A. Chapter 1

1. Know the basic functions of the kidneys in the body
   a) To excrete end-products of body metabolism
   b) To control concentrations of most constituents in body fluids. This includes:
      1') acid-base homeostasis (i.e., hydrogen ion concentration)
      2') electrolyte concentration
      3') water volume

2. Know the components of the urinary system
   a) 2 kidneys
   b) 2 ureters
   c) 1 bladder
   d) 1 urethra

2. Know the following definitions, location, part components in, and/or function of major anatomical structures, as given below:
   ureter- tube between kidney and the bladder
   bladder- storage structure for urine (holds 500 mL)
   urethra - tube through which urine exits the body
   renal pelvis- large tubular part of the kidney through which urine drains out of the kidney between the major calyces and the ureter
   calyces- tubular portion that first receives urine from the papilla of the renal pyramid (the minor calyces) which then drains into the major calyces.
   adrenal glands- glands that cap the kidney
   kidney medulla – also called renal pyramid, inner portion of kidney that has cone shape and has striated (lined) texture in which the collecting ducts traverse to the apex
   kidney cortex – outer portion of the kidney (surrounding the medulla) that has granulated appearance, contains glomeruli
   papilla – apex of the renal pyramid
   aorta –the largest artery in the body, the aorta arises from the heart, goes up slightly, and then arches, and then descends through the chest and through the abdomen to where it ends by dividing into two arteries that go to the legs.
   inferior vena cava - returns blood to the heart from the lower part of the body.
   renal artery – artery going from abdominal aorta to the kidney
   renal vein – vein through which blood leaves the kidney which then empties into the inferior vena cava
   glomerulus – capillaries in kidney where filtration occur
   Bowman’s capsule – cuplike structure that receives filtrate from the glomerulus
   renal corpuscle – glomerulus plus Bowman’s capsule
   efferent arteriole – blood vessel that enters glomerulus
   afferent arteriole – blood vessel immediately after the glomerulus
peritubular capillaries – capillary network arising from cortical glomeruli and are located in the renal cortex.

vasa recta capillaries - capillary network arising from juxtamedullary glomeruli and loop through the medulla.

components of glomerular membrane (listed in order from capillaries to Bowman’s capsule)

a) endothelial cells – cells lining inside of the capillary, has large openings between cells providing only a course filter
b) basement membrane – meshwork of proteoglycan, collagen and glycoproteins, has large openings providing only a course filter
c) epithelial cells - (called podocytes, for the very distinctly shaped cells that are unique to Bowman’s capsule) cells that line Bowman’s capsule – has large openings that provide only a course filter
d) filtration-slit membrane – layer of unknown composition on top of the podocyte layer that provide the fine-filtering capability of the glomerular membrane (provides exclusion of neutral molecules that are ≥ 80 Angstroms in diameter (≥ 80,000 MW for proteins)

sequence of tubular system (from Bowman’s capsule)

a) Proximal tubule
   1') Early Convoluted Proximal Tubule
   2') Late Convoluted Proximal Tubule
   3') Straight Proximal Tubule
b) Loop of Henle
   1') Thin Limb of Loop of Henle
      a') Thin Descending Limb of Loop of Henle
      b') Thin Ascending Limb of Loop of Henle
   2') Thick Ascending Limb of Loop of Henle
   c) Distal Convoluted Tubule (starts at the point where the tubule passes by the renal corpuscle)
d) Connecting Segment
e) Collecting tubule
   1') Cortical collecting tubule
   2') Medullary collecting tubule (starts at the cortex/medulla interface)

nephron – functional unit of the kidney, the structure of the renal corpuscle and the tubular system up to and including the collecting tubules. The nephron has two types:
cortical nephron – majority of the nephrons in the kidney, have very short thin limbs of Loop of Henle and penetrate only the outer zone of the medulla, glomerulus gives rise to peritubular capillaries after the efferent arteriole.
juxtaglomerular nephron – has long Loop of Henle that penetrate deep into the inner zone of the medulla, with many reaching all the way to the papilla, glomerulus gives rise to vasa recta capillaries after the efferent arteriole.

lobe - part of the kidney consisting of a renal pyramid and cortical arch
lobule – part of the kidney that is in-between the interlobular arteries. This part of the kidney contains all the nephrons that drain into the same collecting duct.
endothelial cells – cells that line blood vessels, lymph vessels, heart and serous cavities (examples abdominal, pericardial, pleural cavities)
epithelial cells – Epithelial cells lines both the outside (skin) and the inside cavities and lumen of bodies. These are the cells that line the inside of the kidney’s tubular system
intercellular cleft – narrow passage way between the endothelial cells in the capillaries providing a passage way for small hydrophilic molecules to enter the interstitial fluid (not large molecules such as medium size and large proteins for all tissues except the liver) (chapter 3).

Macula densa cells – specialized epithelial cells in the distal convoluted tubule that send signals to juxtaglomerular cells to release rennin (chapter 4)
Juxtaglomerular cells – specialized smooth muscle cells surrounding the afferent and efferent arterioles that contain renin granules (chapter 4)

3. Know the size and charge filtration characteristics of the glomerular membrane

There is a SIZE and a CHARGE barrier to filtration through the glomerular membrane provided by the filtration-slit membrane. The glomerular pores are lined with negatively charged glycoproteins and heparin sulfate which repel large negatively charged molecules

a) All SMALL molecules, whether charged or not, will pass through the glomerular membrane
b) All NEUTRAL AND POSITIVELY CHARGED MOLECULES < 80 ANGSTROMS (< 80,000 MW for a protein) will pass through the membrane, although the permeability goes down as the molecule size increases up to a 80 Angstrom diameter size (permeability is especially hindered for larger negatively charged molecules). At 80 Angstrom diameter the molecule is impermeable to the membrane.
c) LARGE (protein size) NEGATIVELY CHARGED molecules that are less than 80 Angstroms in diameter, but big enough to be repelled by the negatively charged glomerular pores, will NOT pass through the glomerular membrane. An example of this is albumin.

4. Know 20% rule:
   • 20% of cardiac output (blood) is directed to the kidneys
   • 20% of plasma is filtered by the kidneys in one pass of the blood through the kidneys
B. Chapter 2

1. Know the various compartments and sub-compartments of water in the body:
   - Amounts of water in each
   - Classification of what is considered ICF, ECF, and transcellular
   - Major chemical compositional differences of each (ICF and ECF)
     (know the top two cations and anions in these two compartments)
   - Compositional differences between plasma and ISF
   - Difference between blood, plasma, serum
   - Difference between plasma and plasma water (which is more reflective of the true physiological state?)
   - Characteristics of the interstitium
   - Flow rate of blood pumped out by the heart

2. Know the basic function and characteristics of the lymph system
   - Major functions of lymph and lymph nodes
   - Basic pathway from ISF to blood veins
   - Characteristics such as: flow rate; where most lymph arises from

3. Know the four different processes (diffusion, osmosis, electrostatic, active) which move substances between membranes. For each know: 1) the permeability characteristics of the membrane; 2) whether it passive or active (and why?) 3) the “force” or process driving the movement of the chemical species transferred

4. For osmosis and diffusion, why is the equilibrium state often not equal solute concentration in both compartments?

5. Know the mechanisms explaining why there are different concentrations of anions and cations for plasma and ISF

6. Explain the process of diffusion potential by which a cell has a negative charge. Be able to predict and explain how a change in K⁺ concentration in the ECF will affect the magnitude of the cell potential. Also be able to predict and give an explanation for how the cell potential would change if the permeability characteristics of the membrane changed (i.e., what would be the charge of the cell if the membrane were permeable to Na⁺ instead of K⁺ and why)

7. Explain the Gibbs-Donnan equilibrium effect from the initial transfer of ion from one compartment to another to what is the balancing force that stops the process.

8. How does the cell create (and maintain) a high concentration of K⁺ and a low concentration of Na⁺ compared to the ISF?

9. Be able to calculate osmolarity. How osmolarity is measured as a pressure?
10. What is the difference between osmotic pressure and effective osmotic pressure?

C. Chapter 3

1. Be able to list the three levels of control of blood flow: local (intrinsic; know the two theories of how this is accomplished), nervous system (extrinsic), hormonal (extrinsic).

2. Know what micro-blood vessels have muscles and nerves.

3. Know what effects a parasympathetic and a sympathetic nerve has on an organ, such as the heart.

4. Know the signal pathway for nervous system control of blood flow (and blood pressure). What are the three input signals to the vasomotor center and the three output signals sent to different organs (structures)? For each of the three output signals, what action of the organ (structure) will raise the blood pressure.

5. Be able to state exactly how the baroreceptor will respond to an increase of blood pressure (or a decrease of blood pressure). State what the signal sent to the vasomotor center does and then what signals are sent from the vasomotor center, where these signals are sent, and what actions they cause. Be sure to know whether there is an increase in signal sent or a decrease in signal sent at each point of the circuit.

6. Know at what blood pressures the following receptors (nervous system) are activated: baroreceptors, chemoreceptors, CNS ischemia. Know the location of the various receptors.

7. List and know the mechanisms of the various mechanisms of short term arterial control as given below and also compare the time of action and the extent of correction for each (see the figure 8 in handout):
   a) Nervous system (baroreceptor, chemoreceptor, CNS ischemia)
   b) Hormonal (list 4 hormones)
   c) Capillary fluid shift
   d) Stress relaxation

8. What is the long-term control mechanism of arterial pressure.
9. Compare short-term and long-term arterial pressure control in terms of speed of action, effectiveness, and extent of control.

10. Be able to diagram the various steps of the reaction sequence in which renin generates angiotensin II. Be able to tell what the components are [i.e., protein, proteolytic enzyme, peptide (how many amino acids)] and what other components are needed (such as ACE), and what is the location in the body that these components are generated in (kidney, blood vessel, lungs) and what is the action point of the hormone.

11. Know the two general ways that the body controls short term blood pressure (cardiac output and vascular resistance).

12. Know the difference of mechanism by which blood pressure is increased by constriction of venules compared to constriction of arterioles.

13. Know the components of a capillary vessel (endothelial cell, basement membrane, intercellular cleft).

14. Know how various substances (hydrophilic, ionic, hydrophobic) can go from the capillary to the ISF. Know what organs have wide intercellular clefts and narrow intracellular clefts.

15. What is the brain-blood barrier?

16. Know the components of net effective pressure in moving water between plasma and ISF and how the values of these components are changed.

Chapter 4

1. Know the equation for net filtration pressure and how each of the components will change in disease affecting GFR (see point 32 page 89-90 in handout notes).

2. Know the two resistance points in blood flow into and out of the kidneys. Know how constricting (or dilating) afferent or efferent arteriole will affect glomerular hydrostatic pressure.

3. Know the normal values of arterial pressure, GFR, RBF, RPF, and filtration fraction.

4. You **DO NOT** need to know the derivation, nor do you need to memorize the equation relating the resistance of the afferent arteriole and efferent arteriole to \( P_{GC} \) (equations 7-12 in the chapter notes).
5. Know the chemical mechanism of how GFR is controlled. Start with a temporary increase (or decrease) in GFR and how a chemical signal is affected by a change in GFR, which is then sensed by the macula densa cells. Where is the signal then sent and what chemical factor is then released into where, and how does this eventually causes a correction in GFR (by what mechanism).

6. Compare the general mechanism of autoregulation of blood flow through a tissue and the specific regulation mechanism that apply to the kidney. Why does the metabolic mechanism not apply to the regulation of the kidney blood flow?

7. At what arterial pressures does autoregulation of GFR and RBF occur? At what pressures does it not occur? What overrides autoregulation?

8. Know the formulas for plasma clearance (both corrected and uncorrected) and what properties of substance are needed to measure GFR and RPF. Be able to list the substances that are infused in the determination of GFR and RPF. Know the corrected equation for $C_{PAH}$ and the factor in converting RPF to RBF. Know why the GFR has to be corrected for each individual.

9. Be able to predict how a non-ideal substance (such as one that is reabsorbed, secreted, or partially filtered) will affect the determination of GFR.

10. Be able to do a problem similar to the one in the handout in calculating GFR and RPF.

11. Know the facts of about creatinine measurement of GFR. You DO NOT have to know the chemical structures or reactions of the Jaffe reaction.