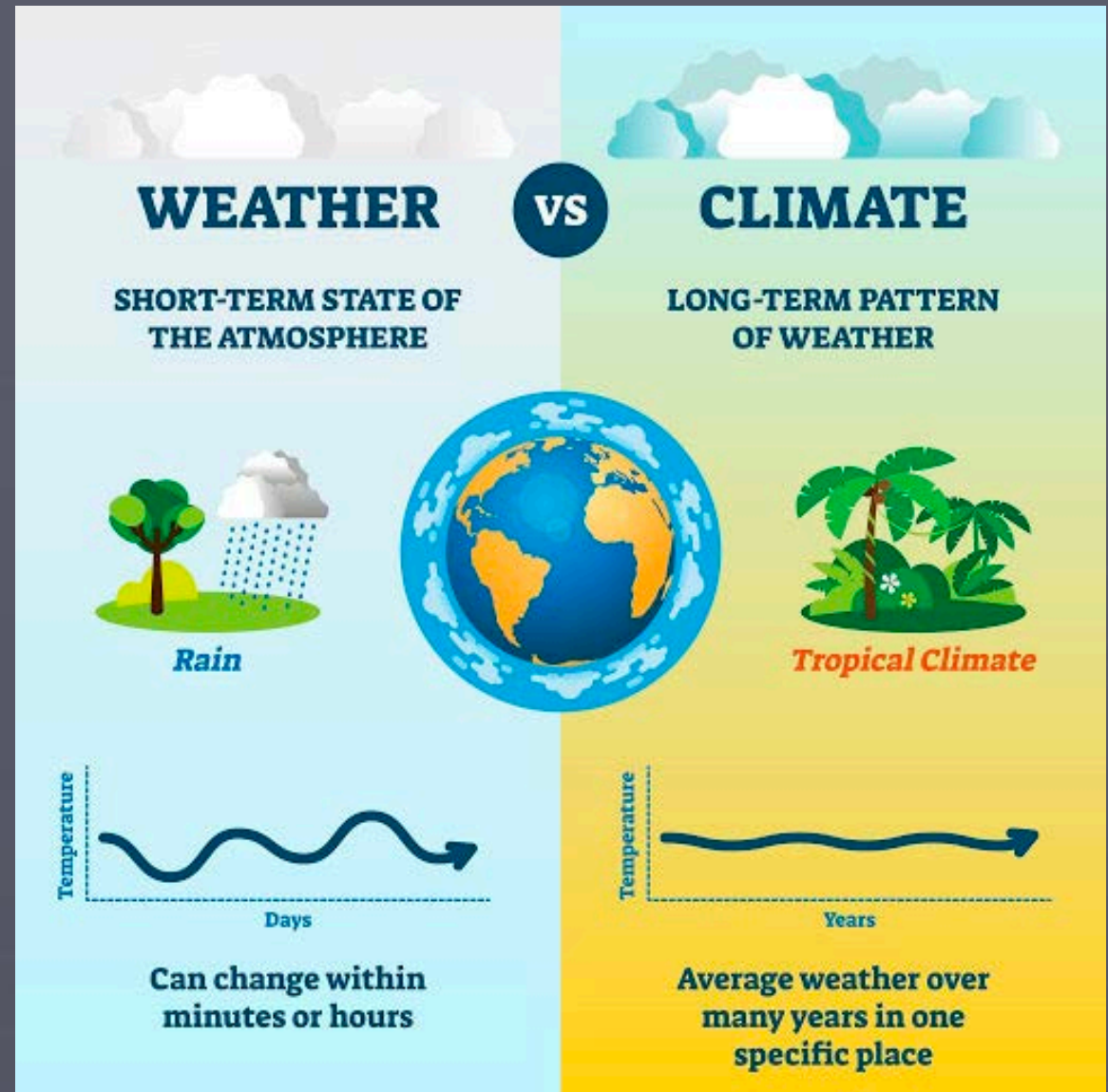


# Classifying Climate

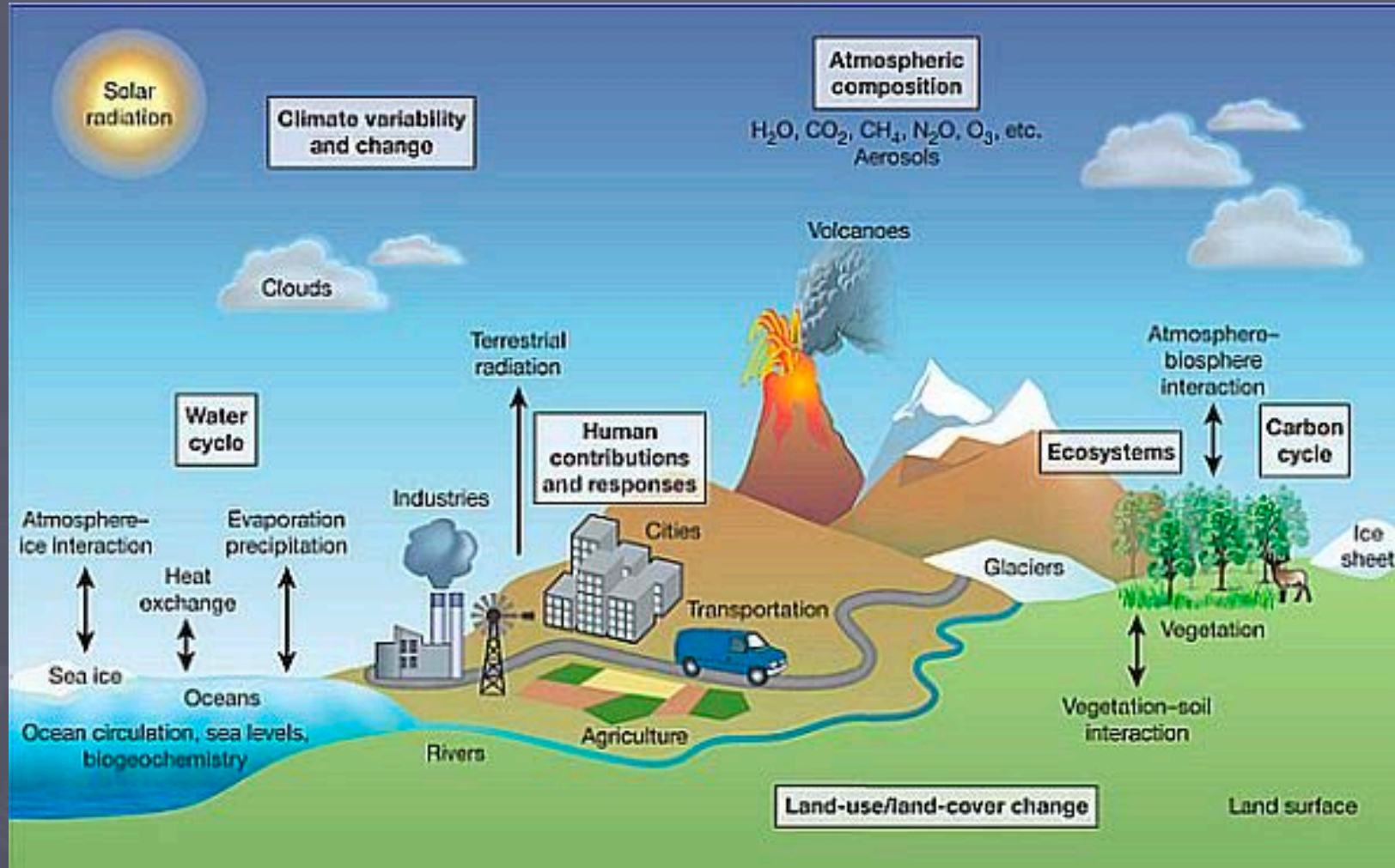
Chapter 9: Earth's Climactic Regions

# Climate Defined

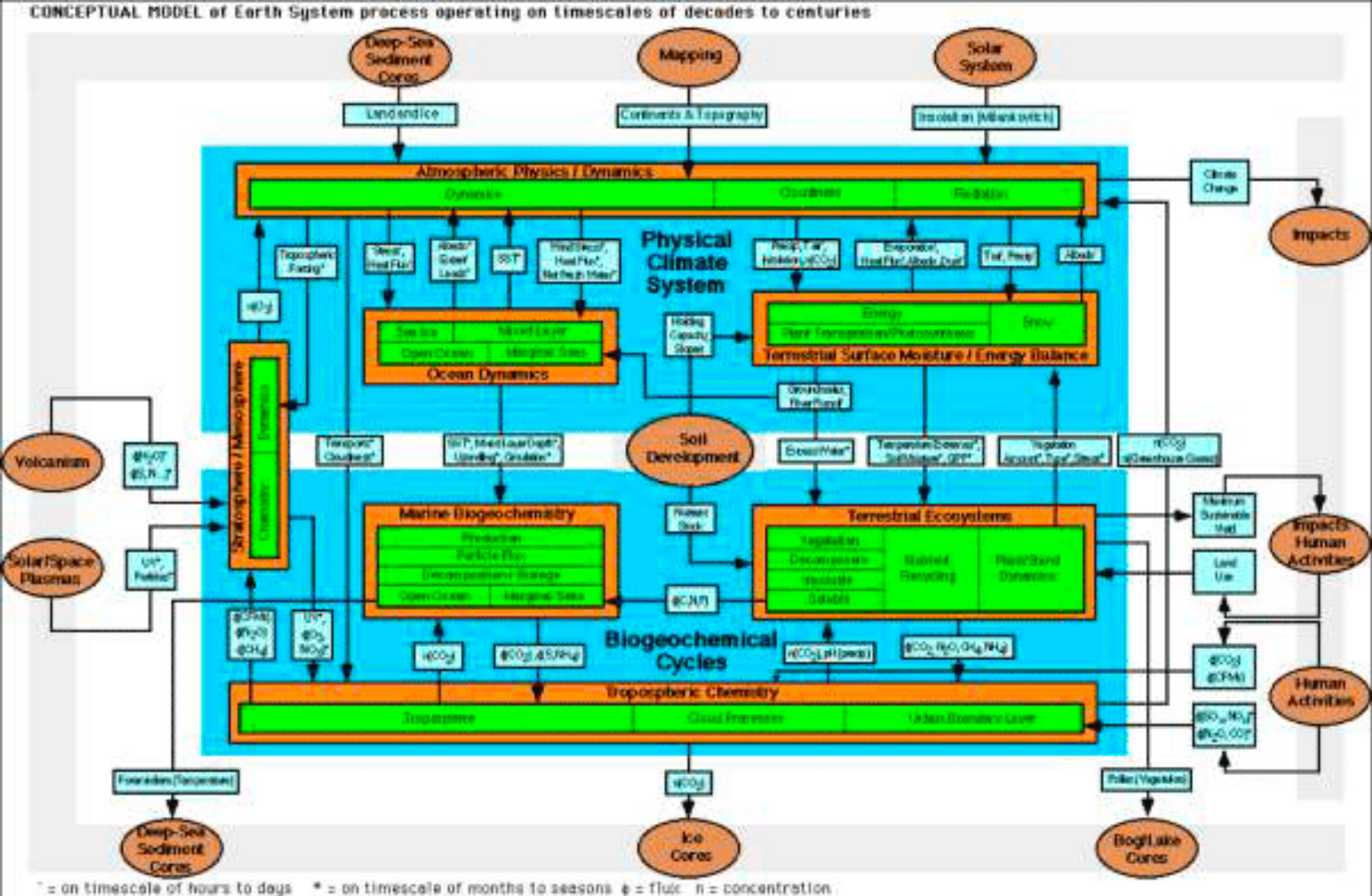
- Climate: Long-term trends in atmospheric changes
  - Mostly marked by changes in precipitation and temperature
- Season: Repeating patterns of changes in precipitation and temperature



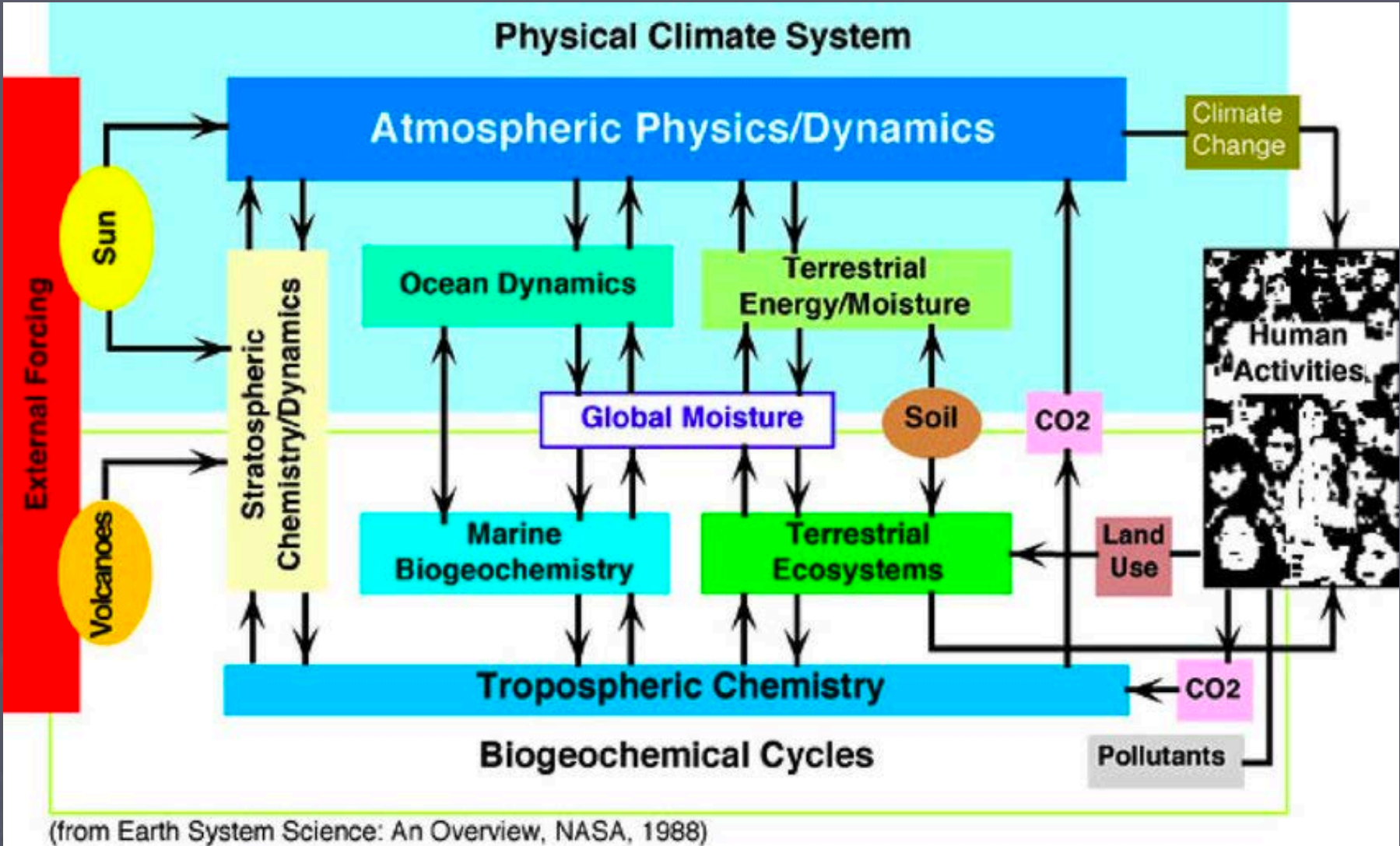
# Natural and Anthropogenic Influences on Climate



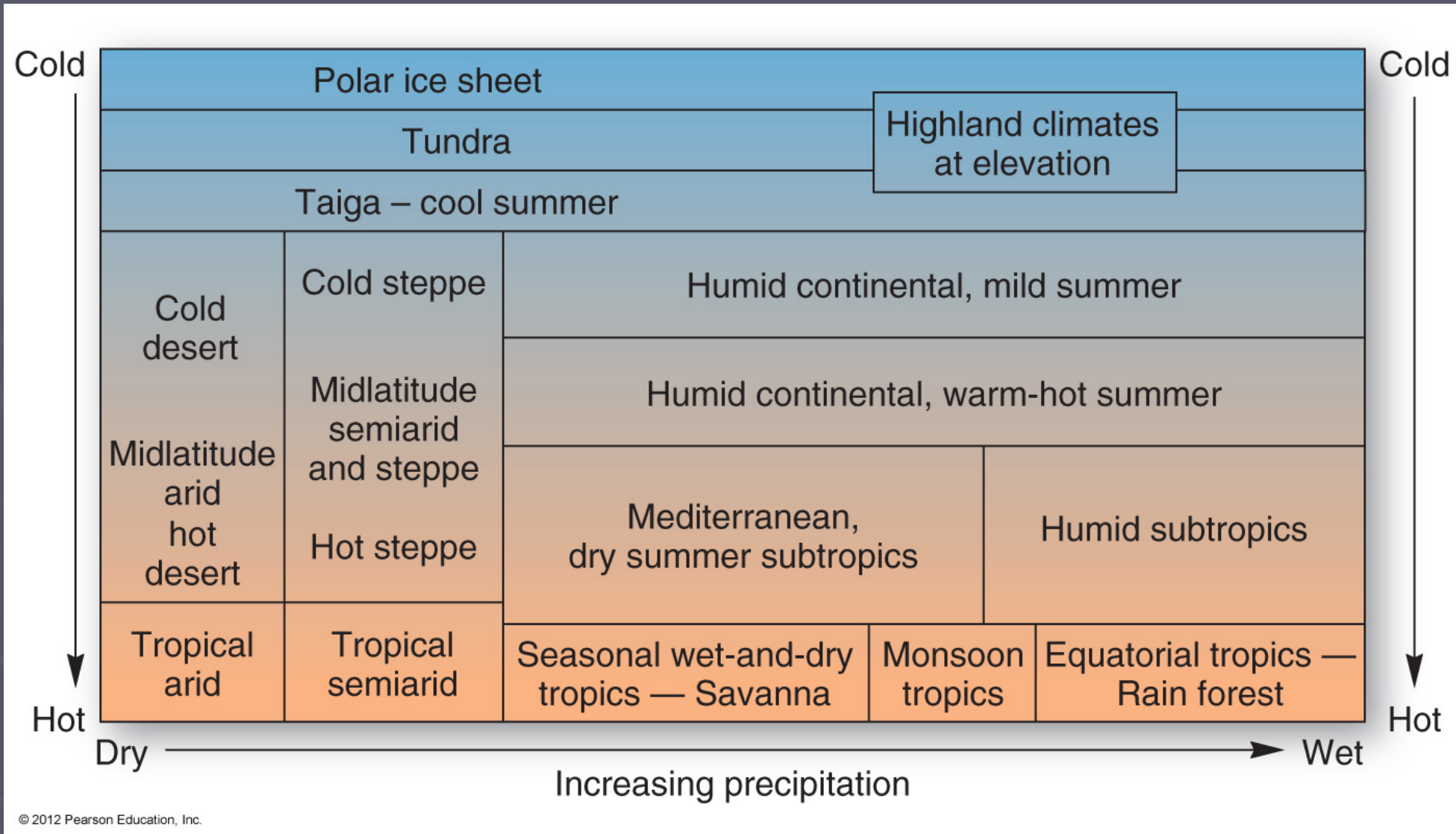
# Bretherton Climate Systems Model



# Bretherton Climate Systems Model (Simplified)

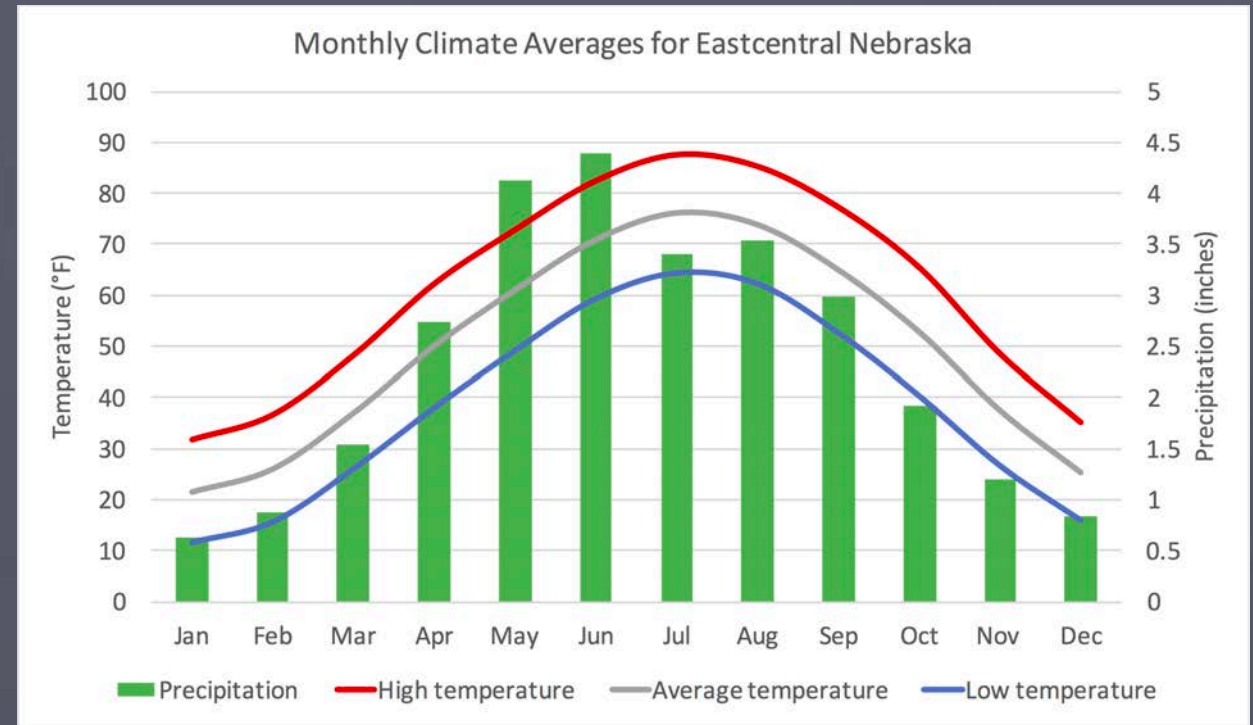


# Climate Relationships



# Climographs

- Climograph: graphic representation of monthly temperature and precipitation for a given area
  - Displays average precipitation and temperature by month
  - Used to classify the climate of that place
    - Can be used to easily compare climates of different locations



# Köppen-Geiger Climate Classification

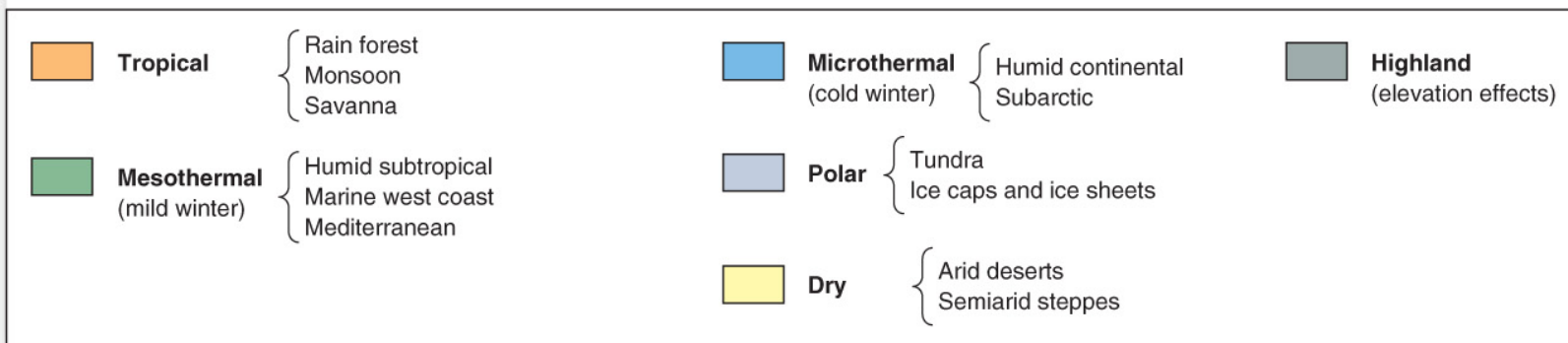
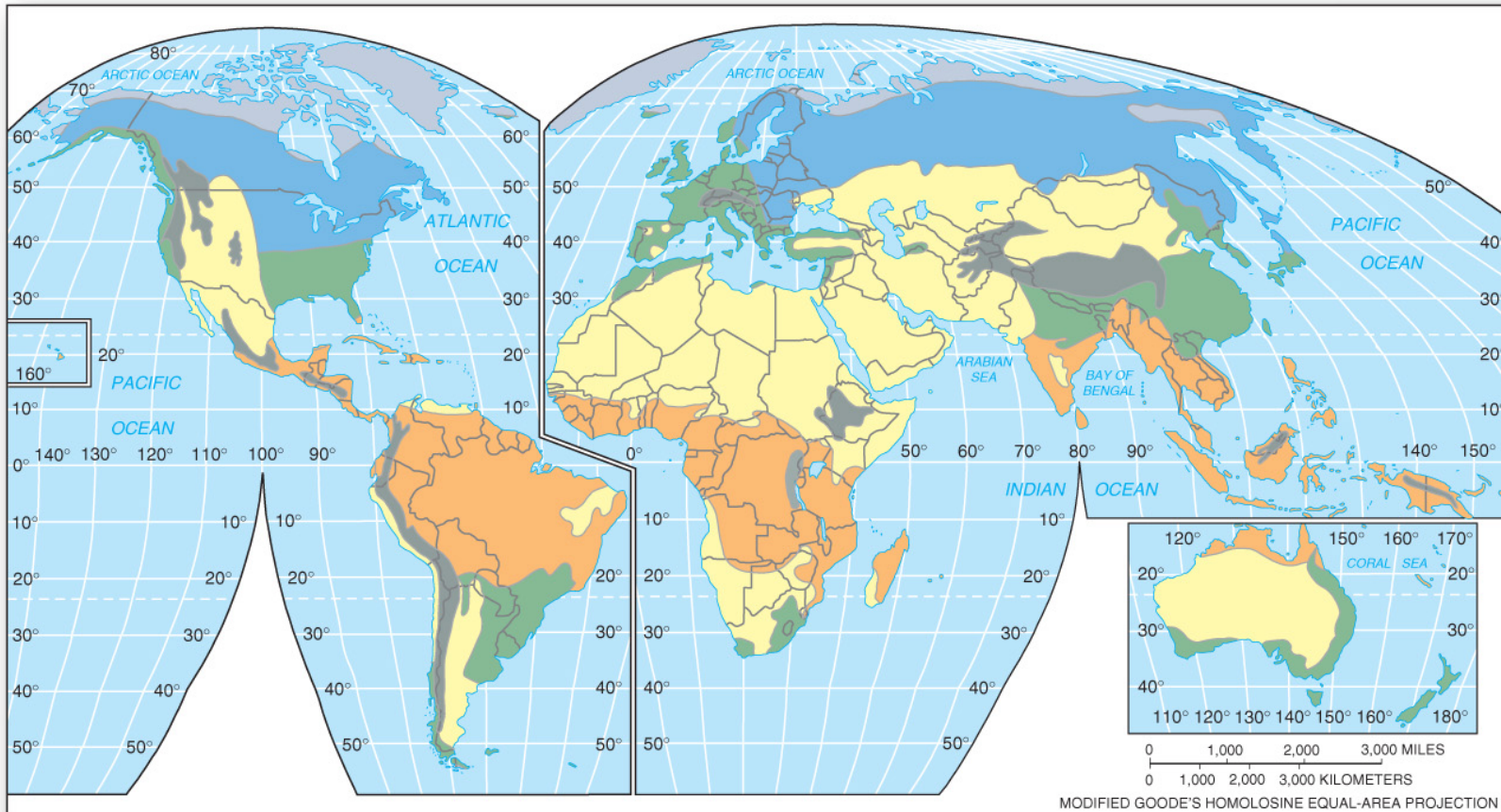
- Developed by Wladimir Köppen in 1884
  - Later amendments by Rudolf Geiger
- Divided climates based on precipitation, weather, and vegetation
  - A – Tropical/Megathermal Climates
  - B – Dry (Desert and semi-Arid) Climates
  - C – Temperate/Mesothermal Climates
  - D – Continental/Microthermal Climates
  - E – Polar Climates
  - H – Highland Climates



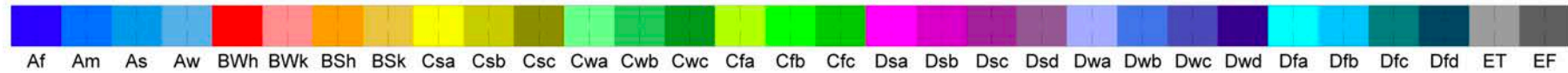
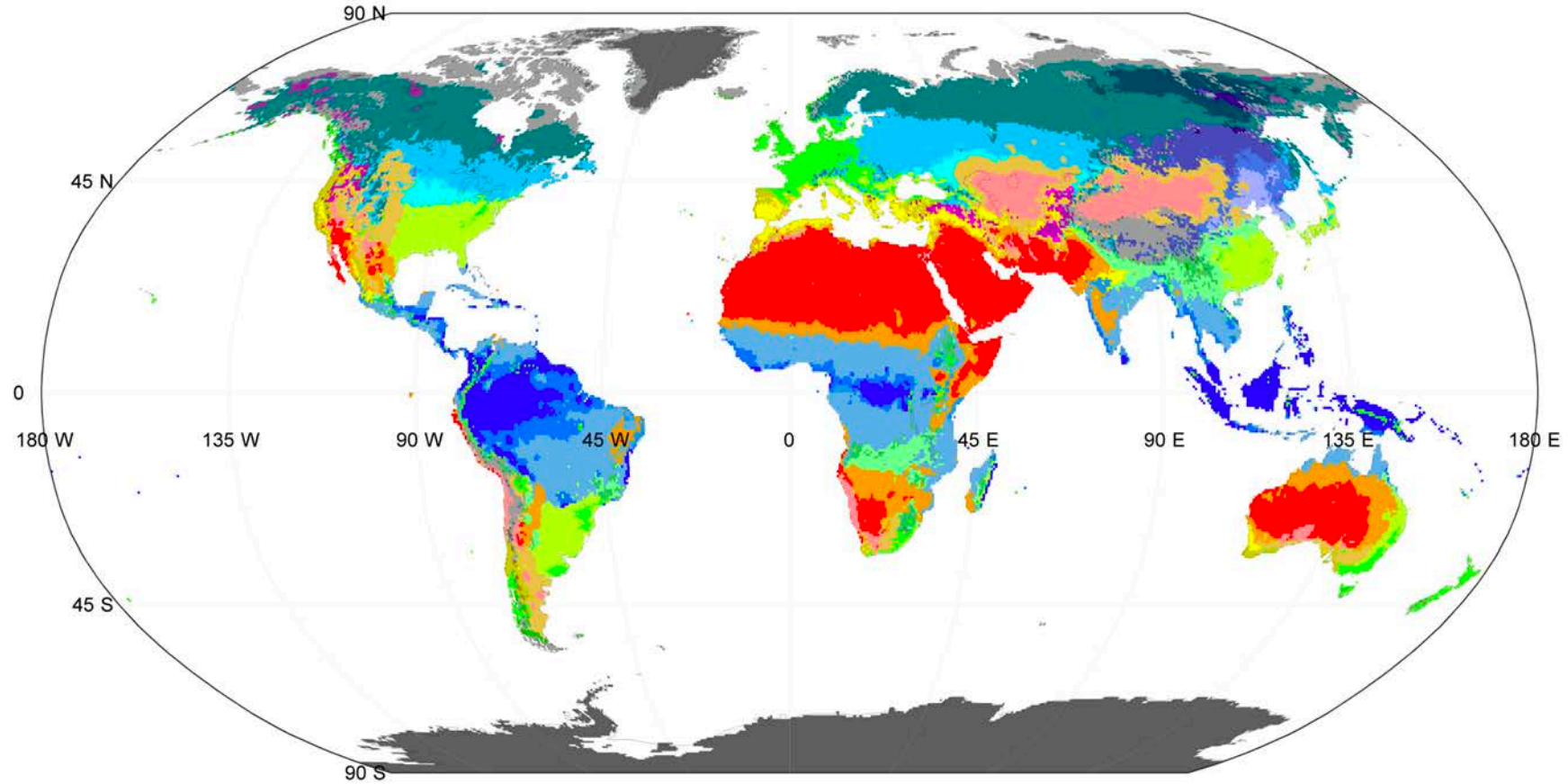
# Köppen Lettering System

Type	Description	Criterion
<b>A</b>	<b>Equatorial climates</b>	$T_{\min} \geq +18 \text{ }^\circ\text{C}$
Af	Equatorial rainforest, fully humid	$P_{\min} \geq 60 \text{ mm}$
Am	Equatorial monsoon	$P_{\text{ann}} \geq 25(100 - P_{\min})$
As	Equatorial savannah with dry summer	$P_{\min} < 60 \text{ mm}$ in summer
Aw	Equatorial savannah with dry winter	$P_{\min} < 60 \text{ mm}$ in winter
<b>B</b>	<b>Arid climates</b>	$P_{\text{ann}} < 10 P_{\text{th}}$
BS	Steppe climate	$P_{\text{ann}} > 5 P_{\text{th}}$
BW	Desert climate	$P_{\text{ann}} \leq 5 P_{\text{th}}$
<b>C</b>	<b>Warm temperate climates</b>	$-3 \text{ }^\circ\text{C} < T_{\min} < +18 \text{ }^\circ\text{C}$
Cs	Warm temperate climate with dry summer	$P_{\text{smin}} < P_{\text{wmin}}$ , $P_{\text{wmax}} > 3 P_{\text{smin}}$ and $P_{\text{smin}} < 40 \text{ mm}$
Cw	Warm temperate climate with dry winter	$P_{\text{wmin}} < P_{\text{smin}}$ and $P_{\text{smax}} > 10 P_{\text{wmin}}$
Cf	Warm temperate climate, fully humid	Neither Cs nor Cw
<b>D</b>	<b>Snow climates</b>	$T_{\min} \leq -3 \text{ }^\circ\text{C}$
Ds	Snow climate with dry summer	$P_{\text{smin}} < P_{\text{wmin}}$ , $P_{\text{wmax}} > 3 P_{\text{smin}}$ and $P_{\text{smin}} < 40 \text{ mm}$
Dw	Snow climate with dry winter	$P_{\text{wmin}} < P_{\text{smin}}$ and $P_{\text{smax}} > 10 P_{\text{wmin}}$
Df	Snow climate, fully humid	Neither Ds nor Dw
<b>E</b>	<b>Polar climates</b>	$T_{\text{max}} < +10 \text{ }^\circ\text{C}$
ET	Tundra climate	$0 \text{ }^\circ\text{C} \leq T_{\text{max}} < +10 \text{ }^\circ\text{C}$
EF	Frost climate	$T_{\text{max}} < 0 \text{ }^\circ\text{C}$

Type	Description	Criteria
h	Hot steppe/desert	$T_{\text{ann}} \geq +18 \text{ }^\circ\text{C}$
k	Cold steppe/desert	$T_{\text{ann}} < +18 \text{ }^\circ\text{C}$
a	Hot summer	$T_{\text{max}} \geq +22 \text{ }^\circ\text{C}$
b	Warm summer	not (a) and at least 4 $T_{\text{mon}} \geq +10 \text{ }^\circ\text{C}$
c	Cool summer and cold winter	not (b) and $T_{\min} > -38 \text{ }^\circ\text{C}$
d	Extremely continental	like (c) but $T_{\min} \leq -38 \text{ }^\circ\text{C}$



# World map of Köppen climate classification for 1901–2010



## First letter

A: Tropical  
 B: Dry  
 C: Mild temperate  
 D: Snow  
 E: Polar

## Second letter

f: Fully humid  
 m: Monsoon  
 s: Dry summer  
 w: Dry winter  
 W: Desert  
 S: Steppe

## Third letter

T: Tundra  
 F: Frost  
 h: Hot arid  
 k: Cold arid  
 a: Hot summer  
 b: Warm summer  
 c: Cool summer  
 d: Cold summer

**Data source:** Terrestrial Air Temperature/Precipitation: 1900–2010 Gridded Monthly Time Series (V 3.01)

**Resolution:** 0.5 degree latitude/longitude

**Website:** <http://hanschen.org/koppen>

**Ref:** Chen, D. and H. W. Chen, 2013: Using the Köppen classification to quantify climate variation and change: An example for 1901–2010. Environmental Development, 6, 69–79, 10.1016/j.envdev.2013.03.007.

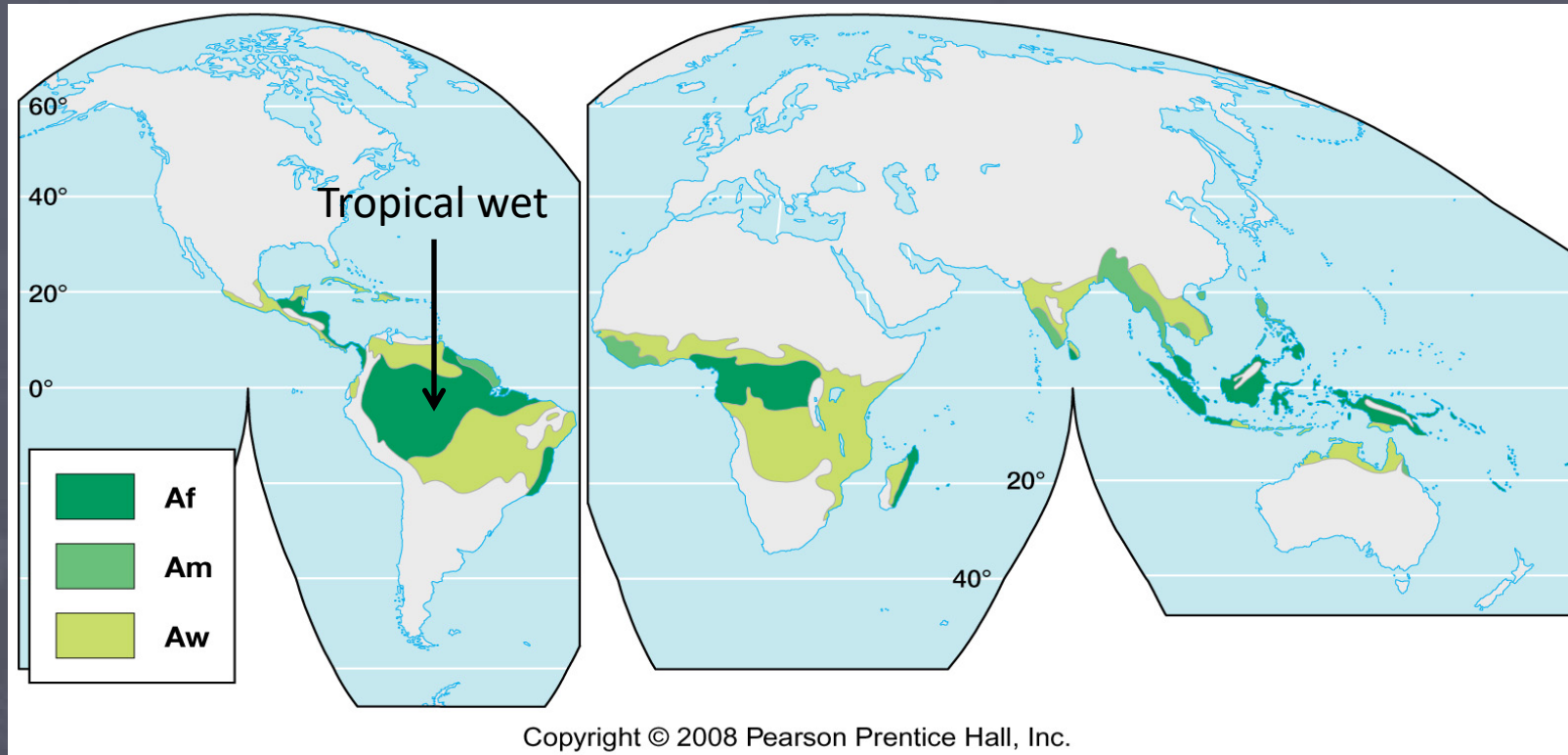
# Tropical Climates - A

- Tropical Rain Forest Climates
- Tropical Monsoon Climates
- Tropical Savanna Climates

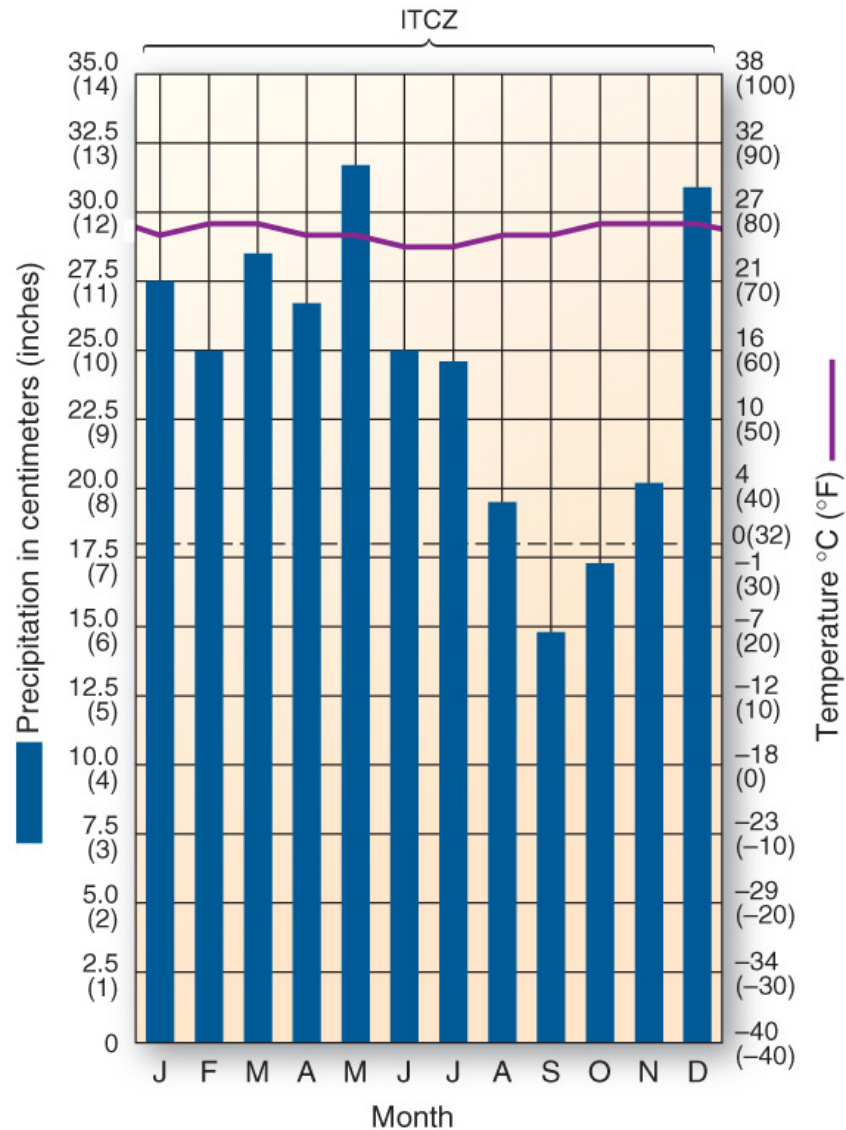


# Tropical Rain Forest - Af

- Very Low Latitudes
- Only true winterless climates - perpetual moisture and warmth
- Some of the wettest places on Earth
  - Primarily due to location of ITCZ



# Tropical Rain Forest



(a)

**Station:** Uaupés, Brazil  
**Lat/long:** 0° 08' S 67° 05' W  
**Avg. Ann. Temp.:** 25°C (77°F)  
**Total Ann. Precip.:** 291.7 cm (114.8 in.)

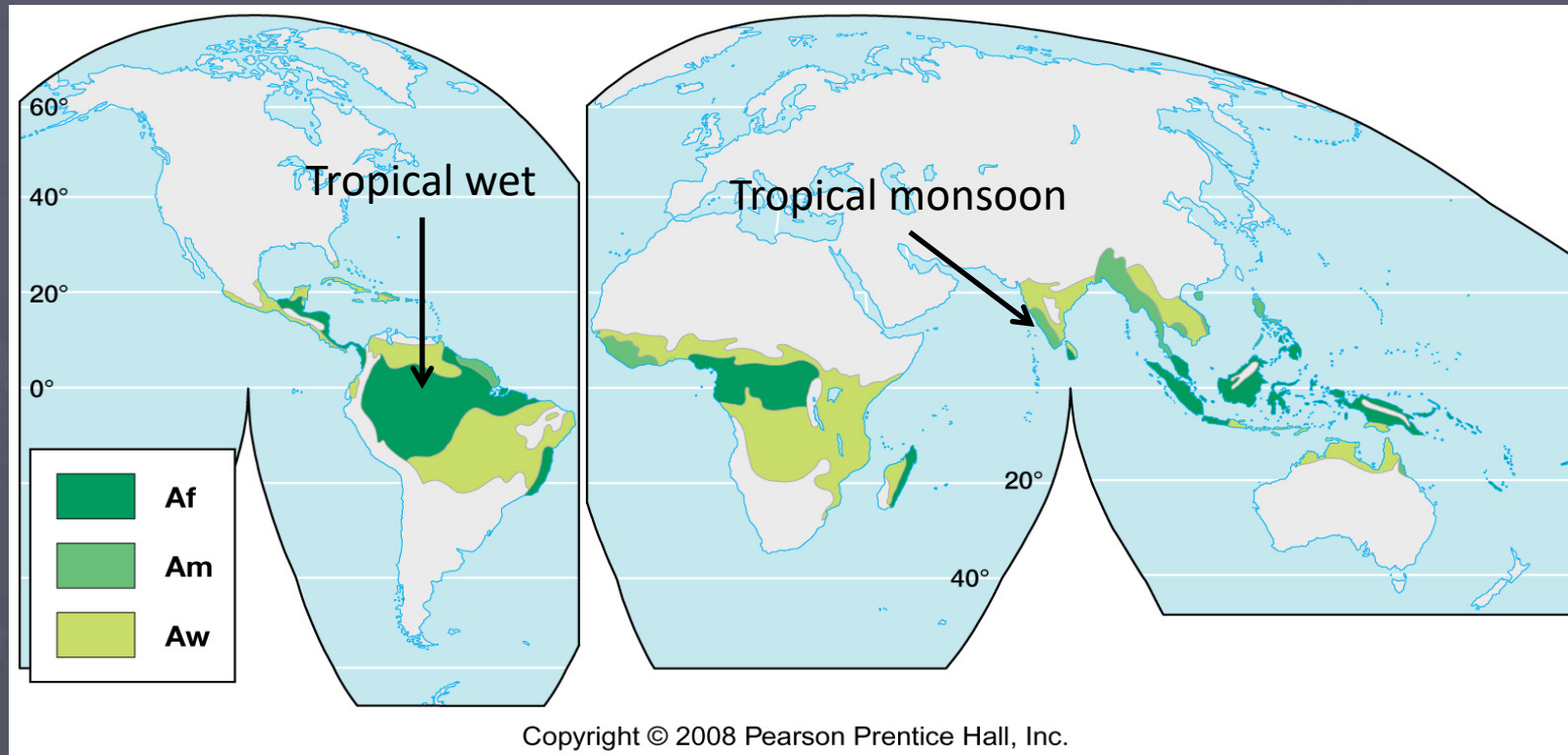
**Elevation:** 86 m (282.2 ft)  
**Population:** 10,000  
**Ann. Temp. Range:** 2°C (3.6°F)  
**Ann. Hr of Sunshine:** 2018



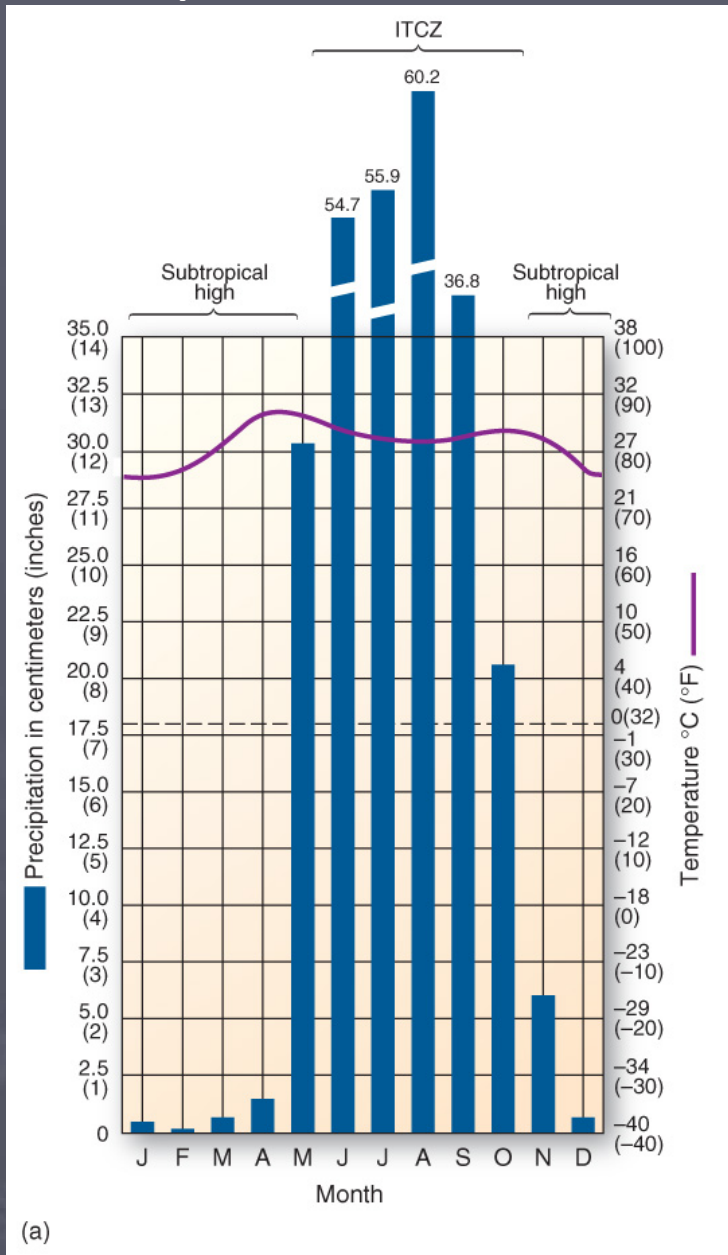
(b)

# Tropical Monsoon - Am

- Warm year-around, but dry season during winter (little precipitation)
- Wet/rainy season occurs when ITCZ shifts north in summer.



# Tropical Monsoon



**Station:** Yangon, Myanmar\*  
**Lat/long:** 16° 47' N 96° 10' E  
**Avg. Ann. Temp.:** 27.3°C (81.1°F)  
**Total Ann. Precip.:** 268.8 cm (105.8 in.)

**Elevation:** 23 m (76 ft)  
**Population:** 6,000,000  
**Ann. Temp. Range:** 5.5 C° (9.9 F°)

\*(Formerly Rangoon, Burma)

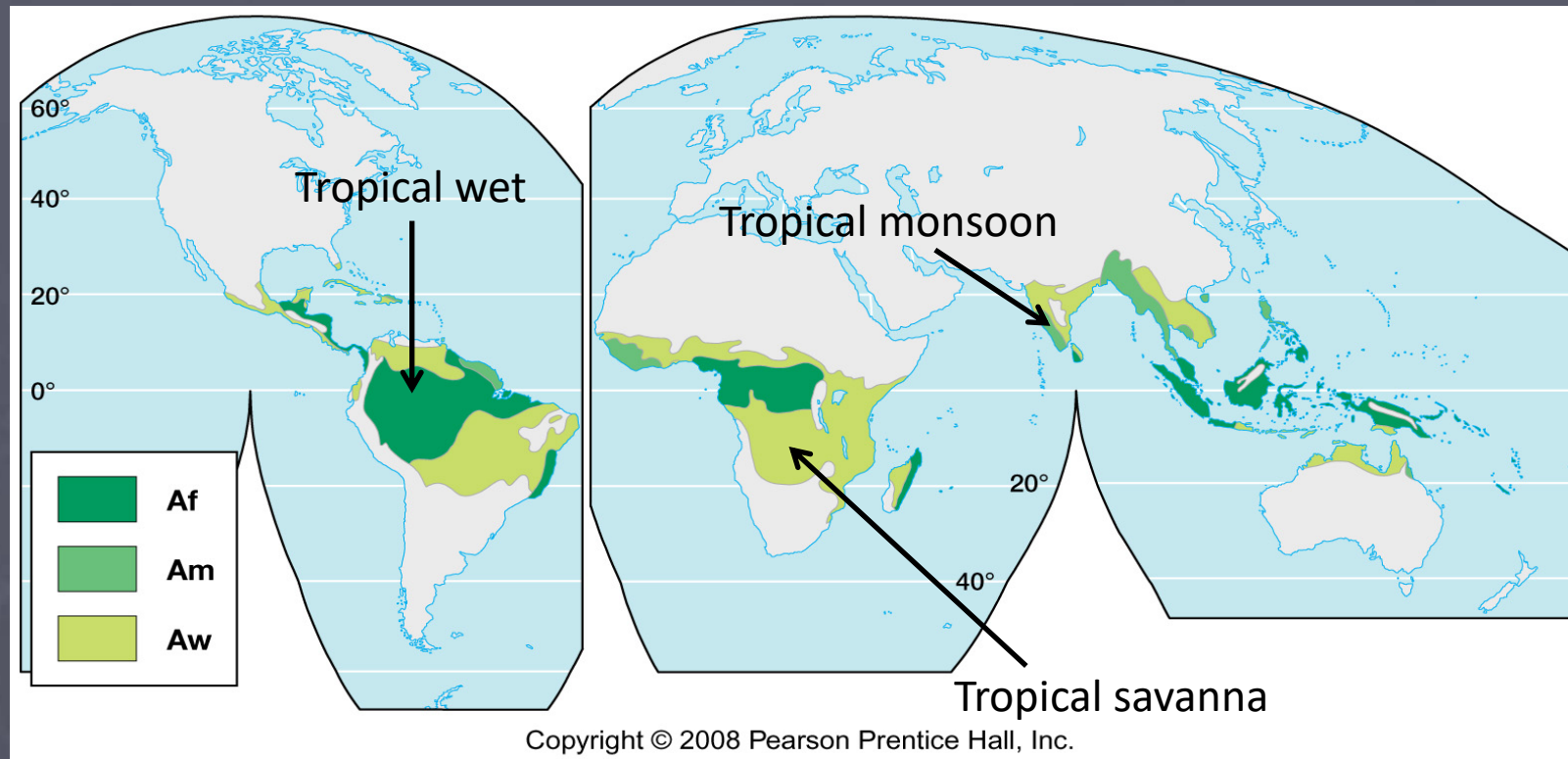


(b)

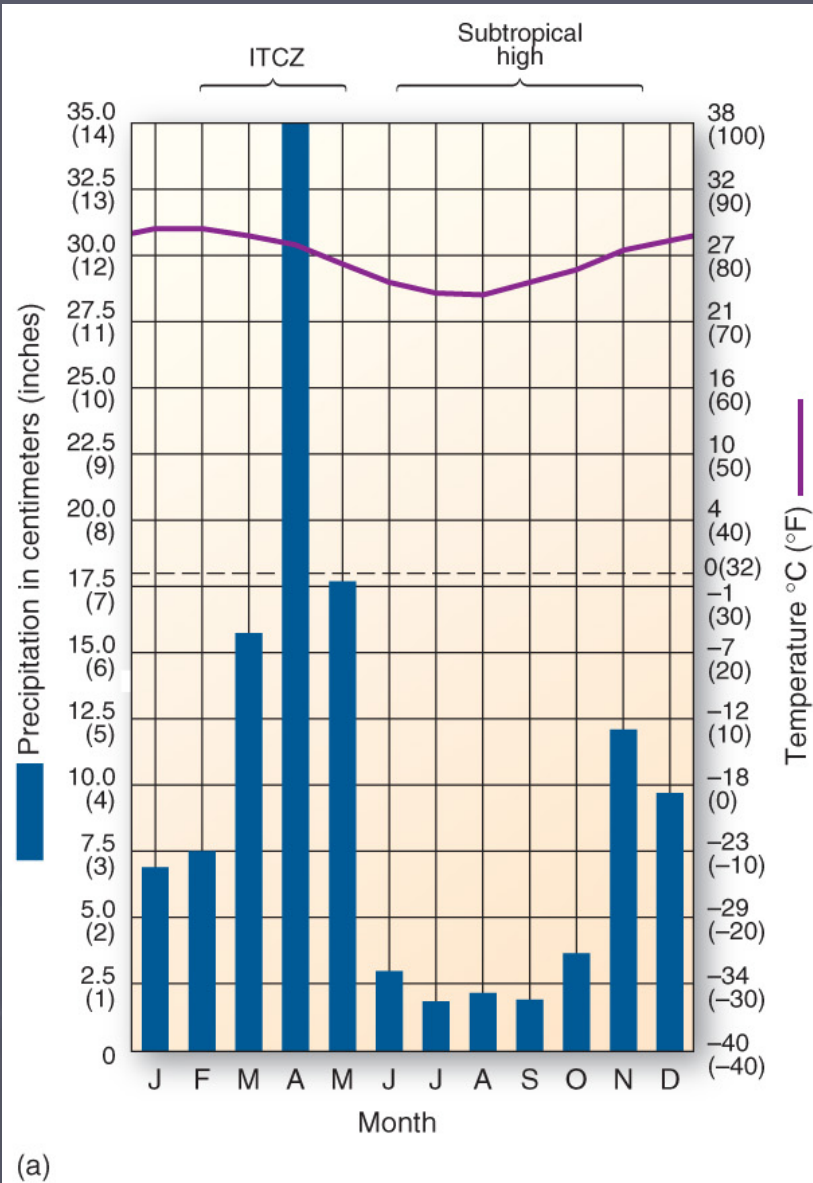


# Tropical Savanna - Aw

- Typically exist slightly poleward of tropical rainforests
- ITCZ only reaches these areas about 6 months out of the year
- Primary vegetation is grasslands and shrubs



# Tropical Savanna



**Station:** Arusha, Tanzania  
**Lat/long:** 3° 24' S 36° 42' E  
**Avg. Ann. Temp.:** 26.5°C (79.7°F)  
**Total Ann. Precip.:** 119 cm (46.9 in.)

**Elevation:** 1387 m (4550 ft)  
**Population:** 1,368,000  
**Ann. Temp. Range:** 4.1 C° (7.4 F°)  
**Ann. Hr of Sunshine:** 2600



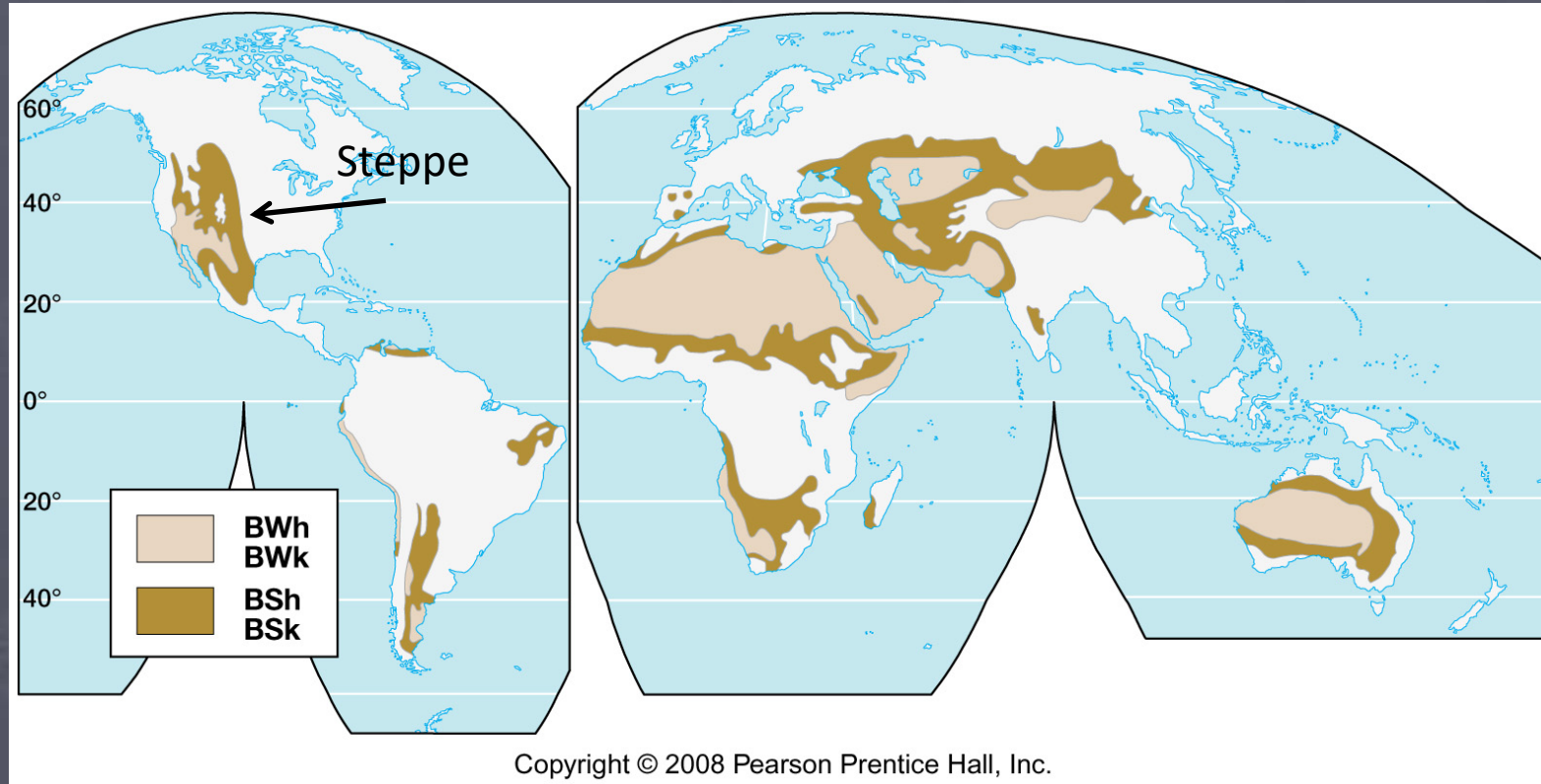
# Dry Climates - B

- Steppe
- Desert



# Steppe - BS

- Semi-arid with 10-20 in rainfall/year
- Not enough rainfall to support large vegetation
  - Most vegetation near streams, rivers, and lakes
- Can be classified as a hot (h) or cold (k) area



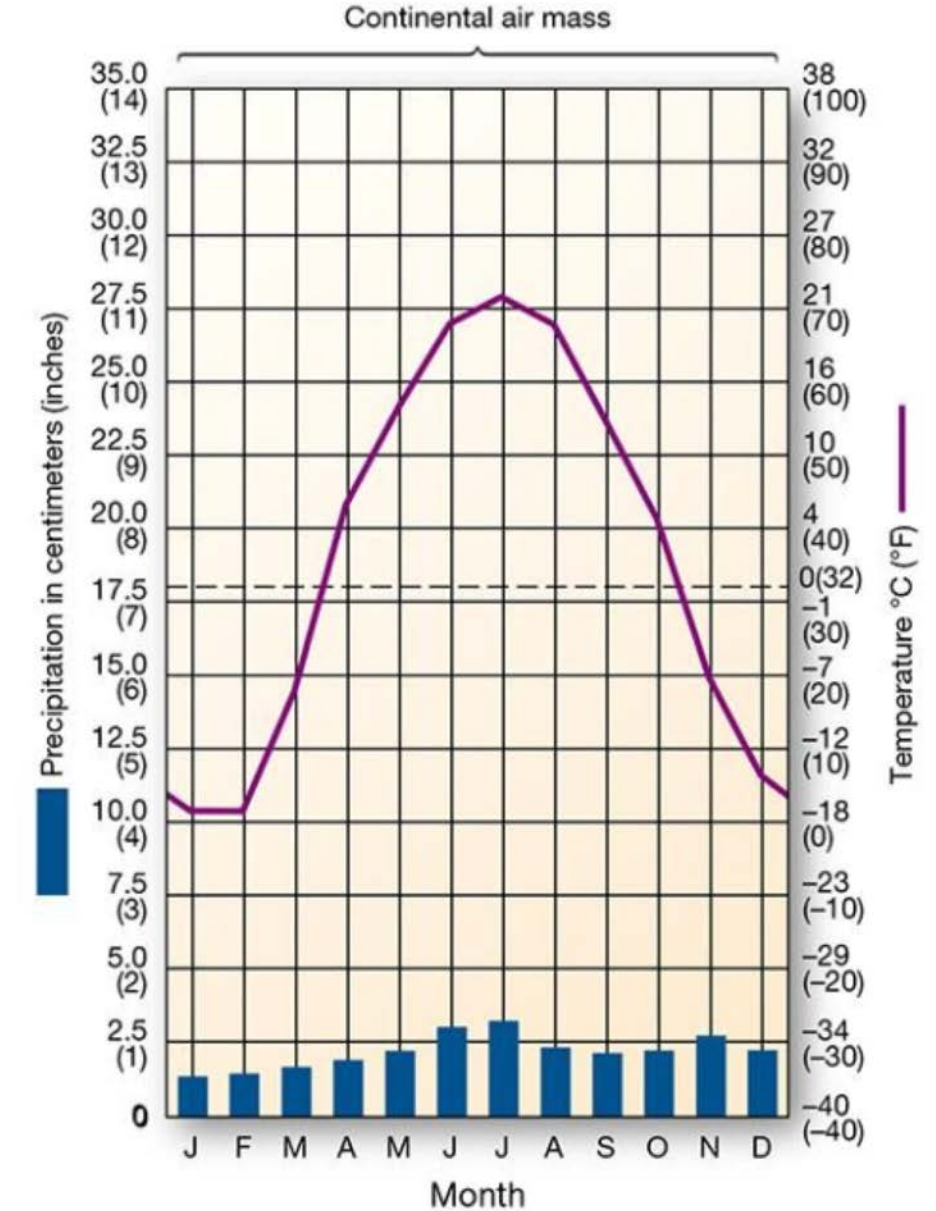
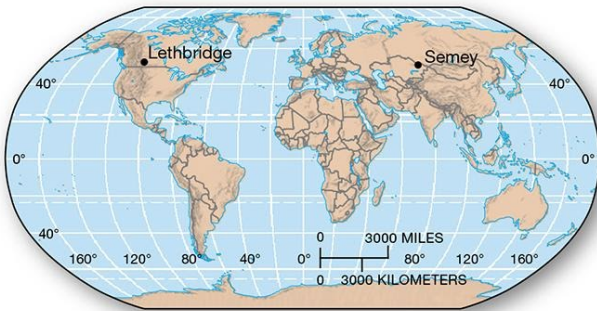
# Steppe

**Station:** Semey, Kazakhstan  
**Lat/long:** 50° 21' N 80° 15' E  
**Avg. Ann. Temp.:** 3°C (37.4°F)  
**Total Ann. Precip.:** 26.4 cm (10.4 in.)

**Elevation:** 206 m (675.9 ft)  
**Population:** 270,500  
**Ann. Temp. Range:** 39 C° (70.2 F°)



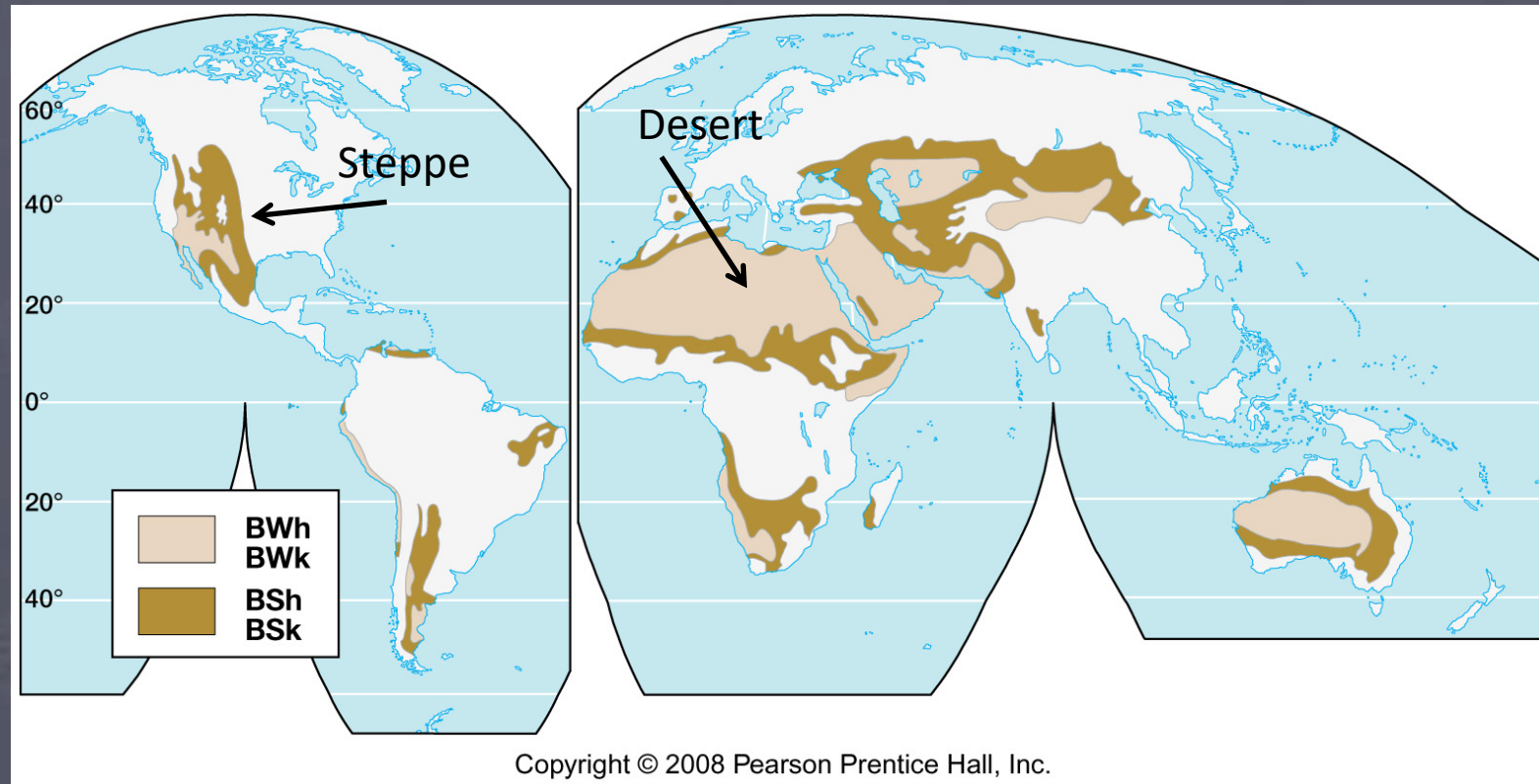
(b) Summer on the cold steppe of eastern Kazakhstan.



(a) Climograph for Semey (Semipalatinsk), Kazakhstan.

# Desert Climates - BW

- Desert: Arid with generally  $< 10$  in/year
  - Again can be classified as hot (h) or cold (k)
- Especially prevalent on the leeward side of mountains and the poleward side of the Tropics

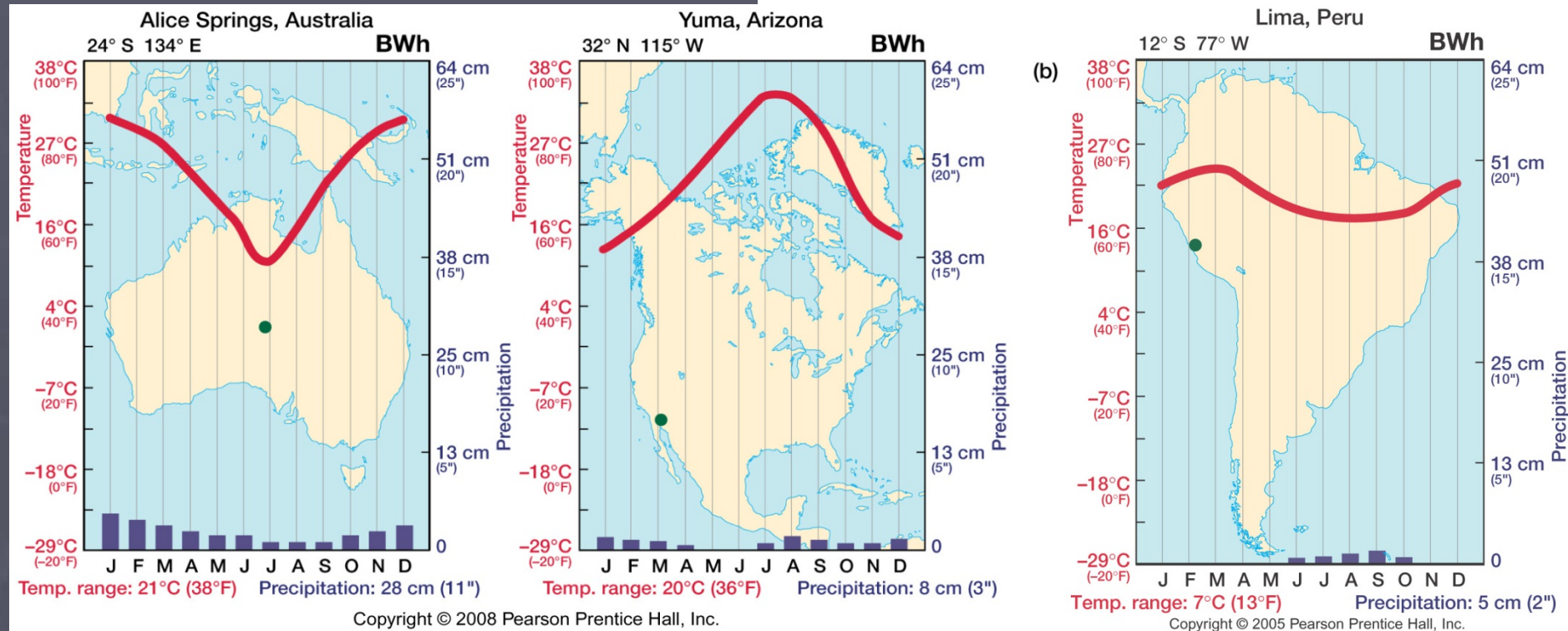


# Desert Climates



(a)

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# Mesothermal Climates

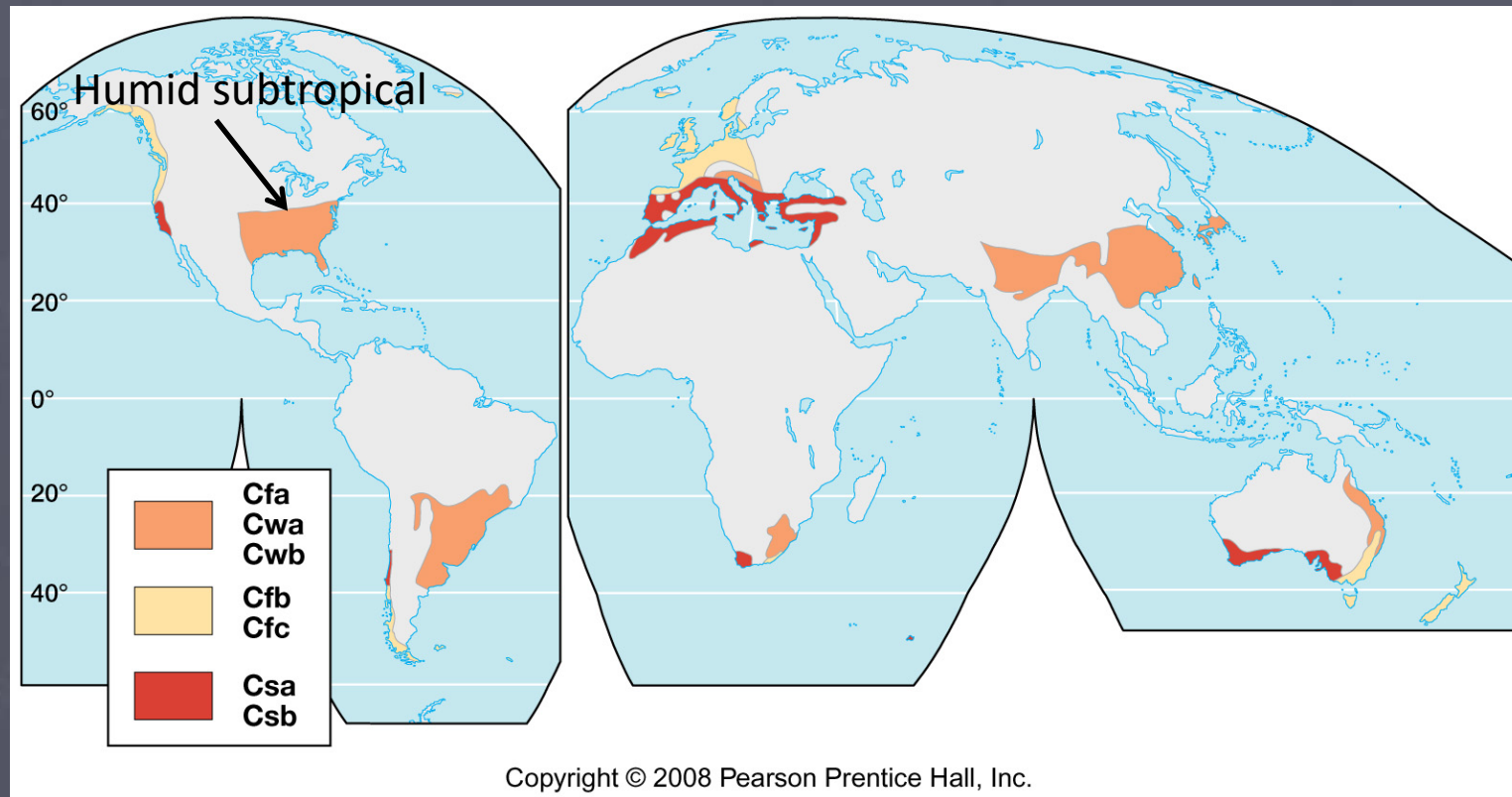
- Humid Subtropical Hot-Summer Climates
- Marine West Coast Climates
- Mediterranean Dry-Summer Climates



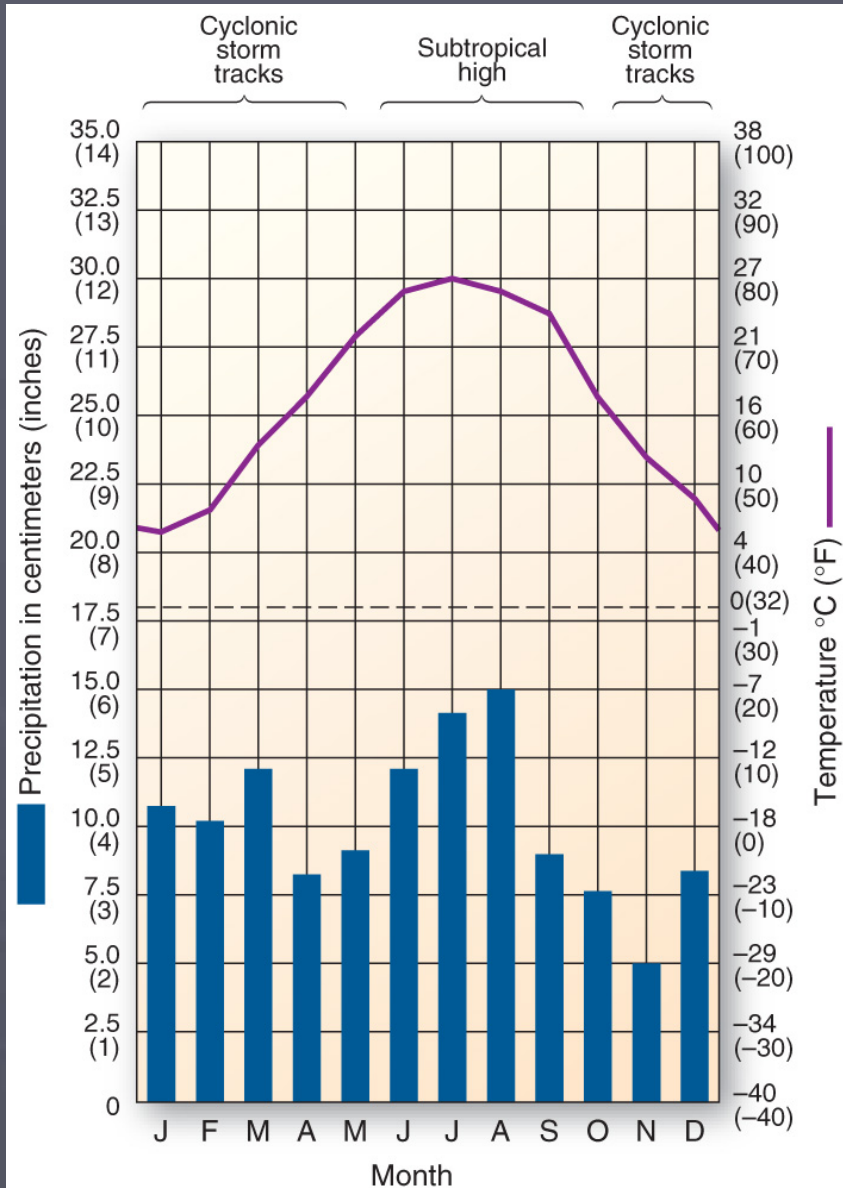


# Humid Subtropical – Cfa, Cwa, Cwb

- Within 25-40 degrees of latitude with some poleward extensions
- Precipitation may be steady all year or seasonal
- Summers hot and humid, winters cooler but not cold



# Humid Subtropical



(a)

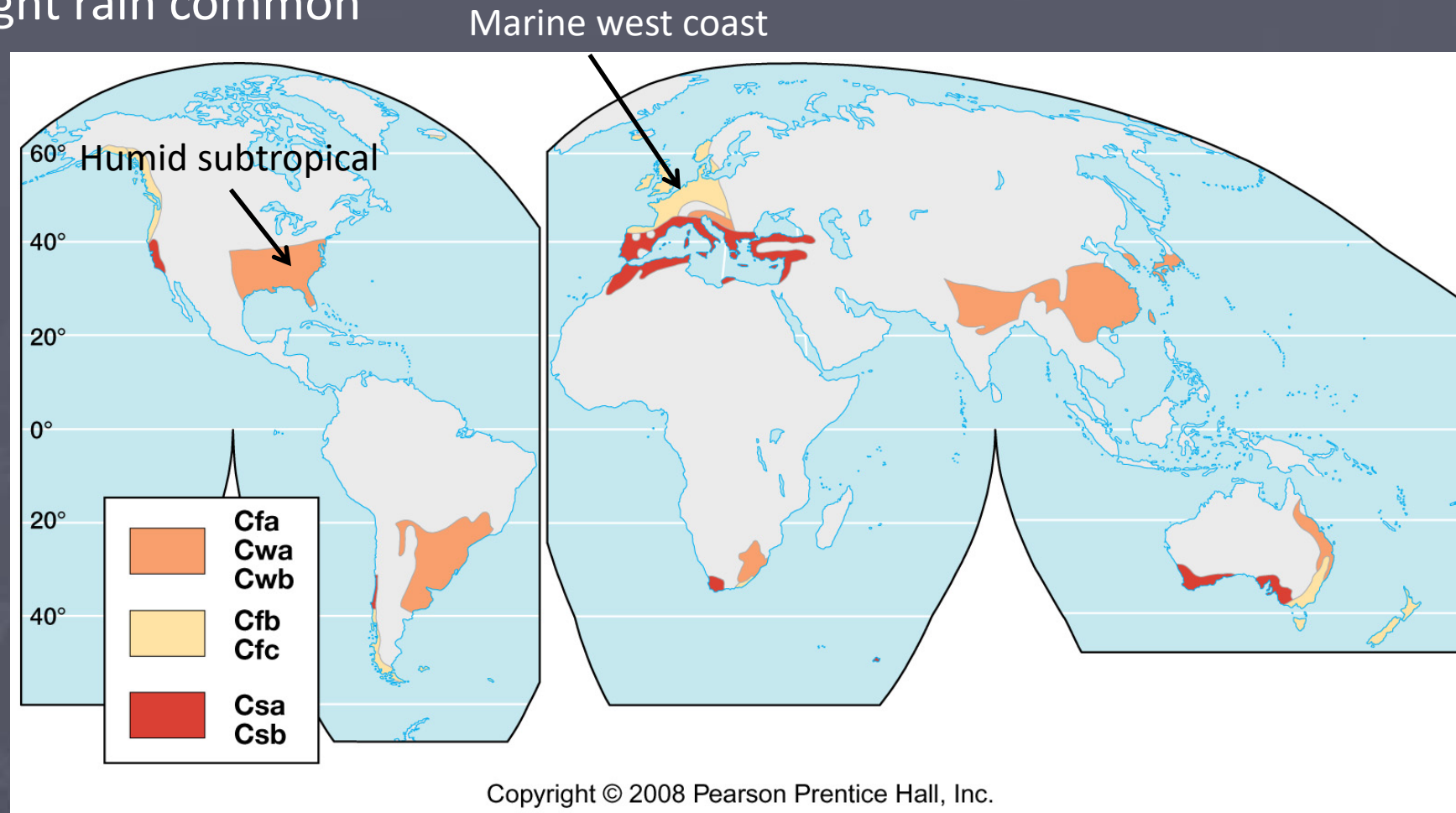
**Station:** Columbia, South Carolina  
**Lat/long:** 34° N 81° W  
**Avg. Ann. Temp.:** 17.3°C (63.1°F)  
**Total Ann. Precip.:** 126.5 cm (49.8 in.)

**Elevation:** 96 m (315 ft)  
**Population:** 116,000  
**Ann. Temp. Range:** 20.7 C° (37.3 F°)  
**Ann. Hr of Sunshine:** 2800



# Marine West Coast – Cfb, Cfc

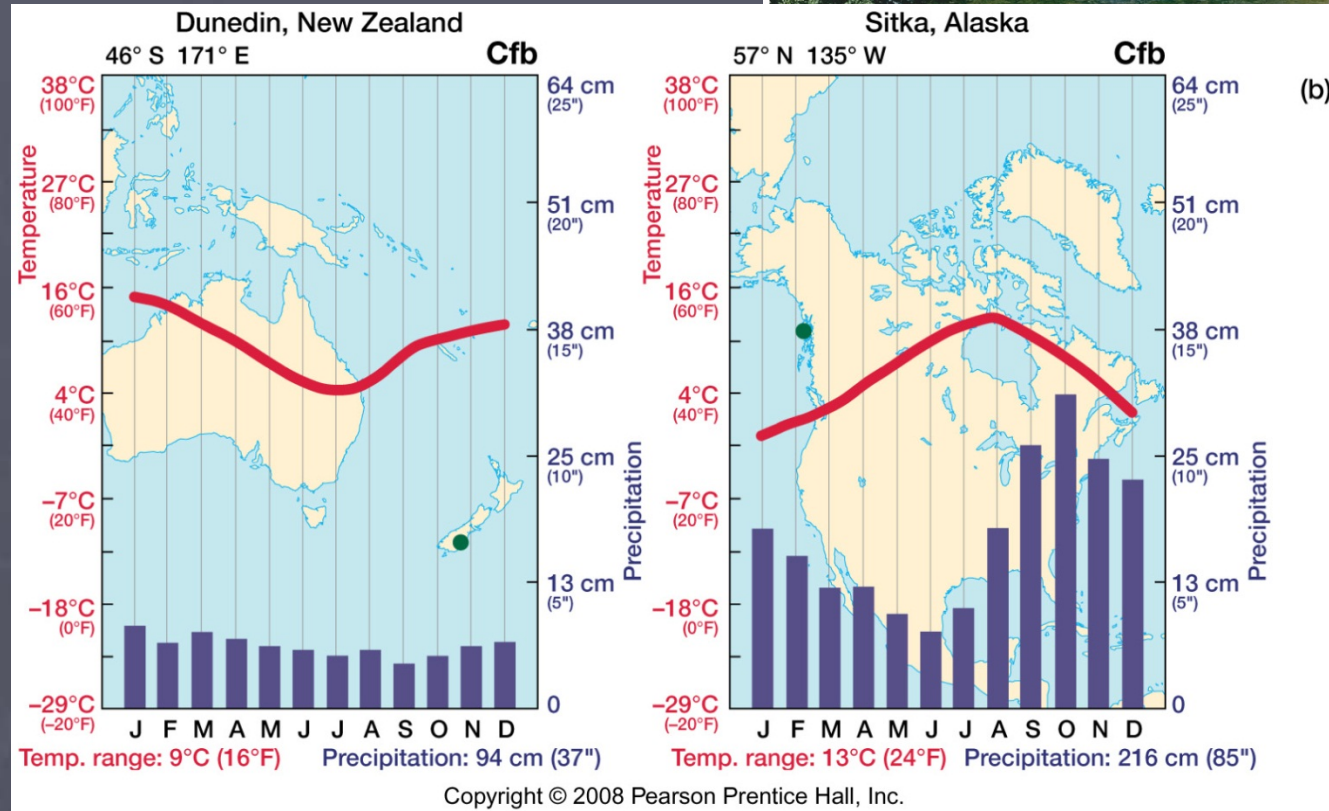
- Mild winters, cool summers
- Dominated by maritime polar air masses
- Fog, light rain common



# Marine West Coast



(a)

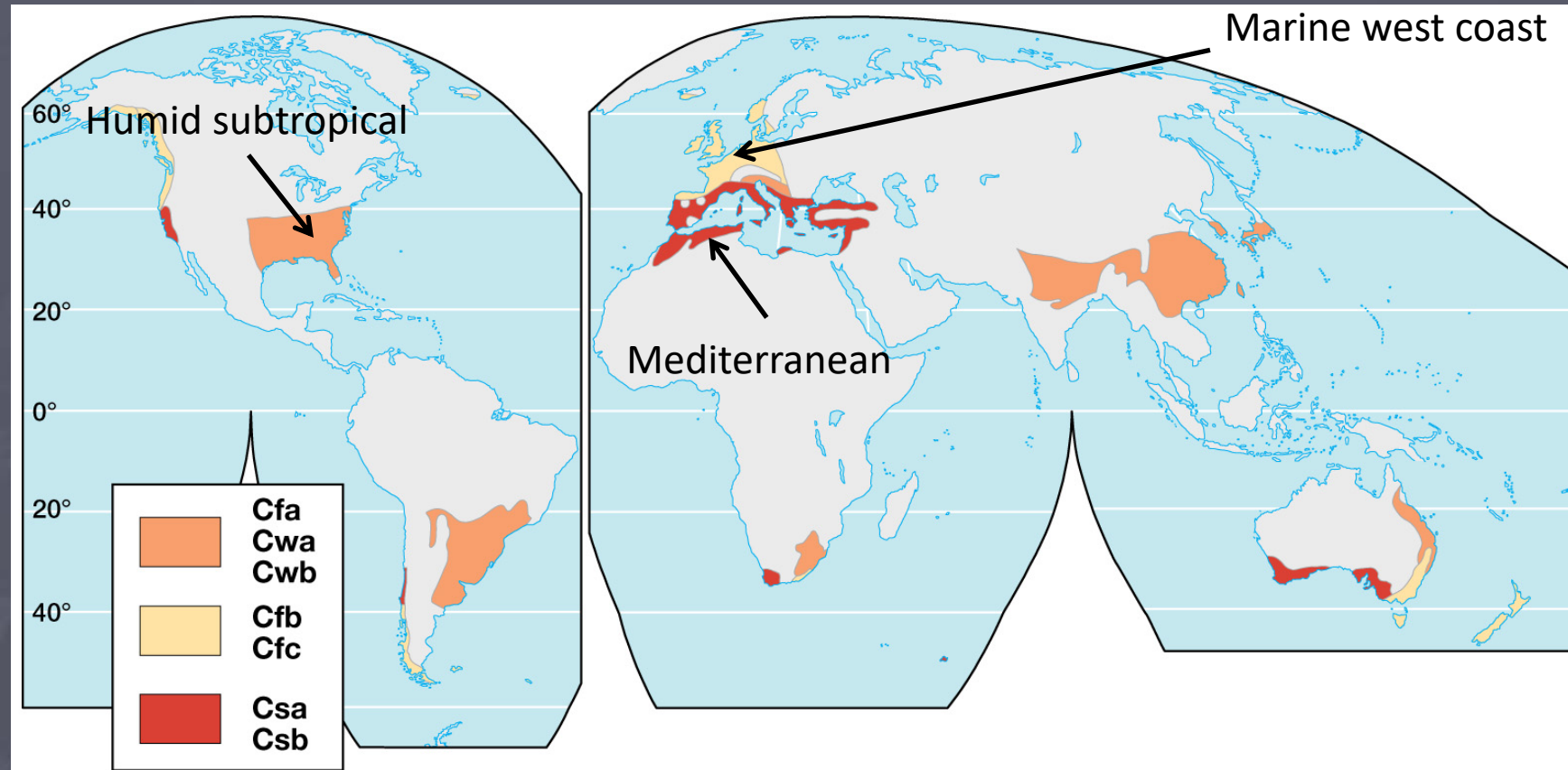


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(b)

# Mediterranean – Csa, Csb

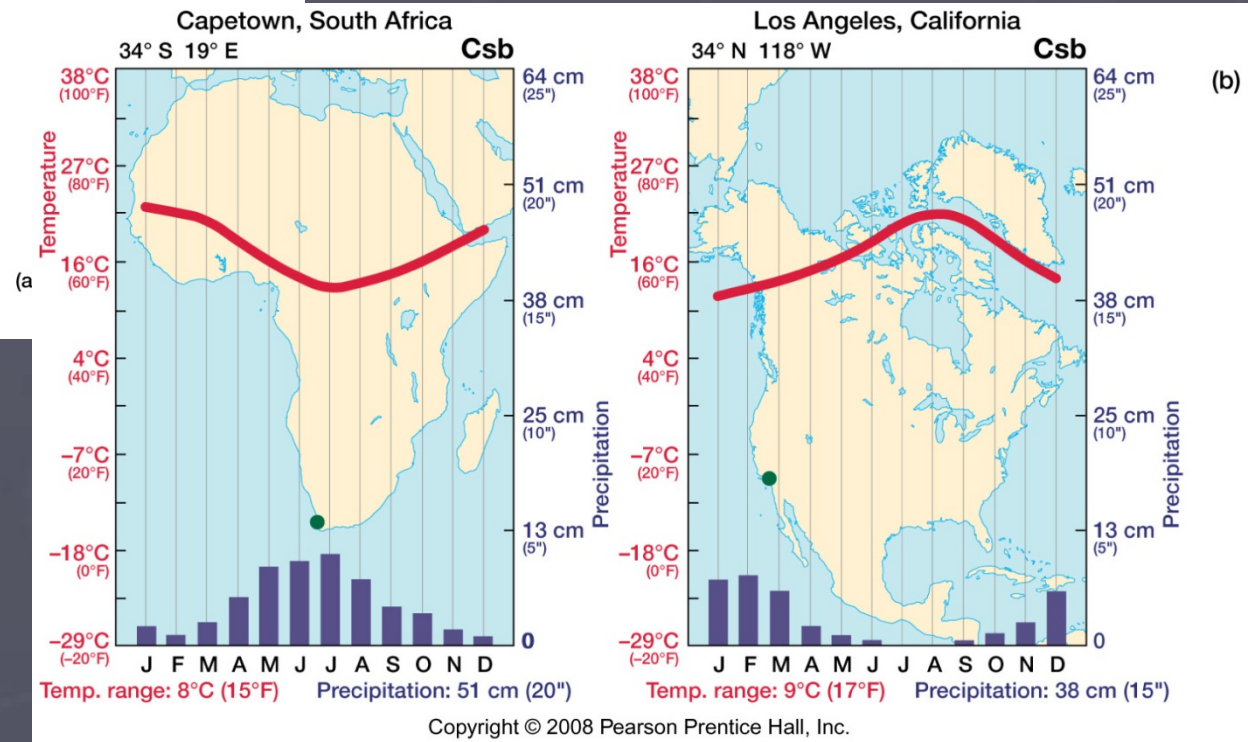
- 70% of annual precipitation occurs in winter.
- Subtropical high blocks moisture during summer.
- Annual precipitation typically around 15-25 inches.



# Mediterranean

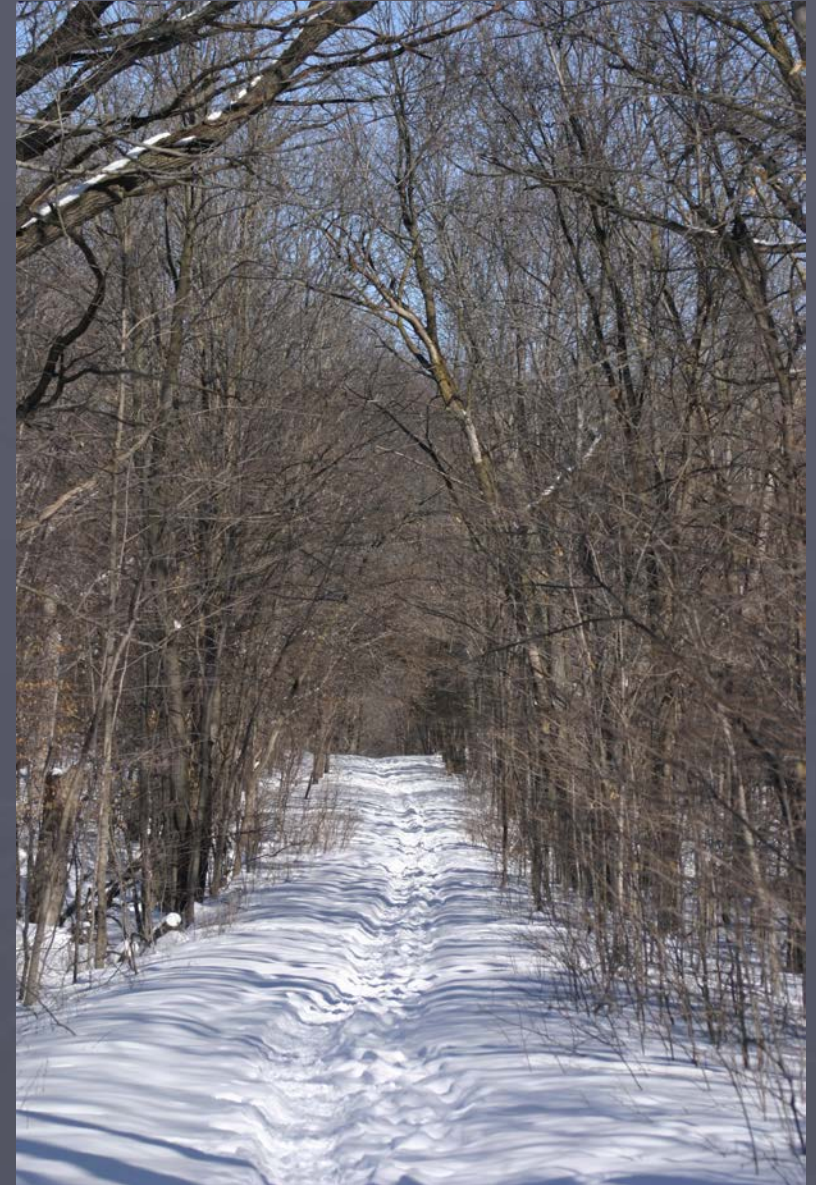


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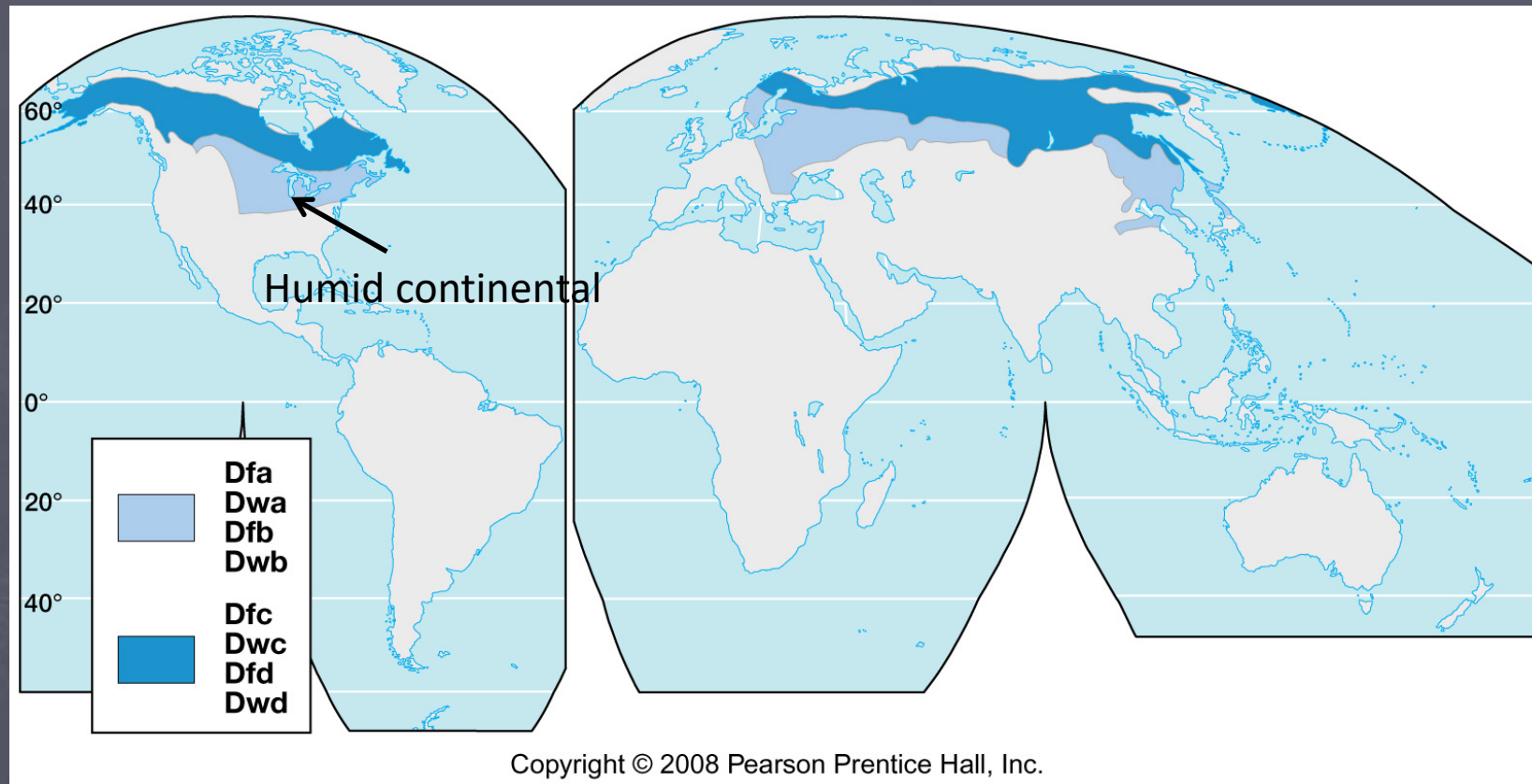
# Microthermal Climates

- Humid Continental
- Subarctic



# Humid Continental Climate – Dfa, Dwa, Dfb, Dwb

- 35–70 degrees latitude
- Precipitation varies
- Large Seasonal variation
  - Winters cold, summers typically warm to hot

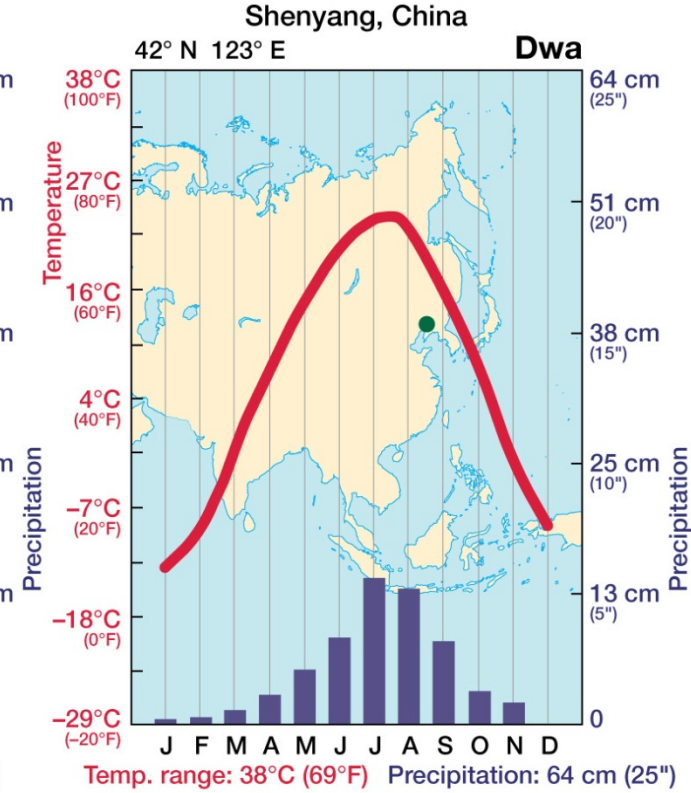
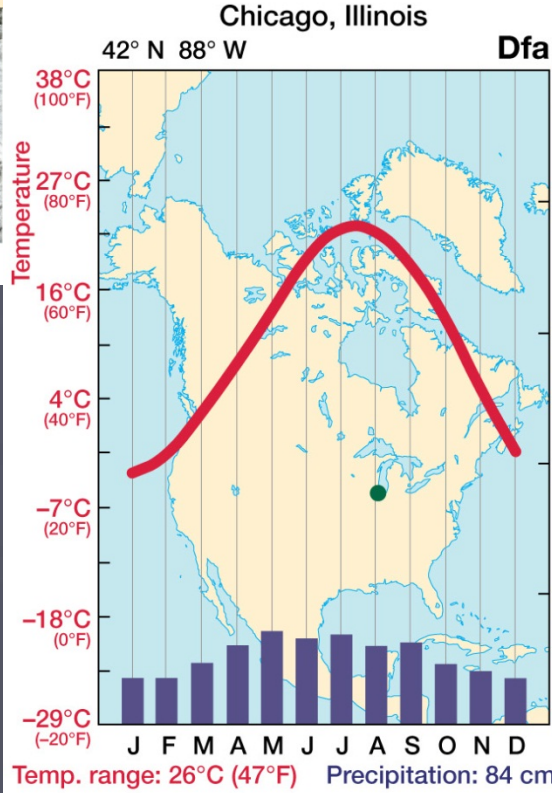




# Humid Continental Climate



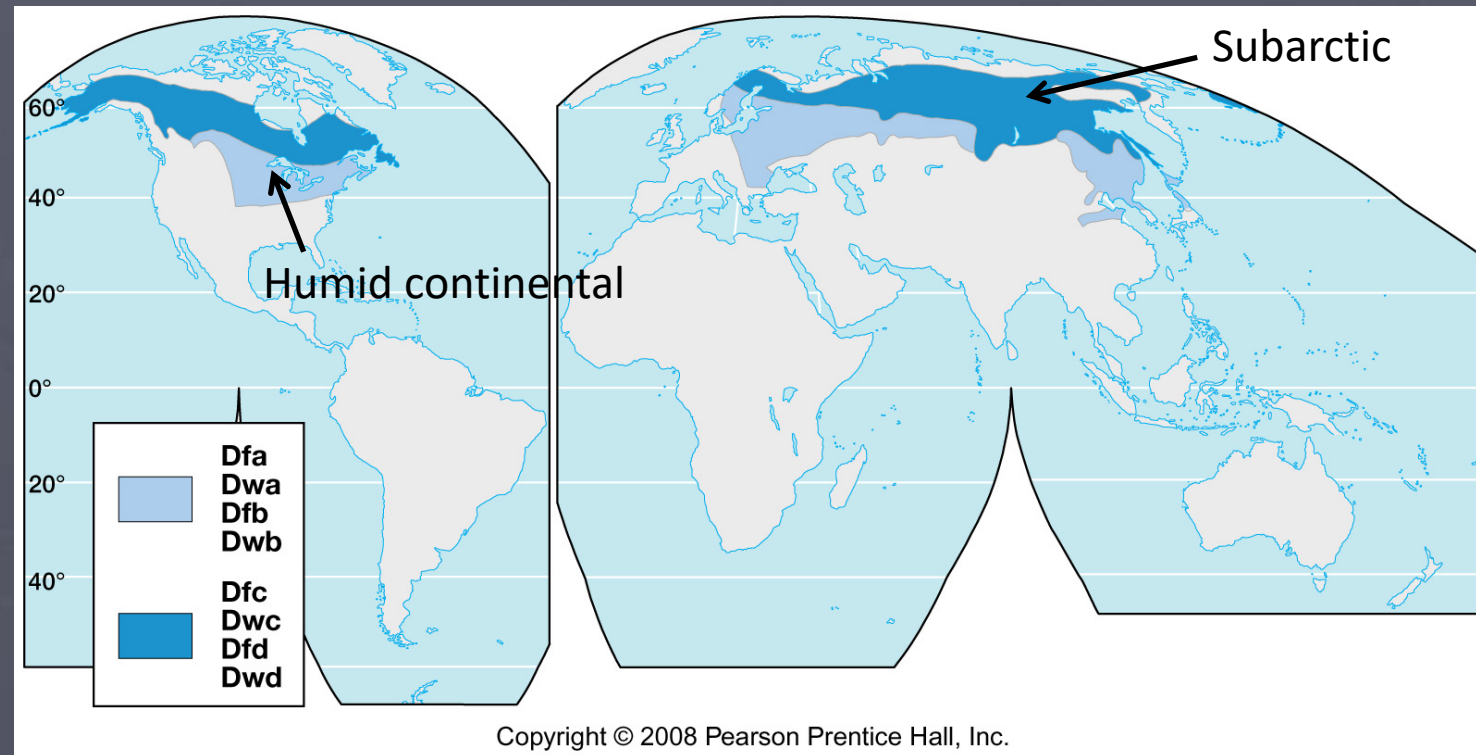
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# Subarctic Climate – Dfc, Dwc, Dfd, Dwd

- Predominantly Northern hemisphere
- Generally poleward of the humid continental climate
- Summers mild, winters often very cold with arctic air common
- Boreal Forests common until tree line

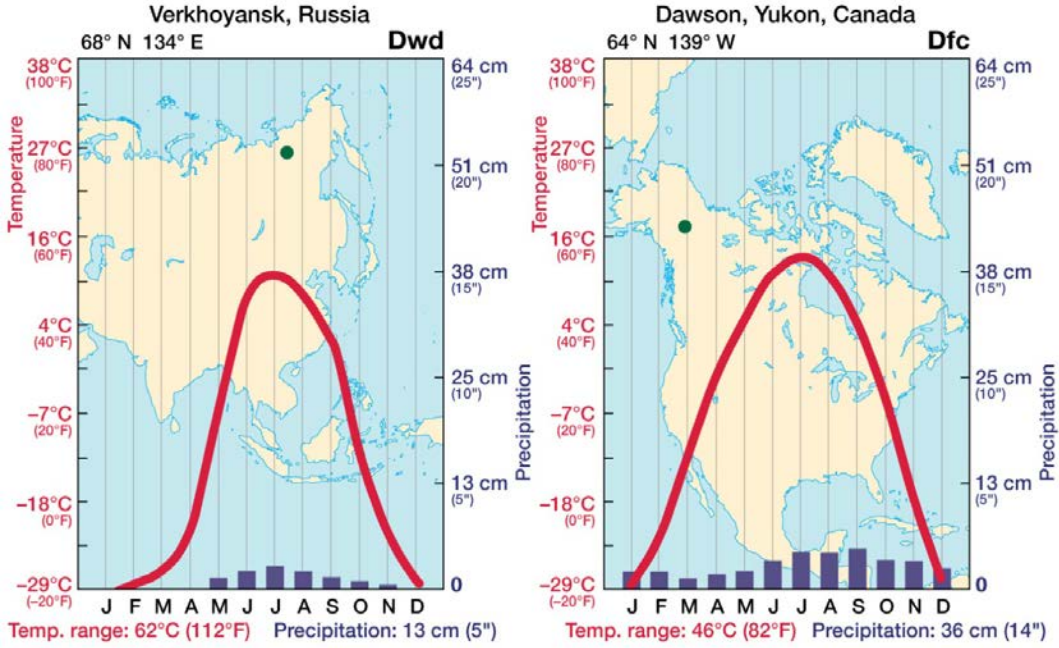


# Subarctic Climate



(a)

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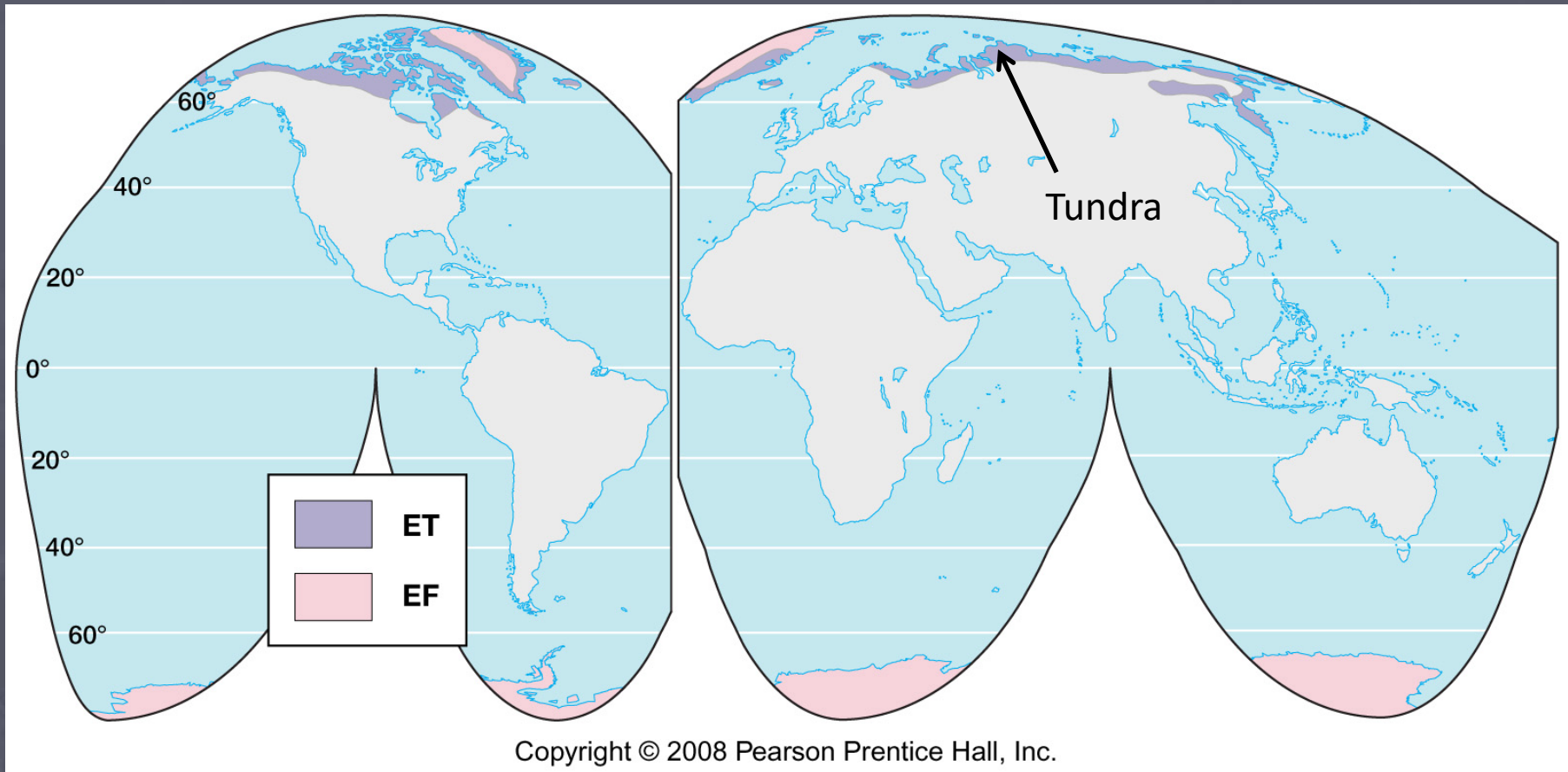
# Polar Climates

- Tundra
- Ice Cap

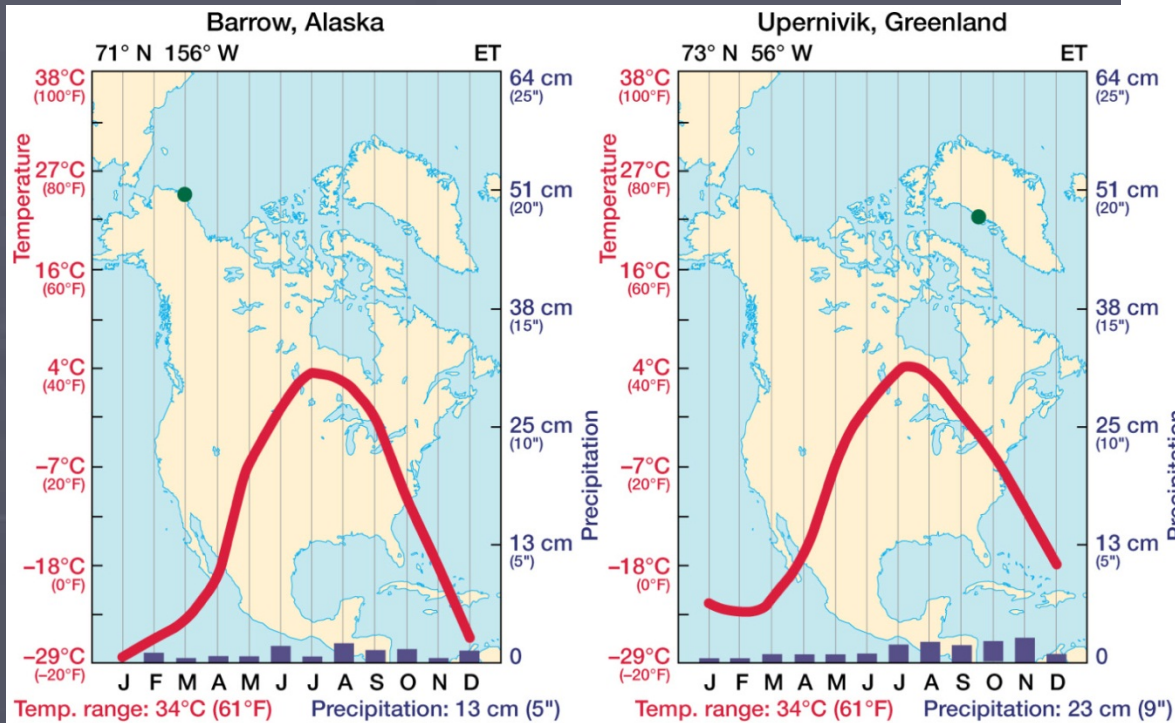


# Tundra Climate - ET

- Generally poleward of 70 degrees of latitude
- Cool to cold year-around
- No trees – too short of growing season



# Tundra Climate



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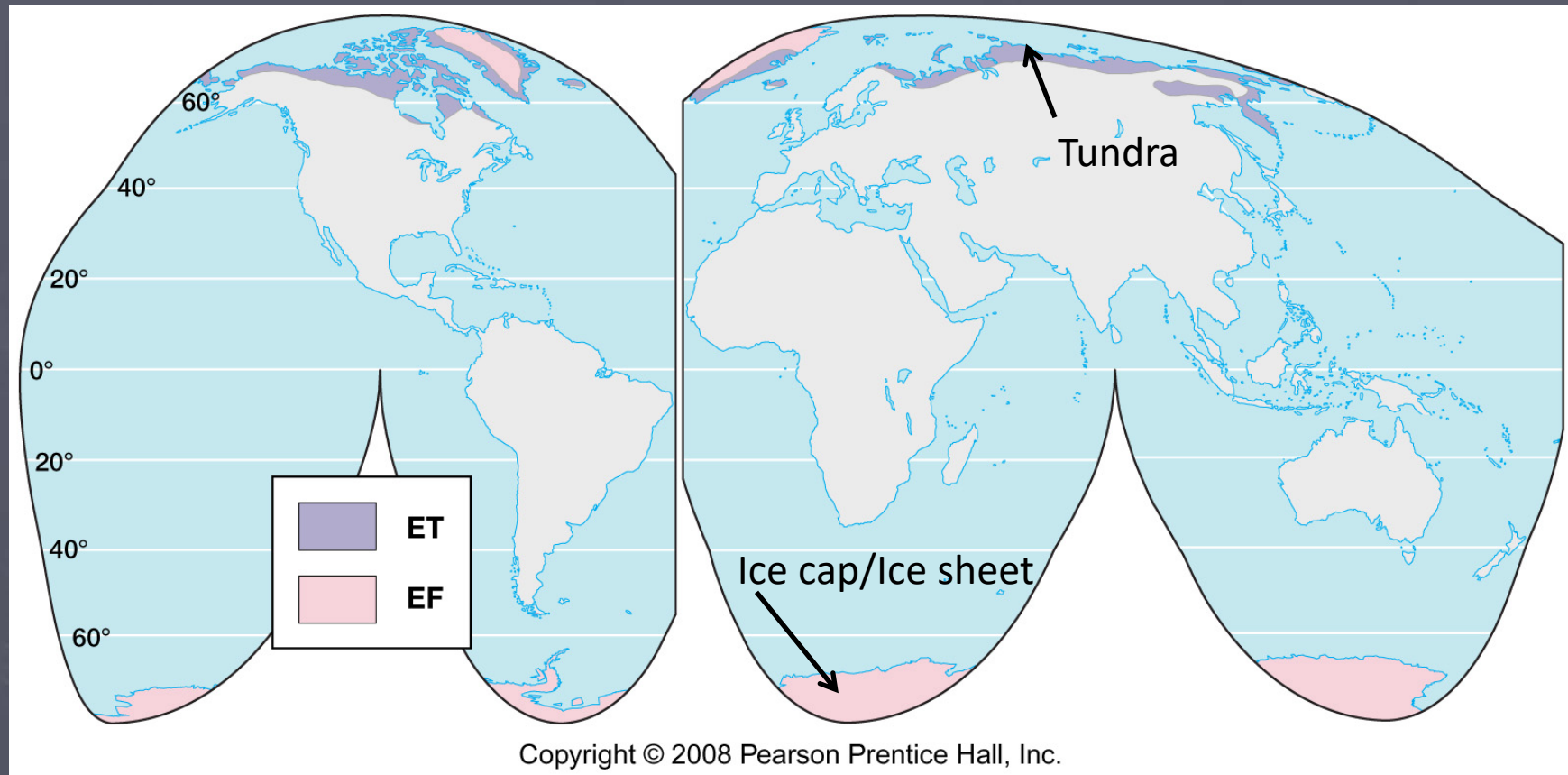
(b)

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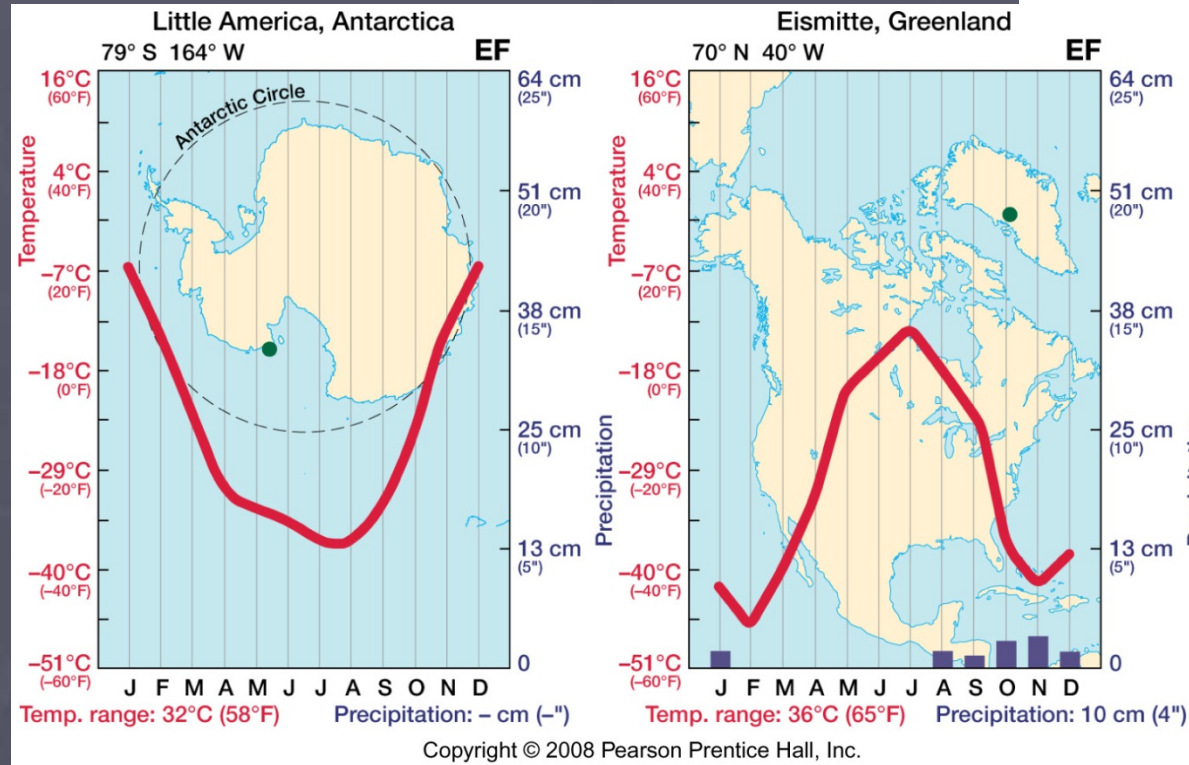
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# Ice Cap/Ice Sheet Climate - EF

- Dominated by cold, dry arctic air masses
- Cold to frigid temperatures
- Little precipitation



# Ice Cap/Ice Sheet Climate



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(a)

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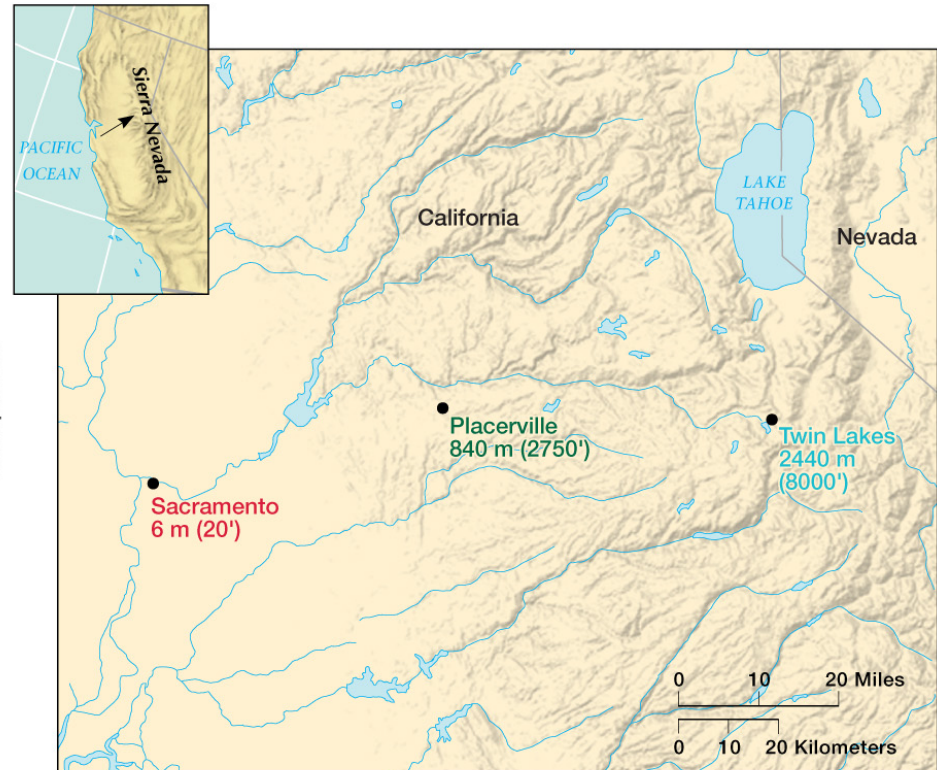
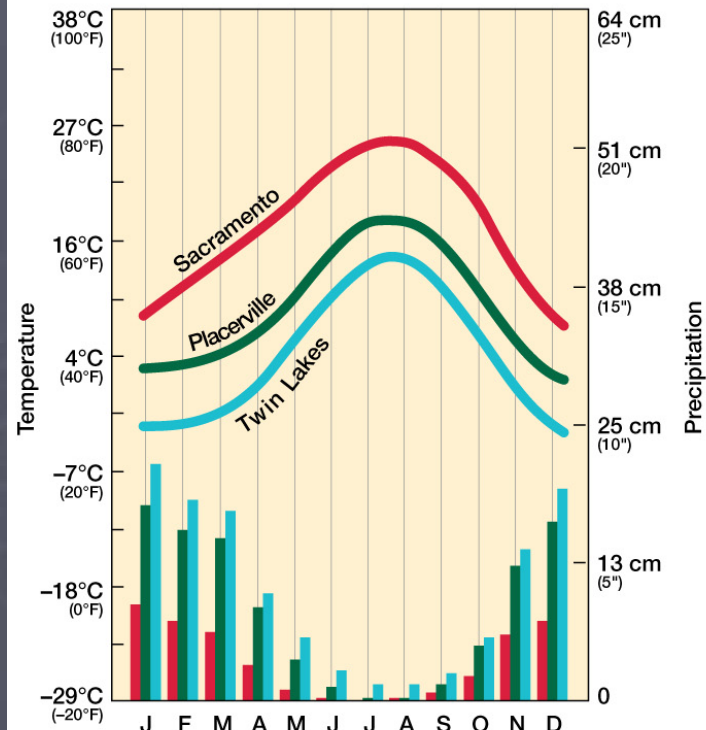
# Highland Climate - H

- High uplands (mountains and plateaus)
- Regardless of latitude, temperature decreases with altitude





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