Making Water! OR is it really Just Water – Just Ask the Nephron!!

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Its just pee! perhaps to the observer (sic), but not to your body. To the body it is a fluid composed of waste products, foreign chemicals, excess electrolytes, etc.; contained in a water medium to help maintain a homeostatic environment in the body. But where does it come from and how is it produced?

The Key Player is the:

Nephron: it is the functional unit of the Renal system.
there are approximately 1,000,000 million nephrons per kidney
they will filter approximately 180L/day or 125mL/min
which means that the entire blood plasma volume of the body is filtered 60 times per day.
* other blood capillaries of the body filter only 4L/day.

Overall function of the nephron
:

1. remove:
   waste products: urea, creatinine, and uric acid
   foreign chemicals: drugs, water soluble vitamins, and food additives, etc.

2. regulate:
   water, inorganic ions, control blood volume, and pH, etc.

3. reclaim: glucose, amino acids, etc.

All of these are performed through a series of processes:

1. Glomerular Filtration (Filtration): glomerular capillaries into the Bowman's Capsule

2. Tubular reabsorption (Reabsorption): tubular lumen of the nephron to the peritubular capillaries

3. Tubular secretion (Secretion): from peritubular capillaries to the tubular lumen of the nephron

Instructions –Team Project

This is **a two-part** project.

Out of Class: Team will build the nephron, label it, and make labels for the substances.
In Class: The model will be used, along with the label of the substances to demonstrate the process from filtration to excretion along the nephron.

* There are questions built into the activity. They may be answered prior to the classroom portion of the activity or after each segment is completed during the actual activity in class.

Step I: Getting to know the Nephron – Build it and Knowledge will Come! **Out of Class**

Using everyday items, build a structural model of the nephron and glomerulus

* *You will want to make sure your model is large enough to label the individual regions of the nephron, and during the classroom portion of this project, adding the substance labels that are moving into and out of the nephron.*

Make the following labels of the Individual Regions of the Nephron and attach them to the model.

Bowman's capsule/Glomerular capsule
Proximal Convoluted Tubule
Loop of Henle
    Descending limb
    Ascending limb
Distal Convoluted Tubule
Collecting Duct

Step II: The Substances **Out of Class**

Make labels for the following substances: abbreviate where possible

* You may need more than one of each of these as you label indicated substances filtered, reabsorbed, and secreted.

\+ Suggestion: read through the in-class portion, and approximate the number of labels needed. Also, bring to class blank labels to prepare in the event that the prepared labels run out.

* Leave a blank area on each label to indicate if the substance is being reabsorbed or secreted

Example: (← water) to indicate reabsorption
(urea →) to indicate a secretion

* Bring these labels, along with your model to class on the day determined for the activity.

Water
Hydrogen (H+)
Sodium (Na+)
Chlorine (Cl-)
Potassium (K+)
Glucose
Amino Acids
Red Blood Cells (erythrocytes)
White Blood Cells (leukocytes)
Large proteins
Calcium (Ca+2)
Magnesium (Mg+2)
Phosphate (PO4-)
Bicarbonate (HCO3-)
Urea
Creatinine
Ammonia
Penicillin

Water-soluble Vitamins
Drugs
Food Additives
Pesticides
Toxins

Step III: Making Pee! Through Processes of Reabsorption and Secretion In Class Activity

1. Starting at the Glomerular Capsule all substances contained in the blood plasma undergo filtration; with the exception of cells and large proteins.

   Draw a large circle on a piece of paper and place the labeled substances in it.
   This represents all the substances contained in the **glomerular filtrate**

   Q: Which of the above substances would you not expect to find in normal glomerular filtrate?

   Answer: _____

2. **Beginning at the Proximal Convoluted Tubule**

   Reabsorption. (leave the tubule lumen of the nephron to the peritubular capillaries – blood plasma)
   100% of all the glucose
   100% of the amino acids
   65% of the water
   67% of the sodium
   67% of the chlorine
   50% of the urea
   almost all of the potassium ions
   phosphate ions
   bicarbonate ions
   calcium ions
   magnesium ions

   Secretion: (leaving the pertubular capillaries to the tubule lumen of the nephron)
   variable amounts of hydrogen ions along with ammonia and potassium ions
   small amount of creatinine and urea
   some drugs and toxins

   Attach the above substances to this region of the nephron.

Q: Which waste solute remains at 100% in the tubular lumen?

Answer: _____

Q: What solute ion is driving the reabsorption of water from the tubular lumen?

Answer: _____

Q: Under what transport mechanism is water reabsorbed?

Answer: _____

3. **Nephron Loop**

Descending Limb
Impermeable to solutes
Permeable to water

Reabsorption
15% more water

Secretion
Urea

Attach the above substances to this region of the nephron

Q: Describe the osmolarity of the tubular filtrate at the most distal end of the descending limb.

Answer: _____

Ascending Limb
Impermeable to water
Permeable to the following solutes:

Reabsorption:
20-30% more sodium
20-30% more potassium
35% chlorine
additional bicarbonate ions
variable amounts of calcium and magnesium ions

Q: Describe the filtrate concentration in comparison at the end of the Descending Limb.

Answer: _____

Attach the above substances to this region of the nephron

4. **Initial Segment of the Distal Convoluted Tubule**

Reabsorption
10-15% more water (variable)
5% sodium
5% chlorine
calcium ions
bicarbonate ions

Secretions:

variable amounts of hydrogen ions
potassium ions
creatinine
penicillin
foreign chemicals:
drugs, toxins, pesticides, etc.

Q: What substances are still contained in the filtrate at this point?

Answer: _____

Attach the above substances to this region of the nephron.

5. **Last part of the Distal Convoluted Tubule and the Collecting Duct**
(Region of Final Adjustment for water and pH)

Reabsorption:

5-9% water (stimulated by antidiuretic hormone – ADH)
1-4% sodium
variable amounts of the bicarbonate ions
variable amounts of urea

Secretion:

potassium ion (variable amounts based on dietary intake)
hydrogen ions (variable amounts to maintain acid-base homeostasis

Attach the above substances to this region of the nephron

6. **What's Left – Your Pee":**

Q: Based on the amount of water contained in the glomerular filtrate, is the final product dilute or concentrated?

Answer: _____

Q: Based on the waste products contained in the glomerular filtrate, which substances will be totally excreted in the urine?

Answer: _____

Q: Based on the waste products contained in the glomerular filtrate with substance, was only partially reclaimed (even after several secretions)?

Answer: _____

Q: Based on your knowledge of acid-base homeostasis, which ions were most responsible for regulating levels?

Answer: _____

Q. Why is it significant to reabsorb the bicarbonate ion? (What is its function in the body?)

Answer: _____

Summary:

Just making water – NOT. It is an intricate process, which takes place in one of a million nephrons, to maintain an internal environmental balance within your body.

So the next time, you are making water, thank your kidneys for a "Great Job"!

Instructor's Page

Course-level as prepared: This project is prepared for as a one-semester A&P activity, although it may be modified to include GFR, Tm, renal threshold, transport mechanisms, channels, control by the central nervous system and hormones used in homeostasis – depending on the creativity of the instructor. The project may also be modified to accommodate a lower-level A&P; at our college BIO106 – students going into Pharmacy Technology and Dental Assisting that are required to know just the basics of each system.

Class Activity: I prepared this activity as a small team project (3-5 students per team). In Part I the team will design and build a nephron, and prepare labels for the classroom portion (Part II) of the activity. I did not plan a grading scheme as part of the class activity. Questions that are built into each activity may be answered outside of and then check during the activity, or after each segment completed in class, and then collected for grading (optional).

Optional: They may also be re-worded and used as an assessment tool to check understanding (graded or ungraded instructor's option).

Option: Individual Team Project – Assigned Activity:

This project may also be an assigned individual group project of a particular physiological process which takes place in the body. The team would still be made up of 3-5 students, with the same criteria, except they would build, and completely label the regions of the nephron, and present the flow of substrates during a class presentation at the end of the semester. The questions built into the activity are meant to assist in focusing process at each step, or may be used at a later time as an assessment tool. Grading would be in accord to each instructor's criteria; suggestions: accuracy of the nephron and the labeled regions, accuracy of the substance flow at each region, accuracy in answering the questions. On an individual basis: define areas of responsibility: designer, material procurement, builder, quality controller, secretary/logbook recorder, etc. I have also added discussion questions that were taken from several on-hand text (reference added at the end of each question), that may be used as part of the grading criteria.

The following are discussion topics that may follow the classroom activity or be used as part of the individual team project requirements.

Discussion Topics:

1. If a person were doing strenuous work on a hot day and perspiring heavily, would there be a great deal of ADH in the blood or very little? Explain your answer.

Taken from *The Human Body in Health & Disease*, 4th ed., Thibodeau and Patton

* Points: What does ADH do?
How does it work?
What region of the nephron does it act on?

2. A class of antihypertensive drugs called loop diuretics prevents sodium reabsorption in the nephron loop. How could a drug like this lower blood pressure?

Taken from *Memmler's The Human Body in Health and Disease*, 10th ed., Barbara Janson Cohen

3. Mr. G. was in a car accident and lost a great deal of blood. He has been in the intensive care unit for 24 hours, and his condition is stable. His doctor, however, is concerned about possible kidney damage and finds these reports about Mr. G.: urinary output in 24 hours is 500 mL, blood urea is elevated, and his blood creatinine level is elevated.

Based on this information, are Mr. G.'s kidneys' functioning normally? *Justify your answer.
Is Mr. G in total renal failure? Give a reason to support your answer.

Taken from *Essentials of Anatomy and Physiology*, 4th ed. Student Workbook, Valerie C. Scanlon, Tina Sanders.

4. Mr. R is taking penicillin to cure a throat infection. He must take the drug frequently, because the kidney clears penicillin very efficiently. That is, all of the penicillin that enters the renal artery leaves the kidney in the urine. However, only some of the penicillin molecules will be filtered into the glomerular capsule. How can the kidney excrete all of the penicillin it receives?

Taken from *Memmler's The Human Body in Health and Disease*, 10th ed., Study Guide, Barbara Janson Cohen, Kerry L. Hull

* What is your answer based on?

* Point: Only 20% of the blood entering the afferent arteriole will result in glomerular filtrate; 80% is returned to the cardiovascular system.