Mineral Nutrition

How do plants get minerals?

Mineral Nutrition

- Types of minerals
- Getting minerals from the soil
- Getting minerals to the leaves
- Obtaining Nitrogen

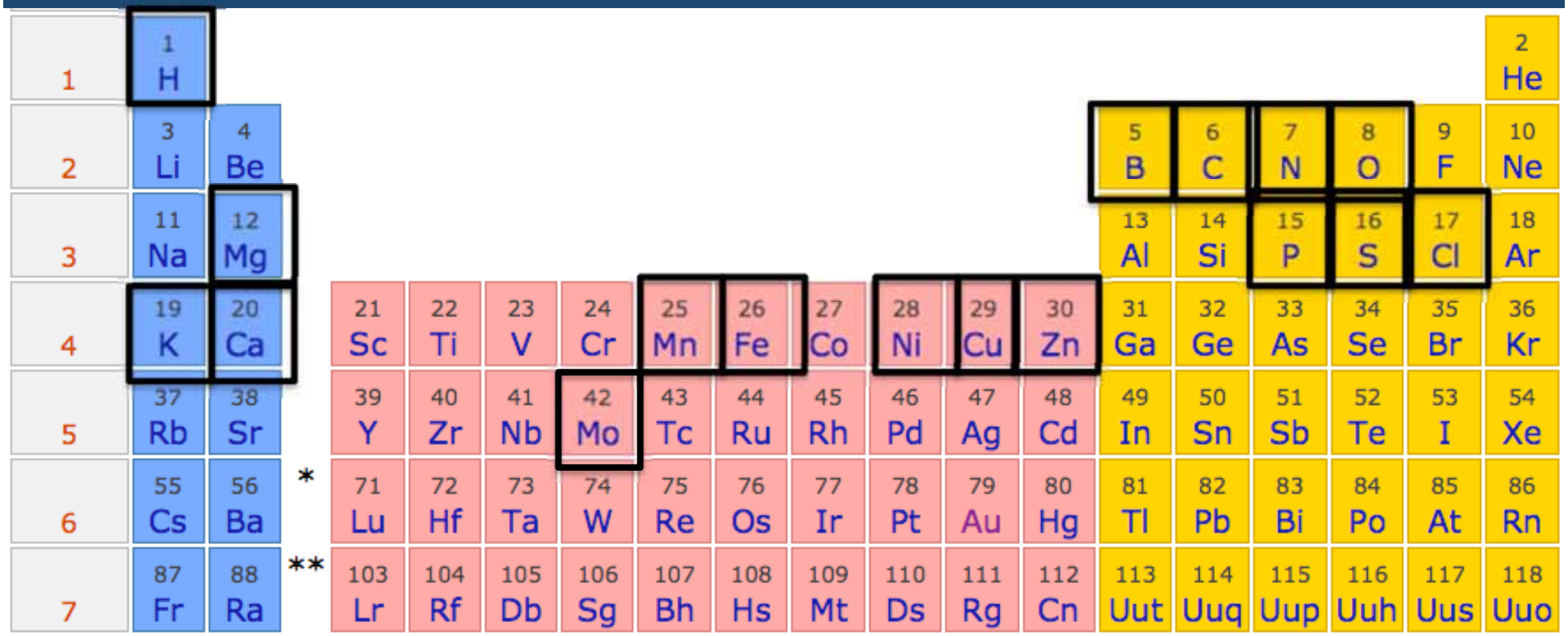
Essential Nutrients

Criteria

1. Needed for a specific structure or function
2. Required for growth and reproduction

- Carbon, Hydrogen, and Oxygen make up 96% of the dry weight of a plant

Essential Nutrients



http://www.webelements.com/

Question

How did we determine which nutrients were essential? Macro and micro?

We removed them!

(controlled experimentation)

Hydroponics

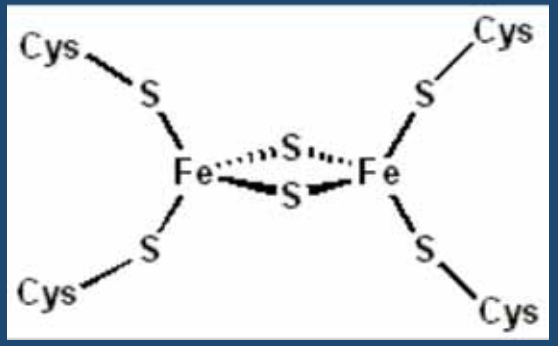
http://www.riverpoolsandspas.com/blog/bid/33628/Do-Fiberglass-Pools-Work-with-Shrink-Swell-Clay-and-other-Soil-Conditions

http://linguisticcapital.wordpress.com/2011/08/28/of-world-population-hydroponic-cucumbers-and-milk/

Essential Nutrients

Micronutrients

- Needed in small quantities (1 ppt)
- Used as enzyme cofactors
  - Example: Iron needed in ferredoxin (PS I)



http://en.wikipedia.org/wiki/Ferredoxin

Micronutrients

TABLE 38.1 **Essential Nutrients**

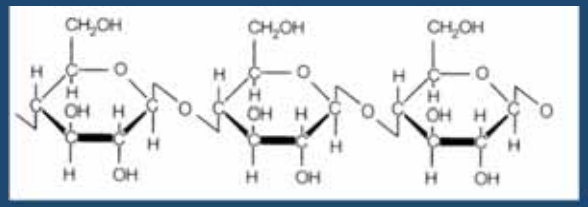
Element	Form Available to Plants	Functions	Average % Dry Weight*	Deficiency Symptoms
Obtained from soil				
(b) Micronutrients				
Chlorine	Cl^-	Needed for water-splitting step of photosynthesis; functions in water balance and electrical balance	0.01	Wilting at leaf tips; general chlorosis and necrosis of leaves or development of bronze color
Iron	Fe^{3+} (ferric ion) Fe^{2+} (ferrous ion)	Necessary for chlorophyll synthesis; component of cytochromes and ferredoxin; enzyme cofactor	0.01	Chlorosis between veins of young leaves
Manganese	Mn^{2+}	Involved in photosynthetic O_2 evolution; enzyme activator; important in electron transfer	0.005	Chlorosis between leaf veins and small necrotic spots
Zinc	Zn^{2+}	Involved in synthesis of the plant hormone auxin; maintenance of ribosome structure; enzyme activation	0.002	Small internodes; stunted and and distorted ("puckered") leaves
Boron	$H_2BO_3^-$ (borate ion)	Cofactor in chlorophyll synthesis; possible role in sugar transport; aids in regulation of enzyme function	0.002	Black necrosis in young leaves and buds
Copper	Cu^+ (cuprous ion) Cu^{2+} (cupric ion)	Cofactor of some enzymes; present in lignin of xylem	0.0006	Dark-green leaves with necrotic spots; twisted and malformed leaves
Nickel	Ni^{2+}	Cofactor for enzyme functioning in nitrogen metabolism	[no data]	Necrosis at leaf tips
Molybdenum	MoO_4^{2-} (molybdate ion)	Cofactor in nitrogen reduction; essential for nitrogen fixation	0.00001	Chlorosis between veins; necrosis of older leaves

*These percentages were obtained by drying vascular plants and then documenting what proportion of the waterless mass consists of various elements.

Table 38.1 pg 839

Essential Nutrients

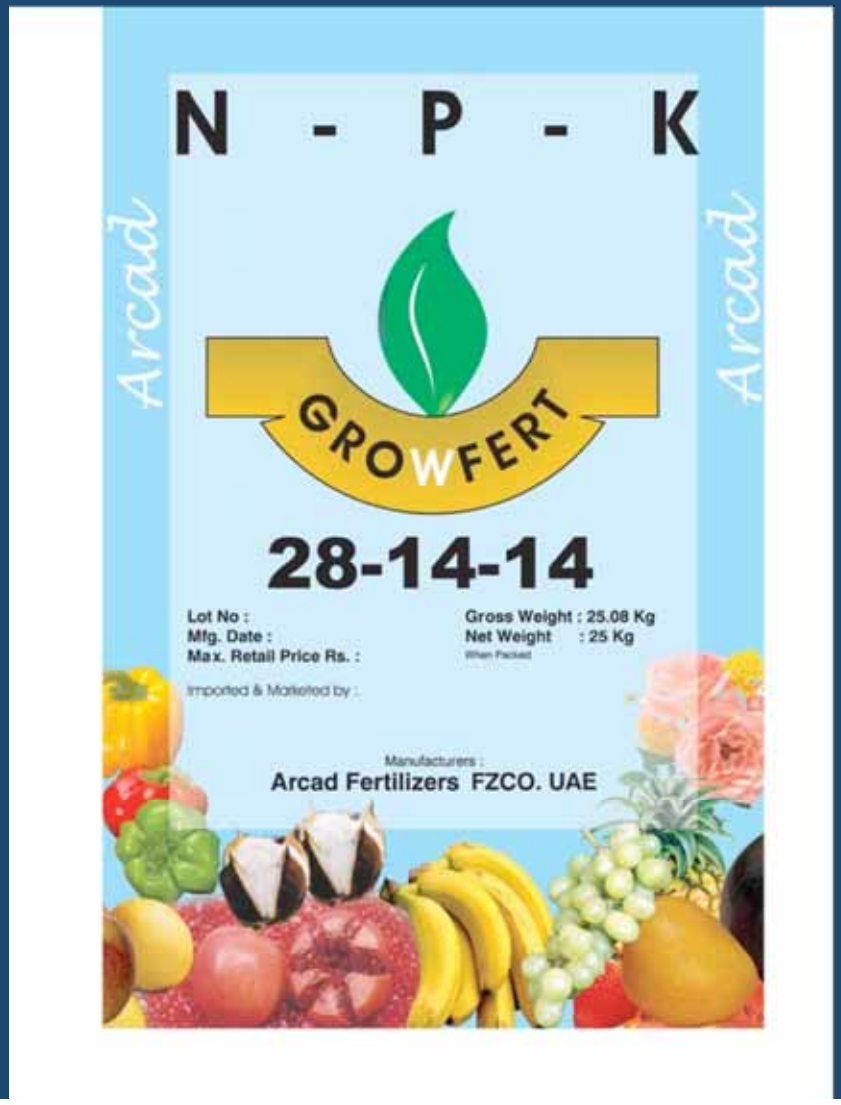
Cellulose



Macronutrients

- Needed in large quantities
- Needed in macromolecules
  - Proteins, carbohydrates, nucleic acids, phospholipids, etc.

Nitrogen-Phosphorus-Potassium
N – P – K



http://www.tradenote.net/NPK_2/

http://www.lowes.com/cd_Fertilizer+Buying+Guide_543192373_

N – P – K

- These numbers represent the percentage (by weight) of the three major nutrients required for healthy plant growth

http://www.learn2grow.com/gardeningguides/fertilizer/basics/understandingfertilizernumbers.aspx

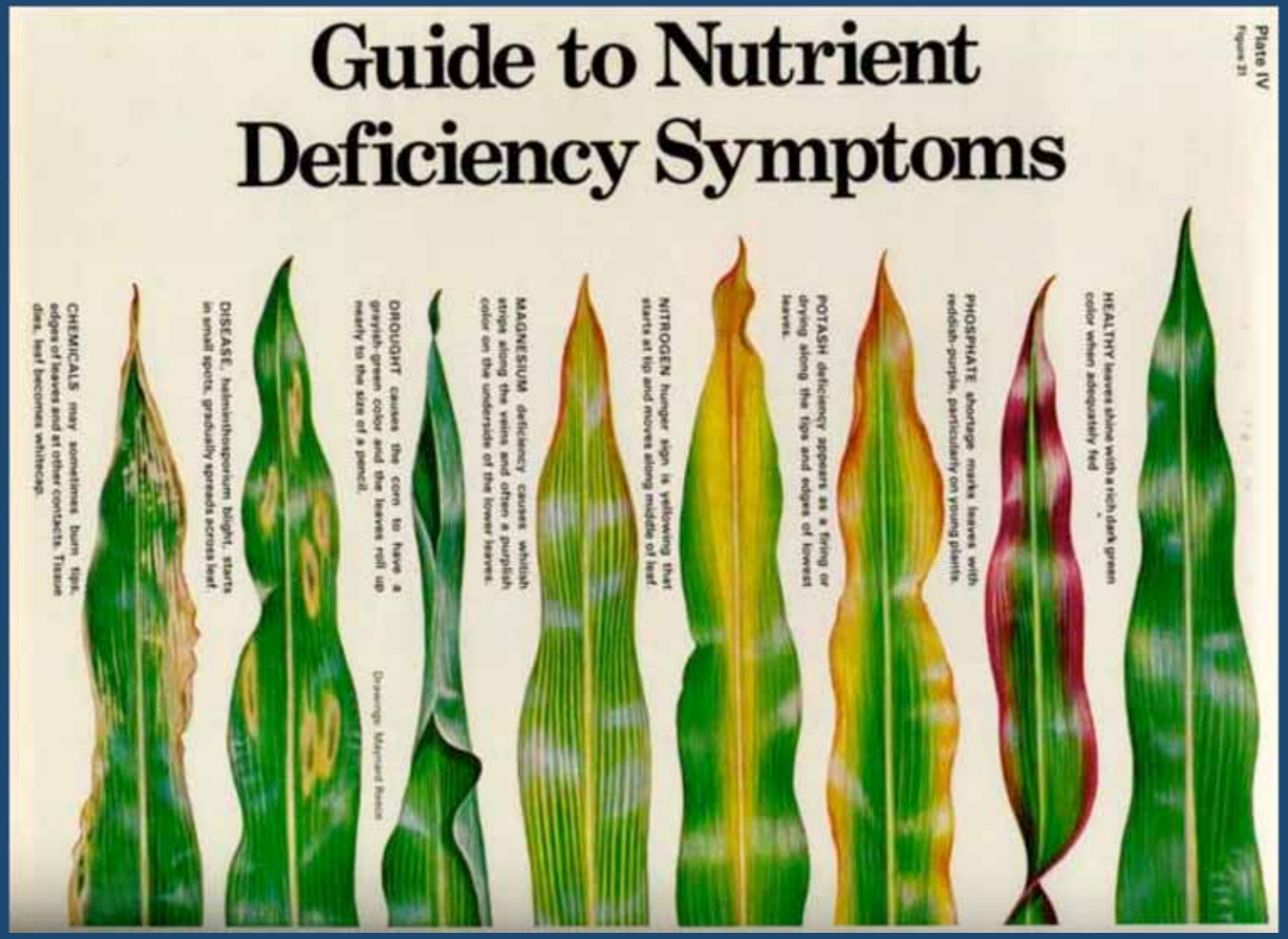
http://www.lowes.com/cd_Fertilizer+Buying+Guide_543192373_

TABLE 38.1 **Essential Nutrients**

Element	Form Available to Plants	Functions	Average % Dry Weight*	Deficiency Symptoms ??
Obtained from CO_2 or H_2O	96% of the dry weight			
Oxygen	O_2, H_2O	Electron acceptor in cellular respiration; major component of organic compounds	45	Usually affects roots—cells suffocate, leading to root rot and wilting
Carbon	CO_2	Substrate for photosynthesis; major component of organic compounds	45	Slow growth (starvation)
Hydrogen	H_2O	Major component of organic compounds; electrical balance and establishment of electrochemical gradients	6	Slow growth due to cell death (desiccation)
*These percentages were obtained by drying vascular plants and then documenting what proportion of the waterless mass consists of various elements.				
Obtained from soil				
(a) Macronutrients				
Nitrogen	NO_3^- (nitrate) NH_4^+ (ammonium ion)	Component of nucleic acids, proteins, hormones, and coenzymes	1.5	Failure to thrive; chlorosis (yellowing of leaves)
Potassium	K^+	Cofactor for many enzymes; necessary for osmotic adjustment in cells; required for synthesis of organic molecules	1.0	Chlorosis at margins of leaves or in mottled pattern; weak stems; short internodes
Calcium	Ca^{2+}	Regulatory functions; role in cell wall structure; stabilizes membranes; second messenger in signal transduction	0.5	Necrosis (small spots of dead cells) in meristems; deformation of young leaves; stunted, highly branched root system
Magnesium	Mg^{2+}	Chlorophyll component; activates many enzymes	0.2	Chlorosis between leaf veins; premature leaf drop
Phosphorus	$H_2PO_4^-$ (dihydrogen phosphate ion) HPO_4^{2-} (hydrogen phosphate ion)	Component of ATP nucleic acids, phospholipids, and several coenzymes	0.2	Stunted growth in young plants; dark green leaves with necrosis
Sulfur	SO_4^{2-} (sulfate ion)	Component of protein and coenzymes	0.1	Stunted growth; chlorosis

*These percentages were obtained by drying vascular plants and then documenting what proportion of the waterless mass consists of various elements.

Nutrient Deficiency



Question

- What are micronutrients often used for?

- What are the three most important macronutrients in the soil?

Getting Minerals from the Soil

Obtained from soil				
(a) Macronutrients				
Nitrogen	NO_3^- (nitrate) NH_4^+ (ammonium ion)	Component of nucleic acids, proteins, hormones, and coenzymes	1.5	Failure to thrive; chlorosis (yellowing of leaves)
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http://petandbaby.com/2011/pictures-of-cute-puppies/

http://www.mentalfloss.com/blogs/archives/52946

Nutrients and availability

Cation	Anion
(+) charge mineral	(-) charged mineral
Bound to soil (-)	dissolves in water
K^{+} Ca^{2+}	HPO_4^{2-} NO_3^{-}

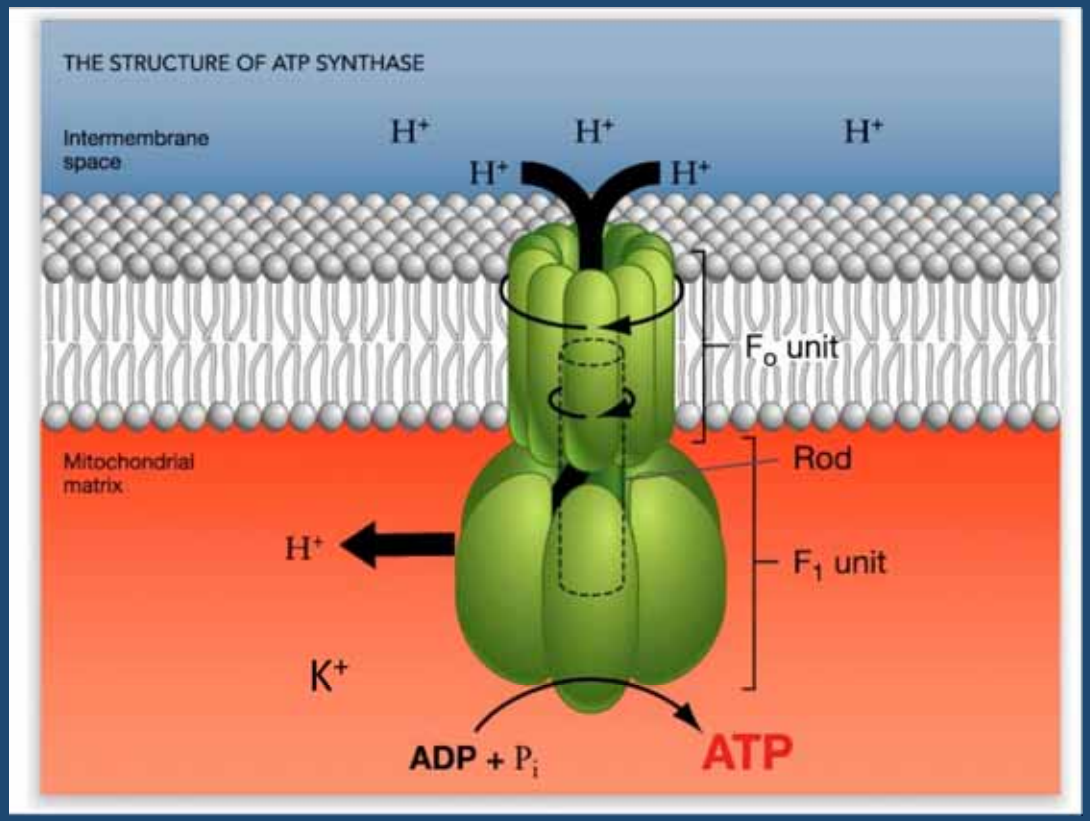
The plant's dilemma:

How to import molecules against a concentration gradient

How to import both positive and negative molecules

Importing molecules against a concentration gradient

What is this molecule?



What if we changed the direction of the reaction?

Creates a positive charge outside the root hair (-200 mV)

Encourages positive molecules to enter the roots

http://baraza.wildlifedirect.org/2009/09/28/lions-in-nairobi-park/

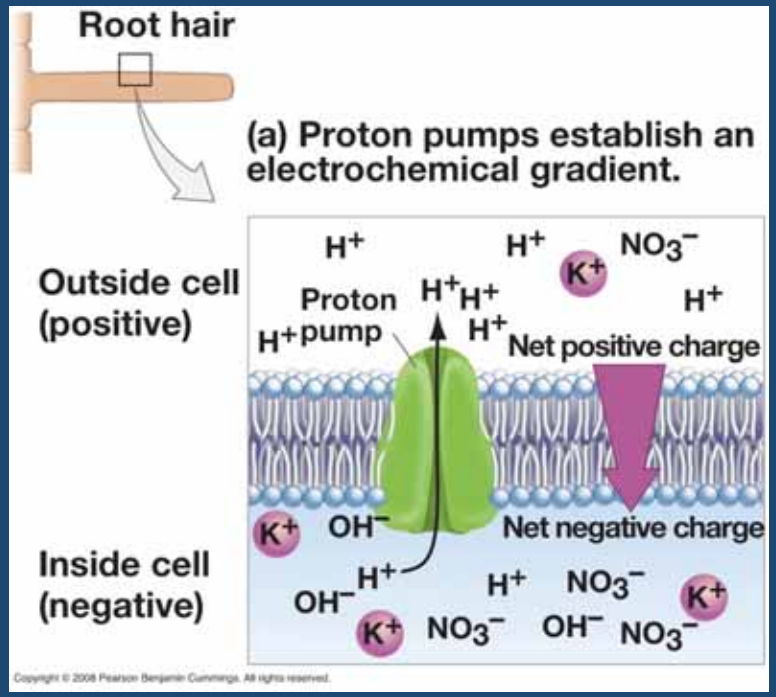
http://www.uic.edu/classes/bios/bios100/lectf03am/

Nutrient transport

http://longorshortcapital.com/stick-and-the-eskimo.htm

1. Establish an charge difference

2. Positively charged ions pass with the help of channel proteins



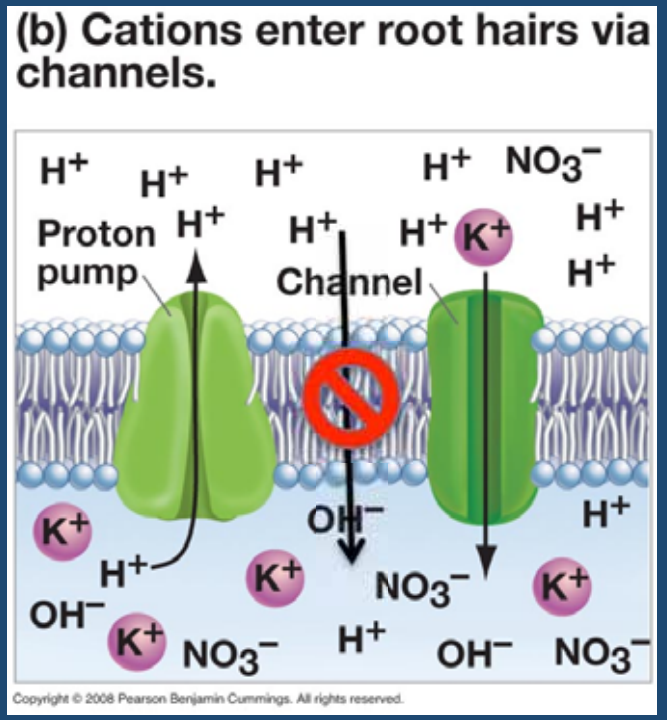
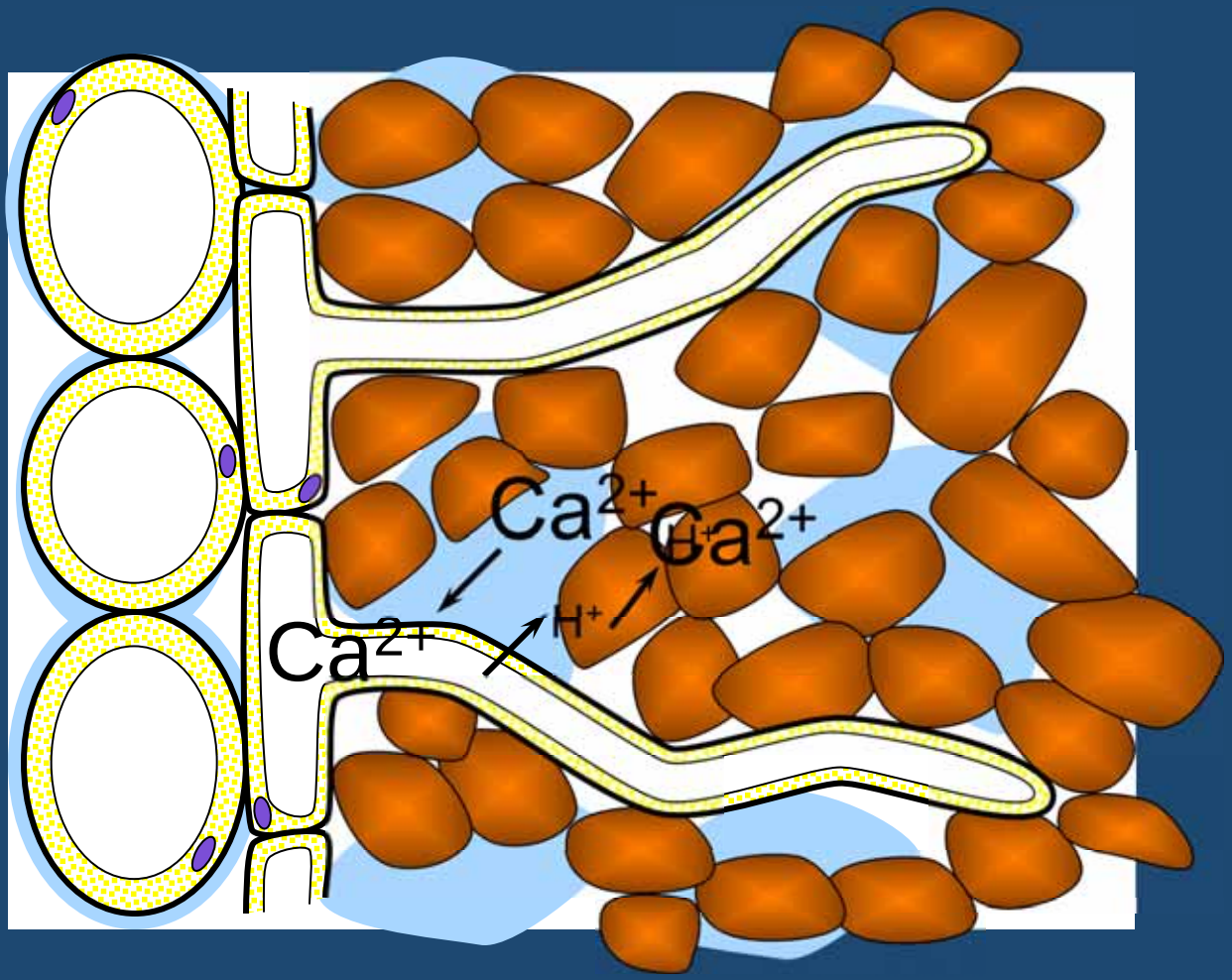


Figure 38.10 pg 845

Root hairs increase the surface area of a root for water and mineral uptake.

http://www.firstpeople.us/pictures/wolves/1024x768/Growling-and-Angry-1024x768.html

Root hairs are responsible for cation exchange



http://consilience.typepad.com/sharks/

Minerals in the Soil

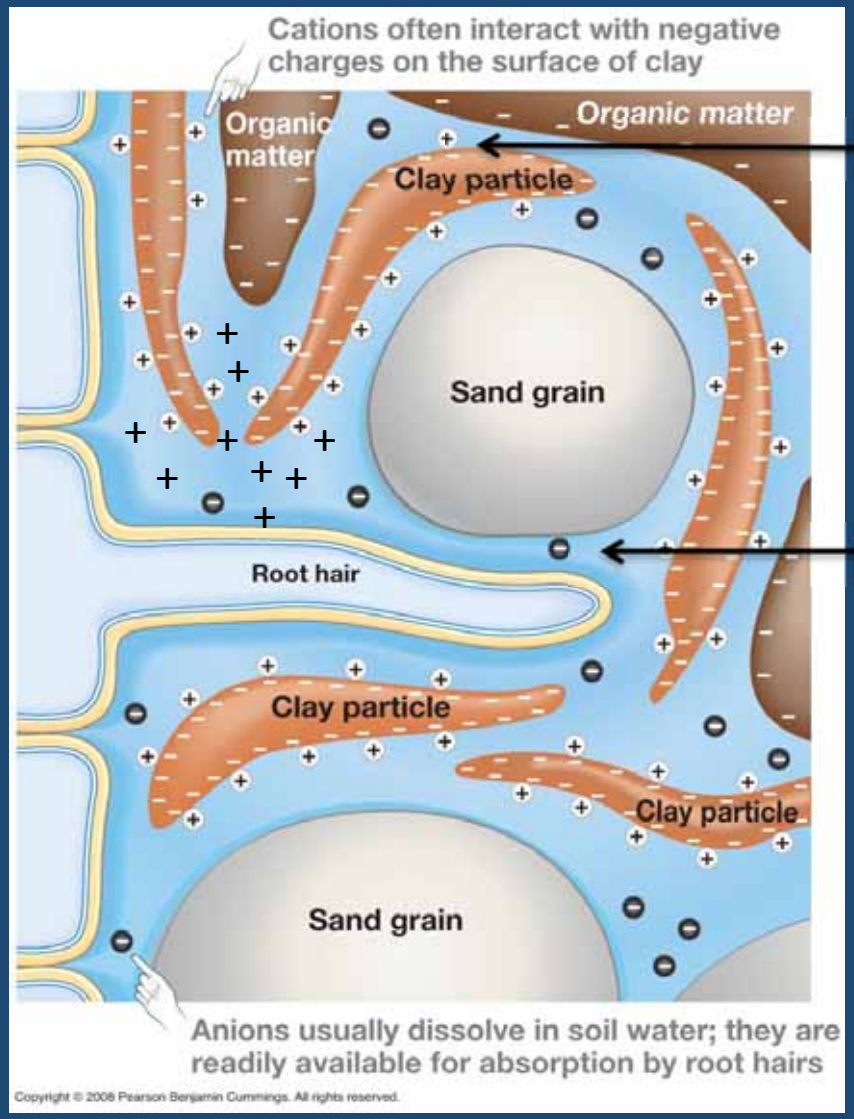


Figure 38.7 pg. 843

Cations (+) sticking to the (-) charged soil particles

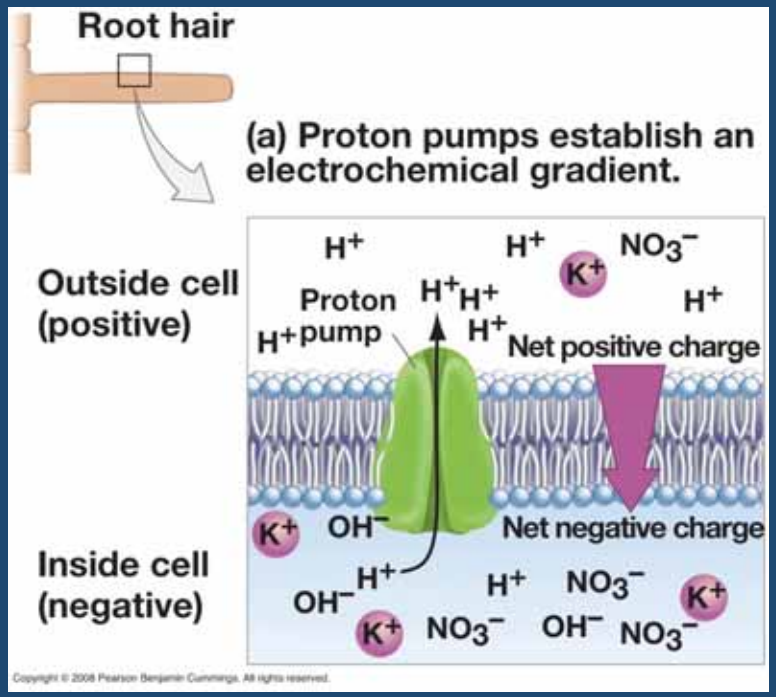
Water-souble anions drifting in the water.

http://animals.nationalgeographic.com/animals/reptiles/nile-crocodile/

Acquiring Anions (-)
Cotransporters

1. Establish a charge difference

2. Import the (-) charged molecule with a costransporter



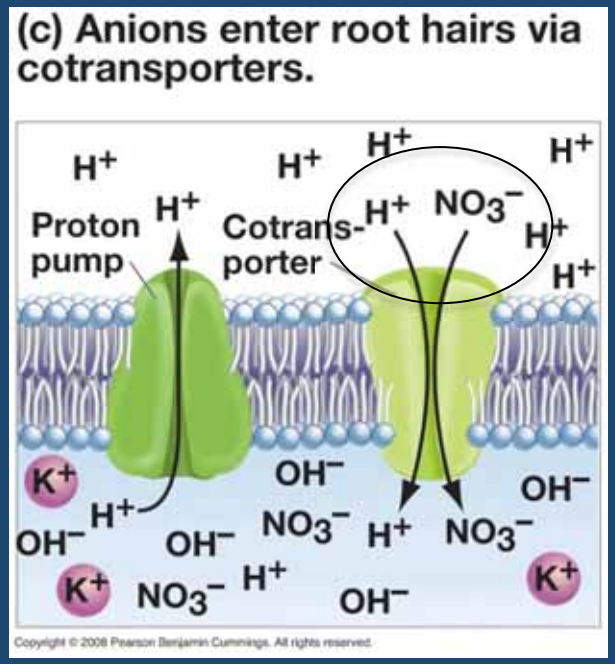
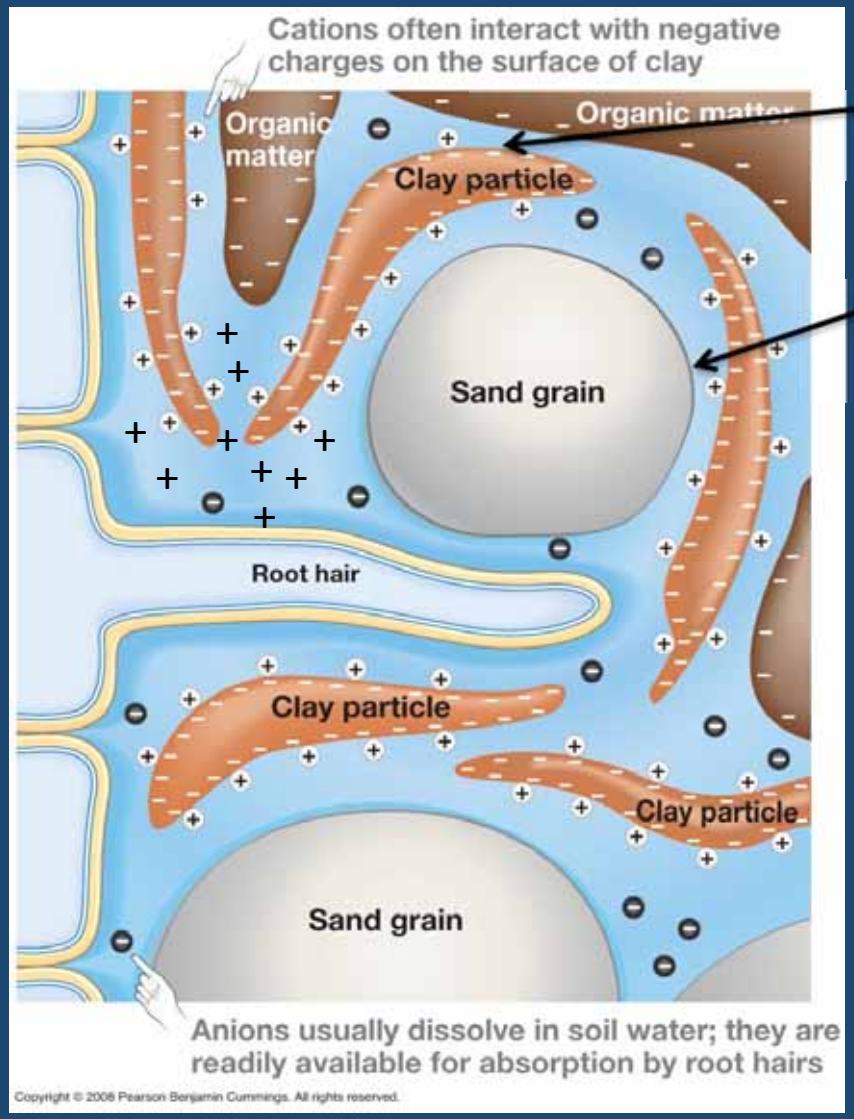


Figure 38.10 pg 845

Minerals in the Soil



Look at all of these cations

What happens if we introduce more minerals to the soil?

Figure 38.7 pg. 843

http://animals.nationalgeographic.com/animals/reptiles/nile-crocodile/

Video 52:17

Minerals in the Soil

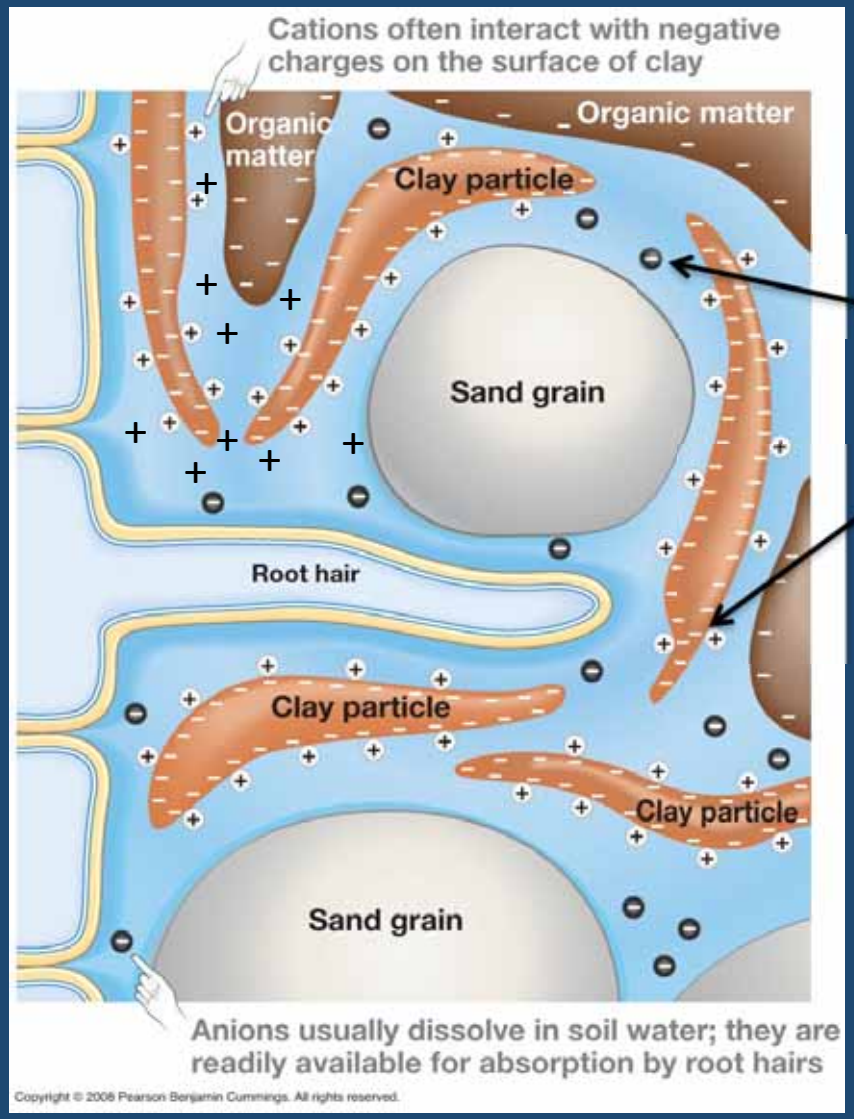


Figure 38.7 pg. 843

Electrolytes:

Ion salts added to soil. (K^+ Na^+)

<u>Roles reversed</u>
Anions stick to (+) electrolytes

Cations (+) wash away in solution

Plants lose access

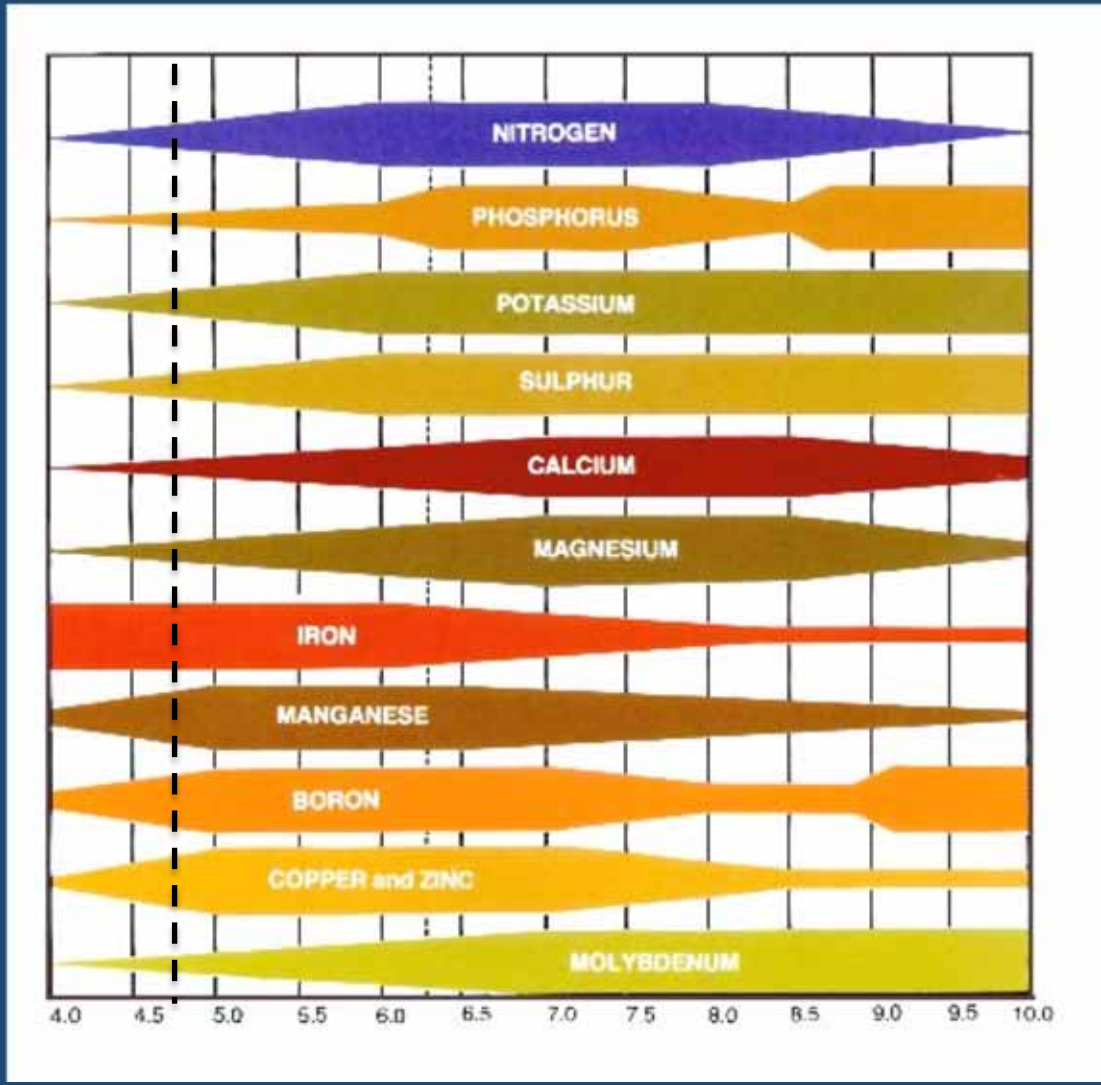
Brawndo: not what plants crave!

http://animals.nationalgeographic.com/animals/reptiles/nile-crocodile/

Minerals only available at certain pH

So what can a plant do to get essential nutrients at these pHs?

Low pH:
High productivity
High rainfall



http://organicgarden.org.uk/gardening/soil/soil-chemistry

Carnivorous plants

Soil pH is less than 4

These plants don't need to eat bugs as a carbon source. Plants are only interested in the minerals.

Saracennia (pitcher plant) leaves hold water to drown insects and mine their bodies for minerals

Questions

- The proton gradient surrounding the root hairs is established by what enzyme?

- What kind of charged particle is freely dissolved in the water surrounding a root hair?