

The Plant Kingdom

A Handbook

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SAMPLE ENTRY

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Organisms

Angiosperms are the most diverse group of all living plants (in terms of the number of different species).

Dicots: magnolia; ranunculus; cabbage; cacti; cotton; tomato; willow; mints; rose; apple; melons; legumes such as beans and peas; wisteria; carrot; sunflower; and other typical flowering, fruiting plants, including "hardwood"

trees and shrubs.

Monocots: aloes, asparagus, garlic, hyacinths, Joshua tree, lilies, onions, and tulips; palms; pineapple; crocus, gladiolus, and iris; orchids; grasses, including bamboo, sugar cane, and grains (such as rice, wheat, corn, oats, barley, and rye); etc. Although their amino acids must be supplemented in our diets with the amino acids from legumes (in order for our bodies to metabolically synthesize proteins), grains have always been "the staff of life" for human civilizations.

Environments

Typically on land, sometimes on or in water, and occasionally on other plants. In particular, grasses are dominant in more terrestrial habitats than are dominated by any other group of plants in the "Cenozoic" (the modern geologic era).

Gross Structure

Cellulosic walls give shape to individual cells.

Forming either a fibrous or taproot system, roots anchor the plant to the soil, absorb water (with solutes) from the soil, and conduct water (with solutes) up to shoots and photosynthesized foods down from shoots. Although they do not have normal buds like shoots, some roots do form shoots and additional roots, from "adventitious" buds.

New growth arises on shoots from buds, formed at the shoot tips and in the axils (where the leaves or side-branches meet the stem). A sequence of short days followed by low

temperatures may induce the scale-protected buds of woody plants to go and stay dormant, as in fall and over winter.

Young, "primary" growth—cell-division in the "apical meristems," of root- and shoot-tips, coupled with cell-elongation—produces growth in length; whereas "secondary" growth—arising from cell-divisions in the "vascular cambium," between the wood and the bark of roots and stems—produces growth in girth. In such monocot trees as palms, primary growth continues at the top of the shoot—there is no true secondary growth.

Produced from shoot tips in definite, species-specific patterns, angiosperm leaves are typically flat and thin, with "petioles" (leafstalks) and "veins" (which strengthen the blades and, being composed of vascular tissue, conduct water with solutes, from the roots, as well as foods, photosynthesized in the leaves).

Dicots are very small to very large plants with fleshy to woody roots, fleshy to woody stems (one trunk in trees, more in shrubs), typically broad evergreen or deciduous leaves with net-patterned veins, and flowers whose parts are typically arranged in groups of four or five.

Monocots are small to large plants with typically fleshy roots, typically fleshy stems, typically strap-like leaves with parallel-patterned veins, and flowers (beardlike in grasses) whose parts are typically arranged in groups of three.

Energy Capture

Although a few angiosperms are parasitic on other plants (such as mistletoe on various trees) and others (such as the Venus flytrap) are "saprophytic" (living on decaying organic matter), in most angiosperms light-energy is photosynthetically captured, by chloroplasts (especially in the "parenchyma" cells between the upper and lower "epidermis" of leaves). Some grasses perform an extraordinarily efficient type of photosynthesis.

Materials Exchange

Water vapor and gases flow especially through "stomata" pores (each regulated by a pair of "guard cells") in leaves—carbon dioxide flows in and oxygen flows out for photosynthesis, during the day; and oxygen flows in and carbon dioxide flows out for respiration, both day and night. "Transpiration" is the evaporation of water from plant tissues, especially leaves. A waxy "cuticle" covering over the epidermal cells helps prevent water loss from shoots, bark helps prevent water loss from any woody stems of dicots, and hardened outer tissues help prevent water loss from the shoots of monocots. In addition, these protective outer structures can act as barriers to pathogens, parasites, and predators (which can also be repelled by such external growths as spines or thorns).

Countless "root hairs," growing on the tips of roots just behind the cell-elongation zone, absorb most of the water and dissolved minerals for vascular plants. The soil—consisting of both inorganic and organic matter, both living and

non-living—provides roots with support, air, water, and minerals. The chemical elements required for plant life are easily remembered by reciting this little saying: "C. Hopkin's Cafe, managed by my cousins Mo and Clyde"—C [carbon], H [hydrogen], and O [oxygen] are provided by carbon dioxide and water; and provided by soil minerals are P [phosphorus], K [potassium], N [nitrogen], S [sulfur], Ca [calcium], Fe [iron], Mg [magnesium], B [boron], Mn [manganese], Cu [copper], Zn [zinc], Mo [molybdenum], and Cl [chlorine] (Additional elements are sometimes required, by certain plants in certain soils.).

Internal Transport

Typically, sugars and other food molecules, photosynthesized in leaves, are "translocated" through "phloem" tissue, down to roots and out to other food-consuming "sinks": Theoretically, food molecules are actively transported into and out of the living phloem cells; and water "osmotically" follows, creating positive water pressure within the phloem and within growing, food-consuming cells.

In contrast, water and dissolved solutes, absorbed in roots, move through non-living "xylem" tissue, up to leaves: Theoretically, water molecules are "transpired" (evaporated by solar energy) through the stomata; and a column of water (held together by its hydrogen bonds) cohesively follows, under negative pressure (tension) within the xylem.

The phloem of angiosperms typically includes "sieve-tube members" (connected end-to-end,

via "sieve plates," into "sieve tubes," and typically regulated—and probably powered—by "companion cells"); and the xylem of angiosperms typically includes not only non-living "tracheids" (communicating via "pit pairs," in their side walls) but also non-living "vessel elements" (connected, via perforations in their end walls, into "vessels").

Within the young, "primary" stem are the following tissues (from the outside in): The "epidermis," composed of water-conserving epidermal cells, guard cells, and/or epidermal hairs; the "cortex," composed of supportive "collenchyma" cells, hardened "sclerenchyma" fibers and "sclerids," and food- and water-storing "parenchyma" cells; the vascular tissue, composed of food-conducting phloem (consisting of supportive fibers, the conductive sieve-tube members with companion cells, and food-storing parenchyma cells) and water- (and solute-) conducting xylem (consisting of supportive fibers, the supportive and conductive tracheids, the conductive vessel elements, and food-storing parenchyma); the "pith," composed mostly of food- and water-storing parenchyma with supportive sclerids; and "pith rays," extending from the pith outward, in between the vascular bundles, and composed of food- and water-storing and -conducting parenchyma cells.

Typically, the vascular tissues in primary stems are grouped together in bundles (typically with the phloem to the outside and the xylem to the inside)—forming strands running the length of the stem and arranged in a circle in the cross-section of the stem. In monocots, the vascular bundles are distributed throughout the cross-

section of the stem, not just in a circle.

When present, secondary growth in the stems of dicots is laid down by a cylinder of "vascular cambium," formed from the "meristematic" tissue remaining between the primary phloem and xylem (within each vascular bundle) plus some of the parenchyma cells in the pith rays (between the vascular bundles): Laid-down to the outside is "secondary phloem," which (with corky tissues produced from "cork cambiums," arising to the exterior) form the bark; and laid-down to the inside (in annual rings, in Temperate climates) is "secondary xylem," consisting of young, active "sapwood" (which eventually matures into inactive "heartwood"). Secondary tissues are typically not produced in monocots, although there is a fibrous—not grained—"wood" in such monocots as palm trees.

The young, primary tissues in the root are (from the outside in) the protective epidermis, the food-storing cortex (with the filtering "endodermis" as its innermost layer of cells), the "pericycle" (which may eventually produce side roots and secondary tissues), and the vascular tissues—the water- (and solute-) conducting primary xylem (star-shaped in cross-section) and the food-conducting phloem (lying between the arms of the xylem). Unlike in the stems, there is no pith in the center of the roots of dicots and many monocots.

When present, secondary growth in roots is laid-down by a vascular cambium formed from "procambium" cells (meristematic cells remaining between the primary xylem and

phloem) plus cells of the pericycle (around the tips of xylem arms): Like in the stem, to the outside is laid-down secondary phloem, which (with tissues from cork cambiums, arising to the exterior) forms the bark; and to the inside is laid-down secondary xylem (wood).

In healthy plants, a copious production of rubbery "latex" or other sap can kill invading pests.

Developmental Control

Genetic, as typically determining leaf shape and flower structure—both features are typically useful in plant identification (although leaf shape sometimes varies with the age of the plant or with environmental conditions).

Hormonal: In angiosperms (and many other plants) the effects of such environmental stimuli as light, temperature, and even touch are typically transmitted by hormones, which—in various concentrations and combinations, in various tissues, at different times—also regulate and coordinate virtually all aspects of plant growth and development. There are five basic types of hormones.

"Auxins" typically promote organ formation, tissue organization, cell division, cell elongation, metabolism, translocation, growth movements, and "apical dominance" (of topshoots over sideshoots) and typically inhibit leaf abscission.

"Gibberellins" typically promote cell elongation, cell division, metabolism, and flowering and typically inhibit dormancy and organ formation.

"Cytokinins" typically promote cell division, cell enlargement, organ formation, and nutrient movement and typically inhibit dormancy, apical dominance, and death of tissues.

"Abscissic acid" typically promotes dormancy, flowering, abscission, and closure of the stomata and typically inhibits the action of gibberellins.

"Ethylene" gas typically promotes growth movements, abscission, death of tissues, and ripening of fruits (Ethylene is the gas used commercially to ripen bananas etc.).

Asexual Reproduction

Via vegetative body parts.

Sexual Reproduction

Typically "monoecious" but often "dioecious" (with separate sexes—that is, with male and female plants). Like other higher plants, the diploid sporophyte is dominant to the dependent, haploid gametophytes. *(Note: These and other botanical terms are defined previously in the text, as they have evolved with earlier groups of plants.)*

Flowers—keys to angiosperm success—arise on shoots from floral buds (evolved from leaf buds), which form at the shoot tips or in the axils (where the leaves or side-branches meet the stem). Flowers may be produced either alone or together, in well-defined "inflorescences." Many plants—the so-called "long day" and "short day" plants—produce flowers only in response to

appropriate night-length.

Mounted on the typically swollen "receptacle" of a "pedicel" (flower stalk), a flower is typically composed—from outside to inside—of a "perianth," typically several "stamens," and one to many "pistils" ("Complete" flowers have all parts; "perfect" flowers have the parts of both sexes.). The perianth is composed of the "calyx" (the assemblage of "sepals," floral bracts) and, within this, the "corolla" (the assemblage of "petals," which are also modified leaves). A stamen is composed of the typically bulbous "anther" (bearing pollen), atop the typically long "filament." A pistil (consisting of one or more fused "carpels," modified leaves) is composed of the typically sticky "stigma" (which receives the pollen), at the end of the typically long "style" (through which the pollen tube will grow), at whose base is the typically swollen "ovary" (which eventually contains the seeds and ripens into the fruit).

The stamen is a microsporophyll (modified leaf). Within the pollen sacs (microsporangia) in the anthers, many microspore mother cells ("pollen mother cells") each produce—via meiosis—four haploid microspores, each of which forms—via mitosis—two cells or nuclei within: A "generative" cell/nucleus and a "tube" cell/nucleus. The outer wall of the microspore hardens (and sometimes becomes sculptured), thus forming a grain of pollen (the young male gametophyte), which is released and disseminated. In typical dicots and some monocots, showy, perfumed flowers attract insects, birds, bats, and other small animals (with whom they have often co-evolved), which

drink from the floral nectaries and, as they visit other flowers, coincidentally spread the pollen. In some dicots and such monocots as grass plants, the flowers are not showy or perfumed; and the pollen is typically spread by the wind.

Typically growing on a stalk within a carpel (a megasporophyll modified leaf) of an ovary is the "ovule," consisting of a pair of "integuments" (with a "micropyle" opening at their lower end) surrounding "nucellus" tissue (the megasporangium), embedded within which are megaspore mother cells, each of which produce—via meiosis—four haploid megaspores, three of which typically die and one of which develops into a typically round "embryo sac" (the female gametophyte), typically consisting of an egg cell (near the micropyle end of the embryo sac), a pair of accompanying "synergid" cells (the evolutionary remnants of an archegonium), a central "endosperm mother cell" (containing two haploid "polar" nuclei), and three "antipodal cells" (opposite the micropyle-end of the embryo sac).

Viable seeds (that is, containing embryos) are occasionally formed "parthenogenetically" (that is, without sexual fertilization), in some species.

Typically, after a pollen grain reaches the sticky stigma, it germinates into a pollen tube and grows through the style to the ovary. Typically, the generative cell, inside the grain of pollen, divides into two sperm nuclei, which (with the tube nucleus) travel within the growing pollen tube (the mature male gametophyte, without an antheridium) through the micropyle, into the ovule, and through the nucellus tissue: Because

the sperm nuclei are delivered directly to the embryo sac, the sperms do not need to be—and, in fact, are not—flagellated (Unlike the sperm of most lower plants, they do not have to swim through environmental water.). Unlike all other plants, there is a "double fertilization" in angiosperms: One sperm nucleus fertilizes the egg—thus forming a diploid zygote—and the other sperm nucleus fertilizes the two haploid nuclei in the endosperm mother cell—thus forming a triploid "primary endosperm cell." The zygote develops into the embryo sporophyte. The primary endosperm cell develops into the "endosperm," which (as the rest of the female gametophyte decomposes) nourishes the developing embryo (pushed by an attached "suspensor" to well within the endosperm). Especially in grains, the endosperm may persist to eventually nourish the seedling (which will germinate after a period of dormancy); although in most dicots, the endosperm is entirely consumed by the developing embryo: Food is eventually stored in the "cotyledons" (seedling leaves)—two in dicots, one in monocots. The nucellus is usually consumed by the developing embryo but sometimes persists as a food-storing "perisperm"; and the integuments typically form a hard coat around the seed, borne within the ovary, which ripens as the fruit (typically developing only if the flower has been pollinated and the egg, fertilized).

A "simple fruit" (maturing from a single ovary, which may however be composed of several carpels, such as the segments of an orange) may be fleshy (such as an apple) or dry; and a dry fruit may be either "dehiscent" (such as a bean pod), opening when ripe, or "indehiscent" (such

as a walnut), not opening when the seeds are mature. An "aggregate fruit" (such as a raspberry) is composed of several ovaries growing separately within a single flower, borne on a single receptacle (which is the edible part of a strawberry—its little hard "seeds" are the actual fruits); and a "multiple fruit" (such as a pineapple) is composed of several ovaries from several flowers growing together as one.

Typically, fleshy fruits attract hungry animals, who carry the seeds in their gut to new locations; and hard fruits (such as the grain of a grass plant or the winged pod of a maple tree) help spread seeds on the fur or feathers of animals or on the currents of wind or water.

Typically, the dormancy of a seed is broken (that is, its germination is triggered) by an environmental condition—or a sequence of environmental conditions—that signals a favorable place and/or time: Factors involved include light, temperature, moisture, and/or abrasion (which naturally occurs after the seed has been washed downstream from the parent plant and which allows chemical inhibitors of germination, such as the traces of cyanide found in almond seeds, to be leached-out of the seedcoat by rainwater).

All in all, angiosperms have become the dominant terrestrial flora on Earth because of their adaptations for reproductive success: flowers—enhancing cross-pollination and, thus, genetic diversity—and fruits—enhancing seed dispersal.