BLOOD PRESSURE REGULATION 📈

Blood pressure (BP) must be maintained within a narrow physiological range to ensure adequate tissue perfusion and organ function.

- Hypotension → inadequate organ perfusion → organ dysfunction → may progress to ischemic tissue necrosis ⚠️
- Hypertension → chronic vascular injury → end-organ damage → major risk factor for atherosclerosis 🫀

Determinants of Blood Pressure

Blood Pressure = Cardiac Output × Peripheral Vascular Resistance

Both components are influenced by genetic and environmental factors.

1. Cardiac Output (CO)

Cardiac Output = Stroke Volume × Heart Rate

A. Stroke Volume

The most important determinant of stroke volume is filling pressure, which depends on:

- Blood volume
- Sodium homeostasis (key regulator)

🧠 *Concept:*

More sodium → more water retention → increased blood volume → increased venous return → ↑ stroke volume → ↑ BP

B. Heart Rate & Myocardial Contractility

Regulated by the autonomic nervous system:

- α-adrenergic system → vasoconstriction
- β-adrenergic system →

- ↑ heart rate
- ↑ myocardial contractility

Both indirectly increase blood pressure ⚡

---

2. Peripheral Vascular Resistance (PVR)

Peripheral resistance is regulated mainly at the level of arterioles.

Key Principle

Vascular tone reflects a balance between vasoconstrictors and vasodilators.

Vasoconstrictors vs Vasodilators

Vasoconstrictors 🟥	Vasodilators 🟩
Angiotensin II	Nitric oxide (NO)

Catecholamines	Prostaglandins
Endothelin	Kinins

Autoregulation of Resistance Vessels

Resistance vessels can regulate their own tone to protect tissues.

Autoregulation (Flowchart):
↑ Blood flow → Stretch of arteriolar wall → Reflex vasoconstriction → Protection against hyperperfusion

---

Local Metabolic Control

Blood pressure is fine-tuned locally by:

- ↓ pH (acidosis)
- Hypoxia

These cause vasodilation to match local metabolic demand 🧪

Role of Kidneys, Heart & Adrenal Glands

These organs interact to:

- Regulate vascular tone
- Control blood volume
- Maintain sodium balance

Sodium Homeostasis⭐

- Kidneys filter ~170 L plasma/day
- Contains ~23 moles of sodium
- Average dietary intake ≈ 100 mEq/day
- To maintain balance:
    - 99.5% of filtered sodium must be reabsorbed

Where is Sodium Reabsorbed?

- ~98% → reabsorbed by constitutively active transporters
- Remaining ~2% → regulated reabsorption via ENaC

🔑 Key Exam Point:
It is the last 2% of sodium, regulated by aldosterone, that determines net sodium balance and blood pressure.

ENaC Regulation (Flowchart):

Renin-angiotensin system activation → Aldosterone release → ENaC activation in distal nephron → ↑ Sodium reabsorption → ↑ Water retention → ↑ Blood volume → ↑ Blood pressure 📈

Renin-Angiotensin-Aldosterone System (RAAS) ⭐

Renin

- A proteolytic enzyme

- Produced by juxtaglomerular (JG) cells
    - Modified smooth muscle cells around afferent arterioles

Stimuli for Renin Release

- ↓ Blood pressure in afferent arteriole
- ↓ Sodium delivery to distal convoluted tubule

🧠 *Why sodium delivery falls:*

↓ GFR (e.g., low cardiac output)

→ ↑ proximal sodium reabsorption

→ ↓ sodium reaching distal tubule

RAAS Pathway (Flowchart):

↓ Blood pressure / ↓ Na^+ delivery → Renin release (kidney) → Angiotensinogen → Angiotensin I → ACE (endothelium) → Angiotensin II

Actions of Angiotensin II ⭐

Angiotensin II raises BP by three major mechanisms:

1. Vascular smooth muscle contraction → ↑ PVR
2. Aldosterone secretion → ↑ sodium & water retention
3. Direct ↑ tubular sodium reabsorption

Aldosterone

- Secreted by adrenal cortex
- Acts on:
    - Distal convoluted tubules
    - Collecting ducts

Effects

- ↑ Sodium reabsorption
- ↑ Water reabsorption
- ↑ Potassium excretion

➡️ Net effect: ↑ Blood volume → ↑ Blood pressure 💧

Counter-Regulatory Vasodilators

To prevent excessive vasoconstriction, kidneys produce:

- Prostaglandins
- Nitric oxide (NO)

These oppose angiotensin II–mediated vasopressor effects, maintaining balance ⚖️

Natriuretic Peptides (ANP & BNP) ⭐

Source

- Released from:
  - Atrial myocardium
  - Ventricular myocardium

Stimulus

- Volume expansion
- Increased cardiac wall stretch

Actions (Flowchart):

Volume expansion → Natriuretic peptide release → ↓ Sodium reabsorption in distal tubules → ↑ Sodium excretion (natriuresis) → ↑ Water excretion (diuresis) → ↓ Blood volume → ↓ Blood pressure 📉

Additional effect:

- Systemic vasodilation

Exam Pearls 📝

- BP = CO × PVR
- Last 2% of sodium reabsorption determines long-term BP
- RAAS is the most important hormonal regulator of BP
- Natriuretic peptides oppose RAAS
- Hypertension → end-organ damage + atherosclerosis risk

-> The End <-