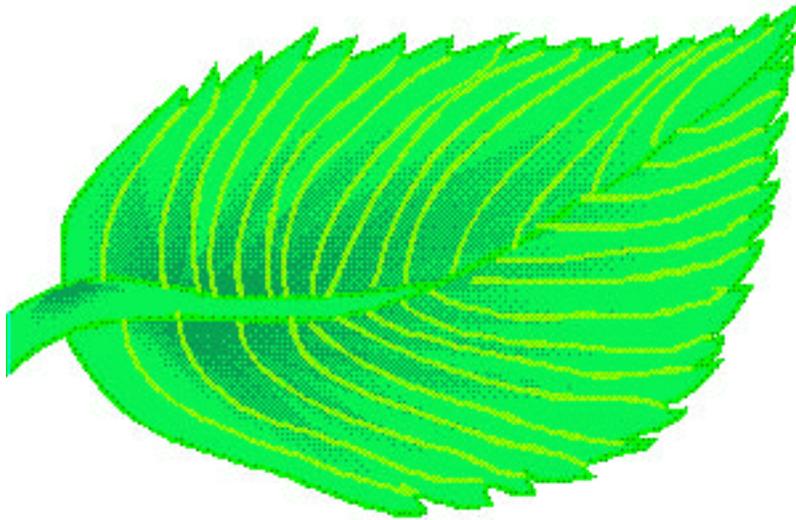


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The Leaf
Program Supplement



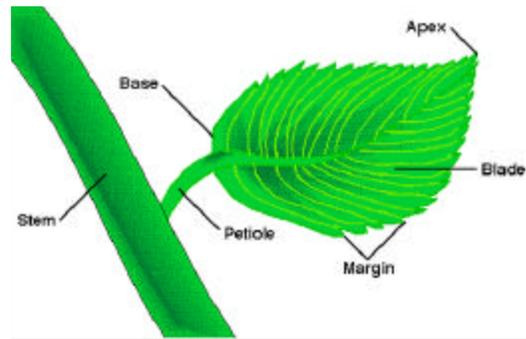
The Leaf TEACHING OBJECTIVES

The following subject areas are illustrated throughout the Interactive Biology Multimedia Courseware program, *The Leaf*. Ideally, these areas would be augmented with additional course work outside of this program. (*Click on a subject to jump ahead.*)

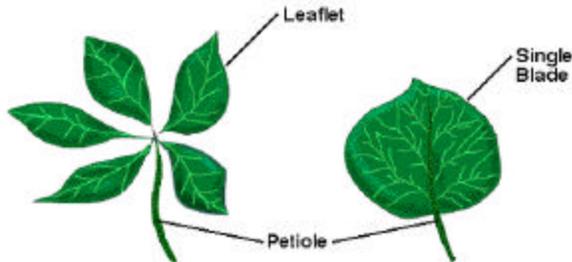
- **Basic Leaf Anatomy**
- **Substance Transport: Venation and Conducting Tissue.**
- **Tissues and Cells of the Leaf**
- **Transpiration and Photosynthesis**
- **The Importance of Leaves**

Study Guide #1 BASIC LEAF ANATOMY

Higher plants generally have distinct roots, stems and leaves. The contribution of the leaf is critical to the life of the plant. The basic parts of the leaf are the thin, wide blade and the petiole or stalk which connects the leaf to the stem.



The blade has three parts: the apex or tip, the base or bottom, and the margin or edge which extends from the apex to the base. Each feature occurs in a variety of shapes. The apex may appear round, flat or pointed. The margin can be smooth, jagged or lobed, and the base may be round, flat or heart shaped. The combination of these varying shapes determines the appearance of the blade.

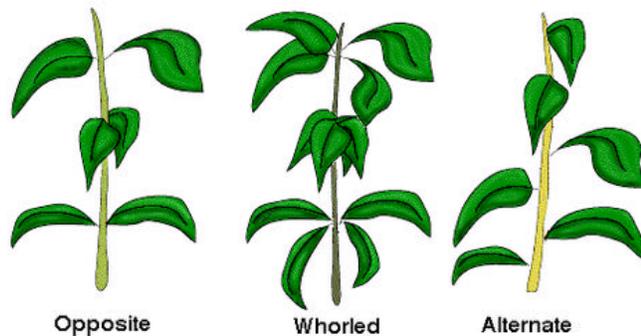


Compound Leaf Simple Leaf

Leaves can be categorized based on the number of blades. Simple leaves have only one blade whereas compound leaves have two or more. The blades of a compound leaf are called leaflets.

The position of leaf attachment to the stem generally follows three patterns. The point of attachment to the stem is called the node. The leaves are alternate if only one is attached to each node and their position alternates from one side of the stem to the other. The pattern is opposite if two leaves are attached on opposing sides of the node. If three or more leaves are attached around a node the pattern is whorled.

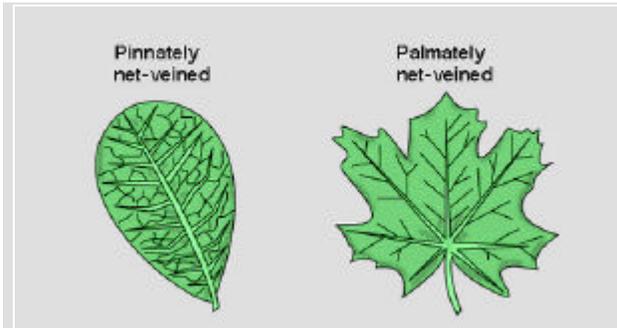
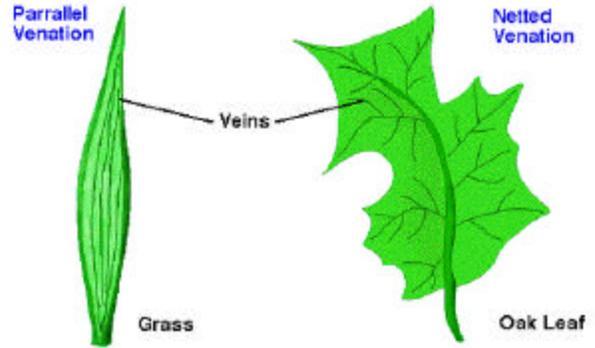
Leaf Arrangement Patterns



Study Guide #2 SUBSTANCE TRANSPORT

Food synthesized by the leaves of green plants is transported to provide nutrition to other cells. Water and dissolved minerals are moved to the leaf from other parts of the plant. Often times these substances travel great distances, such as movement within a 300-foot tall redwood tree. Within the leaf, transportation occurs in a series of veins.

Venation is the arrangement of veins in the leaf. Depending on the type of leaf, the veins may be parallel, running side by side in the same direction, or netted, branching off from a central vein or midrib. Pinnately net-veined leaves have a feather-like pattern of veins in two rows along a central axis. In palmately net-veined leaves, the veins radiate from a central point in a fanlike manner.

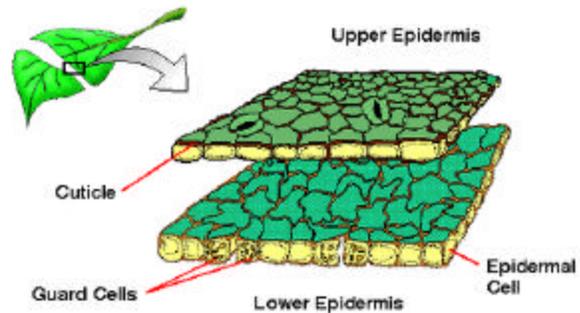


Two types of conducting tissue, xylem and phloem, can be found within the veins of the leaf. Xylem is involved in the transport of water and dissolved minerals from the stem, through the petiole, to the leaf. Phloem conducts food from the leaf to the rest of the plant. If the phloem is severed and the food

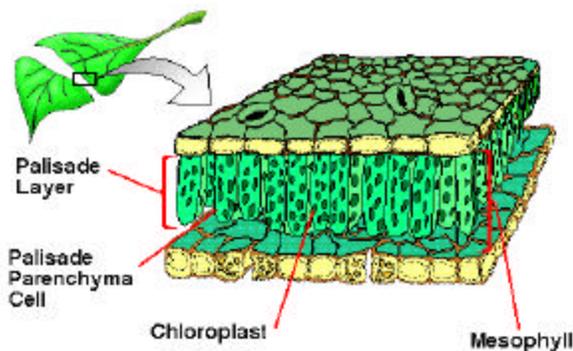
supply to the root is cut off, the plant will eventually die.

Study Guide #3 TISSUES & CELLS OF LEAVES

Viewing a section of a leaf blade through a microscope shows that the leaf is composed of many different types of tissues and cells. The outermost covering of the leaf is called the epidermis. The epidermal cells produce a waxy substance called cutin, which regulates water loss. A layer of cutin surrounding the leaf is called the cuticle. The upper and lower epidermal layers are composed of a single band of epidermal cells interspersed with pores. Two modified epidermal cells called guard cells surround each pore. A pair of guard cells together with the pore is called a stoma (plural, stomata). Generally more stomata are found in the lower epidermis.



When water is absorbed by the guard cells they swell causing the gap or pore between them to open. Through the open pore, substances such as water vapor and oxygen leave and carbon dioxide enters the plant. The loss of water, and consequent collapse of the guard cells, closes the pore and stops the transport of gases to and from the plant. In this way the stomata regulate gas movement between the leaf and its surroundings.



Between the upper and lower epidermis is the mesophyll layer. The mesophyll is comprised of two sub-layers known as the palisade layer and the spongy layer. The palisade layer lies just below the upper epidermis and is composed of long, narrow palisade parenchyma cells. These cells, with their numerous chloroplasts, provide the primary site

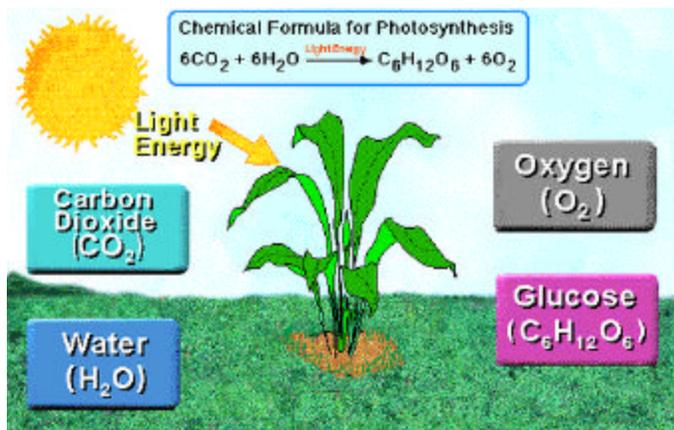
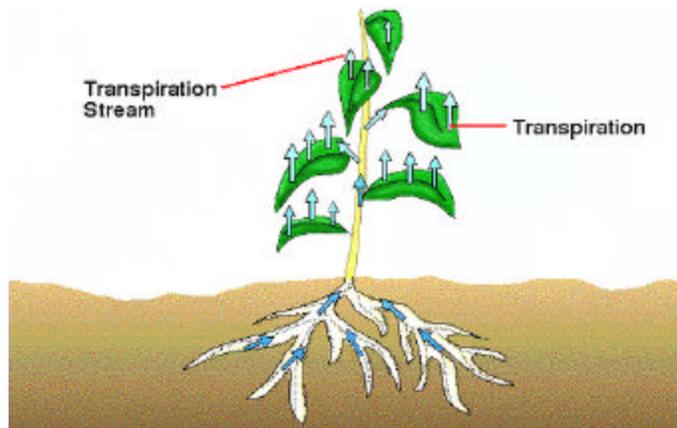
for photosynthesis in the plant. Between the palisade layer and the lower epidermis lies a spongy layer of irregularly shaped cells called spongy parenchyma cells. The abundant air space surrounding the spongy parenchyma cells permits the exchange of gases between the leaf and its environment.

Study Guide #4 TRANSPIRATION AND PHOTOSYNTHESIS

As discussed earlier, veins act as the transporting mechanism for water, food and dissolved minerals within the plant. These veins are surrounded by a layer of parenchyma cells called the bundle sheath through which all substances moving to or from the veins must pass.

Although most plants absorb large amounts of water, they actually use only a small fraction of that amount. Water absorbed by the roots moves up through the stems and the leaves via the transpiration stream. Surplus water evaporates from the leaves in a process called transpiration.

Water vapor evaporating from the leaf cells through the stomata is replenished by water from neighboring mesophyll cells. In turn, that water is replaced by water from other adjacent cells, hence maintaining a stream of water moving up the plant from areas of higher to lower concentration.



photosynthesis is the chloroplasts embedded in the palisade parenchyma cells of the mesophyll.

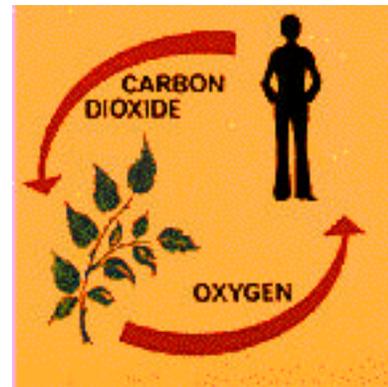
Photosynthesis is the process by which plants synthesize nutrients from carbon dioxide and water, using light as the source of energy. The ultimate products of photosynthesis are the sugar glucose, which is used as food for the plant and oxygen, which is eliminated as a waste product. The site of

Study Guide #5 THE IMPORTANCE OF LEAVES

Leaves are essential to the life of the plant. Without leaves, plants would be unable to produce food or to rid themselves of excess water.

Without photosynthesis the earth would soon run out of food and oxygen. The ability of green plants to capture the energy of sunlight and convert it into nutrition for the rest of the community is vital to all living things. Animals and plants that are incapable of obtaining energy from light directly must obtain it indirectly by consuming plants or animals that have been nourished by green plants.

The gaseous exchange between the leaf and the environment that takes place during photosynthesis is also essential to animals. Oxygen, which is vital to life, is provided when it is released into the atmosphere as a waste product. The leaf as a raw product in photosynthesis uses excess carbon dioxide that gathers in the atmosphere due to the respiration of plants and animals. In this manner green plants maintain a balance between the amount of oxygen and carbon dioxide in the environment.



Leaves also provide humans with many of our favorite culinary ingredients such as lettuce, tea, herbs and spices. A multitude of medicinal uses for leaves also exists.

The Leaf QUIZ PACK

The following quizzes are meant to test student understanding of specific topic areas covered in the Interactive Biology program, *The Leaf*. Many, but not all, of these questions have been addressed directly in the study guides designed to strengthen student understanding of these topics.

QUIZ #1	Basic Leaf Anatomy
QUIZ #2	Substance Transport
QUIZ #3	Tissues and Cells of the Leaf
QUIZ #4	Transpiration and Photosynthesis
EXAM	Comprehensive Exam

Quiz #1
BASIC LEAF ANATOMY

1. The stalk connecting the leaf to the stem is called a _____.
 - A. blade
 - B. apex
 - C. stipule
 - D. petiole

2. The tip of the blade is called the _____.
 - A. apex
 - B. petiole
 - C. margin
 - D. phloem

3. In the opposite pattern of leaf attachment the leaves grow individually and alternate from one side of the stem to the other.
 - A. True
 - B. False

4. _____ leaves have two or more blades called leaflets.
 - A. Pinnate
 - B. Compound
 - C. Bundled
 - D. Simple

5. The margin of the blade extends from the _____ to the _____.
 - A. petiole, base
 - B. base, stem
 - C. apex, base
 - D. epidermis, mesophyll

6. If three or more leaves are attached around a node the pattern is called _____.

- A. whorled
- B. palisade
- C. alternate
- D. None of the above

Quiz #2
SUBSTANCE TRANSPORT

1. The venation of pinnately net-veined leaves resembles a _____.
 - A. fan
 - C. train track
 - D. feather

2. _____ transports water and dissolved minerals from the stem to the leaf.
 - A. Phloem
 - B. Xylem
 - C. Guard cells
 - D. All of the above

3. Grass is an example of a simple leaf with netted venation.
 - A. True
 - B. False

4. The two main conducting tissues found in the veins of a leaf are _____ and _____.
 - A. cuticle, epidermis
 - B. mesophyll, parenchyma
 - C. mesophyll, phloem
 - D. xylem, phloem

5. Leaves that have only one blade on a petiole are called _____.
 - A. simple
 - B. pinnate
 - C. palmate
 - D. compound

6. The transportation system within the leaf is made up of a series of _____.
- A. bundle sheaths
 - B. parenchyma cells
 - C. veins
 - D. petioles
7. Food is primarily synthesized in the root of the plant and transported to the leaves by the phloem.
- A. True
 - B. False

Quiz #3
TISSUES & CELLS OF LEAVES

1. The _____ layer is composed of palisade and spongy parenchyma layers.
 - A. upper epidermal
 - B. phloem
 - C. mesophyll
 - D. cuticle

2. A stoma is comprised of two _____ cells and a pore.
 - A. guard
 - B. parenchyma
 - C. spongy
 - D. chloroplast

3. The primary function of the chloroplasts is regulation of gas movement between the leaf and the environment.
 - A. True
 - B. False

4. The bundle sheath is made up of _____ cells.
 - A. phloem
 - B. parenchyma
 - C. chloroplast
 - D. epidermal

5. The _____ layer lies between the palisade layer and the lower epidermis.
 - A. xylem
 - B. upper epidermis
 - C. phloem
 - D. spongy

6. The epidermal cells produce a protective covering called the _____ which protects the plant from excessive water loss.
- A. stoma
 - B. cuticle
 - C. bundle sheath
 - D. margin
7. Generally, more stomata are found in the lower epidermis than the upper epidermis.
- A. True
 - B. False
8. The absorption of water by the guard cells causes the pores to _____ and regulates _____.
- A. open, water loss
 - B. close, gas movement
 - C. open, gas movement
 - D. close, water loss

Quiz #4
TRANSPIRATION & PHOTOSYNTHESIS

1. The movement of water from the roots to the leaves is called the dissipation stream.
 - A. True
 - B. False

2. The products of photosynthesis include _____ and _____.
 - A. carbon dioxide, water
 - B. glucose, carbon dioxide
 - C. water, oxygen
 - D. glucose, oxygen

3. Water evaporates from the leaves through the _____.
 - A. bundle sheath
 - B. stomata
 - C. veins
 - D. parenchyma cells

4. The source of energy for photosynthesis is glucose.
 - A. True
 - B. False

5. The _____ parenchyma cells with their many _____ provide the primary site for photosynthesis in the plant.
 - A. spongy, air spaces
 - B. spongy, chloroplasts
 - C. palisade, chloroplasts
 - D. palisade, guard cells

6. _____ is one of the raw products necessary for photosynthesis.
- A. Oxygen
 - B. Glucose
 - C. Carbon dioxide
 - D. All of the above
7. The respiration of animals creates excess _____ in the environment which is used by leaves in photosynthesis.
- A. oxygen
 - B. carbon dioxide
 - C. water vapor
 - D. none of the above

The Leaf COMPREHENSIVE EXAM

The following exam is based on the *Interactive Biology* program, The Leaf. Most, but not all, of these questions have been addressed directly in the study guides. All of the questions on this exam, however, are based on information put forth in the program.

Please determine if the following statements are true or false.

1. Grass is an example of a simple leaf with parallel venation.

A. True
B. False

2. Phloem transports food from the leaf to the rest of the plant.

A. True
B. False

3. The bundle sheath produces a protective covering called the cuticle, which protects the plant from excessive water loss.

A. True
B. False

4. Carbon dioxide is a product of photosynthesis.

A. True
B. False

In the following portion of the exam, please choose the letter beside the word, words, or phrase that best completes each sentence.

5. Water evaporates from the leaves through the _____.

A. stomata
B. veins
C. parenchyma cells
D. bundle sheath

6. The respiration of animals creates excess _____ in the environment, which is one of the raw products necessary for photosynthesis.
- A. oxygen
 - B. water vapor
 - C. carbon dioxide
 - D. All of the above
7. The venation of palmately net-veined leaves resembles a _____.
- A. train track
 - B. feather
 - C. fan
8. Leaves that have two or more blades on a petiole are called _____.
- A. simple
 - B. pinnate
 - C. palmate
 - D. compound
9. The bundle sheath is made up of _____ cells.
- A. phloem
 - B. parenchyma
 - C. chloroplast
 - D. epidermal
10. The _____ layer lies between the upper epidermis and the spongy layer.
- A. palisade
 - B. xylem
 - C. phloem
 - D. petiole

11. The area between the tip and the bottom of the blade is called the _____.

- A. apex
- B. base
- C. cuticle
- D. margin

12. If three or more leaves are attached around a node the pattern is called _____.

- A. pinnate
- B. whorled
- C. alternate
- D. simple

13. The stalk connecting the leaf to the stem is called a _____.

- A. stipule
- B. base
- C. vein
- D. petiole

14. The _____ parenchyma cells are long and narrow with numerous chloroplasts.

- A. spongy
- B. epidermal
- C. palisade
- D. palmate

15. _____ transports water and dissolved minerals from the stem to the leaf.

- A. The palisade layer
- B. Xylem
- C. The bundle sheath
- D. Phloem

16. A stoma is comprised of two _____ cells and a pore.
- A. guard
 - B. parenchyma
 - C. spongy
 - D. chloroplast
17. The absorption of water by the guard cells causes the pores to _____ and regulates _____.
- A. open, water loss
 - B. open, gas movement
 - C. close, water loss
 - D. close, gas movement
18. The _____ layer is composed of palisade and spongy parenchyma layers.
- A. upper epidermal
 - B. phloem
 - C. mesophyll
 - D. cuticle
19. In the _____ pattern of leaf attachment the leaves grow in pairs on the stem.
- A. opposite
 - B. alternate
 - C. simple
 - D. whorled
20. The products of photosynthesis are _____ and _____.
- A. carbon dioxide, water
 - B. glucose, oxygen
 - C. glucose, water
 - D. carbon dioxide, oxygen

21. _____ leaves have two or more blades called leaflets.
- A. Pinnate
 - B. Bundled
 - C. Simple
 - D. Compound
22. The transportation system within the leaf is made up of a series of _____.
- A. veins
 - B. petioles
 - C. parenchyma cells
 - D. bundle sheaths
23. The primary function of the stomata is _____.
- A. transport of food from the leaf to the other cells of the plant
 - B. photosynthesis
 - C. regulation of gas movement between the leaf and the atmosphere
 - D. transport of water and dissolved minerals from the stem to the leaf
24. The _____ secretes cutin.
- A. mesophyll
 - B. epidermis
 - C. palisade parenchyma cells
 - D. guard cells
25. The bundle sheath is a layer or two of _____ cells that surround the veins.
- A. guard
 - B. epidermal
 - C. parenchyma
 - D. cutin

In the following section, please fill in the word or phrase that best completes the following sentences.

26. The conducting tissues of the plant can be found in the _____.
27. The movement of water from the roots to the leaves is called the _____ stream.
28. The _____ layer is comprised of irregularly shaped cells with abundant air space which permits the exchange of gases between the leaf and its environment.
29. The two main conducting tissues of the leaf are _____ and _____.
30. The _____ is the tip of the leaf blade.
31. The energy source of photosynthesis is _____.
32. The mesophyll layer is composed of two sub-layers known as the _____ layer and the _____ layer.
33. Photosynthesis provides animals with _____ which is released into the atmosphere as a waste product.
34. _____ are specialized epidermal cells found in pairs that are separated by a pore to form a stoma.

**The Leaf
ANSWER GUIDE**

QUIZ PACK

QUIZ #1	QUIZ #2	QUIZ #3	QUIZ #4
1. D	1. C	1. C	1. B
2. A	2. B	2. A	2. D
3. B	3. B	3. B	3. B
4. B	4. D	4. B	4. B
5. B	5. A	5. D	5. C
6. C	6. C	6. B	6. C
7. A	7. B	7. A	7. B
		8. C	

COMPREHENSIVE EXAM

1. A	11. D	21. D	31. light
2. A	12. B	22. A	32. palisade, spongy
3. B	13. D	23. C	33. oxygen
4. B	14. C	24. B	34. guard cells
5. A	15. B	25. C	
6. C	16. A	26. veins	
7. C	17. B	27. transpiration	
8. D	18. C	28. spongy	
9. B	19. A	29. xylem, phloem	
10. A	20. B	30.. apex	

The Leaf GLOSSARY

alternate leaf arrangement: pattern of leaf arrangement in which leaves grow individually and alternate from one side of the stem to the other.

apex: the tip of the blade on a leaf.

base: the bottom of the blade on a leaf.

blade: the side, thin part of a leaf.

bundle sheath: layer or two of parenchyma cells that surround the veins. Materials must pass through this to move between the veins and the various other tissues in a plant.

carbon dioxide (CO₂): a gas molecule that is a building block of photosynthesis.

Chloroplasts: structures in cells where photosynthesis takes place.

compound leaves: leaves that consist of several leaflets branching off one petiole.

cuticle: layer of cutin that surrounds the leaf, protecting it from extensive water loss.

cutin: waxy substance surrounding the leaf that is secreted by epidermal cells.

epidermal cells: cells usually seen in a single layer that compose the epidermis and secrete cutin.

epidermis: outermost covering of the leaf composed of epidermal cells and guard cells, and surrounded by cutin.

food web: describes a series of feeding relationships between organisms in a given community.

glucose (C₆H₁₂O₆): a sugar molecule produced in photosynthesis that serves as the plant's main food source.

guard cells: specialized cells found in pairs that are separated by a pore, composing the stoma. Guard cells are found in the epidermal layer.

leaflets: multiple blades branching off one petiole, as seen in compound leaves.

light energy: a form of energy derived from sunlight that is stored in the chlorophyll of leaves. Light energy facilitates the conversion of water and carbon dioxide into glucose and oxygen in photosynthesis.

lower epidermis: bottom layer of the leaf, composed of epidermal cells and guard cells and covered by a cuticle.

margin: the edge of the blade on a leaf, extending from the apex to the base.

mesophyll: portion of the leaf between the upper and lower epidermis that is composed of palisade and spongy parenchyma.

midrib: central vein that is seen in the middle of a leaf with netted venation.

netted venation: branching pattern of veins in leaves as seen in an oak leaf.

node: point of attachment of a leaf to a stem.

opposite leaf arrangement: pattern of leaf arrangement in which leaves grow in pairs on the stem, opposite one another.

oxygen (O₂): a gas molecule that is a waste product of photosynthesis.

palisade layer: layer of palisade parenchyma cells immediately below the upper epidermis in the mesophyll of leaves. This is the primary site of photosynthesis.

palisade parenchyma cells: long, narrow cells with many chloroplasts that compose the palisade layer of the mesophyll in leaves. Photosynthesis primarily occurs in these cells.

palmate: branching pattern of veins in leaves where the veins radiate from a central point in a fanlike manner.

parallel venation: parallel alignment of veins in leaves as seen in a grass blade.

parenchyma cells: cells in plants that are thin walled and fit loosely together. There are three types in the mesophyll of leaves: palisade parenchyma cells, spongy parenchyma cells, and bundle sheath parenchyma cells.

petiole: the stalk connecting the leaf to the stem.

phloem: conducting tissue in veins by which food exits the leaf to nourish the rest of the plant.

photosynthesis: process by which plants convert carbon dioxide and water, using light energy, into glucose and oxygen. Glucose is the plant's primary food supply.

pinnate: branching pattern of veins in leaves arranged along a longitudinal axis, resembling a feather.

simple leaves: leaves that consist of a single blade on a petiole.

spongy layer: layer of irregularly shaped spongy parenchyma cells that lie below the palisade layer and above the lower epidermis in the mesophyll of leaves. These cells are interspersed with air spaces that facilitate gas exchange.

spongy parenchyma cells: irregularly shaped parenchyma cells with few chloroplasts that compose the spongy layer of the mesophyll. Spaces between these cells allow for gas exchange.

stoma: composed of a pair of guard cells separated by a pore. By the opening and closing of the pore, gas movement is regulated between the environment and the leaf.

stomata: plural for stoma.

transpiration: movement of excess water in the form of water vapor out of leaves into the atmosphere through open stomata.

transpiration stream: continuous movement of water from the roots, up through the stems, into leaves where it ultimately enters the atmosphere through transpiration.

upper epidermis: top layer of the leaf, composed of epidermal cells and covered by a cuticle.

veins: mode of transport for dissolved minerals and water to move up through the plant into the leaf, and for food to move from the leaf into the rest of the plant.

venation: the arrangement of veins in a leaf.

water (H₂O): another building block of photosynthesis.

whorled leaf arrangement: pattern of leaf arrangement where groups of leaves grow in circular patterns around portions of the stem.

xylem: conducting tissue in veins by which water and dissolved minerals enter the leaf.