Arterial blood pressure

Blood pressure is the force exerted by blood against a vessel wall.

It maintains blood flow through capillaries.

It depends on blood volume & compliance (distensibility) of blood vessels.

Arterial B.P. is not constant, it rises during ventricular systole (contraction) & falls during ventricular diastole (relaxation).

Systolic B.P.

Is the **peak** (highest) B.P. measured during ventricular systole **= 120 mmHg,** in a young Person at rest.

Diastolic B.P.

Is the **minimum** B.P. at the end of ventricular diastole **= 80 mmHg,** in a young person at rest.

Pulse pressure

Is the **difference** between systolic and diastolic B.P.

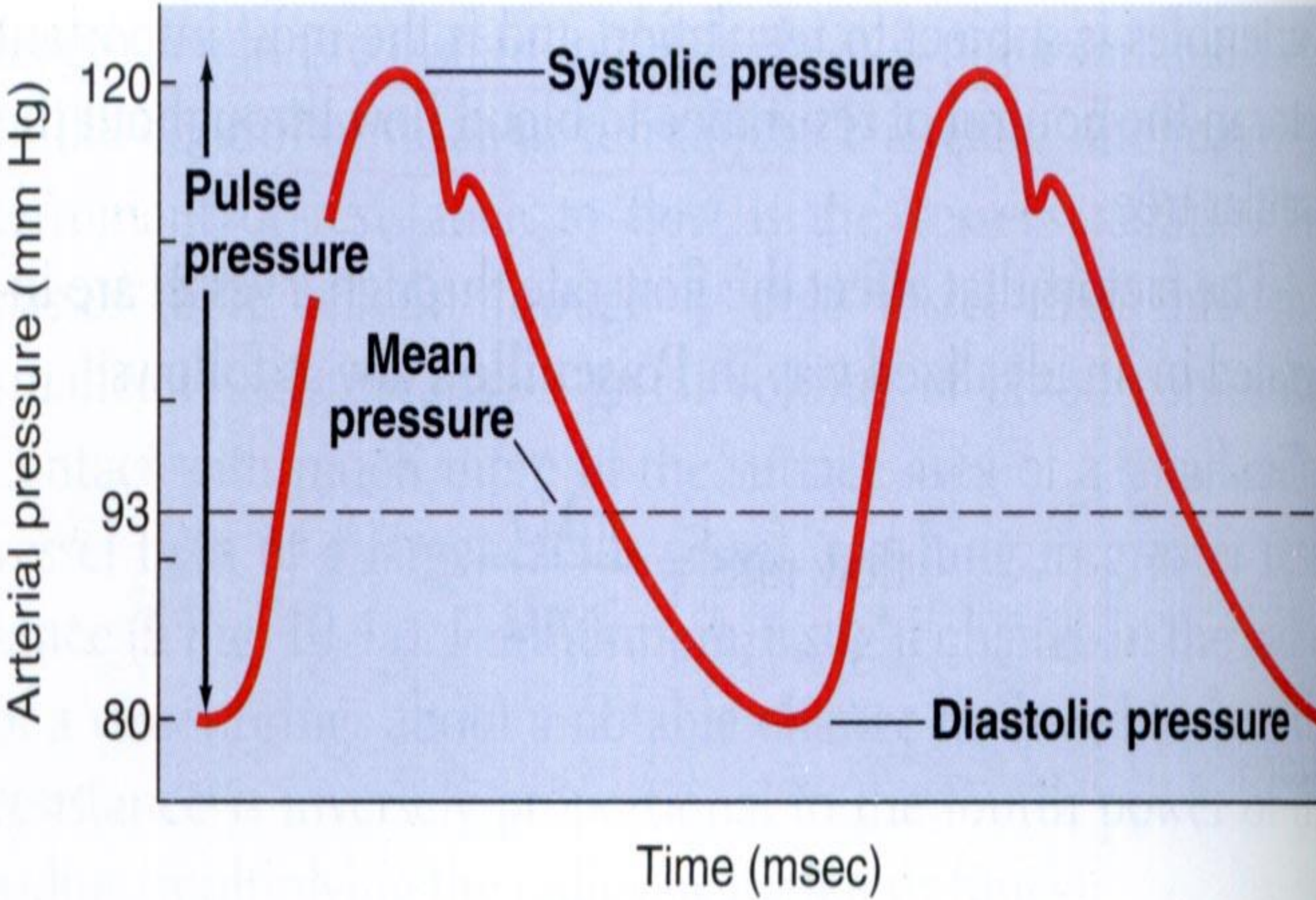

Arterial pressure (mm Hg)
120
93
80
Systolic pressure
Pulse pressure
Mean pressure
Diastolic pressure
Time (msec)

FIGURE 10.7

Mean B.P.

Calculated by adding one-third of the pulse pressure to the diastolic BP.

If B.P. = 120/90 mmHg.

The mean BP = $90 + \frac{120 - 90}{3}$

$= 90 + 10 = 100$ mmHg.

Mean arterial BP = C.O. x total peripheral resistance.

C.O. determines systolic BP.

Total peripheral resistance determines diastolic BP.

Physiological variations in BP

- Age
- Sex
- Body mass index
- Meals
- Exercise
- Posture
- Anxiety
- ↓ Slightly during inspiration and ↑ Slightly during expiration

Determinants of arterial BP

- Total peripheral resistance (TPR)
- Cardiac output (CO)
- Blood viscosity.
- Blood volume.

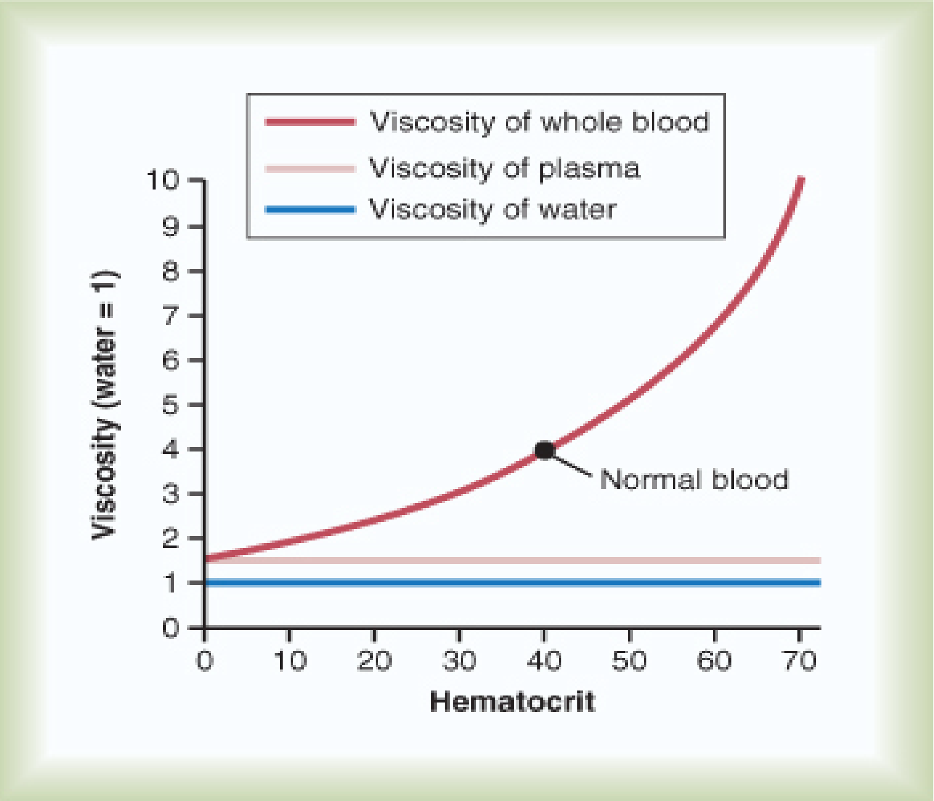
Arterial BP = CO X TPR

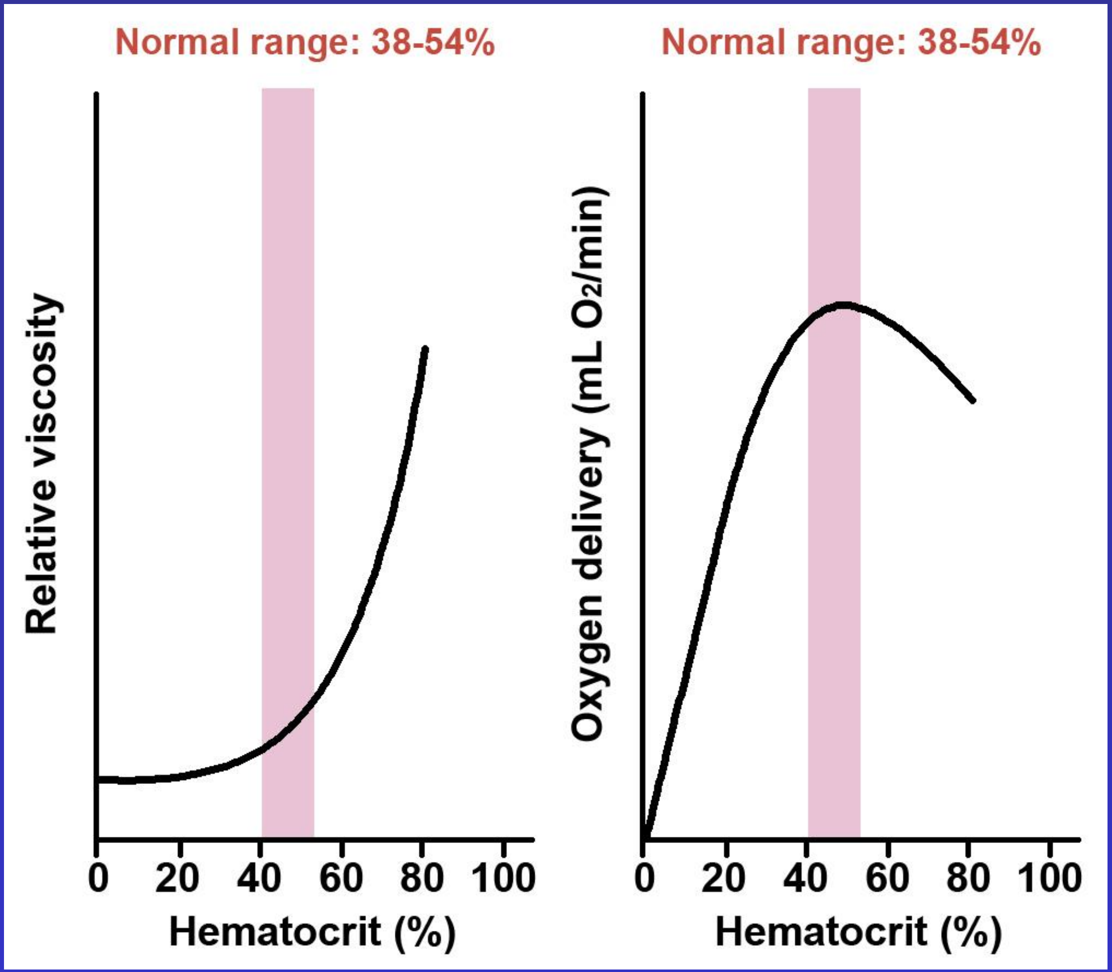
Factors affecting diameter of arterioles

- *Vasodilator agents:*
  - Adenosine
  - Atrial natriuretic peptide (ANP)
  - ↑ potassium or Hydrogen ions.
  - ↓ Oxygen or ↑ CO_2
  - Histamine
  - Nitric oxide and lactic acid
  - Prostacyclin

- *Vasoconstrictor agents:*
  - Noradrenaline
  - Sympathomimetic drugs.
  - Vasopressin
  - Angiotensin II
  - Endothelin-1

Blood viscosity: Hematocrit





Effect of hematocrit on blood viscosity. Above-normal hematocrits produce a sharp increase in viscosity. Because increased viscosity raises vascular resistance, hemoglobin and oxygen delivery may fall when the hematocrit rises above the normal range.

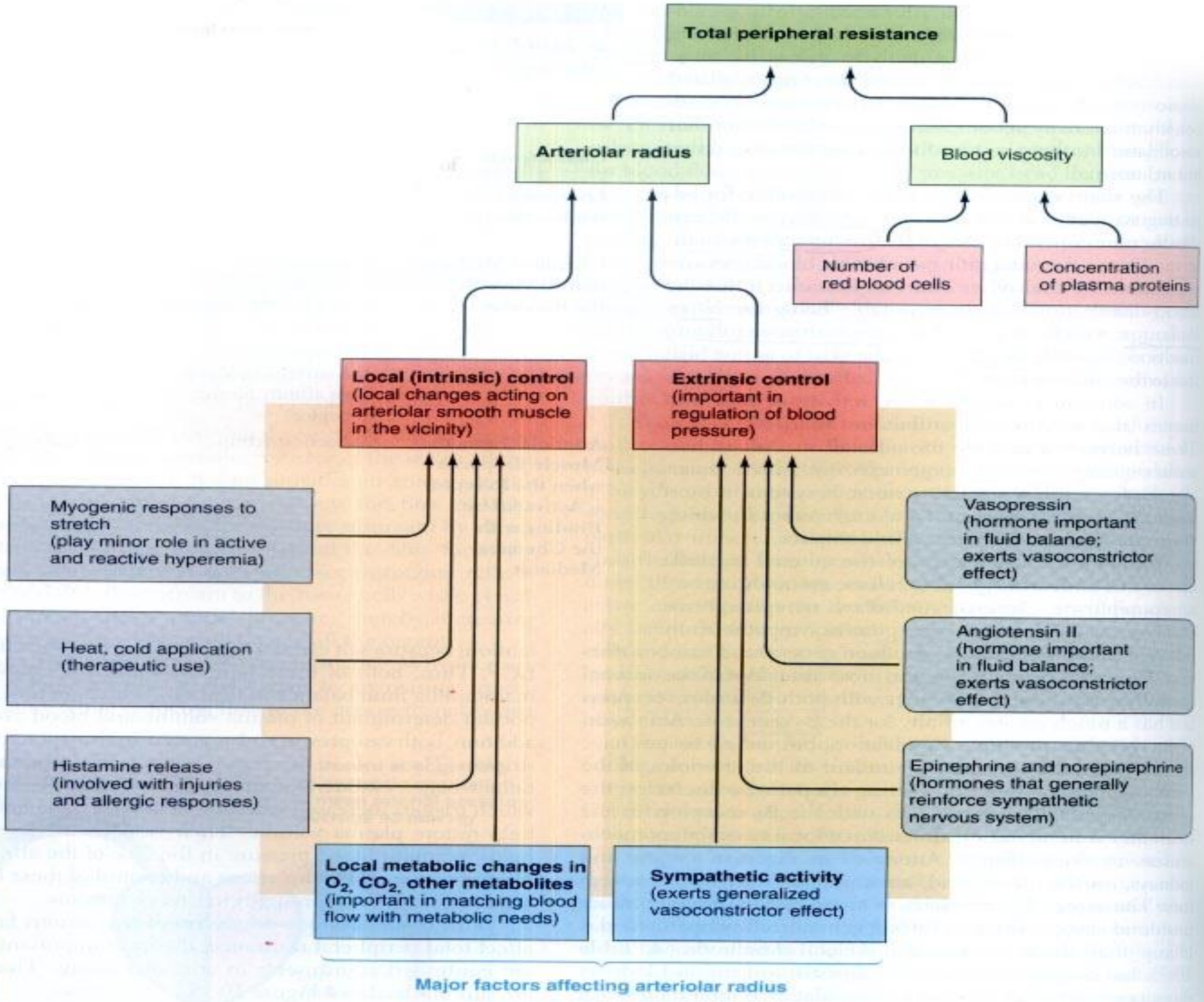
Blood Viscosity

↓ Plasma protein → ↓ blood viscosity

Hypoalbumenimia:

Burns.

Malnutrition


Total peripheral resistance
Arteriolar radius
Blood viscosity
Number of red blood cells
Concentration of plasma proteins
Local (intrinsic) control (local changes acting on arteriolar smooth muscle in the vicinity)
Extrinsic control (important in regulation of blood pressure)
Myogenic responses to stretch (play minor role in active and reactive hyperemia)
Heat, cold application (therapeutic use)
Histamine release (involved with injuries and allergic responses)
Local metabolic changes in O_2, CO_2, other metabolites (important in matching blood flow with metabolic needs)
Sympathetic activity (exerts generalized vasoconstrictor effect)
Vasopressin (hormone important in fluid balance; exerts vasoconstrictor effect)
Angiotensin II (hormone important in fluid balance; exerts vasoconstrictor effect)
Epinephrine and norepinephrine (hormones that generally reinforce sympathetic nervous system)
Major factors affecting arteriolar radius

Effect of Blood Volume

Changes in blood volume affect arterial pressure by changing cardiac output:

An increase in blood volume increases end–diastolic volume → ↑ ventricular preload → ↑ ventricular stroke volume by the Frank-Starling mechanism.

↑ Stroke volume → ↑ cardiac output and ↑ arterial blood pressure.

Hemodynamics

Is the branch of physiology concerned with The physical principles governing:
Pressure, Flow, Resistance, Volume, and Compliance as they relate to the CVS.

Resistance to blood flow results from the inner friction & viscosity of blood.

Pressure flow and resistance are related by:
(Ohm's Law), Q = ΔP/R .

Q = blood flow.
ΔP = the pressure difference between the two ends of the vessel.
R = Resistance.

Resistance depends on the radius & length of the blood vessel & the viscosity of blood (Poiseuille's law).

$Q = \Delta P / R$.

$R = V \times L / r^4$

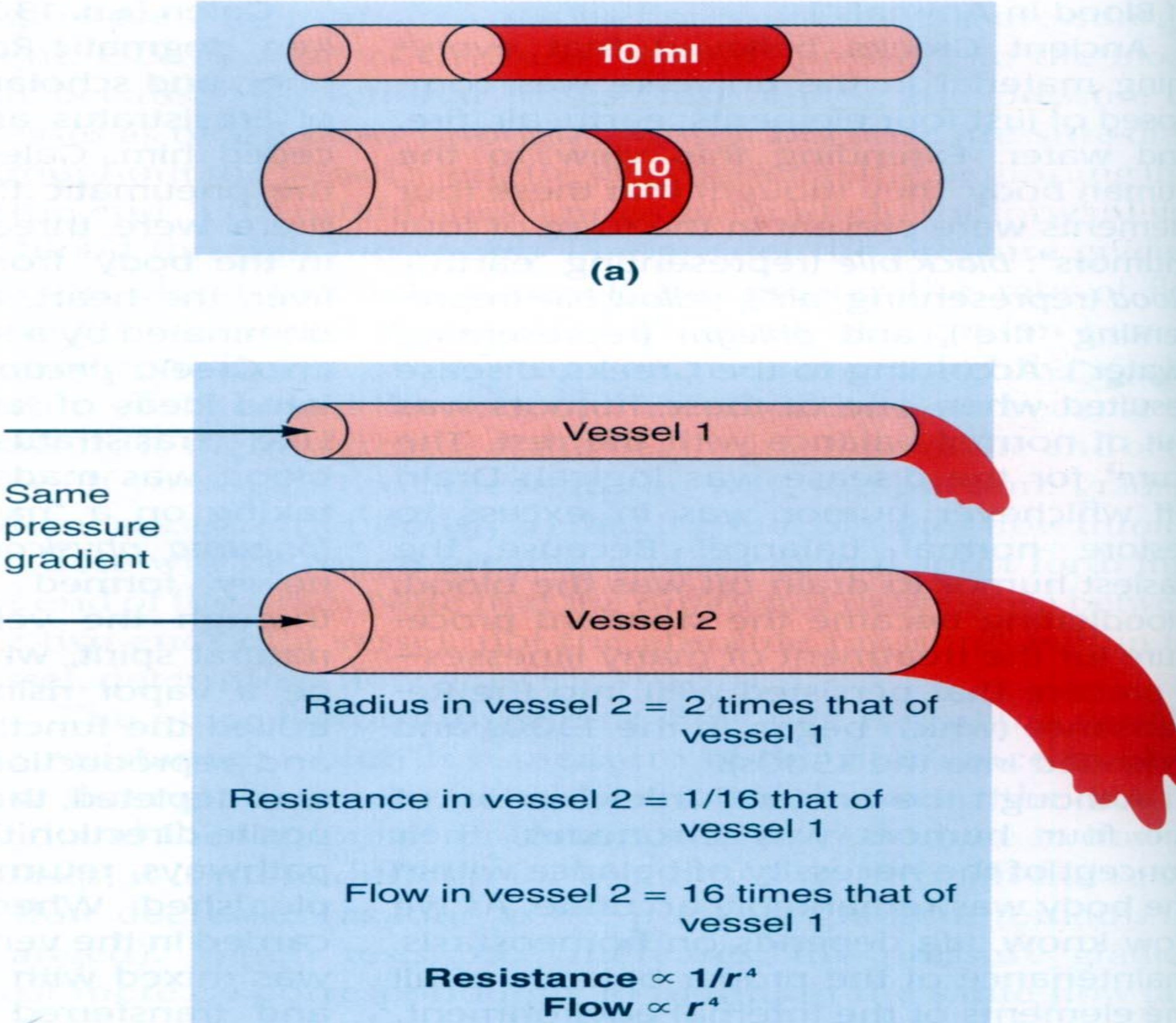
$Q = \Delta P \times r^4 / V \times L$.

Length does not change, and viscosity rarely changes enough to have a significant effect on resistance.

There for small changes in arteriolar radius can cause large changes in blood flow.

$$Q \sim r^4$$

$$R \sim 1 / r^4$$



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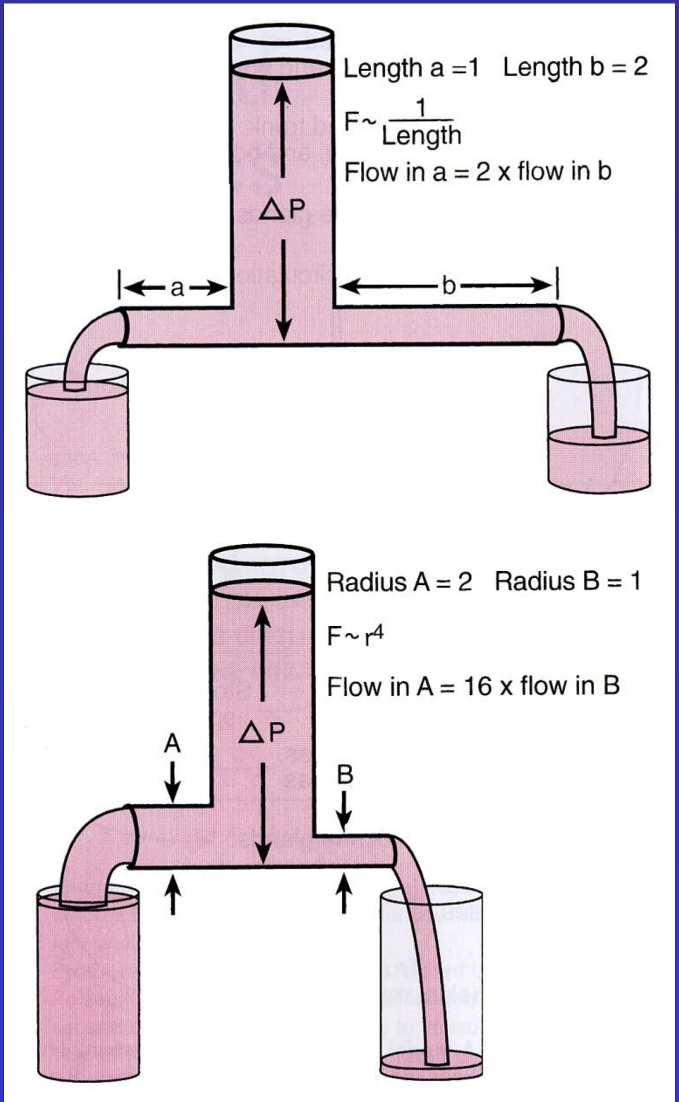
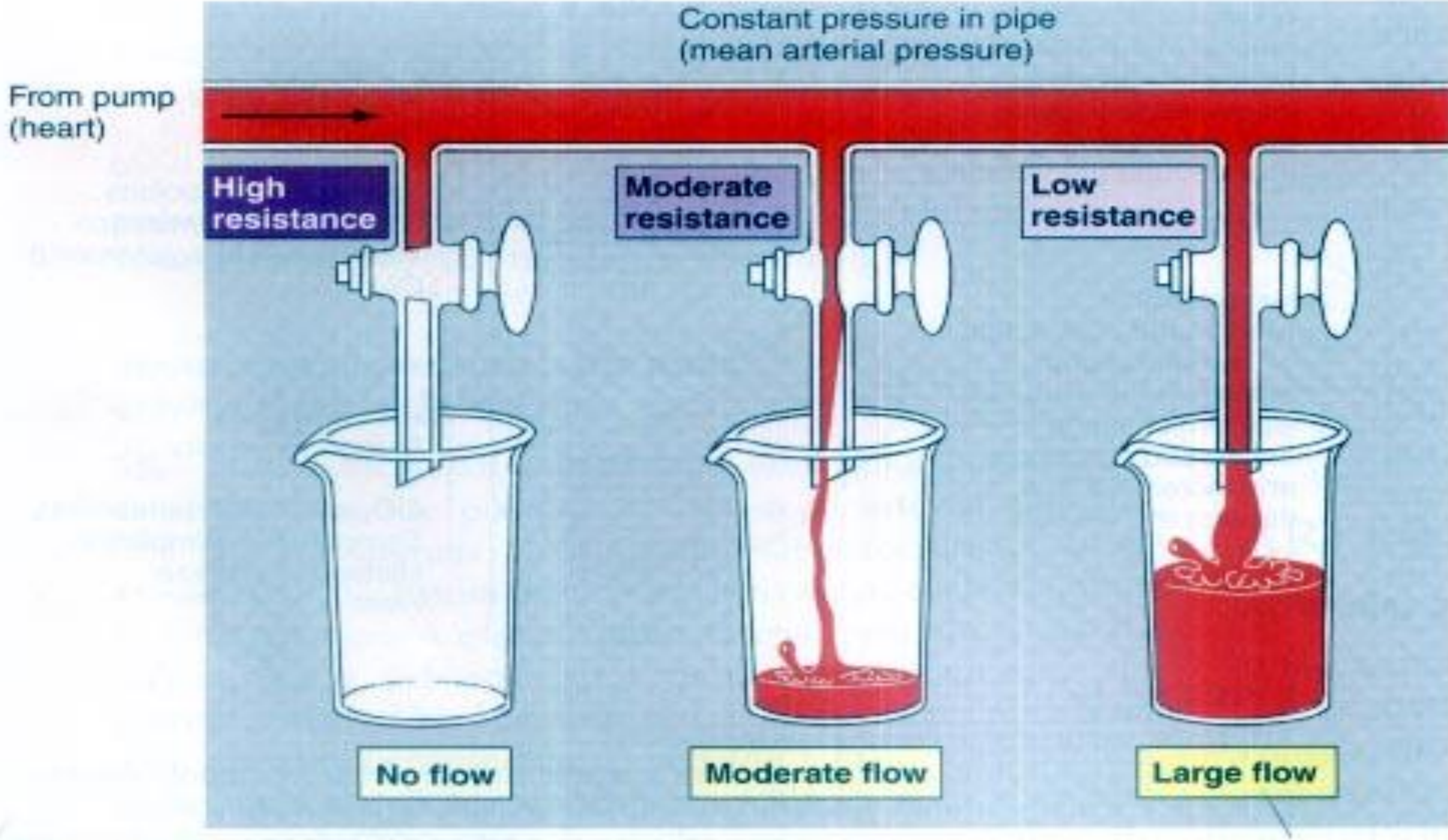


The influence of tube length and radius on flow. Because flow is determined by the fourth power of the radius, small changes in radius have a much greater effect than small changes in length. Furthermore, changes in blood vessel length do not occur over short periods of time and are not involved in the physiological control of blood flow. The pressure difference (ΔP) driving flow is the result of the height of the column of fluid above the openings of tubes A and B.

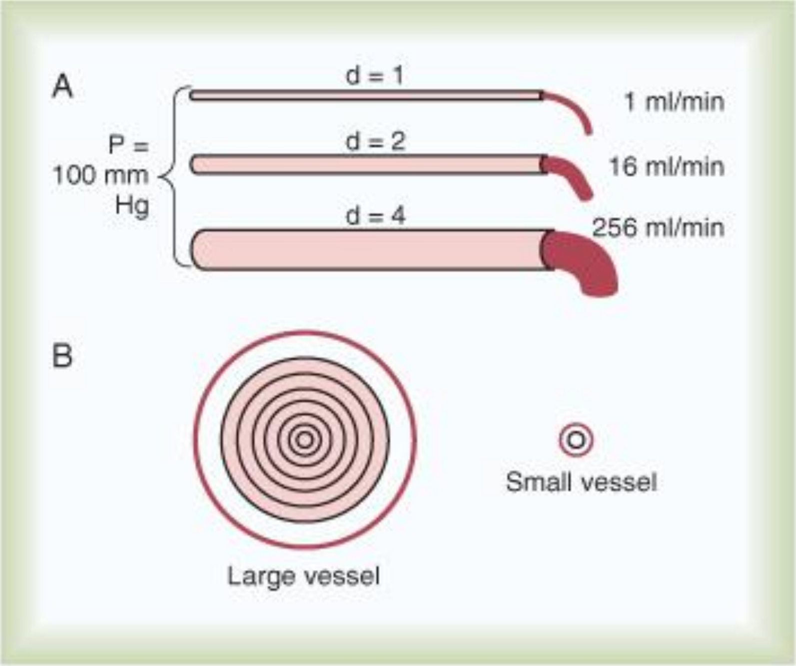


Valves = Arterioles

FIGURE 10-11

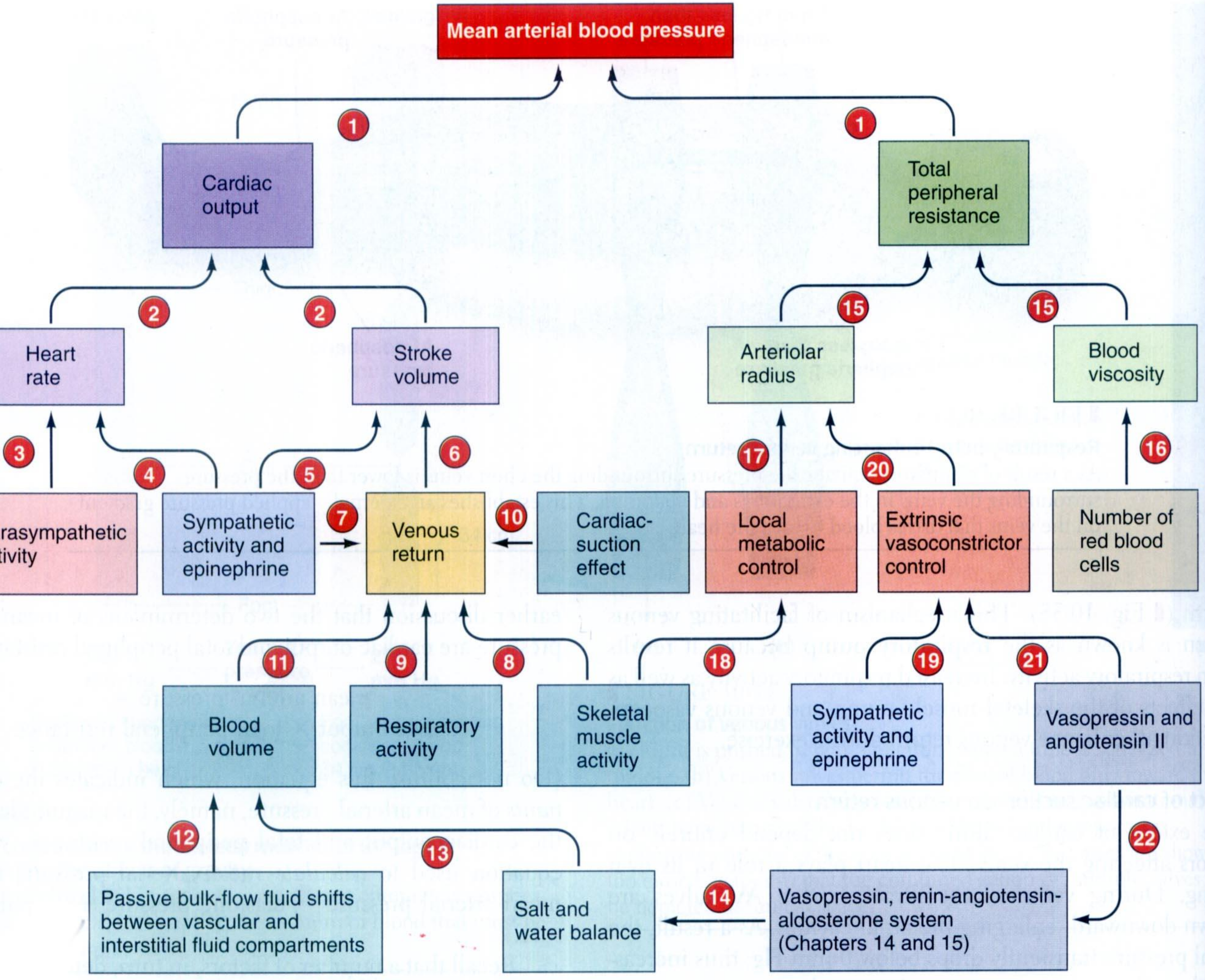
Flow rate as a function of resistance

Flow rate as a function of resistance



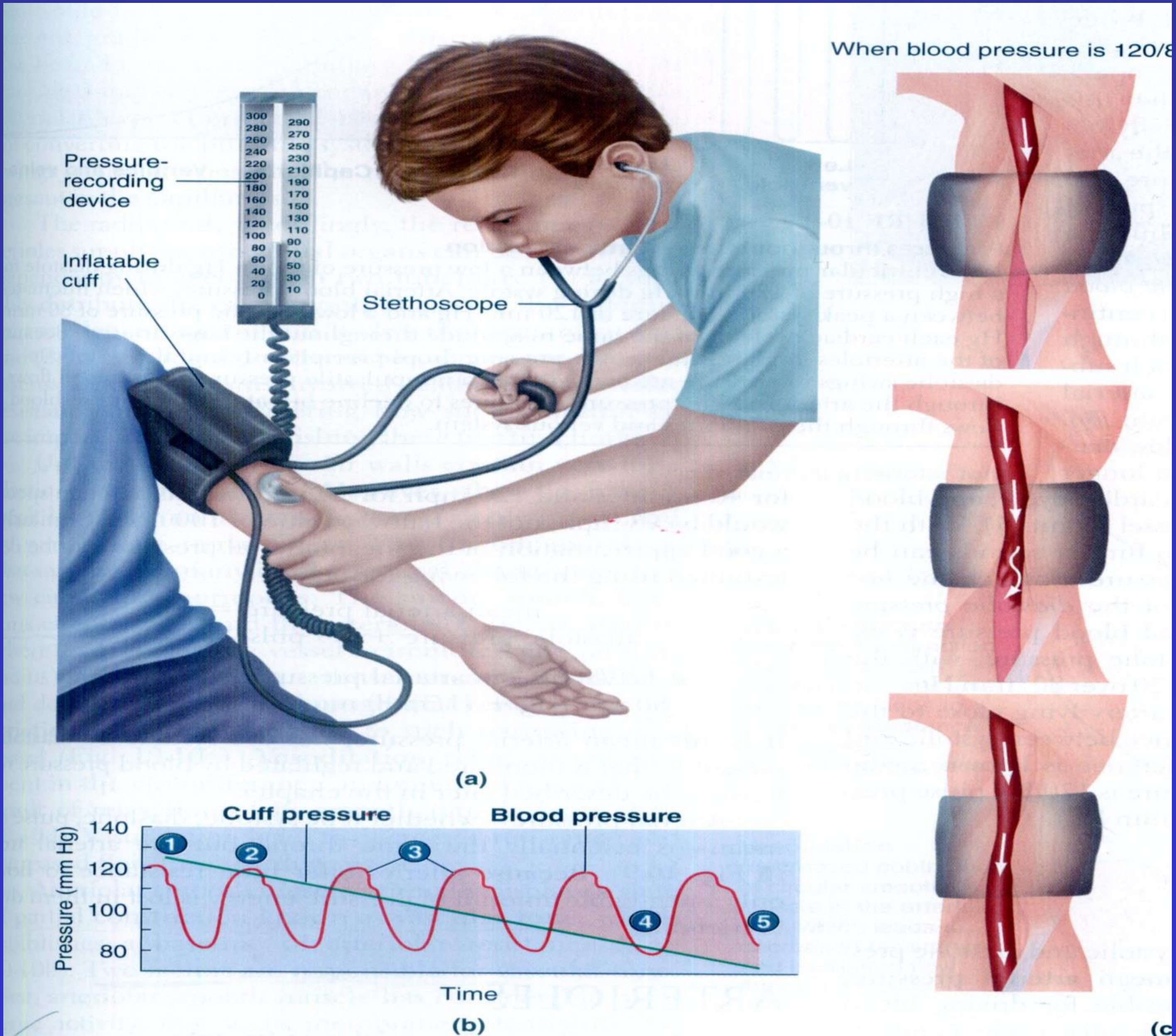
Arterioles & small arteries are called (resistance vessels).

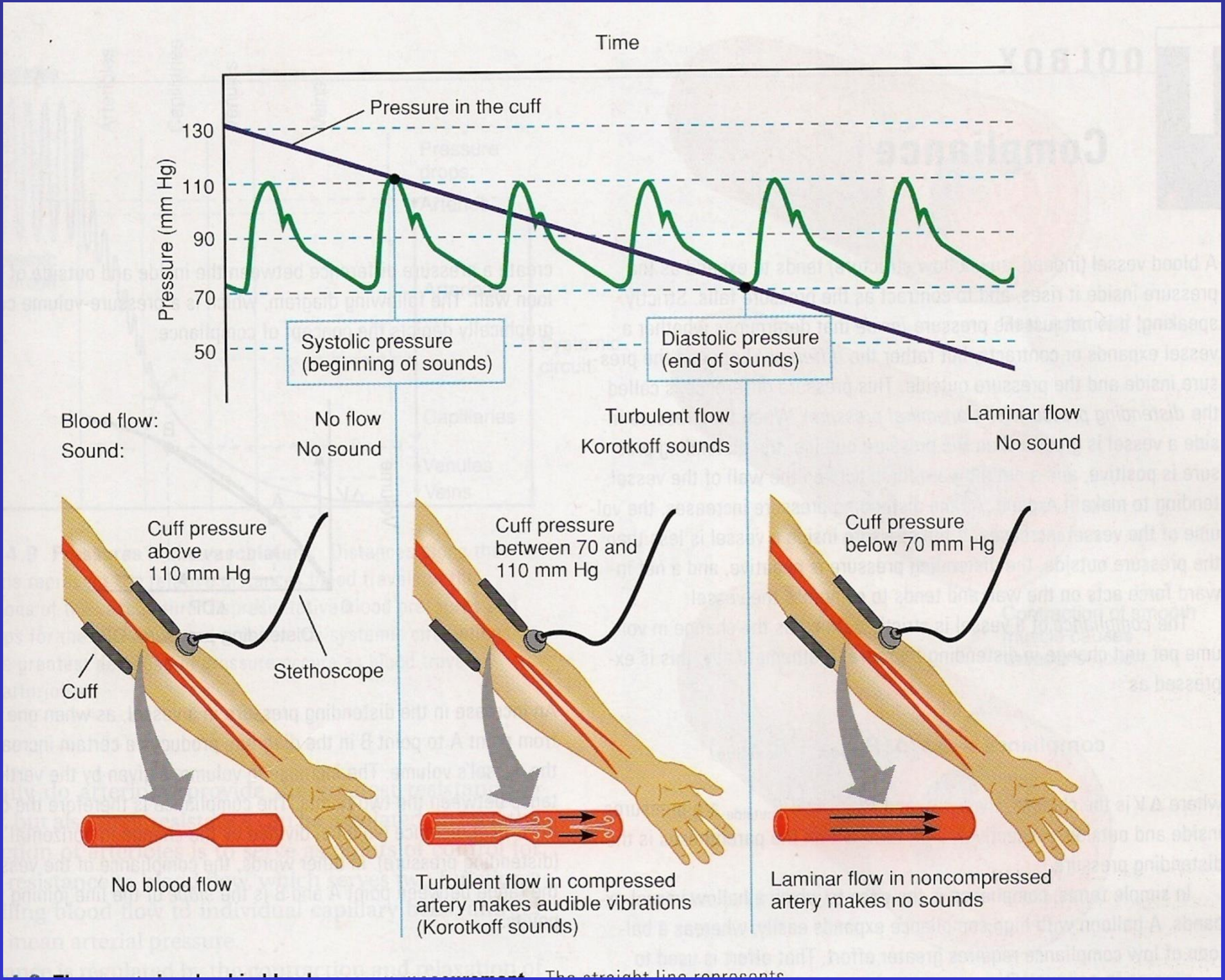
They determine the mean arterial blood pressure.

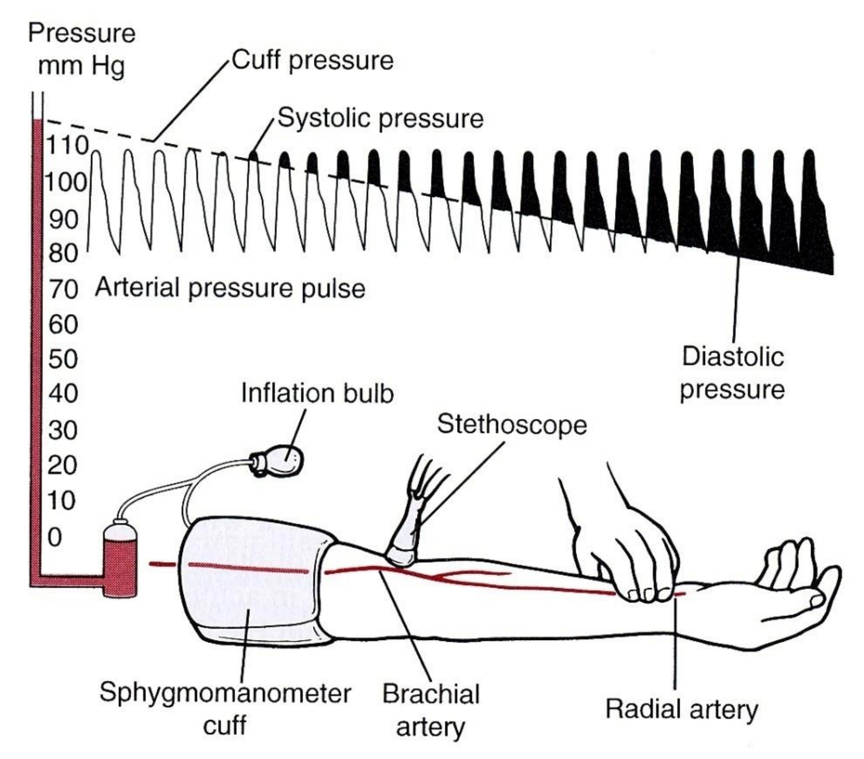


Mean arterial blood pressure
1
1
Cardiac output
Total peripheral resistance
2
2
15
15
Heart rate
Stroke volume
Arteriolar radius
Blood viscosity
3
4
5
6
17
20
16
rasympathetic
tivity
Sympathetic activity and epinephrine
7
Venous return
10
Cardiac-suction effect
Local metabolic control
Extrinsic vasoconstrictor control
Number of red blood cells
11
9
8
18
19
21
Blood volume
Respiratory activity
Skeletal muscle activity
Sympathetic activity and epinephrine
Vasopressin and angiotensin II
12
13
22
14
Passive bulk-flow fluid shifts between vascular and interstitial fluid compartments
Salt and water balance
Vasopressin, renin-angiotensin-aldosterone system (Chapters 14 and 15)

Measurement of B.P.




Time
Pressure in the cuff
Pressure (mm Hg)
130
110
90
70
50
Systolic pressure
(beginning of sounds)
Diastolic pressure
(end of sounds)
Blood flow:
Sound:
No flow
No sound
Turbulent flow
Korotkoff sounds
Laminar flow
No sound
Cuff pressure
above
110 mm Hg
Cuff
Stethoscope
Cuff pressure
between 70 and
110 mm Hg
Cuff pressure
below 70 mm Hg
No blood flow
Turbulent flow in compressed
artery makes audible vibrations
(Korotkoff sounds)
Laminar flow in noncompressed
artery makes no sounds



Systolic pressure can also be estimated by palpating the radial artery and noting the cuff pressure at which the first pulsation is felt.

Types of blood flow

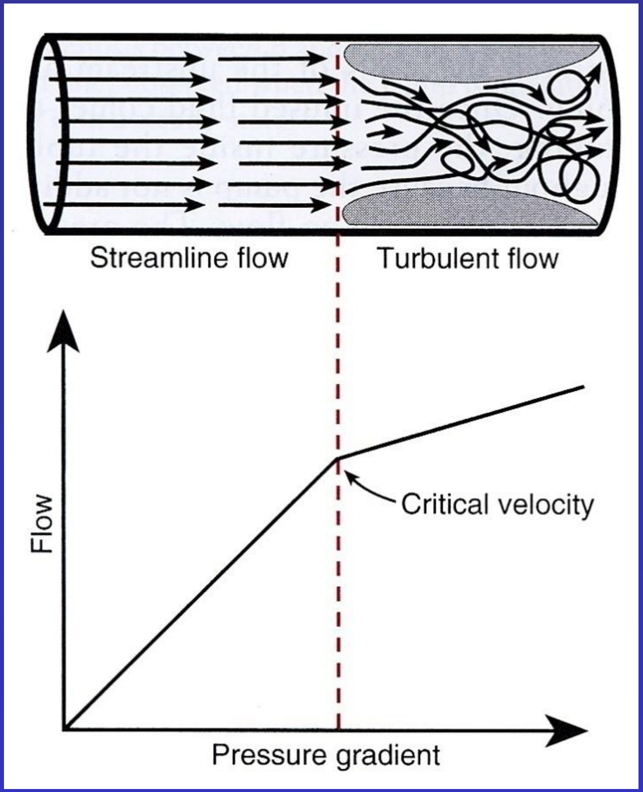
Laminar (Streamline) flow :

Smooth flow at a steady rate. The central portion of blood stays in the center of the vessel → Less friction.

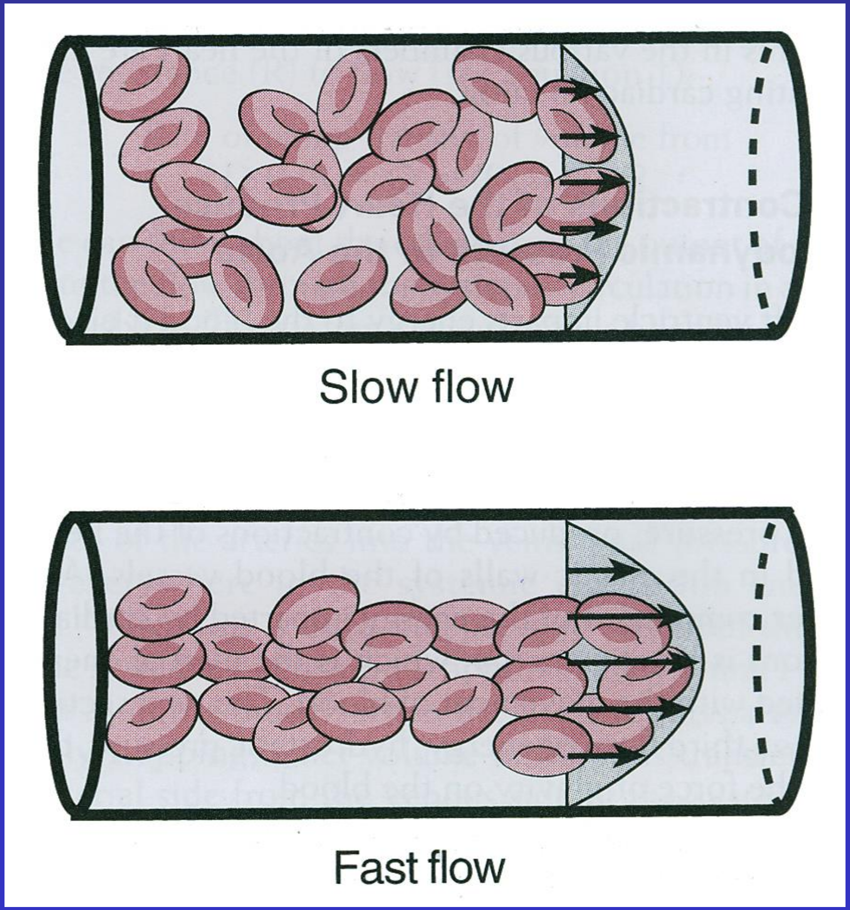
Turbulent flow :

High flow rate in all directions (Mixing) → increase resistance & slow flow rate.

In restricted blood flow or valvular lesions bruits or murmurs can be heard.



Streamline and turbulent blood flow. Blood flow is streamlined until a critical flow velocity is reached. When flow is streamlined, concentric layers of fluid slip past each other with the slowest layers at the interface between blood and vessel wall. The fastest layers are in the center of the blood vessel. When the critical velocity is reached, turbulent flow results. In the presence of turbulent flow, flow does not increase as much for a given rise in pressure because energy is lost in the turbulence.



Axial streamline and flow velocity. The distribution of red blood cells in blood vessel depends on flow velocity. As flow velocity increases, red blood cells move toward the center of the blood vessel (axial streaming), where velocity is highest. Axial streaming of red blood cells lowers the apparent viscosity of blood

Hypertension in adults is a BP greater than 140/90.

BP at or below 120/80 is normal.

Values between 121/81 and 139/89 indicate a state of pre-hypertension.

Hypertension increases the work load of the heart → enlargement of the left ventricle → ↑ muscle mass → ↑ oxygen demand.

Insufficient coronary circulation → symptoms of ischemic heart disease.

Dangers of hypertension

Silent killer:

Patients are asymptomatic until substantial vascular damage occurs.

Atherosclerosis increases afterload.

Increase workload of the heart.

Congestive heart failure.

Damage cerebral blood vessels.

Cerebral vascular accident (stroke)

Chronic renal failure.

Elastic rebound

During systole the arterial walls expand to accommodate the extra amount of blood pumped by the ventricles.

During diastole the BP falls, the arteries recoil to their original dimensions (Elastic rebound) → maintains blood flow in the arteries when the ventricle is in diastole.

Blood pressure,
wall, depends o
vessel and the **co**
(how easily they

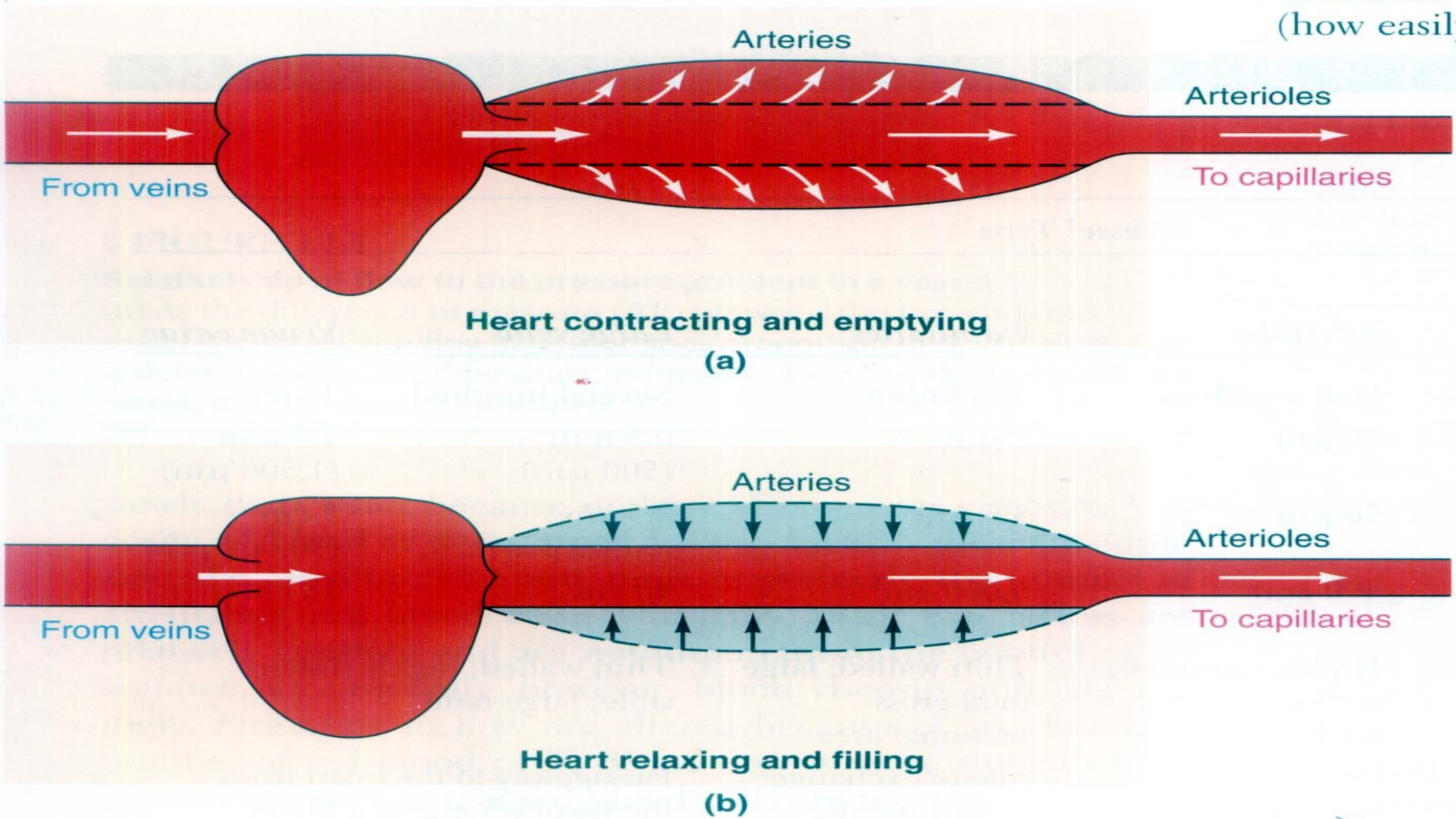


FIGURE 10-6

Arteries as a pressure reservoir

Because of their elasticity, arteries act as a pressure reservoir. (a) The elastic arteries distend during cardiac systole as more blood is ejected into them than drains off into the narrow, high-resistance arterioles downstream. (b) The elastic recoil of arteries during cardiac diastole continues driving the blood forward when the heart is not pumping.

Regulation of ABP

- **Short-term regulation:**
  - Baroreceptor reflexes.
  - Chemoreceptor reflexes.
  - Atrial reflexes.
  - CNS-ischemic response.

- **Long-term regulation:**
  - Role of the kidney.

- **Intermediate regulation:**
  - Capillary fluid shift

Reflex Mechanisms Controlling Arterial Pressure

1- The baroreceptors:

Stretch receptors in large systemic arteries (particularly the carotid artery and aorta).

2- Carotid and aortic chemoreceptors :

Monitor changes of oxygen, carbon dioxide, and hydrogen ions.

3- CNS ischemic responses.

Baroreceptor reflexes

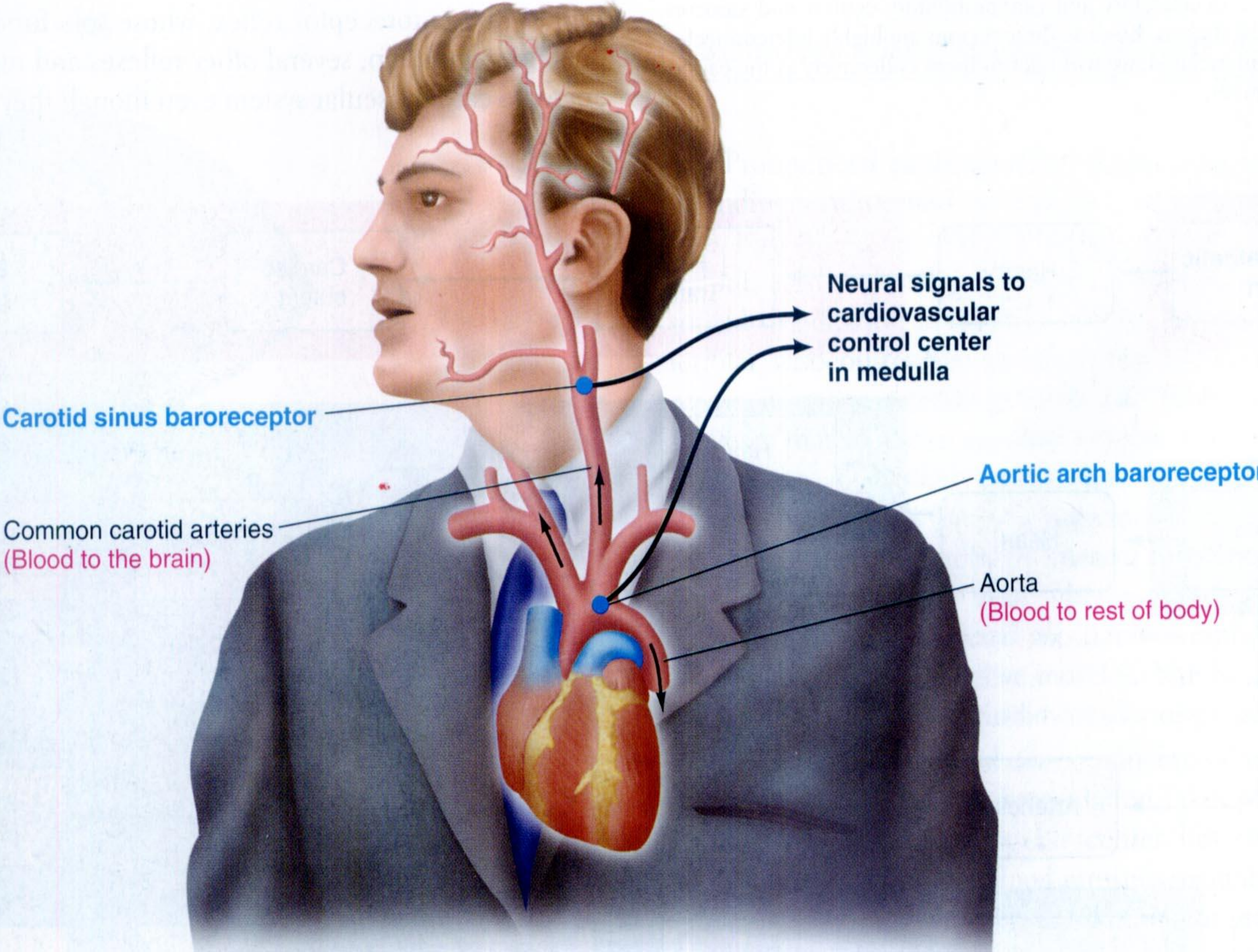
Monitor the degree of stretch of expansible organs.

Located in the:

1- Carotid sinuses.

2- Aortic sinuses.

3- The wall of the right atrium.

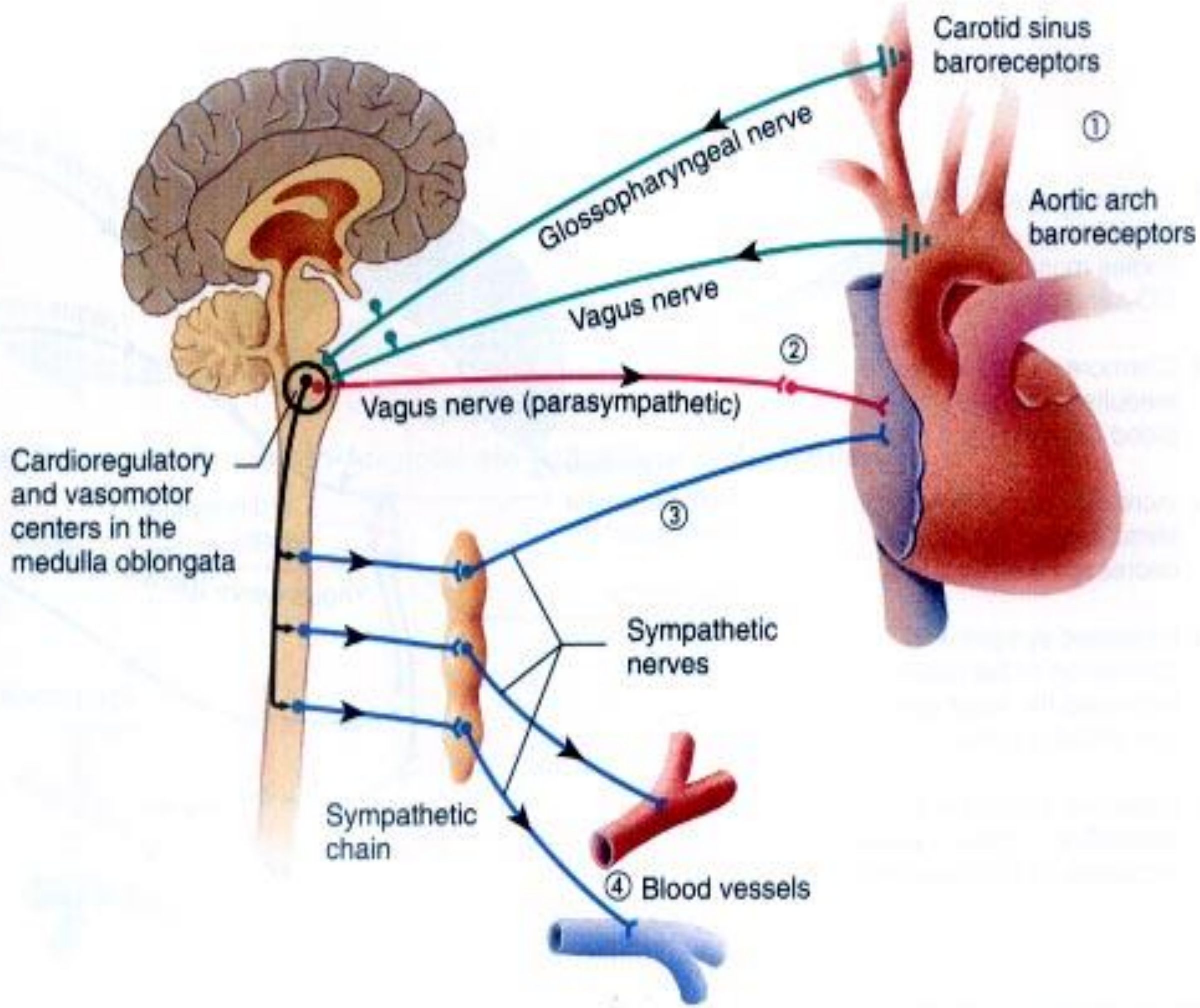

Neural signals to
cardiovascular
control center
in medulla
Carotid sinus baroreceptor
Aortic arch baroreceptor
Common carotid arteries
(Blood to the brain)
Aorta
(Blood to rest of body)

1. Baroreceptors in the carotid sinus and aortic arch monitor blood pressure.

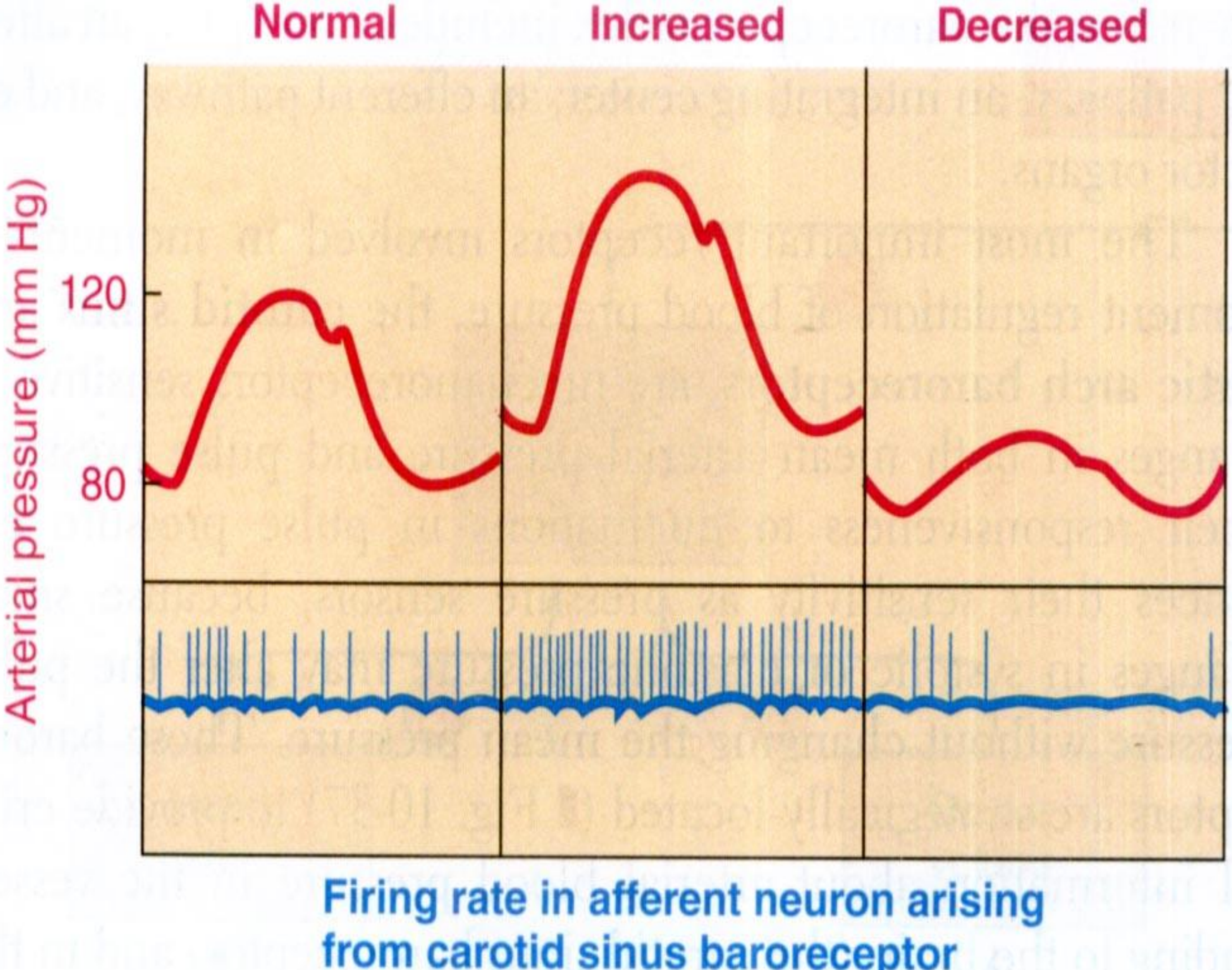
2. Increased parasympathetic stimulation of the heart decreases the heart rate.

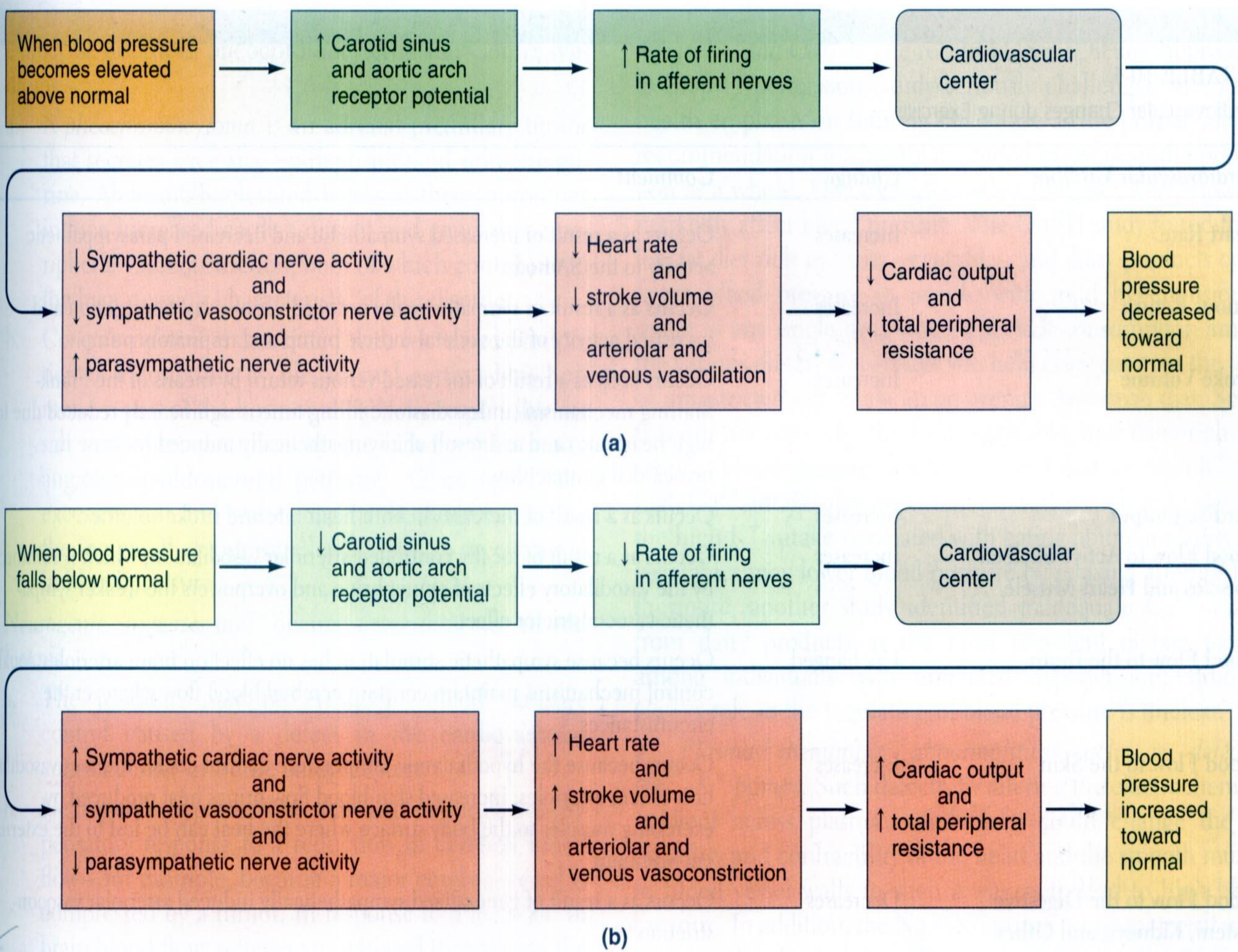
3. Increased sympathetic stimulation of the heart increases the heart rate and stroke volume.

4. Increased sympathetic stimulation of blood vessels increases vasoconstriction.



Baroreceptor Reflex Control of Blood Pressure
Figure 21.39


Normal
Increased
Decreased
Arterial pressure (mm Hg)
120
80
Firing rate in afferent neuron arising
from carotid sinus baroreceptor


When blood pressure becomes elevated above normal
↑ Carotid sinus and aortic arch receptor potential
↑ Rate of firing in afferent nerves
Cardiovascular center
↓ Sympathetic cardiac nerve activity and ↓ sympathetic vasoconstrictor nerve activity and ↑ parasympathetic nerve activity
↓ Heart rate and ↓ stroke volume and arteriolar and venous vasodilation
↓ Cardiac output and ↓ total peripheral resistance
Blood pressure decreased toward normal
(a)
When blood pressure falls below normal
↓ Carotid sinus and aortic arch receptor potential
↓ Rate of firing in afferent nerves
Cardiovascular center
↑ Sympathetic cardiac nerve activity and ↑ sympathetic vasoconstrictor nerve activity and ↓ parasympathetic nerve activity
↑ Heart rate and ↑ stroke volume and arteriolar and venous vasoconstriction
↑ Cardiac output and ↑ total peripheral resistance
Blood pressure increased toward normal
(b)

Denervation of the baroreceptors can lead to paroxysmal hypertension.

Chemoreceptors

Very similar to baroreceptors, except that they respond to chemical changes.

At low O_2 or high CO_2 or H^+ (as occurs during low pressure because of decreased blood flow), chemoreceptors are stimulated.

Chemoreceptors excite the vasomotor center, Which elevates the arterial pressure.

CNS Ischemic Response

- If blood flow is decreased to the vasomotor center in the lower brainstem and CO_2 accumulates, the CNS ischemic response is initiated.

- Very strong sympathetic stimulation causing major vasoconstriction and cardiac acceleration.

- Sometimes called the "last ditch stand".

Atrial baroreceptors (low pressure receptors)

Respond to stretch of the wall of the right atrium.

↑ atrial pressure → stimulate CV center → ↑ H.R.& ↑ C.O (Bainbridge reflex) → prevent damming of blood in veins, atria & pulmonary Circulation.

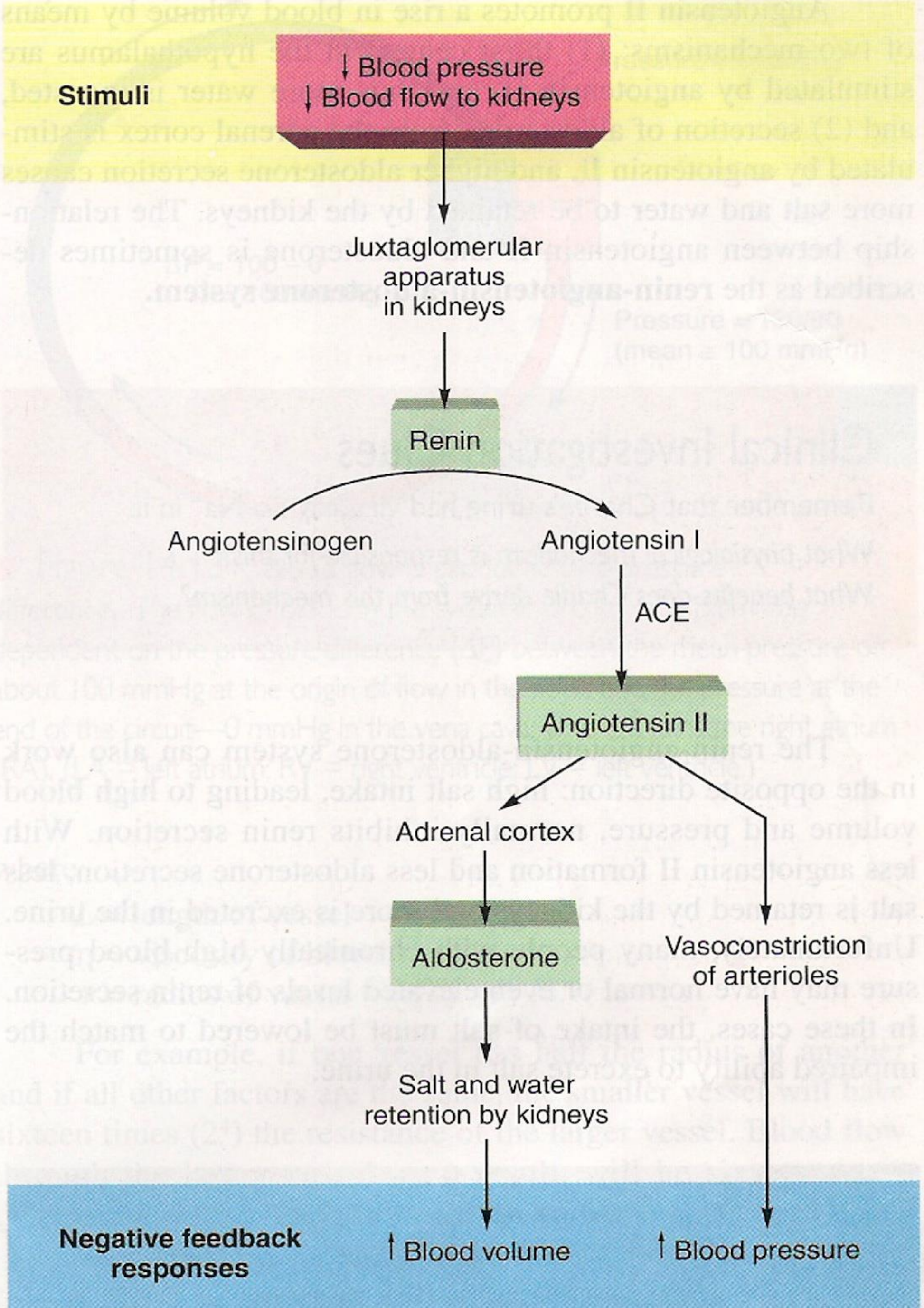
Atrial stretch also → dilate afferent arterioles → ↑ GFR → ↓ ADH & ↑ ANP hormone secretion → ↑ urine output. → ↓ B.P.

Intermediate regulation of BP (Respond from 30 minutes to several hours)

1- Renin - Angiotensin vasoconstrictor mechanism.

2- Capillary shift mechanism (Fluid shift from the interstitial spaces into blood capillaries) → ↑ Blood volume.

3- Stress relaxation changes of the vasculature.


Stimuli
↓ Blood pressure
↓ Blood flow to kidneys
Juxtaglomerular apparatus in kidneys
Renin
Angiotensinogen
Angiotensin I
ACE
Angiotensin II
Adrenal cortex
Aldosterone
Vasoconstriction of arterioles
Salt and water retention by kidneys
Negative feedback responses
↑ Blood volume
↑ Blood pressure

Long-term Regulation of Arterial Pressure by the Kidneys

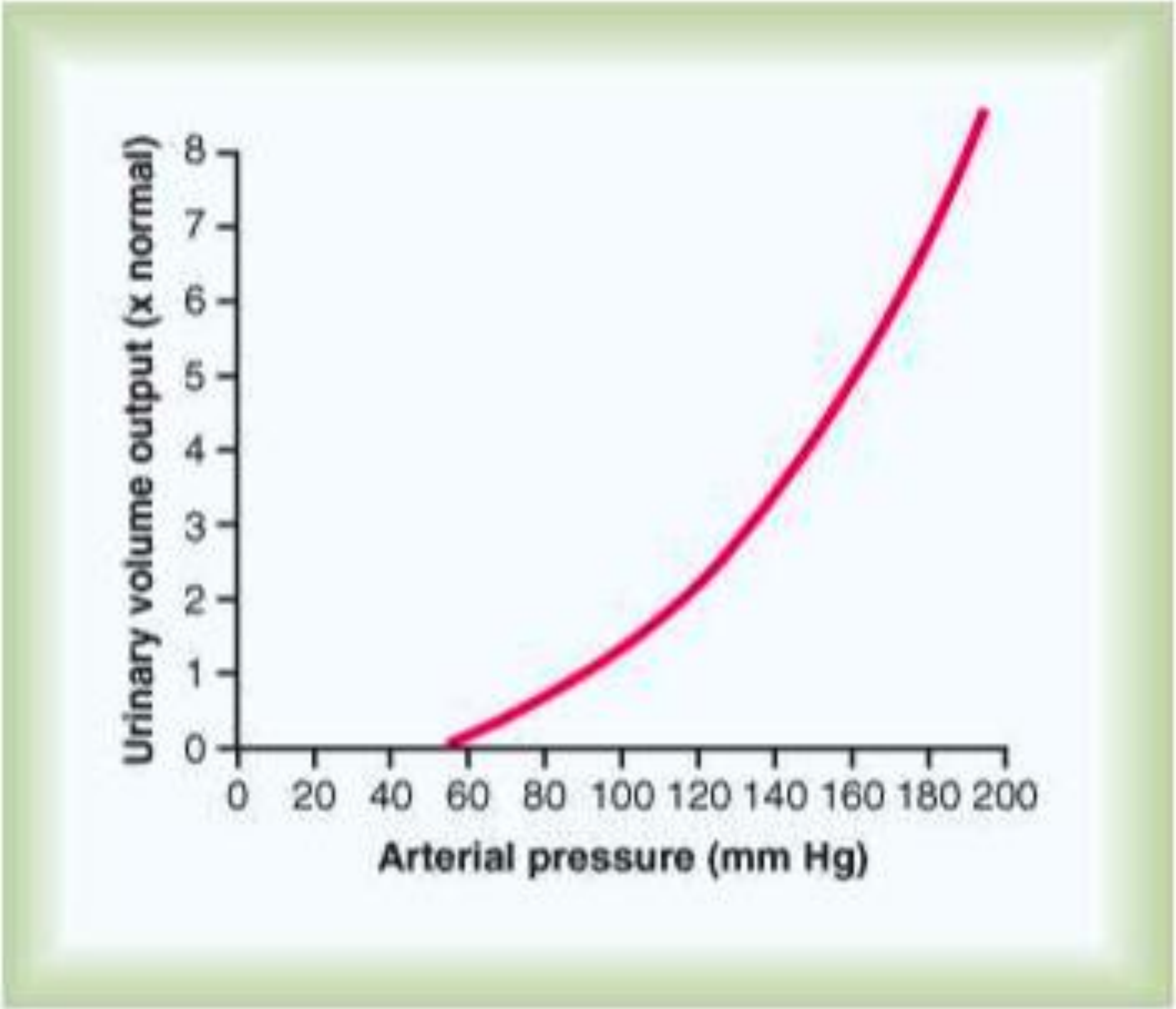
- **The kidneys control the level of H_2O and NaCl in the body, thus controlling the volume of the extracellular fluid and blood.**

- **By controlling blood volume, the kidneys control arterial pressure.**

- **Increased arterial pressure results in increased renal output of H_2O (pressure diuresis) and salt (pressure natiuresis).**

Renal Urinary Output Curve

19-1



Hormonal regulation of CVS

The endocrine system provides both short-term and long term regulation of CVS.

Epinephrine, and Norepinephrine, stimulate C.O. and vasoconstriction.

Other hormones for long-term regulation of arterial BP include:

1- Antidiuretic hormone (ADH).
2- Angiotensin II.
3- Erythropoietin.
4- Atrial natriuretic peptides (ANP).

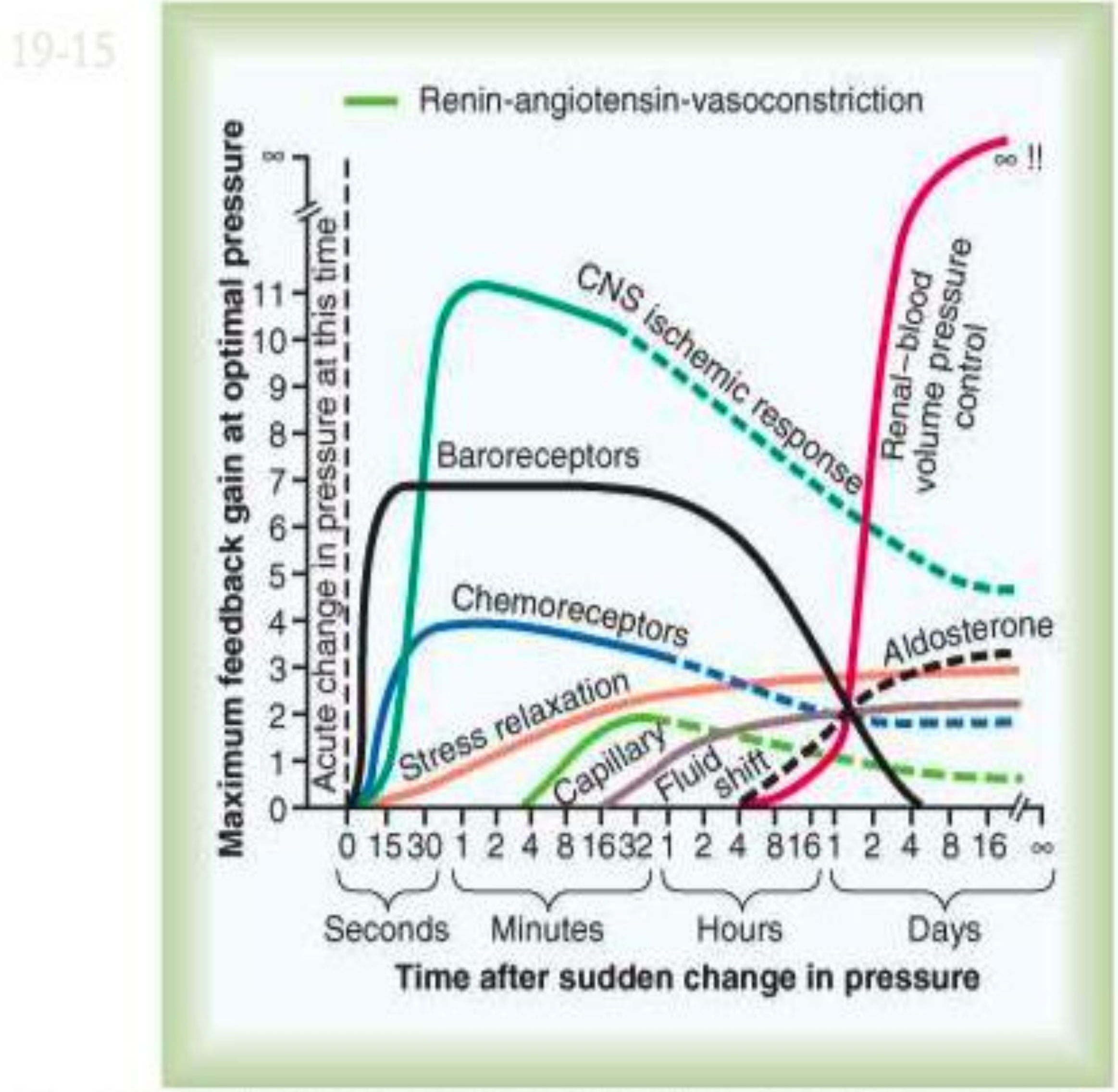
High BP Leads to:

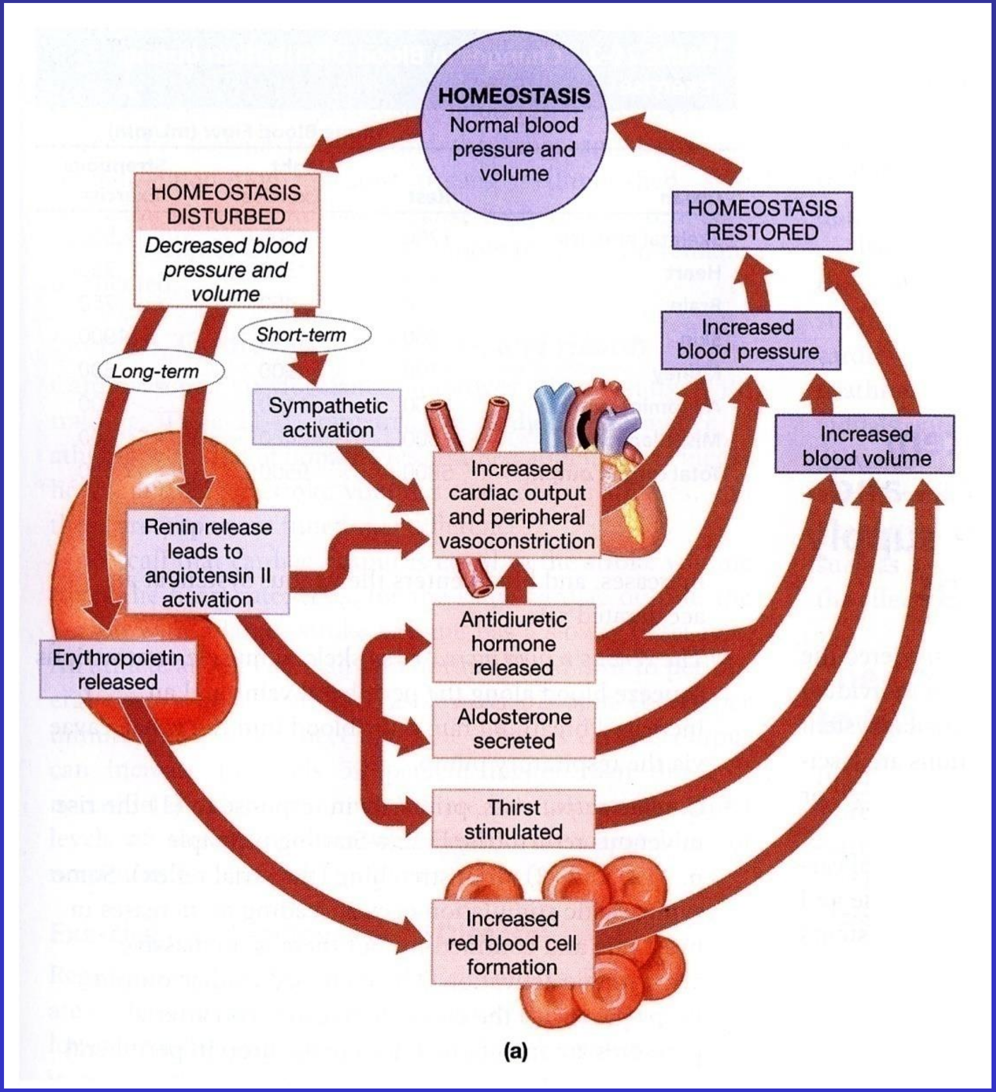
1- ↓ Antidiuretic hormone (ADH) secretion.
2- ↓ Angiotensin II hormone secretion
3- ↓ Aldosterone hormone secretion
4- ↓ Erythropoietin hormone secretion.
5- ↑ Atrial natriuretic peptides (ANP) hormone secretion.

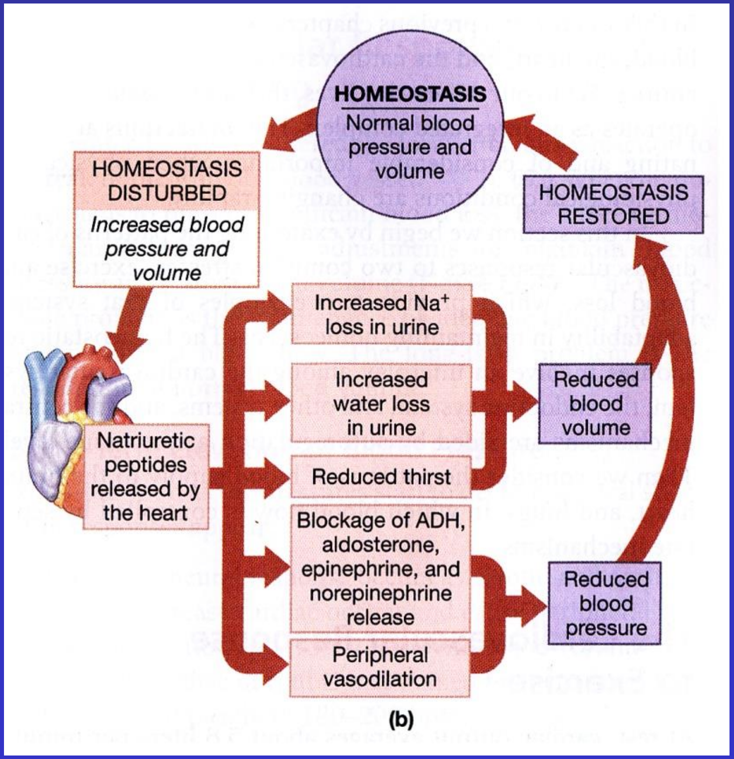
Low BP Leads to:

1- ↑ Antidiuretic hormone (ADH) secretion.
2- ↑ Aldosterone hormone secretion
3- ↑ Angiotensin II hormone secretion .
4- ↓ Natriuretic peptides (ANP) hormone secretion
5- ↑ Erythropoietin hormone secretion → ↑ RBCS, take few days.

Summary of Arterial Pressure Regulation







The Hormonal Regulation of Blood Pressure and Blood Volume. Shown are factors that compensate for (a) decreased blood pressure and volume and for (b) increased blood pressure and volume.