URINARY SYSTEM

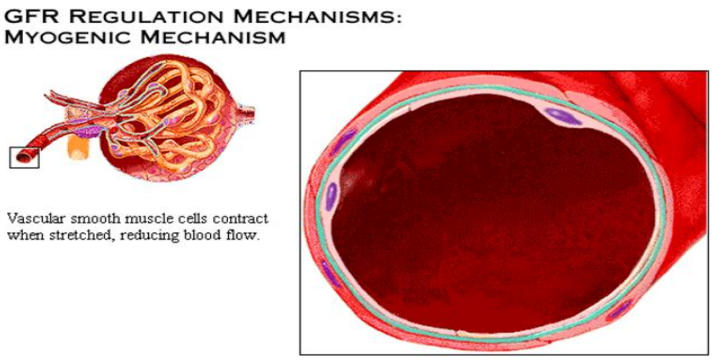
LECT. 2

Renal Autoregulation

Renal autoregulation is important to maintain the glomerular filtration rate (**GFR)**. Blood flow to kidneys remains normal even when the mean arterial blood pressure varies widely ***between 60 and 180 mm Hg***. This helps to maintain normal GFR. **Two mechanisms are involved in renal autoregulation:**
1. Myogenic response. 2. Tubuloglomerular feedback.

1. Myogenic Response

- Whenever the blood flow to kidneys increases, it stretches the elastic wall of the afferent arteriole.
- Stretch of the vessel wall increases the flow of calcium ions from extracellular fluid (ECF) into the cells.
- The influx of calcium ions leads to the contraction of smooth muscles in afferent arteriole which causes constriction of afferent arteriole.
- So, the blood flow is decreased.



2. Tubuloglomerular Feedback

Macula densa plays an important role in tubuloglomerular feedback which controls the renal blood flow and GFR.

SPECIAL FEATURES OF RENAL CIRCULATION

The renal circulation has some special features to cope up with the functions of the kidneys. Such special features are:
1. The renal arteries arise directly from the aorta. So the pressure in aorta is very high and it facilitates a high blood flow to the renal parenchyma.
2. Kidneys receive about 1,300 mL of blood per minute, i.e. about **26% of cardiac output**. Kidneys are the second organs to receive maximum blood flow, the first organ being **the liver** which receives 1,500 mL per minute, i.e. about **30% of cardiac output**.

3. Whole amount of blood which flows to kidney has to pass through the glomerular capillaries before entering the venous system. Because of this, the blood is completely filtered at the renal glomeruli.
4. Renal circulation has a portal system, i.e. a double network of capillaries namely glomerular capillaries and peritubular capillaries.
5. Renal **glomerular capillaries form high pressure bed** with a pressure of **60 to 70 mm Hg**. It is much greater than the capillary pressure elsewhere in the body, which is **only about 25 to 30 mm Hg**. High pressure is maintained in the glomerular capillaries because the diameter of afferent arteriole is more than that of efferent arteriole. The high capillary pressure augments glomerular filtration.
6. The **peritubular capillaries** form a low pressure bed with a pressure of **8 to 10 mm Hg**. This low pressure helps tubular reabsorption.
7. The autoregulation of renal blood flow is well established.

Urine formation

is a blood-cleansing function.

- Normally, *about **26%** of cardiac output enters the kidneys* to get rid of unwanted substances in urine.
- Normally, *about **1 to 1.5 L of urine** is formed every day.*

The mechanism of urine formation includes three processes:
1. Glomerular filtration.
2. Tubular reabsorption.
3. 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 (Fig. 42.1)

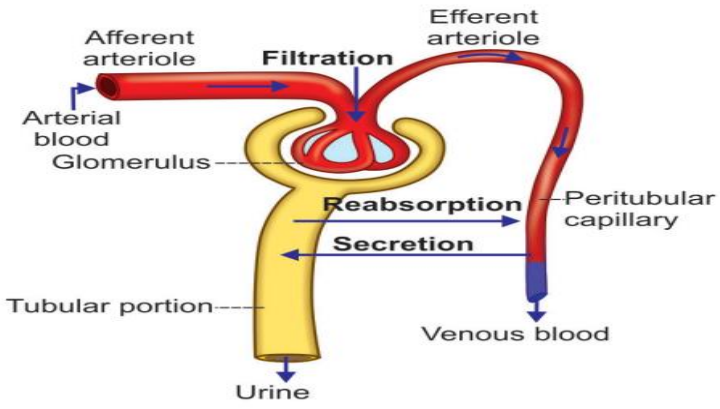


FIGURE 42.1: Events of urine formation

GLOMERULAR FILTRATION

Glomerular filtration is the process by which the blood that passes through glomerular capillaries is filtered through the filtration membrane. It is the first

process of urine formation. The structure of filtration membrane is well suited for this.

Filtration Membrane It is formed by three layers:
1. Glomerular capillary membrane.
2. Basement membrane.
3. Visceral layer of Bowman's capsule.

1. Glomerular Capillary Membrane

- The **glomerular capillary membrane** is formed by single layer of endothelial cells which are attached to the basement membrane.
- The capillary membrane has many pores called **fenestra** or **filtration pores** with a diameter of **0.1 µ.**

2. Basement Membrane

- The basement membrane of glomerular capillaries fuses with the basement membrane of visceral layer of Bowman's capsule.
- The basement membrane separates the endothelium of glomerular capillary and the epithelium of visceral layer of Bowman's capsule.

3. Visceral Layer of Bowman's Capsule

- This is composed of a single layer of flattened epithelial cells resting on a basement membrane.
- Each cell is connected with the basement membrane by cytoplasmic extensions called **pedicles or feet**.
- The pedicles are *arranged in an interdigitating manner leaving small cleft-like spaces in between. The cleft-like space is called slit pore*. Filtration takes place through these slit pores. The epithelial cells with pedicles are called podocytes (refer Fig. 39.4).

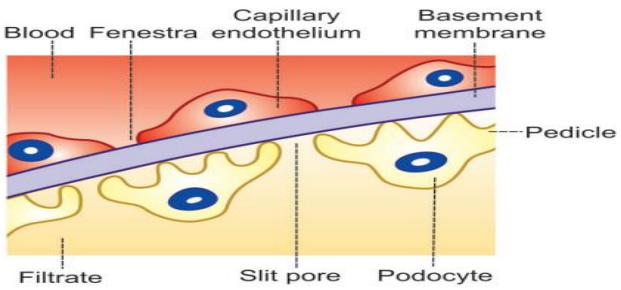


FIGURE 39.4: Filtering membrane in renal corpuscle. It is formed by capillary endothelium on one side (red) and visceral layer of Bowman's capsule (yellow) on the other side.

Process of Glomerular Filtration

When the blood passes through the glomerular capillaries, the plasma is filtered into the Bowman's **capsule.** ***All the substances of plasma are filtered, except the plasma proteins.*** The filtered fluid is ***called glomerular filtrate.***

GLOMERULAR FILTRATION RATE GFR

Glomerular filtration rate (GFR) is defined as the total quantity of filtrate formed in all the nephrons of both the kidneys in the given unit of time. ***The normal GFR is 125 mL per minute or about 180 L per day.***

FILTRATION FRACTION

Filtration fraction is the fraction (portion) of the renal plasma flow(**650ml/min)** which becomes the filtrate. It is the ratio between renal plasma flow and glomerular filtration rate. It is expressed in percentage. *The normal filtration fraction varies from 15 to 20%.*

$$\text{Filtration fraction} = \frac{\text{GFR}}{\text{Renal plasma flow}} \times 100$$

$$= \frac{125 \text{ mL/min}}{650 \text{ mL/min}} \times 100$$

$$= 19.2\%.$$

PRESSURES DETERMINING FILTRATION

The pressures, which determine the GFR, are:

1. **Glomerular capillary pressure**.
2. **Colloidal osmotic pressure in the glomeruli.**
3. **Hydrostatic pressure in the Bowman's capsule**.

1. Glomerular Capillary Pressure

It is the pressure *exerted by the blood in glomerular capillaries*. ***It is about 60 mm Hg***, and ***varies between 45 and 70 mm Hg.*** **Glomerular capillary pressure is the highest capillary pressure in the body.** This pressure favors glomerular filtration.

2. Colloidal Osmotic Pressure COP

It is ***exerted by plasma proteins in the glomeruli***, it is also called **oncotic pressure**. The plasma proteins are not filtered through the glomerular capillaries and remain in the glomerular capillaries. These **proteins develop the colloidal osmotic pressure which is about 25 mm Hg**. **It opposes glomerular filtration.**

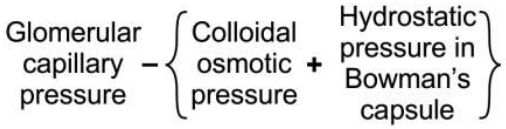
3. Hydrostatic Pressure in Bowman's Capsule

It is the ***pressure exerted by the filtrate in Bowman's capsule***. It is **also called capsular pressure.** It is about 15 mm Hg. It *also opposes glomerular filtration.*

Net Filtration Pressure

Net filtration pressure is the balance between pressure favoring filtration and pressures opposing filtration. It is otherwise known as effective filtration pressure or essential filtration pressure.

The net filtration pressure is given by:



= 60 – (25 + 15) = 20 mm Hg.

Normal net filtration pressure is about 20 mm Hg, and it varies between 15 and 20 mm Hg.

FACTORS REGULATING (AFFECTING) GFR

1. Renal Blood Flow

It is the most important factor that is necessary for glomerular filtration. *GFR is* ***directly proportional*** *to renal blood flow.* The renal blood flow itself is controlled by autoregulation

2. Tubuloglomerular Feedback

Tubuloglomerular feedback is the mechanism that regulates GFR through renal tubule and macula densa (Fig. 42.2). ***Macula densa*** *of juxtaglomerular apparatus in the terminal portion of thick ascending limb is* ***sensitive to the sodium chloride*** *in the tubular fluid.*

- When glomerular filtrate passes through the terminal portion of thick ascending segment, **macula densa acts like a sensor**.
- It **detects the concentration of sodium chloride** in the tubular fluid
- **Accordingly alters the glomerular blood flow and GFR**.

When the concentration of sodium chloride increases in the filtrate ***Macula densa*** *releases* ***adenosine from ATP***. Adenosine *causes constriction of afferent arteriole.* So the *blood flow through glomerulus decreases* ***leading to decrease in GFR***.

When the concentration of sodium chloride decreases in the filtrate ***Macula densa*** *secretes* ***prostaglandin (PGE2), bradykinin*** *and* ***renin***. *PGE2 and bradykinin cause* ***dilatation of afferent arteriole***. ***Renin*** *induces the formation of angiotensin II which causes* ***constriction of efferent arteriole***. The dilatation of afferent arteriole and constriction of efferent arteriole leads to increase in glomerular blood flow and GFR.

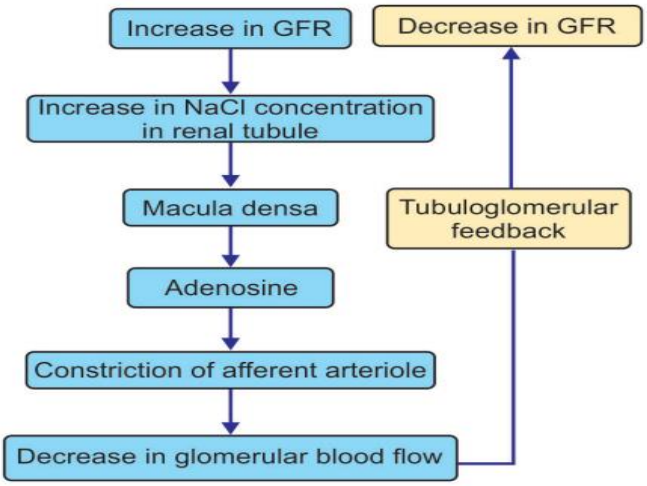


FIGURE 42.2: Tubuloglomerular feedback. GFR = Glomerular filtration rate, NaCl = Sodium chloride.

3. Glomerular Capillary Pressure

The GFR is *directly proportional* to glomerular capillary pressure. The capillary pressure, in turn depends upon the renal blood flow and arterial blood pressure.

4. Colloidal Osmotic Pressure

*The **GFR** is inversely proportional to **COP** which is exerted by plasma proteins* in the glomerular capillary blood. *When COP increases as in case of dehydration or increased plasma protein level, GFR decreases. During hypoproteinemia, COP is low and GFR increases.*

5. Hydrostatic Pressure in Bowman's Capsule

GFR is *inversely proportional* to this. The hydrostatic pressure in Bowman's capsule increases in conditions like obstruction of urethra and edema of kidney beneath renal capsule.

6. Constriction of Afferent Arteriole

The ***constriction of afferent arteriole*** reduces the blood flow to the glomerular capillaries which in turn ***reduces GFR***

7. Constriction of Efferent Arteriole

If efferent arteriole is constricted, initially *the **GFR increases** because of stagnation of blood in the capillaries.*

Later when all the substances are filtered from this blood, further filtration does not occur, because the efferent arteriolar constriction prevents outflow of blood from glomerulus and no fresh blood enters the glomerulus for filtration.

8. Systemic Arterial Pressure

- Renal blood flow or GFR **are not affected till the mean arterial blood pressure is between 60 and 180 mm Hg.**
- It is due to the **autoregulatory mechanism**.

- Variation in pressure above 180 mm Hg or below 60 mm Hg affects the renal blood flow and GFR accordingly, **because the autoregulatory mechanism fails beyond this range.**

9. Sympathetic Stimulation

- **Afferent** and **efferent arterioles** are supplied by **sympathetic nerves**.
- The **mild or moderate stimulation of sympathetic nerves does not cause any significant change** either in renal blood flow or GFR.
- **Strong sympathetic stimulation** causes **severe constriction of the blood vessels**.
- The **effect is more severe on the efferent arterioles** than on the **afferent arterioles.**
- So, **initially there is increase in filtration**, *but later it decreases*.
- However, if the stimulation is continued for more than 30 minutes, there is recovery of both renal blood flow and GFR. It is because of reduction in sympathetic neurotransmitter.

10. Surface Area of Capillary Membrane

- GFR is directly proportional to the surface area of the capillary membrane.
- If the glomerular capillary membrane is affected as in the cases of some renal diseases, the surface area for filtration **decreases**. So there is reduction in GFR.

11. Permeability of Capillary Membrane

- GFR is directly proportional to the permeability of glomerular capillary membrane.
- In **many abnormal conditions** like **hypoxia**, lack of blood supply, presence of **toxic agents**, etc. the **permeability of the capillary membrane increases**.
- In such conditions, even plasma **proteins are filtered and excreted** in urine.

12. Contraction of Glomerular Mesangial Cells

Glomerular mesangial cells are situated in between the glomerular capillaries. **Contraction of these cells decreases surface** area of capillaries **resulting in reduction in GFR.**

13. Hormonal and Other Factors

Many hormones and other secretory factors alter GFR by affecting the blood flow through glomerulus.

Factors increasing GFR by vasodilatation

i. Atrial natriuretic peptide.
ii. Brain natriuretic peptide.
iii.cAMP.
iv. Dopamine.
v. Endothelium-derived nitric oxide "**NO**".
vi. Prostaglandin E2 (PGE2).

Factors **decreasing GFR** by **vasoconstriction**

i. Angiotensin II.
ii. Endothelin.

iii. Noradrenaline.
iv. Platelet-activating factor.
v. Platelet-derived growth factor.
vi. Prostaglandin F2 (PGF2)

TUBULAR REABSORPTION

- *Tubular reabsorption is the process by which water and other substances are transported from renal tubules back to the blood.*
- When the glomerular filtrate flows through the tubular portion of nephron large quantity of water (**more than 99%),** electrolytes and other substances are reabsorbed by the tubular epithelial cells.
- The reabsorbed substances move into the interstitial fluid of renal medulla. And, the substances move into the blood in peritubular capillaries.
- The substances are taken back into the blood from the glomerular filtrate, the entire process is called **tubular reabsorption**.

SELECTIVE REABSORPTION

- **Tubular reabsorption** is known as **selective reabsorption** because essential substances such as ***glucose, amino acids and vitamins are completely reabsorbed from renal tubule***.
- Unwanted substances like metabolic waste products are excreted through urine.

MECHANISM OF REABSORPTION

The 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 (up-hill) gradient.
- It needs liberation of energy which is derived from ATP. Substances reabsorbed actively.
- The 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 (down-hill) gradient.
- This process does not need energy. Substances reabsorbed passively The substances reabsorbed passively are **chloride, urea** and **water**.

SITE OF REABSORPTION

The reabsorption of the substances occurs in almost all the segments of tubular portion of nephron.

1. Substances Reabsorbed from Proximal Convoluted Tubule

- About 7/8 of the filtrate (**about 88%**) is reabsorbed in PCT (PCT).
- The brush border of the epithelial cell in PCT increases the surface area and facilitates reabsorption.

- Substances reabsorbed from PCT are **glucose**, **amino acids**, **sodium**, **potassium**, **calcium**, **bicarbonates**, **chlorides**, **phosphates**, **uric acid** and **water**.

2. Substances Reabsorbed from Loop of Henle

substances reabsorbed from loop of Henle are **sodium** and **chloride**.

3. Substances Reabsorbed from Distal Convoluted Tubule

substances reabsorbed from DCT ***Sodium, calcium, bicarbonate*** *and* ***water*** .

REGULATION OF TUBULAR REABSORPTION

Tubular reabsorption is regulated by three factors:

1. Glomerulotubular balance. 2. Hormonal factors. 3. Nervous factors.

1. Glomerulotubular Balance

- Glomerulotubular balance is the balance between the **filtration** and **reabsorption** of **solutes** and **water** in kidney.
- **When GFR increases**, the tubular load of solutes and water in the **PCT** is increased.
- It is **followed by increase in the reabsorption** of solutes and water.
- This process helps in the constant reabsorption of solute, particularly sodium and water from renal tubule.

Mechanism of glomerulotubular balance

- **When *GFR increases***, more amount of plasma proteins accumulates in the glomerulus so, *the osmotic pressure increases* in the blood by the time *it* ***reaches efferent arteriole*** *and* ***peritubular capillaries***.
- The **elevated osmotic pressure** **in the peritubular capillaries** **increases reabsorption of sodium and water from the tubule into the capillary blood**.

2. Hormonal Factors

The hormones which regulate GFR are listed in Table 42.1.

TABLE 42.1: Hormones regulating tubular reabsorption

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

3. Nervous Factor

*Activation of sympathetic nervous system increases the tubular reabsorption (particularly of **sodium**) from renal tubules*. It also **increases the tubular reabsorption indirectly** by stimulating secretion of renin from juxtaglomerular cell.

***Renin** causes formation of angiotensin II which **increases the sodium reabsorption**.*

TRANSPORT MAXIMUM – Tm VALUE

Tubular transport maximum or Tm is the rate at which a substance is reabsorbed from the renal tubule. For example, the transport maximum for glucose (TmG), is 375 mg/minute in adult males and about 300 mg/minute in adult females.

REABSORPTION OF IMPORTANT SUBSTANCES

Reabsorption of Sodium

99% of **sodium** is **reabsorbed** in **PCT** and remaining **1%** in other segments (except descending limb) and collecting duct.

Reabsorption of Water

Reabsorption of water from PCT

- Obligatory reabsorption of water in PCT, which is secondary to sodium reabsorption. When sodium is reabsorbed from the tubule, the osmotic pressure decreases, it causes osmosis of water from renal tubule.

Reabsorption of water from DCT and **collecting duct**

- In facultative reabsorption, the collecting ducts become more permeable to water due to the effect of ADH, so water is reabsorbed by osmosis.
- Normally, the DCT and the collecting duct *are **not permeable to water***.
- But in the presence of (ADH), these segments *become permeable to water* and so it is reabsorbed.
  - ADH combines with V2 receptors in the tubular epithelial membrane and activates cyclic AMP increases the permeability of the tubules for water by activating the water channels.

Reabsorption of Glucose

- **Completely reabsorbed in the PCT** *It is transported by secondary active transport mechanism.*
- *Glucose and sodium bind to a common carrier protein in the luminal membrane of tubular epithelium and enter the cell.*
- Renal threshold for glucose is ***180 mg/dL in venous blood***. When the blood level reaches 180 mg/dL **glucose is not reabsorbed completely** and appears in urine.
- *Tubular maximum for glucose (TmG) In adult male, TmG is 375 mg/minute and in adult females, it is about 300 mg/minute.*

Reabsorption of Bicarbonates

- *Bicarbonate is reabsorbed actively, mostly in **proximal tubule***.
- It is reabsorbed in the *form of* **CO_2**.

- In the tubular cells, **CO2** combines with water to form carbonic acid.
- It immediately dissociates into **H2** and **bicarbonate**.
- Bicarbonate from the tubular cell enters the interstitium.
- **Bicarbonate combines** with **Na** to form **sodium bicarbonate** (Fig. 44.1).

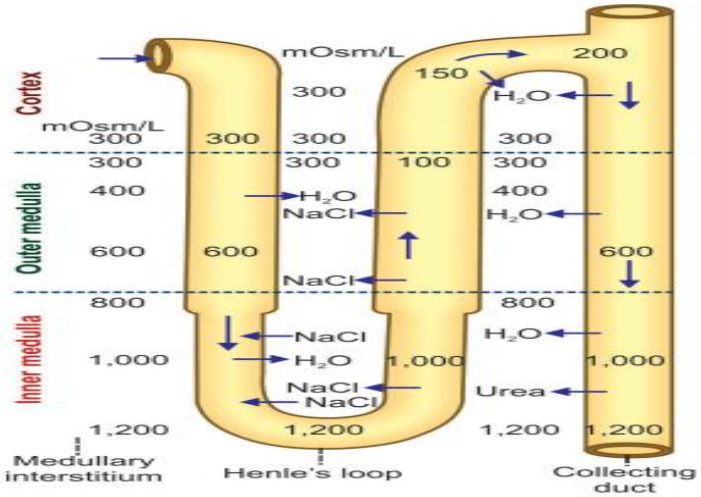


FIGURE 43.1: Countercurrent multiplier. Numerical indicate osmolarity (mOsm/L).

TUBULAR SECRETION

Tubular secretion is the process by which the **substances** are **transported from blood** into **renal tubules**.

SUBSTANCES SECRETED IN DIFFERENT SEGMENTS OF RENAL TUBULES

1. Potassium is secreted actively by sodium-potassium pump in **PCT***and* **DCT** *and* **collecting ducts**.

2. Ammonia is secreted in the **PCT**.

3. Hydrogen ions are secreted in the **PCT***and* **DCT**.

Maximum hydrogen ion secretion occurs in PCT.

URINE CONCENTRATION

When the glomerular filtrate passes through renal tubule, its osmolarity is altered in different segments as described below (Fig. 43.4).

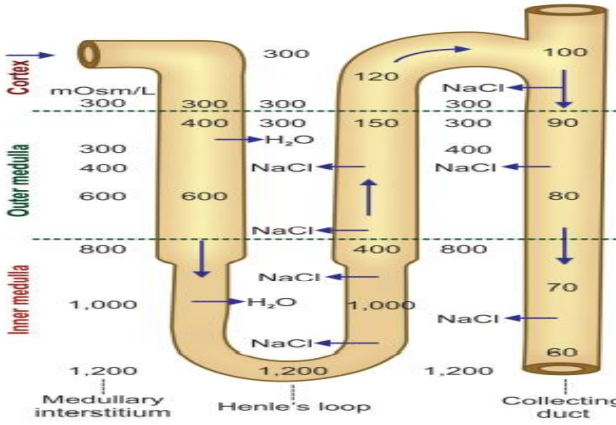


FIGURE 43.4: Mechanism for the formation of dilute urine. Numerical indicate osmolarity (mOsm/L).

1. BOWMAN'S CAPSULE

The glomerular filtrate collected at the Bowman's capsule is isotonic to plasma. This is because it contains all the substances of plasma except proteins. The osmolarity of the filtrate at Bowman's capsule is 300 mOsm/L.

2. PROXIMAL CONVOLUTED TUBULE

When the filtrate flows through **PCT**, 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's capsule, i.e. 300 mOsm/L. Thus, *in **PCT**, the fluid is isotonic to plasma*. *ADH increases the permeability for water in **DCT** and **collecting duct**.*

3. THICK DESCENDING SEGMENT

When the fluid *passes from PCT into the thick descending* segment, *water is reabsorbed from the 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'S LOOP

*As the thin descending segment of Henle's 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 SEGMENT OF HENLE'S 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. DCT 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. Reabsorption of large quantity of water increases the osmolarity to 1,200 mOsm/L (refer Fig. 43.3). The urine becomes hypertonic to plasma.

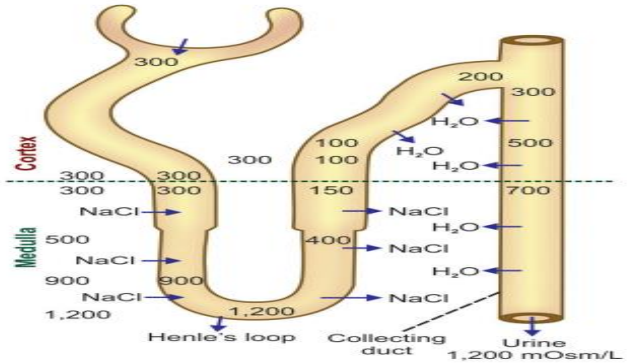


FIGURE 43.3: Role of ADH in the formation of concentrated urine. ADH increases the permeability for water in distal convoluted tubule and collecting duct.

Renal Function Tests

PROPERTIES AND COMPOSITION OF NORMAL URINE

PROPERTIES OF URINE

Volume: 1,000 to 1,500 mL/day
Reaction: Slightly acidic with pH of 4.5 to 6
Specific gravity: 1.010 to 1.025
Color: Normally, urine is straw colored
Odor: Fresh urine has light aromatic odor. If stored for some time, the odor becomes stronger due to bacterial decomposition

COMPOSITION OF URINE

Urine consists of **water** and **solids**. Solids include **organic** and **inorganic** substances (Fig. 45.1).

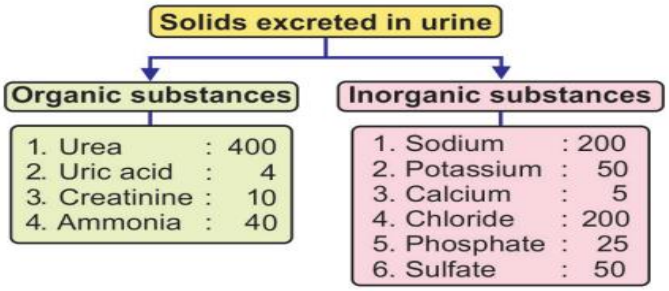


FIGURE 45.1: Quantity of solids excreted in urine (mMol/day)

RENAL FUNCTION TESTS

Renal function tests are the group of tests that are performed to assess the functions of kidney. The renal function tests are of three types:

1. Examination of urine alone.
2. Examination of blood alone.
3. Examination of blood and urine.

EXAMINATION OF URINE – URINALYSIS

Routine Examination of Urine

During the routine examination of urine, the following are determined:

I. **Specific gravity:** Normally it is 1.010 to 1.025. But, in some conditions like chronic nephritis, it is decreased.

II. **Presence of normal constituents of urine in abnormal quantity:** Normally, substances like water, salt, amino acids and creatinine are excreted in urine either in greater or lesser amount. But, if abnormally large amount is excreted, it suggests some abnormal functional status of kidney. If 4 to 5 liters of water is excreted consistently per day, it is suggestive of diabetes insipidus. Abnormally low amount of water excretion indicates nephritis. Abnormal amount of salts or nutritive substances like amino acids appear in urine during congenital tubular defects. Abnormal albumin excretion occurs in defective filtration. Abnormal amount of glucose is excreted in diabetes mellitus.

III. Microscopic examination: This reveals the presence of red blood cells, pus cells, epithelial cells, casts and crystals which suggests the renal pathology.

EXAMINATION OF BLOOD

The level of plasma proteins, urea, uric acid and creatinine are determined in blood. The blood level of these substances is altered in renal failure.

EXAMINATION OF BLOOD AND URINE

Plasma Clearance

Plasma clearance is defined as the amount of plasma that is cleared off a substance in a given unit of time. It is also known as **renal clearance**. It is based on Fick's principle. The determination of clearance value for certain substances helps in assessing the following renal functions:

1. Glomerular filtration rate.

2. Renal plasma flow.
3. Renal blood flow.
To determine the plasma clearance of a particular substance, measurement of the following factors is required:
1. Volume of urine excreted.
2. Concentration of the substance in urine.
3. The concentration of the substance in blood.
The formula to calculate clearance value is:
C = UP/P Where,
C = Clearance
U = Concentration of the substance in urine
V = Volume of urine flow
P = Concentration of the substance in plasma

1. **Measurement of Glomerular Filtration Rate**
   A substance that is completely filtered but neither reabsorbed nor secreted should be used to measure glomerular filtration rate (GFR). Inulin is a substance that is completely filtered. And, it is neither reabsorbed nor secreted. So, inulin is the ideal substance used to measure GFR.

   Inulin clearance
   A known amount of inulin is injected into the body. After sometime, the concentration of inulin in plasma and urine and the volume of urine excreted are estimated. For example,
   Concentration of
   inulin in urine = 125 mg/dL
   Plasma concentration = 1 mg/dL
   Volume of urine output = 1 mL/min
   Thus,
   Glomerular filtration rate = UV/P

   2. Measurement of Renal Plasma Flow
   To measure renal plasma flow, a substance, which is filtered and secreted but not reabsorbed, should be used. Such a substance is para-aminohippuric acid (PAH). PAH clearance indicates the amount of plasma passed through kidneys.
   A known amount of PAH is injected into the body. After sometime, the concentration of PAH in plasma and urine and the volume of urine excreted are estimated.
   For example,
   Concentration of PAH
   in urine = 66 mg/dL
   Plasma concentration = 0.1 mg/dL
   Volume of urine output = 1 mL/min
   Thus,
   Renal plasma flow = UV /P
   66 × 1 /0.1
   = 660 mL/min

3. Measurement of Renal Blood Flow

To determine renal blood flow value of two factors is necessary:

i. Renal plasma flow.
ii. Percentage of plasma volume in the blood.

i. Renal plasma flow

Renal plasma flow is measured by using PAH clearance.

ii. Percentage of plasma volume in the blood

The percentage of plasma volume is indirectly determined by using PCV. For example, if PCV is 45%, the plasma volume in the blood is 100 – 45 = 55%, i.e. 55 mL of plasma is present in every 100 mL of blood.

Renal blood flow is calculated with the values of renal plasma flow and % of plasma in blood by using a formula given below:

Renal blood flow = *Renal plasma flow / % of plasma in blood*

For example,

Renal plasma flow = 660 mL/min

Amount of plasma in blood = 55%

Renal blood flow = 660/ 55/100

660 × 100 / 55 = 1,200 mL/min

MICTURITION

FUNCTIONAL ANATOMY OF URINARY BLADDER

Urinary bladder consists of the body, neck and internal urethral sphincter. The smooth muscle forming the body of bladder is called ***detrusor muscle***. At the posterior surface of the bladder wall, there is a *triangular area called* ***trigone***. At the upper angles of this trigone, ***two ureters*** *enter the bladder*. The lower part of the bladder is narrow and forms ***the neck***. *The distal end of the bladder is guarded by* ***internal urethral sphincter***. This sphincter is made up of detrusor muscle. It opens towards urethra. ***At the distal end of urethra, there is external urethral sphincter.*** It is *made up of* ***skeleta****l muscle fibers.* Therefore, it is responsible for **voluntary control of micturition**.

NERVE SUPPLY TO URINARY BLADDER AND SPHINCTERS

Urinary bladder and the internal sphincter are supplied by ***sympathetic*** and ***parasympathetic divisions*** of autonomic nervous system whereas, the external sphincter is supplied by the somatic nerve fibers.

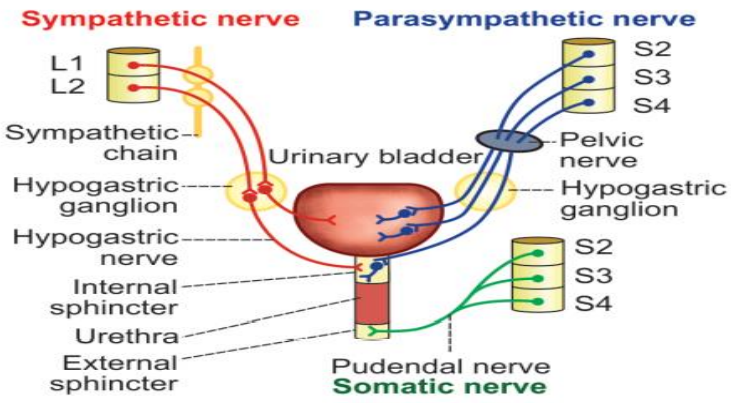


FIGURE 46.1: Nerve supply to urinary bladder and urethra

References:

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