General Anatomy Module

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Embryology of the UGS

UGS Development

- **By the end of this session, you should be able to:**

1. Identify the different steps and components that will eventually lead to formation of the urogenital tract in both sexes

Embryonic Kidney

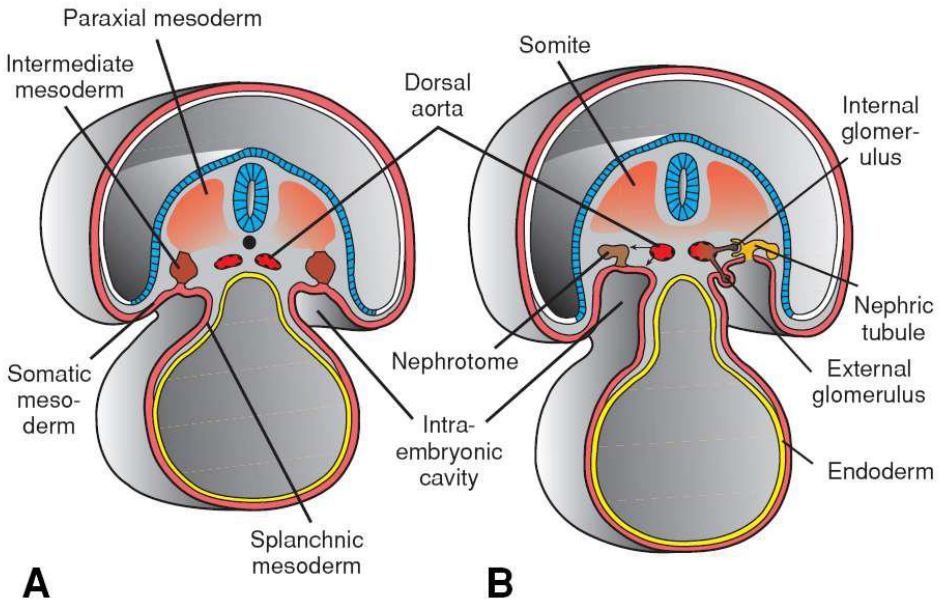
- Three slightly overlapping kidney systems are formed in a cranial to caudal sequence during intrauterine life in humans:

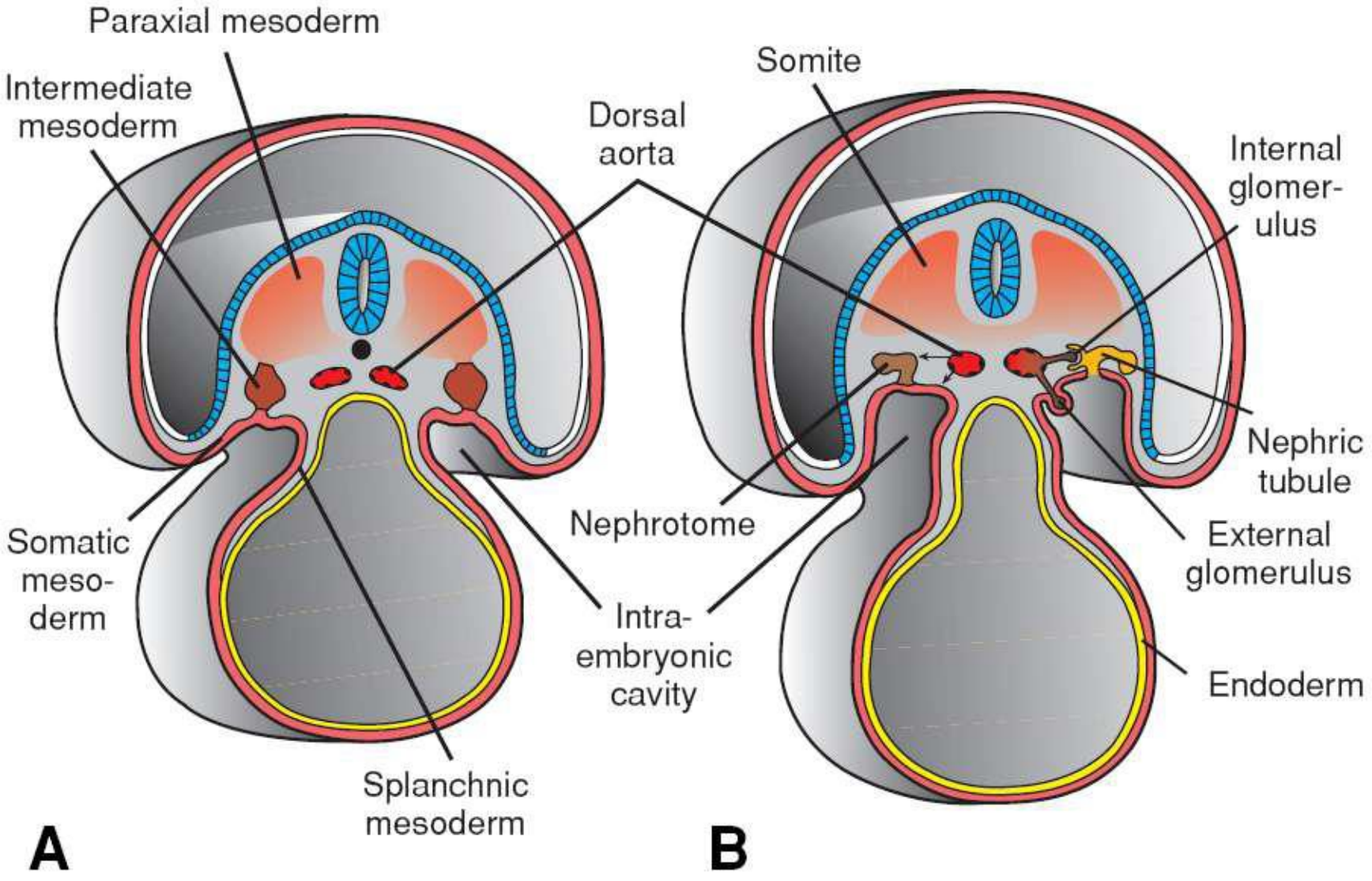
1. **The pronephros, (rudimentary and nonfunctional).**
2. **The mesonephros, (function for a short time during the early fetal period).**
3. **The metanephros, (forms the permanent kidney)**

Intermediate Mesoderm

- Early Development – 3 successive stages

- Pronephros, Mesonephros, Metanephros




Paraxial mesoderm
Intermediate mesoderm
Somatic meso-derm
Splanchnic mesoderm
A
Dorsal aorta
Somite
Internal glomer-ulus
Nephrotome
Nephric tubule
External glomerulus
Intra-embryonic cavity
Endoderm
B

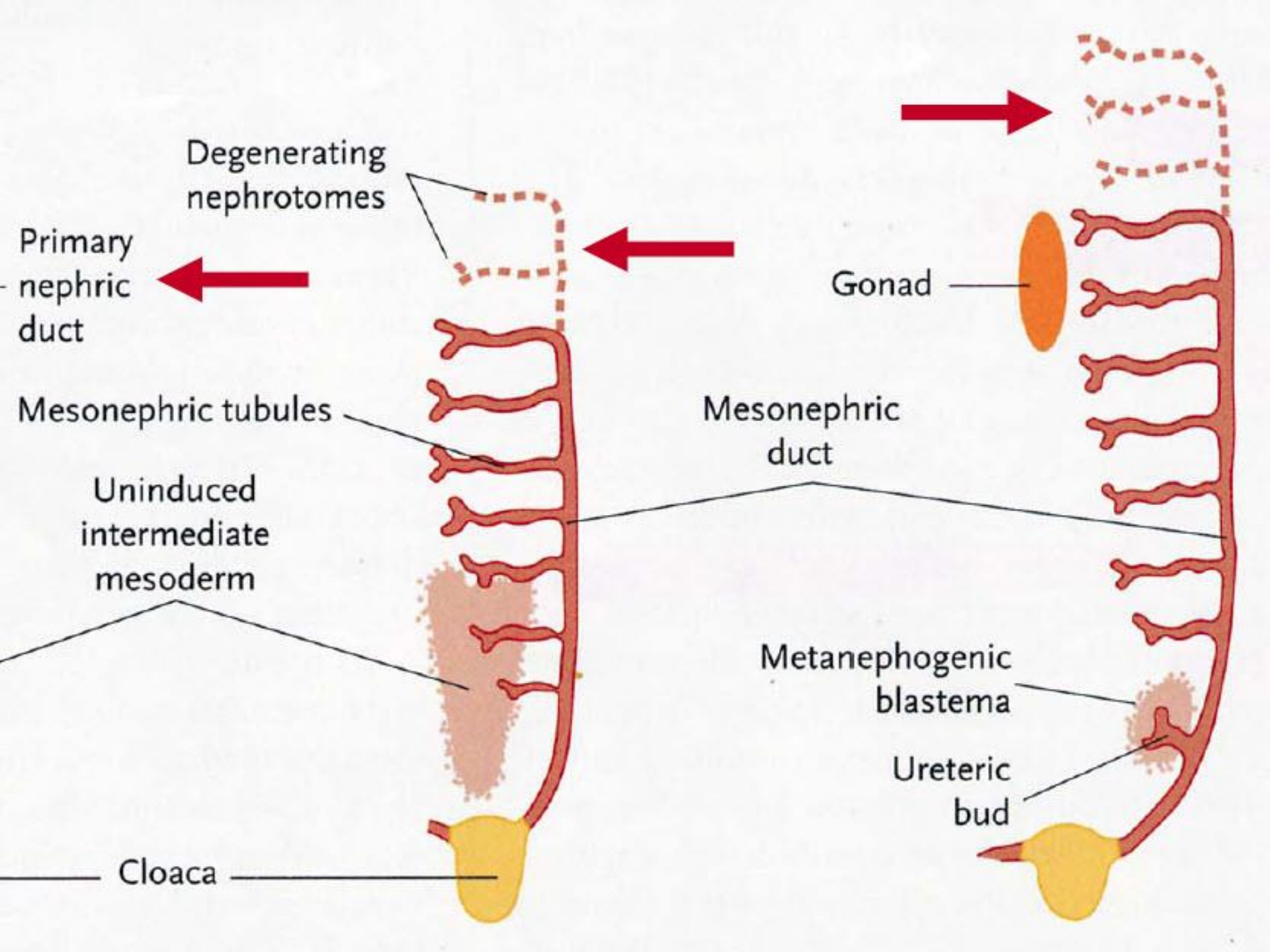
Pronephros

- **At the beginning** of the **fourth week**, the pronephros is represented by **7 to 10 solid cell groups** in the cervical region (***Non Functional***)

- These groups form vestigial excretory units, **nephrotomes**, that ***regress before more caudal ones are formed.***

Pronephros

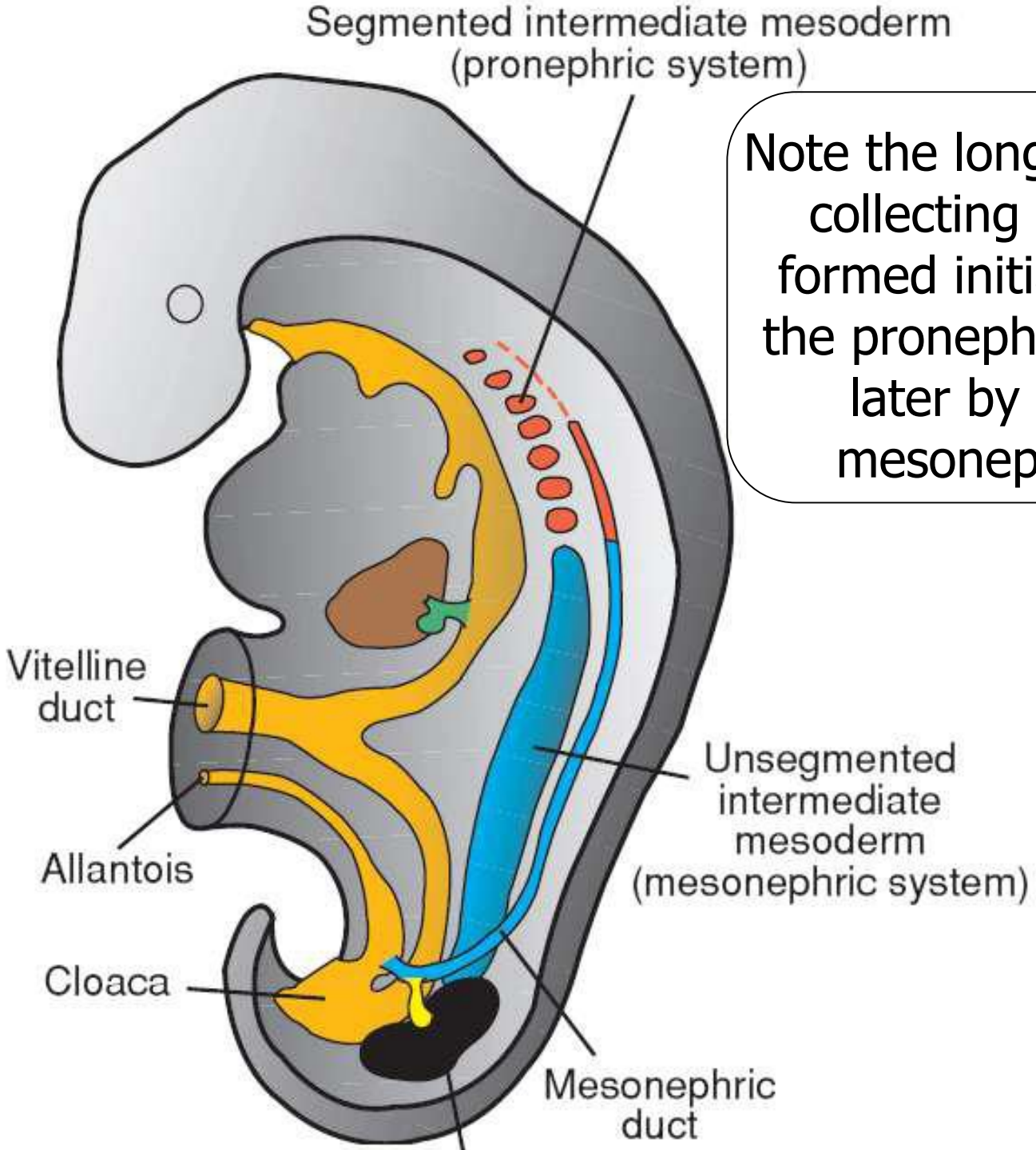
- **By the end** of the **fourth week**, all indications of the pronephric system have **disappeared** leaving ***Primary nephric duct*** extends caudally to ***become*** the ***Mesonephric duct***


Degenerating nephrotomes
Primary nephric duct
Mesonephric tubules
Uninduced intermediate mesoderm
Cloaca
Gonad
Mesonephric duct
Metanephogenic blastema
Ureteric bud

Pronephros

- In cervical and upper thoracic regions intermediate mesoderm is segmented

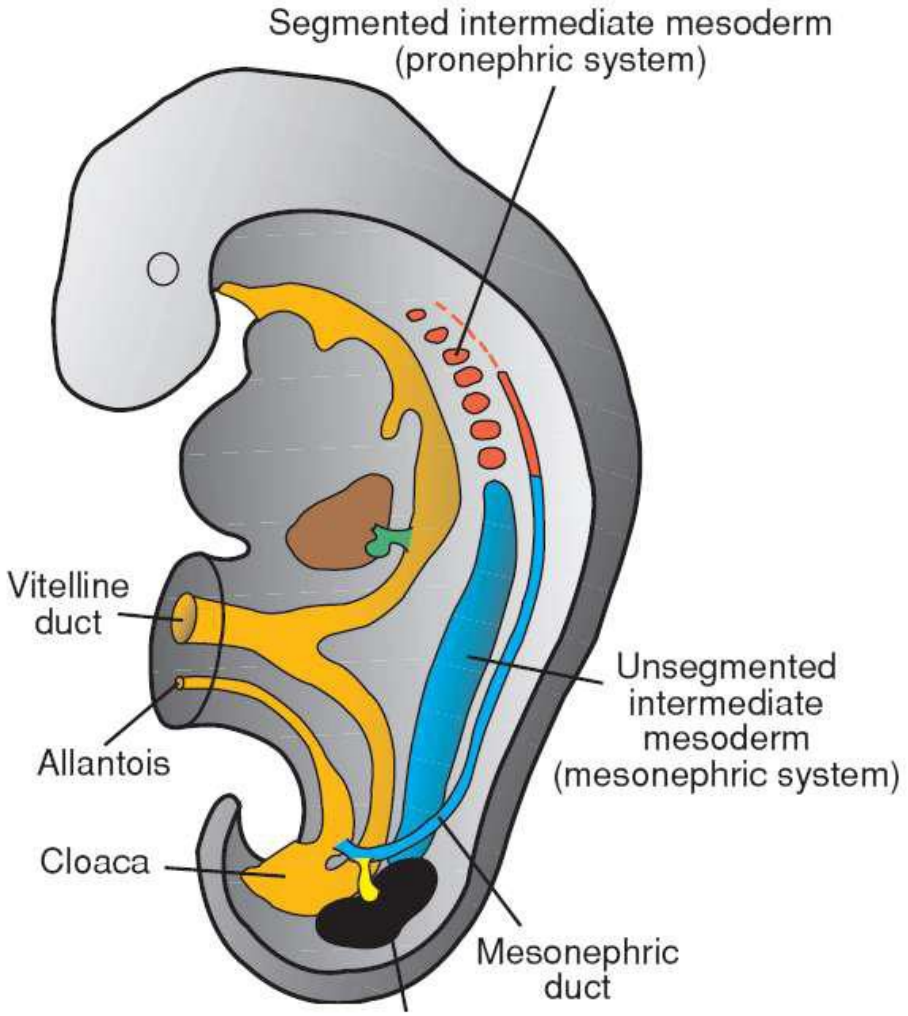
- In lower thoracic, lumbar, and sacral regions it forms a solid, unsegmented mass of tissue, the nephrogenic cord.



Note the longitudinal collecting duct, formed initially by the pronephros but later by the mesonephros

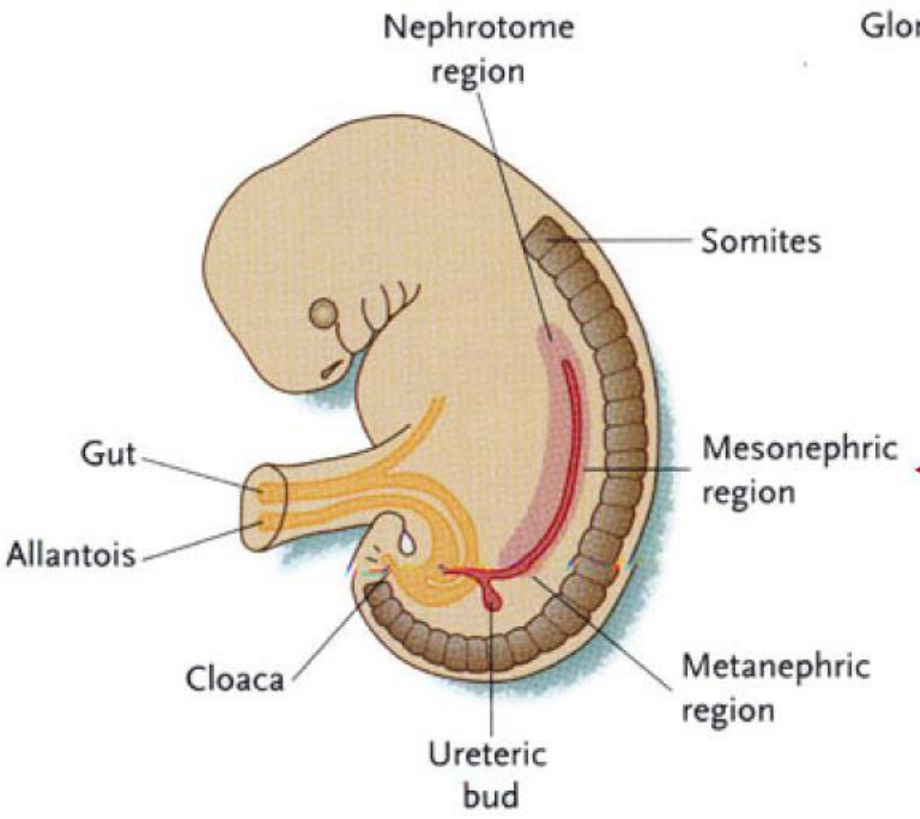
Pronephros

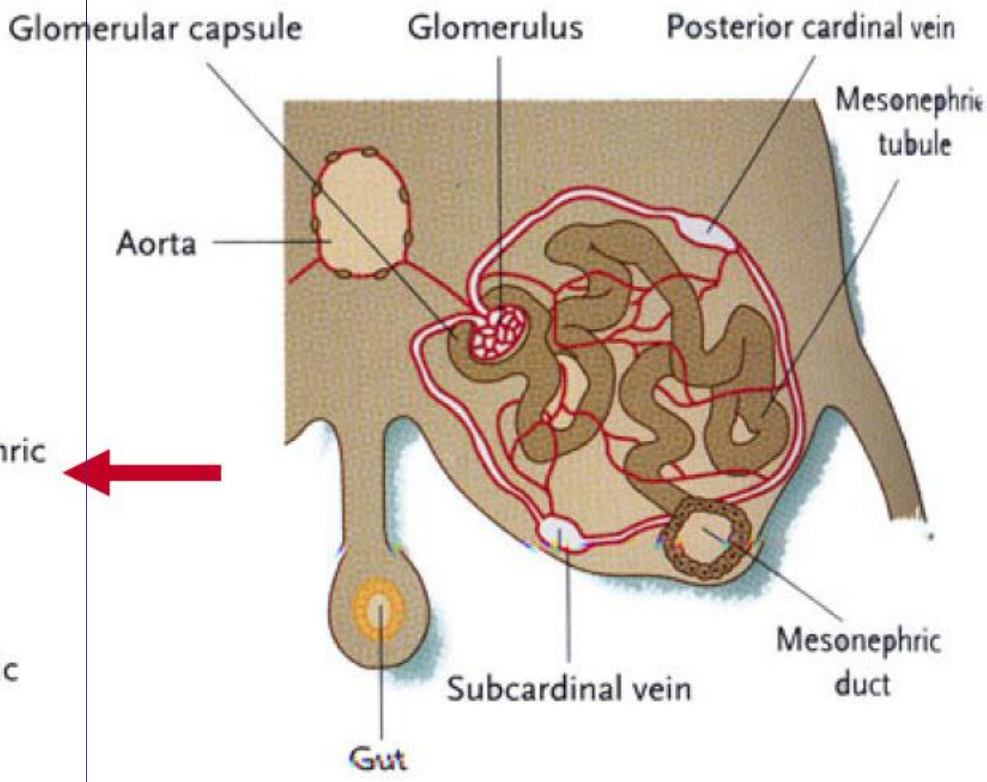
- Excretory tubules of the pronephric and mesonephric systems in a 5-week-old embryo.



Mesonephros

- The mesonephros and mesonephric ducts are derived from intermediate mesoderm from upper thoracic to upper lumbar (L3) segments.
- Early in the fourth week, the first excretory tubules of the mesonephros appear.
- They lengthen rapidly, form an S-shaped loop, and acquire a tuft of capillaries that will form a glomerulus at their medial extremity.


Nephrotome region
Somites
Gut
Mesonephric region
Allantois
Cloaca
Metanephric region
Ureteric bud

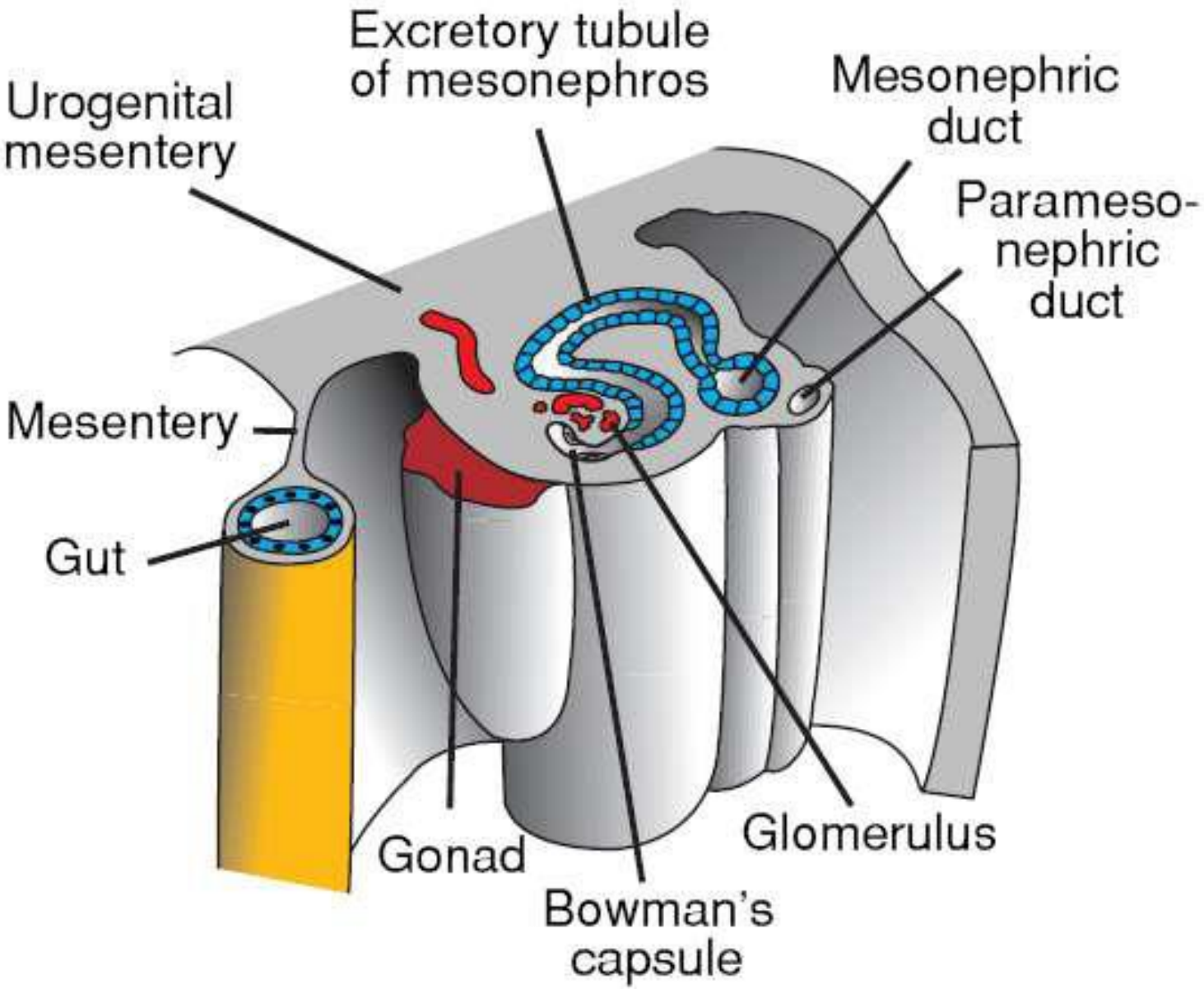

Glomerular capsule
Glomerulus
Posterior cardinal vein
Mesonephric tubule
Aorta
Subcardinal vein
Mesonephric duct
Gut

Mesonephros

- In the middle of the second month the mesonephros forms a large ovoid organ on each side of the midline.

- Since the developing gonad is on its medial side, the ridge formed by both organs is known as the **urogenital ridge.**

- **The caudal tubules are still differentiating, The cranial** tubules and glomeruli show degenerative changes, and by the end of the second month the majority have disappeared.

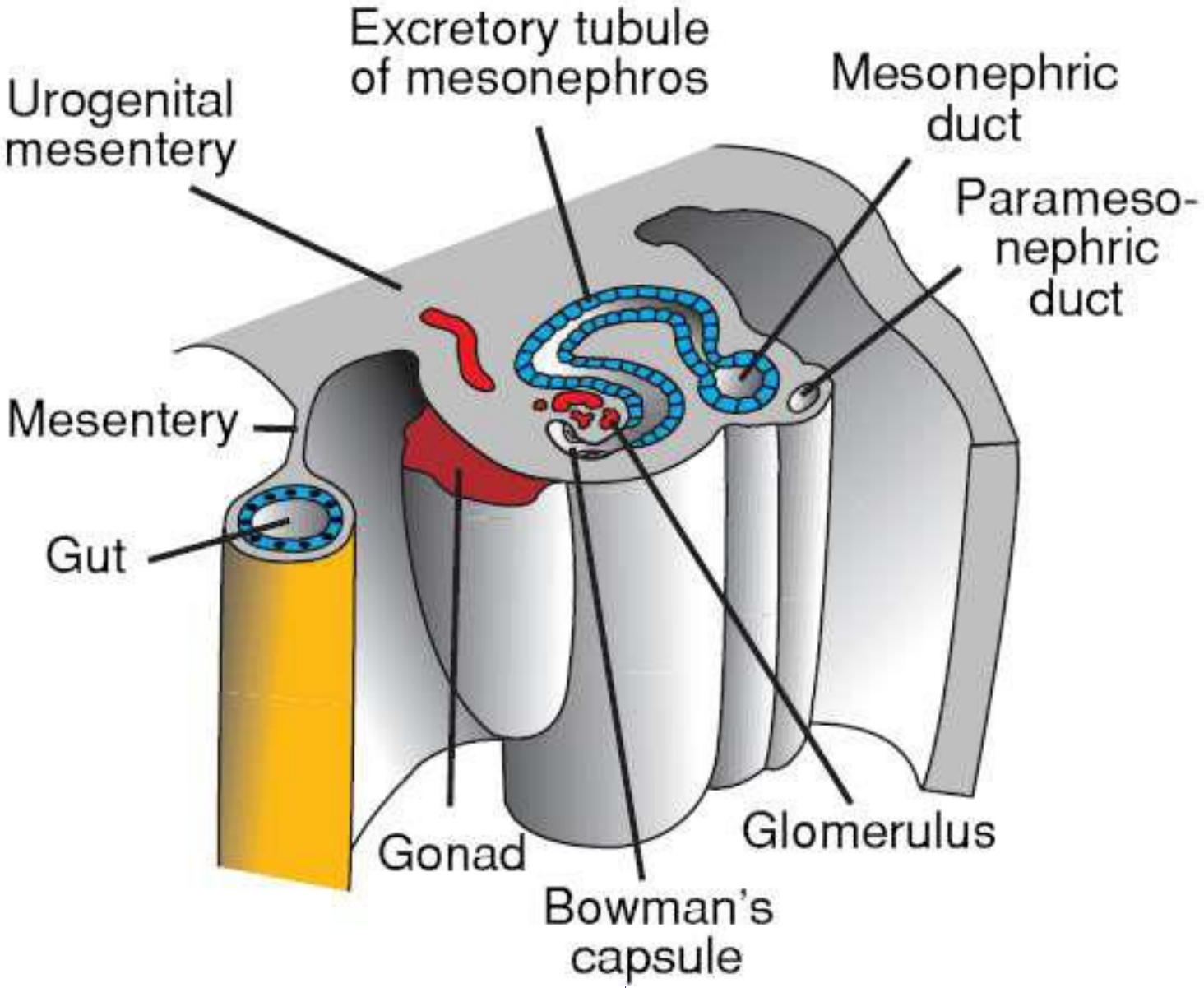


- **Note the appearance of Bowman's capsule and the gonadal ridge.**

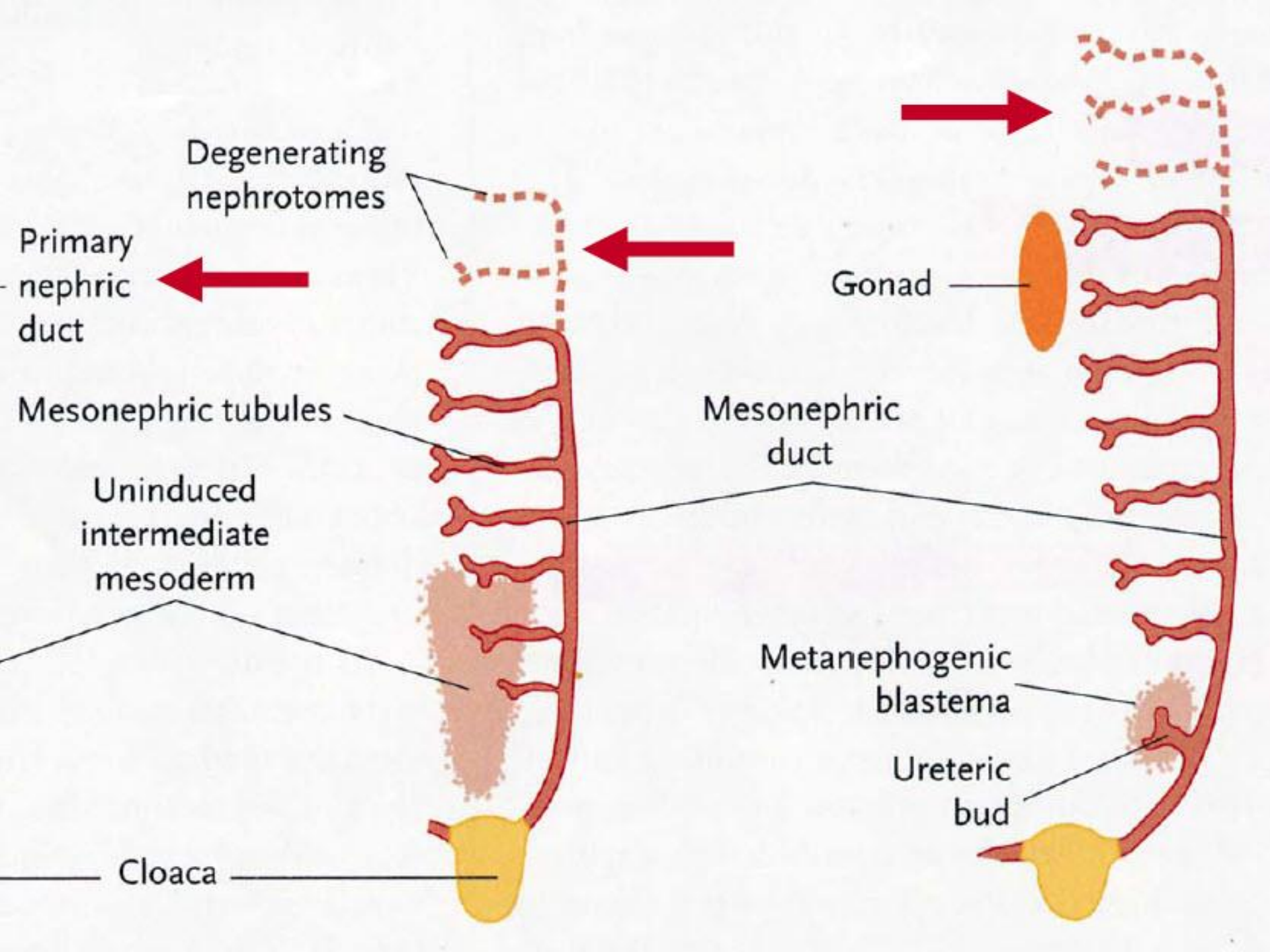
Mesonephros

- Around the glomerulus the tubules form **Bowman's capsule, and together these structures** constitute a **renal corpuscle.**

- **Laterally the tubule enters the longitudinal** collecting duct known as the **mesonephric or wolffian duct**.



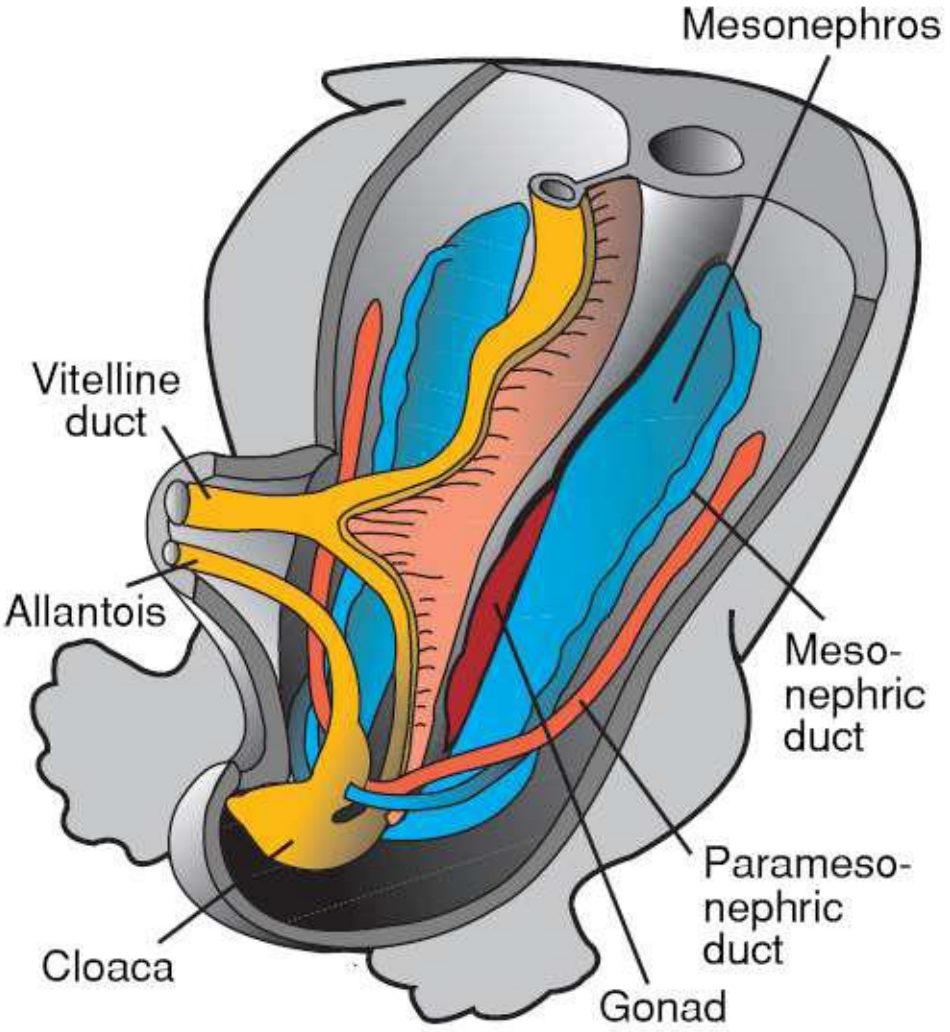
- **Note the appearance of Bowman's capsule and the gonadal ridge.**


Degenerating nephrotomes
Primary nephric duct
Mesonephric tubules
Uninduced intermediate mesoderm
Cloaca
Gonad
Mesonephric duct
Metanephogenic blastema
Ureteric bud

Mesonephros

- **In the male a few of the caudal tubules and the mesonephric duct persist and participate in formation of the genital system, but they disappear in the female.**

- Note the mesonephric duct (wolffian duct) runs along the lateral side of the mesonephros and the relation of the gonad and the mesonephros



Metanephros

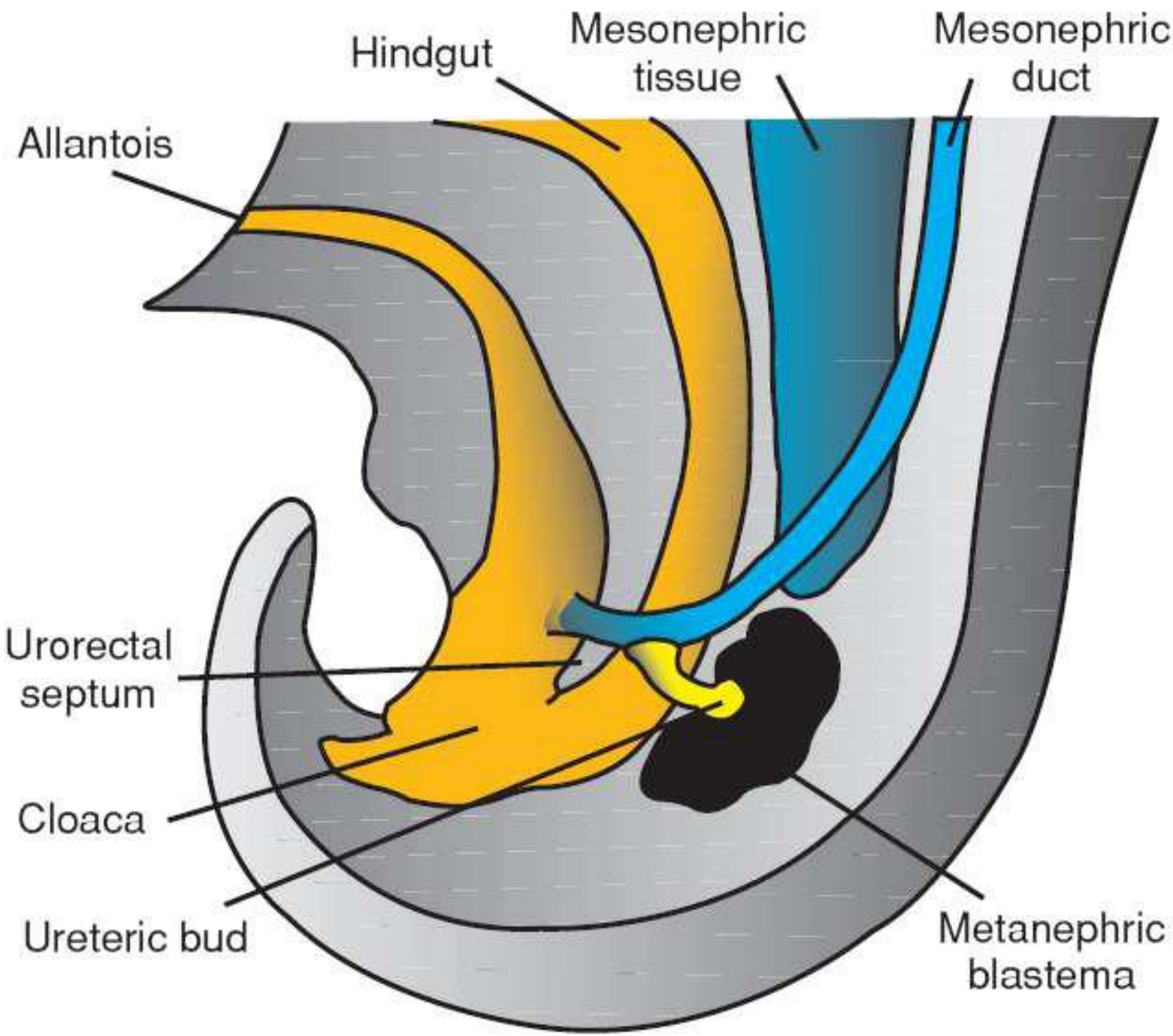
The Definitive Kidney

- The third urinary organ, the **metanephros, or permanent kidney, appears** in the fifth week.

Metanephros

- Its excretory units develop from **metanephric mesoderm** in the same manner as in the mesonephric system.

- The development of the duct system differs from that of the other kidney systems


Hindgut
Mesonephric tissue
Mesonephric duct
Allantois
Urorectal septum
Cloaca
Ureteric bud
Metanephric blastema

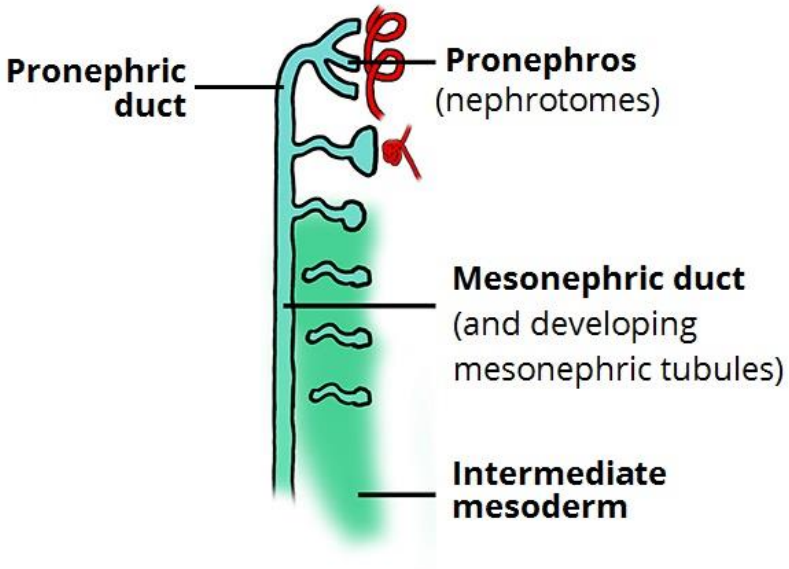
Metanephros

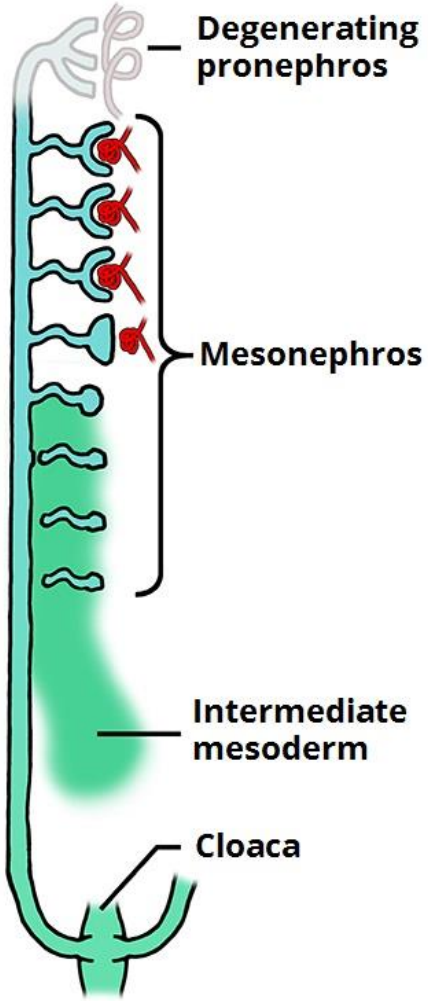
- ***Collecting System***

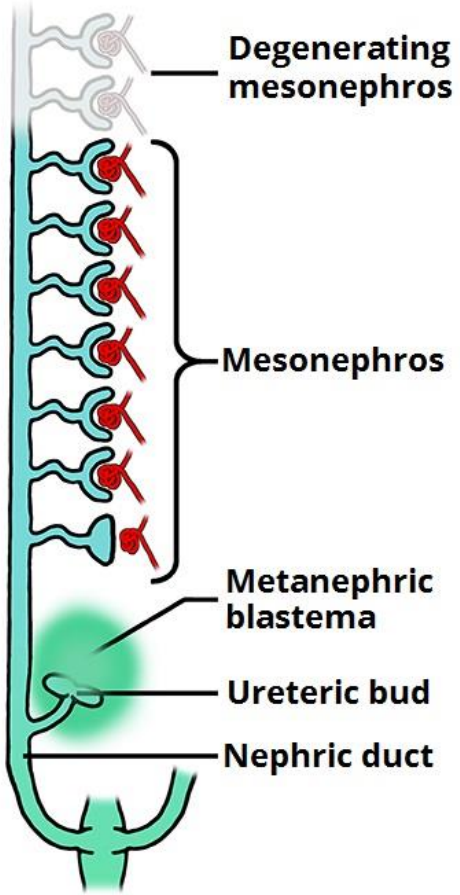
- **Collecting ducts** of the permanent kidney **develop** from the **ureteric bud from the *distal part of the metanephric duct*.**

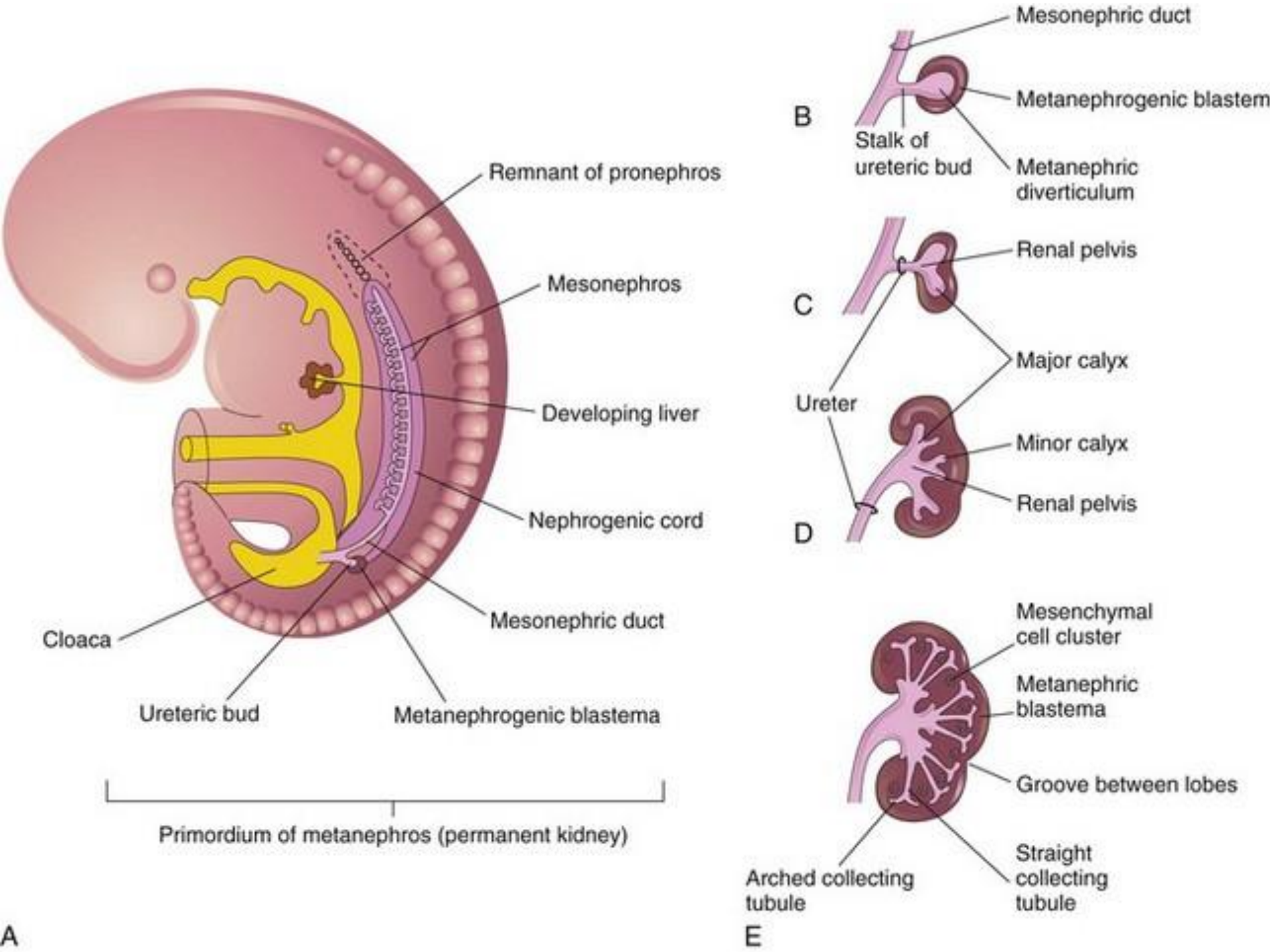
- **The bud penetrates** the metanephric tissue.

- **The bud dilates**, forming the primitive **renal pelvis, and splits into cranial and caudal portions (**the future major calyces**).**


Pronephric duct
Pronephros
(nephrotomes)
Mesonephric duct
(and developing
mesonephric tubules)
Intermediate
mesoderm

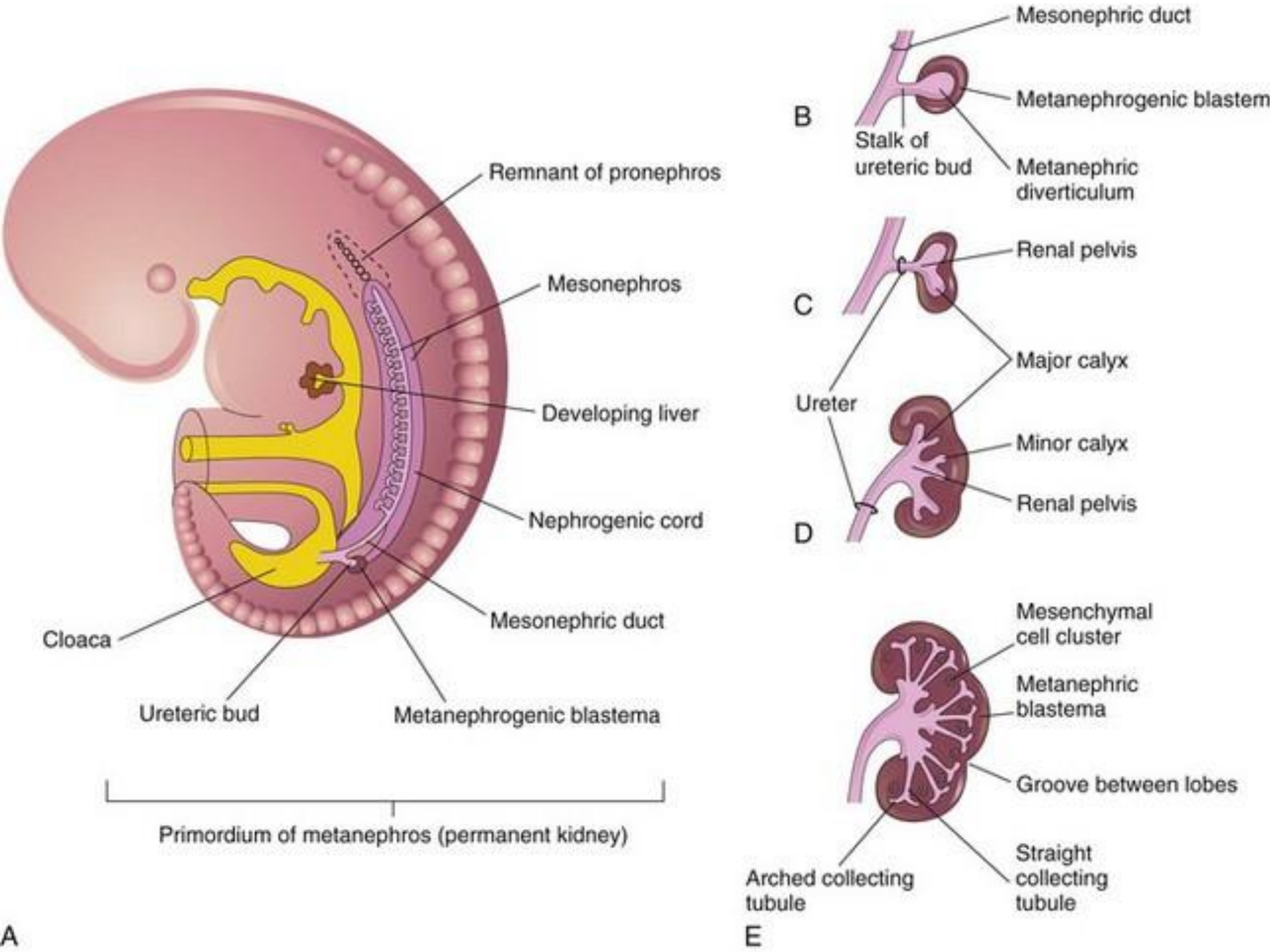

Degenerating
pronephros
Mesonephros
Intermediate
mesoderm
Cloaca


Degenerating
mesonephros
Mesonephros
Metanephric
blastema
Ureteric bud
Nephric duct


Remnant of pronephros
Mesonephros
Developing liver
Nephrogenic cord
Mesonephric duct
Cloaca
Ureteric bud
Metanephrogenic blastema
Primordium of metanephros (permanent kidney)
A
Mesonephric duct
B
Metanephrogenic blastem
Stalk of ureteric bud
Metanephric diverticulum
Renal pelvis
C
Major calyx
Ureter
Minor calyx
Renal pelvis
D
Mesenchymal cell cluster
Metanephric blastema
Groove between lobes
Arched collecting tubule
Straight collecting tubule
E

Metanephros

- Each **calyx** forms **two new buds** while penetrating the metanephric tissue.
- These **buds continue to subdivide until 12 or more generations of tubules have formed.**
- Meanwhile, at the periphery **more tubules form until the end of the fifth month**


Remnant of pronephros
Mesonephros
Developing liver
Nephrogenic cord
Mesonephric duct
Cloaca
Ureteric bud
Metanephrogenic blastema
Primordium of metanephros (permanent kidney)
A
Mesonephric duct
B
Metanephrogenic blastem
Stalk of ureteric bud
Metanephric diverticulum
Renal pelvis
C
Major calyx
Ureter
Minor calyx
Renal pelvis
D
Mesenchymal cell cluster
Metanephric blastema
Groove between lobes
Arched collecting tubule
Straight collecting tubule
E

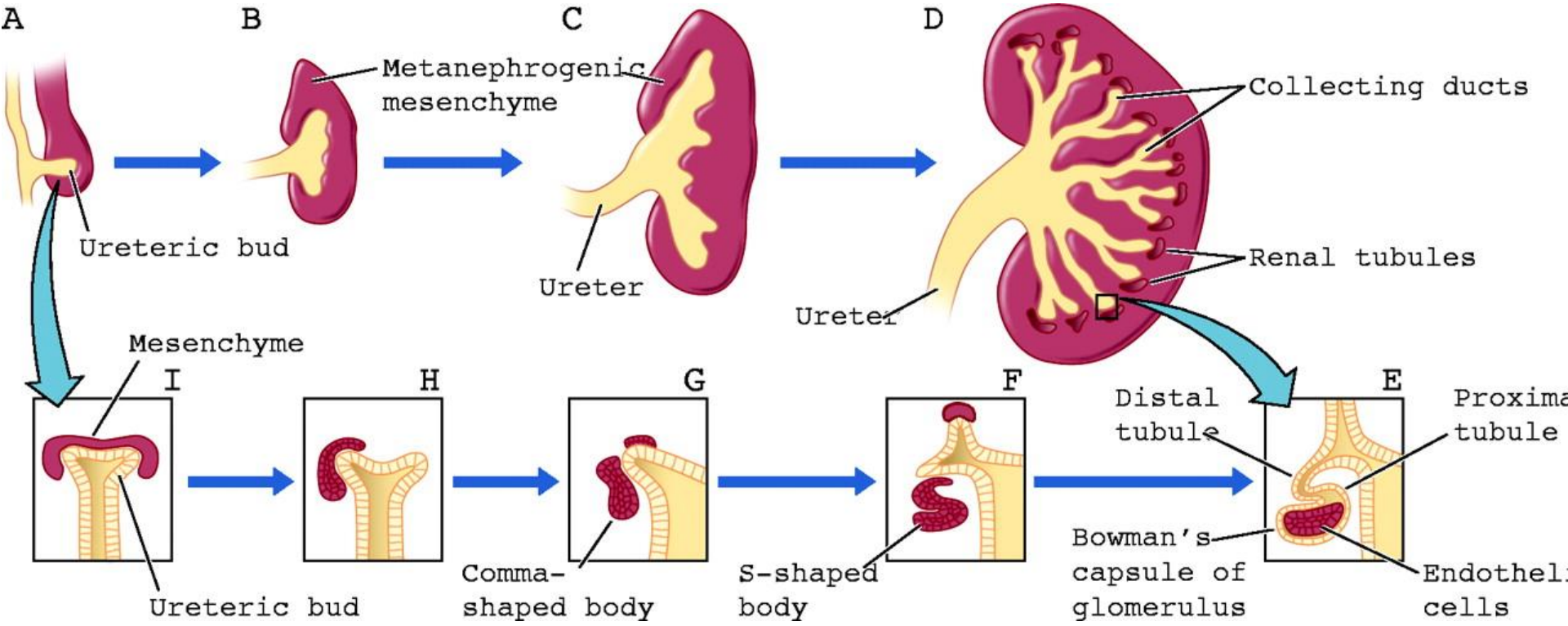
Metanephros

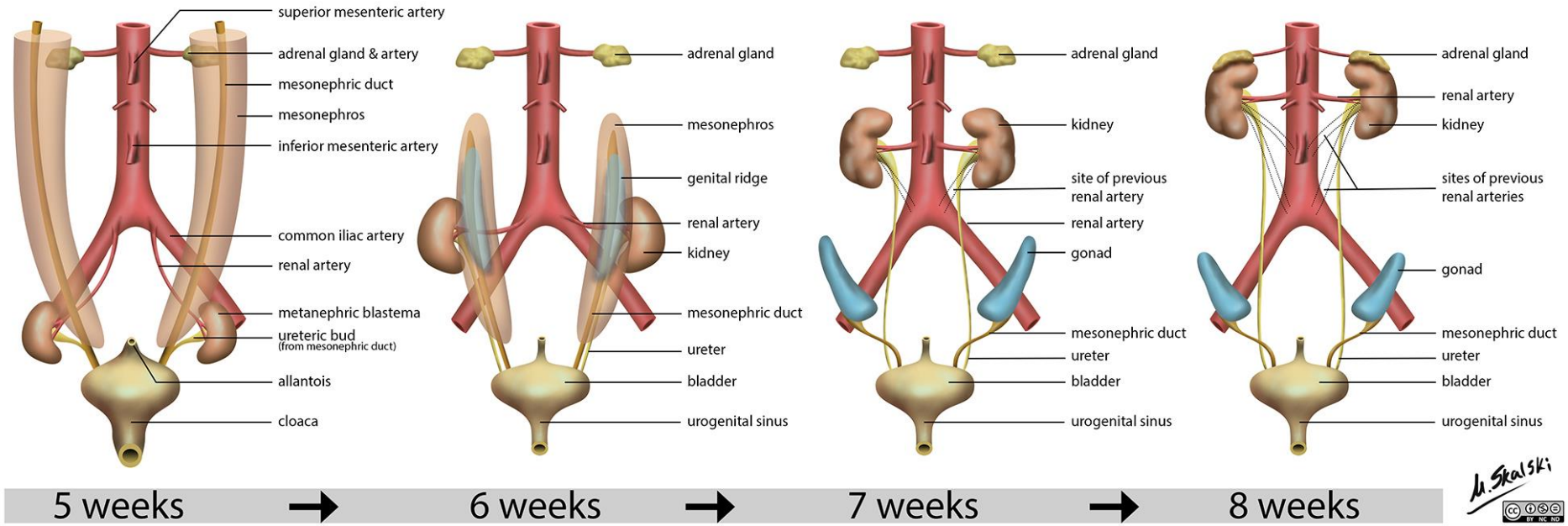
- The tubules of **the second order enlarge and absorb those of the third and fourth generations**, forming the **minor calyces of the renal pelvis**.

- Collecting tubules of the fifth and successive generations form the **renal pyramid.**

- ***The ureteric bud gives rise to the:***

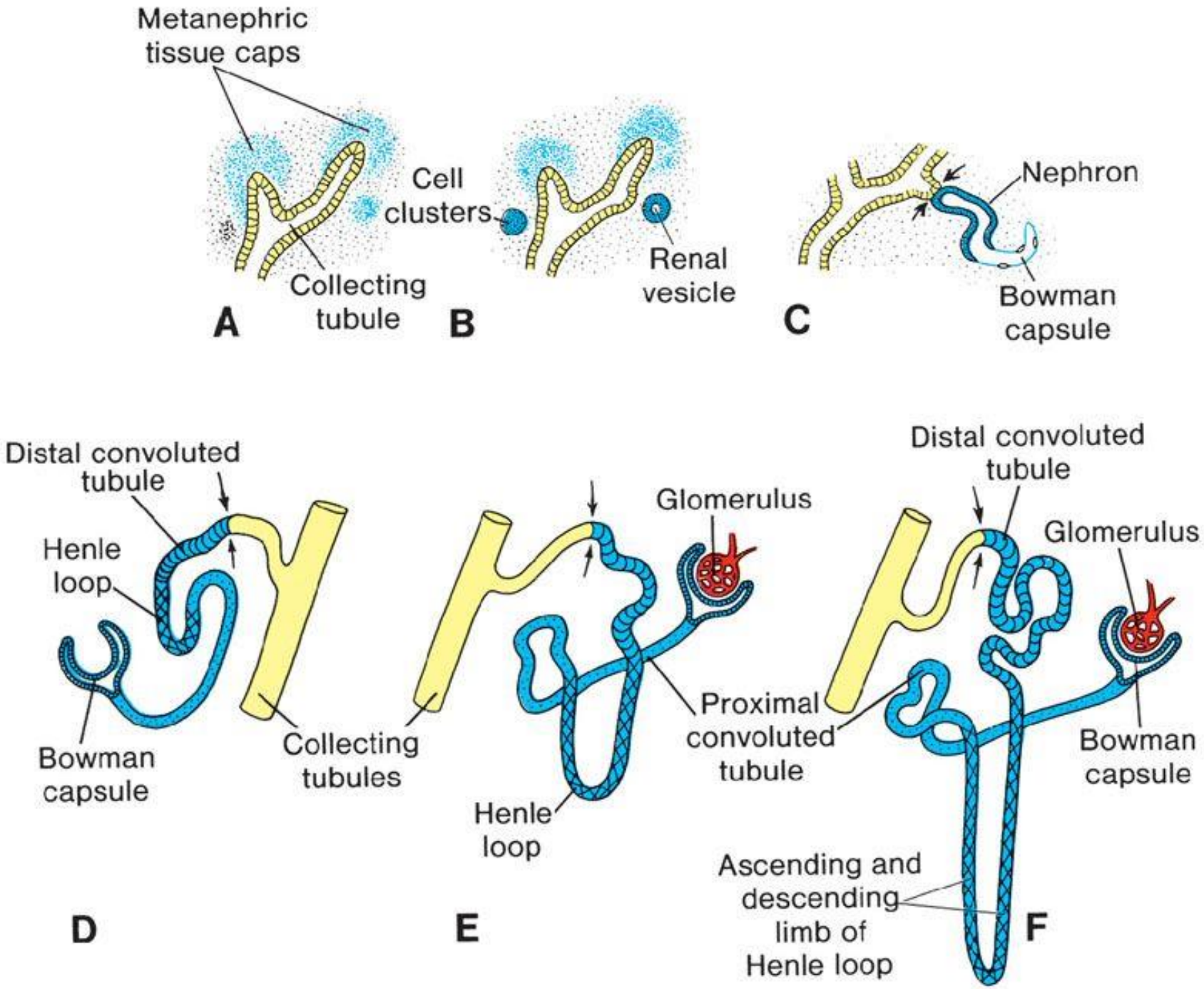
1. **Ureter,**
2. **Renal pelvis,**
3. **Major and minor calyces,**
4. **1 million to 3 million collecting tubules.**


A
B
C
D
Metanephrogenic mesenchyme
Collecting ducts
Ureteric bud
Renal tubules
Ureter
Ureter
Mesenchyme
I
H
G
F
E
Distal tubule
Proxima tubule
Ureteric bud
Comma-shaped body
S-shaped body
Bowman's capsule of glomerulus
Endothel cells


superior mesenteric artery
adrenal gland & artery
mesonephric duct
mesonephros
inferior mesenteric artery
common iliac artery
renal artery
metanephric blastema
ureteric bud
(from mesonephric duct)
allantois
cloaca
adrenal gland
mesonephros
genital ridge
renal artery
kidney
mesonephric duct
ureter
bladder
urogenital sinus
adrenal gland
kidney
site of previous
renal artery
renal artery
gonad
mesonephric duct
ureter
bladder
urogenital sinus
adrenal gland
renal artery
kidney
sites of previous
renal arteries
gonad
mesonephric duct
ureter
bladder
urogenital sinus
5 weeks
6 weeks
7 weeks
8 weeks

Excretory System

- **Each newly formed collecting tubule is covered at its distal** end by a **metanephric tissue cap.**
- Cells of the tissue cap form small vesicles, the **renal vesicles, Renal vesicles** give rise to small S-shaped tubules.
- *Capillaries grow* into the pocket at one end of the S and differentiate into **glomeruli.**
- **These** tubules, together with their glomeruli, form **nephrons, or excretory units.**

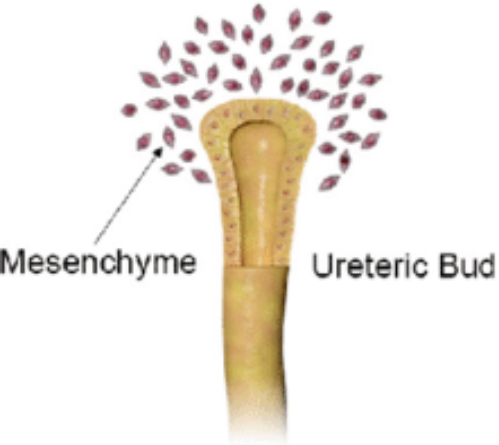

Metanephric tissue caps
Collecting tubule
A
Cell clusters
Renal vesicle
B
Nephron
Bowman capsule
C
Distal convoluted tubule
Henle loop
Bowman capsule
Collecting tubules
D
Glomerulus
Proximal convoluted tubule
Henle loop
E
Distal convoluted tubule
Glomerulus
Bowman capsule
Ascending and descending limb of Henle loop
F

Excretory System

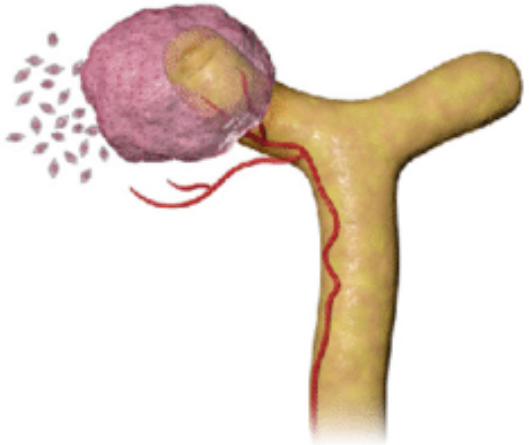
- **The** proximal end of each nephron forms **Bowman's capsule.**

- The distal end *forms an open* connection with one of the collecting tubules, establishing a passageway from Bowman's capsule to the collecting unit. Continuous lengthening of the excretory tubule results in formation of the **proximal convoluted tubule, loop of Henle, and distal convoluted tubule.**

Nephrogenesis

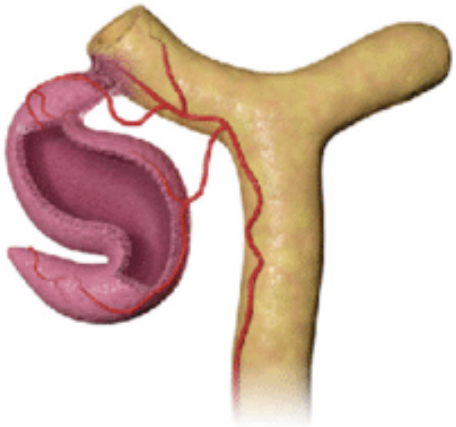


Outgrowth of ureteric bud into mesenchyme

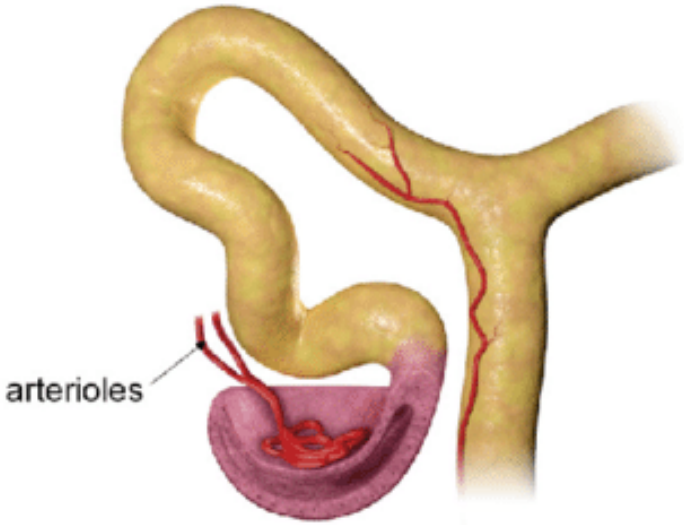


Condensation of mesenchyme

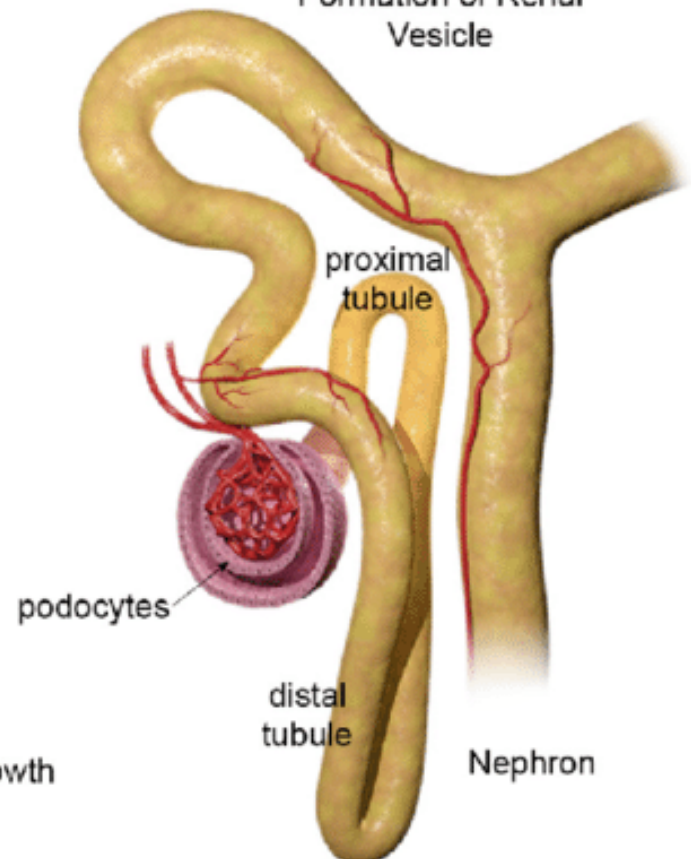
Formation of Renal Vesicle



S-shape body - epithelialization and tubule differentiation



Glomerulogenesis - vascular ingrowth and tubule elongation



Nephron

Excretory System

- ***Finally to summarize, The kidney*** develops from two sources:

A. Metanephric mesoderm, which provides excretory units.
B. The ureteric bud, which gives rise to the collecting system.

- Nephrons are formed until birth, at which time there are approximately 1 million in each kidney.

Excretory System

- Urine production begins early in gestation, soon after differentiation of the glomerular capillaries, which start to form by the 10th week.

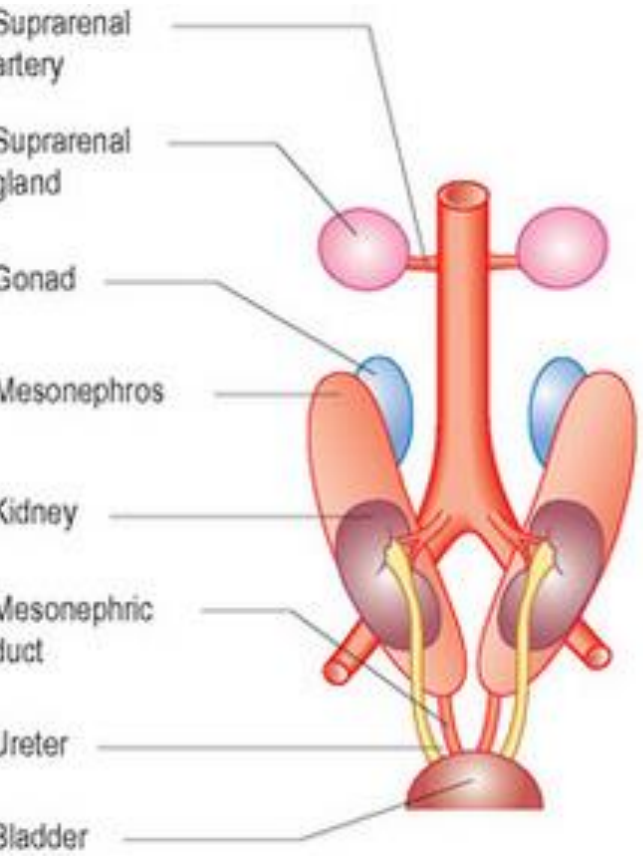
- At birth the kidneys ***have a lobulated appearance***, but the ***lobulation disappears*** during ***infancy*** as a result of further growth of the nephrons, although there is no increase in their number

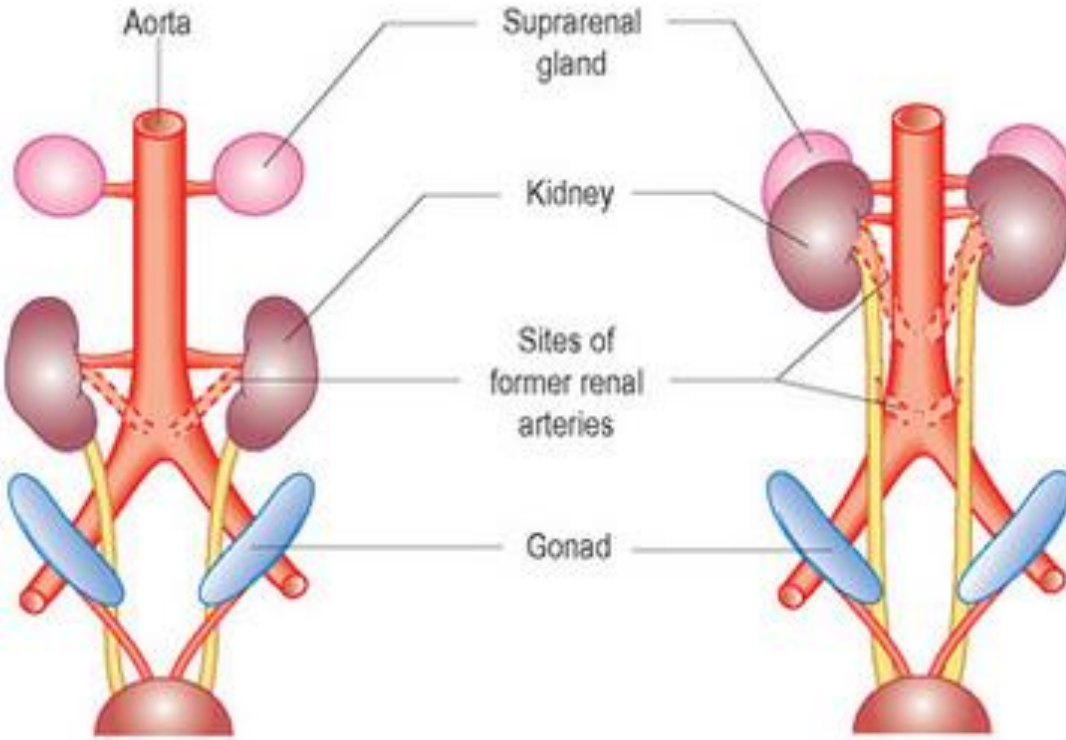
Position of the Kidney

- The kidney, initially in the pelvic region, later shifts to a more cranial position in the abdomen.

- This **ascent of the kidney is caused by development of** body curvature and by growth of the body in the lumbar and sacral regions.

- **In the pelvis** the metanephros receives its arterial supply from a **pelvic branch of the aorta**.

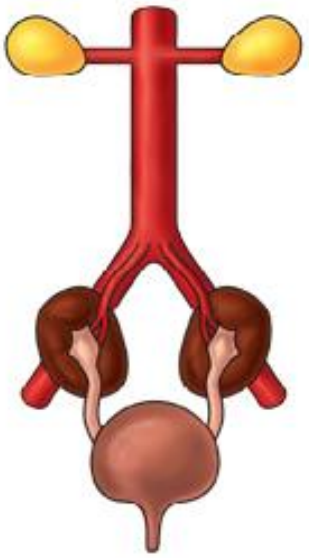

Suprarenal artery
Suprarenal gland
Gonad
Mesonephros
Kidney
Mesonephric duct
Ureter
Bladder


Aorta
Suprarenal gland
Kidney
Sites of former renal arteries
Gonad

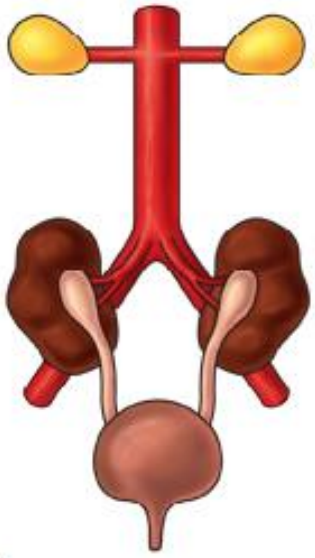
Position of the Kidney

- **During its ascent** to the abdominal level, it is vascularized by arteries that **originate from the aorta at continuously higher levels.**

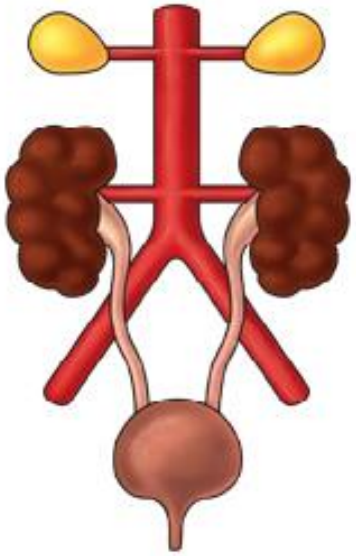
- **The lower vessels usually degenerate, but** some may remain forming ***aberrant renal arteries.***



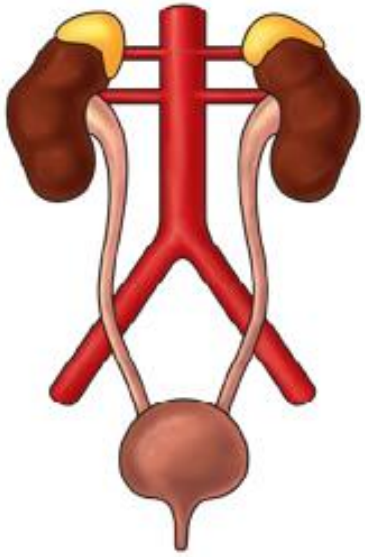
A



B

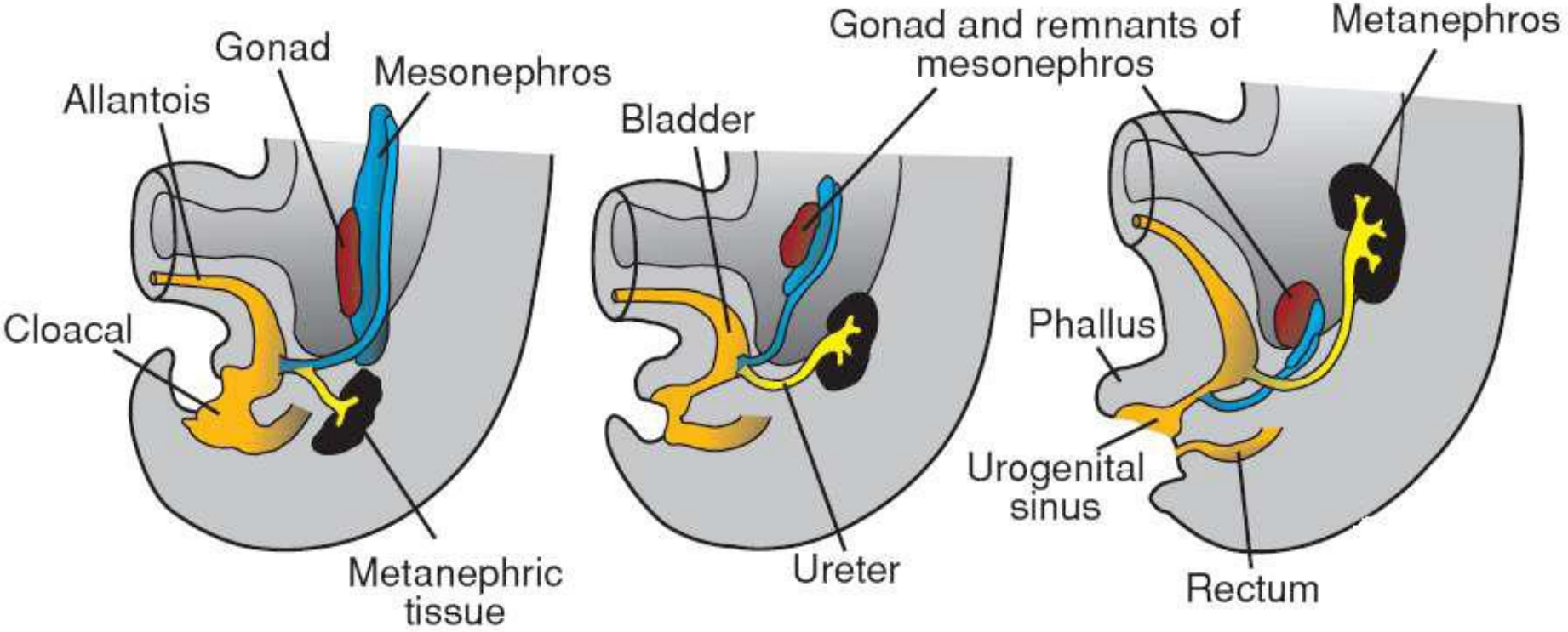


C



D

Renal Ascent and Gonadal Descent

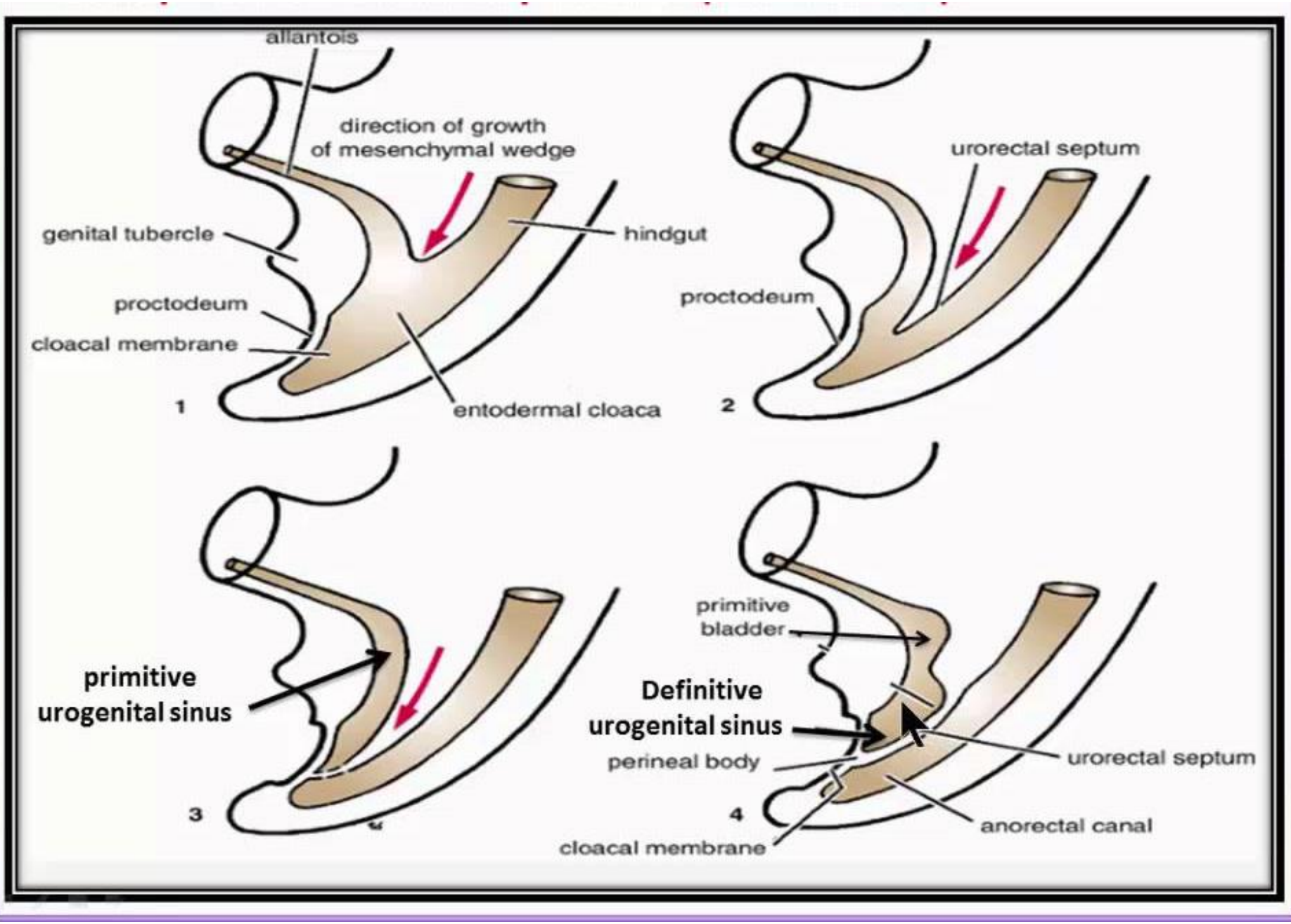


Urinary Bladder

- During **the fourth to seventh weeks** of development the **cloaca divides into** the **urogenital sinus anteriorly and the anal canal posteriorly**.

- The **urorectal septum is a layer of mesoderm between the** primitive anal canal and the urogenital sinus.

- **The tip of the septum will form the perineal body.**


allantois
direction of growth
of mesenchymal wedge
genital tubercle
hindgut
proctodeum
cloacal membrane
entodermal cloaca
1
urorectal septum
proctodeum
2
primitive
urogenital sinus
3
primitive
bladder
Definitive
urogenital sinus
perineal body
urorectal septum
anorectal canal
4
cloacal membrane

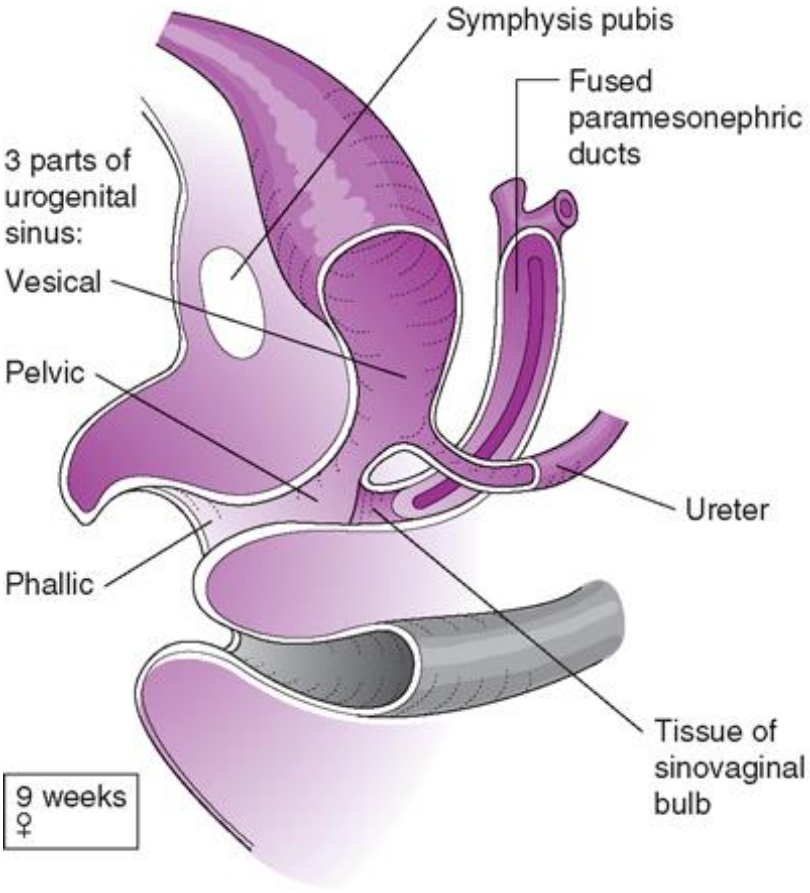
Urinary Bladder

- **Three portions of the urogenital sinus** can be distinguished:

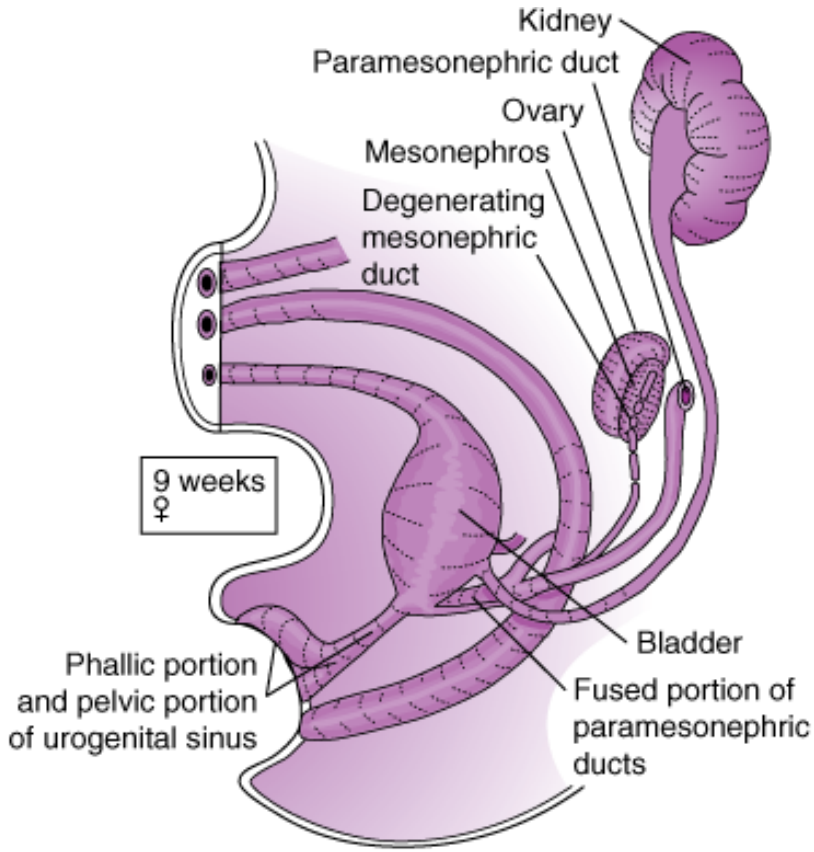
1. The **urinary bladder (vesical part),** (the upper and largest part).

2. The **pelvic part of the urogenital sinus,** (narrow canal)

3. The **phallic part of the urogenital sinus,**(flattened from side to side).



Source: DeCherney AH, Nathan L, Laufer N, Roman AS: *CURRENT Diagnosis & Treatment: Obstetrics & Gynecology,* 11th Edition: www.accessmedicine.com



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Urinary Bladder

- Initially the bladder is continuous with the allantois, **but** when the lumen of the allantois is obliterated, the **urachus, remains and connects** the apex of the bladder with the umbilicus.

- **In the adult**, it is known as the **median umbilical ligament.**

Allantois
Mesonephric duct
Urorectal septum
Urogenital sinus
Cloacal membrane
Cloaca
E
Ductus deferens
Ureter
Urachus
Early bladder
Seminal vesicle
Genital tubercle
Trigone
Rectum
F

Urinary Bladder

- **The next part is a narrow** canal, the **pelvic part of the urogenital sinus, in the male gives** rise to the **prostatic and membranous parts of the urethra.**

- The last part is the **phallic part of the urogenital sinus.**

- **It is flattened from side to side, and** as the genital tubercle grows, **this part of the sinus will be pulled ventrally.**

Allantois
Mesonephric duct
Urorectal septum
Urogenital sinus
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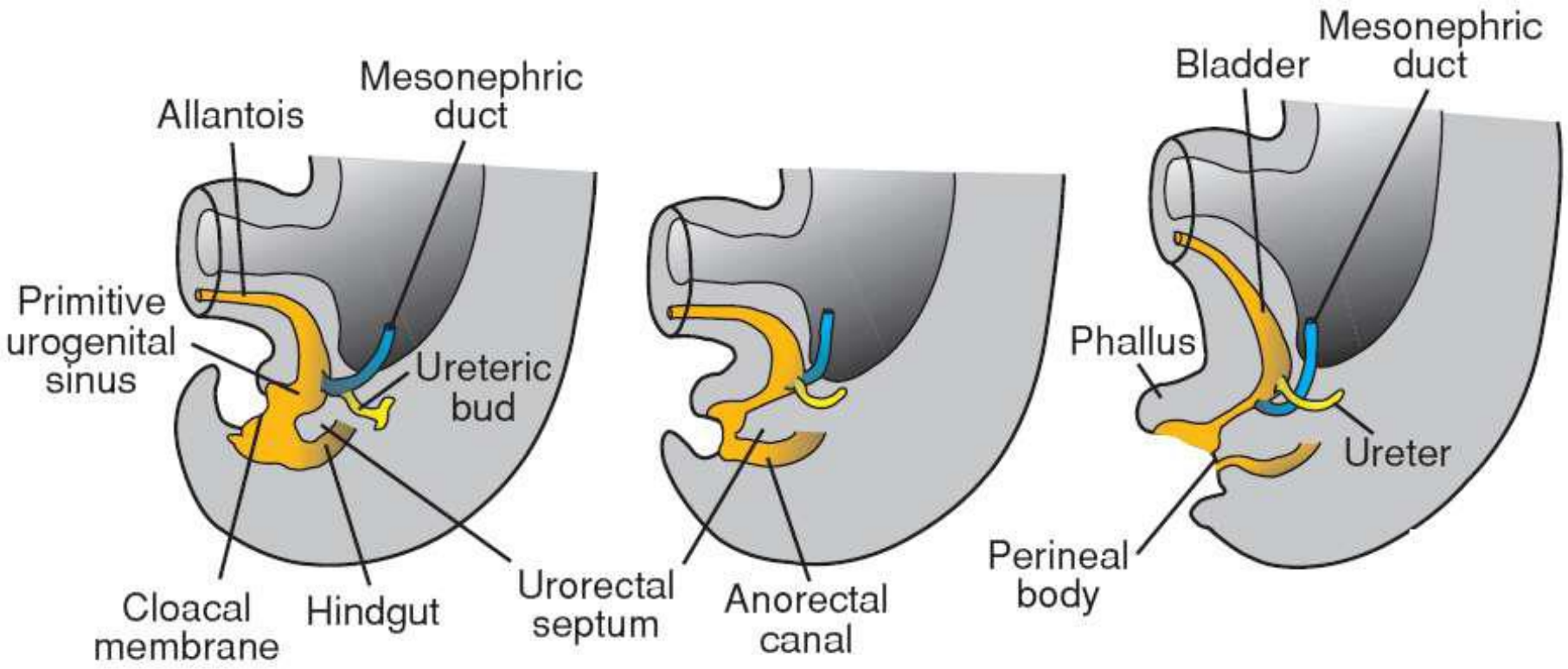
E
Ductus deferens
Ureter
Urachus
Early bladder
Seminal vesicle
Genital tubercle
Trigone
Rectum
F

Urinary Bladder

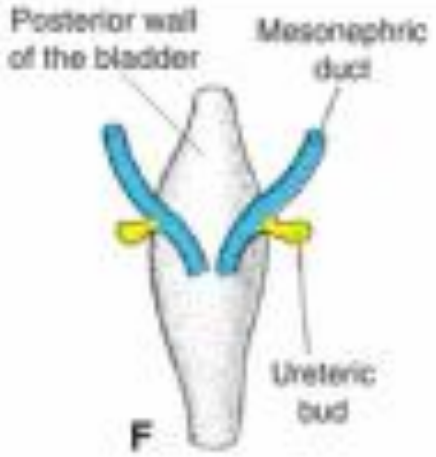
- The caudal portions of the mesonephric ducts are absorbed into the wall of the urinary bladder (***forming the trigone***).

- **The ureters enter the bladder separately.**

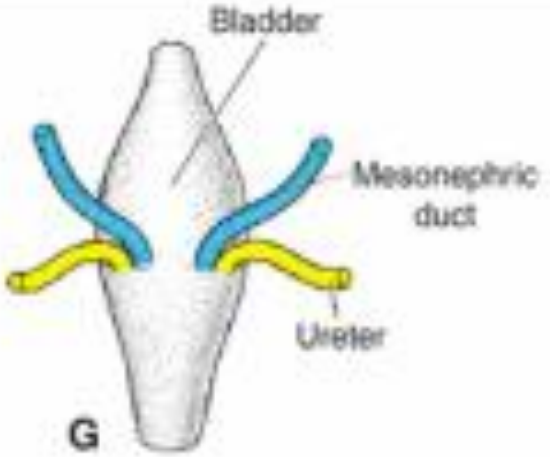
- *As a result of ascent of the kidneys, the* orifices of the ureters move farther cranially; **those of the mesonephric ducts move close together to enter the prostatic urethra and in the male become the ejaculatory ducts.**



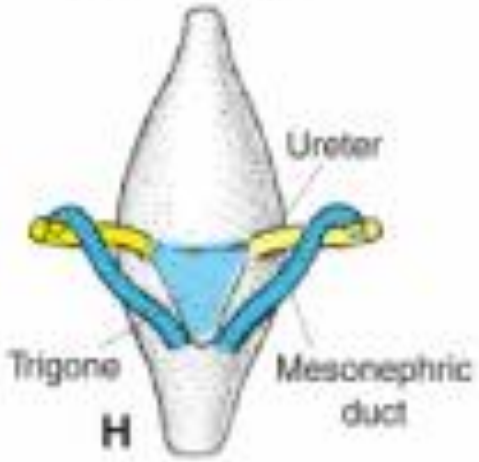
- **The mesonephric duct is gradually absorbed into the wall of the urogenital sinus (*forming the trigone*), and the ureters enter separately**



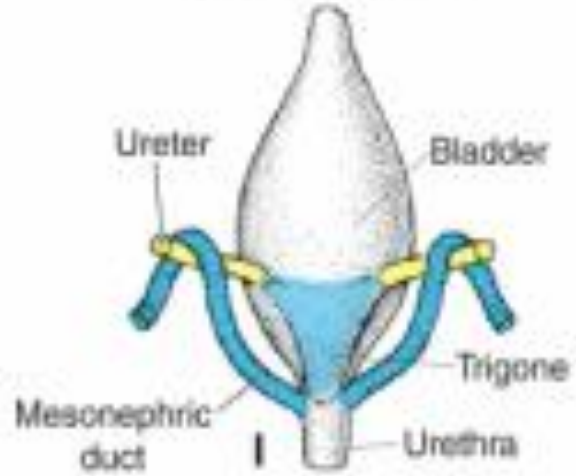
Incorporation of the Mesonephric Ducts into the Posterior Bladder Wall



Incorporation of the Mesonephric Ducts into the Posterior Bladder Wall



Incorporation of the Mesonephric Ducts into the Posterior Bladder Wall



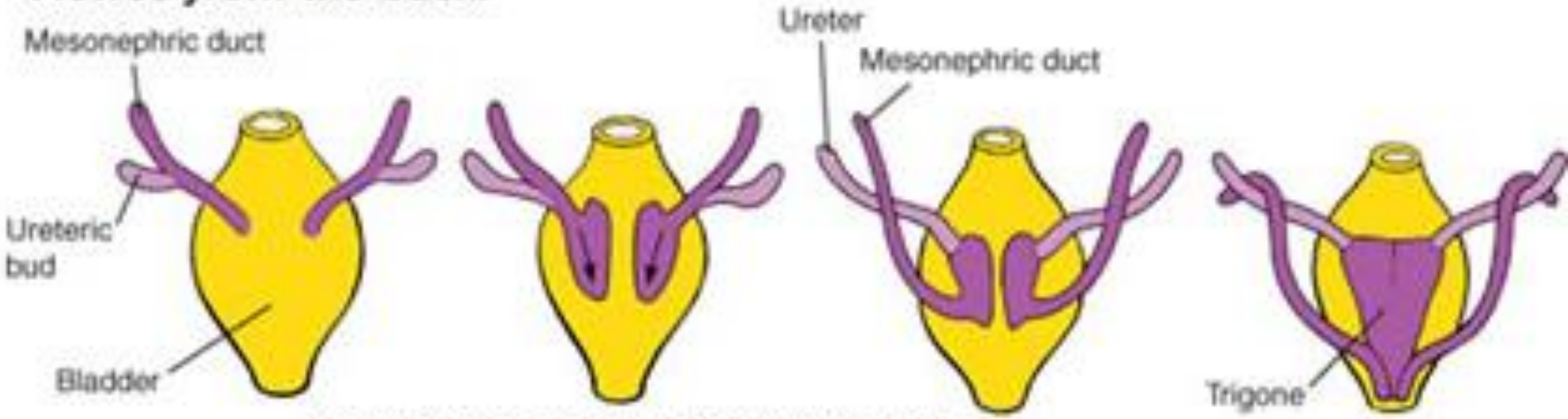
Incorporation of the Mesonephric Ducts into the Posterior Bladder Wall

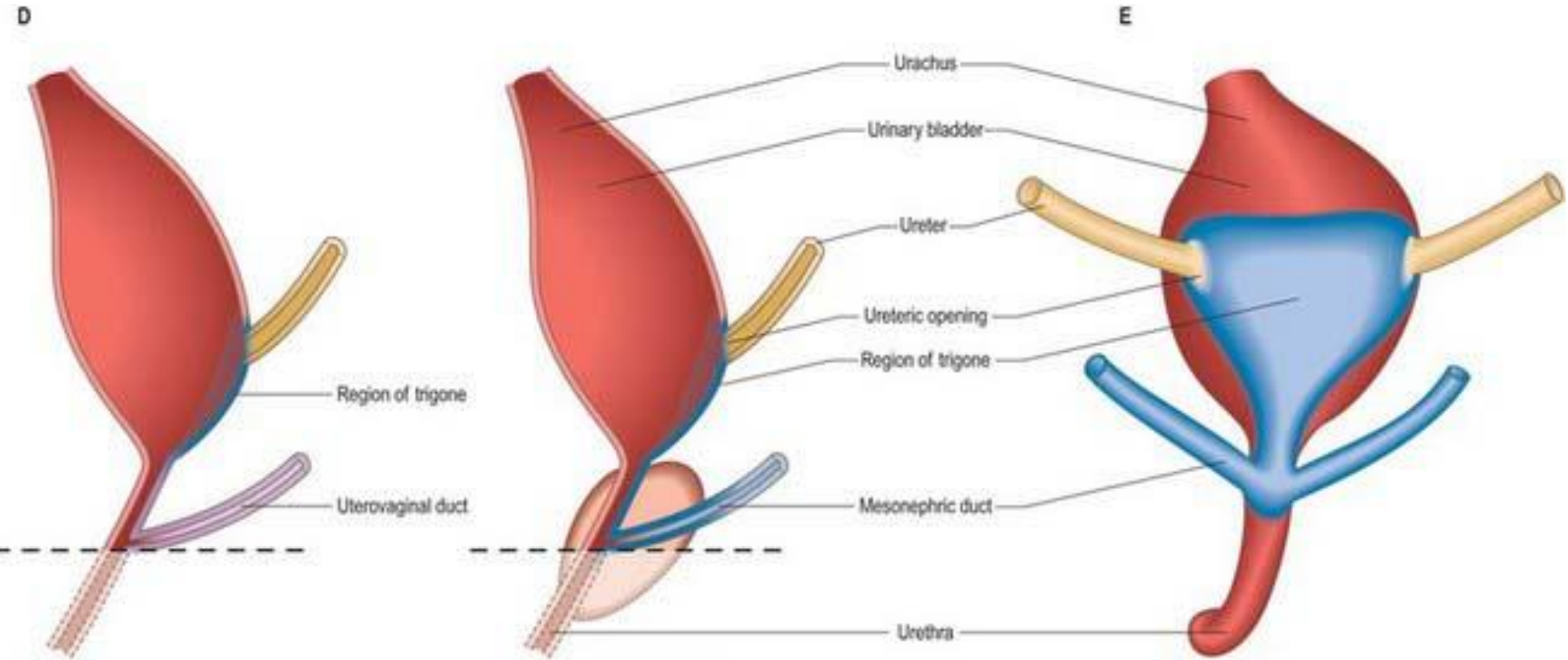
Urinary Bladder

- The mucosa at the posterior wall of the bladder formed by incorporation of the ducts (the **trigone of the bladder) is also mesodermal.**

- **With time** the mesodermal lining of the trigone is replaced by endodermal epithelium, ***so that finally the inside of the bladder is completely lined with endodermal epithelium***

Viewed from the back:





n the female the fused paramesonephric
ducts form the uterovaginal duct.
The mesonephric ducts degenerate.

In the male the mesonephric ducts
form the vas deferens which enter
the urethra through the prostate gland.

Urethra

- The epithelium of the urethra in both sexes originates in the endoderm

- At the end of the third month, epithelium of the prostatic urethra begins to proliferate and forms a number of outgrowths that penetrate the surrounding mesenchyme.

Urethra

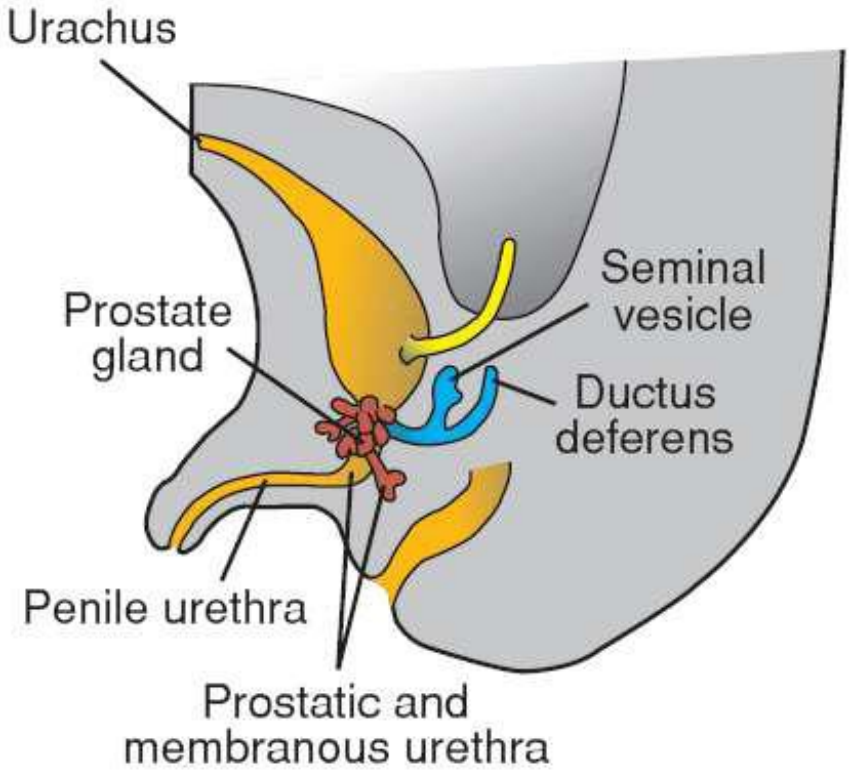
- In the male, these buds form the ***prostate gland .***

- *In the female, the cranial part of the urethra gives rise to the* ***urethral and paraurethral glands***

- In the male the ***definitive urogenital sinus (phallic portion)*** develops into the ***penile urethra***.

- The ***prostate gland*** is formed by ***buds*** from the ***urethra***

- ***Seminal vesicles*** are formed by ***budding*** from the ***ductus deferens***

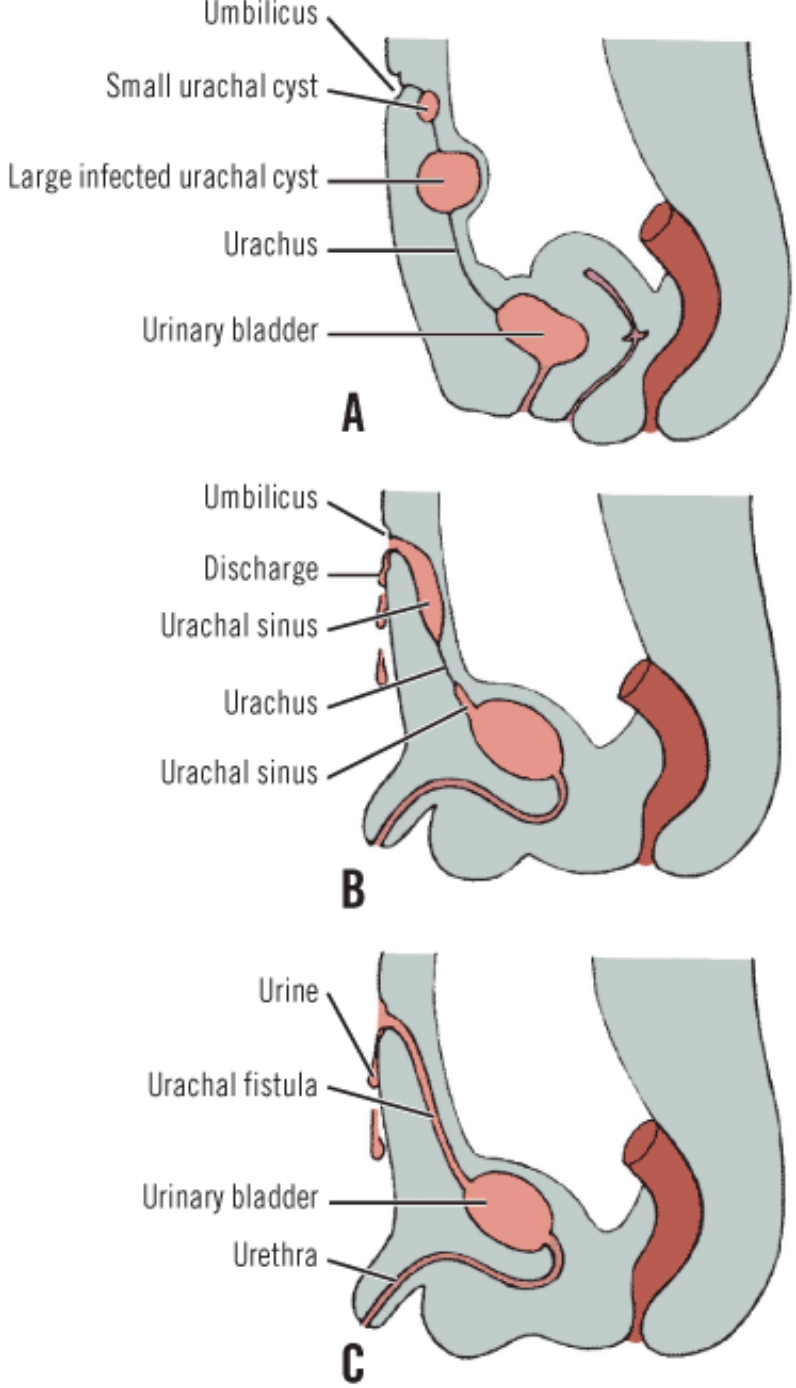


Bladder Defects

1. ***Urachal fistula*** (may cause urine to drain from the umbilicus).

2. ***Urachal cyst*** (If only a local area of the allantois persists, results in a cystic dilation).

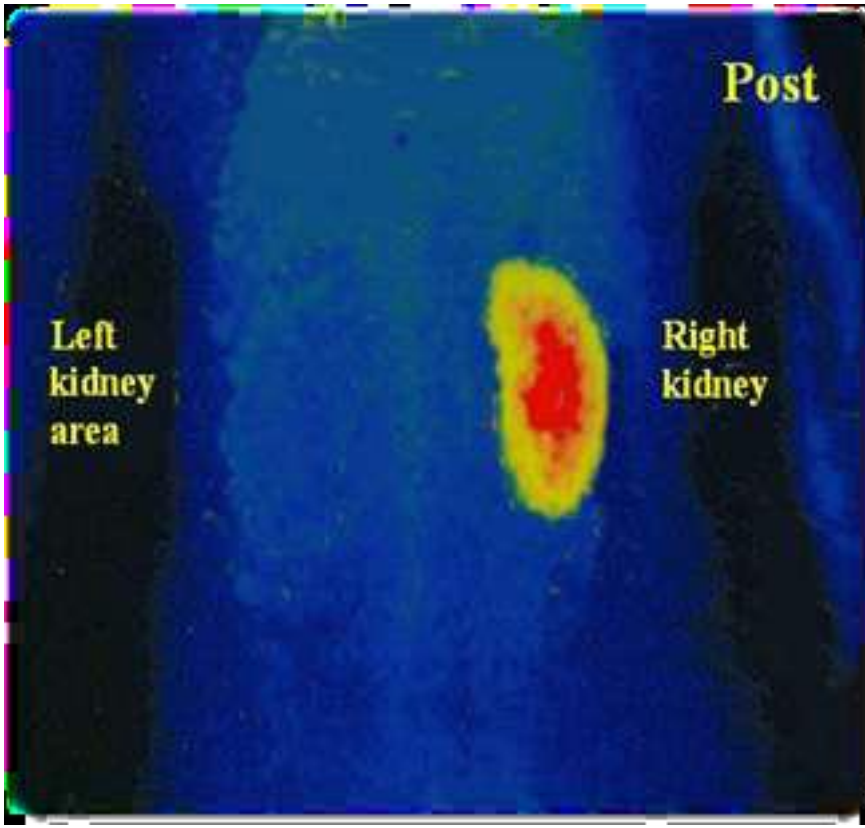
3. ***Urachal sinus*** (When the lumen in the upper part persists). This sinus is usually continuous with the urinary bladder.



Formation Anomalies

- ***RENAL AGENESIS***

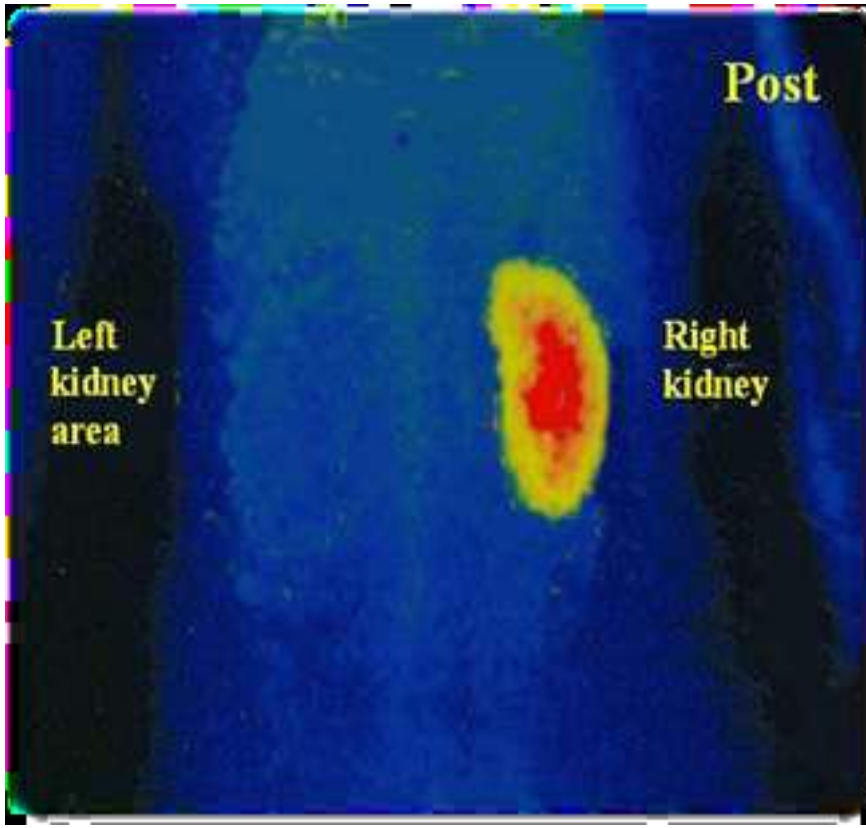
- Kidney is either absent or undeveloped.
- It usually causes no symptoms and is found incidental. 1:500 – 1:3200 live births



Formation Anomalies

- ***RENAL AGENESIS***

- In bilateral renal agenesis, the amount of amniotic fluid may be small (oligohydramnios). The fetus is born alive since the kidneys are not necessary before birth, however death occurs within a few days after birth.



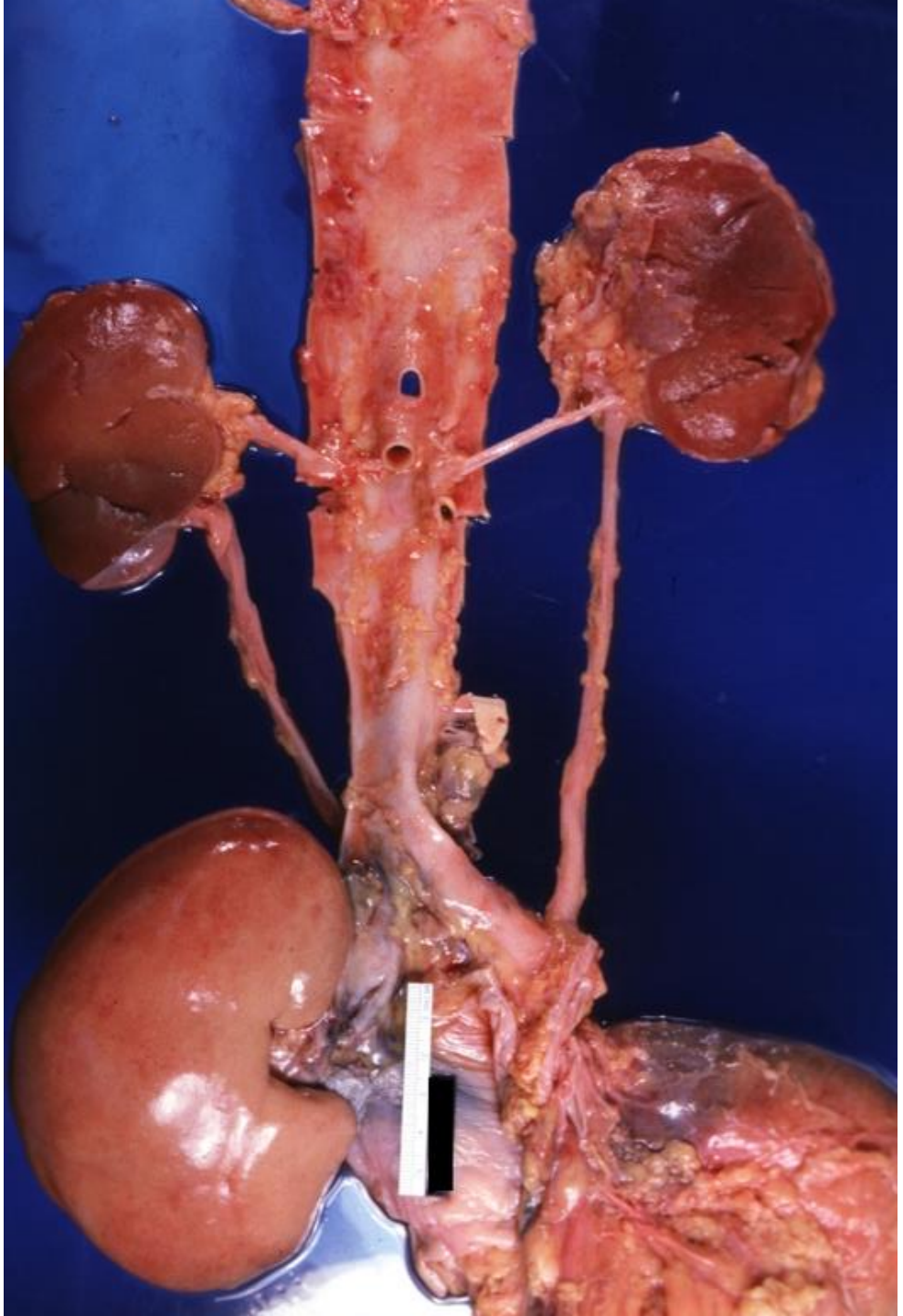
Formation Anomalies

- ***Renal Hypoplasia:*** This appears as one small kidney with the other one larger. Associated with hypertension requiring nephrectomy.

- ***Double kidney:*** Caused by early splitting of the ureteric bud on one side.

Unilateral renal hypoplasia/dysplasia

Extra Kidney



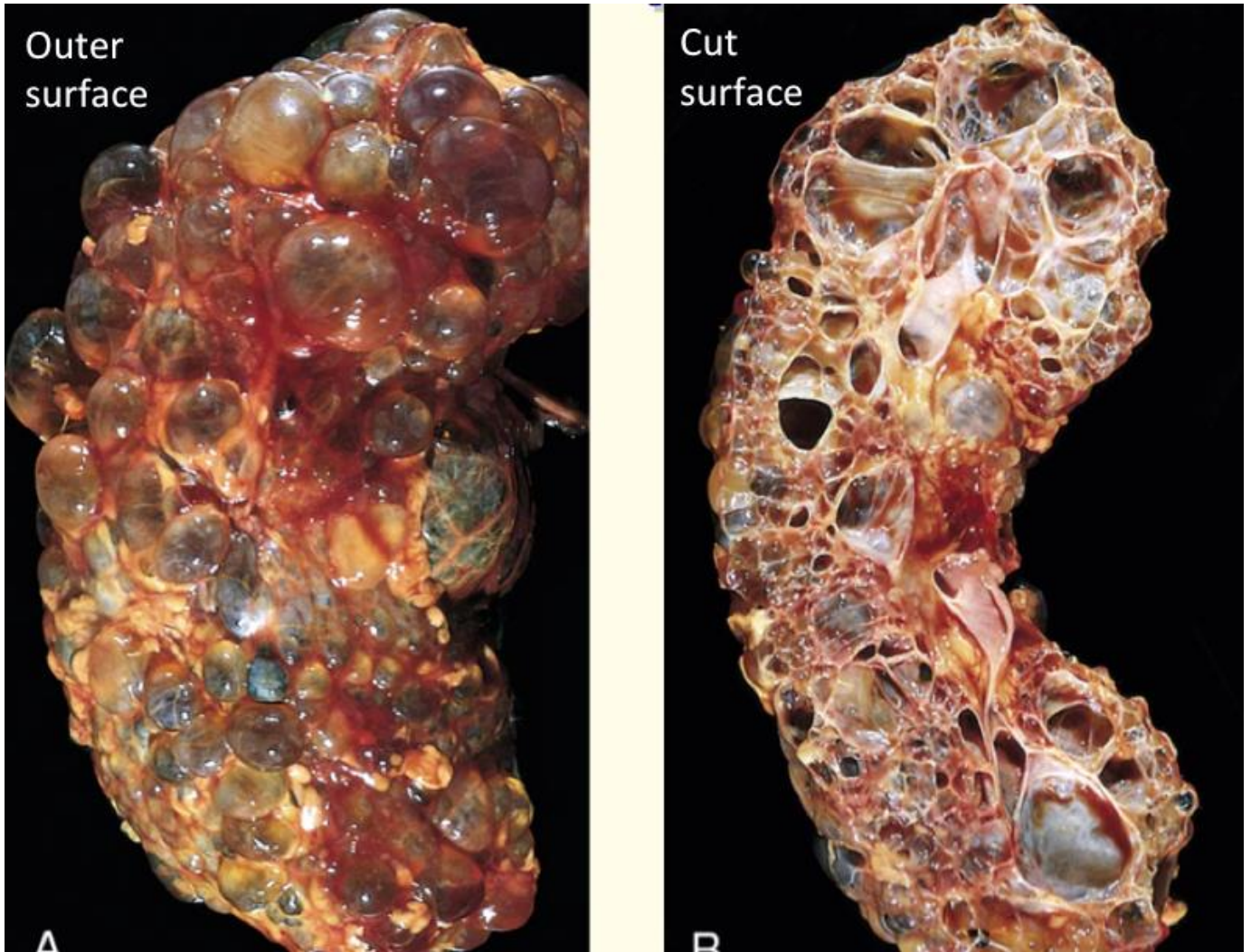
Formation Anomalies

- ***Congenital Cystic Kidney:***

- Caused by *failure of union between some collecting and excretory tubules*. The latter (especially the convoluted tubules) become distended by urine forming cysts.

- These cysts may be so numerous with little active renal tissue left in-between (***polycystic kidney***) or one large cyst is found close to one pole of the kidney (***solitary cyst***).

Polycystic kidney



Solitary Cystic kidney

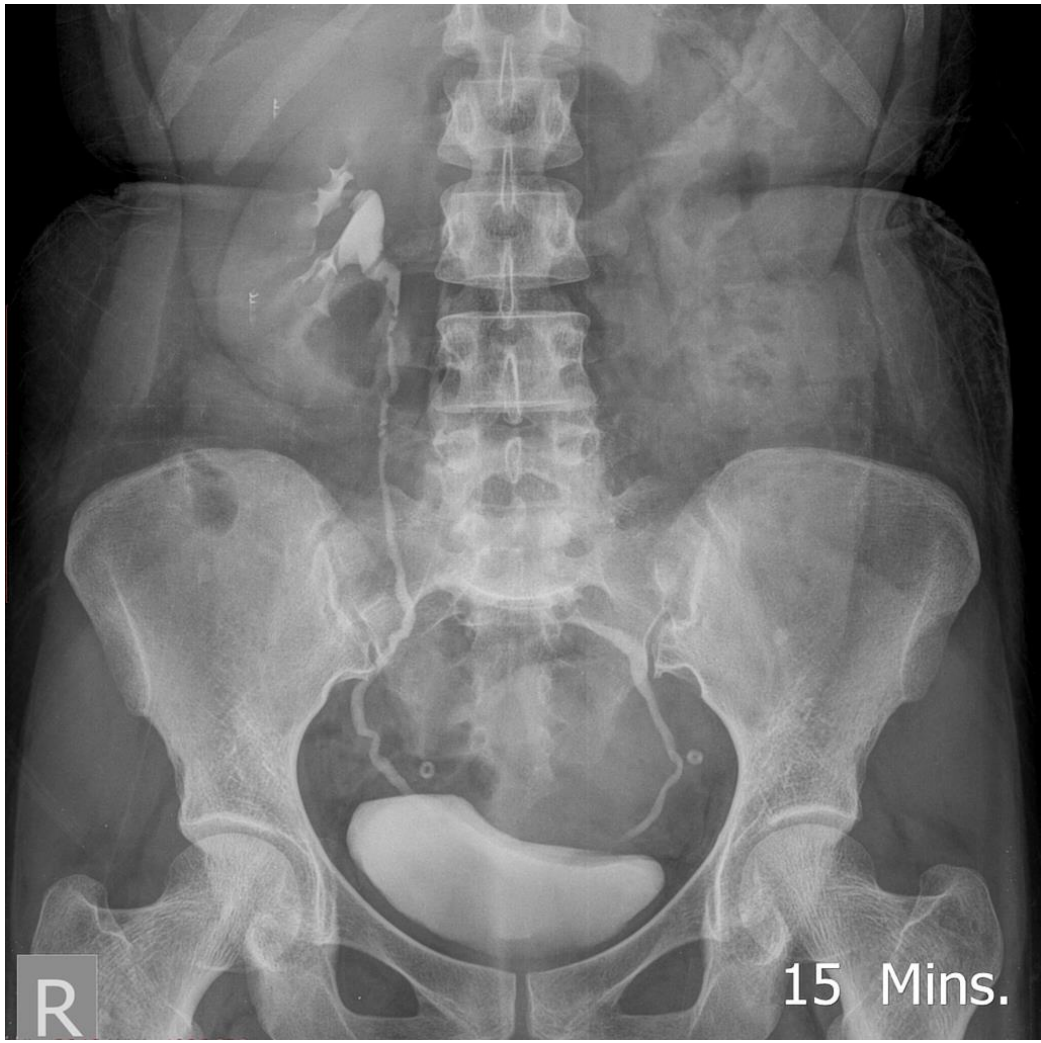
Persistent Fetal Lobulations

Position Anomalies

- ***Aberrant renal artery***

Position Anomalies

- ***Ectopic Kidney***



Shape Anomalies

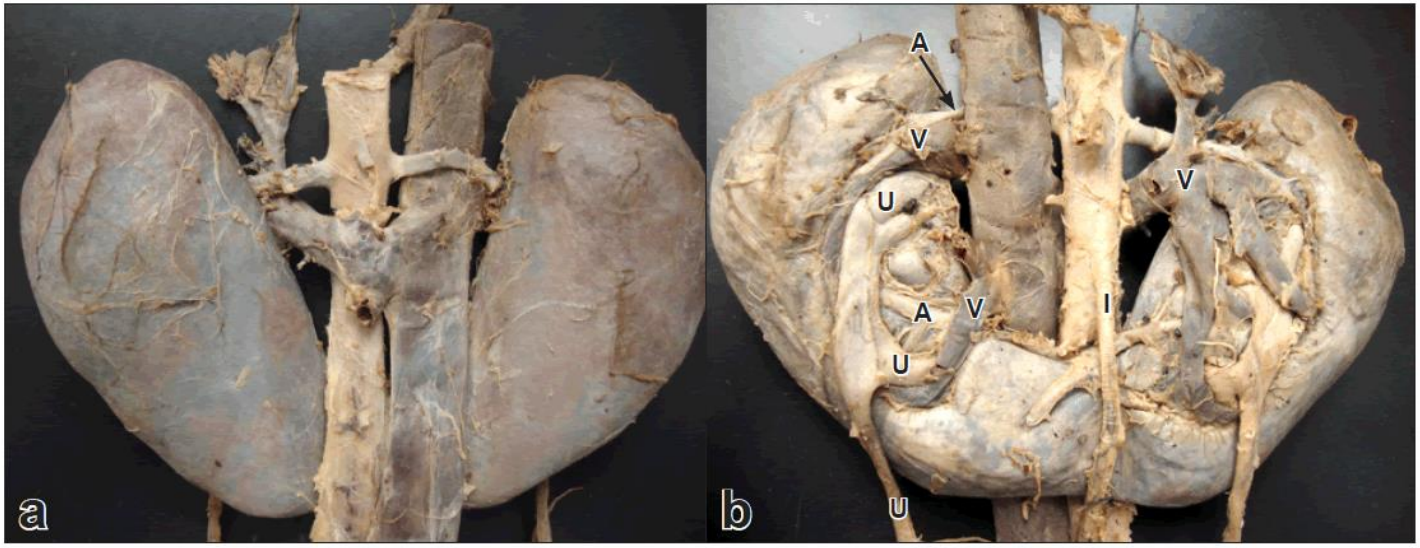
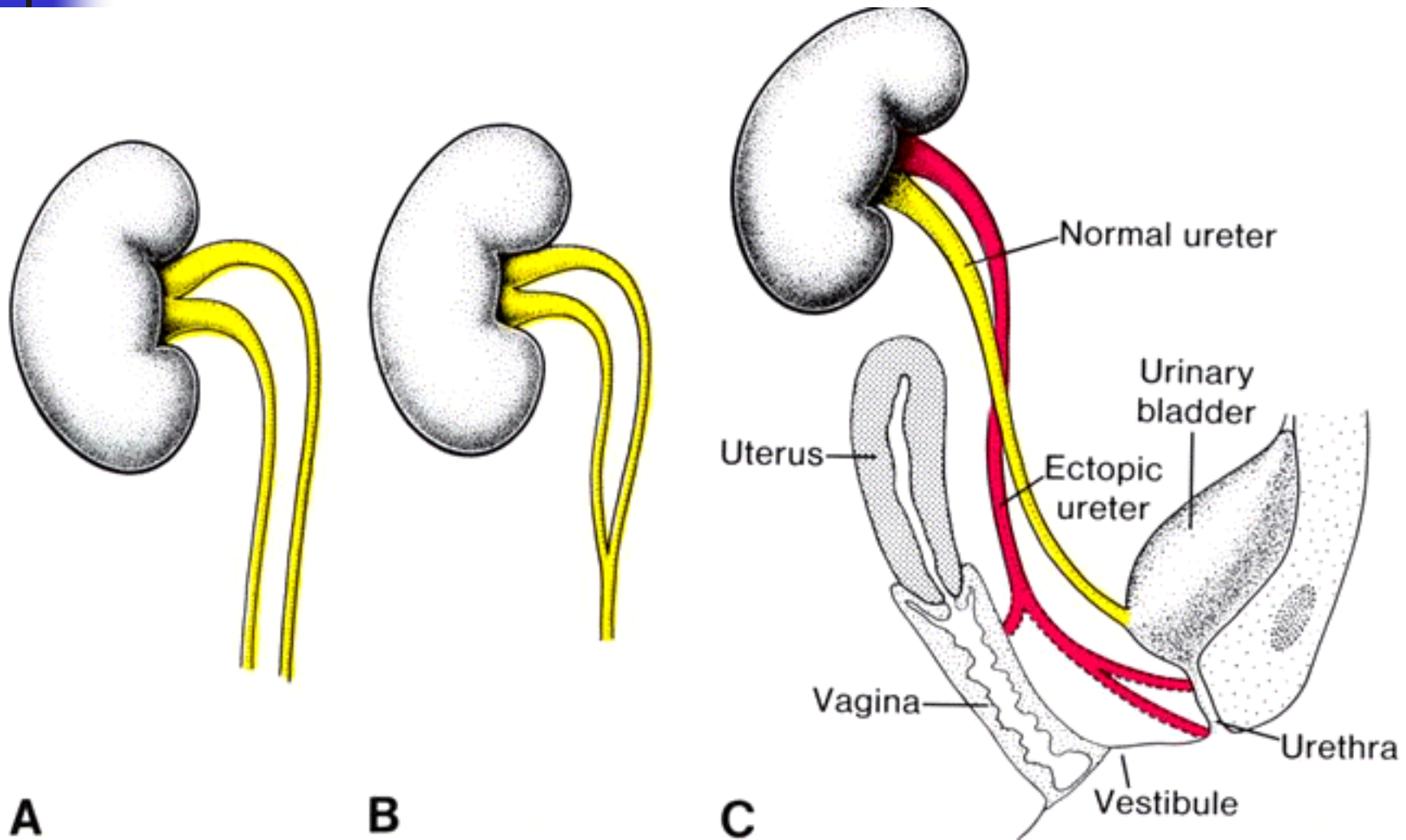


Figure 1. a) Posterior view of the horseshoe kidney. **b)** Anterior view of the horseshoe kidney. A horseshoe kidney with a wide hilum, fused inferiorly, below the *inferior mesenteric artery (I)* with double *renal arteries (A)*. There are two *renal veins (V)* on the right with a single *renal vein (V)* on the left.

- **Horse shoe kidney**

Double / Ectopic ureter



- For further inquiries ***PLZ*** feel free to contact at any time through email

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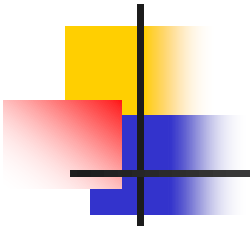

Thank You