The Respiratory System

A Brief Overview
Although we associate the respiratory system with breathing and gas exchange (oxygen, carbon dioxide), it actually has a number of different functions.

The two primary functions of the respiratory system are necessary for life. First, the respiratory system allows the exchange of gases (oxygen and carbon dioxide) between the environment and the blood: oxygen is brought into the blood and carbon dioxide is removed. Second, the respiratory system is the main way that blood pH (acidity) is controlled. Carbon dioxide dissolves in the blood to form an acid so if the blood is too acidic, we will breath faster and deeper to remove more carbon dioxide. If the blood isn’t acidic enough, we will breath slower to keep more carbon dioxide.

The secondary functions of the respiratory system are not necessary for life. First, the movement of air contributes to voice production. We produce speech by vibrating air passing through a part of the respiratory tract called the larynx. Second, our sense of smell relies on detecting chemicals called odorants in the air that passes through our nasal cavity.
Respiratory Anatomy

- **Air passages:**
  - Nasal cavity
  - Pharynx (throat)
    - Tonsils
  - Larynx
    - Epiglottis
  - Trachea
  - Bronchi

Before gases can be exchanged, the air has to be taken to the lungs. There are several hollow organs that move air from the outside world deep into the lungs.

First, air that is inhaled through the nares (nostrils) enters the **nasal cavity**. In the nasal cavity, we can detect odorants and perceive smells. The air passes from the nasal cavity into the **pharynx** (the throat). The entrance to the throat is surrounded by a ring of six **tonsils**, which protect the body from infection by trapping and destroying bacteria in the air we breathe.

Air passes from the pharynx down into the **larynx**, which about midway down your neck. The larynx has two jobs: 1) it houses the vocal cords, which vibrate to produce our voice (this is why the larynx is sometimes called the “voicebox.”) 2) It routes food into the esophagus (toward the stomach) and air into the trachea (toward the lungs). The larynx does this by rising when we swallow and pressing against a flap of cartilage called the **epiglottis**. This closes off the trachea, making sure that swallowed food goes only into the esophagus.

The **trachea** is the windpipe. It is a firm cartilage-lined tube that carries air (only air, no food or liquid) down into the lungs. At its end, the trachea splits into left and right **bronchi**, which enter the lungs themselves.
While the air is moving through all of these hollow organs, it is changed in three very important ways. First, the air is warmed by our body heat. In addition, most of the respiratory passages are lined with cells called *goblet cells* that secrete sticky, wet mucous onto the walls of the organs. The mucous moistens the air as it travels on its way to the lungs, and it also traps much of the dust, dirt, and bacteria that would otherwise foul the lungs.

So, in short, air that reaches the lungs is warmer, moister, and cleaner than the air that entered the nasal cavity.
The body’s two lungs are located in the thoracic cavity (chest cavity) and take up most of the space there. The lungs are pretty big – the base (wide end) of each lung rests on a large muscle called the diaphragm at the bottom of the rib cage while the apex (pointier end) protrudes all the way up to the area of the collarbone.

As the bronchi enter the lungs, the branch many times into smaller and smaller air passageways. The smallest of the air passageways are called bronchioles, which end in tiny round sacs called alveoli. The alveoli are the only place in the respiratory system where materials are exchanged between the air and the blood. The rest of the respiratory system is just “pipes” that move air.

In the alveoli, gases diffuse naturally across the alveoli walls into the blood (oxygen) or out of the blood (carbon dioxide).
The word **ventilation** refers to breathing and it has two phases: **inspiration** means breathing in, or inhaling, while **expiration** means breathing out, or exhaling.

Ventilation involves two sets of muscles. First the **diaphragm** is a large muscle that is attached to the bottom of the ribcage and stretches all the way across the body (front-to-back) like the skin of a drum. Normally, the diaphragm is domed like a parachute, but when it contracts, it pulls down and flattens out, making the thoracic cavity larger. A second set of muscles, the **external intercostal muscles**, are attached to the fronts of the ribs and can pull the chest cavity out and up, which also makes it larger.

During inspiration, the diaphragm and external intercostal muscles contract. This makes the thoracic cavity larger. The walls of the lungs are pulled apart and air is “sucked” into the lungs. During expiration, the diaphragm and external intercostal muscles just passively relax. The chest cavity naturally returns to its original size, which squeezes the lungs and pushes the air, now with less oxygen but more carbon dioxide, out.
Respiratory Physiology

- **Pulmonary Volumes**
  - Tidal volume
  - Inspiratory reserve volume
  - Expiratory reserve volume
  - Residual volume

- **Vital capacity:**
  - TV + IRV + ERV

There are several ways to look at the amount of air the lungs can hold or move.
- A person’s *tidal volume* is the amount of air they move during a normal, everyday breath.
- The *inspiratory reserve volume* is the amount of air you can suck into the lungs after you have completed a normal inspiration. When the big bad wolf “huffed and puffed,” he was filling up his inspiratory reserve volume.
- The *expiratory reserve volume* is the amount of air you can force out of the lungs after a normal expiration. You may get a little lightheaded if you try to demonstrate this!
- Although you can force a lot of air out of your lungs, you can never get it all out. The *residual volume* is the amount of air that is still in the lungs, even after your blow as much out as possible. Since the lungs always have a residual volume of air in them, the walls of the lungs will never touch. Good thing! If they did, they might stick together and collapse the lung.

The *vital capacity* is the total amount of air that can possibly be exhaled by a person. When the wolf “huffed and puffed and blew the house in,” he was blowing out his vital capacity. It is the tidal volume, plus the inspiratory reserve volume, plus the expiratory reserve volume. To demonstrate this, take as deep a breath as you can, then blow out as much air as you can.
Respiratory Physiology

• **Gas exchange**
  • Diffusion

• **Gas transport**
  • **Oxygen**
    • Hemoglobin in RBCs
  • **Carbon dioxide**
    • Mostly carbonic acid

Remember that gases are only exchanged between the air and blood in the alveoli of the lungs. The gas exchange is a natural, passive process that doesn’t require any energy or effort. Since the air is high in oxygen and the blood is low in oxygen, the oxygen naturally diffuses from the air to the blood. Since the blood is low in carbon dioxide and the blood coming back from the body is high in carbon dioxide, carbon dioxide naturally diffuses from the blood to the air.
Respiratory Physiology

- Control of breathing
  - Most important: carbon dioxide in blood!!!
  - Oxygen
  - Neural factors

Although it might seem to be common sense that blood oxygen levels control how hard and fast we breathe, that's not the case at all. In reality, a part of our brain called the medulla oblongata constantly monitors the amount of carbon dioxide in the blood. As the blood's level of carbon dioxide rises, the brain makes us breathe deeper and faster to get rid of the excess.

Oxygen does play a role in controlling breathing, but only if blood oxygen levels are very low.

In addition, other parts of the brain have some control over our breathing. For example, you can hold your breath for a short time or speed up your own breathing. During times of emotional stress, or when preparing for exercise, your breathing rate will increase, too.