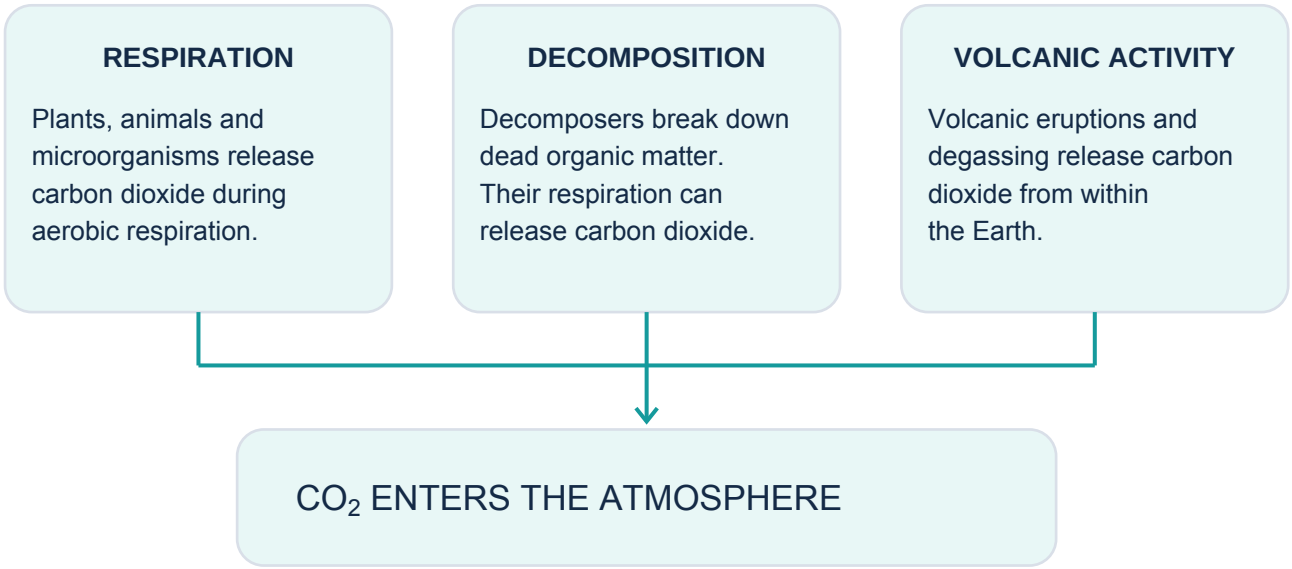
Carbon dioxide has natural sources

Carbon dioxide (CO_2) is a gas, not a suspended particle. Natural processes continually return carbon to the atmosphere; other processes remove it. Topic 7.4 focuses on identifying these natural sources.

1. THREE CORE NATURAL SOURCES



Arrows show release pathways, not their relative quantities.

2. RESPIRATION AND DECAY ARE CONNECTED

During aerobic decomposition, bacteria and fungi use organic matter and release carbon dioxide through respiration. Plants respire too, in both light and darkness. Photosynthesis removes carbon dioxide; plant respiration returns some of that carbon to the air.

3. EXTENSION: NATURAL DOES NOT MEAN UNCHANGING

Atmospheric carbon dioxide reflects releases and removals together. Fossil-fuel burning adds carbon to this cycle. Natural sources do not explain away the human contribution: present-day human carbon dioxide emissions greatly exceed volcanic emissions. Volcanoes are a natural source, not the main cause of today's human-driven increase.

Respiration, decomposition and carbon exchange: NASA, The Carbon Cycle.
Volcanic and human carbon dioxide: USGS, Volcanoes Can Affect Climate.

Scope: College Board AP Environmental Science CED, Topic 7.4, p. 144.

Particles enter air in many ways

Particulate matter (PM) consists of solid particles or liquid droplets suspended in air. Unlike CO_2, PM is a mixture, not one chemical. A single natural event can release both gases and particles.

1. MATCH EACH NATURAL SOURCE TO ITS PARTICLES

1 **Wind erosion**

Mineral dust lifted from dry soil and exposed surfaces.

2 **Ocean spray**

Sea-salt droplets and particles generated by breaking waves.

3 **Naturally ignited wildfires**

Smoke particles, including soot and organic material, plus ash.

4 **Volcanic eruptions**

Rock, mineral and glass fragments emitted as volcanic ash.

5 **Living organisms**

Pollen, fungal spores and other biological particles.

2. EXTENSION: PARTICLE SIZE IS A SEPARATE PROPERTY

PM_{10}: particles with aerodynamic diameters generally 10 μm or smaller.
$PM_{2.5}$: fine particles generally 2.5 μm or smaller, a subset of PM_{10}.

These labels describe size fractions, not chemical identities. Dust, ash and smoke each contain a range of sizes; not every pollen grain or ash fragment qualifies as PM_{10}. A source name alone cannot identify the size fraction. One micrometer (μm) is one-millionth of a meter.

Natural dust, sea salt, fires and biological PM: US EPA, PM Air Quality Overview.
Definition and size fractions: US EPA, Particulate Matter Basics.
Composition of ash: USGS, Volcanic Ash Impacts and Mitigation.

Scope: College Board AP Environmental Science CED, Topic 7.4, p. 144.

Identify the source and the evidence

Natural origin does not guarantee harmlessness. Distinguish what is emitted, its physical form and the evidence needed to assess it. The applications below extend the core natural-source content.

1. EXTENSION: ONE EVENT, DIFFERENT ATMOSPHERIC PRODUCTS

A lightning-ignited wildfire can release carbon dioxide gas and smoke particles. A volcano can emit carbon dioxide, ash and sulfur dioxide gas.

Volcanic sulfur dioxide may react to form sulfate aerosols: these are secondary particles, unlike directly emitted ash. A gas precursor and the particles formed from it are not the same substance.

2. EXTENSION: EFFECTS DEPEND ON THE MATERIAL

Carbon dioxide absorbs infrared radiation and contributes to the greenhouse effect. Inhaled fine particles can harm the respiratory and cardiovascular systems, and particles can reduce visibility.

Some volcanic sulfate aerosols reflect sunlight and temporarily cool the surface. Do not assume every particulate has the same climate effect or that a natural source eliminates health risk.

3. EXTENSION: MEASURE PARTICLES WITH A FILTER

Illustrative method: pass a measured volume of air through a pre-weighed filter. Condition the filter consistently before both weighings, use a field blank to check contamination, and repeat samples.

Blank-corrected mass gain = 240 μg; sampled air = 12 m^3
Particle mass concentration = 240 ÷ 12 = 20 $\mu g/m^3$

A size-selective inlet is needed to target a fraction such as $PM_{2.5}$. The result describes collected particle mass, not CO_2 gas. Filter mass alone cannot tell whether particles came from dust, smoke or another source; compare weather, timing and composition.

Gas and aerosol climate effects: USGS, Volcanoes Can Affect Climate.
Particle health and visibility effects: US EPA, Health and Environmental Effects of PM.
Filter sampling and quality checks: US EPA, Quality Assurance Guidance 2.12.

Scope: College Board AP Environmental Science CED, Topic 7.4, p. 144.