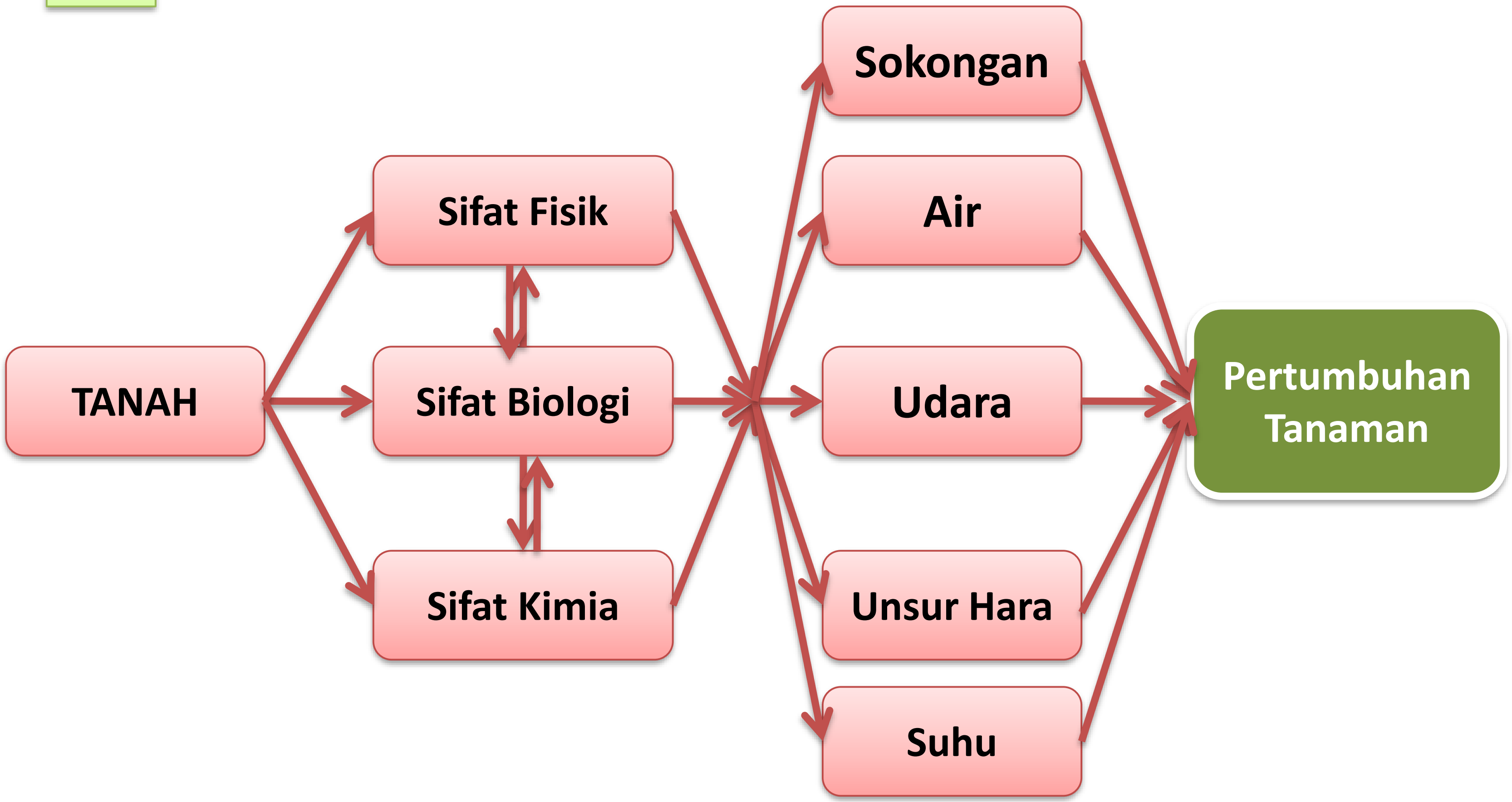
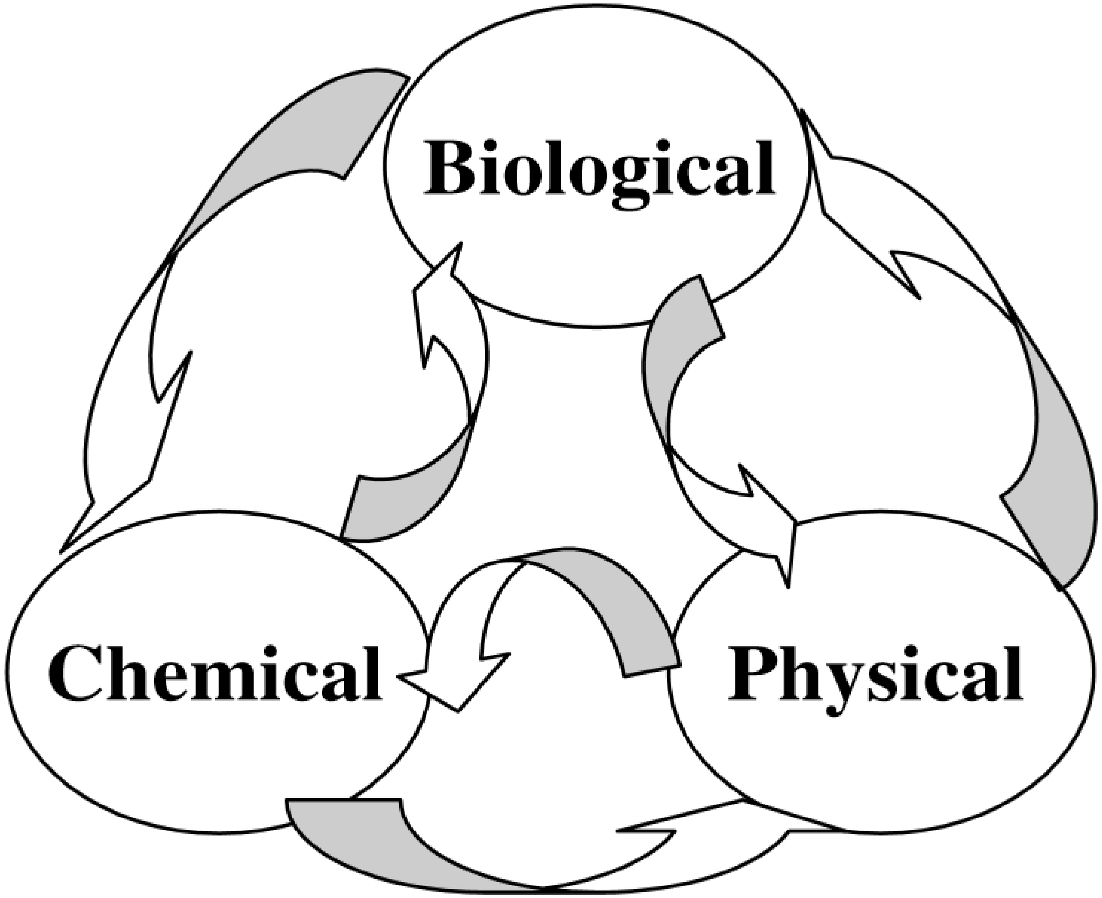
III. HUBUNGAN TANAH DAN TANAMAN





Soil biological, physical and chemical processes are interrelated.

3. DASAR HUBUNGAN TANAH DAN TANAMAN

3.1. Pendahuluan

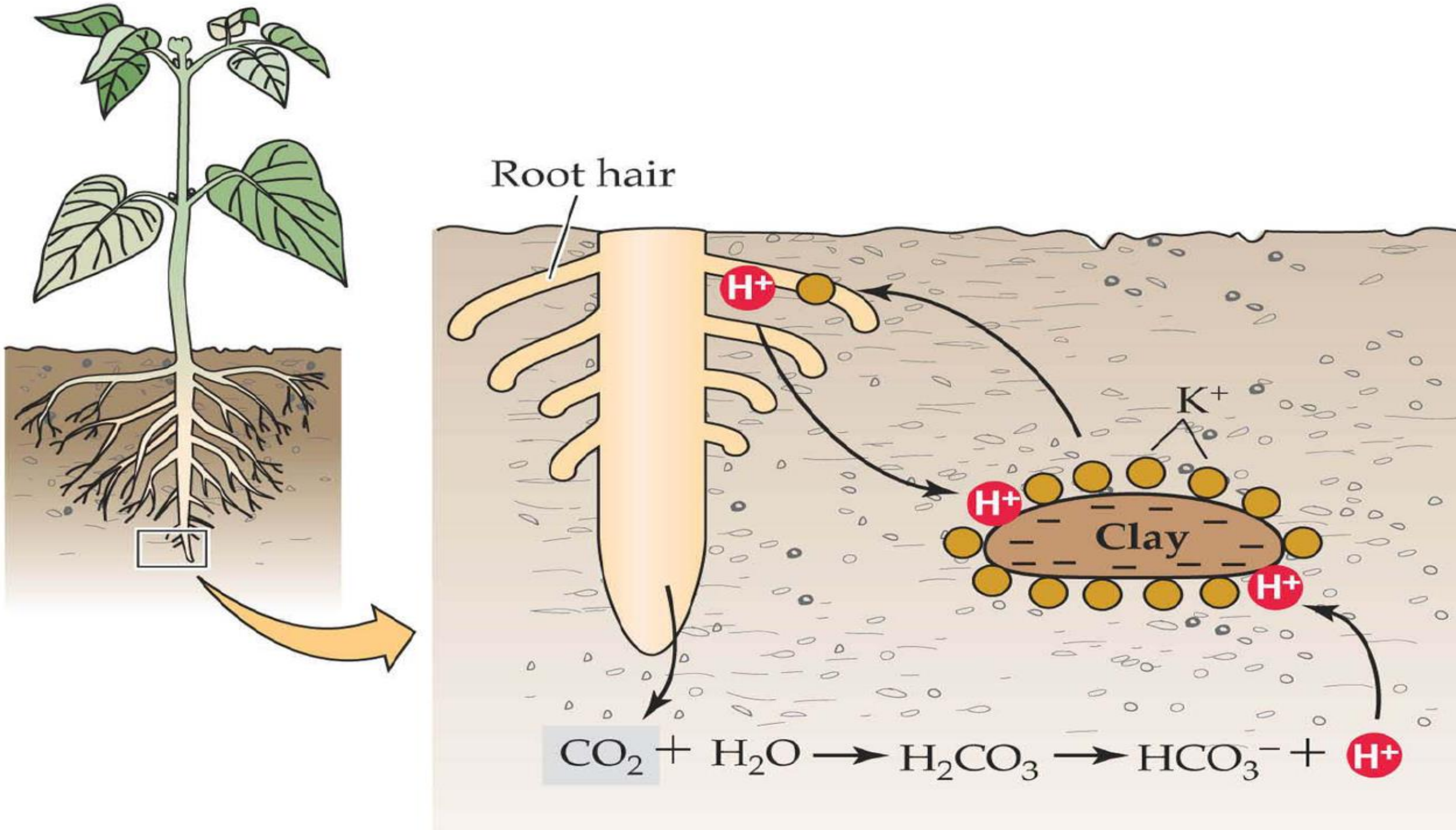
- Ilmu Kesuburan Tanah termasuk ke dalam edafologi yang merupakan bagian dari ilmu tanah yang mempelajari hubungan tanah dengan tanaman
- This chapter will studies:
  1. three ways nutrients in the soil reach plant roots
  2. major mechanism(s) of supply for each essential element
  3. the characteristics of roots and root systems influence nutrient uptake
  4. how plant roots absorb nutrients

3. DASAR HUBUNGAN TANAH DAN TANAMAN

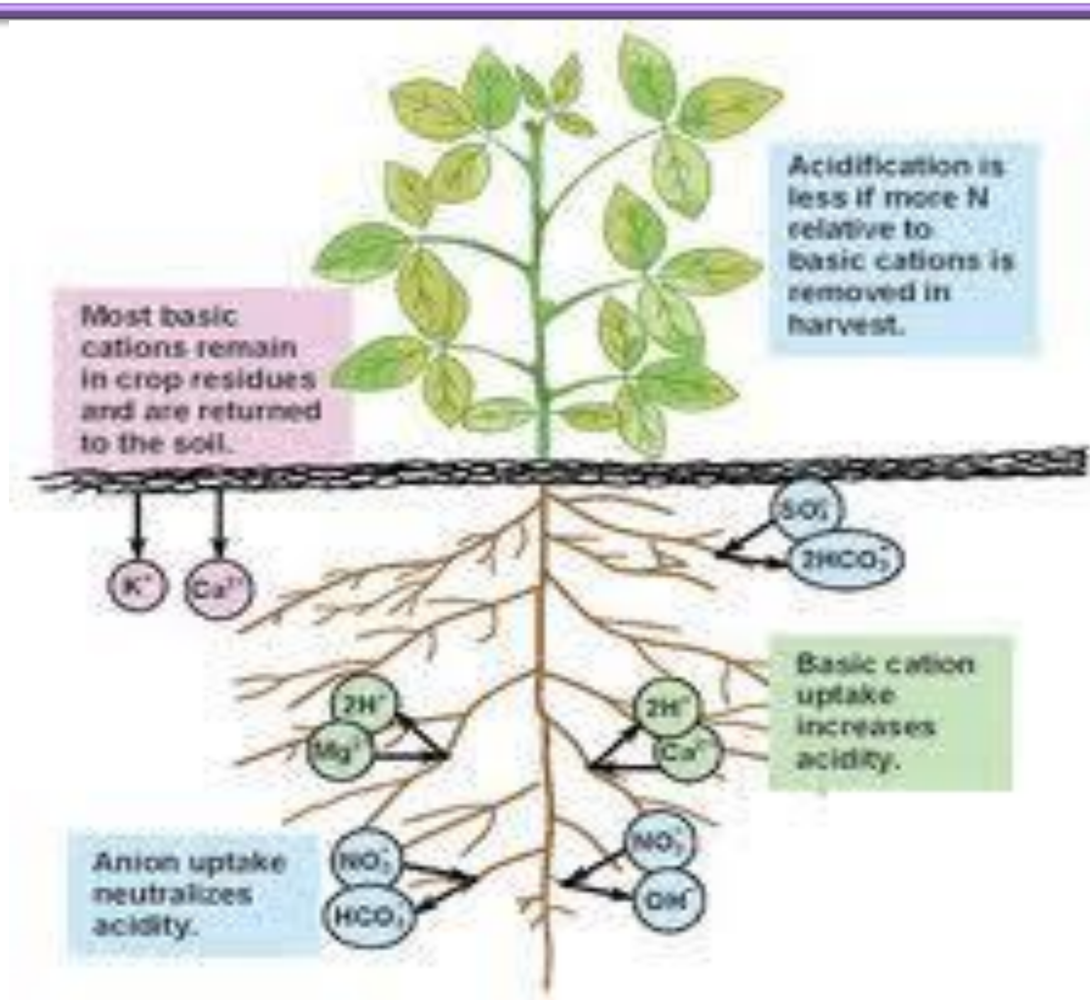
- **Nutrient Transport and Nutrient Uptake**

- Learning objectives:
  - Understand the three ways nutrients in the soil reach plant roots
  - Know the major mechanism(s) of supply for each essential element
  - Know how the characteristics of roots and root systems influence nutrient uptake
  - Be able to describe how plant roots absorb nutrients

3. DASAR HUBUNGAN TANAH DAN TANAMAN



3. DASAR HUBUNGAN TANAH DAN TANAMAN



3. DASAR HUBUNGAN TANAH DAN TANAMAN

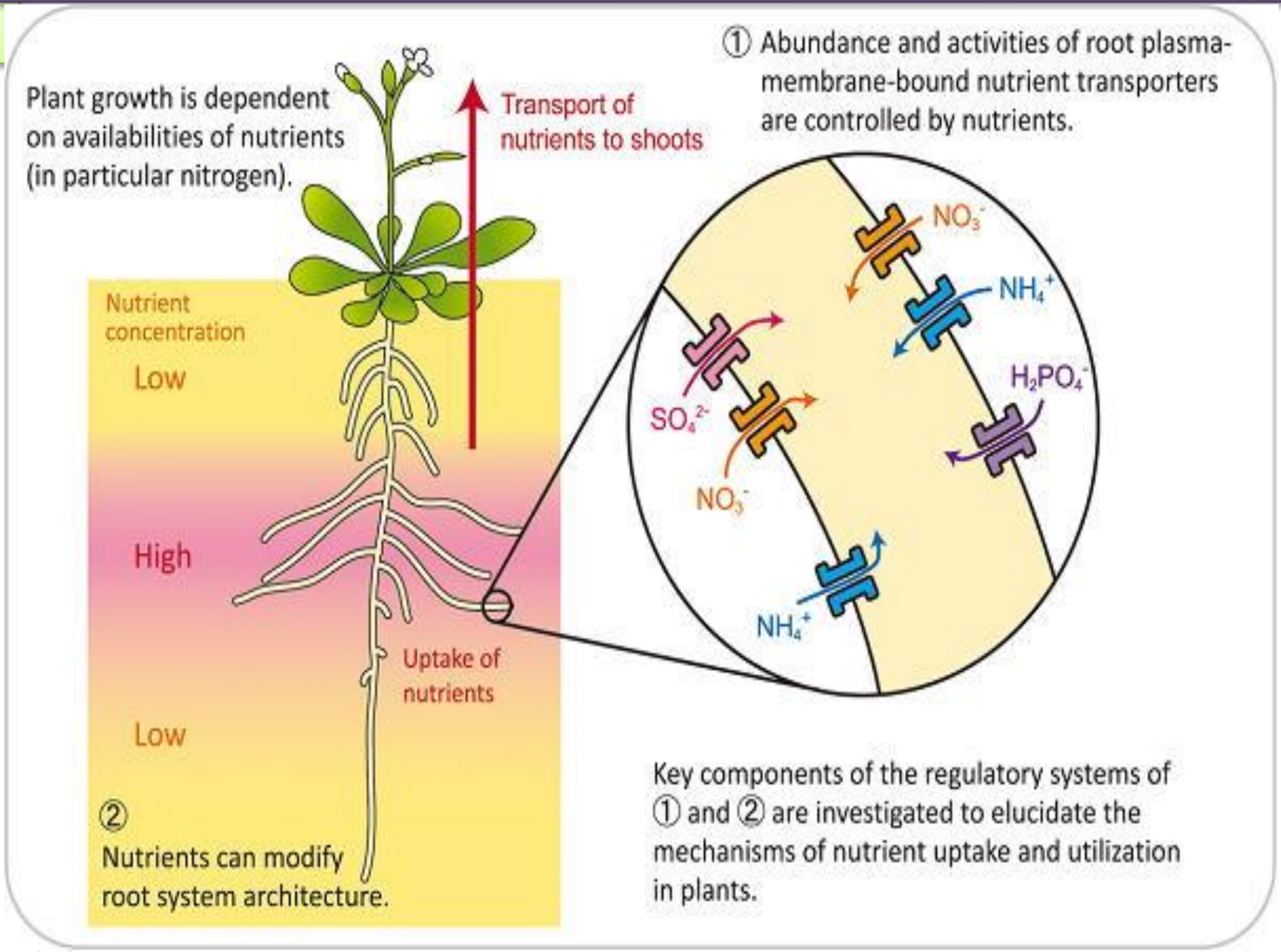
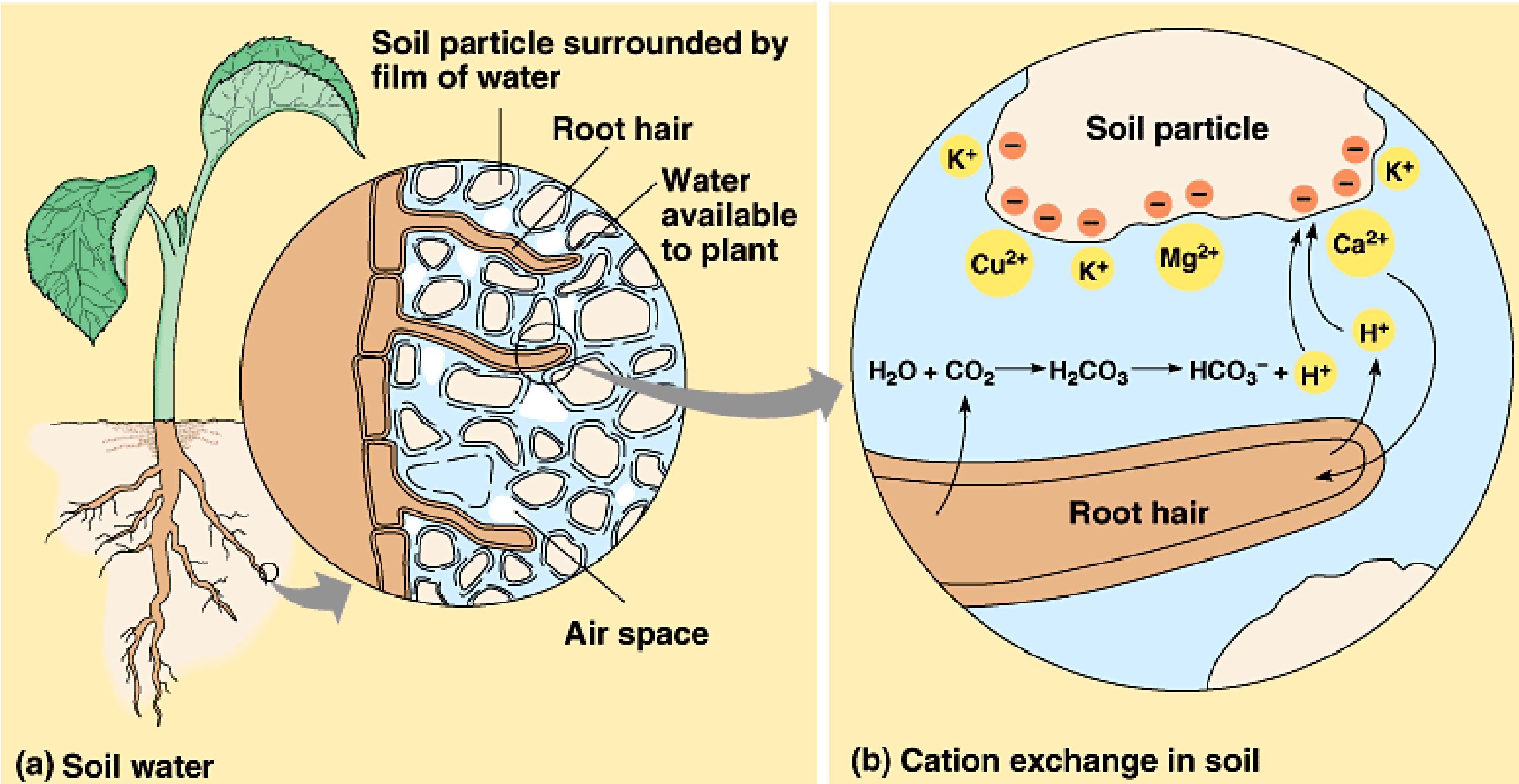


Figure 37.6 The availability of soil water and minerals



3. DASAR HUBUNGAN TANAH DAN TANAMAN

➢ **Movement of Ions from Soils to Roots**

- **Three major methods of nutrient supply**
  - **Root interception**
  - **Mass flow**
  - **Diffusion**

3. DASAR HUBUNGAN TANAH DAN TANAMAN

❑ Root interception

- Roots grow through soil
- Contact soil particle surfaces
- Root surfaces contact adsorbed nutrient ions

Interception

- Roots grow through soil pore spaces & intercept nutrients in their path
- Amount of interception depends on the volume of roots in pore spaces
- Nutrients present as soluble ions in the soil solution (NO3, SO4)
- Ions adsorbed to negatively-charged (clay or organic matter) soil particles (Ca, Mg, K)

3. DASAR HUBUNGAN TANAH DAN TANAMAN

❑ Root cation exchange capacity

– Mainly due to carboxyl groups (as in OM)

$$COOH \longleftrightarrow COO^- + H^+$$

– Monocots
  - 10 - 30 meq/100 g
  - Take up monovalent cations more readily

– Dicots
  - 40 - 100 meq/100 g
  - Take up divalent cations more readily

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Nutrients intercepted by roots**
  – Quantity depends on:
    - Soil concentration of nutrients
    - Volume of soil displaced by root system
  – Roots occupy <1% up to ~2% of soil volume
    - Even in surface soil (topsoil) where root density is greatest

3. DASAR HUBUNGAN TANAH DAN TANAMAN

Percentage of the Total Soil Volume Occupied by Plant Roots of Different Crops(in the surface 8-inches of soil)

Crop	Root Volume (%)
Kentucky Bluegrass	2.8
Winter Rye	0.9
Oat	0.6
Soybean	0.4 - 0.9
Corn	0.4

Adapted from S. Barber, *Soil Nutrient Bioavailability*, 1984

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Root interception**
  - Relatively small, but still an important contribution to nutrients reaching root surfaces
  - Most significant for :
    - Nutrients present in high concentrations (e.g. Ca, Mg)
    - Nutrients required in small amounts (e.g. Zn, Mn, and other micronutrients)

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Factors affecting root interception**
  - Anything that restricts root growth
    - Dry soil
    - Compaction
    - Low soil pH
    - Poor aeration
    - Root disease, insects, nematodes
    - High or low soil temperature
  - Root growth is necessary for all three mechanisms of nutrient supply, but absolutely essential for root interception to occur

Mass Flow

- Water is the carrier of the nutrients moving through soil to root surfaces where it is absorbed
- Soil water contains nutrients such as NO_3, SO_4, Ca,Mg, K, P, micronutrients.
- Amount of mass-flow to roots depends on:

  > Relative mobility of a given nutrient in the soil

  > Concentration of nutrient in soil water

  > Amount of water used by the plant

  > Nutrient needs of the plant by this mechanism
- Nutrients not held by clays or organic matter will reach roots by mass flow (NO_3, SO_4)

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Mass flow**
  - Dissolved nutrients carried in flow of water to plant roots
  - Flow driven by:
    - Transpiration (the major factor)
    - Evaporation
    - Percolation

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Nutrients supplied by mass flow**
  - Quantity proportional to:
    - Rate of flow (volume of water transpired)
    - Solution concentration of nutrient

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Nutrients supplied by mass flow**
  - Supplies most of the required amounts of "mobile" nutrients
    - NO_3^-, SO_4^{2-}, Cl^-, and H_3BO_3
  - Often supplies more than the required amounts of Ca, Mg
  - Can meet Cu, Mn, and Mo requirements
  - Can supply a significant portion of required Fe and Zn

3. DASAR HUBUNGAN TANAH DAN TANAMAN

Factors affecting mass flow

- Soil water content
  - Dry soil ⟶ no nutrient movement
- Temperature
  - Low temperature reduces transpiration and evaporation
- Size of root system
  - Affects water uptake (and therefore movement)
    - Both amount of water and the volume of soil it comes from
  - Root density much less critical for nutrient supply by mass flow than for root interception and diffusion

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- **Diffusion**
  - Ion movement from an area of high concentration to an area of low concentration
    - Roots absorb nutrients from soil solution
    - Concentration at root surface decreases compared to "bulk" soil solution
    - Ions diffuse down concentration gradient toward root surface

Diffusion

- Takes place when plant doesn’t receive adequate nutrients from other methods
- If nutrient concentration in soil adjacent to root surfaces is greater than inside root, there will be a gradient towards root.
- Nutrients move slowly by diffusion along concentration gradient toward the root (from areas of higher concentration to areas of lower concentration)

- If more nutrients are transported to the roots than they can absorb, nutrients may:
- Accumulate near roots
- Leach below the root zone
- Mass flow can typically supply adequate N, K, SO4
- Ca & Mg supplied by interception
- P supplied by diffusion - none by mass flow and only little by root interception
- The rate of diffusion is greater when more water is present, which makes phosphorus more available.

- **Nutrients moved by diffusion**
  - Important for nutrients that interact strongly with the soil
  - Primary mechanism for supplying P and K
  - Important for micronutrients, especially Fe and Zn

- **Factors affecting diffusion**
  - Fick's Law
  - dC/dt = D*e* * A * dC/dX
    - dC/dt = diffusion rate (change in concentration over time)
    - D*e* = effective diffusion coefficient
    - A = cross sectional area for diffusion
    - dC/dX = concentration gradient (change in concentration over distance)

- **Factors affecting diffusion**
  - Diffusion rate directly proportional to concentration gradient, diffusion coefficient, and the area available for diffusion to occur
  - Effective diffusion coefficient
    - D*e* = D*w* *
- *q* * (1/T) * (1/b)
  - D*w* = diffusion coefficient in water
  - *q= volumetric soil water content*
  - *T = tortuosity factor*
  - *b = soil buffering capacity*

- ***Effective diffusion coefficient***
  - *Diffusion coefficient in water (Dw)*
    - *Includes a temperature factor*
    - *Colder = slower diffusion*
  - *Soil water content*
    - *Drier soil = slower diffusion*
    - *Less water = less area to diffuse through*
  - *Tortuosity*
    - *Pathways through soil are not direct*
    - *Around soil particles, through thin water films*
    - *Affected by texture and water content*

- *Tortuosity*
    - *Pathways through soil are not direct*
    - *Around soil particles, through thin water films*
    - *Affected by texture and water content*
        - *More clay = longer diffusion pathway*
        - *Thinner water films = longer path*
- *Buffering capacity*

- *Nutrients can be removed by adsorption as they move through soil, reducing diffusion rate*

Percent of nutrients taken up by a corn normally supplied by root interception, mass flow and diffusion

Nutrient	Interception	Mass flow	Diffusion
N	< 1	80	19
P	2	5	93
K	2	18	80
Ca	150	375	0
Mg	33	600	0
S	5	300	0

- ***How far can nutrients diffuse in a growing season?***
  - *Diffusion distances are very short*
    - *K ~ 0.2 cm*
    - *P ~ 0.02 cm*
  - *Size and density of plant root systems is very important for nutrients supplied by diffusion*
  - *Has implications for fertilizer placement*

- ***Nutrient mobility***
  - *Mobility affects fertilizer recommendations and environmental management of a nutrient*
  - *Mobility depends on strength of interactions between nutrient and soil*
  - *Nutrients supplied primarily by mass flow are considered mobile nutrients*
    - *e.g. N, S, Cl, B*
  - *Nutrients supplied primarily by diffusion are considered immobile nutrients*
    - *e.g. P,*

- ***Immobile nutrients***
  - *Yield proportional to concentration of nutrient near root surface*
  - *Nutrient sufficiency levels based on relative yield potential,*
    - *Do not vary with growing conditions*
    - *In favorable growing conditions, greater root growth increases nutrient uptake*
      - *Proportionate feeding*
  - *Soil tests are indexes of availability*
    - *Estimate relative amounts of available nutrients*
    - *Percentage of sufficiency*
  - *Fertilizer recommendations are not based on yield goals*

- ***Mobile nutrients***
  - *Yield proportional to total quantity of nutrient in root zone*
  - *Nutrient sufficiency levels depend upon growing conditions and <u>absolute</u> yield potential*
  - *Root density has limited effects on nutrient uptake*
  - *Soil tests must estimate the total quantity of nutrient in the root zone*
  - *Fertilizer recommendations depend upon yield goals*

Root Growth and Nutrient Absorption

- ***Healthy, vigorous root systems***
  - *Extensive, well-distributed root systems*
  - *Draw nutrients from a larger volume of soil*
    - *Tap a larger nutrient supply*
  - *Take up more nutrients*
  - *Important root characteristics are:*
    - *Root length*
      - *Both vertical and horizontal*
    - *Root branching*
    - *Root hairs*

- ***Root surface area***
  - *Key factor in uptake*
    - *Size of the absorbing surface on roots*
    - *Small, fine roots have more surface area than the same mass of large roots*
  - *Adaptations to increase surface area*
    - *Root hairs*
    - *Mycorrhizae*

- ***Root hairs***
  - *Perpendicular extensions of epidermis just behind root tip*
  - *Increase root surface area by 2-10 times*
    - *Length ~0.1-1.5 mm, depending on species and environment*
  - *In low P soils, root hairs are longer*
  - *Lifespan a few days to a few weeks*
    - *Actively growing "feeder" roots required to continually renew these important absorbing surfaces*

- ***Mycorrhizae***
  - *Function as extensions of plant root system*
    - *"fungus roots"*
    - *Myco = fungus, rhizae = roots*
  - *Symbiotic associations between soil fungi and plant roots*
    - *Mycorrhizae obtain photosynthate (food) from plant roots*
    - *Plants receive additional water and nutrients*

- ***Mycorrhizae***
  - *May extend over 3-inches into surrounding soil*
  - *Increase root surface area up to 10-fold*
  - *Particularly important for P uptake*
    - *In low P soils*
    - *Can also increase Zn and Cu*
  - *Tillage disrupts mycorrhizae*
    - *Also less extensive when nutrient levels are high*

- ***Soil properties affecting root growth***

    1. *Bulk Density / Structure*
        - *Compaction*
    2. *Aeration*
    3. *Water-holding capacity*
    4. *pH*
    5. *Nutrients availability*
    6. *Temperature*

Ion absorption by plants

- *Most nutrients are absorbed by roots in an inorganic form*
- *After reaching a root surface, nutrient ions are transported to plant leaves in a series of steps*
- *Passive root uptake*
- *Active root uptake*
- *Translocation*

Root structure

a.Ions must move through (or around) several layers of root tissue

b. Epidermis

- outermost layer of cells

c. Cortex

- large, irregularly shaped cells with extracellular space between them

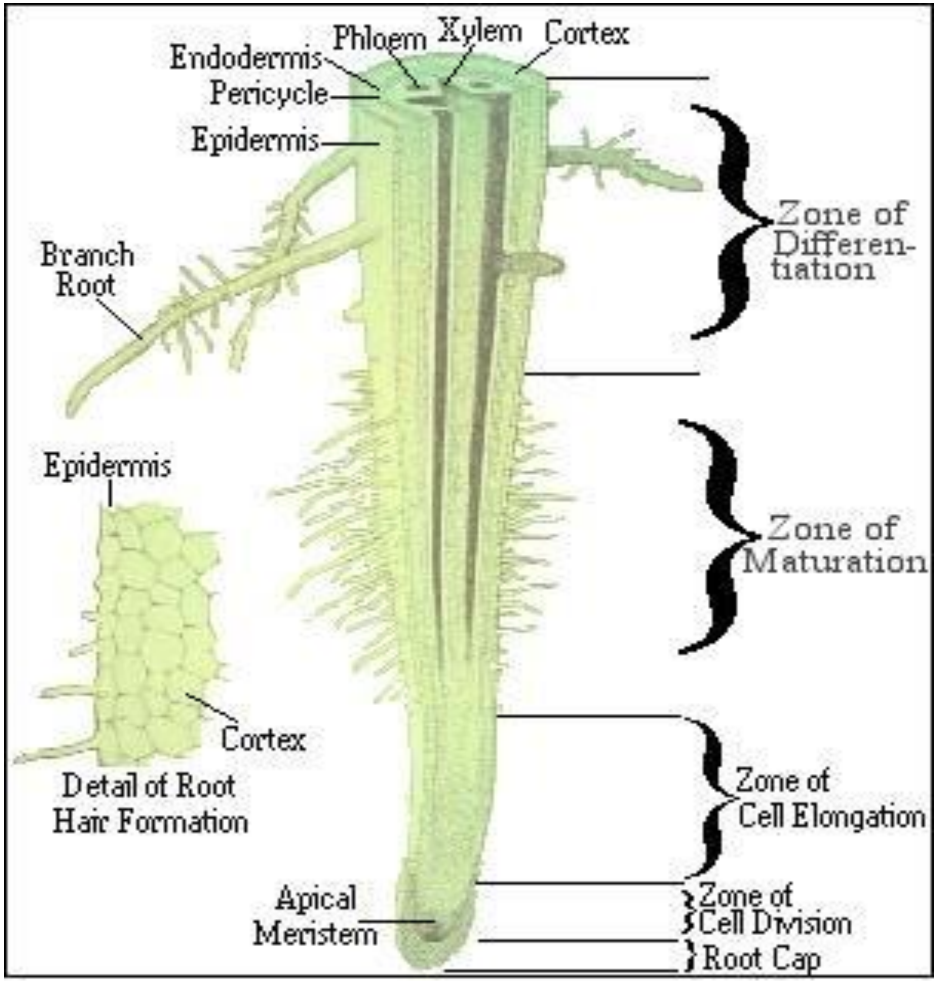
d. Endodermis

- cell layer with suberized band, Casparian strip, barrier to movement into stele

e. Stele

- contains the xylem, which transports water and ions to the shoot

Root Anatomy



Passive movement

a. Diffusion and ion exchange

b. From epidermis

→ through cortex → to endodermis

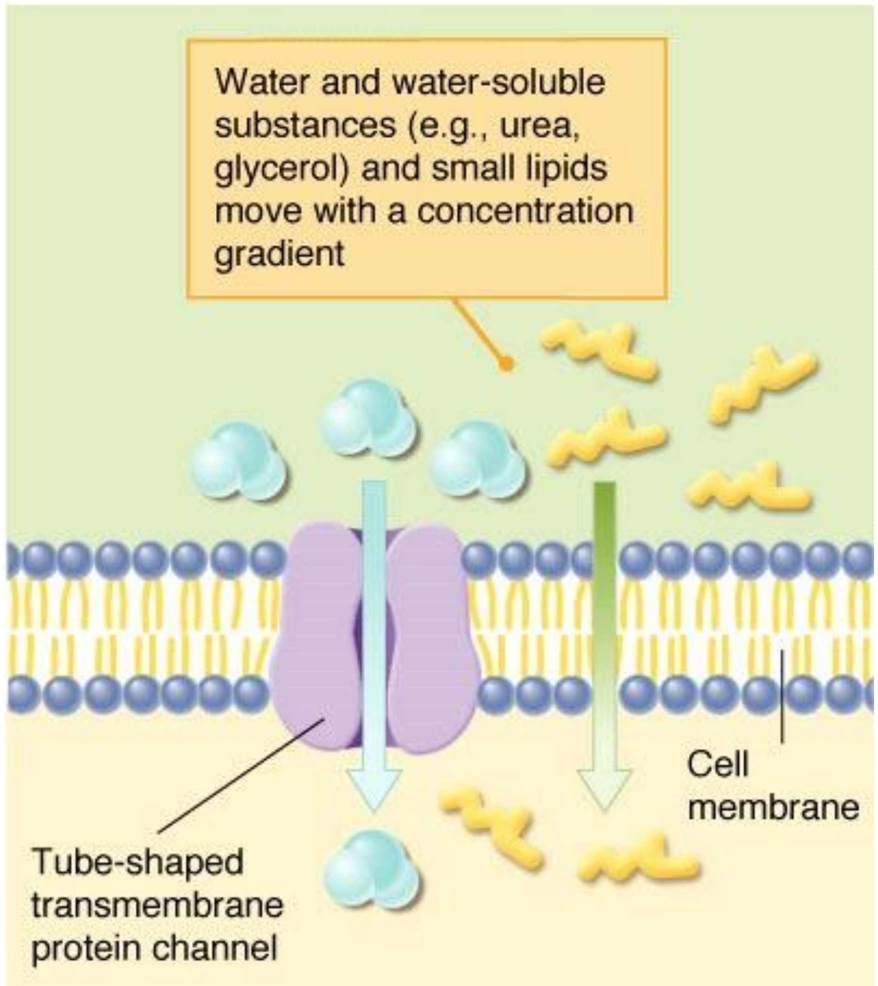
c. Apoplast (or apparent free space)

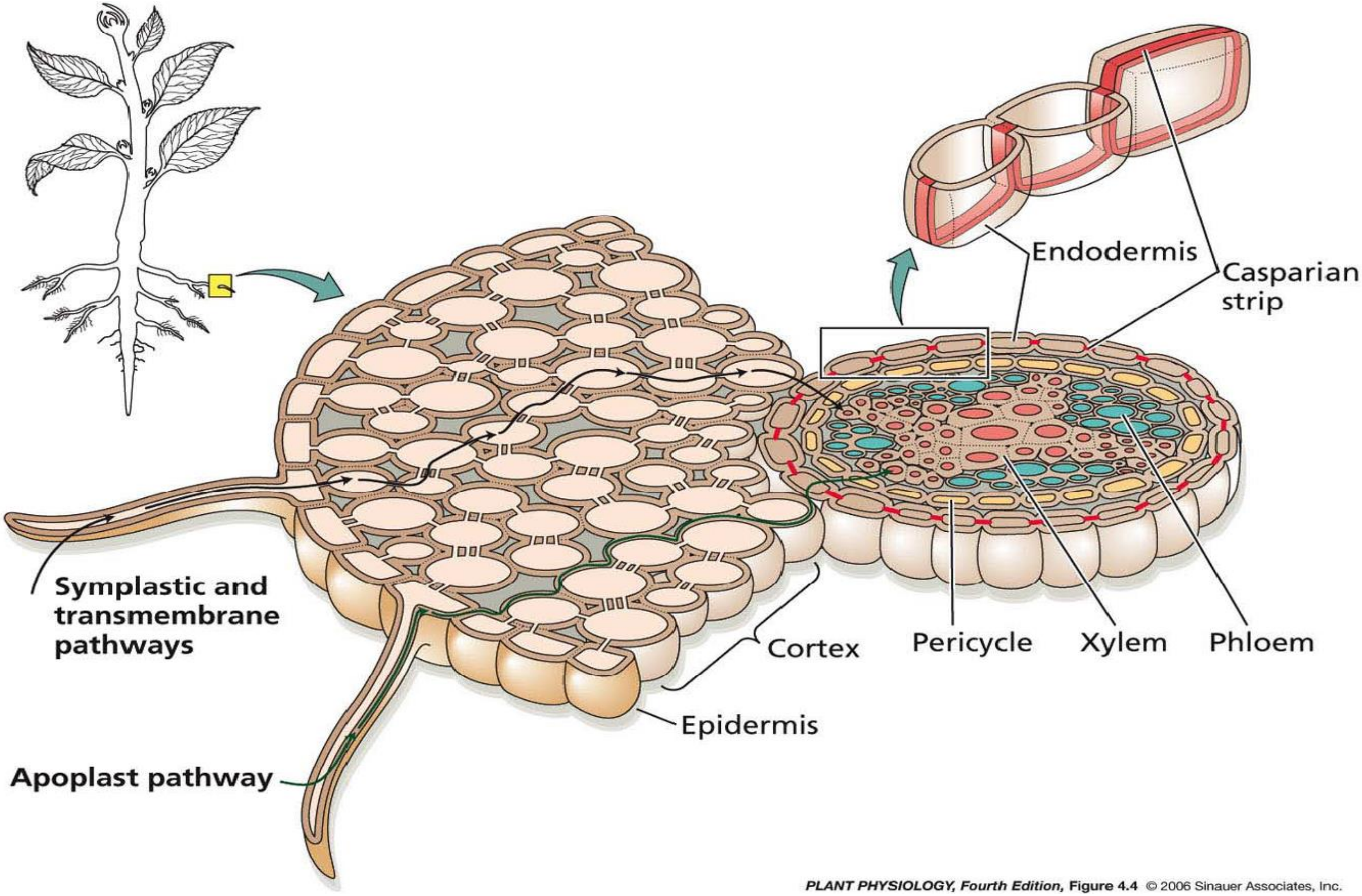
- *Extracellular*

  within and between cell walls

d. Root CEC is in cell walls

PASSIVE DIFFUSION





Gambar Passive dan active movement

Active movement

a. Must cross cell membrane

b. Symplast

- *Intracellular*

  interconnected cytoplasmic pathway between cells

c. Active transport across membrane

d. Selective uptake of nutrient ions

- ***Active ion uptake***
  - *Energy required to move nutrients across cell membrane*
  - *Concentrations higher within cell than outside cell*
  - *Movement against an electrochemical gradient*
  - *Energy comes from cellular metabolism*

- ***Ion carriers***

  a. Transport across membrane mediated by carriers

  b. Carriers located within membrane

    - *Bind to ion on outer boundary*

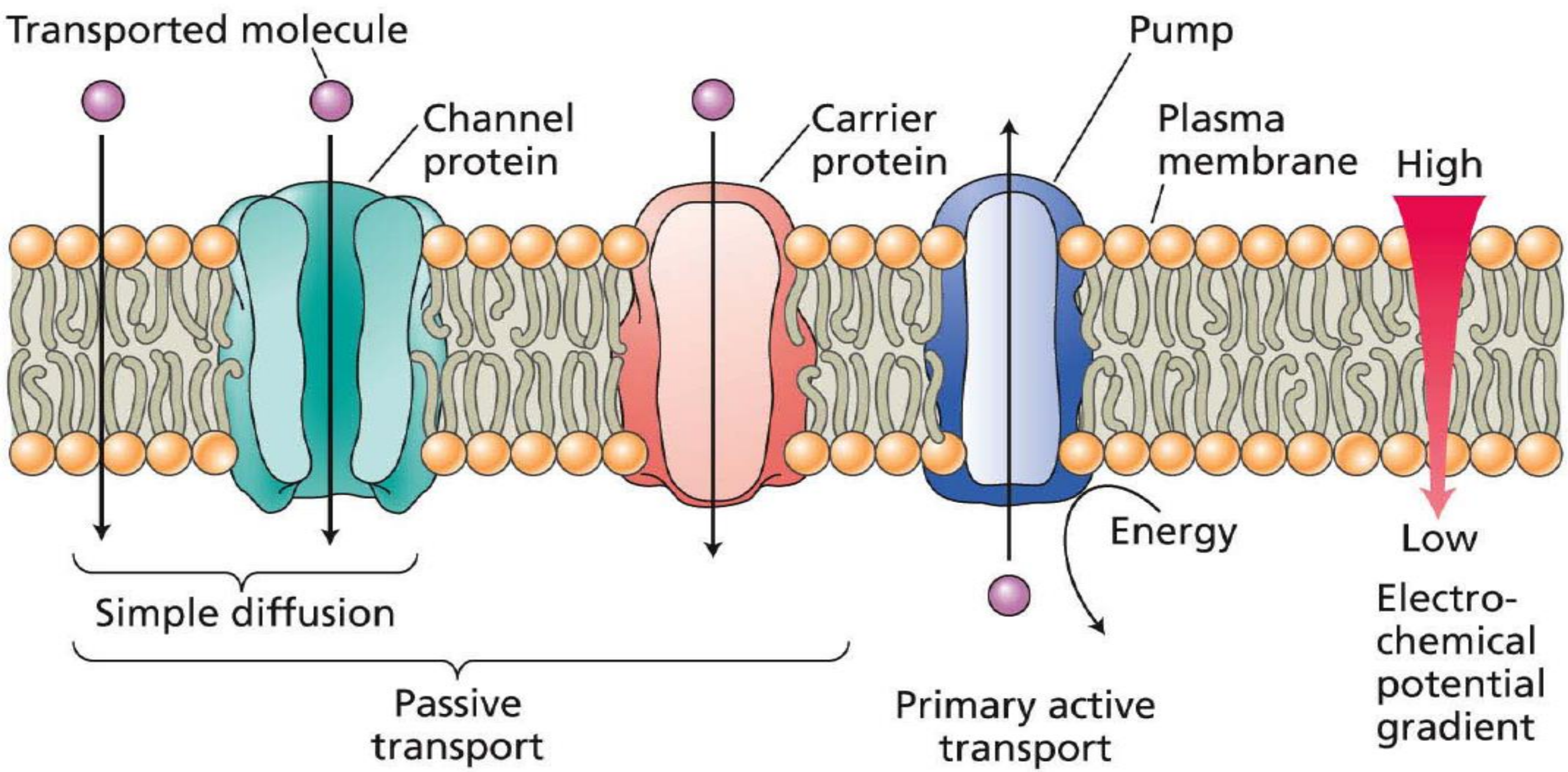
  ⟶ move across membrane ⟶ release ion into cytoplasm

  c. Carriers are selective

    - *Specific carriers for most ions*

3. DASAR HUBUNGAN TANAH DAN TANAMAN

- ***Active Transport***
  - *Enables plants to be selective about what elements enter roots*
  - *To maintain electrical neutrality in root cells, roots release H^+ and OH^-*
    - *Cation uptake: release of H^+*
    - *Anion uptake: release of OH^-*
  - *Cation uptake generally > anion uptake, so affect rhizosphere pH*


Transported molecule
Channel protein
Carrier protein
Pump
Plasma membrane
High
Low
Energy
Simple diffusion
Passive transport
Primary active transport
Electro-chemical potential gradient

- ***Rhizosphere (rhizo = root)***
  - *Zone of soil immediately adjacent to plant roots (~1-4 mm)*
  - *Area of active microbial activity*
    - *Organic root exudates provide a food supply*
  - *Both rhizosphere pH and microbial activity affect nutrient availability*
    - *e.g. solubility and chelation*

- ***Rhizosphere***
  - *Rhizosphere and nutrient availability*
    - *Lower pH and organic acids can increase solubility*
    - *Roots and rhizosphere microbes can both produce chelates*
    - *Roots and microbial activity can also increase solubility by lowering redox potential*
  - *Both rhizosphere pH and microbial activity affect nutrient availability*

- ***Active Transport***
  - *Enables plants to accumulate essential nutrients*
  - *Plants differ in their ability to accumulate nutrients at low soil concentrations*
  - *Genetic differences in uptake, translocation, root growth, root metabolism, rhizosphere environment, and other factors*

- ***Plant roots***
  - *Unseen and often ignored*
    - *Below ground and hard to study*
  - *Not just passive absorbers of nutrients*
    - *Active transport and selective uptake*
    - *Modify soil around the root to increase nutrient availability*
  - *Soil fertility is not complete without considering the "organs of uptake"*

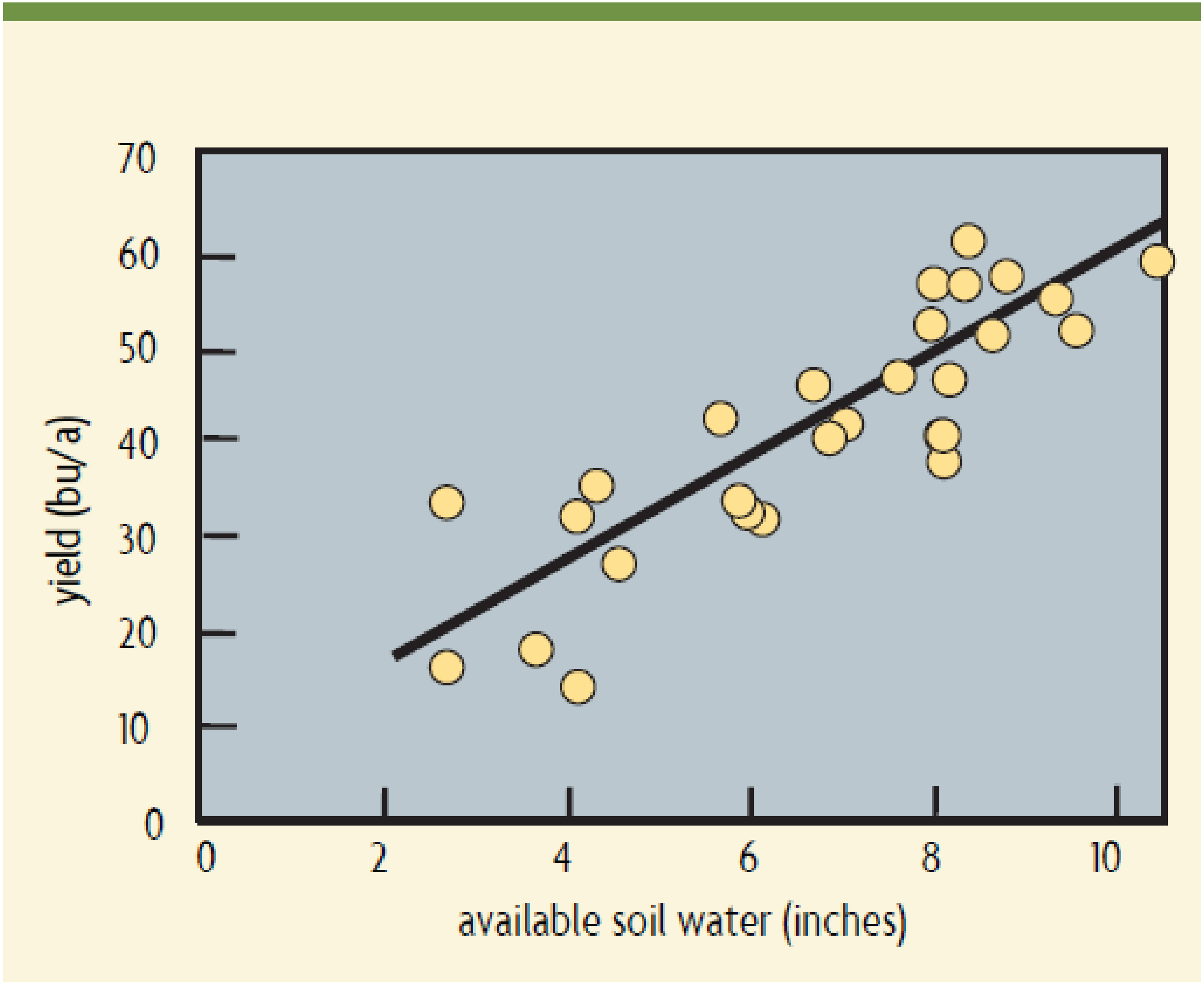


Figure 9.1. Relationship between winter wheat grain yield and soil water at wheat planting over six years. Modified from Nielsen et al. (2002).