



Chapter 15

Air Pollution and Stratospheric Ozone Depletion

Air Pollution

- ▣ Air pollution- the introduction of chemicals, particulate matter, or microorganisms into the atmosphere at concentrations high enough to harm plants, animals, and materials such as buildings, or to alter ecosystems.

Major Air Pollutants

- ▣ Sulfur Dioxide
- ▣ Nitrogen Oxides
- ▣ Carbon Oxides
- ▣ Particulate Matter
- ▣ Volatiles Organic Compounds
- ▣ Ozone
- ▣ Lead
- ▣ Mercury

TABLE 15.1 Major air pollutants			
Compound	Symbol	Human-derived sources	Effects/impacts
Criteria air pollutants			
Sulfur dioxide	SO ₂	Combustion of fuels that contain sulfur, including coal, oil, gasoline.	Respiratory irritant, can exacerbate asthma and other respiratory ailments. SO ₂ gas can harm stomates and other plant tissue. Converts to sulfuric acid in atmosphere, which is harmful to aquatic life and some vegetation.
Nitrogen oxides	NO _x	All combustion in the atmosphere including fossil fuel combustion, wood, and other biomass burning.	Respiratory irritant, increases susceptibility to respiratory infection. An ozone precursor, leads to formation of photochemical smog. Converts to nitric acid in atmosphere, which is harmful to aquatic life and some vegetation. Also contributes to overfertilizing terrestrial and aquatic systems (as discussed in Chapter 3).
Carbon monoxide	CO	Incomplete combustion of any kind, malfunctioning exhaust systems, and poorly ventilated cooking fires	Bonds to hemoglobin thereby interfering with oxygen transport in the bloodstream. Causes headaches in humans at low concentrations; can cause death with prolonged exposure at high concentrations.
Particulate matter	PM ₁₀ (smaller than 10 micrometers) PM _{2.5} (2.5 micrometers and less)	Combustion of coal, oil, and diesel, and of biofuels such as manure and wood. Agriculture, road construction, and other activities that mobilize soil, soot, and dust.	Can exacerbate respiratory and cardiovascular disease and reduce lung function. May lead to premature death. Reduces visibility, and contributes to haze and smog.
Lead	Pb	Gasoline additive, oil and gasoline, coal, old paint.	Impairs central nervous system. At low concentrations, can have measurable effects on learning and ability to concentrate.
Ozone	O ₃	A secondary pollutant formed by the combination of sunlight, water, oxygen, VOCs, and NO _x .	Reduces lung function and exacerbates respiratory symptoms. A degrading agent to plant surfaces. Damages materials such as rubber and plastic.
Other air pollutants			
Volatile organic compounds	VOC	Evaporation of fuels, solvents, paints; improper combustion of fuels such as gasoline.	A precursor to ozone formation.
Mercury	Hg	Coal, oil, gold mining.	Impairs central nervous system. Bioaccumulates in the food chain.
Carbon dioxide	CO ₂	Combustion of fossil fuels and clearing of land.	Affects climate and alters ecosystems by increasing greenhouse gas concentrations.

Table 15.1

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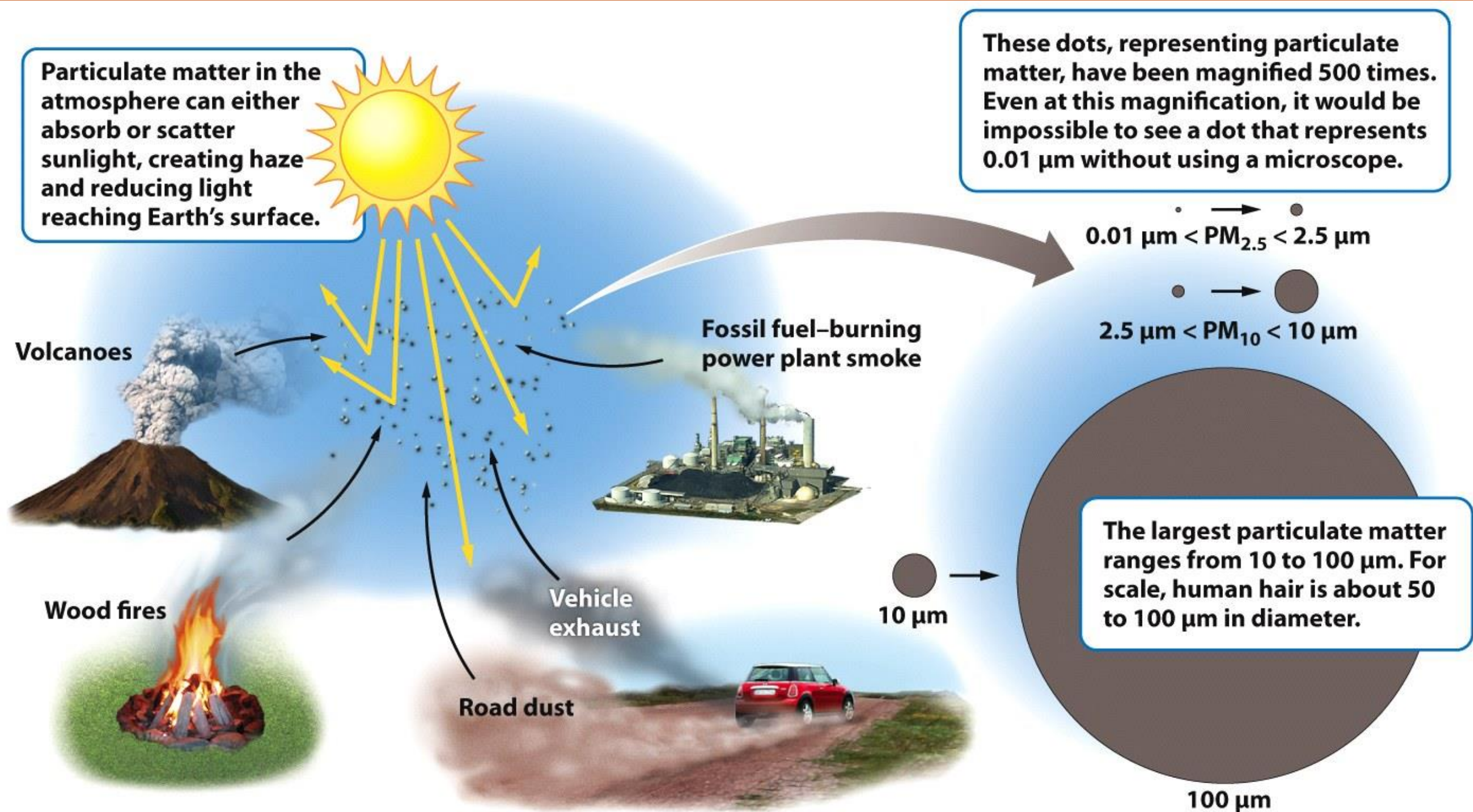


Figure 15.2

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Primary Pollutants

- ▣ Primary pollutants- polluting compounds that come directly out of the smoke-stack, exhaust pip, or natural emission source.
- ▣ Examples: CO, CO₂, SO₂, NO_x, and most suspended particulate matter.

Secondary Pollutants

- ▣ Secondary pollutants- pollutants that have undergone transformation in the presence of sunlight, water, oxygen, or other compounds.
- ▣ Examples: ozone, sulfate and nitrate

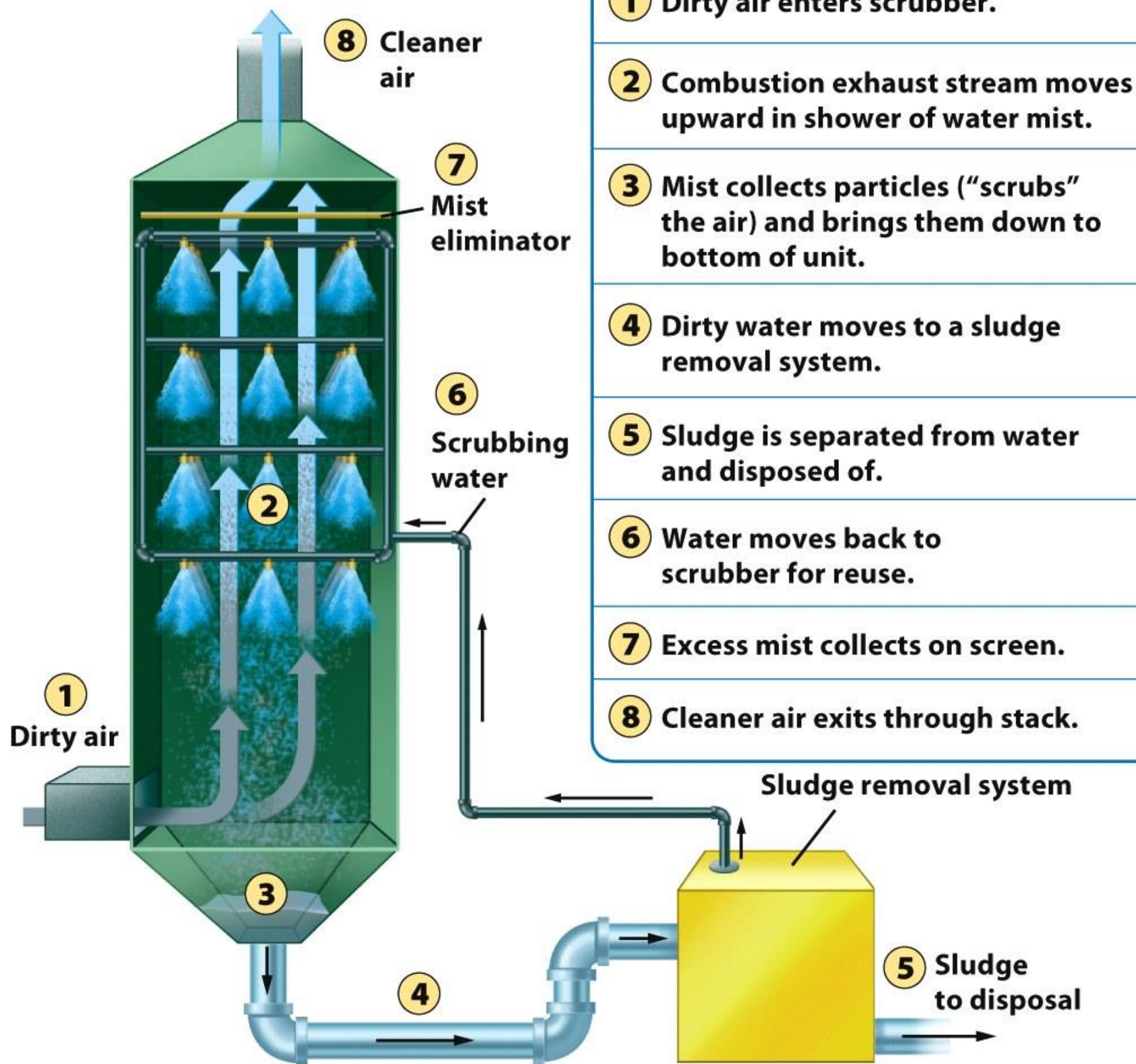


Figure 15.13

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Natural Sources of Air Pollution

- ▣ Volcanoes
- ▣ Lightning
- ▣ Forest fires
- ▣ Plants

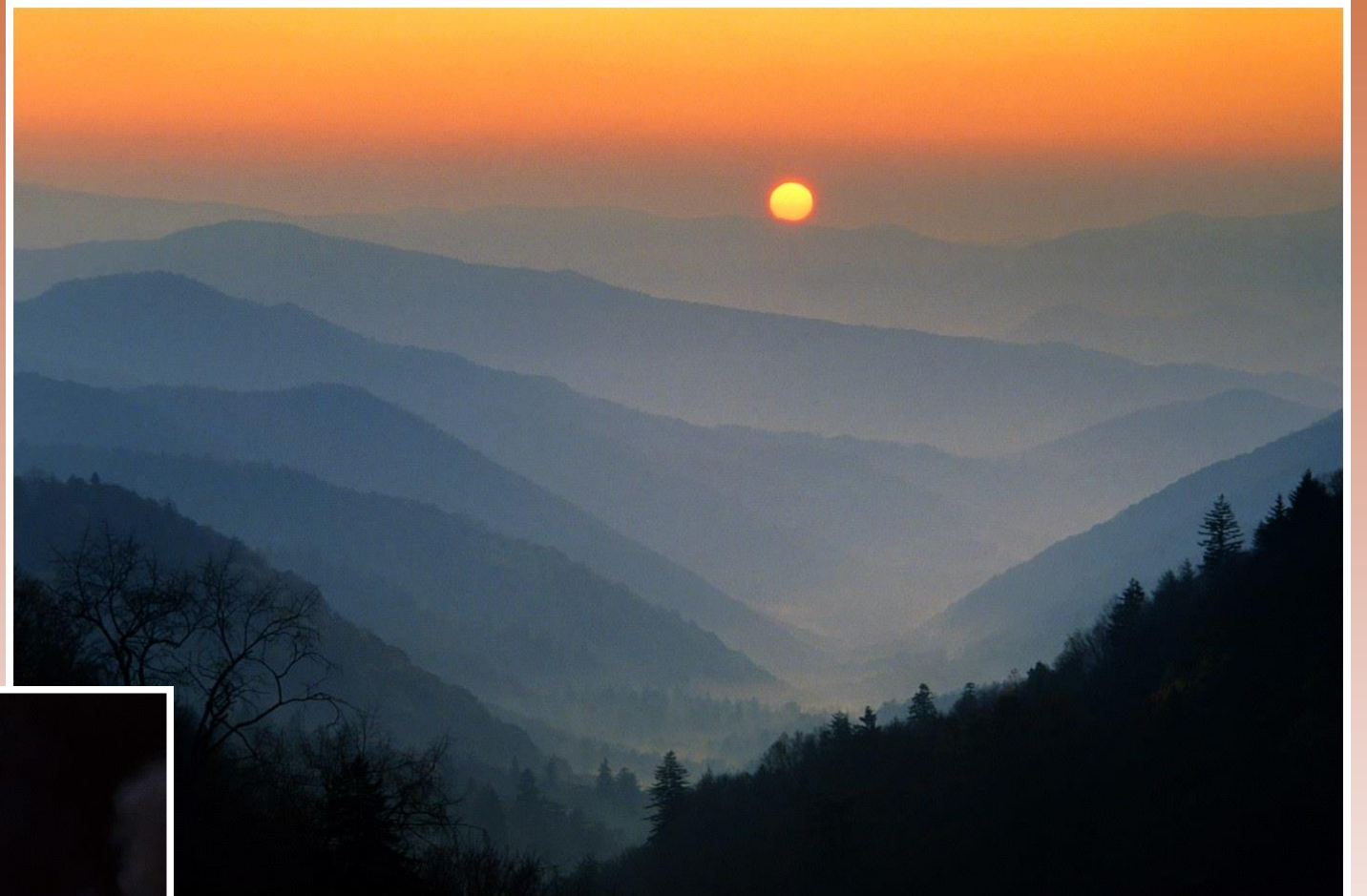
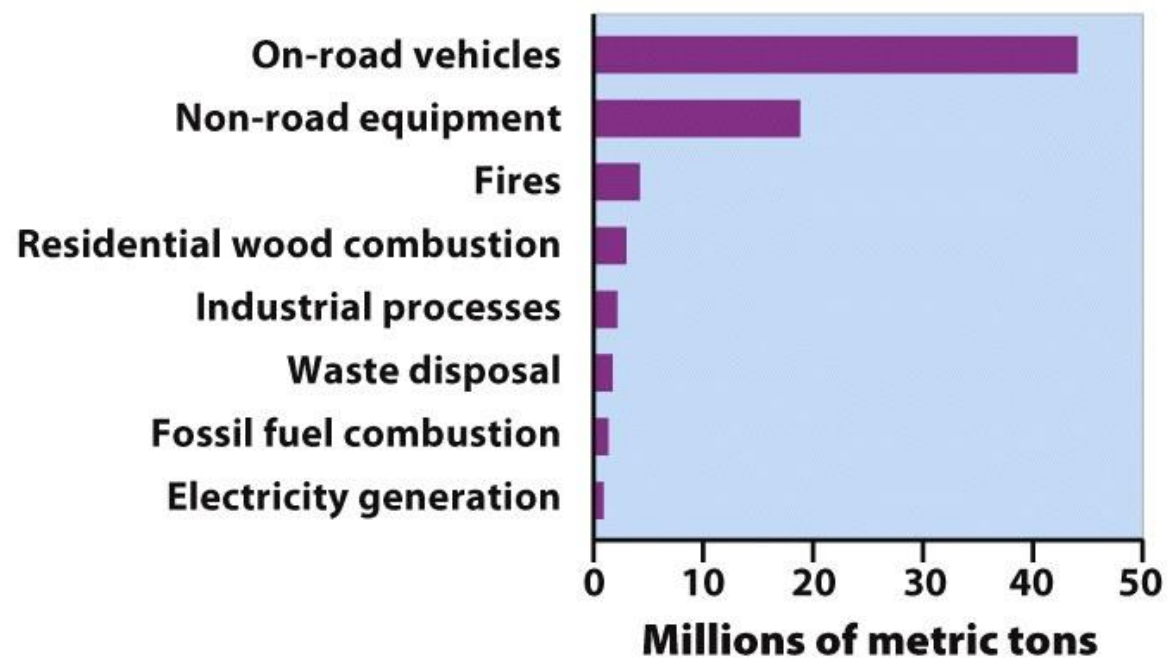


Figure 15.4a
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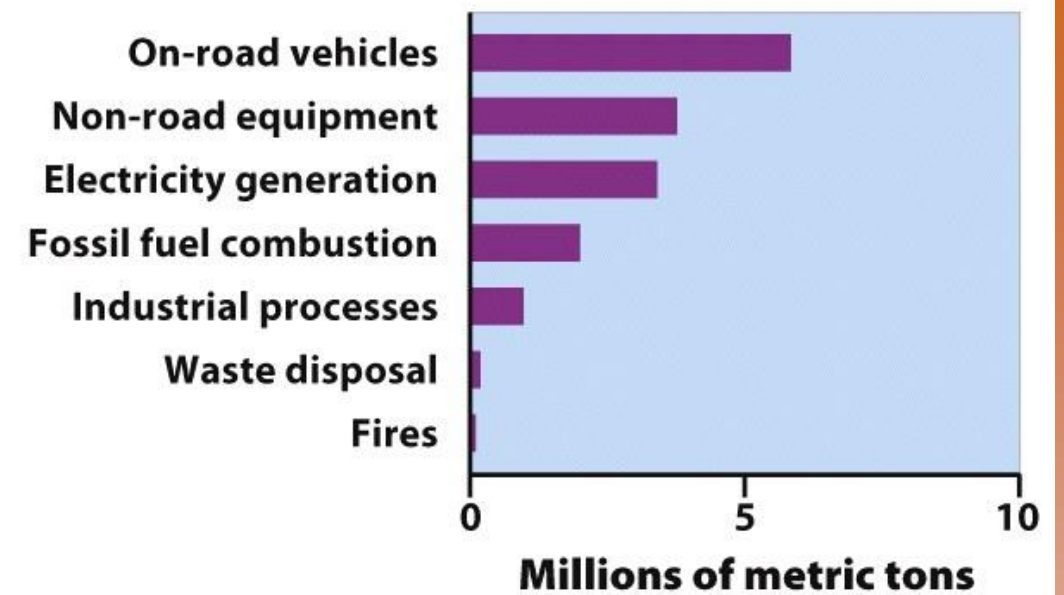
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Anthropogenic Sources of Air Pollution

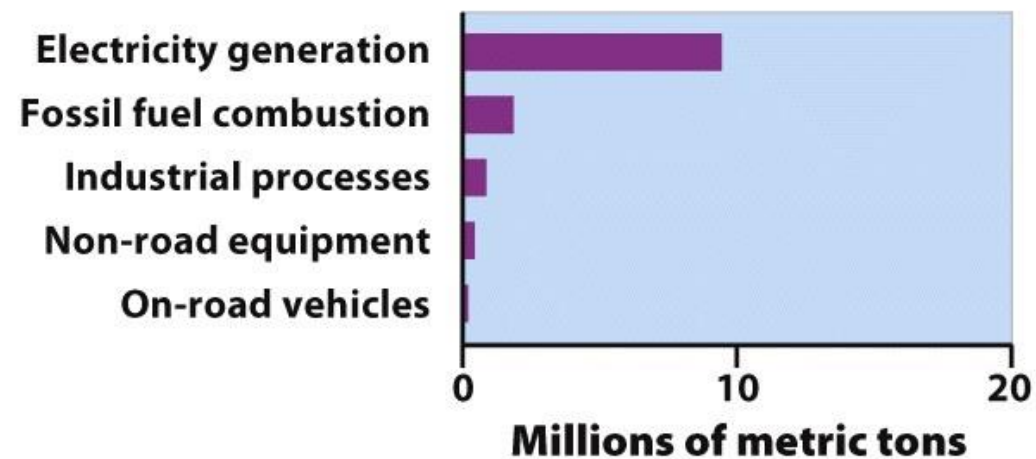
- ▣ On-road vehicles
- ▣ Power plants
- ▣ Industrial processes
- ▣ Waste disposal



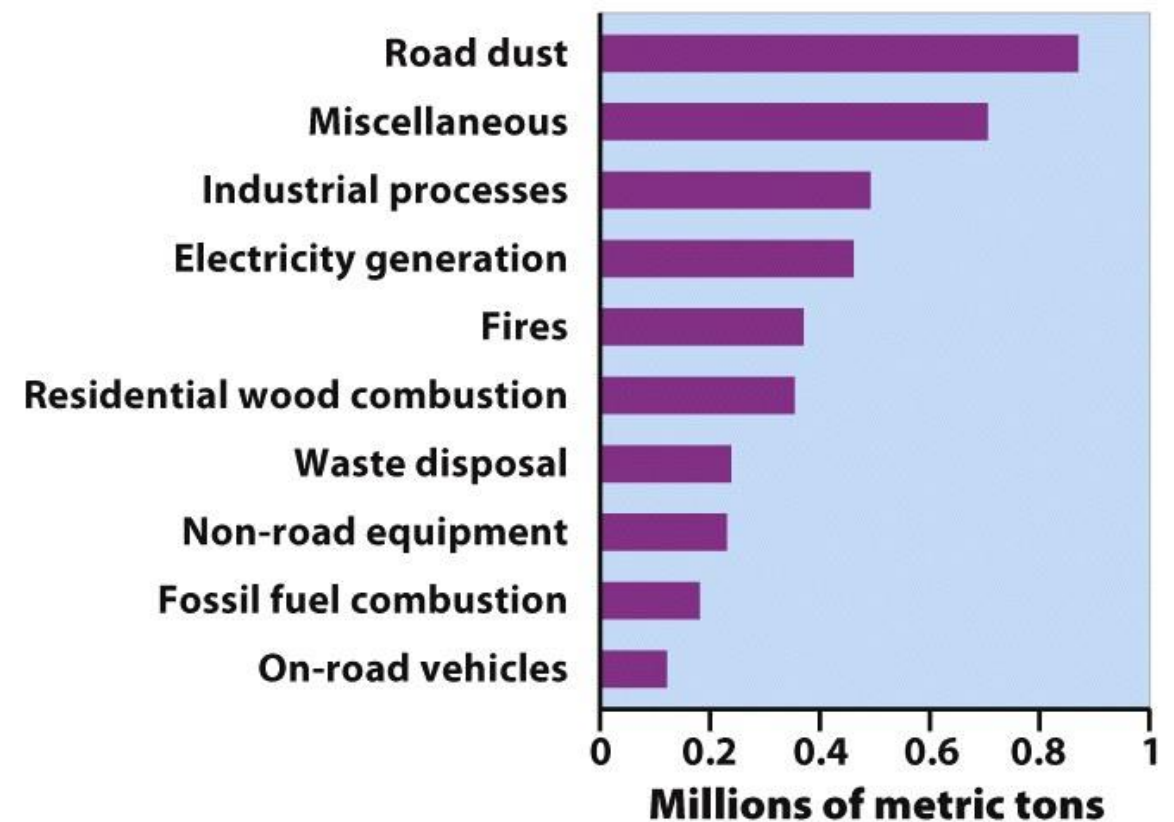
(a) Carbon monoxide



(b) Nitrogen oxides



(c) Sulfur dioxide



(d) Particulate matter (PM_{2.5})

Figure 15.5

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Photochemical Smog

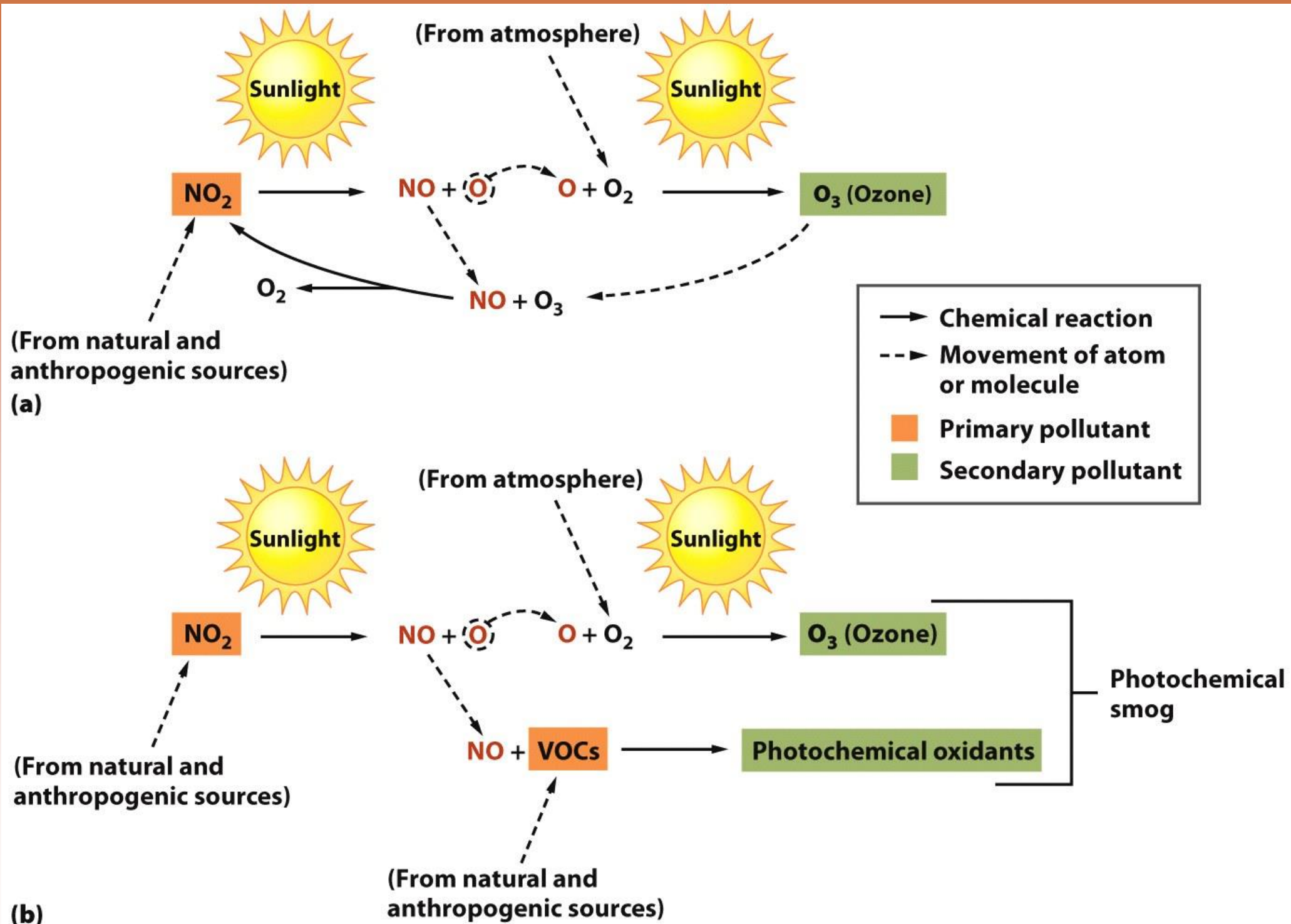


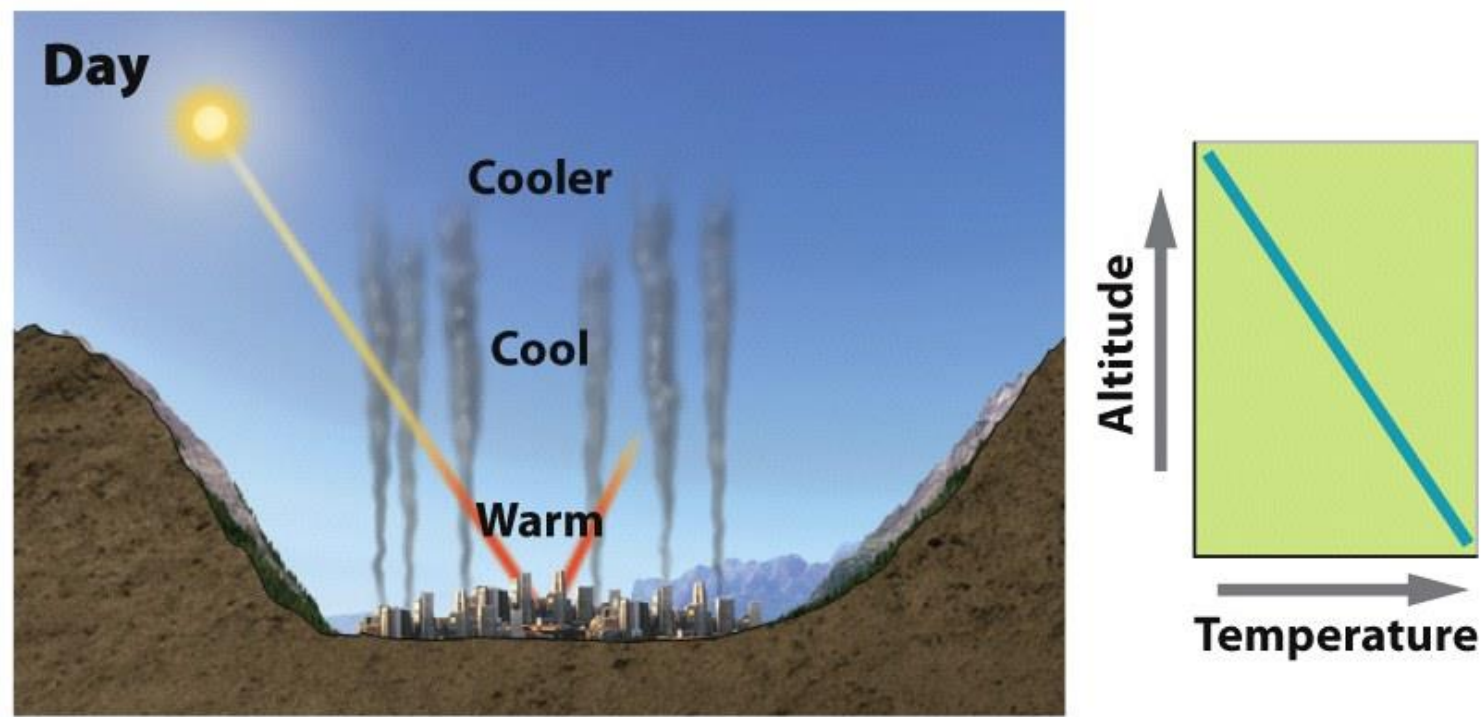
Figure 15.7

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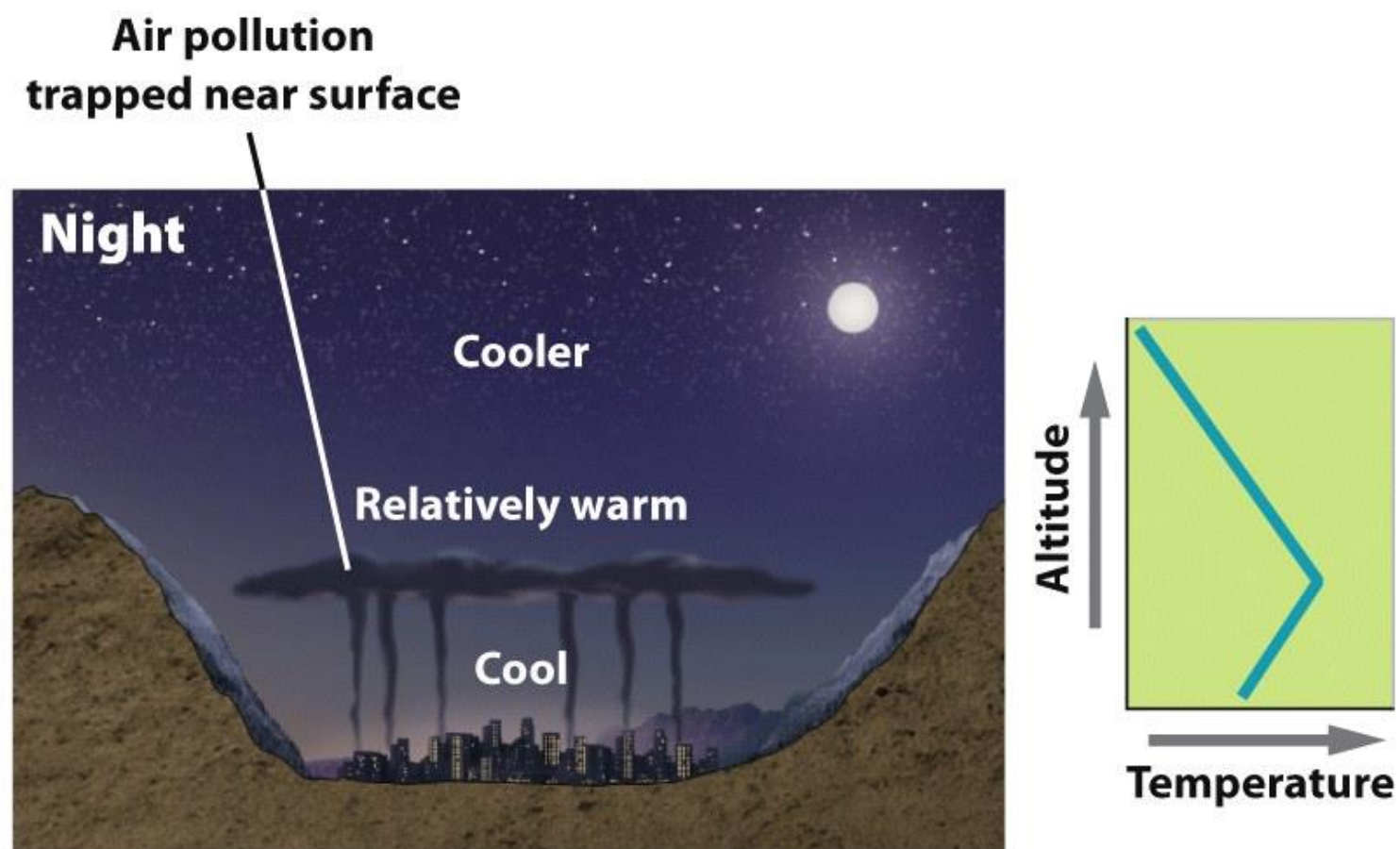
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Thermal Inversions

- ▣ Thermal Inversion- when a relatively warm layer of air at mid-altitude covers a layer of cold, dense air below.
- ▣ The warm inversion layer traps emissions that then accumulate beneath it.



(a) Normal conditions



(b) Thermal inversion

Figure 15.8

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Acid Deposition

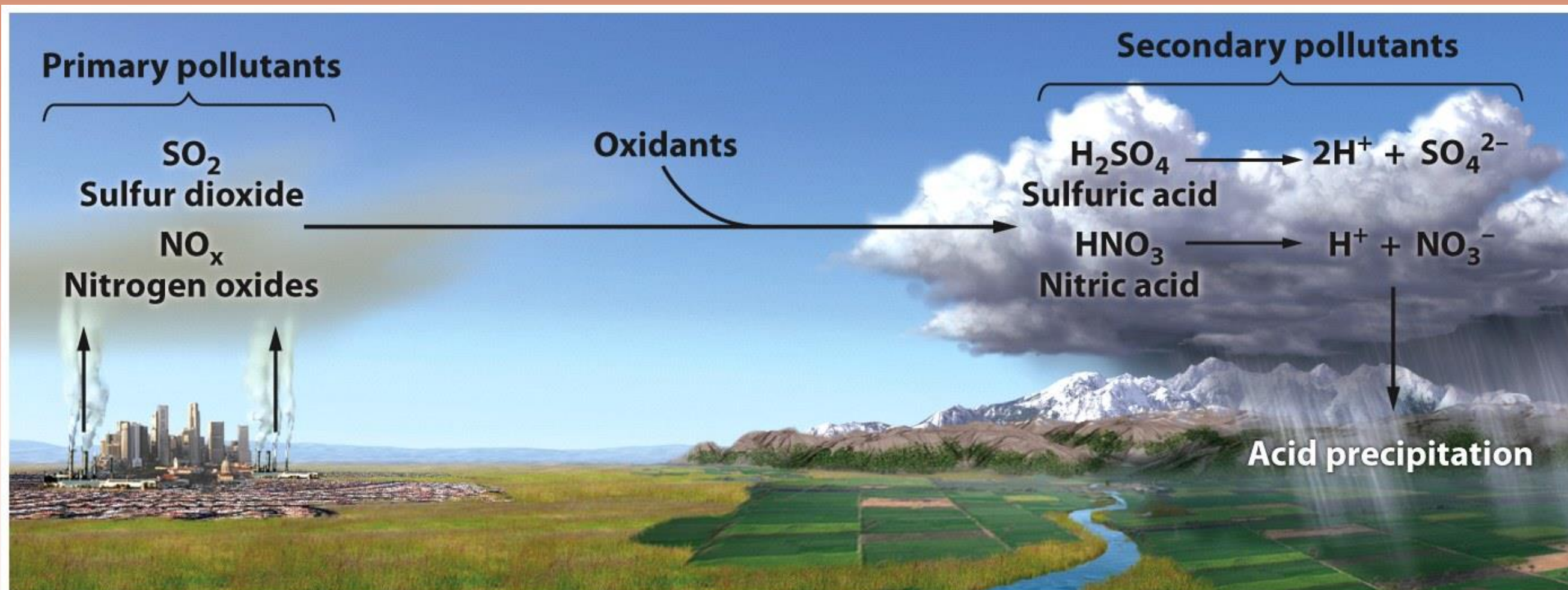


Figure 15.9

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Acid Deposition

- ▣ Acid deposition- occurs when nitrogen oxides and sulfur oxides are released into the atmosphere and combine with atmospheric oxygen and water. These form the secondary pollutants nitric acid and sulfuric acid.
- ▣ These secondary pollutants further break down into nitrate and sulfate which cause the acid in acid deposition.

Effects of Acid Deposition

- ▣ Lowering the pH of lake water
- ▣ Decreasing species diversity of aquatic organisms
- ▣ Mobilizing metals that are found in soils and releasing these into surface waters
- ▣ Damaging statues, monuments, and buildings

Ways to Prevent Air Pollution

- ▣ Removing sulfur dioxide from coal by fluidized bed combustion
- ▣ Catalytic converters on cars
- ▣ Scrubbers on smoke stacks
- ▣ Baghouse filters
- ▣ Electrostatic precipitators

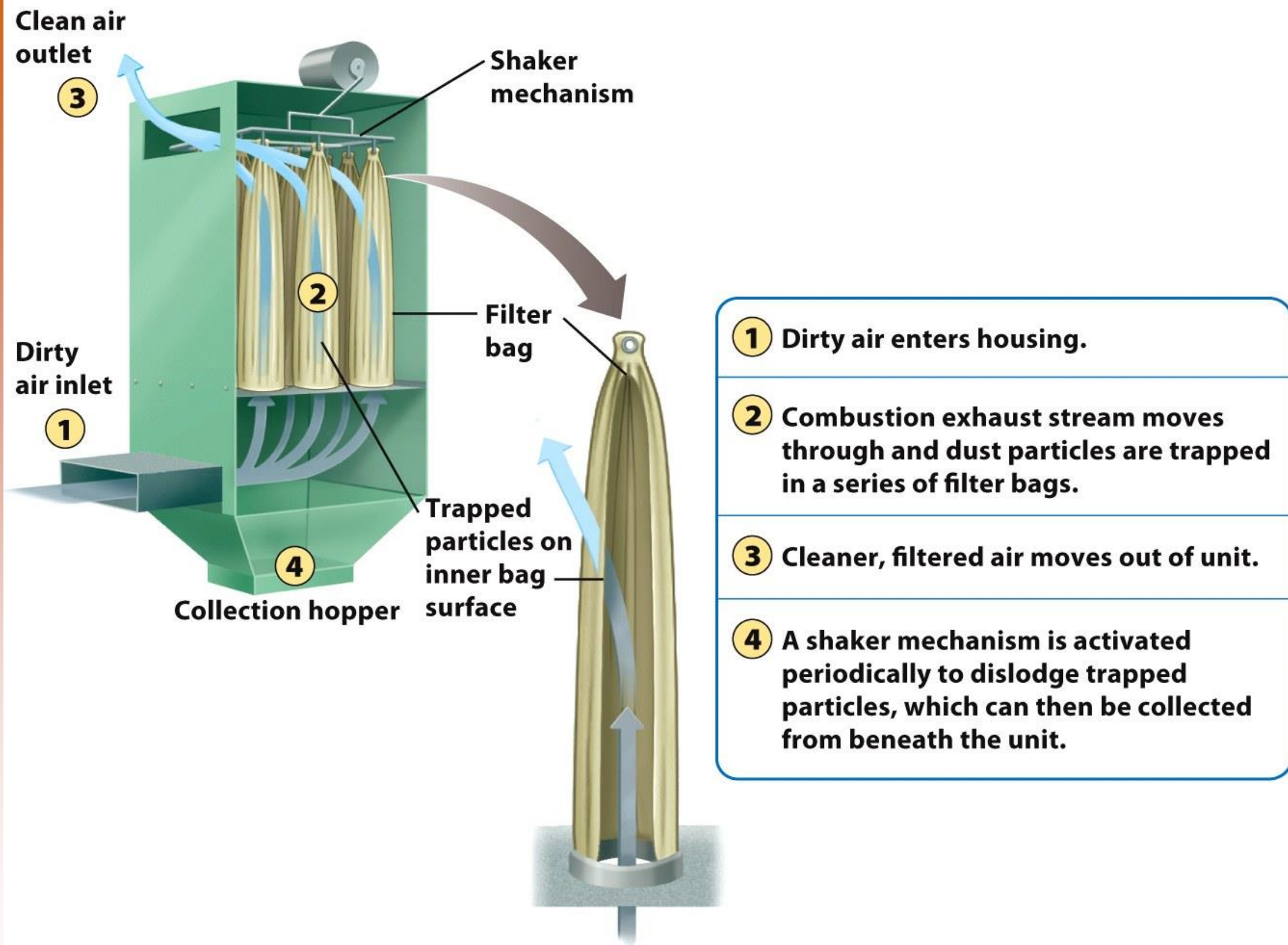
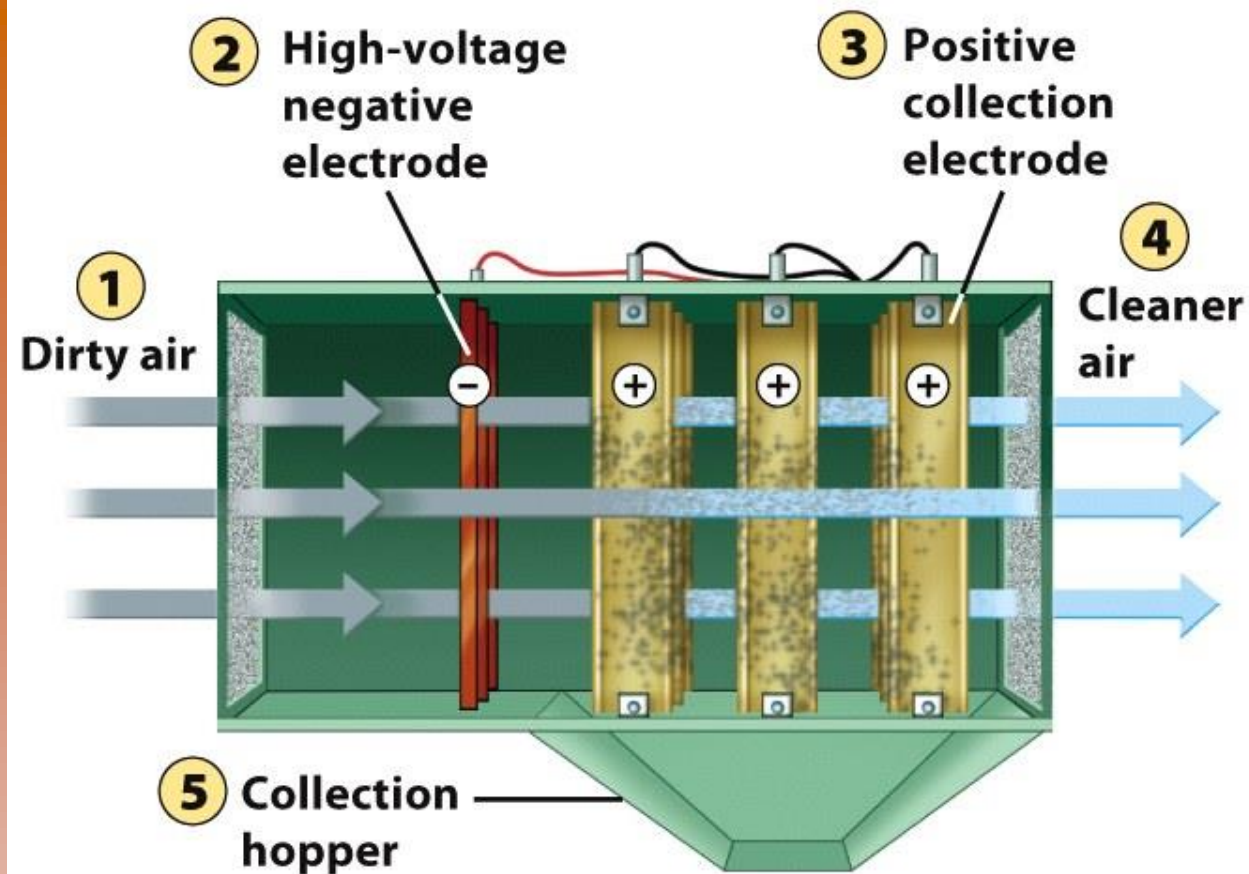


Figure 15.11

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- 1** Dirty air enters precipitator unit.
- 2** Particles in combustion exhaust stream pass by negatively charged plates, which gives them a negative charge.
- 3** The negatively charged particles are attracted to positively charged collection plates.
- 4** Cleaner air moves out of the unit.
- 5** The positive collection plates are periodically discharged, which causes the particles to fall off so that they can be removed from the system.

Figure 15.12

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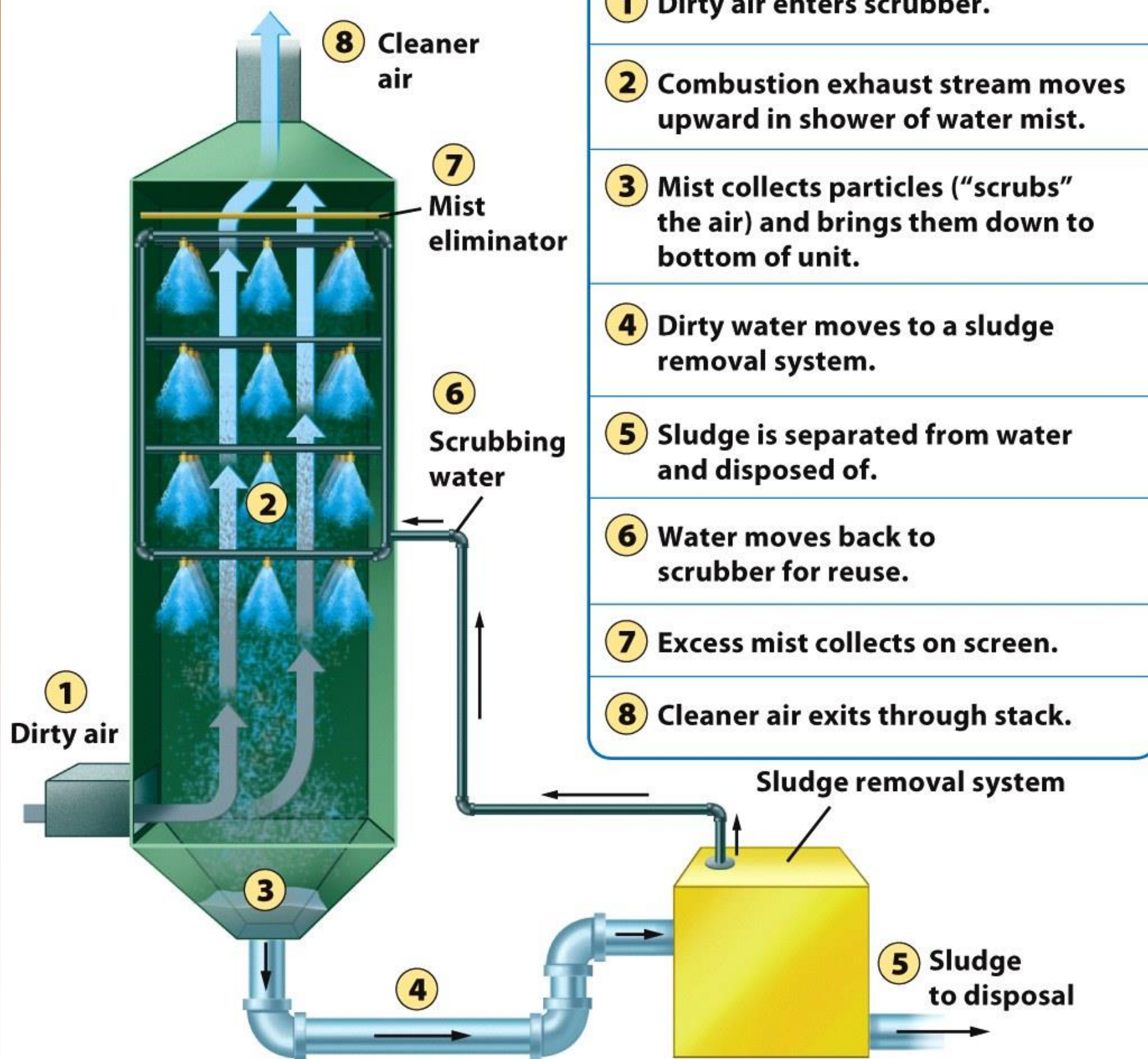


Figure 15.13

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Stratospheric Ozone

- ▣ The stratospheric ozone layer exists roughly 45-60 kilometers above the Earth.
- ▣ Ozone has the ability to absorb ultraviolet radiation and protect life on Earth.

Formation and Breakdown of Ozone

- ▣ First, UV-C radiation breaks the bonds holding together the oxygen molecule O_2 , leaving two free oxygen atoms:
 $O_2 + \text{UV-C} \rightarrow 2O$
- ▣ Sometimes the free oxygen atoms result in ozone:
 $O_2 + O \rightarrow O_3$
- ▣ Ozone is broken down into O_2 and free oxygen atoms when it absorbs both UV-C and UV-B ultraviolet light:
 $O_3 + \text{UV-B or UV-C} \rightarrow O_2 + O$

Anthropogenic Contributions to Ozone Destruction

- ▣ Certain chemicals can break down ozone, particularly chlorine.
- ▣ The major source of chlorine in the stratosphere is a compound known as chlorofluorocarbons (CFCs)
- ▣ CFCs are used in refrigeration and air conditioning, as propellants in aerosol cans and as “blowing agents” to inject air into foam products like Styrofoam.

Anthropogenic Contributions to Ozone Destruction

- ▣ When CFCs are released into the troposphere they make their way to the stratosphere.
- ▣ The ultraviolet radiation present has enough energy to break the bond connecting chlorine to the CFC molecule.
- ▣ which can then break apart the ozone molecules.

Anthropogenic Contributions to Ozone Destruction

- First, chlorine breaks ozone's bonds and pulls off one atom of oxygen, forming a chlorine monoxide molecule and O₂:
$$\text{O}_3 + \text{Cl} \rightarrow \text{ClO} + \text{O}_2$$
- Next, a free oxygen atom pulls the oxygen atom from ClO, liberating the chlorine and creating one oxygen molecule:
$$\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$$
- One chlorine atom can catalyze the breakdown of as many as 100,000 ozone molecules before it leaves the stratosphere.

Depletion of the Ozone Layer

- ▣ Global Ozone concentrations had decreased by more than 10%.
- ▣ Depletion was greatest at the poles
- ▣ Decreased stratospheric ozone has increased the amount of UV-B radiation that reaches the surface of Earth.

Indoor Air Pollutants

- ▣ Wood, animal manure or coal used for cooking and heating in developing countries.
- ▣ Asbestos
- ▣ Carbon Monoxide
- ▣ Radon
- ▣ VOCs in home products