Understanding How the Nephron Concentrates Urea in Urine: An Experimental Approach Using Dialysis Bags

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Introduction

- Nephron's multiple sections are differentially permeable to water and salt.
- Normal urea concentration in the blood is 2.5-7.1 mM, while it is 342-490 mM in the urine (a hundred fold difference).
  - Students struggle to understand how urea can become so concentrated.
- Simple rules of diffusion/osmosis are followed.
- Salt concentration is higher in the medullae than the cortex.
  - This sets up different concentration gradients within the kidney.
  - As a result, more reliance on passive transport (no energy needed)

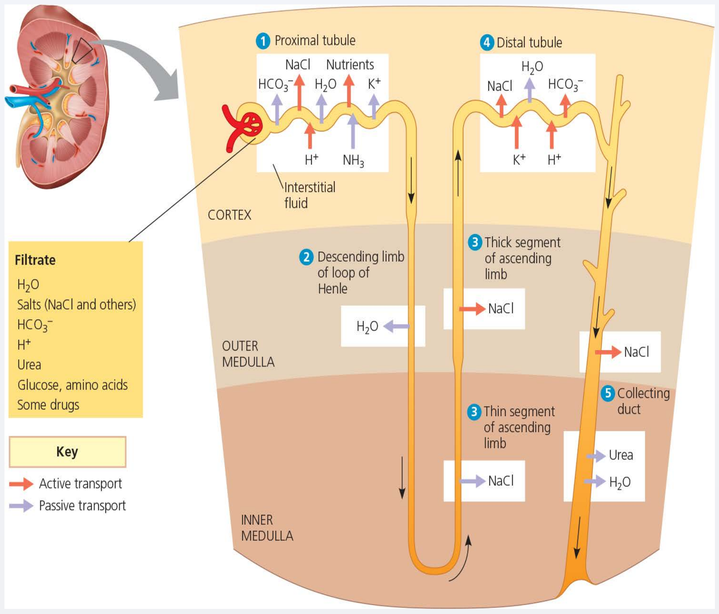


Image from Campbell's Biology

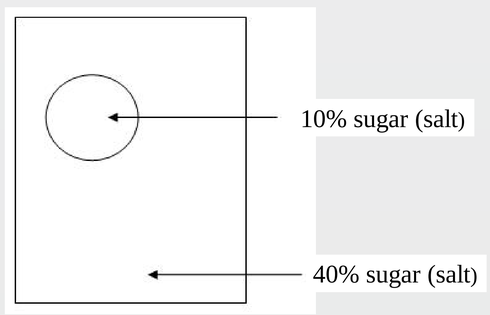
Objectives for Students

Understanding how urea becomes concentrated

- The nephron is not permeable to urea (mostly).
- Water (and thus volume) is lost from the filtrate when the filtrate moves towards the medulla.
  - Reducing volume is key to concentrating urea in urine.
- Salt is lost from the filtrate when the filtrate moves towards the cortex.
  - Salt goes into the medulla, increasing salt concentration there and driving passive transport, allowing water and salt to be removed from the filtrate.

Methods

- Since salt can move through the dialysis bag, sugar is used instead when salt should not be able to get though the bag.
- Urea is hypothetical, starting at 1%.
- Students are asked to predict movement of molecules and changes in concentration, using a diagram:



Bag 1: Descending Loop of Henle

- Permeable to water, but not salt.
- Starts at 10mL water, 10% sugar (salt), 1% urea (hypothetical) in dialysis bag.
- Placed in beaker of 40% sugar for 20 minutes.
- Measure new volume, use $C_1V_1 = C_2V_2$ to determine new concentrations for urea and salt.

Bag 2: Ascending Loop of Henle

- Permeable to salt, but not water.
- Starts with dialysis bag V_2 at C_2 of salt.
- Placed in beaker of 100% dH_2O for 20 minutes.
- Volume stays the same, use Conductivity Probe to determine new concentration of salt.

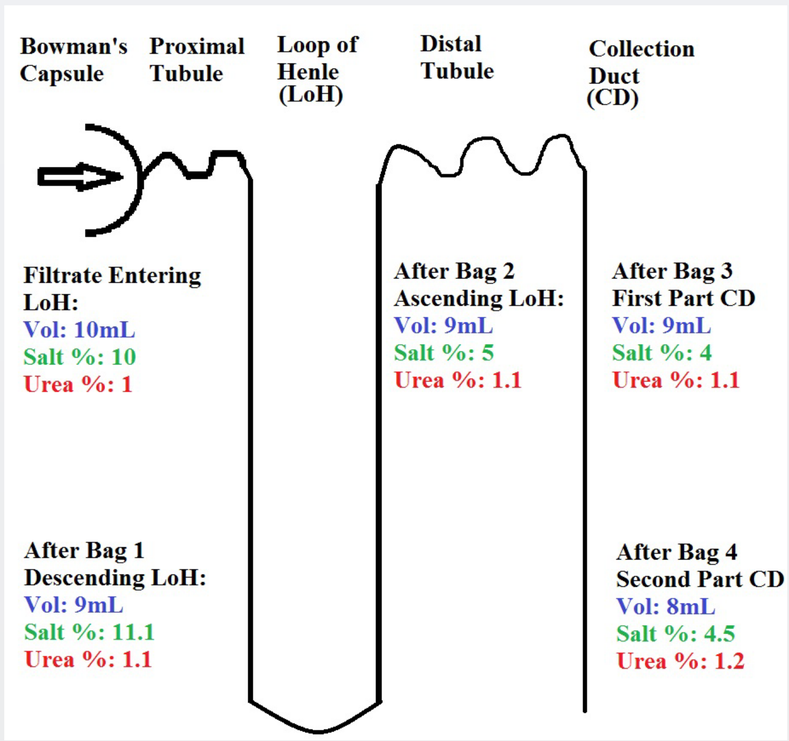
Bag 3: First Part of Collection Duct

- Permeable to salt, not water
- Starts with dialysis bag as Bag 2 (after), run the same as Bag 2.

Bag 4: Second Part of Collection Duct

- Permeable to water, but not salt
- Starts with dialysis bag as Bag 3 (after) run the same as Bag 1.

Sample Results



Questions for Students

- When salt leaves the Ascending Loop of Henle (Bag 2), where does it go? How does this help maintain the different salt concentrations of the medulla and cortex?
- Explain how changing volume of water and salt results in an increasing concentration of urea as the experiment proceeds.

Future Directions

- Adding a colored dye for urea.
- Including proximal and distal tubules (as calculations).