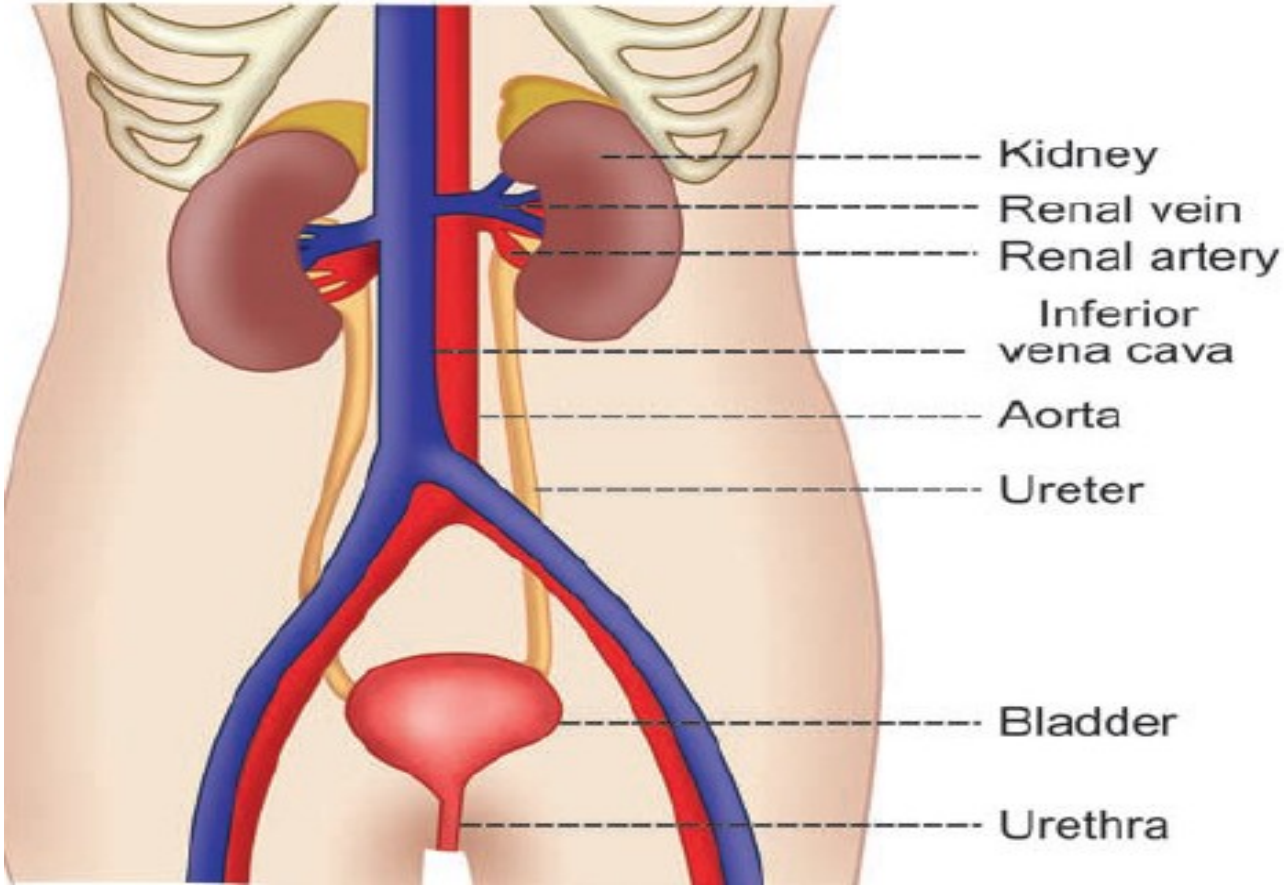
Renal Physiology



The urinary system

- **Organ system** that **produces**, **stores** and **carries urine.**
  - Includes:
    - **kidneys(2)**,
    - **Ureters(2)**,
    - **Urinary bladder**, and
    - **Urethra**.

Functional structures of the kidney

A. Shape: **Bean shaped**

Wt: both weigh ~ 300g

Blood supply: ~ 26% CO

B. three layers

Cortex: **light outer**
Medulla: **dark inner**

Renal sinus

C. Deeper structures

Nerves, blood vessels and lymphatic's enter through *helium*

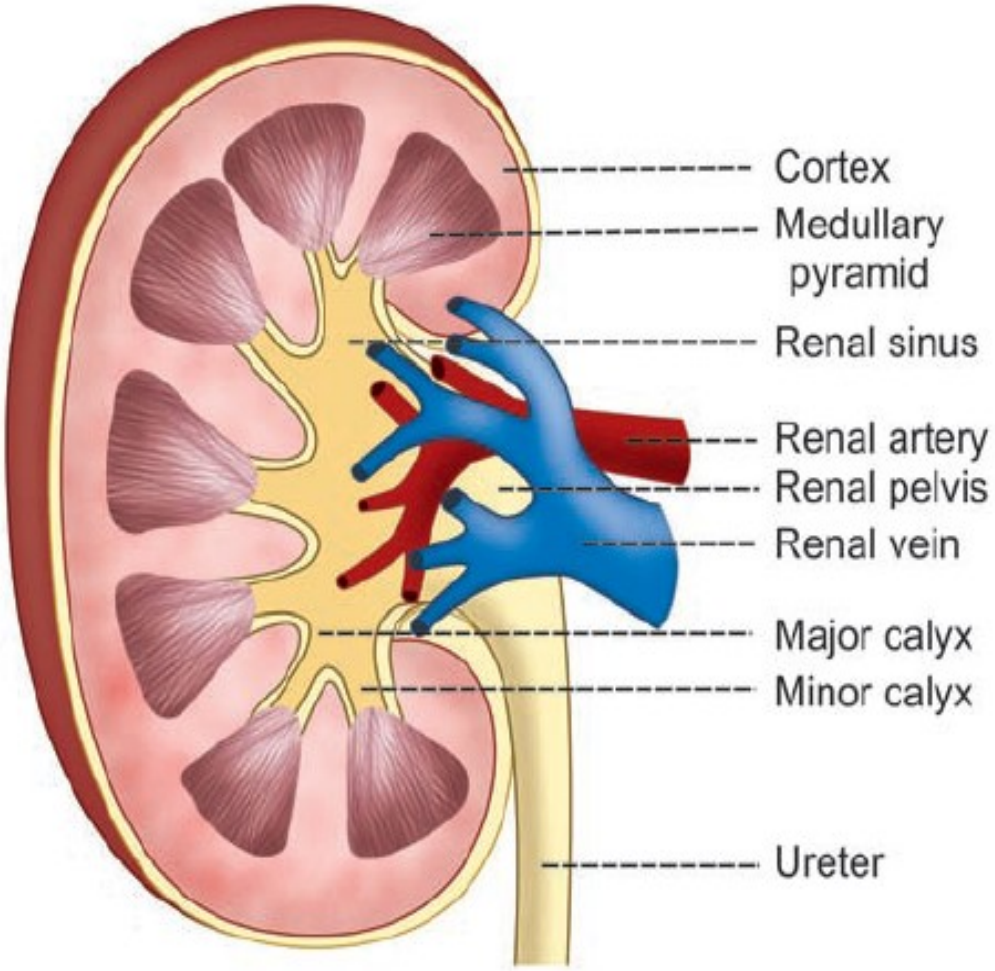


FIGURE 48.2: Longitudinal section of kidney

Figure 6-1: Gross anatomy of the kidney.

Function of Kidney

A. Homeostasis (regulation)

- **H_20 and electrolyte balance**
- **acid-base balance in the body**
- **Regulation of blood calcium level**
- **Regulation of BP**
  - ✓ By regulating the volume of extracellular fluid
  - ✓ Through **renin-angiotensin mechanism.**

B. Excretion

- **Excretion of metabolic wastes in urine (creatinine, urea, uric acid, drugs, hormones etc)**

C. Endocrine function

- **Renin, erythropoietin, Vit. D_3 production**

Renal Blood Vessels

- **Afferent arteriole:**
  - Delivers blood **into the glomeruli.**
- **Glomeruli**:
  - **Capillary network** that produces **filtrate that enters the urinary tubules.**
- **Efferent arteriole:**
  - Delivers blood from glomeruli **to peritubular capillaries.**
- **Peritubular capillaries:**
  - Drain blood into the venous system

Nephron

- **Nephron** is structural and functional unit of kidney.
- Each kidney consists of 1 to 1.3 millions of nephrons.

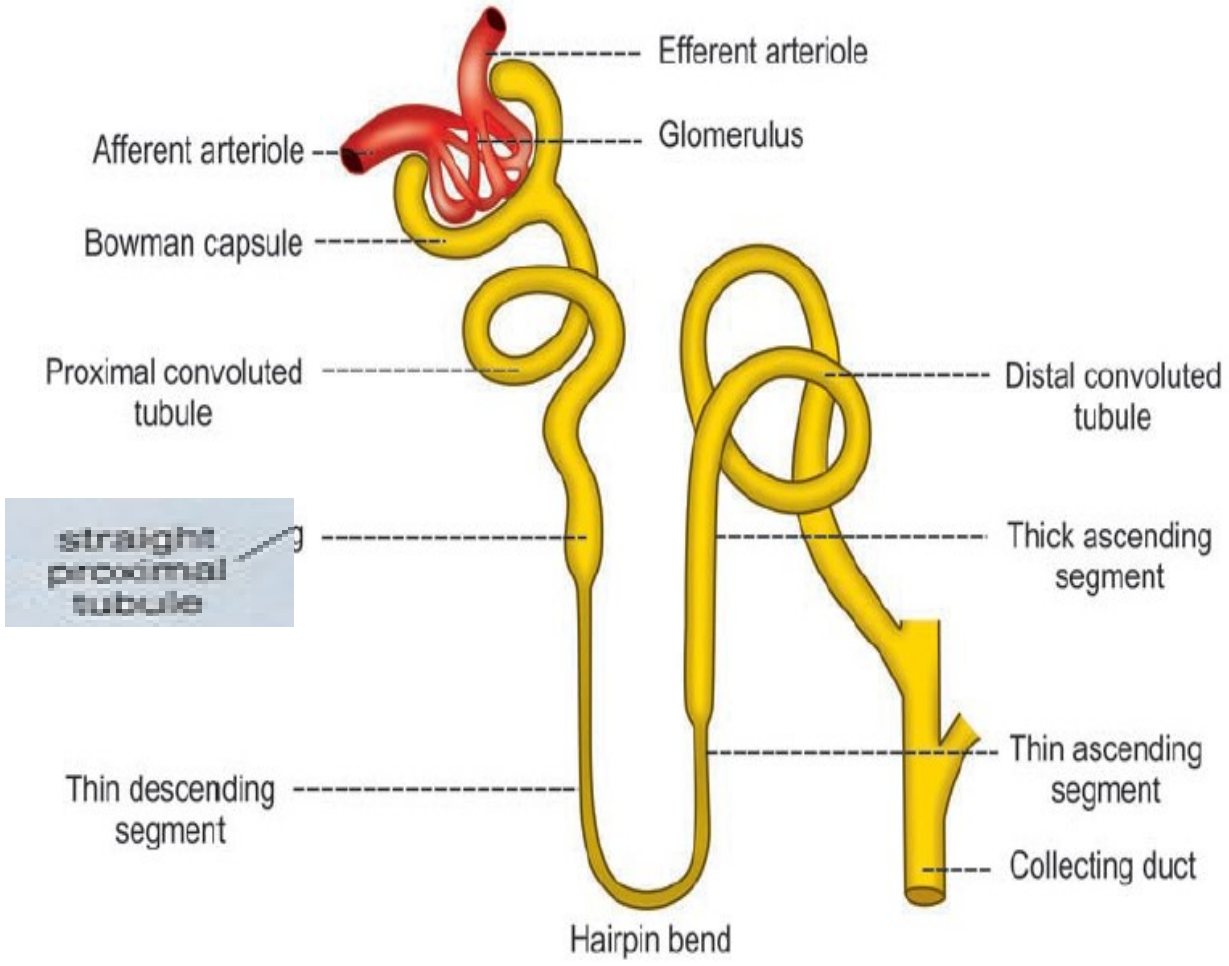


FIGURE 49.1: Structure of nephron

Cont’d

- Its main function is to **regulate water and soluble substances** by
  - **Filtering the blood plasma**,
  - **Reabsorbing what is needed** and
  - **Excreting the rest as urine.**

Different parts of the Nephron

Nephron consists of **Renal corpuscle(Glomerulus + bowman's capsule)** and **renal tubule.**

A. Glomerulus: is a capillary tuft and is a place of filtration.

B. Proximal convoluted tubule: place of major absorption

C. Loop of Henle:

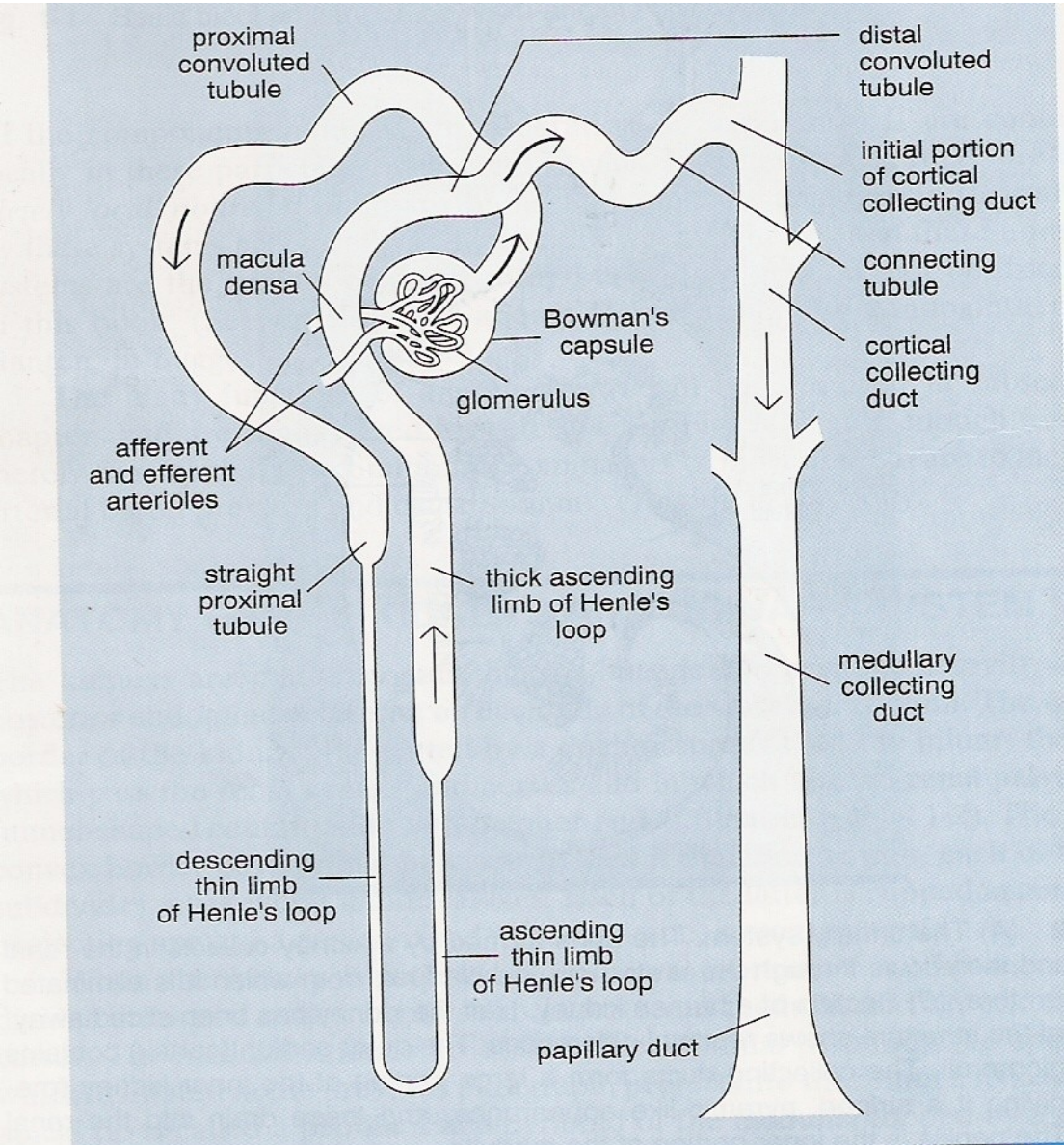
- **Descending thin segment**
- **Ascending thick segment**

D. Distal convoluted tubule:

- **diluting segment**

E. Collecting duct

- **Is site of ADH activity**



Proximal Convoluted Tubule

- **Single layer of cuboidal cells** with **millions** of **microvilli**.
  - **Increase surface area for reabsorption**.
- PCT functions:
  - **Reabsorption**.
  - **Secretion**.

Loop of Henle

- Fluid passes from PCT to LH.
- **Descending limb:**
  - **H_20 reabsorption.**
- **Ascending limb:**
  - Active transport of **Na^+.**
  - **Impermeable to H_20.**

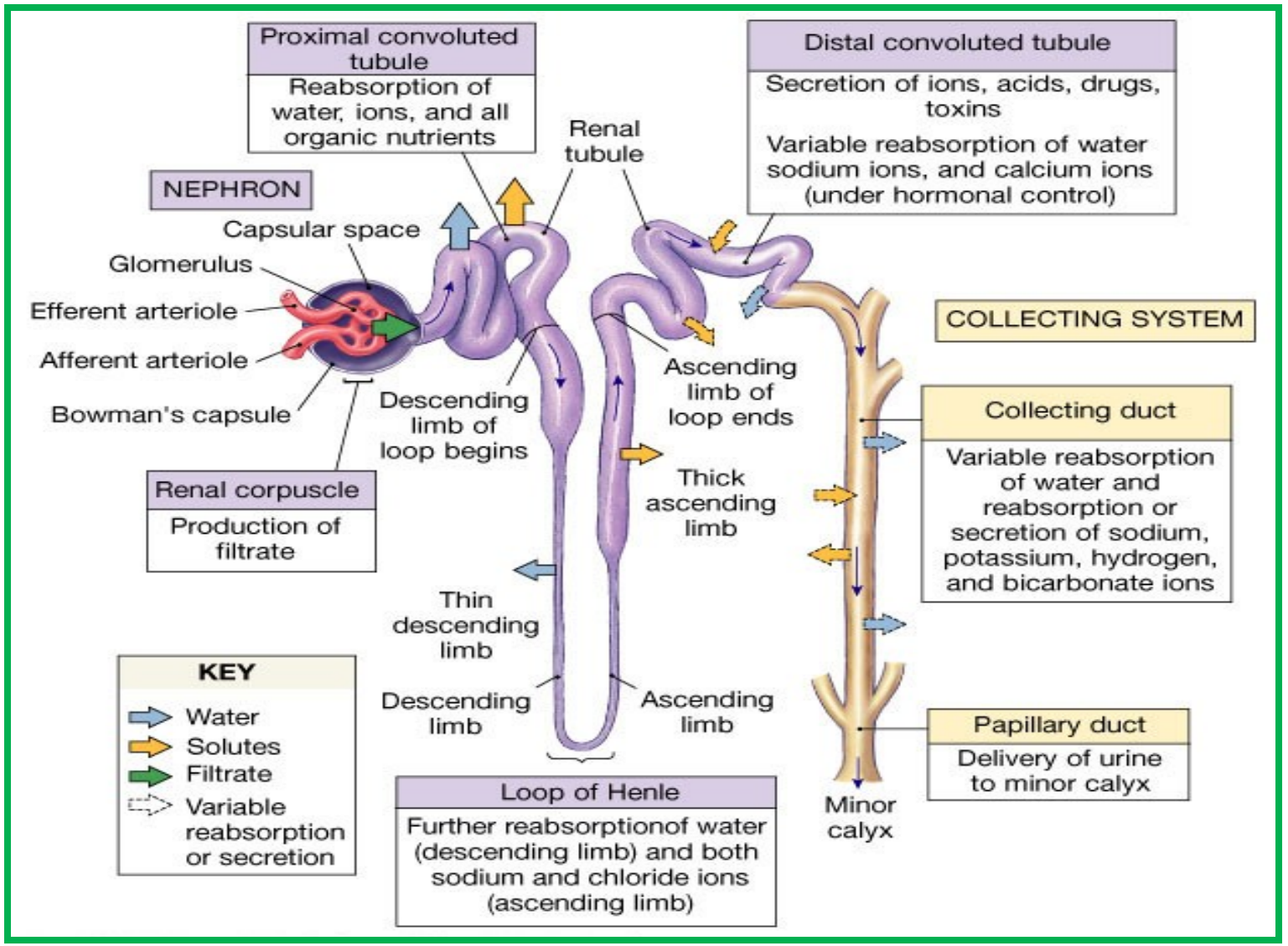
Distal Convoluted Tubule

- Contains **few microvilli.**
- Functions:
  - **Secretion**.
  - **Reabsorption**.
- Terminates in collecting duct.

Collecting Duct

- Receives fluid from the DCT of several nephrons.
- **Passes through renal pyramid** into **minor calyx.**
- Functions:
  - **Reabsorption**
    - H_20 reabsorption influenced by **ADH.**
  - Secretion

cont'd


Proximal convoluted tubule
Reabsorption of water, ions, and all organic nutrients
Distal convoluted tubule
Secretion of ions, acids, drugs, toxins
Variable reabsorption of water sodium ions, and calcium ions (under hormonal control)
Renal tubule
NEPHRON
Capsular space
Glomerulus
Efferent arteriole
Afferent arteriole
Bowman's capsule
COLLECTING SYSTEM
Ascending limb of loop ends
Descending limb of loop begins
Collecting duct
Variable reabsorption of water and reabsorption or secretion of sodium, potassium, hydrogen, and bicarbonate ions
Renal corpuscle
Production of filtrate
Thick ascending limb
Thin descending limb
KEY
Water
Solutes
Filtrate
Variable reabsorption or secretion
Descending limb
Ascending limb
Papillary duct
Delivery of urine to minor calyx
Loop of Henle
Further reabsorptionof water (descending limb) and both sodium and chloride ions (ascending limb)
Minor calyx

Structure of the glomerulus, site of filtration

3-layers of the filtration membrane

a. Glomerular capillary endothelial layer with fenestrae (pores).

b. Basement membrane

c. Visceral portion of the Bowman's epithelial layer with podocytes.

✓ Podocytes are finger-like processes which produce slits for filtration.

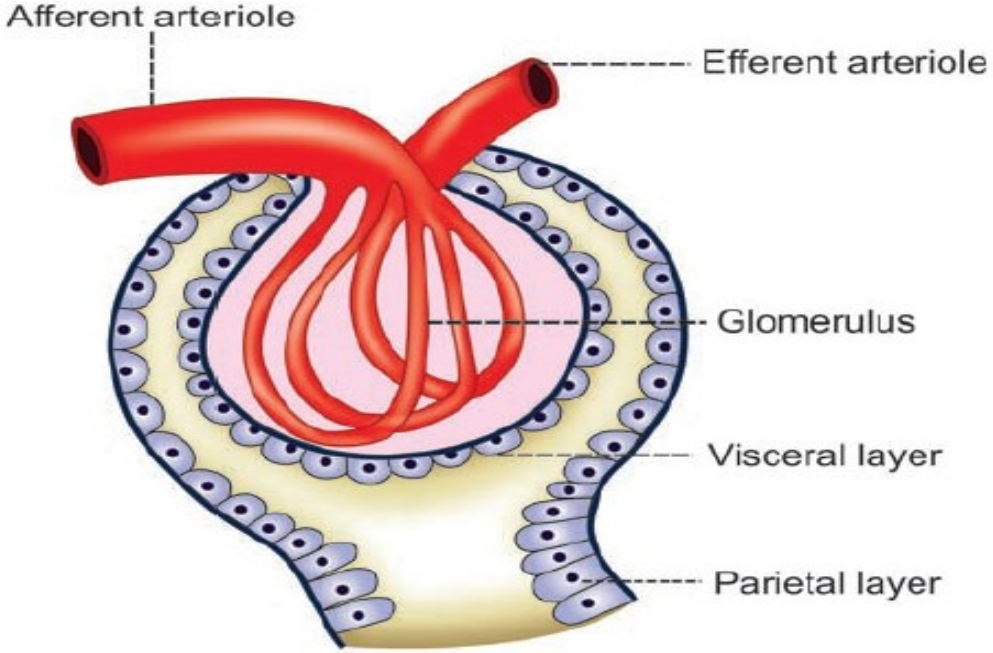
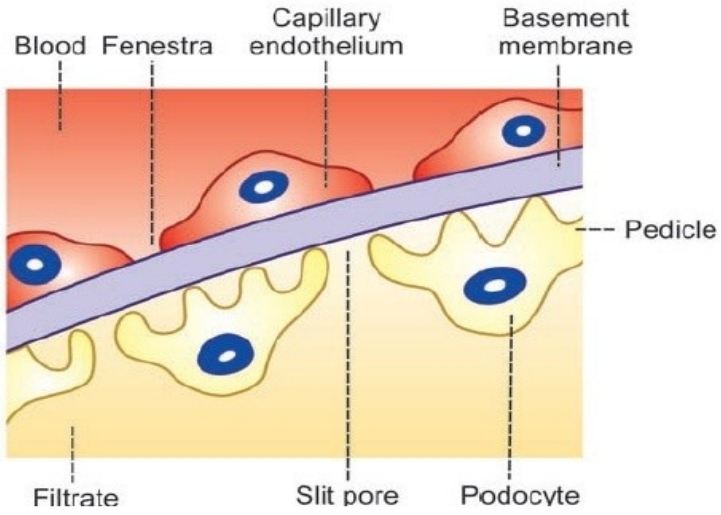


FIGURE 49.3: Renal corpuscle



Renal Autoregulation(AR)

- **AR is an intrinsic (local) mechanism of the kidney by which GFR and RBF remain constant in conditions of wide fluctuations in ABP (arterial blood pressure).**
- **Though pressure fluctuates b/n 80 to 170 mm Hg, GFR and RBF remain more or less constant.**

- **The main function of autoregulation in the kidneys is to maintain a relatively constant GFR and renal blood flow.**

Mechanisms of Auto-regulation

❖ Two mechanisms are involved in renal autoregulation:

1. Myogenic response(**stress relaxation)**
2. Tubuloglomerular feedback**.**

1. Myogenic Response

- **When the blood flow to kidneys increases, it stretches the elastic wall of the afferent arteriole**
- **But , after a while, the smooth muscles of arterioles contract strongly and cause decreases in renal blood flow and finally in decrease of GFR.**

Con't

- **<u>The mechanism</u>: is that increased stretch by high ABP causes increased Ca^{2+} entry into smooth muscles of arterioles that in turn induce heavy constriction of the arteriolar walls.**
- **If <u>arterial blood pressure decreases</u>**, the tonic contraction of arterioles disappears and as the result, the **arterioles are <u>dilated</u>**.

2. Tubuloglomerular feedback

- **Macula densa plays an important role in tubuloglomerular** feedback
- **The level of Nacl in the filtrate is detected by macula densa cells.**

❖ **When there is a decrease in GFR due to decrease in ABP, then the following effects take place:**

1. **Afferent arteriolar feedback mechanism that causes vasodilatation of afferent arteriole and thereby increase GFR.**

2. **Efferent arteriolar feedback mechanism that causes vasoconstriction of efferent arterioles to cause increased GFR.**

✓ **This is effected by production of Renin from the kidney that finally forms Angiotensin II**

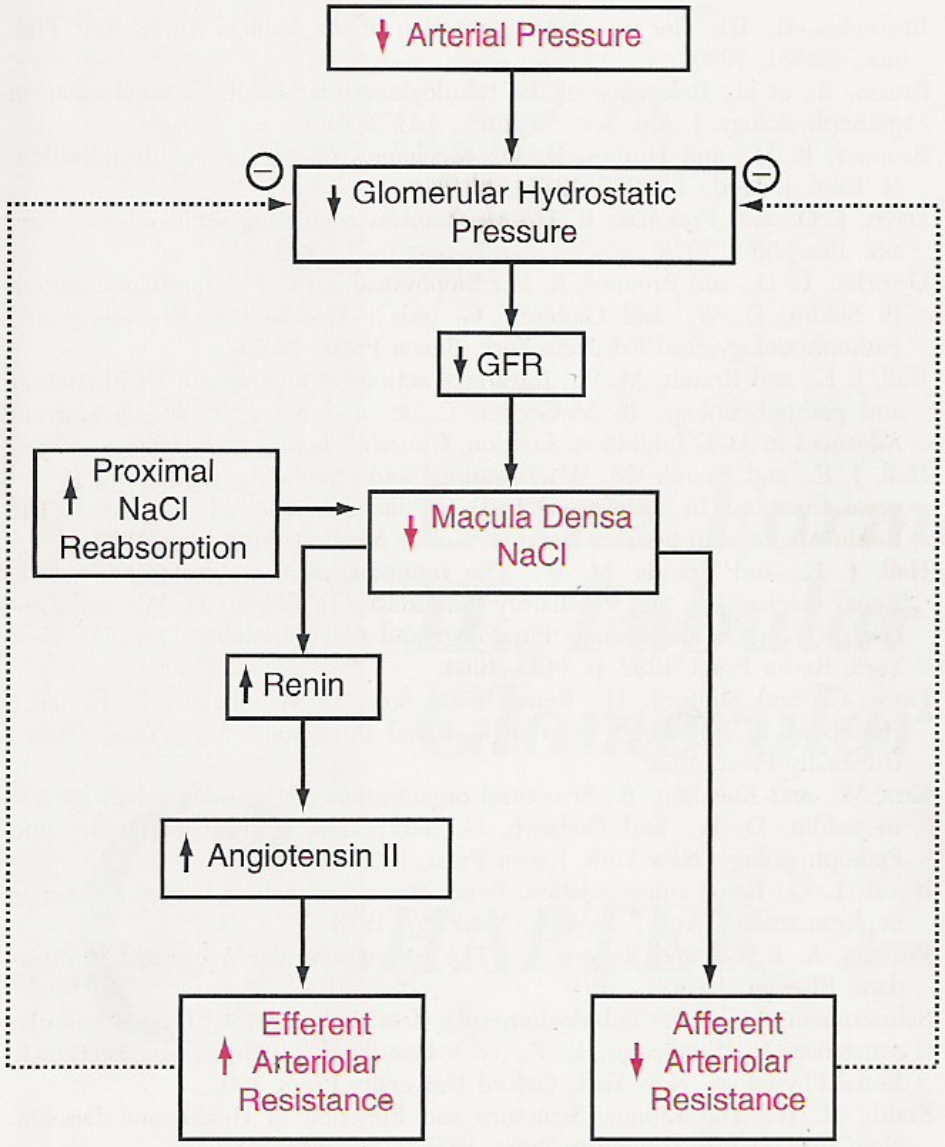
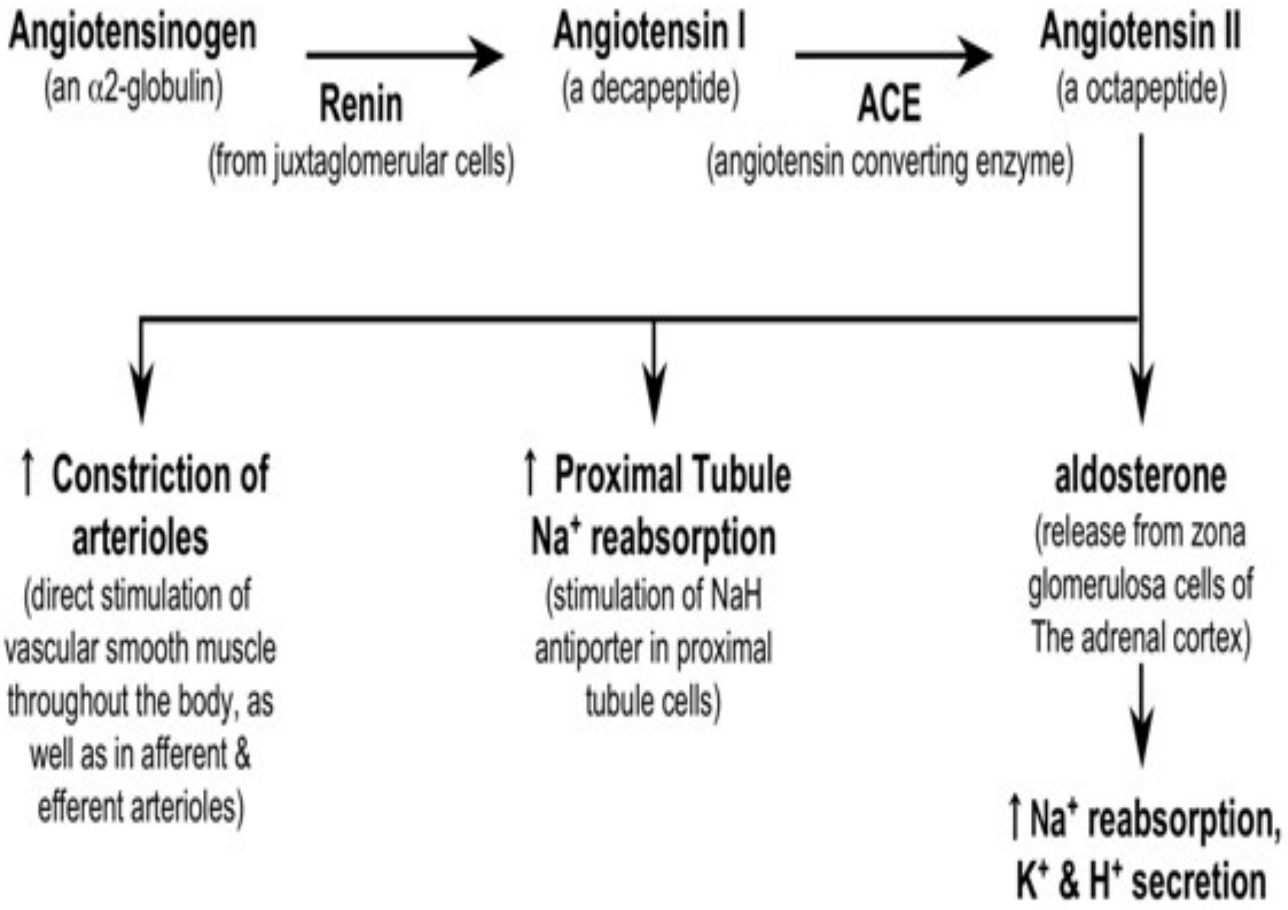


Figure 26-15. Macula densa feedback mechanism for autoregulation of glomerular hydrostatic pressure and glomerular filtration rate during decreased renal arterial pressure.

Renin angiotensin aldosterone system (RAAS) in regulation of GFR and ABP

Stimuli for renin secretion

1. Low blood pressure
2. Low ECF volume
3. Sympathetic stimulation
4. Low plasma sodium



Urine formation

- Urine formation is a blood cleansing function.
- Normally, about 1300 ml of blood (26% CO) enters the kidneys.
- Normal urinary output is

  1 to 1.5 L/day.
- **There are 3 processes of urine formation.**
  - ✓ **Glomerular filtration**
  - ✓ **Tubular reabsorption**
  - ✓ **Tubular secretion**

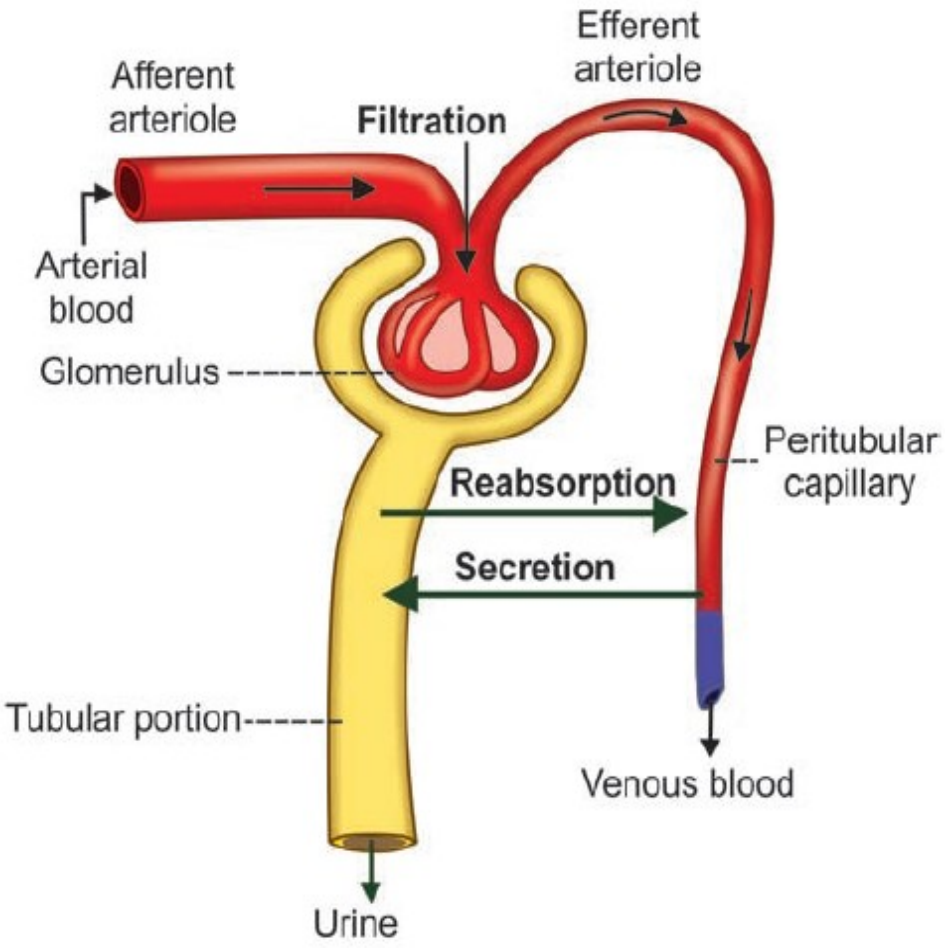
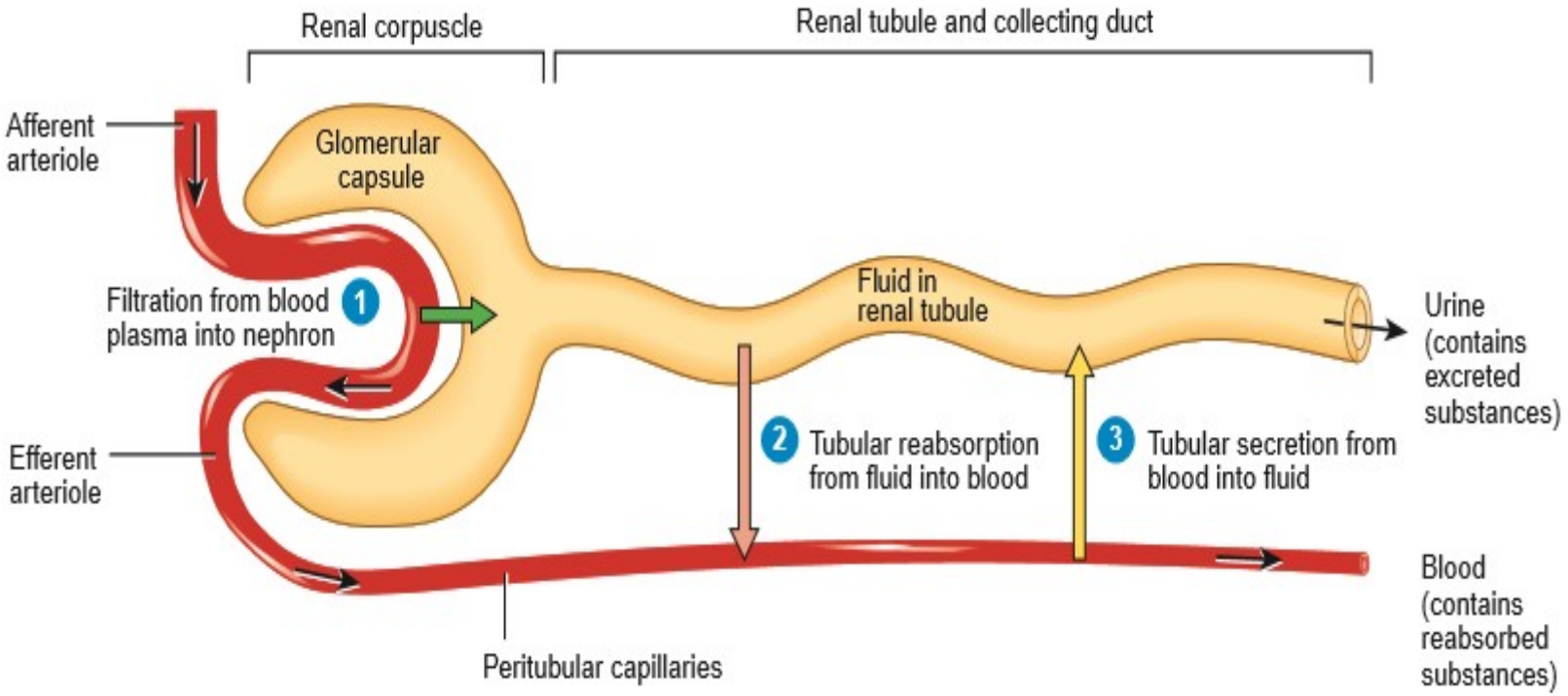


FIGURE 52.1: Events of urine formation


Renal corpuscle
Renal tubule and collecting duct
Afferent arteriole
Glomerular capsule
Filtration from blood plasma into nephron
1
Fluid in renal tubule
Urine (contains excreted substances)
Efferent arteriole
2
Tubular reabsorption from fluid into blood
3
Tubular secretion from blood into fluid
Blood (contains reabsorbed substances)
Peritubular capillaries

1.Glomerular filtration (GF)

- GF is the process by which the blood is filtered while passing through the glomerular capillaries by filtration membrane.
- It is the first process of urine formation.
- All the substances of plasma are filtered except the **plasma proteins.**

Cont’d

❖ **Glomerular filtration rate (GFR)**

- The amount of filtrate formed in all the renal corpuscles of both kidneys each minute.
- Normal GFR is 125 mL/minute or about 180 L/day
- kidneys maintain a relatively constant GFR

Pressures determining GFR

- GFR is directly related to the pressures that determine net filtration pressure;

1. ***Glomerular Capillary Pressure***

- It is the blood pressure in glomerular capillaries
- **It is high pressure (55-60 mm Hg)** which is important to filter substances to the tubules.

2. ***Colloidal Osmotic Pressure/ plasma oncotic pressure***

- It is the pressure exerted by plasma proteins in the glomeruli.
- It is about **30 mm Hg.**
- It opposes glomerular filtration.

3. Hydrostatic Pressure in Bowman Capsule

- It is pressure exerted against the filtration membrane by fluid already in the capsular space and renal tubule.
- It is about **15 mm Hg**.
- It also opposes glomerular filtration.

4. Bowman's capsule Oncotic pressure (O mmHg).

Net Filtration Pressure

- Net filtration pressure is the total pressure that promotes filtration.

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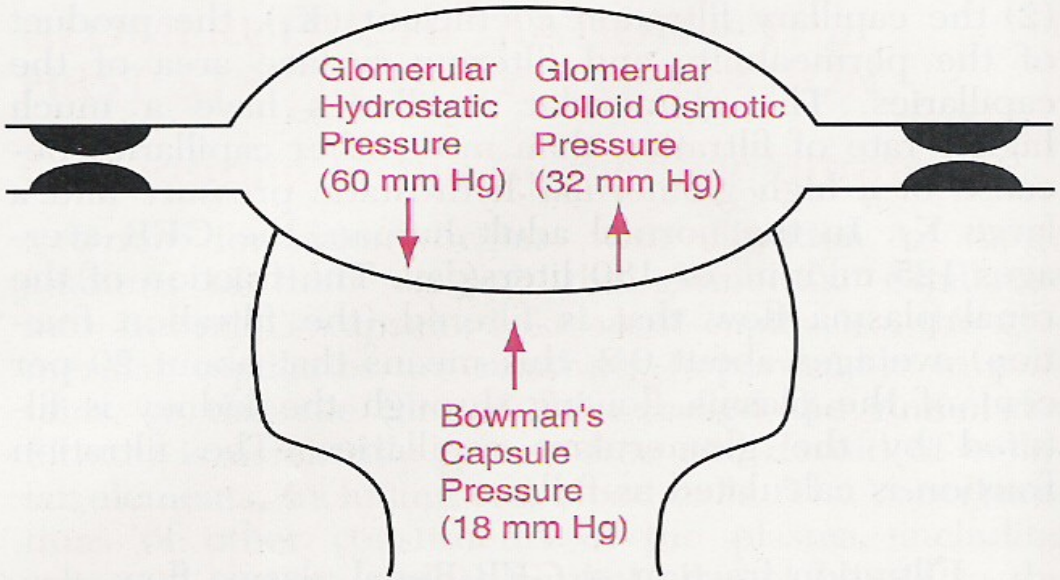
NFP = pushing

minus Pulling

NFP = 55 – (30 + 15)

= 10 mm Hg

- **This 10 mm Hg cause filtration to occur.**
- **The filtrate joins bowman's capsule and then to proximal tubule.**



Net Filtration Pressure (10 mm Hg) = Glomerular Hydrostatic Pressure (60 mm Hg) – Bowman's Capsule Pressure (18 mm Hg) – Glomerular Oncotic Pressure (32 mm Hg)

Figure 26-10. Summary of forces causing filtration by the glomerular capillaries. The values shown are estimates for normal humans.

Factors regulating (affecting) GFR

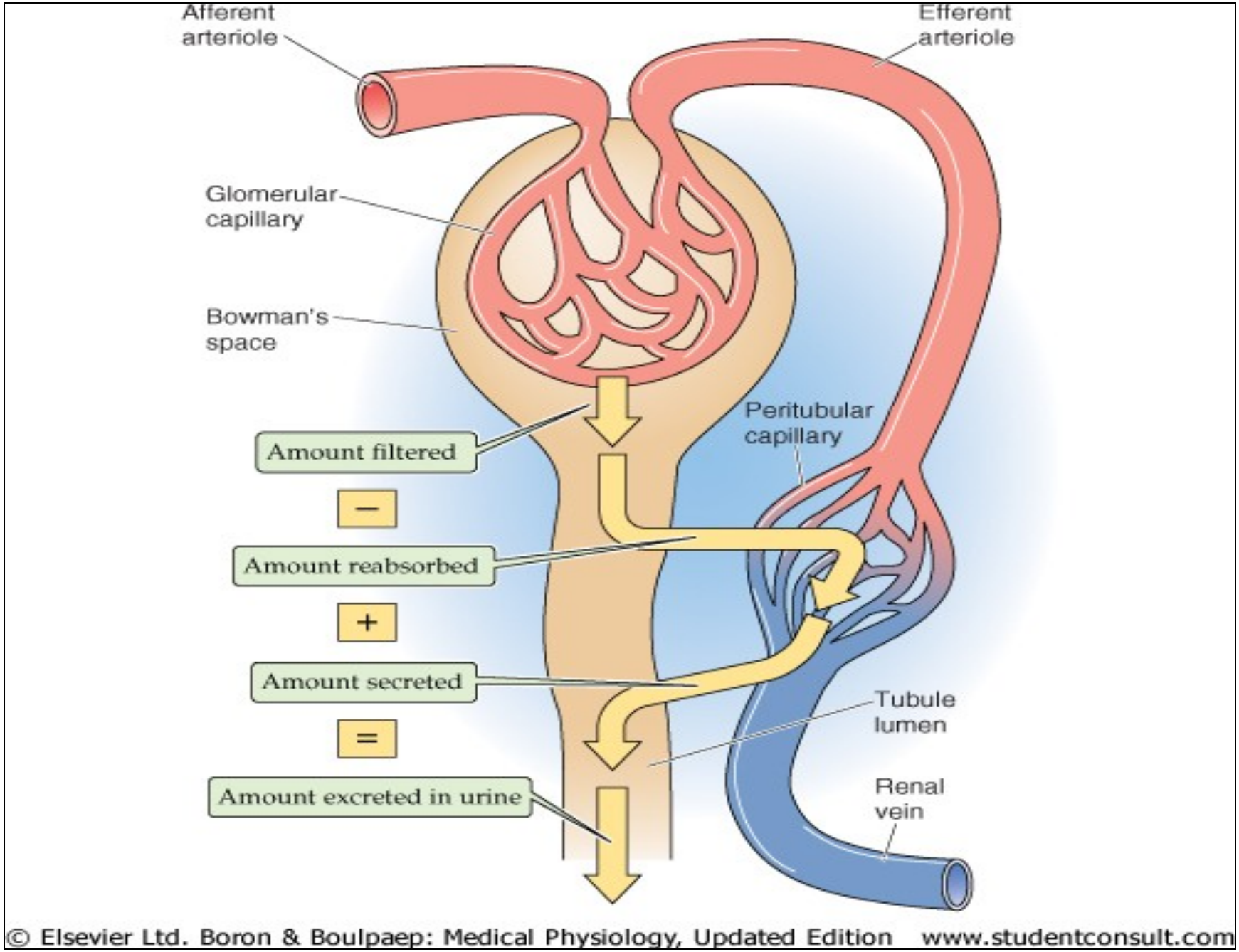
- *Renal Blood Flow*
- *Glomerular Capillary Pressure*
- *Surface Area of Capillary Membrane*
- *Permeability of Capillary Membrane*

Directly proportional to GFR

- ***Hydrostatic Pressure in Bowman Capsule*** *&* ***Colloidal Osmotic Pressure*** *are* ***inversely*** *related to GFR.*

2.Tubular reabsorption

- ✓ **Tubular reabsorption** is the process by which water and other substances are transported from renal tubules back to the blood.
- ✓ The tubular cells reabsorb only the substances necessary for the body. 178.5 L/day (99%) of filtrate reabsorb
  1.5 L/day (<1%) lost as urine
- ✓ The reabsorbed substances move into the interstitial fluid of renal medulla.
- ✓ From here, the substances move into the blood in peritubular capillaries.



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- ✓ **Peritubular capillaries provide nutrients for tubules and retrieve the fluid that the tubules reabsorb.**
- ✓ **Oncotic pressure is greater than hydrostatic pressure in peritubular capillaries and this makes Reabsorption to be easier.**
  - **Reabsorb 99% H_2O, 100% glucose, 99.5% Na^+ and 50% urea.**
  - **Most of this occurs at proximal convoluted tubule**

Mechanism of reabsorption

- Basic transport mechanisms involved in tubular reabsorption are of two types:

    1. Active reabsorption
    2. Passive reabsorption.

- Reabsorption of substances from **tubular lumen** into the **peritubular capillary** occurs by two routes:

    1. Trancelluar route
    2. Paracellular route.

Summary of reabsorption processes in the tubules

Generally the reabsorption process in different tubular segments are the following.

1) In the proximal tubule

- **About 65% of the filtrate is reabsorbed.**
  - **These includes: electrolytes like Na+, K+, Cl-, etc;**
  - **Moreover, organic substances like, glucose & amino acid are completely reabsorbed.**

2) Reabsorption of the filtrate in the Loop of Henley

- **Descending limb**
  - **At the descending limb H_2O escapes to the interestitium from the lumen and creates hyperosmolar environment inside the lumen to a level of 1200 mOsm/l)**

- **Ascending limb:**
  - **Is impermeable to water but permeable to solutes.**
  - **Diffusion of NaCl to the interestium by active transport causes a hypoosmolar environment, which is about = 100 mOsm/l**
  - **finally the dilute fluid enters the distal tubule from the thick ascending limb**

3) Reabsorption of the filtrate in distal tubule and collecting duct

- **Some 18 to 19% of the filtrate is reabsorbed in the distal and collecting duct.**
- **Only 1 to 2 liters of the filtrate (1%) is excreted as urine, where ADH plays a big role in concentration and dilution of urine**

3.Tubular secretion_

- It is the process by which the substances are transported from the **Peritubular capillaries** and **interstitial fluid** into the tubular lumen.
- Toxic or unwanted metabolic by-products are secreted like **Creatinine, NH_3, urea, uric acid & some drugs are excreted.**

Concentration and dilution of urine

A. Why necessary to excrete a concentrated urine?

– ***To save water and thus control ECF- volume during dehydration.***

B. Why necessary to excrete a dilute urine?

– ***To remove excess H_2O (fluid overload) from the body during hyperhydration.***

- **Generally, concentration and dilution of urine is important to regulate the water and solute (osmolality) level of the ECF-volume.**

Properties of urine

- **Volume** : **1 to 1.5 L/day**
- **Color** : Yellow or amber but varies with urine concentration and diet.
- Odor : Fresh urine has light aromatic odor.
- **If stored for some time, the odor becomes stronger** due to **bacterial decomposition.**

Diuretics

- are substances that slow renal reabsorption of water and cause diuresis, an elevated urine flow rate.
- These **substances increase** the **excretion of water, sodium and chloride through urine.**
- **Increase urine volume excreted.**
  - Increase the proportion of glomerular filtrate that is excreted as urine.
- Diuretic agents **increase the urine formation**, by **influencing any of the processes involved in urine formation.**

- Diuretics are commonly called **‘water pills’.**