Plants, soil, and nutrients

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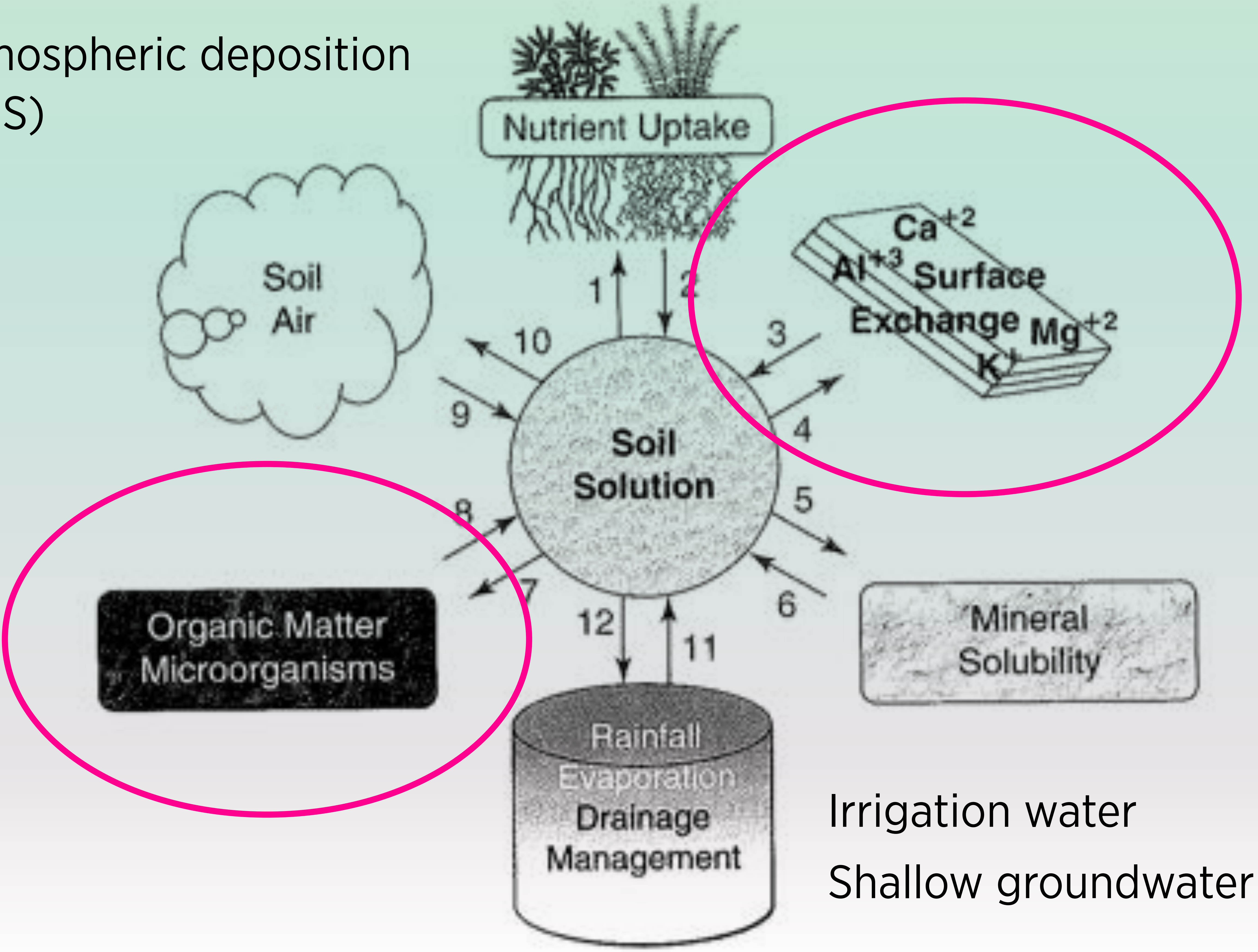
Where do plants get their nutrients?

Atmospheric deposition
(N, S)



Irrigation water

Shallow groundwater

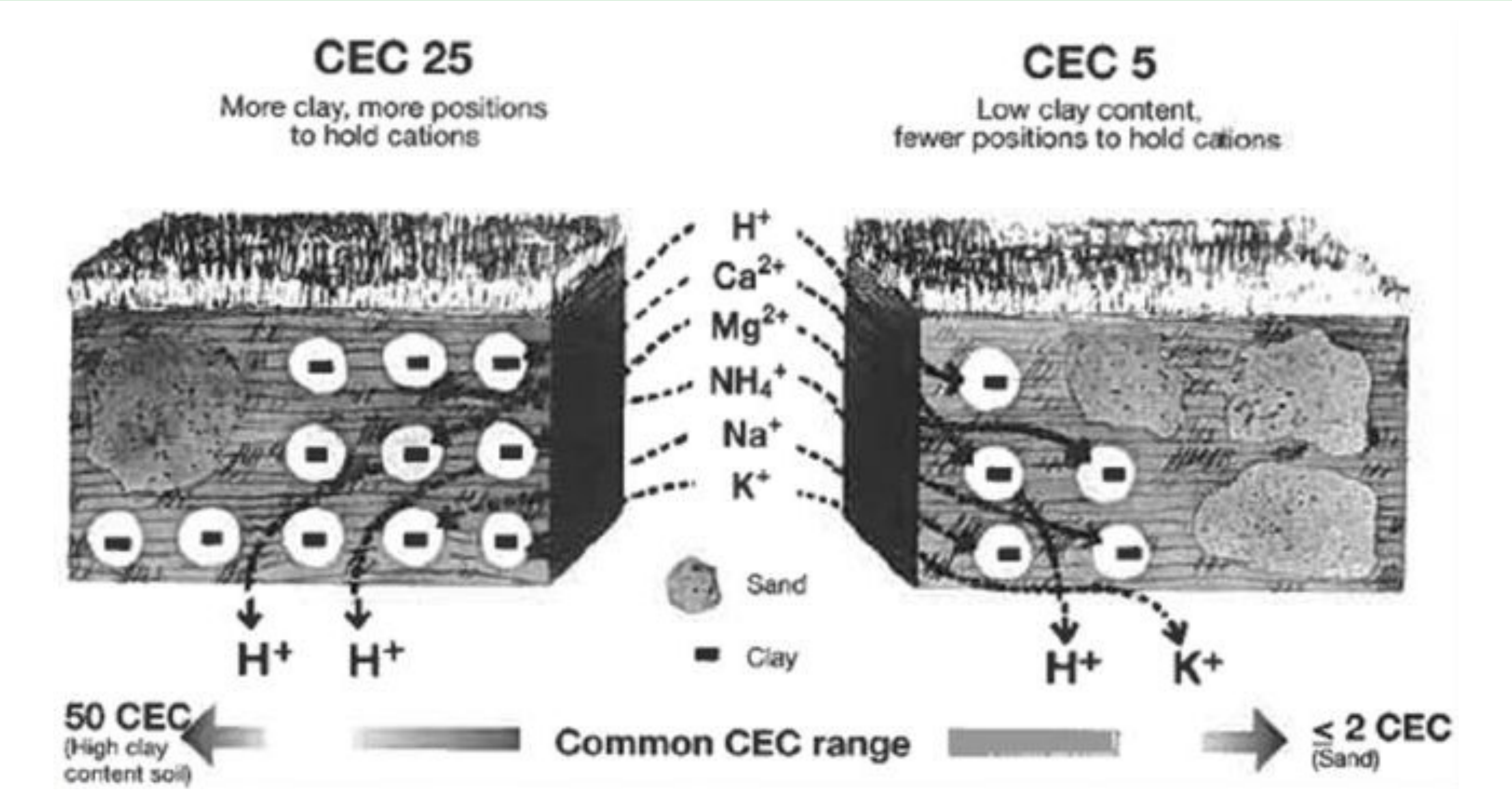
What is surface exchange?

Soil:

- Is negatively charged
- Therefore has the ability to hold positive ions (cations)

The total number of negative charges determines:

- How many cations can be held
- This is called Cation Exchange Capacity (CEC)
- How tightly cations are held



Clays have greater CECs than sand

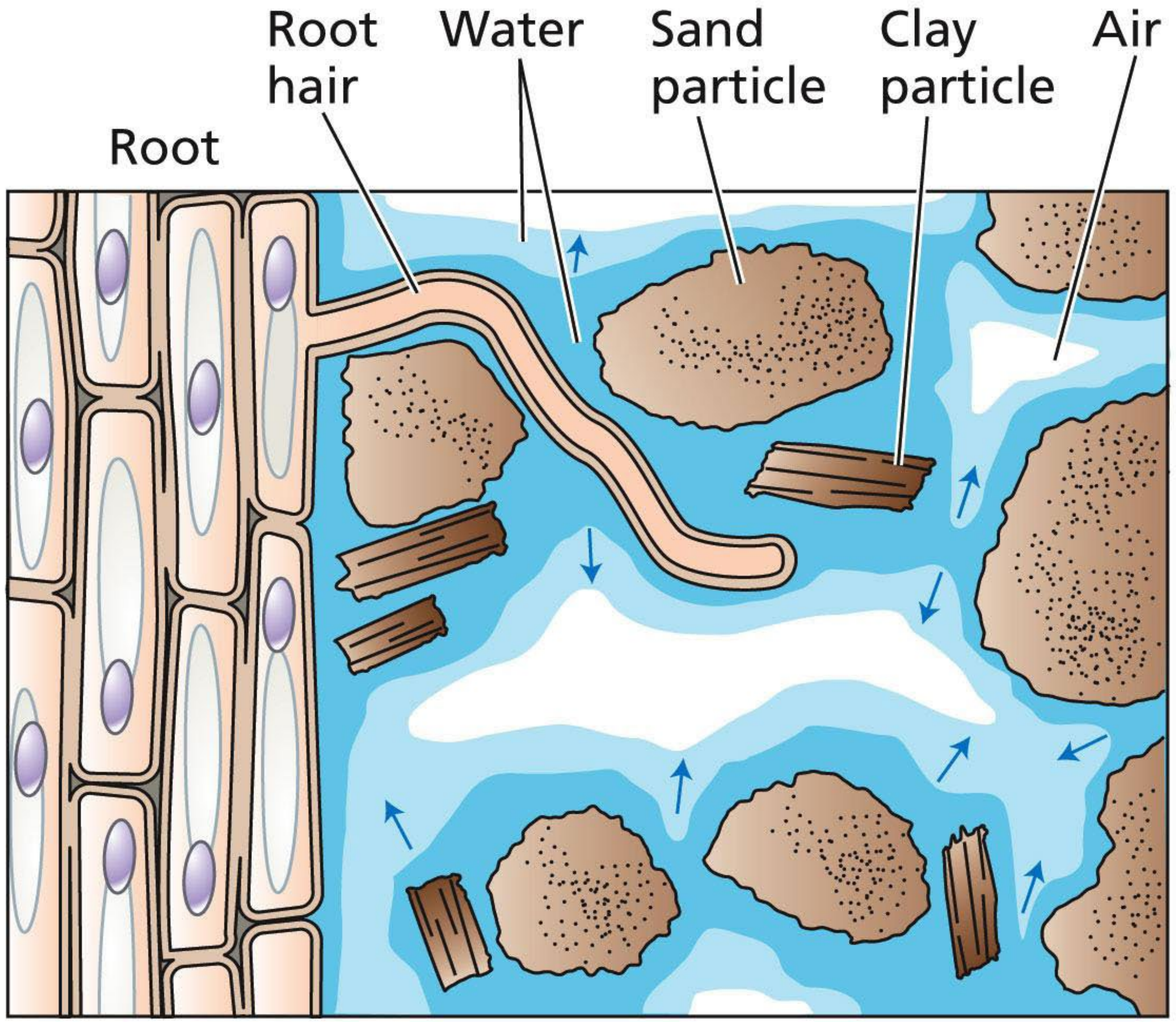
How do plants take up mineral nutrients?

a. Direct contact with nutrients

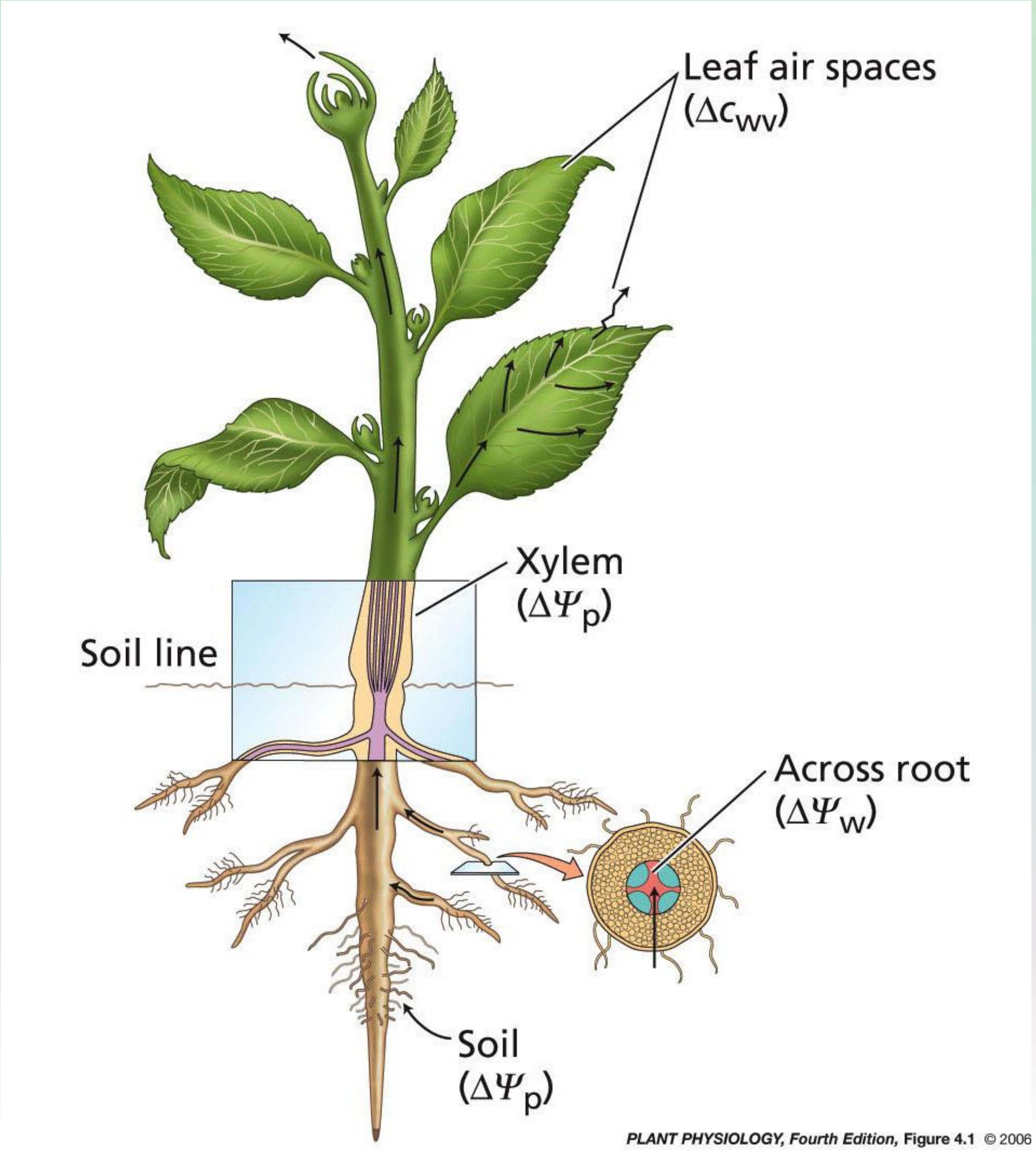
b. Through ions dissolved in water

c. Through soil microbial interactions

All are correct, but B is the most frequent.



Surface exchange and transpiration



Water is pulled through the plant.
Water movement into plant also pulls in mineral nutrients.

What are the most important mineral nutrients for plants?

Macronutrients
(high concentrations, 0.1–2%)

- N
- P
- K
- Ca
- S
- Mg

Micronutrients
(low concentrations, 0.0001–0.01%)

- Fe
- Zn
- Mn
- Mo
- B
- Cu
- Cl
- Ni

Mineral nutrient	Function
Group 1	**Nutrients found in carbon compounds**
N	Part of amino acids (make up proteins), DNA, RNA, pigments like chlorophyll
S	Part of some amino acids (needed for proteins), plant defense (breaks down herbicides)
Group 2	**Nutrients for energy storage or structural integrity**
P	Used for energy (ATP), phosphorylated sugars, part of cell membranes (phospholipids), DNA and RNA backbones
Si	Helps cell walls remain strong, fights off pathogen attacks
B	Needed for cell wall strength (binds to parts of the cell wall), needed for cell expansion.

Adapted from Taiz et al. (2015), Plant Physiology and Development. 6th ed, page 121.

Mineral nutrient	Function
Group 3	**Nutrients that remain in ionic form**
K	Help plants maintain turgor, water regulation, needed for enzymes to work (cofactor)
Ca	Stomatal opening and closing, needed for cell wall strength, helps enzymes work, plant signaling
Mg	**Helps enzymes turn on/off, center ion of chlorophyll**
Cl	Helps generate oxygen during photosynthesis, balances charges in cells
Zn	Component of enzymes that break down toxins
Na	Needed in C4 plants (like corn) to get the molecules needed for photosynthesis, can act in place of K sometimes

Adapted from Taiz et al. (2015), Plant Physiology and Development. 6th ed, page 121.

Summary

- **Soil supplies nutrients to plants**
- **Crop's need to produce its optimum yield usually exceeds what the soil can provide**
  - Fertilizer is applied
- **Major nutrients needed are:**
  - Nitrogen
  - Phosphorus
  - Potassium
- **Soil pH (concentration of hydrogen ions)**
  - Can influence nutrient availability if too far from neutral

Nitrogen cycle

How might we teach the N cycle to understand soil tests and N use?

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Nitrogen

- **Nitrogen is needed for organism growth, maintenance and repair.** Examples:
  - Building amino acids for proteins (enzymes, muscles)
  - DNA Structure (nitrogen bases)
  - Chlorophyll and pigments

Nitrogen symbols and terms

N_2	Atmospheric nitrogen
NH_3	Ammonia
NH_4^+	Ammonium
NO_2^-	Nitrite
NO_3^-	Nitrate

Fixing nitrogen

Atmosphere: 78% Nitrogen (N_2)

This form of nitrogen un-usable form for plants (and animals)

How does nitrogen get into the usable form?

- It must be fixed

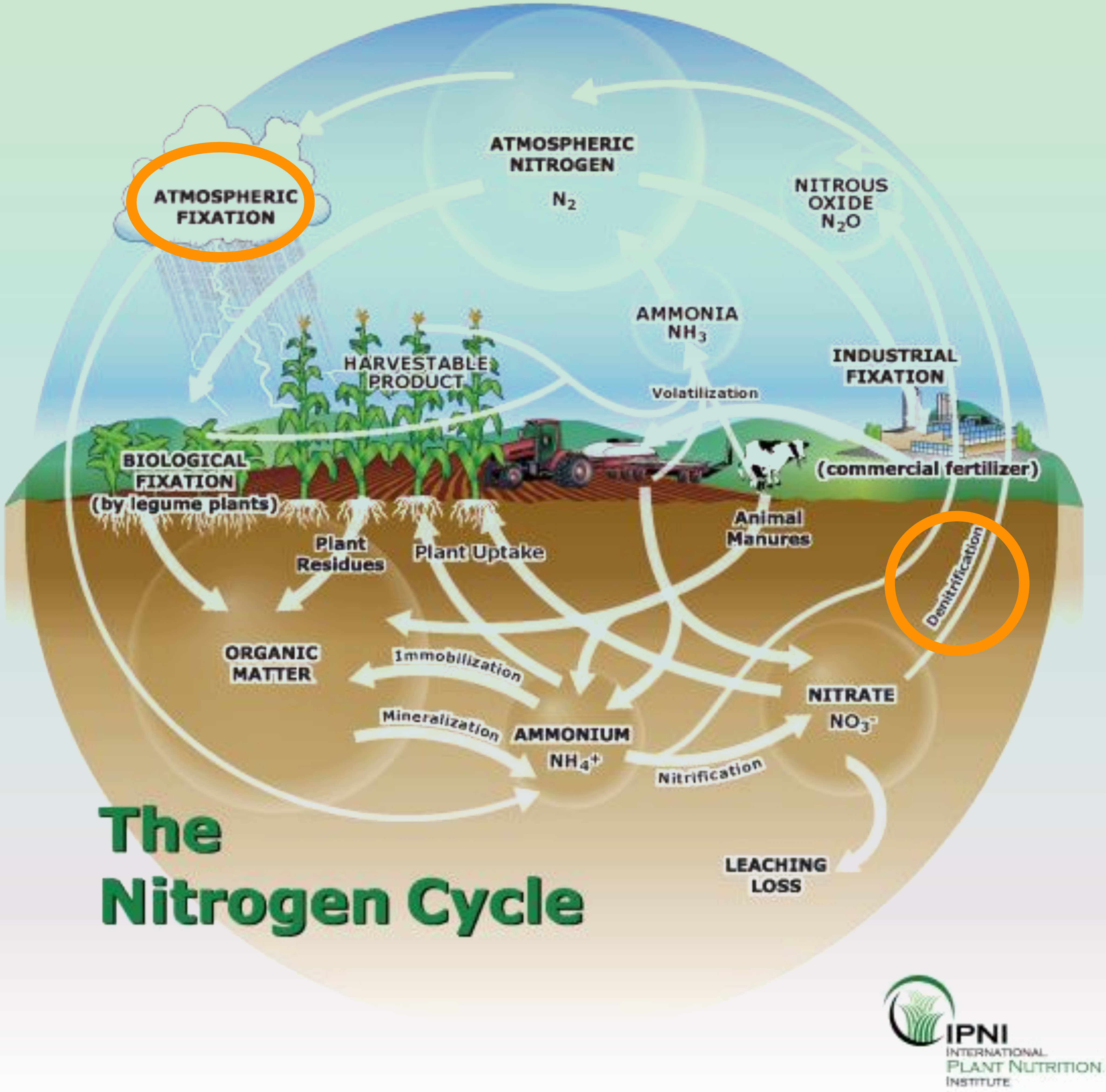
How?

- Naturally: Lightning, Fires, Bacteria
- Synthetic: Fertilizers

Nitrogen cycle conversions of gases

Nitrogen fixation: Atmospheric nitrogen (N_2) converted into ammonium (NH_4^+) by nitrogen-fixing bacteria

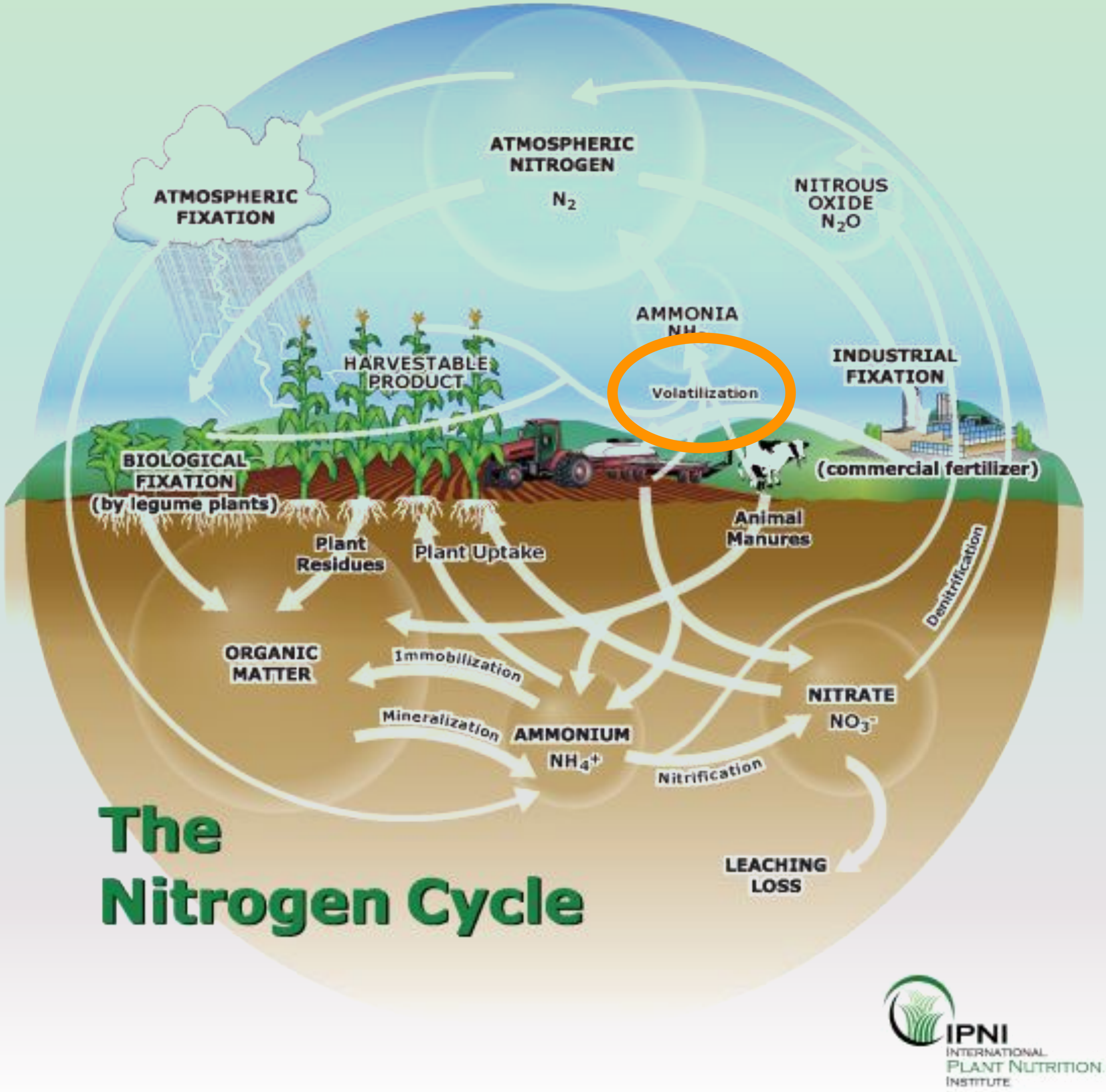
Denitrification: Return of nitrogen back to the atmosphere by converting nitrogen compounds to atmospheric nitrogen (N_2) by denitrifying bacteria



Nitrogen cycle conversions of gases

Volatilization: Return of ammonia gas to atmosphere. Dependent on:

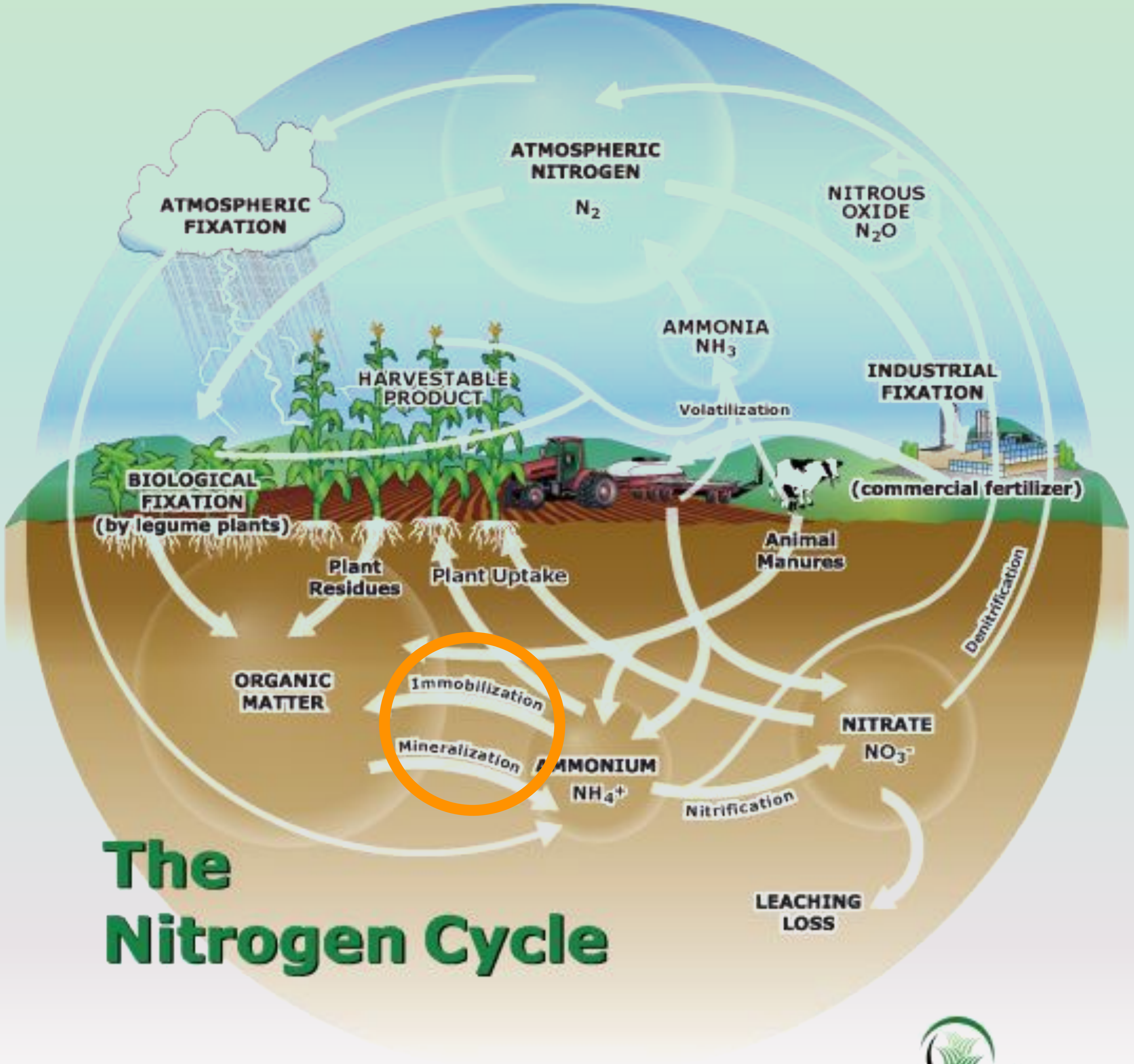
- Soil pH (above 7.5), temperature (increases as temp increases), moisture (evaporation promotes it)
- Type of fertilizer and method of placement



Nitrogen cycle organic material

Ammonification/mineralization: Organic compounds from crop residue, wastes or dead organisms converted into ammonium (NH_4^+) by decomposing bacteria

Immobilization: Conversion of mineral nitrogen forms (NH_4^+ and NO_3^-) into organic material and biomass like plants and microbes



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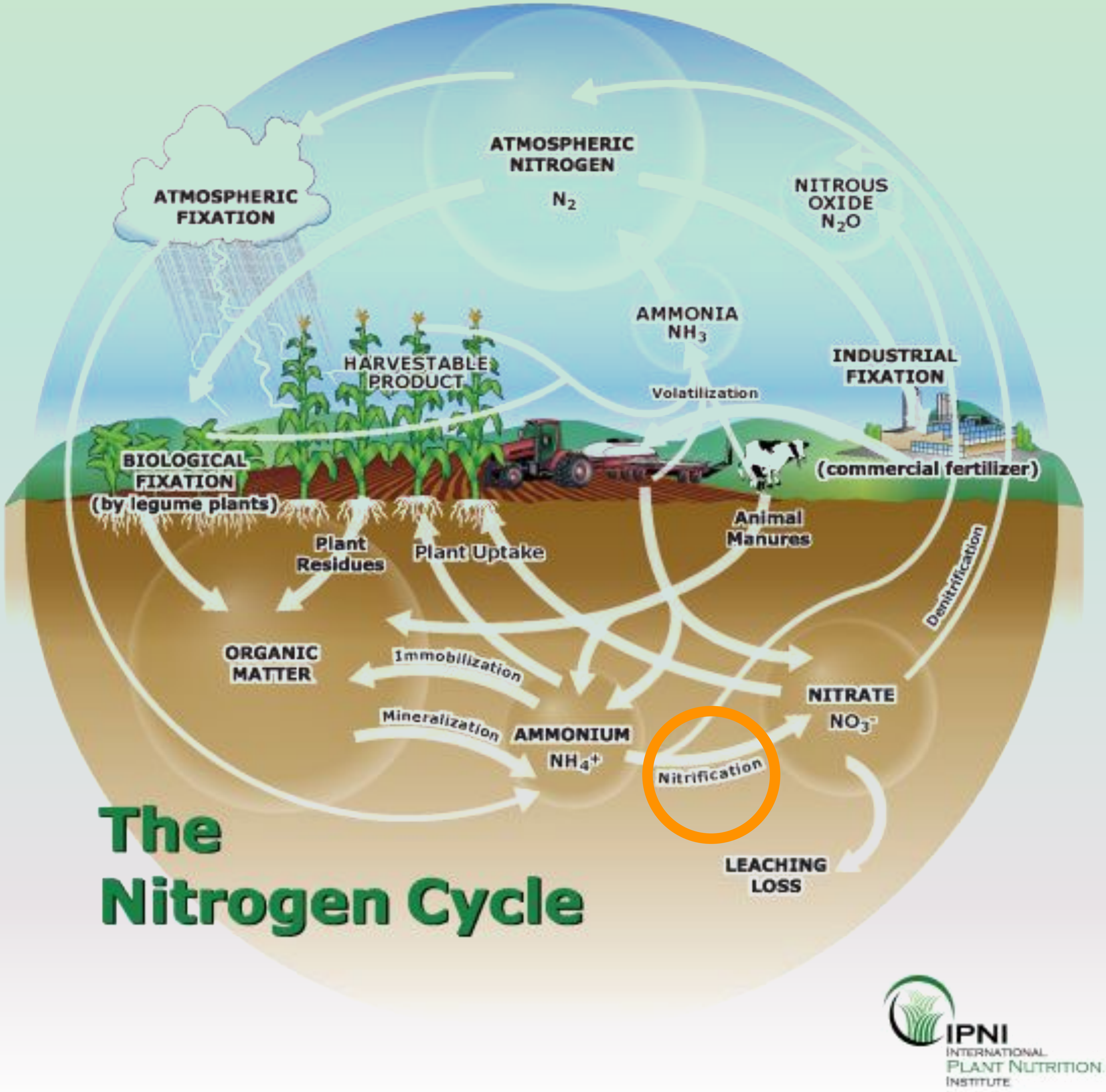
Nitrogen cycle: ammonium to nitrate

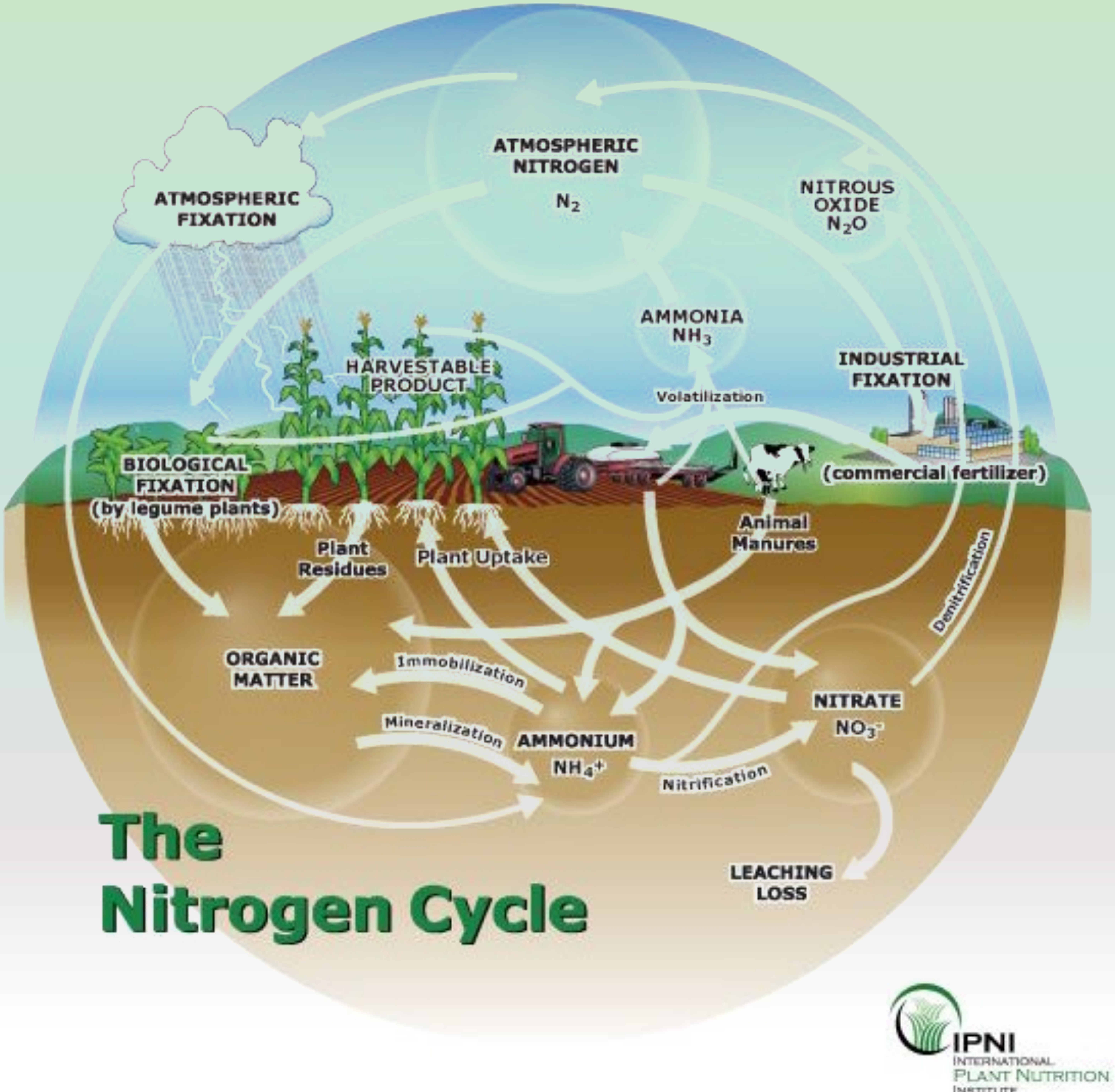
Nitrification: Two-step reaction converting ammonium (NH_4^+) to nitrite (NO_2^-) to nitrate (NO_3^-) by two kinds of nitrifying bacteria



Nitrogen cycle

Which process takes the longest?

What happens to excess N?



ATMOSPHERIC FIXATION
ATMOSPHERIC NITROGEN
N_2
NITROUS OXIDE
N_2O
AMMONIA
NH_3
HARVESTABLE PRODUCT
Volatilization
INDUSTRIAL FIXATION
(commercial fertilizer)
BIOLOGICAL FIXATION
(by legume plants)
Plant Residues
Plant Uptake
Animal Manures
Denitrification
ORGANIC MATTER
Immobilization
Mineralization
AMMONIUM
NH_4^+
Nitrification
NITRATE
NO_3^-
LEACHING LOSS
The Nitrogen Cycle
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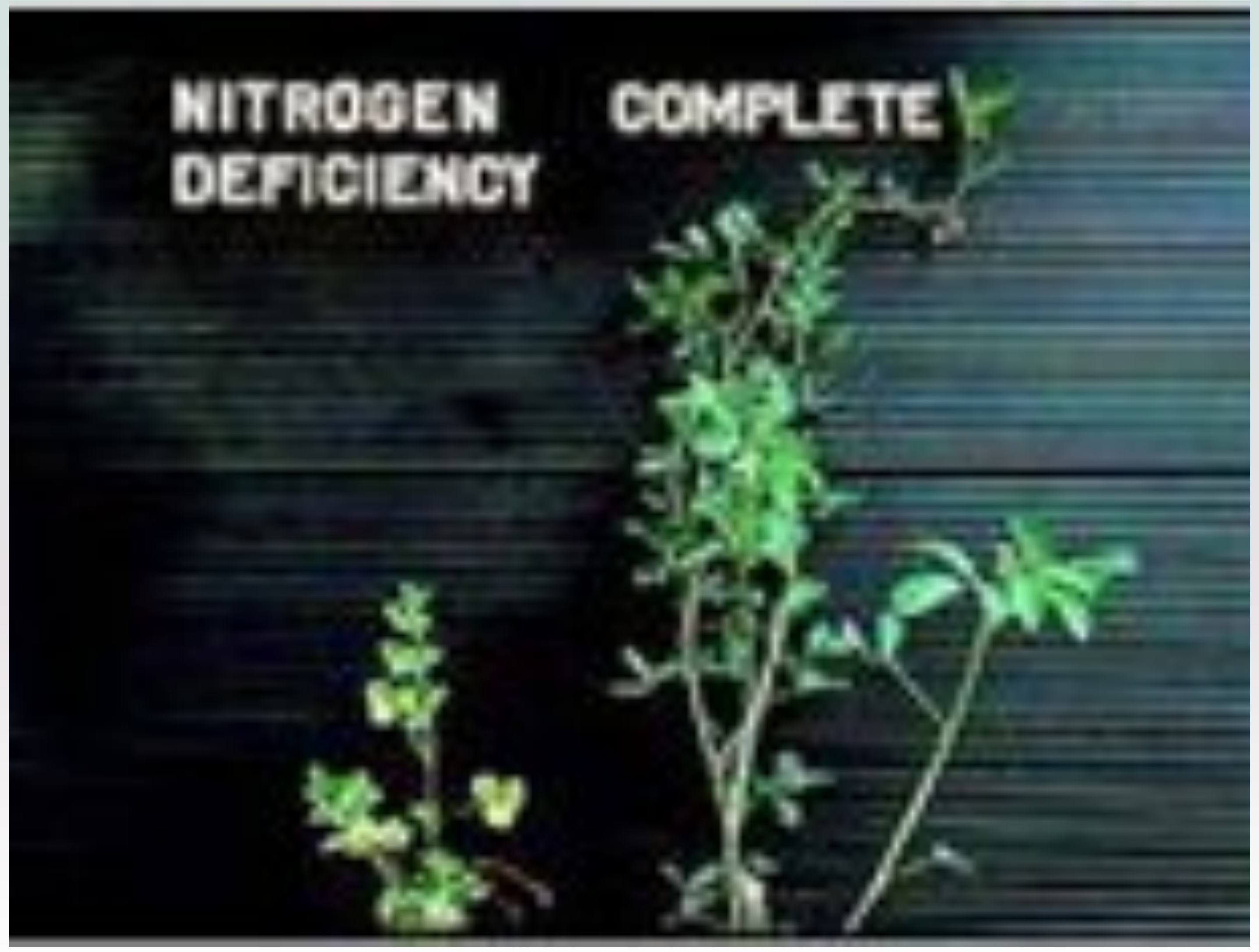
N deficiency in corn

N deficiency in soybeans and alfalfa



- Pale green plants
- Pale yellow leading to brown older leaves (veins not prominent)
- Can cause stunting and reduced branching
- Occurs when nodulation is limiting (usually early in the season) or low N soils

P deficiency in corn

- Purpling of leaf margins
  - Older leaves
  - Emerging leaves look normal
- Reduced growth rate
- Can have poor root development or injury

P deficiency in soybean

- Stunted growth
- Dark green color
- Necrotic spots on the leaves
- Purpling of the older leaves

K deficiency in corn

- Yellowing of leaf margins
- Older leaves
- Emerging leaves look normal
- Reduced growth rate

K deficiency in soybean

- Older leaves
- Bright yellow leaf margins
  - Interveinal chlorosis
- Stunting

Which nutrients are of most concern for environmental protection?

Water quality concerns

Eutrophication

- Excess nutrients in a waterbody
  - Stimulates algal growth, can lead to hypoxia
  - P is major driver in freshwater
  - N also contributes
- Alters light availability for plant growth
- Bacteria decomposing algae dissolved reduce O_2

Hypoxia

- Condition of a waterbody that is deficient in oxygen (low oxygen conditions)
  - Less than 2–3 ppm O_2
  - Nitrogen is a major driver in saltwater
  - P also contributes
- Caused by decomposition of algal blooms by bacteria