NAME: OMONIYI RACHEAL TOLUSE

MATRIC NO.: 18/MHS02/152

LEVEL: 200

DEPARTMENT: NURSING SCIENCE

COURSE TITLE: PHYSIOLOGY

COURSE CODE: PHS 212

ASSIGNMEMT TITLE: RENAL PHYSIOLOGY

<u>Question</u>

Explain urine formation and concentration

Urine Concentration

The human kidney can form urine with a total solute concentration greater or lower than that of plasma. Maximum and minimum urine osmolalities in humans are about 1,200 to 1,400 mOsm/kg H2O and 30 to 40 mOsm/kg H2O, respectively.
We next consider the mechanisms involved in producing osmotically concentrated or dilute urine.
Ability to concentrate urine osmotically is an important adaptation to life on land.
When the kidneys form osmotically concentrated urine, they save water for the body. The kidneys have the task of getting rid of excess solutes (e.g., urea and various salts), which requires the excretion of solvent (water). Suppose, for example, we excrete 600 mOsm of solutes per day. If we were only capable of excreting urine that is isosmotic to plasma (~300 mOsm/kg H2O), then we would need to excrete 2.0 L H2O/d. If we can excrete the solutes in urine, which is four times more concentrated than plasma (1,200 mOsm/kg H2O), then only 0.5 L H2O/d would be required. By excreting solutes in osmotically concentrated urine, the kidneys in effect save 1.5 L H2O (2.0–0.5 L H2O) for the body. The ability to concentrate the urine decreases the amount of water we are obliged to find and drink each day.

Urine concentrating ability can be looked at in two ways. We can determine what the urine osmolality (or specific gravity) is compared to the plasma, or the Uosm/Posm ratio. In people, a maximal value is about 4 to 5, a value that might be observed in a dehydrated, otherwise healthy, individual. Or, we can calculate how much solute-free water per unit time the kidneys save or eliminate in the urine; this quantity is called the *free water clearance* (or *free water production*), abbreviated Ch2o. Ch2o is calculated from the following
equation:

$$Ch2o = V - Cosm \quad (11)$$

where V is the urine flow rate and Cosm (the osmolal clearance) is defined as Uosm × V/Posm. If we factor out V in equation 11, we get:

$$Ch2o = V(1 - Uosm/Posm) \quad (12)$$

From equation 12, we see that if the Uosm/Posm ratio is >1 (osmotically concentrated urine), Ch2o is negative; if Uosm/
Posm = 1 (urine isosmotic to plasma), then Ch2o is zero; and
if Uosm/Posm is <1 (osmotically dilute urine), then Ch2o is positive.

Arginine vasopressin promotes the excretion of osmotically concentrated urine.

Changes in urine osmolality are normally brought about largely by changes in plasma levels of **arginine vasopressin (AVP)**, also known as **antidiuretic hormone**. In the absence of AVP, the kidney collecting ducts are relatively water impermeable. Reabsorption of solute across a water-impermeable epithelium leads to osmotically dilute urine. In the presence of AVP, collecting duct water permeability is increased. Because the medullary interstitial fluid is hyperosmotic, water reabsorption in the medullary collecting ducts can lead to the production of osmotically concentrated urine.

Osmolarity of glomerular filtrate is same as that of plasma and it is 300 mOsm/L. But, normally urine is concentrated and its osmolarity is four times more than that of plasma, i.e. 1,200 mOsm/L. Osmolarity of urine depends upon two factors:

1. Water content in the body
2. Antidiuretic hormone (ADH).

Mechanism of urine formation is the same for dilute urine and concentrated urine till the fluid reaches the distal convoluted tubule. However, dilution or concentration of urine depends upon water content of the body.

FORMATION OF DILUTE URINE

When, water content in the body increases, kidney excretes dilute urine. This is achieved by inhibition of ADH secretion from posterior pituitary . So water reabsorption from renal tubules does not take place leading to excretion of large amount of water. This makes the urine dilute.

FORMATION OF CONCENTRATED URINE

When the water content in body decreases, kidney retains water and excretes concentrated urine. Formation of concentrated urine is not as simple as that of dilute urine.

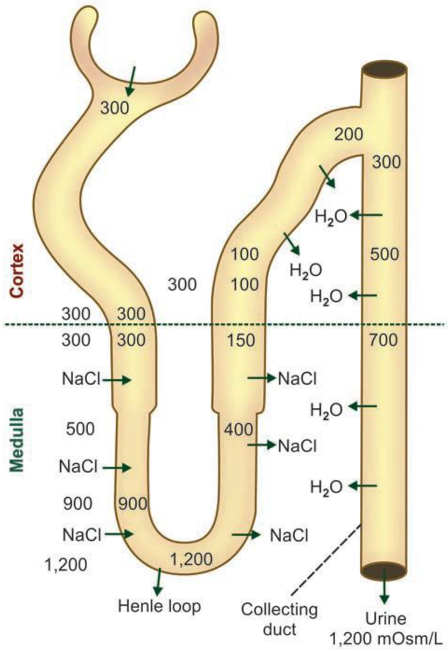
It involves two processes:

1. Development and maintenance of medullary gradient by countercurrent system
2. Secretion of ADH.

When the glomerular filtrate passes through renal tubule, its osmolarity is altered in different segments as described below.

1. BOWMAN CAPSULE

Glomerular filtrate collected at the Bowman capsule is isotonic to plasma. This is because it contains all the substances of plasma except proteins. Osmolarity of the filtrate at Bowman capsule is 300 mOsm/L.



Role of ADH in the formation of concentrated urine. ADH increases the permeability for water in distal convoluted tubule and collecting duct. Numerical indicate osmolarity (mOsm/L)

2. PROXIMAL CONVOLUTED TUBULE

When the filtrate flows through proximal convoluted tubule, there is active reabsorption of sodium and chloride followed by obligatory reabsorption of water.

So, the osmolarity of fluid remains the same as in the case of Bowman capsule, i.e. 300 mOsm/L. Thus, in proximal convoluted tubules, the fluid is isotonic to plasma.

3. THICK DESCENDING SEGMENT

When the fluid passes from proximal convoluted tubule into the thick descending segment, water is reabsorbed from tubule into outer medullary interstitium by means of osmosis. It is due to the increased osmolarity in the medullary interstitium, i.e. outside the thick descending tubule. The osmolarity of the fluid inside this segment is between 450 and 600 mOsm/L. That means the fluid is slightly hypertonic to plasma.

4. THIN DESCENDING SEGMENT OF HENLE LOOP

As the thin descending segment of Henle loop passes through the inner medullary interstitium (which is increasingly hypertonic) more water is reabsorbed. This segment is highly permeable to water and so the osmolarity of tubular fluid becomes equal to that of the surrounding medullary interstitium. In the short loops of cortical nephrons, the osmolarity of fluid at the hairpin bend of loop becomes 600 mOsm/L. And, in the long loops of juxtamedullary nephrons, at the hairpin bend, the osmolarity is 1,200 mOsm/L. Thus in this segment the fluid is hypertonic to plasma.

5. THIN ASCENDING SEGMENTOF HENLE LOOP

When the thin ascending segment of the loop ascends upwards through the medullary region, osmolarity decreases gradually.

Due to concentration gradient, sodium chloride diffuses out of tubular fluid and osmolarity decreases to 400 mOsm/L. The fluid in this segment is slightly hypertonic to plasma.

6. THICK ASCENDING SEGMENT

This segment is impermeable to water. But there is active reabsorption of sodium and chloride from this. Reabsorption of sodium decreases the osmolarity of tubular fluid to a greater extent. The osmolarity is between 150 and 200 mOsm/L. The fluid inside becomes hypotonic to plasma.

7. DISTAL CONVOLUTED TUBULE AND COLLECTING DUCT

In the presence of ADH, distal convoluted tubule and collecting duct become permeable to water resulting in water reabsorption and final concentration of urine. It is found that in the collecting duct, Principal (P) cells are responsible for ADH induced water reabsorption. Reabsorption of large quantity of water increases the osmolarity to 1,200 mOsm/L .The urine becomes hypertonic to plasma.

URINE FORMATION

Every day, about 190 quarts (180 liters) of blood plasma pass through the nephrons of the kidneys. Most of that liquid—about 188 quarts—is cleansed and returned to the bloodstream. The remainder is removed from the body as urine.

Urine formation involves three processes:

A. Glomerular filtration

B. Tubular reabsorption

C. Tubular secretion.

Among these three processes filtration is the function of the glomerulus. Reabsorption and secretion are the functions of tubular portion of the nephron

1. Filtration: Blood from the renal artery enters the nephrons of each kidney and passes through the tiny filtering units of the glomeruli. Blood pressure inside the capillaries of each glomerulus pushes water, small molecules (such as glucose, amino acids, and waste products like urea), and electrolytes into the Bowman's capsule, while leaving the larger blood cells and proteins in the bloodstream. The filtered fluids are called the glomerular filtrate. The amount of filtrate that forms in the glomerular capsule of both kidneys every minute is called the glomerular filtration rate (GFR). In a healthy adult, the normal GFR is about 4.2 ounces (125 milliliters) per minute.

Pressures, which determine the GFR are:

1. Glomerular capillary pressure

2. Colloidal osmotic pressure in the glomeruli

3. Hydrostatic pressure in the Bowman capsule.

These pressures determine the GFR by either favoring or opposing the filtration

2. Reabsorption: When the glomerular filtrate exits the glomerular capsule, it enters the proximal convoluted tubules. Nearly all of the water, sodium, and nutrients such as glucose, potassium, and protein are reabsorbed from the filtrate into the bloodstream. About half of the urea is also reabsorbed; the rest is excreted in the urine. The movement of these substances occurs through active and passive transport. Glucose, amino acids, sodium, and potassium are carried across the cells of the tubules via active transport. Water is reabsorbed passively via osmosis.

Basic transport mechanisms involved in tubular reabsorption are of two types:

1. Active reabsorption

2. Passive reabsorption.

1. *Active Reabsorption*

Active reabsorption is the movement of molecules against the **electrochemical (uphill) gradient.** It needs liberation of energy, which is derived from ATP.

Substances reabsorbed actively from the renal tubule are sodium, calcium, potassium, phosphates, sulfates, bicarbonates, glucose, amino acids, ascorbic acid, uric acid and ketone bodies.

2. *Passive Reabsorption*

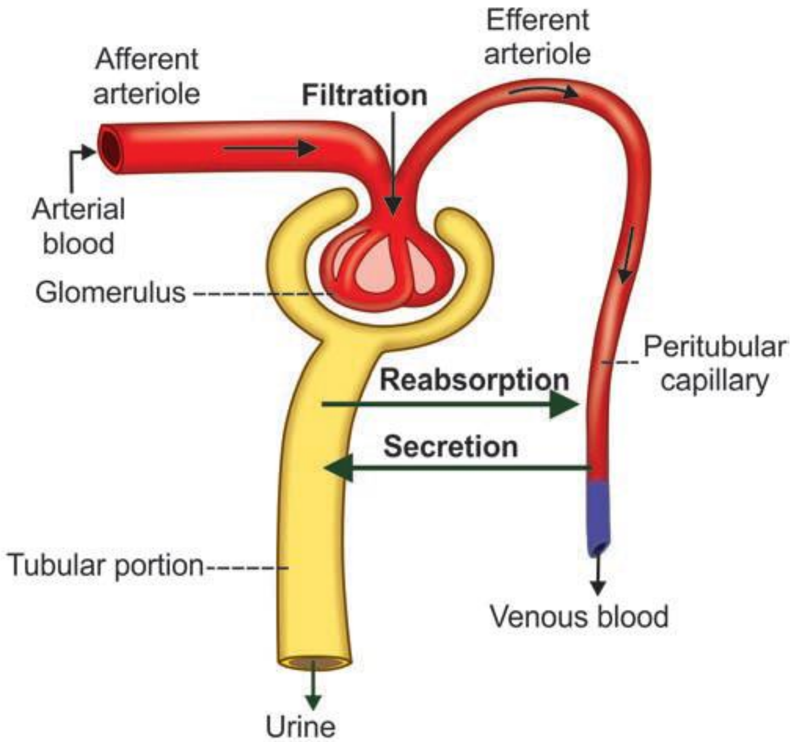
Passive reabsorption is the movement of molecules along the **electrochemical (downhill) gradient.** This process does not need energy.
Substances reabsorbed passively are chloride, urea and water.

Hormone	Action
Aldosterone	Increases sodium reabsorption in ascending limb, distal convoluted tubule and collecting duct
Angiotensin II	Increases sodium reabsorption in proximal tubule, thick ascending limb, distal tubule and collecting duct (mainly in proximal convoluted tubule
Antidiuretic hormone	Increases water reabsorption in distal convoluted tubule and collecting duct
Atrial natriuretic factor	Decreases sodium reabsorption
Brain natriuretic factor	Decreases sodium reabsorption
Parathormone	Increases reabsorption of calcium, magnesium and hydrogen Decreases phosphate reabsorption
Calcitonin	Decreases calcium reabsorption

Hormones regulating tubular reasorption

3. Secretion: Tubular secretion is the process by which the substances are transported from blood into renal tubules. It is also called tubular excretion. In addition to reabsorption from renal tubules, some substances are also secreted into the lumen from the peritubular capillaries through the tubular epithelial cells.
Dye phenol red was the first substance found to be secreted in renal tubules in experimental conditions.

As the filtrate enters the loop of Henle and moves up the distal convoluted tubule, wastes from the blood are added. Secretion is essentially reabsorption in reverse—rather than substances moving from the filtrate into the blood, they move from the blood into the filtrate. Substances added to the filtrate may include excess hydrogen, potassium, nitrogenous wastes (urea, creatinine, and uric acid), and certain drugs (such as penicillin). After rising up the ascending limb of the loop of Henle, the filtrate moves through the distal convoluted tubule and into the collecting duct, where it is referred to as urine.



Events that occur at urine formation