There are few similarities between horses and automobiles, but in a manner of speaking, the horse's circulatory and respiratory systems constitute its engine. The food a horse consumes is its fuel. The fuel is converted into nutritional energy that powers the muscles. The respiratory system provides oxygen to facilitate metabolism, and the cardiovascular or circulatory system delivers the oxygen and nutrients to tissues as well as carrying off waste products that are produced when the "engine" is running.

We'll take a close look at these two systems and the manner in which they function.

**Respiratory System**

The purpose of the respiratory system can be stated simply and succinctly: It functions to exchange oxygen and carbon dioxide. Oxygen is inspired for use by the tissues, and carbon dioxide (CO2) is exhaled as a waste product.

The amount of oxygen required and the volume of CO2 produced varies with the level of exercise. During intense exercise, the tissues require a great deal more oxygen than when the horse is at rest, and strenuous exercise, of course, means more CO2 must be removed. To accomplish all that is required during exercise involves an increased respiration rate.

Before we get involved with that, let's take a look at how air is inspired and processed by the equine respiratory system.

Air passes through the nostrils and along a lengthy nasal cavity, then it passes over the larynx and pharynx. After passing through the trachea, the inspired air arrives at the bronchial trees within the lungs. Gas exchange occurs in the alveoli, where the circulatory system receives oxygen and delivers it to tissues throughout the body, along with nutrients absorbed from the digestive system.
The air then passes over the larynx and pharynx. When everything is working as it should, there is a smooth flow of air or food through this general area. When the horse swallows food, the pharynx and soft palate are positioned so food is moved into the esophagus rather than the trachea. When the horse is breathing, but not swallowing, there is an open channel into the trachea. The larynx also functions as barrier to prevent food from entering the trachea.

After passing through the trachea, the inspired air arrives at the bronchial trees within the lungs. The conducting airways of the bronchial tree divide into smaller and smaller bronchi. When cartilaginous plates are no longer present in the walls of the smallest bronchi, the airway is termed a bronchiole. The bronchioles, in turn, join with the alveolar ducts that terminate in the functional units of the lungs where gas exchange actually occurs--the alveoli.

The alveoli are small out-pouchings along the walls of the alveolar sacs and alveolar ducts. It is through the walls of these tiny pouches that gas exchange takes place. The exchange occurs between air within alveoli and blood within the capillaries in the alveolar walls.

The alveoli have very thin walls between oxygen-laden air in the lungs and the blood vessels that contain red blood cells that will carry oxygen to tissues throughout the body. It is at this point that the two systems--respiratory and circulatory--join forces. The oxygen binds to hemoglobin for transport by the circulatory system to the tissues. The oxygen-laden red blood cells carry their valuable product to the tissues, where cell metabolism occurs and CO2 is produced. The blood then heads back to the lungs via the veins, but this time it is loaded with more CO2 than oxygen.

How much oxygen is taken in and how much CO2 is expired depends on the amount of exercise. When the horse is at rest, its respiration rate is very low, with the animal sometimes taking 10 to 14 breaths or fewer per minute.

However, when strenuous exercise is involved, the respiration rate increases dramatically as the lungs move into high gear to satisfy the burgeoning demand for oxygen throughout the body. There also is a pronounced change in the effort involved. When the horse breathes while at rest, very little effort is required. However, when it breathes rapidly to satisfy the increasing demand for oxygen, it is another matter. Now, the intercostal (situated between the ribs) muscles and diaphragm are called on to expand the chest, which, in turn, allows for expansion of the lungs. The lung expansion allows for a greater quantity of air to be inspired. The amount of air inspired and expired with each breath is called tidal volume. As indicated, the number of breaths taken per minute is referred to as respiration rate or respiration frequency. Still another term involved is minute volume. Simply put, this is the amount of air inspired and expired in one minute.

The change in minute volume during exercise can be dramatic. During rest, for example, the minute volume for a normal horse might be 150 liters per minute. During a fast gallop, this can quickly increase to 1,500 liters per minute. Because minute volume is a combination of
respiration rate and tidal volume, a horse can increase it either by breathing faster, breathing more deeply, or both.

However, there is a limit to the minute volume that can be achieved during maximal exercise. When the horse is at a maximum exercise level—a heart rate that has reached 200 beats per minute and beyond—the blood leaving the lungs might not be carrying enough oxygen to adequately service the tissues. This condition is referred to as arterial hypoxia. Generally speaking, the respiratory system can deliver the required oxygen—at least for a limited time—when the heart rate is 180 beats per minute or less. When the heart rate is beyond that point, it is only a matter of time before the system will begin to falter.

Limiting Problems

Unfortunately, there are circumstances other than exercise that affect the amount of oxygen that can be utilized.

RAO One of the most troublesome conditions that affect respiration is recurrent airway obstruction, or heaves, formerly known as chronic obstructive pulmonary disease (COPD). Basically, RAO is inflammation of the small bronchioles in the lungs. When RAO strikes, the lower airway system is unable to function effectively. The inflammation serves to develop obstructions within the delicate airways and air is unable to flow freely. As the condition worsens, more and more physical effort is involved when the horse inspires air.

Recurrent airway obstruction can be caused by a number of conditions, with dusty hay and a dusty environment often being implicated.

EIPH Still another condition is known as exercise-induced pulmonary hemorrhage (EIPH). Simply put, this condition involves the presence of blood in the respiratory tract during exercise. Horses with this condition often are referred to as "bleeders." The condition shows up in racehorses more than in any other discipline, although it can be found after any strenuous exercise.

Roaring The larynx, which plays an important role in the eating/breathing process, also can cause problems. In some horses, the larynx does not open completely when the horse is breathing. In addition to limiting the amount of air inspired, this condition also can result in noisy air intake, often referred to as "roaring." The technical term is laryngeal hemiplegia (or left laryngeal hemiplegia since it occurs most often on the horse's left side, the exact cause for this is unknown).

There are many other problems that can affect the intake and exchange of air in the horse's respiratory system. The bottom line is that healthy lungs and airways are important, especially to the exercising horse.

Cardiovascular System

We turn now to the cardiovascular or circulatory system of the horse. This consists of blood, blood vessels through which the blood flows, and the heart that provides power for the flow of blood.
The normal adult horse weighing 1,000 pounds will have about 13.2 gallons of blood in its body. The blood is composed of red blood cells (erythrocytes), white blood cells (leukocytes), platelets, and liquid (plasma).

As indicated in the discussion on the respiratory system, the red blood cells have an iron-containing protein known as hemoglobin, which binds oxygen for transportation to the tissues. This is the primary function of the red blood cells. The main role for the white blood cells is to work with the rest of the immune system to defend against bacterial invasions. Platelets function in the blood clotting process.

The key element in the entire vascular system, of course, is the heart, whose job it is to pump blood through the circulatory system. The flow of blood is through a system of blood vessels. When blood is pumped from the heart, it travels through a network of arteries, arterioles, capillaries, and venules. After completing that part of the route in the equine body, it is returned to the heart through large veins.

The heart itself is divided into two halves. Each of the halves of this large, muscular organ (3.3-8.8 pounds) has two chambers—the atrium and ventricle. It works like this: The right atrium and ventricle pump blood into the lungs, where it is loaded with oxygen. The oxygen-laden blood returns to the left side of the heart, where the left atrium and ventricle then pump it throughout the body.

Thus, it becomes obvious that the prime function of the circulatory system is to deliver oxygen to tissues throughout the body, along with nutrients absorbed from the digestive system. It also acts as something of a garbage disposal by delivering the end products of cellular metabolism to the lungs and kidneys for removal.

The circulatory system also fills another, less spectacular role by helping to dissipate heat by diverting blood toward the skin surface during exercise.
Earlier, we pointed out that when exercise levels increase, so does the horse's respiration rate. The same is true for the circulatory system. As demands on the body are increased, the horse's heart rate goes up so that more oxygen and nutrients can be delivered to the tissues. The heart rate, quite simply, is the number of times a horse's heart beats during a minute.

When a horse is at rest, his heart rate might be as low as 25 beats per minute. When he is exercising at the maximal rate, the heart rate can shoot as high as 250 beats per minute. Obviously, the horse can sustain this type of effort for only a short period of time. When the heart is beating at about 250 beats per minute, the cardiac output is at the rate of approximately 55 gallons of blood being pumped by the heart per minute.

Another term utilized in discussions of the cardiovascular system is stroke volume. This is the amount of blood pumped with each beat of the heart. When we multiply heart rate by stroke volume, we come up with another term--cardiac output. This is the total amount of blood pumped by the heart in a given time frame.

The metabolic activity of the horse determines blood flow. The higher the activity level, the higher the blood flow. The reason the heart rate increases with movement is that when a horse makes the transition from rest to exercise, heavy demands are made on limb muscles as they increase locomotion. This increased metabolic activity calls for increased blood flow, and the heart rate and stroke volume go up.

A unique aspect of the equine circulatory system is that red blood cells are stored in the spleen and are released on demand. This means during strenuous exercise, the horse can call on reserve red cell supplies to help meet demand. It also explains why horses suffer less from altitude changes than humans. When a human goes from low to high altitude, a period of adjustment is required. The horse simply releases more red blood cells from the spleen to satisfy the increased demand for oxygen.

As mentioned earlier, blood is also utilized in the cooling process during exercise. However, if the horse is exercising maximally for a long period of time, this can result in a domino-effect series of events. As more and more of the blood is sent to the skin during the cooling process, dehydration becomes a factor as plasma is lost in the process. Thus, it becomes something of a catch-22. The blood helps cool the horse, but the loss of plasma through dehydration means that it is losing some of the oxygen-carrying capacity to fuel tissues.

As is the case with the respiratory system, a strong healthy circulatory system is needed if a horse is to remain healthy and productive during serious exercise.

Take-Home Message

While all the horse's body systems work together to keep the animal alive and active, the circulatory and respiratory systems have a special relationship. The flow of blood and oxygen can make the difference between a champion and an ordinary horse, or when problems develop, it can mean the difference between life and death.