WATER AND IRRIGATION

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WATER IN ARIZONA

- Although January 2023 was the 14th wettest in 129 years, Yavapai County is often in a state of drought
- Arizona's Colorado River water right has been reduced:
  - 2022-18%
  - 2023-21%
  - 2024-18%
- As populations grow, there is concern that this is placing higher demands on a limited water supply

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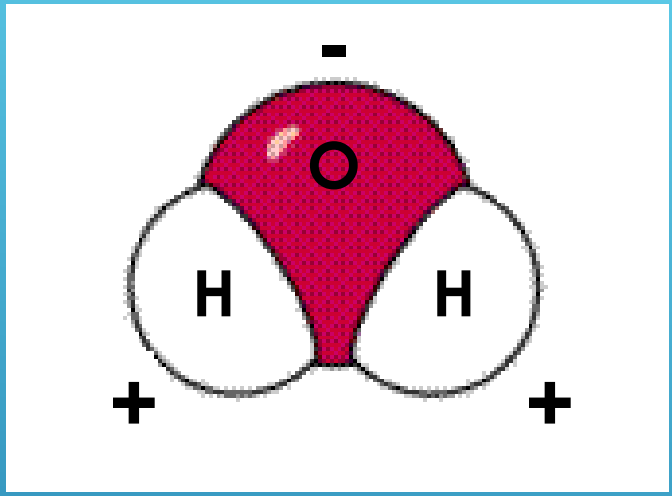
WHAT DO WE HOPE TO LEARN ABOUT WATER AND IRRIGATION?

- **How water interacts with our environment**
- **How plants utilize water**
- **How, when, and where to irrigate plants**
- **The Parts of a home/small irrigation system**

MOLECULAR STRUCTURE OF WATER



H_2O

- One oxygen atom
- Two hydrogen atoms

Not symmetrical

- Electrons spend more time near the oxygen and less near the hydrogen
- Water molecule is polar

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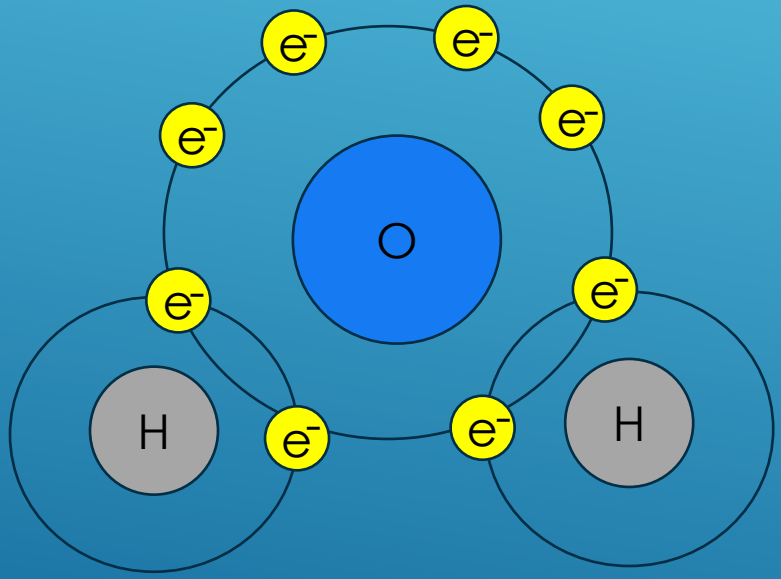
IDEALIZED BONDING



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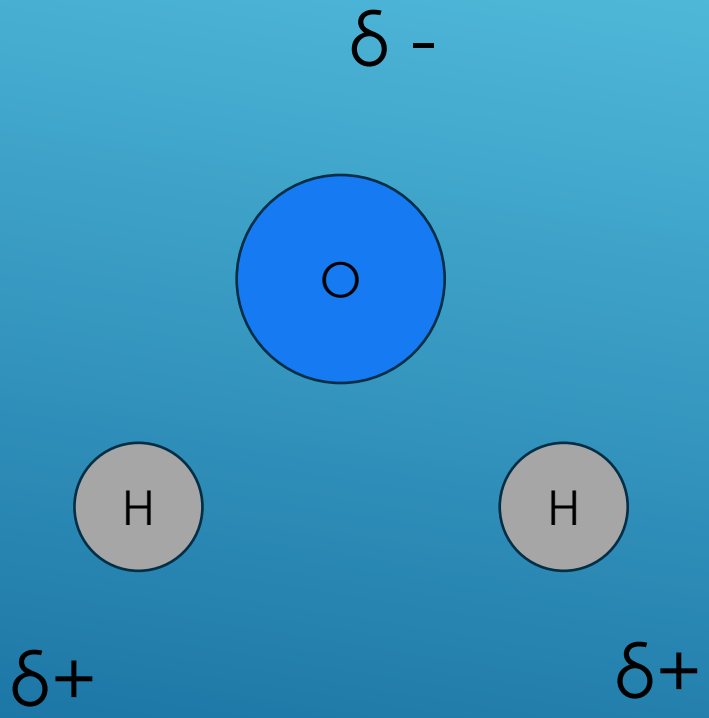
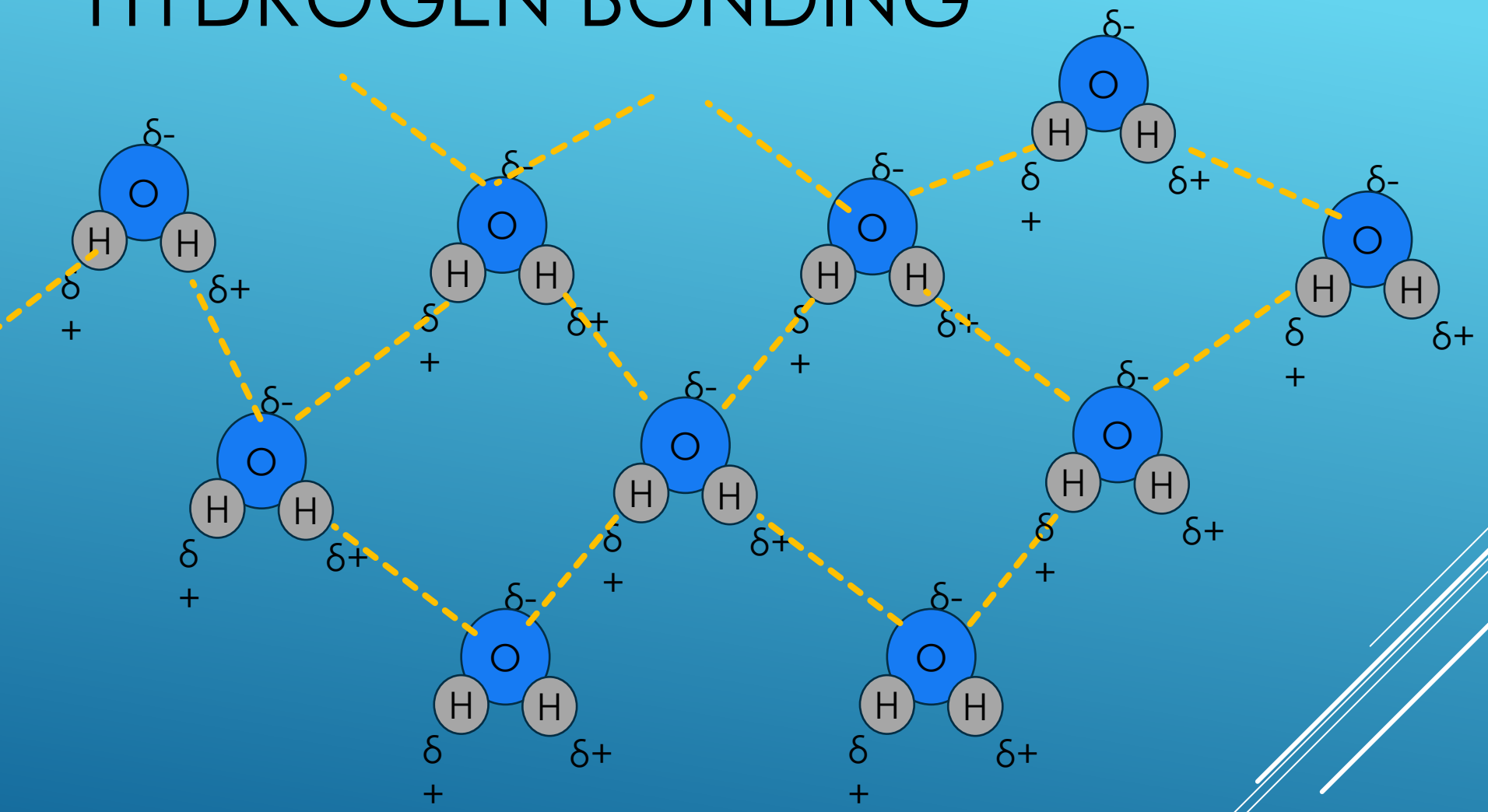
REALITY OF BONDING

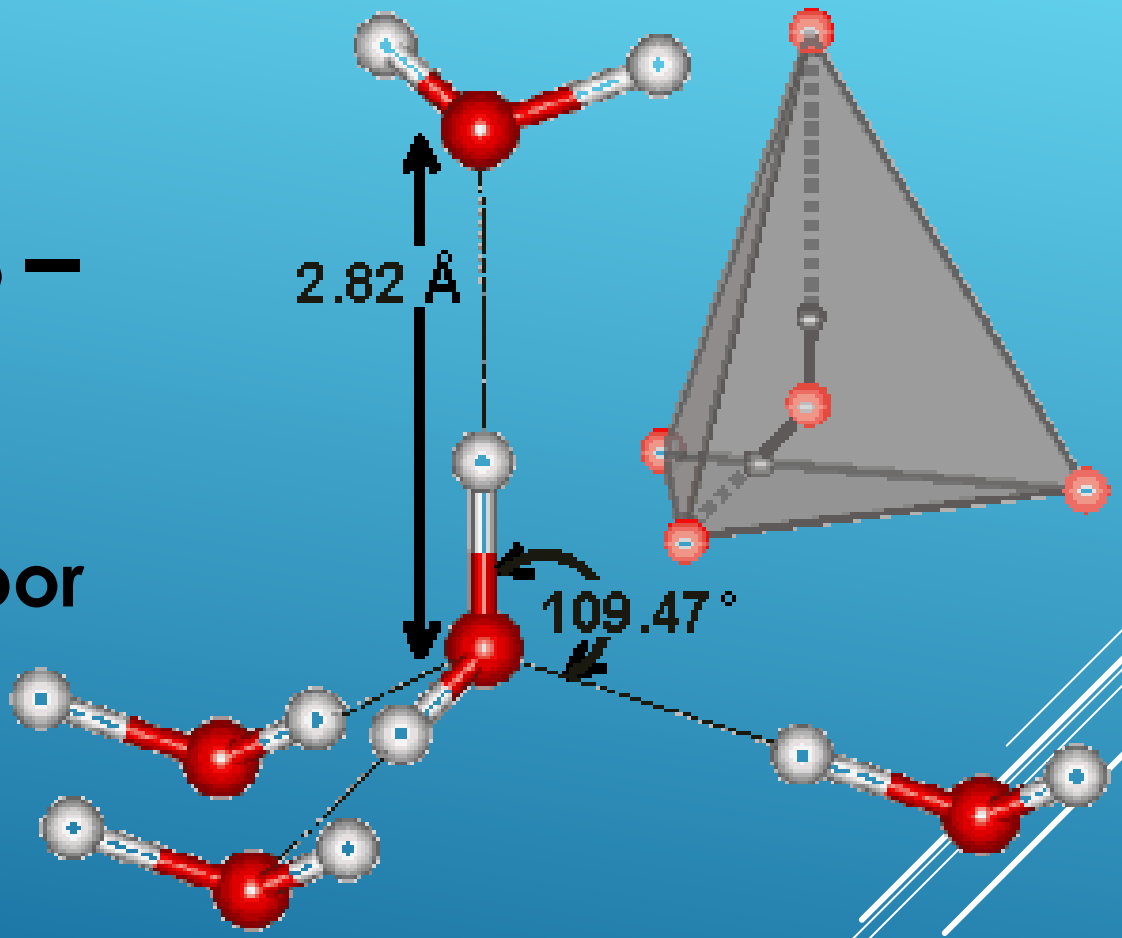


HYDROGEN BONDING



HYDROGEN BONDING

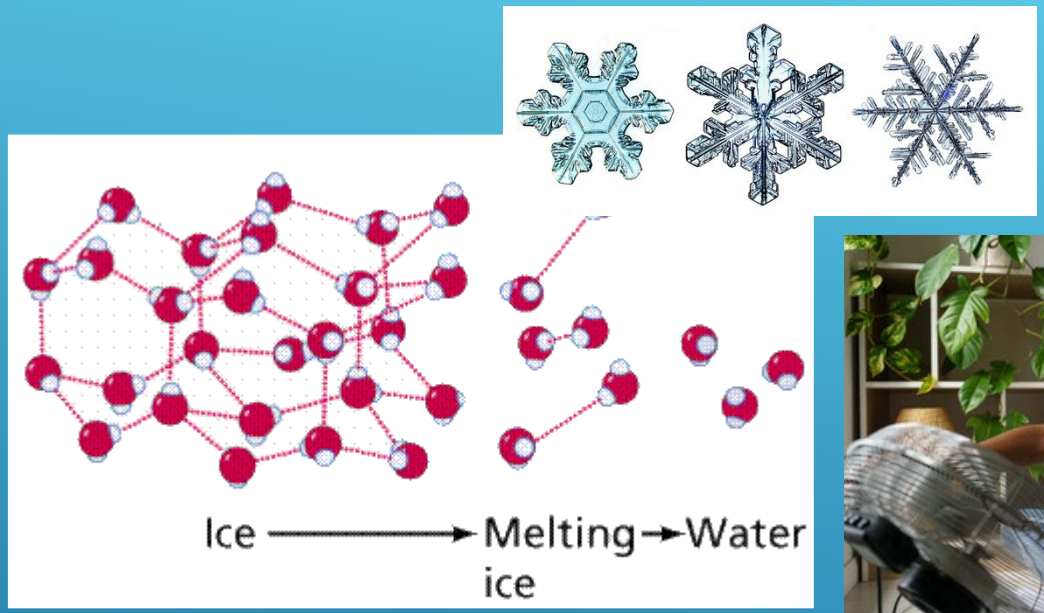
- + attracted to −
- Each H_2O is bonded to its nearest neighbor



SPECIAL PROPERTIES OF WATER

- Physical States:
  - Heat Capacity
  - Evaporative cooling of water
  - Ice is less dense than liquid water
- Cohesion- water sticks together through hydrogen-bonding
- Adhesion-water sticks to other things
- Surface Tension
- Capillary Action
- Solvent-nature of water
- Pure water has a pH of 7 (neutral)
- Pure water does not conduct electricity

PHYSICAL STATES



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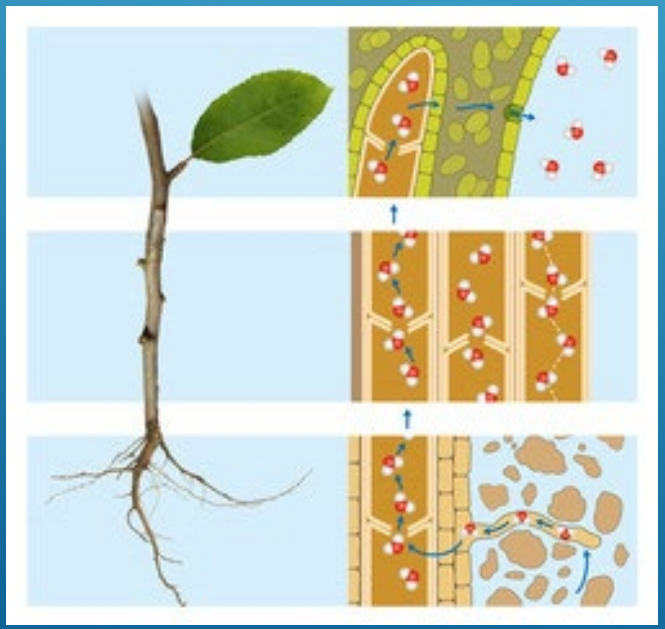
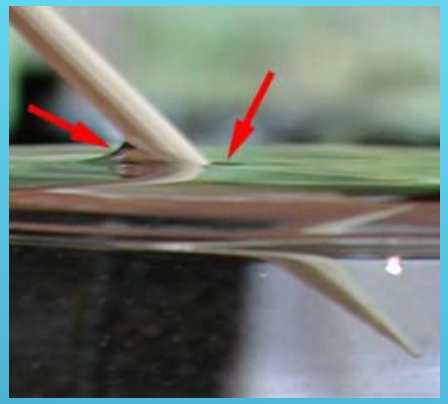
COHESION

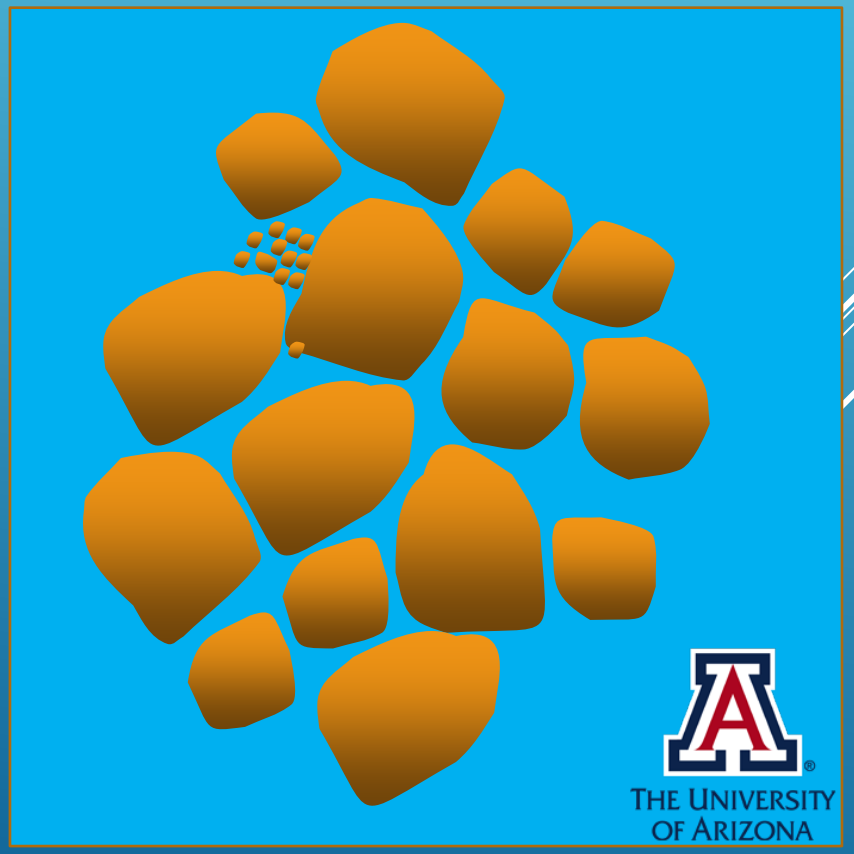
- The attraction water to itself – “Co”=together



ADHESION

- The attraction of water to other surfaces/substances





SURFACE TENSION

- Interaction between hydrogen bonding and the earth's gravitational pull

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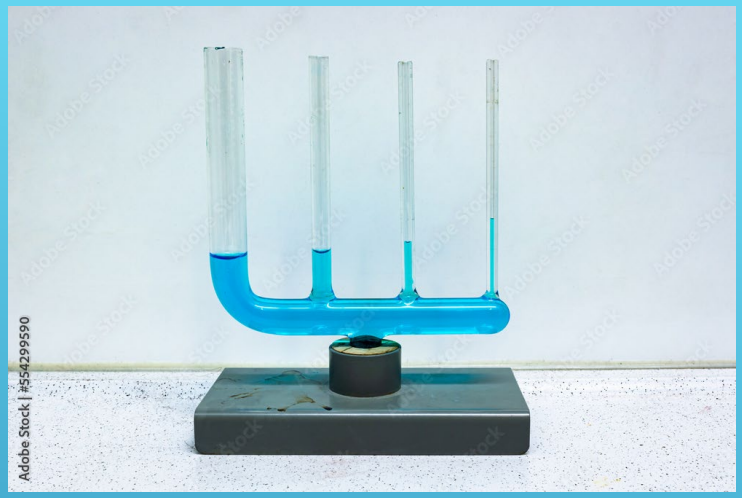
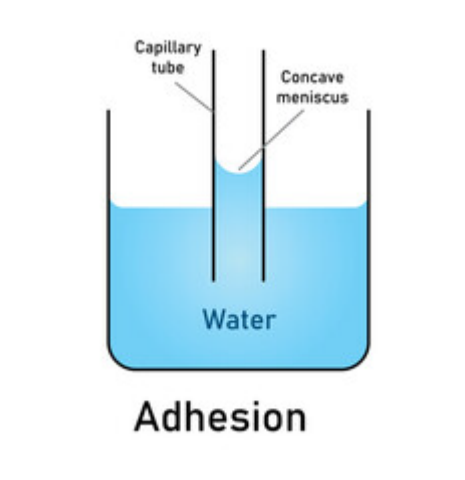
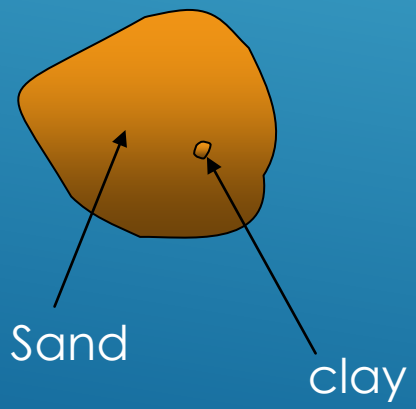
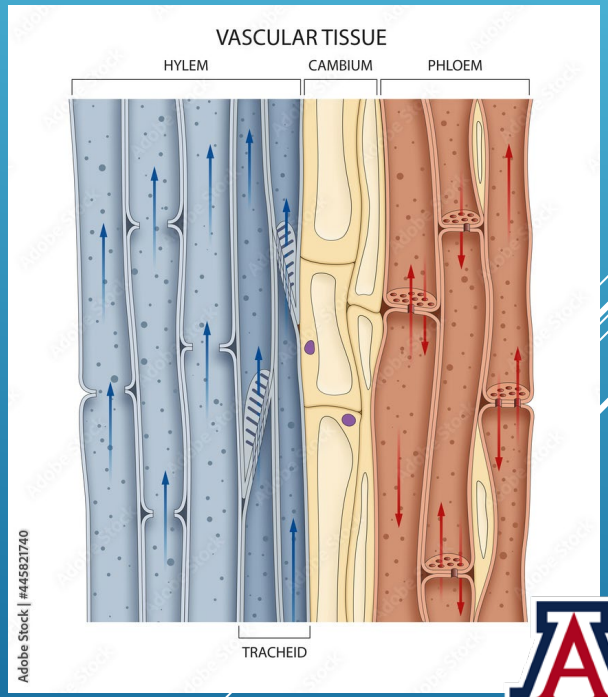
CAPILLARY ACTION

- "Wettable" surfaces cause a film of water to partially pull away from other water molecules and cling to the surface.
- Capillary action is important in soil and plant/water relations.









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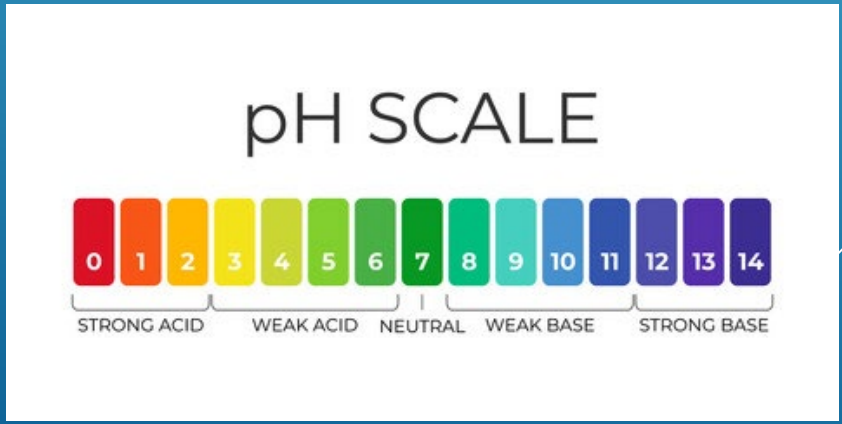
PH: ALKALINITY/ACIDITY

- The measurement of the H+ ions found in that substance
- The scale goes from 0 to 14
- 7 is neutral
- Below 7 is acidic
- Above 7 is alkaline (or basic)
- One pH unit represents a ten-fold change in H+ concentration



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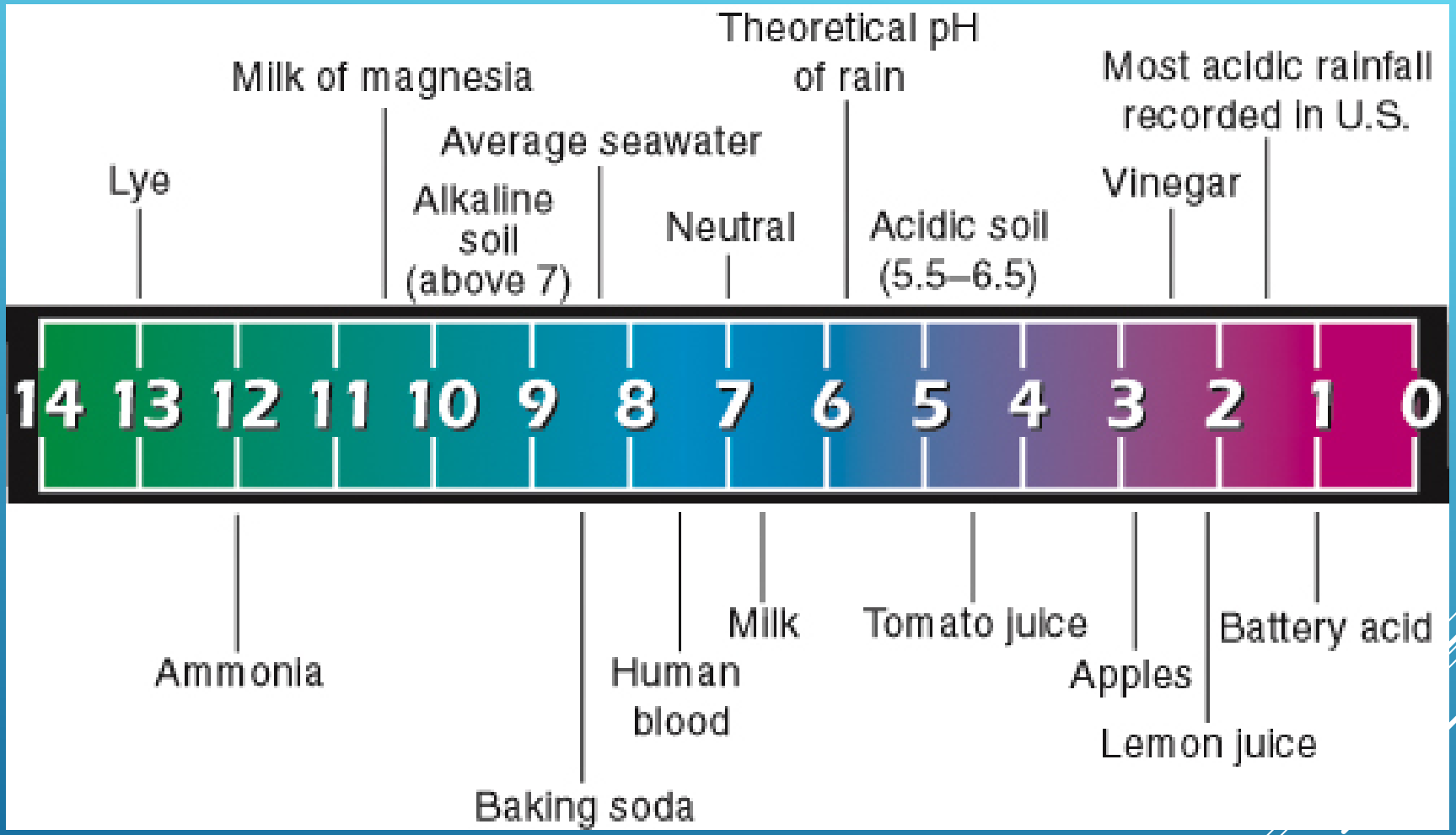

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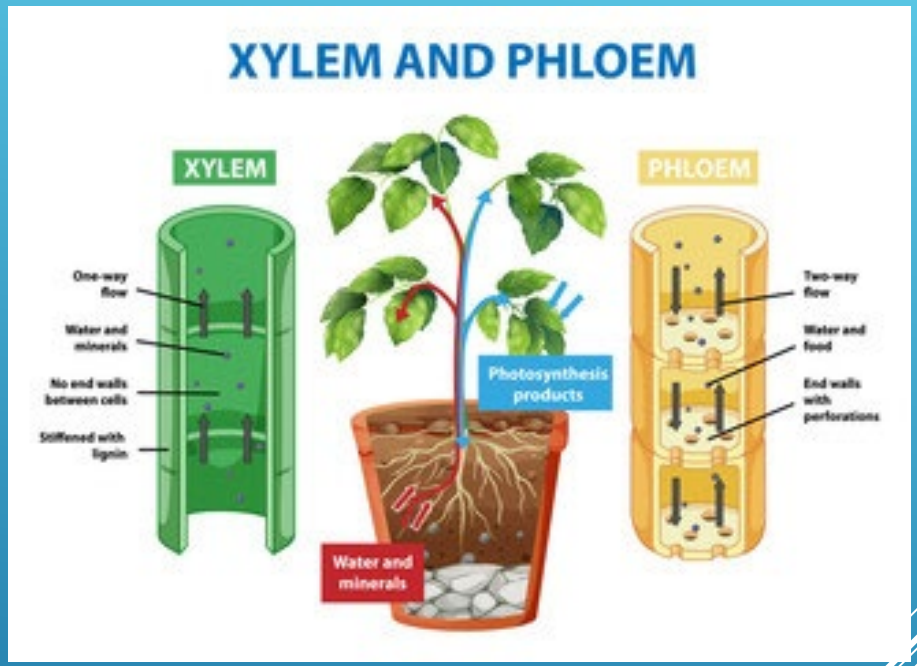
SOLVENT PROPERTIES

- Interacts with other polar and charged compounds
- Is repelled by non-polar compounds
- Small size allows it to saturate areas
- Can convey other substances in solutions



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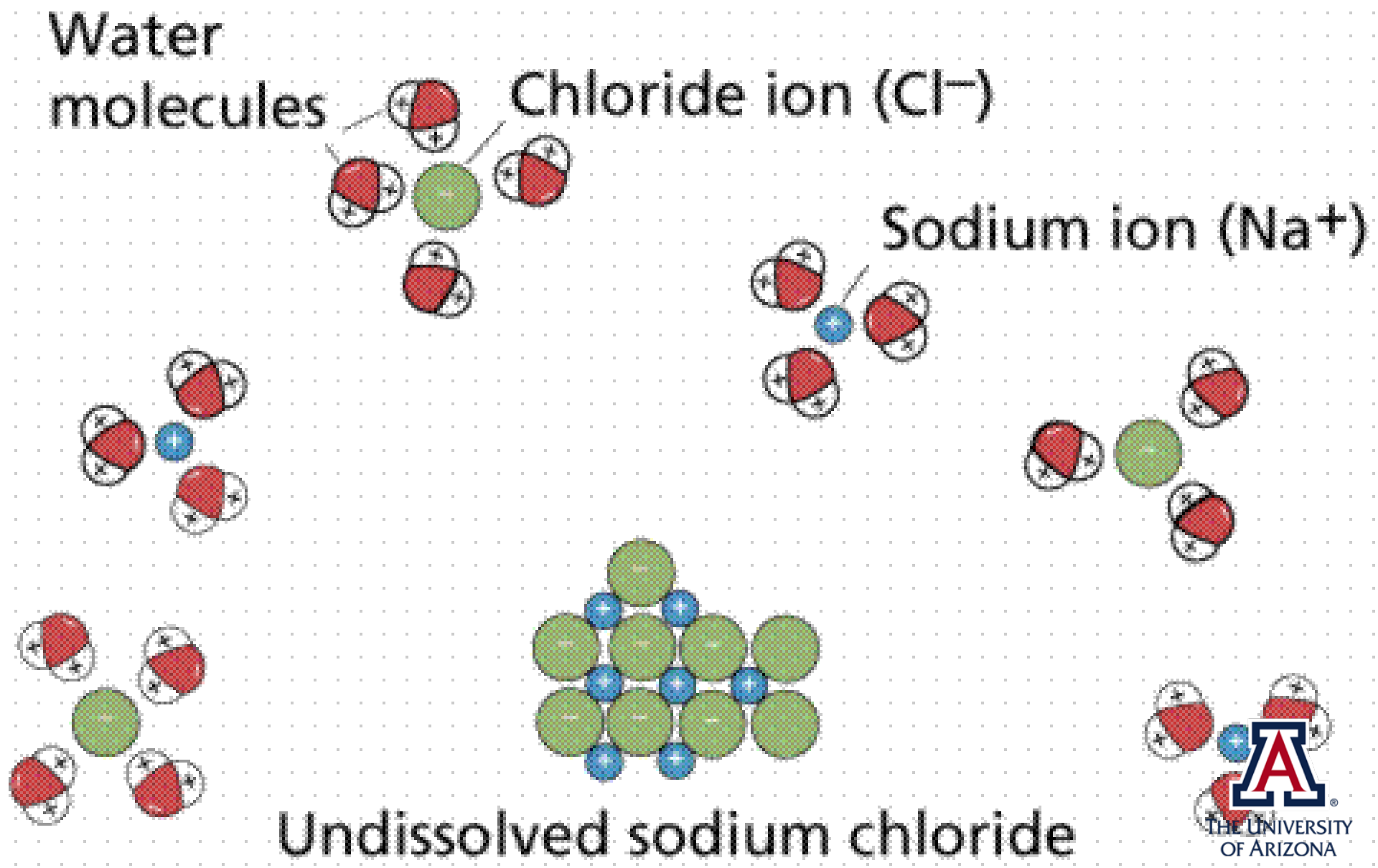
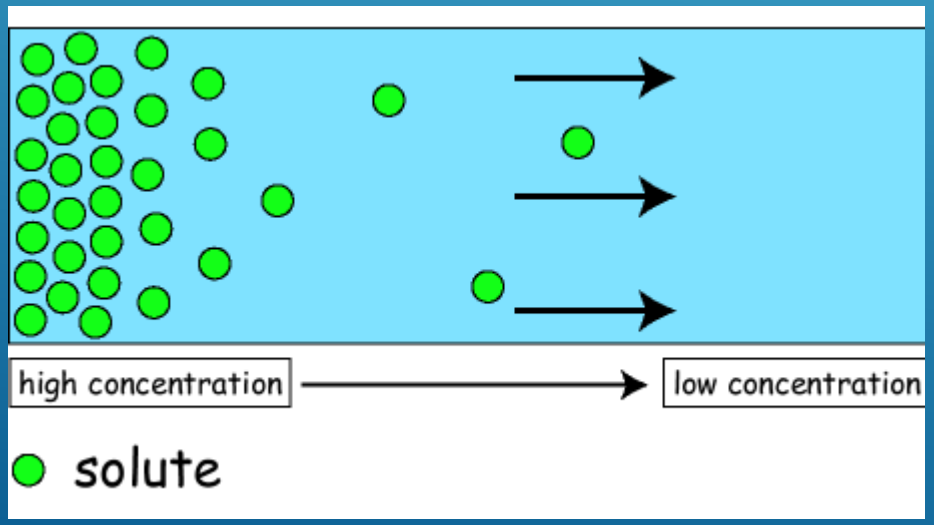
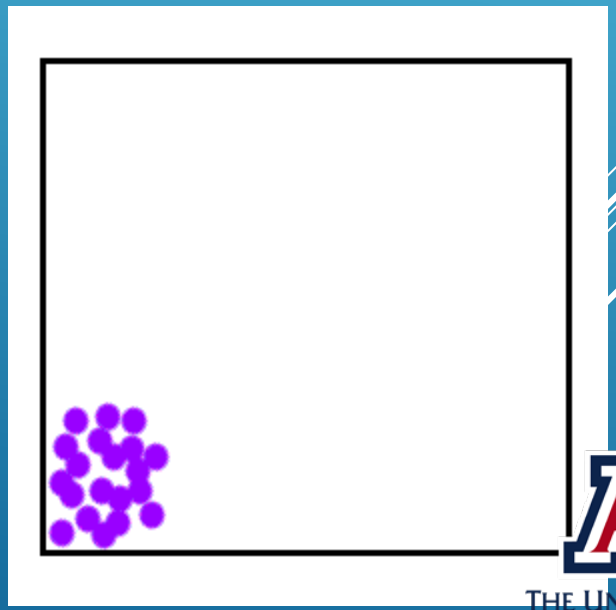
SODIUM CHLORIDE IN SOLUTION



DIFFUSION

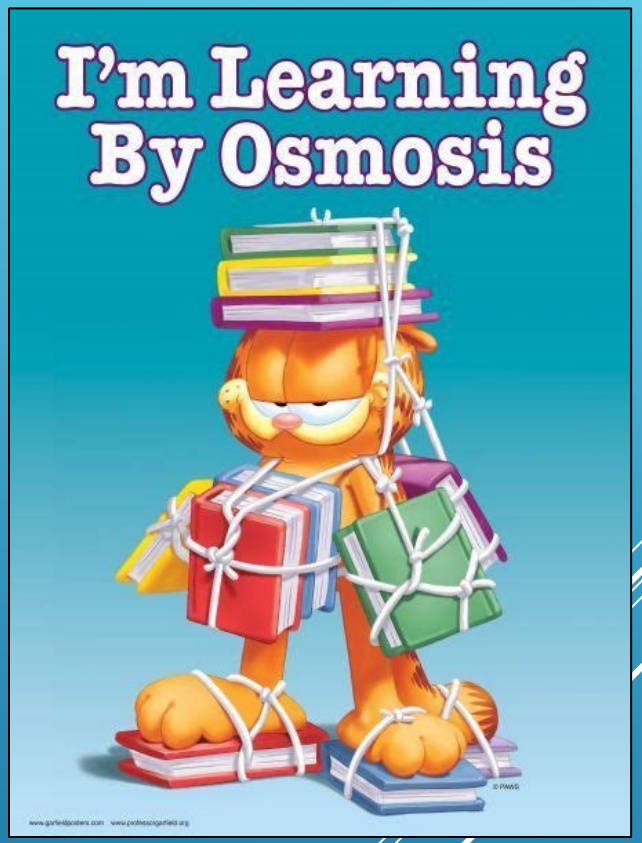
- The tendency of substances to move from areas of high concentration to areas of low concentration
- At equilibrium, they remain as far apart as possible





OSMOSIS

- Osmosis is the net movement of water across a selectively permeable membrane driven by a difference in solute concentrations on the two sides of the membrane
- The water moves from the area of higher solute concentration to the area of lower solute concentration until equilibrium is reached



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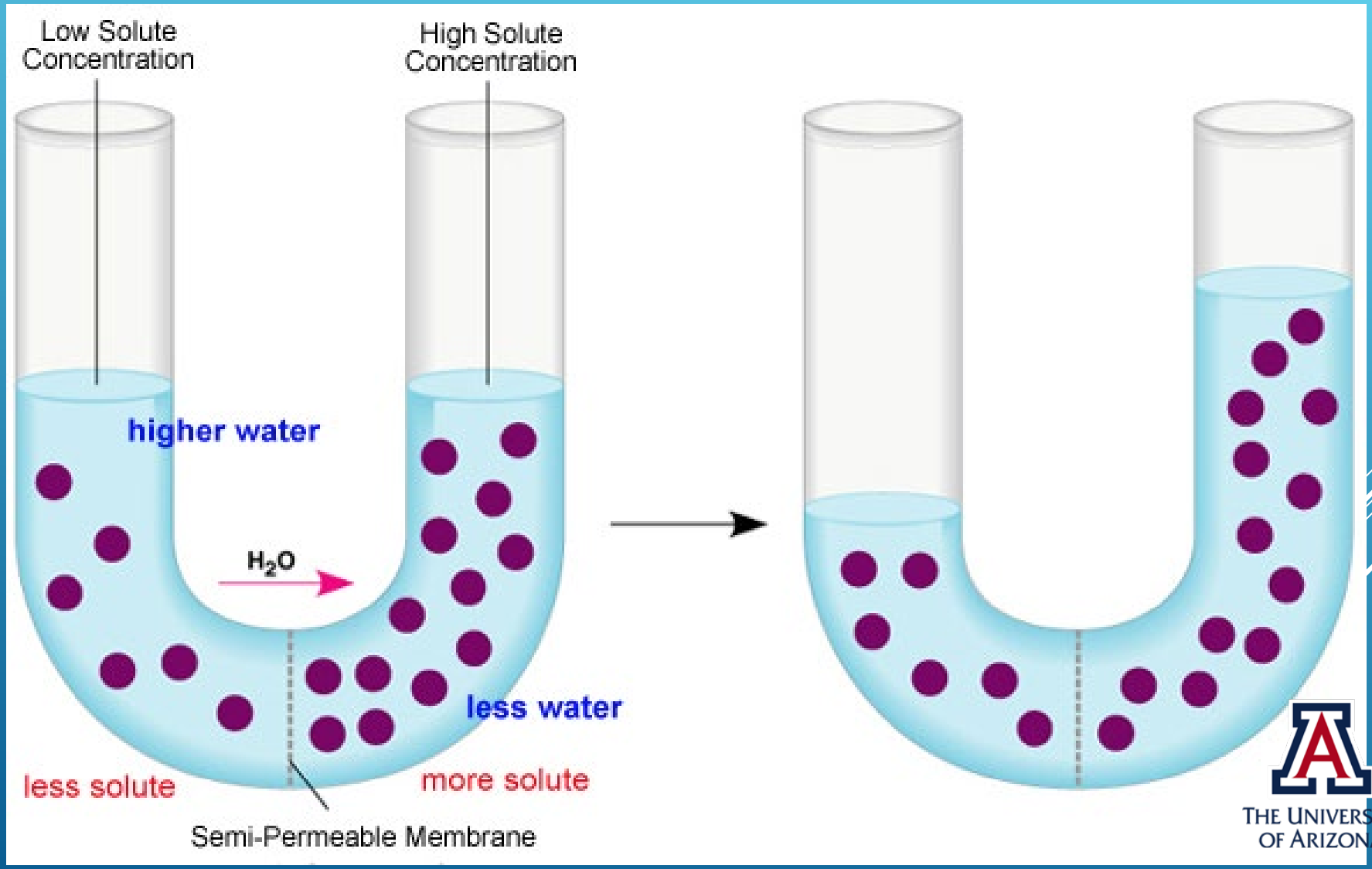
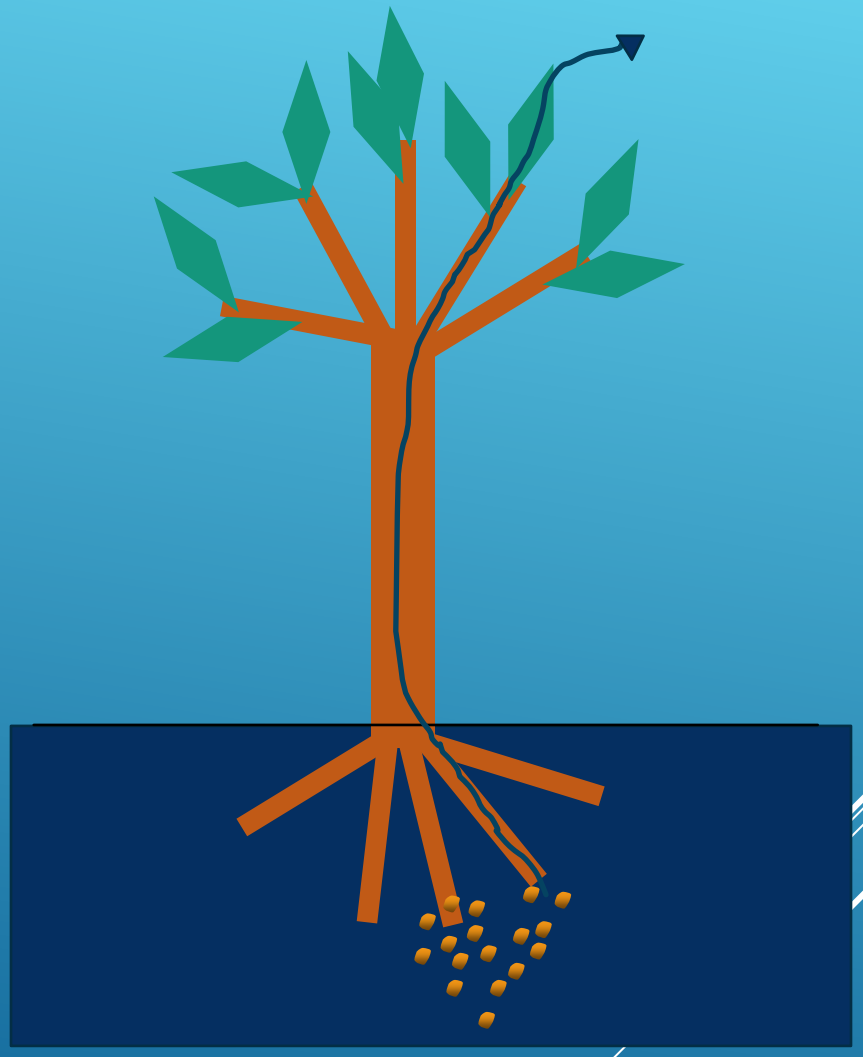
OSMOSIS



COHESION-TENSION THEORY & THE SOIL-PLANT-ATMOSPHERIC CONTINUUM

- Water moves from high to low <u>concentrations</u>
- Concentration is highest in wet soil and lowest in dry atmosphere



Transpiration—Cohesion Hypothesis

Evaporation (the driving force)

The lower water potential of air causes evaporation from cell walls.

This lowers the water potential in cell walls and in cytoplasm.

Cohesion (in xylem)

Cohesion holds water columns together in capillary-sized xylem elements.

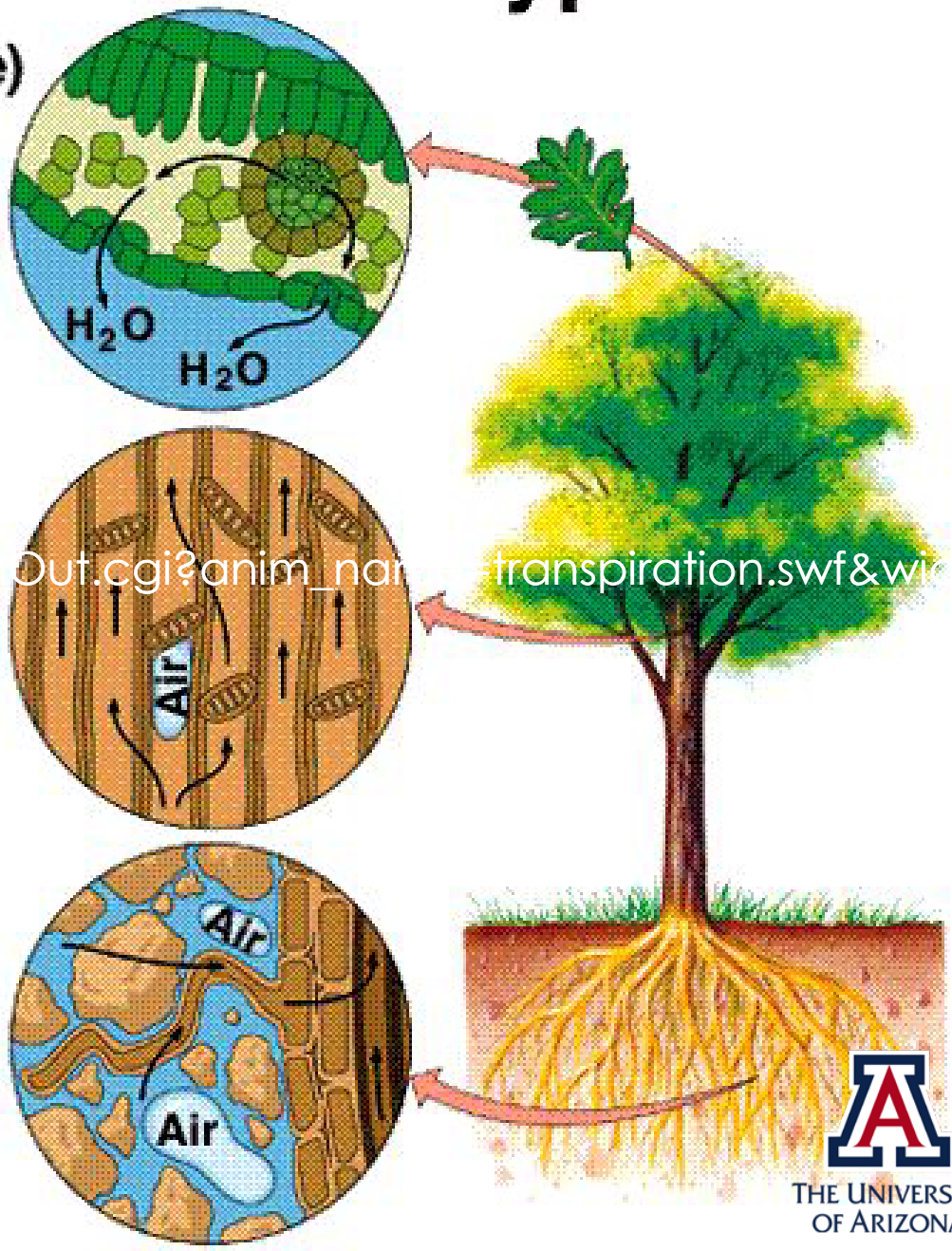
Air bubbles block movement of water to next element.

Water uptake (from soil)

Lower water potential in root cells draws water from soil.

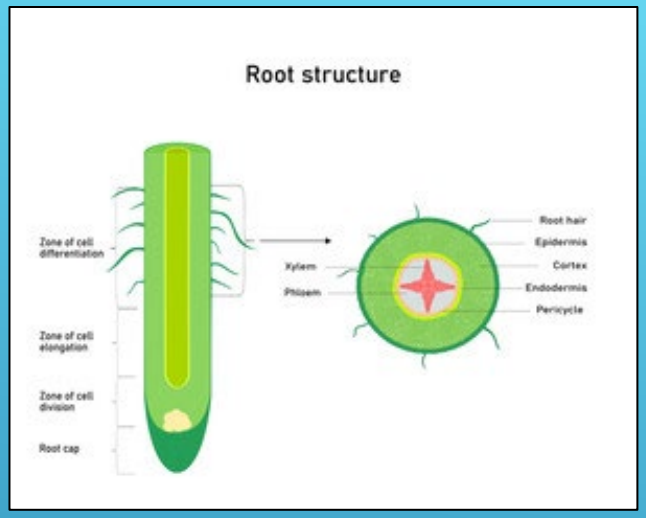
The absorptive surface increases with the production of more root hairs.

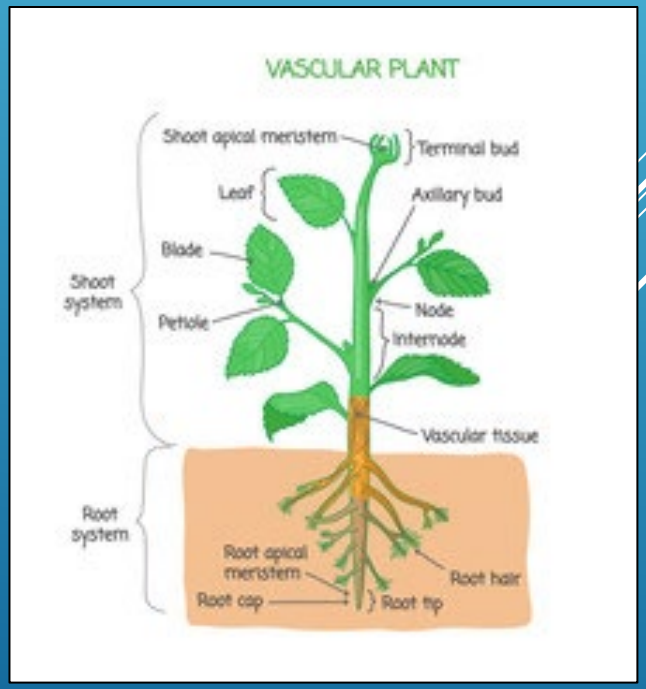
Water moves through endodermis by osmosis.



ROOTS

- Principle site of water and nutrient uptake S
- Size of root system depends on:
  - Competition
  - Soil type
  - Water and nutrient availability
- Root hairs-ephemeral, fine structures that maximize surface area of the roots
- Lateral roots-formed when insufficient resources are encountered
- Give off "exudates" that attract microbial community

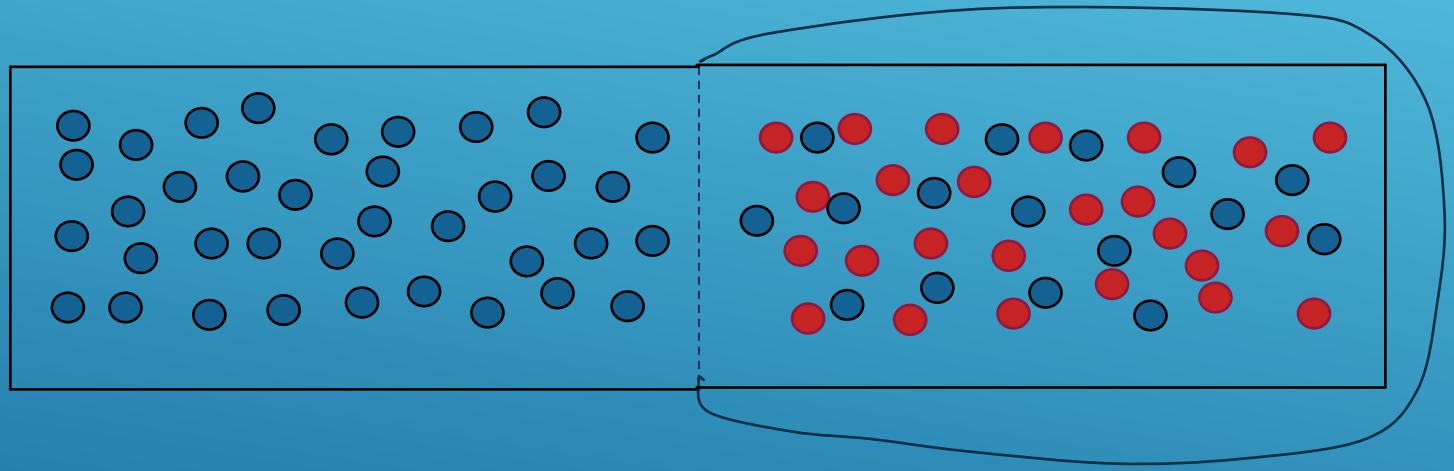




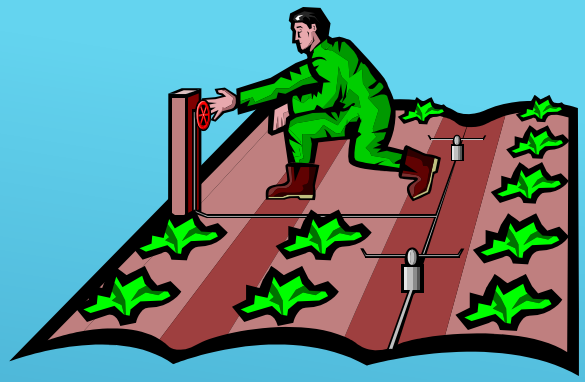
BUDBREAK

- When soils warm up, plants become active
- Need to provide nutrient and water to buds
- Plant use water to expand first leaves
- "Bleeding"-water moving up plants prior to bud break
- How do plants pull up water if there are no leaves to transpire??

Bud Break: Osmosis Creates Root Pressure



IRRIGATION



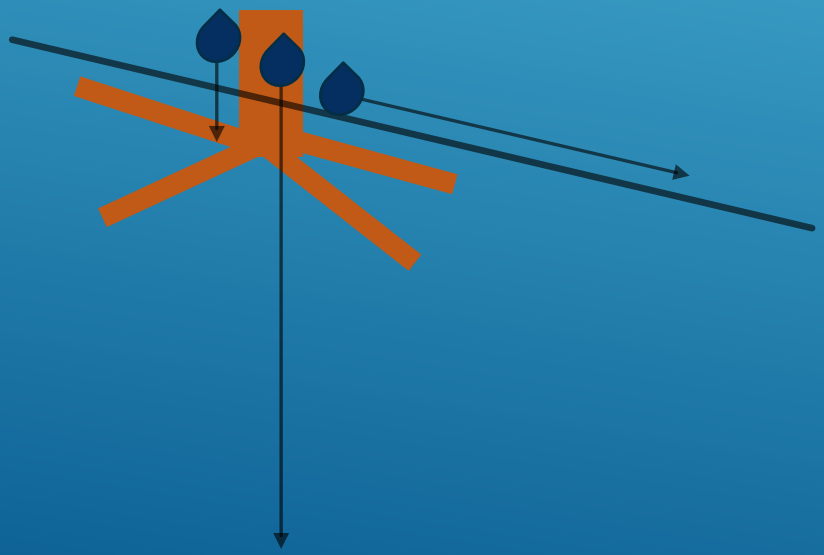
- Art and Science of providing to proper quantity of water to plant roots when it is needed
- Plants and irrigation techniques should be suited to:
  - Climate (macro and micro)
  - Topography
  - Soil
  - Available water (quality and quantity)

HOW DOES WATER BEHAVE IN SOIL?

1. Gravity moves it in (infiltration)
2. Gravity + Capillary Action moves it down and horizontally (percolation)
3. Evaporation and transpiration removes water from soil
4. Capillary action moves it upward
5. Diurnal effect
    - Day - dries
    - Night - equilibrates

HOW WATER MOVES THROUGH SOIL

- Infiltration: movement of water into soil
- Deep percolation: water lost below the root zone
- Runoff: when more water is applied than can infiltrate

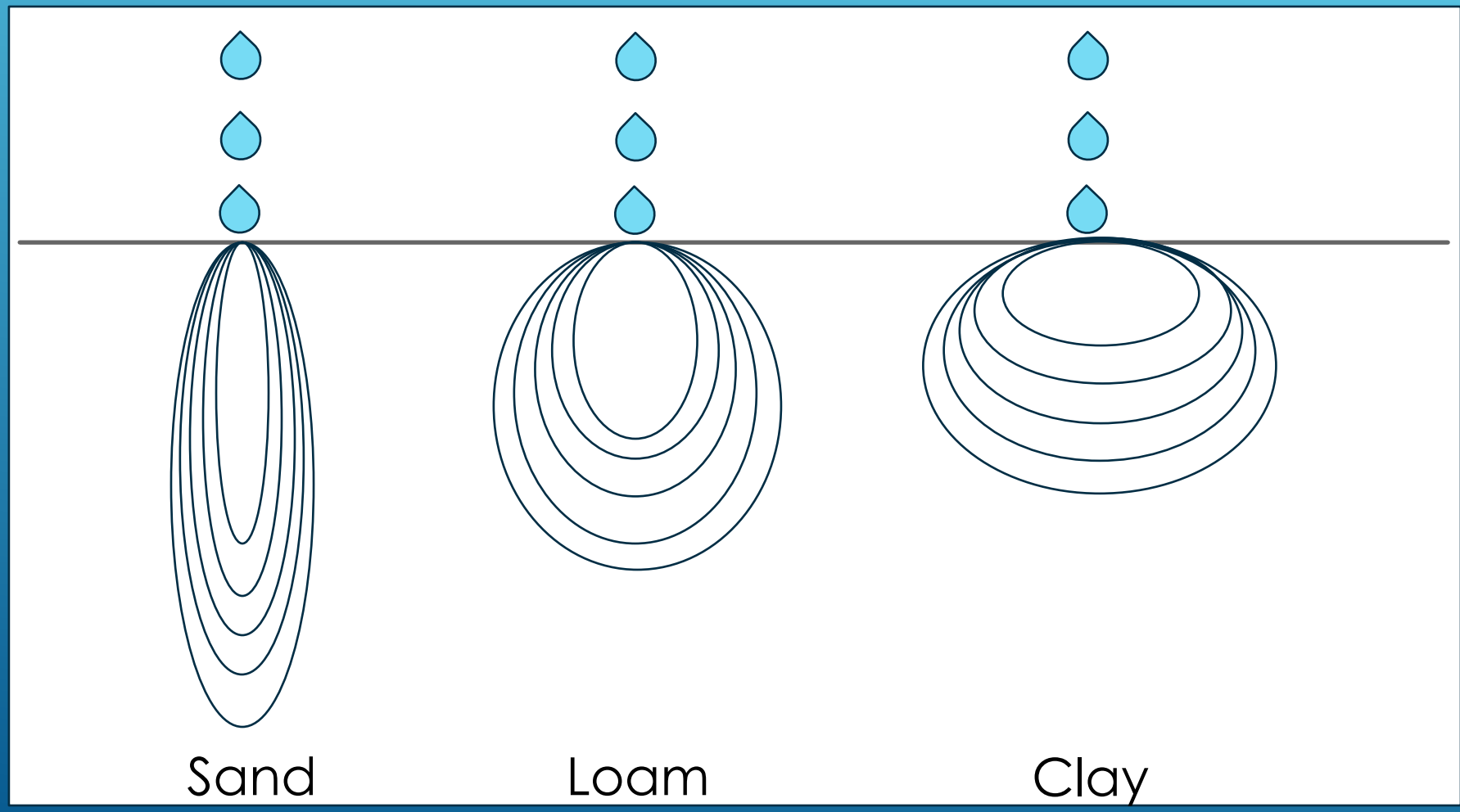


HOW WATER MOVES THROUGH SOIL

- Sandy soils hold less water than clay
  - Need to be watered less, more frequently to avoid deep percolation

- Clay soil hold more water than sand, but water infiltrates more slowly
  - Prone to runoff, need to be watered less frequently

HOW WATER MOVES THROUGH SOIL



AVAILABLE SOIL WATER

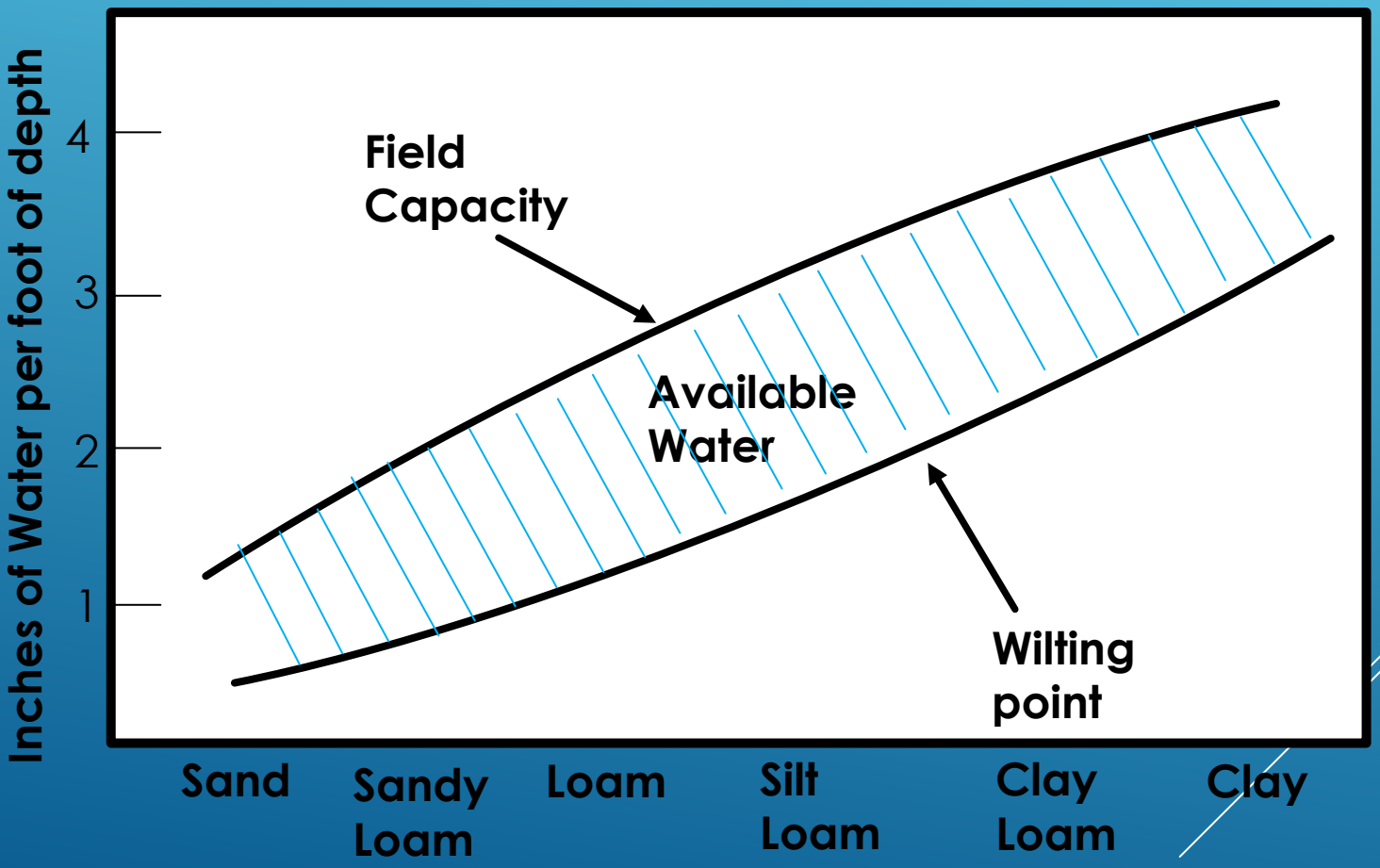
Dried soil

Wilting point (plants die)

Field capacity

Saturated soil

WATER AVAILABILITY



ASSESSING THE DRAINAGE OF YOUR SITE

Perform a Drainage Test:

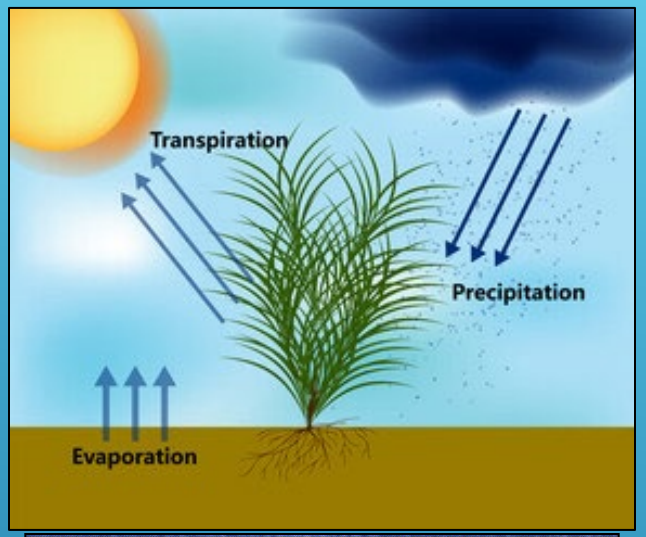
1. Dig a hole the size of a 5-gallon bucket
2. Fill hole with water
3. Let the soil absorb water for an hour or two
4. Fill again with water
5. Hole should drain within 24 hours; if it doesn't, you have a drainage restriction such as a caliche layer

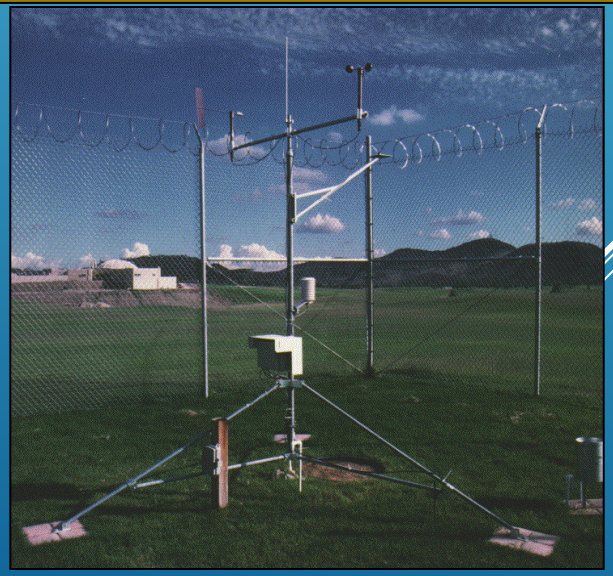
HOW MUCH WATER DO PLANTS REQUIRE?

- Most water plants is lost through transpiration
- Most needs to be replaced through irrigation/precipitation
- Soil water is also lost through soil evaporation

TRANSPIRATION + EVAPORATION = EVAPOTRANSPIRATION (ET)

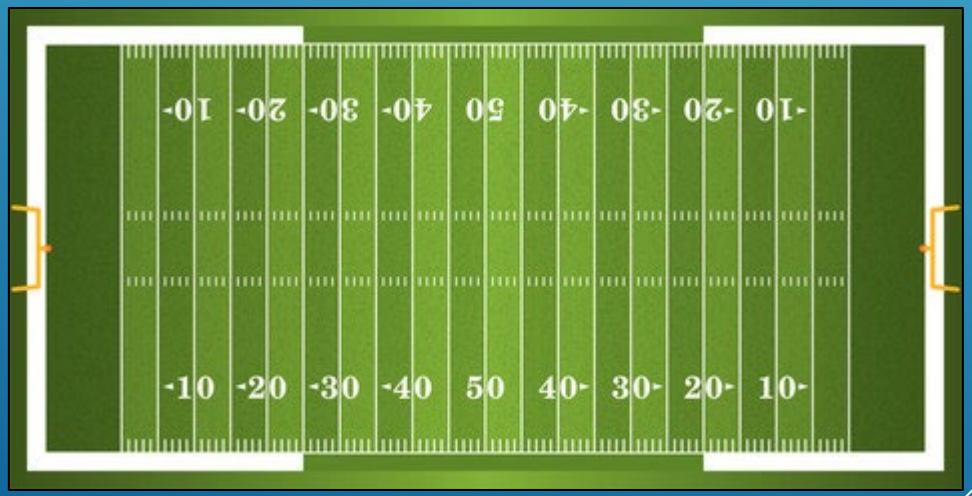
- Evapotranspiration (Et) is the sum of both.
- Usually talked about as inches per day (volume)
- ET is a function of:
  - Temperature
  - Relative humidity
  - Solar radiation
  - Wind speed
- Different plants have different Et demands





ACRE/FEET

- Common large-scale measurement of water
- The volume of water with an area of a acre one foot deep
- Football field =1.32 acres



WINE GRAPE EVAPOTRANSPIRATION

$$ET_{grapes} = ET_0 \times K_c \times K_{RDI} / Eff$$

Evapotranspiration: total water evaporated from a land surface

ET_0 = Reference evapotranspiration based on full-grown alfalfa or clipped grass

K_c = Crop Coefficient for well-watered grapevine (<1.0)

K_{RDI} = percentage of vine ET used for Regulated Deficit Irrigation (RDI) (≤ 1.0)

Eff = Irrigation system efficiency (>.85)

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ORIGINS OF DROUGHT RESISTANCE IN WINE GRAPES

- Early Cultivation (8000 BP) began in dry regions of the "Old World"
  - Eastern Mediterranean
  - Fertile Crescent
  - Southern Caucasus

$$ET_{grapes} = ET_0 \times K_c \times K_{RDI} / Eff$$

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WINE GRAPES ARE WATER-EFFICIENT

Crop	Water Requirement (acre-ft)/acre/year
Alfalfa	4-6’
Cotton	5’
Bermudagrass	3-5’
Habiturf®	3’ or less
Wine grapes	1.5-3’
Native Landscaping	N/A

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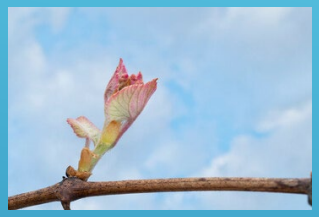
- Water use is often measured as evapotranspiration

WINE GRAPES EMPLOY DEFICIT IRRIGATION

$$ET_{grapes} = ET_0 \times K_c \times K_{RDI} / Eff$$

- **Budbreak to Fruitset**: Irrigation to full Et_{grapes}
- **Fruitset to Veraison** (color change): employ deficit irrigation (K_{RDI})
- **Veraison to Harvest**: employ deficit irrigation (K_{RDI})
- **Harvest to dormancy**: If growth has stopped, soil profile should be filled



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DRIP IRRIGATION EFFICIENCY (EFF)

$$ET_{grapes} = ET_0 \times K_c \times K_{RDI} / Eff$$

Irrigation Delivery	Efficiency
Furrow/Flood	40-50%
Overhead Sprinkler	60-75%
Drip Irrigation	85-95%

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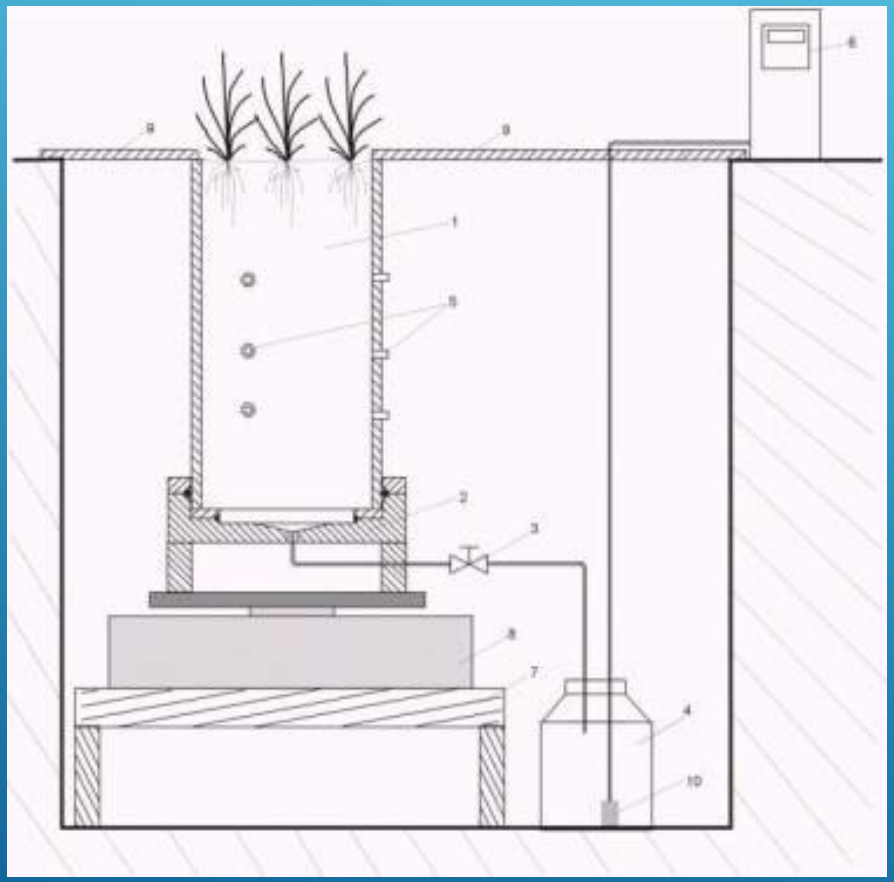
LYSIMETERS ARE USED TO MEASURE ACTUAL WATER USE



WEIGHT OF WATER ON/IN SOIL

- Table is 3' x 6' (36 ft^2)
- 1 inch of water on that table weighs…
- 187 lbs
- 6 inches of water = 1,122 lbs
- Soil compaction can occur during flood irrigation
- Water also displaces air potentially leading to plant stress

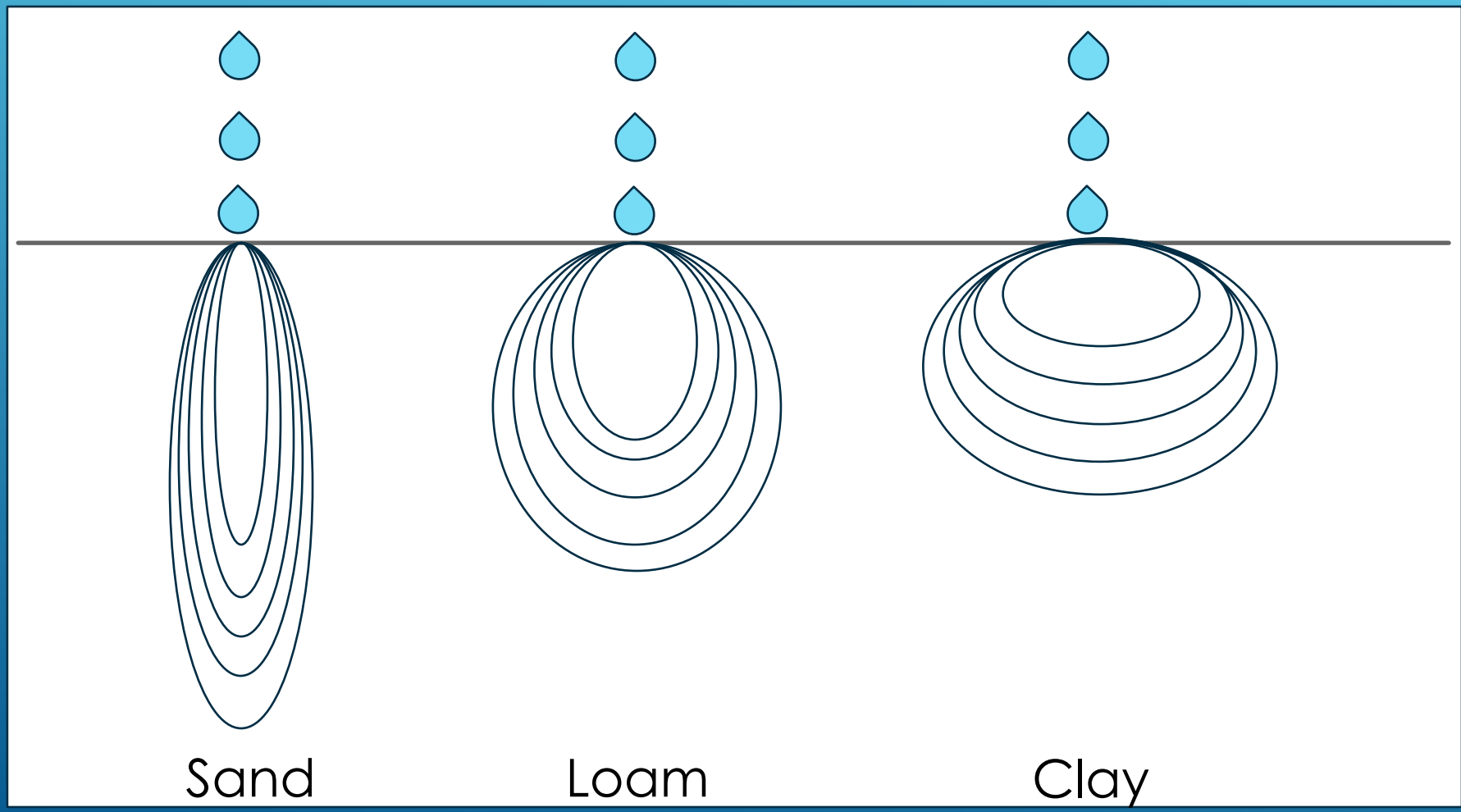
USEFUL CONSTANTS/CONVERSIONS

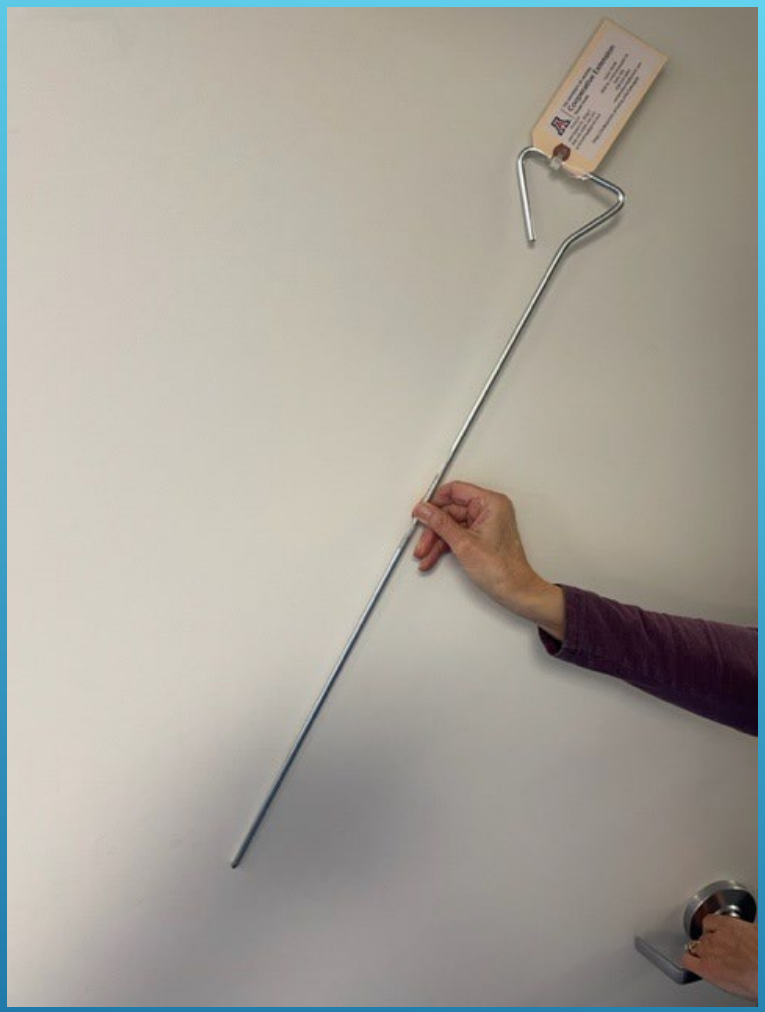
- Weight: 62.416 pounds per cubic foot at 32°F
- Weight: 8.33 pounds/gallon, 0.036 pounds/cubic inch
- Density: 1 gram per cubic centimeter (cc) at 39.2°F
- 1 gallon = 4 quarts = 8 pints = 128 ounces = 231 cubic inches
- 1 liter = 0.2642 gallons = 1.0568 quart = 61.02 cubic inches
- 1 Acre-Foot = 325,851 gallons = 43,560 cubic feet

HOW DEEP TO WATER

- 1 inch of water will:
  - Go 12" deep in a sandy loam
  - 8-10" deep in a loam
  - 4-6" deep in a clay loam
- To irrigate each soil to a three-foot depth, you need to apply:
  - 3" on a sandy loam
  - 4" on a loam
  - 6" on a clay loam

HOW WATER MOVES THROUGH SOIL



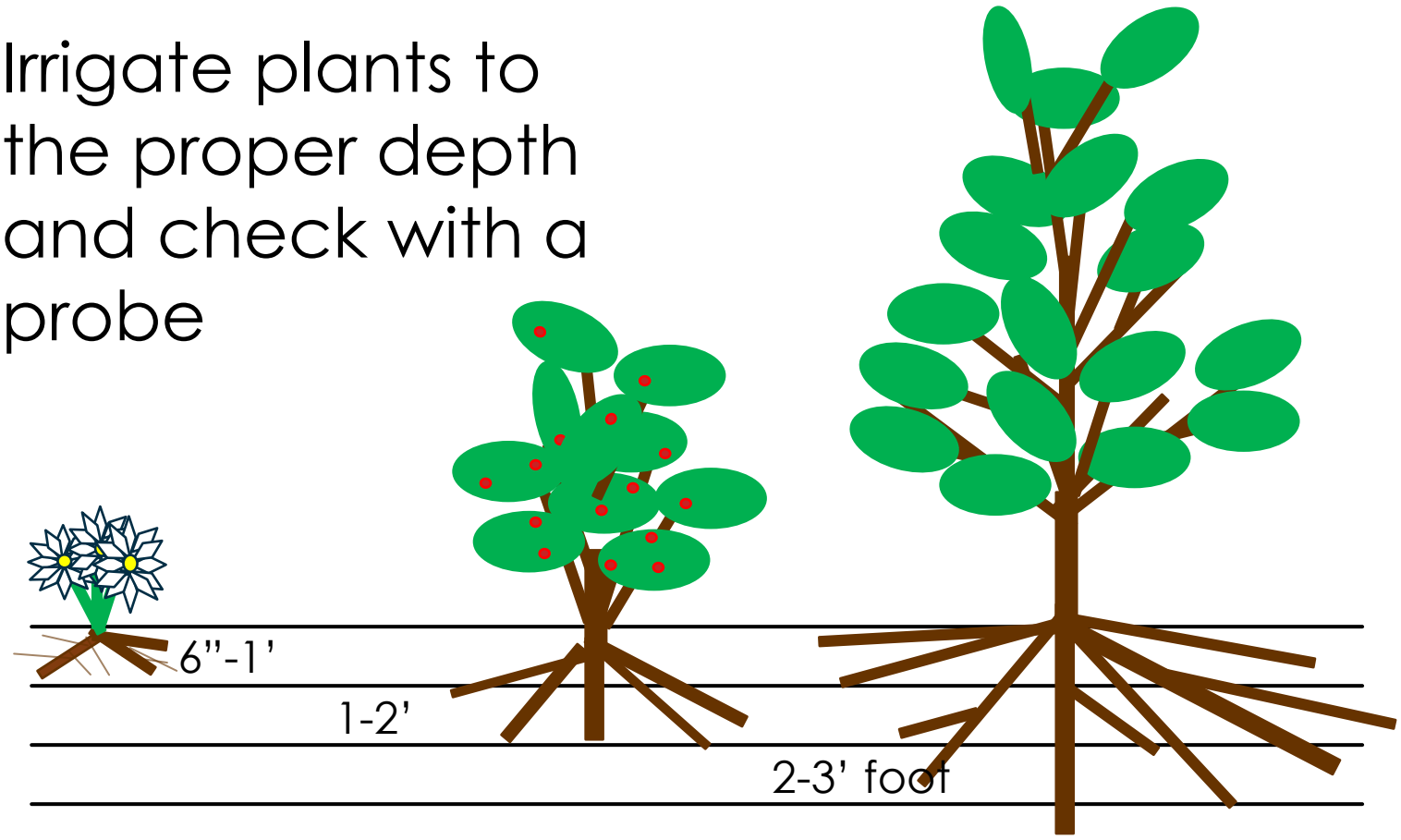


Probe sold in Master Gardener office used to check watering depth

Soil core can be used to check water as well

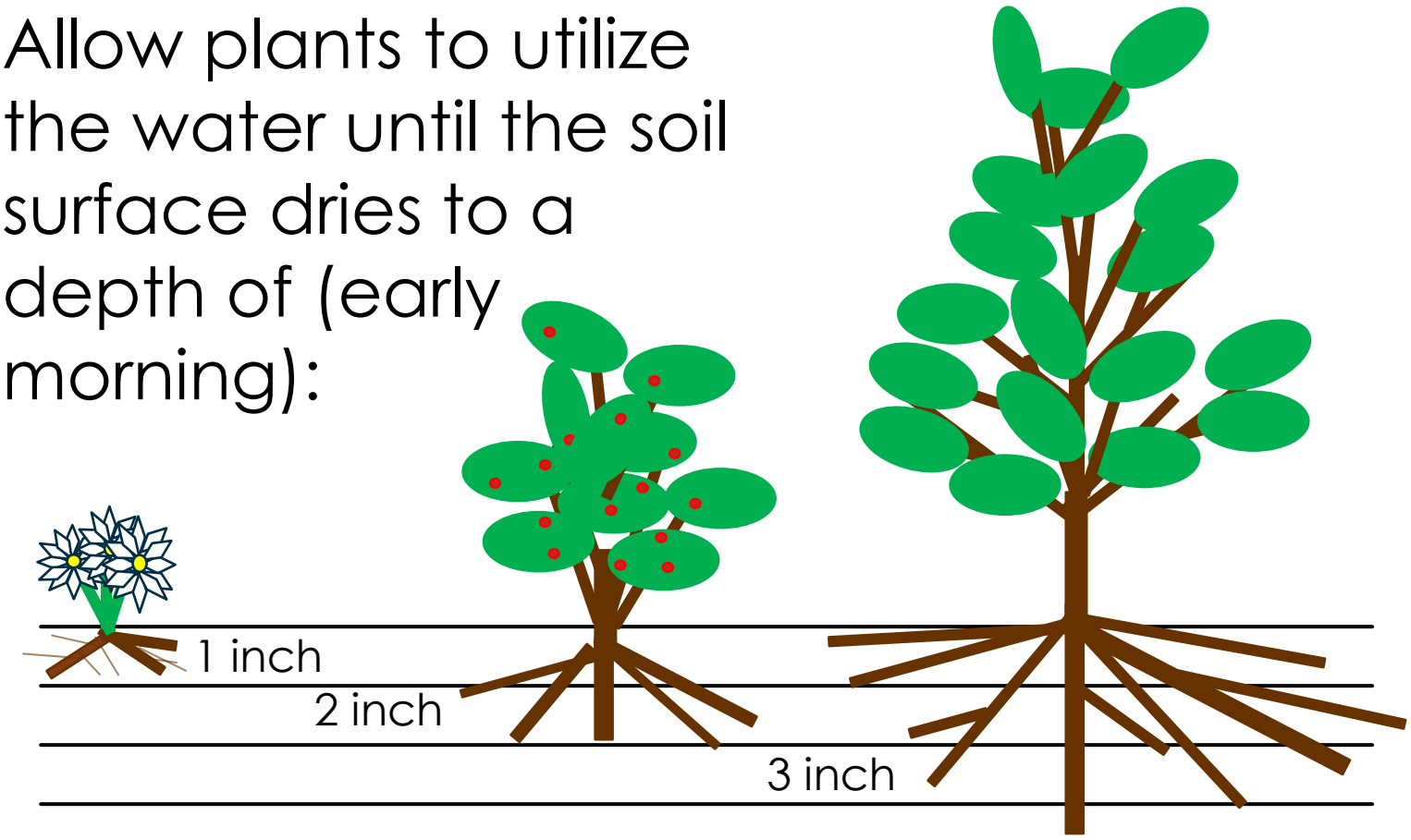
ONE, TWO, THREE RULE

Irrigate plants to the proper depth and check with a probe



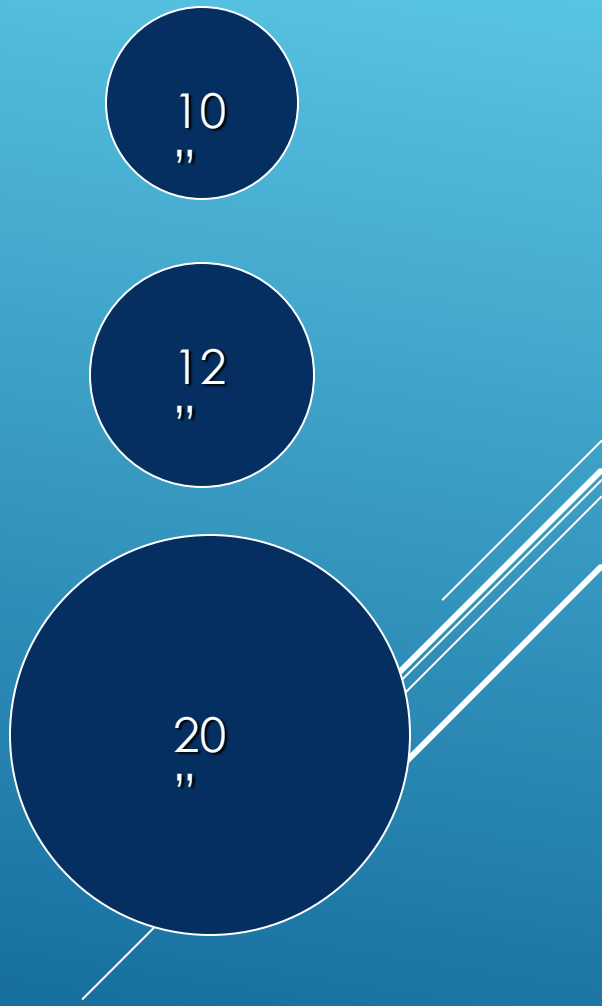
ONE, TWO, THREE RULE

Allow plants to utilize the water until the soil surface dries to a depth of (early morning):



WHAT AREA DO I NEED TO WATER: TERRY MIKEL'S LAW OF PIZZA

- As the radius of the root system doubles, the area of the root system increases by four times
- $A=\pi r^2$
- 10" pizza = 79 in^2
- 12" pizza = 113 in^2
- 20" pizza = 314 in^2



HOW TO KNOW WHEN TO WATER: LOOK….

- Check in the morning
- New leaves smaller
- Internode length shortening
- Wilted leaves
- Change in leaf color (darker, duller, grayer)
- Yellowing basal leaves
- Dropping leaves

THE "FEEL" TEST

- Dig down about 6-8"
- Water when about 50% of soil moisture is depleted
- Eventually you will learn the soil and plants

"FEEL" TEST

Available Moisture	Sand	Sandy Loam	Clay Loam	Clay
Close to 0%	Dry, loose, falls through fingers	Dry, loose, falls through fingers	Dry clods that break into powder	Hard clods, difficult to break
50% or less	Dry, won't form a ball	Dry, won't form a ball	Crumbly, but will form a ball	Pliable, will form a ball
50% to 75%	Dry, won't form a ball	Forms a ball temporarily	Forms ball, pliable	Forms ball, will ribbon
75% to field Capacity	Sticks together slightly, weak ball	Weak ball, breaks easily	Forms a ball, very pliable, slick	Easily ribbons, feels slick
Field Capacity	Squeeze; leaves hand moist	Squeeze; leaves hand moist	Squeeze; leaves hand moist	Squeeze; leaves hand moist
Above Field Capacity	Free water released	Free water released	Free water released	Free water released

TURFGRASS IN THE UNITED STATES

- Constitute the largest irrigated crop in America (almost 40 million acres)
  - Vast majority are residential lawns

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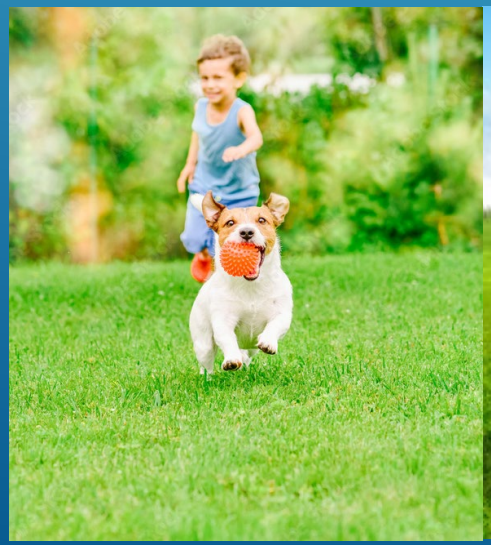

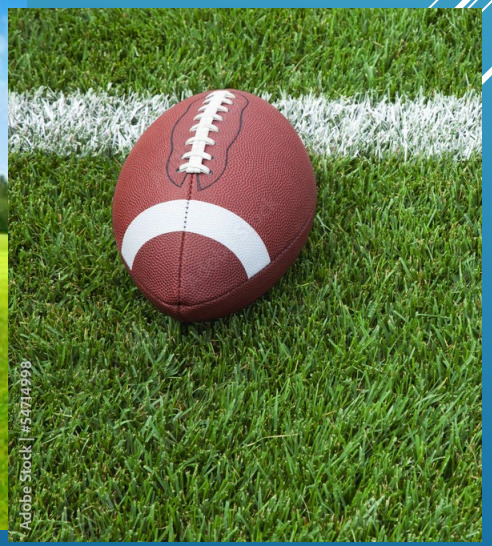

TURF BENEFITS VS COSTS

The Good:

- Color
- Texture
- Ability to withstand foot/tire traffic

The Bad:

- High Water use
- High Fertilizer use
- High Pesticide use
- High costs
- Frequent mowing
- Pathogens
- Some turf extremely invasive

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ALTERNATIVE: NATIVE PLANT LANDSCAPING

Plants that occurred in the region before the settlement of Europeans

Velvet Mesquite (Prosopis velutina)

Parry's Agave (Agave parryi)

NATIVE PLANT MANAGEMENT

- Give water and manage weeds during first 2 years of establishment
- Give supplemental water during extremely hot, dry summers
- Be mindful of microclimate
- Contact landscape architect

Arizona Cypress (Cupressus arizonica)

Parry's Penstemon (Penstemon parryi)

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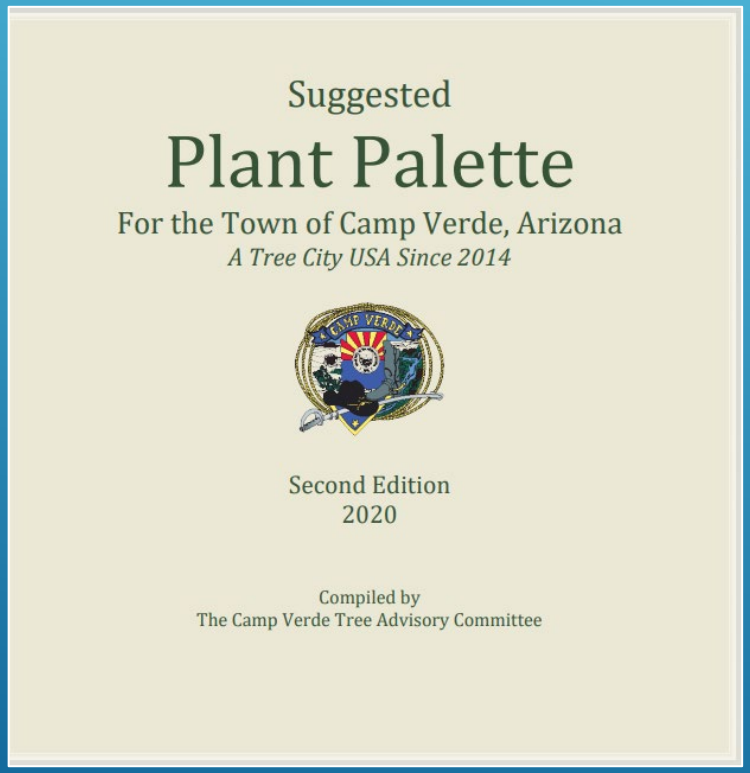
NATIVE PLANT RESOURCES



www.campverde.az.gov

cals.Arizona.edu/yavapaiplants/

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ALTERNATIVE : NORTH AMERICAN TURFGRASSES
EXAMPLE: BUFFALOGRASS (BOUTELOUA DACTYLOIDES)

Advantages

- Drought resistant
- Slow-growing
- Low nutrient requirement

Disadvantages

- Some sensitivity to foot traffic
- Less resistant to invasive weeds
- Color (grey/green) less aesthetically appealing
- Under winter/water stress conditions, will go dormant

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ALTERNATIVE : NORTH AMERICAN TURFGRASS EXAMPLE: HABITURF ®

- Developed at the University of Texas at Austin Ladybird Johnson Wildflower Center
- **62 % Buffalograss** (bouteloua {formerly Buchloe} dactyloides)
  - Perennial, C4 turfgrass
- **30% Blue Grama** (bouteloua gracillis)
  - Perennial, C4 bunchgrass
- **8% Curly-mesquite** (Hilaria belangeri)
  - Perennial, C4 bunchgrass
- Available at Douglas King Company:

  www.dkseeds.com

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Review

The performance of native and non-native turfgrass monocultures and native turfgrass polycultures: An ecological approach to sustainable lawns

Mark Simmons[a,*], Michelle Bertelsen[a], Steve Windhager[b,1], Holly Zafian[b,2]

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ARTICLE INFO ABSTRACT

- **Weeds:**
  - Total weed cover was lower in native compared to non-native plots
  - High-diversity assemblage had 63% less dandelion than the bermudagrass plot
- **Mowing:**
  - Bermudagrass grew much faster between mowing periods than natives
- **Composition:**
  - High-diversity assemblage ended with:
    - 3 co-dominants (>25% each): blue grama, buffalograss, curly-mesquite
    - 2 sub-dominants (<5% each): hairy and Texas grama
    - Hairy tridens and Poverty dropseed were undetectable

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HORTICULTURAL VS. ECOLOGICAL APPROACHES

Horticultural Approach

- Select and modify a single species (monoculture)
- Fit a wide range of requirements
- Requires heavy management

Ecological Approach

- Mimic a plant community
- Accounts for multiple biotic and abiotic processes
  - Soil
  - Rainfall
  - Pathogens
  - Grazing
  - Weeds

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POTENTIAL CONS AND PROS OF NATIVE POLYCULTURE TURF

CONS

- Color (blue/green)
- Foot traffic?
- Go dormant/brown with drought or cool season

PROS

- Dormant grass may be preferable to xeriscape in some scenarios
- Water and Nutrient efficiency
- Reduced maintenance

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IRRIGATION TIPS:

- Water deeply and infrequently (mature plants)
  - Encourages plants to root deeper
  - Lower proportion lost to evaporation
- Irrigate early in the morning or at night, reducing evaporation before percolation
- Adjust your watering schedule as needed:
  - Plant Species
  - Plant age
  - Rain events
  - Heat
  - wind

IRRIGATION METHODS-DRIP

- Frequent, slow and precise application of water through emitters
- Tube or tape that may have emitters installed or be blank
- Emitters are made in different sizes
- Emitters can plug, animals can chew

IRRIGATION METHODS-SPRINKLER HEADS

- Excellent for turf and ground covers
- Not as good for trees and shrubs
- Need a good design (consider hiring a professional to design the system)
- Still need repair and maintenance
- Do not mix and match incompatible nozzles and head types or brands.

IRRIGATION METHODS-OTHER

- Soaker hoses work great for trees, shrubs, vegetables, and annuals
- Good, old fashioned hose spraying works well for natives that only need periodic watering during drought

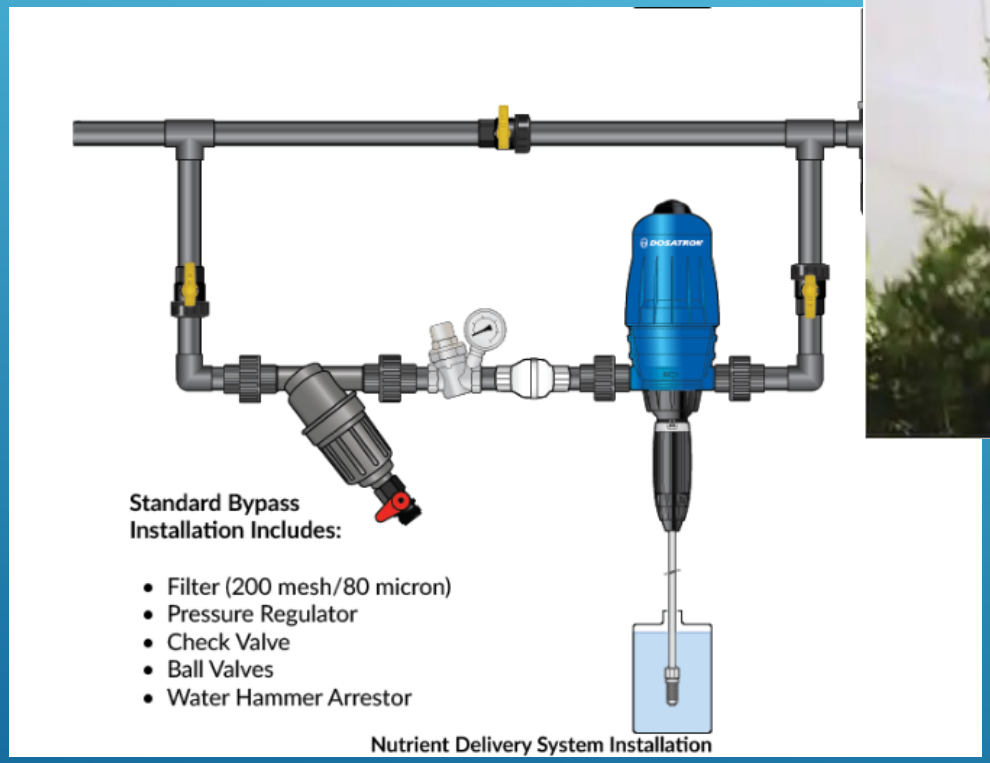
IRRIGATION METHODS-TIMERS, MANIFOLDS AND SOLENOIDS

- Design system for optimum pressure
- Reset times for different times of year
- Check system periodically to make sure it is working correctly
- Turn off after rains

IRRIGATION METHODS-FILTRATION

- Particularly important for:
  - Wells
  - Drip irrigation

IRRIGATION METHODS: INJECTION



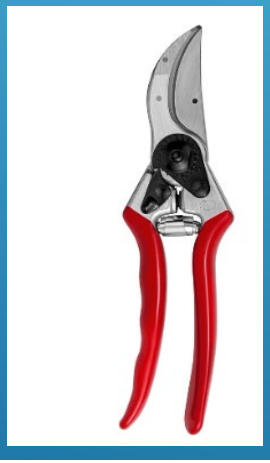
Backflow preventer for garden hose

IRRIGATION METHODS- DELIVERY

- Pressure regulators
- PVC
- Poly tube
- Spaghetti tube
- Drip tape
- Flex tube
- ¼ turn valves

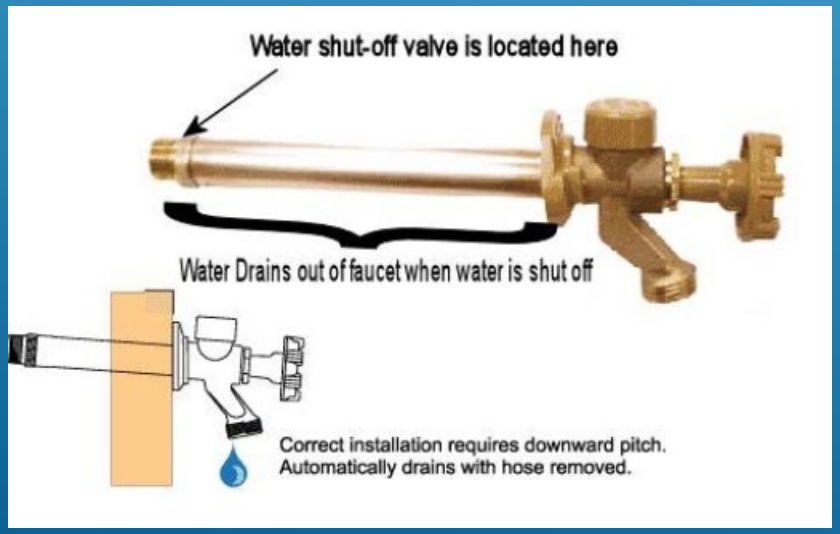
IRRIGATION METHODS- BUILDING AND REPAIR TOOLS

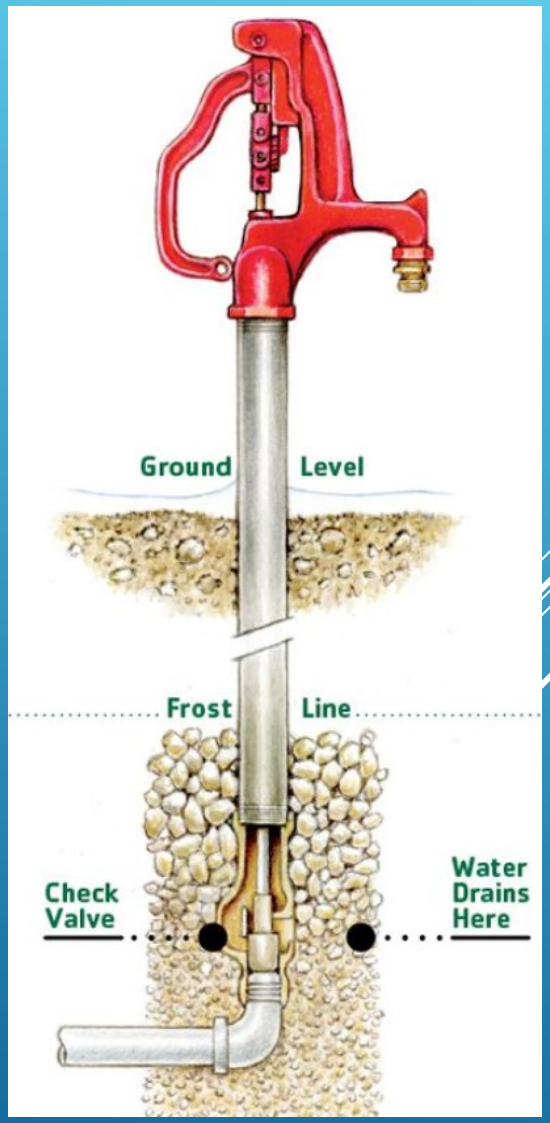
- PVC Cutter
- PVC Cement
- PVC Primer
- Couplers
- Punch
- Pruners
- “Goof” plugs
- Sprinkler key



WINTERIZING IRRIGATION

- Drain system
- Compressed air
- Frost-free spigot





PRO TIPS

- Use plumber's tape on threaded connections that don't have rubber gaskets
- Use pipe thread sealant and tape to ensure a tight seal
- Rebar-bundling wire and a twister are great for keeping couplers on tight
- An old section (2") of PVC works great for kinking-off drip tube

WATER & IRRIGATION WRAP-UP

- The special properties of water make life possible
- Soil, weather, and plant type dictate irrigation scheduling
- Do not overwater or fertilize native and/or drought tolerant plants and cause them to grow too much
- Do not assume that just because a plant is native and/or drought tolerant that it does not need irrigation
- Plants need some water in winter, evergreens also need adequate water in winter