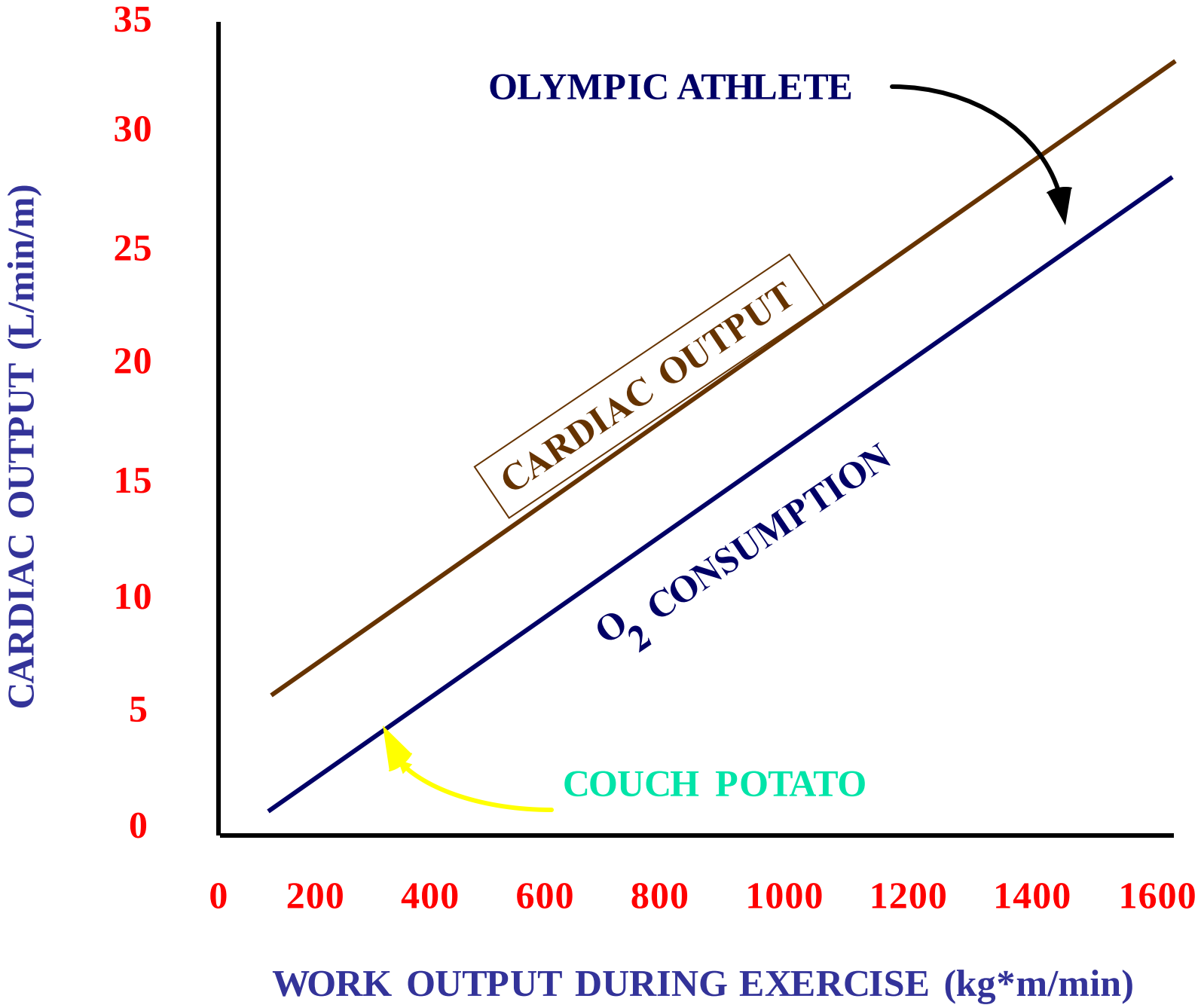
Control of blood tissue blood flow

Objectives

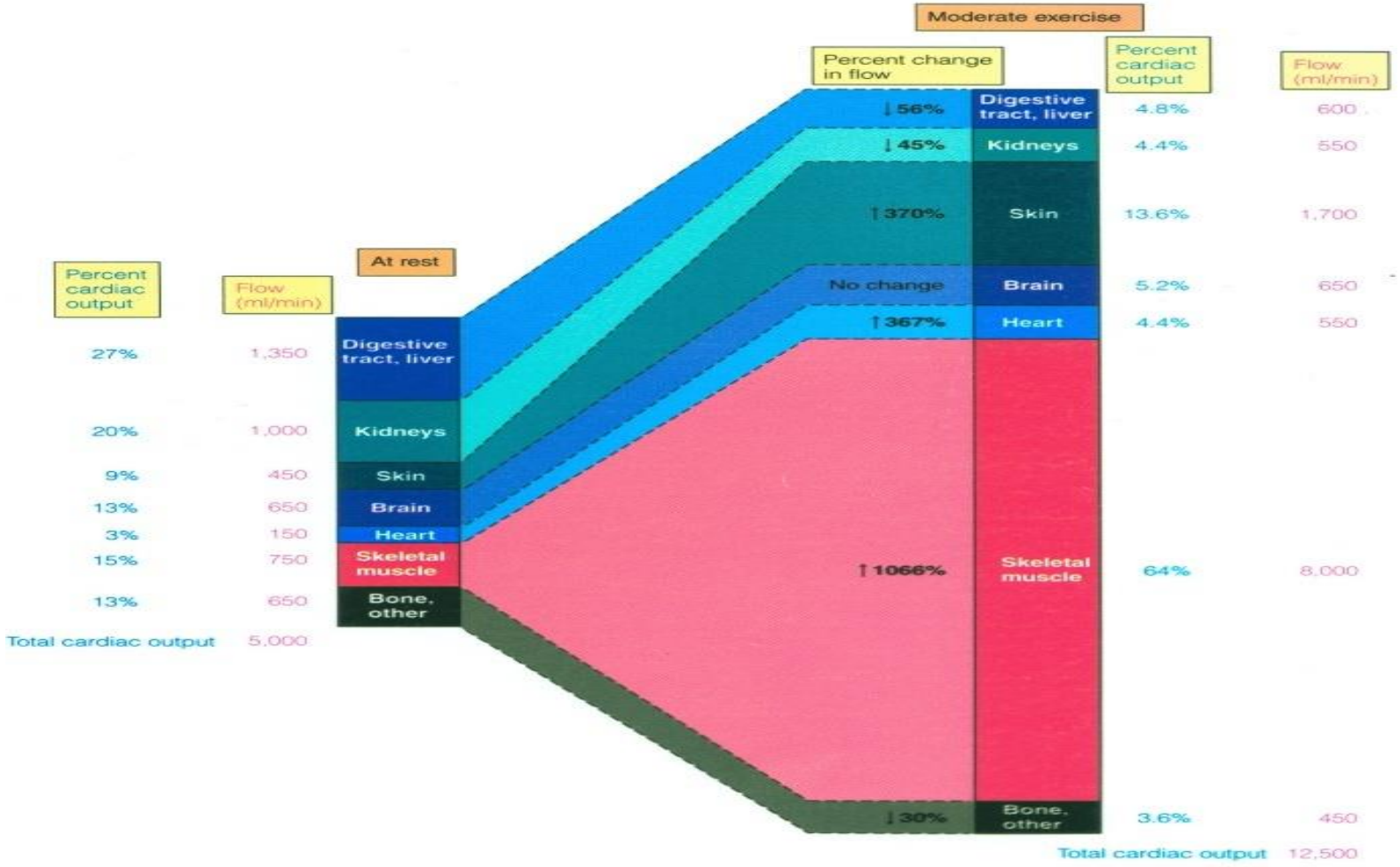
- List factors that affect tissue blood flow.
- Describe the vasodilator and oxygen demand theories.
- Point out the mechanisms of autoregulation.
- Describe how angiogenesis occurs.
- Inter-relat how various humoral factors affect blood flow.

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.*


35
30
25
20
15
10
5
0
CARDIAC OUTPUT (L/min/m)
OLYMPIC ATHLETE
CARDIAC OUTPUT
O_2 CONSUMPTION
COUCH POTATO
0
200
400
600
800
1000
1200
1400
1600
WORK OUTPUT DURING EXERCISE (kg*m/min)

Magnitude & Distribution of CO at Rest & During Moderate Exercise



Variations in Tissue Blood Flow

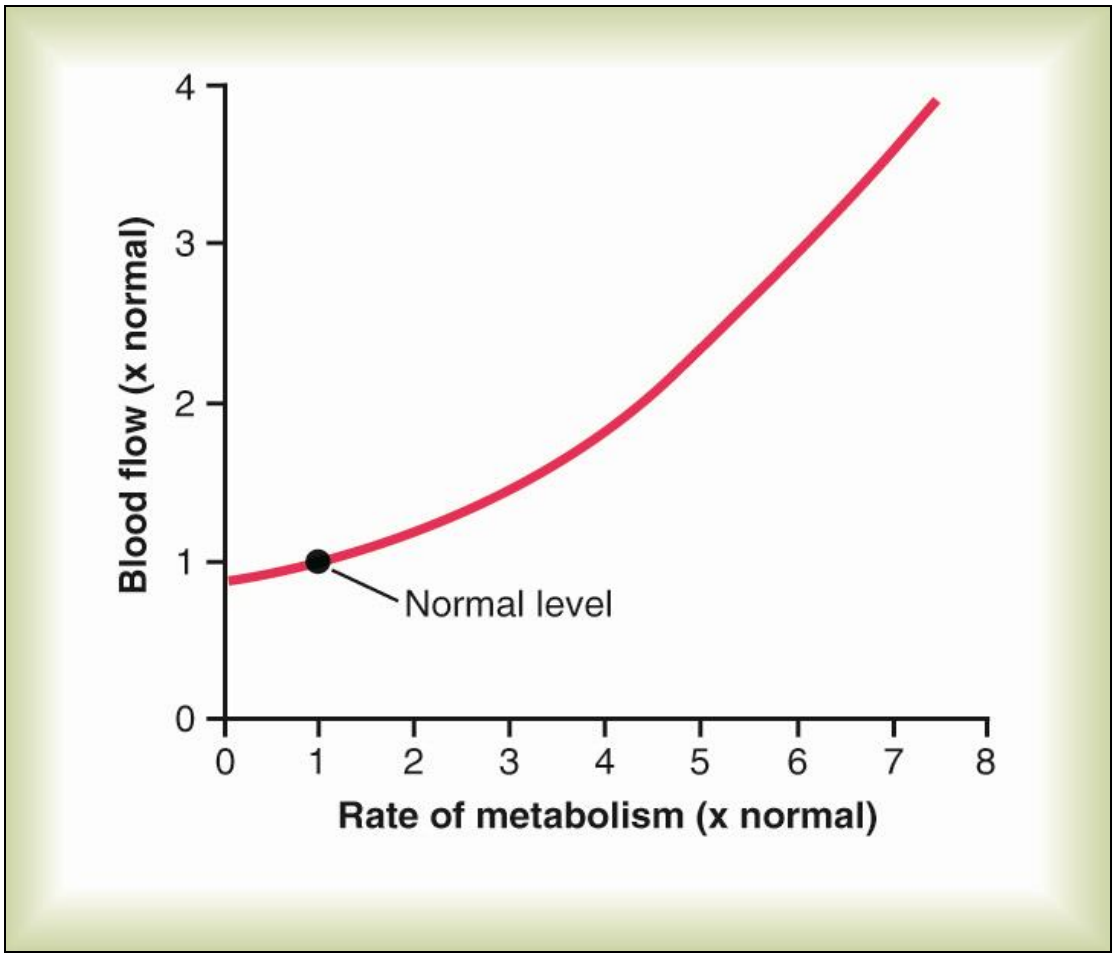
	Per cent	ml/min	ml/min/ 100 gm
Brain	14	700	50
Heart	4	200	70
Bronchi	2	100	25
Kidneys	22	1100	360
Liver	27	1350	95
Portal	(21)	(1050)	
Arterial	(6)	(300)	
Muscle (inactive state)	15	750	4
Bone	5	250	3
Skin (cool weather)	6	300	3
Thyroid gland	1	50	160
Adrenal glands	0.5	25	300
Other tissues	3.5	175	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*

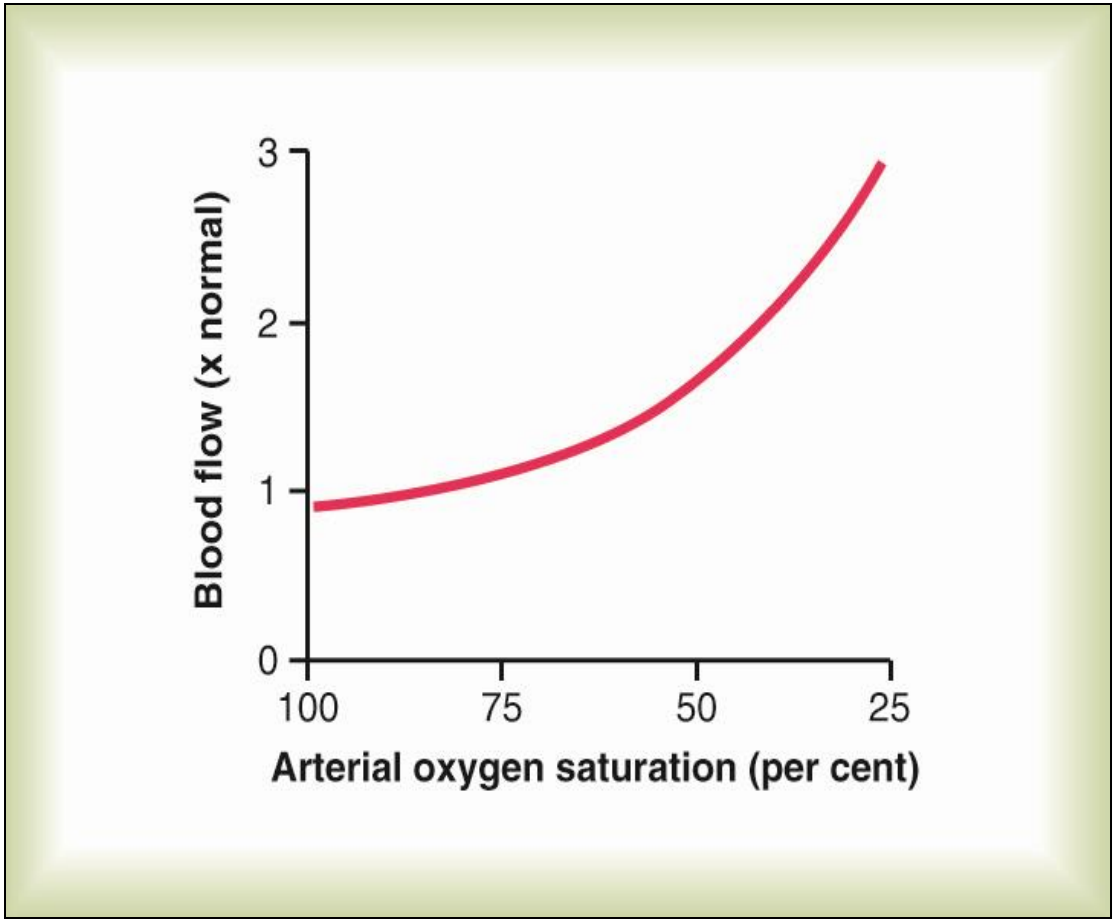
Effect of Tissue Metabolic Rate on Tissue Blood Flow

↑ Tissue Metabolism → ↑ Blood Flow



Effect of Tissue Oxygen concentration on Blood Flow

Tissue Oxygen Concentration ⟵ ⟰ **Blood Flow**



Relationship between Pressure, Flow, and Resistance

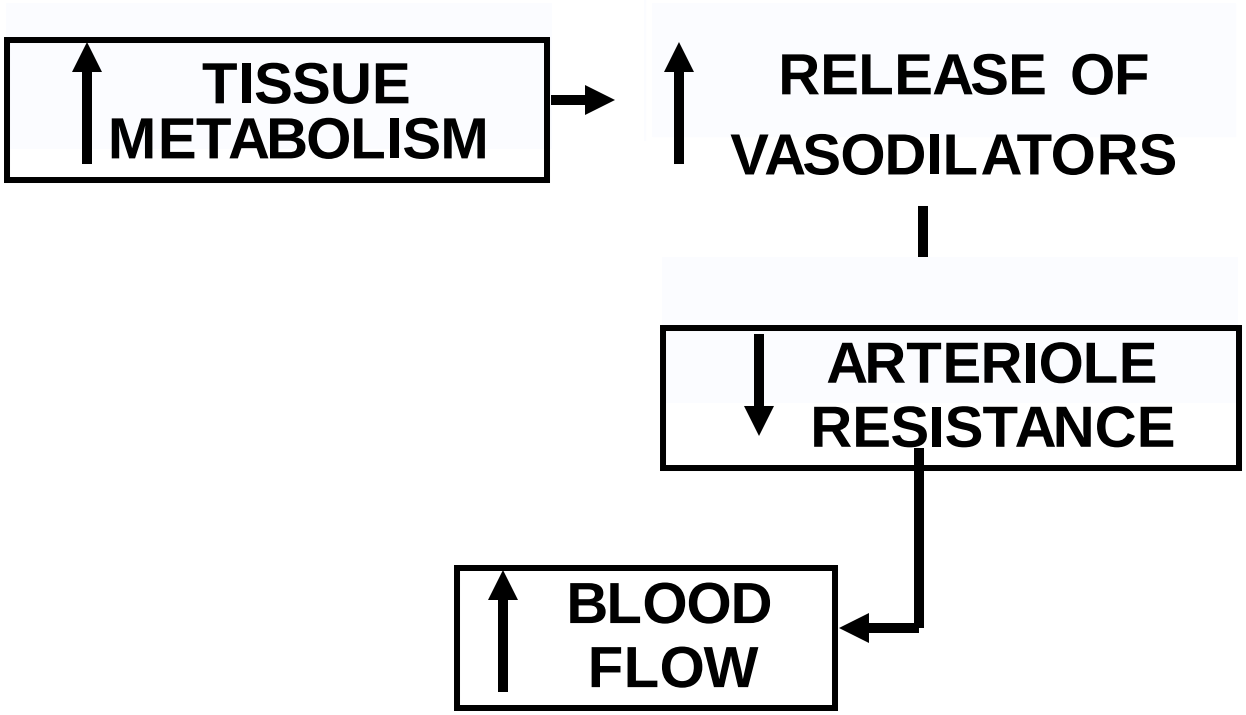
- $F=\Delta P/R$
- *Flow* (F) through a blood vessel is determined by:

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

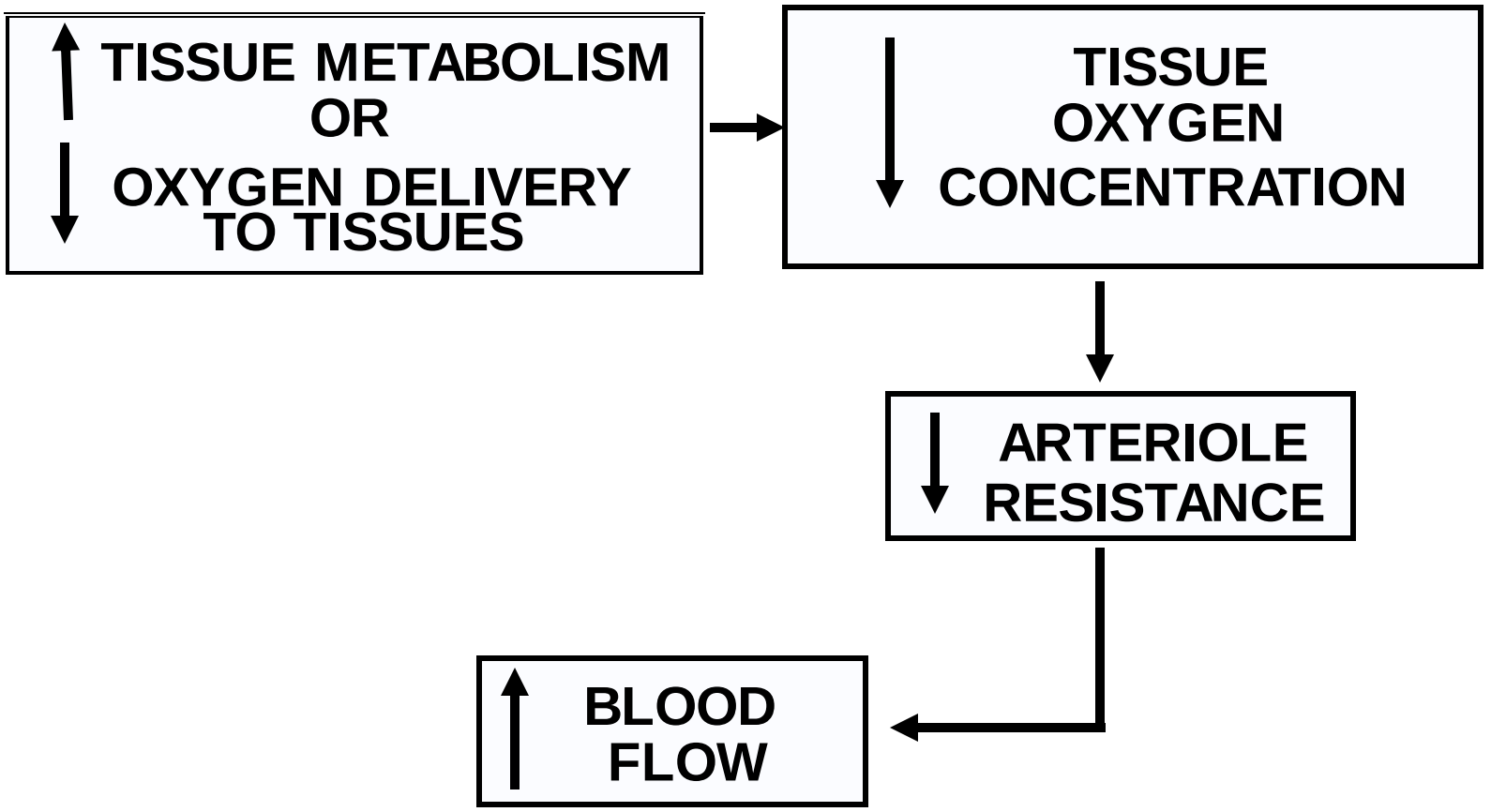
  2) *Resistance* (R) of the vessel

Vasodilator Theory for Blood Flow Control

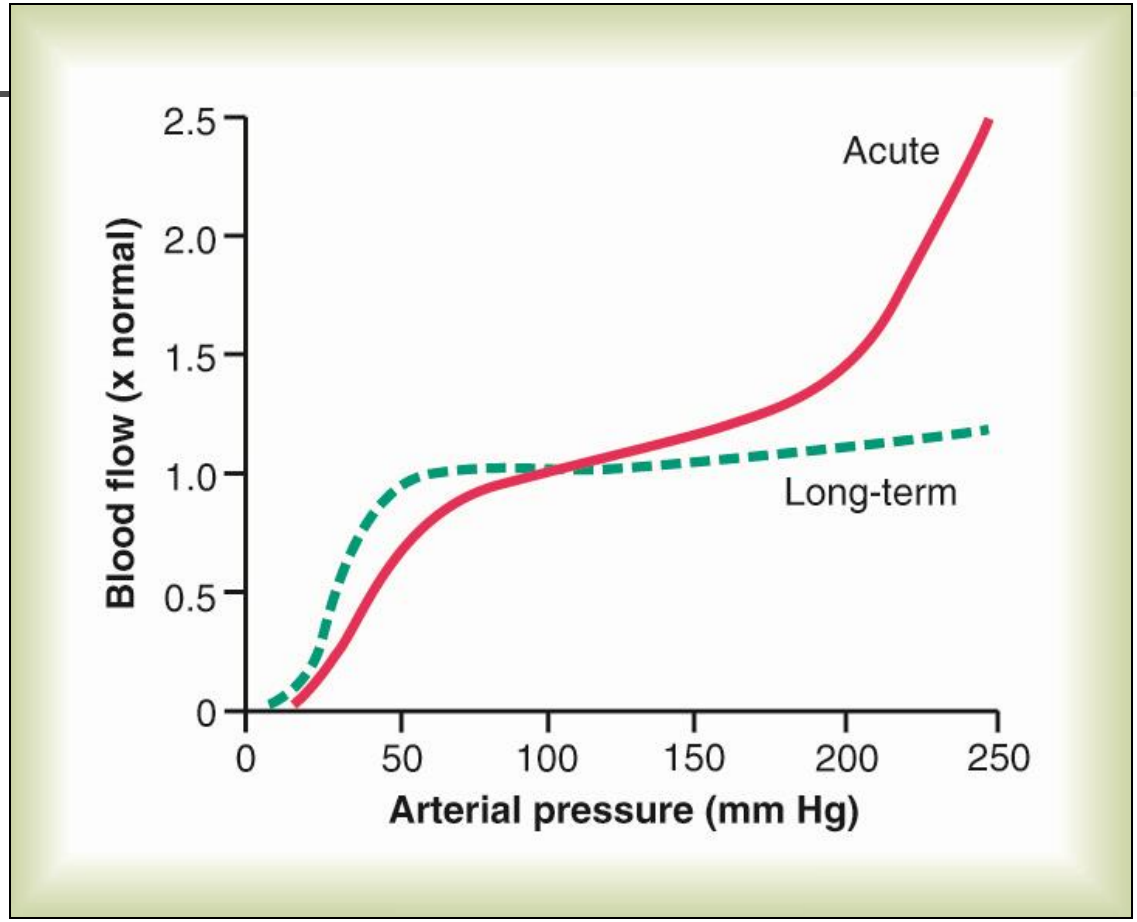
- Local Vasodilators: **Adenosine**, **CO2**, **Lactic acid**, **ADP compounds**, **Histamine**, **K^+ ions**, **H^+ ions**, **Prostacyclin**, **Bradykinin**, and **Nitrous oxid (NO)**



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.

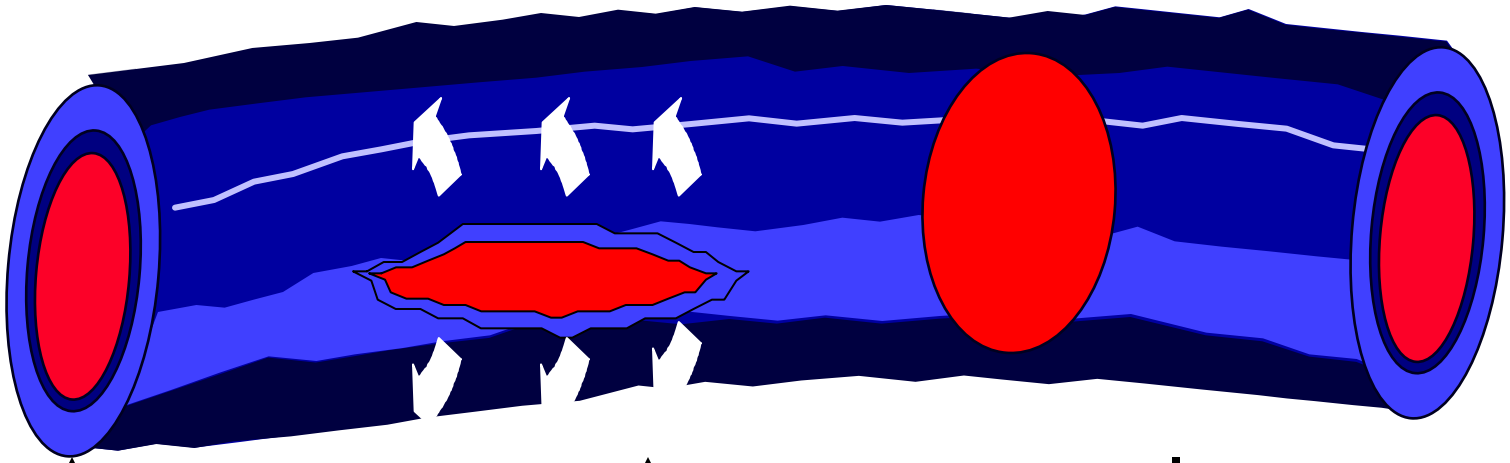
Blood Flow Autoregulation Theories

- *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)



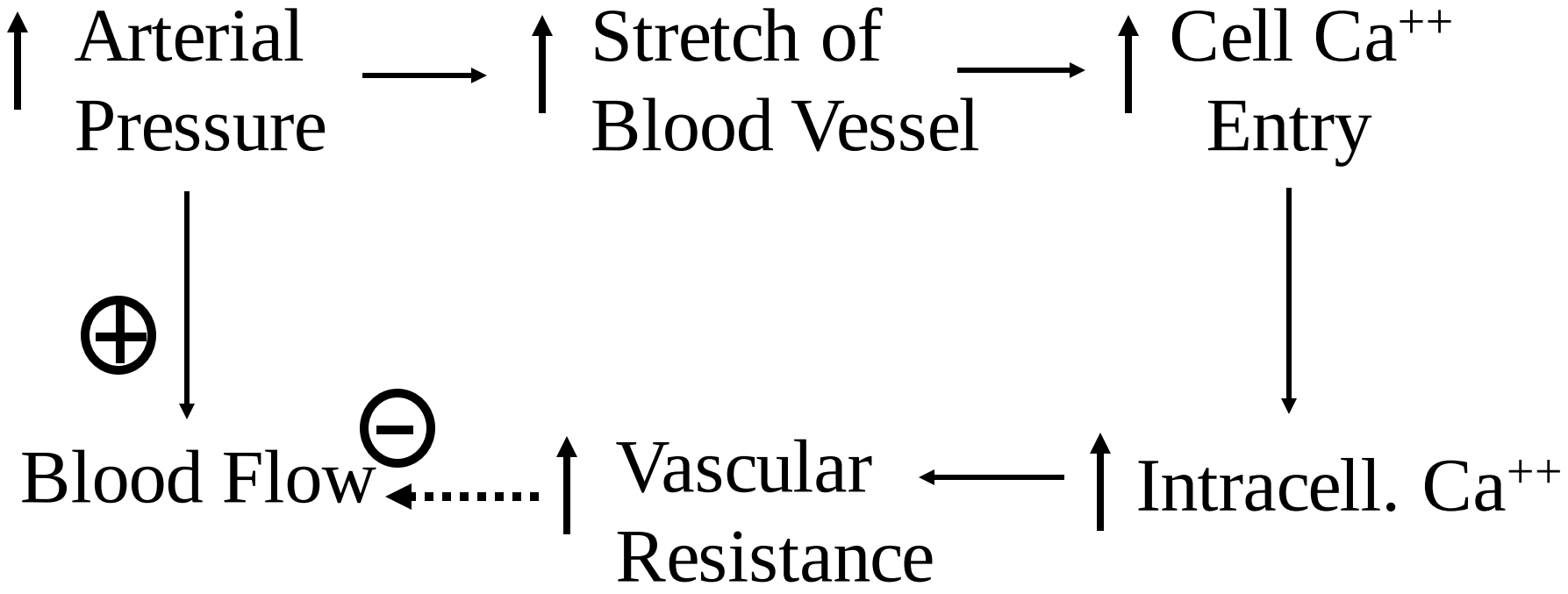
↑ **PRESSURE** → ↑ **TENSION** → ↓ **RADIUS**

↑ **(to maintain tension constant)**

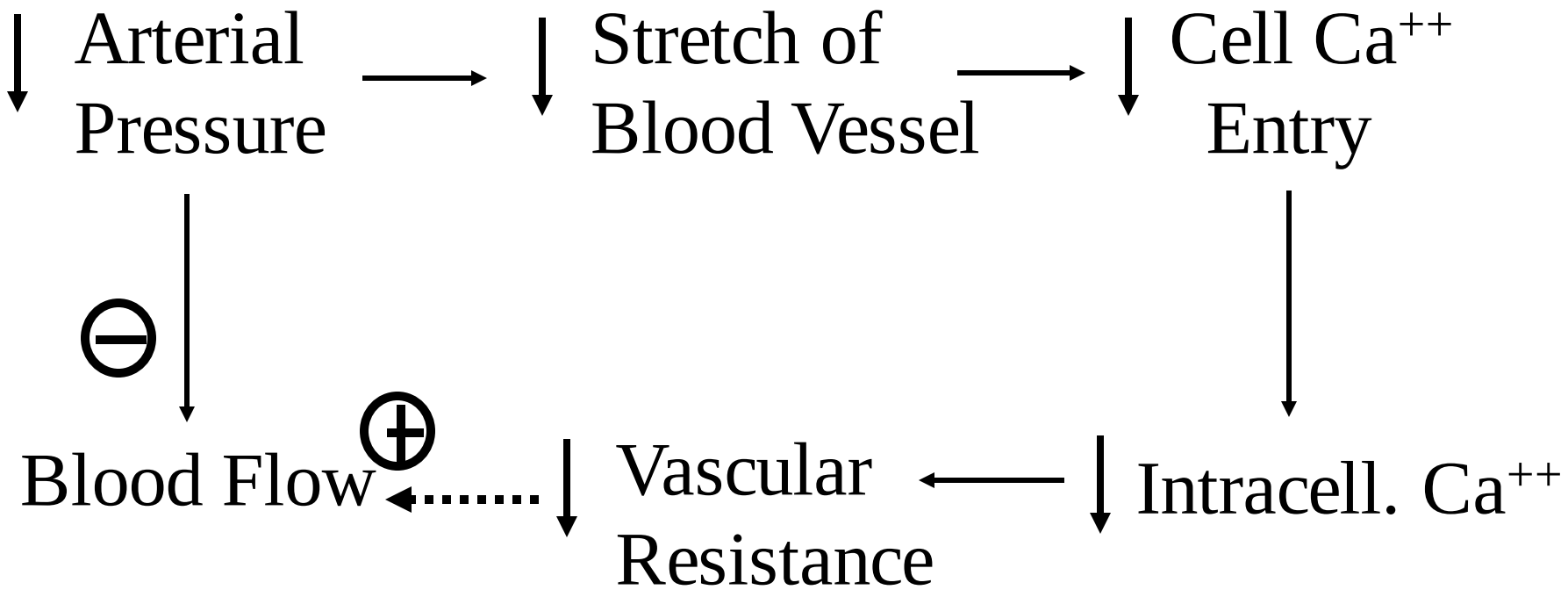
↓ **PRESSURE** → ↓ **TENSION** → ↑ **RADIUS**

↑ **(to maintain tension constant)**

Myogenic Mechanism



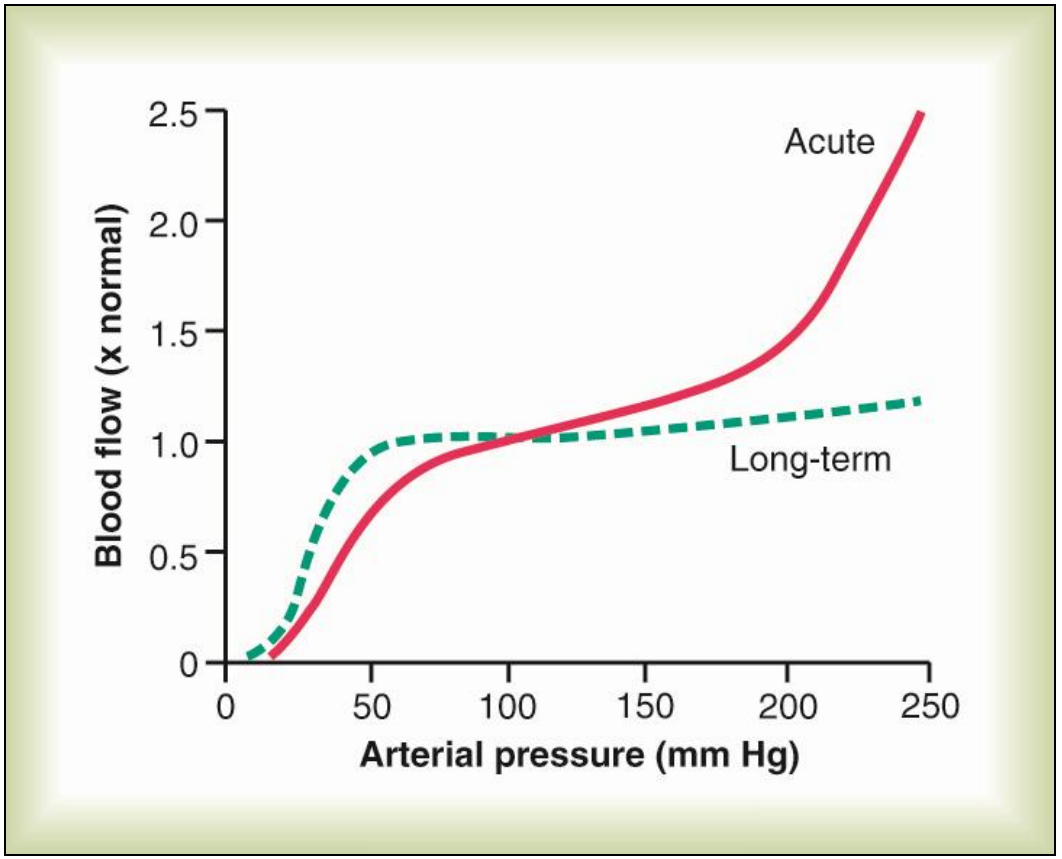
Myogenic Mechanism



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***

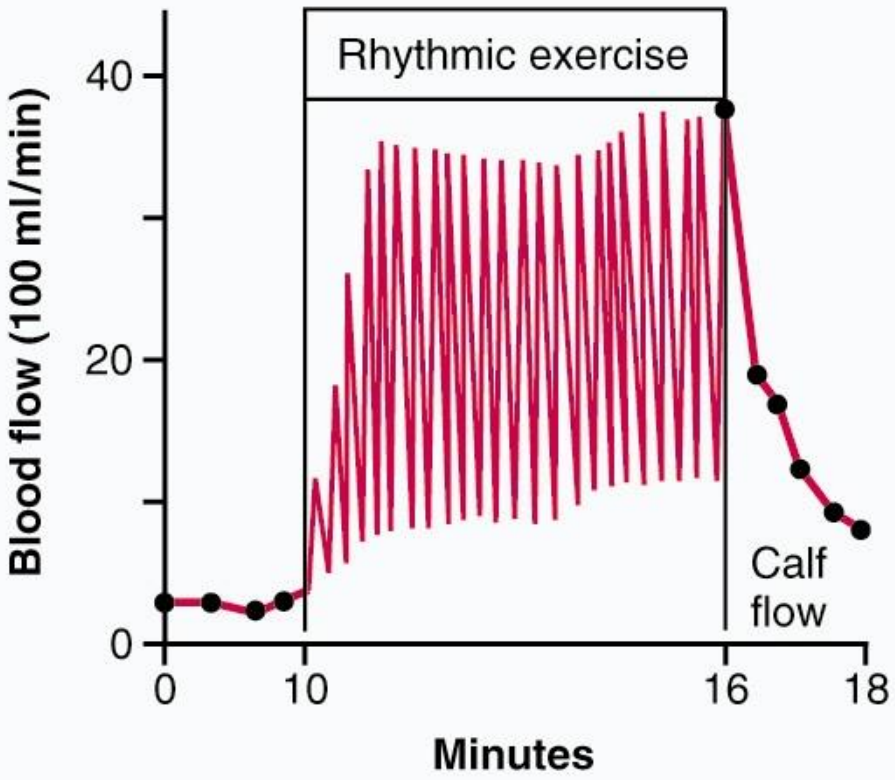
Humoral Regulation of Blood Flow

- 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

Exercise and Muscle Blood Flow



Muscle Blood Flow During Exercise

- Can 20 fold during exercise.
- Muscle makes up a large portion of body mass Þ great effect on Cardiac output.
- Resting blood flow = 3 to 4 ml/min/100 gm muscle.
- Oxygen delivery can be increased by increasing the extraction ratio from 25% up t0 75%
- Capillary density ’s markedly.
- Most blood flow occurs between contractions.

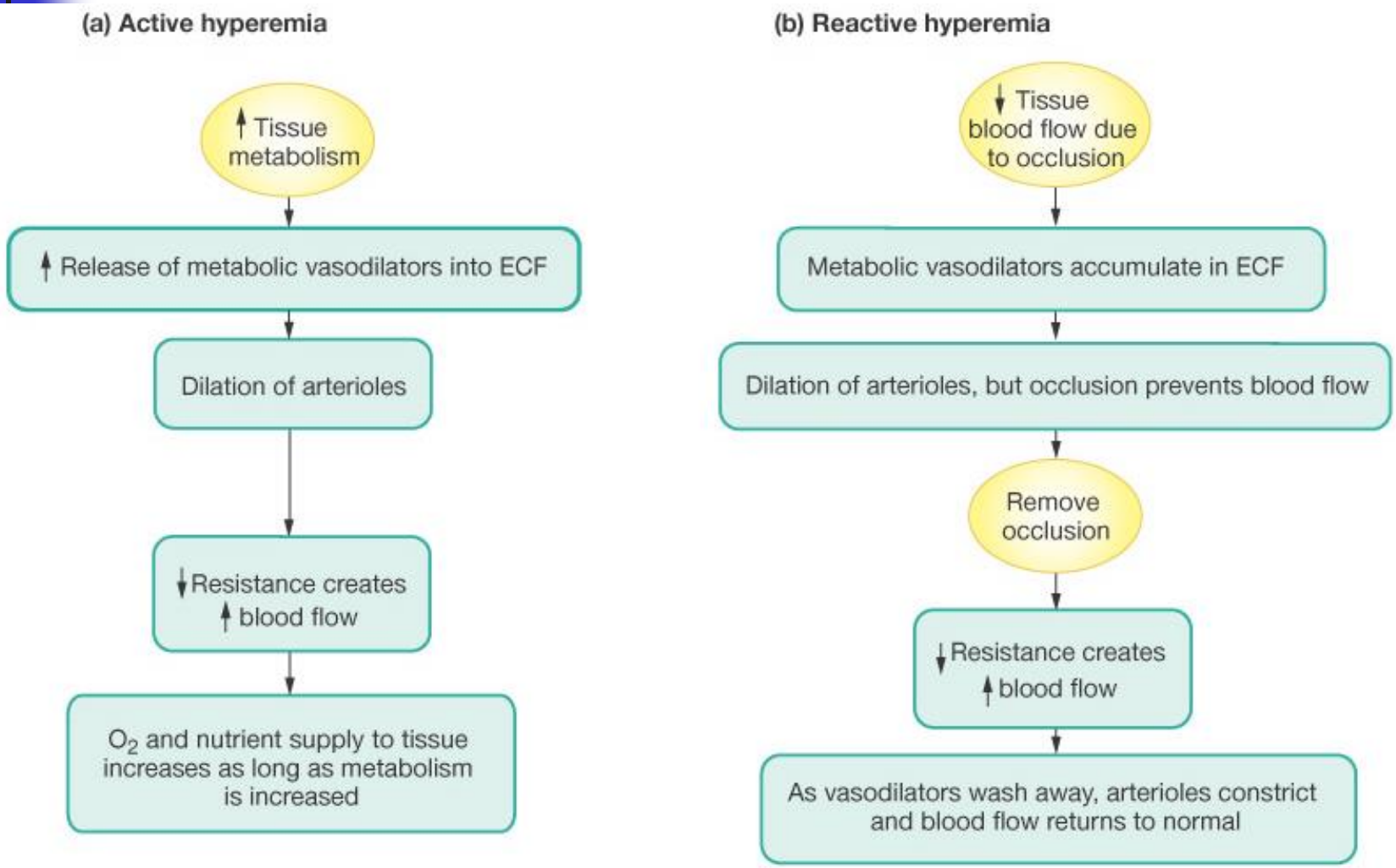
Local Regulation of Muscle Blood Flow during Exercise

- ↓ O_2 during exercise affects vascular smooth muscle directly ⇒ vasodilation.
- Vasodilators (which ones?)
  1. K^+
  2. Adenosine
  3. Osmolality
  4. EDRF (nitric oxide)

Nervous Regulation

- Sympathetic release of norepinephrine (mainly α).
- Adrenals release epinephrine (β and α) norepinephrine (α + a little β).
  - β receptors ⇒ vasodilation mainly in muscle and the liver.
  - α receptors ⇒ vasoconstriction in kidney and gut.

Arteriole Resistance: Control of Local Blood Flow



Thank You