

# The functional anatomy of the urinary system

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### Plan

- Development of the kidneys and their abnormalities
- Development of the urinary ways and their abnormalities
- Kidney functional anatomy, topography
- Ureter features, topography, function
- Urinary bladder features, topography, function
- Male and female urethra gender particularities, functions
- Examination in a living person

Urogenital apparatus

Urogenital apparatus includes:

- Urinary system;
- Female genital system;
- Male genital system.

**Urogenital apparatus** is concerned with *reproduction* and *urinary excretion*.

Although their functions are unrelated, the structures involved in excretion and reproduction are morphologically associated and often use common ducts. Kidney development

#### The kidney develop from *intermediate mesoderm* (or nephrogenic mesoderm).



### Intermediate mesoderm

The *intermediate mesoderm* gives rise to the kidney and indifferent gonad.



### Kidney development or nephrogenesis

- The development of the kidney includes a series of successive phases:
- Pronephros (a vestigial structure, disappears by the 4<sup>th</sup> week of embryogenesis);
- Mesonephros (principal excretory organ during 4-8<sup>th</sup> weeks of embryogenesis);
- Metanephros (permanent and functional kidney, arises at 5<sup>th</sup> week of embryogenesis).



### Kidney development or nephrogenesis

- Pronephros pronephric tubules, pronephric duct;
- Mesonephros mesonephric tubules, mesonephric duct or Wolffian duct;
- Metanephros ureteric bud (or metanephric diverticulum), metanephric blastema.



## Ascents of kidneys

- During the 5<sup>th</sup>-6<sup>th</sup> weeks of embryogenesis the kidneys lie in the pelvis with hilum pointed anteriorly.
- As the pelvis and abdomen grow the kidneys move upward.
- By the 7<sup>th</sup> week the hilum points medially and the kidneys ale located in the abdomen.

- As the kidney ascends it receives new segmental arteries from the aorta and loses those vessels below (`climbing a ladder`).
- Thus sometimes there is more than one renal artery.

### Abnormalities of kidney

- Abnormalities of number,
- Abnormalities of form and fusion,
- Abnormalities of ascent,
- Abnormalities of rotation,
- Abnormalities of collecting system,
- Abnormalities of renal vasculature.

# **Supernumerary kidney** develops as a result of splitting of the metanephric blastema.





## **Renal agenesis –** ureteric bud (metanephric diverticulum) fails to develop.



# *Horseshoe kidney* – inferior poles of the kidneys are fused.





### **Multichystic dysplastic kidney** is characterized by presence of multiple, noncommunicating cysts.



Multicystic Dysplastic

# *Ectopic pelvic kidney* fails to climb towards its normal position.



# **Accessory and multiple renal vessels** – kidney is supplied by more than one vessel.





### Development of urinary tract

The collecting ducts, papillary ducts, minor calyces, major calyces, renal pelvis and ureter derived from ureteric bud (or metanephric diverticulum).



### Development of urinary tract

> The **urinary bladder** develops from three sources:

- *Urogenital sinus* (a part of cloaca) gives rise to the major part of the urinary bladder;
- Allantois (its proximal part) gives rise to the apex of the urinary bladder;
- Absorbed parts of mesonephric ducts form the trigone of the urinary bladder.

### Development of urinary bladder



- **Bifid renal pelvis** and **ureter** result from division of the ureteric bud. It may be unilateral or bilateral.
  - Partial ureteric duplication (Y-shaped ureter);
- Incomplete ureteric duplication with ureters joining near bladder wall (V-shaped ureter).



# **Double ureter (complete duplication)** – drain separately into the urinary bladder.



## **Bladder exstrophy** is a rare birth defect in which the urinary bladder develops outside the fetus.



Female infant with bladder exstrophy

### Urinary system consists of:

- Uropoetic organs:
- a) **Kidneys** which produce urine.
- Urinary tract (excretory passages):
- a) Minor calyces, major calyces, renal pelvis;
- b) Ureters;
- c) Urinary bladder;
- d) Urethra.



### Kidney (ren, nephros), functions

#### Functions:

- 1. The kidneys *form the urine* (remove the excess water, salts and wastes of the protein metabolism).
- 2. The kidneys produce important hormones: erythropoietin (regulates erythropoiesis) and renin (a part of renin-angiotensin-aldosterone system, which regulate blood pressure).

Kidney, topography

The **right kidney** lies slightly inferior to the left kidney, owing to its relationship to the liver.

- **Topography** of kidneys includes:
- Holotopy (kidneys are located in the lateral regions (flanks) of the abdomen);
- Skeletotopy (kidneys are located on each side of the vertebral column at the level of TII L3 vertebrae);
- 3. Syntopy (kidneys have relations with muscles and viscera).

## Kidney, skeletotopy

### Left kidney:

- a) Upper pole of the kidney middle of **TII**;
- b) Lower pole of the kidney superior border of **L3**.
- Right kidney (is located on the half vertebra below):
- a) Upper pole of the kidney inferior border of **TII;**
- b) Lower pole of the kidney middle of **L3**.



## Kidney, syntopy

Posteriorly:

- a) the **right kidney** is related to the 12<sup>th</sup> rib, diaphragm, transversus abdominis, quadratus lumborum and psoas major;
- b) the left kidney is related to the II<sup>th</sup> and I2<sup>th</sup> ribs, diaphragm, transversus abdominis, quadratus lumborum and psoas major;





## Kidney, syntopy

• Anteriorly:

- a) the *right kidney* is related to the liver, duodenum, ascending colon, jejunum;
- b) the **left kidney** is related to the stomach, pancreas, jejunum, spleen and descending colon.
- suprarenal (adrenal) glands are superior and anterior to the kidneys.

Syntopy of Kidney Anterior Aspect



### Kidney, syntopy



### Kidney, external features

Kidney is bean-shaped and has:

- two surfaces: anterior and posterior;
- two borders: medial and lateral;
- two ends (or poles): superior and inferior.

On the medial border the **renal hilum** (a depression) is located, where the *renal artery* enters, and *renal vein* and *renal pelvis* (or *ureter*) leave the renal sinus.

**PS.** Renal vein located anteriorly, renal artery in the middle, renal pelvis (or ureter) posteriorly.

### Kidney (ren, nephros)



### Fixation apparatus of kidney:

- **Renal** (muscular) **bed**;
- **Renal pedicle** (renal artery, renal vein, ureter);
- **Renal capsules** (fibrous and adipose capsules);
- Renal fascia or Gerota`s fascia (consists of prerenal and retrorenal laminae);
- Peritoneum (kidneys lie extra- or retroperitoneally);
- Intra-abdominal pressure.

### Fixation apparatus of kidney:



# Internal (macro-microscopic) structure of kidney

- I. Renal parenchyma:
- Renal cortex outer layer of kidney;
- Renal medulla inner layer of kidney arranged into the pyramids (of Malpighi).
- **2. Renal sinus** (a hollow within kidney).



### Renal sinus

- The renal hilum continuous with the **renal sinus,** a space within the kidney, which is occupied by:
- minor calyces,
- major calyces;
- renal pelvis;
- vessels;
- nerves;
- variable amount of fat.



# Internal (macro-microscopic) structure of kidney

- **Renal lobe** comprises a renal pyramid as well as renal cortex which surrounds it.
- ▶ **Renal segment** consists of 2 3 renal lobes.
- There are 5 renal segments:
- I. superior segment;
- 2. anterior superior segment;
- 3. anterior inferior segment;
- 4. inferior segment;
- 5. posterior segment.

### Segmental structure of the kidney



### Nephron – functional and structural unit of kidney

- There are about 1.000.000 nephrons in each human kidney.
- Each *nephron* consists of two parts:
- Renal corpuscle, producing primary urine (150-180 | daily);
- Renal tubule, producing secondary urine (1.5 - 2 l daily).



### Nephron – functional and structural unit of kidney

**I. Renal** (Malpighian) **corpuscle** comprises:

- a) **glomerulus** (a network of capillaries);
- b) glomerular (Bowman`s) capsule.
- 2. Renal (uriniferous) tubule consists of:
- a) proximal convoluted tubule;
- b) loop of Henle;
- c) distal convoluted tubule.

The final urine is conveyed through the **collecting ducts, papillary ducts** into the renal calyces, and then into the renal pelvis.



# Nephron – functional and structural unit of kidney

![](_page_38_Figure_1.jpeg)

![](_page_38_Figure_2.jpeg)

# Nephron – functional and structural unit of kidney

There are two kind of nephrons:

- Cortical nephrons (80%):
- almost entirely are located within cortex;
- have short loops of Henle;

#### Juxtamedullary nephrons (20%):

- which renal corpuscles are located near cortex-medulla junction;
- have long loops of Henle, that extend deep into the renal medulla.

### Urine formation

- The three processes of urine formation are, as follows:
- (glomerular) *filtration*,
- (tubular)
  reabsorption,
- (tubular) secretion.

![](_page_40_Figure_5.jpeg)

### Urine formation (phases)

- Formation of primary urine (by glomerular filtration) 150-180 | daily;
- Formation of secondary urine (by tubular reabsorption and secretion) – 1.5 -2 | daily.

## Juxtaglomerular apparatus

- Juxtaglomerular apparatus consists of three types of cells:
- Macula densa (a part of distal convoluted tubule of the same nephron);
- Juxtaglomerular cells or granular cells (secrete renin);
- 3. Extraglomerular mesangial cells (`polar cushion`).

![](_page_42_Figure_5.jpeg)

### Juxtaglomerular apparatus

- **Macula densa** (modified tubular epithelium) responds to changes in the sodium chloride levels.
- Juxtaglomerular cells (mioepithelioid cells) located in the media of the afferent arterioles as they enter into the glomeruli. They secrete renin.
- **Extraglomerular mesangial cells** are located in the junction between the afferent and efferent arterioles, but their significance is unknown.

PS. **Excess secretion of renin** by the juxtaglomerular cells can lead to excess activity of the *renin-angiotensin-aldosterone system*, **hypertension** and an increase in blood volume.

### Juxtaglomerular apparatus

![](_page_44_Figure_1.jpeg)

- muscular tubes, which connect the kidneys to the urinary bladder;
- have 3 parts: abdominal, pelvic, intramural (or intravesical);
- their walls consist of 4 layers: mucosa, submucosa, muscular coat and adventitia.

### Ureters

![](_page_46_Picture_1.jpeg)

- when empty, the adult urinary bladder is located in the pelvic cavity;
- In infants and young children is in the abdominal cavity even empty;
- it is separated from the pubic bones by the *retropubic space* (of Retzius);
- its neck is held firmly by the *puboprostatic ligament* in males and *pubovesical ligament* in females.

- It has 4 parts:
- a) apex of bladder;
- b) body of bladder;
- c) fundus of bladder;
- d) neck of bladder.
- The *ureteric orifices* and the *internal urethral orifice* are at the angles of the **trigone of bladder.**

![](_page_49_Figure_1.jpeg)

Figure 5.33. Parts of the urinary bladder in the female.

D

![](_page_49_Picture_3.jpeg)

- Its walls consists of:
- a) **Mucosa**, which forms the folds, except of the trigone of bladder;
- b) **Submucosa,** absent at the level of the trigone of bladder;
- c) **Muscular coat,** which forms the detrusor muscle and internal uretheral sphincter;
- d) **Serous coat** (visceral peritoneum).

**PS.** The empty bladder has the **extraperitoneal position**, the full bladder has the **mesoperitoneal position**.

#### **URINARY BLADDER**

![](_page_51_Figure_2.jpeg)

### Female urethra

- It is a short fibromuscular tube (3-5 cm).
- It lies anterior to the vagina.
- It begins at the neck of the urinary bladder by the internal urethral orifice (or internal urinary meatus).
- It opens into the vestibule of vagina by the external urethral orifice (or external urinary meatus).
- It has two parts:
- I. intramural part (corresponds with the neck of bladder);
- 2. *perineal part* (which pierces the perineum).

### Female urethra

![](_page_53_Figure_1.jpeg)

### Male urethra

- It is a fibromuscular tube that begins at the neck of the urinary bladder (*internal urethral orifice*) and ends at the level of the glands penis (*external urethral orifice*).
- It is significantly longer in males than females (20 cm).
- It consists of four parts:
- I. preprostatic (or intramural) part (0.5 cm);
- 2. prostatic part (3 cm);
- 3. membranous part (1 cm);
- 4. spongy part (16 cm).

### Male urethra

![](_page_55_Figure_1.jpeg)

### Male urethra (curvatures)

![](_page_56_Figure_1.jpeg)

### Male urethra

### Constrictions:

- External urethral orifice (or external urinary meatus);
- Membranous part of urethra;
- 3. Internal urethral orifice (or internal urinary meatus).

![](_page_57_Figure_5.jpeg)

### Male urethra

### Dilatations:

- Navicular fossa (within the glans penis);
- 2. Urethral bulb (within the bulb of penis);
- 3. **Prostatic part** of urethra.

![](_page_58_Figure_5.jpeg)

### Urethra

- It is a passageway for urine.
- It serves an additional purpose in men, as it is also utilized as a passageway for semen during ejaculation.

Male urethra (two parts separated by external urethral sphincter):

- I. anterior urethra (spongy part);
- 2. **posterior urethra** (intramural, prostatic and membranous parts).

Male urethra (two parts separated by suspensory ligament of penis):

- I. fixed part (pelvic part):
- 2. mobile part (penile part).

### Urethra, gender differences

![](_page_60_Figure_1.jpeg)

#### **Distal and Proximal Urethra**

### Examination on a living person

- Clinical (physical) methods of examination:
- a) Inspection,
- b) **Palpation** (size, shape and consistency of the organ),
- c) Percussion.

- Paraclinical methods of examination:
- a) X-ray examination (urography, cystography),
- b) Ultrasound examination,
- c) **CT** (computerized tomography),
- d) Endoscopic examination (cystoscopy),
- e) MRI or MRT.

### Urethral catheterization

## It is done to remove urine from a person who is unable to micturate.

![](_page_62_Figure_2.jpeg)

### Urinary system

![](_page_63_Picture_1.jpeg)