I. Anatomy of the Urinary System

A. The Kidney

1. Kidney basic structure

   a. Renal artery – carries blood into kidney from the aorta. Total renal blood flow = 1200 ml/min

   b. Renal vein – carries blood from the kidney to the vena cava

   c. Cortex of the kidney is a three layer capsule outer covering

   d. Medulla is the central area of the kidney and contains 8-12 renal pyramids

   e. Renal pelvis - collects from all the renal pyramids

   f. Ureter – carries the urine to the bladder

2. Nephron – the functional or working unit, a little over 1 million/kidney

   a. Types of juxtamedullary nephrons: Based on location, some are in the cortex (cortical nephrons) and others straddle cortex/medulla (medullary nephrons).

   b. Nephritis is the inflammation of kidney tissue

      1) Pyelonephritis – inflammation with bacterial infection

      2) Glomerulonephritis – inflammation without bacterial infection

   c. Nephrosis is kidney degeneration without inflammation

   d. Has two major parts: glomerulus (Renal Corpuscle), and renal tubules

      1) Glomerulus – is highly specialized “tuff” of capillaries, involved in filtration (ultrafiltration) located in the cortex area

         a) Afferent arteriole - arteriole that carries blood from the renal artery into the nephron

         b) Glomerular capillaries or glomerulus - the specialized capillaries of the glomerulus where the non-selective filtration occurs

c) Efferent arteriole - arteriole carrying the blood from the nephron, to eventually return to the renal vein. As the blood leaves, it passes close to the renal tubules and some reabsorption of substances occurs.

2) Renal tubules

a) Bowman's capsule – cup-shaped sac encircling the glomerulus, collects the ultrafiltrate from the glomerulus.

b) Proximal convoluted tubule – connected to and immediately following the Bowman's capsule. Reabsorption of water and essential substances begins.

c) Loop of Henle - more reabsorption

d) Distal convoluted tubule - more reabsorption of sodium and water. Final concentration of the filtrate begins.

(1) Juxtaglomerular apparatus - Located where the distal convoluted tubule passes very close to the glomerulus, between (and in close contact with) the afferent and efferent arterioles.
(2) Macula densa - As part of the distal convoluted tubule, these special cells and those surrounding the afferent and efferent arterioles are sensitive to, the amount of filtrate flow (through the distal tubule) and its chloride concentration. This information is used to determine the regulation of a hormone like substance, (renin-angiotensin), and also to selectively regulate the individual arterioles.

e) Collecting tubule - further concentrates filtrate

f) Renal pelvis – extends outside the kidney and merges with the ureter

B. Ureter - tubules between the kidneys and the bladder

C. Bladder

1. Elastic muscular sac

2. Collects and stores urine

3. Cystitis – inflammation of the bladder wall, often associated with infection

4. In an adult a volume of 200-400 ml. Creates pressure causing special nerve cells (stretch receptors) to become excited

D. Urethra

1. Canal that conducts urine from the bladder to the outside of the body

2. Micturition

3. Urethritis

II. Physiology of Urine Formation

A. Functions of the kidney

1. Elimination of excess water

2. Elimination of waste products of metabolism

3. Elimination of foreign substances

4. Retention of substances necessary for normal body function

5. Regulation of electrolyte balance and osmotic pressure of body fluids (BP)

6. Contains substances needed for RBC production (erythropoiesis)

7. Maintenance of blood pressure

B. Glomerular filtration

1. Glomerular capillary system – allows selected components of the blood plasma to pass through the semi-permeable membrane into the capsular space of Bowman's capsule

2. Ultrafiltration

3. Modified blood leaves the glomerular capillaries through the efferent arterioles. These arterioles then become vessels that participate in the reabsorption process.

C. Renal tubular function

1. After leaving the Bowman's capsule, the plasma ultrafiltrate passes through tubules where the process of reabsorption, secretion and concentration will result in the formation of urine.

   a. Reabsorption - substance removed from filtrate and returned to blood.

   b. Secretion - substance passed from blood into tubular filtrate

2. Endocrine influence – hormones that affect the excretion/reabsorption of sodium, potassium and water

   a. Aldosterone - activated by changes in blood flow to kidney and body's Na concentration.

      1) Source – adrenal cortex

      2) Site of action – epithelium of distal and collecting tubules

      3) Effect – promotes the active reabsorption of sodium (and secretion of potassium). Also increases water retention.

   b. Renin - enzyme produced in the kidney when BP drops, causes the production of aldosterone.

   c. Anti-diuretic hormone (ADH) - Vasopressin

      1) Source – posterior pituitary gland - controlled by the body's state of dehydration.

      2) Site of action – collecting tubules

      3) Mode of action – presence of ADH makes the tubules permeable to water. Increased ADH = increased permeability, increased reabsorption of water, decreased volume of urine (increased concentration).

      4) Effects

         a) Decreases urine volume
         b) Concentrates the urine
         c) Adds water to the blood
         d) Dilutes blood solutes

3. Renal "active transport" is the transport of substances through tubular epithelial cells by means of special chemical transport mechanisms. Substance to be reabsorbed must combine with a carrier protein contained in membrane of renal tubular cells.

    a. Nutrients
    b. Ions

4. Passive reabsorption (transport) – When ions, glucose, etc., have been transported out of the tubules, the water remaining is in high concentration and will diffuse. There is movement of molecules across a membrane as a result of differences in their concentrations or electrical potential.

    a. H_2O – follows the actively transported solutes

    b. Ions – certain ions (i.e., chloride) may or may not be actively transported, but will be passively reabsorbed with the water

5. Failure to reabsorb unwanted substances such as body produced end products of metabolism

    a. Urea

    b. Creatinine

    c. Others – phosphates, sulfates and uric acid

D. Renal Threshold (Maximal Reabsorptive Capacity) - when the plasma concentration of a substance that is normally completely reabsorbed reaches an abnormally high level, it reaches a point when no more can be absorbed. At this point it "spills over" into the urine. The plasma concentration at which this happens is called the Renal Threshold.

E. Electrolyte balance - must eliminate excess acid formed by dietary intake and body metabolism.

1. Sodium

    a. Renin – angiotensin – aldosterone system -

    b. Effects on other electrolytes

2. Calcium is reabsorbed in the proximal tubule under the influence of parathyroid hormone

3. Phosphorus reabsorption in the proximal tubule is depressed by parathyroid hormone

4. Magnesium regulation parallels calcium

F. Acid-base regulation - maintain overall blood/body pH of 7.4

1. Elimination of metabolic acids

2. Secretion of hydrogen ions

3. Generation of bicarbonate ions

4. Filtered buffers

5. Secretion of ammonia

G. Diseases of the Kidney

1. Nephritis – inflammation of kidney tissue

   a. Causes – toxins, drugs, infections etc.

   b. Types – glomerular nephritis, pyelonephritis

   c. Results – nephrotic syndrome (increased urine protein, red cells in urine, formation of cellular and granular casts, etc.), leading to hypertension and uremia

2. Uremia – increased urea in the blood due to the inability of the kidneys to properly clean the blood