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## 2.2. ANATOMY OF MALE GENITAL ORGANS

**Male genital organs** (Fig. 2.3) **(*organa genitalia masculina*) include testes with their tunics, deferent ducts with seminal vesicles, the prostate, bulbourethral glands, the penis and the male urethra, which represents a mixed-type genitourinary tube.**

**Testes** are two oval bodies, slightly squished from their sides and located in the scrotum. The length of the testis is on average 4 cm, its width is 3 cm, and the weight is from 15 to 25 g. The left testicle is usually slightly lower than the right one. The *spermatic cord* (*funiculus spermaticus*) and the *epididymis* are located close to the posterior edge of the testis; the epididymis is located along the posterior edge. *Epididymis* is a narrow long unit, which has a superior, slightly thickened part — the head (*caput epididymidis*), and the inferior, more pointed end — the tail (*cauda epididymidis*); the intermediate part is represented by the body (*corpus epididymidis*).

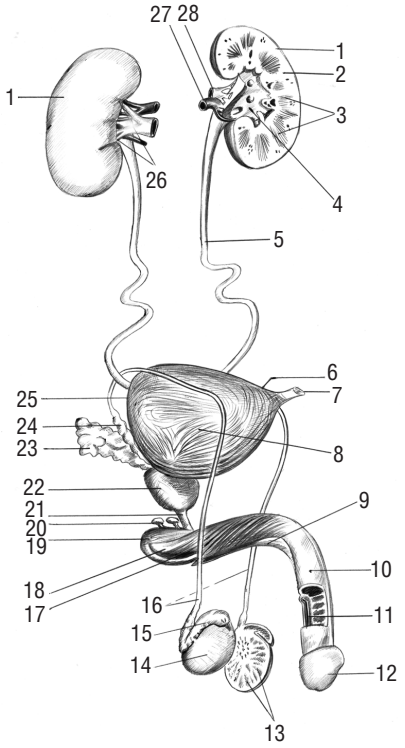


**Fig. 2.3.** Male genitourinary organs: 1 — kidney; 2 — renal cortex; 3 — renal pyramids; 4 — renal pelvis; 5 — ureter; 6 — bladder apex; 7 — median umbilical fold; 8 — bladder body; 9 — penile shaft; 10 — dorsum of the penis; 11 — spongy part of the urethra; 12 — penile balanus; 13 — testicular lobules; 14 — testis; 15 — epididymis; 16 — deferent ducts; 17 — bulbocavernosus muscle; 18 — the root of the penis; 19 — bulbospongiosus muscle; 20 — bulbourethral gland; 21 — membranous part of the urethra; 22 — prostate; 23 — seminal vesicle; 24 — ampulla of the deferent duct; 25 — bladder fundus; 26 — renal hilum; 27 — renal artery; 28 — renal vein

The testis is surrounded by a thick fibrous whitish tunic (*tunica albuginea*) lying directly on its parenchyma. Along the posterior edge of the testes, the fibrous tissue of this tunic slightly penetrates the glandular tissue in the form of an incomplete vertical septum or thickening (*mediastinum testis*); it branches off beamlike fibrous septula (*septula testis*), which attach with their external ends to the internal surface (*tunicae albugineae*) and thus divide the entire testicular parenchyma into lobules (*lobuli testis*). The number of testicular lobules reaches 250–300. Apices of lobuli face the testicular septum (*mediastinum testis*), while their bases face the albugineous tunic *tunica albuginea*. The epididymis also has a *tunica albuginea*, but a thinner one.

**The testicular parenchyma** consists of seminiferous tubules. There are *convoluted* (*tubuli seminiferi contorti*) and *straight* (*tubuli seminiferi recti*) seminiferous tubules. Each lobule contains 2–3 or more tubules. Having a winding direction in the lobule itself (*tubuli seminiferi contorti*) and getting closer to the testicular septum (*mediastinum testis*), the convoluted tubules connected with each other, and directly at the *mediastinum* narrow into

short straight seminiferous tubules. Straight tubules open into the *rete testis* located within the *mediastinum*. 12–15 efferent ducts (*ductuli efferentes testis*) open from the rete testis, which are directed to the head of the epididymus. Upon exiting the testis, efferent ducts become convoluted and form several conical lobes of the epididymis (*lobulis coni epididymidis*). *Ductuli efferentes* open into a single epididymal duct (*ductus epididymidis*), which, forming multiple curves, continues into the deferent duct (*ductus deferens*). The deferent duct (*ductus deferens*), epididymal lobuli (*lobuli epididymidis*) and its initial part jointly form the head of the epididymis.

Spermatozoa (the main component of the sperm — *sperma*) are formed only in *tubuli seminiferi contorti*. *Tubuli recti* and tubules of the rete testis belong to deferent ducts. Only a small amount of the liquid sperm component is produced by testes, as it is mainly secreted by the accessory genital glands opening into the deferent ducts.

Arteries supplying the testis and the epididymis are *a. testicularis*, *a. ductus deferentis,* and partially *a. cremasterica*. The venous blood drains from the *testis* and *epididymis* into the pampiniform plexus (*plexus pampiniformis*) and then into the testicular vein (*v. testicularis*).

Lymphatic vessels from the testis run within the spermatic cord and, bypassing the inguinal nodes, end in the lumbar lymphatic nodes (*nody lymphatici lumbales*). This, as well as the high position of *a.* and *v. testiculares*, is related to testicular origin in the lumbar region. Testicular nerves form sympathetic plexuses *plexus testicularis* and *plexus deferentialis,* around the arteries with the same names.

**Deferent ducts** (*ductus deferens*) arise directly from the epididymal canal, differing from the latter one by larger wall thickness. Being separated from the testis by the vessels (*a.* and *v. testiculares*), the deferent duct ascends and enters the spermatic cord.

As a part of the spermatic cord, *ductus deferens* passes vertically upwards to the superficial inguinal ring. Passing in the inguinal canal obliquely superiorly and laterally, it leaves *vasa testiculares* (that are directed to the lumbar region) at the deep inguinal ring and runs inferiorly and backwardly along the lateral pelvic wall, while being covered with the peritoneum. When reaching the bladder, the duct curves to its fundus and reaches the prostate. In the inferior region, it significantly dilates as an ampulla of the deferent duct (*ampulla ductus deferentis*). The length of the *ductus deferens* is 40–45 cm, its average diameter is 2.5 mm, while the lumen width is only 0.2–0.5 mm. The wall of the *ductus deferens* consists of three layers: external fibrous, middle muscular, and internal mucous.

**Seminal vesicles** (*vesiculae seminales*) lie laterally to deferent ducts, between the bladder fundus and the rectum. Each extended seminal vesicle has a length up to 12 cm, and non-extended — 5 cm. The inferior pointed end of the seminal vesicle runs into a narrow excretory duct (*ductus excretorius*), which is connected at the acute angle with the ipsilateral *ductus deferens*, jointly forming the ejaculatory duct (*ductus ejaculatorius*). The latter one is a very thin canal about 2 cm long, which, beginning from the place of *ductus deferens* and *ductus excretorius* confluence, passes through the prostate and opens into the prostatic urethral part with a narrow opening at the base of the seminal colliculus.

Walls of the seminal vesicles consist of the same layers as *ductus deferens*. Seminal vesicles are excretory organs that produce the liquid part of the sperm.

*Vessels ans nerves*: *ductus deferens* is supplied by *a. ductus deferentis* (a branch of *a. iliaca interna*), seminal vesicles — by *aa. vesicalis inferior, ductus deferentis, rectales*. Venous drainage is arranged along *v. deferentialis*, which runs into *v. iliaca interna*. The lymph is drained into external, internal iliac and sacral lymphatic nodes. *Ductus deferens* and seminal vesicles are innervated by *plexus deferentialis* nerves formed from *plexus hypogastricus inferior*.

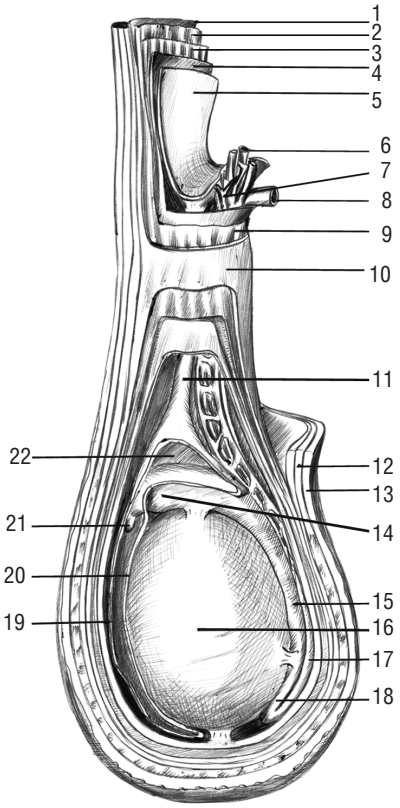


**Fig. 2.4.** Testicular and spermatic cord tunics: 1 — external oblique abdominal muscle; 2 — internal oblique abdominal muscle; 3 — transverse abdominal muscle; 4 — transverse fascia; 5 — abdomen; 6 — testicular artery; 7 — pampiniform (venous) plexus; 8 — deferent duct; 9 — internal spermatic fascia; 10 — external spermatic fascia; 11 — vaginal process of the peritoneum; 12 — tunica dartos; 13 — skin; 14 — head of the epididymis; 15 — corpus of the epididymis; 16 — testis; 17 — deferent duct; 18 — tail of the epididymis; 19 — vaginal tunic of the testis (parietal layer); 20 — vaginal tunic of the testis (visceral layer); 21 — epididymal appendage; 22 — serous cavity of the testis

**The spermatic cord** (*funiculus maticus*) is a round cord 16–20 cm long covered with the external seminal fascia and located between the internal inguinal ring and the upper pole of the testis. It includes a deferent duct, a testicular artery, an artery of the deferent duct, a pampiniform venous plexus, lymphatic vessels of the testis and epididymis, nerves, and the vaginal process of the peritoneum.

**Scrotum** is a separate bulging of the anterior abdominal wall. It consists of two separate chambers which house testes, epididymis and a part of the spermatic cord.

**Testicular and spermatic cord tunics**, counting from the outside, are as follows: skin (*cutis*); dartos (*tunica dartos*); external spermatic fascia (*fascia spermatica externa*); fascia of the cremaster muscle (*fascia cremasterica*); cremaster muscle (*m. cremaster*); internal spermatic fascia (*fascia spermatic interna*); vaginal tunic of the testis (*tunica vaginalis testis*) (Fig. 2.4). Such a large amount of testicular tunics corresponds to specific layers of the anterior abdominal wall. When moving from the abdominal cavity, the testis kind of lugs away from the peritoneum and fasciae of abdominal muscles and becomes enveloped by them. As a result, the following testicular tunics are formed in accordance with the structure of the anterior abdominal wall layers.

1. Scrotum skin is thin and darker if compared to other body parts. It has multiple large sebaceous glands, the secretion of which has a typical odor.

2. Tunica dartos is located immediately under the skin. It is a continuation of subcutaneous connective tissue from the inguinal region and the perineum, but it lacks fat. It contains a significant amount of smooth muscular

tissue. *Tunica dartos* forms a separate sac for each testis that are connected along the midlin in a manner so as to form a septum (*septum scroti*) attached at the *raphe* line.

3. An external spermatic fascia is an extension of the superficial abdominal fascia.

4. The fascia of the cremaster muscle is a continuation of *the fascia intercruralis* originating from the edges of the superficial inguinal ring; it covers *m. cremaster*, therefore, it is called *fascia cremasterica*.

5. The cremaster muscle consists of bands of striated muscular fibers that are a continuation of the transverse abdominal muscle (*m. transversus abdominis*). When *m. cremaster* is contracted, the testis is pulled upwards.

6. The internal spermatic fascia is located just under *m. cremaster*. It is a continuation of *fascia transversalis*, it encircles all parts of the spermatic cord and is adjacent to the external surface of the serous testicular tunic.

7. The vaginal tunic of the testis is formed from the vaginal process of the abdomen (*processus vaginalis*) and forms a closed serous sac consisting of two laminae — parietal (*lamina parietalis*) and visceral (*lamina visceralis*). A large amount of serous fluid may accumulate between them in pathological cases, with the formation of hydrocele (see the Section 14.3).

**Penis** forms external genitalia jointly with the scrotum. It consists of three bodies: *paired cavernous corpus* (*corpus cavernosum penis*) and *unpaired spongious corpus* (*corpus spongiosum penis*). The names of these bodies are associated with that they consist of multiple trabeculae, fibrous-elastic cords with an admixture of non-striated muscular fibers, among the thick plexus of which there are gaps — cavernas lined with endothelium and filled with blood (Fig. 2.5).

*Corpora cavernosa penis* represents two long cylindrical bodies with pointed ends from which the posterior ends diverge and form penile cruses (*crura penis*) that attach to inferior rami of the pubic bones. *Corpus spongiosum penis* covered with an albugineous tunic (*tunica albuginea corporis spongiosi*) is located under cavernous corpora of the penis and is pierced with urethra through the entire length. It has a lesser diameter (1 cm) than two other cavernous corpora, but, unlike them, it is thickened on both ends forming the *glans penis* anteriorly and the bulbus (*bulbus penis*) posteriorly.

The posterior part of the penis attached to the pubic bones is called the *root* (*radix penis*). Anteriorly the penis ends with a glans. The intermediate part between the glans and the root is called a *corpus* (*corpus penis*). The superior surface of the corpus is wider than the inferior one and is called *"dorsum"* (*dorsum penis*). *Corpus spongiosum penis* is adjacent to the inferior surface. A penile glans has a vertical fissure — *external urethral orifice* (*ostium urethra externum*); from the dorsal and lateral sides it slightly protrudes above the level of the cavernous bodies — this glans edge is called *"corona glandis"*, and the narrowing behind it — *"collum glandis"*.

At the base of the glans, the penile skin forms a free fold called "foreskin" (or *preputium*). On the inferior side of the penile glans, the foreskin is connected with the penile skin by the frenulum (*frenulum preputii*). Around *corona glandis* and on the internal layer of the skin, sebaceous glands with variable sizes (*glandulae preputiales*) are located. The secretion of these glands is a part of preputial sebum (*smegma preputii*), which is collected in the space between the glans and the preputium — a preputial cavity that opens anteriorly with an orifice that allows the glans out when the preputium is shifted posteriorly.

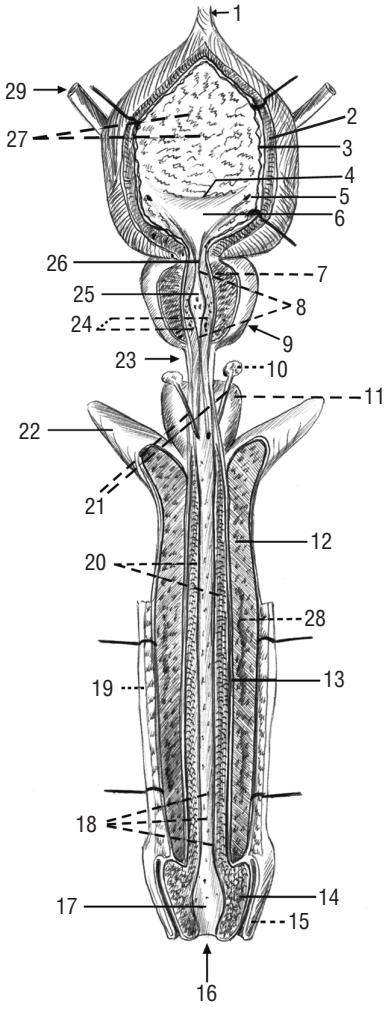


**Fig. 2.5.** The urinary bladder, male urethra, the prostate, cavernous and spongious corpora of the penis: 1 — median umbilical fold; 2 — muscular layer of the urinary bladder; 3 — submucous base; 4 — interureteral fold; 5 — ureteral orifice; 6 — the urinary bladder triangle; 7 — muscular substance of the prostate; 8 — prostatic part of the urethra; 9 — prostate; 10 — bulbourethral glands; 11 — bulbus of the penis; 12 — cavernous corpora of the penis; 13 — albugineous tunic of cavernous bodies; 14 — penile glans; 15 — preputium; 16 — external orifice of the male urethra; 17 — navicular fossa of the urethra; 18 — lacunae or cryptae of the urethra; 19 — skin; 20 — spongy body of the penis; 21 — excretory duct of the bulbourethral gland; 22 — penile crus; 23 — membranous part of the urethra; 24 — prostatic duct; 25 — seminal colliculus of the prostate; 26 — internal urethral orifice; 27 — mucous folds; 28 — deep penile artery; 29 — right ureter

The size of the penis depends on blood volume in the chambers of cavernous and spongy bodies. The blood is supplied to the penis through *aa. profundae et dorsalis penis*. Arterial branches, passing within the connective tissue septa, are divided into thin helicine arteries that open directly into the cavernous spaces. Veins draining blood from the cavernous bodies (*venae cavernosae*) drain into *vv. profundae penis* and *v. dorsalis penis*. Due to the special structure of penile blood vessels, the blood may be retained in the cavernous bodies, which leads to their thickening in erection.

Penile arteries are the branches of *a. femoralis* and *a. pudenda interna*. The venous drainage occurs along *vv. dorsales penis superficialis et profundae* into *v. femoralis* and into *plexus venosus vesicalis*. The lymph is drained into *Inn. lymphoidi inguinales* and the nodes of the lesser pelvic cavity.

Afferent innervation is provided by *n. pudendus*, efferent sympathetic innervation — by *plexus hypogastrics inferior*, parasympathetic innervation — by *nn. erigentes*.

**Male urethra** (*urethra masculina*) is a tube 16–22 cm long with the diameter of 0.5–0.7 cm, which extends from the urinary bladder to the external urethral orifice on the penile glans (see Fig. 2.5). The *urethra* serves not only for urine excretion but also for the passage of sperm, which enters the urethra through the *ductus ejaculatorius*. The urethra passes through different formations, so three parts are distinguished in it: *pars prostatica*, *pars membranacea* and *pars spongiosa*.

*The prostatic part* (*pars prostatica*), which is the closest to the urinary bladder, passes through the prostate (see Fig. 2.5). Its length is about 2.5 cm. The prostatic part, especially its middle region, is the widest and the most extensible area of the urethra.

A small median eminence called — *seminal colliculus* (*colliculus seminalis*) (Fig. 2, see the color insert) can be identified on the posterior wall.

Along the circumference of the prostatic urethral part, there is a ring of muscular fibers comprising smooth prostatic muscular tissue and acting as the third (involuntary) urethral sphincter.

*Membranous part* (*pars membranacea*) is an area of the urethra extending from the prostate apex to the *bulbus penis*; its length is about 1 cm. Therefore, this urethral part is the shortest and the narrowest of all three parts. It lies posteriorly and inferiorly to the arcuate pubic ligament (*lig. arcuatum pubis*), piercing the *diaphragma urogenitale* with its superior and inferior fasciae on the way; the lower end of the membranous part in the place of inferior fascia piercing is the narrowest and the least extensible part of the urethra, which should be taken into account when inserting the catheter so as not to damage the urethra. The membranous part of the urethra is surrounded by the muscular fibers of the voluntary sphincter (*m. sphincter urethrae*).

The *spongy part* (*pars spongiosa*), about 15 cm in length, is surrounded by the tissue of *corpus spongiosum penis*. The urethral part is slightly dilated relatively to the *bulbus penis*; the diameter of the remaining part of the urethra is even, while approximately 1 cm of the glans is dilated again, thus forming a navicular fossa of the urethra (*fossa navicularis urethrae*). The external orifice is a poorly extensible part of the urethra, which should be considered during catheterization.

Apart from the anatomical division of the urethra into three parts, it is also typically divided into two parts (according to the course of inflammatory processes) in the urological practice: *anterior urethra* (*pars spongiosa*) (Fig. 1, see the color insert) and *posterior urethra* — other two parts (Fig. 2, see the color insert). The border between them is the urethral sphincter, which prevents infection penetration from the anterior urethra to the posterior urethra.

Along the entire mucous membrane, except for the part closest to the external orifice, multiple glands open into the urethra (*glandulae urethrales*, old name — *glandulae littrei*, hence the inflammation of these glands is called littritis). Besides, small cavities — urethral lacunae (*lacunae urethrales*) are located predominantly on the superior wall of the urethra, especially anteriorly to the bulbus; their orifices face anteriorly and are covered with valvules. On the outside of the submucous base, a layer of non-striated muscular fibers is located (longitudinal on the inside and circular on the outside).

Urethral arteries originate from the branches of *a. pudenda interna*. Different urethral parts are supplied by different sources: *pars prostatica* — by branches of *a. rectalis media* and *a. vesicalis inferior*; *pars membranacea* — by *a. rectalis inferior* and *a. perinealis*; *pars spongiosa* — by *a. pudenda interna*. *A. dorsalis penis and a. profunda penis also participate in the vascularization of urethral walls.*

Venous blood is drained to penile and vesical veins. The lymph is drained from *pars prostatica* to prostatic lymphatic vessels, from *pars membranacea* and *pars spongiosa* — to inguinal lymphatic nodes. The innervation is provided from *nn. perinei* and *n. dorsalis penis* (from *n. pudendus*), as well as from the autonomous *plexus prostaticus*.

**Bulbourethral glands** (*glandulae bulbourethrales*) are two glandules, each having the diameter of 0.5–0.7 cm, which are located within the *diaphragma urogenitale* above the posterior end of *bulbus penis*, posteriorly to *pars membranacea urethrae*. The excretory duct of these glands opens into the spongy part of the urethra in the region

of the *bulbus*. The glands excrete viscous fluid, which protects the urethral walls against irritation from urine.

Arteries to the bulbourethral glands originate from the *a. pudendae internae*. Venous drainage proceeds to the veins of the *bulbus* and the *diaphragmae urogenitale*. Lymphatic vessels are directed to the *Inn. lymphoidi iliaci interni*. The glands are innervated by the *n. pudendus*, as well as from the autonomous plexus called *plexus prostaticus*.

The **prostate** (*prostata*) is an unpaired glandular-muscular organ, which has the shape of a truncated cone. It has an *apex, a base (basis), anterior* and *posterior surfaces (facies anterior et posterior)* (see Fig. 2.5). Its weight is about 25 g; vertical size is approximately 3 cm, horizontal size is 4 cm, sagittal size is about 2.5 cm. It eccentrically encloses the initial part of the urethra and is closely adjacent to the bladder fundus with its base, and the urogenital diaphragm with its apex. The posterior surface of the prostate borders the rectal wall, being separated from it only with a thin plate of the pelvic fascia (*septum rectovesicale*). The urethra passes through the prostate from its base to the apex, locating itself in the median plane, closer to its anterior surface.

*Seminal vesicles* are adjacent to the prostate posteriorly and superiorly, while *deferent ducts* lie medially to the vesicles. The excretory duct of the seminal vesicle merges with the dilated part of the deferent duct at an acute angle. Ejaculatory ducts (*ductus ejaculatorius*) formed as a result of this penetrate the posterior surface of the prostate, being directed in its surface inferiorly, medially and anteriorly, opening into the *pars prostatica urethrae* with two orifices on the seminal colliculus. The fissure-shaped orifice on the apex of the seminal colliculus leads to a small blind pouch located in the thickness of the prostate, which is called *"the prostatic utriculus"* (*utriculus prostaticus*). This name indicates the origin of this formation from confluent inferior ends of *ductus paramesonephricus*, from which the uterus and the vagina originate in females.

On the outside, the prostate is covered with a capsule rich in elastic fibers and containing strong bands of smooth muscles comprising a circular prostatic muscle. Superiorly, it merges with the circular muscular layer of the urinary bladder; inferiorly it joins the muscles forming the voluntary sphincter of the membranous urethral part.

The lobes are distinguished in the prostate macroscopically: two lateral lobes — *the right* and *the left*, separated from each other by a groove (detected on palpation), and a *middle* lobe (isthmus), which is located between the posterior urethral surface, the urinary bladder fundus and both ejaculatory ducts.

Microscopic (morphological) analysis of the prostate does not confirm its division into separate lobes. The prostate consists of 30–50 tubular-alveolar glands, between which the connective tissue rich in smooth muscular fibers is located. Prostatic glandules open into the prostatic part of the urethra around the seminal collicles with 20–30 excretory ducts. Periurethral glands are also located in the submucous layer of the prostatic part of the urethra; each of them opens into the urethral lumen.

The prostate is supplied by the *aa. vesicalis inferiores* and the *aa. rectalis mediae*. They penetrate it by multiple branches along the ejaculatory ducts, forming a rich capillary network. A large number of prostatic veins, anastomosing with one another, form a plexus around it, which is a part of the urogenital venous plexus that is connected to the rectal venous plexus.

Lymphatic vessels originate from the prostatic parenchyma and form a rich lymphatic network around it, especially on its inferior surface. From there, the lymph is drained into the prevesical lymphatic nodes, to lymphatic vessels running near the ureters and the deferent ducts along lateral pelvic walls towards the external and the internal iliac lymphatic nodes.

The prostate is innervated by sensitive and post-ganglionic sympathetic and parasympathetic nerve fibers from the inferior hypogastric plexus (*plexus hypogastricus inferior*).

The **seminal colliculus** (*colliculus seminalis*), or the seminal crest, is an elongated eminence located on the posterior wall of the prostatic part of the urethra. The eminence has a length of about 2 cm, the width of 3–4 mm, and the height of 3–4 mm. Its base is comprised by the longitudinal axial band of elastic fibers connected with longitudinal muscular fibers of the vesical triangle and the membranous part of the urethra.

A large number of nerve fibers and endings can be found between the elastic fibers. The surface of the seminal colliculus is covered by transient-type epithelium.

The central part of the seminal colliculus body is occupied by the prostatic or the male utriculus (*utriculus prostaticus*). It is a rudiment of fused terminal parts of the Mullerian ducts (its length is 5–10 mm, depth 3–5 mm, width 2–4 mm). An orifice with the diameter of 1–2 mm opens in its center on the seminal colliculus and leads to the male utriculus cavity, to the depth down to 3–5 mm. Orifices of ejaculatory ducts open at the sides of the entrance to the male utriculus and sometimes on the bottom of its cavity (one on the right and one on the left). Recesses, where ostia of the excretory prostatic ducts open, are found on both sides of the seminal colliculus.

## 2.3. PHYSIOLOGY OF KIDNEYS AND URINARY TRACT

The **kidney** is a parenchymatous and the most complex organ of the urinary system. Its structural and functional units are nephrons, which provide all basic organ functions during the process of urine formation. These include regulation of the water and electrolyte balance of the body; retention of vital substances, such as protein and glucose; maintenance of the acid-base balance; excretion of metabolism products, water-soluble toxins, drugs; regulation of osmotic and blood pressure, erythropoiesis; endocrine function.

***Regulation of the water and electrolyte balance of the body.*** Kidneys allow people to eat and drink according to their habits without changing the composition of liquid and electrolyte parameters of the body.

The blood supply to the kidneys is normally 20% of cardiac output. Approximately 99% of the blood supply is accounted for the cortical layer and 1% — for the medullary layer of the kidneys. The majority of nephrons are located in the cortical, external layer of the organ. The medullary, internal layer of the kidney contains specific nephrons in the juxtamedullary region located on the border of the medullary layer. These nephrons have high concentrating ability, the mechanism of which will be discussed later.

A kidney is a truly unique organ having *two capillary basins* that consist of two capillary types: *glomerular*, staying under high pressure and performing filtration, and

*paratubular*, with low pressure. All that enables to filtrate and reabsorb large volumes of fluid.

A **nephron** is a structural-functional unit of the kidney. Each kidney contains about a million nephrons. A nephron consists of the *glomerulus* and *tubules* (Fig. 2.6). Tubules are divided into the following parts: *a proximal tubule, a medullary (Henle) loop*, and *a distal tubule* draining into the collecting tubule. The urine is formed as a result of the three-phase process: 1) *simple filtration*; 2) *selective reabsorption*; 3) *passive reabsorption and excretion*.

***Filtration*** occurs through a semipermeable wall of glomerular capillaries, which is mainly impermeable for proteins and large molecules. Thus, the filtrate does not contain protein and cellular elements. The glomerular filtrate is formed by blood squishing through the glomerular capillaries. The driving force of the filtration is the hydrostatic pressure which is regulated by the afferent and the efferent arterioles, and provided by the blood pressure.

Every minute, about 20% of the kidney plasma flow (125 ml/min) is filtrated, which is equal to the glomerular filtration rate.

To preserve relatively constant values of the renal blood flow and the glomerular filtration rate, a rather constant hydrostatic pressure is maintained in the glomeruli. If the blood pressure changes, contraction or expansion of the afferent or the efferent arterioles (muscular-type vessels entering and exiting each glomerulus) occurs. This process is called *"autoregulation"*.

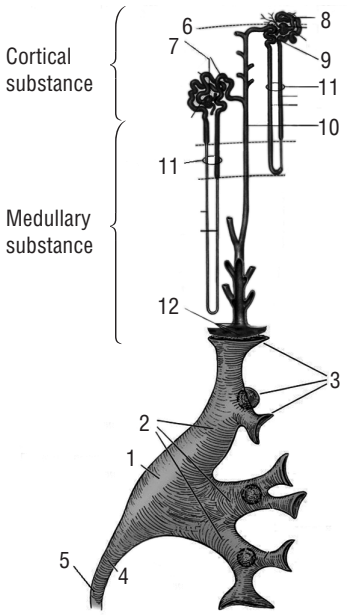


**Fig. 2.6.** Urine formation and excretion: 1 — renal pelvis; 2 — large calices; 3 — small calices; 4 — pyeloureteral segment; 5 — ureter; 6 — capsule; 7 — renal corpuscle; 8 — proximal convoluted tubule; 9 — distal convoluted tubule; 10 — collecting tubule; 11 — loop of the nephron; 12 — cribriform area of the renal papilla

The autoregulation of the glomerular filtration rate is achieved by the renal blood flow self-regulation and the feedback mechanism, which is known as the "Glomerular-tubular balance").

***Glomerotubular balance.*** When glomerular filtration rate decreases, the fluid flow in tubules decreases, and the time of sodium and chlorine ions reabsorption increases. The decreased amount of sodium and chlorine ions reaching the distal tubule leads to decreased resistance of the afferent arterioles and is accompanied by renal blood flow increase. With that, renin secretion from the juxtaglomerular apparatus increases, which stimulates the release of angiotensin II causing contraction of the efferent arterioles. Increased hydrostatic pressure in glomerular capillaries returns the glomerular filtration rate to its normal values.

*The juxtaglomerular complex* consists of dense macule (*macula densa*) cells — juxtaglomerular cells representing a specific epitheli-

um of the distal tubule, which is sensitive to the sodium ion concentration and is able to have an impact on the smooth muscle cells of the afferent and the efferent arterioles. *Macula densa* cells also secrete renin — an enzyme converting serum protein angiotensinogen into angiotensin I. Consequently, an angiotensin-converting enzyme, which is formed in small amounts in the lungs, proximal tubules and other tissues, converts angiotensin I into angiotensin II inducing vasoconstriction and increasing the blood pressure. Angiotensin II also stimulates the adrenal cortex, increasing aldosterone secretion, which, in its turn, causes water and sodium retention, thus increasing the circulating blood volume.

The described scheme of glomerulotubular balance maintenance represents a negative feedback system. In other words, the initial stimulus of the system is the decreased circulating blood volume that leads to a decrease in the renal perfusion pressure. When the circulating blood volume, kidney perfusion and the glomerular filtration rate restore, the system responds by the decreased or stopped responding to the initial stimulus.

***Selective or passive reabsorption.*** The function of renal tubules is the selective reabsorption of 99% of the glomerular filtrate. The proximal tubule absorbs 60% of all dissolved substances, including 100% of glucose and amino acids, 90% of bicarbonate, and 80–90% of inorganic phosphorus and water.

Reabsorption occurs through active and passive transport. The active transport requires energy to move substances against the electrochemical or the concentration gradient. This is the main determinant of oxygen consumption by kidneys. By means of passive transport, substances are reabsorbed along electrochemical and concentration gradients or along the pressure gradient.

Reabsorption mainly occurs through the active transport of substances and free movement of water according to the osmosis principle. When substances are actively reabsorbed, their concentrations decrease with consequent osmotic activity decrease in the lumen of the tubule. Then, due to the presence of the osmotic forces, water shifts from the tubule to the interstitium, where the concentration of osmotically active substances is higher.

The **Henle loop** is a part of the tubule descending or "bending" from the cortical layer to the medullary one (a descending limb) and then returning to the renal cortex (an ascending limb). If necessary, the urine concentrates specifically in this part of the tubule. This is possible due to the high concentration of substances in the medullary layer interstitium, which is maintained due to the presence of the counterflow-revolving system. The counterflow-revolving system maintains a high osmotic gradient in the medullary layer interstitium, which allows kidneys to concentrate the urine. The Henle loop is a counterflow-revolving multiplier, while *vasa recta* (a part of the pericapillary system, included into the medullary layer in the area of a high concentration of substances absorbed from the primary urine) is a counterflow-revolving exchanger, the mechanism of which is described below.

*Functions of different Henle loop parts.* The descending limb of the Henle loop is relatively impermeable for dissolved substances and well permeable for water transported from the tubule along the osmotic gradient: the fluid in the tubule becomes hyperosmolar.

The thin segment of the ascending limb of the Henle loop is almost impermeable for water, but at the same time permeable for dissolved substances, especially sodium and chlorine ions transferred along the concentration gradient from the tubular lumen, the fluid in which becomes isotonic and then hypotonic, as ions leave it. Urea absorbed into the medullary layer interstitium from the collecting tubule diffuses into the ascending limb. This maintains urea concentration in the medullary layer interstitium, playing an important role in the urine concentration process.

The thick segment of the ascending limb of the Henle loop and the initial part of the distal tubule is not permeable for water. However, active transport of sodium and chlorine ions occurs here from the tubule lumen, due to which the fluid of this tubule part becomes very hypotonic.

The distal tubule and the collecting tubule: final urine concentration depends on the amount of the antidiuretic hormone secreted by the posterior pituitary lobe. In the presence of the antidiuretic hormone, the distal tubule and the collecting tubule become permeable for water. When the collecting tubule passes through the medullary layer with a high interstitial concentration of substances, water leaves the tubule lumen, and concentrated urine is formed. In the absence of the antidiuretic hormone, the walls of the distal tubule become impermeable for water; thus, a large amount of diluted urine is formed.

A close link between the hypothalamus and the posterior pituitary exists. Osmoreceptor cells sensitive to changes of the osmotic blood pressure are present in the hypothalamus. In the case of excessive water consumption, osmotic blood pressure decreases, but in the case of water deficit, the reverse process occurs. When the osmotic blood pressure increases, nerve impulses from the hypothalamus stimulate the posterior pituitary and increase secretion of the antidiuretic hormone. As a result of antidiuretic hormone production, water loss through kidneys decreases, as it is reabsorbed in the collecting tubules.

***Vasa recta*** interact with the Henle loop through a complex mechanism aimed at urine concentration through counterflow-revolving metabolism. In the absence of *vasa recta*, the high concentration of substances in the medullary layer would be washed away with the blood flow. Substances diffuse from the vessels carrying blood directly to the cortical layer and into vessels descending into the medullary layer, while water acts oppositely: it moves from the descending vessels to the ascending vessels. Using a similar shunt, this system allows substances and water to recirculate within the medullary layer.

***Maintenance of the acid-base balance.*** Lungs and kidneys together maintain the pH of the blood and the extracellular fluid within the limits of 7.35–7.45 (34–46 nmol/l — $H^+$ concentration). Carbon dioxide ($CO_2$) dissolved in blood is an acid and is eliminated by the lungs. Kidneys remove the linked acid through three processes: tubular acid secretion, glomerular filtration of buffers bound linked with $H^+$, and ammonia formation.

1. Tubular acid secretion: sodium bicarbonate is filtered in the glomerulus, reabsorbing then in the proximal tubule. Sodium is reabsorbed by the $Na^+/H^+$-ion pump, exchanging $Na^+$ for $H^+$-ions on the membranes of the proximal tubule epithelium. The $Na^+/K^+$-pump transports sodium through the cell from the primary urine in exchange for potassium.

2. Glomerular filtration of buffers linked with $H^+$:

A. A primary part of filtrated bicarbonate is reabsorbed (90% in the proximal tubule). $H^+$ released during tubular acid secretion (see above) linking with bicarbonate ($HCO_3$), forms the carbonic acid:

$$H^+ + HCO_3 = H_2CO_3.$$

Carbonic anhydrase presenting in the proximal tubule cells catalyzes the reaction of carbonic acid cleavage into $CO_2$ and $H_2O$. $CO_2$ diffuses into the epithelial cell and forms carbonic acid in the presence of carbonic anhydrase. The latter one ionizes to $H^+$ and $HCO_3$. $H^+$ is further pumped out from the cell into the tubule lumen with the $Na^+/H^+$-pump, and sodium is returned to plasma with the $Na^+/K^+$-pump (see above); while the water is absorbed passively.

B. Other buffers, including the inorganic phosphate (HPO3), urates and creatinine ions, are excreted in the distal part of the nephron into urine as acids if they are linked with $H^+$.

3. Ammonia ($NH_3$) is formed enzymatically from glutamine and other amino acids and is secreted into nephron tubules. Ammonia in combination with $H^+$-ion secreted into urine forms a non-diffusing ammonia-ion ($NH_4^+$) excreted with urine.

***Excretion of metabolic products.*** Their filtration occurs during the blood flow passage along the glomerulus. Some substances unnecessary for the body and foreign substances, e.g., drugs, cannot be excreted from the body by means of filtration. Such substances are secreted into nephron tubules and excreted from the body with urine.

***Hormones and kidneys.*** Renin increases the production of angiotensin II released in case of intravascular volume decrease, e.g., in blood loss or dehydration. This leads to:

- constriction of the efferent arterioles for the maintenance of glomerular filtration rate by means of increased filtration pressure in the glomerulus;
- aldosterone release from the cortical layer of the adrenal glands;
- increased antidiuretic hormone secretion by the posterior pituitary lobe;
- positive inotropic action on the heart and arterial vasoconstriction.

*Aldosterone* increases reabsorption of sodium and water ions in the distal tubule and the collecting tubule, where $Na^+$ exchanges for $K^+$ and hydrogen ions with specific cellular pumps. Aldosterone secretion increases upon reduction of $Na^+$ concentration in the blood serum. This can happen, for example, when a large volume of gastric juice is lost since it contains a significant amount of sodium, chlorine, hydrogen and potassium ions. Consequently, it is impossible to correct the emerging alkalosis and hypokalemia without preliminary compensation for sodium ions with isotonic sodium chloride solution.

*Atrial natriuretic peptide* is secreted when atrial pressure increases, e.g., in heart failure or fluid overload. Atrial natriuretic peptide leads to increased losses of sodium, chlorides and water predominantly due to the increase of the glomerular filtration rate.

*Antidiuretic hormone* increases the permeability of the walls of the distal tubule and the collecting tubule for water, and, thus, concentrates urine. On the other hand, if antidiuretic hormone secretion is decreased, a significant amount of "diluted" urine is formed. A similar situation occurs predominantly when sodium concentration in the

blood plasma falls after consuming large water volumes. The sodium level decrease is controlled by osmoreceptors. In blood loss or dehydration, hormones interact with each other, which plays an important role in the maintenance of a normal intravascular volume.

Other substances synthesized by kidneys include 1,25-dihydroxy-vitamin D (the most active form of the vitamin D), ensuring calcium absorption from the intestine, and erythropoietin, stimulating red blood cells production. The production of these substances decreases in renal failure.

***Physiology of urination.*** Urine formed in kidney tubules is excreted into the renal calyx, and then, during its systole phase, it enters the renal pelvis. The pelvis is gradually filled with water, and, upon achieving the irritation threshold, impulses from baroreceptors emerge, renal pelvis muscles contract, the ureteral lumen opens, and urine moves into the urinary bladder due to contractions of the ureteral walls.

The function of the lower urinary tract consists of two phases — *urine accumulation* (reservoir function) and its *evacuation*. Along with that, a specific but uniform working mechanism of the bladder and the occlusive apparatus can be observed, i.e., alternation between bladder filling and voiding. Under physiological conditions, the bladder filling occurs subconsciously and very slowly (2–4 h in adults), while evacuation is performed as desired and ends in 20–30 s. In children under 1.5–2 years old, the urination is reflex-based. During growth, with the development of the conducting pathways between spinal centers and the brain, the urination becomes controlled.

Urine accumulation and evacuation processes are ensured by the specific anatomical formations and form a single functional system. Urine retention is ensured by the following formations: urinary bladder neck and proximal urethra, which is often considered as an internal sphincter (or a smooth-muscle bladder sphincter), external sphincter (or striated urethral sphincter), pelvic floor muscles. Urine accumulation is ensured by the urinary bladder muscles. The process of urine retention is functionally related to a complex of physiological mechanisms of both the occlusive apparatus and the urinary bladder, which is ensured by the reflex actions and exclusively mechanical components.

For easier understanding of normal function and dysfunction of the lower urinary tract, it is better to discuss the features of their neural regulation. Afferent innervation of the urinary bladder and the urethra is ensured by the *receptors* sensitive to pain, temperature, and pressure impacts. Sensitive receptors are present in all layers of the urinary bladder, but their maximum quantity is located in the Lieutaud triangle region. Dramatically specific urinary bladder receptors reacting to quick changes of its volume and endings perceiving slow internal pressure changes are distinguished. According to the degree of adaptation to filling, *phasic* and *tonic* urinary bladder receptors are distinguished, An important role in the act of urination belongs to the receptors in the urethral wall, especially in its proximal part, as well as the sensitive receptors of striated urethral and perineal muscles.

All nervous impulses generated in the lower urinary tract achieve central regions of the nervous system, which enables a coordinated urination act. Nervous centers include:

- intermediolateral columnar cells and cells of the ventral horns of the grey matter in the sacral region of the spinal cord;
- reticular formation in the brain stem;

- cerebellum which receives nervous impulses from the detrusor and pelvic floor muscles through the spinocerebellar tract;
- anterior group of hypothalamic nuclei;
- basal ganglia, formations of a brain stem cell: caudate nucleus, lentiform nucleus, substantia nigra, nucleus ruber;
- thalami (non-specific thalamic nuclei located in the internal layer);
- brain cortex — the coordination center of the urination act.

The efferent regulation system of the urination act begins from the brain cortex, and such cortical centers regulating the urination act — is a functional and dynamic notion that has multiple conditional-reflex links, apart from the constant anatomical presentation. Descending fibers arise from cells of the 5$^{th}$ cerebral cortex layer; they pass to subcortical formations and then to the spinal cord. However, it is considered that there is no significant evidence of the presence of a direct corticospinal tract, but rather multiple short tracts and intermediate points exist.

Axons passing through the ventral reticulospinal tract to spinal voiding centers arise in the medial reticular formation. Cerebro-spinal urination centers are located in the thoracolumbar and the sacral regions of the spinal cord, which corresponds to parasympathetic and sympathetic parts of the autonomous nervous system. Motor preganglionic sympathetic neurons originate from the cells that are localized in intermediolateral nuclei of segments from $Th_{12}$ to $L_2$ and participate in the formation of the celiac nerves and ganglia of the celiac plexus. Preganglionic fibers pass through the ganglia of the paravertebral trunk and end in the nodes of vesical plexuses as a part of the celiac nerve. Postganglionic fibers are directed to the detrusor, the urinary bladder neck and the Lieutaud triangle. Adrenergic receptors are located in the lower urinary tract unevenly: α-adrenoreceptors predominate in the region of the urinary bladder neck, proximal urethra, prostate; β-adrenergic receptors are located in the urinary bladder corpus. Receptors release adrenergic neuromediators (norepinephrine and epinephrine). $\alpha_{1A}$- and $\alpha_{1D}$-adrenoreceptors prevail in the urinary system. Fig. 2.7 demonstrates the localization of adrenoreceptors in the urinary bladder, the prostate and the urethra.

Parasympathetic efferent groups passing to the lower urinary tract start with the cellular bodies in the sacral parasympathetic nuclei (intermediolateral grey matter) from $S_2$–$S_4$ segments. Motor fibers direct themselves to the vesical plexus through the ventral root, and then within pelvic and hypogastric nerves. Cholinergic receptors prevail in the area of the urinary bladder body and are practically not found in the proximal urethra.

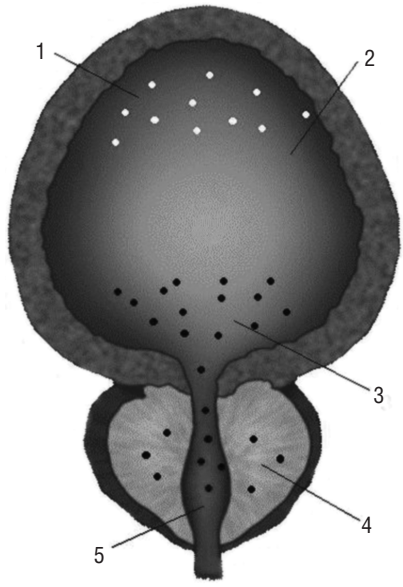


**Fig. 2.7.** Localization of adrenoreceptors in the urinary bladder, the prostate and the urethra: 1 — β-adrenoreceptors; 2 — urinary bladder; 3 — α-adrenoreceptors; 4 — prostate; 5 — proximal urethra

Excitation of the parasympathetic nervous system leads to detrusor contraction. Excitation of the sympathetic nervous system causes ambiguous functional changes. Thus, motor β-adrenergic effect causes detrusor relaxation and opening of ureteral ostia; the α-adrenergic impact causes contraction of the trigonal muscle, and intramural muscles of ureters increases the tone of the region of the internal sphincter and the proximal urethra.

Thus, the cumulative action of the sympathetic innervation on the lower urinary tract consists of the constant maintenance of the tone of the internal sphincter and the proximal urethra, opening of the ureteral ostia, and detrusor relaxation along with the urinary bladder filling. Sympathetic impact completion coincides with the urination reflex activation.

Apart from sympathetic and parasympathetic innervation, the urination act is also regulated by the somatic nervous system. Efferent neurons passing from the grey matter of the anterior horn of the spinal segments $S_2$–$S_4$ through the pudendal plexus and the pudendal nerve end in the region of the striated external sphincter and in the pelvic floor muscles.

The urination act is ensured through complex reflex regulation of the central and the peripheral nervous system. The reflex mechanisms are coordinated in time. Reflex activity reflects the sum of all exciting and inhibiting nervous impulses acting on the lower urinary tract apparatus.

The urination act takes place as follows. The contracting *m. detrusor urinae* squeezes the urine from the urinary bladder to the urethra opening due to relaxation of its sphincters: the involuntary (*m. sphincter vesicae*) and the voluntary (*m. sphincter urethrae*). Along with that, in males, the muscular part of the prostate acting as the third (involuntary) sphincter also relaxes. The urinary bladder becomes closed upon relaxation of the *m. detrusor* and contraction of the specified sphincters.

The excitation of the urination center causes impulsation in the parasympathetic fibers of the pelvic splanchnic nerves (*nn. splanchnici pelvici*), while the external sphincter muscle is innervated by the somatic nerve — a branch of the pudendal nerve (*n. pudendus*).

Urine movement along the urethra plays an important role in the urination act: it stimulates the urinary bladder contraction reflexively along the afferent fibers of the pudendal nerve. Urine entering the posterior parts of the urethra and expansion of the urethra contribute to the bladder muscle contraction. Afferent and efferent impulses of this reflex are transmitted through the hypogastric nerve (*n. hypogastricus*).

## 2.4. PHYSIOLOGY OF MALE GENITAL ORGANS

### 2.4.1. Coitus physiology

**Sexual intercourse** (*synonym:* coitus, coupling, copulation) is a fragment of the complex sexual behavioral pattern in humans. Despite the fact that sexual intercourse is a paired physiological process, changes in male and female organisms differ significantly. As sexual intercourse usually occurs in intimate conditions, physiological body changes before, during, and after the coitus were described rather theoretically. At present, mainly thanks to studies on volunteers using special devices that record changes in the male and the female bodies during the intercourse, its physiology has been elucidated.

There are several coitus stages that change one another and are united by the general term "sexual cycle":

- excitation;
- "plateau";
- orgasm;
- regression (detumescence).

Sexual intercourse is usually preceded by a period of mutual petting. For normal coitus in males, the participation of consecutive structural-functional components is required:

1) neurohumoral component determined by the activity of the central nervous and the endocrine systems which ensure the libido strength and excitability of the relevant segments of the central nervous system that regulate sexual behavior;
2) psychic component determined by the activity of the cerebral cortex that ensures libido orientation and erection before the coitus begins;
3) erection component determined predominantly by the activity of the spinal centers, during which the penis enters the vagina and frictions occur (penile movements in the vagina);
4) ejaculatory-orgasmic, which is also mostly determined by the activity of the spinal centers, during which ejaculation occurs, and orgasm emerges.

During the excitation stage of the sexual stimulation in males, blood flow to genitals increases, while venous drainage along the veins becomes slightly complicated. This leads to cavernous penile bodies overfilling with blood and penis enlargement. It is presumed that parasympathetic control of the vessels lumen is the leading one in erection emergence.

Penis insertion and frictions lead to increased libido, tachycardia and tachypnea, blood pressure increase and facial hyperemia in males. Maximal values of the blood pressure and the heart rate increase are achieved during orgasm in males, which is experienced as a lustful feeling. The orgasm in males starts with rhythmic contractions of deferent, the ejaculatory ducts and the seminal vesicles. Along with that, ejaculate is excreted outside under high pressure. The orgasm in males lasts several seconds, after which the normal erection quickly weakens and detumescence (decreased blood filling of genitals) occurs. It is followed by a period of sexual refractivity. The repeated erection is possible sometimes later.

Clear definition of the notions "norm", "normal" in the sexual physiology of the intercourse is quite difficult due to the extreme overlapping of biological, social and individual personality features. It is presumed that if sexual life does not cause the feelings of tiredness, unsatisfaction if partners remain cheerful and vigorous, it is evident that their sexual life is optimal.

## 2.4.2. Hormonal regulation of physiological functions

**Male sexual glands (testes).** Spermatogenesis processes and the formation of male sex hormones (**androgens**) occurs in them.

**Spermatogenesis** (from Greek *"sperma"*, genitive case, *"spermatos"* — seed and *"genesis"* — formation) is the process of transformation of diploid male germ cells into haploid, free and differentiated cells — **spermatozoa**.

There are four periods of spermatogenesis: 1) *reproduction*; 2) *growth*; 3) *division and maturation*; 4) *formation, or spermiogenesis (spermiotheliosis)*. In the first period, diploid initial male germ cells (spermatogonia) are divided several times by means of mitosis (the number of divisions in each species is constant). In the second period, the germ cells (1st order spermatocytes) enlarge, and their nucleus undergoes prolonged prophase, during which the conjugation of homologous chromosomes and crossing-over accompanied by the exchange of homologous chromosome parts occur, with the formation of tetrades. In the third period, two maturation divisions (meiosis) occur, and the chromosome number is reduced by half (along with that, during the first division, homologous chromosomes diverge to spindle poles in some tetrades, while during the second one — chromatides diverge; in other — just the opposite, chromatides diverge first, followed by homologous chromosomes).

Thus, each first-order spermatocyte gives two second-order spermatocytes, which form four haploid cells (**spermatides**) with identical sizes after the second division. The latter ones are not divided, they enter the fourth period of spermatogenesis, or spermiogenesis, and transform into spermatozoa: the spermatid shape changes from a rounded to an elongated one, some new structures are formed (acrosome, paranucleus, flagella, etc.), while others disappear (ribosomes, endoplasmic reticulum, etc.). The majority of the cytoplasm disappears from the cell. An elongated nucleus with condensed chromatin and an acrosome (a derivative of the Golgi apparatus) is located on the apical cell pole and form a spermatozoal head; the centriole is usually located near the basal nucleus pole, giving rise to flagella; mitochondria surround the centriole or form the so-called paranucleus located in the intermediate spermatozoal part. Mature spermatozoa accumulate in the epididymis. Spermatogenesis continues in males until the old age.

Duration of the complete spermatogenesis consisting of four cycles is from 64 to 75 days. However, spermatozoa mature not simultaneously: at any moment, hundreds and hundreds of cells in the tubule wall can be found at different spermatogenesis stages (early, intermediate and final). One cycle of the germinal epithelium is approximately 16 days.

**Androgens** are formed in the interstitial cells, or *glandulocytes* (Leidig cells), localized in the interstitium between the seminiferous tubules and amount to about 20% of the general testicular weight. A small amount of male sex hormones is also produced in the reticular zone of the adrenal cortex.

Androgens include several glucocorticoid hormones, the most important of them being testosterone. Production of this hormone defines adequate development of the primary and the secondary male sexual features (masculinizing effect). During the puberty period, under the impact of testosterone, penis and testes grow, the male pattern of hair distribution appears, the voice tone changes. Besides, testosterone increases protein synthesis (anabolic effect), which leads to the accelerated growth, physical development and muscle mass increase. Testosterone influences the processes of bone formation — it accelerates the formation of a protein bone matrix, increases calcium salt deposition in it. As a result, bone growth, thickness and durability increase. In testosterone hyperproduction, metabolism accelerates, and the number of red blood cells increases in blood.

The mechanism of testosterone action is caused by its penetration inside the cell, transformation into a more active form (dihydrotestosterone) and further binding

with the nuclear and the organelle receptors, which leads to changes in protein and nucleic acid synthesis. Testosterone secretion is regulated by the luteinizing hormone of the anterior pituitary, the production of which increases during the puberty period. If the amount of testosterone increases in the blood, the production of luteinizing hormone is inhibited by the negative feedback mechanism. The decreased production of both gonadotropic (follicle-stimulating and luteinizing) hormones also occurs during the spermatogenesis processes acceleration.

In boys before the age of 10–11, active glandulocytes (Leidig cells), in which androgens are produced, are generally absent. However, testosterone secretion in these cells occurs during the intrauterine development period and is preserved with the child during the first days of life. This is related to the stimulating action of the chorionic gonadotropin produced by the placenta.

Insufficient secretion of male sex hormones leads to the development of eunuchoidism, the main signs of which include retardation of the primary and the secondary sexual characters development, disproportioned bony skeleton (disproportionately long extremities with a relatively small body), increased fat deposition on the chest, in the lower abdomen and on the thighs. Mammary glands enlargement (gynecomastia) is also observed frequently. The deficit of male sex hormones also leads to specific neuropsychiatric changes, in particular to the absence of libido to the opposite sex and lack of other typical male psychophysiological characters.

**Accessory sex organs** are constantly exposed to the action of androgens, which promote their correct formation and normal functioning. Testosterone stimulates the formation of fructose in the seminal vesicles, citric acid and phosphatase in the prostate, carnitine in the epididymis, etc.

**Decreased amount of fructose**, citric acid, acid phosphatase, carnitine in the semen can be the sign of decreased endocrine testicular function. It was detected that approximately 7–10 days after bilateral orchiectomy, the accessory sex organs of male rodents get atrophied to the minimum point.

The normal testosterone level in the plasma of an adult male is 12–35 nmol/l or 345–1010 ng/dl.

## TEST QUESTIONS

1. What is the structure of the kidney?
2. What is a structural-functional kidney unit?
3. Describe the mechanism of urine formation.
4. What is the endocrine kidney function?
5. What are the physiological narrowings of the ureter?
6. What is the structure of the urinary bladder wall? What is the Lieutaud triangle?
7. Enumerate parts of the male urethra.
8. What are number and the structure of the testicular membranes?
9. Describe the prostate structure and function.
10. Describe the coitus physiology.
11. What spermatogenesis stages do exist?