

# CACTACEAE

Diversity of morphology, function, and habitat

Dr. Ed Leuck

Gila Native Plant Society

Friday, May 15, 2020

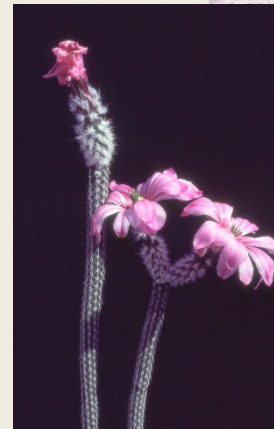
7 pm



# CACTACEAE

Diversity of morphology, function, and habitat

125 genera, 1500 species



# Closest relatives?

No fossil history (maybe an Eocene prickly pear in Utah)

Portulacaceae: many succulents, CAM and C4 simultaneously in some  
Didieriaceae : S/SW Madagascar, CAM PHS

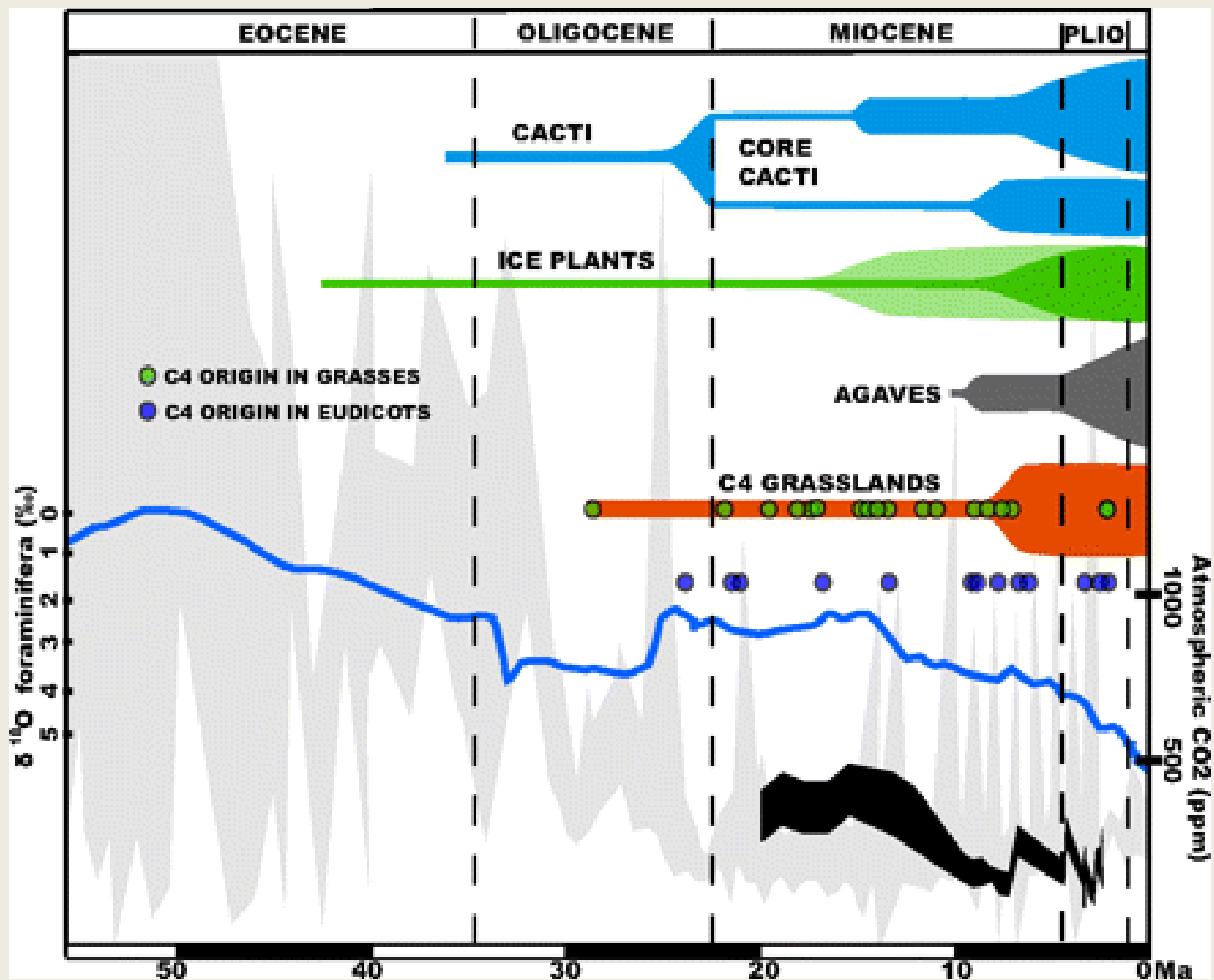


*Talinopsis frutescens*

Cacti are known as fossils only from a few bits of debris in ground sloth dung.



*Alluandia procera*

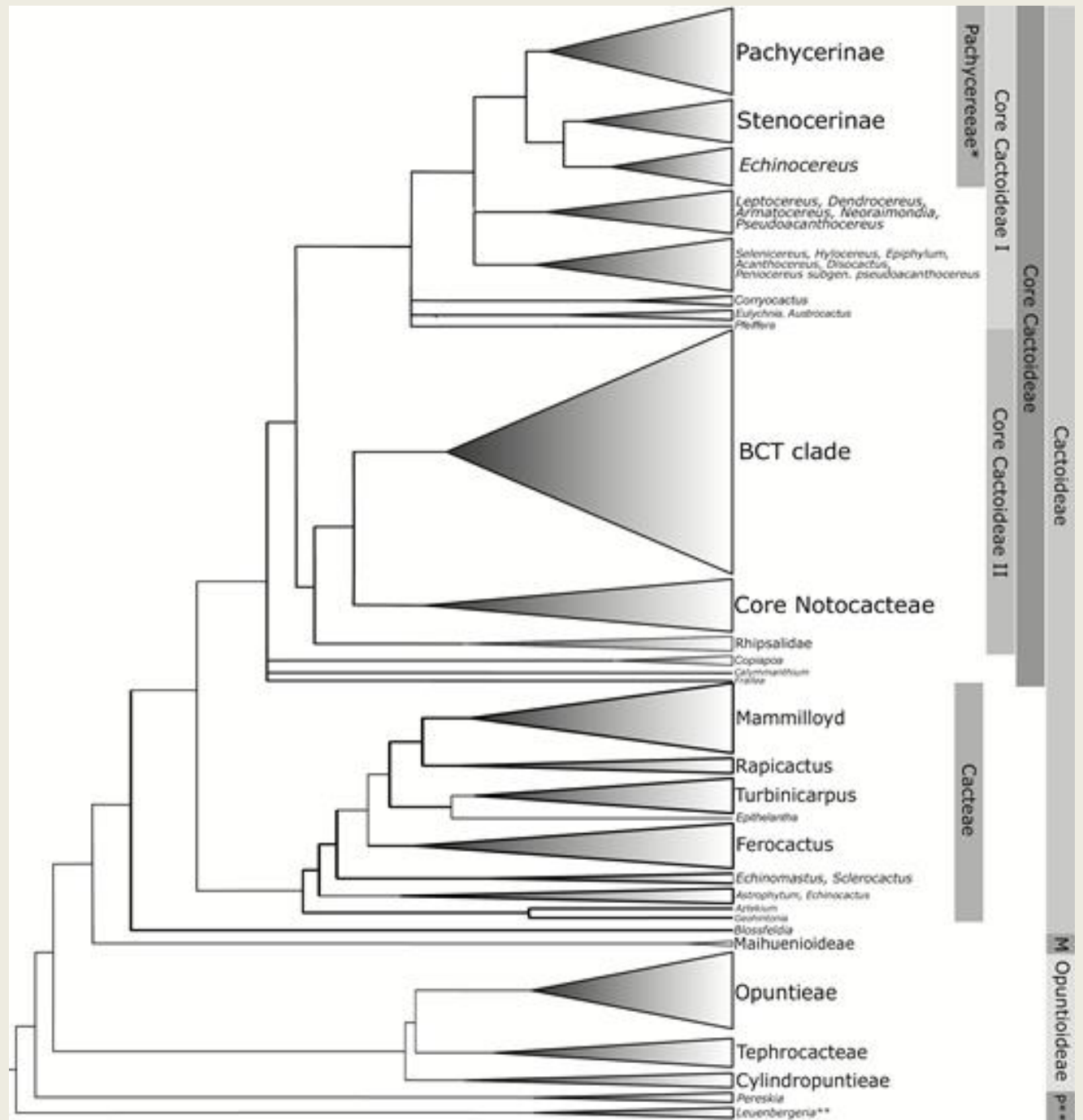


### Contemporaneous and recent radiations of the world's major succulent plant lineages

Mónica Arakaki, Pascal-Antoine Christin, Reto Nyffeler, Anita Lendel, Urs Eggli, R. Matthew Ogburn, Elizabeth Spriggs, Michael J. Moore, and Erika J. Edwards

PNAS May 17, 2011 108 (20) 8379-8384; <https://doi.org/10.1073/pnas.1100628108>

Origin and Diversification in the  
 Cactaceae. Pablo C  
 Guerrero, Lucas C  
 Majure, Amelia Cornejo-  
 Romero, Tania Hernández-  
 Hernández  
*Journal of Heredity*, Volume 110:  
 pp4-21 2019



# Native Range of the Cactaceae



*Opuntia fragilis*

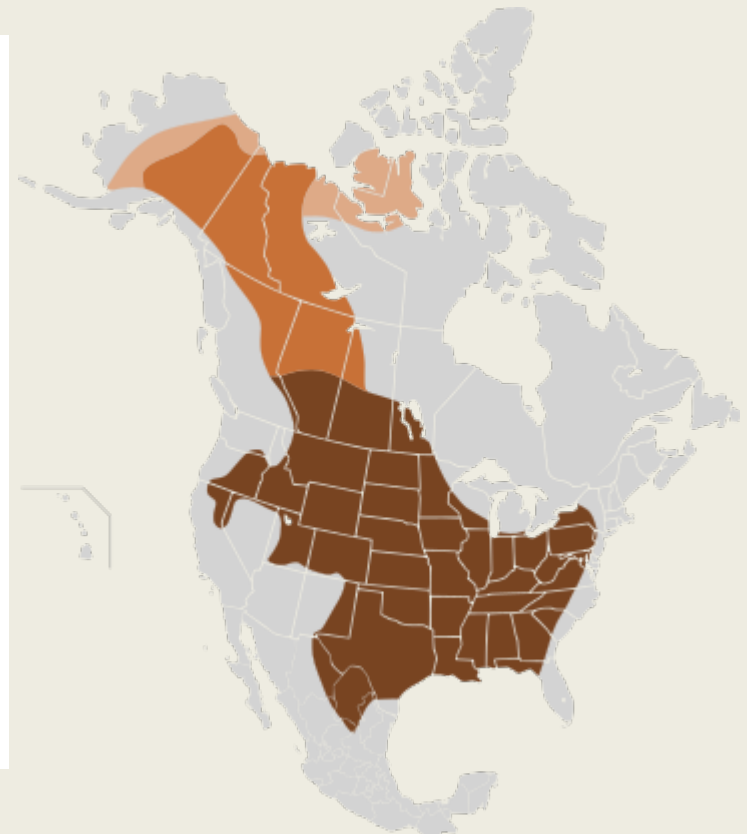


*Maihuenia poeppigii*

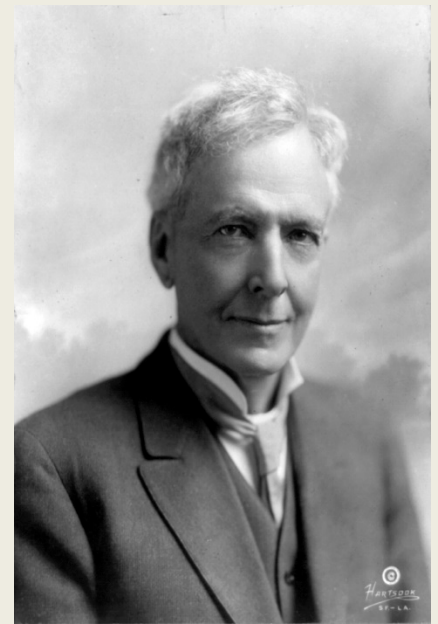


*Rhipsalis baccifera*





# Luther Burbank



Attempted to develop spineless prickly pear cacti: fruits for food, pads for cattle forage and human consumption

Vegetate the deserts of the world





[Heuzé V., Tran G., 2017. Prickly pear \(\*Opuntia ficus-indica\*\). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. <https://www.feedipedia.org/node/120> Last updated on November 28, 2017, 16:04](#)  
English correction by Tim Smith (Animal Science consultant) and H  l  ne Thiollet (AFZ)



It is recommended to process cladodes before feeding them to livestock. Several feeding and processing methods have been described ([Lopez-Garcia et al., 2001](#)):

**Direct feeding:** *Opuntia* plants are browsed whole, including spines, by cattle, sheep and goats. This practice is harmful to the animals.

**Removal of cladode edge:** the upper portion of the cladodes, where the largest number of thorns is present, is removed with a knife, allowing animals to feed on the plant. Its main disadvantage is the waste of cladodes.

**Singeing-off of spines of whole plants:** the plant is completely flamed with a propane or kerosene burner, and the animals are allowed to consume it down to the base. It is combined with grazing in the case of sheep and goats.

**Extensive cladode cutting and superficial burning:** this practice eliminates spines and allows animals to eat the whole cladodes directly in the field. The cladodes may be cut into small pieces.

**Singeing and chopping in situ:** the cladodes are harvested and their spines burned with firewood or gas torch. Then they are chopped and offered to animals.

**Cladode harvesting from dense stands:** cladodes are transported to the farm, their spines are burned off, and they are cut into small pieces.



Peeled prickly pear fruit selections at a Mexican market in Zacatecas (Wikipedia)



Silver City Wal-Mart



Outside Tucson 1978



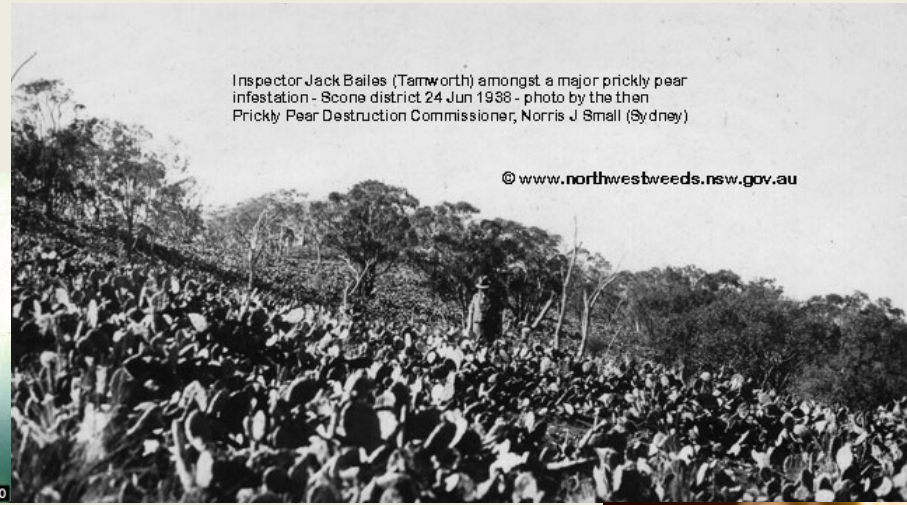
Etsy



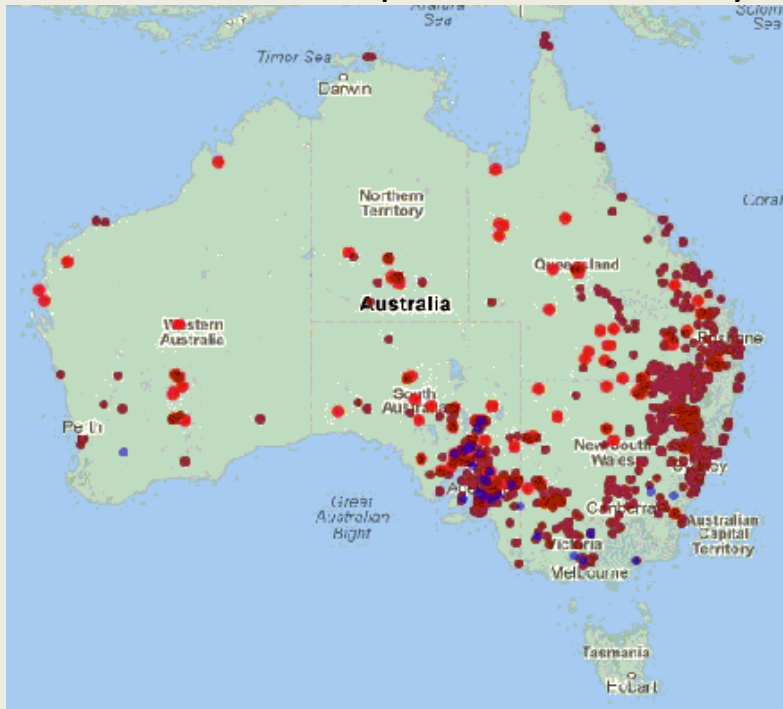
National Park Service

# Prickly pear in Australia

introduced in 1800s for living fence and cochineal dye

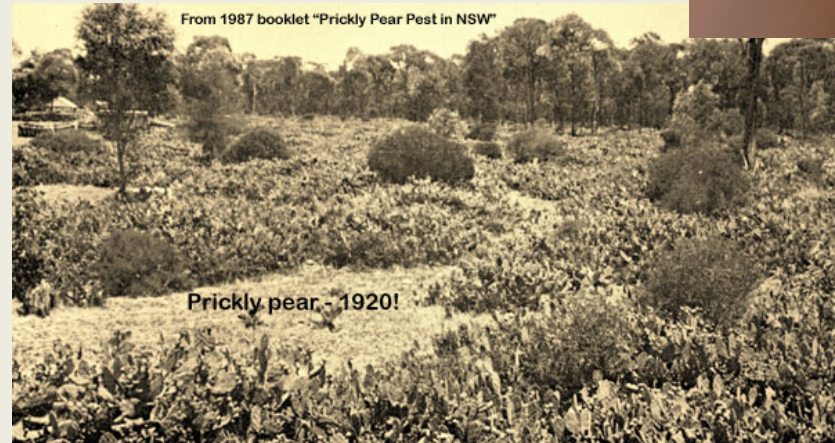


No predator/herbivore/pests  
Rendered 15,000 sq miles unusable by 1920



1920s worldwide effort to find biological control

*Cactoblastis cactorum* from Argentina





<https://www.biographic.com/a-plague-of-cactus/>

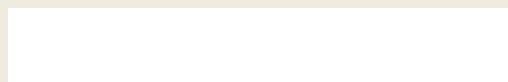
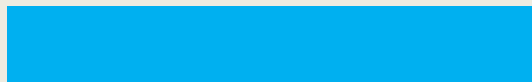
<https://www.cnn.com/2019/12/09/africa/kenya-devil-cactus-intl/index.html>

<https://www.biographic.com/a-plague-of-cactus/>



# Family Characteristics

- Succulence/ stems expand and contract
- Leaves replaced by perennial spines
- Waxy cuticle on the epidermis
- CAM photosynthesis
- Areole anatomy (twin meristems)
- Flowers with inferior ovaries, tepaloid perianth, lots of stamens
- Betalain floral pigments (no blues, purple: red/pink/yellow/violet/white)
- n = 11

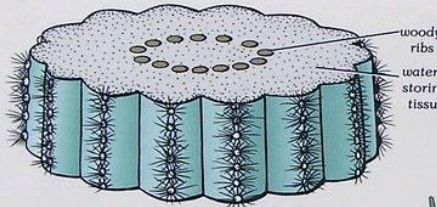


## Why Does the Saguaro Cactus Have Ribs?

**Ribs allow the cactus to expand and contract in response to the amount of moisture it is storing.**

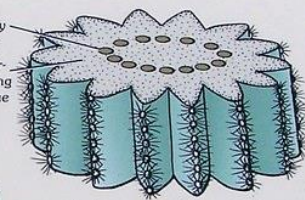
The ability to store water is an adaptation that helps saguaros live in the desert, where they can survive for several months without rain.

Cross-section of an  
E X P A N D E D  
Saguaro Cactus



A large saguaro can store up to 6 tons of water!

Cross-section of a  
C O N T R A C T E D  
Saguaro Cactus

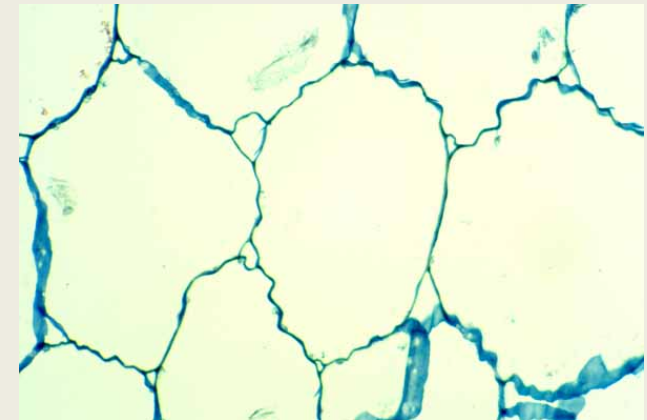
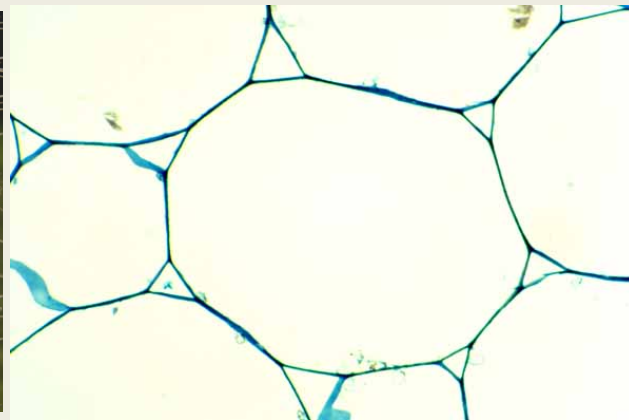


A large saguaro can lose 2/3 of its stored water and still live!



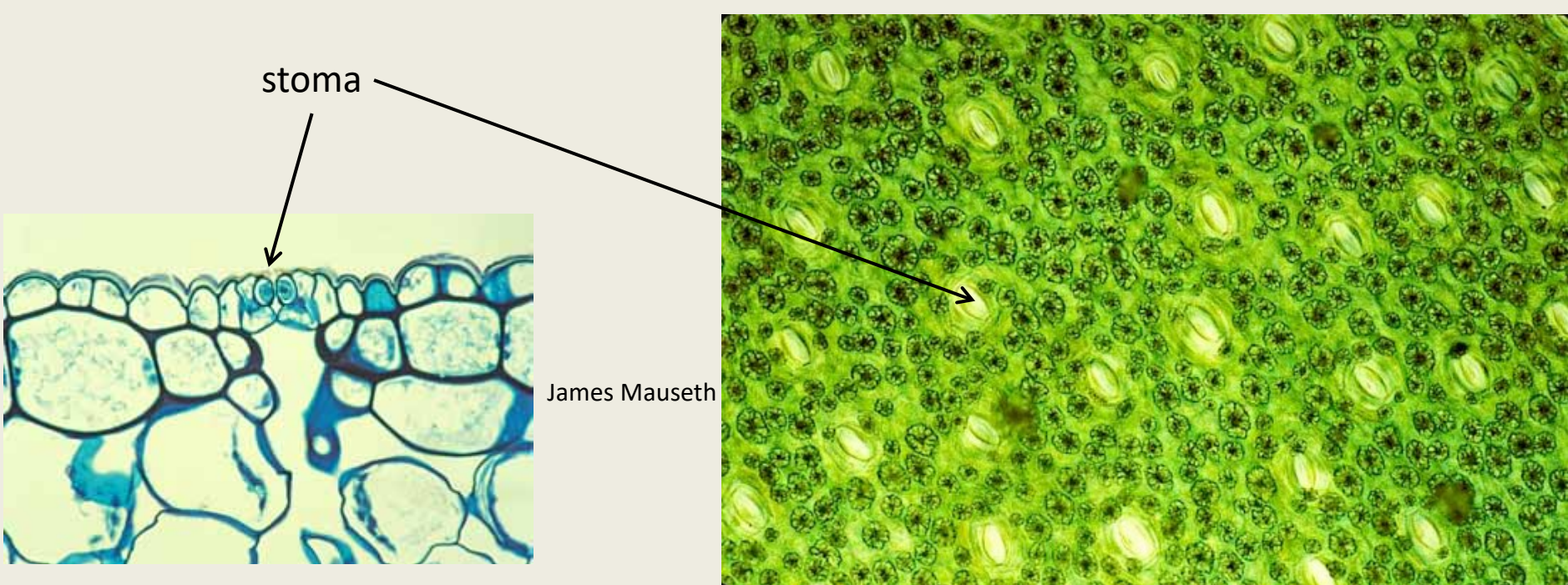
Shallow, widespread roots quickly draw up rainwater, even after a very short rain. Additional roots, called "rain roots," grow within a few hours of a rainfall to capture even more moisture.





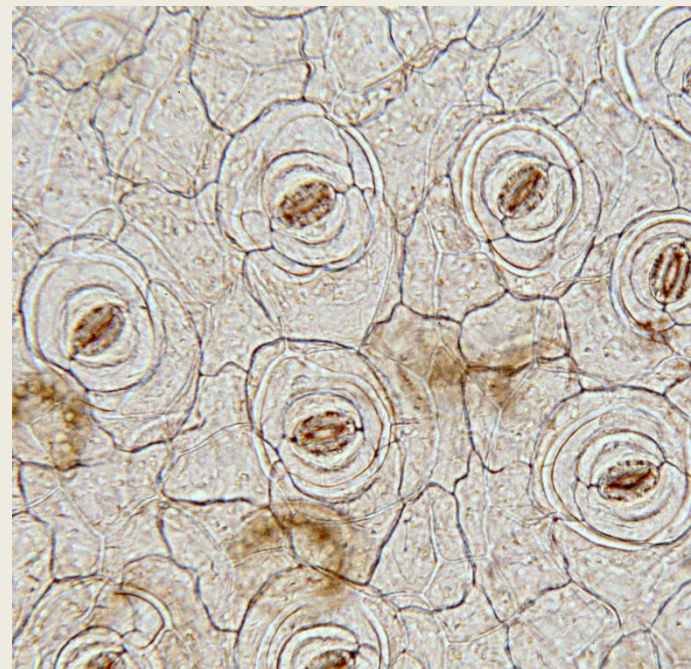
James Mauseth - UT





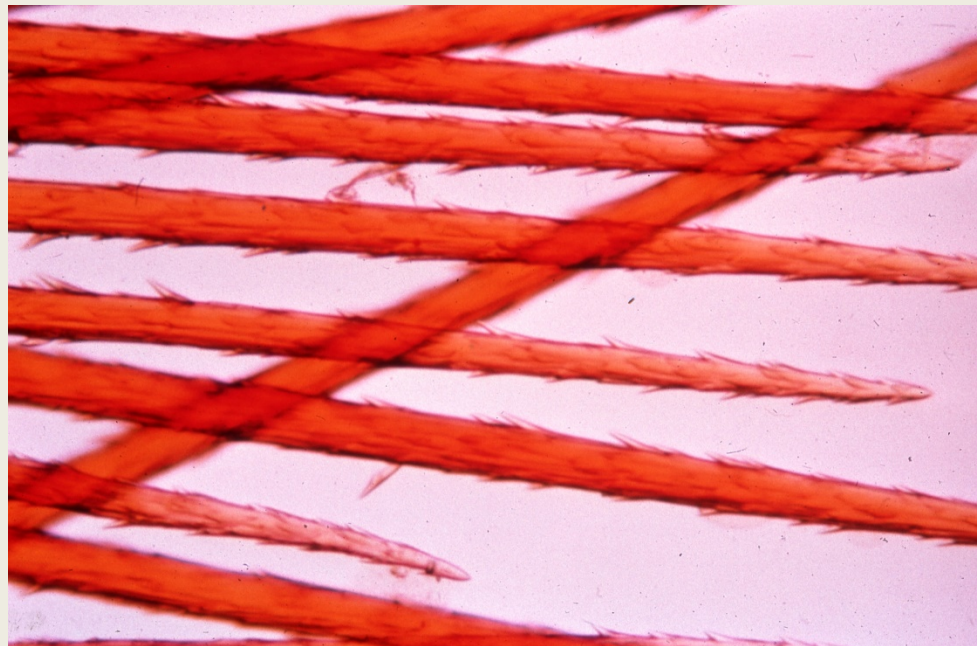
Chlorophyllous cells are hypodermal, and the waxy epidermis is penetrated by stomata. Note that these are stomata on STEMS, not leaves, and must persist for years, not months.

The epidermis is generally thin, and perennial (or stoma would not be retained) unless it becomes meristematic in age and produces corky or fibrous tissues.





Spines are modified leaves, not stem tissue as are prickles or thorns, and arise from axillary meristems.

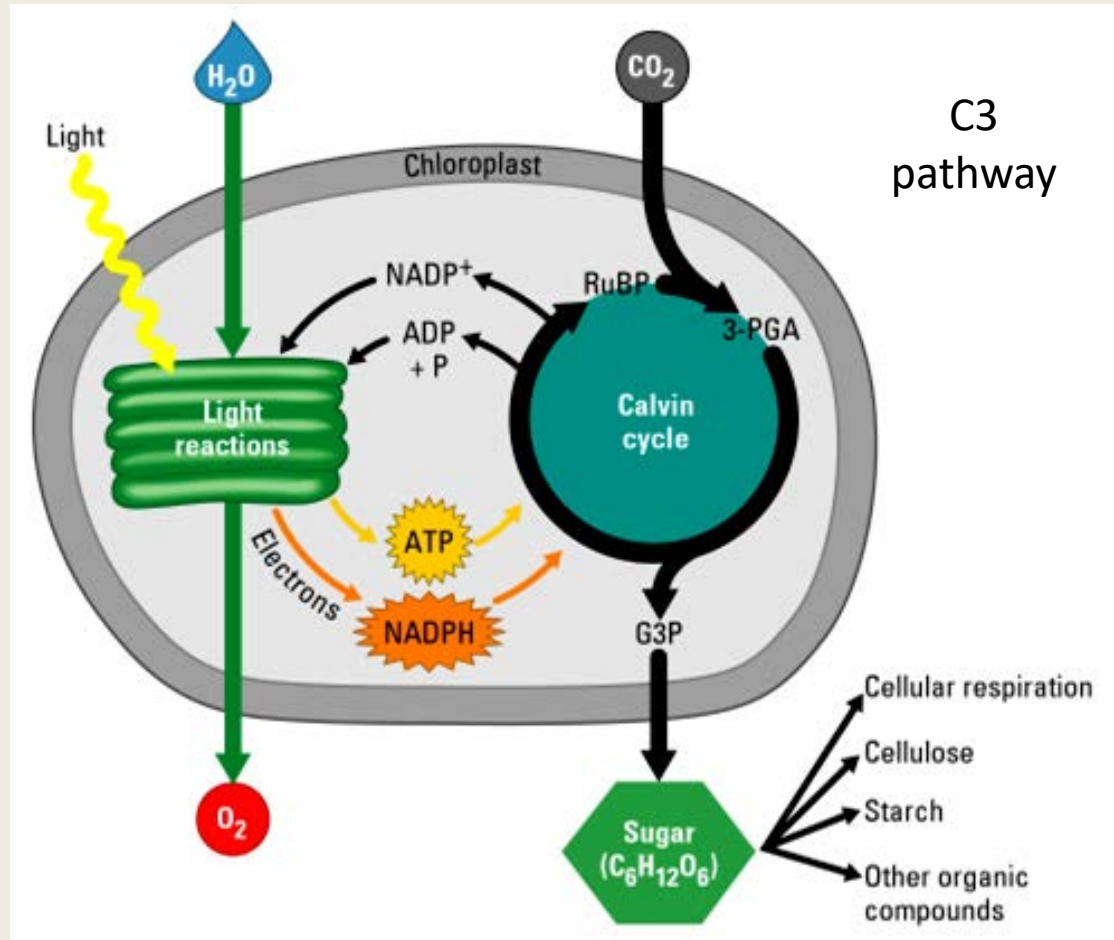
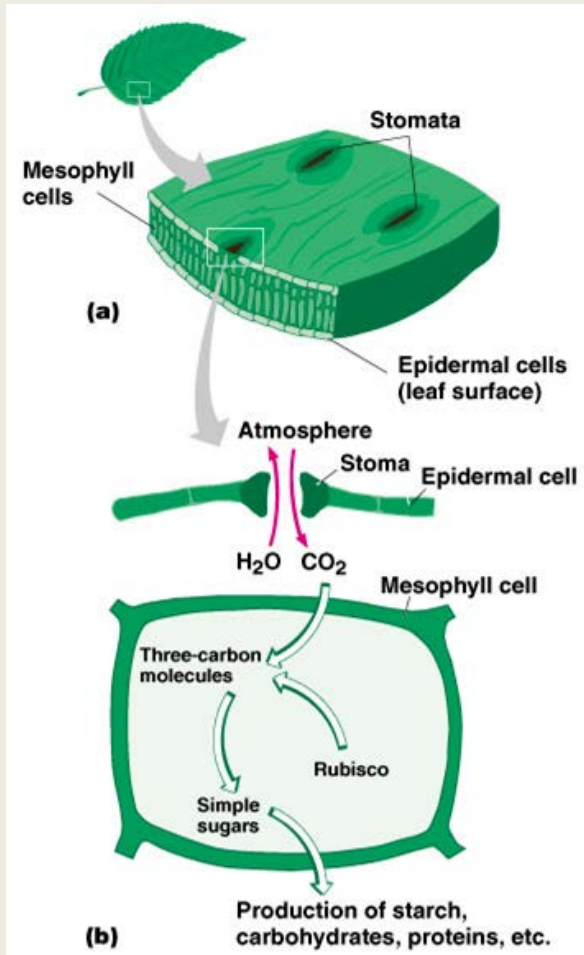


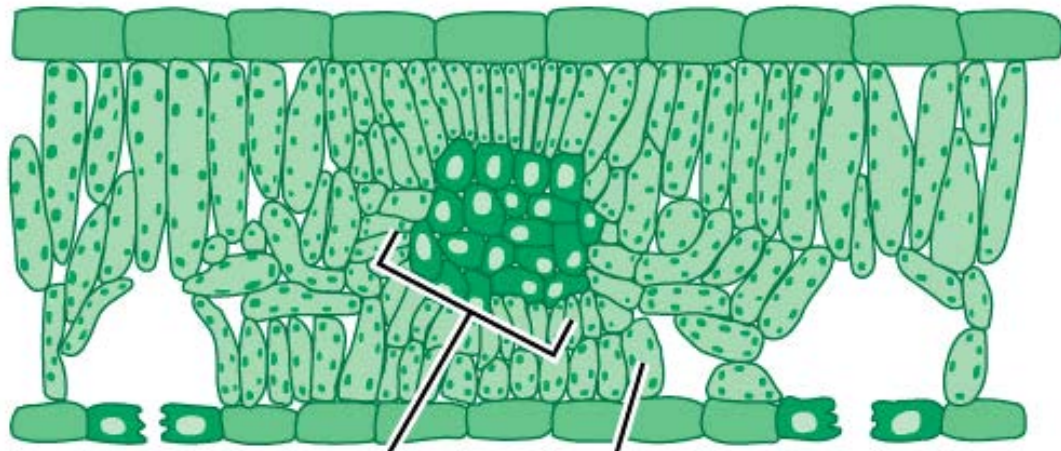
Glochids of the prickly pears have recurved barbs.



# Photosynthetic pathway in cacti

- Only one way to make sugar: RuBP carboxylase fixes atmospheric carbon dioxide into 3-PGA
- Two options (fixation enzymes) for fixing atmospheric carbon dioxide into an organic molecule
- Require the opening of stomata to provide carbon dioxide: only 420 ppm in the air diffusing in
- Stomata normally open in daytime to capture rare gas when light energy is available





(a)

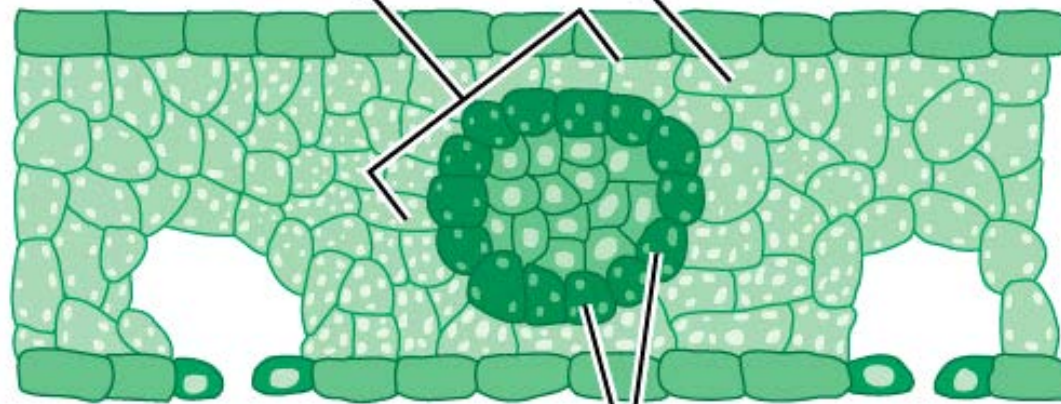
Stoma

C3 pathway

Vascular bundles

Mesophyll cells

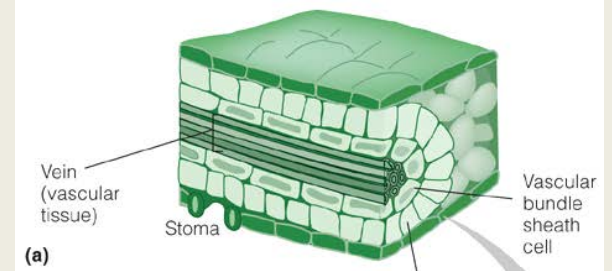
C4 pathway



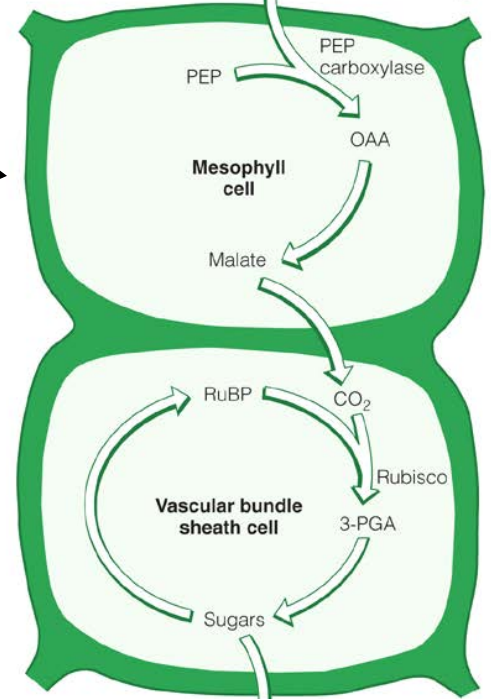
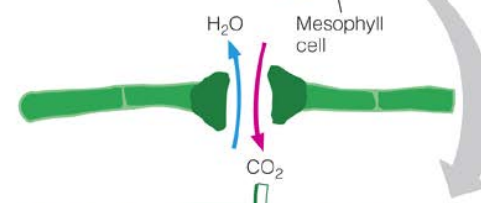
(b)

Stoma

Bundle sheath cells



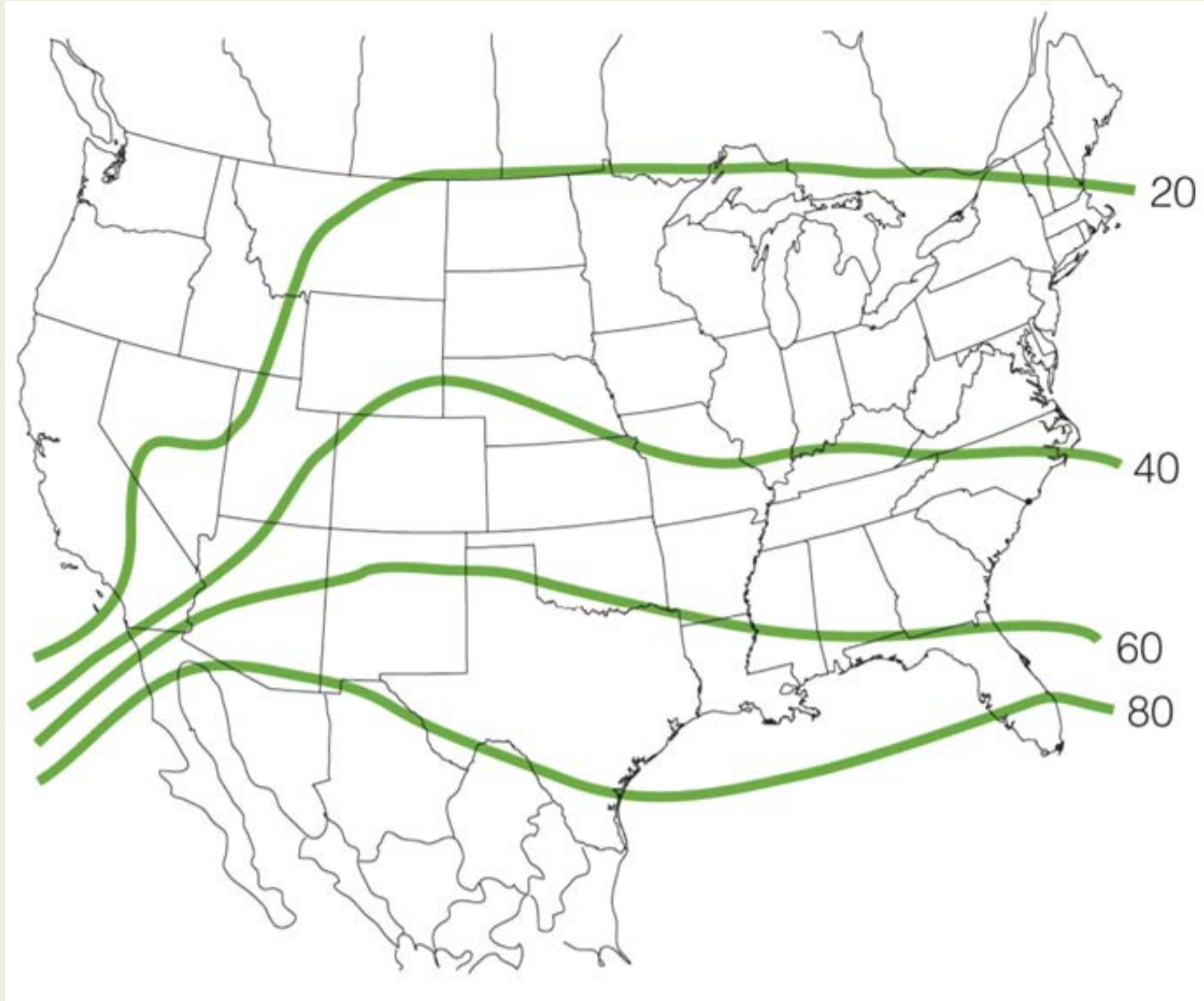
(a)



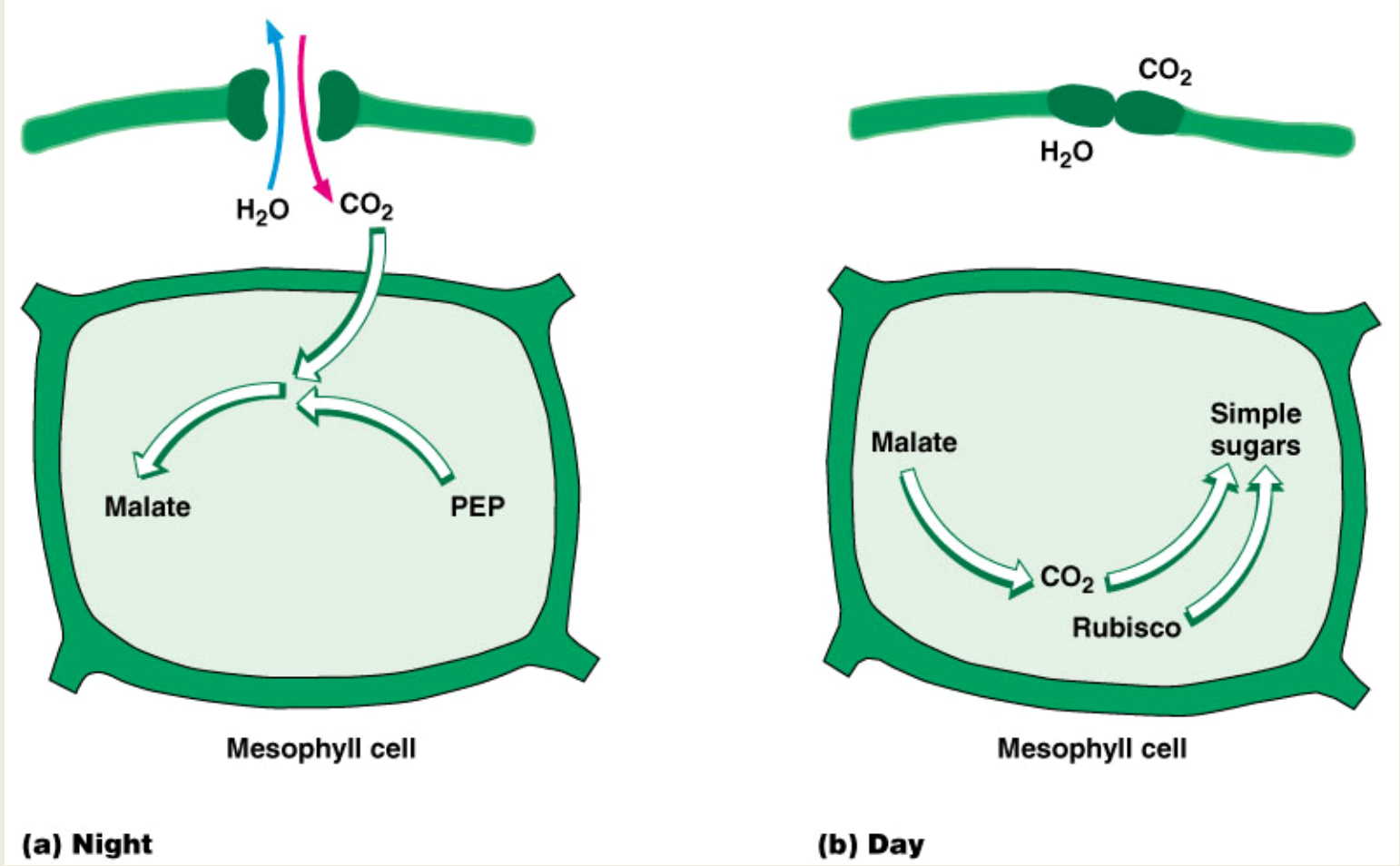
(b)

To transport tissues

# % occurrence of C<sub>4</sub> Grass species



# CAM Photosynthesis





## CAM plants

Found in 10  
monocot and  
25 dicot  
families



Exclusive usage only in Cactaceae and Crassulaceae

CAM operates C4 at night to capture  $\text{CO}_2$ , releasing  $\text{CO}_2$  in daytime for the C3 pathway to make sugar.

Stomata in stems open at night when water stress is less, then close in daytime to conserve water.

The amount of sugar made is limited by the amount of  $\text{CO}_2$  fixed at night, which is limited by stored ATP and  $\text{NADPH}_2$  from the previous day

Net PHS rates much lower than C3 or C4 plants.

All cacti are CAM plants except *Pereskia*, which does C3 in leaves and maybe CAM in young stems that are still green, and *Maihuenia*.

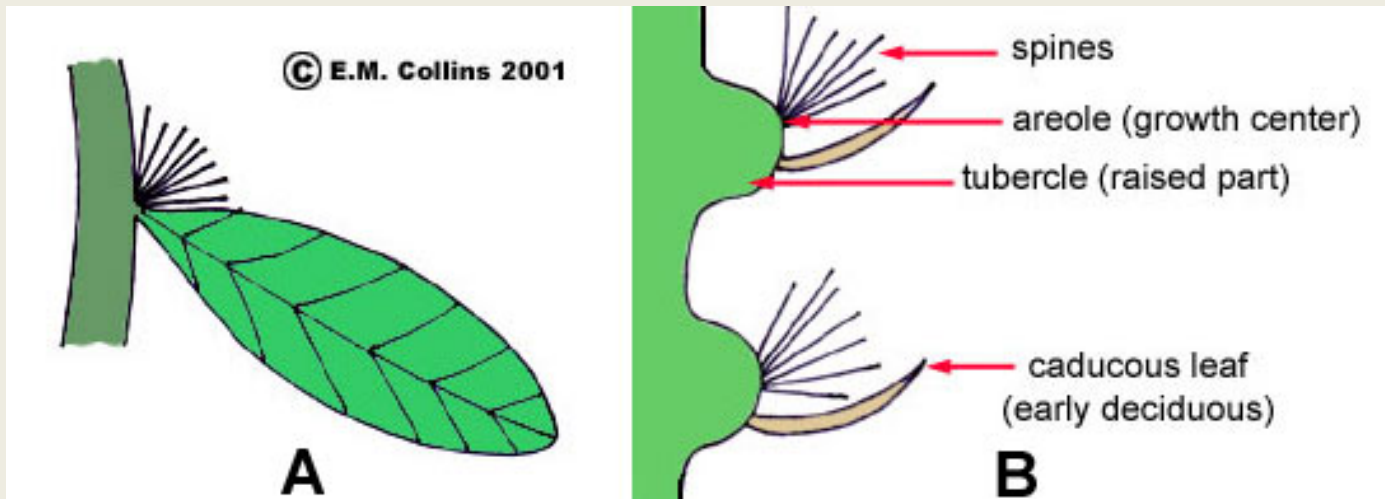


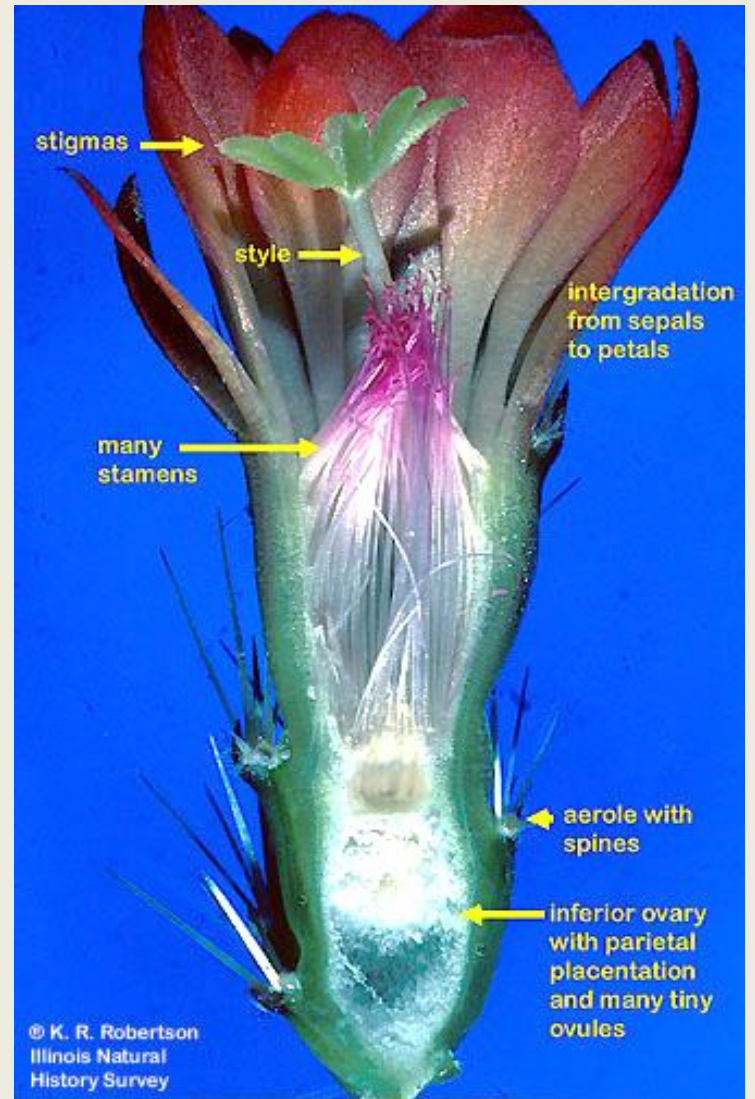
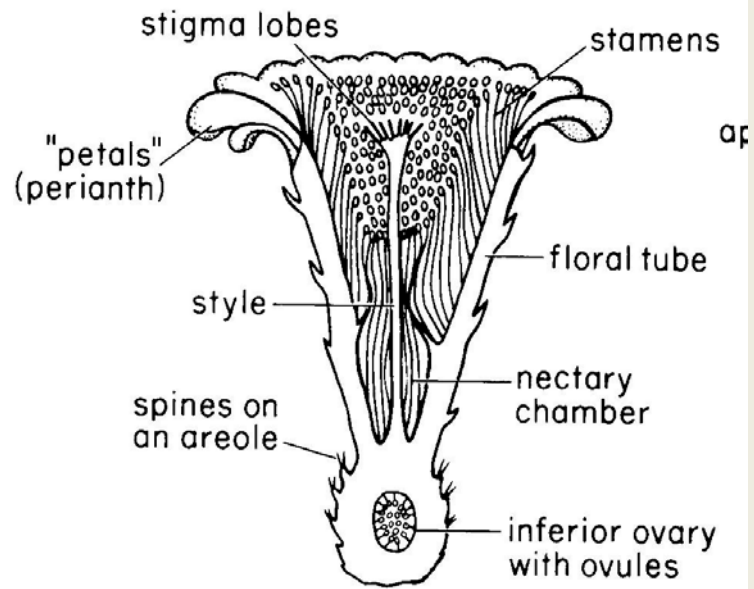


# Areole anatomy

Dual function meristem: one produces spines, other an adaxial axillary bud for producing flowers and /or branches

Normally only function once







*Echinocereus reichenbachii*  
anther squash 100X



Coryphantha anther  
squash 400X

Theophrastus used the word “kaktos” for some now unknown spiny plant. Latin “cactus”.

Columbus brought back a “*Echinomelocactus*” from his travels to cultivate in Europe.

## Cactus taxonomists

Linnaeus – had two cacti, a *Cactus* from Jamaica (*Melocactus* now) and a *Pereskia* from unspecified Caribbean location in 1737, but included fifteen species (all placed in the genus *Cactus*) in *Species Plantarum* in 1753.

Described genera were raised to the family level in 1789 by de Jussieu.

The genus *Cactus* was eliminated as too confusing by 1905 Vienna Code even though the family name was conserved. (*Mammillaria* chosen as the type genus). Many lack type specimens.

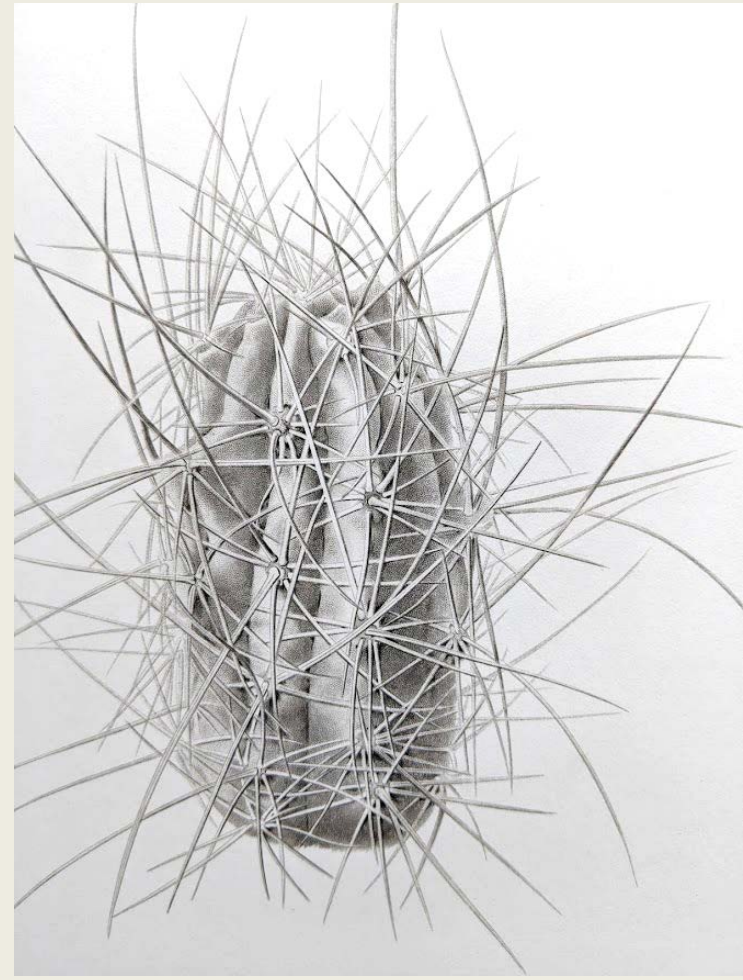
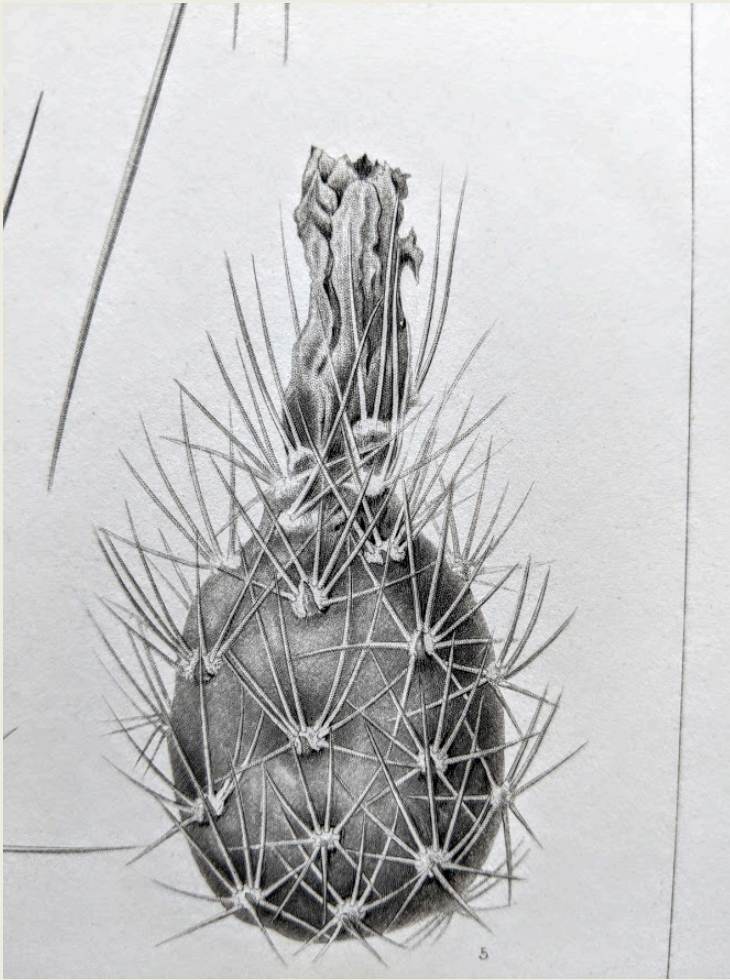
Dr. George Engelmann of St. Louis produced many treatises on cacti, including the *Cactaceae of the Boundary* (US-Mexico border, under Emory) , *Cactae of Emory’s Reconnaissance* (Fort Leavenworth, Missouri to San Diego), and *Synopsis of the Cactaceae of the United States and adjacent regions*, and other explorations by Whipple, Wheeler, Ives, Simpson.

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### VIII. — CACTACEÆ OF THE BOUNDARY.

FROM REPORT OF THE UNITED STATES AND MEXICAN BOUNDARY SURVEY, UNDER THE ORDER OF LIEUT.-COL. W. H. EMORY,  
MAJOR FIRST CAVALRY, AND UNITED STATES COMMISSIONER. II. PART I. pp. 1-78. Washington, 1859.

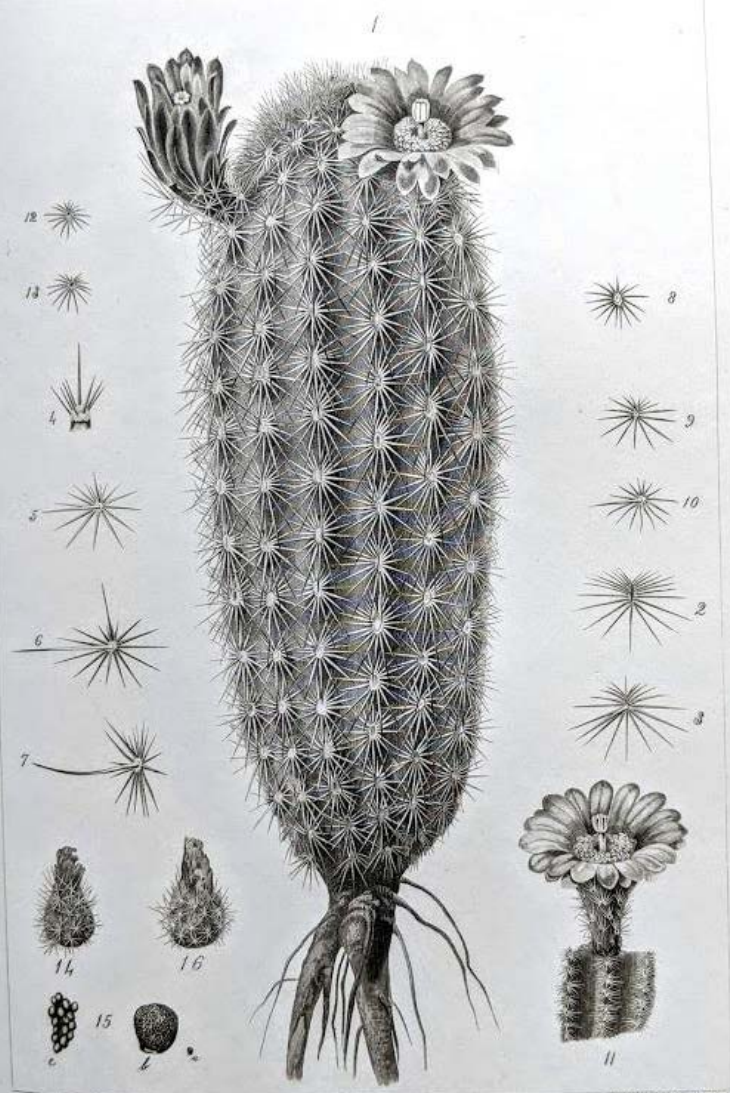
#### I. MAMILLARIA, HAW.<sup>1</sup>



*Cereus (now Echinocereus) stramineus* fruit and stem



CEREUS CHLORANTHUS



CEREUS VIRIDIFLORUS

*Cereus (Echinocereus) chloranthus* and *Cereus (Echinocereus) viridiflorus* var. *cylindricus* original illustrations accompanying descriptions of these new taxa.

N. L. Britton and J. N. Rose produced *The Cactaceae* in 1920, 2<sup>nd</sup> ed 1937, with 124 genera and 1235 species under the auspices of the Carnegie Institute and the National Herbarium. Both line drawings and real photographs included with full descriptions and much habitat information.

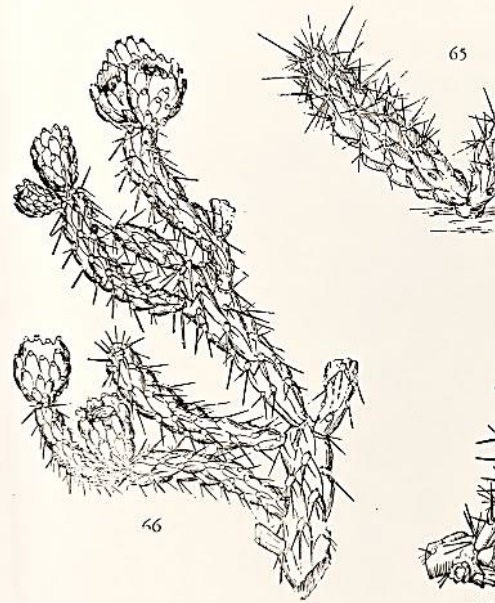
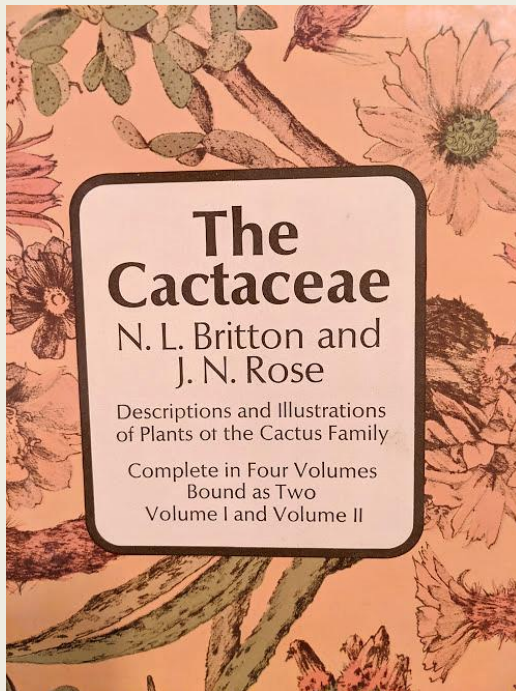
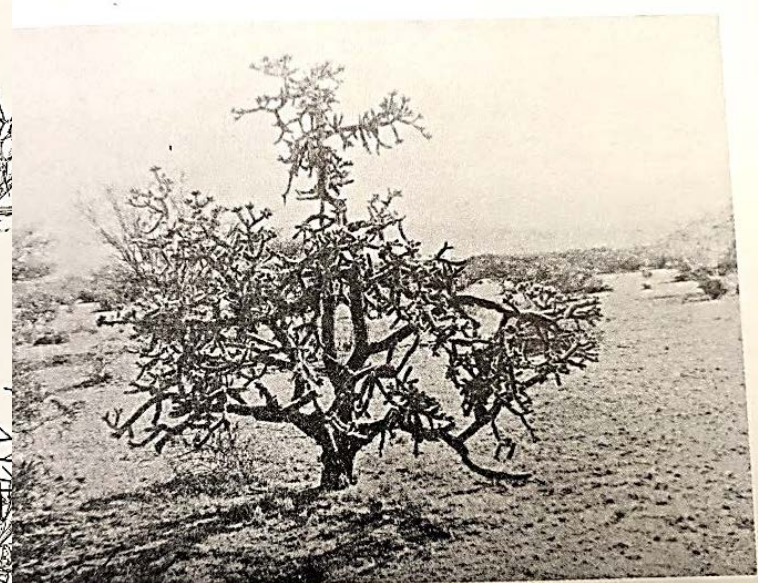


FIG. 64.—*Opuntia davisii*.  $\times 0.5$ .



FIG. 65.—*Opuntia viridiflora*.  
 Fruits of *Opuntia fulgida*.



A very open plant of *Opuntia spinosior*.

Curt Backeberg (1894-1966) traveled extensively in central and South America and published the 4,000 page, 6 volume *Die Cactaceae* and the smaller *Kakteenlexikon* in 1966. He named or renamed 1200 species without any type specimens. According to David Hunt, cactus specialist at Kew Gardens, he "left a trail of nomenclatural chaos that will probably vex cactus taxonomists for centuries."



# Cactaceae subclassifications

- Subfamily Pereskioideae
- Subfamily Opuntioideae
- Subfamily Cactoideae
- Subfamily Maihuenioideae

2 species at high altitude in southern Andes  
in southern Chile and Argentina

True leaves, no CAM

Mat-forming cushion plant

*Maihuenia patagonica*



*Maihuenia poeppigii*



# Pereskioideae

True persistent non-succulent leaves with C3 photosynthesis

Stomata open in day as other C3 plants

Drought-inducible stomatal switching and CAM

Young stems (green) may do low-level CAM

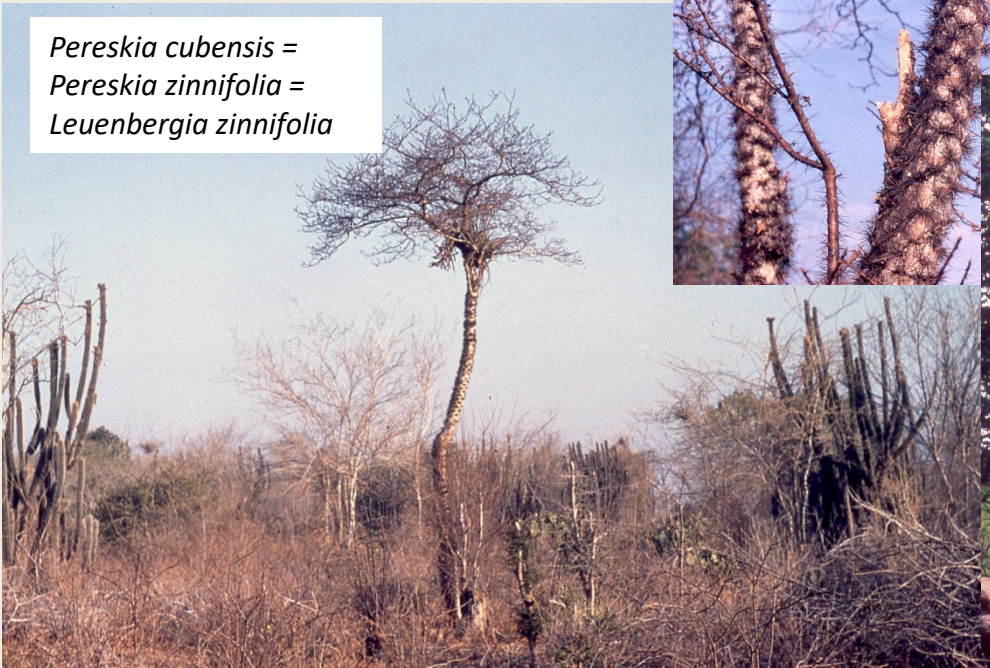
Woody trees and large shrubs

Eastern Mexico and some Caribbean islands, central America, also south of the Amazon

No stomata on stems



*Pereskia cubensis* =  
*Pereskia zinnifolia* =  
*Leuenbergia zinnifolia*



*Pereskia autumnalis* =  
*Pereskia lynchnidiflora*





*Pereskia aculeata*



*Pereskia corrugata*  
= *Leuenbergia bleo*



*Pereskia saccharosa*



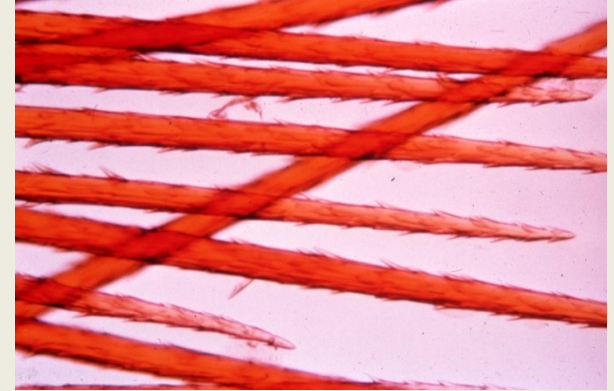
*Pereskia diaz-romero*



*Pereskia grandifolia*

# Opuntioideae

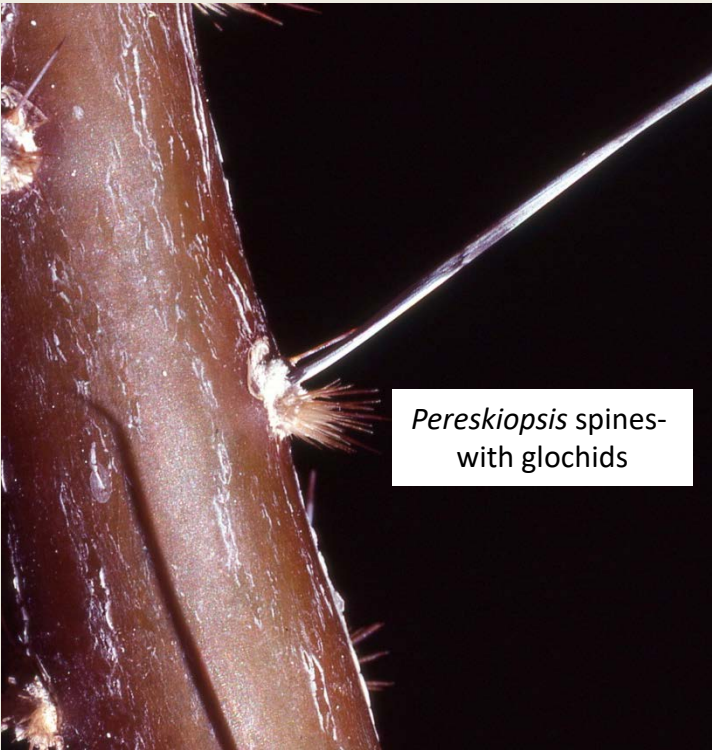
- Glochids as well as spines (may be deciduous)
- True leaves on juvenile growth (caducous)
- Stems often jointed – cladodes or cladophylls
- Stems lack a thick cortex, cortical bundles, or collapsible cortical cells
- No ribs or tubercles



Cannot absorb or transfer water intercellularly as well as other cacti



Primitive ones have persistent succulent leaves



*Pereskia* spines-  
with glochids



*Austrocyllindropuntia*

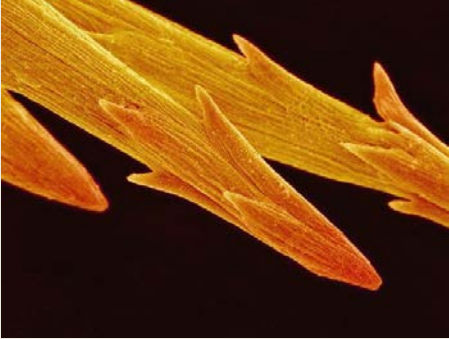


*Pereskia spathulata*



Four or five tribes: best known are the

**Cylindropuntiae** (chollas – round stems) 4 genera



*Austrocylindropuntia* (South America)

*Cylindropuntia* – upright, cylindrical joints, papery sheaths on barbed spines

*Grusonia* – low, clumping

*Pereskiopsis* - shrubby, true succulent evergreen leaves

**Opuntiae** (prickly pears –flat stems) about 6 genera

*Opuntia* – flattened, rounded stems, upright or spreading, spines lack papery sheaths, not barbed  
glochids with recurved barbs



# Cactoideae

Highly reduced leaves are the sole monophyly

Intron loss in chloroplast gene *rpoC1* – present in first two subfamilies

Ribs or tubercles

Relatively thin cuticle (1-10 $\mu$ ) in most

Collapsible cortical cells: expand and contract readily, made possible by the cortical vascular bundles lacking in Opuntioideae: wide-band tracheids are elastic and change with the water available within to avoid cavitation

80 % of all cactus species: 9 tribes, about 100 genera

Only two of the tribes are monophyletic : emphasizes that taxonomy is for our benefit and does not reflect shared evolutionary history : multiple independent origins of similar characteristics

Great diversity of form and habitat: other than prickly pears and chollas, all the cacti you've ever seen

United States genera: *Acanthocereus*, *Ariocarpus*, *Carnegiea*, *Coryphantha*, *Echinocactus*, *Echinocereus*, *Epithelantha*, *Escobaria*, *Ferocactus*, *Lophophora*, *Mammillaria*, *Melocactus*, *Neolloydia*, *Pachycereus*, *Pediocactus*, *Peniocereus*, *Sclerocactus*, *Stenocereus*, *Thelocactus*.



*Melocactus salvador*  
Guanica, PR

*Melocactus matanzanus*  
cephalium



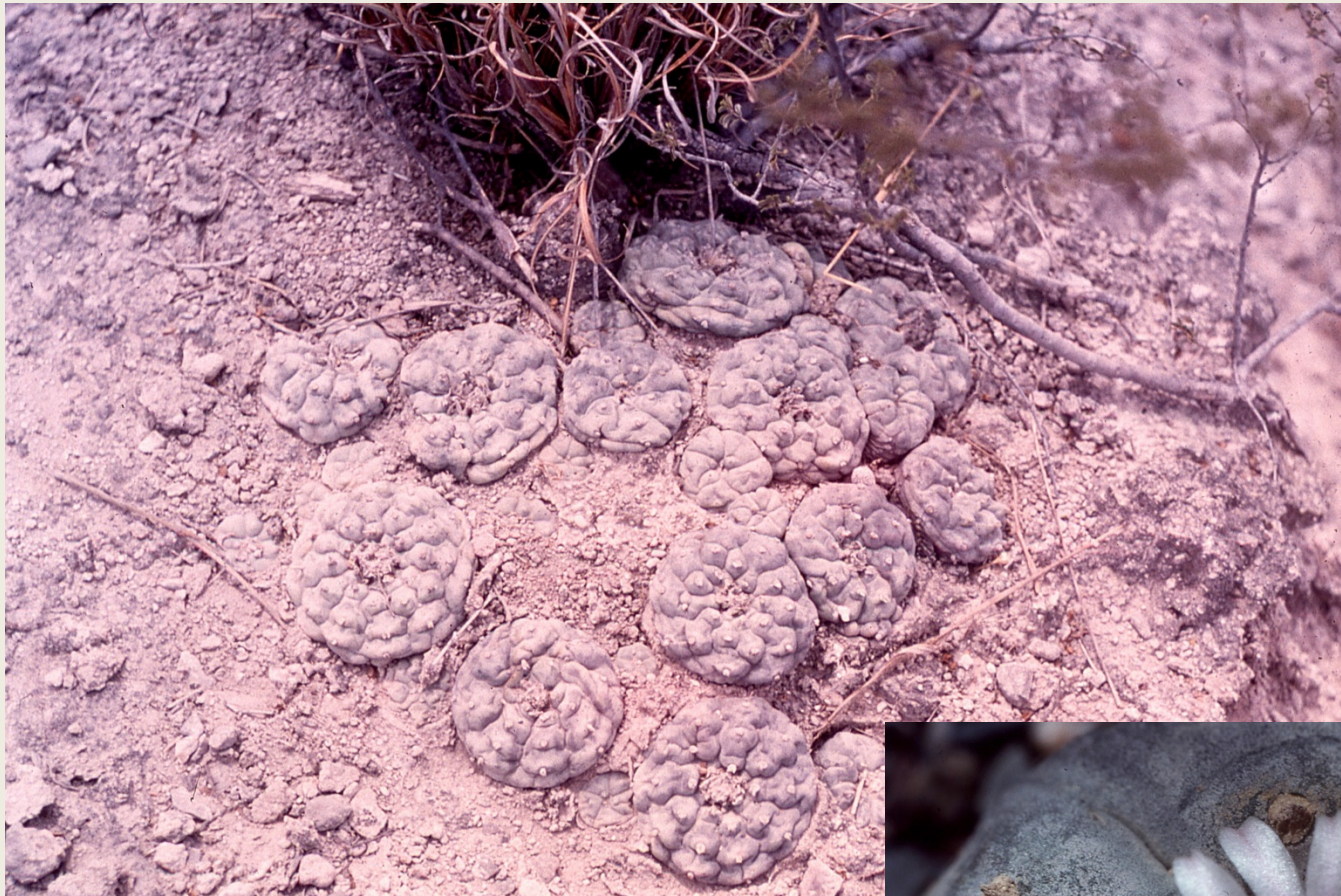




*Ariocarpus fissuratus*  
Boquillas, TX

One of the few cacti  
with a thick cuticle





*Lophophora williamsii*  
San Luis Potosi, MX



*Leuchtenbergia principis*



Thick, succulent roots also – cooler temperatures underground, also no need to support the water weight, out-of-sight of thirsty animals

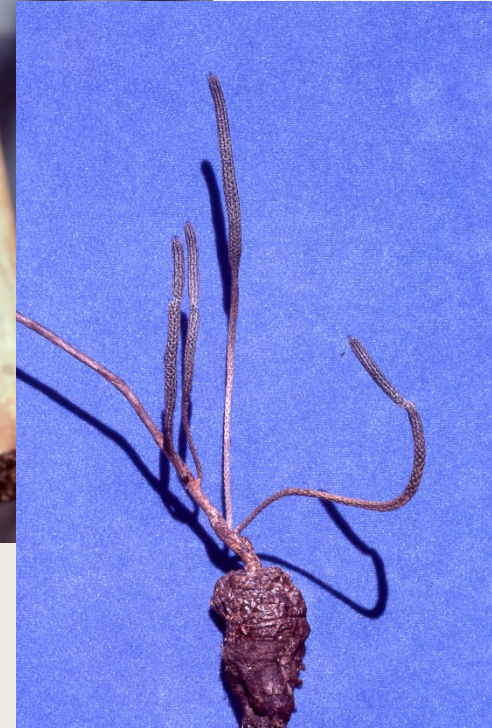


*Stenocactus multicostatus*  
Wavy ribs



San Lorenzo Junction, Nuevo Leon, MX

*Wilcoxia poselgeri*

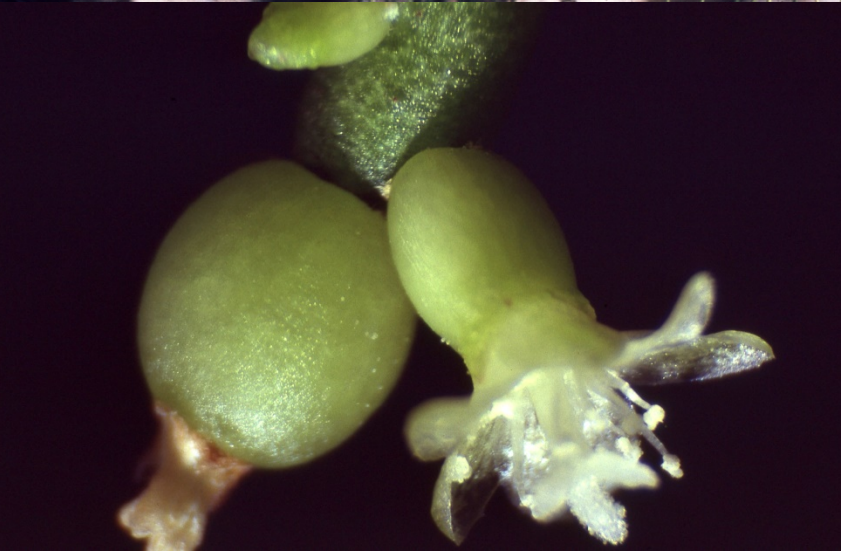


Landfill road, Roma, TX



*Rhipsalis  
cassytha*

Pinar del Rio, Sora, Cuba





*Schlumbergera  
truncata*



*Epiphyllum* sp.



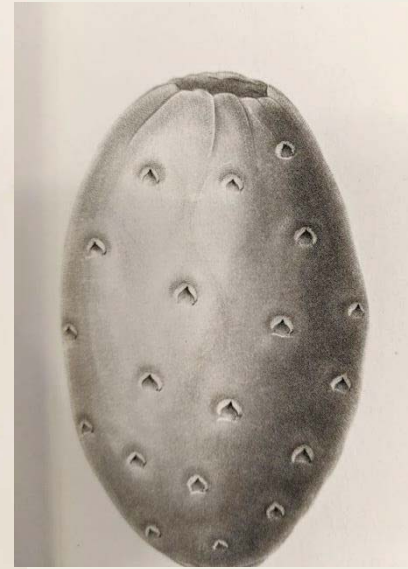
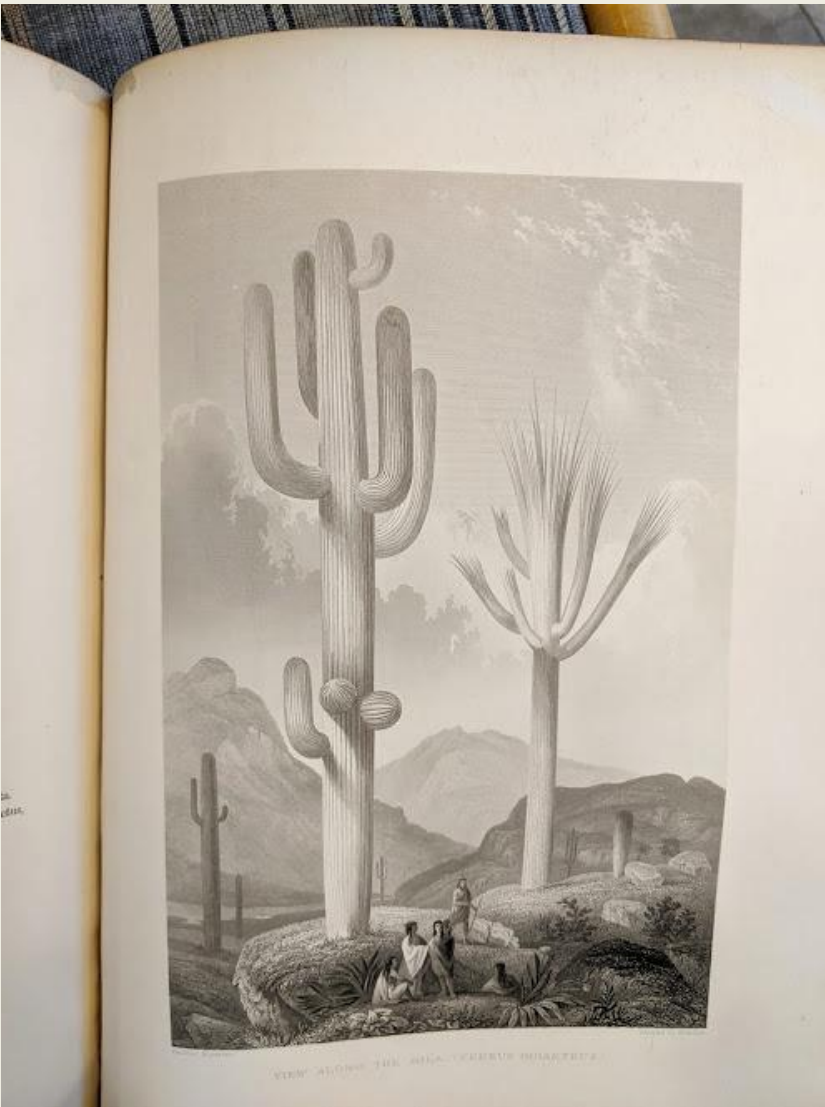




*Acanthocereus*  
*pentagonus*  
Laguna Atascosa, TX



*Carnegiea gigantea*



Frontispiece for *Cactaceae of the Mexican Boundary*



# New Mexico Cacti

*Coryphantha (inc Escobaria)*

*Cylindropuntia*

*Echinocactus*

*Echinocereus*

*Echinomastus*

*Epithelantha*

*Ferocactus*

*Grusonia*

*Mammillaria*

*Opuntia*

*Pediocactus*

*Peniocereus*

*Sclerocactus (inc. Glandulicactus)*



# New Mexico Cacti

Gila Native Plant Society

June 19, 2020

7 pm

