Advanced Tree Biology: Primer On Essential Elements & Tree Health

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Life on Earth is a function of water, geology, atmosphere, and genetics. Life extracts materials in many forms from the Earth system and generates more complex materials using energy derived from chemical transformations and sunlight. Past and current success in material accumulation and concentration, plus failure of any life-generated materials to be instantly decomposed, provide the basis for many trophic levels of life to exist. The foundation of Earth's ecology rests primarily with sunlight-capturing and material-extracting green plants.

Green plants use fabricated organic materials, with associated inorganic elements, to capture light within narrow wavelength windows. This light energy is momentarily held within specialized compounds which allow time for chemical reactions to transfer energy away into other materials. These energy dense materials help generate a series of mass and energy exchanges, and build and maintain concentration gradients within biological membranes. Energy extracted from light is used to perform work in a cell and is transported on organic compounds to other cells within an organism. Trees do all of this energy capture and organic building, plus transport materials long distances, and live many years.

Components

Eighty percent (80%) of all materials in a living tree is water taken from soil, with minute amounts taken directly from the atmosphere and precipitation. Of the remaining materials seen as a tree, roughly 19% are three elements derived from water and carbon-dioxide gas. These elements (i.e. carbon (C), hydrogen (H), and oxygen (O)) are chemically combined and boosted to a higher energy level (i.e. reduced) and are visible as all tree parts. The remaining ~1% of tree material is composed of essential elements removed from soil, although small amounts of some essential elements (i.e. sulfur (S) and chlorine (Cl)) can be extracted from the atmosphere .

The sunlight powered synthesis process of a tree leads to other organisms consuming tree materials in some form, whether herbivores, parasites, scavengers, or symbionts. All organisms deriving life energy from this process generate waste, shed parts, and die. Synthesized materials outside living membranes decompose into simpler components, finally releasing all essential elements to the environment. These essential elements are usually reprocessed by other local organisms, chemically held within the soil, or eroded / leached away from the site.

Elements of Life

Trees utilize 19 elements for life processes. Many more elements can be found inside a tree, but their concentrations are related to their concentrations in the environment. All elements essential for tree life are varied in chemistry and provide varied biochemical services within a tree. Some are used in only one or two processes (i.e. molybdenum (Mo)), while others are used to swaddle everything else (i.e. potassium (K)) within a water bath. Understanding tree essential elements help tree health care providers better manage trees and sites. Defining what is meant by an "element" and an "essential element" is a key first step to better tree health care.

Not Nutrient!

It is critical in discussing tree essential elements to place clear definitions around traditional terms sometimes mistakenly used. Failure to maintain definitional discipline generates useless jargon and can lead to mistakes. The first definitional error can occur around the term "nutrient." A tree nutrient is a compound with potential chemical energy associated within its chemical bonds, and can be used by a tree for transferring energy and / or building structural materials. For example, sugars are nutrients while nitrogen atoms are essential elements and not nutrients. The word "nutrient" has become jargon because of its highly variable and broadly defined applications under many different contexts, leading to continually imprecise and inaccurate usage.

Elemental

A tree "element" is any natural element found within a tree and its rhizosphere, or found on tree surfaces. An element is a basic unit of matter with a carefully defined number of nucleus protons, associated with various nucleus neutrons, both encased within various quantum shells of electrons. Each element is represented by a name, symbol, atomic number (number of protons), and atomic weight (number of protons plus neutrons).

Various elements in trees represent the concentration of an element within the environment, or may be accumulated out of equilibrium with the general environment and soil, within both tree apoplast and symplast. As many as 90 elements have been found in trees. Most serve no identifiable role in supporting tree life. Elements in trees are the result of absorption, deposition, accumulation, pollution, poisoning, or chance. Some elements are included in critical parts of biological components and as part of living processes within a tree. Many elements are simply present in a tree as a result of where a tree grows.

Essential!

A tree "essential element" is required for normal tree growth and reproduction over many years, and cannot be completely substituted for by another element. An element is essential if without it a tree: 1) dies; 2) shows severe deficiency symptoms restricting growth, survival, and defense; or, 3) exhibits a stunted or abnormal appearance when the element is unavailable or not present.

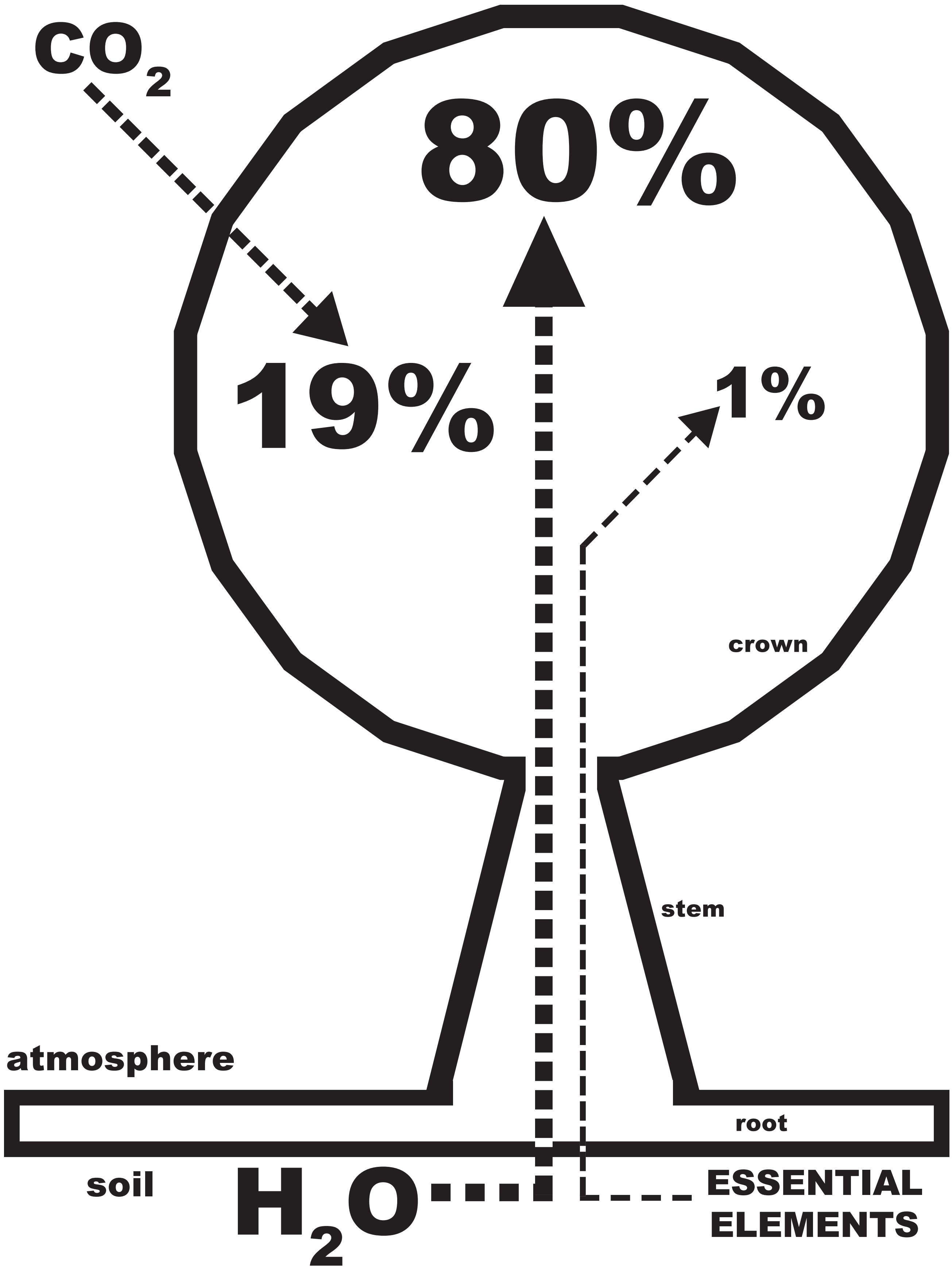
Some essential elements can be partially or temporarily substituted for in different metabolic or structural roles. For example, manganese (Mn) can partially substitute for both iron (Fe) and magnesium (Mg) in some enzymes and process steps over the short run, but not in all process steps all the time. Another example of partial substitution of elements is the use of nonessential sodium ions (Na^{+}) for essential potassium (K^{+}).

Summarry

Trees require 19 elements from the environment, plus tremendous amounts of water, to survive and thrive. In a soil, weathering of minerals and organic matter are two key sources for sustaining essential element balance in trees, while enriching essential elements on a site may be needed for adequate or better performance.

At one time or another, each essential element could be at a deficient level, toxic level, or at a biologically and therapeutically adequate level. Trying to balance all 19 elements is difficult, for both a tree and for a tree health care provider. Only a few elements generate short term (i.e. noticeable) growth gains. Some do not show significant visual symptoms until well into damaging deficiency. Some deficient essential elements show similar visual symptoms with many other essential elements deficiencies or toxicities, causing management by visual symptoms to be fraught with errors.

All tree essential elements and water are needed to keep a tree healthy and structurally sound. Tree life depends upon these "essential 20!"

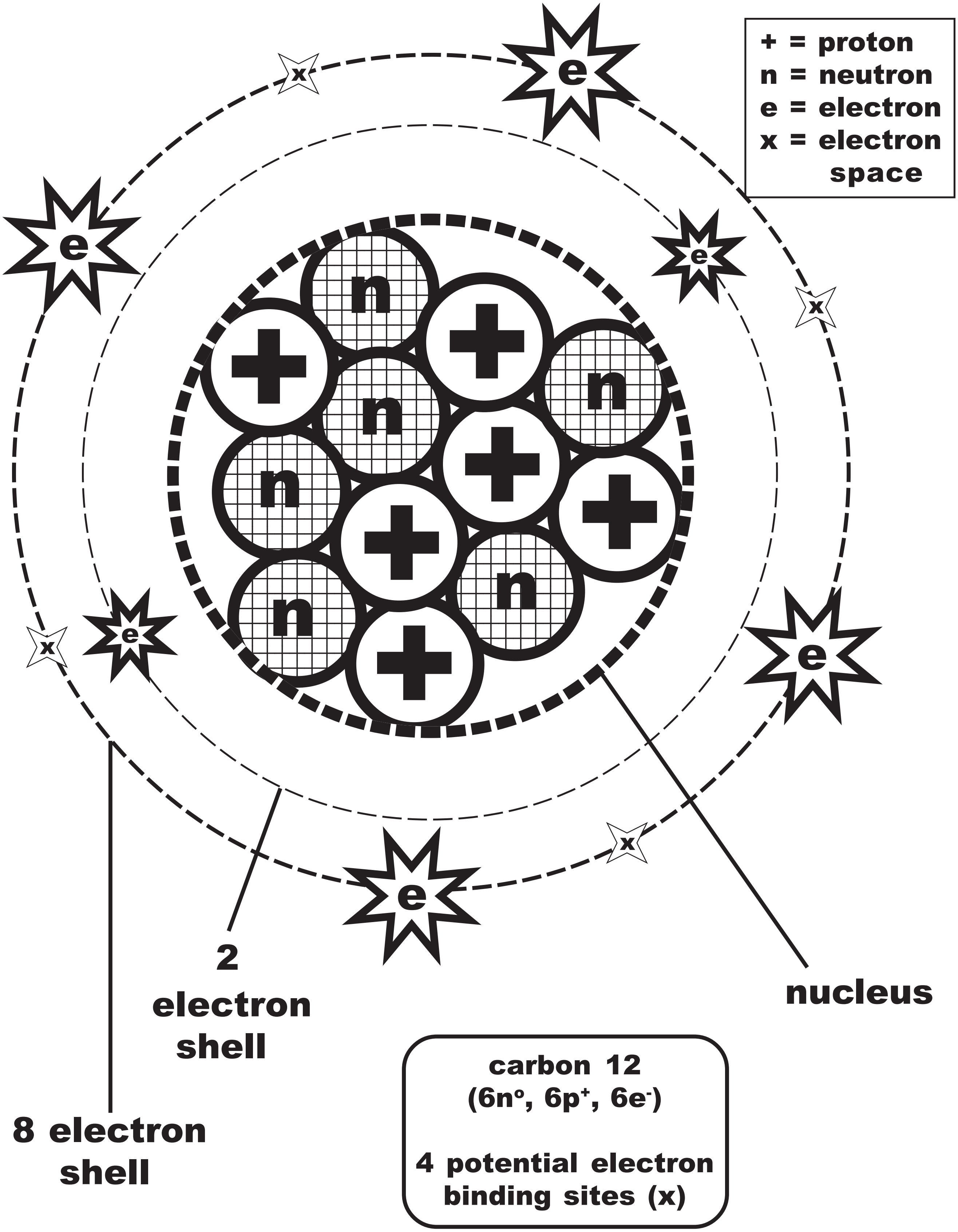


General sources of tree life materials.

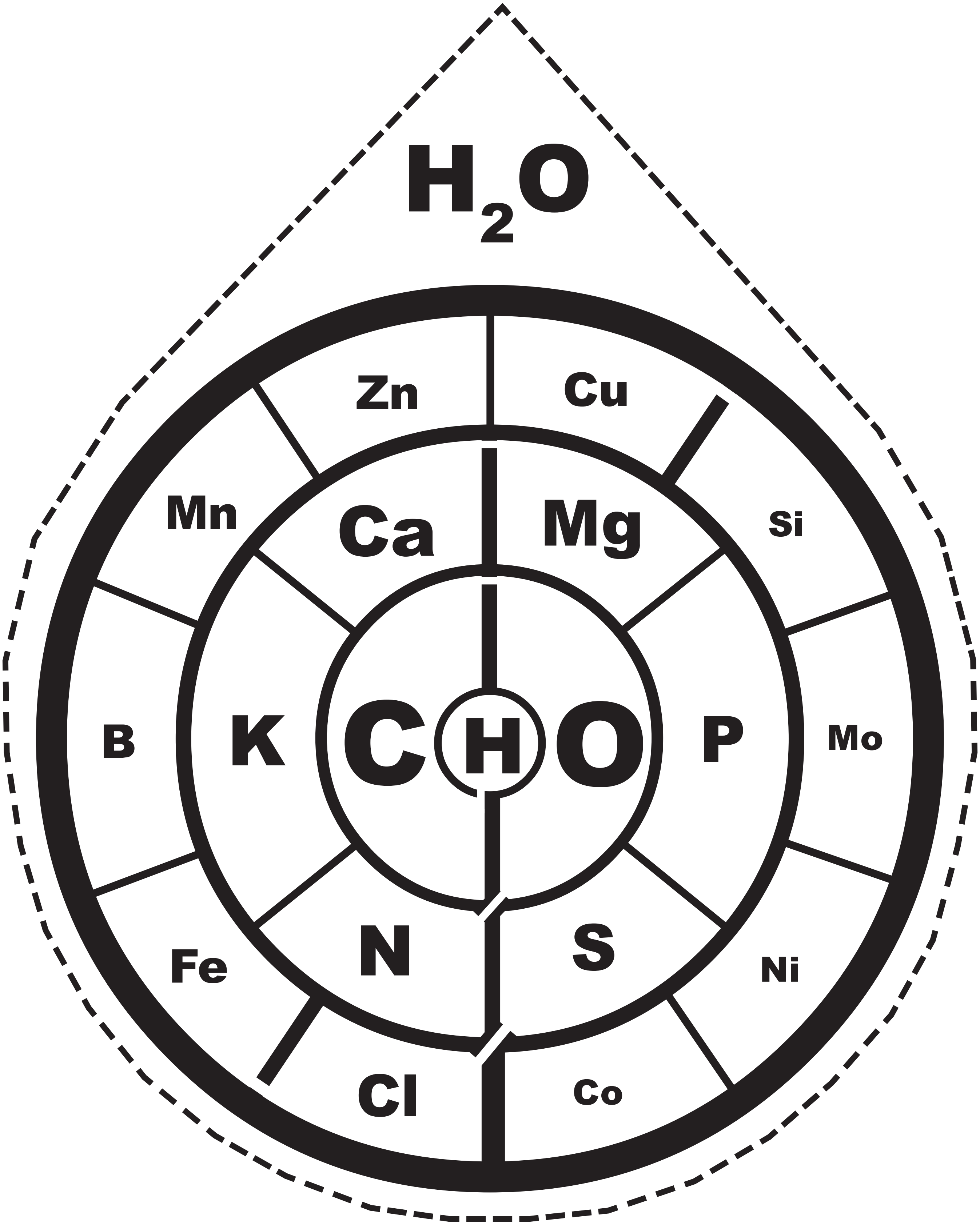
element symbol	element name
B	boron
C	carbon
Ca	calcium
Cl	clorine
Co	cobalt
Cu	copper
Fe	iron
H	hydrogen
K	potassium
Mg	magnesium
Mn	manganese
Mo	molybdinum
N	nitrogen
Ni	nickel
O	oxygen
P	phosphorus
S	sulfur
Si	silicon
Zn	zinc

19 essential elements

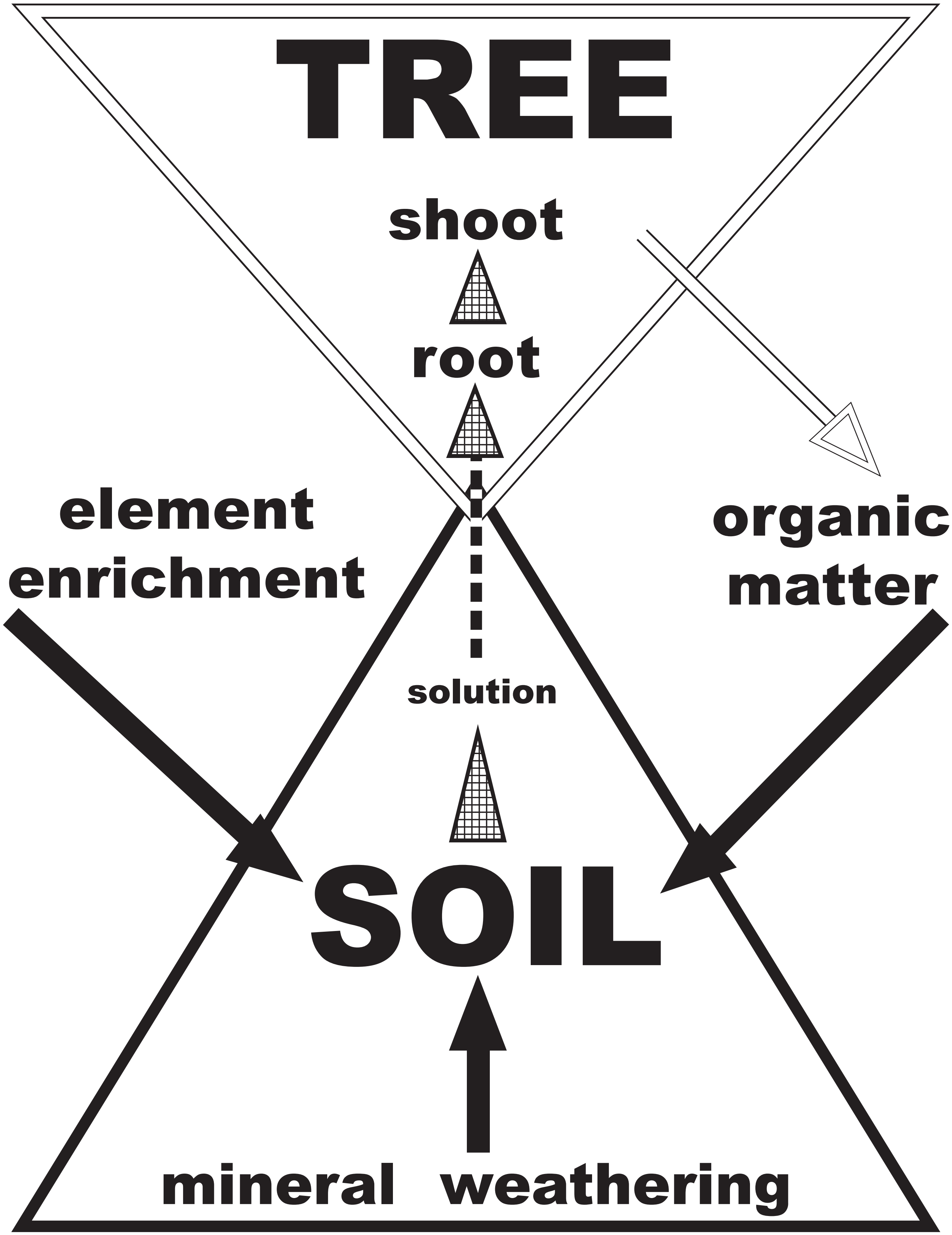
Elements essential for sustaining tree life processes in alphabetical order. All these elements are transported and utilized in a tree within a water bath.



Diagrammatic, two dimensional, cross-sectional view of a carbon atom and its components.



The Coder Spiral of Tree Essential Elements.
The farther beyond the center, the smaller the concentration required.



The three sources of tree essential elements in soils.

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