EXERCISE 8 | CLIMATE CLASSIFICATION AND REGIONAL CLIMATES

PURPOSE

The purpose of this exercise is to learn how climate data is organized to create a world classification of climate, and to gain an understanding of the influence of continentality, topography, and ocean currents on the spatial patterns of climate.

LEARNING OBJECTIVES

By the end of this exercise you should be able to

- use the Köppen system to classify a climate;
- describe differences in seasonal temperature and precipitation patterns for different climate types and explain factors responsible for these differences;
- explain how ocean currents affect air stability and precipitation; and
- explain how mountains affect spatial patterns of precipitation and climate type.

INTRODUCTION

Examining a map of the world distribution of climates reveals a mosaic of climates spread across the earth. The geography of earth's climate is the evolutionary result of billions of years of earth history and is created by the changing composition of the atmosphere, the shifting of continents, biologic regulators, and astronomical events such as the tilt of the earth's axis, and meteors. If one looks closely at this apparent hodge-podge of climates, subtle regularities reveal themselves and point to the causal factors that created them. The first step in determining the cause of climate patterns requires us to organize a vast amount of information in a sensible and easily communicated way.

Global Climate Controls

The present-day climate of a region is the result of the complex interaction of location, wind and pressure systems, water bodies, and topography. The latitude of a place determines the amount of solar radiation received, because latitude affects sun angle and day length. Latitude also determines which global wind or pressure systems are dominant. The tropical rainy climates are dominated by the rain-producing **intertropical convergence zone.** The tropical dry climates are dominated by the rain-suppressing **subtropical highs.** The seasonal precipitation typical of some subtropical climates is due to the shifting presence of the subtropical high- and **subpolar low**-pressure cells. For example, the dry summer subtropical climate, sometimes called the Mediterranean climate, experiences its dry period when the subtropical high dominates. The rainy period occurs when the subpolar low dominates. The variable climate conditions of the midlatitudes are in part a reflection of the migratory nature of the **polar front jet stream** and the subpolar low.

Ocean currents and mountain systems are elements that provide important regional controls of climate. Surface winds created by the subtropical highs are responsible for most of the major ocean currents, which have a moderating effect on the temperature of a coastal region. That is, ocean currents tend to decrease the range of temperatures experienced by a place. Recall that large bodies of water, like oceans, are **heat reservoirs,** absorbing heat slowly and retaining it for long periods of time. Thus, water temperatures change quite slowly, as does the air temperature above water. Oceanic air will not heat up or cool down as much as will air sitting above a land surface.

In addition to affecting temperature, ocean currents can have an extreme effect on the amount of moisture a coastal region receives. Cold ocean currents act to stabilize the air at the surface, thus preventing uplift and precipitation. Warm ocean currents can help promote instability in the air, enhancing uplift and precipitation. **Upwelling** of cold water (from the lower depths of the ocean) enhances the effect of a cold water current. Upwelling is especially strong along coasts with a steep continental shelf. This helps explain why water off the west coast of South America is so cool even near the equator.

Since ocean currents essentially parallel the direction of the global wind system, if we know the direction of the winds diverging around the subtropical highs, we can determine where the major oceans currents flow. Likewise, we can determine which ocean currents are cold and which are warm. Currents flowing away from the Poles are cold, whereas currents flowing away from the equator are warm.

The orientation of a mountain range with respect to the prevailing winds of a region can play a significant role in influencing the weather and climate of a region. Midlatitude weather systems tend to move in a west-to-east direction in the Northern Hemisphere. Most major mountain systems in North and South America show a north-south orientation while many European and Asian mountain systems are oriented in an east-west direction. As a result, maritime air masses penetrate farther inland in Europe than they do in North America. This creates "oceanic" climate conditions (high average humidity, high rainfall, and small temperature ranges) farther into the interior of Europe than in North America. The north-south aligned mountains in North America cause uplift and precipitation on their windward western slopes and dry conditions on the leeward eastern slopes.

Climate Classification

The geographic distribution of atmospheric phenomena is complex to say the least. The spatial and temporal variation of climate elements (e.g., air temperature, precipitation, air masses, areas of cyclogenesis, topography) results in place-to-place variations of environmental conditions. Such complex variation makes the study of climate quite difficult. This requires the adoption of a framework for arranging the vast information concerning climate, that is, a classification of climate.

Classification is a fundamental tool of science. The objectives of classification are three-fold: (1) to organize large quantities of information, (2) to speed retrieval of information, and (3) to facilitate communication of information. Climate classification is concerned with the organization of climatic data in such a way that both descriptive and analytical generalizations can be made. In addition, it attempts to store information in an orderly fashion for easy reference and communication, often in the form of maps, graphs, or tables. The usefulness of any particular classification system is largely determined by its intended use.

There are three basic types of classification systems—empirical, genetic, and applied. An **empirical classification** system classifies climates solely on the basis of observable features (e.g., temperature, precipitation). A **genetic classification** system classifies climates according to the cause of observable features (e.g., frequency of air mass invasions, influence of orographic barriers, influence of particular wind and pressure belts). **Applied classification** systems assist in the solution of specialized problems. Explanations of the distribution of natural vegetation or assessment of the distribution of soil moisture availability are two examples where applied classifications have been formulated. Applied classifications have used precipitation, potential evapotranspiration, and indices of moisture adequacy or thermal efficiency as classification criteria.

Köppen Climate Classification

The climate classification used in this exercise was developed by Wladimir Köppen and is based upon annual and monthly means of temperature and precipitation. The Köppen classification identifies five main groups of climates (designated by capital letters), all but one, the dry group, being thermally defined. They are as follows:

A-type climates: Tropical rainy climates; hot all seasons

B-type climates: Dry climates

C-type climates: Warm temperate rainy climates; mild winters

D-type climates: Boreal climates; severe winters

E-type climates: Polar climates

A sixth group for highland climate (H) is also recognized but has no temperature or precipitation criteria. Highland climate is that in which climate conditions change significantly over a short horizontal distance due to altitudinal variations.

In order to represent the main climate types, additional letters are used. The second letter pertains to precipitation characteristics and the third to temperature. Table 8.1 describes the main climate types and Table 8.2 explains the symbols and criteria utilized for subdividing the main climate types.

Procedure for Classifying Climate

The procedure for determining the climate of a place should be worked through step-by-step.

1. Determine if the station is an E-type climate (refer to Table 8.2). If it is, go to step 2; if not, proceed to step 3.
2. Determine if the station is an ET or EF climate (see Table 8.2).
3. Determine if the station is a dry climate. If the station has a dry climate, identify the appropriate subcategories. If it is not an arid climate, continue on to step 4. Use Figure 8.1 if 70% of precipitation falls during the summer. Use Figure 8.2 if 70% of precipitation falls during the winter. Note that the summer season is April through September for the Northern Hemisphere, while the winter season is October through March. This is reversed for the Southern Hemisphere. Use Figure 8.3 if neither half of year has more than 70% of annual precipitation.
4. Determine if the station is an A-type climate (refer to Table 8.2). If so, go to step 5; if not, skip to step 6.
5. Determine subcategory of A-type climate, using Figure 8.4.
6. Determine if the station is a C- or D-type climate (refer to Table 8.2). Continue to step 7.
7. Identify the appropriate subcategories of the C- or D-type climate (Table 8.2).

TABLE 8.1	MAIN CLIMATE TYPES
Af	Tropical rainforest. Hot; rainy through all seasons.
Am	Tropical monsoon. Hot; pronounced wet season.
Aw	Tropical savanna. Hot; pronounced dry season (usually the low sun period).
BSh	Tropical steppe. Semiarid; hot.
BSk	Midlatitude steppe. Semiarid; cool or cold.
BWh	Tropical desert. Arid; hot.
BWk	Midlatitude desert. Arid; cool or cold.
Cfa	Humid subtropical. Mild winter; moist through all seasons; long, hot summer.
Cfb	Marine. Mild winter; moist through all seasons; warm summer.
Cfc	Marine. Mild winter; moist through all seasons; short, cool summer.
Csa	Interior Mediterranean. Mild winter; dry summer; hot summer.
Csb	Coastal Mediterranean. Mild winter; dry summer; cool summer.
Cwa	Subtropical monsoon. Mild winter; dry winter; hot summer.
Cwb	Tropical upland. Mild winter; dry winter; short, warm summer.
Dfa	Humid continental. Severe winter; moist through all seasons; long, hot summer.
Dfb	Humid continental. Severe winter; moist through all seasons; short, warm summer.
Dfc	Subarctic. Severe winter; moist through all seasons; short, cool summer.
Dfd	Subarctic. Extremely cold winter; moist through all seasons; short summer.
Dwa	Humid continental. Severe winter; dry winter; long, hot summer.
Dwb	Humid continental. Severe winter; dry winter; warm summer.
Dwc	Subarctic. Severe winter; dry winter; short, cool summer.
Dwd	Subarctic. Extremely cold winter; dry winter, short, cool summer.
ET	Tundra. Very short summer.
EF	Perpetual ice and snow.
H	Undifferentiated highland climates.

TABLE 8.2 SIMPLIFIED KÖPPEN CLASSIFICATION OF CLIMATE

First Letter	Second Letter	Third Letter
E Warmest month <10°C	**T** Warmest month between 10° – 0°C **F** Warmest month <0°C	Not applicable
B Arid and semiarid climate	**S** Semiarid climate; see Figures 8.1, 8.2, or 8.3. **W** Arid climate; see Figures 8.1, 8.2, or 8.3.	**h** Mean annual temperature is >18°C **k** Mean annual temperature is <18°C
A Coolest month >18°C	**f** Driest month precipitation ≥60mm **m** Seasonally, excessively moist; see Figure 8.4. **w** Driest month in winter half of year; precipitation in driest month ≤60mm.	Not applicable
C Coldest month 18° - 0°C; at least one month >10°C	**s** Driest month in summer half of year with ≤40mm of precipitation and <$^1/_3$ of the wettest winter month. **w** Driest month in winter half of year with <$^1/_{10}$ precipitation of wettest summer month. **f** Does not meet criteria for s or w above (moist all year)	**a** Warmest month ≥22°C **b** Warmest month <22°C with at least 4 months >10°C **c** Warmest month <22°C with 1 - 3 months >10°C
D Coldest month <0°C; at least one month >10°C	**s** Same as above **w** Same as above **f** Same as above	**a** Same as above **b** Same as above **c** Same as above **d** Coldest month < – 38°C
H Highland	Not applicable	Not applicable

FIGURE 8.1 SUMMER MAXIMUM PRECIPITATION

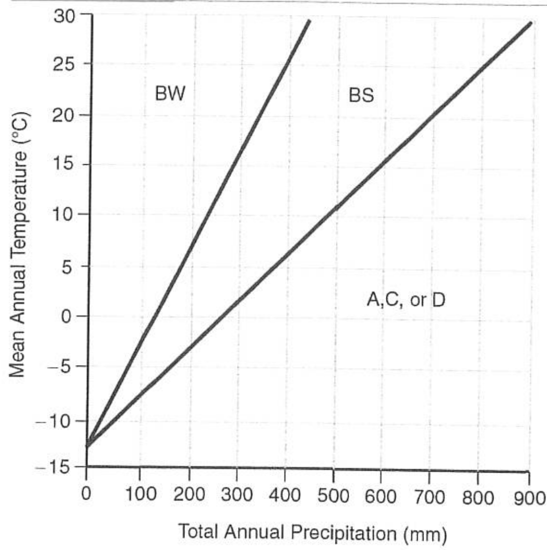


FIGURE 8.2 WINTER MAXIMUM PRECIPITATION

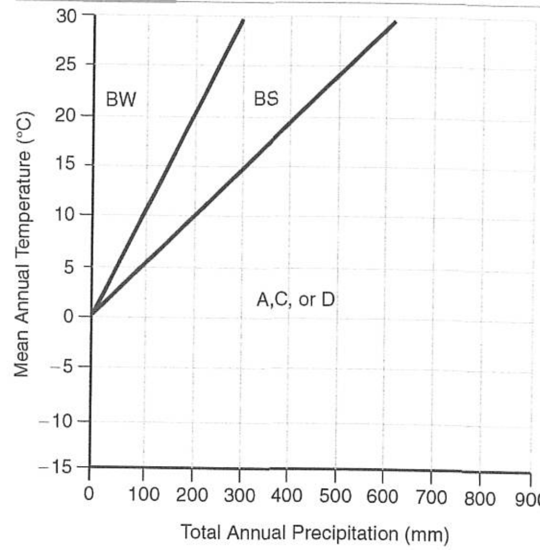


FIGURE 8.3 EVENLY DISTRIBUTED PRECIPITATION

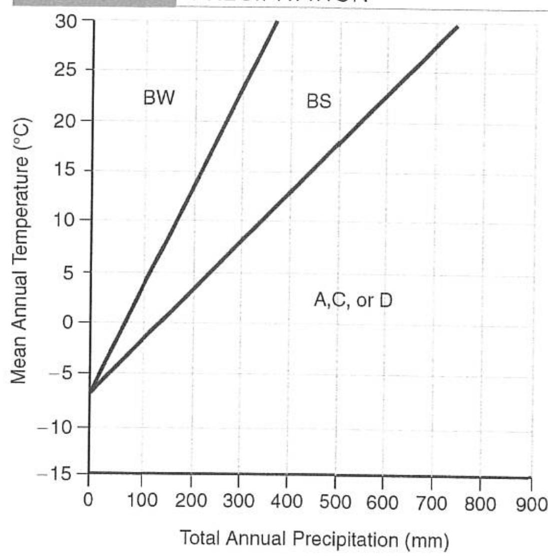
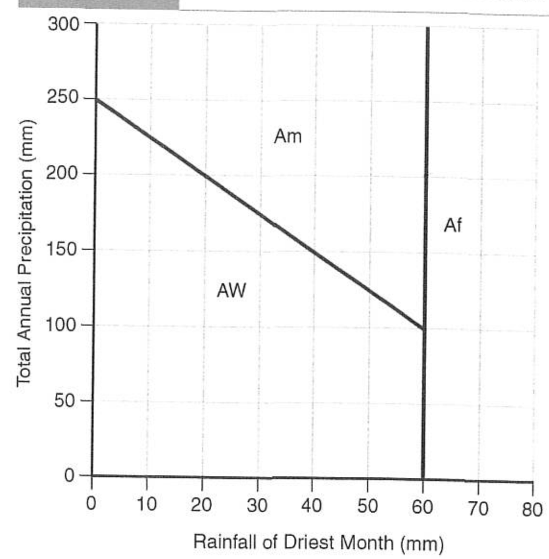


FIGURE 8.4 BOUNDARIES OF A-TYPE CLIMATES



IMPORTANT TERMS, PHRASES, AND CONCEPTS

intertropical convergence zone
subtropical high
subpolar low
polar front jet stream
heat reservoirs
upwelling
empirical classification
genetic classification
applied classification

Name: ______________________ **Section:** ______________________

PART 1 | CLIMATE CLASSIFICATION AND DISTRIBUTION

1. Plot the stations listed in Table 8.3 on the world map provided in Figure 8.5.

TABLE 8.3 CLIMATE DATA FOR SELECTED CITIES

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Iquitos, Peru (3°S,73°W)												
T (°C)	25.6	25.6	24.4	25	24.4	23.3	23.3	24.4	24.4	25	25.6	25.6
P (mm)	259	249	310	165	254	188	168	117	221	183	213	292
Chennai, India (13°N,80°E)												
T (°C)	24.5	25.8	27.9	30.5	32.7	32.5	30.7	30.1	29.7	28.1	26.0	24.6
P (mm)	24	7	15	25	52	53	83	124	118	267	308	157
Rangoon, Myanmar (17°N,96°E)												
T (°C)	24.3	25.2	27.2	29.8	29.5	27.8	27.6	27.1	27.6	28.3	27.7	25.0
P (mm)	8	5	6	17	260	524	492	574	398	208	34	3
Faya, Chad (18°N,21°E)												
T (°C)	20.3	22.5	26.2	30.3	33.4	34.1	33.3	32.7	32.6	29.8	24.5	21.2
P (mm)	0	0	0	0	.5	1.1	4.4	10.9	.9	0	0	0
Colorado Springs, Colorado (39°N,105°W)												
T (°C)	−1.7	0.0	2.9	8.0	13.0	18.3	21.5	20.1	15.7	9.9	3.2	−1.2
P (mm)	7.5	9.0	21.9	31.5	56.8	53.5	74.0	70.2	32.6	20.8	12.8	9.5
Sacramento, California (39°N,122°W)												
T (°C)	8	10	12	16	19	22	25	24	23	18	12	9
P (mm)	81	76	60	36	15	3	—	1	5	20	37	82

(continued)

TABLE 8.3 CLIMATE DATA FOR SELECTED CITIES (*CONTINUED*)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Montgomery, Alabama (32°N,86°W)												
T (°C)	7.9	10	13.9	18.2	22.3	26.1	27.6	27.3	24.7	18.6	13.2	9.3
P (mm)	109.6	129.4	152.6	114.8	100.9	94.3	126.7	85.2	113.9	61.3	92.4	128.9
Dubuque, Iowa (42°N,90°W)												
T (°C)	- 8.9	- 6.0	1.0	8.6	14.7	19.8	22.3	21	16.4	10.2	2.3	- 5.7
P (mm)	33.6	31.7	70.6	98.9	107.5	103.9	106.6	113.7	104.5	66.4	65.3	46
Barrow, Alaska (71°N,156°W)												
T (°C)	- 25.6	- 27.6	- 26.1	- 19	- 7	1.1	4	3.2	- 0.8	- 10.2	- 18.7	- 24
P (mm)	4.2	3.8	3.3	3.7	3.3	7.8	21.8	22.8	14.7	12.8	6.4	4.5
Albuquerque, New Mexico (35°N,106°W)												
T (°C)	1.2	4.4	8.2	12.8	17.8	23.4	25.8	24.3	20.3	13.8	6.8	1.8
P (mm)	10.3	10.5	12.4	11.1	13.8	13.3	33.4	39.3	23.3	21.5	11.7	13.3
Greenwich, England (51°N,0°)												
T (°C)	3.9	4.2	5.7	8.5	11.9	15.2	17	16.6	14.2	10.3	6.6	4.8
P (mm)	48.9	38.8	39.3	41.4	47	48.3	59	59.6	52.4	65.2	59.3	51.2
Dawson, Canada (64°N,139°W)												
T (°C)	- 28.6	- 23.8	- 14.5	- 1.6	7.8	13.7	15.3	12.5	6	- 3.5	- 17.2	- 24.9
P (mm)	19	16	12.1	11.1	23.7	34.2	45.1	43.2	33.3	29.2	25.5	24.2

2. Figure 8.6 contains climographs for all but four of the cities listed in Table 8.3. On the blank climographs provided in Figure 8.6, construct climographs for these four cities—Iquitos, Colorado Springs, Dubuque, and Dawson. Plot temperature as a line graph and precipitation as a bar graph.
3. Compute and enter the following statistics at the bottom of each climograph.
   a. Temperature range
   b. Average annual temperature
   c. Total annual precipitation
   d. Total summer precipitation
   e. Total winter precipitation

FIGURE 8.5 WORLD MAP

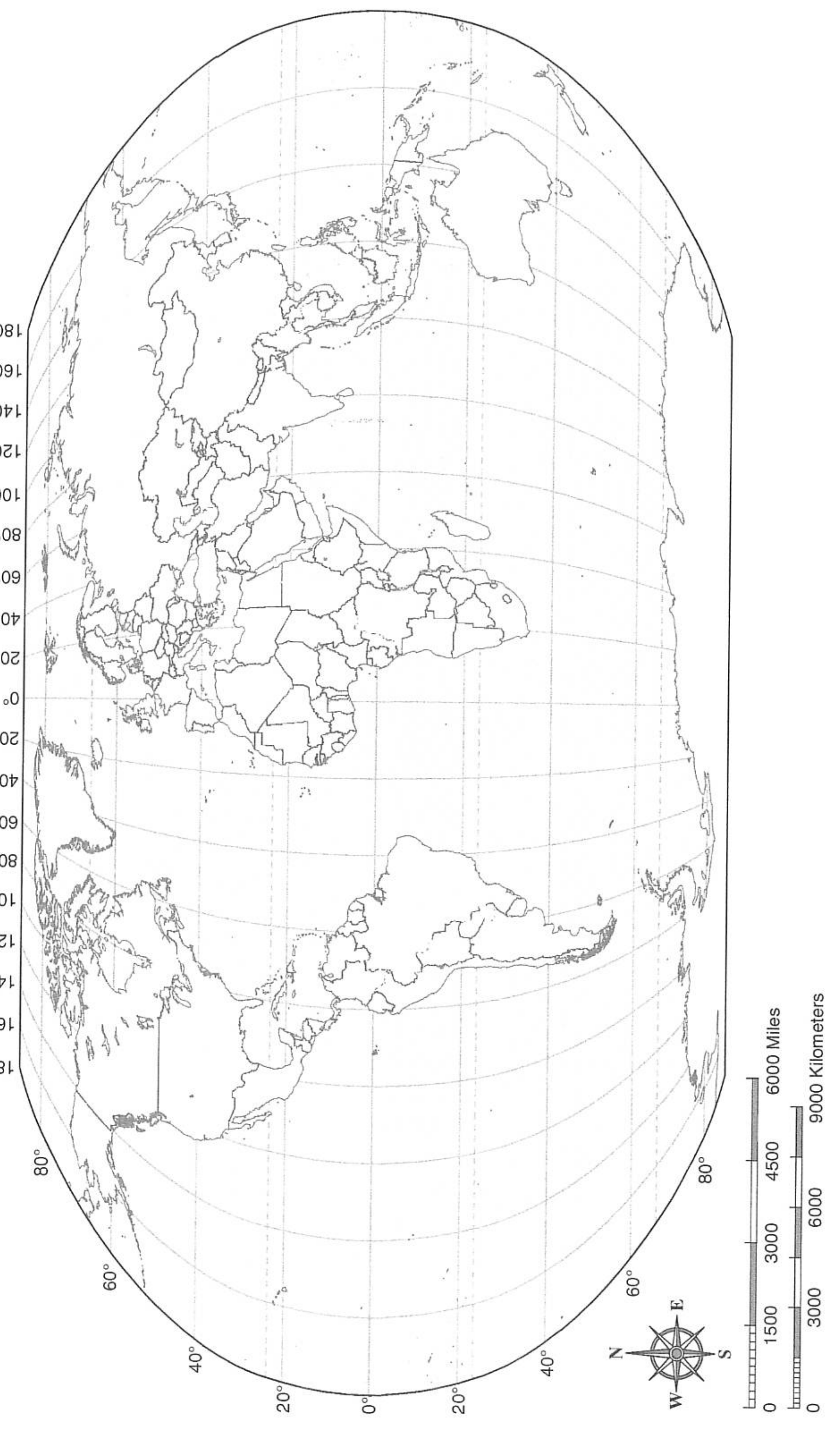
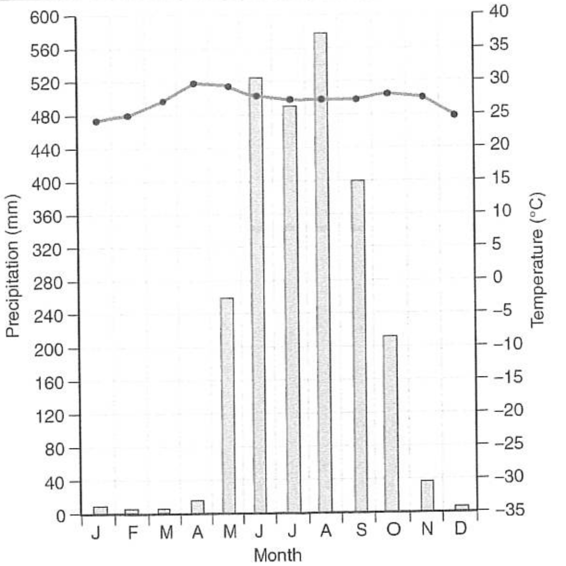
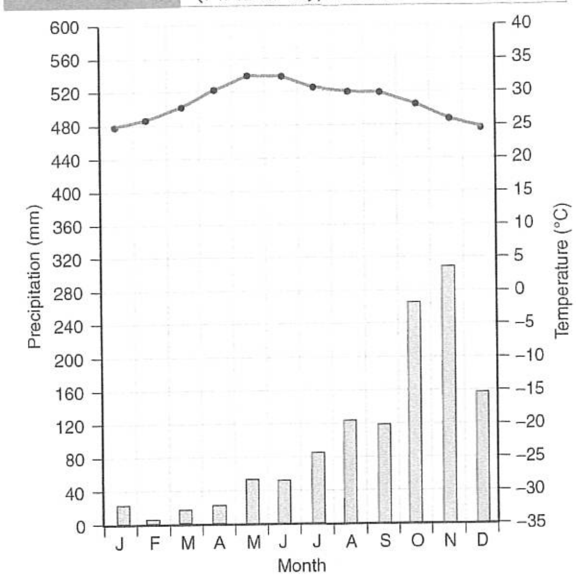


FIGURE 8.6a CLIMOGRAPH—RANGOON, MYANMAR



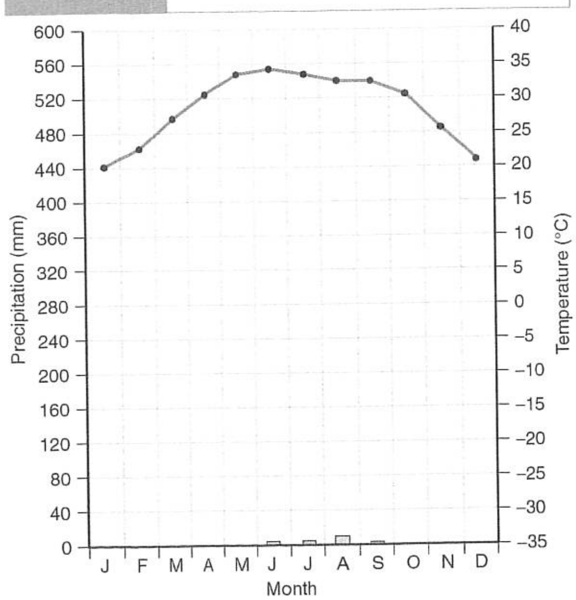
Climate	Tropical Monsoon
Annual Temperature Range	5.5°C
Avg. Annual Temperature	27.3°C
Summer Precipitation	2265.0 mm
Winter Precipitation	264.0 mm
Total Annual Precipitation	2529.0 mm

FIGURE 8.6b CLIMOGRAPH—CHENNAI (MADRAS), INDIA



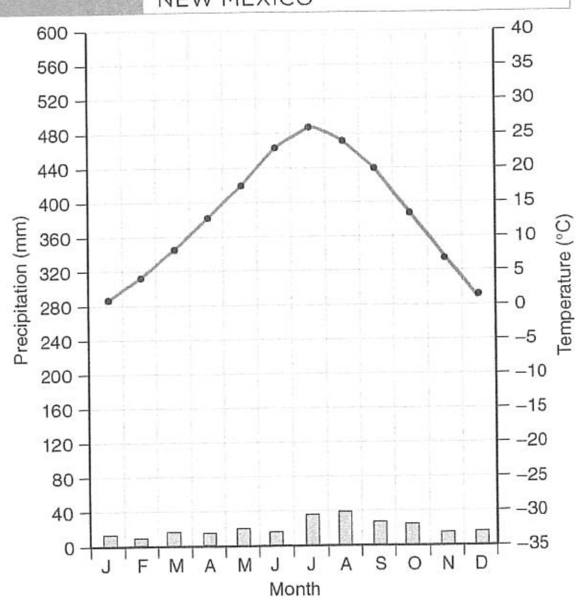
Climate	Tropical Savanna
Annual Temperature Range	8.2°C
Avg. Annual Temperature	28.6°C
Summer Precipitation	455.0 mm
Winter Precipitation	778.0 mm
Total Annual Precipitation	1233.0 mm

FIGURE 8.6c CLIMOGRAPH—FAYA, CHAD



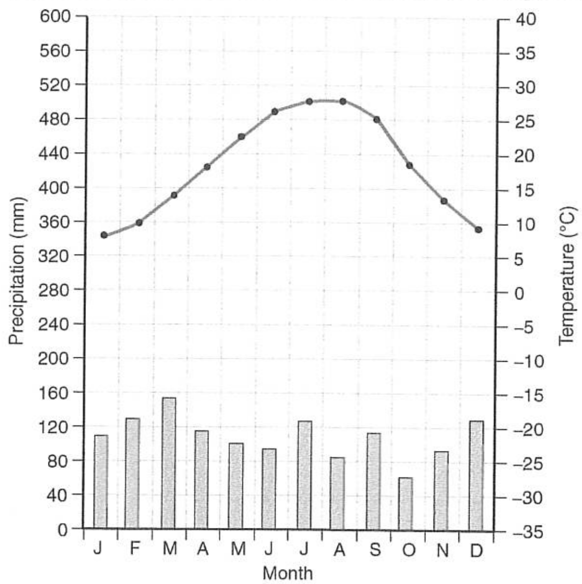
Climate	Tropical Desert
Annual Temperature Range	13.8°C
Avg. Annual Temperature	28.7°C
Summer Precipitation	16.0 mm
Winter Precipitation	0.0 mm
Total Annual Precipitation	16.0 mm

FIGURE 8.6d CLIMOGRAPH—ALBUQUERQUE, NEW MEXICO



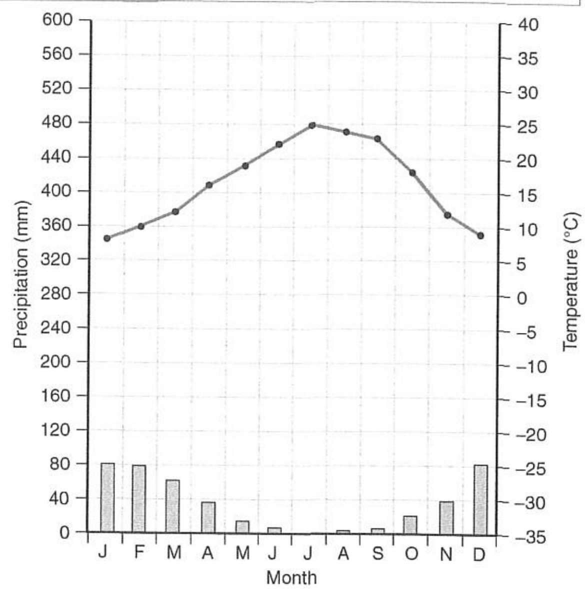
Climate	Midlatitude Desert
Annual Temperature Range	24.6°C
Avg. Annual Temperature	13.4°C
Summer Precipitation	134.2 mm
Winter Precipitation	79.7 mm
Total Annual Precipitation	213.9 mm

FIGURE 8.6e CLIMOGRAPH—MONTGOMERY, ALABAMA



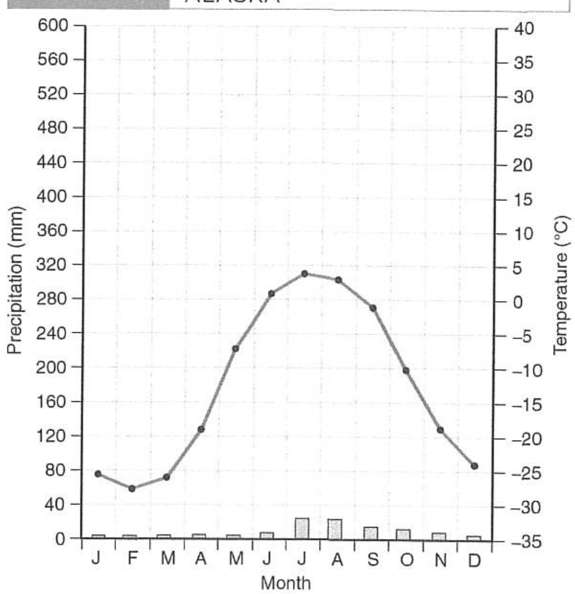
Climate	Humid Subtropical
Annual Temperature Range	19.7°C
Avg. Annual Temperature	18.3°C
Summer Precipitation	635.8 mm
Winter Precipitation	674.2 mm
Total Annual Precipitation	1310.0 mm

FIGURE 8.6f CLIMOGRAPH—SACRAMENTO, CALIFORNIA



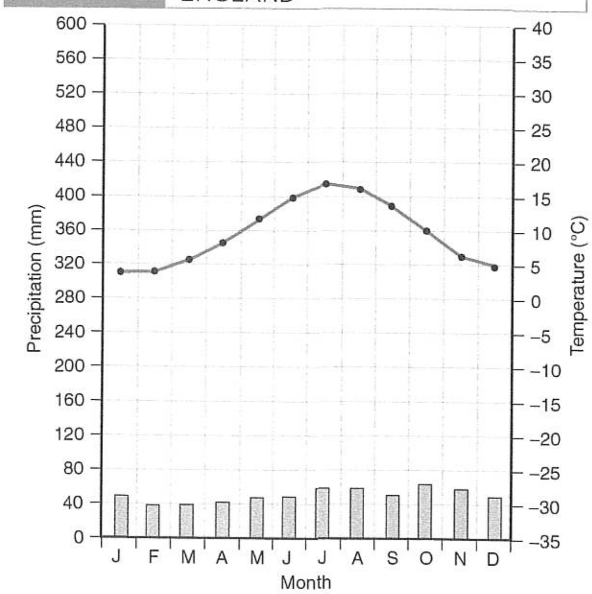
Climate	Mediterranean
Annual Temperature Range	17.0°C
Avg. Annual Temperature	16.5°C
Summer Precipitation	60.0 mm
Winter Precipitation	356.0 mm
Total Annual Precipitation	416.0 mm

FIGURE 8.6g CLIMOGRAPH—BARROW, ALASKA



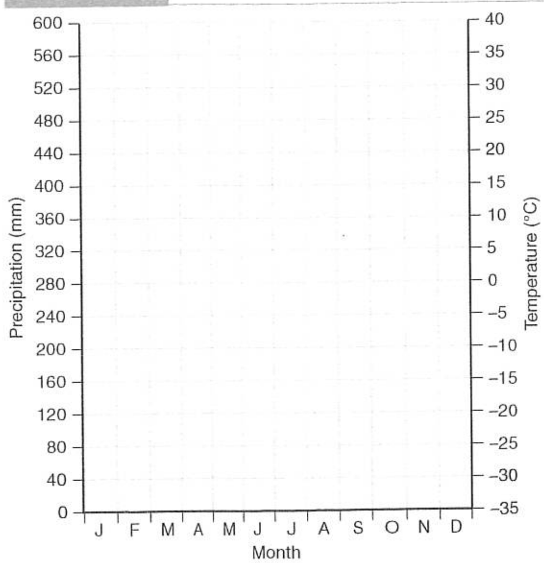
Climate	Tundra
Annual Temperature Range	31.6°C
Avg. Annual Temperature	−12.6°C
Summer Precipitation	74.1 mm
Winter Precipitation	35.0 mm
Total Annual Precipitation	109.1 mm

FIGURE 8.6h CLIMOGRAPH—GREENWICH, ENGLAND



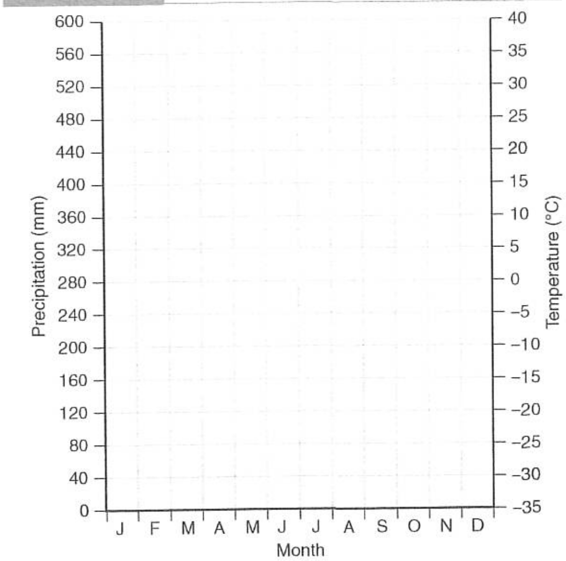
Climate	Marine
Annual Temperature Range	13.1°C
Avg. Annual Temperature	9.9°C
Summer Precipitation	307.7 mm
Winter Precipitation	302.7 mm
Total Annual Precipitation	610.4 mm

FIGURE 8.6i CLIMOGRAPH—______________



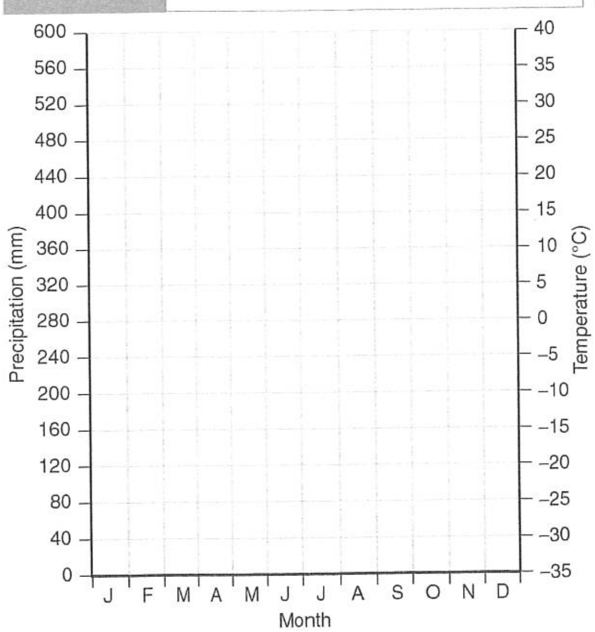
Climate ______________
Annual Temperature Range ______________
Avg. Annual Temperature ______________
Summer Precipitation ______________
Winter Precipitation ______________
Total Annual Precipitation ______________

FIGURE 8.6j CLIMOGRAPH—______________



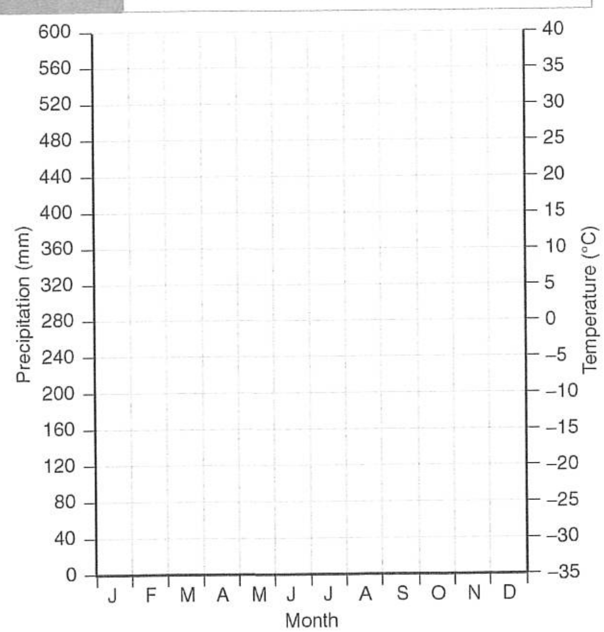
Climate ______________
Annual Temperature Range ______________
Avg. Annual Temperature ______________
Summer Precipitation ______________
Winter Precipitation ______________
Total Annual Precipitation ______________

FIGURE 8.6k CLIMOGRAPH—______________



Climate ______________
Annual Temperature Range ______________
Avg. Annual Temperature ______________
Summer Precipitation ______________
Winter Precipitation ______________
Total Annual Precipitation ______________

FIGURE 8.6l CLIMOGRAPH—______________



Climate ______________
Annual Temperature Range ______________
Avg. Annual Temperature ______________
Summer Precipitation ______________
Winter Precipitation ______________
Total Annual Precipitation ______________

4. Use Tables 8.2 and 8.3 and Figures 8.1 through 8.4 to classify each station's climate.
   Use the data in Table 8.3, the summary data associated with the climographs in Figure 8.6, and your knowledge of climates to answer the remaining questions.

5. a. During which sun period (high or low) does most of the precipitation occur in Iquitos, Peru?

   b. What is responsible for the large amount of precipitation during this time?

6. Compare and contrast the seasonal temperature and precipitation variations of the rainforest and monsoon climates.

7. What is responsible for Colorado Springs' dry climate?

8. How do the midlatitude desert (BWk) climates differ from the tropical desert (BWh) climates?

9. Sacramento, California, and Montgomery, Alabama, are located at about the same latitude and have similar average annual temperatures. Why do they have such different precipitation regimes?

10. a. When (summer or winter season) does most of the precipitation fall in the subarctic climates?

    b. Why?

11. Why does Sacramento receive most of its precipitation during the winter?

12. a. Which climate station has the largest temperature range? ____________________

    b. What is responsible for its large temperature range?

13. a. On the graph provided, plot the temperature range (listed in Figure 8.6) on the *Y*-axis versus latitude (listed in Table 8.3) on the *X*-axis for each of the stations in Table 8.3. There is no need to differentiate between Northern and Southern Hemisphere locations.

    b. Estimate the position and draw a trend line (straight line) through the plotted points.

14. Describe the relationship between latitude and temperature range represented by your trend line.

15. a. Which points seem to deviate vertically the most from the trend line?

    b. Is there anything about their location that explains their large deviations?