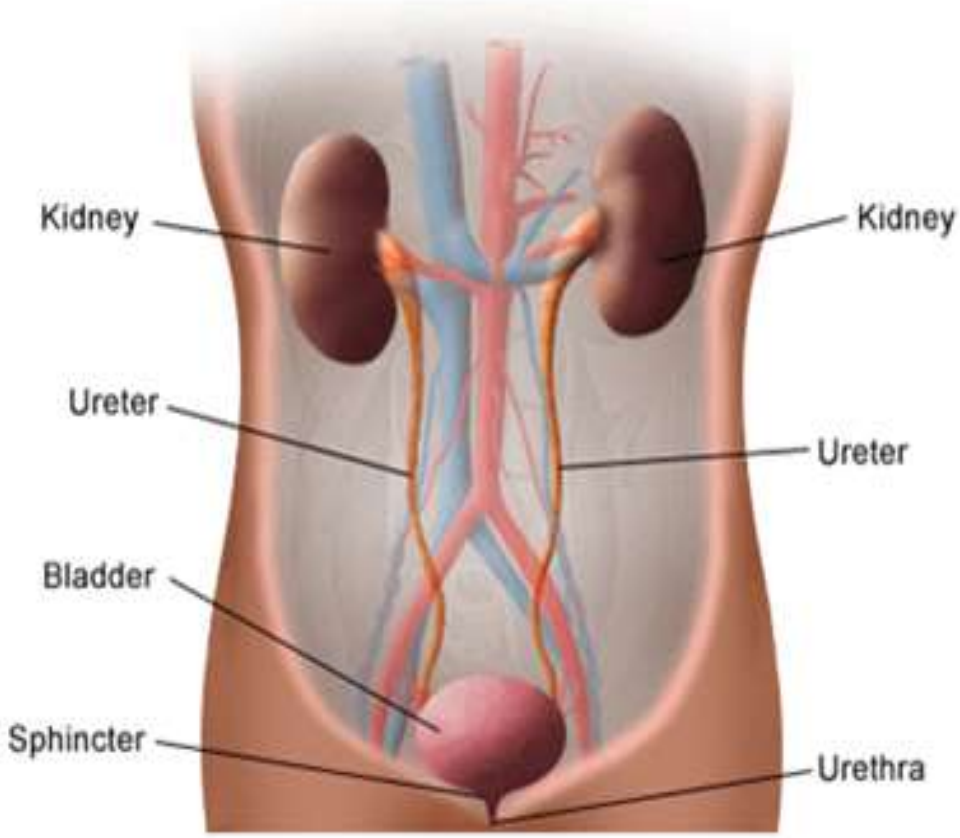
LECTURE NO (1)

Renal Physiology

Introduction

&

Renal blood flow



Major Functions of the Kidneys

1. Regulation:

- **Body fluid volume and Osmolarity.**
- **Electrolyte balance.**
- **Acid-base balance.**
- **Blood pressure.**

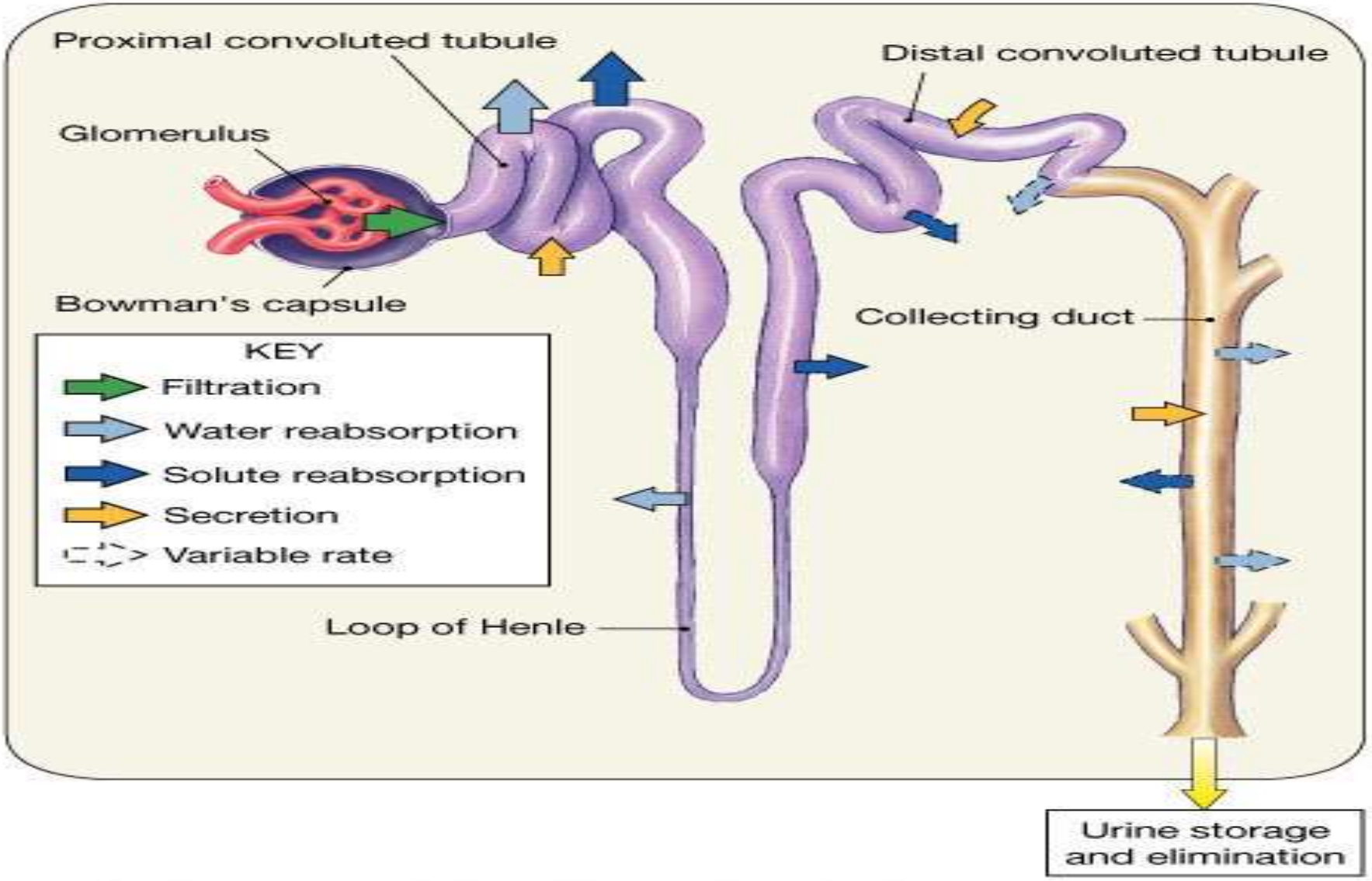
2. Excretion:-

- **Metabolic waste products.**
- **Foreign substances (end product of drugs.).**
- **Excess substance (water, etc).**

3. Secretion:-

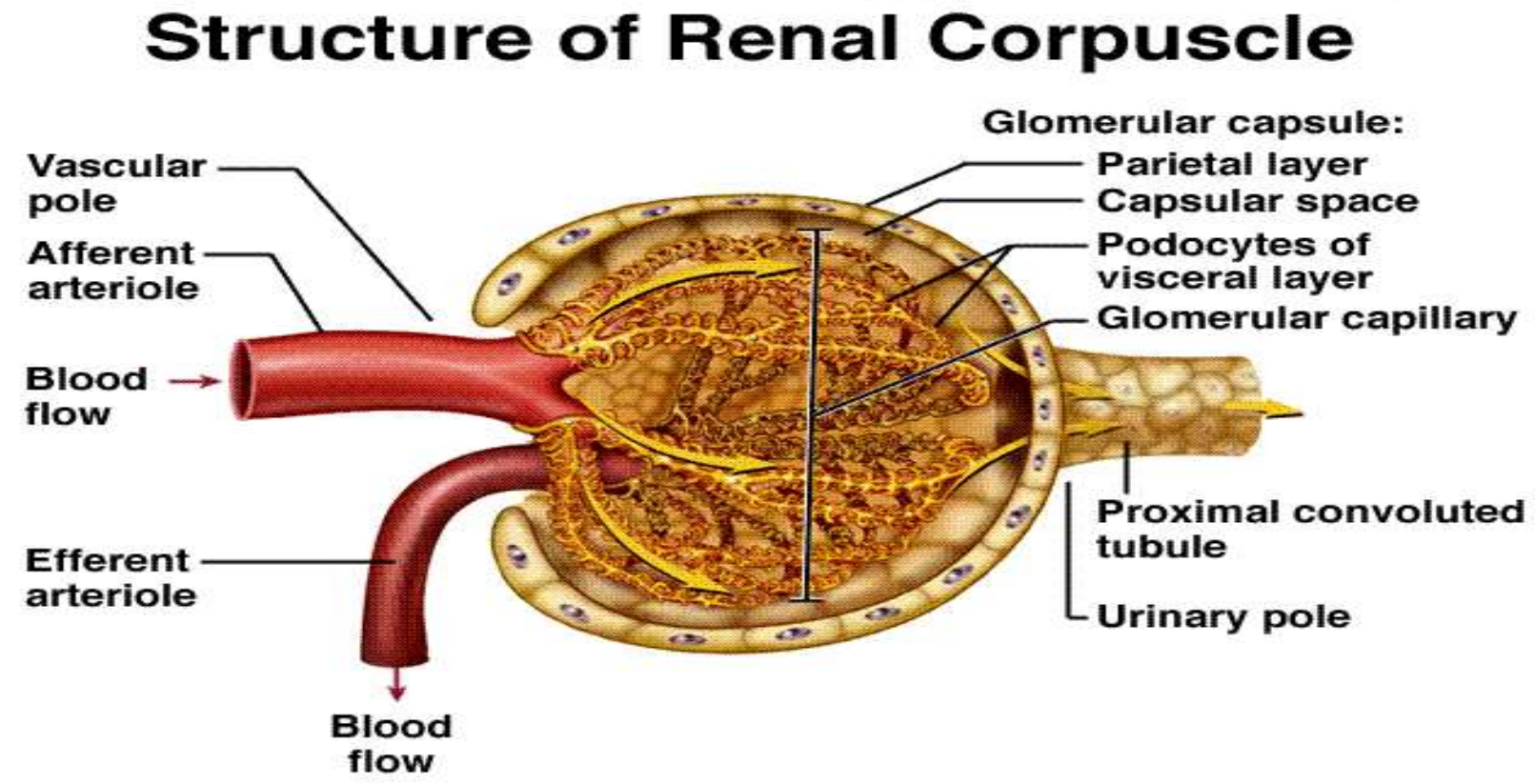
- **Erythropoietin**
- **1,25-dihydroxy vitamin D3.**
- **Renin**
- **Prostaglandin**

The nephron


Proximal convoluted tubule
Distal convoluted tubule
Glomerulus
Bowman's capsule
Collecting duct
KEY
Filtration
Water reabsorption
Solute reabsorption
Secretion
Variable rate
Loop of Henle
Urine storage and elimination

➢ The glomerulus:

✓ **Is a tuft of capillaries enclosed within a Bowman's capsule.**

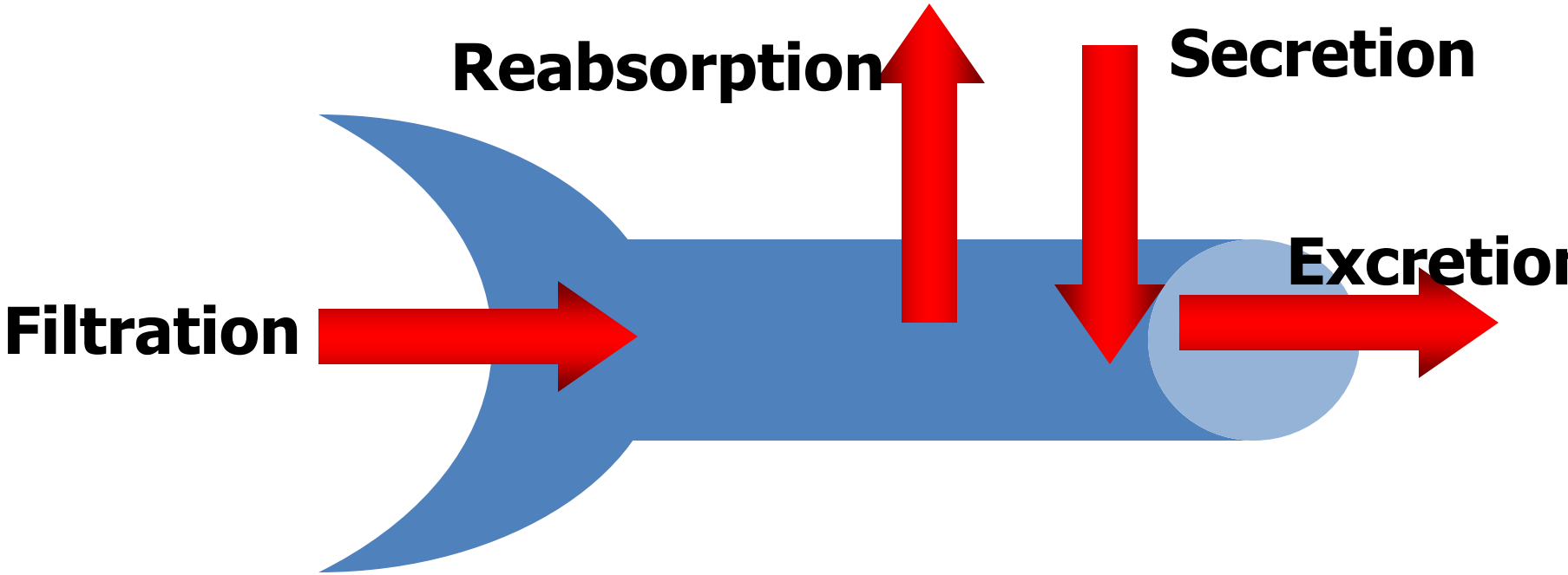


✓ ***The tubules:***

- **Are specialized for reabsorption & excretion.**
- **They include:**

1. **The proximal convoluted tubules (PCT).**
2. **The loop of Henle (LH).**
3. **The distal convoluted tubules (DCT).**
4. **The collecting duct (CDs).**

Functions of the Nephron



✓ Filtration:

- First step in urine formation.
- Bulk transport of fluid from blood to kidney tubule.
- Blood cells and proteins don't filter.
- Result of hydrostatic pressure.
- GFR = 125ml/min 180 L/day.

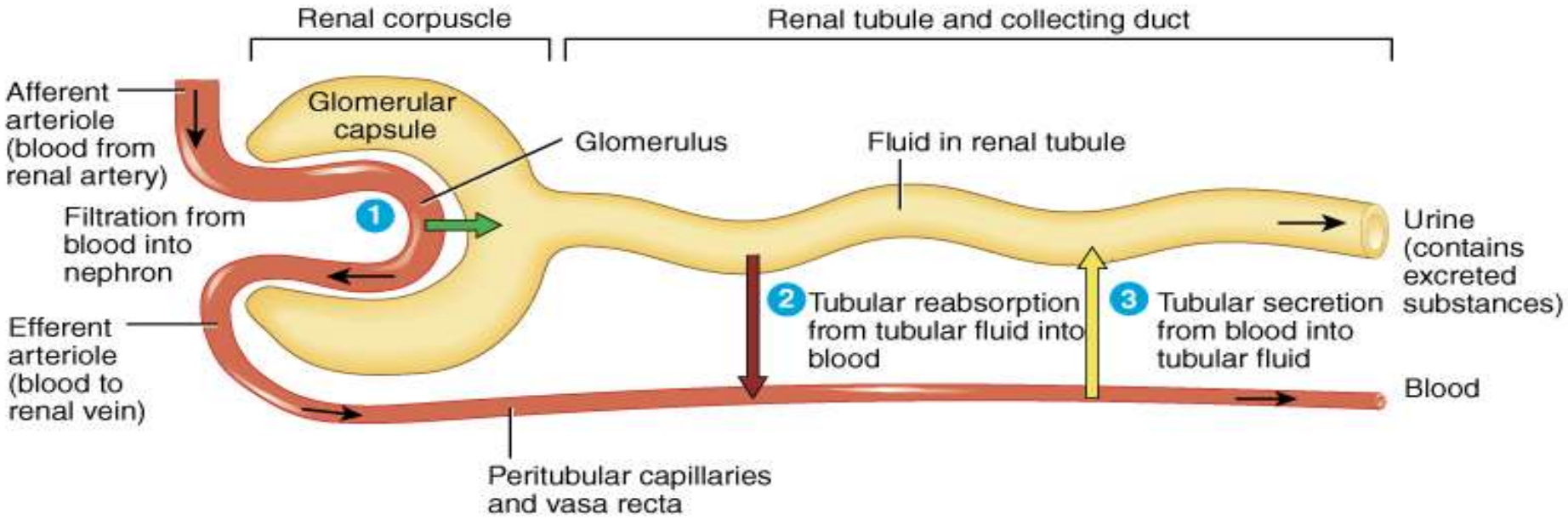
✓ ***Reabsorption:-***

- ❖ **Process of returning filtered material to bloodstream**
- ❖ **99% filtrate. (124 ml/min)**
- ❖ **May involve transport protein.**
- ❖ **Normally glucose is totally reabsorbed.**

✓ ***Secretion:-***

- ❖ **Material added to lumen of kidney from blood.**
- ❖ **Active transport (usually) of toxins and foreign. substances.**
- ❖ **e.g: secretion of Saccharine & Penicillin.**

Basic Functions of a Nephron



✓ **Nephrons perform three basic functions:**

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

20-25% of plasma that enters the glomerulus is filtered

✓ Excretion:

- **Loss of fluid from body in form of urine**

Amount of Solute Excreted	=	Amount Filtered	+	Amount Secreted	-	Amount Reabsorbed

Types of nephron

(A) Cortical nephron:

- **These have their glomeruli in the outer portion of the renal cortex.**
- **They constitute 85% of the total numbers of nephrons**
- **Has short tubules(loop of Henle).**

(B) Juxtaglomerular nephrons:-

- **These have their glomeruli in the inner portion of the renal cortex (near to the renal medulla).**
- **Constitute about 15% of the total number of nephrons.**
- **have long loop of Henle.**

(i) Some nephrons dip deep into the medulla.

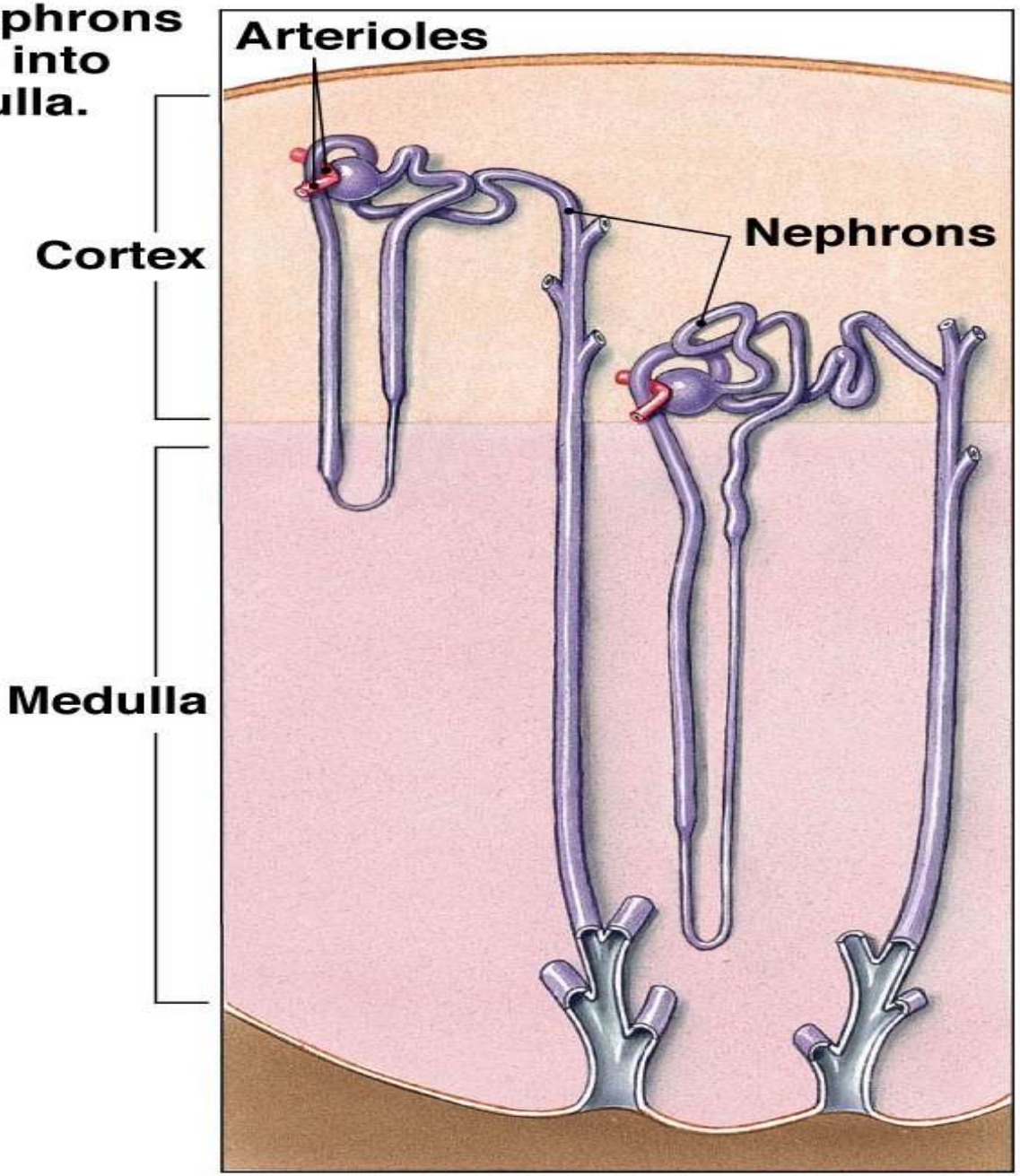


Figure 19-1i

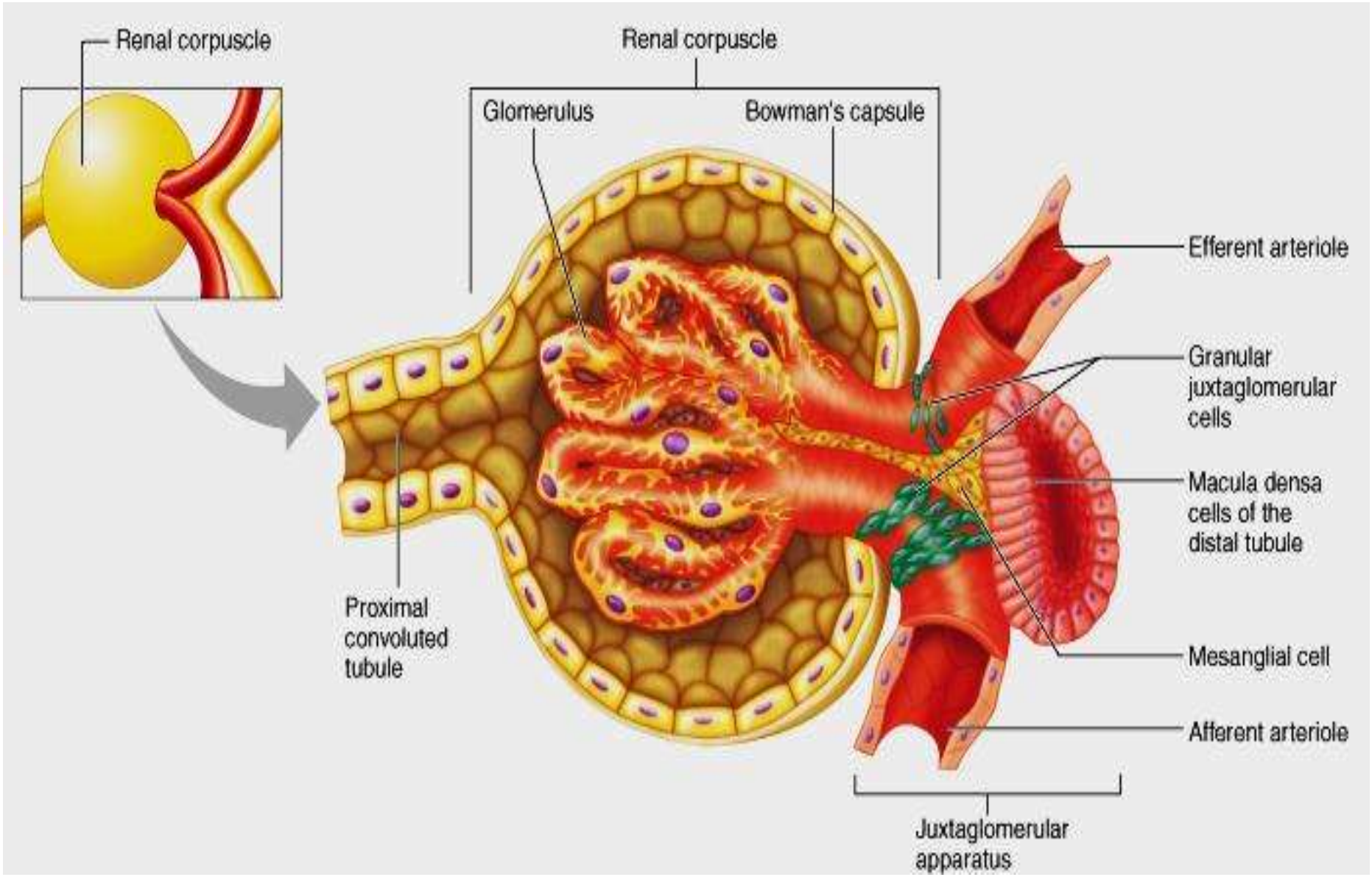
Juxtaglomerular apparatus (JGA)

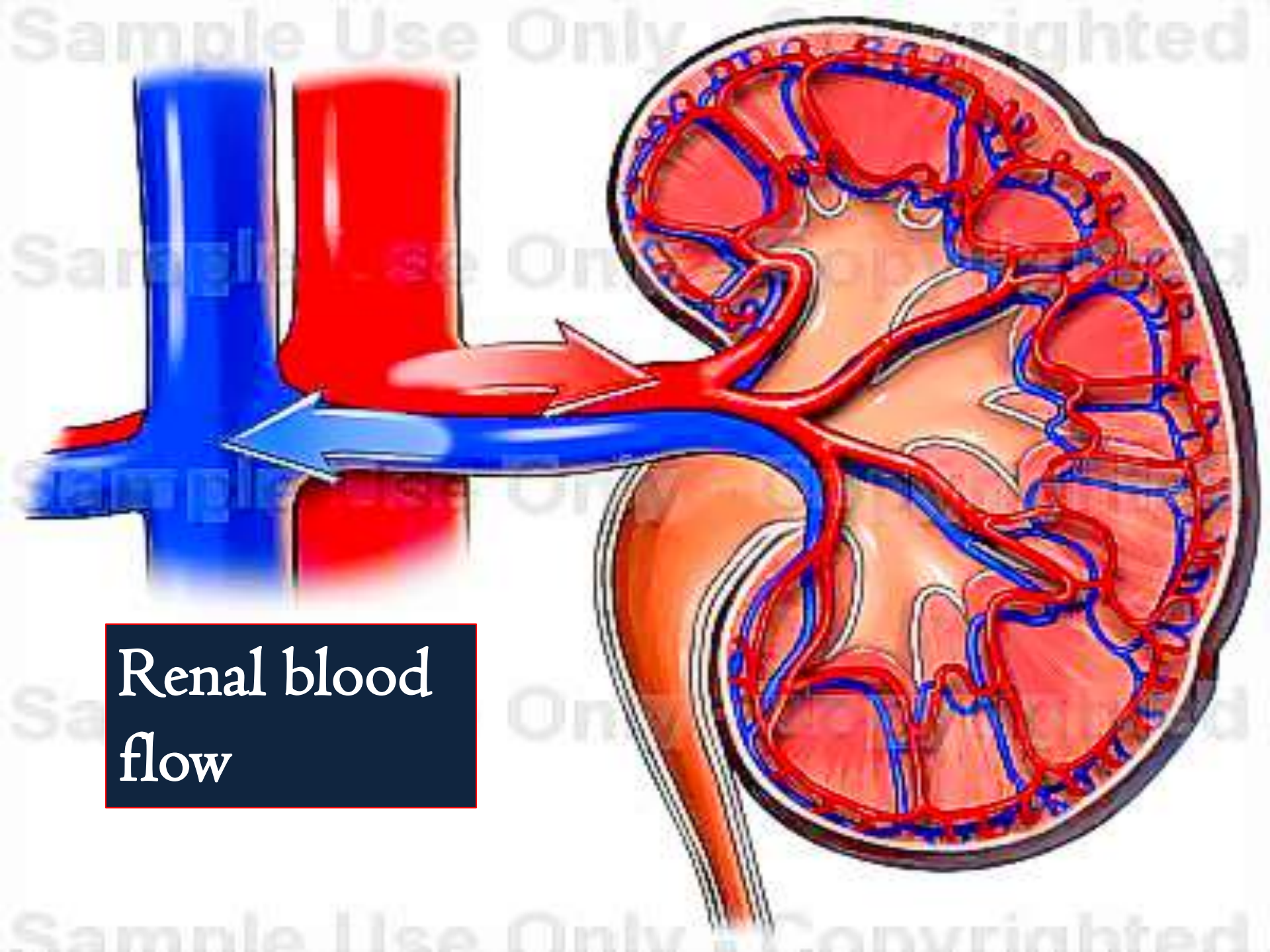
- **It is a secretory structure formed by the following structure:-**

1. **Juxtaglomerular cells.**
2. **Macula densa cells.**
3. **Lacis cells.**

- ***Macula densa:***
- **Closely packed distal tubule cells.**
- **Lie adjacent to JG cells.**
- **Function as chemoreceptors or osmoreceptors.**
- ***Mesanglial cells:*** **control the glomerular filtration rate.**

JGA


Renal corpuscle
Renal corpuscle
Glomerulus
Bowman's capsule
Efferent arteriole
Granular juxtaglomerular cells
Macula densa cells of the distal tubule
Proximal convoluted tubule
Mesanglial cell
Afferent arteriole
Juxtaglomerular apparatus



Renal blood flow

THE RENAL BLOOD FLOW (RBF)

- RBF is about 1200 ml/ min.
- The flow is much greater in the renal cortex.
- 2-5 % pass in the vasa recta resulting in a sluggish flow in the renal medulla.
- Important for the process of urine concentration

✓ ***THE RENAL FRACTION :***

- This is the portion of the COP that pass through the kidneys normally it less than 25% ranging from 12 – 30 % of the COP

MEASUREMENT OF THE RBF

- **The RBF can be measured by determination of the renal plasma flow (RPF) & the hematocrit.**
- ***Determination of the RPF:***
- **RPF is determined by estimating the clearance of the (para-aminohippurate) PAH.**
- **the clearance of a substance is the volume of plasma from which the substance was completely cleared by the kidneys per unit time.**

The formula of clearance

- **Clearance of X = Ux .V / Px**

Px = plasma concentration of X

Ux = urine concentration of X

V = urine flow per min

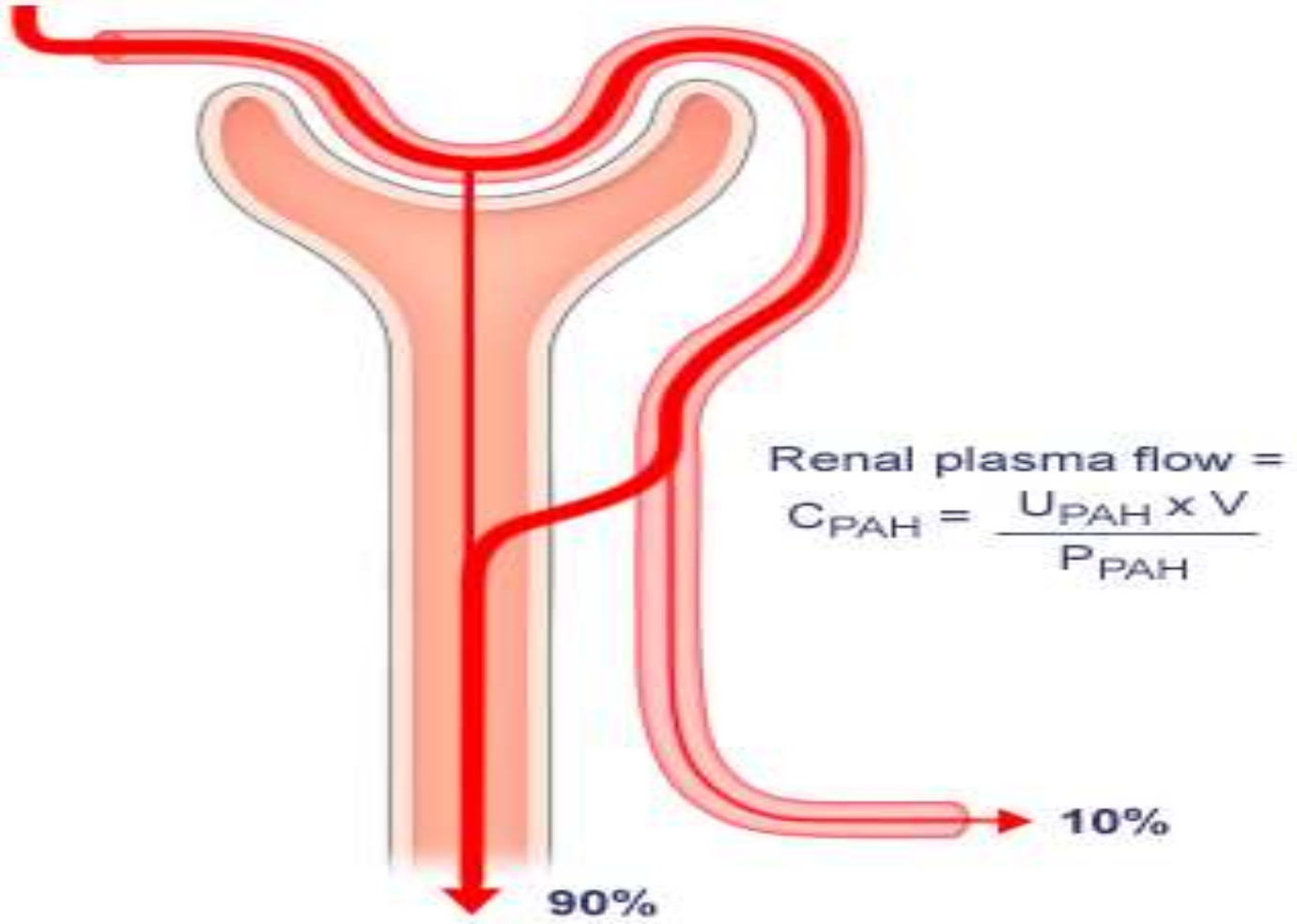
Characteristics of the PAH

- Nontoxic & can be easily measured in the blood & urine.
- Not affect the RBF & is not metabolized , stored or produce by the kidneys
- freely filtered in the glomeruli.
- Highly secreted by renal tubules.
- Not reabsorbed.

- ***PAH is injected i.v:***
- **The volume of urine / min (V) , suppose its 1 ml/min**
- **The concentration of PAH / ml urine (U) , suppose it is 6.25 mg /ml**
- **The concentration of PAH / ml plasma (P) , suppose it is 0.01 mg /ml**
- **PAH clearance = (v) x (U)/ (P) , so that it equal to 6.25 x 1 / 0.01 = 625 ml/min**
- **which is the RPF / min because almost all plasma is cleared**

- **Only about 90% of the PAH in the arterial plasma is excreted.**
- **This percentage is called the extraction ratio of the PAH.**
- **The calculated RPF (625 ml/min) represents only about 90% of the actual RPF & is called the effective RPF (ERPF).**
- **The actual RPF = ERPF/90% = 700ml/min.**
- **The normal value is 650 – 700 ml/ min**

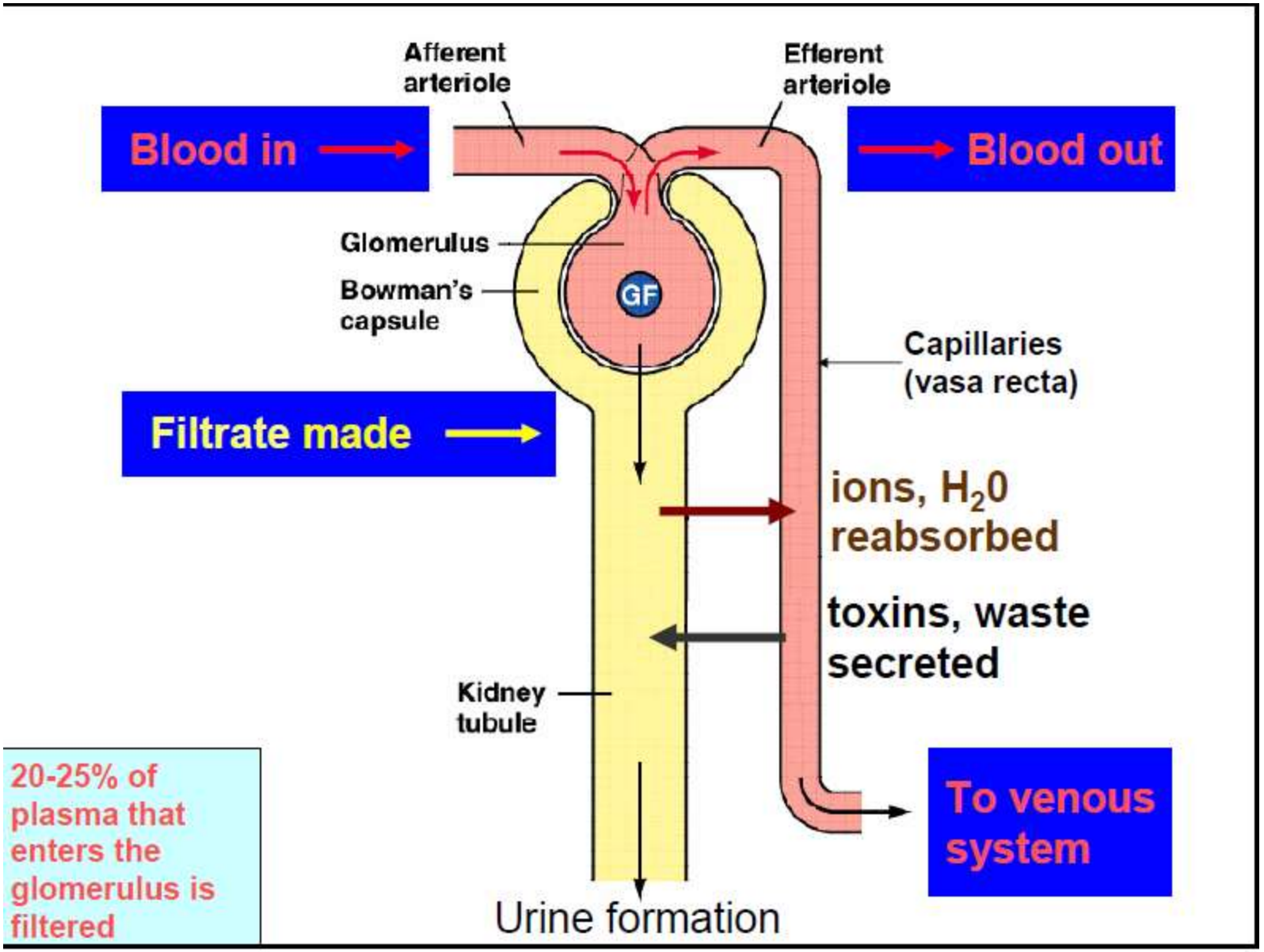
Renal Handling of PAH



- **If the measured hematocrit is 45%.**
- **plasma represent 55% (i.e 1- Hct) of the total blood.**
- **RBF= RPF X 1/1-Hct =1273 ml/min.**
- **The normal value of RBF 1200 – 1300 ml/ min.**

REGULATION OF THE RBF

- **The RBF is directly proportional to the mean arterial blood pressure & inversely proportional to the renal vascular resistance (RVR) .**
- **The RVR determined by the diameter of the glomerular afferent & efferent arterioles.**


Afferent arteriole
Efferent arteriole
Blood in
Blood out
Glomerulus
Bowman's capsule
GF
Capillaries (vasa recta)
Filtrate made
ions, H_20 reabsorbed
toxins, waste secreted
Kidney tubule
To venous system
Urine formation
20-25% of plasma that enters the glomerulus is filtered

(a) Catecholamines & strong symp Stimulation:

- **Causes afferent arterioles V.C.**
- **Leading to an increase of RVR & a decrease of RBF.**

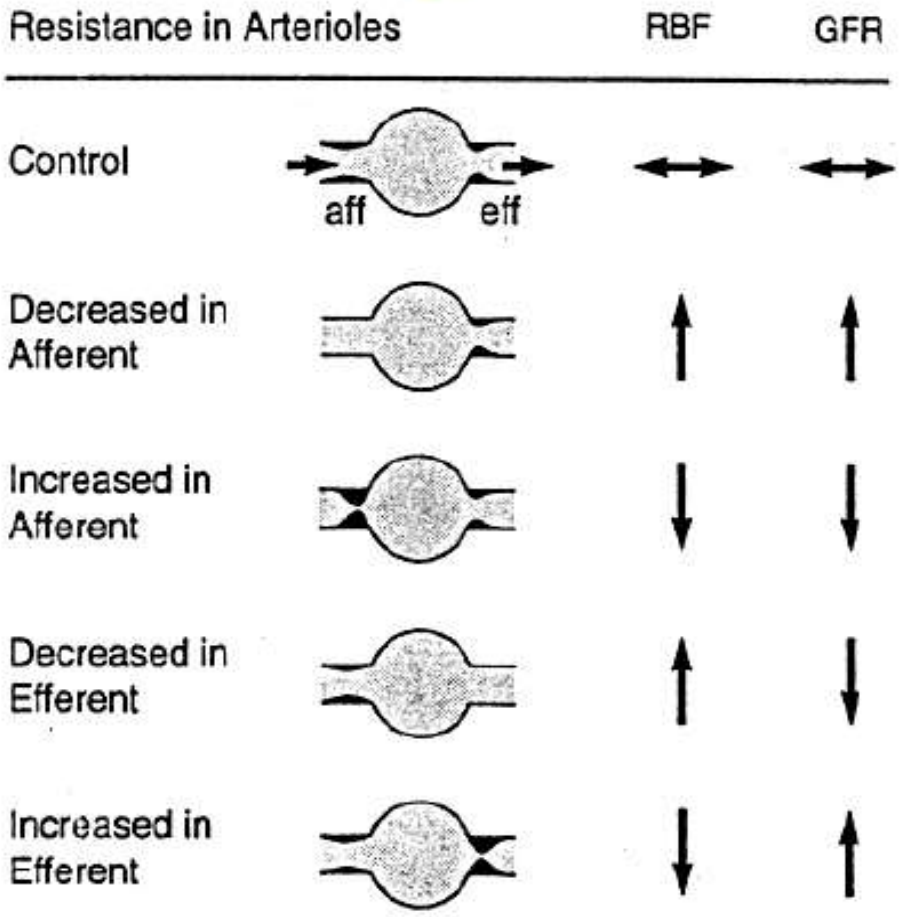
(b) Ach & other V.D. drugs (e.g. caffeine):

- **↓ the RVR &↑ the RBF.**

Mechanisms for Achieving Selective & Independent Changes in GFR and RBF

$$RBF = \frac{\Delta P}{R}$$

$$P_{GC} \propto \frac{R_E}{R_A}$$



(c) Prostaglandins:

- **Some of these local hormones are vasodilators (PGI2, PGF2)↑the RBF.**
- **Other are vasoconstrictor (thromboxane A2) which ↓ the RBF.**

(d) Angiotensin II:

- **Causes efferent arterioles V.C leading to an ↑ of RVR and a ↓of the RBF.**

(e) ADH (Vasopressin)

- **In physiological levels only constricts vasa recta.**
- **In large doses cause afferent arteriolar V.C. and decrease the RBF.**

Effect of sympathetic stimulation on the kidney

- **Sympathetic fibers supply the following renal structure**

1. ***Juxtaglomerular cells:***
   - ✓ **Act on the β1 - adrenergic receptors**
   - ✓ **Increase renin secretion**
2. ***Renal tubules :***
   - ✓ **Direct action**
   - ✓ **Increase Na+ reabsorption**
3. ***Renal arterioles:***
   - ✓ **Act on the α1- adrenergic receptors**
   - ✓ **decrease renal blood flow & GFR**

Autoregulation of the RBF

- Intrinsic mechanism in the kidney.
- Keeps the RBF nearly constant despite changes in the arterial blood pressure between 80 & 160 mmHg .
- the GFR is also autoregulated within this range but, beyond that range both are markedly changed.

Mechanisms of autoregulation of the RBF

1. ***When the arterial B.P. rises from 100 to 160 mmHg***

- **Constriction of the afferent arterioles occurs.**
- **The RBF is kept relatively constant in spite of increased B.P.**
- **This is produced by one of the following mechanisms :-**

A. **Myogenic mechanism**

B. **Tubulo-glomerular feedback mechanism**

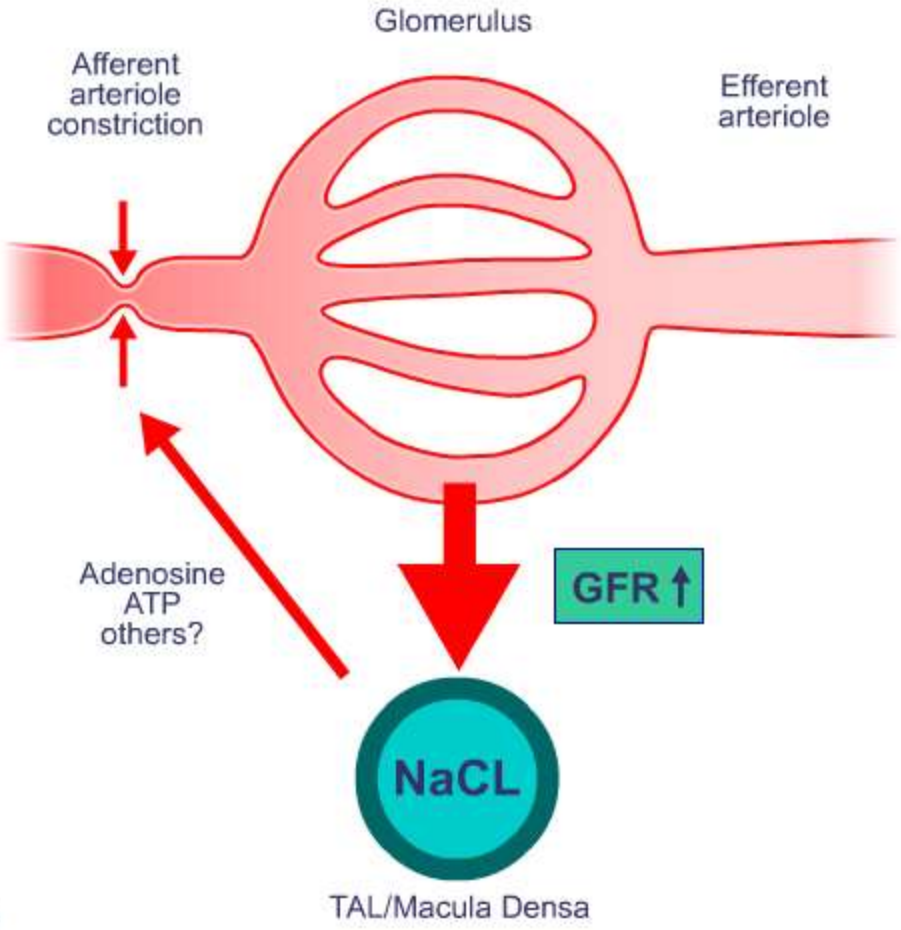
(a) Myogenic mechanism:

- **Rise of the B.P. Stretches the afferent arterioles which constrict by a direct contractile response of the smooth muscle in their walls to stretch.**

(b) Tubuloglomerular feedback mechanism:

- **Rise of the blood pressure ↑ the glomerular filtration.**
- **The rate of the flow through the ascending limb of the LH & the first part of DCT also increases .**
- **This initiates a signal from the macula densa (as a result of the ↑ Na+ & K+ concentrations).**
- **Resulting in V.C. of the afferent arterioles which ↓ the RBF.**
- **This action is mediated by adenosine.**

Tubuloglomerular Feedback



step

Overview

MM

(2) when the arterial B.P. falls from 100 to 80 mmHg:

- **The afferent arterioles dilated.**
- **The RBF is kept relatively constant.**
- ***Mechanism: (tubuloglomerular feedback):-***
- **fall of the B.P. ↓ The glomerular filtration → the rate of flow through the ascending limb of LH & first part of the DCT ↓ → signal from the macula densa cells is initiated which produces V.D. Of the afferent arterioles by releasing prostaglandins.**

- ***At low perfusion pressure:***
- **Angiotensin II constrict the efferent arterioles & maintaining the GFR.**

Regional blood flow

- The main function of the renal cortex is filtration of large volume of blood through the glomeruli.
- Cortical blood flow is relatively great.
- The main function of the renal medulla is the urine concentration & maintenance of the osmotic gradient in the medulla requires low blood flow.