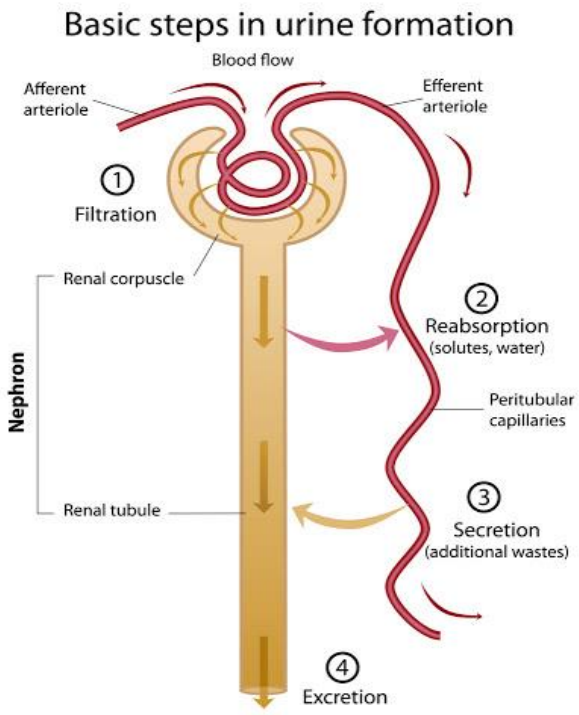
UNIT- 3 PHYSIOLOGY OF URINE FORMATION

Urine formation is a blood cleansing function. Normally, about 1,300 mL of blood (26% of cardiac output) enters the kidneys. Kidneys excrete the unwanted substances along with water from the blood as urine. **Normal urinary output is 1 L/day to 1.5 L/day.**

When blood passes through glomerular capillaries, the plasma is filtered into the Bowman capsule. This process is called **glomerular filtration**.

Filtrate from Bowman capsule passes through the tubular portion of the nephron. While passing through the tubule, the filtrate undergoes various changes both in quality and in quantity. Many wanted substances like glucose, amino acids, water and electrolytes are reabsorbed from the tubules. This process is called **tubular reabsorption.**

Some unwanted substances are secreted into the tubule from peritubular blood vessels. This process is called **tubular secretion or excretion.**



Glomerular filtration

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

Glomerular filtration is called **ultrafiltration** because even the minute particles are filtered. But, the plasma proteins are not filtered due to their large molecular size. The protein molecules are larger than the slit pores present in the endothelium of capillaries. Thus, the glomerular filtrate contains all the substances present in plasma except the plasma proteins.

Glomerular filtrate is collected in experimental animals by micropuncture technique. This technique involves insertion of a **micropipette** into the Bowman capsule and aspiration of filtrate.

Glomerular filtration rate

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.

Normal GFR is **125 mL/minute or about 180 L/day**.

Filtration fraction

Filtration fraction is the fraction (portion) of the renal plasma, which becomes the filtrate. It is the ratio and is expressed in percentage.

Filtration fraction = $\frac{GFR}{Renal\ plasma\ flow}$ X 100 $\frac{125mL/min}{650mL/min}$ X 100 = 19.2%

Normal filtration fraction varies from **15% to 20%.**

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

Factors regulating GFR

- **Renal Blood Flow**

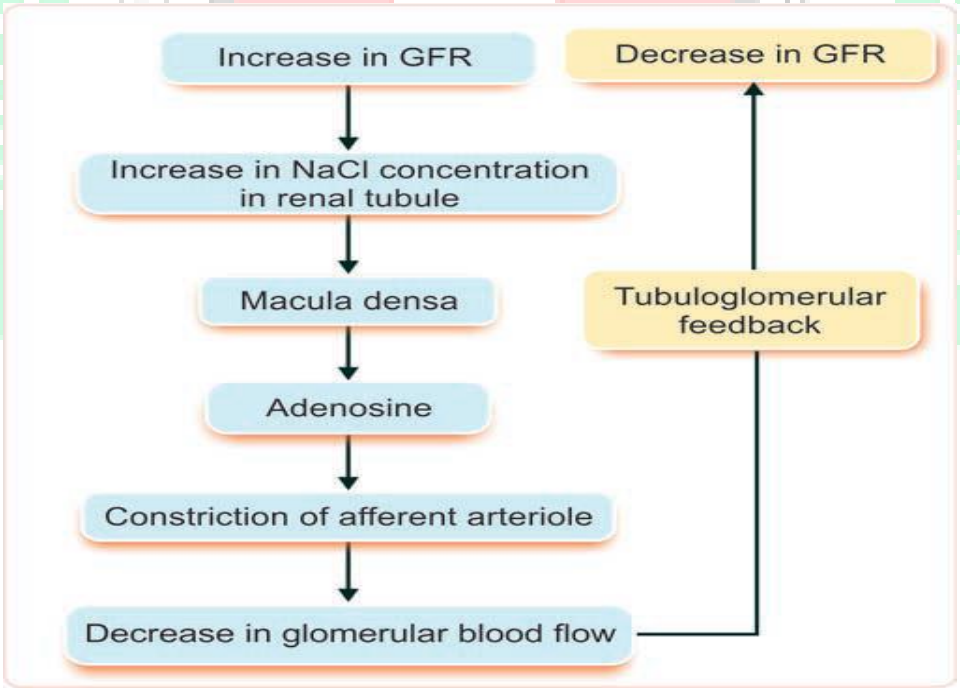
It is the most important factor that is necessary for glomerular filtration. GFR is directly proportional to renal blood flow. The renal blood flow itself is controlled by **autoregulation.**

- **Tubuloglomerular Feedback**

Tubuloglomerular feedback is the mechanism that regulates GFR through renal tubule and macula densa.

- **Glomerular Capillary Pressure**

Glomerular filtration rate is directly proportional to glomerular capillary pressure. Normal glomerular capillary pressure is 60 mm Hg.



- **Colloidal Osmotic Pressure**

Glomerular filtration rate is inversely proportional to colloidal osmotic pressure, which is exerted by plasma proteins in the glomerular capillary blood. Normal colloidal osmotic pressure is 25 mm Hg.

- **Hydrostatic Pressure in Bowman Capsule**

GFR is inversely proportional to this. Normally, it is 15mm Hg.

- **Constriction of Afferent Arteriole**

Constriction of afferent arteriole reduces the blood flow to the glomerular capillaries, which in turn reduces GFR.

- **Constriction of Efferent Arteriole**

If efferent arteriole is constricted, initially the GFR increases because of stagnation of blood in the capillaries. the efferent arteriolar constriction prevents outflow of blood from glomerulus and no fresh blood enters the glomerulus for filtration.

- **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.

- **Permeability of Capillary Membrane**

GFR is directly proportional to the permeability of glomerular capillary membrane.

- **Contraction of Glomerular Mesangial Cells**

Contraction of these cells decreases surface area of capillaries resulting in reduction in GFR.

❖ **Hormonal and Other Factors**

Factors increasing GFR by vasodilatation

i. Atrial natriuretic peptide

ii. Brain natriuretic peptide

iii. cAMP

iv. Dopamine

v. Endothelial derived nitric oxide

vi. Prostaglandin (PGE2).

Factors decreasing GFR by vasoconstriction

i. Angiotensin II

ii. Endothelins

iii. Noradrenaline

iv. Platelet activating factor

v. Platelet derived growth factor

vi. Prostaglandin (PGF2).

TUBULAR REABSORPTION

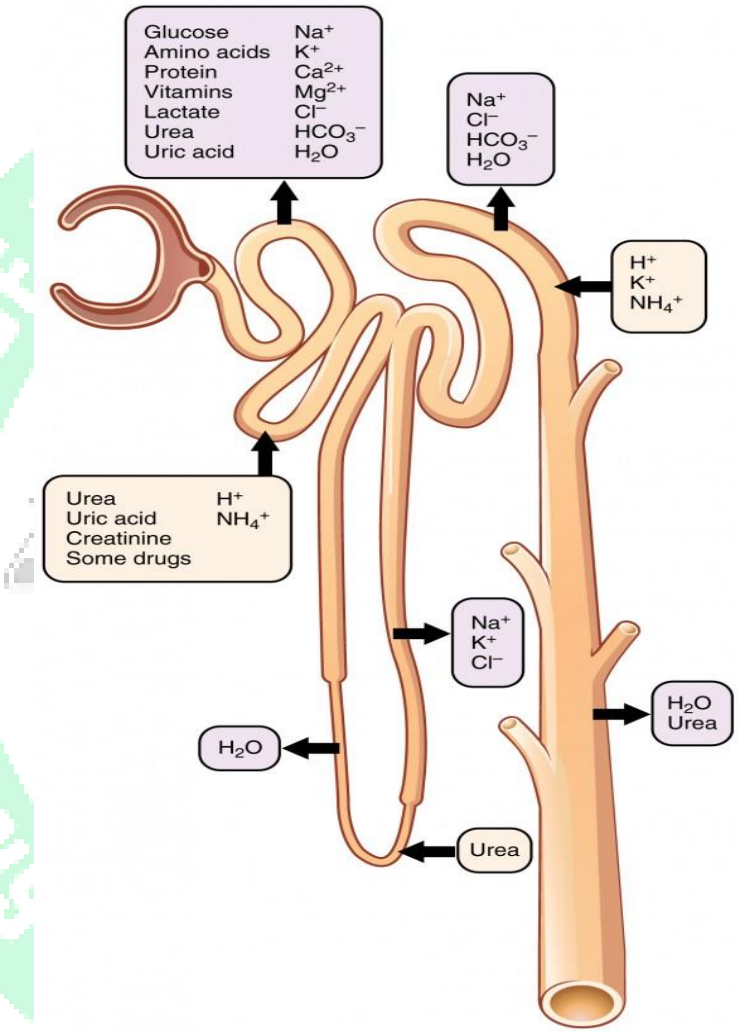
Tubular reabsorption is known as selective reabsorption because the tubular cells reabsorb only the substances necessary for the body. Essential substances such as glucose, amino acids and vitamins are completely reabsorbed from renal tubule. Whereas the unwanted substances like metabolic waste products are not reabsorbed and excreted through urine.

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

*Active reabsorption *Passive reabsorption.

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

Substances reabsorbed passively are chloride, urea and water.



Routes of reabsorption

Reabsorption of substances from tubular lumen into the peritubular capillary occurs by two routes:

1. Trancelluar route 2. Paracellular route.

Site of reabsorption

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 proximal convoluted tubule. Substances reabsorbed from proximal convoluted tubule are glucose, amino acids, sodium, potassium, Calcium, bicarbonates, chlorides, phosphates, urea, 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

Sodium, calcium, bicarbonate and water are reabsorbed from distal convoluted tubule.

Tubular reabsorption is regulated by

- Glomerulotubular balance
- Hormonal factors
- Nervous factors

When GFR increases, the tubular load of solutes and water in the proximal convoluted tubule is increased. It is followed by increase in the reabsorption of solutes and water.

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 cells.

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

TUBULAR SECRETION

It 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.

Substances secreted in different segments of renal tubules

- Potassium is secreted actively by sodium potassium pump in proximal and distal convoluted tubules and collecting ducts
- Ammonia is secreted in the proximal convoluted tubule
- Hydrogen ions are secreted in the proximal and distal convoluted tubules. Maximum hydrogen ion secretion occurs in proximal tubule
- Urea is secreted in loop of Henle.

Thus, urine is formed in nephron by the processes of glomerular filtration, selective reabsorption and tubular secretion.

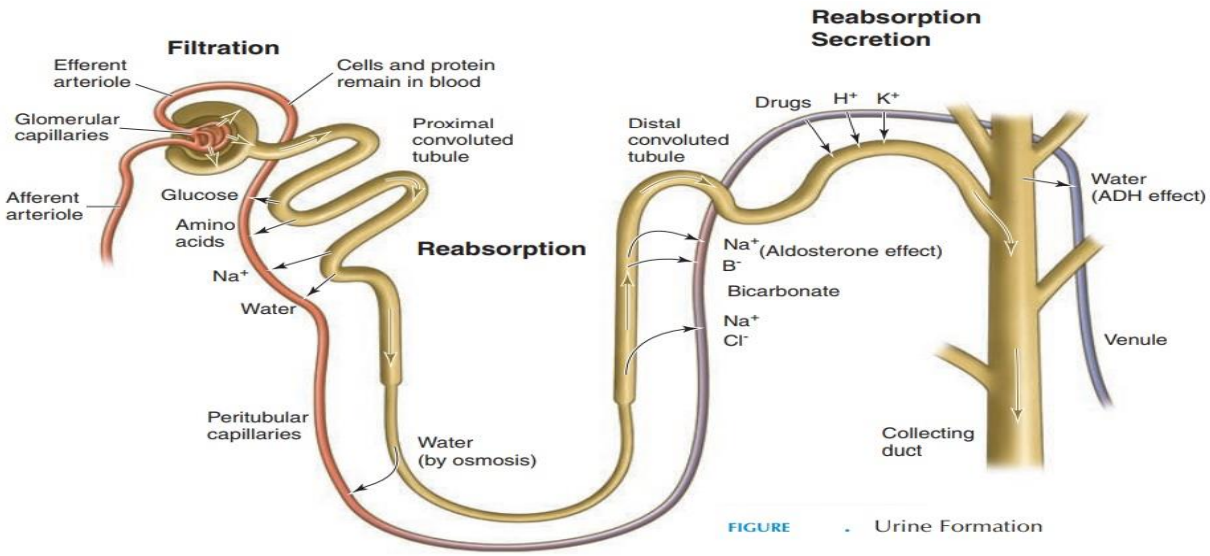


FIGURE . Urine Formation