CHAPTER 37: WHAT DO PLANTS NEED TO LIVE AND HOW DO THEY GET IT?

Elemental Composition of Living Organisms

WHAT ARE ORGANISMS MADE OF?

Element	*Human*	*Alfalfa*	*Bacterium*
Carbon	19.37%	11.34%	12.14%
Hydrogen	9.31	8.72	9.94
Oxygen	62.81	77.90	73.68
Nitrogen	5.14	0.83	3.04
Phosphorus	0.63	0.71	0.60
Sulfur	0.64	0.10	0.32
CHNOPS Total:	97.90%	99.60%	99.72%

Living organisms are mostly water
90 % + for plants and fungi
60%+ for humans

95% of PLANTS: C, H, O, N, P, S.

Von Helmut's messed up experiment

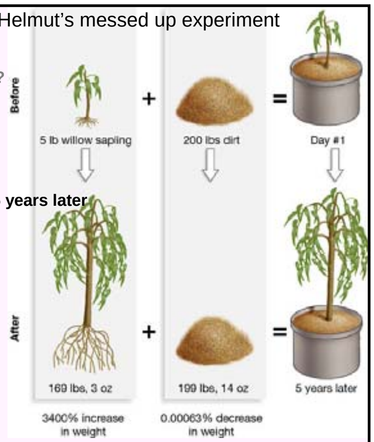
WHERE DOES THE MASS OF A PLANT COME FROM ?

He concluded that plant material came from water

Didn't know that air has mass: CO_2

Ignored the 2 ounce difference !

Critical nutrients in the 2 ounces



- The uptake of nutrients occurs at both the roots and the leaves.
  - Roots, through mycorrhizae and root hairs, absorb water and minerals from the soil.
  - Carbon dioxide diffuses into leaves from the surrounding air through stomata.

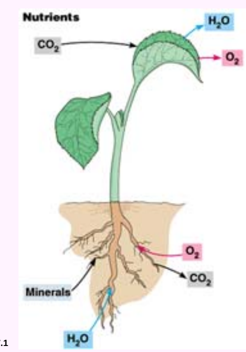


Fig. 37.1

WHAT DO PLANTS NEED TO LIVE?

C HOPK'NS CaMg

MACRONUTRIENTS - required in large quantities			
FROM WATER AND AIR			
Carbon	C	45%	carbohydrates (sugars, starch, cellulose), lipids, proteins, nucleic acids = C, H, 0
Oxygen	O	45%	
Hydrogen	H	6%	
FROM SOIL/ FERTILIZER			
Nitrogen	N	1.5%	protein, amino acids
Phosphorus	P	0.2%	nucleic acids, ATP
Potassium	K	1.0%	catalyst, ion transport
Sulfur	S	0.1%	amino acids
Magnesium	Mg	0.2%	chlorophyll
Calcium	Ca	0.5%	cell wall component

MICRONUTRIENTS ARE <u>REQUIRED</u> IN SMALL QUANTITIES

(Usually co-factors)

MICRONUTRIENTS		
Iron	Fe	chlorophyll synthesis
Manganese	Mn	activates enzymes
Boron	B	cell wall component
Chlorine	Cl	photosynthesis reactions
Zinc	Zn	activiates enzymes
Copper	Cu	component of enzymes
Molybdenum	Mo	involved in N fixation

WHAT DEFINES AN ESSENTIAL ELEMENT?

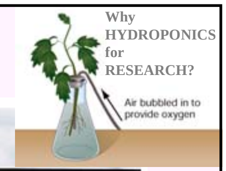
1. Required for growth and reproduction
2. No other element can substitute
3. Necessary for a specific structure or function

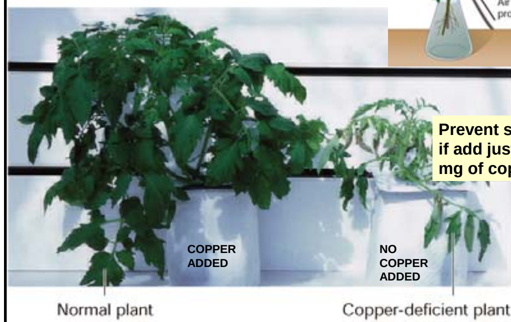
MACRONUTRIENTS

MICRONUTRIENTS

HOW DO NUTRIENT DEFICIENCIES AFFECT PLANTS?

What kind of nutrient experiments can we do?





Prevent symptoms if add just 0.002 mg of copper !

THE EFFECTS OF ALL ESSENTIAL NUTRIENTS HAVE BEEN STUDIED

- Hydroponic culture can determine which mineral elements are actually essential nutrients.
  - Plants are grown in solutions of various minerals dissolved in known concentrations.
  - If the absence of a particular mineral, such as potassium, causes a plant to become abnormal in appearance when compared to controls grown in a complete mineral medium, then that element is essential.

Fig. 37.2

The symptoms of a mineral deficiency depend on the function and mobility of the element

- The symptoms of a mineral deficiency depend partly on the function of that nutrient in the plant.
  - For example, a magnesium deficiency, an ingredient of chlorophyll, causes yellowing of the leaves, or chlorosis.

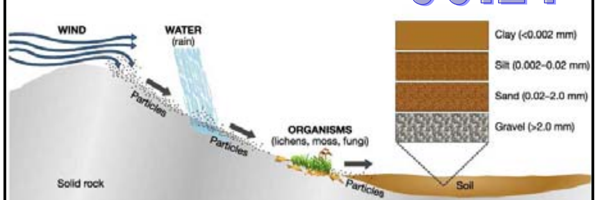
Fig. 37.3

- One way to ensure optimal mineral nutrition is to grow plants hydroponically on nutrient solutions that can be precisely regulated.
  - This technique is practiced commercially, but the requirements for labor and equipment make it relatively expensive compared with growing crops in soil.

Fig. 37.4

WHERE DO NUTRIENTS COME FROM?

SOIL !



1. Breakdown of rock to make particles
2. Decomposed organic matter
3. Living organisms

ELEMENTS ARE FOUND IN THE SOIL AS IONS

NEGATIVE IONS

dissolve in water
absorbed by plants
leach out with rain
anions!

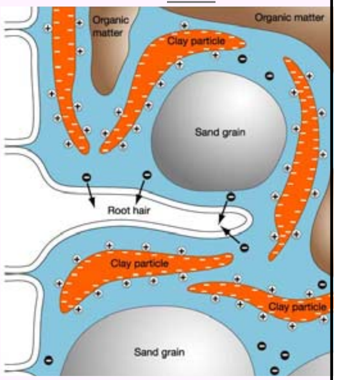
Cl^-, HPO_4^-, NO_3^-

POSITIVE IONS

bind to clay/OM
resist leaching
hard for plants to absorb
cations

K^+ Ca^{2+}

Exception:
phosphate (-) binds to soil



WHAT AFFECTS NUTRIENT AVAILABILITY ?

1. SOIL TEXTURE

binds ions
amount oxygen
root penetration

2. CHEMICAL COMPOSITION

Ions present
pH – acid or alkaline soil

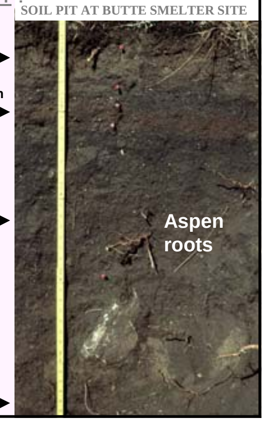
3. SOIL COMPOSITION

organic matter
moisture

determines which plant species can grow

organic layer →
smelter pollution 1800's →
mineral soil →
bedrock →

SOIL PIT AT BUTTE SMELTER SITE



HOW DO NUTRIENT-CONTAINING IONS GET INSIDE THE ROOT ?

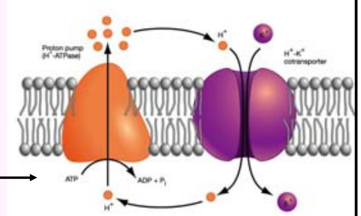
PASSIVE UPTAKE

ACTIVE UPTAKE

AGAINST A GRADIENT TAKES ENERGY (ATP)
SPECIAL CHANNELS

PROTON PUMP

ATP used →



HOW DO PLANTS KEEP POISONOUS IONS OUT ?

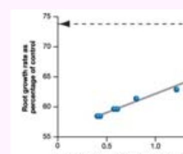
PASSIVE EXCLUSION

salt tolerance varies in plants
salt tolerant plants take up less salt
fewer sodium channels !

WHAT DO PLANTS DO IF TOXIC IONS GET IN?

ACTIVE EXCLUSION

copper tolerance varies in plants
copper tolerant plants have more metal-binding proteins inside

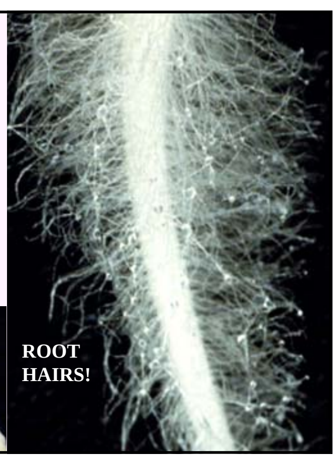


Uptake of nutrients depends on surface area

ROOT HAIRS "INCREASE SURFACE AREA OF ROOTS"

BY HOW MUCH?

CAN WE ESTIMATE THE INCREASE ?



ROOT HAIRS: 3 mm long, 10 um diam.
ROOT: 1 mm in diameter
180 ROOT HAIRS/mm of root

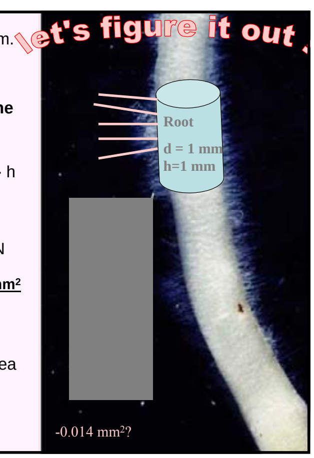
How much do root hairs increase the surface area of *Arabidopsis?*

Surface area ROOT (cylinder) = π d · h
= 3.14 x 1 mm x 1 mm = **3.14mm²**

SA of 180 HAIRS (cylinder) = π d·h·N

3.14 x.01 mm x 3 mm x 180 hairs =**16.2 mm²**

possibilities:
16.2/3.14 = 5.5 times more surface area



- After a heavy rainfall, water drains away from the larger spaces of the soil, but smaller spaces retain water because of its attraction for the soil particles, which have electrically charged surfaces.
  - Some water adheres so tightly to hydrophilic particles that it cannot be extracted by plants, but some water bound less tightly to the particles can be absorbed by roots.

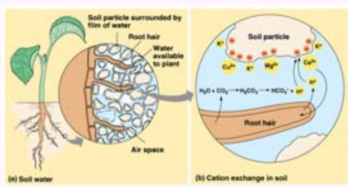


Fig. 37.6

<u>MYCORRHIZAL FUNGI</u>

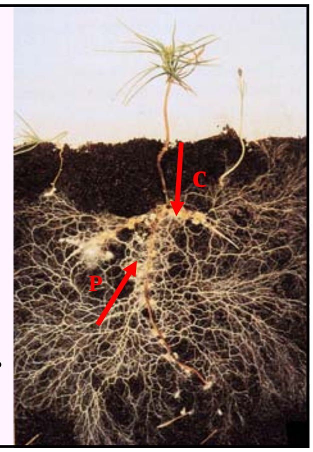
INCREASE SURFACE AREA OF ROOTS EVEN FURTHER !

<u>SYMBIOSIS</u>

FUNGUS PROVIDES <u>PHOSPHORUS</u> (P) TO THE PLANT

PLANT PROVIDES <u>SUGARS</u> (C) TO THE FUNGUS

How could we test this hypothesis?



<u>RADIOACTIVE TRACERS</u> IN BIOLOGY

<u>Radioactive isotopes</u> are important biological tools

They can be used to 'label' elements so they can be 'traced'

<u>Audioradiography</u>:

1. Plants take up isotopes, (C^{14} for example)
2. Dry plants & place on "unexposed film" in the dark
3. Isotopes emit radiation, flashes of light "exposes" the "film"
4. The film is developed
5. Exposed areas are dark, indicate where the element is located

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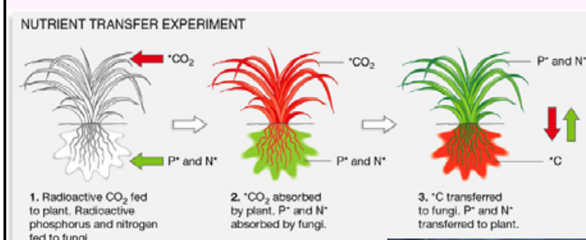
How could we gather evidence to show that a plant and mycorrhizal fungus are mutually beneficial?



WHAT ORGANISMS TRANSFER NUTRIENTS TO PLANTS?

MYCORRHIZAL FUNGI !

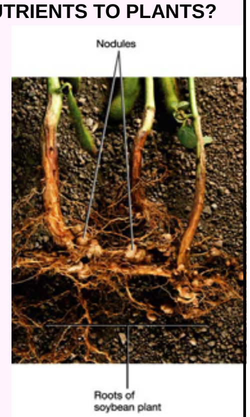
90% of plants (phosphorus)

NITROGEN-FIXING BACTERIA

legumes (peas, beans, alfalfa)

N^2 gas (from air) → "fixed" to ammonia

Plants can use ammonia !



WHAT ARE SOME UNUSUAL PLANT ADAPTATIONS FOR GAINING NUTRIENTS ?

1. <u>EPIPHYTES</u>

   live on other plants,

   absorb nutrients in rainwater, dust, and air!

   not parasites

2. **PARASITIC PLANTS**

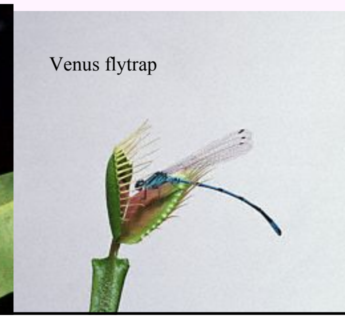
steal nutrients from other plants
mostly sugars from their roots

Fungus can be involved !

mistletoe

3. **CARNIVOROUS PLANTS**

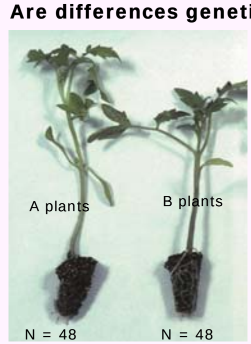
photosynthesis
get extra nitrogen from insects
release digestive enzymes & absorb the nutrients



Sundews capture insects on sticky hairs and digest them !

captured mosquito

Are differences genetic or environmental?



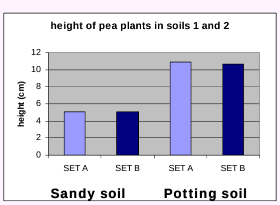
When grown under same conditions:

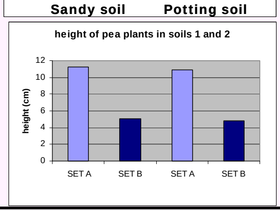
Mean A = 10.5

Mean B = 4.25

How can you set up an experiment to determine this?

Plant types A and B were grown in 2 soil types under the same conditions.
Are differences between A and B environmental or genetic?





A LOT GOES ON IN SOIL !

2. Soil conservation is one step toward sustainable agriculture

- It takes centuries for a soil to become fertile through the breakdown of soil and the accumulation of organic material.
- However, human mismanagement can destroy soil fertility within just a few years.
- Soil mismanagement has been a recurring problem in human history.

– Several years of drought resulted in the loss of centimeters of topsoil that were blown away by the winds.
  - Millions of hectares of farmland became useless, and hundreds of thousands of people were forced to abandon their homes and land.

Fig. 37.7

- Valuable topsoil is lost to wind and water erosion each year.
  – This can be reduced by planting rows of trees between fields as a windbreak and terracing a hillside to prevent topsoil from washing away.
  – Some crops such as alfalfa and wheat provide good ground cover and protect soil better than corn and other crops that are usually planted in rows.

Fig. 37.8