I. Anatomy of the Urinary System
   A. Kidneys
      1. Right lower than Left*
      2. Retroperitoneal
      3. Layers that secure kidneys in the abdominal cavity
         a. Renal fascia
         b. Perinephric fat (Adipose) capsule
         c. Fibrous capsule
      4. Renal Hilum
         a. Renal arteries
         b. Renal veins
         c. Renal Nerves
         d. Ureters
      5. Renal Cortex
      6. Renal Medulla
         a. Renal (Medullary) Pyramids
            1) Renal lobe
            2) Renal papilla or Apex
         b. Renal Columns
      7. Renal Pelvis – Cavity within is Renal Sinus
         a. Major Calyx (Calyces)
         b. Minor Calyx (Calyces)
B. Nephrons > 1,000,000 per Kidney

1. Types
   a. Cortical Nephron ~ 85%
   b. Juxtamedullary Nephron ~ 15%

2. Regions
   a. Renal Corpuscle – Filtration
      1) Glomerular (Bowman’s) Capsule
         a) Parietal (Capsular) Epithelium
            (1) Simple Squamous Epithelium
      2) Glomerulus
         a) Visceral (Glomerular) Epithelium
            (1) Podocytes
            (a) Pedicels
               [1] Wrap around the Fenestrated Endothelium of the Glomerulus
            (b) Filtration slits
      3) Capsular Space – Filtrate
b. Renal tubule – Reabsorption and Secretion
   1) Proximal Convoluted Tubule (PCT)
      a) Simple cuboidal with microvilli
   2) Nephron loop (Loop of Henle)
      a) Descending limb – mostly thin
         (1) Simple Squamous Epithelium
      b) Ascending limb
   3) Distal Convoluted Tubule (DCT)
      a) Simple cuboidal with some microvilli

3. Collecting System
   a. DCT of multiple nephrons empty into Collecting Duct (Striped appearance of pyramids) by way of a Connecting Tubule
   b. Collecting Ducts open into Papillary Duct
      1) 25 – 35 Papillary Ducts per Renal Pyramid
   c. Papillary Duct empties into Minor Calyx

4. Juxtaglomerular apparatus (JGA)
      1) Blood pressure sensors in afferent arteriole walls
   b. Macula densa – Columnar chemoreceptor cells
      1) Superior end of the ascending limb of the nephron loop where it joins the distal convoluted tubule (abutting the JG cells)
         a) NaCl concentration
C. Blood Supply to the Kidney

1. Renal Artery
   a. Segmental Arteries (5)
      1) Interlobar Arteries (In Renal Columns)
         a) Arcuate Arteries
            (1) Cortical Radiate Arteries
            (Interlobular Arteries)
               (a) Afferent Arterioles

2. Glomerulus (Glomeruli) – Unusual Capillary Bed
   a. Fed by Afferent Arterioles
   b. Drained by Efferent Arterioles
      1) Peritubular Capillaries – In Cortex
      2) Vasa Recta – Capillaries that parallel nephron loop

3. Renal Veins
   1) Interlobar Veins
      a) Arcuate Veins
         (1) Cortical Radiate Veins (Interlobular Veins)
            (a) Venules drain
               [1] Peritubular Capillaries
               [2] Vasa Recta
            (b) NOTE: NO Segmental Veins
D. Ureters, Urinary Bladder, and Urethra

1. Ureters
   a. Mucosa
      1) Transitional Epithelium
      2) Lamina propria
   b. Muscularis – Peristalsis
      1) Inner Longitudinal
      2) Outer Circular
   c. Adventitia
      1) Areolar with Adipose

2. Urinary Bladder
   a. Rugae
   b. Fundus
   c. Trigone
      1) No Rugae in this area
   d. Mucosa
      1) Transitional Epithelium
      2) Lamina propria
   e. Submucosa
f. Muscularis (Detrusor muscle)
   1) Inner Longitudinal
   2) Middle Circular
      a) Internal Urethral sphincter
         (1) Smooth muscle
      b) External Urethral sphincter
         (1) Skeletal muscle
            (a) Incontinence
   3) Outer Longitudinal

g. Visceral Peritoneum

h. Micturition
   1) 700 – 800 ml Capacity
   2) Micturition Reflex – 200 ml

3. Urethra
   a. Male
      1) Prostatic
      2) Membranous
      3) Spongy (Penile)
   b. Female
      1) External Urethral Orifice
   c. Mucosa
      1) Stratified Squamous Epithelium

E. Clinical Application: Nephroptosis or Renal Ptosis (Floating Kidney)
II. Physiology of the Urinary System
   A. Summary of Renal Function
      1. Filtration – Renal Corpuscle
         a. High pressure glomerulus
            1) Fed & Drained by arterioles
            2) Afferent Arteriole has a larger diameter lumen than the Efferent Arteriole
      2. Tubular Reabsorption – Renal tubule
         a. Low pressure Peritubular capillary bed
            1) Passive – osmosis
            2) Active transport – selective
               a) Countertransport mechanisms
      3. Tubular Secretion – Renal tubule
      4. Urine Concentration with ADH & Aldosterone
B. Urinalysis

1. Physical Analysis of Urine
   a. pH
      1) Average 6.0
      2) Range 4.5 – 8.0
         a) Acid ash (High-protein diet)
         b) Alkaline ash (Vegetable fiber diet)
   b. Specific gravity
      1) Range 1.003 – 1.030
         a) Renal calculi (Kidney stones)
      2) Urinometer or Refractometer
   c. Color
      1) Urochrome
   d. Turbidity (Cloudiness)
e. Odor
2. Chemical Analysis of Urine
   a. Normal Urinary Constituents
      1) Water
      2) Urea – Deamination of amino acids
      3) Creatinine – Breakdown of creatine phosphate (in muscle tissue)
      4) Uric Acid – Breakdown of nucleic acids
      5) Many Electrolytes – Varies with diet
         a) Sodium ions Na⁺
         b) Chloride ions Cl⁻
         c) Ammonium ions NH₄⁻
         d) Potassium ions K⁺
         e) Calcium ions Ca⁺²
         f) Magnesium ions Mg⁺²
      6) Small amounts of hormones, pigments, carbohydrates, fatty acids, mucin, and enzymes
      7) Medicines, Vitamins, and other Drugs
b. Abnormal Urinary Constituents

1) Ketones (Ketone bodies)
   a) Ketosis (Ketonuria)

2) Glucose
   a) Glucosuria

3) Albumin – trace is normal
   a) Albuminuria

4) Erythrocytes
   a) Hematuria

5) Leukocytes
   a) Pyuria

6) Hemoglobin
   a) Hemoglobinuria

7) Bilirubin
   a) Bilirubinuria
      (1) Jaundice

8) Urobilinogen – some present normally
   a) Urobilinogenuria

9) Nitrites
   a) Gram negative bacteria (E. coli)
   b) Clinical Application: Urinary Tract Infection (UTI)
3. Microscopic Examination of Urine
   a. Cells
      1) Epithelial Cells
         a) Squamous Epithelial Cells
         b) Transitional Epithelial Cells
      2) Leukocytes – Pus cells (WBC)
      3) Erythrocytes (RBC)
   b. Crystals
      1) Ammonium-magnesium phosphate
      2) Uric acid
      3) Calcium carbonate
      4) Calcium oxalate
      5) Cholesterol crystals
      6) Calcium phosphate
c. Casts
   1) Hyaline Cast
   2) Granular cast
   3) Epithelial cast
   4) Pus cast
   5) Red blood cell casts

d. Mucus
   1) Mucous threads

e. Microbes
   1) Bacteria
   2) Yeast
   3) Trichomonas

f. Clinical Application: Renal Calculi (Kidney stones)
   1) Lithotripsy