This lecture will present the histology of the kidney and urinary tract, which includes the ureter and the urinary bladder. The urethra is also a part of the urinary tract. However, its histology will be presented in the lectures on the male and female reproductive tracts and organs.

These are the resources for text reading and practical lab exercises that will complement this lecture.

This is the vocabulary of terms related to the content of this lecture.
Histology of Urinary Organs

Learning Outcomes

- After completing a study of this lecture and working through the related laboratory exercise, you should be able to:
  - list, describe and give the function(s) of the components of the urinary system.
  - describe and identify the gross and macroscopic aspects of the kidney.
  - describe and identify the components of the kidney cortex and medulla.
  - define what is meant by a kidney lobe and a kidney lobule.
  - trace blood flow through the kidney, naming the vessels in order from the renal artery to the renal vein.
  - describe and define a nephron and a unilobular tubule distinguishing between them.
  - define, describe, identify and give the function of the components of a renal corpuscle.
  - describe, identify and give the function of the segments of a nephron.
  - define and describe the components of the glomerular filtration membrane.
  - describe, identify and distinguish between the ureter and urinary bladder.

These are the learning outcomes of this lecture. At the end of the lecture you will be presented with a few questions to aid in assessing your understanding and retention of the important concepts in this lecture.

Lecture Outline

- Overview of the Urinary System
- Location and Gross Structure of the Kidney
- Renal Lobe
- Kidney Blood Vessels
- The Nephron
- The Renal Corpuscle
- Filtration Apparatus of the Kidney
- Juxtaglomerular Apparatus
- Kidney Lobes, Lobules & Medullary Rays
- The Urinary Tract: Kidney Pelvis, Ureter and Bladder
- Quiz

This is the outline of topics presented in this lecture. Each topic listed on this slide is hyperlinked to the first slide in that topic sequence with return hyperlinks back to this lecture outline slide.

Overview of Urinary System

- Paired Kidneys
  - Excretes waste products & water (urine), control water & electrolytes in tissues, maintains pH of blood, contributes to the regulation of blood pressure and helps to regulate the density of erythrocytes in circulating blood (hematocrit)
- Paired Ureters
  - Delivers urine made by the kidneys to the urinary bladder
- Urinary Bladder
  - Stores urine
- Urethra (presented in lectures on male and female reproductive tract and organs)
  - Delivers urine to the external environment.

The urinary system consists of three organs – kidneys, right and left ureters and the urinary bladder. The kidneys have multiple functions that include excreting waste products, controlling hydration of the cells and tissues of the body, maintaining the proper concentration of electrolytes like sodium chloride, calcium chloride etc., playing an important role in maintaining normal blood pressure and even secreting a hormone, erythropoietin, that stimulates the bone marrow to produce and release more erythrocytes if the hematocrit falls below the normal range. Under hypoxic conditions such as going to a high altitude, an increased level of erythropoietin is secreted by cells in the kidney that causes the production of more red blood cells. This helps one adapt to high altitude by increasing the number of oxygen carrying cells. The ureters deliver urine to the urinary bladder, the urinary bladder stores urine to be later expelled by the act of urination, and the urethra is the conduit that carries the urine outside of the body. The urethras of the male and female will be presented in the lectures on the male and female reproductive tracts and organs.
Urine, Urination & Micturition

- Urine is a sterile body liquid by-product secreted by kidneys, transported by ureters, stored in the urinary bladder and, excreted through the urethra through the act of urination.
- Micturition is the process of eliminating liquid by-products of metabolism in the urine.
- Urine is an aqueous solution of greater than 95% water, with the remaining constituents, in order of decreasing concentration urea 9.3 g/L, chloride 1.87 g/L, sodium 1.17 g/L, potassium 0.75 g/L, creatinine 0.67 g/L and other dissolved ions, inorganic and organic compounds.
- Normal color of urine is pale yellow due to a by-product of the breakdown of aging Red Blood Cells. Dark yellow urine can be an indication of dehydration (urine is concentrated to conserve water). Colorless urine is usually because of over-hydration, a condition that is considered healthier than dehydration.

Perspective on the Kidney

What is Man, when you come to think upon him, but a minutely set, ingenious machine for turning, with infinite artfulness, the red wine of Shiraz into urine?

—Isak Dinesen (1885-1962)  
(from 'The Dreamers' in Seven Gothic Tales, 1934)
The kidneys are located in the abdominal region at a level between Thoracic Vertebra 12 (T12) and Lumbar Vertebra 3 (L3). The left kidney is located slightly superior to the right kidney. If a cross-section were made at the level of the dotted line the image on the right displays what would be seen. The right and left kidneys can be seen to be located in the posterior part of the abdomen surrounded by fat. Even in the thinnest persons, there is always some fat surrounding the kidneys. The fat serves to protect and cushion the kidneys from injury. They are located posterior or behind the peritoneum – retroperitoneal location. Underneath the peritoneum (serosa) is a capsule composed of dense connective tissue. A normal life can be lived with only one kidney so there is 100% backup in kidney function.

The image is a photograph of a normal kidney taken at autopsy showing how it appears. Observe that it is shaped like a bean. It is deep red colored due to the enormous amount of blood flowing through and contained within the kidney. Its surface is smooth because, except for its posterior aspect, it is covered with a serosa composed of mesothelium and loose connective tissue. As you can observe in this photograph of an unfixed, fresh kidney, the surface is also shiny or glistening. This is due to the mesothelial covering. It reminds one of ‘saran wrap’. The loose connective tissue of the serosa blends the underlying capsule of the kidney that is composed of dense connective tissue. This inset is a microscopic view of the serosa and the capsule. The dense connective tissue of the capsule on the posterior aspect of the kidney is not covered with a serosa. The capsule there blends in with the connective tissue of the fascia of the deep muscles of the back. The capsule of the kidney supports and contains the delicate tubules that make up the bulk of the kidney. The hilum of the kidney is where the renal artery and vein carry blood into and out of the kidney….and where the ureter is attached.
The kidney histologically is classified as a solid organ that is organized into an outer cortex and inner medulla. It helps to think of the cortex of the kidney as a huge filter that is made up of nearly one million glomeruli (little rounded beds of capillaries), each having its own funnel collecting urine in as many tubules. Each funnel begins as an epithelial lined capsule called Bowman’s capsule that surrounds the bed of capillaries. All of the glomeruli in Bowman’s capsules are located exclusively in the cortex of the kidney. The tubules carrying the filtrate of blood that is the beginning of urine formation go through a tortuous path in the cortex, loop into the medulla, then back into the cortex to finally merge with collecting tubules, then collecting ducts. The collecting ducts converge in each lobe at the renal papilla (the apex of each lobe) as if a renal pyramid were a larger funnel. Urine finally is emptied into the renal pelvis from each renal medullary pyramid and the contents of the pelvis flow into the ureter. Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware. http://www.udel.edu/biology/Wags/histopage/illuspage/iu/urinarysystemppt.htm

This is a histological section through the cortex and medulla of a single renal lobe stained with hematoxylin and eosin. The dotted line is the boundary between the cortex and medulla. A renal lobe is a pyramidal shaped portion of the medulla with its associated cortex. There are 7 kidney lobes in the average human. Observe that glomeruli are only present in the cortex. Observe the triangular shape of the medulla in this lobe (it is pyramid shaped in the 3rd dimension). Observe the apex of the renal pyramid at the renal papilla where urine is emptied into a minor calyx. The image on the right is this same specimen only with two nephrons and collecting ducts overlying the histological specimen. The nephron begin with a Bowman’s capsule that contains a tuft of capillaries, the glomerulus (red). Continuing from Bowman’s capsule and sharing a continuity with its lumen are proximal and distal convoluted tubules with loops of Henle intervening between the two convoluted tubules. Observe that each of the two nephrons is connected and empties their contents into a collecting duct. The combination of a nephron and it collecting duct is called a uriniferous tubule. Each kidney has on the order of one million nephrons. With each kidney lobe the nephrons are organized into collections residing in several lobules. The nephrons that drain into a single
collecting duct make up the tissue that forms a lobule. Blood is delivered to two adjacent lobules via an interlobular artery. Next the blood vessels of the kidney will be presented, followed by the structure of the lobules and then the detailed structure and function of a nephron, the functional unit of the kidney. Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware. 
http://www.udel.edu/biology/Wags/histopage/illuspage/iu/urinarysystemppt.htm

In this drawing illustrating the blood vessels that supply and drain the kidney we shall follow the path of blood flow. Blood enters the kidney via the renal artery then flows into the interlobar arteries into the arcuate arteries that arch between the cortex and medulla. Smaller arteries, the interlobular arteries, branch at right angles from the arcuate arteries going straight into the cortex. Companion interlobular veins drain the cortex into the arcuate veins, then blood is collected in each interlobar vein and finally blood flows out of the kidney through the renal vein. If we look closer at this rectangular area of a section of the cortex and medulla we see the details of the blood supply to one nephron (colored green) and a collecting duct (colored yellow). The nephron begins at the Renal Corpuscle (Bowman’s capsule and a glomerulus). A nephron is composed first of a convoluted tubule, next the loop of Henle then, the distal convoluted tubule ending with a connection to a connecting tubule that then joins a collecting duct (yellow). Now observe the arcuate artery and vein gives rise and drains the interlobular artery and vein, respectively. The interlobular arteries and veins are always located between kidney lobules (lobules are subsections of the kidney lobes – more about that later). The capillaries in the glomerulus are supplied with blood from the afferent arteriole and drained of blood by the efferent arteriole. (This is a unique arrangement because the capillaries are supplied and drained of blood by arterioles). Finally, observe that there are two medullary capillary plexi, one in the interstitium between the tubules and the other surrounding the loop of Henle (LH). The interstitial capillary plexi are fed by a branch of the afferent arteriole and drain via a tributary into the arcuate vein. The cortical and medullary tubule plexi are fed by the efferent arterioles and drain via a tributary into the arcuate veins. As we will see in the next two slides, the interlobular arteries course between kidney lobules.

Source of drawings: R. Wagner, Department of Biological Sciences, University of Delaware. 
http://www.udel.edu/biology/Wags/histopage/illuspage/iu/urinarysystemppt.htm
Histology of Urinary Organs

A nephron consists of the renal corpuscle (made up of Bowman’s capsule enclosing several capillary loops called a glomerulus), a proximal convoluted tubule, a loop of Henle (consisting of a descending straight portion of the thick proximal tubule, the thin segment of tubule, and the ascending straight portion of the distal tubule) and the tubule segment that connects to a collecting duct. From Bowman’s capsule and it lumen throughout to the collecting duct the lumen is continuous between the components of the nephron. The nephron is the functional unit of the kidney. The nephron and the collecting duct that it connects to make up the uriniferous tubule. Many nephrons connect to a single collecting duct. The number of nephrons for each kidney in normal adult humans ranges from as low as 230,000 to over 2 million. Studies have suggested that an inborn deficit of nephrons predisposes an individual to acquired kidney disease, including hypertension.

With an understanding of the blood vessels of the kidney, their relationship to the nephrons and the components of a nephron, you are prepared learn how a kidney lobe is organized. Each kidney lobe is subdivided into lobules. The lobules are organized around the collecting ducts that collect urine from the nephrons. So, where do these nephrons reside and how are they placed in the kidney lobules. This is a section of the kidney cortex. If the framed in area is enlarged two medullary rays will be seen. Observe the parallel profiles of longitudinal sections through collecting ducts and thick ascending/descending segments of the loops of Henle. Between the two medullary rays seen here is the cortical labyrinth of multiple cross-sections and oblique sections through the convoluted tubules among which are several glomeruli. Further enlargement as seen in the right image confirms the longitudinal profiles in the medullary ray and the sections through glomeruli and convoluted tubules on either side of the medullary ray. A medullary ray lies at the center of a kidney lobule and an interlobular artery lies between two adjacent lobules. The next slide will present a kidney lobe in more detail.
In this low power view of the kidney cortex two lobules are shown. A lobule consists of all of the nephrons that connect and empty their product and contents into a collecting duct. The collecting ducts are located in regions running at right angles to the surface of the cortex. The loops of Henle components of the nephrons are located in this same region and the region is called a medullary ray. Note the location of the medullary rays in this image. When a portion of a medullary ray is enlarged one can see the longitudinal profiles of collecting ducts and the straight portions of the descending and ascending loops of Henle with a glomerulus and the convoluted portions of the nephron tubules on either side. The medullary ray is the center of a lobule. The convoluted tubules and glomeruli reside in the regions on either side and this is known as the cortical labyrinth (CL). The border between two kidney lobules is formed by an interlobular artery the branches of which are afferent arterioles supplying the glomeruli of the lobule located in the cortical labyrinth. Observe the example outlined in the low magnification and how the interlobular artery and one of its branches appears in the enlargement. In the next few slides the detailed histology of each segment of a nephron will be presented.

This slide presents the types of cells that make up the wall of each of the segments of the nephron. Connecting to the renal corpuscle is the proximal convoluted tubule that is lined with simple cuboidal epithelium. The apical surface of each cell has microvilli that project into the lumen resembling a brush, thus called a ‘brush border’ making the apical surface of these cells look fuzzy at low magnification. The base of the cells shows striations that are a reflection of the many infoldings of the basal cell membrane with many mitochondria. Proximal tubule cells are very eosinophilic due to the large amount of intracellular membrane and mitochondria present. Distal convoluted tubule cells are shorter cuboidal cells than the proximal ones. The lumen border of these cells is very smooth because the distal tubule cells do not have microvilli projecting into the lumen, i.e. no ‘brush border’. The cells of the loop of Henle are low cuboidal cells in the thick segment of the loop and very flat squamous cells lining the thin segment of the loop. The cells of the collecting duct are columnar forming a simple columnar epithelium. A unique feature of this epithelium is that you can see the borders or divisions between the cells. This is because the cells do not interdigitate laterally with each other in the collecting duct as they do in the proximal and distal tubules.
Histology of Urinary Organs

Nephron Segment Functions

1. Proximal Convoluted Tubule
   Resorbs water, proteins, glucose and sodium

2. Descending side loop of Henle permeable to water and salts. Urea enters here.
   Water is resorbed to interstitium.

3. Ascending side loop of Henle is impermeable to water but transports more Na and Cl to interstitium.


5. Modifies the water content of urine if ADH induces further resorption here to increase body’s fluid volume. More water absorbed results in a more concentrated urine.

Blood is filtered across two cells (endothelial and epithelial) and a basement membrane. The ultrafiltrate of blood does not include any formed elements, just water, proteins less than 100,000 molecular weight, uric acid, urea, glucose, amino acids, and various electrolytes. As you can see, much of the filtrate is reabsorbed. The proximal tubule resorbs water, proteins, glucose and sodium. The descending side of the loop of Henle is permeable to water and salts so these go out of the tubule and urea enters the tubule. The ascending side of the loop of Henle is impermeable to water, but Na and Cl are transported to the interstitium making the interstitium very hypertonic. The distal tubule is impermeable to water and the hormone aldosterone transports sodium and chloride out of the urine. Finally, in the collecting duct the water content of urine is modified depending on the level of ADH. Now the details of the filtration apparatus in the renal corpuscle will be presented, illustrated and explained. Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware. http://www.udel.edu/biology/Wags/histopage/illuspimage/iu/urinarysystemppt.htm

The epithelial cells of Bowman’s capsule, the endothelial cells of the capillaries of the glomerulus and the special connective tissue cells, mesangial cells, which fill in between the capillaries, all make up what is known as the renal corpuscle. (Recall that the lymphatic nodules in the spleen are called ‘splenic corpuscles’). The renal corpuscle has a vascular pole where the afferent and efferent arterioles carry blood into and collect blood from the glomerular capillaries. At the opposite end is the urinary pole at which site the proximal convoluted tubule begins. The lumen of the proximal tubule is continuous with the urinary space at the urinary pole. The glomerulus consists of several loops of capillaries the lumens of which are continuous with those of the afferent and efferent arterioles. The endothelium of the glomerular capillaries is enclosed with the visceral layer of Bowman’s capsule. The parietal layer of Bowman’s capsule lines the wall of Bowman’s capsule. At the vascular pole the end of the distal convoluted tubule touches the afferent arteriole. At this point the cells of the distal tubule change orientation so that the apical ends are facing the afferent arteriole. This collection of cells is known as the macula densa (literally means a dense spot because the cells are so close together). Finally,
there are the mesangial cells of the glomerulus. Mesangial cells are specialized pericytes located among the glomerular capillaries. They function to provide structural support for and regulate blood flow of the glomerular capillaries by their contractile activity. Some of them secrete collagen and laminin that keeps those components of the basement membrane renewed. Mesangial cells are also phagocytic. They help keep the basement membrane cleared of complex immunoglobulins that can clog the filtration membrane. Now we shall examine the structure that forms the filtration membrane in the glomerulus.

Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware. http://www.udel.edu/biology/Wags/histopage/illuspimage/iu/urinarysystemppt.htm

On the left is a medium high magnification view of the cortex of a kidney stained with H & E. The renal corpuscle is seen in the center with its vascular pole and urinary space (US). Below the corpuscle an example of a proximal convoluted tubule and a distal convoluted tubule are labeled. Observe the erythrocytes in the capillaries of the glomerulus. The image on the right is a scanning electron micrograph of a renal corpuscle with part of Bowman’s capsule removed. The structures that look like worms are capillaries. At several loci along the capillaries you can see swellings, some of which are labeled Po. These are the cell bodies of the cells that make up the visceral layer of Bowman’s capsule and they are called Podocytes. This term denotes the fact that these cells have processes that look like feet that end upon and enclose the endothelium of the capillaries. The filtration membrane of the kidney glomerulus involves the capillary endothelium, an intervening basement membrane and the podocyte. We shall now look into the relationship between these 3 structures and how they form the filtration membrane.
This is a view at high magnification of part of a glomerulus and surrounding proximal convoluted tubules. First note the scale = 25 microns. Observe the erythrocytes in the capillaries of the glomerulus. Note the nucleus of an endothelial cell in one of the capillaries at the green arrow, and, a neutrophil in another capillary at the yellow arrow. Now note the urinary space that is labeled S. Next at the red arrow is a nucleus of one of the simple squamous epithelial cells that form the parietal layer of Bowman’s capsule. Next observe the nucleus of a podocyte at the blue arrow. Podocytes form the visceral layer of Bowman’s capsule. Finally, observe the very thin membrane that intervenes between the urinary space the lumen of a capillary at the black triangular arrow. This is the membrane that filters blood. Water, glucose, proteins and electrolytes, but not formed elements of the blood, pass from the capillary lumen to the urinary space across this membrane. Now we will look at this membrane in detail.

Both images were created with a Scanning Electron Microscope. The left image shows the cell body of a podocyte with its primary and smaller secondary (foot processes) enveloping the outside of a glomerular capillary. The right image is taken of the inside of a glomerular capillary and the edge showing the relationship between the podocyte and its foot processes (P) and the endothelial cell (E). The view is as if the specimen in the left image was cracked open in a plane parallel to the red dotted line. In the upper right part of the right image observe the tiny holes. These are the fenestrations (little windows or openings) in the endothelial cell (EF). The next slide will display a section through a glomerular capillary and podocyte as viewed in a transmission electron microscope.
This transmission electron microscope shows part of a glomerular capillary surrounded by the foot processes of a podocyte. Note the erythrocyte in the lumen of the capillary. The electron dense material in the lumen of the capillary is protein. The red arrow points at one of several fenestrations in the endothelium of the capillary. Foot processes are labeled (fp)….look in upper left of the image. Between each of the foot processes is a thin line (small arrows). This is a diaphragm or membrane that is attached to each foot process and extends between them. Now look between the endothelial cell and the podocyte foot processes and observe the basement membrane (B). The glomerular filtration membrane consists of 1) the fenestrated endothelial cell, 2) the basement membrane and 3) the podocyte foot processes and their diaphragms.

This figure from Kierszenbaum’s Histology & Cell Biology text nicely demonstrates and illustrates the relationship between the structures of the filtration membrane and how they perform the function of filtration. First to note is that the fenestrations in the endothelial cells have no diaphragms so that proteins, electrolytes, water etc can flow easily out of the plasma into the basement membrane. However, the fenestrations are no more than 90 nanometers in diameter…..much too small for any of the formed elements of the blood to pass. So that is a first order of filtration to keep the formed elements within the lumen of the capillary. The next important aspect to know is that the glycoproteins extending from the cell membrane of the endothelial cells are negatively charged. This slows down the passing of large anionic proteins in the plasma of the blood. The basement membrane and the cell membrane of the foot processes also are heavy in negatively charged glycoproteins that add to the slowing of passing of large anionic protein molecules. Finally, the filtration slit diaphragm is like a sieve that further filters proteins. The final result is that some albumin makes its way into the urinary space, but larger proteins of the blood plasma like gamma globulins are unable to pass through.
The juxtaglomerular apparatus literally means an apparatus next to or very intimately associated with the glomerulus. It is located at the vascular pole and consists of special smooth muscle cells of the afferent arteriole that synthesize and secrete upon proper stimulus, renin, and the macula densa which is the collection of cells of the distal tubule in direct relationship to the afferent arteriole smooth muscle cells that contain the renin. Observe the cartoon that illustrates these relationships. The juxtaglomerular apparatus regulates blood pressure. Renin is the active substance that is released and then converted to angiotensin I and eventually to angiotensin II in the lung. Angiotensin II is a powerful vasoconstrictor that targets the smooth muscle cells of arterioles. Renin is released from the cells of the afferent arteriole by either mechanoreceptors that sense a change in length of the smooth muscle cells due to a fall in blood pressure, or, by a decrease in sodium in the distal convoluted tubule. The cells of the macula densa sense this change in sodium concentration and convey that to the cells in the smooth muscle of the afferent arteriole that contains renin.

Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware. http://www.udel.edu/biology/Wags/histopage/illusp age/iu/urinarysystemppt.htm

Acute post-streptococcal glomerulonephritis is an infection of the glomerulus by streptococcal bacteria. A normal glomerulus is shown beside one with glomerulonephritis. Recall that bacteria attract neutrophils from the blood vessels. Several of many neutrophils are indicated by the arrows in the right image. Acute proliferative glomerulonephritis is a disorder of the glomeruli (glomerulonephritis), or small blood vessels in the kidneys. It is a common complication of infections, typically streptococcal skin infection (impetigo) and streptococcal pharyngitis, for which it is also known as post infectious or post streptococcal glomerulonephritis. The exact pathology remains unclear, but it is believed to be type III hypersensitivity reaction. Immune complexes (antigen-antibody complexes formed during an infection) become lodged in the glomerular basement membrane below the podocyte foot processes. This creates a lumpy bumpy appearance on light microscopy and subepithelial humps on electron microscopy. Complement activation leads to destruction of the basement membrane. It has also been proposed that specific antigens from certain nephrotoxic streptococcal infections have a high affinity for basement membrane proteins, giving rise to particularly severe, long lasting antibody response. This is an example of one of the complications that can occur as side effect of our body’s immune response.
Stepping back from the detail, it should be helpful to study this slide where you have a low magnification view of a histological section through a kidney lobe on the left and a drawing showing the placement of the nephrons + collecting ducts = uriniferous tubules. Recall that the renal corpuscles with glomeruli are only located in the cortex. Note that there are nephrons with long and short loops off Henle. Observe also that some nephrons begin close to the capsule, others in the middle of the cortex and still others near the junction of the cortex with the medulla. The so-called juxta-medullary nephrons have the longest the loops and they are the ones that contribute most to making the urine hypertonic thus conserving water under the influence of antidiuretic hormone (ADH). The outer stripe contains the thick ascending and descending segments of the loops of Henle, the inner stripe contains a mixture of thick descending and thin segments of the loops, and the inner zone is composed of only collecting ducts and thin segments of the loops of Henle. Observe how the medullary rays are the straight tubules in the cortex, ascending and descending thick segments of the loop of Henle, and along with the collecting ducts in the cortex form profiles that are relatively parallel. The medullary rays are the center of the kidney lobules, the sub-components of the kidney lobes. Think of the tubules in the medullary rays as the stems of a bouquet of flowers and the convoluted tubules the connecting stems to the flowers which are the glomeruli. One half way between each medullary ray in the cortex is the boundary between two lobules and that is the location of the interlobular artery and vein.
The Urinary Tract

Function is to: collect, store, & expel the urine
linied with Transitional epithelium (Urothelium)

specialized chemical protection, with an ability to be stretched

Pelvis & Ureter
Urinary Bladder
Urethra

The Ureter

MUCOSA with transitional epithelium
LUMEN folded-in stellate shape
MUSCULARIS int. longitudinal outer circular
Note: reverse of gut muscular arrangement

ADVENTITIA

This lecture concludes with a presentation of the Urinary Tract. The urinary tract begins with the pelvis of the kidney. Urine flows from the pelvis into the paired ureters and then into the urinary bladder that stores urine until the bladder is full. Urine is then emptied via the urethra. The entire urinary tract is lined with a specialized epithelium consisting of several layers of cells the surface cells of which are dome shaped and have a special relationship between intracellular membrane vesicles and the cell membrane to provide a way for the epithelium to stretch without being torn.

Source of drawing: R. Wagner, Department of Biological Sciences, University of Delaware.
http://www.udel.edu/biology/Wags/histopage/illuspage/iu/urinarysystemppt.htm

The ureter has a mucosa consisting of transitional epithelium, a basal lamina and loose connective tissue. The lumen is often stellate or star shaped in histological sections due to the contraction of the smooth muscle between harvesting the tissue and fixation. Contraction of the smooth muscle in the wall causes folding of the mucosa. The muscle arrangement of smooth muscles in the ureter is inner longitudinal and outer circular. This arrangement makes it possible for the ureter lumen to become larger or smaller in diameter, and the longitudinal muscle makes it possible for the ureter to literally move urine toward the urinary bladder by a 'milking' process. The ureter is wrapped with loose connective tissue, the adventitia.
The urinary bladder is shaped like a ball and it has also three layers, a mucosa, a muscle layer and an adventitia. The epithelium of the mucosa is also transitional epithelium. The smooth muscle fascicles envelope the bladder in bands that course in multiple directions. Think of the urinary bladder as a ball around which you wrap rubber bands (smooth muscle fascicles) until you have multiple layers running in all directions so that when the bands of smooth muscle contract in a coordinated manner, the ball becomes smaller and smaller to squeeze urine from the bladder into the urethra. If you have ever taken the cover off of a golf ball, particularly the older ones, then you can picture this. At least the older golf balls are wrapped with many, many rubber bands oriented in every way imaginable. The superior and lateral aspects of the bladder are wrapped with a tunic called the serosa that is the same as the peritoneum, a loose connective tissue covered with a simple squamous epithelium (a mesothelium). The anterior and posterior surfaces of the bladder are covered with an adventitia, a loose connective tissue similar to the outer covering of the esophagus.

The epithelium of the urinary bladder is transitional epithelium. It is a very unique structure arrangement. The surface cells are dome shaped when the bladder is not full or stretched. These cells are called facet cells as they face and border the lumen. We shall examine these cells in more detail.
Facet cells are large cells composing the superficial layer of the transitional epithelium lining the bladder. They face the lumen and that is why they are called facet cells. The cell membranes bordering the lumen of these cells are thickened forming a face or facet. The term facet can mean the surface of an object as in the facets of a diamond, or, it can mean any definable aspect of a subject. These cells frequently have two nuclei (bi-nucleated) and the cells can be polyhedral (many sided) when the bladder is empty, or, when the bladder is full, these cells are stretchable so that they become flattened. So, the facets of the superficial cells are the thickened cell membranes. The vesicles are thickened cell membrane stored inside of the superficial transitional epithelial cells in an empty bladder when the epithelium is not stretched. When the bladder fills with urine the epithelium is stretched. The cells enlarge via the vesicles fusing with the cell membrane to provide more area for the stretching cells. Thus the bladder can expand greatly with the epithelium still intact.

This additional illustration is included for clarity in the explanation of how the facet cells of the urinary bladder epithelium function to allow stretch of the epithelium without tearing. In a distended bladder the vesicles fuse with the surface membrane to expand its area and in a collapsed or empty bladder parts of the surface cell membrane are incorporated back into the cytoplasm as vesicles.
Transitional cell carcinoma (TCC, also urothelial cell carcinoma or UCC) is a type of cancer that typically occurs in the urinary system: the kidney and urinary bladder. It is the most common type of bladder cancer. TCC arises from the transitional epithelium, a tissue lining the inner surface of these hollow organs. In this low power view of a specimen from the bladder note the masses of cancer cells that have invaded into the underlying connective tissue indicating that this is a malignant carcinoma. Observe the concentration of lymphocytes nearby. These are most likely T-cells that are attempting to attack the cancer cells but most likely not that effective. Recall that T-cells are very mobile and attach cells directly that forms the basis of cellular immunity. When this boxed in area is viewed at higher magnification the cancer cells, T-cells and a patch of relatively normal transitional epithelium can be observed. Note the lymphocytes also in the blood vessel.

Transitional cell carcinoma (TCC) can be very difficult to treat. Treatment for limited stage TCC is surgical resection of the tumor, but reoccurrence is common. Chemotherapy for TCC consists of the MVAC regimen (methotrexate, vinblastine, adriamycin and cisplatin). TCC can also be treated with infusions of BCG into the bladder. BCG stands for bacillus Calmette-Guerin solution. It contains weakened bacteria that stimulate the immune system to kill cancer cells in the bladder. This treatment is usually done once a week for six weeks. Side effects can include irritation of the bladder, an urgent need to urinate, and the need to urinate frequently. This is known as biological therapy because its mechanism is to recruit cells of the immune system (T-cells) to kill the cancer cell by cellular immunity.

Summary

- This lecture began with an overview of the urinary system, followed by a presentation of the location and gross structure of the kidneys.
- Next the renal lobe was illustrated and defined in the context of a low magnification histological section through the kidney.
- Then, the blood vessels that enter, course through and leave the kidney were illustrated and the sequence of blood flow was described.
- After that, the segments and histology of the nephron were presented.
- The lecture continued with a presentation of the renal corpuscle showing the relationship of its parts; Bowman’s capsule and the glomerulus.
- Following that the filtration apparatus, the glomerular filtration membrane was presented.
- The special arrangement involving the end of the distal tubule (macula densa) and afferent arteriole, the juxtaglomerular apparatus was presented.
- Finally, the histology of the urinary tract was illustrated and explained.