

BOTANY

Division B & C · Starter Pack

2026 – 2027 Season

A study aid covering plant structure, growth & transport, classification, genetics, ecology, and the Division C extensions — built from the official Event Description.

Pack Contents

Note slides: Content slides are organized by topic, moving from plant anatomy through classification, genetics, and ecology, ending with the Division C-only extensions.

Notes section: Additional detail and exam context appear in the Notes section beneath each slide — use them for deeper review or flashcards.

How to use it: Work through the deck in order, then focus on the Division C section only if your team competes at that level.

KEY TERMS

Division B

Middle school competition level.

Division C

High school level; includes extra advanced topics.

Event Snapshot

Description: Participants demonstrate their knowledge of plant life and general botany principles.

Team & time: A team of up to 2 students competes; the event runs about 50 minutes.

Materials allowed: Up to two Class II calculators and one double-sided 8.5" x 11" reference sheet, which may be laminated or in a sheet protector.

KEY TERMS

Class II calculator

Standard scientific calculator; no programmable or graphing features.

Materials & Setup

Supervisor-provided: Live or preserved specimens, photographs, tables, graphs of data, microscopes, and slides are supplied by event supervisors — do not bring your own specimens.

Safety note: Any toxic, irritating, or liquid-preserved specimens (e.g., algae, protists) are presented in closed, non-breakable containers.

Reference sheet rules: Only one sheet of paper per team is allowed — no affixed labels, and no multiple sheets even inside one protector.

KEY TERMS

Sheet protector

A clear sleeve that may hold the team's single allowed reference sheet.

Competition Format

Test style: Botany runs as either a sit-down written exam or a series of laboratory stations with questions — hosts choose the format.

Core skills tested: Mastery of plant cell structure, roots, stems, leaves, spore-forming bodies, and flowers, plus growth, differentiation, and transport of gases, water, and nutrients.

Scoring: The highest score wins; pre-selected questions are used to break ties, so accuracy on harder questions matters.

KEY TERMS

Lab station

A hands-on task or specimen set with its own question(s), rotated between teams.

SECTION 01

Plant Structure & Anatomy

The building blocks: cells, organs, and reproductive structures.

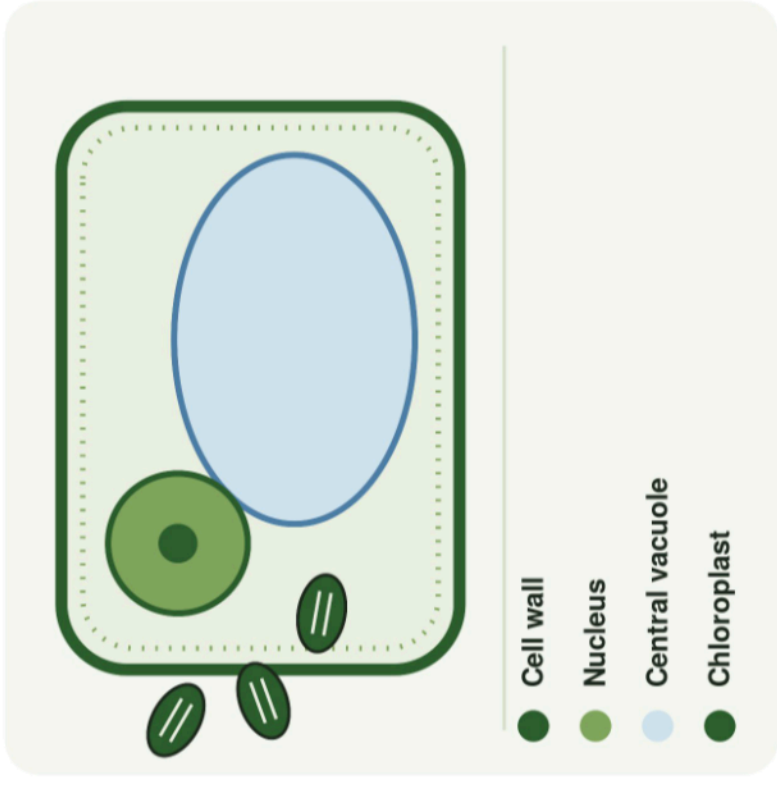
- 01 Plant Cell Structure
- 02 Roots
- 03 Stems
- 04 Leaves
- 05 Spore-Forming Bodies
- 06 Flowers

Plant Cell Structure

Distinguishing features: Plant cells have a rigid cellulose cell wall, a large central vacuole, and plastids (including chloroplasts) that animal cells lack.

Key organelles: Chloroplasts carry out photosynthesis; the central vacuole maintains turgor pressure and stores water, pigments, and waste products.

Cell-to-cell connections: Plasmodesmata are channels through cell walls that let water, nutrients, and signals pass directly between neighboring cells.

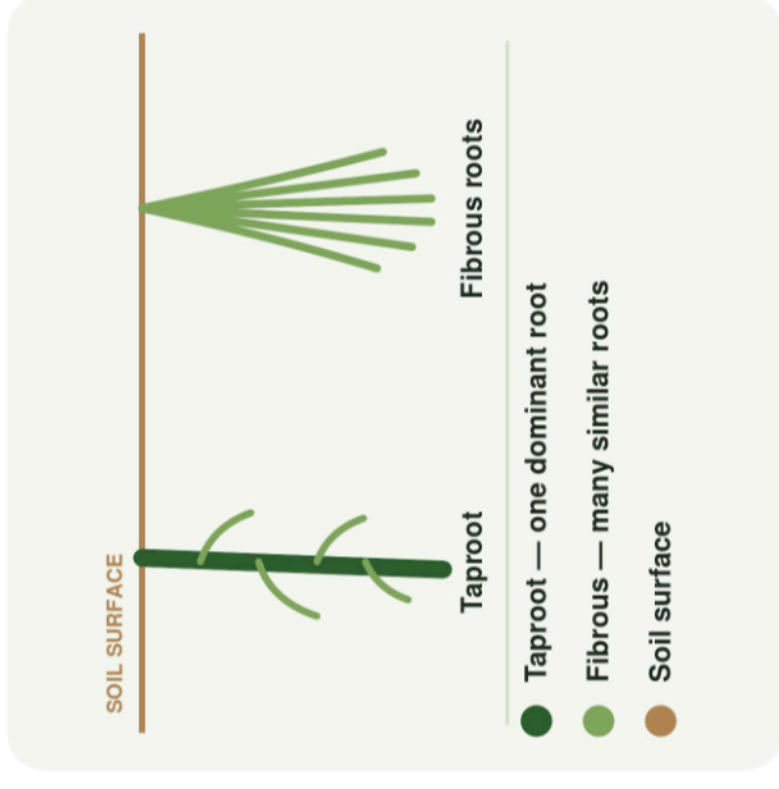


Roots

Primary functions: Anchor the plant, absorb water and dissolved minerals, and often store carbohydrates (e.g., taproots like carrots).

Structure: Root hairs vastly increase surface area for absorption; the root cap protects the actively dividing root apical meristem as it pushes through soil.

Two systems: Taproot systems (one dominant root, common in dicots) versus fibrous root systems (many similar-sized roots, common in monocots and grasses).

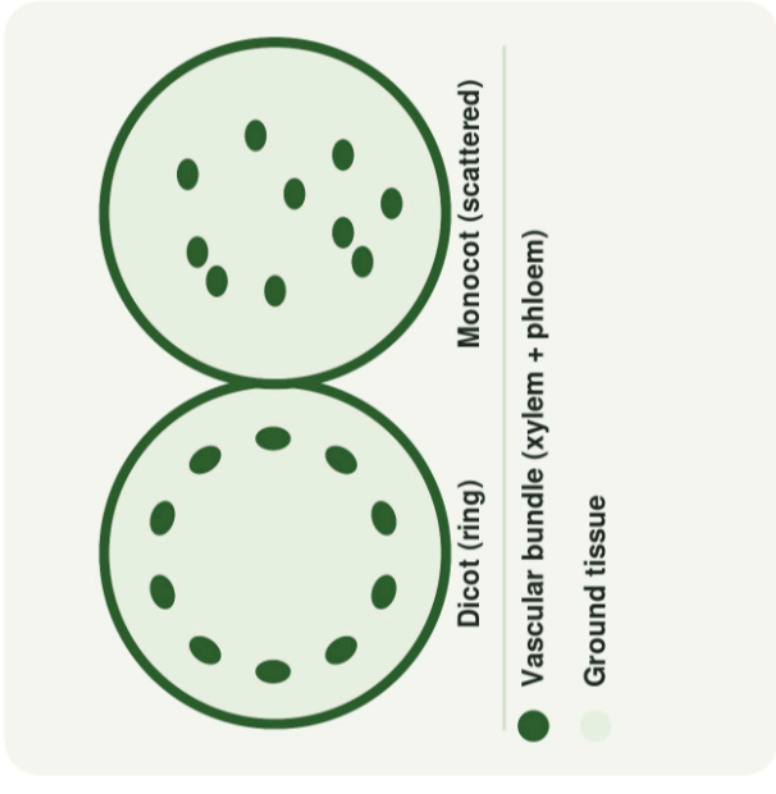


Stems

Primary functions: Support the plant body, position leaves for light capture, and transport water and nutrients between roots and leaves via vascular tissue.

Vascular arrangement: In dicots, vascular bundles are arranged in a ring; in monocots, they are scattered throughout the stem.

Modified stems: Rhizomes, tubers, corms, and bulbs are underground stems specialized for storage and vegetative (asexual) reproduction.

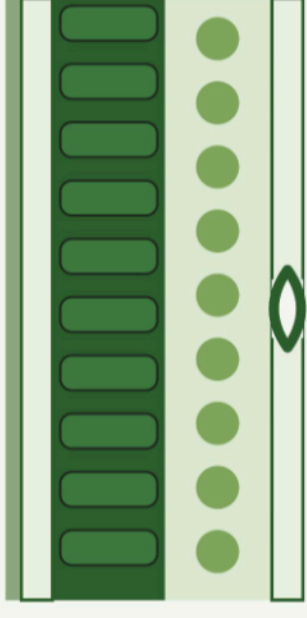


Leaves

Primary function: The main site of photosynthesis, with a broad, flat blade that maximizes light absorption.

Internal structure: Palisade mesophyll (upper, chloroplast-dense) and spongy mesophyll (lower, air-space-rich for gas exchange) sit between the upper and lower epidermis.

Gas exchange: Stomata, typically concentrated on the lower epidermis, open and close via paired guard cells to regulate CO₂ intake and water loss.



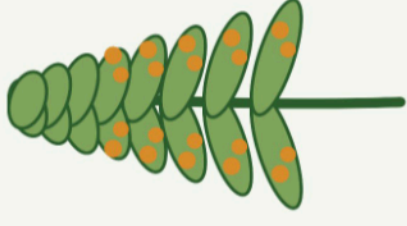
- Palisade mesophyll (top)
- Spongy mesophyll (air spaces)
- Epidermis + waxy cuticle
- Stoma (guard cells)

Spore-Forming Bodies

Where they occur: Found in non-flowering plants such as mosses, ferns, and their relatives, which reproduce using spores instead of seeds.

Ferns: Sori — clusters of sporangia — form on the underside of fern fronds and release haploid spores by the thousands.

Mosses: A stalked capsule (sporangium) sits atop the gametophyte and releases spores that germinate into new gametophytes.



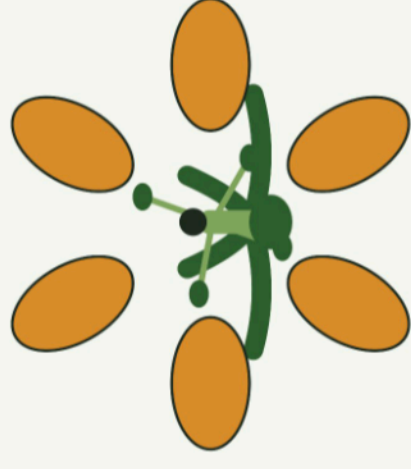
- Rachis (central stalk)
- Leaflet (pinna)
- Sorus — cluster of sporangia

Flowers

Reproductive parts: The pistil (stigma, style, ovary) is the female structure; the stamen (anther, filament) is the male structure that produces pollen.

Protective/attractive parts: Sepals (often green, protect the bud) and petals (often colorful, attract pollinators) surround the reproductive organs.

After fertilization: The ovary develops into a fruit, and ovules develop into seeds — a key link between flower structure and fruit/seed identification questions.



- Petal — attracts pollinators
- Sepal — protects the bud
- Stamen — anther + filament
- Pistil — stigma, style, ovary

SECTION 02

Growth, Transport & Photosynthesis

How plants build tissue and move water, sugar, and gas.

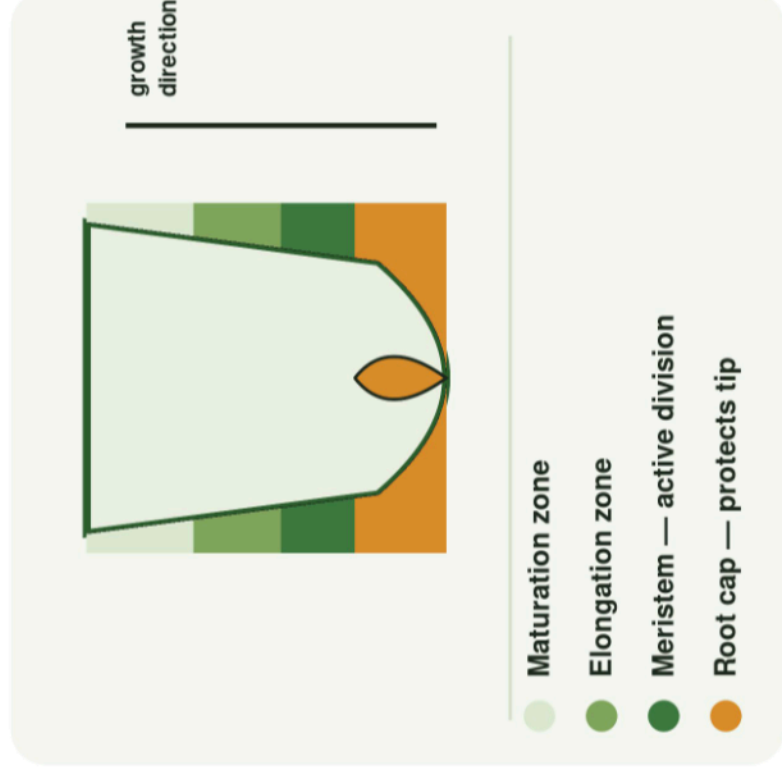
- 01 Growth & Differentiation
- 02 Xylem vs. Phloem
- 03 Gas Exchange
- 04 Photosynthesis

Growth and Differentiation

Meristems: Undifferentiated, actively dividing tissue found at root tips and shoot tips (apical meristems) drives primary growth in length.

Secondary growth: Lateral meristems — vascular cambium and cork cambium — add girth (width) in woody plants.

Differentiation: Cells derived from meristems specialize into dermal, ground, and vascular tissue systems as the plant develops.



Xylem vs. Phloem

XY

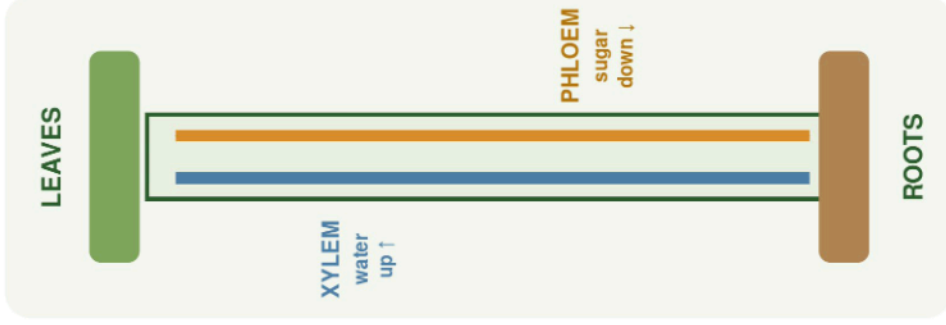
Xylem

- Dead at maturity — tracheids and/or vessel elements form continuous tubes
- Carries water and dissolved minerals from roots to leaves
- Movement is one-directional: root → leaf
- Driven by transpirational pull plus water's cohesion and adhesion

PH

Phloem

- Living tissue — sieve-tube elements and companion cells
- Carries sugars made during photosynthesis to where they're needed
- Flow runs source → sink and can reverse seasonally
- Driven by pressure-flow: loading sugar at the source draws in water

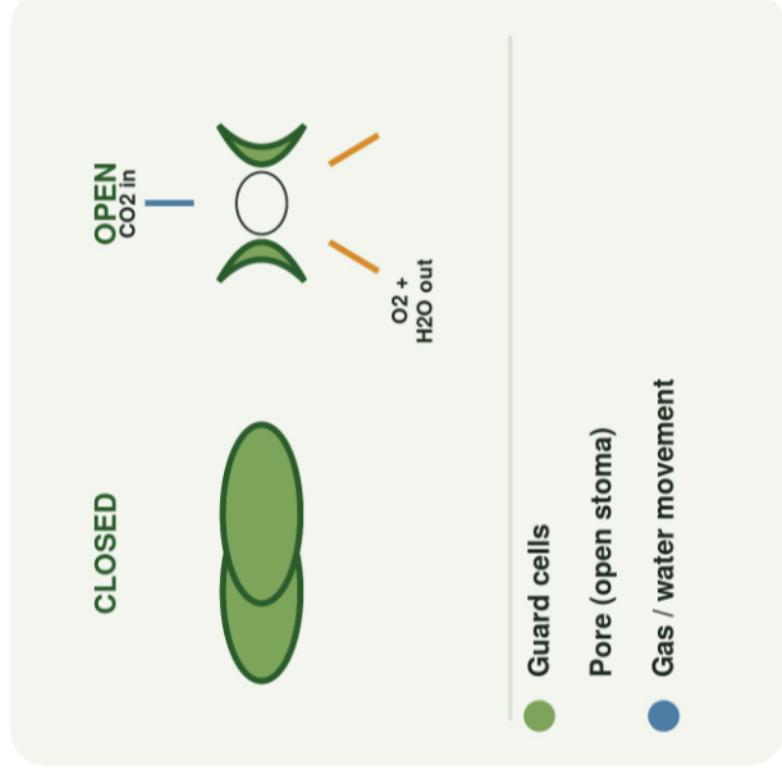


Gas Exchange

Stomata: Microscopic pores, mostly on leaf undersides, open to take in CO₂ for photosynthesis and release O₂ and water vapor.

Guard cells: Pairs of specialized cells control stomatal opening and closing in response to light, CO₂ levels, and water availability.

Respiration: Plants also respire continuously, consuming O₂ and releasing CO₂ — this happens day and night, unlike photosynthesis.

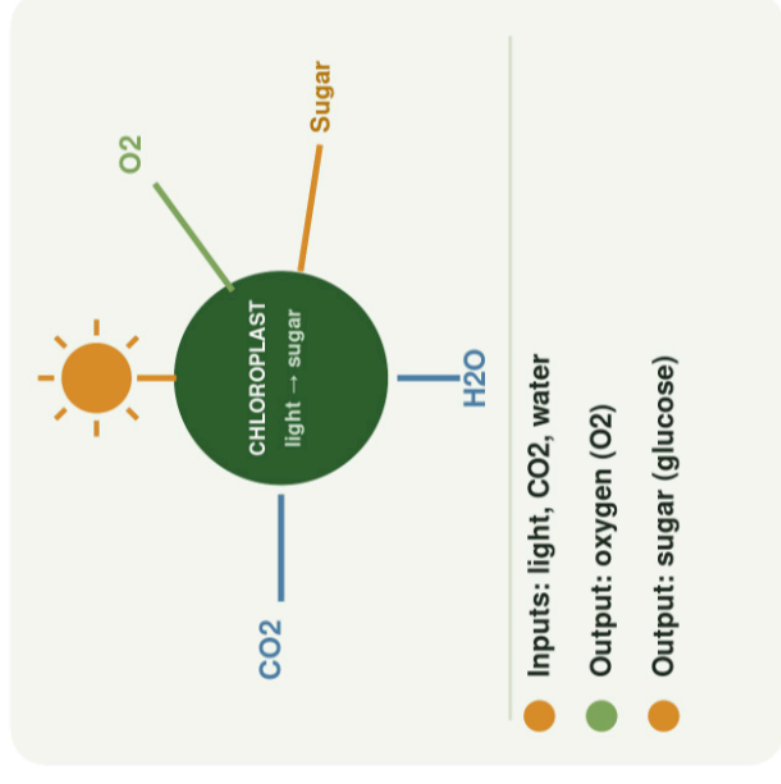


Photosynthesis

Overall reaction: $6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$, occurring inside chloroplasts.

Two stages: Light-dependent reactions (thylakoid membranes) capture light energy to produce ATP/NADPH and O_2 ; the Calvin cycle (stroma) uses that energy to fix CO_2 into sugar.

Key pigment: Chlorophyll absorbs mostly red and blue light and reflects green light, which is why most leaves appear green.



SECTION 03

Classification & Diversity

Sorting plants into groups using structural and reproductive clues.

- 01 Algae vs. Multicellular Plants
- 02 Monocots vs. Dicots
- 03 Embryophytes vs. Cryptogams
- 04 Woody vs. Herbaceous Plants
- 05 Major Taxonomic Groups

Algae vs. Multicellular Plants

Algae: A diverse, mostly aquatic group; many are unicellular or simple multicellular organisms that photosynthesize but lack true roots, stems, and leaves.

Multicellular land plants: Have specialized tissues and organs — true roots, stems, leaves, and (in most groups) vascular tissue — adapted for life on land.

Why it matters: Algae are often studied alongside 'true' plants because they photosynthesize, but they lack the specialized reproductive and vascular structures land plants evolved.

KEY TERMS

Embryophyte

A land plant that nourishes a multicellular embryo — algae are not embryophytes.

Monocots vs. Dicots

M

Monocots

- One cotyledon (seed leaf)
- Parallel leaf veins
- Fibrous root system
- Flower parts in multiples of 3
- Scattered vascular bundles in the stem

D

Dicots

- Two cotyledons (seed leaves)
- Net (reticulate) leaf venation
- Taproot system
- Flower parts in multiples of 4 or 5
- Vascular bundles arranged in a ring

Embryophytes vs. Cryptogams

Embryophytes: Land plants that retain and nourish a multicellular embryo inside the parent plant — includes mosses, ferns, gymnosperms, and angiosperms.

Cryptogams: An older, informal term for plants that reproduce via spores rather than seeds (mosses, liverworts, ferns) — 'hidden reproduction,' since no visible flower or seed is produced.

The overlap: All cryptogams (in this sense) are embryophytes, but not all embryophytes are cryptogams — seed plants are embryophytes but not cryptogams.

KEY TERMS

Cryptogam

Literally 'hidden marriage' — a spore-reproducing plant with no visible flower or seed.

Woody vs. Herbaceous Plants

W

Woody

- Produces lignified secondary xylem (wood) via a vascular cambium
- Stems persist above ground and thicken year after year
- Includes trees and shrubs
- Above-ground structures survive winter dormancy

H

Herbaceous

- Little or no woody tissue; stems are typically green and flexible
- Above-ground stems often die back to the ground each year
- May be annual, biennial, or perennial
- Perennials survive winter via underground roots, rhizomes, or bulbs

Major Taxonomic Groups

Bryophytes: Non-vascular land plants (mosses, liverworts, hornworts); gametophyte-dominant life cycle, and require water for fertilization.

Pteridophytes: Vascular, spore-producing ferns and relatives; sporophyte-dominant, but still require water for fertilization (motile sperm).

Gymnosperms & angiosperms: Gymnosperms (conifers, cycads) produce 'naked' seeds, typically in cones; angiosperms (flowering plants) produce seeds enclosed in a fruit from a flower's ovary.



SECTION 04

Genetics, Reproduction & Evolution

How plant traits pass on, and how plant life has changed over time.

- 01 Basic Plant Genetics
- 02 Plant Reproduction
- 03 History of Botany
- 04 Paleobotany & Plant Evolution

Basic Plant Genetics

Ploidy alternation: Plant life cycles alternate between a haploid gametophyte generation and a diploid sporophyte generation — alternation of generations.

Inheritance basics: Mendelian inheritance (dominant/recessive alleles, segregation, independent assortment) applies to plants just as in animals; Mendel's own experiments used pea plants.

Polyploidy: Plants tolerate extra chromosome sets far better than most animals — polyploidy is common in crop breeding and speciation (e.g., wheat, strawberries).

KEY TERMS

Polyploidy

Having more than two complete sets of chromosomes; common in plants.

Alternation of generations

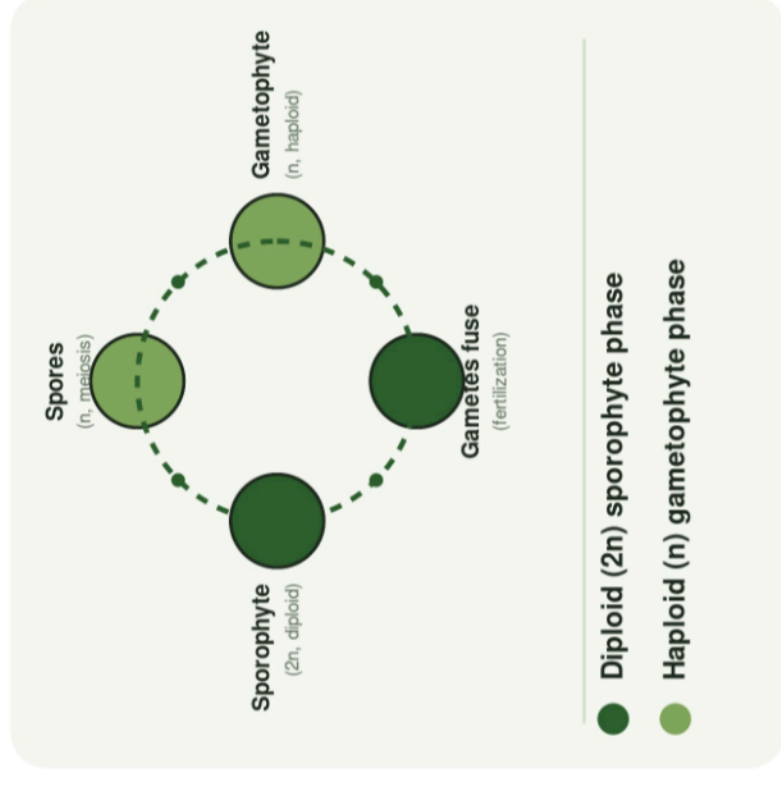
A life cycle that alternates haploid and diploid multicellular phases.

Plant Reproduction

Sexual reproduction: Involves pollination (transfer of pollen to a stigma) and fertilization; agents include wind, water, insects, birds, and other animals.

Asexual reproduction: Produces genetically identical offspring via structures like runners, rhizomes, tubers, bulbs, or cuttings — no pollination required.

Alternation of generations: The diploid sporophyte produces haploid spores by meiosis; spores grow into a haploid gametophyte that produces gametes by mitosis, which fuse to restart the cycle.



History of Botany

Early foundations: Theophrastus (ancient Greece) is often called the 'father of botany' for his systematic descriptions of plants; herbalists across many cultures cataloged medicinal plants for centuries.

Classification milestones: Carl Linnaeus formalized binomial nomenclature and a hierarchical classification system in the 1700s — the basis of the naming system still used today.

Modern botany: The microscope (17th century) revealed plant cell structure; modern molecular and genetic tools let scientists reclassify plant relationships based on DNA evidence.

KEY TERMS

Binomial nomenclature

The two-part Latin naming system (Genus species) formalized by Linnaeus.

Paleobotany & Plant Evolution

What paleobotany studies: The fossil record of plants — impressions, casts, petrified wood, amber inclusions, and preserved spores/pollen — used to reconstruct how plants evolved.

Major milestones: Plants colonized land roughly 470 million years ago; vascular tissue, seeds, and flowers each evolved later, in that general order, expanding plants into drier, more varied habitats.

Evidence and tools: Pollen and spores are especially useful fossils because their tough outer walls preserve well and help reconstruct past climates and vegetation.

KEY TERMS

Sporopollenin

The tough, decay-resistant polymer in spore and pollen walls that helps them fossilize.

SECTION 05

Ecology & Human Interaction

Plants in cycles, communities, agriculture, and disease.

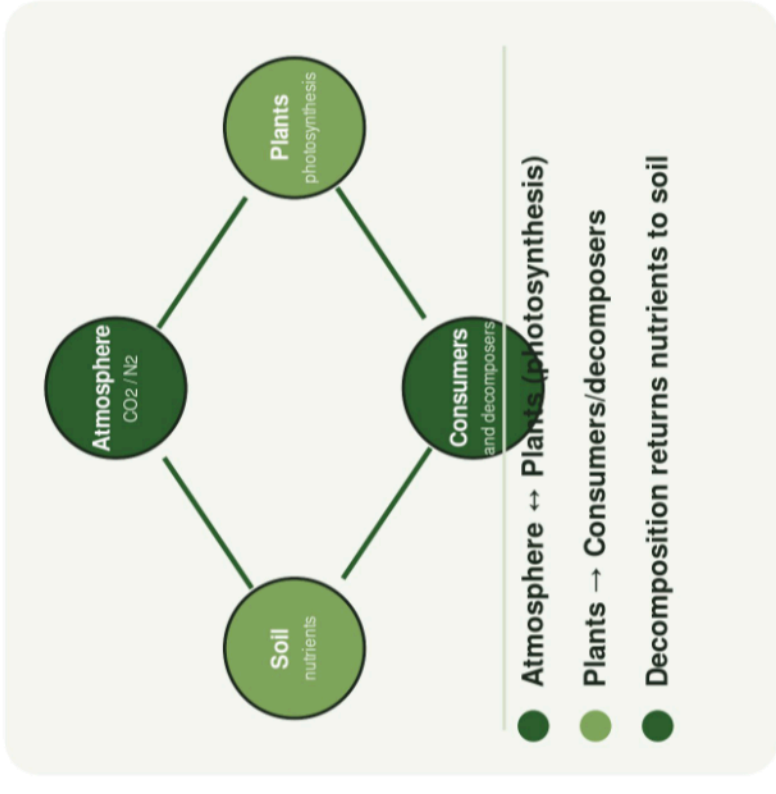
- 01 Global Energy & Nutrient Cycles
- 02 Competition in the Plant Community
- 03 Use by Animals & Humans
- 04 Genetically Modified Organisms
- 05 Foodstuffs & Plant Products
- 06 Plant Diseases: Deficiencies
- 07 Plant Diseases: Infections

Global Energy & Nutrient Cycles

Energy: As primary producers, plants convert light energy into chemical energy, forming the base of nearly all terrestrial food webs.

Carbon cycle: Photosynthesis removes CO₂ from the atmosphere; respiration and decomposition return it — making plants central to the global carbon cycle and climate regulation.

Nutrient cycling: Plants take up nitrogen, phosphorus, and other minerals from soil and return them through leaf litter and decomposition; legumes partner with nitrogen-fixing bacteria.

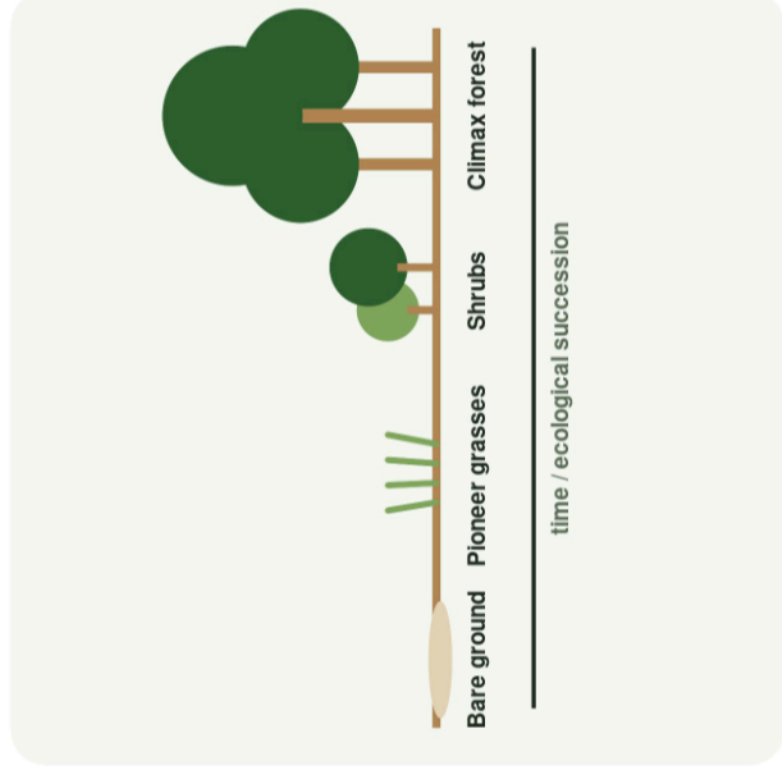


Competition in the Plant Community

Resources competed for: Light, water, soil nutrients, and physical space are the primary resources plants compete for within a community.

Strategies: Some plants grow tall quickly to capture light (fast-growing pioneers); others tolerate shade and grow slowly beneath a canopy (climax species).

Succession: Ecological succession describes the predictable replacement of plant communities over time, from pioneer species on bare ground to a stable climax community.



Use of Plant Materials by Animals & Humans

Ecological uses: Plants provide food, shelter, and nesting material for animals, and many animal-plant relationships (like pollination) are mutually beneficial.

Human material uses: Wood (construction, paper), fibers (cotton, linen), and plant-derived chemicals (rubber, dyes, drugs) all originate from plant tissues.

Historical role: Domestication of plants for food, fiber, and medicine is a foundation of human civilization and agriculture.

KEY TERMS

Domestication

Selective breeding of wild plants over generations for human use.

Genetically Modified Organisms (GMOs)

What GMOs are: Organisms whose genome has been altered using genetic engineering, often to introduce a trait not naturally present (e.g., pest resistance, herbicide tolerance).

Common techniques: Agrobacterium-mediated transformation and gene guns (biolistics) are classic gene-transfer methods; CRISPR-based gene editing is an increasingly common modern tool.

Examples: Bt corn (built-in pest resistance) and Golden Rice (enhanced vitamin A) are well-known examples; GMOs remain a topic of active scientific and public debate.

KEY TERMS

Agrobacterium

A soil bacterium commonly used as a natural gene-delivery tool in plant engineering.

CRISPR

A precise gene-editing technology used to add, remove, or alter DNA sequences.

Production of Foodstuffs & Plant Products

Staple crops: Cereals (wheat, rice, corn), legumes (beans, soy), and tubers (potatoes) supply most of the world's caloric intake.

Processing: Many plant products require processing to be useful — fermentation (bread, wine), extraction (oils, sugar), and refining (flour) all transform raw plant material.

Non-food products: Plants also supply industrial and consumer products: cotton and linen fibers, natural rubber, essential oils, and pharmaceuticals derived from plant compounds.

KEY TERMS

Staple crop

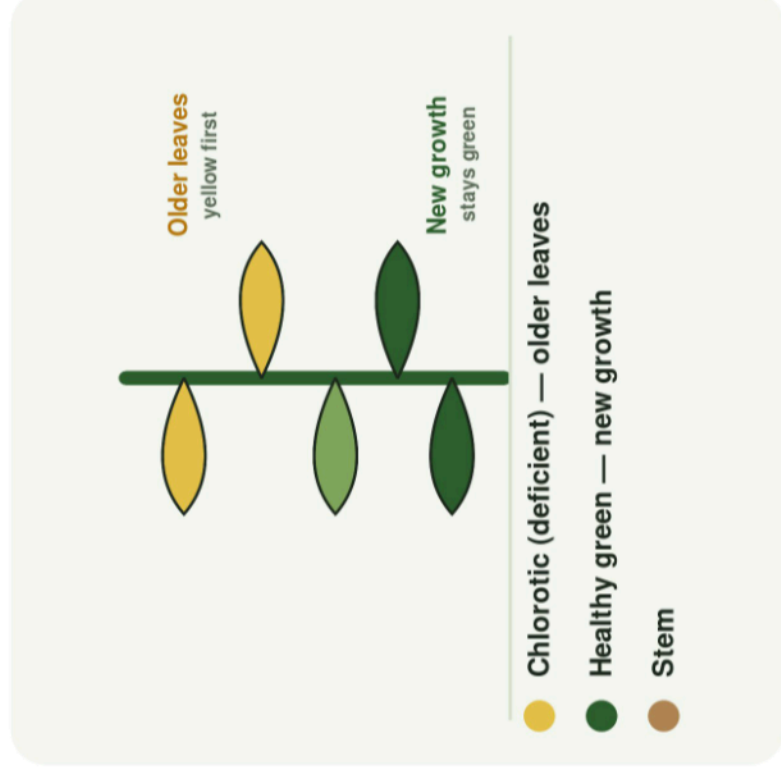
A food crop that supplies a large share of a population's caloric needs.

Plant Diseases: Nutrient Deficiencies

Nitrogen deficiency: General yellowing (chlorosis) starting with older/lower leaves, plus stunted growth — nitrogen is mobile and gets redirected to new growth first.

Iron/magnesium deficiency: Interveinal chlorosis (yellowing between veins while veins stay green) — iron deficiency shows first in young leaves, magnesium in older leaves.

Diagnostic approach: Where symptoms first appear (old vs. new growth) reveals whether a nutrient is mobile (relocated from old to new tissue) or immobile within the plant.



Plant Diseases: Infections

Fungal pathogens: The most common cause of plant disease; examples include powdery mildew, rusts, and blights — often spread by spores in humid conditions.

Bacterial & viral pathogens: Bacteria cause diseases like fire blight and bacterial wilt; viruses (e.g., tobacco mosaic virus) cause mottled leaf patterns and stunted growth, often spread by insect vectors.

Plant defenses: Physical barriers (cuticle, bark), chemical defenses (toxins, antimicrobial compounds), and induced responses (localized cell death to wall off infection) all help plants resist pathogens.

KEY TERMS

Vector

An organism (often an insect) that transmits a pathogen between plants.

Hypersensitive response

Rapid, localized cell death that helps wall off an infection.

DIVISION C ONLY

Additional Topics for Division C

Required for high school (Division C) teams only — skip this section for Division B.

- 01** Principles of Horticulture
- 02** Principles of Aquaculture
- 03** Plant Biochemistry
- 04** Medicine & Environmental Management
- 05** Importance of Plant Diversity

Principles of Horticulture

Definition & scope: The science and art of cultivating fruits, vegetables, flowers, and ornamental plants, blending plant biology with practical growing techniques.

Core practices: Propagation methods (seeds, cuttings, grafting, layering), soil and fertility management, pruning, and pest/disease management.

Controlled environments: Greenhouses and hydroponic/soiless systems allow growers to control light, temperature, and nutrients year-round.

KEY TERMS

Grafting

Joining a scion (top growth) to a rootstock, often to combine desirable fruit with disease-resistant roots.

Principles of Aquaculture

Scope for this event: Cultivation of aquatic plants and algae (e.g., seaweed, duckweed, algae for biofuel) alongside general aquaculture principles.

Water quality factors: Light penetration, dissolved nutrients, pH, and temperature all affect growth rates of cultivated aquatic plants and algae.

Applications: Aquatic plant and algae cultivation supports food production, biofuel research, water filtration (bioremediation), and the aquarium/ornamental trade.

KEY TERMS

Bioremediation

Using living organisms, including aquatic plants, to remove pollutants from water or soil.

Plant Biochemistry

Primary metabolites: Carbohydrates, lipids, proteins, and nucleic acids that support core plant growth and function, similar to other organisms.

Secondary metabolites: Compounds not essential for basic survival but important for defense, signaling, or attraction — alkaloids, terpenoids, and phenolics (including flavonoids and tannins).

Applied relevance: Many secondary metabolites are the basis of plant-derived medicines, flavors, fragrances, and natural pesticides.

KEY TERMS

Alkaloid

A nitrogen-containing secondary metabolite (e.g., caffeine, nicotine).

Tannin

A bitter phenolic compound involved in plant defense (e.g., in tea).

Medicine & Environmental Management

Medicine: A large share of pharmaceuticals originate from or were inspired by plant compounds (e.g., aspirin from willow bark salicin, taxol from Pacific yew, digitalis from foxglove).

Environmental management: Phytoremediation uses plants to extract, degrade, or contain pollutants (heavy metals, organic contaminants) from soil and water.

Ecosystem services: Plants stabilize soil against erosion, filter air and water pollutants, and buffer against flooding — services increasingly built into environmental planning.

KEY TERMS

Phytoremediation

Using plants to remove or neutralize contaminants from soil or water.

Importance of Plant Diversity

Genetic resource: Wild and heirloom plant varieties are a genetic reservoir for breeding disease resistance, climate tolerance, and yield improvements into crops.

Ecosystem stability: Diverse plant communities support more diverse animal communities and are generally more resilient to disease outbreaks and disturbance.

Conservation tools: Seed banks (e.g., the Svalbard Global Seed Vault) and botanical gardens preserve plant diversity against habitat loss and climate change.

KEY TERMS

Monoculture

A large area planted with a single crop variety — efficient but vulnerable.

Seed bank

A facility that stores seeds to preserve genetic diversity long-term.

Sample Question Types

Identification: Identify a structure from a microscope slide, photo, or specimen — e.g., 'What leaf structure is shown on this slide?'

Data interpretation: Read a graph or table — for example, identifying the peak chlorophyll absorbance wavelength from an absorption spectrum.

Applied reasoning: Compare groups (ferns vs. flowering plants), predict ecological outcomes (the next stage of succession), or explain a process (the role of plants in the nitrogen cycle).

Scoring & Event Day Tips

Scoring: The highest total score wins; pre-selected questions are used to break ties — don't skip the hardest-looking questions.

Format flexibility: Be ready for either a sit-down written exam or laboratory stations — practice both timed written tests and hands-on specimen identification.

Reference sheet strategy: Since only one double-sided sheet is allowed, prioritize diagrams, comparison tables (like monocot vs. dicot), and terms your team consistently mixes up.

Study Tips & Closing

- 1 Build comparison tables for paired concepts (xylem vs. phloem, monocot vs. dicot, gymnosperm vs. angiosperm) — this event rewards clear categorical thinking.
- 2 Practice with real specimens and images whenever possible; identification skills don't transfer well from text alone.
- 3 Review the official Science Olympiad rules manual for the current season before competition — required topics can change year to year.

Good luck! This deck is a starting point — pair it with practice exams, specimen practice, and hands-on lab time for the best results.

Science Olympiad

Botany - Division B

Regional Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 30 questions: 21 multiple choice, 4 multi-select (select ALL correct answers), and 5 short answer. Five questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Which structure is unique to plant cells and not found in animal cells?

- A. Mitochondrion
- B. Cell wall
- C. Nucleus
- D. Ribosome

2. Figure 1 shows a plant cell. Which labeled organelle is the site of photosynthesis? [See Figure 1]

- A. Nucleus
- B. Mitochondrion
- C. Chloroplast
- D. Central vacuole

3. The large, fluid-filled organelle that helps maintain turgor pressure in plant cells is the:

- A. Central vacuole
- B. Golgi apparatus
- C. Ribosome
- D. Peroxisome

4. Which best describes plasmodesmata?

- A. Pores that allow direct communication between adjacent plant cells
- B. The waxy outer covering of leaves
- C. A type of plant hormone
- D. Cells that make up xylem tissue

5. Figure 5 shows a root tip. Which labeled zone protects the delicate dividing cells as the root pushes through soil? [See Figure 5]

- A. Root cap
- B. Apical meristem
- C. Area of elongation
- D. Area of maturation

6. Root hairs primarily function to:

- A. Anchor the plant deeply in soil
- B. Increase surface area for water and mineral absorption

- C. Store large amounts of starch
- D. Photosynthesize

7. Which best distinguishes a herbaceous plant from a woody plant?

- A. Herbaceous plants have soft, non-woody stems, while woody plants produce wood/bark
- B. Herbaceous plants never flower
- C. Woody plants cannot photosynthesize
- D. There is no meaningful difference

8. Figure 2 shows a cross-section of a leaf. Which labeled structure allows gas exchange between the leaf interior and the atmosphere? [See Figure 2]

- A. Cuticle
- B. Upper epidermis
- C. Stoma
- D. Spongy mesophyll

9. Which tissue transports water and dissolved minerals from the roots upward through a plant?

- A. Phloem
- B. Xylem
- C. Epidermis
- D. Cortex

10. Which tissue transports sugars produced during photosynthesis to other parts of the plant?

- A. Xylem
- B. Phloem
- C. Cambium
- D. Cuticle

11. Figure 3 shows a flower. Which labeled structure produces pollen? [See Figure 3]

- A. Sepal
- B. Petal
- C. Anther
- D. Stigma

12. Figure 3 shows a flower. Which labeled structure receives pollen during pollination? [See Figure 3]

- A. Stigma
- B. Ovary
- C. Filament
- D. Sepal

13. After fertilization, the ovary of a flower typically develops into the:

- A. Seed coat
- B. Fruit
- C. Petal
- D. Root

14. Figure 4 compares monocot and dicot seeds. Which best describes the key difference shown? [See Figure 4]

- A. Monocot seeds have one cotyledon; dicot seeds have two
- B. Monocot seeds have no seed coat
- C. Dicot seeds never contain an embryo
- D. There is no structural difference between them

15. Which group of plants disperses via spores rather than seeds?

- A. Gymnosperms
- B. Angiosperms
- C. Ferns
- D. Both A and B

16. Which best describes gymnosperms?

- A. Seed plants that produce 'naked' seeds, often in cones, without flowers
- B. Flowering plants that produce fruit
- C. Non-vascular plants like mosses
- D. Single-celled algae

17. Which is the best example of a monocot?

- A. Corn
- B. Bean
- C. Oak tree
- D. Rose

18. During photosynthesis, plants convert light energy into chemical energy stored in:

- A. Water
- B. Glucose
- C. Oxygen gas
- D. Carbon dioxide

19. Which pigment is primarily responsible for capturing light energy for photosynthesis?

- A. Chlorophyll
- B. Melanin
- C. Hemoglobin
- D. Keratin

20. Which gas is a waste product released during photosynthesis?

- A. Carbon dioxide
- B. Nitrogen
- C. Oxygen
- D. Methane

21. Genetically modified (GM) crops are most commonly engineered for traits such as:

- A. Herbicide resistance and pest resistance
- B. Loss of the ability to photosynthesize
- C. Inability to reproduce under any conditions
- D. Reduced nutritional content

22. Which of the following are examples of vascular plants? (Select all that apply)

- A. Ferns
- B. Mosses
- C. Angiosperms
- D. Gymnosperms

23. Which of the following are functions of leaves? (Select all that apply)

- A. Photosynthesis
- B. Gas exchange
- C. Water absorption from soil
- D. Transpiration

24. Which of the following are parts of a complete flower? (Select all that apply)

- A. Sepal
- B. Petal
- C. Root hair
- D. Stamen

25. Which of the following are ways humans commonly use plant materials? (Select all that apply)

- A. Food
- B. Medicine
- C. Building materials/fiber
- D. None of the above

26. List three structures found in plant cells but not in animal cells, and briefly state the function of each.

27. Explain the difference between the functions of xylem and phloem.

28. Describe the process of pollination and explain why it is important for plant reproduction.

29. Write the general word equation for photosynthesis and identify the reactants and products.

30. Explain one key difference between monocots and dicots, other than the number of cotyledons.

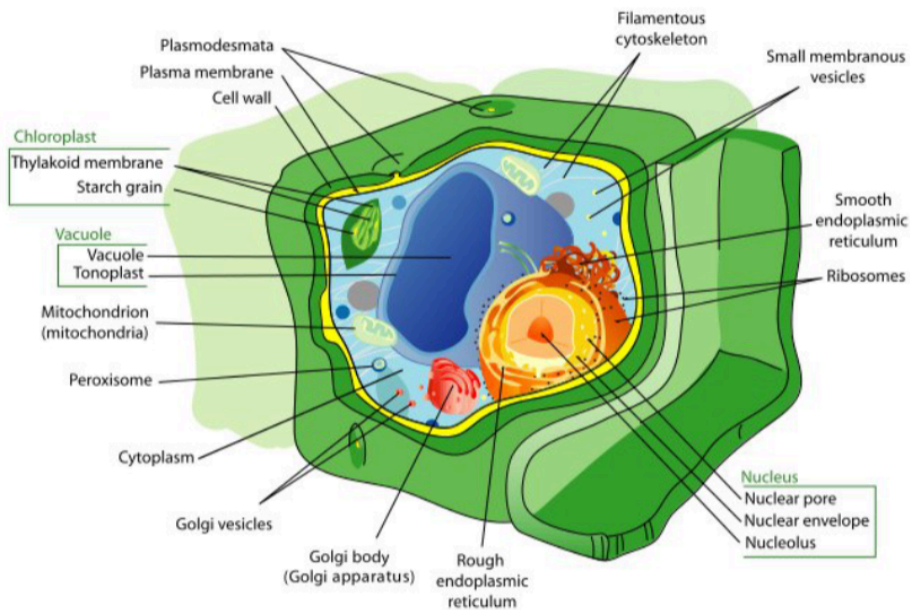
Science Olympiad – Botany

Division B – Regional Exam

IMAGE REFERENCE

Figure 1

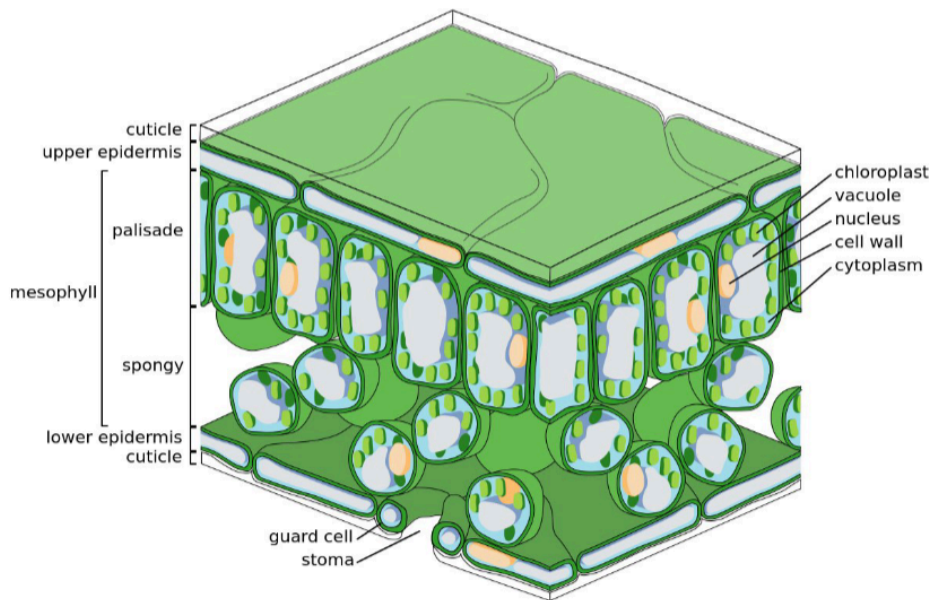
Used in question(s) 2. Labeled diagram of a generalized plant cell, showing the cell wall, cell membrane, nucleus, chloroplast, central vacuole, mitochondrion, Golgi apparatus, endoplasmic reticulum, ribosomes, and other organelles.



Wikimedia Commons, File:Plant_cell_structure-en.svg, author LadyofHats – Public Domain.

Figure 2

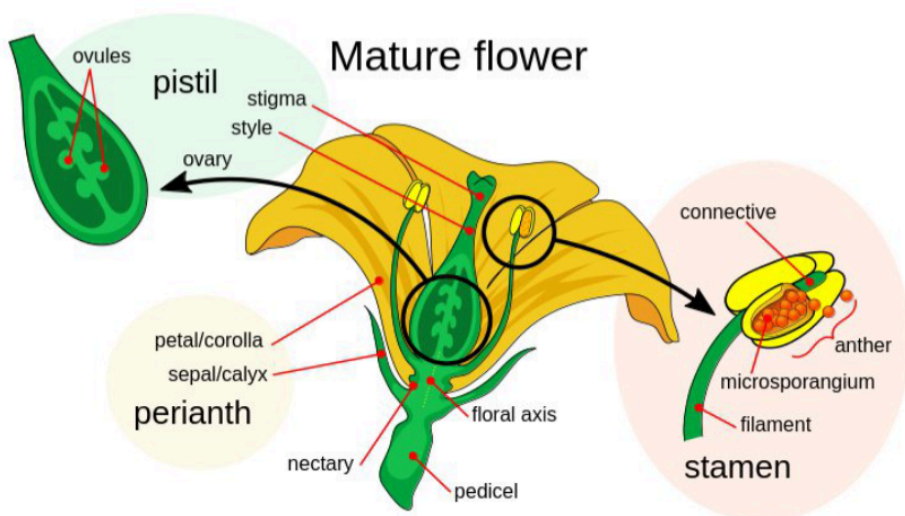
Used in question(s) 8. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg — CC BY-SA 3.0.

Figure 3

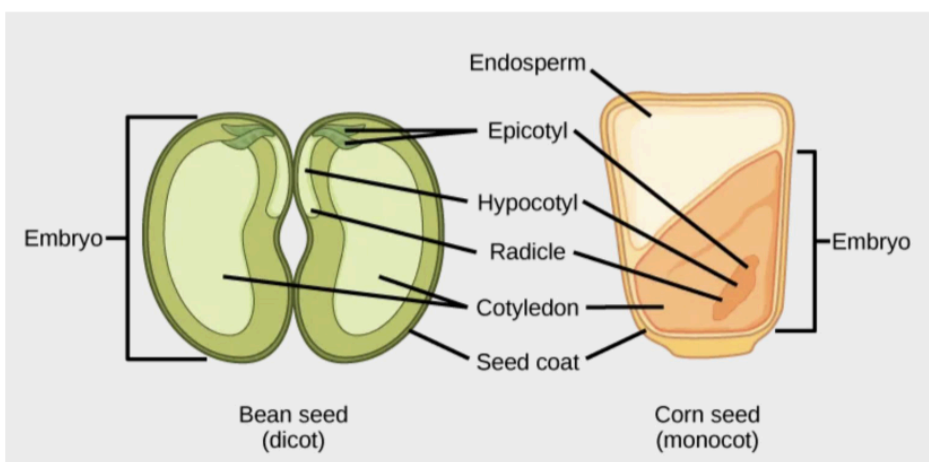
Used in question(s) 11, 12. Labeled diagram of a mature, complete flower: the perianth (sepal/calyx, petal/corolla), the pistil (stigma, style, ovary, ovules), and the stamen (anther, filament, connective, microsporangium).



Wikimedia Commons, File:Mature_flower_diagram.svg, author LadyofHats — Public Domain.

Figure 4

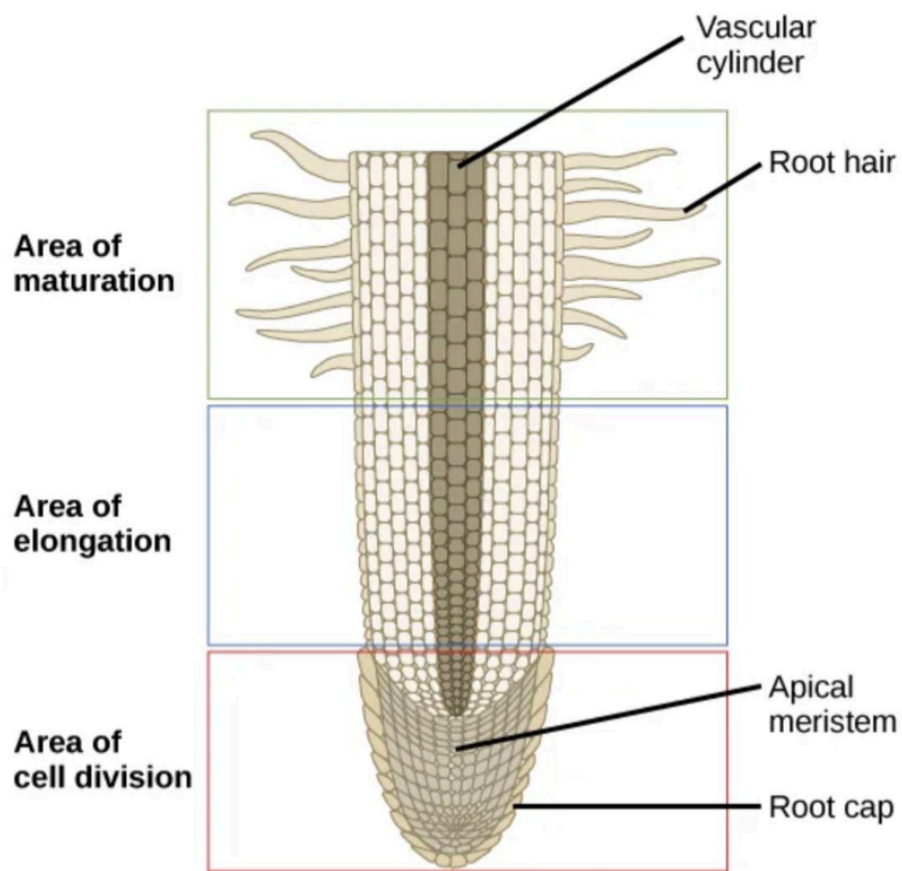
Used in question(s) 14. Diagram comparing a dicot seed (bean), with two cotyledons, and a monocot seed (corn), with a single cotyledon and large endosperm; both labeled with the seed coat, epicotyl, hypocotyl, and radicle.



OpenStax, Biology 2e, Figure 32.20, section 32.2 Pollination and Fertilization — CC BY 4.0.

Figure 5

Used in question(s) 5. Longitudinal diagram of a root tip, labeled with the root cap, apical meristem (area of cell division), area of elongation, area of maturation, root hairs, and vascular cylinder.



OpenStax, Biology 2e, Figure 30.16, section 30.3 Roots — CC BY 4.0.

Science Olympiad – Botany

Division B – Regional Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	B
2	C
3	A
4	A
5	A
6	B
7	A
8	C
9	B
10	B
11	C
12	A
13	B
14	A
15	C
16	A
17	A
18	B
19	A
20	C
21	A
22	A, C, D
23	A, B, D
24	A, B, D
25	A, B, C

Short Answer / Long Answer – Model Answers

26. Any three of: cell wall (support/protection), central vacuole (turgor pressure/storage), chloroplast (photosynthesis), plasmodesmata (cell-to-cell communication).

27. Xylem transports water and dissolved minerals upward from roots to leaves (dead cells, one-way flow). Phloem transports sugars made during photosynthesis from source to sink tissues (living cells, can move in either direction).

28. Pollination is the transfer of pollen from the anther to the stigma. It is important because it enables fertilization, which leads to seed and fruit production and allows genetic variation through sexual reproduction.

29. Carbon dioxide + water + light energy → glucose + oxygen. Reactants: CO₂ and H₂O (using light energy); Products: glucose (C₆H₁₂O₆) and O₂.

30. Any one valid difference besides cotyledon number, e.g.: leaf venation (parallel in monocots vs. net-like/branching in dicots), vascular bundle arrangement (scattered in monocots vs. ring in dicots), flower parts in multiples of 3 (monocots) vs. 4 or 5 (dicots), or fibrous (monocot) vs. taproot (dicot) root systems.

Science Olympiad

Botany - Division C

Regional Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 30 questions: 21 multiple choice, 4 multi-select (select ALL correct answers), and 5 short answer. Five questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Figure 1 shows a plant cell. Water potential differences that drive osmosis across the cell are most directly influenced by the labeled structure that regulates solute concentration inside the cell. Which labeled structure is this? [See Figure 1]

- A. Cell wall
- B. Central vacuole
- C. Ribosome
- D. Golgi apparatus

2. Water potential (Ψ) in a plant cell is the sum of which two main components?

- A. Solute potential and pressure potential
- B. Turgor pressure and cell wall rigidity only
- C. Osmotic pressure and light intensity
- D. Temperature and humidity

3. A plant cell placed in a hypotonic solution will most likely:

- A. Undergo plasmolysis
- B. Take in water and become turgid, without bursting due to the cell wall
- C. Lose all its water
- D. Immediately die

4. Figure 2 shows a leaf cross-section. In a xerophyte adapted to arid conditions, which labeled feature would most likely be modified (e.g., thickened) to reduce water loss? [See Figure 2]

- A. Cuticle
- B. Palisade mesophyll
- C. Vein
- D. Spongy mesophyll

5. C4 plants have evolved a specialized leaf anatomy (Kranz anatomy) that helps them:

- A. Minimize photorespiration by concentrating CO₂ around RuBisCO in bundle sheath cells
- B. Eliminate the need for stomata entirely
- C. Perform photosynthesis without chlorophyll
- D. Avoid the need for water altogether

6. CAM (Crassulacean Acid Metabolism) plants, such as many succulents, primarily conserve water by:

- A. Opening stomata at night to fix CO₂ into organic acids, then closing stomata during the day while performing the Calvin cycle
- B. Never opening their stomata
- C. Performing photosynthesis only underground
- D. Eliminating the need for CO₂

7. Figure 4 shows a stem cross-section with the xylem and phloem tissue labeled. According to the pressure-flow (mass flow) hypothesis, movement of sugars through the phloem tissue shown is driven by: [See Figure 4]

- A. A pressure gradient created by loading sugar at the source and unloading at the sink
- B. The same cohesion-tension mechanism as xylem
- C. Active pumping by chloroplasts
- D. Gravity alone

8. Figure 3 shows an absorption spectrum. An action spectrum for photosynthesis (rate of photosynthesis vs. wavelength) closely matches this absorption spectrum, which is evidence that: [See Figure 3]

- A. The pigments shown are responsible for driving photosynthesis
- B. Photosynthesis does not depend on pigments
- C. Only green light drives photosynthesis
- D. Temperature, not light, controls photosynthesis rate

9. Photorespiration occurs when RuBisCO binds oxygen instead of carbon dioxide, and is more common:

- A. On hot, dry days when stomata close and O₂ builds up relative to CO₂ inside the leaf
- B. Only at night
- C. Only in aquatic plants
- D. Only in C₄ plants

10. Figure 5 shows a flower. Self-pollination is prevented in some species by structural separation of which two labeled structures maturing at different times? [See Figure 5]

- A. Anther and stigma
- B. Sepal and petal
- C. Ovary and ovule
- D. Filament and style

11. Heterospory, the production of two distinct spore types (microspores and megaspores), is a characteristic of:

- A. All bryophytes
- B. Seed plants and a few seedless vascular plants
- C. Algae exclusively
- D. No plant groups

12. Which best distinguishes homosporous from heterosporous plant life cycles?

- A. Homosporous plants produce one spore type that develops into a bisexual gametophyte; heterosporous plants produce two spore types that develop into separate male and female gametophytes
- B. Only heterosporous plants have a sporophyte generation
- C. Homosporous plants do not undergo meiosis
- D. There is no meaningful difference

13. In hydroponics, a soilless growing method used in horticulture, plants are typically supplied nutrients through:

- A. A nutrient-rich water solution circulated around the roots
- B. Direct injection into leaves only
- C. Photosynthesis alone
- D. Symbiotic fungi exclusively

14. Secondary metabolites in plants, such as alkaloids and terpenoids, primarily function to:

- A. Defend against herbivores and pathogens, and can also attract pollinators
- B. Directly produce ATP
- C. Replace the need for chlorophyll
- D. Serve as the primary structural component of cell walls

15. Apoplastic transport of water refers to movement:

- A. Through the cell walls and intercellular spaces, without crossing cell membranes
- B. Exclusively through the cytoplasm of connected cells
- C. Only through the phloem
- D. Only at night

16. The Casparian strip, found in root endodermal cells, functions to:

- A. Force water and minerals to cross a cell membrane (symplastic route) before entering the vascular tissue, allowing selective filtering
- B. Prevent all water from entering the root
- C. Produce chlorophyll in roots
- D. Store starch exclusively

17. Which best explains why girdling (removing a ring of bark, including phloem) around a tree trunk eventually kills the tree?

- A. It disrupts phloem transport, starving the roots of sugars produced by the leaves, while xylem (deeper in the wood) may continue functioning temporarily
- B. It disrupts xylem transport only, so leaves wilt immediately
- C. It has no effect since bark is not living tissue
- D. It only affects flower production

18. Which best describes the evolutionary significance of the seed habit in gymnosperms and angiosperms compared to seedless plants?

- A. Seeds provide a protected, desiccation-resistant structure with stored nutrients, reducing dependence on water for reproduction and improving dispersal
- B. Seeds eliminate the need for pollination
- C. Seeds are less resistant to environmental stress than spores
- D. Seeds only benefit aquatic plants

19. Phytoremediation refers to the use of plants to:

- A. Remove or neutralize pollutants from soil, water, or air
- B. Increase pesticide concentrations in soil
- C. Replace the need for crop rotation
- D. Eliminate photosynthesis in contaminated areas

20. Aquaculture involving aquatic plants (e.g., algae or seaweed farming) is significant because it can:

- A. Provide food, biofuel feedstock, and help absorb excess nutrients from water
- B. Only be used for ornamental purposes
- C. Increase water pollution exclusively
- D. Replace the need for terrestrial agriculture entirely

21. Maintaining plant diversity in agricultural and natural systems is important primarily because it:

- A. Increases resilience to pests, disease, and environmental change, and preserves genetic resources for future breeding
- B. Has no measurable ecological benefit
- C. Always decreases crop yield
- D. Eliminates the need for pollinators

22. Which of the following describe apoplastic vs. symplastic water transport correctly? (Select all that apply)

- A. Apoplastic transport moves through cell walls and extracellular spaces
- B. Symplastic transport moves through connected cytoplasm via plasmodesmata
- C. Both routes are blocked entirely by the Casparian strip with no exceptions
- D. Water crossing the Casparian strip must take the symplastic route

23. Which of the following are adaptations that help C4 and CAM plants reduce photorespiration and/or water loss compared to typical C3 plants? (Select all that apply)

- A. Kranz anatomy concentrating CO₂ (C4)
- B. Temporal separation of CO₂ fixation and the Calvin cycle (CAM)
- C. Complete elimination of stomata
- D. Spatial separation of initial CO₂ fixation from the Calvin cycle (C4)

24. Which of the following are considered secondary metabolites produced by plants? (Select all that apply)

- A. Alkaloids
- B. Terpenoids
- C. Glucose (a primary metabolite)
- D. Phenolics/tannins

25. Which of the following are advantages of the seed habit over spore-based reproduction? (Select all that apply)

- A. Stored nutrients for the embryo
- B. Protection from desiccation
- C. Reduced need for pollination or fertilization mechanisms entirely
- D. Improved dispersal potential (e.g., via fruit)

26. Explain the difference between apoplastic and symplastic water transport in roots, and describe the role of the Casparian strip.

27. Compare C3, C4, and CAM photosynthesis in terms of when and where CO₂ is initially fixed.

28. Explain the pressure-flow (mass flow) hypothesis of phloem transport.

29. Explain how phytoremediation works and give one example of how plants can be used to address environmental contamination.

30. Explain why the evolution of seeds is considered a major evolutionary advantage over spore-based reproduction for colonizing dry land.

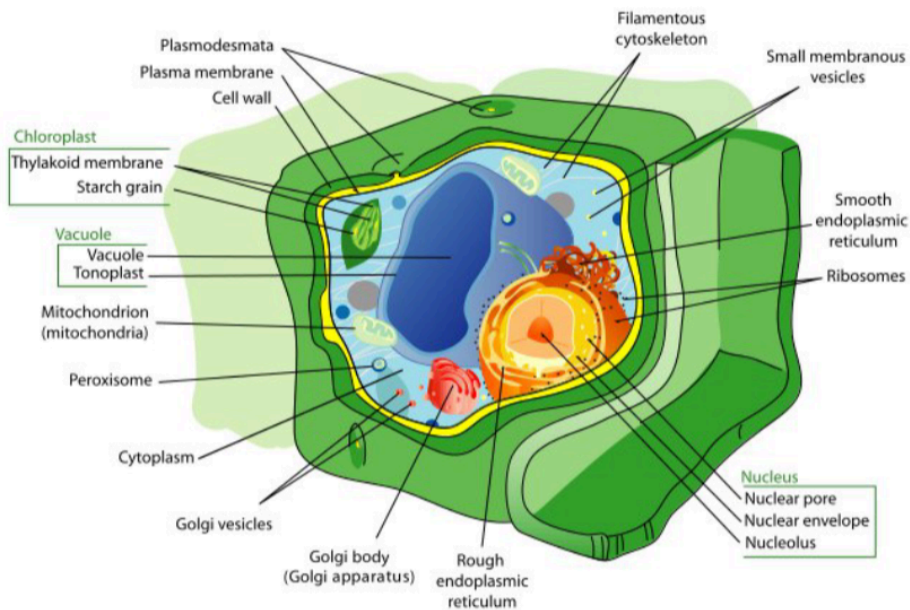
Science Olympiad – Botany

Division C – Regional Exam

IMAGE REFERENCE

Figure 1

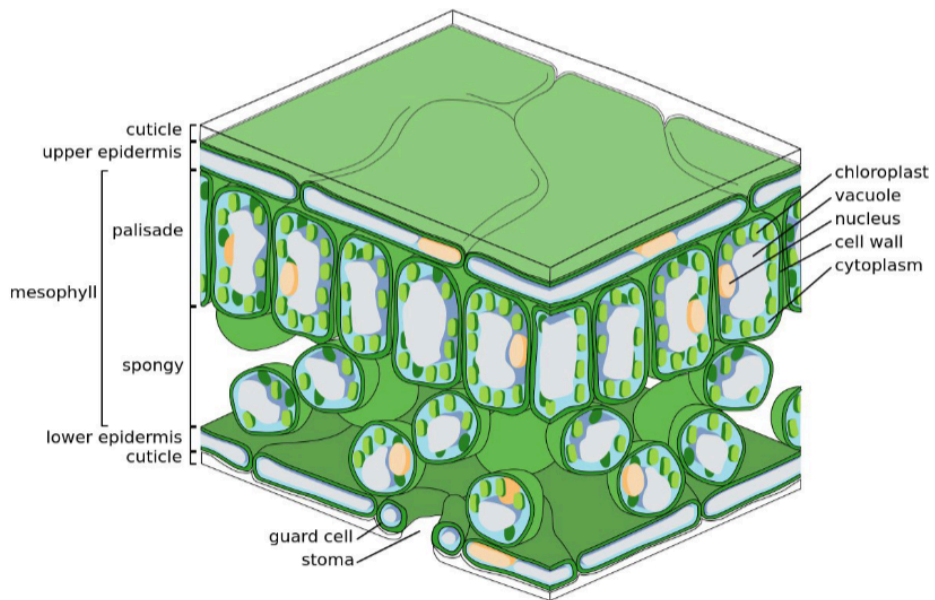
Used in question(s) 1. Labeled diagram of a generalized plant cell, showing the cell wall, cell membrane, nucleus, chloroplast, central vacuole, mitochondrion, Golgi apparatus, endoplasmic reticulum, ribosomes, and other organelles.



Wikimedia Commons, File:Plant_cell_structure-en.svg, author LadyofHats – Public Domain.

Figure 2

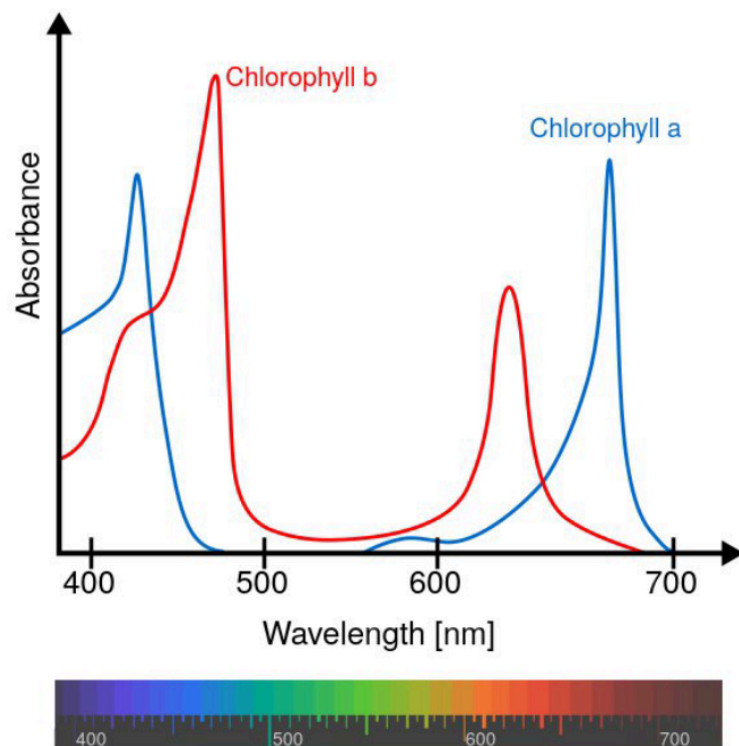
Used in question(s) 4. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg — CC BY-SA 3.0.

Figure 3

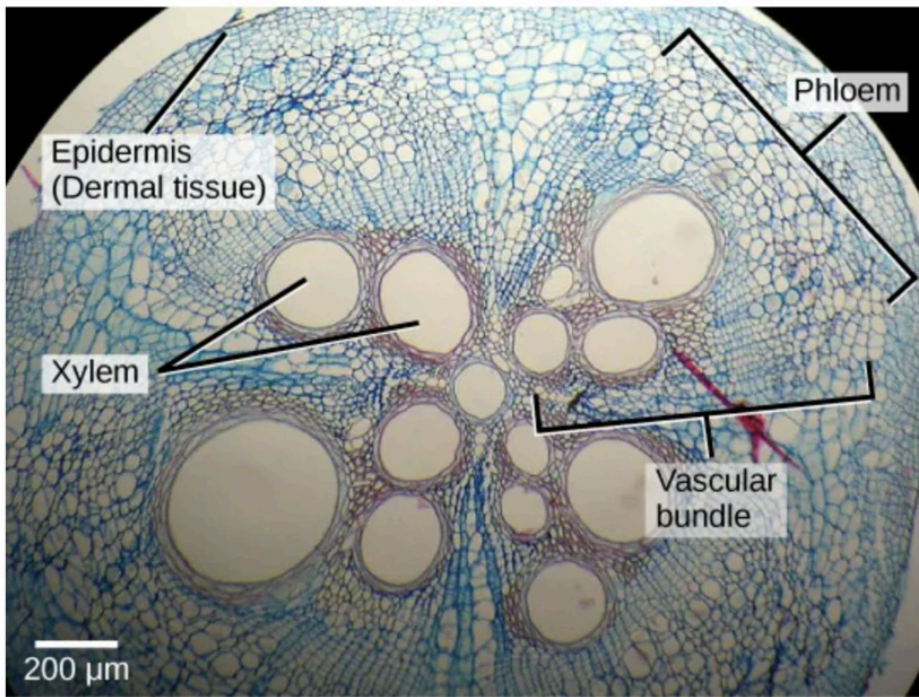
Used in question(s) 8. Graph of the light absorption spectra of chlorophyll a and chlorophyll b, plotting absorbance against wavelength (nm) across the visible spectrum.



Wikimedia Commons, File:Chlorophyll_ab_spectra-en.svg — CC BY-SA 3.0.

Figure 4

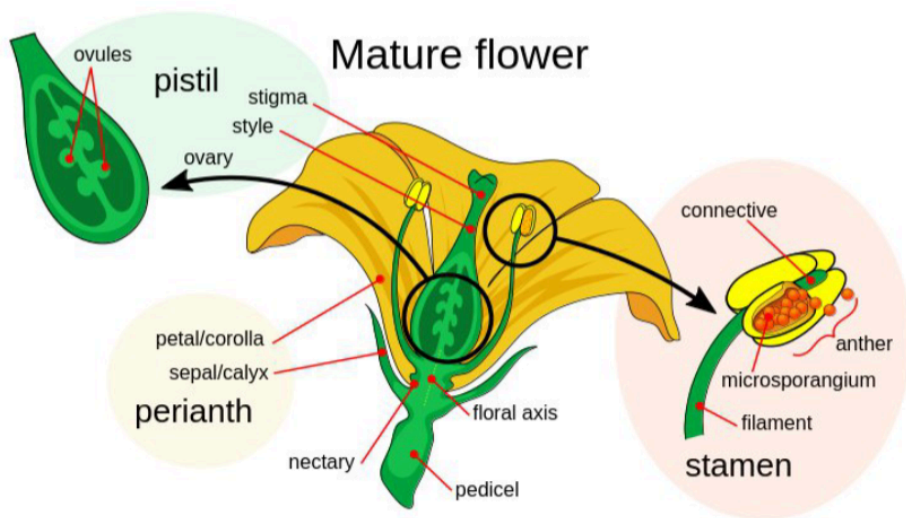
Used in question(s) 7. Light micrograph of a herbaceous stem cross-section, labeled with the epidermis (dermal tissue), a vascular bundle, xylem, and phloem.



OpenStax, *Biology 2e*, stem anatomy micrograph, section 30.2 Stems — CC BY 4.0.

Figure 5

Used in question(s) 10. Labeled diagram of a mature, complete flower: the perianth (sepal/calyx, petal/corolla), the pistil (stigma, style, ovary, ovules), and the stamen (anther, filament, connective, microsporangium).



Wikimedia Commons, File:Mature_flower_diagram.svg, author LadyofHats — Public Domain.

Science Olympiad – Botany

Division C – Regional Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	B
2	A
3	B
4	A
5	A
6	A
7	A
8	A
9	A
10	A
11	B
12	A
13	A
14	A
15	A
16	A
17	A
18	A
19	A
20	A
21	A
22	A, B, D
23	A, B, D
24	A, B, D
25	A, B, D

Short Answer / Long Answer – Model Answers

26. Apoplastic transport moves through cell walls/intercellular spaces without crossing membranes; symplastic transport moves through the cytoplasm via plasmodesmata. The Casparian strip (a waxy band in the endodermis) blocks the apoplastic route, forcing water and solutes to cross a selectively permeable membrane (symplastic route) before entering the vascular cylinder.

27. C3: CO₂ is fixed directly by RuBisCO in mesophyll cells during the day. C4: CO₂ is first fixed by PEP carboxylase in mesophyll cells, then shuttled to bundle sheath cells for the Calvin cycle

(spatial separation), still during the day. CAM: CO₂ is fixed at night into organic acids and stored, then released for the Calvin cycle during the day with stomata closed (temporal separation).

28. Sugars are actively loaded into phloem sieve tubes at the source, lowering water potential there and drawing water in from the xylem, which raises pressure. This pressure gradient pushes the sugar-water solution through the phloem to the sink, where sugar is unloaded, water potential rises, and water exits back into the xylem.

29. Phytoremediation uses plants to remove, contain, or break down pollutants in soil, water, or air — for example, sunflowers or Indian mustard absorbing and concentrating heavy metals (like lead or cadmium) from contaminated soil through their roots.

30. Seeds protect the embryo from desiccation, provide a stored food supply, and can remain dormant and be dispersed over time and distance — unlike spores, seed plants do not need external water for fertilization since pollen delivers sperm directly to the egg, allowing colonization of much drier terrestrial habitats.

Science Olympiad

Botany - Division B

State Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 50 questions: 35 multiple choice, 5 multi-select (select ALL correct answers), and 10 short answer. Eight questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Figure 1 shows a plant cell. Which labeled structure controls what enters and exits the cell? [See Figure 1]

- A. Cell wall
- B. Cell membrane
- C. Nucleus
- D. Chloroplast

2. The rigid plant cell wall is primarily composed of:

- A. Chitin
- B. Cellulose
- C. Keratin
- D. Peptidoglycan

3. Meristem tissue is significant because it:

- A. Consists of undifferentiated cells capable of continued cell division and growth
- B. Only exists in animal cells
- C. Cannot divide once formed
- D. Is found exclusively in flowers

4. Which best distinguishes primary growth from secondary growth in plants?

- A. Primary growth increases length via apical meristems; secondary growth increases girth via lateral meristems
- B. Primary growth only occurs in roots
- C. Secondary growth occurs only in monocots
- D. There is no meaningful distinction

5. Turgor pressure in plant cells is created by:

- A. Water entering the central vacuole, pushing the cell membrane against the cell wall
- B. Loss of water from the cell
- C. Cell wall degradation
- D. Chloroplast movement

6. A wilted plant most directly indicates:

- A. Excess turgor pressure
- B. Loss of turgor pressure due to insufficient water in cells
- C. Too much photosynthesis
- D. Excess mineral uptake

7. Figure 2 shows a root tip. Which labeled zone is where cells elongate, pushing the root tip further into the soil? [See Figure 2]

- A. Root cap
- B. Apical meristem
- C. Zone of elongation
- D. Zone of maturation

8. Figure 3 compares monocot and dicot roots. Which best describes a key difference typically shown? [See Figure 3]

- A. Dicot roots often have vascular tissue in a star-shaped pattern; monocot roots often have vascular tissue arranged in a ring around a central pith
- B. Monocot roots never have root hairs
- C. Dicot roots lack xylem
- D. There is no structural difference

9. A fibrous root system, common in monocots, is best described as:

- A. A single, thick main root that grows deep into the soil
- B. A dense network of many similarly-sized roots spreading near the surface
- C. Roots that grow entirely above ground
- D. Roots incapable of absorbing water

10. Figure 4 shows a herbaceous dicot stem cross-section. Which labeled tissue is responsible for storage and support in the center of the stem? [See Figure 4]

- A. Epidermis
- B. Cortex
- C. Vascular bundles
- D. Pith

11. In a woody stem, annual growth rings are formed primarily due to:

- A. Seasonal changes in the rate of xylem production by the vascular cambium
- B. Seasonal leaf color change
- C. Bark shedding each year
- D. Root growth patterns

12. Figure 5 shows a leaf cross-section. Which labeled layer is most densely packed with chloroplasts and specialized for photosynthesis? [See Figure 5]

- A. Cuticle
- B. Upper epidermis
- C. Palisade mesophyll
- D. Spongy mesophyll

13. Transpiration refers to:

- A. The uptake of water by roots only
- B. The evaporation of water vapor from leaf surfaces, mainly through stomata
- C. The production of sugar in leaves
- D. The movement of pollen between flowers

14. A modified stem that grows underground and stores nutrients, such as a potato, is called a:

- A. Tuber
- B. Taproot
- C. Petal
- D. Anther

15. Figure 6 shows a flower. Which labeled structure develops into the fruit after fertilization? [See Figure 6]

- A. Sepal
- B. Petal
- C. Anther
- D. Ovary

16. Wind-pollinated flowers typically have:

- A. Bright, showy petals and strong scent
- B. Small, inconspicuous petals and produce large amounts of lightweight pollen
- C. No pollen at all
- D. Extremely large, sticky pollen grains

17. Figure 7 compares monocot and dicot seeds. Where is stored food located in a typical dicot seed? [See Figure 7]

- A. In the two cotyledons
- B. In the seed coat only
- C. It is not stored in dicot seeds
- D. In the anther

18. Alternation of generations in plants refers to:

- A. A life cycle that alternates between a multicellular haploid (gametophyte) stage and a multicellular diploid (sporophyte) stage
- B. Alternating between sexual and asexual reproduction each generation only
- C. The switch between day and night growth
- D. A pattern unique to flowering plants

19. In most mosses, which generation is the larger, more visible plant?

- A. The sporophyte
- B. The gametophyte
- C. Both are equally visible
- D. Neither generation is visible

20. Which best describes the role of sepals in a flower?

- A. They protect the flower bud before it opens
- B. They produce pollen
- C. They receive pollen
- D. They develop into seeds

21. Which term describes plants like mosses and liverworts that lack true vascular tissue?

- A. Bryophytes
- B. Gymnosperms
- C. Angiosperms
- D. Pteridophytes

22. Which best distinguishes embryophytes (land plants) from algae?

- A. Embryophytes protect a developing embryo within the parent plant tissue; most algae do not
- B. Algae are always larger than embryophytes
- C. Embryophytes are always aquatic
- D. There is no meaningful difference

23. Conifers (such as pine trees) are classified as:

- A. Angiosperms
- B. Gymnosperms
- C. Bryophytes
- D. Algae

24. Which is a defining feature of angiosperms not shared by gymnosperms?

- A. They produce flowers and enclose their seeds within a fruit
- B. They produce seeds
- C. They are photosynthetic
- D. They have roots

25. Which of the following is classified as an alga rather than a true (embryophyte) plant?

- A. Kelp
- B. Moss
- C. Fern
- D. Pine tree

26. Figure 8 shows a light absorption spectrum. Chlorophyll absorbs light most strongly in which regions?
[See Figure 8]

- A. Green and yellow light
- B. Blue and red light
- C. Only ultraviolet light
- D. Only infrared light

27. Figure 8 shows absorption curves for several pigments. Leaves appear green primarily because chlorophyll: [See Figure 8]

- A. Absorbs green light strongly
- B. Reflects/transmits green light rather than absorbing it
- C. Converts all light to green light
- D. Contains no pigments at all

28. Photosynthesis takes place in which two main stages?

- A. Light-dependent reactions and the Calvin cycle (light-independent reactions)
- B. Glycolysis and the Krebs cycle
- C. Mitosis and meiosis
- D. Transpiration and translocation

29. Where in the chloroplast do the light-dependent reactions occur?

- A. Stroma
- B. Thylakoid membrane
- C. Outer membrane only
- D. Cell wall

30. Which raw material, along with water, is required for photosynthesis?

- A. Oxygen gas
- B. Carbon dioxide
- C. Glucose
- D. Nitrogen gas

31. Crop rotation, a common agricultural practice, primarily helps by:

- A. Reducing soil nutrient depletion and pest/disease buildup
- B. Eliminating the need for sunlight
- C. Preventing all plant diseases permanently
- D. Increasing soil salinity

32. A plant showing yellowing between the veins of its leaves (interveinal chlorosis) most likely has a deficiency in:

- A. Iron or magnesium
- B. Excess water
- C. Excess sunlight
- D. Excess carbon dioxide

33. In ecological succession, the first species to colonize a disturbed or bare area are called:

- A. Climax species
- B. Pioneer species
- C. Keystone species
- D. Invasive species only

34. Allelopathy refers to:

- A. A plant releasing chemicals that inhibit the growth of nearby competing plants
- B. Two plants sharing nutrients cooperatively
- C. A type of plant disease
- D. A pollination strategy

35. Legume plants (like beans and peas) contribute to soil fertility mainly by:

- A. Hosting nitrogen-fixing bacteria in root nodules
- B. Absorbing all soil nitrogen without returning any
- C. Releasing large amounts of carbon dioxide
- D. Preventing water infiltration

36. Which of the following are functions of roots? (Select all that apply)

- A. Water and mineral absorption
- B. Anchoring the plant
- C. Photosynthesis (primary function)
- D. Nutrient storage

37. Which of the following are required inputs for photosynthesis? (Select all that apply)

- A. Carbon dioxide
- B. Water
- C. Light energy
- D. Oxygen gas

38. Which of the following are considered seedless plants? (Select all that apply)

- A. Mosses
- B. Ferns
- C. Conifers
- D. Flowering plants

39. Which of the following can be signs of plant nutrient deficiency? (Select all that apply)

- A. Yellowing leaves (chlorosis)
- B. Stunted growth
- C. Vivid green, oversized leaves
- D. Necrotic (dead/brown) leaf spots

40. Which of the following plant groups reproduce via spores rather than seeds? (Select all that apply)

- A. Mosses
- B. Ferns
- C. Gymnosperms
- D. Angiosperms

41. Explain how turgor pressure helps support non-woody plants, and what happens to a plant when it loses turgor pressure.

42. Describe the path water takes from the soil to being released into the atmosphere, naming at least four structures/processes.

43. Explain the difference between primary growth and secondary growth in plants.

44. Explain the difference between self-pollination and cross-pollination, and describe one adaptation that promotes cross-pollination.

45. Explain what alternation of generations means, using the terms gametophyte and sporophyte.

46. Compare bryophytes, ferns, gymnosperms, and angiosperms in terms of the presence of vascular tissue and seeds.

47. Explain the role of water in photosynthesis, including where the oxygen released during photosynthesis actually comes from.

48. Explain why leaves appear green, referencing the absorption and reflection of light by chlorophyll.

49. Explain how plants contribute to both the carbon cycle and the nitrogen cycle.

50. Describe one way genetically modified (GM) crops have been engineered to benefit agriculture, and explain the modification.

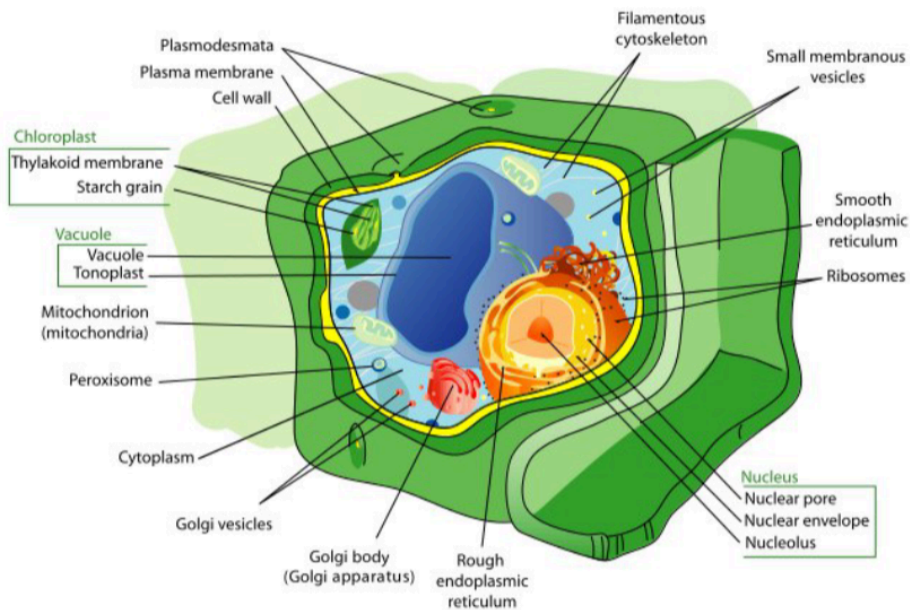
Science Olympiad – Botany

Division B – State Exam

IMAGE REFERENCE

Figure 1

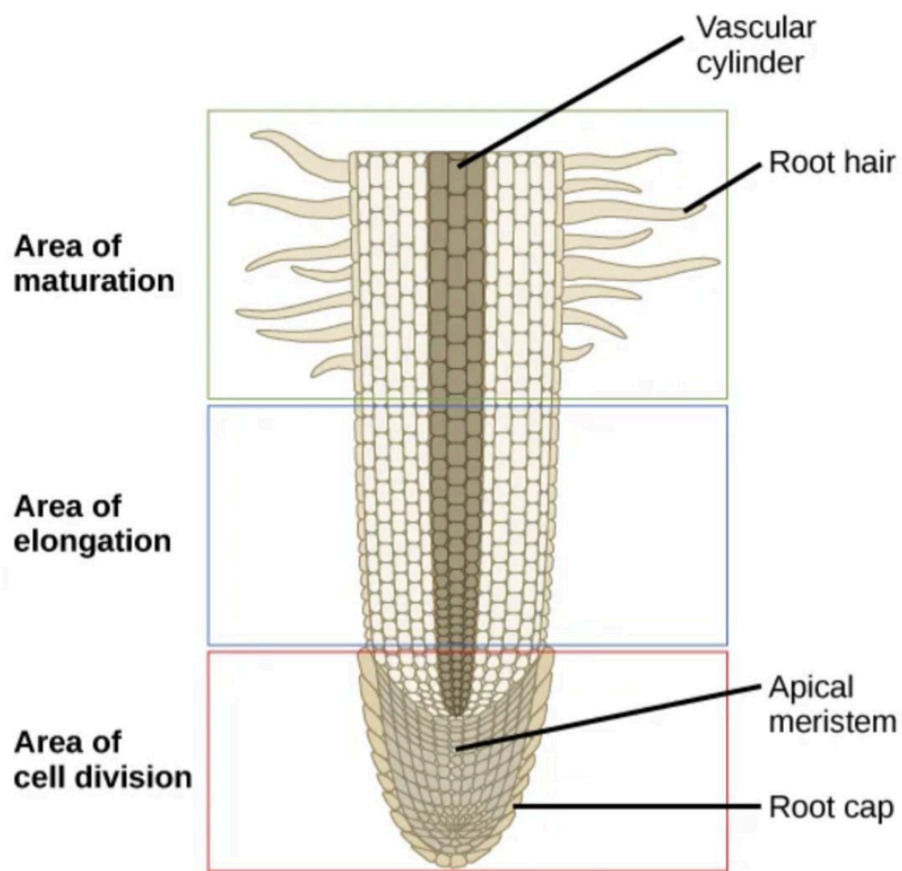
Used in question(s) 1. Labeled diagram of a generalized plant cell, showing the cell wall, cell membrane, nucleus, chloroplast, central vacuole, mitochondrion, Golgi apparatus, endoplasmic reticulum, ribosomes, and other organelles.



Wikimedia Commons, File:Plant_cell_structure-en.svg, author LadyofHats – Public Domain.

Figure 2

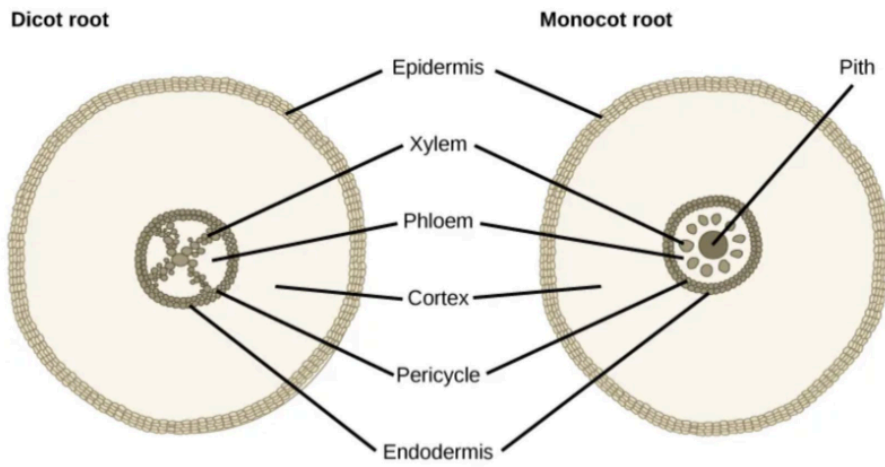
Used in question(s) 7. Longitudinal diagram of a root tip, labeled with the root cap, apical meristem (area of cell division), area of elongation, area of maturation, root hairs, and vascular cylinder.



OpenStax, Biology 2e, Figure 30.16, section 30.3 Roots — CC BY 4.0.

Figure 3

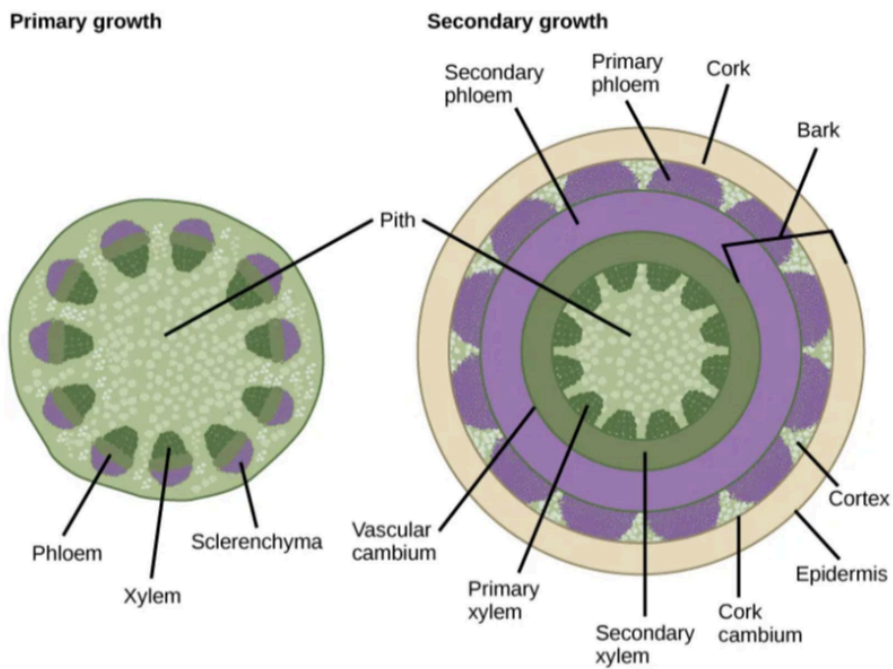
Used in question(s) 8. Side-by-side diagram comparing a dicot root cross-section (X-shaped vascular tissue) and a monocot root cross-section (vascular tissue in a ring around a central pith), labeled with epidermis, cortex, endodermis, pericycle, xylem, and phloem.



OpenStax, Biology 2e, Figure 30.18, section 30.3 Roots – CC BY 4.0.

Figure 4

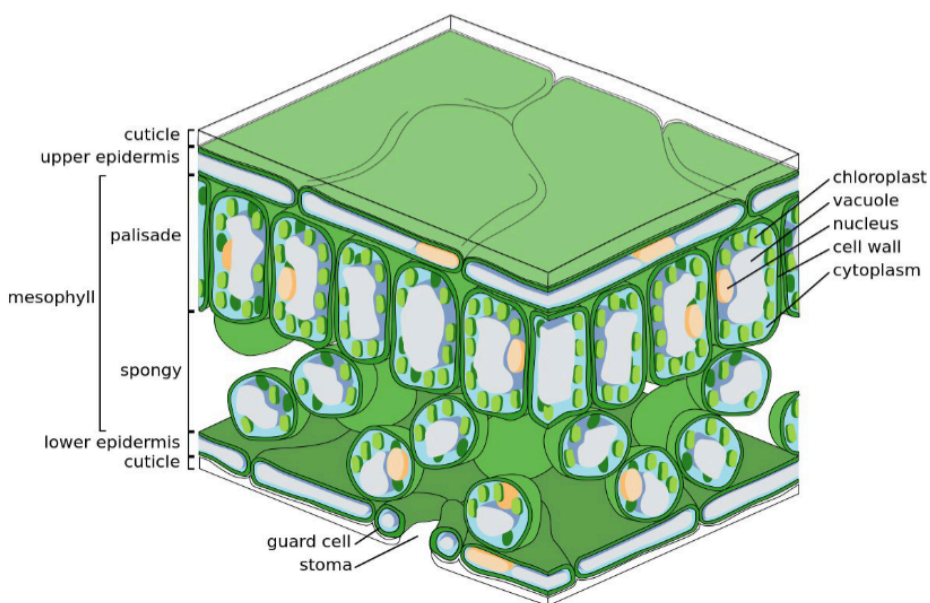
Used in question(s) 10. Diagram comparing a herbaceous stem cross-section undergoing primary growth (pith, xylem, phloem, sclerenchyma) with a woody stem cross-section undergoing secondary growth (vascular cambium, secondary xylem/phloem, cork cambium, cork, bark).



OpenStax, Biology 2e, Figure 30.10, section 30.2 Stems — CC BY 4.0.

Figure 5

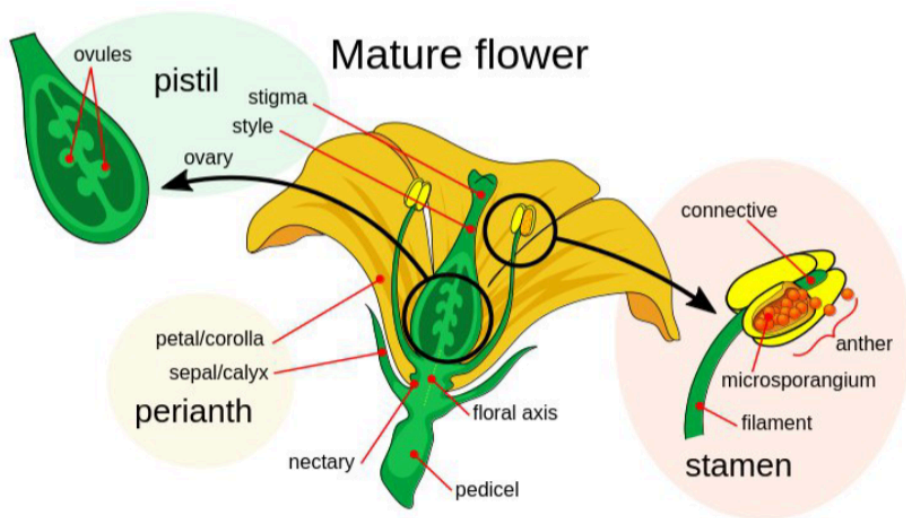
Used in question(s) 12. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg — CC BY-SA 3.0.

Figure 6

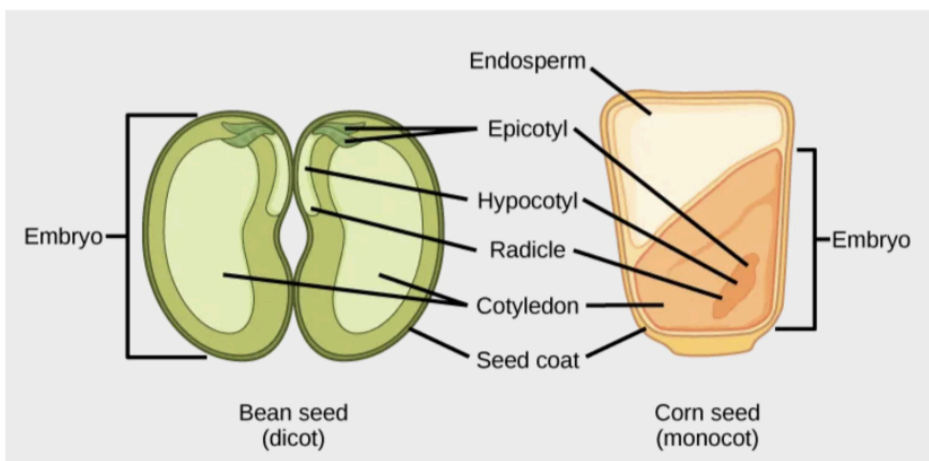
Used in question(s) 15. Labeled diagram of a mature, complete flower: the perianth (sepal/calyx, petal/corolla), the pistil (stigma, style, ovary, ovules), and the stamen (anther, filament, connective, microsporangium).



Wikimedia Commons, File:Mature_flower_diagram.svg, author LadyofHats — Public Domain.

Figure 7

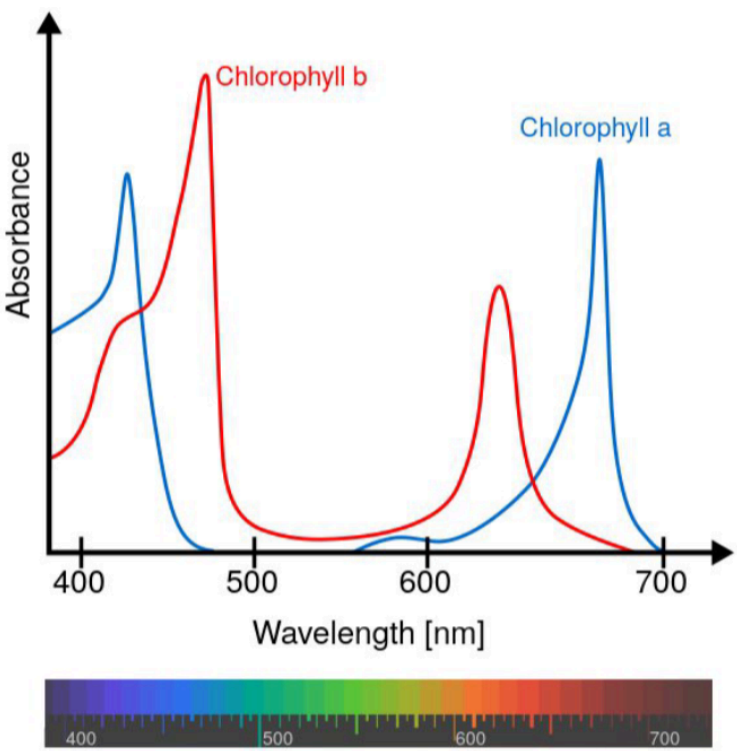
Used in question(s) 17. Diagram comparing a dicot seed (bean), with two cotyledons, and a monocot seed (corn), with a single cotyledon and large endosperm; both labeled with the seed coat, epicotyl, hypocotyl, and radicle.



OpenStax, Biology 2e, Figure 32.20, section 32.2 Pollination and Fertilization — CC BY 4.0.

Figure 8

Used in question(s) 26, 27. Graph of the light absorption spectra of chlorophyll a and chlorophyll b, plotting absorbance against wavelength (nm) across the visible spectrum.



Wikimedia Commons, File:Chlorophyll_ab_spectra-en.svg – CC BY-SA 3.0.

Science Olympiad – Botany

Division B – State Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	B
2	B
3	A
4	A
5	A
6	B
7	C
8	A
9	B
10	D
11	A
12	C
13	B
14	A
15	D
16	B
17	A
18	A
19	B
20	A
21	A
22	A
23	B
24	A
25	A
26	B
27	B
28	A
29	B
30	B
31	A
32	A
33	B
34	A
35	A
36	A, B, D
37	A, B, C
38	A, B
39	A, B, D

Short Answer / Long Answer — Model Answers

41. Water enters the central vacuole by osmosis, pushing the cell membrane against the cell wall and creating turgor pressure that keeps non-woody tissue rigid. When a plant loses water, turgor pressure drops, cells become flaccid, and the plant wilts.

42. Root hairs absorb water from soil → water moves into xylem in the root → xylem carries water up through the stem to the leaves → water moves into mesophyll cells and evaporates → water vapor exits through stomata as transpiration.

43. Primary growth increases a plant's length and results from cell division at apical meristems (root and shoot tips). Secondary growth increases a plant's girth/thickness and results from cell division at lateral meristems (vascular cambium and cork cambium), mainly in woody plants.

44. Self-pollination is the transfer of pollen within the same flower or plant; cross-pollination is the transfer of pollen between different plants of the same species, which increases genetic diversity. One adaptation that promotes cross-pollination: protandry/protogyny (anthers and stigma of the same flower mature at different times) or dioecy (separate male and female plants).

45. Alternation of generations is a life cycle that alternates between a multicellular haploid gametophyte stage (produces gametes by mitosis) and a multicellular diploid sporophyte stage (produces spores by meiosis).

46. Bryophytes: no vascular tissue, no seeds (spores). Ferns: vascular tissue, no seeds (spores). Gymnosperms: vascular tissue, seeds (naked, borne in cones). Angiosperms: vascular tissue, seeds (enclosed in fruit).

47. Water is split during the light-dependent reactions (photolysis) to supply electrons and hydrogen ions needed to replace those lost by chlorophyll; the oxygen released during photosynthesis comes from this splitting of water, not from carbon dioxide.

48. Chlorophyll absorbs red and blue wavelengths of light strongly for photosynthesis but reflects and transmits green light rather than absorbing it, which is why leaves appear green to our eyes.

49. Carbon cycle: plants remove CO₂ from the atmosphere during photosynthesis and release some back through respiration; dead plant matter returns carbon to the soil/atmosphere through decomposition. Nitrogen cycle: plants (especially legumes, via nitrogen-fixing root-nodule bacteria) convert atmospheric nitrogen or soil nitrates into usable forms, which then move through the food web.

50. Example: Bt corn has been engineered with a gene from the bacterium *Bacillus thuringiensis* that produces a protein toxic to specific insect pests, giving the plant built-in pest resistance and reducing the need for chemical pesticides. (Any valid GM example — herbicide resistance, drought tolerance, etc. — with an explanation of the modification is acceptable.)

Science Olympiad

Botany - Division C

State Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 50 questions: 35 multiple choice, 5 multi-select (select ALL correct answers), and 10 short answer. Eight questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Which best describes the relationship between water potential and the direction of osmotic water movement?

- A. Water moves from a region of lower water potential to higher water potential
- B. Water moves from a region of higher water potential to lower water potential
- C. Water potential has no effect on osmosis
- D. Water only moves based on temperature, not water potential

2. Solute potential (osmotic potential) becomes more negative as:

- A. Solute concentration increases
- B. Solute concentration decreases
- C. Pressure potential increases
- D. Temperature decreases only

3. A fully turgid plant cell at equilibrium with pure water has a water potential of approximately:

- A. Zero (pressure potential balances solute potential)
- B. Always strongly negative
- C. Always strongly positive
- D. Undefined

4. Which best describes the difference between primary and secondary cell walls in plant cells?

- A. Primary walls are thin and flexible, deposited during cell growth; secondary walls are thicker, often lignified, and deposited after the cell stops growing
- B. Secondary walls form before primary walls in all cells
- C. Only root cells have secondary walls
- D. There is no structural distinction

5. Lignin, a key component of secondary cell walls in wood, primarily provides:

- A. Rigidity and resistance to compression, enabling trees to grow tall
- B. A source of stored sugar
- C. Flexibility for cell expansion
- D. A pathway for phloem transport

6. Which best explains why guard cells can change shape to open and close stomata, while most surrounding epidermal cells cannot?

- A. Guard cells have unevenly thickened cell walls (thicker on the inner side), causing asymmetric bending as turgor pressure changes
- B. Guard cells have no cell wall at all
- C. Guard cells lack chloroplasts, unlike epidermal cells
- D. Guard cells are dead at maturity

7. Figure 1 compares monocot and dicot root cross-sections. Which best explains the functional significance of the star-shaped (actinostele) vascular arrangement often seen in dicot roots? [See Figure 1]

- A. It maximizes strength against pulling/tension forces as the root anchors the plant
- B. It has no functional significance
- C. It only occurs in aquatic roots
- D. It prevents any water uptake

8. Figure 2 shows a herbaceous dicot stem. The scattered arrangement of vascular bundles seen in monocot stems (unlike this ringed dicot arrangement) makes monocots generally: [See Figure 2]

- A. Less able to undergo secondary growth (thickening) via a vascular cambium
- B. More capable of extensive secondary growth than dicots
- C. Incapable of any vascular transport
- D. Identical in growth capacity to dicots

9. Figure 3 shows a woody stem. Which labeled tissue, if girdled/removed in a ring around the trunk, would most directly starve the roots by blocking sugar transport? [See Figure 3]

- A. Xylem
- B. Phloem
- C. Pith
- D. Cork cambium

10. Heartwood, the older, non-functional xylem at the center of a tree trunk, differs from sapwood in that heartwood:

- A. No longer conducts water but often provides structural support and may contain defensive compounds
- B. Is the only living tissue in the trunk
- C. Conducts water more efficiently than sapwood
- D. Is produced by the cork cambium

11. Figure 4 shows a leaf cross-section. Which labeled feature would you expect to be present at much higher density on the lower epidermis than the upper epidermis in most dicot leaves? [See Figure 4]

- A. Stomata
- B. Cuticle thickness
- C. Palisade mesophyll cells
- D. Xylem only

12. Which best explains why most stomata are located on the lower (abaxial) surface of leaves in many plant species?

- A. It reduces direct sun exposure on the stomata, helping to minimize water loss via evaporation
- B. It has no adaptive explanation
- C. It maximizes water loss for cooling
- D. It is required for photosynthesis to occur at all

13. Which best describes the adaptive significance of sunken stomata within crypts, found in some xerophytes?

- A. They trap humid air near the stomata, reducing the water vapor concentration gradient and thus transpiration rate
- B. They increase transpiration to cool the leaf
- C. They eliminate the need for photosynthesis
- D. They have no effect on water loss

14. Which best describes the function of aerenchyma tissue found in many wetland/aquatic plants?

- A. Air-filled tissue that facilitates oxygen diffusion to submerged/waterlogged roots
- B. A type of vascular tissue exclusive to xylem
- C. A pigment used in photosynthesis
- D. A defensive chemical compound

15. Thigmotropism, a directional growth response to touch (e.g., a vine's tendrils coiling around a support), is primarily mediated by:

- A. Differential growth rates on opposite sides of the responding organ, influenced by hormones such as auxin
- B. Immediate cell death on the touched side
- C. Chlorophyll degradation
- D. A response unrelated to any hormone

16. Which best explains phototropism (bending of a stem toward light) at the cellular/hormonal level?

- A. Auxin accumulates on the shaded side of the stem, promoting greater cell elongation there and causing the stem to bend toward the light
- B. Auxin is destroyed by light exposure entirely
- C. Chlorophyll directly causes cell elongation
- D. Phototropism does not involve any hormone

17. Figure 6 shows the alternation-of-generations life cycle of a moss. Which labeled generation is the larger, dominant, free-living photosynthetic plant body (unlike in vascular plants, where this generation is greatly reduced)? [See Figure 6]

- A. Gametophyte
- B. Sporophyte
- C. Spore only
- D. Zygote only

18. Which best explains why fern sperm, like moss sperm, are still dependent on a film of external water despite ferns having true vascular tissue?

- A. Fern sperm are flagellated and must physically swim to reach the egg on the gametophyte, a constraint unrelated to vascular tissue
- B. Ferns lack any mechanism for fertilization
- C. Vascular tissue directly transports sperm to the egg
- D. Fern gametophytes are never exposed to water

19. Figure 7 compares monocot and dicot seeds. The single cotyledon in a monocot seed (e.g., corn) often functions primarily to: [See Figure 7]

- A. Absorb and transfer nutrients from the endosperm to the growing embryo
- B. Directly perform photosynthesis before germination
- C. Produce pollen
- D. Form the seed coat

20. Apomixis in plants refers to:

- A. The production of seeds without fertilization, resulting in offspring genetically identical to the parent
- B. A type of animal pollination
- C. The process of seed dispersal by wind only
- D. A disease affecting flower development

21. Which best explains the adaptive advantage of dioecious plants (having separate male and female individuals) compared to hermaphroditic (monoecious/perfect-flowered) plants?

- A. Dioecy enforces cross-pollination, increasing genetic diversity and reducing inbreeding
- B. Dioecy always increases self-pollination rates
- C. Dioecious plants cannot reproduce sexually at all
- D. There is no adaptive advantage to dioecy

22. Vernalization refers to:

- A. A required period of cold exposure that triggers flowering in certain plant species
- B. The process of seed coat formation
- C. A type of asexual reproduction
- D. The breakdown of chlorophyll in autumn

23. Which best explains why cladistic (phylogenetic) classification of plants may differ from older classification systems based purely on visible morphology?

- A. Molecular/genetic data can reveal evolutionary relationships not always apparent from physical appearance alone
- B. Cladistics relies exclusively on flower color
- C. Older systems were always more accurate than modern genetic data
- D. Cladistics ignores all evolutionary relationships

24. The fossil record suggests that seed plants (an evolutionary innovation) provided a significant advantage over earlier seedless plants primarily by:

- A. Reducing dependence on water for fertilization, allowing colonization of drier habitats
- B. Eliminating the need for photosynthesis
- C. Making plants immune to all environmental stress
- D. Preventing any further plant evolution

25. Which best explains the ecological/evolutionary significance of mycorrhizal associations appearing early in land plant fossil history?

- A. They likely helped early land plants (with limited root systems) acquire water and nutrients from soil, aiding the colonization of land
- B. They had no role in early plant evolution
- C. They only benefit the fungus, never the plant
- D. They are unique to modern flowering plants

26. Which best describes a key distinction between lycophytes (e.g., club mosses) and true ferns among seedless vascular plants?

- A. Lycophytes have simpler leaves (microphylls) with a single unbranched vein, while ferns have larger leaves (megaphylls) with branching venation
- B. Lycophytes are not vascular plants
- C. Ferns lack spores entirely
- D. There is no meaningful anatomical distinction

27. Which best explains why angiosperms are considered the most diverse and dominant plant group in most modern terrestrial ecosystems?

- A. Traits like flowers, fruit, and efficient vascular tissue have enabled rapid diversification and adaptation to a wide range of habitats and pollinators
- B. Angiosperms evolved before any other plant group
- C. Angiosperms cannot reproduce sexually
- D. Angiosperms lack vascular tissue, simplifying their growth

28. Figure 5 shows an absorption spectrum. If a plant were grown exclusively under pure green light, which best predicts the effect on its photosynthetic rate relative to red or blue light of equal intensity? [See Figure 5]

- A. Photosynthetic rate would be lower, since chlorophyll absorbs green light poorly
- B. Photosynthetic rate would be higher than under red or blue light
- C. There would be no difference at all
- D. The plant could not survive any exposure to green light

29. The Z-scheme of photosynthesis describes:

- A. The path of electron flow through Photosystem II and Photosystem I during the light-dependent reactions
- B. The shape of the Calvin cycle
- C. A pattern of leaf arrangement on a stem
- D. The branching pattern of xylem vessels

30. Which best explains why RuBisCO's dual affinity for both CO₂ and O₂ is considered evolutionarily significant/limiting?

- A. It can lead to photorespiration when O₂ outcompetes CO₂ for binding, reducing net photosynthetic efficiency, especially under hot/dry conditions
- B. It has no effect on photosynthetic efficiency
- C. It only binds CO₂, never O₂
- D. It is unrelated to the evolution of C₄/CAM pathways

31. Chemiosmosis, the process that generates ATP during the light-dependent reactions, relies on:

- A. A proton (H⁺) gradient across the thylakoid membrane driving ATP synthase
- B. Direct conversion of light into ATP with no intermediate steps
- C. Glucose breakdown
- D. A magnesium ion gradient

32. Which best describes why increasing light intensity beyond a certain point no longer increases the rate of photosynthesis in most plants?

- A. Another factor, such as CO₂ concentration or temperature (enzyme activity), becomes the limiting factor
- B. Photosynthesis rate always increases indefinitely with light intensity
- C. Chlorophyll is destroyed at high light intensities in all cases
- D. Light has no relationship to photosynthetic rate

33. In horticultural grafting, the rootstock is chosen primarily for traits such as:

- A. Disease resistance, hardiness, and root vigor, while the scion determines the above-ground fruit/flower characteristics
- B. Fruit flavor exclusively
- C. Flower color exclusively
- D. Grafting has no effect on plant traits

34. Which best describes a key challenge specific to aquaponics/aquaculture systems that combine fish and plant production?

- A. Balancing nutrient (e.g., ammonia/nitrate) levels so they support plant growth without harming the fish, and vice versa
- B. Aquaponics requires no water management at all
- C. Plants grown this way cannot use any nutrients from fish waste
- D. Aquaponics eliminates the need for any light source

35. Many plant-derived medicines (e.g., taxol from Pacific yew, aspirin's precursor salicin from willow bark) originate from:

- A. Secondary metabolites that plants produce, often originally for defense, which happen to have pharmacological effects in humans
- B. Primary metabolites like glucose exclusively
- C. Compounds with no biological function in the plant
- D. Structures unrelated to plant chemistry

36. Figure 4 shows a leaf cross-section with the stomata labeled. Which of the following favor increased transpiration rate through the stomata shown, and therefore a faster pull of water up through the xylem? (Select all that apply) [See Figure 4]

- A. High temperature
- B. Low humidity
- C. High wind speed
- D. Stomata fully closed

37. Which of the following are adaptations found in C₄ plants to improve photosynthetic efficiency under hot, dry conditions? (Select all that apply)

- A. Kranz anatomy (bundle sheath cells surrounding vascular tissue)
- B. Spatial separation of initial CO₂ fixation from the Calvin cycle
- C. Complete loss of RuBisCO
- D. A CO₂-concentrating mechanism that reduces photorespiration

38. Which of the following are true regarding heterosporous plants? (Select all that apply)

- A. They produce both microspores and megaspores
- B. Microspores develop into male gametophytes
- C. Megaspores develop into female gametophytes
- D. All heterosporous plants are angiosperms

39. Which of the following are examples of secondary plant metabolites? (Select all that apply)

- A. Alkaloids
- B. Terpenoids
- C. Starch (a storage carbohydrate)
- D. Phenolic compounds

40. Which of the following influence a plant cell's total water potential? (Select all that apply)

- A. Solute (osmotic) potential
- B. Pressure potential
- C. Cell color
- D. Number of chloroplasts

41. Explain how solute potential and pressure potential combine to determine a plant cell's total water potential, and how this determines the direction of water movement.

42. Explain how stomatal density and distribution (e.g., more stomata on the lower leaf surface) represent an adaptation to reduce water loss while still allowing gas exchange.

43. Explain the hormonal mechanism behind phototropism, referencing auxin distribution.

44. Explain why fern and moss sperm require water to reach the egg, and explain how this constraint is overcome in seed plants.

45. Explain the adaptive significance of dioecy (separate male and female plants) in promoting genetic diversity.

46. Explain why the evolution of lignin and vascular tissue was important for plants to grow taller and colonize a wider range of terrestrial habitats.

47. Explain the concept of a limiting factor in photosynthesis, using light intensity, CO₂ concentration, and temperature as examples.

48. Explain why photorespiration is considered wasteful for the plant, and describe one adaptation (C₄ or CAM) that reduces it.

49. Explain the biological basis for why many plant secondary metabolites (originally evolved for defense) have found use as human medicines.

50. Explain the potential ecological benefits and risks of using algae/aquatic plant aquaculture on a large scale.

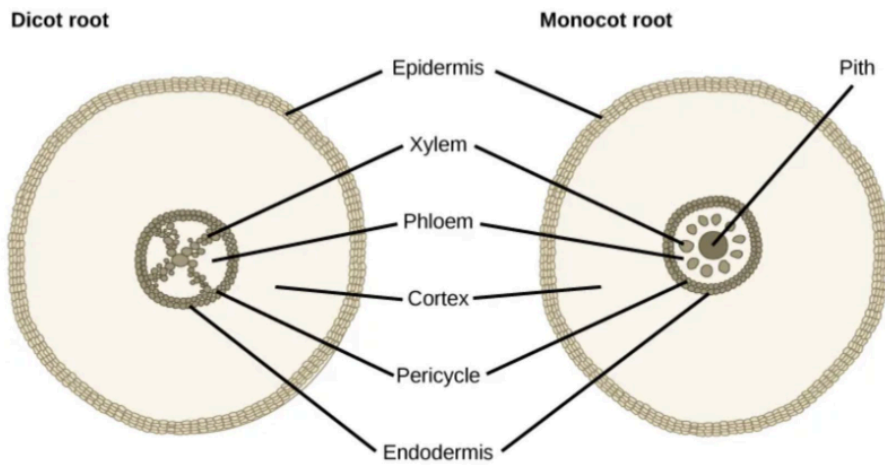
Science Olympiad – Botany

Division C – State Exam

IMAGE REFERENCE

Figure 1

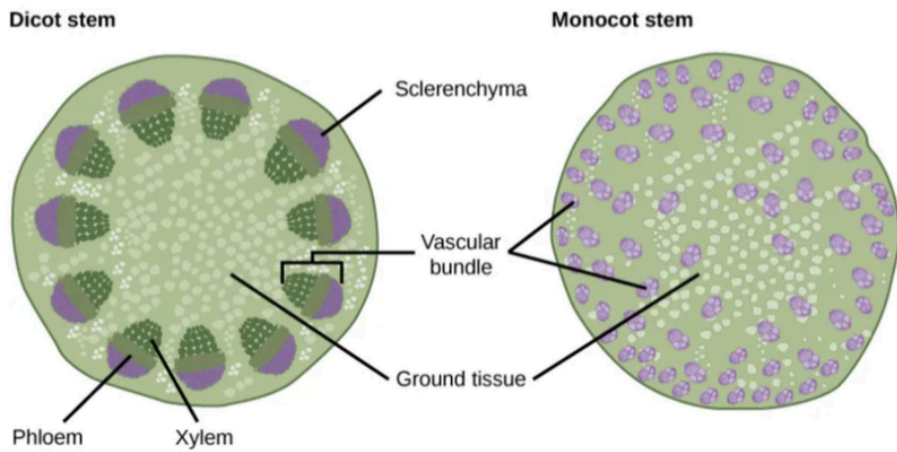
Used in question(s) 7. Side-by-side diagram comparing a dicot root cross-section (X-shaped vascular tissue) and a monocot root cross-section (vascular tissue in a ring around a central pith), labeled with epidermis, cortex, endodermis, pericycle, xylem, and phloem.



OpenStax, Biology 2e, Figure 30.18, section 30.3 Roots – CC BY 4.0.

Figure 2

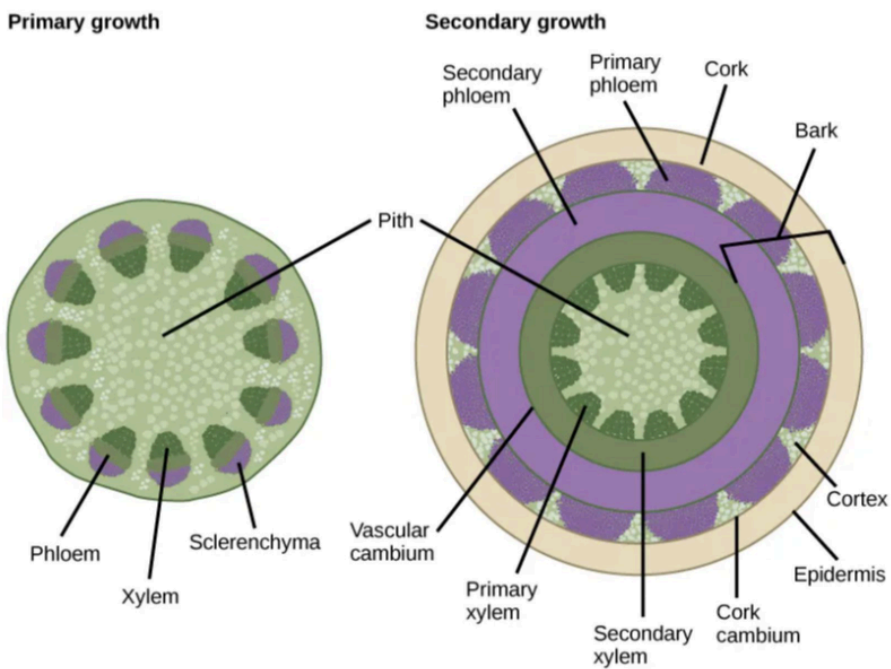
Used in question(s) 8. Side-by-side diagram comparing a dicot stem cross-section (vascular bundles arranged in a ring, with sclerenchyma and ground tissue) and a monocot stem cross-section (vascular bundles scattered throughout the ground tissue).



OpenStax, Biology 2e, Figure 30.9, section 30.2 Stems — CC BY 4.0.

Figure 3

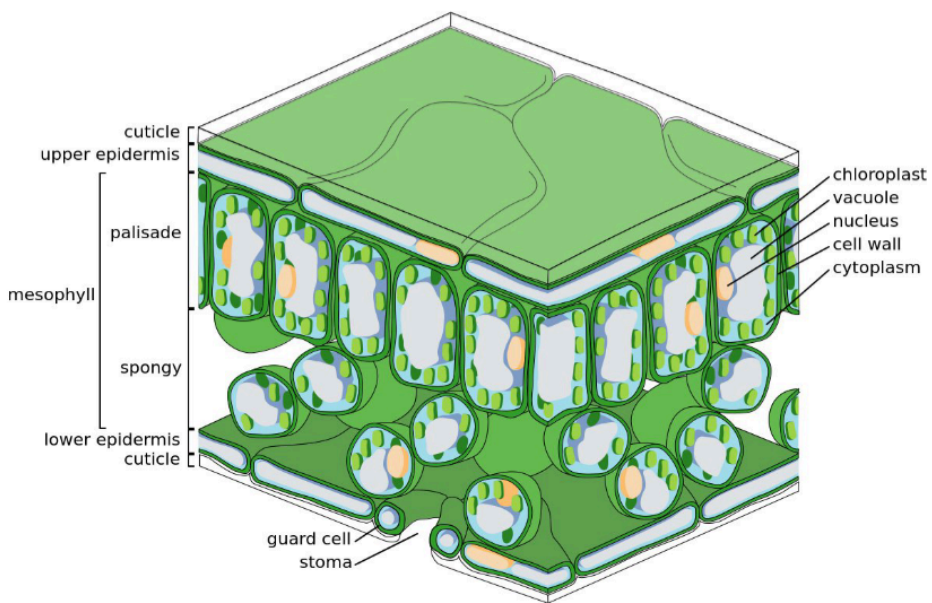
Used in question(s) 9. Diagram comparing a herbaceous stem cross-section undergoing primary growth (pith, xylem, phloem, sclerenchyma) with a woody stem cross-section undergoing secondary growth (vascular cambium, secondary xylem/phloem, cork cambium, cork, bark).



OpenStax, Biology 2e, Figure 30.10, section 30.2 Stems — CC BY 4.0.

Figure 4

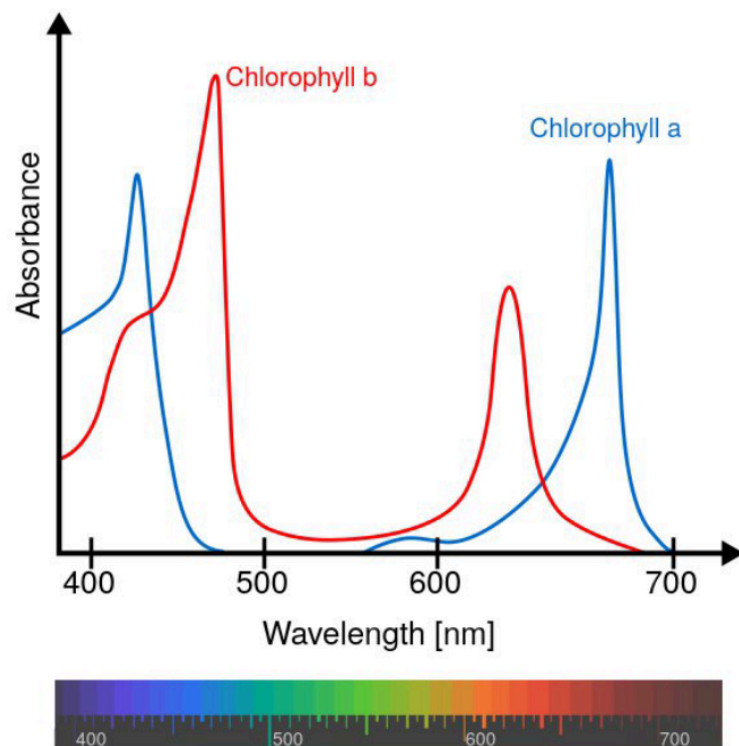
Used in question(s) 11, 36. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg — CC BY-SA 3.0.

Figure 5

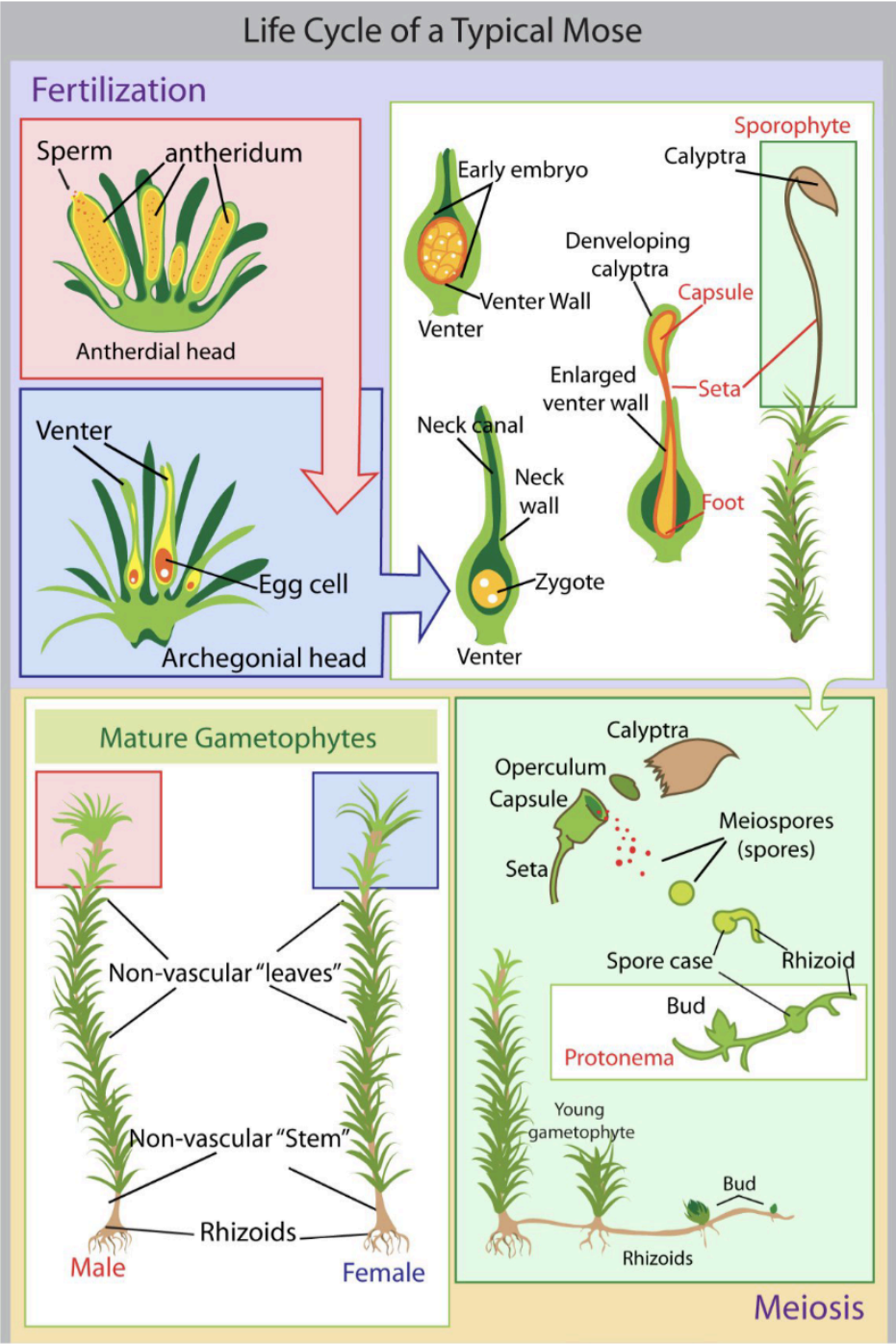
Used in question(s) 28. Graph of the light absorption spectra of chlorophyll a and chlorophyll b, plotting absorbance against wavelength (nm) across the visible spectrum.



Wikimedia Commons, File:Chlorophyll_ab_spectra-en.svg – CC BY-SA 3.0.

Figure 6

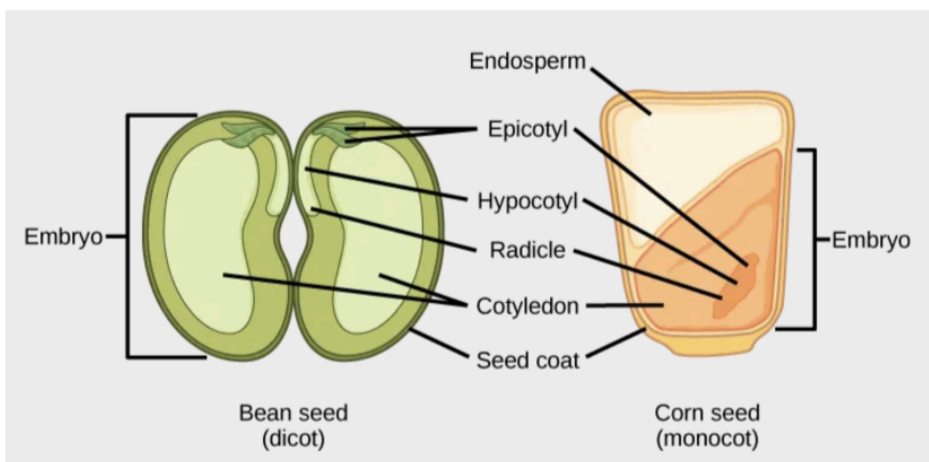
Used in question(s) 17. Diagram of the alternation-of-generations life cycle of a typical moss: the male and female gametophytes (non-vascular “leaves,” “stem,” and rhizoids), fertilization, the sporophyte (seta, capsule, calyptra), meiosis, and spore germination into the protonema.



Wikimedia Commons, File:Moss_life_Cycle.jpg, author LadyofHats — Public Domain.

Figure 7

Used in question(s) 19. Diagram comparing a dicot seed (bean), with two cotyledons, and a monocot seed (corn), with a single cotyledon and large endosperm; both labeled with the seed coat, epicotyl, hypocotyl, and radicle.



OpenStax, Biology 2e, Figure 32.20, section 32.2 Pollination and Fertilization – CC BY 4.0.

Science Olympiad – Botany

Division C – State Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	B
2	A
3	A
4	A
5	A
6	A
7	A
8	A
9	B
10	A
11	A
12	A
13	A
14	A
15	A
16	A
17	A
18	A
19	A
20	A
21	A
22	A
23	A
24	A
25	A
26	A
27	A
28	A
29	A
30	A
31	A
32	A
33	A
34	A
35	A
36	A, B, C
37	A, B, D
38	A, B, C
39	A, B, D

Short Answer / Long Answer – Model Answers

41. Total water potential = solute potential + pressure potential. Water moves from an area of higher (less negative) water potential to an area of lower (more negative) water potential.

42. Having more stomata on the shaded, cooler lower leaf surface reduces direct sun exposure and heat, lowering the rate of water loss by evaporation, while still allowing enough gas exchange (CO₂ in, O₂ out) for photosynthesis.

43. Auxin produced at the shoot tip accumulates on the shaded side of the stem when light comes from one direction. This causes cells on the shaded side to elongate more than cells on the lit side, bending the stem toward the light.

44. Fern and moss sperm are flagellated and must swim through a film of external water to reach the egg in the archegonium, so fertilization depends on a moist environment. In seed plants, pollen (containing sperm) is carried by wind or animals and grows a pollen tube directly to the egg, removing the need for external water.

45. Dioecy (separate male and female plants) makes self-pollination impossible, forcing cross-pollination between genetically different individuals. This increases genetic diversity in offspring and reduces inbreeding depression, improving a population's ability to adapt to change.

46. Lignin provides rigidity and resistance to compression, allowing plants to stand upright and grow taller. Vascular tissue (xylem and phloem) allows efficient long-distance transport of water, minerals, and sugars. Together they freed plants from relying on diffusion alone, allowing them to grow larger and colonize drier terrestrial habitats farther from constant water sources.

47. At any given time, photosynthesis is limited by whichever factor – light intensity, CO₂ concentration, or temperature (enzyme activity) – is in shortest relative supply, even if the other factors are abundant. Increasing that one limiting factor raises the photosynthetic rate until another factor becomes limiting.

48. Photorespiration is wasteful because RuBisCO binds O₂ instead of CO₂, consuming energy and releasing CO₂ without producing usable sugar, lowering photosynthetic efficiency. C₄ plants reduce this using Kranz anatomy to concentrate CO₂ around RuBisCO in bundle sheath cells; CAM plants reduce it by fixing CO₂ at night and running the Calvin cycle during the day with stomata closed.

49. Plants originally evolved secondary metabolites (alkaloids, terpenoids, etc.) as chemical defenses against herbivores and pathogens. Because these compounds are biologically active and interact with animal (including human) receptors and enzymes, some have useful pharmacological effects and have been developed into medicines, such as taxol (a cancer drug from Pacific yew) or salicin from willow bark (the basis for aspirin).

50. Benefits: algae/aquatic plant aquaculture can provide food and biofuel feedstock, and can absorb excess nutrients (nitrogen/phosphorus) from water, reducing eutrophication. Risks: escaped or overgrown algae can deplete oxygen when they die and decompose, potentially harm native aquatic ecosystems, or become invasive.

Science Olympiad

Botany - Division B

National Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 80 questions: 60 multiple choice, 5 multi-select (select ALL correct answers), 10 short answer, and 5 long answer. Fifteen questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Figure 1 shows a plant cell. Which labeled organelle is responsible for photosynthesis? [See Figure 1]

- A. Nucleus
- B. Mitochondrion
- C. Chloroplast
- D. Central vacuole

2. Which pair of organelles/structures are both involved in processing and packaging proteins for secretion out of a plant cell?

- A. Rough endoplasmic reticulum and Golgi apparatus
- B. Cell wall and vacuole
- C. Nucleus and mitochondrion
- D. Chloroplast and peroxisome

3. In addition to maintaining turgor pressure, the plant central vacuole commonly also functions to:

- A. Store pigments, waste products, and defensive compounds
- B. Produce ATP through cellular respiration
- C. Synthesize chlorophyll exclusively
- D. Replicate the cell's DNA

4. Plasmodesmata are best described as:

- A. Pores that allow direct communication/transport between adjacent plant cells
- B. The waxy outer covering of leaves
- C. A type of plant hormone
- D. Cells that make up xylem tissue

5. Chloroplasts are believed to have originated through:

- A. Endosymbiosis of a photosynthetic bacterium
- B. Random mutation of the nucleus
- C. Fusion of two mitochondria
- D. Direct absorption from soil

- 6. Which type of meristem is located at root and shoot tips, responsible for increasing plant length?**
- A. Apical meristem
 - B. Lateral meristem
 - C. Cork cambium exclusively
 - D. Ground meristem only
- 7. A tree increasing in trunk diameter (girth) year after year is primarily the result of:**
- A. Secondary growth from lateral meristems (vascular cambium)
 - B. Apical meristem activity alone
 - C. Root hair proliferation
 - D. Increased leaf number only
- 8. Which best explains why a plant cell does not burst when placed in pure water (a strongly hypotonic environment), unlike an animal cell?**
- A. The rigid cell wall resists expansion once turgor pressure builds, counteracting further water entry
 - B. Plant cells lack a cell membrane
 - C. Plant cells cannot absorb water
 - D. Plant cells have no internal pressure
- 9. Which best describes the function of the Golgi apparatus in a plant cell?**
- A. Modifying, sorting, and packaging proteins and other molecules for transport
 - B. Producing ATP through cellular respiration
 - C. Absorbing light for photosynthesis
 - D. Storing genetic material
- 10. Plasmolysis occurs when a plant cell is placed in a hypertonic solution and:**
- A. Water leaves the cell, causing the cell membrane to pull away from the cell wall
 - B. Water enters the cell, increasing turgor pressure
 - C. The cell wall dissolves
 - D. The nucleus divides
- 11. Which cell type forms the outermost protective layer of a young root or shoot?**
- A. Epidermis
 - B. Cortex
 - C. Pith
 - D. Xylem
- 12. The vascular cambium is a type of:**
- A. Lateral meristem responsible for secondary growth (increasing stem/root girth)
 - B. Apical meristem responsible for increasing length
 - C. Ground tissue
 - D. Epidermal tissue
- 13. Sclerenchyma and collenchyma are both examples of:**
- A. Plant support/strengthening tissues
 - B. Types of chlorophyll
 - C. Plant hormones
 - D. Reproductive structures

14. Which best describes the function of companion cells in phloem?

- A. They support the metabolic functions of adjacent sieve tube elements, which lack a nucleus
- B. They transport water exclusively
- C. They produce pollen
- D. They form the outer bark

15. Figure 2 compares monocot and dicot roots. Which best describes a key structural difference typically shown? [See Figure 2]

- A. Dicot roots often have vascular tissue in a star-shaped pattern; monocot roots often have vascular tissue arranged in a ring around a central pith
- B. Monocot roots never have root hairs
- C. Dicot roots lack xylem
- D. There is no structural difference

16. A taproot system, common in dicots, is best described as:

- A. A single, dominant main root that grows deep, with smaller lateral roots branching off
- B. A dense mat of similarly-sized roots near the soil surface
- C. Roots that grow entirely above ground
- D. A root system found only in aquatic plants

17. Figure 3 shows a herbaceous dicot stem. Which labeled tissue provides structural support and storage in the center of the stem? [See Figure 3]

- A. Epidermis
- B. Cortex
- C. Vascular bundles
- D. Pith

18. Figure 4 shows a woody stem cross-section. Which labeled tissue produces new xylem and phloem cells each growing season? [See Figure 4]

- A. Bark
- B. Cork cambium
- C. Vascular cambium
- D. Pith

19. Figure 4 shows a woody stem. Annual growth rings are visible in which labeled tissue? [See Figure 4]

- A. Xylem
- B. Cork cambium
- C. Bark only
- D. Pith

20. The cork cambium in a woody stem produces:

- A. Xylem
- B. Phloem
- C. The outer protective bark tissue
- D. Chlorophyll

21. Figure 5 shows a leaf cross-section. Which labeled structure is a waxy layer that reduces water loss from the leaf surface? [See Figure 5]

- A. Cuticle
- B. Palisade mesophyll
- C. Vein
- D. Spongy mesophyll

22. Figure 5 shows a leaf. Which labeled layer's loosely packed arrangement allows efficient gas diffusion to and from the stomata? [See Figure 5]

- A. Palisade mesophyll
- B. Spongy mesophyll
- C. Cuticle
- D. Upper epidermis

23. Guard cells regulate the opening and closing of the stoma primarily in response to:

- A. Changes in turgor pressure within the guard cells
- B. Random chance
- C. Soil pH only
- D. Root pressure alone

24. Which best describes parallel leaf venation?

- A. Veins run alongside each other from base to tip, typical of monocots
- B. Veins branch in a net-like pattern, typical of dicots
- C. Veins are entirely absent
- D. Veins only occur in roots

25. An onion is an example of which type of modified underground storage structure?

- A. Bulb
- B. Taproot
- C. Runner
- D. Corm

26. Which of the following is an example of a modified leaf?

- A. A cactus spine
- B. A tree trunk
- C. A taproot
- D. A stamen

27. A rhizome is best described as:

- A. A horizontal underground stem that can produce roots and shoots
- B. A type of flower petal
- C. A pollen-producing structure
- D. A fruit type

28. Figure 3 shows a stem cross-section with xylem tissue labeled. Root pressure contributes to water movement in the xylem tissue shown primarily by: [See Figure 3]

- A. Actively pushing water upward from the roots, especially notable at night when transpiration is low
- B. Pulling water down from the leaves
- C. Only functioning in gymnosperms
- D. Having no effect on water transport

29. Deciduous trees drop their leaves seasonally primarily to:

- A. Reduce water loss during periods when water uptake is limited (e.g., winter)
- B. Increase photosynthesis in winter
- C. Prevent pollination
- D. Attract more pollinators

30. Which best describes the function of the epidermis's waxy cuticle on leaves and stems?

- A. It reduces water loss and provides a barrier against pathogens
- B. It is the primary site of photosynthesis
- C. It absorbs minerals from soil
- D. It produces pollen

31. Figure 6 shows a flower. Which labeled structure produces pollen? [See Figure 6]

- A. Sepal
- B. Petal
- C. Anther
- D. Stigma

32. Figure 6 shows a flower. Which labeled structure contains the ovule(s) that develop into seeds after fertilization? [See Figure 6]

- A. Sepal
- B. Petal
- C. Anther
- D. Ovary

33. Animal-pollinated (e.g., insect-pollinated) flowers typically have:

- A. Bright colors, scent, and/or nectar to attract pollinators
- B. No pollen at all
- C. Only microscopic, colorless petals
- D. Pollen too heavy to be carried by any animal

34. Figure 9 compares monocot and dicot seeds. Where is stored food located in a typical dicot seed? [See Figure 9]

- A. In the two cotyledons
- B. In the seed coat only
- C. It is not stored in dicot seeds
- D. In the anther

35. Asexual reproduction in plants can occur through which of the following?

- A. Runners/stolons (e.g., strawberries)
- B. Seed germination only
- C. Pollination only
- D. Meiosis exclusively

36. Figure 7 shows the alternation of generations. Which labeled stage produces spores through meiosis? [See Figure 7]

- A. Gametophyte
- B. Sporophyte
- C. Gamete
- D. Zygote

37. Figure 7 shows the alternation of generations. Which labeled stage produces gametes (sperm and egg)? [See Figure 7]

- A. Gametophyte
- B. Sporophyte
- C. Spore only
- D. None of the stages

38. A moss sporophyte typically remains attached to and dependent on the gametophyte for nutrition. This relationship is best described as:

- A. The sporophyte is physically attached to and nutritionally dependent on the parent gametophyte
- B. The sporophyte is entirely independent and free-living
- C. The gametophyte depends on the sporophyte for all nutrition
- D. The two generations never coexist

39. In ferns, which generation is the larger, more visible plant (the familiar fern frond)?

- A. The gametophyte
- B. The sporophyte
- C. Both are equally visible
- D. Neither generation is visible

40. Double fertilization, a process unique to angiosperms, produces:

- A. A diploid zygote and a triploid endosperm
- B. Two separate embryos
- C. Only pollen grains
- D. A haploid seed coat

41. Hornworts, liverworts, and mosses are all grouped together as:

- A. Bryophytes
- B. Gymnosperms
- C. Angiosperms
- D. Pteridophytes

42. Which best explains why land plants (embryophytes) are thought to have evolved from a green algal ancestor?

- A. Shared pigments (chlorophyll a and b) and cell wall composition (cellulose) with green algae, among other similarities
- B. Land plants and algae share no similarities
- C. All algae are classified as land plants
- D. Land plants evolved independently with no algal ancestry

43. Ferns are classified as:

- A. Seedless vascular plants
- B. Non-vascular plants
- C. Gymnosperms
- D. Angiosperms

44. Which best describes how gymnosperm seeds are typically borne, as compared to angiosperm seeds?

- A. 'Naked,' often on the surface of cone scales, without being enclosed in a fruit
- B. Always enclosed inside a fleshy fruit
- C. Gymnosperms do not produce seeds
- D. Inside a flower's ovary, like angiosperms

45. Which best explains why flowers are considered a major evolutionary innovation of angiosperms?

- A. They enable more efficient, targeted pollination (often via animal pollinators) compared to the wind-pollination relied on by most gymnosperms
- B. Flowers eliminate the need for pollination entirely
- C. Flowers only occur in seedless plants
- D. Flowers prevent seed formation

46. Unlike true embryophyte plants, most algae lack which feature that helps protect a developing embryo?

- A. Protective, multicellular structures surrounding the embryo (e.g., archegonia)
- B. Chlorophyll
- C. Cell walls
- D. The ability to photosynthesize

47. Which historical botanist developed the binomial nomenclature system used to classify organisms?

- A. Charles Darwin
- B. Carl Linnaeus
- C. Gregor Mendel
- D. Louis Pasteur

48. Fossilized plant evidence suggests that vascular land plants first evolved during which general geologic period?

- A. The Cambrian (before land plants existed)
- B. The Silurian/Devonian periods
- C. The Cretaceous only
- D. The present era only

49. Figure 8 shows the absorption spectra of chlorophyll a and chlorophyll b. Which best describes a key difference between the two curves shown? [See Figure 8]

- A. The two curves peak at slightly different wavelengths in the blue and red regions, though both absorb poorly in the green
- B. Chlorophyll b absorbs no light at any wavelength
- C. Chlorophyll a absorbs strongly only in the green region
- D. The two curves are identical at every wavelength

50. Figure 8 shows the absorption spectra of chlorophyll a and chlorophyll b. A wavelength of light (e.g., green light) where both curves show near-zero absorbance would result in: [See Figure 8]

- A. Maximum photosynthetic rate
- B. Little to no photosynthesis occurring from that wavelength, since the light is not being absorbed by the pigments
- C. Immediate plant death
- D. No effect on absorbance at any other wavelength

51. The overall products of photosynthesis (glucose and oxygen) are generated using energy ultimately captured during the:

- A. Light-dependent reactions only, with no involvement of the Calvin cycle
- B. Light-dependent reactions, which power the Calvin cycle's fixation of carbon into sugar
- C. Calvin cycle alone, independent of light
- D. Process of transpiration

52. Which structure within the chloroplast is the fluid-filled space where the Calvin cycle takes place?

- A. Thylakoid membrane
- B. Stroma
- C. Outer chloroplast membrane
- D. Granum stack only

53. The Calvin cycle uses ATP and NADPH (produced by the light-dependent reactions) to:

- A. Fix carbon dioxide into organic sugar molecules
- B. Split water into oxygen and hydrogen
- C. Produce chlorophyll
- D. Transport water through xylem

54. Carotenoids are accessory pigments that:

- A. Absorb additional wavelengths of light (mainly blue-green) and pass energy to chlorophyll, and can also protect against excess light damage
- B. Are the primary pigment used in all photosynthesis
- C. Absorb only red light
- D. Have no role in photosynthesis

55. Monoculture (growing a single crop species repeatedly over large areas) increases agricultural risk primarily because it:

- A. Makes the entire crop more vulnerable to a single pest or disease outbreak
- B. Always increases soil fertility indefinitely
- C. Eliminates the need for irrigation
- D. Has no known agricultural drawbacks

56. A plant with stunted, spindly growth and older leaves turning uniformly pale yellow (not just between the veins) most likely has a deficiency in:

- A. Nitrogen
- B. Excess water
- C. Excess sunlight
- D. Excess carbon dioxide

57. A relatively stable, long-term community of species that persists at the end of ecological succession is called the:

- A. Pioneer community
- B. Climax community
- C. Keystone community
- D. Invasive community

58. Which best describes competitive exclusion among plants in a shared habitat?

- A. Two species competing for the same limited resource cannot indefinitely coexist; one will typically outcompete the other
- B. All competing plant species always coexist indefinitely with no effect on each other
- C. Competition only occurs between animals, never plants
- D. Competitive exclusion always favors the smaller species

59. Mycorrhizal fungi form a mutualistic relationship with plant roots primarily by:

- A. Extending the effective root surface area to improve water/nutrient (especially phosphorus) uptake, in exchange for sugars from the plant
- B. Causing disease in most host plants
- C. Preventing any water absorption
- D. Replacing the need for photosynthesis

60. Powdery mildew, a common plant disease, is caused by:

- A. Fungi
- B. Viruses
- C. Nutrient excess
- D. Insufficient light only

61. Which of the following are structures/tissues found within a typical stem? (Select all that apply)

- A. Vascular bundles
- B. Pith
- C. Root cap
- D. Epidermis

62. Which of the following occur during the light-dependent reactions of photosynthesis? (Select all that apply)

- A. Splitting of water (photolysis)
- B. Production of ATP
- C. Fixation of carbon dioxide into sugar
- D. Production of NADPH

63. Which of the following are considered seed plants? (Select all that apply)

- A. Gymnosperms
- B. Angiosperms
- C. Ferns
- D. Mosses

64. Which of the following are common causes of plant disease? (Select all that apply)

- A. Fungal pathogens
- B. Bacterial pathogens
- C. Viral pathogens
- D. Excess chlorophyll production

65. Which of the following are methods of asexual plant reproduction? (Select all that apply)

- A. Runners/stolons
- B. Rhizomes
- C. Seed germination following fertilization
- D. Tubers (e.g., potato eyes sprouting)

66. Explain the relationship between water potential, osmosis, and turgor pressure in plant cells.

67. Explain how the cohesion-tension mechanism allows water to rise to the top of a tall tree without any active pumping.

68. Explain why phloem, unlike xylem, consists of living cells at maturity, and what this means for how it functions.

69. Explain how annual growth rings form in a woody stem, and how they can be used to estimate a tree's age.

70. Explain the adaptive advantage of heterospory (producing separate microspores and megaspores) over homosporous.

71. Describe the process of double fertilization in angiosperms and explain what each of the two fertilization events produces.

72. Explain why mosses are generally restricted to small sizes and moist habitats, referencing their lack of vascular tissue and reproductive biology.

73. Explain the role of accessory pigments like carotenoids in photosynthesis, beyond the role of chlorophyll.

74. Explain how nitrogen-fixing bacteria in legume root nodules benefit both the plant and agricultural soil fertility.

75. Explain one potential benefit and one potential concern associated with genetically modified (GM) crops.

76. Explain, in detail, how water moves from the roots to the top of a tall tree, including the roles of root pressure, capillary action, and the cohesion-tension mechanism driven by transpiration.

77. Describe, in detail, the light-dependent and light-independent (Calvin cycle) reactions of photosynthesis, including where each occurs and what is produced.

78. Describe, in detail, the complete life cycle of a flowering plant (angiosperm), from pollination through seed germination.

79. Compare and contrast three major plant groups (choose from: bryophytes, ferns, gymnosperms, angiosperms), including their vascular tissue, reproductive structures, and dependence on water for reproduction.

80. Explain, in detail, how plants compete for resources in a community and describe the process of ecological succession from a disturbed area to a mature (climax) community.

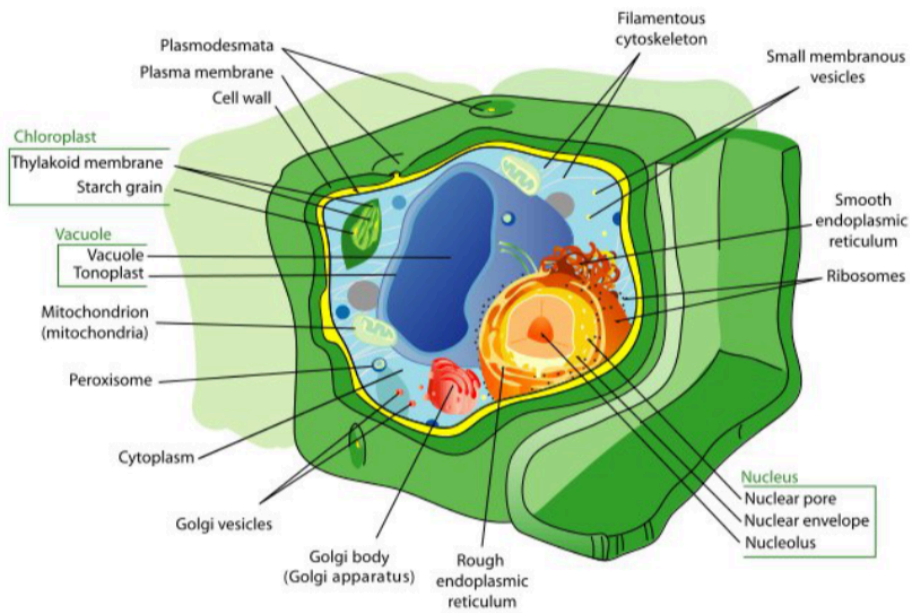
Science Olympiad – Botany

Division B – National Exam

IMAGE REFERENCE

Figure 1

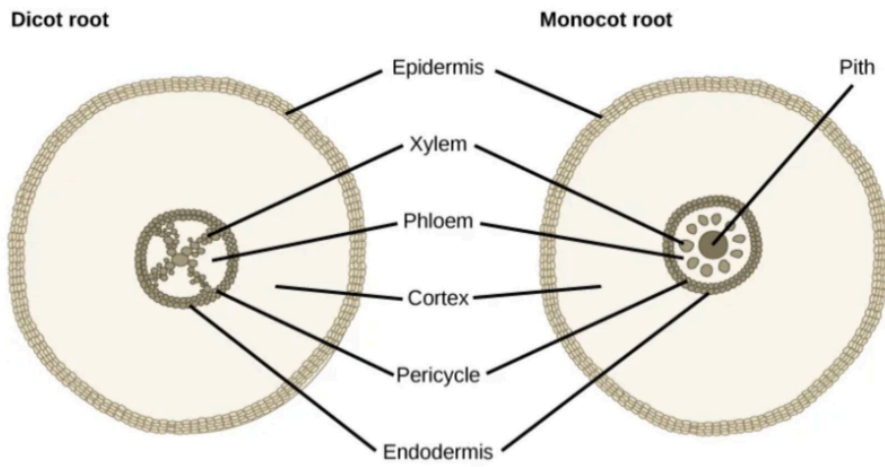
Used in question(s) 1. Labeled diagram of a generalized plant cell, showing the cell wall, cell membrane, nucleus, chloroplast, central vacuole, mitochondrion, Golgi apparatus, endoplasmic reticulum, ribosomes, and other organelles.



Wikimedia Commons, File:Plant_cell_structure-en.svg, author LadyofHats – Public Domain.

Figure 2

Used in question(s) 15. Side-by-side diagram comparing a dicot root cross-section (X-shaped vascular tissue) and a monocot root cross-section (vascular tissue in a ring around a central pith), labeled with epidermis, cortex, endodermis, pericycle, xylem, and phloem.



OpenStax, Biology 2e, Figure 30.18, section 30.3 Roots – CC BY 4.0.

Figure 3

Used in question(s) 17, 28. Diagram comparing a herbaceous stem cross-section undergoing primary growth (pith, xylem, phloem, sclerenchyma) with a woody stem cross-section undergoing secondary growth (vascular cambium, secondary xylem/phloem, cork cambium, cork, bark).

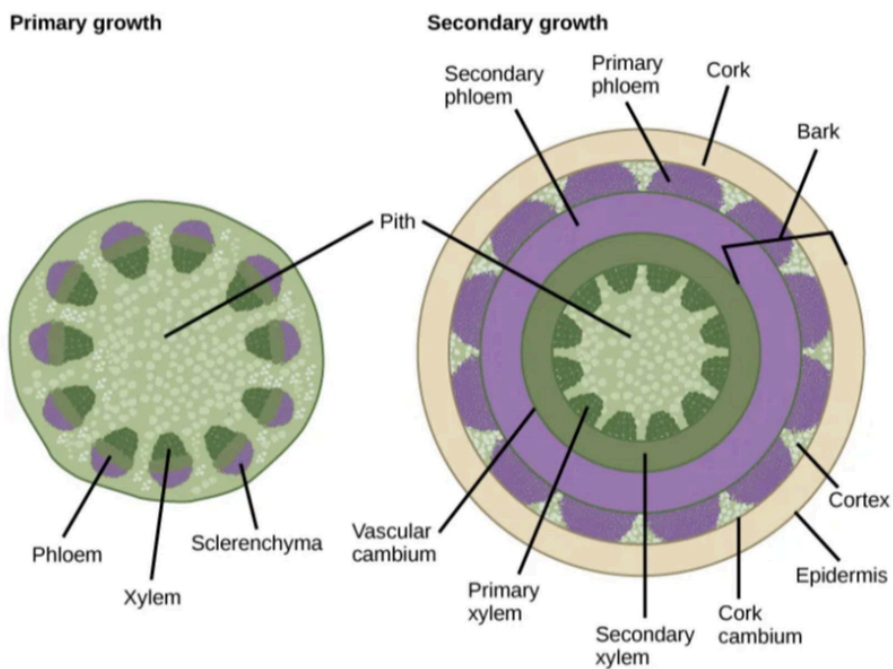


Figure 4

Used in question(s) 18, 19. Diagram comparing a herbaceous stem cross-section undergoing primary growth (pith, xylem, phloem, sclerenchyma) with a woody stem cross-section undergoing secondary growth (vascular cambium, secondary xylem/phloem, cork cambium, cork, bark).

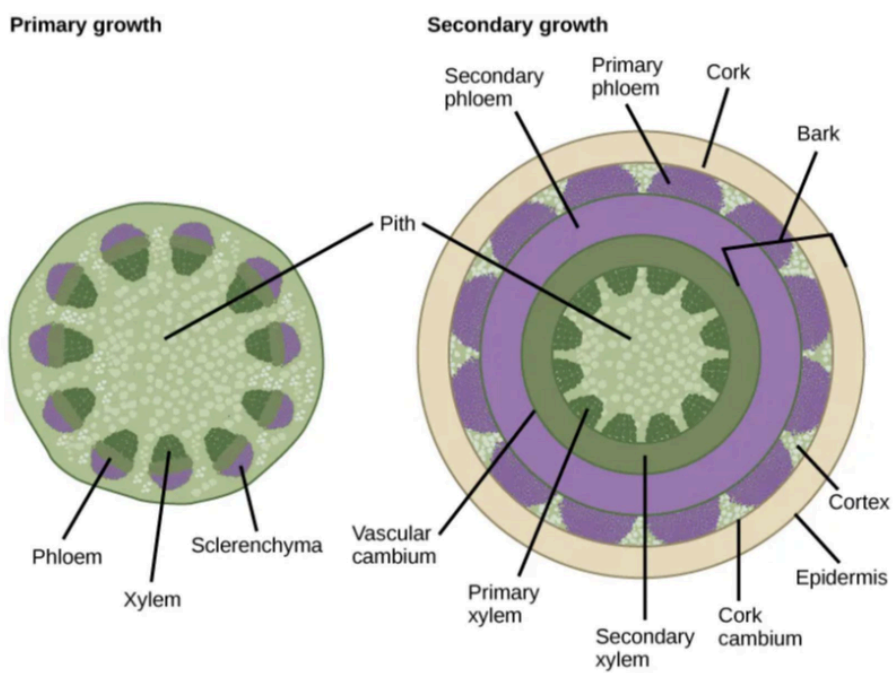
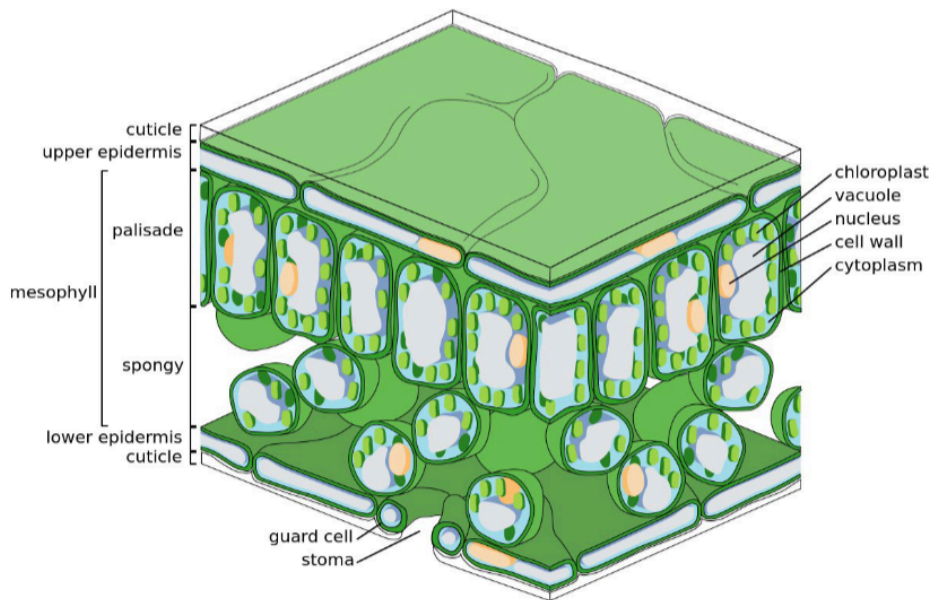


Figure 5

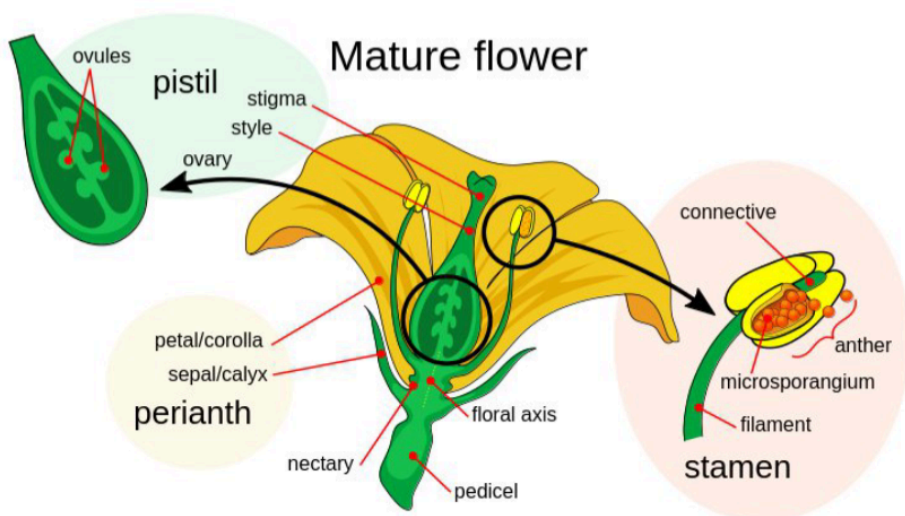
Used in question(s) 21, 22. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg — CC BY-SA 3.0.

Figure 6

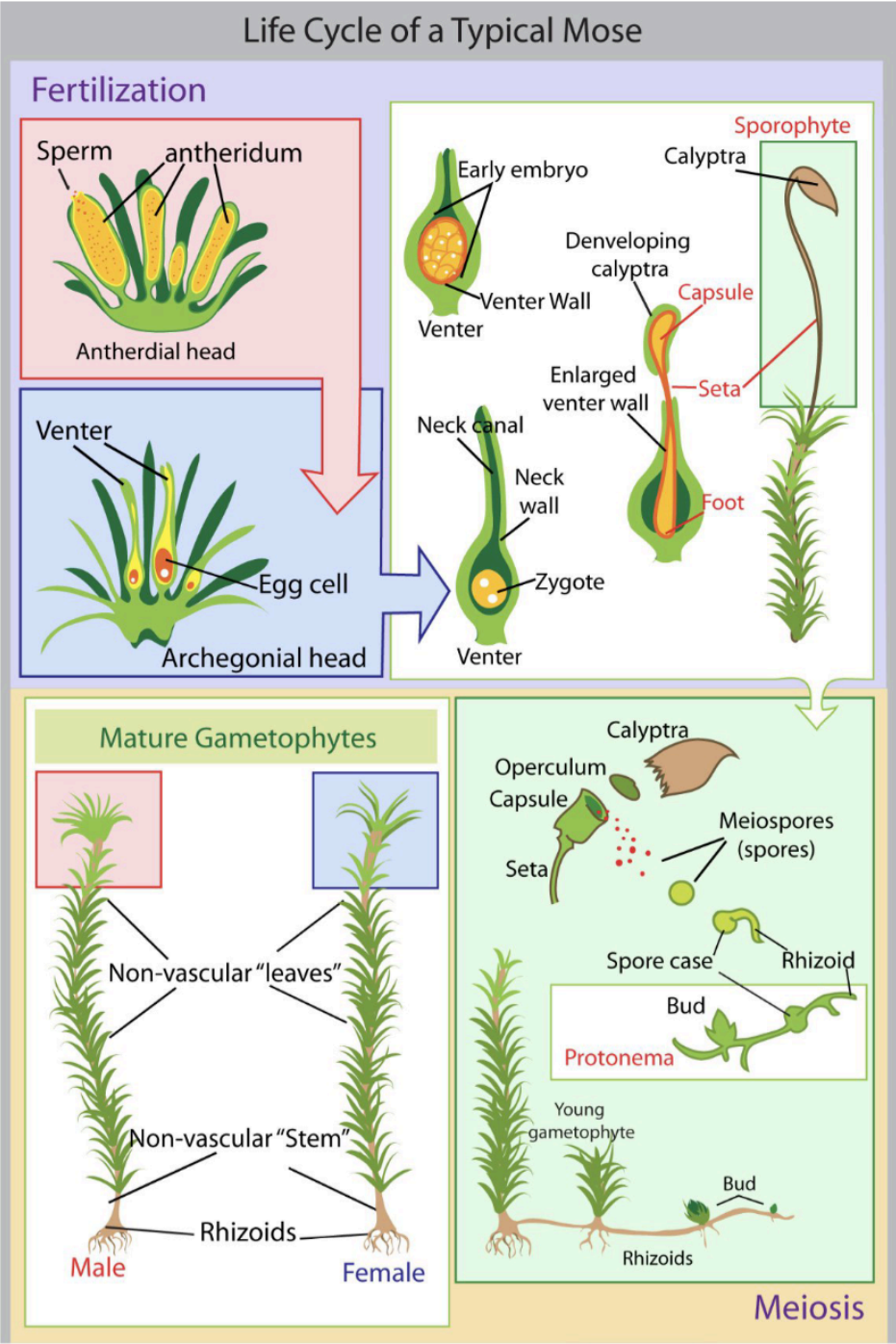
Used in question(s) 31, 32. Labeled diagram of a mature, complete flower: the perianth (sepal/calyx, petal/corolla), the pistil (stigma, style, ovary, ovules), and the stamen (anther, filament, connective, microsporangium).



Wikimedia Commons, File:Mature_flower_diagram.svg, author LadyofHats — Public Domain.

Figure 7

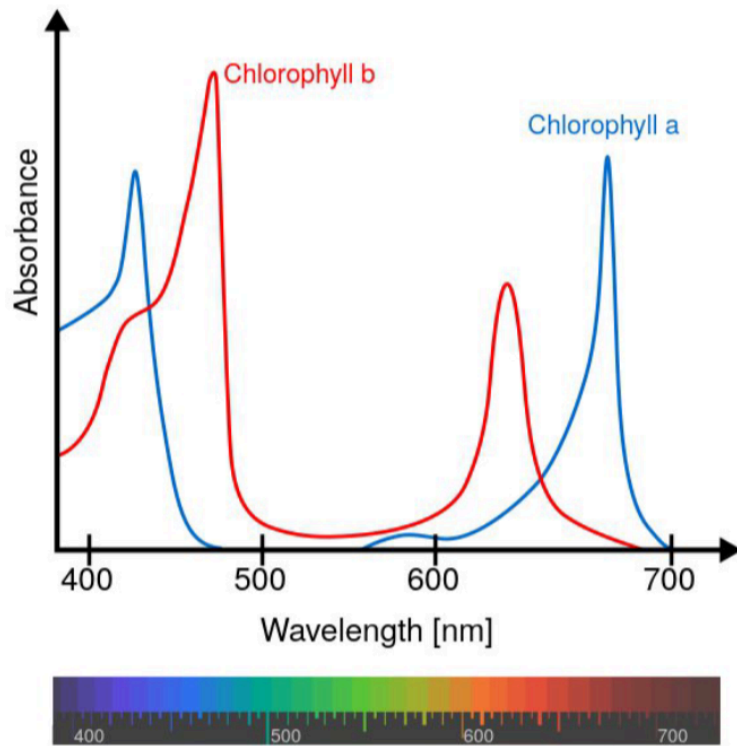
Used in question(s) 36, 37. Diagram of the alternation-of-generations life cycle of a typical moss: the male and female gametophytes (non-vascular “leaves,” “stem,” and rhizoids), fertilization, the sporophyte (seta, capsule, calyptra), meiosis, and spore germination into the protonema.



Wikimedia Commons, File:Moss_life_Cycle.jpg, author LadyofHats — Public Domain.

Figure 8

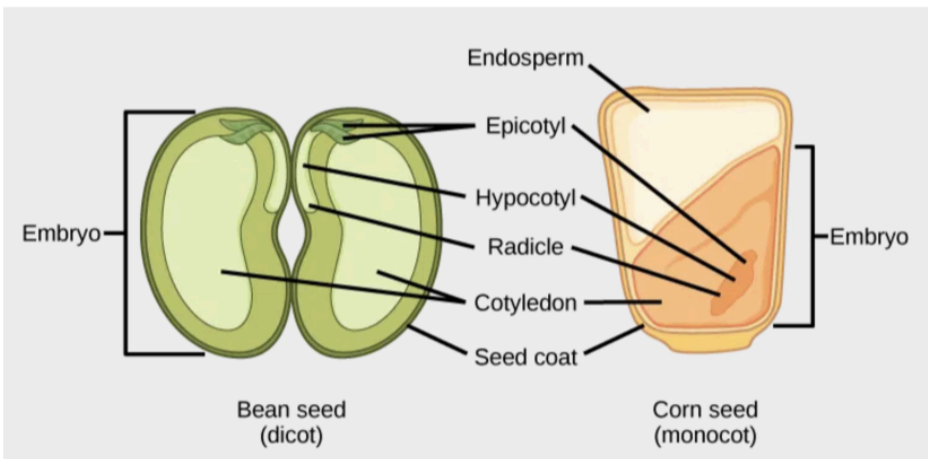
Used in question(s) 49, 50. Graph of the light absorption spectra of chlorophyll a and chlorophyll b, plotting absorbance against wavelength (nm) across the visible spectrum.



Wikimedia Commons, File:Chlorophyll_ab_spectra-en.svg — CC BY-SA 3.0.

Figure 9

Used in question(s) 34. Diagram comparing a dicot seed (bean), with two cotyledons, and a monocot seed (corn), with a single cotyledon and large endosperm; both labeled with the seed coat, epicotyl, hypocotyl, and radicle.



OpenStax, Biology 2e, Figure 32.20, section 32.2 Pollination and Fertilization — CC BY 4.0.

Science Olympiad – Botany

Division B – National Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	C
2	A
3	A
4	A
5	A
6	A
7	A
8	A
9	A
10	A
11	A
12	A
13	A
14	A
15	A
16	A
17	D
18	C
19	A
20	C
21	A
22	B
23	A
24	A
25	A
26	A
27	A
28	A
29	A
30	A
31	C
32	D
33	A
34	A
35	A
36	B
37	A
38	A
39	B

40	A
41	A
42	A
43	A
44	A
45	A
46	A
47	B
48	B
49	A
50	B
51	B
52	B
53	A
54	A
55	A
56	A
57	B
58	A
59	A
60	A
61	A, B, D
62	A, B, D
63	A, B
64	A, B, C
65	A, B, D

Short Answer / Long Answer — Model Answers

66. Water moves by osmosis from areas of higher water potential to areas of lower water potential. As water enters a plant cell (into the central vacuole), it increases the cell's pressure potential against the rigid cell wall, generating turgor pressure that keeps the cell firm.

67. Transpiration of water vapor from leaf stomata creates negative pressure (tension) that pulls water upward through the xylem. Water molecules are strongly attracted to each other (cohesion, via hydrogen bonding) and to the walls of narrow xylem vessels (adhesion), forming a continuous, unbroken column that can be pulled upward passively, with no active pumping required.

68. Phloem sieve tube elements are supported by living companion cells because moving sugars from source to sink requires active loading and unloading (using ATP) against concentration gradients — unlike xylem, which passively transports water through dead, hollow cells.

69. Each growing season, the vascular cambium produces new xylem: wide, less dense cells in spring (early wood) and narrower, denser cells later in the season (late wood), creating a visible ring boundary. Counting the number of rings estimates a tree's age, and ring width/spacing can indicate favorable or unfavorable growing conditions in a given year.

70. Producing separate microspores (which develop into male gametophytes) and megaspores (which develop into female gametophytes) allows greater specialization of male and female function and set the evolutionary stage for the development of seeds, enabling more efficient resource allocation and eventual protection of the female gametophyte/embryo.

71. In double fertilization, one sperm cell fuses with the egg to form the diploid zygote, which develops into the embryo; the second sperm cell fuses with two polar nuclei to form the triploid endosperm, which serves as a food reserve for the developing embryo.

72. Mosses lack vascular tissue, so they cannot efficiently transport water or nutrients over long distances or provide the structural support needed to grow tall, restricting them to a low, compact growth form. Their flagellated sperm must swim through a film of external water to reach the egg in the archegonium, so mosses are restricted to consistently moist habitats where fertilization can occur.

73. Carotenoids absorb wavelengths of light (mainly blue-green) that chlorophyll absorbs poorly, broadening the range of usable light and passing that captured energy to chlorophyll at the reaction center. They also protect the plant by dissipating excess light energy as heat and quenching reactive oxygen species, preventing photodamage.

74. Rhizobium bacteria living in legume root nodules convert atmospheric nitrogen gas (N_2) into ammonia, a form the plant can use, in exchange for sugars from the plant. This enriches soil nitrogen content when the plant matter decomposes, improving fertility and reducing the need for synthetic nitrogen fertilizer in crop rotation systems.

75. Benefit (example): pest-resistant Bt crops reduce the need for chemical pesticide application and can increase yield. Concern (example): possible reduction in genetic diversity, gene flow to wild relatives, or increased dependency on seed from a small number of suppliers. (Any valid, well-explained benefit and concern is acceptable.)

76. Root pressure, generated by active mineral uptake into root xylem creating an osmotic gradient, provides a modest upward push, most noticeable at night when transpiration is low.

Capillary action – the adhesion of water to the narrow walls of xylem vessels – contributes a small additional lift. The dominant mechanism, however, is cohesion-tension: transpiration (evaporation of water vapor from leaf stomata) creates negative pressure/tension at the top of the plant; because water molecules cohere to one another via hydrogen bonding and adhere to the xylem walls, this tension pulls a continuous, unbroken column of water from the roots all the way up through the xylem to the leaves of even very tall trees, without any active pumping by the plant.

77. Light-dependent reactions occur in the thylakoid membranes of the chloroplast: chlorophyll absorbs light, water is split (photolysis), releasing oxygen gas, and the resulting electron transport chain produces ATP (via chemiosmosis) and NADPH. The Calvin cycle (light-independent reactions) occurs in the stroma: it uses the ATP and NADPH from the light reactions to fix carbon dioxide (via the enzyme RuBisCO) into organic 3-carbon sugar molecules (G3P), which are used to build glucose and other carbohydrates.

78. Pollination transfers pollen from the anther to the stigma; a pollen tube grows down the style to the ovule, where double fertilization occurs, producing a diploid zygote (embryo) and triploid endosperm (food supply). The fertilized ovule develops into a seed, and the surrounding ovary develops into a fruit. After dispersal, the seed germinates under favorable conditions – the radicle emerges first to form the root, followed by the shoot – and the seedling grows into a mature plant capable of producing its own flowers, completing the cycle.

79. A strong answer compares the chosen three groups on: (1) vascular tissue – present or absent, and its effect on size/habitat range; (2) reproductive structures – spores vs. seeds, cones vs. flowers/fruit; and (3) water dependence for reproduction – groups with swimming sperm (bryophytes, ferns) need external water for fertilization, while seed plants (gymnosperms, angiosperms) use pollen and do not.

80. Plants compete for limited light, water, nutrients, and space; taller or faster-growing species can shade out or outcompete others for these resources (competitive exclusion). In ecological succession, pioneer species (e.g., lichens, mosses, hardy grasses) are the first to colonize disturbed or bare land, gradually improving soil conditions; over time they are replaced by larger shrubs and trees in a predictable sequence of stages, until a relatively stable, long-lasting climax community – the group of species best adapted to the local long-term conditions – is reached.

Science Olympiad

Botany - Division C

National Exam

Team Name / Number: _____

Participants: _____

Instructions: This exam contains 80 questions: 60 multiple choice, 5 multi-select (select ALL correct answers), 10 short answer, and 5 long answer. Ten questions require analysis of a figure; each referenced figure is listed by number and description in the separate Image Reference document. Write all answers directly on this exam.

1. Figure 1 shows a plant cell. Which labeled organelle contains its own DNA and ribosomes, consistent with an endosymbiotic origin? [See Figure 1]

- A. Nucleus
- B. Central vacuole
- C. Chloroplast
- D. Golgi apparatus

2. Which best describes the role of pectin in the plant cell wall, particularly the middle lamella?

- A. It acts as a gel-like adhesive that binds adjacent plant cell walls together
- B. It is the primary photosynthetic pigment
- C. It replaces the need for cellulose entirely
- D. It functions only in root cells

3. Which best describes the relationship between cell wall pressure potential and the point of incipient plasmolysis?

- A. Incipient plasmolysis occurs when pressure potential drops to approximately zero, as the protoplast just begins to pull away from the cell wall
- B. Incipient plasmolysis occurs at maximum turgor pressure
- C. Pressure potential is unrelated to plasmolysis
- D. Incipient plasmolysis only occurs in dead cells

4. Which best explains why xylem vessel elements, unlike tracheids, allow more efficient bulk water flow?

- A. Vessel elements have perforation plates connecting end-to-end, forming continuous open tubes, while tracheids rely on pits between overlapping, closed cells
- B. Tracheids are wider than vessel elements
- C. Vessel elements are found only in gymnosperms
- D. There is no functional difference between the two

5. Which best explains the mechanism by which the Casparian strip forces water and minerals to cross a selectively permeable membrane before entering the root's vascular cylinder?

- A. A waxy, waterproof band (suberin) in the radial and transverse walls of endodermal cells blocks the apoplastic pathway at that layer
- B. It physically blocks the xylem itself
- C. It is located in the epidermis, not the endodermis
- D. It has no known function

6. Which best explains the functional advantage of having both apical and lateral (intercalary) meristems in grasses (monocots)?

- A. Intercalary meristems located at the base of leaf blades/internodes allow rapid regrowth after grazing or mowing, since the growing tissue is not removed
- B. Grasses lack any meristematic tissue
- C. Intercalary meristems only occur in gymnosperms
- D. This arrangement prevents any regrowth after damage

7. Which best describes the biochemical basis for how abscisic acid (ABA) triggers stomatal closure during drought stress?

- A. ABA triggers ion efflux from guard cells, decreasing their turgor pressure and causing the stoma to close
- B. ABA increases turgor pressure in guard cells, opening the stoma further
- C. ABA has no effect on guard cell function
- D. ABA only affects root cells, not guard cells

8. Which plant hormone is primarily associated with promoting seed/bud dormancy and closing stomata under water stress?

- A. Auxin
- B. Absciscic acid
- C. Gibberellin
- D. Ethylene

9. Which plant hormone is most closely associated with fruit ripening and the response to mechanical stress/wounding?

- A. Ethylene
- B. Cytokinin
- C. Auxin
- D. Absciscic acid

10. Gibberellins are best known for promoting:

- A. Stem elongation and breaking seed dormancy
- B. Stomatal closure
- C. Leaf abscission exclusively
- D. Root hair formation exclusively

11. Cytokinins, often produced in root tips, primarily promote:

- A. Cell division and lateral bud growth, and delay leaf senescence
- B. Fruit ripening exclusively
- C. Stomatal closure exclusively
- D. Root elongation inhibition only

12. Apical dominance, in which the main shoot tip suppresses growth of lateral buds, is primarily maintained by:

- A. High auxin levels from the apical meristem inhibiting lateral bud growth, counteracted by cytokinin
- B. High cytokinin levels from the apical meristem alone
- C. Complete absence of any hormone in lateral buds
- D. Ethylene produced by lateral buds

13. Which best explains why removing (pinching) the terminal bud of a plant often causes bushier growth?

- A. Removing the auxin-producing apical meristem releases lateral buds from apical dominance, allowing them to grow
- B. It has no effect on lateral bud growth
- C. It permanently kills all lateral buds
- D. It increases auxin transport to lateral buds, suppressing them further

14. Which best describes the role of statoliths (starch-containing plastids) in gravitropism?

- A. They settle toward the bottom of specialized cells under gravity, helping the plant detect its orientation and triggering asymmetric hormone distribution
- B. They are involved exclusively in photosynthesis
- C. They have no role in detecting gravity
- D. They are found only in leaf cells

15. Figure 2 compares monocot and dicot roots. Which best explains why monocot roots (often with a ring of vascular tissue around a central pith) tend not to undergo extensive secondary growth? [See Figure 2]

- A. Most monocots lack a vascular cambium capable of producing substantial secondary xylem/phloem
- B. Monocot roots have no xylem at all
- C. Monocot roots grow exclusively underground with no limit on thickness
- D. There is no difference in secondary growth capacity

16. Figure 3 shows a woody stem. A wide growth ring compared to adjacent rings would most likely indicate: [See Figure 3]

- A. A favorable growing season (ample water/nutrients) for that year
- B. A drought or otherwise unfavorable growing season
- C. The tree's age at that point
- D. Nothing meaningful about growing conditions

17. Figure 10 shows a herbaceous dicot stem. Which labeled tissue would you expect to show the greatest increase in cell number if the plant later begins secondary growth (becoming somewhat woody)? [See Figure 10]

- A. Vascular bundles (specifically the region containing the vascular cambium)
- B. Epidermis
- C. Cortex only
- D. Pith only

18. Which best explains why xerophytes (plants adapted to arid environments) commonly have a reduced surface-area-to-volume ratio (e.g., cacti)?

- A. A lower surface-area-to-volume ratio reduces the relative area exposed for water loss via transpiration
- B. It increases water loss to help cool the plant
- C. It has no relationship to water conservation
- D. It maximizes light absorption exclusively, unrelated to water

19. Which best explains why halophytes (salt-tolerant plants) often have specialized salt glands or succulent tissue?

- A. These adaptations help exclude, excrete, or dilute excess salt, preventing osmotic damage to cells in saline environments
- B. They have no adaptive function related to salt
- C. They increase salt uptake to the point of toxicity
- D. They only function in freshwater habitats

20. Figure 4 shows a leaf cross-section. In a shade-adapted leaf compared to a sun leaf, which labeled tissue is typically thinner, since less light-capturing capacity is needed? [See Figure 4]

- A. Palisade mesophyll
- B. Cuticle only
- C. Vein only
- D. Guard cells only

21. Which best describes the quantitative relationship between transpiration rate and the vapor pressure deficit (VPD) between the leaf interior and the surrounding air?

- A. Transpiration rate generally increases as VPD increases (drier air relative to the leaf's saturated interior)
- B. Transpiration rate is unrelated to VPD
- C. Transpiration rate decreases as VPD increases
- D. VPD only affects root water uptake, not transpiration

22. Figure 10 shows a stem cross-section with xylem tissue labeled. Which best explains why boiling/heating xylem sap disrupts water transport through the xylem tissue shown (an experimental technique used to demonstrate the cohesion-tension mechanism)? [See Figure 10]

- A. It introduces air bubbles (cavitation/embolism) that break the continuous water column, interrupting the tension-driven pull of water
- B. It has no effect on water transport
- C. It increases the strength of hydrogen bonds between water molecules
- D. It only affects phloem, not xylem

23. Which best describes the process of vernalization's molecular basis in many plants?

- A. Prolonged cold exposure epigenetically represses a floral repressor gene, eventually allowing flowering genes to be expressed
- B. Cold exposure destroys all flowering-related genes permanently
- C. Vernalization has no molecular basis; it is purely behavioral
- D. Vernalization only affects root growth, not flowering

24. Which best explains the adaptive significance of reaction wood (e.g., tension wood in leaning dicot trees)?

- A. It forms with altered cell wall composition/orientation to help redirect the leaning trunk or branch back toward a more vertical growth habit
- B. It has no functional role
- C. It only forms in response to drought, never mechanical stress
- D. It is identical in composition to normal wood

25. Which best explains why some plants exhibit heterophylly (producing different leaf shapes on the same plant, e.g., aquatic vs. aerial leaves)?

- A. Developmental plasticity allows leaf form to be optimized for the specific environmental conditions (e.g., submerged vs. aerial) each leaf develops in
- B. It is always a random, non-adaptive mutation
- C. It only occurs due to disease
- D. All leaves on a plant are always genetically programmed to be identical regardless of environment

26. Which best describes the function of lenticels in woody bark?

- A. Small pores that allow gas exchange between internal stem tissues and the atmosphere through the otherwise impermeable bark
- B. Structures that produce chlorophyll in bark
- C. A type of flower bud
- D. Cells responsible for phloem loading

27. Which best explains why epiphytic plants (e.g., many orchids and bromeliads) often have specialized velamen tissue on their roots?

- A. Velamen is a spongy, absorptive tissue that helps capture and retain water/nutrients from rain and humid air, since epiphyte roots are not in soil
- B. Velamen prevents any water absorption
- C. Velamen is a photosynthetic tissue found only in leaves
- D. Velamen has no known function

28. Which best explains the ecological role of buttress roots seen in some large tropical trees?

- A. They provide additional structural support/stability in shallow, often nutrient-poor tropical soils
- B. They function primarily in nutrient absorption, not support
- C. They are a vestigial, non-functional structure
- D. They only occur in desert plants

29. Which best explains why plants in nutrient-poor bogs (e.g., pitcher plants, sundews) have evolved carnivory?

- A. Capturing and digesting insects supplements limited soil nitrogen/phosphorus availability in these habitats
- B. Carnivory replaces the need for photosynthesis entirely
- C. Carnivorous plants cannot photosynthesize
- D. Carnivory has no relationship to nutrient availability

30. Which best explains why deep taproots are common in many desert perennials?

- A. They can access water tables deep below the surface that are unavailable to shallow-rooted plants
- B. They only function for structural support, never water access
- C. Taproots increase water loss
- D. Taproots are only found in aquatic plants

31. Figure 5 shows a flower. Protandry, in which a labeled structure matures and releases pollen before the pistil of the same flower becomes receptive, helps prevent self-pollination. Which labeled structure matures first in protandry? [See Figure 5]

- A. Sepal
- B. Petal
- C. Anther (stamen)
- D. Stigma

32. Which best explains why many angiosperms have evolved self-incompatibility mechanisms (biochemically rejecting their own pollen)?

- A. It enforces outcrossing, increasing genetic diversity and avoiding the negative effects of inbreeding depression
- B. It has no adaptive benefit
- C. It ensures 100% self-pollination success
- D. It only occurs in wind-pollinated species

33. Figure 8 compares monocot and dicot seeds. Which best explains why monocot seeds like corn retain a large endosperm at maturity, unlike many dicot seeds where the endosperm is absorbed by the cotyledons before maturity? [See Figure 8]

- A. In many monocots, the single cotyledon does not fully absorb the endosperm, leaving it as the primary food reserve for germination
- B. Monocots never produce endosperm
- C. Dicots always retain more endosperm than monocots
- D. Endosperm formation is unrelated to seed structure

34. Which best explains the evolutionary significance of coevolution between angiosperms and their animal pollinators (e.g., specific flower shapes matching specific pollinator mouthparts)?

- A. Reciprocal selective pressures have shaped both flower traits and pollinator traits over time, often increasing pollination efficiency/specificity for both partners
- B. Coevolution only affects the pollinator, never the plant
- C. Flower shape has no relationship to pollinator anatomy
- D. Coevolution prevents any further evolutionary change in either species

35. Which best explains why many fruits have evolved fleshy, sugary tissue surrounding their seeds?

- A. It attracts animals that eat the fruit and disperse the seeds (often unharmed) via their digestive tract or by carrying the fruit away
- B. It has no role in seed dispersal
- C. It prevents any animal from eating the fruit
- D. It is used exclusively for photosynthesis

36. Which best explains the adaptive advantage of seed dormancy?

- A. It allows seeds to delay germination until environmental conditions (e.g., temperature, moisture, light, fire) are favorable for seedling survival
- B. Dormancy has no adaptive value
- C. Dormant seeds can never germinate
- D. Dormancy only occurs in aquatic plants

37. Figure 6 shows an alternation of generations. Which best explains why the sporophyte generation is dominant (larger and longer-lived) in seed plants, unlike in mosses? [See Figure 6]

- A. Evolutionary trends in land plants favored an increasingly dominant, independent sporophyte with a reduced, dependent gametophyte
- B. Seed plant gametophytes are always larger than the sporophyte
- C. Seed plants lack a sporophyte generation entirely
- D. There is no evolutionary trend regarding generation dominance

38. Which best describes the process of pollen tube guidance toward the ovule?

- A. Chemical signals (e.g., from synergid cells near the egg) guide pollen tube growth through the style toward the micropyle of the ovule
- B. Pollen tubes grow in a completely random direction
- C. Pollen tube growth is guided exclusively by gravity
- D. No signaling is involved in pollen tube growth

39. Which best explains why some orchid species have evolved flowers that mimic the appearance and pheromones of female insects (pseudocopulation)?

- A. This deceives male insects into attempting to mate with the flower, resulting in pollen transfer without offering any nectar reward
- B. It is purely coincidental with no pollination benefit
- C. It prevents all pollination from occurring
- D. It only occurs in wind-pollinated plants

40. Which best describes polyploidy's role in angiosperm evolution and modern crop breeding?

- A. Polyploidy (having extra sets of chromosomes) can create instant reproductive isolation and is associated with larger fruit/organ size, and has been exploited to develop many modern crop varieties
- B. Polyploidy always causes immediate plant death
- C. Polyploidy has never played a role in plant evolution
- D. Polyploidy only occurs in animals, not plants

41. Which best describes the currently favored hypothesis for the evolutionary relationship between land plants (embryophytes) and green algae?

- A. Land plants evolved from a lineage of charophyte (streptophyte) green algae, based on shared biochemical and genetic traits
- B. Land plants evolved independently of any algal lineage
- C. Land plants are more closely related to fungi than to any algae
- D. Land plants evolved from red algae exclusively

42. Which best explains why bryophytes are considered an important model for understanding the earliest stages of land plant evolution?

- A. They retain many ancestral traits (e.g., dependence on water for fertilization, lack of true vascular tissue) thought to characterize the earliest land plants
- B. Bryophytes are the most recently evolved plant group
- C. Bryophytes have no relevance to understanding plant evolution
- D. Bryophytes are more closely related to angiosperms than to any other plant group

43. Which best explains why the evolution of the seed habit is considered convergent in some respects between gymnosperms and certain extinct seed ferns?

- A. Multiple separate lineages independently evolved seed-like reproductive structures, suggesting seeds offered a strong selective advantage in more than one plant lineage
- B. Only gymnosperms have ever produced seeds
- C. Seed ferns and gymnosperms are the exact same taxonomic group
- D. Convergent evolution does not apply to plants

44. Which best explains why the study of paleobotany (fossil plants) relies heavily on evidence such as cuticle structure, spore/pollen morphology (palynology), and petrified wood anatomy?

- A. These structures are often well-preserved and can reveal details about the plant's identity, physiology, and the environment it lived in
- B. Fossil plants never preserve any identifiable structures
- C. Only flower color is useful for identifying fossil plants
- D. Paleobotany relies exclusively on DNA extracted from fossils

45. Which best explains the ecological concept of a keystone plant species?

- A. A species whose presence has a disproportionately large effect on the structure/function of its ecosystem relative to its abundance
- B. Any plant species found in large numbers within an ecosystem
- C. A species with no measurable ecological effect
- D. A term that only applies to animal species, never plants

46. Which best explains why invasive plant species often outcompete native plants in a new environment?

- A. They may lack natural predators/pathogens in the new environment and can sometimes exploit resources more efficiently than native competitors
- B. Invasive species are always less competitive than native species
- C. Invasive species cannot reproduce in new environments
- D. Native species always outcompete any introduced species

47. Which best explains why biodiversity hotspots (regions with exceptionally high plant endemism) are prioritized in conservation efforts?

- A. They contain a disproportionately large number of species found nowhere else, so their loss would result in disproportionate global biodiversity loss
- B. They contain no unique species
- C. All ecosystems have identical levels of endemism
- D. Biodiversity hotspots are always the least biologically significant regions

48. Which best describes why gene banks/seed banks (e.g., the Svalbard Global Seed Vault) are considered important conservation tools?

- A. They preserve genetic diversity of crop and wild plant species as a safeguard against extinction, disease, or catastrophic crop failure
- B. They serve no practical conservation purpose
- C. They only store animal genetic material
- D. They eliminate the need for any in-situ conservation efforts

49. Figure 7 shows the absorption spectra of chlorophyll a and chlorophyll b. Which best explains why an action spectrum for photosynthesis is not identical to a pure chlorophyll a absorption spectrum, but instead better matches the combined absorption of chlorophyll a and chlorophyll b shown here? [See Figure 7]

- A. Chlorophyll b captures additional wavelengths of light and transfers that energy to chlorophyll a at the reaction center, broadening the usable light spectrum beyond chlorophyll a alone
- B. Only chlorophyll a is ever involved in photosynthesis
- C. Chlorophyll b blocks photosynthesis
- D. Action spectra are unrelated to pigment absorption

50. Which best explains the function of the oxygen-evolving complex associated with Photosystem II?

- A. It catalyzes the splitting of water molecules, releasing electrons, protons, and oxygen gas
- B. It captures CO₂ for the Calvin cycle
- C. It produces ATP directly with no proton gradient involved
- D. It has no role in the light-dependent reactions

51. Which best explains why cyclic electron flow (as opposed to linear/non-cyclic electron flow) occurs in some chloroplasts?

- A. It generates additional ATP without producing NADPH, helping balance the ATP:NADPH ratio needed by the Calvin cycle
- B. It produces only NADPH with no ATP
- C. It has no functional role in photosynthesis
- D. It only occurs in the absence of light

52. Which best explains why CAM photosynthesis, despite reducing water loss, generally results in slower overall growth rates compared to C₃ or C₄ plants?

- A. Fixing and storing CO₂ as organic acids overnight for use the next day limits the total amount of CO₂ that can be processed compared to continuous daytime fixation
- B. CAM plants photosynthesize faster than C₃/C₄ plants
- C. CAM plants have no growth limitations
- D. CAM has no effect on plant growth rate

53. Which best explains the significance of the compensation point (the light intensity at which photosynthetic CO₂ uptake equals respiratory CO₂ release)?

- A. Below the compensation point, a plant has net negative carbon balance (using more energy than it produces) and cannot sustain growth
- B. The compensation point has no practical significance
- C. Above the compensation point, plants always stop photosynthesizing
- D. The compensation point only applies to CAM plants

54. Which best describes why shade-adapted (sciophyte) plants often have a lower light compensation point than sun-adapted plants?

- A. Shade plants have adaptations (e.g., larger/more efficient chlorophyll arrangement, lower respiration rate) that allow net positive carbon gain at lower light levels
- B. Shade plants require more light than sun plants to reach compensation point
- C. Light compensation point is identical for all plant species
- D. Shade plants cannot photosynthesize at all

55. Which best explains why increasing atmospheric CO₂ concentration tends to benefit C₃ plants proportionally more than C₄ plants?

- A. C₃ plants (lacking a CO₂-concentrating mechanism) are more directly limited by ambient CO₂ availability, while C₄ plants already concentrate CO₂ internally
- B. C₄ plants always benefit more from increased CO₂ than C₃ plants
- C. CO₂ concentration has no effect on either C₃ or C₄ photosynthesis
- D. C₃ plants are unaffected by atmospheric CO₂ levels

56. Which best describes the biochemical fate of the 3-carbon sugar (G3P) produced by the Calvin cycle?

- A. Most G3P is recycled to regenerate RuBP, while a smaller fraction is used to synthesize glucose and other organic molecules
- B. All G3P immediately leaves the chloroplast as oxygen gas
- C. G3P is only used to produce chlorophyll
- D. G3P has no further biochemical role

57. Which best describes the mechanism of action of glyphosate, a widely used herbicide, and why glyphosate-resistant GM crops were developed?

- A. Glyphosate inhibits an enzyme (EPSP synthase) in the shikimate pathway essential for amino acid synthesis in plants; resistant crops carry an insensitive version of this enzyme, allowing the herbicide to kill weeds without harming the crop
- B. Glyphosate has no known mechanism of action
- C. Glyphosate resistance was achieved by removing chlorophyll from crop plants
- D. Glyphosate targets animal nervous systems exclusively, with no plant-specific mechanism

58. Which best describes a key principle of integrated pest management (IPM) in horticulture/agriculture?

- A. Combining biological, cultural, and chemical control methods strategically to minimize pest damage while reducing reliance on any single method (especially broad chemical pesticides)
- B. Relying exclusively on a single chemical pesticide for all pest problems
- C. Eliminating all insects from an agricultural system indiscriminately
- D. IPM has no relevance to modern horticulture

59. Which best describes why plant biochemists study the shikimate pathway?

- A. It is a plant-specific (and microbial) pathway producing aromatic amino acids and many secondary metabolites, and is a target for herbicides since it is absent in animals
- B. It is found only in animals
- C. It has no relevance to secondary metabolite production
- D. It exclusively produces chlorophyll

60. Which best describes a major goal of modern crop breeding programs focused on preserving/utilizing plant genetic diversity?

- A. Incorporating traits from wild relatives or heirloom varieties (e.g., disease resistance, drought tolerance) to improve resilience of modern crop cultivars
- B. Reducing all crop varieties to a single genetically identical strain worldwide
- C. Genetic diversity has no value in crop breeding
- D. Wild plant relatives have no useful traits for breeding

61. Which of the following plant hormones are primarily associated with promoting growth (rather than dormancy/senescence)? (Select all that apply)

- A. Auxin
- B. Gibberellin
- C. Absciscic acid
- D. Cytokinin

62. Which of the following are adaptations commonly found in xerophytes (arid-adapted plants)? (Select all that apply)

- A. Thick cuticle
- B. Reduced leaf surface area
- C. Sunken stomata
- D. Extremely thin, unprotected leaf surfaces

63. Which of the following mechanisms help promote cross-pollination/outcrossing in flowering plants? (Select all that apply)

- A. Dioecy (separate male and female plants)
- B. Protandry/protogyny (staggered maturation of anthers and stigma)
- C. Self-incompatibility systems
- D. Simultaneous maturation of anthers and stigma in a single flower with no other barriers

64. Which of the following factors can act as limiting factors for the rate of photosynthesis? (Select all that apply)

- A. Light intensity
- B. CO₂ concentration
- C. Temperature
- D. Leaf color, independent of pigment content

65. Which of the following are goals of integrated pest management (IPM)? (Select all that apply)

- A. Reducing reliance on broad-spectrum chemical pesticides
- B. Using biological controls (e.g., beneficial insects) where appropriate
- C. Monitoring pest populations to guide intervention timing
- D. Applying maximum pesticide doses regardless of pest population level

66. Explain how auxin and cytokinin interact to regulate apical dominance, and predict what would happen if the apical meristem were removed.

67. Explain how the cohesion-tension mechanism can be disrupted by cavitation (air bubble formation) in xylem, and describe one anatomical feature that helps limit the spread of an embolism.

68. Explain why reaction wood forms in leaning trees and describe how it helps correct the tree's orientation over time.

69. Explain the adaptive significance of self-incompatibility systems in angiosperms, and describe one general mechanism by which a plant can recognize and reject its own pollen.

70. Explain why the sporophyte generation became dominant over the course of land plant evolution, from bryophytes through seed plants.

71. Explain how paleobotanical evidence (e.g., fossilized spores, cuticles, or wood) can be used to reconstruct ancient plant evolution and paleoclimates.

72. Explain why maintaining crop genetic diversity (e.g., through seed banks) is considered important for global food security.

73. Explain the concept of the light compensation point and why shade-adapted plants typically have a lower compensation point than sun-adapted plants.

74. Explain why rising atmospheric CO₂ tends to benefit C₃ plants more than C₄ plants, in terms of their differing photosynthetic mechanisms.

75. Explain the mechanism of action of glyphosate herbicide and how glyphosate-resistant GM crops were engineered to tolerate it.

76. Explain, in detail, the cohesion-tension theory of water transport in xylem, including the roles of transpiration, water's cohesive/adhesive properties, root pressure, and the risk of cavitation/embolism, and describe how this mechanism allows water to reach the tops of very tall trees without any active pumping.

77. Compare and contrast C3, C4, and CAM photosynthesis in detail, including where and when CO2 is fixed in each pathway, the anatomical/biochemical adaptations involved, and the ecological conditions under which each pathway is most advantageous.

78. Describe, in detail, the mechanisms angiosperms have evolved to promote cross-pollination and avoid self-fertilization, including structural, temporal, and biochemical strategies, and explain the evolutionary advantage of outcrossing.

79. Trace, in detail, the evolutionary history of land plants from the earliest bryophyte-like ancestors through the rise of angiosperms, explaining the major innovations (e.g., vascular tissue, seeds, flowers) that characterized each transition and the selective advantages each provided.

80. Explain, in detail, the biochemical basis of plant secondary metabolite production, including at least two classes of secondary metabolites, their ecological function in the plant, and at least one application of plant secondary metabolites in human medicine or agriculture.

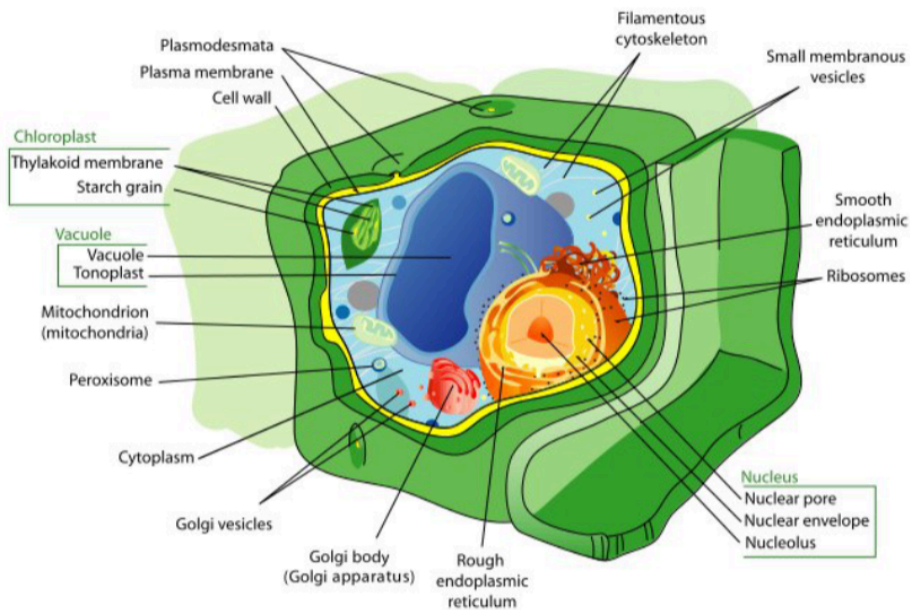
Science Olympiad – Botany

Division C – National Exam

IMAGE REFERENCE

Figure 1

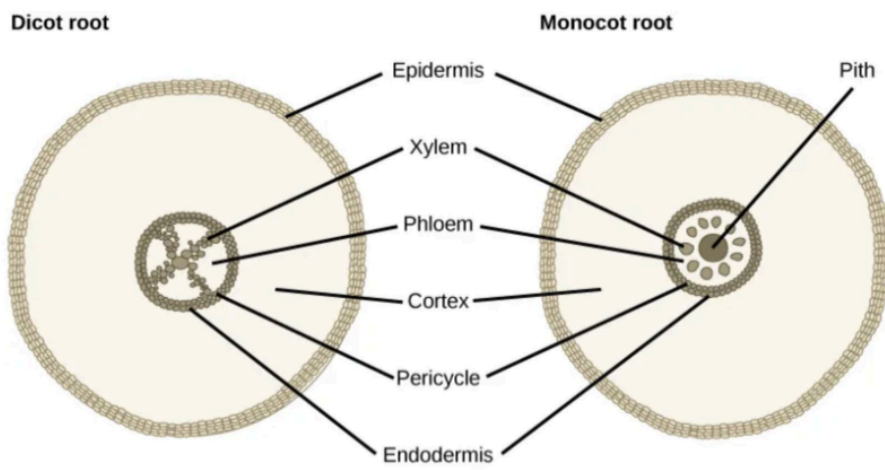
Used in question(s) 1. Labeled diagram of a generalized plant cell, showing the cell wall, cell membrane, nucleus, chloroplast, central vacuole, mitochondrion, Golgi apparatus, endoplasmic reticulum, ribosomes, and other organelles.



Wikimedia Commons, File:Plant_cell_structure-en.svg, author LadyofHats – Public Domain.

Figure 2

Used in question(s) 15. Side-by-side diagram comparing a dicot root cross-section (X-shaped vascular tissue) and a monocot root cross-section (vascular tissue in a ring around a central pith), labeled with epidermis, cortex, endodermis, pericycle, xylem, and phloem.



OpenStax, Biology 2e, Figure 30.18, section 30.3 Roots – CC BY 4.0.

Figure 3

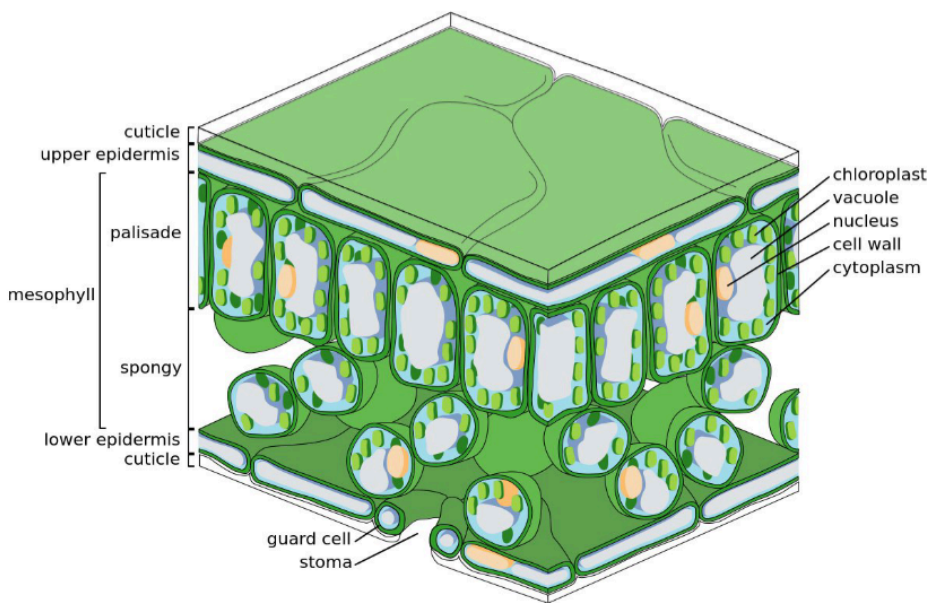
Used in question(s) 16. Real photograph of a cut tree trunk cross-section, showing the concentric annual growth rings.



Wikimedia Commons, File:Tree_rings.jpg, photo by Arnoldius – CC BY-SA 2.5.

Figure 4

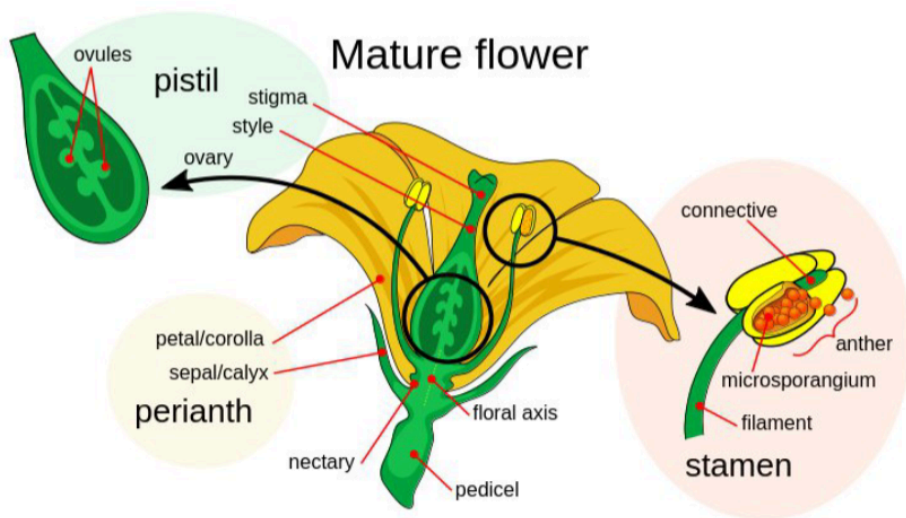
Used in question(s) 20. 3D cutaway diagram of a leaf cross-section: cuticle, upper epidermis, palisade mesophyll, spongy mesophyll, lower epidermis, guard cells, and stoma, with chloroplast/vacuole/nucleus/cell wall/cytoplasm labeled within a cell.



Wikimedia Commons, File:Leaf_Tissue_Structure.svg – CC BY-SA 3.0.

Figure 5

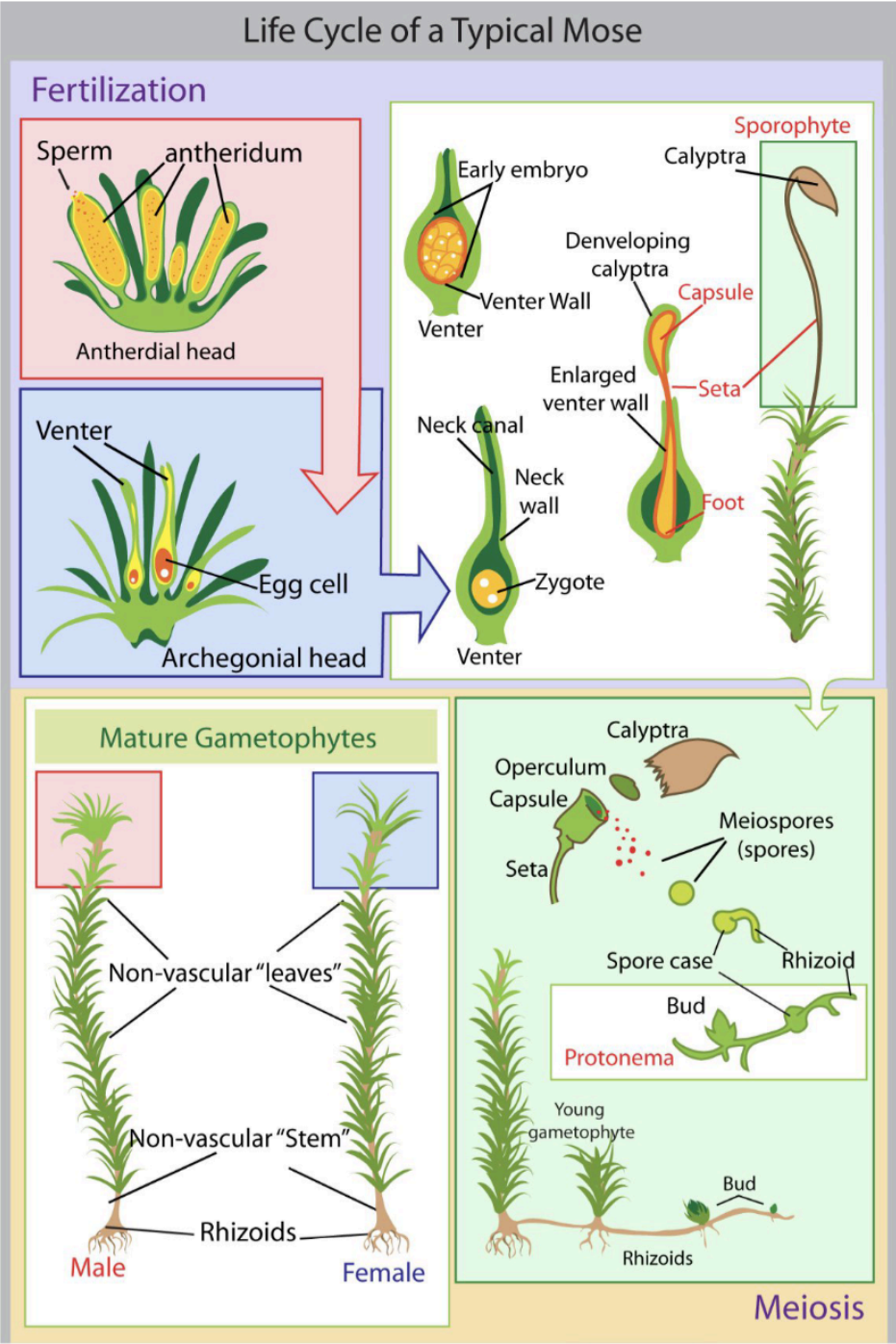
Used in question(s) 31. Labeled diagram of a mature, complete flower: the perianth (sepal/calyx, petal/corolla), the pistil (stigma, style, ovary, ovules), and the stamen (anther, filament, connective, microsporangium).



Wikimedia Commons, File:Mature_flower_diagram.svg, author LadyofHats — Public Domain.

Figure 6

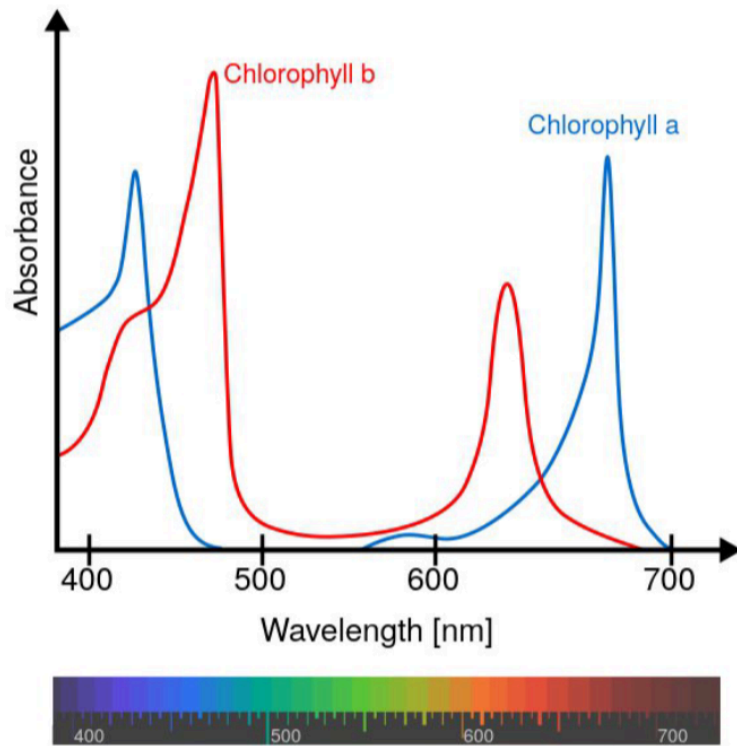
Used in question(s) 37. Diagram of the alternation-of-generations life cycle of a typical moss: the male and female gametophytes (non-vascular “leaves,” “stem,” and rhizoids), fertilization, the sporophyte (seta, capsule, calyptra), meiosis, and spore germination into the protonema.



Wikimedia Commons, File:Moss_life_Cycle.jpg, author LadyofHats — Public Domain.

Figure 7

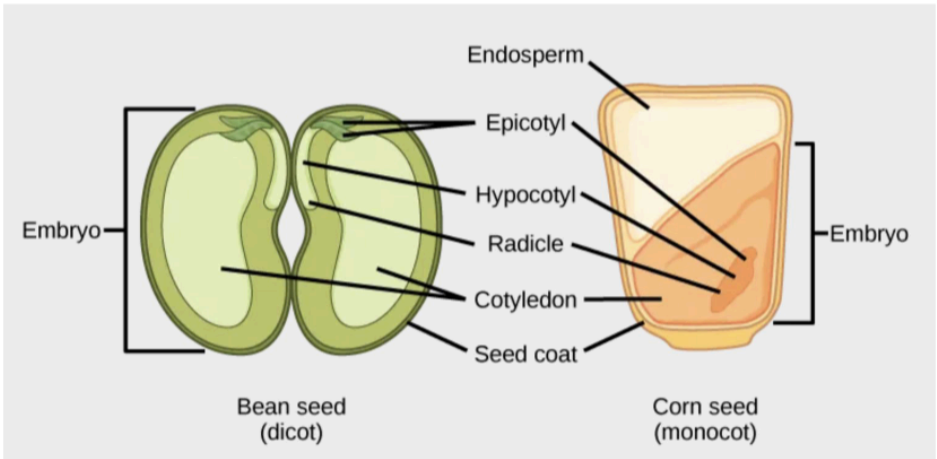
Used in question(s) 49. Graph of the light absorption spectra of chlorophyll a and chlorophyll b, plotting absorbance against wavelength (nm) across the visible spectrum.



Wikimedia Commons, File:Chlorophyll_ab_spectra-en.svg – CC BY-SA 3.0.

Figure 8

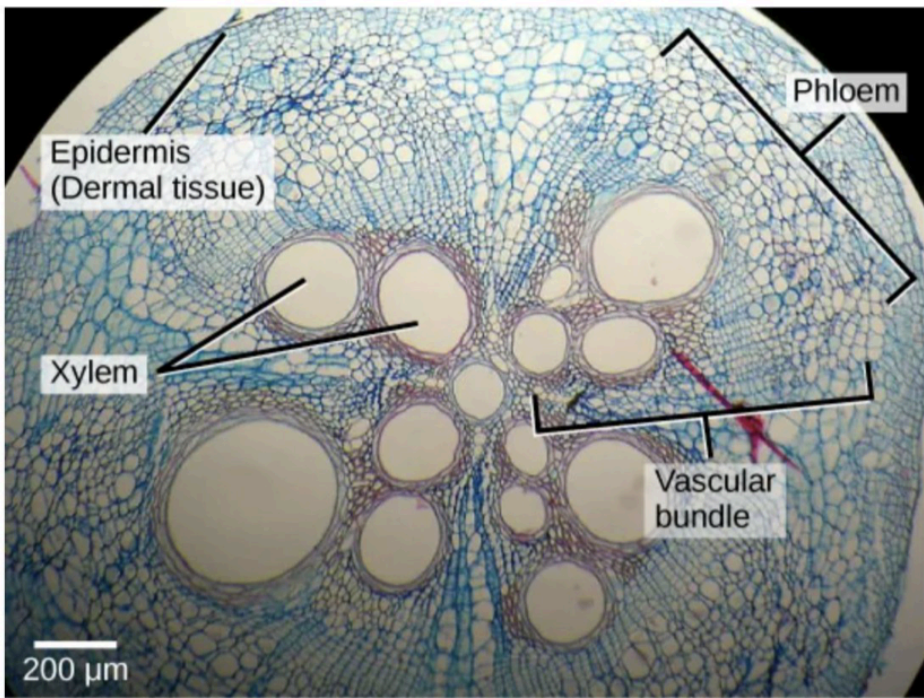
Used in question(s) 33. Diagram comparing a dicot seed (bean), with two cotyledons, and a monocot seed (corn), with a single cotyledon and large endosperm; both labeled with the seed coat, epicotyl, hypocotyl, and radicle.



OpenStax, Biology 2e, Figure 32.20, section 32.2 Pollination and Fertilization — CC BY 4.0.

Figure 10

Used in question(s) 17, 22. Light micrograph of a herbaceous stem cross-section, labeled with the epidermis (dermal tissue), a vascular bundle, xylem, and phloem.



OpenStax, Biology 2e, stem anatomy micrograph, section 30.2 Stems — CC BY 4.0.

Science Olympiad – Botany

Division C – National Exam

Answer Key

Multiple Choice & Multi-Select

Q#	Correct Answer
1	C
2	A
3	A
4	A
5	A
6	A
7	A
8	B
9	A
10	A
11	A
12	A
13	A
14	A
15	A
16	A
17	A
18	A
19	A
20	A
21	A
22	A
23	A
24	A
25	A
26	A
27	A
28	A
29	A
30	A
31	C
32	A
33	A
34	A
35	A
36	A
37	A
38	A
39	A

40	A
41	A
42	A
43	A
44	A
45	A
46	A
47	A
48	A
49	A
50	A
51	A
52	A
53	A
54	A
55	A
56	A
57	A
58	A
59	A
60	A
61	A, B, D
62	A, B, C
63	A, B, C
64	A, B, C
65	A, B, C

Short Answer / Long Answer — Model Answers

66. High auxin produced by the apical meristem is transported down the stem and inhibits growth of lateral buds, while root-produced cytokinin promotes lateral bud growth; the ratio of the two hormones determines whether lateral buds stay dormant. If the apical meristem is removed, auxin levels fall, releasing lateral buds from inhibition and causing bushier growth.

67. Cavitation occurs when tension in the xylem water column becomes too great, or air enters through a wound, forming a bubble that breaks the continuous water column and blocks flow in that vessel (embolism). Pit membranes between adjacent xylem cells allow water to reroute around a blocked vessel while preventing the air bubble itself from spreading into neighboring, still-functional vessels.

68. Reaction wood forms due to asymmetric hormone (auxin) distribution and mechanical stress signaling in a leaning trunk or branch, causing unequal growth on opposite sides of the stem (compression wood on the lower side in gymnosperms; tension wood on the upper side in angiosperms). This asymmetric growth pushes or pulls the trunk back toward a more vertical orientation over time.

69. Self-incompatibility prevents self-fertilization, which would otherwise reduce genetic diversity and risk inbreeding depression; it forces outcrossing, increasing genetic variation and long-term adaptability. Mechanism: proteins on the pollen and the stigma/style (e.g., at the S-locus) recognize genetically matching "self" pollen and trigger a biochemical response, such as pistil RNases degrading pollen tube RNA, arresting its growth before fertilization.

70. Natural selection favored an increasingly independent, larger sporophyte because diploidy provides a genetic buffer against harmful mutations, and because the sporophyte generation does not need external water for reproduction once pollen and seeds evolved. This trend culminated in seed plants, where the gametophyte is reduced to a microscopic stage (pollen grain, embryo sac) that is fully dependent on and protected by the dominant sporophyte.

71. Fossilized spores and pollen (palynology) identify which plant groups were present and can indicate past vegetation and climate; cuticle structure (e.g., stomatal density) can be used to estimate historical atmospheric CO₂ levels; and petrified wood anatomy (cell structure, growth ring patterns) reveals growth rates and seasonal climate conditions — together allowing reconstruction of ancient ecosystems and climates.

72. Maintaining crop genetic diversity (e.g., in seed banks) preserves a reservoir of traits — such as disease resistance, drought tolerance, or pest resistance — that breeders can draw on to adapt crops to new challenges like emerging pathogens or climate change. Without this diversity, crops become vulnerable to catastrophic, widespread failure from a single pest, disease, or environmental stress.

73. The light compensation point is the light intensity at which photosynthetic CO₂ uptake equals respiratory CO₂ release (net carbon gain = zero). Shade-adapted plants typically have a lower compensation point because they have adaptations such as more efficient chlorophyll/light-capturing arrangements and lower respiration rates, allowing them to achieve net positive carbon gain even at the low light levels found in shaded understory environments.

74. C₃ plants fix CO₂ directly via RuBisCO with no CO₂-concentrating mechanism, so they are more directly limited by ambient CO₂ availability and prone to photorespiration; rising atmospheric CO₂ therefore increases their photosynthetic rate substantially. C₄ plants already concentrate CO₂ around RuBisCO internally via their Kranz anatomy, so they are less limited by ambient CO₂ and see comparatively smaller gains as atmospheric CO₂ rises.

75. Glyphosate inhibits the enzyme EPSP synthase in the shikimate pathway, which plants need to synthesize essential aromatic amino acids; without this pathway, treated plants die. Glyphosate-resistant GM crops were engineered by inserting a gene (often from a bacterium) that encodes a version of EPSP synthase that glyphosate cannot bind, allowing the crop to survive herbicide application that kills susceptible weeds.

76. Transpiration – evaporation of water vapor from leaf mesophyll cells through stomata – creates negative pressure (tension) at the top of the plant. Because water molecules are strongly cohesive (hydrogen-bonded to each other) and adhesive (bonded to the walls of narrow xylem vessels), this tension pulls a continuous, unbroken column of water upward from the roots to the leaves without any active pumping. Root pressure, generated by active mineral uptake creating an osmotic gradient in root xylem, provides a smaller secondary upward force, most significant at night when transpiration is low. If tension becomes too great, or air enters through a wound or freeze-thaw event, cavitation can occur, forming an air bubble (embolism) that blocks flow in that vessel; pit membranes between adjacent vessels help contain the bubble and prevent it from spreading, allowing water to reroute around the blockage. Together, these properties let water reach the very top of even the tallest trees.

77. C3: CO₂ is fixed directly by RuBisCO into a 3-carbon compound in mesophyll cell chloroplasts during the day; no special anatomy is required. C3 is most efficient in cool, moist environments with normal CO₂ levels but is prone to photorespiration when stomata close in heat/drought. C4: CO₂ is first fixed by PEP carboxylase into a 4-carbon compound in mesophyll cells, then shuttled into bundle sheath cells (Kranz anatomy) where it is released and re-fixed by RuBisCO; this spatial separation concentrates CO₂ and minimizes photorespiration, making C4 advantageous in hot, sunny, dry climates. CAM: CO₂ is fixed at night by PEP carboxylase and stored as organic acids in vacuoles; during the day, stomata stay closed to conserve water while stored CO₂ is released for the Calvin cycle. This temporal separation is advantageous in very arid environments (e.g., succulents, cacti), though the limited nightly CO₂ storage capacity results in slower overall growth.

78. Structural strategies include dioecy (separate male and female plants) and heterostyly, which physically prevent self-pollination. Temporal strategies include protandry and protogyny, in which anthers and stigma of the same flower mature at different times, preventing self-pollination within a flower. Biochemical strategies include self-incompatibility systems, in which the stigma/style biochemically recognizes and rejects genetically similar (self) pollen, halting pollen tube growth before fertilization. All of these mechanisms promote outcrossing, which increases genetic diversity in offspring, improving a population's ability to adapt to environmental change and avoiding the fitness costs of inbreeding depression.

79. Land plants evolved from charophyte green algal ancestors. Early bryophytes lacked vascular tissue and true roots, restricting them to small size and moist habitats, and relied on external water for flagellated sperm to reach the egg. The evolution of vascular tissue and

lignin in early tracheophytes (e.g., ferns) provided structural support and efficient internal transport, allowing taller growth and colonization of drier habitats, though these plants still needed water for fertilization. The evolution of seeds in gymnosperms further reduced the need for external water in reproduction (via pollen) and protected the embryo with stored food and a seed coat, while further reducing the gametophyte generation. Finally, angiosperms evolved flowers, which enabled more efficient, targeted pollination (often via coevolved animal pollinators), and fruit, which aids seed protection and dispersal – innovations that drove their rapid diversification into the most species-rich plant group today.

80. Secondary metabolites are compounds not directly required for basic growth but provide ecological advantages. Alkaloids (e.g., nicotine, caffeine, morphine) often serve as chemical defenses, deterring herbivores through toxicity or bitterness. Terpenoids (e.g., essential oils, resins) can defend against herbivores/pathogens and, in some cases, attract pollinators through scent. (Phenolics/tannins, a third valid class, deter herbivory by binding proteins and reducing digestibility, and provide antioxidant/UV protection.) Human applications include medicines derived from these compounds – for example, morphine as a painkiller, taxol (from Pacific yew) as a chemotherapy drug, and salicin from willow bark as the precursor to aspirin – as well as agricultural uses such as pyrethrins (from chrysanthemums) as natural pesticides.