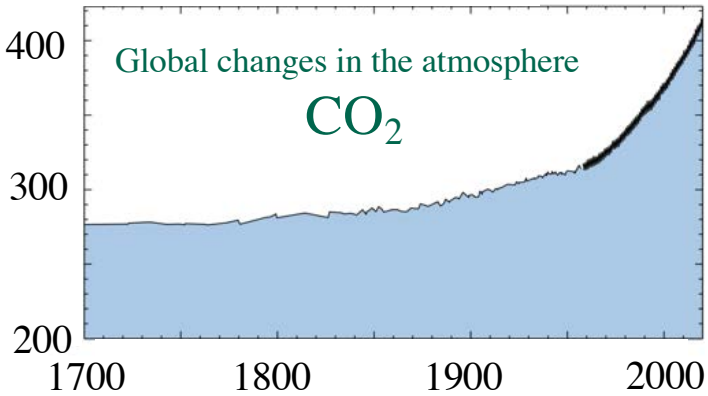
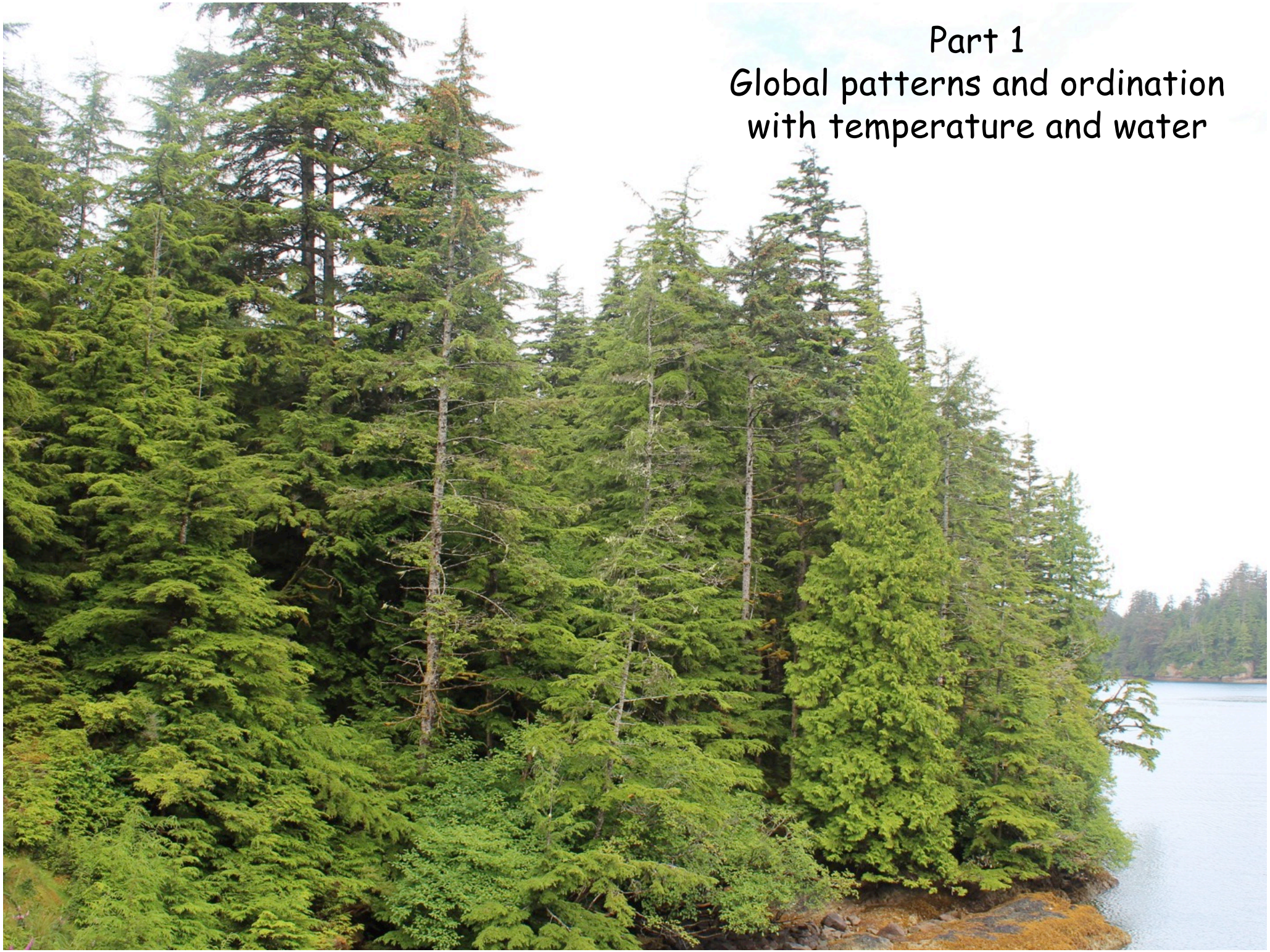


Topic 3

Biomes and Climate Relationships

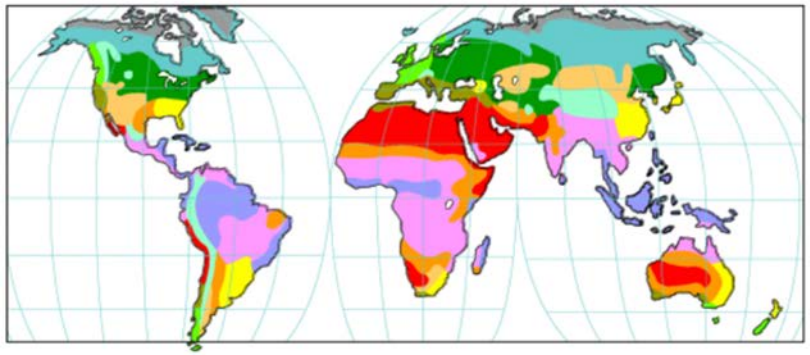
Plant Ecology in a Changing World

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



Part 1
Global patterns and ordination with temperature and water

Communities, ecoregions, biomes, and ecosystems



Let's not get lost in terminology, but a few definitions are helpful.

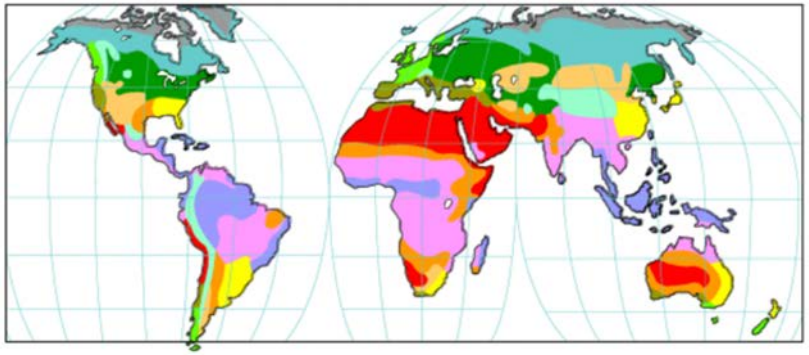
Communities are aggregations of plants within a designated geographical unit. (Möbius, 1877)

Ecoregions are large areas of similar plant communities living in similar climates recurring in predictable patterns. (Bailey 1989)

Biomes are communities of plants and animals classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment. (Clements, 1916)

Ecosystems describes the integration of communities of plants and animals, soils, microbes, and physical environment. The abiotic and biotic components of an ecosystem are linked through energy and nutrient cycles. (Tansley, 1935)

Biome and climate relationships



Our objectives are to

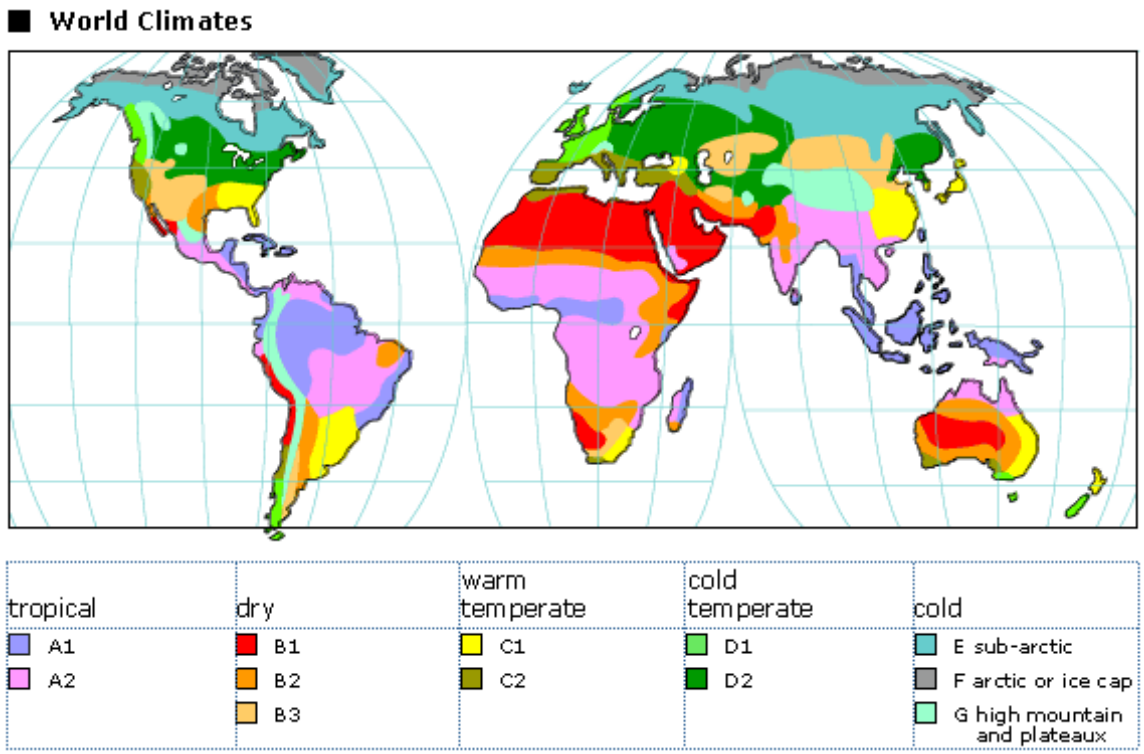
- understand biome-climate relationships sufficiently to to make predictions on the expected biome (vegetation) within a climate zone under stable or equilibrium conditions
- to predict biome distributions in the future
- to reconstruct biome distributions in the past

Our approaches are to

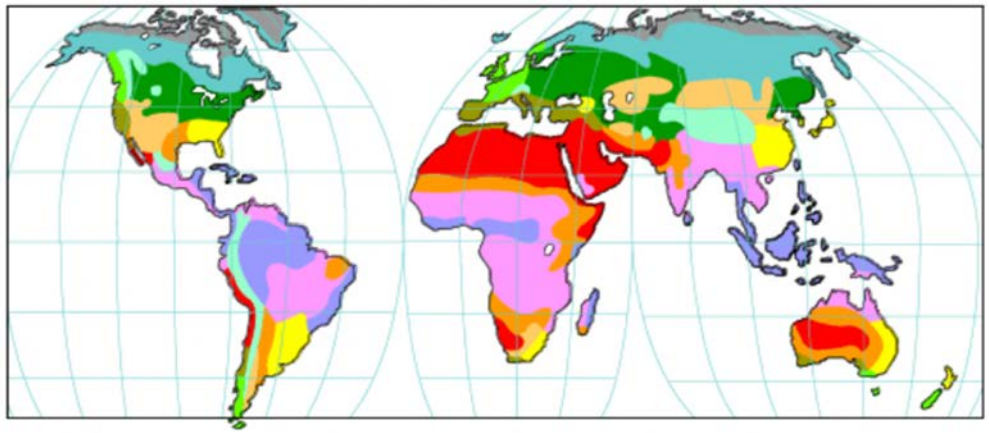
- classify plants on the basis of life form
- explore life form similarities in similar climates
- classify climate with a visual approach (climate diagrams)
- explore analogous climates

Climate and vegetation relationships

- There are global latitudinal and continental climate patterns
- Similar climatic regions occur at equivalent latitudes north and south of equator on all continents
- These patterns result in repeatable (convergent) vegetation structure
- Particular biomes or vegetation types are associated with specific climate zones



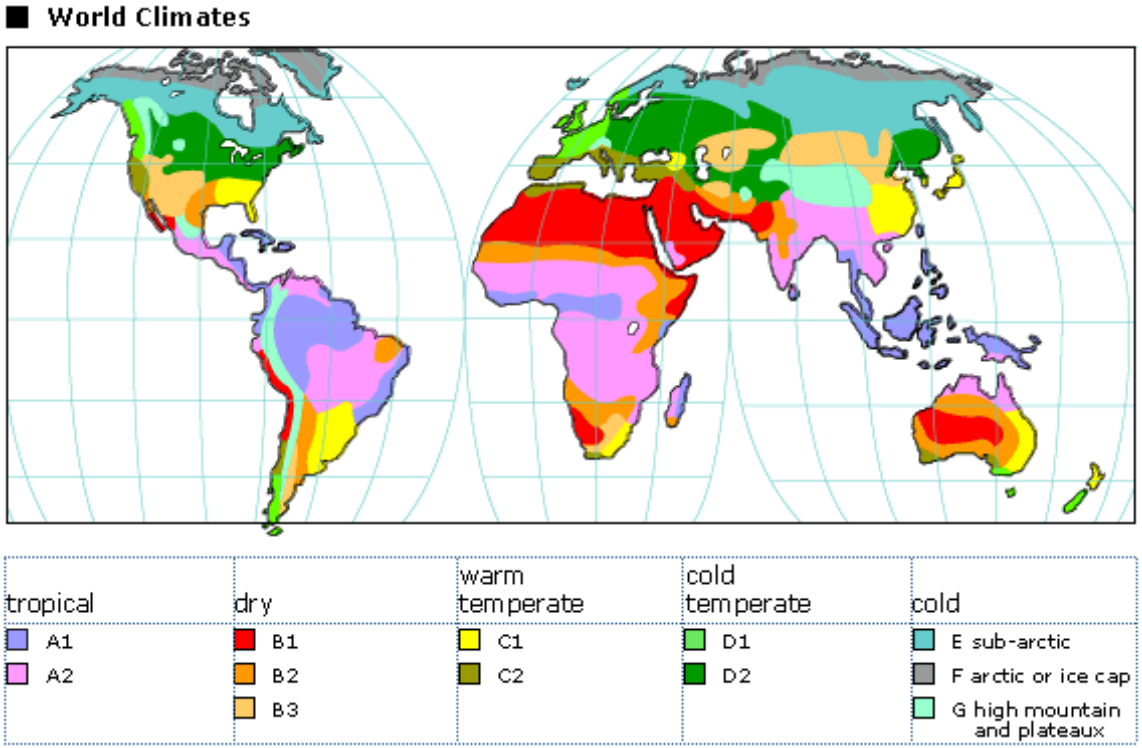
What are the major biomes and where are they located?



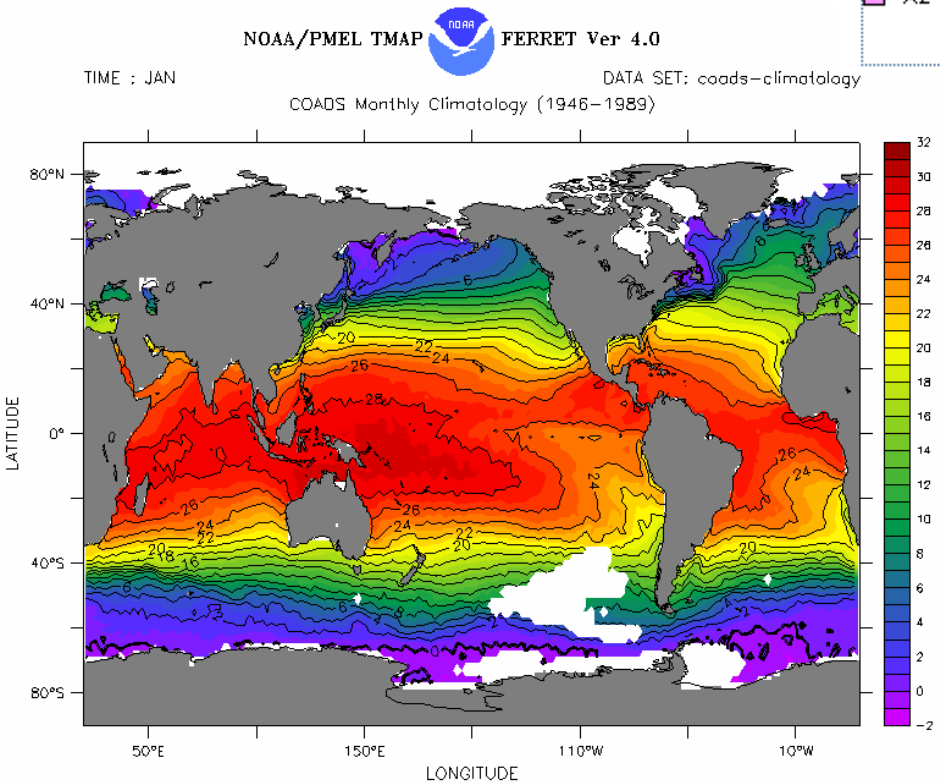
	Temperature zone		
	Polar	Temperate	Tropical
Tundra	X	X	-
Forest			
Taiga	X	-	-
Coniferous	-	X	-
Deciduous	-	X	-
Rainforest	-	-	X
Savanna	-	X	X
Mediterranean shrub	-	X	-
Steppe	-	X	-
Grassland	-	X	X
Desert	-	X	X

Koppen climate classification

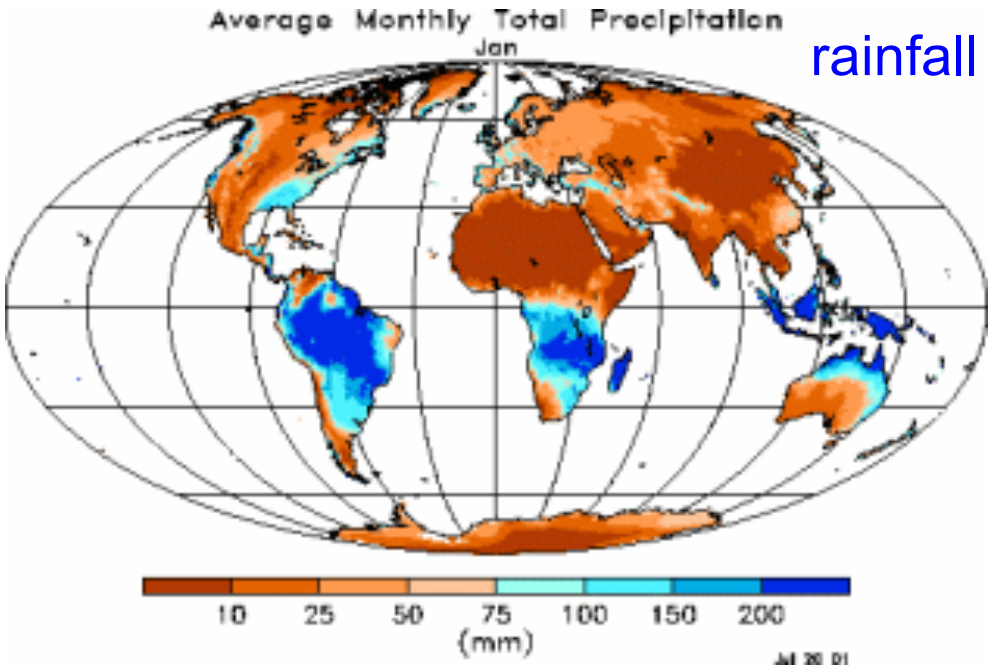
terrestrial



oceanic



rainfall

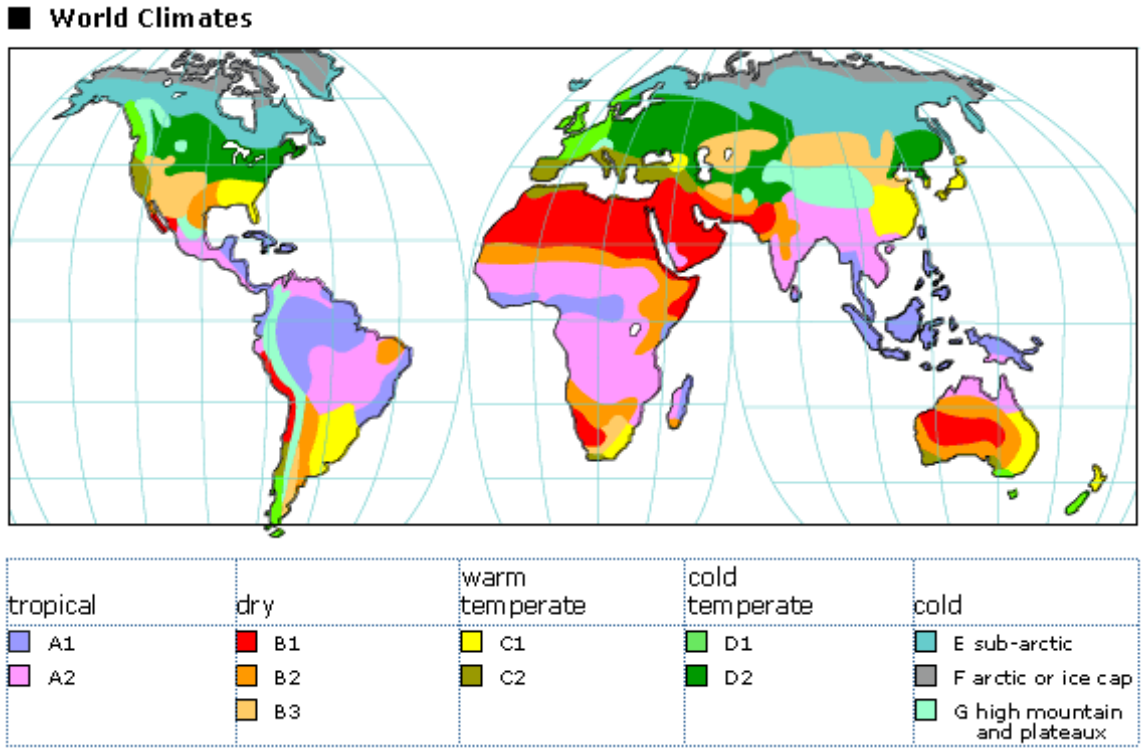


http://ferret.wrc.noaa.gov/ferret/bigpix2.gif

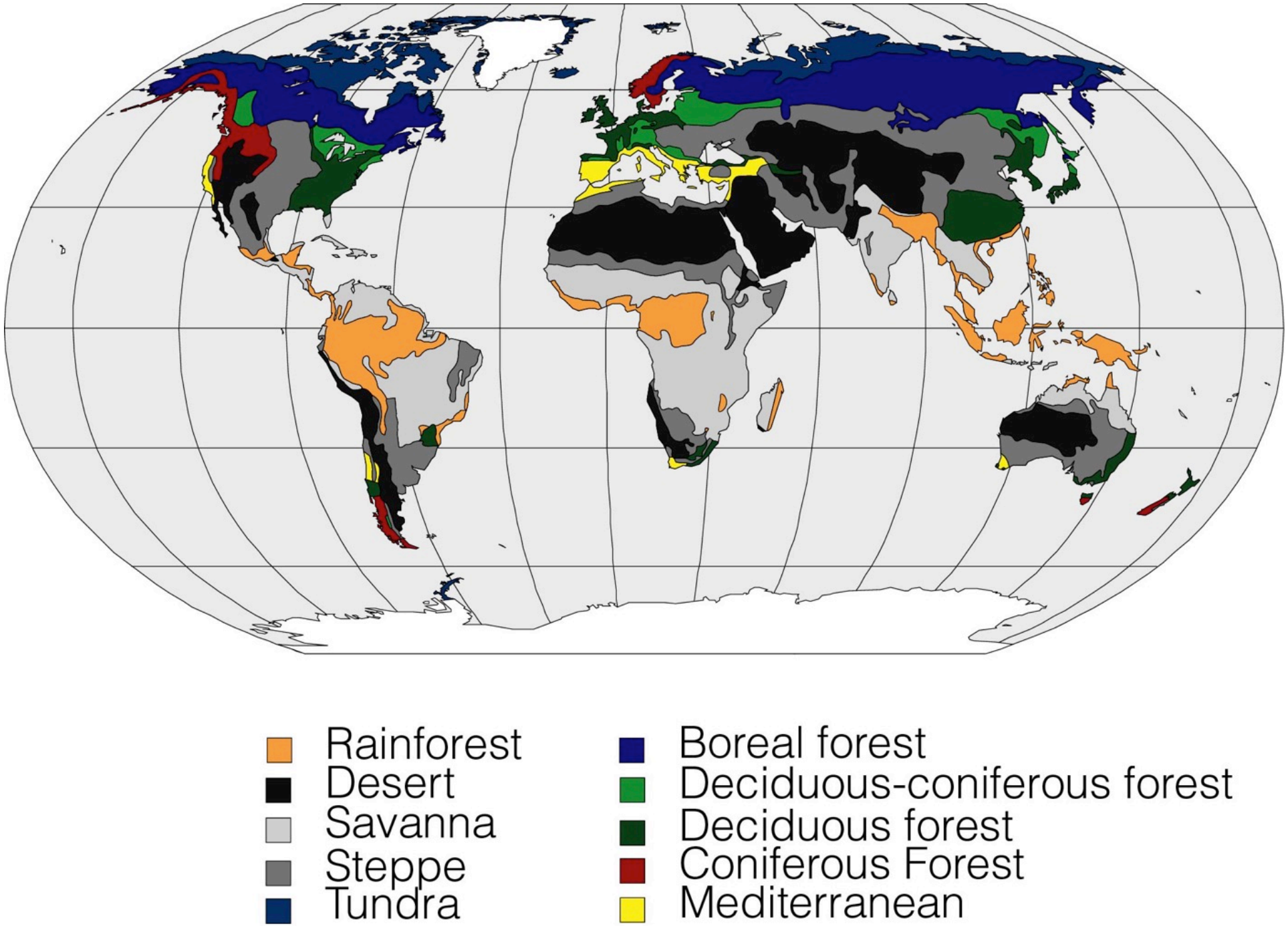
http://climate.geog.udel.edu/~climate/gif_files/title_map.gif

There are multiple ways of classifying vegetation-climate relationships

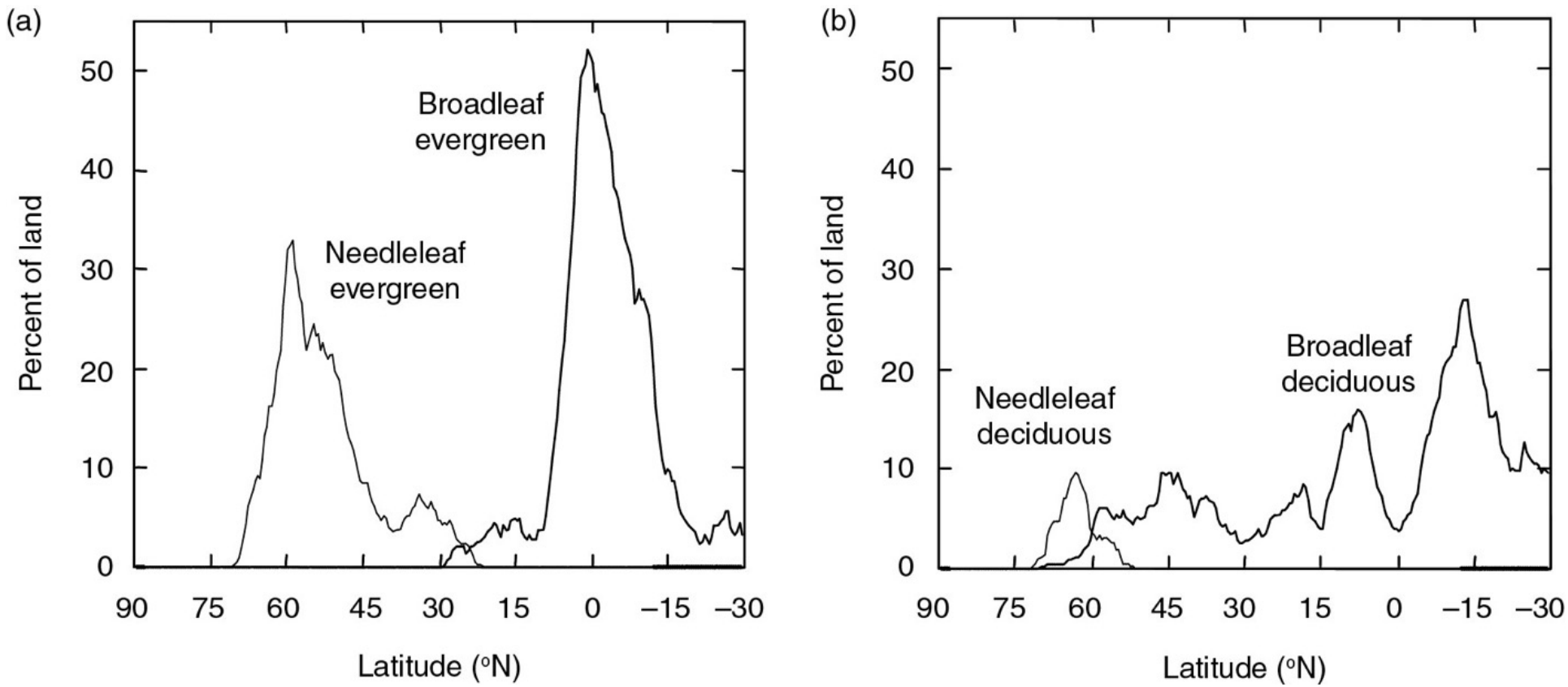
- There are global latitudinal and continental climate patterns
- Similar climatic regions occur at equivalent latitudes north and south of equator on all continents
- These patterns result in repeatable (convergent) vegetation structure
- Particular biomes or vegetation types are associated with specific climate zones



The global distribution of biomes

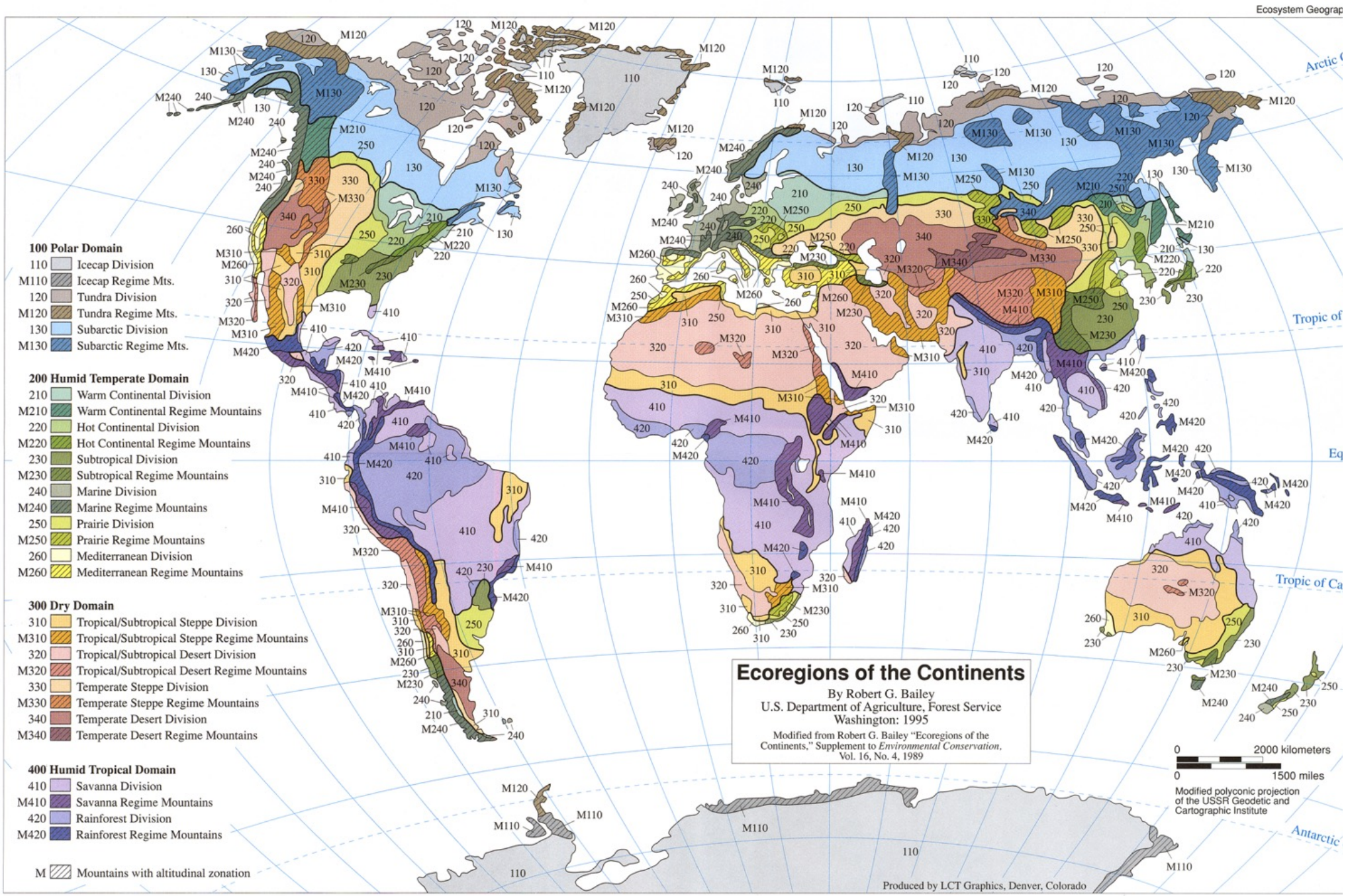


Needleleaf evergreen plants (conifers) dominate polar latitudes, whereas broadleaf evergreen (angiosperms) dominate equatorial latitudes

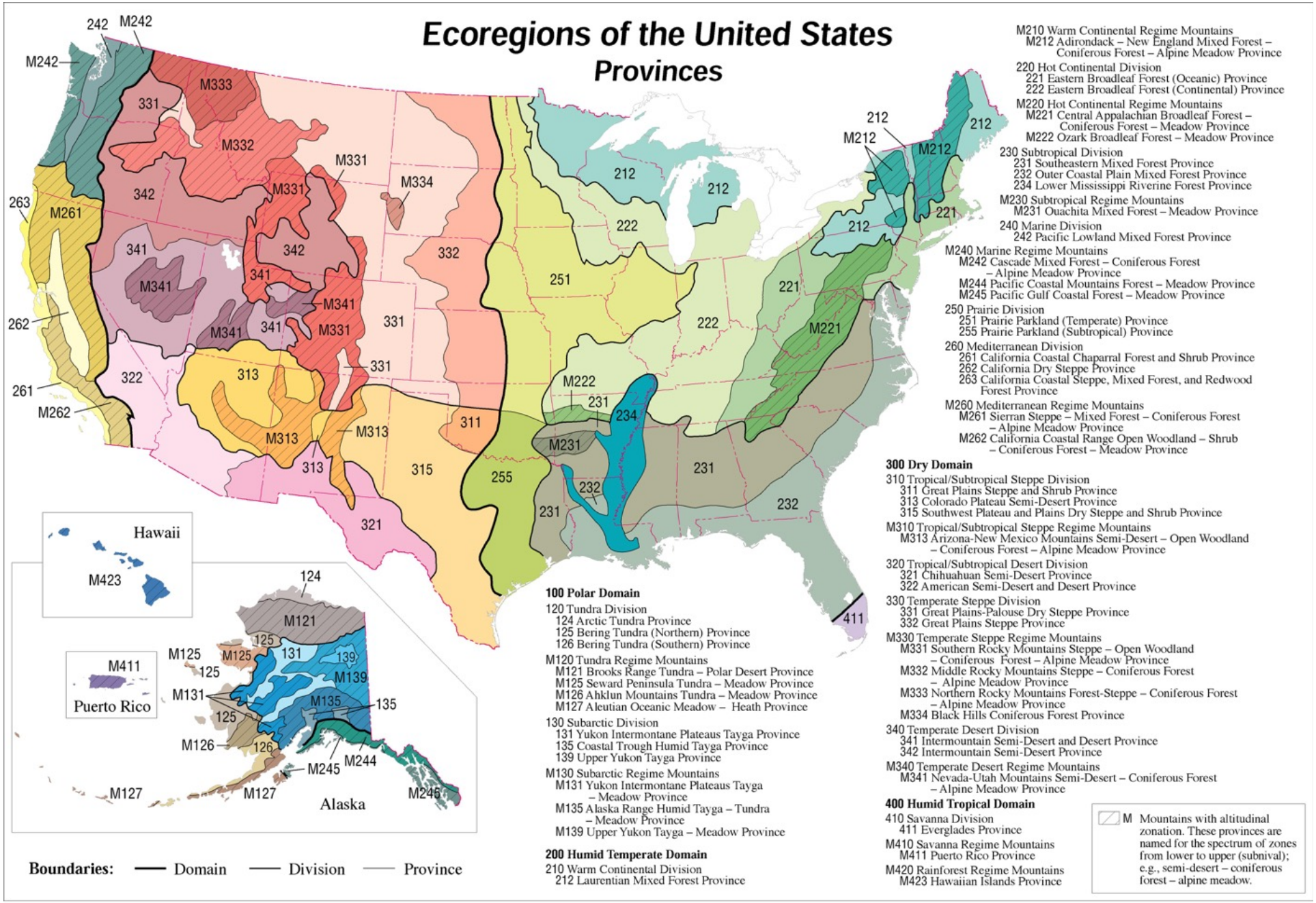


Bonan Fig 18.12, 2015

Bailey's ecoregions dividing the world into four domains

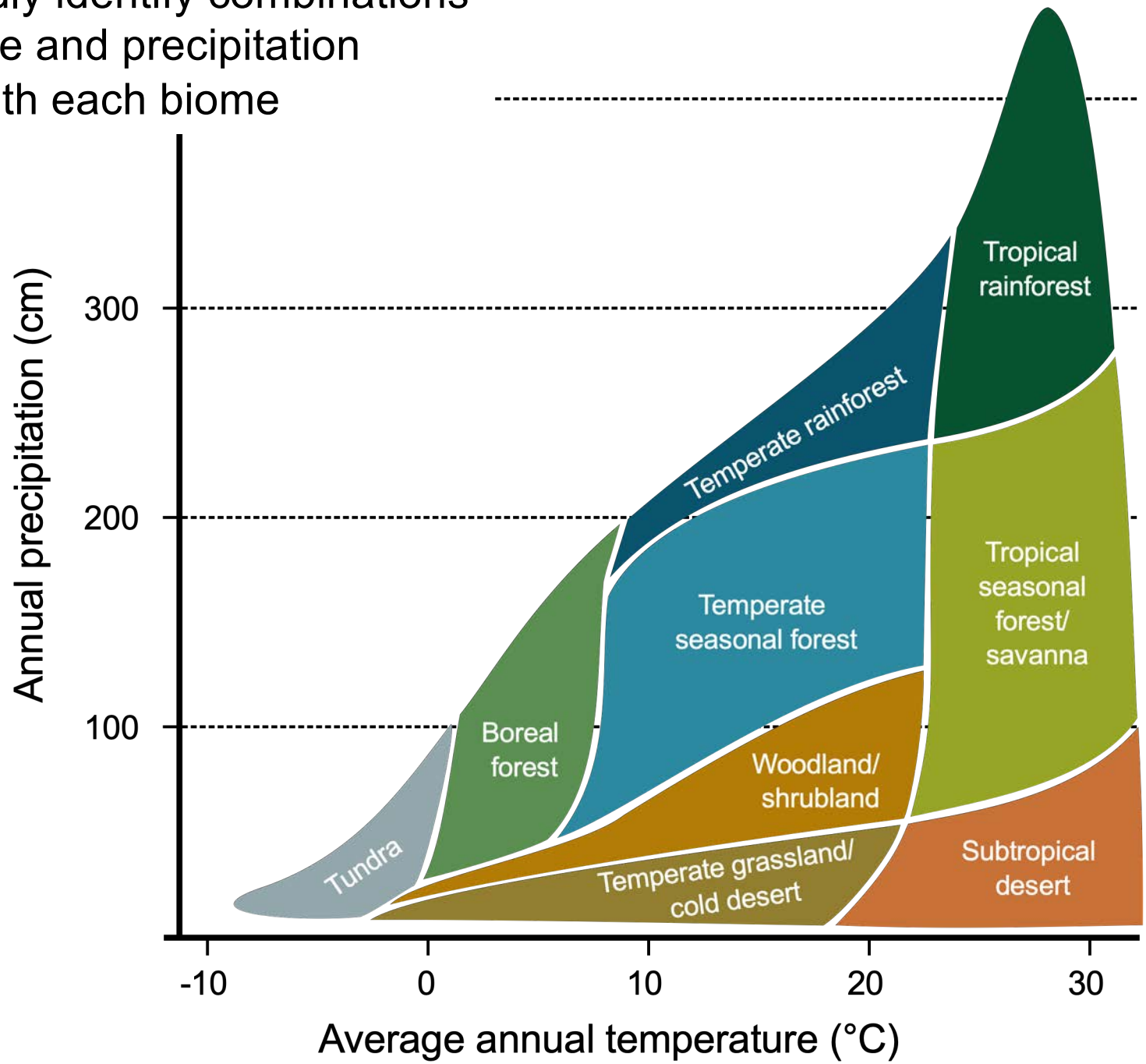


Bailey's ecoregions dividing the United States into four domains



Source: R.G. Bailey [Ecoregions of the United States, USDA Forest Service (scale 1:7,500,000, revised 1994)]

We can broadly identify combinations of temperature and precipitation associated with each biome



Part 2
Classifying vegetation on the basis of form and structure

We will classify vegetation on the basis of structural characteristics

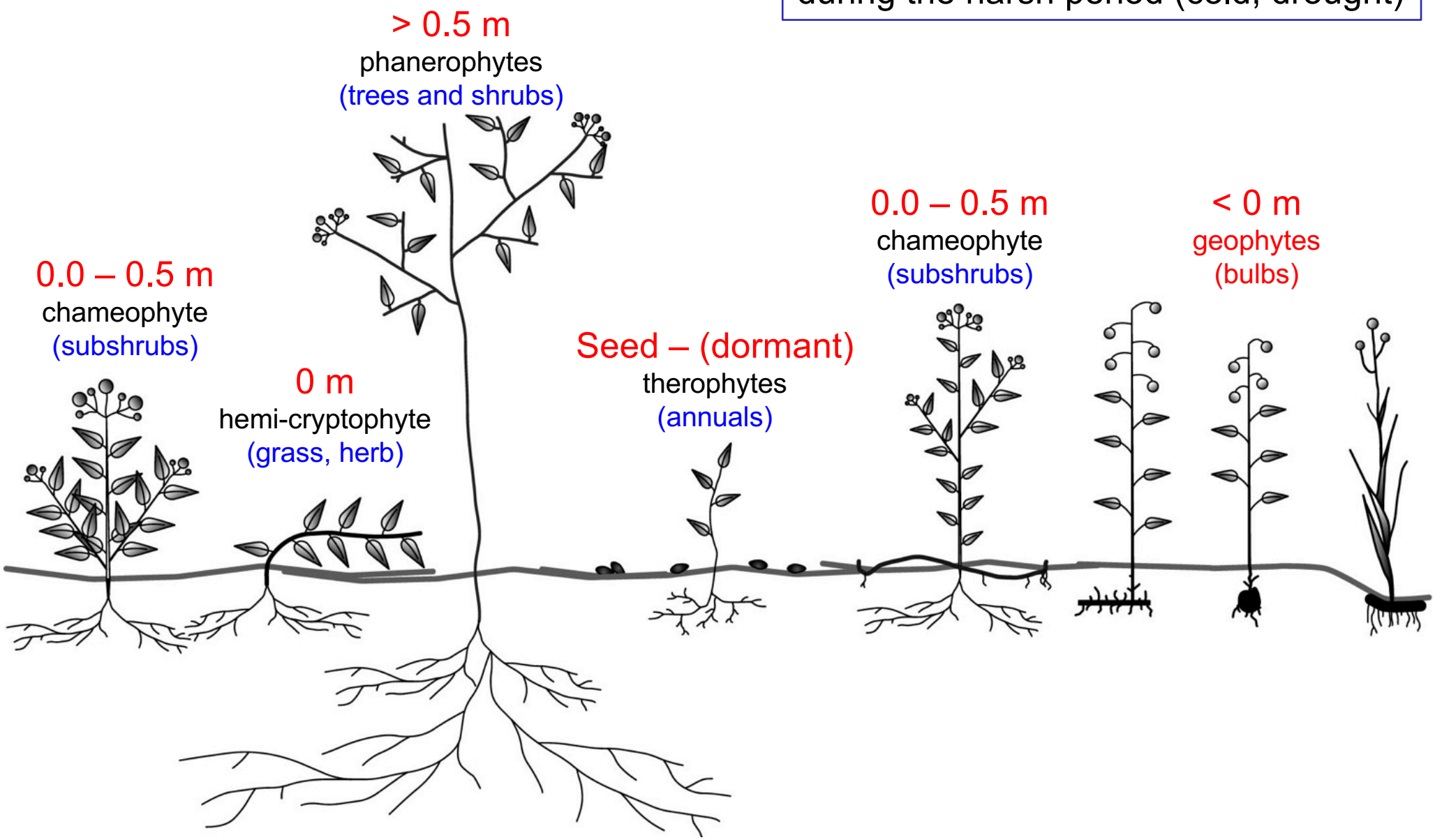
- location of the perennating bud (Raunkiaer classification)

Other classification approaches might include

leaf size
leaf shape
leaf phenology
life history

Raunkiaer life forms

Raunkiaer's approach was based on the location of the perrenating buds during the harsh period (cold, drought)



Why did Raunkiaer choose perennating buds?

- They represent a measure of the kind and degree of protection offered to meristematic tissues during unfavorable season ("resting period")
- Guiding principle - character must be structural (easy to identify) and essential

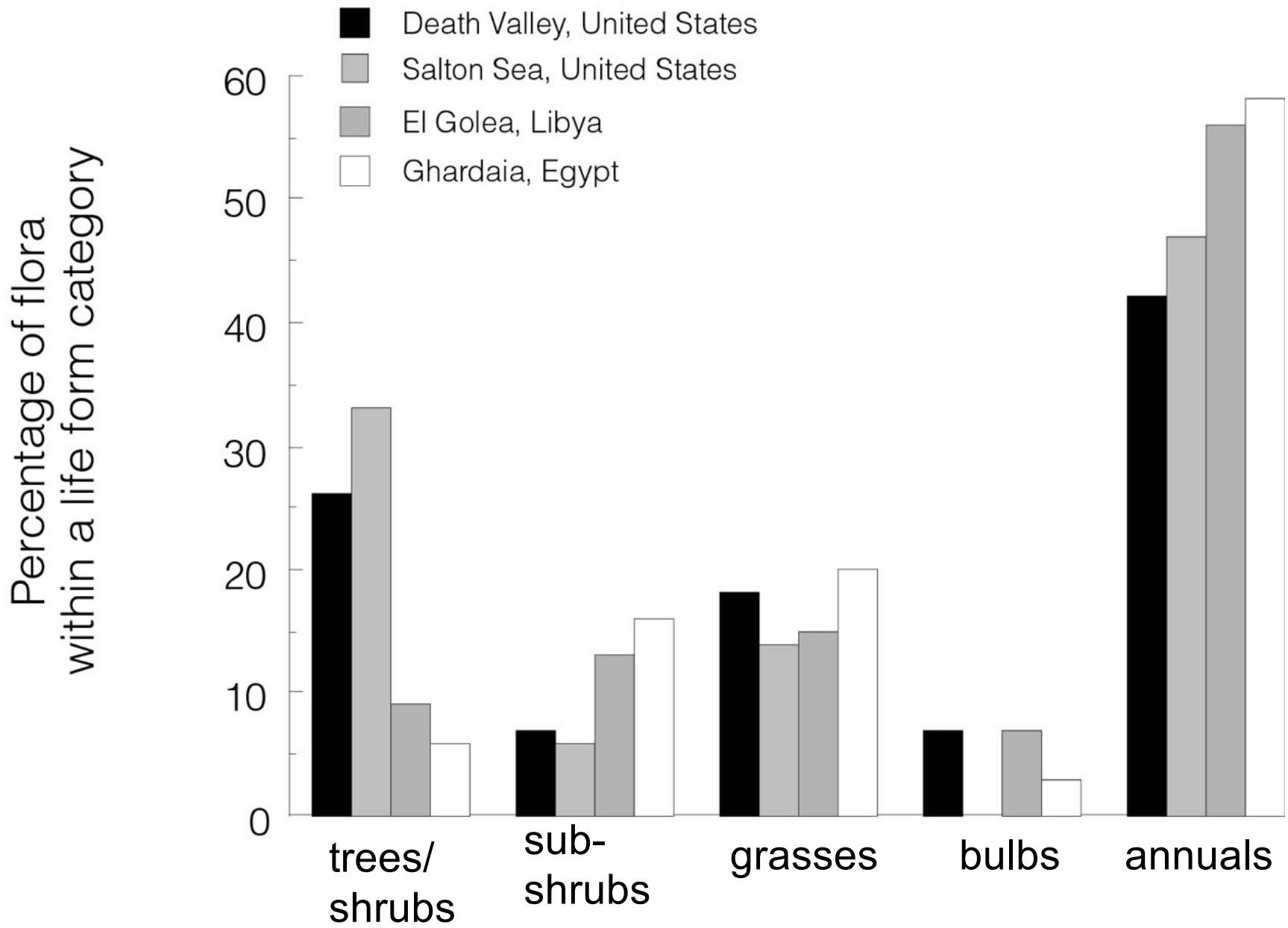
Hypothesis - plants have different ecological amplitudes (more or less limited in their capacity to endure different environmental stresses)

Raunkaier biome comparisons

Distribution by %	wet tropical	hot desert	cold tundra
Phanerophyte (tree)	**61**	26	1
Chamaephyte (subshrub)	6	7	23
Hemicryptophyte (grass)	12	18	**61**
Geophyte (bulb)	5	7	15
Therophyte (annual)	16	**42**	1



Similarities in Raunkiaer life form distributions across four deserts



Today plant functional types are used in global models

- called dynamic global vegetation models (DGVM)
- 7 plant functional types (PFTs)

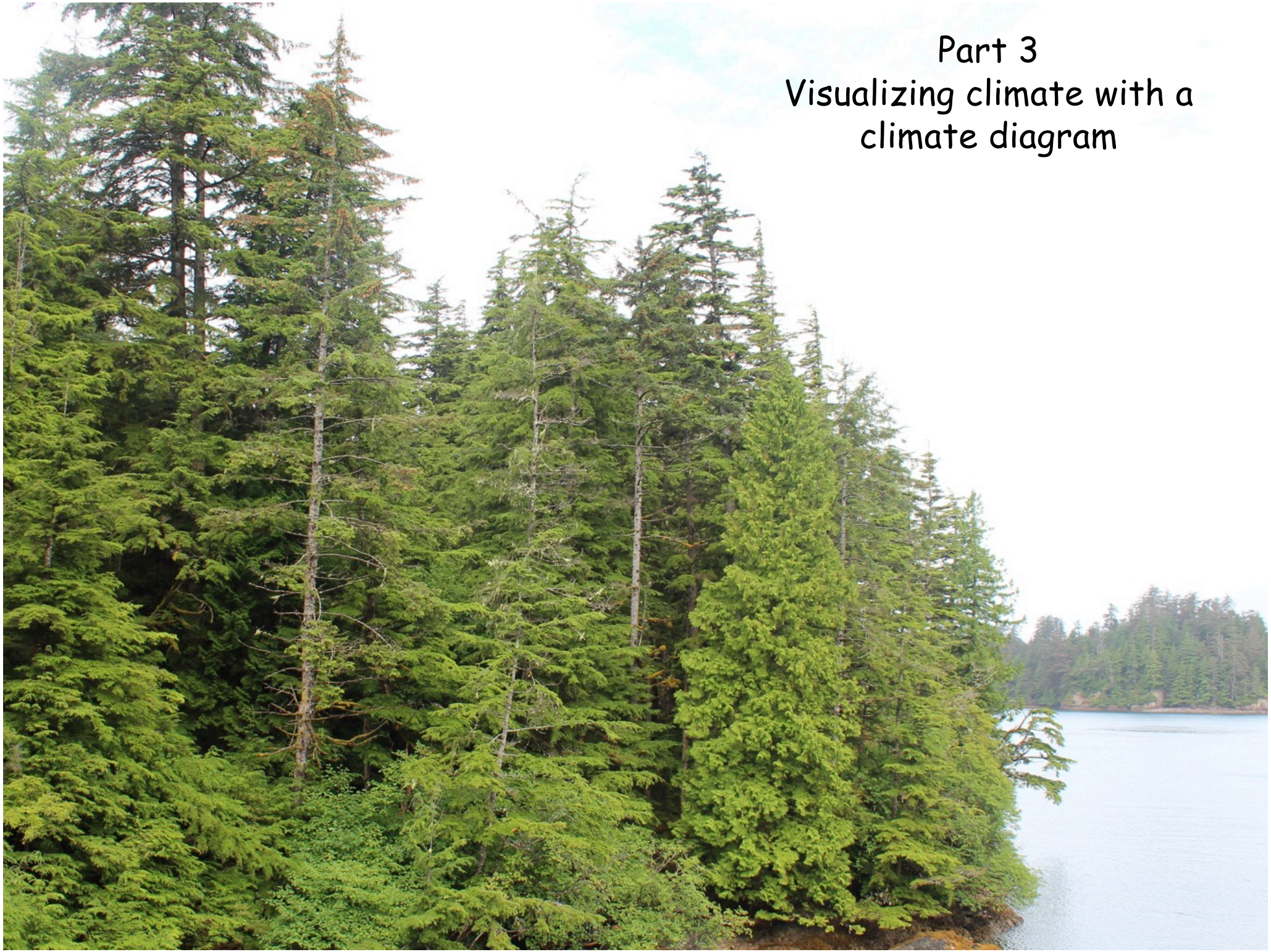
  Needle leaf evergreen tree – boreal, temperate
  Needle leaf deciduous tree - boreal
  Broadleaf evergreen tree – temperate, tropical
  Broadleaf deciduous tree – boreal, temperate, tropical
  Shrub
  Grass – C_3 or C_4
  Crop – C_3 or C_4

- structural, physiological features are used as input in DGVMs (e.g., Vmax, LAI, leaf optical properties)

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 16, NO. 2, 10.1029/2000GB001360, 2002

Landscapes as patches of plant functional types: An integrating concept for climate and ecosystem models

Gordon B. Bonan and Samuel Levis
National Center for Atmospheric Research, Boulder, Colorado, USA



Part 3
Visualizing climate with a climate diagram

Climate can be visualized using precipitation and temperature

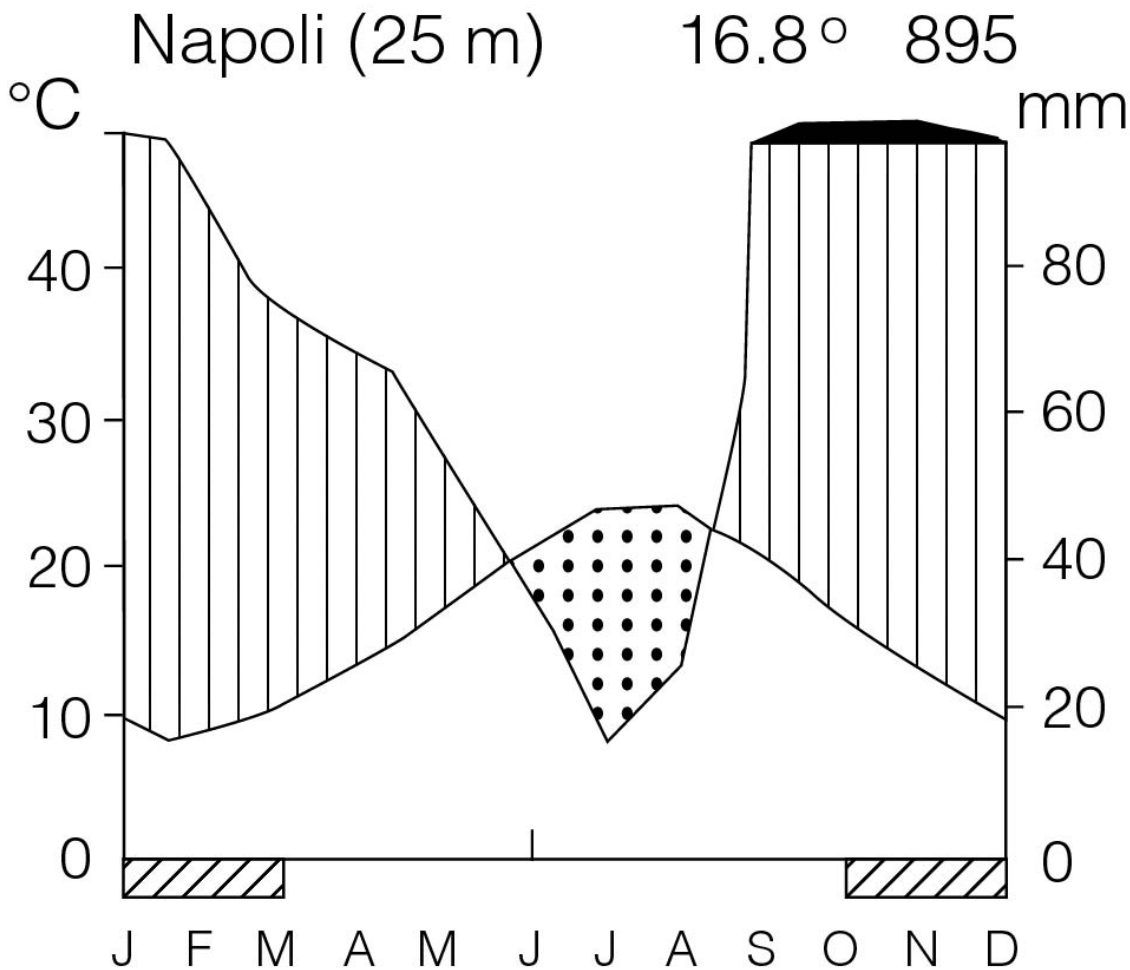
Climate diagram

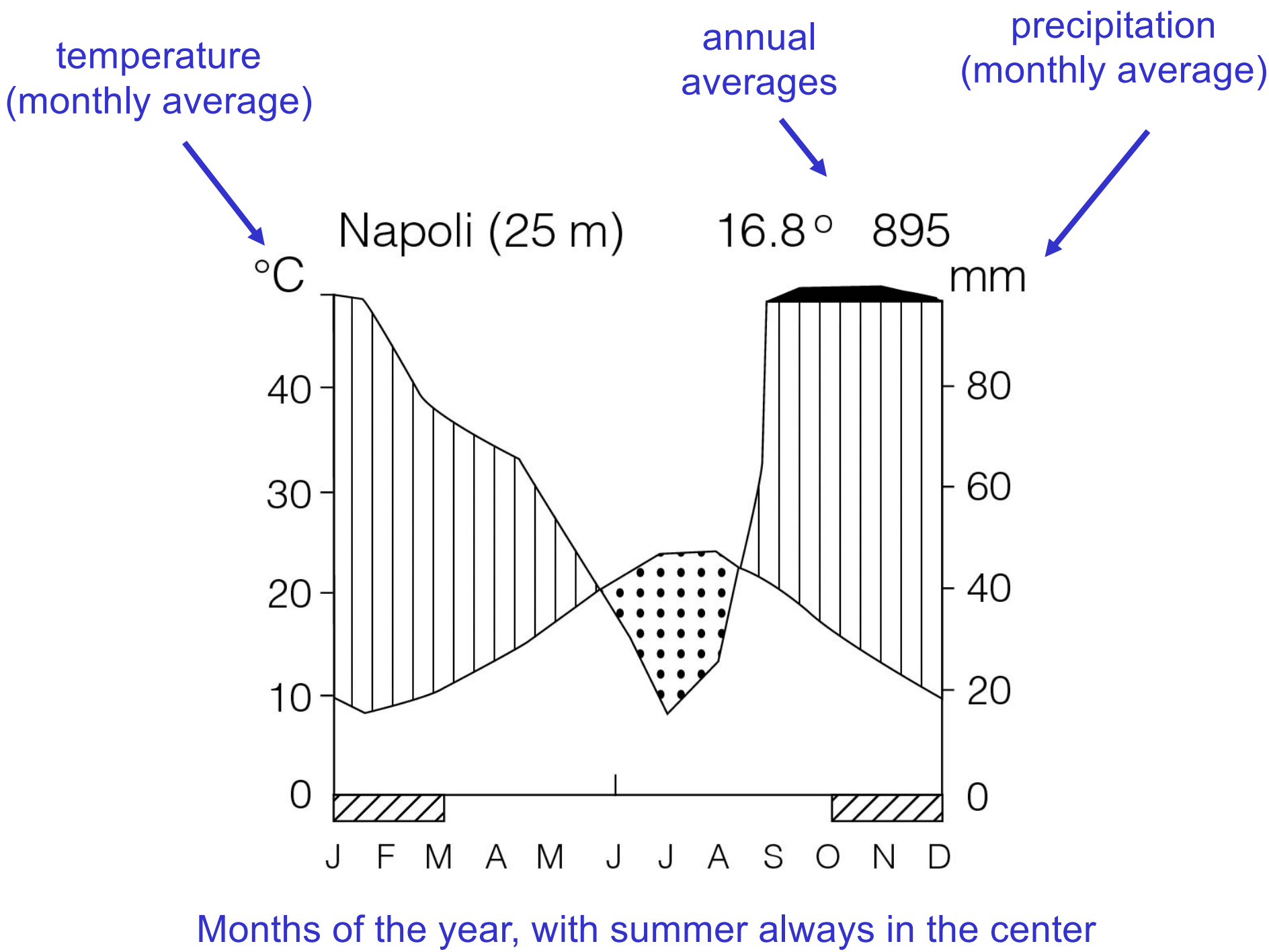
as designed by Heinrich Walter

Napoli (Naples) is in a Mediterranean climate

A Mediterranean climate is defined as having cool, wet winters and hot, dry summers

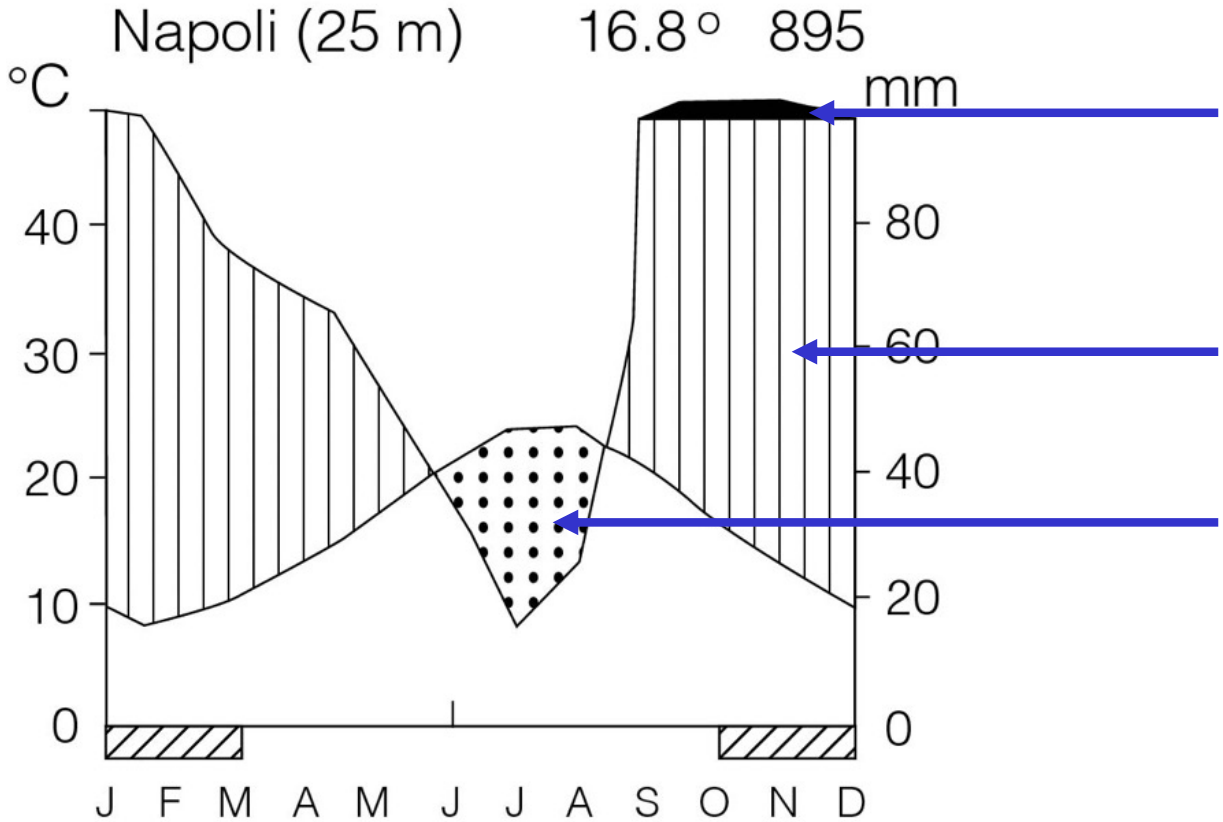
A climate diagram allows one to visually depict climate periods: as wet-dry and cold-hot




temperature
(monthly average)
annual
averages
precipitation
(monthly average)
Napoli (25 m)
16.8°
895
°C
mm
40
30
20
10
0
80
60
40
20
0
J F M A M J J A S O N D
Months of the year, with summer always in the center

Climate diagram scaling is 10° C = 20 mm, which approximates expected evapotranspiration at that temperature

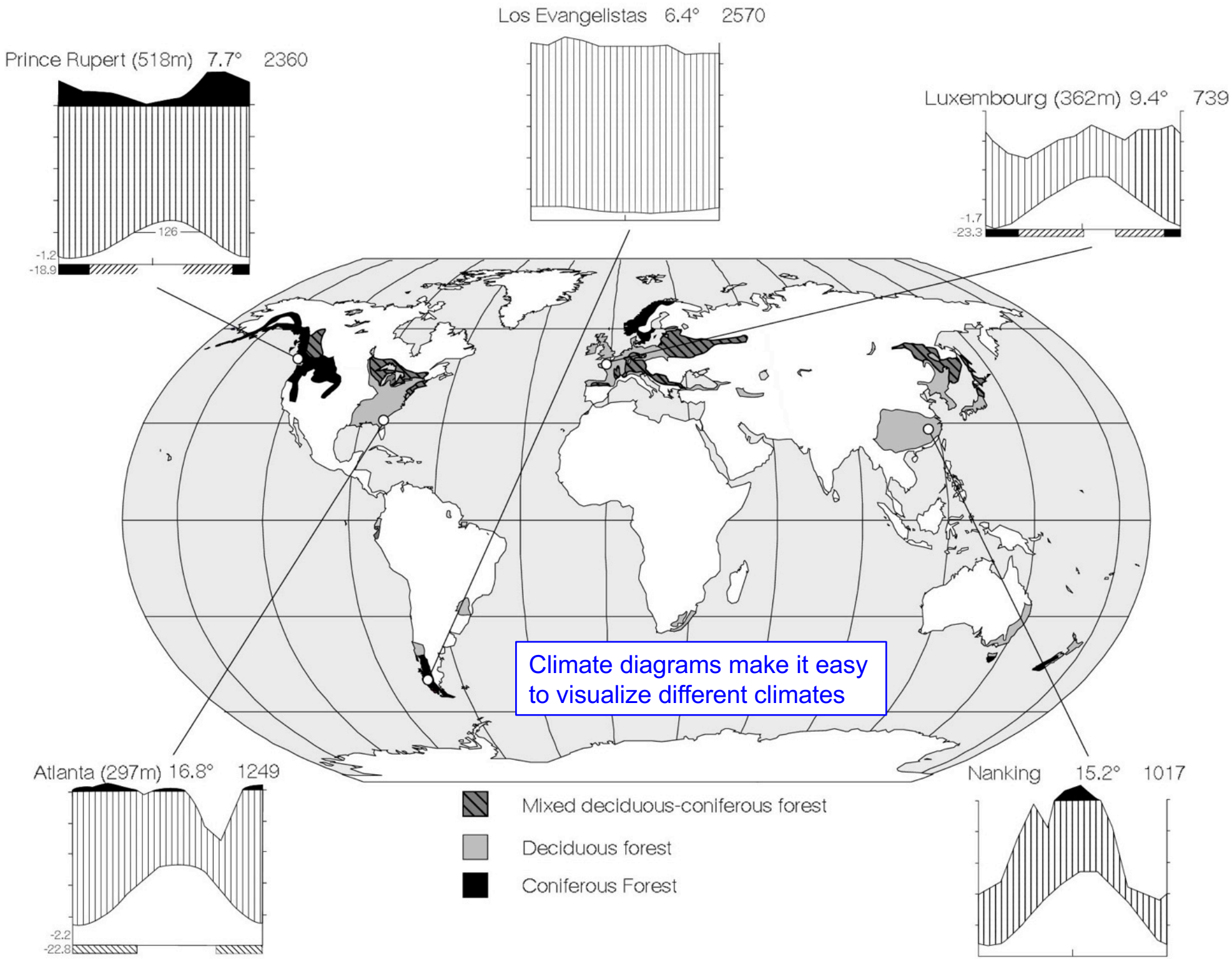
With climate diagram
we can visualize
monthly site water balance



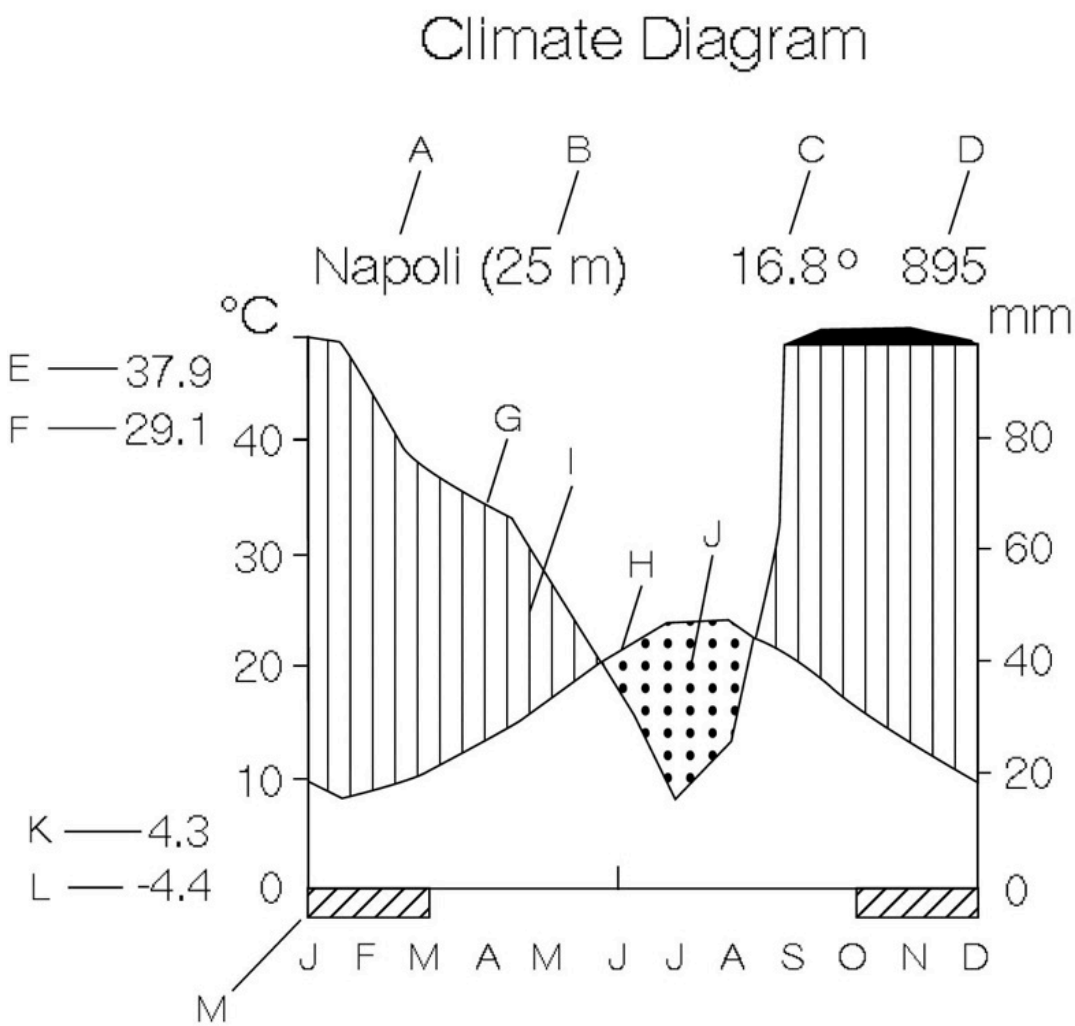
excessive humid period (black)

humid period (vertical stripe)

arid period (stipled)

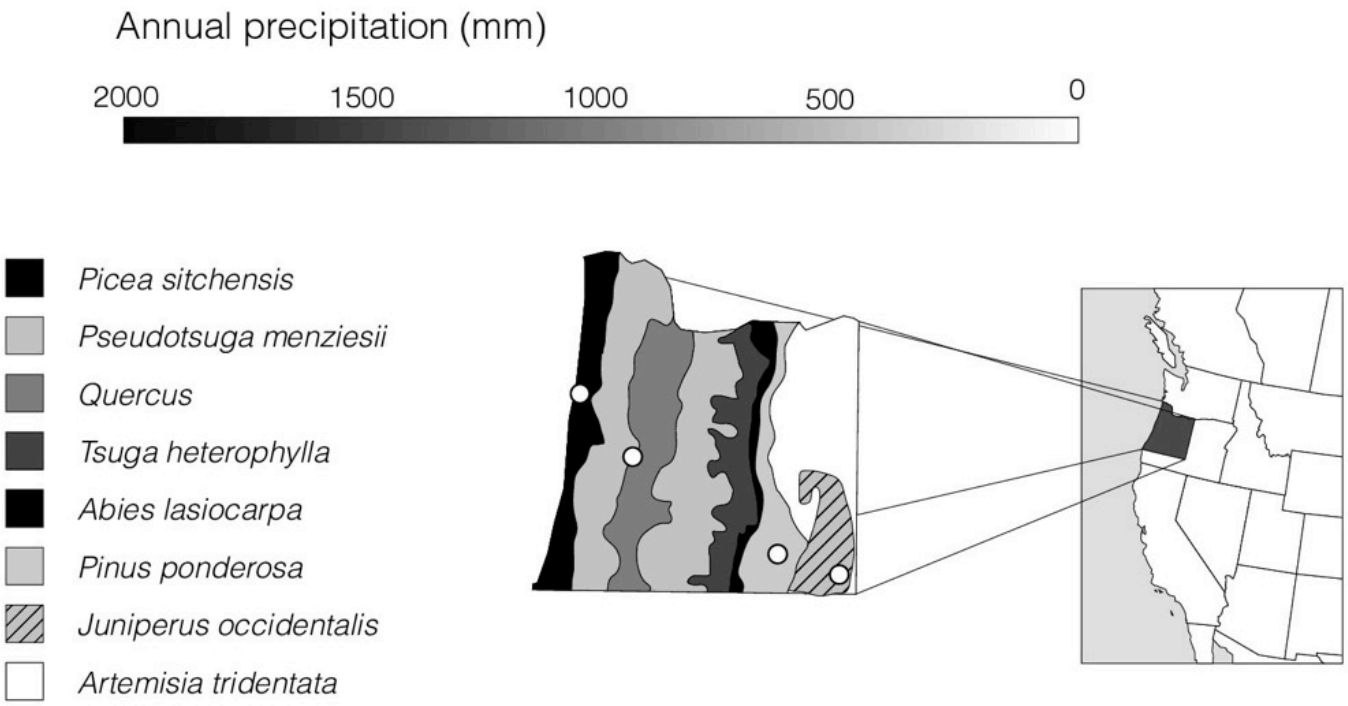

Los Evangelistas 6.4° 2570
Prince Rupert (518m) 7.7° 2360
126
-1.2
-18.9
Luxembourg (362m) 9.4° 739
-1.7
-23.3
Climate diagrams make it easy to visualize different climates
Atlanta (297m) 16.8° 1249
-2.2
-22.8
Nanking 15.2° 1017
Mixed deciduous-coniferous forest
Deciduous forest
Coniferous Forest

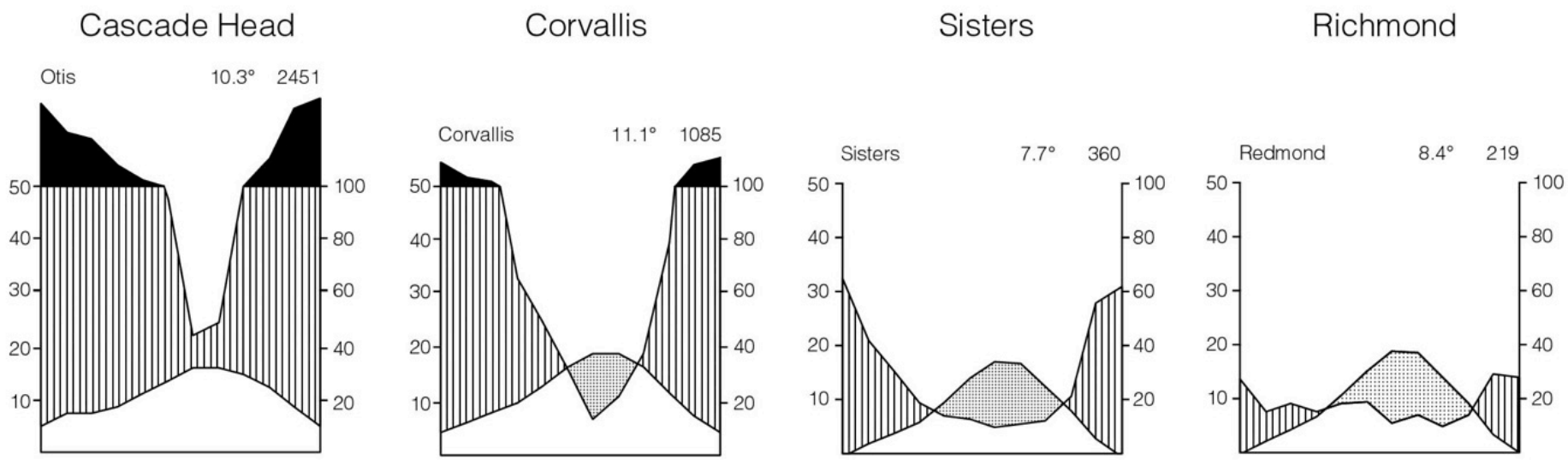
A detailed description of a complete climate diagram according to Walter



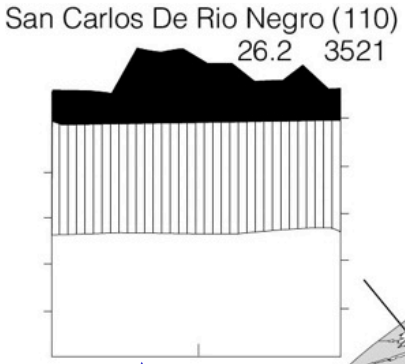
A - Station name
B - Altitude (meters)
C - Mean annual temperature (°C)
D - Mean annual precipitation (mm)
E - Absolute maximum temperature (°C)
F - Mean daily maximum of the hottest month (°C)
G - Monthly mean precipitation (mm)
H - Monthly mean temperature (°C)
I - Humid period (vertical lines)
J - Dry period (dots)
K - Mean daily minimum temperature of the coldest month (°C)
L - Absolute minimum temperature (°C)
M - Months with an absolute minimum below 0°C

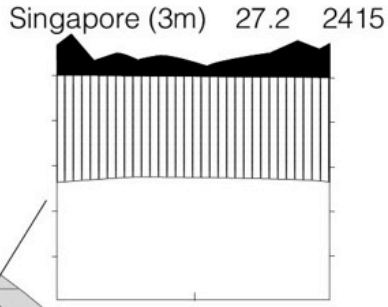
Climate diagrams and plant distribution in Oregon



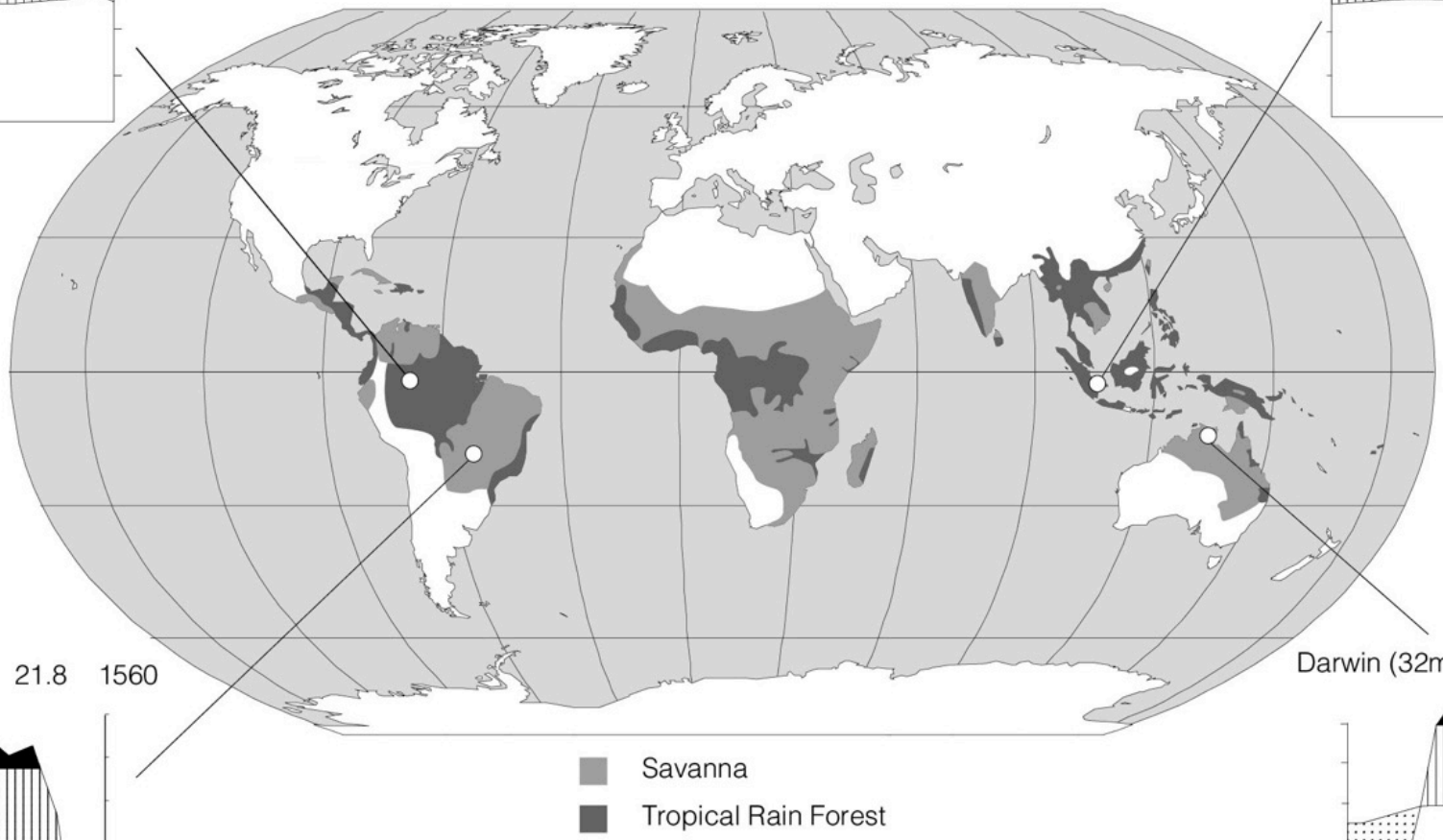


Compare contrasting equatorial climates

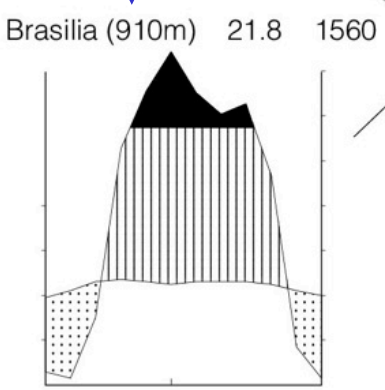


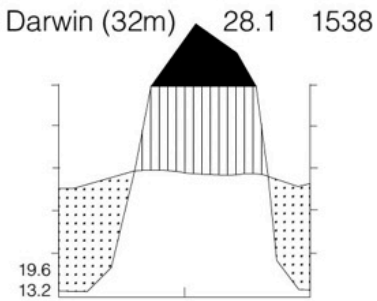


year-round rainfall (aseasonal)

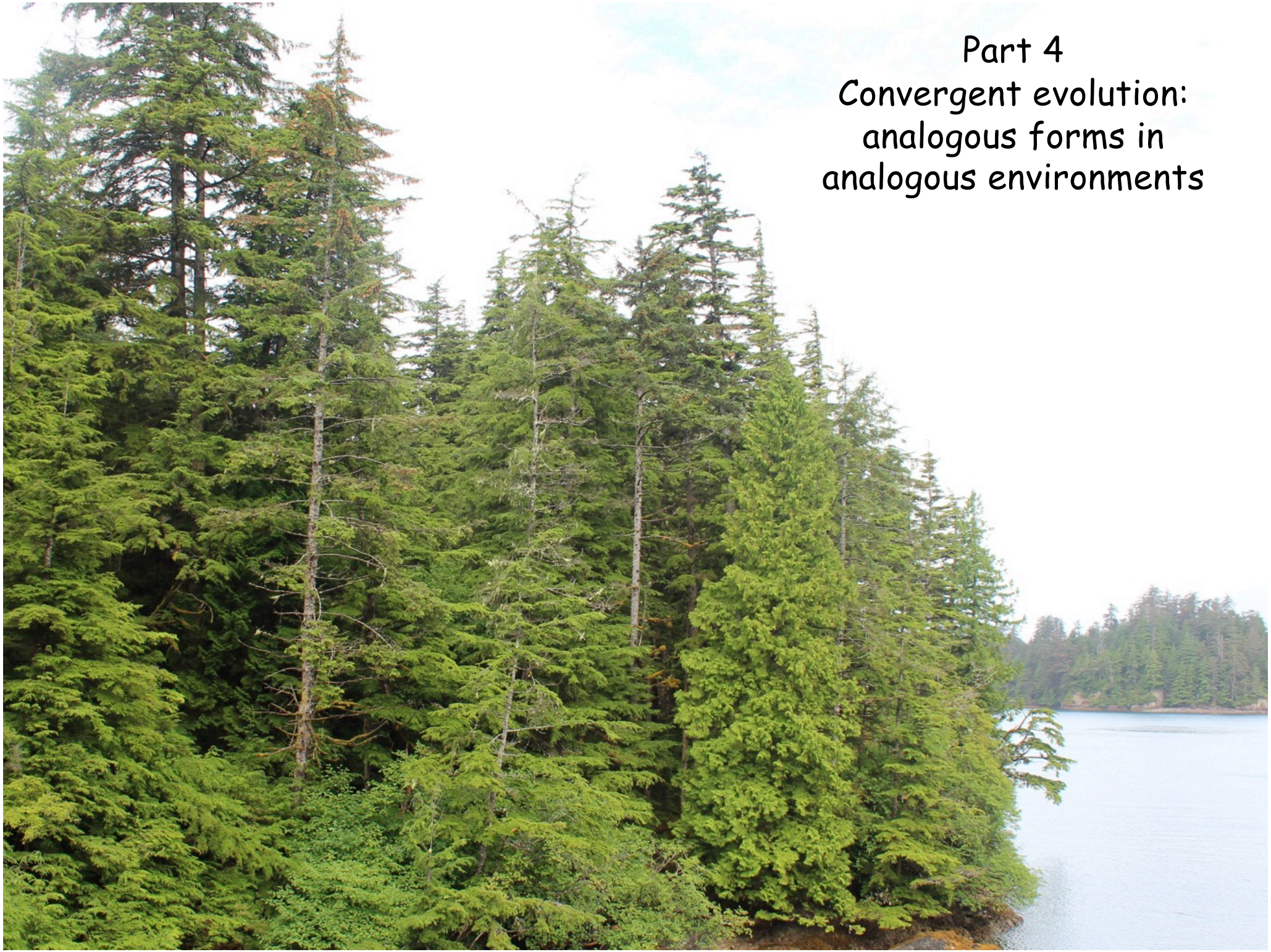


seasonal monsoon





Climates can be very similar on different continents (aseasonal versus monsoonal climates)



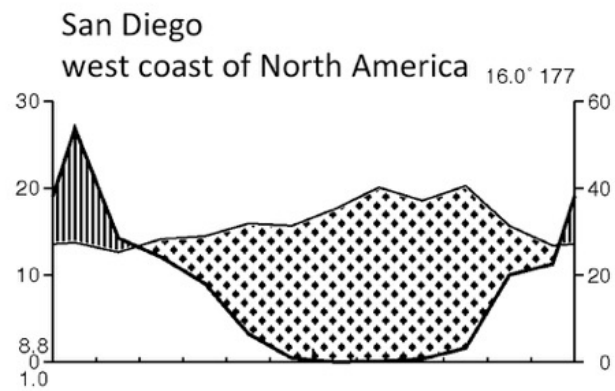
Part 4
Convergent evolution: analogous forms in analogous environments

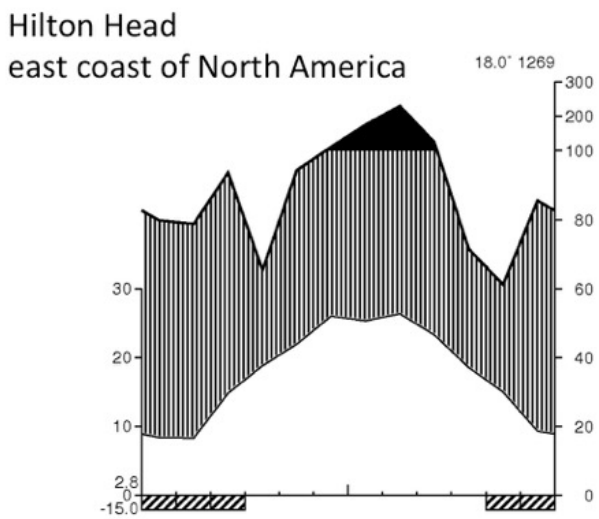
Convergent evolution is the concept that similar climates should select for similar plant life forms, irrespective of phylogenetic history

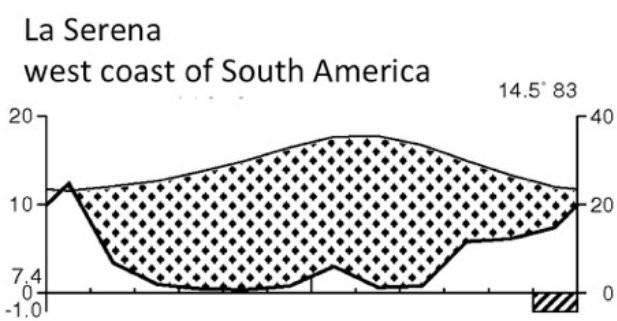
Here we have two pairs of locations with similar climates.

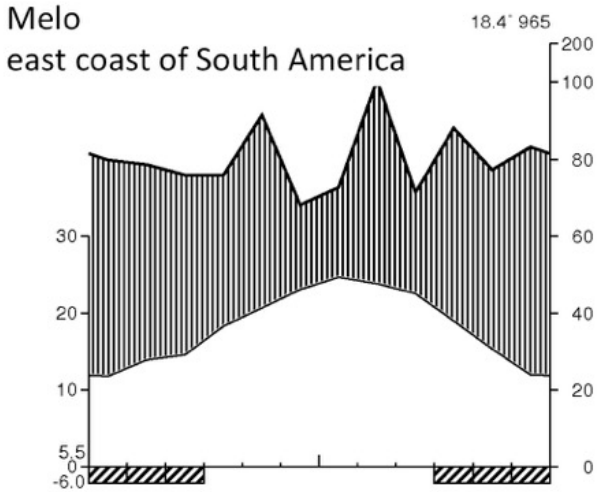
Each location is at about the same latitude, but climates are different depending on west vs east coasts.

In convergent evolution is occurring, we would expect the vegetation in San Diego to be more similar to that in La Serena, even though they are on different continents.



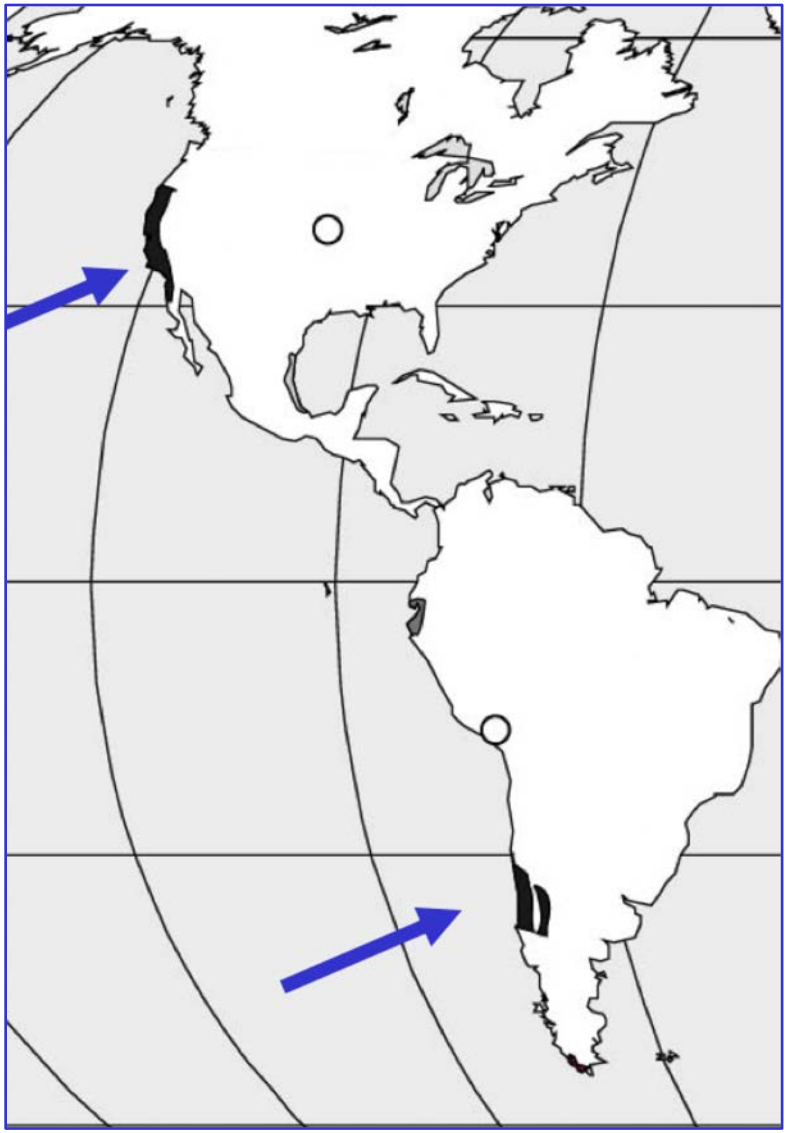






Perhaps the best known examples are Mediterranean climates, where not only there is convergence in vegetation, but we find that there are similar foods grown in these climates, such as olives and grapes (wine).

Consider coastal California and Chile; both are Mediterranean climates



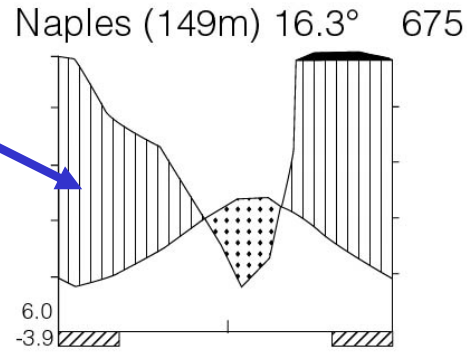
Let's explore examples that show that natural selection favors evolution of analogous structures in similar environments

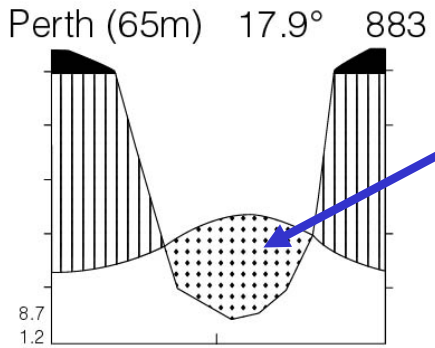
Mediterranean vegetation

Mediterranean-climate vegetation is dominated by dense, perennial shrubs of 2-4 m stature; these plants have adapted to fires, which are common in this climate

Mediterranean climates are located on the western sides of all continents

winter wet





summer dry

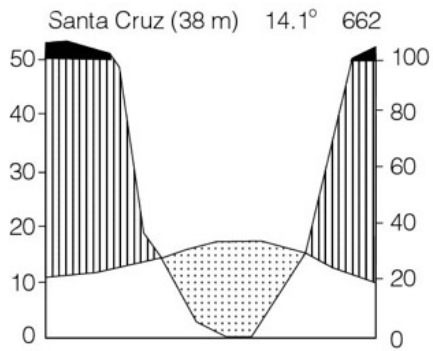
‘chaparral’ in southern California’

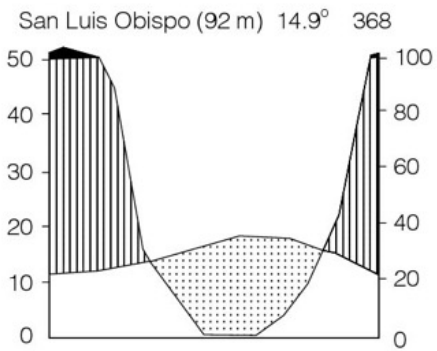
http://room42.wikispaces.com/file/view/555_PS-Chamise-RS-chaparral.jpg/34450629/585x416/555_PS-Chamise-RS-chaparral.jpg
http://www.calacademy.org/exhibits/california_hotspot/images/chaparral_mountains.jpg
http://www.roebuckclasses.com/105/images/physical/biome/chaparral.jpg

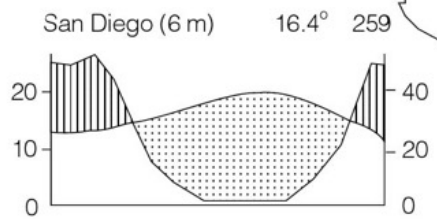
‘chaparral’ in Greece, where it is known as ‘maquis’

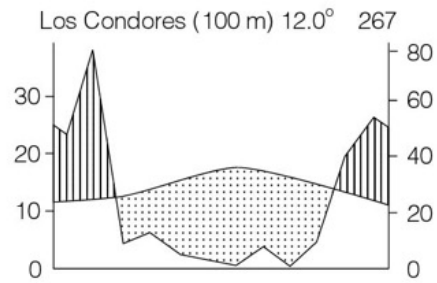

‘chaparral’ in Chile, where it is known as ‘matorral’

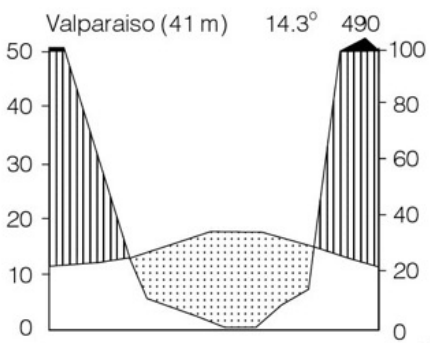
Gradients in Mediterranean climates

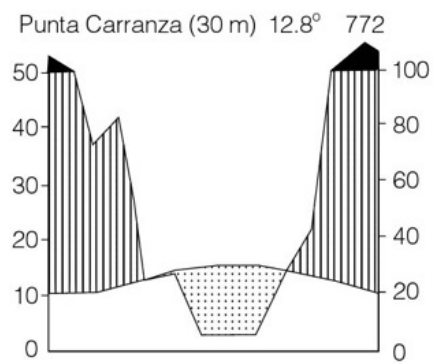










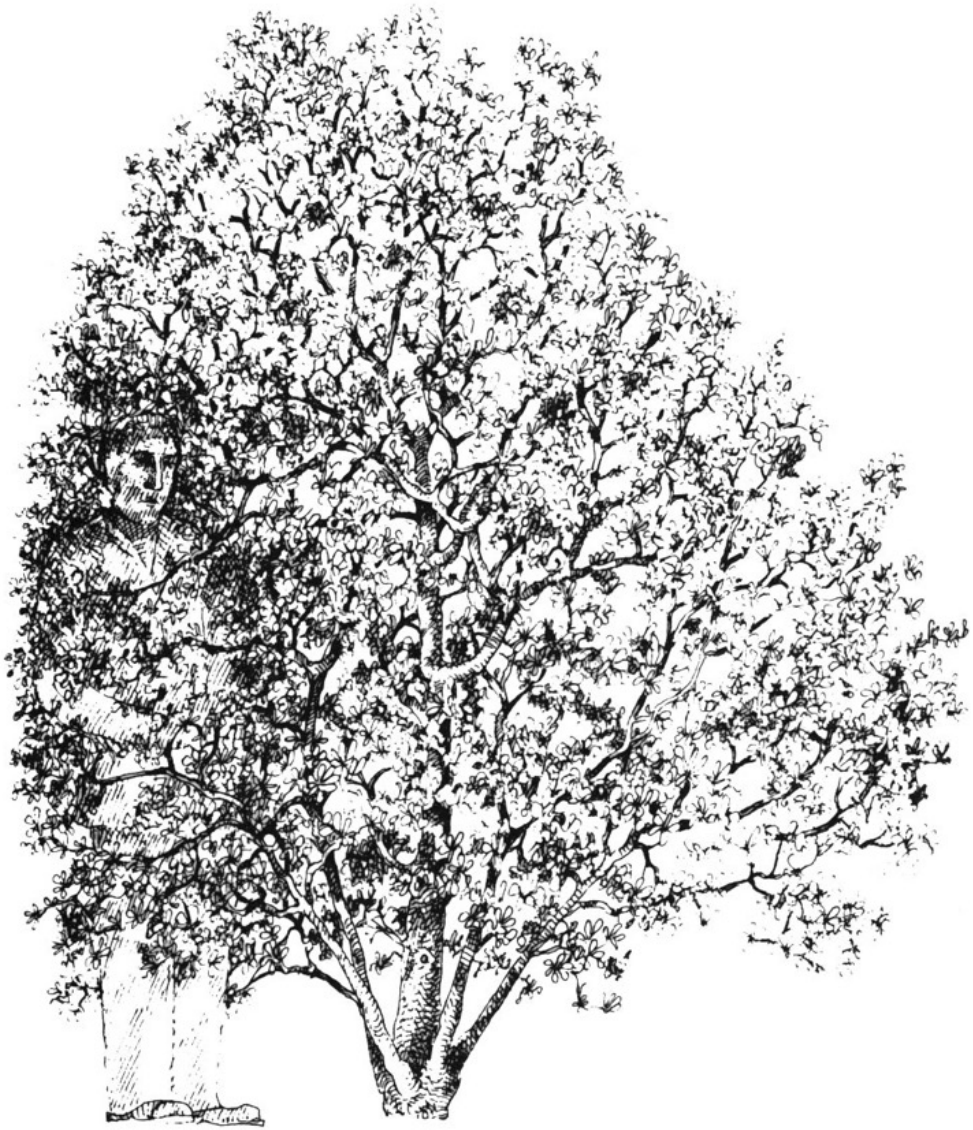


Note similarity in climates between Chile and California

We also note convergence in vegetation, with unrelated plant species looking like each other in form and phenology

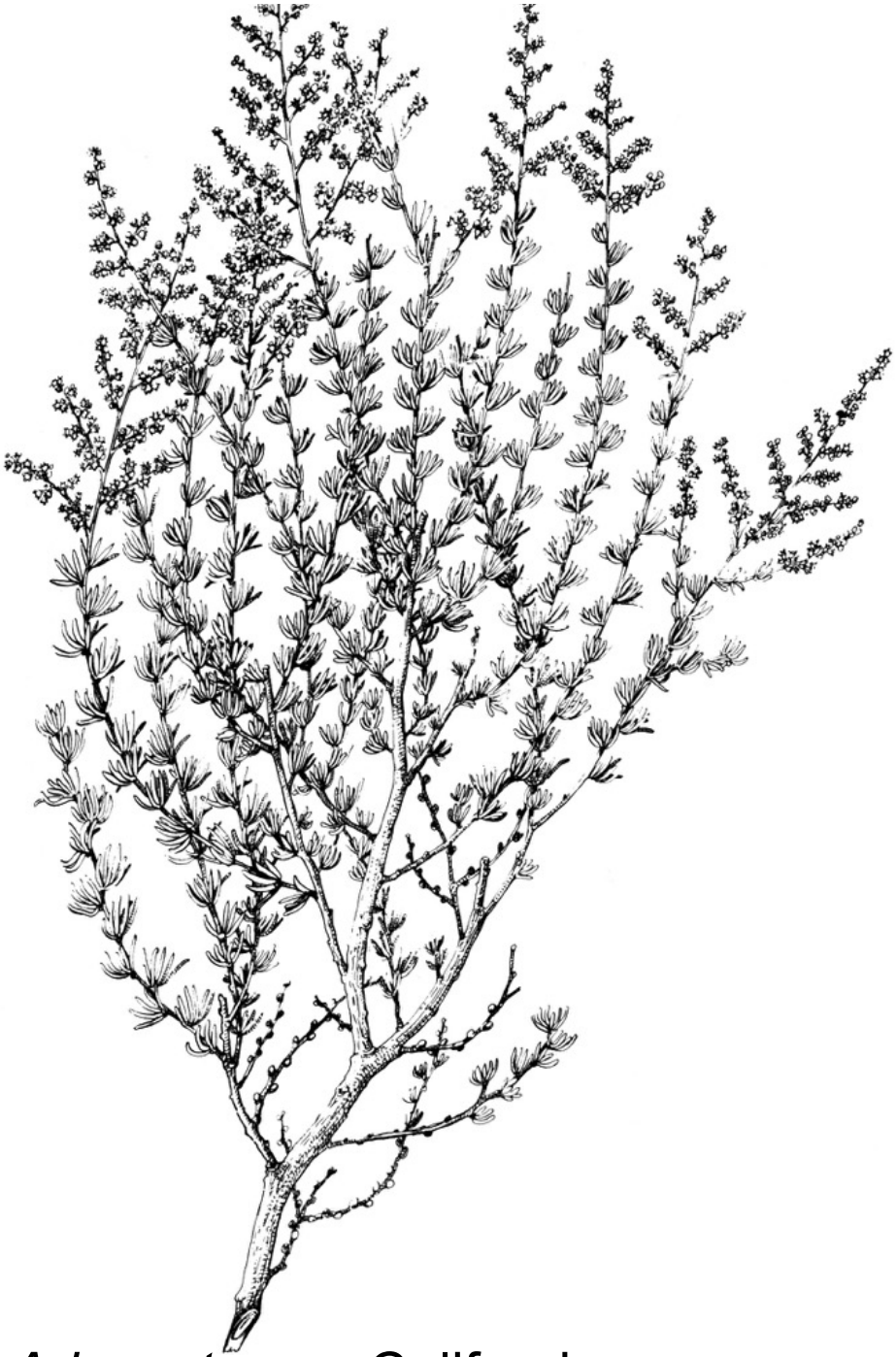
Quercus - California

Quillaja - Chile

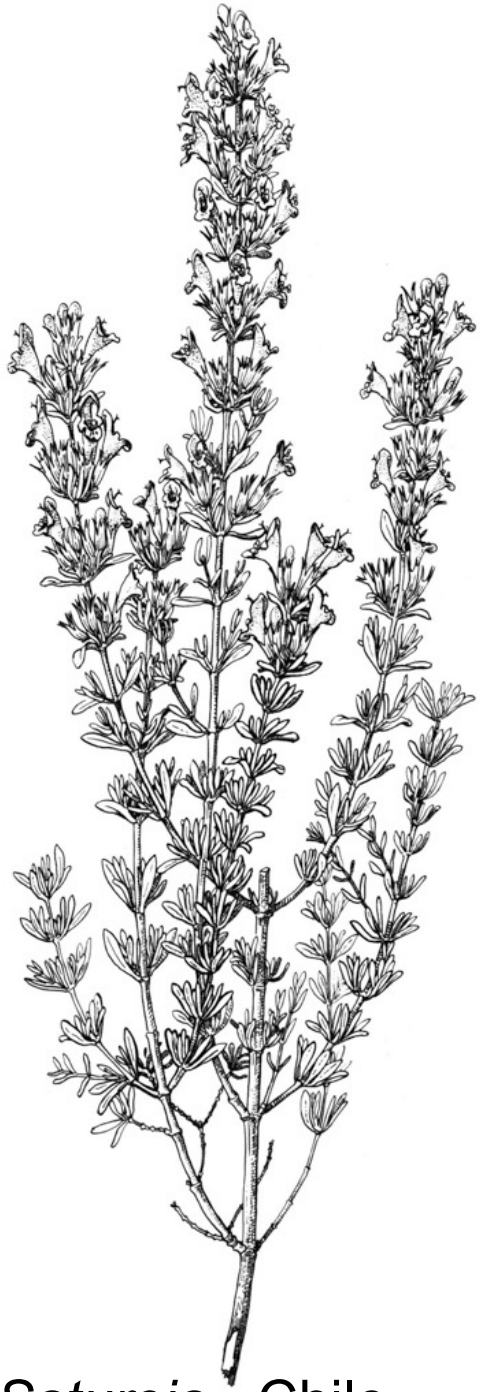


Quercus - California

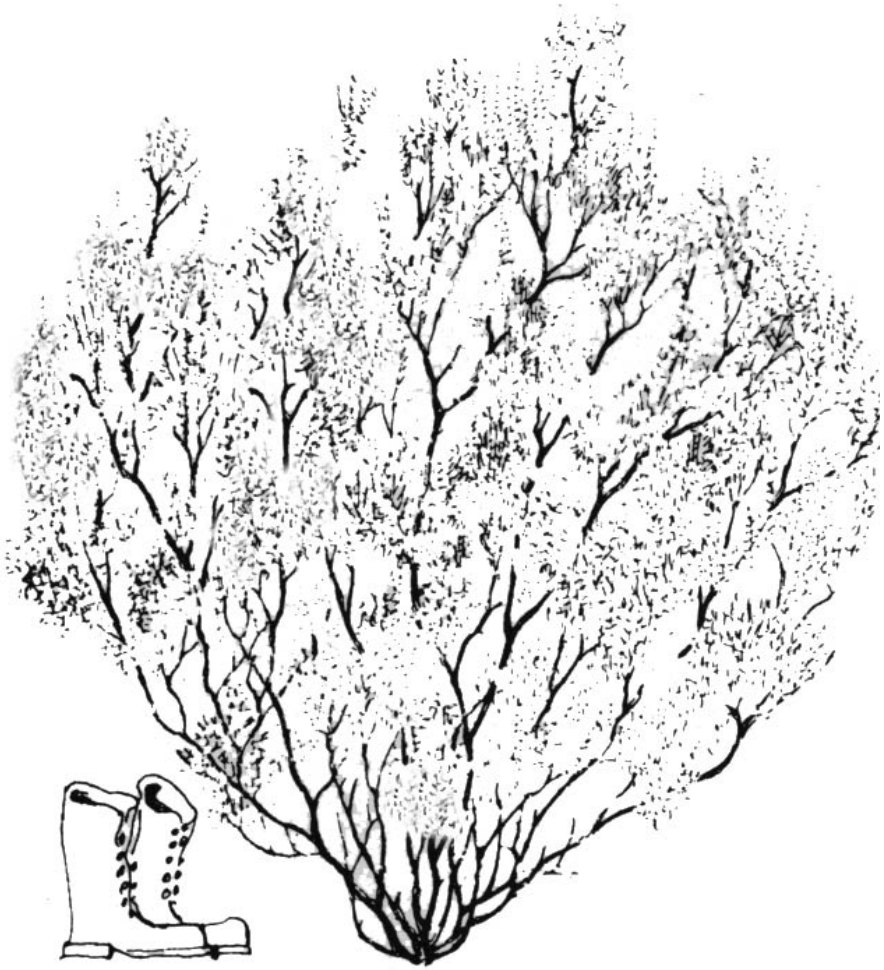
Quillaja - Chile



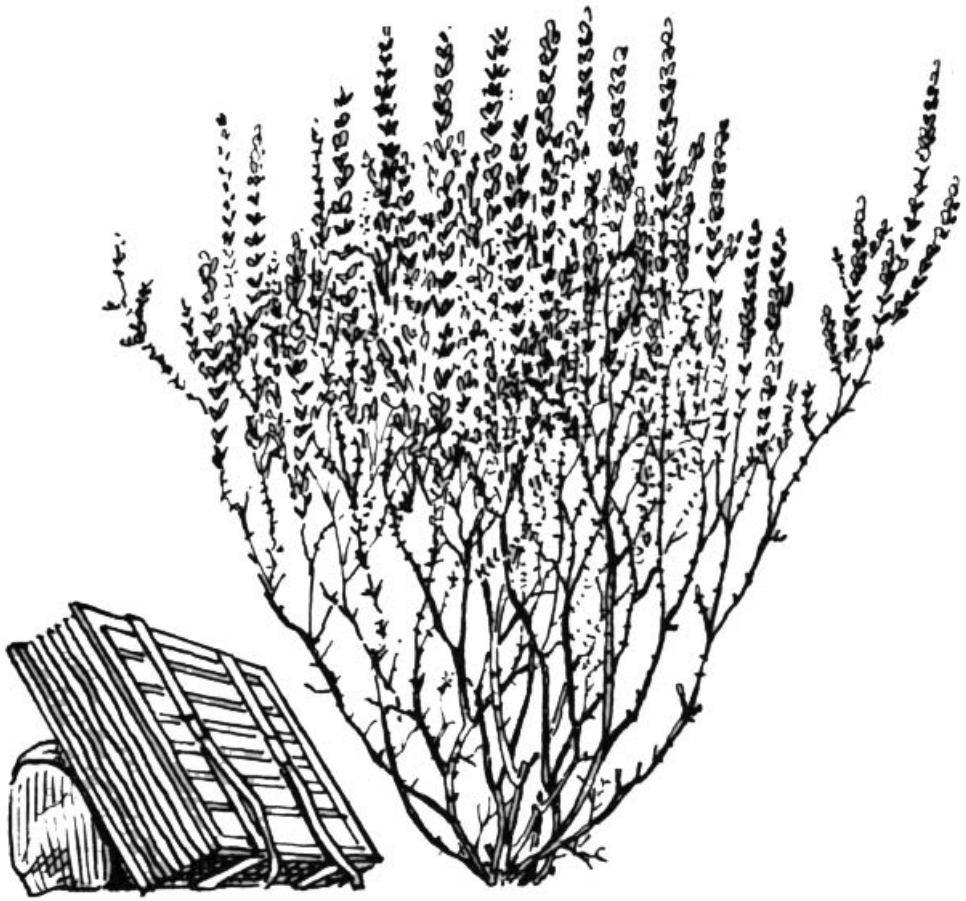
Adenostoma - California



Satureja - Chile



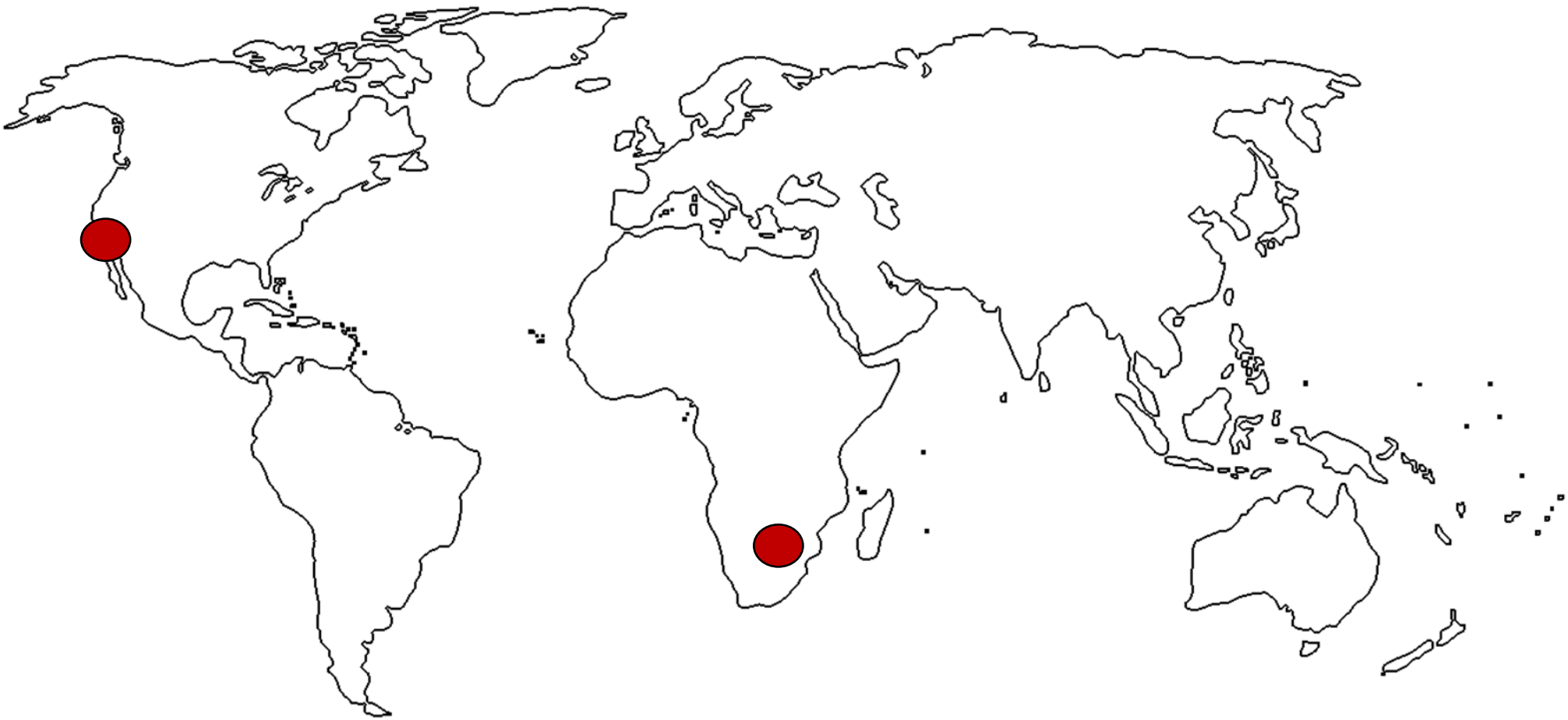
Adenostoma - California



Satureja - Chile

Convergent evolution – an arid lands example

Analogous physiognomy and leaves in analogous environments




Fouquieria splendens
(SW USA)

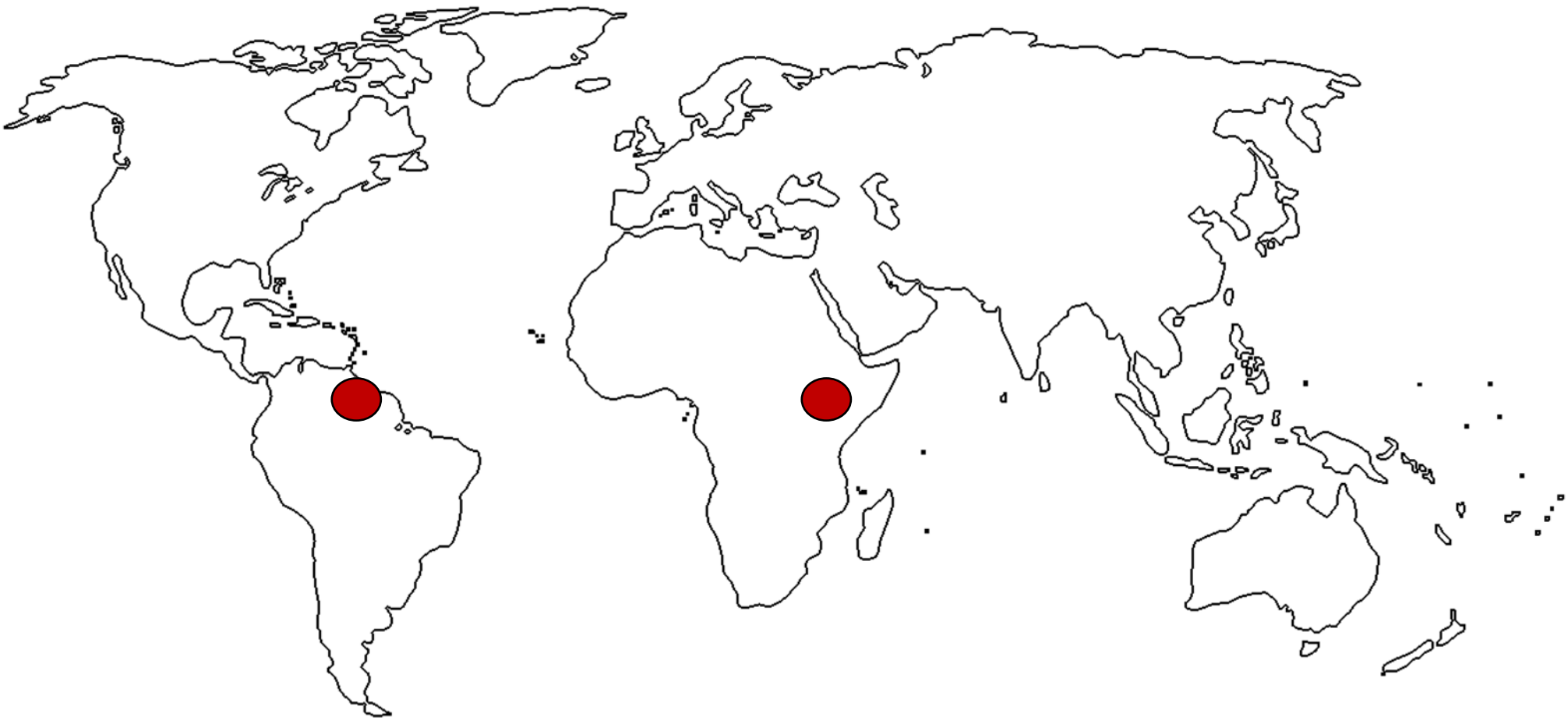

Alluaudia procera
(Madascar)


Fouquieria splendens
(SW USA)


Alluaudia procera
(Madascar)

Convergent evolution in tropical alpine ecosystems

Analogous physiognomy and leaves in analogous environments




Senecio keniodendron
(5,000 m, Kenya)
www.mergili.at/worldimages

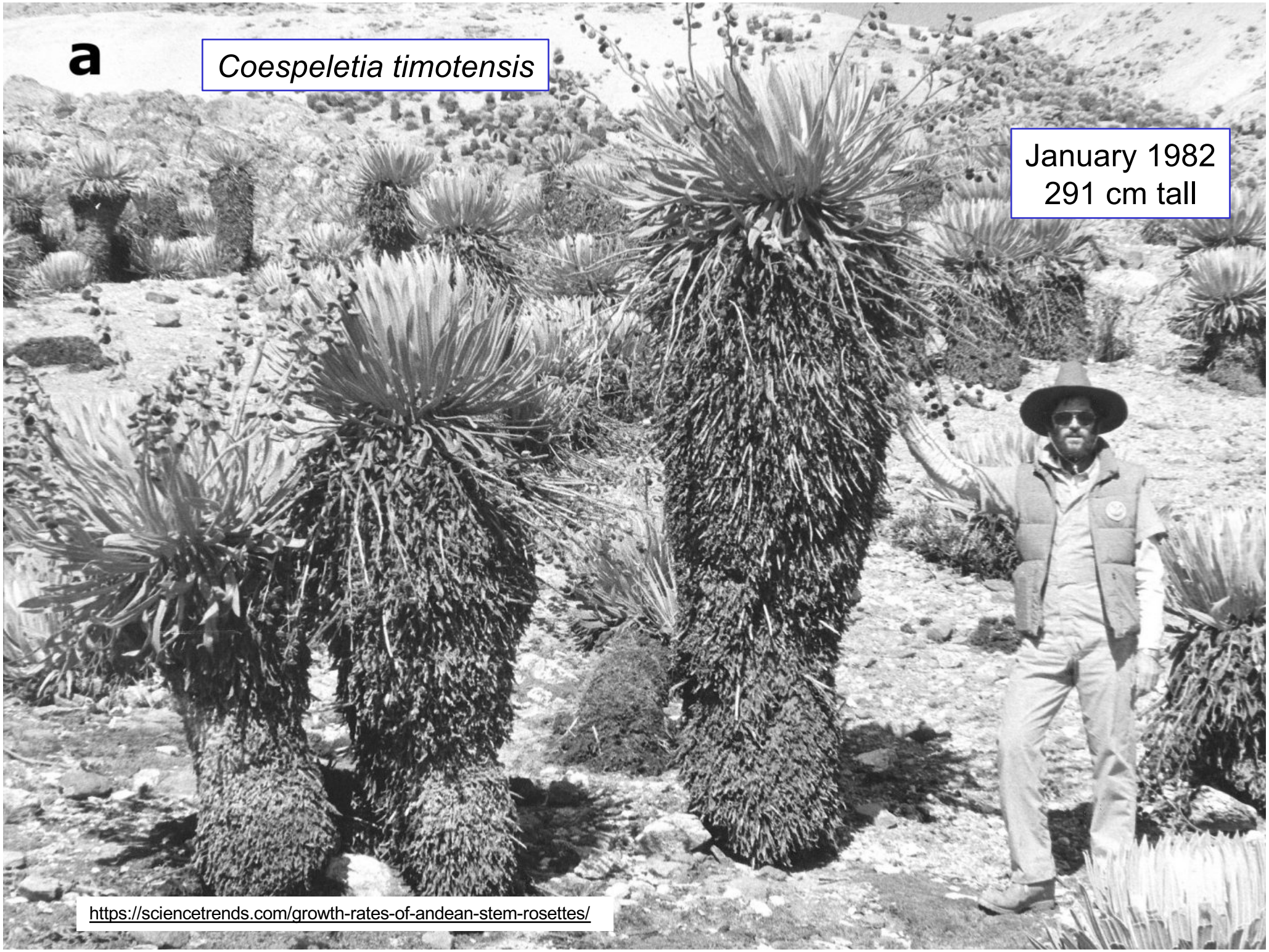

Espeletia hartwegiana
(Páramos del Ángel, Ecuador)
https://www.mergili.at/worldimages

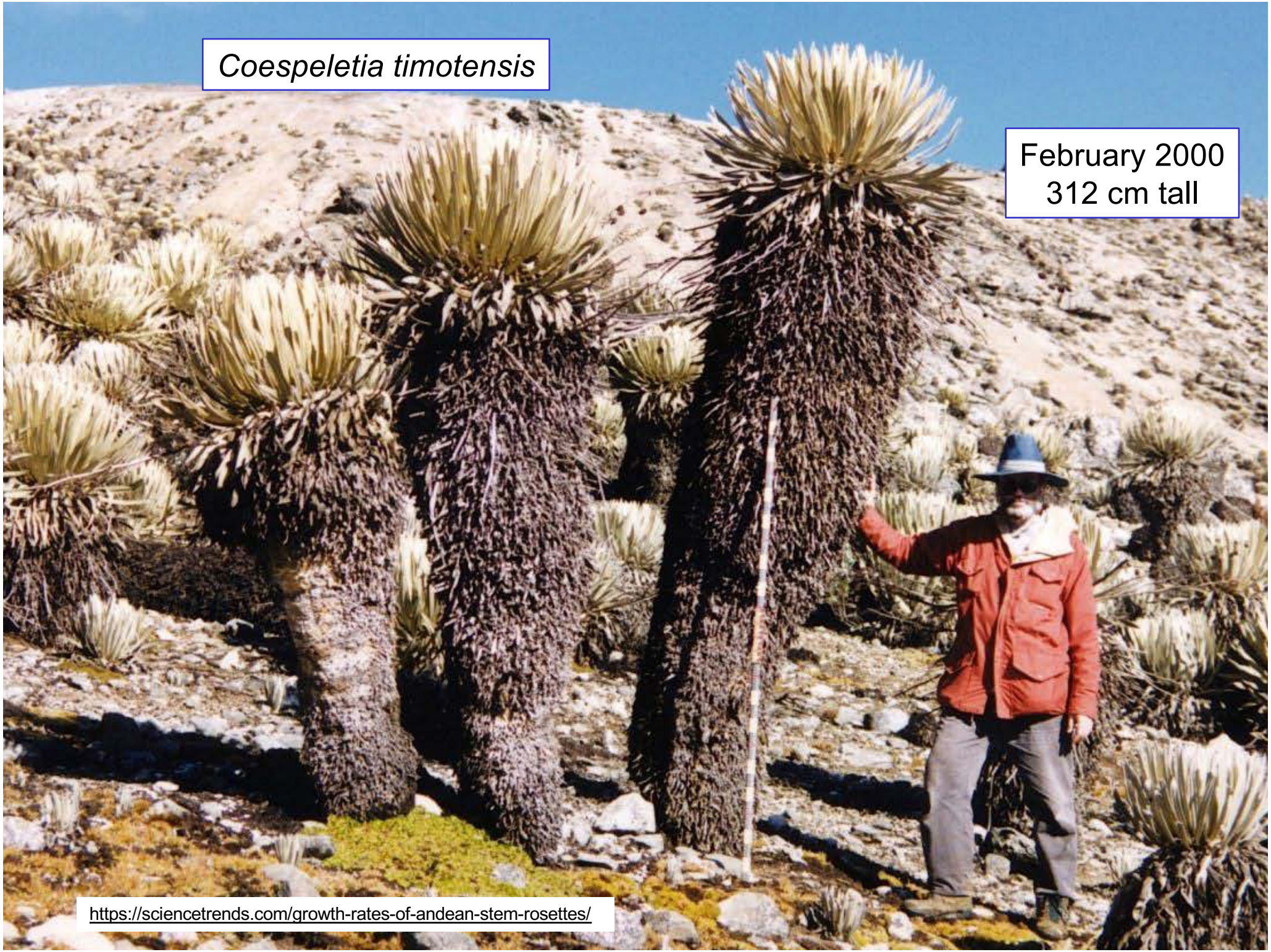

Espeletia hartwegiana
flickr.com/photos/amalavidaty


Senecio keniodendron
flickr.com/photos/davidbygott

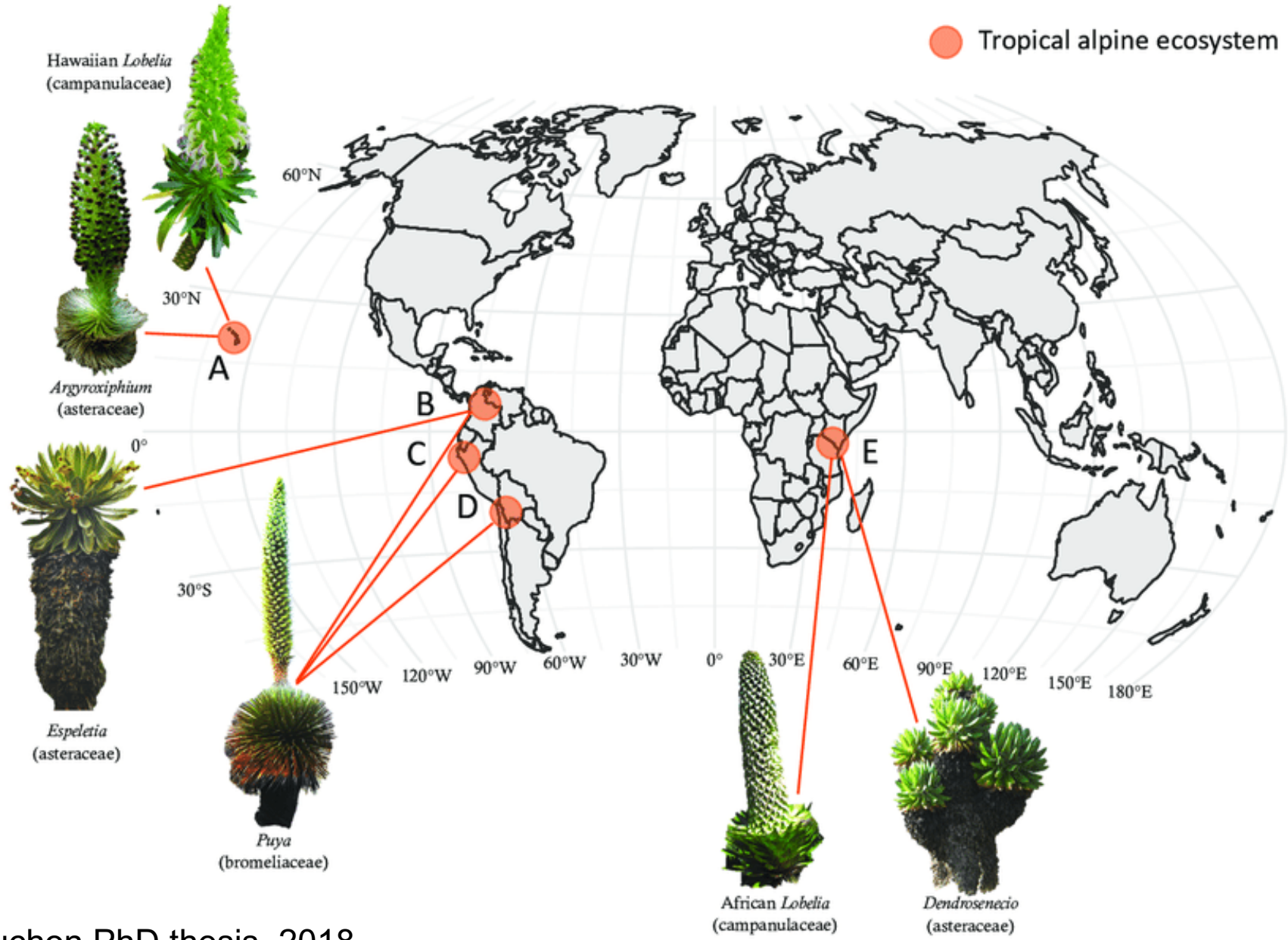

Espeletia hartwegiana


Senecio keniodendron
iob.uu.se/research/systematic-biology/hedberg


a
Coespeletia timotensis
January 1982
291 cm tall
https://sciencetrends.com/growth-rates-of-andean-stem-rosettes/


Coespeletia timotensis
February 2000
312 cm tall
https://sciencetrends.com/growth-rates-of-andean-stem-rosettes/

Convergent evolution in tropical alpine ecosystems



C. Pouchon PhD thesis, 2018


Azorella compacta
(6,300 m, Chile)
www.mergili.at/worldimages