

Dilution and Concentration of Urine

Physiology
Team

431 RENAL BLOCK

➤ Urine concentration:

- The ability of the kidney to **concentrate urine** (conserve water) is important function in **regulating Extracellular volume (ECV), Extracellular Fluid osmolality**. “the more water in ECV the less the osmolality will be”.
- When there is **excess** water in the body the body fluid osmolality is **reduced** “there is so much water with less solute”, the kidney will excrete urine with an osmolality as low as **50 mOsm/liter**. “diluted”
- When there is a deficiency of water and extracellular fluids osmolality is high “less water and so much solute”, the kidney can excrete urine with a concentration of about **1200 to 1400 mOsm/liter**. “concentrated”

- Diluted urine: the urine excreted has more water and less solute = مخفف

- concentrated urine: the urine excreted has less water and more solute = مركز

- When water intake is normal: “in normal person”
 - Urine flow is **1-2 ml/min**
 - Urine osmolality is between **500-700 mOsm/kg**.
- Obligatory urine volume:
 - It is the minimum urine volume in which the excreted solute can be dissolved and excreted = 0.5 L/min

NEPHRON TYPES:

- **Superficial (cortical) [85 %]:**
Capable of forming dilute urine

- **Juxtamedullary [15 %]:**
Capable of forming concentrated (> 300 mOsm/kg)urine

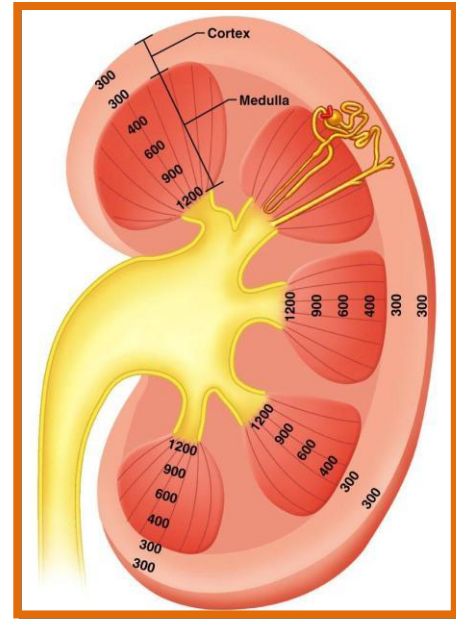
1-2 % Blood Flows through JuxtaMedullary Nephrons

➤ **Range of volume and osmolality regulated by the kidney**

- Urine Osmolality varies between 30-1200 mosm/kg
- Urine volume varies between 0.5-20ml/minute
- “These ranges show what the kidney can do in the normal and the abnormal conditions”

➤ **The basic requirements for forming a concentrated or diluted urine:**

1. Controlled secretion of antidiuretic hormone (ADH), which regulates the permeability of the distal tubules and collecting ducts to water. “High ADH causes high reabsorption and less water in the urine”
2. A high osmolarity of the renal medullary interstitial fluid, which provides the osmotic gradient necessary for water reabsorption to occur in the presence of high level of ADH “water osmotic gradient will move water from low to high osmolarity which is necessary for water reabsorption”



The graded hyper-osmolar medulla
 * AS you go deep in the medulla the osmolarity increase

Loop of henle	
Ascending Loop	Descending Loop
impermeable to water	highly permeable to water
permeable to Na⁺(mediated by Na⁺/K⁺/2Cl⁻-apical carrier -inhibited by furosemide (Lasix))	impermeable to Na ⁺
Na⁺/K⁺-ATPase actively pumps out sodium of cell into interstitium	water exit promoted

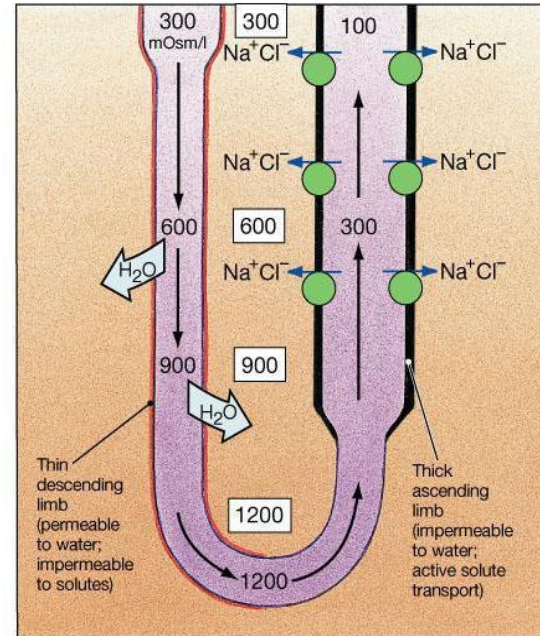
➤ Counter-Current Mechanism

• The hyperosmotic Renal Medullary Interstitium:

- produced by Counter-Current multiplier.
- Provides the osmotic gradient necessary for water reabsorption
- Formed by the thick Ascending limb of loop of Henle and Collecting Ducts
- Is formed mainly by Juxta-medullary nephrons

1. Counter current multiplier

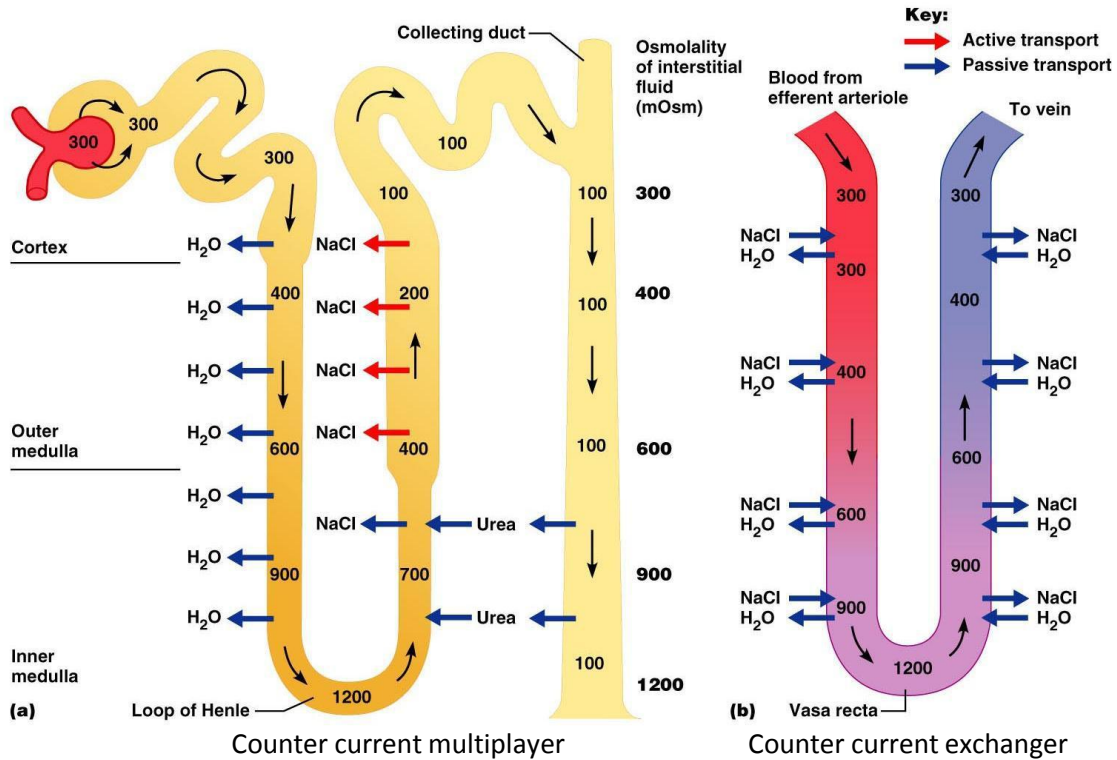
- Produces the hyperosmotic Medullary Interstitium
- Medullary hyper osmolality is due to solute deposition on medullary interstitium
 - NaCl reabsorbed from the thick ascending limb of loop of henle is deposited on medullary interstitium
 - Urea reabsorbed from collecting duct to medullary interstitium also contribute to medullary hyperosmolality (Urea contributes about 40 to 50 percent of the osmolarity (500-600 mOsm/L) of the renal medullary interstitium when the kidney is forming a maximally concentrated urine.)
- Water will be absorbed from the collecting duct to peritubular capillaries in the presence of ADH due to osmotic gradient
- Thiazide (diuretics) block NaCl reabsorption on thick ascending loop → Diuresis
 - Mechanism:
 - ◆ “no salt reabsorption” Salt remains in filtrate will drag water → Osmotic diuresis
 - ◆ Decreases medullary osmolality therefore water cannot be reabsorbed from collecting duct (No osmotic gradient) → diuresis



(b) Active transport of NaCl along the ascending thick limb results in the movement of water from the descending limb.

2. Renal circulation Counter current exchanger

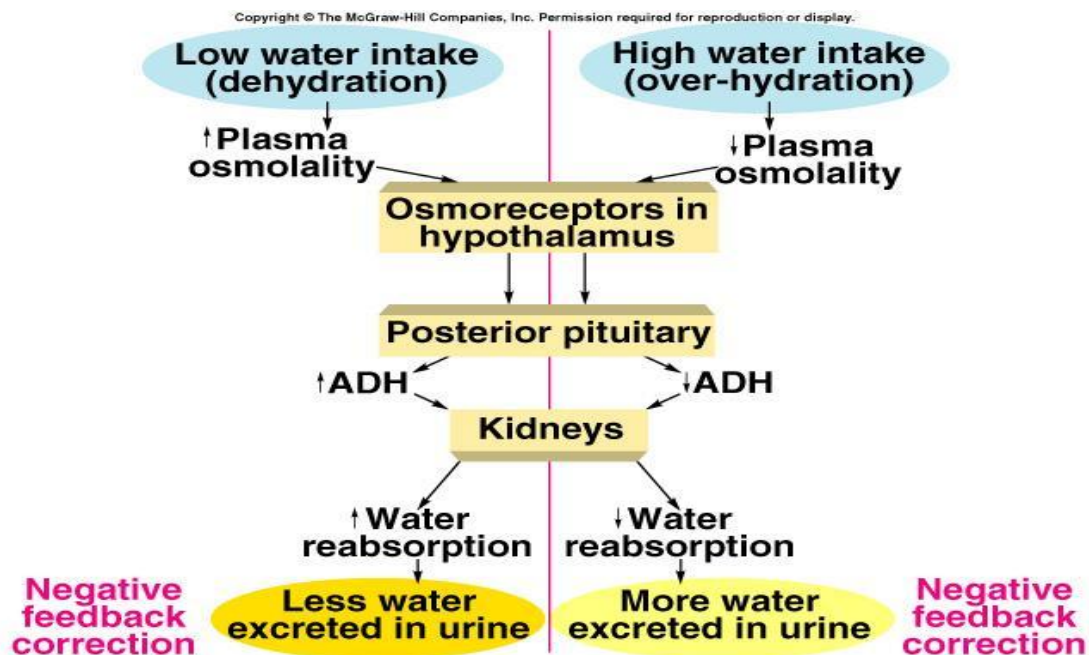
- Maintains hyper osmolar medulla (PASSIVE PROCESS)
- Blood supply to medulla is by Vasarecta only 2 % (sluggish flow)
- Descending limb: water pass out into hyper osmolar medulla carrying O₂ & nutrient, NaCl will enter the blood increasing its osmolalty
- Ascending limb:
 - water will be absorbed back to the hyper osmolar blood carrying CO₂, waste product & NaCl will leave the blood deposited as its in the medulla
 - Therefore blood leave the hyperosmolar medulla undisturbed.
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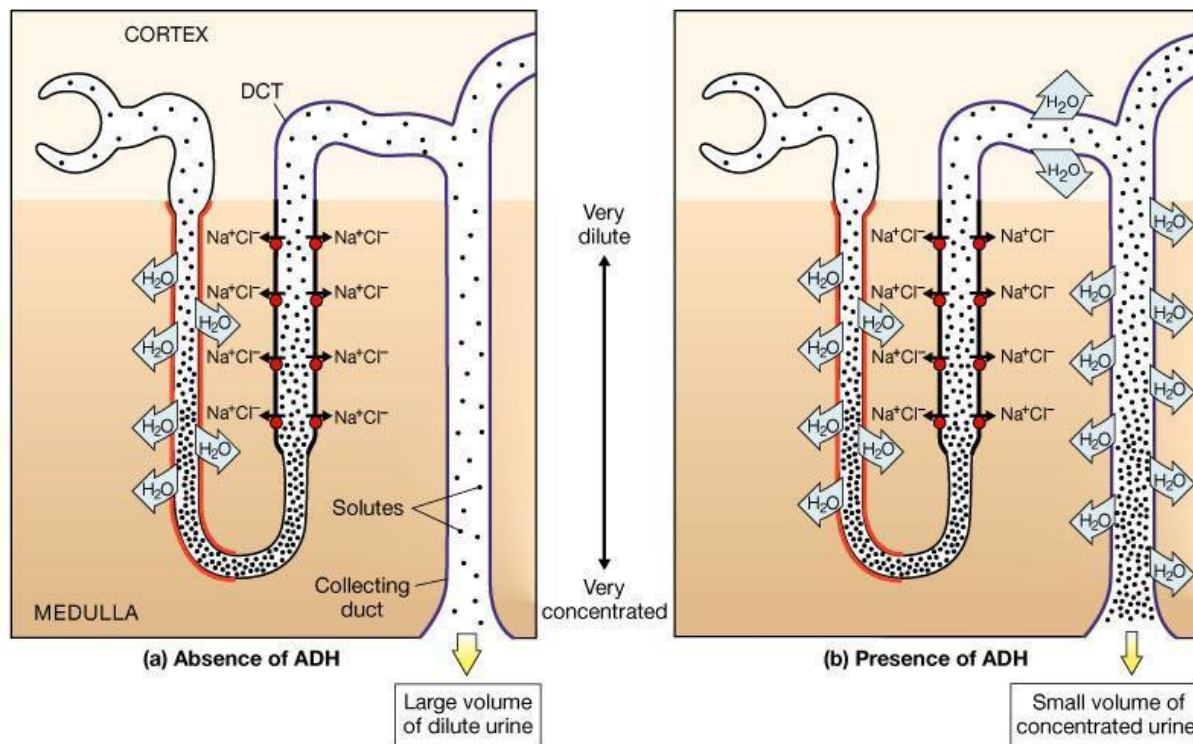
Dr.sitelbnat said: that is all what you need to know about countercurrent mechanism because it is a bit complicated, but if you have the interest to know more about it check the last page 😊

➤ Role of ADH

- Water reabsorbed from collecting duct (by osmosis) is determined by the ADH (anti-diuretic hormone)
- Osmoreceptors in the **hypothalamus** detect the low levels of water (high osmolarity), then it sends an impulse to the **pituitary** gland which releases ADH into the bloodstream.
- ADH makes the wall of the collecting duct more permeable to water.
- In the present of ADH more water is reabsorbed and less is excreted.



The Effects of ADH on the distal collecting duct and Collecting Ducts



➤ Diuresis

- Is increase of urine output.
 - Water diuresis:
 - Drinking large quantity of water → dilute ECF → ↓ADH → no water reabsorption in collecting duct → large volume of dilute urine excreted
 - Osmotic diuresis
 - Diabetes → Filtration of excessive osmotic active substances (glucose, mannitol) → Drag water with it → Large volume of hyperosmolar urine
 - Polyurea: Diabetes insipidus

Diabetes insipidus: is a condition characterized by excessive thirst and excretion of large amounts of severely diluted urine.

it is either a problem with the production of antidiuretic hormone (cranial diabetes insipidus) or kidney's response to antidiuretic hormone (nephrogenic diabetes insipidus).

SUMMARY

- Normal kidneys have tremendous capability to vary the relative proportions of solutes and water in the urine in response to various challenges. When there is excess water in the body and body fluid osmolarity is reduced, the kidney can excrete urine with an osmolarity as low as 50 mOsm/
 - When there is a deficit of water and extracellular fluid osmolarity is high, the kidney can excrete urine with a concentration of 1200 to 1400 mOsm/L
 - There is a powerful feedback system for regulating plasma osmolarity and sodium concentration that operates by altering renal excretion of water independently of the rate of solute excretion. A primary effector of this feedback is *antidiuretic hormone (ADH)*, also called *vasopressin*.
 - **LOOPS OF HENLE OF JUXTA MEDULLARY NEPHRONS** establish hyperosmolality of interstitium of medulla. They are called **COUNTER CURRENT MULTIPLIERS**
 - **VASA RECTA** maintain hyperosmolality established by counter current multipliers. They are called **COUNTER CURRENT EXCHANGERS**
 - The medullary blood flow is low, accounting for less than 5 per cent of the total renal blood flow. This sluggish blood flow is sufficient to supply the metabolic needs of the tissues but helps to minimize solute loss from the medullary interstitium.
 - The vasa recta serve as countercurrent exchangers, minimizing washout of solutes from the medullary interstitium unlike the cortical nephrons .
- Urea has a major role in the concentration of urine

Questions

T or F:

- 1- When the water concentration in body fluids increases the secretion of ADH increases.
- 2- Noura is dehydrated. His extracellular fluids osmolality is high; so her kidney will excrete diluted urine.

MCQs:

- 3- The countercurrent mechanism takes place in:
 - a) Juxtamedullary nephron
 - b) Cortical nephrone
 - c) Both.
- 4- The function of the countercurrent multiplier is to:
 - a) Produces the hyperosmotic Medullary Interstitium
 - b) Maintains hyper osmolar medulla
 - c) Secretes ADH
- 5- The ADH promotes water reabsorption through the walls of the:
 - a) Thick Ascending limb of loop of Henle.
 - b) Distal convoluted tubule and collecting duct.
 - c) Vasa recta.
- 6- Which one of the following produces the hyperosmotic Medullary Interstitium?
 - a) NaCl reabsorbed from the thick ascending limb of loop of henle to medullay interstitium
 - b) Urea reabsorbed from collecting duct to medullary interstitium
 - c) Both A and B

Answers:

1-F, 2- F, 3-A, 4-A, 5-B, 6-C

Explanation of Countercurrent mechanism

- Countercurrent multiplier system is a system that expends energy to create a concentration gradient.
- Water flows from the tubular fluid of the descending limb of the loop of Henle into the medullary space.
- The ascending limb is impermeable to water (because of a lack of aquaporin, a common transporter protein for water channels in all cells except the walls of the ascending limb of the loop of Henle), but here Na^+ , Cl^- , and K^+ are actively transported into the medullary space, making the filtrate (in lumen) hypotonic (with a higher water potential). This constitutes the single effect of the countercurrent multiplication process.
- Active transport of these ions from the thick ascending limb creates an osmotic pressure drawing water from the descending limb into the hyperosmolar medullary space, making the filtrate hypertonic (with a lower water potential).
- The countercurrent flow within the descending and ascending limb thus increases, or multiplies the osmotic gradient between tubular fluid and interstitial space.
- Urea diffuses into the thin loop of Henle, and then passes through the distal tubules, and finally passes back into the collecting duct. The recirculation of urea helps to trap urea in the renal medulla and contributes to the hyperosmolarity of the renal medulla”.

For further explanation:

- 1- <http://eamcetzology.blogspot.com/2008/08/countercurrent-multiplier.html>
- 2- <http://eamcetzology.blogspot.com/2008/08/countercurrent-exchanger.html>
- 3- <http://bcs.whfreeman.com/thelifewire8e/pages/bcs-main.asp?s=51000&n=00040&i=51040.01&v=chapter&o=&ns=0&uid=0&rau=0>

Videos:

- 1- <http://www.youtube.com/watch?v=ws-hQEXbT6U&feature=related>
- 2- <http://www.youtube.com/watch?v=Xbl8eY-BeXY&feature=related>