

Alcorn + Nobel
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is possible with sanitation and use of resistant varieties. Another New World (northwest South America, Panama, Costa Rica) disease is Monilia pod rot (watery pod rot), caused by the fungus *Monilia roreri*. Damage to pods can be severe. Control measures include removal of affected pods and use of resistant varieties. Swollen shoot, a virus disease transmitted by mealybugs, occurs only in western Africa and causes deformation of the tree and considerable economic loss. Eradication programs have been attempted. Some tolerance to the disease has been found. Other occasional problems include wilt, caused by the fungus *Ceratocystis fimbriata* and commonly spread by *Xyleborus* borers; and cushion galls, caused by a species of *Calonectria*. See PLANT PATHOLOGY; PLANT VIRUSES AND VIROIDS.

George A. Zentmyer

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Cachexia

The severe wasting syndrome that accompanies such diseases as cancer, infection, or parasitic infestation. Occasionally, it is also observed in noninvasive conditions, such as severe cardiac failure. The causes of cachexia are only partially understood. However, it is clear that most cachexia is caused by diminished consumption of nutrients rather than by a hypermetabolic state.

Anorexia, the proximal cause of this problem, is thought to be related to the expression of endogenous factors collectively termed cytokines, some of which have now been identified. For example, tumor necrosis factor, a protein (also known as cachectin), when administered to animals for a long period of time, causes a syndrome of cachexia indistinguishable from that produced by chronic disease. Inhibitors of tumor necrosis factor activity may partially alleviate cachexia caused by experimental tumors. It is likely that other cytokines are also involved, and that together these agents cause wasting of such severity that it may lead to death in a wide variety of diseases. See ANOREXIA NERVOSA; CYTOKINE.

It is unclear whether cytokines suppress appetite through a direct action on satiety centers in the hypothalamus or through peripheral effects (such as effects on the bowel or other enteric structures), which then project to the central nervous system. Another clinical feature related to cachexia appears to be caused by a direct effect of cytokines (notably tumor necrosis factor and interleukin-1) on stem cells and stromal cells of the bone marrow. Tumor necrosis factor and interleukin-1 also appear to mobilize lipid through direct effects on adipocytes.

The cytokines that cause cachexia are produced mainly by cells of the immune system, especially macrophages. Synthesis is triggered by contact with molecules produced by microbial pathogens or tumor cells. Induction of synthesis depends upon

both transcriptional and translational activation pathways. Rational strategies for alleviation of cachexia include eradicating the underlying infection or tumor, blocking cytokine synthesis with agents that specifically interrupt the requisite signaling pathways, or inhibiting cytokine activity with specific antibodies or other antagonists. Oral or intravenous administration of nutrients is likely to be effective if the process has not advanced to a point at which utilization of nutrients is impaired. See ONCOLOGY.

Bruce Beutler

Cactus

The common name for any member of the cactus family (Cactaceae). There are 120 genera with perhaps 1700 species, nearly all indigenous to America. The cacti are among the most extremely drought-resistant plants, and consequently they thrive in very arid regions. The group is characterized by a fleshy habit, presence of spines and bristles, and large,

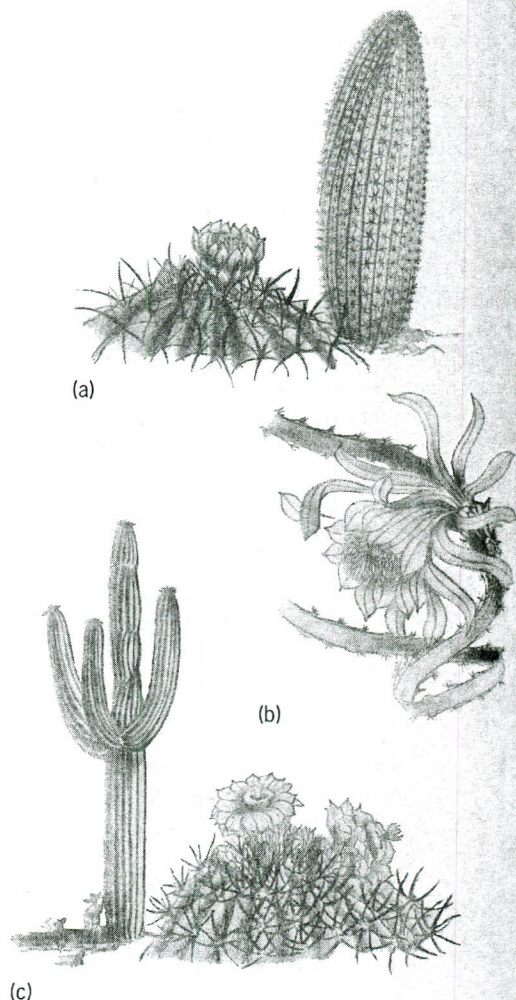


Fig. 1. Three examples of cacti. (a) Mule cactus, with closeup of flower, maximum height of 6 ft (2 m). (b) Flower of night-blooming *Cereus*, maximum height of 40 ft (12 m). (c) Saguaro, maximum height of 70 ft (21 m), with closeup of flower.

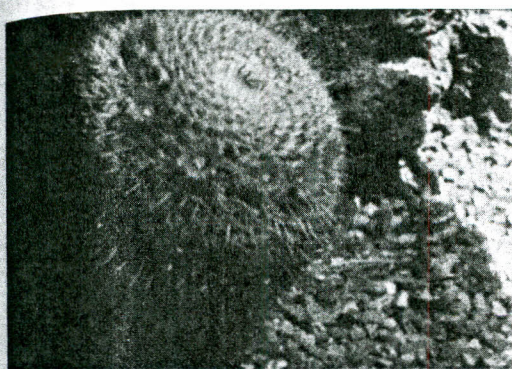


Fig. 2. *Mamillaria vaupellii* var. *flavispina*.

brightly colored, solitary flowers. There is a great variety of body shapes and patterns, and many of the species are grown as ornamentals or oddities (Figs. 1 and 2). A few have edible fruits. The cochineal insect, which produces a valuable red dye, is cultivated chiefly on the cochineal cactus (*Nopalea cochenillifera*). The saguaro (*Cereus giganteus*) of Arizona and Sonora is the largest of the cacti, attaining a height of 70 ft (21m). See CARYOPHYLLALES.

Perry D. Strausbaugh/Earl L. Core

Cacti grow in many habitats, ranging from epiphytes living on trees in dense tropical forests to large, isolated plants in deserts. In all cases, various adaptations that lead to water conservation are apparent. For example, the stems of most cacti are massive and can store large amounts of water that sustain the plants during prolonged drought. Adaptations for water conservation also occur on a metabolic level. Cacti are increasingly recognized as important crops, especially in arid and semiarid regions. Perhaps the most widespread use of cacti is as ornamentals; collectors and hobbyists worldwide cherish their shapes, attractive flowers, and ability to tolerate long periods without watering.

Cactus roots are shallow [most occur within 20 cm (8 in.) of the soil surface], which allows the plants to respond rapidly to light desert rainfalls, as only a small depth of soil needs to be wetted. Moreover, roots represent only a small fraction of a cactus plant (generally only 7–12% of the total plant dry weight), suggesting that a relatively small root surface area is necessary to supply sufficient water from the soil. A conventional way to represent the water storage capacity of a plant is the volume available for water storage divided by the area across which water can be lost to the air by transpiration. This volume-to-area ratio is high for cacti compared with the majority of plants, whose photosynthetic organs are thin flat leaves. The leaves of most cacti are ephemeral or absent, so the photosynthetic organs are the relatively massive green stems. Besides the obvious succulence of the stems of cacti, their cells are relatively large with prominent vacuoles.

Another adaptation of cacti to arid conditions is their relatively slow loss of water to the air. Cacti have a thick waxy cuticle on their stems, which acts

as a waterproofing skin. Also, the pores (called stomata or stomates) in the cactus skin that are necessary for the uptake of carbon dioxide (CO_2) from the atmosphere tend to open only at night. The opening of stomata allows the vaporized water within the plant to escape to the atmosphere. Because the stem and the air temperatures are lower and the relative humidity is higher at night than during the daytime, much less water (generally 80–90% less) is lost by transpiration during the nocturnal opening of stomata by cacti compared with the daytime stomatal opening of most other plants.

The opening of stomata at night presents a problem for photosynthesis, which requires light. Specifically, photosynthesis uses atmospheric carbon dioxide and the energy of sunlight to form sugars in the chloroplasts of the chlorenchyma (the green tissue that occurs outside the whitish water-storage tissue). Open stomata are necessary for appreciable uptake of carbon dioxide, which at night for cacti is attached to the three-carbon compound phosphoenolpyruvate to form a four-carbon acid such as malic acid. During the night the acid accumulates in the large vacuoles of cactus chlorenchyma cells; during the next daytime, when the stomata have closed, carbon dioxide is released from the accumulated acid within the stems of cacti. Carbon dioxide is then fixed into sugars via photosynthesis when sunlight is available as the energy source. The opening of stomata and the increase in chlorenchyma acidity during the night followed by decarboxylation of organic acids and the formation of photosynthetic products during the daytime is known as crassulacean acid metabolism (CAM), because it was first discovered in the plant family Crassulaceae.

Crassulacean acid metabolism is crucial for the adaptation of cacti to the dry conditions characteristic of deserts. Its water-conserving attribute is also important in the increasing cultivation of cacti for their fruits and as fodder for livestock, particularly cattle. Currently just over 1 million hectares (2.5 million acres) of cacti are cultivated, mostly for the prickly pear cactus, *Opuntia ficus-indica* (the second most cultivated crassulacean acid metabolic species is pineapple, *Ananas comosus*). In particular, *O. ficus-indica* is extensively cultivated in Brazil (the leading country with over 300,000 ha) and northern Africa for fodder. In Mexico, fruit production is the main usage (about 60,000 ha); young stem segments of *O. ficus-indica* are also used in Mexico as a vegetable, termed nopalitos. Commercialization of its fruit, generally called cactus pears, requires the removal of the irritating and skin-penetrating glochids from the surface and even the application of a wax that improves appearance and prolongs shelf-life. Another use of mature stem segments of *O. ficus-indica* (and a few other cactus species), either on the plant or removed and placed in sheds, is for infestation by females of the scale insect *Dactylopius opuntiae*, which produce the brilliant red dye cochineal. Cochineal (carminic acid), 80% of which is currently produced in Peru, leads to colors ranging from

yellow to purple for fabrics, foodstuffs, and even liqueurs.

Fruits termed pitayas, pitajayas, and various other names of more than 20 species of cacti are collected from the wild and sold locally throughout Latin America. These are produced by tall columnar cacti such as *Cereus peruvianus*, *Stenocereus griseus*, and *S. queretaroensis* as well as by vinelike cacti such as *Hylocereus polyrbizus*, *H. undatus*, and *Selenicereus megalanthus*. The pulp color varies from white to orange to deep purple; the seeds are small (like kiwi seeds) and readily ingested. The peels do not have the nasty glochids of *O. ficus-indica*, but certain postharvest problems such as a short shelf life require further investigation, and the market would also welcome greater year-round availability.

Cacti can grow in regions not suitable for other crops. Moreover, growth of cacti responds favorably to increasing levels of atmospheric carbon dioxide, and cacti can survive increasing atmospheric temperatures, two aspects of global climate change. Areas for cultivation of opuntias used for fodder are expanding, as are markets for fruits of many species. Indeed, because water is the principal limiting factor for agriculture in much of the world, the water-conserving qualities of cacti augur well for their increased commercialization in the future.

Park S. Nobel

Several diseases of wild cacti are known. The most conspicuous of these is probably bacterial soft rot of saguaro cacti, which is usually seen in older plants. Affected tissues appear as dark, soft lesions that usually develop a light-green border; these lesions frequently leak a dark, odorous fluid. Infected branches may fall, and the fleshy tissue of diseased plants may be destroyed in several weeks to a few months, leaving bare the woody supportive ribs (xylem elements) of the plant. Control by chemical sprays or soil drenches is not feasible. Therefore, when symptoms are first noted, rotting tissues should be removed. If the rot is limited, $\frac{1}{2}$ in. (13 mm) of surrounding healthy tissue should also be discarded. Immediately the cavity should be washed thoroughly with a solution of one part household bleach and nine parts water with the washing repeated in 18 to 24 h; the wound should be left open. Infections so treated frequently do not spread. Plants with numerous or large lesions should be removed and the debris thoroughly treated with the diluted bleach, or burned, or deeply buried.

The same controls apply to similarly infected organ-pipe cacti. Infected prickly-pear cacti initially have similar symptoms, but internal tissues can become so liquefied that pads bulge. The infected pad should be promptly destroyed, and the former point of attachment treated with bleach.

Recent studies in the United States have established that the soft-rot disease is caused by bacteria in the genus *Erwinia*, particularly *E. cacticida*. This species has also been isolated from rotting cacti in Australia and Mexico.

Saguaro cacti may be toppled by heavy winds

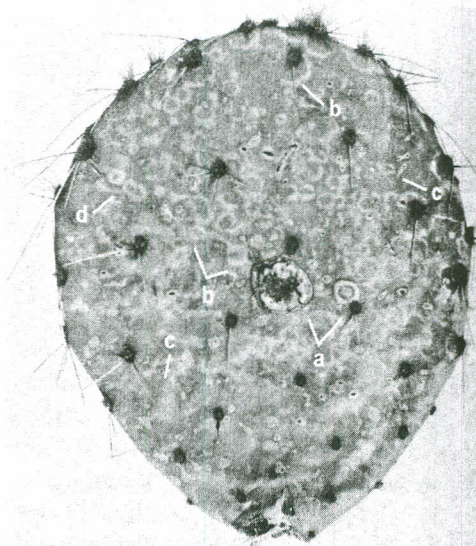


Fig. 3. Disease symptoms on prickly-pear pad: (a) lesions caused by *Phyllosticta concava*; (b) virus-induced symptoms; (c) injuries from penetrating cactus spines; (d) ring pattern caused by feeding insects. (From S. M. Alcorn, R. L. Gilbertson, and M. R. Nelson, *Some diseases of cacti in Arizona*, *Prog. Agr. Ariz.*, 27(3):3-5, 1975)

following soil-soaking rains. Roots of these plants usually have been previously weakened by the root- and wood-rotting fungus *Poria carnegeiana*. Wind-thrown plants tend to be mature specimens; no control is known.

Prickly pears can be infected by other pathogens. Certain viruses cause whitish rings or irregularly shaped patterns to develop on pads (Fig. 3). Severely affected plants also are stunted. The light-colored lines usually are narrow. By contrast, rings caused by the feeding of sap-sucking insects have small, central green areas with broad, light-colored margins. Presumably, sap-sucking insects carry the viruses between plants, but "new" infected plants will develop if diseased pads root after their detachment from the parent plant. The fungus *Phyllosticta concava* causes the formation of generally circular, whitish to tan, depressed, dry lesions on pads; these areas usually become covered with black, slightly raised "dots". An infection may penetrate to the opposite side, where a similar lesion forms. Infected tissue can disintegrate, leaving a hole through the pad. Fungicidal sprays will minimize infections, which start in cool, rainy periods. See PLANT PATHOLOGY.

Stanley M. Alcorn

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A relatively rare chemical element, symbol Cd, atomic number 48, closely related to zinc, with which it is usually associated in nature. Cadmium was discovered by F. Stromeyer in Germany in 1817 in a sample of zinc carbonate. It does not occur uncombined in nature, and the one true cadmium mineral, greenockite (cadmium sulfide), is not a commercial source of the metal. Almost all of the cadmium produced is obtained as a by-product of the smelting and refining of zinc ores, which usually contain 0.2-0.4% cadmium.

The United States, Canada, Mexico, Australia, Belgium-Luxembourg, and the Republic of Korea are principal sources, although not all are producers.

Physical properties. Cadmium is a silvery-white ductile metal with a faint bluish tinge. It is softer and more malleable than zinc, but slightly harder than tin. It has an atomic weight of 112.40, a specific gravity (sp gr) of 8.65 at 20°C (68°F), and its metallic radius is 0.154 nanometer. Its melting point of 321°C (610°F) and boiling point of 765°C (1409°F) are lower than those of zinc. There are eight naturally occurring stable isotopes, and eleven artificial unstable radio isotopes have been reported. *See* TIN; ZINC.

Chemical properties. Cadmium is the middle member of group II (zinc, cadmium, and mercury) in the periodic table, and its chemical properties generally are intermediate between zinc and mercury. Like zinc, cadmium loses its luster in moist air and is rapidly corroded by moist ammonia and moist sulfur dioxide. Most acids will dissolve cadmium, but not as rapidly as zinc. Cadmium is very soluble in concentrated ammonium nitrate solution, and such solutions are used by electroplaters to strip cadmium from plated steel or iron objects. Cadmium oxide and hydroxide, unlike those of zinc, are insoluble in excess sodium hydroxide. The cadmium ion is displaced by zinc metal in acidic sulfate solutions.

Cadmium oxide, CdO, is a brown powder (sp gr 6.95 at 20°C or 78°F) used mainly to prepare cadmium electroplating baths, and can be made by heating the hydroxide or burning the metal. It is more easily reduced to a metal by heating with carbon than zinc oxide. This property, as well as the fact that cadmium is more volatile than zinc, is important in the recovery of cadmium in zinc ore smelting operations and from lead and copper smelting where zinc and cadmium are present.

Cadmium sulfide, CdS, is obtained as a bright yellow precipitate by passing hydrogen sulfide through a solution containing cadmium ions. The precipitate is insoluble in cold dilute acid, and use is made of this property in the detection of the presence of cadmium by qualitative analysis procedures. CdS (cadmium yellow) and cadmium sulfoselenide (cadmium red) are permanent useful pigments. These compounds exhibit a strong photovoltaic response to visible light, and are becoming of interest in solar energy applications.

The Weston standard cell, which gives a nearly constant potential (1.0186 V), uses cadmium sulfate, $3\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$, as an electrolyte.

Cadmium halide compounds are generally similar to the corresponding zinc halide compounds, except that the cadmium halides are less ionized and do not hydrolyze in water as much as the corresponding zinc compounds. Except for the fluoride, cadmium halides are considerably less soluble in water than the zinc compounds. Cadmium iodide is the least ionized of the cadmium and zinc halides and, like cadmium fluoride, does not form hydrates.

Toxicity. The fumes of cadmium, its compounds, and solutions of its compounds are very toxic, and cadmium-plated articles should not be used in food, nor should cadmium-coated articles be welded or used in ovens.

Analytical methods. Cadmium can be determined gravimetrically by the sulfate method, by precipitation as the beta-naphthoquinoline complex, or by electrodeposition from faintly alkaline cyanide solution. Volumetrically, the cadmium ion can be titrated with the chelating agent ethylenediaminetetraacetate (EDTA), using Eriochrome Black T indicator. It is also easily determined polarographically, a method particularly suitable when zinc is present, and also by emission spectroscopy, by atomic absorption spectroscopy, and by electron microprobe analysis.

Uses. The main use of cadmium is in the plating of iron and steel, and to a much less extent of other alloys, such as copper and brass, to protect them from corrosion. Although cadmium can be deposited from acidic baths such as the sulfate (used in the electrowinning of cadmium) and the fluoborate, nearly all commercial plating for protective coatings is done in cyanide baths (composed of 20-25 g/liter cadmium oxide dissolved in 100-125 g/liter