DEVELOPMET OF THE URINARY SYSTEM

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Objectives of the Lecture:

By the end of the lecture the student should be able to:

. What is the origin of the kidneys.
. Enumerate the names of the successive kidneys.
. Where is the pronephros lie?
. Describe the nephrotomes.
. Describe the mesonephros.
. Where is the mesonephros lie?
. When the metanephros appear?
. Describe the surface of the ureters.
. What is the mesonephric duct and its fate?
. What are the changes in the developing kidney?
. Mention the congenital anomalies of the kidneys.
. Describe normal development of the ureter and its anomalies
. Describe normal development of urinary bladder and its anomalies
. Describe normal development of urethrae and its anomalies

Urogenital system

Functionally:

- **Can be divided into two entirely different components:**
  1. **Urinary system**
  2. **Genital system**

Embryologically and anatomically:

- **Two are intimately interwoven**
- **Both develop from a common mesodermal ridge (*intermediate mesoderm*) along posterior wall of abdominal cavity**
- **Initially, excretory ducts of both systems enter a common cavity, *cloaca***

KIDNEY

- Develops from intermediate mesoderm

- Three successive kidneys are formed during intrauterine life in human.

These are:

1. Pronephros
2. Mesonephros
3. Metanephros or permanent kidney

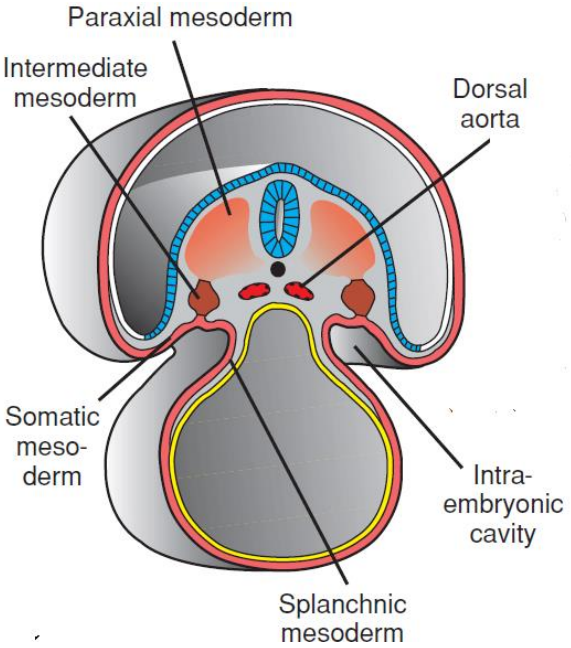
1. Pronephros:

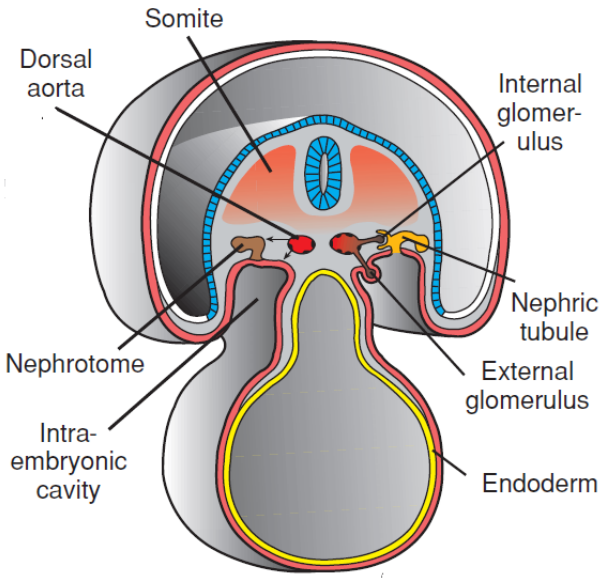
- The first kidney to appear.

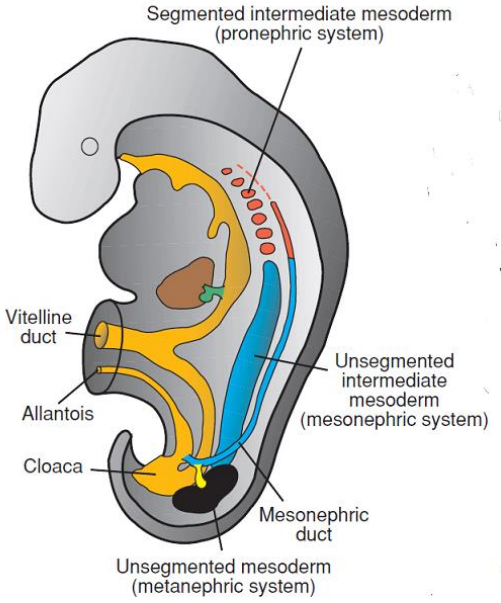
At beginning of 4th week, Develops in cervical region in the form of 7 to 10 solid masses known as **nephrotomes**.

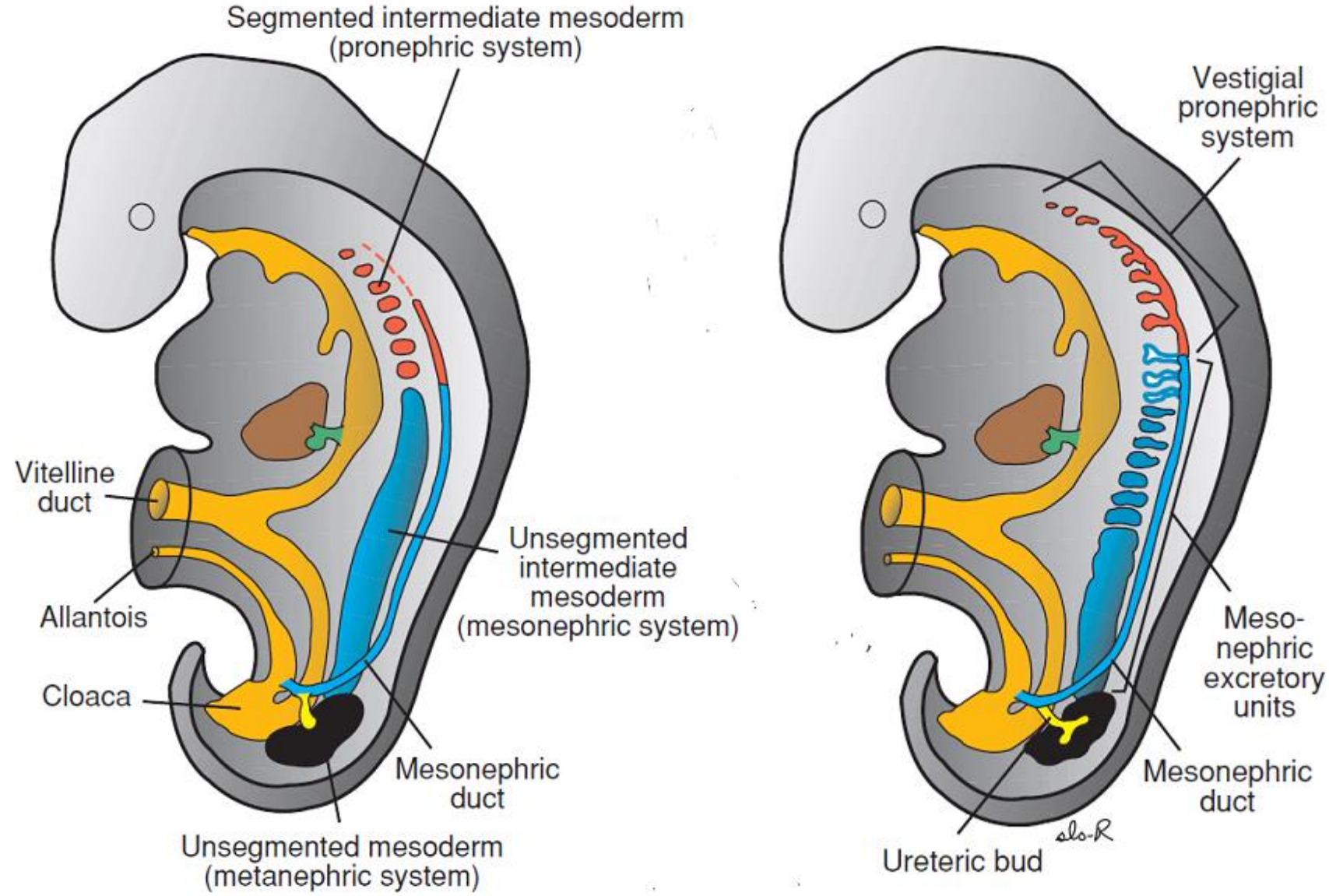
- These nephrotomes regress before more caudal ones are formed.

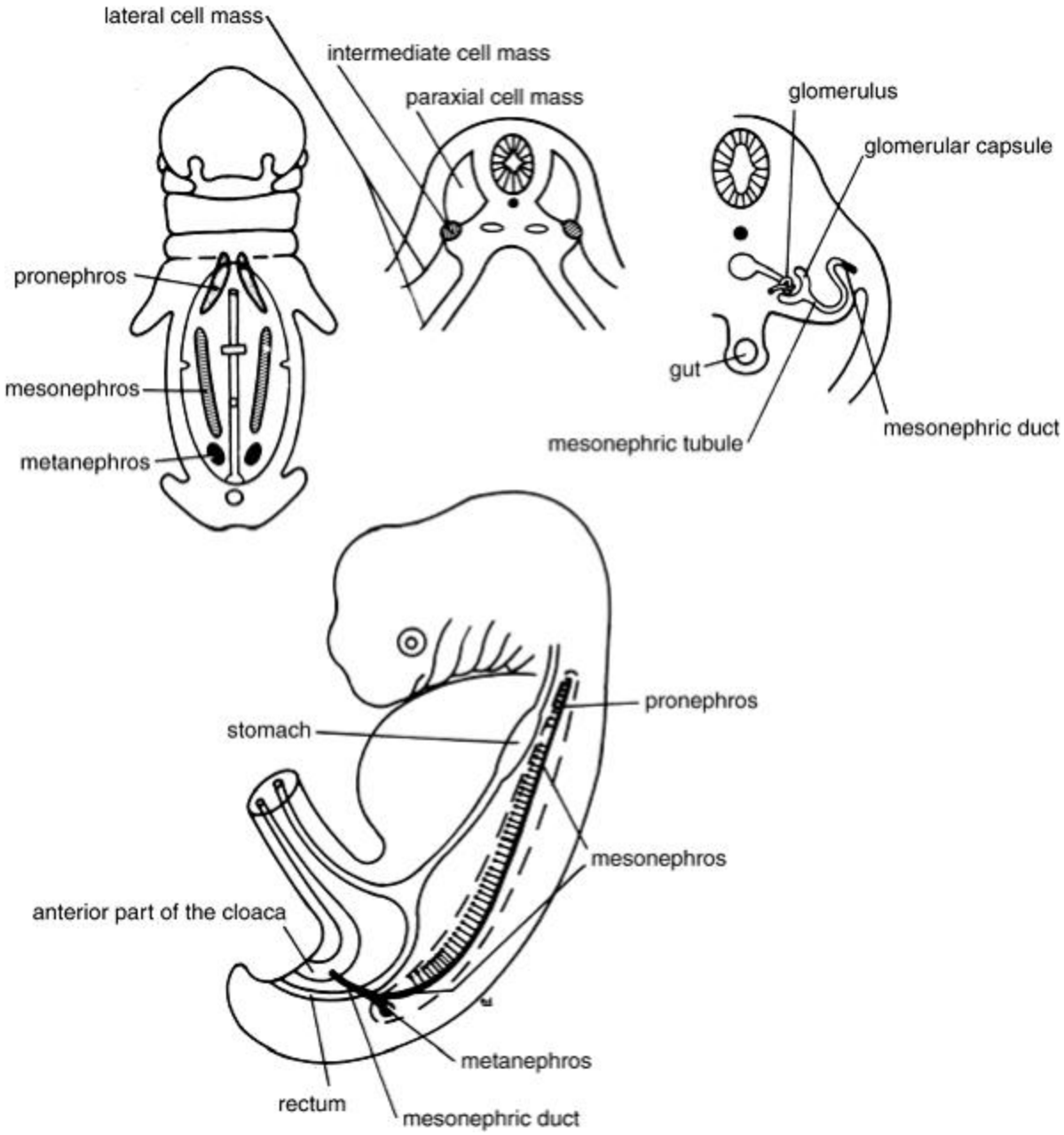
- **By end of 4th week**, **pronephric system disappeared.**








Segmented intermediate mesoderm
(pronephric system)
Vitelline duct
Allantois
Cloaca
Unsegmented intermediate mesoderm
(mesonephric system)
Mesonephric duct
Unsegmented mesoderm
(metanephric system)
Vestigial pronephric system
Meso-nephric excretory units
Mesonephric duct
Ureteric bud


lateral cell mass
intermediate cell mass
paraxial cell mass
pronephros
mesonephros
metanephros
glomerulus
glomerular capsule
gut
mesonephric tubule
mesonephric duct
stomach
pronephros
mesonephros
anterior part of the cloaca
metanephros
rectum
mesonephric duct

Mesonephros

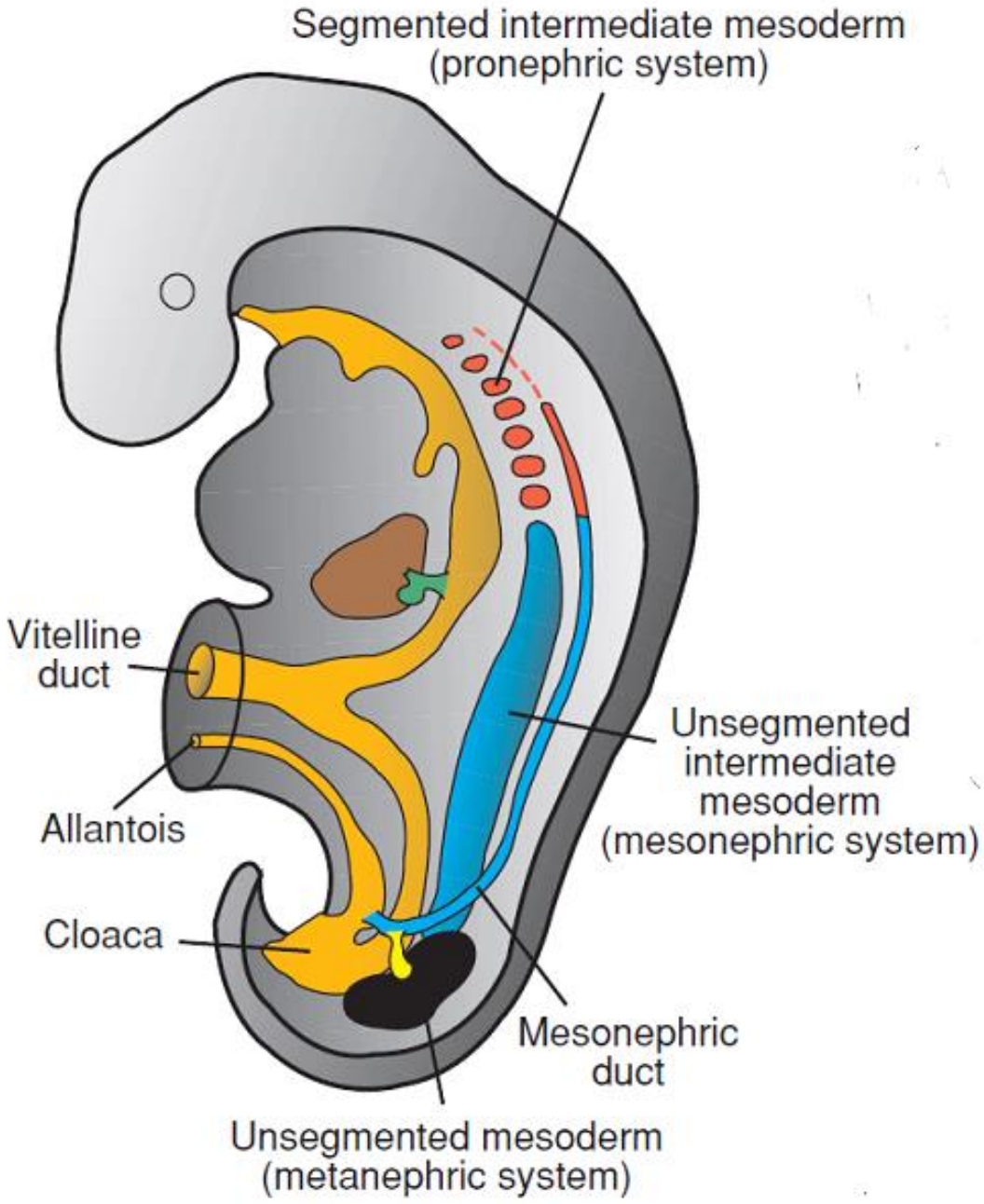
- The 2nd kidney to appear

-Develops in thoracic and upper lumbar regions of intermediate mesoderm during regression of pronephric tubules.

- **Mesoderm of intermediate cell mass** gives rise to **mesonephric tubules**.

- Each tubule elongates forming an S-shaped loop which acquires a glomerulus at its medial end forming a Bowman's capsule.

- Laterally, the tubules join a collecting duct known as **mesonephric** or **Wolffian duct**.


Segmented intermediate mesoderm
(pronephric system)
Vitelline
duct
Allantois
Cloaca
Unsegmented
intermediate
mesoderm
(mesonephric system)
Mesonephric
duct
Unsegmented mesoderm
(metanephric system)

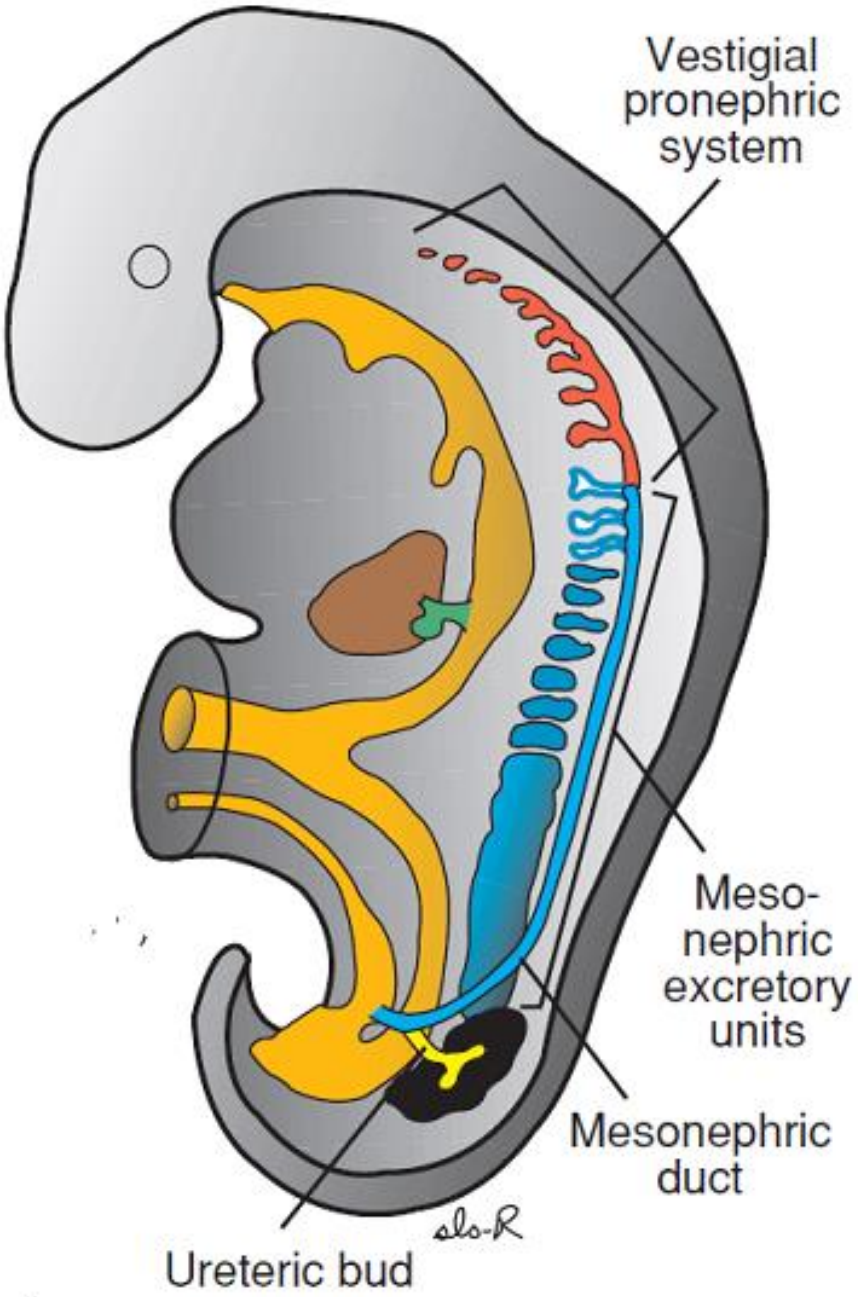
-**In middle of the 2nd month**,
-**Mesonephros forms a large ovoid organ on each side of midline.**
-**Since the gonad develops on its side the ridge formed called urogenital ridge**

- While caudal tubules are still differentiating, cranial ones - start to degenerate and

- By end of the 2nd month the majority disappear.

In male, -

- A few of caudal tubules and mesonephric duct - persist and participate in formation of genital system.


Vestigial pronephric system
Meso-nephric excretory units
Mesonephric duct
Ureteric bud
slo-R

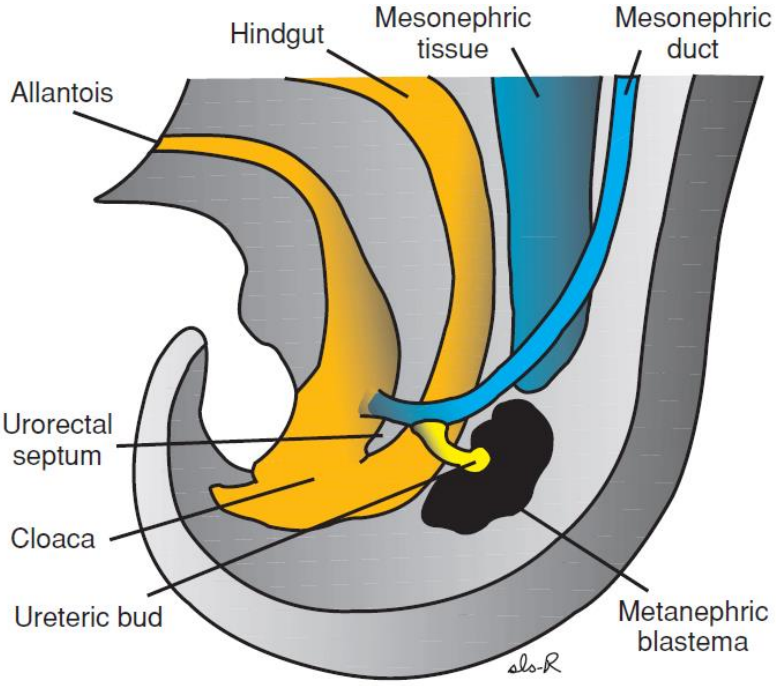
Metanephros

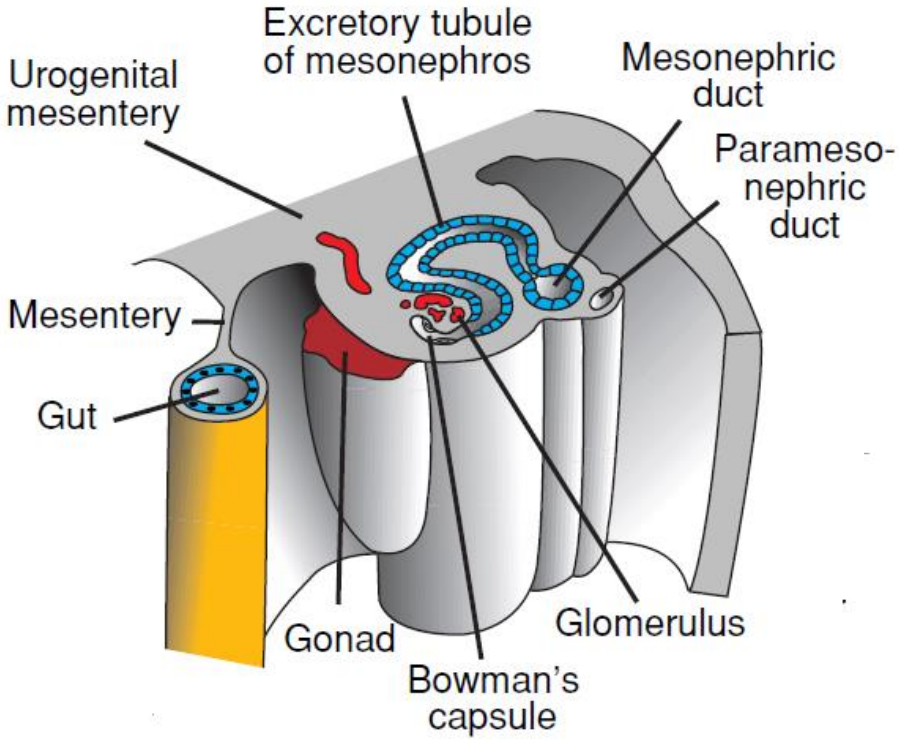
- The 3rd or permanent kidney

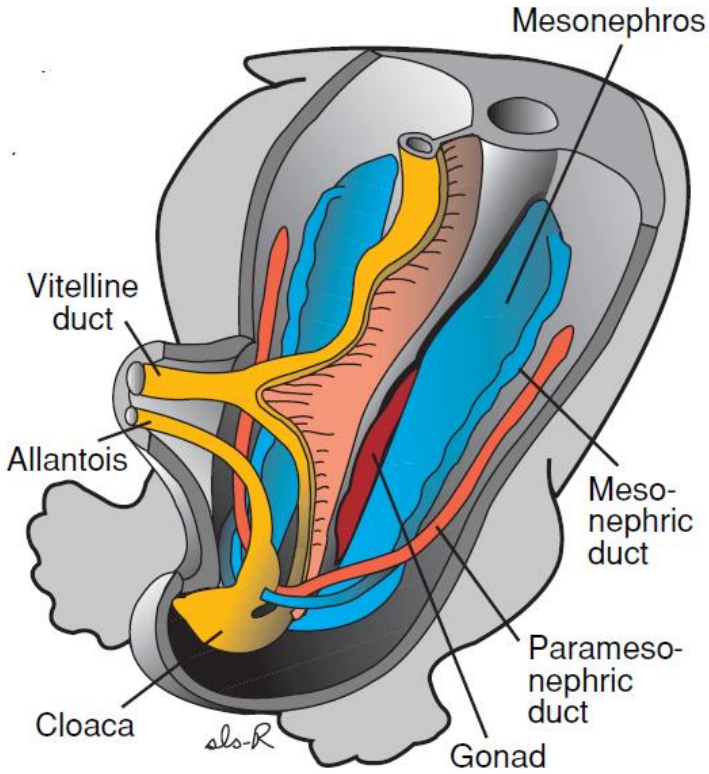
- Appears in 5th month in lower lumbar and sacral regions of intermediate cell mass.

1- The collecting system: - Develops from ureteric bud.

* The bud arises as an outgrowth from mesonephric duct close to its entrance to cloaca.




Excretory tubule
of mesonephros
Urogenital
mesentery
Mesonephric
duct
Parameso-
nephric
duct
Mesentery
Gut
Gonad
Glomerulus
Bowman's
capsule


Mesonephros
Vitelline
duct
Allantois
Meso-
nephric
duct
Parameso-
nephric
duct
Cloaca
Gonad

* Cranial end of the bud grows up and penetrate metanephric tissue, which forms a cap over its distal end.

* Then, cranial end dilates forming **primitive renal pelvis** and rest of the bud elongates forming the **ureter**.

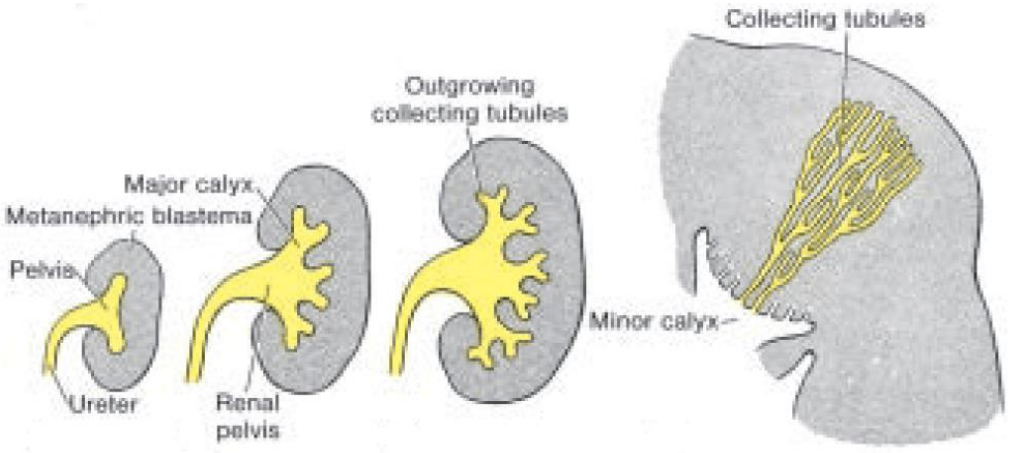
* **The pelvis:**

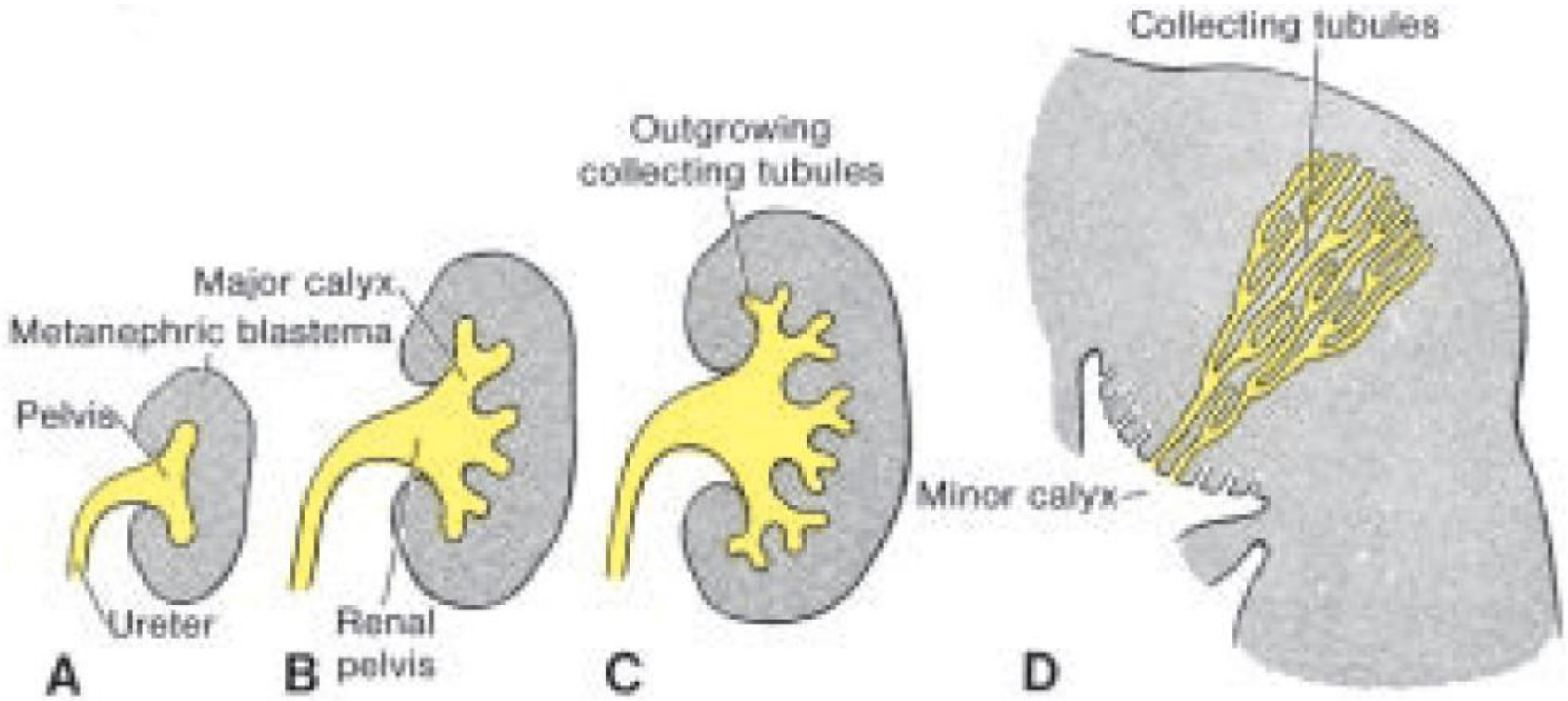
- Divides continuously into several generations of divisions, up to 12 or more generations, penetrating metanephric tissue forming:

a. Major calyces

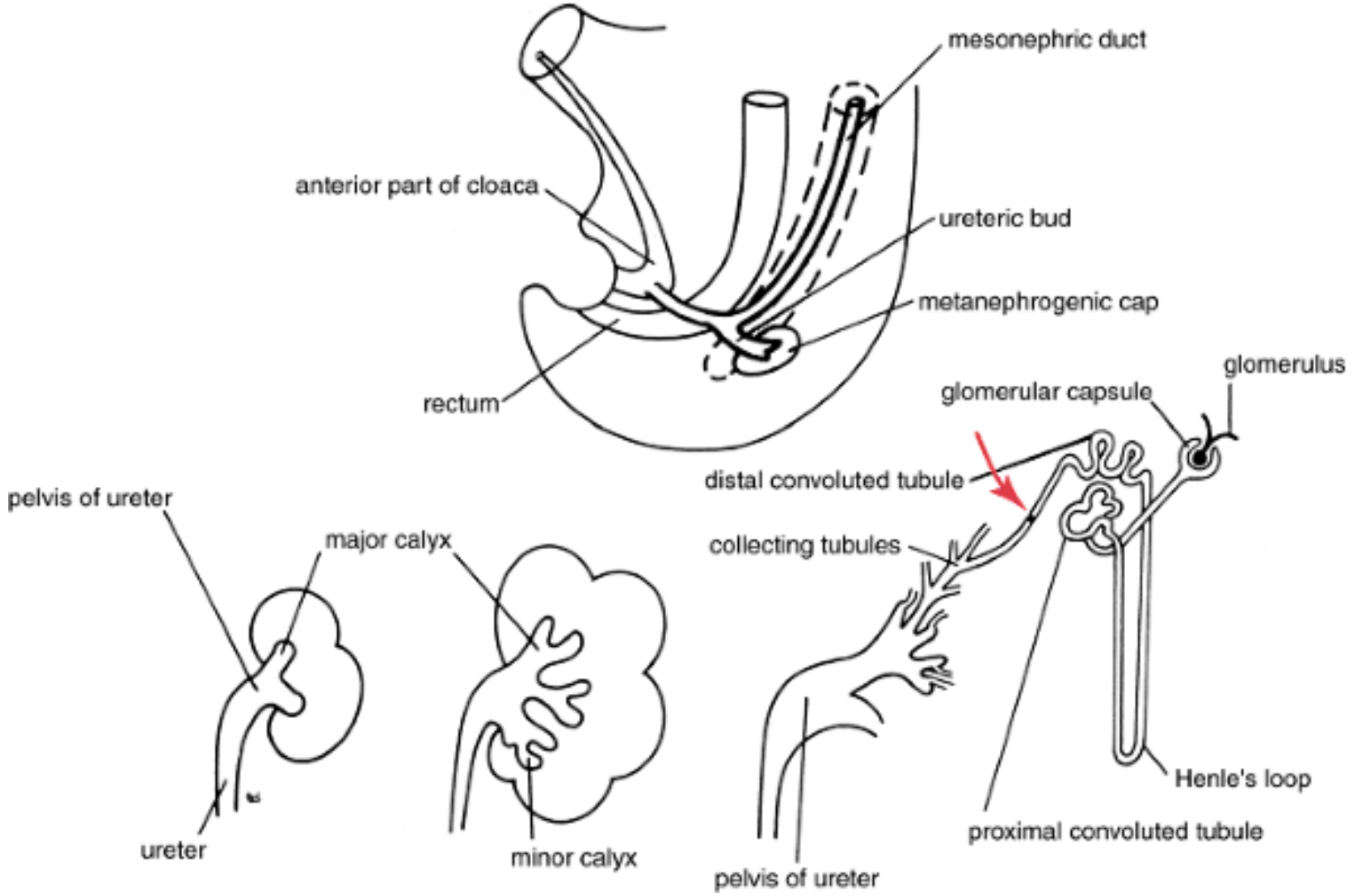
b. Minor calyces

c. Collecting tubules





Development of the renal pelvis, calyces, and collecting tubules of the metanephros. **A.** 6 weeks. **B.** At the end of the sixth week. **C.** 7 weeks, **D.** Newborn. Note the pyramid form of the collecting tubules entering the minor calyx.



Origin of ureteric bud from mesonephric duct and formation of major and minor calyces and collecting tubules. Arrow indicates point of union between collecting tubules and convoluted tubules

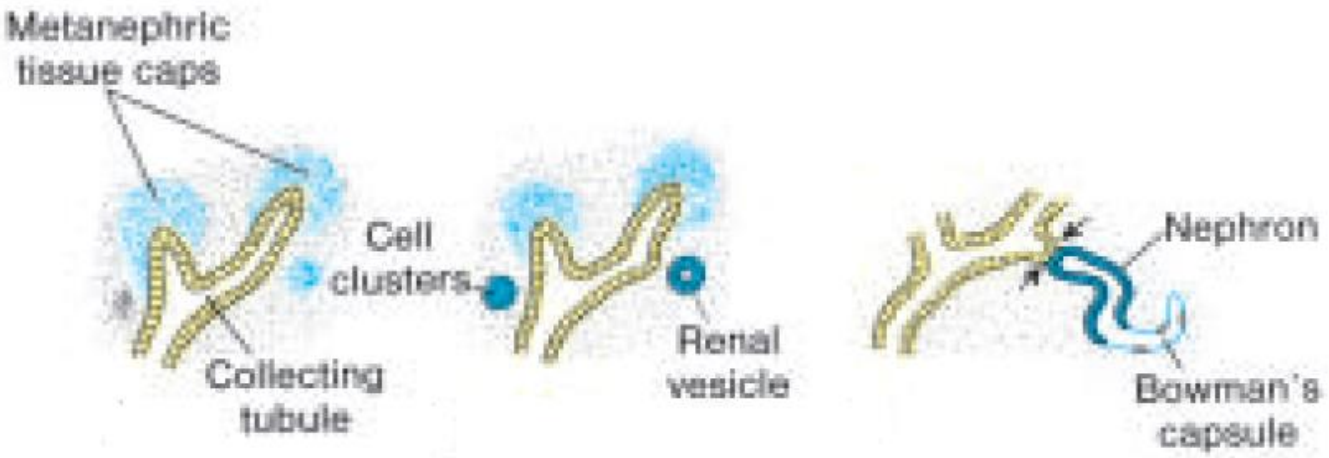
2- Excretory system:

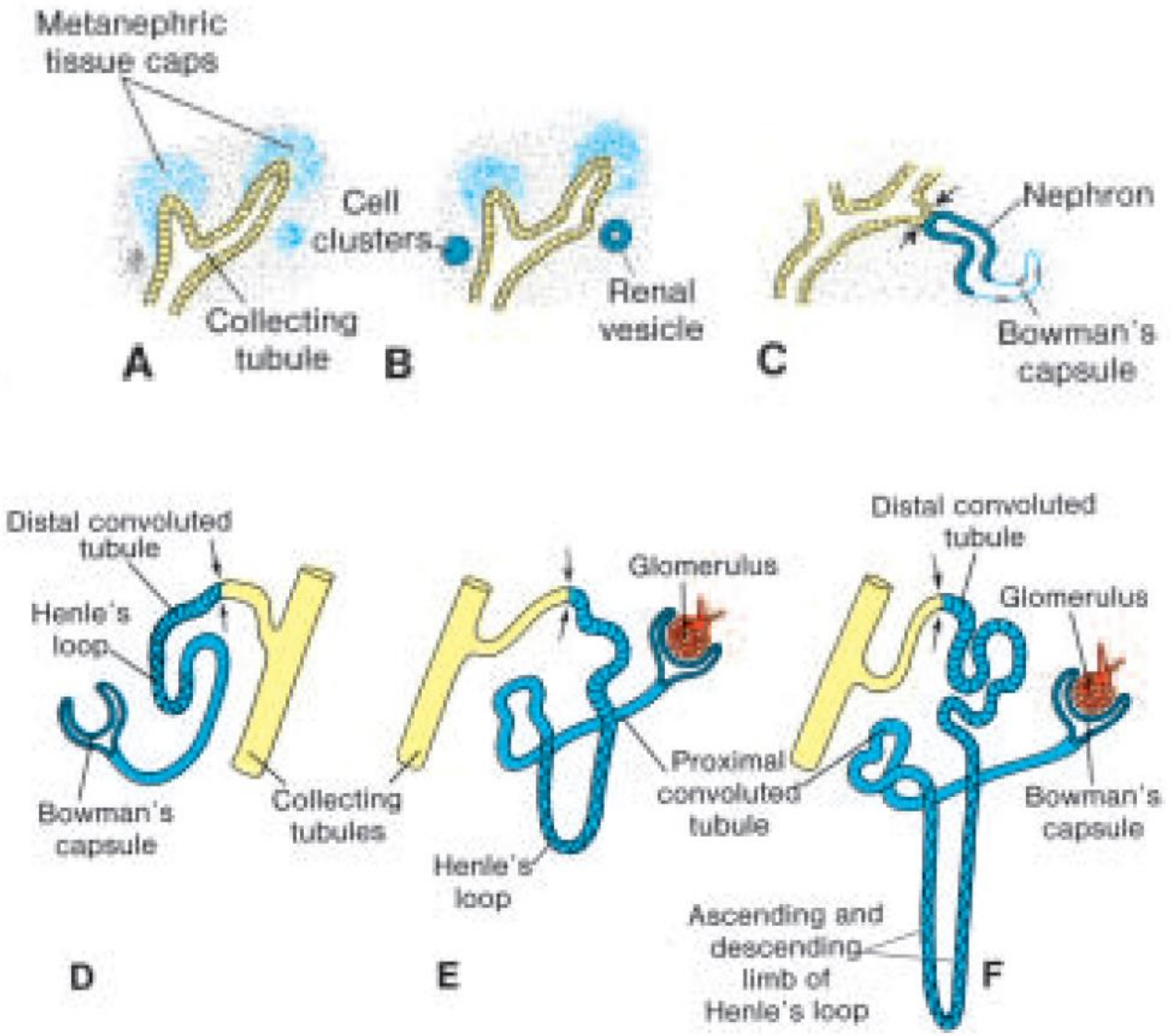
- Develops from ***metanephric tissue***

* Metanephros becomes segmented repeatedly by branching ureteric bud

* Each newly formed collecting tubule becomes covered by a ***metanephric tissue cap***.

* Cells of the tissue cap form small vesicles, ***renal vesicles***, which give rise to ***S-shaped tubules*** that form ***nephrons.***



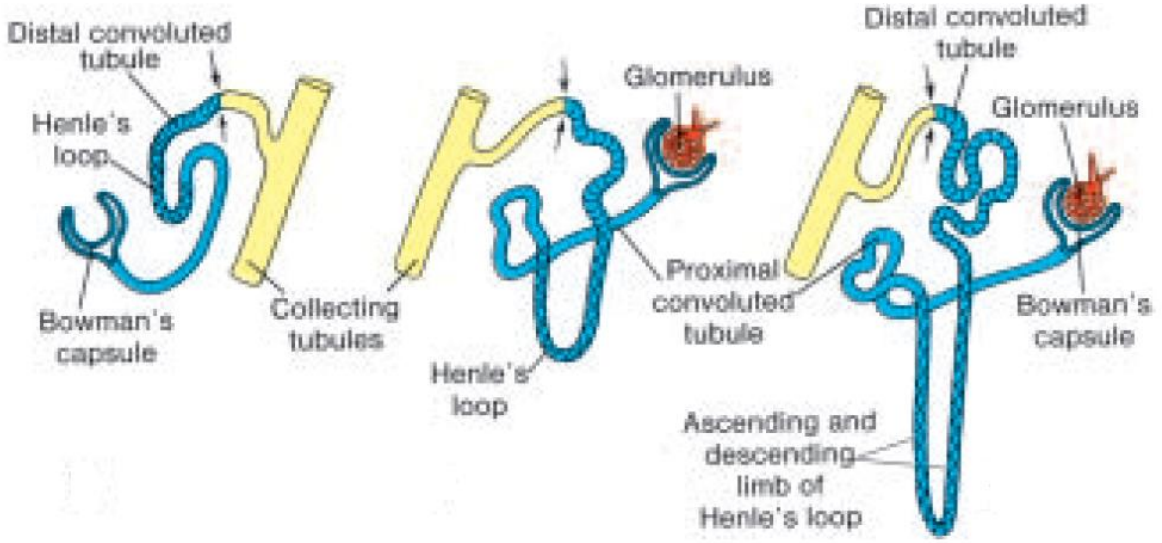


Development of a metanephric excretory unit. *Arrows*, the place where the excretory unit (*blue*) establishes an open communication with the collecting system (*yellow*), allowing flow of urine from the glomerulus into the collecting ducts.

*** One end of the nephron forms Bowman's capsule that acquires a glomerulus of capillaries formed by local angiogenesis.**

*** Other end forms an open connection with one of collecting tubules.**

Continuous lengthening of the tubule results in formation of:
a. Proximal convoluted tubule b. Loop of Henle•
C. Distal convoluted tubule•



Nephrons are formed until birth

- At birth, There are about 1 million nephrons in each kidney.

Urine production:-

- Begins early in gestation by about 10th week (after formation of glomerular capillaries)

- Passes into amniotic cavity and mixes with amniotic fluid

- The fluid is swallowed by the fetus and recycles through the kidneys.

During fetal life,

- Kidneys are not responsible for excretion of waste products.

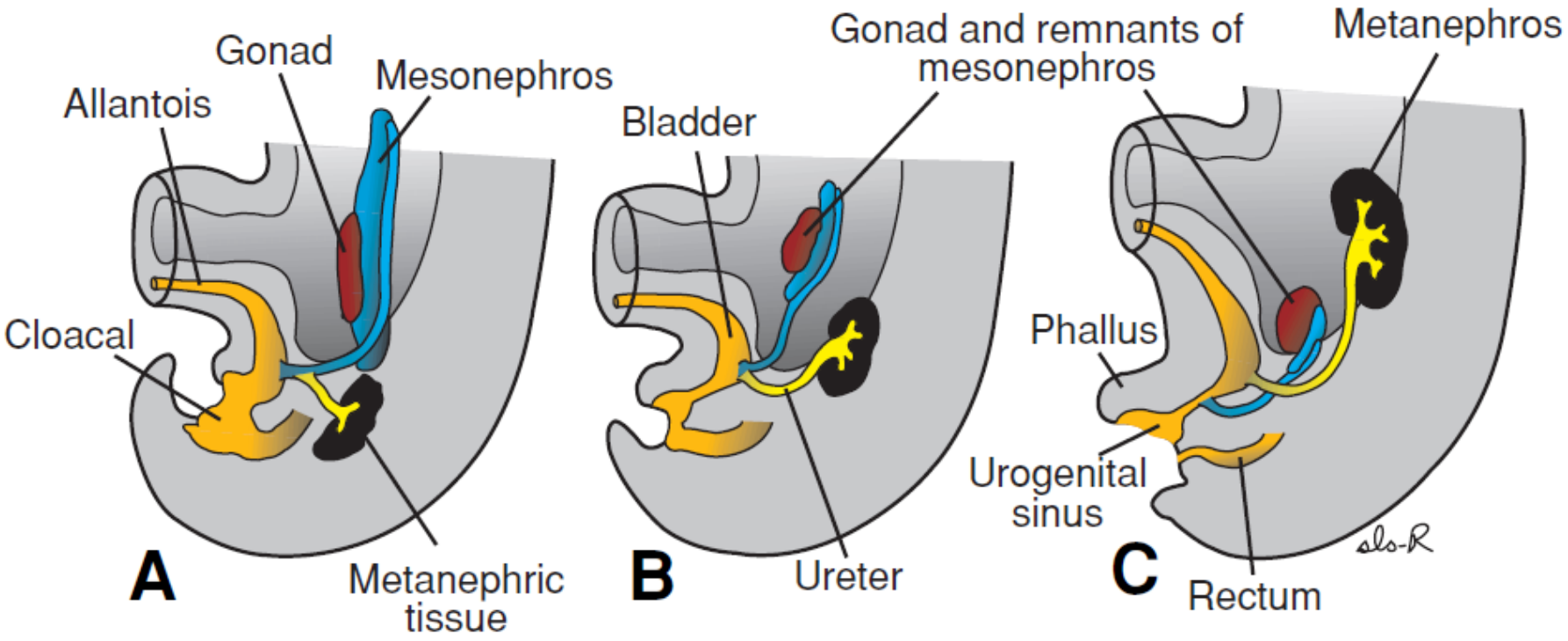
Changes in the developing kidney:

1- Change in shape: At birth the kidneys have a lobulated appearance which disappears during infancy as the result of growth of the nephrons.

2- Change in position: At 1st the kidney is located in the pelvis, later it shifts to the abdomen due to growth of the body in the lumbar and sacral regions.

3- Change in blood supply: In the pelvis, it receives its blood supply from the median sacral artery. During its ascent it is supplied by arteries from the common iliac artery then the aorta at successively higher levels. The lower vessels usually degenerate.

4- Change in direction: At 1st the hilum looks forwards, then the kidney rotates so that the hilum looks medially.



A to **C.** Ascent of the kidneys. Note the change in position between the mesonephric and metanephric systems. The mesonephric system degenerates almost entirely, and only a few remnants persist in close contact with the gonad. In both male and female embryos, the gonads descend from their original level to a much lower position.

Congenital anomalies of the kidney:

1- Renal agenesis: May be unilateral or bilateral

2- Congenital cystic kidney: Caused by failure of union between some collecting and excretory tubules

- May be polycystic kidney or solitary cyst

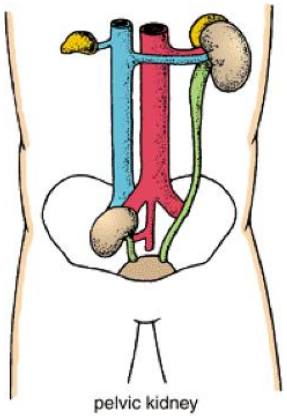
3- Double kidney: Caused by early splitting of ureteric bud.

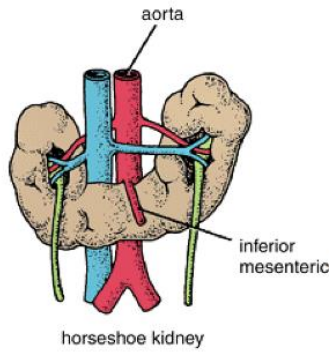
4- Pelvic kidney: Caused by failure of the kidney to ascend.

5- Horseshoe kidney: The kidneys fuse at their lower poles.

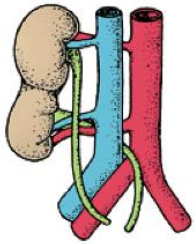
6- Persistent fetal lobulation.

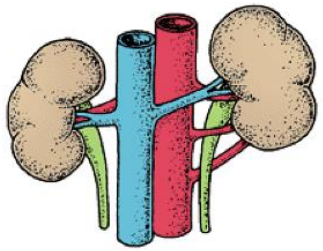
7- Aberrant renal artery: Caused by persistence of one or more of transient arteries.

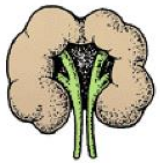

pelvic kidney

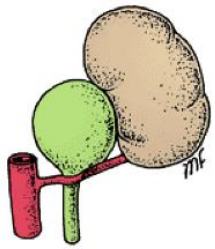


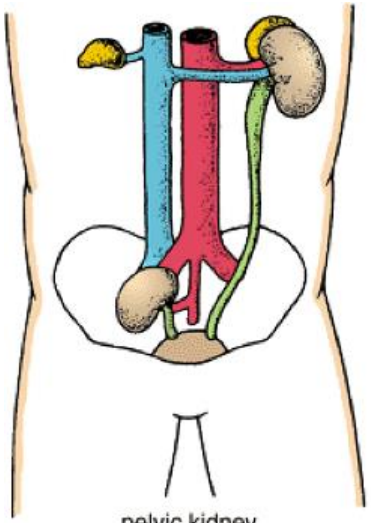
horseshoe kidney


unilateral double kidney

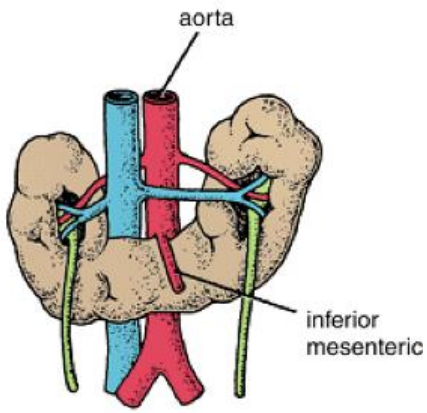

aberrant renal arteries


rosette kidney (cake kidney)

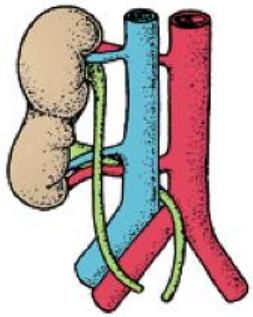

aberrant renal artery causing urinary obstruction



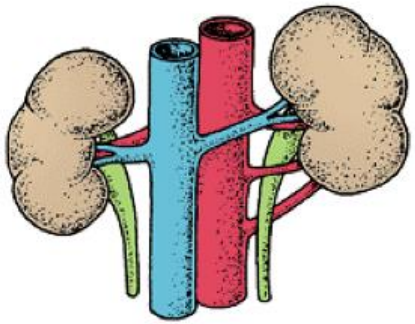
pelvic kidney



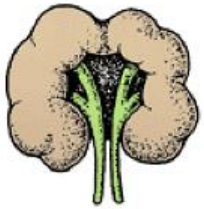
horseshoe kidney



unilateral double kidney



aberrant renal arteries



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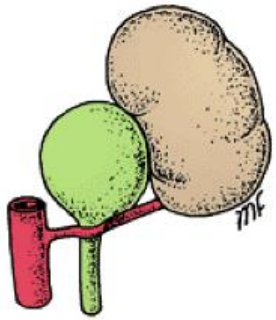

aberrant renal artery causing
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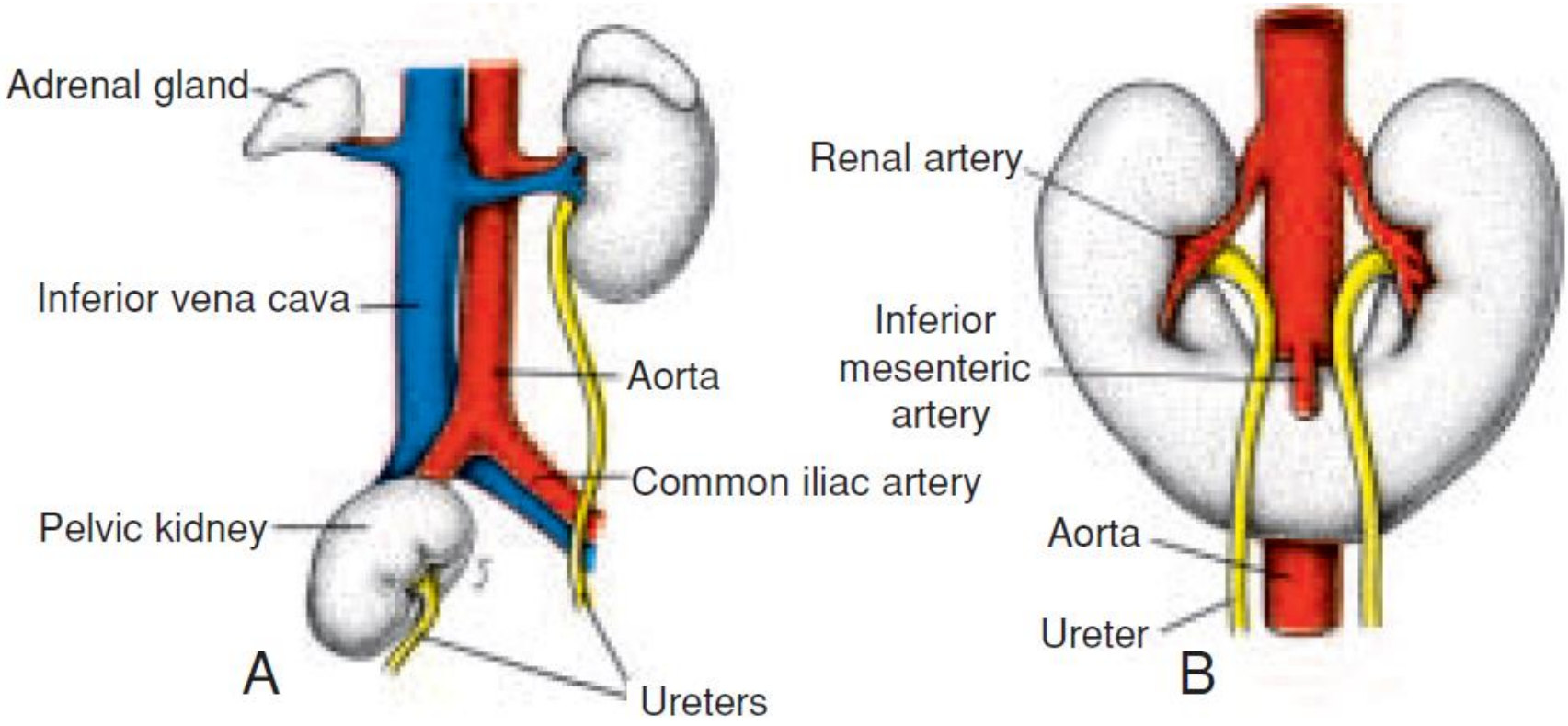


A. Unilateral pelvic kidney showing position of the adrenal gland on the affected side
B. Horse-kidneys showing position of inferior mesenteric artery

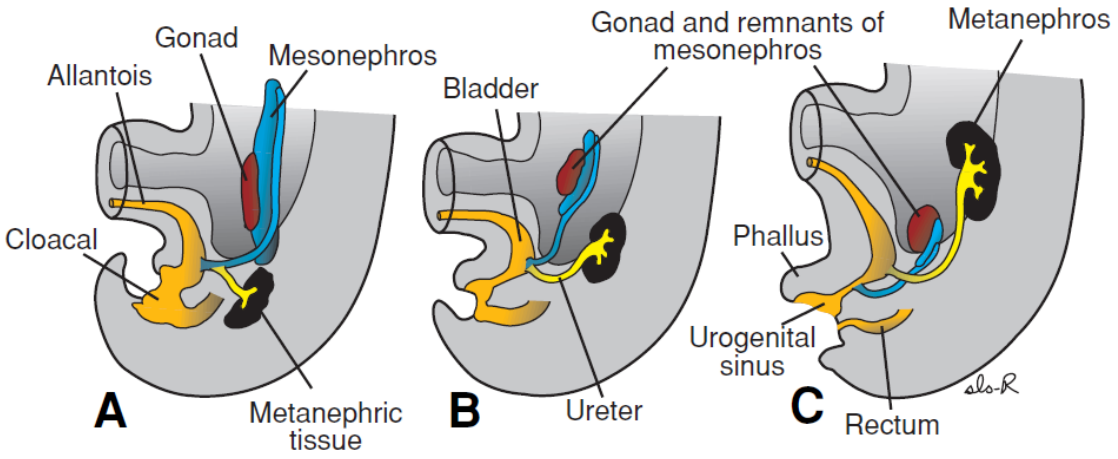
URETER

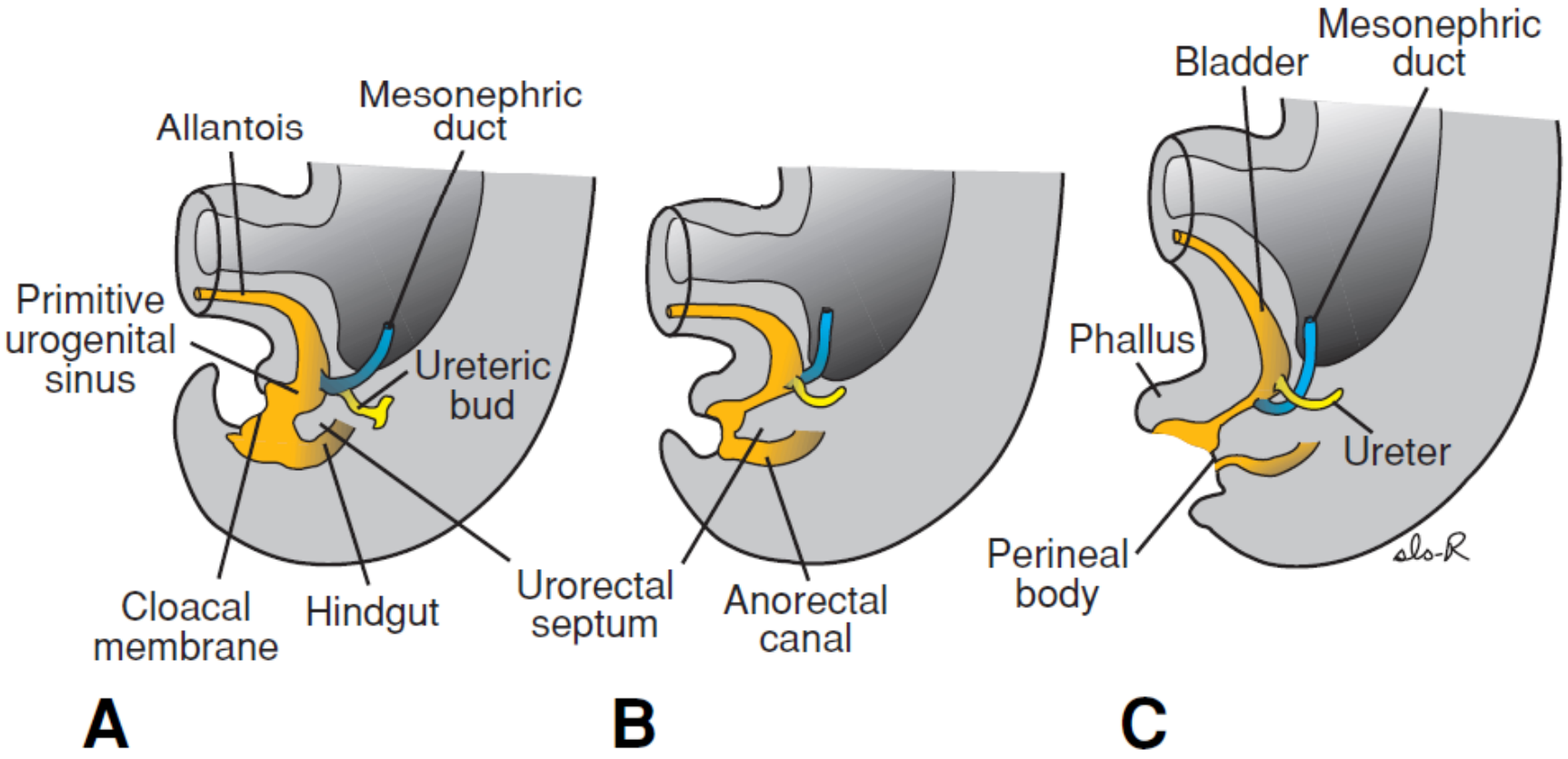
- Develops from the ureteric bud which arises from mesonephric duct.

- Caudal part of the mesonephric duct (below ureteric bud) is absorbed into ventral part of the cloaca to form trigone of the urinary bladder.

- As a result, the 2 ureteric buds and the 2 mesonephric ducts open separately into the urinary bladder.

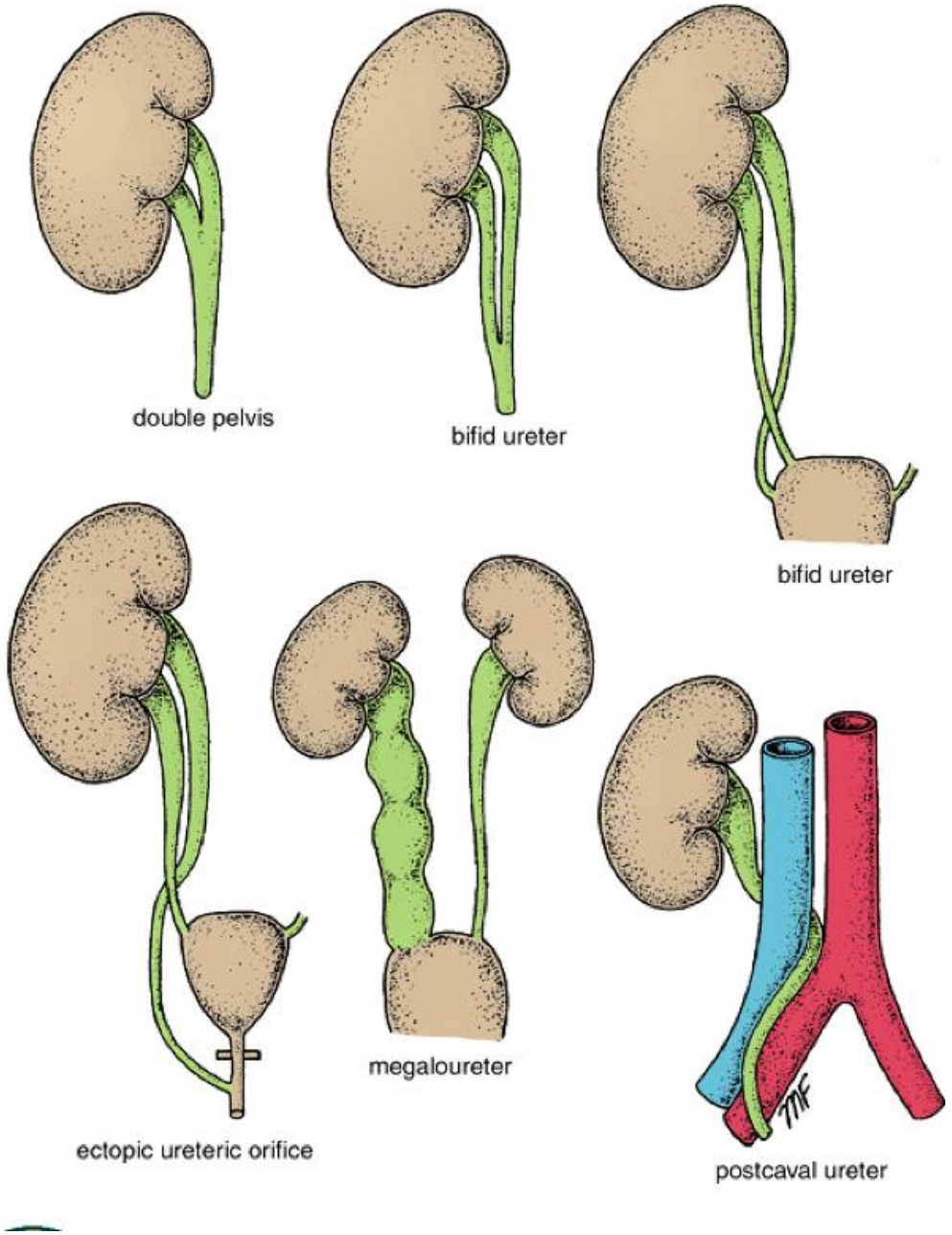
- As the result of ascent of the kidneys, *ureters elongate*.

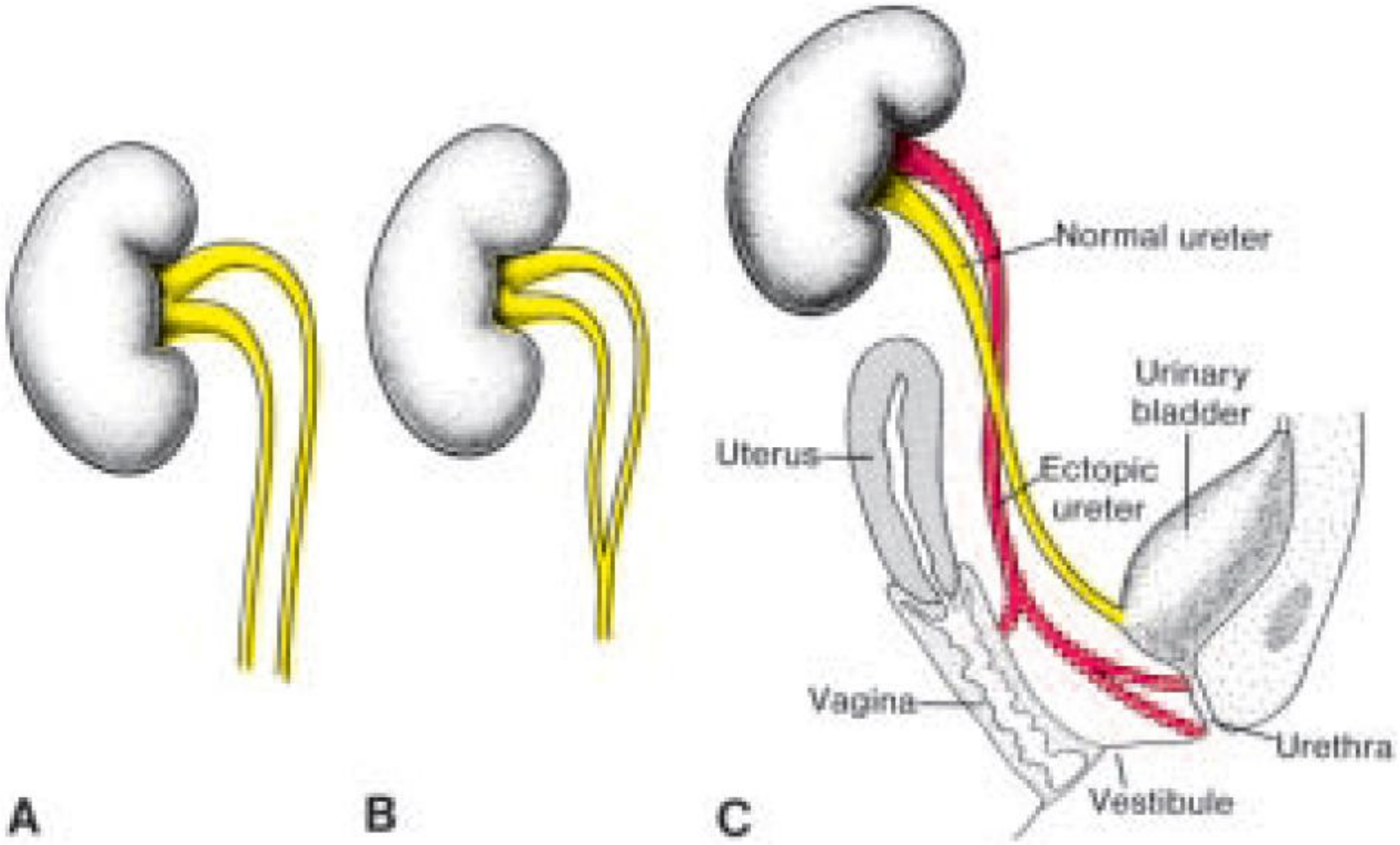




Divisions of the cloaca into the urogenital sinus and anorectal canal. The mesonephric duct is gradually absorbed into the wall of the urogenital sinus, and the ureters enter separately. **A.** At the end of the fifth week. **B.** 7 weeks. **C.** 8 weeks.

Some common congenital anomalies of the ureter.





A. Complete double ureter
B. Partial double ureter
C. Possible sites of ectopic ureteral openings in the vagina, urethra and vestibule

Urinary Bladder and Urethra

Derived from 2 sources:

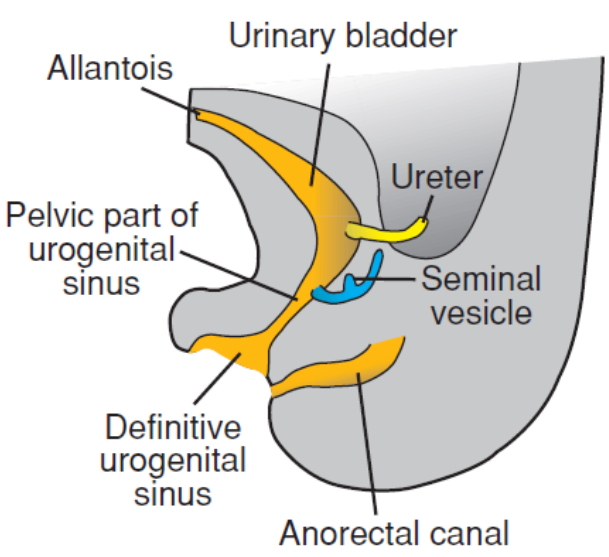
1- Endoderm of part of cloaca:

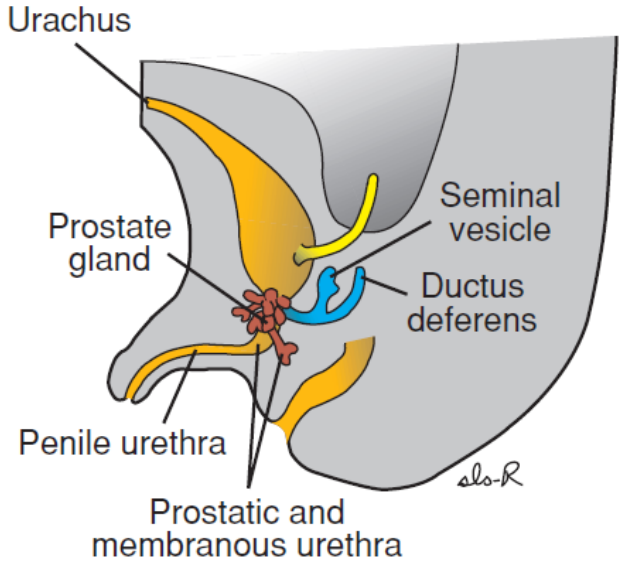
- Cloaca is divided by urorectal septum into 2 parts:

a- Primitive urogenital sinus: Ventral part

- Closed caudally by urogenital membrane
- Connected to mesonephric ducts and allantois which extends to umbilicus.

b- Anorectal canal: Closed caudally by anal membrane.





Primitive urogenital sinus differentiates into 3 portions:

a- Vesical portion: Cranial largest part

- Its apex is connected to the allantois

- In male: Gives epithelium of most of urinary bladder and part of prostatic urethera.

In female: Gives epithelium of most of urinary bladder and whole urethera

- Intraembryonic part of allantois constricts forming urachus, fibrous cord that connects apex of the bladder with the umbilicus.

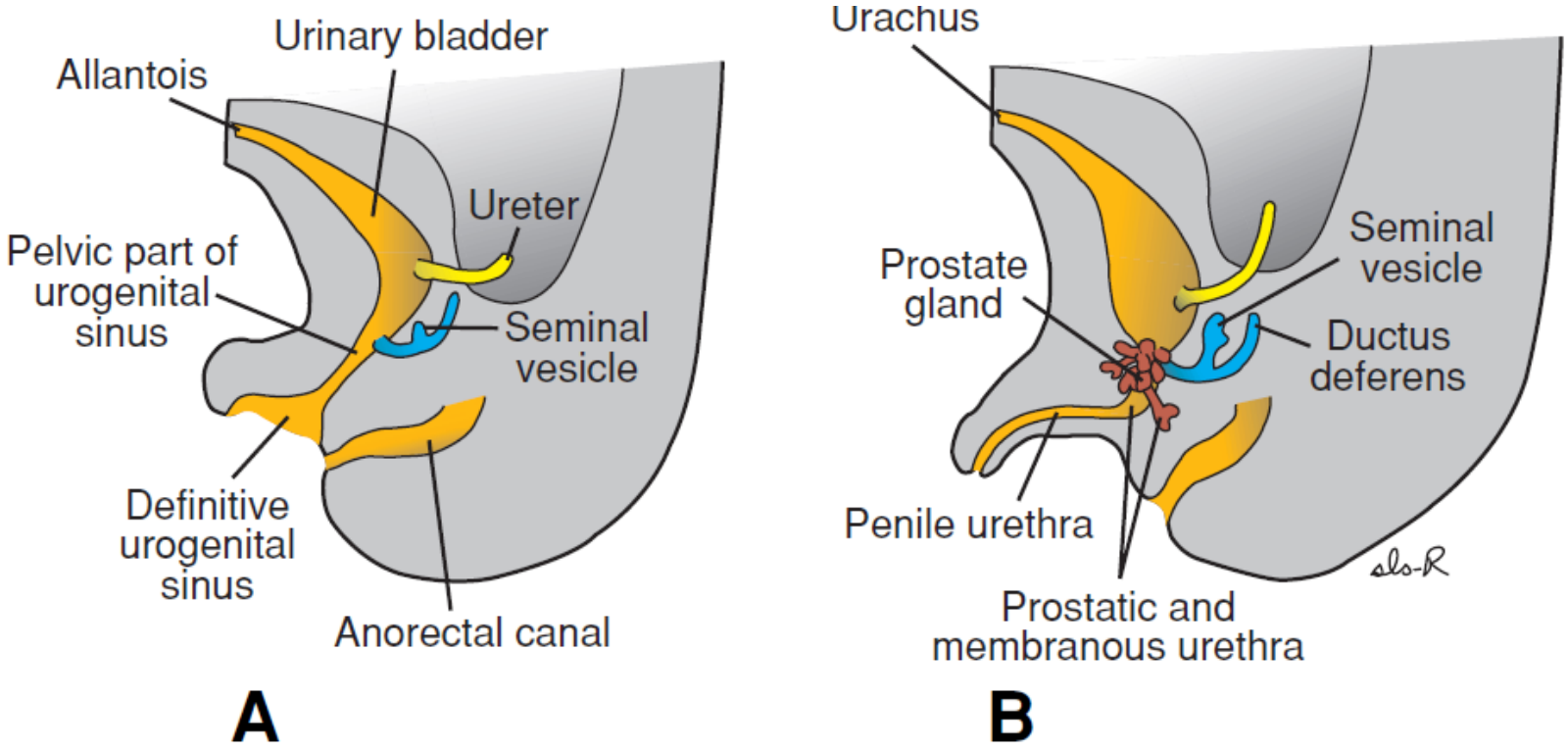
In adults: Urachus forms median umbilical ligament.

b- Pelvic portion: Middle narrow part

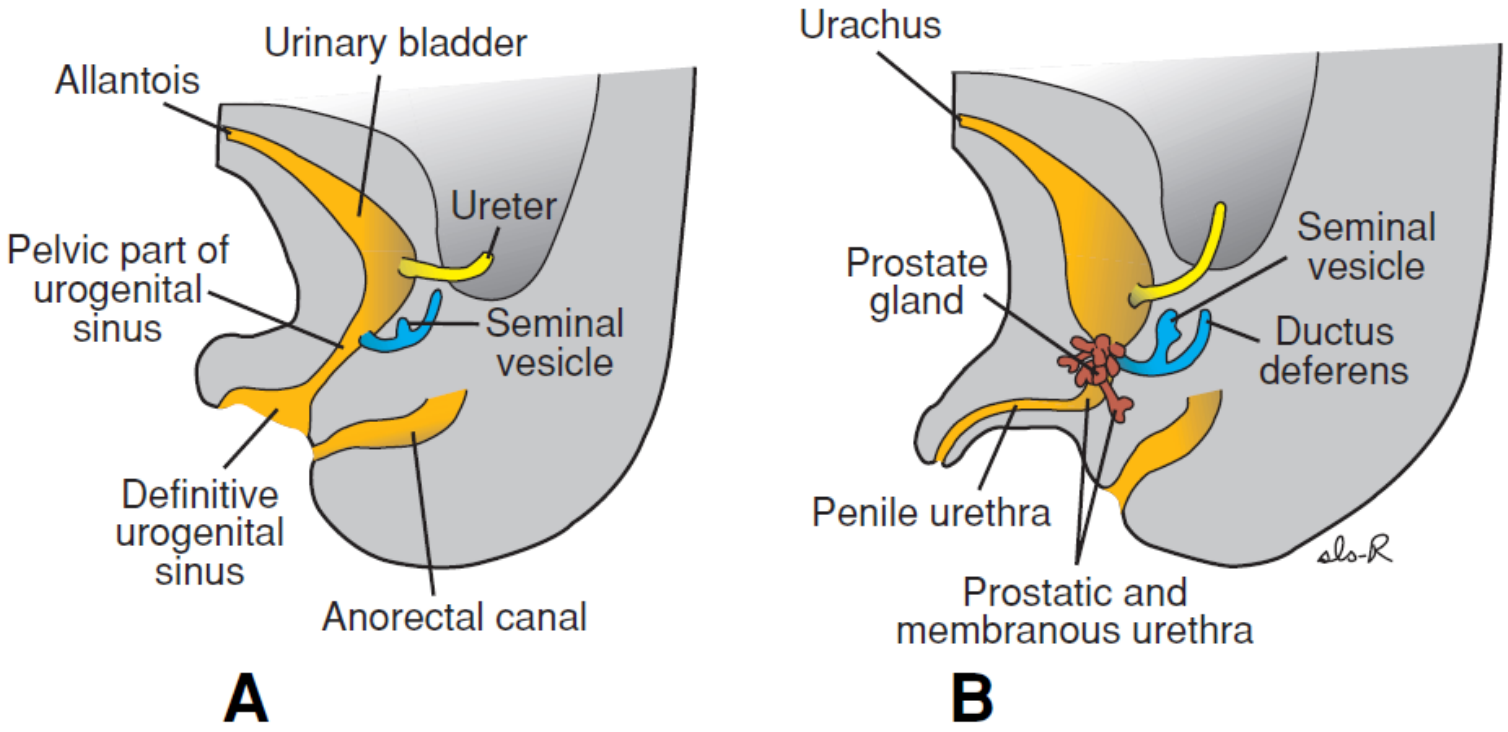
- Mesonephric ducts are attached between vesical and pelvic portions.

c- Phallic portion: Caudal part

- Closed by urogenital membrane



A. Development of the urogenital sinus into the urinary bladder and definitive urogenital sinus. **B.** In the male the definitive urogenital sinus develops into the penile urethra. The prostate gland is formed by buds from the urethra, and seminal vesicles are formed by budding from the ductus deferens.



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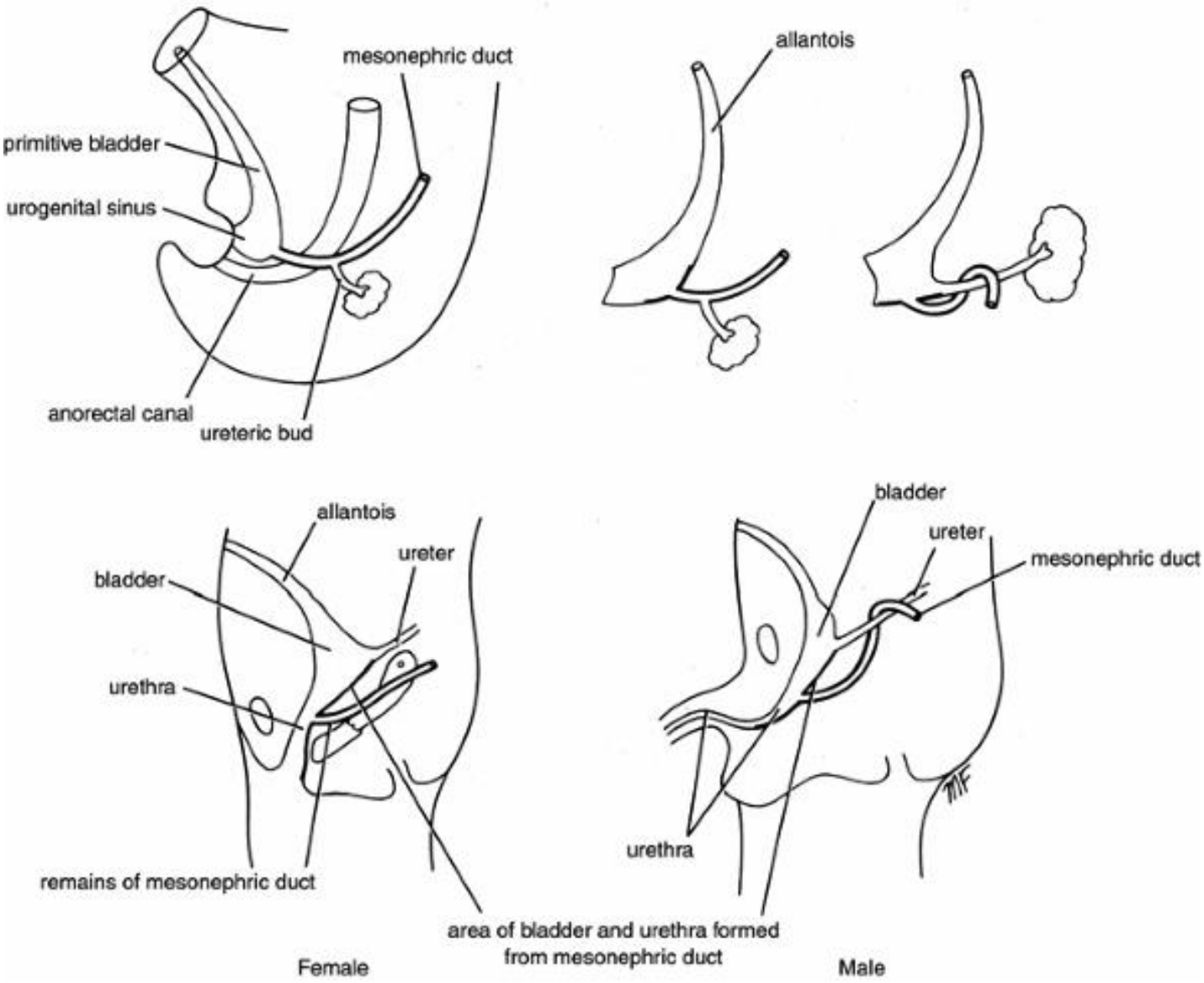
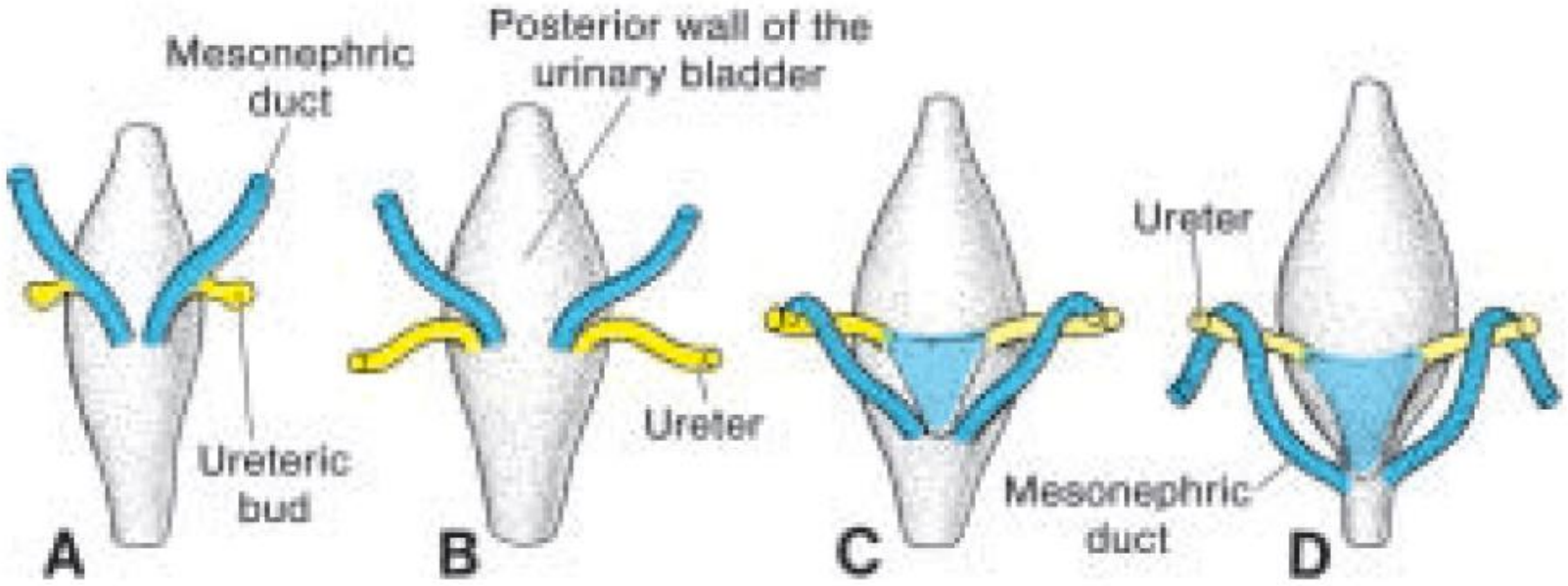


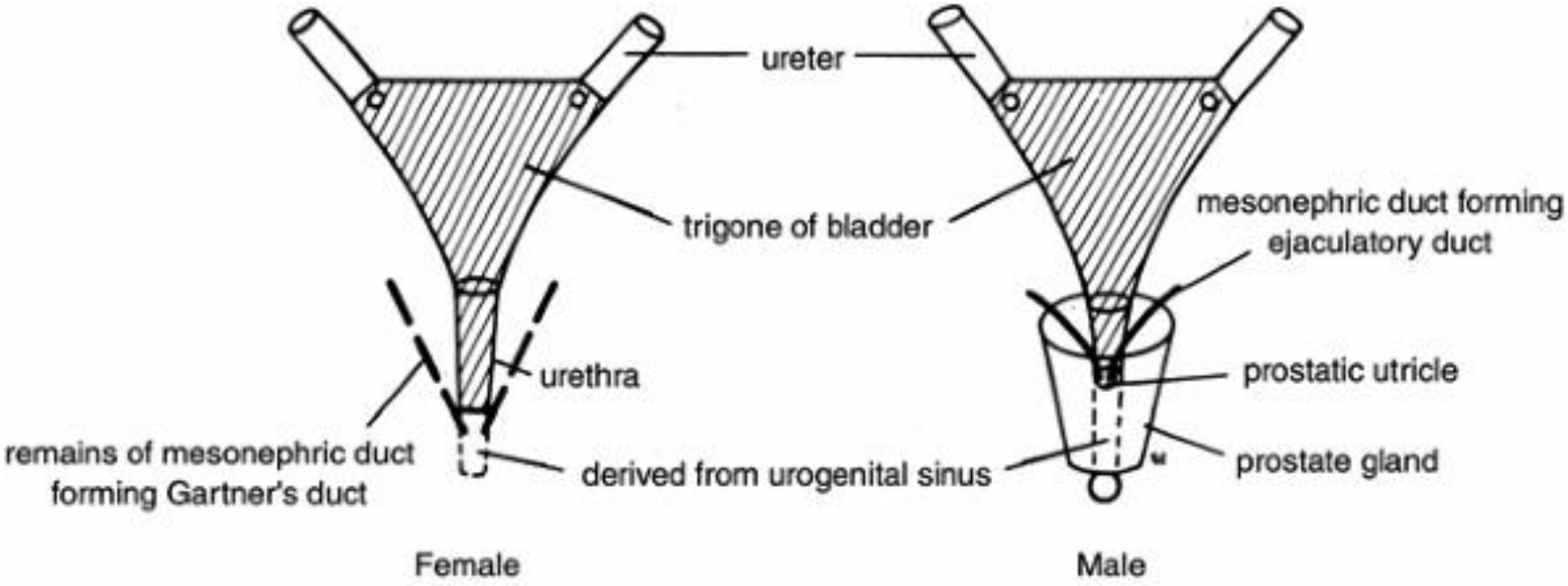
Formation of urinary bladder from anterior part of cloaca and terminal parts of mesonephric ducts in both sexes.

2- Mesoderm of lower part of mesonephric ducts:

- Caudal ends of mesonephric ducts below ureteric buds are absorbed forming trigone of the urinary bladder

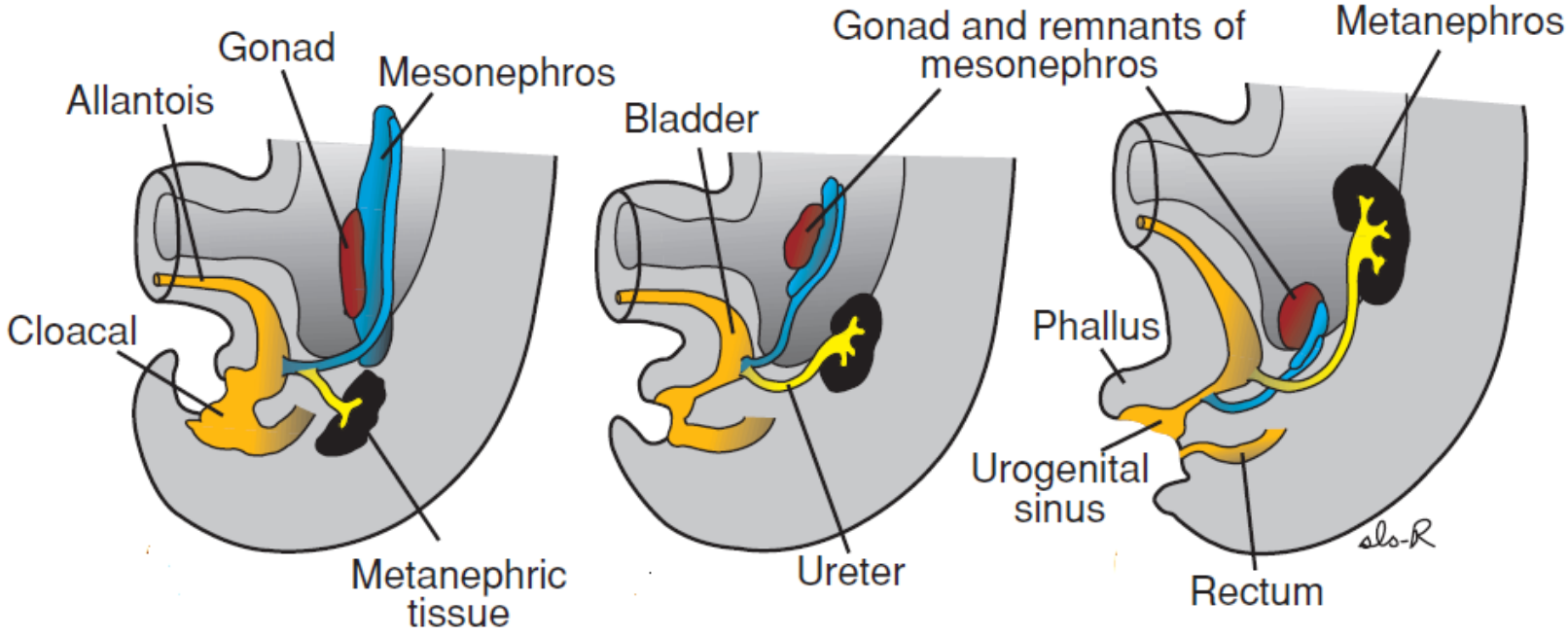


Dorsal views of the bladder showing the relation of the ureters and mesonephric ducts during development. Initially the ureters are formed by an outgrowth of the mesonephric duct **(A),** but with time they assume a separate entrance into the urinary bladder **(B–D)**. Note the trigone of the bladder formed by incorporation of the mesonephric ducts **(C** and **D)**.



Parts of the bladder and urethra derived from mesonephric ducts in both sexes (hatch marks). Lower end of urethra in the female and lower part of prostatic urethra in the male are formed from urogenital sinus.

- As kidneys ascend, ureteric orifices are dragged cranio-laterally while mesonephric ducts remain at a lower level.



NOTES:

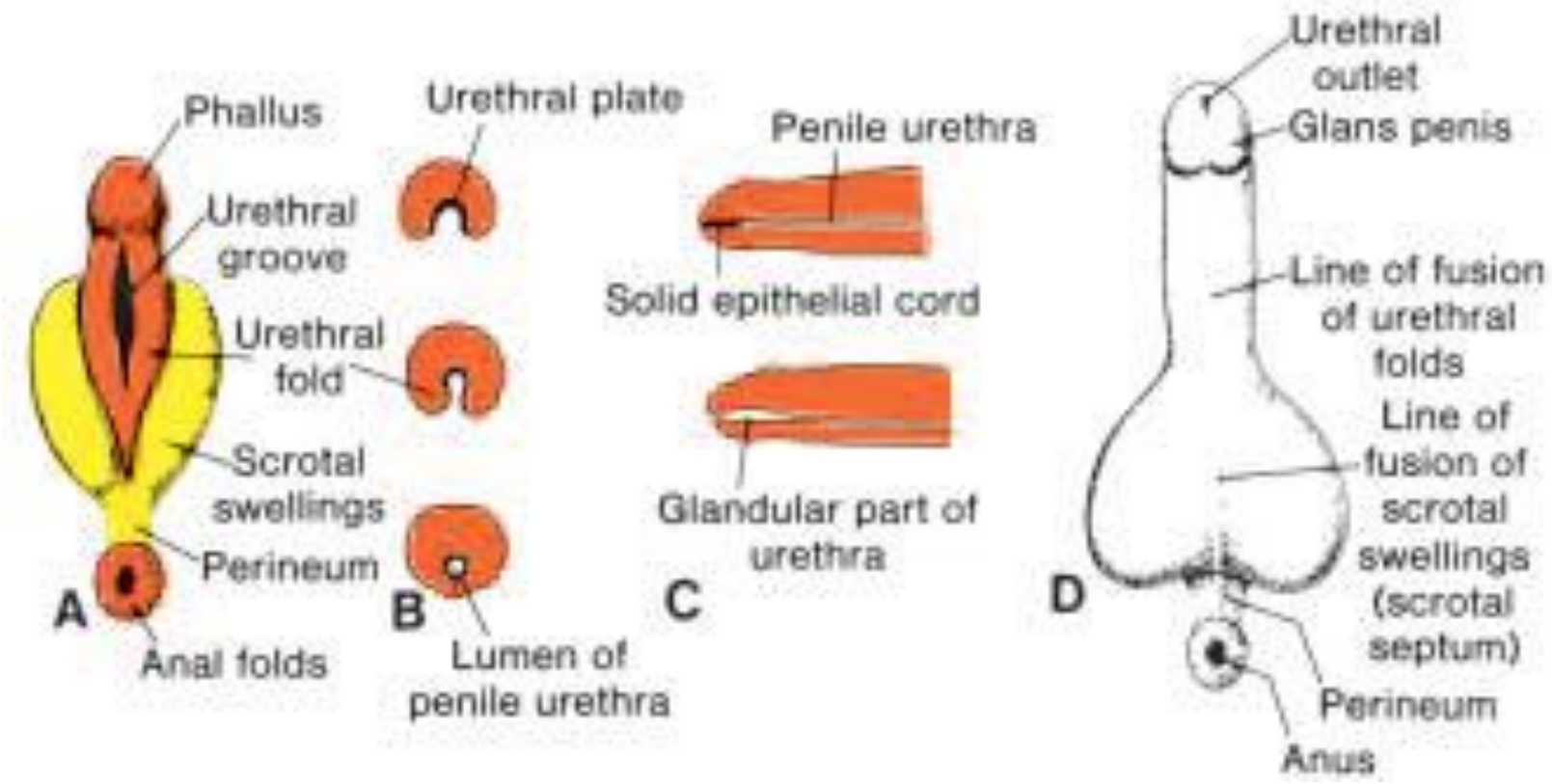
- Rest of bladder wall is derived from surrounding splanchnic mesoderm.

- At birth: Urinary bladder is an abdominal organ.

- At puberty: It becomes a pelvic organ.

- As trigone of the bladder develops from mesonephric ducts, it is mesodermal.

-With time: Mesodermal lining is replaced by endodermal epithelium that spread from rest of the bladder.



A. Development of external genitalia in the male at 10 weeks.

B. Note: Deep urethral groove flanked by urethral folds.

B. Transverse sections through the phallus during formation of penile urethra. Urogenital groove is bridged by urethral folds.

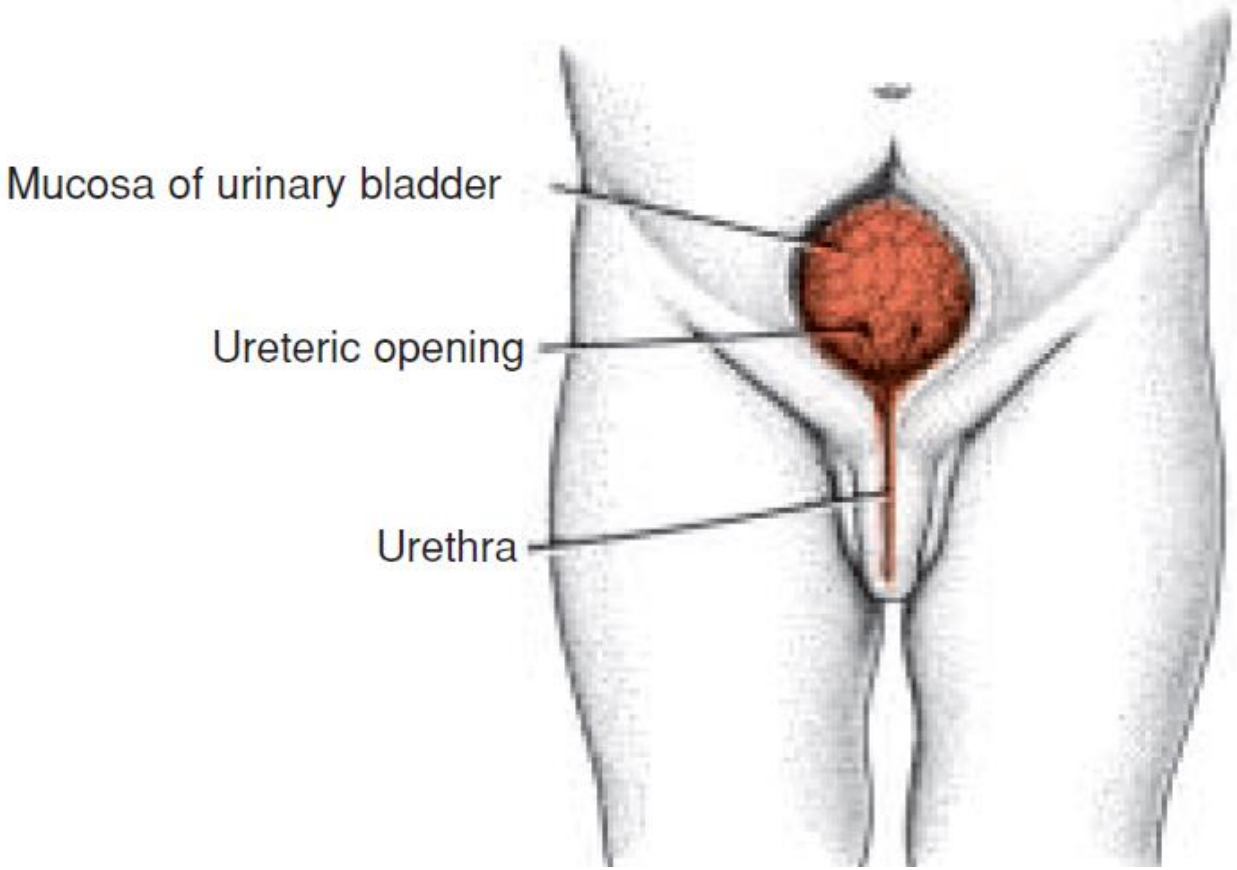
C. Development of glandular portion of the penile urethra.

D. Newborn.

Congenital anomalies of urinary bladder and urethra:

1- Ectopia vesical with epispadius:

- Mucosa of posterior bladder wall is exposed to the outside due to absence of the anterior wall together with overlying anterior abdominal wall

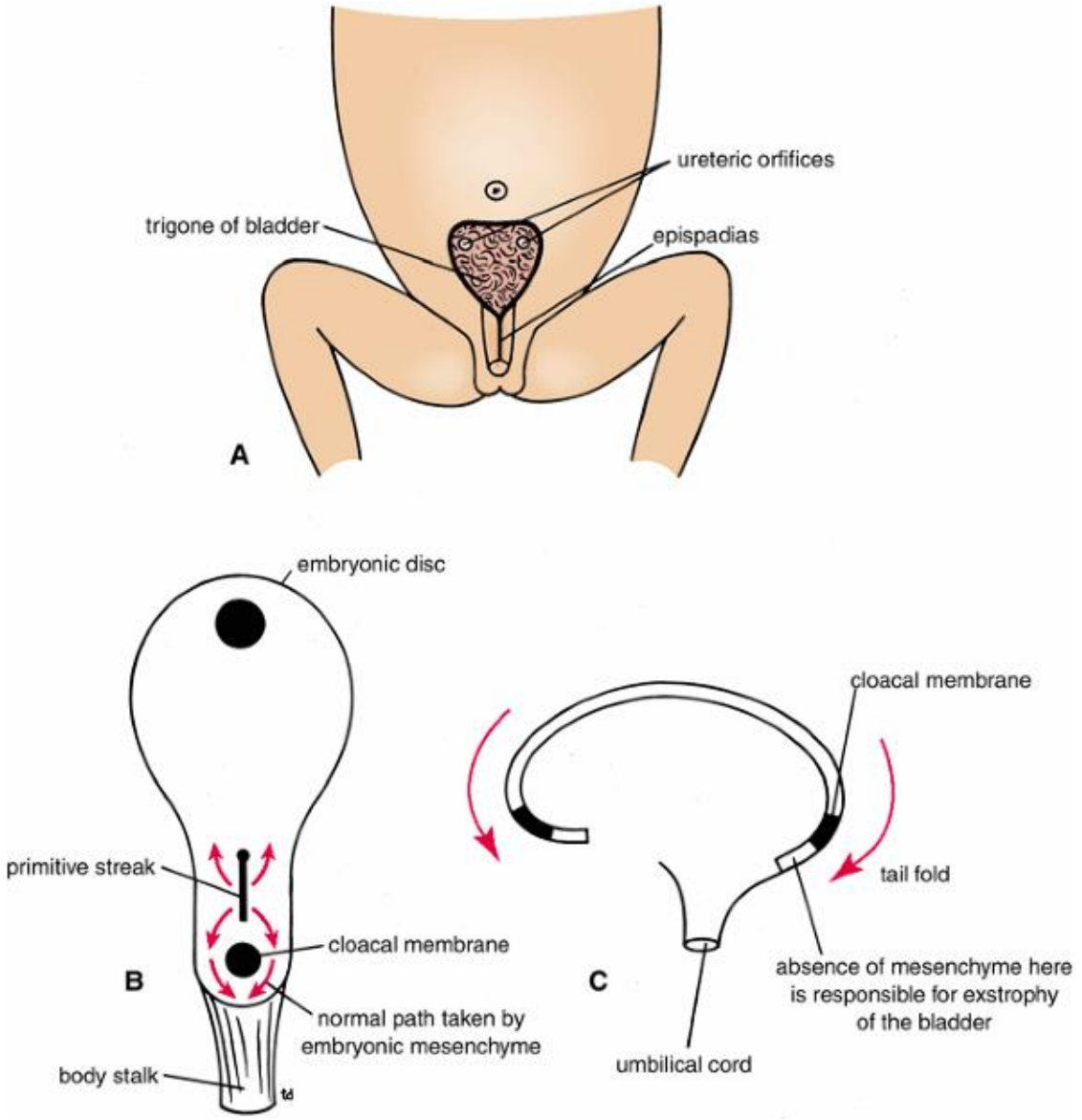


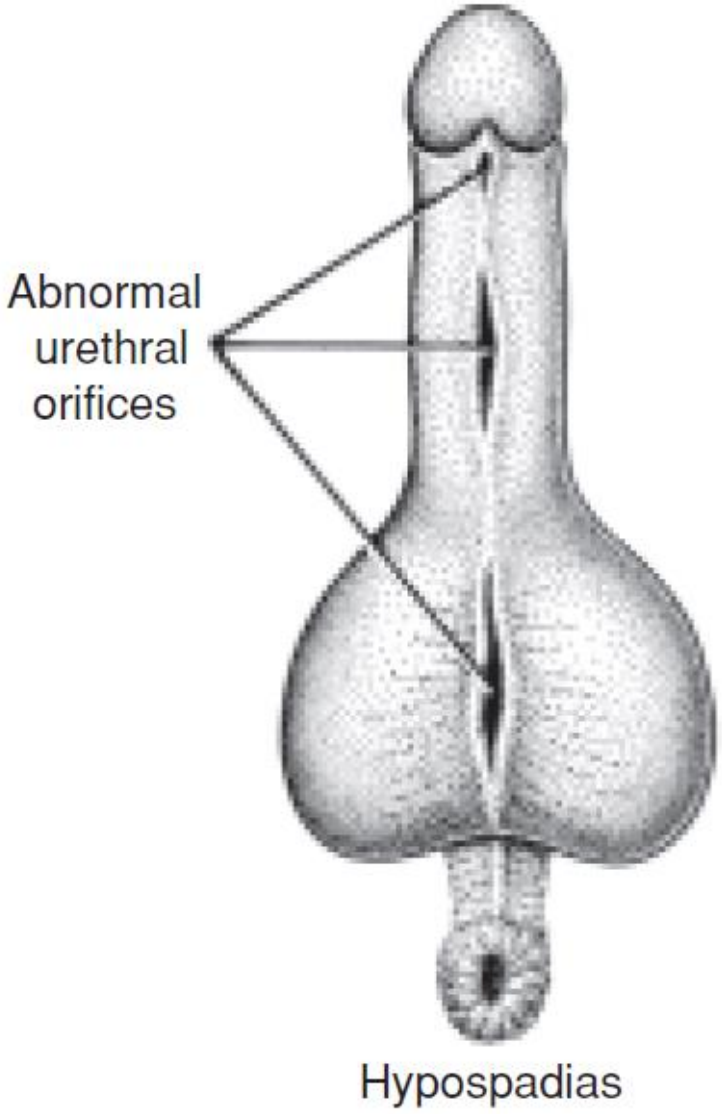
1. Ectopia Vesica with epispadius:

A. Exstrophy of bladder:

B. Dorsal view of embryonic disc. Normal path taken by growing embryonic mesenchyme in region of cloaca.

C. Fetus as seen from the side. Head and tail folds have developed, but mesenchyme has failed to enter ventral body wall between the cloaca and umbilical cord.





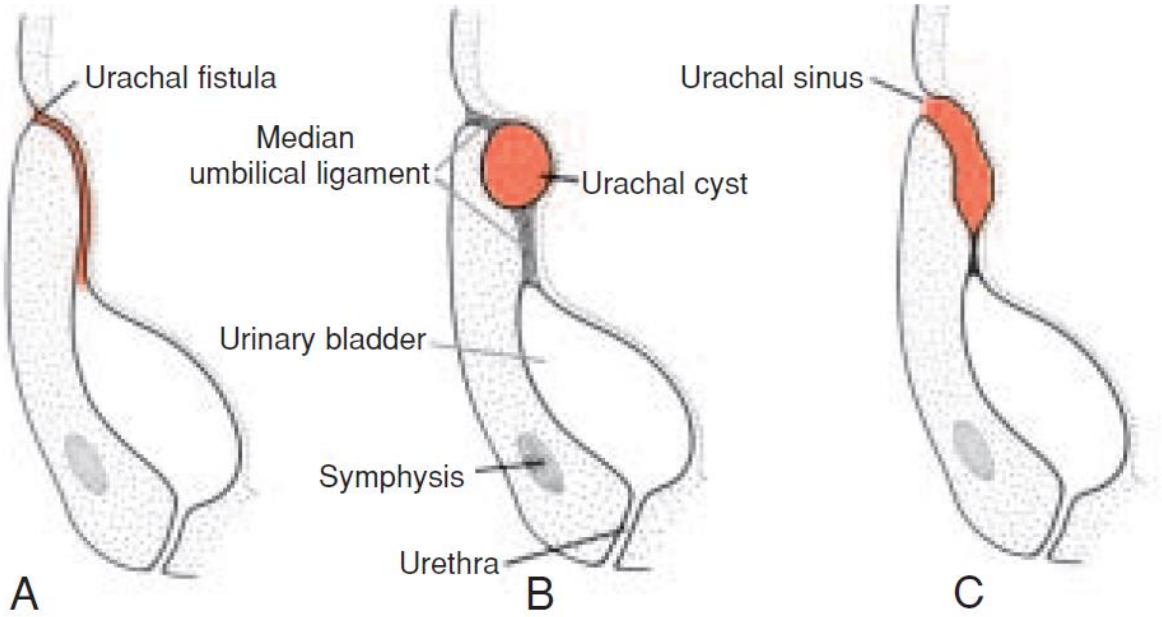
2. Hypospadius; Urethra is open on ventral surface of the penis

3. Patent urachus:

a- Urachal fistula: Allantois does not constrict and urine flow from the umbilicus.

c- Urachal cyst: Cystic dilatation along course of urachus

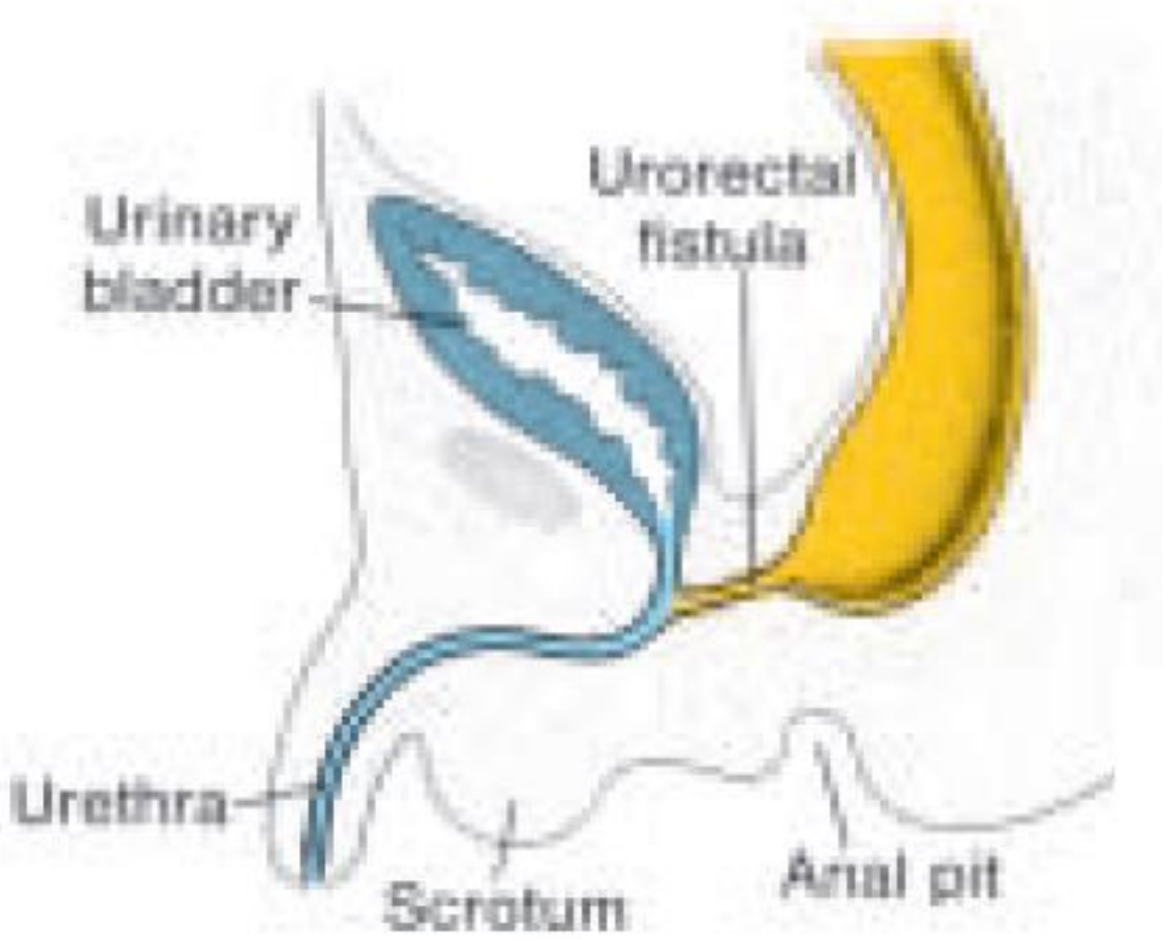
b- Urachal sinus: Patent upper part of the urachus.



A. Urachal fistula. **B.** Urachal cyst. **C.** Urachal sinus. The sinus may or may not be in open communication with the urinary bladder.

3- Recto-vesical fistula:

- Caused by incomplete urorectal septum.



THANK YOU