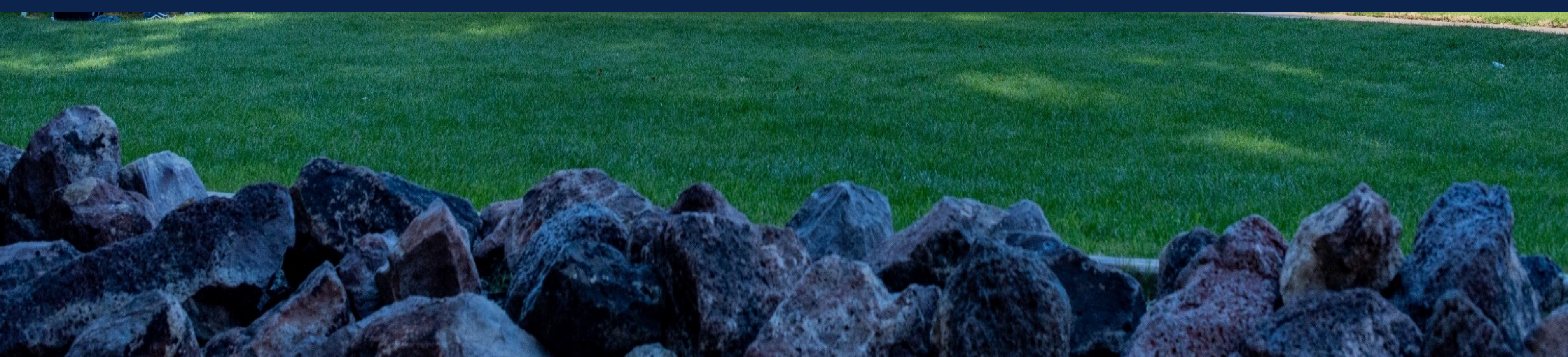
NSF NRT-InFEWS: Indigenous Food, Energy, and Water Security and Sovereignty Presents:

Food, Energy and Water (FEWS) Learning Modules

June 2021



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MODULE 3: HYDROPONICS & GROWING SYSTEMS
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MODULE 4: CEA PLANT NUTRITION
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THE UNIVERSITY OF ARIZONA

INDIGE-FEWSS FOOD MODULE 4

CEA PLANT NUTRITION

Presented by: Ruth Pannill

THE UNIVERSITY OF ARIZONA

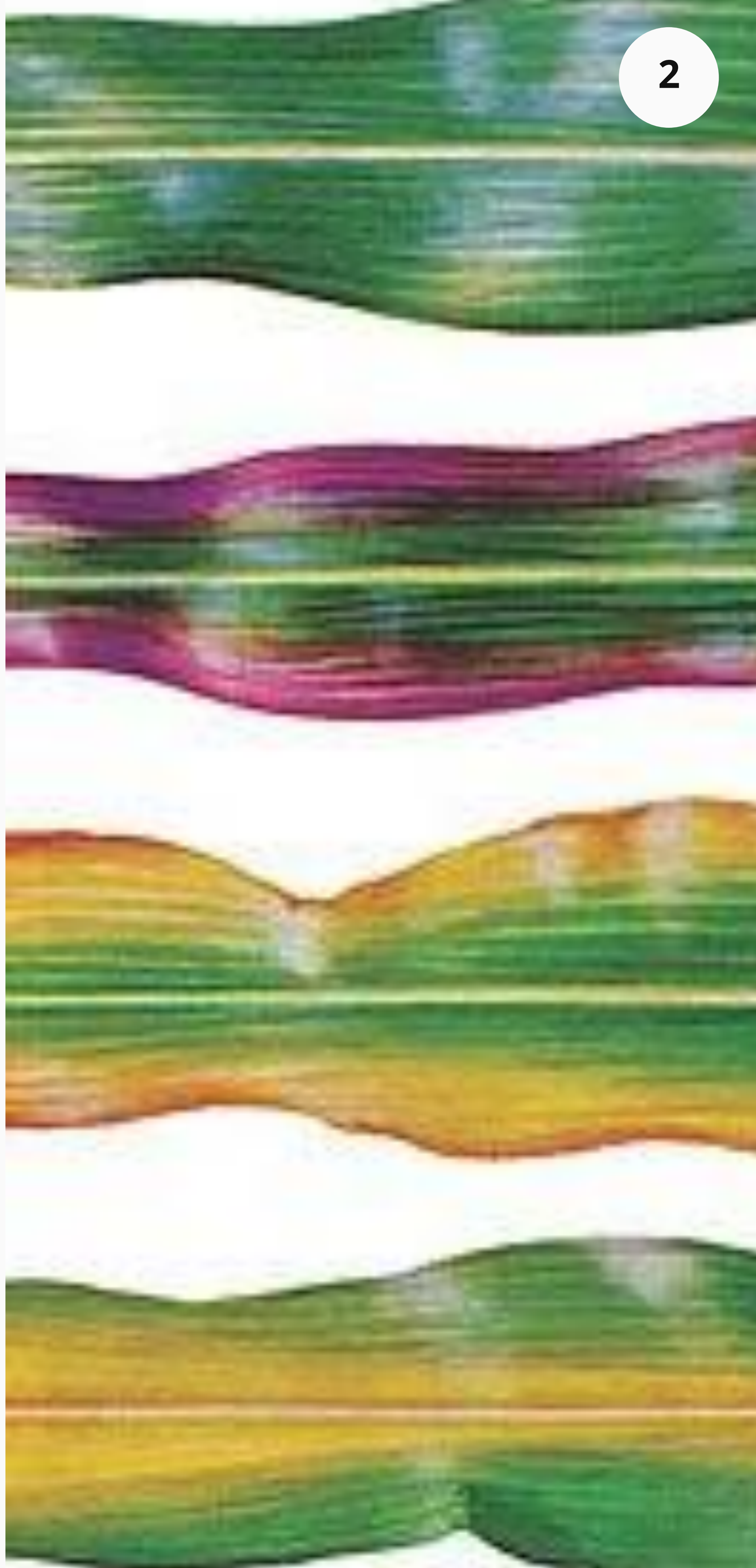
Learning Objectives

Students will be able to....

- **describe why nutrient solutions are used and why they are important in controlled environment agriculture (CEA).**
- **identify the important chemical qualities of nutrient solutions and describe how to measure them.**

Presentation Outline:

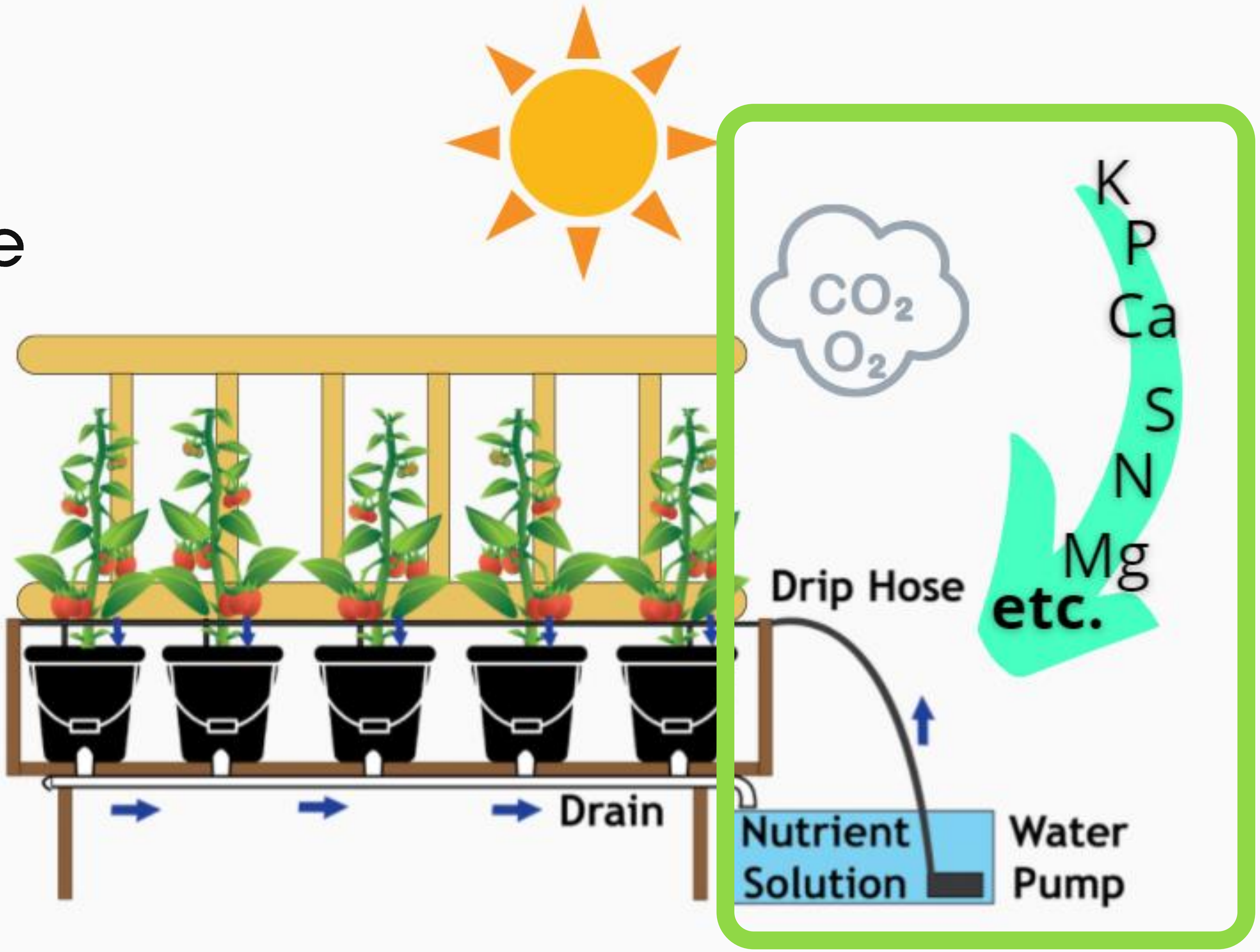
- Essential Elements for Plants
- Nutrient Deficiencies
- Water Chemistry (electrical conductivity & pH)
- Testing for pH and electrical conductivity
- Nutrient Solutions



Essential Elements for Plant Growth

ESSENTIAL ELEMENT:

Critical for a plant to complete its life cycle



Graphic created by Alex Trahan

16 Essential Elements

3 Basic Nutrients

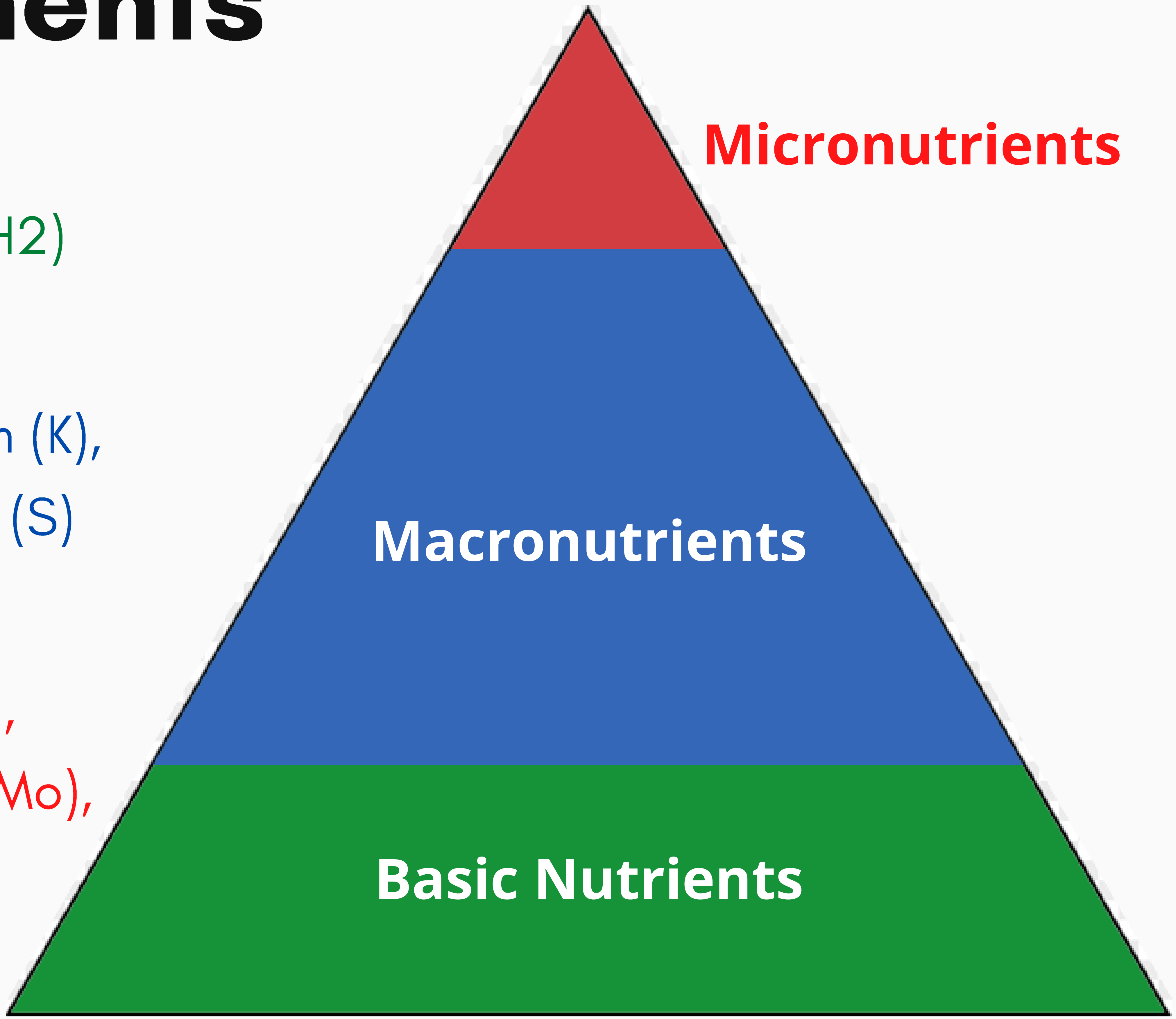
Carbon (C), Oxygen (O2), Hydrogen (H2)

6 Macronutrients

Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S)

7 Micronutrients

- Iron (Fe), Manganese (Mn), Boron (B), Zinc (Zn), Copper (Cu), Molybdenum (Mo), Chloride (Cl)



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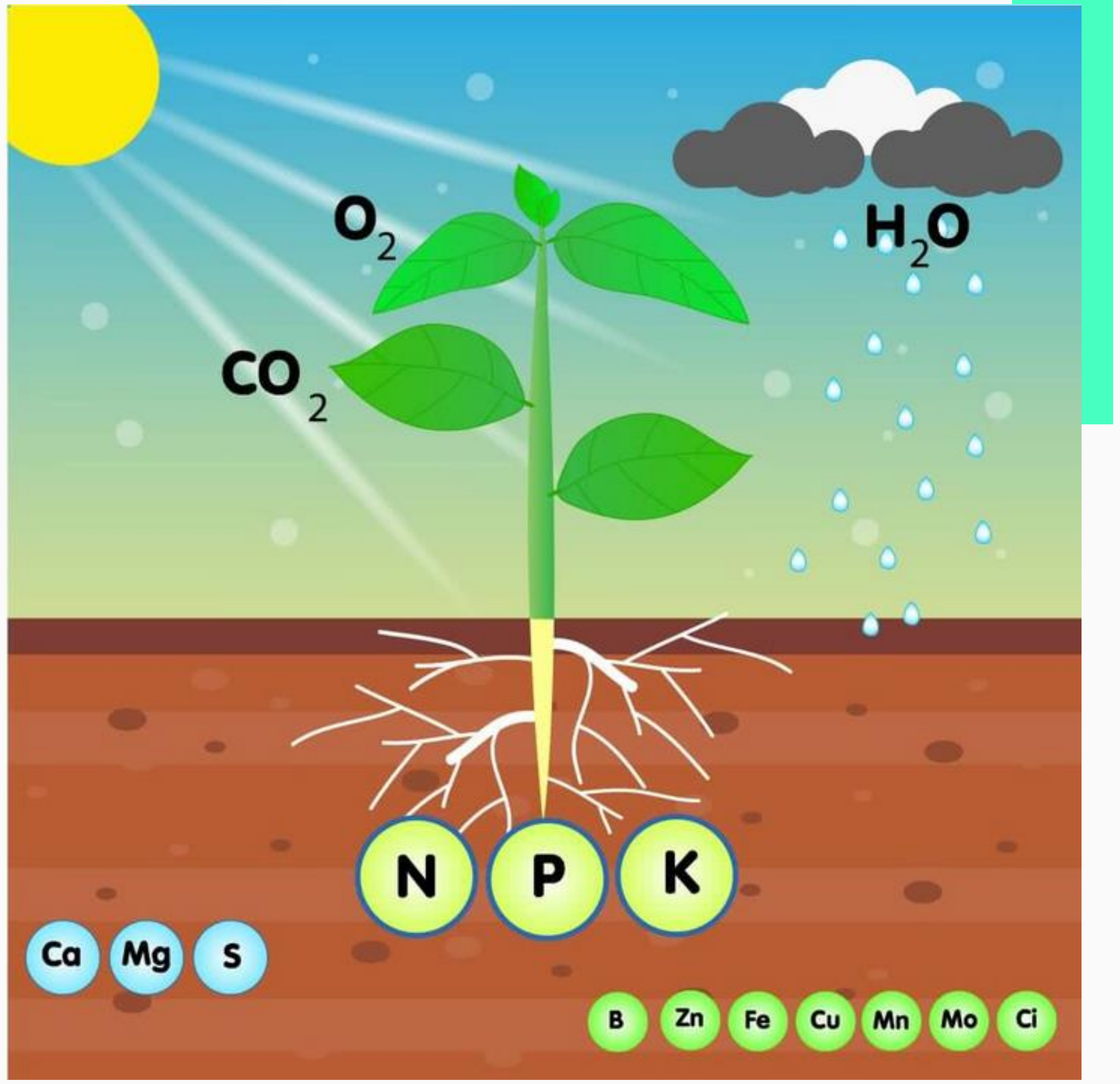
16 Essential Elements for Plant Growth

ESSENTIAL:

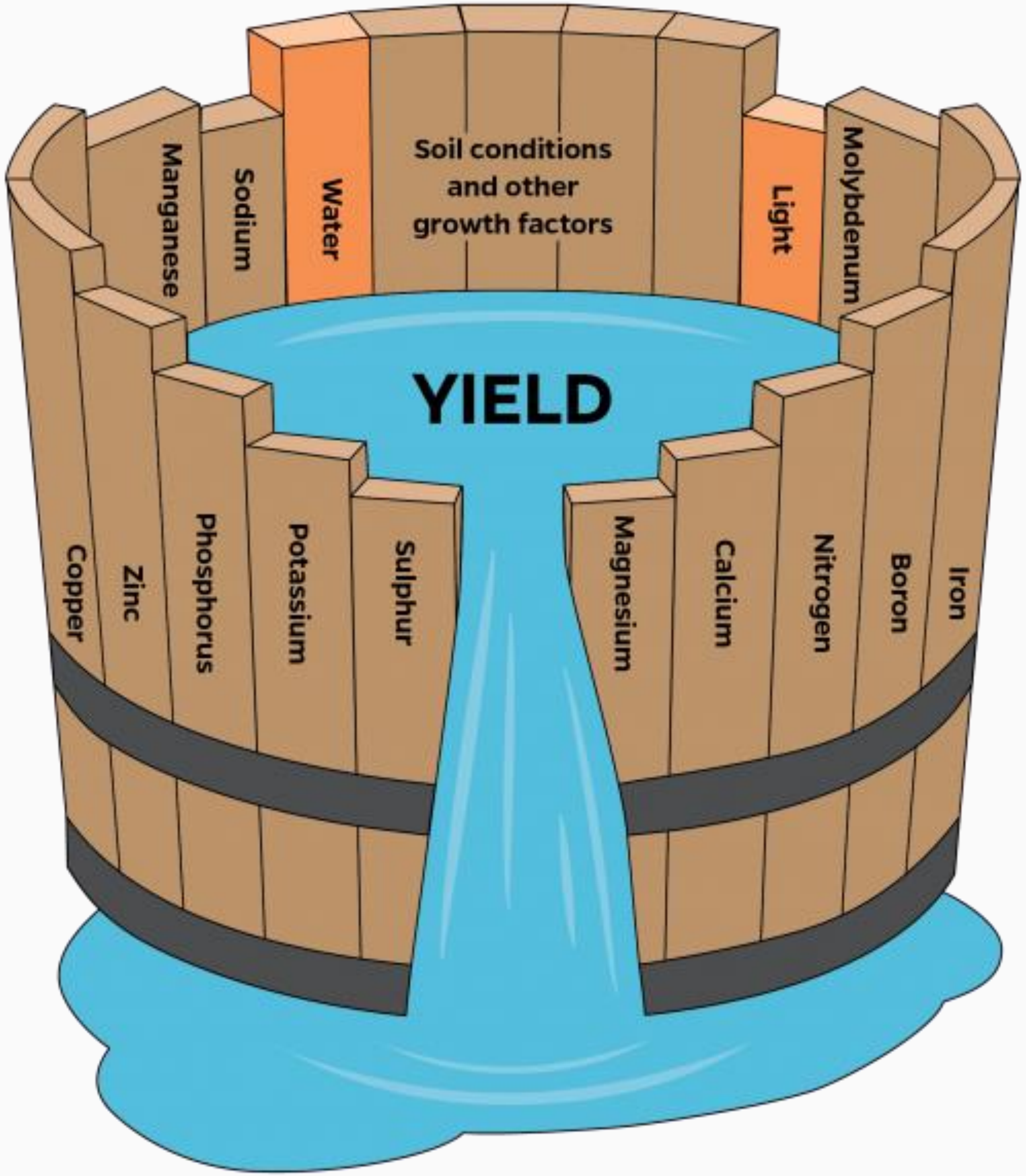
- **The plant can't complete its life cycle without it**
- The element action is specific – *no substitutes*
- The element is part of:
  - Critical structures (Ca in walls, Mg in chlorophyll)
  - Component of critical metabolite
    - Involved in normal growth, development, and reproduction, or other critical ecological function
  - Required for the action of an essential enzyme
    - Critical for chemical reactions



HTTPS://WWW.UGAOO.COM/KNOWLEDGE-CENTER/FUNCTIONS-OF-13-MINERAL-NUTRIENTS-IN-PLANTS/

Nutrient Deficiency & the Law of the Minimum

Plant growth is limited by the most deficient essential element

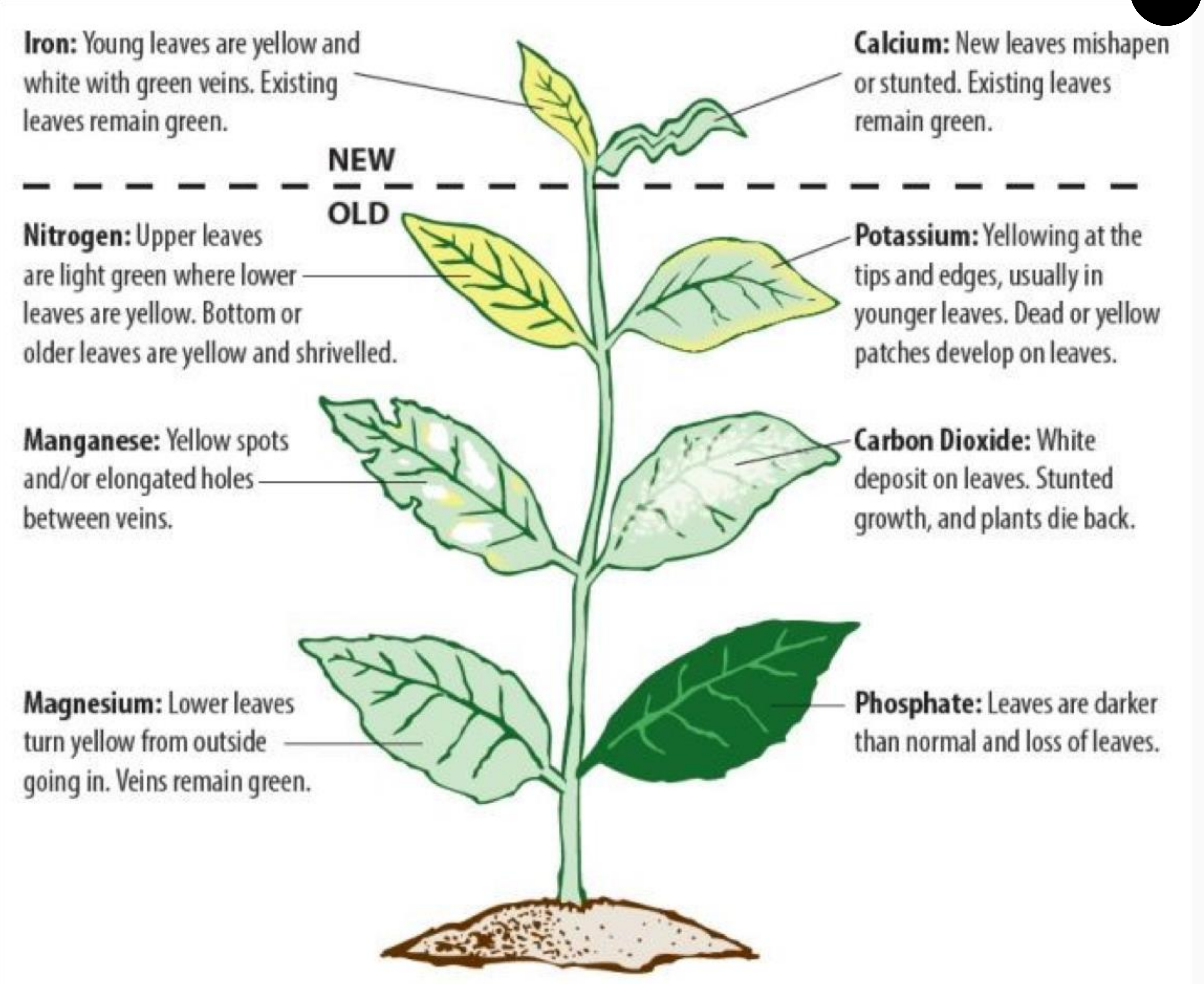


HTTPS://ARCOSASPECIALTYMATERIALS.COM/LIEBIGS-LAW-OF-MINIMUM/

Signs of Nutrient Deficiency

Nutrient deficiency can prevent plants from completing their life cycle – can sometimes be seen visually on the plant

*NOTE: **Symptoms vary from plant to plant***



HTTPS://IBIOLOGIA.COM/TRACE-ELEMENTS-IN-SOIL-AND-PLANTS/

Different Formulas for Different Crops

Vining Crop and **Leafy Greens**

- Recipes are tweaked for the needs of different crops AND different stages of plant growth
- Ex. Tweak the vining crop recipe for different vining crop types (i.e. tomatoes and peppers).

Three basic hydroponic formulas:

CROP	N	P	K	Mg	Ca
Tomatoes	200	50	360	45	185
Cucumbers	230	40	315	42	175
Peppers	175	39	235	28	150

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Water Chemistry & Nutrient Solutions

- *Fertilizers must be able to dissolve in water*
- When they dissolve, **ions** (charged elements/compounds) are released into solution (becomes **nutrient solution**)

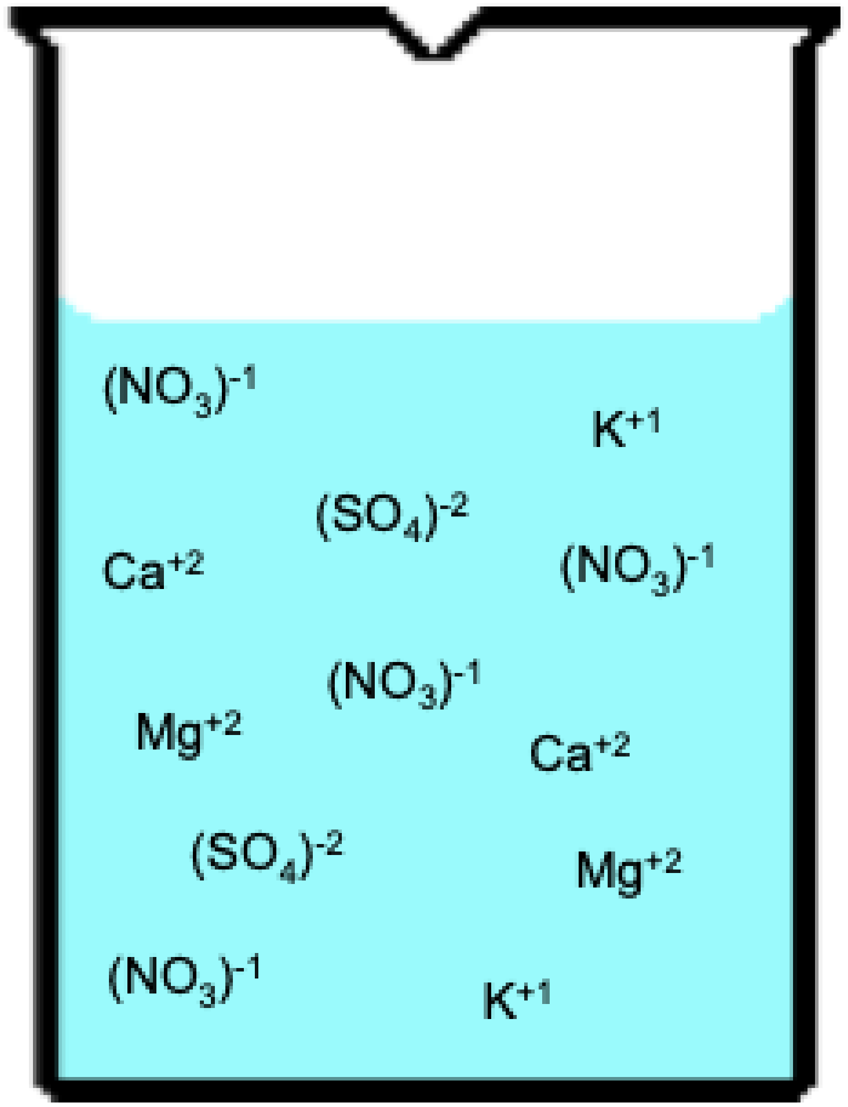
Chemical reactions for dissolution of fertilizer

Fertilizer

$MgSO_4 \rightarrow Mg^{+2} + (SO_4)^{-2}$
magnesium sulfate

$Ca(NO_3)_2 \rightarrow Ca^{+2} + 2(NO_3)^{-1}$
calcium nitrate

$KNO_3 \rightarrow K^{+1} + (NO_3)^{-1}$
potassium nitrate



Water Chemistry & Nutrient Solutions

Each fertilizer has a different solubility in water, affected by **pH, water temperature**, and the **interaction of other ions** that are with it in the same solution (activity of the solution)

Fertilizer

$MgSO_4 \rightarrow Mg^{+2} + (SO_4)^{-2}$

magnesium sulfate

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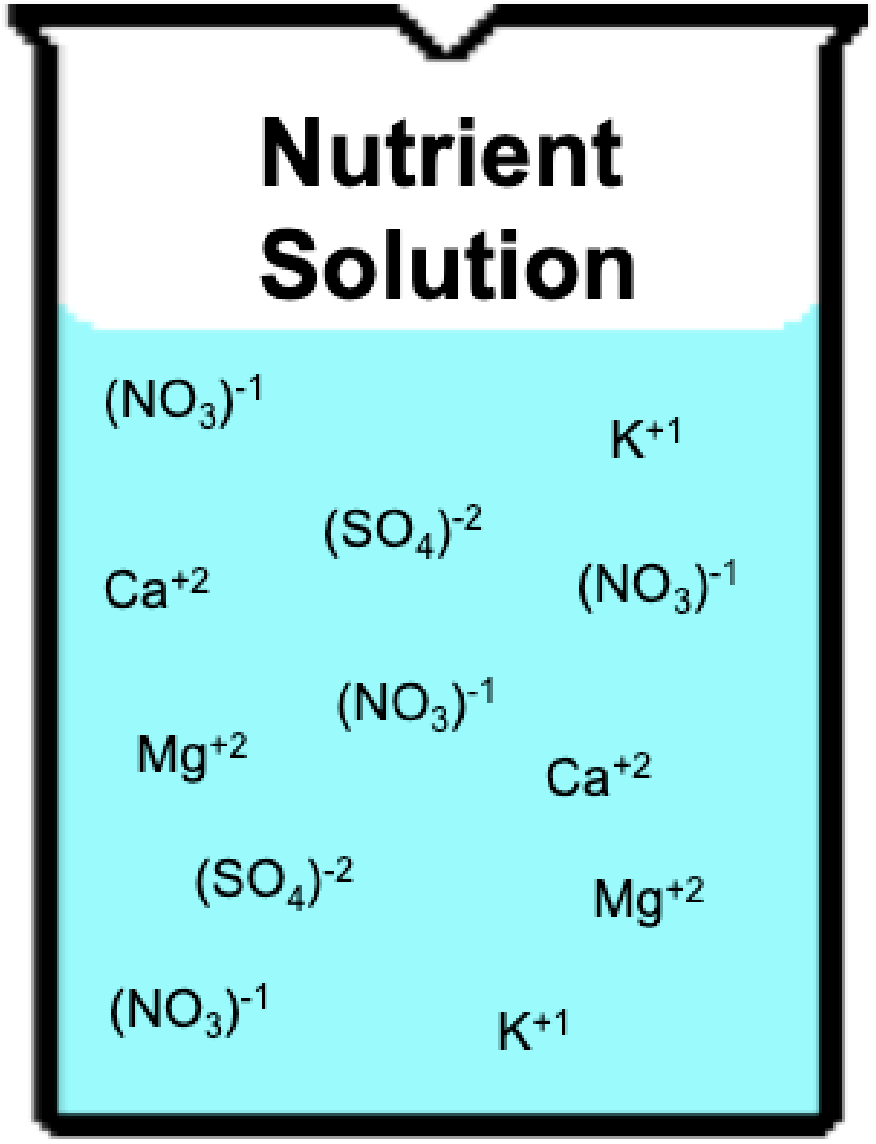


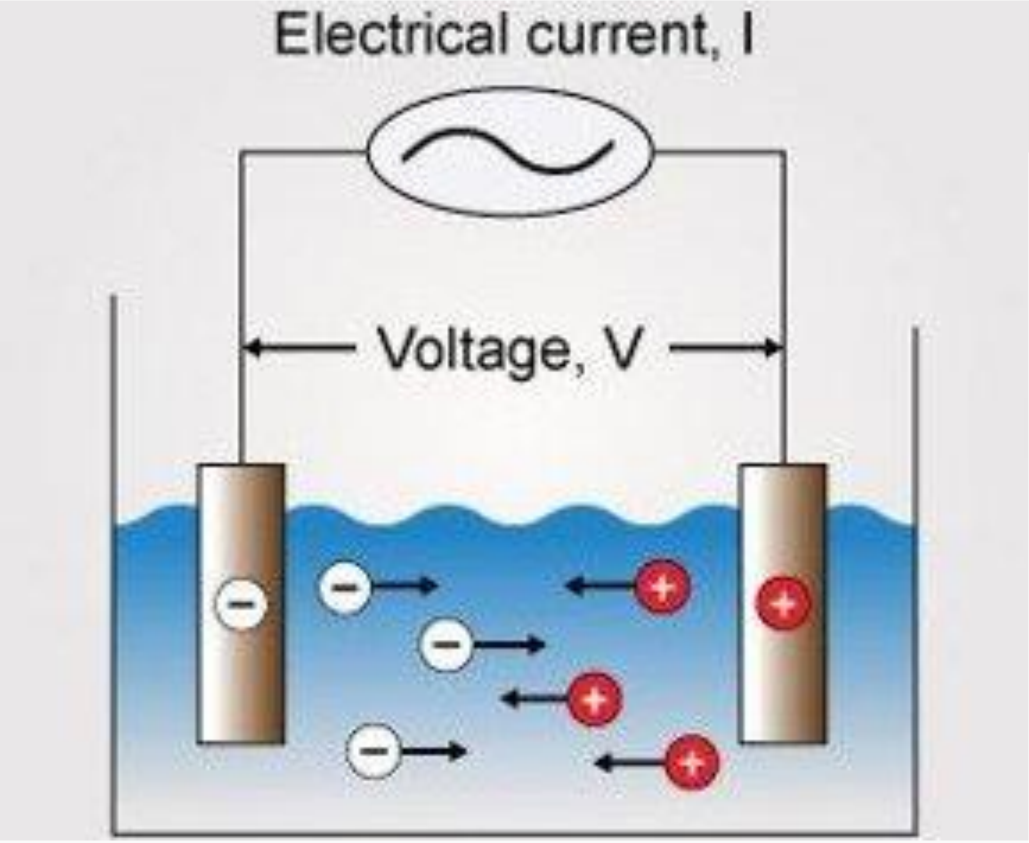
Measuring Nutrient Solutions

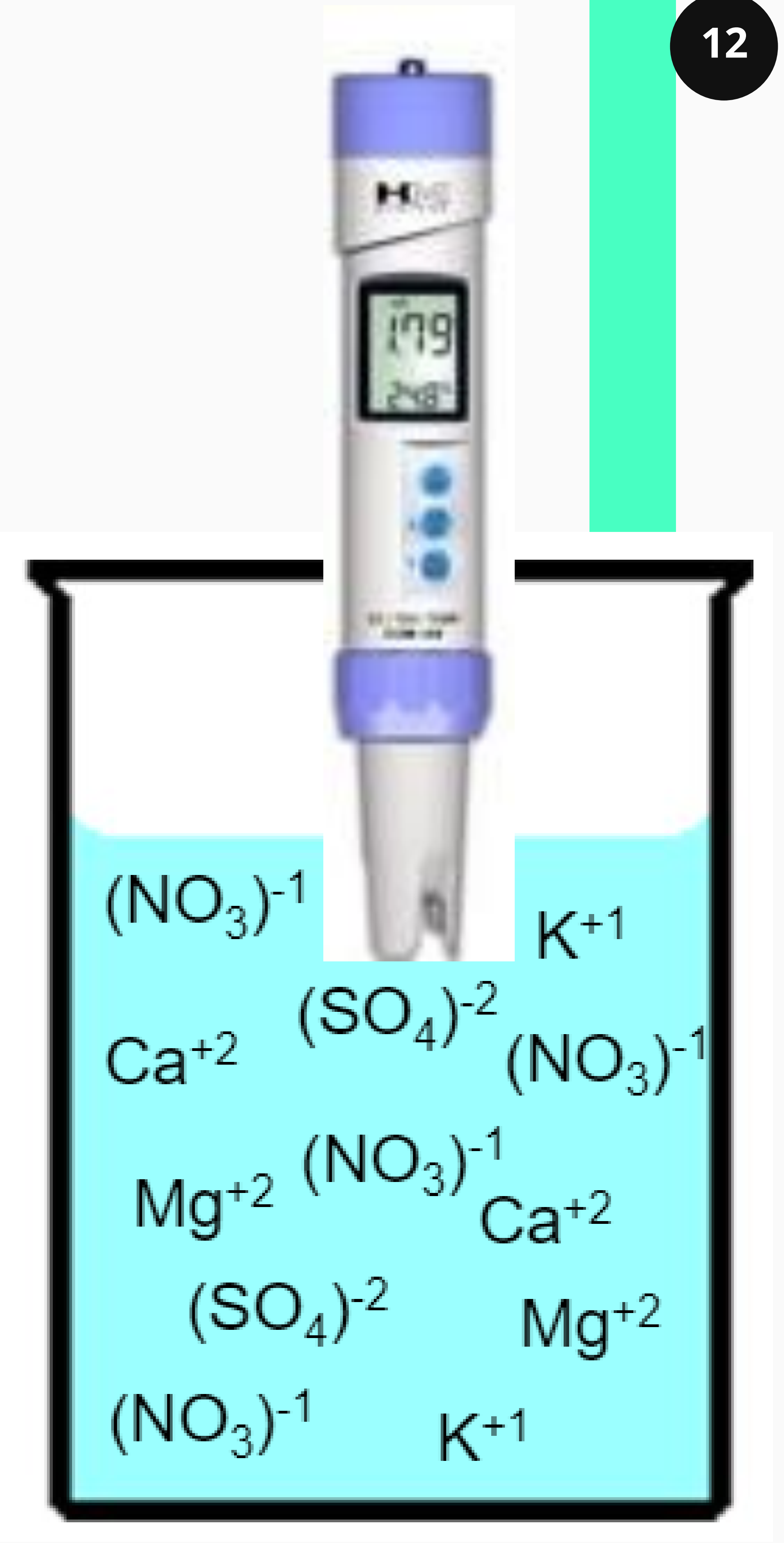
Electrical Conductivity & pH

What are they and how are they measured?

Measuring Nutrient Solutions
Electrical Conductivity

Electrical Conductivity (EC) = a measure of the amount of ions floating around in the nutrient solution





Technically it measures the amount of electric current that passes between a positively charged metal and negatively charged metal (milliSiemens/centimeter) (mS/cm)

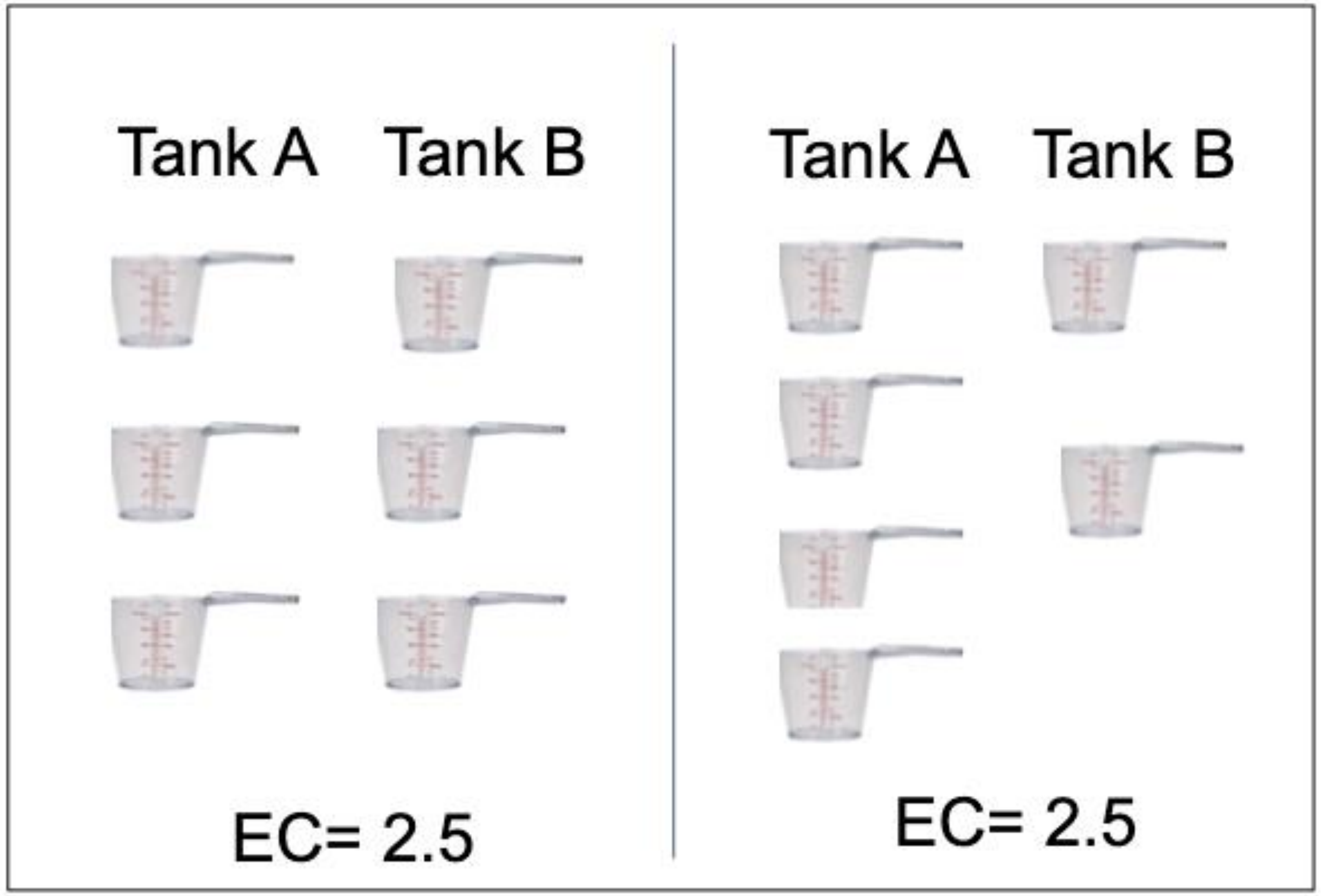
Measuring Nutrient Solutions
Electrical Conductivity

Electrical Conductivity (EC) = a measure of the amount of ions floating around in the nutrient solution

Why do we measure EC?

- Gives an idea of:
  - The strength of the nutrient solution
  - How well the nutrient solution will support plant growth

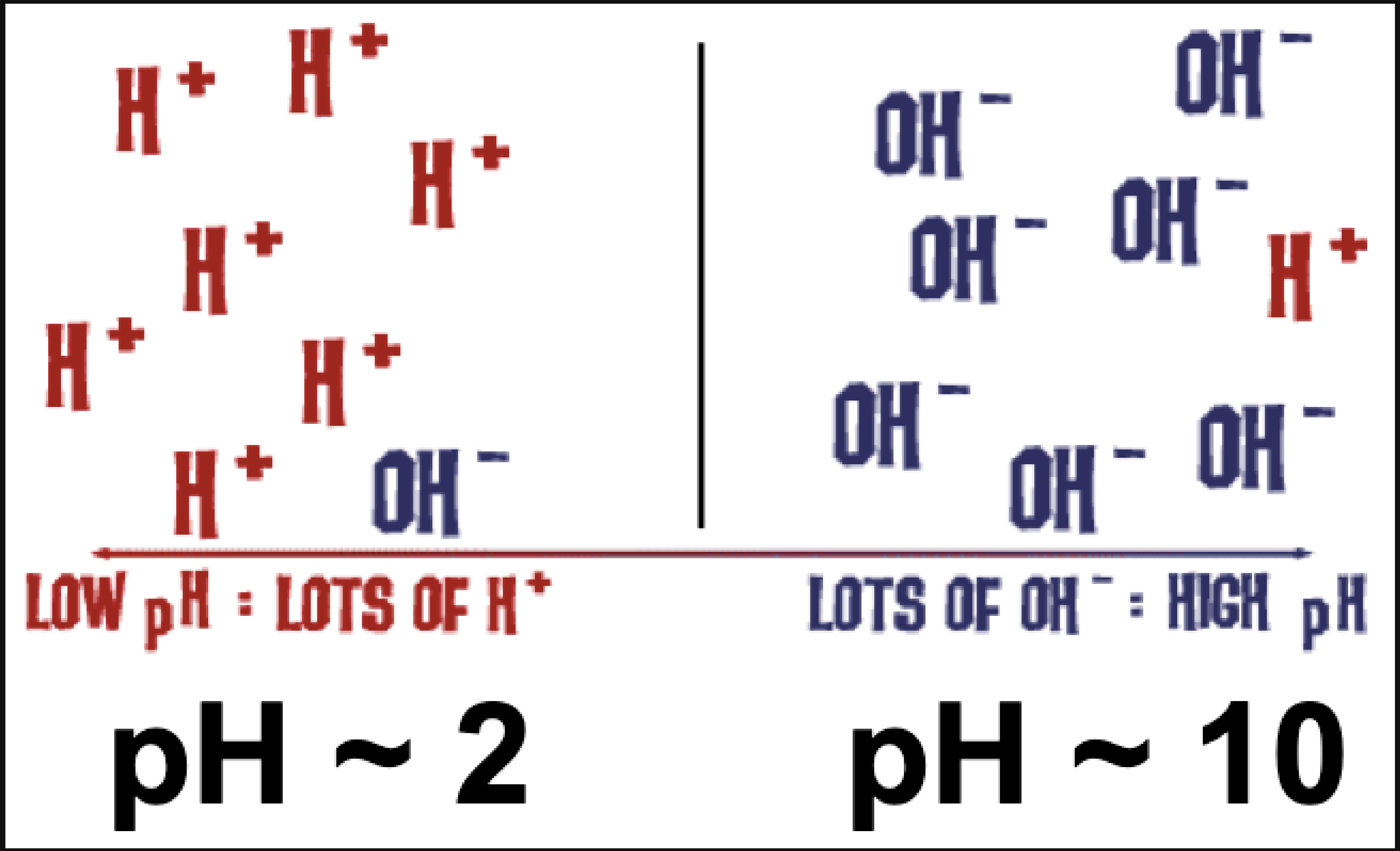
It DOES NOT tell you which ions are present or which ions are missing



Measuring Nutrient Solutions

pH

pH = a measure of how **acidic** or **basic** (alkaline) a nutrient solution is



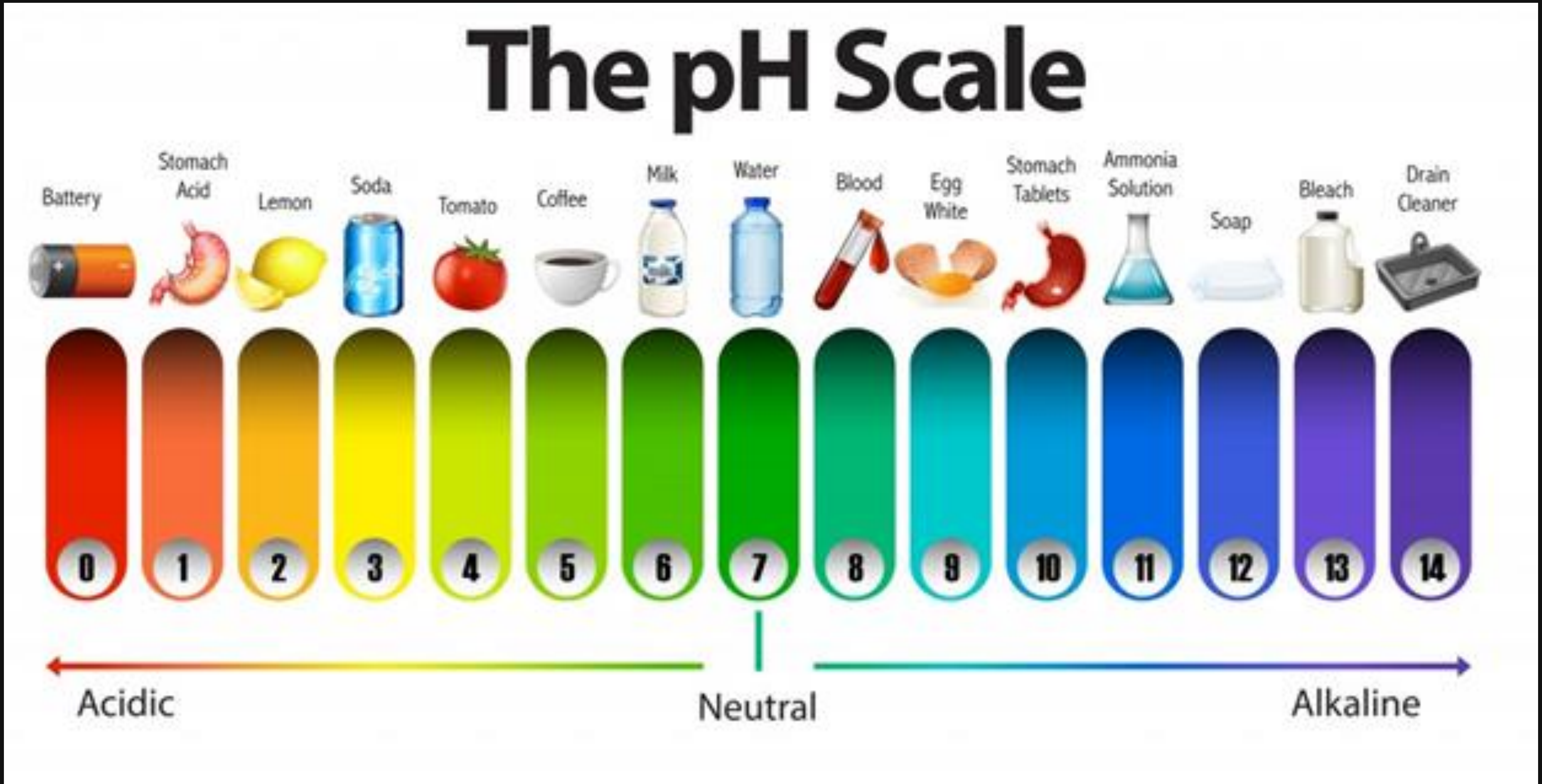
H+ (hydrogen ion)

OH- (hydroxide ion)

Measuring Nutrient Solutions

pH

pH is measured on a scale of 0 (most acidic) to 14 (most basic/alkaline)



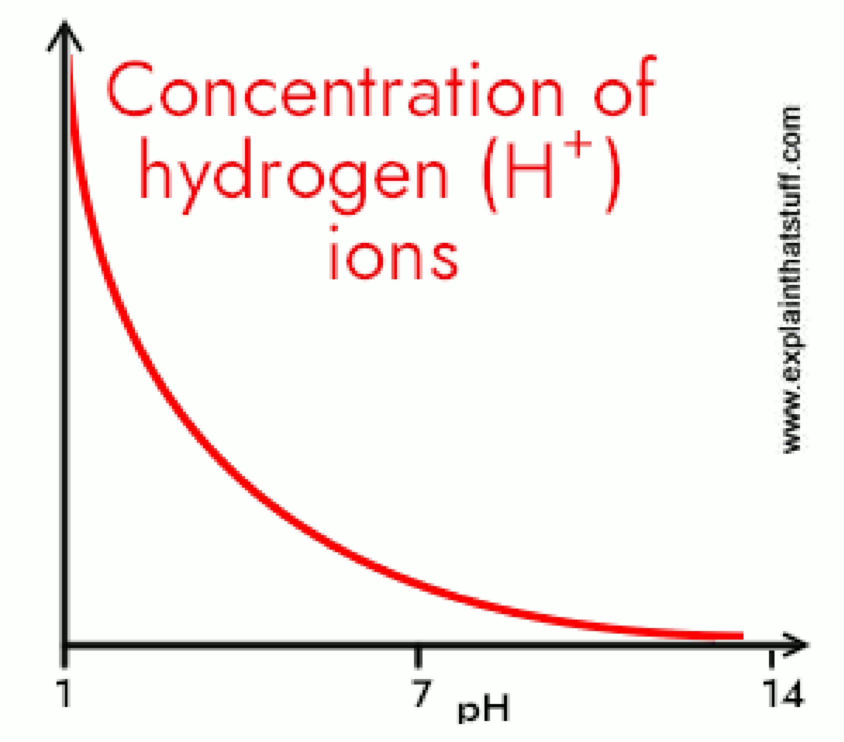
HTTPS://WWW.SCIENCEABC.COM/PURE-SCIENCES/CAN-PH-HAVE-VALUES-OUT-OF-THE-0-14-RANGE.HTML

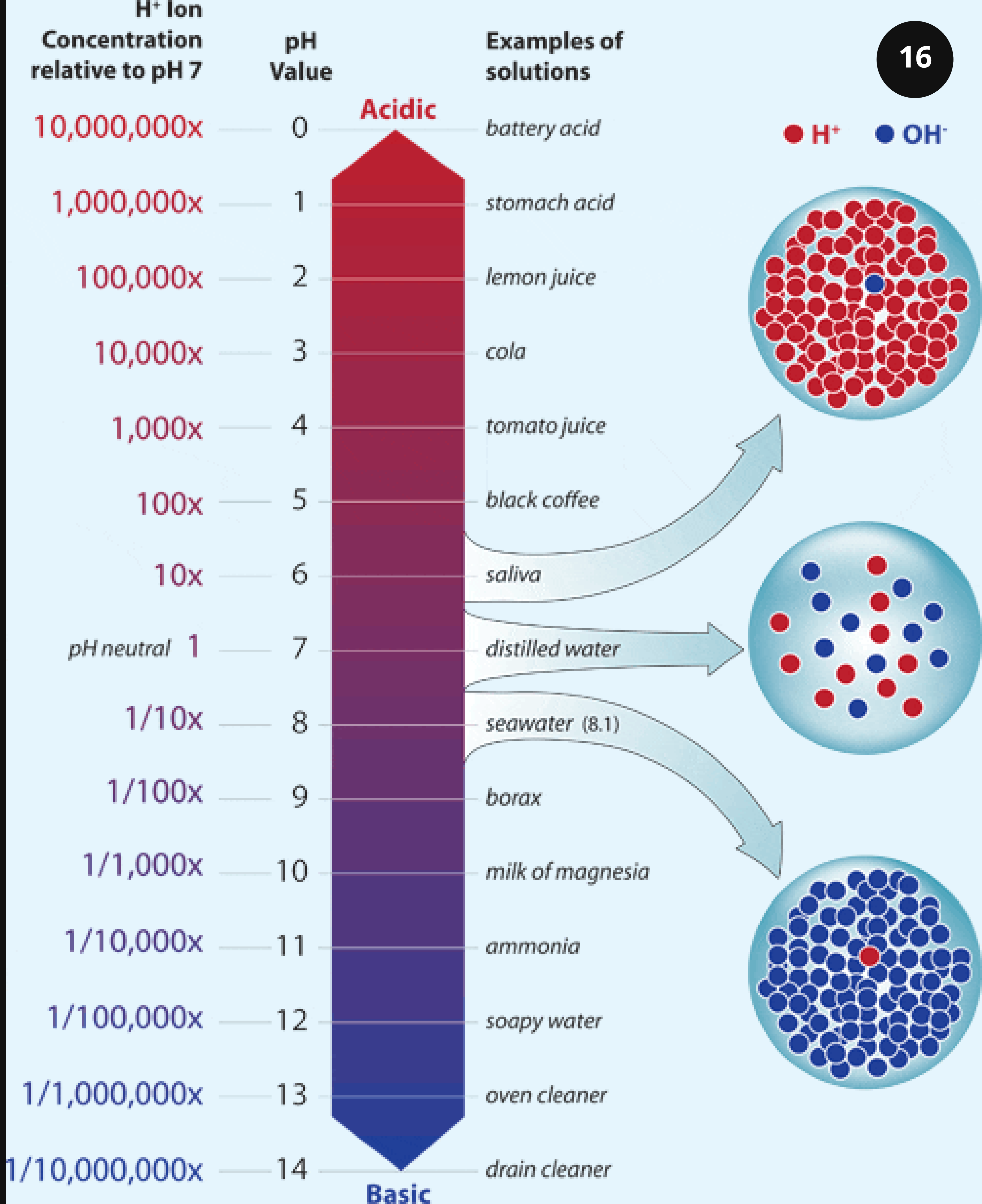
Measuring Nutrient Solutions

pH

A change in pH by 1 unit is a **10x increase or decrease** in concentration of H+ ions

A solution with pH 5 has 10x more H+ ions than a solution with pH 6





HTTPS://WWW.WHOI.EDU/OCEANUS/FEATURE/SMALL-DROP-IN-PH-MEANS-BIG-CHANGE-IN-ACIDITY/

Measuring Nutrient Solutions

pH

Important in hydroponics for two reasons:

- pH must be at the right level to keep as much fertilizer dissolved as possible (plants only take up nutrients as IONS)
- Different plants like different pH levels

NOTE: pH is not the only factor affecting the availability of ions to the roots. (**pH, water temperature, and the interaction of other ions**)

pH 4.0-6.0

Blueberries prefer acidic to slightly acidic soils

pH 6.0-7.5

Pole beans prefer slightly acidic to neutral soils

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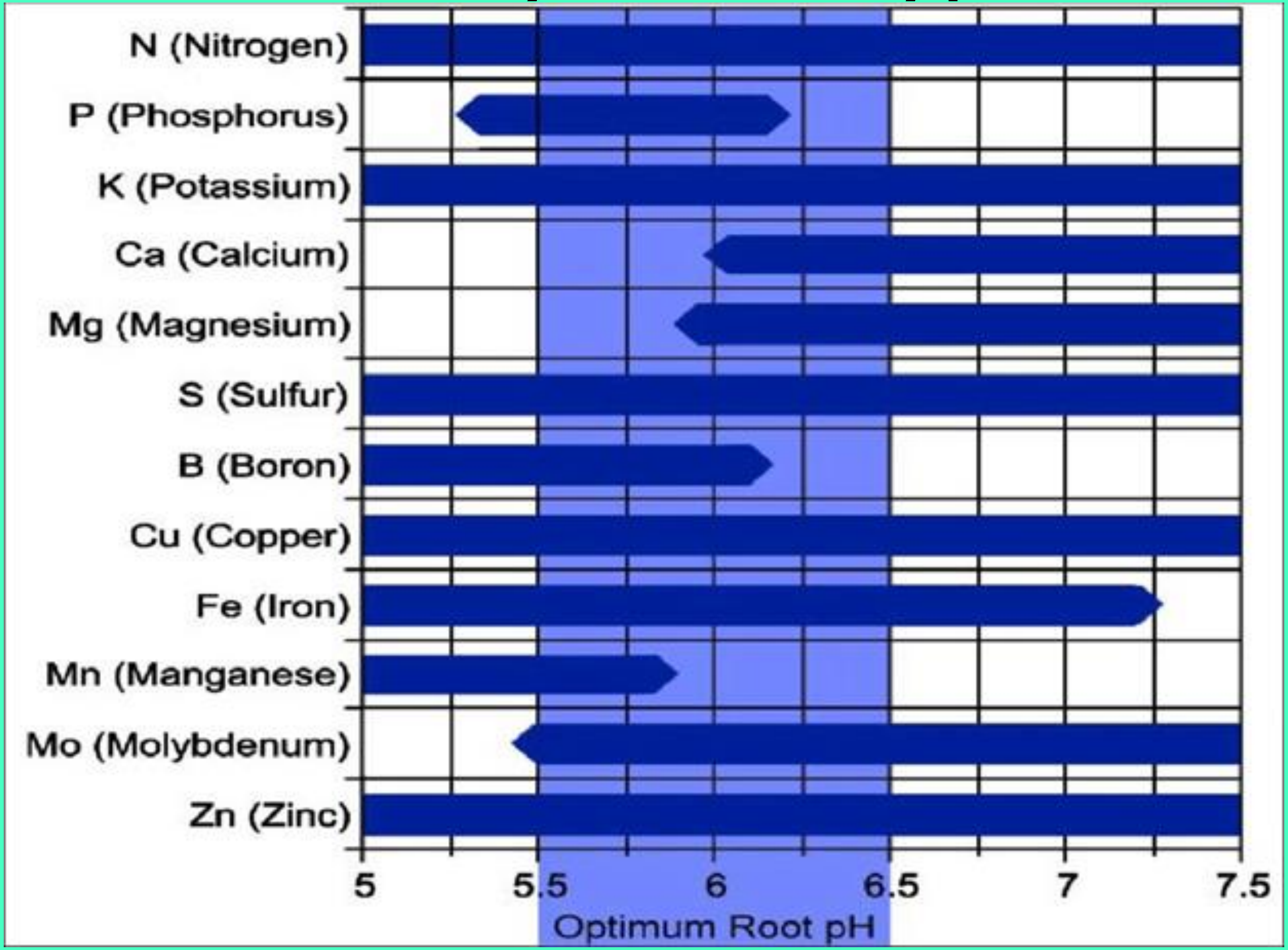
Nutrient Availability in solution by pH



For all plants there is a particular pH level that will produce optimum results. This pH level will vary from plant to plant, but in general most plants prefer a slightly acidic growing environment between 5.5 to 6.5 (Trejo-Tellez and Gomez, 2012)

HTTPS://WWW.RESEARCHGATE.NET/PUBLICATION/346953811_HYDROPONICS_CULTIVATION_OF_CROPS

Measuring Nutrient Solutions

pH

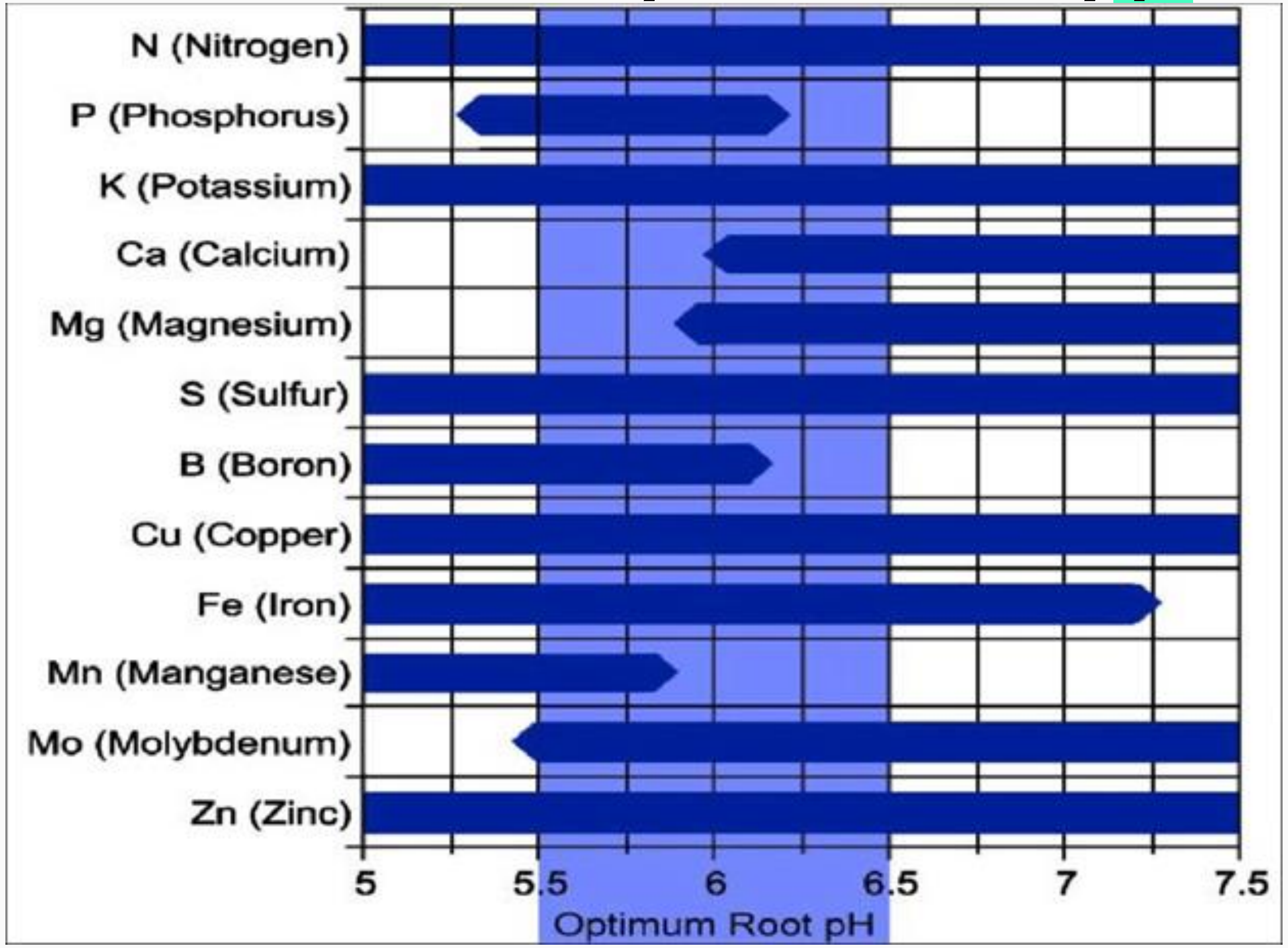
Nutrient "Lockout"

When nutrient solution conditions are such that certain nutrients become bound to something else (precipitate) and therefore is no longer in ionic form and is no longer available to be taken up by the plant.

May be caused by:

- Too high or low a pH
- Excessive amounts of one or more other nutrients.

Nutrient Availability in solution by pH



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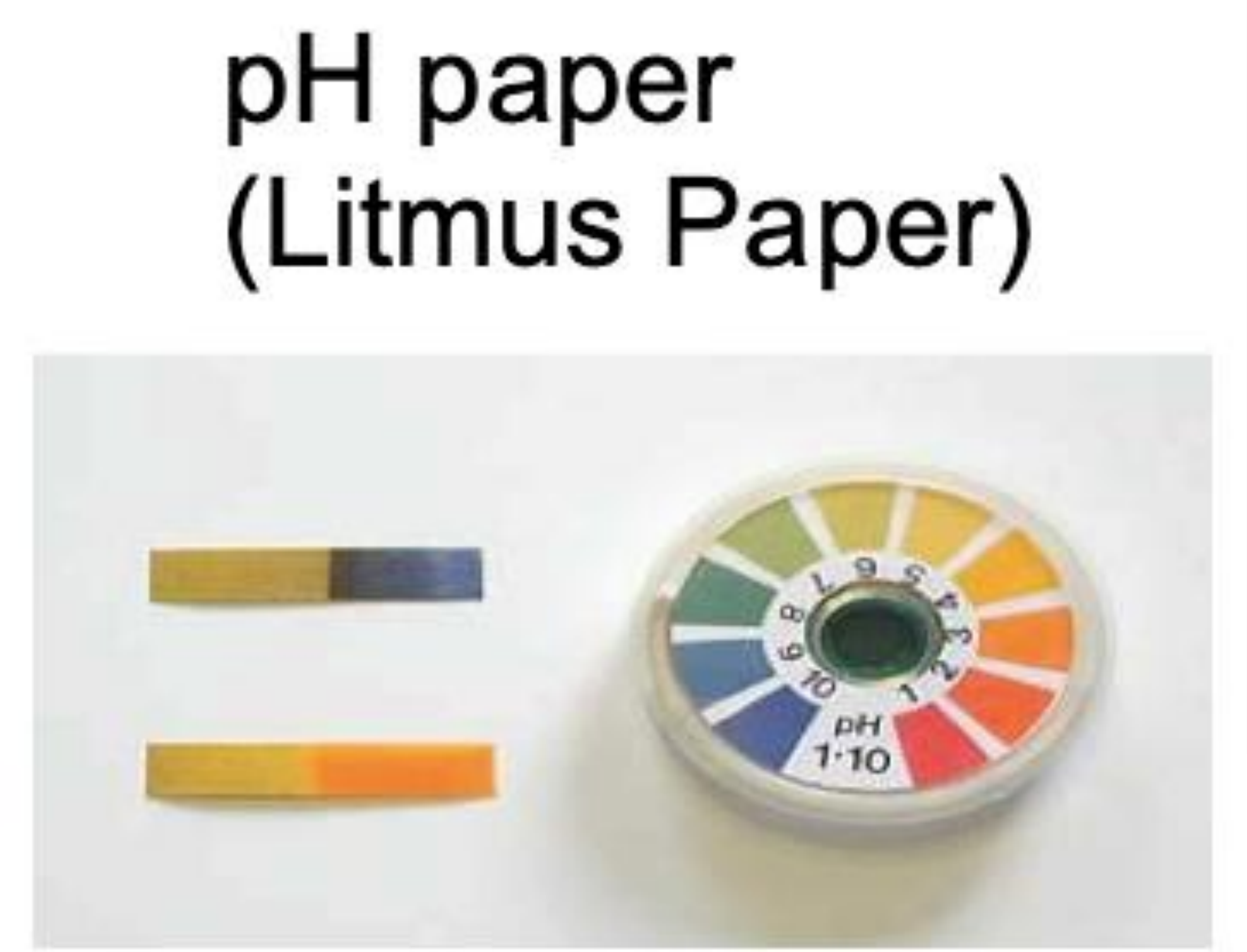
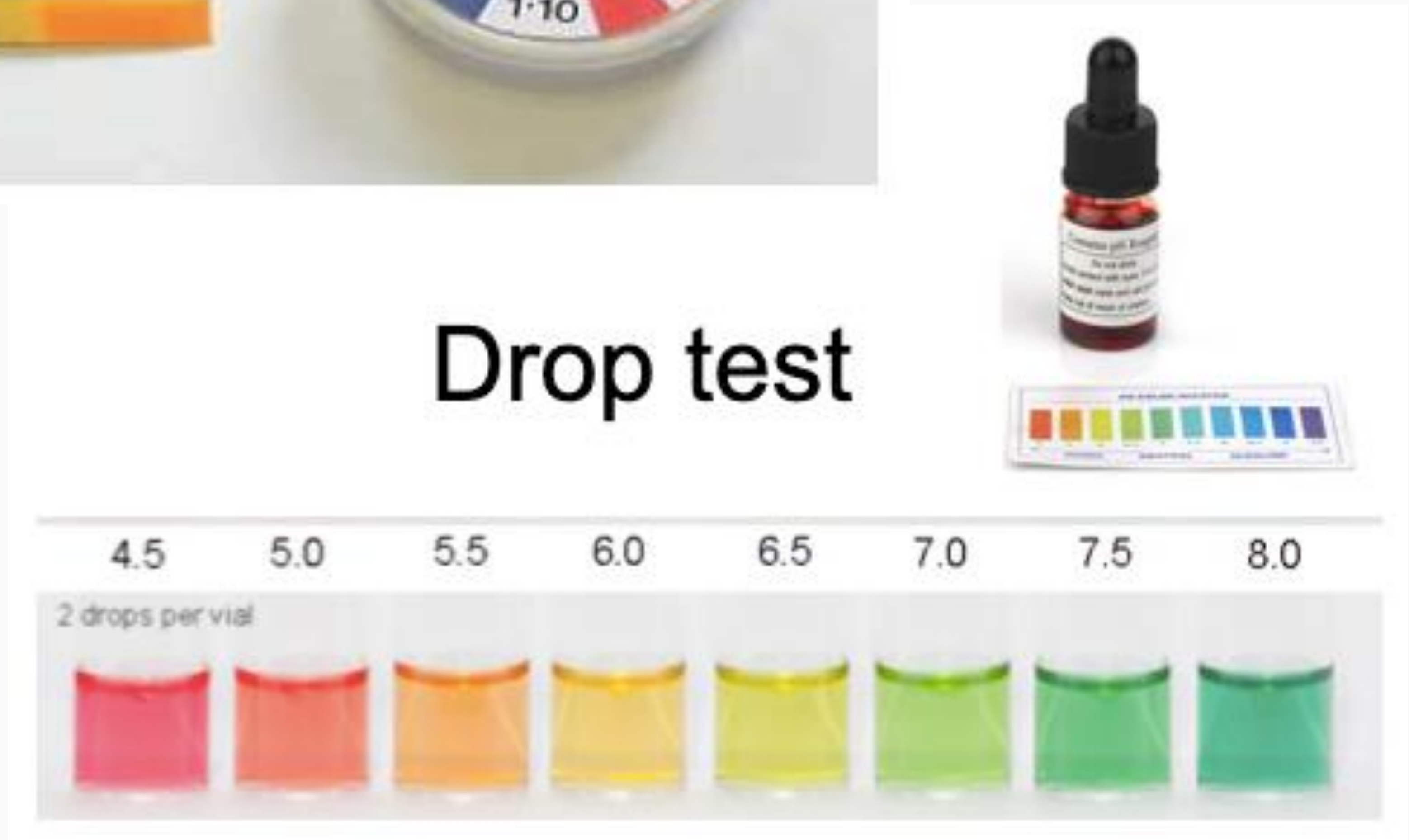
Measuring Nutrient Solutions

pH

How do we measure pH?





Maintaining the Nutrient Solution

How do we keep our nutrient solution at the ideal EC and pH levels?

EC – add more ions (nutrients) to the solution as plants take them up

pH – use acid or base (majority of the time you will be adding acid to decrease pH)

Acids Used in Hydroponics:

- Nitric, HNO_3 (strongest)
  - pH 1.0
- Sulfuric, H_2SO_4 (weak)
  - pH 1.2
- Phosphoric, H_3PO_4 (weakest)
  - pH 1.5
- Citric (organic approved)
  - pH 2.2

PH VALUES FROM HTTPS://WWW.ENGINEERINGTOOLBOX.COM/ACIDS-PH-D_401.HTML

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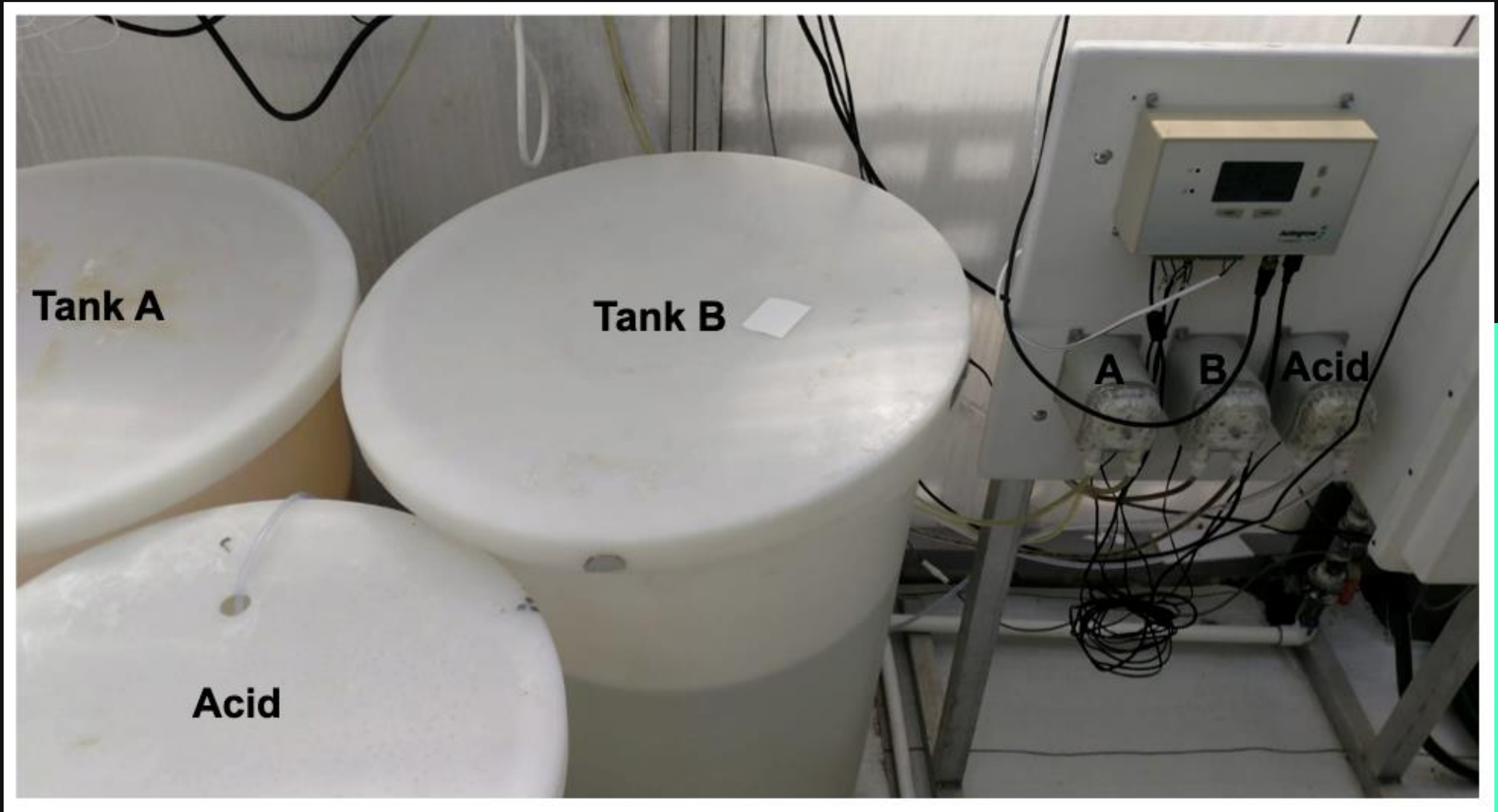
Nutrient Dispensing System

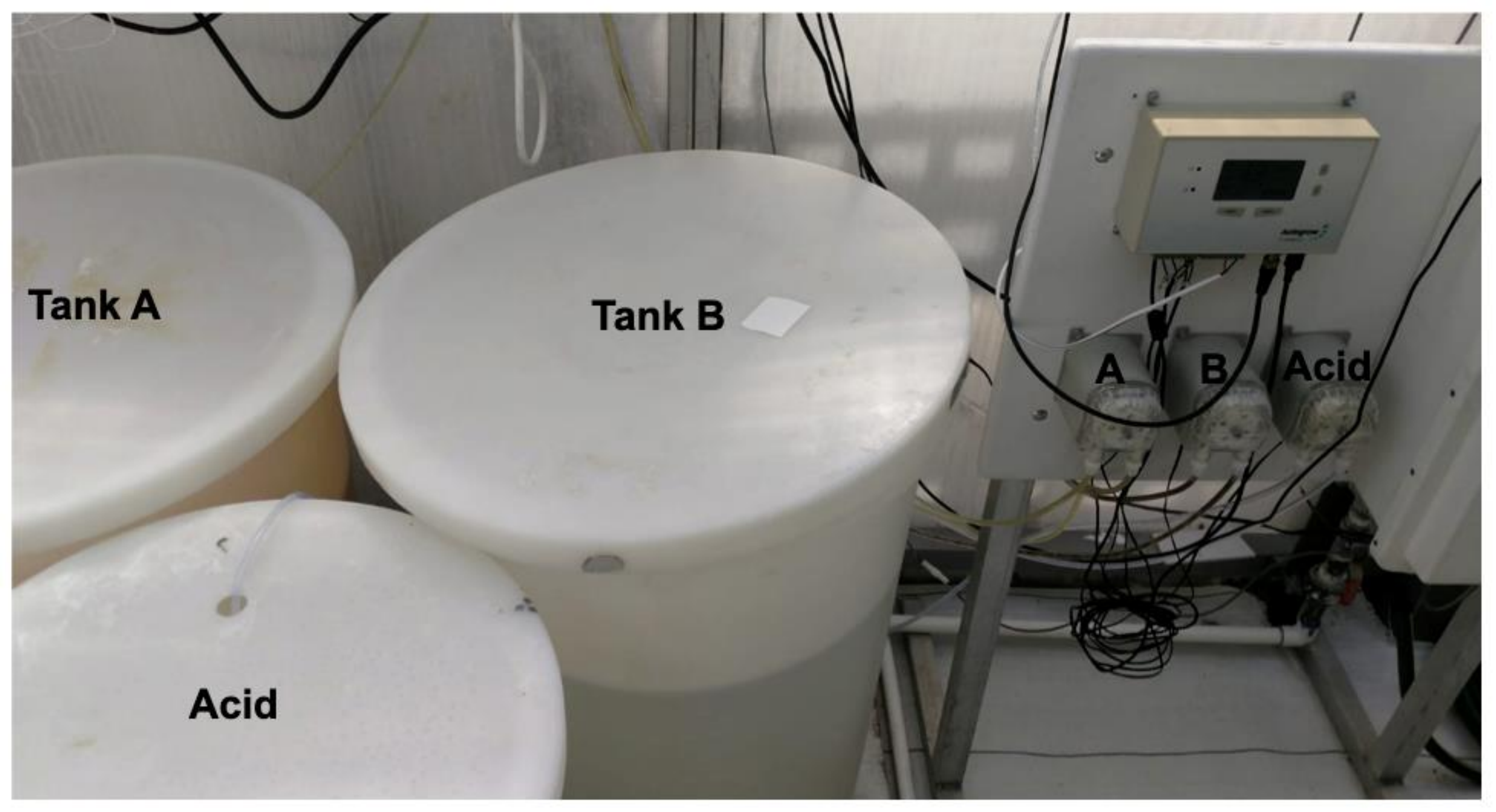


Nutrient Dispensing System

Tank B: *Remaining Macro & Micronutrients (including phosphorous and sulfur)*

Tank A: *Calcium*, Potassium, and Iron Compounds*

**Calcium separated from Phosphate and Sulfate compounds to prevent nutrient lockout (precipitation)*



Computer and Pumps

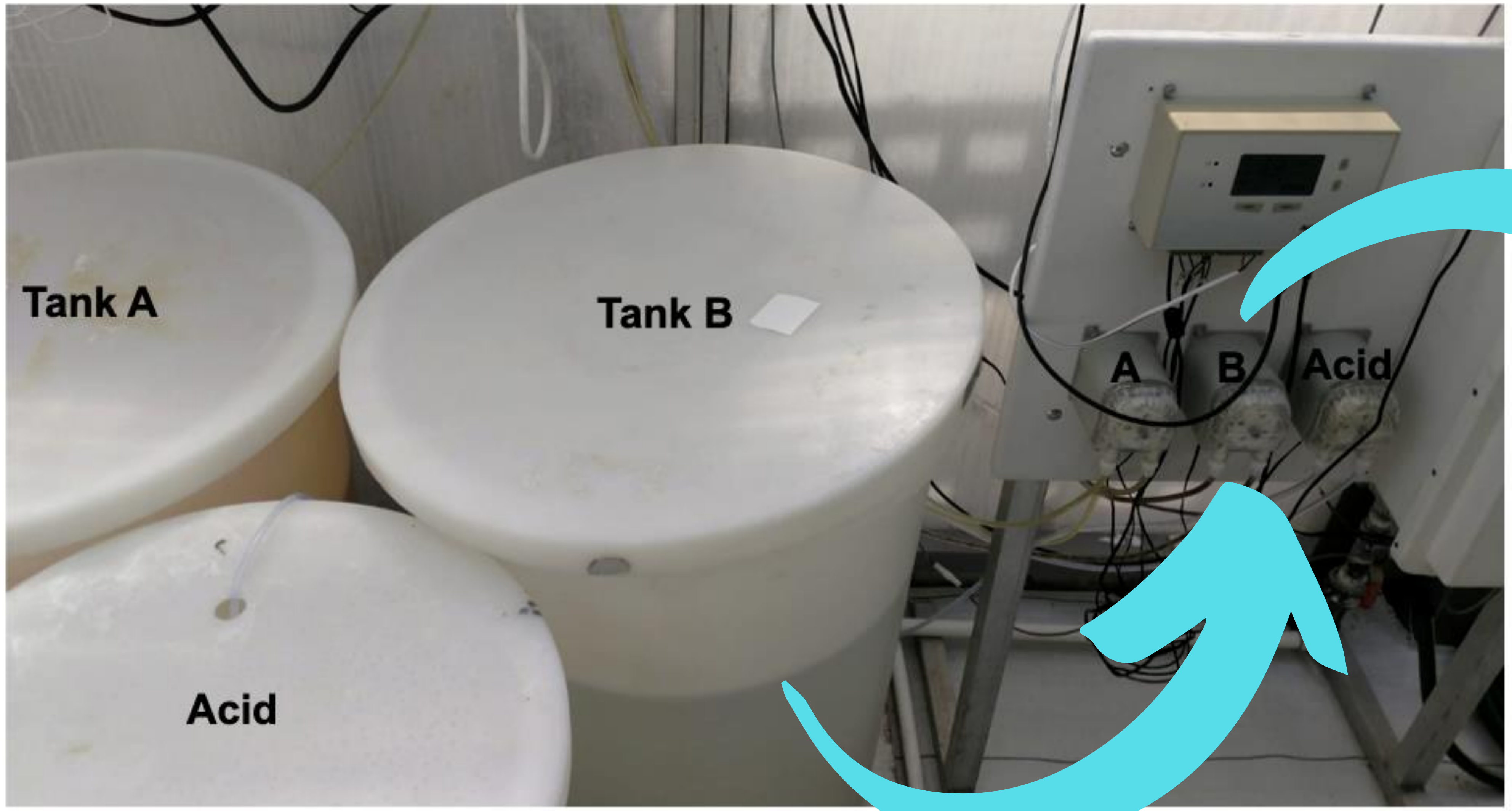
Acid Tank: *used to lower pH*

Example of Nutrient System

- pH and EC meters monitor the nutrient solution
- The computer uses that information to control the pumps and adjust the nutrient solution as needed

pH meter

EC meter



Review Questions

The electrical conductivity of your nutrient solution is 1.79 mS/cm. Your target EC is 2.5 mS/cm. You should....

A. Add more nutrients to the solution
B. Add an acid to the solution
C. Add more plants

The electrical conductivity of your nutrient solution is 1.79 mS/cm. Your target EC is 2.5 mS/cm. You should....

A. **Add more nutrients to the solution**

Your EC is lower than desired. This likely means plants have taken up the nutrients in solution and more should be added.

B. **Add an acid to the solution**

C. **Add more plants**

You measure the pH of your nutrient solution and it is 7.83. Your plants prefer a pH of 6. You should.....

A. Add more fertilizer to the solution
B. Add an acid to the solution to decrease the pH
C. Add a base to your solution to decrease the pH
D. Add more plants

You measure the pH of your nutrient solution and it is 7.83. Your plants prefer a pH of 6. You should.....

A. **Add more fertilizer to the solution**

B. **<u>Add an acid to the solution to decrease the pH</u>**

Your pH is higher than desired. This likely means the plants have been absorbing nutrients, which causes a natural rise in pH. Acid should be added to prevent nutrient lockout of essential elements.

C. **Add a base to your solution to decrease the pH**

D. **Add more plants**

Definitions

ESSENTIAL ELEMENT

Critical for a plant to complete its life cycle

NUTRIENT DEFICIENCY

Plant growth is limited by the most deficient essential element

ION

Charged element or compound

NUTRIENT SOLUTION

A mixture of essential elements/minerals that plants need to grow

SOLUBILITY

The ability to be dissolved, especially in water

ELECTRICAL CONDUCTIVITY

A measure of the amount of ions floating around in the nutrient solution

PH

The measure of how acidic or basic a nutrient solution is

NUTRIENT LOCKOUT

When the chemical qualities of a nutrient solution cause nutrients to bind to each other (precipitate) and become unavailable to plants

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RESEARCH, INNOVATION & IMPACT
Arizona Institutes for Resilience

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