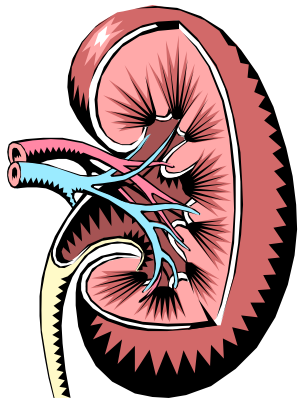
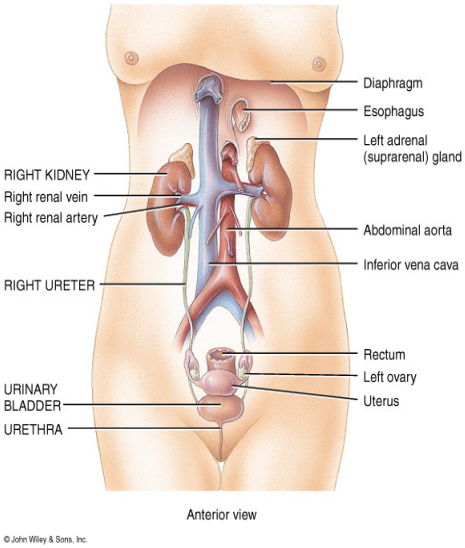
Bio& 242:
Unit 2 / Lecture 1



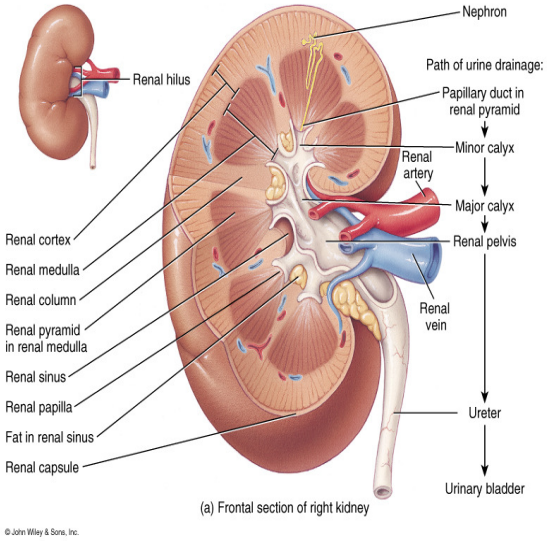
Major Functions of the Kidneys and the Urinary System

1. **Regulation of blood ionic composition**
2. **Maintenance of blood osmolarity**
3. **Regulation of blood volume**
4. **Regulation of blood pressure**
5. **Regulation of blood pH**



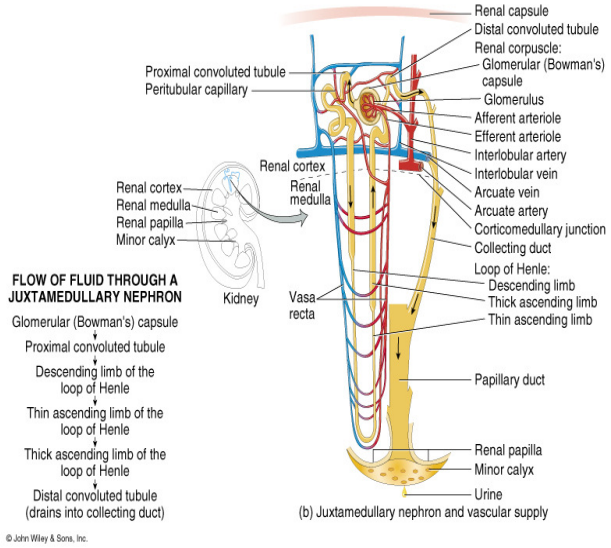
Major Functions of the Kidneys and the Urinary System

6. **Release of hormones**
   calcitriol – active form of Vitamin D, helps control calcium homeostasis.
   erythropoietin – stimulates RBC production
7. **Regulation of blood glucose levels via gluconeogenesis**

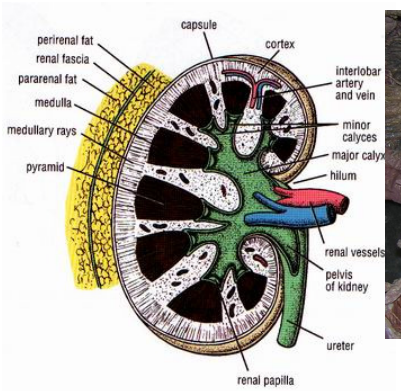


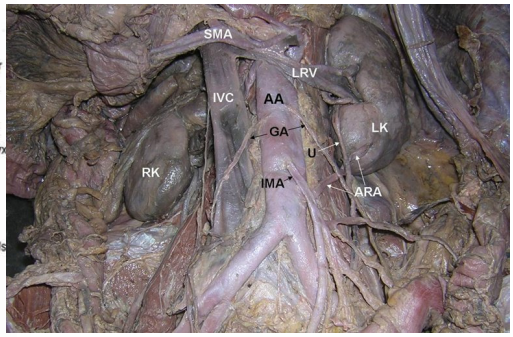
Major Functions of the Kidneys and the Urinary System

8. **Excretion of wastes and foreign substances**



Location of the kidney





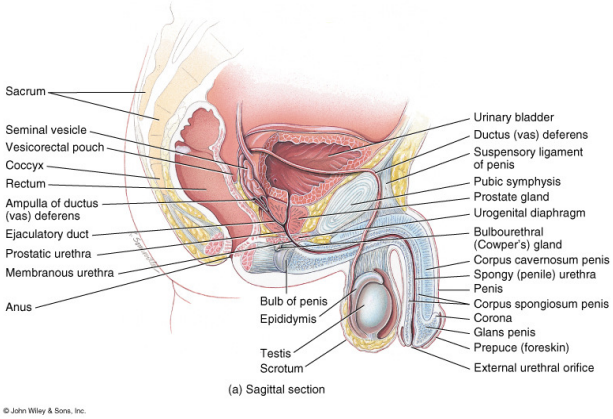
- Three layers of tissue surround each kidney:
- *1. renal fascia (outermost layer)*
- *2. adipose capsule (middle layer)*
- *3. renal capsule (innermost layer)*

The Kidney is Retroperitoneal:
In a pocket of the parietal Peritoneum against the dorsal wall of the abdomen.

The Male Urethra

Specializations of the male urethra:

1. **Prostatic urethra**
2. **Membranous urethra**
3. **Penile urethra**



Urology: *The branch of Medicine related to health care of the male and female Urinary system (Bladder and urethra) and the male reproductive system is called.*

Nephron: The Functional Unit of the Kidneys

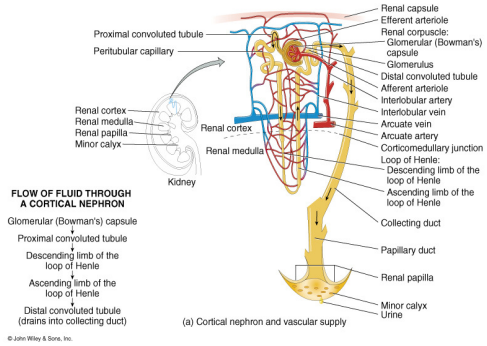
Nephrology: *The specialized branch of medicine that deals with structure, function of the Kidney in urine formation.*

- **Cortical Nephrons:**

  80 to 85% of nephrons. Have short Loops of Henle that lay mainly in the cortex

- **Juxtamedullary Nephrons:**

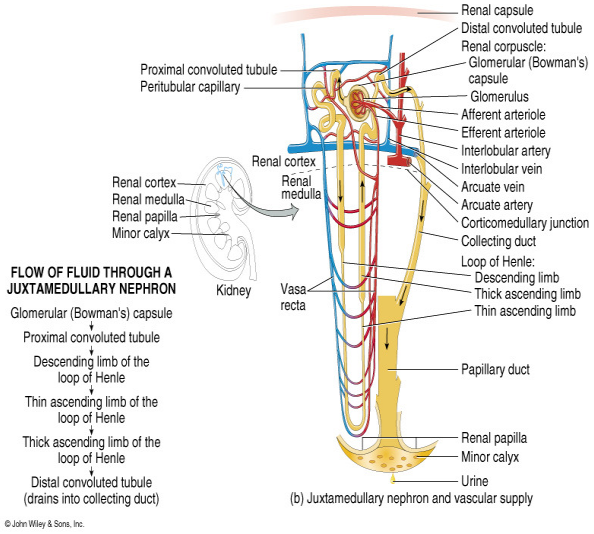
  15 to 20% of nephrons. Have long Loops of Henle that extend into the deepest regions of the medulla. Produce the most concentrated urine.



The Anatomy of a Nephron

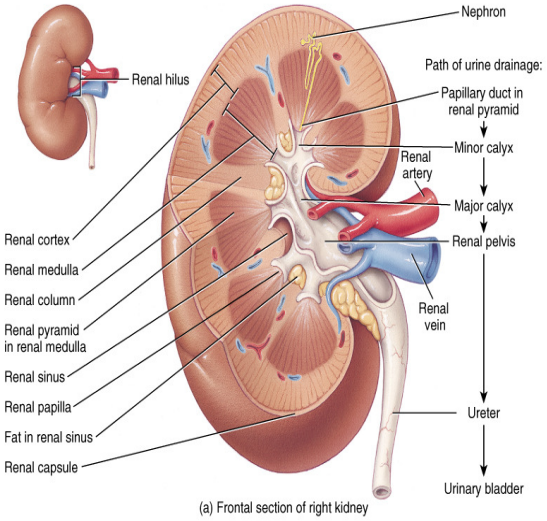
- **Subdivision of a Nephron:**

1. **Renal Corpuscle**
2. **Proximal Convoluted tubule**
3. **Descending Loop of Henle**
4. **Ascending Loop of Henle**
5. **Distal Convoluted tubule**
6. **Collecting duct**
7. **Papillary duct**

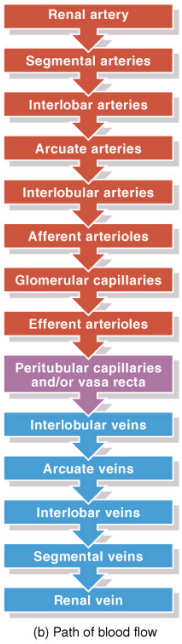


Urine Drainage through the Kidney and body

- From papillary duc
- Minor Calyx
- Major Calyx
- Renal pelvis
- Ureter
- Urinary Bladder
- Urethra:
  - prostatic
  - membranous
  - penile

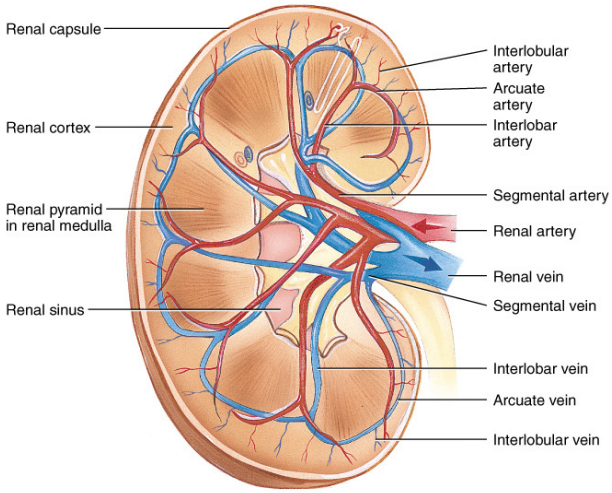


(a) Frontal section of right kidney



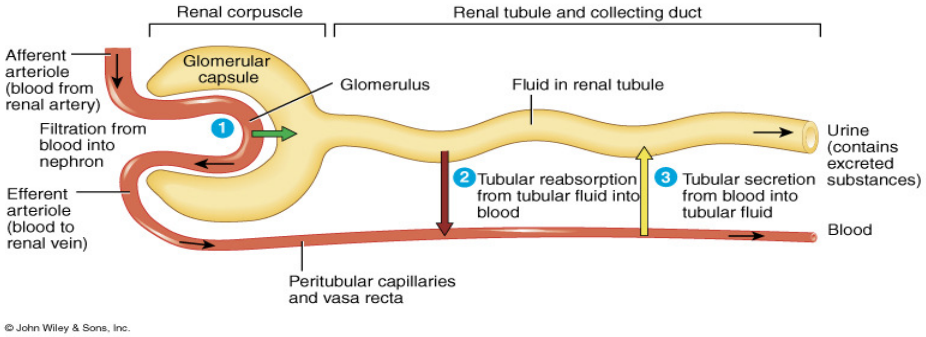
(b) Path of blood flow

Blood flow through the Kidney



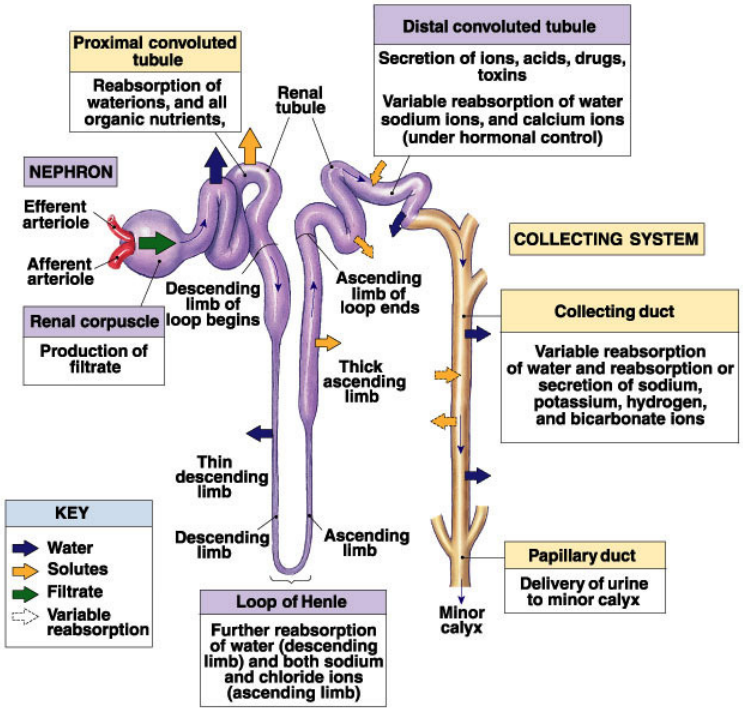
(a) Frontal section of right kidney

Basic Functions of a Nephron

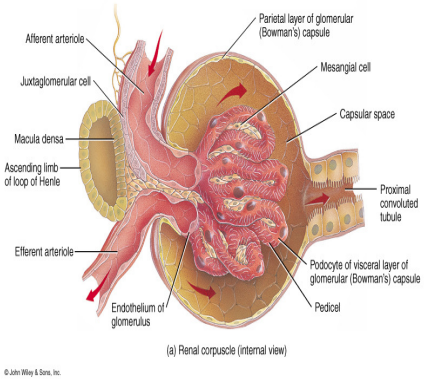


Nephrons perform three basic functions:

1. *glomerular filtration*
2. *tubular reabsorption*
3. *tubular secretion*

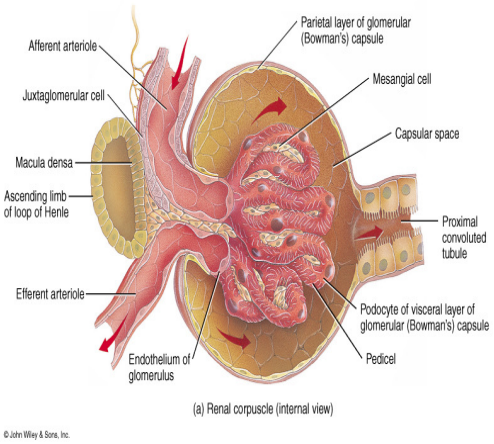


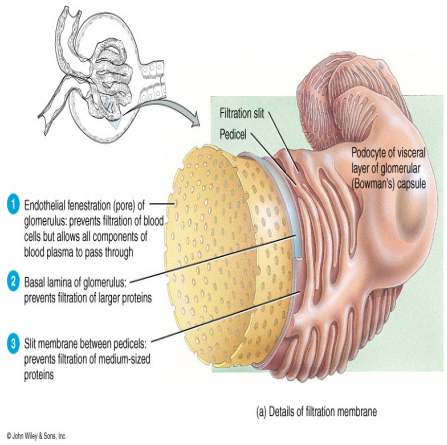
The Glomerular Filtration Membrane



The filtration membrane is the filtering unit of a nephron.
This endothelial-capsular membrane consists of:
1) the glomerular endothelium
2) the glomerular basement membrane
3) slit membranes between pedicels of podocytes

The Glomerular Filtration Membrane





Filtration Pressures and Glomerular Filtration Rate

- **Filtration Pressure is the force that drives the fluid and its dissolved substances through the glomerular filter**

Net Filtration pressure NPF (or Net Hydrostatic Pressure NHP) is the difference between three pressures:

1. **Glomerular (blood) hydrostatic pressure GHP or GBHP**
2. **Capsular Hydrostatic Pressure (CHP)**
3. **(Blood) Colloid Osmotic Pressure (BCOP)**

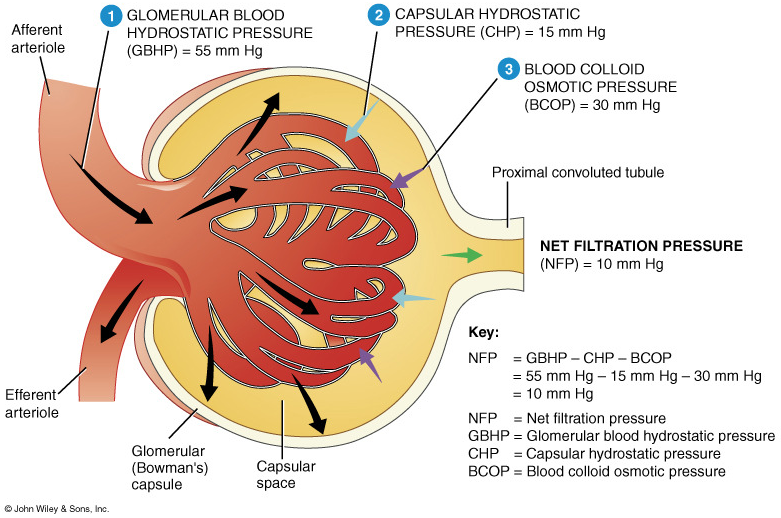
The relationship can be expressed by

$$NPF = GBHP - (CHP + BCOP)$$

Glomerular Filtration Rate: amount of filtrate the kidneys produce each minute. (about 125 ml per minute)

Determined by a creatinine clearance test

Factors affecting filtration rate in the kidney



Regulation of Glomerular Filtration Rate
Renal Auto-regulation

Regulation	Major Stimulus	Mechanism	Effect on GFR
Myogenic	Stretching of afferent arteriole walls due to increased systematic BP	Contraction of smooth muscles in afferent arteriole wall	Decrease GFR by constricting the lumen
	Decline in glomerular blood pressure	Dilation of AA and G. capillaries Constriction of EA	Increases GFR

Regulation of Glomerular Filtration Rate
Neural Regulation

Regulation	Major Stimulus	Mechanism	Effect on GFR
Tubuloglomerular feedback	Rapid increase in Na+ and Cl- In lumen at the macula densa due to increased BP	Decreased release of Nitric Oxide by JGA causing AA constriction	Decrease GFR and filtrate volume

Regulation of Glomerular Filtration Rate Neural Regulation

Regulation	Major Stimulus	Mechanism	Effect on GFR
Sympathetic Nerves (Autonomic)	Acute fall in systematic blood pressure. Release of norepinephrine	Constriction of afferent arterioles	Decrease GFR and filtrate volume to maintain blood volume

Regulation of Glomerular Filtration Rate Hormonal Regulation

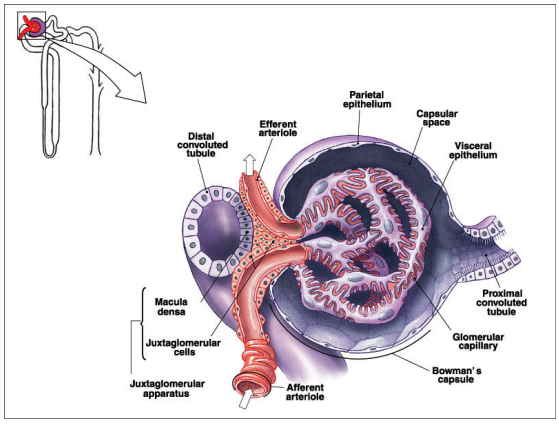
Regulation	Major Stimulus	Mechanism	Effect on GFR
Angiotensin II	Decreased blood volume or decreased blood pressure	Constriction of both afferent and efferent arterioles	Decreases GFR
Atrial natriuretic peptide	Stretching of the arterial walls due to increased blood volume	Relaxation of the mesangial cells increasing filtration surface	Increases GFR

Regulation of Glomerular Filtration Rate
Hormonal Regulation

Regulation	Major Stimulus	Mechanism	Effect on GFR
Antidiuretic hormone ADH	**Increased Angiotensin II or decreased volume of extracellular fluid**	**Stimulate insertion of aquaporin-2 (water channels) In apical membrane or principal cells**	**Increases blood volume to return GFR to normal**
Aldosterone	**Secreted from adrenal cortex because of increased Angiotensin II levels**	**Increases reabsorption of Na+ and water by principal cells of the DCT collecting duct**	**Increases blood volume to return GFR to normal**

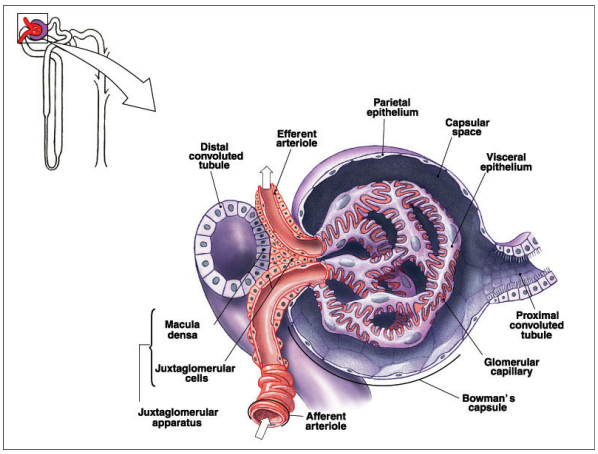
juxtaglomerular apparatus (JGA)

Consist of the juxtaglomerular cells of an afferent or efferent arteriole and the macula densa cells of the distal convoluted tubule. The JGA helps regulate blood pressure and the rate of blood filtration by the kidneys.

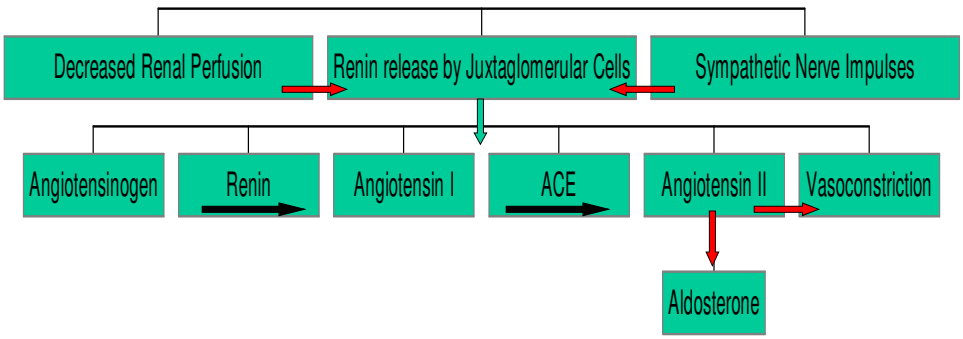


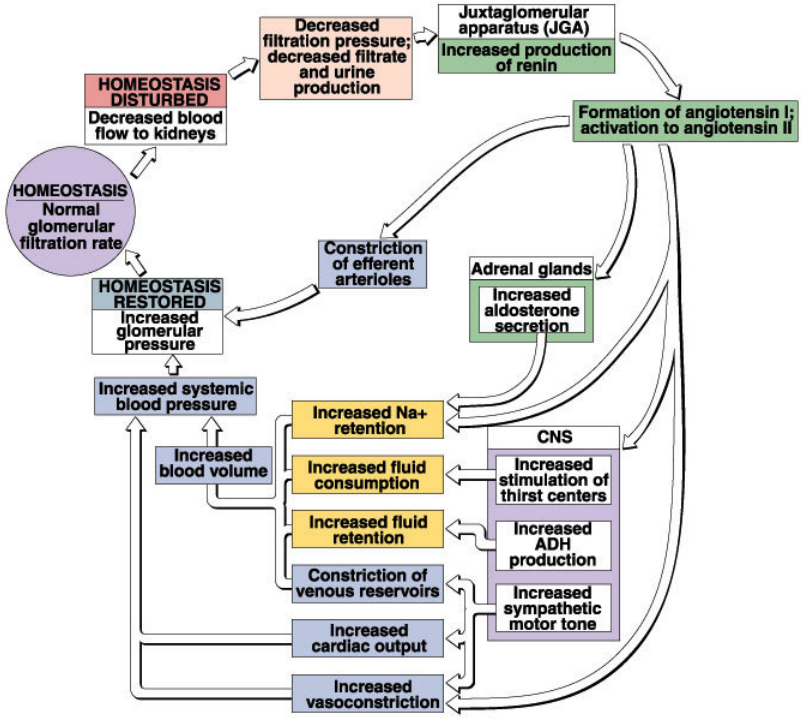
Angiotensin II Pathway

1. **Renin is released to the blood by JGA cells due to decreased renal blood flow or perfusion.**
2. **Renin converts a plasma protein (angiotensinogen) into angiotensin I**
3. **Angiotensin-Converting Enzyme (ACE) in the lungs convertes Angiotensin I into Angiotensin II**



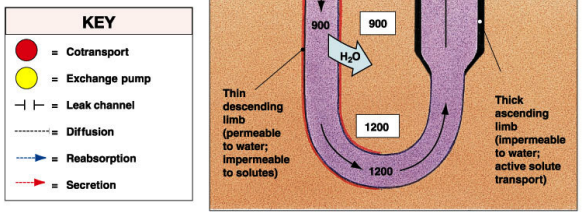
Renin – Angiotensin - Aldosterone System





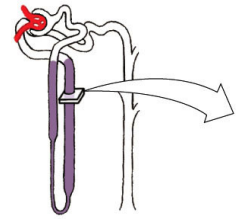
Urine Concentration via Countercurrent Multiplication

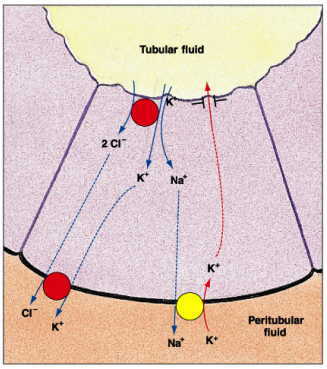
- **Thin descending limb of Henle is permeable to water but not solutes**
- **Thick ascending limb of Henle is impermeable to water and solutes. Contains active transport mechanisms for sodium and chloride.**

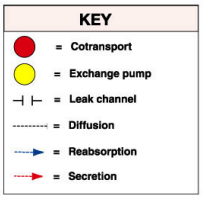


Urine Concentration via Countercurrent Multiplication

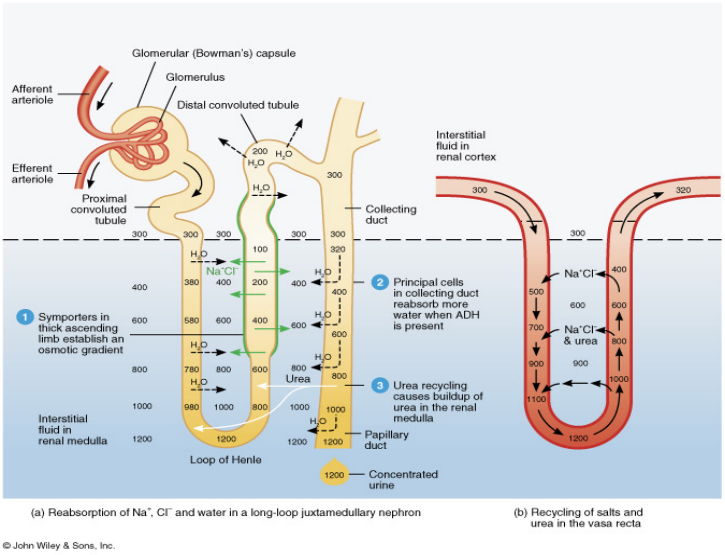
- **Sodium and Chloride are reabsorbed by thick ascending limb into the peritubular fluid**
- **These ions elevate the medulla osmotic pressure**
- **This increases osmotic flow of water out of the thin descending limb**
- **Increased osmotic potential of tubular filtrate increases active transport in the TAL**







Urine Concentration via Countercurrent Multiplication



Roles of the Different Nephron Regions in Urine Formation

Proximal Convoluted tubule

Reabsorption:

60%-70% of water (108 to 116 L/D)

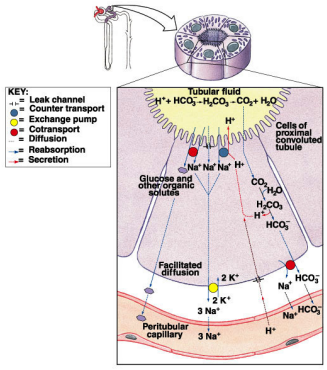
(obligatory water reabsorption)

100% of glucose and other sugars, amino acids, and some vitamins

60%-70% sodium and chloride, along with calcium, magnesium, phosphate, and bicarbonate

Secretion:

Hydrogen ions, ammonium ions, creatinine, drugs, toxins



Roles of the Different Nephron Regions in Urine Formation

Loop of Henle

Reabsorption:

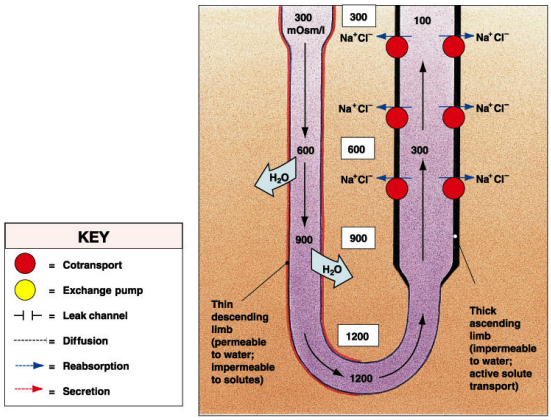
Descending limb

25% of the water

(obligatory water reabsorption)

Thick Ascending limb

20-25% of the sodium and chloride to help maintain the countercurrent system



Roles of the Different Nephron Regions in Urine Formation

Distal Convoluted Tubule

Reabsorption:

Up to 5% of water under ADH control (principle cells)

(Facultative water reabsorption)

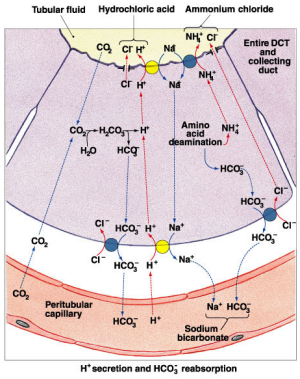
Variable amounts of sodium and chloride under Aldosterone control (principle cells)

Variable amounts of bicarbonate (intercalated cells)

Variable amounts of Calcium controlled by parathyroid hormone

Secretion:

Hydrogen ions, ammonium ions, Creatinine, drugs , toxins



Roles of the Different Nephron Regions in Urine Formation

Collecting Duct

Reabsorption:

Variable amounts of water under ADH control (principle cells)

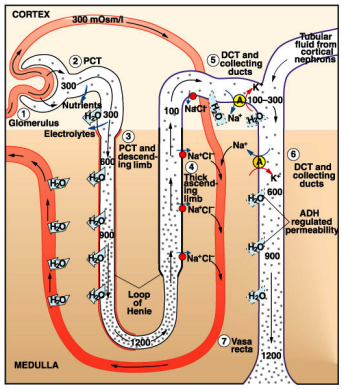
(Facultative water reabsorption)

Variable amounts of sodium and chloride under Aldosterone control (principle cells)

Variable amounts of bicarbonate (intercalated cells)

Secretion:

Potassium and hydrogen ions



Summary of the roles of the different nephron regions in urine formation