

Biology-Respiratory Systems and Associated Topics

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Abstract

This paper presents a comprehensive overview of the human respiratory system, focusing on anatomical structure, physiological function, and regulatory mechanisms that sustain breathing and systemic homeostasis. The discussion outlines the airflow pathway beginning at the nasal passages, where filtration, humidification, and defense against airborne particles occur, and continues through the pharynx, larynx, trachea, bronchi, and bronchioles to the alveolar respiratory zone. Within the lungs, gas exchange is facilitated by alveoli and pulmonary capillaries, allowing oxygen uptake and carbon dioxide removal while supporting cellular energy production and metabolic balance. Structural protection is provided by pleural membranes and coordinated pressure dynamics involving atmospheric, intrapulmonary, and intrapleural forces, which together regulate ventilation efficiency. The autonomic nervous system contributes to airway tone, glandular activity, and muscular coordination, ensuring stable respiratory rhythm and functional equilibrium between pulmonary and systemic circulation. Additional roles of the respiratory system include maintenance of acid base balance, thermoregulation, and support of overall physiological resilience. The paper also highlights the importance of preserving respiratory health through environmental awareness, physical activity, and preventative care. By integrating anatomical detail with functional mechanisms, this work emphasizes the critical role of respiration in sustaining vitality, maintaining internal stability, and supporting long term human health.

Introduction

The respiratory system is essential for human survival. It plays a central role in maintaining physiological stability by supplying oxygen to the body and eliminating carbon dioxide. This continuous exchange of gases supports cellular metabolism, maintains blood acid-base balance, contributes to heart rate regulation, and supports immune function (Ahookhosh p.145). To achieve efficient gas exchange, the respiratory system works in coordination with multiple organs and tissues.

The respiratory pathway consists of the nose, mouth, pharynx (throat), larynx (voice box), trachea (windpipe), bronchi, lungs, and alveoli. Air typically enters through the nasal or oral cavities, where it is filtered and directed through the pharynx to the larynx. The larynx supports sound production and airflow regulation, while the trachea connects the upper airway to the lungs through branching bronchi. Within the lungs, alveolar sacs facilitate the exchange of oxygen and carbon dioxide during

external respiration, allowing oxygen to enter the bloodstream while carbon dioxide is removed.

Understanding the structure and function of the respiratory system is critical for healthcare professionals, as it supports accurate diagnosis and treatment of respiratory conditions (Akgül p.610). Because oxygen delivery and carbon dioxide removal are fundamental to maintaining life, dysfunction within this system can lead to significant health complications. Beyond clinical practice, studying respiration enhances knowledge of how body systems interact and how environmental or disease-related factors influence physiological processes. A comprehensive understanding of respiratory anatomy and physiology therefore contributes to improved healthcare outcomes and broader scientific research. This paper aims to examine the respiratory system in detail, emphasizing its role in physical function and its relevance to environmental and health considerations.

Learning Objectives of the Respiratory System

This work focuses on expanding knowledge of the respiratory system, one of the most essential physiological systems in the human body. Its primary function is to supply oxygen to tissues and organs while removing carbon dioxide, thereby maintaining proper gas balance and supporting cellular metabolism. Understanding the structure and function of respiratory anatomy is fundamental to overall health, as disruptions in respiration can affect multiple organ systems and physiological processes (Benarroch p. 60). This paper outlines key learning objectives that provide a comprehensive foundation for understanding respiratory physiology and its role in maintaining homeostasis.

Organization of the Respiratory System

The respiratory system is composed of several interconnected structures, including the nares, pharynx, larynx, trachea, bronchi, lungs, and respiratory muscles. This study aims to describe how each component contributes to airflow regulation and supports the continuous process of inhalation and exhalation. Emphasis is placed on structural organization and functional integration, illustrating how air travels through the airway and reaches the alveoli for gas exchange.

Mechanics of Breathing

A detailed explanation of respiratory mechanics will be presented, focusing on the processes of inspiration and expiration. The role of the diaphragm and intercostal muscles will be examined to demonstrate how pressure changes within the thoracic cavity influence lung expansion and recoil. Understanding these mechanical principles clarifies how airflow is generated and regulated during normal breathing patterns.

Ventilation-Perfusion Relationships

The study will explore ventilation-perfusion relationships and their significance in efficient gas exchange. By examining how airflow within the alveoli aligns with blood flow in surrounding capillaries, this section highlights the importance of maintaining proper oxygenation and carbon dioxide removal (Benarroch p. 59). Imbalances in this relationship will also be discussed to illustrate how respiratory efficiency may be compromised.

Oxygen and Carbon Dioxide Transport

Another objective is to explain how oxygen and carbon dioxide are transported throughout the body. The paper will examine how inhaled oxygen binds to hemoglobin and circulates through the bloodstream while carbon dioxide is transported back to the lungs for elimination (Biswas p. 160). Particular attention will be given to the role of hemoglobin concentration and how fluctuations may influence tissue oxygen delivery and overall physiological function.

Control of Breathing

Regulation of breathing will be addressed through an overview of central and peripheral chemoreceptors and their role in main-

taining respiratory rhythm (Chiner-Vives p. 160). This section will also examine the influence of the autonomic nervous system and hormonal factors, including cortisol and adrenaline, on breathing rate and depth during stress or physical exertion.

Alveolar - Arterial Equilibration

The paper will further describe alveolar-arterial equilibration and its role in sustaining gas balance between the lungs and blood-stream (Guo NP). By comparing alveolar gas concentrations with arterial blood gases, this section demonstrates how respiratory efficiency can be evaluated and how alterations may signal underlying physiological changes.

Effects of Low and High Gas Pressure on the Body

Another learning objective is to examine how variations in environmental or physiological gas pressure affect the respiratory system. The study will explain how changes in pressure influence lung expansion, vascular tension, and the efficiency of oxygen and carbon dioxide exchange (Holtzman p. 890).

Effects of Exercise on the Respiratory System

Finally, the investigation will discuss how physical activity impacts respiratory performance. Exercise increases breathing frequency, tidal volume, and lung capacity, enhancing gas exchange within the alveoli. This section will also describe adaptations in airflow dynamics and diffusion processes that occur during increased metabolic demand (Kampjut p. 74).

The Respiratory System

The anatomical structure responsible for breathing is composed of multiple interconnected components. The nose serves as an initial air filter before air reaches the lungs, while the mouth provides an alternative pathway when nasal airflow is obstructed. Additional structures, including the pharynx, larynx, trachea, and bronchi, play essential roles in respiration by directing air toward the lungs (Kiyokawa p.70). The bronchi branch from the trachea and transport air into the lungs, where oxygen is absorbed and carbon dioxide is expelled during exhalation. Beneath the lungs lies the dome-shaped diaphragm, a primary muscle that regulates airflow by controlling expansion and contraction of the thoracic cavity.

The respiratory system is indispensable for maintaining normal physiological function. Beyond gas exchange, it supports energy production through oxygen uptake and helps regulate temperature, humidity, and acid-base balance within inhaled and exhaled air (Loaiza-Ceballos p.113). Maintaining respiratory health through avoidance of pollutants such as smoke or dust, combined with regular physical activity, contributes to optimal lung performance and overall well-being.

The Process of Respiration

Respiration enables the intake of oxygen and removal of carbon dioxide, processes essential for sustaining cellular metabolism. Breathing begins when air enters through the nasal or oral cavities, where it is filtered, warmed, and humidified before traveling through the trachea. Air then passes into the primary bronchi, branching into smaller airways that lead to alveoli, the primary sites of gas exchange. Within the alveoli, oxygen diffuses into surrounding capillaries while carbon dioxide moves in the opposite direction to be expelled during exhalation (Mettelman p.760).

The diaphragm plays a central role in regulating lung pressure and enabling inhalation and exhalation. Once oxygen enters the blood-stream, it is transported to cells where it supports energy production, while carbon dioxide generated through metabolism is returned to the lungs for elimination. In addition to oxygen and carbon dioxide exchange, respiration involves the movement of nitrogen and water vapor. This continuous cycle maintains acid-base balance, contributes to temperature regulation, and supports physiological stability. Respiration also influences biochemical processes associated with hormone signaling and enzyme activity, highlighting its broader role in sustaining bodily functions (Pesonen p.15).

The Function of the Respiratory System

The respiratory system performs the essential task of delivering oxygen to tissues while removing carbon dioxide, a metabolic by-product. Oxygen is necessary for converting nutrients into energy, whereas excess carbon dioxide can disrupt internal balance by contributing to acidosis. Through ventilation, the respiratory system assists in regulating body temperature and maintaining pH stability (Petit p.74). It also protects against environmental hazards by filtering airborne bacteria, viruses, and particulate matter.

Survival depends on efficient respiratory function, as insufficient oxygen supply can impair organ and tissue performance. In addition to gas exchange, respiration contributes to homeostasis by supporting temperature regulation, maintaining acid-base equilibrium, and defending against environmental stressors. Structurally, the lungs serve as the primary sites of gas transfer and consist of two lobes on the left and three lobes on the right (Pivniouk p.950). Air reaches the lungs through the trachea, which connects to the larynx, an organ responsible for airflow regulation and vocalization.

During respiration, inhaled air travels through the upper airway to the lungs, where oxygen is absorbed into the bloodstream through specialized vascular networks. Red blood cells then transport oxygen throughout the body to sustain metabolic activity and maintain homeostasis. The respiratory system also contributes to thermoregulation and acid-base balance while protecting against inhaled toxins through mucus, cilia, and immune-responsive lung cells (Shojaie p.4790). Collectively, the coordinated action of the nose, mouth, throat, trachea, bronchi, lungs, and diaphragm ensures efficient breathing and supports overall physiological stability.

Functions of the Respiratory System: Overview

The respiratory system is one of the body's most essential physiological systems, responsible for supplying oxygen to cells and removing carbon dioxide. Structures including the nose, mouth, pharynx, larynx, trachea, bronchi, and lungs work together to facilitate this process. Its primary role involves gas exchange between the atmosphere and the bloodstream while maintaining stable blood pH levels. Additionally, the respiratory system contributes to sound production and protects delicate alveolar structures, both of which are essential for human health. Understanding these functions remains critical for medical professionals and researchers seeking to advance respiratory care and physiological knowledge.

Oxygen Exchange

The primary function of the respiratory system is to facilitate oxygen exchange between inhaled air and the body's cells. This process begins in the nasal cavity, where incoming air is filtered, warmed, and humidified before passing through the pharynx and larynx into the trachea and bronchi. Air ultimately reaches the alveoli within the lungs, which serve as the principal sites of gas exchange. Oxygen diffuses across the alveolar membrane into the bloodstream, supporting cellular energy production, while carbon dioxide moves in the opposite direction to be eliminated through exhalation. This coordinated process of oxygen uptake and carbon dioxide removal forms the basis of respiration.

Carbon Dioxide Exchange

The respiratory system also plays a critical role in removing carbon dioxide generated through cellular metabolism. Carbon dioxide produced within tissues enters the bloodstream and travels to the lungs, where it diffuses from pulmonary capillaries into the alveoli. During exhalation, this gas is expelled from the body. Simultaneously, oxygen binds to hemoglobin within red blood cells and is transported throughout the body to support tissue function. This exchange occurs continuously and largely without conscious effort, sustaining physiological balance throughout daily activities.

pH Control in the Blood

Respiration is essential for maintaining blood pH balance. Carbon dioxide acts as an acid within the bloodstream, and elevated levels can lower pH, disrupting internal stability. Through controlled breathing, the lungs regulate carbon dioxide concentration by expelling

excess gas during exhalation. Air travels through the respiratory tract into progressively smaller airways until it reaches the alveoli, where diffusion gradients allow oxygen to enter the bloodstream and carbon dioxide to leave it. Oxygen-rich blood is then circulated by the heart to tissues, where metabolic processes produce carbon dioxide that must be removed to maintain equilibrium. By adjusting breathing patterns, the respiratory system helps preserve acid-base balance and ensures proper physiological function.

The respiratory system is therefore fundamental to maintaining overall health. Efficient gas exchange supports cellular oxygenation, stabilizes blood chemistry, and prevents harmful accumulation of metabolic waste products that could impair normal body processes.

Vocalizations

In addition to gas exchange, the respiratory system contributes to sound production and communication. Vocalizations originate in the larynx, where airflow causes the vocal folds to vibrate, producing sound waves. The pitch and tone of these sounds are modified by movements of the tongue, lips, and oral cavity, which reshape airflow as it exits the body. Speech production requires coordinated activity between respiratory muscles, including the diaphragm and intercostal muscles, and structures within the throat and mouth.

The vocal folds consist of small muscular tissues that adjust tension and position to create variations in sound. Changes in airflow, vocal tract shape, and lip positioning allow for a wide range of vocal expressions. This dynamic interaction between the respiratory system and articulatory structures enables communication through speech, music, and other forms of vocal expression. Although complex, these processes rely on controlled breathing patterns that synchronize airflow with muscular movements to generate clear and varied sounds.

Alveoli Protection

The respiratory system plays a vital role in protecting the delicate alveoli, which are responsible for oxygen exchange but remain vulnerable to environmental pollutants and harmful chemicals. Protective mechanisms include filtering incoming air before it reaches the lungs, humidifying airflow to reduce irritation, and producing mucus that traps dust particles and foreign substances. Temperature regulation is also important, as maintaining stable conditions within the lungs helps preserve alveolar integrity. Additionally, immune defenses within the respiratory system produce antibodies and other protective factors that help prevent infections capable of damaging alveolar structures (Pivniouk p.950).

Proper regulation of lung pH further contributes to alveolar protection by preventing damage caused by acidic or alkaline imbalances. The respiratory system also helps prevent excess fluid accumulation within lung tissue, which could impair gas exchange and compromise respiratory function. Maintaining healthy alveoli is essential, as injury to these air sacs can reduce or prevent effective oxygen transfer. Through coordinated filtration, immune defense, and physiological regulation, the respiratory system preserves the structural integrity necessary for efficient breathing and overall health.

Functional Anatomy

The respiratory system consists of a coordinated network of organs that work together to transfer gases between the environment and the body. Key structures include the nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles, and alveoli, all of which contribute to maintaining efficient respiration. Functionally, the system is divided into two primary regions: the conducting zone and the respiratory zone. The conducting zone filters, warms, humidifies, and transports air, whereas the respiratory zone facilitates gas exchange with the bloodstream.

The nose is a primary entry point for air and contains external nares, internal nares, and the nasal cavity. Within this cavity, mucous membranes and cilia capture airborne particles such as dust or pollen, protecting the lungs from potential irritation. Olfactory receptors located within specialized glands detect odors and transmit neural signals for sensory processing. Through these mechanisms, the nasal cavity not only supports respiration but also contributes to environmental awareness and protective reflexes.

The pharynx serves as a muscular passageway connecting the nasal and oral cavities to the lower respiratory tract. It allows airflow while protecting deeper lung structures from foreign particles. The larynx regulates airflow and supports vocalization, while the trachea connects the upper airway to the bronchi. Reinforced by cartilage rings, the trachea maintains an open pathway for air movement during inhalation and exhalation (Pivniouk p.950). Its inner lining contains mucous membranes and cilia that trap debris and prevent obstruction.

The trachea divides into right and left bronchi, which carry air into each lung. These bronchi branch into progressively smaller bronchioles that lead to the alveoli, where gas exchange occurs. The thin walls of the alveoli allow oxygen to diffuse into surrounding capillaries while carbon dioxide exits the bloodstream for removal. This intricate anatomical arrangement ensures efficient oxygen delivery and carbon dioxide elimination, processes essential for sustaining cellular function.

Collectively, respiratory structures regulate airflow, filter harmful substances, and adjust temperature and humidity according to environmental conditions. Without the coordinated action of these components, the transfer of oxygen and carbon dioxide necessary for life would not be possible. The nose and nasal cavity, in particular, serve as protective gateways, ensuring that incoming air is conditioned appropriately before reaching sensitive lung tissue. Their combined roles in filtration, humidification, and olfactory detection contribute significantly to maintaining respiratory health and overall physiological stability.

The Nose

The nose is an integral component of the respiratory system, responsible for air intake, filtration, and olfactory perception. Structurally, it consists of two nostrils, a nasal cavity, and a septum that separates the passages. Mucous membranes lining the nasal cavity trap impurities while also regulating temperature and humidity before air enters the lungs. Olfactory receptors within the nasal region detect odors originating from environmental exposures or ingested substances, contributing to sensory awareness alongside respiratory function.

Functions of the Nose

Providing An Airway for Respiration

The nose plays a central role in directing airflow to and from the lungs while supporting the exchange of oxygen and carbon dioxide. Incoming air passes through nasal passages lined with mucus and fine hairs that filter particles such as dust and bacteria. After filtration, air moves into the nasal cavity and continues through the pharynx toward the larynx and trachea, ultimately reaching the bronchi and bronchioles before arriving at the alveoli where gas exchange occurs (Liang NP).

Adaptive mechanisms within the nasal cavity enhance respiratory efficiency. The combination of mucus and cilia acts as a protective filtration system, preventing harmful substances from entering deeper regions of the respiratory tract. These processes ensure smooth airflow and help maintain optimal respiratory function, emphasizing the importance of nasal health in sustaining effective breathing.

Moistening and Warming Air

A critical function of the nose is conditioning inhaled air by warming and humidifying it before it reaches the lungs. Moisture released from mucous membranes prevents dryness and irritation within respiratory passages, reducing coughing and breathing discomfort. Humidified air also limits the number of airborne particles that enter the lungs, lowering the risk of respiratory irritation.

The nasal cavity contains an extensive network of blood vessels that raise the temperature of incoming air, while glands produce mucus that maintains adequate moisture levels (Wang NP). This process ensures that air reaching the lungs is properly conditioned for efficient gas exchange. By stabilizing humidity and temperature, the nose supports respiratory comfort and promotes effective oxygen absorption within pulmonary tissues (Telang NP).

Filtering Inspired Air

The nose functions as the first line of defense against airborne pollutants. Nasal cavities lined with mucous membranes and turbinate structures trap particulate matter, bacteria, pollen, and other debris. Mucus binds these particles, preventing them from reaching the lungs and helping maintain respiratory health. In response to irritants, protective reflexes such as sneezing and increased mucus production may occur, narrowing airways temporarily to limit exposure (Guerrieri p.1-13).

Beyond filtration, the nose contributes to sensory perception and vocal resonance. Olfactory receptors assist in detecting airborne chemicals, while the shape of the nasal cavity influences vocal tone during speech. Through these combined roles, the nose supports respiration, communication, and environmental awareness, highlighting its importance in maintaining overall respiratory function and safety.

Serving as a Resonating Center for Speech

An important component of the respiratory system, the nose, contributes to speech by acting as a resonating chamber for sound. In addition to facilitating airflow, the nasal structures modify sound waves produced by the vocal cords, enhancing vocal clarity and projection. The internal structure of the nasal cavity, divided by the nasal septum, forms chambers that influence sound resonance and support clearer articulation during speech (Guerrieri p.1-13).

Mucous membranes lining the nasal passages contribute to vibration and airflow modulation, directing sound waves toward the oral and respiratory pathways. The shape and configuration of the nasal cavity help refine tone and reduce distortion, allowing individuals to communicate effectively. Nasal conchae, the curved plates within the nasal cavity, assist in dispersing airflow and enhancing resonance, while turbinate structures influence sound intensity. Additionally, the paranasal sinuses alter sound frequencies, contributing to vocal depth and audibility (Gupta p.5-13).

Through these structural adaptations, the nose functions as more than an airway; it supports vocal modulation and speech production. By enhancing resonance and shaping sound waves, nasal anatomy plays a key role in communication, music, and language expression (Lou p.528-532). Maintaining nasal health is therefore essential not only for breathing but also for clear and effective speech.

Housing the Olfactory Receptors

Located within the upper nasal cavity, olfactory receptors form a specialized sensory system responsible for detecting airborne chemicals and odors. These receptor cells, embedded within the olfactory epithelium, transmit signals to the brain that allow recognition and interpretation of scents. This function assists in identifying environmental cues, food sources, and potential hazards such as smoke or toxic gases.

Adaptations within this sensory region allow rapid detection of odor molecules as air passes through the nasal passages. Sensitivity to a wide range of chemical compounds enables discrimination between different scents, while responsiveness to changes in humidity and temperature provides additional information about air quality (Gupta p.5-13).

Continuous sensory input from these receptors contributes to environmental awareness and protective reflexes. By detecting potentially harmful substances and supporting flavor perception, this system plays an essential role in both respiratory protection and daily physiological function.

Pharynx

Within the respiratory tract, the pharynx functions as a shared passageway for both respiratory and digestive systems, connecting the nasal and oral cavities to the larynx and esophagus. This anatomical structure is divided into three regions: the nasopharynx, oropharynx, and laryngopharynx, each performing distinct but coordinated roles. The nasopharynx primarily supports airflow, the oropharynx allows the passage of both air and ingested materials, and the laryngopharynx directs substances toward either the trachea

or esophagus while helping protect the airway from foreign particles (Smith p.313). Through its structural organization, this region contributes significantly to breathing, swallowing, and protective reflexes.

Functions of the Pharynx

Passageway for Air Entering the Body

Air entering through the nasal or oral cavities travels through the pharynx before reaching the lower respiratory tract. Located in the neck, this structure contains mucous membranes that help filter, warm, and humidify inhaled air. The nasopharynx processes airflow from the nasal cavity, while the oropharynx permits combined airflow from both nose and mouth. The laryngopharynx guides air toward the larynx and trachea, supporting efficient respiration (Smith p.313). Moist mucosal linings trap airborne particles, preventing contaminants from reaching deeper lung tissues and helping maintain respiratory health (Dantas NP).

Moistening and Warming Incoming Air

Humidification and temperature regulation occur as inhaled air passes along the pharyngeal walls. Mucous membranes secrete moisture that lubricates airflow, reducing dryness and irritation within the respiratory tract. Cilia lining the surface assist in capturing dust, pollen, and microorganisms, adding an additional layer of defense (Dailey p.467). By conditioning incoming air, this region helps protect lung tissue and contributes to overall respiratory comfort while supporting normal speech and swallowing functions.

Contribution to Speech Production

During phonation, airflow moving through the pharynx influences sound resonance and vocal quality. Muscular adjustments within the pharyngeal walls alter the size and shape of the airway, affecting tone and volume during speech. Coordinated activity between respiratory muscles and laryngeal structures allows sound waves to travel through this region, shaping audible communication. In addition to vocal modulation, mucosal surfaces help filter inhaled air, maintaining airway cleanliness during breathing and speaking (Malhotra p.72).

Preventing Food and Liquids from Entering the Airway

Protection of the airway is a major function of the pharynx. During swallowing, the epiglottis folds downward to block entry into the trachea, directing food and liquids toward the esophagus instead. The soft palate also contributes by separating the nasal cavity from the oral cavity, preventing materials from entering inappropriate passages (Donner p.197). Muscular contractions and mucous secretions provide additional safeguards, reducing the risk of aspiration and supporting safe swallowing.

Muscular Role in Swallowing

Coordinated contractions within the pharyngeal muscles propel food and liquids toward the esophagus. Acting as a cylindrical muscular pathway, this structure supports both respiration and digestion. Sequential contraction and relaxation guide ingested materials downward through peristaltic movements, ensuring efficient transfer into the gastrointestinal tract (Smith p.313; Donner p.197). Through these actions, the pharynx maintains balance between breathing and swallowing throughout daily physiological activity.

Nasopharynx

Positioned behind the nasal cavity, the nasopharynx represents the uppermost section of the pharynx. Lined with ciliated epithelium and mucus-secreting glands, this region filters, warms, and humidifies inhaled air before it travels toward the larynx and trachea. By conditioning airflow, the nasopharynx supports respiratory efficiency while also contributing to sound resonance during speech.

Functions of the Nasopharynx

Filtering and Humidifying Air Entering the Lungs

Air passing through this region undergoes filtration and humidification to ensure it is safe for the lower respiratory tract. Cilia located on the epithelial surface trap dust, microorganisms, and other airborne particles, while mucus maintains moisture levels and supports comfortable airflow. As conditioned air moves toward the trachea, additional filtration and warming occur, preparing it for gas exchange within the lungs. Proper functioning of this process is essential for maintaining respiratory health and protecting lung tissue.

Producing Mucus to Trap and Expel Pathogens and Foreign Particles

Goblet cells within the nasopharyngeal lining produce mucus that captures pathogens and debris entering the airway. Controlled by the autonomic nervous system, mucus secretion forms a protective barrier that traps foreign materials and assists in their removal through swallowing or expulsion (Pivniouk p.950). This mucus also contains immune components that help defend against infection while keeping airways moist and reducing irritation. Through these combined protective mechanisms, the nasopharynx plays a crucial role in preserving airway health and preventing respiratory complications.

Regulating Airflow Between the Nose and The Mouth.

Regulation of airflow between nasal and oral passages is a key function of the nasopharynx. Lined with ciliated epithelial cells, this region helps prevent foreign particles and debris from entering the lungs while also assisting in humidifying and warming inhaled air. The coordinated movement of cilia removes toxins and contaminants, supporting airway cleanliness and respiratory efficiency.

Airflow adjustments occur according to the body's physiological demands. During increased physical activity, airflow through the nasopharynx expands to allow greater ventilation, whereas reduced respiratory demand, such as during sleep, results in decreased airflow. Acting as a functional regulator, this region helps balance ventilation while protecting lung tissue from airborne irritants. In addition to respiratory regulation, the nasopharynx contributes to vocal modulation by influencing airflow between the mouth and nasal cavity, which can subtly affect vocal tone and resonance (Pivniouk p.950).

Acting as a Resonator to Modify the Pitch of Speech

Resonance within the nasopharyngeal cavity contributes to vocal tone and speech clarity. Air passing through this air-filled chamber interacts with surrounding anatomical structures, including the soft palate and uvula, creating acoustic resonance that influences pitch and vocal quality. Variations in chamber size and airflow volume affect both loudness and tonal characteristics, allowing individuals to produce diverse vocal expressions.

Resonance generated within the vocal tract depends on coordinated airflow through the throat, mouth, and nasal passages. Vibrations originating at the vocal folds travel through these spaces, where anatomical structures modify sound frequency and intensity. Through these mechanisms, the nasopharynx assists in maintaining vocal tone, clarity, and articulation while also functioning as a protective barrier separating upper and lower respiratory pathways.

Protective features within this region include mucus production and ciliary activity, which trap and remove airborne contaminants before they reach the lungs. Lymphatic tissues produce immune components that help defend against pathogens, while mucus maintains airway moisture and reduces irritation (Pivniouk p.950). These combined roles demonstrate how resonance, protection, and respiratory regulation occur simultaneously within the nasopharyngeal structure.

Helping to Maintain a Normal Body Temperature

Thermoregulation is supported by vascular structures within the nasopharynx. A dense network of blood vessels within the mucosal lining helps adjust the temperature of inhaled air before it reaches the lungs. Heat exchange between circulating blood and incoming airflow contributes to maintaining stable respiratory conditions and overall comfort during breathing.

Moisture released from surrounding glands further assists in cooling or warming inhaled air as needed. Adenoid tissue located near the posterior nasal cavity contributes to immune defense while also supporting airflow regulation. Through these mechanisms, the nasopharynx helps maintain consistent internal conditions despite changes in environmental temperature.

Secreting Hormones to Regulate Breathing

Regulation of breathing patterns involves complex interactions between neural and chemical signals. While hormonal influences such as epinephrine and norepinephrine affect respiratory rate and depth, these signals originate primarily from systemic physiological regulation rather than direct secretion within the nasopharynx itself. Airflow passing through this region contributes indirectly to respiratory reflexes that influence breathing intensity, oxygen uptake, and carbon dioxide removal.

In addition to respiratory control, immune responses within nasopharyngeal tissues help defend against pathogens by promoting antibody activity and modulating inflammatory processes. These protective responses support overall airway health and contribute to maintaining balanced respiratory function.

Oropharynx

Located at the junction of the nasal and oral cavities, the oropharynx functions as a shared passageway for both air and ingested materials. Lined with mucous membranes and containing structures such as the palatine tonsils, base of the tongue, uvula, and soft palate, this region directs airflow toward the lungs while guiding food toward the esophagus. Through coordinated muscular activity, it maintains balance between respiratory and digestive processes.

Functions of the Oropharynx

Serves as an Airway to and from the Lungs

Air traveling between the external environment and the lungs passes through the oropharynx, which connects the nasal cavity to the larynx. Inhalation allows air to enter through nasal or oral openings, while exhalation expels gases outward through the same pathways. Mucous membranes within this region help trap pollutants such as dust and debris, supporting respiratory protection. Ciliary movement assists in clearing contaminants, contributing to clean airflow and healthy lung function.

Warms and Moistens Inhaled Air

Humidification and warming of incoming air continue within the oropharynx. Mucous membranes containing small glands secrete moisture that prevents dryness within respiratory tissues. Blood vessels located beneath the mucosal surface aid in temperature regulation, ensuring that inhaled air reaches the lungs in a conditioned state.

As air moves through this region, the moist lining transfers humidity to the airflow, reducing irritation and promoting efficient breathing. These processes are particularly important when inhaling cold or dry air, as they help maintain comfort and protect delicate respiratory tissues from environmental stress.

Houses the Tongue and Vocal Structures

The oropharynx supports both respiratory and digestive functions by accommodating structures essential for swallowing and speech. Positioned at the back of the oral cavity, this region contains the tongue and connects functionally with vocal structures located within the larynx. Movement of food and liquids is guided by the tongue, while airflow passing toward the larynx contributes to sound production.

Muscular coordination within this region allows the tongue to assist in manipulating food, initiating swallowing, and shaping speech sounds. Its anatomical divisions, including the root, body, and tip, support taste perception and articulation. Vocal folds located within the larynx vibrate as air passes through them, producing audible sound. Adjustments in muscle tension and airflow help regulate pitch

and volume, allowing clear vocal expression while maintaining open airways during breathing.

Together, these coordinated structures contribute to both respiration and digestion. Efficient movement of the tongue and controlled vibration of vocal folds support safe swallowing, continuous airflow, and effective communication.

Aids in Swallowing Food and Liquids

Initiation and coordination of swallowing begin within the oropharyngeal region. During ingestion, the tongue propels food toward the back of the mouth, while the soft palate and surrounding tissues prevent material from entering the nasal cavity. Saliva produced by nearby glands lubricates food, facilitating smoother passage toward the digestive tract. A coordinated sequence of muscular contractions and relaxations moves ingested material from the mouth into the esophagus. This process allows respiration and swallowing to remain balanced, ensuring that airflow continues safely while food and liquids are transported efficiently.

Produces Sound During Speech

Vocalization depends on airflow traveling from the lungs through the larynx and into the pharyngeal spaces. Within this region, resonance and articulation modify sound waves generated by the vibrating vocal folds. Movements of the tongue, lips, and cheeks interact with the oropharyngeal cavity to shape speech sounds and determine vocal tone.

Differences between voiced and unvoiced speech arise from variations in airflow and muscular control. Resonance within the pharyngeal space helps regulate pitch, intensity, and clarity, allowing speech to remain fluid and intelligible. Controlled breathing during communication ensures a steady airflow that supports vocal endurance and expression.

Laryngopharynx

Situated between the esophagus and larynx, the laryngopharynx functions as a shared passageway for air and ingested materials. Lined with mucous membranes, this region assists in protecting the airway while contributing to swallowing and vocal resonance (McCormick p.130). Through coordinated muscular actions, it directs air toward the trachea and food toward the esophagus, maintaining balance between respiratory and digestive processes.

Functions of the Laryngopharynx

Producing Voice Sounds

Speech production involves coordinated activity among the laryngeal cartilages, vocal folds, and surrounding muscles. As air flows upward from the lungs, vibrations within the vocal folds generate sound, while pharyngeal muscles modify resonance and tone. Laryngeal cartilages help regulate tension on the vocal folds, influencing pitch and frequency during communication (Yading p.1-10). Pharyngeal constrictor muscles assist in controlling airflow and protecting the airway by preventing foreign particles from entering deeper lung structures. These coordinated actions allow clear vocal expression while maintaining respiratory protection (McCormick p.130).

Swallowing Food and Liquid

During swallowing, the laryngopharynx plays a coordinated protective and transport role by guiding ingested materials toward the esophagus while safeguarding the airway. As food or liquid is moved posteriorly by the tongue, muscular activity within the pharyngeal walls directs the bolus downward. At the same time, the larynx elevates and the epiglottis shifts to partially cover the entrance to the trachea, reducing the risk of aspiration (Mizuno p.1-10). This coordinated action ensures that respiratory airflow and digestive movement do not interfere with one another.

Pharyngeal constrictor muscles contract sequentially, generating a controlled wave that moves food into the esophagus. Following entry into the esophagus, peristaltic contractions continue transporting the material toward the stomach for digestion. Lubrication

provided by mucous secretions reduces friction and supports smooth passage, allowing swallowing to occur efficiently even during simultaneous breathing cycles. Through these integrated muscular and structural adaptations, the laryngopharynx maintains balance between respiration and ingestion, ensuring airway protection while enabling effective nutrient intake.

Filtering Air

Protection of the lower respiratory tract relies in part on filtration processes occurring within the laryngopharynx. Mucous membranes lining this region contain ciliated epithelial cells that trap airborne particles, including dust, microorganisms, and environmental pollutants. Sticky mucus binds these particles, preventing them from progressing toward sensitive alveolar tissues, while coordinated ciliary motion moves debris toward the throat for removal or swallowing.

Beyond mechanical filtration, airflow passing through this region is humidified and conditioned, reducing irritation to deeper lung structures. Muscular adjustments within the airway help regulate airflow patterns, maintaining stable ventilation during breathing and speech. Moisture secretions also contribute to maintaining mucosal integrity, decreasing the likelihood of dryness-related inflammation or infection.

Through the combined actions of mucus production, ciliary movement, and controlled airflow, the laryngopharynx supports respiratory defense while preserving optimal conditions for gas exchange. These protective mechanisms ensure that inhaled air reaching the lungs is cleaner, properly humidified, and less likely to introduce harmful substances into the lower respiratory system.

Protecting the Trachea

Protection of the trachea is one of the primary roles of the laryngopharynx within the respiratory system. This funnel-shaped region, positioned between the pharynx and larynx, forms a protective passage lined with mucous membranes that help prevent foreign materials such as food or liquids from entering the airway. Structural features, including the epiglottis and aryepiglottic folds, work together to guide ingested substances toward the esophagus while shielding the tracheal opening (Mizuno p.1-10).

During swallowing, the epiglottis, a flexible cartilage structure, folds downward to cover the entrance to the trachea, reducing the risk of aspiration. The aryepiglottic folds assist by forming a protective channel that redirects food and fluids away from the larynx. Beyond mechanical protection, mucous membranes trap microorganisms and debris, lowering the likelihood of infection. Continuous mucus secretion also maintains lubrication, preventing dryness and irritation along the tracheal lining while supporting smooth airflow (Kuo NP). Through these coordinated mechanisms, the laryngopharynx preserves airway integrity and protects sensitive lung tissues.

Regulating Airflow

Airflow regulation within the upper respiratory tract depends on coordinated interactions between the laryngopharynx, larynx, and surrounding muscular structures. Acting as a transitional region, this area helps guide air between the lungs and external environment while preventing foreign materials from entering the airway. Structural components such as the epiglottis, pharyngeal walls, and laryngeal framework work together to maintain balanced airflow (Yading p.1-10).

Muscular contractions adjust airway diameter, allowing increased airflow during physical activity and reduced airflow during rest. While one set of muscles contracts, others relax to maintain smooth respiratory movement. Air passing through this region also contributes to sound production, as vibrations originating at the vocal folds are shaped by the surrounding pharyngeal space. Resonance within the nasal and oral cavities further amplifies sound, demonstrating the combined respiratory and vocal functions of this anatomical region (Mizuno p.1-10).

Larynx

The larynx, commonly referred to as the voice box, is a central organ within the upper respiratory tract located in the neck. Its primary roles include regulating airflow, producing sound, and protecting the airway during swallowing. Containing the vocal folds, this structure allows vibrations to occur as air passes through, generating audible speech. In addition to vocalization, closure of the airway during swallowing prevents airway obstruction by food or liquids, supporting both respiration and digestion.

Functions of the Larynx

Producing Sound

Sound production occurs when airflow from the lungs passes through the vocal folds, causing them to vibrate. The laryngeal framework includes several cartilages, such as the thyroid cartilage, arytenoid cartilages, epiglottis, and cricoid cartilage, which collectively regulate vocal fold tension and positioning. Arytenoid cartilages adjust the degree of vocal fold movement, allowing variation in pitch and tone. The thyroid cartilage provides structural support, while the cricoid cartilage forms a stable connection between the larynx and trachea.

Resonance from surrounding throat and oral structures amplifies sound before it becomes audible speech. Proper function of the larynx is essential not only for communication but also for maintaining safe breathing and swallowing mechanisms (Allen p.174-204).

Functions as an Airway for Respiration

Air traveling from the nasal or oral cavities into the lungs passes through the larynx. Regulation of airflow occurs through changes in the size of the glottis, the opening between the vocal folds. During breathing, the glottis widens to allow oxygen to enter and carbon dioxide to exit efficiently. During speech, controlled narrowing of this space allows vibrations that produce sound (Wallace p.250).

Protective actions also occur here. The epiglottis acts as a valve that closes over the airway during swallowing, preventing food or liquids from entering the trachea (Osbeck NP). These combined roles make the larynx essential for respiration, communication, and airway safety.

Regulates Airflow to the Lungs

Airflow control within the larynx allows the respiratory system to adapt to varying physical demands. Expansion of the airway during activities such as exercise permits increased ventilation, while relaxation during rest allows steady breathing. Flexible vocal folds respond to airflow changes, supporting both respiration and speech production (Wallace p.250).

Filtering and protective mechanisms also operate here, helping reduce the entry of dust, smoke, or irritants into deeper respiratory structures. Through coordinated muscular adjustments, airflow remains balanced and efficient, contributing to overall respiratory stability.

Maintains Thoracic Pressure to Facilitate Breathing

Maintenance of thoracic pressure is another critical function supported by the larynx. Acting as a regulatory valve between upper and lower airways, this structure helps control airflow during inhalation and exhalation. Movement of the diaphragm during breathing changes thoracic pressure, and adjustments in laryngeal positioning assist in stabilizing these pressure variations (Allen p.174-204).

During inhalation, the airway opens to allow oxygen to enter the lungs as thoracic pressure decreases. During exhalation, subtle changes in vocal fold tension help regulate airflow leaving the lungs. These coordinated movements ensure efficient ventilation while also enabling speech production and airway protection.

The Trachea

Commonly referred to as the windpipe, the trachea is a cylindrical airway that plays a central role in respiration by conducting air from the nasal or oral cavities to the lungs. Positioned below the larynx, this tube-like structure extends several inches downward before dividing into the right and left primary bronchi, which direct airflow into their respective lungs (Reid p.1266-1274). Structural integrity is maintained through a series of C-shaped cartilaginous rings that prevent collapse while still allowing flexibility during breathing.

The inner lining of the trachea consists of smooth muscle and mucous membranes equipped with cilia. These microscopic hair-like projections move rhythmically to trap and remove dust, microorganisms, and other airborne particles. Mucus secreted by specialized cells moistens inhaled air and helps capture foreign material, ensuring that airflow remains clean and conditioned before reaching the delicate alveoli. Through these combined structural and protective mechanisms, the trachea maintains uninterrupted airflow while safeguarding the lower respiratory tract.

Health Issues Related to the Trachea

Like many respiratory structures, the trachea is vulnerable to environmental exposures and infectious conditions. Smoking remains one of the most significant causes of tracheal irritation and damage. Inhalation of tobacco smoke inflames the mucosal lining, reduces ciliary function, and can impair oxygen exchange efficiency. Chronic exposure may contribute to conditions such as chronic obstructive pulmonary disease (COPD), which restricts airflow and leads to symptoms including coughing, wheezing, and breathing difficulty.

Prolonged irritation may also lead to the development of noncancerous growths such as tracheal polyps, which can obstruct airflow and require medical evaluation or surgical intervention (Kiyokawa p.67-79). Additionally, smokers face an increased risk of malignant changes within airway tissues, emphasizing the importance of preventative care and early detection.

Fungal infections, including histoplasmosis, represent another potential health concern affecting the trachea. Symptoms may include persistent coughing, throat discomfort, fever, and difficulty breathing. In severe cases, infection can spread to other parts of the respiratory system, requiring prompt treatment with appropriate medications. Early medical attention and regular health monitoring remain essential to prevent complications and preserve respiratory function.

Adaptations of Trachea to its Functions

Several structural adaptations allow the trachea to perform its role efficiently. Measuring approximately 10 cm in length and supported by sixteen to twenty C-shaped cartilage rings, this airway maintains an open passage while permitting expansion and contraction during breathing. Smooth muscle fibers connecting these rings allow subtle changes in diameter, enabling adjustments in airflow according to the body's oxygen demands.

The tracheal lining contains ciliated epithelial cells and mucus-secreting goblet cells that work together to remove inhaled contaminants. Mucus traps particles, while coordinated ciliary movement sweeps debris upward toward the throat for elimination, reducing the risk of respiratory infection (Smeltz p.1902-1913). This system also prevents dehydration of airway tissues by maintaining adequate moisture levels.

Additional protective adaptations include the epiglottis, which prevents food from entering the airway during swallowing, and the flexible nature of the tracheal walls, which allows increased airflow during periods of heightened activity. The cartilage rings provide mechanical strength without sacrificing flexibility, ensuring that airflow remains stable even during changes in thoracic pressure.

Air passing through the trachea is warmed and humidified before reaching the lungs, creating optimal conditions for gas exchange. Similar protective features extend into the bronchi and bronchioles, where cilia and mucus continue filtering inhaled air. By combining structural support, filtration, and airflow regulation, the trachea serves as a vital conduit that maintains respiratory efficiency while

protecting the lungs from environmental threats (Reid p.1266-1274).

Bronchi and Subdivisions

Air passes from the trachea into the lungs through the bronchi, which serve as the primary conducting airways of the lower respiratory tract. These tubular structures are lined with ciliated epithelium and supported by smooth muscle and cartilage, allowing them to maintain structural integrity while facilitating airflow. The trachea divides into the right and left main bronchi, each entering its respective lung before branching into secondary (lobar) bronchi and then tertiary (segmental) bronchi that supply individual bronchopulmonary segments (Savelieva p.40). This branching network forms the bronchial tree, an intricate system that progressively decreases in diameter as it extends deeper into the lungs.

From the segmental bronchi, airways continue dividing into smaller bronchioles, which lack cartilage but retain smooth muscle capable of adjusting airway diameter. These bronchioles eventually lead to terminal bronchioles and alveolar ducts that connect to alveolar sacs, where gas exchange occurs. Throughout this pathway, coordinated contraction and relaxation of smooth muscle regulate airflow resistance, allowing the respiratory system to adapt to varying oxygen demands (Azmeera NP). Ciliated epithelial cells lining the airway walls move mucus upward toward the throat, assisting in debris removal and maintaining airway cleanliness.

Various conditions can affect the bronchi and their subdivisions. Inflammation caused by infections, allergens, or environmental irritants may result in bronchitis, characterized by coughing, mucus production, and breathing difficulty. Chronic conditions such as asthma or chronic obstructive pulmonary disease (COPD) narrow the airways, increasing resistance to airflow and causing symptoms including wheezing and shortness of breath (Fernández-Parra p.240). External factors such as air pollution, cigarette smoke, and chemical exposure may further compromise bronchial function, increasing susceptibility to respiratory complications.

The structural organization of the bronchial tree plays a critical role in regulating ventilation within the lungs. As airways become progressively smaller, airflow velocity changes, enabling efficient distribution of oxygen while trapping particulate matter before it reaches delicate alveolar tissue. Smooth muscle surrounding bronchioles responds to autonomic signals, constricting during exhalation or relaxing to allow greater airflow during inhalation. These adjustments help maintain stable breathing patterns during both rest and physical activity (Teramoto NP).

Specialized cells within the bronchi and bronchioles contribute to airway protection. Goblet cells secrete mucus that captures dust, pathogens, and other contaminants, while cilia propel this material upward in a coordinated movement known as the mucociliary escalator. This process transports trapped debris toward the throat, where it can be swallowed or expelled, preventing accumulation within the lungs (Saeki p.370). Immune cells present within the airway lining provide an additional defense by identifying and eliminating harmful particles that bypass initial filtration.

Beyond airflow regulation, the bronchial network assists in maintaining lung inflation and facilitating the removal of excess secretions. By directing air into progressively smaller passages, the bronchi ensures even distribution throughout pulmonary tissues. This branching design supports efficient ventilation while minimizing the risk of obstruction. When blockages occur, however, mucus clearance becomes impaired, leading to reduced airflow and potential respiratory distress.

Gas exchange ultimately occurs at the alveolar level, but the bronchi and their subdivisions remain essential for delivering conditioned air to these sites. As air moves through the bronchial tree, it is filtered, warmed, and humidified, preparing it for interaction with pulmonary capillaries (Schulze p.437). The coordinated activity of smooth muscle, cilia, and mucus production ensures that inhaled air reaches the alveoli in an optimal state for oxygen absorption and carbon dioxide removal.

A key defense mechanism operating within this region is the mucociliary escalator. Continuous rhythmic movement of cilia transports mucus and trapped particles away from the lungs, preserving airway patency and reducing infection risk. This system works continuously to maintain respiratory health by preventing accumulation of harmful substances within the bronchial passages (Teramoto

NP). Proper function of this mechanism is essential for sustaining clear airways and supporting efficient breathing throughout life.

Respiratory Zone

The respiratory zone represents the portion of the respiratory system where gas exchange occurs between inhaled air and circulating blood. This region includes respiratory bronchioles, alveolar ducts, and alveoli, which together form a highly specialized network designed for efficient oxygen uptake and carbon dioxide removal. Respiratory bronchioles arise from terminal bronchioles and mark the transition from conducting airways to structures capable of gas exchange. Their walls are lined with simple cuboidal epithelium and surrounded by smooth muscle that regulates airflow, ensuring proper distribution of air toward distal regions of the lungs (Zhang Chap.127).

Respiratory bronchioles play an important role in maintaining airway patency while supporting immune defense. Ciliated cells help move mucus and trapped particles away from delicate lung tissues, while specialized epithelial cells contribute to surfactant production, reducing surface tension and preventing collapse of nearby alveoli during exhalation (Jeong NP). Smooth muscle surrounding these airways adjusts airway diameter in response to physiological demands, increasing resistance when contracted and allowing expanded airflow when relaxed. These structural adaptations ensure that inhaled air reaches the alveoli efficiently while protecting against debris and microbial invasion.

Extending from respiratory bronchioles are alveolar ducts, narrow passageways that connect bronchioles to clusters of alveolar sacs. Their walls are extremely thin and composed largely of simple squamous epithelium, allowing rapid diffusion of gases. Although primarily designed for gas exchange, alveolar ducts also assist in regulating airflow and maintaining pressure gradients between larger airways and the terminal gas-exchanging units (Barbarino NP). Smooth muscle fibers encircle these ducts, enabling subtle adjustments in airway diameter that help stabilize airflow patterns and support efficient ventilation.

Cells within the alveolar ducts contribute to maintaining lung stability and moisture balance. Surfactant-producing cells reduce internal surface tension, preventing airway collapse while promoting easier expansion during inhalation. Mucosal structures and residual ciliary action assist in moving debris away from sensitive regions, helping maintain cleanliness within the distal airways. Adequate humidification within this region supports tissue integrity and reduces susceptibility to irritation or infection (Holtzman p.887-895).

At the terminal end of the respiratory zone lie the alveoli, microscopic air sacs that serve as the primary site of gas exchange. Each alveolus is surrounded by a dense network of capillaries, allowing oxygen to diffuse into the bloodstream while carbon dioxide exits for elimination during exhalation. The extremely thin walls of the alveoli, composed of simple squamous epithelial cells, minimize diffusion distance and maximize efficiency. This structural design supports rapid exchange of gases while maintaining stable pressure relationships between the lungs and the external environment (Jeong NP).

Alveoli also play a critical role in immune defense and respiratory stability. Alveolar macrophages patrol these spaces, identifying and removing pathogens, particulate matter, and cellular debris. Surfactant secreted by specialized cells reduces surface tension within the alveoli, preventing collapse and maintaining open airspaces essential for continuous gas exchange (Barbarino NP). This surfactant layer also contributes to lung elasticity, allowing the lungs to expand and recoil efficiently with each breath.

Two primary cell types line the alveolar surface and support respiratory function. Type I alveolar cells form a thin, flattened barrier that facilitates diffusion of oxygen and carbon dioxide across the alveolar membrane. Type II alveolar cells, characterized by their cuboidal shape, produce surfactants composed of phospholipids and proteins that stabilize alveolar walls and reduce the effort required for breathing (Fernández-Parra p.240). These cells also contribute to repair and regeneration of the alveolar lining following injury, maintaining structural integrity over time.

Terminal bronchioles, respiratory bronchioles, alveolar ducts, and alveoli function together to maintain optimal pressure gradients within the lungs. Negative pressure generated during inhalation draws air into these regions, while coordinated relaxation during

exhalation facilitates removal of carbon dioxide and other waste gases (Barbarino NP). This balance of airflow regulation, surfactant production, and immune protection ensures that the respiratory zone operates efficiently while safeguarding delicate lung tissue from environmental stressors.

Overall, the respiratory zone represents the most specialized portion of the pulmonary system. Its intricate architecture supports continuous gas exchange while maintaining structural stability, airway cleanliness, and immune defense. Without the coordinated function of respiratory bronchioles, alveolar ducts, and alveoli, the transfer of oxygen into circulation and removal of carbon dioxide would not be possible, underscoring the critical role of this region in sustaining life.

Health Issues Related to Respiratory Zone

The respiratory zone is vulnerable to a wide range of health conditions that vary in severity from mild irritation to life-threatening disease. Because this region contains the delicate structures responsible for gas exchange, inflammation or structural damage can significantly impair oxygen delivery and carbon dioxide removal. Common disorders affecting this area include asthma, chronic obstructive pulmonary disease (COPD), lung cancer, allergies, and environmentally induced respiratory irritation. Exposure to pollutants such as dust, smoke, and chemical particles may trigger symptoms including wheezing, sneezing, coughing, and difficulty breathing, particularly in individuals with pre-existing respiratory conditions (Jeong NP).

Asthma is characterized by airway inflammation, bronchospasm, and excess mucus production, which collectively narrow the airways and reduce airflow. Individuals with asthma often experience chest tightness, shortness of breath, and episodic wheezing. Management strategies typically involve medication therapies designed to control inflammation and improve airway dilation, combined with lifestyle modifications such as avoiding environmental triggers and maintaining consistent respiratory care routines. Preventative approaches focus on minimizing exposure to allergens or irritants that can provoke exacerbations.

Chronic obstructive pulmonary disease represents another major condition affecting the respiratory zone. COPD develops gradually as airway narrowing and destruction of lung tissue reduce respiratory efficiency. Patients commonly report persistent cough, mucus production, and progressive shortness of breath. Long-term management may involve pharmacological therapies, pulmonary rehabilitation, oxygen supplementation, and lifestyle changes such as smoking cessation. In advanced cases, surgical interventions may be considered to improve lung function or relieve symptoms.

Lung cancer is a serious disorder involving uncontrolled growth of abnormal cells within pulmonary tissue. Because the respiratory zone contains extensive alveolar structures, malignant changes in this area can significantly disrupt gas exchange. Symptoms may resemble other respiratory diseases, including persistent coughing, wheezing, fatigue, and breathing difficulty, which can delay early diagnosis. Medical evaluation often includes imaging techniques such as X-ray or computed tomography (CT) scans to detect abnormal growths (Holtzman p.887-895). Treatment options vary depending on disease stage and may include chemotherapy, radiation therapy, surgical removal of affected tissue, or immunotherapy.

Allergic reactions and environmental exposures can also affect the respiratory zone by triggering inflammatory responses within the airways. These reactions may lead to increased mucus production, airway sensitivity, and temporary impairment of breathing efficiency. Managing such conditions often requires reducing exposure to irritants alongside supportive therapies that promote airway stability.

Overall, maintaining respiratory health is essential for preserving the function of the respiratory zone. Early recognition of symptoms, combined with appropriate medical care and preventative lifestyle measures, can help reduce disease progression and protect the delicate structures responsible for gas exchange. Because this region plays a direct role in sustaining oxygen supply throughout the body, even minor disturbances can have widespread physiological effects, emphasizing the importance of respiratory awareness and proactive care.

Lung Gross Anatomy

The lungs are positioned within the thoracic cavity, protected by the ribs, sternum, and vertebral column. This cavity is divided into two pleural spaces, each containing a lung surrounded by a protective double-layered membrane known as the pleura. The visceral pleura adheres directly to the lung surface, while the parietal pleura lines the inner chest wall. Between these layers lies the pleural cavity, which contains a thin lubricating fluid that allows smooth lung movement during respiration and reduces friction against surrounding structures (Schulze p.437). Superiorly, each lung extends toward the apex, whereas the base rests on the diaphragm, a dome-shaped muscle that separates the thoracic and abdominal cavities and plays a central role in breathing mechanics.

Structurally, the right lung is larger and divided into three lobes: superior, middle, and inferior. The left lung contains two lobes to accommodate the cardiac notch, an indentation that allows space for the heart. Each lobe is separated by fissures that permit independent expansion during ventilation. Air enters the lungs through the main stem bronchi, which branch into lobar bronchi and subsequently into segmental bronchi that distribute airflow throughout pulmonary segments. These branches continue to divide into bronchioles that terminate in alveolar sacs, where gas exchange occurs between air and surrounding capillaries.

The lungs contain an extensive network of pulmonary arteries and veins that transport blood for oxygenation and carbon dioxide removal. Pulmonary arteries carry deoxygenated blood from the right ventricle to the lungs, while pulmonary veins return oxygenated blood to the left atrium of the heart. Lymphatic vessels and lymph nodes are also present, contributing to immune defense and fluid regulation within lung tissue. Supporting ligaments and connective tissues stabilize the lungs while allowing the flexibility necessary for expansion during inhalation.

Each lung occupies its own pleural cavity and is enveloped by muscles essential for ventilation. The intercostal muscles, located between the ribs, assist in elevating and lowering the rib cage during breathing. The diaphragm contracts and flattens during inhalation to increase thoracic volume, allowing air to enter the lungs, and relaxes during exhalation to facilitate air expulsion. Together, the pleural membranes, respiratory muscles, bronchi, and alveoli form an integrated system that supports effective gas exchange and respiratory movement.

The lungs present three major surfaces: anterior, lateral, and posterior. The anterior surface lies closest to the ribs and is often described as costal because it conforms to the curvature of the rib cage. This region is covered by pleura and is more susceptible to trauma due to its position. The lateral surface extends between the anterior and posterior aspects and contributes to the characteristic spongy structure of lung tissue. The posterior surface faces the vertebral column and is less accessible but remains vital for maintaining adequate blood flow and supporting normal gas exchange (Fernández-Parra p.240). All surfaces are lined with pleural membranes that provide protection and maintain proper positioning within the thoracic cavity.

The medial surface contains the hilum, an indentation through which primary bronchi, pulmonary vessels, nerves, and lymphatic structures enter and exit the lung. Within this region, bronchi branch into progressively smaller pathways that lead to bronchioles and alveoli. The hilum also accommodates pulmonary veins returning oxygenated blood to the heart and arteries delivering deoxygenated blood to be oxygenated within the lungs (Kiyokawa p.67-79). This arrangement allows efficient circulation and coordination between respiratory and cardiovascular systems.

The apex of each lung extends upward into the thoracic inlet, while the base rests securely on the diaphragm. The mediastinum, located centrally between the lungs, contains the heart and major vessels. Costal surfaces contact the rib cage laterally, contributing to lung shape and mechanical stability. Within each pulmonary lobe lies the bronchial tree, an intricate network responsible for directing airflow to regions of gas exchange. Alveoli, surrounded by dense capillary networks, allow oxygen diffusion into the bloodstream and removal of carbon dioxide during exhalation.

Segmental organization further distinguishes the right and left lungs. The left lung contains superior and inferior lobes separated by an oblique fissure, whereas the right lung contains superior, middle, and inferior lobes divided by oblique and horizontal fissures.

Each lobe is subdivided into bronchopulmonary segments supplied by tertiary bronchi. These segments allow localized ventilation and help isolate infection or damage within specific areas. The right lung generally demonstrates greater volume due to the absence of the cardiac notch, while the left lung accommodates cardiac positioning.

Efficient lung function depends on the coordinated action of bronchi, alveoli, pleura, respiratory muscles, and vascular structures. Oxygen entering the alveoli diffuses across thin epithelial walls into surrounding capillaries, while carbon dioxide moves in the opposite direction to be expelled from the body. The presence of pleural fluid, elastic connective tissues, and muscle-driven ventilation ensures that lungs expand and recoil smoothly with each breath.

Despite their resilience, lung tissues are susceptible to health complications including infection, inflammation, and obstruction. Bacterial, viral, or fungal pathogens can cause pneumonia or other respiratory infections, while allergies or irritants may trigger inflammation that restricts airflow. Tumors, mucus accumulation, or foreign objects can obstruct airways and interfere with gas exchange. Early recognition of respiratory symptoms and timely medical evaluation are essential for maintaining pulmonary health and preventing severe complications (Holtzman p.887-895).

Innervation - Blood Supply

Innervation and blood supply are fundamental components of respiratory physiology because they regulate breathing mechanics while delivering oxygen and nutrients necessary for tissue survival. Neural control of the respiratory organs is primarily mediated by the autonomic nervous system, whereas vascular structures ensure continuous circulation between the lungs and the heart. Together, these systems coordinate airflow regulation, gas exchange, and metabolic support for pulmonary tissues.

The autonomic nervous system governs lung function through parasympathetic and sympathetic pathways. Parasympathetic innervation is largely provided by the vagus nerve, which supplies nerve fibers to the airways, respiratory muscles, and alveolar structures. Signals transmitted through the vagus nerve influence airway tone, mucus secretion, and breathing rhythm by modulating smooth muscle activity. In contrast, sympathetic stimulation promotes bronchodilation by relaxing airway muscles, allowing greater airflow during increased metabolic demand. This balance between parasympathetic and sympathetic activity helps maintain stable oxygen levels and appropriate respiratory responses to environmental or physiological changes (Teramoto NP).

Respiratory tissues receive blood through both pulmonary and bronchial circulations. Pulmonary arteries transport deoxygenated blood from the right ventricle of the heart to the lungs, where it passes through extensive capillary networks surrounding the alveoli. Within these capillaries, carbon dioxide diffuses out of the blood while oxygen moves into circulation. Oxygenated blood then returns to the left atrium through the pulmonary veins, ensuring delivery of oxygen to systemic tissues (Kiyokawa p.67-79). This pulmonary circulation is essential for sustaining efficient gas exchange and maintaining internal homeostasis.

In addition to pulmonary circulation, bronchial arteries supply oxygenated blood directly to lung tissues, including the bronchi, connective tissues, and supporting structures. These vessels originate from the aorta and provide nutrients required for maintaining airway integrity. Bronchial veins and lymphatic vessels assist in fluid drainage and immune surveillance, removing waste products and preventing fluid accumulation within pulmonary tissue. The lymphatic system plays a complementary role by transporting lymph fluid to regional lymph nodes, where pathogens and debris are filtered to protect the respiratory system from infection.

Capillary networks within the alveolar walls facilitate the diffusion of gases while supporting metabolic activity of surrounding cells. Specialized nerve fibers embedded within vascular and airway structures help regulate airway diameter by influencing smooth muscle contraction. This neural-vascular interaction ensures that airflow is matched to the body's oxygen demands, particularly during physical activity or stress. Coordination between the brainstem and spinal cord further refines respiratory rhythm by integrating signals from chemoreceptors and mechanoreceptors that monitor oxygen, carbon dioxide, and pressure levels.

Bronchial arteries also contribute indirectly to respiratory regulation by supporting tissues involved in airway innervation. Adequate blood flow maintains nerve function, allowing signals that adjust breathing rate, depth, and airway resistance. Without proper

vascular supply, pulmonary tissues would be unable to sustain the energy requirements needed for gas exchange or immune defense. The tracheal arteries and surrounding vascular networks provide additional support by nourishing airway walls and maintaining mucosal health, ensuring that airflow remains unobstructed.

Autonomic nerve activity plays a central role in maintaining airway stability. Sympathetic activation leads to bronchodilation, increasing airflow during exercise or stress, whereas parasympathetic stimulation promotes bronchoconstriction and mucus secretion during rest or protective responses. These neural mechanisms work alongside pulmonary circulation to preserve efficient ventilation and prevent excessive carbon dioxide buildup within the body. Pulmonary circulation continually moves blood between the heart and lungs, ensuring that oxygen uptake and carbon dioxide removal occur with each breath cycle.

Disruptions in innervation or blood supply can significantly affect respiratory health. Reduced nerve stimulation or impaired vascular flow may decrease lung capacity and contribute to symptoms such as fatigue, shortness of breath, or reduced exercise tolerance. Insufficient oxygen delivery to respiratory tissues can increase susceptibility to infection, leading to coughing, chest discomfort, or fever. In severe cases, compromised neural or vascular function may elevate the risk of respiratory failure or chronic lung disorders characterized by wheezing, persistent coughing, and impaired breathing efficiency (Holtzman p.887-895).

Maintaining proper innervation and blood circulation is therefore essential for sustaining normal respiratory performance. Through the coordinated interaction of autonomic nerves, pulmonary vessels, bronchial arteries, and lymphatic structures, the respiratory system achieves precise regulation of airflow, oxygen transport, and immune protection. This integrated network ensures that lung tissues receive the nutrients and neural signals required to support continuous breathing and overall physiological stability.

The Pleura

Two delicate pleural membranes surround the lungs and separate them from the chest wall, forming an essential component of respiratory anatomy. The outer layer, known as the parietal pleura, is a thin serous membrane that lines the inner surface of the thoracic cavity, including the ribs and diaphragm. The inner layer, called the visceral pleura, closely adheres to the surface of the lungs and follows their contours during expansion and recoil. Between these layers lies the pleural cavity, which contains a small amount of lubricating serous fluid that allows the membranes to glide smoothly against one another during breathing.

This lubricated interface reduces friction as the lungs move within the thoracic cavity, enabling efficient inspiration and expiration (Schulze p.437). The pleurae also help maintain lung inflation by creating a slight negative pressure within the pleural space, preventing lung collapse during exhalation. In addition to their mechanical role, these membranes contribute to immune defense by forming a protective barrier that limits the spread of infectious agents toward delicate pulmonary tissues.

The pleural layers function together to stabilize the lungs and coordinate their movement with the chest wall. During inhalation, expansion of the thoracic cavity lowers intrapleural pressure, allowing the lungs to expand. During exhalation, the cavity recoils, helping regulate lung volume and preventing overinflation. The thin film of serous fluid between the pleural layers not only reduces mechanical resistance but also absorbs minor impacts, acting as a shock-absorbing mechanism that protects the lungs from trauma and excessive movement (Teramoto NP; Kiyokawa p.67-79). By anchoring the lungs to the thoracic structures while allowing flexible motion, the pleurae ensure stable respiratory mechanics and continuous airflow.

Important Pressures

Several pressures work together to regulate airflow and maintain efficient gas exchange within the respiratory system. Among the most significant is atmospheric pressure (P_{atm}), the external pressure exerted by the surrounding air, averaging approximately 760 mmHg at sea level. Atmospheric pressure plays a fundamental role in keeping the lungs expanded and allowing air to move into the respiratory tract. Adequate air density, influenced by atmospheric pressure, ensures that sufficient oxygen is available for delivery to tissues. Changes in this pressure affect the alveoli and bronchi by influencing lung expansion and airway patency, thereby supporting

effective ventilation.

Intrapulmonary pressure (Palv) refers to the pressure within the alveoli. During inhalation, expansion of the lungs decreases intrapulmonary pressure below atmospheric levels, creating a gradient that draws air inward. During exhalation, the pressure rises above atmospheric levels, pushing air out of the lungs. Proper regulation of intrapulmonary pressure is essential for maintaining balanced airflow and preventing conditions such as airway obstruction or uneven lung inflation. Abnormal pressure changes may contribute to respiratory disorders including asthma, bronchitis, or chronic obstructive pulmonary disease (COPD), while excessive pressure imbalance can lead to alveolar collapse, known as atelectasis. Pressure gradients between alveoli and surrounding capillaries also facilitate gas diffusion, allowing oxygen to enter the bloodstream and carbon dioxide to exit.

Another critical component is intrapleural pressure (Pip), the pressure within the pleural cavity. This pressure is normally slightly negative relative to atmospheric pressure, helping keep the lungs expanded against the chest wall. During inhalation, contraction of the diaphragm and expansion of the thoracic cavity further decrease intrapleural pressure, drawing air into the lungs. During exhalation, relaxation of respiratory muscles allows intrapleural pressure to rise, aiding in air expulsion. Maintaining appropriate intrapleural pressure prevents lung collapse and ensures smooth respiratory mechanics. If this pressure balance is disrupted, conditions such as pneumothorax may occur, in which air enters the pleural space and compromises lung expansion.

Together, atmospheric, intrapulmonary, and intrapleural pressures create the gradients necessary for airflow and gas exchange. Continuous adjustments in these pressures maintain alveolar inflation, support efficient oxygen diffusion, and preserve respiratory stability. Their coordinated regulation ensures that breathing remains a dynamic yet balanced process essential for sustaining life.

Conclusion

In summary, the respiratory system is a fundamental component of human physiology, responsible for delivering oxygen to the body and removing carbon dioxide to sustain life. Proper respiratory function supports survival by maintaining efficient gas exchange, stabilizing blood pH levels, influencing heart rate, and contributing to immune defense. This system operates through the coordinated function of multiple organs and tissues, including the nasal and oral cavities, pharynx, larynx, trachea, bronchi, bronchioles, lungs, and alveoli. Air typically enters through the nasal or oral passages, where it is filtered, warmed, and humidified before moving through the pharynx and larynx. The trachea conducts airflow into the bronchi, which branch extensively within the lungs and ultimately deliver air to the alveoli, where oxygen and carbon dioxide exchange occurs during external respiration.

The respiratory process begins with inhalation, followed by the passage of air through progressively smaller airways until it reaches the alveolar sacs. At this level, oxygen diffuses into surrounding capillaries and is transported throughout the body to support cellular metabolism, while carbon dioxide produced by tissues returns to the lungs for removal during exhalation. The diaphragm and intercostal muscles regulate pressure changes that enable airflow, ensuring that the lungs expand and recoil efficiently. Respiration not only facilitates gas exchange but also contributes to maintaining acid-base balance, regulating temperature through airflow, and supporting metabolic processes that require oxygen for energy production.

Innervation and blood supply remain essential for sustaining respiratory activity. Pulmonary arteries deliver deoxygenated blood to the lungs for oxygenation, while pulmonary veins return oxygen-rich blood to the heart. Bronchial arteries provide nutrients to lung tissues, and neural control through autonomic pathways regulates breathing rate, airway diameter, and respiratory muscle activity. Disruptions in these systems may lead to reduced lung function, increased infection risk, or respiratory failure, highlighting the importance of coordinated vascular and neural support within pulmonary structures.

Pressure dynamics also play a central role in respiratory mechanics. Atmospheric pressure allows air to enter the lungs, intrapulmonary pressure drives airflow during inhalation and exhalation, and intrapleural pressure maintains lung expansion by creating a negative pressure gradient within the pleural cavity. These pressure relationships ensure continuous ventilation and efficient gas diffusion at the alveolar level. When these pressure balances are disrupted, lung function may be compromised, emphasizing the importance of

maintaining proper respiratory mechanics.

Understanding the anatomy and physiology of the respiratory system is essential for accurately identifying and managing respiratory disorders. Comprehensive knowledge of airway structure, gas exchange mechanisms, vascular supply, and neural regulation allows healthcare professionals to recognize dysfunction early and develop effective treatment strategies. Ultimately, respiration remains a continuous and vital process that sustains cellular activity, preserves physiological balance, and supports overall health throughout life.

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