The Lungs — Anatomy and Pathology

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Oxygenation of blood and the elimination of carbon dioxide represent the primary function of the lungs. Pulmonary diseases are common and found in every age group. Knowledge of pulmonary anatomy is essential for the analysis of different clinical scenarios. The following article provides an overview of the location, the structure, and the function of the lungs.

Location of the Lungs

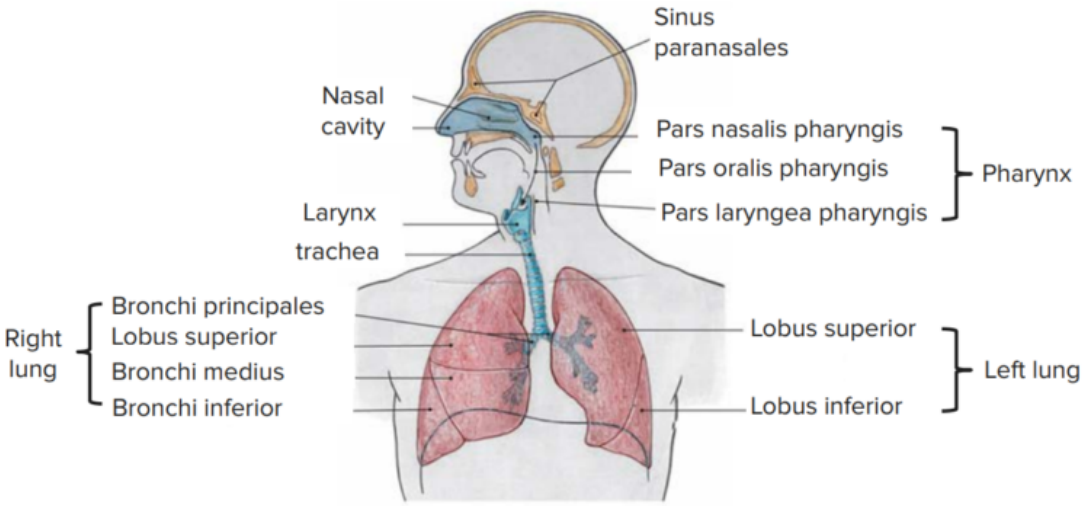
Each pair of lungs completely fills one of the two pleural cavities (cavitas pleuralis). **The pleural cavities are situated on the left and the right sides of the mediastinum**, respectively. The dorsal expansion reaches the thoracic spine. Ventrally, the two pleural cavities are located in front and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

The close connection between the lung and the heart results in the so-called cardiac impression, which in turn leads to the formation of a 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. The other two major body cavities include the abdominal (cavitas abdominalis) and pelvic (cavitas pelvis) cavities.

Pulmonary expansion depends on breathing. Whereas the apex of the lung (apex pulmonalis) always reaches the upper thoracic aperture, the base of the lung (basis

pulmonis) is closely connected to the diaphragm.

Shape and Structure of the Respiratory Tract



Overview of the respiratory tract. Image by Lecturio

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

The remainder of the pulmonary structure is identical. The lung is further divided into apex (apex pulmonis), base (basis pulmonis), surface, and border. The surface is covered with a serous coat, the visceral pleura, and is rose to grey in a healthy individual. Depending on the location and relationship with the thorax, the surface (facies pulmonis) is divided into costal, mediastinal, diaphragmatic, and interlobar surfaces.

The transition from visceral to parietal pleura occurs in the area of mediastinal surface. Thus, a fold appears as the pulmonary ligament in a dissected lung. The pleural cavity (cavitas pleuralis) is present between the two pleural sheets. It is filled with fluid and ensures effortless sliding of the sheets against each other. Also, the negative pressure (-5 cm H_2O) in the pleural cavity holds the lung in place within the pleural cavities and ensures that it remains unfolded. In the absence of this negative pressure, the lungs collapse due to the inherent elasticity of its parenchyma (see pneumothorax).

The pulmonary hilum is located in the middle of the mediastinal surface, also referred to simply as the hilum. The hilum represents the entrance and exit for the bronchi, vessels, lymphatic channels, and pulmonary sympathetic and parasympathetic nerves. 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 surfaces by the inferior border.

Lung segments (segmenta bronchopulmonales)

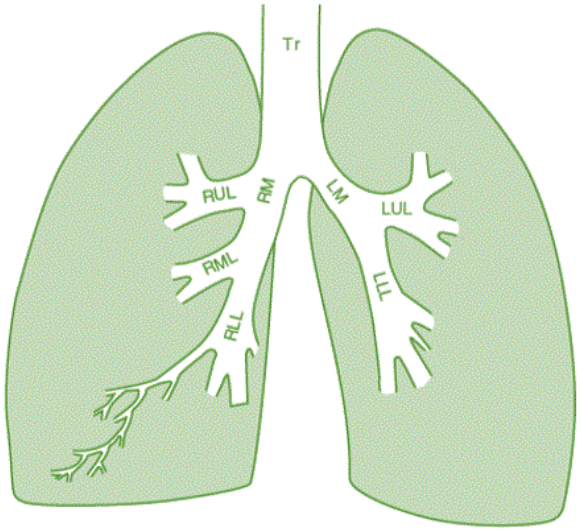
In addition to the distinction between lobes, the individual segments in each lobe can be separated by the bronchial tree. **The center of each segment contains a**

segmental bronchus as well as a segmental branch of the pulmonary artery and vein. Both lungs are subdivided into 10 segments each. Due to the presence of the heart, the left lung carries a cardiac notch (incisura cardiaca). As a result, the tiny segment VII is included in segment VIII.

Right lung	Left lung
Superior lobe • Apical segment (I) • Posterior segment (II) • Anterior segment (III)	Superior lobe • Apico-posterior segment (I + II) • Anterior segment (III) • Superior lingular segment (IV) • Inferior lingular segment (V)
Middle lobe • Lateral segment (IV) • Medial segment (V)	
Inferior lobe • Superior segment (VI) • Medial-basal segment (VII) • Anterior-basal segment (VIII) • Lateral-basal segment (IX) • Posterior-basal segment (X)	Inferior lobe • Superior segment (VI) • Middle-basal segment (VII) • Anterior-basal segment (VIII) • Lateral-basal segment (IX) • Posterior-basal segment (X

Bronchial tree

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



'Bronchial tree' Image created by Lecturio

The main stem, lobar, segmental, subsegmental bronchi, and terminal bronchioles constitute the conducting airway, whereas the respiratory bronchioles, the alveolar ducts, and the alveolar sacs represent the respiratory airway. The structure of larger and smaller airways differs greatly, which plays a substantial role in disease.

Successive branching to form smaller bronchi that are divided further into:

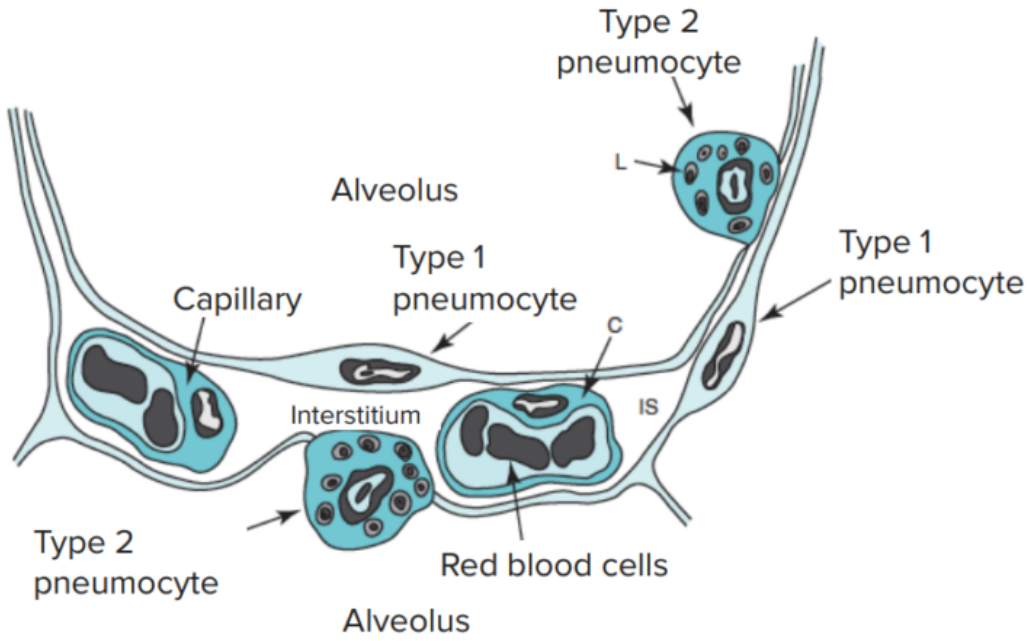
1. Right and left main bronchi
2. Left side
    - Left upper and left lower lobe bronchi. Lingula bronchi divide off left upper lobe bronchus.
3. Right side
    - Right upper and intermedius bronchi. The latter dividing into the right

middle and lower lobe bronchi.

The bronchial wall is **stabilized by cartilaginous plates**, which are lacking in the bronchioles. The tunica media of the bronchioles is instead composed of smooth musculature. Further, the ciliated pseudo-stratified epithelium is changed to a ciliated single-layer prismatic epithelium. The respiratory segment of the bronchial tree starting with the terminal bronchioles does not contain any globlet cells. Instead, alveoli can be found in this portion. The respiratory bronchioles represent the narrowest airways in the lungs, measuring 1/50th inch across.

The alveoli are little hollow cavities with a diameter of 150—500 µm. Two types of pneumocytes (alveolar epithelial cells) 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 rare and secrete a surfactant. The surfactant decreases the surface tension of the alveoli and prevents them from collapse. The overall alveolar surface for gas exchange is 100-120 m^2, roughly the size of a soccer field.



Alveolar/capillary barrier. Image by Lecturio

Lungs: blood supply

Note: In the right hilum, the bronchus and the artery are roughly on the same level, with the artery anterior to the bronchus and the veins located caudally. In the left hilum, artery, bronchus, and vein are aligned on top of each other, with the artery located superior.
The pulmonary hilum represents the vascular entrance and exit in the lung. Depending on the function, the public vessels including pulmonary arteries and veins, which are responsible for gas exchange, can be distinguished from private vessels supplying the lung.

The pulmonary arteries originate in 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 form two pulmonary veins on each side. The branching of the arteries follows the branching of the bronchi, whereas the veins run between the segments, independent of the bronchi.

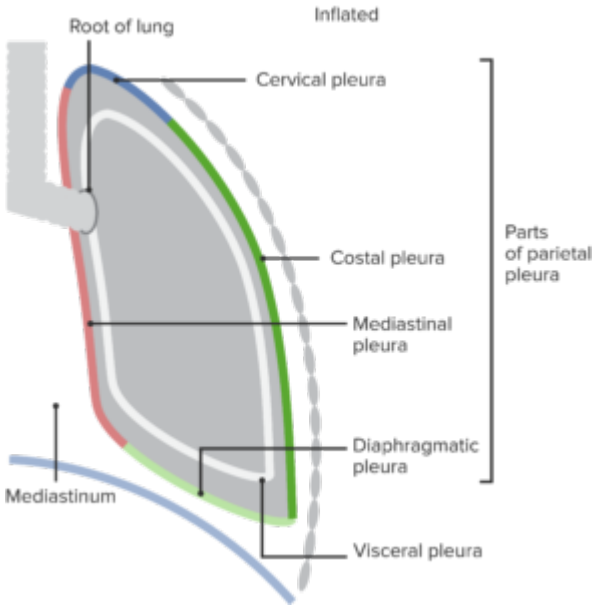
The bronchial arteries supply blood to the bronchi and the pulmonary connective tissue. They originate in the thoracic aorta (and also from the internal thoracic artery, rarely). They traverse the bronchial branches, ending almost at the level of the respiratory bronchioles. They anastomose with the branches of the pulmonary arteries, and together, supply the visceral pleura of the lung.

Much of the oxygenated blood supplied by the bronchial arteries is returned via 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 bed**. This phenomenon 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, they lead to the accessory hemiazygos vein. Each bronchial artery also bears a branch that supplies the esophagus.

Pulmonary Lymphatic Vessels and Nerves

Similar to 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 via the sympathetic trunk. Parasympathetic fibers induce bronchoconstriction, whereas sympathetic fibers cause bronchodilation.



Parietal pleura. Image by Lecturio

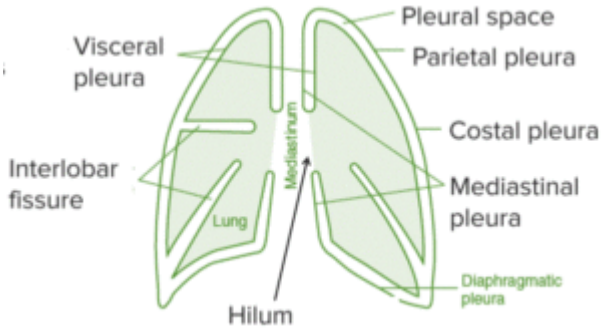
Additionally, the pulmonary plexus receives afferent vegetative fibers, which mostly comprise strain sensors in the bronchial wall. In the event of extreme stretching, these fibers inhibit the respiratory center via the Hering-Breuer reflex. Several nerves ensure sensory innervation of the parietal pleura. The 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.

Pulmonary lymphatic drainage includes superficial and deep systems. The superficial system is drained by the network immediately below the pleura and directly drains into the bronchopulmonary lymph nodes at the hilum. After crossing the junction of the intrapulmonary lymph nodes, they eventually drain into the deep system. The lymph from the bronchopulmonary lymph nodes reaches the superior and inferior tracheobronchial lymph nodes. Finally, it reaches the bronchomediastinal trunk via the paratracheal lymph nodes.

Note: Pulmonary lymphatic drainage is an important route for lung tumor metastasis.

Mechanics of Respiration

A rhythmic change in thoracic diameter occurs during breathing. Under negative pressure in the pleural cavity, the lung alters the thoracic volume. During inspiration, two mechanisms ensure enlargement of pulmonary volume: First, the expansion of the thorax via external intercostal muscles elevates the ribs, and second, the contraction of the diaphragm. The diaphragm is the main muscle used in shallow breathing, and the only muscle active during sleep.



"Pleura" Image created by Lecturio

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

In contrast to inspiration, expiration is mainly a passive process, which is triggered by the elastic recoil forces of the lung and the thorax. However, during forced expiration, muscular activity results in rapid reduction in thoracic diameter.

Muscles affecting inspiration	Muscles affecting expiration
Diaphragm	Subcostal muscle
External intercostal muscles	Internal intercostal muscles
Levatores costarum, intertransversarii	Transversus thoracis
Superior and inferior posterior serratus	
Scalene muscles	

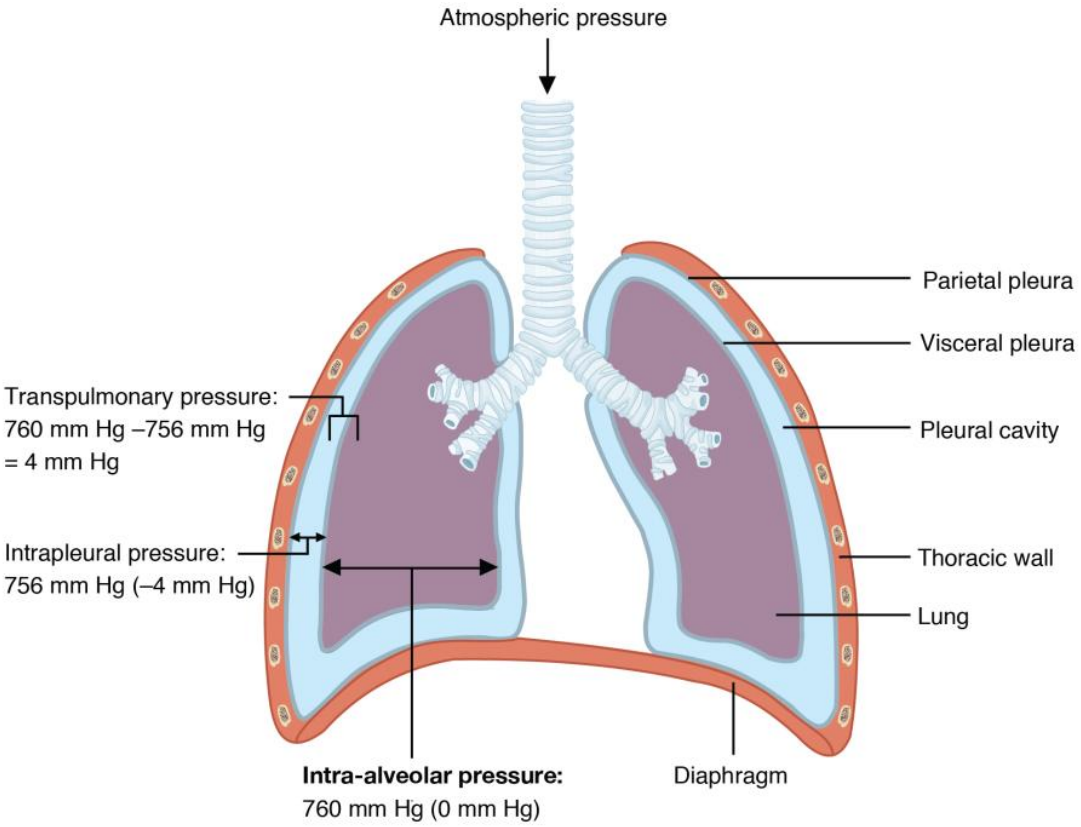


Image: 'Intrapulmonary and Intrapleural Pressure Relationships' by Phil Schatz. License: CC BY 4.0

Pulmonary Examination

Pulmonary examination is a part of the clinical curriculum in medical studies. However, an overview is provided here.

Clinical examination is based on anamnesis

Inspection	Cyanosis? Use of accessory muscles of respiration? Determination of breathing frequency (standard value: 12–15 breaths per minute)
Palpation	Check for thoracic stability (applying pressure on the clavicle cranially on both sides)
Percussion	The lung generates a sonorous sound, whereas liver and spleen produce a dull sound. Thus, the caudal lung edges can be determined.
Auscultation	Auscultation is performed in direct comparison with the opposite side. Vesicular breathing sound is normal, whereas a weak breathing sound points to pleural effusion, pneumothorax, or chronic obstructive bronchitis. Pronounced respiratory sound occurs in patients with pneumonia.
Sputum	Depending on color and consistency, different several diagnoses are possible. Additionally, direct detection of pathogens is possible.

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

Sonography	Imaging of pleural effusion
X-Ray	Graphic presentation of the lung as a dark area. Brighter areas or shadows suggest pathologies. Examination of lung vessels, recesses, and tracheal location and course.
CT Chest	In the pulmonary window, differentiation of solid tumors, lymph node swelling, or pulmonary fibrosis can be made.

Invasive measures such as bronchoalveolar lavage with biopsy is indicated in case of a suspected bronchial carcinoma. Pulmonary function parameters are evaluated via ergospirometry.

Further, laboratory parameters provide important information related to lung function. Blood gas analysis is an important method to analyze oxygen saturation of the arterial and venous blood.

Lung Diseases

Pneumothorax

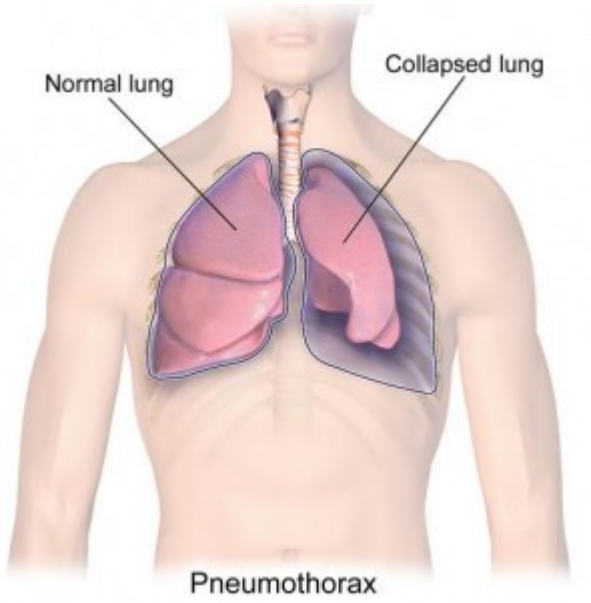


Image: 'Pneumothorax. See a full animation of this medical topic' by BruceBlaus. License: CC BY 3.0

Pneumothorax is defined as the **accumulation of air between the visceral and the parietal pleura**. As a result, the negative pressure in the pleural cavity is lost, which leads to pulmonary collapse on the affected side. A closed pneumothorax lacking connection with the external air can be distinguished from an open pneumothorax.

Depending on the etiology, **pneumothorax can be classified into spontaneous, traumatic, and iatrogenic types**. Spontaneous pneumothorax often occurs in young, asthenic men and is often caused by the rupture of congenital emphysemic bullae just under the pleura. Clinical symptoms of pneumothorax include dyspnea, piercing chest pain on the affected side, and asymmetric motion of the thorax (decreased and trailing motion of the affected side). Tension pneumothorax is a possible complication. In this case, a mediastinal shift occurs toward the healthy side leading to compression of the healthy lung. The increased intrathoracic pressure interferes with the 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 industrialized countries.

Pneumonia can be classified into several types:

- Pathologically and anatomically: localization and expansion
- Etiology: infectious, physicalchemical pollutants, and circulatory defects

- Clinical: primary/secondary pneumonia, acute/chronic pneumonia
- Point of origin: community-acquired pneumonia (CAP) or hospital-acquired pneumonia (HAP) (earliest 48–72 h after hospitalization)

Bronchial asthma

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

Chronic obstructive pulmonary disease (COPD)

Similar to asthma, COPD is an obstructive lung disease. However, the **obstruction is multifactorial**. It is triggered by ruptured alveoli and formation of air sacs called bullae, which compress the normal lung tissue. It is characterized by chronic bronchitis, and overproduction of mucous and bronchoconstriction (due to the overreaction of the airways as in asthma). The obstruction occurs progressively over several years and is associated with chronic inflammation of the lung as a reaction to chemical noxae such as tar from the smoke.

Chronic bronchitis

According to the World Health Organization, chronic bronchitis exists if a patient **manifest cough with sputum every day for at least three months each year over a period of 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 such as inorganic or organic dust and systemic diseases including sarcoidosis or collagenosis. Unlike COPD, which is associated with increased lung volume, pulmonary fibrosis is associated with decreased lung volume.

Bronchial carcinoma: lung cancer

Bronchial carcinoma is the **most frequent cause of death due to cancer** in men and the third most frequent cause of death in women (after breast and colon cancers). The main risk factor is smoking tobacco, which accounts for 85% of bronchial carcinomas. The 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 daily by the number of years the person has smoked.

Other risk factors include occupational carcinogens. Asbestos exposure, which accounts for > 90% of all compensated lung cancer cases, is the most important risk factor. In addition to carcinogens, genetic predisposition and other risk factors such as lung scars play a key role in the pathophysiology of bronchial carcinoma. Histologically, bronchial carcinomas are classified into small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC). Constituting 85% of all cases of lung cancer, NSCLC is more frequent and further classified into squamous cell carcinoma, adenocarcinoma, large-cell carcinoma, squamous adenocarcinoma, sarcomatoid carcinoma, carcinoid tumor, and salivary gland

tumors.

Adenocarcinomas are located peripherally and are the most frequent form of lung cancer in non-smokers. Squamous cell carcinomas and SCLC are mainly localized to the central areas of the lung, which interfere with pulmonary resection.

Pulmonary metastases

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

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Notes