Ministry of health Republic of Belarus
Establishment of education "Gomel state medical university"

Department of histology, cytology and embryology

MANUAL
for 1-st year students of faculty of foreign students on gynecology

Topic: 11:
HISTOPHYSIOLOGY OF THE URINARY SYSTEM

Duration 4 hours

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THE MOTIVATIONAL CHARACTERISTIC OF THE THEME

Urinary system very important for organism, participation in regulation of a water salt exchange (maintenance of a homeostasis) and endocrine functions (in kidneys hormones erythropoietin and rennin are produced. In cases of their diseases the homeostasis is broken, thus there can be an accumulation of water in tissues (hypostases), a self-poisoning with its products of a nitrogenous exchange (uremia), etc.

With the purpose of correct diagnostics and successful treatment of diseases of organs of urinary system in a nephrological and urological practice widely use methods of the laboratory analysis, clinical tests and others.

THE PURPOSE

To study a microscopic and ultramicroscopic structure and histophysiologies of kidneys

PROBLEMS

The student should know:

1. The Structure of kidneys and their structurally functional unit – nephron.
2. Features of blood supply of kidneys.
3. Features of a structure of urethra.

The student should be able:

1. To define under a microscope in structure of kidneys, collective tubes and blood vessels
2. To define the elements of urinary system
3. To define structural features of the basic parts of nephron.

REQUIREMENTS TO THE INITIAL LEVEL OF KNOWLEDGE

It is necessary for students to repeat a structure of a kidney and blood supply of a kidney from anatomy.

CONTROL QUESTIONS FROM RELATED SUBJECTS

1. Anatomy and topography of kidneys, urethra and a bladder.
2. Blood supply and enervation of kidneys.

CONTROL QUESTIONS ON THE THEME

1. Sources and the basic stages developments of kidneys.
2. A kidney. A structure and function
3. Concept about nephron, morph-physiological and its classification.
4. A filtrational barrier in nephron.
5. Collective tubules, a structure and function.

THE PRACTICAL PART

1. The Scheme of developments of kidneys – to enter designations (Exercise № 1 in album)
2. The Scheme of blood supply and a structure of nephron – to enter designations (Exercise № 2 in album)

3. The Scheme of a filtrational barrier – to enter designations(Exercise № 4 in album)

4. Microscopy histological preparations and their sketch in album (Exercise № 3, 6 and 7 in album)

5. Studying diagrams

SLIDES

1. Kidney.
2. Urethra.
3. Urinary bladder.

QUESTIONS FOR SELF-CHECKING KNOWLEDGE

1. Sources and basic stages of embryonic development of kidney.
2. Basic scheme of structure and tissues of kidney.
3. The nephron: morph-physiological characteristic of its parts.
4. Structure and functions of renal corpuscle.
5. Structure of the internal layer of Bowman's capsule. Podocytes.
6. Glomerular filtration barrier.
7. Structure and functions of proximal part of the nephron.
8. Thin tubule of Henle's loop.
9. Structure and functions of distal part of the nephron.
10. Collecting ducts.
11. Juxtaglomerular apparatus. Structure, functions, characteristic of cells.
12. Prostaglandin apparatus.
13. Features of kidney's blood supply.
14. Types of the nephrons.

HISTOPHYSIOLOGY OF THE URINARY SYSTEM

The urinary system consists of the two kidneys, the two ureters, the urinary bladder, and the urethra.

The urinary system is responsible for the production, storage, and passing of urine,

Kidney functions.

1. Production, storage, and passing of urine,
2. Excretion
3. Electrolyte and water balance
4. Acid-base balance
5. Blood pressure regulation
6. Regulation of red blood cell formation
6. Addition of hydroxyl groups to vitamin D [1].

The kidneys are large, bean-shaped organs. The kidney is contained within a thin, collagenous **renal capsule** and *is* surrounded by a mass of perirenal adipose tissue.

Kidney tissue consists of the *cortex*, and the *medulla*. In humans, the renal medulla is composed of 10 – 18 conical or pyramidal structures, the **medullary pyramids.**

The nephron is the basic functional unit of the kidney. Each kidney is composed of 1-4 million nephrons. Each nephron consists of a tuft of capillaries, called the *glomerulus*, and a t*ubule* [1 – 3].

1. A dilated portion, the renal corpuscle (*Malpighian)*;
2. The proximal thick segment (proximal convoluted tubule and *pars recta)*
3. The thin limbs of the *loop of Henle*;
4. The distal thick segment (*pars recta,* a *macula densa* and distal convoluted tubule).
5. Collecting tubules

Collecting tubules + *nephron* = uriniferous tubule

Each uriniferous tubule begins with a double-layered cup, called *Bowman's capsule.* Within the cup is the glomerulus. Together, the glomerulus and Bowman's capsule constitute the *renal, or Malpighian, corpuscle.* Continuing from Bowman's capsule, the remaining segments of the uriniferous tubule are: the proximal thick segment*;* the thin segment; and the distal thick segment [3]**.**

The descending limb (pars recta) of the proximal thick segment, the thin segment and its hairpin turn, and the ascending limb (pars recta) of the distal thick segment are collectively called the *loop of Henle.*

Two types of nephrons are identified, based in part, on where the glomerulus is located. A nephron whose glomerulus is adjacent to the base of the pyramid is called *juxta-medullary;* other nephrons are called *cortical.* Juxta-medullary nephrons have long loops of Henle and long thin segments that extend well into the inner region of the pyramid. Cortical nephrons have short loops of Henle, extending only into the outer region of the pyramid. They are typical of the nephrons where in the hairpin turn occurs in the distal thick segment.

The nephrons empty into collecting tubules. These travel first in the medullary rays and then in the pyramid to its apex where a number of large collecting ducts, called *ducts of Bellini,* open into the calyx [2].

Renal corpuscle consists of a glomerulus and Bowman's capsule – double-layer cup. The internal layer of the capsule envelops the capillaries of the glomerulus and is called the **visceral layer,** whereas the external layer forms the outer limit of the renal corpuscle and is called the **parietal layer.** Urinary space is between the 2 layers**,** which receives the fluid filtered through the capillary wall and the visceral layer. Each renal corpuscle has a **vascular pole,** where the **afferent arteriole** enters, subdivides into capillaries, forming the renal glomerulus and the **efferent arteriole** leaves and a **urinary pole,** where the proximal convoluted tubule begins.

The renal corpuscle is a filtration apparatus of the kidney. The filtration is the first step in the process of urine formation.

The glomerular capillaries contain numerous large fenestrations. The diaphragm that spans the fenestrations in other capillaries is absent in glomerular capillaries. The visceral layer consists of modified epithelial cells designated as **podocytes**. They have a cell body and numerous processes, which, in turn, contain secondary processes, called foot processes or pedicels. The elongated spaces between them are called filtration slits. The filtration slit membrane spans the slits [4, 5].

The glomerular capillary endothelium and the podocytes constitute two of the three components of the filtration apparatus. The third component (really) is the glomerular basement membrane that occupies the space between the endothelium and podocytes. This basal lamina is derived from the fusion of capillary- and podocyte-produced basal laminae. As compared to typical membranes the glomerular basement membrane is very thick (about 300 nm). It is made up of three layers. *Under normal conditions, the filtration barrier prevents cells and large molecules, such as proteins, from entering Bowman's space.*

Filtration barrier includes:

(a) the capillary endothelium,

(b) podocytes

(c) *glomerular basement membrane* [1, 6].

Glomerular capillaries are supported by the *mesangium* which is made up of mesangial cells. These cells may act as macrophages and serve to clean the basal lamina of particulate material that accumulates during the filtration process. The mesangium becomes prominent in a disease called glomerulonephritis.

The parietal layer of Bowman's capsule consists of a simple squarnous epithelium. It is continuous with the cuboidal or columnar epithelium of the proximal convoluted tubule.

Proximal Convoluted Tubule

The cells of this epithelium have an acidophilic cytoplasm. The cell apex possesses abundant microvilli which form a **brush border.** The basal portions have abundant membrane invaginations. Mitochondria are concentrated here.

Proximal convoluted tubules are surrounded by peritubular capillaries.

The processes of reabsorption and excretion begin here. The proximal convoluted tubule reabsorbs all of the glucose and amino acids and about 85% of the sodium chloride and water contained in the filtrate.

In addition to these activities, the proximal convoluted tubule secretes creatinine and substances foreign to the organism such as para-aminohippuric acid, phenol red, and iodopyracct (an iodinated organic compound used as an x-ray contrast medium) from the interstitial plasma into the filtrate. This is an active process referred to as tubular secretion. Study of the rates of secretion of these substances is useful in the clinical evaluation of kidney function [1, 3].

Loop of Henle

The loop of Henle is a U-shaped structure consisting of

(1) a **thick descending limb,** very similar in structure to the proximal convoluted tubule;

(2) a **thin descending limb; (3) a thin ascending limb;**

(4) a thick ascending limb, which closeJy resembles the distal convoluted tubule in structure. In the outer medulla, the thick descending limb, with an outer diameter of about 60 ^m, suddenly narrows to about 12 mkm and continues as the thin descending limb. The lumen of this segment of the nephron is wide because the wall consists of squamous epithelial cells whose nuclei protrude only slightly into the lumen (Figs 20- 15 and 20- 16). A brush border is absent, but short, irregularly spaced microvilli are present. There is some variation in cell structure along the length of the thin limb. Until recently, the thin ascending limb was believed to actively transport Na^f from the lumen into the renal interstitium. However, these cells do not have the ultras true tural characteristics of ion-transporting cells. The thin limbs resemble blood capillaries, with which they may be confused; differences in content, appearance of nuclei, and thickness of the wall are the main criteria used for differentiation [1 – 3].

Approximately one-seventh of all nephrons are located near the corticomedullary junction and are therefore called **juxtamedullary nephrons.** The other nephrons are called

cortical nephrons. All nephrons participate in the processes of filtration, reabsorption, and secretion. However, juxtamedullary nephrons are of prime importance in establishing the gradient of hypcrtonicity in the medullary interstitium. which is the basis of the kidney's ability to produce a hypertonic urine. Juxtamedullary nephrons have very long loops of Henle, extending deep into the medulla. These loops consist of a short thick descending limb, long thin descending and ascending limbs, and a thick ascending limb (Fig 20- 13). Cortical nephrons have very short descending thin limbs and no thin ascending limbs (Fig 20-2). The thin limbs of juxtamedullary nephrons are responsible for producing the hypertonic environment of the medullary interstitium [1 – 3].

Distal Convoluted Tubule is the last segment of the nephron. This tubule is lined by simple cuboidal epithelium. Proximal and distal convoluted tubules both round in the cortex. But the lumens of the distal tubules are larger, and because cells are flatter and smaller than those of the proximal tubule, more cells and more nuclei are seen in the distal tubule wall. Distal tubule cells are less acidophilic than proximal, and they do not have the prominent brush borders. The apical canaliculi are absent.

The basal infoldings of plasma membrane and associated mitochondria are very prominent and reach almost to the luminal surface of the cell. (basal striations) This feature is characteristic of cells involved in the active transport of ions.

In the distal convoluted tubule, if aldosterone is present in high enough concentration, sodium is reabsorbed and potassium ions are secreted. It is the site of the mechanism controlling the total salt and water in the body. The distal tubule also secretes hydrogen and ammonium ions into tubular urine. This activity is essential for maintenance of the acid-base balance in the blood [3 – 6].

The distal convoluted tubule establishes contact with the vascular pole of the renal corpuscle of its parent nephron. At this point of close contact, called juxtaglomerular region, cells of the distal convoluted tubule usually become columnar, and their nuclei are closely packed together. This segment, which appears darker in microscopic preparations, is called the **macula densa.** The functional significance of the macula densa may be to transfer to the afferent arteriole data on the osmolarity of the fluid in the distal tubule.

The terminal part of the distal convoluted tubule is again straight. This part is called the junctionaj tubule or connecting tubule, and ends by joining a collecting duct.

Mesangial cells contain filaments similar to myosin. They bear angiotensin II receptors. It is believed that stimulation by angiotensin causes the fibrils to contract. In this way mesangial cells may play a role in controlling blood flow through the glomerulus [3].

Collecting Tubules & Ducts

Urine passes from the distal convoluted tubules to collecting tubules, which join each other, forming larger, straight collecting ducts, the **papillary ducts of Bellini.**

The smaller collecting tubules are lined with cuboidal epithelium. As they penetrate deeper into the medulla, their cells become taller until they are columnar cells. The diameter of the collecting duct reaches 200 //.m near the tips of the pyramids.

The walls of collecting tubules are lined by two types of cells. The majority of cells (called *clear cells)* have very few organelles, a few microvilli and some basal infoldings. The lining epithelium also contains some *dark cells* (or *intercalated cells).* These bear microvilli, but no basal infoldings are seen. They contain numerous mitochondria [1 – 5].

In the medulla, collecting ducts are a major component of the urine-concentrating mechanism.

The epithelium of collecting ducts is responsive to antidiuretic hormone. If water intake is limited, ADH is secreted, and the epithelium of the collecting ducts becomes permeable to water [2, 6].

Blood Circulation

Two sets of arterioles and capillaries intervene between the renal artery and vein. The first capillary system, present in glomeruli, is concerned exclusively with the removal of waste products from blood. It does not supply oxygen to renal tissues. Exchanges of gases (oxygen, carbon dioxide) between blood and renal tissue is entirely through the second capillary system (present around tubules).

The interlobular arteries give off branches, the *afferent arterioles.* Afferent arterioles give rise to the glomerular tuft of capillaries. The glomerular capillaries reunite to form an *efferent arteriole* that, in turn, gives rise to a second network of capillaries, the *peritubular capillaries,* that will nourish the proximal and distal tubules and carry away reabsorbed ions and low-molecular-weight materials. The arrangement of these capillaries differs according to whether they spring from cortical or juxtamedullary glomeruli. Efferent arterioles from cortical glomeruli lead into a peritubular capillary network that surrounds the local uriniferous tubules. Efferent arterioles from juxtamedullary glomeruli descend into the medulla alongside the loop of Henle; they break up into smaller vessels that continue toward the apex of the pyramid but make hairpin turns at various levels to return, again as straight vessels, toward the base of the pyramid.

The vasa recta, or straight vessels, are situated so that blood circulation does not disturb the osmotic gradient created by the ion pump of the loop of Henle. But the blood can supply oxygen and nutrients to medullary cells and carry away water that passed out of collecting ducts under the influence of ADH [2 – 4].

Juxtaglomerular Apparatus

Adjacent to the renal corpuscle, the media of the afferent arteriole consists of modified smooth muscle cells. These cells, called **Juxtaglomerular (JG)** cells have ellipsoid nuclei and a cytoplasm full of granules. The macula densa of the distal convoluted tubule is usually located close to the region of the afferent arteriole. The macula densa, the juxtaglomerular cells, and the extraglomerular mesanigial cells constitute t*he juxtaglomerular apparatus.*

The granules of the juxtaglomerular cells contain *renin.* Renin is synthesized, stored, and released into the blood from the juxtaglomerular cells. In the blood, it serves to catalyze the cleavage of angiotensin I from angiotensinogen. A converting enzyme, in turn, transforms angiotensin I to the physiologically active form, angiotensin II. The latter is a potent vasoconstrictor that has a regulatory role in the control of renal and systemic vascular resistance [3 – 5].

The fall in NaCl concentration serves as a local tubular signal for stimulation of renin secretion. It would appear, that the cells of the macula densa sense changes in NaCl concentration and, in turn, mediate rerun secretion by the juxtaglomerular cells.

Renal Interstitium

Both the cortex and the medulla contain specialized cells in the spaces between uriniferous tubules and the blood and lymph vessels. **Some** of these **interstitial cells** resemble fibroblasts, and others are probably lymphocytes. In the medulla, some interstitial cells have numerous small lipid droplets in their cytoplasm. These cells may produce a hormone that lowers blood pressure [1].

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