Urinary System
Unknown author

Functions of Urinary System:
1. excretion – excrete wastes

2. regulate blood volume and blood pressure by:
   a. adjusting water loss in urine
   b. releasing erythropoietin
   c. releasing renin

3. regulate plasma concentrations of Na+, K+, Cl^-

4. helping to stabilize blood pH by controlling excretion of H+ and $HCO3^-$

5. Assist liver with detoxifying poisons

Main Organs: kidneys form urine send it through urinary tract (ureter → urinary bladder → urethra)

Urinary Tract Organs
Ureters:
tubes carry urine from renal pelvis of kidney to bladder
inner lining is mucosa: epithelial tissue

middle layer is smooth muscle
peristaltic contractions roughly every 30 seconds

outer layer visceral peritoneum

Urinary Bladder:
muscular sac, posterior to pubic symphysis
lies anterior to the uterus in females

held in place via peritoneum & ligaments (middle & lateral umbilical ligaments)

trigone: triangular region with openings for urethra – works as a funnel
neck of bladder contains internal urethral sphincter: involuntary

innervated by both sympathetic and parasympathetic divisions of ANS

lining is mucosa consisting of epithelial tissue

muscularis layer is smooth muscle: forms detrusor muscle: contracts to expel urine
detrusor muscle also prevents urine from flowing back into ureters

distends: muscles stretch (can hold up to 1 L)
when empty collapses into folds called

Urethra:
drains urine from urinary bladder to outside

female: urethra: anterior to vagina

male urethra longer and subdivided into:
1.) prostatic urethra:
2.) membranous urethra: very short segment in floor of pelvic cavity
3.) penile urethra:

external urethral meatus: opening

external urethral sphincter: (urogenital diaphragm): the valve for urine
voluntary

lining of urethra stratified squamous epithelial tissue

Micturition Reflex: voiding or urination (page 986 figure 26-20)
1.) distension in urinary bladder activates stretch receptors (reflex)
2.) afferent fibers in pelvic nerves carry impulses to spinal cord & to thalamus to cerebral cortex of brain
so become aware of urge.
3.) stimulates parasymp. fibers which cause contraction of bladder & relaxation of internal sphincter.

external sphincter: voluntary can keep it closed
reflex begins when urinary bladder contains about 200 ml of urine – cycles as bladder volume increases
at 500 ml pressure will open internal urethral sphincter

Incontinence:
stress incontinence: from stretched or damaged sphincter muscles: increased intra-abdominal pressure causes urine to leak

damage to CNS, spinal cord or nerves to urinary bladder

Urinary Retention: occurs in males due to enlarged prostate gland (prostatic hypertrophy)

Kidneys:
bean shaped
T12 - L3:
medial indentation termed - hilus: leads into renal sinus
-renal blood vessels, ureters,

adrenal gland is found superior to each kidney

held in place via peritoneum & connective tissue

3 layers of connective tissue surround each kidney
1. renal capsule: innermost layer, directly attaches to kidney
covers outer surface of kidney (layer of collagen)

2. adipose capsule:

3. renal fascia: dense irregular connective tissue
surrounds both the kidney & adrenal gland
anchors kidney to surrounding structures – fuses with peritoneum

Sectional Anatomy of Kidney (page 954)
Cortex, Medulla, Pelvis
1. Renal Cortex:

2. Renal Medulla:
contains renal (medullary) pyramids
papilla : rounded tip – faces renal pelvis
base: flat portion – faces cortex

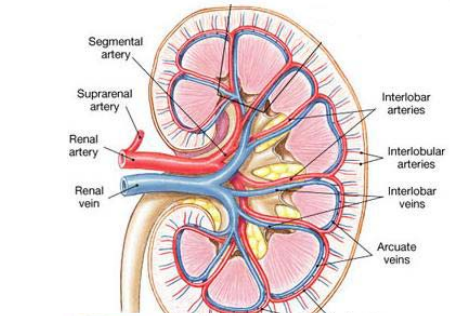
each renal pyramid forms renal lobe
each renal lobe contains nephrons which make urine

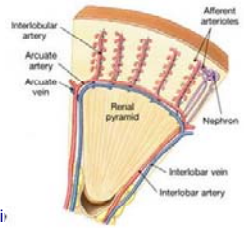
3. Renal Pelvis:
formed from the minor and major calyces (minor calyx, major calyx)
funnel shaped area
collects

pyelitis: infection of renal pelvis (usually from untreated UTI)

pyelonephritis: infection of kidney
- Signs/symptoms: high fever, intense pain on affected side, vomiting, diarrhea, blood and pus in urine
- Tx: intense antibiotic therapy

Blood and Nerve Supply: (p. 955) kidneys receive 20-25% of cardiac output
blood leaves heart to aorta – aortic arch – thoracic aorta – abdominal aorta:
renal arteries enter thru hilus branch into
↓
segmental (lobar) arteries
↓
interlobar arteries (pyramids to cortex)
↓
arcuate arteries(arch along boundary of cortex & medulla
↓
interlobular arteries (supply cortex)
↓
afferent arteriole (takes blood into glomerulus)
↓
glomerulus (capillary network)
↓
efferent arteriole (drains blood from glomerulus)
↓
peritubular capillaries (surround nephron tubules)
↓
venules
↓
interlobular veins
↓
arcuate veins
↓
interlobar veins
↓
renal vein





Blood Flow through kidney assessed by giving PAH (para-ami
PAH is removed from blood by nephrons and eliminated
compare plasma concentration with amount in urine

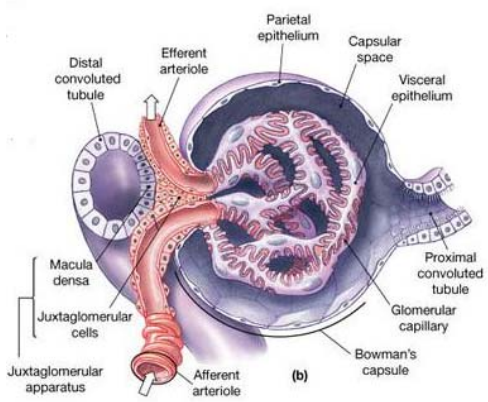
Renal plexus: ANS:
-sympathetic stimulation controls blood vessels: vasoconstriction/vasodilation

Nephrons:
each kidney contains
consists of:
1. glomerular (Bowman's) capsule (surrounds glomerulus)
note Renal Corpuscle is Bowman's capsule & glomerulus

2. proximal convoluted tubule (PCT)
3. Loop of Henle – descending & ascending limbs
4. distal convoluted tubule (DCT)

5. collecting duct.

Adaptations for each region:
1. glomerulus:



Glomerulus:

afferent arteriole:

efferent arteriole:

fenestrated capillaries

Surrounded by Bowman's Capsule

parietal epithelium: outer wall of capsule

visceral epithelium: covers glomerulus

podocytes:

2. Proximal Convoluted Tubule:
- simple cuboidal epithelium

-have microvilli

3. Loop of Henle: descending & ascending limbs
-lower part of descend limb (thin segment) contains simple squamous epithel. and is very permeable to

-ascending limb thick segment:
4. Distal Convoluted Tubule:
- simple cuboidal epithelial cells
-lack

-better suited for

Two types of Nephrons:
1. Cortical Nephrons:

2. Juxtamedullary Nephrons:

Juxtaglomerular Apparatus: regulates BP & rate of filtrate formation
point of contact between

juxtaglomerular (JG) cells in afferent arteriole:
-smooth muscle cells
-contain

-mechanoreceptors:

macula densa:
-contains chemoreceptors (osmoreceptors) respond

Principles of Renal Physiology
47 gallons fluid/day only 1% becomes urine
uses 20-25% of cardiac output
nephrons form the urine

- maintain homeostasis by regulating volume & composition of blood

-excrete wastes (urea, creatinine, uric acid) wastes are in blood, nephron filters them out of blood to eliminate them in urine

Basic Processes of Urine Formation
1.) Filtration: hydrostatic pressure forces water/solutes out of blood into nephron (Bowman's capsule)

2.) Reabsorption: removal of water/solutes from filtrate back into blood

3.) Secretion: transport of solutes from peritubular capillaries back into filtrate

Reabsorption and Secretion use the following methods of transport:
osmosis
diffusion

carrier-mediated transport: requires carrier protein – if saturate carrier protein cannot transport molecule (termed transport maximum or Tm) which indicates renal threshold
if renal threshold reached for reabsorption cannot reabsorb the substance and it is lost in urine

facilitated diffusion

active transport

cotransport

countertransport

1. Glomerular Filtration
filtration is passive
nonselective:
filtration membrane:

glomerular blood pressure is 50 mmHg vs 35 at arterial end of capillary bed

Filtration Membrane:
-filters b/w blood & glomerulus
-porous w/ 3 layers:
1. Fenestrated capillaries:

2. Visceral membrane of podocytes

3. Basement membrane: keeps most proteins out.

Net Filtration Pressure (NFP)
NFP = G.H.P. - (G.O.P.+ Cs.H.P.)
G.H.P. = glomeruluar hydrostatic pressure: (50 mmHg) – dependent on

G.O.P.= glomerular osmotic pressure: (25 mmHg) – dependent on

Cs.H.P.= capsule hydrostatic pressure: (15 mmHg)

NFP = 50 - (25 + 15)
NFP = 10 mmHg

Glomerular Filtration Rate (GFR)
-amount of fluid filtered from blood into kidney per minute – 125 ml/minute

1. total surface area for filtration

2. permeability of filtration membrane

3. NFP

or if there is decreased filtrate and flow:

renal autoregulation: regulates diameter
GFR is directly proportional to NFP therefore anything that alters NFP effects GFR

Regulation of Glomerular Filtration
A. Intrinsic: kidneys (renal) autoregulation

kidney regulate glomerular filtration thru monitoring
if flow rapid (large amounts of filtrate prod.)

1. Myogenic Mech.: responds to pressure changes
smooth muscle contracts when stretched if systemic BP increases,

so it keeps glomerular pressure

if systemic BP falls, causes

2. Tubuloglomerular Feedback Mech.

A. Controlled by Macula Densa cells of juxtaglomerular apparatus

in distal tubules respond to slow flowing filtrate and/or osmotic signals

but if flow is fast or high osmolarity, will release

B. Renin-Angiotensin Mech. (hormonal)
juxtaglomerular cells release renin cause anigiotensinogen to release angtiotensin I which is converted to angiotensin II powerful vsoconstrictor
(angiotensin II constrict efferent arteriole to increase glomerular blood pressure)

-also causes adrenal cortex to release

-travels to CNS to release ADH

3 factors trigger release of renin:
1. Decreased stretch of JG cells

2. Macula Densa cells cause vasodilation

3. Sympathetic nervous system

C. Extrinsic (Autonomic):
sympathetic nervous system

stress or emergency

.

symp. fibers --> epinephrine causes

triggers the release of renin by JG cells

2. Tubular Reabsorption
filtrate contains same as blood plasma except urine:

need to get stuff from filtrate back into blood so it doesn't become urine and is lost

begins when filtrate enters proximal tubules and is moved thru

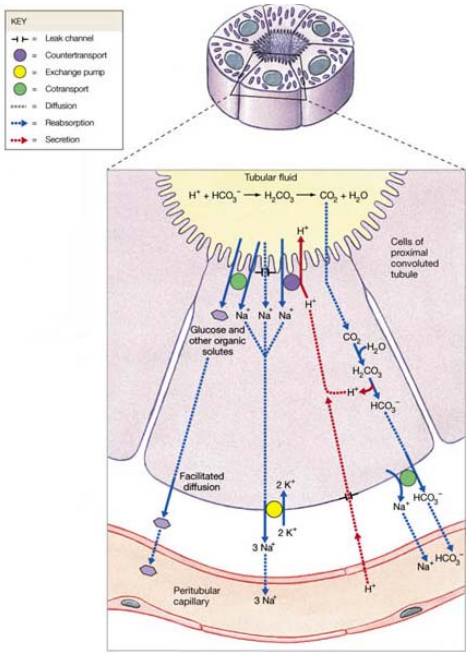
glucose, AA reabsorbed cotransport with Na

active transport: ion pumps for Na^+, K^+, $HCO3^-$, Mg^{++}, PO_4^{3-}

passive reabsorption of: water, urea, Cl^- and lipid soluble molecules

Na+ reabsorbed several ways

Solvent Drag: substances reabsorbed because water reabsorption increases their concentration in the filtrate (creates a concentration gradient for them).



Nonreabsorbed Substances:
because

urea, creatinine, uric acid

Different Regions of Tubules and What They Absorb:

Proximal Convoluted Tubule: most involved in reabsorption
absorbs

Loop of Henle:

Distal tubule:

-Aldosterone: controls

3. Tubular Secretion
blood secretes molecules back into tubule (filtrate)
2nd chance for

H & K are both secreted in exchange for Na

compete for secretion

Important because:
1. Disposing of

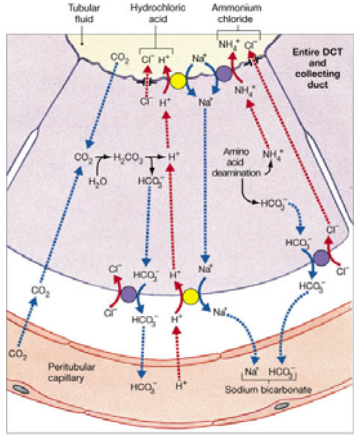
2. Eliminating

3. Getting

4. Controlling

when pH decreases:

when pH increases:



(c) H^+ secretion and HCO_3^- reabsorption

Regulation of Urine Concentration and Volume: Loop of Henle
countercurrent mechanism:

osmolarity of filtrate in prox. convoluted tubule= osmolarity as filtrate moves from cortex to medulla

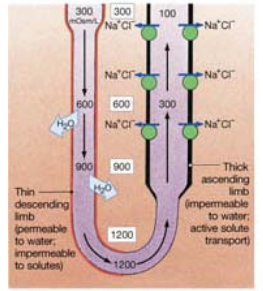
1. Descending limb:
impermeable to

permeable to

2. Ascending limb:
impermeable to

permeable to

3. Collecting tubules in deep medullary regions:
permeable to



(b) Active transport of NaCl along the ascending thick limb results in the movement of water from the descending limb.

as urine passes thru deep medullary regions,

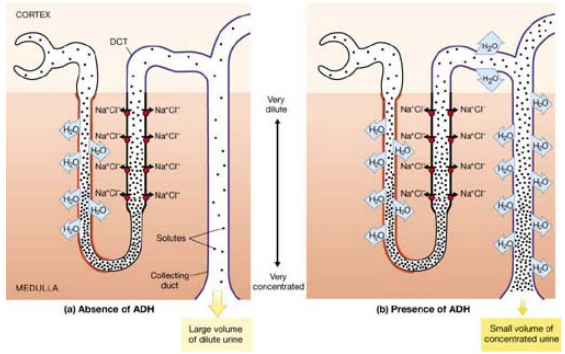
4. Vasa recta acts as countercurrent exchange:
maintains osmotic gradient

found near

establishes a concentration gradient that will allow the passive reabsorption of water from the tubular fluid.

Formation of Dilute Urine:
filtrate diluted as passes thru:

when ADH not released by
posterior pituitary:



Formation of Concentrated Urine:
ADH: decreases urine, by

facultative water reabsorption:

obligatory water reabsorption:

release of ADH:

Diuretics:
enhance
osmotic diuretic:

alcohol:

caffeine:

drugs:

Renal Clearance:

creatinine clearance test used to estimate GFR
monitor creatinine in blood and amount in urine over 24 hr. period

note RC of glucose = 0

RC less than creatinine indicates some of it was reabsorbed

RC of urea= of sodium= creatinine=

RC< 125 means:
RC = 0 indicates:

RC > 125 means

Aging and the Urinary System:
- decrease in number of functional nephrons (30-40% loss between ages 25 – 85)
- reduction in GFR
- reduced sensitivity to ADH
- problems with micturition reflex

Characteristics of Urine:
color:
pH:
normal components of urine: urea, creatinine, ammonia, uric acid, bilirubin, urobilin

Clinical Applications
Urinalysis: Abnormal components of urine:
hematuria
glycosuria
proteinuria (albuminuria)
ketonuria
pyuria
azotemia

Normal Renal Function Tests BOX 28-2

Test	Normal Value	Interpretation
Color	Amber-yellow	Drugs and foods may change color
Turbidity	Clear	Purulent matter will make cloudy
pH	4.6-8.0	Bacteria create an alkaline urine
Specific gravity		Represents concentrating ability or density of urine (i.e., higher when contains glucose or protein; lower with dilute urine)
Adult	1.010-1.025	
Infants	1.010-1.018	
Blood	Negative	Bleeding along urinary tract
MICROSCOPIC URINE		
Bacteria	None	Infection
Red blood cells	Negative	Bleeding along urinary tract
White blood cells	Negative	Urinary tract infection
Crystals	Negative	May have potential for stones
Fat	Negative	Can be associated with nephrosis
Casts	Occasional	A few are normal, may represent renal disease
URINARY CHEMISTRY		
Bilirubin	Negative	Increases may cause dark orange color
Urobilinogen	Negative	
Ketones	Negative	Represents an increase in fat metabolism
Glucose	Negative	Usually signifies hyperglycemia
Sodium	100-260 mEq/24 hr	Can increase or decrease with renal disease
Potassium	25-100 mEq/24 hr	
Protein	Negative-trace	Dysfunction of the glomerulus
NORMAL SERUM VALUES		
BUN	8-25 mg/dl	Elevated with diseased kidneys
Creatinine		Elevated with diseased kidneys
Male	0.6-1.5 mg/dl	
Female	0.6-1.1 mg/dl	
Potassium		Elevated in renal failure

Clinical Applications:

1. Kidney stones (renal calculi)

2. Urinary Tract Infections (UTIs)
bacterial or fungal pathogens

more common in females (shorter, close to anus, sexual intercourse can push bacteria into urethra)

- urethritis: inflammation of urethra
- cystitis: inflammation of urinary bladder
- dysuria:

3. Bladder cancer
3X more prevalent in males
spreads through adjacent lymph nodes/tissue quickly

4. Glomerulonephritis:
antigen-antibody complexes clog up filtration membrane and filtration decreases

5. Renal Failure:

Acute renal failure

Chronic renal failure