Lectures of Human Embryology

Special Embryology

Development of Urinary System

By

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Introduction

1. The intra-embryonic mesoderm is divided into 3 regions:
   - **Medial (para-axial) mesoderm**: is segmented to form somites.
   - **Intermediate mesoderm**: It separates from the somites to form urogenital ridge. This gives rise to urogenital systems.
   - **Lateral plate mesoderm**: in which intra-embryonic coelom appears. It gives rise to serous body cavities.

2. The kidney arises from the **urogenital ridge**. Its development passes into 3 stages (or kidneys) in cranio-caudal sequence as follows:
   - **Pronephros**: It is temporary and non-functional.
   - **Mesonephros**: It is temporary functional at the early fetal stages.
   - **Metanephros**: It is the permanent functional kidney.
**Pronephros (1st kidney)**

- It develops from the intermediate (nephrogenic) mesoderm in the cervical region (at the beginning of the 4th week of intrauterine life).
- The mesoderm on each side is segmented into 7-10 solid masses.
- These masses are canalized to form pronephric tubules (without glomeruli).
- The pronephric tubules open ventrally into the intra-embryonic coelom, while dorsally they join together to form a duct on each side called pronephric duct.
- The duct grows caudally to open into the cloaca.

**Fate:** The pronephric tubules and the cranial (cervical) part disappear (by the beginning of the 5th week).

**Function:** It has no function (no glomeruli) in man.

**N.B.:** It is the permanent and functional kidney in lower animals e.g. amphioxus and some fishes.

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**Mesonephros (Second Kidney)**

- It develops from the intermediate (nephrogenic) mesoderm in the middle part (thoracic and lumbar region).
- The mesoderm on each side is segmented into 70-80 solid clusters.
- Each cluster is canalized to form S-shaped mesonephric tubule.
- The dorsal ends of the mesonephric tubules join the pronephric duct of which its name is now be changed to the mesonephric duct.
- The ventral ends of each mesonephric tubule enlarge. Then each one becomes invaginated by branch of dorsal aorta to form a glomerulus (tuft of blood capillaries) surrounded by **Bowman's capsule** (double-layered cup).

**Fate:**

I. **Mesonephric tubules:** Most of mesonephric tubules disappear except few of them that form the following:

- **In males:**
  - Functional tubules opposite the developing testis: They join the rete testis to form the **efferent ductules** (vasa efferentia).
• **Non functional tubules**, e.g. Superior and inferior aberrant ductules, paradidymis and appendix of epididymis.

- In females: Non functional tubules, e.g. of epoophoron and paroophron.

II. **Mesonephric duct**: It gives the ureteric bud in both sexes.

In addition, it gives rise to the following:

- In male: Male genital ducts; epididymis, vas (ductus) deferens, seminal vesicle and ejaculatory duct.
  
  *N.B.: Seminal vesicle arises as a small bud from the mesonephric duct, near its opening in the cloaca (or future urinary bladder).*

- In females: Non functional ducts e.g. duct of epoophoron and paroophron and Gartner duct (or cyst).

Function: It has a function of excreting urine during the early stages of fetal life.
Metanephros (Third or Permanent Kidney)

It develops during (the 5th week) as follows:

**A.** It arises in the pelvis from 2 sources:
- Ureteric bud: arising from the mesonephric duct.
- Metanephric cap: arising from the intermediate mesoderm (lower or pelvic part).

**B.** Ureteric Bud:
- begins as an outgrowth from the mesonephric duct near its junction with the cloaca.
Then it extends dorso-cranially into the intermediate (nephrogenic) mesoderm.

**C.** Metanephric Cap:
It is formed from condensation of the intermediate mesoderm around the cranial end of the ureteric bud.

**D. Differentiation:**

i. **Ureteric bud:**
   - It elongates to form the ureter.
   - Its cranial end dilates to form the pelvis of the ureter.
   - Then the pelvis divides into major calyces which then divide again into minor calyces and collecting tubules.

ii. **Metanephric cap:**
   - It divides into small masses so that each collecting tubule has its own small cap.
   - Each small cap is differentiated into S-shaped tubule.
   - Continuous growth of the tubule results in the formation of proximal convoluted tubule, loop of Henle and distal convoluted tubule.

**E. Ends of each tubule:**

   - **Proximal "dorsal" end** (of the proximal convoluted tubule): is invaginated by a branch from the dorsal aorta to form *glomerulus* surrounded by *Bowman's capsule*.
   - **Distal "ventral" end** (of the distal convoluted tubule): communicates with (opens into) the corresponding collecting tubule.

**F. Fate (of Site, Hilum position, Blood supply and Lobulation) "S.H.B.L."**

   - As the development of the kidney proceeds, it ascends along the posterior abdominal wall to reach its final position (*opposite level of T₁₂ - L₃ vertebra*).
   - As it ascends, it rotates medially for 90° so that its hilum becomes directed medially instead of previous ventral position in the early stages of development.
   - Also, as the kidney ascends, it changes its supplying blood supply from the pelvic arteries in the pelvis to the abdominal aorta in the abdomen.

   *N.B.: At first it takes arterial supply from the median sacral, then from common iliac and lastly from abdominal aorta.*

   - At birth, the outer surface of kidney shows a lobulated appearance, but this lobulation disappears during the 1st year.
of life (during period of infancy) as a result of further growth of nephrons.

N.B.: Infancy is the early period of childhood or before the ability to walk.

**Nephron** is the structural and functional unit of kidney. Each nephron consists of a **renal (Malpighian) corpuscle** (glomerulus and Bowman’ capsule) and **renal tubules** (proximal convoluted tubule, loop of Henle and distal convoluted tubule).

**In summary:** The kidney is formed of 2 main portions from 2 embryological sources as follows:

1. The **excretory portion** of the kidney develops from the intermediate mesoderm (or called metanephric cap or blastema). This portion consists of **nephron** (which includes Bowman's capsule, proximal convoluted tubule, loop of Henle and distal convoluted tubule).

2. The **collecting portion** of the kidney develops from the ureteric bud. This portion includes the collecting tubules, minor calyces, major calyces, renal pelvis and ureter.

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**Diagrams showing development of kidney:**

- A) Pronephros
- B) Mesonephros and appearance of ureteric bud
- C) Ureter and metanephric cap
- D) Metanephric cap of the collecting tubules
- E) Derivatives of metanephric cap
**Congenital Anomalies of Kidney** (ADEL RACH)

1. **Agenesis** (absence) of the kidney: due to failure of ureteric bud to develop.
2. **Double kidney**: due to early division of the ureteric bud.
3. **Ectopic (or pelvic) kidney**: due to failure of the kidney to ascend.
4. **Lobulated kidney**: due to persistence of the fetal lobulation of the kidney.
5. **Rosette (cake) kidney**: due to adhesions of the 2 kidneys at the hilum during their ascent. It is a pelvic kidney.
6. **Aberrant renal vessels**: A renal artery enters the kidney at its lower pole. It is due persistence of the normal fetal arteries that normally disappear during growth of kidney. They may cause obstruction of the urine flow through the corresponding ureter.
7. **Cystic (solitary or polycystic) kidney**: due to failure of communication between the distal convoluted tubules (derived from the metanephric cap) and the collecting tubules (derived from the ureteric bud). This results in retention of urine in the excretory portion of the kidney, resulting in formation of retention cysts.
8. **Horse-shoe kidney**: due to adhesions of the 2 kidneys at their lower poles. This kidney is located at the level of the lower lumbar vertebra because its ascent is prevented by the origin of the inferior mesenteric artery from the aorta.

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![Diagram of congenital anomalies of kidney](image-url)
**Congenital Anomalies of Ureter**

A. **Atresia of the ureter**: occurs at the ureteric orifice of the urinary bladder.

B. **Bifid ureter (double ureter)**: caused by premature division of ureteric bud into 2 parts.

C. **Caval "post-caval" ureter**: The right ureter ascends behind the inferior vena cava that may be obstructed by it.

D. **Double renal pelvis**: due to division of the ureteric bud near its termination.

E. **Ectopic ureteric orifice**: It results from appearance of another ureteric bud from the same mesonephric duct but the 2 buds share in the formation of one kidney. In this case, one ureter opens into the urinary bladder while the other one opens below it into the urethra or vagina or vestibule.

*Congenital anomalies of ureter: A) Atresia of orifice of ureter at the urinary bladder, B) Bifid ureter, C) Post-caval ureter, D) Double renal pelvis, E) Ectopic ureteric orifice*