

Juxtaglomerular Apparatus

Definition

Juxtaglomerular apparatus is a specialized organ situated near the glomerulus of each nephron (juxta =near).

„ **STRUCTURE OF JUXTAGLOMERULAR APPARATUS**

Juxtaglomerular apparatus is formed by three different structures (Fig. 50.1):

1. Macula densa
2. Extra glomerular mesangial cells
3. Juxtaglomerular cells.

„ **MACULA Densa**

Macula densa is the end portion of thick ascending segment before it opens into distal convoluted tubule. It is situated between afferent and efferent arterioles of the same nephron. It is very close to afferent arteriole. Macula densa is formed by tightly packed cuboidal epithelial cells.

„ **EXTRAGLOMERULAR MESANGIAL CELLS**

Extraglomerular mesangial cells are situated in the triangular region bound by afferent arteriole, efferent arteriole and macula densa. These cells are also called agranular cells, lacis cells or Goormaghtigh cells.

Glomerular Mesangial Cells

Besides extra glomerular mesangial cells there is another type of mesangial cells situated in between glomerular capillaries called glomerular mesangial or intraglomerular mesangial cells.

Glomerular mesangial cells support the glomerular capillary loops by surrounding the capillaries in the form of a cellular network. These cells play an important role in regulating the glomerular filtration by their contractile property.

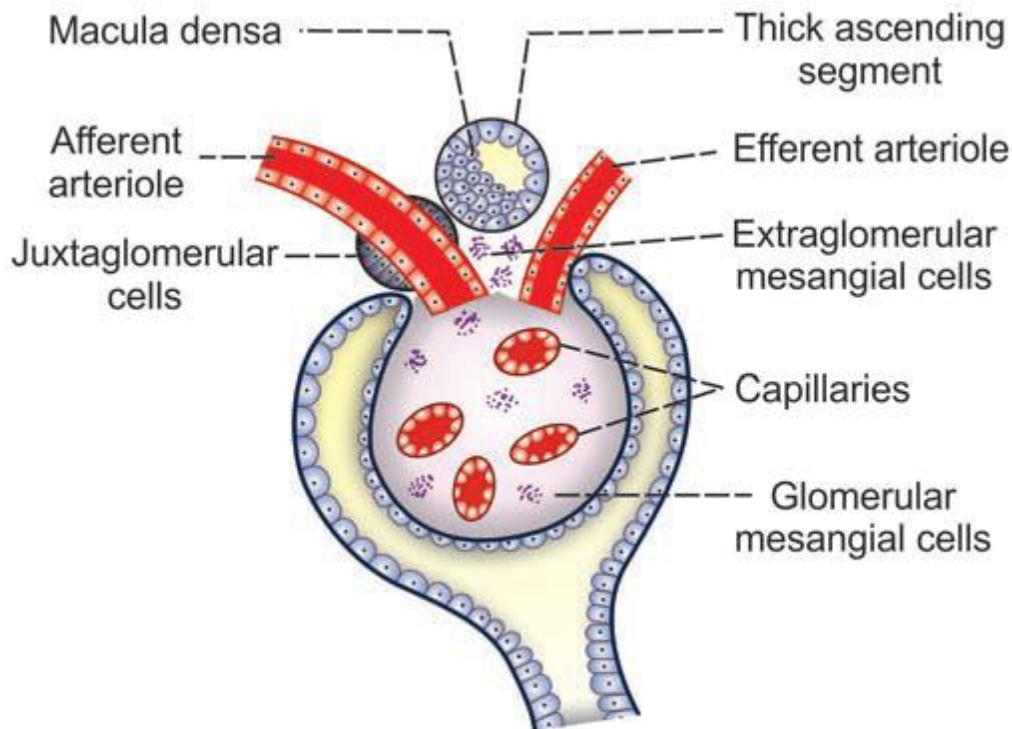


FIGURE 50.1: Juxtaglomerular apparatus

Glomerular mesangial cells are phagocytic in nature. These cells also secrete glomerular interstitial matrix, prostaglandins and cytokines.

„ JUXTAGLOMERULAR CELLS

Juxtaglomerular cells are specialized smooth muscle cells situated in the wall of afferent arteriole just before it enters the Bowman capsule. These smooth muscle cells are mostly present in tunica media and tunica adventitia of the wall of the afferent arteriole. Juxtaglomerular cells are

also called granular cells because of the presence of secretory granules in their cytoplasm.

„ **FUNCTIONS OF JUXTAGLOMERULAR APPARATUS**

Primary function of juxtaglomerular apparatus is the secretion of hormones. It also regulates the glomerular blood flow and glomerular filtration rate.

„ **SECRETION OF HORMONES**

Juxtaglomerular apparatus secretes two hormones:

1. Renin
2. Prostaglandin.

1. Renin

Juxtaglomerular cells secrete renin. Renin is a peptide with 340 amino acids. Along with angiotensins, renin forms the renin-angiotensin system, which is a hormone system that plays an important role in the maintenance of blood pressure (Chapter 103).

Stimulants for renin secretion Secretion of renin is stimulated by four factors:

- i. Fall in arterial blood pressure
- ii. Reduction in the ECF volume
- iii. Increased sympathetic activity
- iv. Decreased load of sodium and chloride in macula densa.

Renin-angiotensin system

When renin is released into the blood, it acts on a specific plasma protein called angiotensinogen or renin substrate. It is the α_2 -globulin. By the activity of renin, the angiotensinogen is converted into a decapeptide called angiotensin I.

Angiotensin I is converted into angiotensin II, which is an octapeptide by the activity of angiotensin-converting enzyme (ACE) secreted from lungs. Most of the conversion of angiotensin I into angiotensin II takes place in lungs.

Angiotensin II has a short half-life of about 1 to 2 minutes. Then it is rapidly degraded into a heptapeptide called angiotensin III by angiotensinases, which are present in RBCs and vascular beds in many tissues. Angiotensin III is converted into angiotensin IV, which is a hexapeptide (Fig. 50.2).

Actions of Angiotensins

Angiotensin I

Angiotensin I is physiologically inactive and serves only as the precursor of angiotensin II.

Angiotensin II

Angiotensin II is the most active form. Its actions are:

On blood vessels:

- i. Angiotensin II increases arterial blood pressure by directly acting on the blood vessels and causing vasoconstriction. It is a potent constrictor of arterioles. Earlier, when its other actions were not found it was called hypertensin.
- ii. It increases blood pressure indirectly by increasing the release of noradrenaline from postganglionic sympathetic fibers. Noradrenaline is a general vasoconstrictor (Chapter 71).

On adrenal cortex:

It stimulates zona glomerulosa of adrenal cortex to secrete aldosterone. Aldosterone acts on renal tubules and increases retention of sodium, which is also responsible for elevation of blood pressure.

On kidney:

- i. Angiotensin II regulates glomerular filtration rate by two ways:
 - a. It constricts the efferent arteriole, which causes decrease in filtration after an initial increase (Chapter 52)
 - b. It contracts the glomerular mesangial cells leading to decrease in surface area of glomerular capillaries and filtration (see above)
- ii. It increases sodium reabsorption from renal tubules. This action is more predominant on proximal tubules.

On brain:

i. Angiotensin II inhibits the baroreceptor reflex and thereby indirectly increases the blood pressure. Baroreceptor reflex is responsible for decreasing the blood pressure (Chapter 103)

ii. It increases water intake by stimulating the thirst center

iii. It increases the secretion of corticotropin-releasing hormone (CRH) from hypothalamus. CRH in turn increases secretion of adrenocorticotrophic hormone (ACTH) from pituitary

iv. It increases secretion of antidiuretic hormone (ADH) from hypothalamus.

Other actions:

Angiotensin II acts as a growth factor in heart and it is thought to cause muscular hypertrophy and cardiac enlargement.

Angiotensin III

Angiotensin III increases the blood pressure and stimulates aldosterone secretion from adrenal cortex. It has 100% adrenocortical stimulating activity and 40% vasopressor activity of angiotensin II.

Angiotensin IV

It also has adrenocortical stimulating and vaso pressor activities.

2. Prostaglandin

Extraglomerular mesangial cells of juxtaglomerular apparatus secrete prostaglandin. Prostaglandin is also secreted by interstitial cells of medulla called type I medullary interstitial cells. Refer Chapter 72 for details.

„ SECRETION OF OTHER SUBSTANCES

1. Extra glomerular mesangial cells of juxtaglomerular apparatus secrete cytokines like interleukin-2 and tumor necrosis factor (Chapter 17)

2. Macula densa secretes thromboxane A₂.

„ REGULATION OF GLOMERULAR BLOOD FLOW AND GLOMERULAR FILTRATION RATE

Macula densa of juxtaglomerular apparatus plays an important role in the feedback mechanism called tubuloglomerular feedback mechanism, which regulates the renal blood flow and glomerular filtration rate (Refer Chapter 52 for details)

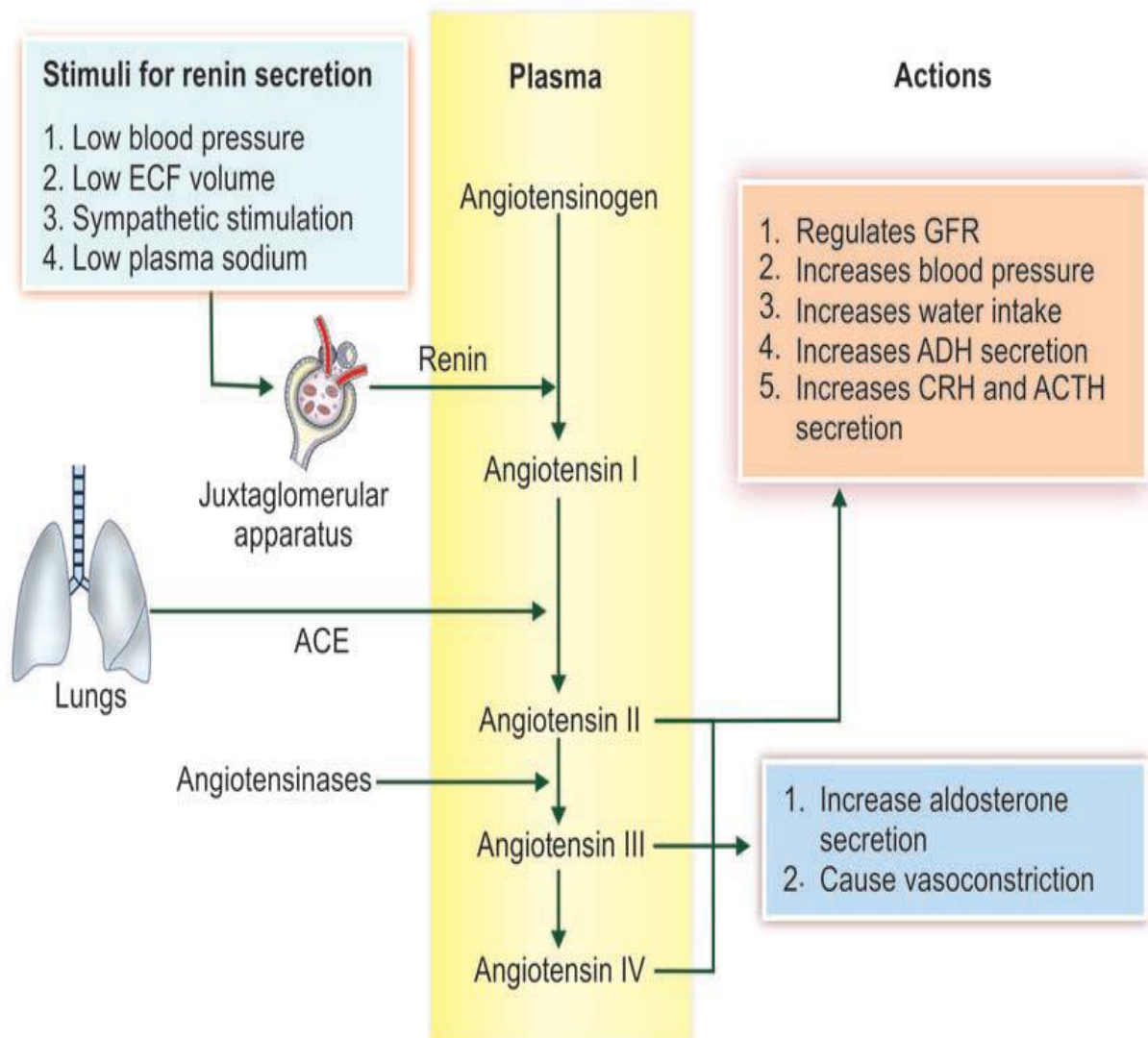


FIGURE 50.2: Renin-angiotensin system. ECF = Extracellular fluid, ACE = Angiotensin-converting enzyme, GFR = Glomerular filtration rate, ADH = Antidiuretic hormone, CRH = Corticotropin-releasing hormone, ACTH = Adrenocorticotrophic hormone.

Renal Circulation

INTRODUCTION

Blood vessels of kidneys are highly specialized to facilitate the functions of nephrons in the formation of urine. In the adults, during resting conditions both the kidneys receive 1,300 mL of blood per minute or about 26% of the cardiac output. Maximum blood supply to kidneys has got the functional significance. Renal arteries supply blood to the kidneys.

„ RENAL BLOOD VESSELS

Renal Artery

Renal artery arises directly from abdominal aorta and enters the kidney through the hilus. While passing through renal sinus, the renal artery divides into many segmental arteries.

Segmental Artery

Segmental artery subdivides into interlobar arteries (Fig. 51.1).

Interlobar Artery

Interlobar artery passes in between the medullary pyramids. At the base of the pyramid, it turns and runs parallel to the base of pyramid forming arcuate artery.

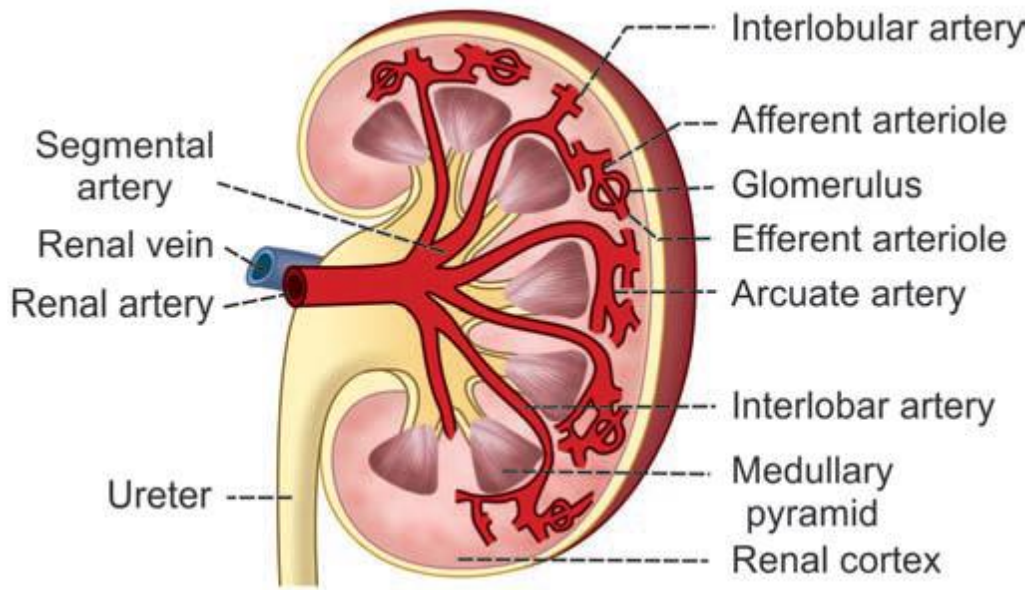


FIGURE 51.1: Renal blood vessels

Arcuate Artery

Each arcuate artery gives rise to interlobular arteries.

Interlobular Artery

Interlobular arteries run through the renal cortex perpendicular to arcuate artery. From each interlobular artery, numerous afferent arterioles arise.

Afferent Arteriole

Afferent arteriole enters the Bowman capsule and forms glomerular capillary tuft. After entering the Bowman capsule, the afferent arteriole divides into 4 or 5 large capillaries.

Glomerular Capillaries

Each large capillary divides into small glomerular capillaries, which form the loops. And, the capillary loops unite to form the efferent arteriole, which leaves the Bowman capsule.

Efferent Arteriole

Efferent arterioles form a second capillary network called per tubular capillaries, which surround the tubular portions of the nephrons. Thus, the renal circulation forms a portal system by the presence of two sets of capillaries namely glomerular capillaries and per tubular capillaries.

Peritubular Capillaries and Vasa Recta

Per tubular capillaries are found around the tubular portion of cortical nephrons only. The tubular portion of juxtamedullary nephrons is supplied by some specialized capillaries called vasa recta.

These capillaries are straight blood vessels hence the name vasa recta. Vasa recta arise directly from the efferent arteriole of the juxtamedullary nephrons and run parallel to the renal tubule into the medulla and ascend up towards the cortex (Fig. 51.2).

Venous System

Per tubular capillaries and vasa recta drain into the venous system.

Venous system starts with per tubular venules and continues as interlobular veins, arcuate veins, interlobar veins, segmental veins and finally the renal vein (Fig. 51.3). Renal vein leaves the kidney through the hilus and joins inferior vena cava.

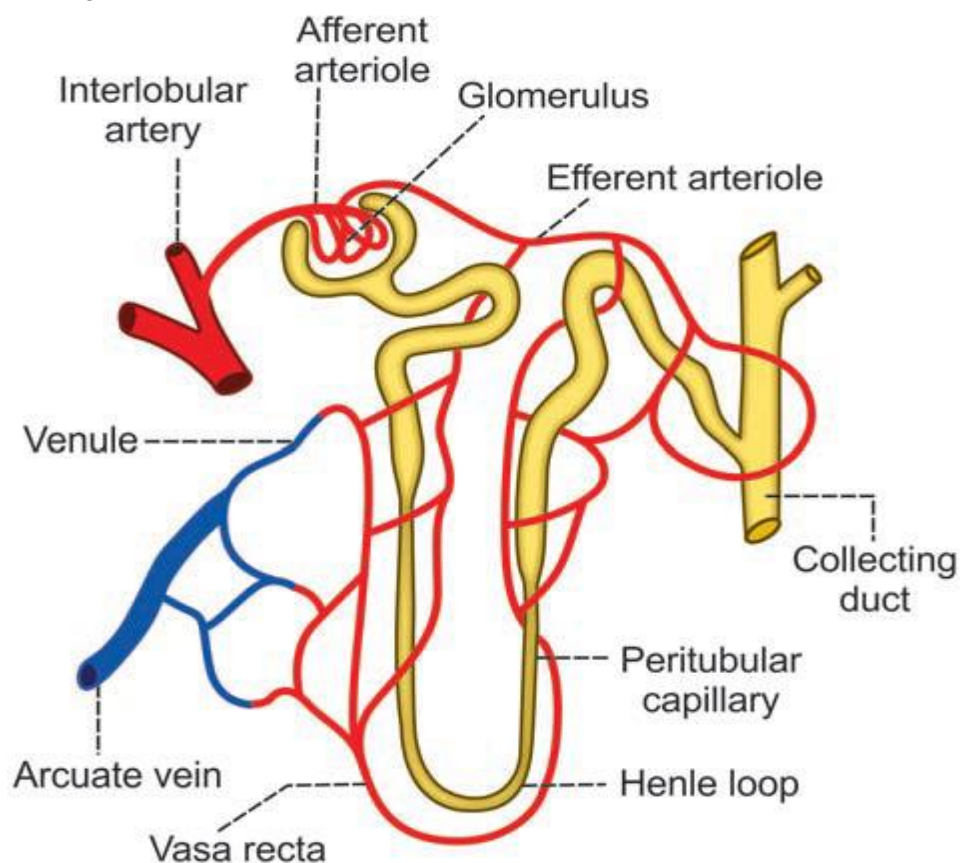


FIGURE 51.2: Renal capillaries

„ **MEASUREMENT OF RENAL BLOOD FLOW**

Blood flow to kidneys is measured by using plasma clearance of para-aminohippuric acid (Refer Chapter 55).

„ **REGULATION OF RENAL BLOOD FLOW**

Renal blood flow is regulated mainly by auto regulation. The nerves innervating renal blood vessels do not have any significant role in this.

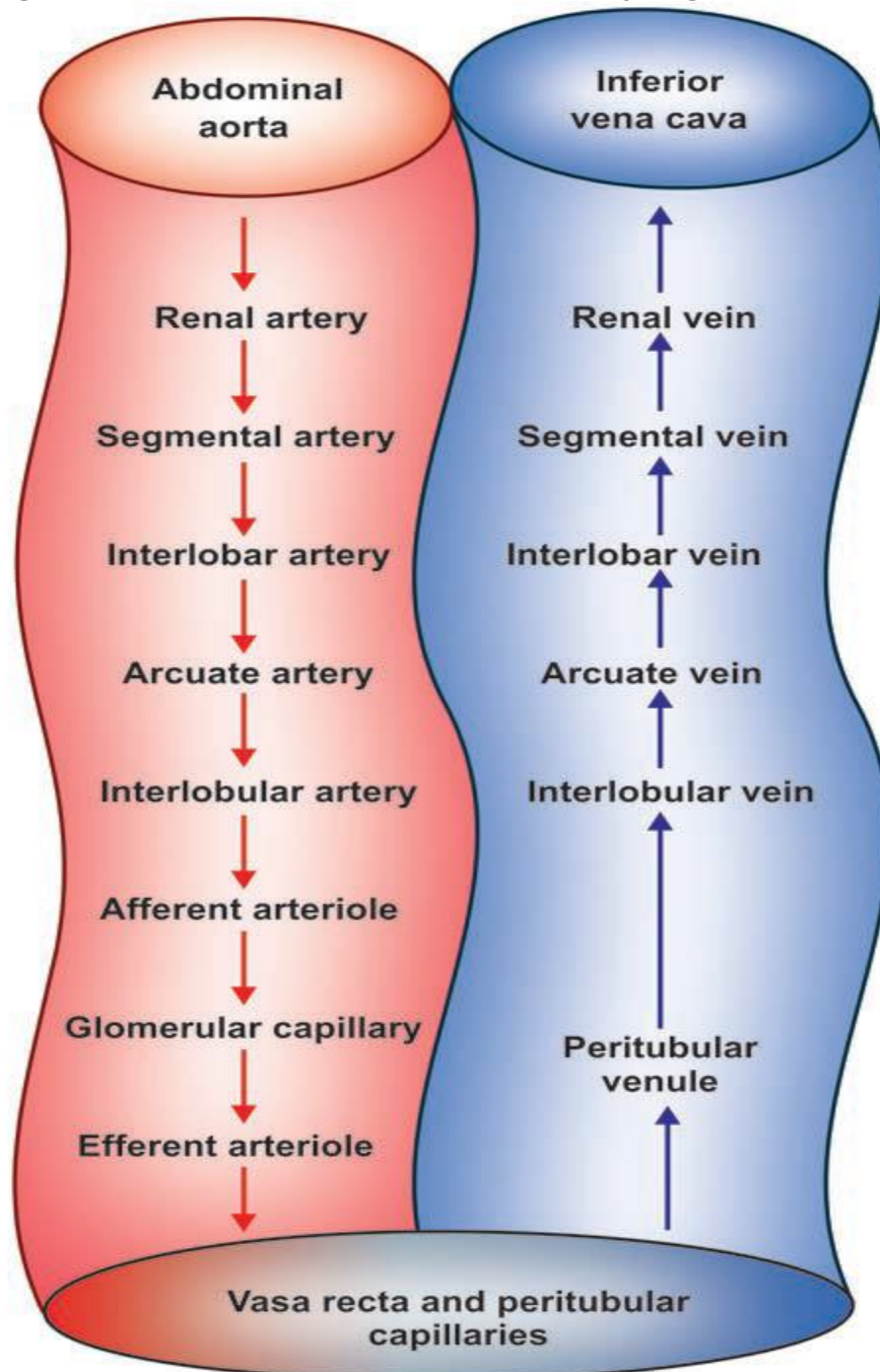


FIGURE 51.3: Schematic diagram showing renal blood flow

Auto Regulation

Auto regulation is the intrinsic ability of an organ to regulate its own blood flow (Chapter 102). Auto regulation is present in some vital organs in the body such as brain, heart and kidneys. It is highly significant and more efficient in kidneys.

Renal Autoregulation

Renal autoregulation is important to maintain the glomerular filtration rate (GFR). Blood flow to kidneys remains normal even when the mean arterial blood pressure vary widely between 60 mm Hg and 180 mmHg. This helps to maintain normal GFR. Two mechanisms are involved in renal auto regulation:

1. Myogenic response
2. Tubuloglomerular feedback.

1. Myogenic Response

Whenever the blood flow to kidneys increases, it stretches the elastic wall of the afferent arteriole. Stretching of the vessel wall increases the flow of calcium ions from extracellular fluid into the cells. The influx of calcium ions leads to the contraction of smooth muscles in afferent arteriole, which causes constriction of afferent arteriole. So, the blood flow is decreased.

2. Tubuloglomerular Feedback

Macula densa plays an important role in tubuloglomerular feedback, which controls the renal blood flow and GFR. Refer Chapter 52 for details.

„ SPECIAL FEATURES OF RENAL CIRCULATION

Renal circulation has some special features to cope up with the functions of the kidneys. Such special features are:

1. Renal arteries arise directly from the aorta. So, the high pressure in aorta facilitates the high blood flow to the kidneys.

2. Both the kidneys receive about 1,300 mL of blood per minute, i.e. about 26% of cardiac output. Kidneys are the second organs to receive maximum blood flow, the first organ being the liver, which receives 1,500 mL per minute, i.e. about 30% of cardiac output.
3. Whole amount of blood, which flows to kidney has to pass through the glomerular capillaries before entering the venous system. Because of this, the blood is completely filtered at the renal glomeruli.
4. Renal circulation has a portal system, i.e. a double network of capillaries, the glomerular capillaries and peritubular capillaries.
5. Renal glomerular capillaries form high pressure bed with a pressure of 60 mm Hg to 70 mm Hg. It is much greater than the capillary pressure elsewhere in the body, which is only about 25 mm Hg to 30 mm Hg. High pressure is maintained in the glomerular capillaries because the diameter of afferent arteriole is more than that of efferent arteriole. The high capillary pressure augments glomerular filtration.
6. Peritubular capillaries form a low pressure bed with a pressure of 8 mm Hg to 10 mm Hg. This low pressure helps tubular reabsorption.
7. Autoregulation of renal blood flow is well established.