Control of blood tissue blood flow

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Objectives

- List factors that affect tissue blood flow.
- Describe the vasodilator and oxygen demand theories.
- Point out the mechanisms of autoregulation.
- Describe how angiogenesis occurs.
- Inter-relat how various humoral factors affect blood flow.

Local Control of Blood Flow

- Each tissue controls its own blood flow in *proportion to its needs.*
- Tissue needs include:
  1) delivery of *oxygen* to tissues
  2) delivery of *nutrients* such as glucose, amino acids, etc.
  3) removal of carbon dioxide hydrogen and other *metabolites* from the tissues
  4) transport various *hormones* and other substances to different tissues
- Flow is closely related to *metabolic rate of tissues.*

Variations in Tissue Blood Flow

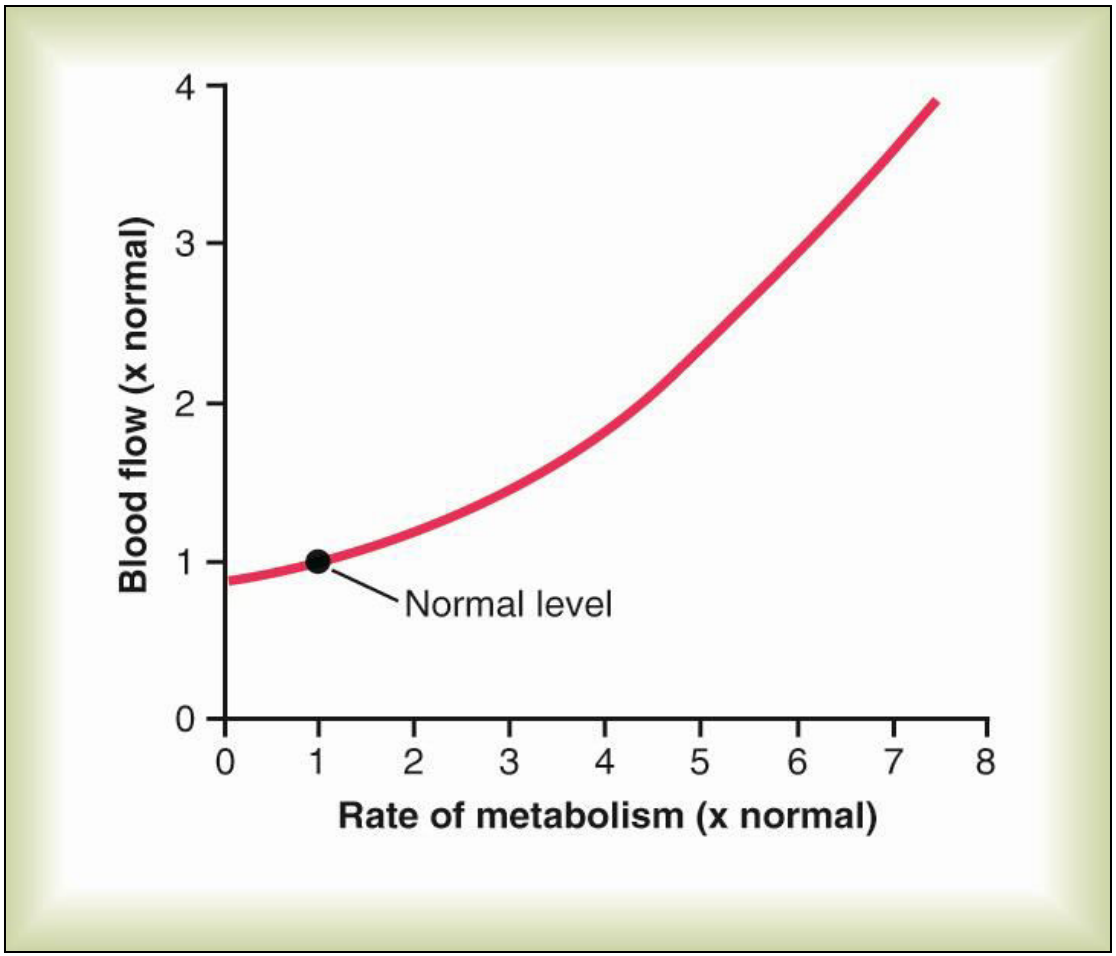
	Percent	ml/min	ml/min/ 100 gm
Brain	14	700	50
Heart	4	200	70
Bronchi	2	100	25
Kidneys	22	1100	360
Liver	27	1350	95
Portal	(21)	(1050)	
Arterial	(6)	(300)	
Muscle (inactive state)	15	750	4
Bone	5	250	3
Skin (cool weather)	6	300	3
Thyroid gland	1	50	160
Adrenal glands	0	.525	300
Other tissues	3.5	175	1.3
Total	100.0	5000	---

Acute Control of Local Blood Flow

- Increases in *tissue metabolism* lead to increases in blood flow.
- Decreases in *oxygen availability* to tissues increases tissue blood flow.
- Two major theories for local blood flow are:
  1) *The vasodilator theory*
  2) *Oxygen demand theory*

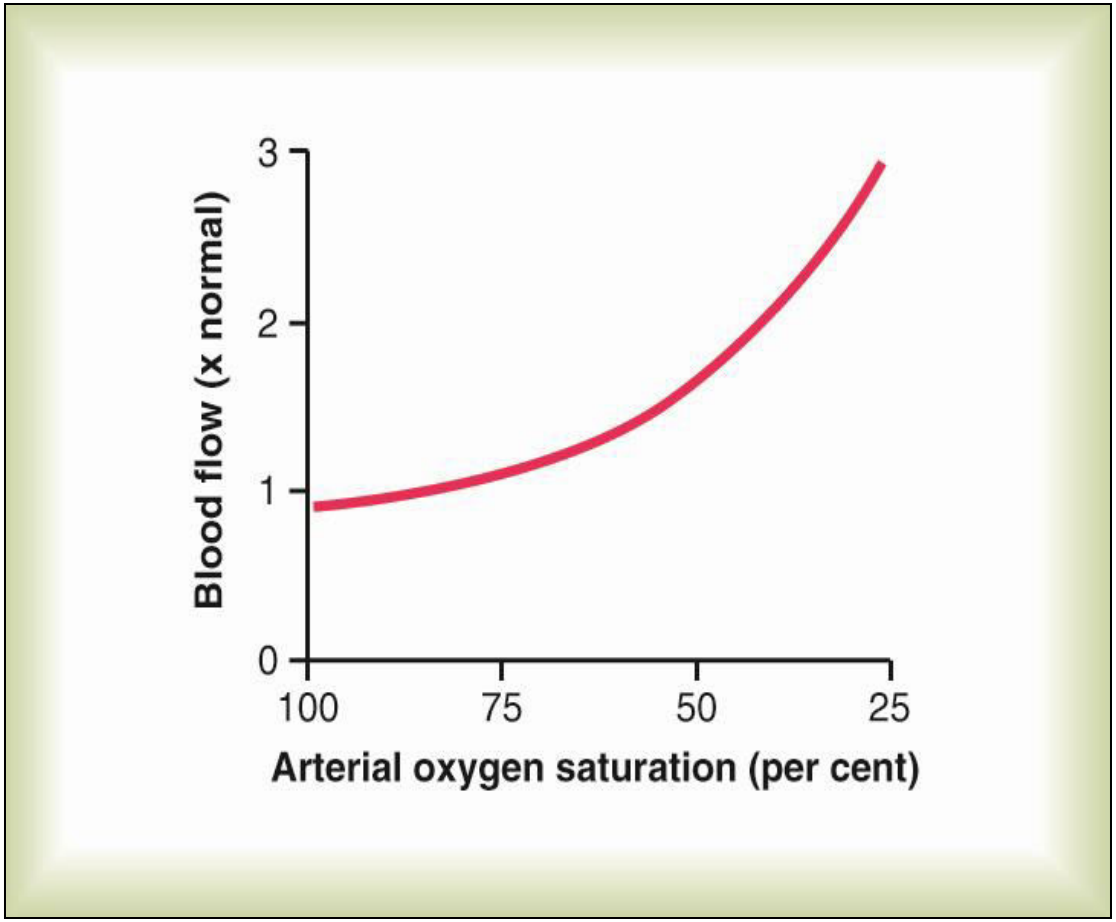
Effect of Tissue Metabolic Rate on Tissue Blood Flow

↑ Tissue Metabolism → ↑ Blood Flow



Effect of Tissue Oxygen concentration on Blood Flow

Tissue Oxygen Concentration ⟵ ⟶ **Blood Flow**



Relationship between Pressure, Flow, and Resistance

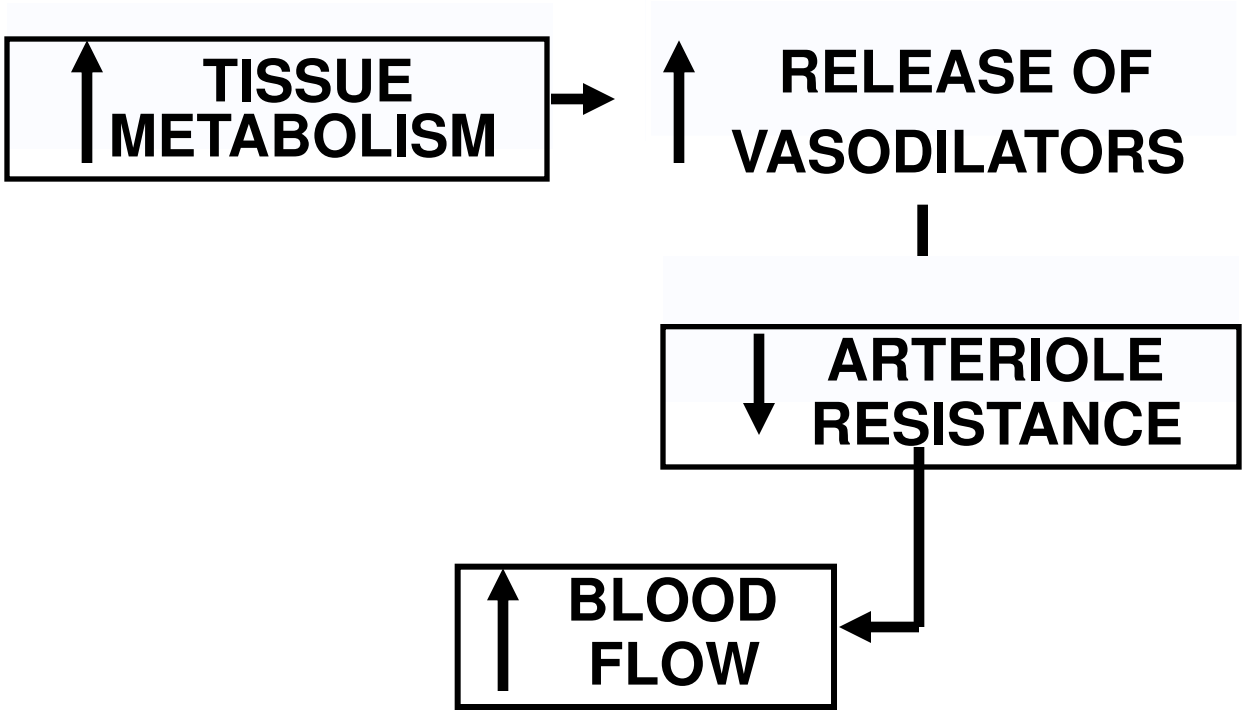
- $F=\Delta P/R$
- *Flow* (F) through a blood vessel is determined by:

  1) The *pressure difference* (Δ P) between the two ends of the vessel

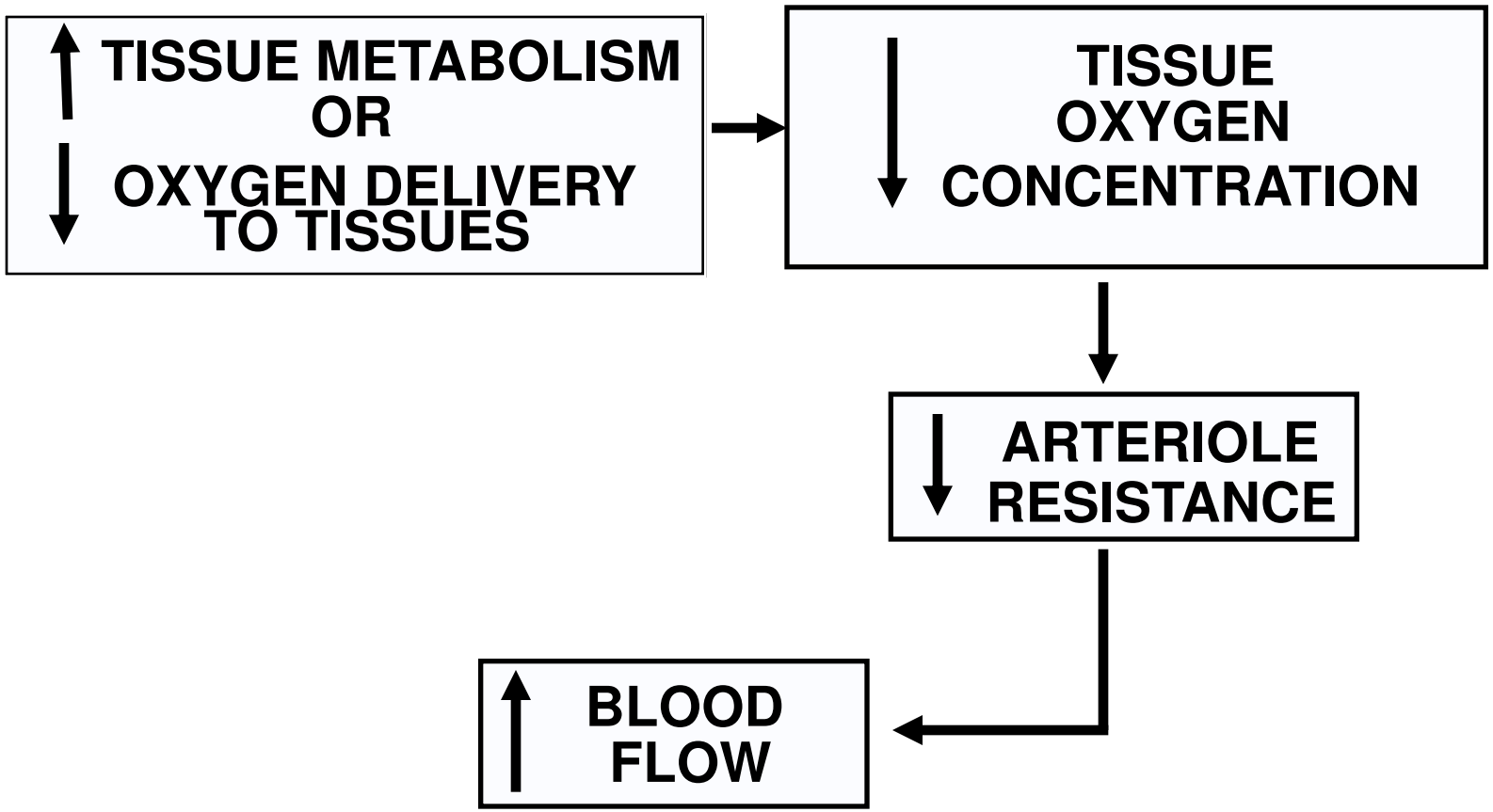
  2) *Resistance* (R) of the vessel

Vasodilator Theory for Blood Flow Control

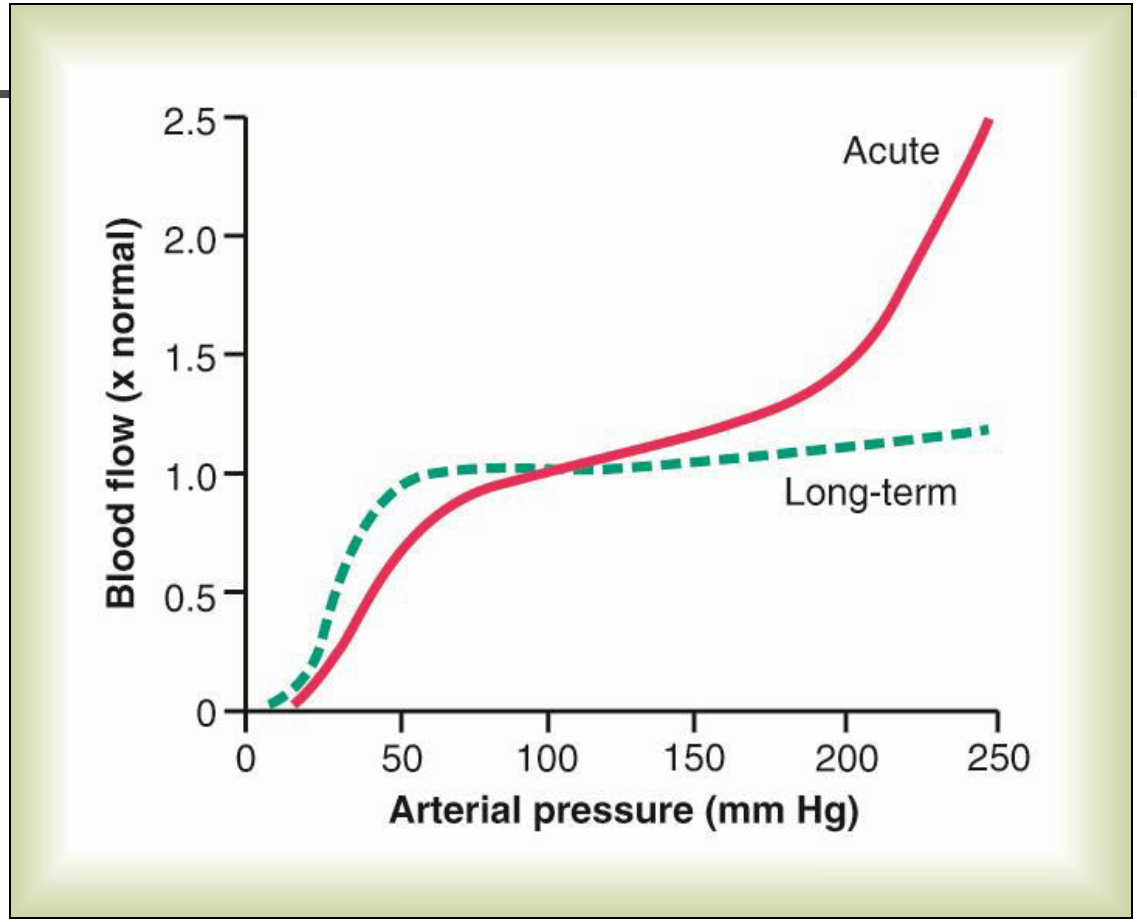
- Local Vasodilators: **Adenosine**, **CO2**, **Lactic acid**, **ADP compounds**, **Histamine**, **K^+ ions**, **H^+ ions**, **Prostacyclin**, **Bradykinin**, and **Nitrous oxid (NO)**



Oxygen Demand Theory for Blood Flow Control



Autoregulation of Blood Flow



Autoregulation - ability of a tissue to maintain blood flow relatively constant over a wide range of arterial pressures.

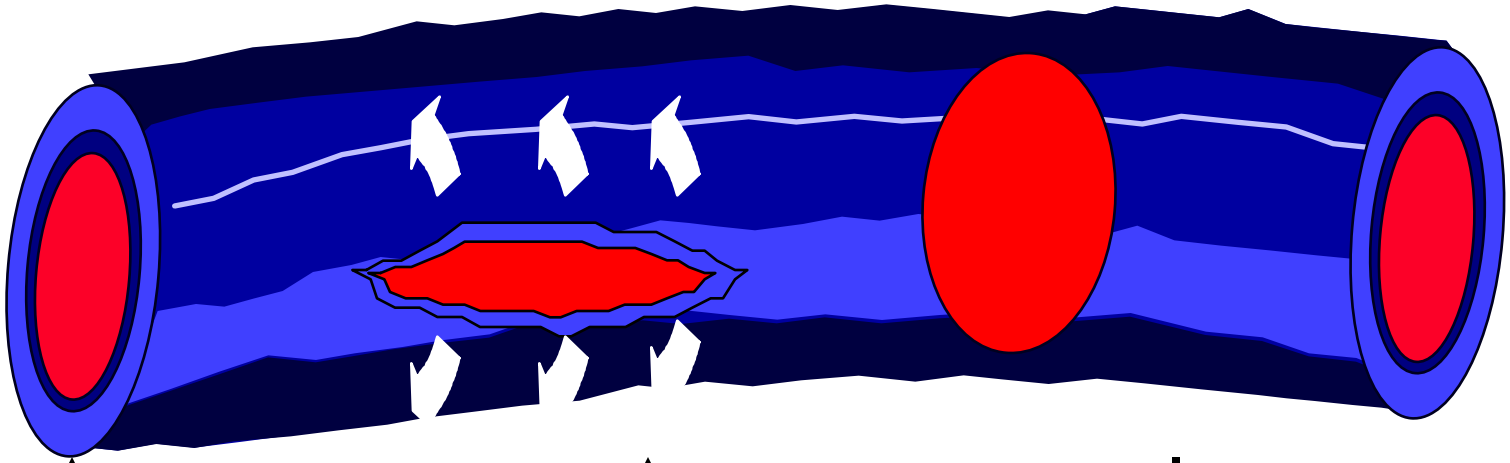
Blood Flow Autoregulation Theories

- *Metabolic theory* suggests that as arterial pressure is decreased, oxygen or nutrient delivery is decreased resulting in release of a vasodilator.
- *Myogenic theory* proposes that as arterial pressure falls the arterioles have an intrinsic property to dilate in response to decreases in wall tension.
- Certain tissues have *other mechanisms* for blood flow control the kidneys have a feedback system between the tubules and arterioles and the brain blood flow is controlled by carbon dioxide and hydrogen ion conc.

Laplace's Law: Myogenic mechanism

TENSION = PRESSURE X RADIUS

(dynes/cm) (dynes/cm^2) (cm)



↑ **PRESSURE** → ↑ **TENSION** → ↓ **RADIUS**

↑ **(to maintain tension constant)**

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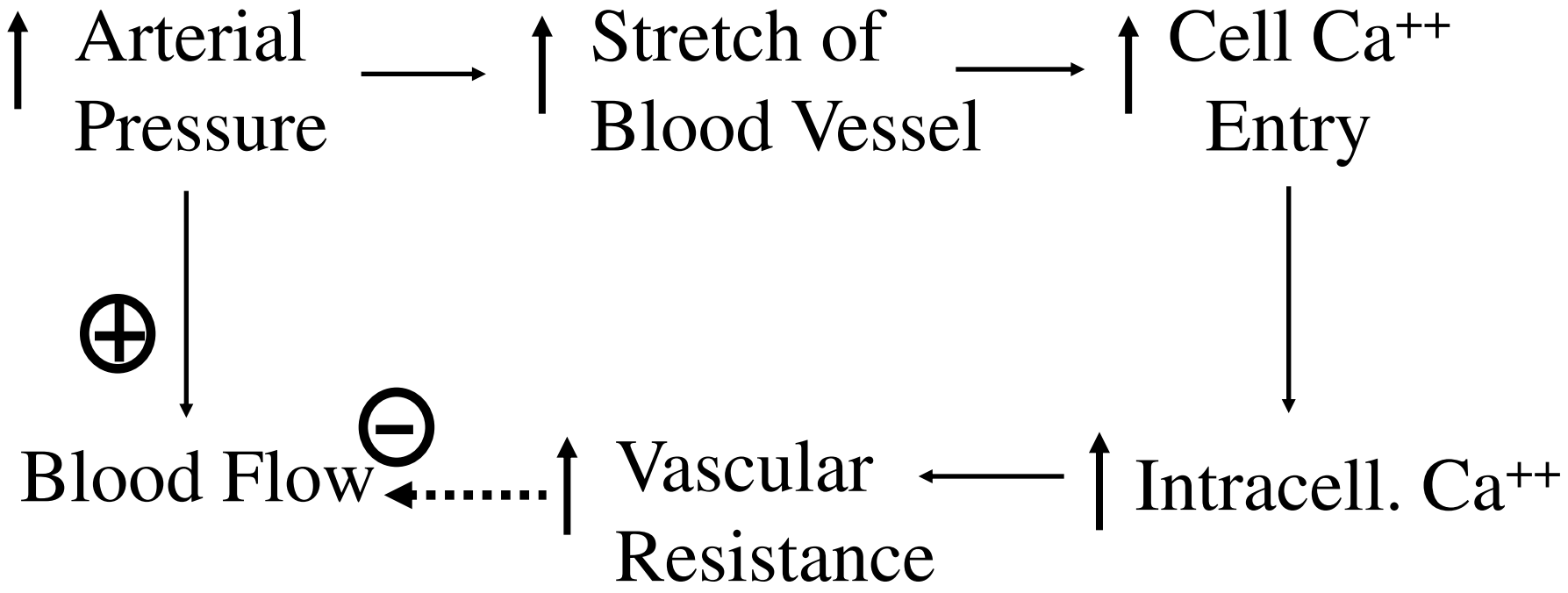
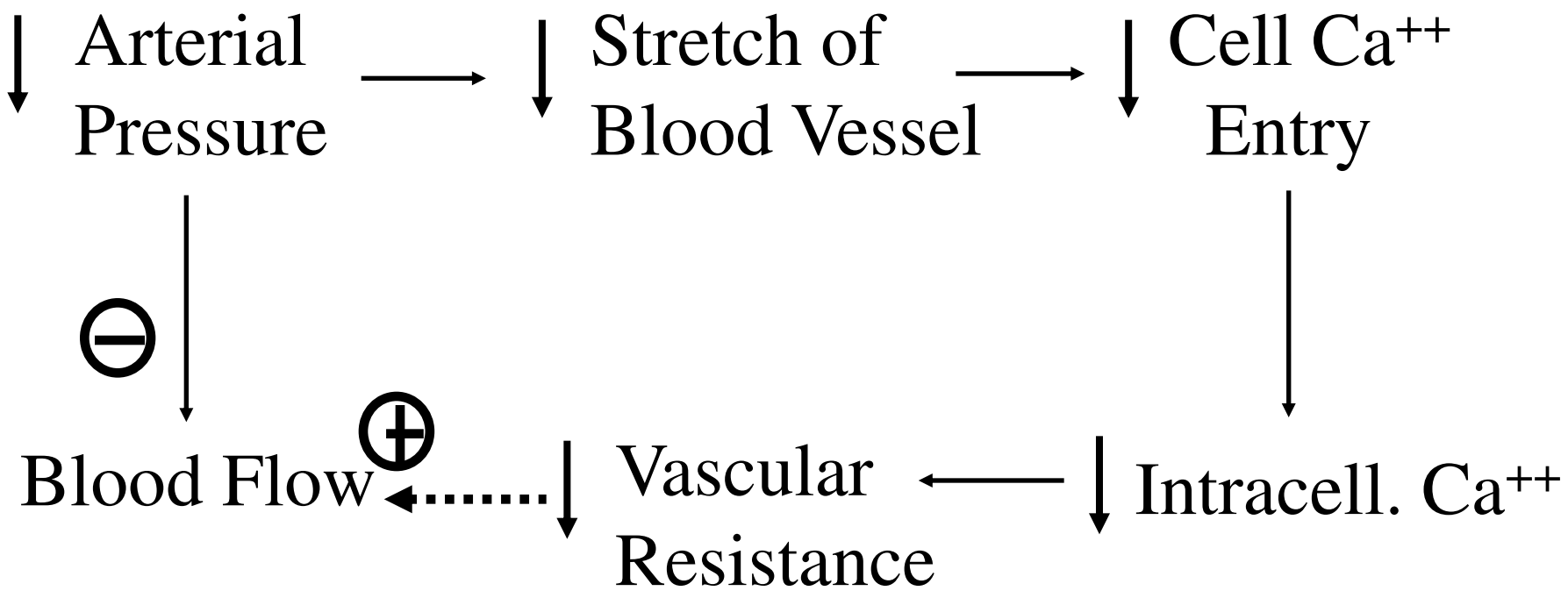
Myogenic Mechanism



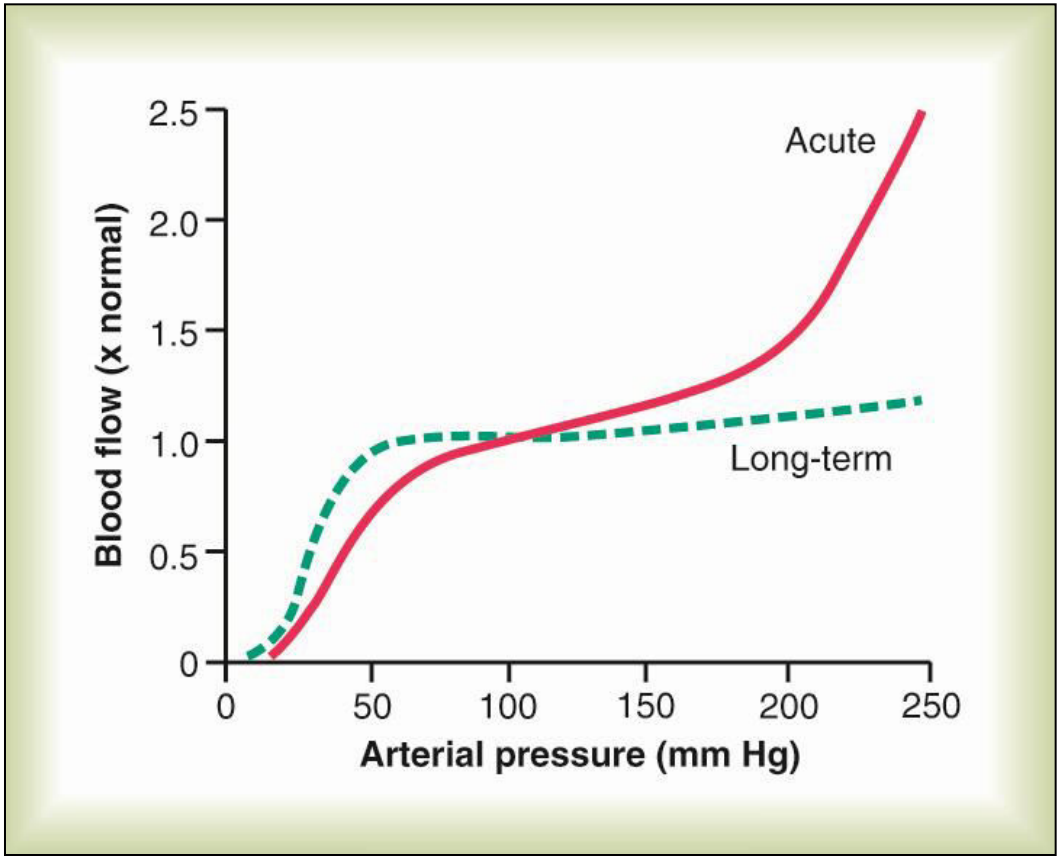
Myogenic Mechanism



Long-term Regulation of Blood Flow

- Long-term regulatory mechanisms which control blood flow are more effective than acute mechanism.
- Long-term local blood flow regulation occurs by changing the degree of vascularity of tissues (***size and number of vessels***).
- *Oxygen* is an important stimulus for regulating tissue vascularity.

Long-term Regulation of Blood Flow



Angiogenesis

- *Angiogenesis* is the growth of new blood vessels.
- Angiogenesis occurs in response to angiogenic factors released from:
  1) ischemic tissue
  2) rapidly growing tissue
  3) tissue with high metabolic rates
- Most angiogenic factors are ***small peptides*** such as vascular endothelial cell growth factors (VEGF), fibroblast growth factor (FGF), and angiogen.
- Example of angiogenesis is ***Retrolental Hyperplasis***

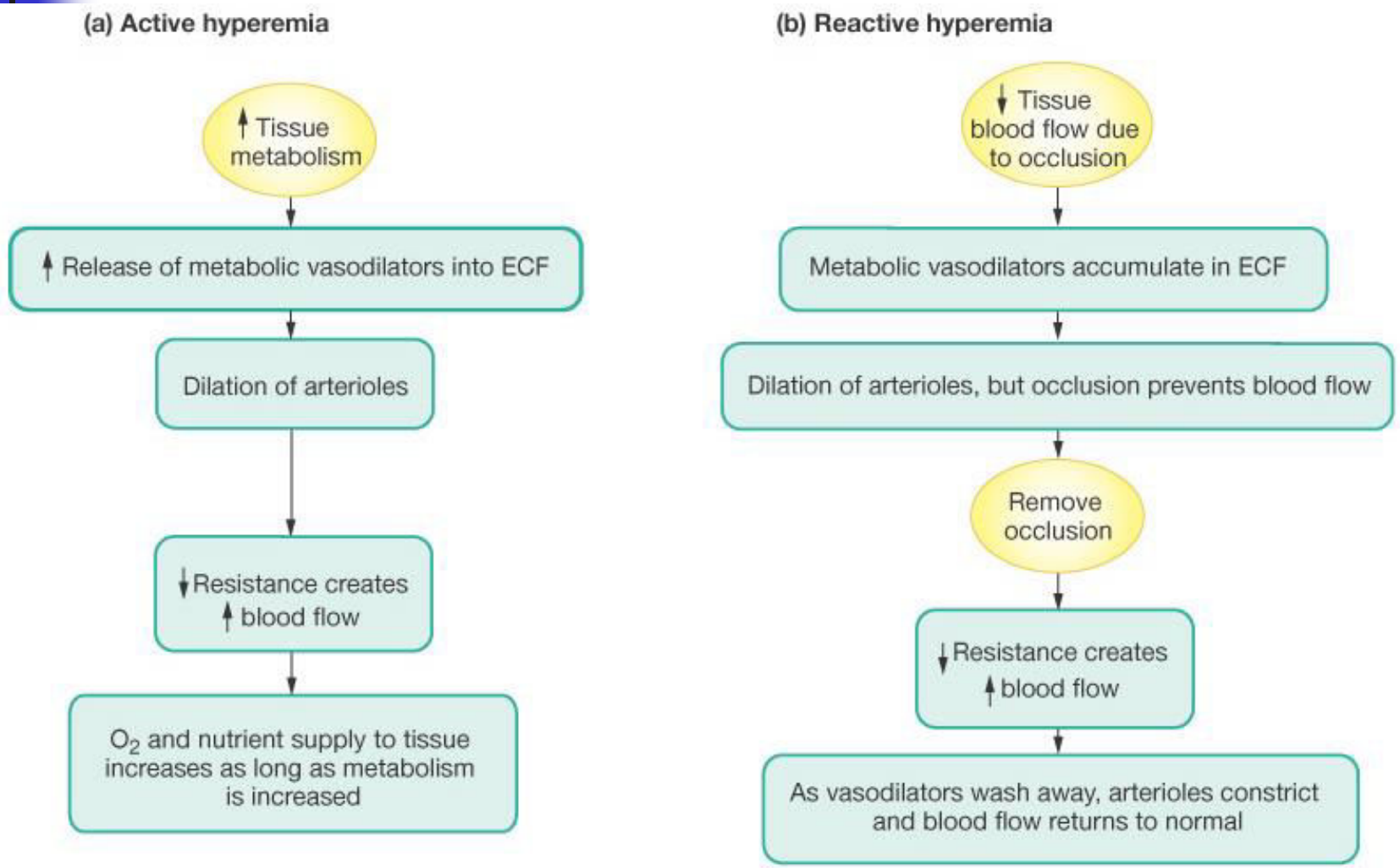
Humoral Regulation of Blood Flow

- Vasoconstrictors
  - Norepinephrine and epinephrine
  - Angiotensin
  - Vasopressin
  - Endothelin
- Vasodilator agents
  - Bradykinin
  - Serotonin
  - Histamine
  - Prostaglandins
  - Nitric oxide

Blood Flow: Skeletal Muscle Regulation

- Muscle blood flow can increase tenfold or more during physical activity as vasodilation occurs
  - Low levels of epinephrine bind to β receptors
  - Cholinergic receptors are occupied
- Intense exercise or sympathetic nervous system activation result in high levels of epinephrine
  - High levels of epinephrine bind to α receptors and cause vasoconstriction
    - This is a protective response to prevent muscle oxygen demands from exceeding cardiac pumping ability

Arteriole Resistance: Control of Local Blood Flow



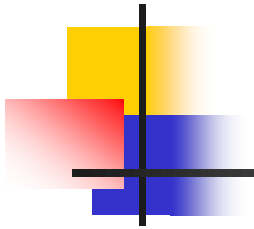
Blood Flow: Brain

- Blood flow to the brain is constant, as neurons are intolerant of ischemia
- Metabolic controls – brain tissue is extremely sensitive to declines in pH, and increased carbon dioxide causes marked vasodilation
- Myogenic controls protect the brain from damaging changes in blood pressure
  - Decreases in MAP cause cerebral vessels to dilate to insure adequate perfusion
  - Increases in MAP cause cerebral vessels to constrict

Blood Flow: Brain

- The brain can regulate is own blood flow in certain circumstances, such as ischemia caused by a tumor
- The brain is vulnerable under extreme systemic pressure changes
  - MAP below 60mm Hg can cause syncope (fainting)
  - MAP above 160 can result in cerebral edema

Blood Flow: Skin



- Blood flow through the skin:
  - Supplies nutrients to cells in response to oxygen need
  - Aids in body temperature regulation and provides a blood reservoir
- Blood flow to venous plexuses below the skin surface:
  - Varies from 50 ml/min to 2500 ml/min, depending upon body temperature
  - Is controlled by sympathetic nervous system reflexes initiated by temperature receptors and the central nervous system

Blood Flow: Lungs

- Blood flow in the pulmonary circulation is unusual in that:
  - The pathway is short
  - Arteries/arterioles are more like veins/venules (thin-walled, with large lumens)
    - They have a much lower arterial pressure (24/8 mm Hg versus 120/80 mm Hg)
  - The autoregulatory mechanism is exactly opposite of that in most tissues
    - Low oxygen levels cause vasoconstriction; high levels promote vasodilation
    - This allows for proper oxygen loading in the lungs

Blood Flow: Heart

- Small vessel coronary circulation is influenced by:
  - Aortic pressure
  - The pumping activity of the ventricles
- During ventricular systole:
  - Coronary vessels compress
  - Myocardial blood flow ceases
  - Stored myoglobin supplies sufficient oxygen
- During ventricular diastole, oxygen and nutrients are carried to the heart
- Extraction ratio is maximum (75%) during rest so an increase demand for oxygen means an increase blood flow

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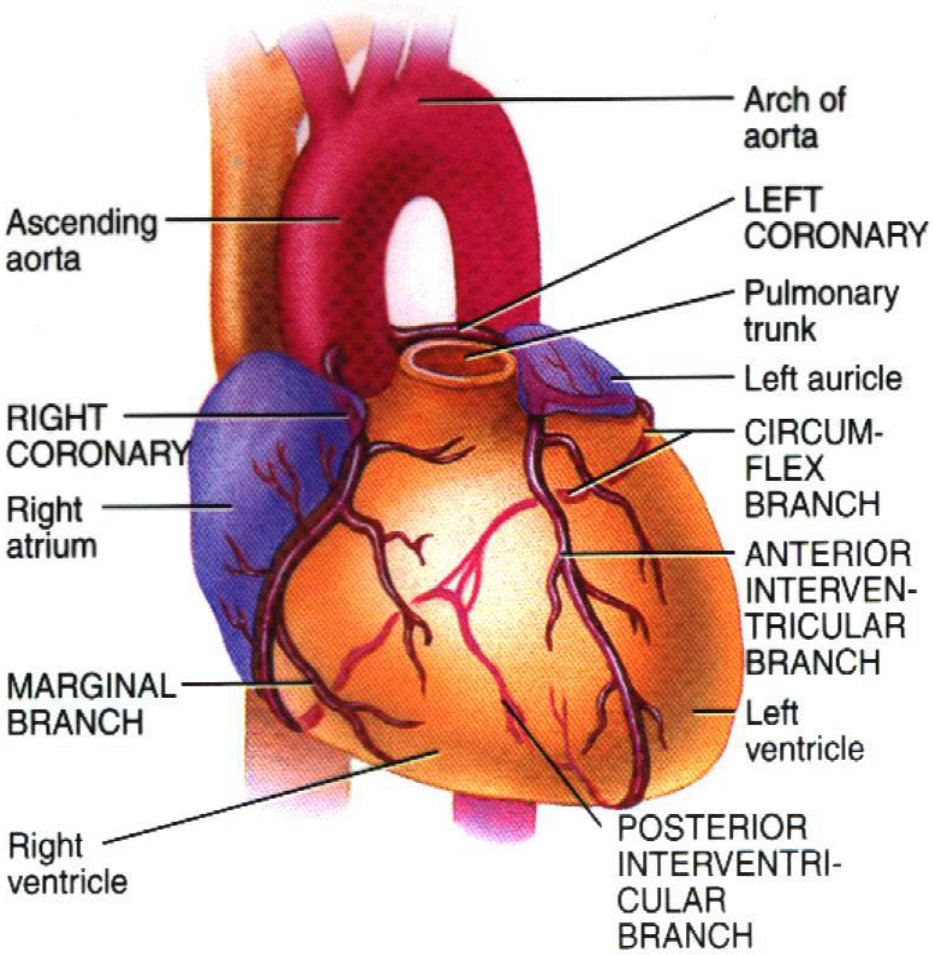
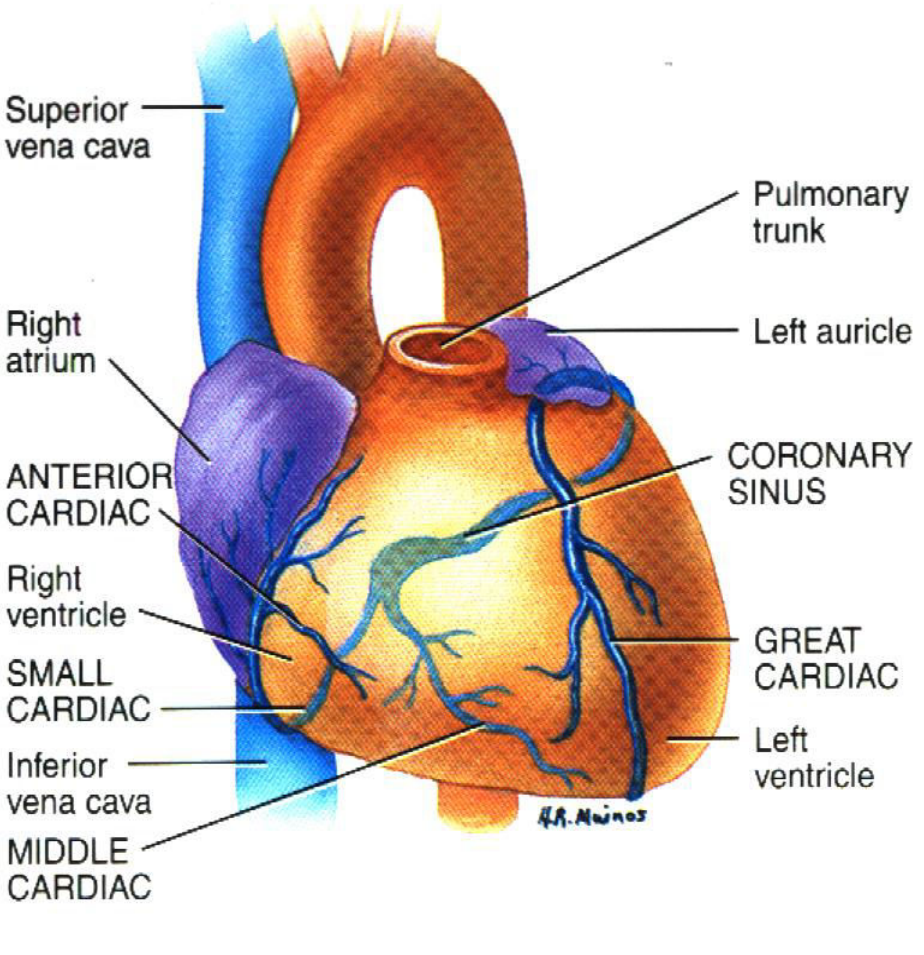
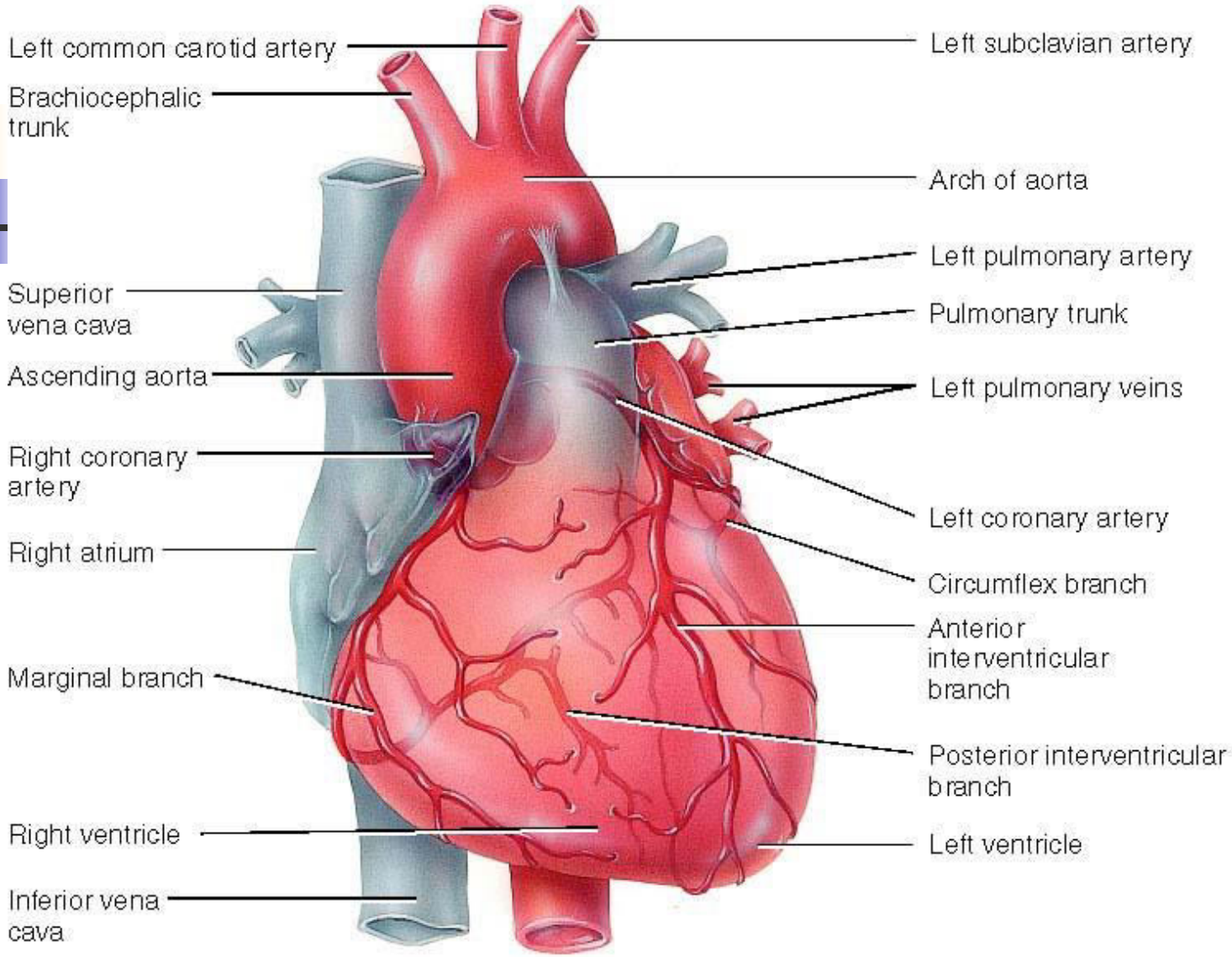


(a) Anterior view of coronary arteries

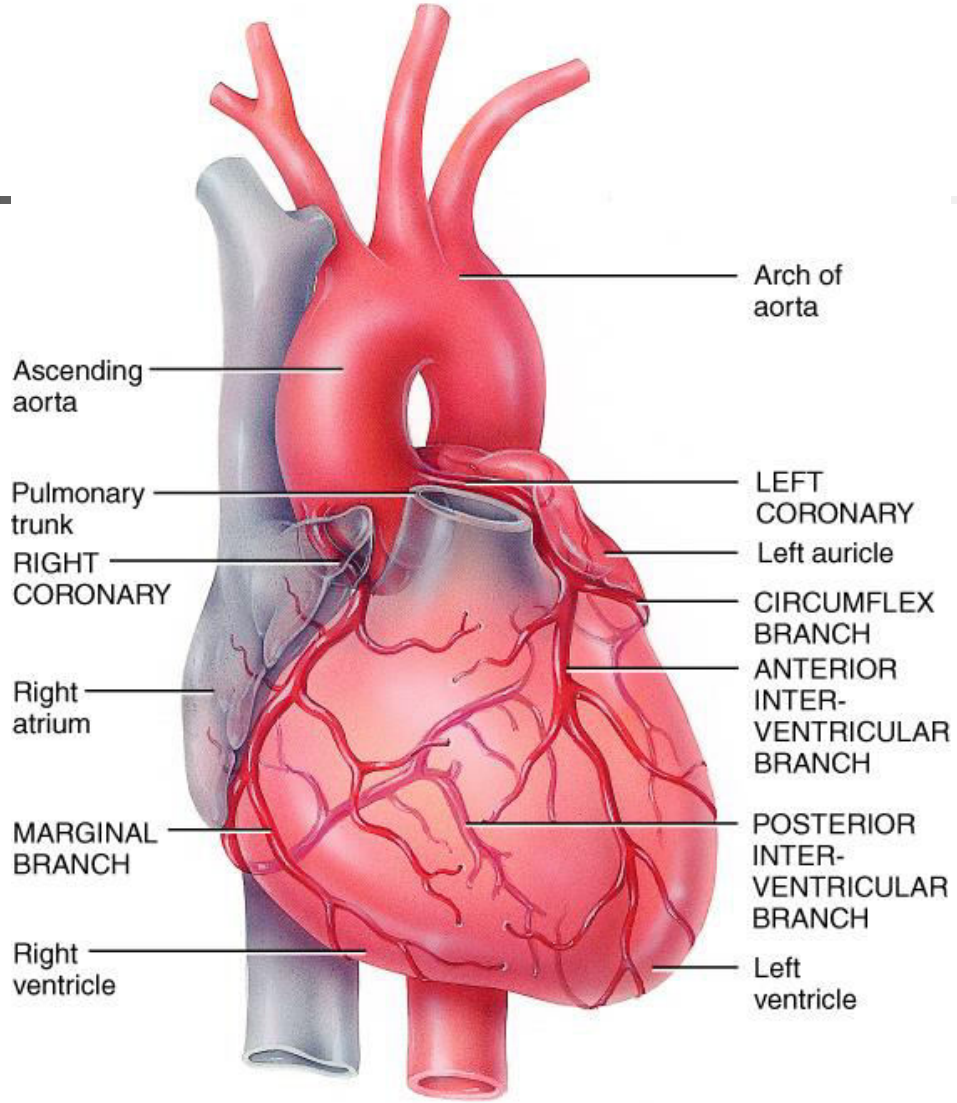


(b) Anterior view of coronary veins

CORONARY CIRCULATION


Left common carotid artery
Brachiocephalic trunk
Superior vena cava
Ascending aorta
Right coronary artery
Right atrium
Marginal branch
Right ventricle
Inferior vena cava
Left subclavian artery
Arch of aorta
Left pulmonary artery
Pulmonary trunk
Left pulmonary veins
Left coronary artery
Circumflex branch
Anterior interventricular branch
Posterior interventricular branch
Left ventricle

21.19



(a) Anterior view of coronary arteries

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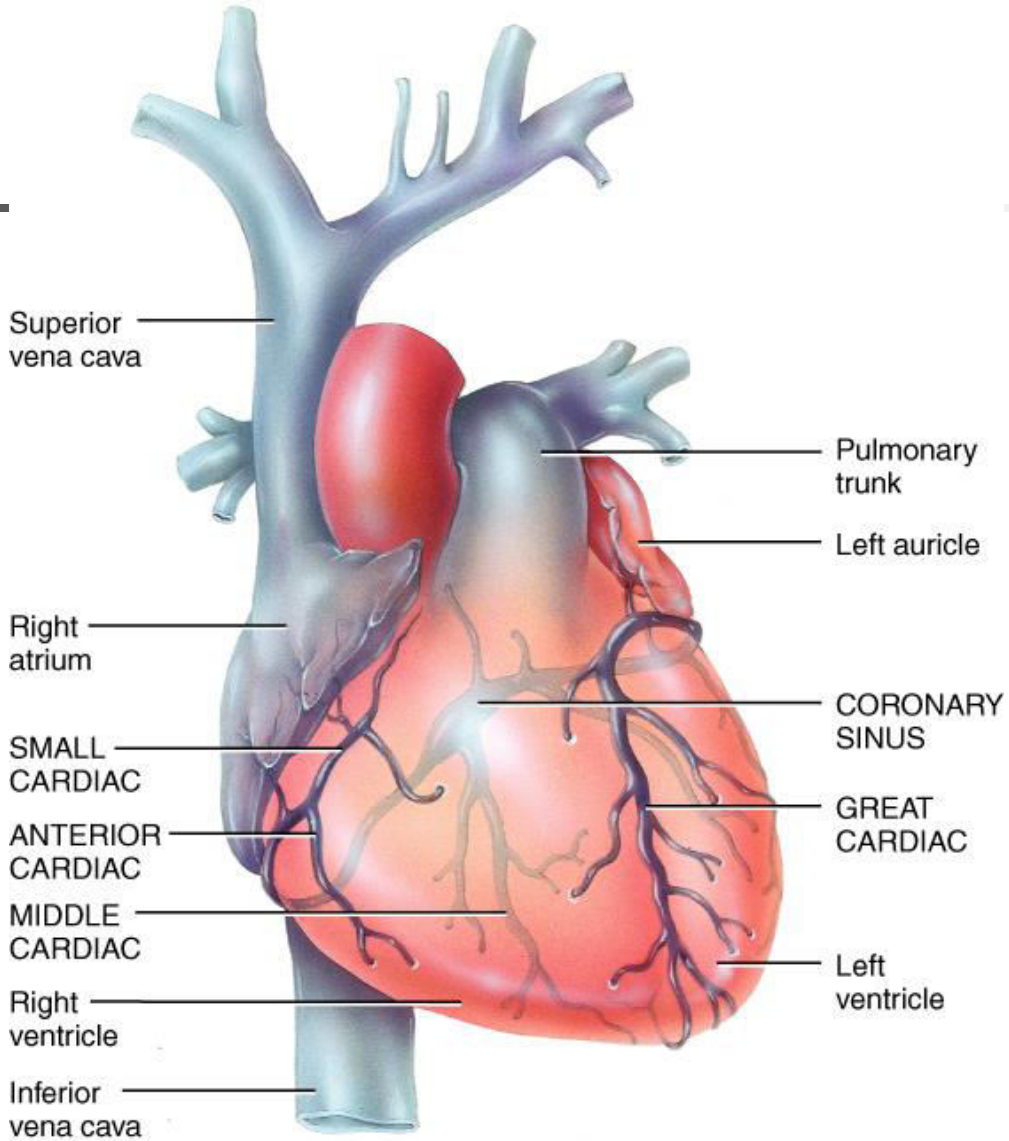

(b) Anterior view of coronary veins

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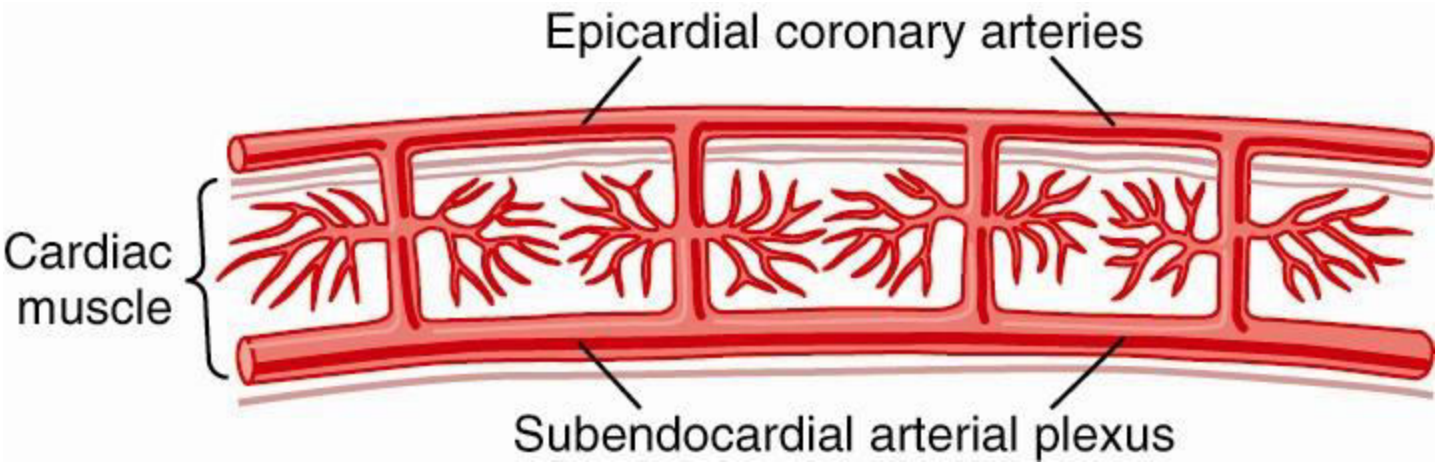
Epicardial and Subendocardial Vasculature



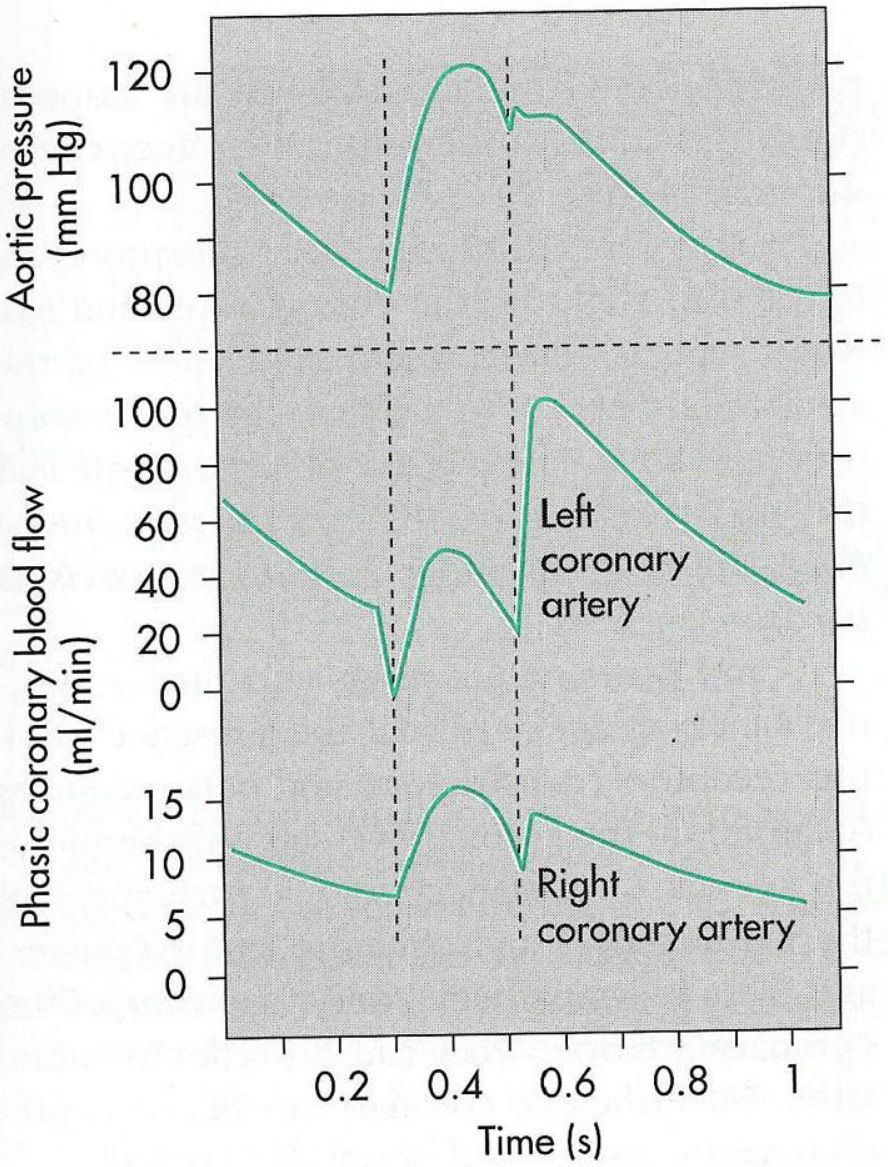
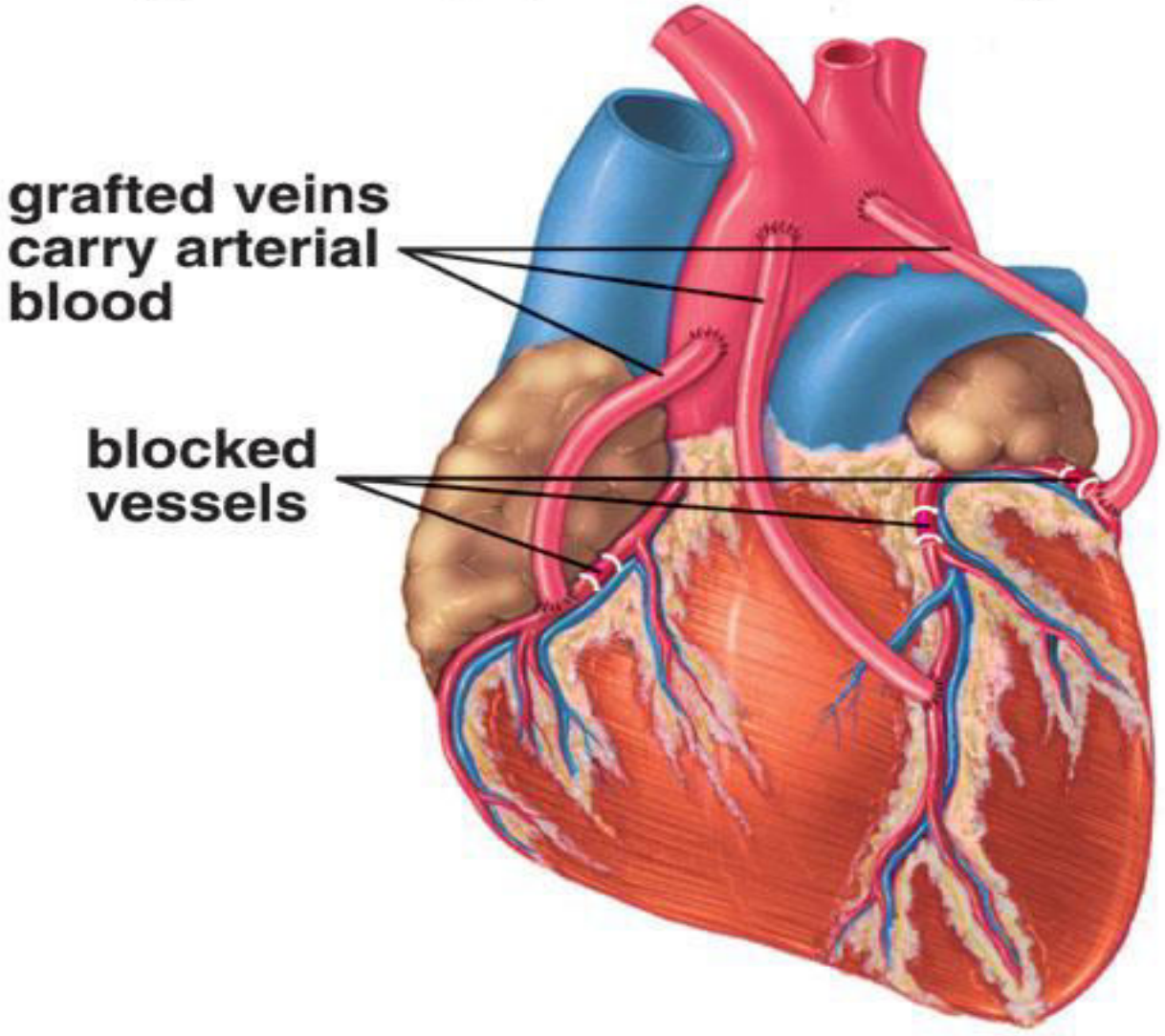
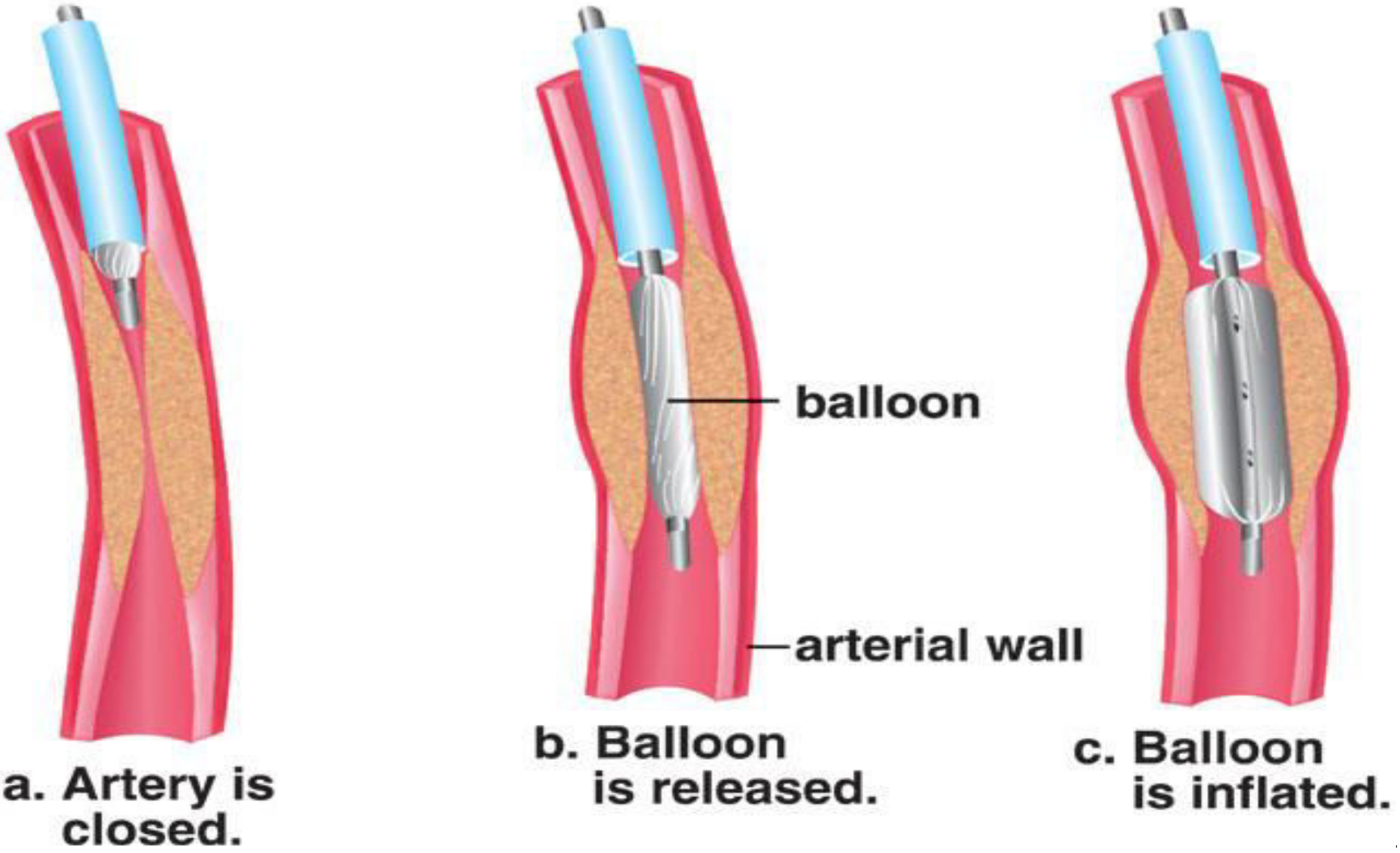


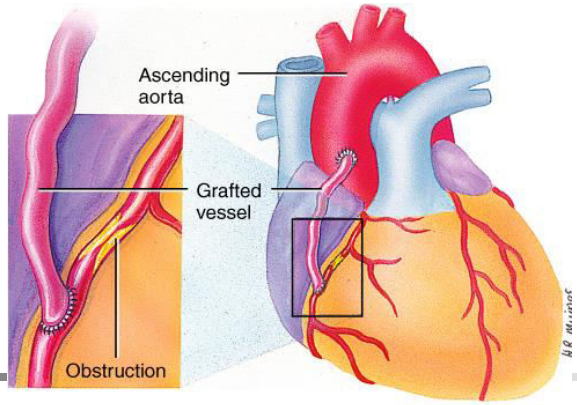
Figure 10-3 ■ Comparison of phasic coronary blood flow in the left and right coronary arteries.

Coronary bypass operation

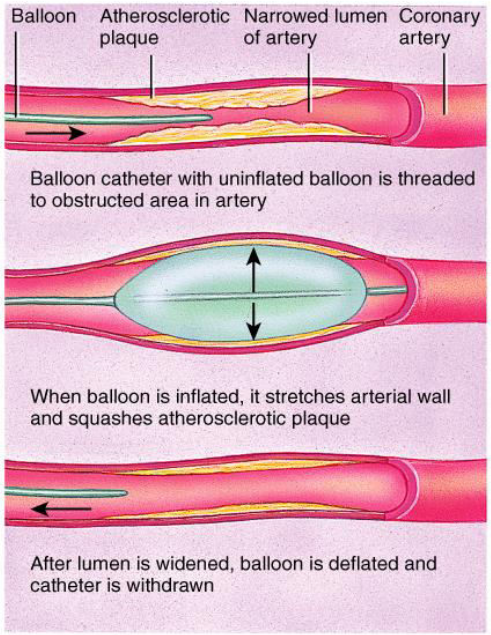


Angioplasty

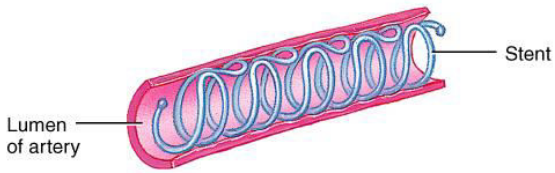




(a) Coronary artery bypass grafting (CABG)



(b) Percutaneous transluminal coronary angioplasty (PTCA)



(c) Stent in an artery

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Thank You

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