# AOHS Foundations of Anatomy and Physiology II

## Lesson 19

### The Urinary System

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Student Resource 19.1

Reading: Anatomy of the Urinary System

AOHS Foundations of Anatomy and Physiology II

Lesson 19

Anatomy of the Urinary System
By the end of this presentation you will know:

- The organs of the urinary system
- Special features of cells in the bladder
- The functions of the urinary system
- The differences between the male and female urinary system
The urinary system is the body’s most important mechanism for homeostasis

The urinary system regulates:
- How much water to get rid of
- How much blood you have
- Blood levels of electrolytes
- The chemical environment surrounding your cells

What are some electrolytes you know of that your body has to regulate through homeostasis?

When you first think about the urinary system, no doubt you think of water. And indeed, the more water you drink, the more you’re aware of your urinary system. But even when you haven’t been hydrating, this system is at work fine-tuning lots of the chemistry that makes your body work. When this system produces urine, it’s doing a lot more than just getting rid of water. It’s deciding how much water should stay in and how much should go out. The volume of water inside you determines how much water is in your blood, and the amount of water in your blood affects your blood pressure. This system also has the important task of regulating how much of the sodium on your French fries stays in the fluid around your cells and how much your body needs to get rid of. Besides sodium, the kidneys also regulate the other electrolytes found in your plasma (fluid portion of blood) and the fluid that bathes the body’s cells. As you know, those ions need to be in at certain values (in balance) for the cells to function properly.
Your digestive and urinary systems have somewhat complementary functions. The digestive system packages up and eliminates undigested waste that was contained in your food but was never absorbed by your body. The urinary system collects and eliminates waste created in the reactions that keep your body going. Some of these waste products include various acids and ammonia-containing compounds such as urea formed when you metabolize proteins and fats. These reactions take place inside every one of your cells, so the urinary system serves to eliminate waste created in every part of your body. If you eat excess amounts of electrolytes, vitamins or water, they will be absorbed in your intestine, enter your bloodstream, and your urinary system will get rid of what you don’t need, as long as the substance is soluble in water.

You can think of your urinary system as something like a treatment plant for the fluids in your body. Everything is sent, via the blood, to this central cleaning facility. If something in the blood isn’t needed or is potentially harmful, out it goes.
The kidneys filter blood and produce urine

The kidneys are the active organ of the urinary system. You have two kidneys, one posterior to the stomach and one posterior to the liver.

Each kidney is about the size of an adult’s fist.

What food gets its name from being shaped like a kidney?

Put your hands against your back and feel your lowest pair of ribs. Just interior to your ribs are your kidneys. Each one is about the size of a fist and colored a deep, brownish red. This red color is partly due to the kidneys’ rich blood supply and network of capillaries: about one-quarter of all your body’s blood goes through them every minute. It’s the kidneys that filter unwanted substances out of your blood and create urine as a way to remove those substances. The kidneys are ensured an ample supply of blood because they are connected directly to the body’s largest blood vessel, the aorta. The blood leaving the kidneys goes to the vena cava. Your kidneys are topped by the adrenal glands, which produce some hormones that the kidneys respond to.

Along with their filtration duties, kidneys are also endocrine glands, secreting important hormones that regulate blood pressure, influence calcium absorption in the intestine and the bones, and stimulate the production of new red blood cells in the bone marrow.
Renal means “associated with the kidney”

The large blood vessels going into the kidneys are the renal artery and vein.

A loss of kidney function is often referred to as renal failure.

What do you think adrenal gland and its hormone, adrenaline, mean?

You may have heard the term renal used to describe something related to the kidneys. The term renal comes from the Latin word for kidneys, renes. The large blood vessels that bring blood to and from the kidneys are called the renal artery and renal vein. When a person loses kidney function, it’s called renal failure. Renal failure is a very serious condition. Without kidney function, homeostasis is thrown off so severely that the person will die. People whose kidneys have stopped working require kidney dialysis, which involves using a machine to do the work of the kidneys.
If you cut a kidney open along the frontal plane, you’ll find several different structures, some of them embedded with a very rich network of capillaries and small blood vessels. The outermost fleshy part of the kidney is called the cortex. The cortex covers an area made of deeper red tissue called the medulla. The tissues of the medulla are organized into shapes that appear as triangles when you look at them in this cut. If you could see them in their three-dimensional reality, you would see that their name, medullary pyramids, more accurately describes what they look like.
Nephrons, the structures that make urine, are found in the renal cortex and medulla

Nephrons create urine by separating and removing wastes, electrolytes, and excess water from the blood.

By bringing these substances into homeostatic balance and leaving what’s not needed outside of the bloodstream, urine is created.

The renal cortex and medulla are jam-packed with tiny tubes called nephrons. Most constituents of blood plasma are filtered into these nephrons and are “processed” as the plasma moves along the length of this tube. Much of this processing involves returning substances to the blood that the body wants to keep. This occurs via the many capillaries that surround the nephrons. Any excess molecules are left in the nephron tube and eventually delivered out of the body as urine. In this way, the kidneys contribute to the homeostatic maintenance of many substances in the blood.
The nephrons empty into tiny urine-collecting tubules that then join together to make larger tubes at the bases of the medullary pyramids. These larger tubes ultimately lead to the ureters. Ureters, like your esophagus, are muscular tubes that keep a substance moving in the desired direction. In this case, the substance is urine and the desired direction is toward the urinary bladder.

We often wake up in the morning realizing that we need to go to the bathroom. Even though you’re lying horizontally in bed, ureters keep the urine moving “downward.” If you had to rely on gravity to get your urine to your bladder, you’d never wake up in the morning needing to go to the bathroom—that would only happen after standing up. So, just as you can swallow food upside down, your bladder can also fill up, no matter what position you’re in.
Each ureter empties urine into the urinary bladder

The urinary bladder holds about 20 ounces. Its inner wall is made of cells that can change shape, allowing the bladder to stretch.

The ureter from each kidney extends and attaches to its side of the bladder, emptying urine into it. The urinary bladder is basically a muscular holding pen for urine until you decide it’s time to go to the bathroom. When your bladder is empty, it’s collapsed, like a deflated balloon. As the ureters deliver urine to it and it begins to fill up, the top of the bladder begins to round and rise upward. As this happens, the inner layer of the bladder performs an ingenious trick: when your bladder is empty, the cells are block shaped. As your bladder fills up, the cells change shape by becoming flatter, allowing the walls of the bladder to stretch. Eventually, when the bladder is about one-quarter full, stretch sensors in the bladder walls tell your brain that you’ve got urine to get rid of. Your brain has voluntary control over the urethra, which is the outflow path of urine from the bladder. But if the bladder stretches too far, and the pressure inside gets too high, the urethra can no longer hold things back! The bladder generally maxes out at about 500 ml (about 20 ounces) of urine. That’s just short of two cans of Coke (one can holds 12 ounces).
Urine leaves the body through the urethra

Like the anus, the urethra has two sphincters, the inner one smooth muscle and the outer one voluntary skeletal muscle.

The length of the urethra is different in males and females.

Getting urine out of the body is similar to the process of getting feces out. Urine leaves through peristalsis in the muscular tube called the urethra. Like the anus, the urethra has two sphincters. The inner one is involuntary, made of smooth muscle. The outer one is made of skeletal muscle and is under conscious control.

In females, the distance from the bladder to the outside of the body is small, and the urethra is only about an inch and a half long. In males, the urethra is about 8 inches long, passing through the length of the penis. In males, the urethra carries both urine and sperm, and so plays a role in both the urinary and reproductive systems.
Because urine contains the products of reactions in your body and the excess of substances you’ve taken in, it can reveal a lot about what is happening inside your body. One of the first signs of diabetes is a high level of glucose in the urine, because the blood levels of glucose get so high in the blood that it escapes through the urine. Prostate and ovarian cancer cells produce antigens that can be detected in the urine of someone who has them, often before the patient shows any other symptoms.

When a woman is pregnant, she produces a hormone that eventually gets removed from the body in her urine. It’s this hormone that a pregnancy test is testing for. Pregnant women are also at risk for several conditions such as a temporary form of diabetes and a vascular condition that can raise blood pressure dangerously high. An important part of prenatal care is a regular urine test for proteins or glucose that would indicate these conditions.

Urine tests in general can be a very simple, noninvasive way for doctors to be able to see into a range of complicated conditions.

What does it say about the kidney’s treatment of drugs and anabolic steroids that they can be detected in a urine test?
Student Resource 19.2

Guide: Nephron Model

Student Names:_______________________________________________________ Date:____________

Directions: With your group, build this model to simulate each stage in the production of urine in the nephron. Then answer the questions that follow each stage.

Later, you’ll use the model to explain to other classmates what’s happening in the stages of urine formation.

Collect the Materials

Check the kit from your teacher to make sure it contains:

- Two clear plastic tubes
- One 4-inch length of mesh tubing
- A container of beads labeled “Components of blood”
- Three plastic spoons, one each green, blue, and white
- One set of labels for filtration models
- One plastic cup with lid
- One plastic cup for water
- One strip of kitchen sponge
- Three black beans
- Tweezers
- Marker
- Scissors
- Ruler
Make and Use the Model

Filtration

Become familiar with this table. It describes what the different beads represent. Then follow the directions for building the model, which are listed below the table.

In the first part of the demonstration, you’ll simulate how the glomerulus filters substances from the blood. Use the chart below to reference which beads represent which types of substances in the blood.

<table>
<thead>
<tr>
<th>Bead size</th>
<th>Bead color</th>
<th>Blood component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>Red</td>
<td>Red blood cells</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>White blood cells</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>Proteins</td>
</tr>
<tr>
<td></td>
<td>Black bean</td>
<td>Drug metabolites</td>
</tr>
<tr>
<td>Small</td>
<td>Green</td>
<td>Amino acids</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>Glucose</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>Sodium</td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td>Urea</td>
</tr>
</tbody>
</table>

To demonstrate filtration in the glomerulus:

1) Empty the “blood components” into one tube and label it “renal artery.” This represents the artery bringing blood to the kidneys for filtration.

2) Label the other tube “renal vein.” This represents the vein bringing filtered blood back to the heart to be oxygenated and circulated.

3) Fill one plastic cup with water. Add water to the renal artery tube so that it’s about two-thirds full.

4) Put one end of the mesh over the end of the renal artery tube, and put the renal vein tube into the other end. (Keep the renal artery upright.) The ends of the two tubes should be an inch or two apart. The mesh represents the wall of the glomerular capillary at the beginning of the nephron.

5) Keeping the renal artery upright, move your model until it’s over an empty plastic cup. Then turn the renal artery sideways, keeping the mesh that’s between the two tubes over the cup so that the water and some of the blood components in it fall into the cup. The collection of things that fall into the cup is the filtrate.

6) If any blood components are stuck in the artery or the glomerulus, tilt the model more so that what doesn’t empty into the cup falls into the renal vein.
Questions:

a) Which blood components move across the glomerular capillary wall into the filtrate?

b) What determines which substances pass through the filter and which don’t?

c) Which of these does your body need and use?

d) Which of these does your body have to get rid of?

Reabsorption

Most of the substances in the filtrate are useful to your body and will be reabsorbed in the next stage of urine formation. Much of the reabsorption of these nutrients takes place in the proximal convoluted tubule (PCT).

Under normal circumstances, your body will make use of all the glucose and amino acids it has. So the body will reabsorb these entirely back into the bloodstream.

Water and sodium, on the other hand, need to be balanced. Too much or too little can throw the body’s chemistry off. These two nutrients are selectively reabsorbed, meaning that the body takes some back in and leaves some out. This process also occurs mainly in the PCT.

Glucose, amino acids, and sodium are all brought back into the blood using active transport. This involves proteins that are specific to each substance and expending energy to make those proteins “pump” the molecules back into the blood.

To demonstrate reabsorption in the PCT:

1) Glucose needs to be removed completely from the filtrate and returned to the blood in the renal vein. The purple spoon represents the specific protein that the body uses to transport glucose. Use the purple spoon to remove all the glucose from the filtrate and place it in the renal vein tube (you will have to remove the mesh from the renal vein to do this).

2) Do the same for amino acids, using the green spoon, which represents the specific protein required to move amino acids.

3) Your body needs some of the sodium, but not all of it. Using the white spoon (the protein that transports sodium ions), move 10 sodium ions from the filtrate to the renal vein.

4) Your body also needs water, but it also needs to use some of the water to dissolve the substances that need to be removed. Water moves back into the blood by diffusion (osmosis). Pour about a quarter of the water from the cup with the filtrate into the renal vein.
Questions
   a) What substance was not reabsorbed at all? Why not?
   b) What is the fate of the material that remains in the cup?
   c) What substance remains in the renal vein that needs to be removed?

Secretion
There are still a few things that need to be removed from the blood and moved into the tubular fluid. Secretion, which occurs mainly in the distal convoluted tubule (DCT), involves removing or further balancing substances that are still in the blood. An example of this would be the removal of drug metabolites.

To demonstrate secretion in the DCT:
   1) Detach the mesh from the renal vein.
   2) Using the tweezers, remove the drug residues and place them in the cup with the filtrate.
   3) Bring the hormone ADH into the system by using a bit of sponge to absorb about half of the water from the filtrate cup and squeeze it out into the renal vein. This represents ADH allowing the tubule walls to let more water out and returning that water to the blood.

Questions:
   a) What is the fate of the drug residues?
   b) How does ADH change the amount of urine that leaves the body in this demonstration? How does it make this change?
Student Resource 19.3

Reading: The Nephron

AOHS

Foundations of Anatomy and Physiology II

Lesson 19

The Nephron
There are about 1 million nephrons in your kidneys. They all work continuously to process fluid, keeping substances the body needs and getting rid of what we don’t need via urine.
Three sections of the nephron contribute to most of fluid processing

- Glomerulus
- Proximal convoluted tubule (PCT)
- Distal convoluted tubule (DCT)

What do proximal and distal refer to in these anatomical structures?

The nephron is a microscopic structure that serves as the interface between the urine and blood. Most of the work the nephron is responsible for is done in three specific segments: the glomerulus, the proximal convoluted tubule (PCT) and the distal convoluted tubule (DCT).

This illustration is simplified, showing only one capillary. A real nephron is surrounded by a dense mesh of these tiny blood vessels. The part of the blood vessel near the beginning section of the nephron squeezes fluid into the nephron in a section called the glomerulus. From there, blood flows past the proximal and distal convoluted tubules, and the blood vessels take in substances moving out of the nephron and back into the blood. What's left at the end of the nephron is urine that leaves the body.
There are three stages to urine production, and they occur in specific areas of the nephron

- **Filtration** occurs in the glomerulus

- **Selective reabsorption** happens in the PCT

- **Reabsorption and secretion** occur in the DCT

Here’s a simplified picture of what happens to create urine: in the glomerulus, plasma and many substances in it are all filtered from the blood into the beginning part of the nephron. The high pressure in the capillaries of the glomerulus forces everything but blood cells out, much like straining chicken broth through a sieve. Some of these substances are wastes and toxins you need to get rid of. But others are substances the body needs and therefore need to be returned to the blood. In the PCT, many of the useful substances, such as glucose, ions, and amino acids, are reabsorbed into your bloodstream. The DCT does a lot of fine-tuning. It makes sure that your blood has the right balance of ions and that any toxins that didn’t leave in the glomerulus get removed from the blood and brought into the nephron. The DCT also makes sure the body has the right amount of water by adjusting the amount of water that gets passed into the urine.

The amount of water reabsorbed into the blood (or lost in the urine) is directed by the antidiuretic hormone, or ADH. As you may recall, ADH is produced in the posterior pituitary.
The glomerulus filters everything but blood cells, proteins, and large proteins from your blood

The glomerulus is a space containing a long, coiled capillary. Pores between cells of the capillary walls let many kinds of substances through.

The blood pressure in the glomerular capillaries is very high, forcing these particles into the glomerular capsule, which is the space surrounding the glomerular capillary.

The glomerulus is made of a coiled capillary and surrounded by a hollow sphere of cells called a glomerular capsule. The glomerular capillaries are special because they are “leakier” than most capillaries in the body. They have larger-than-usual pores between the cells that form their walls. The cells that make up the glomerular capsule, on the other hand, are tightly held together. The blood pressure inside the glomerular capillaries is very high. This pressure forces the blood up against the capillary walls. Particles that are smaller than the pores between the cells get pushed through the pores and into the space inside the glomerular capsule. The fluid that collects, called the filtrate, contains most small molecules flowing in your bloodstream: water, glucose, amino acids, ions, hormones, medications, toxins you’ve consumed, excess water-soluble vitamins, minerals, and many other substances. The filtrate also includes a compound called urea, which is created when your body breaks down proteins or the amino acids they’re made of. Urea contains a lot of nitrogen and is toxic to humans. But the nitrogen can help plants grow, so urea is sometimes used a fertilizer. It can also help hydrate the skin, so it’s sometimes used in face creams.

Particles that are bigger than the spaces between cells in the capillary walls stay inside the capillary. Blood cells and proteins make up most of what stays in the bloodstream after filtration.

Once the filtrate has been pushed out into the glomerular capsule, it continues moving on through the PCT.

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In the PCT, useful substances like glucose, amino acids, and sodium are reabsorbed

When glucose and other solutes go back into the bloodstream, their concentration becomes less inside the tubule.

This change in concentration makes water flow out of the tubule and into the blood via osmosis.

The PCT is where most of the good stuff that got filtered out in the glomerulus gets returned to your bloodstream. As the filtrate makes its way through the tubules, many different types of ions move out of the tubule and back into the bloodstream. Other important nutrients like glucose, amino acids, and hormones also return to the blood. Some of these substances simply diffuse across the walls of the tubule and the capillaries, and others are pumped back into the blood by active transport. Taking all these solutes out of the filtrate lowers their concentrations and increases the concentration of water in the tubules. When this shift in concentration happens, water flows back into the capillaries through osmosis.

All told, the miles of PCTs in your kidneys reabsorb over 150 liters of water a day! In fact, the amount of filtrate produced in the glomerulus is about 100 times more than the amount of urine that’s made from that filtrate. These big numbers tell you two important things: 1) blood is constantly flowing through your kidneys and creating filtrate, and 2) that filtrate is constantly being reabsorbed and urine is constantly being made more concentrated. The final step of concentrating urine occurs as the filtrate moves through the tubule and into the DCT.
In the DCT, antidiuretic hormone (ADH) fine-tunes the balance of water

ADH makes the DCT more permeable to water.

The less water in your body, the more ADH is secreted.

Also in the DCT, some molecules such as potassium and H⁺ ions move from the nephron back into the blood.

The DCT is like the final adjuster on the urine production line. By the time the filtrate reaches the DCT, it's officially considered urine, and the concentration of water in it is a lot less than in the original filtrate. But there is no mechanism to finely regulate the amount of water that gets reabsorbed, or doesn’t get reabsorbed, in the PCT. In the DCT, though, your kidneys adjust the amount of water that stays and goes based on how hydrated you are. If you're short on water, ADH will allow more water to leave the nephron and re-enter the blood. If you've been keeping hydrated, ADH will make the nephron less permeable to water so that you get rid of the water you don’t need.

The DCT also finely controls the pH in your blood. When the pH in your bloodstream decreases (in other words, when there are more H⁺ ions in your blood and it becomes more acidic), H⁺ ions are secreted from the blood capillaries into the tubules. The secretion rate of hydrogen ions is adjusted to keep the pH of your blood within the proper range for your body's chemical reactions. The DCT also regulates potassium levels similarly.

Finally, some substances, like drug residues, that didn’t get filtered out of the blood earlier get removed via secretion and become part of the urine here.
Reading: The Kidneys and Homeostasis

If you don’t fill your digestive tract with any food, your large intestine won’t be sending you to the bathroom. In contrast, even if you’re dehydrating in the desert, your body will still produce urine. That’s because producing urine is the body’s way of getting rid of wastes produced simply by being alive—substances like urea and metabolic acids, which are by-products of normal metabolism. If these compounds and other substances build up in your body fluids, they can make you sick—or worse! Removing these substances requires water, because the only way they can leave the body is if they’re dissolved in it. Thus, your body uses the process of creating urine as a way to maintain homeostasis. In particular, the kidneys manage the amount of substances circulating in your blood, including water, electrolytes, and hydrogen ions (pH).

Water, electrolytes, and blood pressure

It’s no news to you that the more water you drink, the more you have to go to the bathroom. The water you drink eventually ends up in one of three places: inside your cells, between your cells, or in your blood. If you didn’t get rid of excess water, either your cells would swell or the water would accumulate around your cells, causing you to swell up like a water balloon. Your kidneys make sure that doesn’t happen.

Adjusting the volume of water in your body is also very important for maintaining normal blood pressure. More water in the body leads to more blood, which increases blood pressure and makes your heart work harder. Conversely, if you’ve been sweating a whole lot and haven’t been drinking enough, your blood pressure may drop, and you’ll feel faint. In this case, a big glass of water can work wonders.

The water in your body is never just plain old water; it’s always carrying electrolytes—charged ions such as sodium, potassium, and calcium. When you balance the amount of water in your body, balancing the concentration of electrolytes goes along with it. If you eat a salty meal, the concentration of sodium will be higher than it should be. The high concentration of sodium sets a cycle of signals in motion that results in your saying “I’m thirsty.” You drink some water and the concentration of solute is adjusted. If you didn’t take in enough water, or if there’s still excess sodium, the kidneys might ship some sodium out with your urine. On the other hand, if you’ve been sweating (such as with exercise) and losing water, you’ve also been losing sodium. Your body will conserve what it has and not let too much, or any, out in your urine.

The concentrations of sodium and water in your body are tied together, and the kidney’s ability to move sodium into and out of your blood in the kidney is key to being able to adjust blood volume. That’s because, when it comes to things going in and out of your bloodstream, where sodium goes, water follows. Here’s how that works:
In the nephron, sodium is pumped out of the nephron by active transport. When sodium leaves the nephron, it means the concentration of sodium is higher outside of the nephron, and conversely, the concentration of water is lower. The opposite has happened inside the nephron—the concentration of sodium goes down as sodium leaves, and the concentration of water goes up. So, when the movement of sodium changes the concentration gradient, water will follow the sodium by osmosis. A set of hormones controls when your kidneys move sodium out of your blood, and those hormones are triggered by the sodium concentration in your blood. Antidiuretic hormone (ADH) works in tandem with these other hormones to fine-tune the amount of water that stays in, and leaves, the body. ADH, you’ll recall, makes water move back into the blood. Because sodium only moves in and out of the blood via active transport, when water moves, sodium doesn’t necessarily follow. So your body uses hormones in two different ways to control the volume of water and sodium in your blood.

When you’re exercising, for example, the cycle works something like this: when you sweat, you lose some sodium and you lose a lot of water. The result is that there’s less sodium in your body, but the loss of water makes the sodium that’s still there more concentrated. This higher concentration of sodium prompts your body to release ADH, which tells your kidneys, “hang on to the water.” This will “dilute” the high sodium and bring that concentration back to normal. Other hormones act to retain some sodium, bringing both sodium and water levels back to their normal levels. On the other hand, if you eat a lot of salty food and drink excess water, the hormones of the body will tell the kidneys to get rid of any excess ions or water that you have.

Questions:

If you exercise and don’t take in any water, what chemical changes in your body will set off the thirst mechanism?

Explain how hormones and osmosis work to adjust water and sodium levels.

Balancing pH of the blood

The cells in your body don’t have a lot of wiggle room when it comes to the pH they need to function properly. The optimal pH for your cells is around 7.4, just a little more alkaline than neutral (7.0). If the pH wavers as little as 0.3 in either direction, the situation is life threatening. So, maintaining a steady pH is a crucial task.

The task of maintaining pH is going on every second you’re alive, because most of the hydrogen ions (which lower pH and make a fluid more acidic) are made, like many other waste products, by metabolic reactions. Your body is stuck with a familiar problem: stay alive and make
waste products you need to get rid of, or don’t stay alive. Much of your kidneys’ function is really about managing this situation.

Acids produced by metabolic reactions end up in your blood, lymph, and other body fluids. The pH of these fluids is also affected by the food you eat. If you gobble a couple of oranges, you’ll have extra acid molecules to contend with. Your body has two mechanisms to control blood pH. Your respiratory system plays a role by breathing out carbon dioxide (CO₂). If left in the body, CO₂ will combine with water and form acid. When you breathe out, you get rid of the CO₂ before it has a chance to acidify. This process happens within seconds: when your CO₂ levels go up, producing acid, your body detects it quickly and you begin to breathe faster. That’s why, when you exercise, you may find yourself panting. Not only do your cells need more oxygen for the extra work they’re doing but you also need to get rid of all those extra CO₂ molecules.

But acids are produced in many more ways than just CO₂ reacting with water. Fats are broken down into fatty acids, proteins are broken down into amino acids, and muscle movement creates lactic acid as a waste product. Your body also makes waste products on the other side of the pH scale that can raise pH. Your kidneys are able to process and get rid of these molecules, secreting H⁺ ions when necessary to keep pH at the right level. The unwanted acid molecules end up in the urine, which typically has a pH ranging from 4.5 to 8, depending on what you’ve been eating and how much you’ve been exercising.

The kidneys exert their pH control much more slowly than the lungs, and it can take hours or even days to bring things into balance. Ultimately, though, the kidneys are the only organs that can shuttle molecules back and forth, into and out of the blood, keeping blood pH in the necessary range.

Questions

Suppose you exercise for an hour and drink a sports drink afterward. The sports drink contains sodium and has a pH of 2.5. How will your endocrine glands and kidneys respond to the sports drink?

Would you expect the pH of the urine to be higher or lower than the normal range?
Student Resource 19.5

Reading: Urinalysis

Student Name:_______________________________________________________ Date:___________

Directions: Read this background information as homework so that you understand the basics of urinalysis when you simulate it in the upcoming lab experiment. Answer the questions that follow the information.

Why Do a Urine Test?

The urine tests you probably hear about most are the ones athletes go through to determine whether they've been taking performance-enhancing drugs. But urine tests are very useful tools for health professionals diagnosing all kinds of conditions. Health care professionals rely on urine tests to give them clues to what is going on inside someone's body. Because urine contains waste products from substances a person has consumed, taking stock of what's in someone's urine can help a health care professional see what that person has been consuming or how well their body is processing wastes or glucose. There are literally hundreds of conditions that urinalysis is used to detect, and many substances that can be measured. Here are a few of the most common ones.

Ketones

Ketones are a class of chemical compounds. The ketones that might be in urine are created by the breakdown of fats for energy. Ketone levels will be abnormally high when a person is using fat rather than carbs for most of their energy. When you find ketones in a person's urine, it's a sign that he's not getting enough carbohydrates. You'll often find ketones in the urine of people with anorexia, because they don’t eat enough food generally, or in the urine of people on low-carb diets. Ketones in the urine can also mean that the body isn’t processing carbs and getting energy from them, which can be an indicator of diabetes.

Protein

Protein is an important nutrient, and the kidneys don’t usually let it escape in the urine. A urine sample from a healthy patient won’t have any protein in it. But if a patient’s kidneys are damaged or starting to fail, some protein may leak into the urine. When a urine sample has protein in it, it's often a sign that the kidneys are malfunctioning in some way. The more protein in the urine, the worse the kidney function.

Glucose

Glucose is another very important nutrient that your body doesn’t just toss away. A healthy person’s kidneys will reabsorb all of the glucose that’s initially filtered out of the blood in the glomerulus. If a urine sample does contain glucose, it points to one of two things: there’s either an excessive amount of the sugar circulating in the patient’s bloodstream, which would indicate diabetes, or the kidneys aren’t reabsorbing the glucose, which would be a sign of kidney damage. A health care practitioner would look at other urinalysis results for clues as to which of those two conditions is more likely, and then run further tests.

Blood or hemoglobin

Under normal circumstances, all blood cells and hemoglobin stay in the blood in the glomerulus and don't leak into the urine. If a patient’s urine does contain traces of blood or hemoglobin, it could mean that he or she is developing kidney disease. But blood in the urine can also arise from other factors, such as a blow to the kidneys, extremely strenuous exercise, a urinary system infection, or smoking.
pH
The pH value of urine is normally between 4.5 and 8. A lower, or more acidic, urinalysis result usually means that the sample is contaminated with bacteria or is not fresh.

Color and cloudiness
Normal urine is a clear, yellow color. Pale yellow or almost clear urine is a sign that someone is well hydrated and so can get rid of excess water. Urine that's a darker amber color is made when a person is dehydrated and the body conserves all the water it can. Still, even a dehydrated body needs to use some water for urine. Cloudy urine is a sign of a urinary tract infection. The cloudiness may be caused by bacteria in the urine.

Questions:
1) If a urinalysis showed both protein and glucose present in the urine but ketones were normal, what might you suspect is causing that and why?

2) If a patient's urine sample had blood in it, what other information could give you clues about the cause?
Lab 1: Urinalysis

Student Names:_______________________________________________________ Date:___________

Directions: With your partner, visit each of the four urine test stations. Be sure to follow proper lab technique. At each station, record results from the urine test in the chart provided and answer the questions that follow.

At each station, go through the following steps and then record the results:

1) Find a cup for the sample and a strip of test paper.
2) Evaluate the color and cloudiness of the urine sample.
3) Pour just enough urine into the cup so that you can immerse the test strip.
4) Leave the strip in the urine for as long as your teacher tells you (the timing will depend on the brand of test strip).
5) Compare the colors on the strip with the color chart.

<table>
<thead>
<tr>
<th>Station 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality being measured</strong></td>
</tr>
<tr>
<td>Color</td>
</tr>
<tr>
<td>Cloudiness</td>
</tr>
<tr>
<td>Ketones</td>
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<tr>
<td>Glucose</td>
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<tr>
<td>Protein</td>
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<tr>
<td>Blood</td>
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<td>pH</td>
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</tbody>
</table>

**Question:**

1) What condition(s) would these results prompt you to test for further? Why?
Station 2

<table>
<thead>
<tr>
<th>Quality being measured</th>
<th>Result or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td></td>
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<tr>
<td>Cloudiness</td>
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<tr>
<td>Ketones</td>
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<tr>
<td>Glucose</td>
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<tr>
<td>Protein</td>
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<td>Blood</td>
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**Question:**
1) What condition(s) would these results prompt you to test for further? Why?
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<table>
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<td>Color</td>
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<td>Cloudiness</td>
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<td>Ketones</td>
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<td>Glucose</td>
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<td>Protein</td>
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<td>Blood</td>
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<td>pH</td>
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</table>

Question:
1) What condition(s) would these results prompt you to test for further? Why?
Student Resource 19.7

Reading: Urinary System Conditions

Student Name: ___________________________________________ Date: __________

Directions: Complete the reading and answer the questions.

Urinary system conditions fall into two camps: those that affect the urinary tract and those that affect only the kidneys.

**Conditions of the Urinary Tract**

Problems with the urinary tract often involve changes in the amount of urine released, the color of urine, and the frequency with which you need to urinate.

**Urinary tract infection (UTI)**

Unlike feces, ordinary urine is sterile, because under normal conditions there are no bacteria or other microbes living in the urinary tract. Occasionally, bacteria or other infectious organisms do make their way from outside into the urethra and colonize one or more of the structures of the urinary tract, causing a urinary tract infection, or UTI.

Initially, the microbes usually make their home in the urethra or the bladder. An infection in either of these two areas makes urinating a painful, burning, itchy experience, so these infections rarely go unnoticed. UTIs are usually diagnosed with urinalysis and finding microorganisms when looking at a urine sample under a microscope. Females get UTIs more often than males, and that’s due largely to the way bacteria get the opportunity to enter the urinary system. Often, the bacteria that cause the infection are imported from the feces. So it’s important that, after going to the bathroom, females wipe from front to back rather than from back to front, and that males also stay aware and keep anything that’s been near feces away from the urethra.

If a UTI goes untreated, it can make its way to the kidney, where the infection can become very serious. Because the kidneys are the site of exchange of substances into and out of the blood, the bacteria can actually move into the bloodstream, causing infection in the entire circulatory system. Initially, though, most UTI’s are manageable with antibiotics. The moral of this story: if you think you’ve got a UTI, get to the school nurse or a doctor.

**Question #1:** Explain why a UTI can become very dangerous if it reaches the kidneys.
Urethral blockage

Men have a gland called the prostate that sits just below the bladder and surrounds the urethra. In many older men, the prostate becomes enlarged and puts pressure on the urethra, resulting in a variety of symptoms. Men with enlarged prostates may have trouble starting to urinate, the stream of urine may be small or not have much pressure behind it, and the man may feel like he still needs to go to the bathroom even after he just went. There are several medications that can help reduce the symptoms of an enlarged prostate, but they don’t address the blockage. If the space for urine to flow through the urethra is severely reduced, the man may need prostate surgery to remove some of the gland.

Question: Why does an enlarged prostate effect a man’s ability to urinate?

Conditions of the Kidneys

Kidney stones

Imagine you have a small amount of water in a cup. You add a bit of salt, stir, and see it dissolve and disappear. But if you keep adding salt, eventually there will be too much to dissolve in the volume of water, and it will just sit at the bottom of the cup. Even if you have a situation where all the salt dissolves but then you let the cup sit in the sun where some of the water evaporates out, salt will come out of the solution and settle back at the bottom of the cup.

Something similar can happen in your kidneys if you’re dehydrated. Every moment, minerals and substances that can form crystals pass through your kidneys and get filtered into your urine. If you haven’t been drinking enough your urine becomes very concentrated (less water, more minerals). This can cause some minerals to come out of the solution and form crystals. In that case, they’ll form tiny pebbles that can be rather painful as they make their way through the urinary system. Most kidney stones can be eliminated by drinking a lot of water, and pain medications can make the elimination more tolerable. Doctors can use sound waves to break up larger stones or insert small instruments in the urethra to reach the stone and break it up.

Question: How does drinking enough water help prevent kidney stones?
Hangover

Those who overindulge in alcohol and wake with an aching, groggy head can thank their urinary and endocrine systems for the symptoms. Recall that when your body is short of water, your pituitary secretes the hormone ADH, which travels to the kidneys and makes them return water from the urine to the bloodstream. Alcohol keeps the pituitary from releasing ADH, so the water the body needs ends up flowing out with the urine. The resulting dehydration leaves the indulgent drinker in an unpleasant state of nonhomeostasis.

Question: In what way does alcohol affect the endocrine system and thus the kidneys?

Chronic kidney disease (CKD)

On a far more serious note, chronic kidney disease profoundly affects the lives and lifestyles of 26 million people over 18 in the United States—that’s an astounding 1 in every 10 adults. Chronic kidney disease, often just called CKD, usually isn’t a disease in itself but arises because of other conditions. The two most common causes of CKD in the United States are type 2 diabetes and high blood pressure. For people with either of these conditions, one of the most urgent reasons to manage their health is to prevent renal failure. For the rest of us, the best way to fend off CKD and its path to renal failure is to do what we can to prevent high blood pressure and diabetes.

Chronic kidney disease involves a slow deterioration of the function of the kidneys. When the kidneys stop doing their job, it means that a major piece of machinery that maintains homeostasis throughout the body has shut down. Every body system is affected by the loss of homeostasis. Perhaps most obviously, the kidneys no longer remove water the way they should, and so people with CKD often have swelling in their hands and feet. Other, less visible, symptoms also occur, such as muscle cramping or difficulty concentrating as the lack of ion balance begins to affect the nervous system.

The connection between diabetes and CKD is quite complex and not entirely understood, but around 40% of people with type 2 diabetes will develop CKD. The effect of blood pressure on the kidneys is much clearer. Constant high blood pressure causes direct damage to the many blood vessels of the kidneys, especially the glomerular capillary, where filtration occurs. This decreases filtration and prevents the nephrons from getting enough filtrate to process, which is critical to controlling what is in our blood.

Some genetic kidney disorders and conditions caused by inflammation can also lead to chronic kidney disease. Smoking, excessive use of some types of pain relievers, and drinking lots of cola drinks can also increase a person’s risk of CKD. Once a person’s kidneys have been damaged, they can’t be healed, but changes in diet and lifestyle can help slow the progression. Eating less salt eases strain on the kidneys by giving them fewer ions to deal with, and a lower-protein diet will produce less amino acid waste that needs to be eliminated.
Many patients with CKD will eventually lose so much of their kidney function that they will require regular treatments of what is called hemodialysis. The word *dialysis* means a situation in which some solute particles in a solution can diffuse freely across a semipermeable membrane (in this case, things like sodium and glucose) while others, such as blood proteins, can’t. This is what happens in the glomerulus and also what happens in the hemodialysis machine. Hemodialysis is sometimes called kidney dialysis, but the former term is more correct. *Hemo* refers to blood, and it’s the blood that’s being filtered, not the kidneys. While hemodialysis can go a long way in providing a means to achieve homeostasis in the body, it’s a lot less efficient than the kidneys and can be physically taxing.

Patients whose kidneys have completely stopped working are said to have renal failure. These patients are completely dependent on dialysis and their only hope for improvement is a kidney transplant. Kidney transplants have a success rate of about 90%, but the patient is dependent on the donation of a healthy kidney. Kidneys are one of the only organs that one person can donate to another while still alive, because a person can live with only one kidney. In some families, one relative will agree to donate one kidney to another relative who needs it, because donation within a family usually has fewer complications. Even a successful kidney transplant is complicated, though, and such patients must take immunosuppressant drugs for the rest their lives.

**Question:** How does high blood pressure increase the risk of kidney disease?
### Notes: Hemodialysis

**Student Names:** ____________________________________________  **Date:** ____________

**Directions:** Complete the notes as you watch the presentation on hemodialysis.

1. Describe how a dialyzer is similar to and different from a glomerulus.

<table>
<thead>
<tr>
<th>Glomerulus</th>
<th>Dialyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Glomerulus Image]</td>
<td>![Dialyzer Image]</td>
</tr>
</tbody>
</table>

**Shape of blood vessel:**

**Membrane:**

**How things are moved across the membrane:**

**What stays inside the blood vessel:**

**Shape of fibers:**

**Membrane:**

**How things are moved across the membrane:**

**What stays inside the fibers:**
What leaves the blood vessel:

Is the fluid that leaves the glomerulus ready to be removed from the body? Why or why not?

What leaves the fibers:

Is the fluid that leaves the dialyzer ready to be removed from the body? Why or why not?

2. Explain two ways in which a fistula is helpful for a dialysis patient.
   a)
   b)

3. Label the dialysis ports and indicate which is “upstream” of the other. What would happen if they were switched?
4. In the chart below the diagram, describe what is happening at each numbered point on the diagram.

<table>
<thead>
<tr>
<th>Number</th>
<th>What's happening</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td></td>
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<td>3</td>
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<td>6</td>
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</table>
Student Resource 19.9

Reading: Hemodialysis

AOHS
Foundations of Anatomy and Physiology II

Lesson 19

Hemodialysis
By the end of this presentation you will know:

- What a hemodialysis machine does
- How a hemodialysis machine mimics the function of the kidneys
- What a hemodialysis machine can’t do that the kidneys can
- How a patient is connected to a hemodialysis machine
Hemodialysis is the process of cleaning a patient’s blood with a machine

During hemodialysis, a patient’s blood circulates outside of his or her body, through a filter that acts as an artificial kidney. The first hemodialysis was performed in 1924.

For a patient whose kidneys have begun failing, a hemodialysis machine is a lifesaver. The machine acts as a kind of artificial kidney, removing waste products from the blood and bringing electrolyte values to normal levels. The first hemodialysis was done in 1924, on a crude machine. Today’s modern hemodialysis machines work on a similar principle but are far more sophisticated. They are able to adjust to accommodate a patient’s blood pressure in the arteries and the veins while giving digitized measurements of blood chemistry. Dialysis can prolong the life of a person with kidney disease by decades.

So many people in the United State require hemodialysis that there are now many centers, separate from hospitals and other health care facilities, where patients can go for their dialysis treatments. Health care careers like hemodialysis nurse or technician are growing fields as more and more Americans require the procedure.
Inside the dialyzer are hollow parallel fibers made of a semipermeable membrane

The dialyzer membrane allows ions, urea, and other waste products to pass through, but it retains blood cells and proteins.

What part of the nephron does this membrane resemble?

The dialyzer is sort of like the nephron of the dialysis machine, the functional unit where the blood filtration takes place. The modern dialyzer is a tube about a foot long containing thousands of hollow fibers with walls made of a semipermeable membrane. The membrane in the dialyzer lets small particles, like glucose, ions, and urea, diffuse through it, but it keeps blood cells and proteins in the patient’s blood.

The first functional dialyzer was used for the first time in 1943. The patient was a woman with renal failure who’d fallen into a coma caused by the toxins in her blood. She regained consciousness after 11 hours of dialysis. Thankfully, today’s patients can get dialysis long before they are at that point of danger, and their dialysis treatments only last three to four hours.
Blood flows into the dialyzer from one direction, and dialysate flows in from the other

Dialysate is a solution that resembles the liquid part of plasma. A dialysis professional can adjust the composition of the dialysate based on the patient’s specific needs.

What would happen if the dialysate were just water?

The dialyzer is connected to both the patient and a supply of fresh dialysate. Blood flows from the patient’s arm through the dialyzer in one direction, and the dialysate flows through the filter in the other direction. Then each flows out the opposite end of the dialyzer. The blood returns to the patient, and the dialysate goes into a waste container.

The dialysate contains a solution of sodium chloride—also called a saline solution—that’s a bit like the fluid in blood plasma or the fluid between cells. The health care professional performing the dialysis can adjust the chemistry of the dialysate to accommodate what the patient needs. For example, he or she can add glucose if the patient is undernourished or add compounds that will adjust the blood pH.
As blood flows through the fibers, ions and waste products diffuse into the dialysate

Ions and waste products diffuse across the fibers’ semipermeable membranes. This diffusion occurs because concentrations are higher in the blood than in the dialysate.

What are some substances you would expect to find in the dialysate?

Blood moves through the hollow fibers so that it’s surrounded on all sides by semipermeable membrane. Flowing past the blood in the opposite direction is dialysate. The dialysate contains none of the metabolic waste products, such as urea, that the blood does, so their concentrations are high in the blood and zero in the dialysate. Thus, these substances diffuse freely across the membrane—as does excess water—out of the blood and into the dialysate. If glucose is added to the dialysate, it will be present in a higher concentration in the dialysate than in the blood, so that it will diffuse in the opposite direction, from the dialysate into the blood.

An important difference between dialysis and what actually happens in the kidney is the way that the waste products are removed. In the glomerulus, waste products are pushed out through the capillary wall by the pressure of blood going through the capillary. In this process, the vast majority of waste products are removed, as well as excess water, and only blood cells remain. Dialysis relies on diffusion to make waste products leave the bloodstream, which means that in order for a waste product to leave the blood, there must be a higher concentration of that waste product in the blood than in the dialysate. This is why dialysate contains virtually zero concentration of the waste products that must be removed.
One reason dialysis treatments take so long is that blood can only flow so fast. In order to speed the process up a bit, a hemodialysis patient who will be going through the treatment three times a week for years on end will have a vein in their arm surgically altered. There are several ways of doing this, but they all involve using the higher blood pressure in the artery to give a little extra push on the blood going through the vein that will be used for dialysis. The most common type of access is called a fistula. In a fistula, an artery is physically connected to a vein. This means some of the blood flowing down the artery bypasses the slow-moving capillaries and rushes into the vein. A fistula also protects against infection because it provides a permanent place to access the circulatory system for dialysis rather than having to stick needles or expose blood vessels in more areas of the body.

Hemodialysis patients use a surgically altered vein, or access, to provide blood for dialysis

A surgeon will connect an artery to the vein that will be used for dialysis. This connection makes blood flow more quickly through the vein.

The most common type of access is called a fistula, where the vein and artery are sewn together.
Before dialysis, needles are put into two points just past the fistula

Blood goes from the arterial port to the dialyzer.

Blood returns to the body via the venous port, which is always “upstream” from the arterial port.

The patient is connected to the dialysis machine when a needle is put into the vein in her arm just beyond (following the flow of blood) where the fistula has been made. This point, which will be used repeatedly for many dialysis sessions, is called the arterial port. Blood flows from the arterial port through a catheter and to the dialyzer. After it passes through the dialyzer, it returns to the same vein through the venous port. The venous port is always past (following the direction of blood flow) the arterial port, so that it is “upstream” from the blood that hasn’t been cleaned yet, which keeps the cleaned blood separate from the uncleaned blood.
During dialysis, blood passes through a circuit outside the body

You can think of dialysis as a sort of additional stretch of a circulatory system that’s got the machinery to do the job of the kidneys. Blood that needs cleaning goes out the arterial port, through the dialyzer, and back to the body through the venous port. On its journey, a blood pump helps keep it moving, and blood pressure monitors make sure that the pressure in the patient’s arteries and veins is within an acceptable range. While blood is moving through this circuit, dialysate goes from a container with fresh dialysate through the dialyzer, and then to a waste container for used dialysate. For dialysis to work, these two circuits must run at the same time so that dialysate and blood are moving past each other.
A patient who has kidney failure needs dialysis regularly. Most hemodialysis patients have treatments three times a week. During treatment, patients can read, sleep, watch TV, talk on the phone, or do other quiet activities. But they can’t get up and walk around. Dialysis usually takes from three to four hours.

Many patients get their treatments in a dialysis clinic. At the clinic, there are machines for many people and a staff of health care professionals trained in dialysis. Often the same people are at the clinic at the same time and get to know each other during their visits. Some people are able to have dialysis at home. They need space for the machine and a family member or friend who is willing to be trained to help them with the treatments.
Dialysis is effective, but it’s not without side effects and risks

Dialysis patients are often on blood thinners. These drugs make dialysis easier but increase the risk of excessive bleeding.

The access points where needles go into the vein can also easily become infected. Serious infection can spread to the blood.

How serious are these risks compared to the benefits of dialysis?

Regular dialysis can do a good job of keeping a patient’s blood concentrations at appropriate levels, but it isn’t an easy process. Along with having to have blood vessels surgically altered and spend several hours every other day getting treatment, hemodialysis comes with some significant risks. Many hemodialysis patients are on blood thinners, because thinner blood is less likely to clot around the fistula or in the dialysis machine. But blood thinners leave patients vulnerable to excessive bleeding and bruising. The areas in the vein used as ports can also become infected, and because the ports lead straight to the bloodstream, bacteria anywhere in the dialysis circuit, including in the dialysate, can be very dangerous. On a less threatening level, dialysis can leave a patient feeling tired or washed out the next day, which can have a big effect on the life of a patient who has dialysis every other day.
Heart disease and diabetes are the cause of 75% of newly diagnosed kidney disease

While dialysis is a substitute for your kidneys, no machine can match the efficiency and thoroughness of the real thing.

All the things you do to fend off heart disease and diabetes will also lower your risk of kidney disease.

What are some specific things you can do to lower your risk of kidney disease?

Some kidney failure arises from diseases directly associated with the kidneys. But in the United States, that’s a minority of cases. Nearly half of all kidney failure in the United States is related to diabetes, and a quarter stems from heart disease. Together, these two diseases account for three-quarters of the cases of kidney diseases diagnosed each year. This means that you can reduce your chances of getting kidney disease simply by doing the same things you do to keep your cardiovascular system healthy and protect yourself from diabetes. You know what they are: eat well, get some exercise, get enough rest, and do your best to reduce stress.
Lab 2: Dialysis Mini-Model

Directions: With your partner, follow the directions to make a mini-model of a dialysis machine and answer the questions that follow.

To review: during dialysis, blood moves in one direction through a semipermeable membrane. In the space surrounding that membrane, a fluid called dialysate flows in the opposite direction. Dialysate is similar to blood plasma. The blood contains high concentrations of waste products, while the dialysate contains no waste products. During dialysis, waste products diffuse across the membrane from the high concentration of the blood to the low concentration of the dialysate. This process results in cleaner blood that is then returned to the patient.

For this activity, you'll need to remember a few important words:

**Diffusion:** The movement of a substance from an area of high concentration to low concentration.

**Semipermeable membrane:** A membrane that allows some substances to move through it and not others. In the case of dialysis, the membrane has holes small enough to allow small particles such as glucose, ions, and urea through it, but not blood cells.

**Dialysate:** A fluid used during dialysis. Dialysate is similar to blood plasma (but without the hormones and other products carried in the plasma).

In this exercise, you'll make a mini-model of a dialysis machine. It will be much simpler than a real dialysis machine, but you'll be able to see how the machine handles blood. Once you’ve built the machine and put the patient’s blood into it, you’ll analyze the results and suggest any changes you think should be made to keep the patient in homeostasis.

Part 1: Build your model

Obtain a model-building kit from your teacher. Make sure it has all the parts. It should include:

- One tapered test tube with a lid and containing red glitter
- Four small tubes, labeled “glucose,” “protein,” “salt,” and “urea”
- Small plastic bag or envelope containing three different test strips
- One plastic dropper with the tip cut off
- A clear plastic or glass cup
- One 9-inch length of dialysis tubing

To put your model together:

1) Wet one end of the dialysis tubing with tap water and tie a knot in it. Don’t wet the whole length of tubing, just 2 or 3 inches at one end of it.
2) Make your simulated “blood” by adding the following ingredients to the test tube with the glitter:
   a. Glucose
   b. Urea
c. Salt  
d. Protein

3) Fill your tube of blood about half full with hot water. DO NOT completely fill the tube. Half full is enough.

4) Firmly screw the top onto the test tube, making sure that it doesn’t leak. Gently turn the tube upside down a few times, getting the contents well mixed.

5) Immediately transfer the blood to the dialysis tubing using the plastic dropper.

6) Place the dialysis tubing in the clear cup, and fill the cup about three-quarters full of hot water. This hot water represents the dialysate. Your model should look like the drawing below.

**Model of Dialysis Machine**

Consider what’s in the blood, and record your predictions in the first column of the chart below:

<table>
<thead>
<tr>
<th>Substance in blood</th>
<th>Will it diffuse through the tubing?</th>
<th>Results: Did it diffuse?</th>
<th>Should it be added to dialysate to maintain normal values?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red blood cells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Glucose</td>
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<tr>
<td>Salt</td>
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</table>
Now set the dialysis model aside. You’ll return to it in a few minutes, after the blood has had a chance to “dialyze.”

**Part 2: Results and questions**

You’ll need to determine your results and fill in the second column of the chart.

- **a)** Look at the dialysate. Did the yellowish urea waste diffuse into it?
- **b)** Do you see red blood cells in the dialysate?
- **c)** To test for protein, dip one end of the white test strip into the dialysate. A red color indicates the presence of protein.
- **d)** To test for glucose, dip the orange test strip into the dialysate. A blue or green color indicates the presence of glucose.
- **e)** To test for sodium, dip the pink test strip into the dialysate for 10 seconds. A light purple color indicates the presence of sodium.

Fill in your results in the chart.

As you know, the kidneys’ main role is to maintain normal volumes and ion concentrations. The kidneys do this by using a combination of diffusion and active transport to move substances back into the bloodstream after they’ve been pushed out in the glomerulus.

The dialyzer can’t perform active transport, so all the filtration must occur through diffusion. If the dialysate is just water, anything else that can cross the membrane will. To keep needed substances from diffusing out of the blood, their concentration in the dialysate has to be the same as in the blood.

1) Why did some substances diffuse and others didn’t?

2) What substance(s) that are needed in the body diffused out of the blood?

3) What substance(s) can be allowed to diffuse out of the blood as much as possible?

Fill in the third column of the chart identifying which substances would need to be added to a dialysate solution for the patient to maintain normal levels.
### Quiz Preparation: Vocabulary Blocks

**Student Name:** ____________________________________________________________ **Date:** ____________

**Directions:** For each vocabulary word, fill in the empty spaces in each block. Try to use appropriate and specific vocabulary wherever you can. If you make a drawing of the word, the drawing can be an image that will remind you of the concept behind the word. It doesn’t have to be a picture of the word itself. Keep in mind that this exercise is intended to give you ideas that will trigger your memory of the word. Your drawings and verbal answers will likely be different from those of your classmates.

<table>
<thead>
<tr>
<th>Vocabulary word:</th>
<th>Drawing of kidney and kidney location in the body:</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIDNEY</td>
<td></td>
</tr>
<tr>
<td>Parts of the kidney:</td>
<td></td>
</tr>
<tr>
<td>Function of the kidney:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vocabulary word:</th>
<th>Drawing showing the urinary tract and where infection is most likely:</th>
</tr>
</thead>
<tbody>
<tr>
<td>URINARY TRACT INFECTION (UTI)</td>
<td></td>
</tr>
<tr>
<td>Causes:</td>
<td></td>
</tr>
<tr>
<td>Possible complications:</td>
<td></td>
</tr>
<tr>
<td>Vocabulary word: URINE</td>
<td>Drawing representing substances found in urine:</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Where it’s produced:</td>
<td></td>
</tr>
<tr>
<td>Things that can be learned from a sample of it:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vocabulary word: NEPHRON</th>
<th>Drawing showing the three parts of a nephron:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The three main parts:</td>
<td></td>
</tr>
<tr>
<td>Overall function:</td>
<td></td>
</tr>
<tr>
<td>Vocabulary word:</td>
<td>Drawing representing substances that cross the membrane during selective reabsorption (show direction of movement):</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SELECTIVE REABSORPTION</td>
<td></td>
</tr>
<tr>
<td>What it is:</td>
<td></td>
</tr>
<tr>
<td>Where it takes place:</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Vocabulary word:</th>
<th>Drawing that represents what is and is not happening in the kidney of a CKD patient:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHRONIC KIDNEY DISEASE (CKD)</td>
<td></td>
</tr>
<tr>
<td>Causes:</td>
<td></td>
</tr>
<tr>
<td>Possible complications:</td>
<td></td>
</tr>
<tr>
<td>Vocabulary word:</td>
<td>Drawing of a dialyzer:</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>DIALYZER</td>
<td></td>
</tr>
</tbody>
</table>

| What it is and does: |                       |

| How it is similar to and different from a nephron: |                       |