

INTRODUCTION

A. Define: Circulation regulation refers to the ability of the cardiovascular system to adjust cardiac output and blood flow distribution to meet the needs of the body

B. Levels of Regulation

1. Inherent regulation: inherent responses of cardiac muscle and peripheral blood vessels to local stimuli
2. CNS-Endocrine Reflex regulation: regulation involving CNS and endocrine responses to
 - a. maintain systemic arterial pressure
 - b. maintain circulating blood volume
 - c. maintain blood gas concentrations (O₂ & CO₂)
3. Higher CNS-Endocrine control: more complicated regulation, involving
 - a. integration with other organ systems
 - b. learned (conditioned) responses
 - c. emotional and similar responses

INHERENT REGULATION: CARDIAC MECHANISMS

A. Myocardial Contraction Energy-Diastolic Filling Relation (Starling's Law of the Heart; sometimes called Frank-Starling Law or pre-load effect)

STARLING'S LAW OF THE HEART: The larger the ventricle just before contraction begins (end-diastolic volume, EDV), the greater the energy of contraction

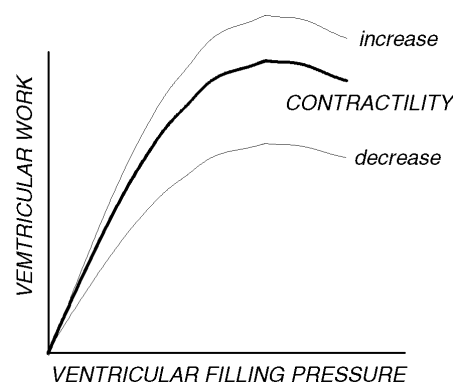
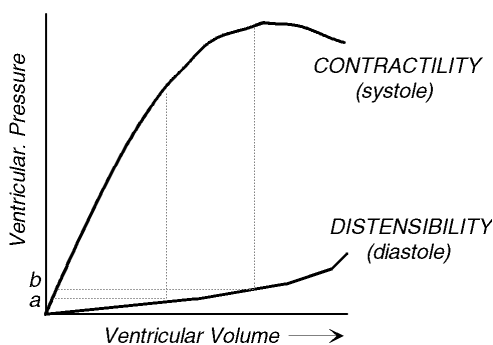
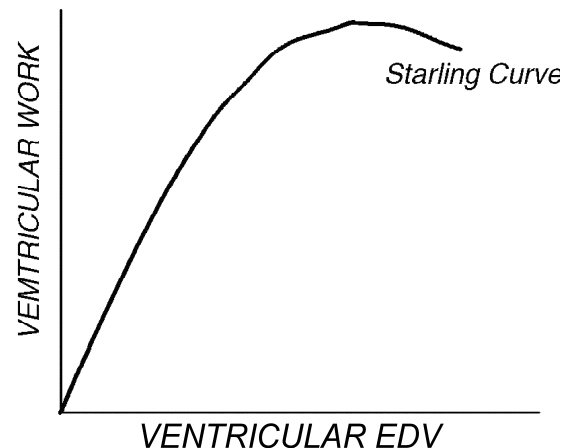
Reasons: (1) the greater efficiency of cardiac contraction at larger volumes is a reflection of the length-tension curve of cardiac muscle, and (2) increased effectiveness of Ca ion on contraction

Note: When the ventricular volume becomes very large, cardiac efficiency begins to decrease (decompensation)

Note: Starling's law can also be plotted as Cardiac Work against Ventricular Filling Pressure or as Maximum Ventricular Pressure against Ventricular Volume. All three types of plots are called Starling's Curves or Contractility curves.

Contractility: curve of maximum ventricular pressure vs. ventricular volume or ventricular filling pressure in systole

Distensibility: curve of ventricular pressure vs. ventricular volume in diastole



INHERENT REGULATION: CARDIAC MECHANISMS (continued)

A. Myocardial Contraction Energy-Diastolic Filling Relation (continued)

Utility

1. Enables to heart to adjust SV (stroke volume) to varying rates of venous return (the rate at which blood returns to the heart from veins); example: increase in exercise, decrease in resting)
2. Limits the reduction in cardiac output in heart failure (until decompensation is reached)

Limitations

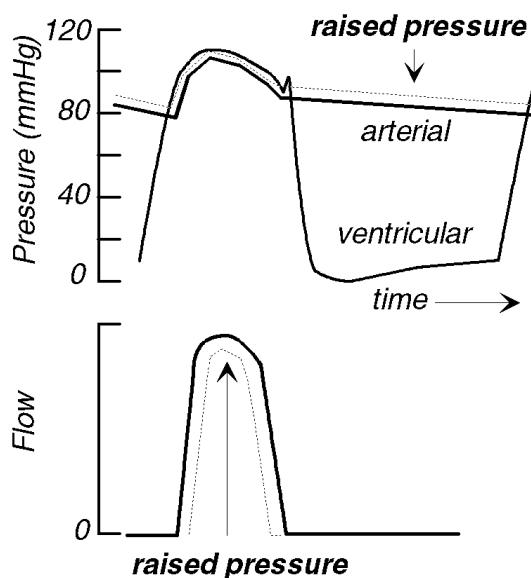
1. Requires an increase in venous pressure, which may lead to edema
2. Only utilizes increase filling to maintain cardiac output; does not utilize increase heart rate or cardiac contractility

B. Cardiac Response to Arterial Pressure Change (After-Load effect)

The higher the arterial pressure, the less the stroke volume; the lower the arterial pressure, the higher the stroke volume

Reasons

- a. The higher the arterial pressure, the later the aortic valve opens and the earlier it closes
- b. The higher the arterial pressure, the more energy the ventricular myocardium must expend in developing force so the less energy it has available for ejecting blood



Utility

1. Enables to heart to adjust SV (stroke volume) to maintain arterial pressure
2. Limits the reduction in cardiac output in heart failure (until decompensation is reached)

Limitations

1. Requires a change in arterial pressure, which may compromise organ perfusion
2. Only utilizes decrease arterial pressure to maintain cardiac output; does not utilize increase heart rate or cardiac contractility

INHERENT REGULATION (continued)

B. Peripheral Mechanisms

1. local vasomotor responses
 - a. response to local concentrations of metabolites
 - b. release of local vasomotor agents
 - c. changes in resistance with pressure
2. local mechanical effects
 - a. muscle pump
 - b. respiratory pump

Utility

1. Enables each vascular bed to adjust perfusion (blood flow) in accordance with its needs

Limitations

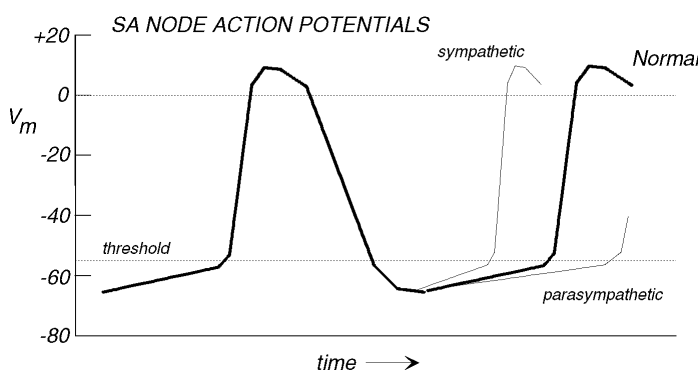
1. each vascular bed responds only to its own needs; no coordination with the needs of other vascular beds
2. in stressful situations, all systemic vascular beds that do not participate in the dilation have reduced blood flow due to the drop in systemic arterial pressure

CENTRAL NERVOUS SYSTEM REFLEXES

A. Motor Mechanisms

1. Heart (muscarinic receptors and beta-1 receptors)
 - a. variation in heart rate by balance between the parasympathetic and sympatho-adrenal systems acting on the cardiac pacemaker

Sympatho-Adrenal $\Rightarrow P_{Na} \ \& \ P_{Ca} \ \uparrow \Rightarrow$ Prepotential slope $\uparrow \Rightarrow$ Heart rate \uparrow
Parasympathetics $\Rightarrow P_K \ \uparrow \ \& \ P_{Ca} \ \downarrow \Rightarrow$ Prepotential slope $\downarrow \Rightarrow$ Heart rate \downarrow



- b. variation in cardiac contractility mediated by the action of the sympatho-adrenal system on cardiac ventricular muscle

Sympatho-Adrenal $\uparrow \Rightarrow P_{Ca} \ \uparrow \Rightarrow$ Contractility \uparrow
Sympatho-Adrenal $\downarrow \Rightarrow P_{Ca} \ \downarrow \Rightarrow$ Contractility \downarrow

Note: effect of calcium channel blockers is to reduce cardiac contractility and cardiac work by reducing the rate at which Ca enters the cell during systole

CENTRAL NERVOUS SYSTEM REFLEXES

A. Motor Mechanisms (continued)

Note: effect of cardiac glycosides (digitalis, digoxin) is to increase cardiac contractility by reducing the rate at which Ca is pumped out of the cell during diastole

Note: Parasympathetics have little effect on contractility

2. Peripheral resistance

- a. variation in arteriolar vasomotor tone by the sympatho-adrenal system
- b. often vasoconstrictor, but varies with vascular bed

B. CNS Centers (integration centers)

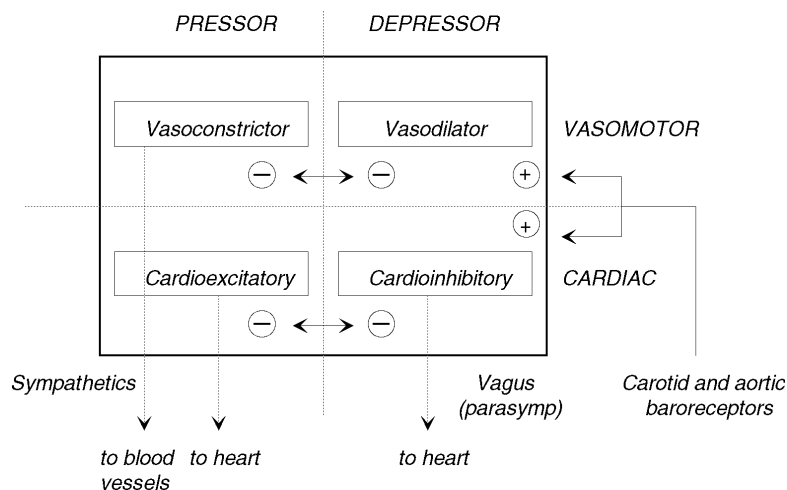
1. Located in the medulla of the brain

2. Cardiac centers

- a. two centers
 - 1) cardioexcitatory (or cardioaccelerator)
 - 2) cardioinhibitory (or cardiodecellerator)
- b. cardioexcitatory and cardioinhibitory centers are reciprocally innervated (mutually inhibitory)
- c. control autonomic outflow to the heart

3. Vasomotor centers

- a. two centers
 - 1) vasoconstrictor
 - 2) vasodilator
- b. vasoconstrictor and vasodilator centers are reciprocally innervated (mutually inhibitory)
- c. control sympatho-adrenal outflow to vascular smooth muscle



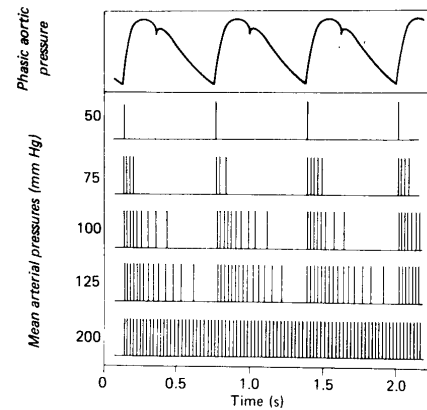
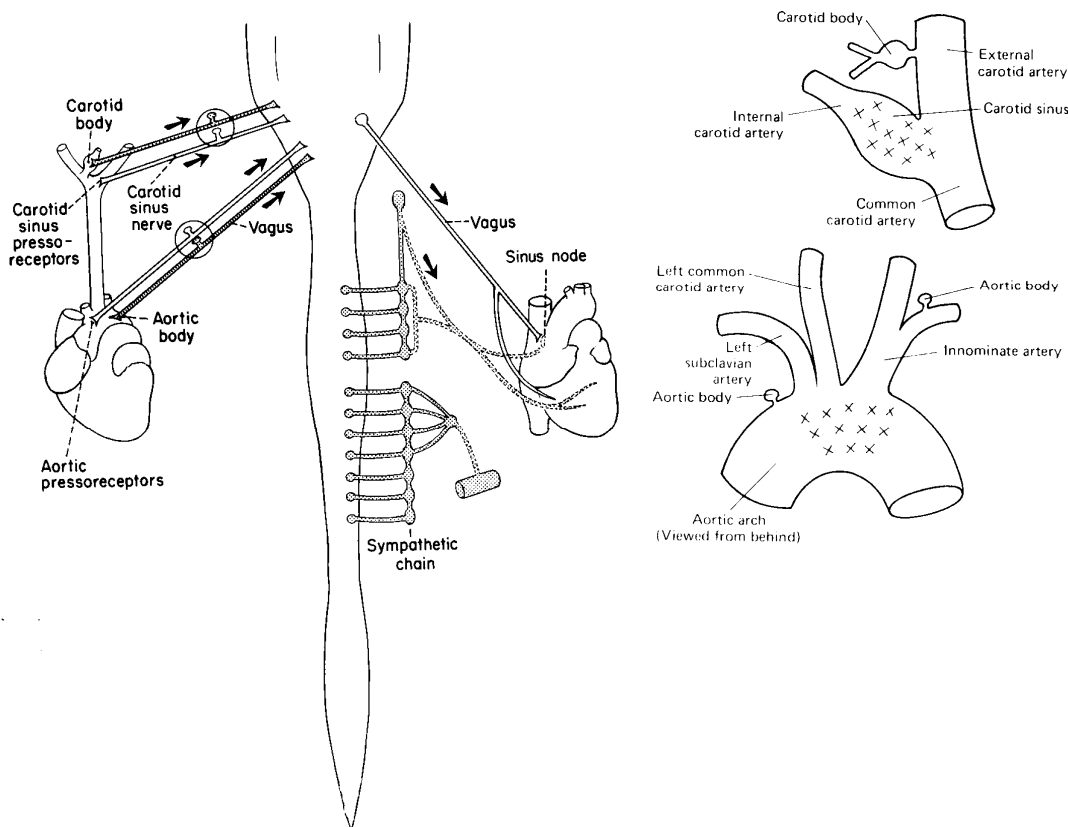
CENTRAL NERVOUS SYSTEM REFLEXES
(continued)

C. Afferent (sensory) Receptors

1. High pressure baroreceptors (pressoreceptor)
 - a. locations
 - 1) carotid sinus
 - 2) aortic arch
 - b. adequate stimulus
 - 1) systemic arterial pressure
 - 2) rate of change of systemic arterial pressure (adapting)
 - c. effect of stimulation
 - 1) activate medullary vasodilator center
 - 2) activate medullary cardioinhibitory center

Notes:

- (1) Because of reciprocal innervation, baroreceptor stimulation inhibits the vasoconstrictor and cardioexcitatory centers
- (2) The net effect of stimulation is to reduce systemic arterial blood pressure
- (3) Decreased pressure at the baroreceptors has the opposite effect to that of increased pressure

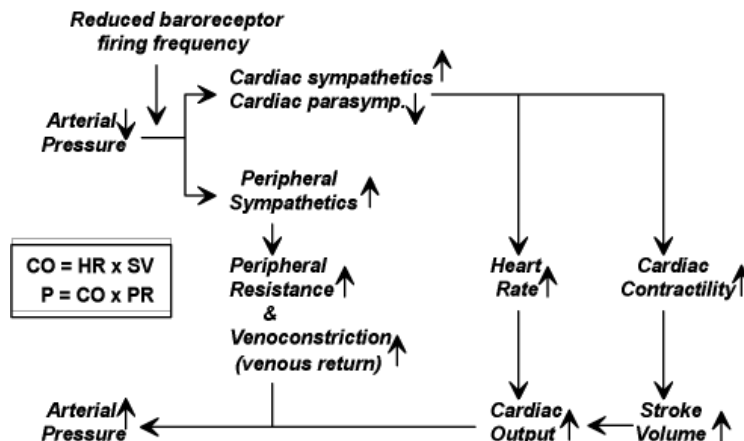


D. Role of High Pressure Baroreceptor Reflex

1. Stabilize systemic arterial blood pressure by negative feedback

Example of Baroreceptor Reflex: Compensation for spontaneous drop in blood pressure; example orthostatic (postural) hypotension

CENTRAL NERVOUS SYSTEM REFLEXES
(continued)



E. Limitation of High Pressure Baroreceptor Reflex

1. Because the reflex adapts, it is only responsible for short-term regulation; that is, it becomes less effective over time

OTHER CARDIOVASCULAR REFLEXES

A.. Low Pressure Baroreceptor Reflexes

1. receptor location: atria
2. reflex action: vasodilation and hypotension; affect renal function
3. role: regulate venous pressure and body fluid volume

Note: Will be covered with renal physiology

B. Chemoreceptor Reflexes

1. locations
 - a. peripheral receptors: carotid and aortic bodies
 - b. central integration: medulla
2. action

$O_2 \downarrow, CO_2 \uparrow, pH \downarrow \implies \text{cardiac output} \uparrow$

3. roles: adjust perfusion to body needs

Note: Chemoreceptor reflexes are more important in regulation of respiration than in regulation of the cardiovascular system and will be covered with the respiratory system

C. Other CNS Influences on Cardiovascular Centers

1. Pain
2. Emotion
3. Respiratory centers

ENDOCRINES ASSOCIATED WITH CV SYSTEM

- A. Renin-angiotensin-aldosterone system
- B. Atrial natriuretic hormone

Note: both of the above are very important in renal regulation and will be covered with that system