Welcome

Plant Growth & Development

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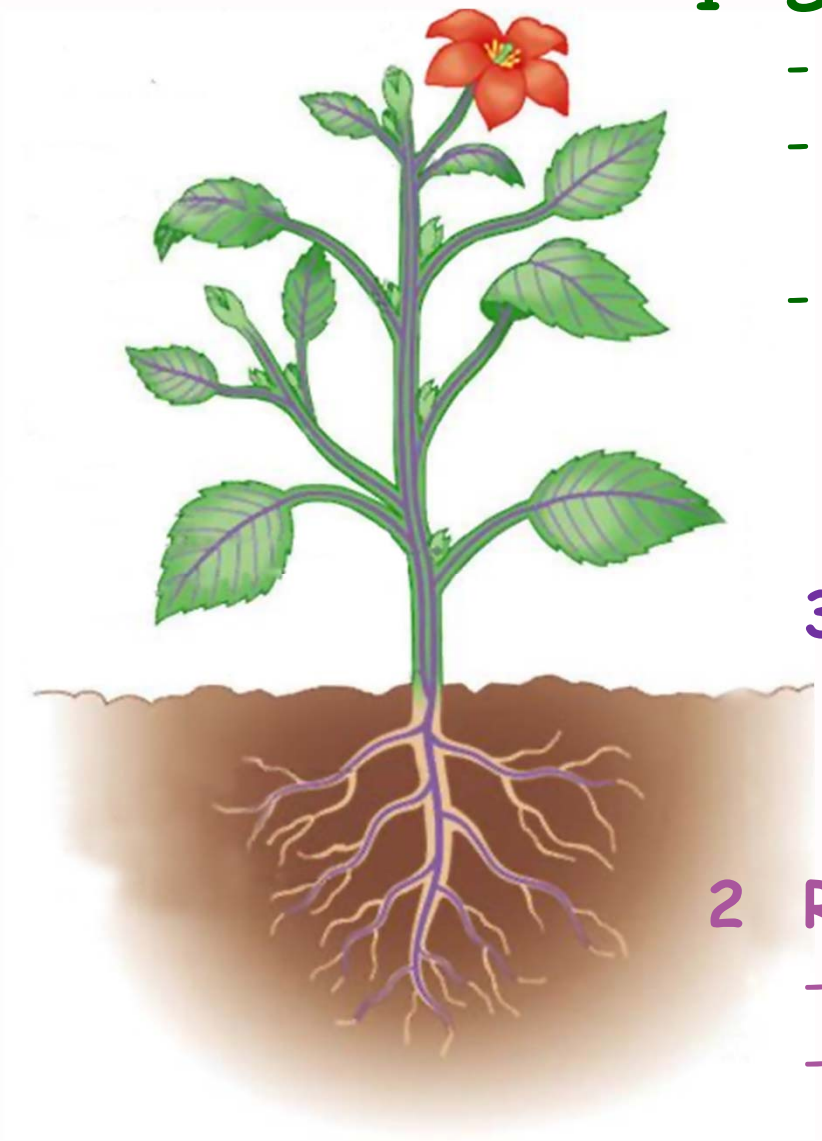
Washington University, St. Louis MO

St. Louis MG Training Class

St. Louis, MO Jan 18, 2018

Class Outline

1:30 – 2:30	Plant Growth & Development
(6:30 – 7:30)	*(material on the quiz)*
2:30 – 2:45	*Break*
(7:30 – 7:45)	
2:45 – 3:45	Photosynthesis -- *(for fun!!)*
(7:45 – 8:45)	*(educational & entertaining)*



1 Shoot System

- photosynthesis in leaves
- stems hold leaves in position to collect maximum light
- buds produce new parts: more stems & leaves and flowers for reproduction

3 Vascular System

- circulate **water** & **food** (**xylem** & **phloem**)

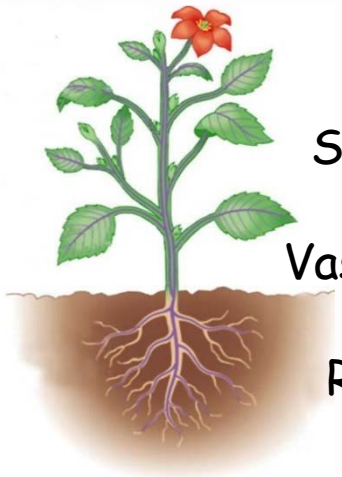
2 Root System

- anchors & supports plant
- absorbs **water** & minerals

Plant Growth and Development

"How to Keep Plants Healthy!"

- **Photosynthesis and Respiration**
- **Environmental Factors**
- **Regulation by Hormones**



Shoot System

Vascular System

Root System

Master Gardening Mission Statement:
Provide Horticultural Information and Assistance to the Public for Community Service and Gardening Pleasure

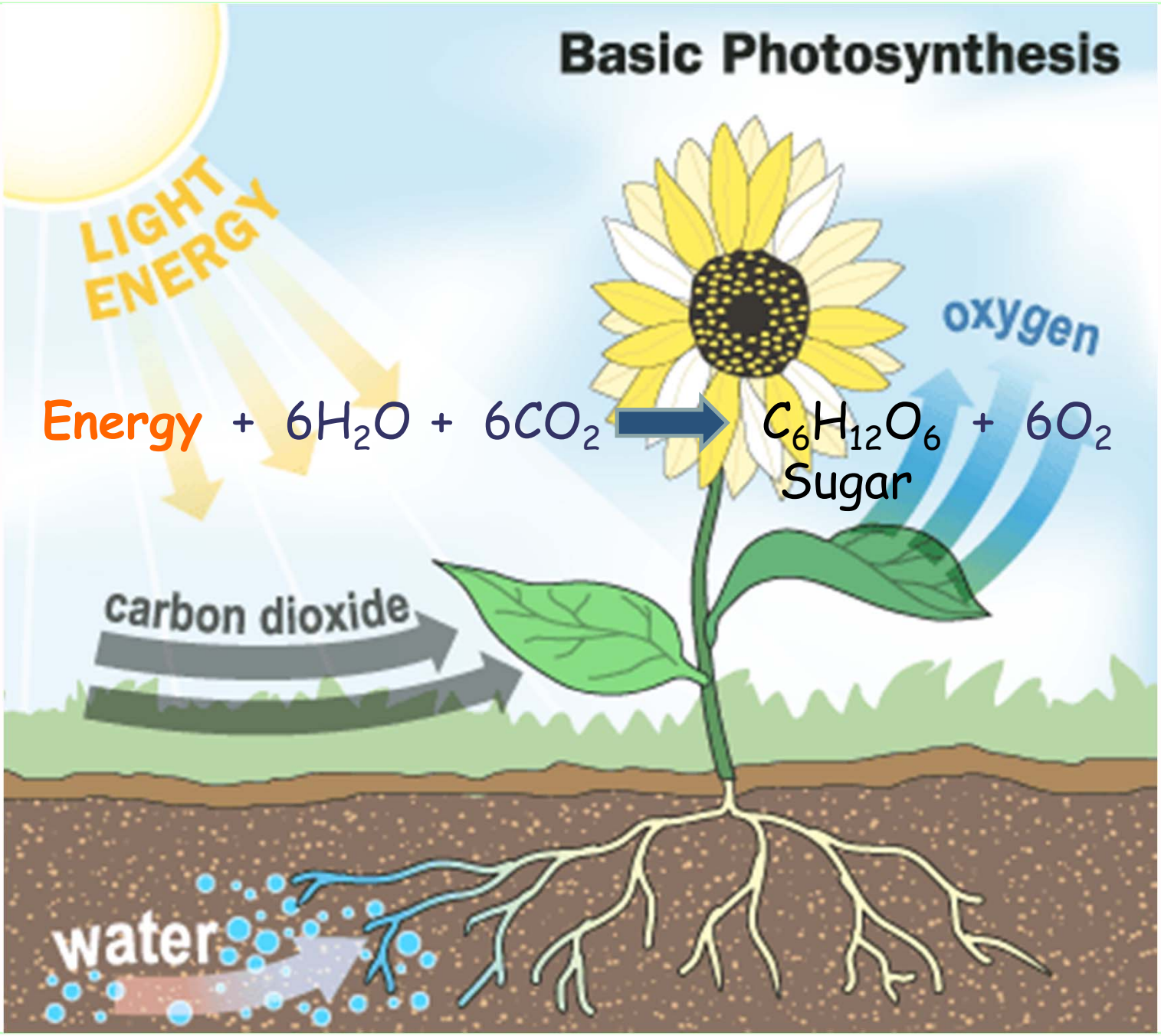
Plant Growth and Development

- **Photosynthesis and Respiration** (~10 mins)
  "Make Food" and "Consume Food"

- **Environmental Factors** (~35 mins)
  - Air Exchange (need CO_2 and O_2)
  - Light
  - Water
  - Temperature
  - *Nutrients (N, P, K and metals from Soil)*
  - *Insects & Animals*
  - *Disease (bacteria, virus)*

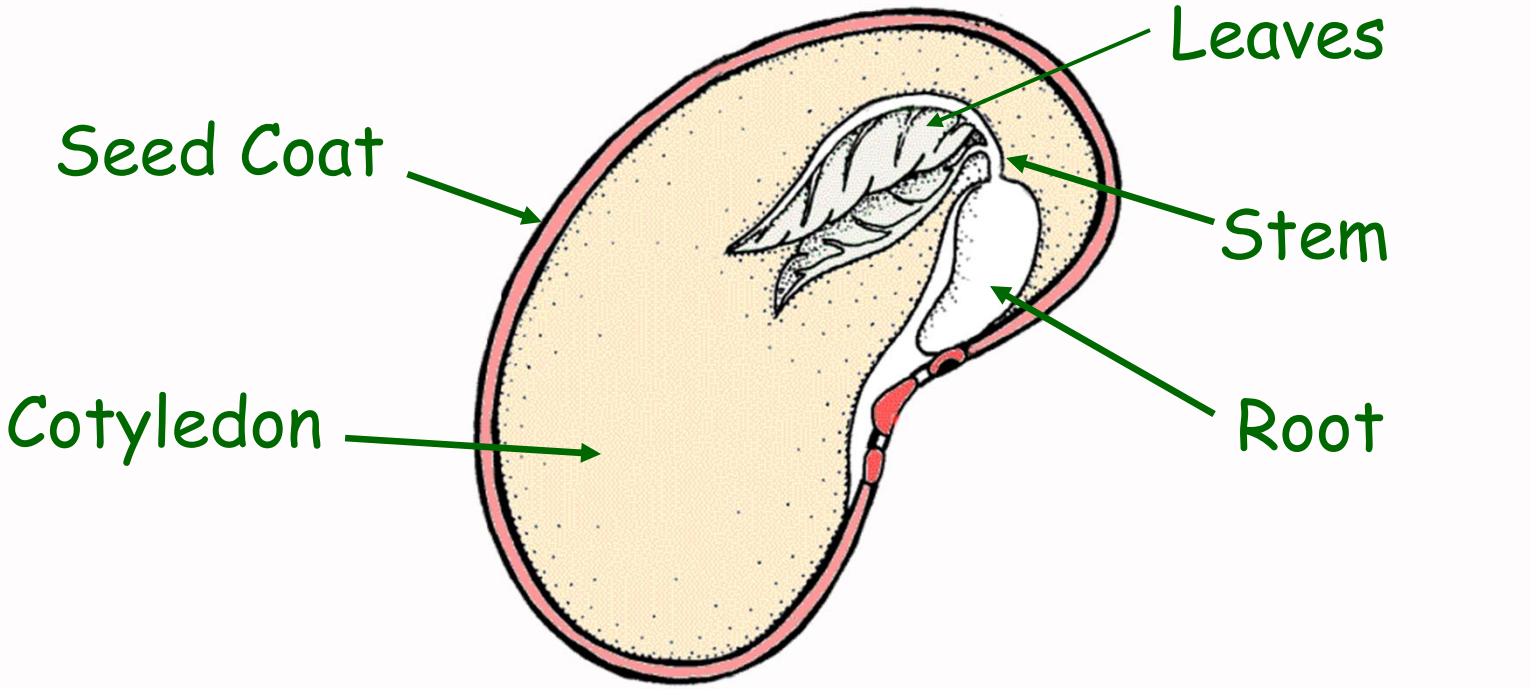
- **Regulation by Hormones** (~10 mins)
  - Signals and Responses

These factors are inter-dependent and affect a plant throughout its life…… starting with seeds.


Basic Photosynthesis
LIGHT ENERGY
oxygen
Energy + 6H2O + 6CO2 → C6H12O6 + 6O2
Sugar
carbon dioxide
water

Respiration

Plant Embryo



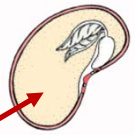
cotyledon = stored up food = *(starches, fats, proteins…)* for the embryonic plant

1 cotyledon = monocot, 2 cotyledons = dicot

Respiration

A peanut plant starts off life with ~6 calories

Respiration



seed's Food (cotyledons)

+ O_2

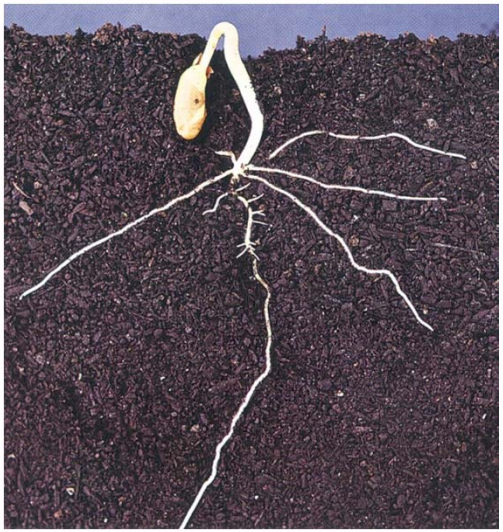
Embryo uses the stored food to grow all this!

Embryonic plant uses the starches/fats/proteins (FOOD) stored in the cotyledons.

"Uses" = "Burns" = Respiration

This seedling is growing the same way we do.
No photosynthesis is taking place here.

Plants Respire 24/7 - just like us



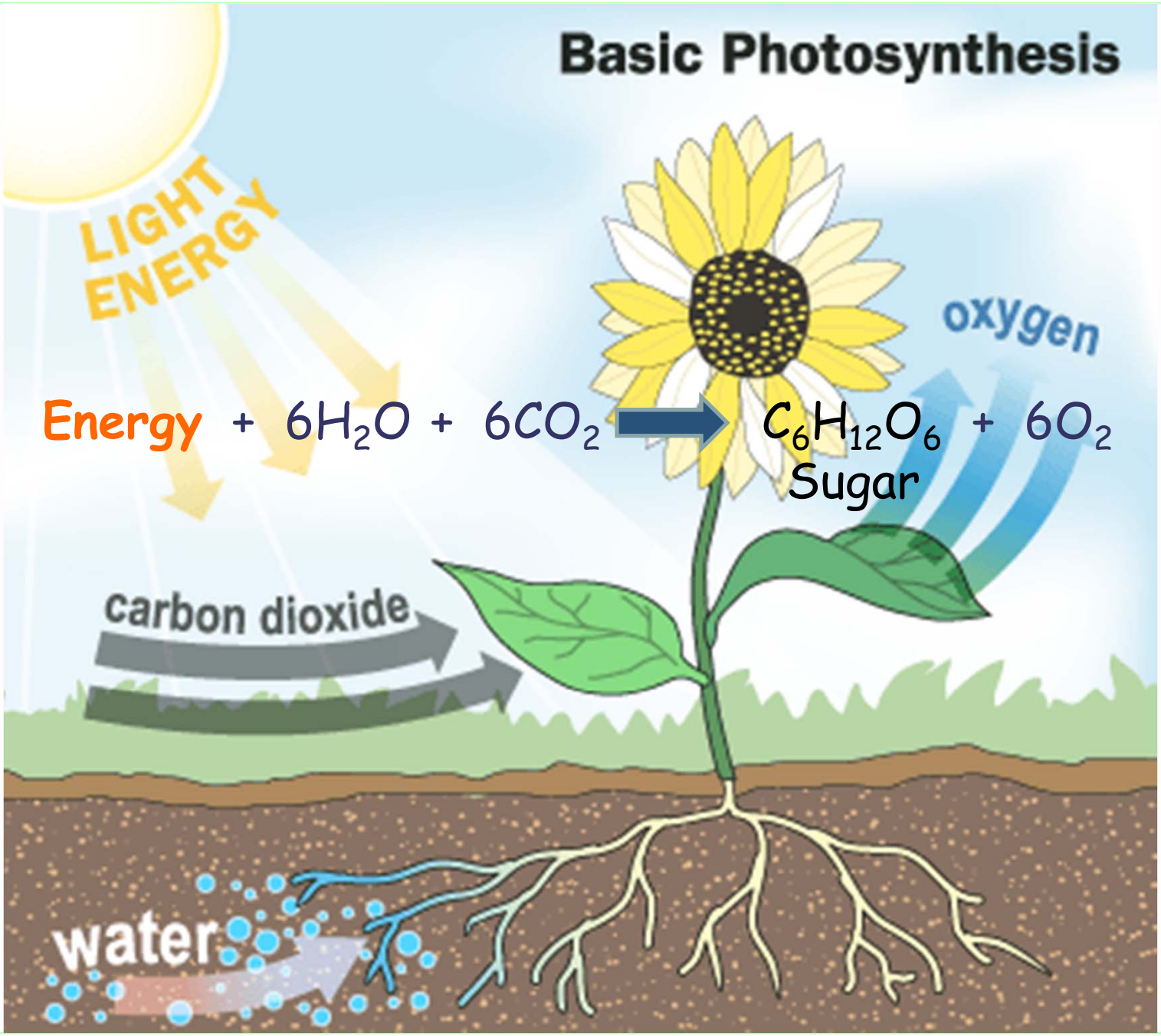
Plants & Animals Respire: (a "controlled burn")

Food + Oxygen → ENERGY + CO_2 + Water

(FUEL + Oxygen → ENERGY + CO_2 + water)

Burning gas in your car is the same thing!

Plants MAKE their food in the first place, by photosynthesis


Basic Photosynthesis
LIGHT ENERGY
oxygen
Energy + 6H2O + 6CO2 → C6H12O6 + 6O2
Sugar
carbon dioxide
water

Photosynthesis and Respiration - Compared

Plants = make food by photosynthesis - #1
AND burn (respire) that food - #2

$6CO_2 + 6H_2O + ENERGY \rightarrow C_6H_{12}O_6 + 6O_2$ **#1**

(sunlight) *(glucose = stored up energy)*

$C_6H_{12}O_6 + 6O_2 \rightarrow ENERGY + 6CO_2 + 6H_2O$ **#2**

(glucose)

(for the plant or for us)

Animals can only do #2.
Our food ultimately comes from photosynthesis.

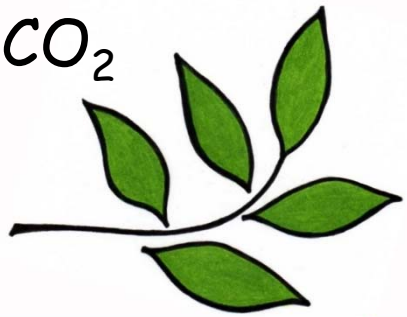
Photosynthesis and Respiration - Compared

Photosynthesis

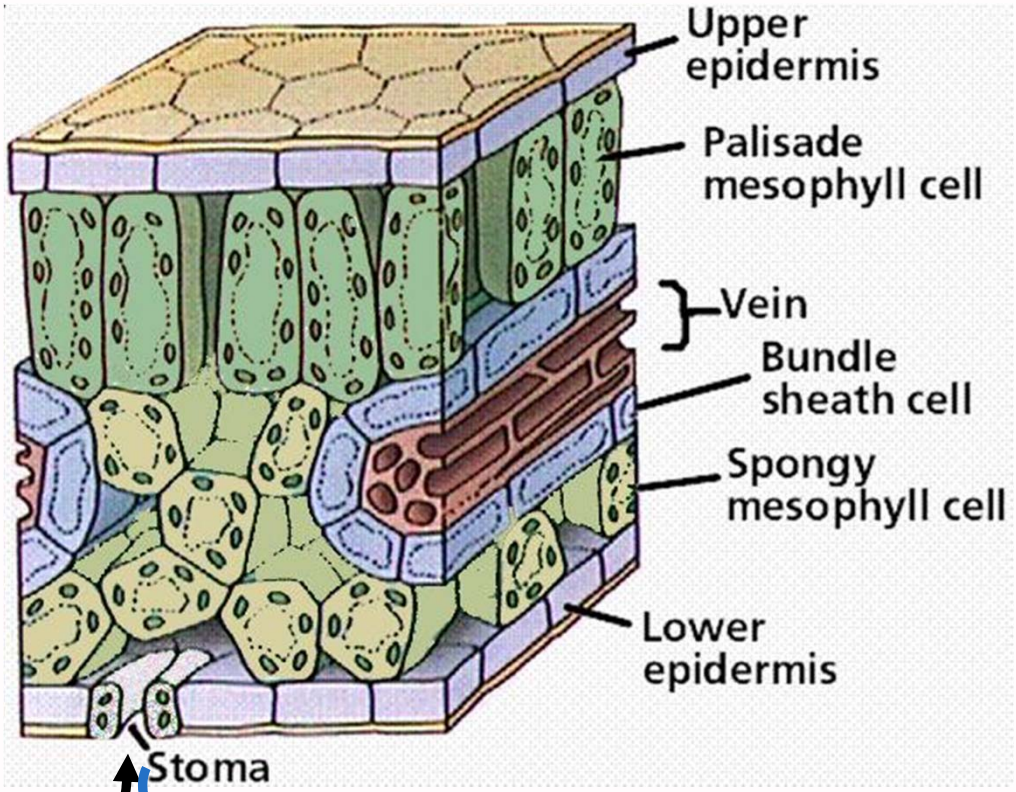
- Plants
- Uses light (energy)
- Water and carbon dioxide are consumed
- Sugars (food) and oxygen are produced
- Uses the energy of light to produce food/fuel from CO_2 and H_2O

Respiration

- Plants and animals
- Yields energy
- Water and carbon dioxide are produced
- Sugars (food) and oxygen are consumed
- Food/fuel is "burned" releasing energy, water and CO_2 -- *same as burning gas in your car or wood in your fireplace*

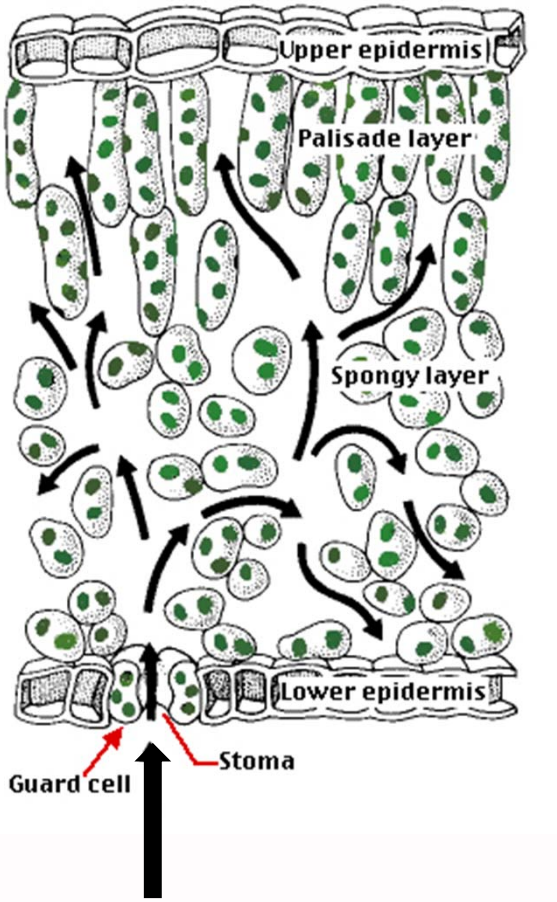


Photosynthesis



H_2O and O_2

CO_2

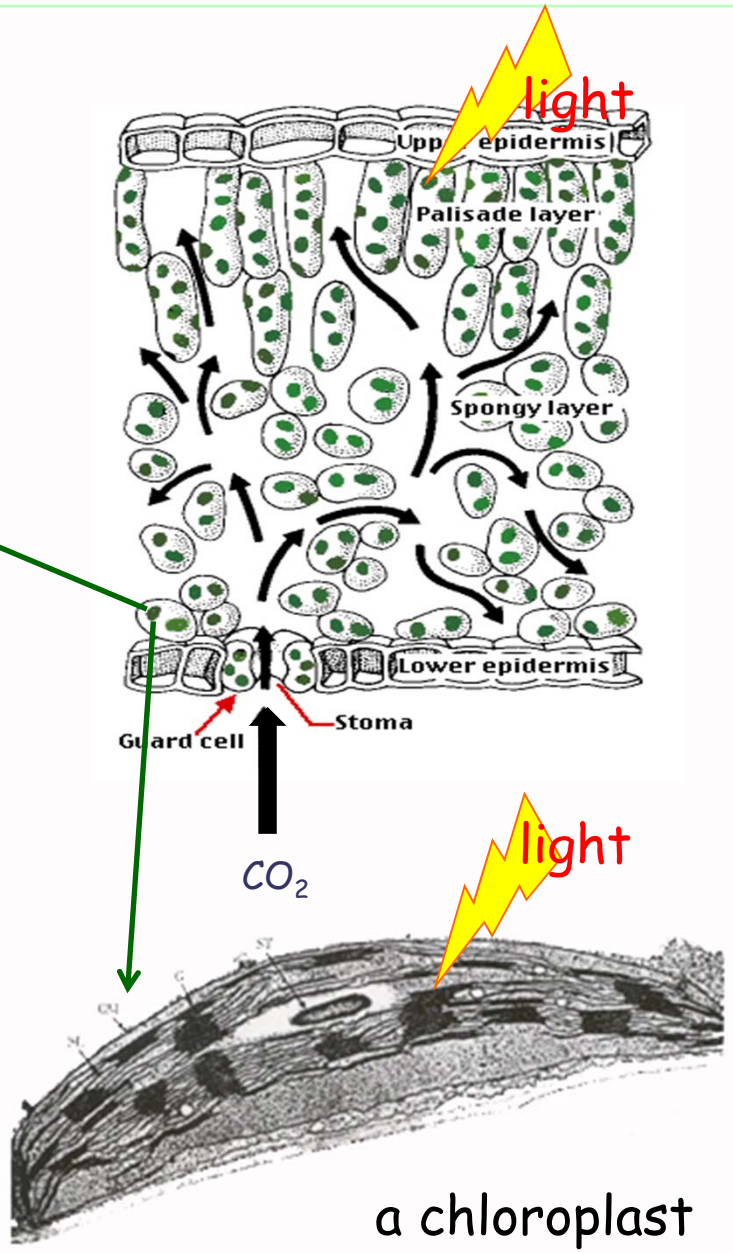


CO_2

Photosynthesis

- Chloroplasts - small bodies inside cells
- Chloroplasts - contain chlorophyll. Chlorophyll captures the energy of sunlight.
- Photosynthesis takes place in chloroplasts

$$6CO_2 + 6H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6O_2$$



a chloroplast

Plant Growth and Development

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Transpiration

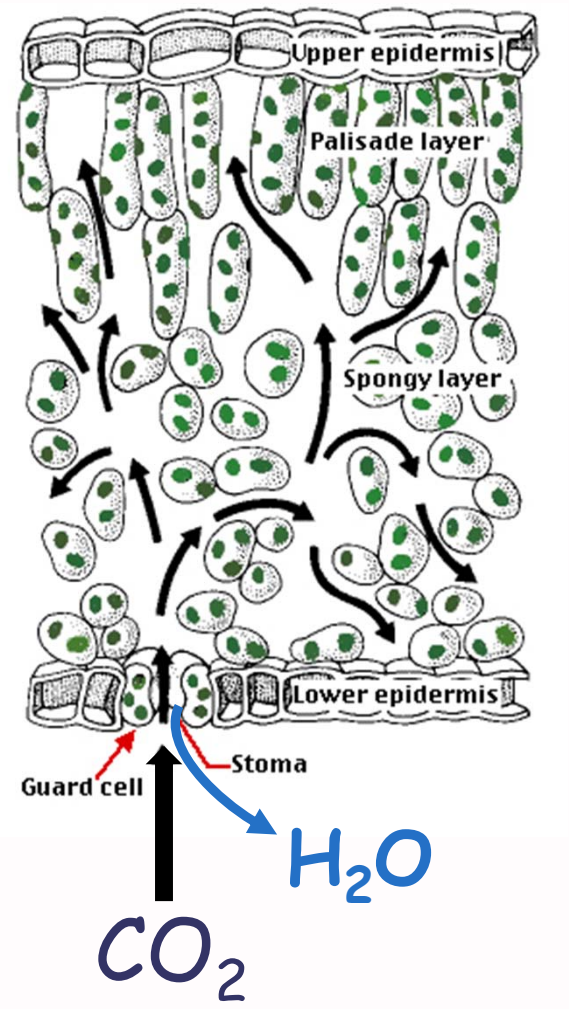
$$6CO_2 + 6H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$$

During the daytime, plants need to keep their stomata OPEN to let in CO_2 for photosynthesis.

A consequence:

Water evaporates at open stomata

TRANSPIRATION =
process of evaporation of water from plants



CO_2 is ~0.04% of the air -
a limiting resource for photosynthesis

Transpiration

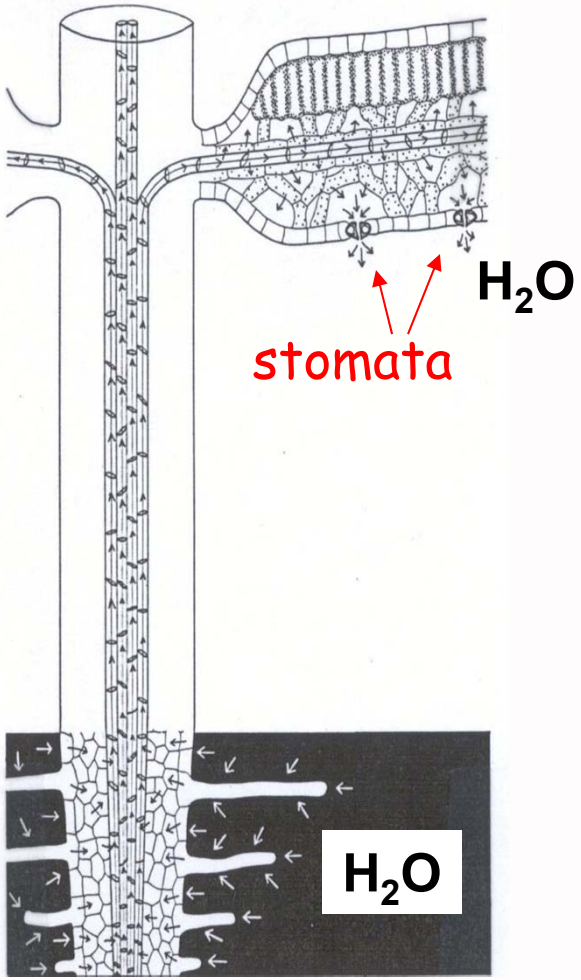
Transpiration =

Process of evaporation of water from plants. (chiefly through their stomata)

Physical Forces

1. *Water rises naturally by capillary action*
2. *Evaporation at the stomata exerts an additional "pull"*

Together these provide a *column, or "chain" of water molecules* from roots to xylem to leaves to stoma.



Transpiration

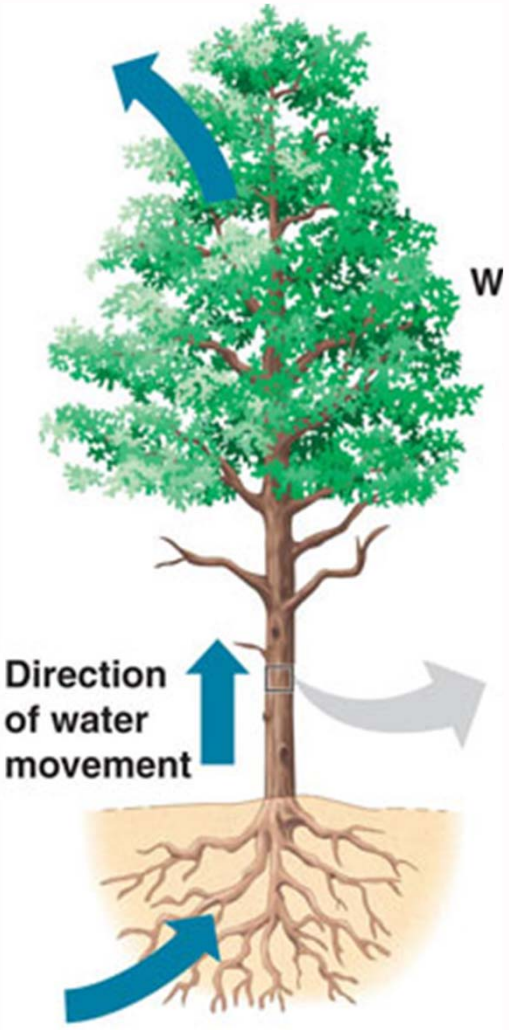
Water movement

- Is passive
- Overcomes gravity to rise hundreds of feet in the air

From around the internet:

- *Mature tree can transpire 50-200 gallons of water a day through its leaves.*
- *A large oak tree can transpire 40,000 gallons of water in a year.*
- *An acre of corn transpires 3,000 to 4,000 gallons of water a day.*

All that water goes out those tiny stoma…

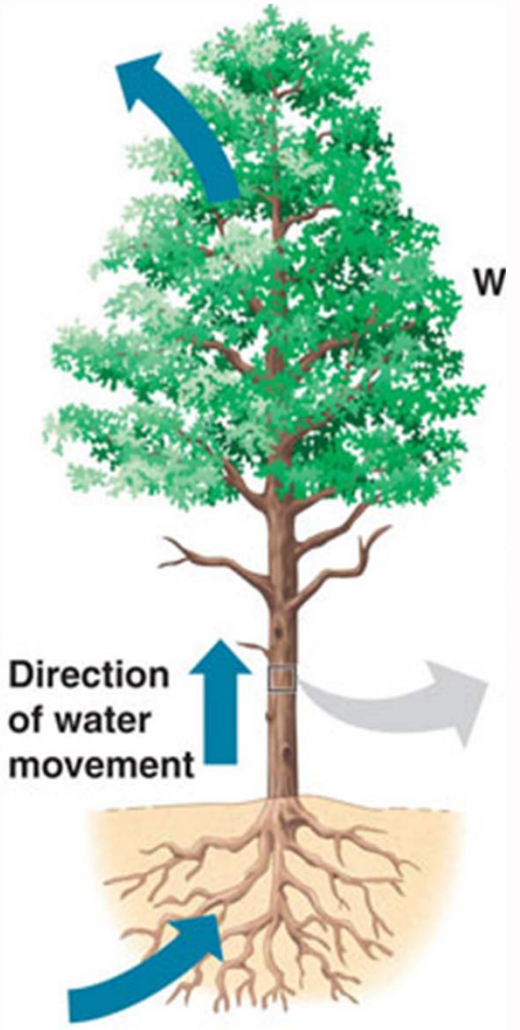


Transpiration

A leaf can have millions of stomata –
usually more on undersides

Number of stomata per square inch of leaf surface

Plant	Upper Epidermis	Lower Epidermis
Apple	none	250,000
Black oak	none	375,000
Bean	26,000	160,000
Pumpkin	18,000	175,000
Corn	39,000	64,000

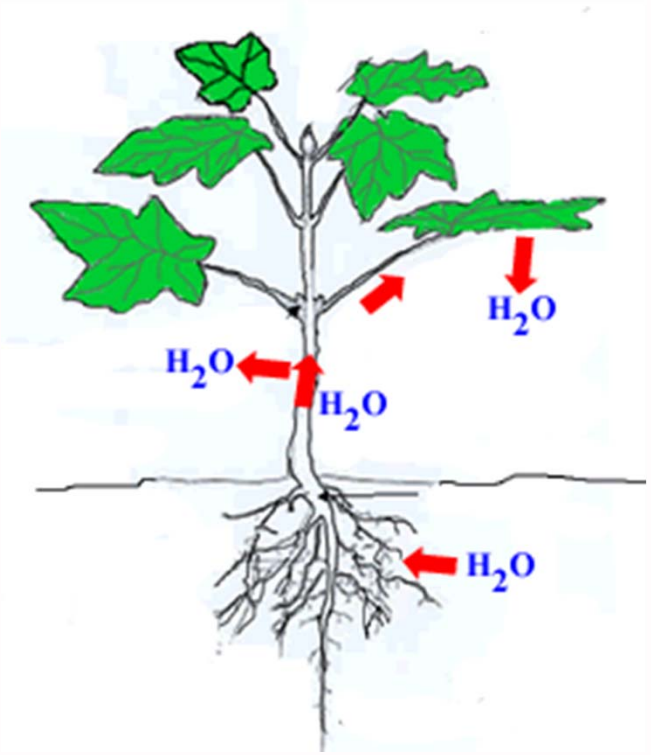


90% of the water entering
the roots is transpired.

Transpiration

The benefits:

1. Cools the plant (important!)
2. Keeps cells hydrated
3. Bring up N, P, K etc. from the soil
4. Supplies the water needed for photosynthesis

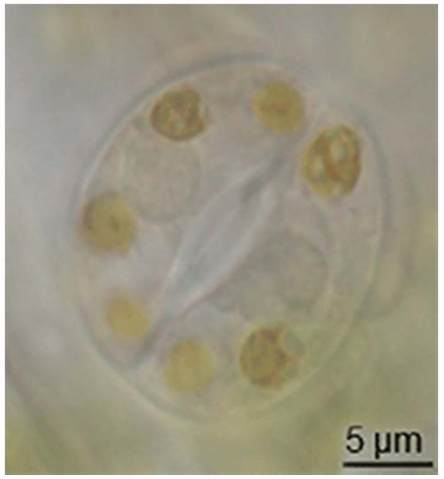


only 1-2% of the total water used goes here

$$6CO_2 + 6H_2O + light = C_6H_{12}O_6 + 6O_2$$

Transpiration

Opening and closing of stomata is regulated primarily by light and water loss.



Hot or windy days, stomata close down to conserve water.

But this means little/no CO_2 is available -

Photosynthesis reduced or stopped at about 86° F

(varies from plant to plant and their habitats of course)

Little photosynthesis goes on during our 100° summer days!
Drought on top of that = extremely STRESSFUL

Transpiration

Throughout the day, plants are continually opening/closing their stomata to balance their need for CO_2 and water against:

- Light
- Temperature
- Water availability in the soil
- Air Quality (humidity, wind, pollution)

Out of balance water loss can lead to a permanent wilting point.

Plant Adaptations to Water Supply

- Hydrophytes – water
- Xerophytes – desert
- Mesophytes – temperate climates

All have adaptations to water supply.

Plant Adaptations to Water Supply

Hydrophytes – water

- Stoma on leaf surface
- No waxy cuticle on leaf
- Reduced roots
- No stoma; even no xylem

Xerophytes – desert

- Extensive shallow roots
- Leaves have become spines that protect the stem
- Stoma on the stem with a hard waxy cuticle

"Winter Burn" of Evergreens

Magnolia, Azaleas & Rhododendrons (boxwood, holly, arborvitae, hemlock)

Winter sun and wind result in elevated transpiration ---- problem during days when the ground is frozen or dry.

Plant can't bring up enough water from the ground
→ → dessication & browning (i.e., cell death)

Winter Burn - Prevention

"The right plant in the right spot"

- Proper placement -- avoid South/SW exposure!
- Make sure plants are well watered going into winter
- Water in winter dry spells

- *Anti-desiccant sprays may help. Pros and cons…..*

Light *---* 1. *Photosynthesis*
2. *Signals for Growth & Development*

Photosynthesis:

Light is the energy stored in Food:

$$6CO_2 + 6H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$$

Light Provides Signals for Growth and Development:

Examples: *When is it time to flower? How does a plant know when fall is coming? Some seeds need light to germinate. How does that seed know whether it's in the light or in the dark?*

Light's Effects on Photosynthesis

Do I really need (those expensive) 'GroLux' Lights?

Standard "white"

reddish 'GroLux'

First Response… "What are you trying to grow?"
Next Response… "Where are you growing that?"

Actually…… simple answer….. mostly no…….

Plants will live under incandescent light.

This is very weak light - not ideal. (Compact fluorescent is no stronger, but way cheaper.)

Most of our common indoor plants grow in nature in low light conditions ---
i.e., are from the forest floor (often from the tropics)

Light's Effects on Photosynthesis

Do I really need (those expensive) "GroLux" Lights?

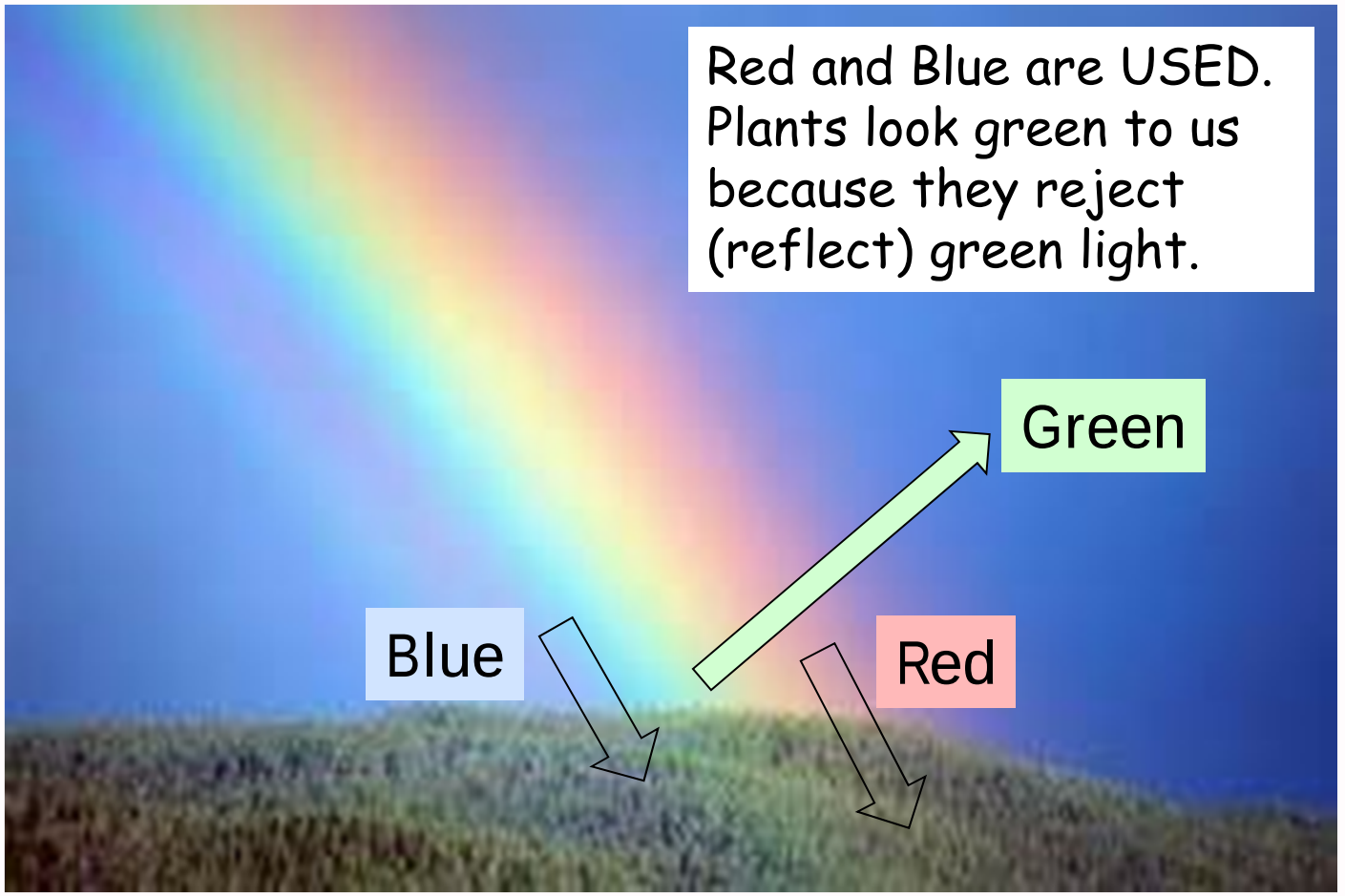
What **kind of light** is good for photosynthesis?

Standard "white"

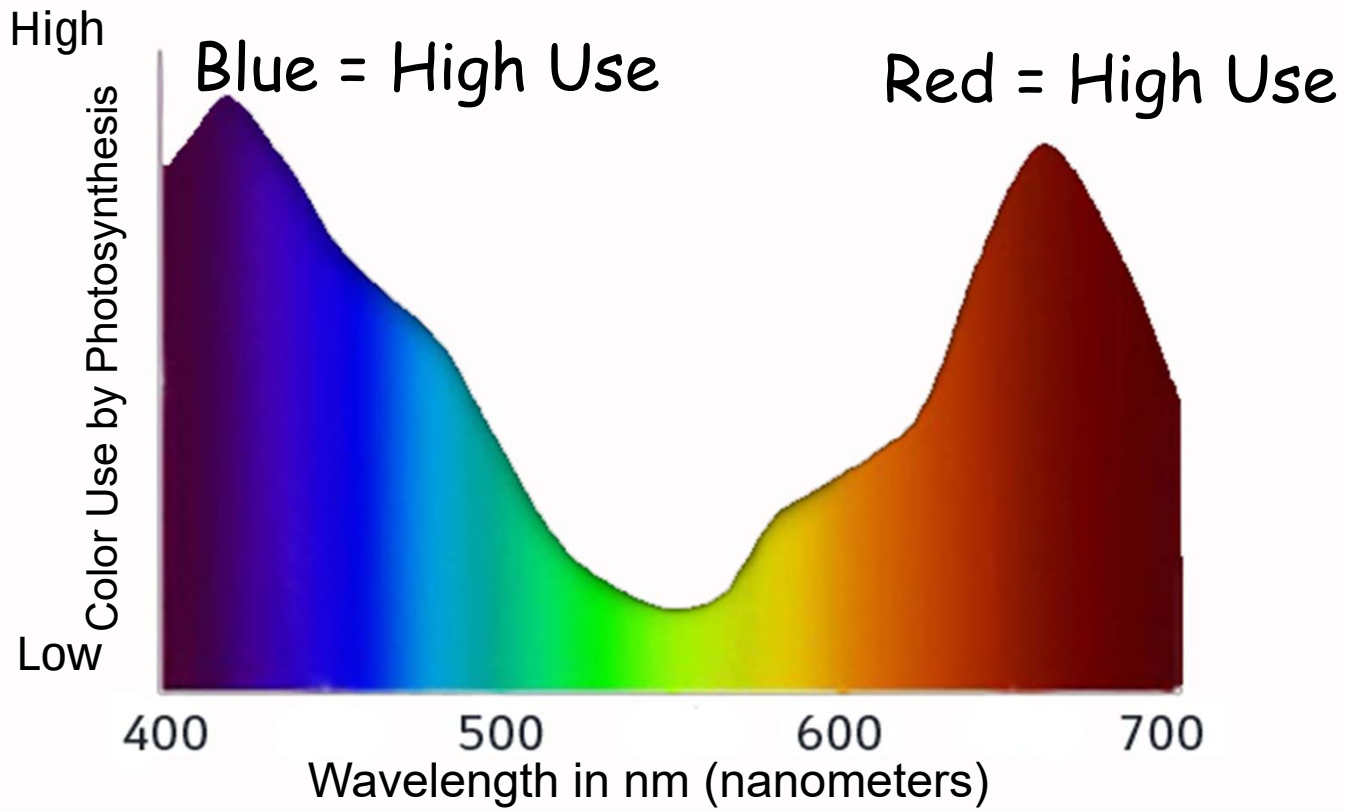
reddish 'GroLux'

Light's Effects on Photosynthesis

What Color of Light is Good for Photosynthesis?



Light's Effects on Photosynthesis



Chlorophyll strongly absorbs both blue and red.

Light's Effects on Photosynthesis

"Cool White" has more blue than red but has both.

"GroLux" & similar are red enhanced, but still has both.

In other words, both bulbs have a mix of colors. Both bulbs are good for photosynthesis. Often, the more important factor for healthy plant growth is →

(where did we start?)

Light's Effects on Photosynthesis

Light Intensity ---

- how many bulbs?
- how many hours a day on?
- how close are the plants to the bulbs?
- any light from a nearby window?

Seeds Anyone?

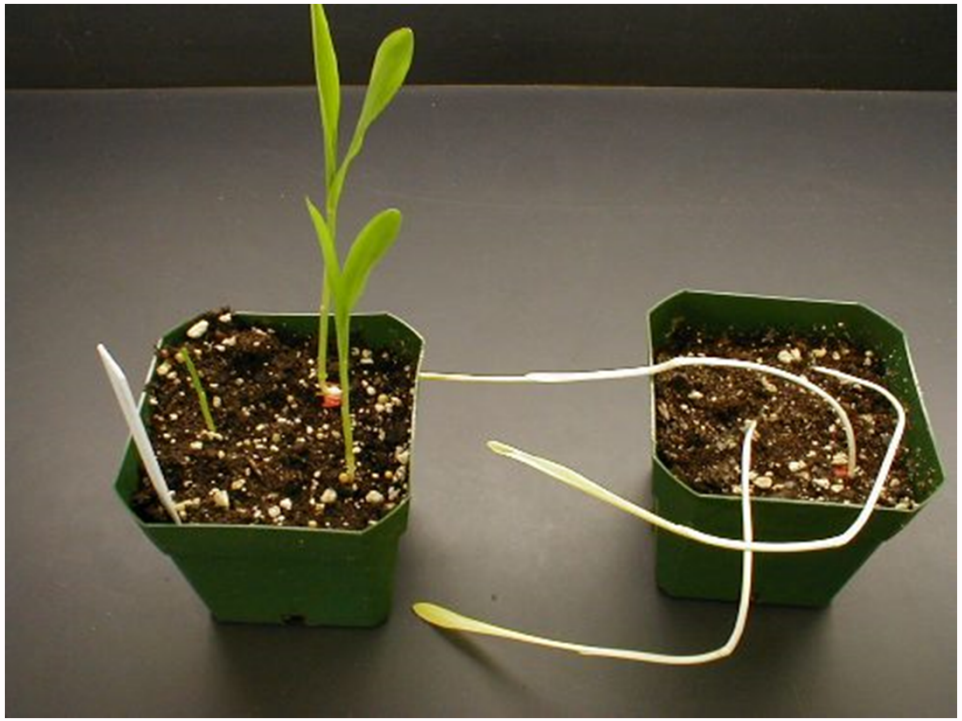
Light's Effects on Photosynthesis

4 fluorescent lights

Lights probably on 14+ hrs a day

Starting seeds is an example of where plain old "white" fluorescent bulbs really is fine.

Light's Effects – Photosynthesis & Growth and Regulation



Normal growth

Etiolated growth

Right:
Seedling had no light, leading to (extremely) weak spindly growth.

"Etiolated"

Light's Effects – Photosynthesis & Growth and Regulation

Another example of a plant that is in the wrong place.

Etiolated growth on a mature plant -

Bending stems and long internode distances as plant reaches for more light.

An example of a growth and regulation effect.

Light's Effects – Photosynthesis & Growth and Regulation

Do NOT need ALL "GroLux" bulbs to have flowers indoors. MANY choices of bulbs today – too many !?!?
(Personal experience: 1 'grolux' bulb per 3 standard white)

Flowering……. Plants using light to direct growth and regulation →

Light's Effects on Growth & Regulation

Poinsettia – Mexico, Central & South America

*Photoperiodism**

Poinsettias need min ~6 weeks of ~14 hours of **uninterrupted** darkness per day (i.e., need a long night) in order to trigger flowering.

Poinsettia – "short-day"

Commercial growers of our holiday poinsettias may need blackout curtains in their greenhouses to protect from streetlights and full moons!

**term for flowering in response to the daily lengths of light versus darkness*

Photoperiodism

- Occurs **in some plants**
- Recognized 1920's & thought then to be a function of the length of daylight, hence the terms:
  - Long-day (Short-night)
  - Short-day (Long-night)

"short-day"

Later it was shown that these plants measure the length of the nights (length of darkness).

Photoperiodism

Christmas Cactus Success:

- Put by a bright window in an unused room in the fall (no light at night for 13 hrs min).
- Needs ~4 weeks of "long nights" but don't expect all cultivars to be the same.

Christmas Cactus = "short-day"

Photoperiodism

Most Plants are "Day Neutral"

(means they don't care about hours of dark versus light)

major food crops: wheat, rice, corn – also roses, tomatoes and most vegetables

Chrysanthemum – Short Day

Long Day Plants – hollyhocks, clover, spinach, iris, black-eyed Susans *Campanula* (bellflowers), *Dianthus* (carnation)

Strawberries – highly bred plants: can choose long-day, short-day or "everbearing" (day neutral)

Plants respond to light!

Is it surprising that plants need to know what time of day it is or what day of the year it is?

They even use different colors to sense and trigger different events.

Main light sensors are called

phytochromes *(phyto = Greek for plant)*

Some sense red light and some sense/use blue light – together they direct (govern) most aspects of plant growth.

Plant Phytochromes: more examples

- Initiate Bud Dormancy – largely a response to shortening days
- End Bud Dormancy – lengthening days of spring, (also to rising temps)
- End Seed Dormancy germination triggered by lengthening days for some seeds

Shortening Days = Time to shut down Results in fall colors

Plants are full of phytochromes – leaves especially, also buds and sometimes even seeds.

Plant Growth and Development

- **Photosynthesis and Respiration**
  "makes food" and "uses food"

- **Environmental Factors Affecting Plant Growth**
  - Light
  - Air Exchange (need CO_2 and O_2)
  - Water
  - Temperature
  - *Soil & Nutrients*
  - *Insects & Animals*
  - *Disease*

- **Regulation of Plant Growth and Development**
  - by Plant Hormones

These factors are inter-dependent and affect the plant throughout its life…… starting with Seeds

Temperature - Vernalization

"Chilling Requirement"

Vernalization –

Requirement for a certain period of cold temperatures in order to break bud & flower

i.e., Plants measure how LONG it's been cold – hours below 40-50° F.

Red Bud

True for many trees, shrubs, perennials in the temperate zones. In winter, both day length and temp can be measured. Such plant is doubly protected against premature growth during midwinter warm spells.

"Forcing" Spring Flowers –

Vernalization (Chilling requirement) must be met first!

Rough Guidelines for when to cut:
FYI – not on quiz

Late Dec - Witch Hazel, Willow
Late Jan - Cornelian Cherry
Early Feb - Forsythia, Redbud, Flowering Quince
March - Flowering Cherry, Apple, Lilac, Dogwood

Chilling requirements vary with species & cultivars - e.g., huge variation for apple (some apples over 1,700 hrs!)
Times for blooms to open indoor vary 2-4 weeks.

Bulbs can be put in a refrigerator to meet the chilling requirement.

.

*Photoperiodism **or** Cool Nighttime Temps*

Christmas Cactus Success:

- Put by a bright window in an unused room in the fall (no light at night for 13 hrs min).

- Or put on an unheated sun porch. 55-60 nights induce flowering on Christmas Cactus regardless of day length.

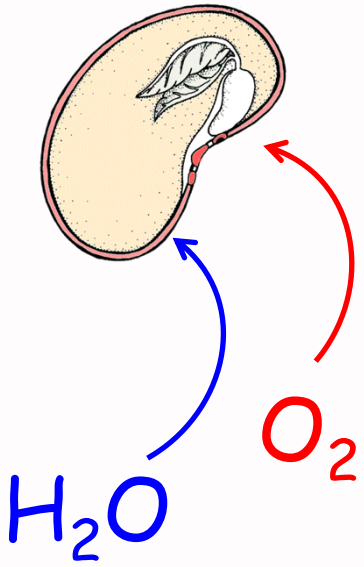
Christmas Cactus = "short-day" OR "cool nights"

- *Phaelenopsis Orchids – Also flower in response to cool nights. Put them outside around Sept 1 for a month. Will initiate a bloom spike in Nov/Dec.*

Seeds – Microcosm of Plant Growth Regulation

Packaged with strategies to delay Germination

- stratification
  (required minimum time at cold temps)
- light
  (phytochromes in seed coat - many small seeds)
- scarification (mechanical)
  (freeze/thaw, bacteria, birds stomach acid, fire)
- chemical inhibition (hormone)
  (abscisic acid – growth inhibitor – in seed coat needs to be leeched away by snow/rain)

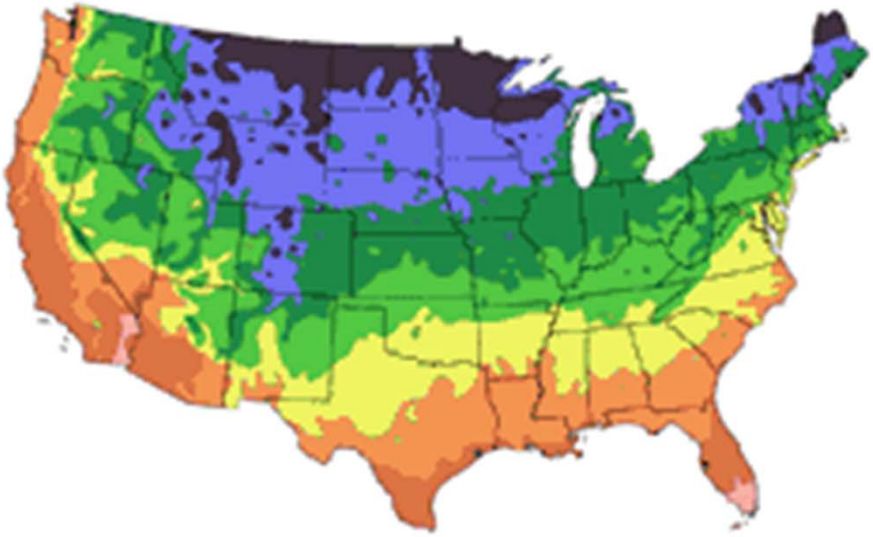


Germination begins with uptake of water and oxygen

Plant cold hardiness zones

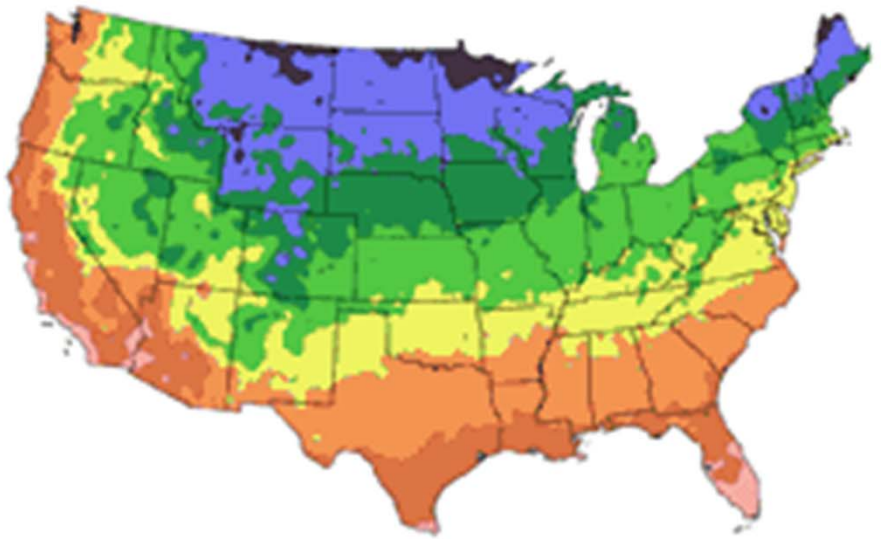
1990 most of Missouri was in zone 5. Now 6

1990 Map



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

2006 Map

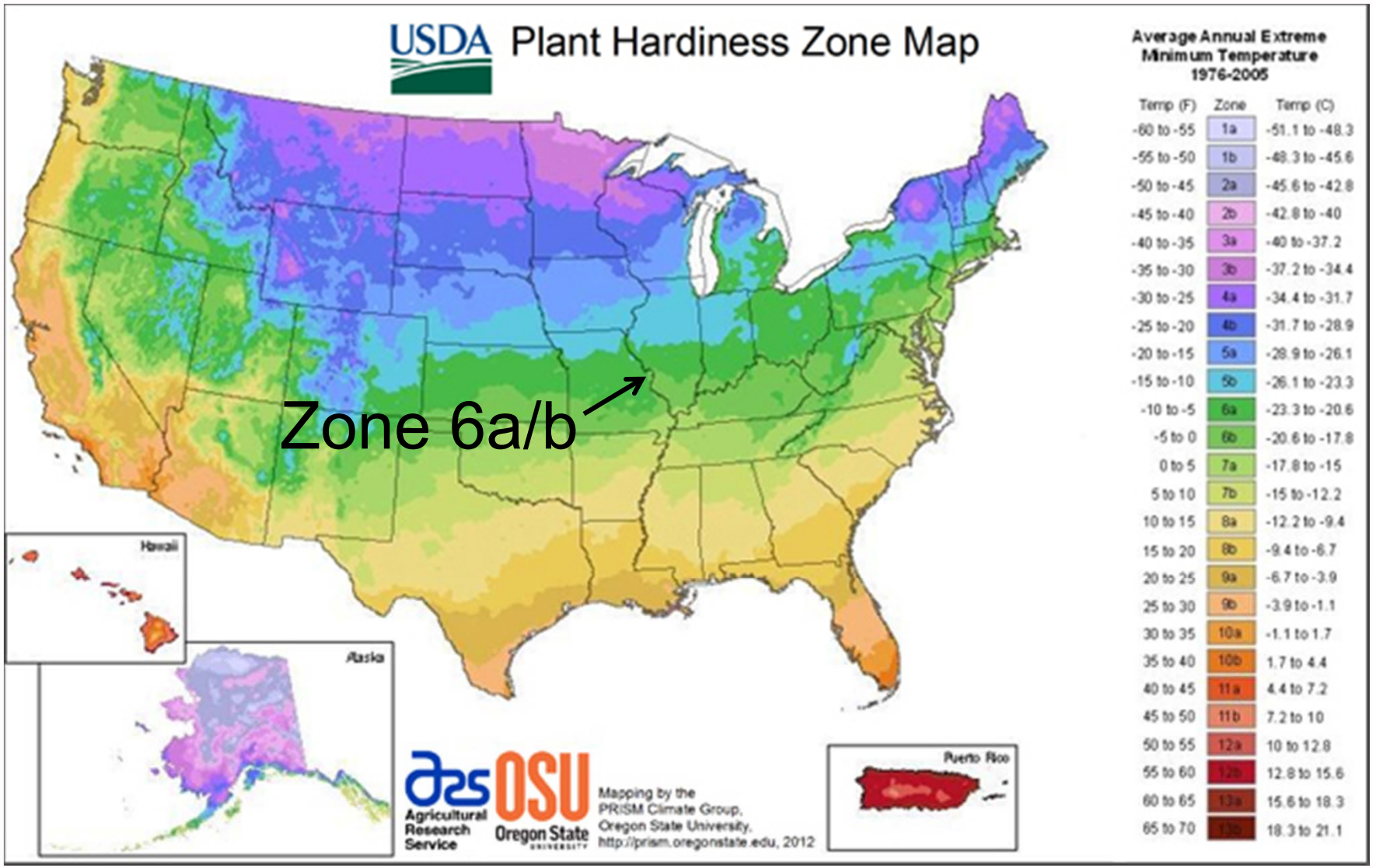


National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

Zone

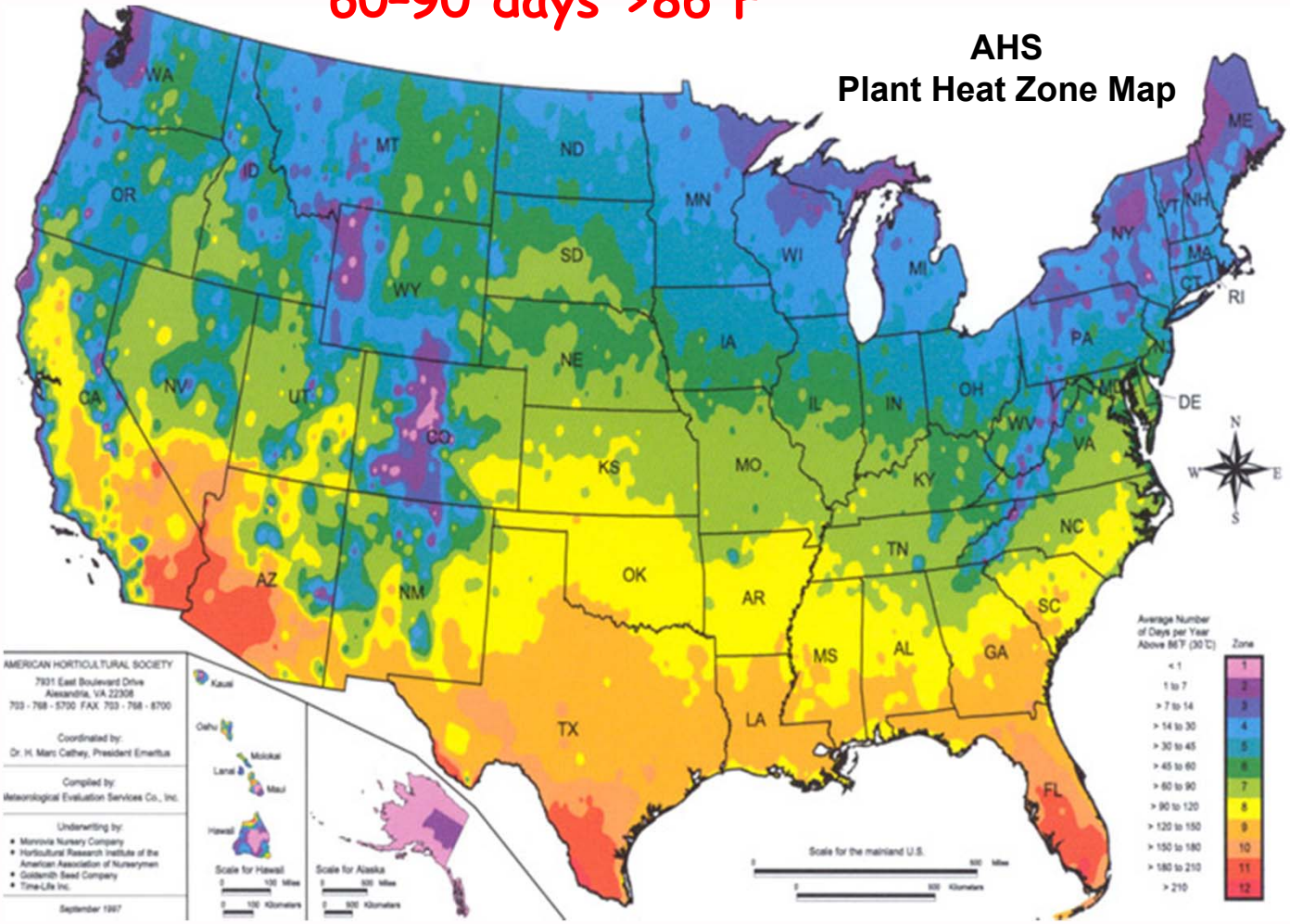
2 3 4 5 6 7 8 9 10

2012 USDA - zones by 5 degrees (1976-2005 data)



1997 American Horticultural Society
Zones by days over 86 F (1974-1995 data)

Missouri = Heat Zone 7
60–90 days >86 F



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⇨ - **Regulation by Hormones** (~10 mins)
  - Signals and Responses

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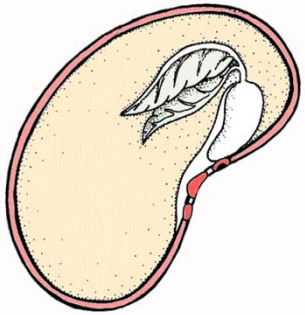
Plant Hormones

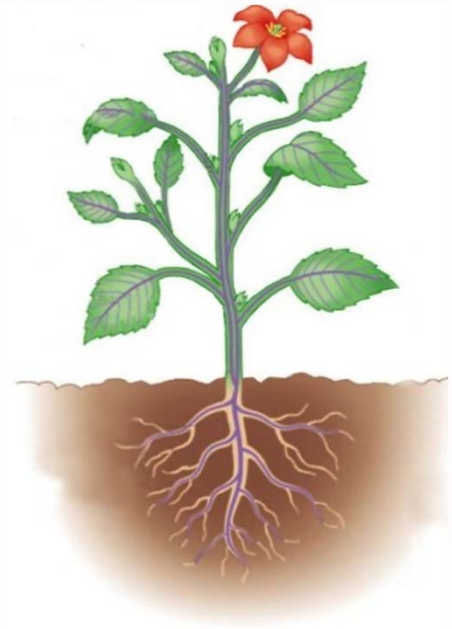
Hormones (or growth regulators)

- Produced in small amounts and translocated to other areas where they affect growth and development
- Five prominent hormones
  - Auxins
  - Gibberellins
  - Cytokinins
  - Ethylene
  - Abscisic Acid

Think like paint: red + blue = purple

Auxin – found in almost every plant tissue





development of the plant embryo
leaf formation
cell enlargement
apical dominance***
root initiation and development
phototropism
gravitropism
fruit development
abscission (leaf drop, fruit drop)

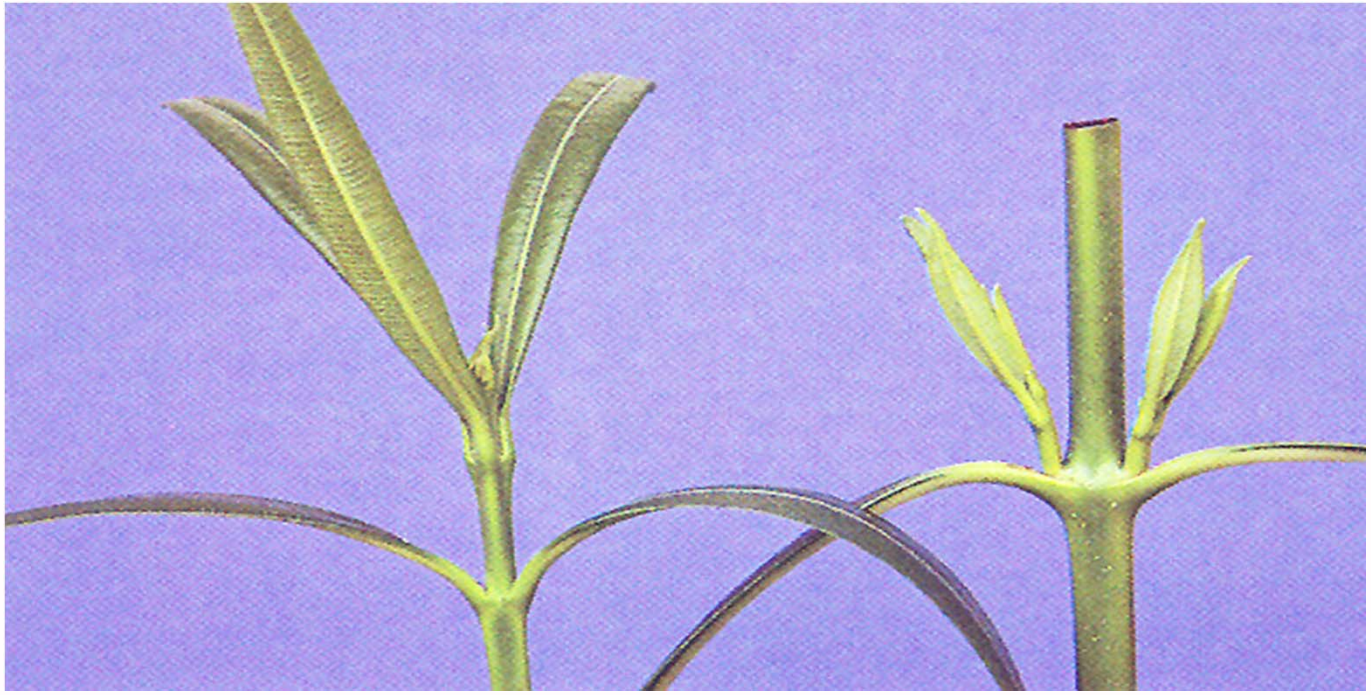
…….and more…..

***Potential Quiz Material other slides FYI

Auxin – Apical Dominance: Growth Suppressor

Auxin produced in apical meristem -- moves down the stem and **suppresses** bud development.

When you "pinch back", the auxin concentration drops and buds begin to grow!



"Pinching Back" for bushiness

Auxin – Apical Dominance: Growth Suppressor

Coleus plant -- notice the gradation of bud development - increasing with increasing distance from the apical meristem.

Auxin is a growth suppressor on upper buds.

Auxin – Uncontrolled Growth Stimulator !!!
Toxic

In higher concentrations auxin causes rapid, distorted growth and disables other functions…..

…….leading to DEATH

Dicots are much more susceptible than monocots, hence auxin's use to kill broadleaf weeds in lawns.

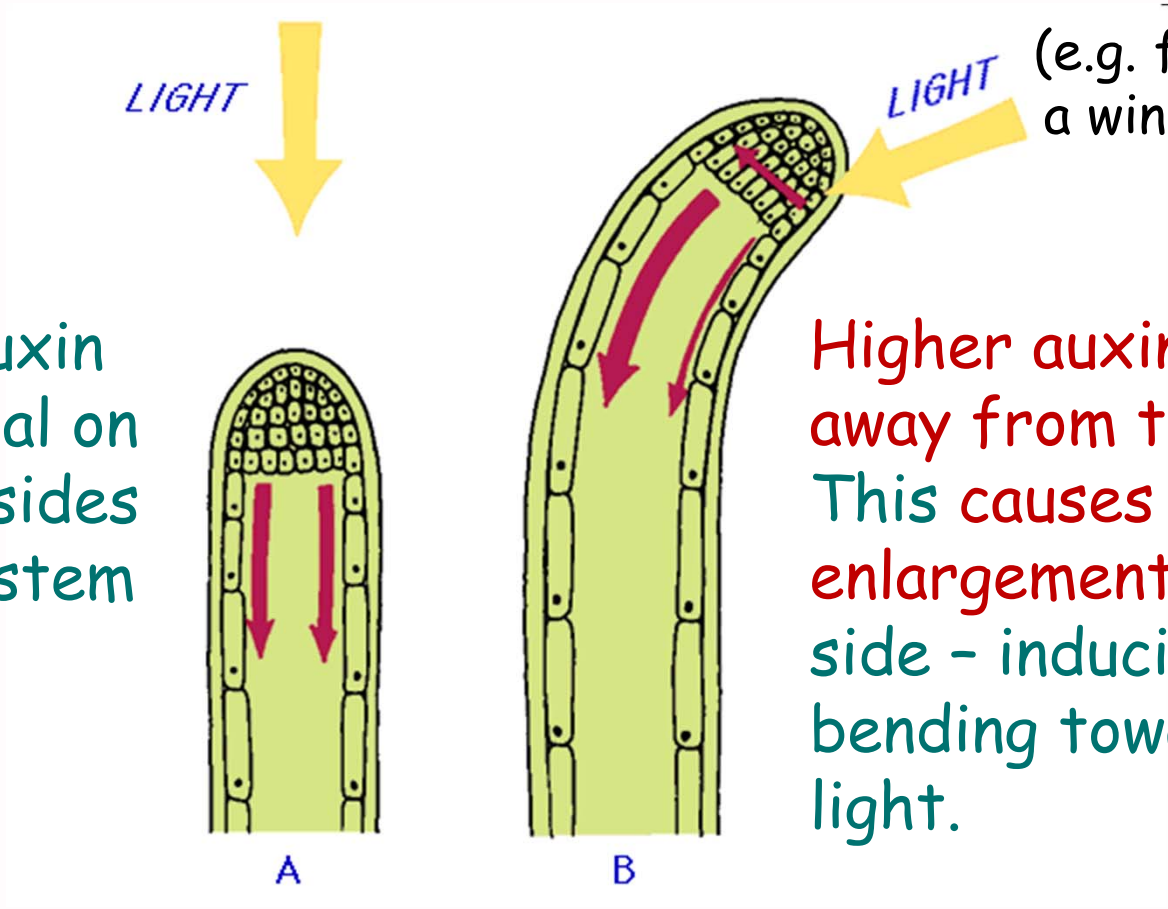
(FYI: A derivative of auxin "2,4-D" is the common "weed" in "weed and feed." Natural auxin is expensive and not very stable.)

Auxin – Rooting Hormone

Applied to stems and leaves
at low concentrations,
auxin promotes roots.

(Natural auxin is expensive and not very stable, so here again synthetic derivatives of auxin are used.)

*Auxin – Phototropism****



***bending toward the light. Tropism = Greek for bending

Auxin - Phototropism

etiolated growth

Auxin responsible for:

- bending via cell enlargement on the darker side.
- cell enlargement between the nodes…. i.e., the large internode distances

Auxin - Geotropism

Stems and roots both respond to gravity, but oppositely.

Coleus lain on its side.

Stems bend upward away from gravity.

In horizontal stems, auxin accumulates on the "bottom" side of the stem (ground side).

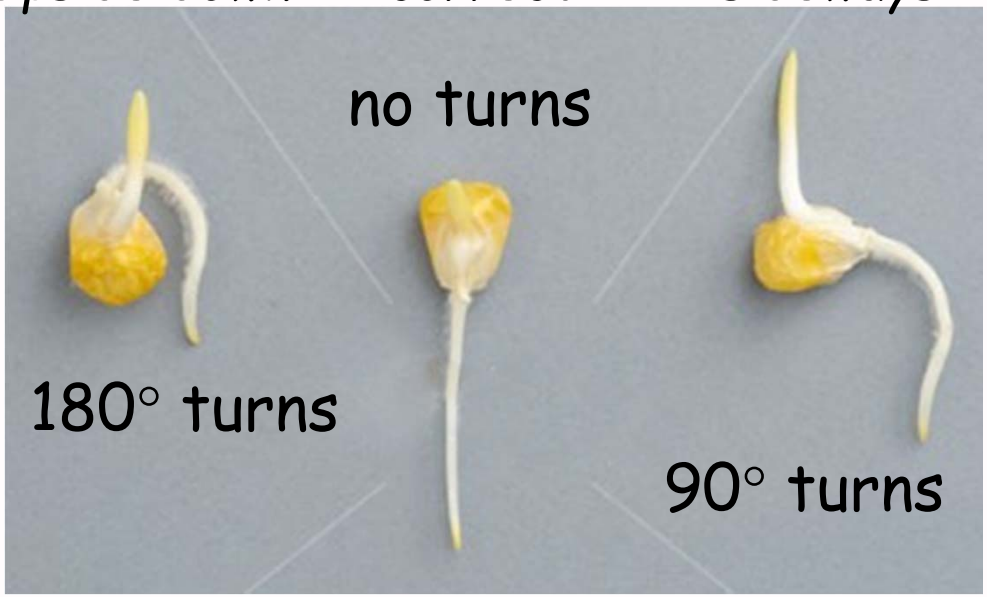
Causes stem to grow on that side and bend up and away from gravitational pull.

Auxin - Geotropism

Stems and roots both respond to gravity

Corn Germinated in different orientations

Upside down *correct* *sideways*



Root figures out where down is.

Stem figures out where up is

It's a good thing!

THANK YOU for your Attention !!!!!

From wikimedia commons. Sunflowers growing near Fargo, ND