Basic Botany
Straightforward Science for Master Gardeners

Joran Viers

Horticulture Extension Agent

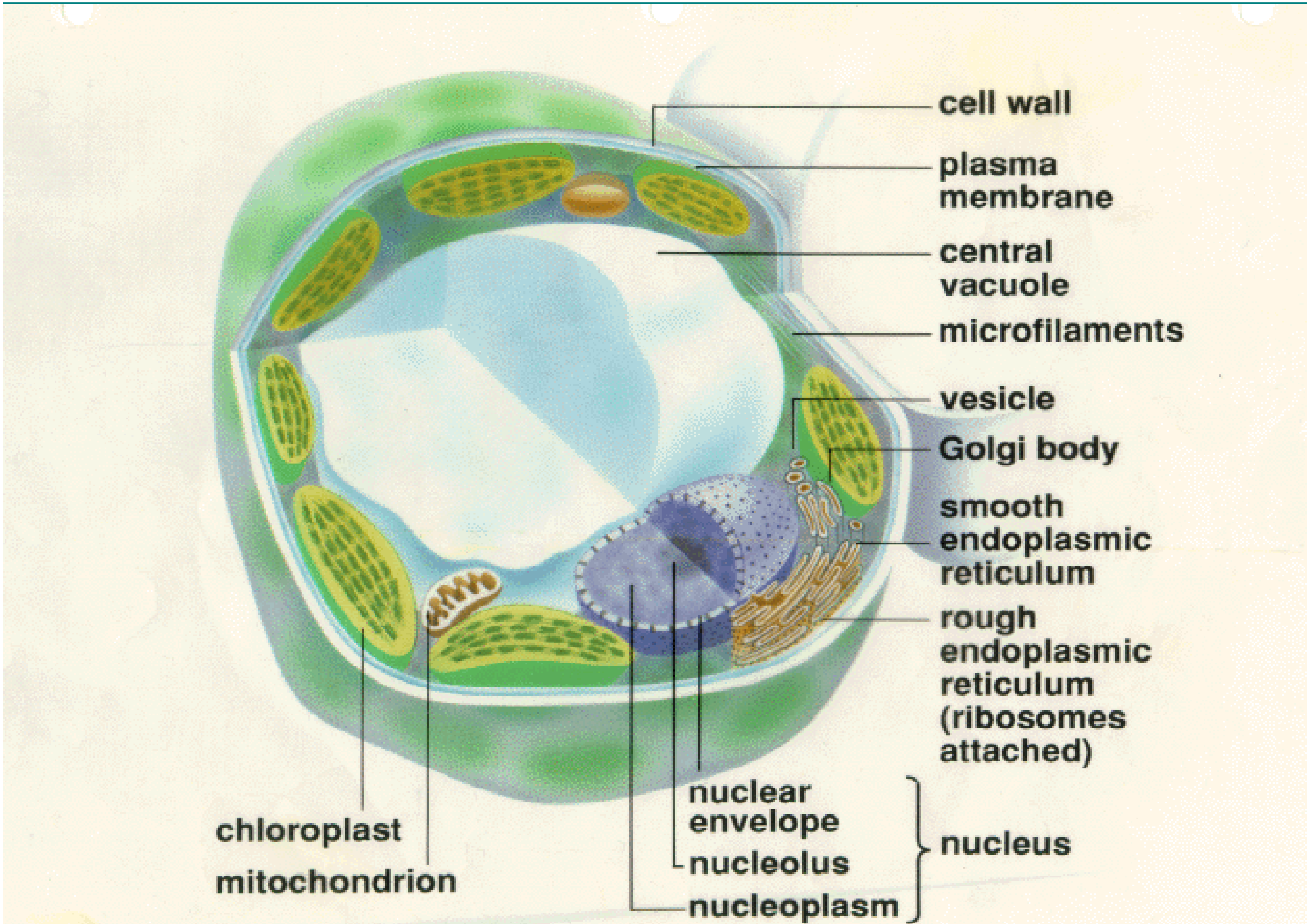
Bernalillo County Cooperative Extension Service

Botany is…

- The branch of Biology focusing on plants; the scientific study of plants.
- For our purposes, three levels of interest:
  - Function: photosynthesis, respiration, growth, reproduction.
  - Form: tissues, tissue systems, plant types (forbs, shrubs, trees, vines), plant associations, ecosystems.
  - Family: evolutionary relatedness of plants.

Functions

- Photosynthesis: how plants make sugars from light, water and CO_2
- Respiration: how plants extract energy from sugars
- Growth: how plants increase in size
- Reproduction: how plants “begat” into subsequent generations



Generalized sketch of a plant cell.

Photosynthesis

General equation:

$$6CO_2 + 12H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Two-steps : first the **light** reaction and then the **dark** reaction. The first depends on light to trap and store energy, the second uses that energy to fix carbon, taking it from CO2 and putting it into simple sugar molecules, from which all other living (organic) molecules are built.

Photosynthesis, continued

Photosynthesis is accompanied by photorespiration, a process which consumes oxygen and releases CO_2; under normal conditions, as much as 50% of the carbon fixed in photosynthesis is lost through re-oxidation to CO_2 during photorespiration; the higher the temperature, the more is lost.

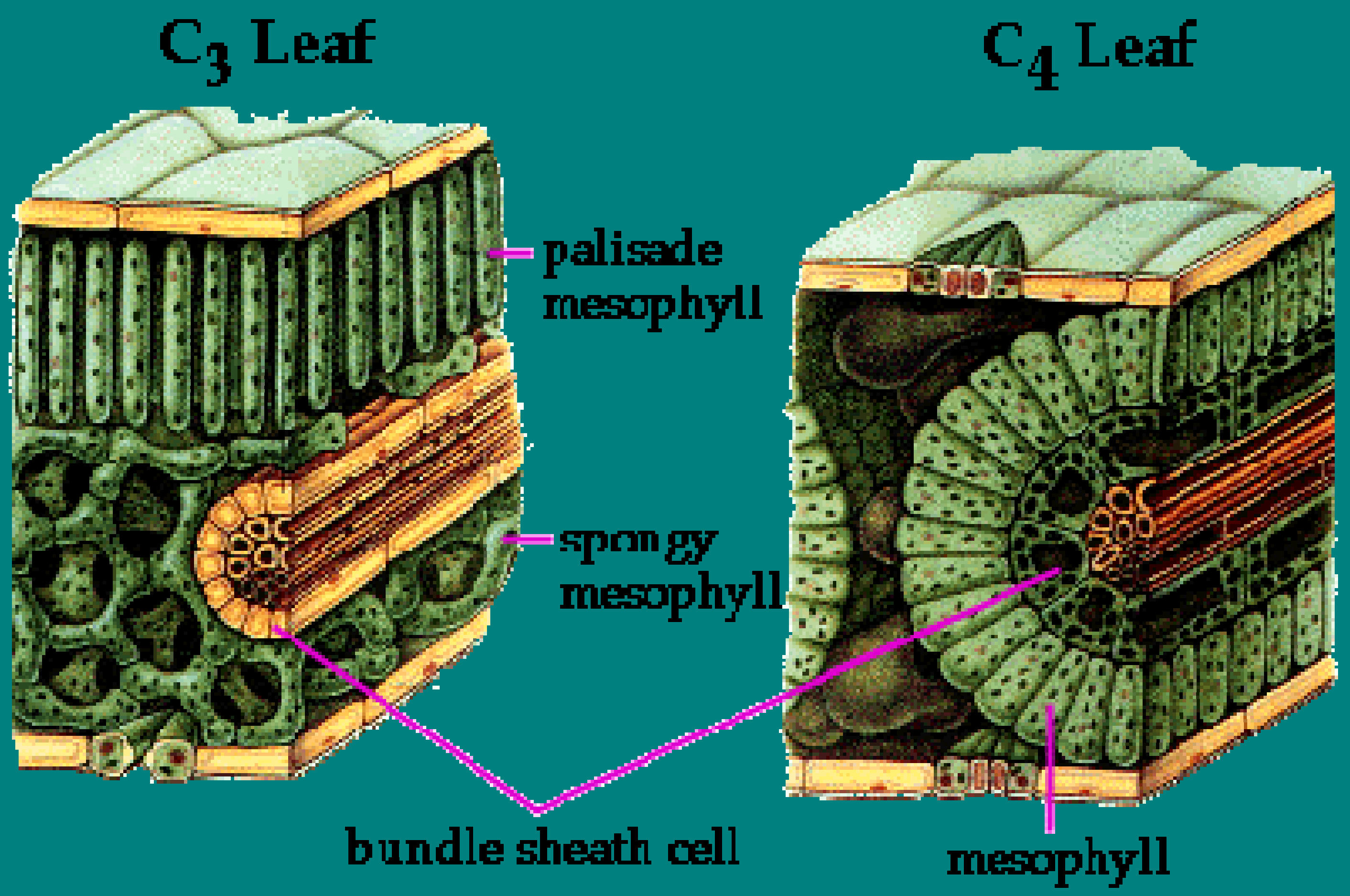
Some plants have evolved different photosynthetic pathways, which are less energy-efficient but more carbon-conserving and thus more effective at high temperatures and under dry conditions.

Alternative Photosynthetic Pathways

C_4: fixed carbon is pumped into specialized cell groups called bundle-sheaths. The result is that net photosynthetic rates in C4 grasses (corn, sorghum, bermuda) can be 2-3 times that of C_3 grasses (wheat, oats, Kentucky blue grass) – but only at high temperatures!

CAM: crassulacean acid metabolism; common in succulents. CO_2 is fixed during the dark (limiting water loss), into malic acid. During the day, while stomata are closed, the malic acid is decarboxylated, and the carbon then proceeds through the chemical process to form simple sugars. CAM photosynthesis is common in a wide variety of plant families, including cacti, succulents and even pineapple.

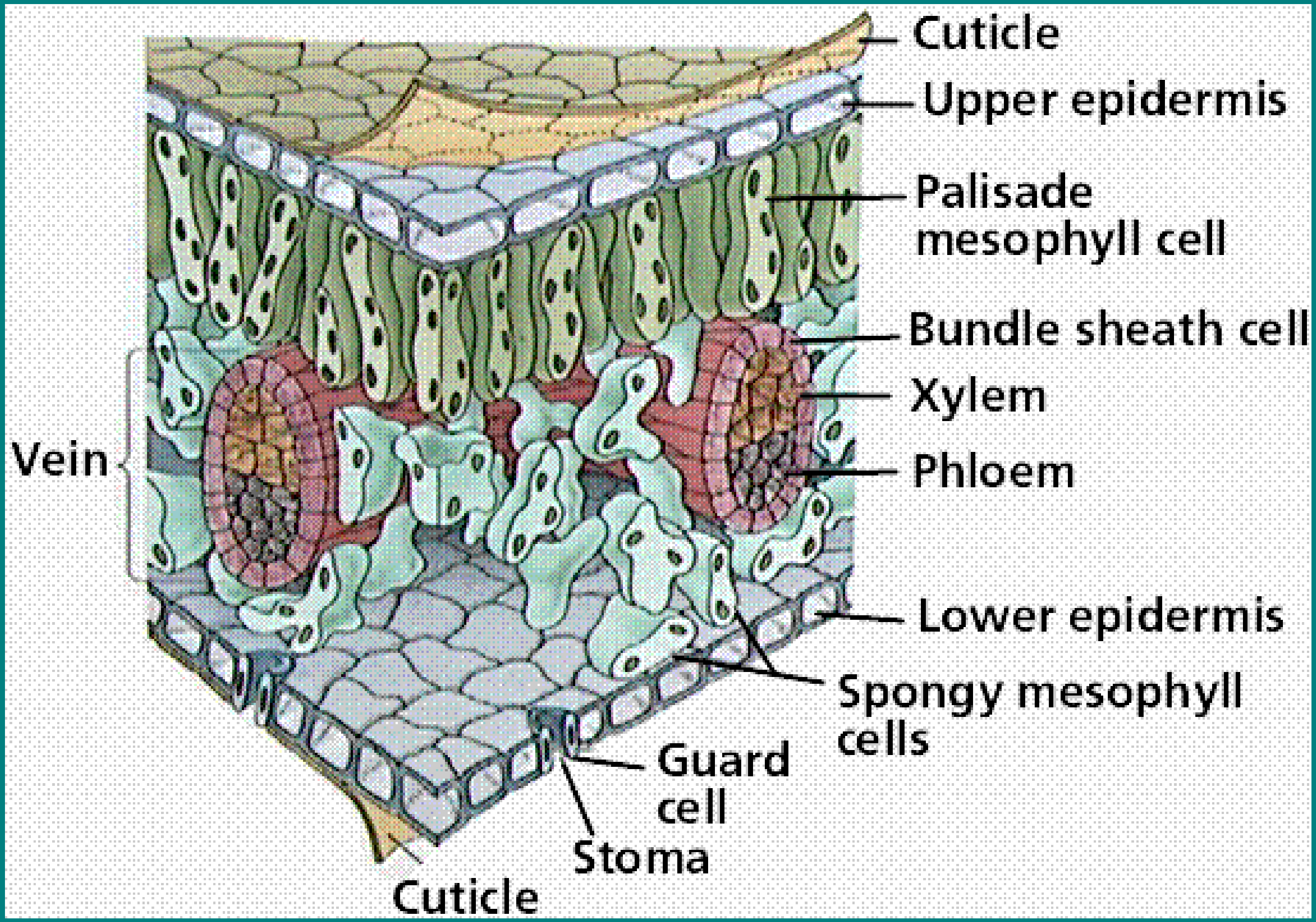
Alternative Photosynthetic Pathways



Photosynthesis

This important plant function occurs in small organelles, called chloroplasts, that are found within certain cells (typically in leaves, maybe in stems). Chlorophyll is a molecule which has the property of responding to light energy in a certain way, which allows the plant to capture that energy.

Photosynthesis occurs in the chloroplasts of the palisade mesophyll cells



Respiration

Plants get energy for metabolic activities in the same way as animals: carbohydrates are broken apart and energy is released.

The carbohydrates come from the results of photosynthesis, i.e. the basic glucose molecule: $C_6H_{12}O_6$

Respiration, cont.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

This is basically a reversal of the photosynthetic reaction. One brings energy into the system, the other frees that energy for use by the plant cells. Respiration takes place in the mitochondria bodies within plant (and animal) cells – they are the cell's "power plants".

Growth

Plants growth is modular. They add mass by adding modular units: leaves, branches, etc. There is no pre-determined number of these units, and removal of some does not (usually) cause ongoing problems for the plant – they simply grow replacements. Contrast this to animals – who here can re-grow a lost hand or foot?

Plants grow both by adding new cells and by increasing the size of existing cells.

Growth, cont.

Plant growth occurs at the meristems. These are regions containing dividing cells that are capable of becoming different kinds of tissue; as they mature, they differentiate into the appropriate tissue type for where they are on the plant.

Meristems are found in certain places in the plant body

Meristems

Apical meristem: found in buds at shoot tips and lateral buds, also in root tips. Primary: originate within seed, source of new meristem tissue; secondary: formed from cells previously not meristematic (often in response to wounding).

Cambium: responsible for lateral growth (increase in girth of perennial woody dicots; produces phoem and xylem.

Cork cambium: produces bark.

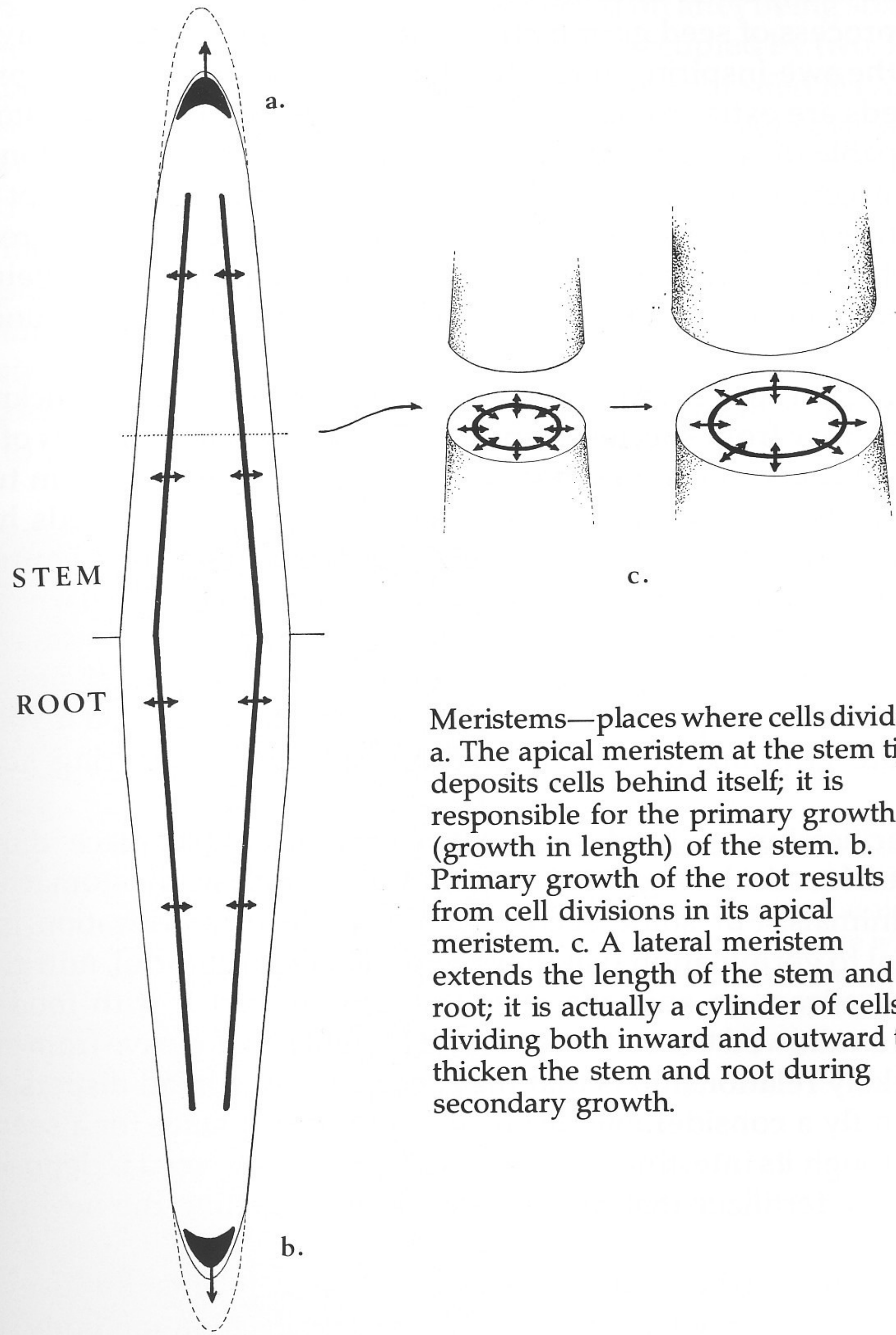
Intercalary meristem: found in monocots, at base of leaves.

Growth, cont.

As meristematic cells divide into two, one cell remains in meristem region (termed initials), the other differentiates into some other tissue type (termed derivatives). This keeps the meristem alive and active.

The derivative cells go through a period of elongation just after “deriving”; this elongation accounts for much of the physical size increase in plant tissue.

From: Botany for Gardeners, by Brian Capon

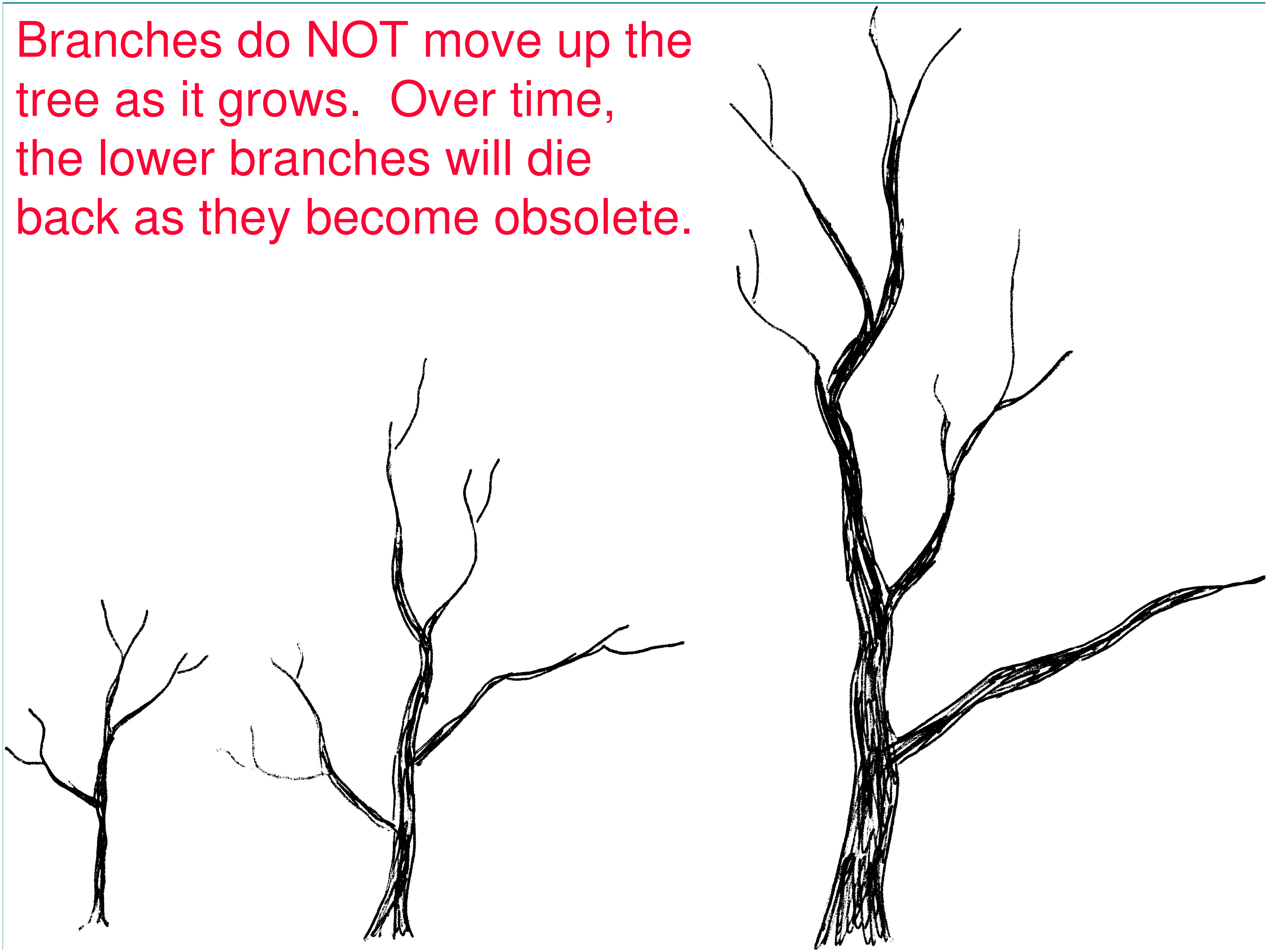


Meristems—places where cells divide. a. The apical meristem at the stem tip deposits cells behind itself; it is responsible for the primary growth (growth in length) of the stem. b. Primary growth of the root results from cell divisions in its apical meristem. c. A lateral meristem extends the length of the stem and root; it is actually a cylinder of cells, dividing both inward and outward to thicken the stem and root during secondary growth.

Secondary growth

Growth resulting from the lateral meristems (cambium), results in increase in girth of woody plant trunks and branches. As the meristem cells divide, those to the outside become phloem, those to the inside xylem tissue.

Branches do NOT move up the tree as it grows. Over time, the lower branches will die back as they become obsolete.



Reproduction

Plants reproduce both sexually and clonally. Clonal, or vegetative, reproduction involves the formation of small bodies capable of becoming a full-fledged plant, but having the same genetic makeup as the parent plant. These "bodies" may be small plantlets (spider plant), or simply leaves (jade plant), or other structures (garlic cloves).

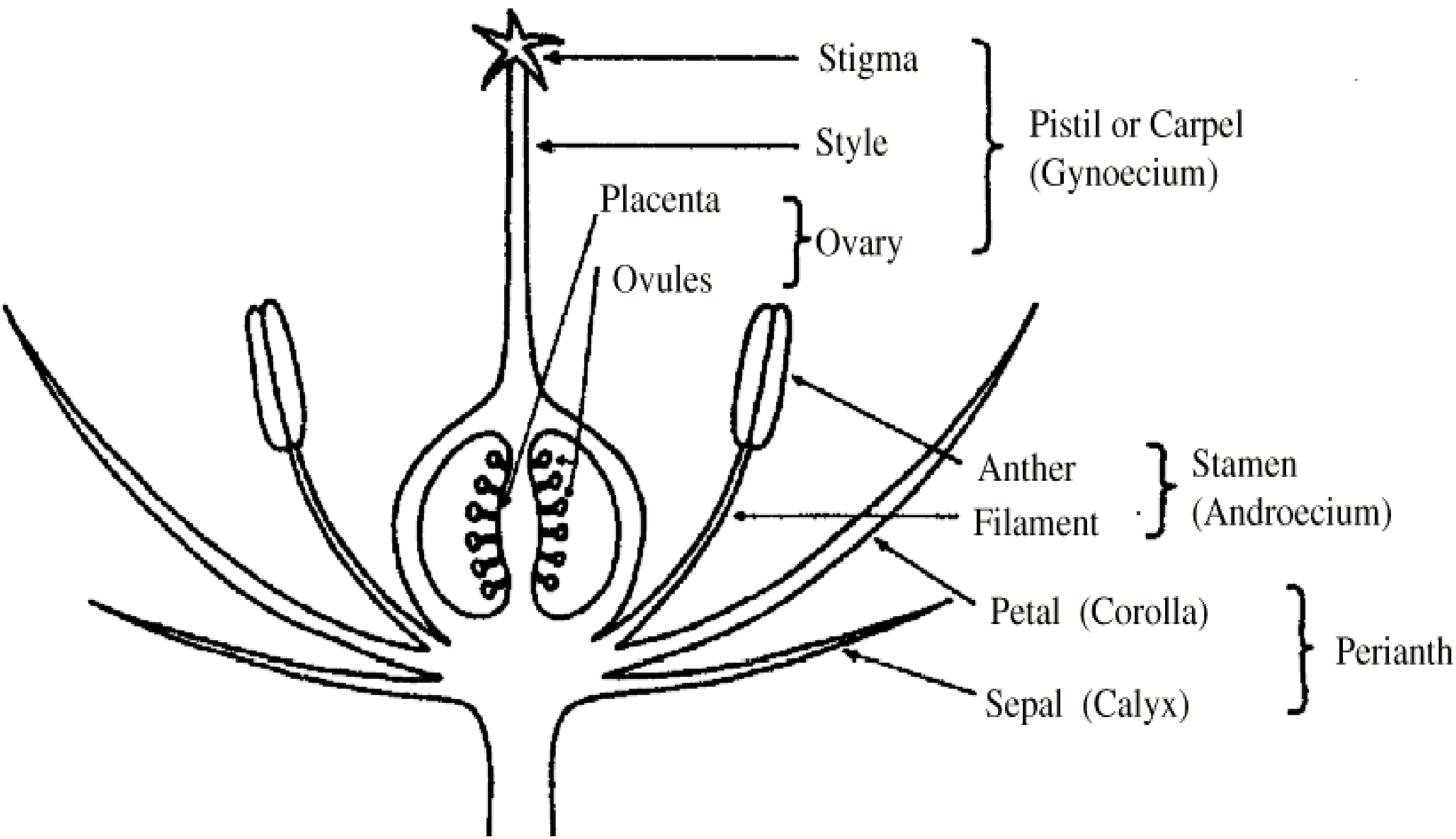
Vegetative reproduction

Reproduction, cont.

Plants produce seeds as the result of sexual reproduction between two genetically distinct individuals, with the new plants (contained within the seeds) having a unique blend of the parents genes. Two types of reproductive structures:

- cones (found on gymnosperms)
- flowers (found on angiosperms).

Schematic of a Complete, Perfect Flower



Flowers…

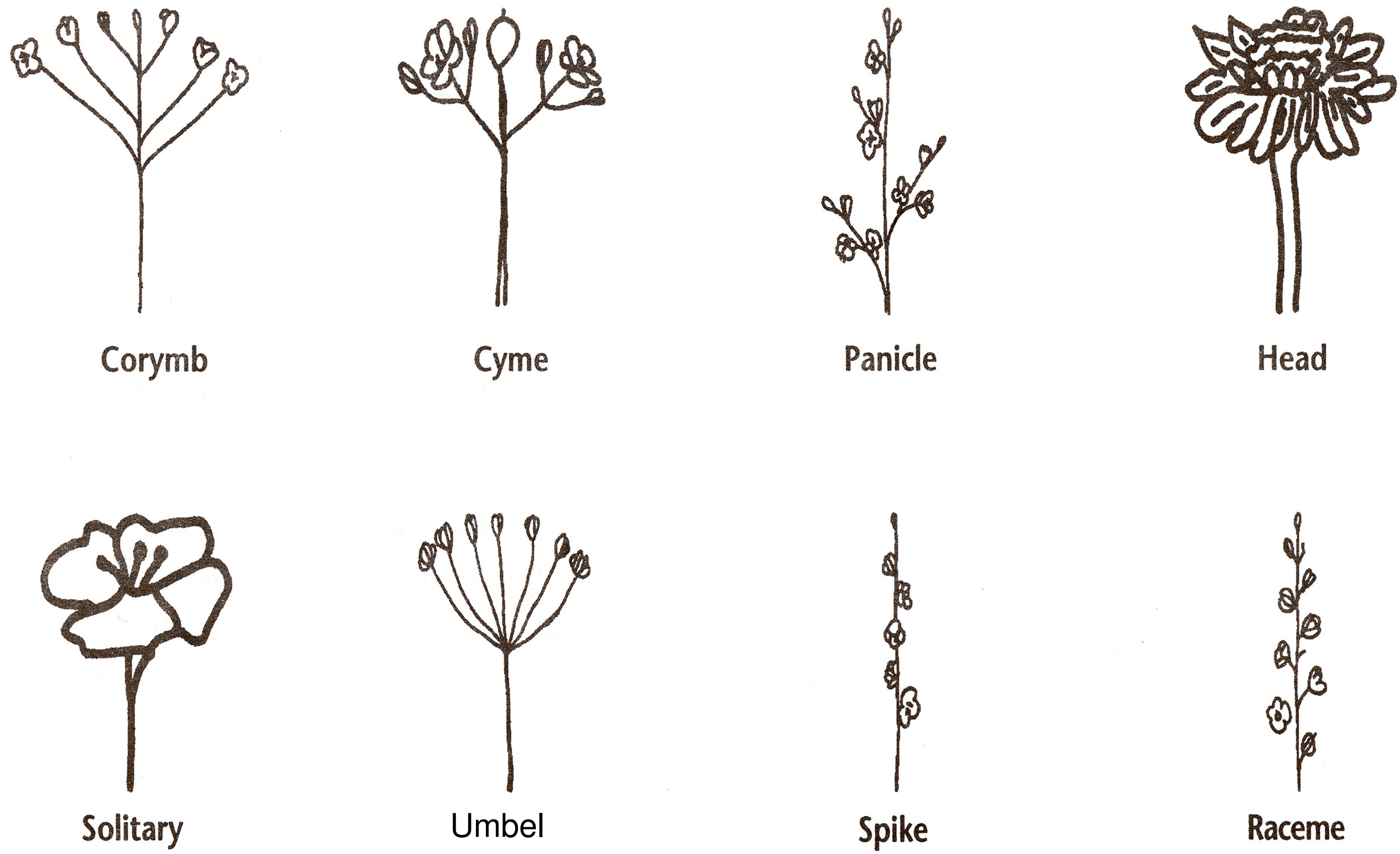
Lupine

Rudbeckia

Iris

Columbine

Inflorescence types



Reproduction, cont.

Two things must happen for seeds to be viable:

- First, flowers must get pollinated – pollen from compatible flower lands on stigma, pollen tube grows out from the pollen into the stigma and style, and sperm cell migrates down pollen tube to the egg cell.
- Then, sperm and egg cells, both being gametes with only one set of chromosomes, need to unite into a zygote with two sets of chromosomes in process called fertilization. The ovule becomes the seed, while the ovary tissue around it becomes the fruit.

Reproduction, cont.

Pollination requires moving the pollen from anthers to stigma. In many plants, this is done by wind. Pine, oak, mulberry, kochia, grasses, junipers…most of the allergenic pollens come from wind-pollinated plants.

In addition to wind, flowers may be pollinated by beetles, bees, wasps, flies, moths, butterflies, birds, bats…a long list of agents can help in pollination, though not with that specific intent.

Reproduction, cont.

Gymnosperms are typically wind-pollinated. Animal-assisted pollination did not evolve until after the evolution of the angiosperm flower. Insects that fed on plants' flowers carried some pollen from flower to flower. Over time, plants and animals coevolved a number of characteristics that make the pollination process more efficient.

AGENT	POLLEN & FLOWER CHARACTERISTICS	ENDUCER/ ENTICEMENT	OTHER
Wind	Abundant, smooth, small pollen grains Dull colored flowers, small or absent petals, sexes often separate; well-exposed stamens and stigmas	None	More common in temperate regions than tropical
Beetles	Large flowers borne singly, or small and aggregated into inflorescence, white or dull color, strong odor (spicy, fruity or fetid, not sweet)	May secrete nectar, or the petals or specialized food bodies eaten directly`	
Bees and other Hymenoptera	Showy, bright petal of yellow or blue color; nectarines at base of corolla tube	Nectar, pollen, sexual trickery	Bees are most common pollinator worldwide.
Birds	Red and yellow, low odor; flower shape restricts access to nectar to appropriate animals only	Heavy nectar loads	
Butterflies	Similar to bee flowers, may include reds	Nectar	
Moths	Night flowering, heavy sweet fragrance, white or pale color	Nectar	
Bats	Large, strong flowers, dull colored, night opening, strong fermenting/fruit-like odors; Copious nectar	Many bats eat pollen; pollen from bat-pollinated species tends to by high in protein compared to insect-pollinated plants.	

Pollinator Table

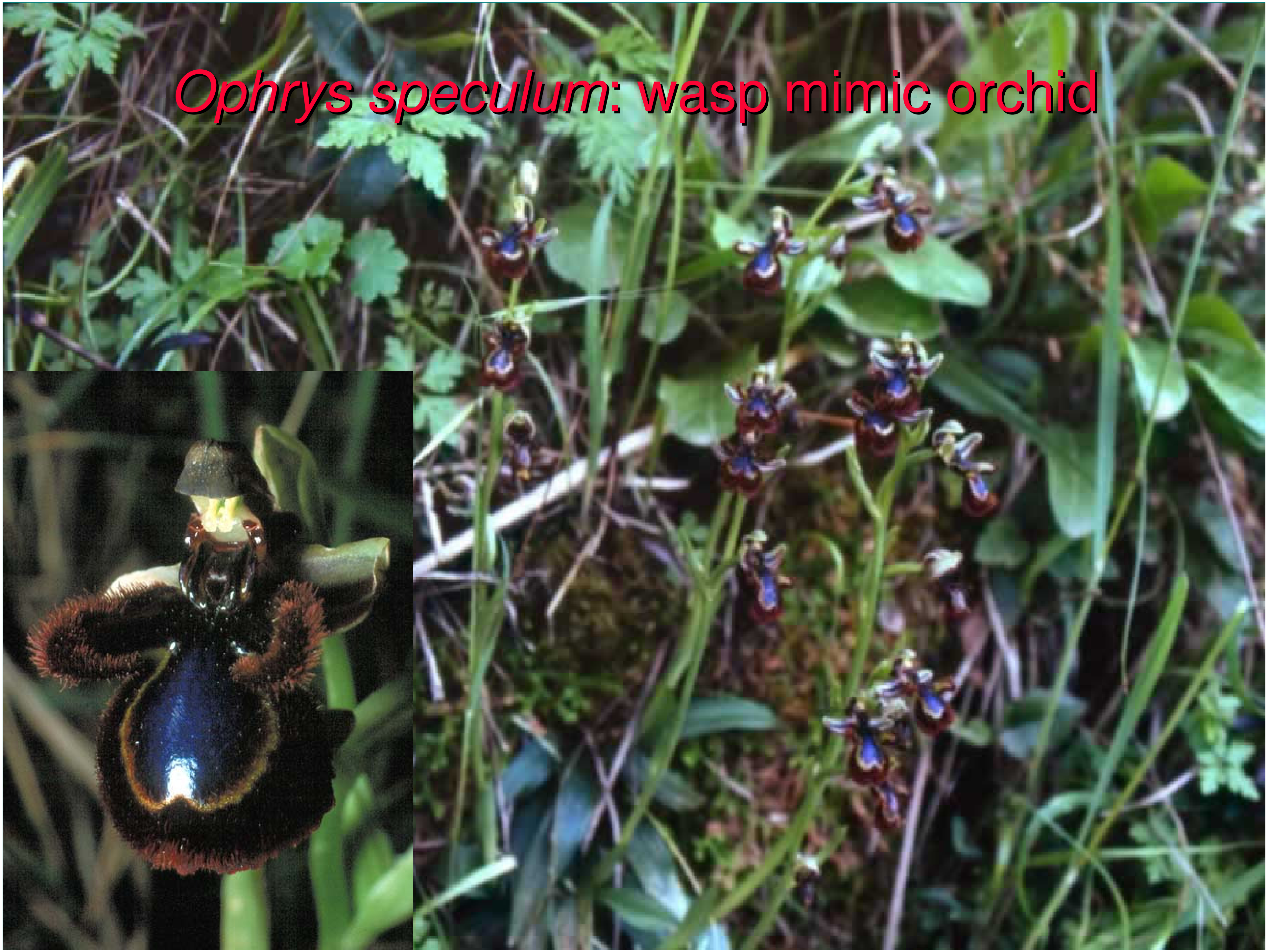
Reproduction, cont.

Plants have to reward animals somehow; typically, nectar is provided as food source, although pollen may be eaten.

Some orchids have flowers that so resemble female bees that males attempt to copulate, thereby picking up and distributing pollen to other flowers.

Some fly-pollinated flowers smell like rotting meat, which bring in carrion flies attracted by the possibility of a meal. While searching for the rotting meat, the flies brush up against anthers and stigmas, thus pollinating the trickster plants.

Ophrys speculum: wasp mimic orchid



Stapelia schinzii and *Symplocarpus foetidus*: carrion-scented flowers

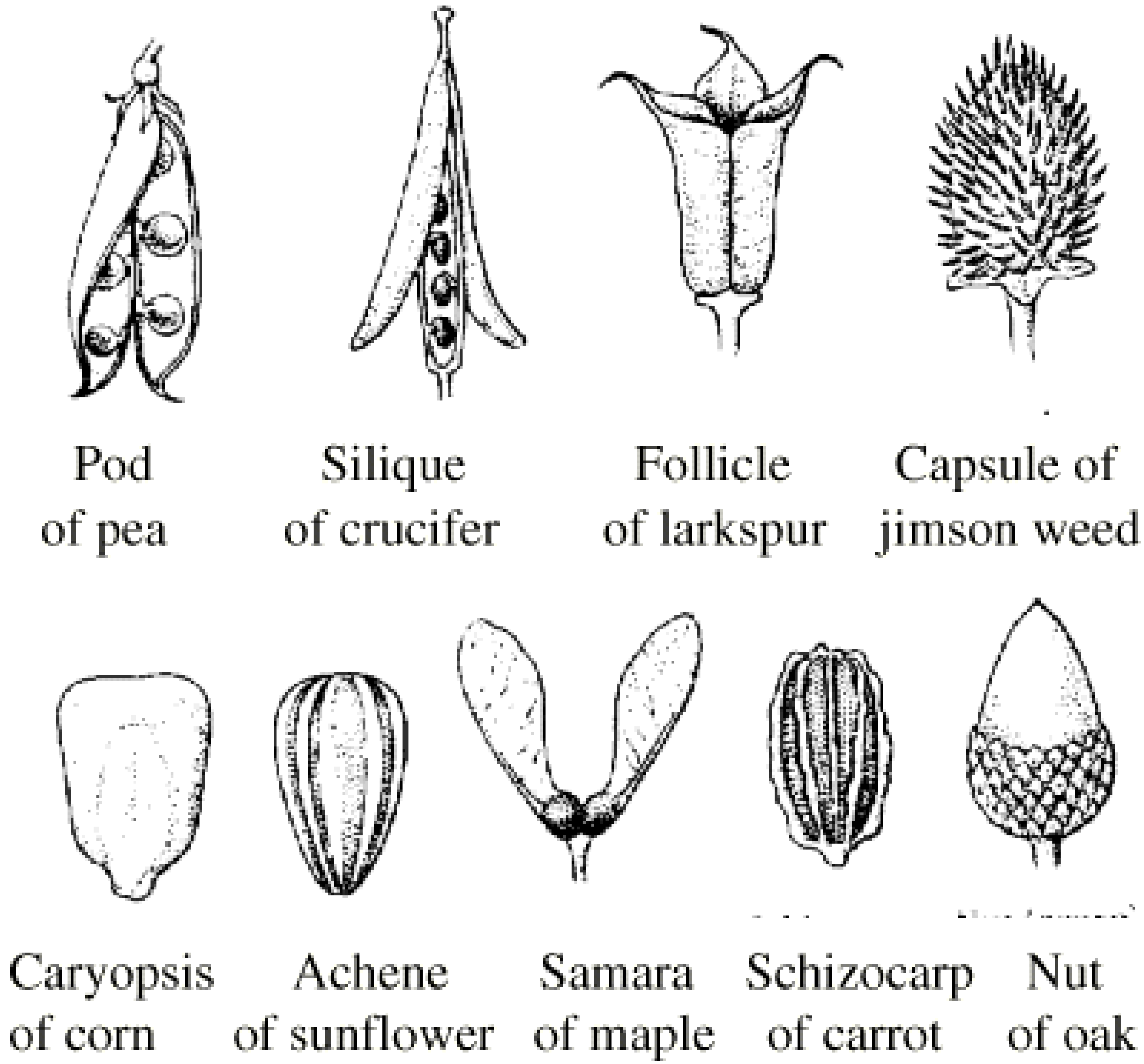
Reproduction, cont.

Once the seeds mature, they need to get out into the wider world. Here is where fruit come in. Fruit structures provide a means of dispersal.

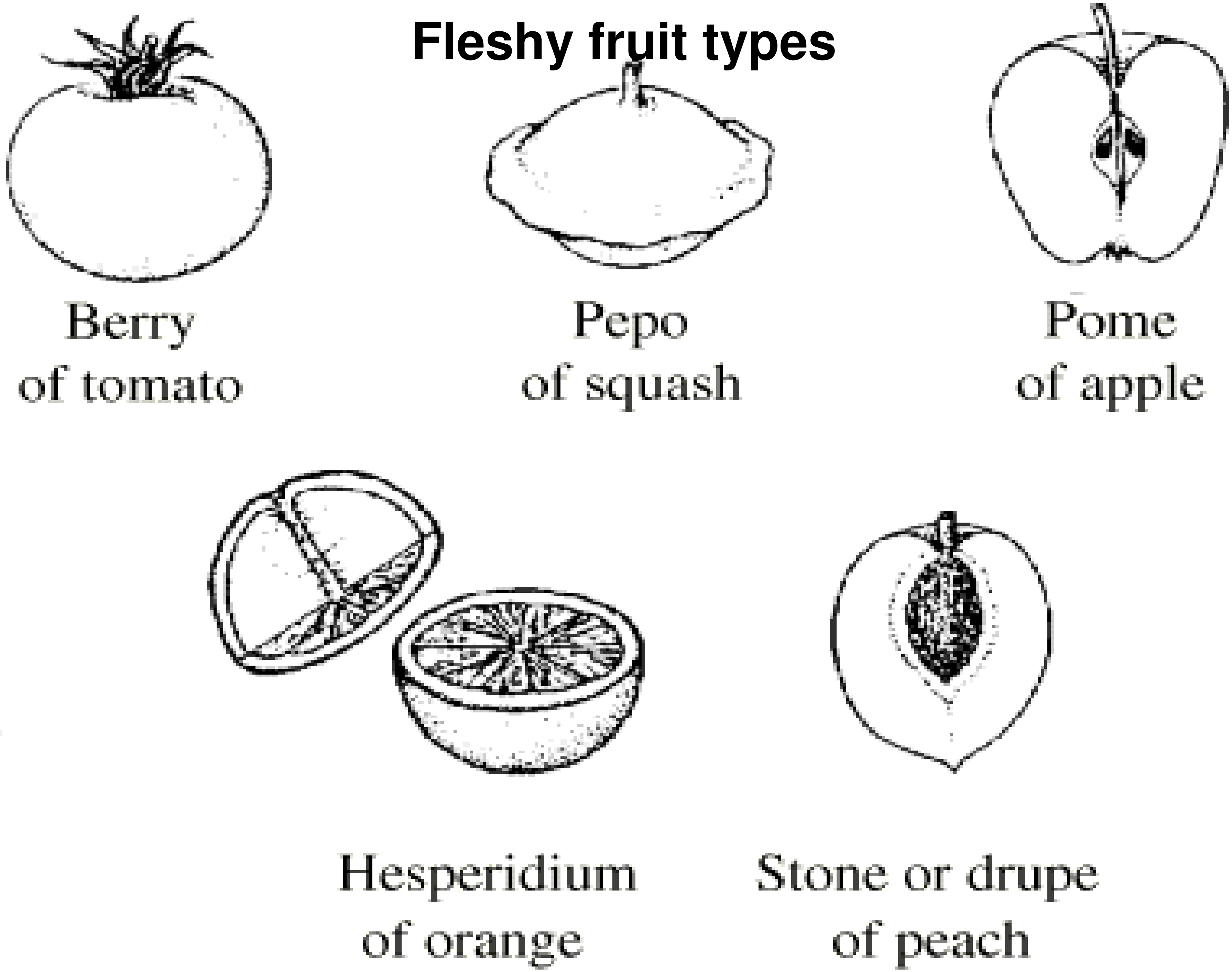
Some structures provide for purely physical dispersal, such as winged fruits of four-wing saltbush, or barbed fruit of puncture vine. Many are adapted to attract animals, which consume the fruit and then deposit seeds at some other site, usually in a fertilizer packet.

Dry Fruit Types		
Name	***Characteristics***	***Examples***
Follicle	Dehiscent; from single carpel that splits down one side at maturity.	Columbine, milkweed
Legume	Dehiscent; like follicles, but split down both sides.	Pea family (Fabaceae)
Silique	Dehiscent; from two fused carpels; at maturity the sides split off, leaving seeds attached to persistent central portion.	Mustard family (Brassicaceae)
Capsule	Dehiscent; from compound ovary with either superior or inferior ovary	Poppy family (Papaveraceae)
Achene	Indehiscent; small single-seeded fruit, seed lies free in the cavity except for attachment by funiculus (stalk of the ovule).	Buttercup family (Ranunculaceae), buckwheat family (Polygonaceae)
Samara	Indehiscent; winged achenes.	Elm, ash
Caryopsis	Indehiscent; achene-like fruit of grasses; seed coat firmly united to fruit wall.	Grass family (Poaceae)
Cypsela	Indehiscent; achene-like, complex; derived from inferior ovary.	Sunflower family (Asteraceae)
Nut	Indehiscent; achene-like, with stony fruit wall and derived from compound ovary.	Acorn, hazelnut, pecan
Schizocarp	Indehiscent; splits at maturity into two or more one-seeded portions.	Parsely family (Apiaceae), maples (Aceraceae), some others.

Dry Fruit Types



Fleshy fruit types



Form

The form, or structure, of plants can be thought of at different levels, from individual tissues to tissue systems, plant types (forbs, shrubs, vines, trees, etc.), up to plant associations (Pinyon-juniper woodland) to ecosystem level.

We can also consider form in terms of parts: roots, shoots, leaves, flowers, etc.

Form, cont.

Tissue: group of cells that are structurally and/or functionally distinct; simple tissue has one cell type, complex tissue has multiple cell types.

There are three basic plant tissue types:

1. Ground, or fundamental, tissue system;
2. Vascular tissue system;
3. Dermal tissue system.

These tissue systems are present in all parts, as in roots, stems, leaves, flowers; this indicates the basic similarity of plant organs and the continuity of the plant body (modular nature).

Form, cont.

Ground tissue system has three tissue types:

1. Parenchyma: progenitor of all other types; common as continuous masses in cortex of stems and roots, in stem pith, in leaf mesophyll and fruit flesh.
2. Collenchyma: common in discrete strands or continuous cylinders in stems and petioles (celery strings are mostly collenchyma).
3. Sclerenchyma: often lack protoplasts at maturity; have thick, lignified secondary cell walls (strengthening and supporting function); fibers (long, slender cells in strands or bundles) and sclerids (short, variable shape; seed coats, nut shells, grittiness of pears).

Form, cont.

Vascular tissue: responsible for movement of water, nutrients, and photosynthate throughout plant body.

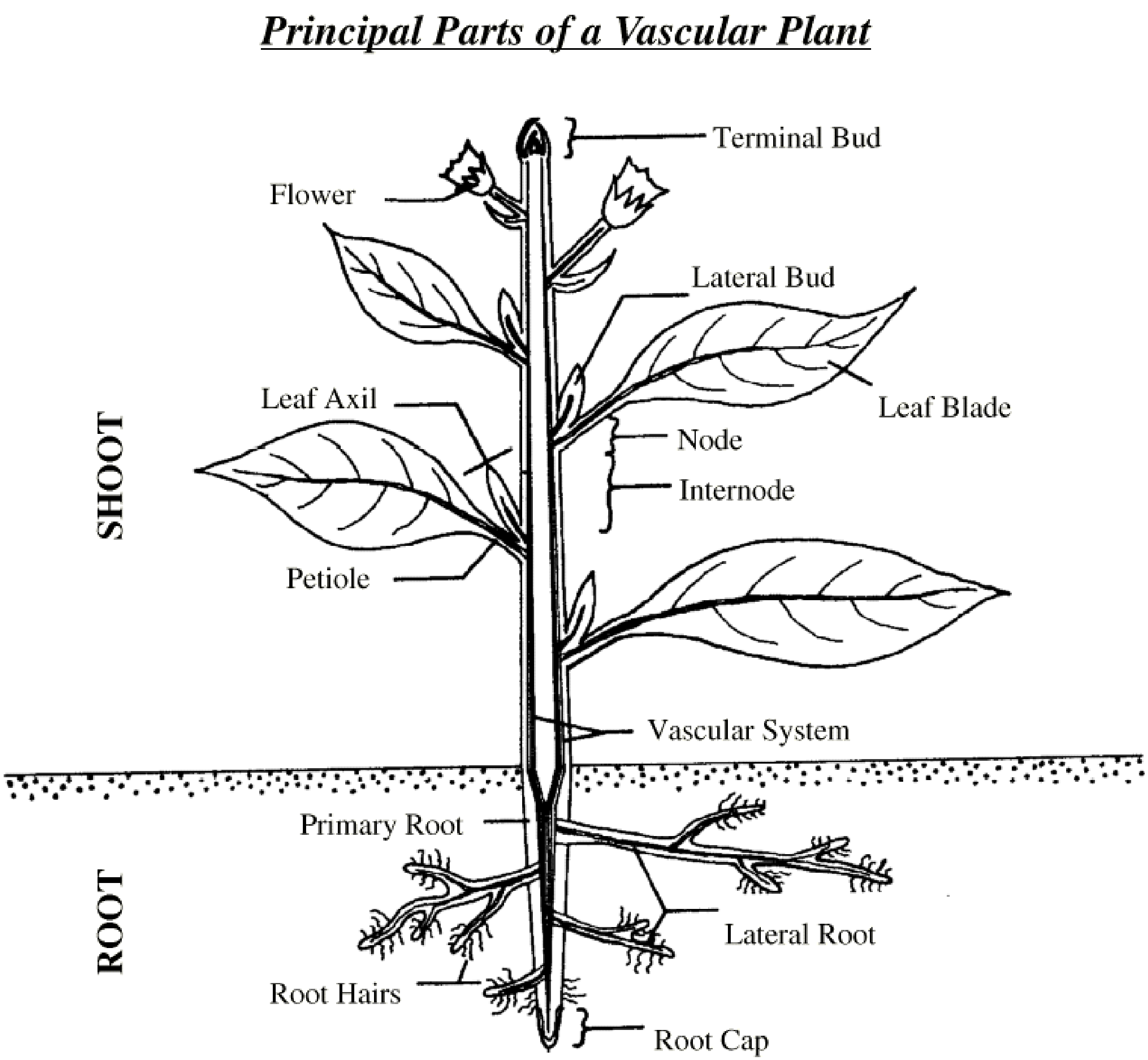
Two types:

1. Xylem: water and mineral conduction, food storage, support.
2. Phloem: food conduction.

Form, cont.

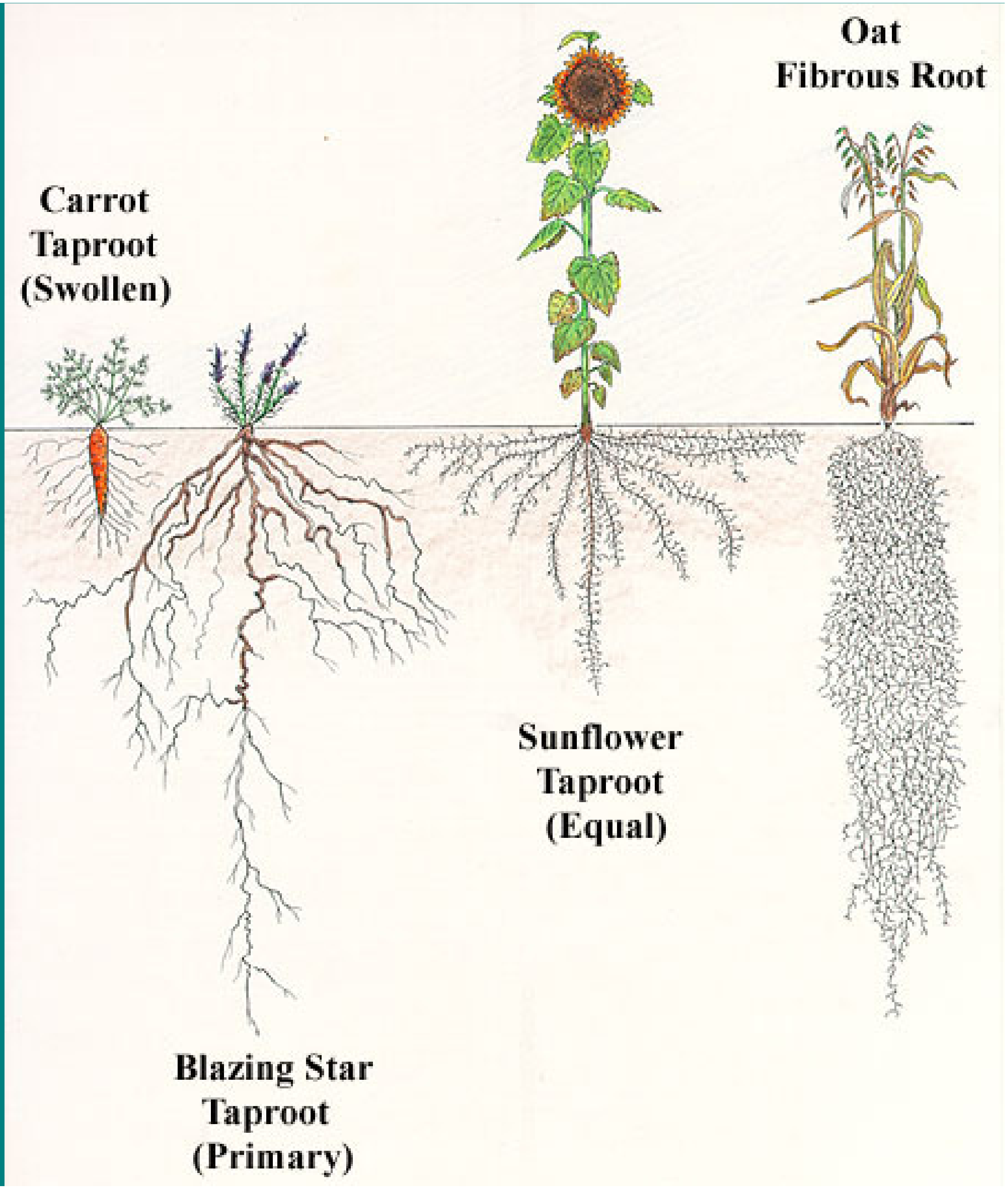
Dermal tissue: the outermost layer, the "skin", of leaves, flowers, fruits, seeds, and relatively young stems and roots. Very variable in function and structure. Usually only one cell layer thick, though some have multiple layers (thought to be for water storage). Closely knit cells provide mechanical protection. Aerial dermal tissue covered with waxy cuticle.

Form: plant parts



Form, cont.

Roots: take in water and nutrients from soil (or air, or other plant's vascular systems), anchor plant to substrate, store food for later growth. Rooting structure is either fibrous or tap-rooting.



Form, cont.

Roots typically make up about 25% of the plants body mass, by weight, but may extend up to three times (or more!) the diameter of the plant canopy.

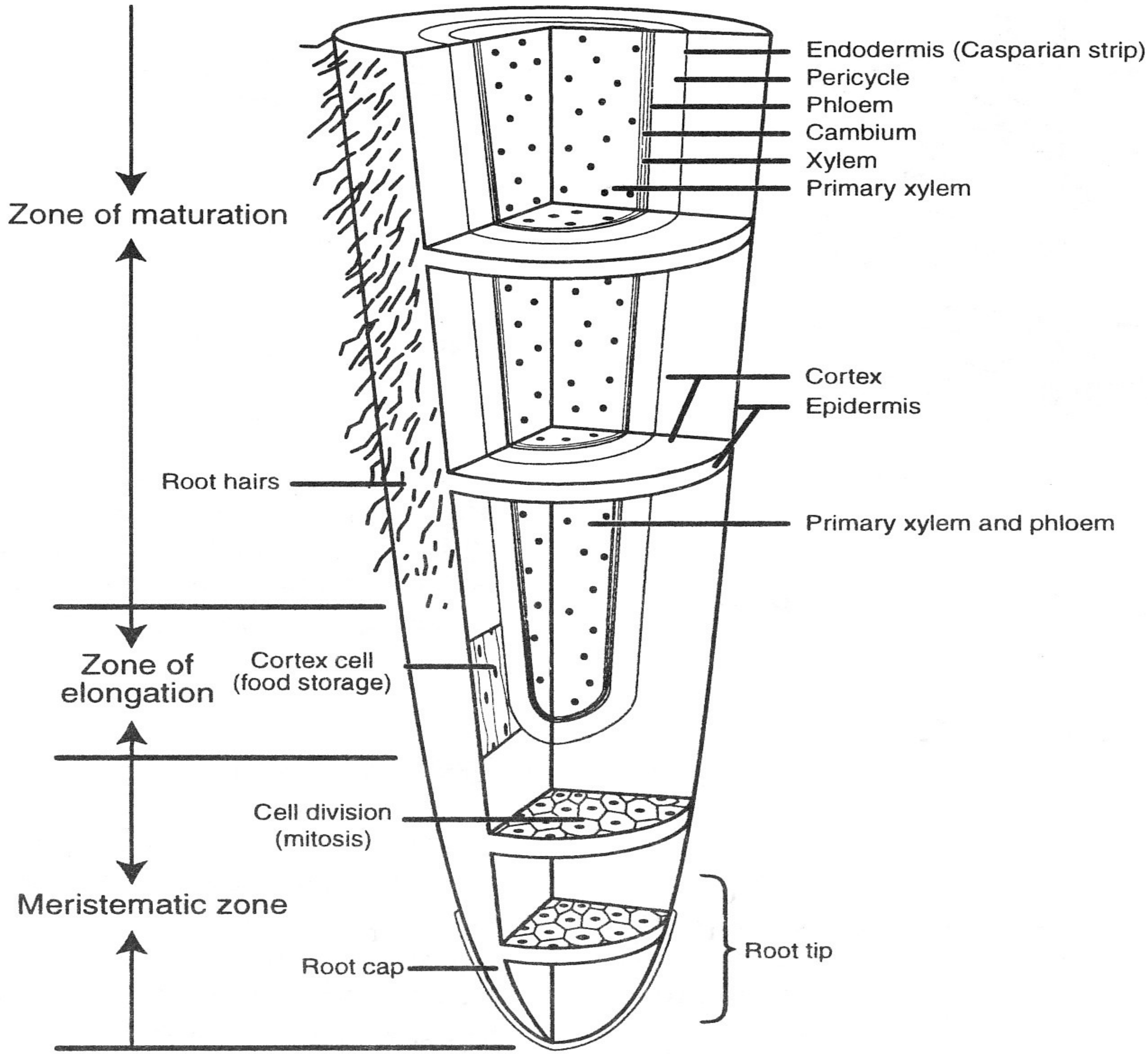
Root hairs, individual cells along the youngest portion of the root, are responsible for actual water and nutrient uptake.

Roots take in water due to the “pull” exerted on the column of water in the xylem as water leaves the leaves due to transpiration (like sucking on a straw).

Roots take in nutrients from the soil solution.

Root hairs

Root structure



Form, cont.

The shoot consists of the plants aerial portion: stems, branches and leaves. Stems' growing tips, or apical buds, are more complex than those of roots.

When the stem is being formed, it divides into nodes, short sections where leaf and axillary buds develop. The sections between nodes are called internodes. These internodes stretch as the stem grows, resulting in leaf placement that maximizes sunlight exposure and air circulation.

Stems

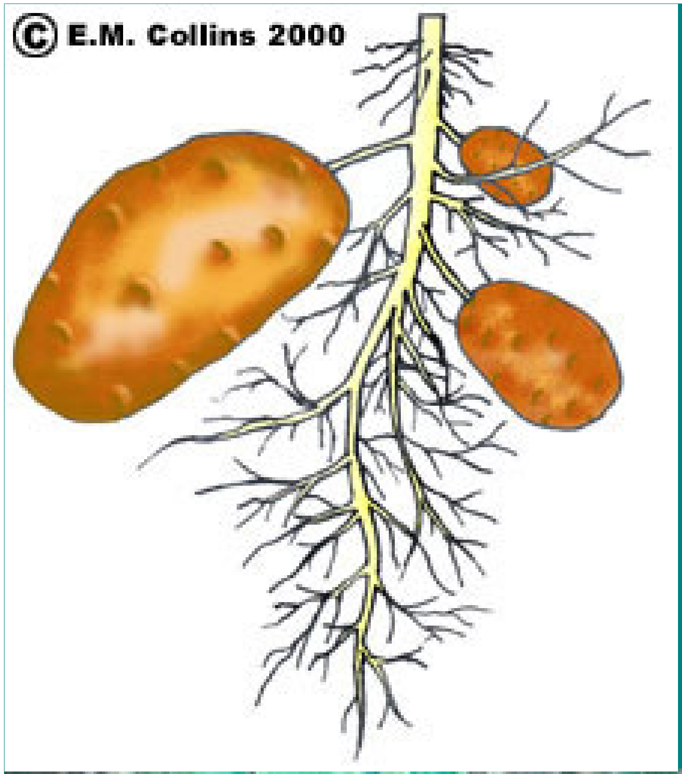
Specialized stem types include:

- ***tubers***, like potato (underground storage);
- ***stolons*** (slender stems growing along ground surface;
- ***rhizomes*** (underground stems);
- ***bulbs*** (large buds consisting of small, conical stem surrounded by numerous scale-like modified leaves);
- ***corms*** (similar to bulbs but made mostly of stem tissue with thin, small leaf tissues);…

Stems, cont.

- ***cladophylls*** (branches that look and function like leaves, as in asparagus or epiphytic cacti);
- ***tendrils*** (modified to aid in support, as in grape, ivy and Virginia creeper);
- ***trunks of terrestrial cacti*** and some other xeric plants, which contain chlorophyll and perform the photosynthesis role for the plant, which may or may not ever have leaves to carry on photosynthesis.

Specialized stem types



Potato tuber

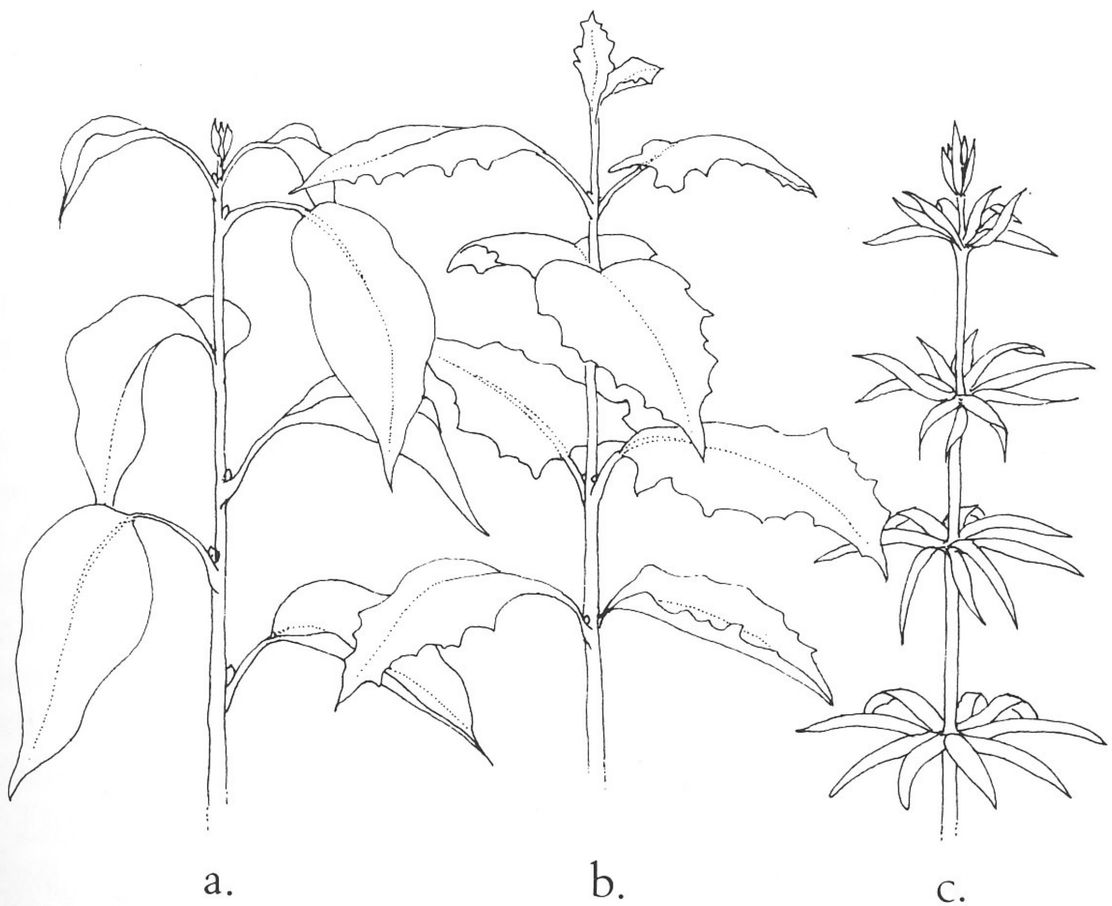
Strawberry stolon

Ginger rhizome

Form, cont.

In most plants, leaves are the food factories, the site of photosynthesis. Leaves are placed on the stem in one of three ways:

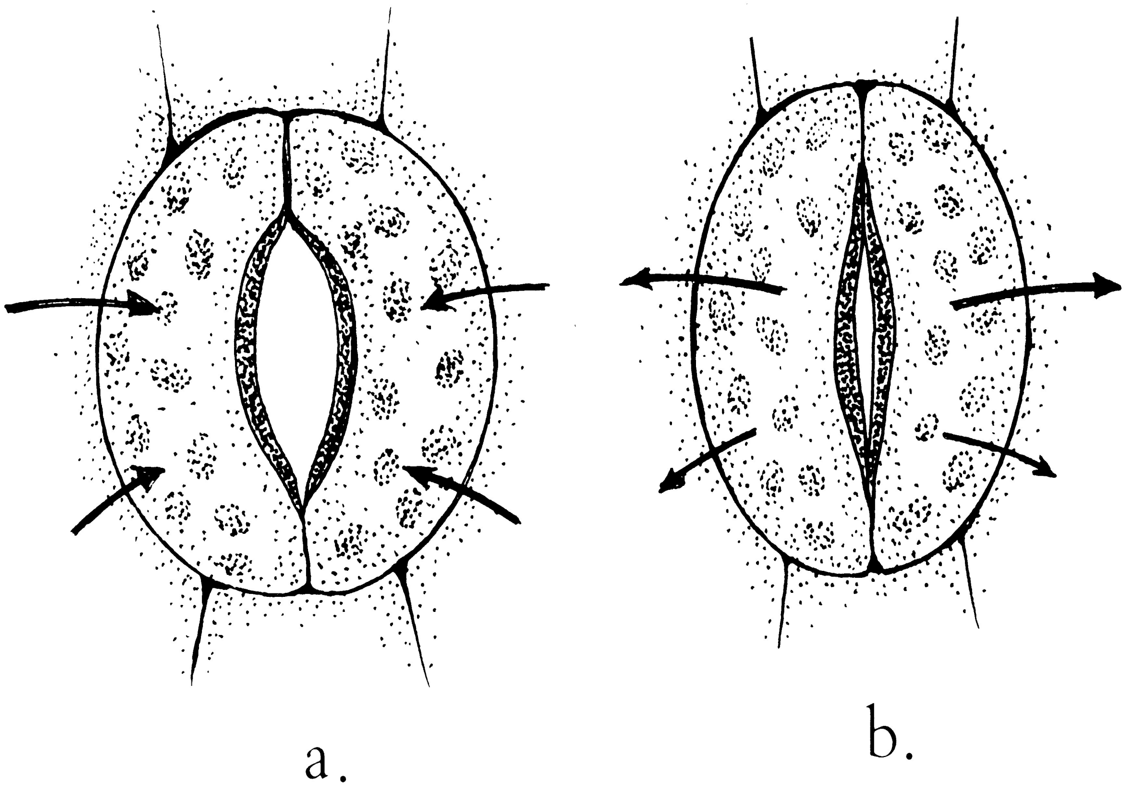
1. Alternate
2. Opposite
3. Whorled



Leaf arrangements: a. alternate, b. opposite, c. whorled.

From: <u>Botany for Gardeners</u>, by Brian Capon

There are small openings on the leaf surfaces, called stomata. These are responsible for allowing gas exchange – carbon dioxide in, oxygen out. Under stress, the plant can close the stoma and limit evapotranspiration, at the cost of lost photosynthesis.



Regulation of stomatal opening. a. A stoma opens when water (arrows) is pumped into the guard cells. The thin, outer wall of each guard cell stretches more than the thick, inner wall. b. When water leaves the guard cells, they relax and the stoma closes.

From: Botany for Gardeners, Brian Capon

Form, cont.

Leaf shape and structure is quite variable. May be determined by the plants evolutionary history - what kind of ecosystem did the plant evolve in?

Many desert adapted plants have small, thick leaves with hairs, which serve to reduce transpiration loss and to shade the chloroplasts.

Leaves of many rainforest trees have “drip tips”, which serve to more quickly channel water off the leaf surface and make it less habitable for disease organisms.

Leaf shape/form modifications

Drip tip on slender, thin leaf.

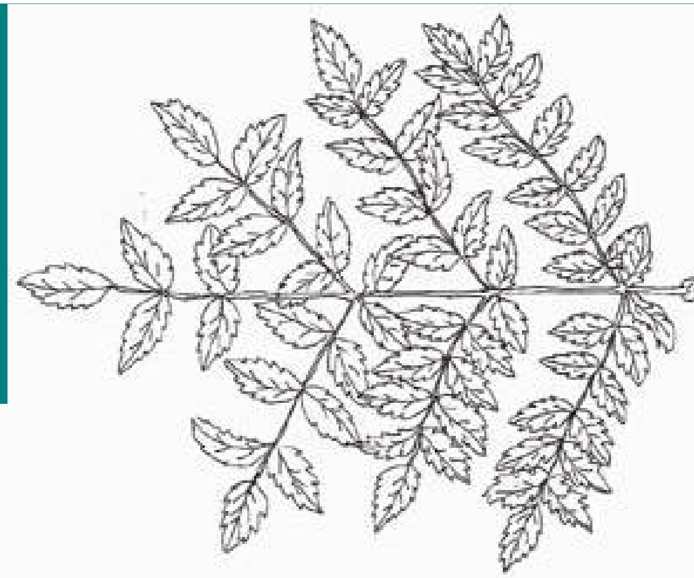
Silvery hairs on thick leaves.

Form: leaf types

Simple

Palmately compound

Pinnately compound



Bipinnately compound

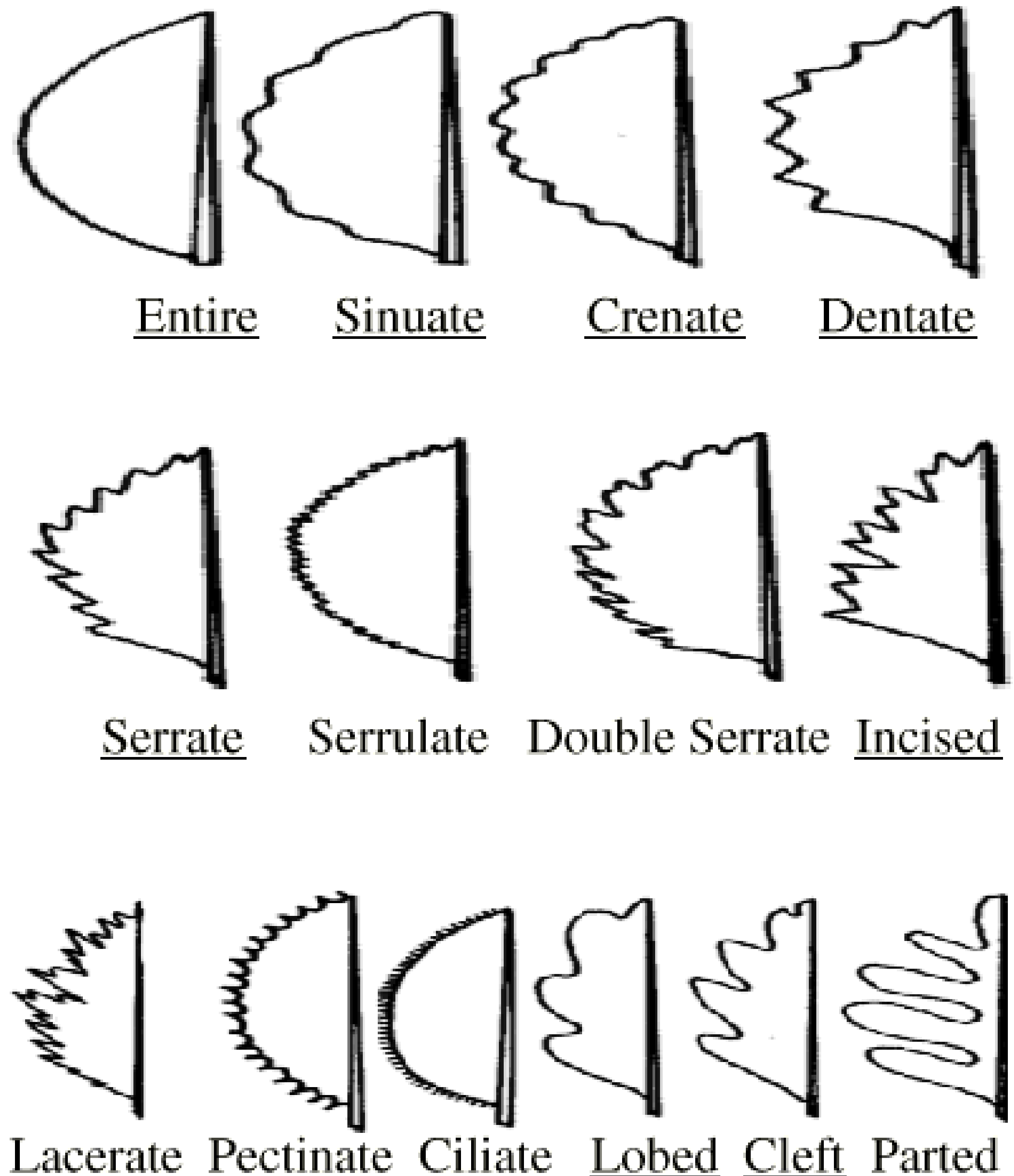
Trifoliate

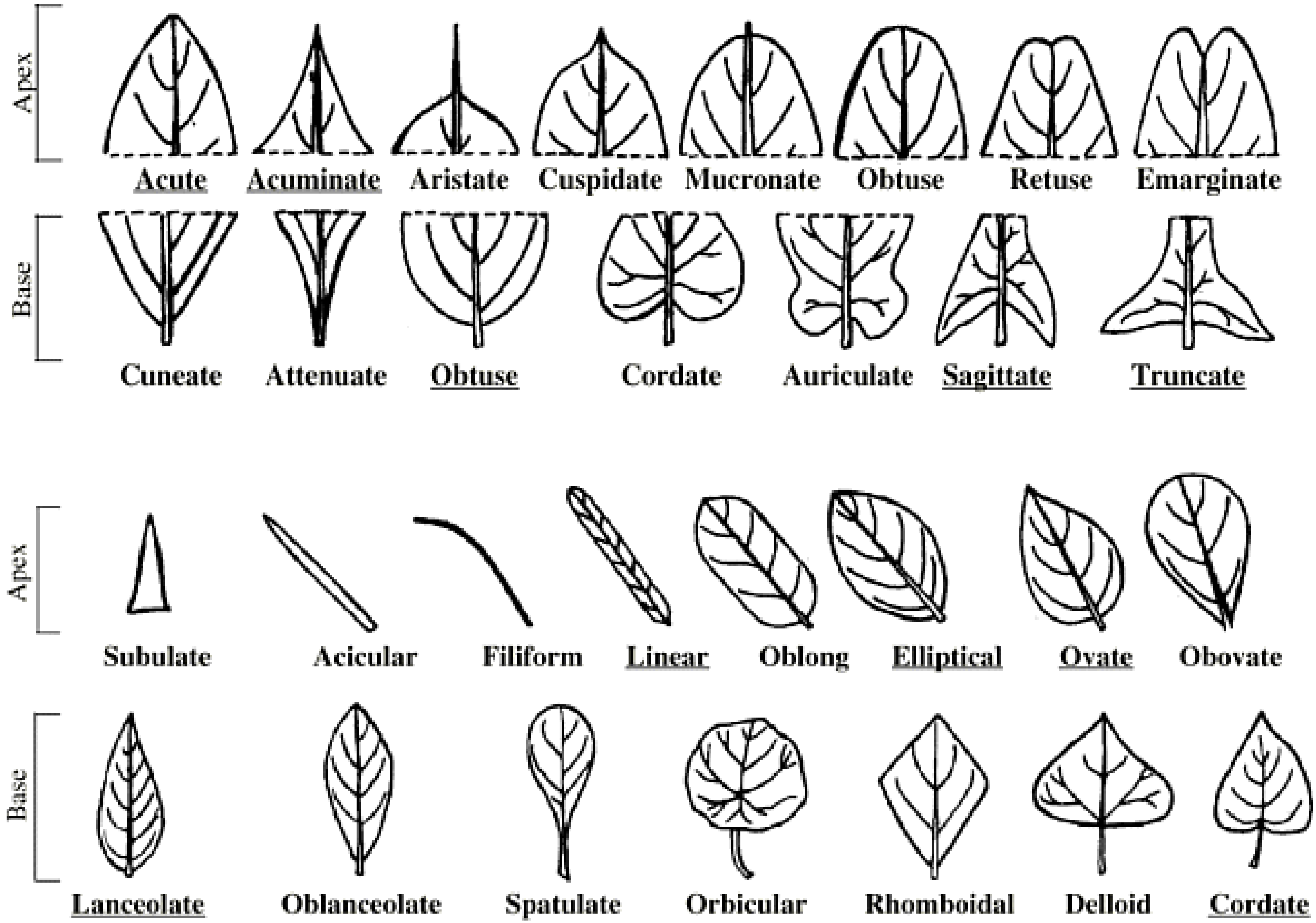
Form, cont.

Characteristics of overall leaf shape, venation, leaf margins, bases and tips can also be distinctive.

Paper birch leaves: alternate, serrate, ovate, acuminate tip, obtuse/ cordate base.

Leaf margins




Apex
Acute
Acuminate
Aristate
Cuspidate
Mucronate
Obtuse
Retuse
Emarginate
Base
Cuneate
Attenuate
Obtuse
Cordate
Auriculate
Sagittate
Truncate
Apex
Subulate
Acicular
Filiform
Linear
Oblong
Elliptical
Ovate
Obovate
Base
Lanceolate
Oblanceolate
Spatulate
Orbicular
Rhomboidal
Delloid
Cordate

Family

Biologists classify living organisms by their relatedness. The basic categories are:

Kingdom

Division (Phylum for animals)

Class

Order

Family

Genus

Species

Increasing degree of specificity – towards a single, definable, named species.

An example of phylogentic classification

- Kingdom=Plantae; Organisms that usually have rigid cell walls and usually possess chlorophyll.
- Subkingdom=Embryophyta; Plants forming embryos.
- Phylum=Tracheophyta; Vascular plants.
- Subphylum=Pterophytina; Generally large, conspicuous leaves, complex vascular system.
- Class=Angiospermae; Flowering plants, seed enclosed in ovary.
- Subclass=Dicotyledoneae; Embryo with two seed leaves.
- Order=Sapindales; Soapberry order consisting of a number of trees and shrubs.
- Family=Aceraceae; Maple family.
- Genus=*Acer;* Maples and box elder.
- Species=*Acer rubrum;* Red maple.

Angiosperm Classes: Monocots vs. Dicots

Characteristic	**Monocot**	**Dicot**
Flower parts	Usually in threes, or multiples of threes	Usually in fours or fives
Cotyledons	One	Two
Leaf venation	Usually parallel	Usually netlike
Primary vascular bundles in stem	Complex arrangement	In a ring
True secondary growth with vascular cambium	Absent	Commonly present