Development of the Urinary System

Excretory portion of urinary system derived from intermediate mesoderm

Week 4: 1st nephrons/renal corpuscles form
• Nephrotomes form and develop hollow lumens to form nephric tubules
• Glomeruli form as 2 lateral branches of dorsal aorta grow into each nephric tubule

3 Distinct Embryonic Kidney Structures

Develop along a temporal cephalocaudal gradient
• pronephros – degenerates
• mesonephros – gives rise to mesonephric duct → forms collecting system of adult kidney
• metanephros – forms excretory system of adult kidney

Both segmented and unsegmented regions
Urogenital ridges form in dorsal body wall
- Grow and protrude into body cavity
- Suspended from dorsal body wall by urogenital mesentary
- Gonads form medially

Cloacal chamber forms with dilation of hindgut

Mesonephros
- both segmented and unsegmented regions
- forms nephrogenic cord
- forms mesonephric/nephrogenic duct which grows caudally and connects to cloaca

Mesonephric tubules
- Form rudimentary functional glomeruli
- Lateral portion of tubule forms mesonephric duct
Urorectal septum divides cloaca of hindgut into 2 chambers
- urinary bladder which is continuous with allantois
- anorectal canal

Ureteric bud
- grows from mesonephric duct
- grows into metanephros/metanephric blastema
- stimulates differentiation of metanephros

Ureteric bud
- bifurcates repeatedly from week 6 through month 5 to form 1-3 million collecting tubules
- continues to grow deeper into metanephric tissue
- forms: ureter, renal pelvis, major and minor calyces, collecting ducts, collecting tubules
- thus, forms all of the collecting system of the kidney

Week 6  Week 7  Birth
Metanephric tissue
- formation of renal vesicles in metanephros is induced by ingrowth of collecting tubules from the ureteric bud
- formation of Bowman’s capsule is induced by differentiation of glomeruli from invading blood vessels
- forms: Bowman’s capsule, proximal tubule, Henle’s loop, distal tubule
- thus, forms all of the excretory portion of the kidney

Renal agenesis:
failure of ureteric bud to grow into metanephros

Congenital polycystic kidney:
abnormal formation of proximal tubule or collecting tubule

Reciprocal Molecular Regulation Between Metanephros and Ureteric Bud
- Metanephric blastema expresses WT1 (primary inducer)
  - makes metanephros competent to respond to ureteric bud induction
  - induces growth and branching of the ureteric bud
- Metanephric mesenchyme expresses GDNF and HGF which stimulates ureteric bud proliferation
- Ureteric bud expresses FGF2 and BMP7
  - stimulates proliferation of metanephros
  - maintains WT1 expression
- Ureteric bud expression of WNT4 and Pax2 induces epithelial differentiation of renal vesicles
  (note: example of epithelial differentiation from mesoderm)
Caused by premature bifurcation of ureteric bud before contact with metanephros

Ectopic ureter is rare but is more common in association with double ureter

Question: If the ureteric buds becomes the ureters and they are an outgrowth of mesonephric duct, why are the adult ureters attached to the bladder?

Answer: The mesonephric ducts are resorbed into the posterior wall of the bladder.

Consequences:
- The resorbed mesonephric tissue forms the smooth trigone region of the bladder.
- The ureters are positioned at the apical corners of the trigone.
- The mesonephric duct resorption continues further: this positions the openings of the mesonephric ducts at the base of the trigone where they will form part of the male reproductive system.
As the urorectal septum divides the cloaca, the caudal end of the urinary bladder narrows to form the urogenital sinus and the urethra.

As the body grows in length and the curvature of the body begins to straighten, the relative position of the kidney in the body changes:
- the kidney ascends from pelvis into abdomen
- rotates 90° laterally during ascent
- vascular supply changes as it ascends: may lead to accessory renal vessels
- the gonad descends: thus the relative position of the gonad and kidney reverse

**Pelvic Kidney**

- Failure to ascend through fork of umbilical arteries
- Ectopic position: usually located at common iliac artery
Horseshoe Kidney

- Abnormal fusion of lower poles of kidneys during ascent
- Ectopic position: ascent impeded by root of inferior mesenteric artery
- Occurs in ~1/600 individuals
- Usually asymptomatic with normal kidney function: is frequently undetected

Bladder Defects

The allantois at the apex of the bladder usually degenerates into a fibrous cord of tissue to form the urachus (median umbilical ligament)

However, the allantois may persist as a urachal fistula, urachal cyst or a urachal sinus.