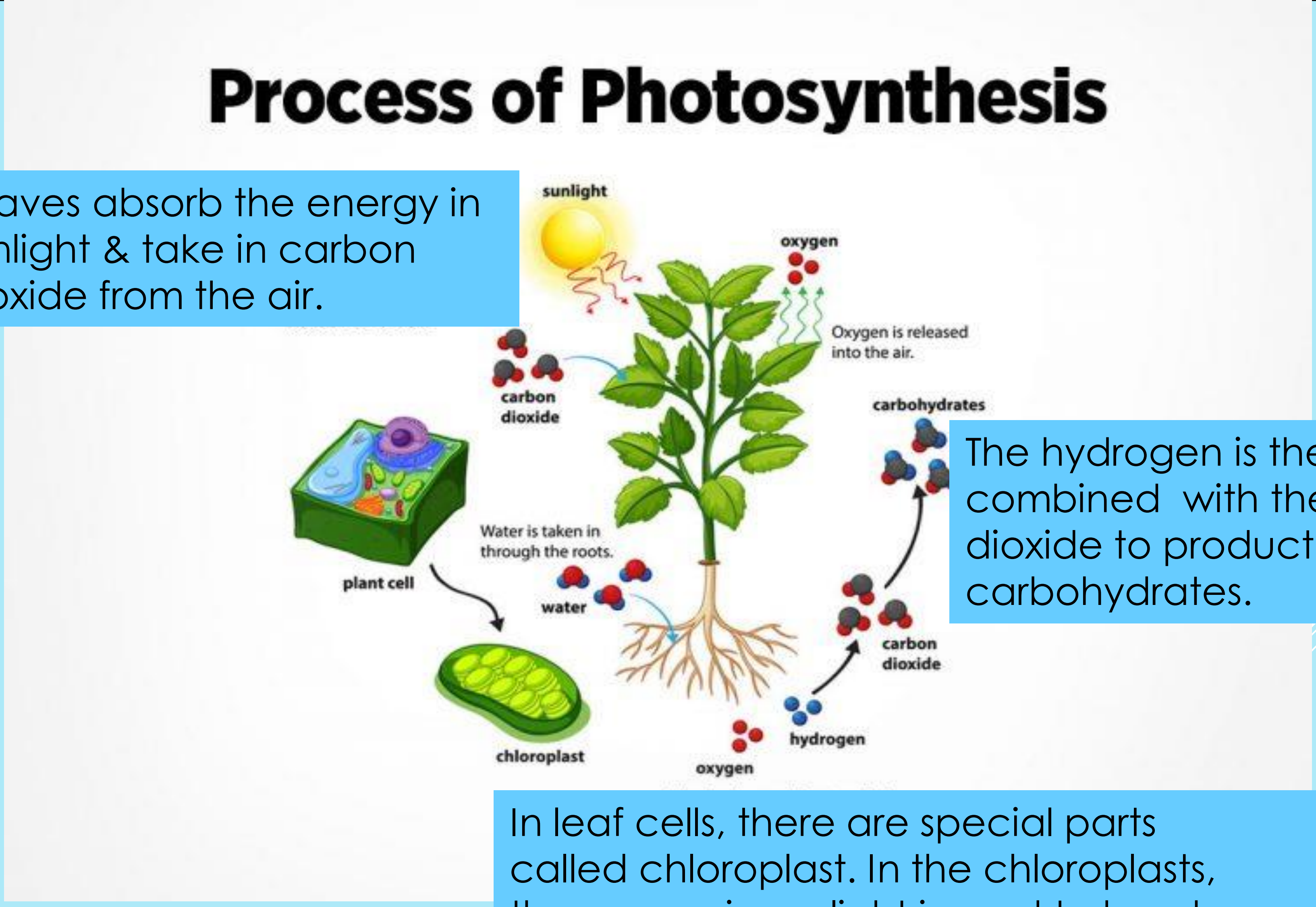
2. As it travels up through the plant it is transferred to the leaves and evaporates through the leaf openings called the Stomata.

3. Some water is used for photosynthesis

A large tree can move 100 gallons of water a day and discharge it into the air as water vapor.

As water leaves the air fills the void, there is always air in the soil, since roots need oxygen to survive.





Leaves absorb the energy in sunlight & take in carbon dioxide from the air.

The hydrogen is then combined with the carbon dioxide to product carbohydrates.

In leaf cells, there are special parts called chloroplast. In the chloroplasts, the energy in sunlight is used to break apart the oxygen and hydrogen molecules.

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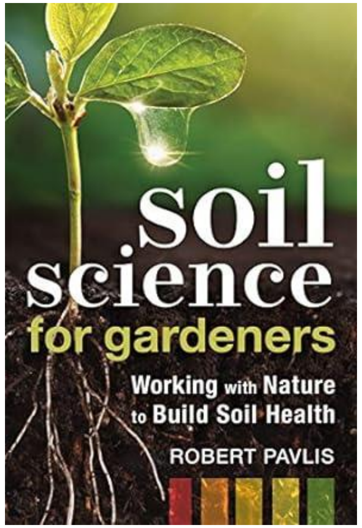

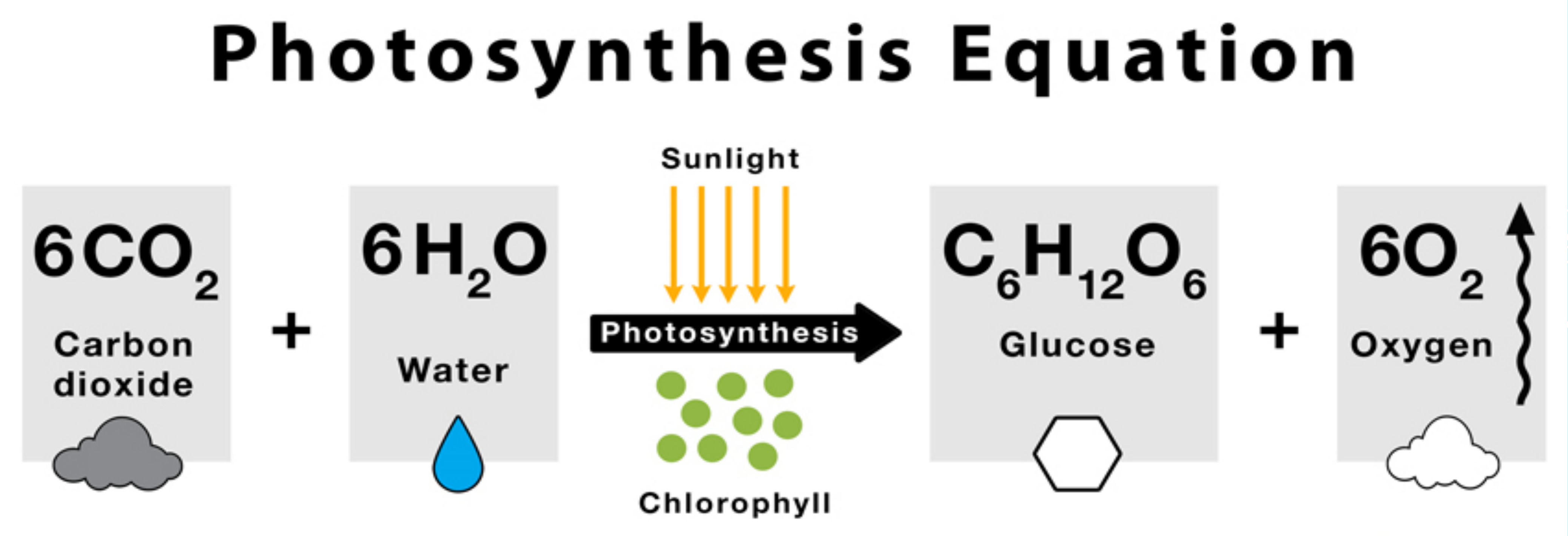

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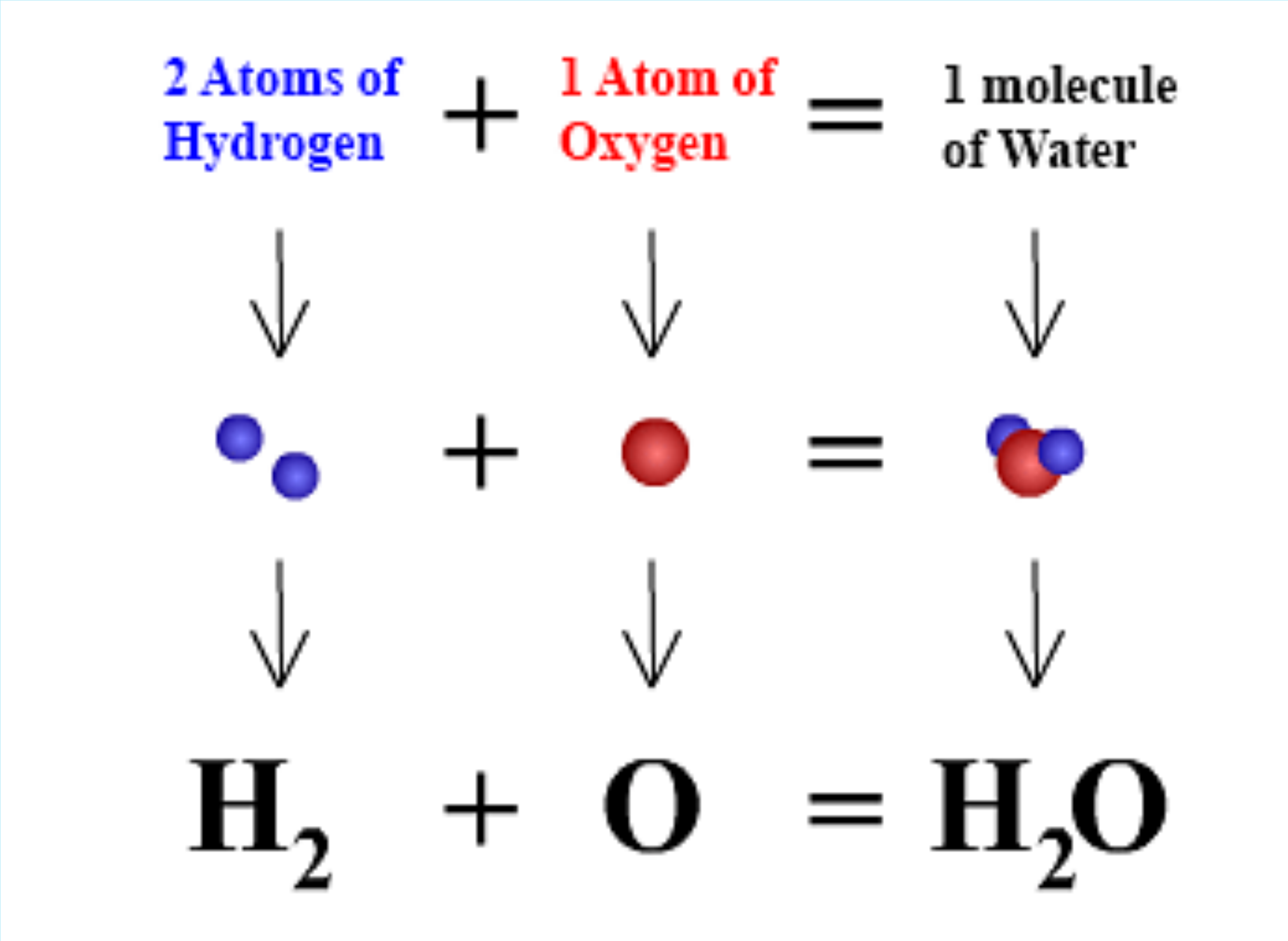
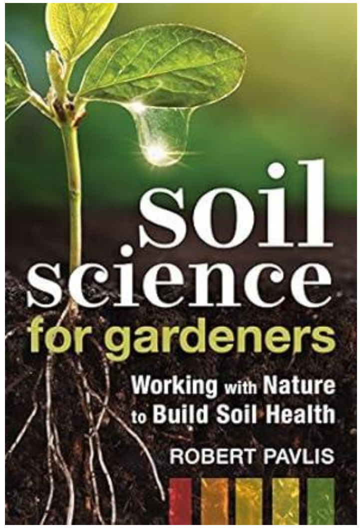
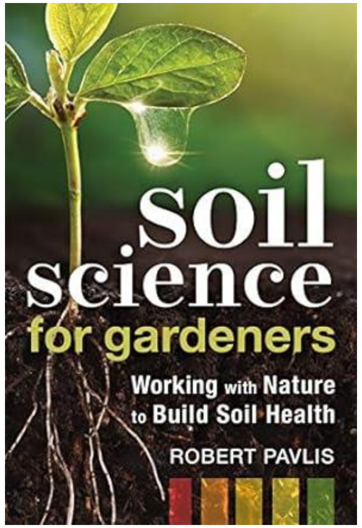
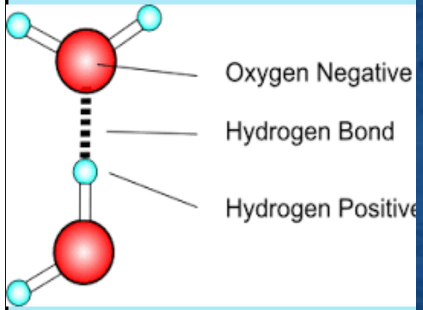


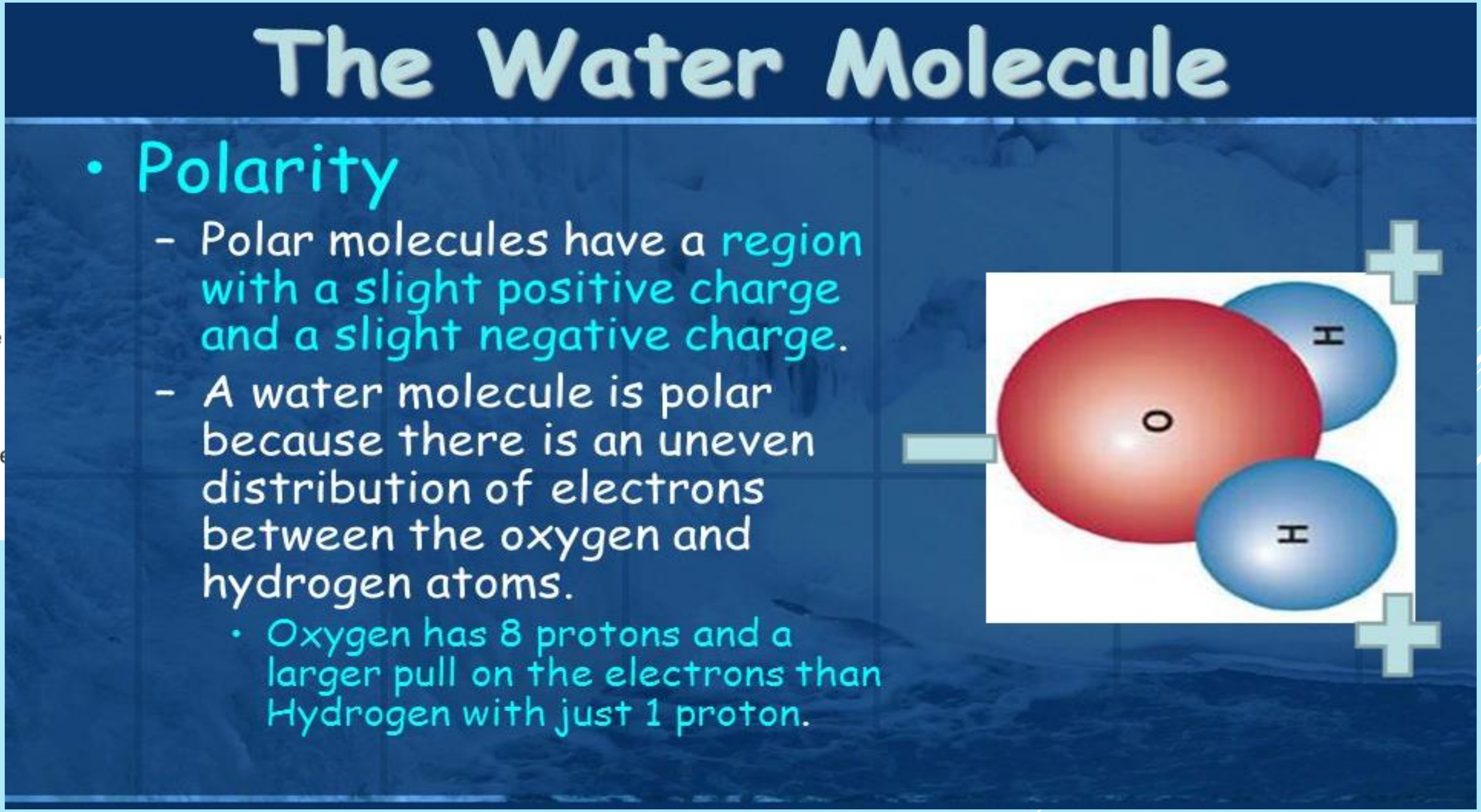


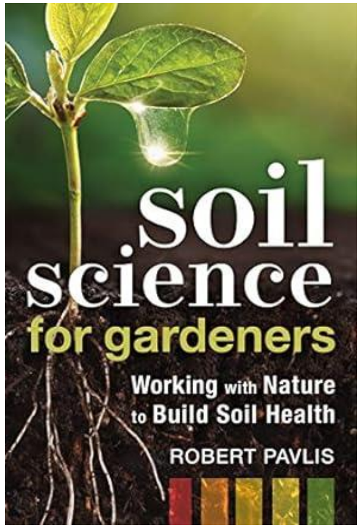
Chemical Nature of Water (19)

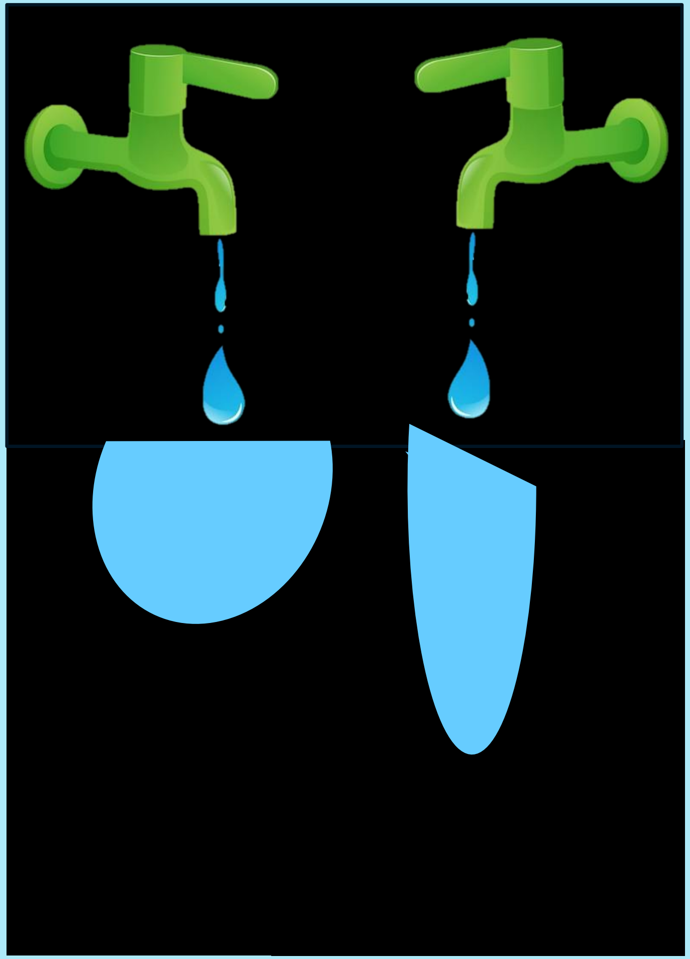
Water molecules, one end is positive one is negative.
They act like magnets, sticky in nature called cohesion.
This plays a key role in how water & nutrients move through the soil.


soil science
for gardeners
Working with Nature to Build Soil Health
ROBERT PAVLIS

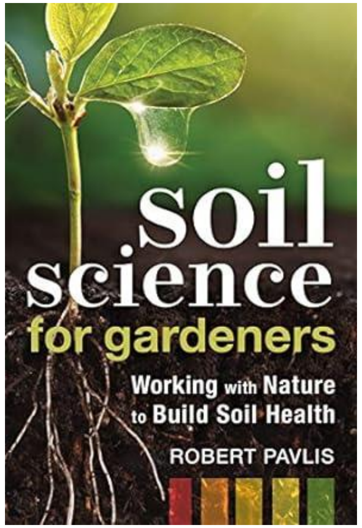

Oxygen Negative
Hydrogen Bond
Hydrogen Positive


The Water Molecule
• Polarity
– Polar molecules have a region with a slight positive charge and a slight negative charge.
– A water molecule is polar because there is an uneven distribution of electrons between the oxygen and hydrogen atoms.
• Oxygen has 8 protons and a larger pull on the electrons than Hydrogen with just 1 proton.
O
H
H





Water dropped onto the soil moves down and sideways due to the interplay of charges on Clay and OM and water. Sand has large pore spaces and almost no charge.



Aggregation and Soil Structure

Aggregation – Arrangement of primary soil particles (sand, silt, clay) around soil organic matter and through particle associations makes the soil stable and structural. Aggregate stability is a good indicator of soil health.

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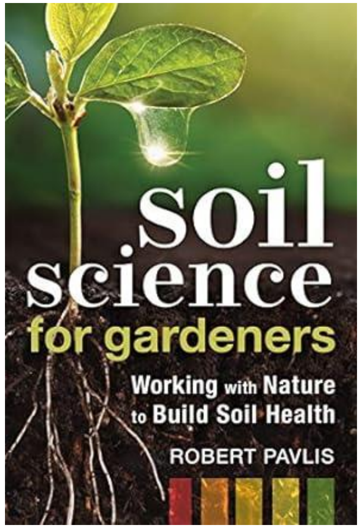
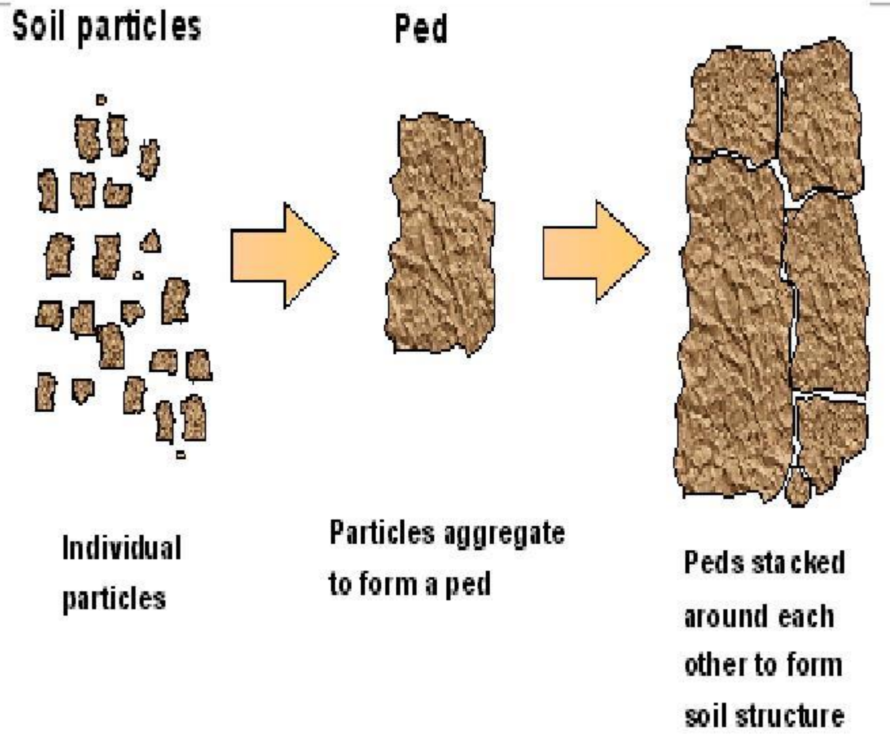


WHAT IS SOIL STRUCTURE:

- It is the aggregation of individual particles that gives the soil its structure. In undistributed soils, these aggregates form different shapes known as **peds.** It is the shape and alignment of the peds, which, combined with particle size/texture, determine the size and number of pore spaces through which water, air, roots and soil organisms can pass.



The level of aggregation determines if the soil is a good performing soil or a poor performing soil. Soil sauces act like a glue sticks sand, silt, clay and organic matter together to form 'Peds".

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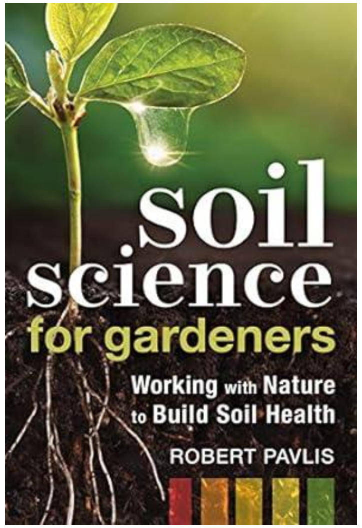

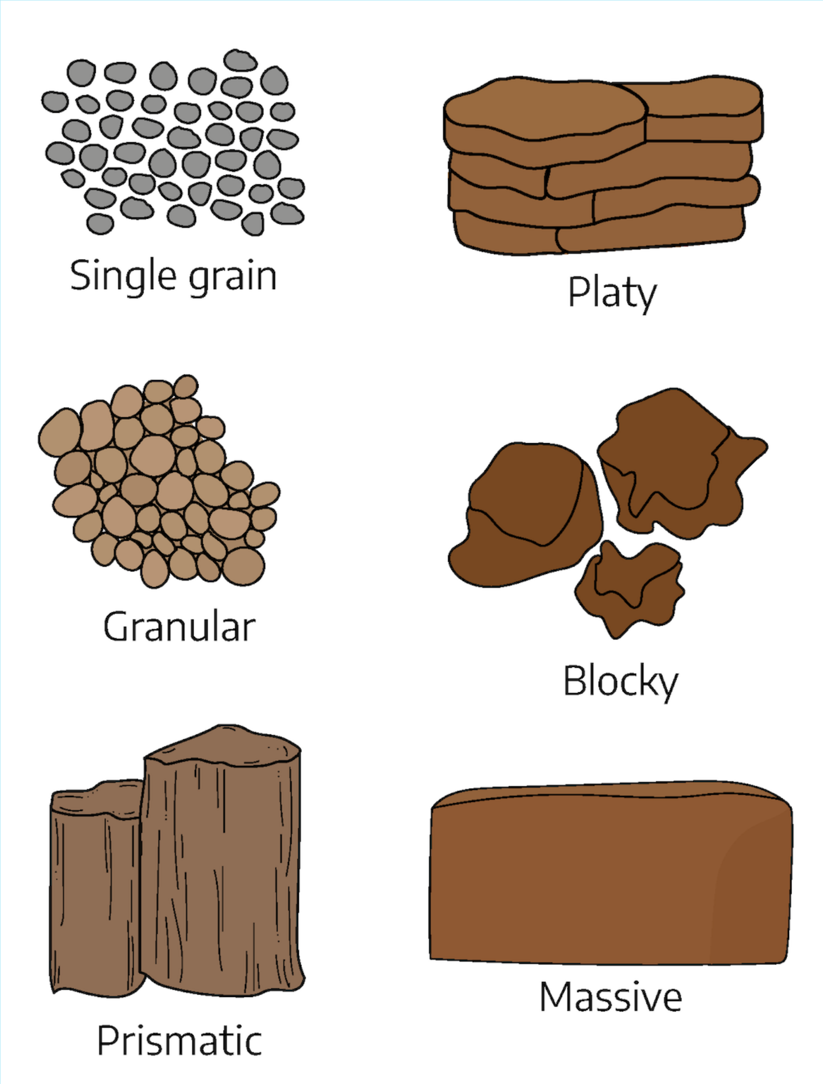

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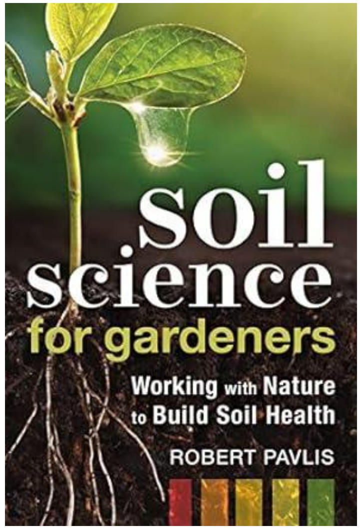

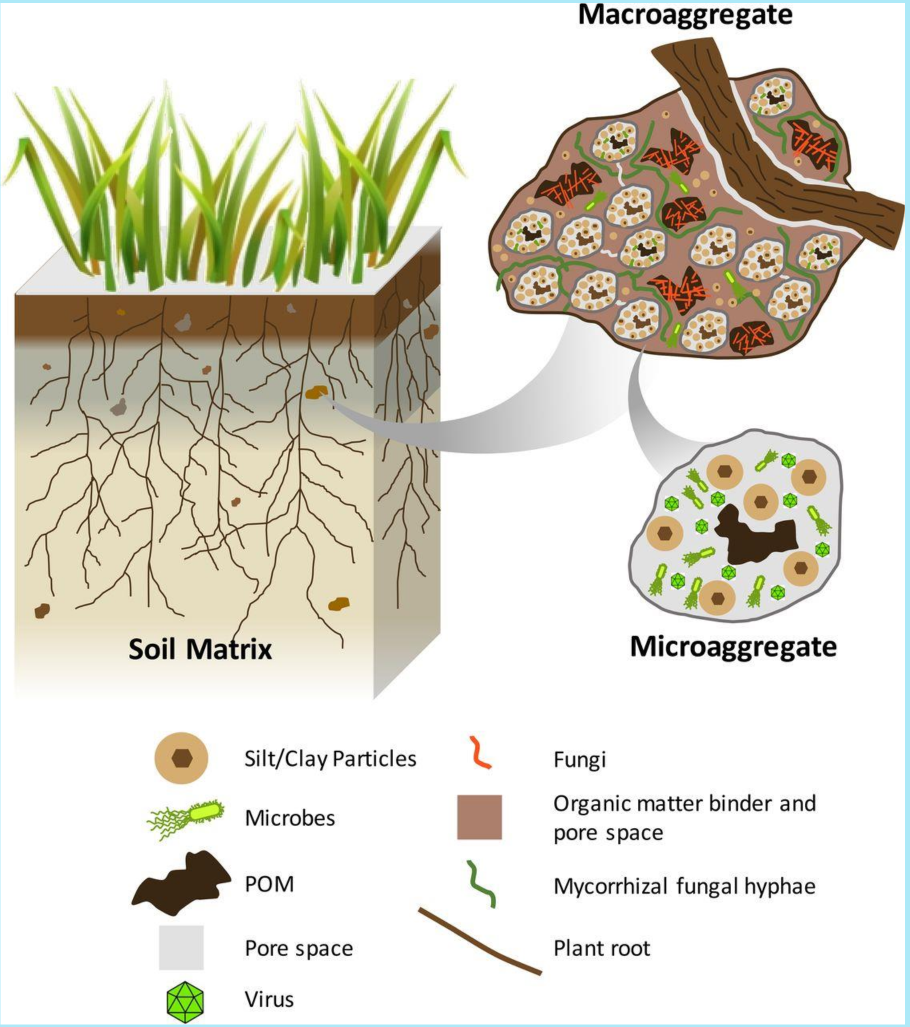

These sauces known as "Life Juices come from plants, bacteria, fungi, earthworms, small insects, clay, iron oxide and organic matter. The best of these binding agents come from microorganisms.

It is a two step process:

Binding agents from soil microbes helps stick the very small soil particles and organic matter together to form microaggregates.

Breakdown Timeframe: decades/centuries

Microaggregates are stuck together by mycelium of fungi and hyphae of actinomycetes(bacteria) to forms the larger macroaggregates.

The greater the fungal biomass the bigger size and greater quantity of the macroaggregates, the healthier the soil.

Breakdown Timeframe: 1-10 years

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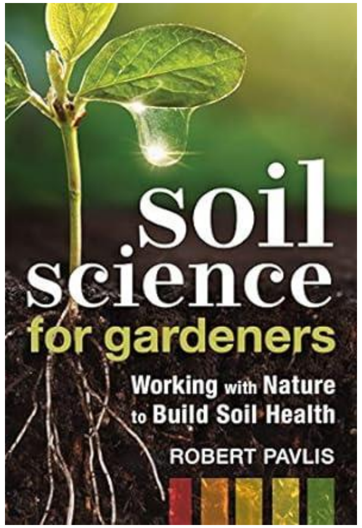

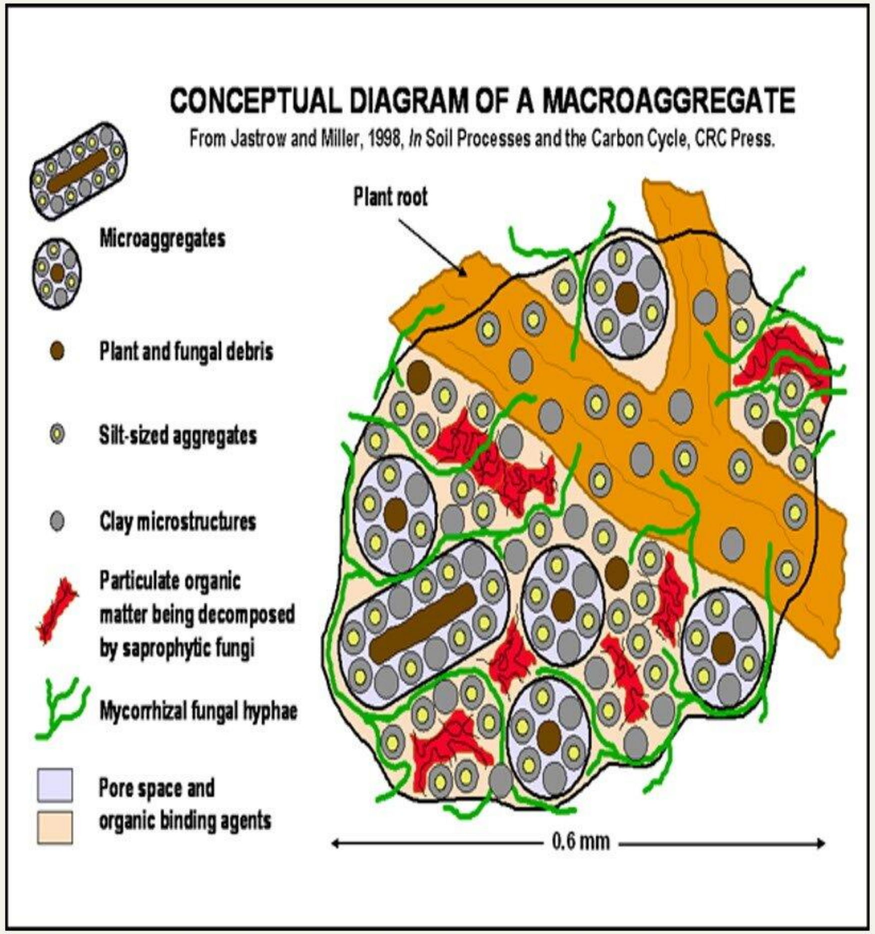

Mycorrhizae are actually a fungus. They exist as very tiny, almost or even entirely microscopic, threads called hyphae. The hyphae are all interconnected into a net-like web called a mycelium, which measures hundreds or thousands of miles—all packed into a tiny area around the plant.

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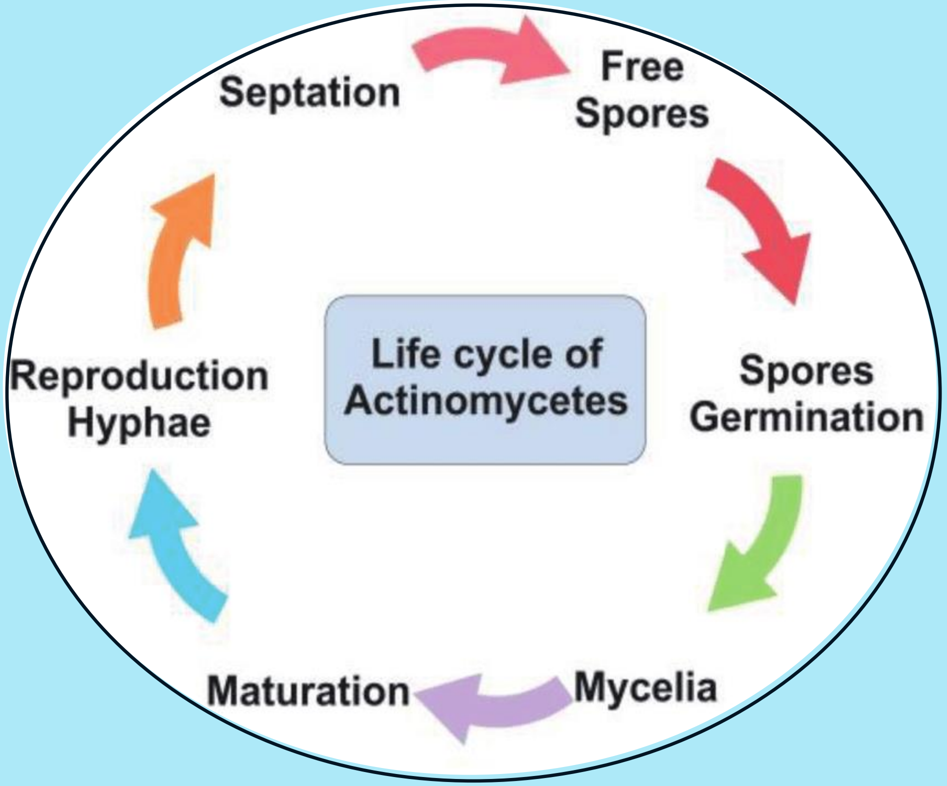
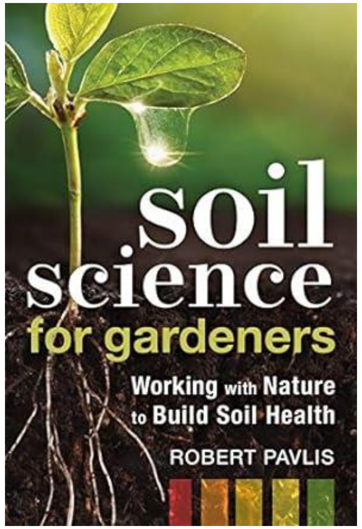
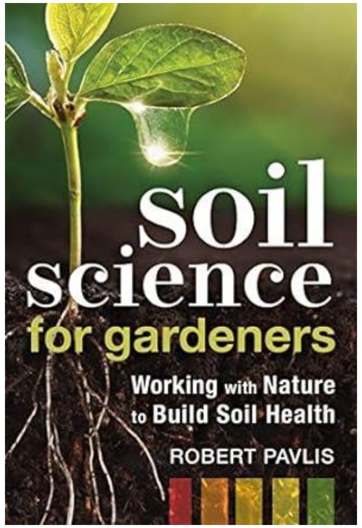




Soil Basics

Soil Health, Naturally

review



Soil Texture vs Soil Structure

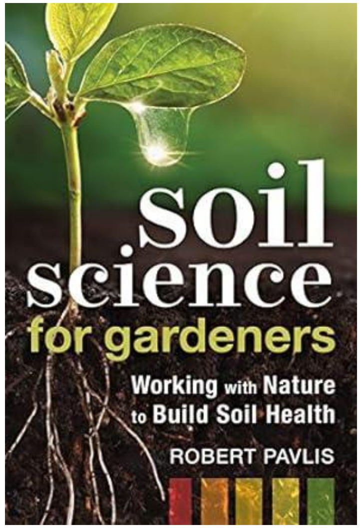
More Information Online WWW.DIFFERENCEBETWEEN.COM

	Soil Texture	Soil Structure
DEFINITION	Soil texture is the proportion of sand, silt, and clay-sized particles that makes the mineral fraction of soil	Soil structure is the way individual particles of sand, silt and clay are assembled
DESCRIPTION	Describes the feel or shape of the soil	Describes the cohesive whole built up of distinct parts
TYPES	Sand, loamy sand, sandy loam, loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay	Platy soil, prismatic, columnar, blocky, granular, wedge, and lenticular

Soil Health, Naturally

Soil Basics

Soil Aggregation



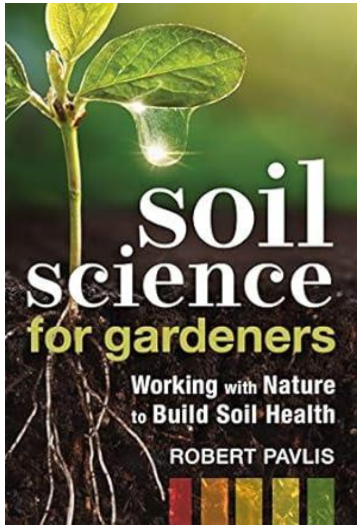
Aggregate structures provided both **large and small pores**. Large soil pores allow water to quickly infiltrate the soil. Smaller soil pores can store plant available water in times of limited rainfall.

Compacted Soil
The soil looks cemented with limited pore spaces.

Aggregated Soil
Has visible pores, root channels and provides earthworm habitat.

Management practices directly effect the level of soil aggregation. High-intensity tillage practices reduce aggregation; whereas, reduced or no-till systems facilitate aggregation.

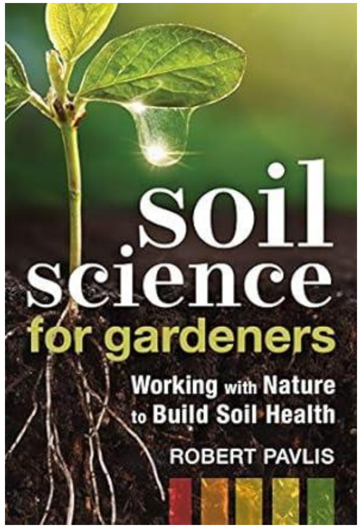
Soil Health, Naturally

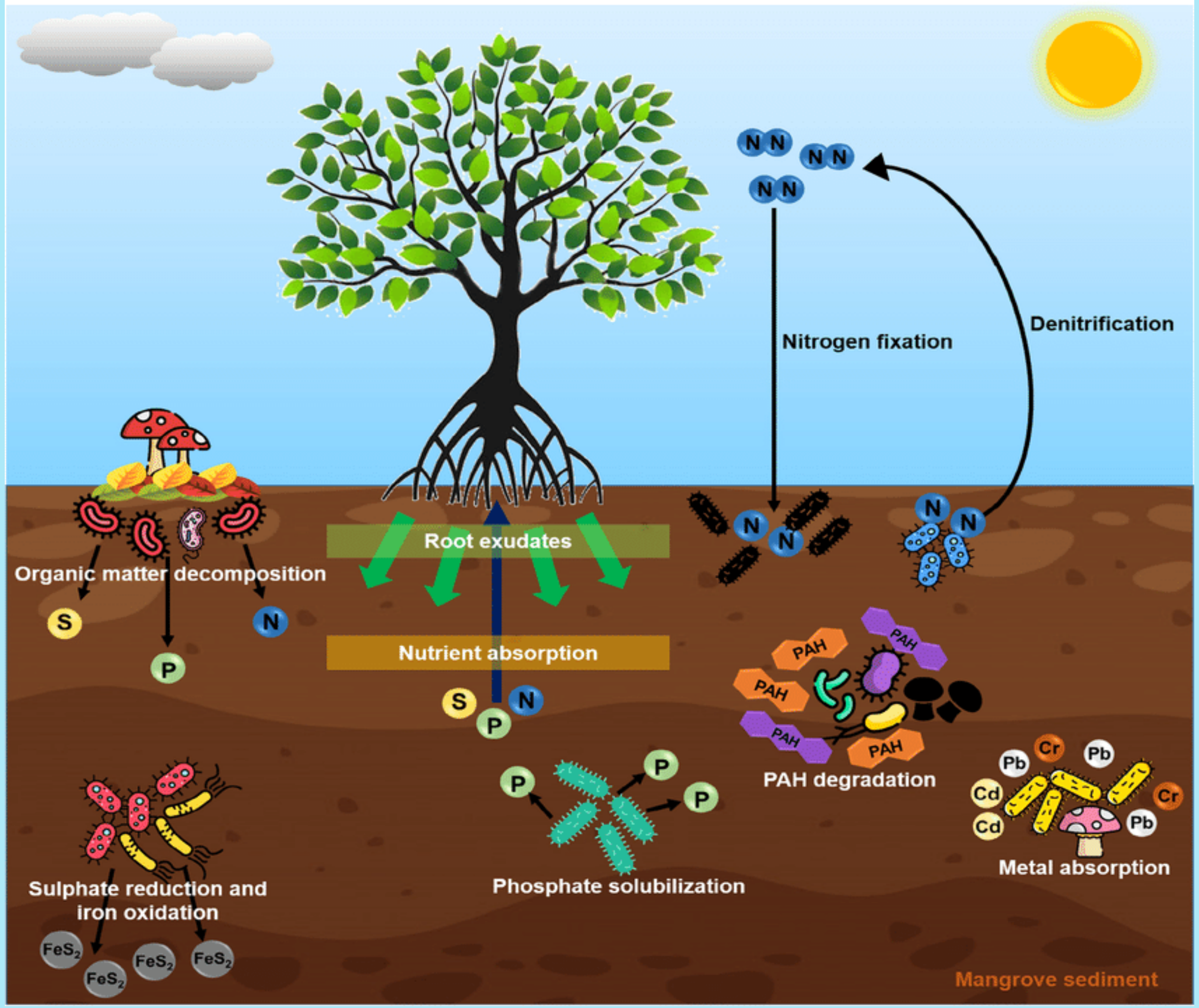


Why are aggregates important?

Good Drainage
Soil Carbon Accumulation
Soil Stability
Healthy root growth
Water and Air Flow

Soil Health, Naturally



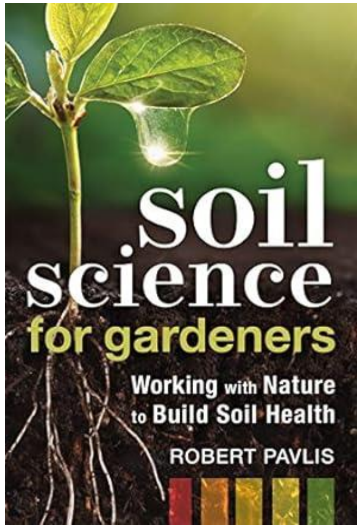


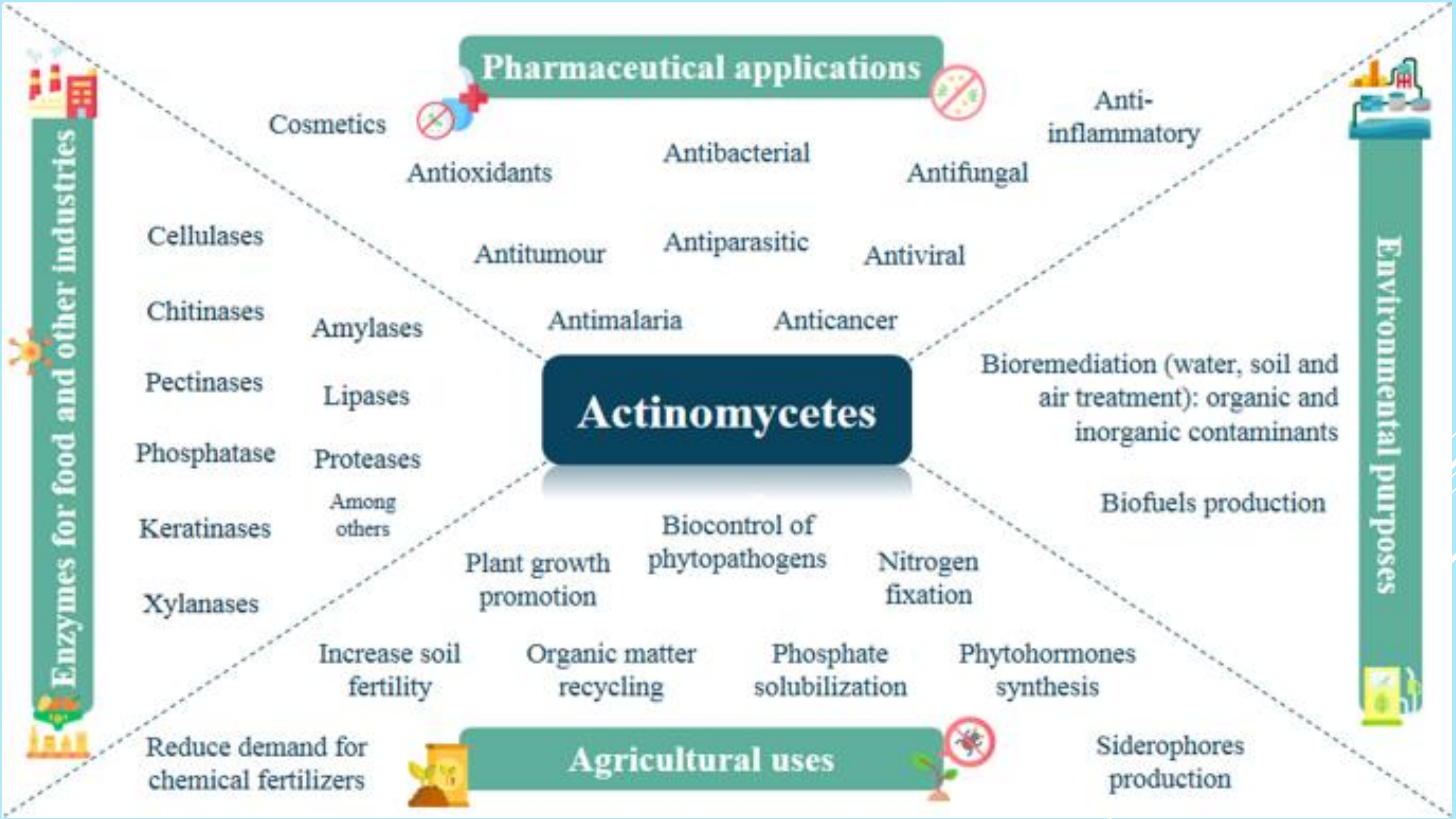
Terminology

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco. PAHs can bind to or form small particles in the air and soil.

Soil Basics

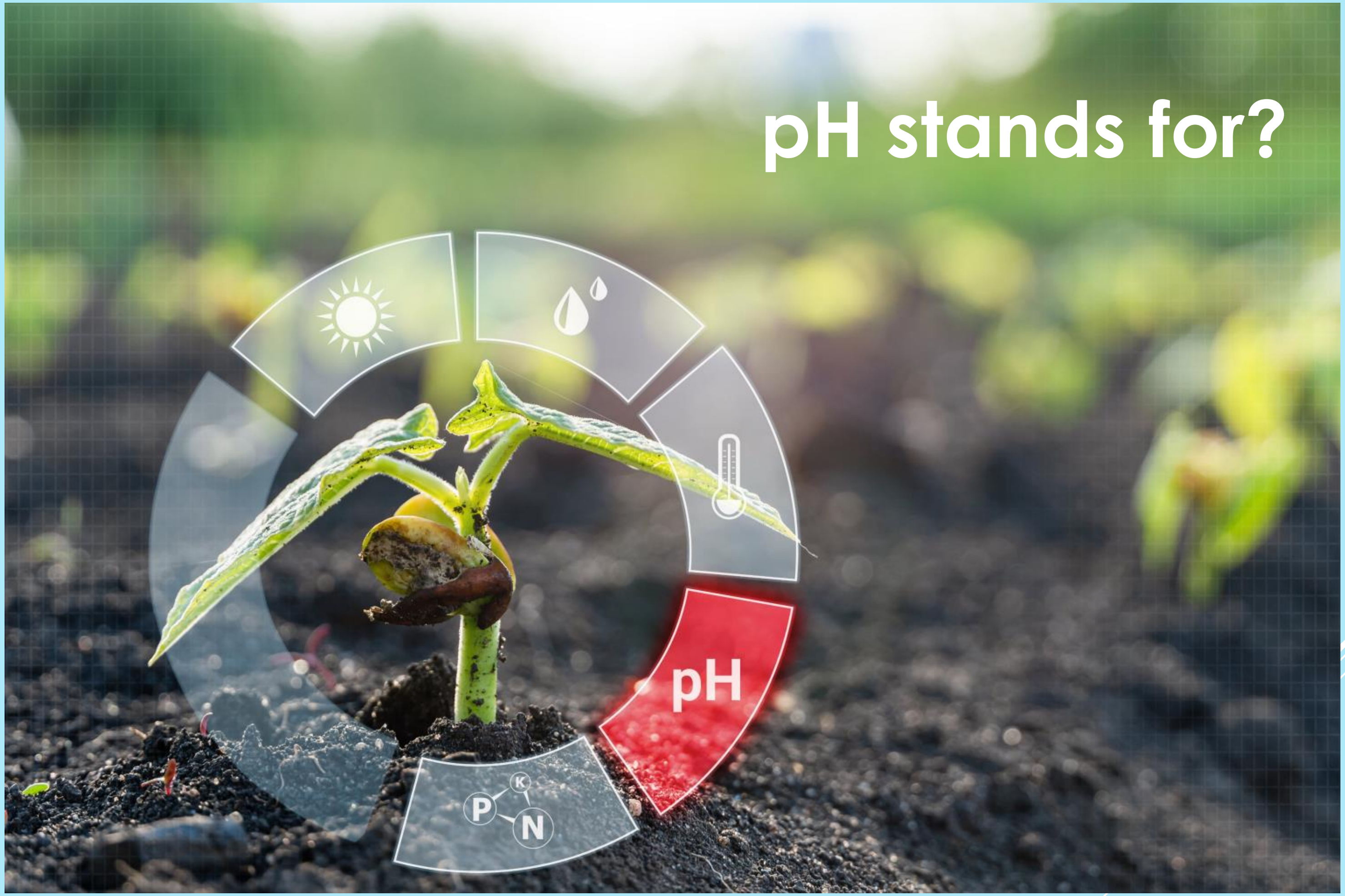
Soil Health, Naturally

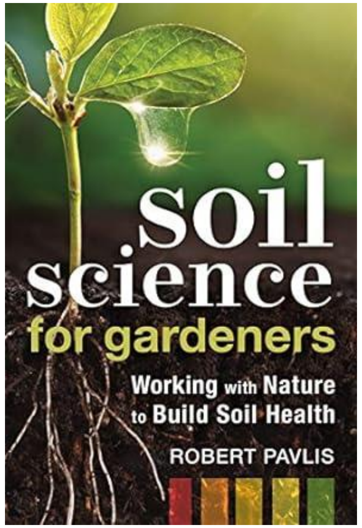




Soil Health, Naturally

Soil pH





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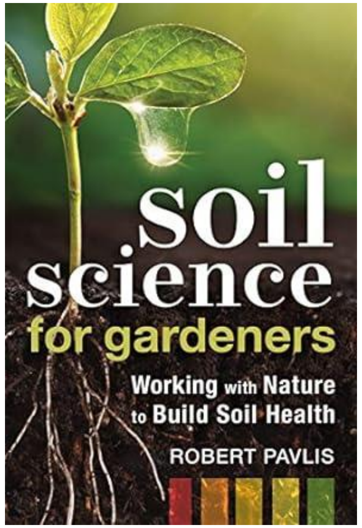
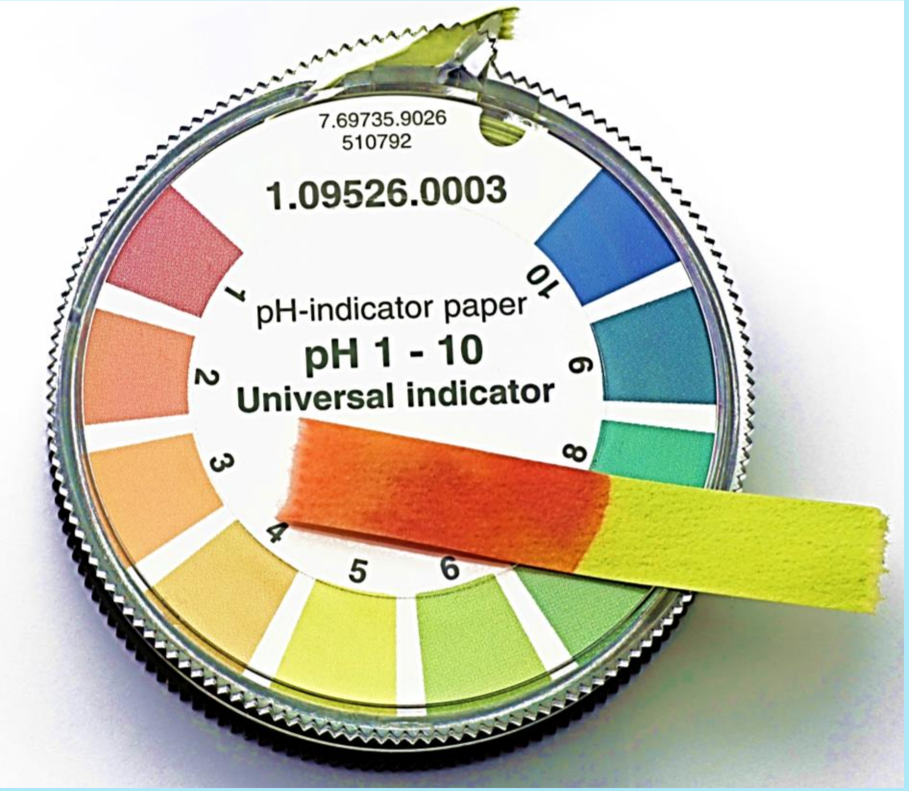
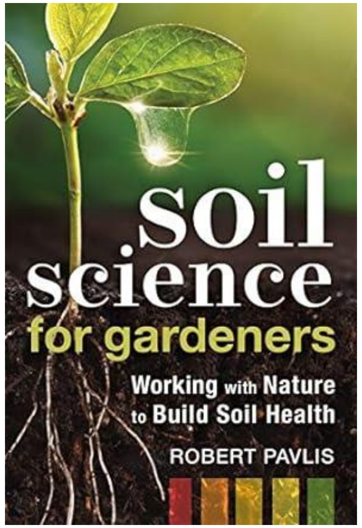




Soil pH

In 1909, a chemist called Sørensen devised a system of measuring the amount of free H^+ ions in a solution. He called it the pH scale because, in German, **p**otenz **H**ydrogen means “Hydrogen concentration”.

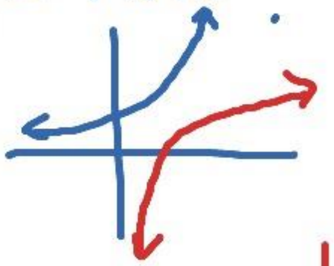
Put simply, pH is a universal scale that's used to determine the acidity or basicity of a substance or solution measured in logarithms.



Soil pH

What is a logarithm?

$f(x) = b^x$



inverse

$x = b^y$

$y = \log_b(x)$

$y = \log_b(x)$ is equivalent to $x = b^y$.

Ex: $\log_{10}\left(\frac{1}{1000}\right) = ?$

$10^{?} = \frac{1}{1000}$

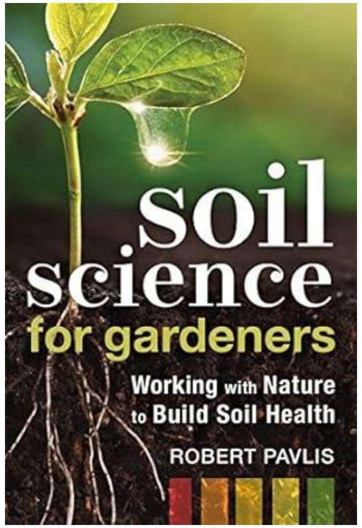
$10^{-3} = \frac{1}{10^3} = \frac{1}{1000}$

$\log_{10}\left(\frac{1}{1000}\right) = -3.$

Soil Health, Naturally

Soil Basics

Soil pH



Neutral

The pH Scale

More alkaline

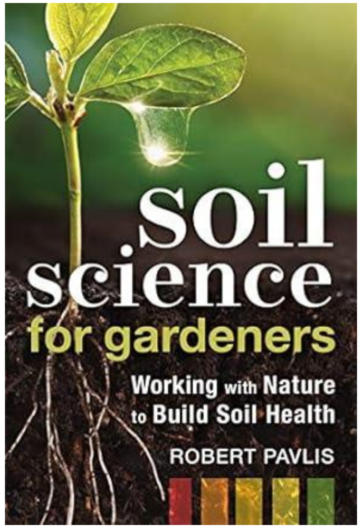
Concentration of Hydrogen ions compared to distilled water

More acid

Concentration of Hydrogen ions compared to distilled water	pH	Examples of solutions and their respective pH
1/10,000,000	14	Liquid drain cleaner, Caustic soda
1/1,000,000	13	bleaches, oven cleaner
1/100,000	12	Soapy water
1/10,000	11	Household Ammonia (11.9)
1/1,000	10	Milk of magnesium (10.5)
1/100	9	Toothpaste (9.9)
1/10	8	Baking soda (8.4), Seawater, Eggs
0	7	"Pure" water (7)
10	6	Urine (6) Milk (6.6)
100	5	Acid rain (5.6) Black coffee (5)
1,000	4	Tomato juice (4.1)
10,000	3	Grapefruit & Orange juice, Soft drink
100,000	2	Lemon juice (2.3) Vinegar (2.9)
1,000,000	1	Hydrochloric acid secreted from the stomach lining (1)
10,000,000	0	Battery Acid

Typical pH for Selected Foods

Most fruits – 2.8 to 4.6; Most vegetables – 5.0 to 7.0; Meats, poultry, seafood – 5.1 to 7.1
Melons – 5.2 to 6.6; Tomatoes - 4.3 to 4.9 (borderline); Rhubarb – 3.1 to 3.4



What effects soil pH?

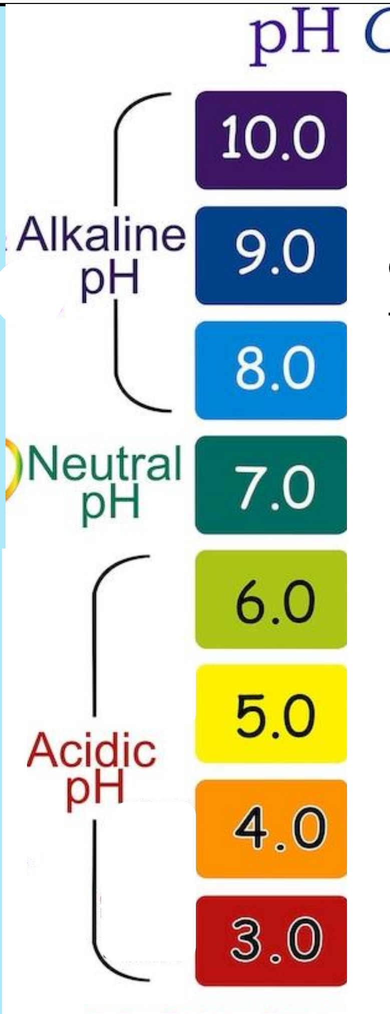
The rock from which the particles are formed.

A calcareous soil contains calcium carbonate (CaCO3) in abundance. There's an underlying layer of chalk or limestone.

Organic soils are different due to they are from decayed plant/animal and not rock

Rain

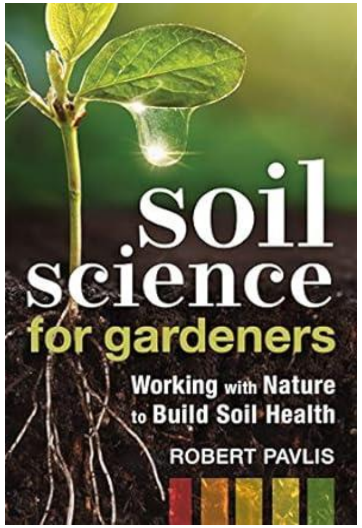
As it falls it picks up CO² when it hits the ground the pH is about 5.5. As more pollutants are picked up the rain becomes more acidic.



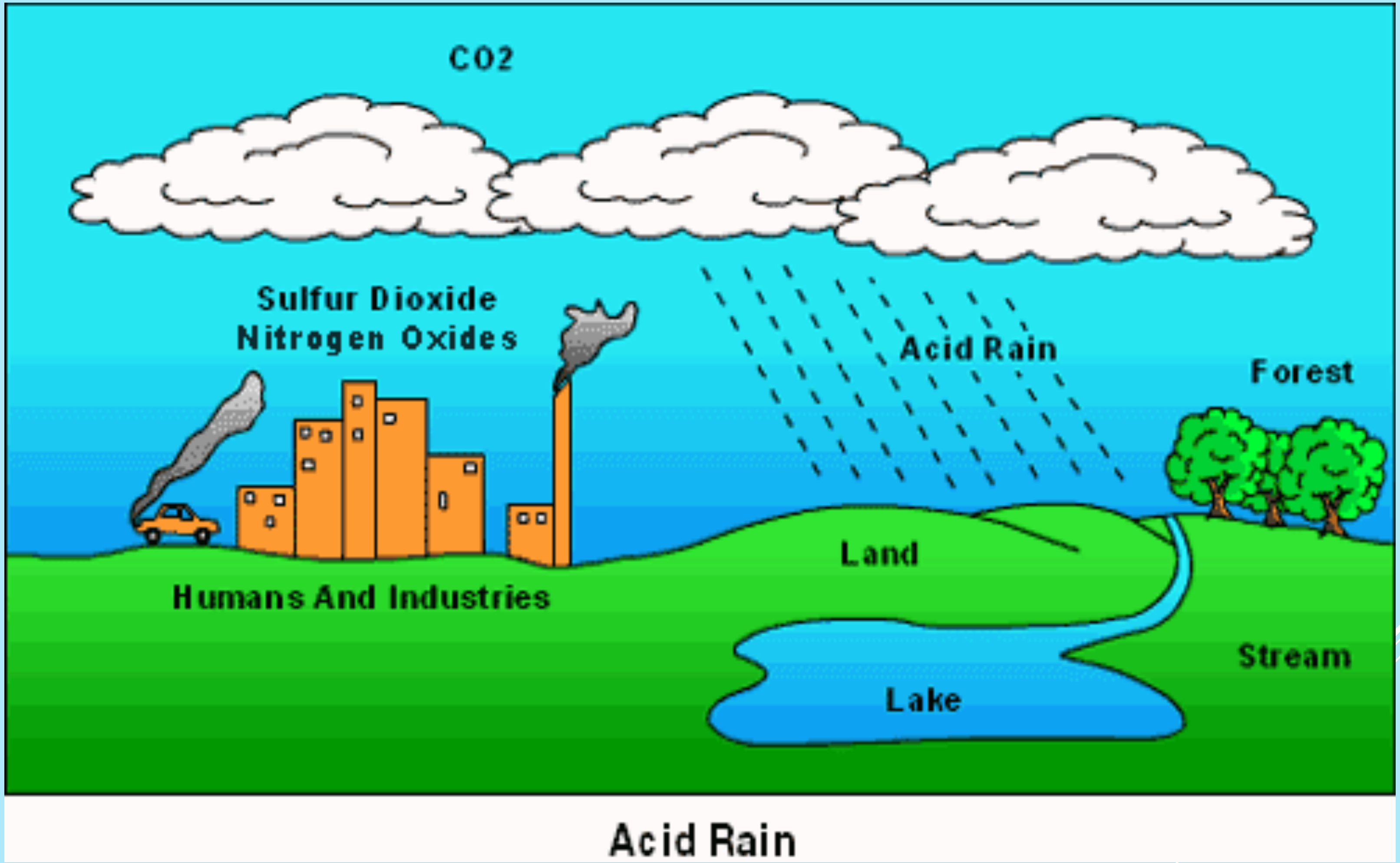
Limestone and Basalt are alkaline rocks that produce alkaline soils

Granite, Sandstone, Shale Acidic rocks that produce acidic soils

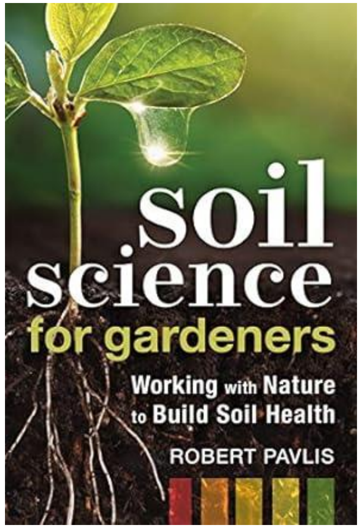
Soil Health, Naturally



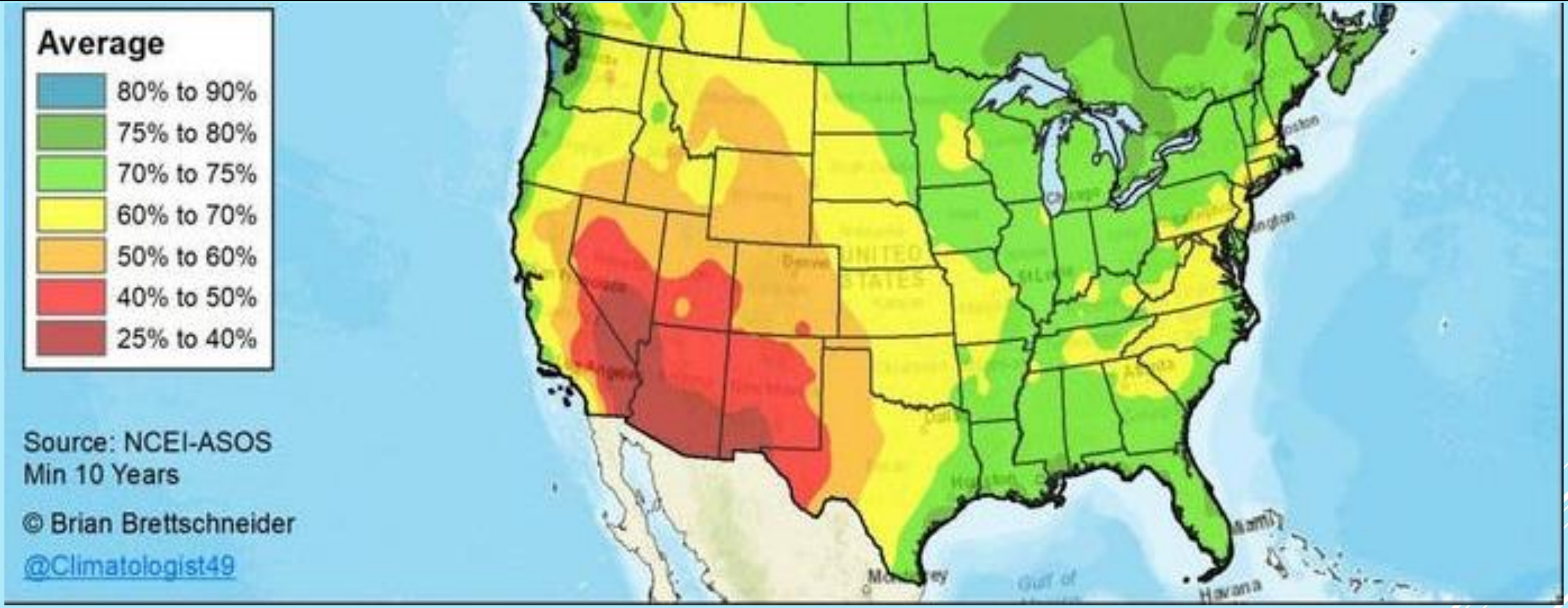
Soil pH



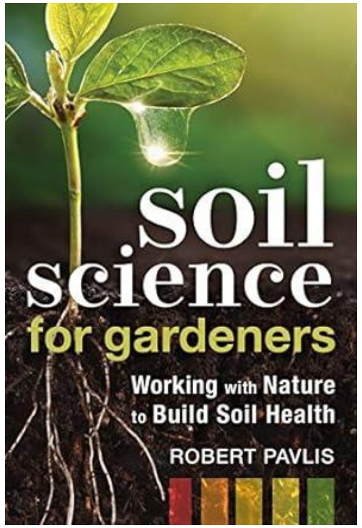
As it falls it picks up CO^2 when it hits the ground the pH is about 5.5. As more pollutants are picked up the rain becomes more acidic.



Soil pH



High rainfall in the east keeps soil acidic by washing minerals(cations) deeper into the soil increasing the hydrogen ions near the surface.
Dry regions in the west, result in water moving from lower levels to the surface
through evaporation. This carries minerals up like calcium and



Soil pH

Natural Process can also acidify the soil.
Respiration of soil roots and organisms produces CO_2 which is acidic.
Decay of organic matter produces organic acids
Plant growth absorbs minerals from the soil leaving behind hydrogen ions.

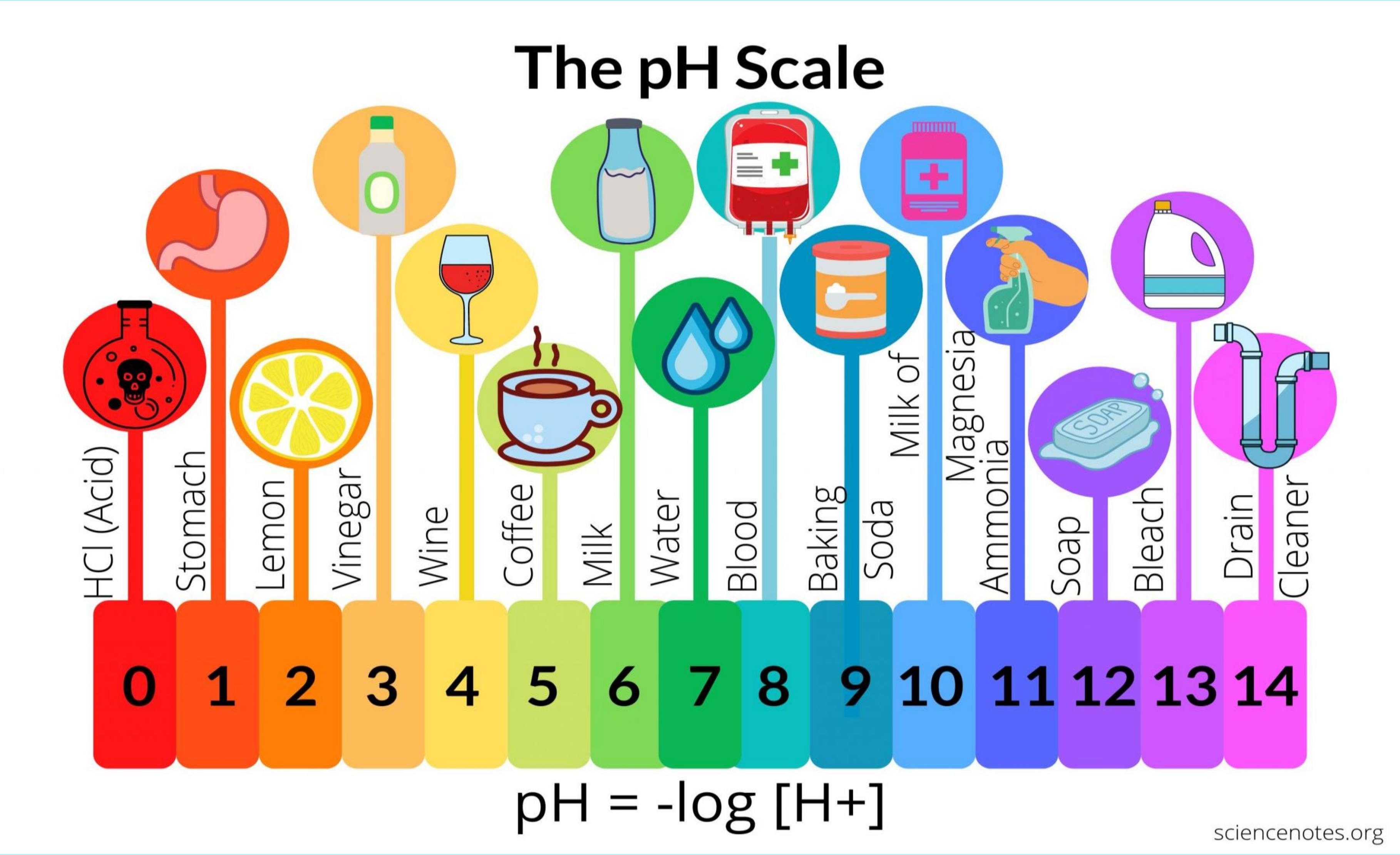
Manual Changes to change the pH:

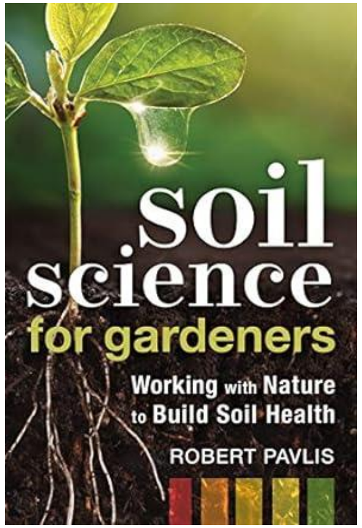
- Sulfur decreases pH
- Lime increases pH
- Fertilizers can increase or decrease pH
- Compost and manures can change pH

These are long term options and according to the book author, the soil can quickly revert back to it's original pH.

Soil Basics

Soil Health, Naturally





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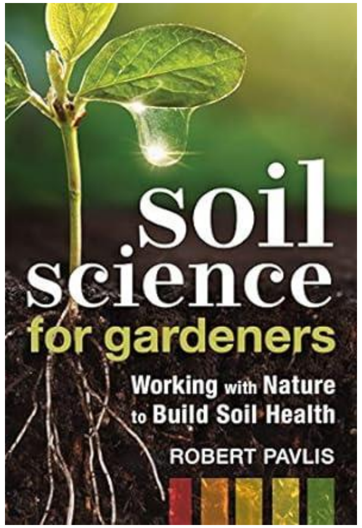


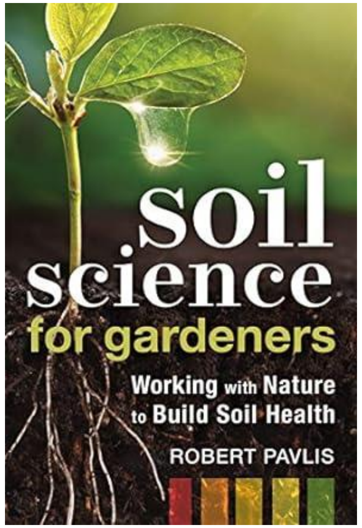
Soil pH

pH affects the nutrient levels in the soil solution and therefore influences plant growth.

A pH around 7 is the goal (on average) to max out uptake on all nutrients.

If you add Hydrogen Ions, the pH becomes lower, more acidic. Lessen the H-Ions the pH rises.

Nutrient availability with regards to high & low pH – see the following chart.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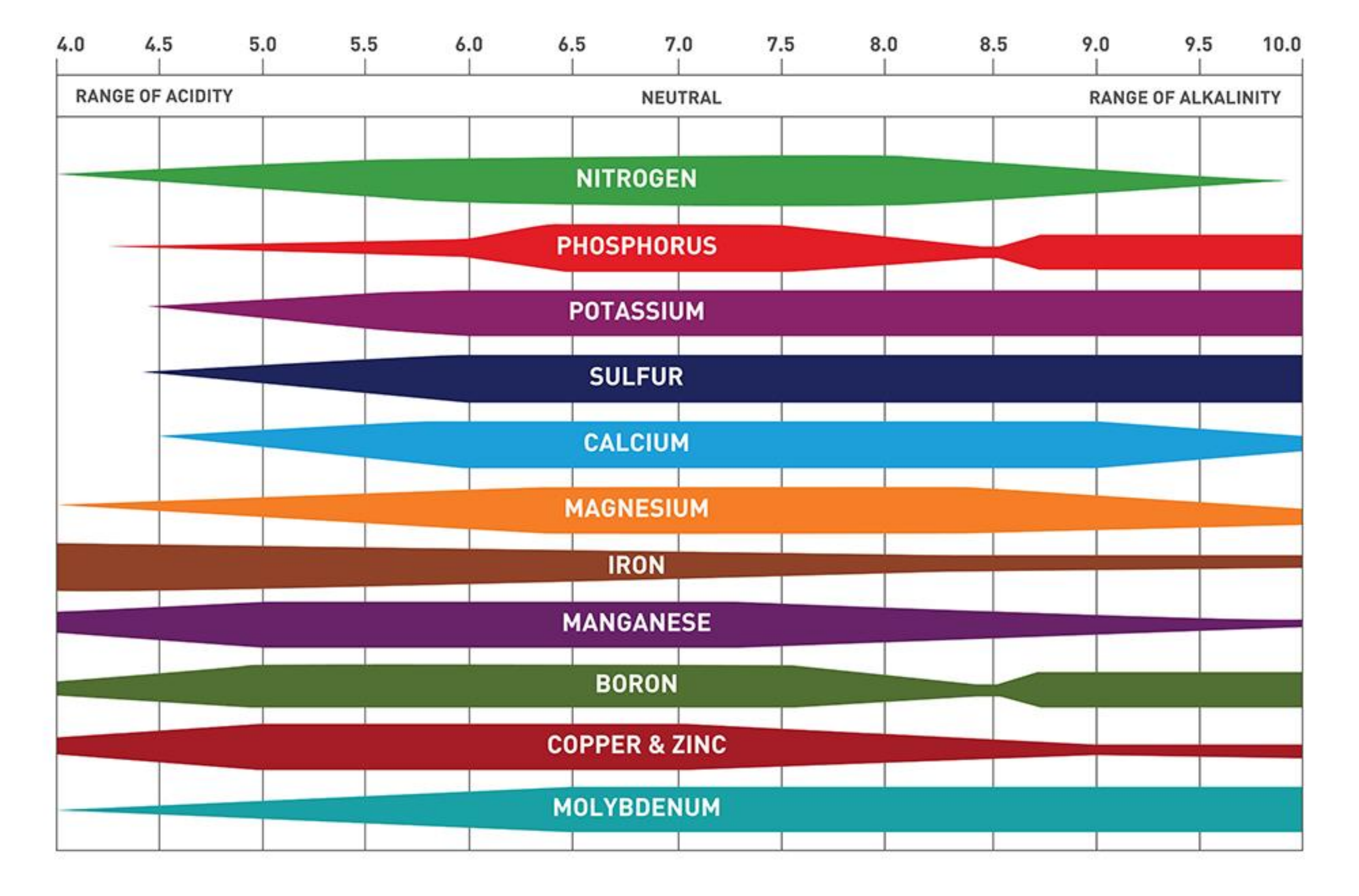
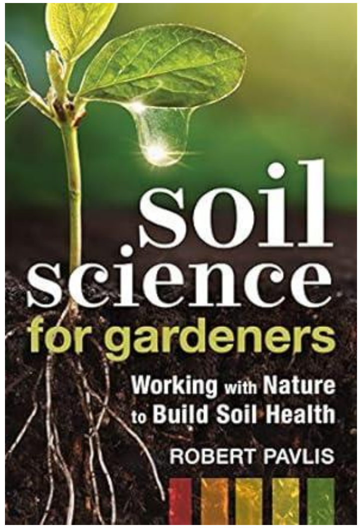
Soil pH


4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
RANGE OF ACIDITY
NEUTRAL
RANGE OF ALKALINITY
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER & ZINC
MOLYBDENUM

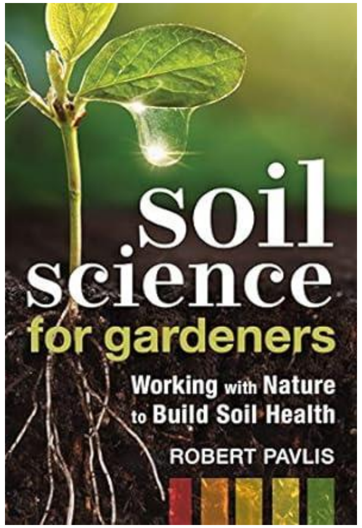


Soil pH

Nitrogen (N), Potassium (K), and Sulfur (S) are major plant nutrients that appear to be less affected directly by soil pH than the others.

Phosphorus (P), is directly affected. At alkaline pH values, greater than pH 7.5, phosphate ions tend to react with Calcium (Ca) & Magnesium (Mg) to form less soluble compounds. At acidic pH values, phosphate ions react with aluminum (Al) and iron (Fe) to again form less soluble compounds. In alkaline soils Calcium reacts with Iron and lowers the available Iron ions.

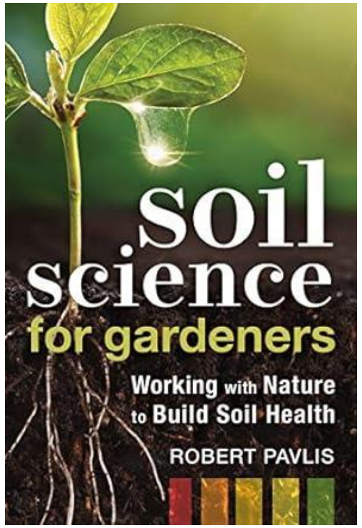
Most of the other nutrients (micronutrients especially) tend to be less available when soil pH is above 7.5, and in fact are optimally available at a slightly acidic pH; 6.5 to 6.8. The exception is Molybdenum (Mo), which appears to be less available under acidic pH levels and more available at moderately alkaline pH levels.



Plant Nutrient Toxicity

As soil pH drops, availability of Magnesium and Calcium declines while Manganese availability increases, often to toxic levels. Below pH of 5.2, the chemistry of the soil changes and Aluminum is released into the soil solution at increasing levels, further acidifying the soil. This “Free Aluminum” also is very harmful to plant roots because Aluminum interferes with Calcium, it can bind with Phosphorus, and can interfere with cell expansion at root tips, effectively stopping root tip development.

Most of the active mineral nutrient uptake occurs in the region just behind the root tips. Without further root tip growth, nutrient uptake will become limited. Effective rooting volume is also reduced, thus placing the plant under additional stress. In severe cases, plants can die.



Plant Nutrient Toxicity

The primary symptoms of adverse soil pH are similar to those that can occur from nutrient deficiencies or excesses (toxicities). High pH causes chlorosis and bleaching in the veins, pale mottling, and blotchy or marginal necrosis of new growth. Damage is primarily due to reduce availability of minerals, especially Iron, Manganese, and Zinc, so any of the symptoms of those deficiencies may occur in high-pH soils.

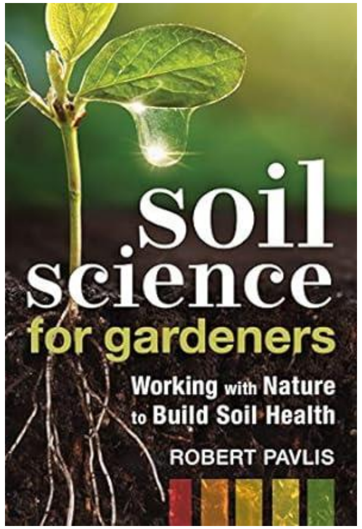
If soil pH is below 5.5, new foliage becomes chlorotic, distorted, and possibly necrotic. Plant growth slows. In severe cases affected roots can become discolored, short, and stubby. Toxicity symptoms result primarily from high levels of Aluminum being released and deficiencies of Calcium and Magnesium. Copper and Manganese toxicity and Phosphorus deficiency symptoms may also occur.

pH and Soil Organisms

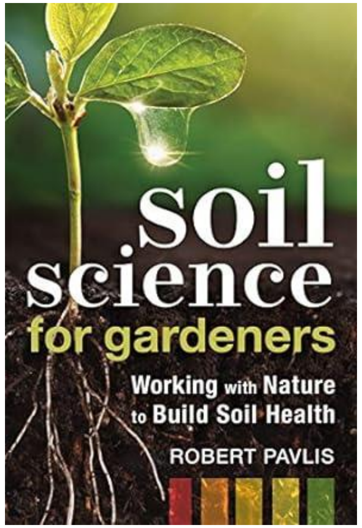
Soil organisms prefer a neutral pH. Earthworms like a pH from 5-7. Fungi prefer an acidic level. Bacteria varies, it can range from 1 to 11.

Soil Health, Naturally

Chapter 2 Plant Nutrients



Understanding Soil Health for Plant Success



Plant nutrients are separated into 2 categories: mineral and non-mineral

- Non-mineral: O, H, C
  - Make up 96% of a plant
- Mineral: N, P, K, Ca, Mg, S & more
  - 4% of a plant's weight
  - 4 sources for mineral nutrients: soil minerals, organic matter, nutrients absorbed onto clay and humus, and the soil solution
    - Not generally available to plants directly

Cellular Respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_20 + 6CO_2 + \textbf{energy}$$

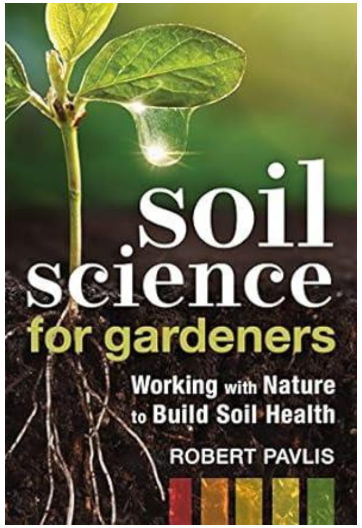
(glucose + oxygen → water + carbon dioxide + energy)

vs

Photosynthesis

$$6\ H_2O + 6\ CO_2 \xrightarrow{\text{Light Energy}} C_6H_{12}O_6 + 6\ O_2$$

(water + carbon dioxide ----ENERGY---> glucose + oxygen)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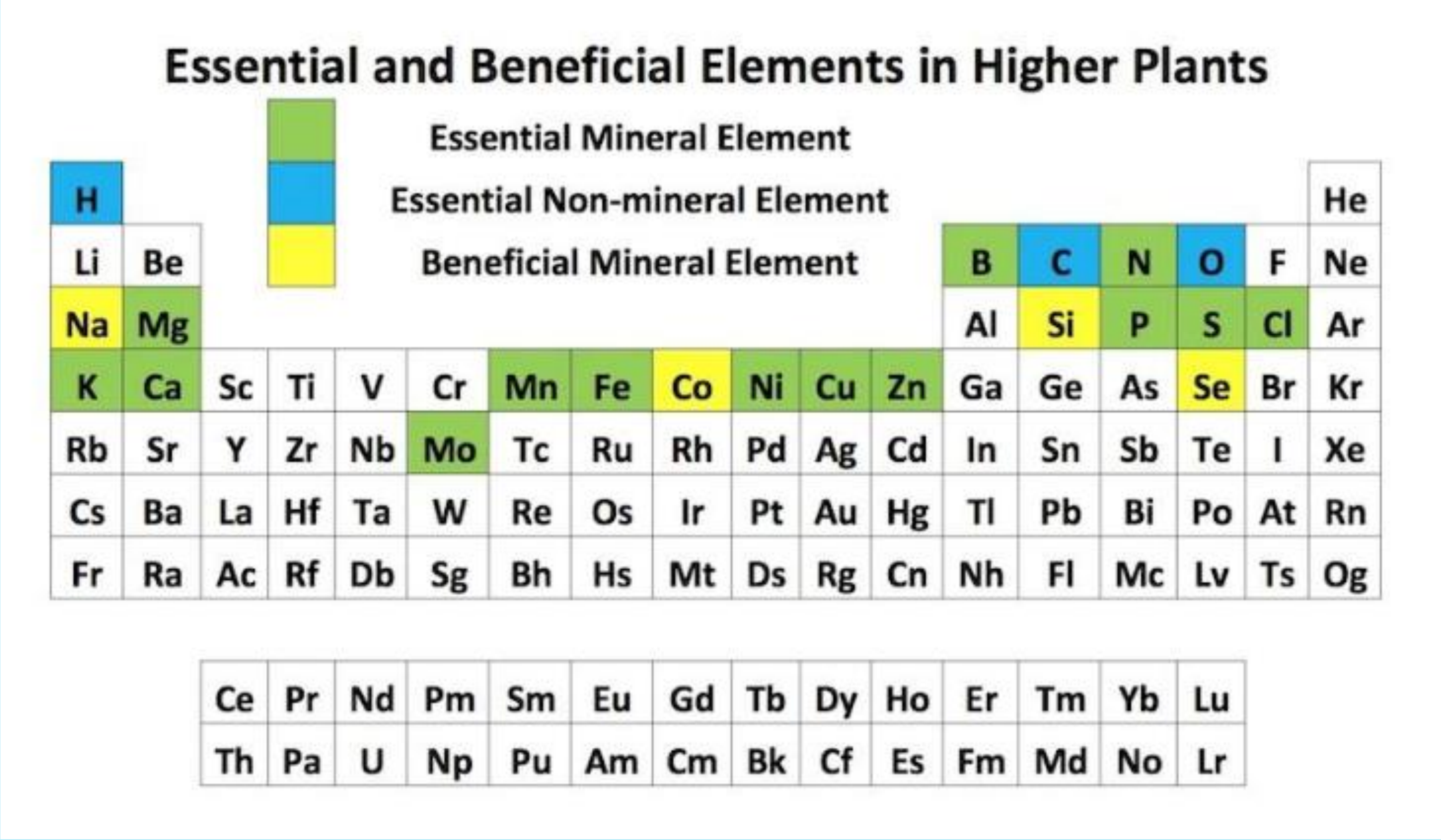
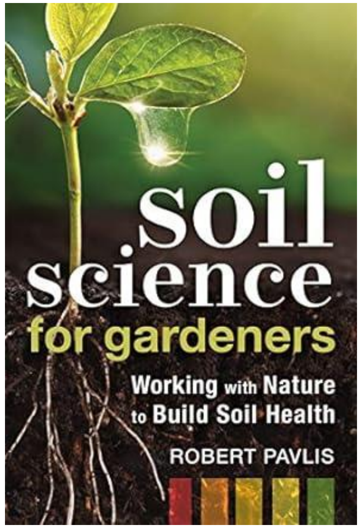
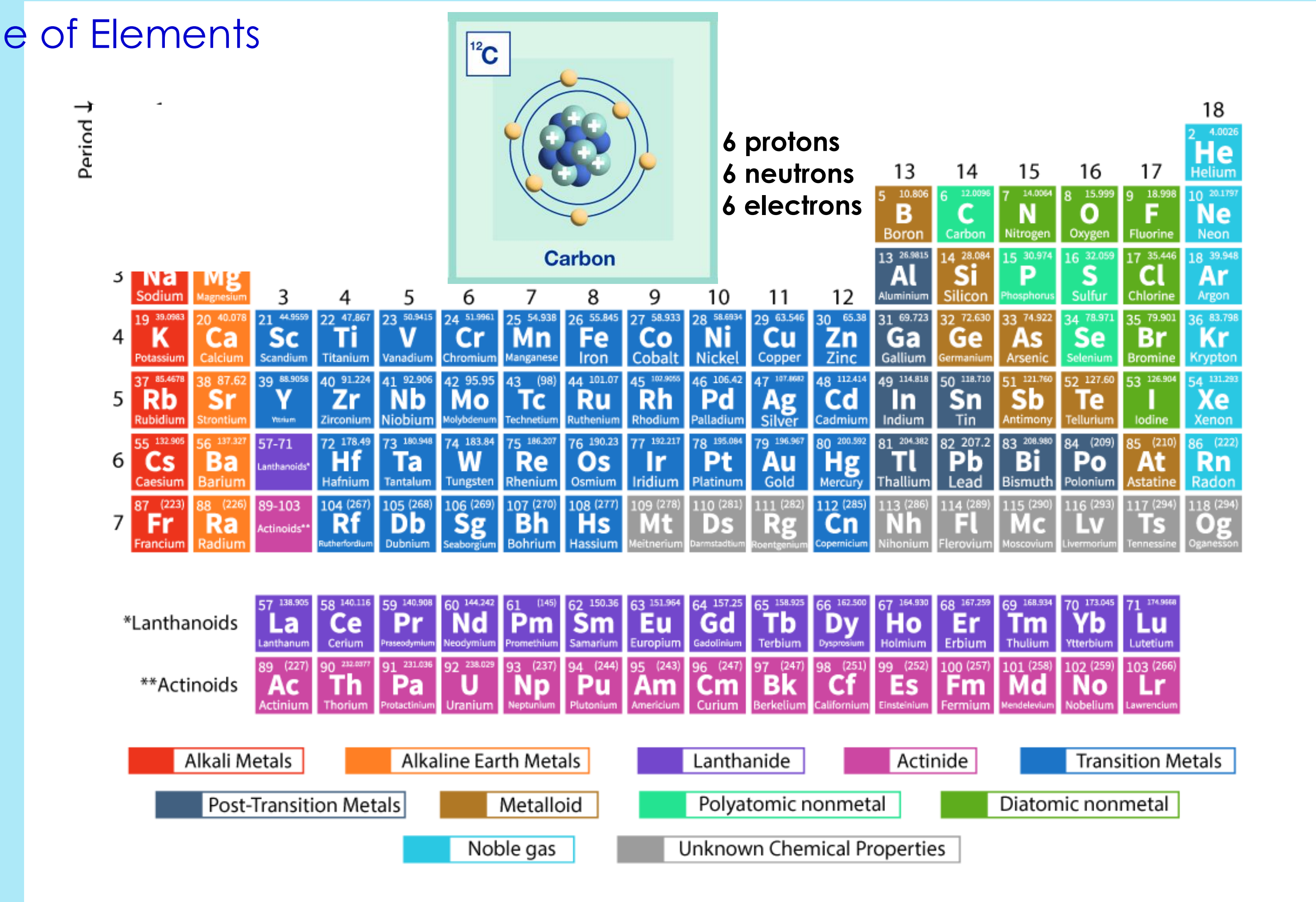
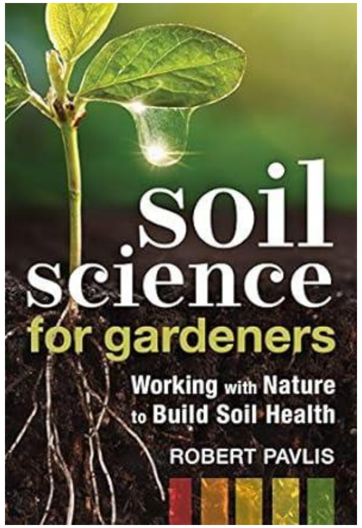

Essential and Beneficial Elements in Higher Plants
Essential Mineral Element
Essential Non-mineral Element
Beneficial Mineral Element
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds Rg Cn Nh Fl Mc Lv Ts Og
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr



Periodic Table of Elements



Soil Health, Naturally



Most plant nutrients are metals and need to be converted into IONS to be used by a plant. These metals interact with other nutrients in the air or soil solution to separate into charged particles (ions).

Ions with a positive charge are cations and ions with a negative charge are anions.

All of the mineral nutrients used by plants form some sort of ion.

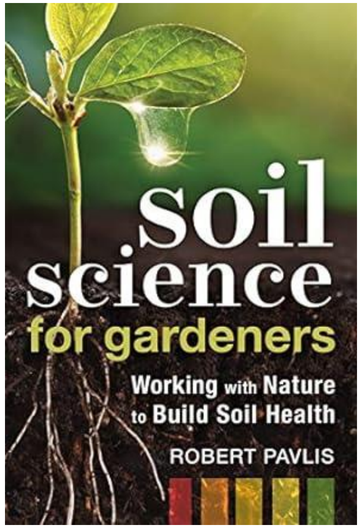
Forms of nutrients taken up by plants

Essential Element	Symbol	Ionic Form
Carbon	C	CO_2
Hydrogen	H	H^+
Oxygen	O	CO_2 , H_20, O_2
Nitrogen	N	NO_3^-, NH_4^+
Phosphorus	P	$H_2PO_4^-$, HPO_4^{2-}
Potassium	K	K^+
Calcium	Ca	Ca^{2+}
Magnesium	Mg	Mg^{2+}
Sulfur	S	SO_4^-

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Plant Nutrients

Soil Health, Naturally



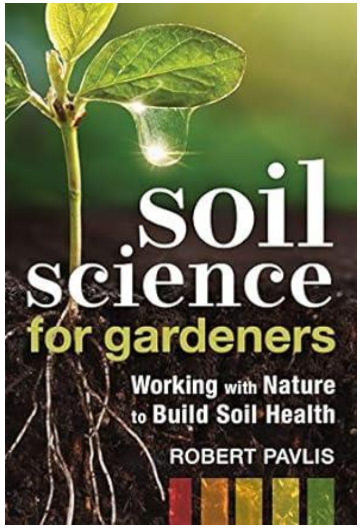
Essential plant nutrients by ionic groups.

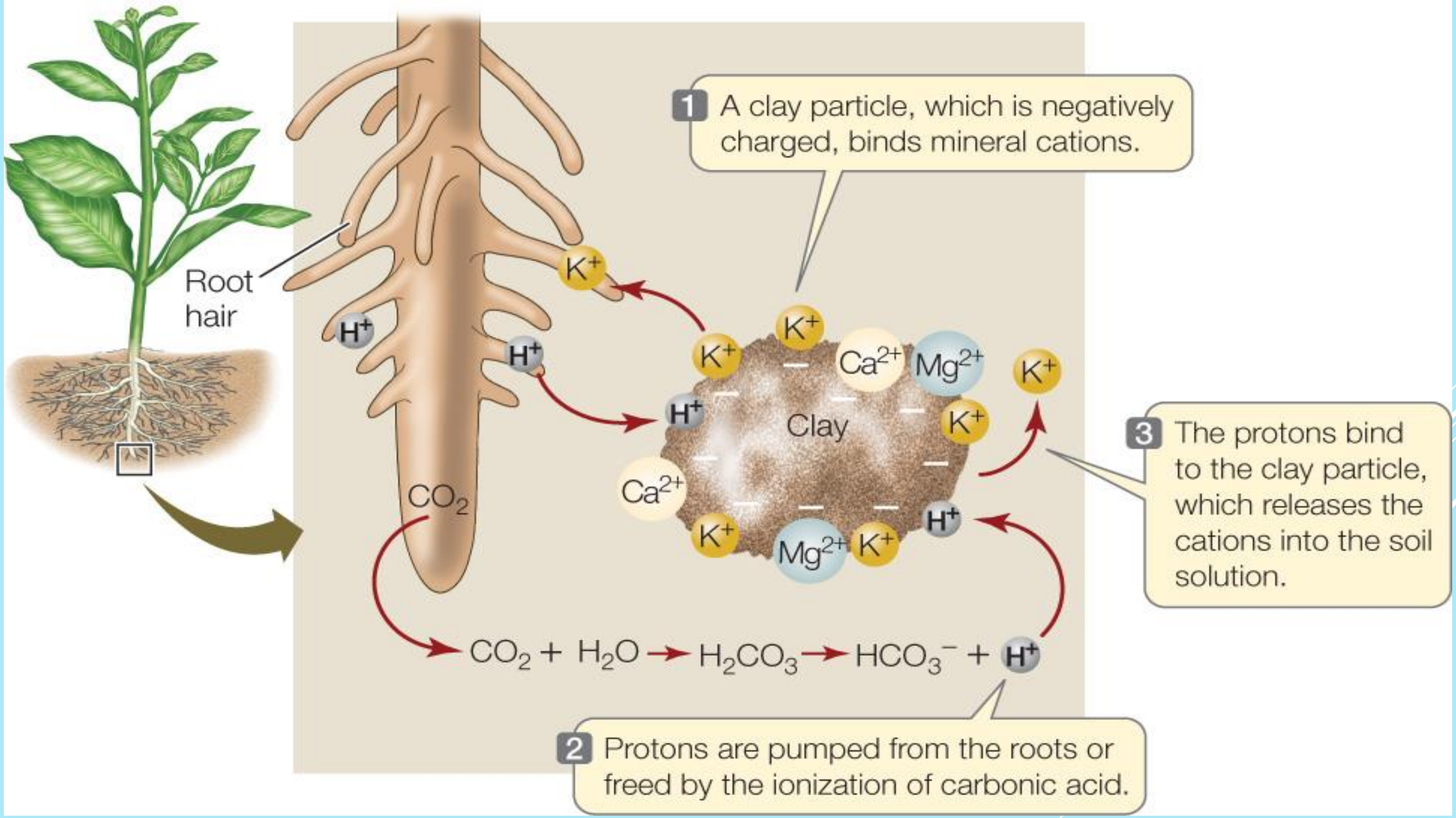
CATIONS			ANIONS		
Element	Chemical Symbol	Plant Available Forms	Element	Chemical Symbol	Plant Available Forms
Nitrogen (Ammonium)	NH_4	NH_4^+	Nitrogen (Nitrate)	NO_3	NO_3^-
Potassium	K	K^+	Phosphorus	P	PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$
Calcium	Ca	Ca^{2+}	Sulfur	S	SO_2, SO_4^{2-}
Magnesium	Mg	Mg^{2+}	Boron	B	H_3BO_3, $B_4O_7^{2-}$
Iron	Fe	Fe^{2+}, Fe^{3+}	Molybdenum	Mo	MoO_4^{2-}
Manganese	Mn	Mn^{2+}	Chlorine	Cl	Cl^-
Zinc	Zn	Zn^{2+}			
Copper	Cu	Cu^+, Cu^{2+}			

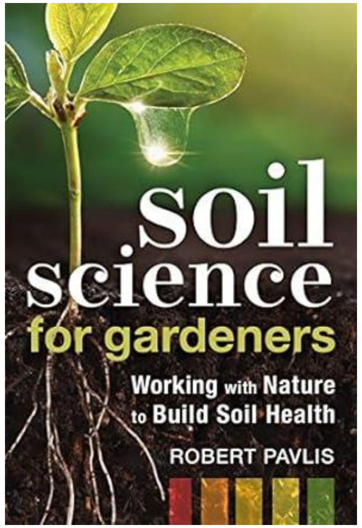
Macronutrients. Micronutrients.

Soil Health, Naturally

Plant Nutrients







What is a salt?

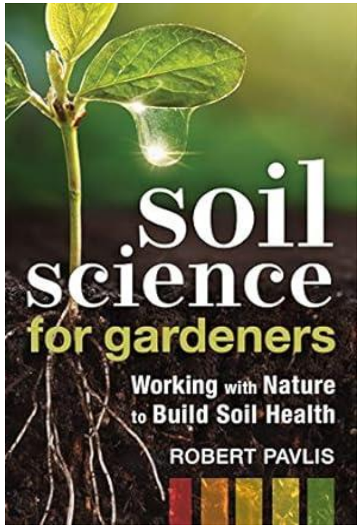
Table salt or road salt releases ions in water. All life including plants, needs some sodium. Just as anything too much is over-kill and can quickly become toxic to plants and microbes.

The harm relates to osmotic pressure.

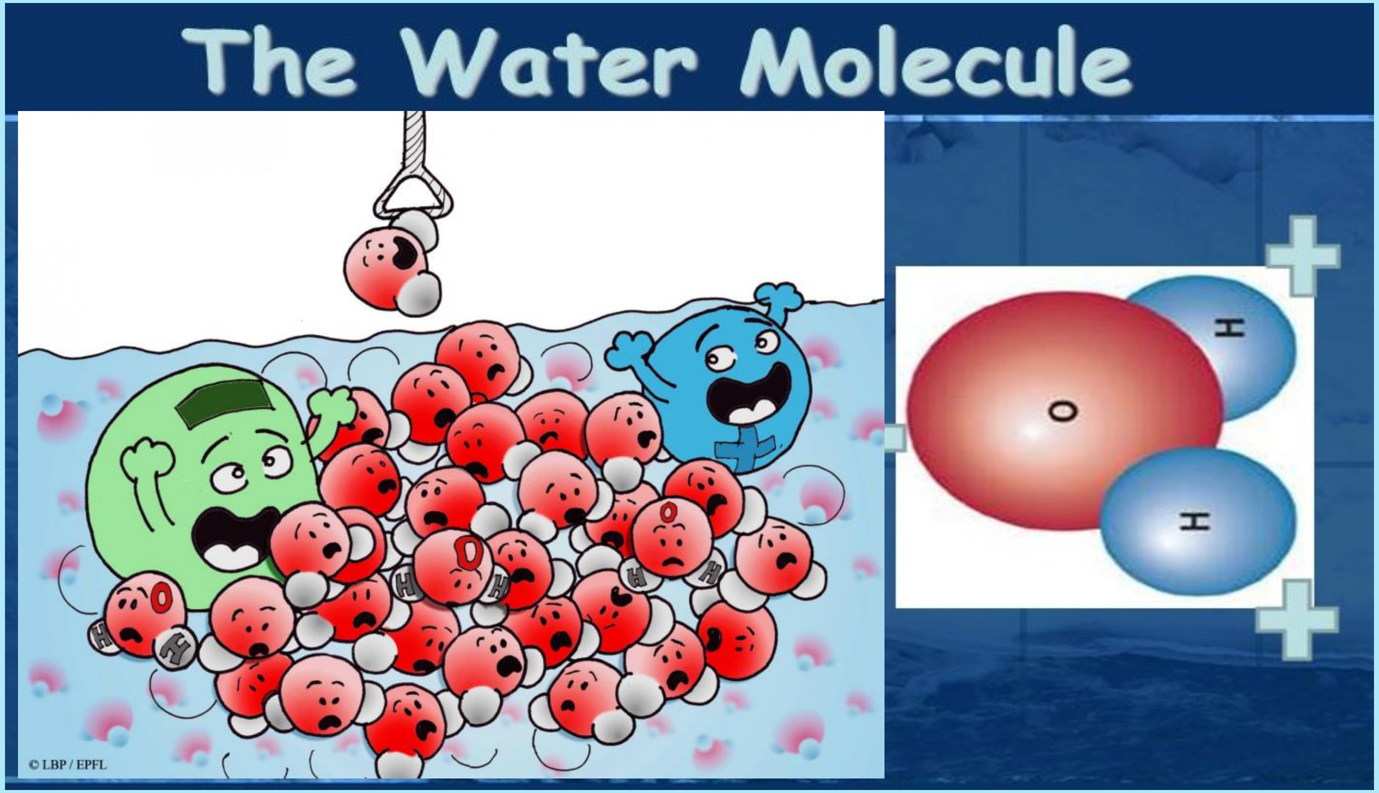
Ions in water act as strong magnets and pull water toward themselves.

If one area has plenty of ions and a neighboring area has very few, water will move from the area with few ions to the one with more.

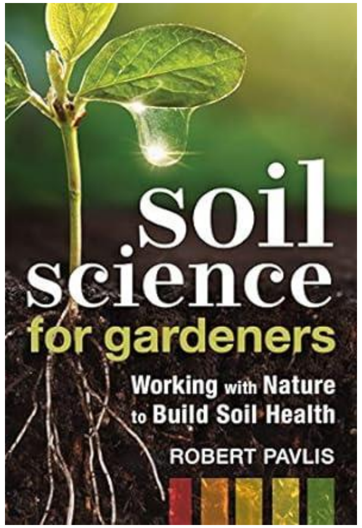
Plants use this to their advantage by keeping a high concentration of ions inside the root which is then transported into the rest of the plant.



The force of positive and negative ions

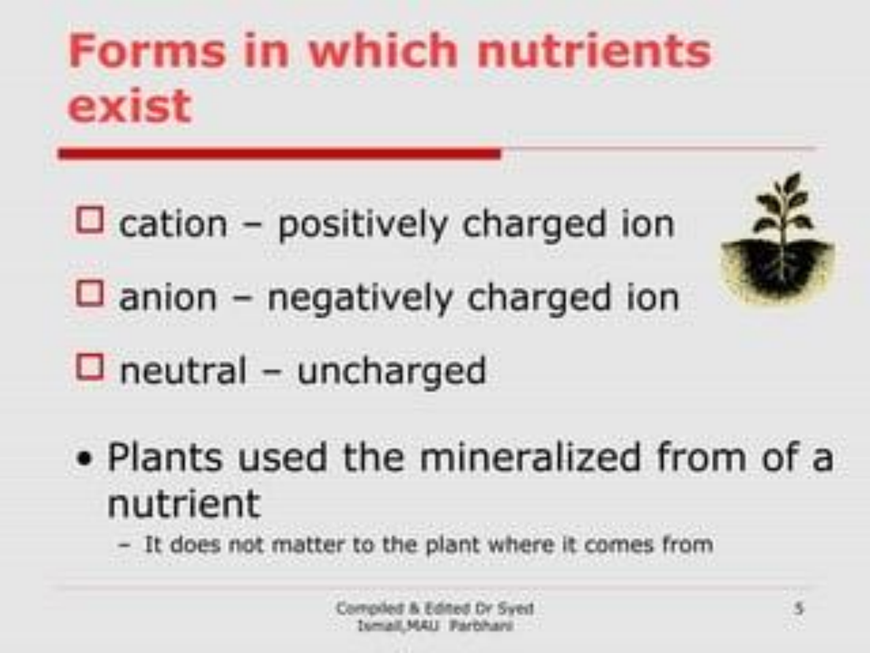


One single ion can impact a million water molecules.



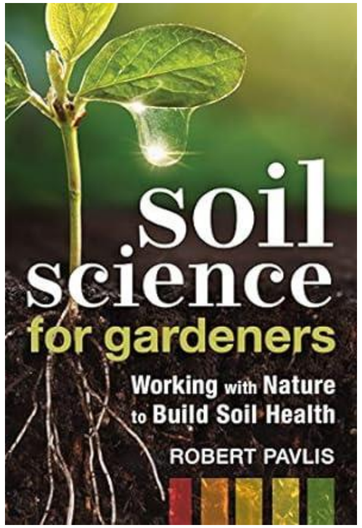
What is a salt?

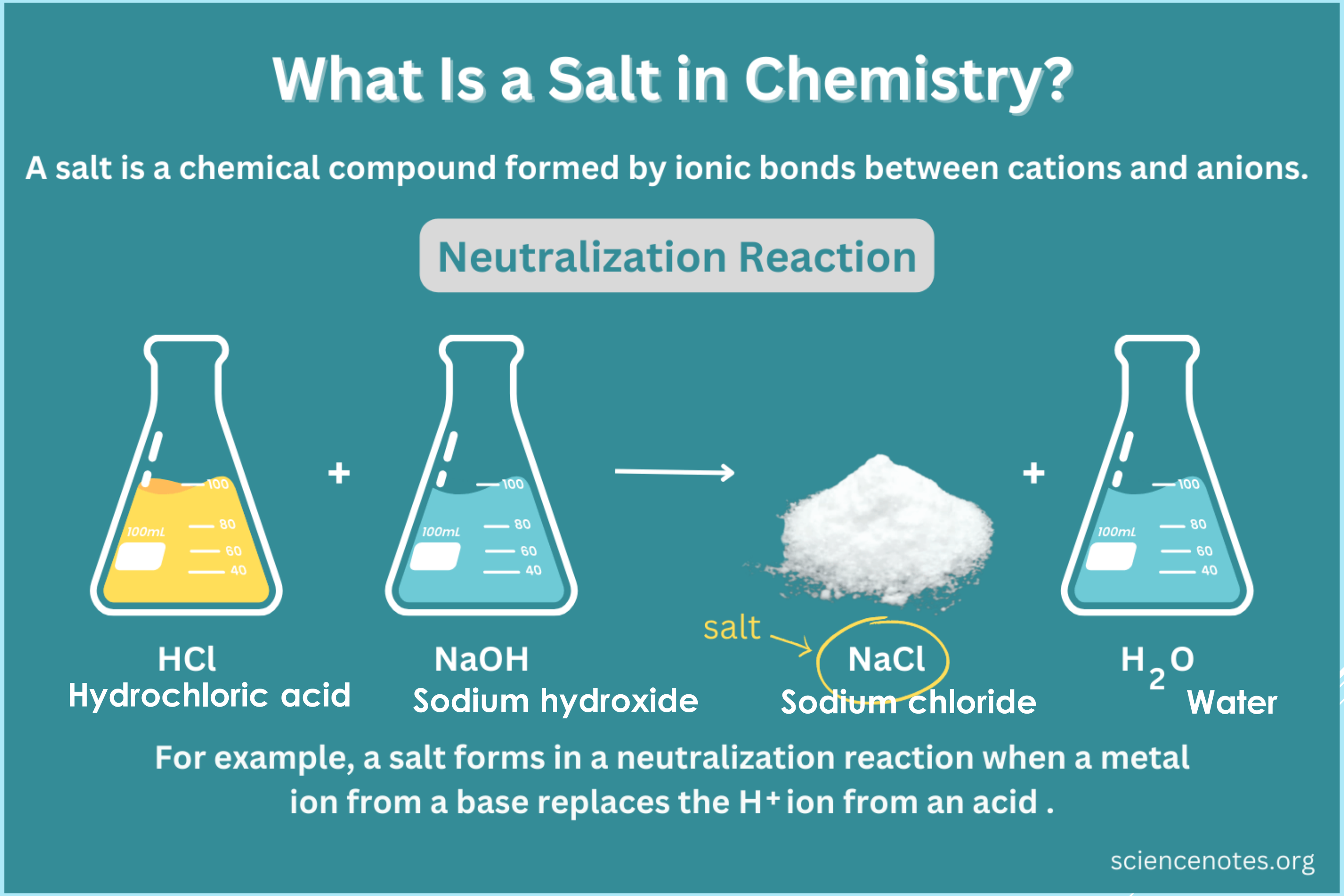
Chemist, soil scientist and this book refers to salt as "any compound made up of ions."



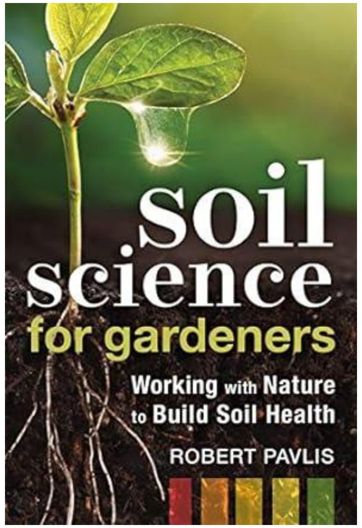
Plant Nutrients

Soil Health, Naturally

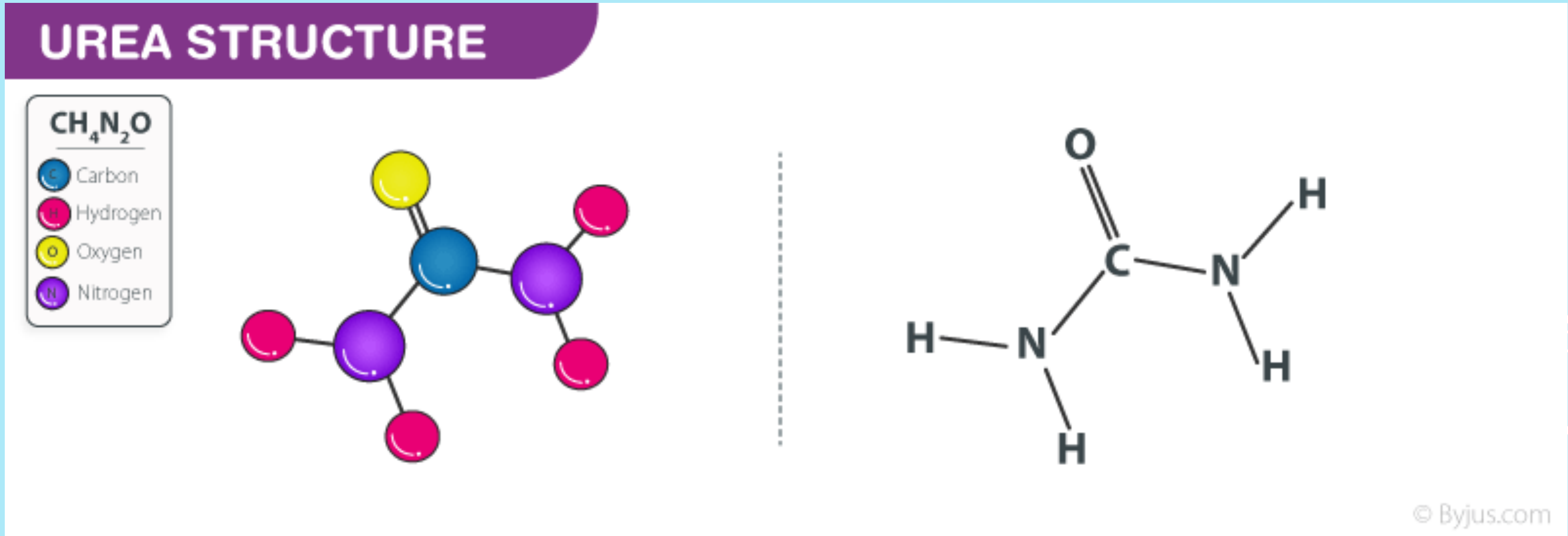




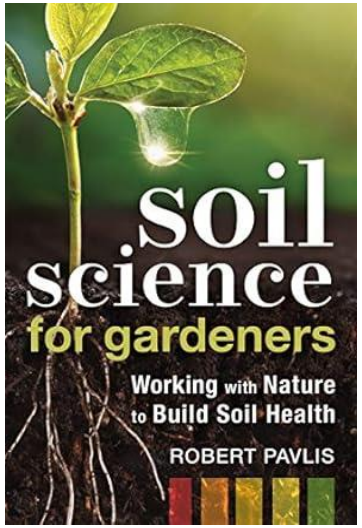
Soil Health, Naturally



Chemical compounds such as ammonium nitrate and potassium phosphate, found in synthetic fertilizers, are also salts.
Urea is an organic molecule made up of carbon, hydrogen, oxygen and nitrogen. It does NOT form ions in water, it is NOT a salt.

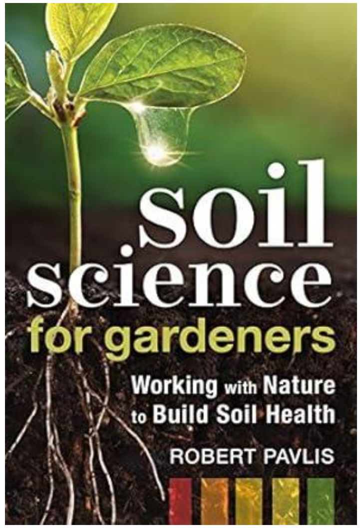


Soil Health, Naturally



Many believe that the salts in synthetic fertilizers harm soil life. Actually, they dissolve in water forming ions, exactly as ions released from organic materials like manure or compost. It is an essential element for soil microbes and plant life.

Used in appropriate amounts, salts do not harm soil life.



When too much fertilizer is used the salts in the fertilizer are released as ions making the concentration of ions outside the roots higher than the inside.

Because of the strong magnetic bond water then flows from inside the root out in the soil solution.

With this loss of water the plant experiences drought-like conditions and the upper leaves will start to dry out.

MOVEMENT OF NUTRIENTS IN SOIL

- Begin by understanding that all nutrients have a charge: All are either Cations(+) or Anions(-).
- Nutrients move through the soils in the soil solution.

In Sand and Silt Soils

These Have little or no electrical charge

* Nutrient ions don't bond to these soil types

*Nutrient ions run readily thru these soil profiles

In Clay and Organic Soils

These have high amount of electrical charge

* Nutrient ions bond strongly with these soil types

* Nutrient ions aren't readily replaced with leaching water but can be replaced by ions that soils have a stronger affinity for ie: Ca verses Na

ESSENTIAL PLANT NUTRIENTS

- Essential is defined as nutrients that the plant needs to survive.

Two major groups:

1st: Carbon, Oxygen & Hydrogen: obtained by air and water

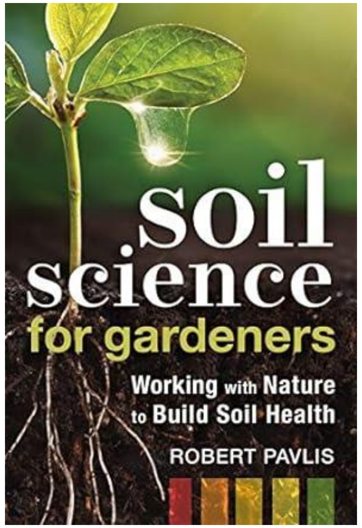
2nd: N,P,K,Ca,Mg,S,B,Cl,Zn,Cu,Mn,Mo: obtained mostly from roots. The exception is in agricultural settings, thru the foliage.

Macros and Micros

Macronutrients: Use in large amounts in plants: N,P,K Ca, Mg, S

Micronutrients or (trace minerals): Used in much smaller amounts in plants.

These include: B, Cl, Cu, Fe, Mn, Mo, Zn and a debatable group Ni,Cl,Co,Si.



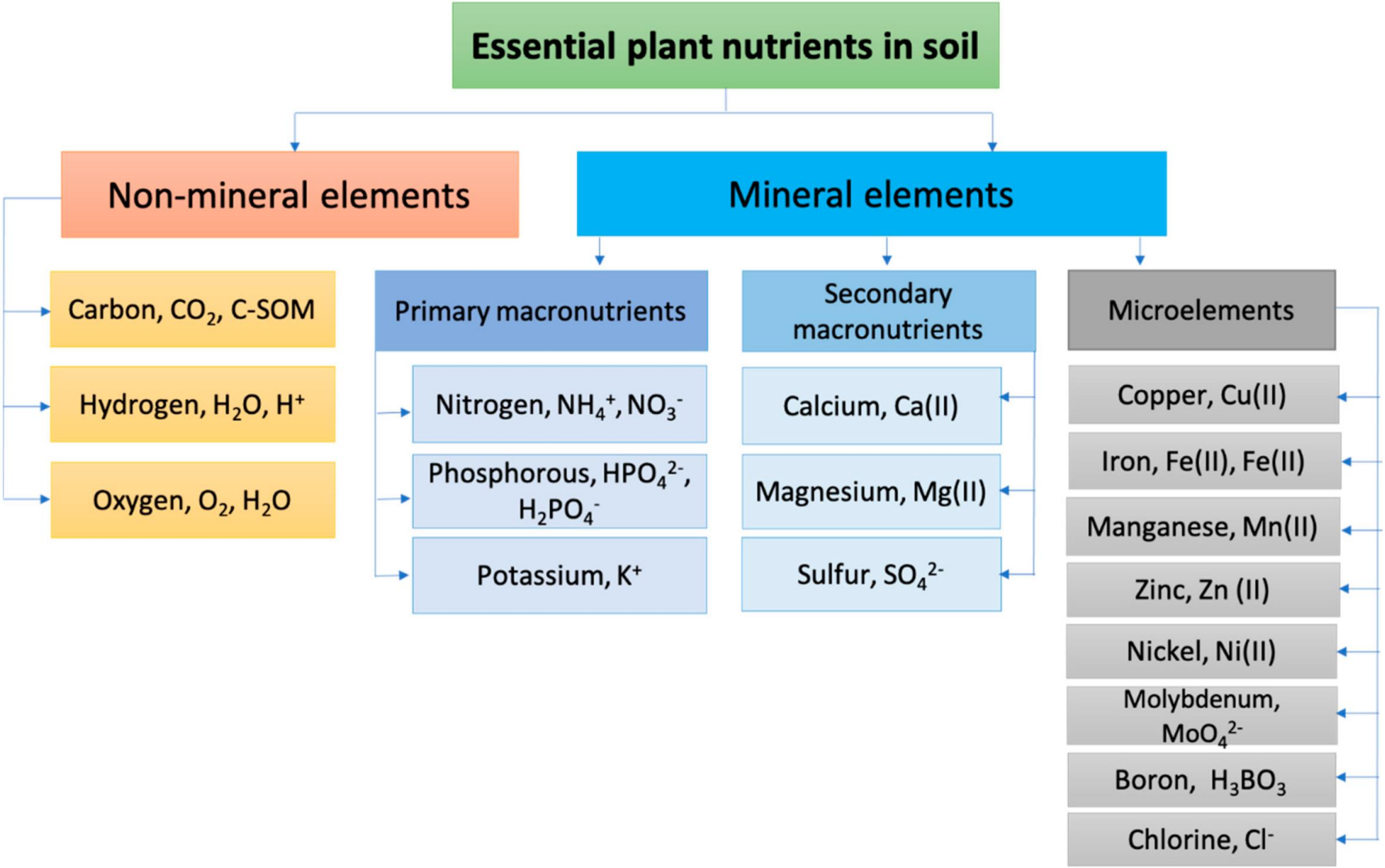
Organic or Synthetic: Which source is best?

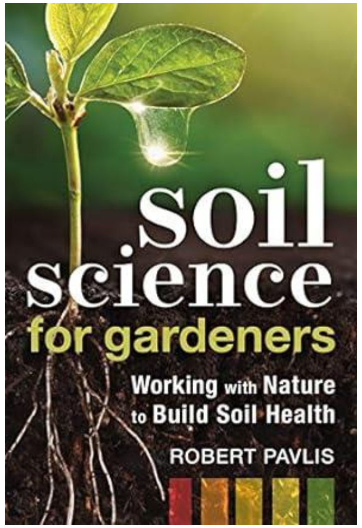
<u>Organic Sources</u>
Manures, compost etc.
Slowly decomposes to
nitrate ions

<u>Synthetic Sources</u>
Synthetic fertilizers
Ammonium nitrate dissolves
into nitrate ions

Nitrate Ions

Nitrate ions are absorbed into plant root


Essential plant nutrients in soil
Non-mineral elements
Mineral elements
Carbon, CO_2, C-SOM
Hydrogen, H_2O, H^+
Oxygen, O_2, H_2O
Primary macronutrients
Nitrogen, NH_4^+, NO_3^-
Phosphorous, HPO_4^{2-}, $H_2PO_4^-$
Potassium, K^+
Secondary macronutrients
Calcium, Ca(II)
Magnesium, Mg(II)
Sulfur, SO_4^{2-}
Microelements
Copper, Cu(II)
Iron, Fe(II), Fe(II)
Manganese, Mn(II)
Zinc, Zn (II)
Nickel, Ni(II)
Molybdenum, MoO_4^{2-}
Boron, H_3BO_3
Chlorine, Cl^-

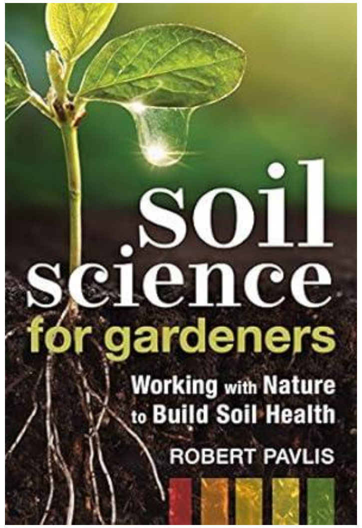


Nitrogen – is the most abundant nutrient in plants. It is important for building Enzymes.

Enzymes are special Proteins, they contain Nitrogen = energy.

Enzymes cause chemical reactions and controls a plant photosynthesis process.

Nitrogen can be found in the plants DNA, RNA (where cells message each other) and in Chlorophyll.

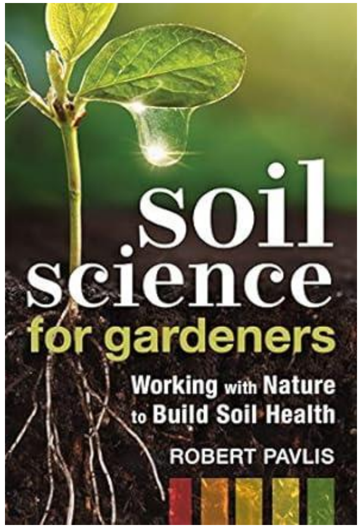


The forms of Nitrogen that are readily available for plant use are – Ammonium and Nitrate.

The main functions of Nitrogen in plants:

Nitrogen is essential for Amino Acids. Amino Acids build up proteins. Nitrogen is also a component of Nucleic Acids, which form the DNA of all living things and holds the genetic code.
Nitrogen is a component of Chlorophyll, which is the site of carbohydrate formation (Photosynthesis). Chlorophyll gives plants their green color.

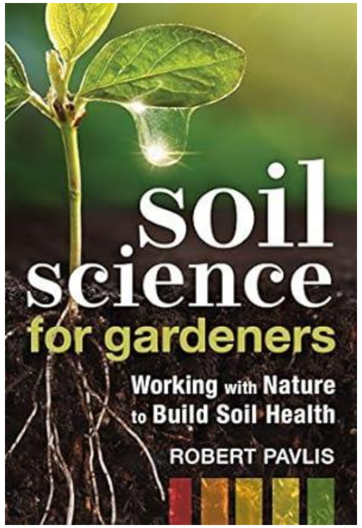
- Photosynthesis occurs at high rates when there is sufficient nitrogen.
- A plant receiving sufficient nitrogen will typically exhibit vigorous plant growth. Leaves will also develop a dark green color.



Most common types of Nitrogens for plant use:

Ammonium (NH_4) – Taken in by plants and used directly by proteins. This nitrate form stays in the soil. NH_4 converts best to a nitrate form when – soil temps are around 80F, 50% Moisture in the soil and the soil pH is near 7. Conditions unfavorable for making nitrates: a soil pH below 5.5, a waterlogged moisture condition, and temperatures under 40F.

Ammonia (NH_3) – is a gas, when compressed into a liquid form it can be injected into the soil and with the soil moisture it turns into NH_4. Then that NH_4 can attach itself to clay & organic matter for use.

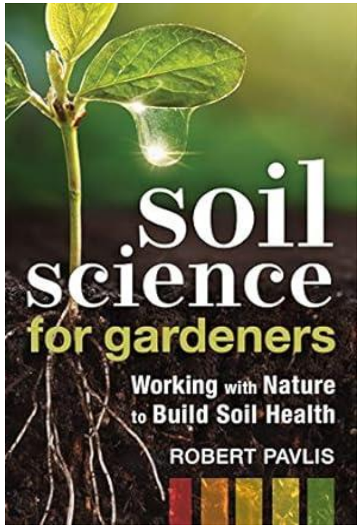


Types of Nitrogens continued:

Nitrate (NO_3) – used by plants for growth and development. Nitrates can be lost through water movement, leaching.

Dinitrogen (N_2) – makes up 78% of the Atmosphere, but cannot be used by plants as is. Nitrification is needed to convert this form into Ammonium.

Urea (CH_4N_2O) – usually undergoes a three-step change before it is taken up by plants. 1st – enzymes in the soil or plant convert the Urea to Ammonia. 2nd, the Ammonia reacts with soil water to form Ammonium. And 3rd, through the action of soil microorganisms, the Ammonium is converted to Nitrate for plant uptake. If not converted, it can be lost through leaching.

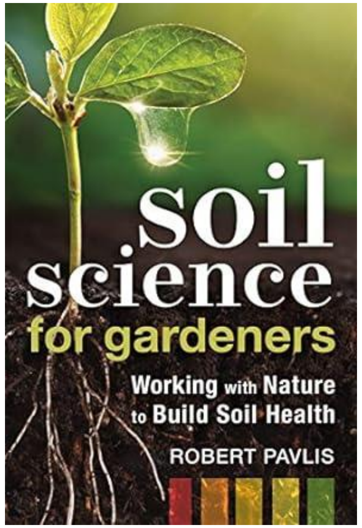


Urea (46-0-0) is what? Organic or Inorganic?

Urea is made in the reaction of carbon dioxide with anhydrous ammonia and is inorganic fertilizer, but chemically is organic material. Urea is synthetic Organic fertilizer because its chemistry contains carbon, hydrogen, and oxygen (CH_4N_2O). So, on the basis of its chemical composition (having carbon) it is organic fertilizer.

What about NutriSphere-N? Coated onto a 46-0-0 prill? Yes or No?

It is a water-soluble organic compound, created from fermentation of maize. It also breaks down in the soil to carbon, hydrogen and oxygen.

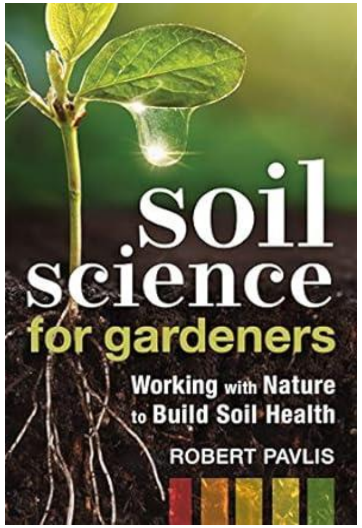


What about NITROFORM™ 38-0-0: Is it Organic?

Simplot says yes, but is it?

There 38-0-0 label reads:

NITROFORM is a non-burning form of slow-release **organic** nitrogen produced by combining urea and formaldehyde under controlled manufacturing conditions. It is **released by soil micro-organisms**, the nitrogen is available during the plant growth cycles when organisms are most active. It contains 71% of its nitrogen as slow-release.



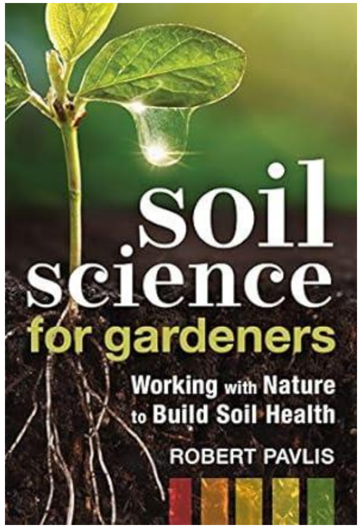
What about NUTRALENE 40-0-0? Is it Organic?

It is not a true Organic, but it is considered to be a “synthetic organic”, because of its covalent carbon bond (the sharing of electrons or molecular bonds) that benefits soil microbes.

So, if the Nitrogen benefits soil microbes, is it organic?

Are Biosolids an organic nitrogen source? Milorganite?

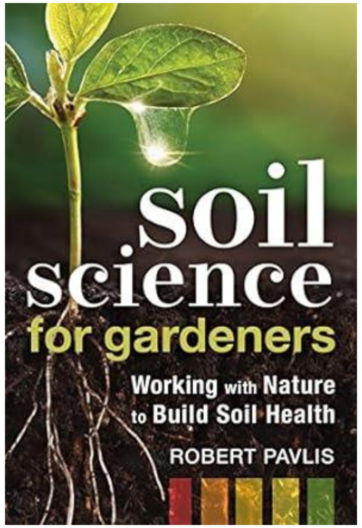
They are not a clean source/product, so no.



Nitrification is the process by which ammonia (NH_3) or ammonium ($NH4^+$) is converted to nitrate (NO_3^-).

Nitrification is the net result of two distinct processes: oxidation of ammonium to nitrite (NO_2^-) by nitrosifying or ammonia-oxidizing bacteria and oxidation of nitrite (NO_2^-) to nitrate (NO_3^-) by the nitrite-oxidizing bacteria.

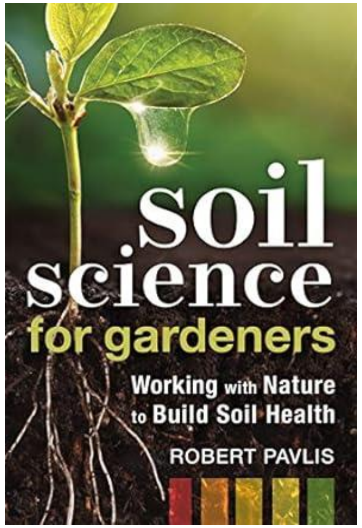
Nitrification is an important step in the nitrogen cycle in soil. Nitrification is an aerobic process performed by small groups of autotrophic bacteria and archaea.



Plant readily available Nitrogen is only about 3% in soils. The rest is tied up as living or dead organic matter.

Nitrate & Nitrite are both anions with a Negative charge.
Ammonium is a cation with a Positive charge.

Ammonium will stick to negatively charged clay and organic matter material therefore slowing down leaching and for this reason Ammonium is a good Nitrogen source for most plants.



Pansies & Petunias like what kind of Nitrogen?

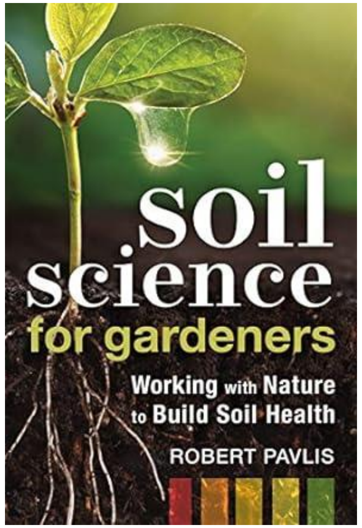
Not ammoniacal. That makes them too juicy, too leafy. Nitrate based blends are received better. They like lower pH blends with slow release.

What about Nitrogen for trees & shrubs?

Research in woody plant nutrition has shown that Nitrogen is the element that yields the greatest growth response in trees and shrubs. Go with slow release N's.

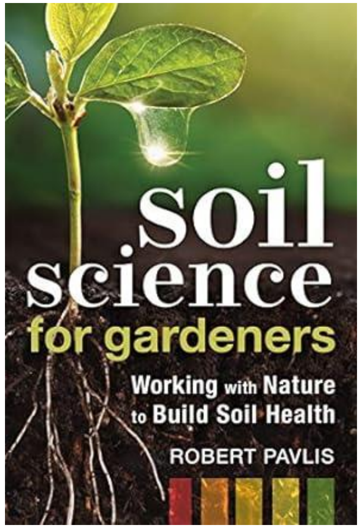
Look at each product label and you'll see what Nitrogen's are in play.

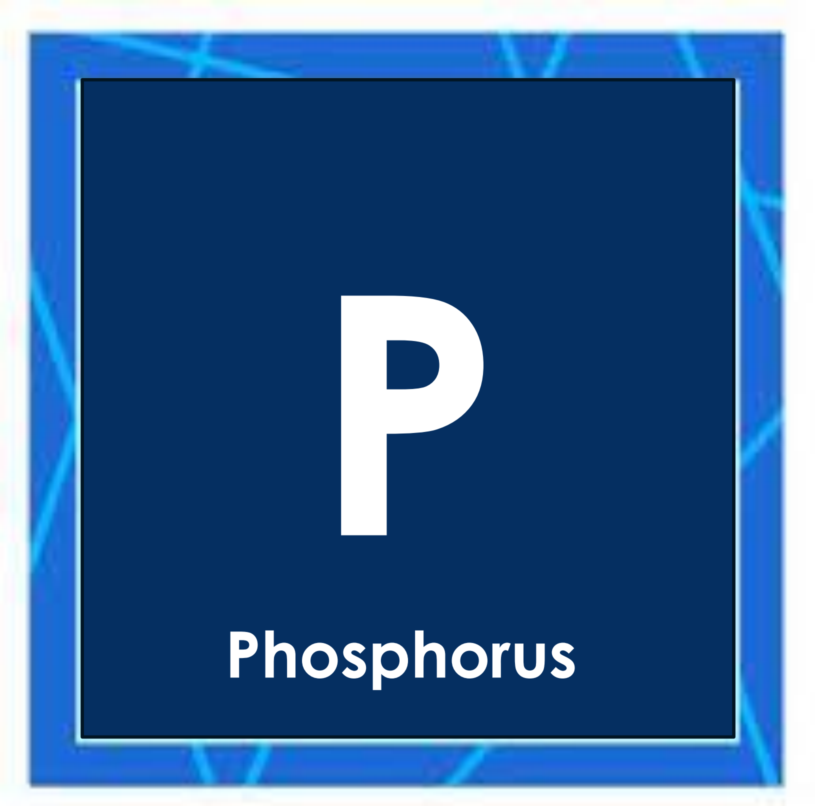
Soil Health, Naturally



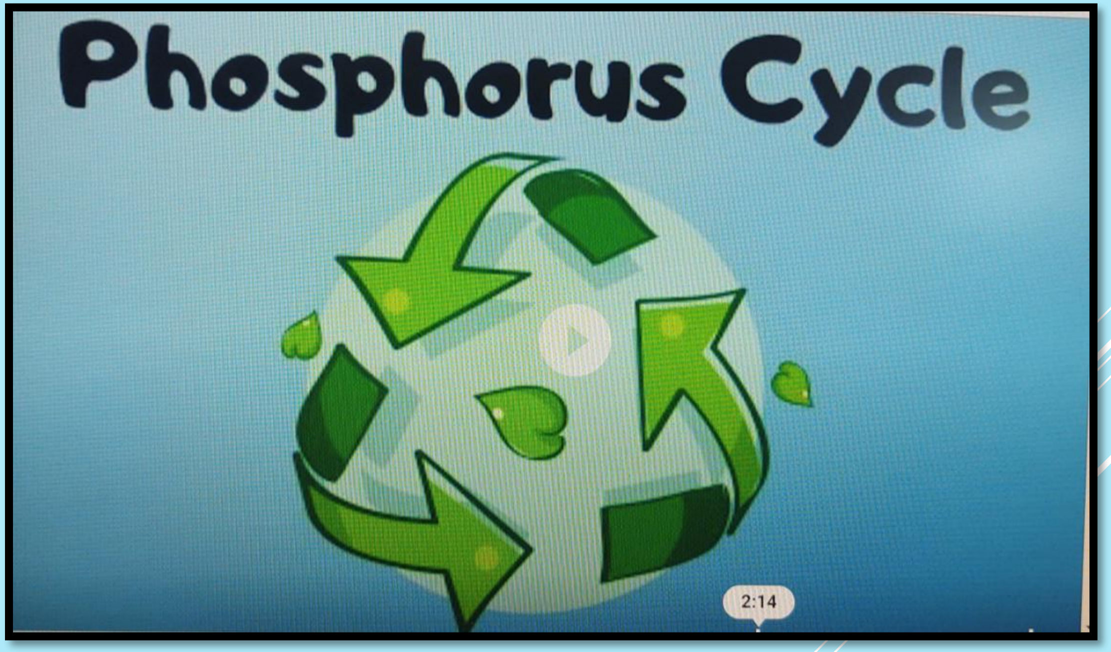
Animal manures contain both organic and inorganic forms of phosphorus. When manure mineralizes, organic phosphorus becomes inorganic phosphorus in solution and is available to plants. Some organic phosphorus is transformed to inorganic form shortly after application but other phosphorus will remain in organic form. Soil organic phosphorus consists of labile and stable fractions. The labile fractions will be mineralized after a short time while the stable fractions may remain in organic form for years.

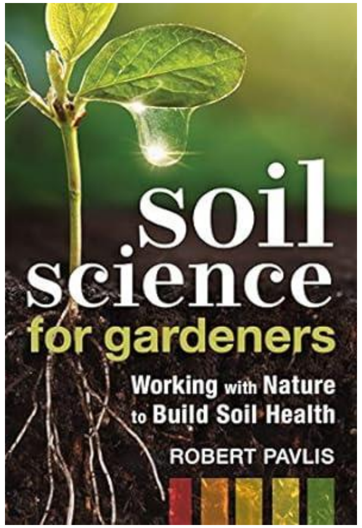
Soil Health, Naturally

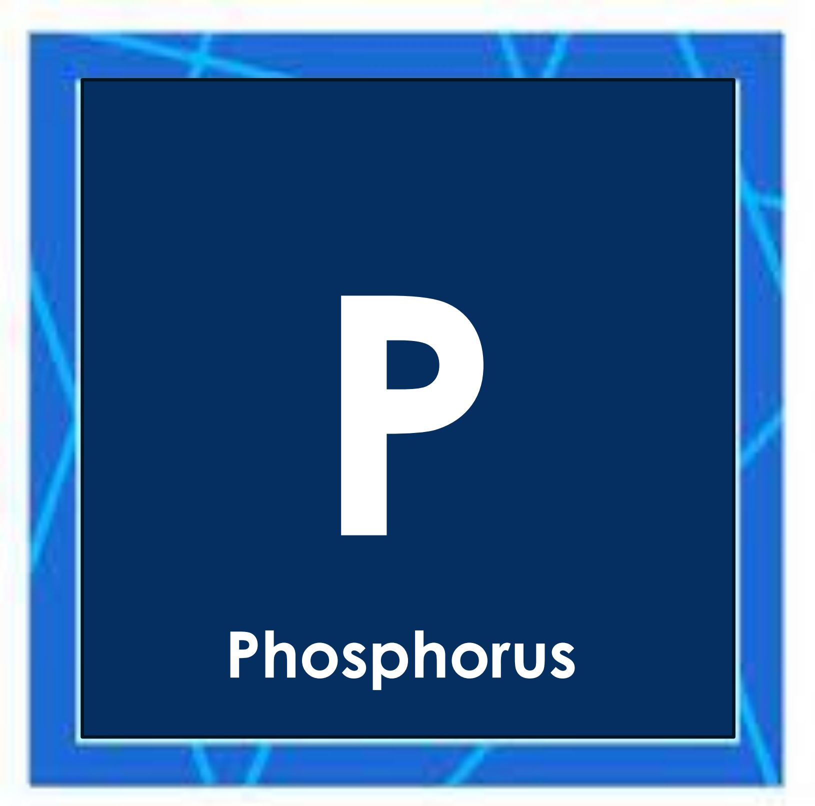




https://www.youtube.com/watch?v=Wzo-uFS7LUA







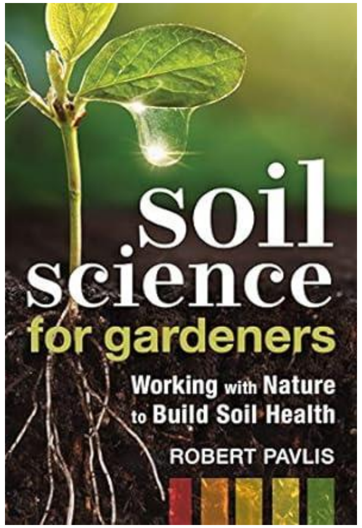
Origin

Naturally derived from dissolved rock commonly known as rock phosphate.

The main mining regions are the Middle East, China and the United States.

Two basic forms exist in the soil

- **Free phosphorus**
- **Tied up phosphorus** from dead and living organic matter

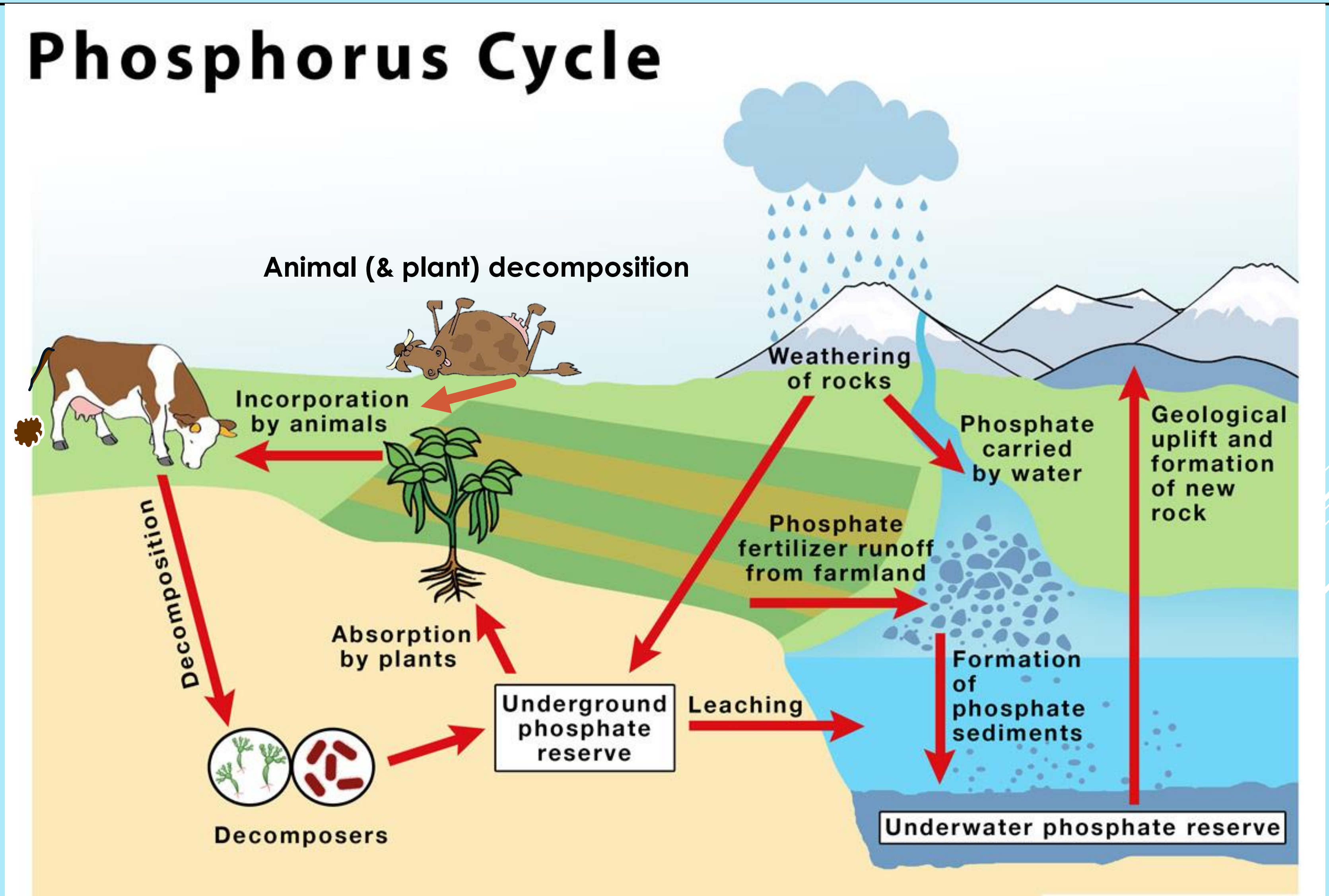


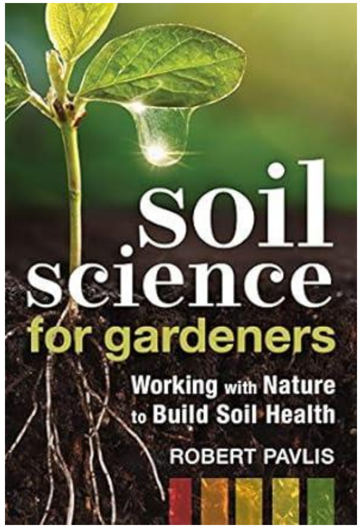
Key Functions

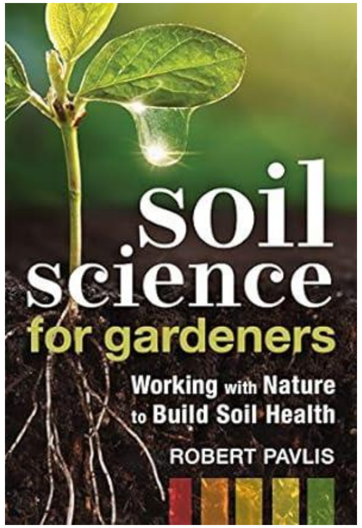
- Plant growth & development
- Bloom set, seed germination
- Captures, stores and converts energy
- A component of ATP, phospholipids & nucleotides
- Formation of cell wall structure
- Drives Photosynthesis
- Regulates metabolism
- Transformation of sugars and starches
- Nutrient movement
- Generational genetic transfer-DNA RNA

Soil Health, Naturally

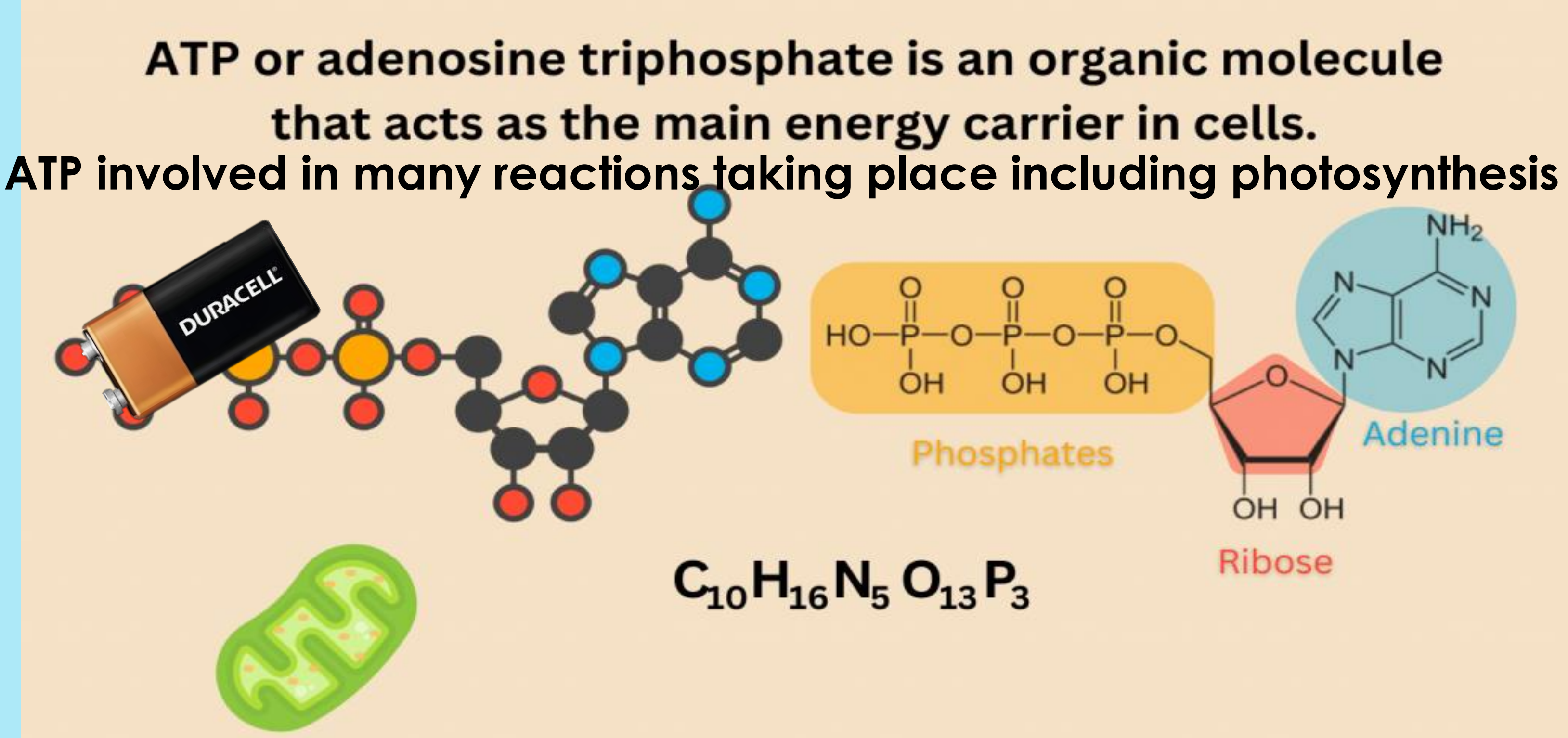
Plant Nutrients

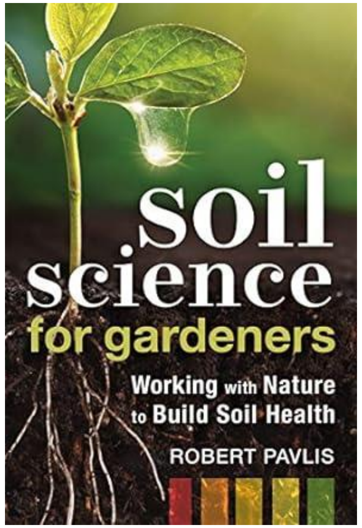


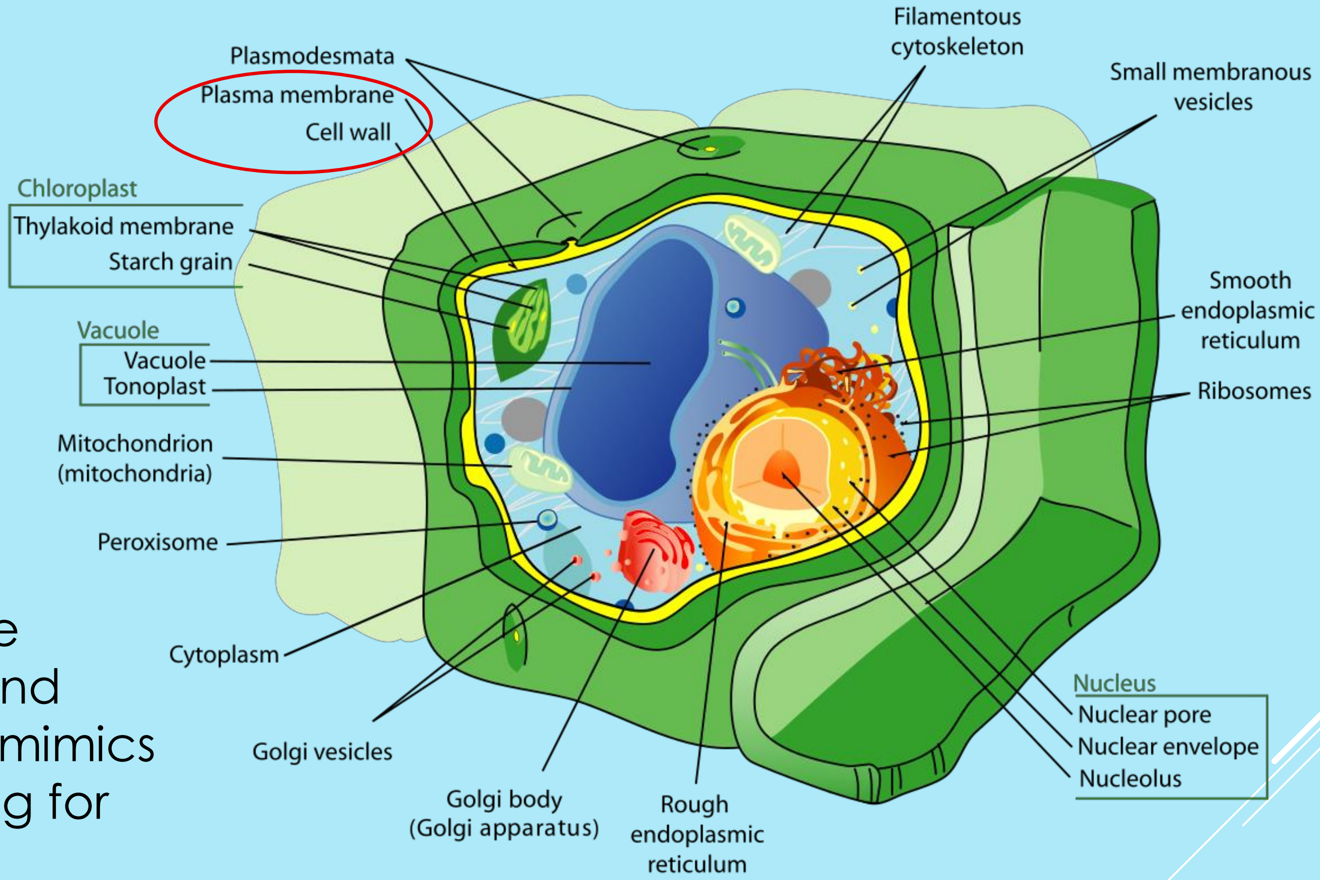




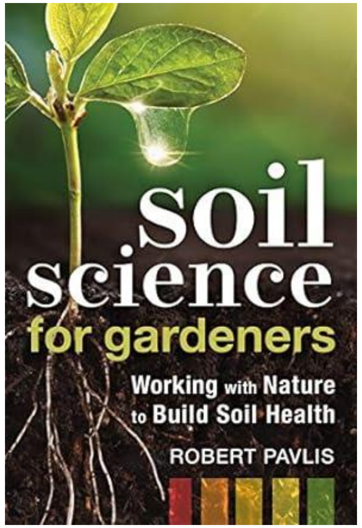
Adenosine triphosphate (**ATP**) is the source of energy for use and storage at the cellular level. The structure of ATP is a **nucleoside triphosphate**, consisting of a nitrogenous base (adenine), a ribose sugar, and three serially bonded phosphate groups.

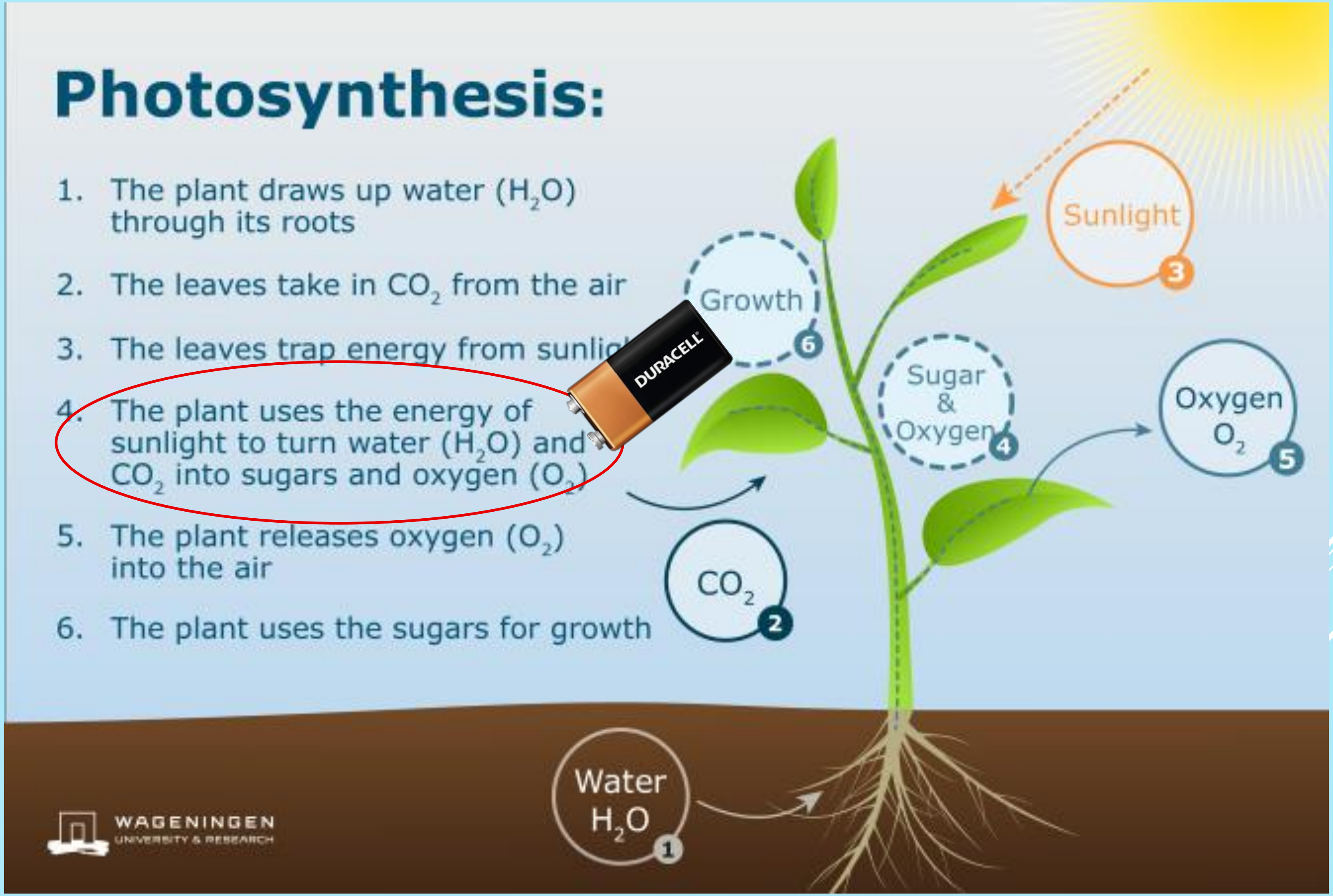




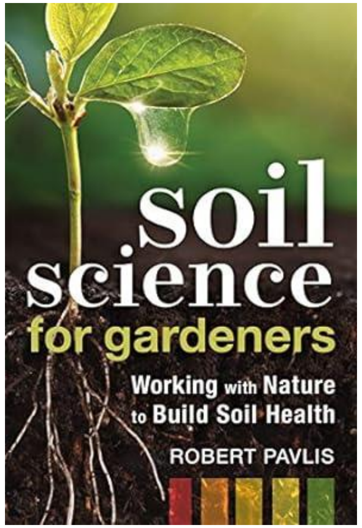


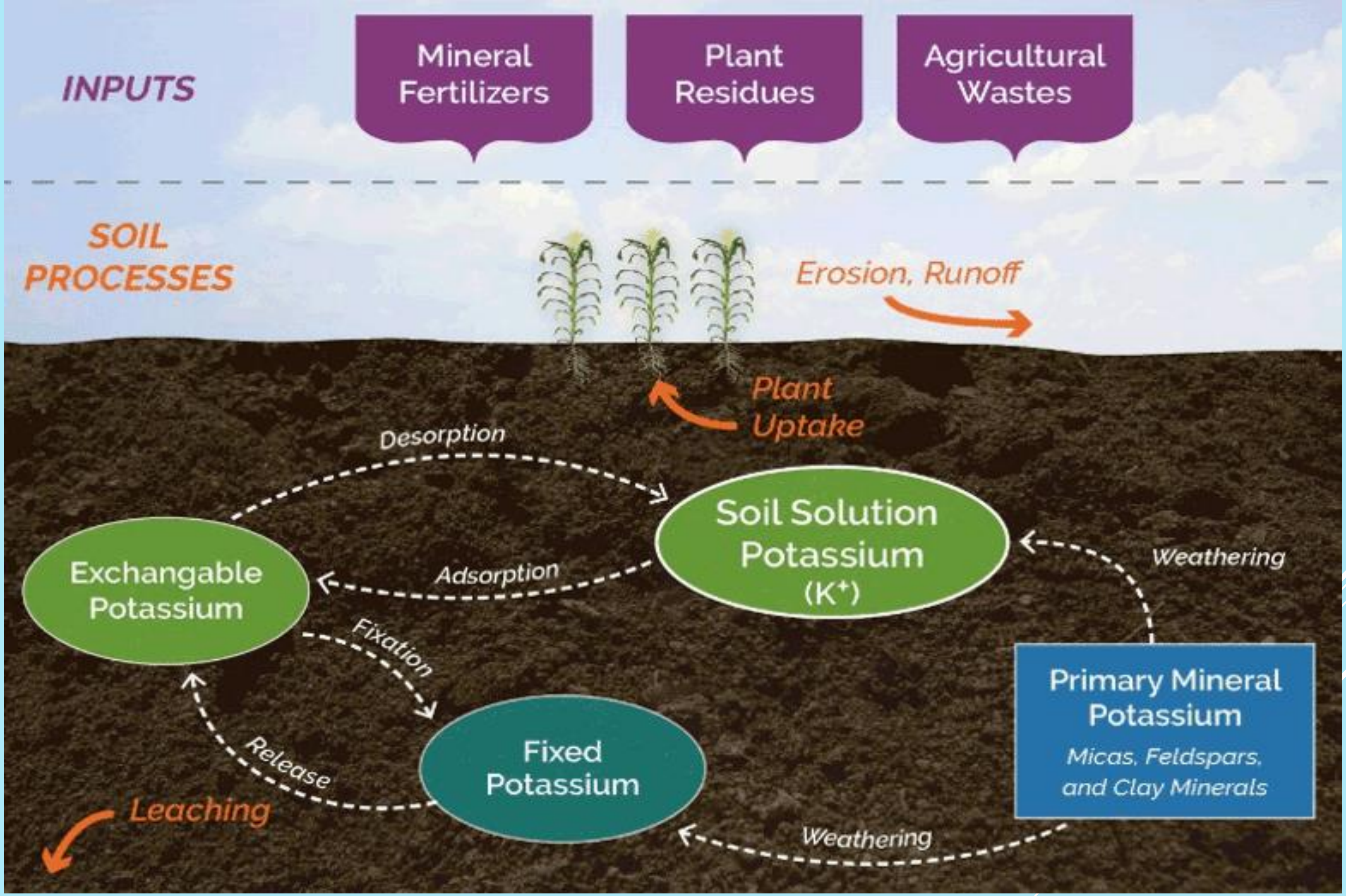
Cell walls are like the walls of a building and the cell membrane mimics the hallways allowing for passage.


soil science
for gardeners
Working with Nature to Build Soil Health
ROBERT PAVLIS

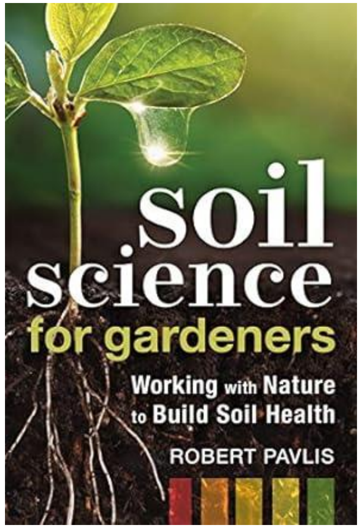

Photosynthesis:
1. The plant draws up water (H_2O) through its roots
2. The leaves take in CO_2 from the air
3. The leaves trap energy from sunlig
4. The plant uses the energy of sunlight to turn water (H_2O) and CO_2 into sugars and oxygen (O_2)
5. The plant releases oxygen (O_2) into the air
6. The plant uses the sugars for growth
DURACELL
Sunlight 3
Growth 6
Sugar & Oxygen 4
Oxygen O_2 5
CO_2 2
Water H_2O 1
WAGENINGEN
UNIVERSITY & RESEARCH

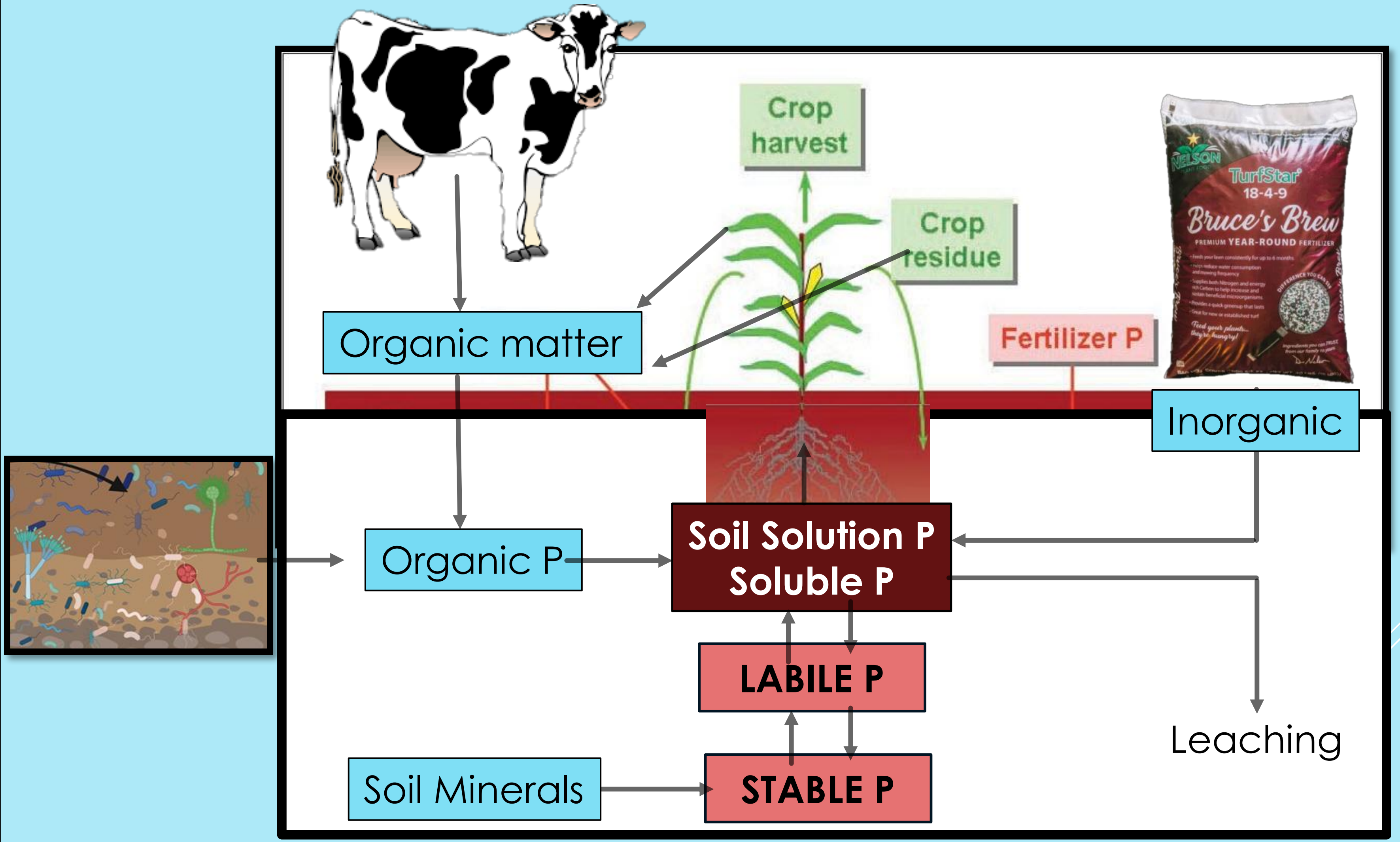
Plant Nutrients

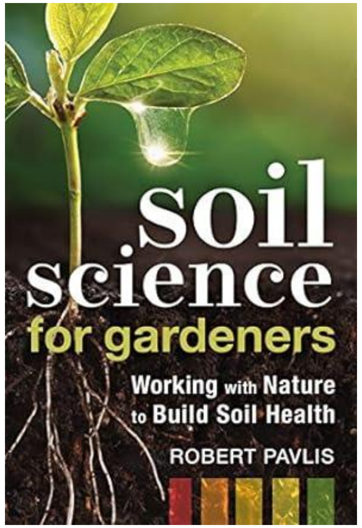




Soil Phosphorus Cycle

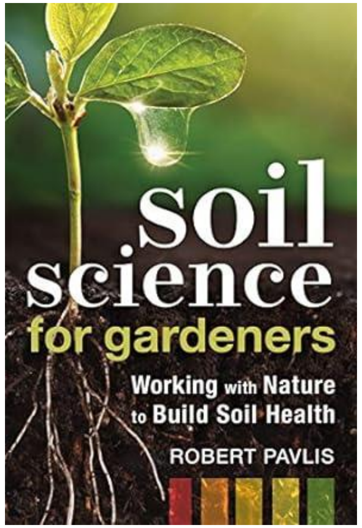


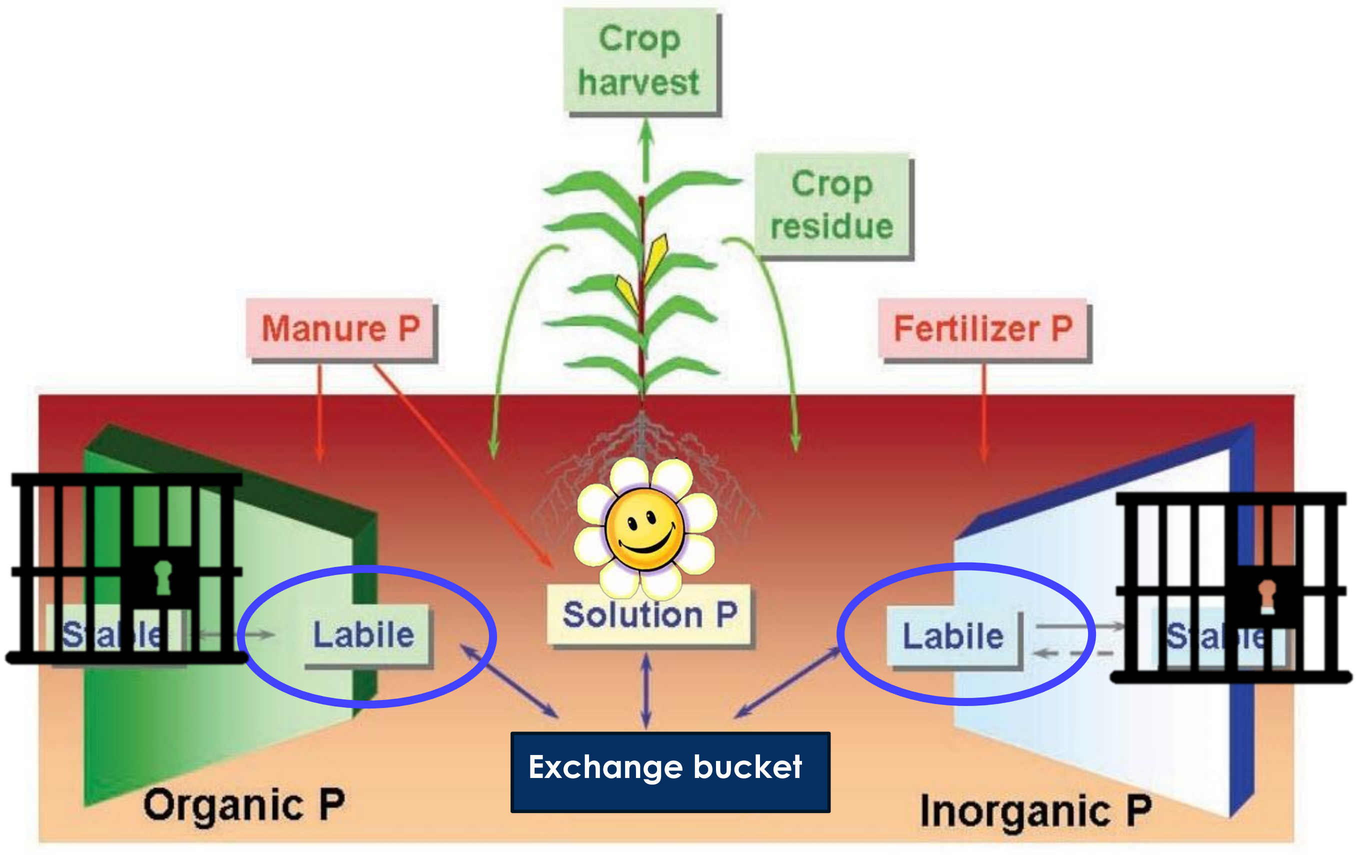




P

When added to the soil P is converted within 24 hours to **Labile** P. This form of P is only available for **a short time** and eventually becomes **Stable P** making access to the plant difficult, it is basically locked away.





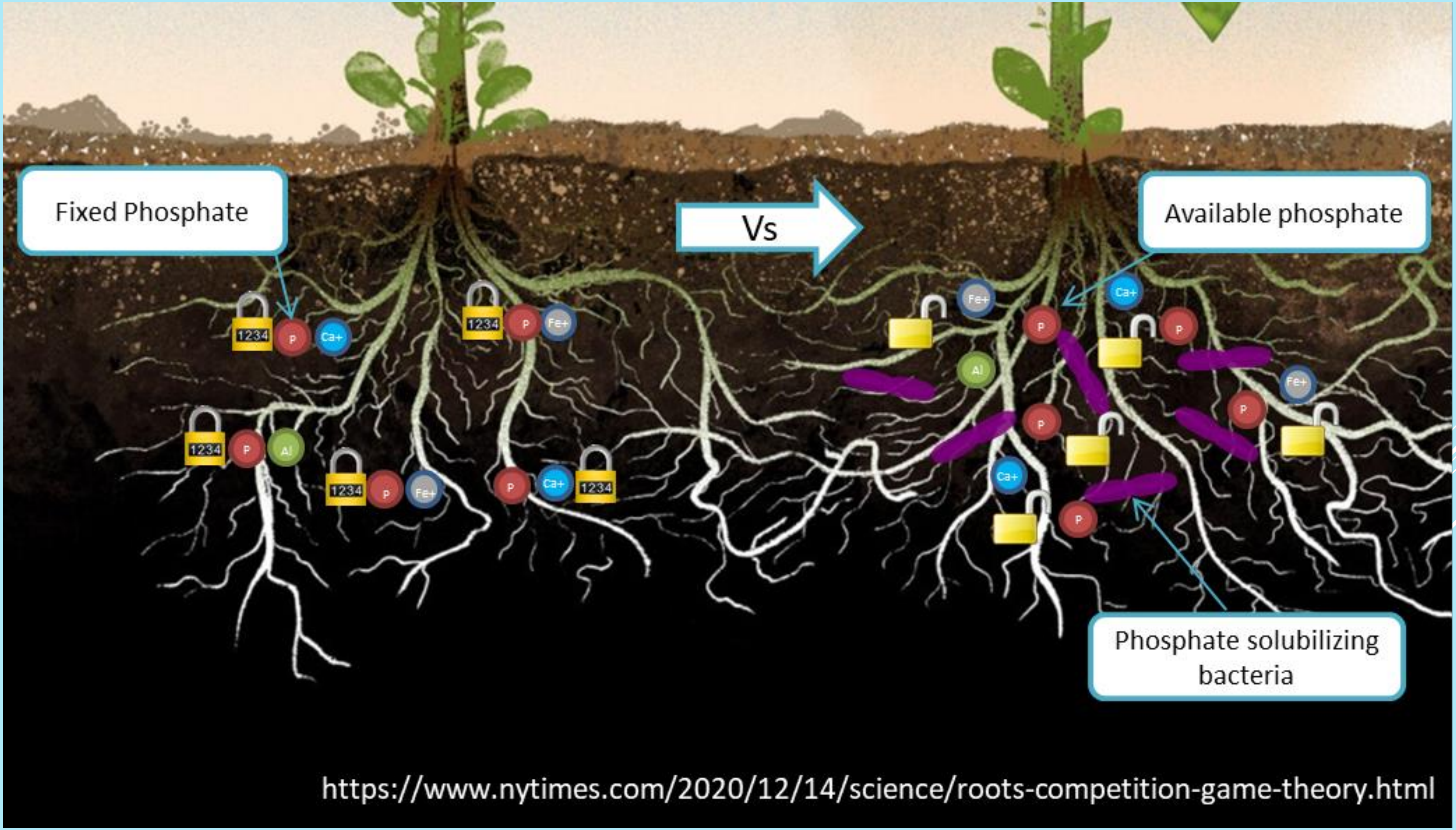
Modified from Figure 34-2 in the LPES Curriculum.

Soluble P in soil solution easy for the plant to access but is in very small quantities.

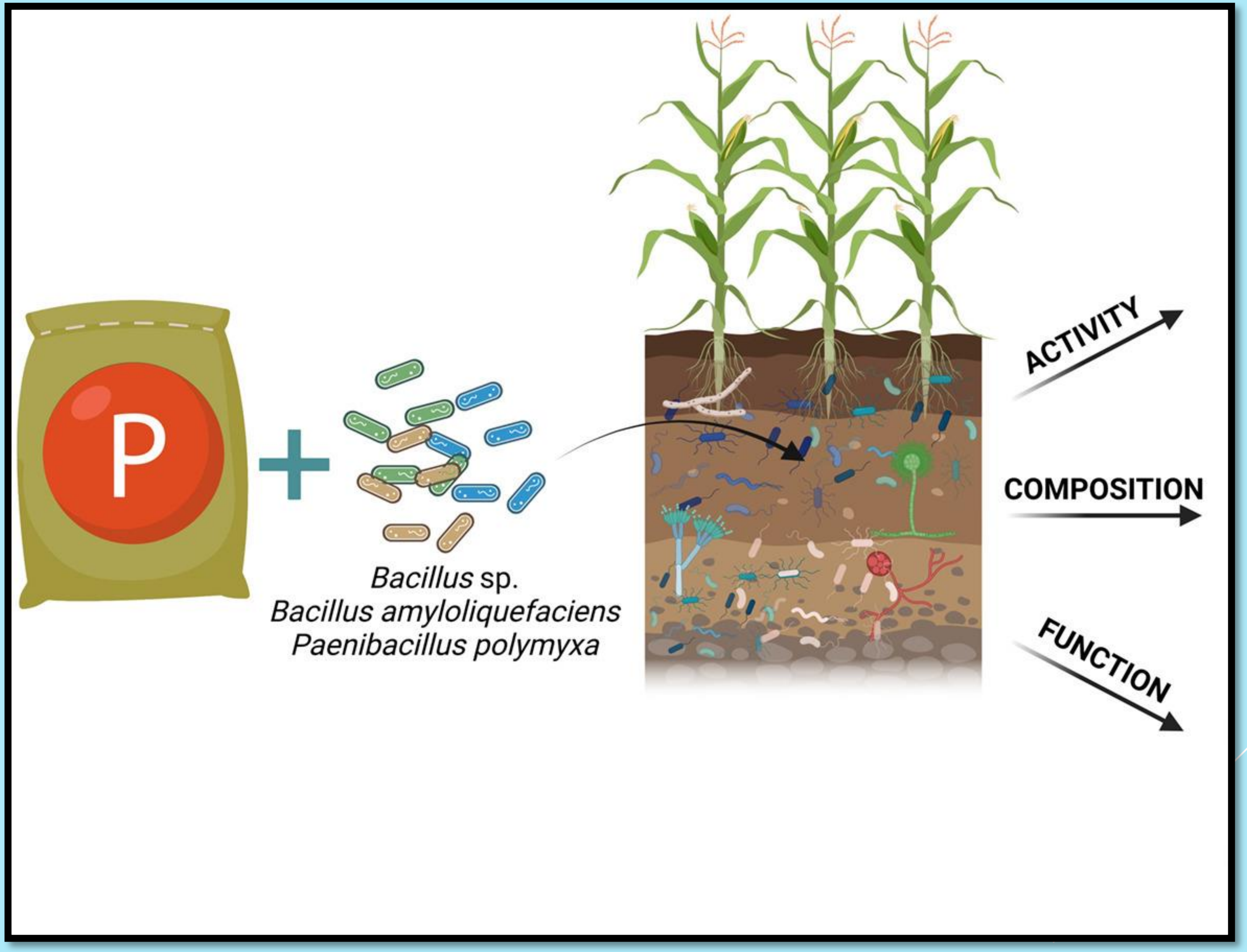
Labile P is held loosely by soil particles

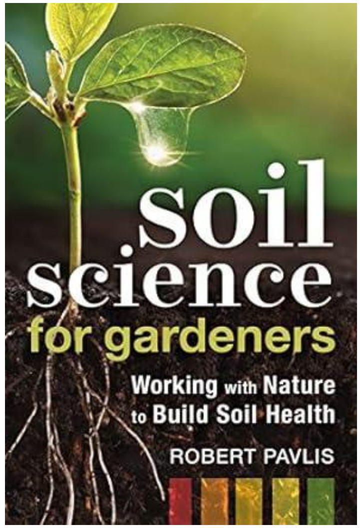
Stable P is the majority of free P but is held strongly by soil particles.

As plants utilize soluble P then some Labile P is converted to Soluble P so there is always some available to the plant

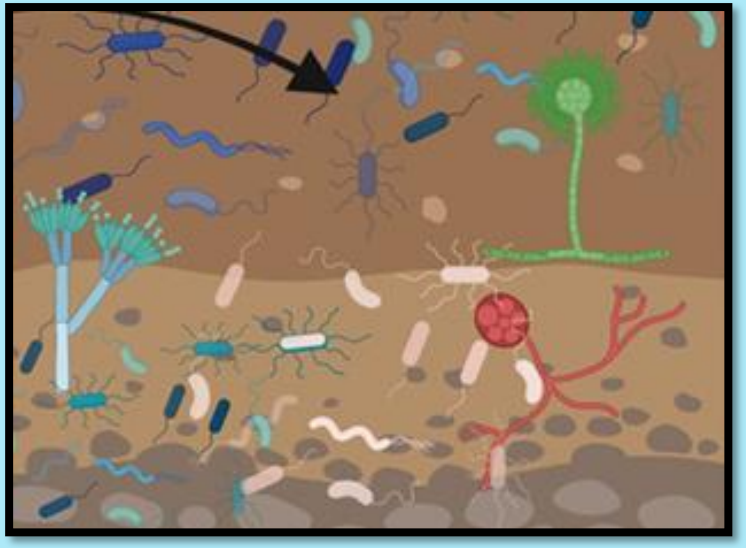

Fixed Phosphate
Vs
Available phosphate
1234
P
Ca+
Fe+
Al
Phosphate solubilizing bacteria
https://www.nytimes.com/2020/12/14/science/roots-competition-game-theory.html

Plant Nutrients





Phosphorus Converters!

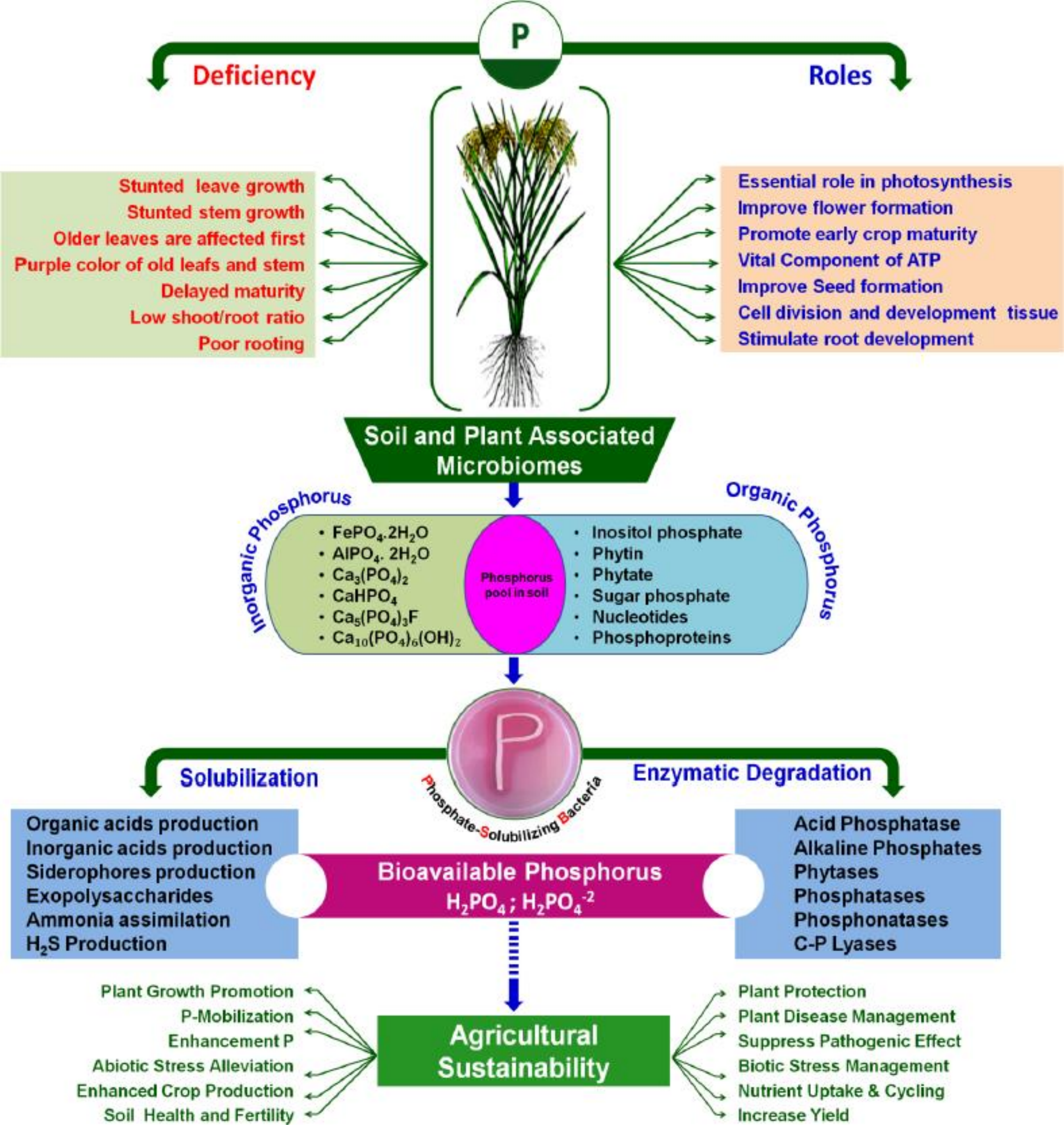


Certain bacteria (such as Thiobacillus and Bacillus) can convert non-available inorganic phosphorus in the soil into a usable (organic or inorganic) form of phosphate. These bacteria can also create siderophores, which **chelate iron** and render it useless to harmful bacteria.

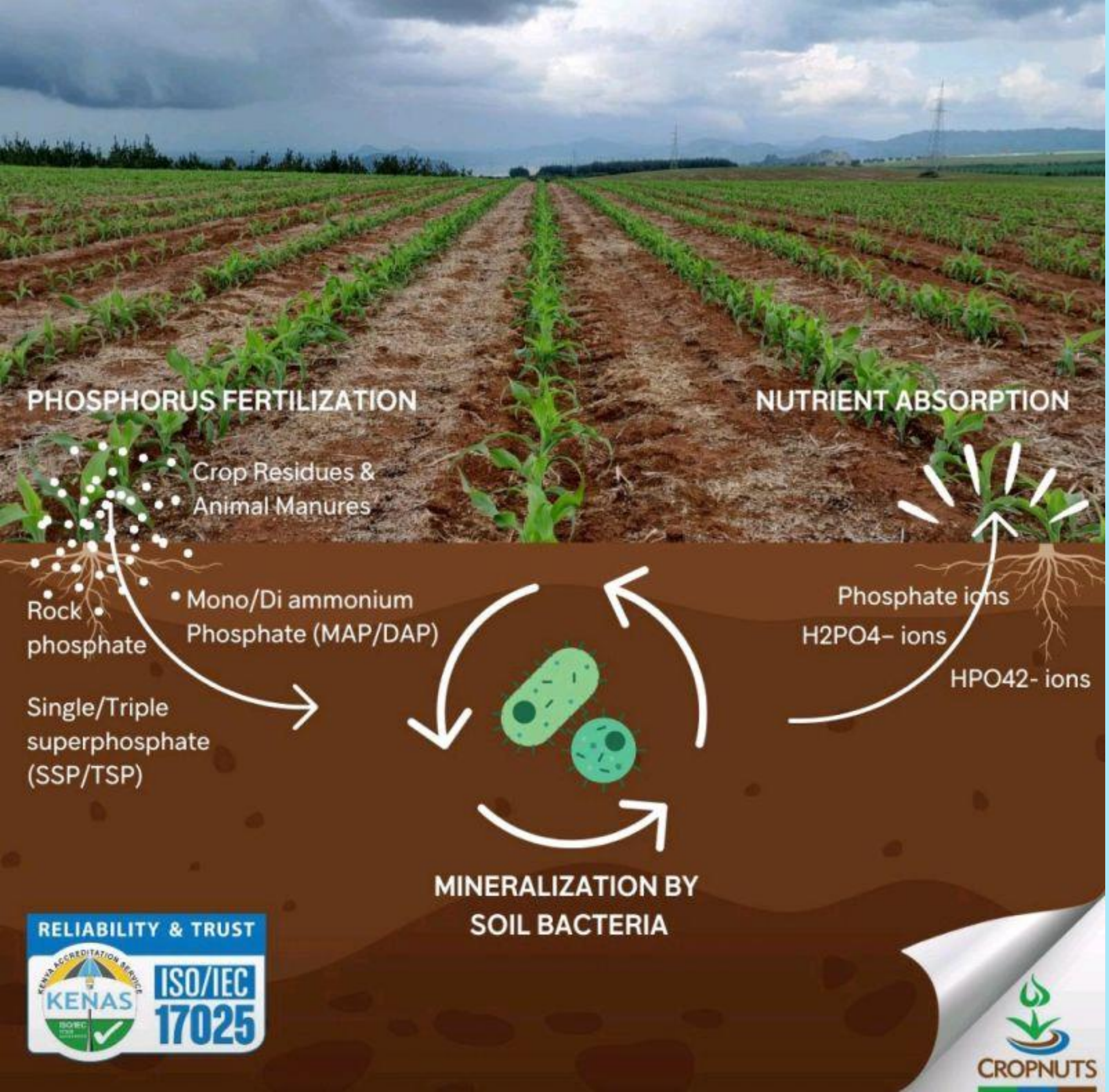
Pseudomonas sp., Rhizobium sp., and Escherichia sp., form the largest microbial communities with Phosphorus solubilization abilities in soil.

eh·sh-ri·kee·uh

Phosphorus-solubilizing bacteria are commonly used plant probiotics that promote plant development by **converting insoluble P into soluble P** that is easily absorbed and used by roots.



P
Deficiency
Roles
Stunted leave growth
Stunted stem growth
Older leaves are affected first
Purple color of old leafs and stem
Delayed maturity
Low shoot/root ratio
Poor rooting
Essential role in photosynthesis
Improve flower formation
Promote early crop maturity
Vital Component of ATP
Improve Seed formation
Cell division and development tissue
Stimulate root development
Soil and Plant Associated Microbiomes
Inorganic Phosphorus
Organic Phosphorus
$FePO_4.2H_2O$
$AlPO_4.2H_2O$
$Ca_3(PO_4)_2$
$CaHPO_4$
$Ca_5(PO_4)_3F$
$Ca_{10}(PO_4)_6(OH)_2$
Phosphorus pool in soil
Inositol phosphate
Phytin
Phytate
Sugar phosphate
Nucleotides
Phosphoproteins
Phosphate-Solubilizing Bacteria
Solubilization
Enzymatic Degradation
Organic acids production
Inorganic acids production
Siderophores production
Exopolysaccharides
Ammonia assimilation
H_2S Production
Bioavailable Phosphorus
H_2PO_4 ; $H_2PO_4^{-2}$
Acid Phosphatase
Alkaline Phosphates
Phytases
Phosphatases
Phosphonatases
C-P Lyases
Agricultural Sustainability
Plant Growth Promotion
P-Mobilization
Enhancement P
Abiotic Stress Alleviation
Enhanced Crop Production
Soil Health and Fertility
Plant Protection
Plant Disease Management
Suppress Pathogenic Effect
Biotic Stress Management
Nutrient Uptake & Cycling
Increase Yield



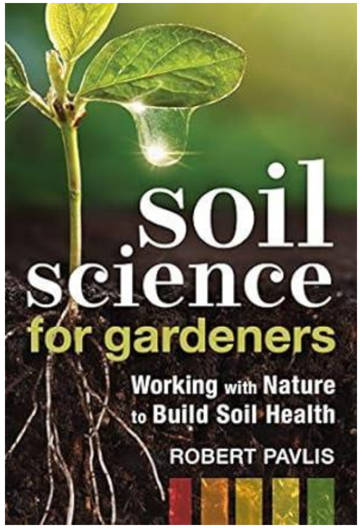
In farming, we mostly see low levels of Phosphorus due to repetitive harvest.
There are two possible exceptions:

Sandy soils that can't bind nutrients
New homes built on farm land

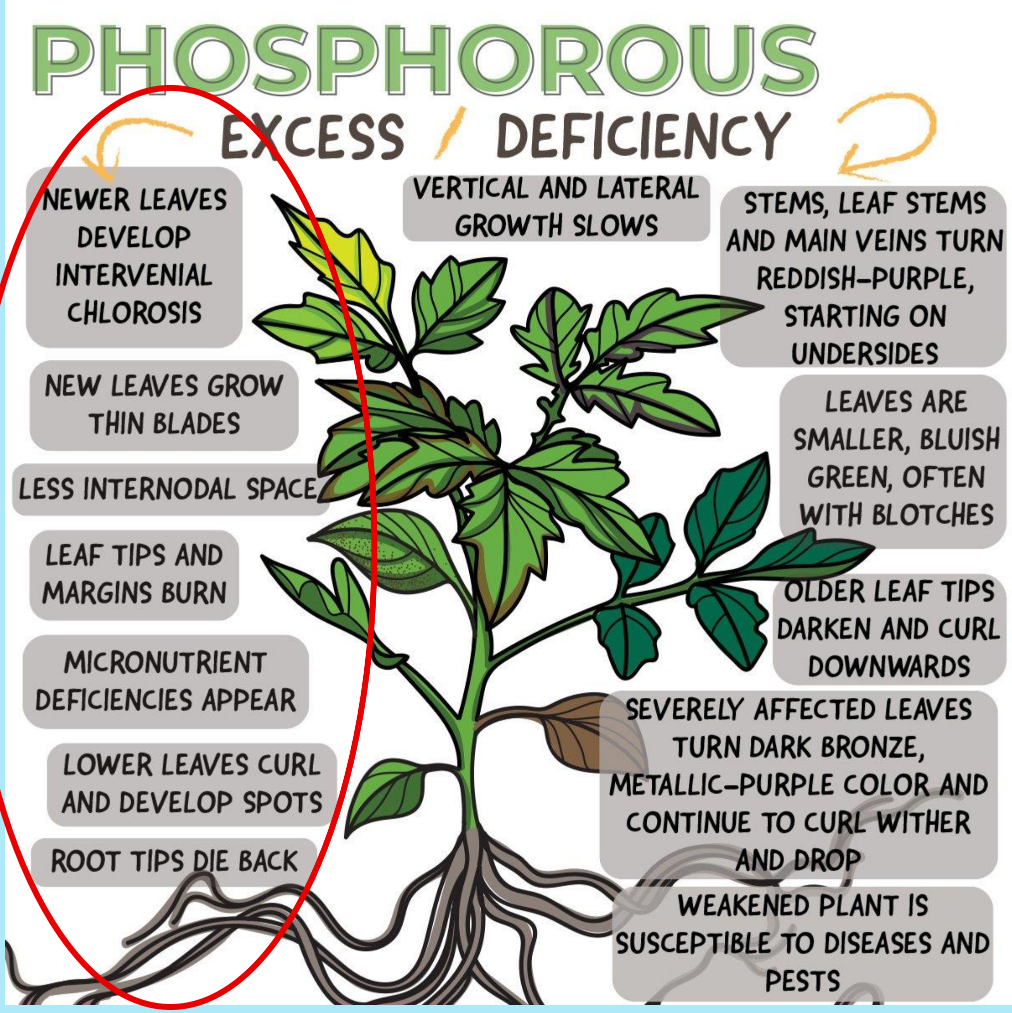
Due to the water way run off studies some States have banned the use of Phosphorus fertilizers.

One myth mentioned in the book, was in early studies of fertilizer, the lack of P resulted in poor root growth leading to suppliers marketing products like transplant fertilizers and root boosters. Bone meal became popular during this time.
Then scientist discovered roots **can** grow just fine provided the soil contains **adequate** P at the time of transplant, or to gain more blooms.
Unless you have deficient levels of P adding more is no benefit to the plant but can pollute lakes and rivers and harm soil micro-organisms.

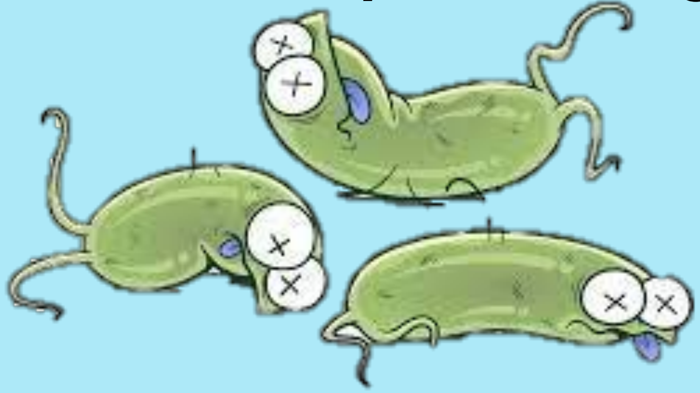
New technology



TOO MUCH for the plant and for the soil microbes!



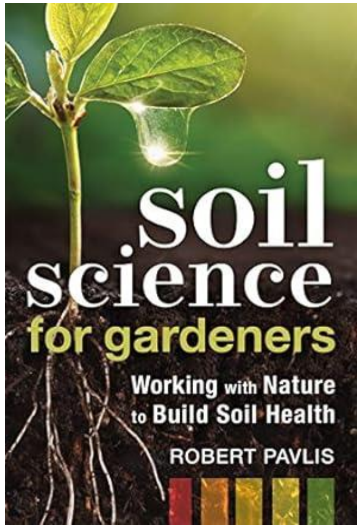
Where's the **mycorrhizal** gang?



They are working the turf area.

Phosphate overload has been labeled the cause of ***Algae Bloom*** that cuts off the oxygen supply in waterways. Phosphate pollution from both fertilizer and soaps (laundry, shampoo, bath) is the main cause of contamination in streams and lakes and in resent years some phosphates have been banned in soap production.

Soil Health, Naturally



Test, Don't Guess!

pH < 7.1 Olsen 16-25ppm

pH >7.1 Bray 26-40ppm

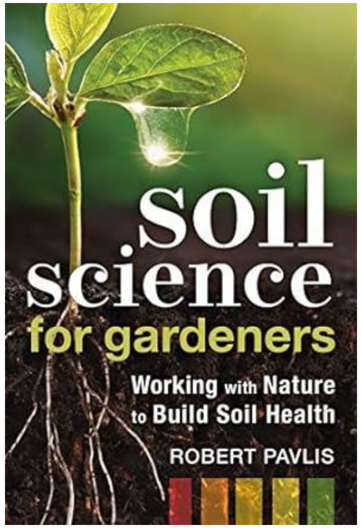
Low
Adequate
Optimum
High

Soil Submission Results

Element	Your Results	Ideal Range	Low	Optimum	High
pH	5.6	6.5 - 7.3			
Nitrate Nitrogen (N)	2 ppm	5.8 - 11.5			
Phosphorus (P) adequate	10 ppm	16 - 21			
Potassium (K)	100 ppm	161 - 201			
Organic Matter	2.0 %	2.5 - 4.5			
Soluble Salts	0.27 mmhos/cm	0 - 0.9			
Calcium (Ca% of CEC)	58 %	65 - 76			
Magnesium (Mg% of CEC)	8.1 %	15 - 21			
Cation Exchange Capacity (CEC)	20.4 meq/100g				

Your Recommended Nutrient Application (lbs/1000 sq ft)

Lime	Nitrogen, N	Phosphorus, P_2O_5	Potassium, K_2O
31	2	1	2



How the P in NPK is Expressed

Phosphorus content in soil, plants and animal rations is expressed as phosphorus (P) content, but phosphorus in fertilizers and manure intended for land application is expressed as **phosphate (P_2O_5).**

- To convert Phosphorus(P) to P_2O_5 concentration, **multiply by 2.29**
- To convert P_2O_5 to Phosphorus(P), **multiply by 0.44**

Most commercial fertilizers use soluble P in the form of Monoammonium phosphate **MAP** or Diammonium phosphate **DAP**.
DAP 18-46-0 and MAP 11-52-0
Nelson products utilizes MAP, it cost a little more but has a bit higher P concentration, when in solution it is a bit more acidic, a perfect "solution" for alkaline soils.

Sources of Phosphorus we utilize

0-46-0 Triple Super
9-44-0 HAFIA MAP
11-52-0 Potash (MAP)
4-10-12 Bone/Blood meal
0-45-0 Di Cal Phosphate

Bone meal provides phosphorus and calcium to plants, along with a largely inconsequential amount of nitrogen. The N-P-K rating of bone meal is typically 3-15-0 along with a calcium content of around 12% (18% CaO equiv.), although it can vary quite a bit depending on the source from 1-13-0 to 3-22-0.

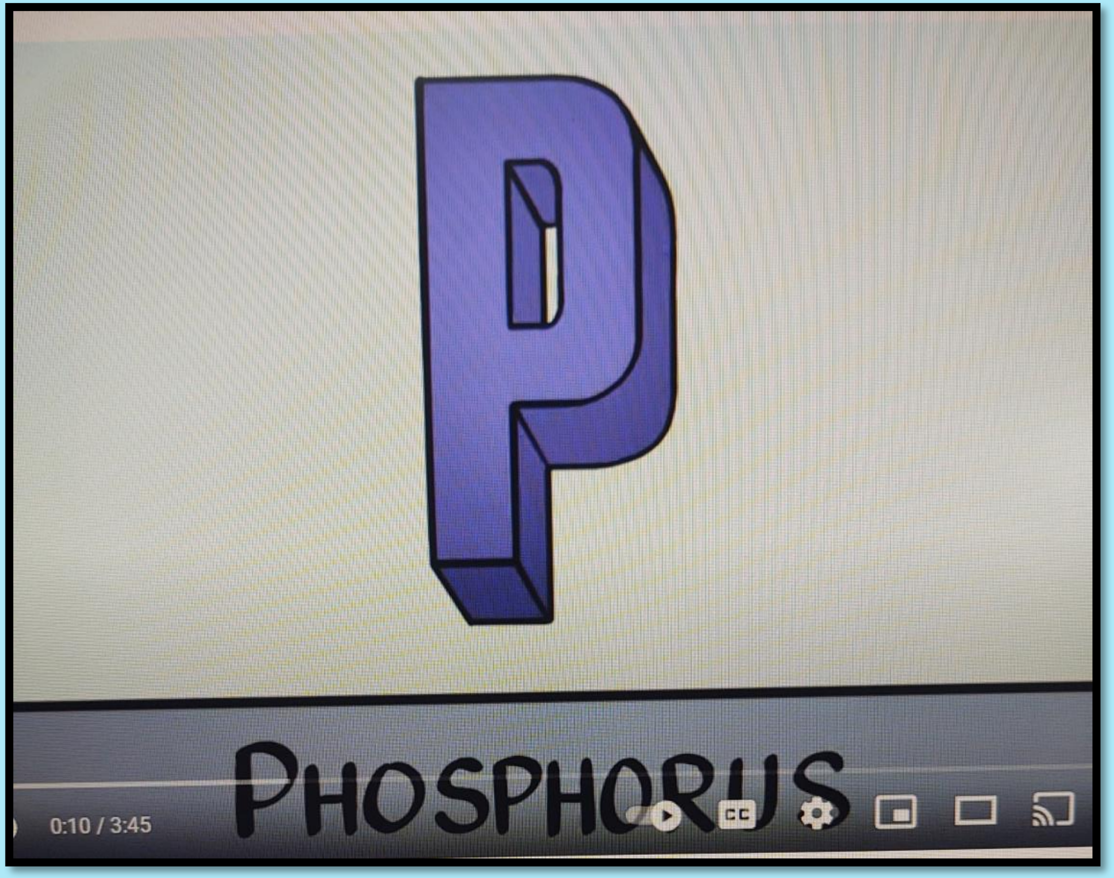
Bone meal increases phosphorous in soil for optimal spring gardening results. Essential in the development of strong root systems, this element is released into the soil for up to four months. Slow, steady delivery of nutrients helps you grow plenty of big, blooming flowers, fruits, and vegetables.


ORGANIC
BONE MEAL
FERTILIZER
Shehri Kisaan
The Urban Farmers
Organic Source of Phosphorus & Calcium
Pure, Steamed & Powdered
Perfect for all Bulbs & Flowers
Grows Plants up to Twice as Big
Builds a Strong Frame starting from Roots
ENHANCE PLANT VITALITY WITH STEAMED ODOURLESS BONE MEAL
UNLEASH THE BENEFITS TODAY
1 RICH IN CALCIUM
Strengthens plant cell walls, promotes sturdy growth
2 RICH IN PHOSPHORUS
Essential for photosynthesis, flowering, fruit yield, and pest resistance
3 SLOW RELEASE
Long-lasting fertilizer, requires minimal application


YUM!

Summary of How Phosphorus Behaves in the Soil

https://www.youtube.com/watch?v=j1HIClkuLnw



Plant Nutrients

Feb 26th