Human Anatomy & Physiology 20

Urinary System

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Instructor

Unit Five

Urinary System URLs

http://www.howstuffworks.com/kidney.htm/printable

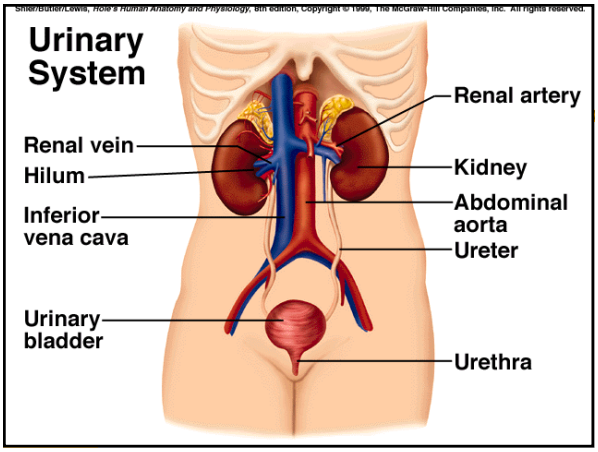
http://kidney.niddk.nih.gov/kudiseases/pubs/Yoururinary/

http://content.jeffersonhospital.org/Content.asp?PageID=P01468

http://nephron.com/htkw.html

Introduction

A. The urinary system consists of two kidneys that filter the blood, two ureters which transport urine from the kidneys, a urinary bladder which collects urine from the ureters & serves as a reservoir, & a tubular urethra to convey waste substances to the outside of the body.



Kidneys

Next to your brain, your kidneys are some of the most complicated pieces of equipment you have. In the next minute more than one quart of blood will pass through your kidneys. It will come out with just the right wastes removed so it can continue to carry on your life's work.

Kidneys are filters. Each is a mass of more than a million tiny filter tubes. Blood is filtered into these tubes and then out again. Wastes are captured in these tubes and left behind. These wastes drain their way out of the kidney, in the form of urine, to your bladder.

Inside the Kidney

Blood rushes into the kidney from a large artery. It flows into even smaller vessels called a glomerulus.

The flow changes from something like a gushing river to many meandering streams.

The ball of blood vessels is enclosed in a capsule made of 2 thin walls. The slowed blood has time to filter into the surrounding membrane. All but the largest particles (like blood cells) filter through the capsule into small tubes. These tubes are called nephrons, & are where the cleaning takes place. All of the valuable parts are reabsorbed into the blood. The wastes stay behind. All the threadlike nephrons point to the kidney's center. That is where the wastes, in the form of urine, are sent.

Urine leaves the kidneys through tubes called ureters, which lead to a storage bag called the bladder. You can sense when your bladder is full. At this point you eliminate hours of wastes in one go.

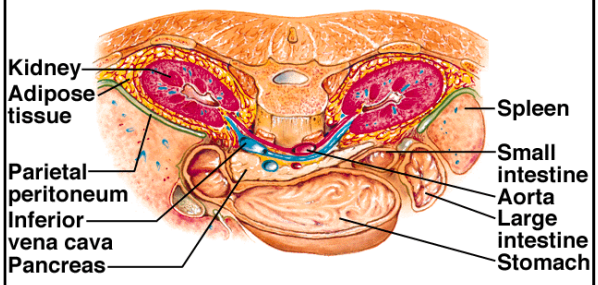
Your kidneys hang near your spine in the middle of your back. They are located on either side of your spine in line with your elbows.
The kidneys are protected by ribs and fat. If anything happened to the all-important filters, it would not be many hours before you would begin to be poisoned by your own wastes.
Humans are well-equipped in the kidney department. Should one fail, you can function quite well with the other. People have been known to survive with only one half of one healthy kidney.

Kidneys

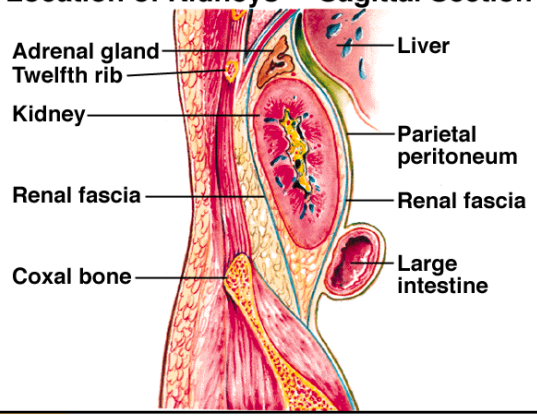
The kidney is a reddish brown, bean-shaped organ 12 centimeters long (about the size of a bar of soap); it is enclosed in a tough, fibrous capsule.

Location of the Kidneys – lie on either side of the vertebral column; retroperitoneal behind the parietal peritoneum & against the deep muscles of the back. Connective tissue & adipose tissue hold them in place

Location of Kidneys — Transverse Section



Location of Kidneys — Sagittal Section



Kidney Structure – lateral surface is convex, but its medial surface is concave leading to the renal sinus/ hilum where blood vessels, nerves, lymphatic vessels, & the ureter pass

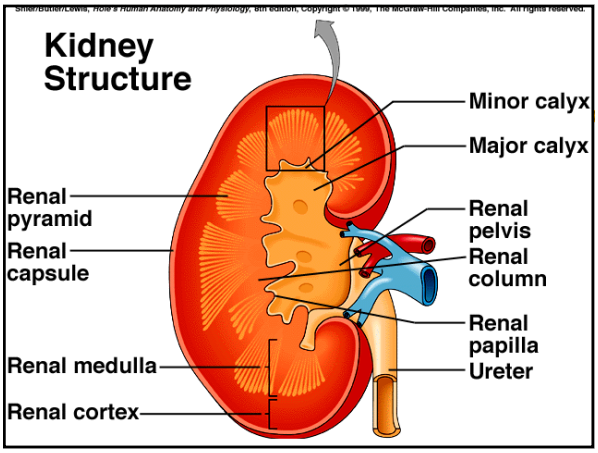
*ureter expands to form the renal pelvis which is located inside the renal sinus; the pelvis subdivides into 2-3 tubes called major & several minor calyces which subdivide into renal papillae

*2 kidney regions – renal medulla & renal cortex

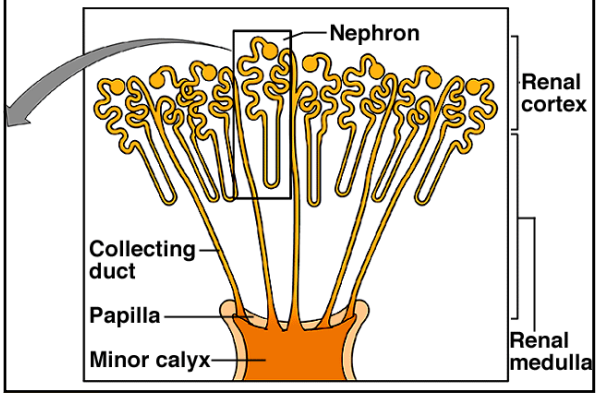
medulla – composed of conical masses of tissue called renal pyramids; appears striated because of microscopic tubules

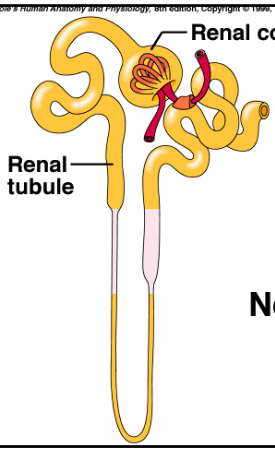
cortex – appears granular due to tiny tubules associated with nephrons (functional units)

Kidney Structure



Renal Pyramid





Nephron

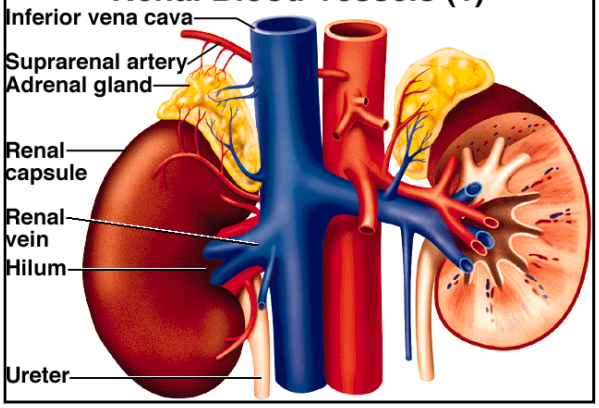
Functions of the Kidneys

1. Remove metabolic wastes from the blood & excrete them to the outside; wastes are nitrogenous & sulfur-containing products of protein metabolism
2. Regulate volume, composition, & pH of body fluids
3. Supply glucose when the liver isn't
4. Secrete renin (an enzyme) – helps regulate Bp & kidney function
5. Secrete erythropoietin (a protein) – stimulates red blood cell production in bone marrow
6. Regulate absorption of Ca ions by activating vitamin D

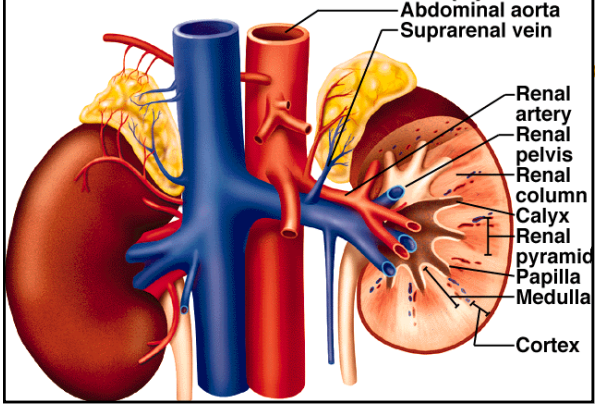
****hemodialysis – a person's blood is rerouted across an artificial membrane that "cleanses" it, removing wastes; patients must use this about 3 times/week

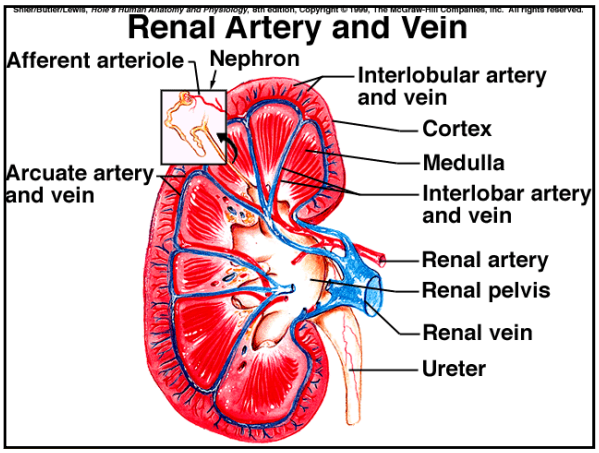
Renal Blood Vessels – Arterial blood flows through the renal artery, interlobar arteries, arcuate arteries, interlobular arteries, afferent arterioles, glomerular capillaries, efferent arterioles, & peritubular capillaries

Renal Blood Vessels (1)



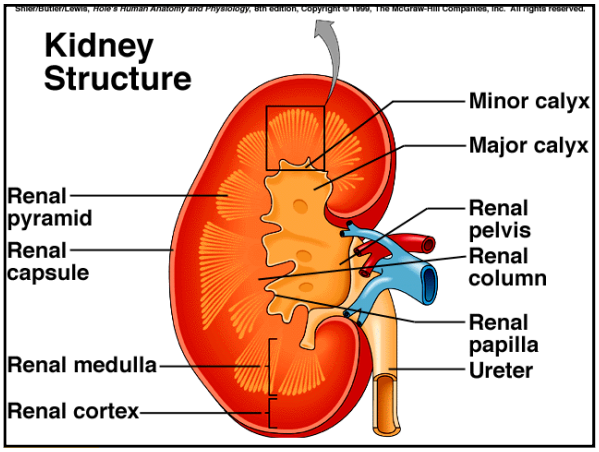
Renal Blood Vessels (2)

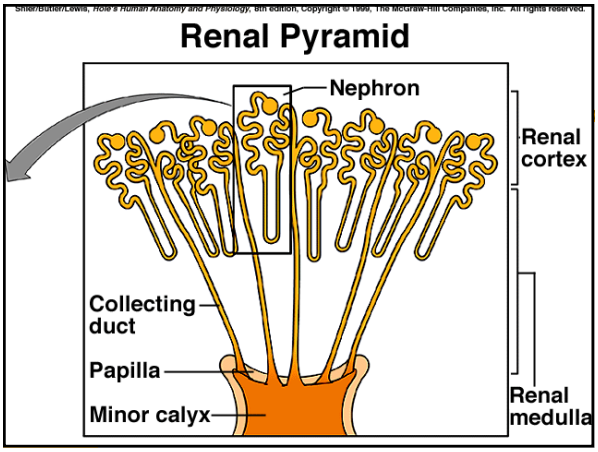


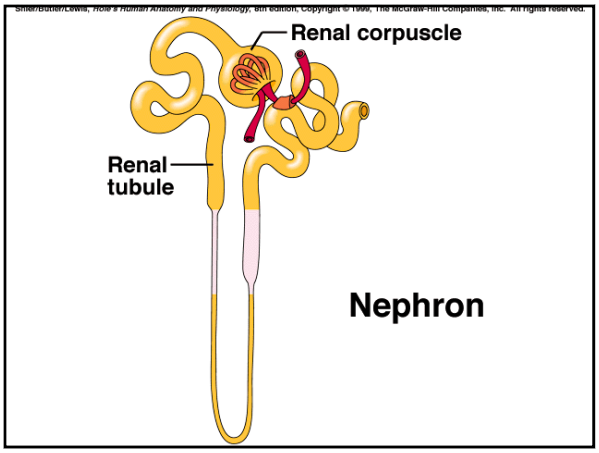


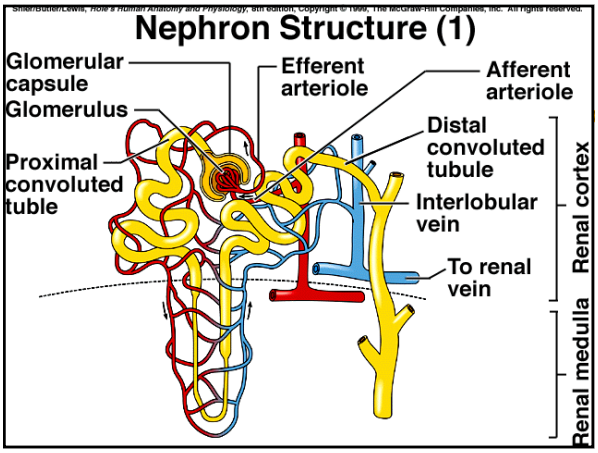
Nephrons (functional unit of the kidney)

- *each kidney contains about 1 million nephrons
- *consists of a renal corpuscle & a renal tubule
- *corpuscle consists of a glomerulus & a glomerular capsule
- *portions of the renal tubule include the proximal convoluted tubule, the nephron loop (loop of Henle, ascending & descending limbs), & the distal convoluted tubules
- *nephron joins a collecting duct, which empties into the minor calyx of the renal pelvis

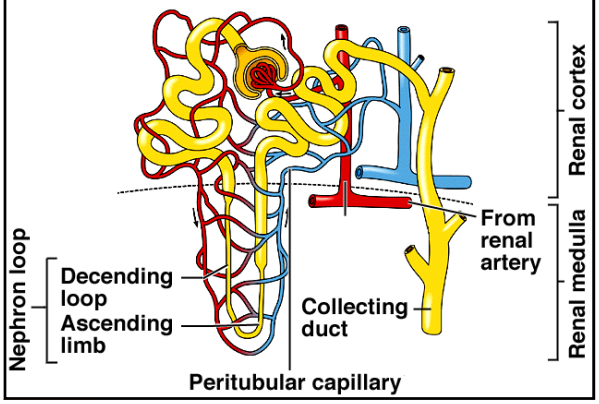








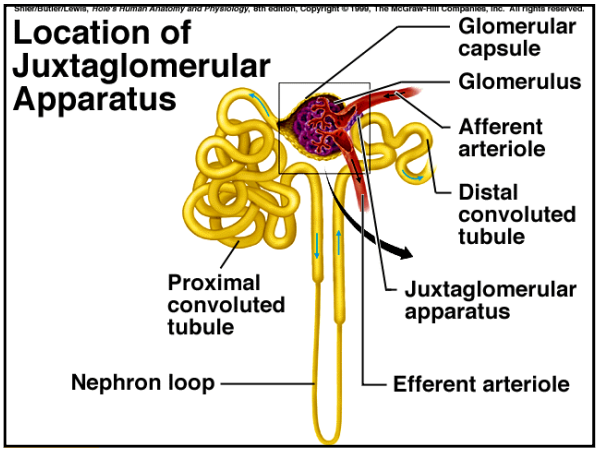
Nephron Structure (2)



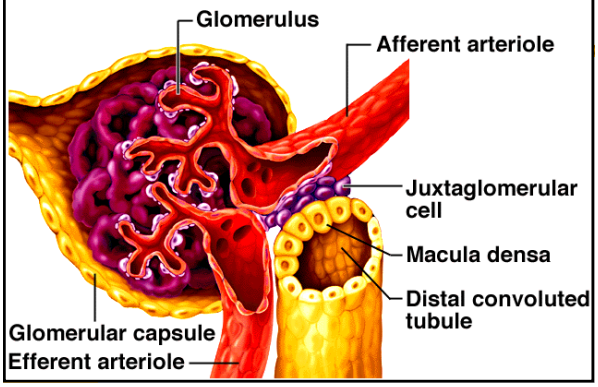
Nephrons (continued)
Juxtaglomerular Apparatus

***juxtaglomerular apparatus – located at the point of contact between the distal convoluted tubule & the afferent & efferent arterioles; consists tall & tightly packed cells called the macula densa & smooth muscle cells called juxtaglomerular cells;**
***this structure is important in regulating the secretion of renin, an enzyme, (helps regulate blood pressure)**

Location of Juxtaglomerular Apparatus



Juxtaglomerular Apparatus

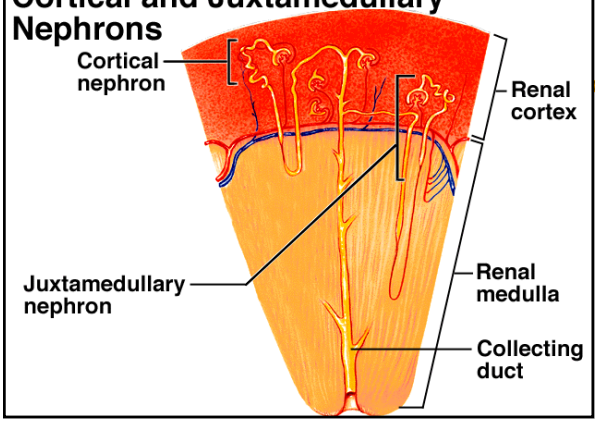


***Cortical & Juxtaglomedullary Nephrons**

***cortical nephrons are the most numerous & have corpuscles near the surface of the kidney & do not reach the medulla**

***juxtamedullary nephrons have corpuscles near the medulla – help regulate water balance**

Cortical and Juxtamedullary Nephrons



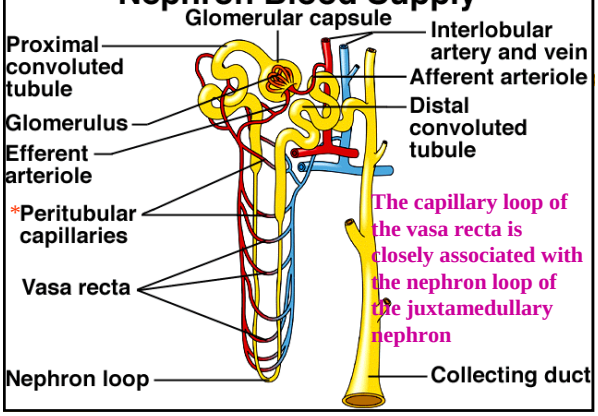
*Blood Supply of a Nephron

1. The glomerular capillary receives blood from the afferent arteriole & passes it (minus wastes) to the efferent arteriole.(afferent arterioles have larger diameters than efferent arterioles > higher pressure in glomerular capillaries compared to other capillaries)

2. The efferent arteriole gives rise to the peritubular capillary system, which surrounds the renal tubule.

3. Capillary loops, called vasa recta, dip down into the medulla.

Nephron Blood Supply



The capillary loop of the vasa recta is closely associated with the nephron loop of the juxtamedullary nephron

Pathway of Blood through Kidney and Nephron

Renal artery
↓
Interlobar artery
↓
Arcuate artery
↓
Interlobular artery
↓
Afferent arteriole
↓
Glomerular capillary
↓
Efferent arteriole
↓
Vasa recta and peritubular capillary
↓
Interlobular vein
↓
Arcuate vein
↓
Interlobar vein
↓
Renal vein

Urine

A lot of people feel a little embarrassed talking about….. Many ancient people used it as soap. Some American Indians used it as mouthwash. In South America it has even been sipped as a refreshing drink. Shocked??? Urine hasn't changed!!!
Healthy, fresh urine is cleaner than spit, cleaner than your hands, & cleaner than the food you eat. Fresh urine has no bacteria in it. It contains about 95% water & 5% urea, (the waste from protein breakdown). It also contains small amounts of normally useful substances which were filtered out of the blood because there was too much of them. Fresh urine has a definite smell. If it stands around it will collect bacteria, which will start its decay. The urea eventually becomes ammonia.

Urine Formation

Nephrons – control compostion of body fluids & remove wastes from the blood = URINE contains wastes, excess H_2O, & eletrolytes

URINE formation involves 3 processes:

(1) glomerular filtration – certain chemicals move from the glomerular capillaries into the renal tubules

(2) tubular reabsorption – some of these chemicals move back into blood plasma

(3) tubular secretion – certain other chemicals move from the peritubular capillaries into the renal tubules

This equation determines the volume of substances excreted in urine.

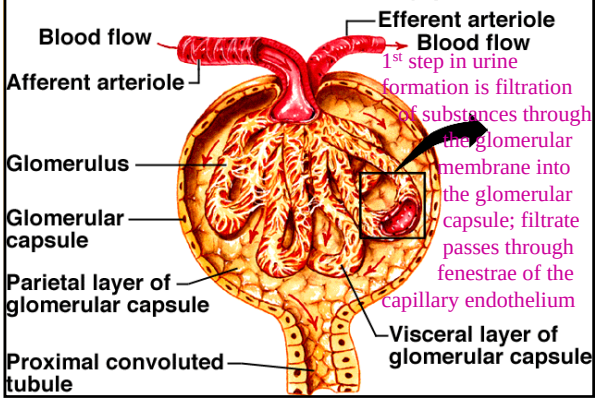
Urinary excretion = glomerular filtration
+ tubular secretion
- tubular reabsorption

Urine Formation

B. Glomerular Filtration – (1st step in urine formation) urine formation begins when water & dissolved materials are filtered out of the glomerular capillary; glomerular capillaries are much more permeable than the capillaries in other tissues due to fenestrae (tiny openings); the glomerular capsule receives the resulting glomerular filtrate (read text for the contents)

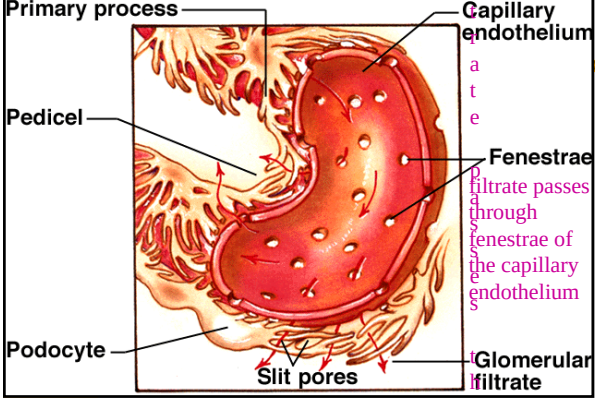
C. Filtration Pressure – hydrostatic pressure inside glomerular capillaries enables filtration; composition of the filtrate is similar to that of tissue fluid

Renal Filtration (1)



1st step in urine formation is filtration of substances through the glomerular membrane into the glomerular capsule; filtrate passes through fenestrae of the capillary endothelium

Renal Filtration (2)



Plasma filtrate passes through fenestrae of the capillary endothelium

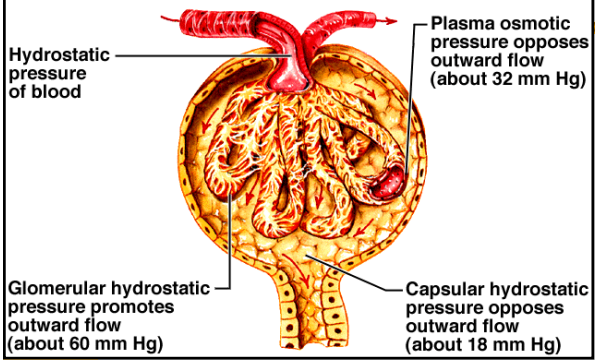
D. Filtration Rate – glomerular filtration rate (GFR) kidneys produce about 125 ml of glomerular fluid/minute, most is reabsorbed

E. Regulation of Filtration Rate – remains constant but can change when the need arises; sympathetic nerves can decrease GFR

Rate affected by hydrostatic & osmotic pressure of the plasma,

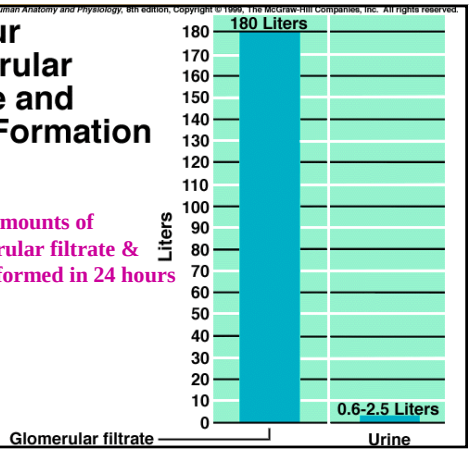
Glomerular Filtration Rate

& the hydrostatic pressure of the fluid in the glomerular capsule

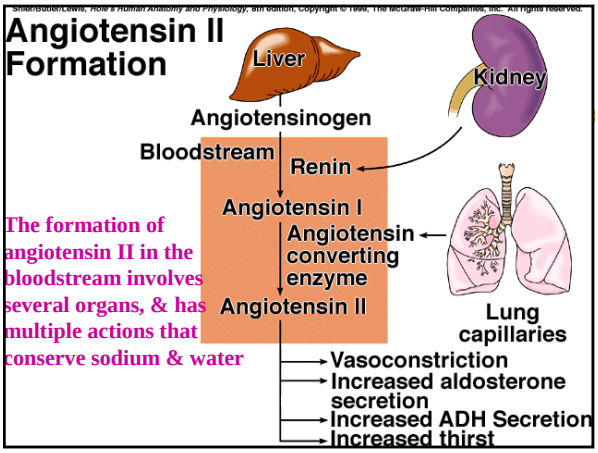


24-Hour Glomerular Filtrate and Urine Formation

Relative amounts of
(a) glomerular filtrate &
(b) urine formed in 24 hours



Angiotensin II Formation



The formation of angiotensin II in the bloodstream involves several organs, & has multiple actions that conserve sodium & water

Tubular Reabsorption – (2nd step in urine formation)

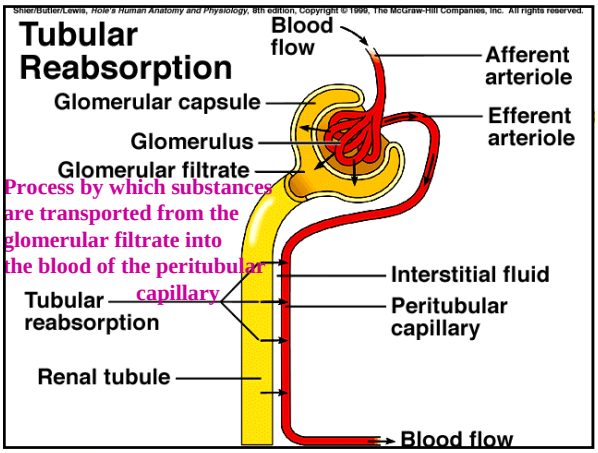
*substances are selectively reabsorbed from the glomerular filtrate

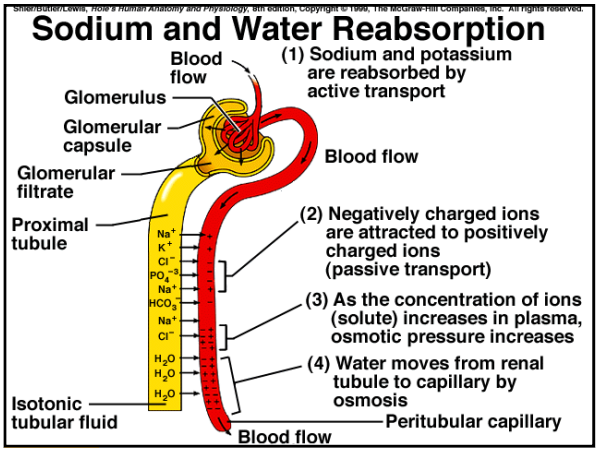
*the permeable peritubular capillary is adapted for reabsorption; it carries low-pressure blood; it is very permeable

*most reabsorption occurs in the proximal tubule, where the epithelial cells possess microvilli; different modes of transport reabsorb substances (ie) active transport, osmosis, & pinocytosis

*if the concentration of a substance in the filtrate exceeds its renal plasma threshold, the excess is excreted as urine

*substances that remain in the filtrate are concentrated as water is reabsorbed



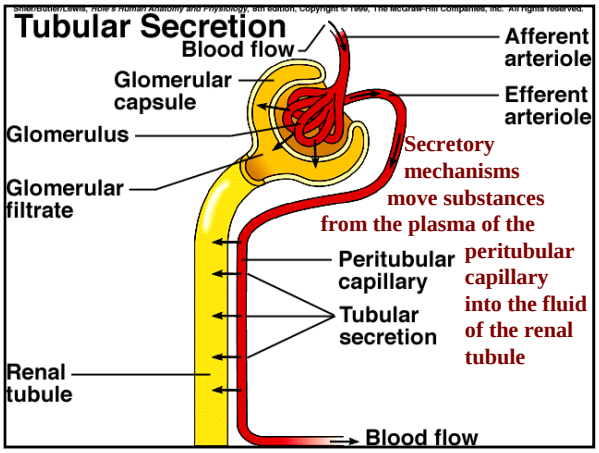


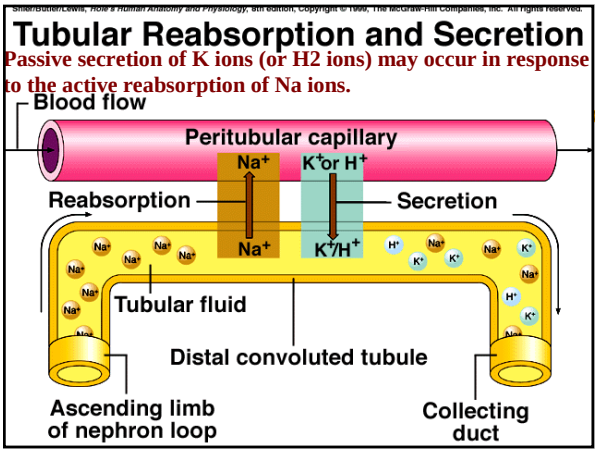
Tubular Secretion:

*Involves movement of certain substances from the blood plasma of the peritubular capillary into the fluid of the renal tubule (ie.) organic compounds, H2 ions, & K ions; occurs by active transport

Urine forms as a result of:

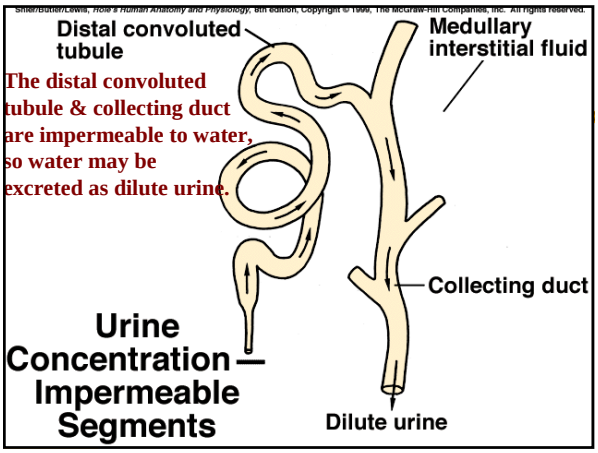
*glomerular filtration of materials from blood plasma
*reabsorption of valuable substances (see text)
*secretion of substances (not-needed) (see text)



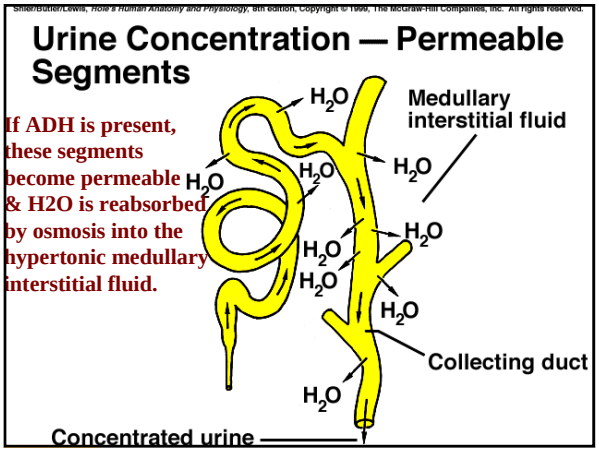


Regulation of Urine Concentration and Volume

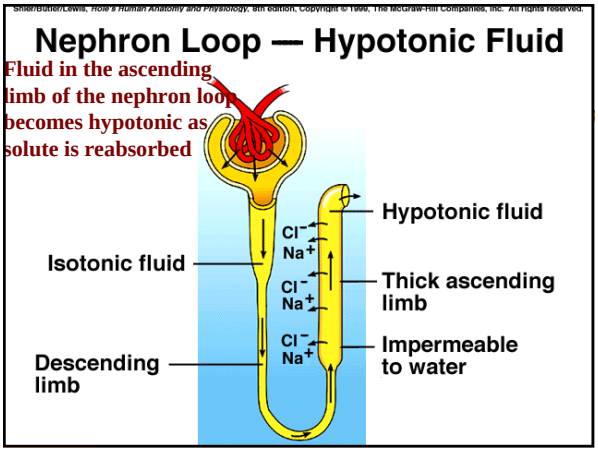
*most of the Na ions are reabsorbed before the urine is excreted; Cl ions are reabsorbed in the ascending limb; tubular fluid becomes hypotonic; water leaves the descending limb by osmosis; NaCl enters & fluid becomes hypertonic; distal tubule & collecting duct are impermeable to water so it is excreted in the urine; this is a countercurrent mechanism



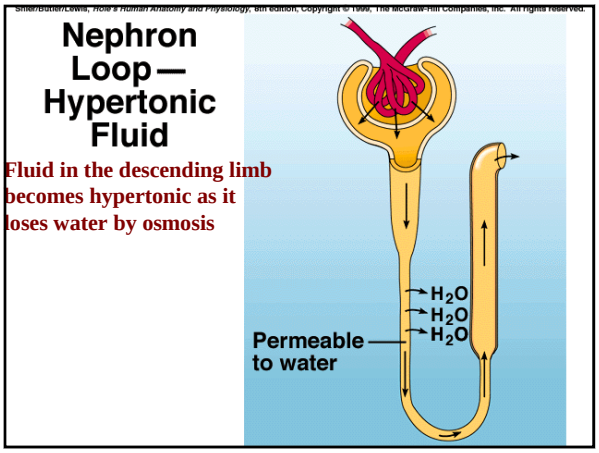
The distal convoluted tubule & collecting duct are impermeable to water, so water may be excreted as dilute urine.



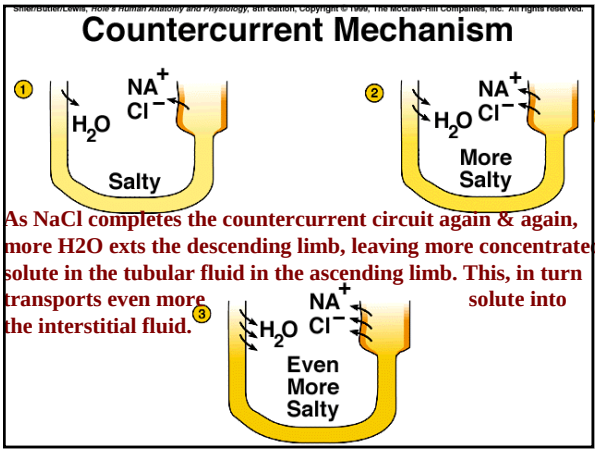
If ADH is present, these segments become permeable & H2O is reabsorbed by osmosis into the hypertonic medullary interstitial fluid.



Fluid in the ascending limb of the nephron loop becomes hypotonic as solute is reabsorbed



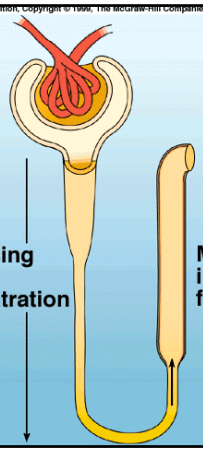
Fluid in the descending limb becomes hypertonic as it loses water by osmosis



As NaCl completes the countercurrent circuit again & again, more H2O exts the descending limb, leaving more concentrate solute in the tubular fluid in the ascending limb. This, in turn transports even more solute into the interstitial fluid.

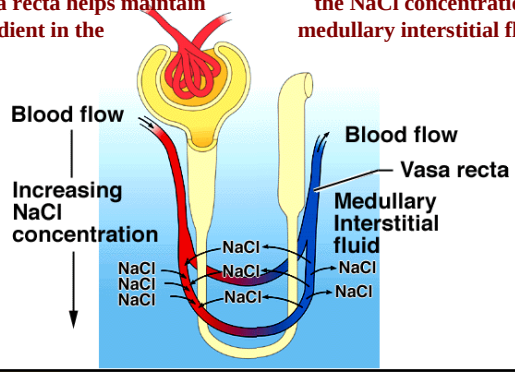
Establishment of NaCl Concentration Gradient

As a result, an NaCl concentration gradient is established in the medullary interstitial fluid



Countercurrent Mechanism—Vasa Recta

A countercurrent mechanism in the vasa recta helps maintain the NaCl concentration gradient in the medullary interstitial fluid



Urea and Uric Acid Excretion

*urea is a by-product of amino acid metabolism; about 50% is excreted in urine; the rest helps reabsorb H2O
*uric acid results from the metabolism of nucleic acids

Urine Composition – 95% water, contains urea, uric acid & creatinine; may contain a trace of amino acids, varying amounts of electrolytes, depending upon dietary intake

*volume of urine varies with the fluid intake & with certain environmental factors

Elimination of Urine

After forming in the nephrons, urine passes from the collecting ducts to the renal papillae, then to the minor and major calyces, and out the renal pelvis to the ureters, urinary bladder, and finally to the urethra, which conveys urine to the outside.

Ureters – a tubular organ that extends from each kidney to the urinary bladder, wall has mucous, muscular, & fibrous layers; peristaltic waves in the ureter force urine to the bladder; obstruction in the ureter stimulates strong peristaltic waves & a reflex that decreases urine production

Bladder

A muscular bag located in the middle of your lower abdomen. It is easy to find if you haven't emptied it in a while. Give the area a poke, & your full-up feelings will let you know when you are on target.

Bladders & balloon water bombs have certain things in common. They both stretch, & they both have limits on how much they can comfortably hold. An adult bladder will hold about one quart of fluid.

A human bladder, like a water balloon, will hold liquid as long as its opening is tightly shut. A living bladder is held shut by a contracting band of muscles called a sphincter. When these sphincter muscles around the opening become relaxed, the liquid inside rushes out, leaving a small shrunken bag.

Bladders do have certain special improvements over balloons A bladder has 3 openings, or doors. It fills constantly through 2 of those, which are connected to tubes from the 2 kidneys.

Your bladder also has a full-up signal system that tells you when it is time to empty. Then the bladder's strong muscular walls do a magnificent job of squeezing a full bladder down to empty.

"Bladder Signals"
You have special nerve endings in your bladder walls called stretch receptors. As your bladder fills, & the walls stretch, the receptors signal the brain that your internal reservoir is getting full. You take notice & think maybe you'd better take steps to do something about it.

If you are busy you might ignore the message. The signal stops & you forget about it for an hour or more. Sooner or later the signal returns. It will come faster and faster as your bladder gets fuller and fuller – until, no matter how hard you try, you can ignore it no longer.

Finally, to relieve yourself of those furious messages, you urinate.

"Amazing facts"

-Each day 180 quarts of blood are pumped through the kidneys. (That's 25% of the blood pumped through your heart, or as much blood as flows through 100 pounds of muscle.)

-Each kidney contains about 1 million tiny tubes, which add up to more than 40 miles in length.

C. Urinary Bladder – distensible organ that stores urine & forces it into the urethra; openings for the ureters & urethra are located at the 3 angles of the trigone in the floor of the urinary bladder; muscle fibers in the wall form the detrusor muscle; a portion of the detrusor muscle forms an internal urethral sphincter

D. Micturition – process of expelling urine; involves contraction of the detrusor muscle & relaxation of the external urethral sphincter; micturition reflex – located in the sacral segments of the spinal cord; nerve centers in the brain & cerebral cortex aid control of urination *****

E. Urethra – conveys urine from the bladder to the outside