STO-118

A Kidney Problem?

Teacher Information

science take-out just add students™

Summary

Students analyze simulated urine samples to determine if the patient's symptoms might be caused by kidney disease. They model normal kidney function and propose an explanation for the presence of protein and red blood cells in the patient's urine.

Core Concepts

- The kidneys maintain homeostasis by keeping blood composition within normal limits.
- The systems of the human body interact to maintain a balanced internal environment.
- A disruption in any human system may result in disease or even death.

Time Required

Two 40-minute class periods

Kit contains

- "Kidneys, Nephrons, and the Urinary System" color graphic
- "Kidney Function Chart"
- Tube of "Patient Urine"
- Urine test strip
- Instructions for Urine Testing
- "Renal Artery" and "Renal Vein" cups
- "Nephron" bowl
- "Glomerulus" screen
- "Blood Components" bag of beads
- "Amino Acid Transport Protein", "Glucose Transport Protein", and "Salt Transport Protein" spoons

Teacher Provides

- Safety goggles
- Access to water
- Paper towel for clean-up

Warning: Choking Hazard This Science Take-Out kit contains small parts. Do not allow children under the age of seven to have access to any kit components.

Reusing *A Kidney Problem?* kits

Kits may be refilled and reused. Allow approximately 30 minutes for refilling 10-15 student kits. Teachers will need to instruct students on how to handle clean-up and return of the re-usable kit materials. For example, teachers might provide the following information for students:

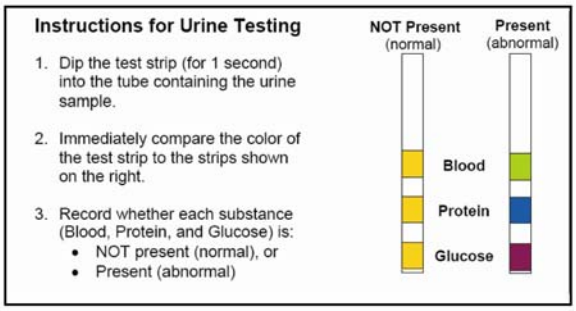
Discard	Return to "Blood Component" bag	Return to kit
• Used urine test strip	• All beads	• Tube of "Patient Urine" • "Blood Components" beads • "Renal Artery" and "Renal Vein" cups • "Nephron" bowl • "Glomerulus" screen • Colored graphic sheet • Spoons • Instructions for Urine Testing

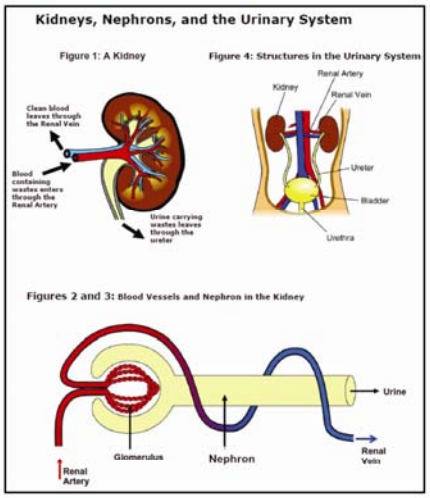
***Note:** Consider laminating printed parts of the kits (such as the fingerprints) that will be reused.

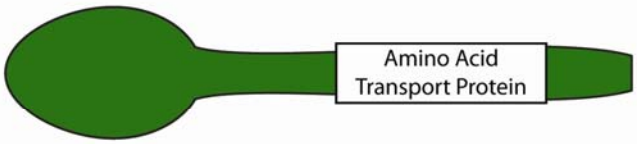
Refills for the *A Kidney Problem?* kits are available at www.sciencetakeout.com. The 10 Kit Refill Pack includes the following materials:

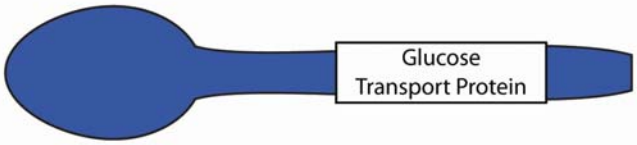
- 10 urine test strips
- 10 ml "Patient Urine Sample"

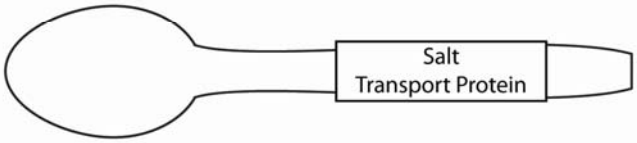
Kit Contents Quick Guide

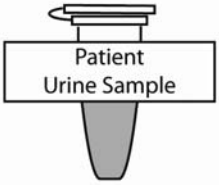


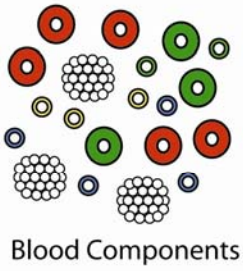


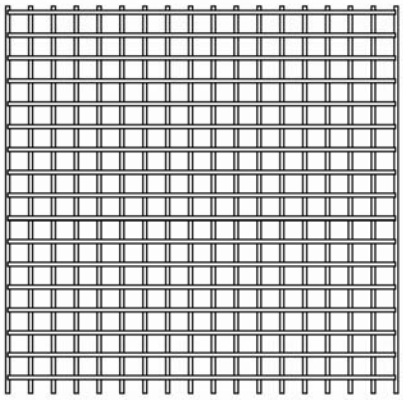


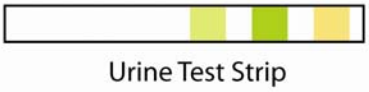


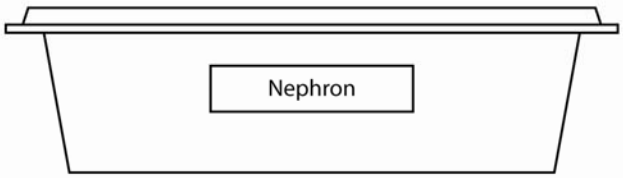


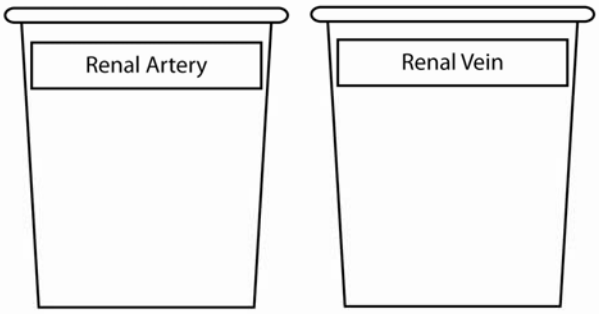












Read these instructions before using Science Take-Out kits

Parental or Adult Supervision Required

This kit should be used only under the supervision of an adult who is committed to ensuring that the safety precautions below, and in the specific laboratory activity, are followed.

Safety Goggles and Gloves Strongly Recommended

We encourage students to adopt safe lab practices, and wear safety goggles and gloves when performing laboratory activities involving chemicals. Safety goggles and gloves are not provided in Science Take-Out kits. They may be purchased from a local hardware store or pharmacy.

Warning: Choking and Chemical Hazard

Science Take-Out kits contain small parts that could pose a choking hazard and chemicals that could be hazardous if ingested. Do not allow children under the age of seven to have access to any kit components. Material Safety Data Sheets (MSDS) provide specific safety information regarding the chemical contents of the kits. MSDS information for each kit is provided in the accompanying teacher instructions.

Chemicals Used in Science Take-Out Kits

Every effort has been made to reduce the use of hazardous chemicals in Science Take-Out kits. Most kits contain common household chemicals or chemicals that pose little or no risk.

General Safety Precautions

1. Work in a clean, uncluttered area. Cover the work area to protect the work surface.
2. Read and follow all instructions carefully.
3. Pay particular attention to following the specific safety precautions included in the kit activity instructions.
4. Goggles and gloves should be worn while performing experiments using chemicals.
5. Do not use the contents of this kit for any other purpose beyond those described in the kit instructions.
6. Do not leave experiment parts or kits where they could be used inappropriately by others.
7. Never taste or ingest any chemicals provided in the kit - they may be toxic.
8. Do not eat, drink, apply make-up or contact lenses while performing experiments.
9. Wash your hands before and after performing experiments.
10. Chemicals used in Science Take-Out experiments may stain or damage skin, clothing or work surfaces. If spills occur, wash the area immediately and thoroughly.
11. At the end of the experiment, return ALL kit components to the kit plastic bag. Dispose of the plastic bag and contents in your regular household trash.

No blood or body fluids from humans or animals are used in Science Take-Out kits. Chemical mixtures are substituted as simulations of these substances.

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 pinkish and cloudy. You suspect that your patient's kidneys may not be functioning normally.

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

You will test a sample of the patient's urine to determine if her kidneys are functioning normally.

1. Test the patient's urine sample.
   - Use the "Instructions for Urine Testing", the urine test strip, and the 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	Patient's Results	Normal Urine
Blood		Not Present
Protein		Not Present
Glucose		Not Present

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

Part 2: How do normal kidney's work?

Your patient doesn't understand that kidneys play a critical role in removing wastes and maintaining homeostasis by keeping blood composition stable—within normal limits. You would like to use a model to explain how normal kidneys work and what happens when kidneys are damaged.

In this activity, you will 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 these lab instructions 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 diagrams **Kidneys, Nephrons, and the Urinary System**. Set this 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. The kidneys

- Excrete (remove) urea and other wastes.
- Regulate the amount of water in the blood.
- Adjust the concentration of various substances in the blood.

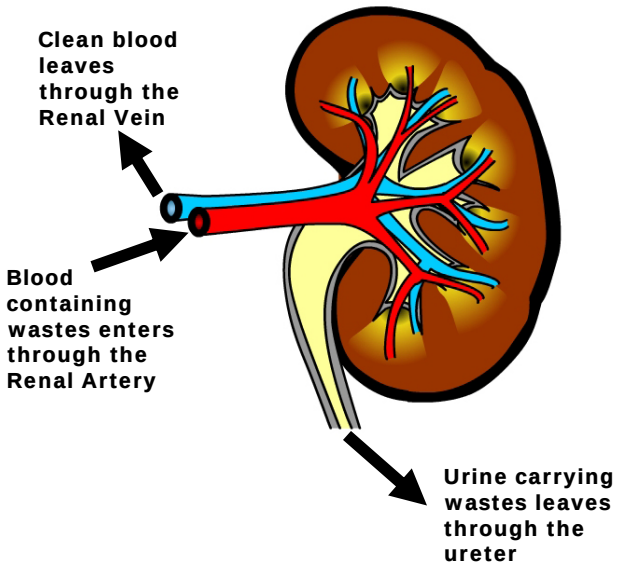
1. Observe Figure 1 (to the right).

   - What blood vessel carries blood containing wastes into the kidney?

   - What blood vessel carries cleaned blood out of the kidney?

   - What structure carries urine that contains the wastes out of the kidney?

Figure 1: A Kidney



Kidney Function

Kidneys regulate the concentrations of substances in the blood. 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 will be excreted in the urine.

You will use a model to help you understand how the kidneys work to maintain the proper concentrations of substances in the blood.

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

KEY

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

2. Blood enters the kidney through the renal artery.
   - Add the contents of the bag labeled "Blood Components" to the cup labeled "Renal Artery."
   - Blood also contains water. Add enough water to fill the cup containing the beads about three quarters full of water.

3. Use the information in the "**Kidney Function**" box and in the **Key** to complete the following table that summarizes the substances present in the blood that enters the kidney.

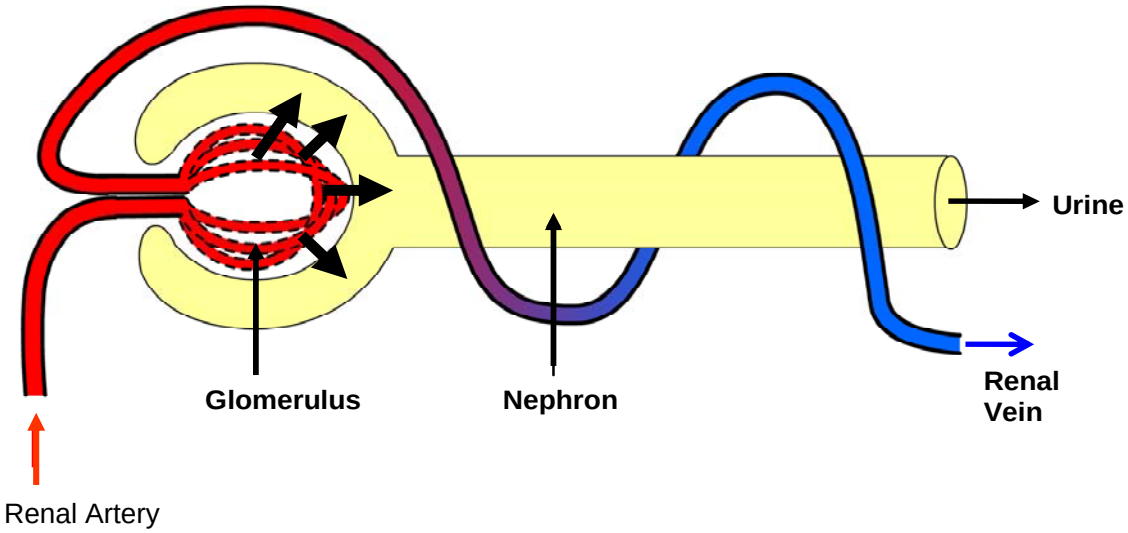
Substance	Represented in model by:	Should be Removed, Balanced, or Kept?
Urea	Small yellow beads	
Glucose		
Amino Acids		
Red Blood Cells		
White Blood Cells		
Proteins		
Salt		
Water	Water in cup	

B. Kidneys Filter Blood

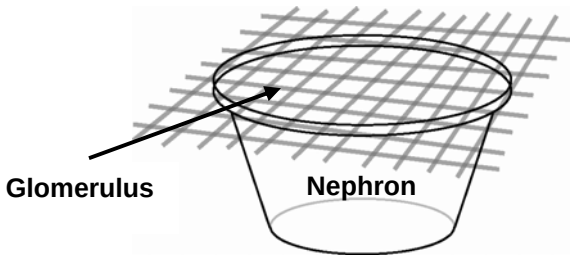
Each kidney contains over 1 million microscopic blood-cleaning structures called **nephrons.** Blood enters the kidney through renal arteries. The renal arteries branch to supply blood to the form tiny balls of capillaries called glomeruli. The walls of the **glomerulus** capillaries are porous. They act like filters to allow small molecules to move 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.**

Figure 2: Filtration allows small molecules to enter the nephron



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



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

6. 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 "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 small substances leave the blood.*

7. Use your model and the Key to complete Boxes A and B on the colored "**Kidney Function Chart**" chart in your lab kit.
   - In **Box A**, write the names of the three blood components that are kept in the blood.
   - In **Box B**, write the names of the five substances (water plus four other substances) that leave the blood to form the filtrate in the nephron.

KEY

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

8. What determines whether a blood component will remain in the blood or enter the nephron?

9. 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 bowl.

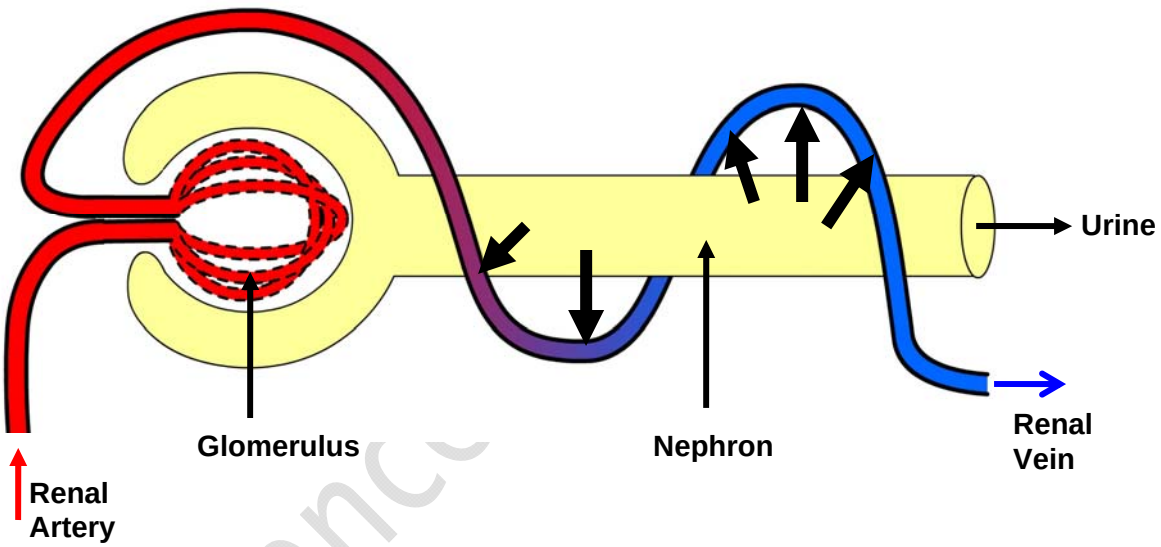
10. Which substances in the filtrate does your body need to remain healthy?

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.

KEY

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

11. What two substances in the filtrate are essential and need to be <u>completely reabsorbed</u>?

12. 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" bowl to the "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. Selective reabsorption is regulated so that these substances are:

- returned to the blood if needed
- 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.

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

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

- To maintain homeostasis, the blood needs to contain the proper amount of salt. The "Renal Vein" cup should contain 5 white beads representing salt.
    - Use the specific "transport protein" (represented by the colored spoon that matches the color of the beads) to pick up and move white beads so that there are 5 white beads in the "Renal Vein" cup.
    - The white beads remaining in the nephron bowl represent **excess salt** that will be excreted in the urine.
- To maintain homeostasis, the blood needs to contain the proper amount of water. The "Renal Vein" cup should be about one-half full of water.
    - Pour enough of the water from the "Nephron" bowl to fill the "Renal Vein" cup approximately one-half full.
    - The water remaining in the "Nephron" bowl represents **excess water** that will be excreted in the urine.

15. If you drink a lot of water, you may produce large amounts of pale yellow urine. If you are dehydrated, you may produce a small amount of dark yellow urine. Apply your understanding of selective reabsorption to explain these observations.

16. The substances that are reabsorbed did not diffuse (move) from the nephron bowl 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 renal vein—active transport or diffusion (passive transport)? Explain your answer.

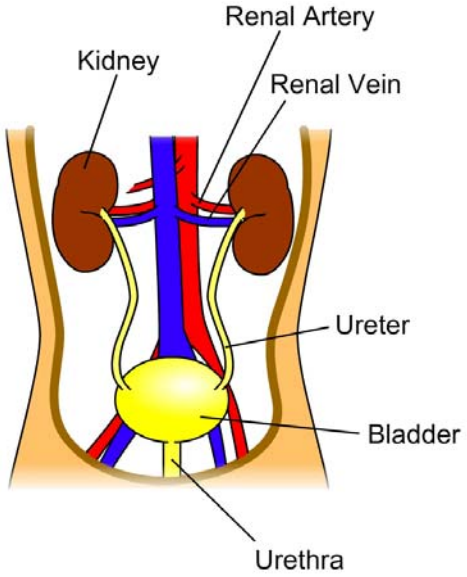
17. The "Renal Vein" cup contains "clean" blood. Complete **Box C** on the "**Kidney Function Chart**." Write the names of the seven blood components that are present in the "clean" blood that leaves the kidney.

Excreted (Not Reabsorbed)

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

19. The substances that remain in the nephron (bowl) are called **urine**. Complete **Box D** on the "**Kidney Function Chart**." Write the names of the three substances that are present in the urine that leaves the nephron.

Figure 4: Structures in the Urinary System



20. The urine produced by the millions of nephrons collects in the hollow center of the kidney and then flows out of the body. List the structures of the urinary system (shown in Figure 4, above) that urine must pass through to exit from the body.

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 happen when kidney structure is damaged and the kidney does not function properly.

Kidney damage may occur as a result of diabetes, high blood pressure, damage by viruses or bacteria, or by an auto-immune disease in which antibodies attack the kidneys.

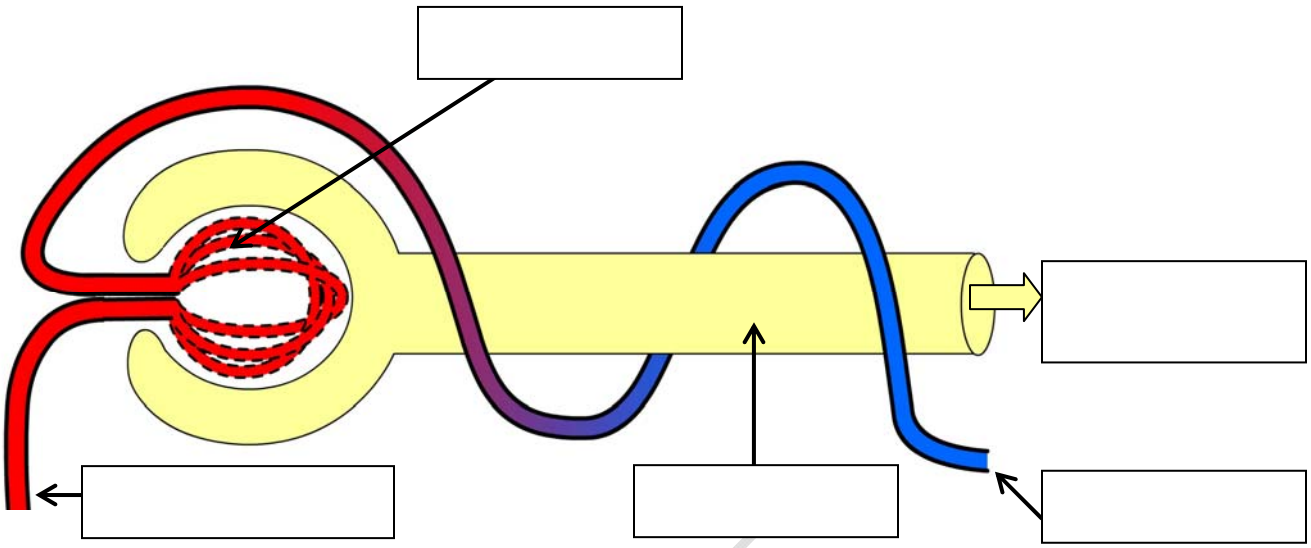
1. Your patient's diabetes has caused kidney disease. What substances in the patient's urine indicate that her kidneys are not functioning properly? (Refer to Part 1, question 2 on page 1)

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, cup, and bowl 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, above using the following terms: renal artery, renal vein, nephron, glomerulus, and urine entering the ureter.

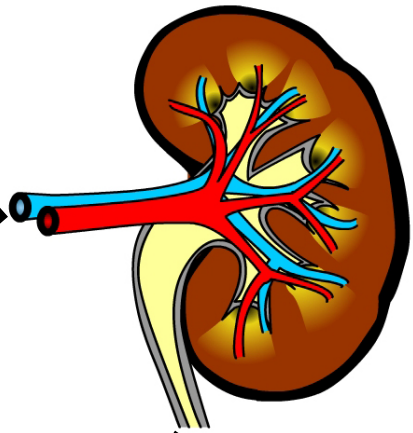
2. Draw a labeled arrow on the diagram to represent the process of **filtration**. In your own words, explain the process of filtration.

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.

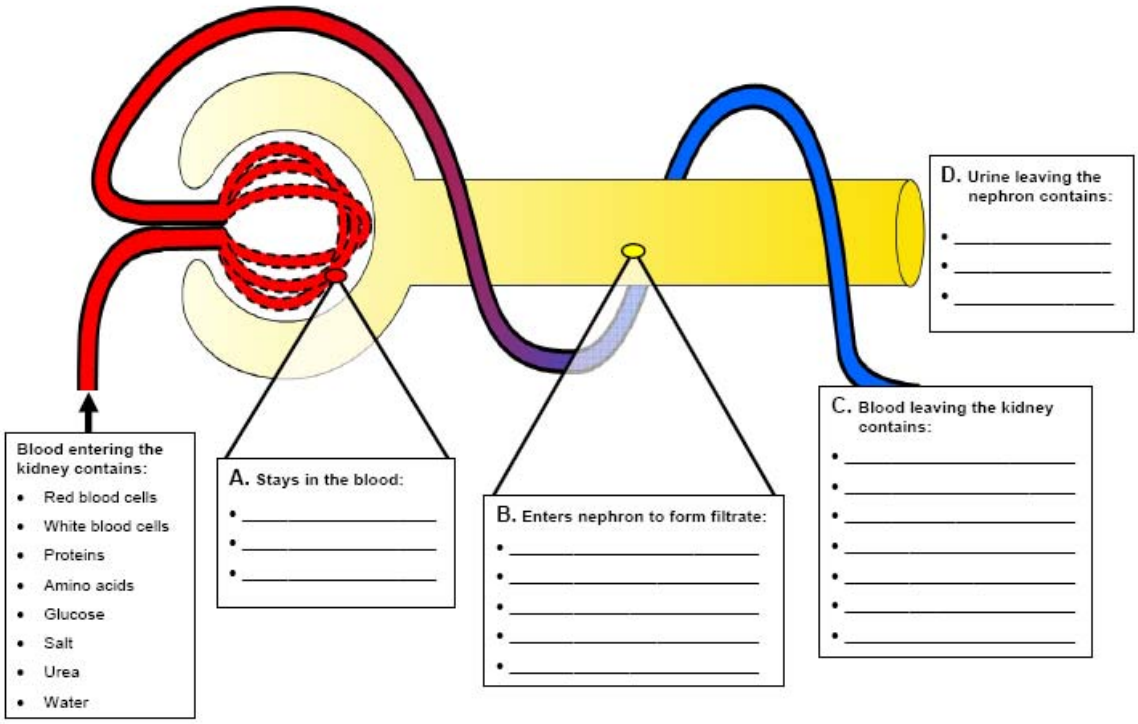
8. Explain why eating large amounts of salty foods increases the amount of salt in the urine?

9. In addition to diabetes, list three 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?

Optional: If you have access to a computer, try the interactive animation of kidney function at http://www.biologymad.com/resources/kidney.swf.Substitute
Click on each of the substances on the left and watch what happens to each different kind as they go through the kidney nephron.

Kidney Function Chart



MATERIAL SAFETY DATA SHEET

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name (as printed on the label): "Patient Urine"

Product identity: pH 7 buffer solution

Distributor: ScholAR Chemistry; 5100 W. Henrietta Rd, Rochester, NY 14586 (866) 260-0501

Medical emergency phone number (Chemtrec): (800) 424-9300

Date of this MSDS: 10/6/10

2. COMPOSITION/INFORMATION ON INGREDIENTS

Product	Ingredients	CAS Numbers	% Weight/Volume (balance is water)
pH 7 buffer	Potassium phosphate monobasic Sodium phosphate dibasic	7778-77-0 7558-79-4	0.15% 0.30%

For all the ingredients
OSHA PEL: TWA – none estab. STEL – none estab.
ACGIH TLV: TWA – none estab. STEL – none estab.
NIOSH REL: TWA – none estab. STEL – none estab.
NIOSH ILDH: none estab.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
Do not ingest. Avoid skin and eye contact. Avoid exposure to vapor or mists.

Potential Health Effects EYES: May cause irritation. SKIN: May cause irritation. INHALATION: n/a
INGESTION: May cause gastrointestinal discomfort and mouth burns .

4. FIRST AID MEASURES

EYES - Flush with water for at least 15 minutes, raising and lowering eyelids occasionally. Get medical attention if irritation persists.

SKIN - Thoroughly wash exposed area for at least 15 minutes. Remove contaminated clothing. Launder contaminated clothing before reuse. Get medical attention if irritation persists.

INGESTION - Do not induce vomiting. If swallowed, if conscious, give plenty of water immediately and call a physician or poison control center. Never give anything by mouth to an unconscious person.

5. FIRE FIGHTING MEASURES

NFPA Rating: Health: 1 Fire: 0 Reactivity: 0
Extinguisher Media: Any means suitable for extinguishing surrounding fire
Special Firefighting Procedures: Firefighters should wear full protective equipment and NIOSH approved self-contained breathing apparatus.
Unusual Fire and Explosion Hazards: No data available

6. SPILL OR LEAK PROCEDURES

Ventilate area of spill. Clean-up personnel should wear proper protective equipment and clothing. Absorb material with suitable absorbent and containerize for disposal.

7. HANDLING AND STORAGE

Store in a cool dry place. This Material is not considered hazardous. Handle using safe laboratory practices.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Respiratory Protection: n/a
Ventilation: Local Exhaust: Preferred Mechanical(General): Acceptable Special/Other: No
Protective Gloves: Natural rubber, Neoprene, PVC or equivalent.
Eye Protection: Splash proof chemical safety goggles should be worn.
Other Protective Clothing or Equipment: Lab coat, apron, eye wash, safety shower.

9. PHYSICAL AND CHEMICAL PROPERTIES

Melting Point: ~0°C Boiling Point: ~100°C
Vapor Pressure: information not available Vapor Density: information not available
Specific Gravity (H_2O=1): ~1 Percent Volatile by Volume: >99
Evaporation Rate: information not available Solubility in Water: soluble
Appearance and Odor: Clear colorless liquid

10. STABILITY AND REACTIVITY

Stability: Stable Materials to Avoid: strong acids and bases
Hazardous Decomposition Products: none known Hazardous Polymerization: will not occur

11. TOXICOLOGICAL INFORMATION

Ingredient	Toxicity (oral-rat) LD_{50}
Sodium phosphate dibasic	17 g/kg
Potassium phosphate monobasic	7100 mg/kg

Effects of Overexposure (for all pH buffers):
Acute: Essentially non-hazardous. Possible irritation of eyes/skin/stomach
Chronic: None known.
Conditions aggravated/Target organs: none known
Target Organs: Eyes, skin, and gastrointestinal tract.
Primary Route(s) of Entry: Ingestion or skin contact.

12. ECOLOGICAL INFORMATION – for all pH buffer products No ecological data available

13. DISPOSAL CONSIDERATIONS – for all pH buffer products

Waste Disposal Methods: Dispose in accordance with all applicable Federal, State and Local regulations. Always contact a permitted waste disposer (TSD) to assure compliance.

14. TRANSPORTATION INFORMATION D.O.T. SHIPPING NAME: Not regulated

15. REGULATORY INFORMATION

EPA regulations: RCRA Hazardous waste number (40 CFR 261.33) – not listed
RCRS Hazardous waste classification (40 CFR 261) – not classified
SARA Toxic Chemical (40 CFR 372.65) – not listed
SARA EHS (Extremely Hazardous Substance (40 CFR 355) – not listed

OSHA regulations: Air Contaminant (29 CFR 1910.1000) – not listed

16. ADDITIONAL INFORMATION

The information provided in this Material Safety Data Sheet represents data from the manufacturer and/or vendor and is accurate to the best of our knowledge. By providing this information, Science Take-Out LLC makes no guarantee or warranty, expressed or implied, concerning the safe use, storage, handling, precautions, and/or disposal of the products covered or the accuracy of the information contained in this fact sheet. It is the responsibility of the user to comply with local, state, and federal laws and regulations concerning the safe use, storage, handling, precautions, and/or disposal of products covered in this fact sheet.