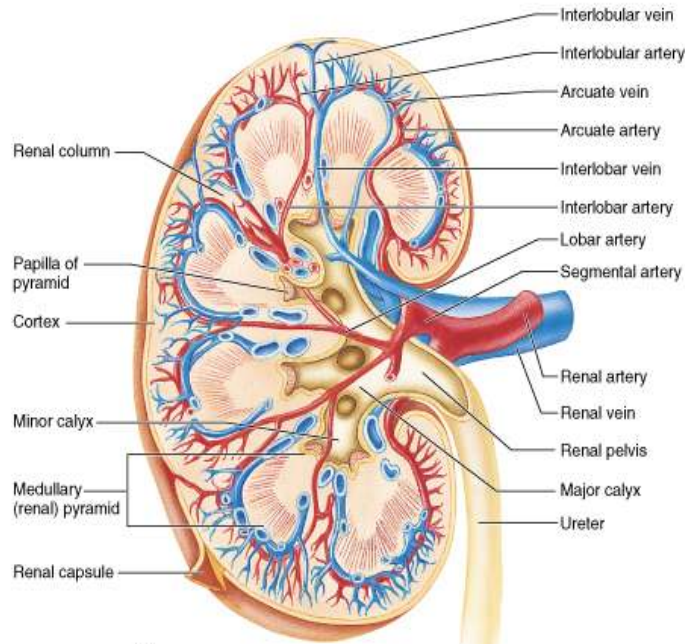
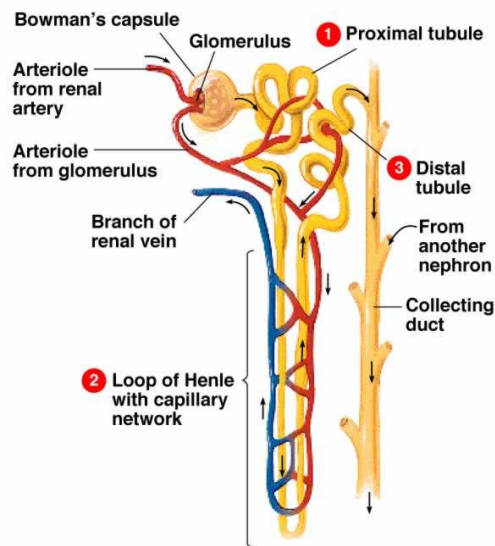


FUNCTIONAL ANATOMY OF THE KIDNEY

Gross structure of the kidney: cortex, medulla (inner and outer zones of outer medulla and papilla or inner medulla), pyramids, renal calyces and pelvis, ureter. Gross size and weight (300-400 g) of kidneys (about 0.5% of body weight) in humans.

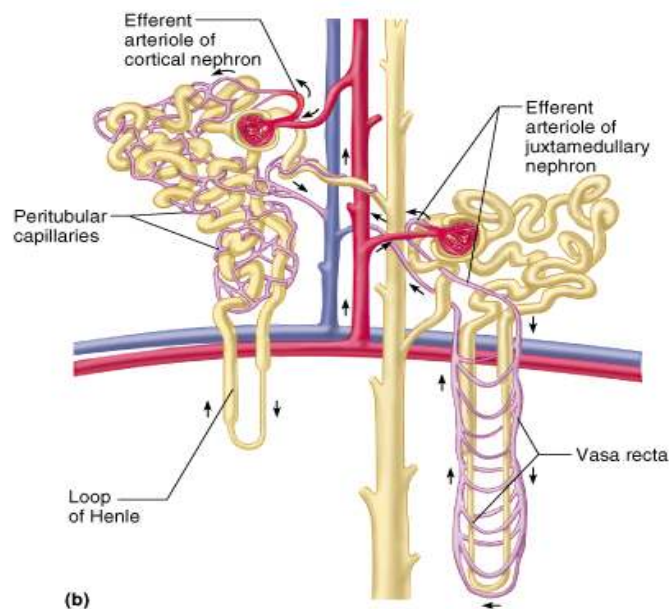


The **nephron** is the basic unit of renal structure and function: it has a **Malpighian corpuscle**, with a **vascular glomerulus** within a **matrix formed by mesangial cells** and an **epithelial Bowman's capsule**. The capsule joins a series of tubules starting with the proximal tubule and followed by the **loop of Henle**, the distal tubule, and ending in the collecting ducts.

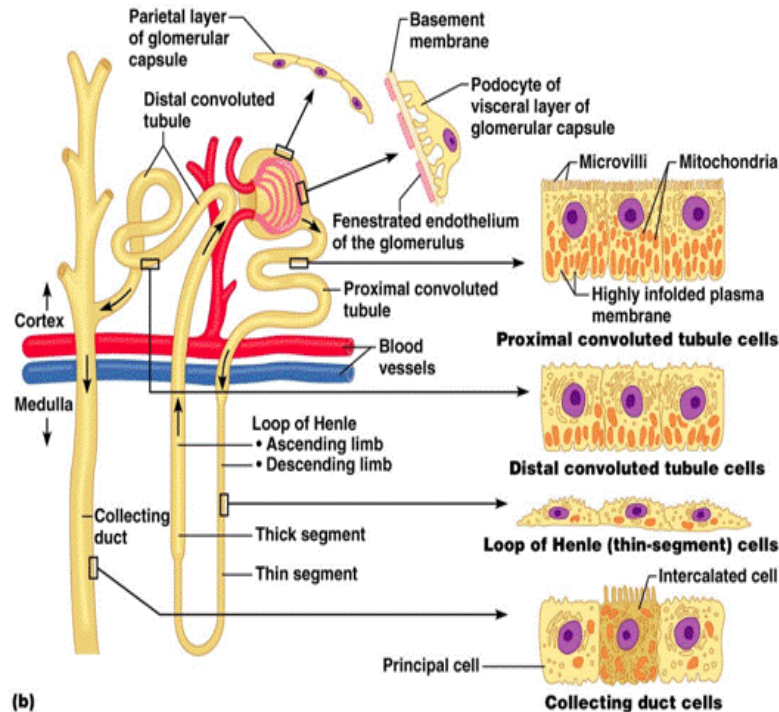


The **proximal tubule** has **convoluted early** and intermediate segments S1 and S2 in the **renal cortex** and a straight segment S3 which enters the **outer medulla**. The **loop of Henle** has medullary thin descending and thin ascending limbs and a thick ascending limb with outer medullary and cortical segments. The cortical distal **diluting segments** includes the **early distal tubule**, that **makes contact with the afferent arteriole** at the **macula densa cells** forming the **juxtaglomerular apparatus**. This is followed by the cortical distal convolutions and the connecting segment. The **collecting duct** has cortical, outer medullary and inner medullary segments.

There are about 1 million nephrons per kidney ($\pm 250,000$). There are **three types** of nephrons: (1) **Superficial nephrons** (30% in humans) with glomerulus in outer cortex and loop of Henle that bends in the outer medulla. (2) **Midcortical nephrons** with glomerulus in the mid cortex and short loops that bend in the outer medulla (10%). Other mid cortical nephrons have loops of intermediate length that bend at various points in the inner medulla (50%). (3) **Juxtamedullary nephrons** have glomeruli in the inner cortex next the medulla and long loops that reach the tip of the papilla (10%). The proportion and length of the long loops of Henle increase in proportion to the urine concentrating capacity of the animal.



Cells of S1 at the PCT and at the TAL have high rates of solute transport, abundant mitochondria, extensive microvilli on the luminal plasma membrane and infoldings of the basolateral membrane. These cells are rich in basolateral **Na-K ATPase**.



In the S2 segments of the PCT there is prominent basolateral infoldings but less **microvilli** and mitochondria than in S1, consistent with participation of S2 in secretory transport. In S3 there is abundant microvilli but basolateral infoldings and mitochondria are less prominent than in S1. The thin limbs of Henle have **flattened cells** with no mitochondria and little ATPase activity. In the collecting ducts there are 3 different cells: principal cells with abundant water channels (**aquaporins**) and **Na-K ATPase**, alpha and beta intercalated, mitochondria-rich cells with abundant proton-ATPases.

The initial step is the formation of a **plasma ultrafiltrate** (plasma without cells or proteins) at Bowman's space through the action of **hydrostatic pressure** in the **glomerular capillaries**. The ultrafiltrate flows along the tubules and is modified by **reabsorption** (retrieval) of important solutes (**sodium salts, glucose, amino acids**) and most **water** from the lumen of the tubules back into the **peritubular capillary blood**. The luminal fluid is also modified by **secretion** (addition) of solutes from the peritubular capillaries (or from the tubule cells) into the lumen.

The proximal tubules reabsorb back into the peritubular capillaries about 2/3 of the Na and water and most of the bicarbonate, glucose and amino acids filtered and the little albumin that may have filtered at the glomeruli.

The **medullary loop of Henle reabsorbs salts with little water** making the medullary interstitium rich in solutes (hyperosmolar) and delivers a solute poor, dilute fluid to the distal tubules. Thus the loop of Henle initiates the processes of urine concentration or dilution.

The distal tubules (cortical diluting segments) continue to dilute the luminal fluid through hormone stimulated transport of NaCl (**aldosterone**) and of Ca salts (**parathormone**). In the connecting segment water reabsorption becomes prominent only when **antidiuretic hormone** is abundant.

The collecting ducts make the final fine **adjustments in composition of the urine** through antidiuretic hormone stimulated water and urea reabsorption, and aldosterone stimulated Na, K and H transport.

About **1.5 L/day of urine** containing about 600 mOsm of solutes (mostly NaCl, KCl and urea) are excreted. These solutes may be excreted in as little as 0.5 L/day or in as much as 12 L/day depending on water availability. The amount of solute excreted depends on diet (more when high protein-K rich diets that generate much urea, or highly salted foods, are eaten).

The kidneys regulate volume (water content and cell volume, sodium content and ECF volume) and composition (concentrations of K, phosphate, bicarbonate, pH) of the body fluids. Through renal plasma clearance ($C=UV/P$) the kidneys clean the body fluids of non-volatile end products such as urea, uric acid, and creatinine. Clearance of secreted and filtered solutes can approach renal plasma flow. Other solutes such as proteins, amino acids and glucose are conserved by the normal kidney and have zero clearance. The kidney produces hormones (erythropoietin, renin-angiotensin and calcitriol). It has also metabolic functions, participating in degradation of peptides such as some hormones, in fasting gluconeogenesis and in transformations of amino acids (glutamine to NH_4 , synthesis of arginine and glycine).
