FROM GROWING TO BIOLOGY: PLANTS

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From Growing to Biology: Plants (Hacisalihoglu)

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About the Author

Dr. Gokhan Hacisalihoglu is a Professor of Biological Sciences at Florida A&M University. He earned his Ph.D. in plant biology from Cornell University, Ithaca, New York. He has several years of experience teaching a variety of university courses from first year General Biology to Plant Anatomy & Development, and Scientist Life Skills. He won many teaching and research awards including FAMU Teaching Innovation Award, FAMU Advanced Teacher of the Year Award, FAMU Teacher of the Year Award, FAMU Research Excellent Award, and Best Professor of the Arts & Sciences. He is a member of the American Society of Plant Biologists. He was a visiting fellow at Michigan State University, Florida State University, Cornell University, and University of Florida. He has received a Fulbright Specialist Award to Japan as an expert consultant in Plant Biology. Throughout his scientific career, Dr. Hacisalihoglu has had the opportunity to mentor and direct a diverse group of undergrad and grad students. Dr. Hacisalihoglu looks forward to developing new collaborations. Subscribe to his YouTube Channel at: https://www.youtube.com/c/DrhaciExplains . Learn more at Twitter @GHAgriFoodbio

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CHAPTER OVERVIEW

1: Chapters

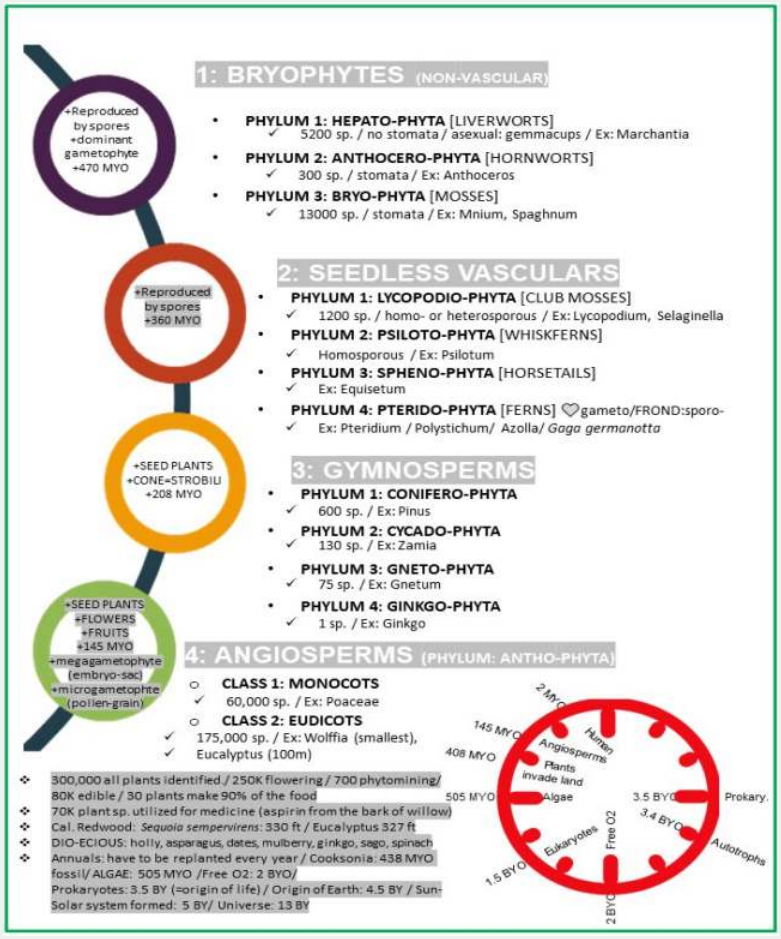
1.1: Plantae Kingdom

Welcome to Plant Biology where all life is dependent on! This book's main focus is learning plant biology. This diverse group of kingdom can go back to 470 million years ago. Green plants synthesize their own food using their special organelles, namely chloroplasts. Green plants demonstrate features including metabolism, **DNA**, emergent properties, regulation, and interaction with environment. Plant growth is a genetically programmed process and is influenced by environment. There is a relationship between structure and function. Moreover, plants have large central vacuoles and cell walls made of cellulose and pectin. There are two phases of life in plants including diploid (2n) sporophyte and haploid (n) gametophyte.

? 1.1.1. Student Learning Outcomes (SLOs)

- **SLO 01.01:** Apply the best practices for learning and mastering plant biology.
- **SLO 01.02:** Describe the reasons we study plants.
- **SLO 01.03:** Distinguish between heterotrophs and autotrophs.
- **SLO 01.04:** Define the 24 hour-(= 4.6 billion years) clock of the Earth.
- **SLO 01.05:** Identify given plant species with their scientific names based on their key features.
- **SLO 01.06:** Explain the differences between monocots and dicots classes.
- **SLO 01.07:** Explain the differences between annuals and perennials.

1.1.2. Big Picture



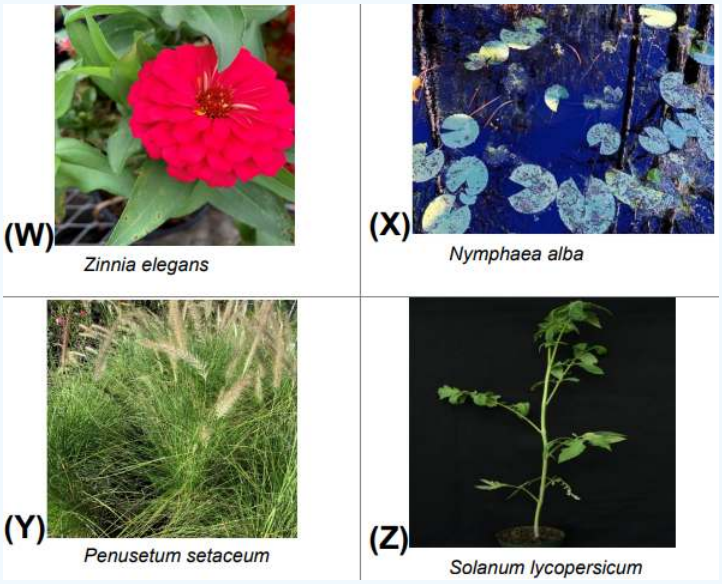
1.1.3. Vocabulary and Key

Botany *(Plant Biology)* 	Study of plants. Branches of biology: Zoology, Botany, Microbiology
Sub-Branches of Botany (Plant bio.)	Plant anatomy, Plant Morphology, Plant Genetics, Plant Physiology, Plant Molecular Biology, Cytology, Ecology
Arabidopsis thaliana	Dicot model organism plant species (n= 5)
Zea mays	Monocot model organism plant species (n= 10)
Duckweed (*Wolffia augusta*)	Smallest flowering plant listed
Bristlecone pine (*Pinus longaeva*)	Oldest living thing listed (~5,000 yrs old)
1-Sequoiadendron giganteum [giant sequoia] nickname= General Sherman ***2-Sequoia sempervirens*** [coast redwood] nickname= Hyperion (just tallest)	Largest plant listed (275 ft [83m] tall X 36 ft [11m] diameter, and 2200 years old). a.k.a. Gen.Sherman located in Sequoia National Park, California, USA). [Skyscrapers→Timessquare3015= 1733m, Kingdom-Tower: 1000m, Shanghai-Tower: 623m, OneWTC=541m, Skyland Istanbul=284m]
Center of origin of plants (N. America)	Sunflower (*Helianthus annuus*), Blueberry (*Vaccinium corymbosum*), and Cranberry (*Vaccinium oxycocco*)
1 lb tea (*Camelia sinensis*)	Can make 300 cups of tea
80,000 plant species	Edible plants (only 2,000 of them used by humans)
30 plant species	Majority used for eating
70,000 medicinal plant species	Gingko (leaf), Ginseng (root), Willow (bark), Aloe (leaf)
15 Anti-Viral plant species 	Astragalus, Cats claw, Calendula, Chaga, Echinacea, Elderberry, Garlic, Ginger, Olive leaf, Oregano.
Rafflesia arnoldii	Largest single flower
Mimosa pudica	Sensitive plant sp. (Fabaceae family)
Cucurbita maxima	Giant Pumpkin (2,295 lb, won the prize of $8,500)

1.1.4. Test Your Knowledge

- Assessment 01.3.1: Provide examples of plant species that provide medicines.
- Assessment 01.3.2: What do plants, algae, and cyanobacteria have in common?
- Assessment 01.3.3: Explain the suggestion you would give to feed the 10 billion world population by 2050.
- Assessment 01.3.4: Explain the importance of green plants and why life is dependent on them.

? 1.1.5. Can You Spot These Plants?



1.1.6.

1. Aloe vera, Neem, Garlic, Nettle, and Lemon balm
2. They all can perform photosynthesis
3. We will need to improve food production $\sim$ **60%** while increasing sustainability
4. Plants and animals are dependent on each other, while both photosynthesis and sun energy makes life possible

1.2: Plant Cells and Tissues

As the building block of living organisms, plant cells were discovered in 1665 by Robert Hooke. Like animals, plants are made of millions of complex eukaryotic cells. Cells make up tissue, and tissue makes up organs, including root, stem, and leaves. Specifically, roots help anchor plants in soil and take up nutrients and water from the soil. The stem is the pathway between the root and leaves, and supports leaves and flowers. Leaves are the main organs that carry out photosynthesis and respiration reactions.

A meristem is the location where the plant grows and differentiates into mature tissue afterward. Therefore, meristems have continuously dividing unspecialized cells. Meristems can be classified under two main groups:

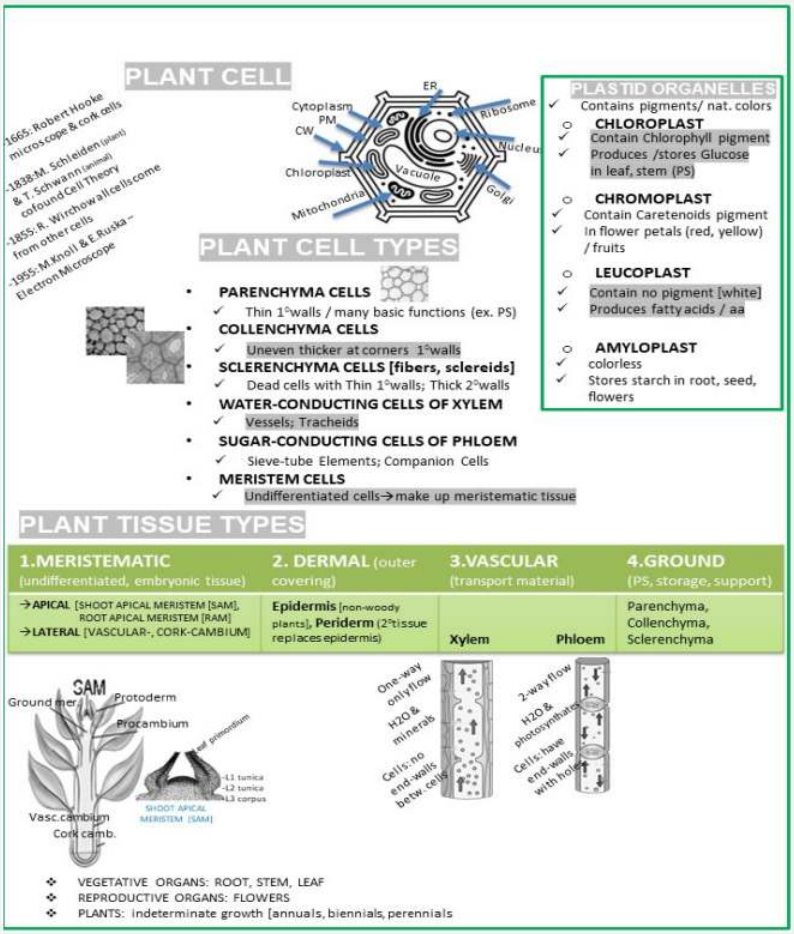
a. **Apical Meristems** (primary growth = length increase via shoot and root tip) [Protoderm / Ground Meristem / Procambium]
b. **Lateral Meristems** (secondary growth = girth increase) [Vascular cambium / Cork cambium]

Finally, tissue growth is very important for root and shoot growth in plants and therefore plays a critical role in agricultural yield.

? 1.2.1. Student Learning Outcomes (SLOs)

- **SLO 02.01:** Apply the best practices for learning and mastering plant cell
- **SLO 02.02:** Identify all organelles (15) of plant cells and their function
- **SLO 02.03:** Distinguish between plant, animal, and bacteria cell
- **SLO 02.04:** Distinguish different plastids such as chloroplasts and amyloplasts
- **SLO 02.05:** Identify given plant species with their scientific names based on their key features
- **SLO 02.06:** Explain the differences between various plant cell types
- **SLO 02.07:** Define the “Cell Theory”

1.2.2. Big Picture



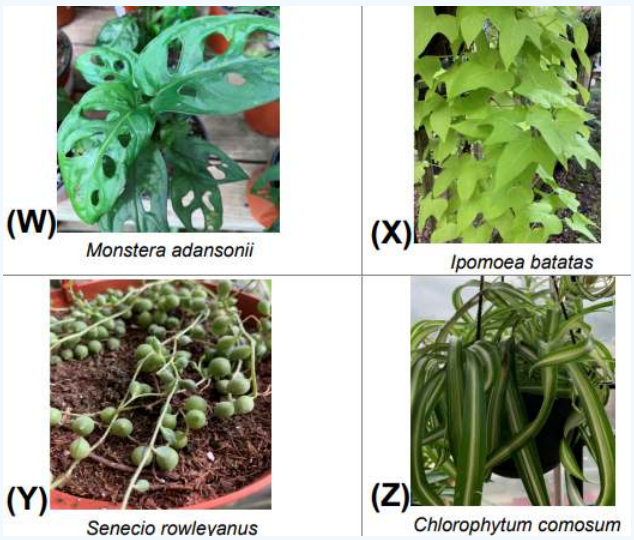
1.2.3. Vocabulary and Key

Orange blossom (*Citrus sinensis*)	Florida state flower
Cell wall (permeable to most molecules)	Found in plant (made of cellulose), fungi (made of chitin /kaytin/), bacteria (made of peptidoglycan), algae
Plasma membrane (PM, semi-permeable and separates living from non-living)	Made of lipid, protein & CH. Diffuse→ rapidly (O_2 & CO_2), Easily (H_2O, methane), w transporters (ions, sugars, aa's)
Cytoplasm (fluid all embedded in from PM to nucleus)	Chemical reactions take place
Chloroplast (food factory uses solar energy)	Plants, Algae, Cyanobacteria (blue-green algae) can carry PS.
Animal: Green sea slug (*Elysia chlorotica*): autotrophic	 Green sea slug: a mollusk that gets chloroplasts from algal food
Plant tissues (Meristematic vs Permanent)	-Meristematic (Epidermis, Parenchyma, Collenchyma, Sclerenchyma) -Permanent (complex = 1+cell type): (xylem, phloem)
Function of meristematic tissues	Protoderm, procambium, and ground meristem
Location / position of meristems (embryonic / undifferentiated regions with continuous active cell division)	Apical meristem (shoot & root tips / Shoot apical meristem SAM, root apical meristem RAM), lateral meristem (thickness of stems /secondary / fascicular, interfascicular vascular cambium, and cork cambium), and intercalary meristem (longitudinal internode growth in grasses)
Cell elongation	Responsible for majority of plant growth, while cell division increases cell# via mitosis
Vascular bundles	xylem (water-conducting) and phloem (food-conducting) tissues
Collenchyma tissue	Such as elongated cells in celery
Sclerenchyma tissue	Classified into fibers and sclereids such as in pears that make it gritty (hardened).
Plant cells >> larger than animal cells	Plant cell size: 0.01-0.1 mm and animal cell size: 0.01–-0.03 mm

1.2.4. Test Your Knowledge

- Assessment 02.3.1: Provide the name of organelles plant cells have but animal cells not.
- Assessment 02.3.2: What animal cell part has similarities to plant cell plasmodesmata?
- Assessment 02.3.3: State the differences between primary and secondary growth.
- Assessment 02.3.4: What are plant cell walls made of?

1.2.5. Can You Spot These Plants?



1.2.6. Check Your Answers

1. Cell walls, chloroplasts, and central vacuole
2. Gap junctions
3. While primary growth is in lengths (elongates), secondary growth is in girth (thickens)
4. Cellulose and pectin

1.3: Root System

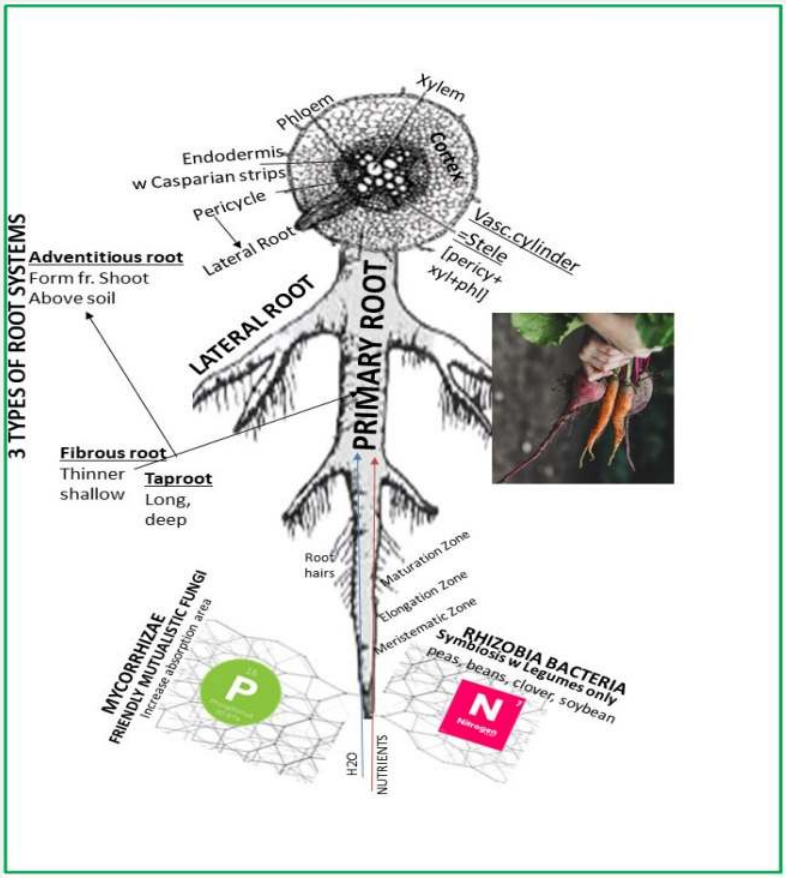
Due to the fact that they are underground, roots don't necessarily get as much appreciation. Root is the underground part of the plant body that provides anchorage and absorption of water and mineral nutrients. Roots originate from the "radicle" part of an embryo in seed. Epidermis is the outermost layer of the root, which is followed by cortex for storage and endodermis. Underneath the endodermis, the next layer is pericycle, which produces lateral roots. The next layer is the vascular tissue, which includes xylem and phloem as innermost parts of the root system. The three regions of the root tip are the meristematic region, the elongation region, and the maturation region. The maturation region is marked with root hairs, whereas the meristematic region is protected by a root cap.

Finally, root tips continuously grow and push through soil throughout plant life. Let's get to the root of plant root system.

1.3.1. Student Learning Outcomes (SLOs)

- **SLO 03.01:** Apply the best practices for learning root system
- **SLO 03.02:** Draw and label three major root systems of Angiosperms
- **SLO 03.03:** Compare the roots of monocots and dicots
- **SLO 03.04:** Explain the differences between apoplastic and symplastic pathways
- **SLO 03.05:** Identify given plant species with their scientific names based on their key features
- **SLO 03.06:** Explain where lateral roots originate
- **SLO 03.07:** Explain how rhizobia works with select plants for providing nitrogen

1.3.2. Big Picture



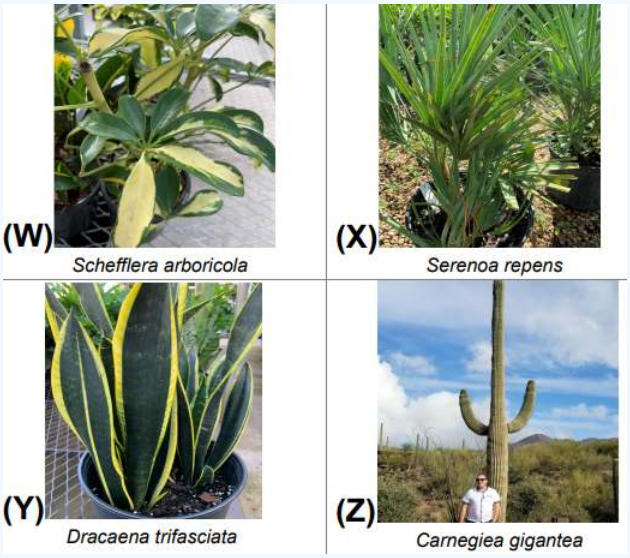
1.3.3. Vocabulary and Key Concepts

Saguaro blossom (*Camegiea gigantea*)	Arizona state flower
Radicle (First root from germination)	The part of embryo where the first root originates from
3 zones of root tip primary growth	Meristematic zone (cell division), elongation zone, and maturation zone (with fully formed xylem, phloem, and root hairs)
Root hairs (elongated /long narrow extension of root epidermal cells)	Absorb water and nutrients from soil with their large surface area
Rhizobia (root association with nitrogen-fixing bacteria)	Legumes plant family has symbiosis with this non-sporous soil bacteria / developing nodular tissue.
Types of Rhizobium and their host plants (all symbiotic invading via root hairs, forming nodules and fixing N while living inside pink nodules)	➢ **Rhizobium** (bean, pea, soybean, chickpea, alfalfa) ➢ **Bradyrhizobium** (parasponia [non-legume evergreen tree]) ➢ **Azorhizobium** (stem and root nodulating) ➢ **Sinorhizobium** (*Medicago sativa* [alfalfa])
Soil (traditional media that provides water and nutrients)	
Hydroponics (roots immersed in nutrient solution)	 Uses 70% less H_2O. Weatherproof. No pesticides. Continuous plant growth. Fast-turn crops: lettuce, arugula, kale, spinach, basil, cilantro, chard, oregano, chives.
Aeroponics (roots dangle in air while mist sprayed to roots)	 Weatherproof. No pesticides. Continuous plant growth.
Aquaponics (fish and plant production combo in hydroponics)	 Weatherproof. No pesticides. Continuous plant growth.

1.3.4. Test Your Knowledge

- Assessment 03.3.1: Provide specific examples of the best plant growth method in Mars
- Assessment 03.3.2: TRUE or FALSE-- Hydroponics increases crop yield 5-fold?
- Assessment 03.3.3: Which plant growth method is more sustainable?
- Assessment 03.3.4: State the differences between soil and hydroponics.

1.3.5. Can You Spot These Plants?



1.3.6. Check Your Answers

1. Although this is still unknown and under research, this may happen in the near future
2. TRUE
3. The growing method that could use more renewable sources together with high yields and environmentally friendly
4. With hydroponics, growers can save water as well as control everything. On the other hand, soil is very important and has much less initial costs

1.4: Shoot System

What is the function of plant shoot system? Plant shoot system of Angiosperms (a.k.a., flowering plants) are composed of stem and stem-attached organs such as leaves, buds, and flowers. The stem of a plant is the primary axis that supports plant leaves and reproductive structures. Furthermore, the stem provides water and minerals to above-ground parts, whereas roots transport photosynthates from source to sink tissues.

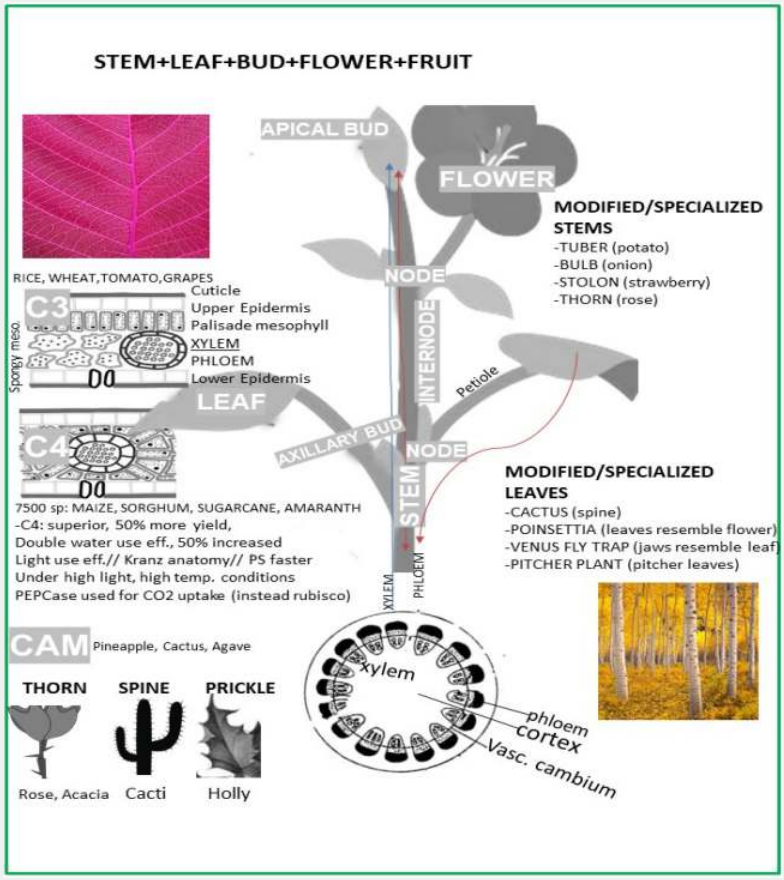
a. *Primary Xylem* [has vessels and tracheids]: produced by procambium then protoxylem and then metaxylem. Transports water and solutes. Their cells are non-living.
b. *Primary Phloem* [has sieve tube elements and companion cells]: produced by procambium. Transports sugars, hormones, and aminoacids from source to sink. Their cells have nucleus.

Leaves are the greenish organ that are considered plant's primary food manufacturing location. Leaves are very diverse in terms of their morphology and architecture. Moreover, leaves are used often in plant identification because of their unique patterns of leaf shape, color, and architectural patterns.

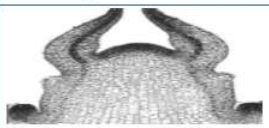
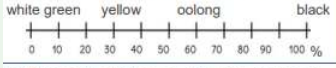
? 1.4.1. Student Learning Outcomes (SLOs)

- **SLO 04.01:** Apply the best practices for learning plant shoot system
- **SLO 04.02:** List basic function of shoot, stem, and leaf
- **SLO 04.03:** Explain why leaves change color
- **SLO 04.04:** Define shoot apical dominance in plants
- **SLO 04.05:** Identify given plant species with their scientific names based on their key features
- **SLO 04.06:** 9. List six major groups of modified stem and modified leaves with examples
- **SLO 04.07:** Draw and label C3, C4, and CAM leaves according to the photosynthesis type

1.4.2. Big Picture



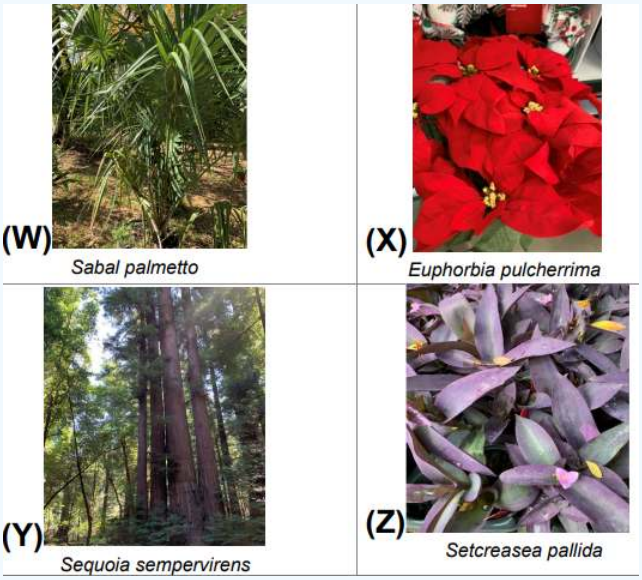
1.4.3. Vocabulary and Key Concepts

Peach blossom (*Prunus persica*)	Delaware state flower
Shoot system (stems + leaves + buds + flowers + fruits)	All above ground parts of plant body (erect, horizontal, or climbing)
Primary growth (caused by shoot apical meristem [SAM]) and **Secondary Growth** (caused by lateral meristems)	 PRIMARY: epidermis, cortex, xylem, and phloem SECONDARY: wood and bark
Stem (made of alternating internodes and nodes→where leaf attached)	 internode node internode
Leaf 	**Fall:** the name originally came from falling leaves **Red** (Anthocyanin): red maples, red sumacs, scarlet oaks, blueberries, grapes **Orange** (Carotene): sugar maples, carrots **Yellow** (Xanthophyll): beeches, ashes, birches, aspens, some oaks **Brown** (Tannin): some oaks
Primary xylem (differentiates from procambium)	Protoxylem: First formed xylem. Contain smaller / narrower elements Metaxylem: Formed later. Contains larger /broader elements.
Primary phloem (differentiates from procambium)	Protophloem Metaphloem
Stoma (singular pore) **Stomata** (plural collection of pores)	**Opens:** Gas exchange for PS. Light. K^+ in guard cells (GC), water in GC. **Closes:** Dark. Flaccid GC. Retain H_2O.
***Camellia sinensis* leaf oxidation %** 	➢ Black tea (max oxidized: cells broken down with rolling machine and let oxidized for 1/2 hr darken and flavor development)
Caffeine (plant-based alkaloid stimulant)  1 cup	➢ 100 mg: in espresso/ latte / cappuccino ➢ 80 mg: in coffee ➢ 30 mg: in black tea ➢ 30 mg: in green tea ➢ 6 mg: in decaf coffee ➢ 3 mg: in decaf tea ➢ 0 mg: in herbal tea

1.4.4. Test Your Knowledge

- Assessment 04.3.1: TRUE or FALSE: The biggest leaf known belongs to Raffia palm.
- Assessment 04.3.2: TRUE or FALSE: Carnivorous plants have modified leaves for capturing small animals to digest and get N.
- Assessment 04.3.3: Compare and contrast monocot leaves and dicot leaves.
- Assessment 04.3.4: Explain how p-proteins protect phloem as damage control.

1.4.5. Can You Spot These Plants?



1.4.6. Check Your Answers

1. TRUE
2. TRUE
3. While monocot leaves have parallel arrangement, dicot leaves have web-like arrangement
4. P proteins are also known as “phloem-specific proteins” seal off by plugging damaged sieve element location

1.5: Systematics

How can we best conserve plant biodiversity? Systematics, a combination of taxonomy and phylogenetics, is critically important in plant biology. It helps us to categorize plants and understand natural diversity. Each plant species has a common name and a scientific name. Scientific names are in Latin and binomial, as follows:

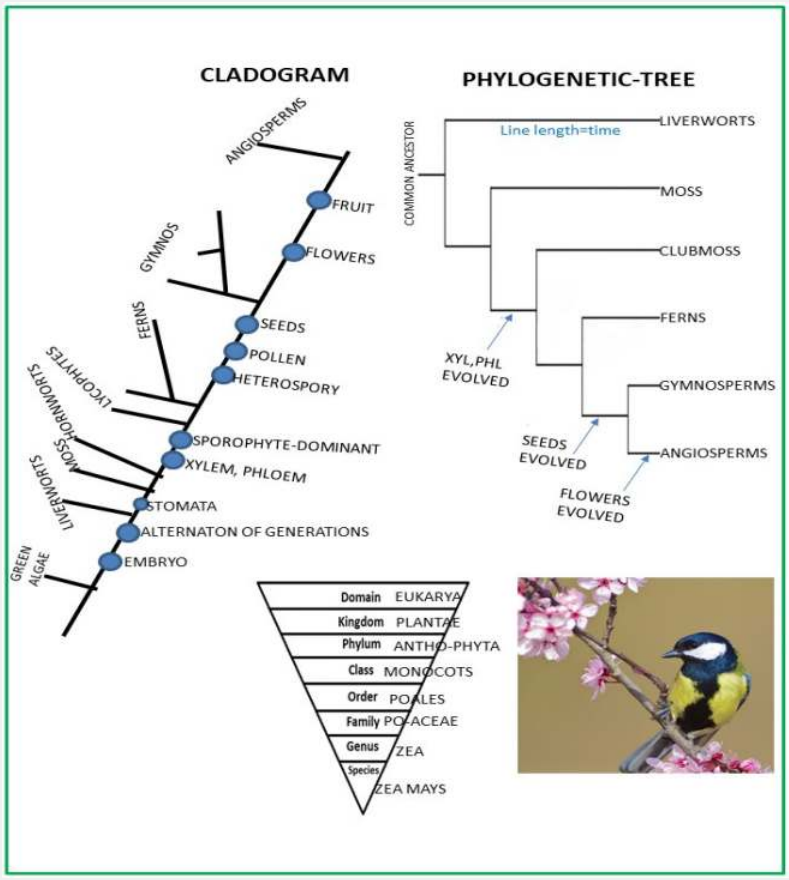
Common name:	**Pea**
Scientific name:	***Pisum sativum***
Family:	**Fabaceae**
Class:	**Dicot**
Varieties:	**garden peas, snow peas, snap peas**

Systematics uses cladograms (mostly morphological characteristics) and phylogenetic trees (morphological plus genetic characteristics). Phylogenetic trees (a.k.a., evolutionary trees) are used in comparing plant species in evolutionary time and distance. Finally, two plant species are considered more related if the phylogenetic tree shows a more recent ancestor.

? 1.5.1. Student Learning Outcomes (SLOs)

- **SLO 05.01:** Apply the best practices for learning systematics
- **SLO 05.02:** Explain binomial system
- **SLO 05.03:** Distinguish between phylogenetic trees and cladograms
- **SLO 05.04:** Distinguish between homologous vs analogous characters
- **SLO 05.05:** Identify given plant species with their scientific names based on their key features
- **SLO 05.06:** Explain the differences between ancestral and derived features
- **SLO 05.07:** Diagram a typical plant cladogram

1.5.2. Big Picture



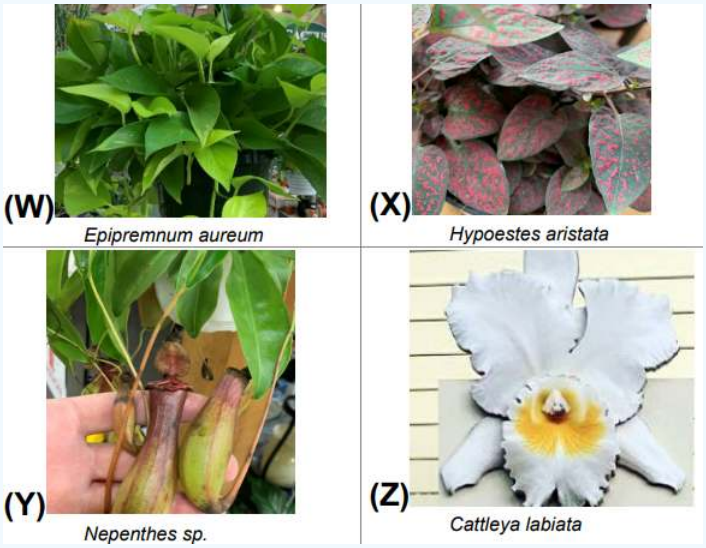
1.5.3. Vocabulary and Key Concepts

Azalea (*Rhododendron*)	Georgia state wildflower
Universe Timeline (13.8 billion yrs)	• 13.8 billion yrs: The Universe, Time begin • 4.5 billion yrs: Earth's origin • 3.5 billion yrs: Life origin (oldest known fossils) • 3.4 billion yrs: Autotrophs • 2.1 billion yrs: Eukaryotes • 2 billion yrs: free O_2 develops in atmosphere • 505 million yrs: Algae • 408 million yrs: Plants invade land • 250 million yrs: Dinosours • 200 million yrs: Mammals • 145 million yrs: Angiosperms • 500 thousand yrs: *Homo sapiens* (1st intelligent h.) • 10 thousand yrs: Agriculture • 5 thousand yrs: Writing • **1st Industrial revolution** (18th century- mechanization of textile industry using machinery, water & steam) • **2nd Industrial revolution** (19th century- mass production using steel, oil, electricity) • **Industry 3.0** (20th century- automated production using electronics, computers, space travel) • **Industry 4.0** 21th century- autonomous decision-making cyber systems, IoT, networks, 3D/4D/5D printing)
Systematics	Study of biological diversity (taxonomy) and evolutionary relationship (phylogeny) among them.
Plant systematics uses	• Plant morphology • Fossil records • Sequences (DNA, RNA, aminoacid)
Ancestral features / traits	Character that originated in the ancestor of taxon.
Derived features / traits	Present in modern organisms but absent in their ancestors. • Alternation of generations • Apical meristems • Mycorrhizae • Cuticle • Multicellular archegonia and antheridia • Sporocytes produce spores via meiosis
Homologous traits	Any traits descended from a common ancestral structure • Thorn of Bougainvillea and tendril of cucumber
Analogous traits	From different groups but having similar function • Thorn of Bougainvillea and spine of cactus
Systema Naturae (1735 1e, 1759 10e)	Written by C. Linnaeus listed 11,000+ species (stones, 7000 plants, 4400 animals)
Species Plantarum (1753)	Written by C. Linnaeus listed description of 6000 plant sp. and their binomials.

1.5.4. Test Your Knowledge

- Assessment 05.3.1: TRUE or FALSE: Carl Linnaeus first proposed the systematics.
- Assessment 05.3.2: TRUE or FALSE: Clades arose before are named "basal".
- Assessment 05.3.3: Provide similarities between cladogram and phylogenetic tree.
- Assessment 05.3.4: List specific characteristics of model plant Arabidopsis thaliana for plant biology.

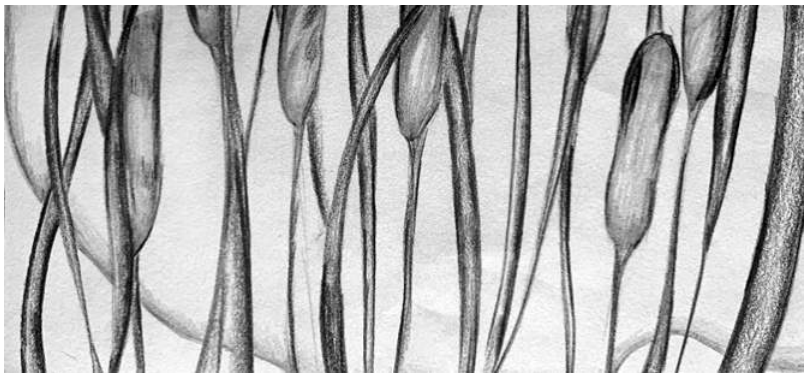
1.5.5. Can You Spot These Plants?



1.5.6. Check Your Answers

1. TRUE
2. TRUE
3. They are used interchangeably. While phylogenetic tree's branch length may be considered important indicator of time / change, cladograms missing this
4. Short generation time. Small genome and mapping completed. Availability of many variants. Easy to grow in the lab

1.6: Algae (Protista Phylum)



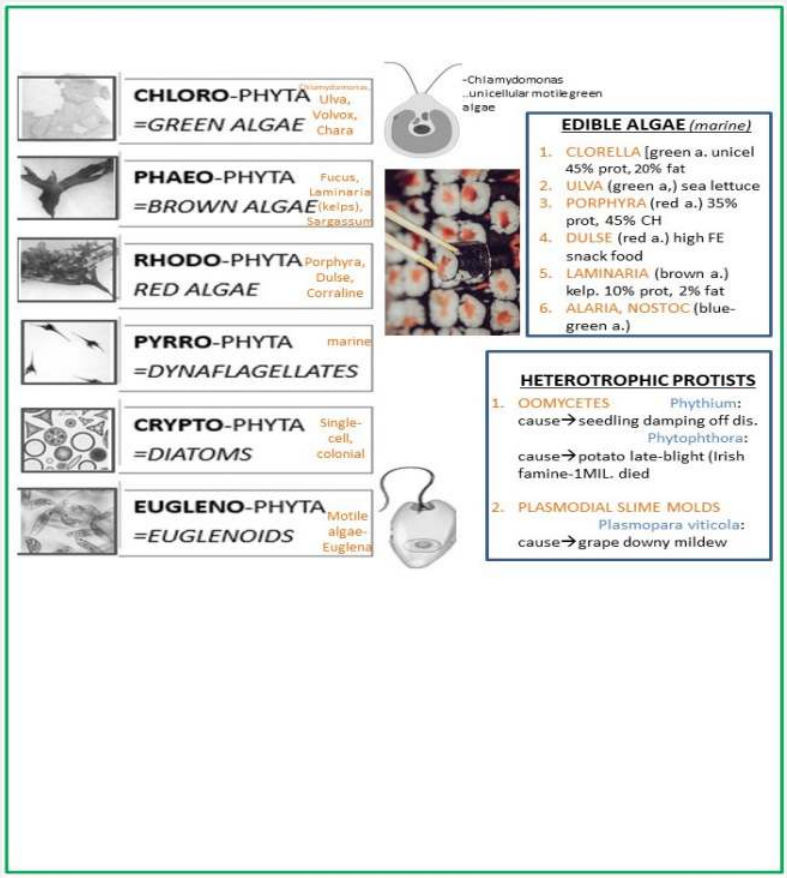
How would algae contribute to the future of food? There is an increasing interest in seaweed, a common name for macro marine algae such as brown, red, and green algae. Moreover, algae may be able to help to future food security since they are rich in nutrients as well as protein content. They could be used in many human diet areas including snacks, sushi, salads, soups, and vegetarian protein source.

One example is red algae species *Porphyra yezoensis* that is commonly used in sushi rolling and contains about 47% protein content.

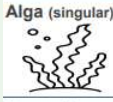
1.6.1. Student Learning Outcomes (SLOs)

- **SLO 06.01:** Apply the best practices for learning algae
- **SLO 06.02:** Describe the main characteristics of Kingdom Protista
- **SLO 06.03:** Distinguish between macro and micro algae
- **SLO 06.04:** Distinguish between Chlamydomonas and Euglena
- **SLO 06.05:** Identify given plant species with their scientific names based on their key features
- **SLO 06.06:** Describe the main characteristics of heterotrophic fungi-like protists
- **SLO 06.07:** Provide examples to phylums of Chloro-, Phaeo-, and Rhodo-phyta

1.6.2. Big Picture



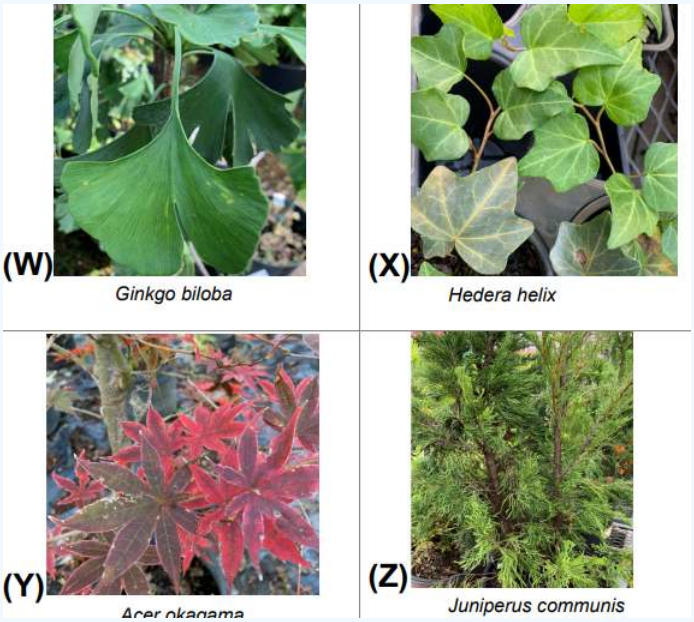
1.6.3. Vocabulary and Key Concepts

Violet (*Viola*)	Illinois state flower
Alga (singular) and **Algae** (plural) 	Belong to Kingdom: Protista with 20,000+ spp. Live in moist environments and non-vascular, no true roots, true stems, or true leaf.
Algae characteristics 	• Unicellular, filamentous, colonial, and some multicellular • World's 50% of all O_2 production • Sexual and asexual reproduction • Have nucleus, starch grains, oil, and vacuole • Marine, freshwater, and some terrestrial
Algae pigments (colorful compounds)	• Chlorophyll (green) • Carotenoids (yellow, red, or orange) • Phycobilins (red or blue in red algae) • Phycocyanin (light-blue) • Phycoerythrin (red) • Fucoxanthin (brown)
Phytoplankton (microscopic algae) 	A variety of plant-like photosynthetic organisms such as: • Diatoms • Dinoflagellates
Seaweeds (macroscopic marine algae) 	Macro-algae with thallus (body) includes: • Brown algae • Red algae • Green algae
Algae products (Vegan) 	• FOOD: Chlorella (high protein content), snacks • NUTRIENTS: rich in Iodine, Omega-3-FA • BIOPLASTICS • BIOFUEL / ENERGY: e.g. *Nannochloropsis salina* (60% oil) • PHARMACEUTICALS: e.g. *Haematococcus pluvialis* (high antioxidant content), Spirulina • COSMETICS: algae pigments • FEEDSTOCK: for fish, pets • BIO-FERTILIZER

1.6.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: The part that attach algae to its substrate is called "holdfast."
- Assessment 2: TRUE or FALSE: Gel-like lab product that originally comes from red algae is called "agar."
- Assessment 3: Provide evidence that green algae is the ancestor of green plants.
- Assessment 4: List the potential of algae as future super-food.

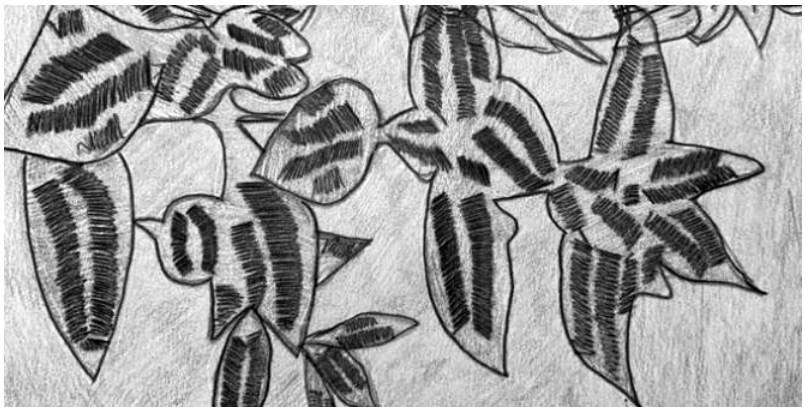
1.6.5. Can You Spot These Plants?



1.6.6. Check Your Answers

1. TRUE
2. TRUE
3. This can be explained by the similarities between green algae and plants
4. Algae definitely has a great potential for future food because of many reasons including high content of protein, minerals, vitamins, as well as its resilience to environmental stress

1.7: Bryophytes



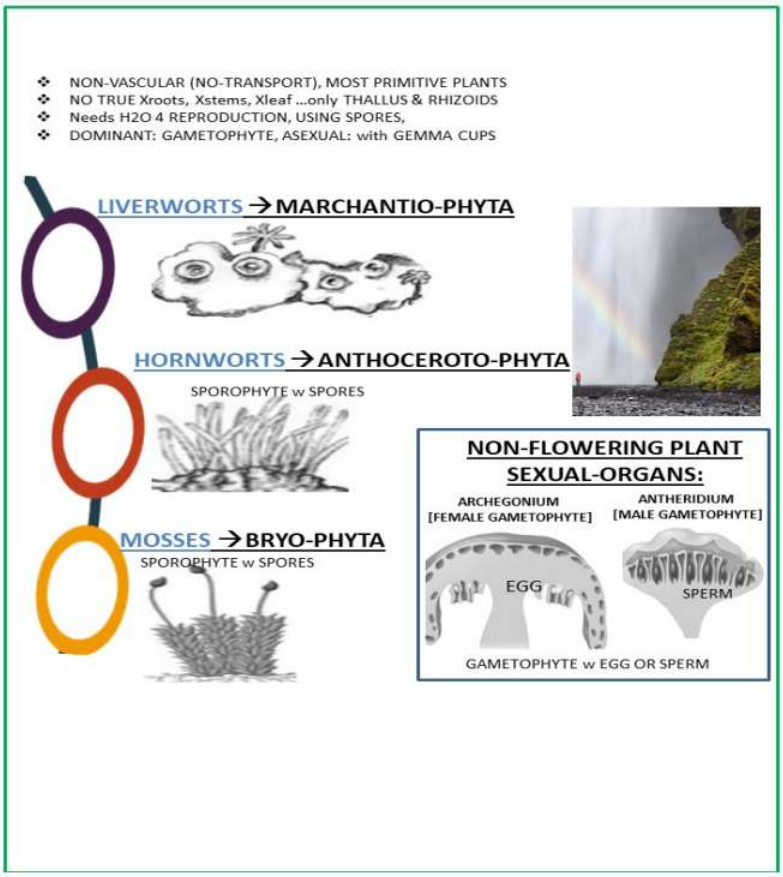
Bryophytes are low key plants with one major requirement, which is water due to their non-vascular anatomy. In return, bryophytes play an important role in soil biodiversity including erosion prevention and water absorption from heavy rainfalls.

By going back to over 450 million years, bryophytes are considered the most ancient Plantae group with no true roots. Furthermore, bryophytes are considered great pioneer plant species together with lichens.

1.7.1. Student Learning Outcomes (SLOs)

- **SLO 07.01:** Apply the best practices for learning bryophytes
- **SLO 07.02:** Describe the characteristics of phylum Marchantiophyta
- **SLO 07.03:** Describe the characteristics of phylum Anthocerotophyta
- **SLO 07.04:** Describe the characteristics of phylum Bryophyta
- **SLO 07.05:** Identify given plant species with their scientific names based on their key features
- **SLO 07.06:** Explain the differences between archegonium and antheridium
- **SLO 07.07:** Identify gemma cups

1.7.2. Big Picture



1.7.3. Vocabulary and Key Concepts

Sunflower (*Helianthus annuus*) 	Kansas state flower
Bryophytes 	• Most primitive plants with 2,000 spp. • They live in moist areas (amphibian plants: lives both on land and in water) • Non-vascular • Their life cycle dependent on H_2O • Together with algae, mosses and liverworts can live in Antarctica
Archegonia (F) and Antheridia (M) Gametophytes	Reproductive organs of non-flowering plants including Bryophytes and Ferns. • Archegonium (singular) has egg (female gametophyte) • Antheridium (singular) has sperm (male gametophyte)
Sphagnum (peat moss) 	• Occupies 1% of the Earth's surface • Has 300 spp. • Used for fuel and retaining H_2O in soil

1.7.4. Test Your Knowledge

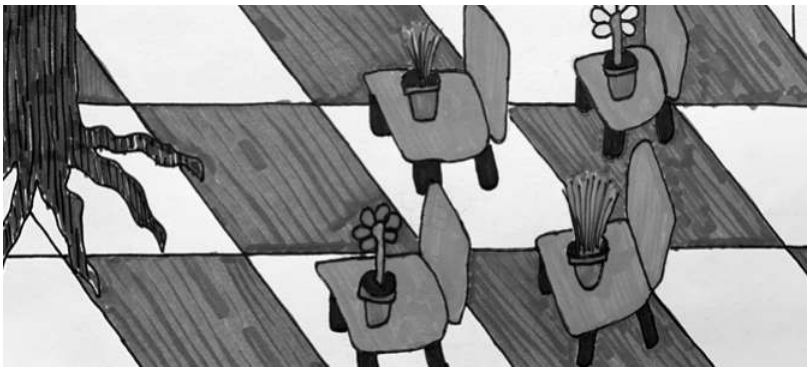
- Assessment 1: TRUE or FALSE: Bryophytes have alternation of generations.
- Assessment 2: TRUE or FALSE: Bryophytes are small plants with 1-2cm height.
- Assessment 3: TRUE or FALSE: Asexual reproduction is carried out by gemmae cups.
- Assessment 4: TRUE or FALSE: Mosses can grow in acidic and high salinity soils.

? 1.7.5. Can You Spot These Plants?

? 1.7.6.

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.8: Seedless Plants



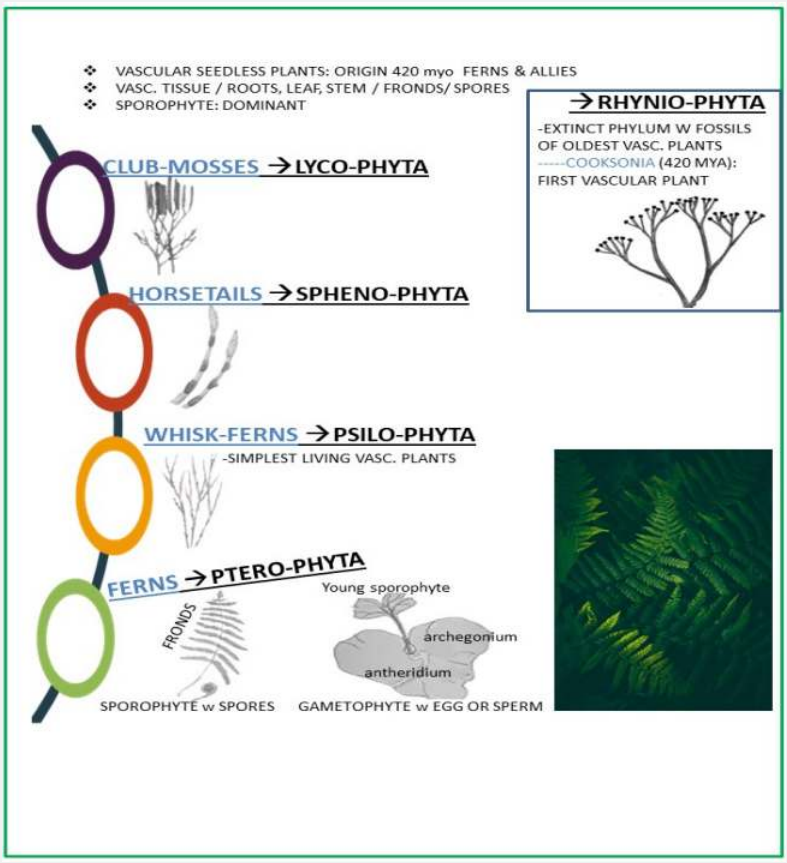
Before seedless citrus or grapes, there were seedless vascular plants existed over 360 million years ago. They use spores for reproduction instead of cones or flowers. For example, whisk ferns (*Psilotum nudum*) are seedless, rootless, leafless ancient vascular plants that carry out photosynthesis via their green stems. Ferns are perennial seedless vascular plants and good at purifying air around them as well as accumulating heavy metals.

Ferns are seedless but they do have sexual reproduction using underside sori spots that are packages of spores. On behalf of flower, they use a large heart-shaped gametophyte with eggs and sperm.

1.8.1. Student Learning Outcomes (SLOs)

- **SLO 08.01:** Apply the best practices for learning seedless vascular plants
- **SLO 08.02:** Describe the characteristics of phylum Lycophyta
- **SLO 08.03:** Describe the characteristics of phylum Sphenophyta
- **SLO 08.04:** Describe the characteristics of phylum Psilophyta
- **SLO 08.05:** Describe the characteristics of phylum Pterophyta
- **SLO 08.06:** Identify given plant species with their scientific names based on their key features
- **SLO 08.07:** Explain how seedless plants reproduce

1.8.2. Big Picture



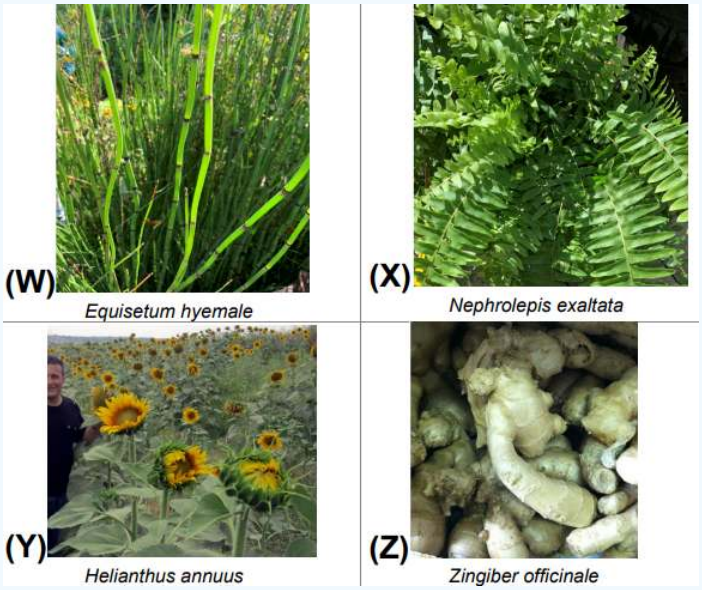
1.8.3. Vocabulary and Key Concepts

Magnolia (*Magnolia*) 	Louisiana and Mississippi state flower
Seedless Vascular Plants: FERNS 	• FERNS: 20,000 spp. vascular plants with no seeds (spore bearing) • Sporophytes (2n)→produce spores and is the dominant generation • Gametophyte / prothallus (n) in heart-shape→produce gametes (archegonia and antheridia) • Have true roots, stems (underground), leaves (fronds with pinna and underneath sori / spores), xylem, and phloem
Seedless Vascular Plants: PSILOTUM 	• *Psilotum nudum*: a lower vascular plant with only stem, underground stem /rhizome (no leaf, root) • Vascular: xylem, phloem, and stoma in protostele • Branches dichotomously • Yellow sporangia on branches
Fern Products	• Metal hyperaccumulator: Arsenic • Bio-fertilizer (N-fixing): *Azolla* fern • Human Food: e.g., fiddleheads of specific ferns. Also Dryopteris (woodfern) used as tea. • Boston ferns used as air filters to purify air and increase humidity • Used as ornamental plants

1.8.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Leaves of lycophytes are microphyll.
- Assessment 2: TRUE or FALSE: The fern sporangia cluster is named sorus.
- Assessment 3: Explain the usage of ferns for phytoremediation.
- Assessment 4: TRUE or FALSE: There are shade-loving tree ferns can grow 30 ft. tall and live 500 years in Australia.

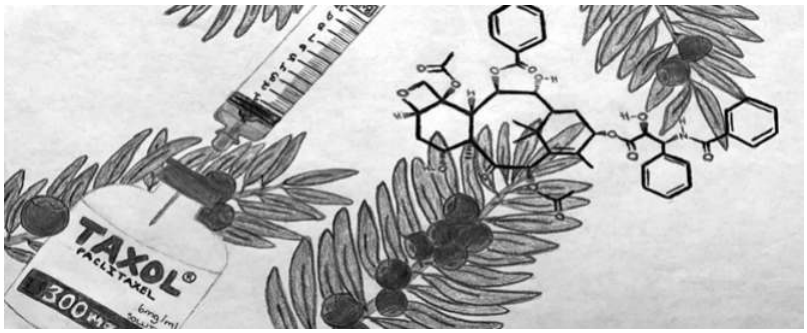
1.8.5. Can You Spot These Plants?



1.8.6. Check Your Answers

1. TRUE
2. TRUE
3. It has been shown that certain fern varieties can remove heavy metals from soil such as arsenic
4. TRUE

1.9: Gymnosperms (Cone Bearing)



Gymnosperms are one of the ancient plant groups with seed production. They are a group of vascular plants with naked (without ovary) seeds. Gymnospems are also heterosporous. Furthermore, gymnosperms produce two different types of cones, namely, large female cones and small male cones. Four groups of gymnosperms are known:

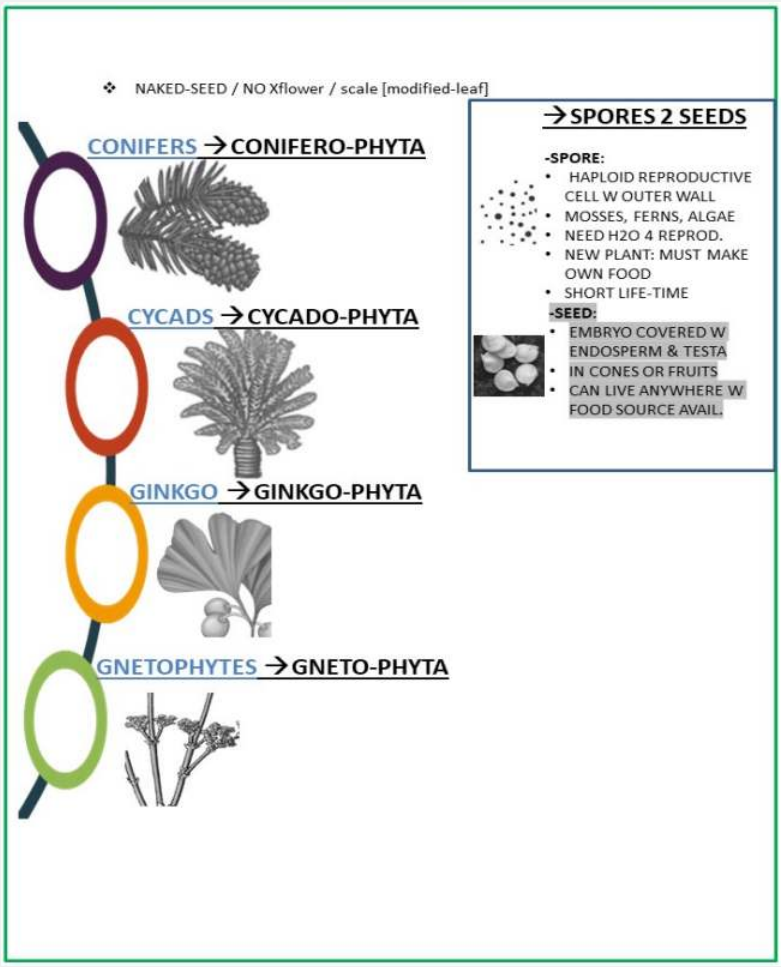
1. **CYCADOPHYTA:** 100 cycad species (cycad, sago palm)
2. **GINKGOPHYTA:** 1 plant species (ginkgo)
3. **GNETOPHYTA:** e.g., ephedra
4. **CONIFEROPHYTA:** 500 species (pine, fir, cedar, juniper, redwoods)

They date back to 250 million years ago. Coniferophyta consists of largest, tallest, and oldest living trees.

1.9.1. Student Learning Outcomes (SL

- **SLO 09.01:** Apply the best practices for learning Gymnosperms
- **SLO 09.02:** Describe the characteristics of phylum Coniferoophyta
- **SLO 09.03:** Describe the characteristics of phylum Cycadophyta
- **SLO 09.04:** Describe the characteristics of phylum Ginkgophyta
- **SLO 09.05:** Identify given plant species with their scientific names based on their key features
- **SLO 09.06:** Describe the characteristics of phylum Gnetophyta
- **SLO 09.07:** Explain the differences between spores and seeds?

1.9.2. Big Picture



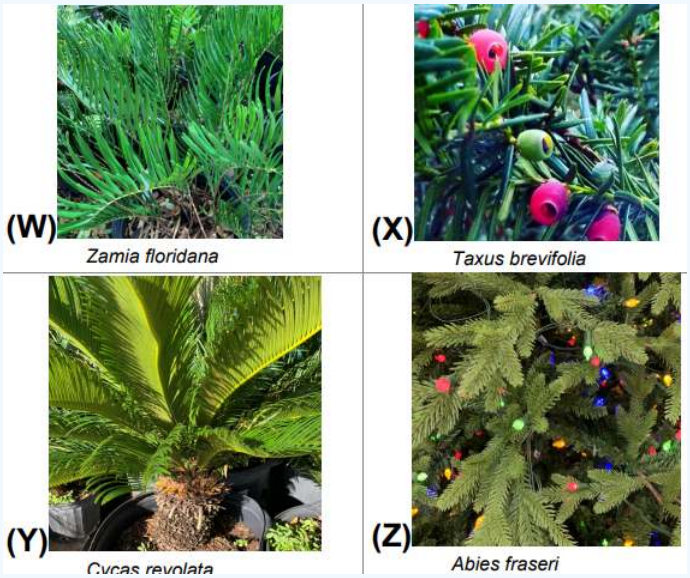
1.9.3. Vocabulary and Key Concepts

Mayflower (*Epigaea*)	Massachusetts state flower
SEED DEVELOPMENT 	• SEED: A small unit of plant that is mature fertilized ovule, has embryo covered with testa (seed coat) • They can be disseminated widely and contain nutrition for the future plant • Endosperm: The food supply of the seed • Epicotyl: Becomes shoot • Radicle: Becomes root
SEED CONES (F)	• Female strobilus / cone carries the seed in scales • Forms more upper part of the trees (easier seed dispersal)
POLLEN  (wind-pollinated)	• Sperms form in pollen • Pollen forms in small pollen cones (staminate cone)
GYMNOSPERMS 	• Tallest, oldest living organisms that make over 30% of the forests • *Zamia integrifolia*: A Florida native cycad
Ginkgo biloba 	• A dioecious plant, male more common • Fan-shape leaves • *Ginkgo biloba*: Single living sp. • Leaf: Medicinal, and resistant to diseases, and insects. • Helps memory, improve circulation

1.9.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Cycads are diecious plants.
- Assessment 2: TRUE or FALSE: Discovery of seed increased success of land plants.
- Assessment 3: Provide specific function for sunken stomata of pine needles.
- Assessment 4: TRUE or FALSE: Most common gymnosperm phylum is conifers.

1.9.5. Can You Spot These Plants?



1.9.6.

1. TRUE
2. TRUE
3. Sunken stomata can help with plant water conservation in pine trees
4. TRUE

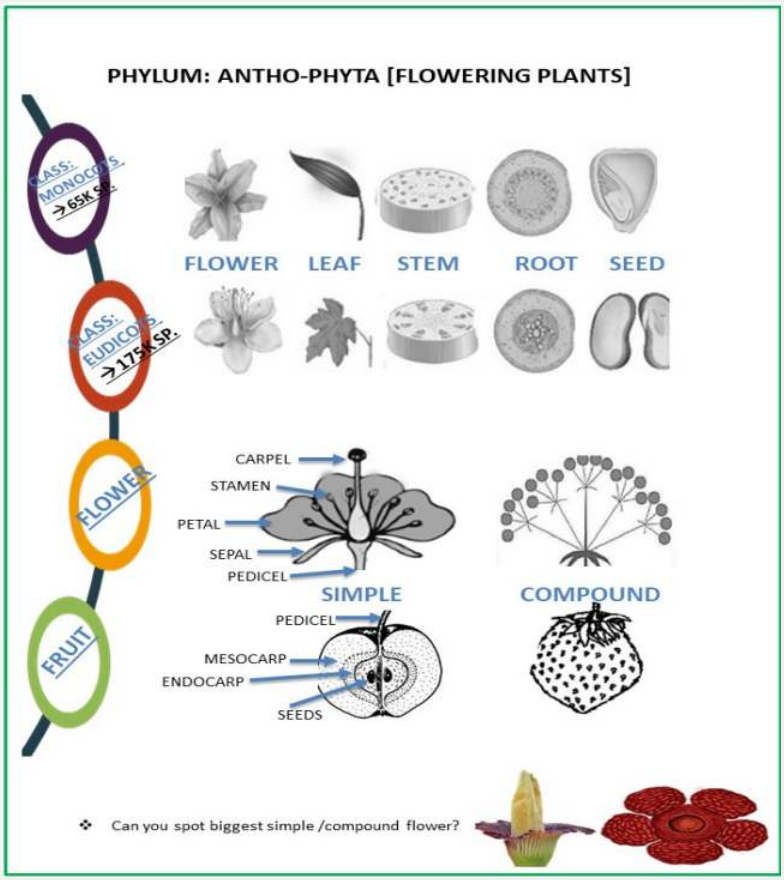
1.10: Flowers, Fruits, and Seeds (Flowering Angiosperms

Dating back to 140 million years ago, flowering plants (angiosperms) evolved and make 80% of today's plants including Arabidopsis. Flowers are the colorful reproductive components of angiosperms (flowering plants). Complete flowers consist of four parts, namely: sepals, petals, stamens, and carpel(s). Pollination is the movement of pollen from stamen to stigma. If pollination occurs with the plant's own stigma, it is called self-pollination. On the other hand, if it occurs with a different plant stigma, it is called cross pollination. Pollen grains are male gametophytes, while the embryo sac is the female gametophyte. Pollinators most commonly used are insects, birds, and the wind. *Rafflesia arnoldii*, as well as *A. titanium* (Titan arum), are considered the largest single flowers found in any plants.

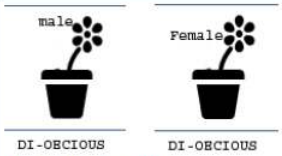
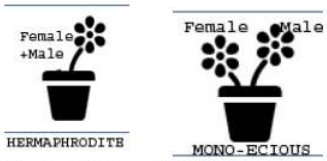
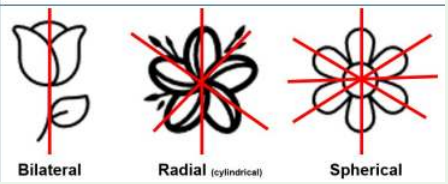
? 1.10.1. Student Learning Outcomes (SLOs)

- **SLO 10.01:** Apply the best practices for learning angiosperms
- **SLO 10.02:** Describe the characteristics of phylum Anthophyta
- **SLO 10.03:** Distinguish between monocot and edicot (dicot) classes
- **SLO 10.04:** Explain how annuals, biennials, and perennials differ
- **SLO 10.05:** Identify given plant species with their scientific names based on their key features
- **SLO 10.06:** Explain the differences between monocots and dicots classes
- **SLO 10.07:** Distinguish between ovary positions of flowers

1.10.2. Big Picture



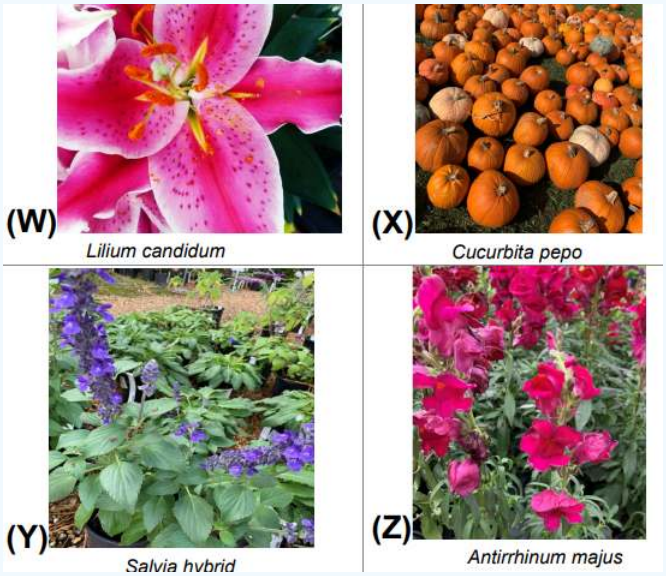
1.10.3. Vocabulary and Key Concepts

Top 5 Plant Families **(240,000 flowering plant sp.)**	**-Po-aceae** (Grass): rice, wheat, maize, oats, sorghum, barley (11,000sp; 50% human calories) **-Fab-aceae** (Legumes, fix up to 200 lb. "N"/acre by Rhizobium bacteria): bean, soybean, pea, chickpea, lentil, peanut, alfalfa, lupins, clover, vetch **-Brassic-aceae** (Cabbage family): cabbage, canola, kale, broccoli, cauliflower, wasabi, arugula, turnips **-Ros-aceae** (Rose family): apples, pears, quince, roses, strawberries, hawthorn, almond, apricot, cherry, peach **-Solan-aceae** (Potato family): potato, tomato, pepper
Hawthorn (*Crataegus*)	Missouri state flower
Imperfect flowers (6% of angiosperms) *Dioecious*= F & M unisexual flowers develop at different individual plants (e.g. papaya, asparagus, ginkgo)	 [like in mammals, birds]
Perfect flowers (self-sufficient) *Monoecious*= F & M flowers develop at different parts of the same plant. (e.g. maize, pumpkin, oak) *Hermaphrodite*= F & M flowers develop at the same flower.	 [like in earthworms, jellyfish]
Monocot flowers	3 sepals + 3 petals [like in maize, tulip]
Dicot flowers	4-5 sepals + 4-5 petals [like in Arabidopsis]
Flower symmetry Bilateral = having 1 symmetry plane Radial = having 3 symmetry planes Spherical = having multiple symmetry planes	

1.10.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Sunflowers moves their head from east to west daily to point to the sun.
- Assessment 2: Compare and contrast pollination and fertilization.
- Assessment 3: Compare and contrast the gametophytes of male and female in angiosperms.
- Assessment 4: Compare and contrast the flowers of monocots and dicots.

? 1.10.5. Can You Spot These Plants?



1.10.6.

1. TRUE
2. While fertilization is a cellular process of fusion of gametes, pollination is limited with transfer of pollen to stigma only
3. While male gametophyte has 3 cells, female gametophyte has 7 cells
4. While monocot flowers parts are in 3s, dicot flower parts are in 4s / 5s

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1.11: Plant Hormones

Plant growth regulators (phytohormones) are small organic molecules that occur naturally in plants. Phytohormones can regulate plant physiological growth processes such as flowering, germination, stem elongation, seed dormancy, fruit ripening, and gene expression.

There are several phytohormones such as gibberellic acid (GA_3) can increase stem growth parameters. Moreover, ethylene can affect fruit ripening in bananas.

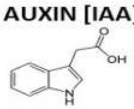
1.11.1. Student Learning Outcomes (SLOs)

- **SLO 11.01:** Apply the best practices for learning phytohormones
- **SLO 11.02:** Describe the characteristics of Auxins and Cytokinins
- **SLO 11.03:** Describe the characteristics of Gibberellins and ABA
- **SLO 11.04:** Describe the characteristics of Ethylene and Salicylic acid
- **SLO 11.05:** Identify given plant species with their scientific names based on their key features
- **SLO 11.06:** Explain the differences between natural and synthetic phytohormones
- **SLO 11.07:** Explain the reason why ABA is named as a stress hormone

1.11.2. Big Picture

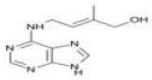
-NATURAL OR SYNTHETIC PLANT GROWTH REGULATORS

1. AUXIN [IAA]: PROMOTES—CELL ENLARGEMENT



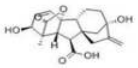
-PRODUCED @SAM
-PROMOTE ROOT INITIATION, FLOWERING, XYLEM DIFFERENTATION, BENDING OF STEMS, APICAL DOMINANCE

2. CYTOKININS [KINETIN]: PROMOTES—CELL DIVISION



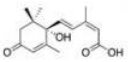
-MADE IN ROOTS
-SHOOT FORMATION // ACTIVATE PHOTOSYNTHESIS
-REMOVE APICAL DOMINANCE// DELAY SENESCENCE (BIOLOGICAL AGING=SENESCENCE)

3. GIBBERELLINS [GA3]: PROMOTES—INTERNODE ELONGATION



-BREAKS DORMANCY
-ENZYME MOBILIZATION @GERMINATION
-FLOWERING, FRUIT DEVELOPMENT
-CAUSE TALLER PLANTS

4. ABSCISIC ACID [ABA]: INHIBITS– CAUSE DORMANCY, STOMA CLOSE



-INHIBITS GERMINATION, OTHER HORMONES
-SUPRESSION FLOWERING, GROWTH, CELL ELONGATION
-ABCISSION (FALLING) OF LEAF

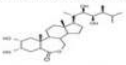
5. ETHYLENE [C2H4]: INHIBITS—SENESCENCE, FRUIT RIPENING

-INHIBITS CELL ELONGATION

6. SALICYLIC ACID [SA]: PROMOTES—DEFENSE// ASPIRIN-LIKE COMPOUND

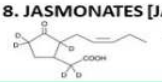
-FROM BARK OF WILLOW TREE
-SYSTEMIC ACQUIRED RESISTANCE (PLANT IMMUNE RESPONSE)

7. BRASSINOSTEROIDS: PROMOTES—CELL ELONG/ CELL DIV// STRESS RESISTANCE



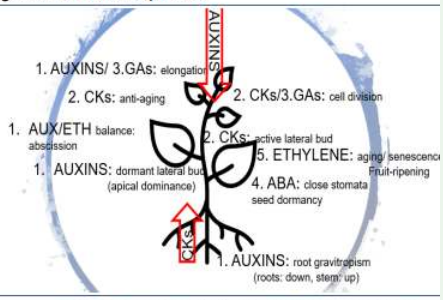
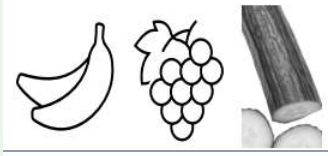
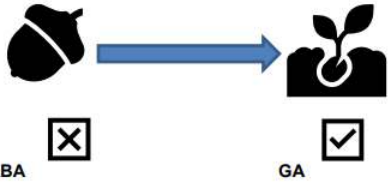
-STEM, POLLEN-TUBE ELONGATION

8. JASMONATES [JA]: REGULATES—PL. RESPONSE TO ABIOTIC STRESS



-PLANT DEFENSE, GROWTH, PS, GENE TRANSCRIPTION

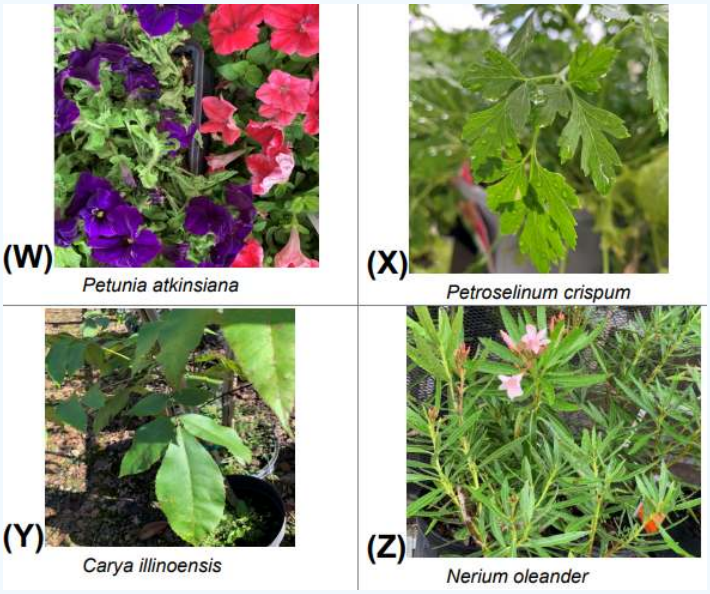
1.11.3. Vocabulary and Key Concepts

Yucca flower (*Yucca*)	New Mexico state flower
Phytohormones (plant hormones, growth bioregulators)	Plant naturally produced organic compounds and signal molecules that influences plant physiology, germination, growth, and development.
Functions of plant hormones (promotes or inhibits)	
Commercial usage of artificial (synthetic) plant hormones 	• Promote root growth in plant cuttings (auxins) • Parthenocarpy: Development of fruit w/out fertilization. Producing seedless fruits by spraying auxins on flowers. • Perfectly ripening fruits such as bananas, mangos, and avocadoes • Create larger fruits (GAs) • Selective weedkillers to break hormone balance and cause weeds to die (synthetic auxins) • Stimulating germination (GAs)
Seed Germination (GA/ABA ratio) **ABA:** cause dormancy (prevents germination) **GA:** break dormancy (promotes germination)	

1.11.4. Test Your Knowledge

- Assessment 11.3.1: TRUE or FALSE: Phytohormones affect plant development process [growth + differentiation]
- Assessment 11.3.2: TRUE or FALSE: Brassinosteroids act locally.
- Assessment 11.3.3: Define seed dormancy and provide a specific function for plants.
- Assessment 11.3.4: TRUE or FALSE: GAs promote bolting (flowering and flower stalk)

1.11.5. Can You Spot These Plants?



1.11.6. Check Your Answers

1. TRUE
2. TRUE
3. Seed dormancy causes not germination of viable seeds even under favorable conditions. Seed dormancy is survival mechanism of controlling germination.
4. TRUE

1.12: Genetics

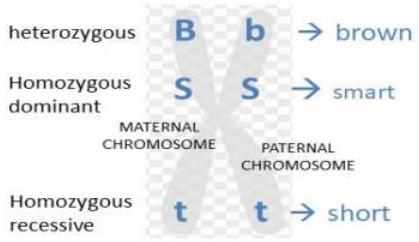
Phenotype such as plant yield is a combination of both genotype and environmental factors. Genetics help plant biologists to understand how it affects plant life and subsequently how to understand plant yield and quality. Furthermore, plant germplasm banks are critically important for increasing diversity and identifying and mapping superior traits in the fight with global climate changes. Finally, developing new plant varieties will help the feeding increasing world population (estimated 10 billion) by the year 2050.

? 1.12.1. Student Learning Outcomes (SLOs)

- **SLO 12.01:** Apply the best practices for learning genetics
- **SLO 12.02:** 2. Explain how Mendel's particulate mechanisms differed from blending hypothesis
- **SLO 12.03:** 3. Explain homozygous, heterozygous, phenotype, genotype, dominant, recessive, monohybrid, dihybrid, incomplete dominance, and co-dominance
- **SLO 12.04:** 4. Describe polygenic inheritance and give an example from plants
- **SLO 12.05:** Identify given plant species with their scientific names based on their key features
- **SLO 12.06:** 5. Explain linked genes and gene mapping in plants
- **SLO 12.07:** 1. Draw and label 10 steps of meiosis

1.12.2. Big Picture

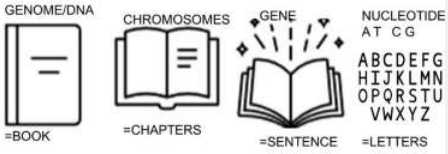
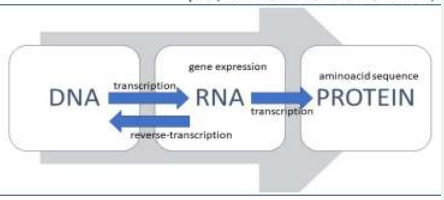
PHENOTYPE = GENOTYPE * ENVIRONMENT



- TRAIT←CONTR.BY GENE(S)....WITH DIFFERENT VERSIONS [ALLELES]

MENDELIAN (NORMAL)	1 gene	3:1 ratio	pea flower color
INHERITANCE		Aa	sickle-cell, cysticfibrosis
INCOMPLETE	Aa	1:2:1 ratio	snapdragon flower color
DOMINANCE [blended]			egplant color
CO-DOMINANCE	AB	1:1 ratio	ABO blood types
DI-HYBRID	2 genes	9:3:3:1 ratio	seed-color & seed-shape
	AaBb		plant-height & flower-color
POLYGENIC (QTL)	mult.genes	complex	height, skincolor, eye color
			seed mass
			high carotenoid content
			Diabetes

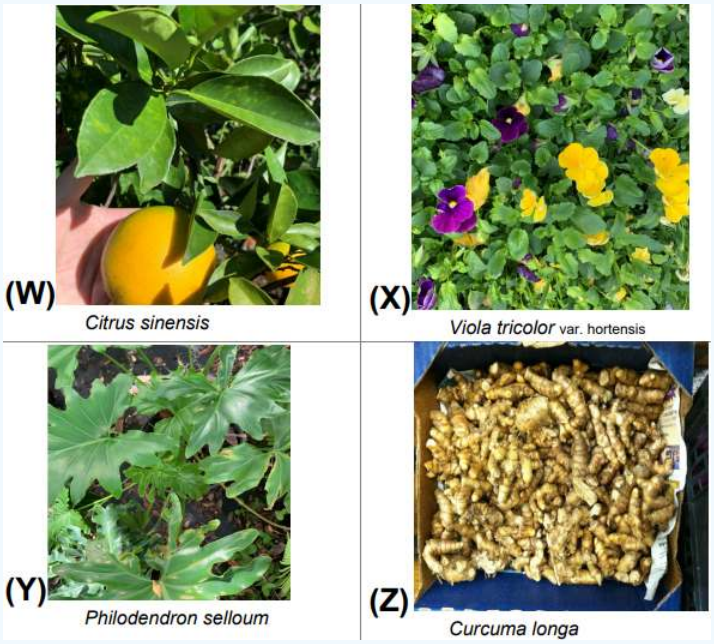
1.12.3. Vocabulary and Key Concepts

Iris (*Iris*)	Tennessee state flower
Trait	An inherited distinguishing characteristic (e.g. eye color, free/attached ear lobe, freckles present or not)
Genetics = heredity + variation	Study of "heredity [parents→traits→offspring]" AND expression variation in organisms
DNA > CHROMOSOMES > GENES	
Alleles 	Different forms of a trait (e.g. blue eye color, green eye color). Offspring receives 1 allele from parent1 and 1 allele from paren2.
Phenotype = Genotype * Environment	
How proteins are made and determined by gene expression of mRNA	
DNA double helix structure 	Discovered by James Watson and Francis Crick (1951)
Gregor Mendel (1822—1884): Father of Genetics	 Mendel JG (1866) Experiments on Plant Hybridization. 7 years experiments on *Pisum sativum*: model plant

1.12.4. Test Your Knowledge

- Assessment 12.3.1: TRUE or FALSE: Mutations are changes in the DNA-sequence.
- Assessment 12.3.2: TRUE or FALSE: Linked genes are on the same chromosome therefore inherited together.
- Assessment 12.3.3: TRUE or FALSE: Snapdragon flower color shows incomplete dominance.
- Assessment 12.3.4: TRUE or FALSE: "Red-and-white Camellia flower" is a good example of plant co-dominance. (Misplaced '&')

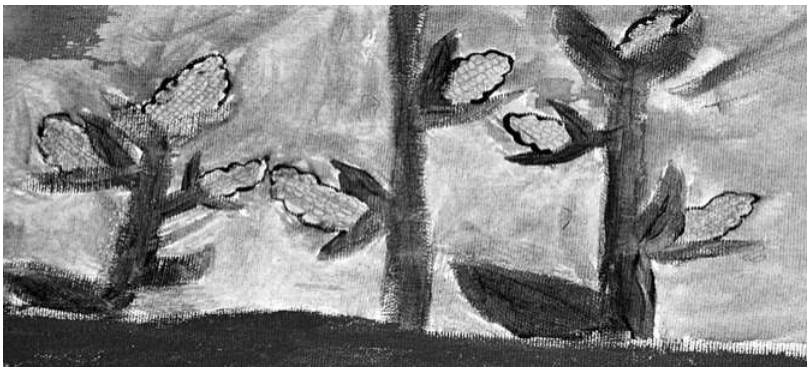
1.12.5. Can You SPot These Plants?



1.12.6. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.13: Plant Nutrition



Nutrition has a critical impact from soil to plants to people levels. Essential nutrients are required by life but cannot be synthesized by the organism. For plants, essential mineral nutrients can be divided into two distinct groups, and they are all required for growth and production:

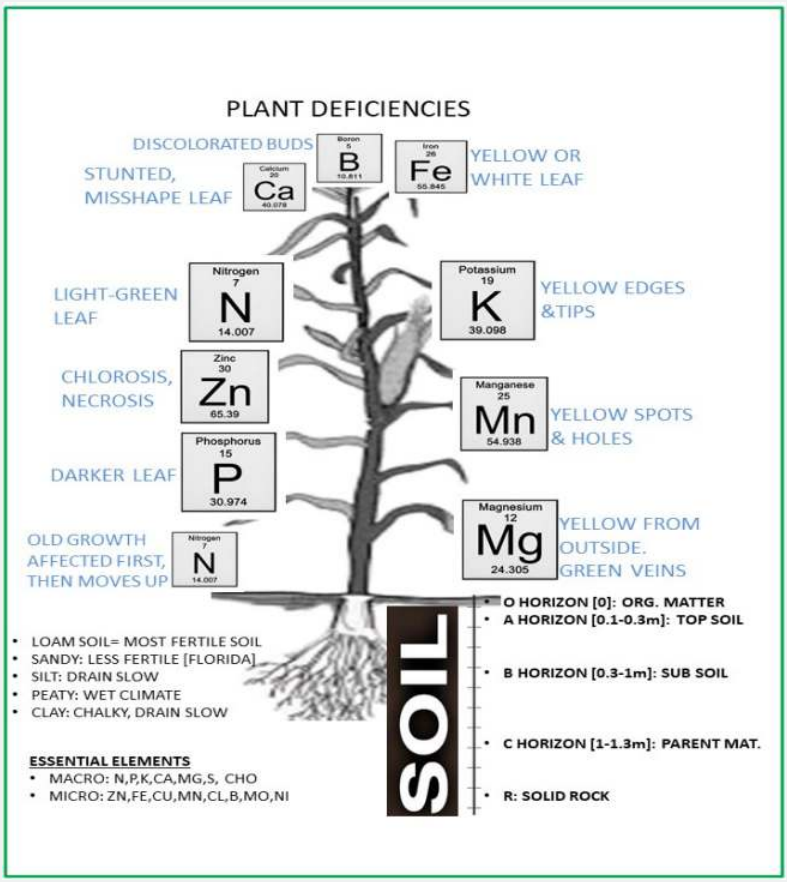
1. Macronutrients (needed in larger amounts): nitrogen (**N**), phosphorus (**P**), potassium (**K**), calcium (**Ca**), magnesium (**Mg**), and sulfur (**S**)
2. Micronutrients (trace elements, needed in smaller amounts): zinc (**Zn**), copper (**Cu**), iron (**Fe**), chloride (**Cl**), manganese (**Mn**), molybdenum (**Mo**), boron (**B**), nickel (**Ni**), selenium (**Se**), iodine (**I**)

Climbing of world population to 10 billion by 2050 will clearly require not only more food production but also higher enhanced efficiency of nutrient usage since they are critical limiting factors.

? 1.13.1. Student Learning Outcomes (SLOs)

- **SLO 13.01:** Apply the best practices for learning plant mineral nutrition
- **SLO 13.02:** Describe the characteristics of **N** (nitrogen), **P** (phosphorus), and **K** (potassium)
- **SLO 13.03:** Describe the importance of zinc (**Zn**) in plants
- **SLO 13.04:** Explain some of the common symptoms of nutrient deficiencies
- **SLO 13.05:** Identify given plant species with their scientific names based on their key features
- **SLO 13.06:** Define soil components
- **SLO 13.07:** Describe mycorrhizae and Rhizobia for plant P and N

1.13.2. Big Picture



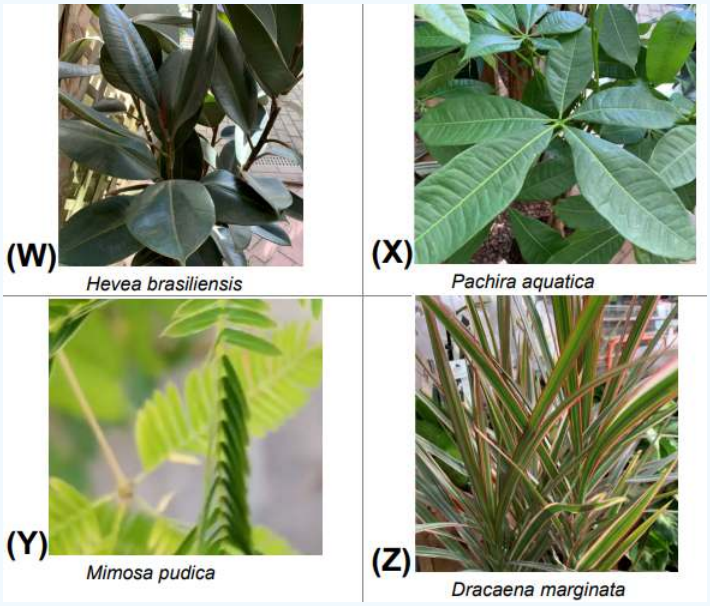
1.13.3. Vocabulary and Key Concepts

Dogwood (*Comus florida*)	Virginia state flower
17 Essential elements	CHO N P K Ca Mg S Zn Fe Cu Mn B Co Ni Cl **Macronutrients** **micronutrients**
Soil pH variation	**ACIDIC SOILS** **pH: 0-7** — Azalea, blackberry, hydrangea **ALKALI SOILS** **pH: 7-14** — Palms, geranium, olive
Deficiency symptoms 	• Yellowing old leaves: N, K, Mg, Zn • Yellowing young leaves: Fe, Mn • Burned old leaf tips: N, Zn • Necrosis: K, Mg, Zn, Fe, Mn • Death growing tips: B, K
Meat eating plants (Plants eat animals-carnivorous plants) 	• Venus flytrap • Pitcher plant • Butterwort • Sundew • Bladderwort • Cobra plant • Waterwheel plant
Plant Foods (Fertilizers)  	Fertilizers are plant food added to soil to supply plant nutrient(s) for crops. • Organic fertilizers: manure, compost, bone meal, tree leaves, eggshells, coffee grounds • Synthetic fertilizers (N-P-K ratio as %)

1.13.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Essential nutrients are the most important for the plant life cycle.
- Assessment 2: NAME THE DEFICIENCY: Old leaf chlorosis, necrotic spots, stunted plants, especially in maize, sorghum, beans, potatoes
- Assessment 3: NAME THE DEFICIENCY: Old leaf yellowing, light-green whole plant, most common nutrient deficiency.
- Assessment 4: NAME THE DEFICIENCY: Burnt leaf tips, purple/dark green old leaf, second most common deficiency.

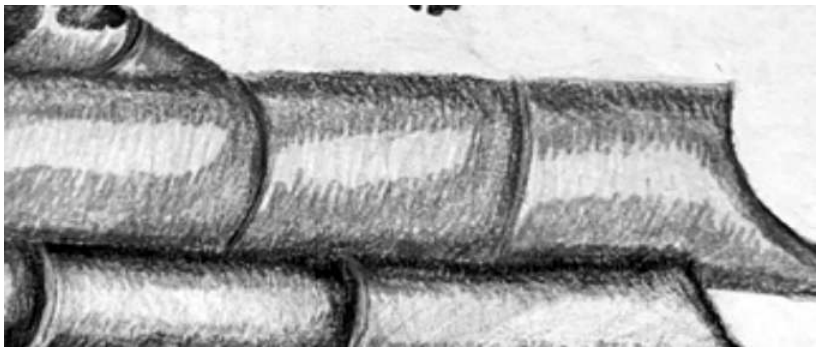
1.13.5. Can You Spot There Plants?



1.13.6. Check Your Answers

1. TRUE
2. **Zn** (zinc deficiency)
3. **N** (nitrogen deficiency)
4. **P** (phosphorus deficiency)

1.14: Water and Solute Transport



Aquaporins, water channels in plant cell plasma membranes, play an important role in plant survival and growth. In return, they can be important players from increased temperatures to photosynthesis in plant life.

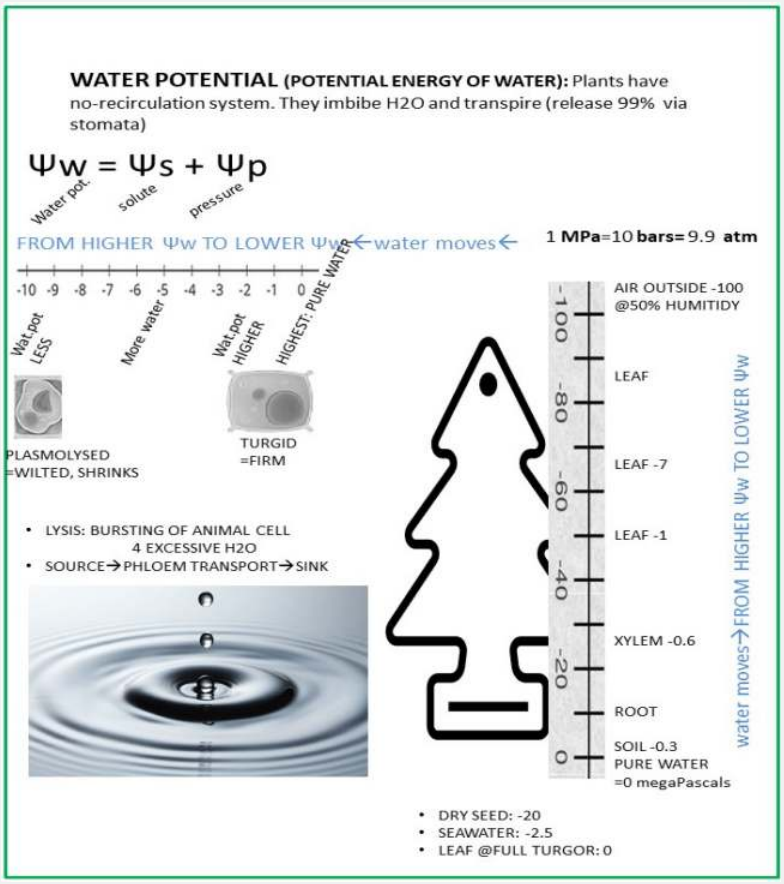
Moreover, solutes are also transported via plasma membranes and critical to plant growth and health. In recent years, substantial research has been carried out to elucidate highly complex transport systems of nutrients such as zinc (**Zn**), iron (**Fe**), and nitrogen (**N**).

Furthermore, osmosis and diffusion help plant water and solute uptake, respectively.

? 1.14.1. Student Learning Outcomes (SLOs)

- **SLO 14.01:** Apply the best practices for learning plant transport
- **SLO 14.02:** Describe the components of water potential
- **SLO 14.03:** Describe the characteristics of passive and active transport
- **SLO 14.04:** Compare plasmolyzed and turgid plant cells
- **SLO 14.05:** Identify given plant species with their scientific names based on their key features
- **SLO 14.06:** Explain the differences between hypertonic and hypotonic solutions
- **SLO 14.07:** Explain the differences between diffusion and osmosis

1.14.2. Big Picture



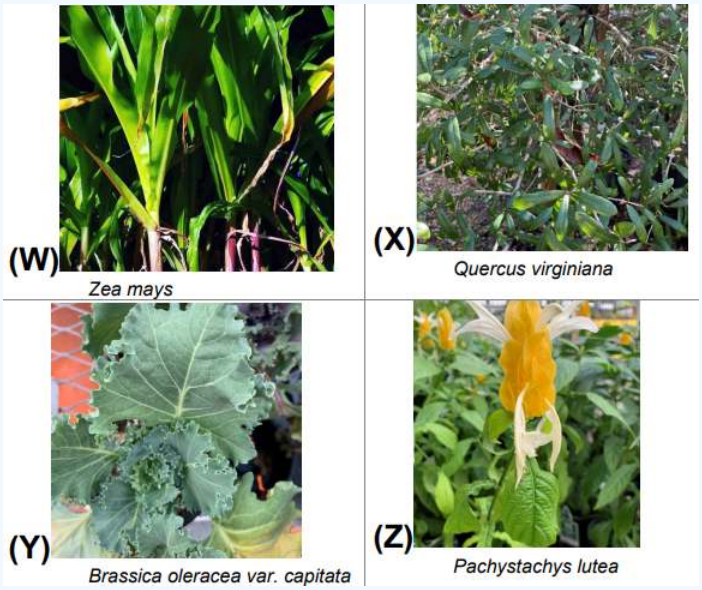
1.14.3. Vocabulary and Key Concepts

Camellia (*Camellia japonica*) 	Alabama state flower
Water 	• Water >> more than>> land on Planet Earth (in the air + surface + ground) • 2.5% Freshwater (1% drinking H_2O) + 97% saltwater (most H_2O)
3 Water Forms 	• H_2O Vapor (gas) @0 ºC • H_2O Liquid (water) @0 to 100 ºC • H_2O Solid (ice) @100 ºC (71 ºC at top of Mt. Everest due to atmospheric pressure <1 atm) • GAS→*condensation*→LIQUID→*freezing/solidifying*→ICE→*heat/melting*→LIQUID→*heat/evaporation*→GAS • SOLID/ICE→*sublimation*→GAS→*deposition*→SOLID/ICE
Plant Cells (80%+ H_2O) 	• Plant cells must maintain TURGOR 0-3 MPa water pressure) with enough H_2O for growing and functioning by stem/leaf tissue rigid (not wilted) (e.g., hypotonic)
Diffusion (ions movement) 	• Moving substances in /out of cell from high concentration to low concentration.
Osmosis (H_2O molecules movement) 	• Absorption of H_2O into root cells because there is more [solutes] in root cells >> soil water. A membrane required therefore only water passes through (but not solids).
Active transport (+energy) 	• Movement into high concentration and may require a transporter. ATP energy required.
Translocation 	• Long distance water (via xylem vessels) and nutrients (via phloem vessels) transport
Stomata (leaf epidermis pores) 	• TRANSPIRATION: Loss of water via transpiration to atmosphere
Phloem sugar transport (translocation) SOURCE TO SINK 	• Sugars move from "sugar sources" to "sugar sinks" • SUGAR SOURCES: Mature leaves • SUGAR SINKS: root, stem, fruit, flower, seed, young leaves

? 1.14.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Xylem is dead at maturity while phloem is alive.
- Assessment.2: TRUE or FALSE: In phloem translocation, sugars move to organs that most needed.
- Assessment.3: Compare and contrast osmosis, diffusion, and active transport.
- Assessment 4: TRUE or FALSE: Guttation is loss of liquid droplets that contain substances [at night] while transpiration is loss of vapors of pure water [during the day].

1.14.5. Can You Spot These Plants?



1.14.6. Check Your Answers

1. TRUE
2. TRUE
3. While all three are movement of particles, diffusion and osmosis are passive transport only
4. TRUE

1.15: Secondary Growth

Cambium growth layers are the main generators of dicot new wood cells (xylem) and inner bark tissues (phloem) in perennial plant species. Secondary growth is caused by secondary tissues in woody dicotyledon and gymnosperm plant species getting wider stems, branches, and roots. Furthermore, almost no secondary growth is observed in herbaceous plants and most monocotyledons. Secondary growth, in general, is a result of two lateral meristems (cambiums):

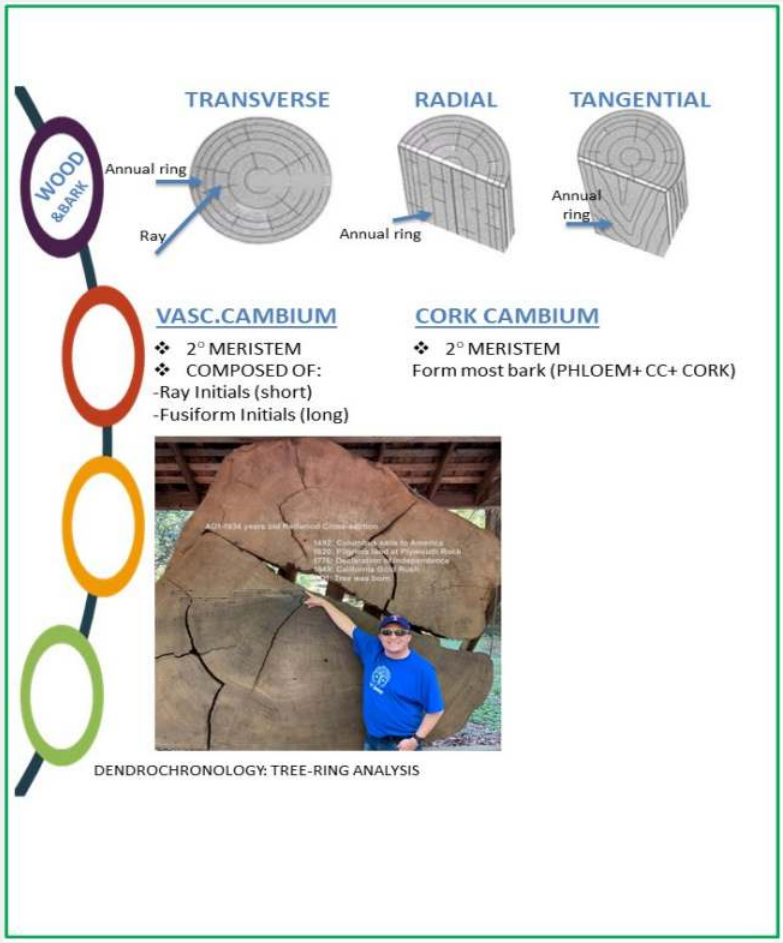
1. **Vascular cambium:** produces secondary xylem and secondary phloem
2. **Cork cambium:** produces periderm (substitutes epidermis)

Perennial trees can live for centuries including bristle cone pines, cypresses, and gingkoes.

1.15.1. Student Learning Outcomes (SLOs)

- **SLO 15.01:** Apply the best practices for learning secondary growth in select plants
- **SLO 15.02:** Define vascular cambium and secondary growth
- **SLO 15.03:** Explain what are tree rings, wood, and bark
- **SLO 15.04:** Describe the characteristics of bark and its components
- **SLO 15.05:** Identify given plant species with their scientific names based on their key features
- **SLO 15.06:** Explain how to determine the age of a tree
- **SLO 15.07:** Describe dendrochronology and its importance

1.15.2. Big Picture



1.15.3. Vocabulary and Key Concepts

Peony (*Peonia*) 	Indiana state flower
Secondary growth	A growth in woody plants that increases thickness using division of 2 lateral meristems (vascular cambium (VC) and cork cambium (CC))
Secondary Growth Products: WOOD 	• WOOD: layers of secondary xylem (annual rings)
Secondary Growth Products: BARK 	• BARK: outer layers of woody stem (secondary phloem +primary phloem + phelloderm + cork cambium (CC) + cork) • Inner bark: phloem • Outer bark (=periderm: cork + CC)
CORKS 	• Cork oak tree (*Quercus suber*) with small dots in their bark (lenticels). Bark is harvested once every 9 years and grows back without harming the tree.
WOODS AND WOOD USES 	• Paper (maple, oak), pencil (cedar, poplar), bats (maple), doors, chairs, beds • Toys • Spoons, chopstick (pine, maple, cherry) • Home construction, furniture • Ships • Musical instruments (mahogany, maple, ash) • Inexpensive woods: pine, poplar • Most expensive rare woods: -bocote wood, sandalwood, pink ivory wood, American black walnut wood.

1.15.4. Test Your Knowledge

- Assessment 15.3.1: TRUE or FALSE: World's largest tree is General Sherman tree (Sequoia giganteum) that is located in California (H: 84m, W:30m).
- Assessment 15.3.2: TRUE or FALSE: World's tallest tree is Hyperion (Sequoia sempervirens) that is located in California (H: 116m).
- Assessment 15.3.3: TRUE or FALSE: Sugar maple sap is used to make syrup.
- Assessment 15.3.4: TRUE or FALSE: Briar wood is resistant to fire (used in pipes)

1.15.5. Can You Spot These Plants?

(W) 
Dracaena cinnabari

(X) 
Agave tequilana

(Y) 
Camellia japonica

(Z) 
Camellia sinensis

1.15.6. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.16: Photosynthesis (PS)

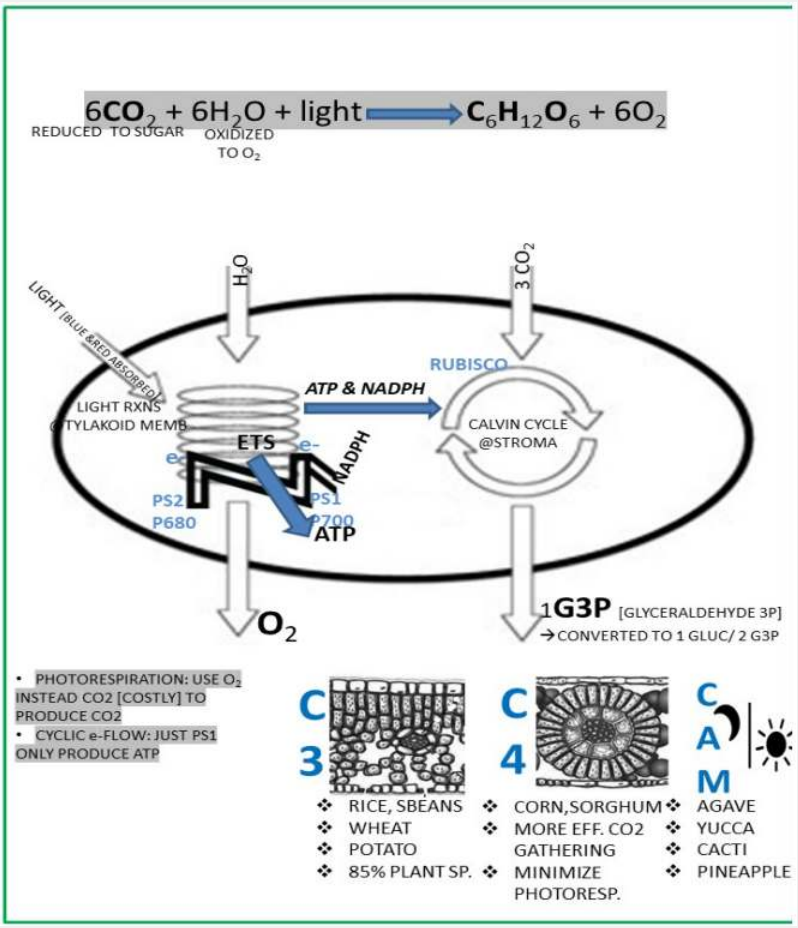
Photosynthesis (PS) means oxygen production to sustain life on planet Earth. Moreover, PS is critically important for food crop yield and therefore future food security. Sunlight is the major source of PS together with chlorophyll in the food making process.

Plants absorb carbondioxide (CO_2) from atmosphere for PS at the optimal temperatures. Lastly, rubisco is both the most abundant enzyme in biosphere and carbon fixing enzyme to produce food. However, some plant species use another more PS-efficient enzyme namely PEP carboxylase via separating light reactions and Calvin cycle. For example C4 plants such as maize and CAM plants such as pineapples separates them in different tissues and different timing, respectively. Lastly, this process helps C4 and CAM plant species to minimize photorespiration usage of O_2 instead of CO_2.

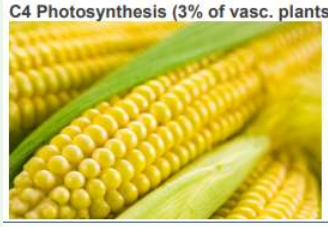
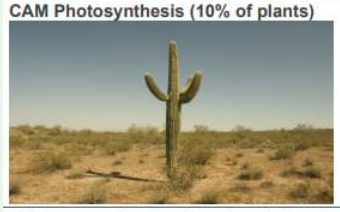
1.16.1. Student Learning Outcomes (SLOs)

- **SLO 16.01:** Apply the best practices for learning photosynthesis
- **SLO 16.02:** Describe the relationship between light and photosynthesis
- **SLO 16.03:** Describe the relationship between chlorophyll and photosynthesis
- **SLO 16.04:** Describe the relationship between CO_2 and photosynthesis
- **SLO 16.05:** Identify given plant species with their scientific names based on their key features
- **SLO 16.06:** Explain the differences between C3, C4, and CAM photosynthesis
- **SLO 16.07:** Explain the differences between light reactions and Calvin cycle?

1.16.2. Big Picture



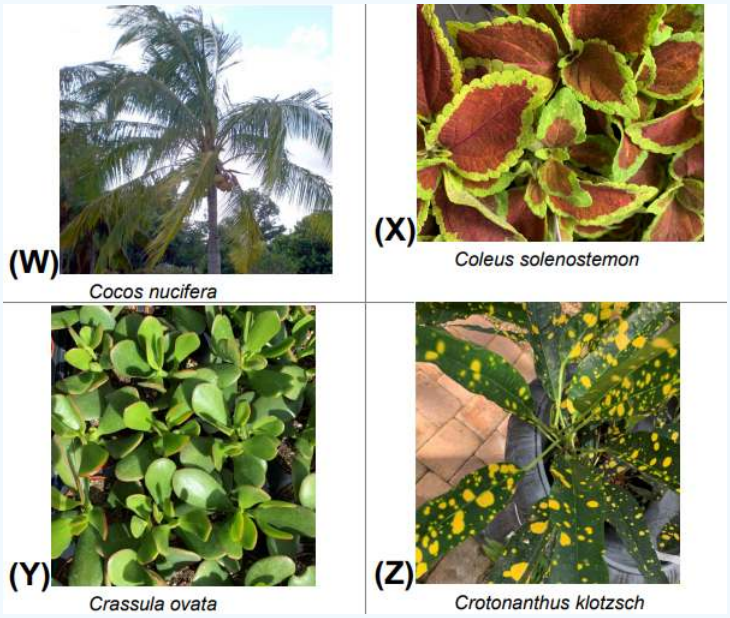
1.16.3. Vocabulary and Key Concepts

Photosynthesis $6\,CO_2 + 6\,H_2O \rightleftharpoons C_6H_{12}O_6 + 6\,O_2$	• Conversion of light energy into chemical energy by plants, algae, and some bacteria
PS Ingredients 	**PS Products** 
Chloroplast 	• Photosynthesis sites in the plant cells • Like solar panels (thylakoids) absorb sunlight • Turn plant parts green due to chlorophyll
C4 Photosynthesis (3% of vasc. plants) 	• Maize, sugarcane, sorghum, millet • Extra ATP needed for pumping acids to BS cells and mesophyll cells • Very efficient and produce more sugars under high temperature conditions
CAM Photosynthesis (10% of plants) 	• Desert succulent plants, Agave, and xerophytes use CAM PS. During the day, they close their stomata and carry out PS similar to C4-PS. • Very water efficient (16,000 sp.)
C3 Photosynthesis (Majority of plants) 	• Rice, wheat, soybean, potato, barley . . . • Inefficient especially with rising temperatures • C3 plants have ½ photosynthetic capacity of C4 plants.

1.16.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Photosynthesis is the reverse of cellular respiration.
- Assessment 2: TRUE or FALSE: Green plants, algae, cyanobacteria, some protists, and few animals can perform photosynthesis.
- Assessment 3: TRUE or FALSE: While phytoplankton produces 70% O_2, land plants produce 30% O_2 of the world.
- Assessment 4: TRUE or FALSE: Marine plants get some light from hydrothermal vents for their photosynthesis.

1.16.5. Can You Spot These Plants?



1.16.6. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.17: Cellular Respiration

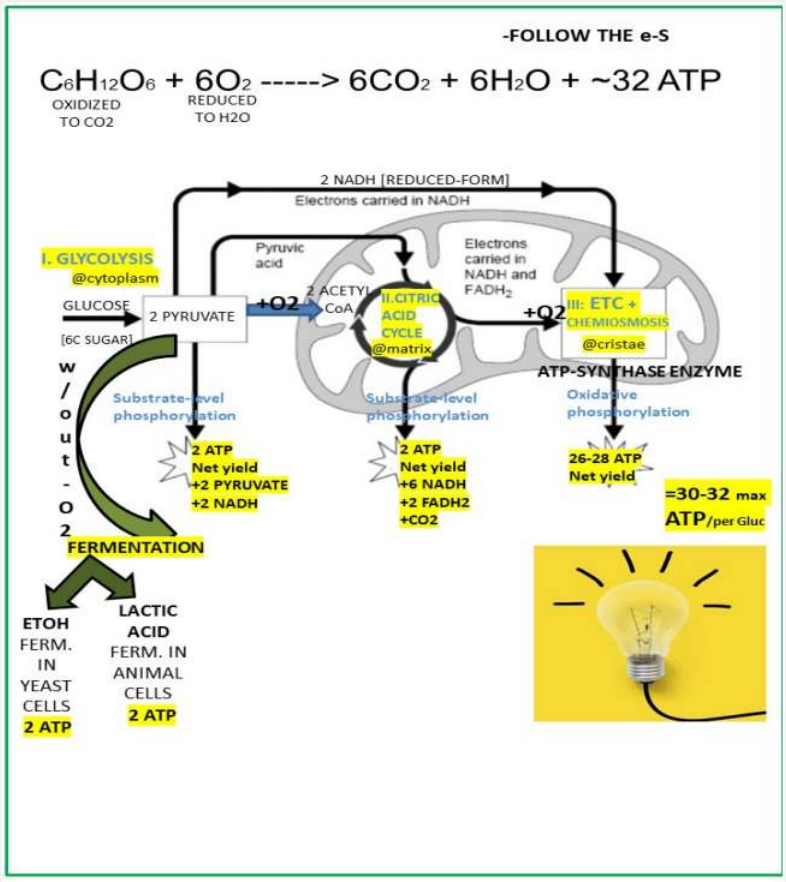
In our planet Earth's 4.6 billion years of age, oxygen became available about 2.3 billion years ago. Therefore, there must have been fermentation used by early bacteria species since there was no oxygen availability.

ATP (adenosine triphosphate) is the main energy resource of cells and product of cellular respiration and fermentation. Lastly, it will be critically important to study plant respiration since it may be enhanced under increasing carbondioxide levels and temperatures.

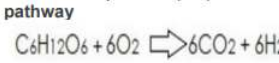
? 1.17.1. Student Learning Outcomes (SLOs)

- **SLO 17.01:** Apply the best practices for learning cellular respiration
- **SLO 17.02:** Describe the characteristics of three main stages of cellular respiration
- **SLO 17.03:** Explain the stage of cellular respiration that produces the most **ATP**
- **SLO 17.04:** Describe the characteristics of mitochondria
- **SLO 17.05:** Identify given plant species with their scientific names based on their key features
- **SLO 17.06:** Explain the differences between cellular respiration and fermentation
- **SLO 17.07:** Explain the differences between substrate level and oxidative phosphorylation

1.17.2. Big Picture



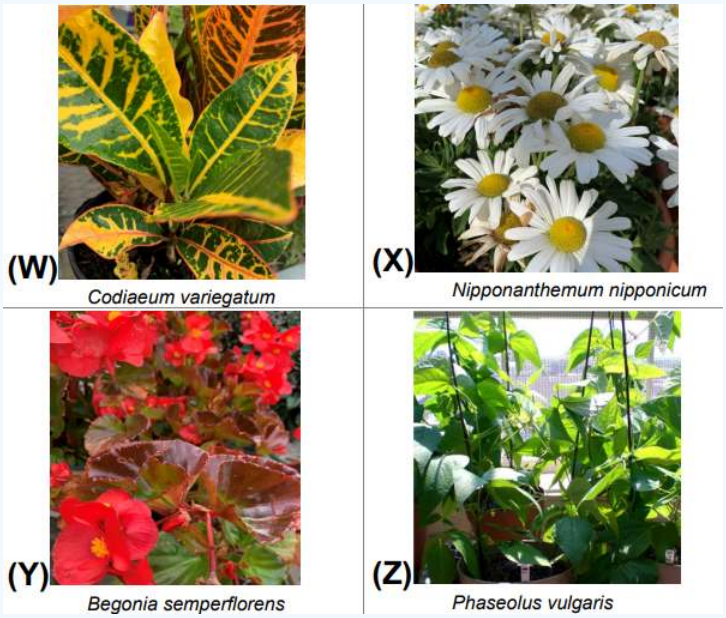
1.17.3. Vocabulary and Key Concepts

Cellular Respiration (CR) metabolic pathway 	• Reverse process of photosynthesis, using chem. energy stored in sugars to obtain energy for plant growth and reproduction.
Mitochondria (mt: powerhouses of cells) 	• mt was originally prokaryote (bacteria): has its DNA (n, 37 genes) and ribosome. An animal cell engulfed it, evolved it to organelle (1.5 billion years ago) • mt cannot be seen under light microscope • mt inherited from mothers' egg (maternal) • mt burns food to produce fuel (ATP) • Plants carry respiration in dark (PS is not possible)
mtDNA	• Siblings/ individuals related maternally have the same mtDNA sequence • mtDNA can identify specific family (37 genes) • Everyone receives mt organelle from their mother
CR PRODUCTS	• Up to 32 ATP yield / per glucose (fats, proteins) • CR converts food to energy with 40% efficiency (60% released as heat)
CR supply energy via using food from PS **PS connection to CR**	• CR causes food loss that must be balanced with PS and CO_2-O_2 cycle • PS>>>occurred before CR ..in order to provide 20% O_2 for atmosphere • Energy needed for germination, root growth, cell division, transport
Chemiosmosis (both in PS & CR) **[CR] membrane: cristae membrane** **[PS] membrane: thylakoid membrane**	• Osmosis of H^+ flow across membrane to drive ATP-synthase enzyme to generate ATP (90% of CR ATP)
FOLLOW THE e^- FLOW in CR	➢ Glucose →Pyruvate & NADH (in cytoplasm) ➢ Acetyl-CoA → NADH & $FADH_2$ (in matrix) ➢ ETC (in inner membrane) ➢ O_2→ H_2O (in matrix)
FOLLOW THE e^- FLOW in PS	✓ H_2O and splitting O_2 ✓ ETC (in thylakoid membrane) ✓ PSI ✓ NADPH (in stroma) ✓ CO_2 (in stroma) ✓ Glucose and Starch

1.17.4. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Mitochondria exist in all cells and originated by a bacteria engulfed by eukaryotes
- Assessment 2: TRUE or FALSE: Plants also do respiration using glycolysis, Krebs cycle, oxidative phosphorylation mostly during the night as well as photo-respiration
- Assessment 3: TRUE or FALSE: While anaerobic respiration produces **2 ATP**, aerobic respiration produces up to **32 ATP**
- Assessment.4: TRUE or FALSE: Lenticels pores in the stem / bark of trees involve gas exchange extensively

1.17.5. Can You Spot These Plants?



1.17.6. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.18: Indoor Vertical Farming and Cultivating Plants in Microgravity

Is vertical farming future of sustainable crop production especially under suboptimal environment conditions such as drought and water shortage? 60% of US tomatoes and 35% of US total fresh produce are imported with considerable shipping carbon print. Vertical farms are automated / partially automated indoor hydroponic / aeroponic farming factories under LED lights.

A variety of fresh plants are currently in vertical farms including lettuce, microgreens, leafy greens, tomato, cucumber, and pea shoots year around with zero pesticides / harmful chemicals. Moreover, plant growing in vertical farms uses no soil, sunlight and therefore not affected by climate stress conditions. Vertical farms may be the future of sustainable plant growing since land and water resources are getting more and more scarce to maximize yield as well as flavor.

? 1.18.1. Student Learning Outcomes (SLOs)

- **SLO 18.01:** Apply the best practices for mastering cultivating plants in microgravity
- **SLO 18.02:** Assess the strategy of growing plants in simulated Martian soil mimics Mars
- **SLO 18.03:** Distinguish between plant-available vs accessible format of nutrients
- **SLO 18.04:** Assess the strategy of employing specific bacteria or fungi that are beneficial to plant growth in a Martian soil environment
- **SLO 18.05:** Explain how vertical farming may cause majority of land and water use.
- **SLO 18.06:** Assess the strategy of employing solar power for vertical farms
- **SLO 18.07:** Explain the benefits of vertical farming

1.18.2. Big Picture

WAYS TO GROW PLANTS	SOIL HYDROPONICS AEROPONICS
SOIL GROWING PLANTS 	• A complex natural medium that originated from bedrocks and organic materials • Soil provides the anchorage as well as essential nutrients and moisture for plants • **NORTH-FLORIDA: USDA Growing-Zone 8** (10–20°F / -12.2–6.7°C) average annual min winter temperature
HYDROPONIC GROWING 	• A nutrient-rich oxygenated water medium to grow plants • Indoor growing with lighting that provides anytime and anywhere plant growing with higher yields
AEROPONIC GROWING PLANTS	• A type of hydroponics: while plant roots dangle in air, they are mist sprayed to provide a moist environment • Indoor growing that provides anytime and anywhere plant growing with higher yields
VERTICAL FARM (indoor) 	• Skyscrapers growing plants in aeroponically with optimized LED light and temperature • Increased yield (4–6 times more than outdoors) • Less water usage in hydroponics than traditional soil growing • More sustainable: Continuous plant production anytime • Weatherproof (no drought, floods, pesticides)
FAST-TURN PLANTS (fast time from seedling to product) • Mostly leaf microgreens, herbs, and vine veggies	• Lettuce • Spinach • Arugula • Basil • Oregano • Chives • Chard • Kale • Cilantro

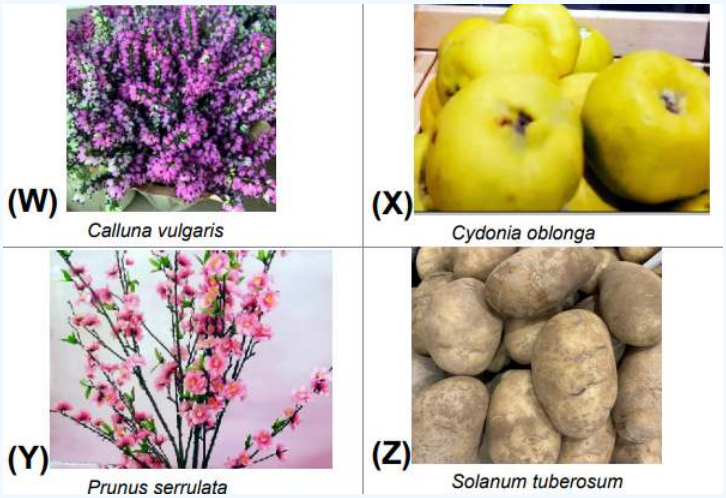
GRAVITY (g) =gravitational pull (meter / sec^2)	**EARTH**:9.8 m/s 	**MARS**: 3.7 m/s	**ISS**:0 Zero Gravity (weightlessness)
Average temp:	14 °C (= 57 °F)	-62 °C (= -81 °F)	
CO_2	0.04%	95%	
O_2	21%	0.17%	
N_2	78%	2.6%	

GROWING PLANTS IN MICROGRAVITY FOR SPACE FOOD (Mars: the most Earth-like planet)	• Plant cultivation on the planet Mars (microgravity = 38% of Earth G) • A sealed-greenhouse dome with Earth-like conditions (air, temp.) • MARS CHALLENGES: cold, low gravity, low oxygen • Very inhospitable planet- need **Terraforming** (transforming Mars to earth-like habitat-increase temperature to 21 °C, melt ice • Alternative: Antarctica (6 months daylight in summer/ Oct. to Feb) Antarctica→Summer temp: -40 °C, winter temp: -70 °C • Alternative: Ocean floors of Earth [underwater cities @300m under; avg. temp: 4 °C]: 71% of Earth is water. Weightlessness. Challenges: Cold, no O_2, pressure (@Sea level=1atm; @300m=30atm)

1.18.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: World food supply needs to increase 60% to feed 10 billion people by the year 2050.
- Assessment 2: TRUE or FALSE: Hydroponics system uses 90% less water than soil growing.
- Assessment 3: TRUE or FALSE: Hydroponics can increase tomato yield almost $6\times$.
- Assessment 4: TRUE or FALSE: Microgreens (collard, arugula, basil, celery, lettuce, spinach) are nutrient packed that are $\sim 100\times$ more nutritious than regular greens.

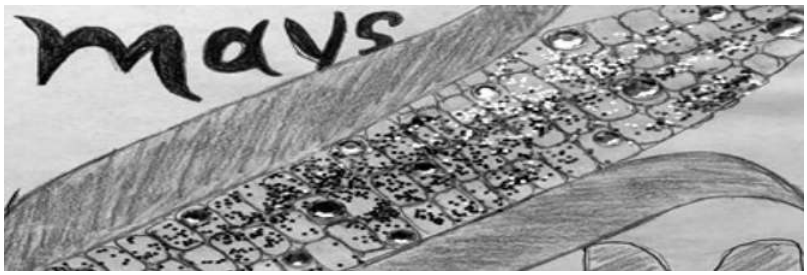
? 1.18.4. Can You Spot These Plants?



? 1.18.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.19: Human Nutrition from Plants and Plant-based Proteins



Superfoods are getting more and more popular due to their superior nutrient-rich characteristics. Many food plants including vegetables (e.g., lettuce, spinach, kale, cabbage), berries (e.g., blueberries), beans, nuts, and whole grains are rich in mineral nutrients and vitamins for human diet. Therefore, planting home gardens, renting garden plots, and visiting local farmers' markets for locally grown are becoming popular worldwide.

On the other hand, plant-based meat (beef, chicken, or fish alternatives) is also gaining popularity (estimated $74 billion economy) by large restaurant chains worldwide. Lastly, there are also other future food alternatives including sea veggies such as sea lettuce, nori, and wakame with protein and nutritional content. In return, these new protein sources may be the answer for sustainable and eco-friendly protein supply for increasing world population.

? 1.19.1. Student Learning Outcomes (SLOs)

- **SLO 19.01:** Apply the best practices for learning plant-based nutrition
- **SLO 19.02:** Describe the characteristics of plant-based proteins
- **SLO 19.03:** Describe the characteristics of health benefits of human nutrition from plants
- **SLO 19.04:** Describe the essential nutrients for human diet
- **SLO 19.05:** Identify given plant species with their scientific names based on their key features
- **SLO 19.06:** Explain the connection between heart health and plant-based diet
- **SLO 19.07:** Explain the differences between carbohydrates, lipids, and proteins for human diet

1.19.2. Big Picture

HUMAN DIET

DIET→ Nutrients (A) ...essential: so can't be synthesized...lack of it cause malnutrition

DIET→ C & N for org. molec building (B)

DIET→ Chem. Energy supply (C) lack of it cause undernutrition

I) MINERALS
(>2,000 mg/day)
P, K, Ca, Mg, S, Na, Cl
Zn, Cu, Fe, F, I, Mn, Se, Co, Cr

II) VITAMINS
----*FAT-SOLUBLE* (taken as gel, require fat for absorption): A-D-E-K
----*H2O-SOLUBLE* (taken as pill): B1-12, C

III) FATTY ACIDS
To be used in membrane making

IV) AA'S (8)
Isoleucine
Leicine
Lysine
Methionine
Phenylalanine
Threonine
Tryptophan
Valine

STAPLE & OTHER FOOD CROPS
(20 sp. →90% food)

MAIZE	SUGAR CANE/S.BEET
RICE	BRASSICACEA
WHEAT	BARLEY
SOYBEANS	GRAPES
POTATO/ SWEET POTATO/YAM	HERBS-SPICES
CASSAVA	(BASIL, DILL, PARSLEY)
SORGHUM	VEGETABLES
PLANTAIN	(TOMATO, LETTUCE)

% DV (REQUIRED DAILY VALUES) [2,000-calorie daily]

nutrient	DV	% of kcals
CARB. TOTAL	300 g	60%
FAT TOTAL	65 g	30%
PROTEIN	50 g	10%

PORTION SIZES
(3-SERVING ALWAYS FOR LOW-CARB DIET)

←1 CUP 1 CH-PORTION = 15 g CH = 1 SERVING

plant-based proteins / meat
(ecological benefits, no cholesterol, no pathogens)

MEATLESS MEAT (PLANT-BASED)

IMPOSSIBLE	BEYOND	
soy-protein	pea-protein	(mimic protein)
sunflower-oil	canola-oil	(mimic fat)
coconut-oil	coconut-oil	

(replicating taste, smell, texture of meat)

FOOD 3D PRINTING

MEATLESS MEAT (PLANT-BASED)

IMPOSSIBLE BURGER	BEYOND BEEF	
soy/potato protein	pea-protein	(mimic protein)
sunflower-oil	canola-oil	(mimic fat)
coconut-oil	coconut-oil	

(replicating taste, smell, texture, nutrition, color of meat)

3D-BENEFITS:	3D-CHALLENGES:
^Customized (for hospitals?)	~Cost
^Easy reproducibility	~Training-costs
^Fine Dining	~Storage
^No baking required (?)	~Processed
^Durable longer	
^Save land, water, animals	

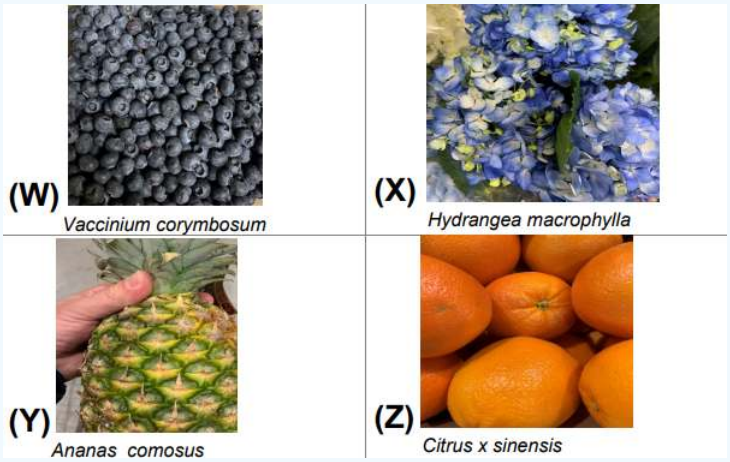
FUTURE FOOD (also manufacturing in space)

- 4D PRINTING: (3D+TIME)→Evolved with time like plants
- 5D PRINTING: (5-axis 3D)→X, Y, Z access + back/fw on them

? 1.19.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Beans and lentils are protein rich plants.
- Assessment 2: TRUE or FALSE: Broccoli is a cruciferous vegetable.
- Assessment 3: TRUE or FALSE: Vegan diet eliminates all animal products and byproducts (dairy, meat, poultry, fish, eggs and honey).
- Assessment 4: TRUE or FALSE: Vegetarian diet eliminates animal products except dairy and eggs.

1.19.4. Can You Spot These Plants?



1.19.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.20: Seed Germination and Seedling Establishment

There is optimal temperature, light / darkness, and moisture requirement for seed germination of plant species. Days to germination varies from a few days (e.g., lettuce, cucumber, corn) to four days (e.g., cabbage, watermelon, kale) to five days (e.g., cauliflower, spinach) to six days (e.g., bean, carrot, eggplant, onion, pea) to seven days (e.g., celery) to eight days (e.g., pepper) to 13 days (e.g., parsley, parsnip) under optimal conditions of temperature and moisture.

Crop rotation rotates crop species three year turn from leaf/stem crops (e.g. cabbage, broccoli, kale) to bulb/tuber crops (e.g., onion, potato, carrot) to fruit /seed crops (e.g., peas, corn, pumpkin, tomato, pepper). Lastly, there are perennial vegetable crops that come back every year such as rhubarb and chives, which have benefits with varying flowering time, extended seasons, and hardiness under suboptimal environment conditions.

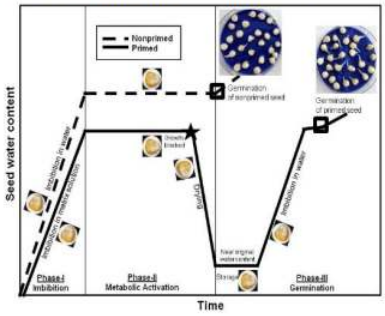
? 1.20.1. Student Learning Outcomes (SLOs)

- **SLO 20.01:** Apply the best practices for learning germination and seedling establishment
- **SLO 20.02:** Describe the characteristics of germination and dormancy
- **SLO 20.03:** Describe the characteristics of basic plant growth requirements
- **SLO 20.04:** Describe the characteristics of favorable conditions and duration for germination
- **SLO 20.05:** Identify given plant species with their scientific names based on their key features
- **SLO 20.06:** Explain how seed germination related to seed quality
- **SLO 20.07:** Explain the nutritive value of seeds

1.20.2. Big Picture

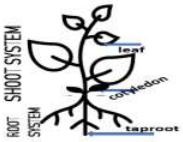
- Early plants had spores (single-cell)
- Later, seed plants discovered seeds (multi-cell)
- Seeds provide ~70% of our food
- Contain embryonic plant (all parts to start a new plant)
- **EMBRYO:** epicotyl + hypocotyl + radicle [becomes plant with leaves]
- **ENDOSPERM:** food store (starch rich)
- **TESTA (seed coat):** protects the seed

SEED PRIMING and GERMINATION



- **Germination:** emergence of radicle through seed coat.
- **Dormancy:** inactive seed status, but capable of activation, that prevents germination under unfavorable environmental conditions
- **GERMINATION REQUIREMENTS**
  - Water (moisture)
  - O_2 (except rice and aquatic plants→ germinate anaerobically)
  - Temperature (20-30°C for many)
  - Light (dark required for: western wheatgrass)
  - Duration
  - Bahia grass: 7–28 days @20–35°C @light
  - Maize: 4–7 days @25°C @dark
  - Bean: 4–7 days @25°C @dark
- **IMBIBITION:** first, H_2O imbibed by dry seed
- Then enzymes break down endosperm
- **SEED PRIMING:** a controlled hydration seed treatment (activates metabolically but stopped before germination and dried back) that enhances seed germination, speed, and uniformity

SEEDLING EMERGENCE



- **Plant growth:** cell enlargement, irreversible change in size (cell, organ, organism)
- **Plant differentiation:** change to more specialized form and function
- **Plant development:** from simple to more advance programmed succession (germination→juvenility→ maturity→flowering→fruiting)

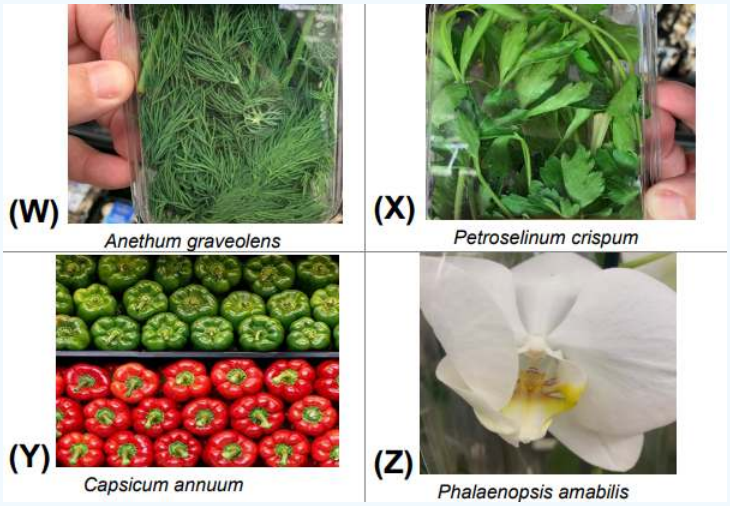
- **YIELD**: amount of crop produced per area of land
- **FACTORS AFFECT YIELD**:

❖ SOIL: pH, nutrients
❖ WEATHER: temperature, moisture, rain
❖ GENOTYPE: genetic factors variability
❖ DISEASES: loss, resistance
❖ TECHNOLOGY ADVANCEMENT

? 1.20.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: A 2,000 year old date seed was found viable.
- Assessment.2: TRUE or FALSE: Double coconut palm (coco de mer, Lodoicea maldivica) seed is considered the largest seed (44 lb).
- Assessment 3: TRUE or FALSE: Flax seeds (linseed) are a great source of Omega-3 fatty acids, while pumpkin seeds are a great source of Omega-6 fatty acids.
- Assessment 4: TRUE or FALSE: Sunflower, lettuce, Swiss chard, radish, Chinese cabbage, tomato, and pea seeds travelled to the International Space Station.

1.20.4. Can You Spot These Plants?



1.20.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.21: Tea Growing, Brew, and Leaves

Tea is one of the most consumed drinks in the world. Various tea categories (e.g., organic / conventional, powder, tea bags) and flavors (e.g., cinnamon, tapioca, lemon, jasmin, chocolate, original).

Tea also is one of the acidic-soil loving plant species. Moreover, all varieties of green, black, oolong, and white teas come from the same plant species, Camellia sinensis. However, the best quality teas usually come from the top two leaves and bud of the each stem of tea plant that can be picked up to four harvests or flushes.

? 1.21.1. Student Learning Outcomes (SLOs)

- **SLO 21.01:** Apply the best practices for learning tea cultivation
- **SLO 21.02:** Describe the characteristics of tea plant (Camellia sinensis)
- **SLO 21.03:** Describe the characteristics of tea processing
- **SLO 21.04:** Describe the characteristics of tea brewing
- **SLO 21.05:** Identify given plant species with their scientific names based on their key features
- **SLO 21.06:** Explain the differences between various tea types
- **SLO 21.07:** Explain the differences between herbal, decaf, and regular tea

1.21.2. Big Picture

TEA (*Camellia sinensis*)

- WORLD: $40 billion, US: $2.5 billion economy annually
- #2 most consumed beverage worldwide after water (3 billion cups / per day)

TEA GROWING

- Largest tea producer leaders:
  - China (38% =2.4 Mil tonnes)
  - India (27% =1.3 Mil tonnes)
  - Kenya (10% =500K tonnes)
  - Sri Lanka (9% =350K tonnes)
  - Turkey (6% =250K tonnes)
  - Japan (2.3% =80K tonnes)

TEA PROCESSSING

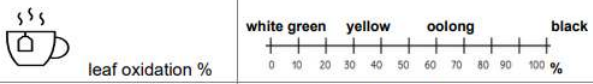
- **Picking**: top 2 young leaves picked by hand (premium)
- **Withering/ Wilting**: blow warm-air over leaves, reduce moisture
- **Panfry/Enzyme kill**: heated pans used to kill ox. enzymes
- **Rolling**: roll leaves
- **Fermentation/Oxidizing**: at warm room racks until oxidation→break down Chlorophyll, release tannins. Aroma formed from oxidation
- **Drying**: blowing 90°C air to reduce moisture (3.5%)

TEA QUALITY / character

- Cultivar / Variety
  - GREEN: Gyokuro (shaded), Sencha, Bancha, Matcha (ground)
  - BLACK: English breakfast (organic gold)
- Flushes:
  - first flush / spring (more caffeine, nutrients)
  - second flush (early summer)
  - autumn flush (October)
- Year of harvest, award-winning tea farm/tea (gold, silver, bronze medal)
- Tea leaf quality: top 2 young leaves + terminal bud. Hand picked is superior because machine easily breaks leaf so large unbroken leaves shows quality
- production quality
- Storage: dry, cool temp, and air-tight container stored
- Brew temp. (96°C), steep time (3–5 min), organic

PREMIUM TEA VARIETIES
Avg. price: $50/lb

- China/Fujian: Da Hong Pao Tea [600K/lb]
- China/Sichuan: Panda Dung Tea (black) [35K/lb]
- China/Fujian: Vintage Narcissus Tea (oolong) [3.2K/lb]
- China/Sichuan: Panda Dung Tea [35K/lb]
- Taiwan: Gao Shan Tea [100/lb]



leaf oxidation %

U.S.-Grown Tea

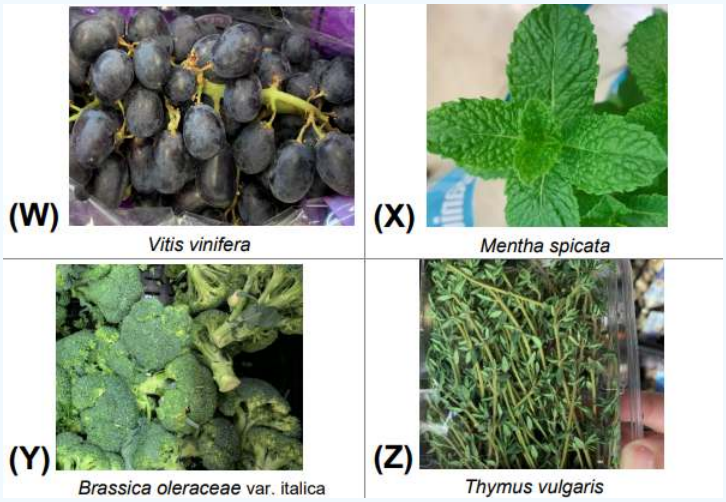
- Global **Matcha Tea** Market (over $4 Bn)
- USDA organic certified tea
- Charleston Tea Garden: produces "American Classic Tea"
- Small tea farms in 15 states (mostly Hawaii)
- **Tea bags:** invented/ patented in NY in 1903
- **Iced tea:** popularized at 1904 World's Fair (St. Louis, MO)
- **Peach tea:** popular tea flavor in the US
- **Bubble tea:** tea + tapioca balls + milk + sugar + flavors

Black tea (
oxidized for 1/

1.21.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: All tea types (black, green, white, and oolong) come from one plant: Camellia sinensis.
- Assessment 2: TRUE or FALSE: Turkey is the top tea consuming country in the world (~7 lb / per capita).
- Assessment 3: TRUE or FALSE: There are really only two words to say "tea": te (by sea) or cha (by land).
- Assessment 4: TRUE or FALSE: Herbal teas are not actually teas since they are derived from other plants (chamomile, rooibos, ginger, lemon, hibiscus, rose).

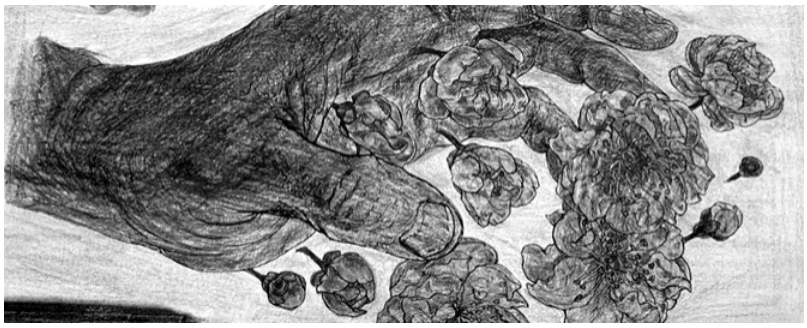
1.21.4. Can You Spot These Plants?



1.21.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.22: Coffee Growing, Roast, Grind, and Beans



How do you take your coffee–regular or decaf? Coffee is the most popular drink in the U.S. However, coffee plant species growing is dominantly around the equator countries such as Brazil, Colombia, Ethiopia, and Indonesia.

Coffee plant (*Coffea sp.*), native to south west Ethiopia with very little genetic diversity, comes from beans of coffee fruit (a.k.a. berry or cherry). A combination of its susceptibility to extreme temperature changes and considering its low genetic diversity make breeders focus on developing more robust shade grown coffee cultivars worldwide.

1.22.1. Student Learning Outcomes (SLOs)

- **SLO 22.01:** Apply the best practices for learning coffee cultivation
- **SLO 22.02:** Describe the characteristics of coffee plant (*Coffea arabica*)
- **SLO 22.03:** Describe the characteristics of coffee processing
- **SLO 22.04:** Describe the characteristics of coffee brewing
- **SLO 22.05:** Identify given plant species with their scientific names based on their key features
- **SLO 22.06:** Explain the differences between various tea coffees
- **SLO 22.07:** Explain the differences between decaf, and regular coffee

1.22.2. Big Picture

COFFEE (*Coffea sp.*)

- WORLD: $43 billion market, US: $4 billion (imports)
- #3 most consumed beverage worldwide after water and tea (Global: 2 billion cups / per day); U.S.: 400 million cups / per day)
- **Caffeine (plant-based alkaloid stimulant) 1 cup**
- 100 mg: in espresso/ latte / cappuccino
- 80 mg: in coffee
- 30 mg: in black tea
- 30 mg: in green tea
- 6 mg: in decaf coffee
- 3 mg: in decaf tea
- 0 mg: in herbal tea

COFFEE GROWING

- **Largest coffee producer leaders (exporters):**
  - Brazil (34% =2.5 Mil tonnes)
  - Vietnam (17% =1.6 Mil tonnes)
  - Colombia (9% =810K tonnes)
  - Indonesia (8% =660K tonnes)
  - Ethiopia (4% =384K tonnes)
  - Honduras (348K tonnes)
  - India (348K tonnes)
  - Uganda (288K tonnes)
  - Guatemala (204K tonnes)
- **Altitude ~~flavor / ~higher quality**
  - VERY HIGH (1500m): Ethiopia, Kenya, Guatemala, Colombia (spicy)
  - HIGH (1200m): C. Rica, Mexico, Sumatra
  - MEDIUM (900m): Brazil (low acidity, sweet)
  - LOW: Hawaii
- **Bean species + many cultivars:**
  - *Coffea arabica* (70%): ARABICA BEANS- starbucks
    - Varieties: Typica, Bourbon, Gesha (Ethiopia)
  - *Coffea canephora* (30%): ROBUSTA- instant coffee

COFFEE PROCESSING

- **Roast and Grind:**
- Light roast: more caffeine
- Dark roast (roasted longer)
- Decaf

- **Brew:**
- Caffeine levels: Decaf<Regular<French Press<Turkish coffee<Espresso

PREMIUM COFFEE VARIETIES

Avg. price coffee beans: $15/lb
Avg. price brewed coffee: $3/cup

- Guatemala: Finca El Injerto Coffee [$500/lb]
- Tailand: Black Ivory Coffee [$1000/lb]
- Colombia: Ospina Dynasty Coffee [$400/lb]
- Indonesia: Kopi Luwak Coffee [$400/lb]
- Panama: Hacienda La Esmeralda [$100/lb]
- Jamaica: Blue Mountain Coffee [$80/lb]

- Red berries→harvest by hand→de-shell →green coffee bean→dry 3d→ready→ship→roast @260°C which will pop the beans 2 times, increase size)→grind→brew
- **Turkish coffee (kahve): Fine ground beans + cold water + sugar.** First coffee house opened in Tahtakale, Istanbul, Turkey in 1475→ made coffee popular. Turks introduced coffee to Europeans.
- **Caffè Americano:** 2 shots of espresso (225mg caffeine) topped/diluted with hot water +steamed milk. Finely ground beans used
- **Cup sizes:**
  - SHORT (8oz = 236 ml)
  - TALL (12 oz = 354 ml)
  - GRANDE (16oz = 473 ml) (DECAF: 14 mg caffeine)
  - VENTI (24oz = 709 ml)
  - TRENTA (31oz = 917 ml)

1.22.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Coffee is native to tropical East Africa highlands (Ethiopia).
- Assessment 2: TRUE or FALSE: 40% of the world's coffee is produced by Brazil.
- Assessment 3: TRUE or FALSE: Finland drinks the most coffee per person in the world.
- Assessment 4: TRUE or FALSE: U.S. is the world's largest coffee importer (2.5 Mil lb.).

1.22.4. Can You Spot These Plants?

(W) 
Persea americana

(X) 

Oryza sativa

(Y) 
Malus domestica

(Z) 
Diospyros virginiana

1.22.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.23: Sustainable Agriculture and Food Systems

How will planet Earth feed 10 billion people with less land and energy by the year 2050? It will clearly require sustainable approaches for crop cultivation and with enhanced resilience to environmental changes as well as reduced carbon footprint to protect the environment.

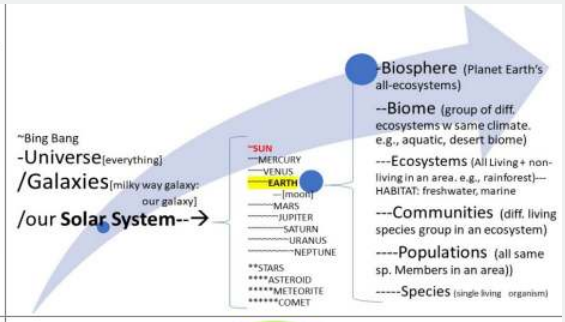
There is an opportunity to promote sustainability as well as high yield, accelerated growth and minimized losses to environmental stress conditions.

? 1.23.1. Student Learning Outcomes (SLOs)

- **SLO 23.01:** Apply the best practices for learning sustainable agriculture
- **SLO 23.02:** Describe the linkage between soil and plant growth
- **SLO 23.03:** Describe the characteristics of sustainability including environment, economic, and community
- **SLO 23.04:** Describe how crop species relates to the economy
- **SLO 23.05:** Identify given plant species with their scientific names based on their key features
- **SLO 23.06:** Describe how crop species relates to the environment
- **SLO 23.07:** Explain the differences between different crop production methods such as organic and conventionally grown

1.23.1. Big Picture

BIOSPHERE OF OUR PLANET EARTH



SUSTAINABLE PLANT SYSTEMS

SUSTAINABILITY→

- Sustainability can be maintained by little non-renewable resources input, minimized pollution (max recycle), and maintained ecologic balance for today and future
-

SUSTAINABLE CROP PRODUCTION and INCREASED DIVERSITY

- **CLIMATE:** Growing season and planting dates
- **SOIL:** testing for macro- and micro-nutrients. High quality soil that absorb moisture as well as drain
- **NUTRIENTS:**
  - N (nitrogen: green shoot and leaf biomass growth)
  - P (phosphorus: flower and fruit growth)
  - K (potassium: root growth)
- **SEED SELECTION:** superb crop variety: Disease resistant, early maturation, and high yield

GROWING ORGANIC

- **HEALTHY SOIL**
- **ORGANIC NUTRIENTS:**
  - N (organic: manure, cover crops, legumes)
  - P (organic: bone meal)
  - K (organic: wood ashes)
- **ORGANIC WEED CONTROL:**
  - Mulch usage: organic matter coverage of soil
- **NATURAL PESTICIDES:**
  - Biological control: usage of natural pred.
  - Naturally resistant varieties usage

CERTIFIED ORGANIC LABEL

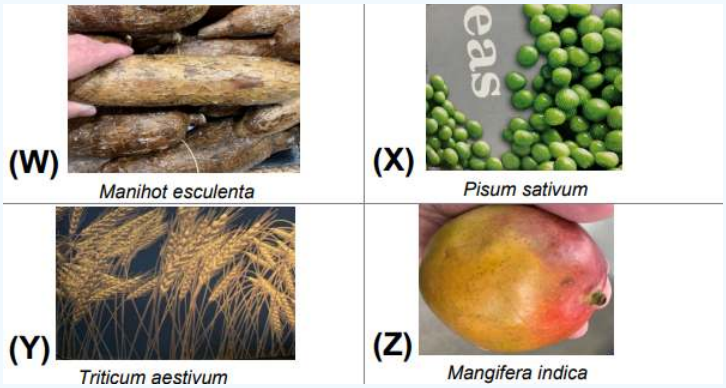
- USDA National Organic Program (NOP) certifies organics seal
  - 100% ORGANIC (100% org. ingredients)
  - ORGANIC (95–99% org. ingredients)

1.23.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: USDA 100% organic certification criteria include not usage of synthetic fertilizers, prohibited pesticides, GMOs, and/ or hormones.
- Assessment 2: TRUE or FALSE: In fruit / veggie labels: 9---- code indicates organic, 8---- code indicates GMO, and only four-digit (4---) code indicates conventionally grown.
- Assessment 3: TRUE or FALSE: South Dakota grows the most sunflowers in the U.S. (5 Mil tones).
- Assessment 4: TRUE or FALSE: One corn ear has an average of 800 seeds (kernels).
- Assessment 5: TRUE or FALSE: Crayons are made of soybean oil.
- Assessment 6: TRUE or FALSE: Florida is the top producer of orange, grapefruit, tomato, watermelon, cucumber, snap beans, squash, and sugar cane in the U.S.
- Assessment 7: TRUE or FALSE: Pierson, Florida is known as the “Fern Capital of the World”

- Assessment 8: TRUE or FALSE: Arabidopsis was the first plant (1982) and potato was the first food plant (1995) grown in outer space.
- Assessment 9: TRUE or FALSE: California is the biggest peach producer.
- Assessment 10: TRUE or FALSE: Georgia is the biggest peanut state and produces $\sim 50\%$ of the U.S. peanut production.

1.23.4. Can You Spot These Plants?



1.23.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE
5. TRUE
6. TRUE
7. TRUE
8. TRUE
9. TRUE
10. TRUE

1.24: Synthetic Biology, and CRISPR Gene Editing in Crops

One of the emerging fields in plant biology is developing crop plant cultivars with more stress resilient, disease resilient, nutrient efficient, and increased yield using new genome editing and design techniques.

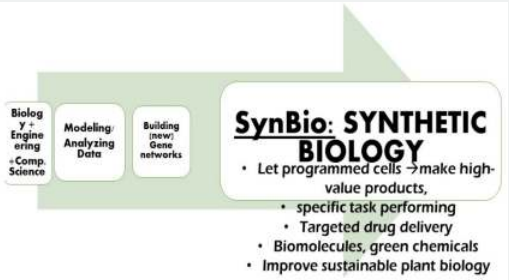
Some of the new products of synthetic biology (SynBio) include chemicals, biofuels, medicines, synthetic cells, plant genes, or promoters. Moreover, adaption of nitrogen fixation to major staple food crops could let non-legumes fix their own nitrogen fertilizer in the future.

1.24.1. Student Learning Outcomes (SLOs)

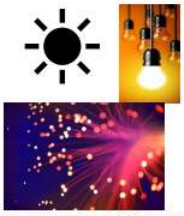
- **SLO 24.01:** Apply the best practices for learning Synthetic Biology, CRISPR Gene Editing
- **SLO 24.02:** Describe the characteristics of CRISPR technology
- **SLO 24.03:** Describe the characteristics of synthetic biology
- **SLO 24.04:** Describe CRISPR/Cas9 tools for plants
- **SLO 24.05:** Identify given plant species with their scientific names based on their key features
- **SLO 24.06:** Explain how CRISPR could be used for improved nutrient usage
- **SLO 24.07:** Explain how CRISPR could be used for improving crop yield

1.24.2. Big Picture

- **MOLECULAR BIOLOGY**: molecular basis of gene
- **SYNTHETIC BIO/SYSTEMS BIO**: fabricate new bio parts / systems reprogram [Gen.Engineering + math modeling + industry ana.]
- **PROMOTER:** regulator to turn a gene ON/OFF



PLANT SYNTHETIC BIO



ENGINEERED SYSTEMS VS NATURAL SYSTEMS

- Modify naturals and / or create new ones
- **ARTIFICIAL PS:** using the largest energy source=SUN. Capture/store energy in a fuel

~Solar-cells + PV-photovoltaic cells_solar panels dependent on weather. Plants in natural PS can get reduced light / filtered light or stored energy and continue PS during cloudy days as well.

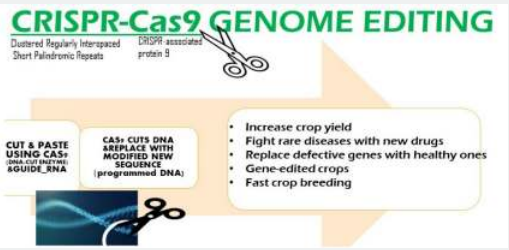
Natural PS:

$$6CO_2 + 6H_2O + \text{light} + \text{Chl.} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- **ARTIFICIAL LEAF:** sunlight→chem. Fuel→store. Challenges: splitting H_2O. to get e's and H. H is stored as fuel in this process.
- **Algae to produce biofuels:** Many advantages include capturing /lowering CO_2 from air.
- **GLOWING TREE:** Engineered by using the glowing enzyme namely luciferase to replace street lights.
- **PLANT-BASED FAKE MEAT:** DNA from plant roots + yeast + other pea protein ingredients. Challenges: cost
- **PRIME SOIL MICROBES:** This can be used to replace chemical fertilizers in agriculture
- **OTHER POTENTIAL PRODUCTS:** Electricity, fuel, water, food polymers, environmentally friendly plastics, and killing cancer cells with programmed microorganisms, create clean water, as well as synthetic biology applications in space with only flying the raw materials and bidesigning / growing them there.

CRISPR-Cas9 GENOME EDITING

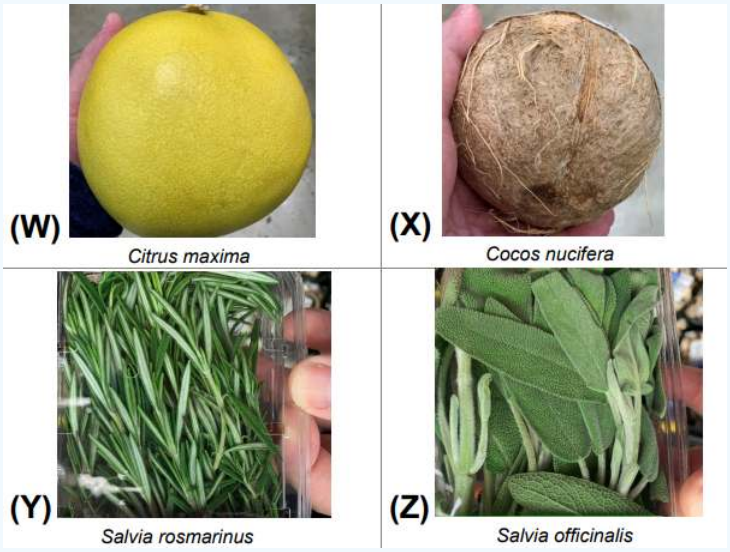
- A non-GMO synBio tool
- NOBEL PRIZE (2020): Jennifer Doudna and Emmanuelle Charpentier
- Can create genome-edited plants
- Stress-tolerant plants
- Nutritionally enhanced plants with desirable traits



1.24.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Dr. George Church (Professor of Genetics @ Harvard) is considered the father of Synthetic Biology.
- Assessment 2: TRUE or FALSE: Self-fertilizing plants may be possible in the future with SynBio.
- Assessment 3: TRUE or FALSE: Programmable plant seeds may be possible in the future with SynBio for colonization of Mars.
- Assessment 4: TRUE or FALSE: Medicine producing plant seeds may be possible in the future with SynBio.

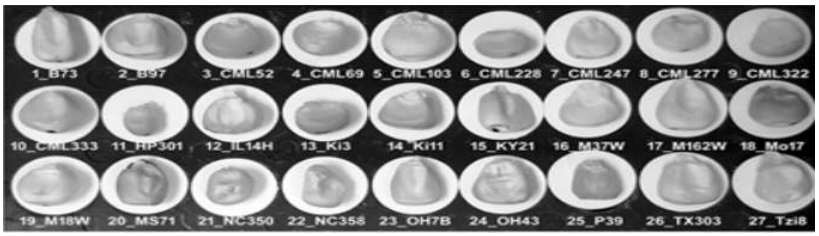
1.24.4. Can You Spot These Plants?



1.24.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.25: Mining Plant Superb Varieties for Increased Resilience to Suboptimal Conditions



Plants are a very important source of food, feed, and fuel. Therefore, exploring their natural diversity and protecting their germplasm resources is key to future food security. Environmental interaction includes the defense of plant species against biotic and abiotic stress tolerance. There are a number of stress factors for plants including: temperature (cold, high), salt, nutrient deficiency, and metal toxicity. As a result, stress conditions can possibly inhibit the plant's growth and development, and therefore, affect plant yield and quality. Furthermore, plant response to environmental stress (both biotic and abiotic) consists of several diverse mechanisms. For example, plant varieties can grow modified structures (e.g., spines) or modify their growth (e.g., shorter stems, modified leaf area) in response to environmental stress and to survive or adapt.

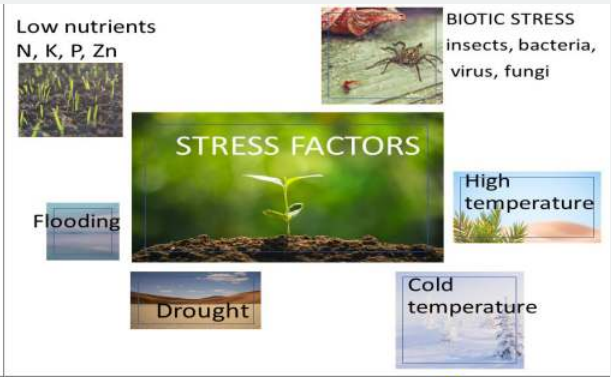
The largest seed bank is the Svalbard Global Seed Vault (1000 m2) in the island of Spitsbergen, Norway that have 4.5 million seed accessions of total 6 million accessions worldwide.

1.25.1. Student Learning Outcomes (SLOs)

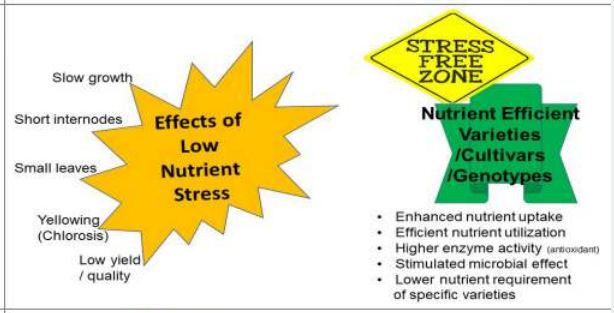
- **SLO 25.01:** Apply the best practices for learning resilience to environmental stress
- **SLO 25.02:** Describe the characteristics of tolerance to high temperature stress
- **SLO 25.03:** Describe the characteristics of tolerance to cold temperature stress
- **SLO 25.04:** Describe the characteristics of tolerance to salt stress
- **SLO 25.05:** Identify given plant species with their scientific names based on their key features
- **SLO 25.06:** Explain importance of genetic variation in plant biology
- **SLO 25.07:** Explain how diverse varieties affect survival of plants

1.25.2. Big Picture

PLANT STRESS FACTORS



STRESS RESILIENCE IN PLANTS



PLANT STRESS

- **BIOTIC STRESS**: caused by living things, such as bacteria, virus, fungi, pests
- **ABIOTIC STRESS**: caused by non-living conditions, such as water, temperature, salt, light

Plant Superb Varieties

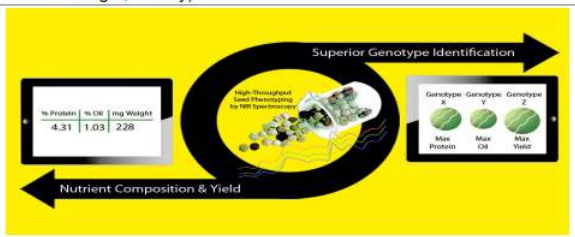
- **A GENOTYPE**: same genetic make-up. Single genotype can have many cultivars.
- **CULTIVAR (CULTIVATED VARIETY):** selected, bred, cultivated by humans.
- **VARIETY (botanically a sub-taxa of sp. With definite variations):** more likely occur in nature
- **INBRED LINES:** come from one / small number common ancestors

GENOTYPIC VARIATIONS AMONG CULTIVARS

- There is genotypic variation as a response to many abiotic stresses
- This can be studied by screening genotypes of crop species under varying doses, duration, and stress conditions
- Great genotypic differences observed and superior cultivars have been identified in several crop species (maize, wheat, beans, soybean, peas, barley, etc.) for several stresses (low Zn, cold, drought, salinity).

SEED PHENOMICS

- Determining single-seed nutrient phenotyping using NIR spectroscopy
- Other techniques: Machine Learning, Image anal., Robot Phenotyping

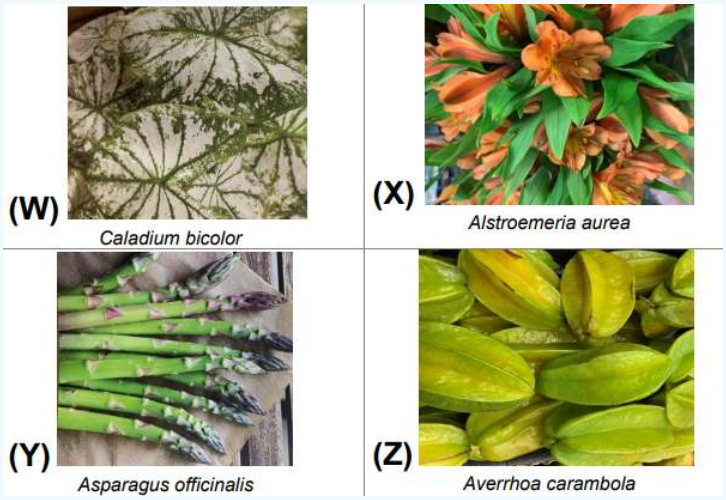


1.25.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: You only need to plant these plants once and harvest for years because they are perennials: asparagus, chives, rhubarb, strawberries.
- Assessment 2: TRUE or FALSE: Needle type of modified leaves are evolutionary adaptation to prevent desiccation and hold more moisture.
- Assessment 3: TRUE or FALSE: All species lived in the sea until ~550 million years ago.
- Assessment 4: TRUE or FALSE: Only 12 crops supply 80% of the world's food supply: sugarcane, maize, rice, wheat, potato, soybean, cassava, tomato, banana, onion, apple, and grape.

- Assessment 5: TRUE or FALSE: The more genetic variation is the better because it will increase survival of some varieties or species.

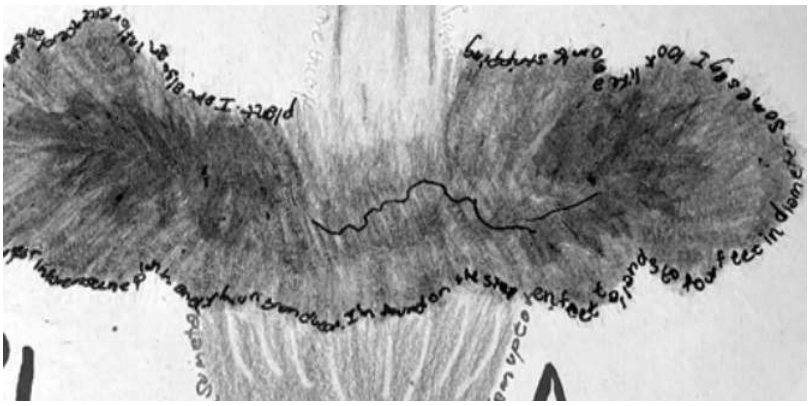
1.25.4. Can You Spot These Plants?



1.25.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.26: Fungi Kingdom



Mushrooms belong to the fungi kingdom. They can provide proteins and many nutrients while minimal harmfulness to environment.

Agaricus bisporus is an over $24 billion economy with varieties such as portobella, cremini, and button mushrooms (both white and brown) in the U.S.

1.26.1. Student Learning Outcomes (SLOs)

- **SLO 26.01:** Apply the best practices for learning Kingdom Fungi
- **SLO 26.02:** Describe the characteristics of fungi habitat
- **SLO 26.03:** Describe the characteristics of phylum Ascomycota
- **SLO 26.04:** Describe the characteristics of phylum Basidiomycota
- **SLO 26.05:** Identify given plant species with their scientific names based on their key features
- **SLO 26.06:** Describe the characteristics of phylum Deuteromycota
- **SLO 26.07:** Describe the characteristics of phylum Glomeromycota

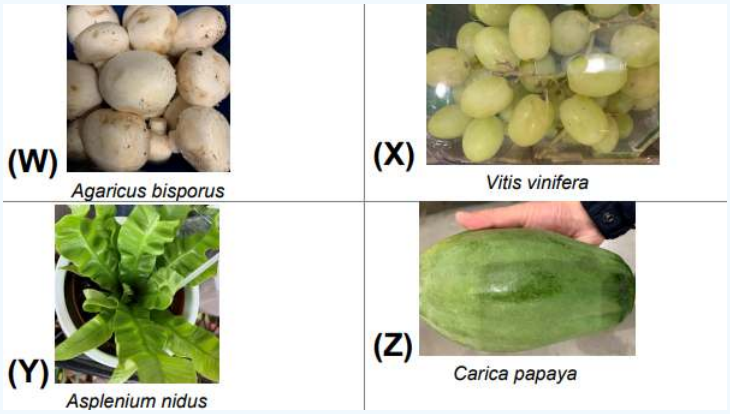
1.26.2. Big Picture

FUNGI  -mycota */my-kota/*→phylum	• Fungus (singular), Fungi (plural) • 1.5 million fungi species • Multicellular (except "yeast") • Feed by absorption • Eukaryotic heterotrophs • Cell walls (made of chitin) • Hypha (1 cell thick) vs mycelium (plural) make up fungi • Aerobic respiration (mostly), and fermentation (yeast) • Reproduce by sexual spores and asexual spores (conidia) • No true roots, stem, leaves
PHYLUM 1: ASCO-MYCOTA [sac fungi]	• 30,000 species • Yeast (beer, wine production) • Ascospores→asci developed • Truffles, mildew, and molds (some)
❖ **YEAST** (single cell) *[Saccharomyces cerevisiae]* 	• SUGAR + YEAST→baking, brewing usage • ***Baker's yeast strain:*** rises the flour-dough when mixed with sugar→produces CO_2 bubbles→rises dough with a spongy structure • ***Brewer's yeast strain*** *(wet):* helps fermentation in wine/beer production
PHYLUM 2: BASIDIO-MYCOTA [club fungi] 	• 25,000 species • Cultivated mushrooms (*Agaricus*), and Rusts • **White-button mushroom: *Agaricus bisporus*** cultivation: most popular one sold in the grocery stores. Protein rich. Vit. B rich. Se rich. Vit. D rich. • **Oyster (yellow)** [*Pleurotus*] **mushroom:** (good in omelets) • **Shiitake mushroom** (good in soups) (fights cancer cells) • **Portobello mushroom:** (good in grill) • **Maitake mushroom:** (good in T2D treatment) • **Lion's mane mushroom:** (medicinal, also stir-fry) •
PHYLUM 3: CHYTRIDIO-MYCOTA [chytrids]	• 750 species • Aquatic decomposers • Flagellate (move)
PHYLUM 4: DEUTERO-MYCOTA [imperfect fungi] 	• 25,000 species • Common green molds and brown molds (*Aspergillus*) • *Penicillin* (antibiotic that enter bacteria cell kills certain bacteria [streptococci] by lysis. Discovered by Alexander Fleming in 1928)
PHYLUM 5: GLOMERO-MYCOTA [sac fungi] 	• 160 species • All mycorrhizae (works with plant roots to provide "P") • 90% plants have mycorrhizae relationship
PHYLUM 6: OO-MYCOTA  [egg fungi]	• 500 species, not true fungi, now under Protista • Their hosts: plants • *Phytophthora infestans*→causes potato late blight (Irish potato famine, 1 mil. fatality in 1845) • *Phythium:* causes seedling damping off disease / decay
PHYLUM 7: ZYGO-MYCOTA [bread molds]	• 750 species • Black bread mold (*Rhizopus*)
LICHENS */lai-kn/* ***=ALGAE + FUNGUS***	• 17,000 species (e.g., *Xanthoria elegans*) • They have symbiotic living relationship, photosynthesize • Resilient to extreme environments [cold, high UV, desiccation] therefore a candidate for Mars colonization.

1.26.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Truffles, rare underground edible fungi, found near chestnut, oak, pine, hazelnut, and pecan roots that exchange nutrients and sugars.
- Assessment 2: TRUE or FALSE: White truffles (alba) can cost $\$3,500/\text{lb}$.
- Assessment 3: TRUE or FALSE: Antibiotic "penicillin" is derived from fungi Penicillium notatum.
- Assessment 4: TRUE or FALSE: There are some fungi that glow in the dark just like fireflies when their luciferin reacts with O_2.

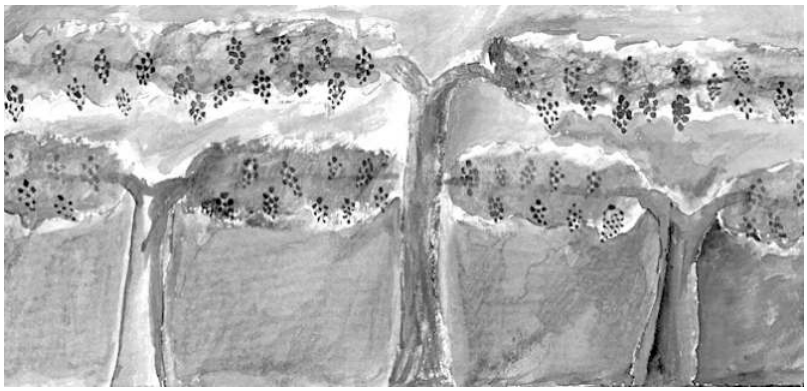
1.26.4. Can You Spot These Plants?



1.26.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE

1.27: Cyanobacteria and Viruses (COVID19 Pandemic Edition)



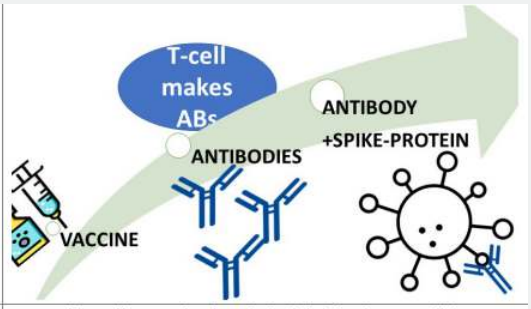
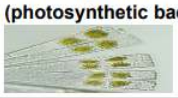
Cyanobacteria is likely one of the bacteria species will help Mars colonization by sustainably growing in Mars soils and environment conditions.

It is known that cyanobacteria helped oxygenation of our planet Earth atmosphere about 2.4 billion years ago. Furthermore, cyanobacteria can not only fix carbondioxide but also nitrogen as well.

? 1.27.1. Student Learning Outcomes (SLOs)

- **SLO 27.01:** Apply the best practicies for learning cyanobacteria and viruses
- **SLO 27.02:** Describe the connection of cyanobacteria to nitrogen cycle
- **SLO 27.03:** Describe the characteristics of photosynthetic cyanobacteria (most)
- **SLO 27.04:** Describe the characteristics of viruses
- **SLO 27.05:** Identify given plant species with their scientific names based on their key features
- **SLO 27.06:** Explain the differences between viruses and their viral structure
- **SLO 27.07:** Explain the mutation and genetic variation of viruses

1.27.2. Big Picture

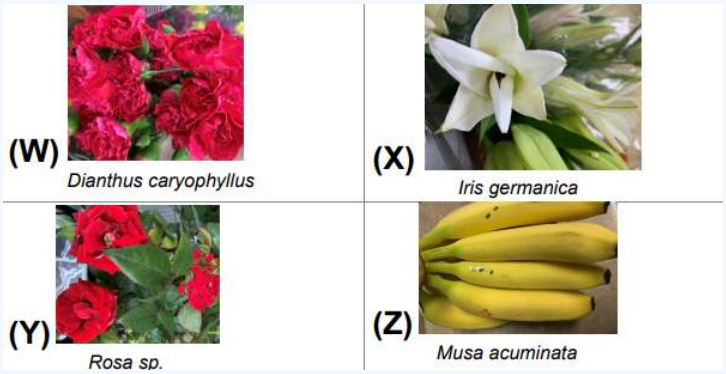
"COVID-19" PANDEMICS CAUSED BY NOVEL CORONAVIRUS 'SARS-COV2'	
VIRUSES • SARS, H1N1, Measles, etc.	• Virus (/vay-rus/-poison in Latin): infectious non-living molecule with a protein coat outside of its genetic material (DNA or RNA). Viruses can only grow / multiply in a living host cell (human, animal, plant, bacteria host)
NEW VARIANTS OF CORONAVIRUSES: ***WT STRAIN:* SARS-COV2**	Mutation~~~~~~>new variants • UK variant (B.1.1.7) • South Afr. variant (B.1.351) • Brazil variant (P.1)
TESTS	PCR TEST (nasal swab) [3-5 d] RAPID ANTIGEN TEST (nasal swab) [1 d] ANTIBODY TEST (blood) [3-5 d]
VACCINES 2021: mRNA vaccines make spike proteins inside your cell therefore produce: • Antibody • Helper-T cells • Killer T-cells (virus vaccines missing this)	PFIZER (mRNA) 95% efficacy MODERNA (mRNA) 94% efficacy NOVAVAX (mRNA) 89% efficacy OXFORD (GMO virus) 70% efficacy J&J (virus) 66% efficacy SINOVAC (inact.virus) 50% efficacy
IMMUNITY	• **HERD-IMMUNITY:** ≤60% of population to develop antibodies • **FULL-IMMUNITY:** everybody susceptible to SARS-COV2
CYANOBACTERIA **(photosynthetic bacteria)** 	• 1st org. developed PS (3.4 billion years ago) also ancestor of organelle chloroplast • Lives in water, soil, desert, and hotsprings • Fixes C as well as N • Can form colonies and be visible • Form Lichens (fungi + CB)
	• Prochlorococcus: most abundant PS-organism (O_2 provider) • Other CB species: *Microcoleus sp., Gloeocapsa, Nostoc, Oscillatoria, Anabaena*
'CYANOBACTERIA' IS A PHYTOPLANKTON	• **COMMON PHYTOPLANKTON (5000 photosynthesizing species)**: ▪ cyanobacteria (bacteria) ▪ diatoms (yellow algae) ▪ dinoflagellate (micro algae) ▪ green algae (algae)
PIONEER SPECIES	• They are considered the first species to move into a new area. Fungi and lichens are good examples of pioneer species could be considered for Mars colonization

1.27.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: COVID-19 is a term for "Coronavirus Disease 2019", named after the year it was first identified (2019).
- Assessment.2: TRUE or FALSE: Over 120+ "COVID-19" vaccine candidates have been proposed worldwide.
- Assessment 3: TRUE or FALSE: COVID-19 has not currently been detected in Antarctica.
- Assessment 4: TRUE or FALSE: SARS-CoV-2 as well as some plant viruses are made of RNA.
- Assessment 5: TRUE or FALSE: A safe distance to stay apart from someone who's sick is a minimum of 1 meter (3 ft).
- Assessment 6: TRUE or FALSE: One COVID-19 infected person infects ~2.5 other people and 5% will need hospital care.
- Assessment 7: TRUE or FALSE: Loss of smell (anosmia) and decreased sense of taste (ageusia) together with cough, fever and shortness of breath are symptoms of COVID-19 (+).
- Assessment 8: TRUE or FALSE: COVID-19 spreads via respiratory droplets that pass from person to person.

- Assessment 9: TRUE or FALSE: 60% alcohol can kill SARS-CoV-2.
- Assessment 10: TRUE or FALSE: Increased risk of serious COVID-19 illness include diabetes as well as blood type A.

1.27.4. Can You Spot These Plants?



1.27.5. Check Your Answers

1. TRUE
2. TRUE
3. TRUE
4. TRUE
5. TRUE
6. TRUE
7. TRUE
8. TRUE
9. TRUE
10. TRUE

1.28: Growth Mindset and Grit

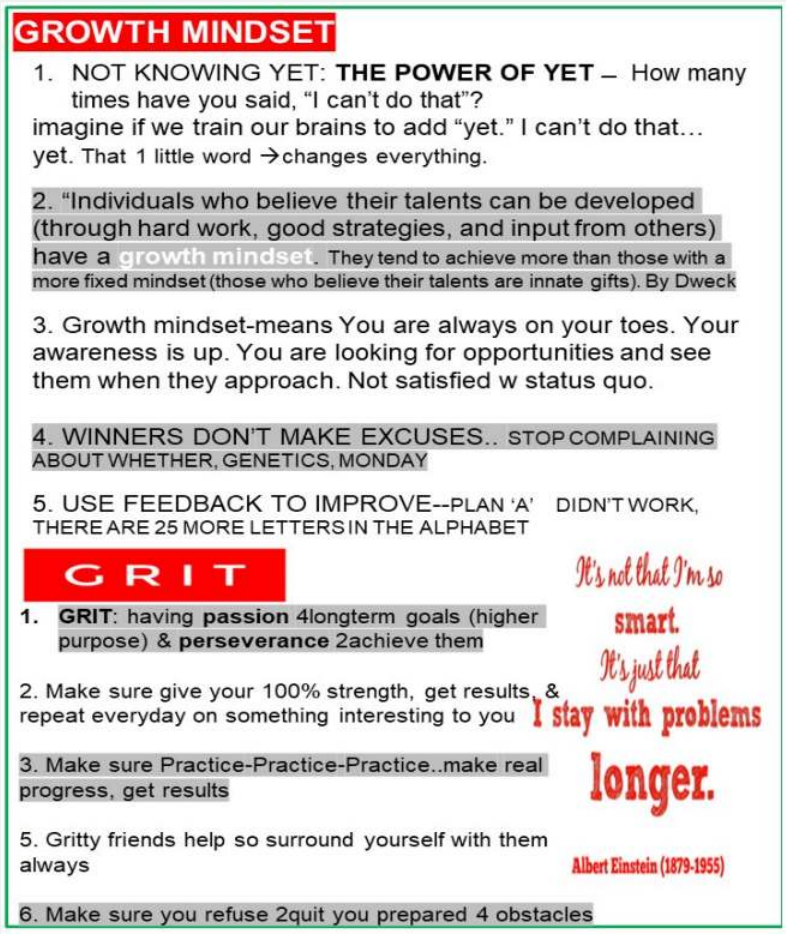
How do cultivate growth mindset? Growth mindset individuals can develop their abilities compare to fixed mindset individuals. Moreover, growth mindset individuals have the attitude of constantly learning new things.

Furthermore, there are increasing research interest in answering the question: Does growth mindset (also grit) help promote undergraduate student performance especially in STEM (science, technology, engineering, and math) field majors?

? 1.28.1. Student Learning Outcomes (SLOs)

- **SLO 28.01:** Apply the best practices for learning Growth Mindset and Grit
- **SLO 28.02:** Describe teh characteristics of Growth Mindset
- **SLO 28.03:** Describe the characteristics of Grit
- **SLO 28.04:** Describe the characteristics developing growth mindset
- **SLO 28.05:** Identify given plant species with their scientific names based on their key features
- **SLO 28.06:** Explain strategies for fostering grit
- **SLO 28.07:** Explain how to learn from failure

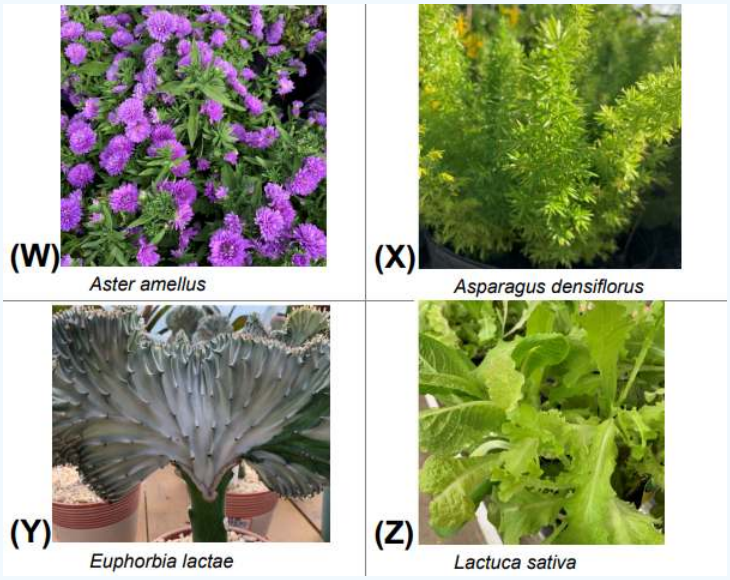
1.28.2. Big Picture



1.28.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: It's possible to grow new brain cells (neurogenesis).
- Assessment 2: Do you have a BIOLOGY growth mindset? (hint: check your GM score).
- Assessment 3: A pandemic such as COVID19 can help cultivate growth mindset. Why?
- Assessment 4: TRUE or FALSE: Several celebrities who failed before succeeding built grit. Give examples. Stephen King, Walt Disney, JK Rowling (Harry Potter), and Bill Gates among others.

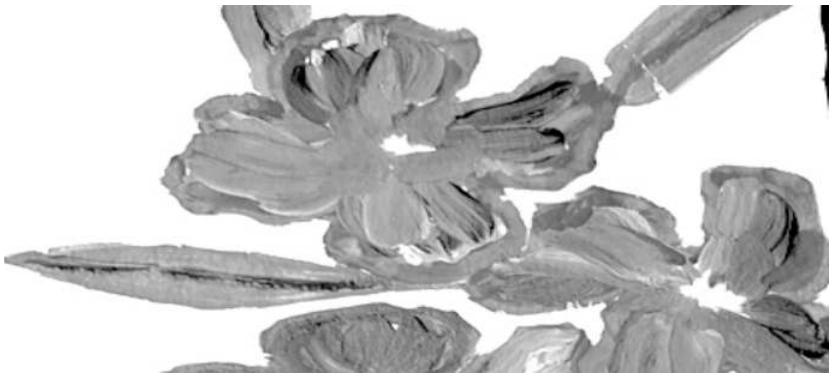
1.28.4. Can You Spot These Plants?



1.28.5. Check Your Answers

1. TRUE
2. Strong growth mindset (45–60 points in Mindset Instrument) also create opportunities for growth and developing new techniques for resilience
3. Because of the fact that crisis like a pandemic
4. TRUE.

1.29: Student Learning



What are the twenty-first-century learning skills that we can integrate in undergraduate education? There are at least four major skills as follows:

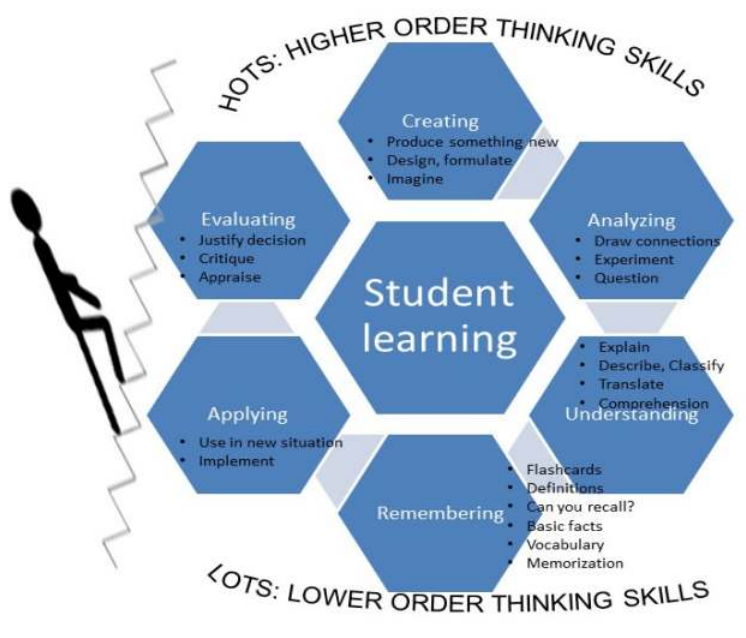
1. Critical thinking
2. Communication
3. Collaboration
4. Creativity

Moreover, undergraduate students need to develop higher-order thinking skills such as creativity and synthesizing in order to be well-prepared for navigating the twenty-first century and success.

1.29.1. Student Learning Outcomes (SLOs)

- **SLO 29.01:** Apply the best practices for learning about student learning
- **SLO 29.02:** Describe the characteristics of how learning works
- **SLO 29.03:** Describe the characteristics of online learning
- **SLO 29.04:** Describe the characteristics of in-person learning
- **SLO 29.05:** Identify given plant species with their scientific names based on their key features
- **SLO 29.06:** Describe the characteristics of hybrid learning
- **SLO 29.07:** Explain classroom technology in the new era of learning

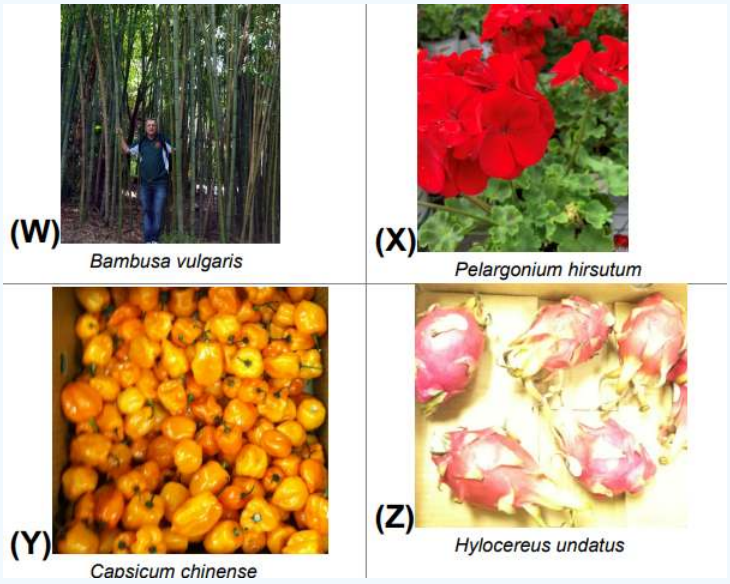
1.29.2. Big Picture



1.29.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Growing plants help students learn valuable skills and concentrate.
- Assessment 2: Multimedia tools such as videos improve learning. Why?
- Assessment 3: TRUE or FALSE: US phone numbers are 7-digits because of the fact that human short-term memory can hold max 7 digits.
- Assessment 4: TRUE or FALSE: Human can remember 65% info as image while 10% as a text.

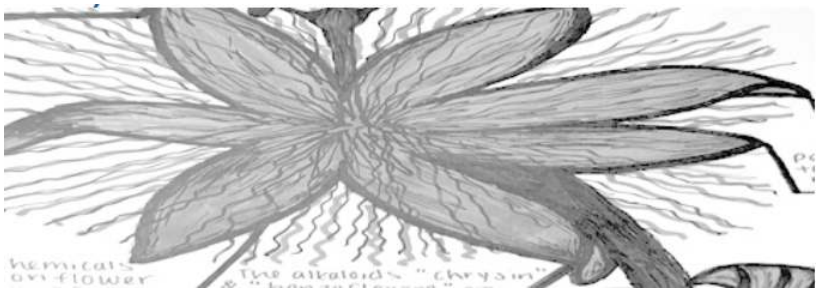
1.29.4. Can You Spot These Plants?



1.29.5. Check Your Answers

1. TRUE
2. Because of the fact that multimedia tools (videos, animation, picture) improve connections of content in both visual and verbal context, it helps brain improve learning.
3. TRUE
4. TRUE

1.30: How to Study STEM (Science, Technology, Engineering, and Math)



What are the best study skills for undergraduate STEM (Science, Technology, Engineering, & Math) subjects? Some effective study methods include as follows:

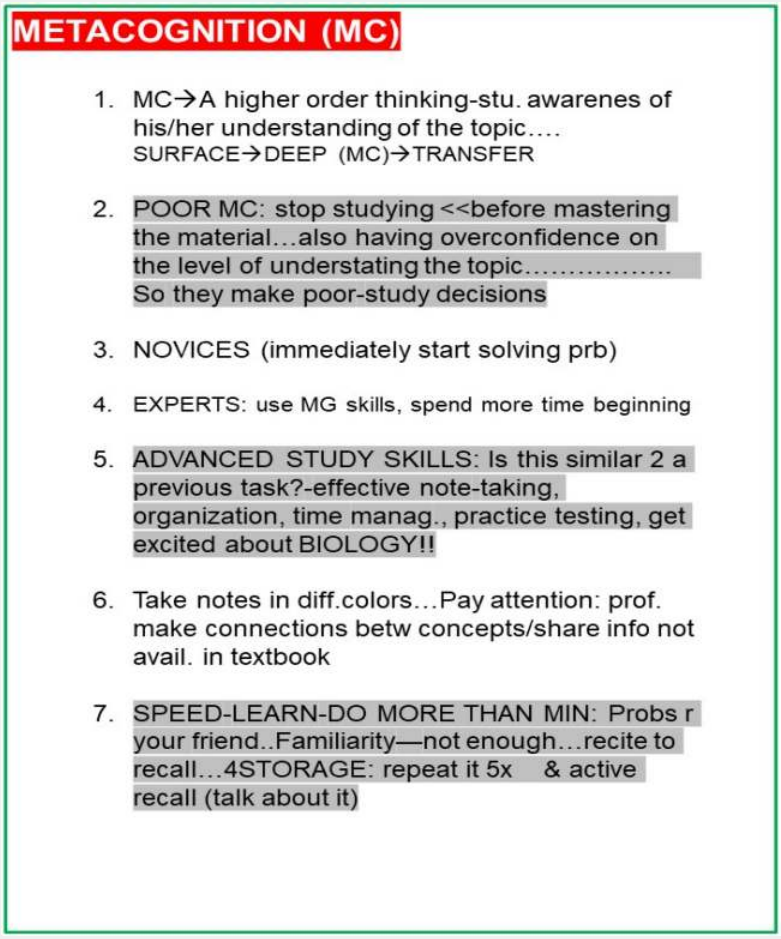
- Attend every class lecture
- Make flashcards and concept maps
- Take your own good notes and repeat them daily
- Read the textbook ahead and repeat
- Use highlighters and colors when studying
- Read it through before answering a question
- Metacognition (MC): Learning how to learn

Moreover, gaining mastery of content gradually help undergraduates to build more confidence, ownership of expertise, and appreciation for STEM fields.

? 1.30.1. Student Learning Outcomes (SLOs)

- **SLO 30.01:** Apply the best practices for learning How to Study Science (STEM)
- **SLO 30.02:** Describe the characteristics of effective studying
- **SLO 30.03:** Describe the characteristics of effective schedule
- **SLO 30.04:** Describe the characteristics of effective note-taking
- **SLO 30.05:** Identify given plant species with their scientific names based on their key features
- **SLO 30.06:** Explain the differences between simply reading and active studying
- **SLO 30.07:** Explain how explaining materials in your own words is an effective learning tool

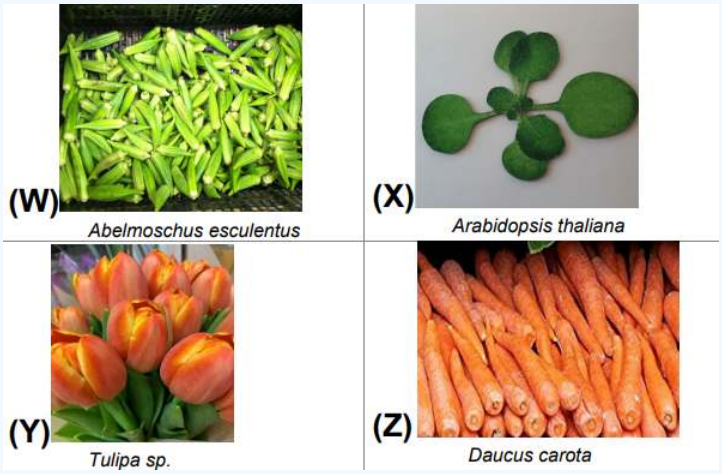
1.30.2. Big Picture: Metacognition (MC)



1.30.3. Test Your Knowledge

- Assessment 1: TRUE or FALSE: Reading on hard-copy material is superior compare to screens.
- Assessment 2: TRUE or FALSE: Active recall with closing the book is superior studying compared to re-reading.
- Assessment 3: Teaching explaining the course material to somebody else is a superior learning technique. Why?
- Assessment 4: TRUE or FALSE: A 30-minute exercise / per day increases brain cell growth and therefore learning.

1.30.4. Can You Spot These Plants?



1.30.5. Check Your Answers

1. TRUE
2. TRUE
3. Because of the fact that memory need to be used regularly in order to perform optimally. Therefore, teaching someone else uses memory and improved learning the material better.
4. TRUE

CHAPTER OVERVIEW

2: Appendix

2.1: Rubric as a Grading Tool

Dimension	Exceeds (12 pts)	Meets (10 pts)	Approaches (7 pts)	Needs Help (5 pts)
I. **TITLE** (summarize conclusion in one sentence				
II. **AUTHOR(S)** (summarize paper in one paragraph with breif intro, methods, results, and conclusion)				
III. **ABSTRACT** (summarize paper in one paragraph with breif intro, methods, results, and conclusions)				
IV. **INTRODUCTION** (provide sufficient background info from literature with paraphrasing and citations)				
V. **MATERIALS & METHODS** (clearly describe the materials and methodology)				
VI. **RESULTS** (present your data in tables and figures format)				
VII. **DISCUSSION** (discuss and explain your results with a clear conclusion)				
VIII. **REFERENCES** (list all references cited in the paper)				
APA FORMAT (sources cited in parenthesis with authors' name and publication year)	(4 pts)	----------	----------	----------

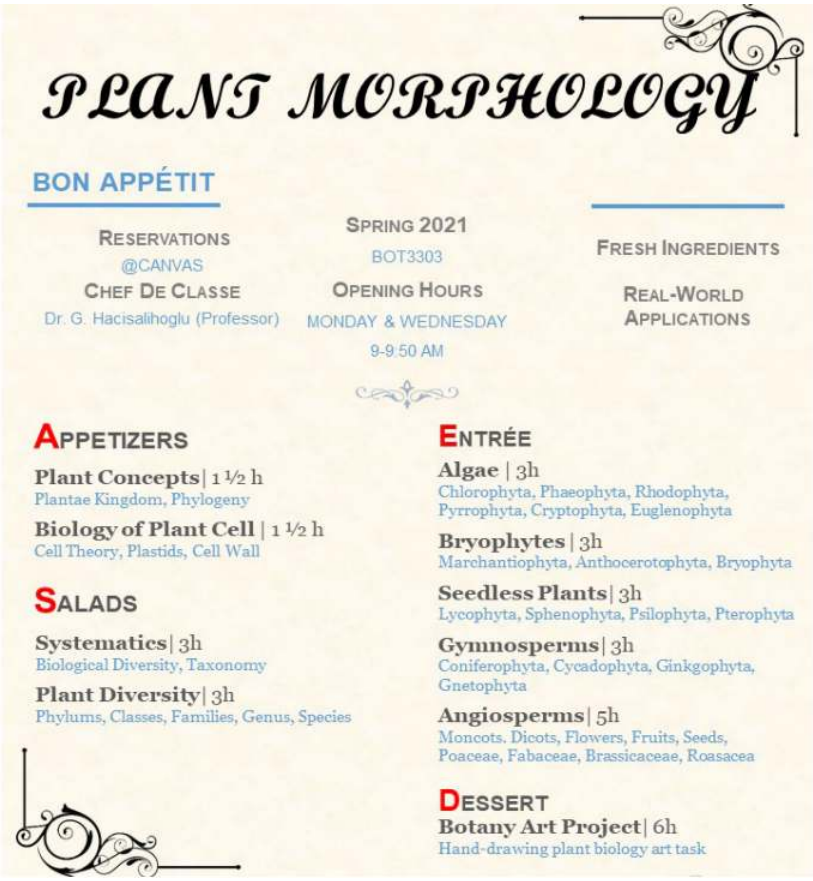
2.2: List of Plant Species Covered in this Book

1	*Abelmoschus esculentus*	Okra		59	*Hypoestes aristata*	Ribbon bush
2	*Abies fraseri*	Fraser fir		60	*Ipomoea batatas*	Sweetpotato
3	*Acer okagama*	Japanese maple		61	*Iris germanica*	Iris
4	*Agaricus bisporus*	Mushroom		62	*Juniperus communis*	Juniper
5	*Agave tequilana*	Blue agave		63	*Lactuca sativa*	Lettuce
6	*Alstroemeria aurea*	Peruvian-lily		64	*Lilium candidum*	Lily
7	*Alstroemeria aurea*	Pineapple		65	*Malus domestica*	Apple
8	*Anethum graveolens*	Dill		66	*Mangifera indica*	Mango
9	*Antirrhinum majus*	Snapdragon		67	*Manihot esculenta*	Cassava (Yuca)
10	*Arabidopsis thaliana*	Arabidopsis		68	*Mentha spicata*	Mint
11	*Asparagus densiflorus*	Asparagus		69	*Mimosa pudica*	Sensitive plant
12	*Asparagus officinalis*	Asparagus		70	*Monstera adansonii*	Swiss cheese plant
13	*Asplenium nidus*	Bird's-nest fern		71	*Musa acuminata*	Banana
14	*Aster amellus*	Aster		72	*Nepenthes sp.*	Pitcher plant
15	*Averrhoa carambola*	Starfruit		73	*Nephrolepis exaltata*	Boston fern
16	*Bambusa vulgaris*	Bamboo		74	*Nerium oleander*	Oleander
17	*Bambusa vulgari*	Begonia		75	*Nipponanthemum nipponicum*	Daisy
18	*Bambusa vulgari* var.capitata	Cabbage		76	*Nymphaea alba*	Waterlily
19	*Bambusa vulgari* var.italica	Broccoli		77	*Oryza sativa*	Rice
20	*Caladium bicolor*	Caladium		78	*Pachira aquatica*	Money tree
21	*Calluna vulgaris*	Heather		79	*Pachystachys lutea*	Golden shrimp plant
22	*Camellia japonica*	Camellia		80	*Pelargonium hirsutum*	Geranium
23	*Camellia*	Tea		81	*Penusetum*	Fountain grass

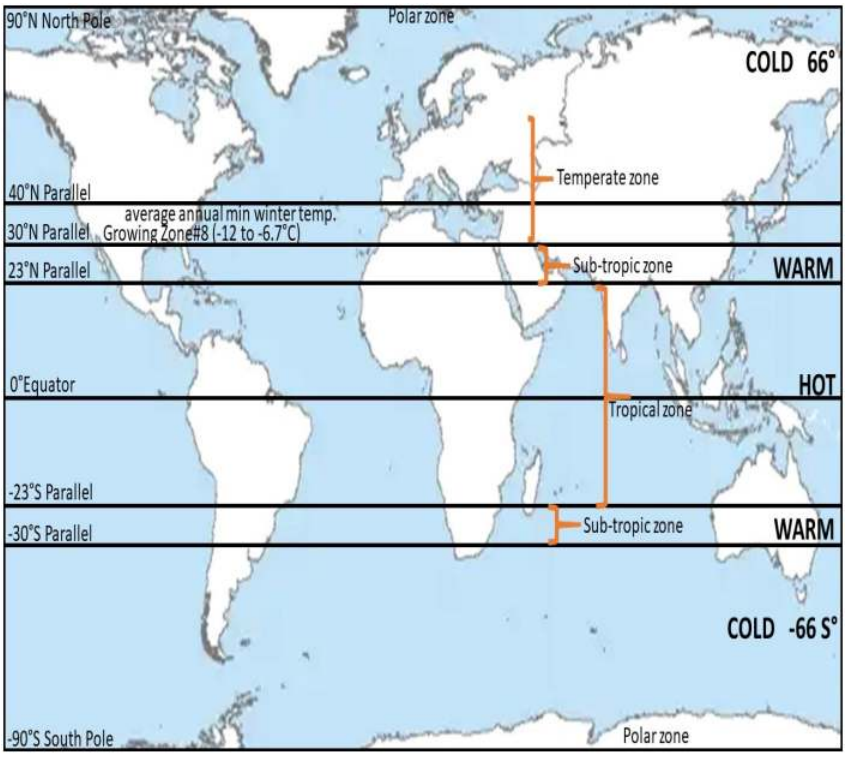
	sinensis				*setaceum*	
24	*Capsicum annuum*	Pepper		82	*Persea americana*	Avocado
25	*Capsicum chinense*	Habanero pepper		83	*Petroselinum crispum*	Parsley
26	*Carica papaya*	Papaya		84	*Petunia atkinsiana*	Petunia
27	*Carnegiea gigantea*	Saguaro		85	*Phalaenopsis amabilis*	Moth orchid
28	*Carya illinoensis*	Pecan		86	*Phaseolus vulgaris*	Bean
29	*Cattleya labiata*	Orchid Cattleya		87	*Philodendron selloum*	Philodendron
30	*Chlorophytum comosum*	Spider plant		88	*Pisum sativum*	Pea
31	*Chlorophytum comosum*	Pomelo		89	*Prunus serrulata*	Sakura cherry
32	*Citrus sinensis*	Orange		90	*Quercus virginiana*	Live oak
33	*Citrus sinensis*	Coconut		91	*Rosa sp.*	Rose
34	*Citrus sinensis*	Croton		92	*Sabal palmetto*	Cabbage palm
35	*Coleus solenostemon*	Coleus		93	*Salvia hybrid*	Salvia
36	*Crassula ovata*	Jade plant		94	*Salvia officinalis*	Sage
37	*Crotonanthus klotzsch*	Croton		95	*Salvia rosmarinus*	Rosemary
38	*Cucurbita pepo*	Pumpkin		96	*Schefflera arboricola*	Dwarf umbrella tree
39	*Curcuma longa*	Turmeric		97	*Selaginella stellata*	Selaginella
40	*Cycas revolata*	Sago palm		98	*Senecio rowleyanus*	String of pearls
41	*Cydonia oblonga*	Quince		99	*Sequoia sempervirens*	Redwood
42	*Daucus carota*	Carrot		100	*Serenoa repens*	Saw palmetto
43	*Dianthus caryophyllus*	Carnation		101	*Setcreasea pallida*	Purple heart
44	*Diospyros virginiana*	Persimmon		102	*Solanum lycopersicum*	Tomato
45	*Dracaena*	Dragon blood		103	*Solanum*	Potato

	cinnabari	tree			*tuberosum*	
46	*Dracaena marginata*	Madagascar dragon tree		104	*Sphagnum sp.*	Moss
47	*Dracaena trifasciata*	Snake plant		105	*Spinacia oleracea*	Spinach
48	*Epipremnum aureum*	Golden pothos		106	*Taxus brevifolia*	Pacific yew
49	*Equisetum hyemale*	Horsetail		107	*Thymus vulgaris*	Thyme
50	*Euphorbia lactae*	Cactae		108	*Triticum aestivum*	Wheat
51	*Euphorbia pulcherrima*	Poinsettia		109	*Tulipa sp.*	Tulips
52	*Ginkgo biloba*	Ginkgo		110	*Vaccinium corymbosum*	Blueberry
53	*Hedera helix*	English ivy		111	*Viola tricolor* var. hortensis	Pansy
54	*Helianthus annuus*	Sunflower		112	*Vitis vinifera*	Grape
55	*Hevea brasiliensis*	Rubber tree		113	*Zamia floridana*	Zamia
56	*Hydrangea macrophylla*	Hydrangea		114	*Zea mays*	Maize
57	*Hylocereus undatus*	Dragon fruit		115	*Zingiber officinale*	Ginger
58	*Hypnum moss*	Moss		116	*Zinnia elegans*	Zinnia

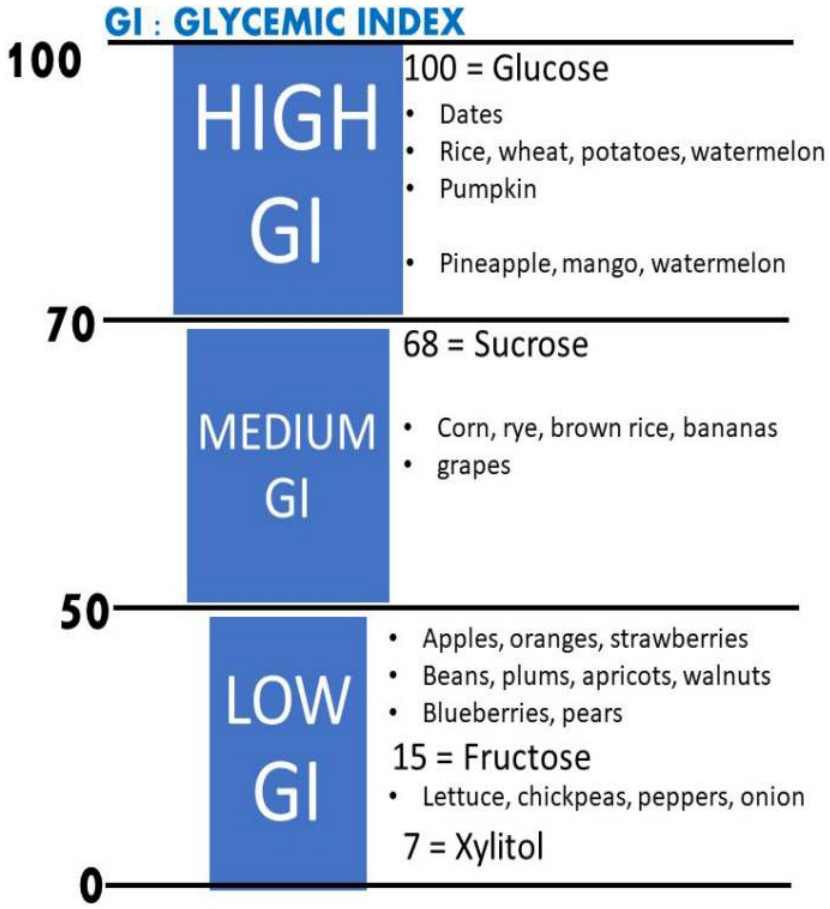
2.3: Course Menu



2.4: Climate Zones and Growing Zones



2.5: Glycemic Index Chart



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