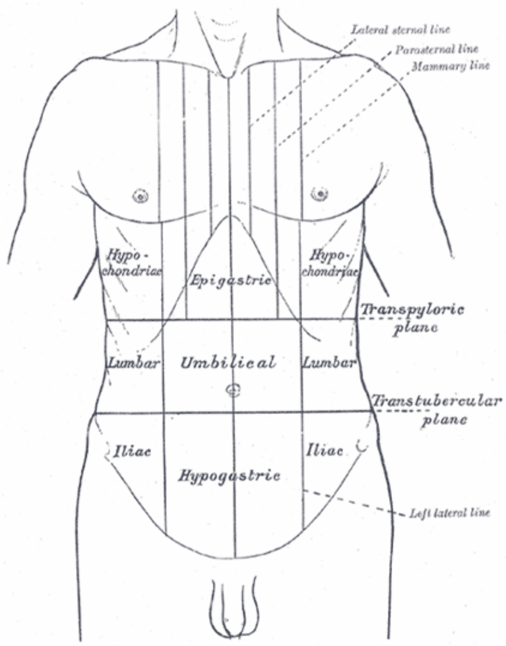
The Human Urinary System

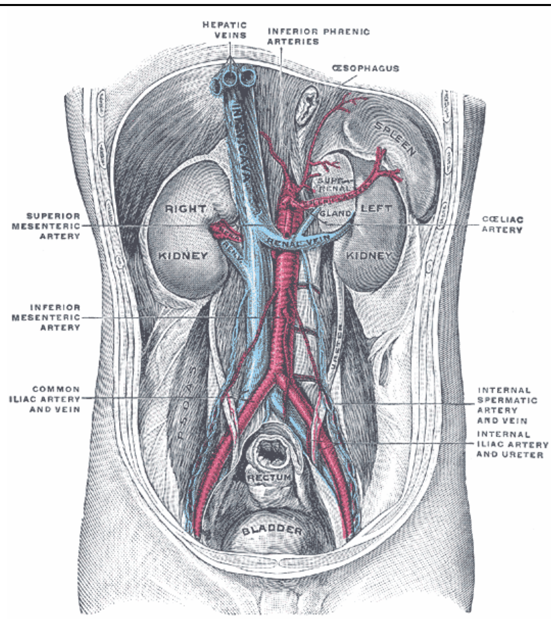
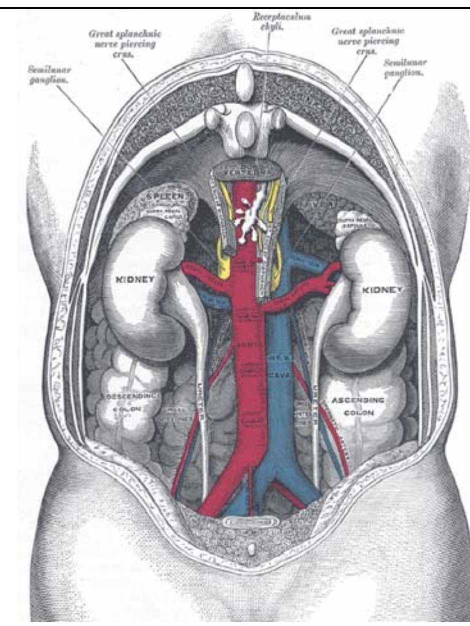
<u>Introduction</u>

<u>Gross Anatomy</u>

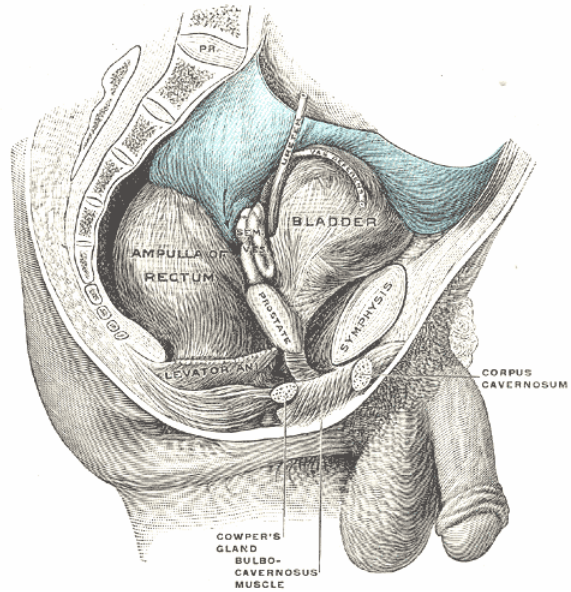
The urinary system consists of 2 kidneys, 2 ureters, one bladder and one urethra. The figure, below, begins the orientation process of the location of some of these organs. You may recollect this graphic from A&P I.



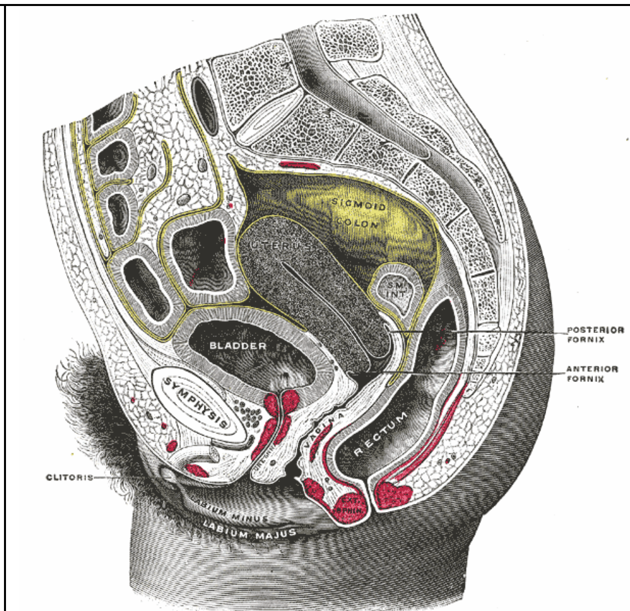
These 3 figures illustrate in closer detail the relation of the urinary system with the remainder of the body:

	
Anterior view of urinary system	Posterior view of urinary system

The next series of graphics illustrate the differences between the male and female urinary systems:

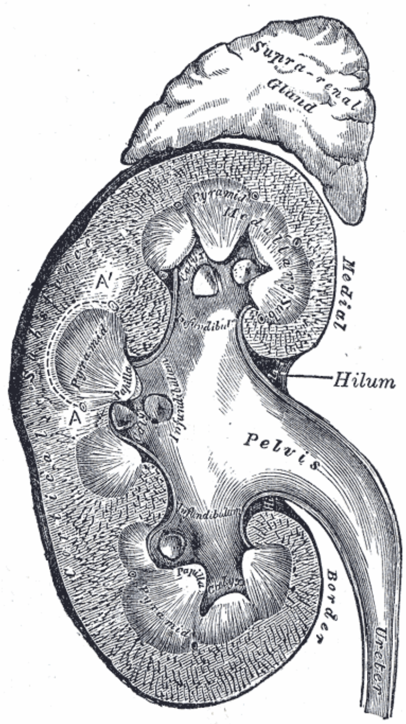


Male urinary system

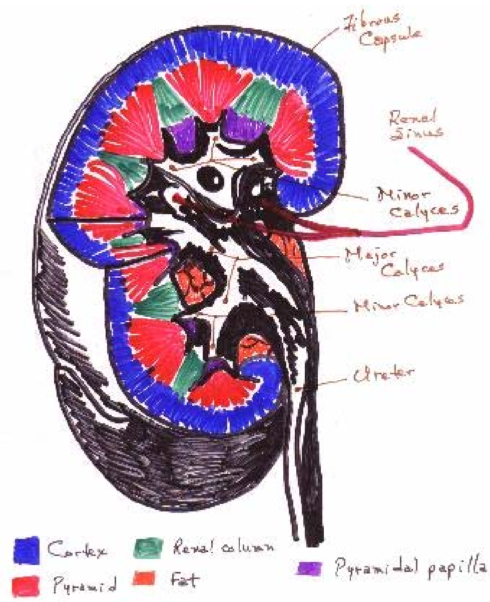


Female urinary system

The kidneys are retroperitoneal, i.e., they are behind the peritoneum against the posterior abdominal wall. The kidneys are paired and bean shaped. They are located just above the waist behind the parietal peritoneum and posterior wall of the abdominal cavity (retroperitoneal). The kidneys are located between T-12 and L-3; the right kidney is slightly lower than the left. Each kidney measures approximately 10-12 cm in length, 5-7.5 cm in width and about 2.5 cm in thickness. The center of the concave, medial border through which the ureter exits the kidney is called the hilus. This hilus is the entrance into a renal cavity called the renal sinus.

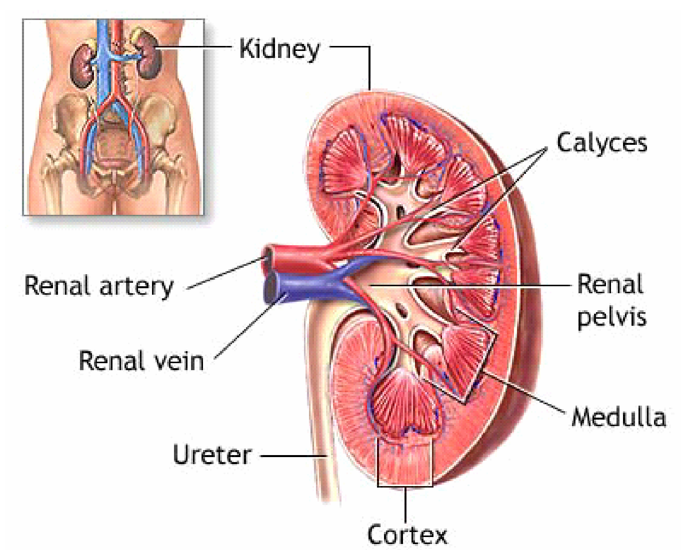


Each kidney is contained in three layers of tissue. The inner-most layer is the renal capsule. This tissue is continuous with the outer coat of the ureter and serves as a trauma barrier and infection barrier for the kidney (similar to the blood-brain barrier at the brain). The middle layer is the adipose capsule. This tissue consists of fatty tissue that encapsulates the renal capsule. The adipose capsule holds the kidney firmly in place within the abdominal cavity. The outer most layer is the renal fascia. This fascia anchors the kidney to surrounding structures and to the abdominal wall.



There are two ureters: one for each kidney. The ureter is an extension of the renal pelvis and extends 25-30 cm to the bladder. The ureters drain the kidneys into the bladder and enter the bladder at the superior lateral angle of its base. Although there are no anatomical valves at the ureteral openings in the bladder, there is a functional (physiological) valve. This "valve" works because the ureters pass obliquely (at an angle) through and into the bladder. As the pressure of the urine in the bladder compresses the ureters, this prevents urine reflux up the ureter. When this valve is not working, bladder infections can travel superiorly to become kidney infections.

The primary function of the ureters as mentioned above is to transport urine from the kidneys to the bladder. This is accomplished by at least three mechanisms: peristalsis, hydrostatic pressure and gravity.



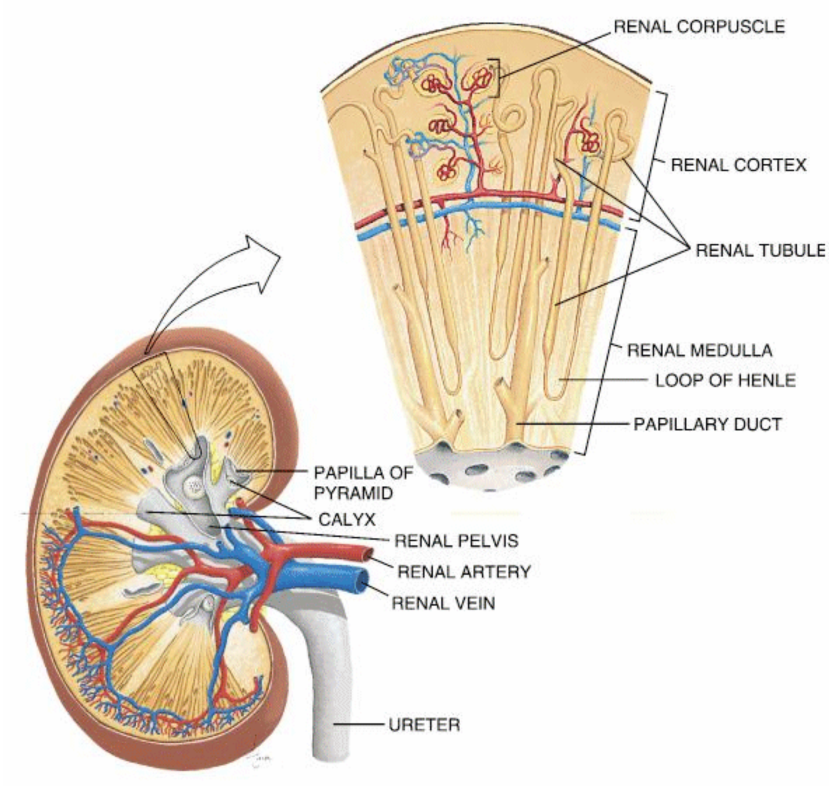
The bladder is a hollow organ posterior to the symphysis pubis. In the male it is directly anterior to the rectum; in the female it is anterior to the vagina and inferior to the uterus. The shape of the bladder is dependent on the volume of urine contained within. When empty, the bladder walls are thicker than when full. The bladder is spherical when slightly distended. The bladder becomes pear-shaped as the volume of urine increases and causes the bladder to rise into the abdominal cavity. The muscular layer which allows for stretch is the detrusor muscle. The muscle is also used to construct the internal sphincter (*sphincter vesiculi*) in both sexes. At the base of the bladder (on the interior floor) there is a smooth triangular area called the trigone. This points anteriorly like a funnel. The three points of the trigone are the ureteral openings posteriorly and the interior urethral orifice, anteriorly.

The urethra is a small tube which leads from the floor of the bladder to the exterior of the body. In females, it lies directly posterior to the symphysis pubis and is in front of the anterior wall of the vagina. Its length is about 1.5 inches and its width is about 0.25 inches. The opening at the exterior is called the urethral meatus and is located between the clitoris and the vagina.

In the male the urethra is about 8 inches long. Immediately below the bladder it passes through the prostate. This helps to protect men from getting urinary tract infections as the prostate secretes seminalplasmin into the urethra after complete urination (micturition). The urethra then pierces the urogenital diaphragm and finally pierces the penis and exits at the urethral meatus. The urethra is the final portion of the urinary system. It serves as the "tube" through which urine exits the body. The male urethra also serves as the tube through which semen is ejaculated.

<u>Microscopic Anatomy and Physiology</u>

The functional unit of the kidney is the nephron:



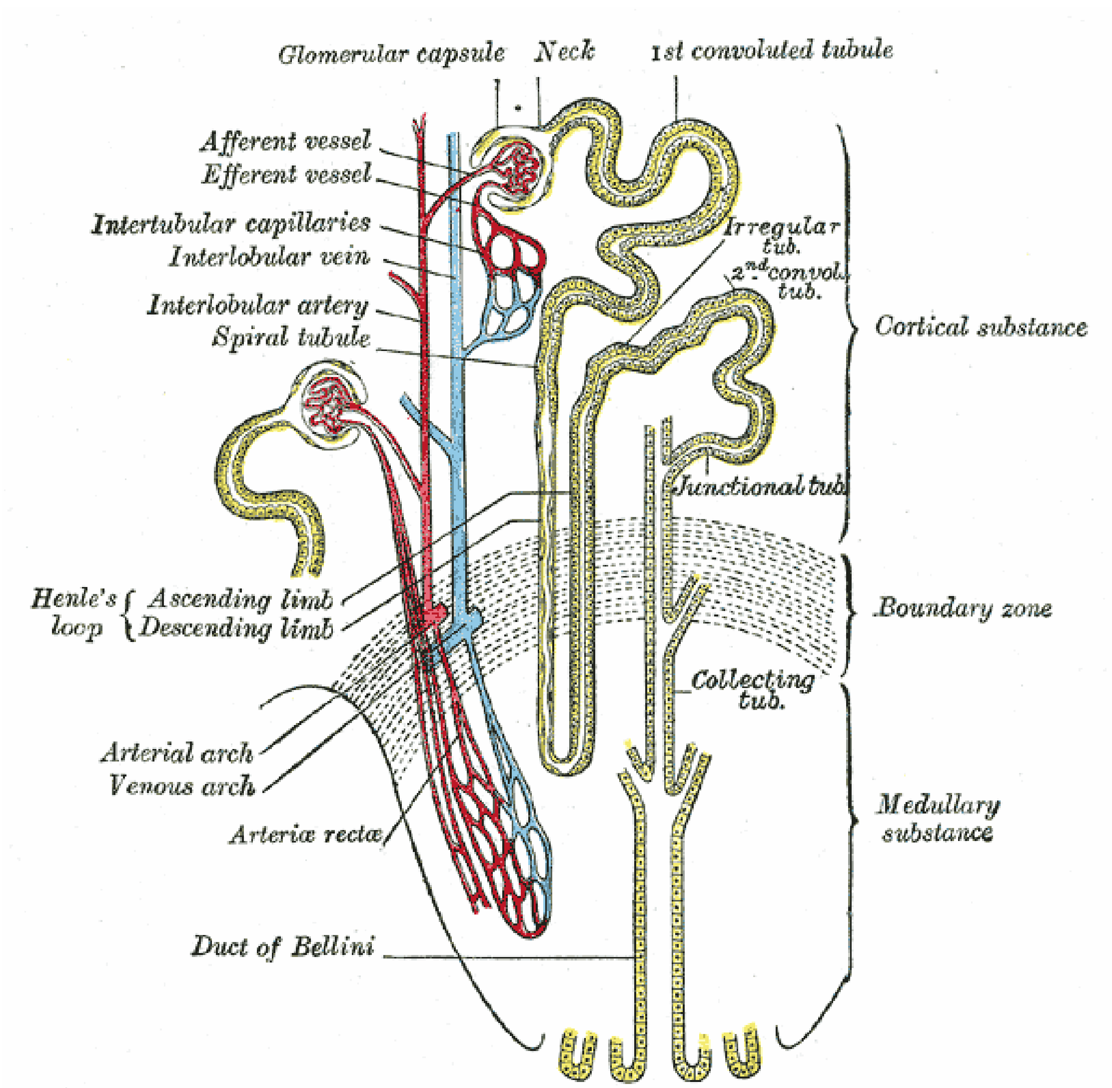
KIDNEY

The nephron functions in filtration, acid-base balance and toxic waste removal from blood. The eliminated materials are collectively called urine. The total volume of blood in our bodies is filtered by the kidneys approximately

60 times in one day. Urine formation requires three processes: glomerular filtration, tubular reabsorption and tubular secretion. All of these depend, necessarily, upon blood flow into and out of the kidney.

In general, each kidney has its own blood supply: the renal artery into the kidney and the renal vein out of the kidney. More specifically, blood enters the kidney through the renal artery and spreads out to the segmental arteries (a.k.a. lobar). From the segmental arteries, the blood flows through the interlobar arteries. The blood is then further spread out through the kidney via the arcuate arteries, then to the interlobular arteries. The blood then goes through (flows into) an afferent arteriole (one of which is distributed to each Bowman's capsule) which divides into a tangle of capillaries called the glomerulus.

The glomerular capillaries reunite to form an efferent arteriole which leads away from (out of) the Bowman's capsule (this arteriole is also smaller than the afferent arteriole). Each efferent arteriole divides to form a capillary network called peritubular capillaries around the convoluted tubules. Eventually, the peritubular capillaries reunite to form interlobular veins. Blood drains from the interlobular veins into the arcuate veins then to the interlobar veins. Blood then drains into the segmental veins. Blood then drains into the segmental veins and leaves the kidney through the single renal vein and exits via the hilus for return to the IVC.



There are three pressures, proper, that are derived from this flow of blood, **Table 1:**

Proper Filtration Pressures		
Glomerular Blood Hydrostatic Pressure	Capsular Hydrostatic Pressure	Blood Colloidal Osmotic Pressure
aka GBHP. The chief filter pressure. Hydrostatic pressure is the force that a fluid under pressure exerts against the walls of its container (similar to making yogurt cheese through cheese cloth: squeeze/twist the cheese cloth around the yogurt and the liquid squooshes through the cheese cloth). Glomerular blood hydrostatic pressure means the blood pressure in the glomerulus. This pressure tends to move fluid out of the glomeruli at a force averaging about 60 mm Hg.	aka CHP. Opposes the GBHP. When the fluid is forced into the capsular space of the Bowman's capsule, it meets the walls of the capsule and the fluid which has already filled the renal tubule. Due to this action, some filtrate is pushed back into the capillary. The amount of "push" is the CHP and is usually around 20 mm Hg.	aka BCOP. Also opposes the GBHP. Because the blood has a much higher concentration of protein than does the filtrate, water would move out of the filtrate and back into the blood vessel if the GBHP were not greater than the BCOP. BCOP generally runs around 30 mm Hg.
Table 1. Summary of the proper filtration pressures in the nephron.		

A derived pressure, the effective filtration pressure (P_{eff}) is the difference between the sum of the latter two pressures (CHP + BCOP) and the first pressure (GBHP):

$$P_{eff} = GBHP - (CHP + BCOP)$$

$$P_{eff} = 60 - (20 + 30) = 10 \text{ mmHg}$$

The P_{eff} is about 10 mm Hg. This amount of pressure produces about 125 mL of filtrate per minute in both kidneys. The P_{eff} is also called the net filtration pressure (NFP). The per cent of the plasma entering the nephrons that actually becomes glomerular filtrate is called the filtration fraction and averages about 16-20%. **Table 2**, below, summarizes P_{eff} variations in three conditions.

Altered P_{eff} in Various Disease States	
Disease/Condition	P_{eff}
Glomerulonephritis	Increased
Hemorrhage	Decreased (pressure of 50 or less = ANURIA)
Fight or flight	Decreased (due to reduced flow through afferent arteriole caused by blood shunting away from the kidneys to the musculature, *ad nauseum*.)
Table 2. Summary of P_{eff} Variations in Three Conditions.	

Although urine formation has been discussed in lecture and will not be presented here, one activity deserves mention/description: the micturition reflex. As urine is produced, it is, of course, drained into the bladder. The bladder wall contains stretch receptors similar to the stretch receptors in the uterus. A urinary volume of 150-400 mL (average bladder volume is about 750 mL) is enough to trigger the stretch receptors to send sensory signals via afferent sacral (parasympathetic) nerves. This information is "down loaded" right at the sacral center in the sacral cord, causing parasympathetic efferent signals to be sent to the detrusor and internal sphincter (*sphincter vesiculi*). These signals cause the detrusor to contract and the internal sphincter to relax. The next step is required before one may "officially" micturate. At the same time that the messages are sent to the sacral cord, afferent messages are also being sent to the cerebral cortex. The signals are interpreted and efferent signals are sent to the external sphincter. This sphincter must relax before one may micturate, hence, micturition may be voluntarily controlled at the level of regulating the external sphincter. Sympathetic innervation, remember, is inhibitory to micturition, e.g., fight or flight.

Experimental: Macroscopic Experiment

While you are preparing to "co-perform" the experience of the urinalysis (UA), at the second break during lecture, perform an *en masse exodus* from the class room to the bathroom. Empty your bladder into a beaker, making sure to obtain at least 250 mL. Bring it back to the lab and let your urine sample set until lecture is completed. Drink a quart (946 mL) of water. Once you have drank the whole quart, record the time in the space below. Drink the water as close to all at once as possible. After lecture is completed, beginning urinating into beakers, recording the time, color, volume and the specific gravity of the specimen in the table below.

Data Table for Urinary Data							
Time	Color	Volume (mL)	Sp.G.	Time	Color	Volume (mL)	Sp.G.

The specific gravity (Sp.G.) of a liquid is simply the density of one liquid divided by the density of water. Since we "fudge" the density of water to be 1 g/mL, the Sp.G. is identical to the density of the urine. This is determined by using a gravitometer or a refractometer. A gravitometer is a graduated cylinder with a calibrated float that one suspends in the urine and reads to determine the Sp.G. of urine, in this case. Your instructor will show you bow to perform this test. The normal range of Sp.G. is about 1.005-1.040. The closer to 1.000 the urine, the more like water or the more dilute it is. The closer to 1.040 the urine, the more concentrated or the less water that is in it (HINT: OSMOSIS!!!!!!). How does your urine compare to each time you urinated?

On your original urine sample (the one you obtained at the break in lecture) determine its Specific Gravity (Sp. G.) using the refractometer. Your professor will instruct you as to its use. Obtain a urine dipstick. Dip it into your urine sample. Record the results as they compare to the chart on the side of the Dipstick can. Record your results below (0 = negative; TR = trace; 1+ to 4+, least to most; number for pH):

Dip Stick Results		
Test	Result (NORMAL)	Comment
Color/Appearance	(pale yellow to amber/clear)	
Specific Gravity (Sp. G.)	(1.005-1.035)	
Leukocytes	(0)	
Nitrite	(0)	
pH	(5-6)	
Protein	(0)	
Glucose	(0)	
Ketones	(0)	
Urobilinogen	(0)	
Bilirubin	(0)	
Blood	(0)	
Hemoglobin	(0)	

As a general rule, positive results for leukocytes and nitrite with an alkaline pH indicate a urinary tract infection; protein in urine may be indicative of exercise or kidney damage; glucose in the urine indicates a problem with glucose metabolism, e.g., diabetes mellitus; positive ketones results may be indicative of exercise or fasting or losing weight or the Atkins diet; the presence of bilirubin in urine is suggestive of liver disease; positive blood results have to be examined with care: if a woman is having her menstrual period, some blood may leak into the urine -- otherwise, blood is indicative of urinary tract infections or lesions.

DO NOT THROW AWAY YOUR URINE SPECIMEN!!!!!!
YOU WILL NEED IT FOR THE NEXT SECTION!!!!!!

Microscopic Experimental Section

Obtain a disposable test tube. Fill it to the top of the white label with your first urine sample. Place it in the centrifuge. When the centrifuges are full, close the safety lids with a "click" and turn the time knob to "5". Have someone stand by the centrifuge so that it does not fall off the bench -- it's not supposed to if each tube has an identical amount of urine in it, BUT ... . Wait for the centrifuge to come to a complete stop. Open the lid and remove the urine tube. Dump the liquid into the sink and wash it away with water. Add 1 drop of methylene blue to the sediment in the bottom of the tube. Vortex your tube. Place one drop of urine on a microscope slide. Put a slip cover on top of it. Examine the slide under 10X. Draw your findings. Examine the slide under 40X. Draw your findings. Refer to your lecture text pp. 475, 477, 481, 482, 483 for references as to what crystals or cells you are observing. If you are not certain, seek assistance from your instructor. Record your drawings below:

Observations at 10X	Observations at 40X

Questions

1) About how long did it take for you to urinate after you drank the water?

2) As you collected your urine, did it get lighter or darker? What would you conclude based upon your response?

3) As you collected your urine, what was the general pattern of the respective Sp.G.'s? Did they parallel the response to question #2?

4) When you finally quit this experiment, what was the total volume of urine you collected? How did it relate to the amount you drank?

5) Teaser Question: What do you think the effect would have been had you drank iced tea instead of plain water in this experiment?

References/Citations/Bibliography/Outside Reading

1. Carman: **Doc Carman's Necessities of Human Anatomy and Physiology, Volume II.** (W.C. Brown: Dubuque) ©1996.

2. Hole: **Human Anatomy and Physiology, Sixth Edition**. (W.C. Brown: Dubuque) © 1993.

3. Kelly, Wood and Enders: **Bailey's Textbook of Microscopic Anatomy, Eighteenth Edition**. (Williams and Wilkins: Baltimore) ©1984.

4. Martin: **Endocrine Physiology**. (Oxford University Press: New York) ©1985.

5. Martini: **Fundamentals of Anatomy and Physiology, Third Edition.** (Simon and Schuster: Englewood Cliffs) ©1995.

6. Mazzaferri: **Endocrinology: A Review of Clinical Endocrinology, Second Edition**. (Medical Examination Publishing Co., Inc.: Garden City, NY) ©1980.

7. Mazzaferri: **Endocrinology Case Studies: A Compilation of 53 Clinical Studies, Third Edition**. (Medical Examination Publishing Co., Inc.: Garden City, NY) ©1981.

8. Moore: **The Developing Human: Clinically Oriented Embryology, Third Edition**. (Saunders: Philadelphia) ©1982.

9. Seely, Stephens and Tate: **Anatomy and Physiology, Second Edition**. (Mosby-Year Book: St. Louis) ©1992.

10. Tortora and Grabowski: **Principles of Anatomy and Physiology, Seventh Edition**. (HarperCollins College Publishers: NY) ©1993.

11. Van De Graf and Fox: **Concepts of Human Anatomy and Physiology, Third Edition**. (W.C Brown: Dubuque) ©1992.