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| **Project 3.4.3: The Blood/Urine Connection**  |

Introduction

Water is obtained from food, drink, and from reactions that occur in the body. The kidneys process and balance the amount of water that enters your system with the amount that is released. The digestive system helps rid the body of solid wastes, but some of the wastes in the blood are the remnants of the digestion of food products. For example, when amino acids are broken down by the body, ammonia (NH3) is formed. This product is so toxic that only small amounts can be tolerated by the body. The liver steps in and helps convert this poison to urea, a safer version of this waste product that can be easily removed in urine.

The urinary system not only controls the body’s fluid balance and rids the body of wastes, but it also helps to regulate the pH of the blood, blood pressure and the volume and composition of the blood. As the kidneys process blood, they regulate the amount of dissolved substances, especially electrolytes such as sodium, potassium, and calcium ions. An imbalance in electrolytes can affect the movement of water in and out of cells as well as impact the function of other body processes that rely on these ions. So how does the body maintain normal levels of electrolytes? Let’s take a closer look at the nephron and see what actually happens when the body produces urine. What your body keeps in is just as important as what it puts out. At specific points along the path through the nephron, various molecules and fluids are filtered back into the blood while others are pushed out to be disposed of in urine.

In this activity, you will build the nephron showing a distinction between vessels containing blood and tubules containing the filtrate that will become urine. A system of arrows and colors will be used to explain the three regulated processes that occur along the path. By exploring the relationship between the structure and function of the nephron, you will discover how the nephron is integrally involved in the maintenance of homeostasis in the body. You will also research and describe the composition of both normal blood and normal urine. Abnormalities in the blood or urine are often the first signal that there is a malfunction in another body system.

Equipment

* Computer with Internet access
* Orange, black, green, purple, blue, brown and pink markers or colored pencils
* Calculator
* Laboratory journal
* Nephron diagram
* ½ Sheet of poster board (optional)
* Red and yellow modeling clay (optional)
* Reference textbook (optional)

Procedure

Part I: Estimating Glomerular Filtration Rate (GFR)

To get an idea of how the nephron works to conserve water, let’s do a little math!

1. Refer back to your kidney map and find the glomerulus. Remember that the glomerulus is the initial filtering sieve of the nephron.
2. Know that the glomerular filtration rate (**GFR**) for all of the nephrons in both kidneys is approximately 125mL per minute. That means that about 125mL of fluid and dissolved substances are filtered out of the blood per minute. The fluid moves into the Bowman’s capsule, the first collecting tube of the nephron. Use this information to complete the calculations and answer the questions below.
* Calculate the GFR per day. Show your work. Express your answer in liters (L) per day.
* About how many 2L soda bottles would you fill per day?
* What do you think about this value? Do you produce this much urine in one day? What must be happening to some of the fluid that is being filtered by the glomerulus?
* If the first part of nephron action is called filtration, what name do you think is given to the second part of the process, where precious water is returned back into the blood?

Part II: A Snapshot of Nephron Action

Take a look at what is really going on inside the nephron.

1. View the Howard Hughes Medical Institution Biointeractive video on kidney function found at <http://www.hhmi.org/biointeractive/cardiovascular/video.html>. Think about how the demonstration shown relates to Part I. Record observations about the structure and function of the nephron in your laboratory journal.
2. Open the Biology Mad Kidney resource video at <http://www.biologymad.com/resources/kidney.swf>.
3. Scroll over the kidney to review the parts of the organ and read about function.
4. Obtain a labeled diagram of the nephron from your teacher and observe its structural components. Your teacher may have you redraw this diagram on a half sheet of poster board.
5. Choose *Nephron* from the dropdown menu on the Biology Mad Kidney resource. Scroll over the parts of the nephron to learn structure names.
6. Use the following websites, along with textbooks or other resources you may find to explore the function of the nephron:
* Sumanas, Inc. - The Mammalian Kidney (great animations!) <http://www.sumanasinc.com/webcontent/animations/content/kidney.html>
* National Space Biomedical Research Institute - The Formation of Urine <http://www.nsbri.org/HumanPhysSpace/focus4/ep-urine.html>
* Campbell Biology - Physiology of the Nephron <http://ex-anatomy.org/gener.html>
* Intellimed Human Anatomy Online: Kidney Blood Filtering <http://www.innerbody.com/image/card08.html>
1. Imagine how the 3-D structure of the nephron would appear. For example, the Bowman’s capsule is a cup-like chamber containing the glomerulus. The filtrate that occurs due to high pressure in the glomerulus empties into the Bowman’s capsule and drains into the proximal convoluted tubule. If desired, sculpt a 3-D Bowman’s capsule out of clay and place it on top of your diagram.
2. Use markers or colored pencils to color all vessels containing blood red and all the tubules that would contain filtrate or urine yellow.
3. Using an orange marker, label the following components of the nephron:
* Efferent arteriole
* Afferent arteriole
* Glomerulus
* Bowman’s capsule
* Proximal convoluted tubule
* Loop of Henle
* Distal convoluted tubule
* Collecting Duct
1. Return to the Biology Mad animation <http://www.biologymad.com/resources/kidney.swf> and click on the structures of the nephron to find out what happens inside the nephron. Pay attention to what substances are moving where.
2. Use a black marker to draw arrows that show the general direction of filtrate and material movement in and out of the nephron’s structural components.
3. Research the points in the nephron’s structure where the three key processes of *filtration*, *reabsorption* and *secretion* occur. Think about how these three processes relate to the composition of blood and to urine.
4. Use a green marker to label where filtration, reabsorption and secretion occur along the nephron.
5. Use purple arrows to show where glucose reabsorption occurs in the nephron. Make sure the arrows are pointing in the correct direction. Is glucose moving from the filtrate to the blood or from the blood to the filtrate?
6. Use blue arrows to show where water reabsorption occurs in the nephron. Make sure the arrows are pointing in the correct direction. Is water moving from the filtrate to the blood or from the blood to the filtrate? NOTE: This may occur in multiple locations in the nephron.
7. Use brown arrows to show where selected ions are reabsorbed in the nephron. Make sure the arrows are pointing in the correct direction and indicate which specific ions/salts are moving. Research the role these ions or salts play in the body and describe your findings in your laboratory journal.
8. Use pink arrows to show where substances are secreted in the nephron. Make sure the arrows are pointing in the correct direction and indicate which ions/substances are most often secreted.
9. Create a key at the bottom or side of the diagram. This key should explain the system of arrows and colors used to show movement of substances in the nephron.
10. With your partner, research the composition of blood and of urine. If you had to provide a recipe for making blood and for making urine, what would the ingredient lists look like? Be as specific as possible. Are there items in the blood that should not show up in urine? Record your findings in your laboratory journal.

Conclusion

1. What is the purpose of reabsorption in the nephron?
2. In what direction are substances moving during the process of secretion? Explain what these substances are and why they are excreted from the body.
3. Explain the role of the digestive system, the respiratory system and the urinary system in the removal of waste. How do these waste products relate to the three core resources?
4. Explain how both the digestive system and the urinary system work to conserve water in the human body.