Chapter 6 - Respiratory system

The objectives of this chapter are:

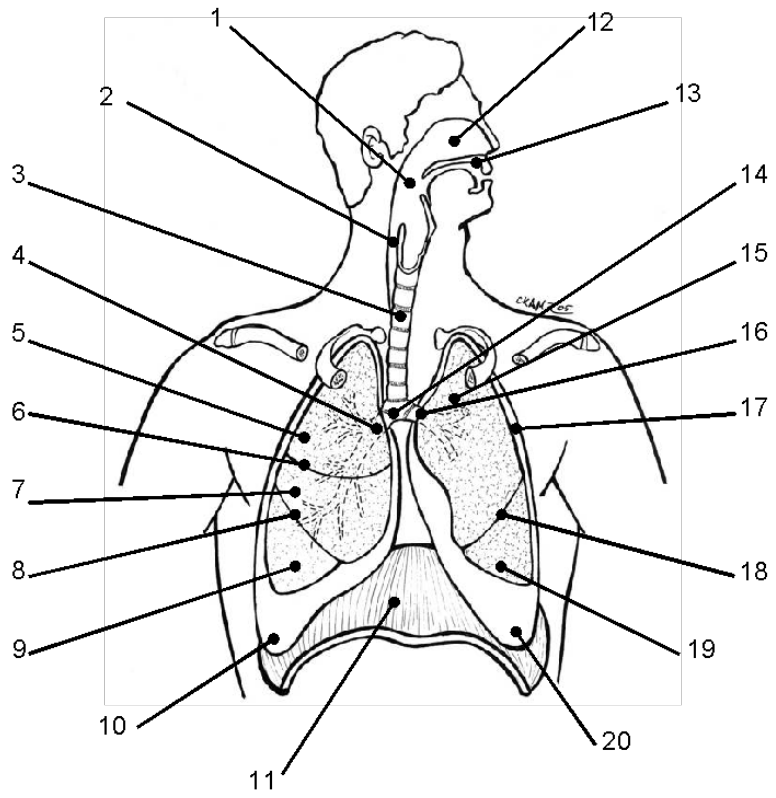
1. Name the parts of the respiratory system.
2. Describe the structure and function of the larynx.
3. Describe the tracheobronchial tree.
4. Describe the right and left lung.
5. Define a pulmonary lobe and a pulmonary segment.
6. Describe the pleura and the pleural cavity.
7. Describe the pulmonary circulation.
8. Describe the mechanics and the muscles of respiration.

1 - Elements of respiratory system

The respiratory system allows gas exchange between the blood and the atmosphere. Part of the respiratory system is larynx which enables the formation of vocal sounds.

The respiratory system consists of the following organs:

- nose,
- paranasal sinuses,
- larynx,
- tracheobronchial tree,
- lungs.



1. Pharynx
2. Laryngopharynx
3. Trachea
4. Right main bronchus
5. Right superior lobe
6. Horizontal fissure of right lung
7. Middle lobe
8. Right oblique fissure
9. Right inferior lobe
10. Right costodiaphragmatic recess
11. Diaphragm
12. Nasal cavity
13. Oral cavity
14. Bifurcation of trachea
15. Left superior lobe
16. Left main bronchus
17. Pleura
18. Left oblique fissure
19. Left inferior lobe
20. Left costodiaphragmatic recess

Figure 217: Scheme of the respiratory system.

In addition to the organs, the pulmonary circulation is also functionally involved in respiration:

- Right ventricle pumps deoxygenated blood into the pulmonary trunk, which divides into the left and right pulmonary artery which carry the blood to the lungs.
- Pulmonary veins carry oxygenated blood from the lungs to the left atrium.

According to the function, the respiratory system can be divided into two zones:

- the conducting zone for transporting the gases to the respiratory zone;
- the respiratory zone for exchanging the gases between the blood and the inhaled air.

The respiratory tract can also be divided into the upper and lower parts:

- the upper respiratory tract includes nose, paranasal sinuses, pharynx, and portion of larynx above the vocal cords;
- The lower respiratory tract includes portion of larynx below the vocal cords, trachea, bronchi, bronchioles, alveolar ducts, alveolar sacs, and alveoli.

1.1 - Nasal cavity and paranasal sinuses

The nasal cavity allows cleaning, heating and humidification of the air. The roof of the nasal cavity is also the site of the organ of smell.

The cavity is divided into the left and right nasal cavity by the nasal septum. The anterior opening into the cavities are the two nostrils. Posteriorly, the nasal cavities communicate with the pharynx through the choanae.

The skeletal roof of the cavity consists of the nasal bone, nasal part of the frontal bone, cribriform plate of the ethmoid bone, and the body of sphenoid bones. The perforated cribriform plate allows passage of the olfactory fibres. The skeletal floor of the nasal cavity is the hard palate, separating the nasal cavity from the oral cavity. The skeletal lateral wall of the nasal cavity is complex, formed by 7 different bones of the cranium. Superior, middle and inferior nasal concha project from the lateral wall into the cavity.

The nasal cavity is lined by nasal mucosa. Specialised epithelium in the respiratory region is called the respiratory epithelium and is formed by ciliated columnar cells. The olfactory region contains the olfactory epithelium.

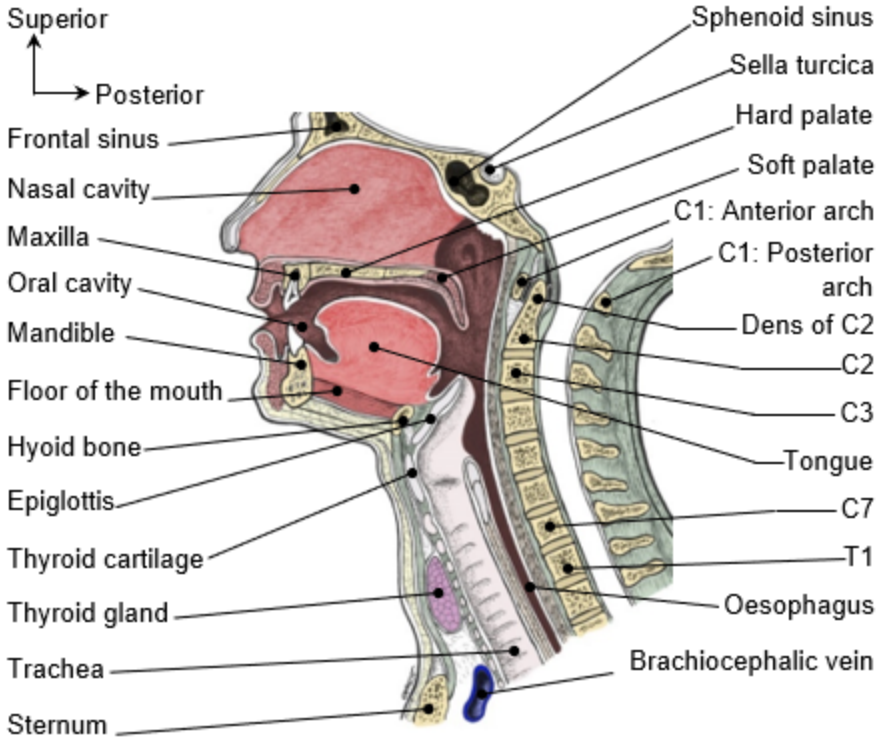


Figure 218: Sagittal section of the head and neck presenting the location and topography of the nasal cavity.

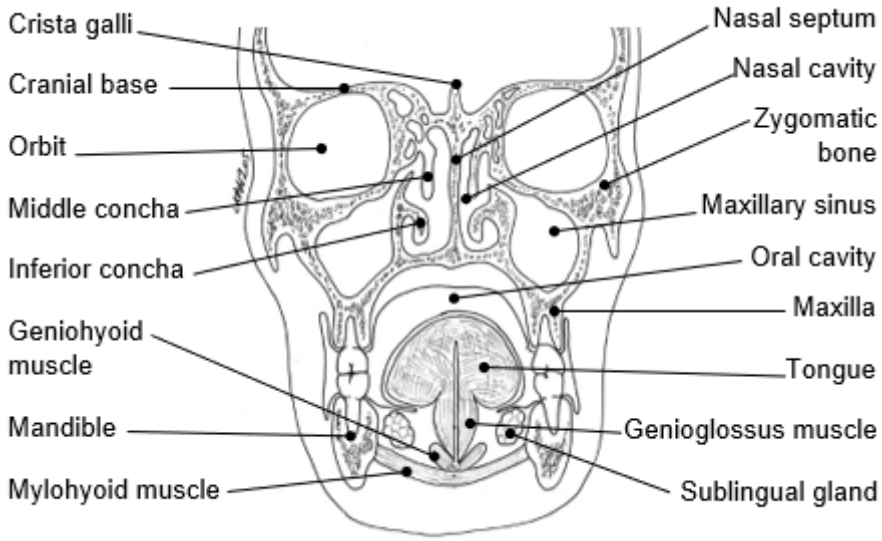


Figure 219: Frontal section of the head showing the location and topography of the nasal cavity.

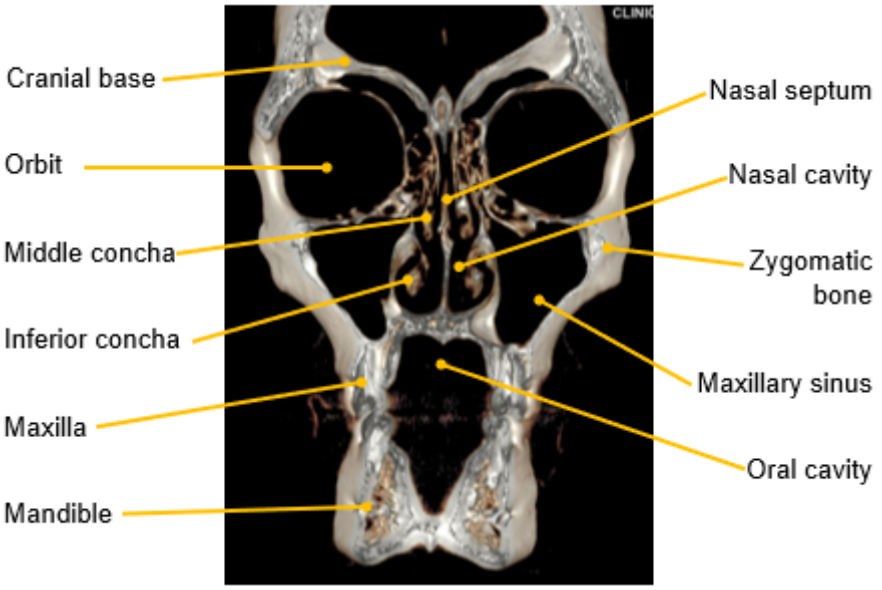


Figure 220: Reconstruction of the frontal CT sections of the head.

The paranasal sinuses are air-filled bony cavities of the maxilla, frontal bone, sphenoid bone, and ethmoid bone. They are lined by a mucous membrane and communicate with the nasal cavity through relatively small openings.

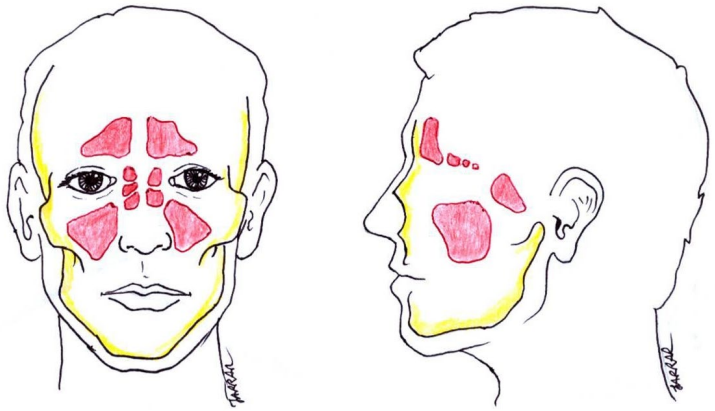


Figure 221: The paranasal sinuses.

1.2 - Pharynx

The pharynx is a junction of the respiratory and the digestive system: it is a part of the digestive system, but also serves as the conduit for the air. It can be divided into the nasopharynx situated behind the nasal cavity, oropharynx situated behind the oral cavity, and laryngopharynx situated behind the larynx.

1.3 - Larynx

The larynx is a part of the respiratory tract between the oropharynx and the trachea. Its skeleton consists of several laryngeal cartilages, connected by membranes, ligaments and synovial laryngeal joints. Tiny laryngeal muscles move the cartilages.

An important part of the larynx are two vocal cords which are essential for phonation. Above the true vocal cords, there are two vestibular folds, also named false vocal cords.

The mucosa lining the laryngeal cavity has a respiratory epithelium, except for the vocal cords which are lined by a stratified squamous epithelium.

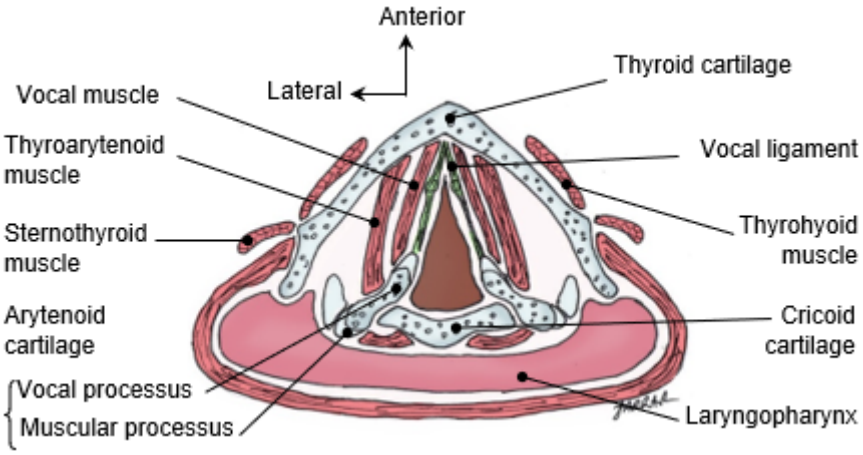


Figure 222: Horizontal section of the larynx.

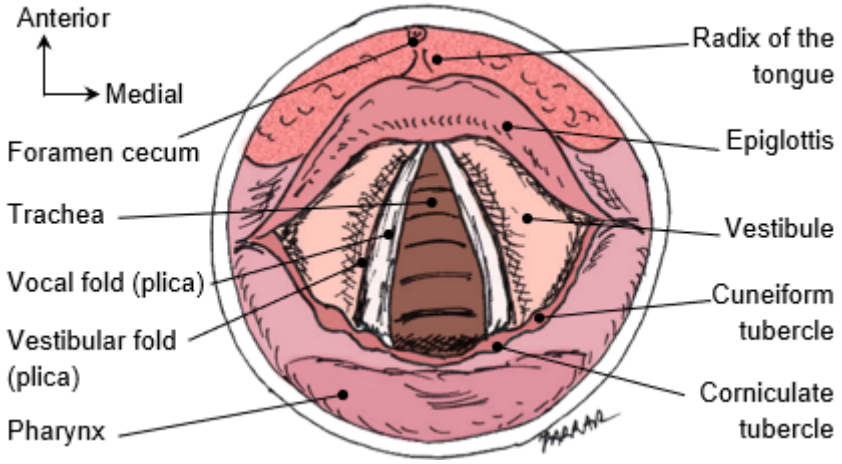


Figure 223: Laryngoscopy.

1.4 - Tracheobronchial tree

The tracheobronchial tree consists of trachea and bronchi.

The trachea is a fibromusculocartilaginous tube, lined with mucosa on the inner surface. It extends from the larynx in the neck into the thorax where it bifurcates above the heart into the left and right main bronchus.

The left and right main bronchus enter the left and right lung ad divide further inside the lung.

The bronchi have similar wall structure as the trachea. The left and right main bronchus enter the left and right lung, respectively, and then divide further inside the lungs into successively finer divisions.

Figure 224: Dissection – anterior view of the viscera of the thorax.

Figure 225: Branching of the tracheobronchial tree.

1.5 - Lungs

The lungs have a spongy, expandable structure and capability of gas exchange between the inhaled air and the blood. Their average air capacity in the adult is 6 litres.

The left and right lung are located in the lateral parts of the thorax, on each side of the mediastinum.

The lungs have a conical shape, with apex on the top and base at the bottom. They have three surfaces: the costal surface is adjacent to the ribs, the diaphragmatic surface is adjacent to the diaphragm, and the medial surface is oriented medially, towards the mediastinum. Deep fissures divide each lung into the lobes:

- The left lung is divided into the superior and inferior lobe by an oblique fissure.
- The right lung is divided into the superior, middle, and inferior lobe by an oblique and a horizontal fissure.

The lobes are further divided into the segments. Each lung consists of 10 segments.

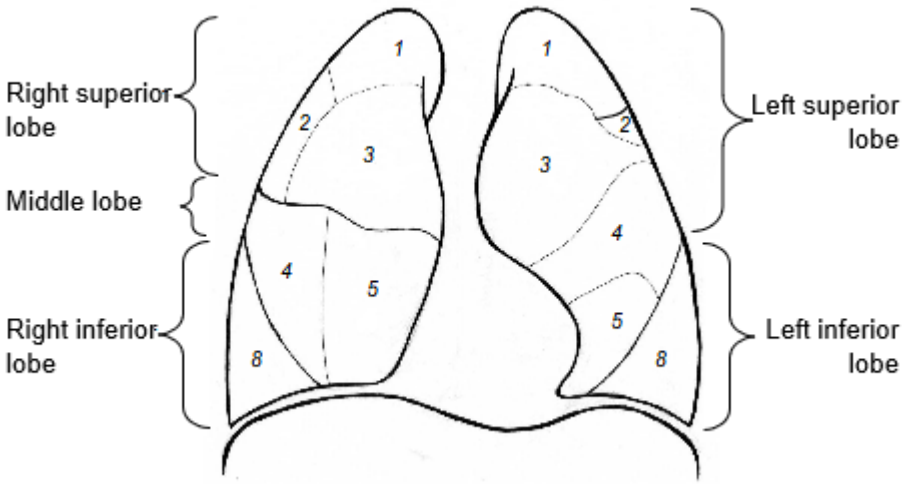


Figure 226: Lung segmentation. Anterior view.

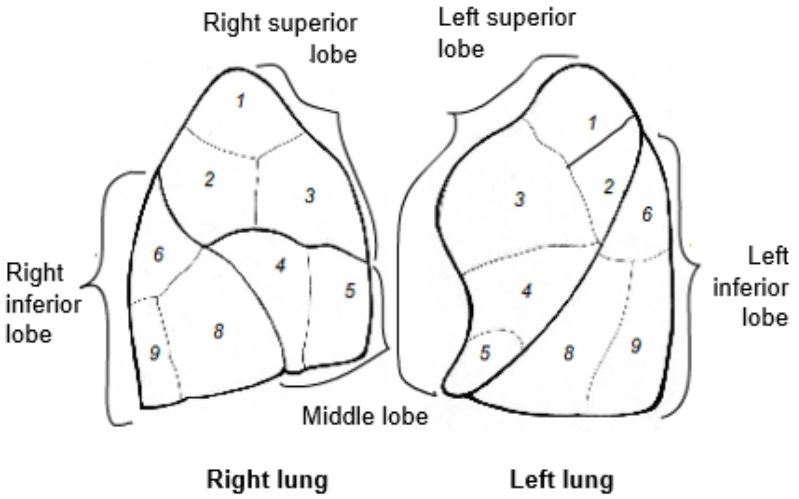


Figure 227: Lung segmentation. Lateral view.

On the medial surface of each lung there is a hilum through which passes the root of lung, containing the neurovascular and airway structures entering or leaving the lung parenchyma: the main bronchus, the pulmonary artery, two pulmonary veins, bronchial vessels, lymph vessels and nodes, and pulmonary autonomic plexus.

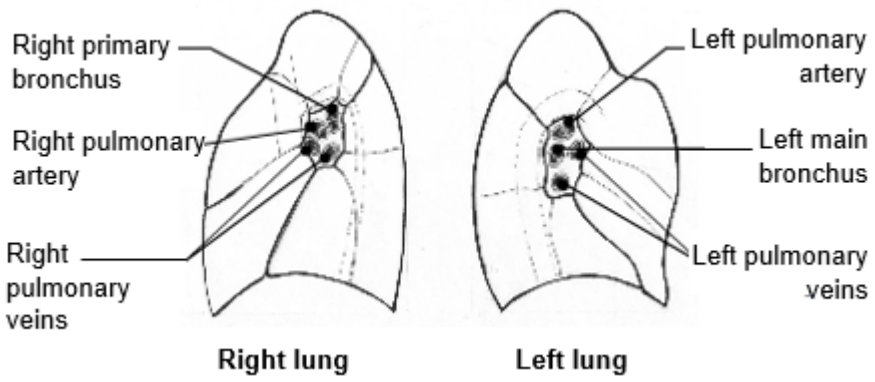


Figure 228: Medial surface of lung with the hilum of lung.

Inside the lung, tracheobronchial tree finally branches into the bronchiole, which do not contain the cartilage in their wall. The bronchioles finally divide into the alveolar sacs with numerous alveoli – the balloon-like vesicles surrounded by the capillary network where the gas exchange takes place.

The pulmonary arteries carrying the oxygen-depleted blood closely follow the course of bronchial tree, and pulmonary arteriole can be found in the centre of the alveolar sac. The pulmonary venules carrying the oxygenated blood lie at the periphery of the alveolar sac, and the pulmonary veins do not follow the tracheobronchial tree closely, but lie close to the border between the two pulmonary segments.

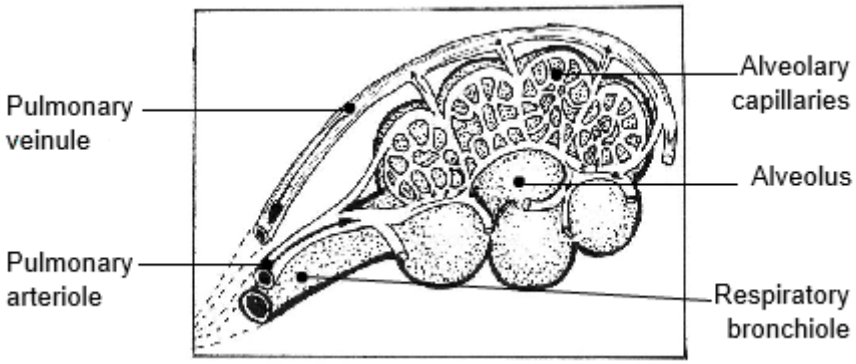


Figure 229: Gas exchange in the alveolar sac.

2 - Pleura and pleural cavity

The pleura is a double-layered serous membrane that covers each lung and lines the walls of thoracic cavity.

- The visceral pleura is attached to the surface of the lung, extending also into the fissures.
- The parietal pleura lines the thoracic wall. It is attached to the ribs and intercostal spaces laterally, to the thoracic surface of the diaphragm inferiorly, and bounds the lateral aspect of the mediastinum.

The two layers of pleura are reflected one into the other on the medial surface of the lung, around the hilum, extending inferiorly as the pulmonary ligament.

The space between the visceral and parietal pleura is called the pleural cavity. It contains a small amount of serous fluid and allows the lung to expand and contract freely. Each lung is surrounded by its own pleura enclosing the pleural cavity – there is no connection between the left and right pleural cavities. Under normal circumstances, the visceral and parietal pleura are in contact with each other; the space between them only appears when there is an air (pneumothorax) or excessive fluid (pleural effusion) inside the pleural cavity.

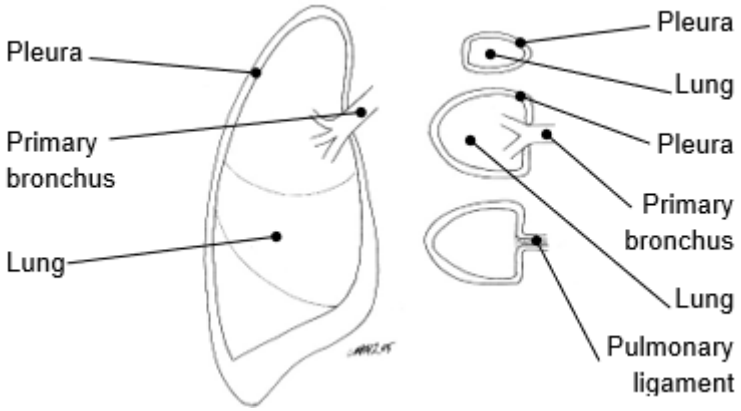


Figure 230: The pleura.

3 - Pulmonary circulation

The pulmonary circulation enables the oxygenation of the blood in the lungs, at the level of alveoli. In contrast to the systemic circulation, the pulmonary arteries transport deoxygenated blood, and the pulmonary veins transport oxygenated blood.

Non-oxygenated blood enters the right atrium through the superior and inferior vena cava. During diastole, it passes from the right atrium into the right ventricle through the tricuspid valve. During systole, the right

ventricle pumps the blood into the pulmonary trunk through the pulmonary valve.

Pulmonary trunk divides into the left and the right pulmonary artery, which enter the left and right lung, respectively, as part of the root of lung.

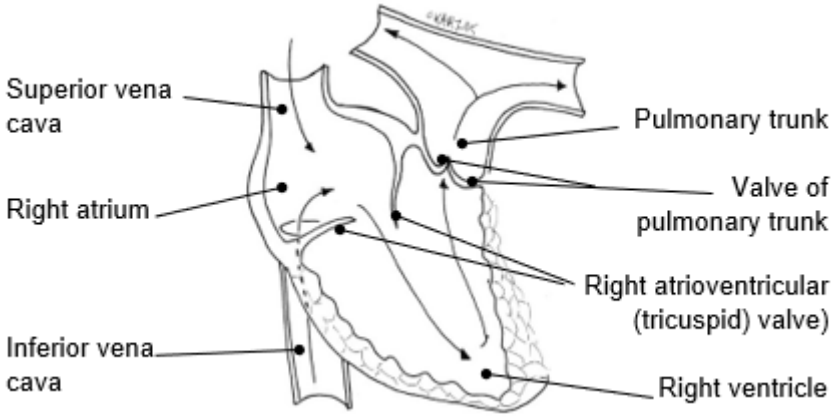


Figure 231: The right heart chambers.

The oxygenated blood leaves the lungs through pulmonary veins, two from each lung. The veins carry the blood to the left atrium.

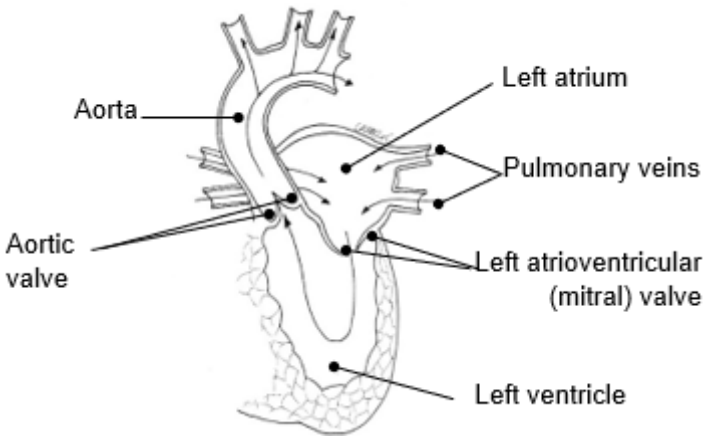


Figure 232: The left heart chambers.

4 - Mechanics of breathing

During breathing, the contraction and relaxation of muscles result in the changes of the volume of the thoracic cavity. The pressure inside the closed pleural cavity is negative in comparison to the atmospheric pressure, and lungs follow the movements of thoracic cavity:

- During inspiration, the inspiratory muscles contract, and the volume of thoracic cage and the lungs increases. This leads to the decrease in the lung pressure and the air enters the lungs.
- During expiration, the inspiratory muscles relax, and the volume of thoracic cage and the lungs decreases. This leads to the increase in the lung pressure and the air exits the lungs.

The inspiratory muscles are the external intercostal muscles and the diaphragm.
The diaphragm is a dome-shaped thin muscle with centrally placed tendon and it separates the chest cavity above from the abdominal cavity below. It is the most important muscle of respiration. Its peripheral part is muscular and is attached to the inner surface of xiphoid process, costal arch, 11^{th} and 12^{th} ribs and lumbar vertebrae. Its central tendinous part is called the central tendon.
The diaphragm is pierced by the structures that pass between the thorax and the abdomen. It has three main openings:

- Aortic hiatus is located posteriorly, at the level of vertebra T12.
- Oesophageal hiatus is also located posteriorly, at the level of vertebra T10.
- Caval foramen is located in the central tendon at the level of vertebra T8.

Actions of the diaphragm:

- its contraction flattens the dome, increasing the volume of the thoracic cavity (inspiration);
- its relaxation decreases the thoracic volume (expiration);

- when it uses the anterolateral abdominal muscles, it assists in increasing intra-abdominal pressure (defecation, vomiting, childbirth, etc.).