

Lungs (lower respiratory tract)

Paired elastic structures enclosed in the thoracic cage, which is an airtight chamber with distensible walls

Ventilation requires movement of the walls of the thoracic cage and of its floor, the diaphragm.

Inspiration (1st third of respiratory cycle): chest capacity is ↑, lung & intrapleural pressure decreases and air flows in through the trachea and bronchi inflating the lungs

Expiration (2nd two thirds of respiratory cycle): chest wall and diaphragm return to previous positions, lungs recoil and force the air out through bronchi and trachea.

Inspiratory phase normally requires energy. Expiratory phase is normally passive, requiring very little energy.

With respiratory diseases, such as COPD, expiration requires energy.

The lungs and wall of the thorax are lined with a serous membrane called the **pleura**.

Visceral pleura covers the lungs; parietal pleura lines the thorax.

Between them is a small amount of pleural fluid.

The pleura and the pleural fluid lubricate the lungs and thorax and permit smooth movement of the lungs in the thoracic cavity.

Each lung is divided into **lobes**, 3 in the right, 2 in the left.

Each lobe is further subdivided into two to five segments separated by fissures, which are extensions of the pleura.

There are several divisions of the **bronchi** within each lobe of the lung.

The 1st division is the **lobar bronchi** (three in the right lung and two in the left lung).

Lobar bronchi divide into segmental bronchi (10 on the right and 8 on the left)

These are the structures identified when choosing the most effective postural drainage position for a given patient.

Segmental bronchi then divide into **subsegmental bronchi**. They are surrounded by connective tissue that contains arteries, lymphatics, and nerves.

The subsegmental bronchi branch into **bronchioles**, which have no cartilage, their patency depends on elastic recoil of surrounding smooth muscle and alveolar pressure.

The bronchioles contain submucosal glands, which produce mucus that covers the inside lining of the airways.

Both the bronchi and bronchioles are also lined with cells that are covered with cilia.

Cilia create a constant whipping motion that propels mucus and foreign substances away from the lungs toward the larynx.

Bronchioles branch into **terminal bronchioles**, which do not have mucus glands or cilia. At this point the conducting airways end.

Terminal bronchioles then become **respiratory bronchioles**. They're the transitional passageways bt the conducting airways and the gas exchange airways. Up to this point, the conducting airways contain about 150 mL of air in the tracheobronchial tree that does not participate in gas exchange; called physiologic dead space.

The respiratory bronchioles then lead into **alveolar ducts** and **alveolar sacs** and then **alveoli**. Oxygen and carbon dioxide exchange takes place in the alveoli.

The lung is made up of about 300 million alveoli, which are arranged in clusters of 15 to 20.

There are three types of alveolar cells.

Type I alveolar cells are epithelial cells that form the alveolar walls.

Type II alveolar secrete surfactant (a phospholipid) that lines the inner surface and prevents alveolar collapse.

Type III alveolar cell macrophages are large phagocytic cells that ingest foreign matter (eg, mucus, bacteria) and act as an important defense mechanism.

The **mucociliary escalator** consists of the ciliary beat that wafts mucous (made by columnar epithelial cells in the respiratory epithelium and the bronchial glands) up the airways. It is responsible for removing particles that sediment out in the airways as a result of the branching of the tracheobronchial tree (filtering mechanism).

Macrophages in the alveolar spaces phagocytose particles and infectious agents that are deposited in the alveoli.

Immune system *Bronchial associated lymphoid tissue* (BALT). The contents of macrophages that migrate to the BALT are processed for production of secretory IgA which prevents pathogens from entering the body.

The **mediastinum** is in the middle of the thorax, between the pleural sacs that contain the two lungs. It extends from the sternum to the vertebral column and contains all the thoracic tissue outside the lungs (heart, thymus, certain large blood vessels [ie, aorta, vena cava], and esophagus).

Respiratory Physiology: cells of the body derive energy from the oxidation of carbs, fats, and proteins. Like any type of combustion, this process requires O₂. Certain vital tissues, such as those of the brain and the heart, cannot survive for long without a continuous supply of oxygen. Oxidation produces CO₂ and it must be removed to prevent buildup of acid waste products.

The respiratory system performs life-sustaining processes such as oxygen transport, respiration and ventilation, and gas exchange.

Oxygen Transport

Oxygen diffuses from the capillary to the interstitial fluid then thru the membrane of tissue cells, where mitochondria use it for cellular respiration.

The movement of carbon dioxide occurs by diffusion in the opposite direction—from cell to blood.

Respiration process of gas exchange between the atmosphere and the blood and between the blood and cells of the body is called respiration

After these tissue-capillary exchanges, blood travels to pulmonary circulation via the venules→veins→vena cava→R atrium→R ventricle→pulmonary artery.

O₂ concentration in blood within the capillaries of the lungs is lower than in the alveoli. CO₂ concentration is higher than in the alveoli.

This concentration gradient allows O₂ to diffuse into the capillaries from the alveoli and CO₂ to diffuse from the capillary to the alveoli.

Ventilation continually replenishes O₂ and removes CO₂ from the airways and lungs.

Ventilation requires movement of the walls of the thoracic cage and of its floor, the diaphragm.

On inspiration, air flows from the environment via the conducting and transitional airways into the alveoli. During expiration, alveolar gas travels in the reverse.

Physical factors that govern air flow in both directions are referred to as the mechanics of ventilation:

Air Pressure Variances - Air flows from a region of higher pressure to a region of lower pressure.

Inspiration (1st third of respiratory cycle): chest capacity is increased (by muscles of respiration) and lung pressure becomes lower than atmospheric pressure.

Air flows in through the trachea and bronchi inflating the lungs.

Expiration (2nd two thirds of respiratory cycle): respiratory muscles relax, the lungs recoil (subatmospheric intrapleural pressure helps prevent them from collapsing completely) reducing capacity and lung pressure is higher than atmospheric pressure.

Air (alveolar gas) is forced out of the lungs.

Inspiratory phase normally requires E. Expiratory phase is normally passive, requiring very little E. W/ respiratory disease, such as COPD, expiration requires E.

Airway Resistance - determined chiefly by the radius or size of the airway through which the air is flowing.

Anything that changes the bronchial diameter or width affects airway resistance and alters the rate of air flow for a given pressure gradient during respiration

With increased resistance, greater-than-normal respiratory effort is required to achieve normal levels of ventilation.

Causes of Increased Airway Resistance:

Contraction of bronchial smooth muscle—as in asthma

Thickening of bronchial mucosa—as in chronic bronchitis

Obstruction of the airway—by mucus, a tumor, or a foreign body

Loss of lung elasticity—as in emphysema (connective tissue encircles the airways)

Compliance/distensibility - is the elasticity & expandability of the lungs and thoracic structures.

Compliance allows the lung volume to increase when the difference in pressure between the atmosphere and thoracic cavity (pressure gradient) causes air to flow in.

Factors that determine lung compliance:

- surface tension of the alveoli (normally low w/presence of surfactant) (w/out surfactant restricts expansion or causes collapse)
- the connective tissue (ie, collagen and elastin) of the lungs.

Compliance is determined by examining the volume–pressure relationship in the lungs and the thorax.

Compliance is **normal** - 1.0 L/cm H₂O - if the lungs and thorax easily stretch and distend when pressure is applied.

Increased compliance occurs if the lungs have lost their elasticity and the thorax is overdistended (eg, in emphysema).

Decreased compliance occurs if the lungs and thorax are “stiff” as in: morbid obesity, pneumothorax, hemothorax, pleural effusion, pulmonary edema, atelectasis, pulmonary fibrosis, and ARDS (acute respiratory distress syndrome)

Measurement of compliance is one method used to assess the progression and improvement in patients with ARDS. Lungs with decreased compliance require greater-than-normal energy expenditure by the patient to achieve normal levels of ventilation. Compliance is usually measured under static conditions.

Lung Volumes and Capacities Lung function, which reflects the mechanics of ventilation, is viewed in terms of lung volumes and lung capacities.

Lung volumes are categorized as tidal vol., inspiratory reserve vol., expiratory reserve vol., & residual vol.

Lung capacity is evaluated in terms of vital cap., inspiratory cap., functional residual cap., & total lung cap.

Term	Symbol	Description	Normal Value*	Significance
Lung Volumes				
Tidal volume	VT or TV	The volume of air inhaled and exhaled with each breath	500 mL or 510 mL/kg	The tidal volume may not vary even with severe disease.,
Inspiratory reserve volume	IRV	The maximum volume of air that can be inhaled after a normal inhalation	3000 mL	
Expiratory reserve volume	ERV	The maximum volume of air that can be exhaled forcibly after a normal exhalation	1100 mL	Expiratory reserve volume is decreased with restrictive conditions, such as obesity, ascites, pregnancy.
Residual volume	RV	The volume of air remaining in the lungs after a maximum exhalation	1200 mL	Residual volume may be increased with obstructive disease.
Lung Capacities				
Vital capacity	VC	The maximum volume of air exhaled from the point of maximum inspiration $VC = TV + IRV + ERV$	4600 mL	A decrease in vital capacity may be found in neuromuscular disease, generalized fatigue, atelectasis, pulmonary edema, COPD, and obesity.
Inspiratory capacity	IC	The maximum volume of air inhaled after normal expiration $IC = TV + IRV$	3500 mL	A decrease in inspiratory capacity may indicate restrictive disease. May also be decreased in obesity.
Functional residual capacity	FRC	The volume of air remaining in the lungs after a normal expiration $FRV = ERV + RV$	2300 mL	Functional residual capacity may be increased with COPD and decreased in ARDS and obesity.
Total lung capacity	TLC	The volume of air in the lungs after a maximum inspiration $TLC = TV + IRV + ERV + RV$	5800 mL	Total lung capacity may be decreased with restrictive disease (atelectasis, pneumonia) and increased in COPD.

*Values for healthy men; women are 2025% less.

ARDS, acute respiratory distress syndrome; COPD, chronic obstructed pulmonary disease.

Table 21-8 Pulmonary Function Tests

Term Used	Symbol	Description	Remarks
Forced vital capacity	FVC	Vital capacity performed with a maximally forced expiratory effort	Forced vital capacity is often reduced in COPD because of air trapping.
Forced expiratory volume (qualified by subscript indicating the time interval in seconds)	FEV _t (usually FEV ₁)	Volume of air exhaled in the specified time during the performance of forced vital capacity; FEV ₁ is volume exhaled in 1 second	A valuable clue to the severity of the expiratory airway obstruction
Ratio of timed forced expiratory volume to forced vital capacity	FEV _t /FVC%, usually FEV ₁ /FVC%	FEV _t expressed as a percentage of the forced vital capacity	Another way of expressing the presence or absence of airway obstruction
Forced expiratory flow	FEF ₂₀₀₋₁₂₀₀	Mean forced expiratory flow between 200 and 1200 mL of the FVC	An indicator of large airway obstruction
Forced midexpiratory flow	FEF _{25-75%}	Mean forced expiratory flow during the middle half of the FVC	Slowed in small airway obstruction
Forced end expiratory flow	FEF _{75-85%}	Mean forced expiratory flow during the terminal portion of the FVC	Slowed in obstruction of smallest airways
Maximal voluntary ventilation	MVV	Volume of air expired in a specified period (12seconds) during repetitive maximal effort	An important factor in exercise tolerance