The main task of the lung is the oxygenation of the blood and the elimination of carbon dioxide. Diseases of the lung are common and seen in every age group. Anatomic knowledge of the lung is key to be able to classify the different clinical pictures. In the following article, you will get an overview of the location, the structure, and the functions of the lung.

Location of the Lungs

Each of the paired lungs completely fills one of the also paired pleural cavities (cavitas pleuralis). Both pleural cavities are situated on the left and right side of the mediastinum, respectively. The dorsal expansion reaches the thoracic spine. Ventrally, the two pleural cavities are located in front and lateral to the pericardium. Due to the asymmetric position of the heart and the pericardium, the left pleural cavity, and hence the left lung, is slightly smaller than the right one.

The intimate contact between lung and heart results in the so-called cardiac impression, which in turn results in the cardiac notch on the left lung (incisura cardiaca). The lingula is located at the caudal end of the cardiac notch. It represents a protrusion of the upper lobe and only exists in the left lung. The mediastinum and the two pleural cavities are situated in the thoracic cavity (cavitas thoracis), which is one of the three major body cavities along with the abdominal cavity (cavitas abdominalis), and the pelvic cavity (cavitas pelvis).

The lung’s expansion depends on breathing. Whereas the apex of the lung (apex pulmonalis) always reaches into the upper thoracic aperture, the base of the lung (basis
pulmonis) is closely related to the diaphragm.

Shape and Structure of the Respiratory Tract

The two lungs have a slightly different external topography. **The left lung has two lobes (superior and inferior), which are separated from each other by the oblique fissure. The right lung consists of three lobes (superior, middle, and inferior lobe).** The oblique and the horizontal fissure separate the three lobes. The fissures reach deep into the lung tissue and are covered with the visceral pleura projecting from the surface of the lung.

The remaining structure of the two lungs is identical. The lung is further divided into apex (apex pulmonis), base (basis pulmonis), surfaces, and borders. The surface is covered with a serous coat, the visceral pleura, and has a rosy to grey coloration in a healthy person. Depending on the location and relationship with the thorax, the surface (facies pulmonis) is divided into the costal surface, the mediastinal surface, the diaphragmatic surface, and the interlobar surface.

In the area of the mediastinal surface, the transition from visceral to parietal pleura takes place. Thus, a fold results, which appears as the pulmonary ligament in a dissected lung. Between the two pleural sheets lays the pleural cavity (cavitas pleuralis), which is filled with fluid and ensures effortless sliding of the sheets against each other. Also, the negative pressure (-5 cm H$_2$O) in the pleural cavity ensures that the lung is held in place within the pleural cavities and stays unfolded. If this pressure would not exist, the lungs would collapse due to their inherent elastic force of its parenchyma (see pneumothorax).

The pulmonary hilum is located in the middle of the mediastinal surface, also referred to as simply the hilum. This is the entrance and exit area for the bronchi, vessels, lymphatic channels, sympathetic and parasympathetic nerves of the lung. The surfaces of the lung transition into the borders (pulmonary margins). The anterior border separates the costal from the mediastinal surfaces. The diaphragmatic surface is separated from the costal and the mediastinal surface by the inferior border.
Lung segments (segmenta bronchopulmonales)

Besides the distinction between lobes, one can separate individual segments in each lobe. This classification directly results from the branching of the bronchi. **In the center of each segment, there is a segmental bronchus, a segmental branch of the pulmonary artery and vein.** Both lungs are subdivided into ten segments. Due to the presence of the heart, the left lung has a cardiac notch (incisura cardiaca). As a result, segment VII is often so small that it is included in segment VIII.

<table>
<thead>
<tr>
<th>Right lung</th>
<th>Left lung</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superior lobe</strong></td>
<td><strong>Superior lobe</strong></td>
</tr>
<tr>
<td>• Apical segment (I)</td>
<td>• Apico-posterior segment (I + II)</td>
</tr>
<tr>
<td>• Posterior segment (II)</td>
<td>• Anterior segment (III)</td>
</tr>
<tr>
<td>• Anterior segment (III)</td>
<td>• Superior lingular segment (IV)</td>
</tr>
<tr>
<td><strong>Middle lobe</strong></td>
<td><strong>Left lung</strong></td>
</tr>
<tr>
<td>• Lateral segment (IV)</td>
<td>• Inferior lingular segment (V)</td>
</tr>
<tr>
<td>• Medial segment (V)</td>
<td></td>
</tr>
<tr>
<td><strong>Inferior lobe</strong></td>
<td><strong>Inferior lobe</strong></td>
</tr>
<tr>
<td>• Superior segment (VI)</td>
<td>• Superior segment (VI)</td>
</tr>
<tr>
<td>• Medial-basal segment (VII)</td>
<td>• Middle-basal segment (VII)</td>
</tr>
<tr>
<td>• Anterior-basal segment (VIII)</td>
<td>• Anterior-basal segment (VIII)</td>
</tr>
<tr>
<td>• Lateral-basal segment (IX)</td>
<td>• Lateral-basal segment (IX)</td>
</tr>
<tr>
<td>• Posterior-basal segment (X)</td>
<td>• Posterior-basal segment (X)</td>
</tr>
</tbody>
</table>

Bronchial tree

The bronchial tree begins at the splitting of the trachea into the two main bronchi (principal bronchi) and delivers moistened air to the alveoli. It consists of conducting airway and a respiratory airway.

The mainstem, lobar, segmental, subsegmental bronchi, and terminal bronchioles form the conducting airway, whereas the respiratory bronchioles, the alveolar ducts, and the alveolar sacs form the respiratory airway. There is a great difference between the structure of larger and smaller airway, a difference that plays a role in disease.

**Branch successively to form smaller bronchi that are divided into the following main divisions:**

1. Right and left main bronchi
2. Left side
   - Left upper and left lower lobe bronchi. Lingula bronchi divide off left upper lobe bronchus

3. Right side
   - Right upper and intermedius bronchi, with the latter dividing into the right middle and lower lobe bronchi

The wall of the bronchi is **stabilized by cartilaginous plates**, which the bronchioles miss, being instead composed of smooth musculature in their tunica media. Also, the epithelium changes from a ciliated pseudo-stratified one to a ciliated single-layer prismatic one. Beginning at the terminal bronchioles, there are no more goblet cells in the respiratory part of the bronchial tree. Instead, alveoli can be found in this part. The respiratory bronchioles are the narrowest airways of the lungs, one-fiftieth of an inch across.

The alveoli are little hollow cavities with a diameter of 150—500 micrometers. There are two types of pneumocytes (alveolar epithelial cells), which line the alveoli. **Most epithelial cells are type I pneumocytes.** They are connected via tight junctions and form the blood-air-barrier along with the basal membrane of the endothelial cells of the surrounding capillaries.

**The larger type II pneumocytes (= niche cells) are spread more rarely and secrete surfactant.** Surfactant decreases the alveoli’s surface tension and prevents them from collapsing. The overall alveolar surface for gas exchange is calculated to be 100-120 square meters, roughly the size of a soccer field.

Vascular supply of the lung

**Note:** In the right hilum, the bronchus and the artery are roughly on the same level, the artery being anterior to the bronchus and the veins are located caudally. In the left hilum, artery, bronchus, and vein are aligned on top of each other, the artery being superior.

**The hilum of the lung is the entrance and exit area for the vessels of the lung.**
Depending on the function, one distinguishes between public vessels, which are responsible for the gas exchange, and the private vessels for the lung’s own supply. The pulmonary arteries and veins are public vessels.

The pulmonary arteries originate from the pulmonary trunk and lead the deoxygenated blood from the right heart to the lung. The oxygenated blood reaches the left atrium via the pulmonary veins, which unite at the hila to two lung veins on each side. It is important to know that the branching of the arteries follows the branching of the bronchi, whereas the veins run between the segments, independent from the bronchi.

The bronchial arteries supply blood to the bronchi and connective tissue of the lungs and originate from the thoracic aorta (seldom also from the internal thoracic artery). They travel with and branch with the bronchi, ending about at the level of the respiratory bronchioles. They anastomose with the branches of the pulmonary arteries, and together, they supply the visceral pleura of the lung in the process.

Much of the oxygenated blood supplied by the bronchial arteries is returned via the pulmonary veins rather than the bronchial veins. As a consequence, blood returning to the left heart is slightly less oxygenated than blood found at the level of the pulmonary capillary beds. This is referred to as a physiologic shunt.

The bronchial veins that are close to the hilum are an exception: On the right side, they lead to the azygos vein, and on the left side, they lead to the accessory hemiazygos vein. Each bronchial artery also has a branch that supplies the esophagus.

**Lymphatic Vessels and Nerves of the Lung**

Like the vascular supply, the lymphatic vessels and nerves run through the hilum. The vegetative nerves form the pulmonary plexus at this point, which receives parasympathetic fibers through the vagal nerve and sympathetic fibers by the sympathetic trunk. Parasympathetic fibers cause bronchoconstriction, whereas sympathetic fibers cause bronchodilation.

Additionally, the pulmonary plexus receives afferent vegetative fibers, which mostly consist of strain sensors in the bronchial wall. In the event of extreme stretching, these
fibers inhibit the respiratory center by means of the Hering-Breuer reflex. Several nerves ensure the parietal pleura’s sensory innervation. The costal part (costal pleura) is supplied by the intercostal nerves, whereas the mediastinal part is innervated by the phrenic nerve. In contrast to the parietal pleura, the visceral pleura is not innervated.

The lymphatic draining of the lung is organized in a superficial and deep system. The superficial system receives draining from the network just under the pleura and directly drains into the bronchopulmonary lymph nodes at the hilum. Passing the intermediate station of the intrapulmonary lymph nodes, they eventually also lead to the deep system. From the bronchopulmonary lymph nodes, the lymph reaches the superior and inferior tracheobronchial lymph nodes. Finally, it reaches the bronchomediastinal trunk via the paratracheal lymph nodes.

**Note:** This is an important route of metastasis of tumors of the lung.

**Mechanics of Respiration**

**In the context of breathing, a rhythmic change in thorax diameter occurs.** Forced by the negative pressure in the pleural cavity, the lung follows this change in volume of the thorax. In inspiration, two mechanisms make for the enlargement of the lung volume: Firstly, the expansion of the thorax via the external intercostal muscles, which elevate the ribs, and secondly, the contraction of the diaphragm. The diaphragm is the main muscle used for shallow breathing, and the only muscle remaining active during sleep.

The costodiaphragmatic recess of the pleural cavity serves as a reserved space for the expansion of the lungs in the course of inspiration. Thus, the edges of the lung can significantly be moved caudally. Another reserve space is the costomediastinal recess, which is situated at the border between the anterior chest wall and the mediastinum. The phrenicomediastinal recess between the diaphragm and pericardium does not represent a considerable reserve space.

In contrast to inspiration, expiration is mainly a passive process, which is caused by the elastic recoil forces of the lung and the thorax. However, muscles have an effect on the process when it comes to forced expiration, which results in a fast reduction in thoracic diameter.

<table>
<thead>
<tr>
<th>Muscles with an effect on inspiration</th>
<th>Muscles with an effect on the expiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragm</td>
<td>Subcostal muscle</td>
</tr>
<tr>
<td>External intercostal muscles</td>
<td>Internal intercostal muscles</td>
</tr>
<tr>
<td>Levatores costarum, intertransversarii muscles</td>
<td>Transversus thoracis muscle</td>
</tr>
</tbody>
</table>
Examination of the Lung

The examination of the lung is a part of the clinical instruction in medical studies. However, an outlook shall be given at this point.

The clinical examination follows the anamnesis:

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Cyanosis? Use of accessory muscles of respiration? Determination of the breathing frequency (standard value: 12–15 breaths per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpation</td>
<td>Check for thoracic stability (applying pressure on the clavicle cranially on both sides)</td>
</tr>
<tr>
<td>Percussion</td>
<td>The lung creates a sonorous sound, whereas liver and spleen create a damped one. This way, the caudal lung edges can be determined.</td>
</tr>
<tr>
<td>Auscultation</td>
<td>The auscultation is performed in direct comparison with the opposite side. A vesicular breathing sound is a normal result. A weakened breathing sound can point to pleural effusion, a pneumothorax, or a chronic obstructive bronchitis. A pronounced sound of respiration can occur in patients with pneumonia.</td>
</tr>
<tr>
<td>Sputum</td>
<td>Depending on coloration and consistency, different several diagnoses are possible. Additionally, a direct detection of pathogens is possible.</td>
</tr>
</tbody>
</table>

Imaging methods can become necessary in order to confirm a tentative diagnosis of pneumonia.

<table>
<thead>
<tr>
<th>Sonography</th>
<th>Imaging of pleural effusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray</td>
<td>Graphic presentation of the lung as a dark area. Brighter areas or shadows suggest pathologies. Examination of lung vessels, recesses, and location and course of the trachea.</td>
</tr>
</tbody>
</table>
In the lung window, differentiated statements concerning solid tumors, swelling of lymph nodes, or pulmonary fibrosis can be made. Invasive measures like a bronchoalveolar lavage with biopsies can be indicated if a bronchial carcinoma is suspected. The examination of the pulmonary function parameters is made in the context of ergospirometry.

Furthermore, laboratory parameters supply important information concerning lung function. Especially, blood gas analysis is a very important method. With it, oxygen saturation in the arterial and venous blood can be analyzed.

Lung Diseases

Pneumothorax

The definition of a pneumothorax is the accumulation of air between the visceral and parietal pleura. As a result, the negative pressure in the pleural cavity is lost, which makes the lung on the affected side collapse. One distinguishes between a closed pneumothorax without connection to the external air, and an open pneumothorax.

Depending on the etiology, pneumothorax can be classified as spontaneous, traumatic, and iatrogenic. A spontaneous pneumothorax often occurs in young, asthenic men and is often caused by the rupture of congenital emphysemic bullae just under the pleura. Clinically, the symptoms of a pneumothorax are dyspnea, piercing chest pain on the affected side, and an asymmetric motion of the thorax (decreased and trailing motion of the affected side). A possible complication is a tension pneumothorax. In this case, a mediastinal shift toward the healthy side occurs. This causes compression of the healthy lung and the increased intrathoracic pressure causes obstruction of venous return to the heart.

Pneumonia (lung inflammation)

Pneumonia is an acute or chronic inflammation of the alveolar space and/or the interstitial lung tissue. It is one of the most frequent deadly infectious diseases in the
There are several ways to classify types of pneumonia:

- Pathologically-anatomically: localization and expansion
- Etiology: infectious, physical/chemical pollutants, circulatory disturbance
- Clinic: primary/secondary pneumonia, acute/chronic pneumonia
- Point of origin: Community-Acquired Pneumonia (CAP) or Hospital-Acquired Pneumonia (HAP) (soonest 48—72 hours after hospitalization)

Bronchial asthma

**Bronchial asthma** is an obstructive lung disease and represents a chronic inflammation of the respiratory tract. The inflammation results in a bronchial obstruction which causes paroxysmal dyspnea. In asthmatics, this bronchial obstruction can be provoked with a methacholine challenge test and can be controlled with sympathomimetic drugs, bronchodilators, and corticosteroid.

COPD (Chronic Obstructive Pulmonary Disease)

Like asthma, **COPD** is an obstructive lung disease. However, the obstruction is multifactorial. It is due to rupture of alveoli and formation of air sacks called bullae which compress normal lung tissue associated with chronic bronchitis, overproduction of mucous and bronchoconstriction (from the overreaction of the airways like asthma). The obstruction proceeds progressively over many years and is associated with a chronic inflammation of the lung as a reaction to chemical noxae like tar from the smoke.

Chronic bronchitis

According to the World Health Organization, **chronic bronchitis** exists if a patient suffers from a cough with sputum production every day for at least three months each year in two consecutive years.

Pulmonary fibrosis

**Pulmonary fibrosis** is an interstitial constrictive lung disease, which is caused by an increase of fibrous connective tissue in the lung. Causes include inhalation of pollutants like inorganic or organic dust and systemic diseases like sarcoidosis or collagenosis. Unlike COPD, which is associated with increased lung volumes, pulmonary fibrosis is associated with decreased lung volumes.

Bronchial carcinoma: lung cancer

**Bronchial carcinoma** is the most frequent cause of death due to cancer in men and third most frequent in women (after breast and colon cancer). The main risk factor is smoking tobacco (smoking accounts for 85% of bronchial carcinomas). Duration and extent of cigarette consumption determine the risk for bronchial cancer. The so-called pack-years are a measure of this risk. They are calculated by multiplying the number of cigarette packs smoked per day by the years the person has smoked.

Other risk factors are occupational carcinogens. Asbestos, with > 90%, is the most important one. Beside carcinogens, genetic predisposition and other risk factors like e.g., lung scars may play a role. Histologically, bronchial carcinomas are classified into small
cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC). With 85 %, NSCLC is more frequent and can further be classified into squamous cell carcinoma, adenocarcinoma, large-cell carcinoma, squamous adenocarcinoma, sarcomatoid carcinoma, carcinoid tumor, and salivary gland tumor.

Adenocarcinomas are located peripherally and are the most frequent form of lung cancer in non-smokers. Squamous cell carcinomas and SCLC are mainly located in the central areas of the lung making lung resection for a cure more difficult.

Pulmonary metastases

Tumors spreading via the bloodstream via the vena cava, such as renal cell carcinomas, bone tumors, liver carcinomas, or carcinomas in the head and neck can metastasize to the lung. Lung carcinomas mainly metastasize to the brain, the liver, the adrenal glands, and the bones.

Review Questions

The solutions can be found below the references.

1. Which statement is true concerning the structure of the lung?
   A. The horizontal fissure of the lung is located on the left lung.
   B. The left lung consists of three lobes.
   C. The left lung consists of nine segments.
   D. The hilum of the lung is located on the diaphragmatic face.
   E. The cardiac notch is located on the right lung.

2. How many segments does the middle lobe of the right lung have?
   A. There is no middle lobe on the right lung.
   B. 1
   C. 2
   D. 3
   E. 4

3. Which of the following muscles is not active in inspiration?
   A. Scalene muscles
   B. Diaphragm
   C. External intercostal muscles
   D. Intertransversarii muscles
   E. Subcostal muscle

References


Correct answers: 1C; 2C; 3E

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