Advance Preparation/Comments

1. Prior to the lab, suggest to the students that they become familiar with the exercise before coming to class. If students have a home computer, or access to a computer on campus, they can become familiar with the general operation of the simulations before coming to class. In particular, they should examine the structure of the nephron in the textbook.

2. A good working knowledge of diffusion, filtration, and osmosis is important in understanding renal function. Suggest to the students that they review those concepts before coming to class.

3. A short introductory presentation with the following elements is often helpful:
   - Review the basics of nephron anatomy and basic renal physiology, focusing on the major concepts such as glomerular filtration and the movement of substances due to passive and active forces.
   - Reinforce the idea of how changing the arteriole diameter influences the filtration pressure in the glomerulus.
   - Use the analogy of a coffee filter when describing the filtration that takes place in the glomerulus.
   - If the students have not been exposed to the concept of carrier transport, a short introduction using glucose as an example might be helpful.
   - Encourage students to make the transition from what they see in the simulation to what they see under microscopic examination.
   - Remind students that they are manipulating a single nephron that represents the function of the entire kidney, but that the living kidney contains many nephrons.

Answers to Questions/Experimental Data

Pre-lab Quiz in the Lab Manual

1. urochrome
2. 6.0
3. False
4. Albumin
5. Hematuria
6. bilirubinuria
7. Casts
8. A precipitate is an insoluble substance that forms.

Activity 1: The Effect of Arteriole Radius on Glomerular Filtration (pp. PEx-132–135)

Predict Question 1: When the radius of the afferent arteriole is decreased, the pressure and filtration rate will both decrease.

Predict Question 2: When the radius of the afferent arteriole is increased, the pressure and filtration rate will both increase.

Predict Question 3: When the radius of the efferent arteriole is decreased, the pressure and filtration rate will both increase.
Chart 1: Effect of Arteriole Radius on Glomerular Filtration

<table>
<thead>
<tr>
<th>Afferent arteriole radius (mm)</th>
<th>Efferent arteriole radius (mm)</th>
<th>Glomerular capillary pressure (mm Hg)</th>
<th>Glomerular filtration rate (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>0.45</td>
<td>55.08</td>
<td>124.99</td>
</tr>
<tr>
<td>0.45</td>
<td>0.45</td>
<td>51.54</td>
<td>81.06</td>
</tr>
<tr>
<td>0.40</td>
<td>0.45</td>
<td>48.52</td>
<td>43.66</td>
</tr>
<tr>
<td>0.35</td>
<td>0.45</td>
<td>46.16</td>
<td>14.35</td>
</tr>
<tr>
<td>0.55</td>
<td>0.45</td>
<td>58.94</td>
<td>172.86</td>
</tr>
<tr>
<td>0.60</td>
<td>0.45</td>
<td>62.88</td>
<td>221.69</td>
</tr>
<tr>
<td>0.50</td>
<td>0.40</td>
<td>55.08</td>
<td>124.99</td>
</tr>
<tr>
<td>0.50</td>
<td>0.35</td>
<td>56.84</td>
<td>146.82</td>
</tr>
<tr>
<td>0.50</td>
<td>0.30</td>
<td>57.34</td>
<td>152.96</td>
</tr>
</tbody>
</table>

Activity Questions:
1. Activation of the sympathetic nerves serves to decrease the radius of the afferent arteriole.
2. The benefit is that urine output will decrease. The kidneys are a blood filter so slowing down the rate of filtration for long periods could lead to abnormal blood composition.

Activity 2: The Effect of Pressure on Glomerular Filtration (pp. PEx-135–PEx-137)

Predict Question 1: Glomerular capillary pressure and filtration rate will increase when you increase the beaker pressure.

Predict Question 2: If you close the one-way valve, pressure will increase in the Bowman’s capsule and filtration rate will decrease.

Chart 2: Effect of Arteriole Radius on Glomerular Filtration

<table>
<thead>
<tr>
<th>Blood pressure (mm Hg)</th>
<th>Valve (open or closed)</th>
<th>Glomerular capillary pressure (mm Hg)</th>
<th>Glomerular filtration rate (ml/min)</th>
<th>Urine volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>closed</td>
<td>49.72</td>
<td>31.97</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>open</td>
<td>49.72</td>
<td>58.57</td>
<td>161.76</td>
</tr>
<tr>
<td>80</td>
<td>open</td>
<td>52.40</td>
<td>91.78</td>
<td>186.23</td>
</tr>
<tr>
<td>90</td>
<td>open</td>
<td>55.08</td>
<td>124.99</td>
<td>200.44</td>
</tr>
<tr>
<td>100</td>
<td>open</td>
<td>57.76</td>
<td>158.20</td>
<td>209.72</td>
</tr>
<tr>
<td>70</td>
<td>closed</td>
<td>49.72</td>
<td>31.97</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>closed</td>
<td>57.76</td>
<td>114.20</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>open</td>
<td>57.76</td>
<td>158.20</td>
<td>209.72</td>
</tr>
</tbody>
</table>

Activity Questions:
1. Based upon this activity, increased blood pressure should increase the glomerular filtration rate.
2. High blood pressure can damage the blood vessels in the kidneys leading to reduced kidney function and kidney failure.

Activity 3: Renal Response to Altered Blood Pressure (pp. PEx-137–PEx-139)

Predict Question 1: If both arteriole radii changes are implemented (increasing the afferent and decreasing the efferent), glomerular filtration rate and pressure will rise above baseline values.
Chart 3: Renal Response to Altered Blood Pressure

<table>
<thead>
<tr>
<th>Afferent arteriole radius (mm)</th>
<th>Efferent arteriole radius (mm)</th>
<th>Blood pressure (mm Hg)</th>
<th>Glomerular capillary pressure (mm Hg)</th>
<th>Glomerular filtration rate (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>0.45</td>
<td>90</td>
<td>55.08</td>
<td>124.99</td>
</tr>
<tr>
<td>0.50</td>
<td>0.45</td>
<td>70</td>
<td>49.72</td>
<td>58.57</td>
</tr>
<tr>
<td>0.60</td>
<td>0.45</td>
<td>70</td>
<td>54.25</td>
<td>114.72</td>
</tr>
<tr>
<td>0.50</td>
<td>0.35</td>
<td>70</td>
<td>51.24</td>
<td>77.41</td>
</tr>
<tr>
<td>0.60</td>
<td>0.35</td>
<td>70</td>
<td>55.58</td>
<td>131.15</td>
</tr>
</tbody>
</table>

Activity Questions:
1. Increased blood pressure can be a result of increased blood volume. For this reason, an increase in urine volume would stabilize blood volume.
2. Diuretics increase the amount of urine output thus decreasing the blood volume. A decrease in blood volume should result in a corresponding decrease in blood pressure.

Activity 4: Solute Gradients and Their Impact on Urine Concentration (pp. PEx-139–PEx-140)

Predict Question 1: When the solute concentration gradient in the interstitial space is increased, the urine volume will decrease and the concentration of the urine will increase.

Chart 4: Solute Gradients and Their Impact on Urine Concentration

<table>
<thead>
<tr>
<th>Urine volume (ml)</th>
<th>Urine concentration (mOsm)</th>
<th>Concentration gradient (mOsm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.57</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>40.28</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>26.86</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>16.86</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>

Activity Questions:
1. Since desert rats have limited water supply, their urine volume will decrease due to an increased solute gradient thus concentrating their urine significantly.
2. Diuretics could work by inhibiting ADH or by altering the solute gradient.

Activity 5: Reabsorption of Glucose via Carrier Proteins (pp. PEx-140–PEx-142)

Predict Question 1: As glucose carriers are added, the glucose concentration in the bladder will increase.

Chart 5: Reabsorption of Glucose via Carrier Proteins

<table>
<thead>
<tr>
<th>Glucose concentration (mM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowman's capsule</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td>6.00</td>
</tr>
</tbody>
</table>
Activity Questions:
1. A physician might taste urine to detect increased glucose in the urine which could indicate diabetes mellitus.

Activity 6: The Effect of Hormones on Urine Formation (pp. PEx-142–PEx-143)

Predict Question 1: When aldosterone is added, the urine volume will decrease.

Predict Question 2: When ADH is added, the urine volume will increase.

Predict Question 3: In the presence of ADH and aldosterone, urine volume will decrease and the concentration will increase.

Chart 6: The Effect of Hormones on Urine Formation

<table>
<thead>
<tr>
<th>Potassium concentration (mM)</th>
<th>Urine volume (ml)</th>
<th>Urine concentration (mOsm)</th>
<th>Aldosterone</th>
<th>ADH</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.25</td>
<td>201.00</td>
<td>100</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>10.42</td>
<td>180.90</td>
<td>100</td>
<td>present</td>
<td>absent</td>
</tr>
<tr>
<td>62.37</td>
<td>16.86</td>
<td>1200</td>
<td>absent</td>
<td>present</td>
</tr>
<tr>
<td>65.37</td>
<td>12.67</td>
<td>1200</td>
<td>present</td>
<td>present</td>
</tr>
</tbody>
</table>

Activity Questions:
1. Ethanol is a diuretic that works by inhibiting ADH. Inhibition of ADH increases urine output.
2. ACE catalyzes the conversion of angiotensin I to angiotensin II. Angiotensin II has a variety of effects that all result in an increase in blood volume and decreased urine output. Therefore, inhibiting this enzyme would increase urine output.
ACTIVITY 1  The Effect of Arteriole Radius on Glomerular Filtration

1. What are two primary functions of the kidney?  
   The two primary functions of the kidney are excretion and regulation.

2. What are the components of the renal corpuscle?  
   The two components of the renal corpuscle are the Bowman’s capsule and the 
   glomerular capillaries (glomerulus).

3. Starting at the renal corpuscle, list the components of the renal tubule as they are encountered by filtrate.  
   1. Proximal convoluted tubule, 2. loop of Henle, 3. Distal convoluted tubule

4. Describe the effect of decreasing the afferent arteriole radius on glomerular capillary pressure and filtration rate. How well 
   did the results compare with your prediction?  
   When the radius of the afferent arteriole was decreased, the pressure and filtration rate both decreased.

5. Describe the effect of increasing the afferent arteriole radius on glomerular capillary pressure and filtration rate. How well 
   did the results compare with your prediction?  
   When the radius of the afferent arteriole was increased, the pressure and filtration rate both increased.

6. Describe the effect of decreasing the efferent arteriole radius on glomerular capillary pressure and filtration rate. How well 
   did the results compare with your prediction?  
   When the radius of the efferent arteriole was decreased, the pressure and filtration rate both increased.

7. Describe the effect of increasing the efferent radius on glomerular capillary pressure and filtration rate.  
   When the radius of the efferent arteriole was increased, the pressure and filtration rate both decreased.

ACTIVITY 2  The Effect of Pressure on Glomerular Filtration

1. As blood pressure increased, what happened to the glomerular capillary pressure and the glomerular filtration rate? How 
   well did the results compare with your prediction?  
   When you increase the blood pressure, glomerular capillary pressure and filtration rate will increase.

2. Compare the urine volume in your baseline data with the urine volume as you increased the blood pressure. How did the 
   urine volume change?  
   As the pressure increased, the urine volume increased proportionally.
3. How could the change in urine volume with the increase in blood pressure be viewed as being beneficial to the body?

Increased blood pressure can be a result of increased blood volume. For this reason, an increase in urine volume would stabilize blood volume.

4. When the one-way valve between the collecting duct and the urinary bladder was closed, what happened to the filtrate pressure in Bowman’s capsule (this is not directly measured in this experiment) and the glomerular filtration rate? How well did the results compare with your prediction? If you close the one-way valve, pressure will increase in the Bowman’s capsule and filtration rate will decrease.

5. How did increasing the blood pressure alter the results when the valve was closed? With increased pressure and the valve closed, the filtration rate decreased but the glomerular pressure stayed the same. Urine output was zero.

**Activity 3** Renal Response to Altered Blood Pressure

1. List the several mechanisms you have explored that change the glomerular filtration rate. How does each mechanism specifically alter the glomerular filtration rate? Both increasing the afferent arteriole radius and decreasing the efferent arteriole resulted in an increase in glomerular filtration rate.

2. Describe and explain what happened to the glomerular capillary pressure and glomerular filtration rate when both arteriole radii changes were implemented simultaneously with the low blood pressure condition. How well did the results compare with your prediction? When both arteriole radii changes were implemented, glomerular filtration rate and pressure rose above baseline values.

3. How could you adjust the afferent or efferent radius to compensate for the effect of reduced blood pressure on the glomerular filtration rate? Increasing the afferent radius or decreasing the efferent would compensate for lowered blood pressure.

4. Which arteriole radius adjustment was more effective at compensating for the effect of low blood pressure on the glomerular filtration rate? Explain why you think this difference occurs. Increasing the afferent radius had a greater effect than decreasing the efferent radius because there was a greater increase in glomerular pressure.

5. In the body, how does a nephron maintain a near-constant glomerular filtration rate despite a constantly fluctuating blood pressure? Intrinsic and extrinsic mechanisms result in changes to the afferent and efferent arterioles to maintain glomerular filtration rate.

404 Review Sheet 9

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**ACTIVITY 4  Solute Gradients and Their Impact on Urine Concentration**

1. What happened to the urine concentration as the solute concentration in the interstitial space was increased? How well did the results compare to your prediction? *When the solute concentration gradient in the interstitial space was increased, the urine volume decreased.*

2. What happened to the volume of urine as the solute concentration in the interstitial space was increased? How well did the results compare to your prediction? *When the solute concentration gradient in the interstitial space was increased, the concentration of the urine increased.*

3. What do you think would happen to urine volume if you did not add ADH to the collecting duct? *The urine volume will increase in the absence of ADH in the collecting duct.*

4. Is most of the tubule filtrate reabsorbed into the body or excreted in urine? Explain. *Most of the tubular filtrate is reabsorbed to prevent fluid loss and maintain homeostasis.*

5. Can the reabsorption of solutes influence water reabsorption from the tubule fluid? Explain. *Yes, the reabsorption of solutes affects water reabsorption because water will follow the solutes by osmosis.*

**ACTIVITY 5  Reabsorption of Glucose via Carrier Proteins**

1. What happens to the concentration of glucose in the urinary bladder as the number of glucose carriers increases? *As glucose carriers were added, the glucose concentration in the bladder increased.*

2. What types of transport are utilized during glucose reabsorption and where do they occur? *Glucose is first reabsorbed by secondary active transport at the apical membrane of PCT cells and then via facilitated diffusion along the basolateral membrane.*

3. Why does the glucose concentration in the urinary bladder become zero in these experiments? *When the number of glucose carriers becomes great enough all of the glucose is reabsorbed.*

4. A person with type 1 diabetes cannot make insulin in the pancreas, and a person with untreated type 2 diabetes does not respond to the insulin that is made in the pancreas. In either case, why would you expect to find glucose in the person’s urine? *The absence of insulin or decreased sensitivity to the hormone, leads to excess glucose in the blood so the carriers reach their maximum transport levels.*
ACTIVITY 6 The Effect of Hormones on Urine Formation

1. How did the addition of aldosterone affect urine volume (compared with baseline)? Can the reabsorption of solutes influence water reabsorption in the nephron? Explain. How well did the results compare with your prediction? When aldosterone was added, the urine volume decreased. Aldosterone results in increased sodium and water reabsorption and increased potassium secretion.

2. How did the addition of ADH affect urine volume (compared with baseline)? How well did the results compare with your prediction? Why did the addition of ADH also affect the concentration of potassium in the urine (compared with baseline)? When ADH was added, the urine volume increased. The addition of ADH resulted in the potassium being more concentrated because the volume of urine decreased.

3. What is the principal determinant for the release of aldosterone from the adrenal cortex? Aldosterone release is stimulated by production of angiotensin II which is under control of the body’s renin-angiotensin system.

4. How did the addition of both aldosterone and ADH affect urine volume (compared with baseline)? How well did the results compare with your prediction? When ADH was added, the urine volume increased.

5. What is the principal determinant for the release of ADH from the posterior pituitary gland? Does ADH favor the formation of dilute or concentrated urine? Explain why. An increase in body fluid osmolarity will stimulate the release of more ADH. ADH favors dilute urine.

6. Which hormone (aldosterone or ADH) has the greater effect on urine volume? Why? ADH has the greater effect on urine volume. ADH is responsible for fluid retention. Aldosterone is primarily increasing sodium uptake and potassium secretion.

7. If ADH is not available, can the urine concentration still vary? Explain your answer. The urine concentration will not vary in the absence of ADH.

8. Consider this situation: you want to reabsorb sodium ions but you do not want to increase the volume of the blood by reabsorbing large amounts of water from the filtrate. Assuming that aldosterone and ADH are both present, how would you adjust the hormones to accomplish the task? In order to reabsorb sodium without affecting urine volume, you would need to increase the amount of aldosterone and decrease ADH.