A Kidney Problem?

The Case:

Ten years ago, your patient was diagnosed with Type 2 diabetes. She has been careless about following the treatment needed to keep her blood glucose levels regulated. Now she is experiencing fatigue, muscle cramps, swollen legs, nausea and back pain. She explains that that her urine is sometimes pinkish and cloudy. You suspect that your patient's kidneys may not be functioning normally.

PART 1:
Are the patient's kidneys functioning normally?

Your Tasks:

- Conduct a urine test.
- Analyze the information from the urine test to determine if the patient's kidneys are functioning normally.

Procedure:

1. Test the patient's urine sample.
   - Use the "Instructions for Urine Testing", urine test strips, and tube of patient urine.
   - Record the results of the tests on Table 1: Results of Patient's Urine Test.

Table 1: Results of Patient's Urine Test

Urine Tests	Patients' Results
Ketones	
Blood	
Protein	
Glucose	

Interpreting Urine Test Results

Ketones

Ketones are present in the urine when a person does not eat enough carbohydrates (for example, in cases of starvation or high-protein diets), or when a person eats enough carbohydrates but his body can't use them properly (for example, if he has diabetes). Ketones are produced when the body metabolizes fat (instead of carbs) to get the energy it needs to keep functioning.

Protein

Protein is not normally present in the urine. Healthy kidneys take wastes out of the blood but leave protein in the blood. Damaged kidneys may fail to separate blood protein from the wastes and protein may leak into the urine. A small amount of protein in urine can be an early sign of kidney disease. As kidney function worsens, the amount of proteins in the urine increases. Other conditions may also result in protein in the urine.

Blood (Hemoglobin)

Normally, red blood cells and hemoglobin are not present in urine. Healthy kidneys do not allow blood cells to move from the blood into the urine. Even small increases in the amount of red blood cells or hemoglobin in urine may indicate disease. Numerous diseases of the kidney and urinary tract, as well as trauma, medications, smoking, or strenuous exercise, can cause red blood cells or hemoglobin to be present in the urine.

Glucose

Glucose is normally not present in urine. When glucose is present it may result from a high concentration of glucose in the blood (due to diabetes) or a kidney problem. Therefore, when glucose is present in the urine, further testing is recommended to identify the specific cause.

2. Read the information in "Interpreting Urine Test Results." What substances are present in the patient's urine that are not present in normal urine?

   _____

3. Are the patient's kidneys functioning normally? State two evidences to support your answer.

   _____

   _____

PART 2:
How do normal kidneys work?

The Case:

Your patient doesn't understand how normal, healthy kidneys work to remove wastes and keep blood composition stable—within normal ranges. You would like to show her how the normal kidneys work and what happens when her kidneys are damaged.

Your Task:

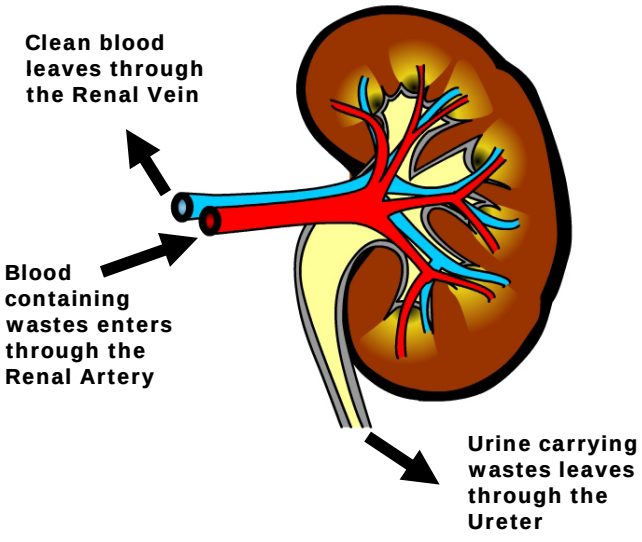
Use a model to illustrate how healthy kidneys work to keep the levels of substances in the blood within normal ranges.

Important Note: **The diagrams in this lab activity are black and white. It is much easier to understand these diagrams if you can look at them in color. Your lab kit contains a sheet of colored diagram. Please set the colored diagram sheet out on your desk so that you can look at it as you work on this lab activity!**

A. Kidneys Regulate the Composition of Blood

Your kidneys play a vital role in maintaining homeostasis. They excrete (remove) urea and other wastes, regulate the amount of water in the blood, and adjust the concentration of various substances in the blood. The substances removed from the blood form urine. The cleaned blood then travels to the heart and is pumped to the rest of the body.

Figure 1: A Kidney



As blood travels through the kidney, some blood components need to be:

- **Kept** in the blood because they are essential. Red blood cells, white blood cells, protein, glucose and amino acids should be kept in the blood. These components should not be present in urine.
- **Removed** from the blood and excreted in the urine because they are toxic (poisonous). Urea is a toxic substance that should be removed from the blood.
- **Balanced** so they are present in the correct concentration in the blood. A certain amount of water and salt is needed by the body and will remain in the blood. If excess water and excess salt are present in the blood, they should be excreted in the urine.

In this lab activity, you will use a model to help you understand how the kidney maintains the proper concentrations of substances in the blood.

KEY

Large Beads	Red = red blood cells
	White = white blood cells
	Green = proteins
Small Beads	Green = amino acids
	Blue = glucose
	White = salt
	Yellow = urea

1. Remove the bag labeled "Blood Components" from your kit. The beads in this bag represent the blood entering the kidney. The key below indicates what blood components are represented by each type of bead.

2. Blood enters the kidney through the renal artery. Add the contents of the bag labeled "Blood Components" to the cup labeled "Blood in the Renal Artery Entering the Kidney."

3. Blood also contains water. Add enough water to fill the cup containing the beads about three quarters full of water.

4. What blood component should be completely **removed** from the blood as it passes through the kidney? What type of bead represents this component?

   _____

5. What five blood components should be **kept** in the blood as they pass through the kidney? What type of bead represents each of these components?

   _____

   _____

   _____

   _____

   _____

6. In addition to water, what blood component should be **balanced** so that they are present in the correct concentrations in the blood? What type of bead represents this component?

   _____

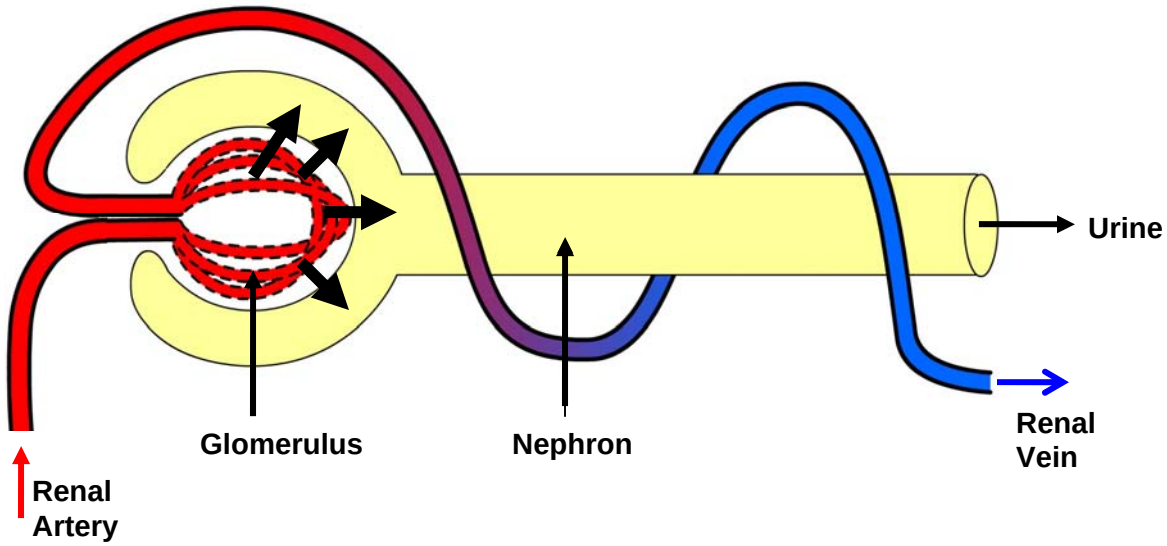
7. What three substances would you expect to find in urine that is **excreted** by the kidney?

   _____

B. Kidneys Filter Blood

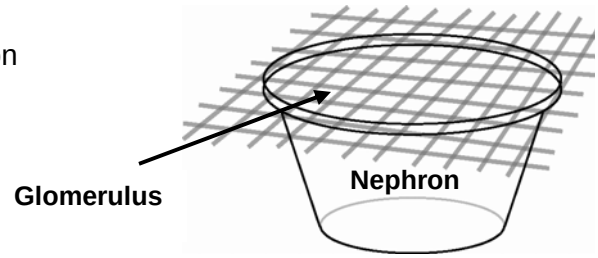
Each kidney contains over 1 million microscopic blood-cleaning units called **nephrons.** A nephron, shown in the diagram below, is a tiny tube with a cup-shaped structure on the end. The cup-shaped part of the nephron surrounds a tight ball of capillaries called a **glomerulus**.

Figure 2: Filtration allows small molecules to enter the nephron



Blood enters the kidney through renal arteries. The renal arteries branch to supply blood to the tiny balls of capillaries called glomeruli. The walls of the **glomerulus** capillaries are porous. They act like filters to allow small molecules to move under pressure from the blood into a cup-like part of the nephron. The movement of materials out of the glomerulus capillaries and into the nephron is known as **filtration.** The fluid that collects in the nephron is called the **filtrate.**

8. Prepare a model of a glomerulus and a nephron by placing the screen (to represent the glomerulus) over the plastic bowl (to represent the nephron) See diagram on the right.



9. Model the process of **filtration** that occurs in the glomerulus. Pour the contents of the "Blood Components" cup onto the screen (the glomerulus) to form a single layer.

10. The materials trapped on top of the screen remain in the blood. Pour the materials that stay on top of the screen into the cup labeled "Blood in Renal Vein." *Note: some of the small beads may remain on top of the screen. This is OK. In fact, this actually occurs in the kidneys. Most, but not all, of the substances leave the blood.*

11. Write the names of the three blood components that are kept in the blood because they are too large to pass through the pores of the glomerulus. (See key to the right)

_____

_____

_____

KEY

Large Beads	Red = red blood cells
	White = white blood cells
	Green = proteins
Small Beads	Green = amino acids
	Blue = glucose
	White = salt
	Yellow = urea

12. The substances that pass through the screen and into the nephron form a fluid called the filtrate. What five substances form the filtrate?

_____

13. What determines which blood components remain in the blood and which components end up in the filtrate in the nephron?

_____

_____

14. Does the process of filtration alone completely separate the wastes from the essential materials? Support your answer with observations of what is present in the nephron cup.

_____

_____

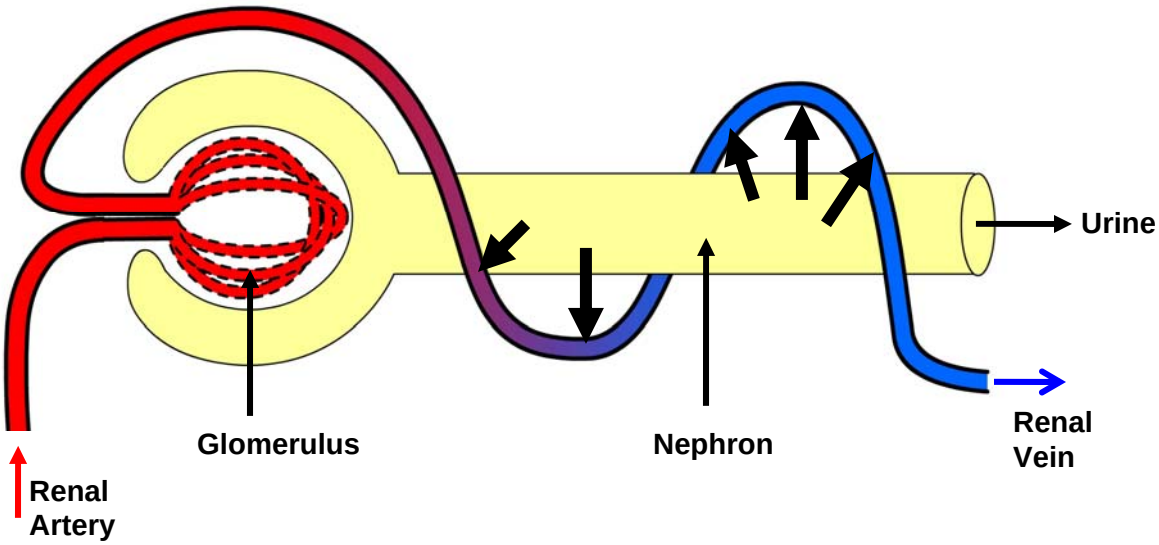
15. Which of the substances in the filtrate does your body need?

_____

C. Kidneys Reabsorb Needed Substances

Obviously you can't afford to lose large amounts of water, salt, glucose, and amino acids in your urine! So a second process, called **reabsorption**, moves essential materials from the nephron back into the blood. Reabsorption occurs when transport proteins molecules in the walls of the nephron return essential substances such as glucose, amino acids, water, and salt to the capillaries that surround the nephron.

Figure 3: Reabsorption returns essential materials to the blood



Complete Reabsorption.

Some essential molecules, such as glucose and amino acids, are **kept** by being **completely reabsorbed.** These molecules should be completely returned to the blood and should not end up in the urine produced by the kidney. Specific transport proteins in the nephron use energy to move these molecules from the nephron into the capillaries that surround the nephron.

16. What two substances in the filtrate are essential and need to be completely reabsorbed?

_____

17. Model the complete reabsorption of these substances. Use the specific "transport proteins" (these are represented by colored spoons that match the color of the beads) to pick up and move ALL of the completely reabsorbed substances from the "Nephron" cup to the "Blood in Renal Vein" cup.

Selective Reabsorption

Other molecules, such as water and salt, are **balanced** by being **selectively reabsorbed** to maintain the proper salt and water balance in the body. Their reabsorption is regulated so that they are returned to the blood if needed but are excreted in the urine if present in excess amounts. Specific transport proteins in the nephron use energy to move these molecules from the nephron into the capillaries that surround the nephron.

18. What two substances should be balanced by being selectively reabsorbed?

    Salt and water

19. Model how selective reabsorption is used to keep the proper amounts of these substances in the blood.

    - The blood needs to contain the proper amount of salt. The "Blood in Renal Vein" cup should contain 5 white beads representing salt. How many white beads will need to be selectively reabsorbed to maintain homeostasis? ***Student answers will vary***
    - Use the specific "transport protein" (represented by the white spoon) to move salt (white beads) so that the blood in the renal vein contains the proper amount of salt (5 white beads). Leave the remaining (excess) salt in the "Nephron" so it can be excreted.
    - The blood needs to contain the proper amount of water. The "Blood in Renal Vein" cup should be about one-half full of water.
    - Pour enough of the water from the "Nephron" cup to fill the "Blood in Renal Vein" cup approximately one-half full. Leave the remaining (excess) water in the "Nephron" cup so that it can be excreted.

20. The substances that are reabsorbed did not automatically move from the nephron cup into the renal vein cup. You needed to use lots of energy to make reabsorption happen. Which process do you think the kidney uses to transport these substances from the nephron to the capillaries—active transport or diffusion (passive transport)? Explain your answer.

    _____

    _____

    _____

21. If you drink a lot of water, you may produce large amounts of urine that has a light yellow color. If you do not drink enough water, you may produce a small amount of urine that has a dark yellow color. How would you explain these observations?

    _____

    _____

    _____

22. The “Blood in the Renal Vein” cup contains “clean” blood. After reabsoption has occurred, what seven substances are present in the “clean” blood in the renal vein?

_____

_____

23. What do you think happens to the “clean” blood in the renal vein?

_____

_____

Excreted (Not Reabsorbed)

24. What substance is NOT reabsorbed from the filtrate? Why is it important that this substance remains in the fluid in the nephron?

_____

25. The substances that remain in the nephron (cup) are called urine. What three substances are present in normal urine?

_____

26. The urine collects in the hollow center of the kidney and then flows out of the body. List the structures of the urinary system that urine must pass through to exit from the body.

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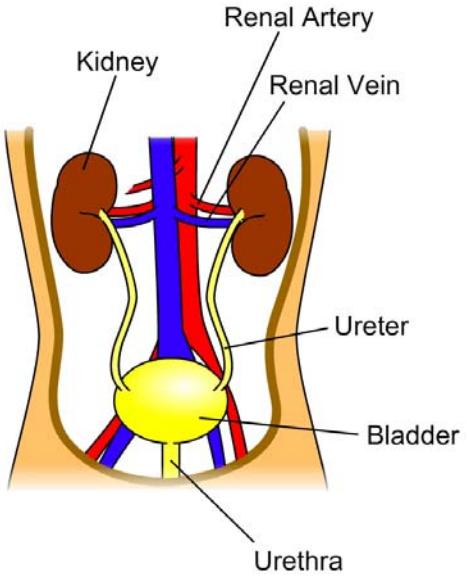
_____

_____

Figure 4: Structures in the Urinary System



Part 3:
What is wrong with the patient's kidneys?

So far you have modeled the function of normal kidneys. Now you will consider what might be going wrong in patients with kidney disease. In patients with kidney disease, the kidney structure is damaged and does not function properly. Kidney damage may occur as a result of diabetes, high blood pressure, abnormal kidney development, damage by viruses or bacteria, or by an auto-immune response in which antibodies attach to the kidneys.

1. Your patient's diabetes has caused kidney disease. What substances in the patient's urine indicate that her kidneys are not functioning properly. (Refer to Part 1, question 2 on page 2)

   _____

2. Your patient reported pinkish and cloudy urine. What substance might cause her urine to be pink? _____ What substance might cause her urine to be cloudy? _____

3. Explain how you could change the beads, screen and cups model that you used to illustrate how kidney damage caused your patient to have blood cells and protein in her urine.

   - What part of the model should be changed?

     _____

   - How should you change this part?

     _____

     _____

   - What kidney structure was represented by this part of the model?

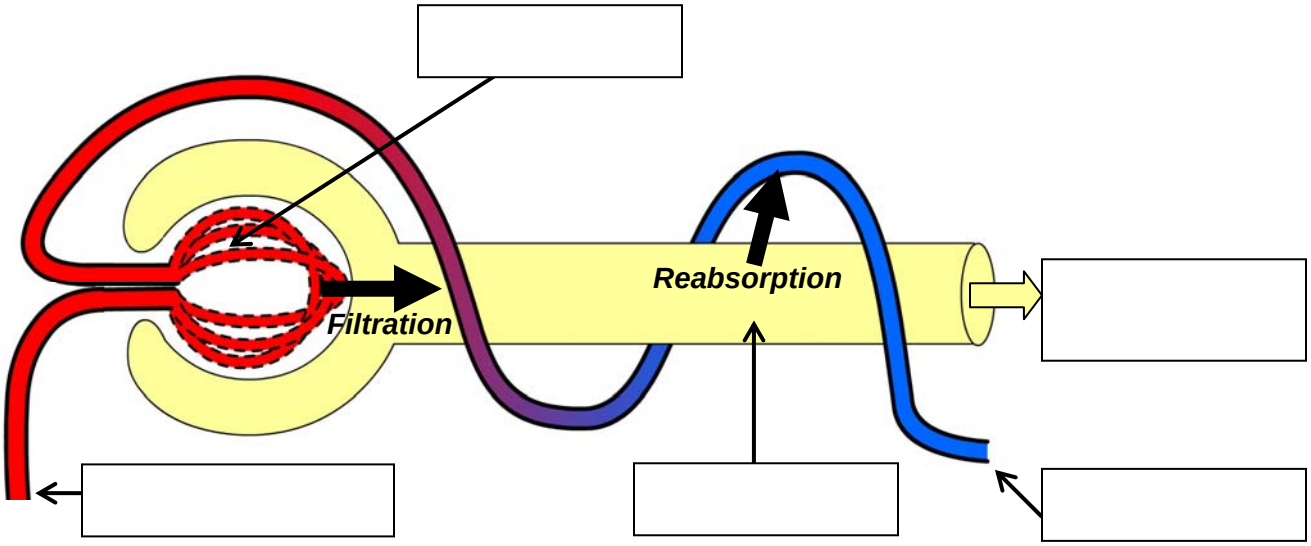
     _____

4. What process (filtration or reabsorption) was not working properly in your patient? Explain how you know.

   _____

   _____

Part 4:
Reviewing and Applying What You Learned



1. Label the diagram using the following terms: renal artery, renal vein, nephron, glomerulus, and urine entering the ureter.

2. Draw a labeled arrow on the diagram to represent the process of filtration. In your own words, explain the process of filtration.

_____

_____

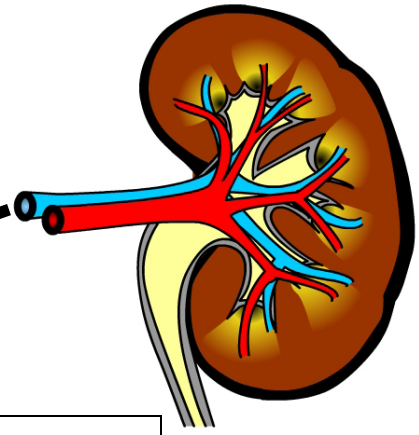
3. Draw a labeled arrow on the diagram to represent the process of reabsorption. In your own words, explain the process of reabsorption.

_____

_____

4. Excretion involves an interaction between the circulatory system and the excretory system. On the diagram above:
   - Put an X in front of the labels for structures that are part of the circulatory system.
   - Put an O in front of the labels for structures that are part of the excretory system.

5. Complete the chart below to indicate what substances should be present in the:
   - clean blood that leaves the kidney through the renal vein
   - urine that leaves the kidney in the ureter



Clean blood in renal vein contains:

Urine in ureter contains:

6. Each day the <u>millions</u> of nephrons in your kidneys produce a total of about 180 liters (47 gallons) of filtrate that flows into your nephron. What would your life be like if your kidneys <u>only</u> carried out filtration (and did not also carry out reabsorption) and all of that fluid became urine?

7. Explain why drinking large amounts of water results in the production of large amounts of urine.

8. Explain why eating large amounts of salty foods increases the amount of salt in the urine?

9. In addition to diabetes, what other things may cause kidney disease?

10. Why is kidney disease a serious health risk? What would happen to a person if their kidneys did not function properly?