

# CHAPTER 9

## METEOROLOGY

• **THE PHYSICAL SETTING: KEY IDEA 2**  
*Most of the phenomena that we observe on Earth involve interactions among components of air, water, and land.*

### The Atmosphere

The **atmosphere** is an "ocean of air." It is a mixture of gases which includes 78% nitrogen, 21% oxygen, and 1% other gases such as ozone, water vapor, and carbon dioxide.

The atmosphere contains small particles of suspended liquids and solids. These particles are from natural and human activities. For example, dust in the air can come from volcanic eruptions and building construction. Pollen, ice crystals, and water drops are from natural events. Ash and soot in the air are mainly from the burning of **fossil fuels** such as coal and oil. These air-borne solids and liquids can affect weather and climate. Dust blocks out sunlight making Earth cooler.

Nearly all the atmosphere is confined to a thin shell surrounding Earth. The atmosphere is divided or **stratified** into four layers. Each layer has its own distinct properties. The **troposphere** is the lowest, densest part. It contains most of the atmospheric gases and moisture, so clouds and storms occur here. Most weather takes place in the troposphere. As you rise through the troposphere, temperature decreases.

The **stratosphere** is the next layer. The air is very dry so clouds rarely occur here. Temperatures increase because **ozone** gas absorbs ultraviolet radiation from the Sun. The mesosphere is very clean. It has no water vapor. Temperature decreases as you rise through the mesosphere. The uppermost layer is the thermosphere. This is where meteors disintegrate. As altitude increases throughout the atmosphere, air pressure and water vapor decrease.

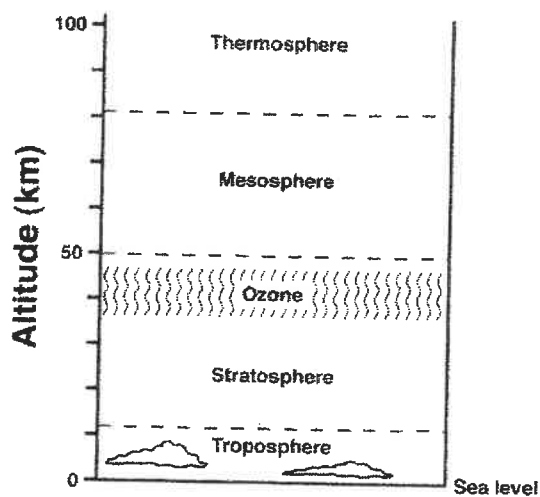


FIGURE 1. LAYERS OF THE ATMOSPHERE

## Review Questions

1. The most abundant gas in the atmosphere is \_\_\_\_\_.
2. As altitude increases, air pressure \_\_\_\_\_.
3. Earth's temperature could become cooler if large amounts of \_\_\_\_\_ block sunlight.
4. Particles can enter the air by \_\_\_\_\_ and \_\_\_\_\_ activities.
5. Using the diagram in **FIGURE 1**, name the atmosphere layer described:
  - a. contains ozone layer \_\_\_\_\_
  - b. found at 70 km altitude \_\_\_\_\_
  - c. most weather occurs here \_\_\_\_\_
  - d. contains the most water vapor \_\_\_\_\_
  - e. closest to sea level \_\_\_\_\_

## Functions of the Atmosphere

The atmosphere supports life by providing breathing gases and moisture. It protects life on Earth from meteor impacts and dangerous **ultraviolet radiation** which is absorbed by ozone. It provides heat energy for life by absorbing heat from the Sun and Earth.

The early atmosphere of Earth had no oxygen, no water vapor, and no ozone. Volcanoes released water vapor, carbon dioxide, and nitrogen from inside Earth. As Earth cooled water vapor condensed to form clouds. Rain fell and formed the oceans, lakes, and rivers. **Photosynthesis** by green plants in the oceans absorbed carbon dioxide and released oxygen. The protective ozone layer was formed once oxygen was available.

Human activities have negatively impacted the atmosphere. Pollutants such as gases, soot, and ash from the burning of fossil fuels have been added to the air. The destruction of forests and continued burning of fossil fuels have increased the amount of carbon dioxide in the air. As a result some scientists believe that Earth's temperature has been rising. Carbon dioxide as well as methane and water vapor are known as **greenhouse gases** because they "trap" heat close to the surface.

**Chlorofluorocarbons (CFCs)**, bromides, and nitrogen oxides also added by human activities have decreased the amount of ozone over certain portions of Earth's surface. These areas are now exposed to more harmful ultraviolet radiation which causes skin cancer in humans and hinders the growth of the plants and animals we depend on.

## Review Questions

6. Dangerous ultraviolet rays are absorbed by \_\_\_\_\_.
7. The atmospheric oxygen is produced by \_\_\_\_\_.
8. The \_\_\_\_\_ layer is being destroyed by CFCs.
9. As the amount of carbon dioxide in the atmosphere increases, temperatures will \_\_\_\_\_.
10. The burning of fossil fuels adds the greenhouse gas, \_\_\_\_\_, to the air.

## Atmospheric Conditions

**Weather** describes the conditions of the atmosphere at a location for a short period of time. The uneven heating of Earth's surface by the Sun cause changes in the weather. **Climate** is the average weather that prevails from season to season and year to year. Climate is more predictable than weather.

The conditions of the atmosphere are measured and recorded at weather stations. As these conditions change, the weather changes. Atmospheric conditions include air temperature, air pressure, humidity, wind, cloud cover, and precipitation.

Atmospheric temperature is caused by the absorption of heat from Earth and from the Sun. Temperatures change with time of day, time of year, latitude, and elevation. Temperature is measured with a thermometer.

Moisture exists in all three states of matter in the atmosphere. Solid moisture includes ice, snow, hail, sleet, and frost. Liquid moisture is in the form of rain, dew, fog, and water droplets. Gaseous moisture is the invisible water vapor which causes **humidity**.

Clouds are made of ice crystals and water droplets. **Precipitation** falls when the ice crystals and water droplets are large enough for gravity to pull them down. Atmospheric moisture comes from evaporation of surface waters mainly the oceans. Plants also release moisture to the air by **transpiration**. The movement of moisture between the atmosphere, lithosphere and the hydrosphere is called the **water cycle**.

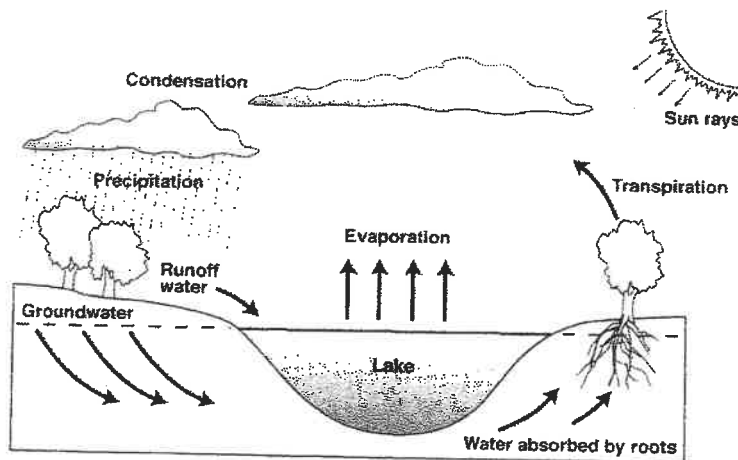


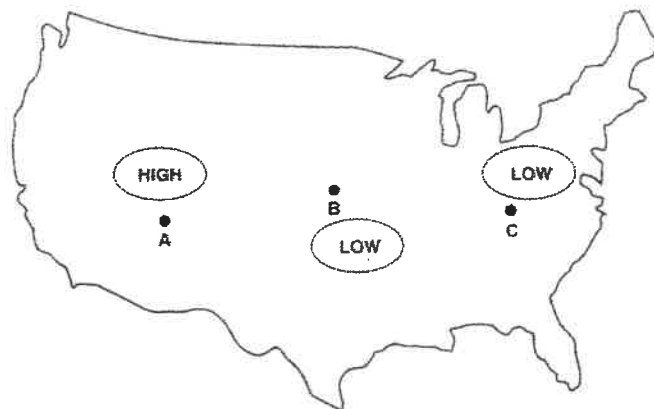
FIGURE 2. WATER CYCLE

**Air pressure** is caused by the weight of air pushing down. As altitude increases, air pressure decreases. **High pressure** air is cool and dry with clear, calm weather. **Low pressure** air is generally warm and moist with cloudy, unstable weather. Pressure describes the air systems which cause our weather. Air pressure is measured with a **barometer**.

**Winds** are horizontal air movements. They are caused by differences in air pressure. Winds move from high pressure to low pressure areas. Winds are named for the direction from which they are blowing. A wind vane indicates the direction from which the wind is blowing. An **anemometer** measures wind speed.

### Review Questions

11. Clouds are made of visible \_\_\_\_\_ and \_\_\_\_\_.
12. Atmospheric moisture returns to Earth's surface during \_\_\_\_\_.
13. The conditions of the atmosphere for the day is called \_\_\_\_\_.
14. The constant movement of water between the air, the land, and the oceans is the \_\_\_\_\_ cycle.
15. The average weather that is the same every year is called \_\_\_\_\_.
16. Water vapor enters the air by evaporation and \_\_\_\_\_ from plants.
17. Stormy, unstable weather is found in \_\_\_\_\_ pressure systems.
18. A high pressure air mass brings \_\_\_\_\_ weather.
19. The USA map indicates the locations of the high and low pressure systems.  
The lettered position probably experiencing clear skies is \_\_\_\_\_.



## Air Masses and Fronts

Weather conditions change due to the movement of air masses. Weather conditions at a location are determined by the temperature, humidity, and pressure of the air mass over that area.

An **air mass** forms when a body of air remains nearly stationary over a large section of Earth's surface. The air acquires its temperature and humidity from that region. If an air mass forms over water, it will be moist with low pressure. If the air mass forms over land, it will be dry with high pressure. Air masses forming in polar regions are cold. Those that form in tropical latitudes are warm.

Air Mass Type	Map Symbol	Formed over...	Characteristics
Continental Tropical	cT	hot land	hot, dry air
Continental Polar	cP	cold land	cold, dry air
Maritime Polar	mP	cool ocean	cool, moist air
Maritime Tropical	mT	warm ocean	warm, moist air

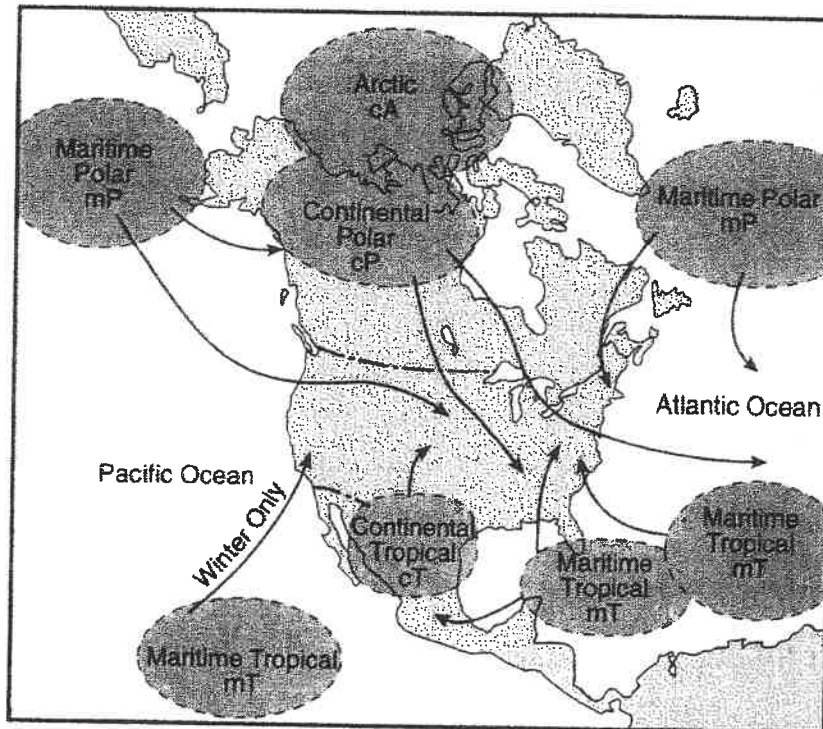


FIGURE 3. TYPES AND SOURCES OF AIR MASSES IN THE USA

**Prevailing winds** and upper air currents determine the movement of air masses. In the United States air masses move from west to east. This fact allows weather forecasts to be made.

**Fronts** are the boundaries between different air masses. Cold fronts are the leading edge of cooler air which is moving towards a region. Warm fronts are the leading edge of warmer air that is moving towards a region. Precipitation is likely to occur at these boundaries when warm, moist air rises above the cooler air. When a front passes there is a change in weather. It causes cloud formation, winds, precipitation, and air pressure and temperature changes.

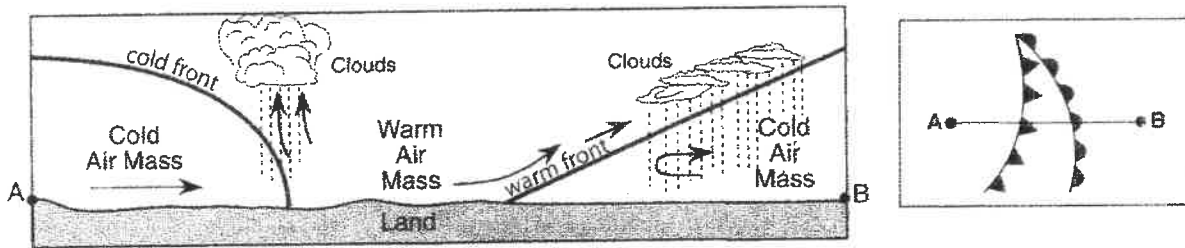
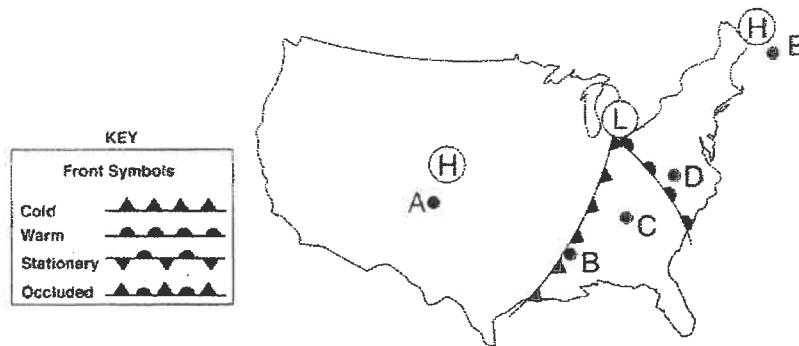


FIGURE 4. MOVEMENT OF AIR MASSES

### Review Questions

20. In the United States air masses move from \_\_\_\_\_ to \_\_\_\_\_.
21. An air mass that is warm and dry will be classified as \_\_\_\_\_.
22. An air mass that forms over northern Canada will be \_\_\_\_\_ and \_\_\_\_\_.
23. Local weather conditions change due to the movement of \_\_\_\_\_.
24. A front is the \_\_\_\_\_ between different air masses.
25. Precipitation is likely to occur along \_\_\_\_\_.
26. The map shows air pressure weather systems in the USA for one day in June. Letters A, B, C, D, and E are locations in the United States.



- a. Locations with clear skies: \_\_\_\_\_ and \_\_\_\_\_
- b. Locations probably experiencing rain: \_\_\_\_\_ and \_\_\_\_\_
- c. A warm front is approaching location \_\_\_\_\_
- d. The low pressure system will move towards \_\_\_\_\_

## Technology Used to Monitor and Forecast Weather

Many instruments are used at ground-based weather stations to measure the conditions of the atmosphere.

### Weather Instruments

INSTRUMENT	MEASURES ...
thermometer	air temperature
barometer	air pressure
psychrometer	humidity, dew point
anemometer	wind speed
wind vane	wind direction
rain gauge	amount of precipitation

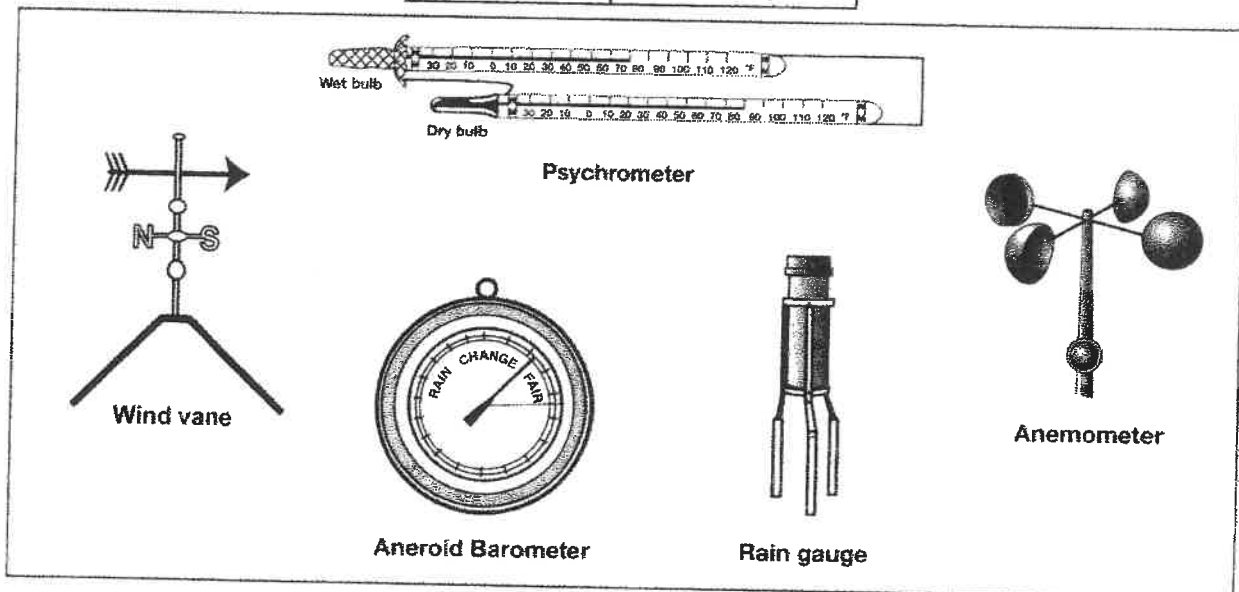


FIGURE 5. COMMON WEATHER INSTRUMENTS

Weather is monitored with weather balloons that send data to weather stations. Satellite photographs show cloud cover. Radar gives information about the intensity and speed of approaching storms. Doppler radar is especially useful in detecting tornadoes. Computers collect and store large amounts of data and compare present weather data to the past.

### Review Questions

27. Doppler radar is useful in locating \_\_\_\_\_.
28. Meteorologists store and compare weather data by using \_\_\_\_\_.
29. Satellite photographs show \_\_\_\_\_.
30. A \_\_\_\_\_ measures air pressure.
31. An anemometer measures \_\_\_\_\_.

## Hazardous Weather

Humans can prepare for and protect themselves against **hazardous weather** if warnings are given. Tornadoes are rapidly rotating, extremely low-pressure storms. A funnel extends down from a thunderstorm cloud. Tornadoes form when very cold air meets very warm air. They are most common in the Midwest where cold, dry air from Canada meets warm, moist air from the Gulf of Mexico. The tornado may be on the ground for a few minutes or a few hours. The path of the tornado is unpredictable. Radar monitors their formation and warnings are sent out. Tornadoes have hazardous winds and flying debris. People in the path of a tornado should seek low shelter immediately or go into or under a sturdy structure.

Thunderstorms usually form along a cold front. Rapidly rising air causes lightning and heavy rain. Thunderstorms may have strong wind, hail, deadly lightning, and the danger of flash floods. People in the path of a thunderstorm should seek shelter indoors, stay off the phone, turn off appliances, and stay away from flood prone areas.

In the winter, ice storms and blizzards pose hazards to people. Blizzards are associated with heavy snow and winds. Drifting snow can stop transportation. An ice storm can disrupt electric and phone services. Ice storms can occur suddenly as rainfall begins to freeze. There is a danger of frostbite and hypothermia. People should stay indoors, not drive, stay warm and have food, water and medical supplies available.

Hurricanes are low-pressure systems, which form over warm, tropical oceans. Winds are greater than 74 miles per hour. Hurricanes have high winds, high waves, flooding from rain, and storm surges of ocean water along coastlines. If you are in the path of a hurricane you should have food, water and all necessary supplies and stay indoors. If you live in a flood prone area you should go to an emergency shelter.

### Review Questions

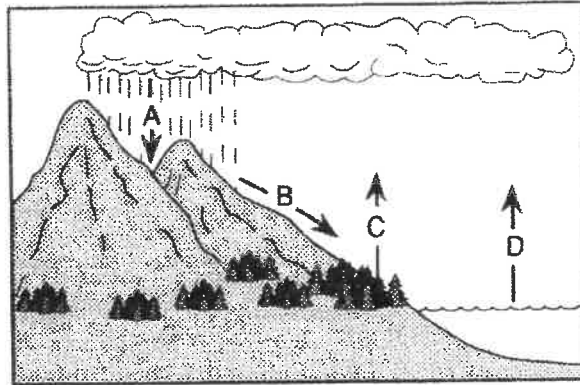
32. Hurricanes form over \_\_\_\_\_.
33. Thunderstorms form along a \_\_\_\_\_ front.
34. Severe winter storms are called \_\_\_\_\_.
35. Hurricane winds are more than \_\_\_\_\_ miles per hour.
36. During a tornado you need to protect yourself from wind and \_\_\_\_\_.
37. Hypothermia can be prevented by \_\_\_\_\_.
38. When a hurricane warning is issued the supplies you need should include \_\_\_\_\_.
39. Name the type of hazardous weather associated with each precaution:
  - a. Leave low lying ocean shorelines in the storm's path \_\_\_\_\_
  - b. Stay indoors and keep yourself warm during the storm \_\_\_\_\_
  - c. Immediately go to a sturdy underground shelter \_\_\_\_\_
  - d. Turn off the computer and do not use the telephone \_\_\_\_\_
40. Tornadoes are most common in the \_\_\_\_\_ section of the USA.



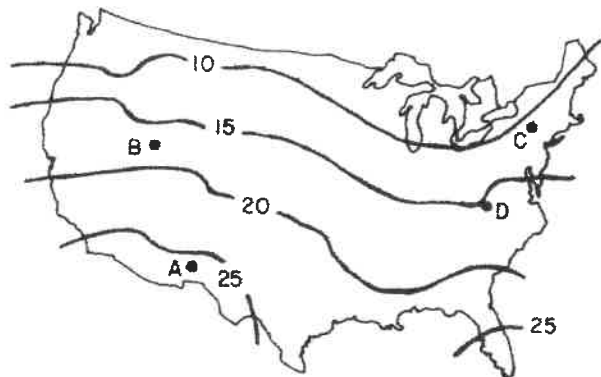
## CHAPTER REVIEW

- The two most common gases in the atmosphere are
  - nitrogen and oxygen
  - nitrogen and water vapor
  - carbon dioxide and water vapor
  - oxygen and carbon dioxide
- Oxygen is continually added to the atmosphere by
  - burning of fossil fuels
  - outgassing by volcanoes
  - photosynthesis by green plants
  - decomposition of organic wastes
- The temperature of Earth's surface can be affected by the amount of atmospheric
  - carbon dioxide
  - nitrogen
  - hydrogen
  - oxygen
- Ultraviolet radiation from the Sun is absorbed in the atmosphere by
  - ozone
  - nitrogen
  - oxygen
  - carbon dioxide
- The weather report states "expect high humidity today." The atmospheric gas responsible for this is
  - oxygen
  - ozone
  - water vapor
  - carbon dioxide
- Which human activity has had the most effect on increasing air pollution?
  - oil spills in oceans
  - burning fossil fuels
  - building on the ocean beaches
  - disposal of wastes in a landfill
- Water vapor is added to the atmosphere by:
  - evaporation only
  - transpiration only
  - evaporation and transpiration
- The main source of water for the atmosphere is Earth's
  - soil
  - plants
  - rivers
  - oceans

Base your answers to **questions 9-12** on the diagram of the water cycle shown below.



9. Which arrow represents transpiration?  
 (1) A                      (2) B                      (3) C                      (4) D
10. Which arrows represent the processes that increase humidity in the air?  
 (1) A and B              (2) A and C              (3) C and D              (4) C and B
11. What provides the energy to move water along arrows **C** and **D**?  
 (1) gravity                  (2) the Sun                  (3) ocean tides              (4) the Moon
12. At which location is condensation occurring?  
 (1) at the water surface                      (3) on the land  
 (2) in the cloud                                  (4) in the forest
13. The map below shows the isotherms connecting positions of equal temperature in degrees Celsius. Which location is the coldest?

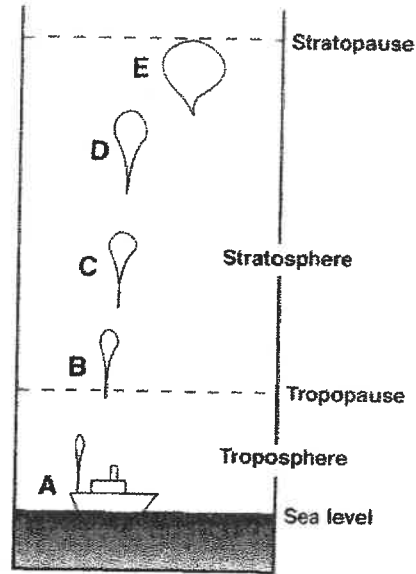


- (1) A                      (2) B                      (3) C                      (4) D

14. Compared to a clear day, on a cloudy day the amount of sunlight reaching Earth's surface is:  
 (1) less                      (2) more                      (3) the same

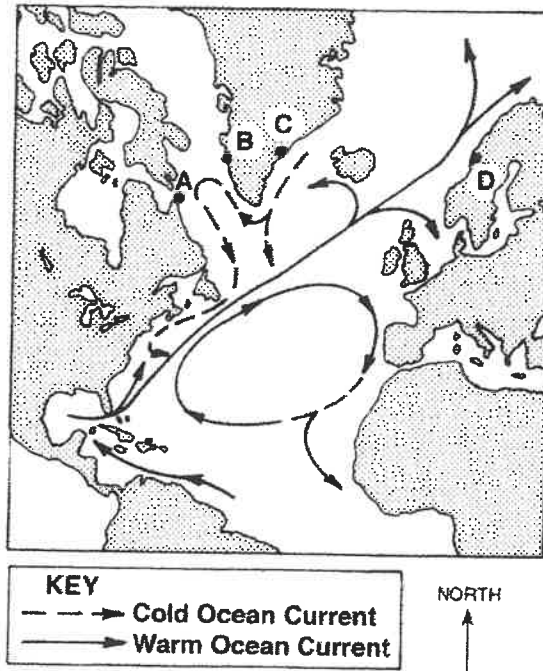
Base your answers to **questions 15-18** on the diagram below which shows the path of a weather balloon released from a ship.

15. At which letter would the highest air pressure be recorded?  
 (1) A    (2) B    (3) C    (4) D
16. At which letter would the highest humidity be recorded?  
 (1) A    (2) B    (3) C    (4) D
17. If a thunderstorm was to move into the area, which position would be most affected?  
 (1) A    (2) B    (3) C    (4) D
18. This diagram shows that the atmosphere is  
 (1) clean                      (3) easily polluted  
 (2) layered                    (4) warm

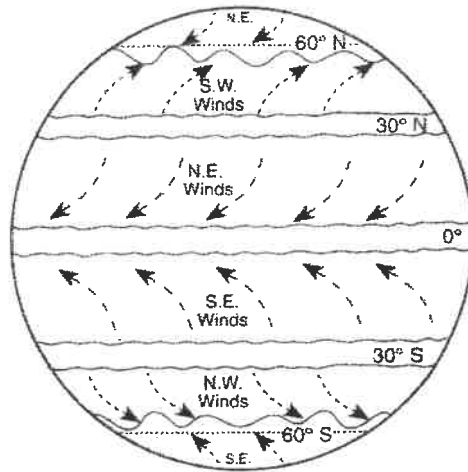


19. Polar climates are colder than tropical climates, because at the Poles the  
 (1) Sun is lower and less direct                      (3) Sun is higher and more direct  
 (2) Sun is lower and more direct                    (4) Sun is higher and less direct
20. The map shows the path of warm and cold ocean currents in the Atlantic Ocean. Which location would have the warmest climate?

- (1) A  
 (2) B  
 (3) C  
 (4) D



Base your answers to **questions 21-23** on the diagram below, which shows the prevailing winds for each latitude zone.



21. At a latitude of 20° N the prevailing wind is from the  
 (1) northwest            (2) northeast            (3) southwest            (4) southeast
22. Which diagram shows the usual paths of low pressure systems across the United States?



(1)



(2)



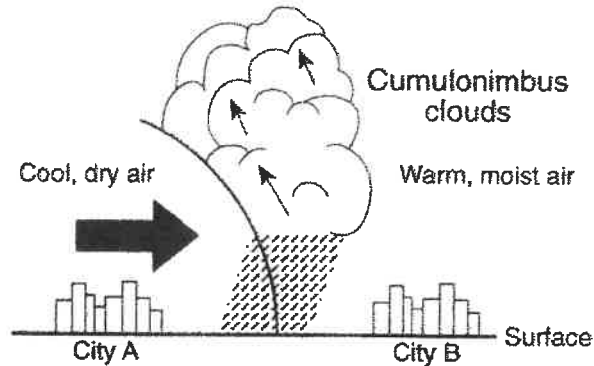
(3)



(4)

23. Winds are caused by differences in  
 (1) humidity            (2) cloud cover            (3) air temperature            (4) air pressure
24. On a weather map, an air mass that is cold and dry would be labeled  
 (1) mP            (2) mT            (3) cT            (4) cP
25. The weather conditions in an air mass are determined by  
 (1) the size of the air mass  
 (2) the area over which the air mass formed  
 (3) the wind speeds in the air mass  
 (4) the amount of moisture in the air mass

Base your answers to **questions 26-28** on the diagrams below which show the location and movement of two different air masses.



26. The air mass over city **B** would be classified as
 

(1) maritime polar	(3) continental tropical
(2) maritime tropical	(4) continental polar
27. The boundary line between the two air masses is known as
 

(1) the eye	(3) a high pressure system
(2) a front	(4) the stratosphere
28. A weather forecast for city **B** would be
  - (1) clearing skies with cooler temperatures
  - (2) increasing clouds with cooler temperatures
  - (3) increasing clouds with warmer temperatures
  - (4) clearing skies with increasing temperatures
29. Tornadoes form when a very cold, dry air mass meets a very warm, moist air mass. Which two air masses could form a tornado when they meet?
 

(1) cP and cT	(3) cP and mT
(2) cT and mP	(4) mP and mT
30. Cool, clear weather is usually found
 

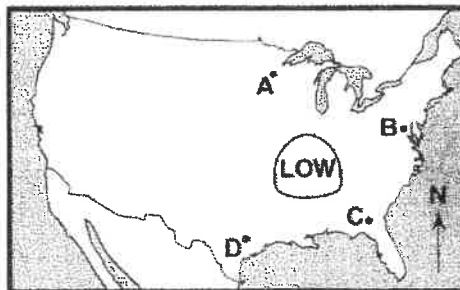
(1) in high pressure systems	(3) at fronts
(2) in low pressure systems	(4) in the tropics
31. Which correctly matches the instrument with the measurement?
 

(1) anemometer, temperature	(3) psychrometer, wind speed
(2) thermometer, humidity	(4) barometer, air pressure
32. Which technology has improved our weather forecasting ability?
 

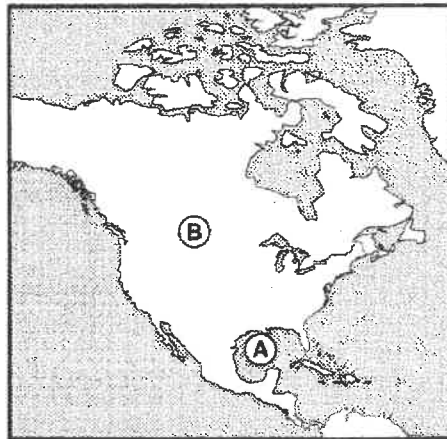
(1) satellites	(3) airplanes
(2) cruise ships	(4) internet

33. On a summer afternoon, the reading on the barometer begins to decrease. This indicates that
- (1) a storm is approaching
  - (2) skies will stay clear
  - (3) weather conditions will improve
  - (4) it will not rain for the next three days
34. Which is a form of precipitation?
- (1) frost
  - (2) snow
  - (3) dew
  - (4) fog
35. The climate of a region describes the
- (1) daily weather conditions
  - (2) yearly weather conditions
  - (3) latitude and altitude of the location
  - (4) wind patterns for the area
36. Toward which point will the Low pressure system move?

- (1) A
- (2) B
- (3) C
- (4) D



Base your answers to **questions 37-38** on the following diagram.  
Locations **A** and **B** are two source regions for air masses that affect the United States.



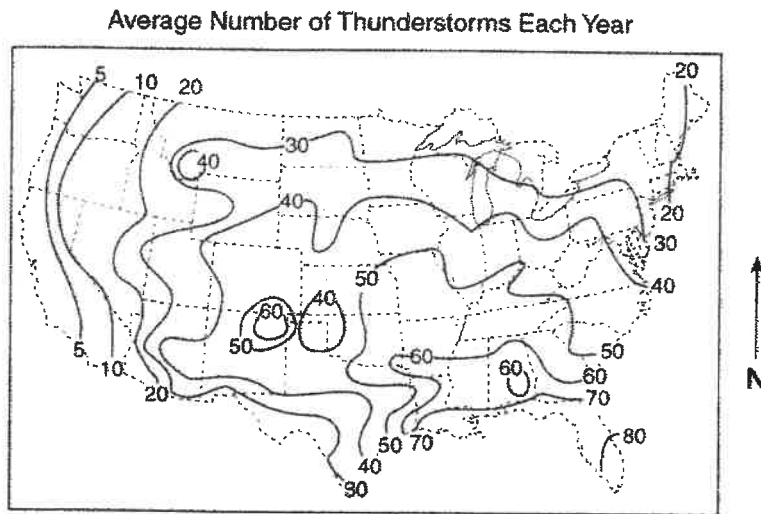
37. Compared to the air mass at B, the air mass at A is
- (1) cooler and drier
  - (2) cooler and wetter
  - (3) warmer and wetter
  - (4) warmer and drier
38. On a weather map the air mass at location B would be labeled
- (1) cP
  - (2) cT
  - (3) mT
  - (4) mP

39. The arrows on the map show the movement of



- (1) Earth's rotation
- (2) northeasterly winds
- (3) tsunamis
- (4) Atlantic Ocean hurricanes

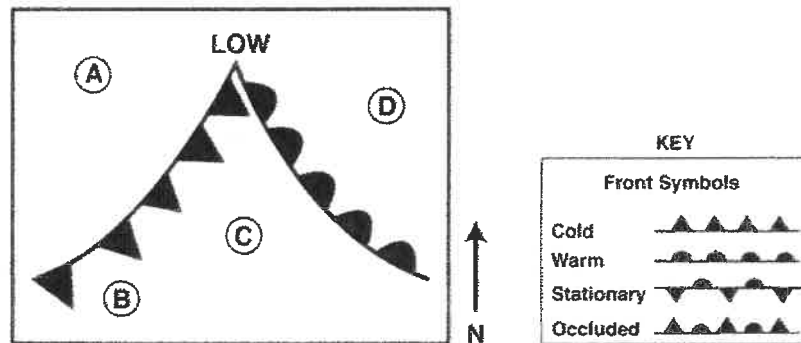
40. The map shows the average number of thunderstorms each year in the United States. What section of the country gets the most thunderstorms?



- (1) northeast
- (2) southeast
- (3) southwest
- (4) northwest

Base your answers to **questions 41-44** on the following diagram.

The diagram is part of a weather map for locations in the eastern United States. The map shows the location of the low pressure system, fronts, and weather stations **A**, **B**, **C**, and **D**.



41. At which station is it most likely raining?  
 (1) A                      (2) B                      (3) C                      (4) D
42. As the front passes **D**, the air temperature will probably  
 (1) decrease              (2) increase              (3) remain the same
43. In the next few hours station **C** can expect cloud cover to  
 (1) decrease              (2) increase              (3) remain the same
44. The cold front is moving towards the  
 (1) northeast              (2) southeast              (3) southwest              (4) northwest