ROOT STRUCTURE AND NUTRIENT ABSORPTION FROM SOIL

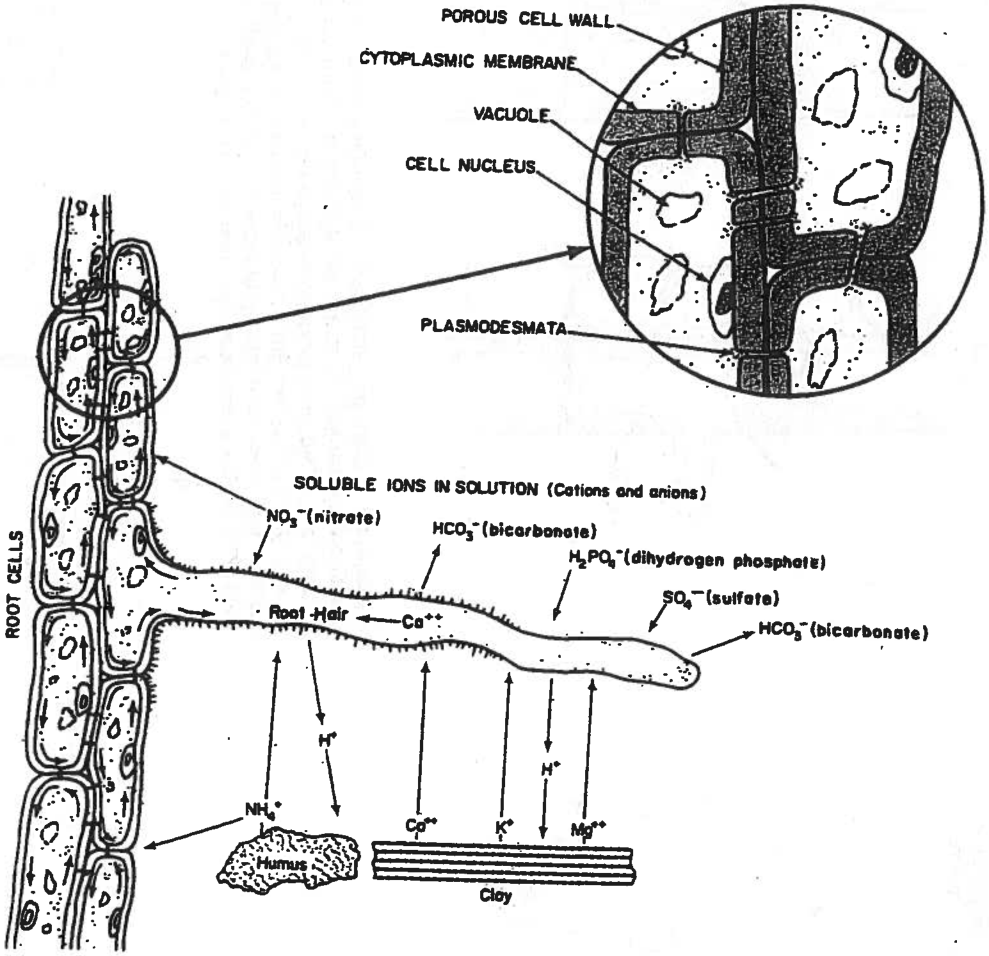
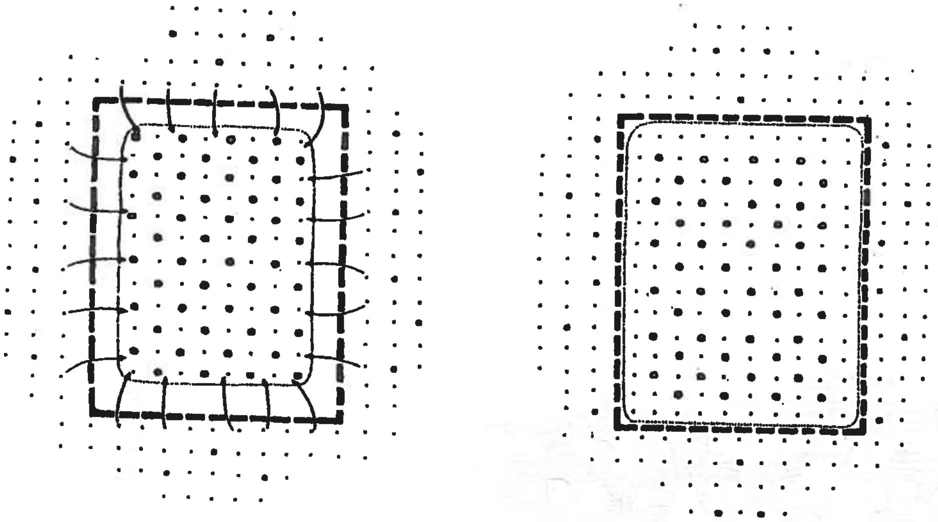


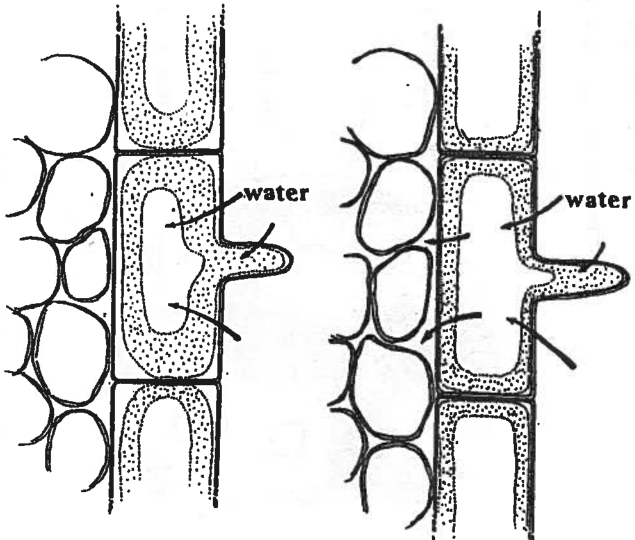
Fig. 7-1 A diagrammatic scheme showing root structure and illustrating how a root hair absorbs nutrients from the soil solution and from adsorbed (exchangeable) ions on a clay crystal or humus colloid. A root hair is an extension of one of the epidermal (surface) cells of the plant root and is thought by some scientists to absorb nearly all the plant's water and nutrients. However, much evidence indicates that older and larger roots are active in water absorption also. Water can move through the cell walls and pore spaces between cells, and thus furnish the cells with large amounts of contact between soil solution and the cell membranes enclosing the active cell protoplasm. Plasmodesmata are fine strand connections of cytoplasm between cells through which water and nutrients move. In the insert they are shown exaggerated in comparative size.

Drawing from:
Soils An Introduction to soils and Plant Growth, Fifth edition
By R.L. Donahue, R.W. Miller, J.C. Shickluna
Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632
Page 212



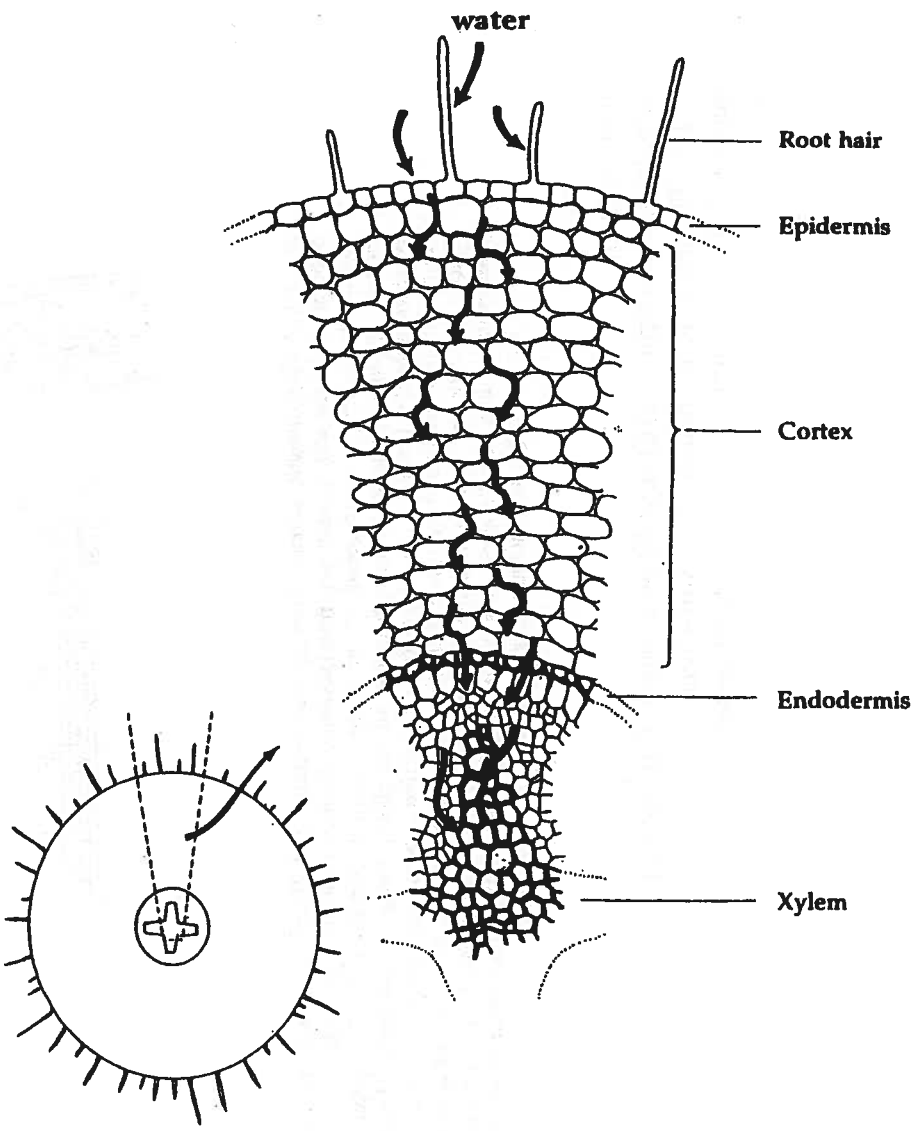
a. b.

Osmosis. a. A cell is occupied by large amounts of dissolved substances (large dots), thereby reducing the space occupied by water molecules (small dots). Since water is more abundant in the dilute, external solution, it diffuses into the cell. The cell membrane prevents the loss of dissolved substances from the cell. b. Osmotic uptake of water creates turgor within the cell when the cell membrane presses against the cell wall. In these diagrams, the cytoplasm and vacuole are treated as one.

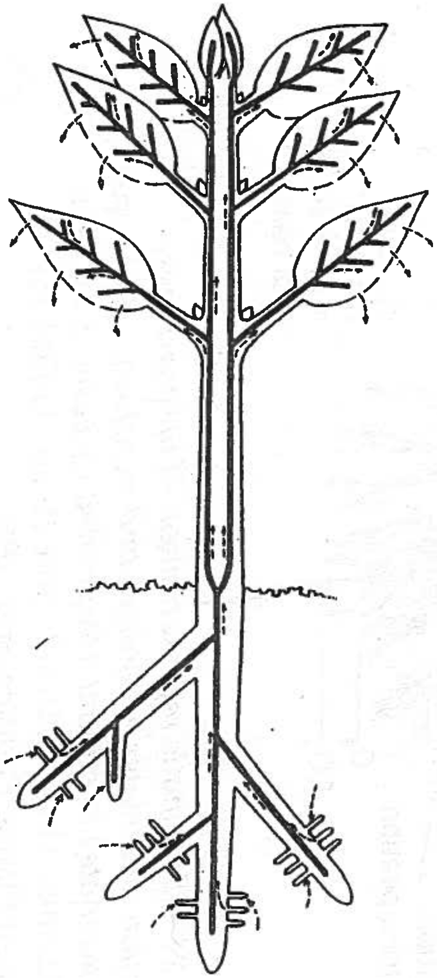


a. b.

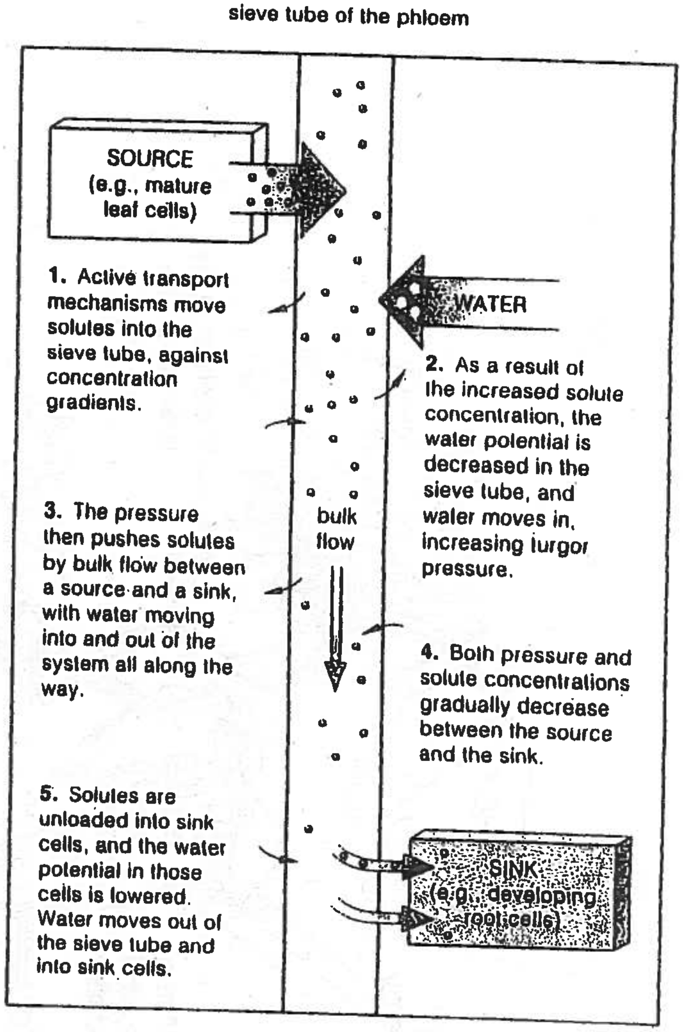
Water uptake by roots. a. Water enters a root's epidermal cells by the process of osmosis. b. As the vacuole becomes inflated, the cytoplasm is pressed against the cell wall creating an internal turgor pressure. At maximum turgor, water is squeezed out of the cell at the same rate as it continues to enter. The water moves into spaces between cortex cells.



The path of water across a root. The epidermis and endodermis function as osmotic pumps that move water from the soil, into the cortex and to the xylem at the center of the root.



The path of water through the plant's inter-connecting xylem.



1. Active transport mechanisms move solutes into the sieve tube, against concentration gradients.

2. As a result of the increased solute concentration, the water potential is decreased in the sieve tube, and water moves in, increasing turgor pressure.

3. The pressure then pushes solutes by bulk flow between a source and a sink, with water moving into and out of the system all along the way.

4. Both pressure and solute concentrations gradually decrease between the source and the sink.

5. Solutes are unloaded into sink cells, and the water potential in those cells is lowered. Water moves out of the sieve tube and into sink cells.

Figure 30.14 Summary of the proposed mechanism of pressure flow in phloem, a vascular tissue of flowering plants.

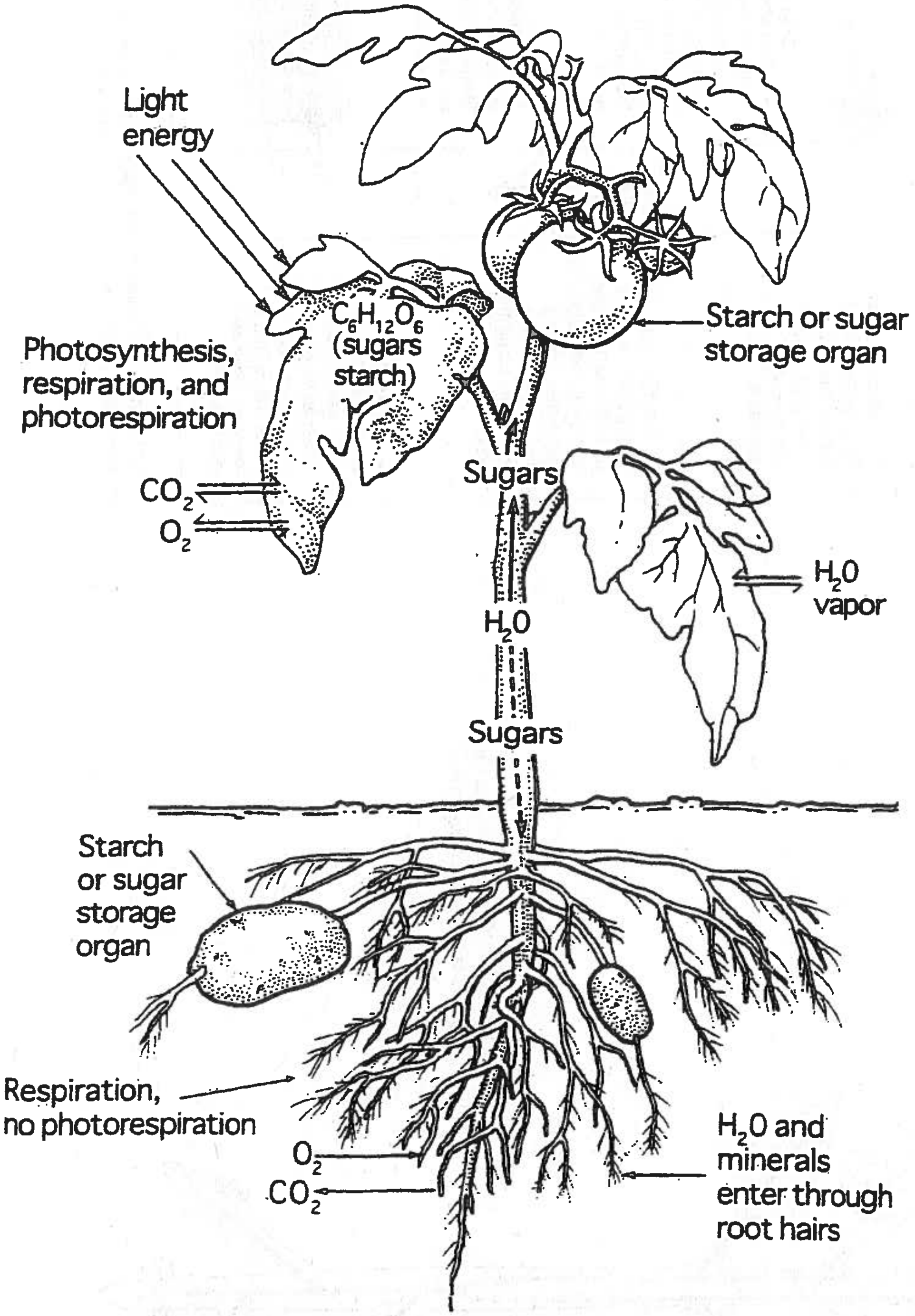
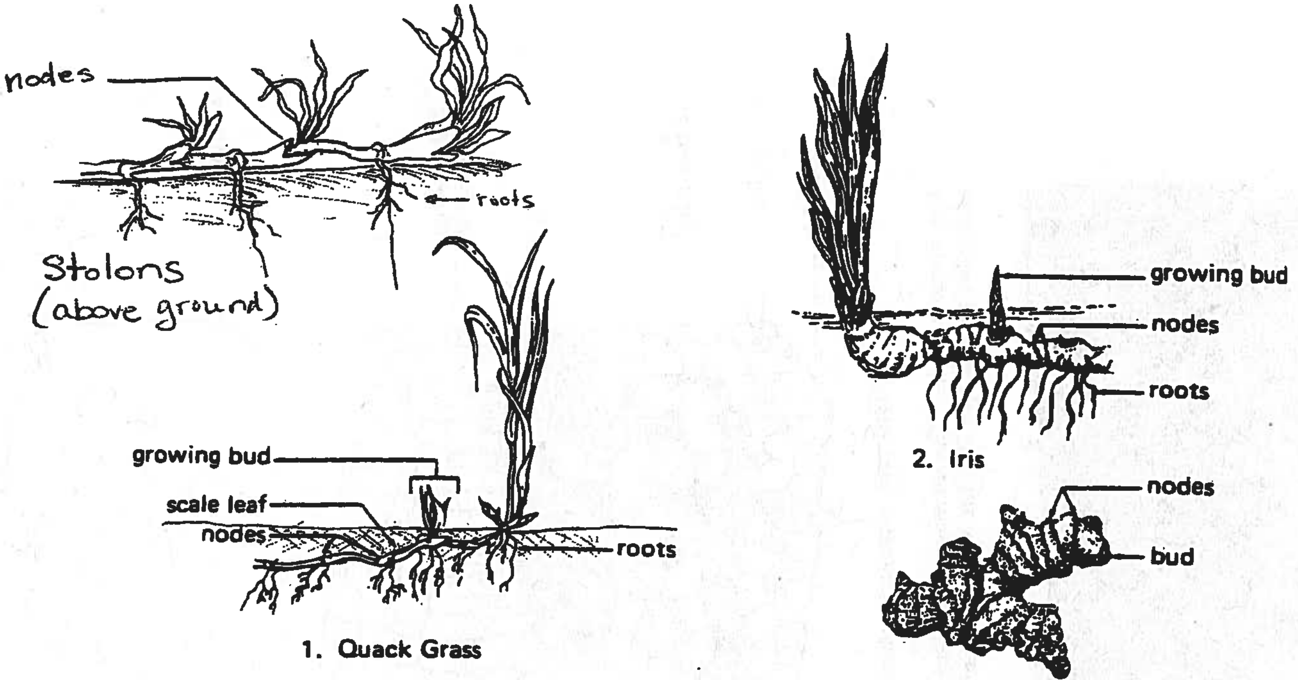


Figure 24.—Schematic representation of photosynthesis, respiration, leaf water exchange, and translocation of sugar (photosynthate) in a plant. (Reprinted by permission from Plant Science: Growth, Development, and Utilization of Cultivated Plants, *Prentice Hall, 1988.)*

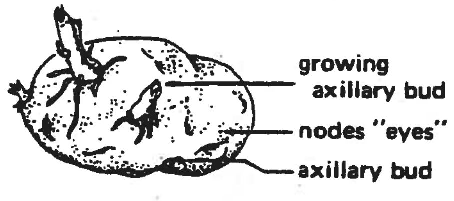


1. Quack Grass

2. Iris

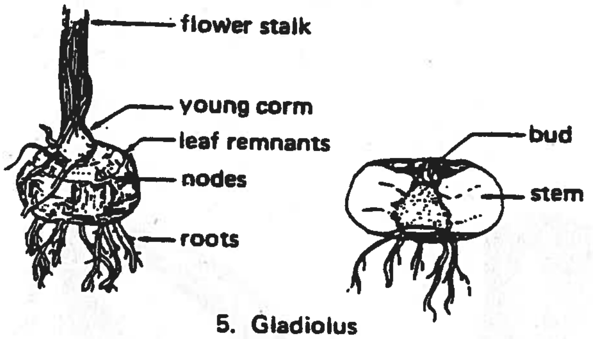
3. Ginger

Figure A. Rhizomes (below ground)



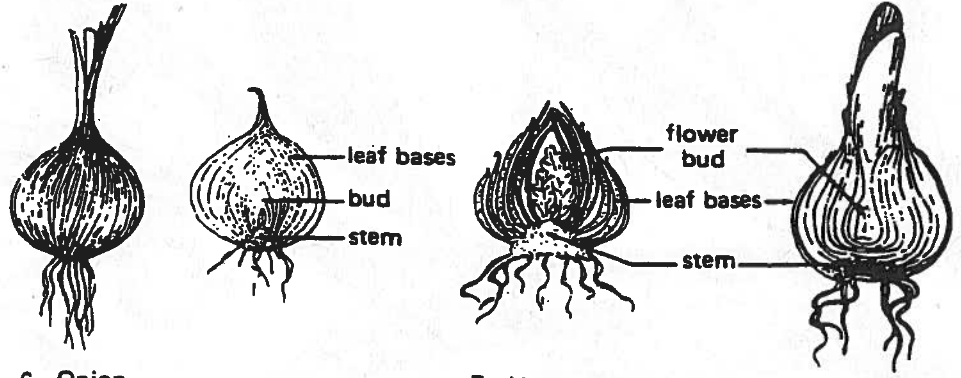
4. Potato

Figure B. Tuber



5. Gladiolus

Figure C. Corm



6. Onion

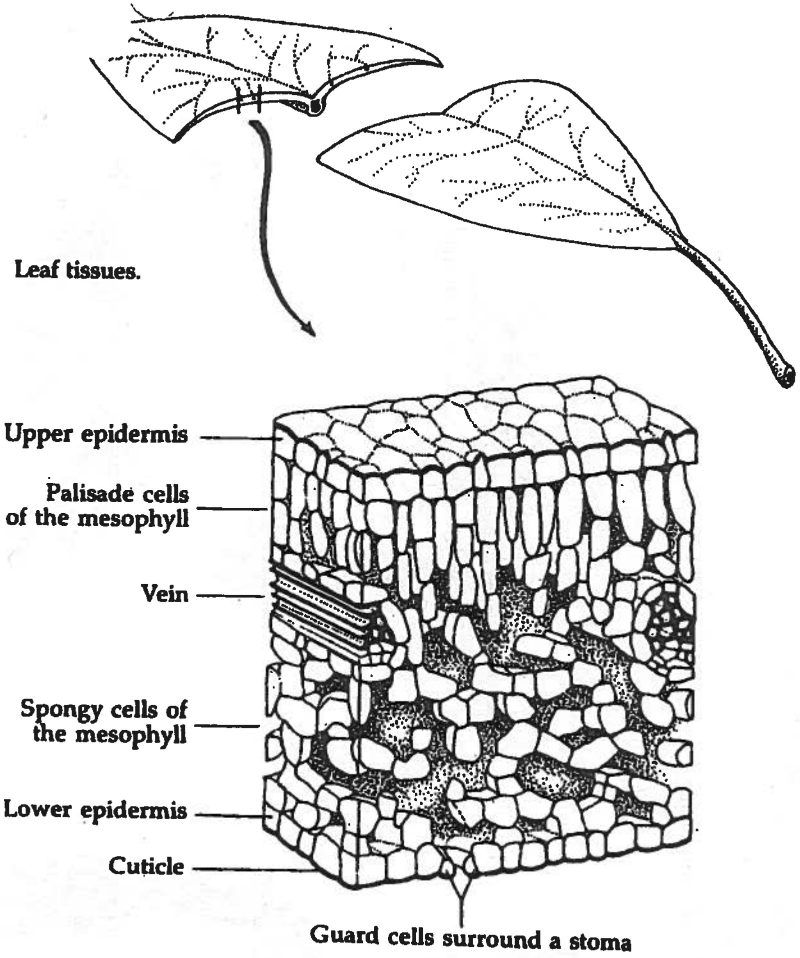
7. Hyacinth

8. Lily

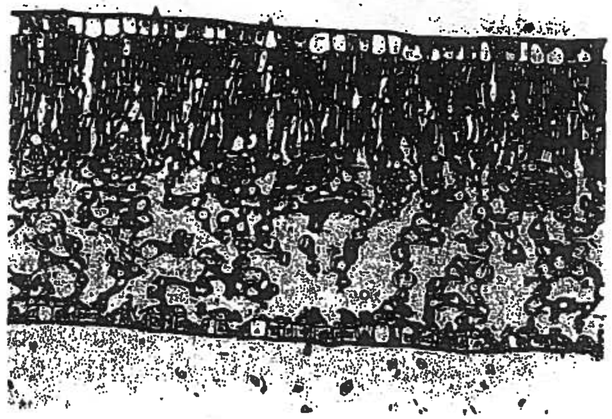
Figure D. Bulbs

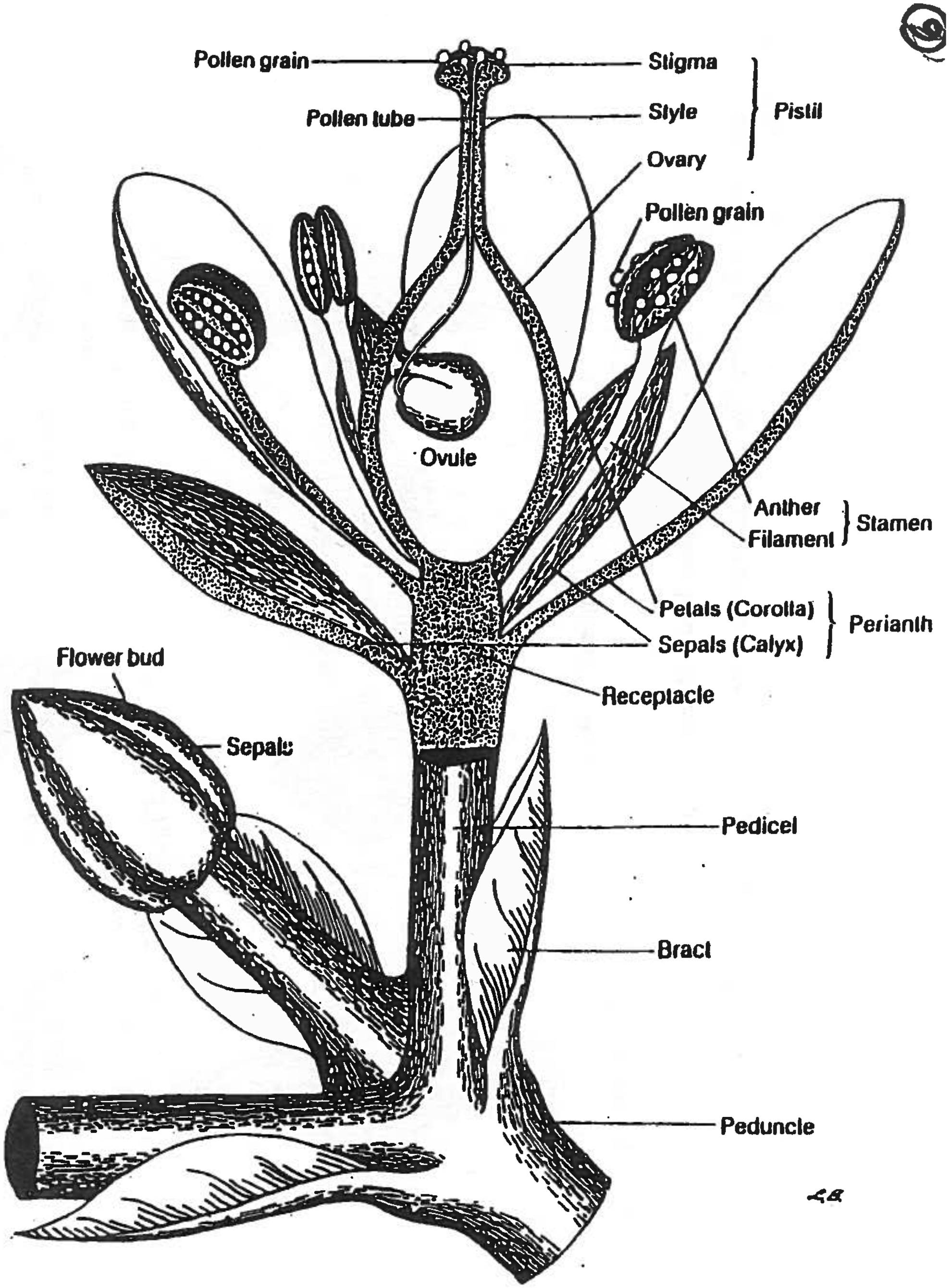
Figure 6-4. Modified Stems.

Taken From: *Laboratory Exercises for General Botany*, Sparling, Shirley, Kendall/Hunt Publishing Co., Debuque, Iowa, 1983.


Leaf tissues.

The anatomy of a leaf. Tissues may be identified by comparing the photograph with the above diagram.





From: Plant Classification, Lyman Benson, Heath & Company, 1979, 2nd Edition, page 50.

During the day, the sugar concentration in the leaf cells increases. That which is not exported out of the leaf is converted to starch, pectins, or gums in the case of prune trees. The increased sugar concentration in the guard cells of the stomata and the increasing loss of water vapor from the leaves, as the daytime temperature rises, cause the stomata to close. Lack of soil moisture will do the same. This "safety valve" closure prevents excess water loss and controls photosynthesis. As the sun sets, photosynthesis ceases. Translocation of sugars from the leaves continues. Starch is dissolved to glucose which is converted to sucrose and sorbitol and pumped into the pipelines. Starch is usually gone by morning and the moisture content is restored so the leaves are primed for another day's work.

Factors influencing photosynthesis

Light intensity. Light intensity on a bright cloudless day in California can reach 12,500 foot-candles, which is probably twice the intensity needed to saturate the photosynthetic apparatus of prune leaves (fig. 3). However, as the outermost leaves of the foliar canopy absorb from 75 to 90 percent of the radiant energy, the lower leaves in the canopy receive far below that of saturation level. Light intensity under the canopy may be as low as 150 to 300 foot-candles, a level of light intensity which may be sufficient for leaves to stimulate flower formation in buds of shaded spurs but may not be enough to supply fruits with carbohydrates for adequate sizing.

Dust, spray residues, and insect and disease damage. Any surface residue, such as dust and spray particles that absorb or reflect light, reduces leaf efficiency. Likewise, when mites and aphids produce many injuries to the leaf epidermis through which water can escape, the resulting stress will cause stomatal closure and lessen the efficiency of the leaves. For the same reasons, diseases which cause *chlorosis* (lack of chlorophyll) or interrupt translocation of water and other substances in and out of leaves reduce photosynthetic efficiency.

Nutrient supply. Each chlorophyll molecule contains 4 atoms of nitrogen and 1 of magnesium. So any deficiency of these elements will result in chlorosis. Other elements such as iron, manganese, copper, boron, molybdenum, and zinc regulate enzyme activity so that their deficiency will also lead to chlorotic conditions or limit growth of leaves.

Water supply. Lack of water causes stress, even without symptoms of wilting. This results in stomatal closure, reduced photosynthesis and cessation of transpiration, which allows not only leaf temperature but that of the limbs and trunk to rise. Not only does growth stop, but potassium leaf scorch, dieback, and sunburning could result.

Carbon dioxide concentration. Carbon dioxide concentration in the atmosphere is fairly constant. Only experimentally has it been shown to be limiting. Plants in controlled growth chambers grow better when the carbon dioxide content is raised.

Leaf number and exposure. While any tissue containing chlorophyll in the cells, e.g., young stems and fruit, can carry on photosynthesis, leaves are the primary organs for photosynthesis in fruit trees. So, the optimum exposure of the maximum number of leaves to light normally results in the greatest yield of dry matter.

ANR Publication # 3269

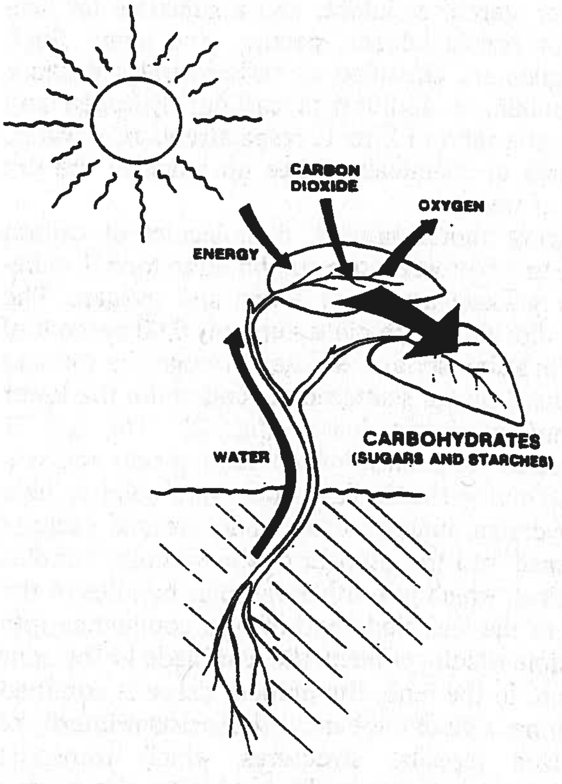


Figure 5. In photosynthesis, green plants use energy from the sun to convert carbon dioxide from the air and water from the soil into sugars, their primary food source. In the process, oxygen is released into the air.

Photosynthesis and respiration

Carbon is an element which, in combination with hydrogen, oxygen, nitrogen, phosphorus, and sulfur, enables living organisms to store and transfer energy via chemical binding and transformation. Only green plants and some bacteria have the capacity of converting inorganic substances to organic compounds, thereby providing food for animal life. In this process known as *photosynthesis*, the green pigments, chlorophyll a and b, trap the energy from the sun and with it convert carbon dioxide and water to a simple carbohydrate which eventually is made into sugar (fig. 1). The reverse process, whereby all plants and animals derive energy or heat from these simple carbohydrates, is called respiration. Two main differences are that respiration takes place in the dark as well as in the light, and that it takes place in the absence of chlorophyll.

One of the earliest principal products (or photosynthates) of photosynthesis is glucose, a six-carbon sugar. It is transformed to other simple sugars, i.e., fructose, sucrose (the main translocated sugar), and sorbitol, a sugar-alcohol. Glucose is also the building block for starch, cellulose, and a substrate for synthesis of hemicelluloses, pectins, and gums. Such compounds are classified as carbohydrates because they contain, in addition to carbon, hydrogen and oxygen at a ratio of 2 to 1, respectively, as in water. This class of chemicals makes up much of the dry matter of trees.

During photosynthesis, 6 molecules of carbon dioxide and 6 of water are combined to form 1 molecule of glucose and 6 of water and oxygen. The carbon dioxide, which makes up only 0.03 percent of the earth's atmosphere, diffuses through the stomata (specialized pores) scattered at random on the lower epidermis of prune leaves (fig. 2). The gas is absorbed by the chlorophyll-containing cells and synthesized during the daylight hours into water soluble carbohydrates, mainly sugars. Sucrose and sorbitol are loaded into the phloem of the vascular bundles (leaf veins), which join other vascular bundles in the midrib of the leaf blade and form a confluence into the petiole which connects the leaf blade to the spur and limb. In the limb, the phloem tissue is confined to the inner side of the bark and consists primarily of specialized pipelike structures which transport organic substances to newly developing shoots and root apices and to the newly forming cells which add girth to the trunk and roots.

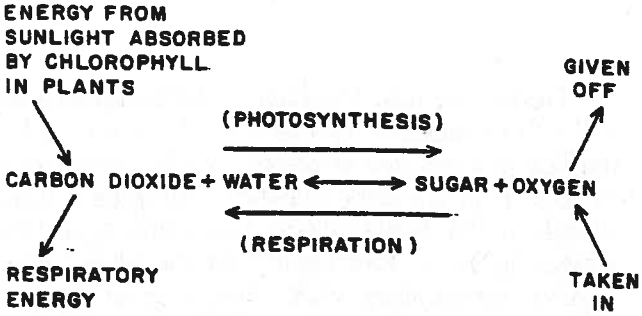


Fig. 1. The conversion of solar radiant energy to chemical energy and oxygen, *photosynthesis*, and the reverse reaction, *respiration*, in which sugar is utilized by living cells to release energy, yielding carbon dioxide and water.

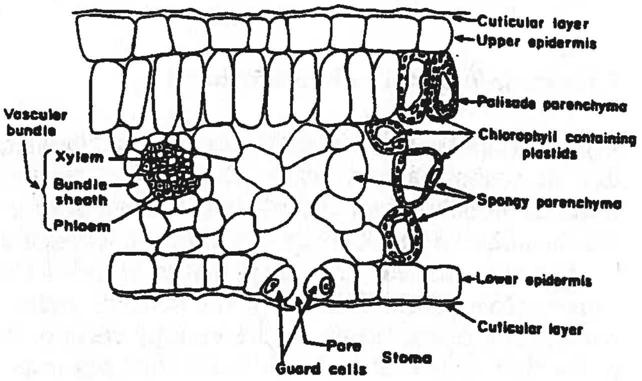
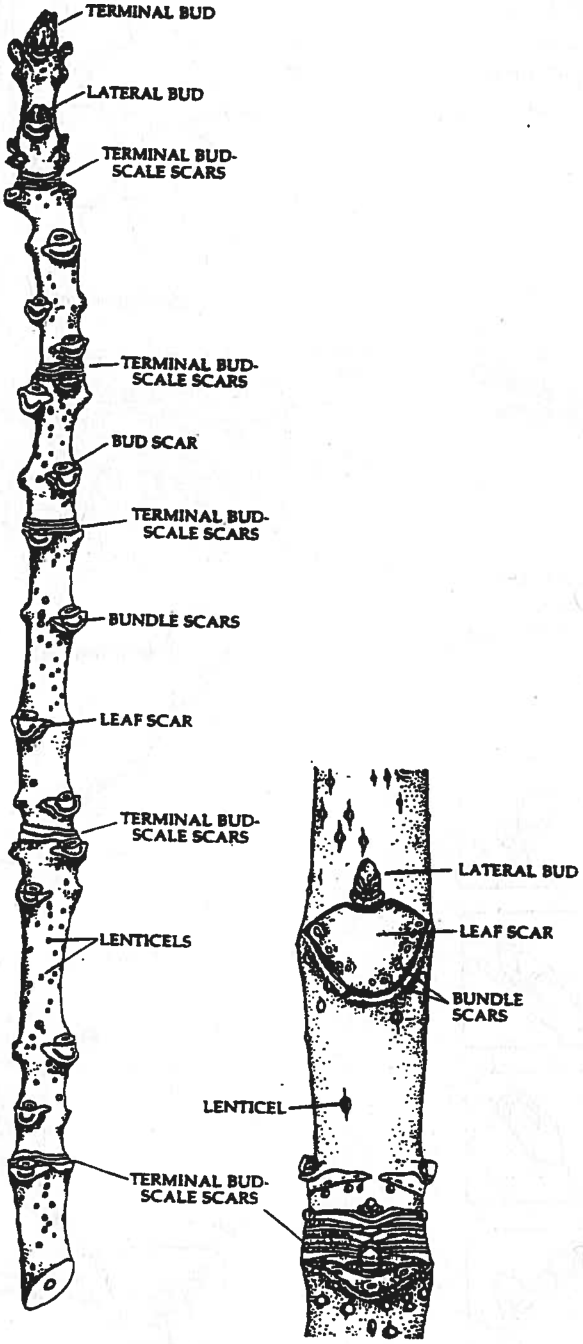


Fig. 2. A prune leaf cross-section showing the location of the stoma and vascular bundle. The plastids containing chlorophyll are shown just in a few cells.

The xylem, which makes up the rest of the vascular bundles, mainly conducts water and nutrients absorbed from the soil solution to the leaves. In stems, trunk, and roots, the xylem tissue is the wood. Each season as the tree grows in diameter, the new xylem adds another "ring" to the trunk so that the age of the tree can be estimated by annual rings. Mineral elements dissolved in the xylem sap usually remain in the leaf cells while the water evaporates from the cell surfaces and escapes from the leaf through the stomata into the atmosphere. This loss of water is known as *transpiration*, a process that helps to keep the leaf temperature down.

Deciduous Woody Twigs



Taken From: *Biology of Plants*, Raven, Peter, Worth Publishers Inc., New York, 1986.

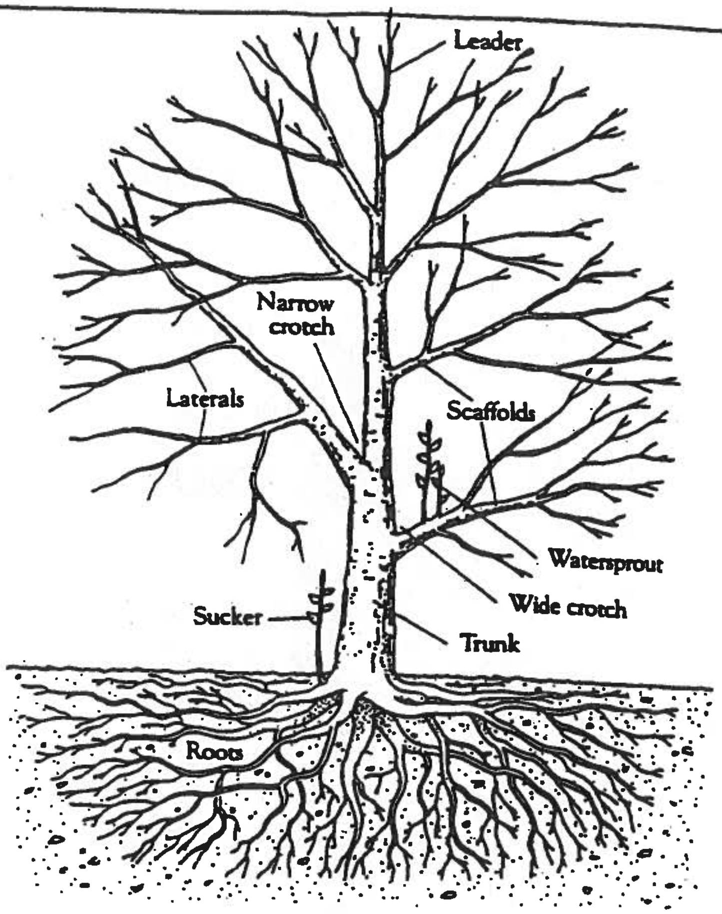
ANATOMY OF A FRUIT TREE

Crotch: A crotch is the angle where branches fork, or where a main limb joins the trunk. Strong crotches are wide angled—45 degrees or more: Weak crotches are narrow.

Scaffold: The main limbs branching from the trunk.

Watersprout: A very vigorous shoot from a dormant bud on an old branch. Remove by cutting at the base.

Sucker: A vigorous shoot from the roots or from below the bud union. Cut off at the base.

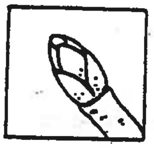


CHOOSING THE RIGHT BUD:

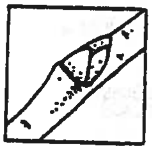
Prune to the lateral bud that will produce the branch you want. An outside bud will usually produce an outside branch. The placement of that bud on the stem points the direction of the new branch.

PARTS OF THE BRANCH

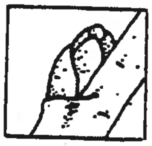
Terminal Bud: The fat bud at a branch tip will always grow first and fastest if you leave it. Cut it, and several buds will grow behind it.



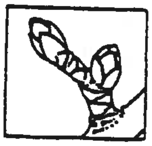
Leaf Bud: Flattish triangle on the side of a branch. To make one grow, cut just above it. Choose buds pointing outward from the trunk so the growing branch will have space and light.



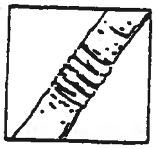
Flower Bud: Plump compared to leaf buds and first to swell in spring. On stone fruits they grow alone or beside leaf buds. On apples and pears they grow with a few leaves.

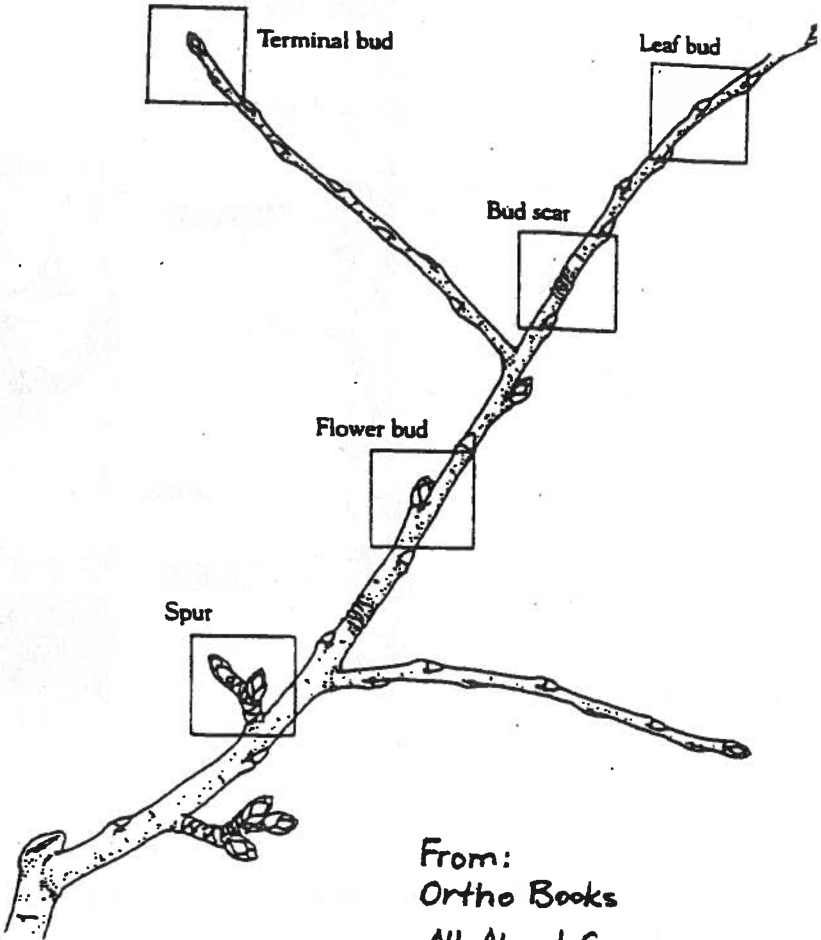


Spurs: Twiglets on apples, pears, plums, and apricots. They grow on older branches, produce fat flower buds, then fruit. Don't remove them.



Bud Scar: A ring on a branch that marks the point where the terminal bud began growing after the dormant season. The line marks the origin of this year's growth.





From:
Ortho Books
All About Growing
Fruits & Berries
1982

TUESDAY, APRIL 27, 2004 YT D1

Science Times

The New York Times

Stretching Between Climates

Desert-like conditions prevail at treetop level.

Drawing water up about 30 stories runs into mechanical limitations.

Leaves are stunted at higher elevations as water becomes scarce.

Near the ground, it is darker, cooler and more humid.

Source: Dr. George Koch, Northern Arizona University

Taller Trees? The Limit Is Plumbing

By CAROL KAESUK YOON

In California, at a secret location in Humboldt Redwoods State Park, stands a 369-foot-high titan that is both the tallest living tree and the tallest organism on earth. Yet this behemoth, the height of a 30-story building, is still growing, begging the question: How tall can a tree get?

To find an answer, a research team has performed an act of scientific derring-do, hauling themselves and their equipment into the top of the world's tallest trees. Reporting in the current Nature, the researchers confirm a longstanding hypothesis that the ultimate obstacle to growing ever higher is water, or lack of it. They predict that even the most rugged trees will be stopped in their tracks at a parching altitude between 400 and 427 feet high.

"It gets spindly up there," said Dr. George Koch, lead author and physiological ecologist at Northern Arizona University. "I'll tell you, it's quite an amazing feeling."

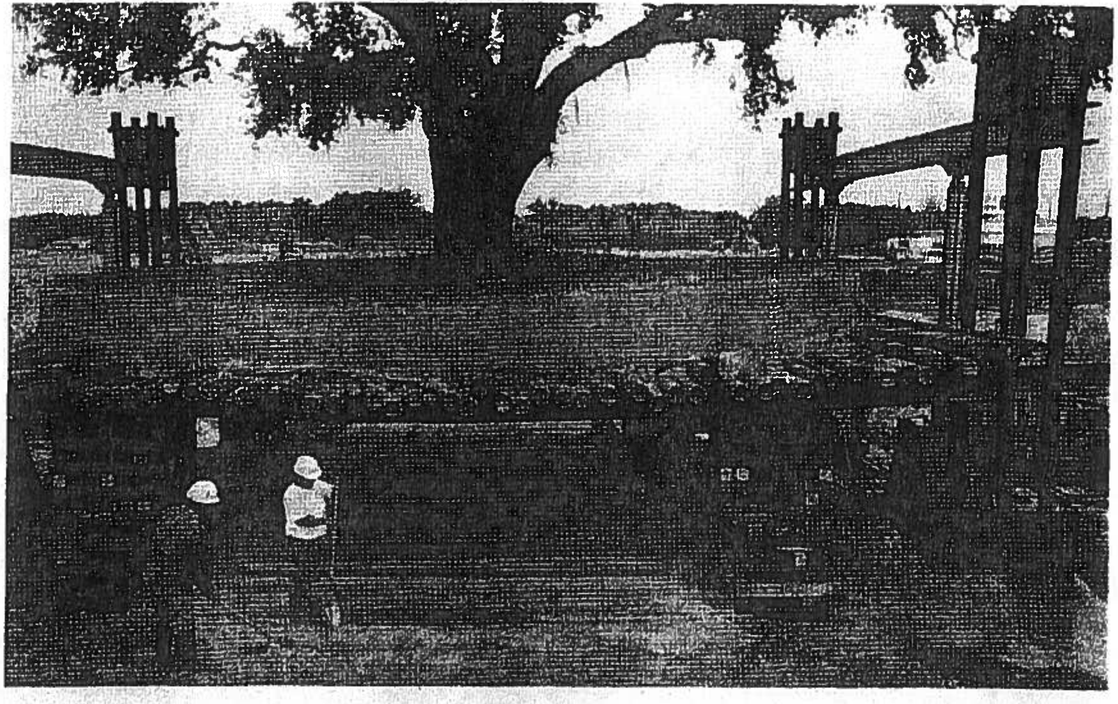
As they climbed, the researchers found the leaves seemed to suffer progressively from a lack of water. More and more like desert leaves, they were smaller, denser, less able to take in carbon dioxide and less efficient at photosynthesizing — all resulting in slower and, at some extreme, no growth.

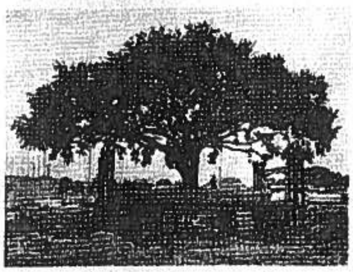
The problem, they say, is that water moves passively in plants, evaporating out of leaves and thereby drawing water upward through the plant from the roots. The higher the leaves, the greater the struggle against gravity and so the drier they tend to be.

To estimate the maximum height for trees, the researchers extrapolated out to the height that water could no longer be drawn upward and leaves could no longer function.

History appears to bear the scientists out. They note that the tallest reliably measured tree ever was a Douglas fir in the Lynn Valley of British Columbia, near Vancouver, which at 413 feet falls neatly into their predicted range.

And, in any event, that's probably awesome enough.





The relocated oak stands five stories tall and weighs nearly as much as a Boeing 747.

Tree Transplant When a big chain store wanted to build on a certain lot in Auburndale, Florida, a 120-year-old oak stood in the way. Rather than cutting it down, the retailer paid more than $100,000 to have the tree transplanted—a practice that's become more common as municipalities require developers to preserve tree canopy, says Dan Joy of the Davey Tree Expert Company, the firm that moved the oak. Saving trees creates positive publicity and attracts crowds who come to watch the process. "It's like the circus coming to town," says Joy. The Auburndale oak's move took six weeks of preparation. After uncovering and trimming its 42-foot-wide root-ball, the movers slid steel rods underneath (above), and the 353-ton tree was lifted onto a trailer for transport to its new home—just 500 yards away, in a wetland preservation area. So far the old tree is doing just fine. *—Peter Gwin*

National Geographic Magazine 2006

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LEAF STRUCTURE

Color the leaf (A), its major morphological regions, the lamina (B) and the petiole (C), and the stem (D) and axillary bud (E) on the three diagrams at the top of the plate.

Leaves come in a variety of shapes and sizes. Most simple *leaves* can be divided into two morphological regions. The broad, or expanded, portion of a *leaf* is called the *lamina,* or blade, in reference to its broad, thin shape. In most *leaves,* the *lamina* functions as the primary photosynthetic surface. The narrow, stalklike portion of the *leaf,* called the *petiole,* which is located between the *lamina* and *stem,* often functions to position the *leaf* for efficient photosynthesis. The portion of the *petiole* near the stem is called the leaf base (not separately colored). Since all *leaves* have one or more *axillary buds* on the *stem* immediately above the attachment point of the *petiole,* in the axil of the *leaf,* this feature serves as a diagnostic trait for a single *leaf.* The *leaves* of some plants, or some *leaves* on some plants, lack a *petiole,* and the *lamina* is attached directly to the *stem. Leaves* lacking a *petiole* are called sessile *leaves.*

Color the venation patterns (F) as well as the previously listed structures on the three leaves labeled "venation" in the middle of the plate.

Three basic patterns of *venation,* formed by the distinctive arrangement of major veins, are commonly encountered. *Leaves* with *pinnate venation* have a single, centrally positioned, main vein running from the base of the *lamina* to its tip. Numerous secondary veins branch at an angle from the central main vein to produce a featherlike pinnate pattern of major veins.

If a few to several major veins arise from a common point near the base of the *lamina* and radiate outward toward the *leaf margin,* often to the tips of lobes, like fingers from a palm, the venation pattern is called *palmate* or digitate.

A third commonly encountered pattern is *parallel venation,* in which several major veins arise from the base of the *lamina,* diverge slightly, and then run roughly parallel for most of the length of the *lamina* before converging toward the leaf tip. This pattern is characteristic of a group of flowering plants called monocots. Numerous small *parallel veins* are typically present (only a few are diagrammatically illustrated).

Color the various leaf margins (G) as well as the previously listed structures illustrated at the bottom of the plate.

Leaf *margins* are used to describe and name leaf types. Numerous variations in leaf *margins* exist, and though only six types are illustrated, they provide a good sample of commonly encountered types. *Entire leaves* have smooth *margins* with no lobes or incisions. Many different forms of *serrate leaves* exist, but the basic pattern is a leaf *margin* with roughly triangular, sharp toothlike projections, or serrations, of the *lamina* that are evenly spaced around the leaf *margin.*

Lobed leaves, as in some oaks, have *margins* with broad, rounded lobes that alternate with rounded clefts that are irregularly spaced. The incised clefts usually are not deeper than about half the distance between the outer leaf *margin* and the midvein; so ample *lamina* separates the deepest cleft *margins* from the midvein.

Parted leaves, as in some oaks and most maples, are divided into several sections by angular, often deep, clefts in the *margins.* The clefts may approach the major veins but do not touch them; so lamina material separates the deepest cleft *margins* from the major veins.

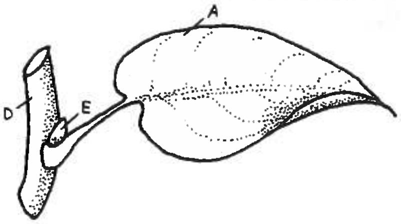
Palmatifid leaves, as in the rice paper plant, have *palmate venation* and deeply incised *margins.* The clefts of the *margins* alternate with the fingerlike lamina lobes that surround the major veins. Though deeply incised, the clefts do not reach the common origin point of the main veins.

Pinnatifid leaves, like *palmatifid leaves,* have deep clefts in the *margin,* but the clefts follow a pinnate venation pattern so that a series of lamina lobes, arranged in a *pinnate pattern,* is present.

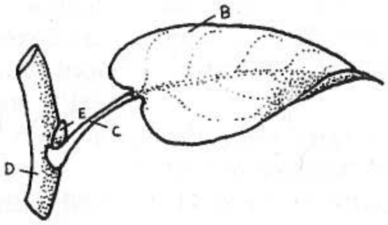
Pages from:
The Botany Coloring Book by Paul Young , Illustrations by Jacquelyn 1982 Guiffré HarperPerennial a division of HarperCollins*Publishers*

BASIC LEAF STRUCTURE ●

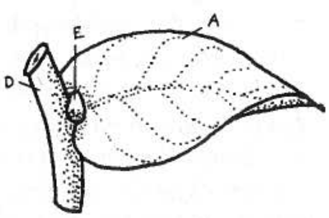
LEAF A
LAMINA B
PETIOLE C
STEM D
AXILLARY BUD E



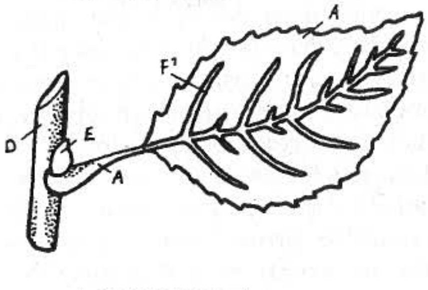
PETIOLATE ★



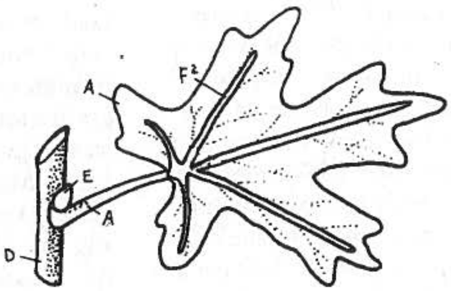
SESSILE ★



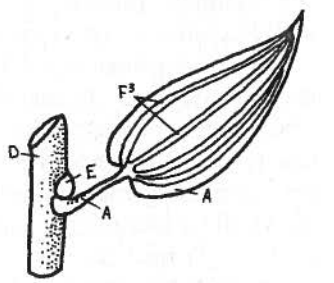
VENATION F



PINNATE F1

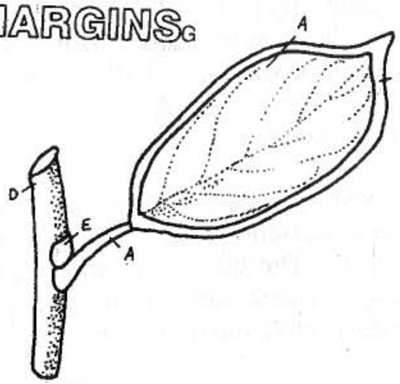


PALMATE F2

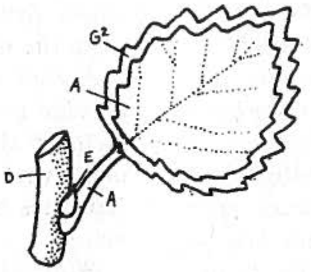


PARALLEL F3

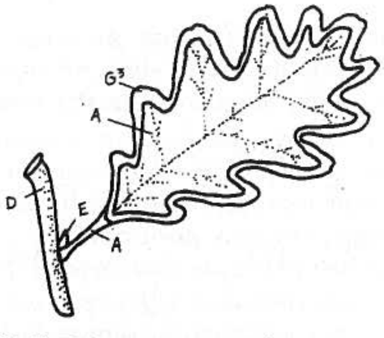
MARGINS G



ENTIRE G1

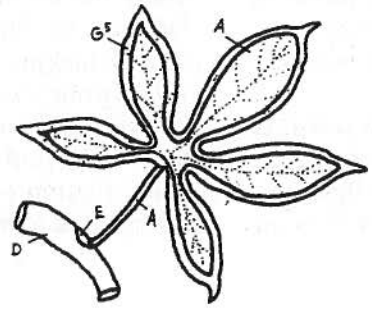


SERRATE G2

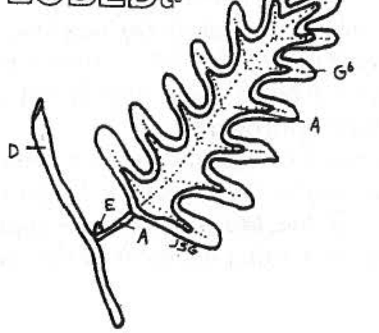


LOBED G3

PARTED G4



PALMATIFID G5



PINNATIFID G6

69

LEAF STRUCTURE

Color the alternate (A), opposite (B), and whorled (C) leaf arrangements and the stems (D) and axillary buds (E) on the diagrams of leaf arrangements at the top of the plate.

Three leaf arrangements, based on the number of leaves present at each node, are recognized. If a single leaf is present at each node, the leaf arrangement is *alternate.* Roses and many other plants have alternate leaves. The leaves, each with one or more axillary buds, are attached to the *stem* in an ascending pattern of spirals about the *stem.* Plants with two leaves present at each node have an *opposite arrangement* of leaves. Two leaves occur opposite one another at each node. Many plants, including maples and coleus, have *opposite* leaves. The presence of three or more leaves at each node, as in Easter lilies, is called a *whorled arrangement* because the leaves appear in whorls at each node. Because of the presence of *axillary buds*, branching patterns usually follow patterns of leaf arrangements.

Color the compound leaf types and the components of a compound leaf, the leaflets (F) and rachis (G), if present, and petiole (H). Note that each type, except bipinnate (K) and ternate (L), is illustrated twice. Color one illustration to show the components and the other with the color of the compound leaf type: odd pinnate (I), even pinnate (J), or palmate (M). Note that in the case of bipinnate (K) and ternate (L), the title only receives a separate leaf-type color.

The blade portion of compound leaves is divided into two or more subdivisions, called *leaflets,* that closely resemble individual leaves. However, a true leaf can always be determined by the presence of one or more *axillary buds* at its point of attachment to the *stem.* Individual *leaflets* never have an *axillary bud* at their base, though the compound leaf they form does have one or more *axillary buds.* In many compound leaves, the midvein forms a narrow, stemlike structure, called the *rachis,* to which the *leaflets* are attached. Thus, without careful observation, *leaflets* appear to be true leaves attached to a true *stem.* The diagnostic feature of a true leaf is the presence of one or more *axillary buds* above its point of attachment. Most compound leaves have a distinct *petiole. Leaflets* may be sessile on the *rachis* or attached to it by a petiolelike stalk.

Many arrangements of *leaflets* in various compound leaves occur, and only a few common types are described here. Pinnately compound leaves have opposite leaflet pairs arranged in a pinnate (featherlike) manner. *Odd pinnate* compound leaves, as in roses, have the *rachis,* or midvein, terminated by a single *leaflet* and therefore an odd number of *leaflets* present on the leaf. In some plants, such as vetch *(Vicia),* the rachis tip is modified into a grasping tendril. In *even pinnate* compound leaves, such as in silktassle tree *(Albizia),* the leaf is terminated by a pair of *leaflets* so that the leaf has an even number of *leaflets* present.

In *bipinnate* compound leaves, the pinnately arranged leaf divisions are further divided in a pinnate manner. The result is a pinnate arrangement of *leaflets* on pinnately arranged branches of the *rachis. Ternate* compound, or trifoliate, leaves, such as found on clover, have three *leaflets.* The overall pattern for ternately compound leaves is multiples of three. For example, a twice ternately compound leaf (not shown) has three clusters of three *leaflets* each. Plants with *palmate* compound leaves, such as lupines, have four or more *leaflets,* all attached to the tip of a true *petiole* at one common point of origin. This arrangement resembles the palm of the hand with the fingers analogous to *leaflets,* hence the name *palmate.* Another name used for this compound leaf type is digitate, in reference to the similarity to the fingers of the hand.

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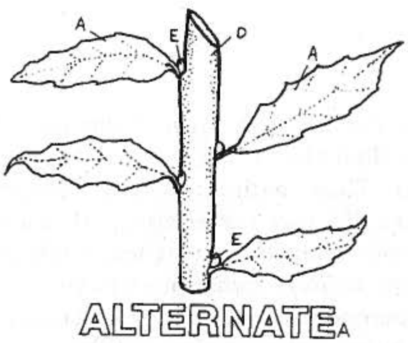
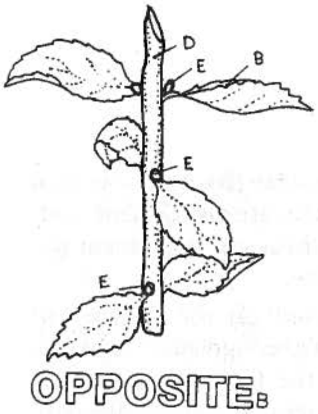
LEAF ARRANGEMENTS AND COMPOUND LEAVES.

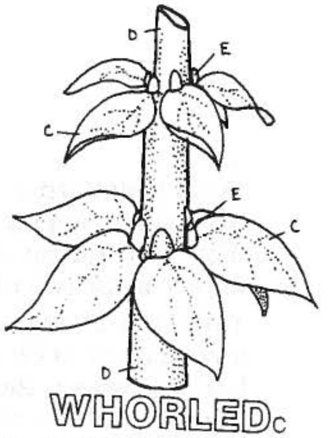
ARRANGEMENT.★



ALTERNATE A

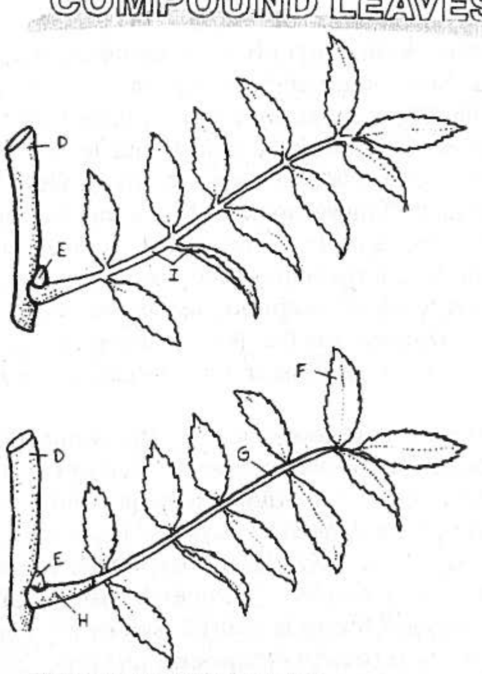


OPPOSITE B

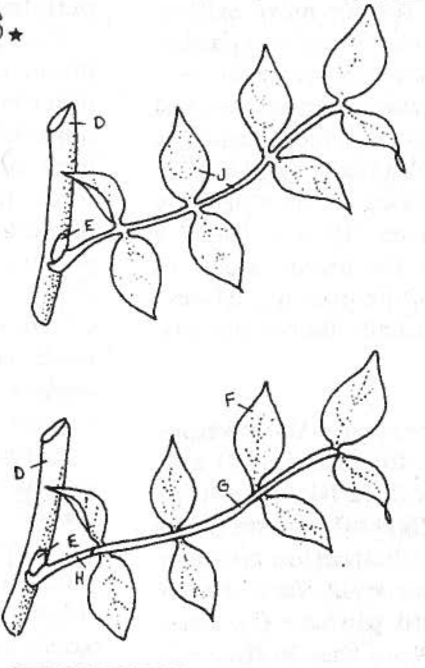


WHORLED C

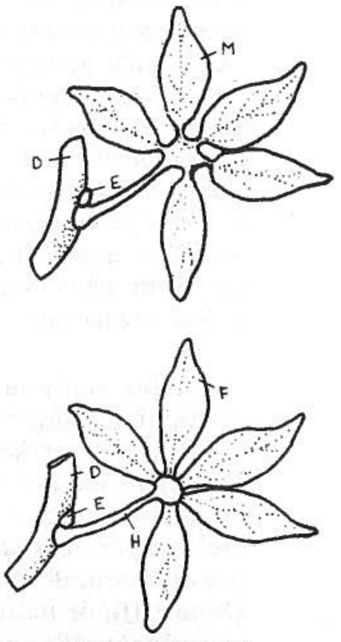
COMPOUND LEAVES.★



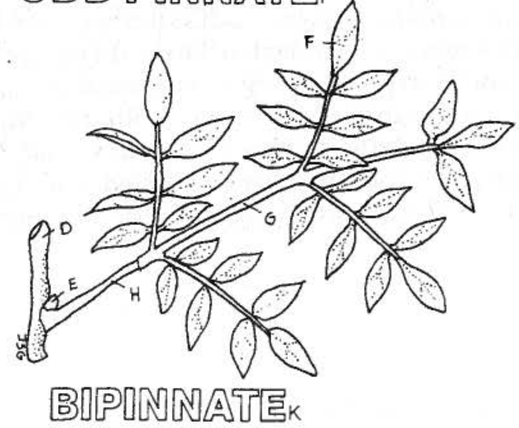
ODD PINNATE I



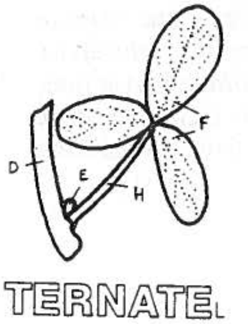
EVEN PINNATE J



PALMATE M



BIPINNATE K



TERNATE L

STEM D
AXILLARY BUD E
LEAFLET F
RACHIS G
PETIOLE H

70

CONTROL OF GROWTH

On the diagrams labeled "phototropism," color the arrows indicating the direction of the light source (A), stem (B), shoot tip (C), leaves (D), cell elongation (E), and the axillary buds (I). Relative plant hormone concentration is indicated by the degree of shading: darker shading for higher concentration. Choose a light color for the stem (B) and shoot tip (C) so the shading will show through.

Phototropism is a plant growth response due to a stimulus provided by a *light source*. Most plant *stems* exhibit a positive phototropic response to light: That is, the *stems* grow toward the *light source*. This effect can be observed in most houseplants, which, due to positive phototropism, tend to grow toward the nearest window. A few plant *stems*, such as the fruit-bearing stems of Kenilworth ivy, are negatively phototropic and grow away from the *light source*. Positive phototropism is an adaptation to position the photosynthetic surfaces in the most favorable position for efficient light reception.

If the primary *light source* is directly above a positively phototropic *stem* (as in the left diagram), the *stem* will grow vertically toward the *light source*. This response is due to plant growth hormones, especially one called auxin, produced by the *shoot tip* and immature *leaves*. (In the diagrams, the *shoot tip* is depicted as a simple dome for clarity.) These hormones regulate *cell elongation* in the zone of *cell elongation* and other aspects of plant growth not included here. When the *light source* is directly above the *shoot tip* (in line with the axis of the growing shoot), the hormones are evenly concentrated (shown by even shading) throughout the *shoot tip* and within any given level of the *stem's* zone of elongation below the *shoot tip*. Therefore, *cell elongation* at any given level is equal, and vertical growth of the *stem* directly toward the *light source* occurs.

If the *light source* is repositioned to one side of the *stem* (*light source* is shown repositioned to the right of the *stem* in the middle diagram), the hormones produced by the *shoot tip* become concentrated (shown by heavy shading) on the side opposite the *light source*. Since the hormones are transported only directly downward in the *stem*, hormonal concentration in the zone of *cell elongation* is also unequal. The result is greater growth, by *cell elongation*, on the side of higher hormone concentration and the curvature of the *stem* toward the light.

When the direction of *stem* growth is once again in line with the *light source* (as in the diagrams on the right), hormonal concentration once again becomes equal throughout the *stem*. *Cell elongation* (as in the tip of the far right diagram) is also once again equal within the zone of *cell elongation*, and the *stem* continues growth directly toward the repositioned light source.

On the diagrams labeled "geotropism," color the previously listed features and the root (F), root tip (G), and direction of gravitational pull (H). Choose a light color for the root (F) and root tip (G).

Geotropism is a plant growth response due to gravitational pull (*gravity*). In plants that normally grow vertically, growth hormones produced by the *shoot tip* and, in the *root*, by the *root tip* are evenly distributed at any given level within the *stem* and *root*. If such a plant is repositioned in a horizontal position (as shown in the middle diagram), geotropic responses can be observed. If a plant is positioned horizontally, hormone concentration within *root* and *stem* become localized on the lower side of the *root* and *stem*. In the *root*, a positive geotropic response is observed as the *root* bends downward into the soil. This is apparently due to the inhibition of *cell elongation* in *root* cells by high concentrations of hormones. Also, growth inhibitors, produced by the *root tip*, transported upward, and then localized on the lower side of the *root*, may be involved.

In the *stem*, a negative geotropic response (growth away from the direction of gravitational pull) is observed as the *stem* bends upward away from the surface. As in a phototropic response, *stem* curvature is due to high concentrations of growth hormones, in this case, on the lower side of the *stem*, that enhance *cell elongation* in that area.

On the diagrams labeled "apical dominance," color the previously listed features and the lateral branches (J).

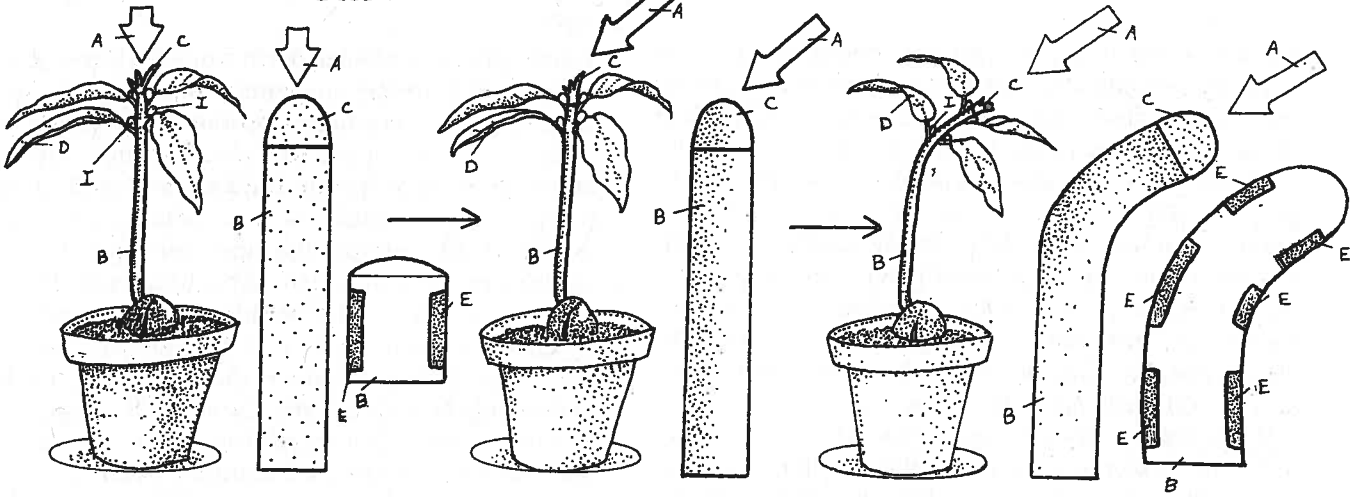
Apical dominance, the inhibition of the development of *axillary buds* into *lateral branches*, is due to the suppressive effects of hormones produced by the growing *shoot tip*. The degree of inhibition among plant species varies and accounts for some differences in growth form. In plants with strong apical dominance, there may be no *lateral branch* formation from *axillary buds* for several nodes below the *shoot tip*. The result is a well-developed, single-stemmed plant.

One means of overcoming apical dominance is by removing the *shoot tip*. Once the *shoot tip* is removed, its hormone production is eliminated. Hormone concentration in the *stem* diminishes, and a number of *axillary buds*, especially those nearer the cut *stem* tip, become active and begin growth.

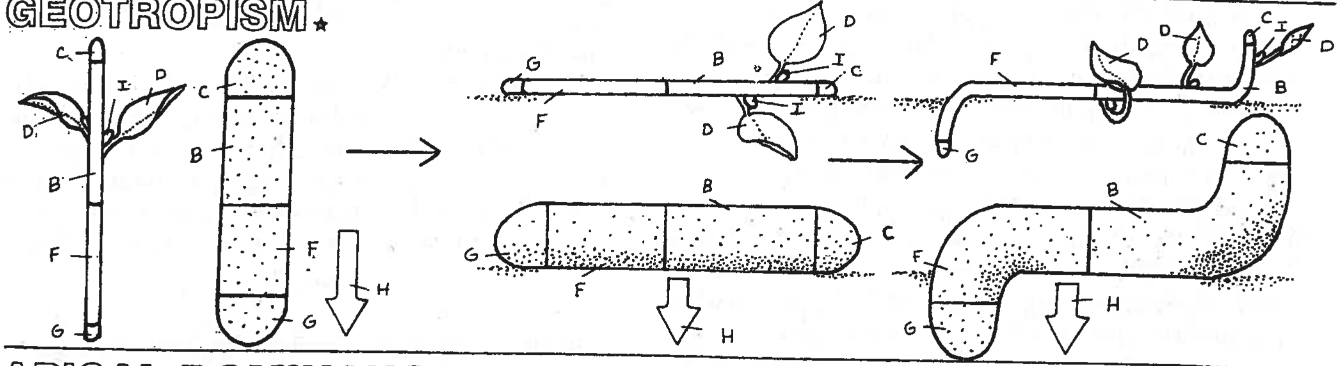
PLANT HORMONE ACTION.

LIGHT SOURCE A
STEM B
SHOOT TIP C
LEAF D
CELL ELONGATION E
ROOT F
ROOT TIP G
GRAVITY H
AXILLARY BUD I
LATERAL BRANCH J

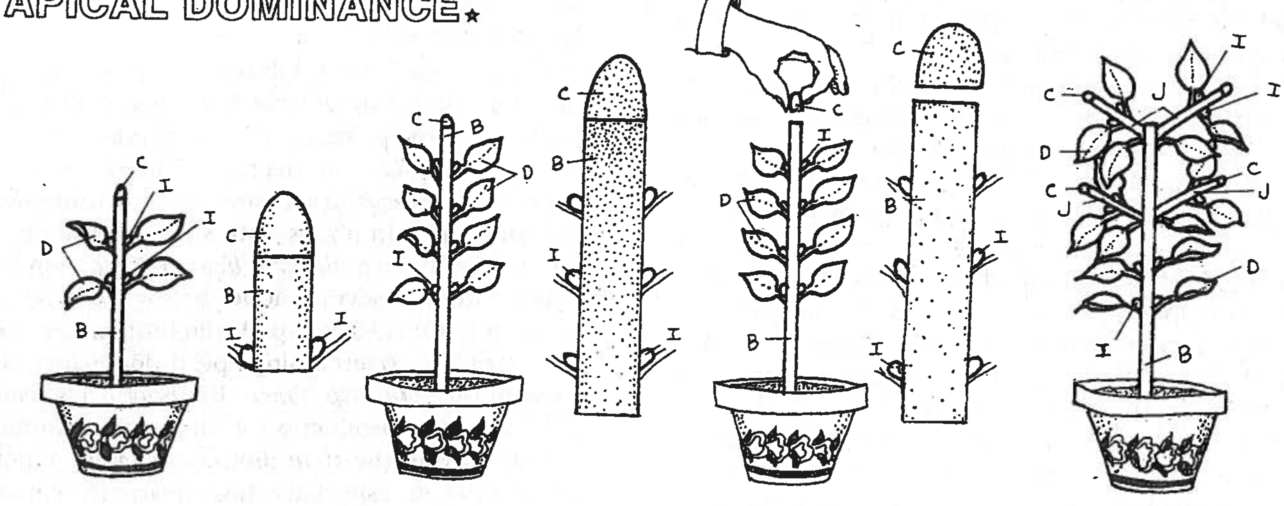
PHOTOTROPISM*



GEOTROPISM*



APICAL DOMINANCE*



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72
STORING FOOD RESERVES

Color the roots (A) and stem (B), leaves (C), and renewal buds (D) of the shoot systems on the three illustrations of bulbs at the top of the plate.

Food storage structures primarily function in the storage of excess food materials, mostly in the form of starches and oils, that were produced by photosynthesis during active growth. They may also function in water storage. Food storage structures are most common in herbaceous perennial plants that die back to ground level or below during dormancy. In most of these plants, the food storage structures function as a reserve energy source for the maintenance of life processes during the dormant period when the plant has no photosynthetic surfaces to manufacture food materials. In biennial and perennial plants, the stored food reserves also provide the plant with an adequate energy supply for rapid shoot establishment during the next growing season. In some plants, food storage structures function as asexual reproduction units, with an ample self-contained energy source to facilitate the successful establishment of new plants.

Food storage structures that function to carry a plant through dormancy are usually produced below ground and consist of highly modified *roots, stems,* or *leaves*. The renewal *buds*, the *buds* that will initiate the next season's growth, are usually at or below ground level. On the other hand, food storage structures that double as asexual reproductive units are produced either above or below ground.

True bulbs consist of compact clusters of thick, fleshy, food storage *leaves*. The reduced *stem* is buried within the *leaves* at the base of the bulb. *Roots* seasonally grow from the base of the *stem*, which has one or more renewal *buds*. An onion bulb consists of concentric layers of tubular, fleshy, food storage *leaves*. Each *leaf* is shaped like a narrow-necked pot. Onions produce one to few renewal *buds*, but a garlic bulb typically has several. In a garlic bulb, each renewal *bud*, along with its surrounding *leaves*, usually one to a few, is called a garlic clove. In many bulbous plants, such as many lilies, the fleshy food storage *leaves* are scalelike and overlapping instead of tubular and sheathing, as in the bulbs of onions and garlics.

Color the roots (A), stem (B), leaves (C), and buds (D) of the corm, rhizome, and tuber illustrated in the middle of the plate.

In some plants, the *stems* or portions of the *stems* form dense, fleshy food storage structures. Corms, fleshy rhizomes, and tubers are types of food storage *stems*. Corms are enlarged, vertically oriented *stems* that often have a flattened globose shape. Since they are *stems*, they have nodes and internodes, but little internodal elongation occurs. A corm's surface is often covered with overlapping layers of dry, papery, scalelike *leaves*. *Roots* may arise from the top of the corm, throughout the corm, or from its base, depending on plant species. The one to few renewal *buds* are located at the top of the *stem*. Corms are typically expended each season, and a new one arises from the top of the previous season's corm, which forms a hardened "basal plate" (not colored) below the new corm. Gladiolas and crocuses produce corms.

Rhizomes and tubers are usually horizontally positioned. Rhizomes are underground *stems* that elongate by seasonal growth. Those modified for food storage, such as an iris rhizome, are thick and fleshy. Growth, due to a terminal renewal *bud* at the tip of each rhizome branch, produces the current season's *leaves* and additional rhizome material. Rhizome branches develop from the axillary *buds* along the rhizome. *Roots* arise along the length of the rhizome.

Tubers are fleshy, enlarged, food storage stem structures produced on a slender, elongate rhizome or on an above-ground *stem*. In the potato, a slender rhizome is terminated by a tuber. The "eye" of a potato tuber (*stem*) consists of a reduced *leaf* (the "eyebrow") and one or more axillary renewal *buds*. Each axillary *bud* may develop into a shoot. In other plants, such as the air potato, above-ground *stems* produce tubers at nodes.

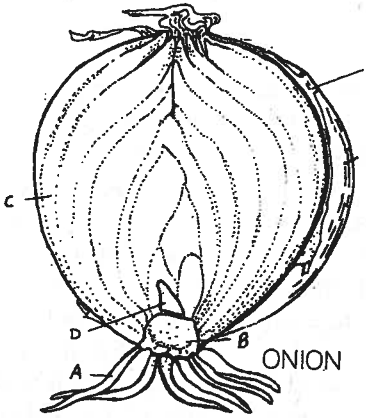
Color the roots (A), stems (B), leaves (C), and buds (D) on the illustrations of storage roots at the bottom of the plate.

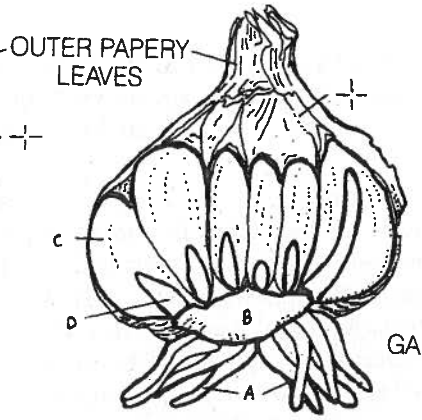
Food storage roots, both clustered tuberous roots and some specialized tap roots, are found in many plant groups. Some plants, such as dahlias and buttercups, have tuberous roots; carrots have tap roots for storage. The renewal *buds* of most storage roots are at the base of the *stem* at the top of the *root*. In these, root material alone will usually not produce a new shoot. In other storage roots, such as the sweet potato, renewal *buds* form scattered on the *root*.

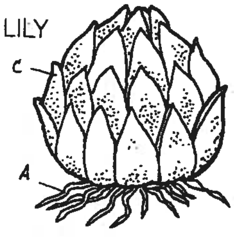
As regions of concentrated food storage, many of these structures are used by humans as a food source. Also, since most of these structures are dormant at some time, they provide a convenient unit for storage and transportation. Most have historic and contemporary importance in human mediated dispersal, but due to their often subterranean position, many have limited importance in natural dispersal.

FOOD STORAGE STRUCTURES

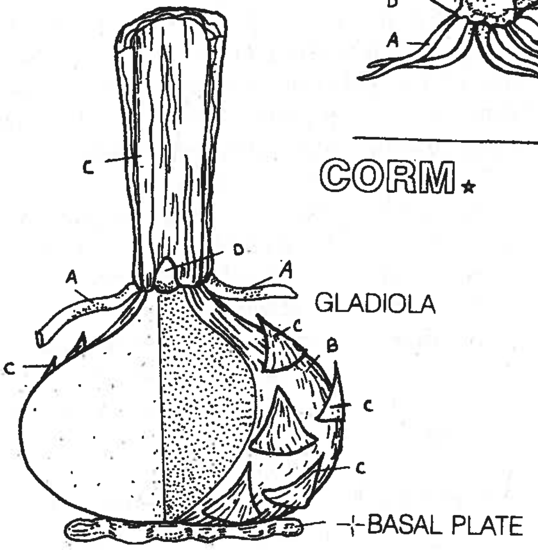
BULB ★



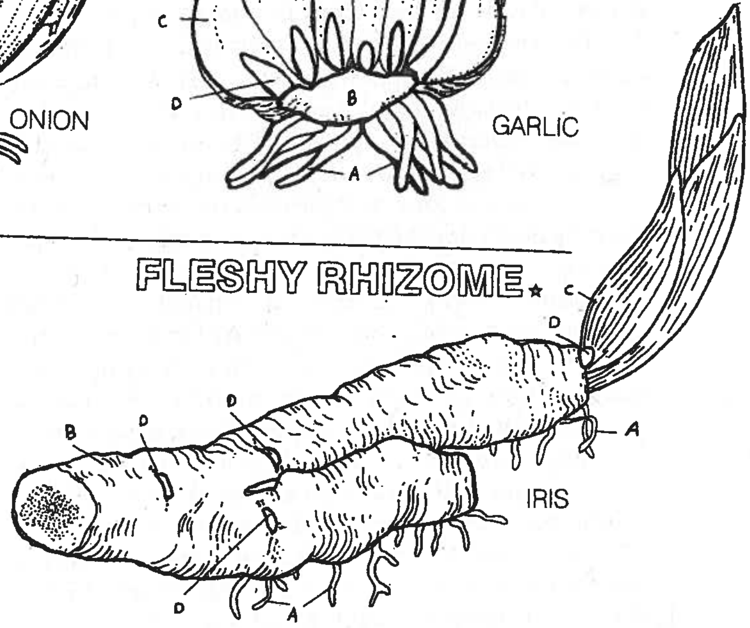




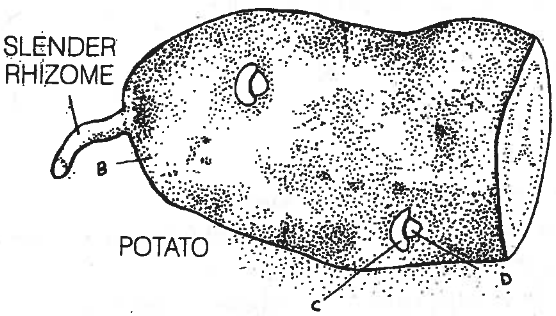
CORM ★

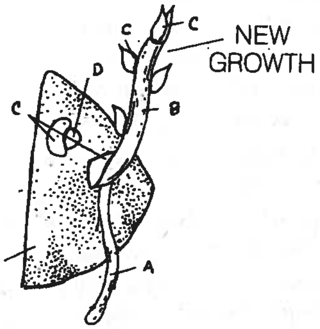


FLESHY RHIZOME ★



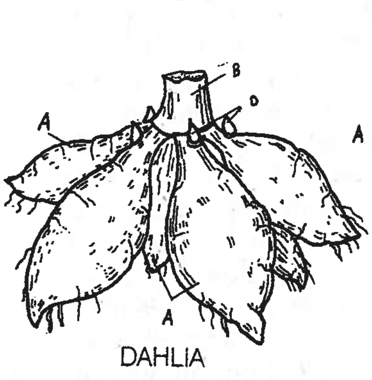
TUBER ★

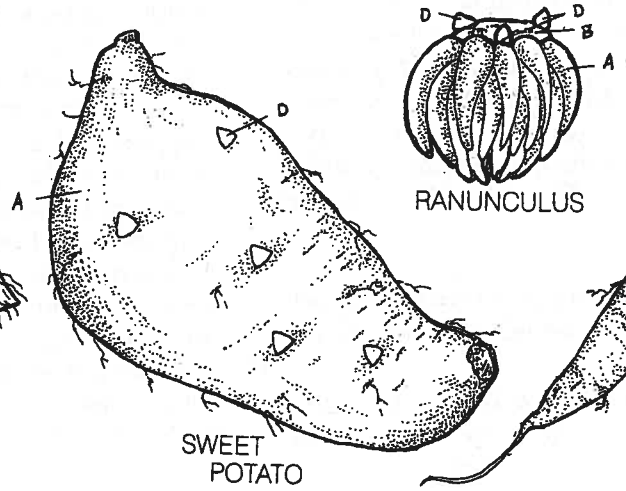


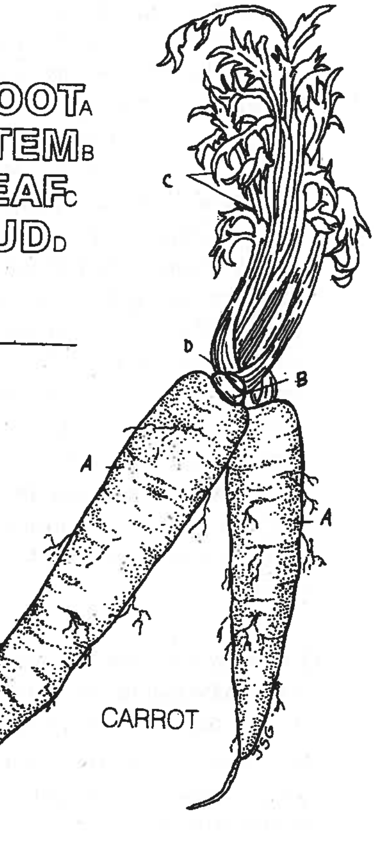


ROOT A
STEM B
LEAF C
BUD D

STORAGE ROOT ★







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