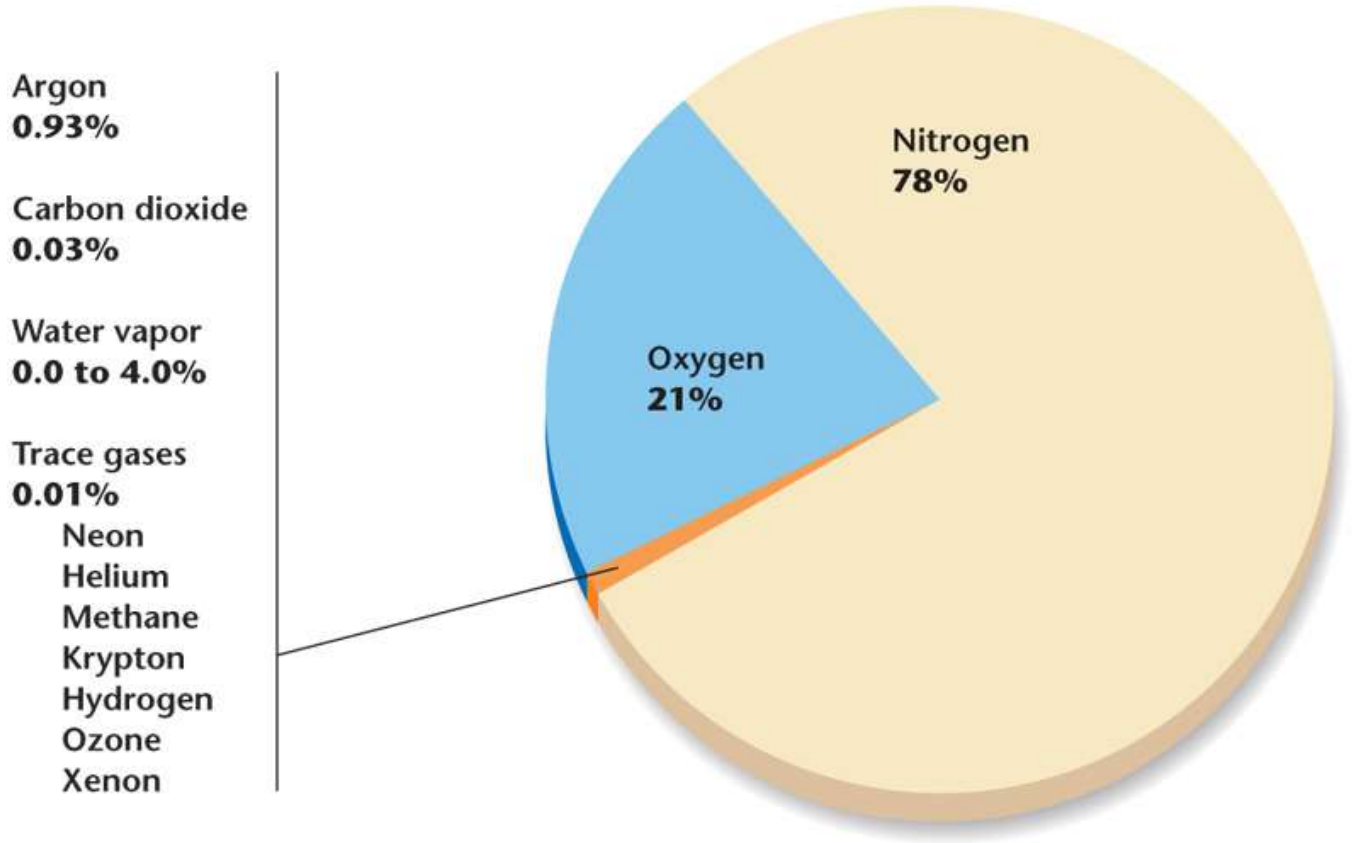
Atmospheric Composition

- Air is a combination of many gases, each with its own unique characteristics.
- About 99 percent of the atmosphere is composed of nitrogen and oxygen, with the remaining one percent consisting of small amounts of argon, hydrogen, carbon dioxide, water vapor, and other gases.

Atmospheric Composition

Percentages of Gases That Make Up Earth's Atmosphere



Atmospheric Composition

Key Atmospheric Gases

- The amount of water vapor in the atmosphere can be as much as four percent of the atmosphere or as little as almost zero.
- Carbon dioxide, another variable gas, makes up under one percent of the atmosphere.
- The levels of both carbon dioxide and water vapor play an important role in regulating the amount of energy the atmosphere absorbs.
- Water is the only substance in the atmosphere that exists in three states: solid, liquid, and gas.

Atmospheric Composition

Key Atmospheric Gases

- When water changes from one state to another, heat is either absorbed or released which greatly affects weather and climate.
- The atmosphere also contains solids in the form of tiny particles of dust, salt, and ice.

Atmospheric Composition

Ozone

- **Ozone** (O_3), is a gas formed by the addition of a third oxygen atom to an oxygen molecule (O_2).
- Evidence indicates that the ozone layer is thinning.

Structure of the Atmosphere

- The atmosphere is made up of several different layers.
- Each layer differs in composition and temperature.

Atmospheric Composition

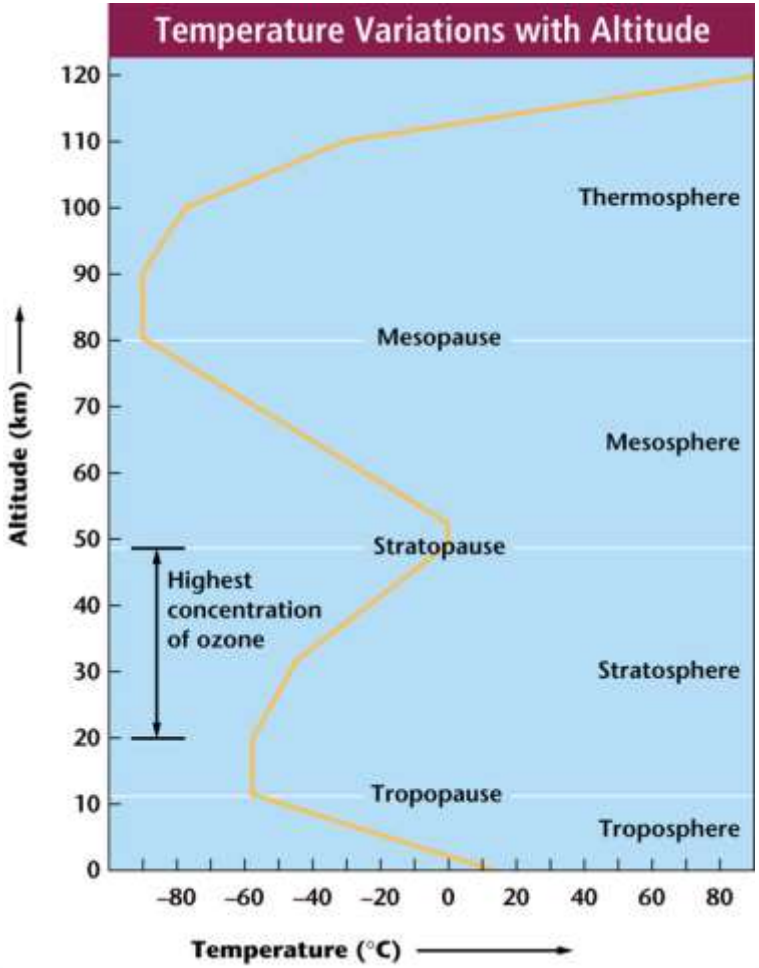
Lower Atmospheric Layers

- The **troposphere**, the layer closest to Earth's surface, contains most of the mass of the atmosphere, including water vapor.
- Most weather takes place in and most air pollution collects in the troposphere.
- The troposphere is characterized by a general decrease in temperature from bottom to top.
- The upper limit of the troposphere, called the tropopause, varies in height.

Atmospheric Composition

Lower Atmospheric Layers

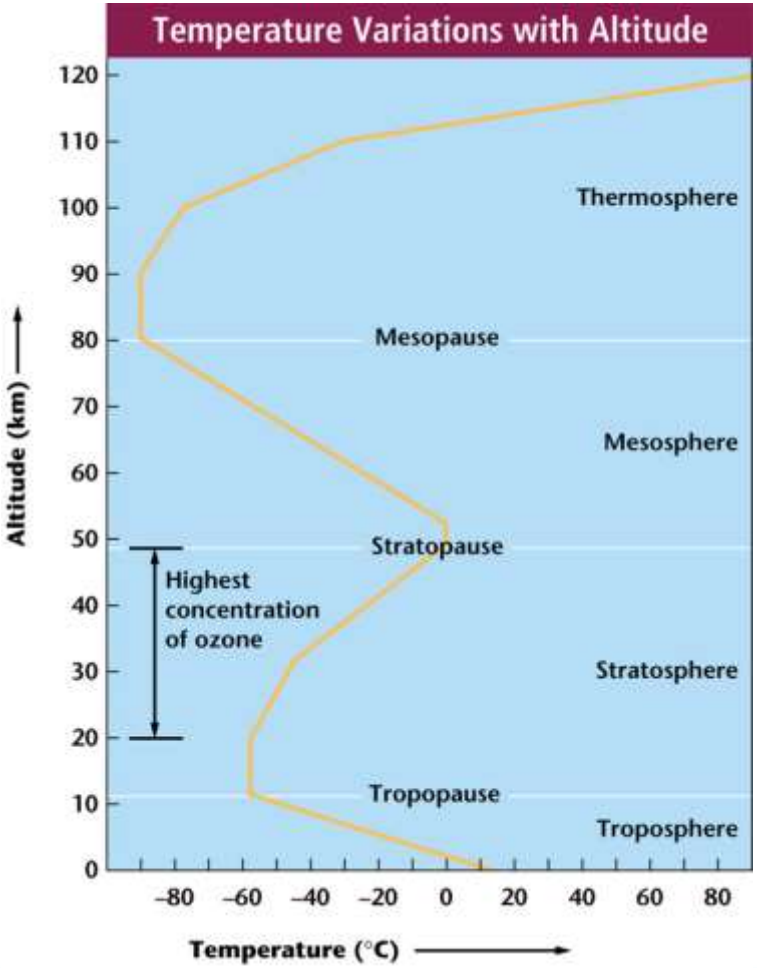
- The **stratosphere**, which is above the tropopause, is a layer made up primarily of concentrated ozone.
  - The stratosphere is heated because ozone absorbs ultraviolet radiation, and air gradually increases in temperature to the top of the layer, called the stratopause.



Atmospheric Composition

Upper Atmospheric Layers

- The **mesosphere** is the atmospheric layer above the stratopause.
  - The top boundary of this layer is the mesopause.
- The **thermosphere** is the atmospheric layer above the mesopause that contains only a minute portion of the atmosphere's mass.



Atmospheric Composition

Upper Atmospheric Layers

- The ionosphere, which is made up of electrically charged particles and layers of progressively lighter gases, is part of the thermosphere.
- The **exosphere**, which is composed of light gases such as helium and hydrogen, is the outermost layer of Earth's atmosphere.
- There is no clear boundary between the atmosphere and space.

Solar Fundamentals

- The Sun is the source of all energy in the atmosphere.
- This energy is transferred to Earth and throughout the atmosphere through radiation, conduction, and convection.

Solar Fundamentals

Radiation

- The Sun is shining on, and therefore warming, some portion of Earth's surface at all times.
- **Radiation** is the transfer of energy through space by visible light, ultraviolet radiation, and other forms of electromagnetic waves.
- While Earth is absorbing solar radiation, it is also continuously sending energy back into space.

Solar Fundamentals

Radiation

- The rate of absorption for any particular area varies depending on the physical characteristics of the area and the amount of solar radiation it receives.
- Most of the solar radiation that travels through the atmosphere does so at short wavelengths, which are not easily absorbed.
- Earth's surface absorbs the solar radiation and then radiates energy with longer wavelengths, which warm the atmosphere through conduction and convection.

Solar Fundamentals

Convection

- **Convection** is the transfer of energy by the flow of a heated substance.
  - Pockets of air near Earth's surface are heated, become less dense than the surrounding air, and rise.
  - As the warm air rises, it expands and starts to cool.
  - When it cools below the temperature of the surrounding air, it increases in density and sinks.
  - Convection currents are among the main mechanisms responsible for the vertical motions of air, which in turn cause different types of weather.

Section Assessment

1. Match the following terms with their definitions.

_B_ radiation

_A_ conduction

_C_ convection

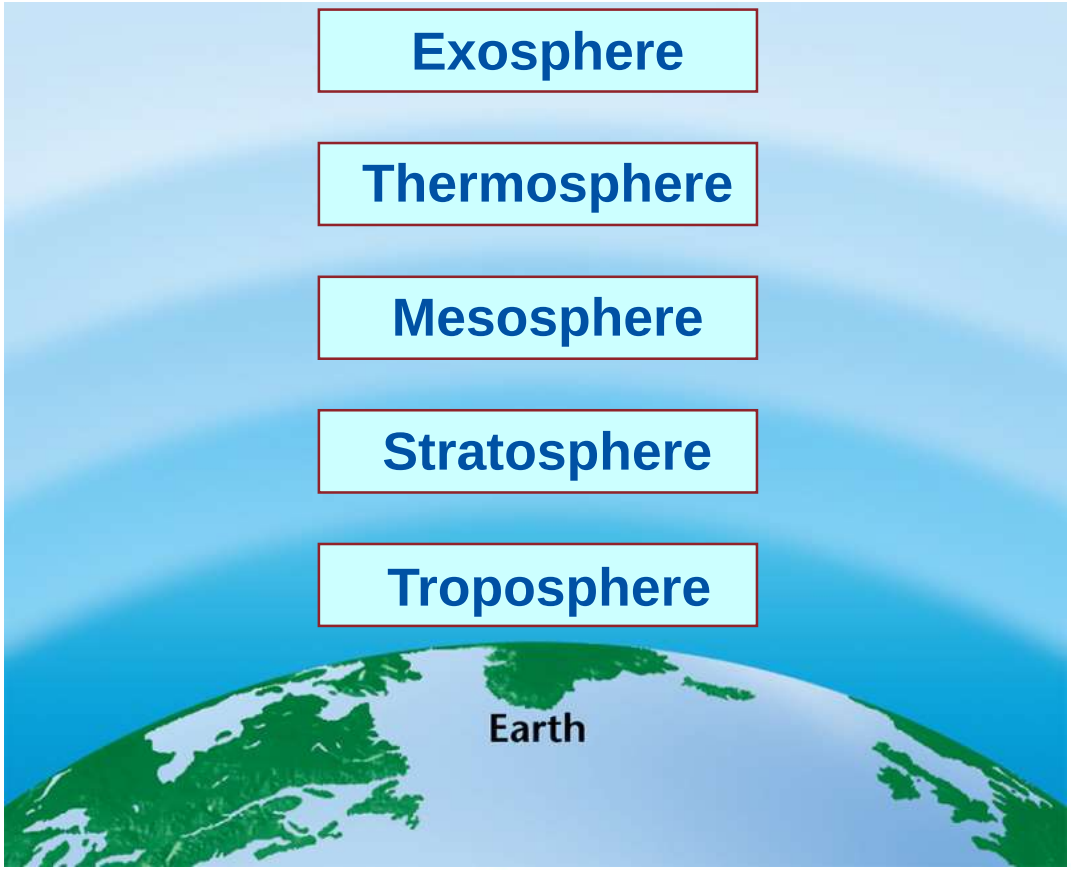
A. the transfer of energy that occurs when molecules collide

B. the transfer of energy through space by visible light, ultraviolet radiation, and other forms of electromagnetic waves

C. the transfer of energy by the flow of a heated substance

Section Assessment

2. Label the layers of Earth's atmosphere.



Section Assessment

3. Why is ozone important?

Ozone absorbs ultraviolet radiation from the sun. If ozone did not control the amount of ultraviolet radiation reaching Earth's surface, our skin could not tolerate exposure to the Sun for very long.

Temperature Versus Heat

- **Temperature** is a measurement of how rapidly or slowly molecules move around.
- **Heat** is the transfer of energy that occurs because of a difference in temperature between substances.

- Heat is the *transfer* of energy that fuels atmospheric processes, while temperature is used to measure and interpret that energy.

Temperature Versus Heat

Dew Point

- The **dew point** is the temperature to which air must be cooled at constant pressure to reach saturation.
  - Saturation is the point at which the air holds as much water vapor as it possibly can.
  - Condensation cannot occur until air is saturated.
- **Condensation** occurs when matter changes state from a gas to a liquid.

Vertical Temperature Changes

- The temperature of the lower atmosphere decreases with increasing distance from Earth's surface.
- An air mass that does not exchange heat with its surroundings will cool off by about 10°C for every 1000 m increase in altitude.
- The dry adiabatic lapse rate is the rate at which unsaturated air, to which no heat is added or removed, will cool.

Air Pressure and Density

- The gravitational attraction between Earth and atmospheric gases causes particles of gas to be pulled toward the center of Earth.
- Air pressure increases as you near the bottom of the atmosphere because of the greater mass of the atmosphere above you.
- Atmospheric pressure decreases with height because there are fewer and fewer gas particles exerting pressure.
- The density of air is proportional to the number of particles of air occupying a particular space.

Pressure-Temperature-Density Relationship

Temperature Inversion

- A **temperature inversion** is an increase in temperature with height in an atmospheric layer.
- This can happen when the lower layers of the atmosphere lose heat to Earth's surface and become cooler than the air above them.
- A temperature inversion can act like a lid to trap pollution under the inversion layer.
- In all cases, the presence or absence of inversions can have a profound effect on weather conditions.

Wind

- Air moves in response to density imbalances created by the unequal heating and cooling of Earth's surface.
- These imbalances, in turn, create areas of high and low pressure.
- Wind can be thought of as air moving from an area of high pressure to an area of low pressure.
- Wind speed generally increases with height in the atmosphere because there is less friction.

Relative Humidity

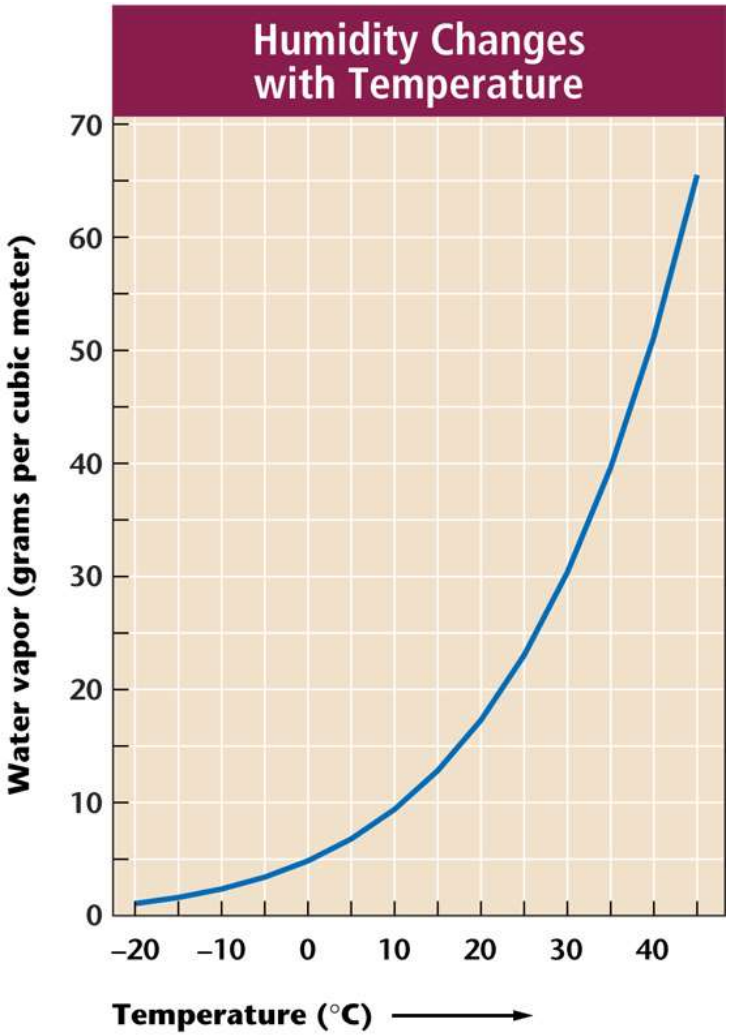
- Air in the lower portion of the atmosphere always contains at least some water vapor.

Humidity is the amount of water vapor in air.

Relative humidity is the ratio of water vapor in a volume of air compared to how much water vapor that volume of air is capable of holding.

Relative Humidity

- Relative humidity varies with temperature because warm air is capable of holding more moisture than cool air.
  - If the temperature of an air parcel increases and no additional water vapor is added, its relative humidity decreases.
  - If more water vapor is added to the parcel, its relative humidity increases.



Relative Humidity

- Relative humidity is expressed as a percentage.
  - If a certain volume of air is holding as much water vapor as it possibly can, then its relative humidity is 100 percent.
  - If that same volume of air is holding half as much water vapor as it can, its relative humidity is 50 percent, and so on.

Section Assessment

1. Match the following terms with their definitions.

_A_ temperature

_D_ heat

_B_ dew point

_C_ humidity

A. a measurement of how rapidly or slowly molecules move around

B. the temperature to which air must be cooled at constant pressure to reach saturation

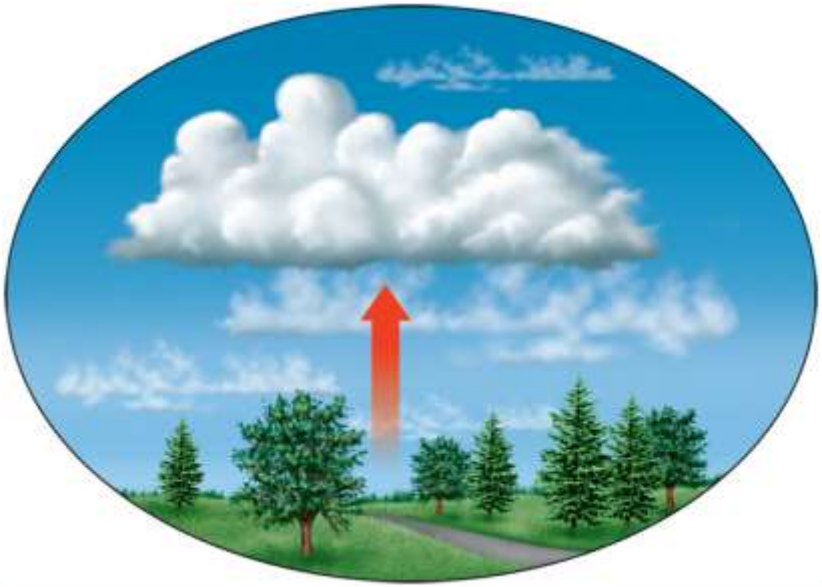
C. the amount of water vapor in air

D. the transfer of energy that occurs because of a difference in temperature between substances

Cloud Formation

- Buoyancy is the tendency for air to rise or sink as a result of differences in density.
- Clouds form when warm, moist air rises, expands, and cools in a convection current.

Condensation nuclei are small particles in the atmosphere around which cloud droplets can form.

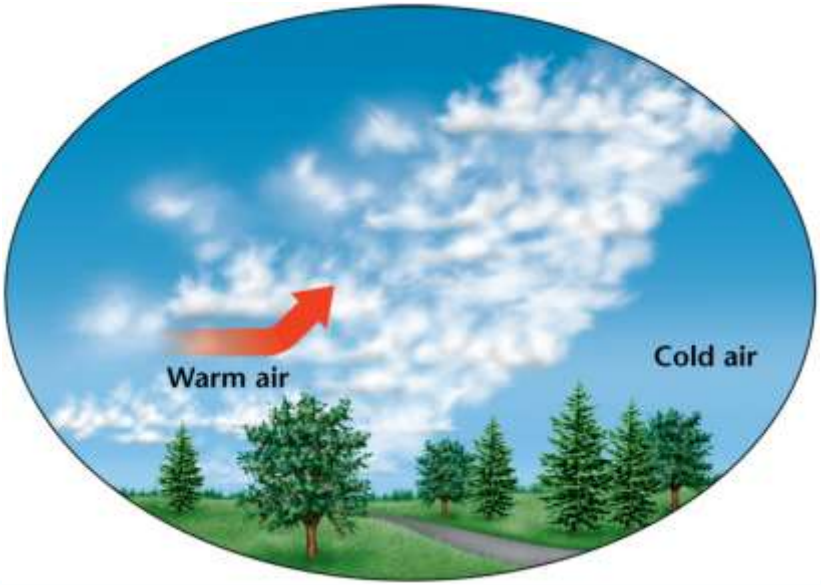


Cloud Formation

- **Orographic lifting** occurs when wind encounters a mountain and the air has no place to go but up.
- The air expands and cools resulting in cloud formation.

Cloud Formation

- Cloud formation occurs with the collision of air masses of different temperatures.
- As warmer air collides with cooler air, the bulk of it will be forced to rise over the more-dense, cold air.
- As the warm air cools, the water vapor in it condenses and forms a cloud.



Cloud Formation

Stability

- How rapidly any given mass of air cools determines its stability.
- **Stability** is the ability of an air mass to resist rising.
- The rate at which an air mass cools depends in part on the temperature of the surface beneath the air.
- Air can become unstable if it is cooler than the surface beneath it.
- If temperature conditions are right and the air mass rises rapidly, it can produce the type of clouds associated with thunderstorms.

Cloud Formation

Latent Heat

- As water vapor in the air condenses, heat is released.
- The energy to change liquid water into a gaseous state is stored in the water vapor.
- **Latent heat** is stored energy in water vapor that is not released to warm the atmosphere until condensation takes place.
- The amount of water vapor present in the atmosphere is a significant source of energy because of the latent heat it contains.

Types of Clouds

- When a mass of rising air reaches its lifted condensation level, or LCL, water vapor condenses.
- If the density of these droplets is great enough, they become visible in the form of a cloud.
- This process can take place at many different altitudes and form different cloud shapes.

Types of Clouds

- Clouds are generally classified according to a system originally developed by English naturalist Luke Howard in 1803.
- The modern system groups clouds by the altitude at which they form and by their shape.
  - Low clouds typically form below 2000 m.
  - Middle clouds form between 2000 m to 6000 m.
  - High clouds composed of ice crystals form above 6000 m.
  - Vertical development clouds spread throughout all altitudes at the same time.

Types of Clouds

Table 11-3 Cloud Classification

Height		Shape	
Prefix		**Prefix**	
Cirro Describes high clouds with bases starting above 6000 m.		**Cirrus** Latin meaning: "hair." Describes wispy, stringy clouds.	
Alto Describes middle clouds with bases between 2000 m to 6000 m.		**Cumulus** Latin meaning: "pile or heap." Describes puffy, lumpy-looking clouds.	
Strato Refers to low clouds below 2000 m.		**Stratus** Latin meaning: "layer." Describes featureless sheets of clouds.	
		Nimbus Latin meaning: "cloud." Describes low, gray rain clouds.	

Types of Clouds

Low Clouds

- If rising air stays warmer than the surrounding air, the cloud will continue to grow.
- If the air does not stay warmer than the surrounding air, the cloud will flatten out and winds will spread layered cumulus clouds.
- Stratus, a layered cloud that covers much or all of the sky, often forms when fog lifts away from Earth's surface.

Types of Clouds

Middle Clouds

- Altocumulus and altostratus clouds, which form at heights between 2000 m and 6000 m, can be either all liquid or a mixture of liquid and ice crystals.
- Middle clouds are usually layered.

Types of Clouds

High Clouds

- Because they form above heights of 6000 m, where temperatures are below freezing, high clouds are made up of ice crystals.
- Cirrus clouds, often have a wispy, indistinct appearance.
- Cirrostratus clouds form as a continuous layer that sometimes covers the sky.

Types of Clouds

Clouds of Vertical Development

- If the air that makes up a cumulus cloud is unstable enough, the cloud will continue to grow.
- As it rises, water vapor condenses, and the air receives additional warmth from the release of latent heat.
- If conditions are right, it can reach nearly 18 000 m.
- A cumulus cloud can thus develop into a full-fledged cumulonimbus cloud that is capable of producing the torrential rains and strong winds that are characteristic of thunderstorms.

Precipitation

- **Coalescence** occurs when cloud droplets collide and join together to form a larger droplet.
- When the droplet becomes too heavy to be held aloft, gravity takes over and it falls to Earth as precipitation.
- **Precipitation** includes all forms of water, both liquid and solid, that fall from clouds including rain, snow, sleet, and hail.

The Water Cycle

- At any one time, only a small percentage of water is present in the atmosphere.
- This water continually moves between the atmosphere and Earth's surface.

The **water cycle** is the constant movement of water between the atmosphere and Earth's surface.

Evaporation is the process of water changing from a liquid to a gas.

Section Assessment

1. Match the following terms with their definitions.

_B_ condensation nuclei

_D_ stability

_A_ coalescence

_C_ latent heat

A. process by which cloud droplets collide and join together to form a larger droplet

B. small particles in the atmosphere around which cloud droplets can form

C. stored energy in water vapor that is not released to warm the atmosphere until condensation takes place

D. the ability of an air mass to resist rising

Section Assessment

2. What is the source of energy that fuels the water cycle?

The water cycle receives its energy from the Sun.

Section Assessment

3. How can latent heat affect the weather?

When latent heat is released during condensation, it can provide energy to a weather system, thereby increasing its intensity.

Study Guide

Section 11.1 Main Ideas

- Earth's atmosphere is made of a combination of several gases, primarily nitrogen and oxygen. It also contains small amounts of water vapor, carbon dioxide, ozone, and dust, which play key roles in the production of weather and climate.
- The atmosphere consists of several layers characterized by differences in temperature. The most important for weather is the lowest layer, the troposphere, where most of the mass of the atmosphere is found.
- The Sun is the source of energy in Earth's atmosphere. Solar energy absorbed by Earth's surface is transferred throughout the atmosphere by the processes of radiation, conduction, and convection.

Section 11.2 Main Ideas

- Heat is the transfer of energy that occurs because of a difference in temperature between substances. Temperature is the measure of how rapidly or slowly molecules move around. Atmospheric temperature generally decreases with altitude.
- Air has mass and exerts a force called atmospheric pressure. Because there are fewer molecules of gas in the upper atmosphere, atmospheric pressure decreases with increasing altitude.
- Wind is the movement of air that results from differences in pressure. Wind speed is affected by friction; mountains, forests, and buildings slow wind down.

Section 11.3 Main Ideas

- Clouds are formed as warm, moist air is forced upward, expands, and cools. Orographic lifting is a method of cloud formation that involves air moving up the side of a mountain. Clouds may also form when air masses of different temperatures collide.
- Clouds are generally classified according to the altitudes at which they form and their shapes.
- As cloud droplets collide, they coalesce into larger droplets, which may fall to Earth as precipitation. The four main types of precipitation are rain, snow, sleet, and hail.
- In the water cycle, water continually moves between Earth's surface and the atmosphere through the processes of evaporation, condensation, and precipitation.

Multiple Choice

1. Which of the following gasses makes up the largest percentage of the atmosphere?

a. oxygen

b. carbon dioxide

c. nitrogen

d. hydrogen

Nitrogen makes up 78 percent of the gases in Earth's atmosphere. *Oxygen* makes up 21 percent. *Carbon dioxide* and *hydrogen* make up part of the remaining one percent.

Multiple Choice

2. In which layer of the atmosphere contains the ozone layer?

a. troposphere

b. stratosphere

c. mesosphere

d. thermosphere

The *ozone layer* is found 20–50 km above Earth's surface placing it below the stratopause in the stratosphere.

Multiple Choice

3. You plan to climb 1500 m up a mountain on a sunny day. What temperature drop should be expected during your climb?

a. 5ºC

b. 10ºC

c. 15ºC

d. 20ºC

Since you will not be climbing high enough to reach the *lifted condensation level* which would be marked by clouds, you should use the *dry adiabatic lapse rate* (10ºC per 1000 m) to figure temperature drop.

Multiple Choice

4. Which atmospheric phenomenon would most likely aid in smog formation?

a. temperature inversion

b. orographic lifting

c. conduction

d. convection

A *temperature inversion* can act like a lid to trap pollution under the inversion layer. *Orographic lifting*, *conduction*, and *convection* all help to mix the atmosphere.

Multiple Choice

5. Which of the following is a cloud of vertical development?

a. altocumulus

b. cumulonimbus

c. nimbostratus

d. stratocumulus

Cumulonimbus clouds begin as *cumulus* clouds and can reach more than 18 000 m into the atmosphere. They are associated with thunderstorms and sometimes have a classic anvil-shaped top.

Short Answer

6. Explain the relationship between air temperature and density.

The relationship between temperature and density is inversely proportional. If an air mass maintains a certain pressure, as temperature increases, density decreases, and as temperature decreases, pressure increases. Air rises when its temperature increases because it is less dense.

Short Answer

7. Why does Earth's surface play a larger role in warming the atmosphere than direct solar radiation?

Solar radiation that travels through the atmosphere does so at short wavelengths that are not easily absorbed by the atmosphere but are absorbed by Earth's surface. The surface then radiates energy back at longer wavelengths that can be absorbed by the atmosphere. The air is then warmed through the processes of conduction and convection.

True or False

8. Identify whether the following statements are true or false.

false 100ºF is equal to 373 K.

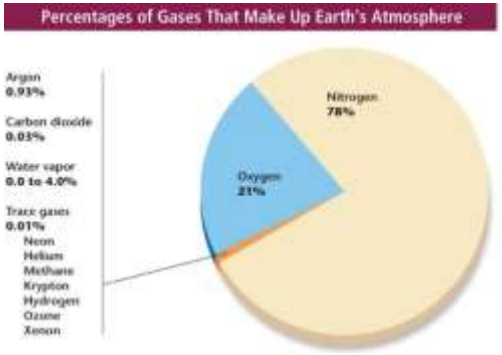
true Most weather occurs in the troposphere.

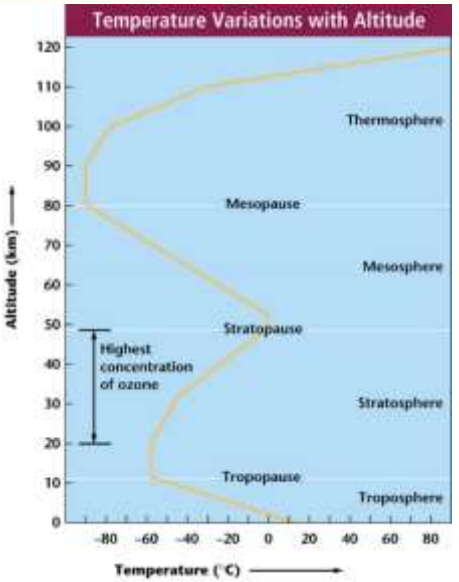
true If the amount of water vapor in the air stays the same as the temperature rises, relative humidity decreases.

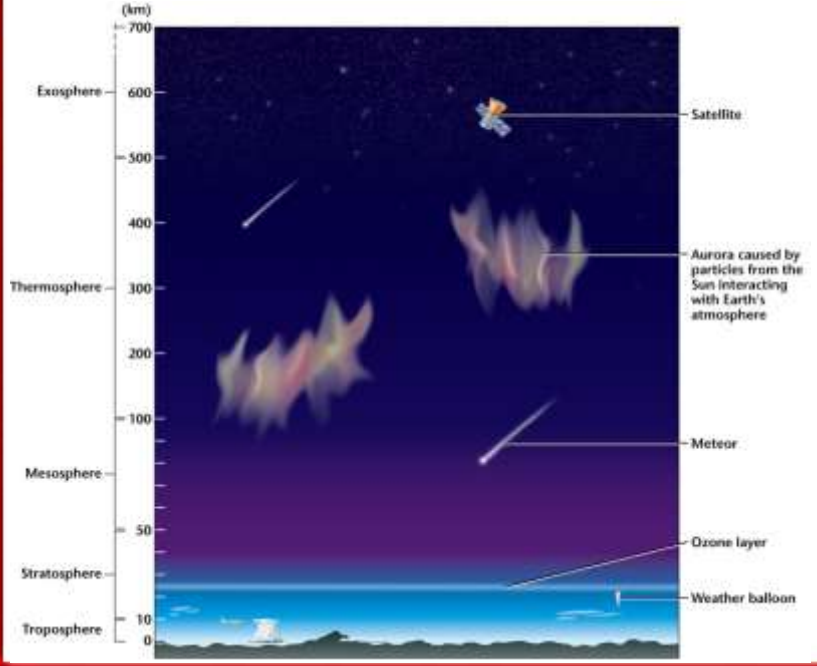
false Latent heat causes the evaporation that fuels the water cycle.

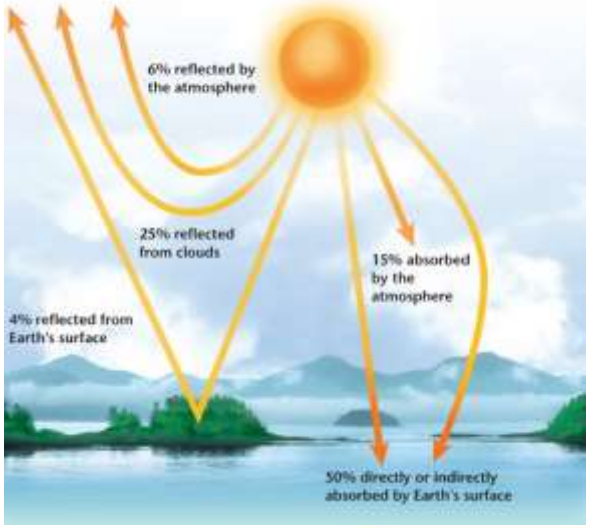
true Conduction affects only a very thin atmospheric layer near Earth's surface.

Chapter 11 Images









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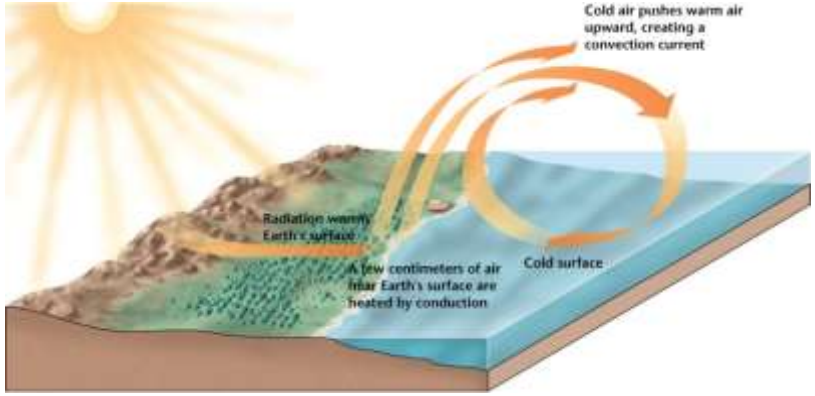

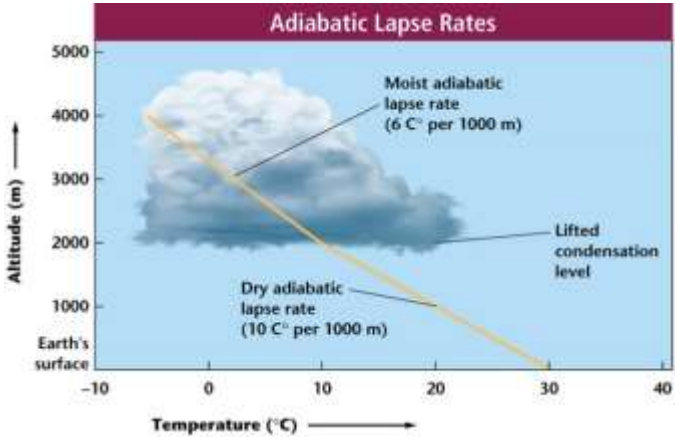

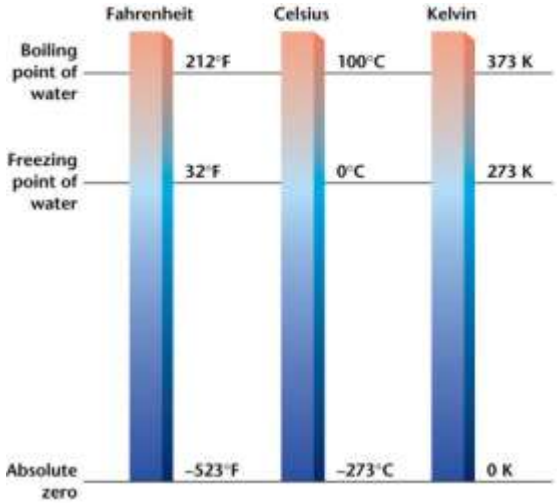

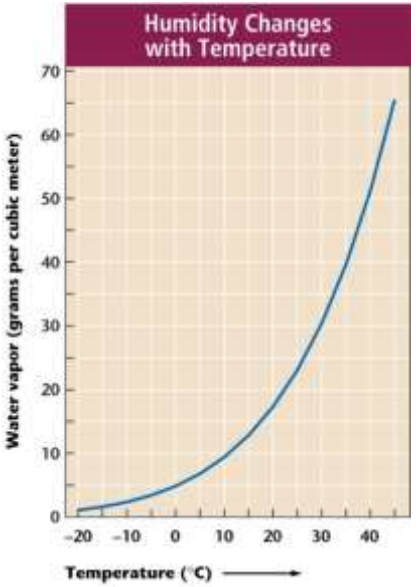

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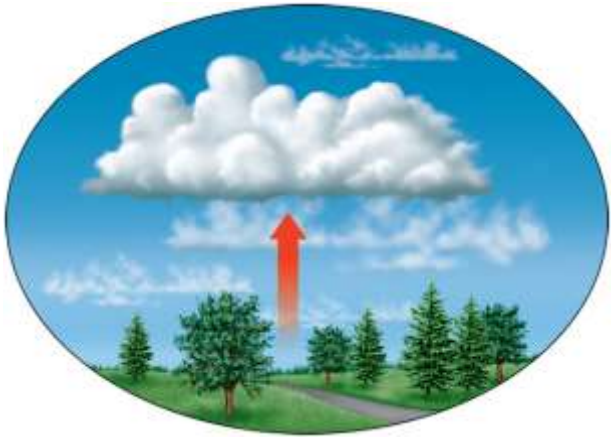

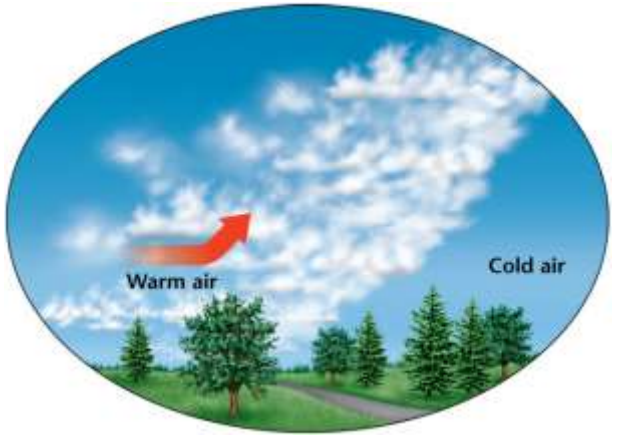

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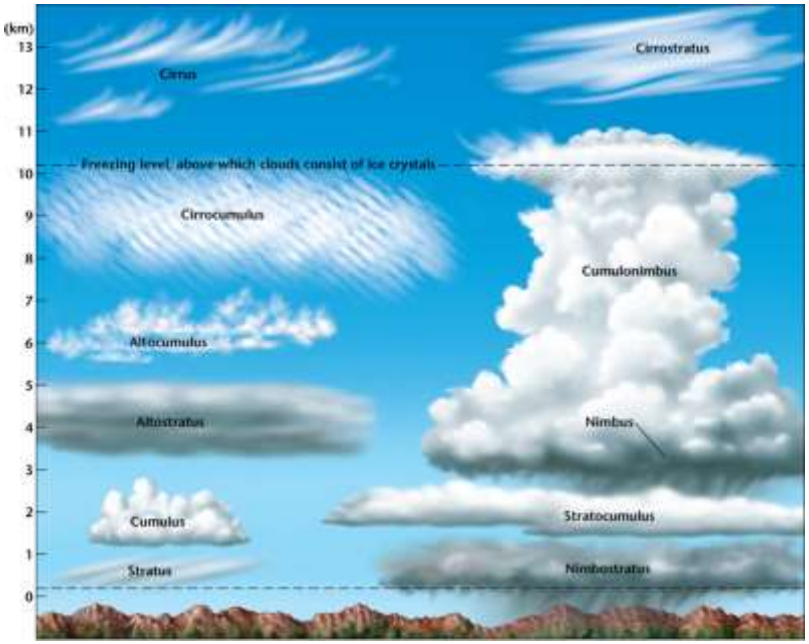

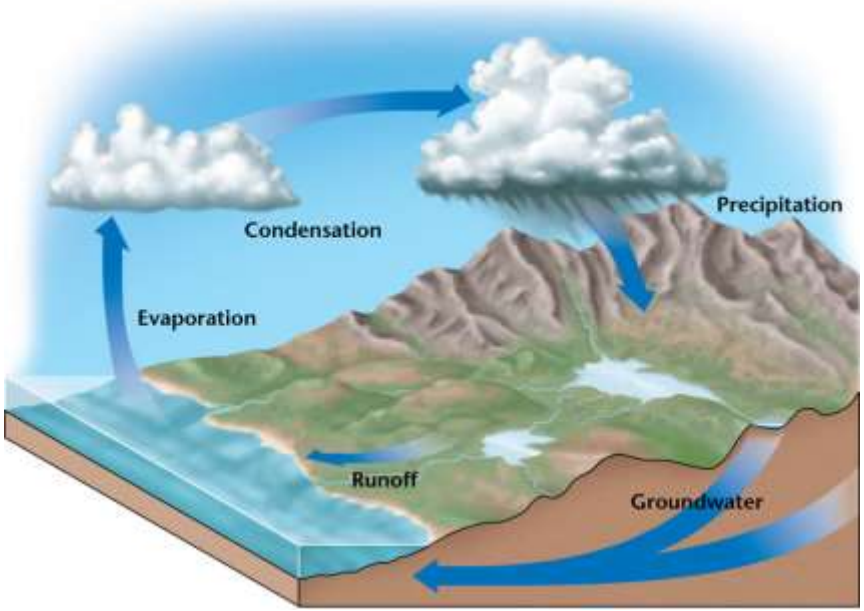

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