ATMOSPHERE

Chapter 17

Section 17.1: The Atmosphere in Balance

Objectives:

- Describe the formation of Earth's early atmosphere and the composition of the lower atmosphere.
- Demonstrate how the Earth system continually recycles gases and how certain activities disturb an atmosphere in balance.

The Composition of the Atmosphere

- Scientists hypothesize that **volcanic eruptions** played the main role in forming Earth's early atmosphere.**
- Gases released from **volcanic eruptions** – primarily **carbon dioxide, sulfur dioxide, water vapor, and nitrogen** – probably made up nearly all of this early atmosphere.
- What about the oxygen?.....

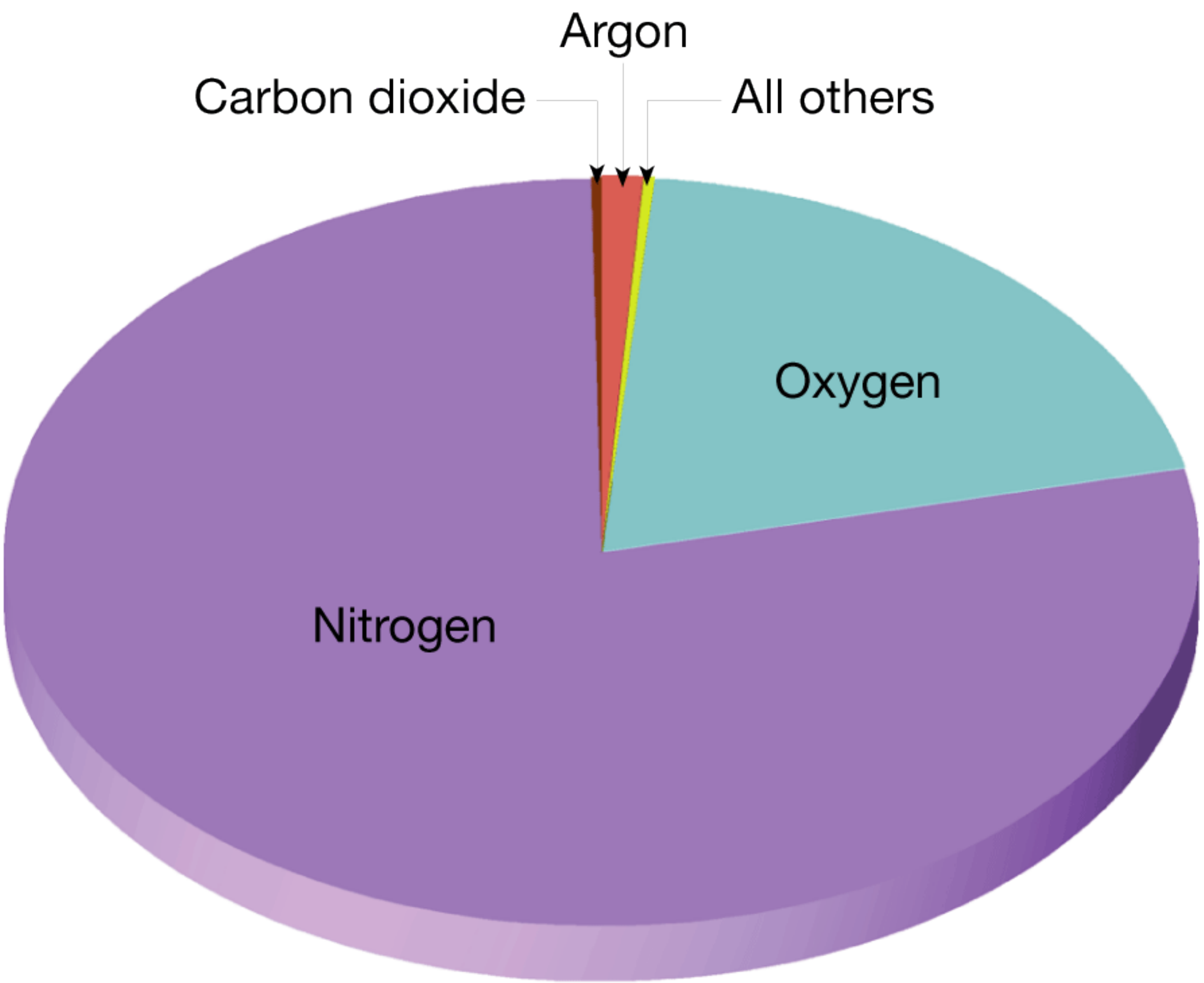
The Composition of the Atmosphere

- Oxygen may have first entered the atmosphere as a result of sunlight splitting water vapor molecules into oxygen and hydrogen.
- The amount of oxygen in the atmosphere increased significantly as early life forms trapped the energy of sunlight through photosynthesis.
- **Photosynthesis** releases oxygen.

The Composition of the Atmosphere

- Today Earth's lower atmosphere is a mixture of many gases called "air".
- The main gases in air are **nitrogen** (78%) and **oxygen** (21%), which together form about 99% of dry air by volume.**
- The remaining 1% is mostly argon and carbon dioxide. Also present are tiny amounts of trace gases, such as helium, hydrogen, and neon.

Volume of Clean, Dry Air



The Composition of the Atmosphere

- The percentage of nitrogen and oxygen are **fairly constant** throughout the atmosphere up **to an altitude of about 80 kilometers**.
- **Water vapor content varies with location, season, and time of day**. Water vapor concentration is higher near the surface. Like carbon dioxide, water vapor absorbs heat given off by Earth. It also absorbs some solar energy.

The Composition of the Atmosphere

- **<u>Carbon dioxide in the air varies with the seasons</u>**. It is lowest during summer and highest during winter. Why?
  - Photosynthesis is highest during the summer months (which removes carbon dioxide from the atmosphere).
- The atmosphere also contains a wide variety of dust particles. Dust includes: tiny grains of rocks, dirt, pollen, salt crystals from sea spray, and soot from fires.

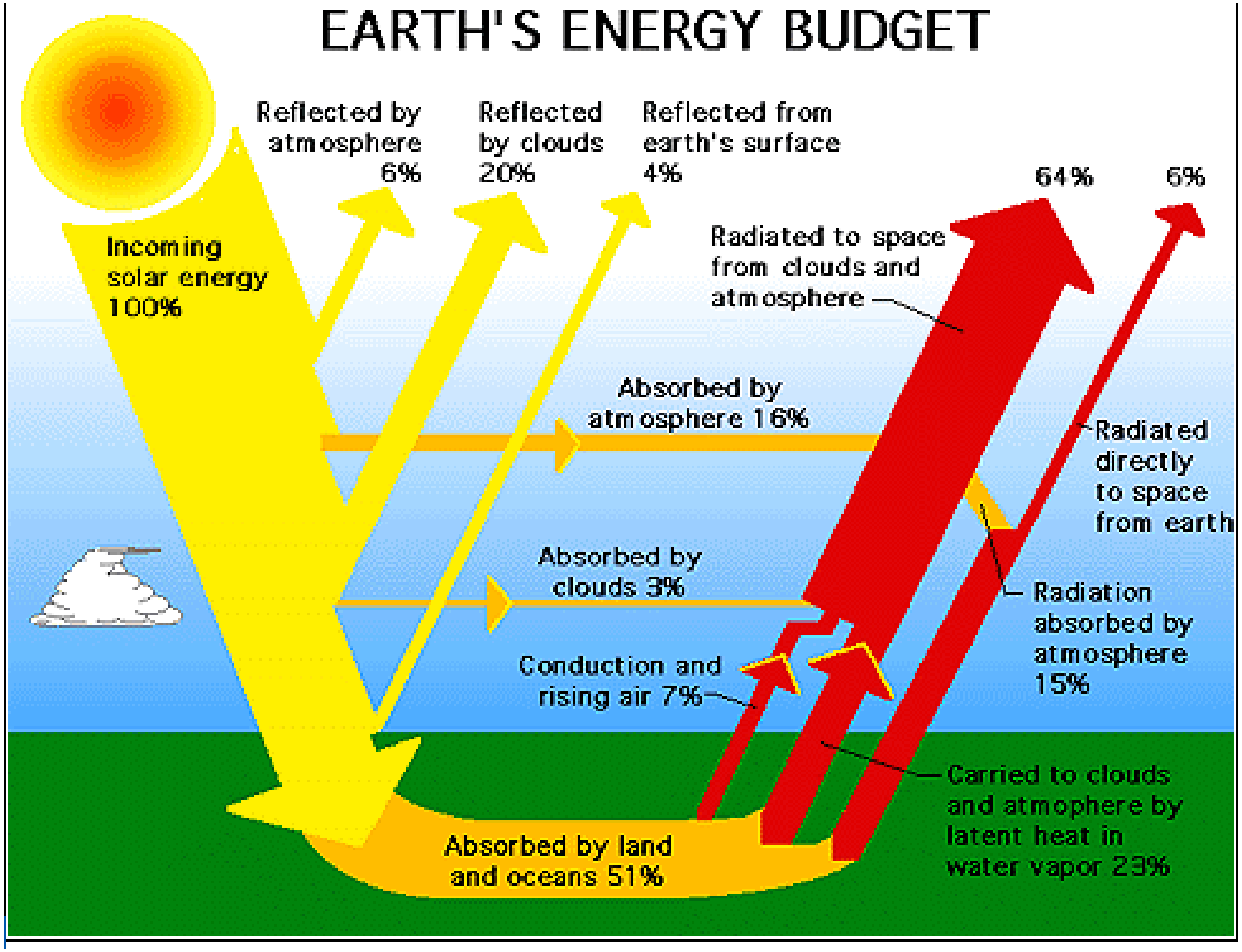
Recycling of Atmospheric Materials

- The **composition of the atmosphere** has **remained stable** throughout Earth's recent history **because** our planet has an **efficient recycling system**.**
- Elements and compounds are constantly moving between the atmosphere and the other parts of the Earth system – the geosphere, hydrosphere, and biosphere.

Recycling of Atmospheric Materials

- An overall balance is maintained because the amount of a given substance leaving the atmosphere equals the amount of that same substance entering the atmosphere over the same period of time.
- The carbon cycle and the water cycle help to maintain this balance. Here's how…

Earth’s Energy Budget – Draw Picture



Recycling of Atmospheric Materials

- Plants take carbon dioxide from the air for photosynthesis and release oxygen.
- In contrast, animals and humans inhale oxygen and exhale carbon dioxide.
- Carbon dioxide is also returned to the atmosphere through the decomposition of organic materials.

Recycling of Atmospheric Materials

- Water vapor enters the atmosphere through evaporation, transpiration from plants, and the exhaled breath of animals and humans.
- Water leaves the atmosphere in the form of precipitation (rain, snow, and hail).

A Delicate Balance

- The balance maintained in the atmosphere may be disturbed by a variety of factors, both natural and of human origin.

A Delicate Balance

- Evidence seems to show that carbon dioxide levels in the atmosphere have been steadily increasing in recent years. Data collected at the Mauna Loa Observatory in Hawaii shows a 16% increase between 1959 and 1999. **Why?**
- The **increase in carbon dioxide levels** seems to be due to human activities, especially the burning of **fossil fuels** (such as coal, gasoline, and natural gas).

A Delicate Balance

- The atmosphere's sensitive balance also involves the energy from the sun. The movement of this energy plays a critical role in keeping Earth habitable.

Ticket Out the Door

1. Scientists hypothesize that Earth's early atmosphere was formed from the release of gases caused by what?

   Extra Credit: How was oxygen introduced into our atmosphere?

2. What are the two main gases that make up Earth's atmosphere?
3. Why is Earth's atmosphere fairly stable?

Section 17.1: Review

1. Describe how the composition of the atmosphere has changed over time.
2. Which two gases make up most of the atmosphere?
3. Draw a diagram showing some of the ways in which carbon dioxide enters and leaves the atmosphere.
4. In what ways might the loss of vegetation as a result of deforestation affect the atmosphere’s balance?

Section 17.2: Heat and the Atmosphere

<u>Objectives</u>:

- Describe how energy from the sun moves through the atmosphere by radiation, conduction, and convection.
- Identify the characteristics of each atmospheric layer.
- Analyze the Earth’s heat budget.

Section 17.2: Heat and the Atmosphere

Key Vocabulary:

- Radiation
- Conduction
- Convection
- Temperature
- Heat
- Troposphere
- Stratosphere
- Ozone
- Mesosphere
- Thermosphere
- Ionosphere
- insolation

Heat and the Atmosphere

- Energy from the sun drives the weather and is essential to almost all life on Earth.
- How does energy from the sun reach Earth across nearly 150,000,000 kilometers of space?
- What happens to the energy after it reaches Earth?

Heat and Temperature

- **Heat** is the **total kinetic energy of all the particles of the substance**.
- A large cup of tea has more heat than a small cup of tea at the same temperature.
- Heat **always flows from high temperature to low**.

Heat and Temperature

- The **temperature** of a substance is a measure of the **average kinetic energy of the atoms** or molecules in that substance.**
- A substance that is boiling has atoms that are moving very fast.

Heat and Temperature

- A **thermometer measures temperature, not heat**.
- Scientists measure temperature using the Celsius scale.
- 0° C => water freezes
- 100° C => water boils

Heating the Atmosphere

Energy Transfer as Heat

- Heat energy enters and moves through the atmosphere in three different ways: **radiation, conduction, and convection**.

Heating the Atmosphere

Energy Transfer as Heat

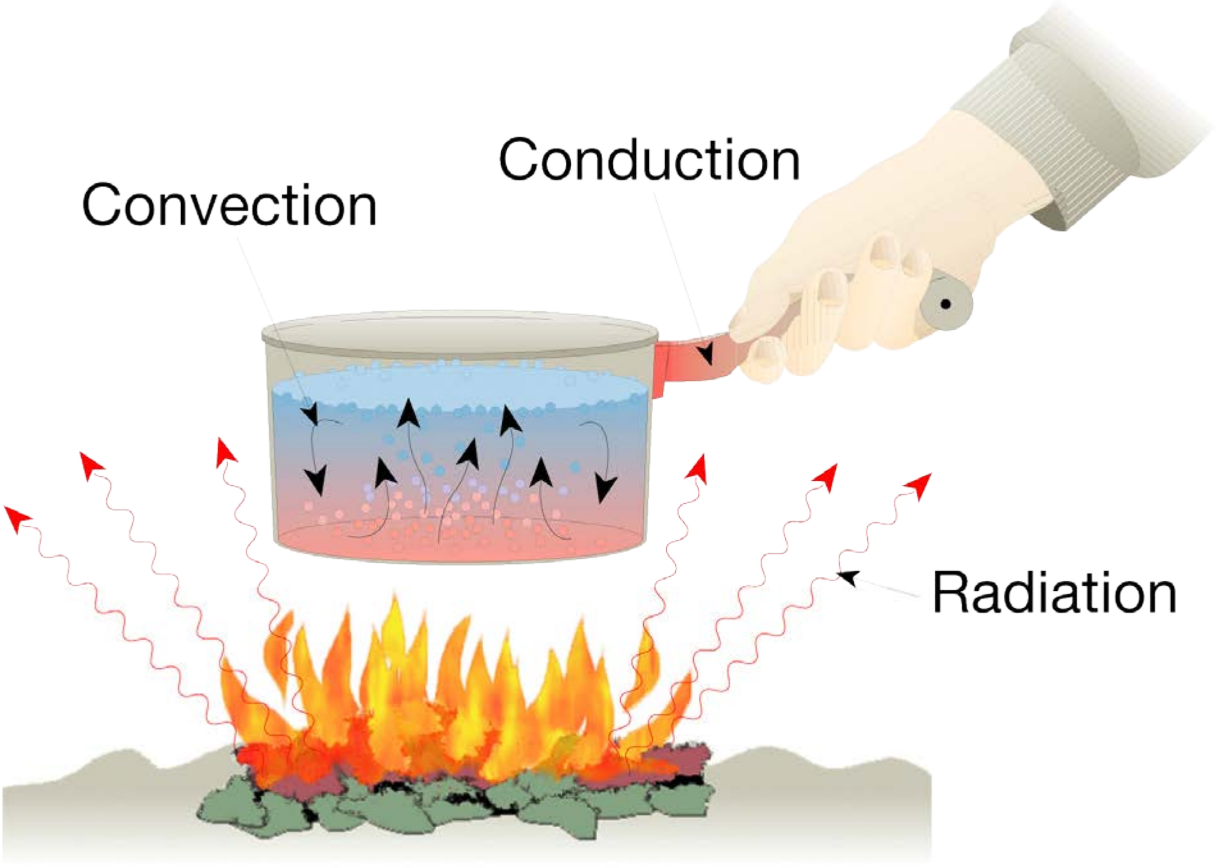
- **Conduction** is the **transfer of heat energy through collisions of the atoms or molecules of a substance**.
- Example: Heat moves by conduction from the hot sand to the soles of your feet.**

Heating the Atmosphere

Energy Transfer as Heat

- **Convection** is the **transfer of heat energy in a liquid or gas through the motion of the liquid** or gas caused by differences in density.
- Example: In a pot of simmering water, the water at the bottom of the pot is heated (by conduction) and rises, cooler water sinks.

Energy Transfer as Heat -Picture

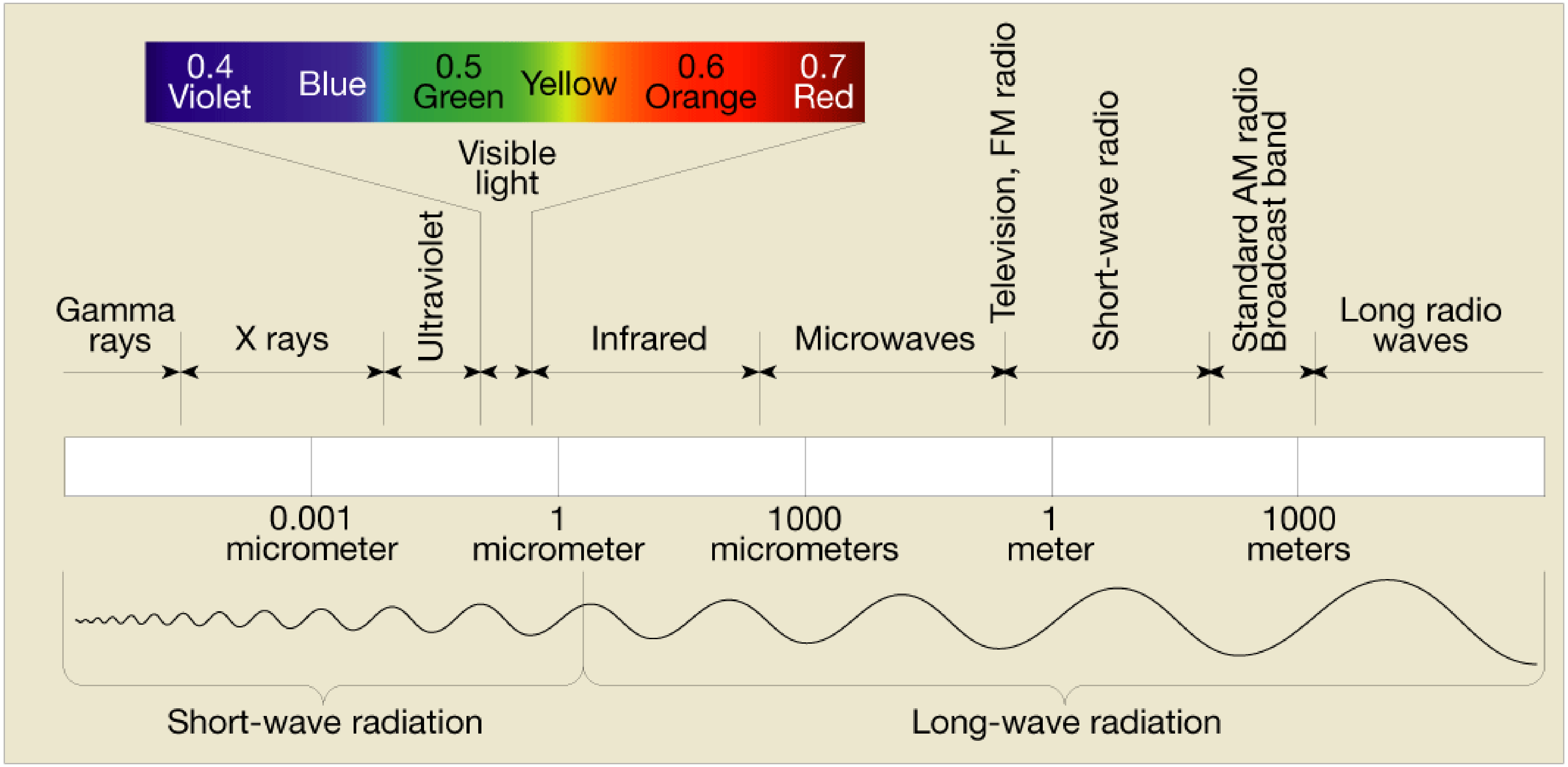


Heating the Atmosphere

Electromagnetic Waves

- The sun emits light and heat as well as the ultraviolet rays that cause a suntan. These forms of energy are only part of a large array of energy emitted by the sun, called the electromagnetic spectrum.

Electromagnetic Spectrum - Diagram



Heating the Atmosphere

- **Radiation** is the **transfer of energy (heat) through space by electromagnetic waves that travel out in all directions**.
- Unlike conduction and convection, which need material to travel through, **radiant energy can travel through the vacuum of space**.

Heating the Atmosphere

Radiation

- All objects, at any temperature, emit radiant energy. Hotter objects radiate more total energy per unit area than colder objects do.
- The **hottest radiating bodies** produce the **shortest wavelengths** of maximum radiation.
- Objects that are **good absorbers** of radiation **are good emitters** as well.

Heating the Atmosphere

What happens to Solar Radiation?

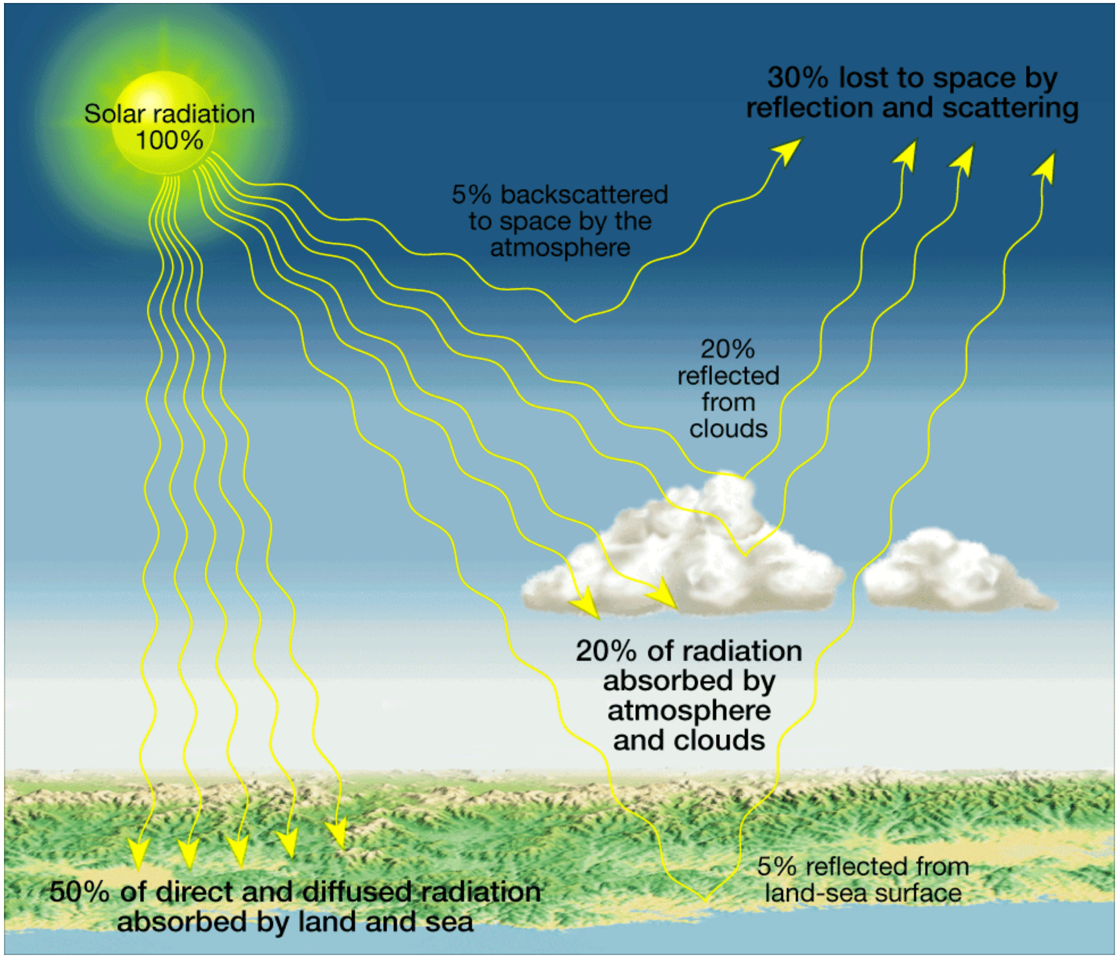
When radiation strikes an object, there usually are three different results.

1. **Some energy is absorbed** by the object.
2. **Substances** such as water and air **are transparent** to certain wavelengths of radiation.
3. **Some radiation may bounce off the object** without being absorbed or transmitted.

Solar Radiation

Energy from the Sun reaches Earth through radiation.**

Radiation is the only way that energy can travel through outer space.



Heating the Atmosphere

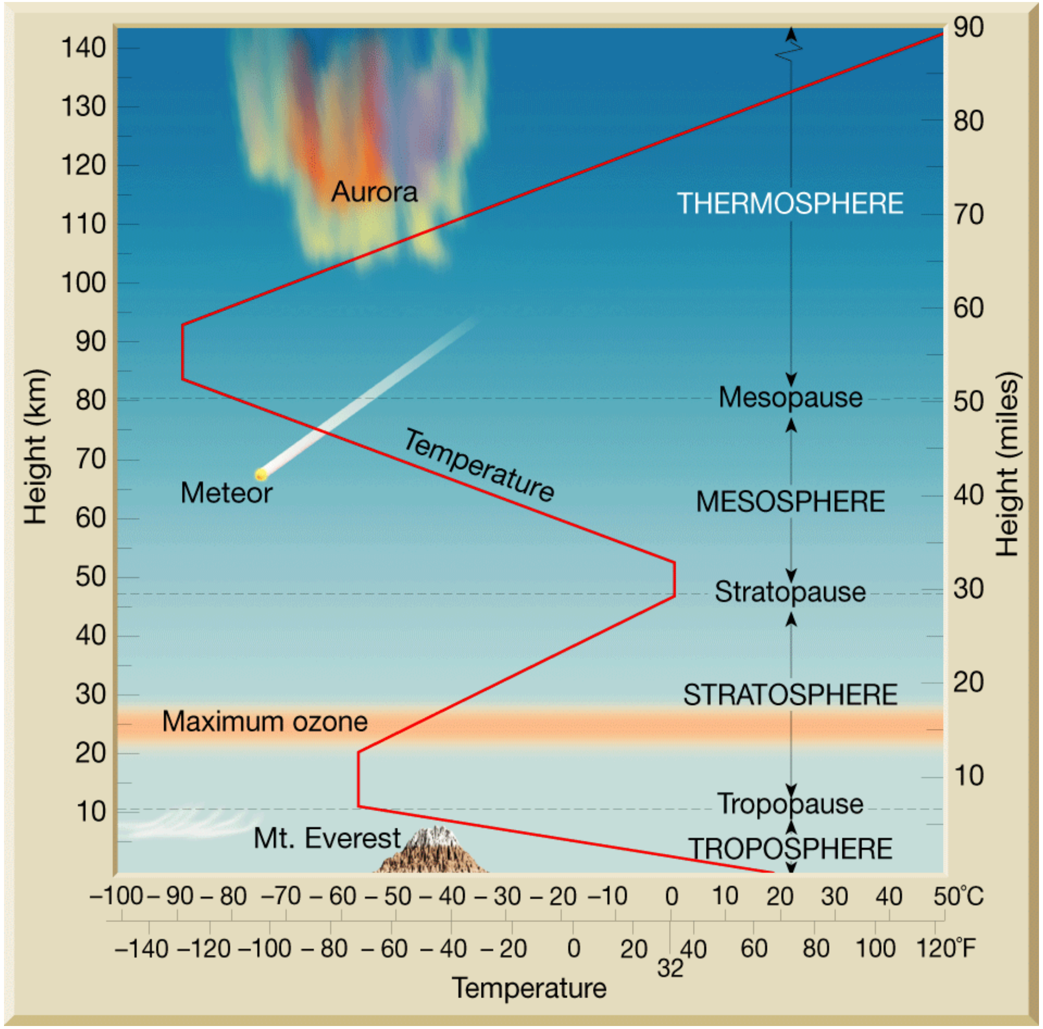
Reflection and Scattering

- **Reflection** occurs when **light bounces off an object**. Reflection radiation has the same intensity as incident radiation.
- **Scattering** produces a **larger number of weaker rays** that travel in different directions.
- **Absorption** - **About 50 percent** of the solar energy that strikes the top of the atmosphere **reaches Earth's surface and is absorbed**.

Structure of the Atmosphere

- The temperature of the atmosphere changes dramatically at varying altitudes.
- Temperature differences are used to divide the atmosphere into four layers:
- **troposphere**,
- **stratosphere**,
- **mesosphere**, and
- **thermosphere**.

Structure of the Atmosphere - Diagram



Draw Diagram

The Troposphere

- "**Tropo**" **means change or turning**.
- The **lowest layer** of our atmosphere.
- **Temperature decreases with altitude**.
- The Troposphere contains about 80% of the total mass of the atmosphere and most of the water vapor in our atmosphere.
- **Almost all weather occurs in the Troposphere**.**

The Tropopause

- The **area between the Troposphere and the Stratosphere**.
- Temperature stops decreasing here.
- The altitude of the Tropopause varies according to latitude. At the equator, the Tropopause is at an altitude of about 16 kilometers, while at the poles is it at an altitude of about 9 kilometers.
- **The jet stream is located just below the Tropopause**.

The Stratosphere

- “**Strato**” **means spreading out**.
- A clear, dry layer of the atmosphere.
- **Temperature increases with altitude**.
- **Temperature increase in the Stratosphere is caused by the presence of ozone**. Ozone **absorbs ultraviolet rays** from the sun and then releases some of this energy in the form of heat.**

The Stratopause

- The area between the Stratosphere and the Mesosphere.
- Located at approximately 50 kilometers above Earth’s surface.

The Mesosphere

- “**Meso**” **means middle**.
- The Mesosphere extends between about 50 and 90 kilometers above Earth’s surface.
- Contains very little ozone, so **temperatures again drop with increasing altitude**.

The Mesopause

- The area between the Mesosphere and the Thermosphere.
- Located approximately 90 kilometers above Earth’s surface.

The Thermosphere

- "**Thermo**" **means heat**.
- The **atmosphere** at this great altitude is **extremely thin**, but the few molecules and atoms present receive such intense solar radiation that temperatures can rise above 1000°C.
- The **Thermosphere is separated into layers of different gases**, with heavier gases in the lower levels and lighter gases in the higher layers.

The Thermosphere

- The lowest layer is composed primarily of nitrogen molecules.
- Next, a layer of oxygen reaches to about 1000 kilometers.
- Above that is a layer of helium that extends to about 2400 kilometers.
- Finally, a layer of hydrogen thins out into space.

2400 kilometers = 1488 miles

The Ionosphere

- The portion of the Thermosphere between about 90 and 500 kilometers above the Earth is also called the **Ionosphere**.
- Why? Because the air there is highly ionized.
- These ions are formed when ultraviolet rays knock electrons off oxygen and nitrogen molecules and oxygen atoms.

The Ionosphere

- The **Ionosphere is affected by solar events**. Huge eruptions associated with sunspots send out large amounts of radiation and ionized particles.
- Because the sun’s particles are electrically charged, they are **deflected by Earth’s magnetic field to the North and South poles**.
- The ionized particles sometimes interact with air molecules to form **auroras**.

Insolation and the Atmosphere

- **Insolation** is **incoming solar radiation**.
- Earth's system only receives about one two-billionth of the sun's rays. (1/2,000,000,000)
- Some insolation is absorbed by gases in the atmosphere, some reaches the Earth's surface without interference. Much of it is scattered by collisions with gas molecules and dust in the atmosphere.
- Where does the scattered insolation go?

Insolation and the Atmosphere

- A global heat budget monitors the overall flow of energy into and out of our atmosphere. A **balanced global heat budget results in global temperatures remaining fairly constant over time**.
- Out of 100 units of insolation, about 30 units returns to space, about 19 units are absorbed by the atmosphere, and about 51 units are absorbed by Earth's surface.**

Insolation and the Atmosphere

- When the budget is balanced, about 70 units of energy are radiated out to space; about 64 units are radiated by the atmosphere and about 6 units are radiated by the Earth’s surface.

Heat Budget of Earth

- Only a small percentage of insolation is absorbed by the atmosphere.
- **Most of the atmosphere's energy is transferred from the surface by radiation, conduction, and the evaporation and condensation of water.****
- This **energy transfer from the Earth's surface is one of the major causes of weather**.

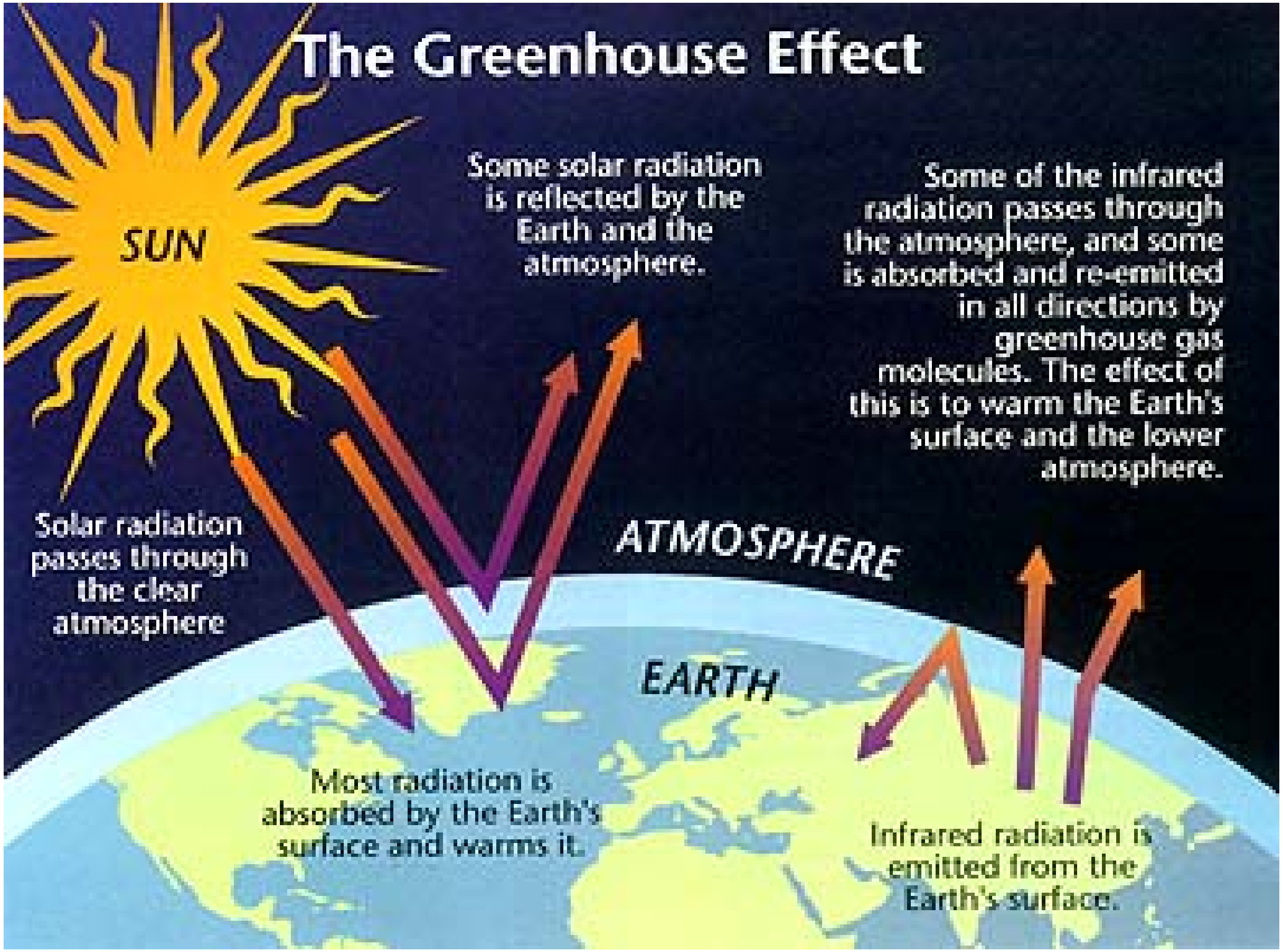
Greenhouse Effect

- The **greenhouse effect** is the heating of Earth's surface and atmosphere from solar radiation being absorbed and emitted by the atmosphere, mainly by water vapor and carbon dioxide.
- The greenhouse effect **results when infrared radiation remains in Earth's atmosphere**.

Greenhouse Effect

- The accumulation of carbon dioxide and water vapor in the atmosphere, absorbs most of the infrared radiation (that the Earth is trying to release back into the atmosphere), preventing it from radiating directly back into space.
- **Is the greenhouse effect a bad thing?**
- 131 years of global warming in 26 seconds

Greenhouse Effect - Diagram



Greenhouse Effect

- **Without the greenhouse effect, much of Earth's heat energy would be lost to outer space.**
- Earth's average temperature would be about 33°C cooler than it is now – **freezing**!**
- The greenhouse effect has helped Earth thrive as a planet.
- However, recently we have seen a significant increase in levels of carbon dioxide in the atmosphere. We are watching to see if the global heat budget is getting out of balance.

Ticket Out the Door

1. Why is ozone important in the stratosphere?
2. In which layer of the atmosphere to almost all weather occur?
3. What is the difference between "heat" and "temperature"?
4. **Extra Credit** – write on back – 2 pts
   - What are the four layers of the atmosphere?

Section 17.2: Review

1. Describe three ways heat is transferred through the atmosphere.
2. Why does temperature gradually decrease with altitude in the troposphere?
3. Compare the temperature changes in the stratosphere with those of the thermosphere. Include the role of the ozone in your explanation.
4. Describe at least two paths that a unit of energy could take from its arrival at Earth’s atmosphere until it is reradiated out to space.
5. Based on what you have learned about the layers of the atmosphere, explain why jets generally fly at or above the tropopause.

Section 17.3: Local Temperature Variations

Objectives

- Identify the factors that cause the intensity of insolation to vary from place to place.
- Describe how the characteristics of a material affect its rate of solar absorption.
- Analyze a temperature map.

Vocabulary

- Isotherm

Local Temperature Variations

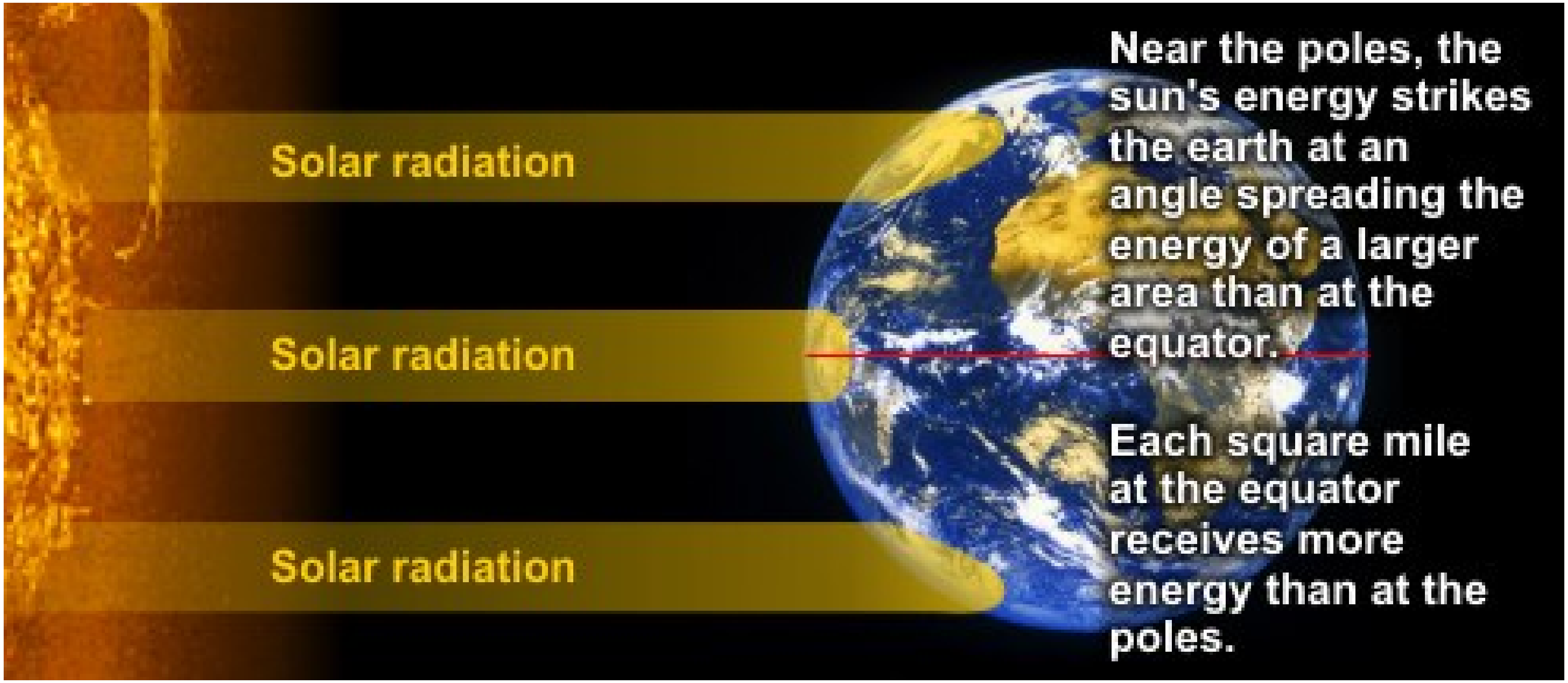
Why does temperature vary from place to place?

- The basic reason is that **insolation** (solar radiation) **heats Earth's surface and atmosphere unevenly.****
- The intensity of **insolation varies** with the **time of day**, the **latitude**, and the **time of the year**.
- The characteristics of a material affect both how much insolation the material absorbs and how the absorbed energy affects the temperature.

Intensity of Insolation (Solar Radiation)

- **Depends on the angle at which the sun's rays strike Earth's surface**.
- When the sun is **directly overhead**, the angle of insolation is 90°, and Earth's surface receives the **maximum amount of energy**.**
- As the angle of insolation decreases, the energy of the rays is spread out over a larger area, so the energy per unit area decreases. Sunlight must also travel farther through the atmosphere, meaning more may be absorbed or reflected before it reaches Earth's surface.

Intensity of Insolation (Solar Radiation) - Diagram



Time of Day

- **At noon** the sun’s rays are closest to vertical, so the **intensity of insolation is greatest** then.**
- However, the **warmest time of the day** is usually in the **afternoon**, when the lower atmosphere has received more heat from the ground than it loses for several hours.
- The **coldest time of the day** is usually **just before sunrise** because the ground and the lower atmosphere have been losing heat all through the night.

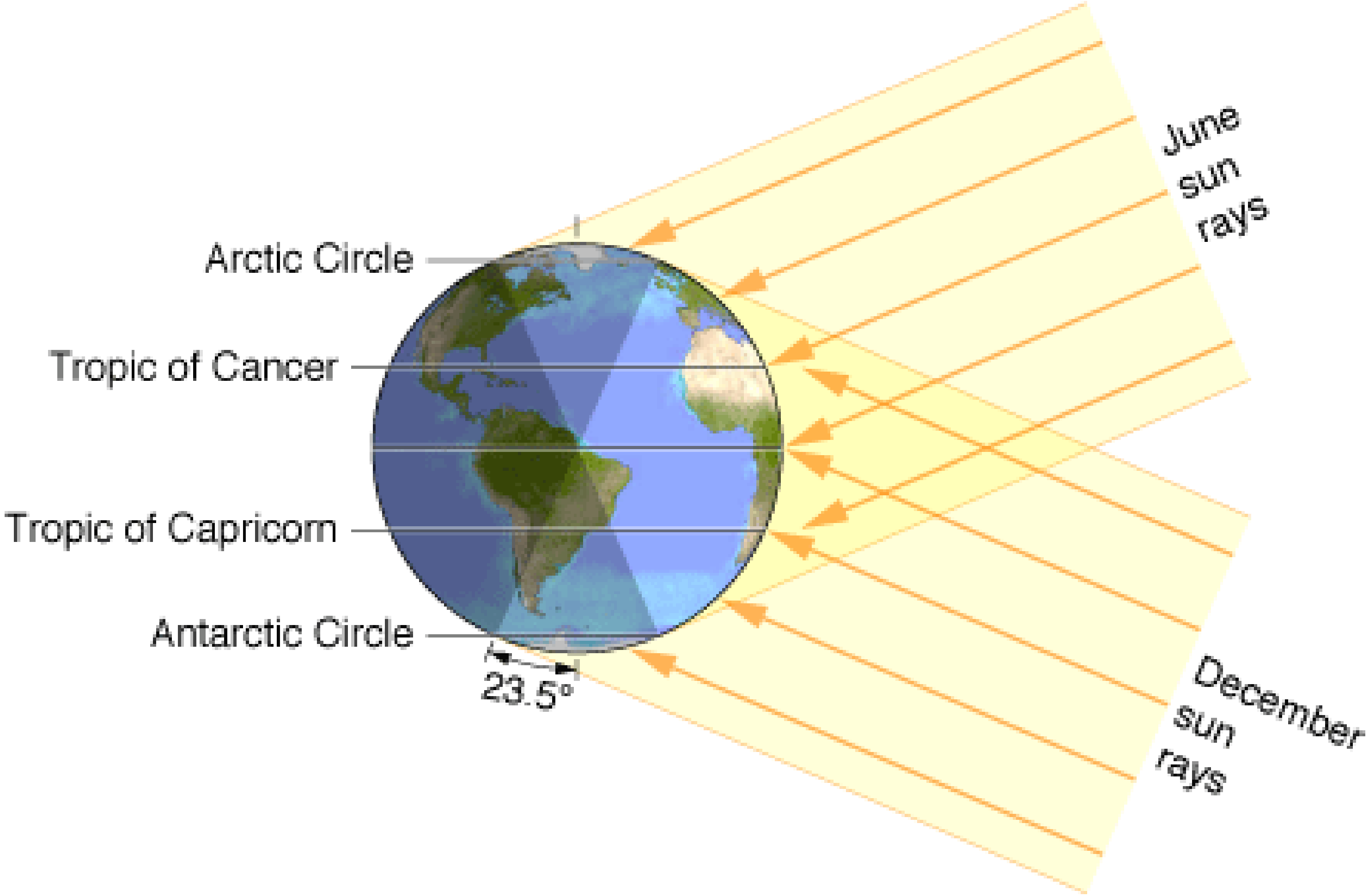
Latitude

- **Near the equator, almost-vertical rays strike the Earth all through the year**.** These areas have hot climates.
- Near the poles, the sun's rays generally strike at low angles. Such areas may even have no sunlight for part of the year. These areas are cold year-round.

Time of Year

- Locations in middle latitudes get near-vertical rays in summer, so summers are hot. The angle of rays in the winter is much lower, so winters are cold.
- The highest temperatures occur after the time of maximum insolation. The most direct sunlight occurs in late June, however, July is usually the warmest month. The weakest sunlight is usually in December, however, January is usually the coldest month.

Time of Year - Picture



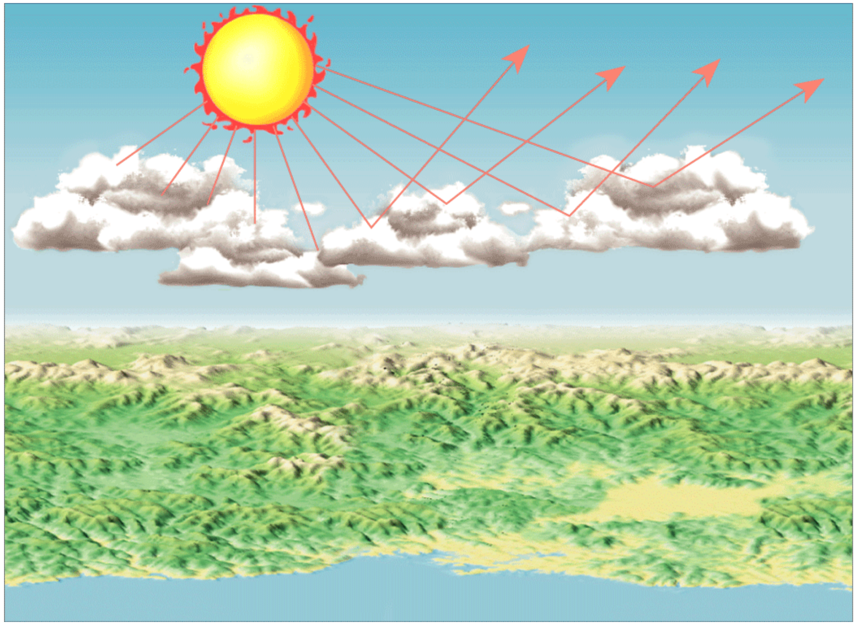
Temperature Variations

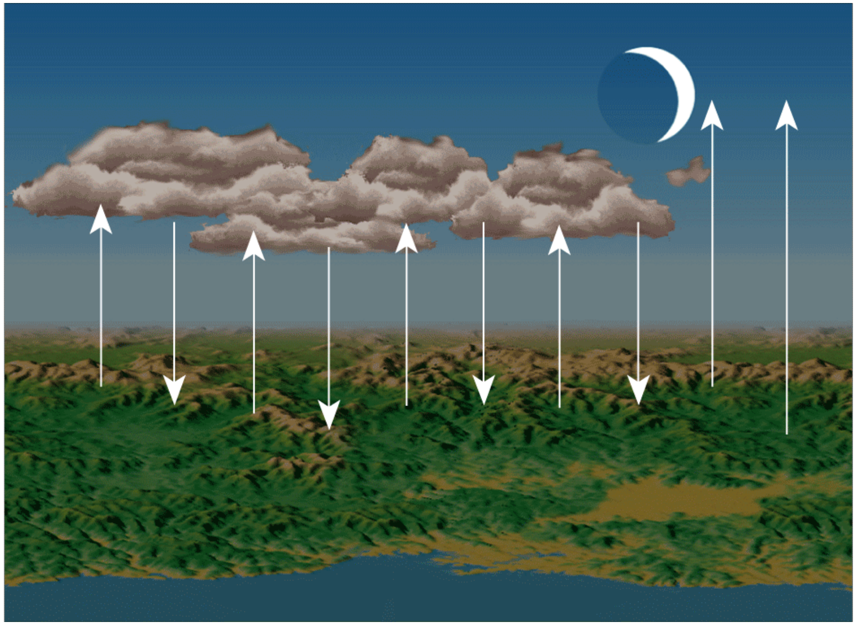
- Factors other than latitude that exert a strong influence on temperature include heating of land and water, altitude, geographic position, cloud cover, and ocean currents.

Cloud Cover

- **Albedo** is the fraction of total radiation that is reflected by any surface.
- Many clouds have a high albedo and therefore reflect back to space a significant portion of the sunlight that strikes them.
- Since clouds can reflect a significant amount of insolation back into space, **more solar energy reaches Earth's surface on clear days**.
- Similarly, more radiation travels from Earth's surface out into space on clear nights than on cloudy nights.

Clouds Reflect and Absorb Radiation - Pictures





Heating of Water and Land

- **Continents are warmer than nearby ocean waters during summer**. In winter, the same continents are colder than the water.

Why does the temperature of land vary more than the temperature of water?

- Land and water warm up and cool off at different rates.
- **Water warms up much more slowly than land** does for many reasons

Heating of Water and Land

- On land, insolation warms only the top few centimeters of soil, but the sun's rays penetrate to a depth of many meters in water.
- In water, some solar energy is used in the process of evaporation.
- **Water requires more energy than land to raise its temperature the same amount** **(about three times more than land).

Heating of Water and Land

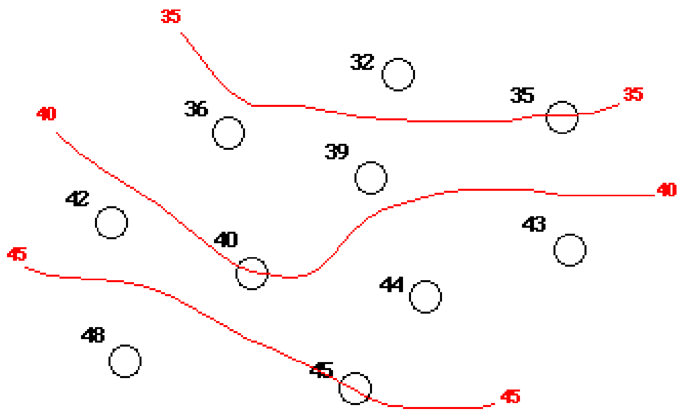
- Dark surfaces absorb more energy than light surfaces.
- Rough surfaces absorb more energy than smooth surfaces.
- Dry ground absorbs more energy than wet ground.
- Snow and ice reflect sunlight and remain cold.

Temperature Maps

- Look at the temperature maps on page 377 in your textbook.
- Notice that the warmest temperatures are south of the equator in January and north of the equator in July. Think of the location of the sun's direct rays during these months.
- **Notice that the warmest and coldest temperatures are over land, not water**.

Temperature Maps

- The lines separating the temperature zones on the maps are called **isotherms**.
- **Iso-** means "**equal**" and –**therm** means "**heat**".
- **Isotherm** lines on maps **connect locations that have the same temperature**.**



Ticket Out the Door

1. Why does temperature vary from place to place?
2. What is an isotherm?
3. At what angle of insolation does the Earth's surface receive the maximum amount of energy?
4. **Extra Credit**: answer on back – 2 pts.

    What does insolation mean?

Section 17.3: Review

1. How does the angle at which sunlight strikes Earth's surface affect the intensity of the sunlight?
2. When does the highest temperature of the day usually occur? Why?
3. Why is it warmer near the equator than near the poles?
4. In the United States, why is it colder in the winter and warmer in the summer?
5. Explain why water does not get as hot as land on a clear summer day.
6. The daily temperature range is the difference between the day's maximum and minimum temperatures. Why is the daily temperature range greater on clear days than on cloudy ones?

Section 17.4: Human Impact on the Atmosphere

Objectives:

- How does human activity affect the atmosphere?

Key Vocabulary:

- air pollutant
- temperature inversion

Human Impact on the Atmosphere

- The modern transportation and manufacturing technologies that provide many benefits for everyday life also have some **negative effects on the environment**.
- These effects include local **air pollution** as well as worldwide problems such as **ozone depletion** and **global warming**.
- Emissions from transportation vehicles account for nearly half the primary pollutants by weight.

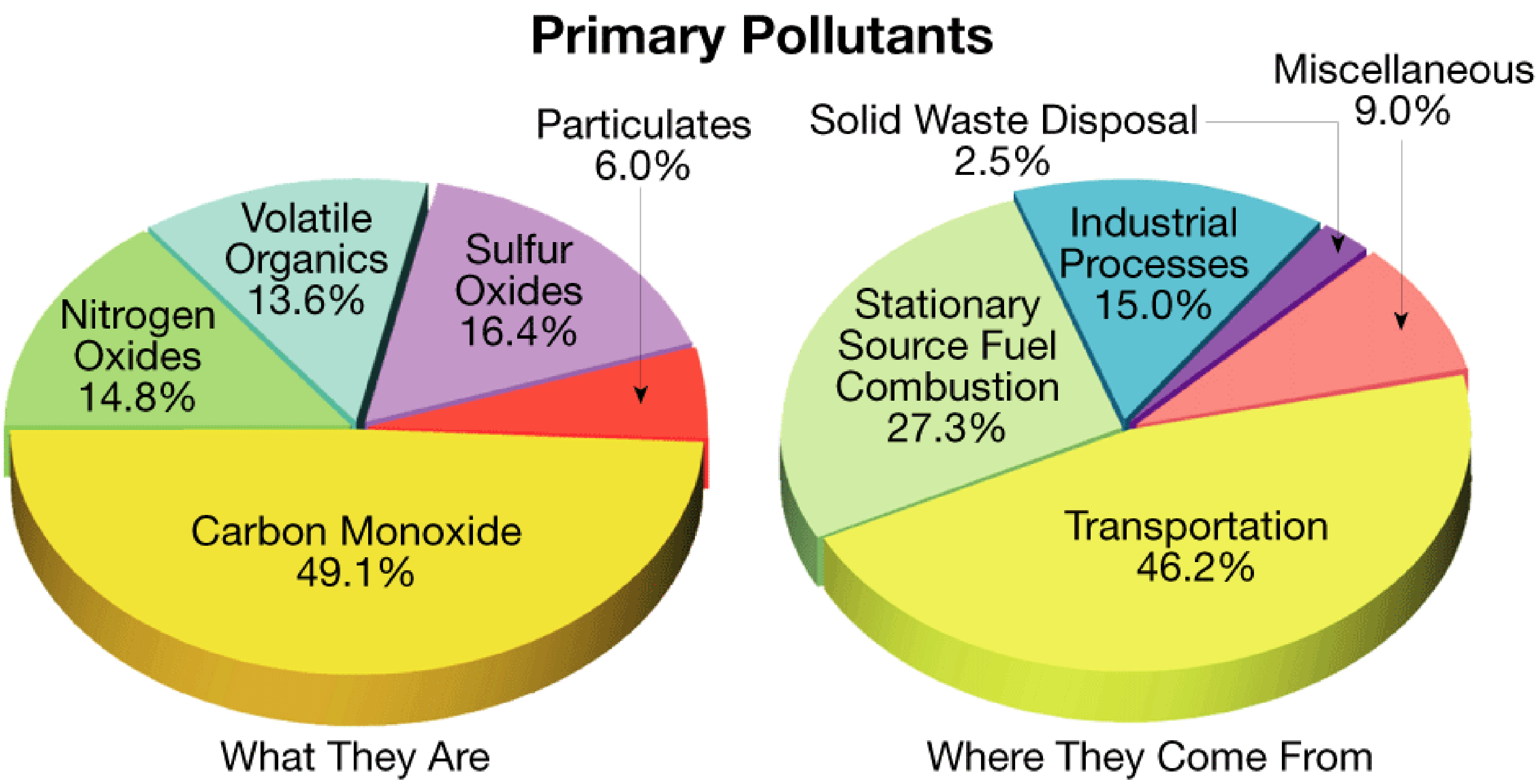
Common Air Pollutants

- An **air pollutant** is any airborne gas or particle that occurs at a concentration capable of harming humans or the environment.
- Some air pollutants are caused by natural sources such as volcanoes and forest fires.
- Human activities produces a significant amount of air pollutants that are of greatest concern today.
- The Clean Air Act of 1970 identified six key pollutants as indicators of air quality.

Common Air Pollutants – Table

POLLUTANT:	MAJOR SOURCE:
Carbon monoxide	Automobile exhaust
Nitrogen dioxide	Burning fossil fuels
Sulfur dioxide	Burning fossil fuels
Particulate matter (dust, smoke, soot, ash)	Factories, power plants, oil refineries
Lead	Smelters, batteries
Ozone	Reactions of nitrogen oxides and hydrocarbons to sunlight

Primary Pollutants - Diagram



Acid Rain

- **Acid rain forms when pollutants such as sulfur dioxide and nitrogen oxides react with water vapor in the air**.
- Acid precipitation can fall as both rain and snow.
- Pollution can significantly raise the acidity of rain in some areas.
- **Acid rain is harmful to plant and animal life**, as well as damaging to structures (especially those build of limestone or marble).

Smog

- **Smog** originally referred to "smoky fog" **resulting from emissions of particulate matter and other pollutants from factories**.
- Today, smog refers to **photochemical smog**, a brownish haze that forms in air polluted with nitrogen oxides and hydrocarbons that **come mainly from automobile exhaust**.**

Smog

- The **sun's rays combining with smog can form ground-level ozone**. While ozone in the stratosphere is good (protecting Earth from ultraviolet radiation), ground-level ozone is a **powerful lung irritant** that can cause respiratory problems and illness.
- Ground-level ozone also interferes with photosynthesis, reducing crop yields and hurting the agricultural industry.

Smog

- The severity of smog depends on atmospheric conditions.
- Usually, convection in the atmosphere keeps the air moving, diluting the pollutants.
- Sometimes **the air at the surface is colder than the air above, so convection does not occur. This situation is called a temperature inversion**.**
- During a temperature inversion, **the warm air traps the pollutants below, allowing smog to build up to sometimes dangerous levels**.

Ozone Depletion

- In the 1970s, scientists began to worry that the atmospheric ozone layer was being harmed by **chlorofluorocarbons (CFCs)**.
- CFCs were widely used in products such as aerosol sprays, air conditioners, and solvents.
- In 1987, more than 170 countries met in Montreal and signed a treaty to reduce and eventually eliminate the production of all CFCs and other ozone-depleting substances by 2006.

Ozone Depletion

- **Since the 1980s, scientists have documented a thinning of the global ozone layer**. An extremely thin area of the ozone layer (popularly called the ozone hole) forms over Antarctica each spring.

- A smaller ozone hole is also being watched over the northern polar region.

- Elimination of CFCs could help return the ozone layer to normal by about 2050.

Global Warming

- Available **data indicate that the average global temperatures have increased by about 1°C since the late 1800s**.
- It is possible that this global warming is part of the natural cycle of temperature changes that have occurred throughout Earth's history.
- So what is all the talk about?

Global Warming

- Scientists are worried about human activities that may be contributing to global warming.
- The level of greenhouse gases has risen significantly over the past two centuries.
- Global deforestation contributes to higher carbon dioxide levels (cutting and burning of trees).
- Models continue to predict that warming will continue. If that is true, what are the worries?

Global Warming

- Preliminary evidence indicates that possible effects of global warming includes the following:
- **Rising sea levels due to melting polar caps**;
- **Increasing frequency and severity of storms** and hurricanes;
- **More frequent heat waves and droughts**; and
- **Relocation of major crop-growing areas**.

Ticket Out the Door

- 1. What causes smog?
- 2. What is a temperature inversion?
- 3. What are two effects of global warming?
- 4. **Extra Credit**: Answer on back – 2 pts.
  - What causes ground-level ozone and what is the problem with it?

Section 17.4: Review

1. List some examples of pollutants created by the burning of fossil fuels. What are the effects of these pollutants?
2. What are some of the damaging effects of acid rain?
3. Explain how a temperature inversion affects smog.
4. What are some human activities suspected of contributing to global warming?