Global Climates

No investigation of the atmosphere is complete without examining the global distribution of the major atmospheric elements. To help understand this worldwide diversity, scientists have devised a variety of classification systems that simplify and describe the general weather conditions that occur at various places on Earth.

Exercise 16 investigates world climates using the system of climate classification devised by Wladimir Köppen (1846–1940). Climographs for several climatic types will be prepared and the global distribution of climates will be examined (Figure 16.1).

Objectives

After you have completed this exercise, you should be able to:

1. Understand the nature of classification systems.
2. Read and prepare a climograph.
3. List the criteria used to define each principal climatic type.
4. Describe the general location of each principal climate group.

Materials

ruler
calculator

Materials Supplied by Your Instructor

world map or atlas

Terms

climate   Köppen system
climatology   climograph

Climate

Climate may be defined as the synthesis, or summary, of weather conditions at a particular place over a long period of time. Climatic classification simplifies the complex distribution of the weather elements for analysis and explanation.

Climatology involves grouping those areas that have similar weather characteristics. Temperature and precipitation are the two elements most commonly used in climate classifications. However, other methods, using different criteria, have also been developed. It should be remembered that any classification is artificial, and its value depends on the intended use.

Examining Global Temperatures

Temperature is one of the most essential elements in any climate classification. Completing questions 1–3 using the temperature data in Table 16.1 will help you gain a better understanding of the relationship between location and temperature.

1. Stations 1–3 in Table 16.1 are representative of three North American cities at approximately 40° North latitude. Choose which station represents each of the following locations, and give the reason for your selection.

   Interior of the continent? _____

   _____

   West coast of the continent? _____

   _____

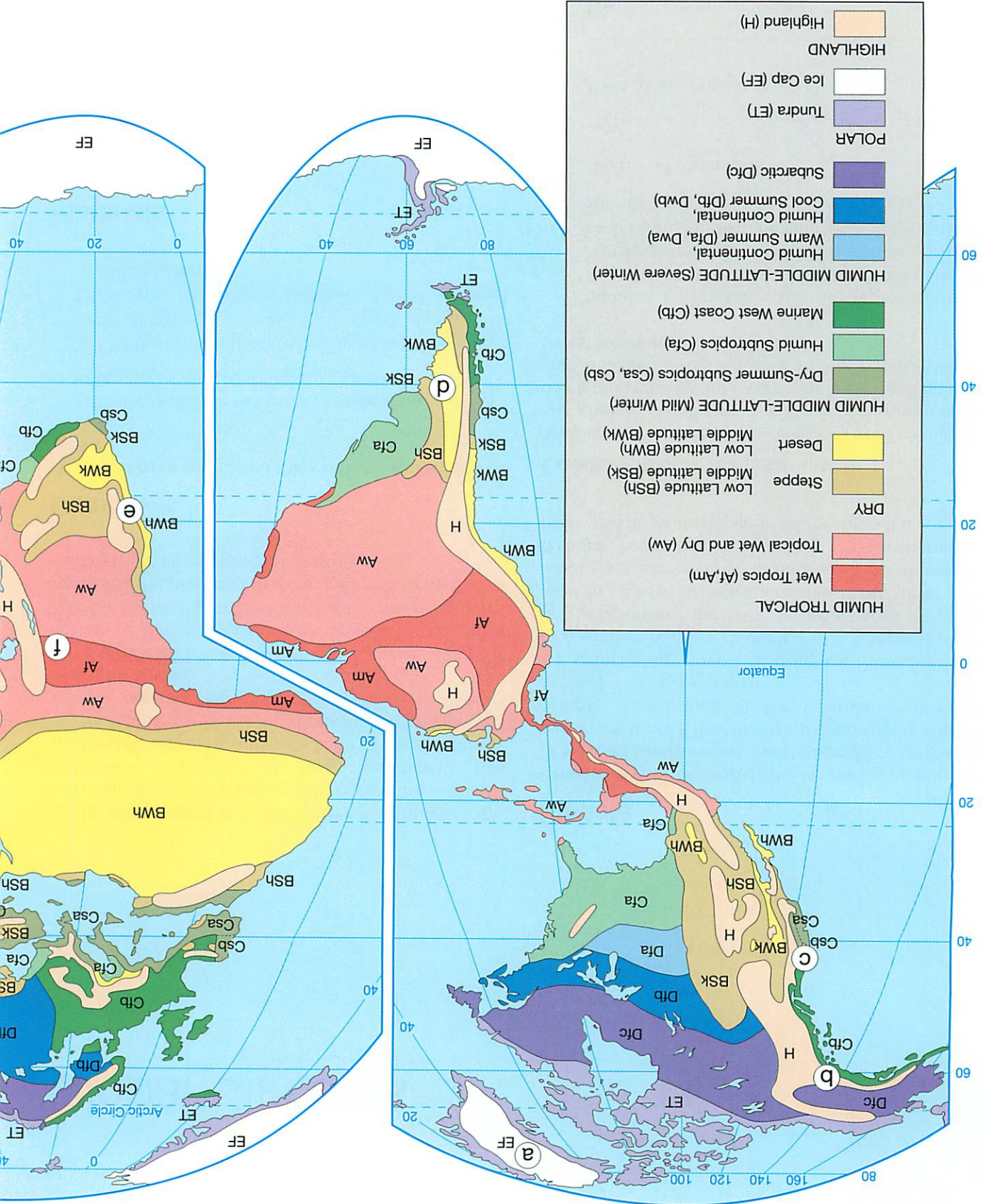   East coast of the continent? _____

   _____

Figure 16.1 Climates of the world (Köppen). (Adapted from E. Willard Miller, *Physical Geography*, Columbus, Ohio, Macmillan/Merrill, 1985. Plate 2)
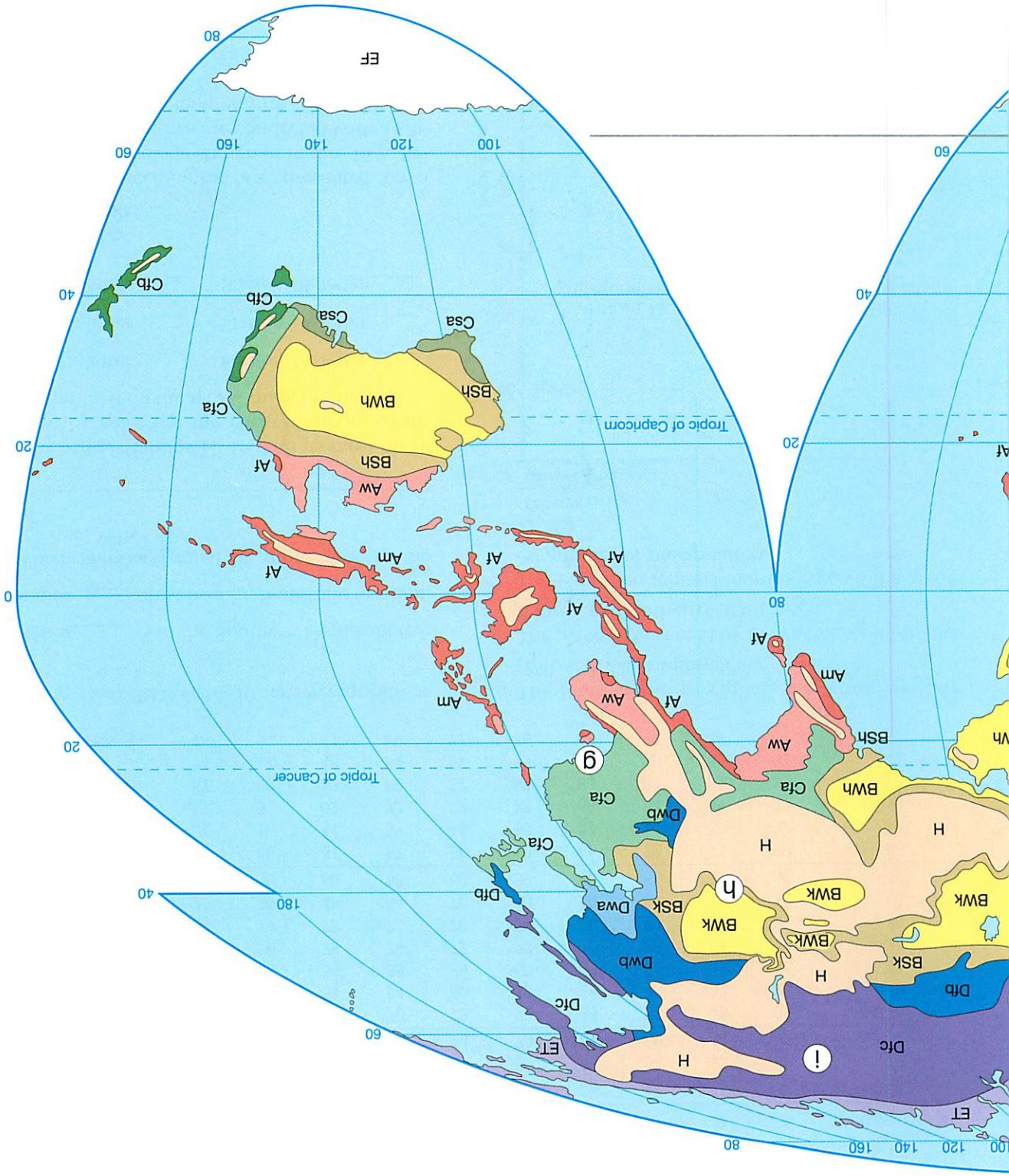
Table 16.1 Annual Temperature Data (°F)

STATION	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL MEAN
1	25	28	36	48	61	72	75	74	66	55	39	28	50
2	48	48	49	50	54	55	57	57	57	54	52	49	52
3	31	31	38	49	60	69	74	73	69	59	44	35	52
4	25	26	35	45	58	70	75	72	65	55	45	35	50
5	20	34	38	46	51	54	60	53	49	40	32	25	40
6	42	48	50	55	56	58	59	60	59	56	48	46	51
7	76	76	76	76	78	78	77	77	76	75	74	74	76
8	90	88	84	79	77	73	70	71	76	79	82	87	80
9	−2	11	25	36	48	54	70	60	50	36	18	10	34
10	59	58	59	59	60	58	60	59	60	58	59	60	59
11	70	69	69	66	61	57	56	60	66	70	71	70	66
12	−46	−35	−10	16	41	59	66	60	42	16	−21	−41	12
13	22	25	37	51	62	72	77	75	66	54	39	27	50
14	82	82	82	83	83	82	82	83	83	83	82	83	83
15	27	30	34	41	48	54	57	55	50	43	36	31	42
16	40	44	48	54	61	69	77	76	67	57	47	41	57

2. Selecting from Stations 4–10, answer questions 2a–c.

   a. Station _____ is in the Southern Hemisphere.

   b. Station _____ must be a high-altitude location.

   c. Which station(s) must be quite close to the equator? Why?

   _____

3. Match each of Stations 11–16 with its most likely location by selecting the corresponding lower-case letter (a–i) on the world map, Figure 16.1.

   Station 11: letter _____   Station 14: letter _____

   Station 12: letter _____   Station 15: letter _____

   Station 13: letter _____   Station 16: letter _____

Using a Climograph

Temperature and precipitation are presented on a **climograph** such as the one shown in Figure 16.2. Average monthly temperatures are connected with a single line and read from the temperature scale on the left axis. Average precipitation for each month is represented with a bar or line and read from the precipitation scale on the right axis.

   Refer to the climograph, Figure 16.2, to answer questions 4–9. Circle the correct response.

4. At the place represented by the climograph, the month of (May, June, January) receives the greatest amount of precipitation.

5. The lowest temperature occurs during the month of (July, December, January).

6. The approximate average annual temperature is (0, 10, 20)°C.

7. The total annual precipitation is approximately (240, 480, 720) millimeters.

8. The place represented by the climograph is in the (Northern, Southern) Hemisphere.

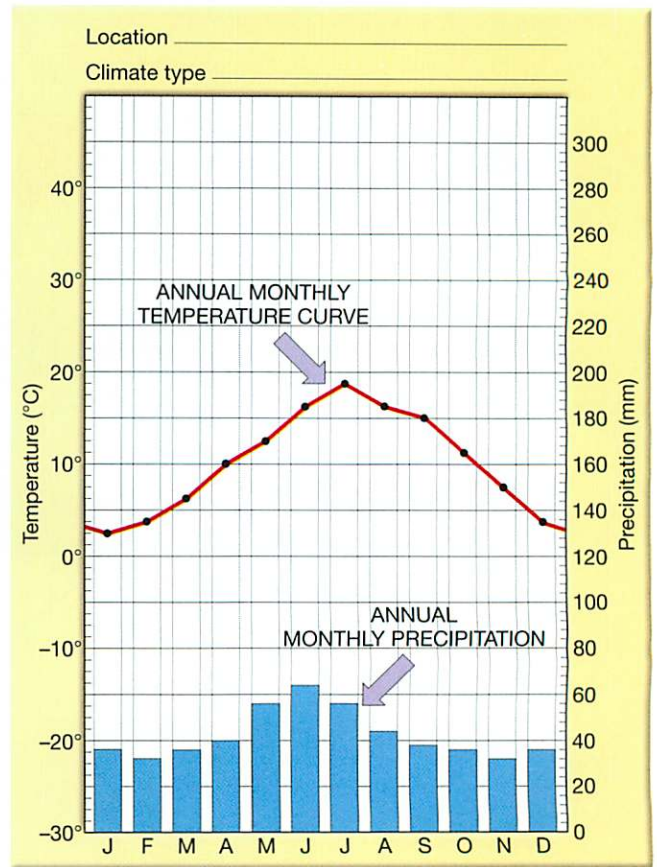9. The (summer, winter) months receive the greatest amount of precipitation.

Figure 16.2 Typical climograph. Letters along the bottom margin represent the months. Average monthly temperatures (°C) are plotted with a single line using the scale on the left axis. Precipitation for each month (in mm) is plotted with a bar using the right axis.
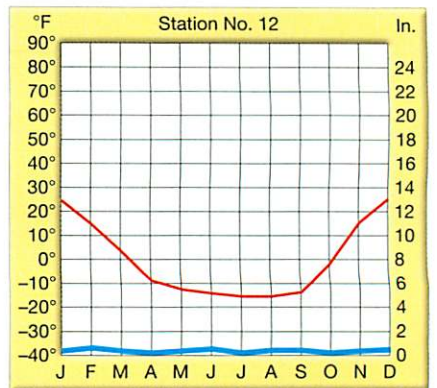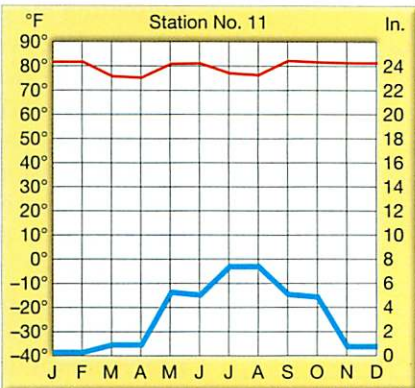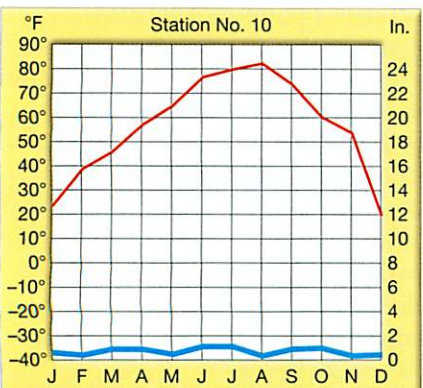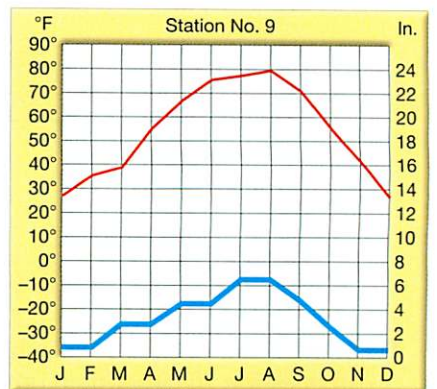
The Nature of Classification

Classification by its nature is an artificial endeavor designed to simplify a large amount of data into manageable units. To accomplish this, decisions must be made as to which criteria and limits best serve the purpose of the classification. Completing questions 10–12 using the climographs in Figure 16.3 will give you some insight into the nature of conceiving a classification scheme.

10. Working in groups of 4 or 5, develop the best possible classification scheme for the stations represented by the climographs in Figure 16.3 by arranging them into groups with similar characteristics. When you have finished, describe your classification system, listing the criteria you established. (*Note:* Making a copy of Figure 16.3 and cutting out individual stations may make it easier to visualize different classification arrangements.)

_____

_____

_____

_____

_____

_____

_____

11. Why is the classification scheme you presented in question 10 better than other possible systems you considered?

_____

_____

_____

_____

_____

12. Compare the classification system your group devised with the systems developed by two other groups. Which is the best classification scheme? Why?

_____

_____

_____

_____

_____

_____

_____

_____

Köppen System of Climatic Classification

Table 16.2 presents the climatic classification system devised by Wladimir Köppen. Since its introduction, the **Köppen system**, with some modification, has become the best-known and most-used classification for presenting the general world pattern of climates.

The Köppen system of climatic classification employs five principal climate groups. Four of the groups are defined on the basis of temperature characteristics and the fifth has precipitation as its primary criterion. Further division of the groups into climatic types allows for a more detailed climatic description. Köppen believed that the distribution of natural vegetation was the best expression of the totality of climate. Therefore, the boundaries he chose were based largely on the limits of certain plant associations. Before you proceed, examine Table 16.2 closely.

13. On Table 16.3, list the names and general characteristics of each principal climate group next to its designated classification letter. Use Table 16.2 as a reference.
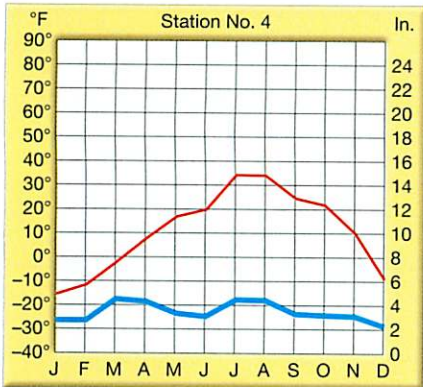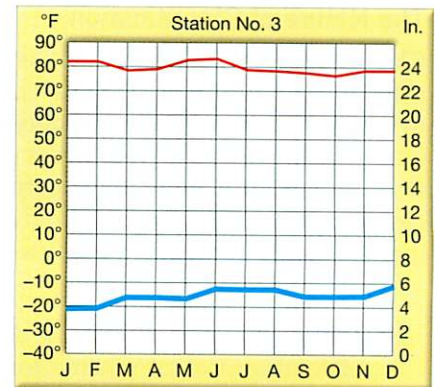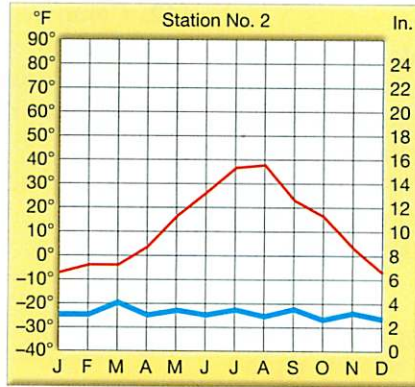
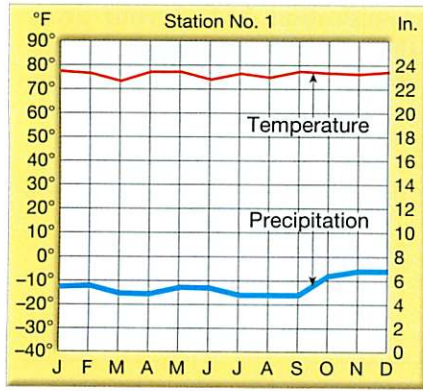**Figure 16.3** Generalized climographs.

Table 16.2   Köppen System of Climatic Classification

NAME	LETTER SYMBOL			CHARACTERISTICS
	1ST	**2ND**	**3RD**	
	A			Average temperature of the coldest month is 18°C or higher
Humid Tropical (type A) Climates		f		Every month has 6 cm of precipitation or more
		m		Short dry season; precipitation in driest month less than 6 cm but equal to or greater than $10 - R/25$ (R is the annual rainfall in cm)
		w		Well-defined winter dry season; precipitation in driest month less than $10 - R/25$
		s		Well-defined summer dry season (rare)
Dry (type B) Climates	B			Potential evaporation exceeds precipitation. The dry–humid boundary is defined by the following formulas: (*Note*: R is average annual precipitation in cm and T is average annual temperature in °C) $R < 2T + 28$ when 70% or more of rain falls in warmer 6 months $R < 2T$ when 70% or more of rain falls in cooler 6 months $R < 2T + 14$ when neither half year has 70% or more of rain
		S		Steppe ⎤
				The BS–BW boundary is 1/2 the dry–humid boundary
		W		Desert ⎦
			h	Average annual temperature is 18°C or greater
			k	Average annual temperature is less than 18°C
	C			Average temperature of the coldest month is under 18°C and above −3°C
Humid Middle-Latitude with Mild Winters (type C) Climates		w		At least ten times as much precipitation in a summer month as in the driest winter month
		s		At least three times as much precipitation in a winter month as in the driest summer month; precipitation in driest summer month less than 4 cm
		f		Criteria for w and s cannot be met
			a	Warmest month is over 22°C; at least 4 months over 10°C
			b	No month above 22°C; at least 4 months over 10°C
			c	One to 3 months above 10°C
	D			Average temperature of coldest month is −3°C or below; average temperature of warmest month is greater than 10°C
Humid Middle-Latitude with Severe Winters (type D) Climates		s		Same as under C climates
		w		Same as under C climates
		f		Same as under C climates
			a	Same as under C climates
			b	Same as under C climates
			c	Same as under C climates
			d	Average temperature of the coldest month is −38°C or below
	E			Average temperature of the warmest month is below 10°C
Polar (type E) Climates		T		Average temperature of the warmest month is greater than 0°C and less than 10°C
		F		Average temperature of the warmest month is 0°C or below

Table 16.3   Characteristics of the Principal Climate Groups

CLIMATE GROUP	NAME	TEMPERATURE AND/OR PRECIPITATION CHARACTERISTICS
A:	_____	_____
B:	_____	_____
C:	_____	_____
D:	_____	_____
E:	_____	_____

Table 16.4 Climatic Data for Representative Stations

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
IQUITOS, PERU (AF); LAT. 3°39′S; 115 M													
Temp. (°C)	25.6	25.6	24.4	25.0	24.4	23.3	23.3	24.4	24.4	25.0	25.6	25.6	24.7
Precip. (mm)	259	249	310	165	254	188	168	117	221	183	213	292	2619
RIO DE JANEIRO, BRAZIL (AW); LAT. 22°50′S; 26 M													
Temp. (°C)	25.9	26.1	25.2	23.9	22.3	21.3	20.8	21.1	21.5	22.3	23.1	24.4	23.2
Precip. (mm)	137	137	143	116	73	43	43	43	53	74	97	127	1086
FAYA, CHAD (BWH); LAT. 18°00′N; 251 M													
Temp. (°C)	20.4	22.7	27.0	30.6	33.8	34.2	33.6	32.7	32.6	30.5	25.5	21.3	28.7
Precip. (mm)	0	0	0	0	0	2	1	11	2	0	0	0	16
SALT LAKE CITY, UTAH (BSK); LAT. 40°46′N; 1288 M													
Temp. (°C)	−2.1	0.9	4.7	9.9	14.7	19.4	24.7	23.6	18.3	11.5	3.4	−0.2	10.7
Precip. (mm)	34	30	40	45	36	25	15	22	13	29	33	31	353
WASHINGTON, D.C. (CFA); LAT. 38°50′N; 20 M													
Temp. (°C)	2.7	3.2	7.1	13.2	18.8	23.4	25.7	24.7	20.9	15.0	8.7	3.4	13.9
Precip. (mm)	77	63	82	80	105	82	105	124	97	78	72	71	1036
BREST, FRANCE (CFB); LAT. 48°24′N; 103 M													
Temp. (°C)	6.1	5.8	7.8	9.2	11.6	14.4	15.6	16.0	14.7	12.0	9.0	7.0	10.8
Precip. (mm)	133	96	83	69	68	56	62	80	87	104	138	150	1126
ROME, ITALY (CSA); LAT. 41°52′N; 3 M													
Temp. (°C)	8.0	9.0	10.9	13.7	17.5	21.6	24.4	24.2	21.5	17.2	12.7	9.5	15.9
Precip. (mm)	83	73	52	50	48	18	9	18	70	110	113	105	749
PEORIA, ILLINOIS (DFA); LAT. 40°45′N; 180 M													
Temp. (°C)	−4.4	−2.2	4.4	10.6	16.7	21.7	23.9	22.7	18.3	11.7	3.8	−2.2	10.4
Precip. (mm)	46	51	69	84	99	97	97	81	97	61	61	51	894
VERKHOYANSK, RUSSIA (DFD); LAT. 67°33′N; 137 M													
Temp. (°C)	−46.8	−43.1	−30.2	−13.5	2.7	12.9	15.7	11.4	2.7	−14.3	−35.7	−44.5	−15.2
Precip. (mm)	7	5	5	4	5	25	33	30	13	11	10	7	155
IVIGTUT, GREENLAND (ET); LAT. 61°12′N; 129 M													
Temp. (°C)	−7.2	−7.2	−4.4	−0.6	4.4	8.3	10.0	8.3	5.0	1.1	−3.3	−6.1	0.7
Precip. (mm)	84	66	86	62	89	81	79	94	150	145	117	79	1132
MCMURDO STATION, ANTARCTICA (EF); LAT. 77°53′S; 2 M													
Temp. (°C)	−4.4	−8.9	−15.5	−22.8	−23.9	−24.4	−26.1	−26.1	−24.4	−18.8	−10.0	−3.9	−17.4
Precip. (mm)	13	18	10	10	10	8	5	8	10	5	5	8	110

Table 16.4 contains climatic data for several stations that are representative of Köppen climatic types. Use the data in Tables 16.2 and 16.4 to answer the following questions.

Humid Tropical (type A) Climates

With the exception of the dry climates, no other climate covers as large an area on Earth as the humid tropical climates.

14. What temperature criterion is used for defining an A climate?

_____

15. Plot the monthly temperature and precipitation data for Iquitos, Peru, an A climate, given in Table 16.4 on the climate chart, Figure 16.4.

Use the Iquitos, Peru, climograph you prepared in question 15 to answer questions 16–19.

16. What is the *annual temperature range* (difference between highest and lowest monthly temperatures) for Iquitos?
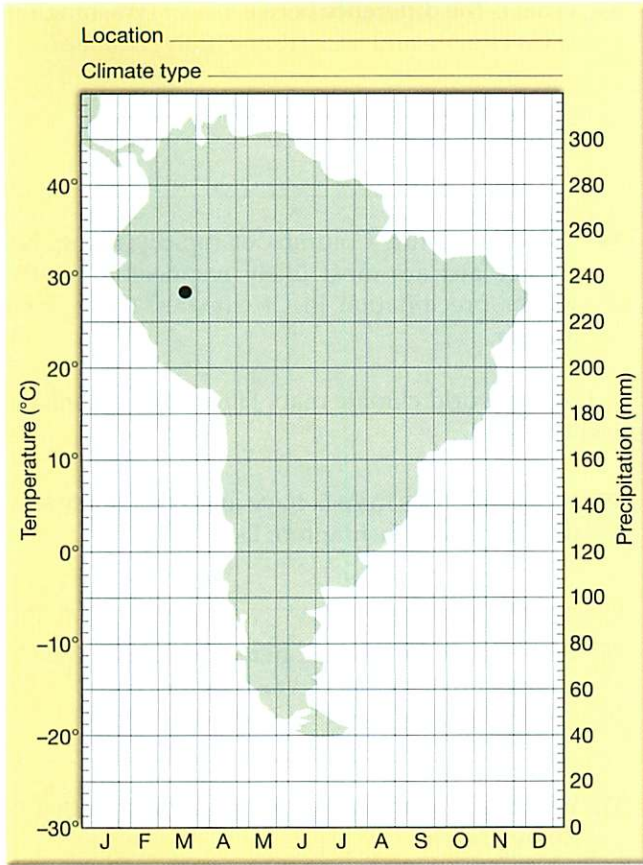
_____ °C

Location _____

Climate type _____

Figure 16.4 Climograph for Iquitos, Peru.

17. Describe the yearly variability of temperature for A climates.

_____

18. Notice that Iquitos receives an average of 2,619 mm of precipitation per year. How many inches of precipitation per year would this equal? (*Hint:* You may have to refer to the conversion tables located on the inside back cover of this manual.)

2,619 mm equals _____ inches

19. The precipitation at Iquitos is (concentrated in one season, distributed throughout the year). Circle your answer.

Use the world climate map, Figure 16.1, to answer questions 20–22.

20. In what latitude belt are A climates located?

_____

21. The most extensive areas of tropical rain forest (Af) climates are located (along coasts, in the interiors) of continents. Circle your answer.

22. Considering the locations of A climates, would weather fronts or columns of rapidly rising, hot

surface air be most likely responsible for the precipitation? Explain your answer.

_____

_____

Dry (type B) Climates

Of all the climate groups, the dry climates cover the greatest portion of Earth's surface. To be classified as a dry climate does not necessarily imply little or no precipitation, but rather indicates that the yearly precipitation is not as great as the potential loss of moisture by evaporation.

23. What are three variables that the Köppen classification uses to establish the boundary between dry and humid climates?

1) _____

2) _____

3) _____

24. What name is applied to the following climatic types?

BW: _____

BS: _____

25. What is the primary cause of arid climates in the tropics?

_____

26. What factors contribute to the formation of arid climates in the middle latitudes?

_____

_____

To answer questions 27 and 28, refer to the world climate map, Figure 16.1.

27. At what latitudes, North and South, are the most extensive arid areas located?

_____

28. The Sahara desert in northern Africa is the largest area in the world with a BWh climate. What are some other regions that have the same climate?

_____

Humid Middle-Latitude Climates with Mild Winters (type C)

A large percentage of the world's population is located in areas with C climates. It is a climate characterized by weather contrasts brought about by changing seasons. On the average, the regions of C climates are dominated by contrasting air masses and associated middle-latitude cyclones.

29. What temperature criterion is used to define the boundary of C climates?

_____

30. Using the data in Table 16.4, on Figure 16.5, prepare climographs for Washington, D.C., and Rome, Italy.

Answer questions 31–34 using the climographs you have constructed for Washington, D.C., and Rome, Italy, Figure 16.5.

31. In what manner are the temperature curves for each of the two cities similar?

_____

32. How does the annual distribution of precipitation vary between the two cities?

_____

33. What is the difference between a Cf (Washington, D.C.) climate and a Cs (Rome, Italy) climate?

_____

_____

34. (Weather fronts, Columns of rapidly rising, hot surface air) are most likely responsible for the winter precipitation in Cf climates. Circle your answer.

Use the world climate map, Figure 16.1, to answer questions 35–37.

35. What countries in Asia have areas of climate similar to that of Washington, D.C.?

_____

36. What Southern Hemisphere countries have climates similar to that of Washington, D.C.?

_____

37. Which U.S. state has a climate similar to that of Rome, Italy?
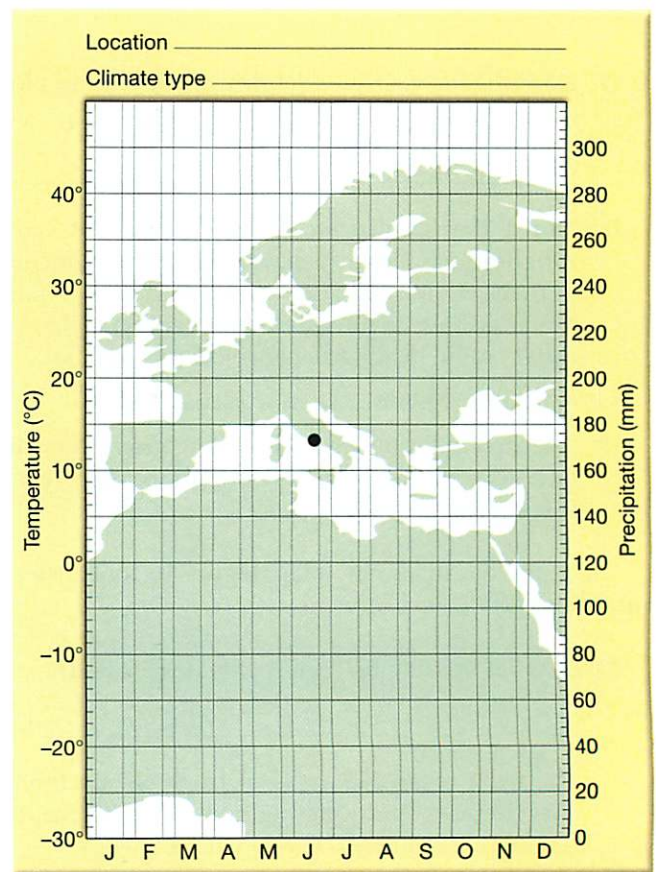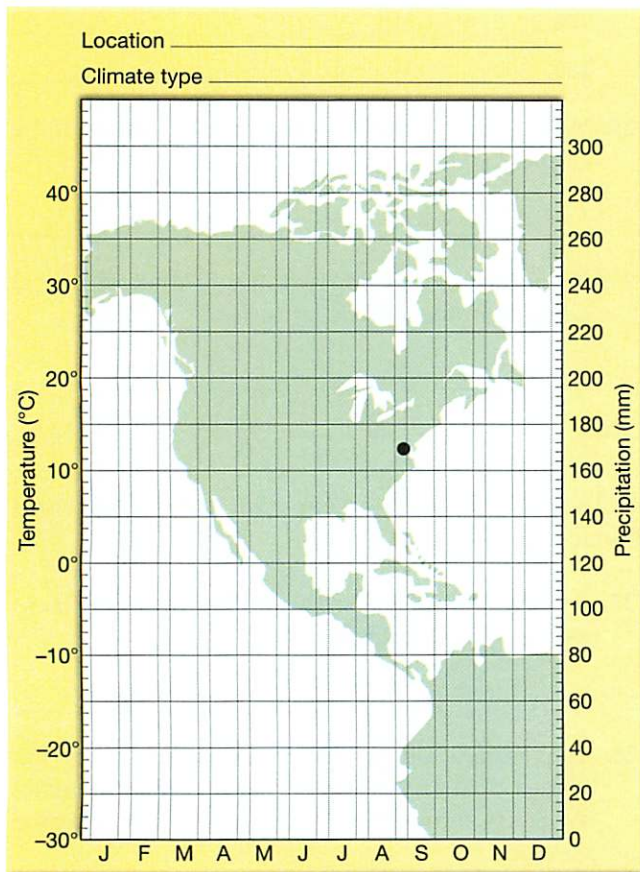
_____

Figure 16.5 Climographs for Washington, D.C., and Rome, Italy.

Humid Middle-Latitude Climates with Severe Winters (type D)

The harsh winters and relatively short growing season restrict agricultural activity in much of the area of D climates. The northern portions of D climate regions are covered by coniferous forests, with lumbering being a significant economic activity.

38. What criteria are used for defining a D climate?

_____

_____

39. Use the data from Table 16.4 to plot a climograph for Peoria, Illinois, on Figure 16.6.

Use the climograph you have constructed for Peoria, Illinois, Figure 16.6, to answer questions 40–42.

40. What is the annual range of temperature in Peoria, Illinois?

_____°C

41. How does the annual range of temperature in Peoria, Illinois, compare to the temperature ranges in Iquitos, Peru, and Rome, Italy?

_____

_____

_____

_____

_____

42. During what season does Peoria receive its greatest precipitation and how does this compare with the seasonal distribution of precipitation for Rome, Italy?

_____

_____

_____

_____

_____

Use the world climate map, Figure 16.1, to answer questions 43–45.

43. Which continent has the greatest continuous expanse of D climates?

_____

44. D climates are located only in the (Northern, Southern) Hemisphere. Circle your answer.

45. Suggest a reason why D climates are located in only the hemisphere you selected in question 44.
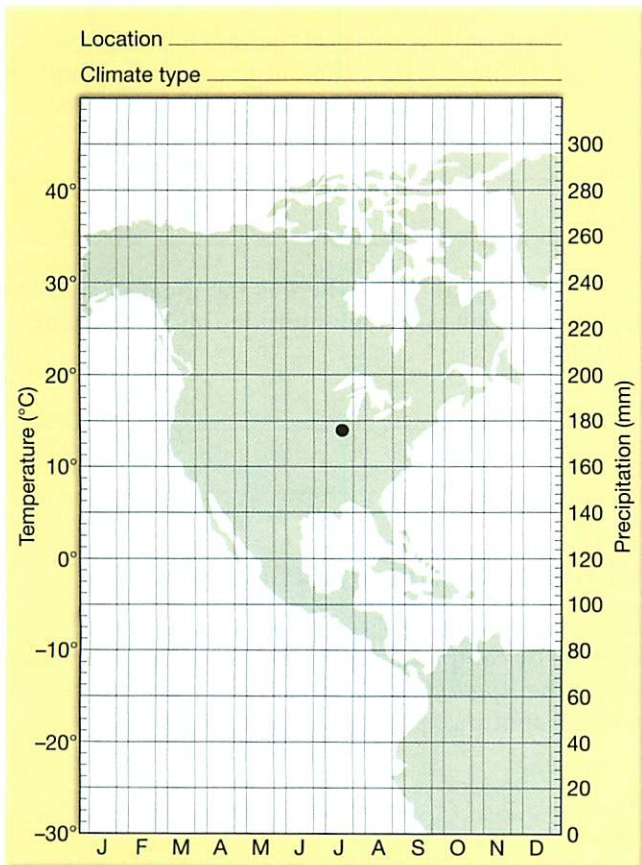
_____

_____

_____

_____

Figure 16.6 Climograph for Peoria, Illinois.

Table 16.5 Climatic Data for Quito, Ecuador

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
QUITO, ECUADOR LAT. 0°, LONG. 79°W; 2770 M													
Temp. (°C)	13	13	13	13	13	13	13	14	14	13	13	13	13
Precip. (mm)	99	110	142	175	137	43	20	30	69	113	95	93	1126

Polar (type E) Climates

The polar climates, found at high latitudes and scattered high altitudes in mountains, are regions of cold temperatures and sparse population. Low evaporation rates allow these areas to be classified as humid, even though the annual precipitation is modest.

46. What criterion is used for defining E climates?

_____

_____

47. Contrast the characteristics and locations of the two basic polar climates.

ET climates: _____

_____

_____

EF climates: _____

_____

_____

Climate and Altitude

Although often not included with the principal climate groups, *high-altitude*, or *highland* (type H) climates exist in all climatic regions. They are the result of the changes in radiation, temperature, humidity, precipitation, and atmospheric pressure that take place with elevation and orientation of mountain slopes.

Examine the climatic data for Quito, Ecuador, in Table 16.5. Quito is located in a region where A climates are expected. However, its altitude of 2,770 meters (9,086 feet) changes its Köppen classification.

48. Use Table 16.5 and Table 16.2 to determine the climatic classification of Quito, Ecuador.

Climate of Quito, Ecuador: _____

Criteria used for the selection of the climate type of Quito, Ecuador: _____

_____

_____

49. Locate Quito, Ecuador, on a map or globe. Considering its location, what effect has altitude had on the climatic classification?

_____

_____

50. Why would you expect the vegetation in the area of Quito to be different from that found at Guayaquil, Ecuador, a city located on the coast?

_____

_____

51. From Figure 16.1, where is the greatest continuous expanse of high-altitude (highland) climate located?

_____

_____

Climate on the Internet

Continue your analysis of the topics presented in this exercise by completing the corresponding online activity on the *Applications & Investigations in Earth Science* website at http://prenhall.com/earthsciencelab

Global Climates

Date Due: _____

Name: _____

Date: _____

Class: _____

After you have finished Exercise 16, complete the following questions. You may have to refer to the exercise for assistance or to locate specific answers. Be prepared to submit this summary/report to your instructor at the designated time.

1. Explain how a climograph is constructed.

_____

_____

_____

2. In your own words, provide some key words to describe the characteristics of each of the following Köppen climate groups.

A climates: _____

_____

B climates: _____

_____

C climates: _____

_____

D climates: _____

_____

E climates: _____

_____

H climates: _____

_____

3. List the general location of each of the following Köppen climate groups.

A climates: _____

_____

B climates: _____

_____

C climates: _____

_____

D climates: _____

_____

E climates: _____

_____

H climates: _____

_____

4. Indicate by name the Köppen climate group best described by each of the following statements.

Vast areas of northern coniferous forests: _____

_____

Smallest annual range of temperature: _____

_____

The highest annual precipitation: _____

_____

Mean temperature of the warmest month is below 10°C: _____

_____

The result of high elevation and mountain slope orientation: _____

_____

Potential evaporation exceeds precipitation: ___

_____

Very little change in the monthly precipitation and temperature throughout the year: _____

_____

Caused by the subsidence of air beneath high pressure cells: _____

_____

5. Using the data in Table 16.6, classify each station according to the most appropriate Köppen climate group. Where in North America is each likely to be located?

Station 1: _____

_____

Station 2: _____

_____

Station 3: _____

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Table 16.6 Climatic Data for Question 5

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Station 1													
Temp. (°C)	1.7	4.4	7.9	13.2	18.4	23.8	25.8	24.8	21.4	14.7	6.7	2.8	13.8
Precip. (mm)	10	10	13	13	20	15	30	32	23	18	10	13	207
Station 2													
Temp. (°C)	−10.4	−8.3	−4.6	3.4	9.4	12.8	16.6	14.9	10.8	5.5	−2.3	−6.4	3.5
Precip. (mm)	18	25	25	30	51	89	64	71	33	20	18	15	459
Station 3													
Temp. (°C)	10.2	10.8	13.7	17.9	22.2	25.7	26.7	26.5	24.2	19.0	13.3	10.0	18.4
Precip. (mm)	66	84	99	74	91	127	196	168	147	71	53	71	1247