

Ch. 25: Urinary System

- Filters blood to remove toxins, wastes, excess ions
 - Regulate volume & composition of blood
 - Maintain water & electrolyte balance

Kidneys

- Retroperitoneal; superior in [lumbar] abdomen
- Cleft = renal hilus
 - Ureters, blood supply, lymphatics, nerves
- Support – renal capsule (protection), adipose capsule (cushion), renal fascia (anchor)
- Internal regions
 - cortex, medulla (pyramids, columns), pelvis (calyces)
- Rich blood supply: arteries & veins
 - renal, segmental, lobar, interlobar, arcuate, interlobular

Microscopic anatomy of kidneys

- Nephrons – blood processing, urine forming filtration units
 - Cortical or Juxtamedullary
 - Glomerulus – ball of capillaries
 - Renal tubule – elongated structure (glomerular/ Bowman's capsule, proximal tubule, loop of Henle, distal tubule)
 - Fenestrated glomerulus allows **filtrate** to pass
 - Long tubule allows filtrate processing before contents pass to collecting duct
 - Collecting ducts > papillary ducts > calyces

Capillaries of the Nephron

- Two capillary beds:
 - 1. Glomerulus *fed* and *drained* by arterioles
 - Afferent & Efferent arterioles
 - Very high pressure
 - 2. Peritubular capillaries
 - Post-glomerular; receive resorbed filtrate
 - Some: vasa recta – capillaries surrounding loop of Henle
- [1. produces filtrate, 2. reclaims filtrate]

Glomerulus

- Where afferent arteriole feeds glomerulus:
 - Juxtaglomerular cells (smooth muscle) – sense blood pressure – secrete renin
 - Macula densa – tubule cells sense filtrate concentration

Glomerulus

- Filtration membrane – filter between blood (in glomerulus) and capsule
- Allows passage of water & small solutes
- Prevents passage of plasma proteins, cells
- Capillary pores (fenestrations): stops cells
- Surrounding basement membrane: stops most proteins

Kidney Physiology

- Filtrate (blood plasma minus proteins) > Urine
 - ~1% of fluid processed leaves body
- Major processes in urine formation/blood balance:
 - 1. glomerular filtration
 - 2. tubular reabsorption
 - 3. tubular secretion

Glomerular Filtration

- Blood enters glomerulus at high pressure
- Filtered through highly permeable membrane
- Small molecules pass; are in = concentration in blood & filtrate
 - Water, glucose, amino acids, wastes
- Net positive filtration pressure forces fluid out of blood
 - BP (opposed by osmotic pressure of blood, capsular pressure)

Glomerular Filtration, cont'd.

- Glomerular filtration rate – amount of filtrate formed per minute
 - Surface area for filtration, permeability, pressure
 - Normally ~125 ml/min (180 L/day)
 - Small changes in BP, hydration alter GFR
 - Regulation critical (too slow – wastes retained; too fast – substances lost)
- Control of GFR:
 - Renal autoregulation, neural controls, renin-angiotensin system

Control of GFR

- Renal autoregulation – internal kidney pressure adjustment
 - Vasodilation of afferent arterioles

- Feedback from blood vessels (myogenic) & juxtaglomerular apparatus (tubuloglomerular)
- Neural control – sympathetic nervous system
- Renin-angiotensin – causes systemic BP rise
 - JG cells release renin > activates angiotensin

Tubular Reabsorption

- Reclaiming of filtrate contents to blood
 - Reabsorbed: nutrients
 - Not reabsorbed: wastes
 - Continually adjusted: water and ions
- Absorptive capabilities vary in tubule regions
 - Proximal: very active; most nutrients
 - Distal, collecting duct:
 - ADH increases water absorption
 - Aldosterone: sodium reabsorption to blood
 - ANP: inhibits sodium reabsorption – lowers blood volume

Tubular Secretion

- In proximal tubule: secretion from peritubular capillaries to filtrate
- Disposal of drugs, wastes, potassium ions not already in filtrate
- Controls/fine-tunes blood pH

Regulation of Urine Concentration & Volume

- Descending/ascending limbs of loop of Henle: different permeabilities to water, ions
 - In juxtamedullary nephrons (long loop)
 - water exits (descending), sodium ions exit (ascending)
- Formation of dilute urine - normal conditions
- Formation of concentrated urine
 - ADH inhibits urine output – increases collecting duct permeability to water
 - Water reabsorbed to blood, concentrating urine/ reducing volume

Urine – characteristics & composition

- Color/clarity – some shade of pale yellow (urochrome); clear after voiding
 - Abnormal: food/drugs, bile pigments, blood
 - Abnormal: infection

- Odor – ammonia after standing (bacterial metabolism); foods/disease
- pH – (4.5-8) altered by diet, retention, infection
- Specific gravity – (1.001-1.035) concentration
 - Abnormal low: kidney malfunction
 - Abnormal high: solute concentration too high

Urine – characteristics & composition cont'd.

- Chemical composition (~95% water)
 - Nitrogenous wastes – breakdown products
 - Urea – protein
 - Uric acids – nucleic acid
 - Creatinine – creatine phosphate
 - Nutrients, other abnormal components normally not present in urine
 - Glycosuria (glucose) – sugar overload or diabetes
 - Protein – exertion, pregnancy, renal trauma or disease
 - Ketones – starvation, diabetes
 - Hematuria (blood/RBC) – trauma, kidney stones, infection
 - Pyuria (leukocytes/WBC) – UTI
 - Bilirubinuria – liver disease

Ureters & Bladder

- Ureters – convey urine to bladder
 - Smooth muscle contractions propel urine (peristalsis)
 - Backflow prevented by bladder filling
- Bladder – temporary urine storage
 - Smooth, collapsible, muscular – retroperitoneal
 - Openings for ureters, urethra – “trigone”
 - Very distensible – has rugae
 - Transitional epithelium/mucosa, thick muscular layer

Urethra

- Thin muscular tube; carries urine from bladder to outside
 - Transitional > columnar > stratified squamous
- Internal urethral sphincter – bladder/urethra
- External urethral sphincter – surrounds urethra – skeletal muscle – voluntary
- Female – 3-4 cm long
 - UTI common: urethritis, cystitis, pyelonephritis
- Male – 20 cm long; also conveys semen

Urination and Control

- Micturition = urination = voiding
- Distention of bladder > stretch receptors > impulses to sacral spinal cord
 - Contraction of internal sphincter (involuntary) – sympathetic ANS
 - Stimulate contraction of external sphincter
- Decision to void (cerebral cortex) - micturition center in pons:
 - Relaxes internal sphincter (parasympathetic ANS)
 - Stimulates relaxation of external sphincter

Renal clearance

- Volume of plasma cleared of a substance in 1 minute
 - Varies substance by substance
 - Expressed in ml/min
 - Renal clearance determines the GFR, renal health
 - Tested with a substance that is not reabsorbed or stored by kidney
 - Renal clearance of each drug, substance measured
 - Max clearance ~140 ml/min (creatinine, many drugs)
 - Clearance of glucose, other nutrients: 0 in healthy normal