Urine Formation

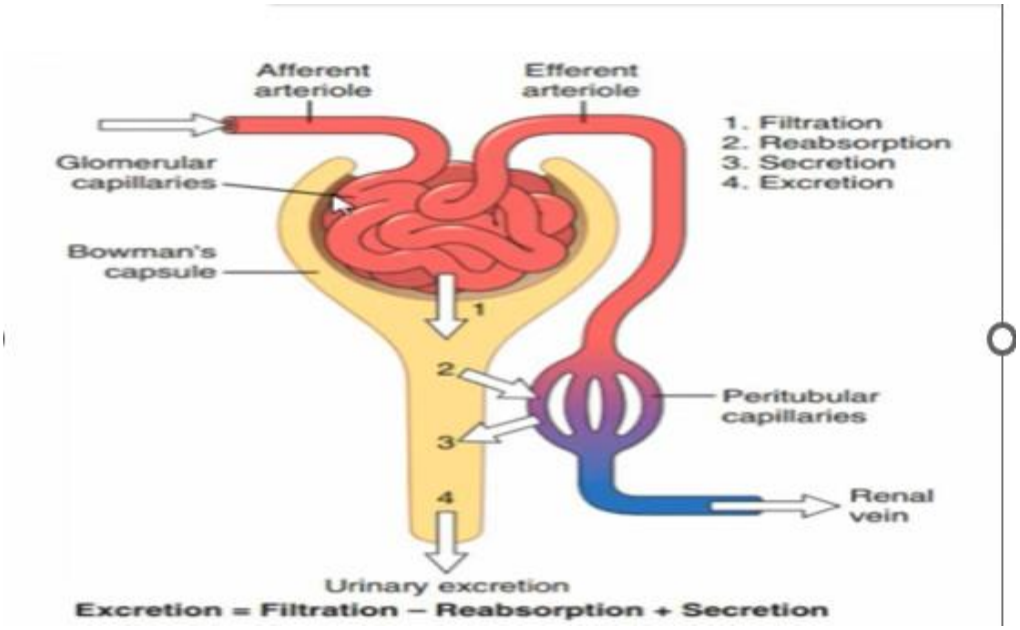
Urine formation is a blood cleansing function. Normally, about 26% of cardiac output enters the kidneys to get rid of unwanted substances. Kidneys excrete the unwanted substances in urine. Normally, about 1 to 1.5 L of urine is formed every day. The mechanism of urine formation includes three processes:

I. Glomerular filtration

II. Tubular reabsorption

III. 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.



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. The 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. 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 plasma proteins. The filtered fluid is called glomerular filtrate. Ultrafiltration The 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 of plasma except the plasma proteins.

GLOMERULAR FILTRATION RATE (GFR) Glomerular filtration rate (GFR) is defined as the total quantity of filtrate formed in all 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.

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 It is exerted by plasma proteins in the glomeruli. 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.

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. Refer previous chapter for details.

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

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, both quantitative and qualitative changes occur. 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, from here, the substances move into the blood in peritubular capillaries. Since 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 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 excreted through urine.

TUBULAR SECRETION

Tubular secretion is the process by which the substances are transported from blood into renal tubules. It is also called tubular excretion.

Micturition

Micturition is a process by which urine is voided from the urinary bladder. It is a reflex process. However, in grown up children and adults, it can be controlled voluntarily to some extent. The functional anatomy and nerve supply of urinary bladder are essential for the process 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

SYMPATHETIC NERVE SUPPLY

Function of Sympathetic

Nerve The stimulation of sympathetic nerve causes relaxation of detrusor muscle and constriction of the internal sphincter. It results in filling of urinary bladder and so, the sympathetic nerve is called nerve of filling.

PARASYMPATHETIC NERVE SUPPLY

Function of Parasympathetic

Nerve The stimulation of pelvic (parasympathetic) nerve causes contraction of detrusor muscle and relaxation of the internal sphincter leading to emptying of urinary bladder. So, the parasympathetic nerve is called the nerve of emptying or nerve of micturition. The pelvic nerve has also the sensory fibers which carry impulses from stretch receptors present on the wall of the urinary bladder and urethra to the central nervous system.

SOMATIC NERVE SUPPLY

The external sphincter is innervated by the somatic nerve called the pudendal nerve. It arises from second, third and fourth sacral segments of the spinal cord.

Table: Functions of nerves supplying urinary bladder and sphincters

Nerve	On detrusor Muscle	On internal sphincter	On external sphincter	Function
Sympathetic nerve	Relaxation	Constriction	Not supplied	Filling of urinary bladder
Parasympathetic nerve	Contraction	Relaxation	Not supplied	Emptying of urinary bladder
Somatic nerve	Not supplied	Not supplied	Constriction	Voluntary control of micturition