

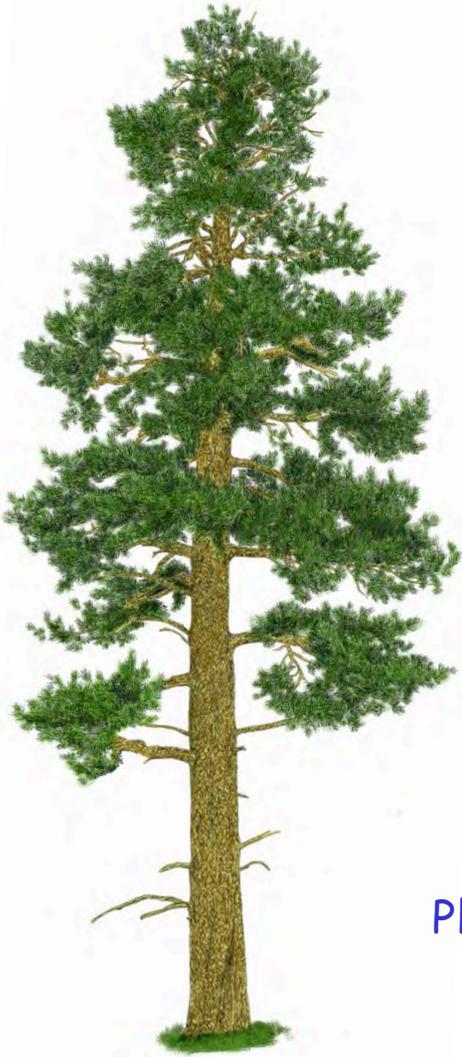
# Desert and Steppe Biomes

## Part 1

### Distribution and climate

Plant Ecology in a Changing World

Jim Ehleringer, University of Utah  
<http://plantecology.net>



What do most people think of when you first say “desert”?





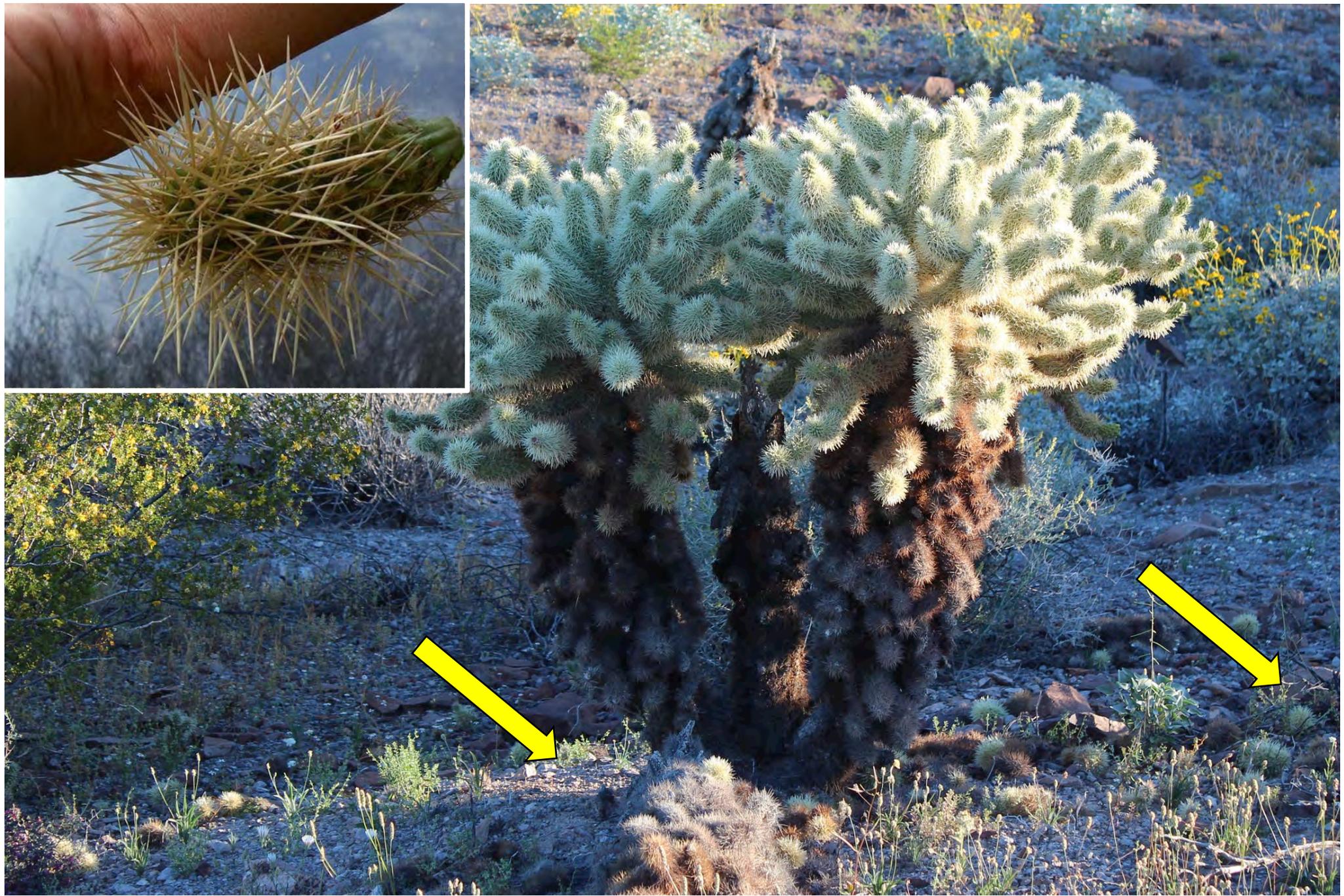
Near monospecific stands of jumping cholla, *Opuntia bigelovii*, a largely asexually reproducing perennial, Oatman, Arizona



And at the same time, the extensive spines increase reflectance of jumping cholla, *Opuntia bigelovii*, Oatman, Arizona



Disarticulating and marescent stems are features of jumping cholla, *Opuntia bigelovii*, Oatman, Arizona



Disarticulating *Opuntia bigelovii* go by the common name “jumping cholla”



*Ferocactus acanthoides*, the barrel cactus, face south in Arizona and Utah, reducing sunlight exposure on the sides of the cactus



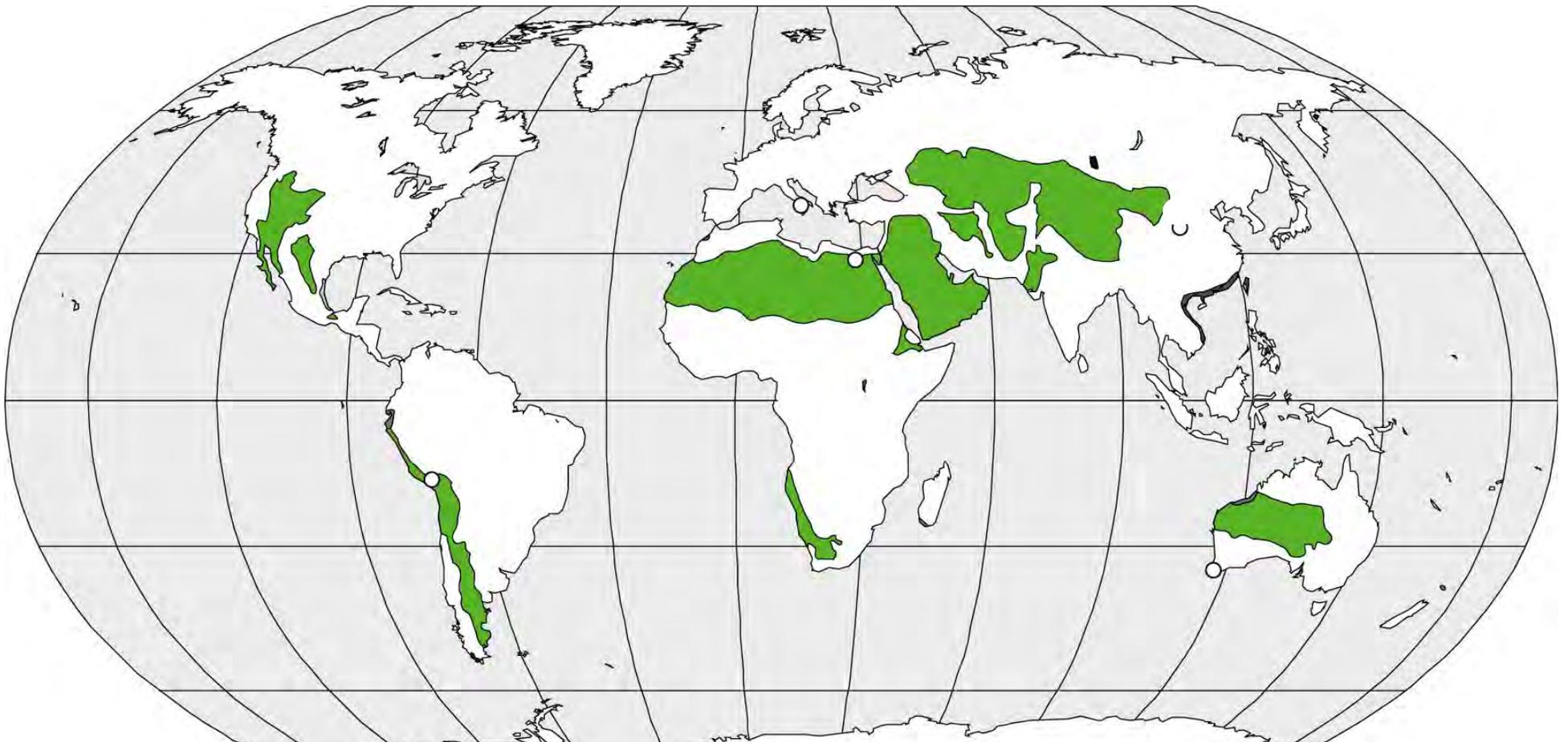


In contrast, *Copiapoa columna-alba* in the Atacama Desert of Chile face north, again reducing sunlight exposure on the sides of the cactus

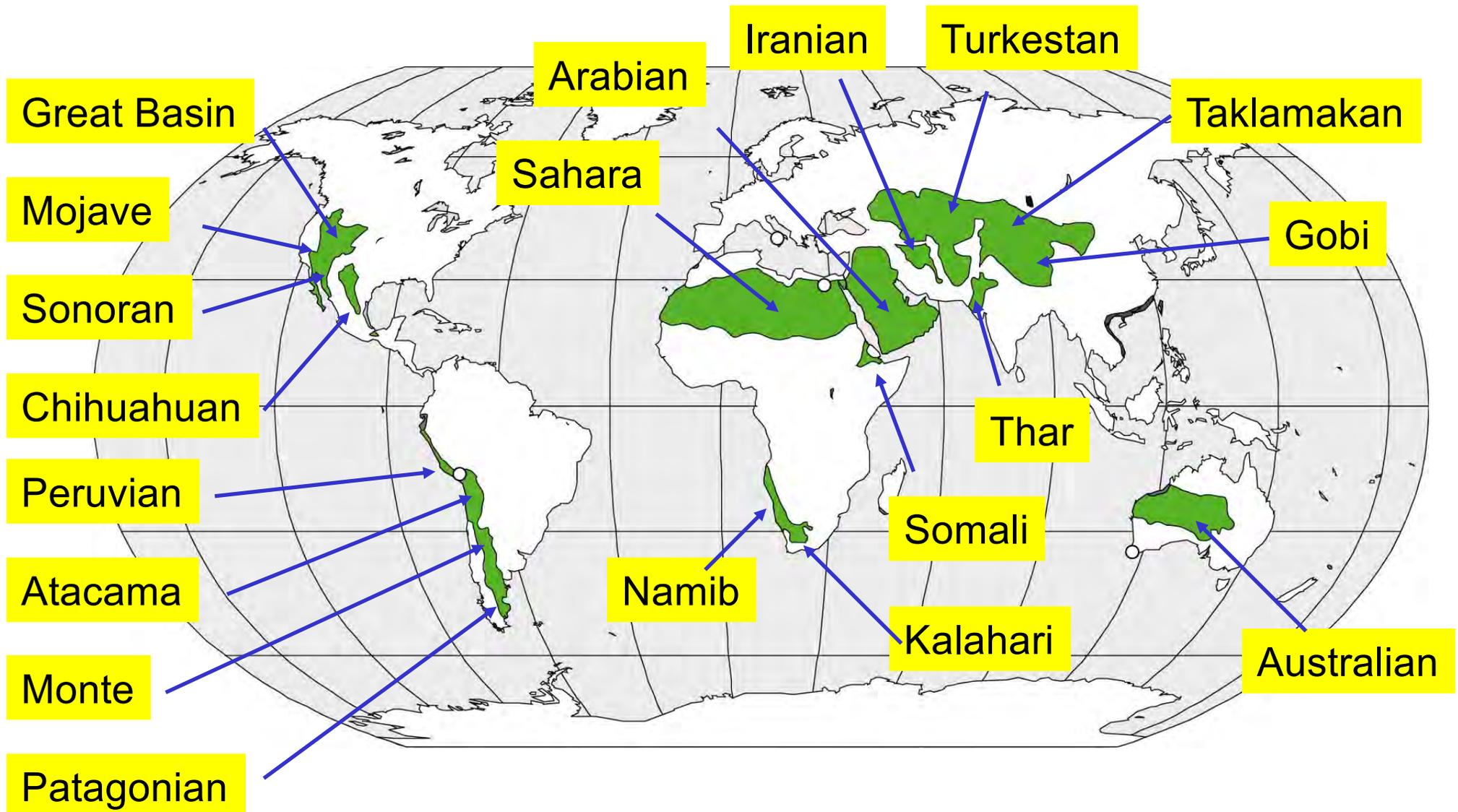


## Desert and steppe biomes

- globally distributed in regions of descending air
- P/E is  $< 1$ ; precipitation is generally  $< 300$  mm annually
- Temperature amplitude reflects interior versus coastal distributions



~ 20-30% of the land surface is classified as arid lands



## Coastal deserts

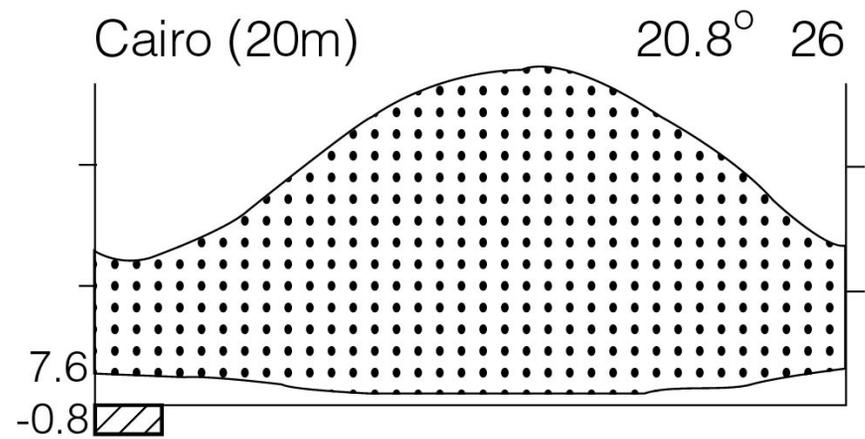
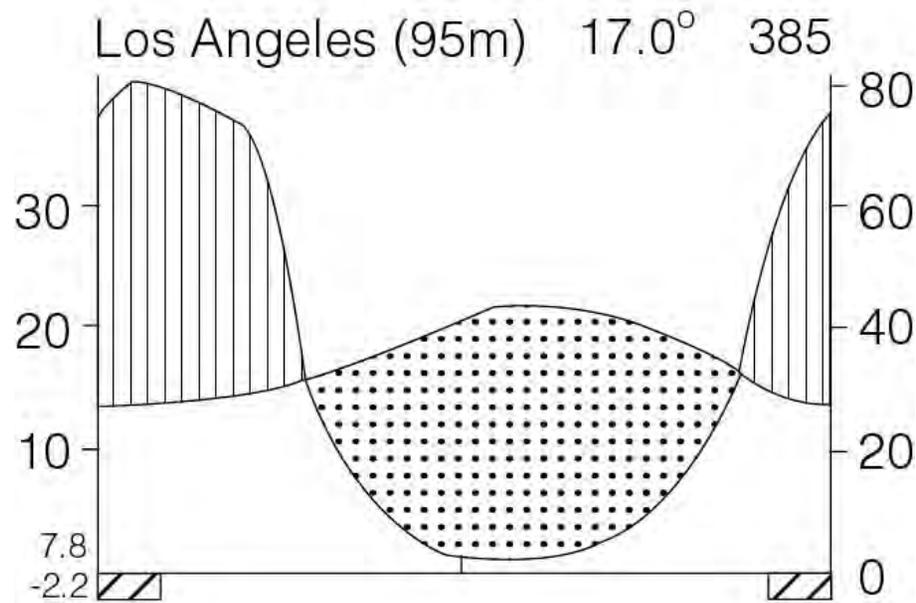
- western portions of continents in areas of cold-water upwellings
- small amplitudes in annual temperatures
- diurnal air temperatures are typically moderate
- typically very low precipitation; El Niño impacted
- typically associated with fog zones



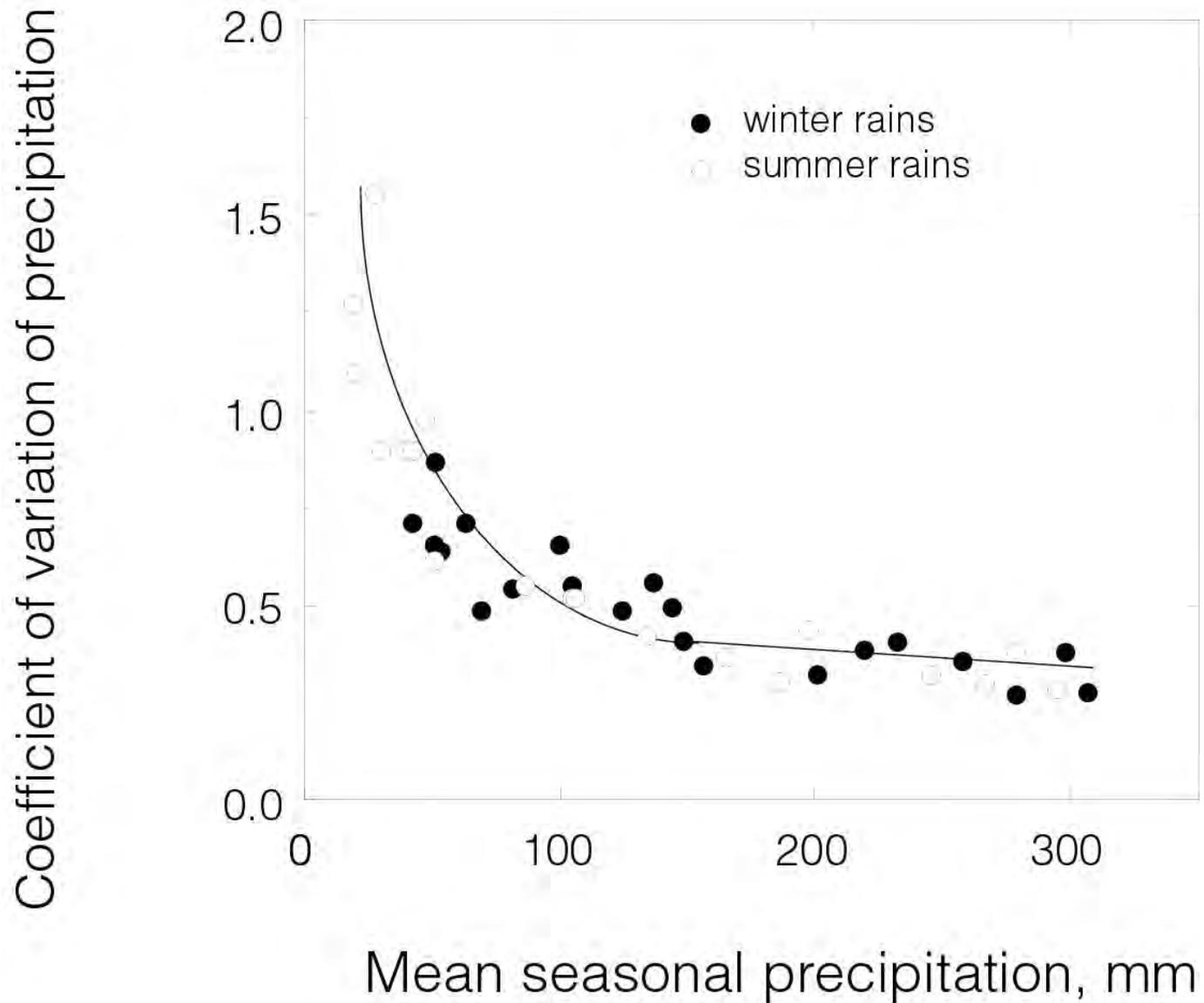
## Interior deserts

- interior portions of continents, often in geographic rain shadows
- large amplitudes in annual temperatures
- diurnal air temperature ranges are often quite high
- may have winter, summer, or bi-seasonal precipitation patterns

# Notice differences in the climate diagrams for Mediterranean and desert climates



# Interannual predictability of precipitation is low in deserts





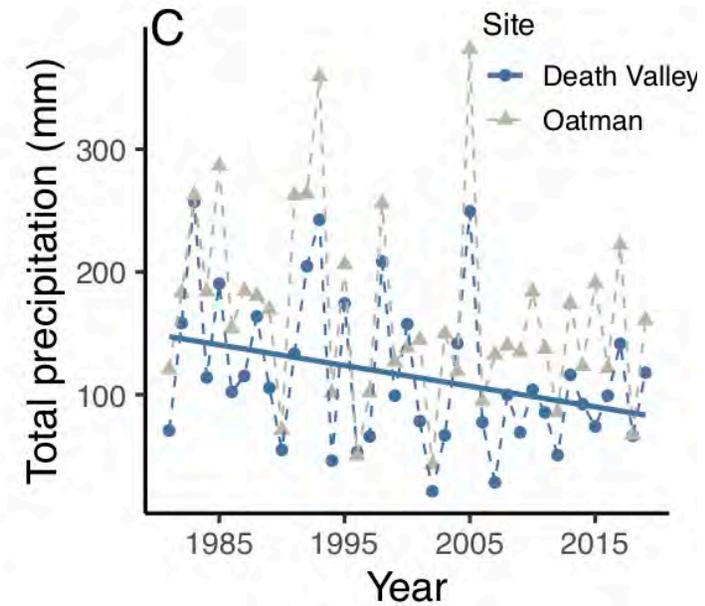
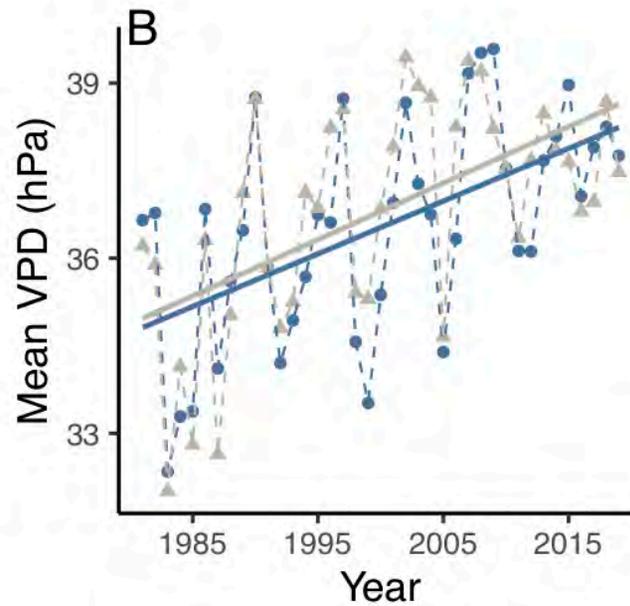
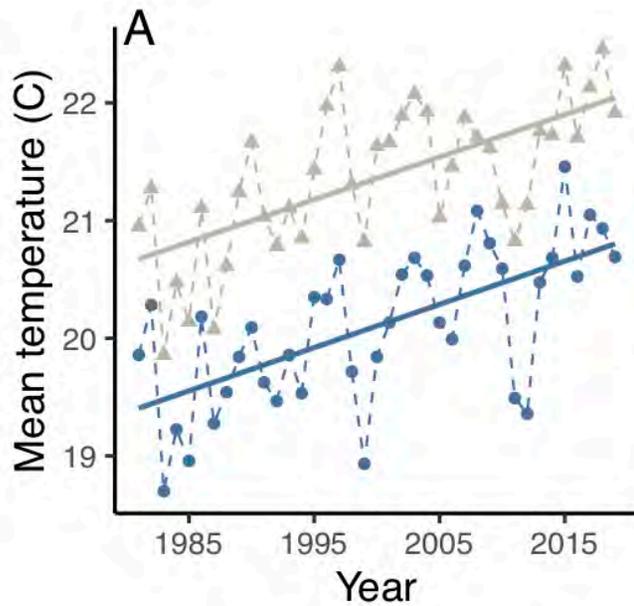
## Desert and steppe biomes changes are happening now

- Climate change is making arid lands a more stressful habitat
- Overgrazing leads to desertification (vegetation loss) or in wetter sites leads to vegetation shifts altering a grass-shrub balance (woody encroachment)
- Invasive species leading to increased fires and to vegetation changes, resulting in invasive annual grasslands



Desert climates are becoming  
... **hotter and drier**

Precipitation ↓  
VPD ↑  
Temperature ↑



Overgrazing in southern Utah leads to loss of grasses and to the expansion of woody species, such as junipers



To sustain grazing in Utah, one BLM solution is chaining



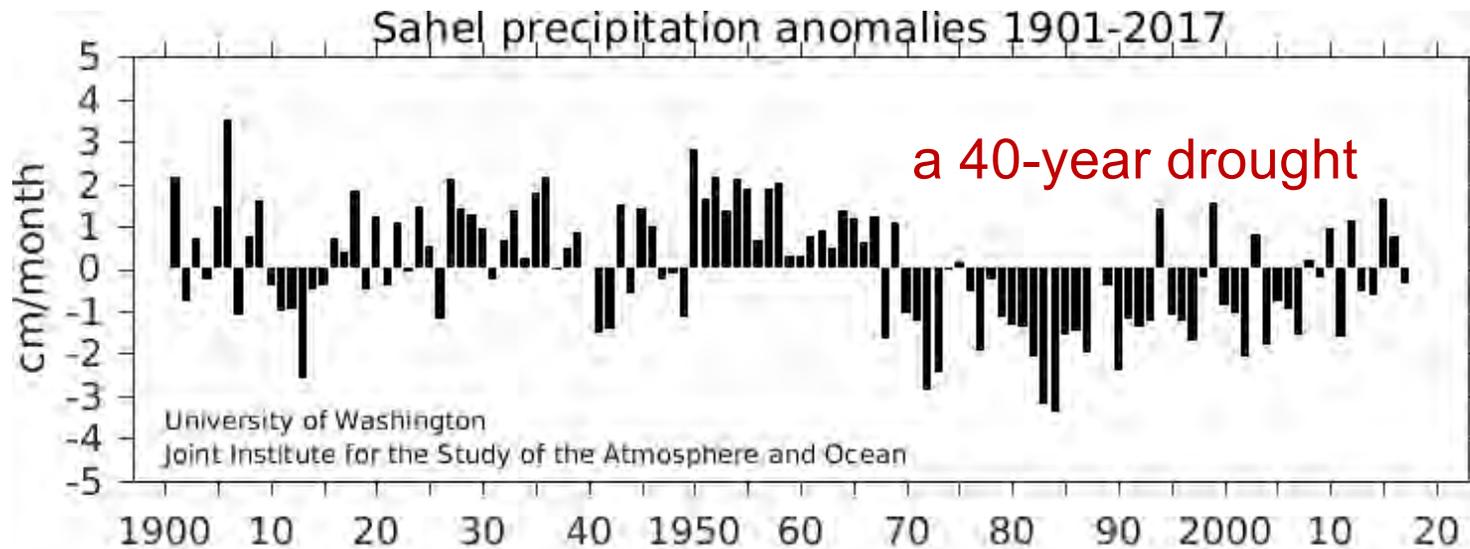
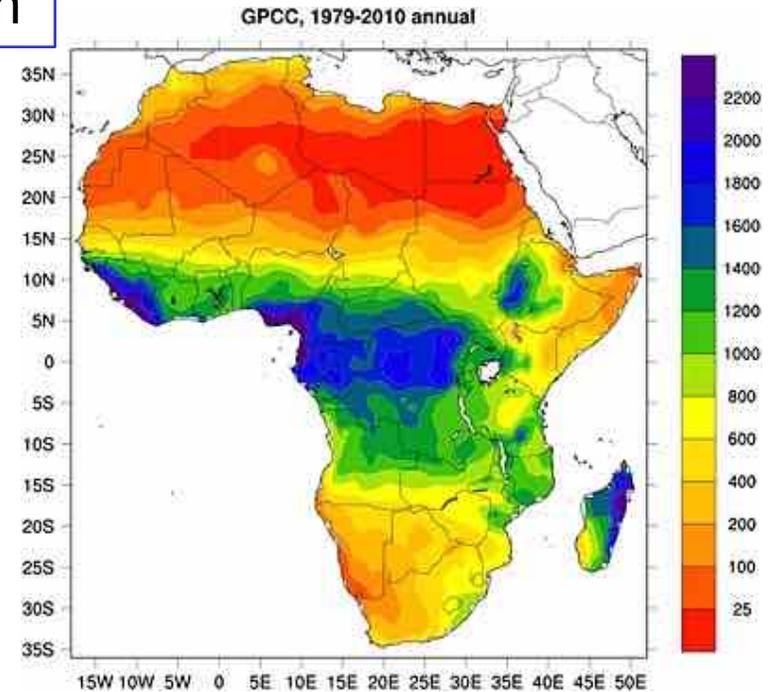
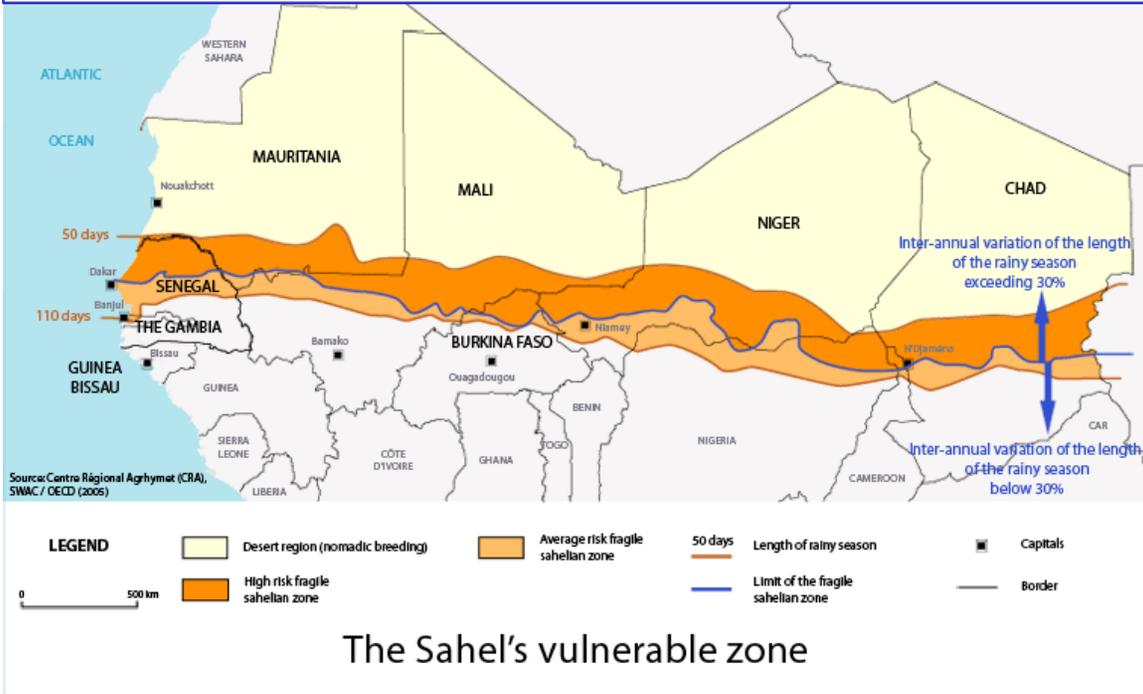
A chain is dragged to uproot shrubs and trees



A chain is dragged to uproot shrubs and trees; then perennial grasses are planted



# Grazing in the Sahel contributes to desertification



June through October averages over 20-10°N, 20°W-10°E. 1900-2017 climatology  
Deutscher Wetterdienst Global Precipitation Climatology Centre data

Buffelgrass (*Pennisetum ciliare*)  
from Africa has invaded the  
Sonorna Desert leading to  
increased fire frequencies



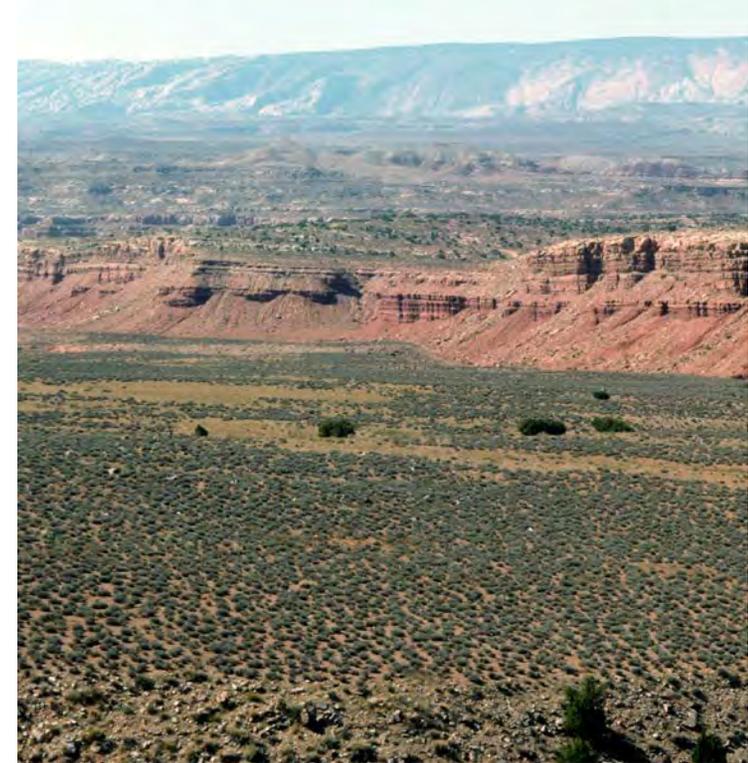


## Part 2

# North American Deserts and Steppes

Plant Ecology in a Changing World

Jim Ehleringer, University of Utah  
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Precipitation patterns distinguish among North American deserts

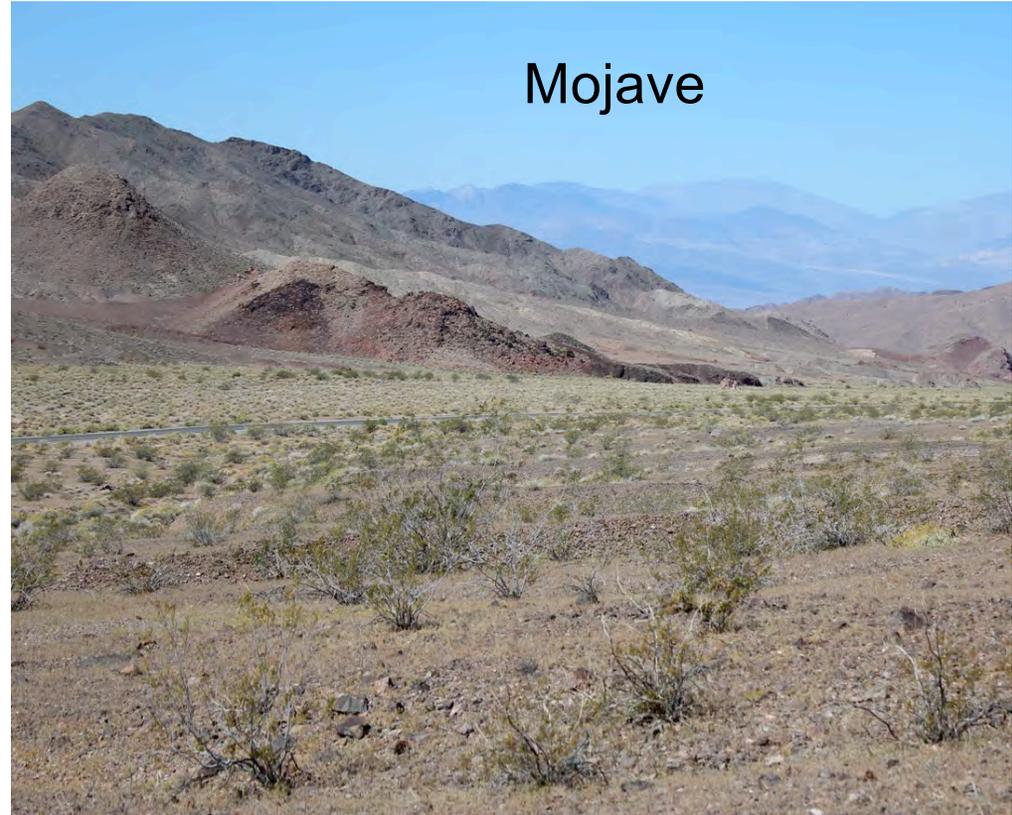
- Sonoran
- Mojave
- Chihuahuan
- Great Basin (steppe)



Sonoran



Chihuahuan



Mojave



The Joshua Tree (*Yucca brevifolia*) is found at the transition between Mohave and Great Basin Deserts





Colorado Plateau desert is dominated by perennial shrubs and grasses; sensitive to annual plant invasions

There are few trees, few annuals, and very few succulents

Blackbrush (*Coleogyne ramosissima*)

Utah Juniper (*Juniperus osteosperma*)  
(aka cedar)

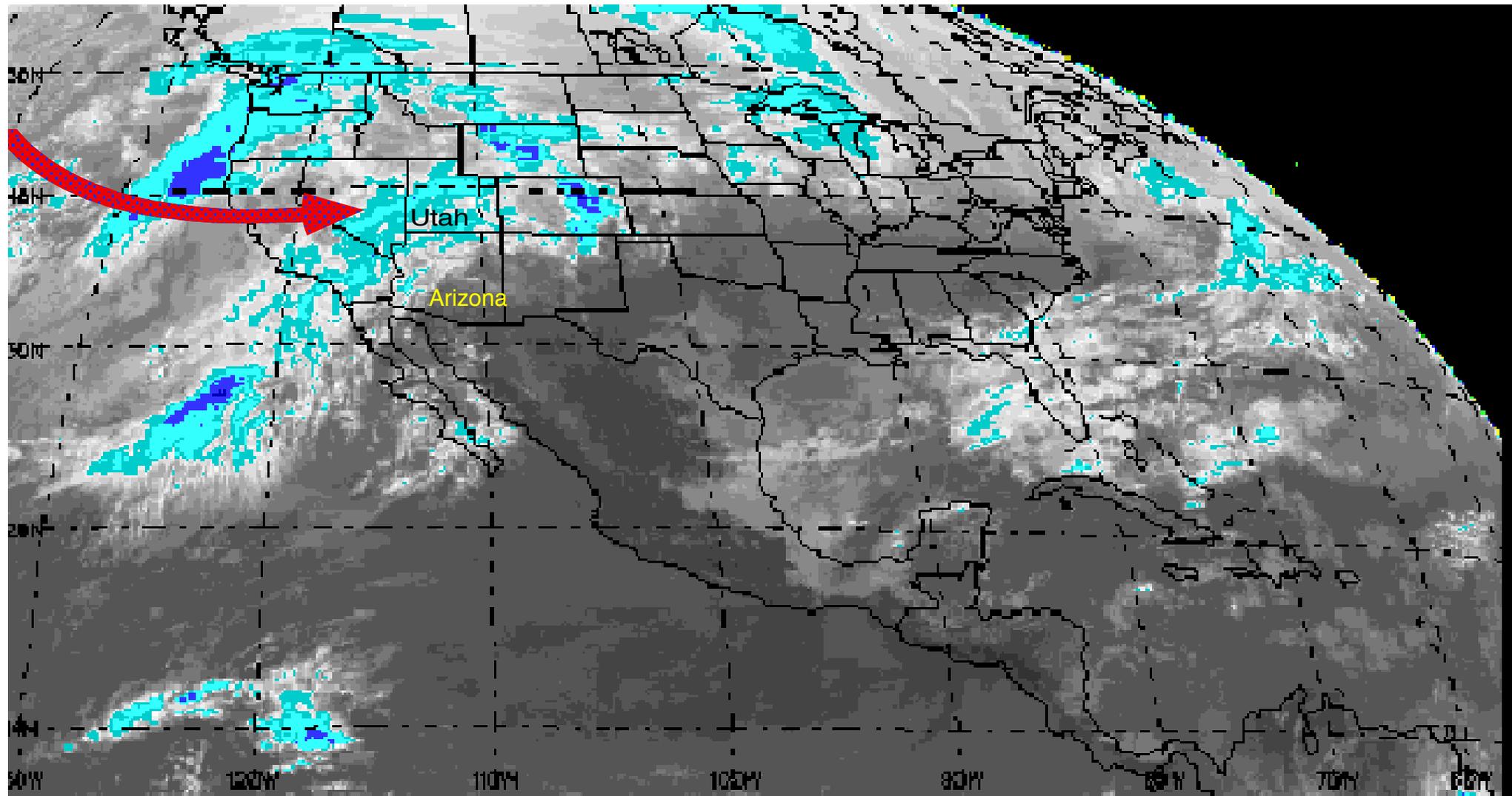


Precipitation in North American deserts is strongly dependent on rain shadow, moisture source, and elevational factors

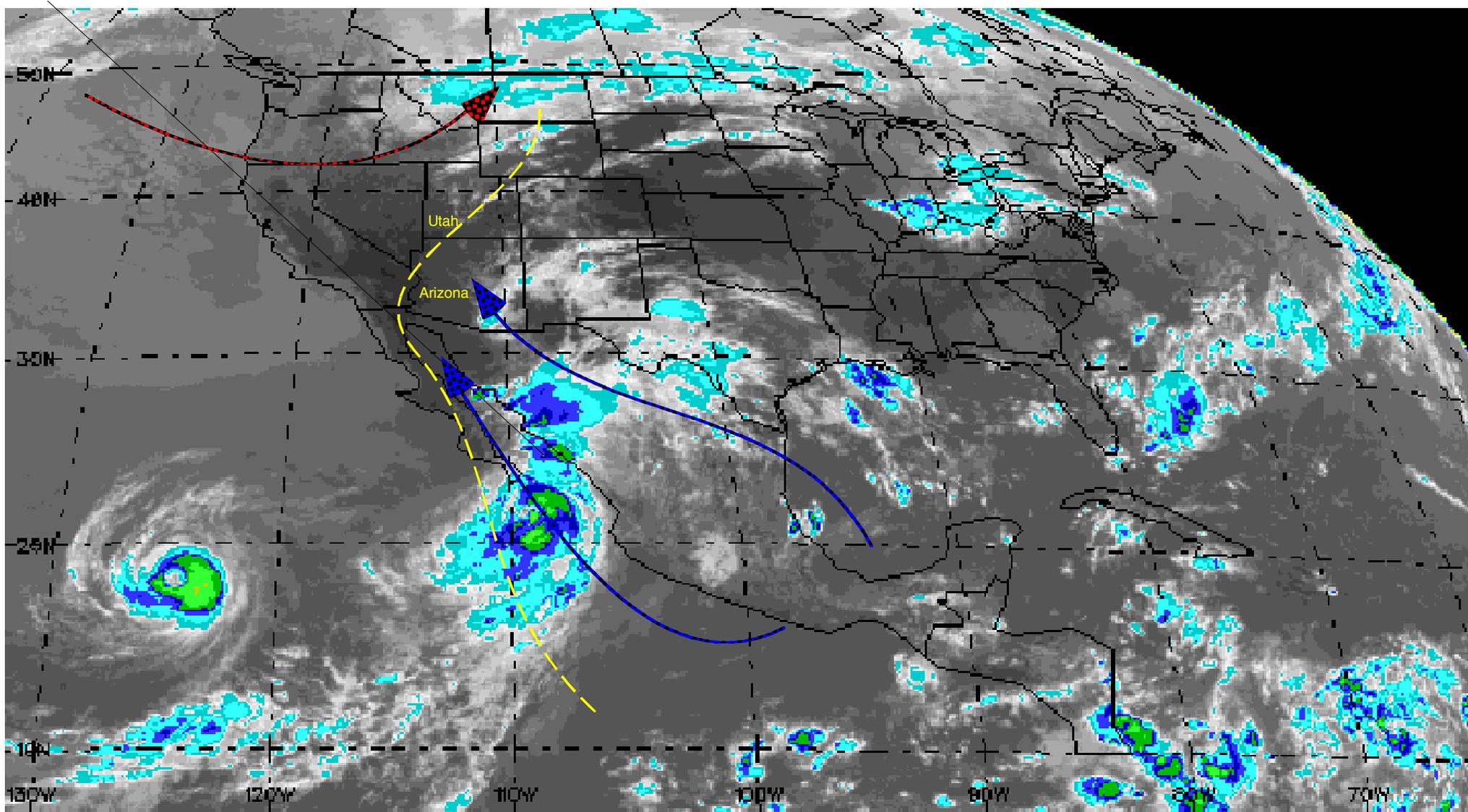
	<b>cold desert</b>	<b>warm desert</b>
winter moisture	Great Basin	Mojave
summer moisture	---	Chihuahuan
bi-seasonal moisture	Colorado Plateau	Sonoran



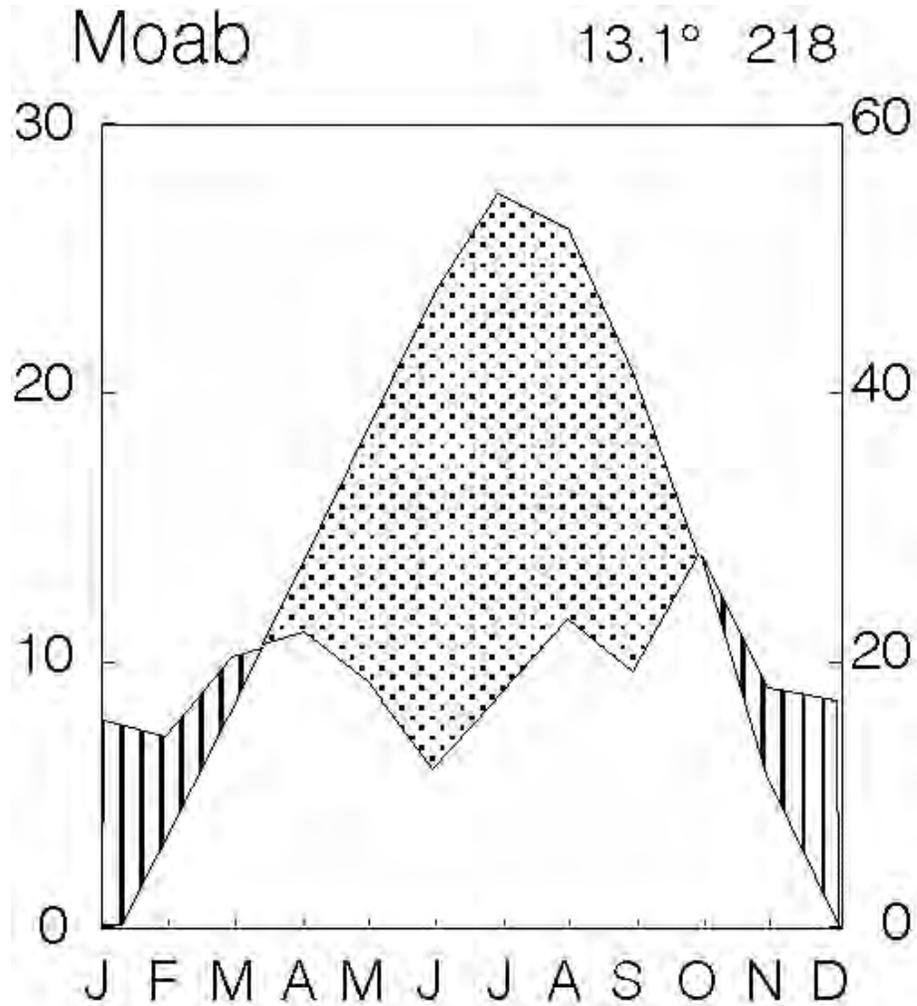
Winter rains are generated from moisture sources in the northern Pacific Ocean



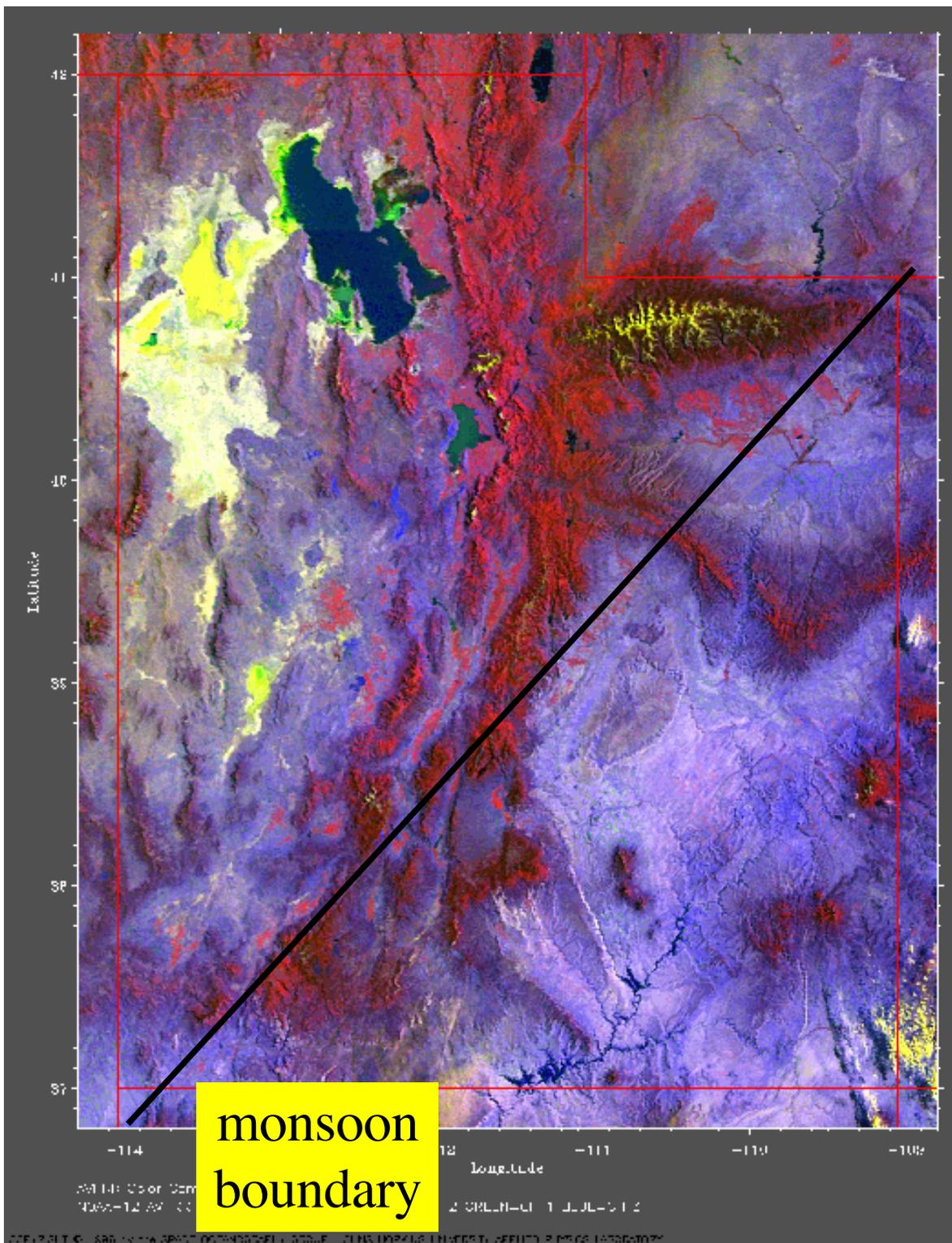
Summer rains are generated from moisture sources in the eastern Pacific Ocean



# Arizona summer monsoon boundary



in Moab, there is an equal probability of precipitation every month



Precipitation in Utah deserts is also strongly dependent on rain shadow, moisture source, and elevation

winter rains -  
primarily northwest, decreasing to south

summer rains -  
primarily southeast, decreasing to north

west deserts -  
primarily saline soils, closed basins

southeast deserts -  
aka Colorado Plateau  
primarily sandstone, red rock country

The winter-precipitation Mojave Desert often has spectacular annual blooms



In contrast, large succulents only appear in deserts with summer rains



Sonoran Desert near Ajo, AZ

Steppe is a term describing interior desert shrublands and grasslands, often applied to Eurasian sites and can be applied to the Intermountain West



Sagebrush steppe (*Artemisia tridentata*) near Shoshone, Idaho

Steppe is a term describing interior desert shrublands and grasslands, often applied to Eurasian sites and can be applied to the Intermountain West



*Bromus tectorum*  
(cheatgrass)

Sagebrush steppe (*Artemisia tridentata*) near Shoshone, Idaho  
Note the sharp background transition from shrubs to grassland

Steppe ecosystems often experience extensive fire conditions, especially here in the Intermountain West following invasion of cheatgrass (*Bromus tectorum*)





## Part 3

# A wide range of adaptive responses

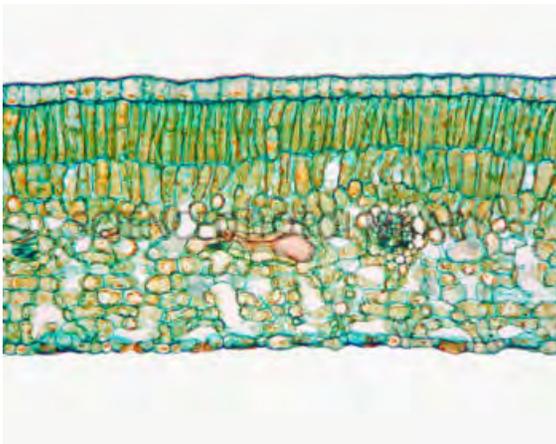
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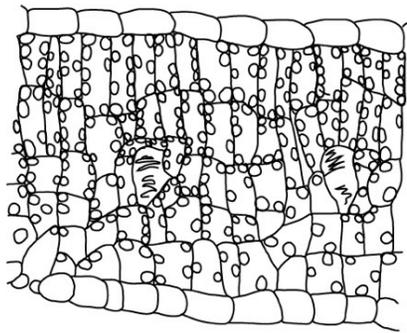


## General vegetation characteristics in desert ecosystems

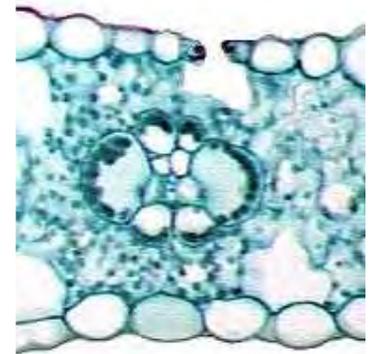
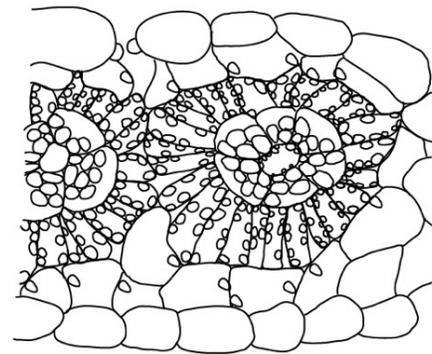
- predominantly annuals and shrubs
- trees typically only occur in riparian zones
- tendency for a limited number of plant families to predominate (e.g., Asteraceae, Chenopodiaceae, Poaceae)
- variations in photosynthetic pathways ( $C_3$ ,  $C_4$ , and CAM)
- $C_4$  and CAM become more common in habitats with summer rains



$C_3$  plants



$C_4$  plants



# General patterns of photosynthetic pathway distribution

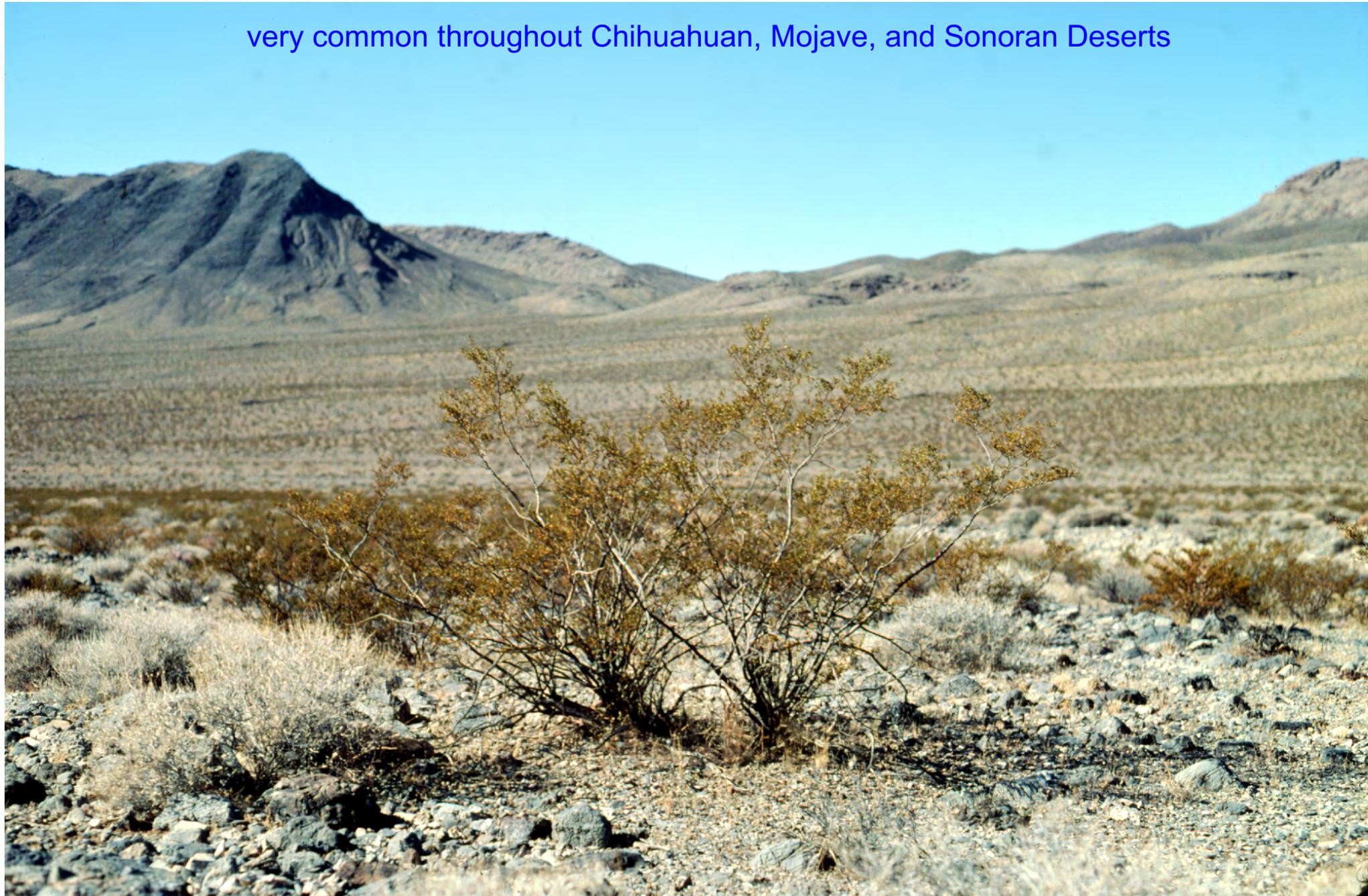
	C3	C4	CAM	C3 - CAM
winter annual	x			
summer annual		x		
winter grass	x			
summer grass		x		
leaf succulent				x
stem succulent			x	
evergreen shrub	x	(halophyte)		
deciduous shrub	x			
tree	x			

Solar tracking leaf movements are common in short-lived annuals.



Evergreen leaves as an adaptive feature:  
*Larrea tridentata* dominates many North American deserts

very common throughout Chihuahuan, Mojave, and Sonoran Deserts



*Larrea* is often referred to as creosote bush. Its evergreen, sticky leaves emit a strong odor. *Larrea* is very drought tolerant (tolerates extreme soil and plant water deficits), with clones surviving for thousands of years.

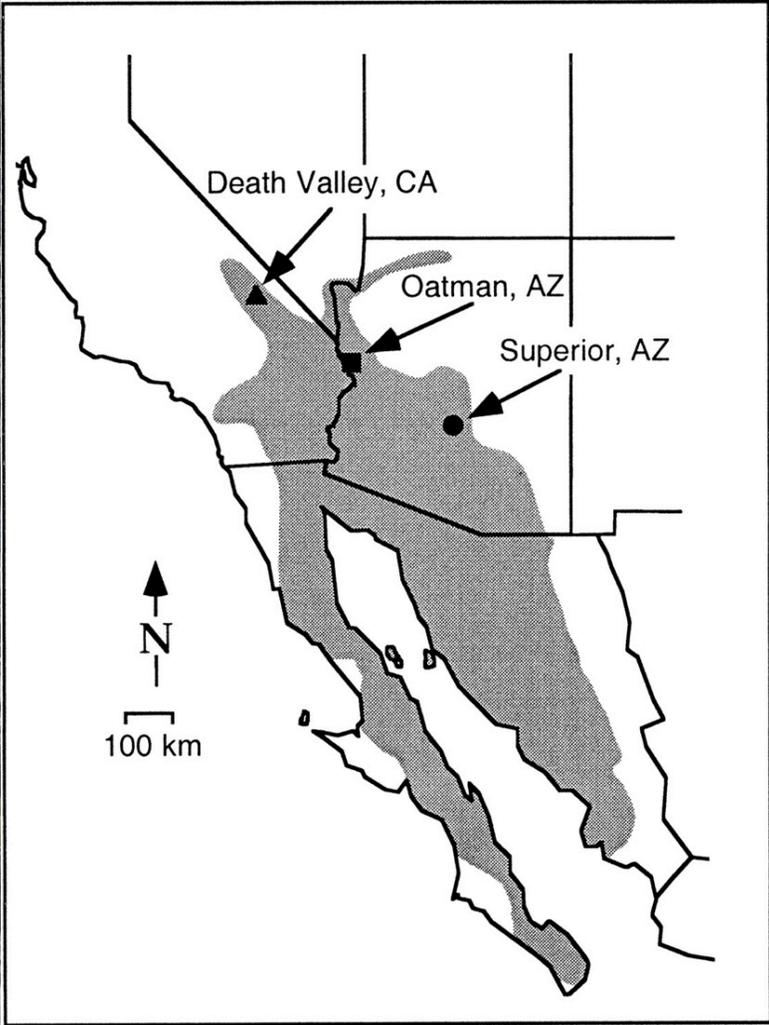


Drought-deciduous leaves as an adaptive feature: *Fouqueria*, a drought-deciduous “tall shrub” of the Sonoran Desert intolerant of water deficits





Other shrubs are less drought tolerant, such as the drought deciduous *Encelia farinosa*



The drought deciduous shrub *Encelia farinosa* acclimates by changing its leaf surface reflectance

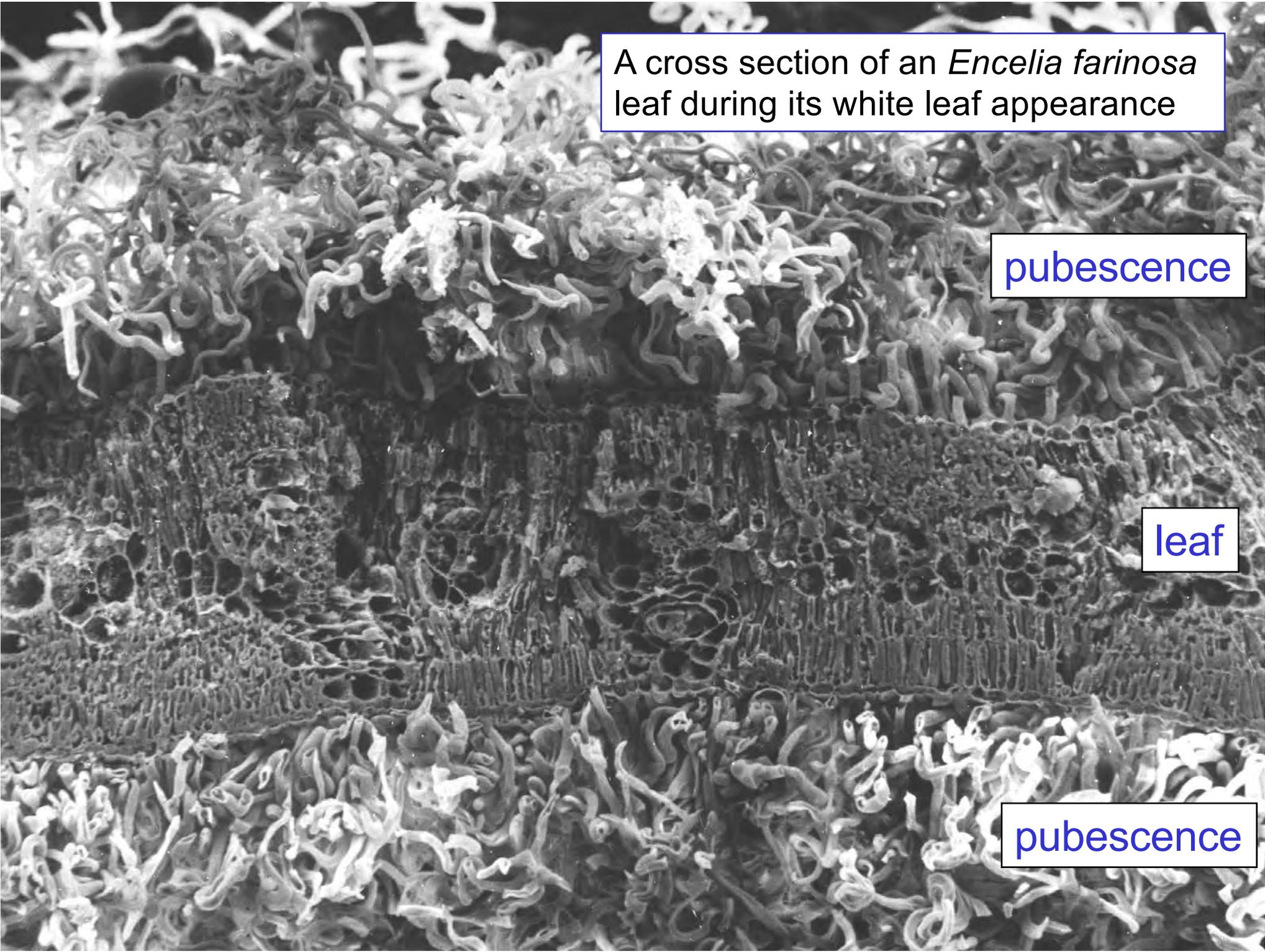


A cross section of an *Encelia farinosa* leaf during its white leaf appearance

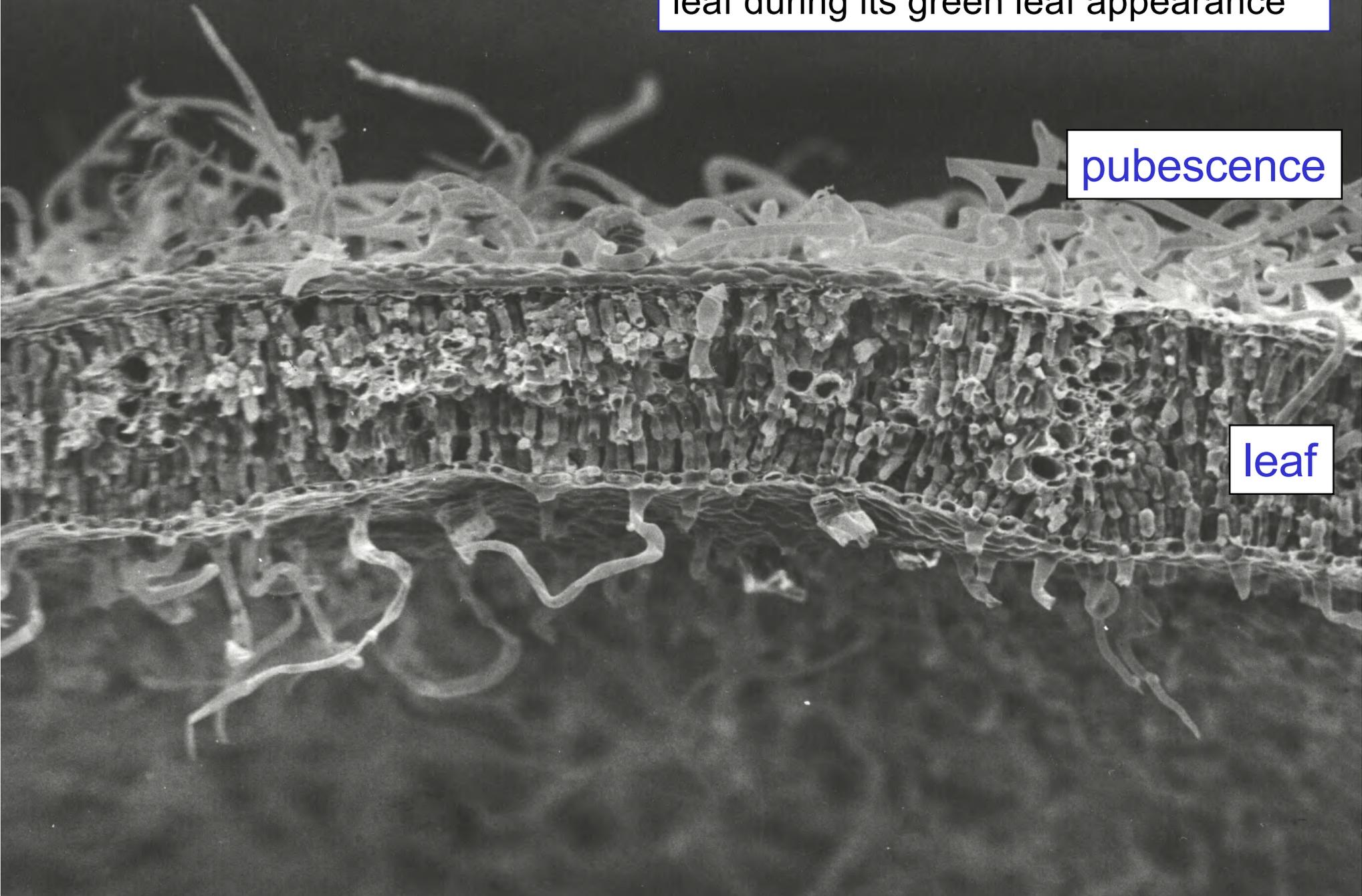
pubescence

leaf

pubescence



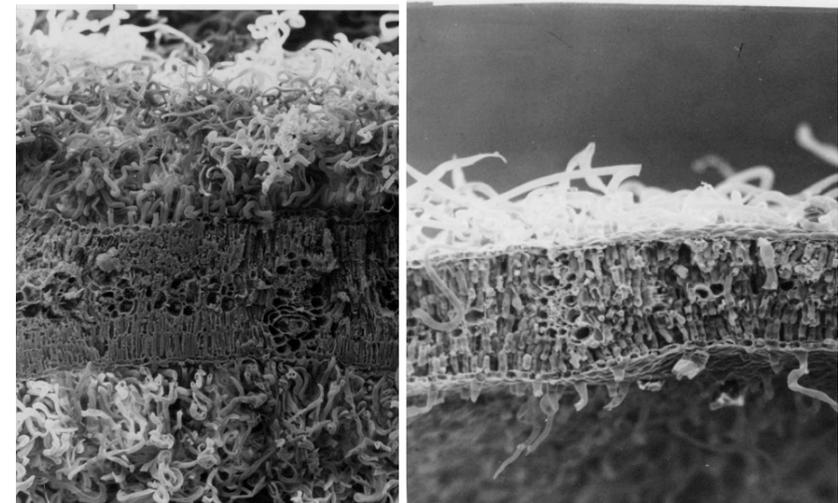
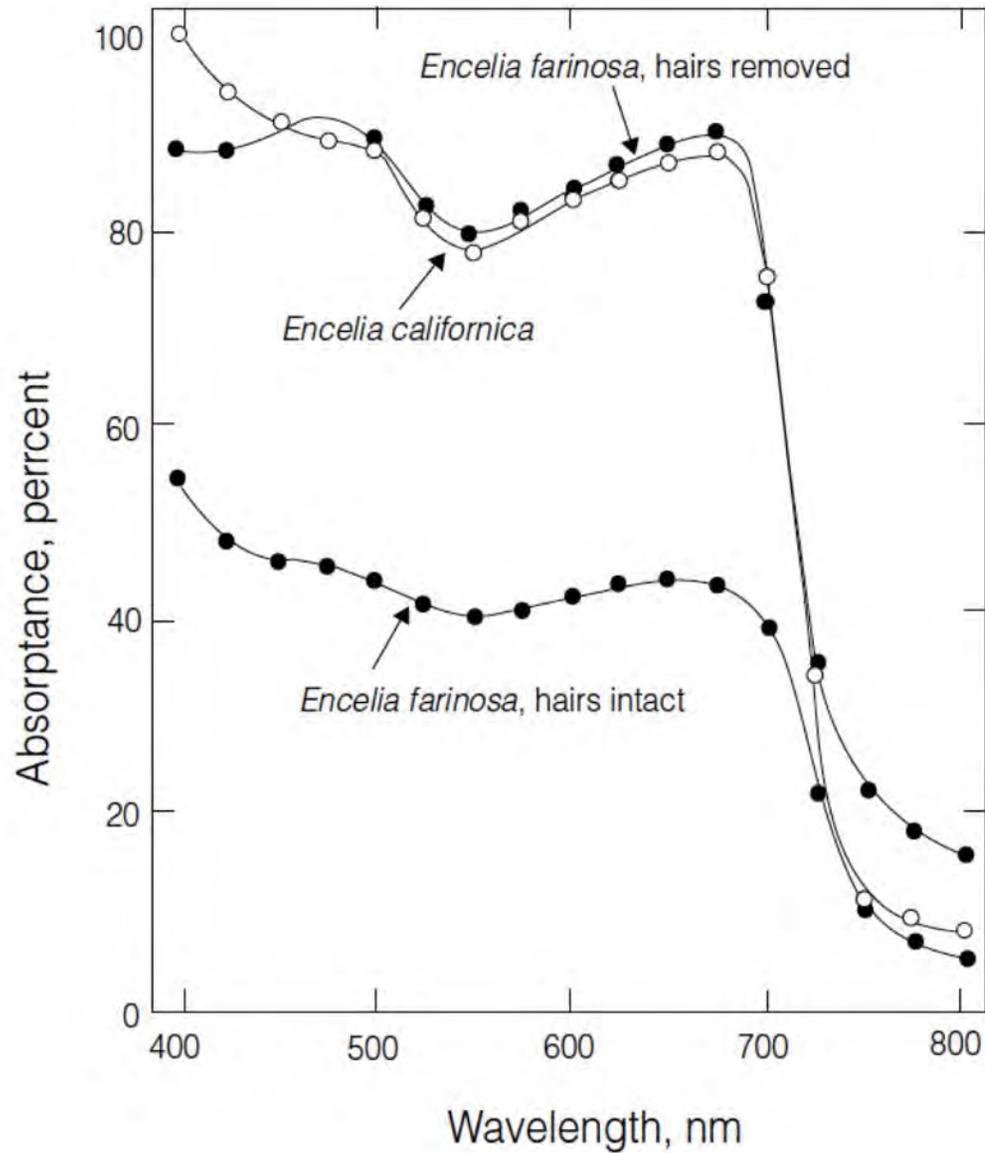
A cross section of an *Encelia farinosa* leaf during its green leaf appearance



pubescence

leaf

# Leaf pubescence changes in *Encelia* result in a 50% absorptance reduction



*Atriplex hymenelytra* leaves (evergreen) also have a reflective surface; dried salt gland on the leaf reflect sunlight (common in Death Valley)





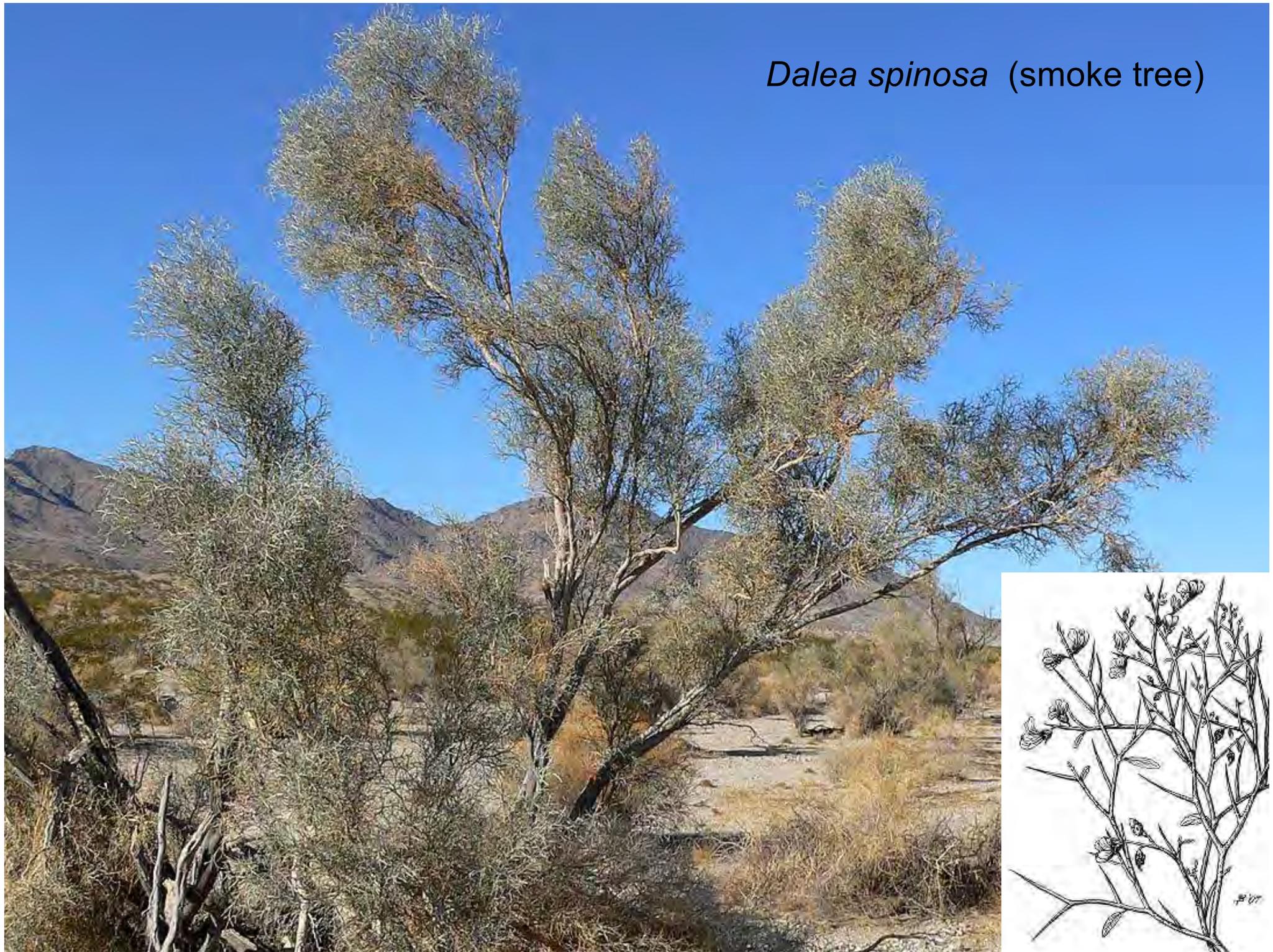
Some species, such as *Oldenbergia* in South Africa, have a reflective hair layer only when leaves are young.



*Washingtonia filifera* (California palm)



*Dalea spinosa* (smoke tree)





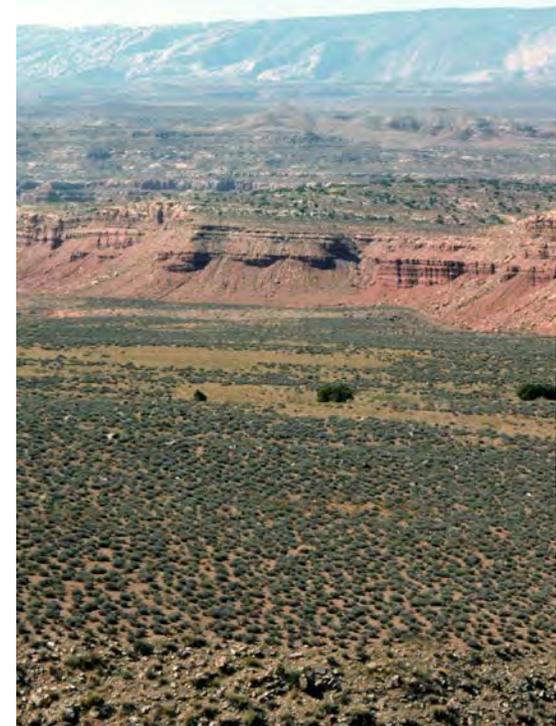
## Part 4

# CAM as a water storage strategy and a means of efficient water use

Plant Ecology in a Changing World

Jim Ehleringer, University of Utah

<http://plantecology.net>





Succulence as a water conservation feature

Cacti are characterized by

- extensive shallow roots
- CAM
- often protective spines
- absence of leaves

*Ferocactus* (Beaver Dams)

note orientation of stem



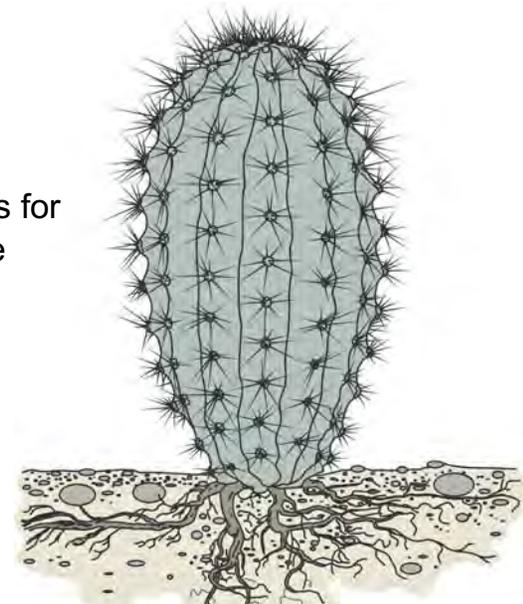
Cacti are diagnostic of locations with summer rain.

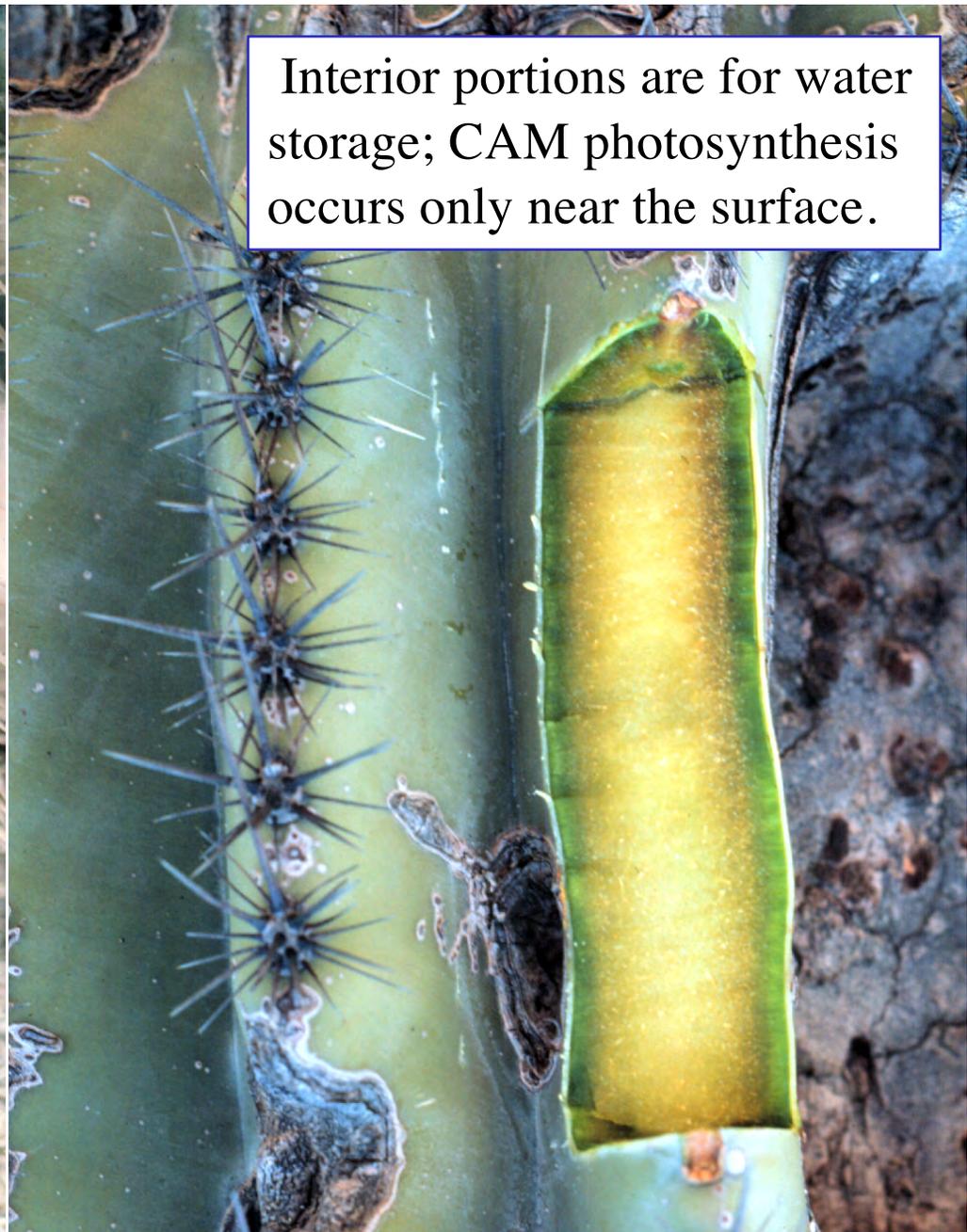
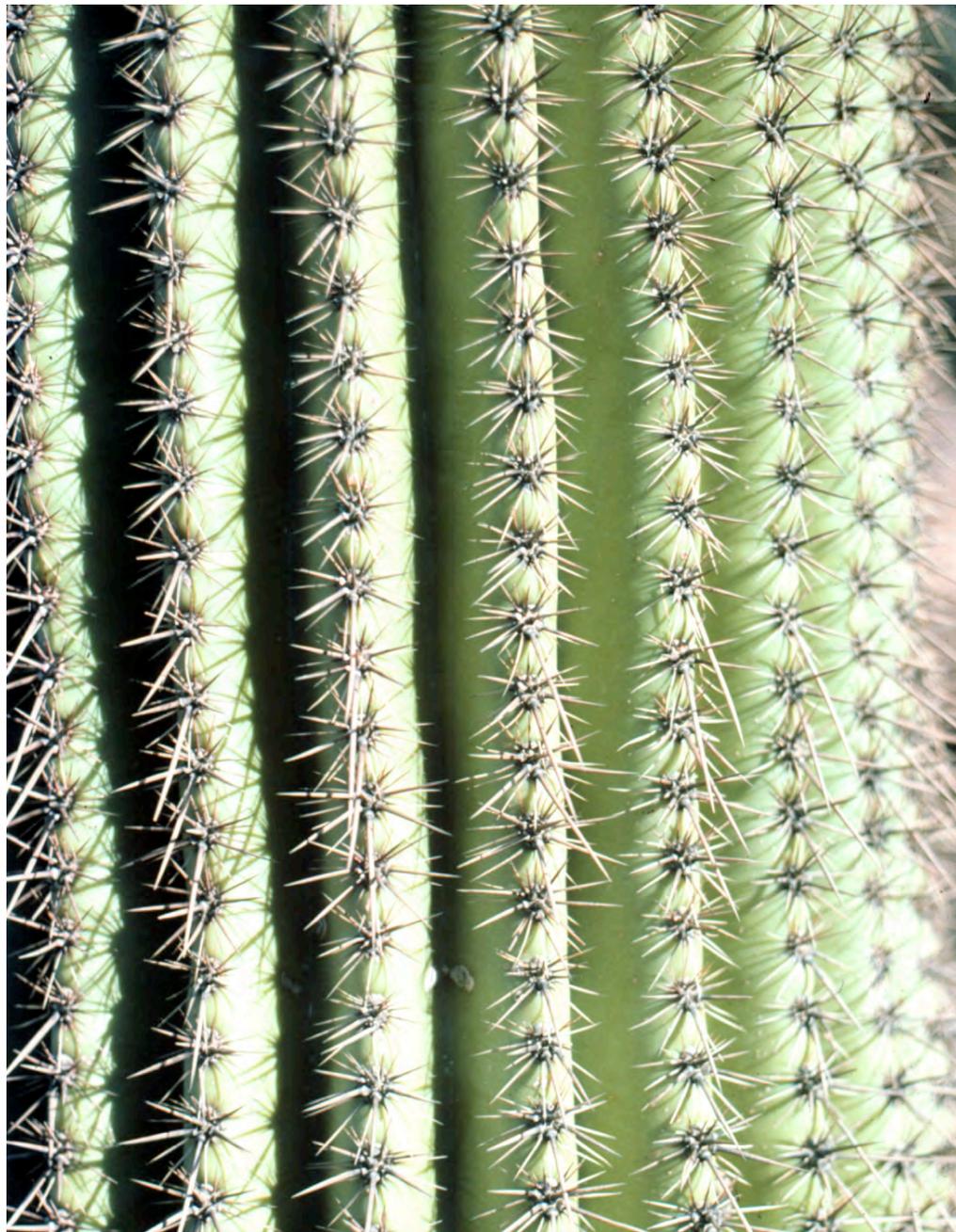
Giant stem succulents, such as this organ pipe cactus, occur only in regions with a high and reliable summer summer rains

- water storage in stems
- surface roots
- CAM

stem architecture allows for extensive water storage

surface roots allow for rapid water uptake following brief summer rain events





The rib or accordion-like structure allows for rapid volumetric expansion and serves as a mechanism to enhance water storage.

In regions with summer rains,  
North American deserts show  
high life-form diversity

Without a doubt, it must  
be a boojum !

*Idria columnaris*, commonly known  
as the boojum, occurs in central  
Baja California where summer rains  
are common. This is a stem succulent  
tree with C<sub>3</sub> photosynthesis grows up  
to 15 m tall. It is closely related to  
*Fouquieria* (ocotillo).



Another stem succulent tree is *Bursera*, the elephant tree of Baja California



Saguaro, *Carnegiea gigantea*





## Part 5

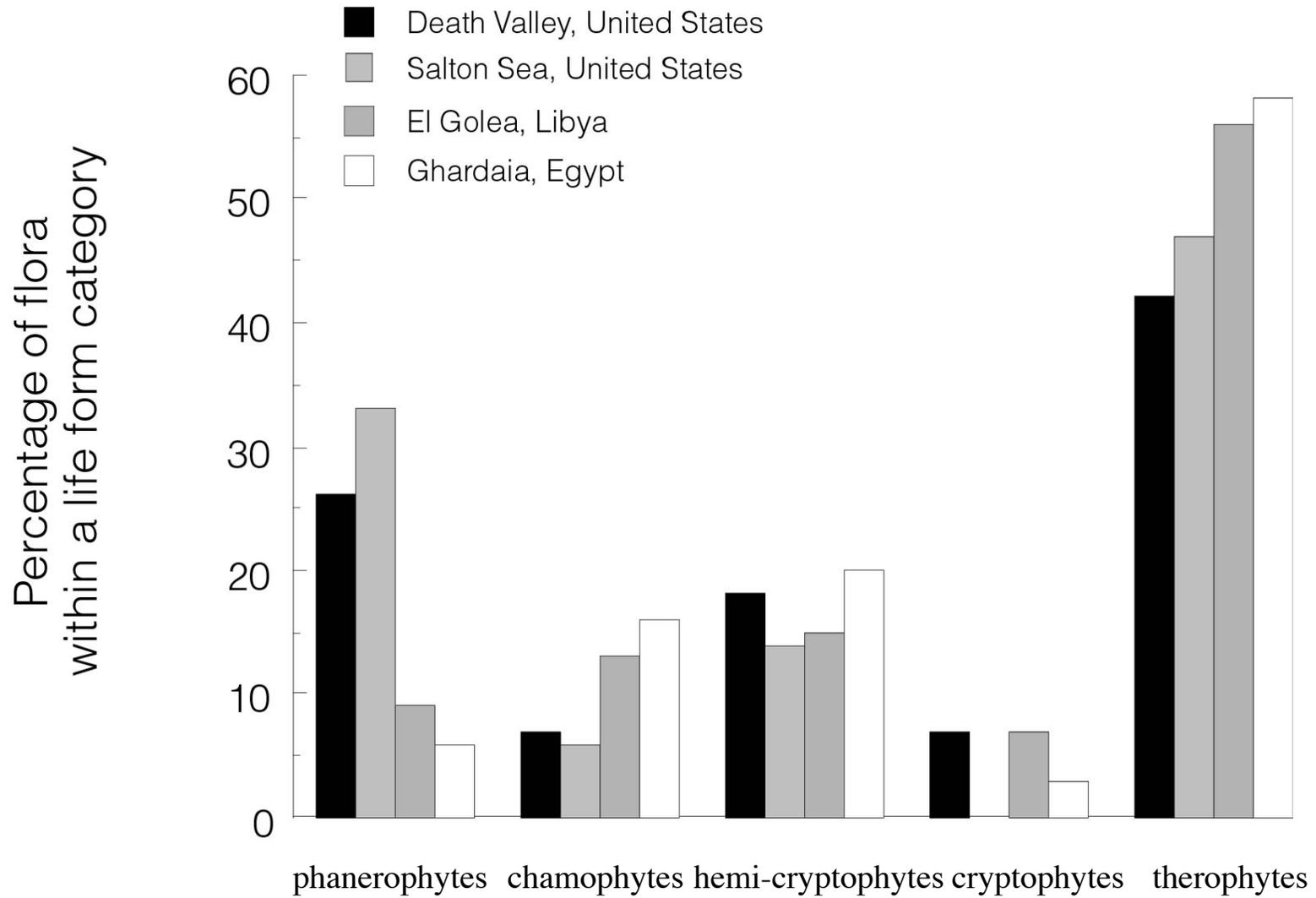
# Variations in life history

Plant Ecology in a Changing World

Jim Ehleringer, University of Utah  
<http://plantecology.net>



# Raunkiaer life form distributions in deserts



A field of the annual *Geraea canescens* in flower near Death Valley



But a few weeks later, the annuals have all died, leaving behind seeds in the soil to persist until the next major rains in 1-4 years

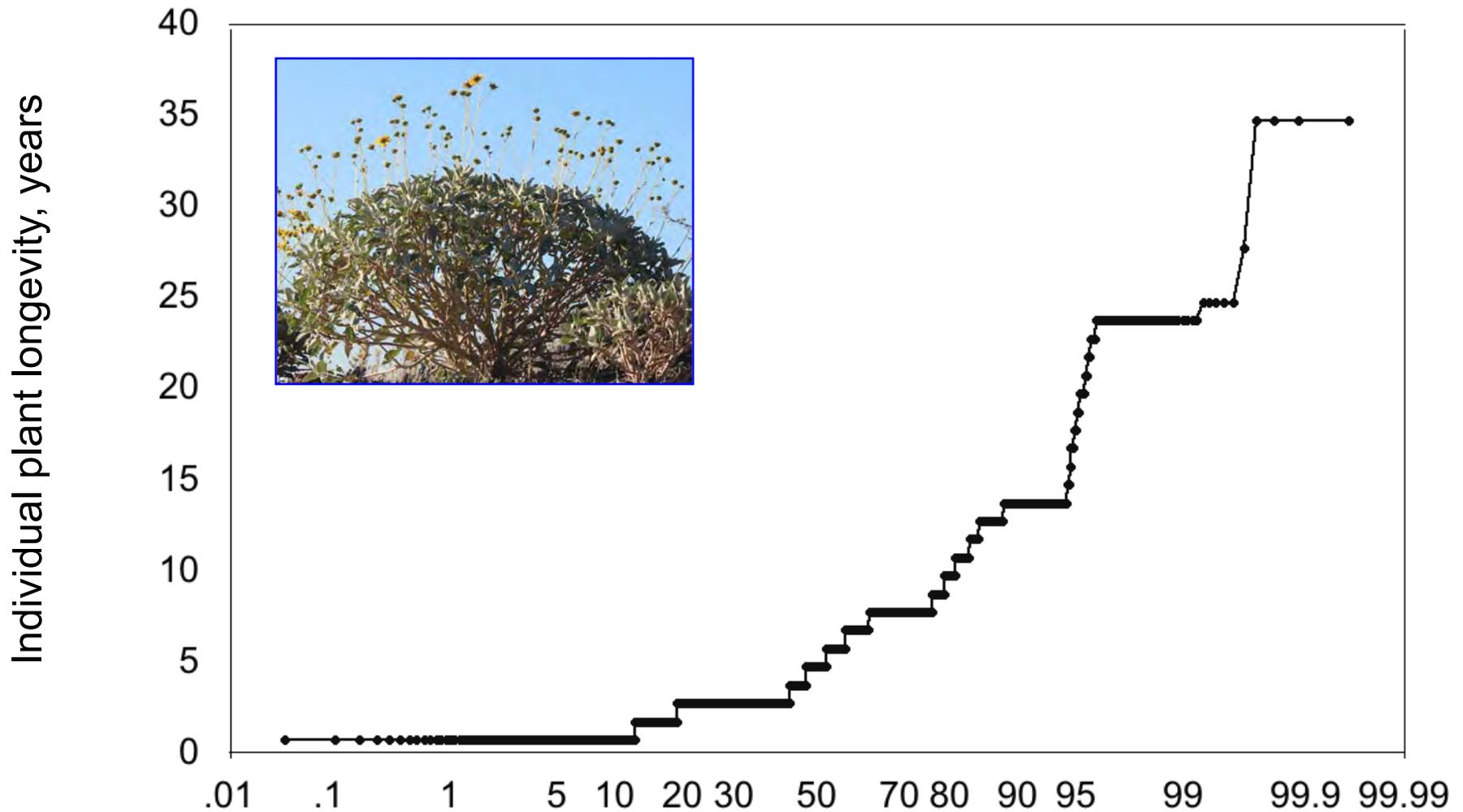


Sonoran Desert - *Encelia farinosa*, *Larrea tridentata*, *Carnegiea gigantea*



# How long do these plants live?

*Encelia farinosa* (POPFAR1)



Cumulative percentage of the population over the last 35 years

Plants compete for water and this competition constrains plant size.  
Neighbor mortality is an opportunity for plants to increase in size.

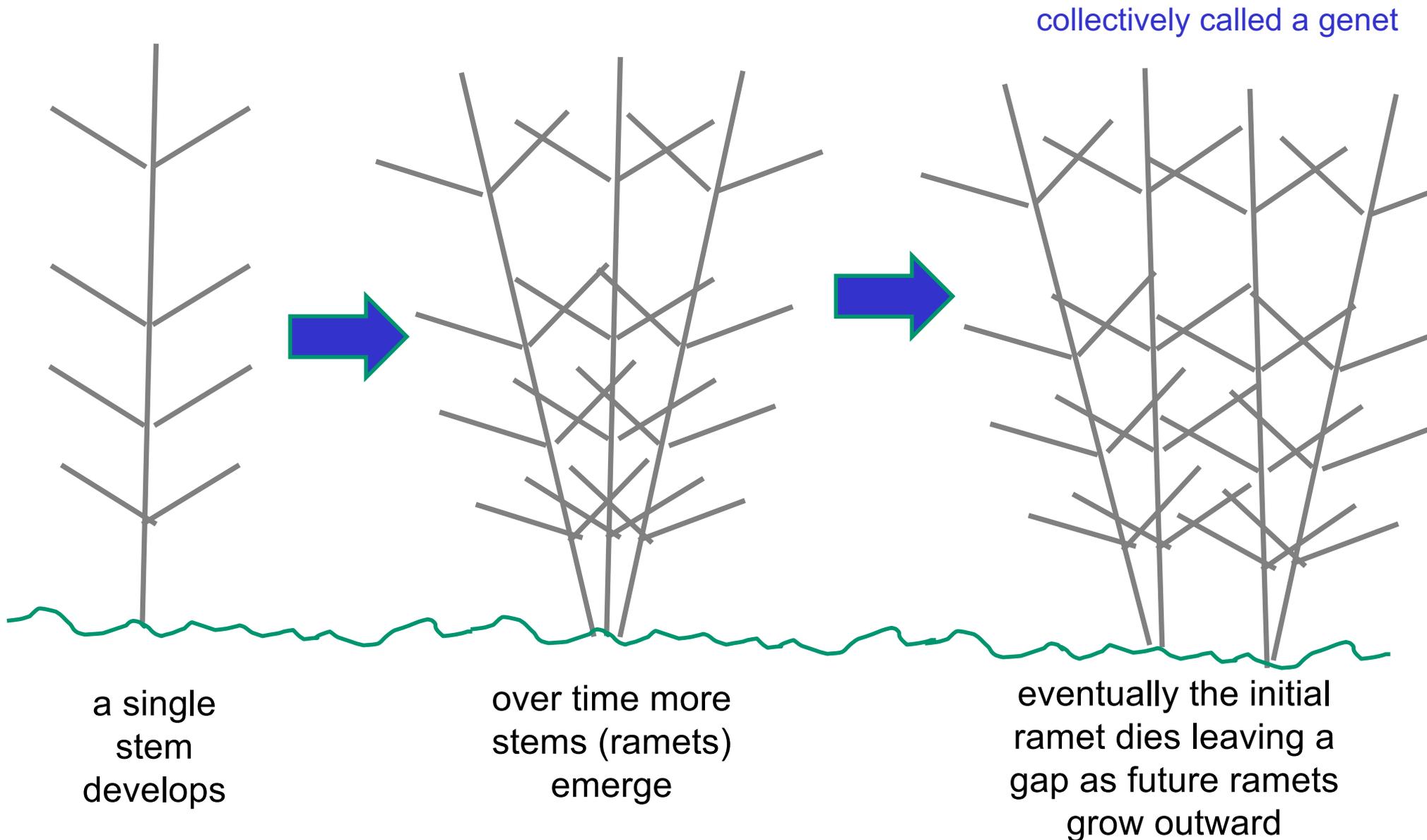
Neighbor-removal experiments confirm that neighbor-free plants rapidly increase in size and maintain leaves longer into drought period.



*Larrea* is a long-lived suffrutescent shrub



## Emergence of a suffrutescent grass or shrub clone



*Larrea tridentata*, a long-lived evergreen-leaf shrub that often clones with suffrutescent stems



*In search of "King Clone"*



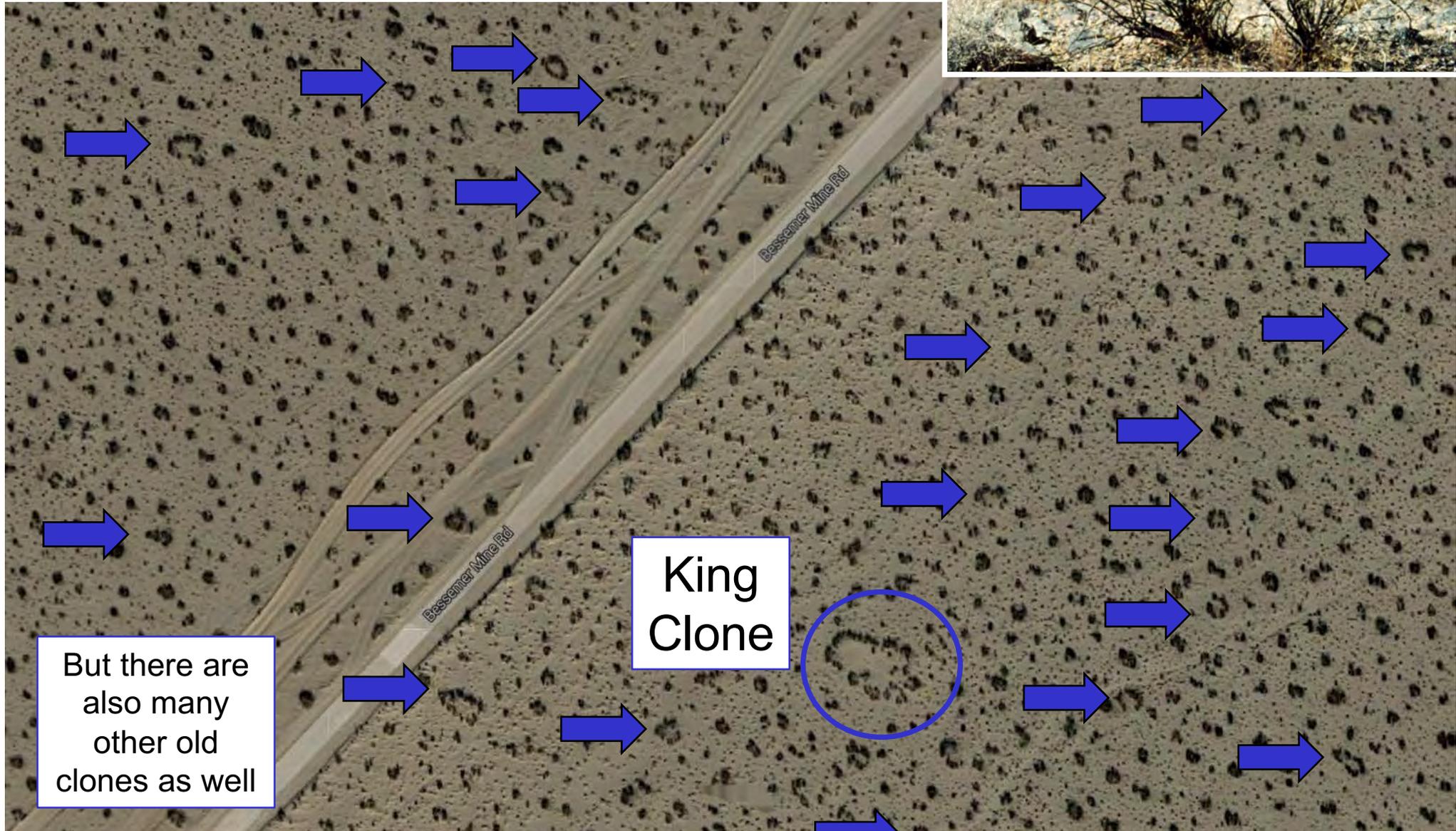
*Larrea tridentata*, a long-lived evergreen-leaf shrub that often clones with suffrutescent stems



Like many desert shrubs, *Larrea* is suffrutescent (multiple stems emerging from a common base). As the interior basal stems die, the plant radiates out to create a ring. “King Clone”, from the Mohave Desert, is thought to be thousands of years old.



*Larrea tridentata*, a long-lived evergreen-leaf shrub that often clones with suffrutescent stems



King Clone

But there are also many other old clones as well



## Part 6

# Long-lived giant succulents

Plant Ecology in a Changing World

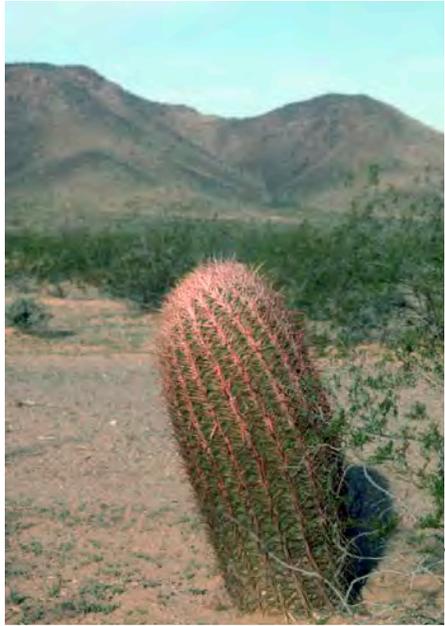
Jim Ehleringer, University of Utah  
<http://plantecology.net>



Deserts are filled with plants having many fascinating adaptations. Take the time to go enjoy our deserts.



Not all succulents are small and less than 1 m tall; some are giant succulents

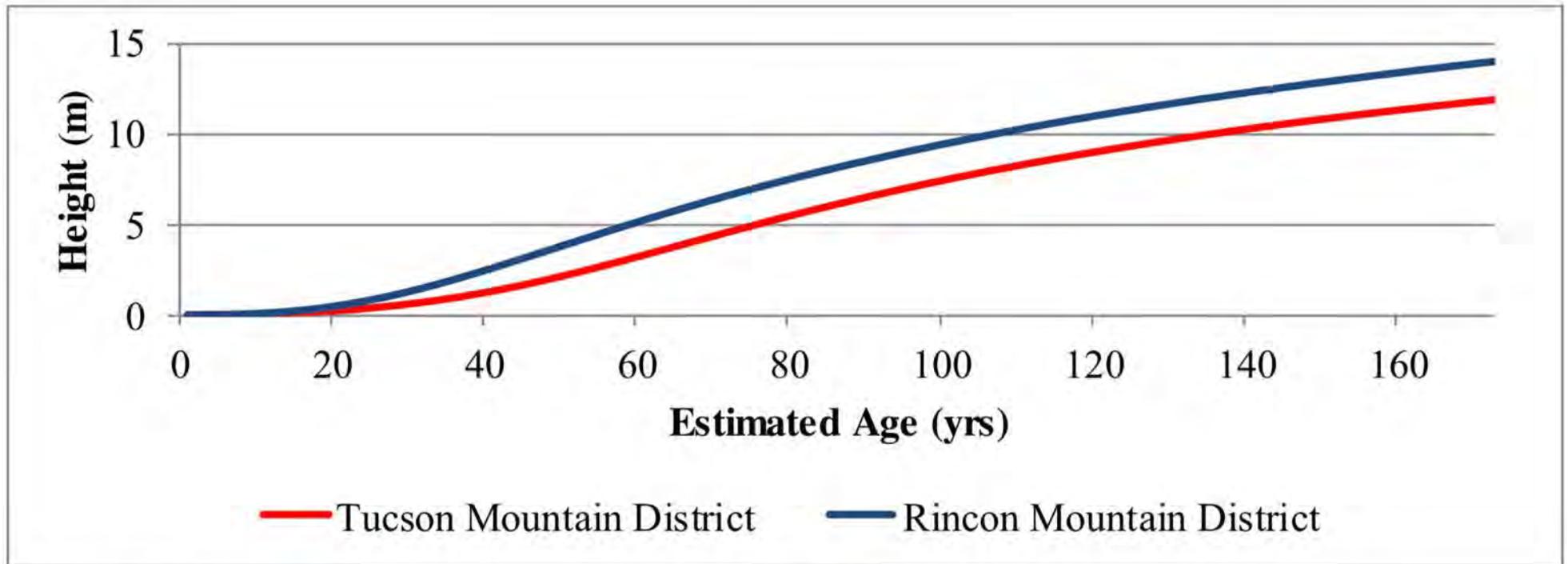




Saguaro, *Carnegiea gigantea*



Saguaro do not reach a height of 10 meters until they are over a 100 years old!



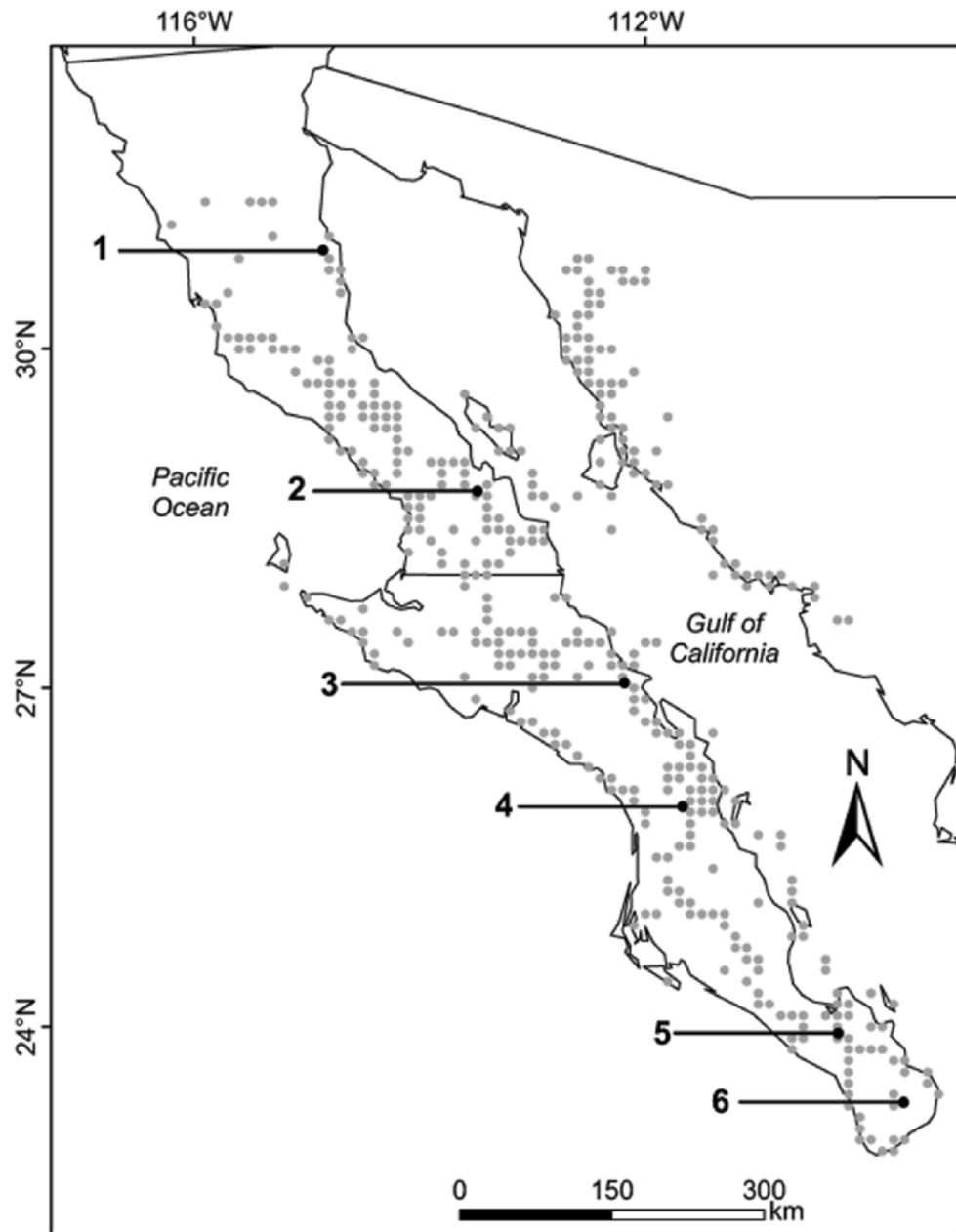
**Figure 9.** Estimated saguaro age at specified height. Data from Steenbergh and Lowe (1983). Note that for this report we used the RMD age-height relationship for both districts because growth rates are based on rainfall totals, which have been similar for both districts during the past decade.

Saguaro ribs swell as the cactus  
takes up and stores water





# Cardon, *Pachycereus pringlei*







Carbon and boojum in  
central Baja California







*Bursera microphylla*, elephant tree, Baja California



Also commonly referred to  
as the elephant tree

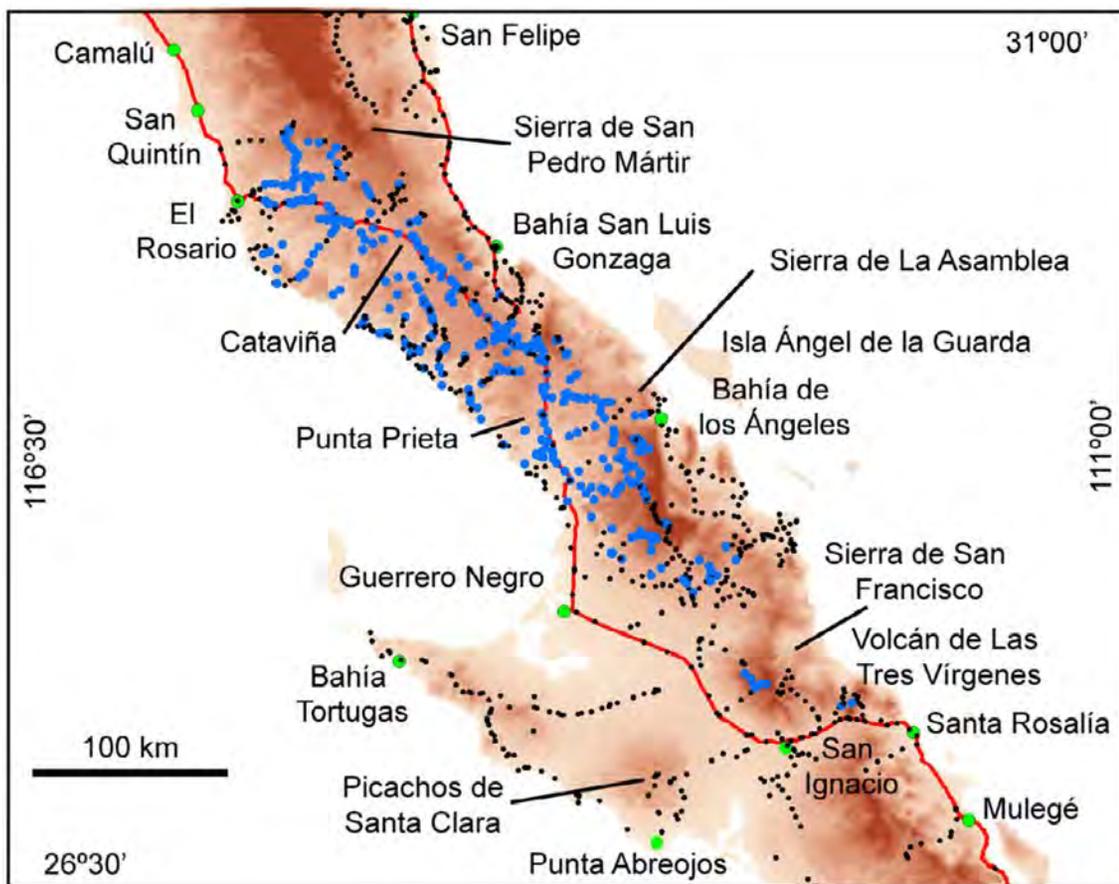
*Pachycormus discolor*  
elephant tree, Baja California



*Bursera microphylla*, elephant tree, Baja California



# Boojum, *Idria columnaris*









# Socotra



*Dracaena cinnabari*, Socotra dragon tree, Socotra



*Dracaena cinnabari*, Socotra dragon tree, Socotra



*Dracaena cinnabari*  
Socotra dragon tree  
Socotra



*Adenium obesum socotranum*, bottle tree, Socotra



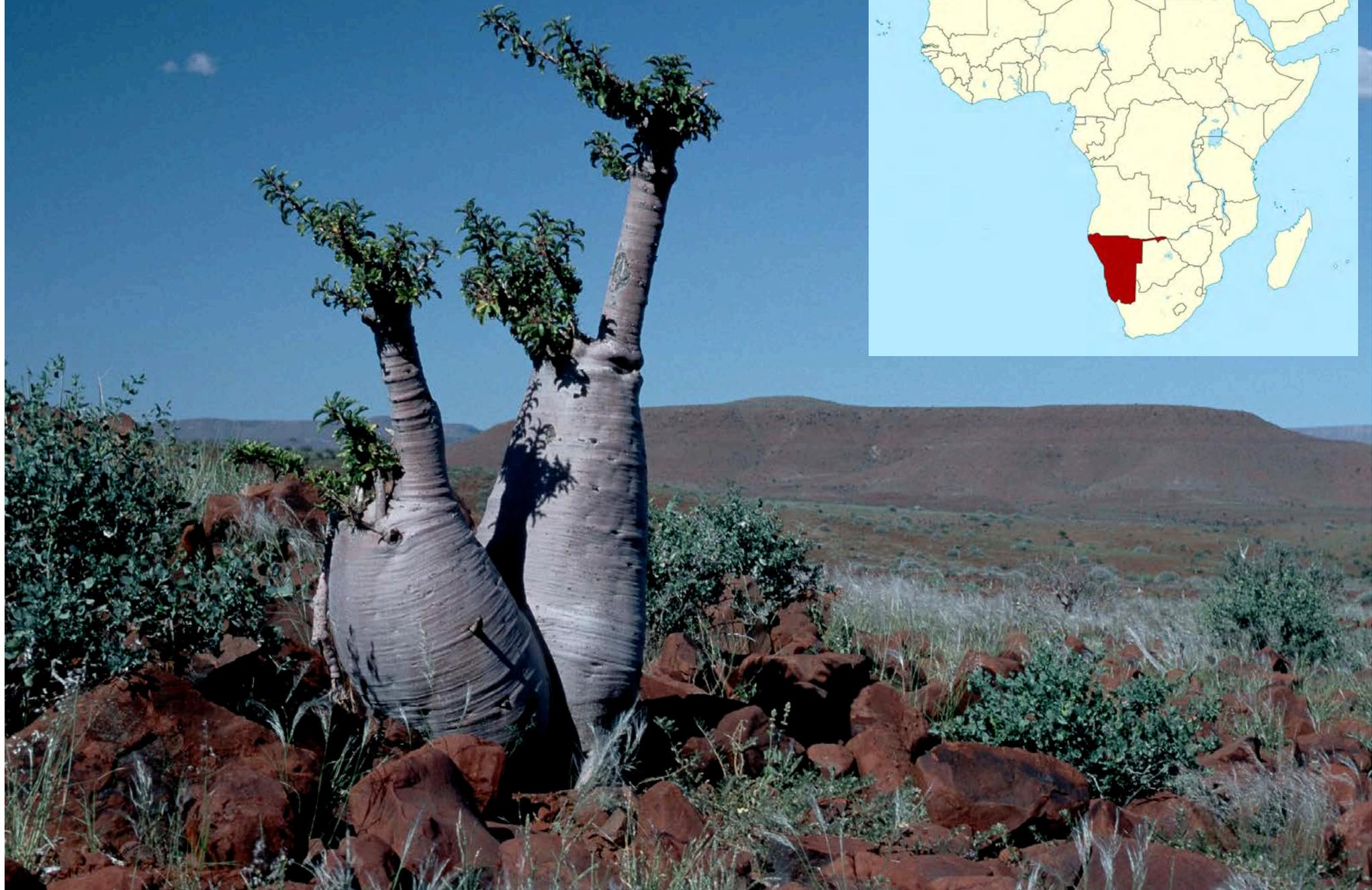
*Adenium obesum socotranum*  
bottle tree  
Socotra



*Adenium obesum socotranum*, bottle tree



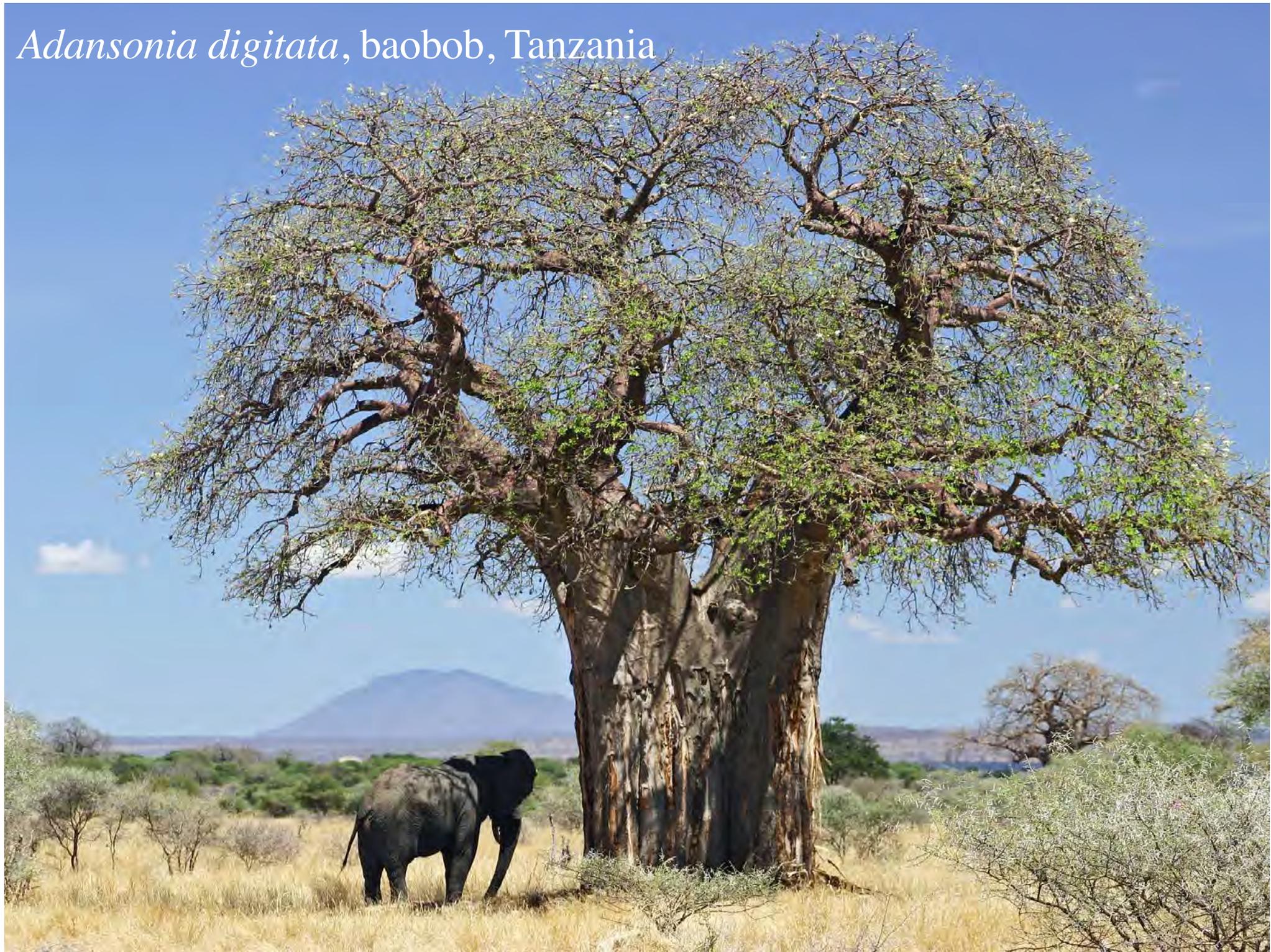
*Pachypodium lealii*, bottle tree, Namibia



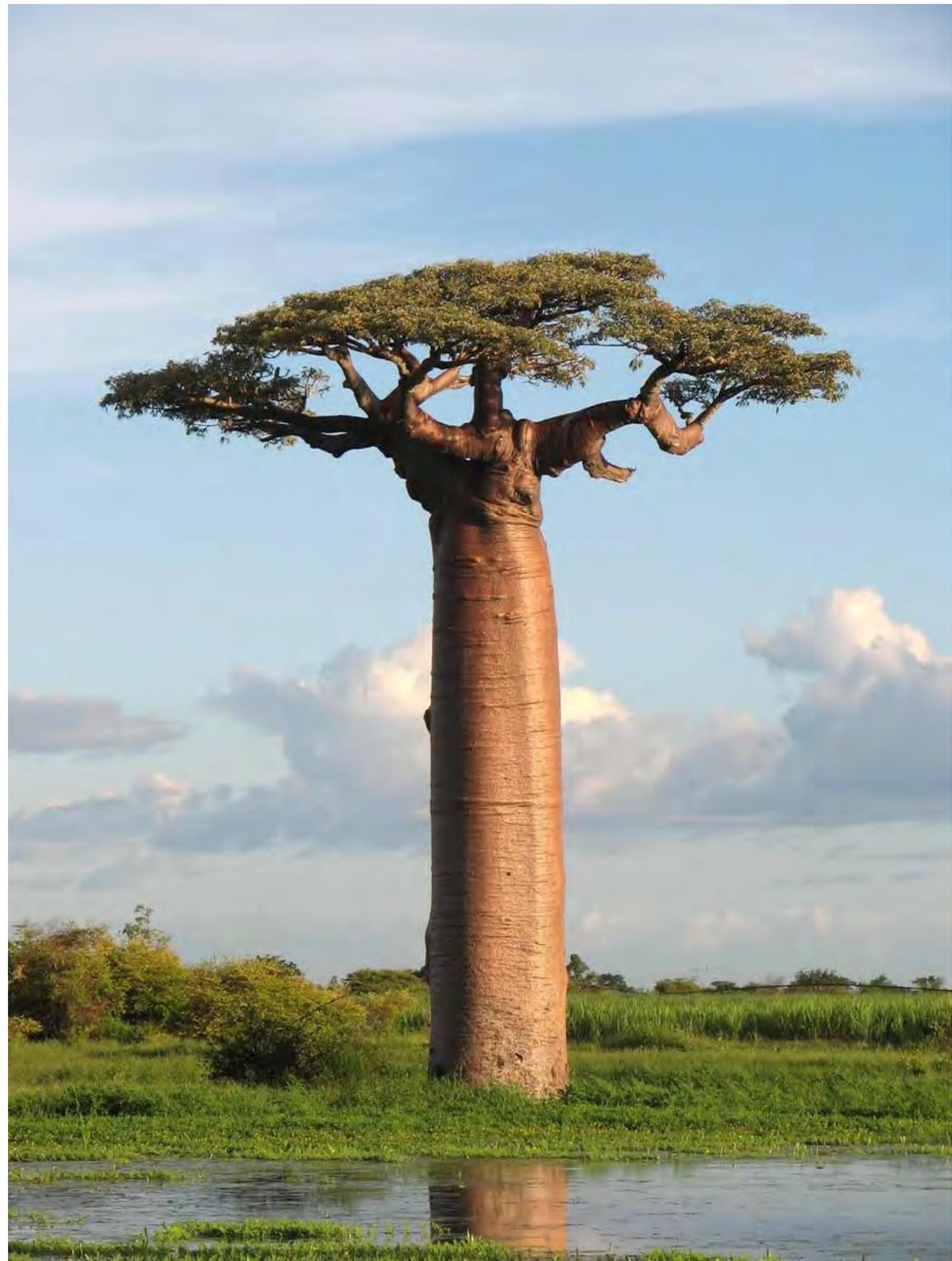
# Baobob trees of Tanzania



*Adansonia digitata*, baobob, Tanzania



# Baobobs of Madagascar





*Adansonia grandidieri*, baobob, Madag



*Adansonia grandidieri*, baobob, Madagascar

