Physiology 1A

Control of the Cardiovascular System

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From this lecture you should:

- Understand the role of the autonomic nervous system in controlling the cardiovascular system.
- Know the mechanism of the baroreceptor reflex in controlling blood pressure
- Appreciate the role of low-pressure baroreceptors in blood pressure maintenance
- Understand that long-term maintenance of blood pressure involves regulation of blood volume, and the kidneys are vital in this role
- Reference: Stanfield 5th ed. Ch. 14 pp. 419 - 427

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Blood pressure

'Vital sign'.
Too low - inadequate perfusion of tissues/organs
Too high - strain, damage to heart, vessels

BP = CO x TPR (Total peripheral resistance)
=120 / 80 mmHg (systolic / diastolic)

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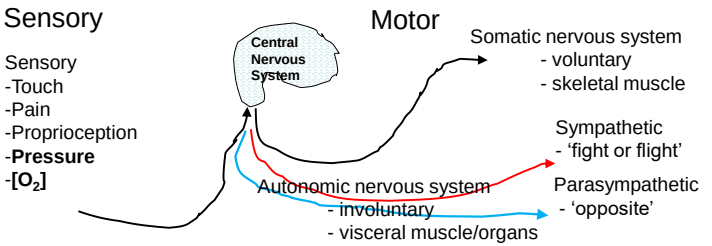
Blood pressure requires careful maintenance and blood flow needs to be directed to where it is needed.
How may flow be changed?

<u>Autonomic Nervous System</u> is main controller.



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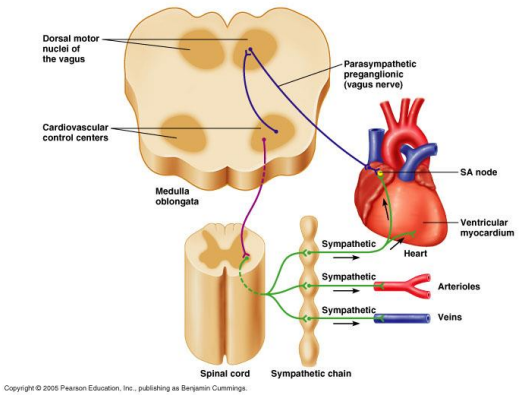
Sympathetic nerves are more heavily involved in cardiovascular control than parasympathetic.



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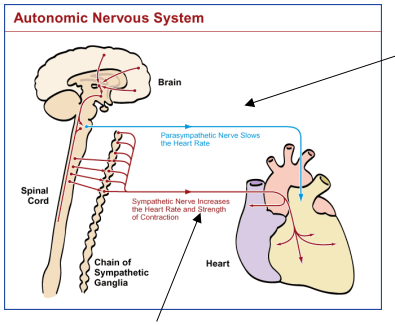

<u>Parasympathetic innervation of heart.</u>

Xth cranial nerve (vagus)

Innervate atria, primarily

Slows heart rate (bradycardia).

Predominant influence under resting conditions

<u>Sympathetic innervation of heart.</u>

Cardiac accelerator nerves (thoracic). Innervate atria and ventricles

Increases heart rate (tachycardia) and force (positive inotropic).

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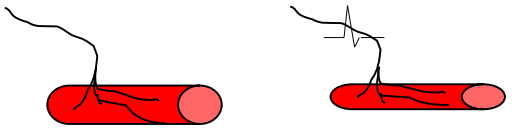

Sympathetic nerve activation causes (mostly) constriction of blood vessels.
- arteries, arterioles and veins
- <u>not</u> capillaries (not innervated)

Vessels are innervated to different extent in different tissues:
High: kidney, GIT, spleen, skin
Low: skeletal muscle, brain

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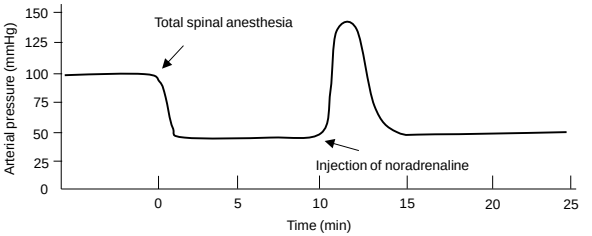
Constant sympathetic nerve activity keeps vessels partially constricted.

Contributes to vascular tone: <u>vasomotor tone</u>

- pressure maintenance

- dilator capacity



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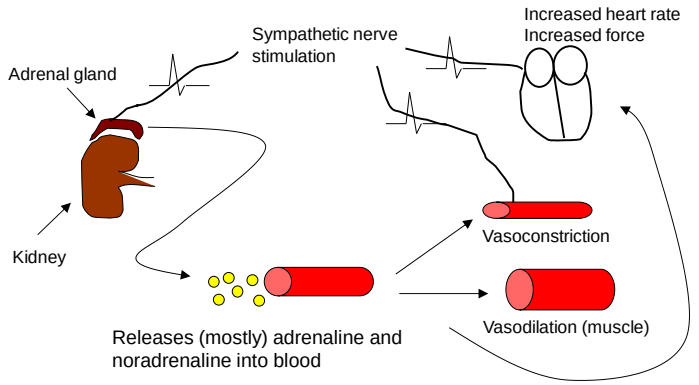
Adrenal medulla stimulation



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Sympathetic nerve stimulation <u>simultaneously:</u>

- constricts arterioles
  increased resistance, blood pressure

- constricts veins
  increased venous return, cardiac output

- increases heart rate and force
  increased cardiac output, blood pressure

Greatly increased velocity of flow through system

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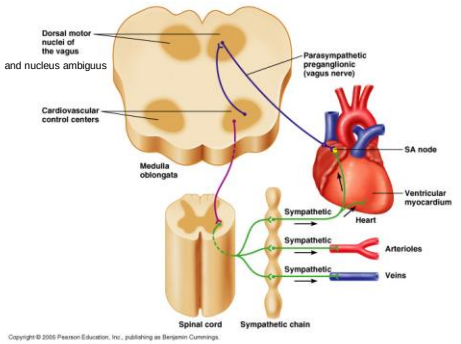
Control of cardiovascular autonomic nerve activity

Cardiovascular control area in brain stem (medulla)



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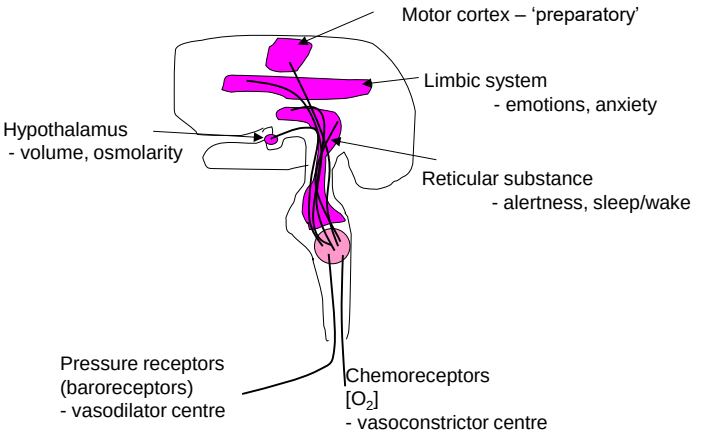
Sensory afferents into cardiovascular centre



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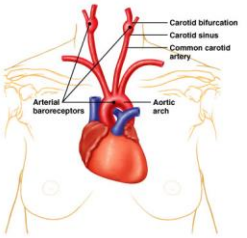
Control of blood pressure: Baroreceptor reflex

Moment-to-moment control of blood pressure is mediated by arterial baroreceptors (pressure receptors).

Arterial baroreceptors have two locations:
Aortic arch
Carotid sinuses



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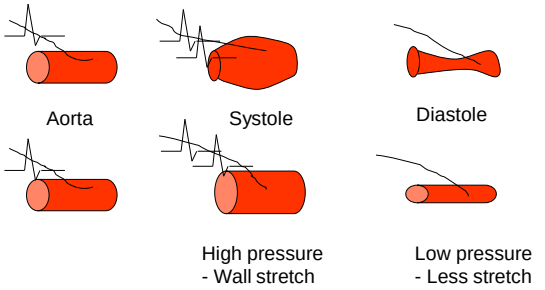
Baroreceptors sense pressure within vessels by stretch of vessel wall.

- Pulse pressure
- Static pressure



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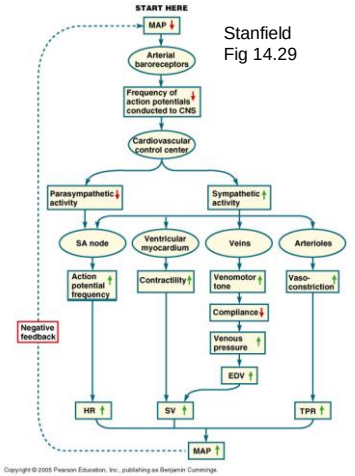
Baroreceptor reflex is a negative feedback loop.

Because baroreceptors are tonically active, decrease in blood pressure produces opposite effect.



Stanfield
Fig 14.29

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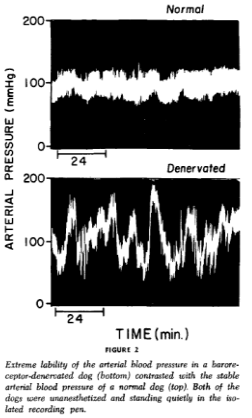

FIGURE 2

Extreme lability of the arterial blood pressure in a baroreceptor-denervated dog (bottom) contrasted with the stable arterial blood pressure of a normal dog (top). Both of the dogs were unanesthetized and standing quietly in the isolated recording pen.

Baroreceptor reflex is for moment-to-moment control:
Postural effects
Intra-thoracic pressure

Not important for long-term control (volume)

Cowley, Liard & Guyton, 1973
Circ. Res. 32, 564-578

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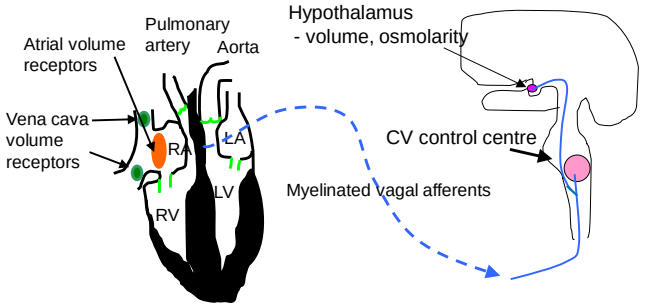
Atrial baroreceptors

Also stretch-sensitive
– <u>volume</u> receptors (low-pressure baroreceptors)



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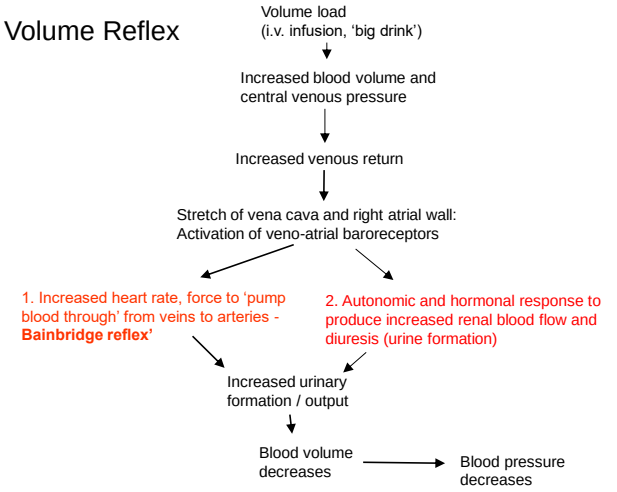
The Volume Reflex



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Long-term control of blood pressure

Accomplished by blood volume regulation.
Number of mechanisms involved.
<u>Kidneys</u> are vital in this role.

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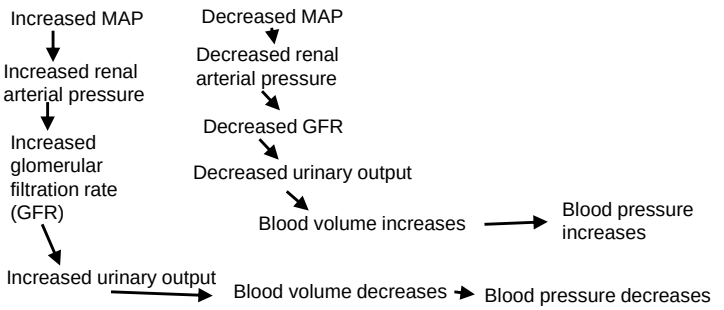
1.<u>Pressure diuresis and natriuresis</u>

Changes in mean arterial blood pressure (MAP) alone cause changes in urinary output (water and Na^+).



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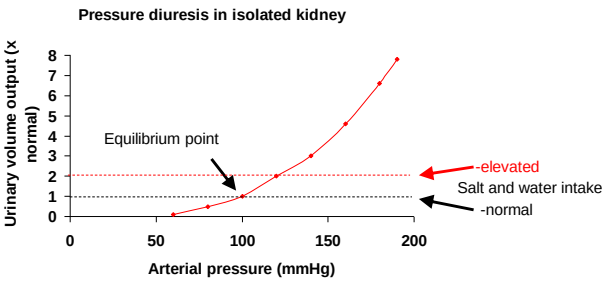

Assumes: constant renal output of salt and water
constant water and salt intake

Increased water/salt intake – elevated pressure (temporary?)

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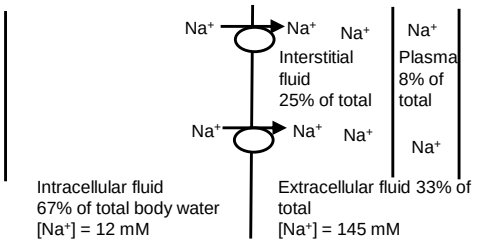
2. Natriuresis (Na^+ excretion)

More difficult to excrete salt by pressure alone. Na^+ accumulation causes increase in extracellular fluid volume and blood pressure:



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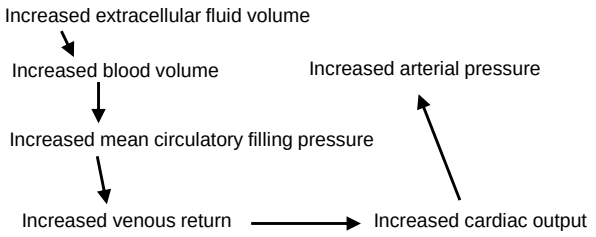
Increased extracellular fluid volume increases blood pressure by increasing plasma volume and cardiac output.



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Salt may be excreted by:

Increasing water intake (thirst)

Anti-diuretic hormone or *vasopressin* (pituitary gland)

- re-absorb water, concentrates urine
- constricts arteries, increasing MAP – pressure diuresis

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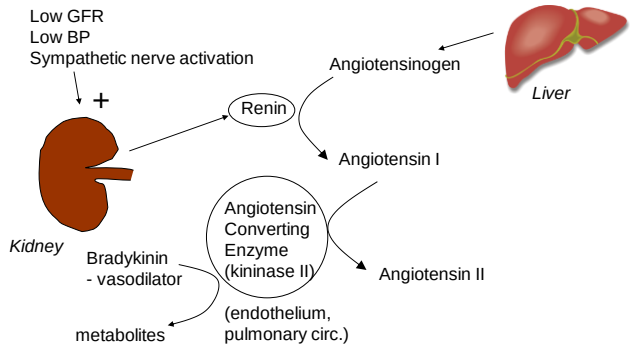
3. Renin-angiotensin system

Kidney acts to combat falls in blood pressure through a hormonal mechanism.



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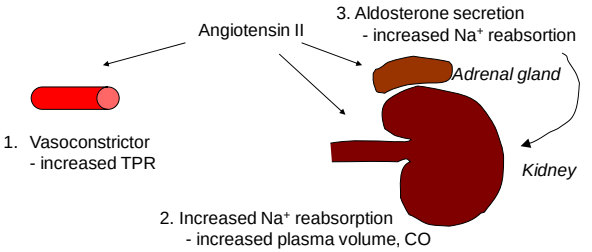

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Target organ or tissue	Neural or hormonal factor	Factor's effect on target	Influence on mean arterial pressure
Heart - SA node	Sympathetic nerves	↑HR	↑MAP
	Parasympathetic nerves	↓HR	↓MAP
	Adrenaline (Epinephrine)	↑HR	↑MAP
Heart - ventricular myocardium	Sympathetic nerves	↑Contractility (↑SV)	↑MAP
	Adrenaline	↑Contractility (↑SV)	↑MAP
Arteriolar smooth muscle	Sympathetic nerves	Vasoconstriction	↑MAP
	Adrenaline	Vasoconstriction or vasodilation, depending on concentration and location	Variable (↑SBP, DBP no change or ↓)
	Vasopressin	Vasoconstriction (↑TPR)	↑ MAP
	Angiotensin II	Vasoconstriction (↑TPR)	↑MAP
Venous smooth muscle	Sympathetic nerves	↑Venomotor tone	↑MAP
	Adrenaline	↑Venous tone	↑MAP

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Summary

- The autonomic nervous system is the main modulator of the cardiovascular system. Sympathetic nerves increase heart rate and force, increasing cardiac output, and constrict (most) blood vessels. Parasympathetic nerves reduce heart rate, reducing cardiac output
- Baroreceptors, located in the aortic arch and carotid bodies, are stimulated by an increase in blood pressure. They cause a reflex slowing of heart rate and reduced sympathetic nerve activity to blood vessels.
- Low-pressure baroreceptors located in the vena cavae and right atrium are activated by an increase in blood volume; they act to decrease blood volume by increasing water loss through the kidney.
- Long-term increases in blood pressure are opposed by a reduction in blood volume, through diuresis and natriuresis; the renin-angiotensin system acts to increase blood volume and peripheral resistance should blood pressure fall.

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