Kidney Dialysis
Teacher information

Summary:
Students create a mini-model of a dialysis machine. They observe which substances diffuse from the bloodstream into the fluid in the dialysis machine. They determine what substances should be added to the dialysis fluid to maintain homeostasis.

Core concepts:
- The processes of diffusion and active transport are important in the movement of materials in living organisms.
- To maintain homeostasis the internal environment must be kept stable - within normal limits that are favorable for cell activities.
- Homeostasis in an organism is constantly threatened. Failure to respond effectively can result in disease or death.

Class time required:
Two 40-minute class period + homework

Teacher preparation:
Each student will need:
- 1 Kidney Dialysis
- 1 color Hemodialysis and Peritoneal Dialysis (Consider laminating this for reuse)
- Safety goggles

Each team of students will need:
- Wide bore dropper with tip cut off
- 9 inch length of “Serpent Skin” tubing or dialysis tubing. “Serpent Skin” can be ordered from Educational Innovations (Catalog # SM-200): www.teachersource.com/BiologyLifeScience/LifeScience/SerpentSkinTubing.aspx
- 10 oz. tall form clear plastic cup
- 15 ml conical tube or test tube labeled “Simulated Red Blood Cells” – add 1-2 ml of red glitter or red seed beads
- 1.5 ml microtube labeled “Glucose” – fill with 1 ml BAKING SODA (not glucose)
- 1.5 ml microtube labeled “Simulated Urea” – fill with 0.5 ml yellow food color and 0.5 ml water
- 1.5 ml microtube labeled “Protein” – fill with 1 ml BAKING SODA (not protein)
- 1 small paper packet of salt
- 1 small plastic bag labeled “Test Paper” - fill this bag with:
  - 1 strip of chromatography paper (white paper)
  - 1 strip of 6-8 narrow range pH paper (orange paper)
  - 1 strip of RED litmus paper (pink paper)

During Class:
1. Group students into lab teams of 2-4 students.
2. Distribute to each student.
   - 1 copy of Kidney Dialysis
   - 1 color copy of Hemodialysis and Peritoneal Dialysis
3. Read The Introduction aloud to the entire class.
4. Ask students to work with their team members to complete the Kidney Dialysis activity.
5. Optional: Ask teams (or the class) to make a list of what they know about kidney dialysis and what questions they have about dialysis. Consider inviting a dialysis patient, nurse from a dialysis center, or nephrologist to visit and answer the students’ questions.

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Quick Guide:

Dialysis Tubing

Cup

Simulated Red Blood Cells

Dropper

Salt

“Protein”

“Glucose”

“Urea”

“Protein,” “Glucose” and “Salt” Test Papers
Hemodialysis

Patients who have severe problems with their kidneys need a dialysis machine to remove harmful substances from their blood. The dialysis machine has one area (A) containing the patient’s blood and another area (B) containing a fluid called dialysate. These two areas are separated by a semipermeable membrane through which small molecules can diffuse. Small waste products such as urea diffuse out of the blood and into the dialysate. The dialysate that flows out of the machine is then discarded.
Peritoneal Dialysis

In peritoneal dialysis, the patient's own peritoneum (lining of the abdominal cavity) is used instead of a dialysis membrane. A sterile plastic tube is inserted into the abdominal cavity, and a solution of glucose (a form of sugar) and salts is periodically injected to fill the abdominal cavity. The fluid comes into contact with delicate blood vessels in the peritoneum. Wastes from the blood diffuse through the membrane of the peritoneum into the dialysis fluid. The used dialysis liquid is periodically drained and replaced with a fresh solution.

No one type of dialysis is best for everyone. Each type has pros and cons that patients will need to evaluate as they make their decision. Hemodialysis must be done by trained health professionals who can watch for any problems such as low blood pressure, blood clots, and bloodstream infections. But, it needs to be done at a hospital or dialysis center on a fairly set schedule. Peritoneal dialysis can be done at home or any clean place and patients can do it by themselves. It must be done every day of the week and may increase the risks for infection of the peritoneum.
Introduction:
Your patient is experiencing kidney failure. Her kidneys are not removing wastes and other undesirable substances from her body. She will need dialysis treatments.

Dialysis treatments use selective (semipermeable) membranes that allow small molecules, like urea, to diffuse out of the blood. The membranes block the diffusion of larger molecules and blood cells so that these will remain in the blood.

One type of dialysis, called hemodialysis, uses a dialysis machine to clean the blood of patients who have problems with their kidneys. Read the colored sheet titled “Hemodialysis.”

Your Tasks:
- Create a simple miniature model of a kidney dialysis machine.
- Determine which molecules can diffuse through the dialysis membrane.
- Explain what substances should be included in the dialysate to ensure that essential and beneficial small molecules are not lost from the blood.

PART 1: Create a Model Dialysis Machine

1. Moisten one end of the dialysis tubing by dipping about one-third of its length into tap water. (DO NOT place the entire dialysis tubing into the water, just wet one end of it.)

2. Close the wet end of the dialysis tubing by tying a knot at the end to make a membrane bag as shown in the diagram on the next page. This bag represents the dialysis machine tube through which a patient’s blood flows.

3. Prepare “artificial blood” by adding the following ingredients to the large test tube that contains simulated red blood cells (red glitter or red beads):
   - Glucose - one small tube of glucose powder
   - Simulated Urea – one small tube of yellow food color
   - Salt - 1 packet of salt
   - Protein - 1 small tube of protein powder
   - Enough hot tap water to fill the large test tube about half full
4. Screw the lid firmly on the tube of “blood.” Wrap a piece of paper towel around the tube, just in case the tube leaks. Gently invert the tube several times to mix the contents. Then immediately use the plastic dropper to transfer the contents into the dialysis tubing bag.

5. Place the dialysis tubing bag into the large cup. Add enough hot water to fill the cup approximately three-quarters full. The hot water represents the liquid in the dialysis machine. This liquid is called dialysate.

6. You have now created your own model dialysis machine! Set your model dialysis machine aside for 10 minutes to allow materials to diffuse through the dialysis membrane. While you wait, complete step 7.

7. The substances in the “artificial blood” in the tube are listed in the chart below. Some of these substances will diffuse from the blood, through the semipermeable membrane, and into the dialysate. Complete Column 1 in the chart below by predicting which substances will diffuse through the semipermeable membrane and into the dialysate. You will complete the other columns later in this lab.

<table>
<thead>
<tr>
<th>Substances in the blood</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Will the substance diffuse through the membrane? (yes or no)</td>
<td>Diffused through dialysis membrane into the dialysate (yes or no)</td>
<td>Should be added to the dialysate to maintain homeostasis (yes or no)</td>
</tr>
<tr>
<td>Urea (waste)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Red Blood Cells</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Proteins</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Glucose</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Salts</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
**PART 2: Which molecules can pass through the dialysis membrane?**

1. Did the yellowish urea wastes diffuse into the dialysate liquid in the cup? Explain how you could determine this. Record the results in Column 2 of the chart on the previous page.
   
   *Yes, the fluid in the cup turned yellow.*

2. Did the red blood cells diffuse into the dialysate liquid in the cup? Explain how you could determine this. Record the results in Column 2 of the chart.
   
   *No, there is no red glitter in the fluid in the cup.*

3. To determine whether protein diffused through the membrane, dip one white protein test strip into the dialysate. If protein is present, the white paper will turn dark red. Record the results of the protein test results in Column 2 of the chart.

4. To determine whether glucose diffused through the membrane, dip one orange glucose test strip into the dialysate. If glucose is present, the orange paper will turn dark blue or green. Record the results of the glucose test results in Column 2 of the chart.

5. To determine whether salt diffused through the membrane, dip one pink salt test strip into the dialysate for 10 seconds. If salt is present, the pink paper will turn a light purple. Record the results of the salt test in Column 2 in the chart on the previous page.

6. Apply your knowledge of diffusion through a membrane to explain why some substances diffused through the membrane and into the dialysate liquid and others substances did not.

   *Red blood cells and protein were too large to pass through the membrane.*
   *Urea, salt and glucose are small enough to pass through the membrane.*
PART 3: What substances should be included in the dialysate to maintain homeostasis?

Read the information below and then answer the questions that follow:

Maintaining Homeostasis

To maintain homeostasis (a state of balance in the body) the concentrations of water and dissolved substances in the body’s internal environment (blood and body liquids) must be kept stable - within normal limits that are favorable for cell activities.

Kidneys help maintain homeostasis by regulating the flow of substances into and out of the bloodstream and by removing wastes from the bloodstream. The cell membranes in the kidneys use a process known as active transport to pump essential materials such as glucose and salts back into the bloodstream.

The dialysis membrane cannot carry out active transport like real kidneys do because it is not a living organ. To maintain homeostasis, the dialysate (liquid) in a real dialysis machine must have the same concentrations of solutes such as glucose and salts as those in normal blood plasma. Therefore:

- If the patient’s blood contains excess concentrations of any solutes, these solutes will diffuse into the dialysate.
- If the patient’s blood plasma lacks the ideal concentration of any solutes, these solutes will diffuse into the patient’s blood.
- Because the dialysate liquid does not contain any waste products such as urea, the wastes diffuse into the dialysate.

Use the information in the box above and the diagram below to answer the following questions

1. Explain why the membrane in a dialysis machine cannot carry out active transport.

   A dialysis membrane is not living.

2. Name two essential body substances that diffuse out of the blood but are needed in the blood to maintain homeostasis.

   glucose and salt
3. Observe the diagram on the right. Explain why glucose and salts would be lost from the patient’s blood if the dialysate contained only water.

*Glucose and salt would diffuse from an area where they have a high concentration to a region where the concentration is low.*

4. According to the diagram, what concentration of glucose and salt should be present in the dialysate to prevent the diffusion of these substances from the patient’s blood?

*Glucose - 0.8 g/L  Salt - 9 g/L*

5. Explain why urea is not added to the dialysate liquid.

*The dialysate liquid does not contain any waste products such as urea so the wastes diffuse into the dialysate.*

6. Complete Column 3 in the chart on page 2 to indicate the substances that should be added to the water in the dialysate to maintain homeostasis.

*In addition to using a hemodialysis machine, there is another option for cleaning waste substances from blood. This technique is called peritoneal dialysis.*

Use the information in the colored sheet titled “Peritoneal Dialysis” to answer the following questions.

7. Describe two ways that hemodialysis and peritoneal dialysis are similar.

*They both: use membranes, use dialysate, remove wastes from blood, are used to treat kidney failure.*

8. Describe two ways that hemodialysis and peritoneal dialysis are different.

*Hemodialysis uses an artificial membrane and a dialysis machine. Peritoneal dialysis uses a body membrane and does not need a dialysis machine.*

9. Explain one reason why a patient might choose hemodialysis instead of peritoneal dialysis.

*It is done by a trained professional who can watch for problems or it does not need to be done every day or it reduces the risk of infection of the peritoneum.*

10. Explain one reason why a patient might choose peritoneal dialysis instead of hemodialysis.

*It can be done at home and by the patient. It does not require a machine or can be done inside the body.*