PHYSIOLOGY

Abstract:

Human physiology is the study of the normal function of body organs and tissues. Body organs that certified nurse assistants study during their training include the skeletal, muscle, skin, nervous, cardiovascular, respiratory, digestive, renal, and endocrine systems, and the role of these organ systems. A basic understanding of how the normal body maintains a stable internal environment and efficient organ system functioning is important in order to recognize the physical stresses that disrupt organ system stability, such as acute and chronic medical problems, diseases, infections. It is also important for all health professionals to know normal human body functions and processes that must adjust to physical variants and environmental stressors or imbalances affecting human health.

Learning Goal:

1. Describe how the human body maintains an optimal internal environment through *homeostasis* by way of *feedback loops*.
2. State the different organ systems of the human body and their functions.
3. Describe how the separate organs of the human renal system function normally to eliminate body waste in urine.

Introduction

Human physiology is defined as the study of the normal function of the organs and tissues of the human body. Physiology is distinct from anatomy in that studying anatomy involves memorization, whereas, physiology requires a deeper understanding of how human organs work and their function. The important functions that will be discussed are homeostasis body temperature, and major organ systems of the body.

Homeostasis And Feedback Loops

The normal body maintains a stable internal environment, which provides efficient functioning of the organ systems. For example, there is a specific range of body temperature within which the organ systems function best, narrow range of sodium in the blood that the body can tolerate, and each organ must receive a certain amount of blood and oxygen.

However, maintaining a balanced, internal environment, such as keeping the body temperature between 36.5-37.5°C/97.7-99.5°F or maintaining a specific amount of blood flow to the kidneys, is complex and challenging under certain circumstances. There are stresses that can easily disrupt this stability, such as acute and chronic medical problems, diseases, infections. There are also day-to-day changes in food and fluid requirements, different levels of physical activity, and constant variations in the needs of the organs and tissue for oxygen, blood flow, and nutrients. The body must adjust these variants as well.

Fortunately, the human body can make changes that maintain an optimal internal environment and it does so by a process called *homeostasis*. Homeostasis works by way of *feedback loops*. The prefix *homeo* means *same* and the suffix *stasis* means *balance*. Homeostasis can be summarized as the different ways the body adjusts to keep its organ systems running. All the vital body processes that keep a person alive, *i.e.*, blood pressure, heart rate, circulation, breathing, digestion, the functioning of the kidneys and the liver and the other organ systems *all use feedback loops to function properly*. None of these are under a person's conscious control.

Example of Feedback Loops

When a person walks quickly up a flight of stairs, leg muscles work harder and need more blood and oxygen. Nerve receptors in the muscles send this information to the brain; they provide the brain with feedback about the internal environment. In this case, the feedback indicates that the leg muscles need more blood and oxygen. In response to this, the brain sends out nerve signals that increase the rate and depth of breathing, which increases heart rate and dilates the blood vessels in the legs. Once the blood and oxygen demands have been fulfilled feedback is sent to the brain that the metabolic needs have been satisfied and the feedback loop is complete.

Temperature Control

Body temperature is a balance between heat production and heat loss. Heat production comes from the normal metabolic processes of energy production, the normal functioning of organs, and from muscular activity. Heat loss happens in one of four ways: conduction, convection, evaporation and radiation.

1. *Conduction*

When two objects are in contact, heat will flow from the hotter object to the colder one. This is called conduction.

2. *Convection*

    Circulating air passing over a warm object pushes away the air that is immediately adjacent to and above that object. That creates a temperature difference between the object and its immediate environment so heat moves to the colder surrounding environment. Convection is why sitting in front of a fan on a hot day will cool a person down.

3. *Evaporation*

    Changing water from a liquid to a gas is called evaporation and this process produces heat. When a person sweats, the water on his or her skin is changed to a gas by the body's heat, so sweating - which is essentially evaporation - is one of the ways a body can lose body heat and maintain a normal temperature.

4. *Radiation*

    Heat naturally moves from a cold object to a warm one. This is a passive process called radiation. The environment is usually cooler than body temperature so heat radiates away from the skin and into the air, helping to maintain normal body temperature. The opposite is true when the air temperature is cold.

The body functions best when the temperature of its internal environment is maintained within a specific range. Normal body temperature is 36.5-37.5°C/97.7-99.5°F, and temperature control is coordinated by a specific area of the brain called the hypothalamus.

The hypothalamus acts as a thermostat in much the same way that a home thermostat works. The hypothalamus receives feedback from temperature receptors in the skin and it also senses the temperature of the blood. Using this information, the hypothalamus can initiate steps to conserve or lose body heat. These can include decreasing or increasing the metabolic rate, constricting or dilating peripheral blood vessels to conserve or lose heat respectively, decreasing or increasing sweating, increasing the heart rate, and increasing the rate and depth of breathing (evaporation) and initiating shivering.

An abnormally low body temperature is called hypothermia and an abnormally high body temperature is called fever. Hypothermia can cause arrhythmias (irregular heart rhythm), bradycardia (slow heart rate), hypotension (low blood pressure), and central nervous system dysfunction. Fever increases heart rate and blood pressure, it can cause muscle damage, febrile seizures in children, and it increases metabolic rate.

Infectious diseases such as the flu often cause fever. This happens because the influenza virus or whatever microorganism is causing the infection “resets” the hypothalamus. The hypothalamus then mistakenly senses that body temperature is too low and begins to increase body temperature - the result is a fever.
Metabolism is essentially the breakdown of nutrients and the use of them to make energy. Using the analogy of a car, metabolism is burning gasoline to make the car move. The metabolic rate is the level of metabolism that is required for the body to function, *i.e.*, the heart beating, the muscles contracting, and food digested, and the metabolic rate can be decreased or increased as needed.

Human Organ Systems

The human body contains many structures and tissues and these are arranged in *organ systems*. An organ system is defined as a group of organs that work together to perform a specific task or tasks. For example, the renal system is comprised of four separate organs, the kidneys, the ureters, the bladder, and the urethra. The renal system has many vital functions, the most obvious being production and excretion of urine. The kidneys produce urine, the ureters transport urine to the bladder, and the bladder stores urine until it is secreted through the urethra.

The organ systems that will be discussed in the following sections are the skeletal system, muscles, and skin, the nervous system, the cardiovascular system, respiratory system, digestive system, renal system, and endocrine system. The organ systems are also responsible for eliminating metabolic by-products, such as through the digestive system, the renal system, the pulmonary circulation and the lungs.

Skeletal, Muscle, And Skin Systems

The bones of the skeletal system, the cartilage, ligaments and tendons, the three types of muscle, and the skin are all physiologically active. However, other than the cardiac muscle (which will be discussed later), the basic functions of these structures and how they work are mentioned briefly.

Many of the organ systems in the body use smooth muscle. Smooth muscle is not under conscious control but depends on the central nervous system to function. Smooth muscle can be contracted or relaxed as needed. In many organs and areas of the body, the smooth muscle is in a constant state of tone. For example, there are muscles that support the spine and for obvious reasons these are always maintained at a certain level of tension. In contrast, skeletal muscles may depend on conscious control because they function by way of the somatic (voluntary) nervous system. By example, this can be seen when a person chooses to stand, walk or run.

Nervous System

The body's nervous system consists of the central nervous system and the peripheral nervous system. The central nervous system includes the spinal cord and brain, while the peripheral nervous system is made up of all the nerves that extend throughout the body beyond the brain and spinal cord. The nervous system coordinates and controls the body in very sophisticated ways.

The basic function of the nervous system is control of voluntary and involuntary body functions. The nervous system coordinates and controls the body at the most basic level by providing people with the ability to see, smell, taste, hear, and touch. The nervous system also gives people the ability to speak, the ability to detect pain and changes in temperature, and the ability to oversee and regulate the functioning of vital organs such as the heart, kidneys, and the lungs.

Some parts of the nervous system are under conscious control such as the skeletal muscles and speech. Many parts of the nervous system are not under conscious control, such as digestion, respiration, and the operation of the major organ systems.

The brain provides memory, problem solving, and abstract thought. It enables a person to think and plan for future events. The brain is also the place where a person's emotions are generated. These functions are controlled by special areas in the brain.

There are areas of the brain that control the cardiovascular system, the renal system, and control higher level functions such as speech, memory, and problem solving. The peripheral nerves send messages to the brain about our external and internal environment. In response, the brain sends out signals through the spinal cord and back through the peripheral nerves to these parts of the body. If there are changes in the external environment (a change in room temperature) or changes in the internal environment (*i.e.*, when a person has pain or one of the body organs is not functioning properly), the brain receives this information and can make corrections.

A stroke is a common neurological event that occurs when a blood vessel in the brain ruptures, or a blood clot obstructs an important blood vessel in the brain. In either case, the brain no longer receives oxygen and nutrients. Brain tissue dies and depending on the location in the brain of the stroke, the person may develop paralysis, lose the power of speech, or suffer some other deficit.

The nervous system sends and receives nerve signals by using substances called *neurotransmitters* and by micro electrical currents. The nerve fibers that travel out to the brain to the organ systems and from the organ systems back to the brain are often compared to electrical wires, and nerve signals are essentially micro electrical currents. However, the nerve fibers are not continuous. There are small gaps between adjacent nerve fibers and between the ends of nerve fibers and the organs. These gaps are called synapses. A nerve signal that reaches the end of a nerve fiber cannot by itself cross a synapse and stimulate an organ. Instead, the nerve signal causes the release of a neurotransmitter. The neurotransmitter travels across the synapse and binds to a receptor on the organ. This binding then stimulates the organ to perform a specific action.

Example: Fall Injury

A 25-year old male falls while on the job and suffers a serious laceration to an artery. Receptors in the blood vessels sense the damage to the blood vessel and the decrease in blood pressure. This information is sent to the brain and the brain send out a nerve signal to the artery. At the end of the nerve fiber(s) connected to the artery, adrenaline is released, crosses the synapse and binds to the artery. Adrenaline is a powerful vasoconstrictor so the artery begins to constrict, slowing the bleeding and increasing blood pressure.

Cardiovascular System

The cardiovascular system, which is also called the circulatory system, is comprised of the blood, the blood vessels, and the heart. The primary function of the cardiovascular system is to circulate blood through the organs and the tissues. A description of the physical process of blood circulation is provided in Figure 1.

Figure 1: The Atria, Ventricles, and Cardio-Pulmonary Circulation

Unoxygenated venous blood from the peripheral circulation flows into the right atrium. ↓ **The right atria contract and pump the unoxygenated blood through the tricuspid valve into the right ventricle.** ↓ **The right ventricle contracts and pumps the unoxygenated blood through the pulmonary valve and into the pulmonary circulation.** ↓ **Unoxygenated blood flowing through the pulmonary circulation combines with oxygen and flows into the left atrium.** ↓ **The left atrium contracts and pumps the oxygenated blood through the mitral valve and into the left ventricle.** ↓ **The left ventricle contracts and pumps oxygenated blood through the aortic valve and out into the peripheral circulation where it can be used by the organs and tissues.**

The cardiovascular system is not under conscious control. It operates by using feedback loops. For example, when the body senses that more oxygen is needed this information is transmitted to the brain through the nervous system. The brain responds by sending out nerve transmissions (which are also information) that can selectively dilate the arteries and increase the heart rate. The information that travels to the brain and from the brain to the body is called feedback; information that is used to modify or control a process.

The components of the cardiovascular system and their functions will be discussed at length but first the blood pressure will be covered in detail. Movement of blood through the circulation and delivery of blood to the tissues and organs depends on a normal blood pressure. Blood pressure effectively “pushes” blood through the circulation. Blood pressure is also partially responsible for moving blood into the organs and tissues. Understanding how the blood, blood vessels, and the heart work to together to initiate and maintain blood pressure is essential for CNAs. Blood pressure will be reviewed and then the physiology of the cardiovascular system will be covered.

Blood Pressure

The cardiovascular system depends on pressure - blood pressure - to move blood through the circulation *and* to move blood into the tissues and organs. The three components of the cardiovascular system each contributes in a specific way toward creating and maintaining blood pressure.

The process of blood pressure control is very complex and this study course will discuss basic concepts. However, this information will give the CNA sufficient knowledge to understand how blood pressure is controlled and maintained.

Blood pressure is created and maintained by the pumping action of the heart, the integrity of the blood vessels, and blood volume.

1. *The Heart and Blood Pressure*

    The heart pumps a volume of blood into the circulation with each heartbeat. Because the cardiovascular system is a closed system this volume of blood creates a rise in pressure in the blood vessels. (Imagine a hose sealed at both ends and filled with water. Rapidly infuse a large volume of water into that system and the pressure inside will quickly rise.) The rise in pressure in the blood vessels is essentially what initiates blood pressure and it also begins moving blood through the circulation. Also, the heart rate must be above a certain level to maintain blood pressure. If the heart rate is very slow, blood pressure will drop because the time between heartbeats would be too long and allow pressure in the system to drop.

2. *Blood Vessels and Blood Pressure*

The short pause between each heartbeat is long enough that without the involvement of the arteries, blood pressure would drop and blood would stop moving. But the arteries have strong, muscular walls and when they are stretched by the blood volume pumped from the heart they "rebound" and squeeze down, pushing the blood further through the circulation. In addition, the nervous system keeps the arteries at a constant level of constriction that is enough to maintain blood pressure - this is called vascular tone.

3. *Blood Volume and Blood Pressure*

The cardiovascular system is a closed system so a normal blood pressure depends in part on having a normal volume of blood. If the volume is too low, blood pressure will fall.

A strong heartbeat and a normal heart rate, vascular tone, and good blood volume work together to maintain blood pressure and a deficit in one can be compensated by an adjustment in another. For example, if someone loses blood volume because of a hemorrhage, the heart rate and force of cardiac contraction will increase and the blood vessels will constrict. An abnormal blood pressure, low or high, is always caused by a problem in the heart, blood vessels, or blood.

Some terms that are useful to a CNA for understanding blood pressure and the cardiovascular system are:

Diastolic Blood Pressure

The pressure in the cardiovascular system between heartbeats

Systolic Blood Pressure

The pressure in the cardiovascular system while the heart is contracting

Stroke Volume

The amount of blood that is pumped by the heart with one contraction

Cardiac Output

The amount of blood the heart pumps in one minute.

Perfusion

The movement of blood through tissues and organs

Blood, Oxygen and Carbon Dioxide, and Blood Clotting

The primary function of the cardiovascular system is to deliver blood to the organs and the tissues. The delivery of blood is critical because: 1) blood carries oxygen to the body, and 2) blood removes carbon dioxide, a primary waste product of metabolism.

Blood is comprised of a liquid and a cellular component. The liquid component is comprised of plasma and serum. The cellular component is comprised of platelets, red blood cells, and white blood cells. The red blood cells are an important part of the cardiovascular system and their primary functions are *oxygen transport* and *carbon dioxide* removal.

1. *Oxygen*

   The air people inhale is mostly nitrogen; only 21% is oxygen (typically abbreviated as O_2). However, oxygen is *essential* for life and the production of energy. Human bodies need fuel to operate. People need the energy that is obtained from that fuel (carbohydrates, fats, proteins, vitamins, minerals, *etc.*) for the muscles to work, for the brain and nervous system to operate, and for all the normal processes such as breathing, growth, repair and recovery from injury or disease, and fighting off illness. However, without oxygen people cannot process the fuel and the nutrients taken in through the diet. Cells and tissues use water, nutrients such as glucose and fats and *oxygen* to form energy, energy that drives every metabolic process in the body, and energy needed to survive. Energy can be produced without oxygen but only in small amounts and not for long. Without oxygen cells, tissues would suffocate and die in much the same way a person would suffocate if the airway were blocked.

2. *Carbon Dioxide*

   The same process that produces energy using oxygen and glucose also produces the metabolic waste product carbon dioxide (typically abbreviated as CO_2). If these waste products were allowed to accumulate, a person's body would not function. This is because carbon dioxide, in one sense, is an acid and if it is not excreted by the lungs the blood level will become too high and the metabolic processes of the organ and tissues will not function normally.

3. *Oxygen Delivery*

Unoxygenated blood from the peripheral circulation is moved through the heart and delivered to the pulmonary circulation in the lungs. Inhaled air that contains oxygen passes through the alveoli in the lungs and combines with a molecule in the blood called *hemoglobin*. Hemoglobin is the primary "transport system" for oxygen. Some oxygen is dissolved in plasma but the majority is carried by hemoglobin. Oxygen binds very tightly to hemoglobin and when the oxygenated blood reaches its destination, the difference in oxygen content and oxygen pressures between the tissues and organs and the blood stimulates the release of oxygen from hemoglobin, and the movement of oxygen from the blood to the body. It may be helpful to think of an inflated balloon. The pressure inside an inflated balloon is greater than the surrounding atmospheric pressure so when the balloon is opened, this pressure difference causes air to rapidly leave the balloon. The same process applies to oxygen that is bound to hemoglobin.

4. *Carbon Dioxide Removal*

Carbon dioxide passes from the cells and into the blood. As with oxygen, this happens because of pressure differences between the carbon dioxide in the cells and the blood. At that point, some carbon dioxide binds to hemoglobin and some of it is dissolved into the plasma but most of it is transported by the red blood cells. This unoxygenated blood with carbon dioxide is carried by the peripheral blood vessels to the heart. It is pumped from the heart into the pulmonary circulation and at that point, the carbon dioxide leaves the red blood cells, the hemoglobin, and the plasma. It enters the alveoli and it is eliminated when a person exhales.

The measurement of the amount of hemoglobin a person has in his or her blood is part of a common laboratory test called a complete blood count, commonly abbreviated as CBC. The normal hemoglobin content for men is 13.5-17.5 grams per 100 milliliters of blood; for women, the normal hemoglobin count is 12.0-15.5 grams per 100 milliliters of blood. The differences between the sexes are primarily explained by blood loss from menstruation.

Table 1: Oxygen and Carbon Dioxide Pressures in Capillaries and Tissues

Oxygen pressure in capillary blood = 100 mm Hg
Oxygen pressure in the tissues = 40 mm Hg
Carbon dioxide pressure in the blood = 40 mm Hg
Carbon dioxide pressure in the tissues = 50 mm Hg

The blood is also involved in the process of *blood clotting*. There are constant small physical impacts to the body that can damage blood vessels and cause bleeding, and there are more obvious hemorrhages, as well. These hemorrhages must be controlled and the body has a clotting process that does so.

When an area of bleeding occurs, three things happen. First, the blood vessels constrict to reduce the blood flow. Second, the platelets gather at the spot and form a plug. Third, clotting factors in the blood form an additional plug at the area of bleeding. In most cases these processes are sufficient to stop the bleeding but if the area of hemorrhage is too large or the patient has taken an anticoagulant drug such as Coumadin, specific therapies may be needed to stop the hemorrhage. Clotting factors are produced by the liver.

Blood clots can form spontaneously. These are called thrombi, and they are common in people who have certain cardiac arrhythmias, heart disease, and hypertension or who are obese. If a piece of a thrombi breaks off it can travel through the circulation and lodge in a cerebral artery. This is called an embolism - more commonly called “throwing a clot” - and if the obstruction of the cerebral artery is big enough the patient may suffer a cardiovascular accident (a stroke).

Blood Vessels

The primary function of the blood vessels is to carry blood through the body. However, the blood vessels are not just simple conduits that passively deliver blood. The blood vessels play an active role in maintaining blood pressure; they can increase or decrease the flow of blood to a specific area as needed; and, they can help stop hemorrhages. The three primary types of blood vessels are arteries, capillaries, and veins.

The arteries are the blood vessels that carry oxygenated blood. The arterial tree begins with the aorta and ends with connections to the capillaries. The arteries are supplied with muscles and nerves and they can contract or dilate to raise or lower the blood pressure as needed.

Located at various points in the arterial tree are nerve endings called baro-receptors (the prefix baro means pressure). The baro-receptors detect changes in blood pressure and if blood pressure is too low or high, nerve signals are sent to the brain. In response, the brain can send nerve signals back to the arteries that stimulate them to constrict or dilate as needed. In addition, if the blood pressure is too low the hormones adrenaline and noradrenaline are released by the adrenal gland and the brain and these hormones are powerful vasoconstrictors. The ability of the arteries to constrict is also a vital part of the body's response to hemorrhage, and it the first step in controlling bleeding.

The capillaries connect the arterial tree to the venous system. The capillaries also carry oxygenated blood. However, the capillaries are microscopic in size and there are far more capillaries than arteries. In addition, the arteries transport oxygenated blood but the capillaries are where the oxygen leaves the blood and enters the tissues and organs *and* the capillaries are where carbon dioxide leaves the cells and tissues and combines with hemoglobin and red blood cells.

The capillaries can constrict or dilate as needed. If an area of the body has a higher need for oxygen than another, the capillary bed will dilate and effectively deliver more blood and oxygen where it is needed.

The veins' primary function is to carry unoxygenated blood to the right side of the heart. This is called the venous return and the veins can constrict or dilate, in a way similar to the arteries, to decrease or increase venous return as needed. If blood pressure is too low the veins will constrict and send more blood to the heart. If the blood pressure is too high the veins will dilate, decreasing blood flow to the heart which will lower both the cardiac output and the blood pressure.

The pressure inside the venous system is comparatively low and the veins are a good distance from the heart. By the time the pulse wave of a heartbeat has reached the venous system the pressure in the veins is too low for the blood to continue and reach the right side of the heart. However, backflow is prevented by one-way valves inside the veins and by pressure differences created when the chest and abdomen expand during inhalation keep the blood moving.

People with heart disease (atherosclerosis) often have cardiac arteries that are clogged by cholesterol deposits. This decreases blood supply and oxygen delivery to the heart. If someone with atherosclerosis engages in activity in which the body needs more oxygen, the heart must pump faster and harder but because the heart has to work harder, it needs more oxygen as well. If the cardiac arteries are clogged and cannot deliver oxygenated blood to the heart muscle can be damaged or die.

The Heart

The heart is a muscle but in one important way it is unlike smooth muscle or skeletal muscle. The cardiac muscle, which is also called the myocardium, can spontaneously contract. This is an intrinsic property of the myocardium and it ensures that blood will always move and circulate.

Heart rate and stroke volume determine how much blood is sent to the body, and both can be increased or decreased as needed. Heart rate is controlled by the sino-atrial (SA) node and the SA node by itself will initiate a heartbeat, usually at a rate of 50-60 beats a minute. Heart rate is also controlled by nervous system feedback loops. These can sense when blood pressure is too low or too high, when the body needs more oxygen, or when there is a significant stress (*i.e.*, bleeding, a heart attack, or a fever) and the feedback loops, working by way of nerve fibers in the heart, can increase or decrease the heart rate as needed.

Stroke volume is determined by how strongly the heart contracts. The strength of a cardiac contraction is influenced by how much blood is in the ventricles; the greater the volume of blood the stronger the contraction. The blood volume in the ventricles depends on blood pressure and on venous return. As with the heart rate, feedback loops control venous return.

Platelets and White Blood Cells

Platelets are small cells that are located in the blood. The primary function of the platelets is to prevent bleeding. When a blood vessel is injured or ruptured, platelets migrate to the area and form a plug. This process is called *activation and adhesion*, and it is the second step in blood clotting.

The white blood cells are also called leukocytes. There are many different types of leukocytes but they all play a role in the immune system and the body's defense against infection.

Respiratory System

The respiratory system, which can also be referred to as the pulmonary system, begins with the nose and oral cavity and ends with the alveoli in the lungs. The respiratory system is comprised of many different structures and each one has its own purpose. But the primary function of the respiratory function is to deliver oxygen to the blood and to eliminate carbon dioxide from the body.

This process is referred to as *gas exchange*. The amount of oxygen delivered and the amount of carbon dioxide eliminated depend on the respiratory rate and the depth of respirations. As with most vital body functions the respiratory system is not under conscious control, but uses feedback mechanisms to regulate gas exchange.

1. *The Need for Oxygen*

   There are oxygen sensors located throughout the body. If the amount of oxygen being delivered is not sufficient these oxygen centers send a nerve signal to the respiratory center in the brain. The respiratory center in turn increases the rate of breathing and the depth of each respiration. The faster and deeper a person breathes the more oxygen can be moved through the alveoli. This feedback loop, along with the dilation of the blood vessels, increases oxygen delivery to areas where it is needed.

2. *Carbon Dioxide Level*

There are also carbon dioxide sensors called chemoreceptors and they function in the same way as the oxygen sensors. When the carbon dioxide level is too high the respiratory center increase the rate and depth of breathing, effectively eliminating more carbon dioxide. The faster and deeper we breathe the more carbon dioxide we eliminate. Most of the time the need to eliminate carbon dioxide is the force that drives our breathing, not the need for oxygen. The body can tolerate low levels of oxygen better than it can tolerate high levels of carbon dioxide.

The need for more oxygen can arise if someone has a fever, during strenuous exercise, or if there is fluid in the lungs from pneumonia or congestive heart failure that prevents oxygen from moving through the alveoli into the blood. The need to eliminate carbon dioxide can happen if there is an infection, a drug overdose, or if someone is in a diabetic hyperglycemic coma.

The body can make rapid adjustments to the rate and depth of breathing or the adjustments can be made slowly over a period of time. For example, when someone begins to run there is an immediate need for increased oxygen delivery and carbon dioxide removal so the rate and depth of breathing are immediately increased. If someone has a chronic cardiac or pulmonary condition the adjustments to the respiratory system occur slowly.

A person's lungs may be damaged from years of cigarette smoking, which may lead to emphysema, which is also called chronic obstructive pulmonary disease (COPD). When a person with COPD inhales, oxygen cannot pass through damaged and scarred lung tissue into the blood. When that person exhales, carbon dioxide cannot leave the blood. The lack of oxygen and the buildup of carbon dioxide cause shortness of breath and an inability to perform simple physical tasks.

Digestive System

The primary functions of the digestive system are the absorption of nutrients and fluids and the elimination of wastes. The digestive system delivers foods, nutrients, and fluids to the body. Once these are in the stomach and the small bowel, the digestive system uses secretions that it produces to break them down so they can be absorbed and used. Undigested food, metabolized drugs, and waste products are passed along through the digestive tract and are eliminated in the form of stool, which is also known as feces.

The digestive system is comprised of the stomach, the small bowel, the large bowel, the rectum, and the anus. There are also three accessory organs that play an important role in digestion; the gall bladder, the liver, and the pancreas. The gall bladder and the liver will be discussed here; the pancreas will be discussed in the section on the endocrine system.

Digestion

Digestion begins in the mouth. Food is broken down into pieces can be swallowed. Mucous secreted by the salivary glands in response to the presence of food in the mouth helps lubricate food and make it easier to swallow. The saliva also contains several digestive enzymes that begin breaking down food so its component nutrients can be absorbed.

The presence of food in the stomach stimulates the production of digestive enzymes. These enzymes physically break down food so that it can be absorbed and they also change the chemical composition of the food so that nutrients can be absorbed. The presence of food also stimulates the stomach to contract and relax. This churning motion further reduces the size of food particles and it also physically moves food out of the stomach and into the small bowel.

Food that enters the small bowels stimulates a rhythmic, wave-like series of muscular contractions called *peristalsis*. Peristalsis moves food through the small bowel, and the small bowel is where the majority of nutrients are absorbed: carbohydrates, fats, proteins, minerals and vitamins. It is also the area of the digestive tract where most of our fluid intake is absorbed. The absorption of nutrients and fluids is an active and a passive process. Liquids and small molecules are able to simply move from through the wall of the small intestine and into the blood stream. Larger molecules such as glucose and certain nutrients must be actively transported.

Any food that that has not been digested by the small bowel then moves into the large bowel. A small amount of nutrients such as vitamin K and the B vitamins are absorbed through the large bowel, but the primary function of this section of the gastrointestinal tract is to form stool and to re-absorb water that the body needs. The formation of stool and the re-absorption of water can be changed as needed. As with the small bowel, the large bowel has many active metabolic processes. For example, there are bacteria in the large bowel that convert dietary vitamin K into the active form of the vitamin that is used for blood clotting.

After leaving the large bowel, the feces are stored in the rectum. Stretch receptors in the rectum sense when the rectum is full and send a nerve signal to the brain. The brain in return initiates a muscular contraction in the walls of the rectum and the feces are expelled. This is called defecation and it is a typical signal-response feedback loop. If the digestive system is not functioning properly, stool can be retained in the digestive tract (constipation) or stool can be excessively formed and eliminated (diarrhea). In either situation, the patient's basic health can be impacted. Constipation can cause hemorrhoids or anal tears, and diarrhea can cause dehydration.

The Liver and the Gall Bladder

The liver has many, many important roles in human physiology. In the digestive system the liver’s function is to produce a liquid substance called *bile*. Bile is needed to break down fats so they can be absorbed. It also plays an important role in the absorption of the fat-soluble vitamins A, D, E, and K.

Bile is stored in the *gall bladder*. The presence of fat in the small bowel causes the release of a hormone called cholecystokinin, and cholecystokinin stimulates the gall bladder to contract and release bile into the small bowel.

As mentioned previously, aside from its role in digestion the liver is a very important organ. The liver stores blood sugar and fat-soluble vitamins, it synthesizes blood clotting factors, it metabolizes drugs and breaks down metabolic wastes, it functions as part of the immune system, and it produces albumin, a protein that helps maintain fluid volume in the circulation. The liver is where almost all drugs are metabolized.

Renal System

The renal system has several very complex functions. It is responsible for excreting the waste products of metabolism, especially the metabolism of protein. It is responsible for maintaining the proper balance of fluid in the body. It makes sure that the blood has exactly the right amount of acidity, and it excretes or retains certain substances such as potassium and sodium in order to maintain their proper concentration in the blood. The renal system accomplishes all of these functions by producing urine and controlling the amount and the composition of the urine that it makes.

Renal function is assessed by measuring the blood urea nitrogen (BUN) and the blood creatinine. Blood urea nitrogen is a breakdown product of protein metabolism, and creatinine is a metabolic by-product of muscle activity. Creatinine and BUN are excreted by the kidneys and measuring their levels in the blood can indicate how or, or poorly the kidneys are functioning. A high BUN and/or creatinine indicate kidney damage of some type.

The renal system uses feedback loops to maintain homeostasis. A major part of the blood flow in the body moves through the kidneys. As the blood passes through the kidneys, urine is formed and delivered to the body. Sophisticated sensors in the kidneys can detect when there is an excess of waste products and increase their rate of elimination in the urine, or if the body needs to conserve an electrolyte such as potassium or sodium these can be reabsorbed from the blood passing through the kidneys.

Other feedback mechanisms in the kidneys sense when the body is dehydrated or when there is a fluid overload. If either of these two situations occurs, the kidneys can respond by making more or less urine. If the level of sodium, potassium, or acids these are produced by metabolism is too high, the kidneys can sense this and change the composition of the urine so that these substances are eliminated or conserved.

Endocrine System

The endocrine system is complicated and comprised of many different glands, but this module will focus exclusively on the pancreas. This is by far the part of the endocrine system that is most important for CNAs to understand.

The major function of the pancreas is to produce insulin. Insulin is a hormone that is necessary for the body to function. When people digest food, a large part of what they eat is changed into glucose, also known as blood sugar. Human organs and tissues require glucose and oxygen to function and survive but glucose cannot enter the cells without insulin. Receptor sites in the pancreas sense the level of glucose in the blood, and the islet cells of the pancreas then release insulin. Insulin activates transport molecules that carry glucose from the bloodstream and into the cells that need it.

The pancreas can sense when the glucose level in the blood is too high or too low and can adjust the amount of insulin it produces. It can also sense when fats and proteins need to be converted into glucose and can secret more insulin as needed.

People with type 2 diabetes do not produce enough insulin and people with type 1 diabetes do not produce any insulin. Because of this the blood sugar level of diabetics must be constantly monitored and most diabetics take medications that lower blood sugar. If the blood sugar is too low, the body - especially the brain - is deprived of fuel and the tissues can die. If the blood sugar is too high for too long, fats and proteins are used for energy and this process can cause a complication called diabetic ketoacidosis (DKA).

Summary

Human physiology is defined as the study of the normal function of the organs and tissues of the human body, and requires a deeper understanding of how human organs work and their function. The human body contains many structures and tissues and these are arranged in organ systems. Organ systems raised in this course included the skeletal, muscle, skin, nervous, cardiovascular, respiratory, digestive, renal, and endocrine systems.

Human body systems comprise groups of organs that work together to perform specific task(s). The example of the renal system was raised, which includes four separate organs - the kidneys, ureters, bladder, and urethra. Certified nurse assistants need to be informed of the vital functions of specific organ systems, including how they maintain normal balance, produce and eliminate certain body substances.