Vascular Physiology

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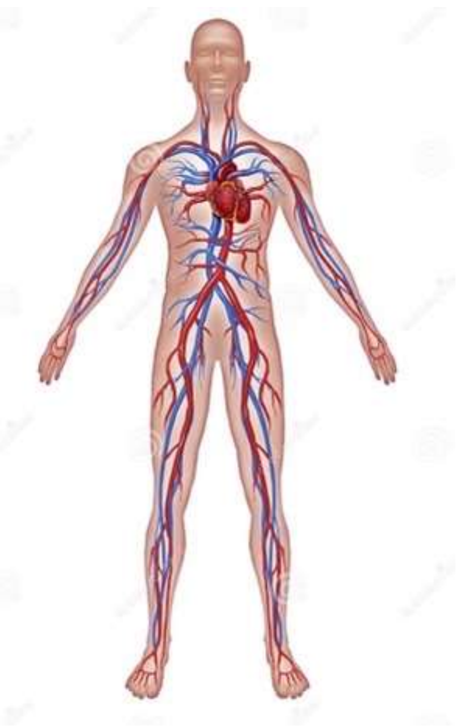
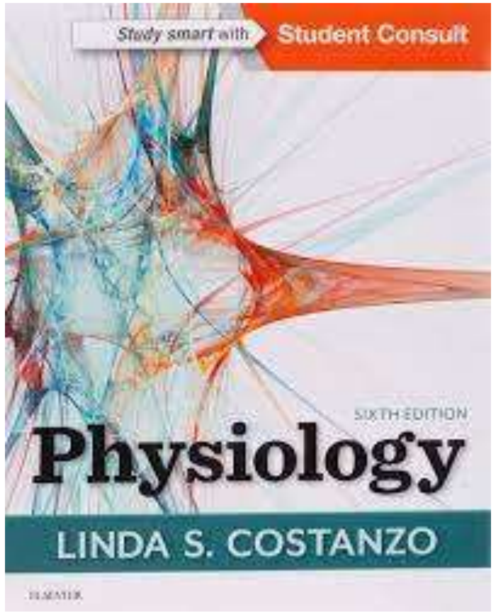


References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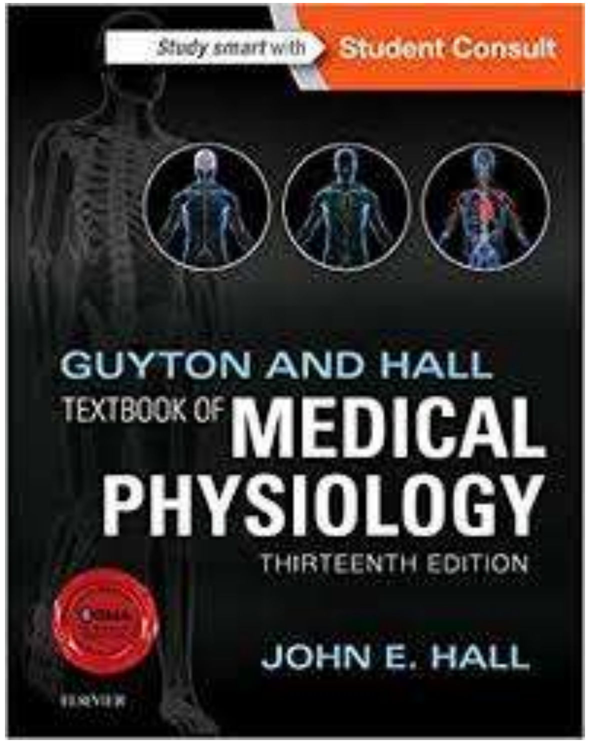
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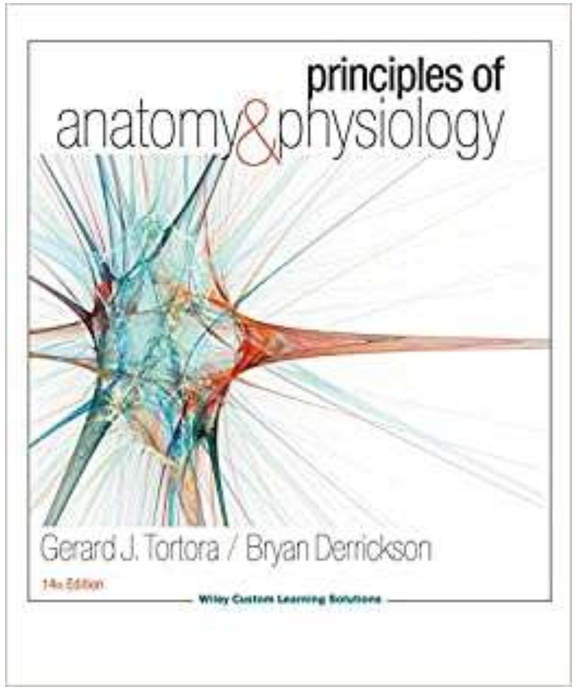
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Nervous regulation of the circulation

Nervous regulation of the circulation

- The innervation of the small arteries and arterioles allows sympathetic stimulation to increase resistance to blood flow and thereby decrease the rate of blood flow through the tissues.
- The innervation of the large vessels, particularly of the veins, makes it possible for sympathetic stimulation to decrease the volume of these vessels. This decrease in volume can push blood into the heart and thereby plays a major role in regulation of heart pumping.

Nervous regulation of the circulation

- sympathetic stimulation markedly increases the activity of the heart, both increasing the heart rate and enhancing its strength and volume of pumping.
- parasympathetic stimulation causes a marked decrease in heart rate and a slight decrease in heart muscle contractility.
- This sympathetic vasoconstrictor effect is especially powerful in the kidneys, intestines, spleen, and skin but is much less potent in skeletal muscle, heart, and the brain.

Why ABP need to be regulated

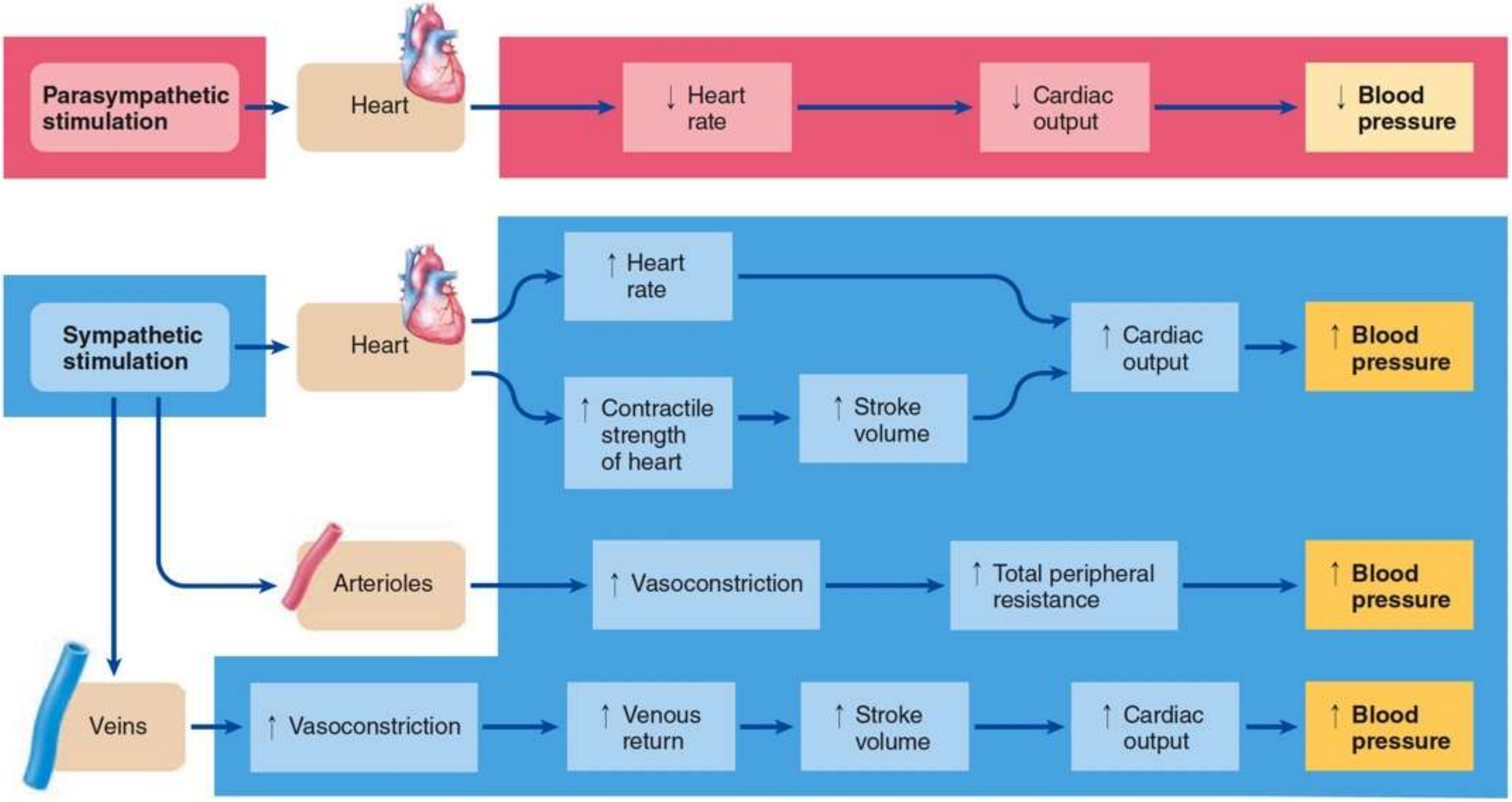
- Mean arterial pressure is the main driving force for propelling blood to the tissues. This pressure must be closely regulated for two reasons.
- First, it must be high enough to ensure sufficient driving pressure; without this pressure, the brain and other organs do not receive adequate flow, no matter what local adjustments are made in the resistance of the arterioles supplying them.
- Second, the pressure must not be so high that it creates extra work for the heart and increases the risk of vascular damage and possible rupture of small blood vessels.

Rapid control of arterial pressure by nervous system

- Three major changes occur due to sympathetic stimulation, each of which helps increase arterial pressure:
- 1. Most arterioles of the systemic circulation are constricted, which greatly increases TPR, thereby increasing the arterial P.
- 2. The veins are strongly constricted. This constriction displaces blood out of the large peripheral blood vessels toward the heart, thus increasing the volume of blood in the heart chambers.

Rapid control of arterial pressure by nervous system

- The heart is directly stimulated by the autonomic nervous system, further enhancing cardiac pumping.
- Much of this enhanced cardiac pumping is caused by an increase in the heart rate.
- In addition, sympathetic nervous signals directly increase the contractile force of the heart muscle, increasing the capability of the heart to pump larger volumes of blood.



Parasympathetic stimulation
Heart
↓ Heart rate
↓ Cardiac output
↓ Blood pressure
Sympathetic stimulation
Heart
↑ Heart rate
↑ Contractile strength of heart
↑ Stroke volume
↑ Cardiac output
↑ Blood pressure
Arterioles
↑ Vasoconstriction
↑ Total peripheral resistance
↑ Blood pressure
Veins
↑ Vasoconstriction
↑ Venous return
↑ Stroke volume
↑ Cardiac output
↑ Blood pressure

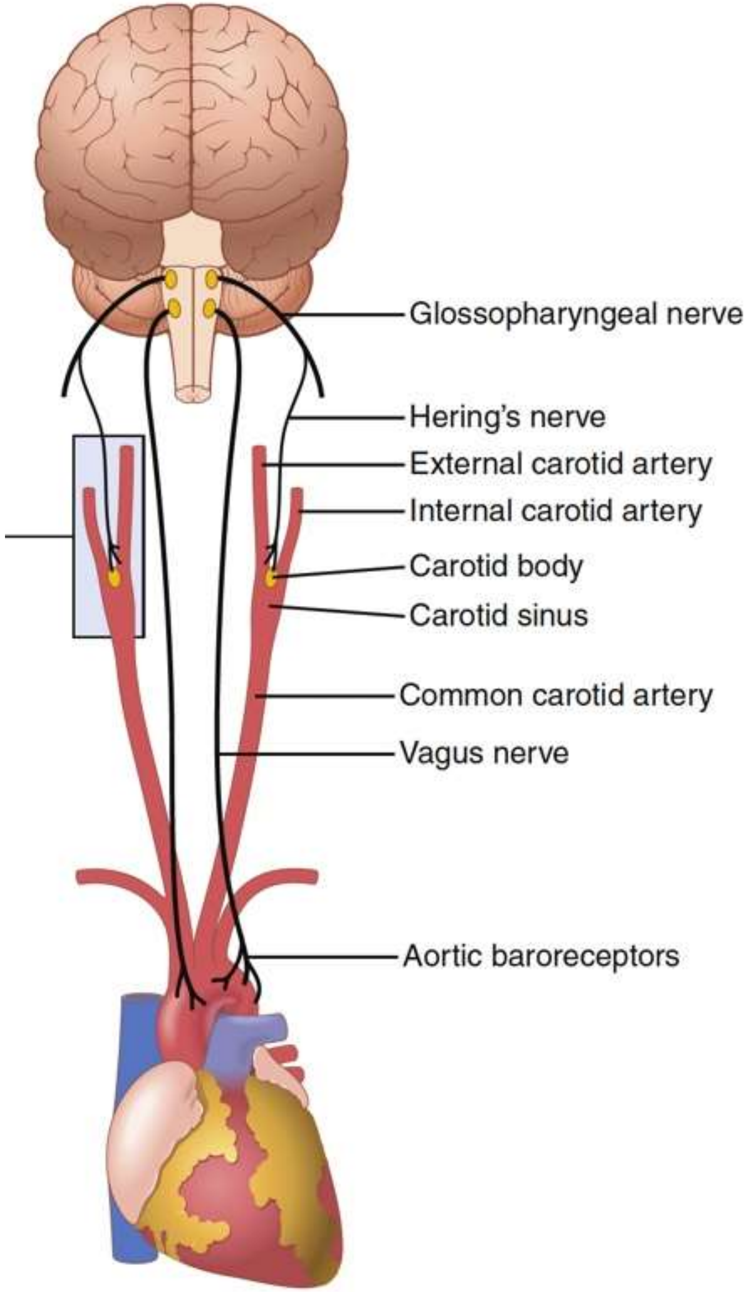
Baroreceptor reflex

- blood pressure is sensed by baroreceptors in the carotid sinus and aortic arch.
- Afferent information about blood pressure is then sent to the medulla via the glossopharyngeal and vagus nerves.
- This information is integrated in the nucleus tractus solitarius, which then directs changes in the activity of several cardiovascular centers.
- These cardiovascular centers are tonically active, and the nucleus tractus solitarius simply directs, via the centers, increases or decreases in outflow from the sympathetic and parasympathetic nervous systems.

Baroreceptor reflex

- A rise in arterial pressure stretches the baroreceptors and causes them to transmit signals into the CNS.
- Feedback signals are then sent back through the autonomic nervous system to the circulation to reduce arterial pressure down toward the normal level.

- in the normal operating range of arterial pressure, around 100 mm Hg, even a slight change in pressure causes a strong change in the baroreflex signal to readjust arterial pressure back toward normal. Thus, the baroreceptor feedback mechanism functions most effectively in the pressure range where it is most needed


Glossopharyngeal nerve
Hering's nerve
External carotid artery
Internal carotid artery
Carotid body
Carotid sinus
Common carotid artery
Vagus nerve
Aortic baroreceptors

Baroreceptor reflex

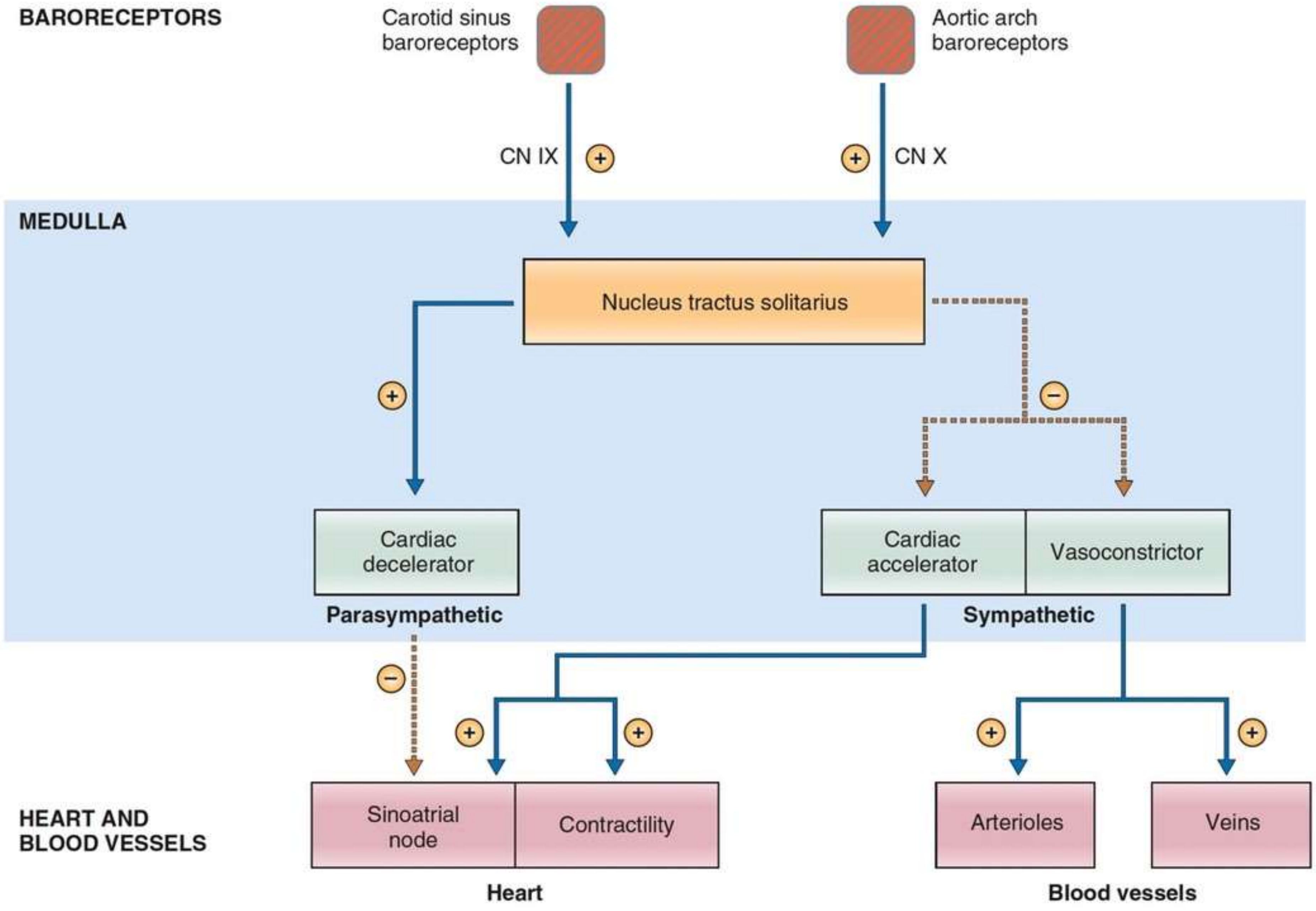
- Although the baroreceptors are sensitive to the absolute level of pressure, they are even more sensitive to changes in pressure and the rate of change of pressure.
- The strongest stimulus for the baroreceptors is a rapid change in arterial pressure.
- That is, if the mean arterial pressure is 150 mm Hg but at that moment is rising rapidly, the rate of impulse transmission may be as much as twice that when the pressure is stationary at 150 mm Hg.

Baroreceptor reflex

- Pressure buffer system:
- A primary purpose of the arterial baroreceptor system is therefore to reduce the minute by minute variation in arterial pressure to about one-third that which would occur if the baroreceptor system were not present.
- the extreme variability of pressure caused by simple events of the day, such as lying down, standing, excitement, eating, defecation, and noises is minimized.
- when the baroreceptors are functioning normally, the mean arterial pressure remains within a narrow range.

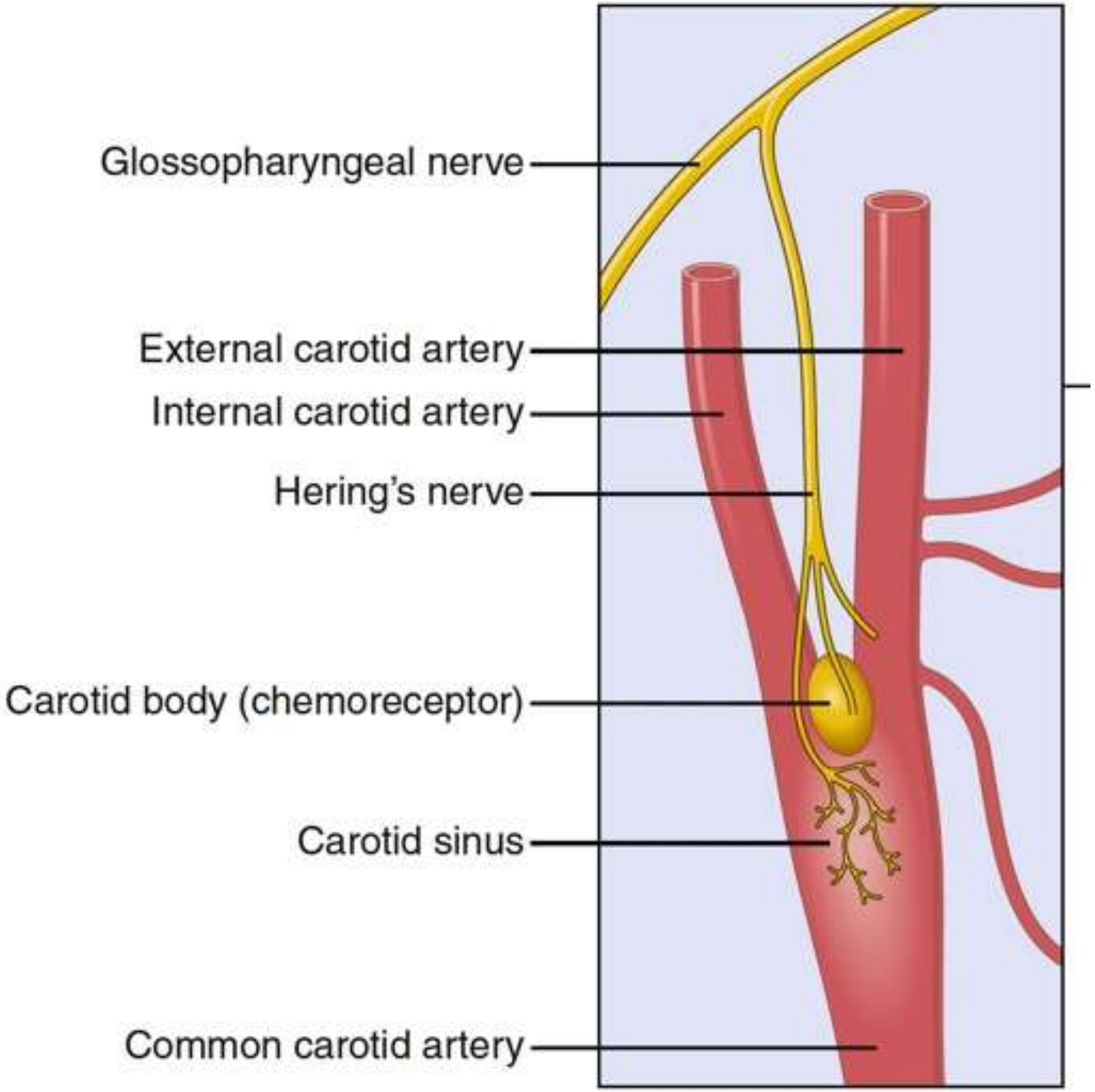
Baroreceptor reflex

- relatively unimportant in chronic regulation of arterial pressure is that they tend to reset in 1 to 2 days to the pressure level to which they are exposed.


BARORECEPTORS
Carotid sinus baroreceptors
Aortic arch baroreceptors
CN IX
+
+
CN X
MEDULLA
Nucleus tractus solitarius
+
−
Cardiac decelerator
Parasympathetic
Cardiac accelerator
Vasoconstrictor
Sympathetic
−
+
+
+
+
HEART AND BLOOD VESSELS
Sinoatrial node
Contractility
Heart
Arterioles
Veins
Blood vessels

Chemoreceptor reflex

- Chemoreceptor organs: carotid bodies and aortic bodies.
- Sensitive to low O_2 or elevated CO_2 and H^+.
- The signals transmitted from the chemoreceptors excite the cardiovascular center, and this response elevates the arterial pressure back toward normal.
- However, this chemoreceptor reflex is not a powerful arterial pressure controller until the arterial pressure falls below 80 mm Hg. Therefore, it is at the lower pressures that this reflex becomes important to help prevent further decreases in arterial pressure.



Glossopharyngeal nerve
External carotid artery
Internal carotid artery
Hering's nerve
Carotid body (chemoreceptor)
Carotid sinus
Common carotid artery

Central chemoreceptors

- Central chemoreceptors are located in the medulla. They are most sensitive to CO_2 and pH and less sensitive to O_2.
- If the brain becomes ischemic (i.e., there is decreased cerebral blood flow), cerebral PCO_2 immediately increases and pH decreases. The medullary chemoreceptors detect these changes and direct an increase in sympathetic outflow that causes intense arteriolar vasoconstriction in many vascular beds and an increase in TPR. Blood flow is thereby redirected to the brain to maintain its perfusion. As a result of this vasoconstriction, BP increases dramatically, even to life-threatening levels.

CNS ischemic response

- Despite the powerful nature of the CNS ischemic response, it does not become significant until the arterial pressure falls far below normal, down to 60 mm Hg and below, reaching its greatest degree of stimulation at a pressure of 15 to 20 mm Hg.
- Therefore, the CNS ischemic response is not one of the normal mechanisms for regulating arterial pressure.
- Instead, it operates principally as an emergency pressure control system that acts rapidly and powerfully to prevent further decrease in arterial pressure whenever blood flow to the brain decreases dangerously close to the lethal level.
- It is sometimes called the last-ditch stand pressure control mechanism.

Cushing reaction

- The Cushing reaction illustrates the role of the cerebral chemoreceptors in maintaining cerebral blood flow. When intracranial pressure increases (e.g., tumors, head injury), there is compression of cerebral arteries, which results in decreased perfusion of the brain. There is an immediate increase in PCO_2 and a decrease in pH because CO_2 generated from brain tissue is not adequately removed by blood flow. The medullary chemoreceptors respond to these changes in PCO_2 and pH by directing an increase in sympathetic outflow to the blood vessels. Again, the overall effect of these changes is to increase TPR and dramatically increase P.

Atrial and pulmonary artery reflexes

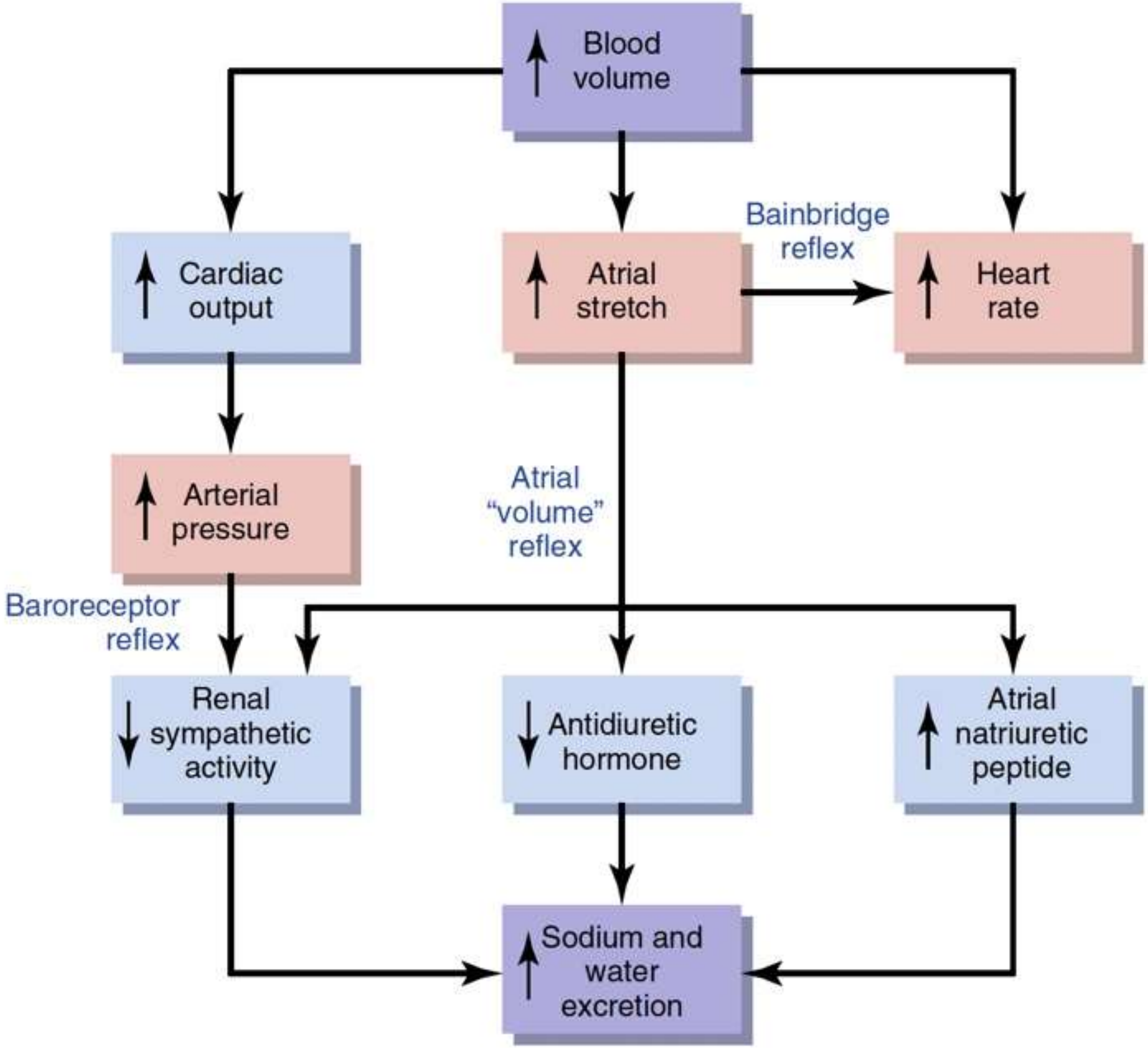
- The atria and pulmonary arteries have stretch receptors in their walls called low-pressure receptors.
- Low-pressure receptors are similar to the baroreceptor stretch receptors of the large systemic arteries.
- These low-pressure receptors play an important role, especially in minimizing arterial pressure changes in response to changes in blood volume.

Atrial reflexes

- Stretch of the atria and activation of low-pressure atrial receptors cause an increase in glomerular filtration and a decrease in reabsorption of the fluid (decreases ADH), consequently increases fluid loss by the kidneys and attenuates the increased blood volume.
- Atrial stretch caused by increased blood volume also elicits release of atrial natriuretic peptide (ANP), a hormone that adds further to the excretion of sodium and water in the urine and return of blood volume toward normal.

Bainbridge reflex

- Increases in atrial pressure sometimes increase the heart rate particularly when the prevailing heart rate is slow.


↑ Blood volume
↑ Cardiac output
↑ Atrial stretch
Bainbridge reflex
↑ Heart rate
↑ Arterial pressure
Atrial "volume" reflex
Baroreceptor reflex
↓ Renal sympathetic activity
↓ Antidiuretic hormone
↑ Atrial natriuretic peptide
↑ Sodium and water excretion

Thank you