Veterinary Bioscience 1: Cardiovascular System

THE UNIVERSITY OF MELBOURNE

FACULTY OF VETERINARY SCIENCE

Lecture Thirteen

Week Three

Semester 2

Modulating Flow and the Baroreflex

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Modulating flow and pressure

- Micro control at the level of tissues
  - Myogenic response to stretch
  - Endothelium dependent response to flow
- Local at the level of the organ or tissue
  - Response to metabolic needs- metabolic hyperaemia
- Macro at the level of the organism- shared by organs- involving the baroreflex
    - Nerve pathways and hormones as mediators

Measures of Cardiovascular Performance

…The maintenance of a pressure gradient is critical to maintaining flow and perfusion of tissues

According to the basic flow equation:

$$\text{Flow (cardiac output)} = \frac{\text{pressure gradient}}{\text{Resistance}}$$

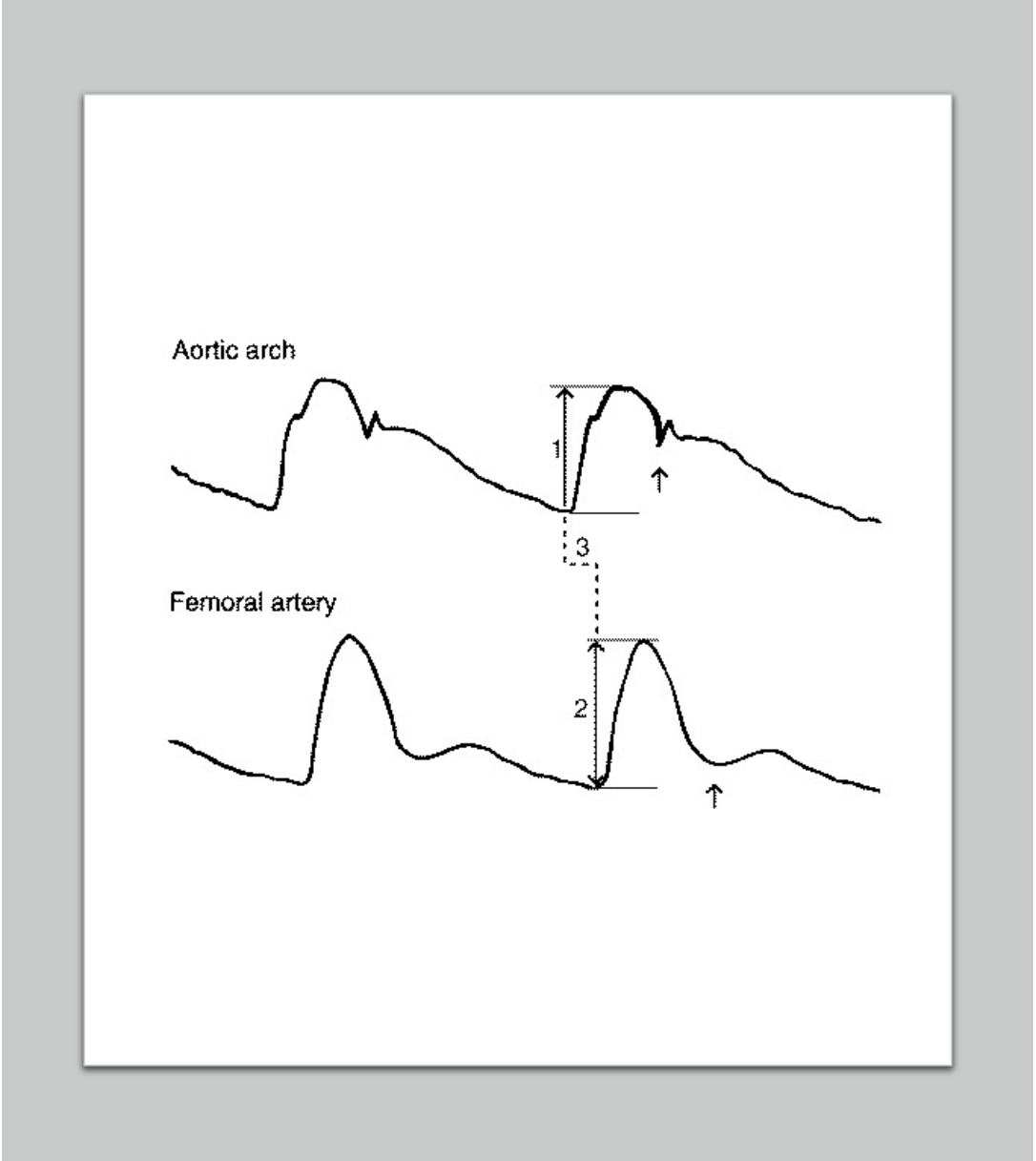
OR

Mean arterial pressure = Cardiac output X resistance

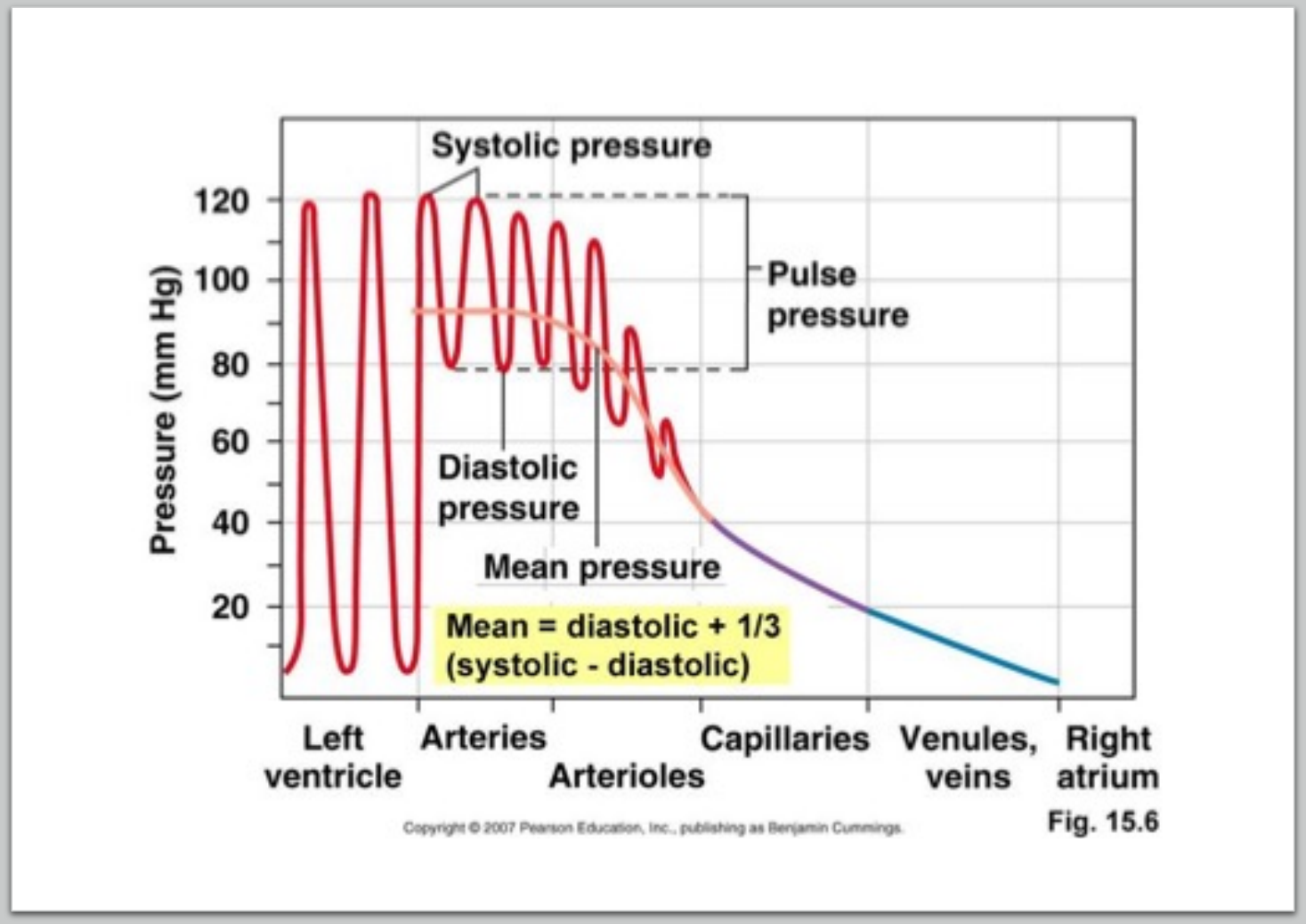
Pressure (mean arterial pressure) is maintained by modulating cardiac output and arteriolar resistance

Understanding flow and pressure…….

- MAP : Mean arterial pressure
  = Diastolic pressure + pulse pressure/3
- Systolic pressure: peak pressure as blood is ejected
- Diastolic pressure: pressure when aortic valve is closed

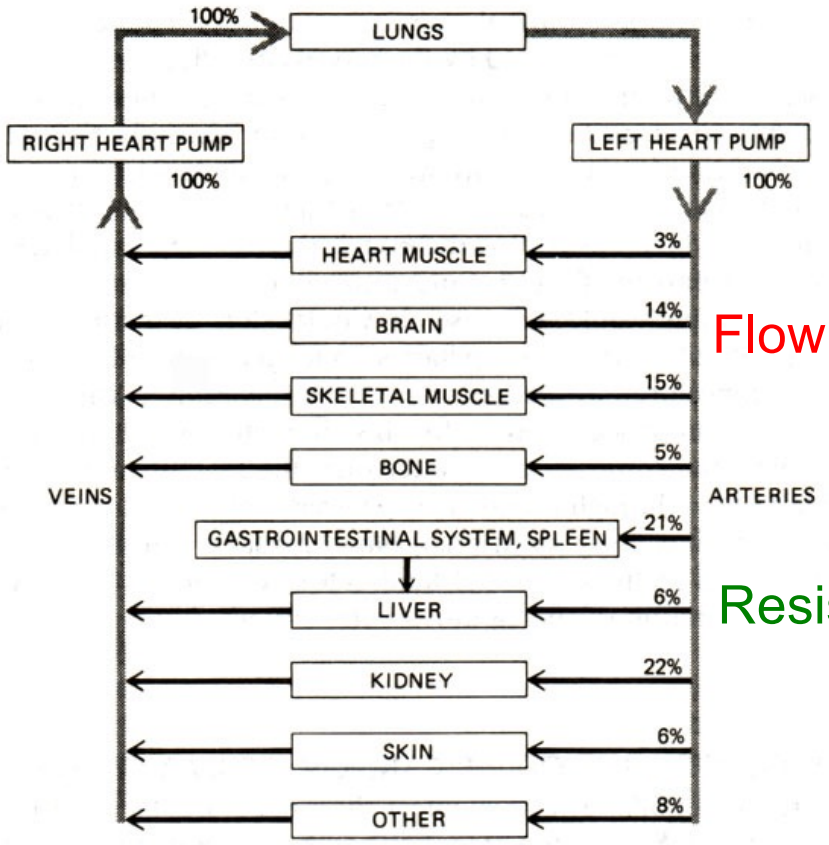


Pressure changes in the vascular tree



Measures of cardiovascular performance

0 mm Hg



100 mm Hg

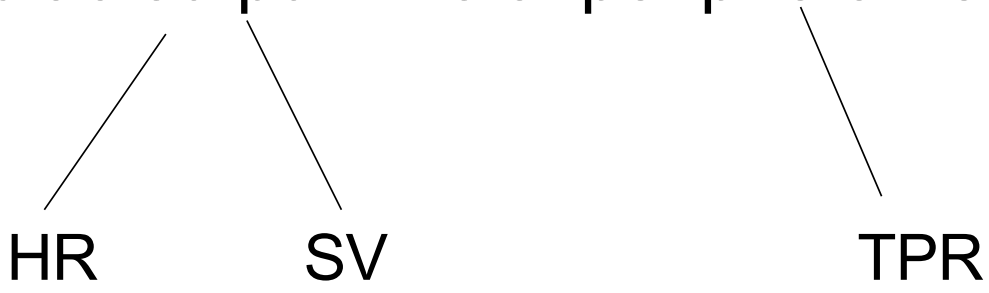
Flow α pressure gradient / resistance

Resistance

Understanding flow and pressure…….

- Mean arterial pressure =

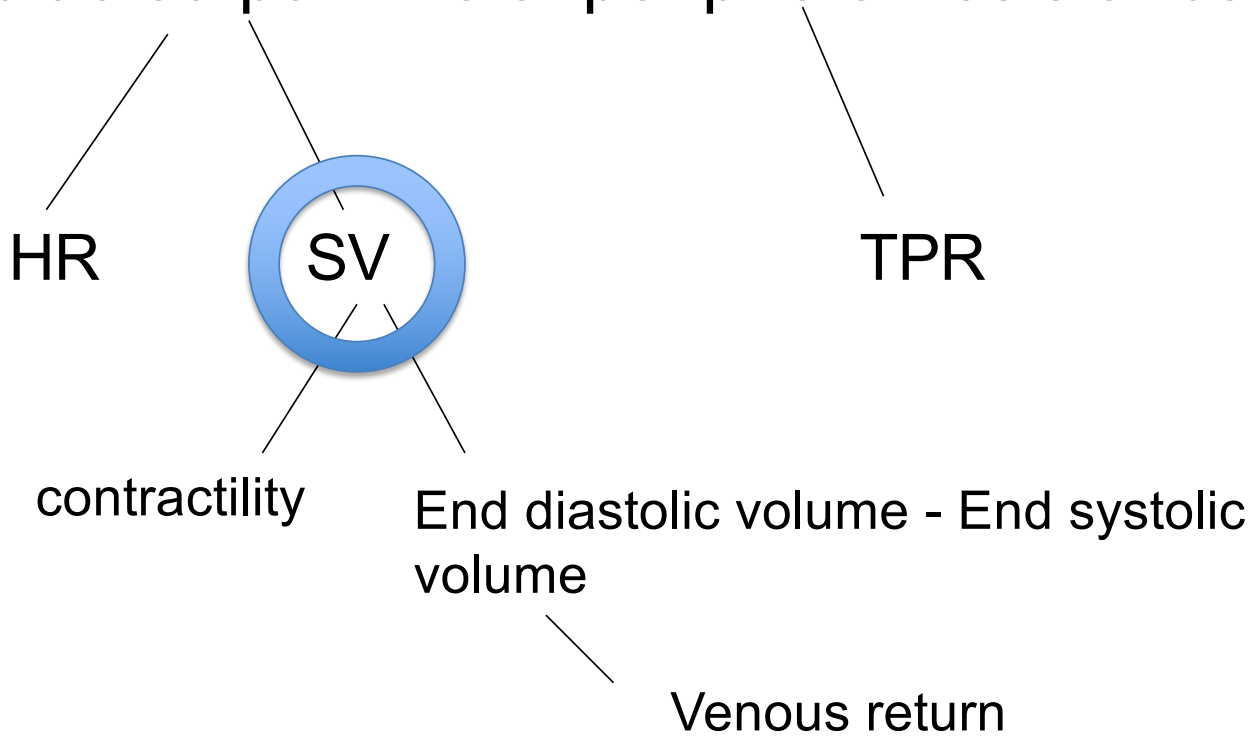
  cardiac output X total peripheral resistance



Factors that affect stroke volume…

- Mean arterial pressure =

  cardiac output X total peripheral resistance



Today's lecture

- How is blood pressure controlled?
  (Cardiovascular function revisited)

- Where are the points of control?

Exploring the elements of the baroreflex arc.

- Where are the receptors?
- What is the stimulus?
- Where is the "black box"?
- What about effectors?
- Getting a response

Where are the points of control?

- Control of systemic arterial pressure is most important mechanism for proper operation of the cardiovascular system
- Control mechanisms are designed to regulate arterial pressure
- (heart rate is NOT monitored)
- This control is called the BAROREFLEX

Components of the BAROREFLEX

- Stimulus
- Sensory receptors- low and high pressure receptors
- Afferent pathways
- Integrating centre in CNS
- Efferent pathways
- Effector organs

High pressure (arterial) baroreceptors

- Are stretch receptors
- Respond rapidly to changes in pressure (within one heart beat)
- Buffer sudden changes in pressure
- If pressure remains elevated for longer periods of time firing rate of receptors decreases leading to new “set point”

Location of arterial baroreceptors

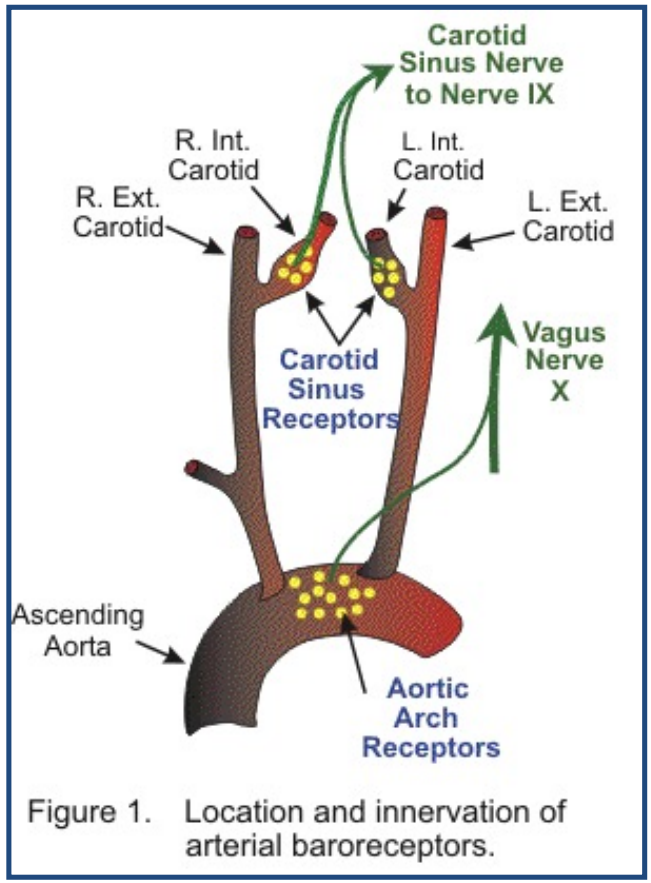
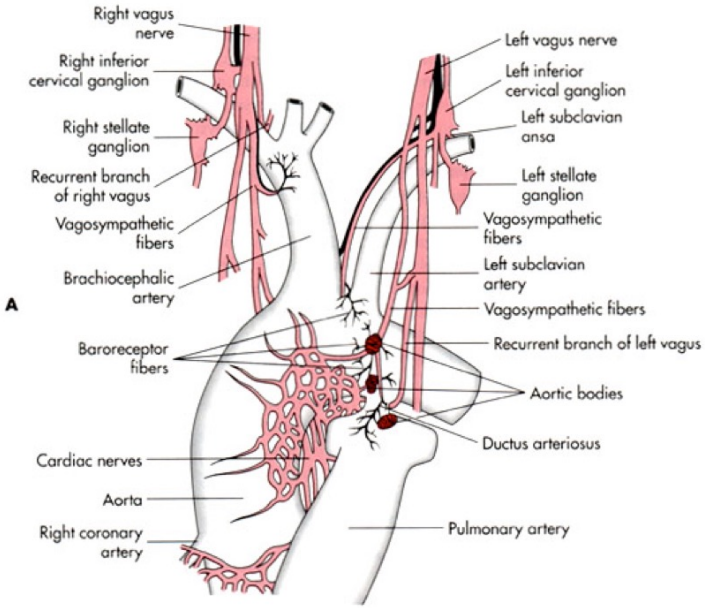


Figure 1. Location and innervation of arterial baroreceptors.

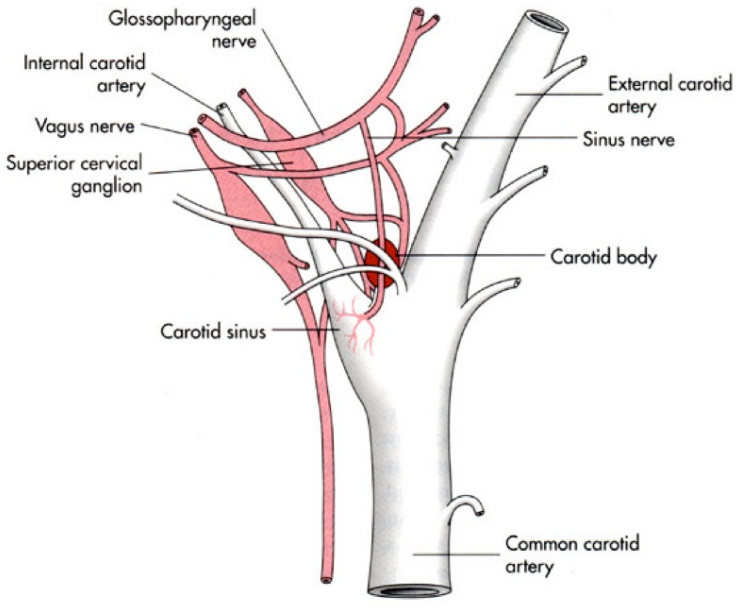
www.cvphysiology.com

Location of arterial baroreceptors

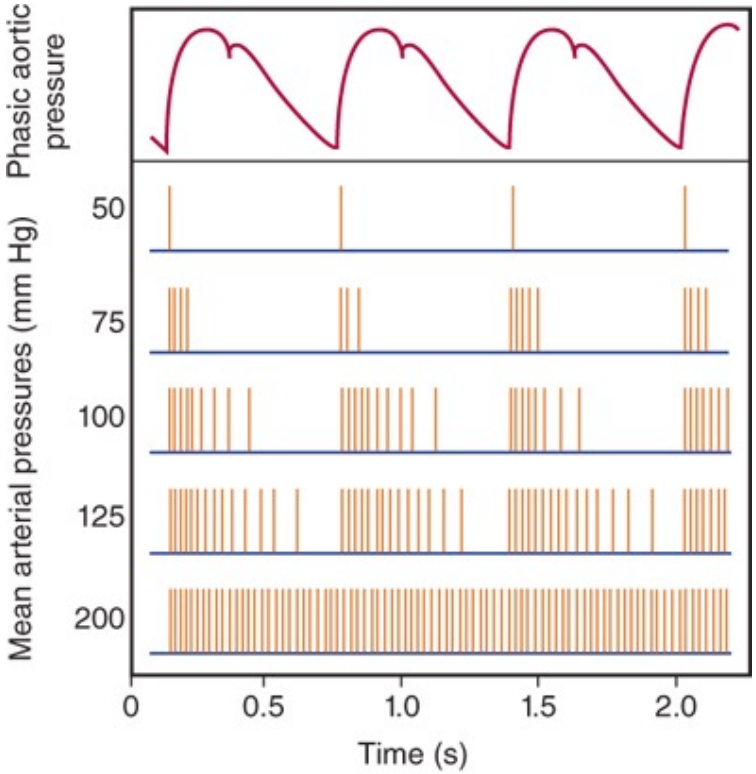
Berne & Levy p183



Aortic baroreceptors respond to pulsatile flow



Carotid sinus baroreceptors respond to non pulsatile stretch



Discharges (vertical lines) in a single afferent nerve fiber from the carotid sinus at various levels of mean arterial pressures, plotted against changes in aortic pressure with time. Baroreceptors are very sensitive to changes in pulse pressure as shown by the record of phasic aortic pressure. (Reproduced with permission from Levy MN, Pappano AJ: Cardiovascular Physiology, 9th ed. Mosby; 2007.)

Cardiopulmonary (low pressure) baroreceptors

- Pressure (stretch) receptors in atria, at junctions of great veins and atria, ventricles and pulmonary veins
- Respond to absolute pressure (rather than change in pressure)
- ie respond to changes in blood volume in heart and great veins (VENOUS RETURN)

Low pressure baroreceptors

- Nerve fibres from these receptors run in vagus nerve to medullary cardiovascular centre in the brain

- Unloading (decreased stretch) of cardiopulmonary receptors by reducing central blood volume --> increased sympathetic drive to heart and blood vessels and decreased parasympathetic drive to heart

Afferent pathways

- In glossopharyngeal nerve (CN 9)
- In vagus nerve (CN 10)

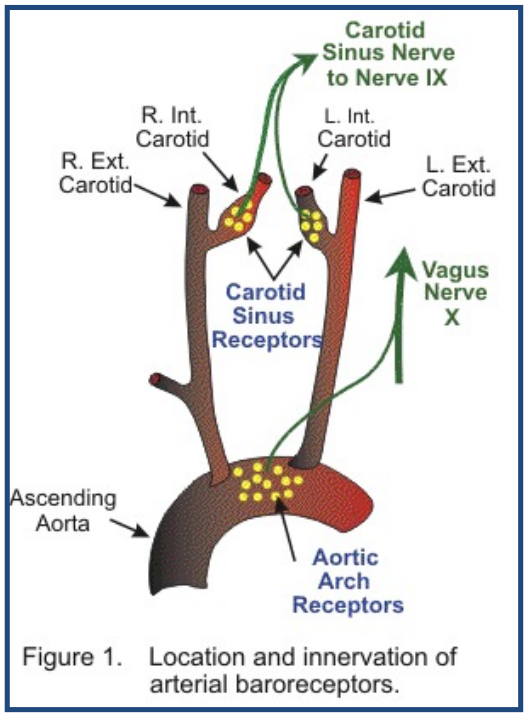


Figure 1. Location and innervation of arterial baroreceptors.

Central integration

- Medullary cardiovascular centre in brain stem
- Pressor region provides normal “tonic” sympathetic stimulation to blood vessels and heart
- Depressor region- stimulated by baroreceptor firing-->
  - Inhibits sympathetic discharge from pressor region

Efferents

- Sympathetic nerve supply to:
  - Heart :
    - Sinoatrial node --> increased rate
    - Myocardium --> increased force
  - Blood vessels
    - Arterioles --> increased TPR
    - Veins --> increased venous return
- Parasympathetic nerve supply to:
  - Heart
    - Sino atrial node --> decreased rate

The Autonomic Nervous system
(a brief refresher!)

- Skeletal muscle – supplied by the SOMATIC nervous system; under voluntary (cerebro-cortical control)

- ALL viscera- (inc heart and blood vessels) supplied by autonomic nervous system involuntary (unconscious control)

Autonomic Nervous System

Sympathetic nervous system-

- Nerves arise from thoracic and lumbar spinal cord
- Neurotransmitter at the effector organ is noradrenaline (or circulating adrenaline from adrenal gland)
- Receptors on the effector organ-
  - alpha receptor (alpha 1 or alpha 2)
  - beta receptor (beta 1 or beta 2)

Autonomic Nervous System

Parasympathetic nervous system-

- Nerves arise from brain or sacral spinal cord
- Neurotransmitter at the effector organ is acetylcholine
- Receptors on the effector organ-
  - Muscarinic receptors

Efferents

- Sympathetic nerve supply to:
  - Heart :
    - Sinoatrial node --> increased rate
    - Myocardium --> increased force
  - Blood vessels
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- Parasympathetic nerve supply to:
  - Heart
    - Sino atrial node --> decreased rate

Effectors of the Baroreflex

1. HEART
   - Change in force of contraction

     sympathetic stimulation --> increased contractility (stroke volume)
   - Change in heart rate
     - Sympathetic stimulation → increased HR
     - Parasympathetic stimulation--> decreased HR

       Cardiac output = HR X SV

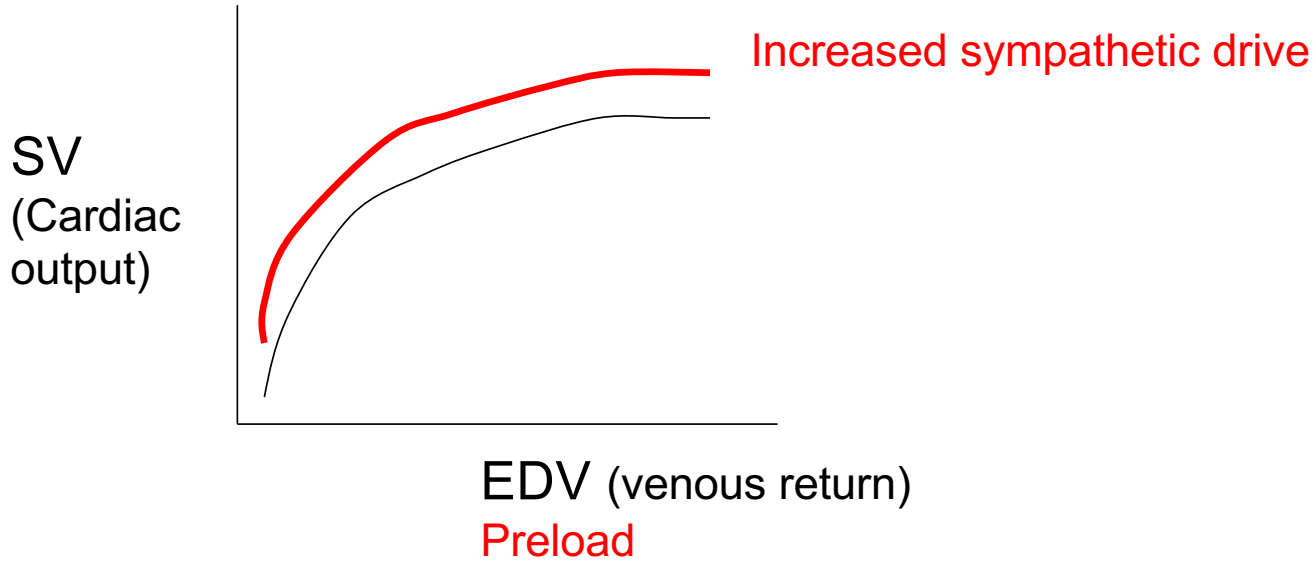
Increased stroke volume

Can be achieved by:

- Increasing muscle length (venous return).. The Frank Starling principle
- Increasing contractility (force generated for any given length) .. By increasing intracellular Ca during contraction

Increasing Stroke Volume

- Venous return (EDV)
- Sympathetic effect on contractility



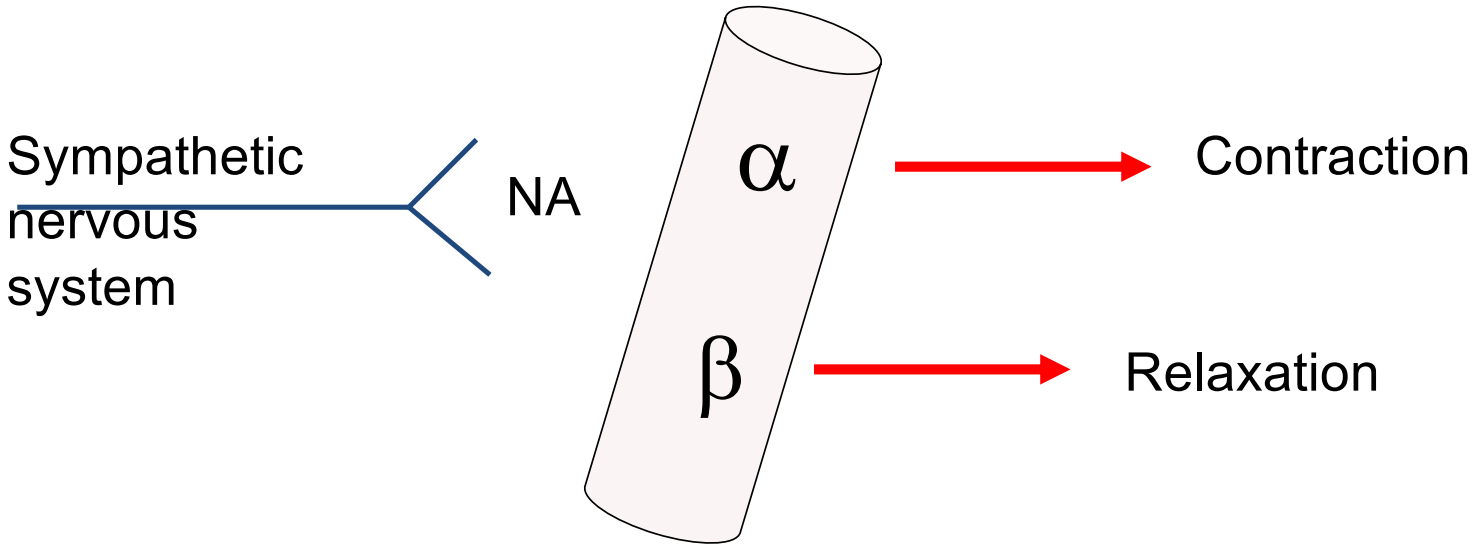
Effectors of the Baroreflex

2 BLOOD VESSELS

- Arterioles
  - Vasoconstriction leads to increased TPR

- Veins
  - Vasoconstriction leads to increased venous return --> increased EDV --> increased stroke volume

Neural control of vascular smooth muscle tone



The ratio of alpha:beta receptors varies in different vascular beds

The ratio of alpha:beta receptors varies in different vascular beds

- Gastrointestinal vasculature:

$$\alpha > \beta$$

- Skeletal muscle vasculature

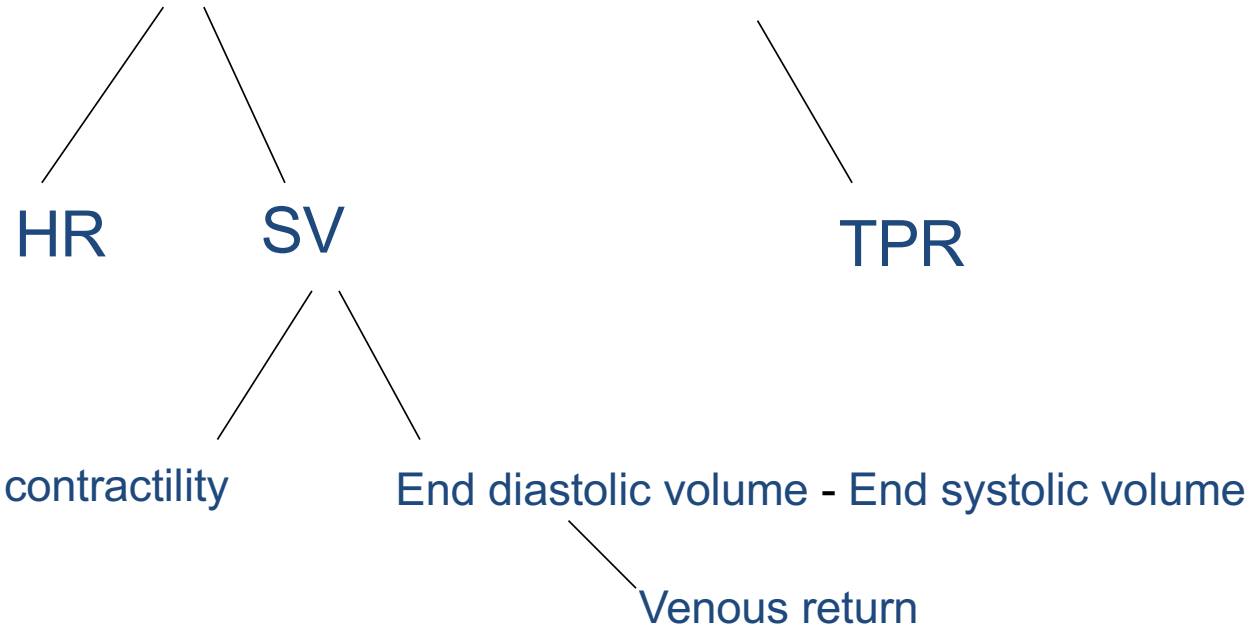
$$\alpha < \beta$$

What are the consequences of this?

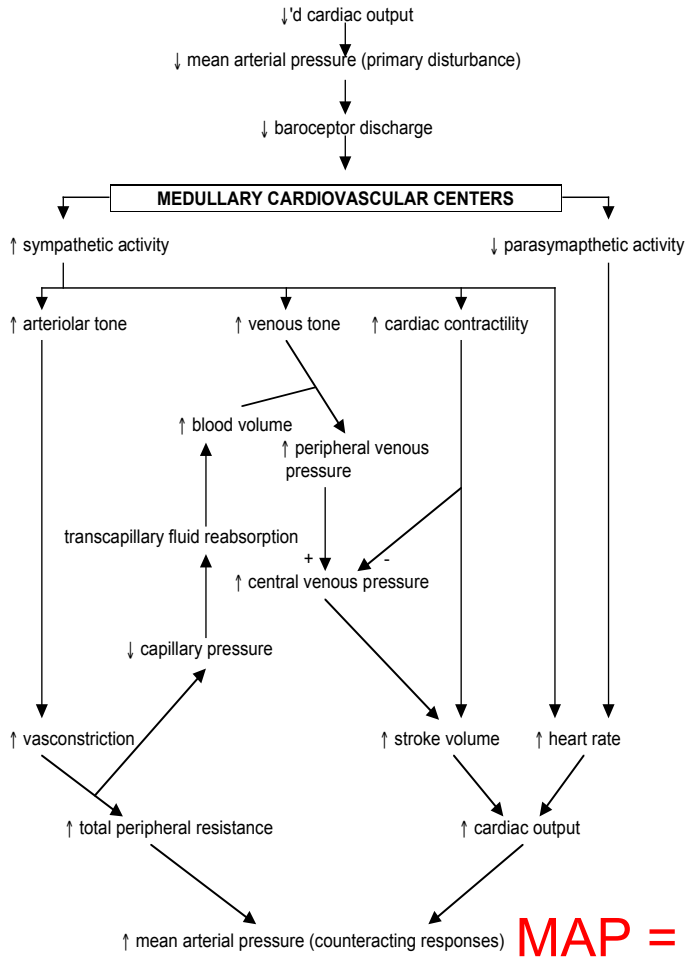
Understanding flow and pressure…….

- Blood pressure =

  cardiac output X total peripheral resistance



The Baroreflex- a negative feedback loop



MAP = CO X TPR

MAP can be increased by increasing:

Heart rate

- Stroke volume
  - contractility and
  - venous return
- Arteriolar resistance

Low pressure baroreceptors… and the response to a chronic fall in cardiac filling

Increased sympathetic drive also leads to:

- Increased stimulation of JG apparatus--> activation of RAAS
- Sodium and water retention
- Increased blood volume
- Also increased release of antidiuretic hormone (ADH)

In summary

- Changes in pressure in major arteries or filling of heart and pulmonary vessels is detected.

- Impulses are relayed to the medullary cardiovascular control centre in the brain…

In Summary..how is blood pressure adjusted?

In the HEART..

By sympathetic and parasympathetic (vagal) fibres supplying the sinoatrial node heart and by sympathetic fibres supplying the myocardium

- Heart rate (sympathetic (β) and vagal supply)
- Contractility (sympathetic (β))

In summary… how is blood pressure adjusted?

In BLOOD VESSELS

By sympathetic nerves supplying arterioles and veins

Venous return (sympathetic (α))

Venoconstriction leads to increased venous return (hence increased stroke volume)

- Arteriolar resistance (sympathetic (α))

Arteriolar constriction leads to increased total peripheral resistance and increased diastolic pressure

Control of Blood pressure

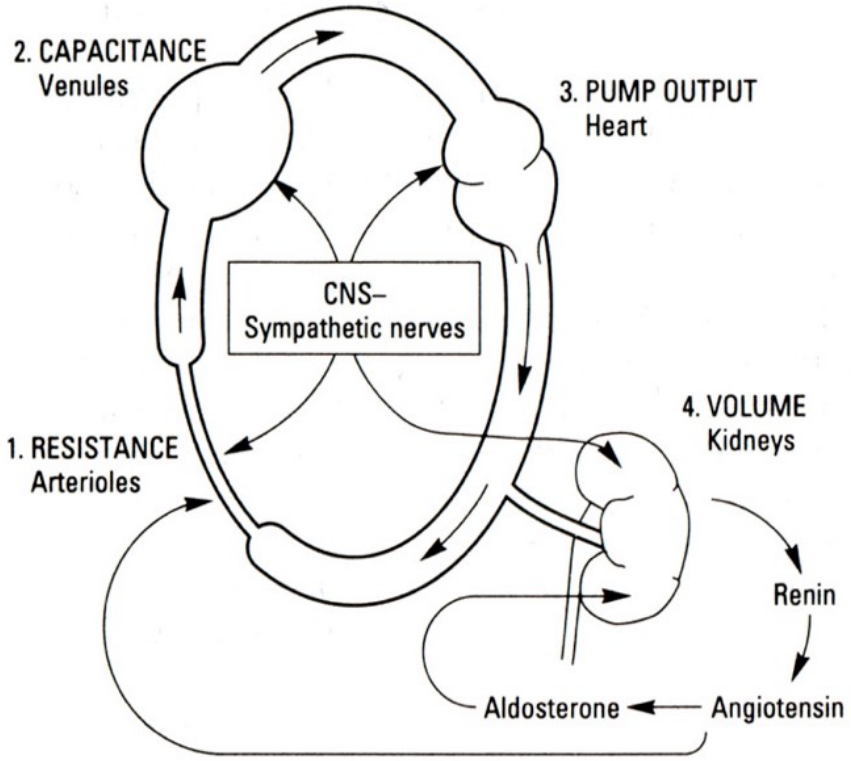


Figure 11–1. Anatomic sites of blood pressure control.

Katzung Pharmacology

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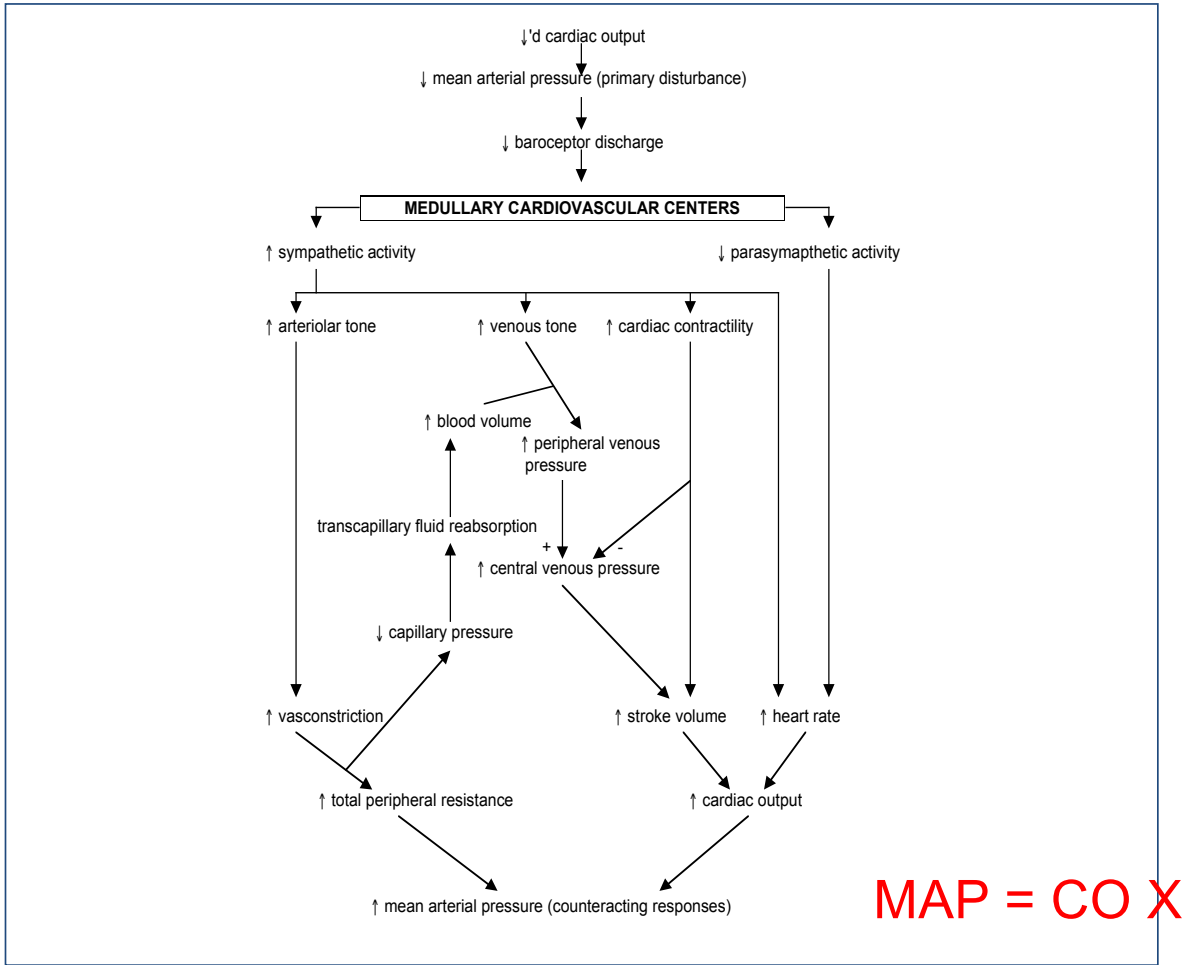

MAP = CO X TPR