Respiratory System (Peer reviewed and edited)

Slide 1: Respiratory System

Slide 2: Functions

Functions of respiratory system include gas exchange, communication, olfaction, and pH regulation. **Gas exchange** refers to the exchange of oxygen and carbon dioxide between blood and air. The respiratory system can also facilitate speech and other vocalization thus allowing for **communication**. **Olfaction** or smell, is the ability to detect airborne chemicals (odors). Since the respiratory system is able to control the carbon dioxide levels in blood, this also allows it help to **regulate blood pH** – we will cover this in more details in a later slide.

Slide 3: Nose and Nasal Cavity

The respiratory system has multiple organs, we will begin with the nose and nasal cavity.

The nose functions to warm, cleanse, and humidify the air. It also detects odors and amplifies the voice by acting as a resonance chamber. The nose also provides protection. Within the nose we can find a number of structures. The **nostrils** (or nares), are the openings into the nose. The facial portion of the nose is formed by the nasal bone and hyaline cartilage. The internal chambers of the nose are called the **nasal cavity**. This space is divided by the **nasal septum**. The nasal cavity contains **nasal conchae**, these are tissue folds containing blood vessels (that warms incoming air) and mucous (that moistens the air.) Each nasal conchae is separated by a **nasal meatus**, these are passageways for air. The nasal cavity is lined with mucous membranes that contain pseudostratified columnar epithelium and cilia.

Slide 4: Pharynx

Following the nasal cavity is the pharynx. The pharynx functions in carrying air between the nasal cavity and the larynx. It also contain tonsils that function in immunity to provide protection. The pharynx has three portions: nasopharynx, oropharynx, and laryngopharynx. The **nasopharynx**, similar to the nasal cavity, is lined with ciliated pseudostratified columnar epithelium thus it is a passageway for air. The **oropharynx** is lined with stratified squamous epithelium (which is thicker and can handle abrasion) therefore it is a passageway for air and food. The **laryngopharynx** is lined with stratified squamous epithelium therefore it is a passageway for air and food.

Slide 5: Larynx “Voice Box”

Following the pharynx is the larynx. The larynx functions in carrying air between the pharynx and trachea. Additional functions of the larynx include sound production and preventing food from entering into the trachea. The airway surrounded by the larynx is referred to as the glottis. The larynx contains: vestibular folds, vocal cords, and several cartilages. The **vestibular folds** of the larynx are muscles that protect the airway by preventing food from entering into the trachea. The **vocal cords** are muscles that produce sound. The larynx has several cartilages, there are

three in particular that you should know: epiglottis, thyroid cartilage, and cricoid cartilage. The **epiglottis** is the uppermost portion and contains elastic cartilage. This structure is similar in function to the vestibular folds in that it also prevents food from entering into the glottis by directing the movement of air (into the glottis) and ingested materials (into the esophagus.) The **thyroid cartilage** (also known as the Adam's apple) is the middle portion and looks like a shield. This structure contains hyaline cartilage and surrounds the vocal cords. The **cricoid cartilage** is the bottom portion and contains hyaline cartilage. It connects the larynx to trachea. The larynx is lined with ciliated pseudostratified columnar epithelium.

Slide 6: Trachea

The trachea is a physical connection between the larynx and bronchial tree. The trachea is a rigid tube supported by C-shaped rings of hyaline cartilage and commonly referred to as the "windpipe". The c-shaped cartilage rings help provide support to the trachea as a passageway for air to the lungs. The trachea is lined with ciliated pseudostratified columnar epithelium. The trachea bifurcates (splits into two) at the distal end to become the right and left main bronchi.

Slide 7: Bronchial Tree

The next set of structures is referred to as the bronchial tree. It is a network of highly branched air tubes that carry air into and out of deep tissues of the lungs. The larger pathways are supported by hyaline cartilage and the smaller pathways are held open by smooth muscle. The branches include: main (primary) bronchi, lobar (secondary) bronchi, segmental (tertiary) bronchi, bronchioles, terminal bronchioles, and respiratory bronchioles. The bronchial tree is lined with ciliated pseudostratified columnar epithelium but become stratified cuboidal as the branches get smaller.

There are two **main bronchi**, a right and left that goes to each lung. These are the largest of the branches that carry air into and out of the lungs. Once in the lung, the main bronchi splits again to go into each lobe of the lung. This branch is referred to as the **lobar bronchi**. The right lung has three lobar bronchi, one each for the superior, middle, and inferior lobes. The left lung has two lobar bronchi, one to the superior and one to the inferior lobe. Once in the lobe, each lobar bronchi will branch a number of times. These branches off of the lobar bronchi are called the **segmental bronchi**. The main, lobar, and segmental bronchi are supported by hyaline cartilage.

Slide 8: Bronchial Tree cont'd

The **bronchioles** are continuations of the segmental bronchi, at this point they lose the supportive cartilage. The bronchioles also transition from skeletal muscle to smooth muscle and ciliated pseudostratified epithelium to ciliated cuboidal. Branching from the bronchioles, are the **terminal bronchioles**. These are the last branches of the air ducts that act solely as an air passageway. They still contain smooth muscle and cilia, however no longer have goblet cells. The terminal bronchioles branches into the **respiratory bronchioles**. In the respiratory bronchioles, we start to lose the smooth muscle and cilia as well. The next structure to follow the respiratory bronchioles lead to the alveolar ducts and alveoli.

Alveoli are microscopic air sacs found on respiratory bronchioles and at the ends of alveolar ducts. There are millions of alveoli in each lung. The alveoli is the main site of gas exchange in the lungs. It is composed of three types of cells: squamous (type 1) alveolar cells, great (type II) alveolar cells, and alveolar macrophages (dust cells). Squamous alveolar cells form the simple squamous epithelium and is crucial for gas exchange as it forms the respiratory membrane along with the endothelium of the blood capillaries. The great alveolar cells produces a fatty fluid (lipoprotein) called **surfactant**. Surfactant prevents the alveoli from sticking to themselves and helps it to re-expand during inhalation. The alveolar macrophage are white blood cells that help to clean dust and bacteria from the alveoli.

The squamous alveolar cell of the alveoli, the endothelium of the blood capillaries, and shared basement membrane form the **respiratory membrane**. These two layers of simple squamous epithelium allow for the gas diffusion back and forth between the alveoli and blood capillaries.

Slide 9: Lungs

The lungs are paired organs that are surrounded by the pleural membrane. They contain the branches of the bronchial tree as discussed in the previous slide. Each lung is divided into lobes; the right lung contains 3 lobes - superior, middle, and inferior and the left lung contains 2 lobes - superior and inferior.

Slide 10: Plurae

The **plurae** are the serous membrane that surrounds the lungs and line the thoracic cavity. The **viscera plura** surrounds the lungs and the **parietal plura** lines the thoracic cavity. The space between these two plurae is referred to as the **pleural cavity**. This cavity contains a small amount of serious fluid. The plurae functions in reducing the friction that occurs during ventilation; it helps to create a pressure gradient for lung expansion during inhalation. The plurae also prevents infections from spreading through the respiratory system.

Slide 11: Ventilation

The process of breathing is referred to as ventilation. Before we can cover ventilation, you will need to understand the composition of air and atmospheric pressure.

Air consists of nitrogen (~78%), oxygen (~21%) & carbon dioxide (~1%). Air also contains trace amounts of other elements and water vapor (the specific percentage depends on humidity)

The force exerted on surfaces by molecules in air is known as **atmospheric pressure.** Total atmospheric pressure is equal to the combined pressures of each component in air. The pressure of each specific component (partial pressure) is directly proportional to its concentration in the mixture. At sea level, atmospheric pressure is 760 mm Hg. This is important to know because molecules move from areas of higher to areas of lower partial pressure – so pay attention to the how the body regulates breathing by changing these pressures.

Slide 12: Ventilation

Ventilation involves inspiration (inhalation) and expiration (exhalation).

Inspiration occurs when you breath in, moving the air into the lungs. This process requires the muscles associated with breathing to contract and pull the thoracic cavity outwards. This results in an increase size (volume) of the thoracic cavity. When the thoracic cavity increases in size the pressure in the lungs decreases. Since the atmospheric pressure outside of the body is higher than inside the lungs, air is forced into the lungs like a vacuum.

Expiration occurs when you breath out, moving the air out of the lungs. This process requires the muscles associated with breathing to relax and push the thoracic cavity inwards. This results in a decrease size (volume) of the thoracic cavity. When the thoracic cavity decreases in size the pressure in the lungs increases. Since the atmospheric pressure outside of the body is lower than inside the lungs, air is forced out of the lungs. Forced expiration uses muscles to rapidly decrease the size of the thoracic cavity to force air out more quickly, this can occur during exercises, singing, coughing, or sneezing.

Slide 13: Gas Exchange

Alveolar gas exchange happens between the alveoli and the blood capillaries that carry deoxygenated blood from the heart. The blood vessels which transitions from the pulmonary arteries to arterioles to capillaries that carry blood from the heart to the lungs is relatively high in CO2 and relatively low in O2. With each inspiration, air is delivered into the lungs and specifically the alveoli. The inspired air is relatively high in O2 and low in CO2.

Due to the partial pressure of oxygen being higher in alveoli than it is in the capillaries, oxygen diffuses across the respiratory membrane from the alveoli into the capillaries. Since the partial pressure of carbon dioxide is higher in capillaries than it is in alveoli, carbon dioxide diffuses across the respiratory membrane from the capillaries into the alveoli.

Click on the link at the bottom of this slide to watch a video on gas exchange.

Slide 14: Gas Exchange

Systemic gas exchange happens throughout the rest of the body tissues and blood vessels. Blood flowing to body tissues through systemic arteries and arterioles have relatively high amounts of oxygen and relatively low amounts of carbon dioxide. Systemic cells have relatively high amounts of CO_2 and relatively low amounts of oxygen due to metabolism (ATP synthesis).

The partial pressure of O_2 is higher in arterial end of systemic capillaries than it is in systemic cells. O_2 diffuses out of the blood in systemic capillaries and enters systemic cells and tissues. The partial pressure of CO_2 is higher in systemic cells and tissues than it is in the arterial ends of systemic capillaries. CO_2 diffuses from systemic cells and tissues into the blood in the systemic capillaries.

Slide 15: Gas Transport

We've discussed how gases are exchanged in the alveoli and remaining body tissues…but how are the gases transported to these sites and throughout the entire body?

Oxygen is mostly transported by the hemoglobin found in red blood cells. A small amount is transported as a dissolved gas in plasma.

Carbon dioxide is transported mainly by bicarbonate ions. The carbon dioxide that enters blood combines with water to form carbonic acid which dissociates and becomes bicarbonate and hydrogen ions. The bicarbonate is then transported through the blood vessels to the lungs where it combines with hydrogen to form carbonic acid which then dissociates into carbon dioxide and water. The carbon dioxide travels across the respiratory membrane from the capillary into the alveoli to be expelled through expiration. The water remains in the plasma. Because of this reaction the amount of CO2 in blood directly influences hydrogen ion levels in blood, thus pH. By facilitating the removal of CO2, the respiratory system helps regulate blood pH. CO2 can also be transported on the globin chains of the hemoglobin found in red blood cells or as a dissolved gas in plasma.

Slide 16: Neural Control of Breathing

A few points about how our breathing is controlled. The exact mechanism for setting the rhythm of respiration remains unknown. Breathing depends on repetitive stimuli of skeletal muscles from brain. Neurons in the medulla oblongata and pons control the unconscious breathing. While voluntary control is provided by the motor cortex.

Slide 17: Brainstem Respiratory Centers

The automatic, unconscious cycle of breathing is controlled by three pairs of respiratory centers in the reticular formation of the medulla oblongata and the pons.

The medullary rhythmicity center is found in the medulla oblongata and has two groups. The ventral respiratory group (VRG) sets the rhythm of breathing, how often you are inhaling. The dorsal respiratory group (DRG) also works on inspiration, in that it modifies the rate to adapt to varying conditions.

The pneumotaxic center is found in the pons. It regulates the shift from inspiration to expiration in quiet breathing.