Blood
Blood is the fluid of life, transporting oxygen from the lungs to body tissue and carbon dioxide from body tissue to the lungs. Blood is the fluid of growth, transporting nourishment from digestion and hormones from glands throughout the body. Blood is the fluid of health, transporting disease fighting substances to the tissue and waste to the kidneys. Because it contains living cells, blood is alive. Red blood cells and white blood cells are responsible for nourishing and cleansing the body.

Without blood, the human body would stop working.

Classification and Structure of Blood Vessels
Blood vessels are the channels or conduits through which blood is distributed to body tissues. The vessels make up two closed systems of tubes that begin and end at the heart. One system, the pulmonary vessels, transports blood from the right ventricle to the lungs and back to the left atrium. The other system, the systemic vessels, carries blood from the left ventricle to the tissues in all parts of the body and then returns the blood to the right atrium. Based on their structure and function, blood vessels are classified as either arteries, capillaries, or veins.

Arteries
Arteries carry blood away from the heart. Pulmonary arteries transport blood that has a low oxygen content from the right ventricle to the lungs. Systemic arteries transport oxygenated blood from the left ventricle to the body tissues. Blood is pumped from the ventricles into large elastic arteries that branch repeatedly into smaller and smaller arteries until the branching results in microscopic arteries called arterioles. The arterioles play a key role in regulating blood flow into the tissue capillaries. About 10 percent of the total blood volume is in the systemic arterial system at any given time.

The wall of an artery consists of three layers. The innermost layer, the tunica intima (also called tunica interna), is simple squamous epithelium surrounded by a connective tissue basement membrane with elastic fibers. The middle layer, the tunica media, is primarily smooth muscle and is usually the thickest layer. It not only provides support for the vessel but also changes vessel diameter to regulate blood flow and blood pressure. The outermost layer, which attaches the vessel to the surrounding tissue, is the tunica externa or tunica adventitia. This layer is connective tissue with varying amounts of elastic and collagenous fibers. The connective tissue in this layer is quite dense where it is adjacent to the tunic media, but it changes to loose connective tissue near the periphery of the vessel.

Capillaries
Capillaries, the smallest and most numerous of the blood vessels, form the connection between the vessels that carry blood away from the heart (arteries) and the vessels that return blood to the heart (veins). The primary function of capillaries is the exchange of materials between the blood and tissue cells.

Capillary distribution varies with the metabolic activity of body tissues. Tissues such as skeletal muscle, liver, and kidney have extensive capillary networks because they are metabolically active and require an abundant supply of oxygen and nutrients. Other tissues, such as connective tissue, have a less abundant supply of capillaries. The epidermis of the skin and the lens and cornea of the eye completely lack a capillary network. About 5 percent of the total blood volume is in the systemic capillaries at any given time. Another 10 percent is in the lungs.

Smooth muscle cells in the arterioles where they branch to form capillaries regulate blood flow from the arterioles into the capillaries.
Veins
Veins carry blood toward the heart. After blood passes through the capillaries, it enters the smallest veins, called venules. From the venules, it flows into progressively larger and larger veins until it reaches the heart. In the pulmonary circuit, the pulmonary veins transport blood from the lungs to the left atrium of the heart. This blood has a high oxygen content because it has just been oxygenated in the lungs. Systemic veins transport blood from the body tissue to the right atrium of the heart. This blood has a reduced oxygen content because the oxygen has been used for metabolic activities in the tissue cells.

The walls of veins have the same three layers as the arteries. Although all the layers are present, there is less smooth muscle and connective tissue. This makes the walls of veins thinner than those of arteries, which is related to the fact that blood in the veins has less pressure than in the arteries. Because the walls of the veins are thinner and less rigid than arteries, veins can hold more blood. Almost 70 percent of the total blood volume is in the veins at any given time. Medium and large veins have venous valves, similar to the semilunar valves associated with the heart, that help keep the blood flowing toward the heart. Venous valves are especially important in the arms and legs, where they prevent the back flow of blood in response to the pull of gravity.

Physiology of Circulation – Role of the Capillaries
In addition to forming the connection between the arteries and veins, capillaries have a vital role in the exchange of gases, nutrients, and metabolic waste products between the blood and the tissue cells. Substances pass through the capillaries’ wall by diffusion, filtration, and osmosis. Oxygen and carbon dioxide move across the capillary wall by diffusion. Fluid movement across a capillary wall is determined by a combination of hydrostatic and osmotic pressure. The net result of the capillary microcirculation created by hydrostatic and osmotic pressure is that substances leave the blood at one end of the capillary and return at the other end.

Blood Flow
Blood flow refers to the movement of blood through the vessels from arteries to the capillaries and then into the veins. Pressure is a measure of the force that the blood exerts against the vessel walls as it moves the blood through the vessels. Like all fluids, blood flows from a high pressure area to a region with lower pressure. Blood flows in the same direction as the decreasing pressure gradient: arteries to capillaries to veins.

The rate, or velocity, of blood flow varies inversely with the total cross-sectional area of the blood vessels. As the total cross-sectional area of the vessels increases, the velocity of flow decreases. Blood flow is slowest in the capillaries, which allows time for exchange of gases and nutrients.

Resistance is a force that opposes the flow of a fluid. In blood vessels, most of the resistance is due to vessel diameter. As vessel diameter decreases, the resistance increases and blood flow decreases.

Very little pressure remains by the time blood leaves the capillaries and enters the venules. Blood flow through the veins is not the direct result of ventricular contraction. Instead, venous return depends on skeletal muscle action, respiratory movements, and constriction of smooth muscle in venous walls.

Pulse and Blood Pressure
Pulse refers to the rhythmic expansion of an artery that is caused by ejection of blood from the ventricle. It can be felt where an artery is close to the surface and rests on something firm.

In common usage, the term blood pressure refers to arterial blood pressure, the pressure in the aorta and its branches. Systolic pressure is due to ventricular contraction. Diastolic pressure occurs during cardiac relaxation. Pulse pressure is the difference between systolic pressure and diastolic pressure. Blood pressure is measured with a sphygmomanometer and is recorded as the systolic pressure over the diastolic pressure. Four major factors interact to affect blood pressure: cardiac output, blood volume, peripheral resistance, and viscosity. When these factors increase, blood
Arterial blood pressure is maintained within normal ranges by changes in cardiac output and peripheral resistance. Pressure receptors (baroreceptors), located in the walls of the large arteries in the thorax and neck, are important for short-term blood pressure regulation.

**Circulatory Pathways**

The blood vessels of the body are functionally divided into two distinctive circuits: pulmonary circuit and systemic circuit. The pump for the pulmonary circuit, which circulates blood through the lungs, is the right ventricle. The left ventricle is the pump for the systemic circuit, which provides the blood supply for the tissue cells of the body.

### Pulmonary Circuit

Pulmonary circulation transports oxygen-poor blood from the right ventricle to the lungs where blood picks up a new blood supply. Then it returns the oxygen-rich blood to the left atrium.

### Systemic Circuit

The systemic circulation provides the functional blood supply to all body tissue. It carries oxygen and nutrients to the cells and picks up carbon dioxide and waste products. Systemic circulation carries oxygenated blood from the left ventricle, through the arteries, to the capillaries in the tissues of the body. From the tissue capillaries, the deoxygenated blood returns through a system of veins to the right atrium of the heart.

The coronary arteries are the only vessels that branch from the ascending aorta. The brachiocephalic, left common carotid, and left subclavian arteries branch from the aortic arch. Blood supply for the brain is provided by the internal carotid and vertebral arteries. The subclavian arteries provide the blood supply for the upper extremity. The celiac, superior mesenteric, suprarenal, renal, gonadal, and inferior mesenteric arteries branch from the abdominal aorta to supply the abdominal viscera. Lumbar arteries provide blood for the muscles and spinal cord. Branches of the external iliac artery provide the blood supply for the lower extremity. The internal iliac artery supplies the pelvic viscera.

### Major Systemic Arteries

All systemic arteries are branches, either directly or indirectly, from the aorta. The aorta ascends from the left ventricle, curves posteriorly and to the left, then descends through the thorax and abdomen. This geography divides the aorta into three portions: ascending aorta, aortic arch, and descending aorta. The descending aorta is further subdivided into the thoracic aorta and abdominal aorta.

### Major Systemic Veins

After blood delivers oxygen to the tissues and picks up carbon dioxide, it returns to the heart through a system of veins. The capillaries, where the gaseous exchange occurs, merge into venules and these converge to form larger and larger veins until the blood reaches either the superior vena cava or inferior vena cava, which drain into the right atrium.

### Fetal Circulation

Most circulatory pathways in a fetus are like those in the adult but there are some notable differences because the lungs, the gastrointestinal tract, and the kidneys are not functioning before birth. The fetus obtains its oxygen and nutrients from the mother and also depends on maternal circulation to carry away the carbon dioxide and waste products.

The umbilical cord contains two umbilical arteries to carry fetal blood to the placenta and one umbilical
vein to carry oxygen-and-nutrient-rich blood from the placenta to the fetus. The ductus venosus allows blood to bypass the immature liver in fetal circulation. The foramen ovale and ductus arteriosus are modifications that permit blood to bypass the lungs in fetal circulation.

The Heart
The heart is a muscular pump that provides the force necessary to circulate the blood to all the tissues in the body. Its function is vital because, to survive, the tissues need a continuous supply of oxygen and nutrients, and metabolic waste products have to be removed. Deprived of these necessities, cells soon undergo irreversible changes that lead to death. While blood is the transport medium, the heart is the organ that keeps the blood moving through the vessels. The normal adult heart pumps about 5 liters of blood every minute throughout life. If it loses its pumping effectiveness for even a few minutes, the individual’s life is jeopardized.

Structure of the Heart
The human heart is a four-chambered muscular organ, shaped and sized roughly like a man’s closed fist with two-thirds of the mass to the left of midline.

The heart is enclosed in a pericardial sac that is lined with the parietal layers of a serous membrane. The visceral layer of the serous membrane forms the epicardium.

Layers of the Heart Wall
Three layers of tissue form the heart wall. The outer layer of the heart wall is the epicardium, the middle layer is the myocardium, and the inner layer is the endocardium.

Chambers of the Heart
The internal cavity of the heart is divided into four chambers:
• Right atrium
• Right ventricle
• Left atrium
• Left ventricle

The two atria are thin-walled chambers that receive blood from the veins. The two ventricles are thick-walled chambers that forcefully pump blood out of the heart. Differences in thickness of the heart chamber walls are due to variations in the amount of myocardium present, which reflects the amount of force each chamber is required to generate.

The right atrium receives deoxygenated blood from systemic veins; the left atrium receives oxygenated blood from the pulmonary veins.

Valves of the Heart
Pumps need a set of valves to keep the fluid flowing in one direction and the heart is no exception. The heart has two types of valves that keep the blood flowing in the correct direction. The valves between the atria and ventricles are called atrioventricular valves (also called cuspid valves), while those at the bases of the large vessels leaving the ventricles are called semilunar valves.

The right atrioventricular valve is the tricuspid valve. The left atrioventricular valve is the bicuspid, or mitral, valve. The valve between the right ventricle and pulmonary trunk is the pulmonary semilunar valve. The valve between the left ventricle and the aorta is the aortic semilunar valve.

When the ventricles contract, atrioventricular valves close to prevent blood from flowing back into the atria. When the ventricles relax, semilunar valves close to prevent blood from flowing back into the ventricles.

Pathway of Blood through the Heart
While it is convenient to describe the flow of blood through the right side of the heart and then through the left side, it is important to realize that both atria contract at the same time and both ventricles contract at the same time. The heart works as two pumps, one on the right and one on the left, working simultaneously. Blood flows from the right atrium to the right ventricle, and then is pumped to the lungs to receive oxygen. From the lungs, the blood flows to the left atrium, then to the left ventricle. From there it is pumped to the systemic
circulation.

**Blood Supply to the Myocardium**

The myocardium of the heart wall is a working muscle that needs a continuous supply of oxygen and nutrients to function with efficiency. For this reason, cardiac muscle has an extensive network of blood vessels to bring oxygen to the contracting cells and to remove waste products.

The right and left coronary arteries, branches of the ascending aorta, supply blood to the walls of the myocardium. After blood passes through the capillaries in the myocardium, it enters a system of cardiac (coronary) veins. Most of the cardiac veins drain into the coronary sinus, which opens into the right atrium.

**Physiology of the Heart**

The work of the heart is to pump blood to the lungs through pulmonary circulation and to the rest of the body through systemic circulation. This is accomplished by systematic contraction and relaxation of the cardiac muscle in the myocardium.

**Conduction System**

An effective cycle for productive pumping of blood requires that the heart be synchronized accurately. Both atria need to contract simultaneously, followed by contraction of both ventricles. Specialized cardiac muscle cells that make up the conduction system of the heart coordinate contraction of the chambers.

The conduction system includes several components. The first part of the conduction system is the sinoatrial node. Without any neural stimulation, the sinoatrial node rhythmically initiates impulses 70 to 80 times per minute. Because it establishes the basic rhythm of the heartbeat, it is called the pacemaker of the heart. Other parts of the conduction system include the atrioventricular node, atrioventricular bundle, bundle branches, and conduction myofibers. All these components coordinate the contraction and relaxation of the heart chambers.

**Cardiac Cycle**

The cardiac cycle refers to the alternating contraction and relaxation of the myocardium in the walls of the heart chambers, coordinated by the conduction system, during one heartbeat. Systole is the contraction phase of the cardiac cycle, and diastole is the relaxation phase. At a normal heart rate, one cardiac cycle lasts for 0.8 second.

**Heart Sounds**

The sounds associated with the heartbeat are due to vibrations in the tissues and blood caused by closure of the valves. Abnormal heart sounds are called murmurs.

**Heart Rate**

The sinoatrial node, acting alone, produces a constant rhythmic heart rate. Regulating factors are reliant on the atrioventricular node to increase or decrease the heart rate to adjust cardiac output to meet the changing needs of the body. Most changes in the heart rate are mediated through the cardiac center in the medulla oblongata of the brain. The center has both sympathetic and parasympathetic components that adjust the heart rate to meet the changing needs of the body.

Peripheral factors such as emotions, ion concentrations, and body temperature may affect heart rate. These are usually mediated through the cardiac center.

**The Cardiovascular System**

The cardiovascular system is sometimes called the blood-vascular or simply the circulatory system. It consists of the heart, which is a muscular pumping device, and a closed system of vessels called arteries, veins, and capillaries. As the name implies, blood contained in the circulatory system is pumped by the heart around a closed circle or circuit of vessels as it passes again and again through the various "circulations" of the body.

As in the adult, survival of the developing embryo depends on the circulation of blood to maintain homeostasis and a favorable cellular environment. In response to this need, the cardiovascular system makes its appearance early in development and reaches a functional state long before any other major organ system. Incredible as it seems, the primitive heart begins to beat regularly early in the fourth week following fertilization.
The vital role of the cardiovascular system in maintaining homeostasis depends on the continuous and controlled movement of blood through the thousands of miles of capillaries that permeate every tissue and reach every cell in the body. It is in the microscopic capillaries that blood performs its ultimate transport function. Nutrients and other essential materials pass from capillary blood into fluids surrounding the cells as waste products are removed.

Numerous control mechanisms help to regulate and integrate the diverse functions and component parts of the cardiovascular system in order to supply blood to specific body areas according to need. These mechanisms ensure a constant internal environment surrounding each body cell regardless of differing demands for nutrients or production of waste products.
Session Review

Here is what we have learned from this unit:

- The cardiovascular system consists of the heart, which is a muscular pumping device, and a closed system of vessels called arteries, veins, and capillaries.
- The vital role of the cardiovascular system in maintaining homeostasis depends on the continuous and controlled movement of blood through the thousands of miles of capillaries that permeate every tissue and reach every cell in the body.
- The heart is a muscular pump that provides the force necessary to circulate the blood to all the tissues in the body.
- Three layers of the heart are the epicardium, the myocardium, and the endocardium.
- The four chambers of the heart are the right atrium, the right ventricle, the left atrium, and the left ventricle.
- Two types of valves of the heart are the atrioventricular valves and semilunar valves.
- Blood flows from the right atrium to the right ventricle and then is pumped to the lungs to receive oxygen. From the lungs, the blood flows to the left atrium, then to the left ventricle. From there it is pumped to the systemic circulation.
- Specialized cardiac muscle cells that make up the conduction system of the heart coordinate contraction of the chambers.
- The pulmonary vessels transport blood from the right ventricle to the lungs and back to the left atrium.
- The systemic vessels carry blood from the left ventricle to the tissues in all parts of the body and then returns the blood to the right atrium.
- Substances pass through the capillary wall by diffusion, filtration, and osmosis.
Please be sure to fill out the information above, complete the test and e-mail or fax it back to us at iridology@netzero.net or 530-878-1119. We will grade your question & answer session and will let you know if we have questions or comments.

Please answer T or F to each of the following:

1. The cardiovascular system begins to develop and reaches a functional state after the development of other major organ systems. _____

2. The function of the heart is vital because, to survive, the tissues need a continuous supply of oxygen and nutrients and metabolic waste products have to be removed from them. _____

3. The normal adult heart pumps about 5 liters of blood every hour throughout life. _____

4. The outer layer of the heart wall is the myocardium, the middle layer is the epicardium, and the inner layer is the endocardium._____

5. When the ventricles contract, atrioventricular valves close to prevent blood from flowing back into the atria. When the ventricles relax, semilunar valves close to prevent blood from flowing back into the ventricles. _____

6. Because the sinoatrial node establishes the basic rhythm of the heartbeat, it is called the pacemaker of the heart. _____

7. Based on their structure and function, blood vessels are classified as the pulmonary vessels, the systemic vessels, arteries, capillaries, or veins. ______

8. Capillaries form the connection between the vessels that carry blood away from the heart and the vessels that return blood to the heart. ______

9. As the total cross-sectional area of the vessels increases, the velocity of flow also increases. ______

10. The pump for the pulmonary circuit, which circulates blood through the lungs, is the left ventricle. ______