Anatomy and Physiology: The Respiratory System

CHAPTER 1

The respiratory system is a complex and vital component of the human body responsible for the exchange of gases between the external environment and our internal environment. The respiratory system plays a crucial role in maintaining the body's homeostasis by ensuring an adequate supply of oxygen to cells and removing waste carbon dioxide.

It is essential to understand the fundamentals to assess and care for patients with respiratory conditions effectively. This chapter explores the anatomy and physiology of the respiratory system, providing readers with a foundational understanding of its structure and function. In the following chapters, respiratory assessments, common disorders and interventions to provide comprehensive, holistic, respiratory care are outlined.

Cells can only survive if they receive a continuous supply of oxygen. As cells use oxygen, a waste gas, carbon dioxide, is produced. If this gas is allowed to build up, carbon dioxide can disrupt cellular activity and interrupt homeostasis. The key function of the respiratory system, therefore, is to ensure that the body extracts sufficient oxygen from the atmosphere and disposes of the excess carbon dioxide. The collection of oxygen and removal of carbon dioxide is known as respiration. Respiration involves the following four distinct processes:

1. Pulmonary ventilation
2. External respiration
3. Transport of gases
4. Internal respiration

All four are examined in this chapter; only pulmonary ventilation and external respiration are the sole responsibility of the respiratory system. As oxygen and carbon dioxide are transported around the body in blood, effective respiration is also reliant upon a fully functioning cardiovascular system.

THE RESPIRATORY SYSTEM

The respiratory system is separated into the upper and lower respiratory tract (see Figure 1.1). Those structures found below the larynx are part of the lower respiratory tract. The respiratory system can also be said to be divided into conduction and respiratory regions. The upper respiratory tract and the uppermost section of the lower respiratory tract form the conduction region, where air is conducted through a series of tubes and vessels. The respiratory region is the functional part of the lungs, where the oxygen diffuses into blood. The structures within the respiratory region are microscopic, they are very fragile and easily damaged by infection. For this reason, the upper and lower respiratory tracts are fashioned in such a way as to fight off any invading airborne bacterial or viral pathogens.

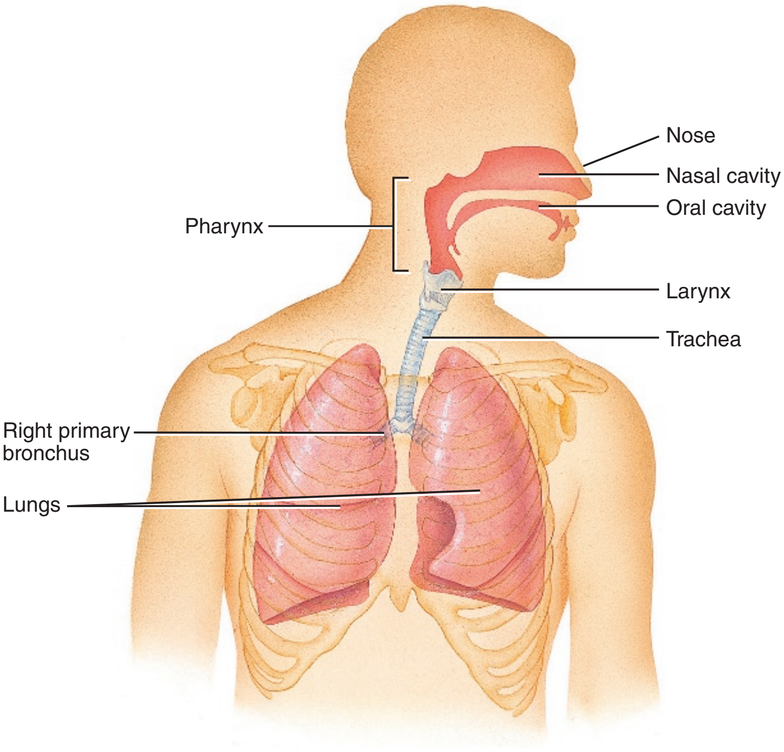

FIGURE 1.1 The upper and lower respiratory system

THE UPPER RESPIRATORY TRACT

Air enters the body via the nasal and oral cavities. The nasal cavity is divided into two equal sections, separated by the nasal septum, which is a structure formed out of the ethmoid bones and the vomer of the skull. The space where air enters the nasal cavity just inside the nostrils is called the vestibule. Beyond each vestibule, the nasal cavities are subdivided into three air passageways, the meatuses, these are three shelf-like projections called the superior, middle and inferior nasal conchae (see Figure 1.2). The region around the superior conchae and upper septum contains olfactory receptors, which are responsible for the sense of smell. The pharynx connects the nasal and oral cavity with the larynx. The pharynx is divided into three regions called the nasopharynx, the oropharynx and the laryngopharynx. The nasopharynx is located behind the nasal cavity and contains two openings that lead to the auditory (eustachian) tubes. The oropharynx and laryngopharynx are found underneath the nasopharynx and behind the oral cavity. The oropharynx and oral cavity are divided by the fauces. Both the oropharynx and the laryngopharynx are passageways for food and drink and also air. To protect these structures from abrasion by food particles and to prevent moisture loss, they are lined with non-keratinised stratified squamous epithelium.

As well as providing the sense of smell, another function of the upper respiratory tract is to ensure that air entering the lower respiratory tract is warm, damp and clean. The vestibule is lined with coarse hairs (cilia) that filter incoming air, ensuring large dust particles do not enter the airways. The conchae are lined with a mucous membrane made of pseudostratified ciliated columnar epithelium, which contains a network of capillaries and a plentiful supply of mucus-secreting

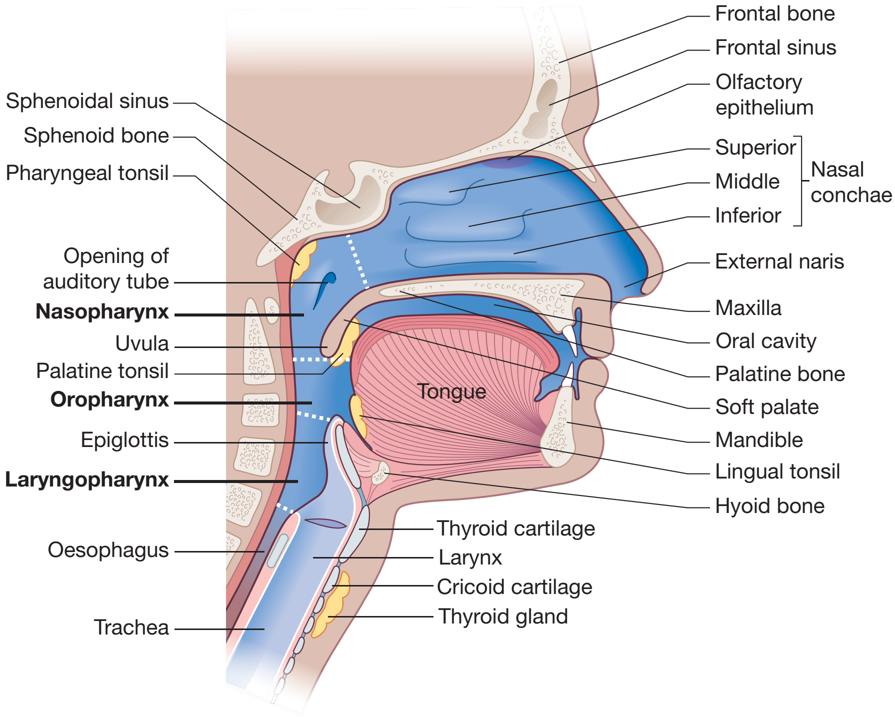

FIGURE 1.2 Structures of the upper respiratory system

goblet cells. The blood flowing through the capillaries warms the passing air, while the mucus moistens it and traps any passing dust particles. The mucus-covered dust particles are propelled by the cilia towards the pharynx, where they are swallowed or expectorated.

To provide further protection, the upper respiratory tract is lined with irritant receptors. When they are stimulated by invading particles (for example, dust or pollen), they force a sneeze, ensuring the offending material is ejected through the nose or mouth. The pharynx contains five tonsils. The two tonsils visible when the mouth is open are the palatine tonsils; located behind the tongue are the lingual tonsils and the pharyngeal tonsil or adenoid sits on the upper back wall of the pharynx. Tonsils are lymph nodules and part of the body's defence system. The epithelial lining of their surface has deep folds, known as crypts. Inhaled bacteria or particles become entangled within the crypts, and they are then engulfed and destroyed.

THE LOWER RESPIRATORY TRACT

This aspect of the respiratory tract includes the larynx, the trachea, the right and left primary bronchi and all the constituents of both lungs (see Figure 1.3). The lungs are two cone-shaped organs almost filling the thorax. They are protected by a framework of bones, the thoracic cage, which consists of the ribs, sternum (breastbone) and vertebrae (spine). The tip of each lung, the apex, extends just above the clavicle (collarbone) and their wider bases sit just above a concave muscle known as the diaphragm. The larynx (voice box) connects the trachea and the laryngopharynx. The remainder of the lower respiratory tract divides into branches of airways. For this reason, the structure of the lower respiratory tract is often referred to as the bronchial tree.

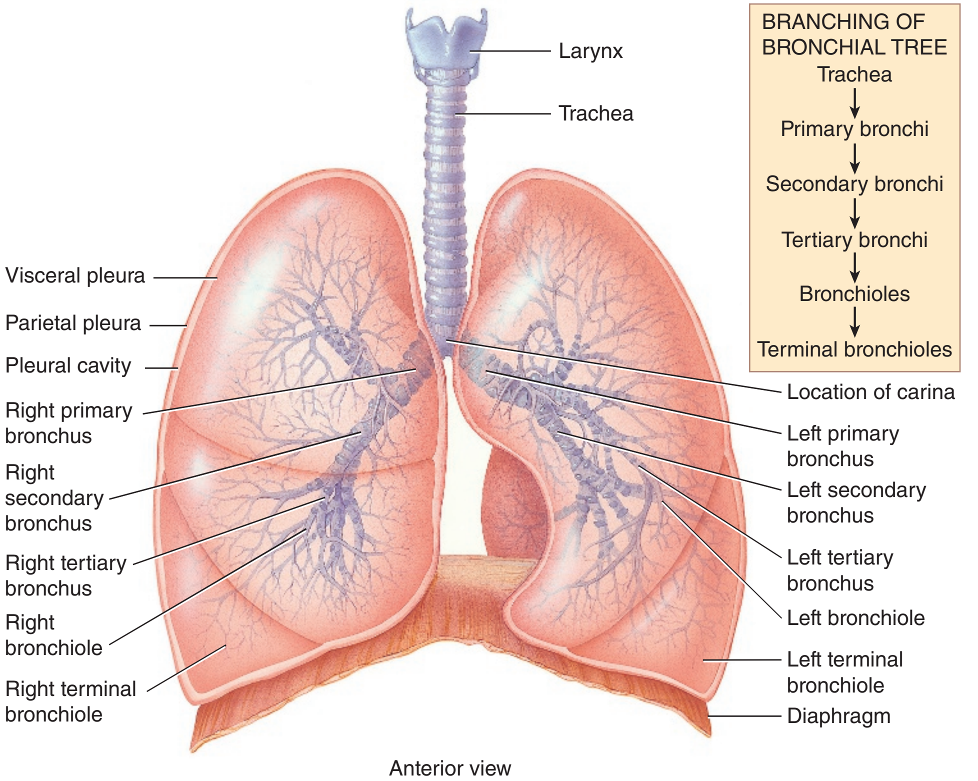

FIGURE 1.3 The lower respiratory tract

LARYNX

This is made up of nine pieces of cartilage tissue: three single pieces and three pairs (see Figure 1.4). The single pieces of cartilage are the thyroid cartilage, the epiglottis and the cricoid cartilage. The thyroid cartilage is more commonly known as the Adam's apple and, together with the cricoid cartilage, protects the vocal cords. The cricothyroid ligament, connecting the thyroid and cricoid cartilage, is the landmark of an emergency airway or tracheostomy (Wheeldon 2020). The epiglottis is a leaf-shaped piece of elastic cartilage attached to the top of the larynx. It protects the airway from food and liquids entering. On swallowing, the epiglottis blocks entry to the larynx and food and liquids are diverted towards the nearby oesophagus. If foreign substances are inhaled, they can block the lower respiratory tract and cut off the body's supply of oxygen. This is a medical emergency known as aspiration and requires the swift removal of the offending substance.

The three pairs of cartilage are the arytenoid, cuneiform and corniculate cartilages (see Figure 1.4). The arytenoid cartilages are the most significant as they influence the movement of the mucous membranes (true vocal folds) that generate the voice. Speaking is, therefore, reliant upon a fully functioning respiratory system. Many obstructive lung disorders, for example, asthma, reduce a person's ability to utter a full sentence without having to draw a new breath (Wheatley 2018).

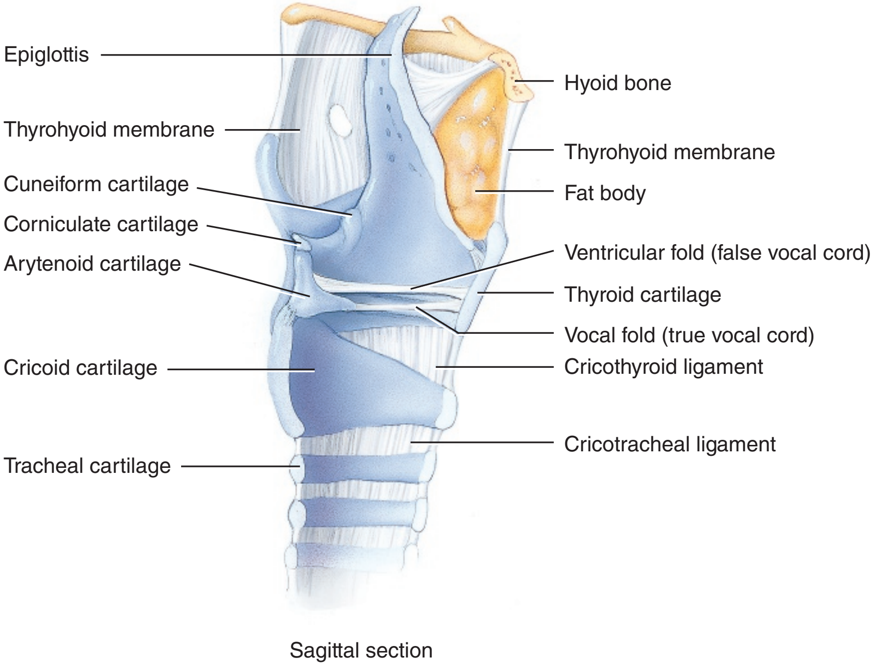

FIGURE 1.4 The larynx

THE TRACHEA

The trachea (or windpipe) is a tubular vessel. It carries air from the larynx down towards the lungs. The trachea is lined with pseudostratified ciliated columnar epithelium, ensuring that any inhaled debris is trapped and propelled upwards towards the oesophagus and pharynx where it is swallowed or expectorated. The trachea and the bronchi also contain irritant receptors, which stimulate a cough, forcing larger invading particles upwards. The outermost layer of the trachea is made up of connective tissue, reinforced by a series of 16–20 C-shaped cartilage rings. These rings stop the trachea from collapsing during an active breathing cycle.

THE LUNGS

The lungs are divided into distinct regions called lobes. There are three lobes in the right lung and two in the left. The heart, along with its major blood vessels, occupies a space between the two lungs called the mediastinum. The lungs are surrounded by two thin protective membranes called the parietal and visceral pleura (see Figure 1.3). The parietal pleura lines the wall of the thorax and the visceral pleura lines the lungs themselves. The space between the two pleurae is the pleural space or cavity, which is tiny and contains a thin film of lubricating fluid. This reduces friction between the two pleurae, allowing the two layers to slide over one another during breathing. The fluid also helps the visceral and parietal pleura to adhere to each other, in the same way, two pieces of glass stick together when they are wet. However, if any substance enters the pleural space, the parietal and visceral pleura may separate, which causes the lung to collapse. Substances that may enter the pleural cavity include blood, fluid, and in most cases, air. A collection of air in the pleural cavity is called pneumothorax (or collapsed lung). Blood in the pleural cavity is referred to as a haemothorax and fluid collecting between the pleura is called a pleural effusion.

BRONCHIAL TREE

In the lungs, the primary bronchi divide into the secondary bronchi, each serving a lobe. The secondary bronchi are split into tertiary bronchi (see Figures 1.5 and 1.6), there are 10 in each lung. Tertiary bronchi continue to divide into a network of bronchioles, eventually

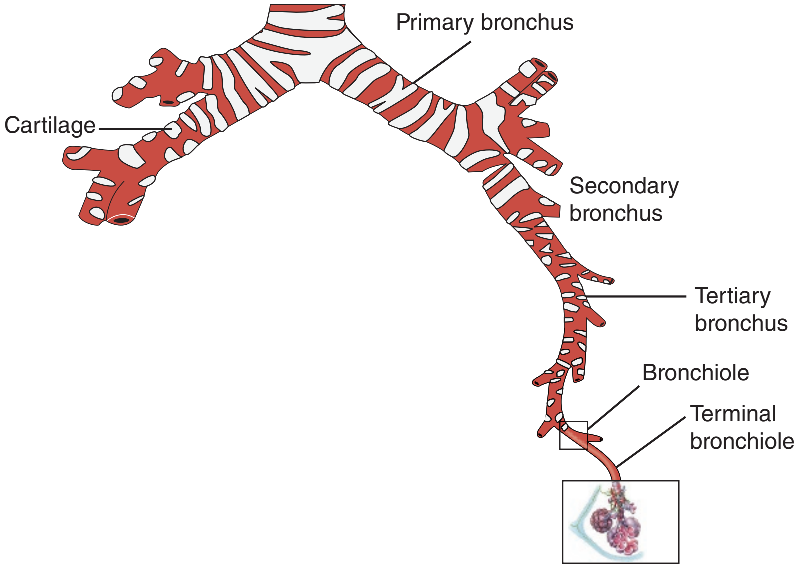

FIGURE 1.5 The bronchial tree and terminal bronchi

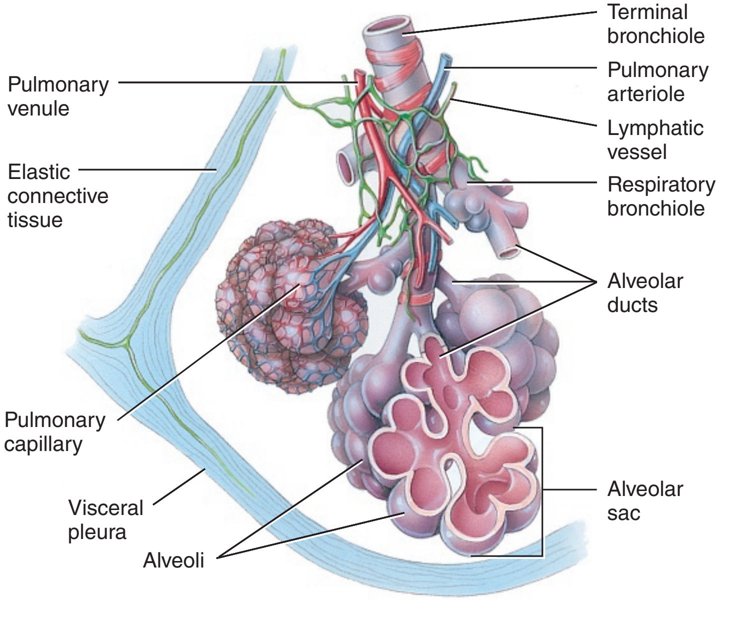

FIGURE 1.6 The bronchial tree and alveoli

leading to a terminal bronchiole. The section of the lung supplied by a terminal bronchiole is referred to as a lobule. Each lobule has its own arterial blood supply and lymph vessels. The bronchial tree continues to subdivide, with the terminal bronchiole leading to a series of respiratory bronchioles, which in turn create several alveolar ducts. The airways terminate with numerous sphere-like structures known as alveoli, which are clustered together to form alveolar sacs (see Figure 1.6). The transfer of oxygen from air to blood only occurs from the respiratory bronchioles onwards. The airways found between the trachea and the respiratory bronchioles form the conduction region of the lungs. The airways found beyond the respiratory bronchioles constitute the functional respiratory region of the lungs. This region accounts for two-thirds of the lungs' surface area (Tortora and Derrickson 2017).

BLOOD SUPPLY

The conduction and respiratory regions of the lungs receive blood from different arteries. Deoxygenated blood is delivered to the lobules via capillaries originating from the right and left pulmonary arteries. Once re-oxygenated, blood is returned to the left-hand side of the heart via one of four pulmonary veins, ready to be ejected into the systemic circulation (see Figure 1.7). The conduction region of the lungs receives oxygenated blood from capillaries that stem from the bronchial arteries, originating from the aorta. Some of the bronchial arteries are connected to the pulmonary arteries, but most blood returns to the heart via the pulmonary or bronchial veins.

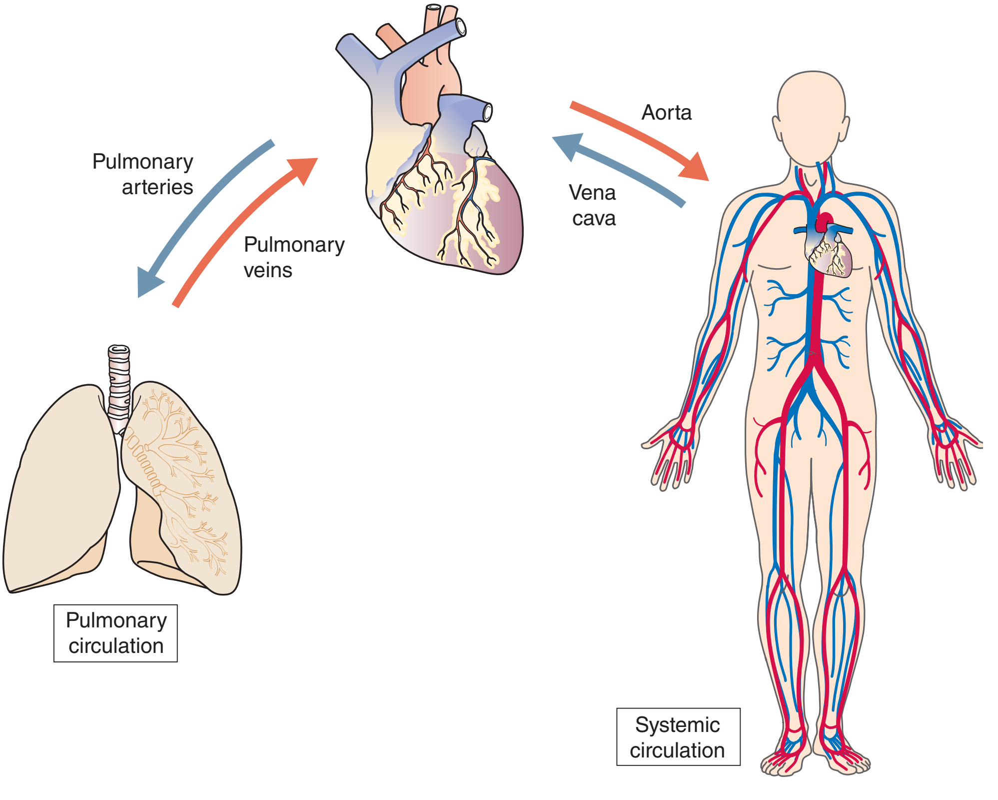

FIGURE 1.7 The flow of blood between the lungs, the heart and the body

RESPIRATION

The process by which oxygen and carbon dioxide are exchanged between the atmosphere and body cells is called respiration. Respiration follows the following four distinct phases (Wheeldon 2020):

1. Pulmonary ventilation: how air gets in and out of the lungs.
2. External respiration: how oxygen diffuses from the lungs to the bloodstream and how carbon dioxide diffuses from blood and to the lungs.
3. Transport of gases: how oxygen and carbon dioxide are transported between the lungs and body tissues.
4. Internal respiration: how oxygen is delivered to and carbon dioxide collected from body cells.

The understanding of all four processes is reliant upon the appreciation of a series of gas laws, see Thomas and Randhawa (2023) and Wheeldon (2020).

PULMONARY VENTILATION

THE MECHANICS OF BREATHING

Pulmonary ventilation describes the process of breathing, which involves the movement of air to pass in and out of the lungs. A change in pressure is required; during inspiration, the intrapulmonary pressure, the pressure within the lungs, is the same as atmospheric pressure. During inspiration, the thorax expands, and the intrapulmonary pressure falls below atmospheric pressure. Because intrapulmonary pressure is now less than atmospheric pressure, the air will naturally enter the lungs until the pressure difference no longer exists. This phenomenon is explained by Boyle's law and Dalton's law.

There are a range of respiratory muscles that are used in achieving thoracic expansion during inspiration (see Figure 1.8). The major muscles of inspiration are the diaphragm and external intercostal muscles. The diaphragm is a dome-shaped skeletal muscle found beneath the lungs at the base of the thorax. There are 11 external intercostal muscles, which sit in the intercostal spaces – the spaces between the ribs. During inspiration, the diaphragm contracts downwards, pulling the lungs with it. Simultaneously, the external intercostal muscles pull the rib cage outwards and upwards. The thorax is now bigger than before, and intrapulmonary pressure is reduced below atmospheric pressure as a result. The most important muscle of inspiration is the diaphragm; 75% of the air that enters the lungs is as a result of diaphragmatic contraction. Expiration is a more passive process. The external intercostal muscles and the diaphragm relax, allowing the natural elastic recoil of the lung tissue to spring back into shape, forcing air back into the atmosphere (see Figure 1.8).

Other respiratory muscles can also be used. The abdominal wall muscles and internal intercostal muscles are used to force air out beyond a normal breath, such as when playing a musical instrument or blowing out a candle. The sternocleidomastoids, the scalenes and the pectoralis can also be used to produce a deep, forceful inspiration. These are referred to as accessory muscles, as they are rarely used in normal, quiet breathing (Rolfe 2019).

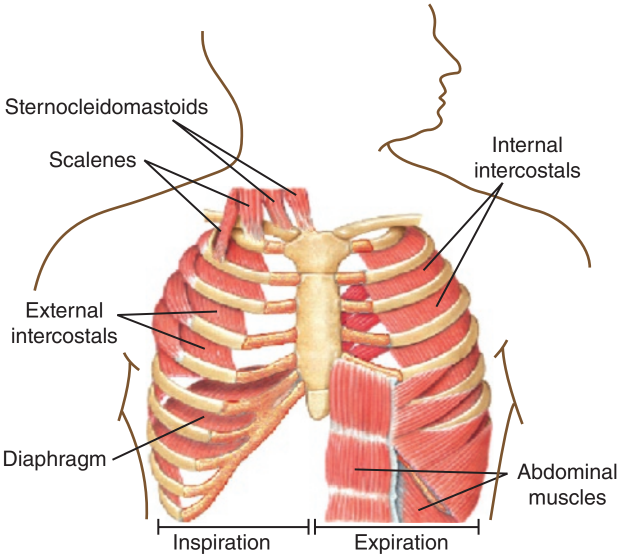

FIGURE 1.8 Muscles involved in pulmonary ventilation

WORK OF BREATHING

During inspiration, respiratory muscles have to overcome various factors that hinder thoracic expansion. The natural elastic recoil of lung tissue, the resistance to airflow through narrow airways and the surface tension forces at the liquid–air interface in the lobule all oppose thoracic expansion. The energy required by the respiratory muscles to overcome the hindering forces is referred to as the work of breathing. The amount of energy expended is kept to a minimum by the ease with which lungs can be stretched (lung compliance). Because of lung compliance, an inhalation of around 500 mL of air is achievable without any noticeable effort. Blowing a similar amount of air into a balloon would take a much greater effort. Lung compliance is aided by a detergent-like substance called surfactant. Whenever a liquid and gas come into close contact with one another, surface tension is generated. Surfactant reduces surface tension occurring where the alveoli meet pulmonary capillary blood flow in the lobule, reducing the amount of energy required to inflate the alveoli.

Work of breathing is also required to overcome airway resistance. As air flows through the bronchial tree, resistance to airflow occurs as the gas molecules begin to collide with one another in the increasingly narrow airways. Despite these opposing forces, the work of breathing accounts for less than 5% of total body energy expenditure. Many lung diseases can affect lung compliance and airway resistance, increasing the work of breathing.

VOLUMES AND CAPACITIES

Lung volumes and capacities measure or estimate the amount of air passing in and out of the lungs. Everyone has a total lung capacity (TLC), which is the total amount of air their lungs are capable of housing. Everyone's TLC will be dependent upon age, sex and height. TLC can be subdivided into a range of potential or actual volumes of air. For example, the amount of air that passes in and out of the lungs during one breath is called the tidal volume V_T. After a normal, quiet breath, the lungs will still have room for a deeper inspiration that could fill the lungs. This potential capacity for inspiration is referred to as inspiratory reserve volume (IRV). Likewise, after a normal, quiet breath, there remains the potential for a larger exhalation. This potential capacity of exhalation is referred to as expiratory reserve volume (ERV). If tidal volume increases, due to exercise, for example, IRV and ERV would be reduced. Tidal volume, IRV and ERV can all be measured. However, because a small volume of air always remains in the lungs, even after maximal exhalation, TLC can only be estimated. This small volume of remaining air is called residual volume (RV). Because RV cannot be exhaled, the total amount of air that could possibly pass in and out of an individual's lungs is a combination of tidal volume, IRV and ERV, which collectively is referred to as vital capacity (Wheeldon 2020).

Other important measures of lung volume include minute volume V_E, alveolar minute ventilation V_A and anatomical dead space V_D. Minute volume V_E is the amount of air breathed in each minute and is calculated by multiplying tidal volume V_T by respiration rate. In healthy individuals, the minute volume is around 6–8 mL/min. However, only the air that travels beyond the terminal bronchioles is engaged in gaseous exchange. For this reason, the air present in the rest of the lungs is referred to as anatomical dead space V_D. Therefore, in order to ascertain exactly how much air is available for gaseous exchange, anatomical dead space has to be accounted for. Alveolar minute ventilation V_A is calculated by subtracting anatomical dead space from minute ventilation. In healthy individuals, this value is approximately 4–6 mL/min.

CONTROL OF BREATHING

The rate and depth of breathing are controlled by the respiratory centres, located in the brainstem, within the areas called the medulla oblongata and pons (see Figure 1.9). The rate of breathing is determined by the inspiratory centre of the medulla oblongata. The expiratory

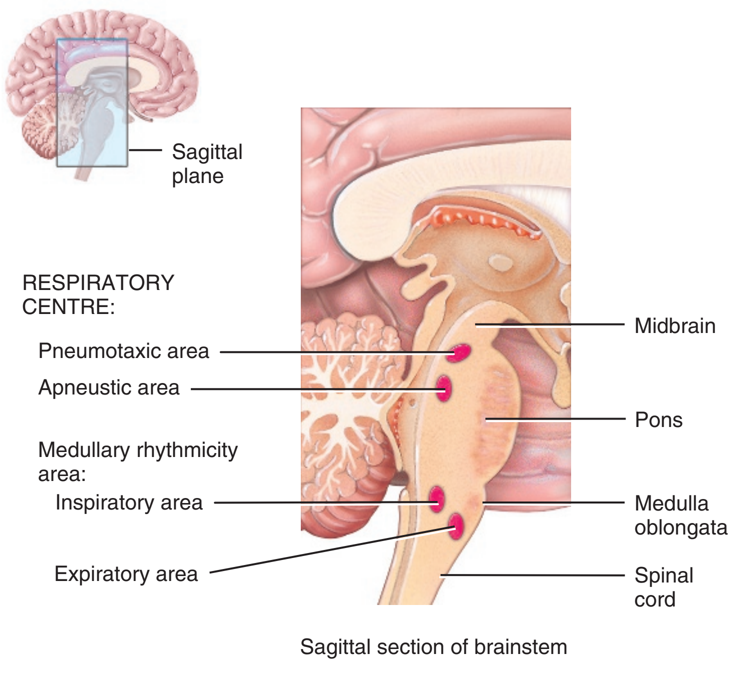

FIGURE 1.9 Respiratory centres of the brain stem

centre is thought to play a role in forced expiration. Also, within the medulla oblongata are specialised chemoreceptors continually analysing carbon dioxide levels within the cerebrospinal fluid. As levels of carbon dioxide rise, messages are sent via the phrenic and intercostal nerves to the diaphragm and intercostal muscles instructing them to contract more frequently and harder, thus increasing respiratory rate and depth. Another set of chemoreceptors located in the aorta and carotid arteries analyse levels of oxygen as well as carbon dioxide. If oxygen falls or carbon dioxide rises, messages are sent to the respiratory centres via the glossopharyngeal and vagus nerves, stimulating further contraction to produce faster, deeper breathing. An increase in carbon dioxide levels has a more powerful effect on respiratory rates than a reduction in oxygen levels.

Breathing is refined by the actions of the pneumotaxic and apneustic centres of the pons. The pneumotaxic centre sends inhibitory signals to the medulla to slow breathing down, while the apneustic centre stimulates the inspiratory centres, lengthening inspiration. Both actions fine-tune breathing, preventing the lungs from becoming overinflated. Respiration rate changes in order to meet the body's oxygen needs.

EXTERNAL RESPIRATION

GASEOUS EXCHANGE

External respiration only occurs beyond the respiratory bronchioles. External respiration is the diffusion of oxygen from the alveoli into pulmonary circulation and the diffusion of carbon dioxide in the opposite direction. Diffusion occurs because gas molecules always move from areas of high concentration to low concentration. Each lobule of the lung has its own arterial blood supply; this blood supply originates from the pulmonary artery, which stems from the right ventricle of the heart. The blood present in the pulmonary artery has been collected from systemic circulation and therefore is low in oxygen and relatively high in carbon dioxide. The amount (and therefore pressure) of oxygen in the alveoli is far greater than in the passing arterial blood supply. Oxygen, therefore, moves passively out of the alveoli and into pulmonary circulation and towards the left-hand side of the heart. As there is less carbon dioxide in the alveoli than in pulmonary circulation, carbon dioxide transfers into the alveoli ready to be exhaled (see Figure 1.10).

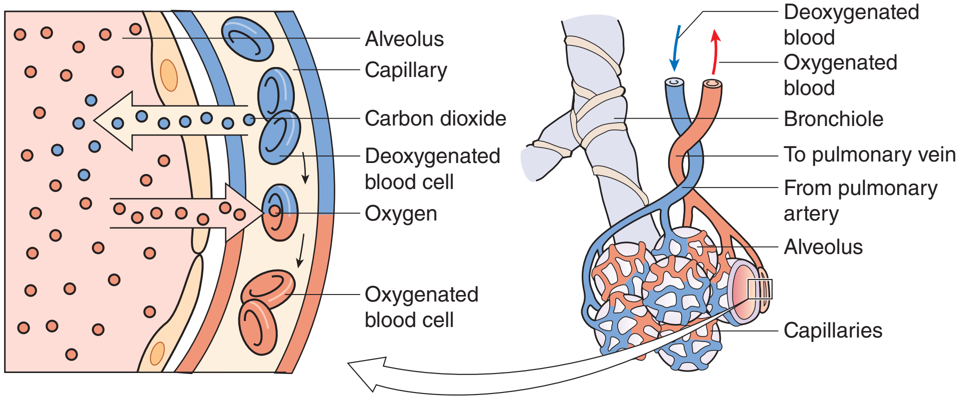

FIGURE 1.10 External respiration: exchange of oxygen and carbon dioxide within the lungs

Table 1.1 Factors influencing diffusion

Factor	Discussion
Surface area	The greater the surface area available for gas exchange, the more efficient diffusion becomes. In the lungs, the millions of alveoli provide a vast surface area for oxygen and carbon dioxide exchange with the blood.
Concentration gradient	Diffusion occurs from areas of higher concentration to areas of lower concentration. In the lungs, oxygen diffuses from the alveoli (where it is in higher concentration) into the bloodstream (where it is in lower concentration), while carbon dioxide diffuses in the opposite direction.
Membrane thickness	The thinner the barrier through which gases must diffuse, the more efficient the process. The respiratory membrane in the lungs, consisting of alveolar and capillary walls, is extremely thin to facilitate quick gas exchange.

FACTORS INFLUENCING DIFFUSION

Efficient gas diffusion in the lung depends on a large surface area, a steep concentration gradient and a thin membrane barrier between the air in the alveoli and the blood in the capillaries. These factors ensure that oxygen is taken up by the bloodstream while carbon dioxide is removed efficiently (see Table 1.1).

VENTILATION AND PERFUSION

Ventilation (V) and perfusion (Q) are two essential processes in the lungs that are crucial for effective gas exchange.

Ventilation refers to the movement of air in and out of the lungs during breathing. When inhaling, fresh air rich in oxygen enters the lungs and when exhaling, air containing carbon dioxide is expelled. Ventilation ensures that oxygen is available in the alveoli for gas exchange.

Perfusion is the blood flow to the lungs' capillaries, which surround the alveoli. It is responsible for transporting oxygen-poor blood from the heart to the lungs and the return of oxygen-rich blood back to the heart. Perfusion ensures that the blood is in close proximity to the alveoli, allowing for the exchange of gases (oxygen into the blood, carbon dioxide out of the blood).

TRANSPORTATION OF GASES

Oxygen and carbon dioxide are transported from the lungs to body tissues in blood. The gases travel in blood plasma and haemoglobin, which is found within erythrocytes.

TRANSPORT OF OXYGEN

Most of the oxygen, around 98.5%, is transported attached to haemoglobin in the erythrocyte. Each erythrocyte contains around 280 million haemoglobin molecules and each haemoglobin molecule has the potential to carry four oxygen molecules. The percentage of haemoglobin carrying oxygen is measured as oxygen saturation (SaO_2). The remaining 1.5% of oxygen is dissolved in blood plasma, often measured in kilopascals (PaO_2), which in health is around 11–13.5 kPa (82–101 mmHg). The delivery of oxygen, therefore, is also reliant upon the presence of an adequate supply of erythrocytes and haemoglobin. In health, the average male would possess between 15 and 18 g of haemoglobin for every 100 mL of blood. Each gram of haemoglobin can carry approximately 1.34 mL of oxygen. Therefore, a male with a haemoglobin of 16 g/dL would have the capacity to carry 21.44 mL of oxygen for every 100 mL of blood ($16 \times 1.34 = 21.44$). This volume of oxygen is referred to as oxygen capacity. It is rare, however, for an individual's haemoglobin to be fully saturated with oxygen. The actual amount of oxygen being transported by haemoglobin is called oxygen content (CaO_2). Oxygen content is determined by oxygen saturation levels. In health, an individual's oxygen saturation level (SaO_2) would normally be between 97 and 99%.

HYPOXIA AND HYPOXAEMIA

Hypoxia is defined as a lack of oxygen within body tissues. Hypoxaemia is defined as a lack of oxygen within arterial blood. Naturally, hypoxaemia will lead to hypoxia as the tissues are receiving less oxygen. However, as respiration also relies on a fully functioning cardiovascular system, hypoxia can also occur even when arterial blood is fully oxygenated.

TRANSPORTATION OF CARBON DIOXIDE

Just like oxygen, a small amount of carbon dioxide, around 10%, is transported in plasma. Carbon dioxide is also transported attached to haemoglobin, but only around 30% is transported that way. Nevertheless, haemoglobin has a greater affinity for carbon dioxide than for oxygen. Within the tissues, this facilitates the release of oxygen as carbon dioxide is being created. However, as carbon dioxide levels increase (hypercapnia), the amount of oxygen binding to haemoglobin is reduced.

ACID–BASE BALANCE

Acid–base balance is the body's way of keeping the level of acidity (pH) in the blood and tissues within a narrow and healthy range to maintain homeostasis. It maintains the right balance between too much acid and too much base.

ACIDS AND BASES

Acids are substances that release hydrogen ions (H^+) in water, making the solution more acidic. Bases are substances that accept hydrogen ions or release hydroxide ions (OH^-) in water, making the solution more alkaline (less acidic).

WHY BALANCE MATTERS

The body needs a specific pH range (around 7.35–7.45) for enzymes and chemical reactions to work properly. If the pH goes too low (acidic) or too high (alkaline), it can disrupt bodily functions and even be life threatening.

HOW THE BODY MAINTAINS BALANCE

The body has natural 'buffers' (chemicals) that can quickly absorb excess hydrogen ions to prevent the blood from becoming too acidic or release them to counteract excessive alkalinity.

The respiratory system has the capability to adjust the pH by changing the breathing rate. Breathing faster or slower can remove or retain carbon dioxide (which can combine with water to form an acid) in the blood. The kidneys can excrete excess acids or bases in the urine in order to help regulate pH. They also play a crucial role in maintaining long-term balance.

Maintaining acid–base balance is essential for the body to function effectively. The body uses buffers, the respiratory system and the kidneys to ensure that the pH stays within a healthy range.

INTERNAL RESPIRATION

Internal respiration describes the exchange of oxygen and carbon dioxide between blood and tissue cells, a phenomenon governed by the same principles as external respiration. Cells use oxygen when manufacturing the cells' prime energy source, adenosine triphosphate (ATP). In addition to ATP, the cells produce water and carbon dioxide. As the cells are continually using oxygen, its concentration within tissues is always lower than within blood. Similarly, the continual use of oxygen ensures that the level of carbon dioxide within tissues is always higher than within the blood. As blood flows through the capillaries, oxygen and carbon dioxide follow their pressure gradients and continually diffuse between blood and tissue. The concentration of oxygen in blood flowing away from the tissues back towards the heart is described as deoxygenated. In reality, if measured, the oxygen saturation of venous blood would probably be around 75%. This means that only around 25% of the oxygen content (CaO_2) leaves the bloodstream, leaving a plentiful supply. The actual amount of oxygen used by the tissues every minute is referred to as oxygen consumption (VO_2) or oxygen extraction ratio.

CONCLUSION

This chapter has provided an underpinning of the anatomy and physiology related to the respiratory system, offering the reader a fundamental understanding of this vital system.

The respiratory system is divided into the upper and lower respiratory tracts. The lower respiratory tract consists of lung tissue and major airways. The structures within the lower respiratory tract are fragile and susceptible to infection. The main function of the upper respiratory tract is to offer protection to the lower respiratory tract. The main function of the lower respiratory tract is the reoxygenation of arterial blood and the expulsion of excess carbon dioxide, a process known as respiration. Respiration involves four distinct physiological processes: pulmonary ventilation (breathing), external respiration (gaseous exchange), transport of gases and internal respiration. Only the first two processes are the sole responsibility of the respiratory system, effective respiration is also reliant upon a fully functioning cardiovascular system.

The knowledge gained in this chapter will be directly applicable to your daily practice. From assessing a patient's respiratory rate and pattern to understanding the pathophysiology of respiratory diseases, you are well on your way to becoming competent and confident in patient-centred respiratory care.

It should be remembered that offering care to people is not just about understanding science, but also about providing compassionate and patient-centred care. Patients with respiratory issues may experience anxiety and discomfort. An understanding of the respiratory system will enable you to communicate effectively, provide emotional support and deliver holistic care. As you progress in education and practice, you will continue to explore and deepen your understanding of the respiratory system. Each patient encountered will present unique challenges and your knowledge will be a beacon guiding you to deliver safe, competent and compassionate care.

In the next chapters, we will further explore respiratory assessments, common respiratory disorders, care interventions and the provision of patient-centred care in the context of respiratory health.

GLOSSARY OF TERMS

Alveoli: Tiny air sacs in the lungs where gas exchange (oxygen and carbon dioxide) with the bloodstream occurs.

Bronchi: The two main branches of the trachea leading to the lungs, where they further divided into smaller bronchioles.

Bronchioles: Small air passages in the lungs that branch off from the bronchi and continue to divide into even smaller airways.

Carbon dioxide: A waste gas produced by cellular metabolism, which is transported in the blood to the lungs for exhalation.

Cilia: Tiny hair-like structures lining the respiratory tract that help trap and remove debris and microorganisms.

Diaphragm: A dome-shaped muscle located beneath the lungs that plays a central role in breathing by contracting (flattening) during inhalation and relaxing during exhalation.

Epiglottis: A flap-like structure in the throat that covers the trachea during swallowing to prevent food or liquid from entering the airway.

Exhalation: The process of breathing out, during which the diaphragm and intercostal muscles relax, decreasing lung volume.

Gas exchange: The transfer of oxygen from inhaled air into the bloodstream and the removal of carbon dioxide from the bloodstream into exhaled air, which occurs in the alveoli.

Inhalation: The process of breathing in, during which the diaphragm and intercostal muscles contract, increasing lung volume.

Larynx: The voice box is located at the top of the trachea, responsible for voice production and protecting the lower airways during swallowing.

Mediastinum: The central compartment of the chest that contains the heart, major blood vessels and other vital structures.

Oxygenation: The process of oxygen entering the bloodstream and being transported to body tissues.

Pharynx: The throat, which serves as a passage for both air and food.

Pleura: A thin, double-layered membrane surrounding each lung and lining the chest cavity, helping to reduce friction during breathing.

Respiration: The process of gas exchange involves both inhalation (breathing in oxygen) and exhalation (removing carbon dioxide).

Surfactant: A substance produced by the alveoli that reduces surface tension in the lungs, preventing their collapse.

Trachea: The windpipe, a tubular structure that carries air from the larynx to the bronchi, providing a passage for air to and from the lungs.

Ventilation: The mechanical process of moving air into and out of the lungs, involving inhalation and exhalation.

MULTIPLE CHOICE QUESTIONS

1. What is the primary function of the respiratory system?
a) To pump blood into the body
b) To digest food
c) To exchange gases with the environment
d) To remove waste products from the body

2. Which of the following structures is NOT part of the upper respiratory tract?
a) Trachea
b) Nasal cavity
c) Pharynx
d) Larynx

3. The tiny air sacs where gas exchange occurs in the lungs are called:
a) Alveoli
b) Bronchioles
c) Trachea
d) Larynx

4. What is the role of the diaphragm in respiration?
a) To protect the lungs from infection
b) To humidify the air we breathe
c) To control the rate of breathing
d) To create changes in lung volume for breathing

5. Which gas is primarily exchanged in the respiratory system?
a) Carbon dioxide (CO_2)
b) Nitrogen (N_2)
c) Oxygen (O_2)
d) Hydrogen (H_2)

6. Which structure separates the oral and nasal cavities from the pharynx?
a) Trachea
b) Larynx
c) Epiglottis
d) Soft palate

7. The windpipe that carries air from the larynx to the bronchi is called the:
a) Pharynx
b) Alveoli
c) Trachea
d) Bronchiole

8. Which of the following is NOT a function of the respiratory system?
   a) Voice production
   b) Regulation of blood pressure
   c) Filtering inhaled air
   d) Gas exchange

9. What is the name of the thin, moist membrane that surrounds each lung and lines the chest cavity?
   a) Pleura
   b) Bronchus
   c) Larynx
   d) Pharynx

10. The exchange of gases (oxygen and carbon dioxide) between the alveoli and the bloodstream occurs by:
    a) Active transport
    b) Osmosis
    c) Diffusion
    d) Filtration

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