Plant Physiology

- Definition
- The Early Years
- Environmental Effects on Plant Growth
  - Light
    - Photosynthesis/Respiration
    - Phototropism/Photoperiodism
    - Other

Plant Physiology

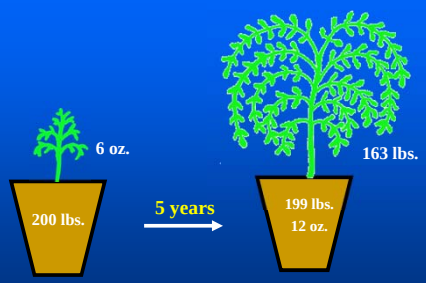
Essential life processes that determine how plants grow and develop

The Early Years

Van Helmont

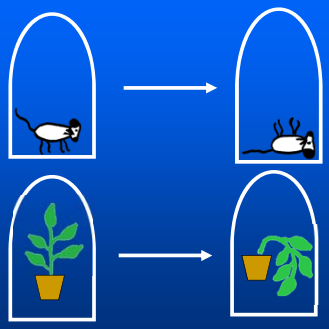
Joseph Priestly

Van Helmont Experiment

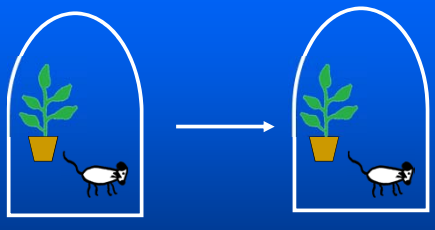


Conclusion: Plants don't consume soil

Joseph Priestly Experiment



Joseph Priestly Experiment



Photosynthesis

$6Co_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + O_2 + \text{energy}$

$6\ Co_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{light}} C_6H_{12}O_6 + O_2 + \text{energy}$ (ATP)

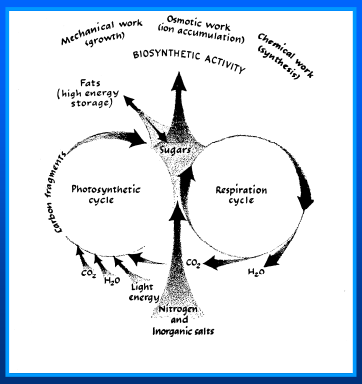
Photosynthesis → Glucose → ATP

Respiration

Glucose
Sucrose
Starch
Amino Acids
Oils

Photosynthesis: A Building Up Process

Respiration: A Break-down Process



Photosynthesis vs. Respiration

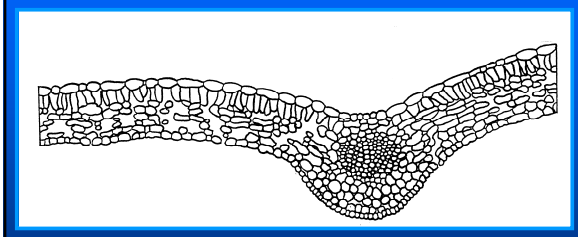
Photosynthesis

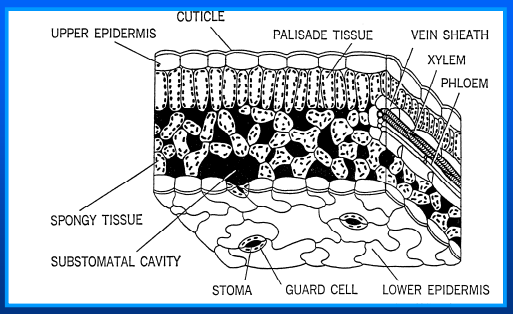
- Occurs only in light
- Occurs only in cells containing chlorophyll
- Produces energy (ATP)
- Increases dry weight

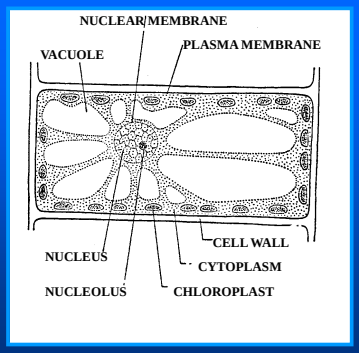
Respiration

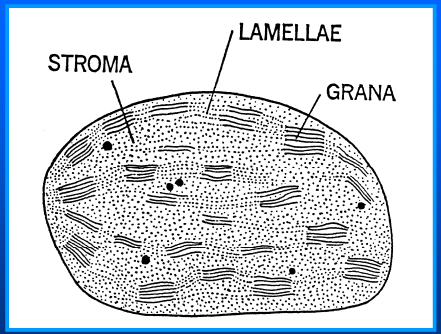
- Occurs in light or dark
- Occurs in all living cells
- Uses energy (ATP)
- Decreases dry weight

Cross-section of Leaf

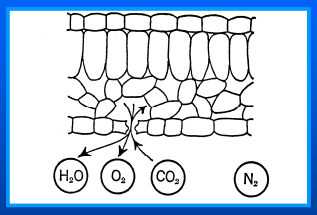






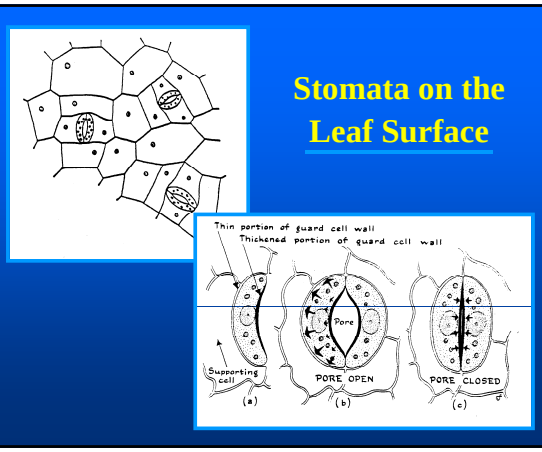


Chloroplast



Gas and Water Exchange Through Stomata (Stomate, singular)

Stomata on the Leaf Surface



Number of Stomata Per Square Inch of Leaf Surface

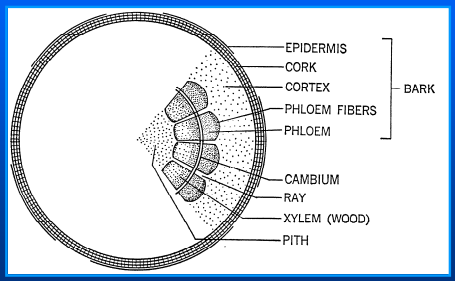
Plant	Upper Epidermis	Lower Epidermis
Apple	None	250,000
Bean	26,000	160,000
Corn	39,000	64,000
Black Oak	None	375,000
Orange	None	290,000
Pumpkin	18,000	175,000
Sunflower	55,000	100,000

Atmospheric elements (carbon, hydrogen, and oxygen) and water vapor move in and out of leaf through the STOMATA

Water and nutrients (N, P, K, Ca, Mg, Fe etc.) move upward in the plant to areas undergoing respiration and food manufacture via the XYLEM

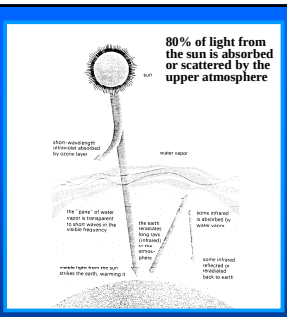
Carbohydrates, starch, water, proteins, amino acids, oils etc. move to areas where needed for growth or to the root for storage via the PHLOEM

Cross-section of a Woody Plant



Light

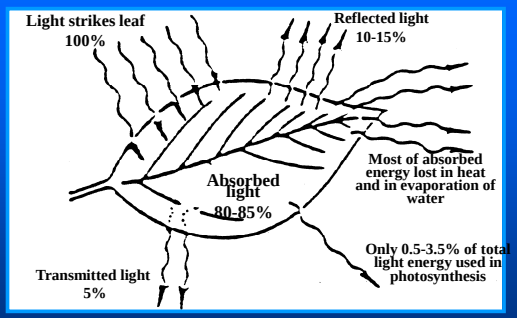
- All life on earth depends directly or indirectly on radiant energy from the sun.
- Each year 3.5 million kilowatts of electrical energy strike the earth.
- Light influences all biological processes.
- Light regulates the earth's temperature.
- Light provides the energy for rain, wind and ocean currents.
- Light travels 93 million miles from the sun to earth at a speed of 186,000 miles per second.



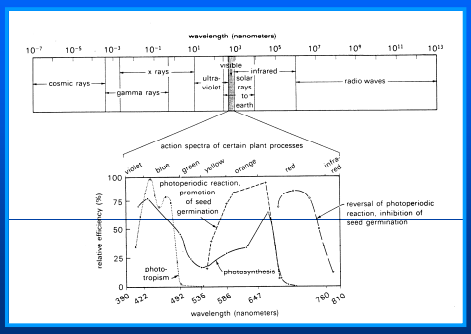
Of the 20% of light reaching the earth's surface, about 98% is absorbed by the earth and re-radiated as heat energy

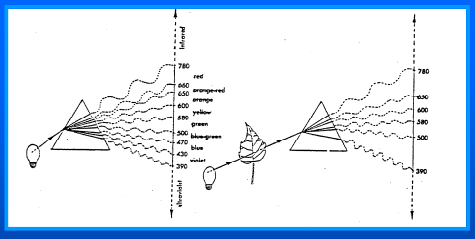
Only 1 to 2% of the light from the sun is used by plants in photosynthesis

Light from the sun is emitted in a series of wavelengths. Wavelengths of similar proportion combine into pulses of light called photons.



The Electromagnetic Spectrum





Plants absorb light in two regions of the visible spectrum: RED and BLUE

This is the basis for Gro- Lights or Full-Spectrum Lights for Plants

Measuring Light

Foot Candles (fc)

A foot candle is the amount of light (illuminance) from a standard candle received on a 1 square foot surface that is 1 foot from a candle.

Average Light Intensities for Various Locations

- Sunny day - 10,000 fc
- Cloudy day - 500-2,000 fc
- Conference room - 20-30 fc
- Reading in home - 20-30 fc
- Stores - 30-100 fc
- Church chapels - 5-10 fc

Plants: 50 to 1,000 ft. candles

Seed Germination

Two 40 watt bulbs placed

6 inches from the seedlings provides 1,000 ft. candles

Placement of Medium-light Plants Under Various Lamps for Maximum Growth

Type of lamp	Distance: plant to lamp	Footcandles
Cool white	11.75 in.	285
Warm white	11.75 in.	285
Gro-Lux Plant Light	7.88 in.	130
Mercury (400w)	4 ft. 11 in.	300
Incandescent, standard	11.75 in.	97

Source: H. M Cathey

Recommended Light Intensities for Maintenance and Growth of Selected Foliage Plants (foot candles)

Species	Maintenance	Optimum Growth
Asparagus fern	100-500	200-400
Shefflera	150-200	200-400
Parlor Palm	50-75	75-100
Ty Plant	75-100	100-150
Dracaena marginata	100-150	200+
Weeping Fig	100-150	150-400+
Boston Fern	50-100	150-200+

Low Light Foliage Plants (50 to 100 fc)

- Chinese evergreen
- Cast iron plant
- Parlor palm
- Jade plant
- English ivy
- Birdnest sansevieria
- Snake plant
- Bamboo palm

Medium Light Foliage Plants (100 to 200 fc)

- Wandering Jew
- Rex Begonia
- Schefflera
- Areca Palm
- Dracaena
- Weeping Fig
- False Aralia
- Boston Fern
- Philodendron
- Aluminum Plant
- Spider Plant
- Pothos
- Nephytis
- Christmas Cactus

High Light Foliage Plants (200+ fc)

- Zebra Plant
- Norfolk Island Pine
- Croton
- Ti Plant
- African Violet
- Cactus
- Gloxinia
- Geranium

Light Adaptability of Woody Ornamentals

Adapted to Shade	Flower Well in Shade	Flower Poorly in Shade
▪ Aucuba	▪ Azalea	▪ Rose
▪ Azalea	▪ Hosta	▪ Clematis
▪ Camellia	▪ Camellia	▪ Forsythia
▪ Cleyera	▪ Dogwood	▪ Hydrangea
▪ Gardenia	▪ Gardenia	▪ Hibiscus
▪ Hosta		▪ Flowering Cherry
▪ Nandina		
▪ Yew		

Effects of Light on Plants

Very High Light:

Leaves smaller/thicker

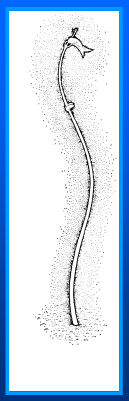
Chlorosis (overall yellowing)

Brown Spots

Very Low Light:

Leaves larger/thinner

Greater internode length - stretching



ETIOLATION

Whitish, spindly stems.

Leaves not fully expanded.

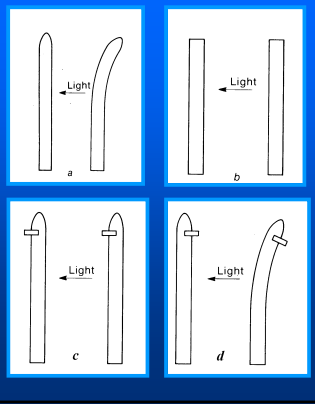
Root system develops poorly.

All tissue highly succulent

Phototropism

A change in the manner of growth of a plant in response to non-uniform illumination. An auxin-related response causing bending toward the strongest light.

Phototropism: F.W. Went Expt. - 1928



Auxin produced in the tip moves downward on the side of the stem opposite the illuminance, causing cell elongation

Light Receptor

Beta carotene

or Riboflavin

Photoperiodism

The response of plants to the lengths of day or night

Discovered 1906: Garner and Allard Maryland Mammoth Tobacco

In the field: Grew 10 to 15 feet tall – would not flower until late fall or winter

Photoperiodism

In the greenhouse, the tobacco would not flower by changing temperature or fertilizer level or with supplemental lighting.

Discovery:

A dark period 4 pm to 9 am is necessary for flowering.

Three Photoperiodic Responses of Plants

Short Day Plants

Long Day Plants

Day Neutral Plants

Three Photoperiodic Responses

Short Day Plants: Initiate flower buds when day length is shorter than the critical day length or when the dark period is longer than the critical night length.

Poinsettia
Chrysanthemum
Aster
Goldenrod
Ragweed
Christmas Cactus
Variegated Spider Plant

Three Photoperiodic Responses

Long Day Plants: Initiate flower buds when the day length is longer than the critical day length or when the dark period is shorter than the critical night length.

Hollyhock
Radish
Beets
Spinach
Iris
Red Clover

Three Photoperiodic Responses

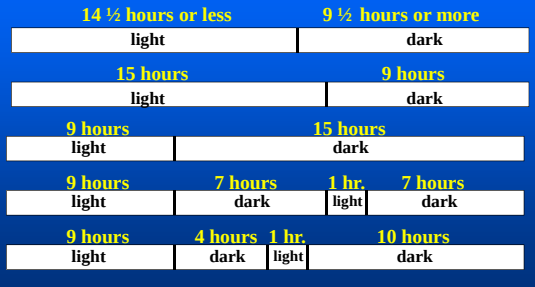
Day Neutral: Flower over a wide range of photoperiods.

Cabbage	Hyacinths
Carrots	Daffodils
Tulips	Tomatoes

Most woody ornamentals are day neutral

Chrysanthemum: Short Day Plant

Initiate flowers when daylength is 14 hours or less or the length of the dark period is 9 ½ hours or more



10 ft. candles of light = 60 watt bulbs, 4 feet apart, 4 feet above plants

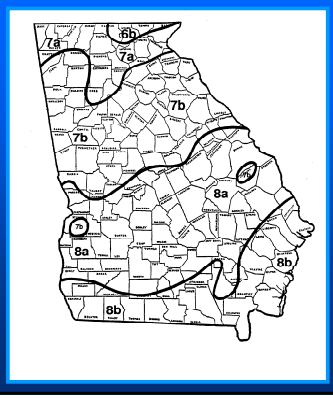
Effect of Light on Seed Germination

Common Name	Light Requirement
Lettuce	Light
Ageratum	Light
Coleus	Light
Dusty Miller	Dark
Gomphrena	Dark
Pansy	Dark
Petunia	Light
Snapdragon	Light

Temperature

- Governs the rate of photosynthesis and respiration.
- Influences fall color - sugars to starch, chlorophyll ceases function and carotenoids (orange) and anthocyanins (red) become evident.
- Influences leaf fall and dormancy.
- Influences fruiting plants. Many horticultural plants have a cold or chilling requirement. (peaches 350-1200 hours below 45 degrees F).
- Influences hardiness (flowers<roots<leaves<stems).

Plant Hardiness Zones



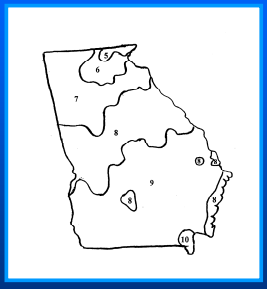
Range of Average Annual Minimum Temperatures for Each Zone

Zone	Range in Degrees F
6b	0 to –5
7a	5 to 0
7b	10 to 5
8a	15 to 10
8b	20 to 15

Root Killing Temp. of Selected Landscape Plants

Species	°F
Southern Magnolia	23
Flowering Dogwood	20
Boxwood	15
Japanese Andromeda	10
Horizontal Juniper	0

Heat Zone Map For Georgia



Ave. no. of days per year above 86 degrees F

Zone	Ave. No. Days
5	30 – 45
6	45 – 60
7	69 – 90
8	90 – 120
9	120 - 150

Heat-Zone Map of U.S.

Full –color Poster - $14.95 each

Available from:

American Horticultural Society
Gardener's Information Service
7931 Boulevard Dr.
Alexandria, VA 22305-1300
www.ahs.org

Water

The lifeblood of plants

Water is essential for:

Chemical reactions in the plant

Translocation of nutrients

Transpiration

Water

The lifeblood of plants

Land plants require about 400 pounds of water for each pound of dry matter processed.

An apple tree needs 50 gallons of water per bushel of apples.

Fresh apple =84% water
Banana=75% water
Peach=87% water

Rates of Water Loss per Day in Mid-summer

Plant	Water Loss (in quarts)
A single corn plant	3-4
A single giant ragweed plant	6-7
A single young 10-ft apple tree	10-20
A 12-foot columnar cactus	0.02
A coconut palm in moist tropics	70-80
A date palm in a desert oasis	400-500

Estimated Water Losses from Single Plants During a Growing Season

Plant	Days	Water Loss (Gallons)
Tomato	100	30
Corn	100	50
Sunflower	90	125
Giant ragweed	90	140
Mature apple tree	188	1,800
Coconut palm, moist tropics	365	4,200
Date palm	365	35,000

Water Movement in Plants

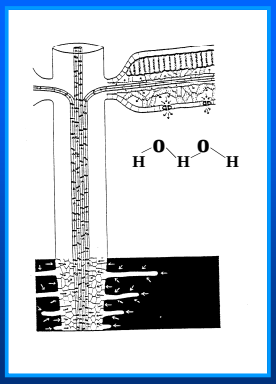
How does water reach the top of our tallest trees?

Root pressure – not found in many species. In those species where it has been found, only enough pressure has been measured to push water to a height of 64 feet.

Water Movement in Plants

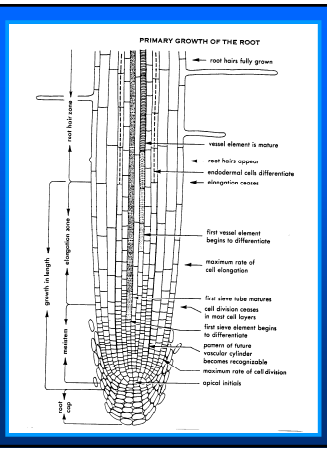
Water is pulled up in the xylem by a transpiration-cohesion-tension mechanism.

Transpirational loss of water causes additional water to be pulled up through the xylem to replace the water lost.



Transpiraton Cohesion/Tension

Water is pulled upward in the plant by a vapor pressure deficit established through the transpiration of water from the leaves.



Water moves into the plant via intercellular spaces between the root cells. It then moves into the vessel elements of the Xylem and is pulled upward in the plant

Sixteen Essential Nutrients for Plant Growth

Atmospheric Nutrients
C - Carbon **H** – Hydrogen
O - Oxygen

Primary Nutrients
N – Nitrogen **P** – Phosphorus
K - Potassium

Secondary Nutrients
Ca – Calcium **Mg** - Magnesium
S - Sulphur

Micro Nutrients
Fe – Iron **Cu** – Copper **Zn** – Zinc **B** – Boron
Mn – Manganese **Mo** – Molybdenum **Cl** - Chlorine

Each Nutrient Has An Important Function In Plants

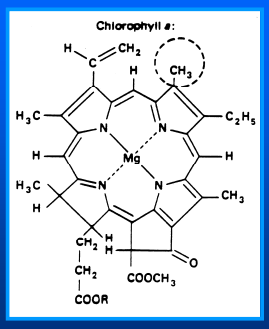
- **Nitrogen**
  - – An essential component of proteins, amino acids, chlorophyll and many other organic compounds
- **Phosphorus**
  - – A component of phosphorylated sugars (ATP, DPM, DNA)
- **Sulphur**
  - – A component of proteins and many other substances

Each Nutrient Has An Important Function In Plants

- **Calcium**
  - – Necessary in calcium pectate in cell walls
- **Iron**
  - – A constituent of important enzymes
- **Magnesium**
  - – A part of the chlorophyll molecule

Trace or minor elements are essential in many chemical reactions

The Chlorophyll Molecule



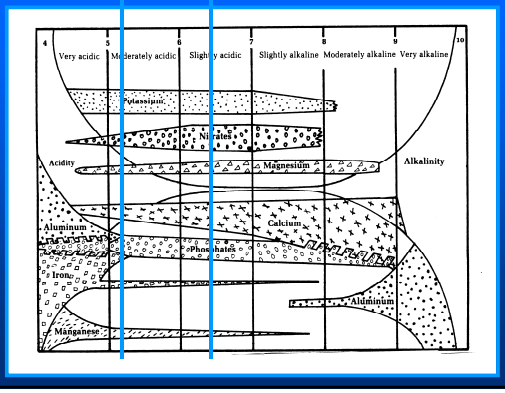
Forms of Elements Used By Plants

Nitrogen	$NH4^{+}$, $NO2^{-}$, NO_3^{-}
Phosphorus	HPO_4^{--}. $H_2PO_4^{-}$
Potassium	K^{+}
Iron	Fe^{++}, Fe^{+++}
Molybdenum	MoO_4^{--}
Manganese	Mn^{++}, Mn^{++++}
Copper	Cu^{+}, Cu^{++}
Carbon	CO_3^{--}, HCO_3^{-}

Forms of Elements Used By Plants

Calcium	Ca^{++}
Magnesium	Mg^{++}
Sulfur	SO_3^{--}, SO_4^{--}
Zinc	Zn^{++}
Boron	BO_3^{---}
Chlorine	Cl^{-}
Water	H^{+}, OH^{-}

pH Effect on Nutrient Availability



Let's Put it All Together

- Water and nutrients move into the plant primarily through the intercellular spaces between the root cells. They move into the internal vascular system called the xylem and are pulled upward in the plant via cohesion and tension resulting from transpirational water loss through the stomata.

- Water and nutrients take part in the food manufacturing process during respiration. Photosynthesis produces the energy for this to occur.

- Growth substances, such as amino acids, proteins and oils, are transported to other areas of the plant (ie. developing fruit, flowers, leaves or roots) via the phloem.
- Carbon dioxide, oxygen and water vapor move in and out of the plant via the stomata or breathing structures on the leaves.
- Light and temperature have a pronounced effect on the rate of photosysthesis and respiration.

Please Answer the Following Questions

1. The pigment responsible for photosynthesis is _____.
2. The catalyst for photosynthesis is _____.
3. Arrange the following to describe photosynthesis:
   Water, Carbohydrates, Light, Oxygen, Energy, Carbon Dioxide
4. The process by which carbohydrates are broken down and combined with nutrient elements to form growth substances is called _____.
5. Describe two symptoms of insufficient light on plants.

6. Poinsettias require a long night period in order to initiate flowers. They are referred to as _____ _____ plants.
7. What is the unit used to measure light?
8. In what regions of the visible spectrum do plants absorb light most efficiently?
9. What are full-spectrum light bulbs?
10. Define the following:
    Phototropism
    Photoperiodism
11. Define etiolation.
12. Water enters the plant primarily through the _____.

13. Water and nutrients move within the plant via the _____ while growth substances move via the _____.
14. The loss of water through the leaves is called _____.
15. List two functions of water in plants.
16. How does water move to the top of a tree 250 feet tall?
17. What is the most desirable pH range for ornamental plants? Why?
18. List three primary nutrients:
    List one secondary nutrient:
    List three micronutrients:

19. Define plant hardiness.
20. In what hardiness zone do you live?