

BREATHING

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Primary Disciplinary Field(s): Biology, Physiology, Psychology

1. Core Definition and Mechanism

Breathing, technically known as pulmonary ventilation, represents the macroscopic mechanical process fundamental to the function of **respiration**. It is defined as the alternating mechanism of moving air between the external environment and the lungs. This cyclical process involves two primary phases: **inhalation** (breathing in, or inspiration) and **exhalation** (breathing out, or expiration). The essential biological purpose of breathing is to ventilate the alveoli of the lungs, thereby facilitating the critical exchange of gases--namely, introducing oxygen (O₂) into the bloodstream and removing metabolic waste, primarily carbon dioxide (CO₂), from the body.

While breathing is often used synonymously with respiration in common parlance, respiration is the broader term encompassing the entire sequence of events that results in the exchange of O₂ and CO₂ between the atmosphere and the body cells, including gas transport and cellular respiration. Breathing is strictly the mechanical component, requiring coordinated muscular and nervous system activity to create pressure gradients that drive airflow. A healthy adult typically undertakes approximately 12 to 20 breaths per minute at rest, a rhythm known as **eupnea**.

2. Physiological Components: The Respiratory System

The mechanical act of breathing relies upon an intricate system of organs and tissues designed for air conduction and gas exchange. Air enters the body through the nose or mouth and travels down the pharynx, larynx, and into the **trachea** (windpipe). The trachea bifurcates into the left and right primary bronchi, which subsequently divide into a massive network of smaller bronchioles, culminating in the respiratory zone of the lungs.

The lungs themselves are highly elastic, sponge-like organs housed within the thoracic cavity and protected by the rib cage. Crucially, the lungs do not contain muscles capable of generating the force required for ventilation; instead, they are entirely dependent on the actions of the surrounding skeletal muscles, primarily the **diaphragm** and the intercostal muscles. The smooth functioning of this system is critical, as disruptions to any component--from airway obstruction to muscular impairment--can severely compromise the body's ability to sustain life through effective gas exchange.

3. The Mechanics of Ventilation (Inhalation and Exhalation)

The movement of air during breathing is governed by pressure differences, following Boyle's Law, which states that pressure and volume are inversely related. During **inhalation**, the process is

typically active and requires muscle contraction. The diaphragm, a large dome-shaped muscle located beneath the lungs, contracts and flattens, moving downward. Simultaneously, the external intercostal muscles contract, pulling the rib cage upward and outward. These coordinated movements increase the volume of the thoracic cavity, which, in turn, decreases the pressure within the lungs (intrapulmonary pressure) below that of the atmospheric pressure. Consequently, air rushes into the lungs until the pressures equalize.

Exhalation (expiration) during quiet rest is generally a passive process. The diaphragm and external intercostals relax, allowing the thoracic cage to return to its original, smaller volume due to the inherent elasticity of the lung tissue and chest wall. This decrease in volume causes the intrapulmonary pressure to rise above atmospheric pressure, forcing air out of the lungs. However, during periods of increased demand, such as exercise, exhalation becomes an active process, utilizing the contraction of the internal intercostal and abdominal muscles to rapidly decrease thoracic volume and expel air more forcefully.

4. Gas Exchange (External Respiration)

While breathing provides the mechanism to move air, the actual life-sustaining function occurs at the microscopic level within the **alveoli**--tiny air sacs numbering in the hundreds of millions within the lungs. This process, known as external respiration, involves the diffusion of gases across the alveolar-capillary membrane.

The efficiency of this gas exchange relies entirely on the principle of partial pressure gradients. Deoxygenated blood arriving at the lungs has a higher concentration of CO₂ and a lower concentration of O₂ compared to the inhaled air within the alveoli. This gradient causes CO₂ to diffuse rapidly from the blood into the alveoli, where it is expelled during exhalation. Conversely, O₂ diffuses quickly from the alveoli into the capillary blood, where it binds primarily to **hemoglobin** in red blood cells for transport throughout the body. The effectiveness of breathing is therefore directly tied to maintaining the integrity of the alveolar structure and the continuous movement of blood through the pulmonary circulation.

5. Control of Breathing (Neural Regulation)

Breathing is unique among bodily functions in that it is both **voluntary** (allowing us to hold our breath or speak) and overwhelmingly **involuntary**. The involuntary rhythm is centrally regulated by the **respiratory center**, located primarily within the medulla oblongata and the pons in the brainstem. This center contains rhythm-generating neurons that establish the basic pace of respiration.

The body maintains precise control over breathing through feedback loops involving **chemoreceptors**. Central chemoreceptors, located in the medulla, are highly sensitive to changes

in the pH level of the cerebrospinal fluid, which is largely influenced by the partial pressure of carbon dioxide (PCO₂). Peripheral chemoreceptors, located in the carotid arteries and the aorta, monitor O₂ and CO₂ levels in the blood. When CO₂ levels rise (leading to increased acidity), the respiratory center is immediately stimulated to increase the rate and depth of breathing (hyperventilation) to expel excess CO₂ and restore balance. While lack of oxygen can stimulate breathing, the body's primary drive to breathe is regulated by carbon dioxide concentration.

6. Types and Patterns of Breathing

Breathing patterns vary significantly based on physiological demands, emotional state, and conscious control. Standard relaxed breathing is known as **eupnea**. Several distinct patterns exist, including:

Diaphragmatic (Abdominal) Breathing: Considered the most efficient form of breathing, relying heavily on the contraction and descent of the diaphragm. It maximizes lung capacity and is typically associated with relaxation and optimal oxygen saturation.

Costal (Thoracic) Breathing: Utilizes the intercostal muscles to expand the rib cage laterally and vertically. This pattern is often shallower and more rapid, frequently observed during mild exertion or states of anxiety.

Hyperventilation: An abnormally fast and deep rate of breathing that exceeds the body's metabolic needs for gas exchange. This leads to an excessive reduction in CO₂ (hypocapnia), often causing symptoms such as dizziness, tingling, and lightheadedness due to changes in blood pH and cerebral blood flow.

Apnea: The temporary cessation of breathing, which can be intentional or a symptom of underlying sleep disorders (e.g., sleep apnea) or neurological failure.

7. Psychological and Clinical Significance

The close relationship between breathing patterns and the autonomic nervous system (ANS) makes breathing a crucial link between physiological state and psychological experience. Rapid, shallow breathing (thoracic breathing) signals the activation of the **sympathetic nervous system**, triggering the "fight or flight" response, which increases heart rate and muscle tension. Conversely, slow, deep, diaphragmatic breathing activates the **parasympathetic nervous system**, promoting rest, digestion, and systemic calm.

In clinical psychology and behavioral medicine, conscious control of breathing is a cornerstone of various therapeutic modalities. Techniques such as **mindfulness meditation**, yoga pranayama, and biofeedback utilize controlled, slow breathing to manage stress, reduce symptoms of anxiety and panic attacks, and improve emotional regulation. Understanding and modifying habitual breathing patterns is recognized as a vital tool for improving overall physical and mental well-being.

8. Further Reading

[Wikipedia: Breathing](#)

[Encyclopedia Britannica: The Mechanics of Breathing](#)

[NCBI Bookshelf: Physiology of Respiration](#)

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