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Name:_____ Class:_____ Date:_____

Ch 01 Earth's Atmosphere

True / False

1. Sayings about the weather, such as “red sky at morning, sailor take warning; red sky at night, sailor's delight” are based on the scientific method.
   a. True
   b. False

ANSWER: False

2. Earth's second atmosphere was lighter than its first atmosphere (which formed some 4.6 billion years ago), and developed through the impact of a series of meteorites.
   a. True
   b. False

ANSWER: False

3. The two most abundant greenhouse gases in Earth’s atmosphere are carbon dioxide and water vapor.
   a. True
   b. False

ANSWER: True

4. Carbon dioxide is a naturally occurring component of the atmosphere.
   a. True
   b. False

ANSWER: True

5. The ozone hole is an actual hole in the atmosphere, a region of complete vacuum.
   a. True
   b. False

ANSWER: False

6. Of the four most abundant gases in our atmosphere, carbon dioxide shows the greatest variation at Earth's surface.
   a. True
   b. False

ANSWER: False

7. Soil dust, salt from ocean waves, forest fire smoke, volcanic ash particles, and pollutants are some of the greenhouse gases found in the atmosphere.
   a. True
   b. False

ANSWER: False

8. On the basis of composition, the layers of the atmosphere from the lowest layer to the highest are the thermosphere, mesosphere, stratosphere, and troposphere.
   a. True
   b. False

ANSWER: False

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9. On an average, temperature increases from the surface to the tropopause (around 10 km), then decreases to the stratopause (around 50 km), then decreases to the mesopause (around 90 km), and then increases through the thermosphere (90–500 km).

a. True

b. False

ANSWER: False

10. Someone who says that "the wind direction today is south" likely means that the wind is blowing from the south.

a. True

b. False

ANSWER: True

11. Fronts are a band of continuity in temperature, humidity, and wind direction.

a. True

b. False

ANSWER: False

12. Meteorology is the study of the atmosphere and its phenomena. The term itself goes back to the Greek philosopher, Aristotle, who wrote a book on natural philosophy entitled *Meteorologica*.

a. True

b. False

ANSWER: True

13. Weather in the middle latitudes tends to move from east to west.

a. True

b. False

ANSWER: False

14. Storms rank in size from the largest to the smallest, as follows: thunderstorm, middle-latitude cyclonic storm, tornado, hurricane.

a. True

b. False

ANSWER: False

15. The lowest average air temperature can be found in the stratosphere.

a. True

b. False

ANSWER: False

16. Weather describes the conditions averaged over a region or over a period, whereas climate describes the condition of the atmosphere at a particular time and place.

a. True

b. False

ANSWER: False

17. An increase in stratospheric ozone could be beneficial for plants, animals, and humans.

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a. True
b. False

ANSWER: True

18. Ultraviolet light from the sun destroys nitrous oxide.
a. True
b. False

ANSWER: True

19. In the mid-1990s, the National Weather Service replaced original radars with sophisticated instruments known as Doppler radars that have the ability to peer into a severe thunderstorm, unveil its winds, and show precipitation intensity.
a. True
b. False

ANSWER: True

20. The mass of air in a rigid container is the same everywhere in the universe.
a. True
b. False

ANSWER: True

21. Our understanding of the atmosphere and how it produces weather is built on the knowledge acquired and applied through the scientific method.
a. True
b. False

ANSWER: True

22. The physical laws that control atmospheric behavior can be represented in software packages known as numerical models.
a. True
b. False

ANSWER: True

23. Any form of water, either liquid or solid (rain or snow), that falls from clouds and reaches the ground is called particulate matter.
a. True
b. False

ANSWER: False

24. A downburst is an intense rotating column of air that extends downward from the base of a thunderstorm with a circulation reaching the ground.
a. True
b. False

ANSWER: False

25. The most abundant gases in the Earth's atmosphere by mass are carbon dioxide and argon.

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a. True
b. False

ANSWER: False

26. The concentration of oxygen is close to 21 percent (by volume) in the upper stratosphere (the same concentration as in the troposphere), and humans can breathe as well there as at sea level.
a. True
b. False

ANSWER: False

27. Wind blows counterclockwise around low-pressure areas, and clockwise around high-pressure areas in the Northern Hemisphere.
a. True
b. False

ANSWER: True

28. The ozone hole is located over the Gulf of Mexico.
a. True
b. False

ANSWER: False

29. In the isothermal zone of the atmosphere, the air temperature, on an average, remains constant with height.
a. True
b. False

ANSWER: True

30. The region where atoms and molecules shoot off into space is sometimes referred to as the exosphere, which represents the upper limit of our atmosphere.
a. True
b. False

ANSWER: True

Multiple Choice

31. In a temperature inversion, air temperature does which of the following?
a. increases with increasing height
b. decreases with increasing height
c. is extremely unstable
d. fluctuates more at night than during the day
e. is warmer during winter than during summer

ANSWER: a

32. The rate at which temperature decreases with height is known as which of the following?
a. temperature slope
b. lapse rate

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c. alpine factor
d. thermocline
e. zipline

ANSWER: b

33. In which atmospheric layer is most of the ionosphere found?
a. troposphere
b. stratosphere
c. mesosphere
d. thermosphere
e. exosphere

ANSWER: d

34. Which process, over millions of years, provided a rich supply of water vapor into the atmosphere that formed into clouds?
a. evaporation
b. condensation
c. precipitation layering
d. outgassing
e. seafloor spreading

ANSWER: d

35. The word “weather” is defined as which of the following?
a. the changes that happen to the planet over time
b. the climate of a region
c. the climate averaged over the course of a year
d. any type of falling precipitation
e. the condition of the atmosphere at a particular time and place

ANSWER: e

36. Wind direction is described as which of the following?
a. the direction from which the wind is blowing
b. the direction to which the wind is blowing
c. always moving directly from high toward low pressure
d. always moving directly from low toward high pressure
e. relative to where the person is standing

ANSWER: a

37. Meteorology is the study of which of the following?
a. landforms
b. the oceans
c. the atmosphere
d. the exosphere
e. extraterrestrial meteoroids that enter the atmosphere

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ANSWER: c

38. Middle latitude cyclonic storms are also known as which of the following?
    a. anticyclones
    b. hurricanes
    c. extratropical cyclones
    d. tornadoes
    e. gust fronts

ANSWER: c

39. Humidity is :
    a. the same in different climates
    b. any form of water that falls from clouds and reaches the ground
    c. a measure of the amount of water vapor in the air
    d. the degree of hotness or coldness of the air
    e. low when the temperature falls

ANSWER: c

40. Precipitation is:
    a. the same in different climates
    b. any form of water that falls from clouds and reaches the ground
    c. rain only
    d. the degree of hotness or coldness of the air
    e. the force of the air above an area

ANSWER: b

41. On a weather map, a cold front is marked by which of the following?
    a. a solid line with arrowheads showing the direction of movement
    b. a red line with half circles
    c. a green line with half circles
    d. a dotted line
    e. a line with hash marks

ANSWER: a

42. In a warm front, what is being replaced?
    a. cool air
    b. polluted air
    c. the troposphere
    d. contrails
    e. humid air

ANSWER: a

43. Which statement relates to weather rather than climate?
    a. The average temperature for the month of January is 28°F.

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b. The lowest temperature ever recorded in Frozenlake, Minnesota, is −57°F.
c. The foggiest month of the year is December.
d. People are worried that the average temperature of the planet is rising.
e. It is cloudy and snowing outside.

ANSWER: e

44. With droughts, most people are affected by which of the following?
a. lightning
b. locusts
c. sciroccos
d. crop failures and food shortages
e. dust storms

ANSWER: d

45. Ozone in the troposphere:
a. is good for people with respiratory illnesses
b. causes warming and is a highly reactive oxidant
c. is not one of the main ingredients of photochemical smog
d. provides healthy levels of vitamin D to humans
e. is an aerosol found in the ionosphere

ANSWER: b

46. Which atmospheric layer has the highest temperature, although one might not perceive it?
a. stratosphere
b. troposphere
c. mesosphere
d. exosphere
e. ionosphere

ANSWER: d

47. What has to be shown to be correct through a series of quantitative tests?
a. theory
b. scientific method
c. hypothesis
d. numerical modeling
e. question

ANSWER: c

48. Earth’s earliest atmosphere was most likely composed of which of the following?
a. water vapor and nitrogen
b. carbon dioxide and helium
c. hydrogen and helium
d. hydrogen and oxygen

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e. noble gases

ANSWER: c

49. Much of the carbon dioxide found in earlier atmospheres is currently locked up in which of the following?

a. granite
b. volcanic rocks
c. sandstone
d. shale
e. carbonate rocks

ANSWER: e

50. There are considerably more air molecules near the Earth's surface than higher up, which means, in comparison, air near the surface:

a. is less dense
b. has the same density
c. is denser
d. has no density
e. is only half as dense

ANSWER: c

51. A geostationary satellite takes pictures of which of the following?

a. the moon as it is seen from Earth
b. other planets as they are seen from Earth
c. different areas on Earth when it is stationary
d. one area on Earth as it moves at the same rate as Earth's spin
e. any recurring geologic event on Earth

ANSWER: d

52. On weather maps cold fronts are drawn:

a. in blue, with arrowheads showing the front's general direction of movement.
b. in red, with arrowheads showing the front's general direction of movement.
c. in blue, with arrowheads pointing away from the front's general direction of movement.
d. in black, with arrowheads showing the front's general direction of movement.
e. in red, with arrowheads pointing away from the front's general direction of movement.

ANSWER: a

53. Weather and climate affect human lives in many ways, but the most immediate effect is related to which of the following?

a. the economy
b. the environment
c. comfort
d. health
e. infrastructure

ANSWER: c

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54. Which two gases comprise the majority of Earth's atmosphere in a relatively thin, gaseous envelope?
    a. nitrogen, oxygen
    b. nitrogen, carbon dioxide
    c. oxygen, carbon dioxide
    d. carbon dioxide, water vapor
    e. oxygen, water vapor

ANSWER: a

55. Which of the following is considered a variable gas in Earth's atmosphere?
    a. water vapor
    b. nitrogen
    c. every noble gas
    d. argon
    e. helium

ANSWER: a

56. Ozone (O_3) in the stratosphere has:
    a. protected life from harmful ultraviolet rays
    b. decreased in concentration by 30 percent
    c. remained at about the same concentration from year to year
    d. disappeared entirely
    e. has doubled in concentration

ANSWER: a

57. Which weather element ***always*** decreases as we climb upward in the atmosphere?
    a. wind
    b. temperature
    c. pressure
    d. moisture
    e. dew point

ANSWER: c

58. Earth's atmosphere is divided into named layers based on the vertical profile of which of the following?
    a. air pressure
    b. air temperature
    c. air density
    d. wind speed
    e. chemical composition

ANSWER: b

59. Almost all of Earth's weather occurs in which layer?
    a. exosphere
    b. stratosphere

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c. mesosphere
d. ionosphere
e. troposphere

ANSWER: e

60. Which of the following is an example of climate?
a. an afternoon thunderstorm in Florida
b. six inches of snow expected to fall in the Northeast
c. heat wave in Europe
d. hail damaging crops in the Midwest
e. warm wet weather in the Amazon rainforest

ANSWER: e

Subjective Short Answer

61. Is there enough oxygen in the stratosphere to breathe comfortably on your own? Explain your answer.

ANSWER: No. The stratosphere is located above 11km. At this height, you are above nearly 90 percent of all the molecules in the atmosphere. For example, at Mount Everest it is common to carry oxygen to the summit that has an altitude of 9 km (29,000 ft) and an air pressure of about 300 mb. The summit of Mount Everest is above nearly 70 percent of all the molecules in the atmosphere. Likewise, a plane must provide oxygen in the cabin and cockpit, otherwise all (including the pilot) will pass out.

62. Explain the concept of air pressure in terms of mass of air above some level. Why does air pressure always decrease with increasing height above the surface?

ANSWER: Air pressure always decreases with increasing height above the surface because as altitude increases, there is always less air above you (because more of it is below you). If more molecules are packed into an air column, the column becomes denser, the air weighs more, and the surface pressure goes up. On the other hand, when fewer molecules are in the air column, the air weighs less, and the surface pressure goes down.

63. If the air temperature at sea level (0 feet) is 60°F, what would be the approximate air temperature at an altitude of 10,000 feet, assuming an average atmospheric lapse rate of 3.6°F per 1,000 feet?

ANSWER: The approximate air temperature would be 24°F.

64. Describe how air pressure decreases with increasing altitude.

ANSWER: The amount of force exerted over an area of surface is called atmospheric pressure or, simply, air pressure. The pressure at any level in the atmosphere may be measured in terms of the total mass of air above any point. As we climb in elevation, fewer air molecules are above us; hence, atmospheric pressure always decreases with increasing height. Like air density, air pressure decreases rapidly at first, then more slowly at higher levels.

65. Why is stratospheric ozone important to plant, animal, and human life?

ANSWER: Stratospheric ozone is important because it shields plants, animals, and humans from the Sun's harmful ultraviolet rays. Stratospheric ozone provides a natural protective shield in the upper atmosphere so that plants on the surface may survive.

66. Where did nitrogen in the atmosphere originate?

ANSWER: Scientists believe nitrogen in our current atmosphere arose from the degassing of volcanoes. Since nitrogen

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gas (N_2) is not reactive, it built up in the Earth's atmosphere over time.

67. Define the concept of weight.

ANSWER: Weight is defined as the mass of an object times the acceleration of gravity; thus, the relationship is weight = mass × gravity.

68. Write an example of a good working hypothesis for a research problem that is interesting to you. For example, you could seek to explain why the striped bass population in a certain lake is growing.

ANSWER: A good hypothesis would be that striped bass population in the lake is increasing because the fish are thriving due to a ban on fishing permits. If this hypothesis is true, fish stocks should decrease if the ban is lifted, and anglers return to fish in the lake.

69. Describe the processes in Earth's history that led to an increase in oxygen in the atmosphere.

ANSWER: Earth's first atmosphere (some 4.6 billion years ago) was most likely *hydrogen* and *helium* as well as hydrogen compounds such as methane and ammonia. After volcanic eruptions and outgassing, the next stage was constant rain for many thousands of years, resulting in an increase in oxygen (O_2) through photo dissociation. After plants evolved, the atmospheric oxygen content increased more rapidly through photosynthesis.

70. Describe the effect that drought can have on human health.

ANSWER: The following health issues could be of concern: crop failures can lead to food shortages and thus malnutrition and even starvation. Lack of income can lead to anxiety and depression.

71. Explain the concept of lapse rate. What is the average or standard lapse rate in the troposphere?

ANSWER: The rate at which the air temperature decreases with height is called the temperature **lapse rate.** The *average* (or *standard*) *lapse rate* in the troposphere is about 6.5°C for every 1000 meters (m) or about 3.6°F for every 1000-ft increase in altitude (see Fig. 1.25). Keep in mind that these values are only averages. On some days, the air becomes colder more quickly as we move upward, which would increase or steepen the lapse rate.

72. Explain the concept of "weather."

ANSWER: "Weather" refers to the condition of the atmosphere at any particular time and place. Weather, which is always changing, includes: air temperature, air pressure, humidity, clouds, precipitation, visibility, and wind.

73. Define meteorology and discuss the origin of the word.

ANSWER: Meteorology is the study of the atmosphere and its phenomena. The term itself goes back to the Greek philosopher Aristotle who, in approximately 340 B.C., wrote a book on natural philosophy entitled *Meteorologica*.

74. Describe the motion of surface winds in the Northern Hemisphere around low-pressure and high-pressure systems.

ANSWER: In the Northern Hemisphere, winds around an area of surface low pressure blow counter clockwise and inward; around an area of a surface high pressure, they blow clockwise and outward.

75. What differences are there between the type of research a climatologist might conduct and a meteorologist.

ANSWER: A climatologist, or climate scientist, may study the interaction of the atmosphere and ocean to see what influence such interchange might have on planet Earth many years from now. A meteorologist uses scientific principles to explain and to forecast atmospheric phenomena.

76. Discuss the relationship between the cost and type of weather and climate events.

ANSWER: Weather- and climate-related events can have enormous economic consequences.

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Ch 01 Earth's Atmosphere

On average, tens of billions of dollars in property damage occur each year in the United States alone. Both violent storms and calmer events can contribute significantly to the cost. Most of us recognize the destruction and cost of violent events such as hurricanes, tornadoes, and flash floods. However, quieter events such as fog can be quite costly. When winds die down and humid air becomes more tranquil, fog may form. Heavy fog can restrict visibility at airports, causing flight delays and cancellations. Every winter, deadly fog-related auto accidents occur along our busy highways and turnpikes.

77. What are the leading explanations for where water on our planet came from?

ANSWER: The majority of water on our planet is believed to have come from its hot interior through outgassing, although some of Earth's water may have come from collisions with meteors and comets.

78. Describe the seasonal variation in the ozone hole over Antarctica?

ANSWER: Stratospheric ozone levels over springtime Antarctica plummet each year during September and October, to the point where so little ozone is observed.

79. Discuss the trend in carbon dioxide levels in the atmosphere recorded at the Mauna Loa Observatory in Hawaii?

ANSWER: The atmospheric concentration of carbon dioxide (CO_2) has risen by almost 30 percent since 1958. This increase means that CO_2 is entering the atmosphere at a greater rate than it is being removed. Higher CO_2 readings occur in winter when plants die and release CO_2 to the atmosphere, and how lower readings occur in summer when more abundant vegetation absorbs CO_2 from the atmosphere.

80. Explain why a person shielded from the sun would not feel the high temperatures in the thermosphere that may exceed 500°C or 900°F?

ANSWER: This situation arises because there are too few molecules in this region of the atmosphere to bump against something (exposed skin, for example) and transfer enough heat to it to make it feel warm. The low density of the thermosphere also means that an air molecule will move an average distance of over one kilometer before colliding with another molecule. A similar air molecule at Earth's surface will move an average distance of less than one-millionth of a centimeter before it collides with another molecule.

Essay

81. What instruments are used in meteorology? What role did the discovery of instruments play in the emergence of the science of meteorology?

ANSWER: The invention of the telegraph in 1843 allowed for the transmission of routine weather observations, which eventually helped facilitate the creation of weather maps and the understanding of air masses and fronts, as well as the discovery of the jet stream.

There are multiple instruments used in meteorology today. The radiosonde is a small, lightweight box equipped with weather instruments and is launched on a weather balloon. As the balloon rises, the radiosonde measures air temperature with a small electrical thermometer (a thermistor) and humidity by sending an electric current across a carbon-coated plate. Air pressure is measured by a small barometer in the radiosonde. The weather data are radioed to a computer that interprets and provides a vertical profile of the atmosphere.

Meteorologists also use remote-sensing platforms like radars and satellite for observations. Radars began their use after World War II and these simple devices were replaced with the more sophisticated Doppler radars, which have the ability to peer into a severe thunderstorm and unveil its wind, as well as show precipitation intensity and type (with recent updates). Additionally, in 1960 the first weather satellite, Tiros 1, was launched. Since then newer satellites provided a wide range of useful information, ranging from day and night time-lapse images of clouds and storms to images that depict swirling ribbons of water vapor flowing around

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the globe. Over the last several decades, even more sophisticated satellites have been developed. These satellites are supplying computers with a far greater network of data so that more accurate forecasts—perhaps extending up to two weeks or more—will be available in the future.
Meteorology took another step forward in the 1950s, when scientists converted the mathematical equations that describe the behavior of the atmosphere into software called numerical models that could be run on new highspeed computers. These calculations were the beginning of numerical weather prediction. Today, computers plot the observations, draw the lines on the map, and forecast the state of the atmosphere for some desired time in the future. Meteorologists evaluate the results from different numerical models and use them to issue public forecasts.

82. Describe how carbon dioxide enters and is removed from the atmosphere?

ANSWER: Carbon dioxide enters the atmosphere mainly from the decay of vegetation, but it also comes from volcanic eruptions, the exhalations of animal life, the burning of fossil fuels (such as coal, oil, and natural gas), and deforestation. The removal of CO_2 from the atmosphere takes place during photosynthesis as plants consume CO_2 to produce oxygen and sugars. The CO_2 is then stored in roots, branches, and leaves. Rain and snow can react with silicate minerals in rocks and remove CO_2 from the atmosphere through a process known as chemical weathering. The oceans serve as a large reservoir for CO_2, as phytoplankton (tiny drifting plants) in surface water fix CO_2 into organic tissues. Carbon dioxide that dissolves directly into surface water mixes downward and circulates through greater depths. Estimates are that the oceans hold more than 50 times the total atmospheric CO_2 content.

83. Describe how air temperature changes in the four main layers of the atmosphere.

ANSWER: The air temperature decreases with height in the troposphere until approximately 11 km. At this level, the air temperature normally stops decreasing with height. Here, the lapse rate is zero. This region, where, on average, the air temperature remains constant with height, is referred to as an *isothermal* (equal temperature) *zone*.

The bottom of this zone marks the top of the troposphere and the beginning of another layer, the stratosphere.

Above the stratosphere is the mesosphere (middle sphere). The air here is extremely thin and the atmospheric pressure is quite low. With an average temperature of −90°C (−130°F), the top of the mesosphere represents the coldest part of Earth's atmosphere.

The "hot layer" above the mesosphere is the thermosphere. Here, oxygen molecules (O_2) absorb energetic solar rays, warming the air. In the thermosphere, there are relatively few atoms and molecules. Consequently, the absorption of a small amount of energetic solar energy can cause a large increase in air temperature that may exceed 500°C, or 900°F. Even though the temperature in the thermosphere is exceedingly high, a person shielded from the sun would not necessarily feel hot. This situation arises because there are too few molecules in this region of the atmosphere to bump against something (exposed skin, for example) and transfer enough heat to it to make it feel warm.

84. Discuss the role that fossils fuels and deforestation have on the amount of carbon dioxide measured in the atmosphere.

ANSWER: The amount of CO_2 in the atmosphere has been steadily increasing since values started being measured in 1958 at the Mauna Loa Observatory in Hawaii. The increase indicates that CO_2 is entering the atmosphere at a greater rate than it is being removed.
The increase appears to be owing mainly to the burning of fossil fuels, such as coal and oil; about half of the CO_2 emitted from fossil fuels remains in the atmosphere, whereas the rest enters the ocean, soil, and plants. Deforestation also plays a role, as cut timber, burned or left to rot, releases CO_2 directly into the air, and the

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trees can no longer remove CO_2 from the atmosphere. Deforestation accounts for perhaps 10 to 15 percent of the observed CO_2 increase in recent years.

85. How has the composition of Earth's atmosphere changed over time? Briefly outline the evolution of Earth's atmosphere.

ANSWER: Earth's first atmosphere (some 4.6 billion years ago) was most likely hydrogen and helium—the two most abundant gases found in the universe—as well as hydrogen compounds, such as methane and ammonia. A second, denser atmosphere gradually enveloped Earth as gases from molten rock within its hot interior escaped through volcanoes and steam vents. We assume that volcanoes spewed out the same gases then as they do today: mostly water vapor (about 80 percent), carbon dioxide (about 10 percent), and up to a few percent nitrogen. As millions of years passed, the constant outpouring of gases from the hot interior (outgassing) provided a rich supply of water vapor, which formed clouds. Rain fell upon the earth for many thousands of years. Large amounts of CO_2 were dissolved in the oceans. The atmosphere gradually became rich in nitrogen (N_2). Oxygen (O_2), the second most abundant gas in today's atmosphere, probably began a slow increase in concentration as energetic rays from the Sun split water vapor (H_2O) into hydrogen and oxygen during a process called photodissociation. The hydrogen, being lighter, probably rose and escaped into space, while the oxygen remained in the atmosphere. After plants evolved, the atmospheric oxygen content increased, probably reaching its present composition about several hundred million years ago.

86. Describe the various types and relative sizes of storms from large to small found in Earth's atmosphere.

ANSWER: Students need to list the four main storm types in the following order from large to small: middle-latitude cyclonic storm systems (or extratropical cyclones), hurricanes, thunderstorms, and tornadoes.
The **middle-latitude cyclonic storm system** (or *extratropical cyclone*) forms outside the tropics and, in the Northern Hemisphere, has winds spinning counterclockwise about its center.
A tropical storm system, with its swirling band of rotating clouds and sustained surface winds of 65 knots (74 mi/hr) or more, is known as a **hurricane.**
Thunderstorms are recognized by tall churning clouds accompanied by lightning, thunder, strong gusty winds, and heavy rain. There are more than roughly a thousand thunderstorms occurring throughout the world at any given moment.
Some thunderstorms can spawn the most violent disturbance in the atmosphere, **tornadoes.** A tornado is an intense rotating column of air that usually extends downward from the base of a thunderstorm with a circulation reaching the ground. Sometimes called *twisters*, or *cyclones*, they may appear as ropes or as a large cylinder.
They can be more than 2 km (1.2 mi) in diameter, although most are less than a football field wide. Most tornadoes have sustained winds below 100 knots, but some can pack winds exceeding 200 knots (230 mi/hr). Sometimes a visibly rotating funnel cloud dips part of the way down from a thunderstorm, then rises without ever forming a tornado.

87. How are fronts defined and displayed on a weather map?

ANSWER: The boundary that separates warm and cool air appears as a heavy, colored line on a weather map. This boundary is a front and is defined by a sharp change in temperature, humidity, and wind direction.
Where the cool air from Canada replaces the warmer air from the Gulf of Mexico, a *cold front* is drawn in blue, with arrowheads showing the front's general direction of movement.
Where the warm Gulf air is replacing cooler air to the north, a *warm front* is drawn in red, with half circles showing its general direction of movement.
Where the cold front has caught up to the warm front and cold air is now replacing cool air, an *occluded front* is drawn in purple, with alternating arrowheads and half circles to show how it is moving.
Along each of the fronts, warm air is rising, producing clouds and precipitation.

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Ch 01 Earth's Atmosphere

88. Discuss the relationship between air pressure and human health.

ANSWER: Arthritic pain is most likely to occur when rising humidity is accompanied by falling pressures. The incidence of heart attacks shows a statistical peak after the passage of warm fronts, when rain and wind are common, and after the passage of cold fronts, when an abrupt change takes place as showery precipitation is accompanied by cold gusty winds. Headaches are common on days when we are forced to squint, often because of hazy skies or a thin, bright overcast layer of high clouds. Some people who live near mountainous regions become irritable or depressed when there is a warm, dry wind blowing downslope (a chinook wind). The relationship between human health and weather phenomena is not clearly understood.

89. Discuss two examples of the impacts that hurricanes have on the lives of millions along the Gulf and Atlantic coastlines.

ANSWER: These large tropical systems can be among the nation's most destructive weather events. More than 250,000 people lost their homes when Hurricane Andrew struck the Miami area in 1992, and nearly 2000 people along the central Gulf Coast were killed by Hurricane Katrina in 2005. A late-season hurricane called *Sandy* took a rare path in October 2012, striking the mid-Atlantic coast from the southeast. Although it was no longer classified as a hurricane when it came ashore, Sandy produced wind gusts topping 80 miles per hour in some areas. Because of its vast size and unusual path, Sandy pushed a huge amount of water into the coast, resulting in catastrophic storm-surge flooding and more than 100 deaths across parts of New Jersey, New York, and New England.

90. Describe four natural and four human-made aerosols present in the atmosphere and the impact they have on both the environment and human health.

ANSWER: Natural sources include: dust and soil from Earth's surface picked up by wind and carried aloft, small saltwater drops from ocean waves are swept into the air (upon evaporating, these drops leave microscopic salt particles suspended in the atmosphere); smoke from forest fires is often carried high above Earth; and volcanoes spew many tons of fine ash particles and gases into the air.
Some natural impurities found in the atmosphere are quite beneficial. Small, floating particles, for instance, act as surfaces on which water vapor condenses to form clouds.
Most human-made impurities (and some natural ones) are a nuisance as well as a health hazard. These we call pollutants. For example, many automobile engines (especially older ones) emit copious amounts of nitrogen dioxide (NO_2), carbon monoxide (CO), and hydrocarbons. In sunlight, nitrogen dioxide reacts with hydrocarbons and other gases to produce surface ozone. Carbon monoxide is a major pollutant of city air. Colorless and odorless, this poisonous gas forms during the incomplete combustion of carbon-containing fuel. Hence, more than half of carbon monoxide in urban areas comes from road vehicles. The burning of sulfur-containing fuels (such as coal and oil) releases sulfur gases into the air. When the atmosphere is sufficiently moist, these gases may transform into tiny dilute drops of sulfuric acid. Rain containing sulfuric acid corrodes metals and painted surfaces and turns freshwater lakes acidic. Acid rain is a major environmental problem, especially downwind from major industrial areas.
Even the tiniest pollutants are a major concern. Particulate matter refers to solid particles and liquid droplets that are small enough to remain suspended in the air. These particles can obscure visibility and cause respiratory and cardiovascular problems.

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Instructor Manual

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Purpose and Perspective of the Chapter

The purpose of this chapter is to overview the Earth's atmosphere and the many ways weather and climate influence our lives. Students should look briefly at the weather map and a satellite image and observe that dispersed throughout the atmosphere are storms and clouds of all sizes and shapes.

Students should learn that our atmosphere is one that is rich in nitrogen and oxygen as well as smaller amounts of other gases, such as water vapor, carbon dioxide, and other greenhouse gases. Increased concentrations of greenhouse gases from human activity are leading to global warming and other forms of climate change.

Students find the various layers of the atmosphere: the troposphere (the lowest layer), where almost all weather events occur, and the stratosphere, where ozone protects us from a portion of the sun's harmful rays. Above the stratosphere lies the mesosphere, where the air temperature drops dramatically with height.

Chapter Objectives

The following objectives are addressed in this chapter:

LO1 List three ways the scientific method can be applied to studying the atmosphere and weather.

LO2 Differentiate between weather and climate.

LO3 Interpret a weather map, applying storm types and concepts such as low pressure, high pressure, and front.

LO4 List the positive and negative effects of climate and weather on human health, agriculture, infrastructure, and the economy.

LO5 Outline the sequence of changes in nitrogen, oxygen, and water vapor over Earth's history.

LO6 Explain the role of gases (including water vapor, carbon dioxide, oxygen, and other greenhouse gases) and pollutants in Earth's atmosphere.

LO7 Describe how air density and air pressure are determined and how they vary as you move upward through Earth's atmosphere.

LO8 Describe the layers of the atmosphere, including their altitudes, temperatures, compositions, and functions.

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Complete List of Chapter Activities and Assessments

The following table organizes activities and assessments by objective, so that you can see how all this content relates to objectives and make decisions about which content you would like to emphasize in your class based on your objectives. For additional guidance, refer to the Teaching Online Guide.

Chapter Objective	PPT Slide	Activity/Assessment	Duration
LO1-LO8	N/A	Knowledge Check	3–5 minutes
LO1-LO8	N/A	Check Your Understanding	5–10 minutes
LO1, LO2	N/A	Concept Visualizations	5–10 minutes
LO2, LO4	N/A	Everyday Scenarios	10–20 minutes
LO1	8–9	Knowledge Check 1	2–3 minutes
LO3	18–19	Knowledge Check 2	2–3 minutes
LO4	24–25	Role-Play Activity 1	5–7 minutes
LO6	31–32	Self-Assessment 1	3–5 minutes
LO8	40–41	Discussion Activity 1	7–10 minutes

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Key Terms

atmosphere: The envelope of gases that surround a planet and are held to it by the planet's gravitational attraction. Earth's atmosphere is mainly nitrogen and oxygen.

aerosols: Tiny suspended solid particles (dust, smoke, etc.) or liquid droplets that enter the atmosphere from either natural or human (anthropogenic) sources, such as the burning of fossil fuels. Sulfur-containing fossil fuels, such as coal, produce *sulfate aerosols*.

air density: The ratio of the mass of a substance to the volume occupied by it. Air density is usually expressed as g/cm^3 or kg/m^3.

air pressure: The pressure exerted by the mass of air above a given point, usually expressed in millibars (mb), inches of mercury (Hg), or in hectopascals (hPa).

carbon dioxide: A colorless, odorless gas whose concentration is about 0.039 percent (390 ppm) in a volume of air near sea level. It is a selective absorber of infrared radiation and, consequently, it is important in Earth's atmospheric greenhouse effect. Solid CO_2 is called *dry ice*.

climate: The accumulation of daily and seasonal weather events over a long period of time.

front: The transition zone between two distinct air masses.

hurricane: A tropical cyclone with sustained winds of at least 64 knots (74 mi/hr).

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ionosphere: An electrified region of the upper atmosphere where fairly large concentrations of ions and free electrons exist.

lapse rate: The rate at which an atmospheric variable (usually temperature) decreases with height.

mesosphere: The atmospheric layer between the stratosphere and the thermosphere. Located at an average elevation between 50 and 80 km above Earth's surface.

meteorology: The study of the atmosphere and atmospheric phenomena as well as the atmosphere's interaction with Earth's surface, oceans, and life in general.

middle latitudes: The region of the world typically described as being between 30° and 50° latitude.

middle-latitude cyclonic storm: A cyclonic storm that most often forms along a front in middle and high latitudes. Also called a middle-latitude cyclonic storm, a depression, and a *low*. It is not a tropical storm or hurricane.

nitrogen: A colorless and odorless gas that occupies about 78 percent of dry air in the lower atmosphere.

outgassing: The release of gases dissolved in hot, molten rock.

oxygen: A colorless and odorless gas that occupies about 21 percent of dry air in the lower atmosphere.

ozone: An almost colorless gaseous form of oxygen with an odor similar to weak chlorine. The highest natural concentration is found in the stratosphere where it is known as stratospheric ozone. It also forms in polluted air near the surface where it is the main ingredient of photochemical smog. Here, it is called *tropospheric ozone*.

pollutants: Any gaseous, chemical, or organic matter that contaminates the atmosphere, soil, or water.

radiosonde: A balloon-borne instrument that measures and transmits pressure, temperature, and humidity to a ground-based receiving station.

stratosphere: The layer of the atmosphere above the troposphere and below the mesosphere (between 10 km and 50 km), generally characterized by an increase in temperature with height.

temperature inversion: An increase in air temperature with height, often simply called an inversion.

thermosphere: The atmospheric layer above the mesosphere (above about 85 km) where the temperature increases rapidly with height.

thunderstorms: A convective storm (cumulonimbus cloud) with lightning and thunder. Thunderstorms can be composed of an ordinary cell, multicells, or a rapidly rotating supercell

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tornadoes: An intense, rotating column of air that often protrudes from a cumuliform cloud in the shape of a funnel or a rope whose circulation is present on the ground.

tropopause: The boundary separating the troposphere from the stratosphere is called tropopause.

troposphere: The layer of the atmosphere extending from Earth's surface up to the tropopause (about 10 km above the ground).

water vapor: Water in a vapor (gaseous) form. Also called *moisture*.

weather: The condition of the atmosphere at any particular time and place.

weather elements: The elements of *air temperature*, *air pressure*, *humidity*, *clouds*, *precipitation*, *visibility*, and *wind* that determine the present state of the atmosphere, the weather.

wind: Air in motion relative to Earth's surface.

wind direction: The direction *from which* the wind is blowing.

wind speed: The rate at which the air moves by a stationary object, usually measured in statute miles per hour (mi/hr), nautical miles per hour (knots), kilometers per hour (km/hr), or meters per second (m/sec).

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What's New in This Chapter

The following elements are improvements in this chapter from the previous edition:

- Chapter 1, "Earth's Atmosphere," continues to serve as a broad overview of the atmosphere. The text begins with a discussion of the scientific method and its importance, followed by a capsule summary of extreme weather events, including recent hurricanes and wildfires and the record-setting U.S. heat, cold, and tornadoes observed in 2021.

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Chapter Outline

The following outline organizes activities (including any existing discussion questions in PowerPoints or other supplements) and assessments by chapter (and therefore by topic), so that you can see how all the content relates to the topics covered in the text. The first number refers to the chapter learning objective; "PPT Slide #" refers to the slide number in the PowerPoint deck for this chapter (provided in the PowerPoints section of the Instructor Resource Center).

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1.1 The Atmosphere and the Scientific Method (LO1, PPT Slides #5–9)

a. Knowledge Check 1, PPT Slides #8-9, 2-3 minutes

1.2 Weather, Climate, and Meteorology (LO2–LO4, PPT Slides #10–25)

a. Meteorology—The Study of the Atmosphere (LO3, PPT Slide #12)
   i. A Satellite's View of the Weather (LO3, PPT Slide #13)
   ii. Storms of All Sizes (LO3, PPT Slide #14)

b. A Glimpse at a Weather Map (L03, PPT Slides #15–17)
   i. Knowledge Check 2, PPT Slides #18–19, 2–3 minutes

c. Weather and Climate in Our Lives (LO4, PPT Slides #20–26)
   i. Role-Play Activity 1, PPT Slides #24–25, 5–7 minutes

1.3 Components of Earth's Atmosphere (LO5–LO6, PPT Slides #26–32)

a. The Early Atmosphere (LO5, PPT Slides #28)
b. Composition of Today's Atmosphere (LO6, PPT Slides #28–30)
   i. Self-Assessment 1, PPT Slides #31–32, 3–5 minutes

1.4 Vertical Structure of the Atmosphere (LO7–LO8, PPT Slides #33–41)

a. A Brief Look at Air Pressure and Air Density (LO7, PPT Slides #34–36)
b. Layers of the Atmosphere (LO8, PPT Slides #37–39)
   i. Discussion Activity 1, PPT Slides #40–41, 7–10 minutes

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TEACHING SUGGESTIONS

1. Fill a water glass completely with water and cover it with a piece of plastic (such as the lid from a tub of butter), being careful to remove any air. Invert the glass. The water remains in the glass because the upward force on the cover due to the pressure of the air is much stronger than the downward gravitational force on the water. The demonstration can be made much more convincing if a 4,000-mL Erlenmeyer flask is used instead of the water glass. When full of water, the flask weighs approximately 10 pounds.
2. Place a candle in the center of a dish and partly fill the dish with water. Light the candle and then cover it with a large jar or beaker. The flame will consume the oxygen inside the jar and reduce the pressure. Water will slowly flow into the jar to re-establish pressure balance. The change in volume will be close to 20%, the volume originally occupied by the oxygen in the air. This demonstration can be used to illustrate the concept of partial pressure, which is later used in the chapter on humidity. The students should also be asked what they think the products of the combustion might be and why these gases do not replace the oxygen and maintain the original pressure in jar. One of the combustion products is water vapor, which condenses as the air in the jar cools. Another combustion product is carbon dioxide, which presumably goes into solution.

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3. Students often confuse water vapor with liquid water. Students should understand that water vapor is an invisible gas. Haze, fog, clouds, and the steam from a boiling pot all become visible when water vapor condenses and forms small drops of liquid water. This can be easily demonstrated using a tea kettle, or by showing a video of water boiling in a tea kettle.
4. The introductory explanations of the air motions associated with high- and low-pressure centers and fronts make this a good place to begin to show and discuss satellite images, loops, and surface weather maps. Download a few satellite loops and discuss the air motions.
5. Encourage students to speculate on how we know the chemical composition of Earth's early atmosphere. What types of gas are involved in "outgassing"?
6. Brief students on the concept of layering while describing the composition of atmospheric gases. Nitrogen comprises 78% of the atmosphere, so if the gases each occupied distinct layers with nitrogen on the bottom, the nitrogen layer would extend from the floor up to about ¾ the distance to the ceiling.
7. Compare the thickness of the atmosphere to that of the skin on an apple. If Earth and the atmosphere combined were shrunk down to the size of an apple, the atmosphere would be about as thick as the skin on the apple.

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Student Projects

1. Have the students mark the positions of fronts and pressure systems for each day on an outline map of the United States. (This information can be obtained, among other places, from the **NOAA Advanced Hydrologic Prediction Service**.)
2. Have students compose a one-week blog or journal, including daily weather maps and weather forecasts. Have the students provide a commentary for each day as to the coincidence of actual and predicted weather.
3. Have students keep a daily record of weather observations, especially significant changes in the weather. Then, periodically, the instructor can supply mean daily data such as high and low temperatures, pressure, dew point, wind speed, cloud cover, and precipitation amounts. The students should plot these data and annotate the graph with their observations. Students can use their graphs to experimentally test concepts developed in class. After studying Chapter 1, for example, students might try to determine whether periods of stormy weather really are associated with lower-than-average surface pressure.
4. Students could attempt to repeat some of the experiments in *Hands-On Meteorology*.
5. Use the University of Wyoming's Department of Atmospheric Science's website (**Atmospheric Soundings**) to identify the altitude of the tropopause at locations on three different continents.

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Group Work

1. **Weather Watching AirBnB**. Imagine that your team has been hired to help a group of investors which will decide where to open an AirBnB or boutique hotel that will attract people who love dramatic weather. In a group, evaluate the weather patterns for North America, and then make a list of three choices. Create a report that describes the location, the types of weather patterns they are likely to see, and the kinds of safety provisions you will need to build in the hotel to assure the guests that they will not be harmed as they enjoy nature's shows.
2. **Global Fire Map**. Imagine that your team has been hired to research the impact of massive fires (forest fires, grass fires, etc.) in the world, and to recommend how to reforest the burned land, given the rainfall and climate patterns, and how to prevent future fires. Create a report with diagrams that shows where and when the fires happened, their impact, and the kinds of vegetation that would grow back, given rain patterns. Then, list suggestions for avoiding fires, taking into consideration local weather patterns.
3. **Every Weather Map Tells a Story**. As a group, put together three weather maps that tell the story of a devastating hail storm that damaged cars in a car lot, bruised cattle in their pastures, and piled up like snow against the sides of buildings and stacked bales of hay (due to strong winds from one direction). Write a narrative that explains the progress of the weather patterns. Be sure to use the proper weather map symbols as established by the American Meteorological Society.

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Answers to Questions for Review

1. Radiant energy from the sun.
2. Investigators use the scientific method by posing a question, putting forth a hypothesis, predicting what the hypothesis would imply if it were true, and carrying out tests to see if the prediction is accurate. To be accepted, a hypothesis has to be shown to be correct through a series of quantitative tests. Studying the atmosphere, however, is somewhat different, because our Earth has only one atmosphere. Despite this limitation, scientists have made vast progress by studying the physics and chemistry of air in the laboratory (for instance, studying the way in which molecules absorb energy) and by extending those understandings to the atmosphere as a whole. Observations using weather instruments allow us to quantify how the atmosphere behaves and to determine whether a prediction is accurate. If a particular kind of weather is being studied, such as hurricanes or snowstorms, a field study can gather additional observations to test specific hypotheses.
3. Seven common weather elements are:
(1) *air temperature*—the degree of hotness or coldness of the air; (2) *air pressure*—the force of the air above an area; (3) *humidity*—a measure of the

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amount of water vapor in the air; (4) *clouds*—a visible mass of tiny water droplets and/or ice crystals that are above Earth's surface; (5) *precipitation*—any form of water, either liquid or solid (rain or snow), that falls from clouds and reaches the ground; (6) *visibility*—the greatest distance one can see; (7) *wind*—the horizontal movement of air.

4. Weather describes the condition of the atmosphere at any particular time and place. Climate describes weather conditions averaged over a region or over a time period.

5. *Meteorology* is the study of the atmosphere and its phenomena. The term itself goes back to the Greek philosopher Aristotle who, about 340 B.C. wrote a book on natural philosophy entitled *Meteorologica*.

6. Middle-latitude cyclonic storm, hurricane, thunderstorm, and tornado.

7. From the south.

8. From west to east.

9. High- and low-pressure systems, fronts, wind speed and direction, cloud cover, and temperatures.

10. Low-pressure systems: counterclockwise. High-pressure systems: clockwise.

11. Weather and climate dictate the type of clothing we buy and wear, the types of crops we plant and harvest, and homes we build. Even if we have appropriate clothing and shelter weather and climate can greatly impact and affect our comfort, well-being, and overall health (e.g., arthritic pain is linked to high humidity and falling air pressures, heart attack incidences are higher after the passage of warm fronts, when rain and wind are common, and after the passage of cold fronts, when an abrupt change takes place as showery precipitation is accompanied by cold gusty winds, and headaches are common on days when we are forced to squint, often due to hazy skies or a thin, bright overcast layer of high clouds). Weather and climate can have dramatic economic impacts, either by saving heating costs in warm winters or by increasing them in cold years.

    Cold weather, coupled with snow and ice typically affects commuter traffic, air travel, schools, and can lead to major power outages. Droughts can result in food shortages, starvation, heat strokes, dehydration, and very destructive wild fires. Strong winds, such as hurricanes, thunderstorms, and tornadoes, can lead to destruction and flash flooding.

12. Earth's first atmosphere (some 4.6 billion years ago) was most likely *hydrogen* and *helium*—the two most abundant gases found in the universe—as well as hydrogen compounds, such as methane and ammonia. A second, denser atmosphere gradually enveloped Earth as gases from molten rock within its hot interior escaped through volcanoes and steam vents. We assume that volcanoes spewed out the same gases then as they do today: mostly water vapor (about 80%), carbon dioxide (about 10%), and up to a few percent nitrogen. As millions of years passed, the constant outpouring of gases from the hot interior (outgassing) provided a rich supply of water vapor, which formed into clouds.

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Rain fell upon Earth for many thousands of years. Large amounts of CO_2 were dissolved in the oceans. The atmosphere gradually became rich in nitrogen (N_2). Oxygen (O_2), the second most abundant gas in today's atmosphere, probably began an extremely slow increase in concentration as energetic rays from the sun split water vapor (H_2O) into hydrogen and oxygen during a process called *photodissociation.* The hydrogen, being lighter, probably rose and escaped into space, while the oxygen remained in the atmosphere. After plants evolved, the atmospheric oxygen content increased more rapidly, probably reaching its present composition about several hundred million years ago. Today's atmosphere consists mostly of molecular nitrogen (N_2), which occupies about 78%, and molecular oxygen (O_2), which makes up about 21% of the total volume of dry air; argon, neon, helium, hydrogen, and xenon make up the remaining 1%. If the latter gases are removed, the percentages for nitrogen and oxygen hold fairly constant up to an elevation of about 80 km (or 50 mi).

13. Nitrogen, oxygen, argon, and water vapor.

14. Water vapor.

15. Ozone and oxygen filter out damaging ultraviolet radiation from the sun, greenhouse gases keep the planet warm, and the atmosphere provides water to drink and oxygen to breathe.

16. Water forms precipitation, releases latent heat, and is a greenhouse gas. Water vapor is extremely important for Earth's heat-energy balance.

17. CO_2 enters the atmosphere through vegetation decay, volcanic eruptions, exhalations of animal life, and through burning of fossil fuels and deforestation. CO_2 removal occurs through photosynthesis, *chemical weathering*, and with the help of phytoplankton, by deposition into Earth's oceans. The amount of CO_2 in the atmosphere has increased over the course of the last 100 plus years due to burning of fossil fuels and deforestation.

18. Soil, dust, salt from ocean waves, forest fire smoke, volcanic ash particles and gases, and pollutants.

19. Water vapor and carbon dioxide.

20. (a) Air is surprisingly heavy, and the more molecules are packed into an air column, the denser an air column becomes, and the more the surface pressure increases. On the other hand, when fewer molecules are in the air column, the air weighs less, and the surface pressure goes down.
(b) Atmospheric pressure decreases with increasing height, because as we climb in elevation, fewer air molecules are above us and a greater number is below us.

21. (a) 29.92 in. Hg, (b) 1013.25 mb, (c) 1013.25 hPa.

22. Troposphere, stratosphere, mesosphere, and thermosphere.

23. Generally, temperature decreases from Earth's surface to the tropopause (i.e., boundary between the troposphere and stratosphere at around 11 km or 36,000

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ft.). It then increases throughout the stratosphere, but decreases again in the mesosphere. The top of the mesosphere (i.e., the mesopause) represents the coldest part of Earth's atmosphere. In the thermosphere, the temperature increases again.

24. (a) Troposphere, (b) stratosphere; thermosphere.
25. Antarctica
26. Since the air in the upper stratosphere is extremely thin and the atmospheric pressure is low mesospheric air contains far fewer oxygen molecules than a breath of tropospheric air.
27. The **ionosphere** is not really a layer, but rather an electrified region within the upper atmosphere where fairly large concentrations of ions and free electrons exist.

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Answers to Questions for Thought and Exploration

1. Climate: It's currently winter so one should wear warm clothes. Weather: It's warmer today than yesterday and hence a person can wear a lighter coat.
2. Answers may vary, but the student should point out that a newspaper weather map typically simplifies information. Cold fronts are often represented in different shades of blue (the darker the blue, the colder the temperature), and warm fronts are shown in shades of red. Cyclones are color-coded with the colors representing different intensities. Professional weather maps will comprise a lot more detailed information, and symbols are different. Cold fronts are displayed by blue triangles drawn onto a blue line (triangle point indicates the direction the cold front is moving), and warm fronts are represented by red half circles along a red line. Isotherms are used to display temperatures and temperature gradients, and isobars to show high- and low-pressure systems. Isobars would show a middle latitude cyclone as a circular low-pressure system.
3. (a) Climate, (b) weather, (c) climate, (d) weather, (e) climate, (f) climate, (g) weather, and (h) climate.
4. The student first needs to be able to pose the right question, and in this case, the question would be "In which direction do weather systems move in the middle latitudes?" Subsequently, the student will come up with a hypothesis, and since the idea is to disprove the friend's hypothesis, it will be "Weather systems in the middle latitudes move from west to east." The student will then investigate potential experiments and tests that could be used to support this hypothesis. For example, if a person could look at wind maps from the middle latitudes that were put together over a period of times. If the student lives in the middle latitudes, s/he could put up a wind sock or wind vane to measure the wind direction. The idea is to design a series of quantitative tests that are

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accepted by the scientific community to prove his hypothesis and disprove the friend's hypothesis.

5. The student will draw an outline of North America and, using different colors, will mark daily positions of cold and warm fronts, and pressure systems over a period of several weeks. The student will be able to conclude in which direction the weather patterns are moving (west to east due to the jet stream), and how North America is affected by cold fronts moving in from the Arctic Circle and warm fronts from the Gulf of Mexico. In addition, a person should be able to point out that middle latitude cyclones are daily phenomena, which drive the weather and produce a wide range of weather phenomena.
6. The student will compose a journal over a one-week period, which will list forecasts, weather maps, and weather-related newspaper articles, and will compare and contrast the forecasted weather with the actual weather of each day. The student will need to understand overall weather patterns, but also the difficulties associated with predicting the weather in certain regions (e.g., mountainous regions).

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Answers to Everyday Scenarios

1. If it is a digital portfolio, the folders can include screenshots, jpegs, PDFs, and more. The daily journal should be in a Word or Google docs document that allows you to make comments.
2. The first step will involve collecting accurate information. Although millions of people rely on weather broadcast on radio and TV, many millions use forecasts obtained on their smartphones or on personal computers. Smartphone applications can be tailored to provide conditions and forecasts for your hometown or wherever you may be traveling. Websites operated by the National Weather Services and private forecasting companies provide a wealth of local, national, and global data and forecasts.

   If you are encountering differences between data you have collected, data from websites, or historic climate data, start with checking the source of your data. Items to consider when using data from collection sites are who maintains the site, what height are the meters located above the ground, what substrate is the meter located on, is the equipment kept in housing or located in direct sunlight. When making comparisons with historic climate data, items to consider are proximity to the ocean and mountain ranges, weather phenomena such El Nino vs La Nina conditions, or hurricane season.
3. The geography of Death Valley causes it to be subject to a rain shadow effect. Humid air masses traveling east from the Pacific Ocean must cross four mountain ranges before they reach the desert valley. As the air masses are forced up and over the mountains, the moisture they carry condenses and falls as rain on the

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western slopes, leaving a dry area, or rain shadow, on the eastern side. Typically, by the time most air masses reach Death Valley, they are bone dry.

However, Death Valley is located in an area where summer rains and flash flooding may occur. Every so often, there are events that are large enough to break weather records and cause significant damage to historic locations and park infrastructure.

In August of 2022, Death Valley was hit by historic monsoonal thunderstorms that caused millions of dollars in damage to roads and facilities. The flooding that hit Death Valley is only seen once in a thousand years. Nearly a year's worth of rain fell in just 3 hours. Other parks in California were also impacted by the summer of 2022's very active monsoon. Roads were damaged in both Mojave National Preserve and the south side of Joshua Tree National Park. The National Weather Service in San Diego, California, also warned of additional surges of monsoonal moisture that would increase the chance of desert and mountain thunderstorms.

The flooding is not only a result of the type of storm. The ground in Death Valley is very dry, which has resulted in the sediments becoming compacted and forming a hardpan. The hardpan behaves as a barrier that stops water from entering back into the ground. This hard, impermeable surface, results in an increase in the volume and rate of surface run-off as less water infiltrates into the ground. Under these conditions, even a small amount of rainfall can trigger flash floods very quickly.

Additional Resources

External Videos or Playlist

- Extreme Weather
- Scientific Method

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APPENDIX

GENERIC RUBRICS

Providing students with rubrics helps them understand expectations and components of assignments. Rubrics help students become more aware of their learning process and progress, and they improve students' work through timely and detailed feedback. Customize these rubrics as you wish. The writing rubric indicates 40 points and the discussion rubric indicates 30 points.

STANDARD WRITING RUBRIC

Criteria	Meets Requirements	Needs Improvement	Incomplete
Content	The assignment clearly and comprehensively addresses all questions in the assignment. 15 points	The assignment partially addresses some or all questions in the assignment. 8 points	The assignment does not address the questions in the assignment. 0 points
Organization and Clarity	The assignment presents ideas in a clear manner and with strong organizational structure. The assignment includes an appropriate introduction, content, and conclusion. Coverage of facts, arguments, and conclusions are logically related and consistent. 10 points	The assignment presents ideas in a mostly clear manner and with a mostly strong organizational structure. The assignment includes an appropriate introduction, content, and conclusion. Coverage of facts, arguments, and conclusions are mostly logically related and consistent. 7 points	The assignment does not present ideas in a clear manner and with strong organizational structure. The assignment includes an introduction, content, and conclusion, but coverage of facts, arguments, and conclusions are not logically related and consistent. 0 points
Research	The assignment is based upon appropriate and adequate academic literature, including peer-reviewed journals and other scholarly work. 5 points	The assignment is based upon adequate academic literature but does not include peer-reviewed journals and other scholarly work. 3 points	The assignment is not based upon appropriate and adequate academic literature and does not include peer-reviewed journals and other scholarly work. 0 points
Research Citation	The assignment follows the required citation guidelines. 5 points	The assignment follows some of the required citation guidelines. 3 points	The assignment does not follow the required citation guidelines. 0 points
Grammar and Spelling	The assignment has two or fewer grammatical and spelling errors. 5 points	The assignment has three to five grammatical and spelling errors. 3 points	The assignment is incomplete or unintelligible. 0 points

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Standard Discussion Rubric

Criteria	Meets Requirements	Needs Improvement	Incomplete
Participation	Submits or participates in discussion by the posted deadlines. Follows all assignments. Instructions for initial post and responses. 5 points	Does not participate or submit discussion by the posted deadlines. Does not follow instructions for initial post and responses. 3 points	Does not participate in discussion. 0 points
Contribution Quality	Comments stay on task. Comments add value to discussion topic. Comments motivate other students to respond. 20 points	Comments may not stay on task. Comments may not add value to discussion topic. Comments may not motivate other students to respond. 10 points	Does not participate in discussion. 0 points
Etiquette	Maintains appropriate language. Offers criticism in a constructive manner. Provides both positive and negative feedback. 5 points	Does not always maintain appropriate language. Offers criticism in an offensive manner. Provides only negative feedback. 3 points	Does not participate in discussion. 0 points

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