Coronary Circulation

Important ! Why?

One third of all deaths in the world result from coronary artery disease.

Almost all elderly people have at least some impairment of the coronary artery circulation.

Aerobic Requirements of the Heart

Survival requires that the heart and brain receive adequate blood supply at all times.

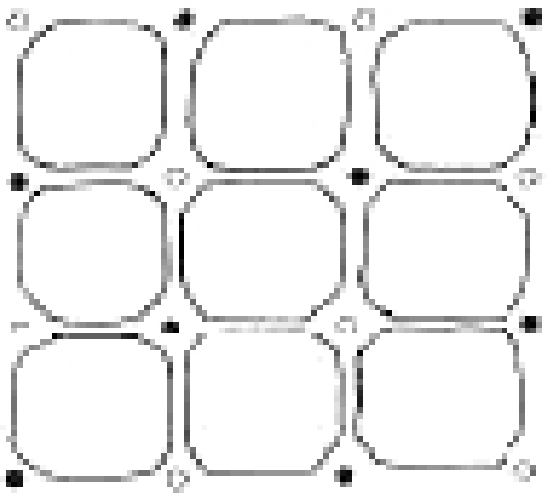
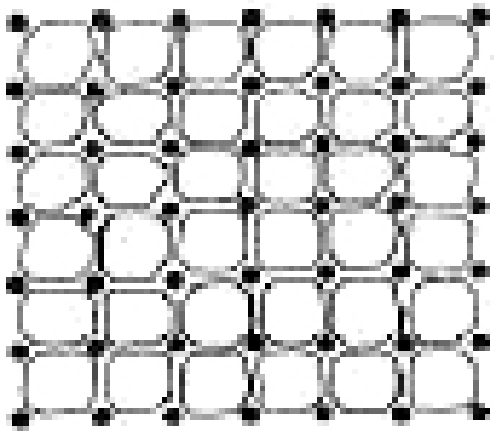
- Coronary arteries supply an enormous number of capillaries.

- Systole contracts the coronary blood vessels.
- Diastole increases blood flow to the heart muscle.

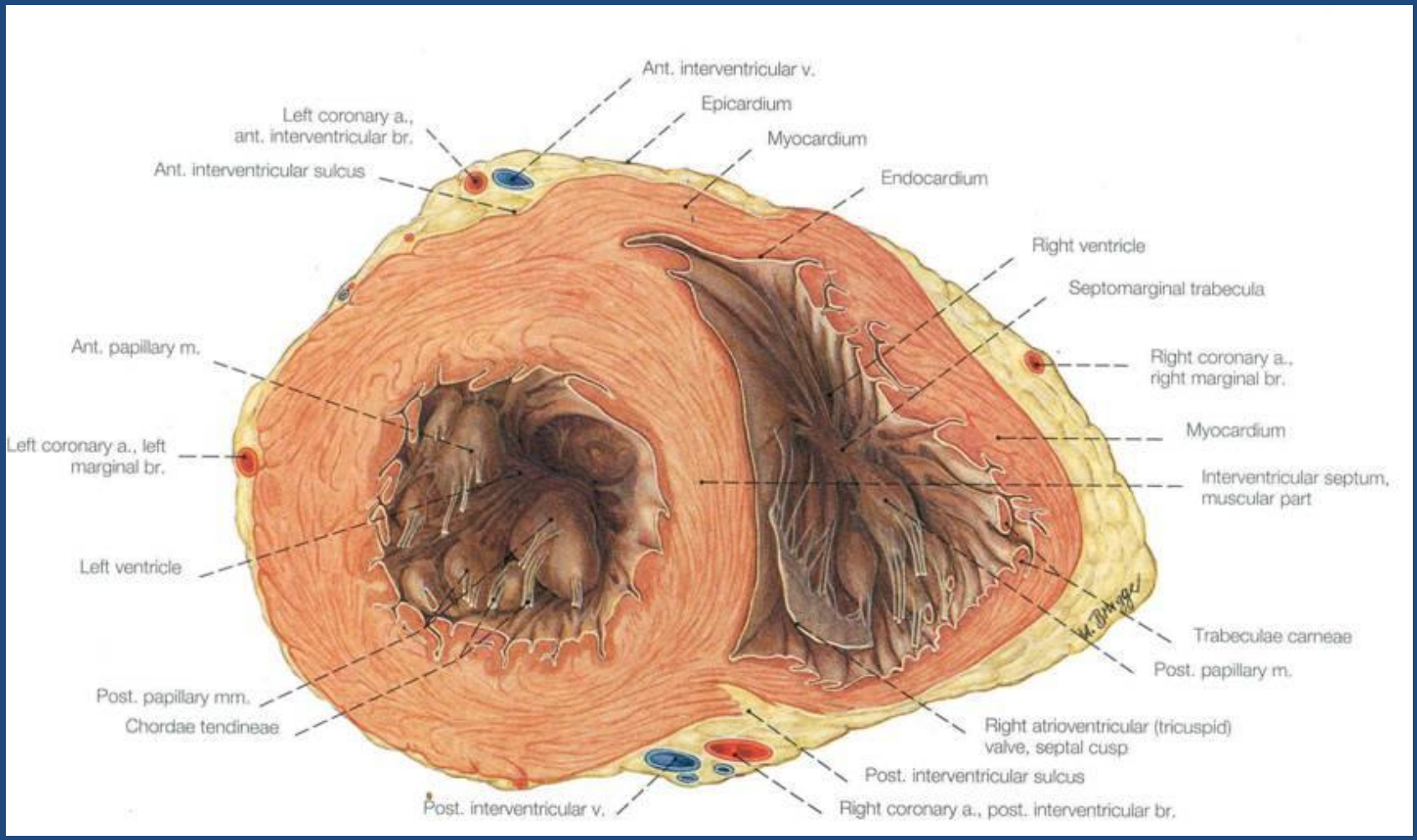
Myocardium contains large amounts of myoglobin.

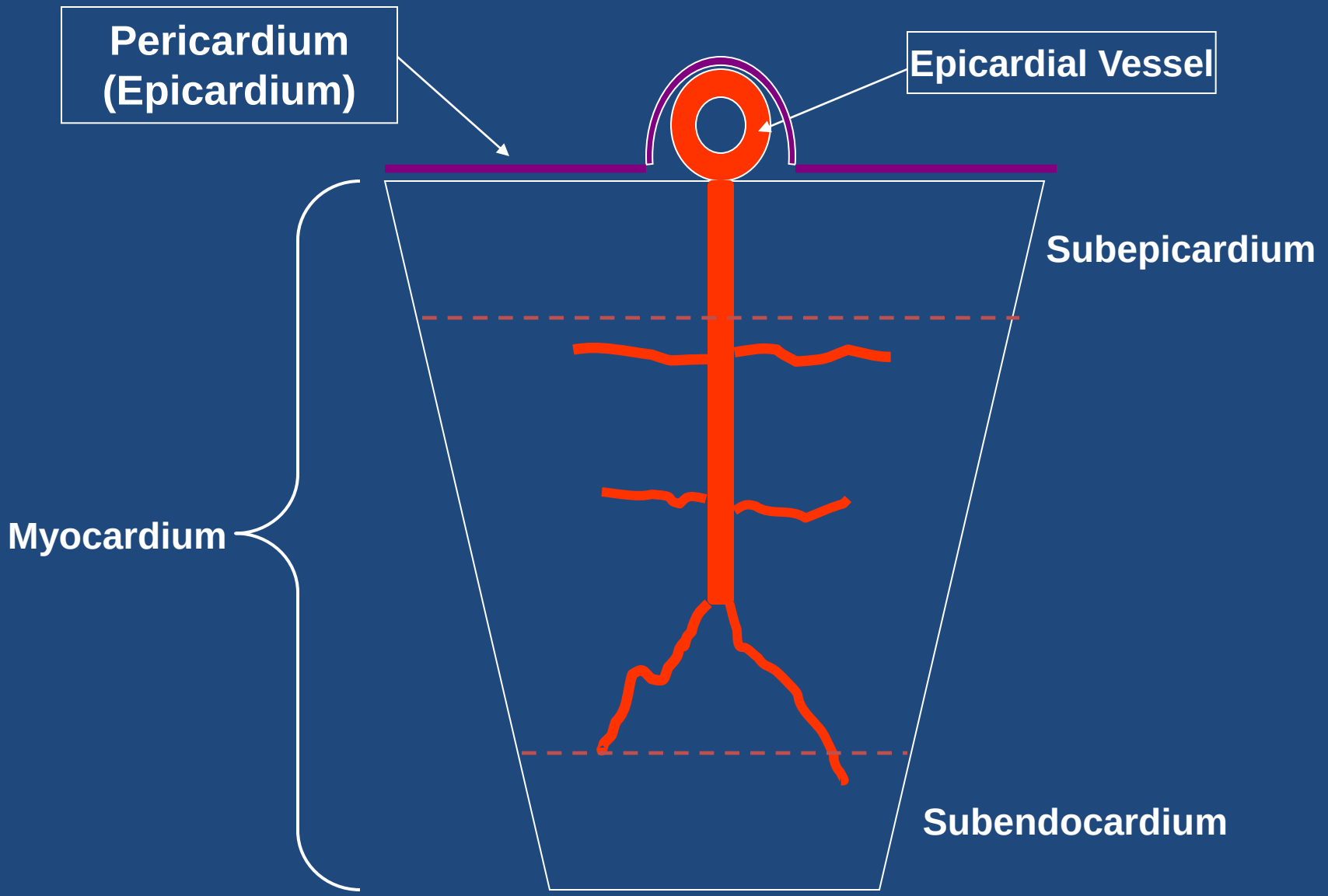
- Myoglobin stores 0_2 during diastole to release during systole.
  - Heart muscle contains increased number of mitochondria and aerobic respiratory enzymes.

Capillary Density in the Heart

	Skeletal muscle	Cardiac muscle
		
Fibre diameter	50 µm	18 µm
Capillaries per mm^2	400	3000

Walls of the ventricles:
Left wall is thicker!




Pericardium
(Epicardium)
Epicardial Vessel
Subepicardium
Myocardium
Subendocardium

Coronary Vascular Resistance

Epicardial conductance vessels:

Contribute only to a **small** % of resistance.

Intramyocardial vessels (arterioles):

Contribute **most** to total coronary vascular resistance.

Blood flow to Heart during Systole & Diastole

During **systole** when heart muscle contracts it **compresses** the coronary arteries therefore → ↓ blood flow to the left ventricle during systole and → ↑ blood flow to the right ventricle during diastole.

To the **subendocardial** portion of the Left ventricle blood flow occurs only during diastole.

Therefore this region is **more prone** to **ischemic damage** and most common site of **myocardial infarction.**

Coronary Circulation:

Resting coronary blood flow = 225 ml/min.

About 4 to 5 % of total cardiac output.

'Work' of the heart under severe conditions may increase 7 to 9 folds.

Coronary blood flow increases 3 to 4 folds to supply the extra nutrients.

CORONARY BLOOD FLOW

At rest, the heart extracts 60-70% of oxygen from each unit of blood delivered to heart (other tissues extract only 25% of O_2).

Why the heart is extracting 60-70% of O_2?

Heart muscle has more mitochondria, up to 40% of cell is occupied by mitochondria, which generate energy for contraction by aerobic metabolism, therefore, heart needs more O_2.

When more oxygen is needed e.g. In exercise, O_2 can be increased to heart only by increasing blood flow.

In aortic stenosis → Ischemia prone to develop.

↓

Increase pressure in ventricle and vessels compressed more.

↓

More O_2 needed due to high workload.

↓

Congestive heart failure
Failure of pumping action
Low effective coronary perfusion

Regulation of Coronary Blood Flow

1- Metabolic control

2- Auto regulation

3- Endothelial control of coronary vascular tone

4- Extravascular compressive forces

5- Neural control

1- Metabolic Control

Coronary circulation is very sensitive to myocardial tissue oxygen tension.

Increased oxygen demand results in a lower tissue oxygen tension.

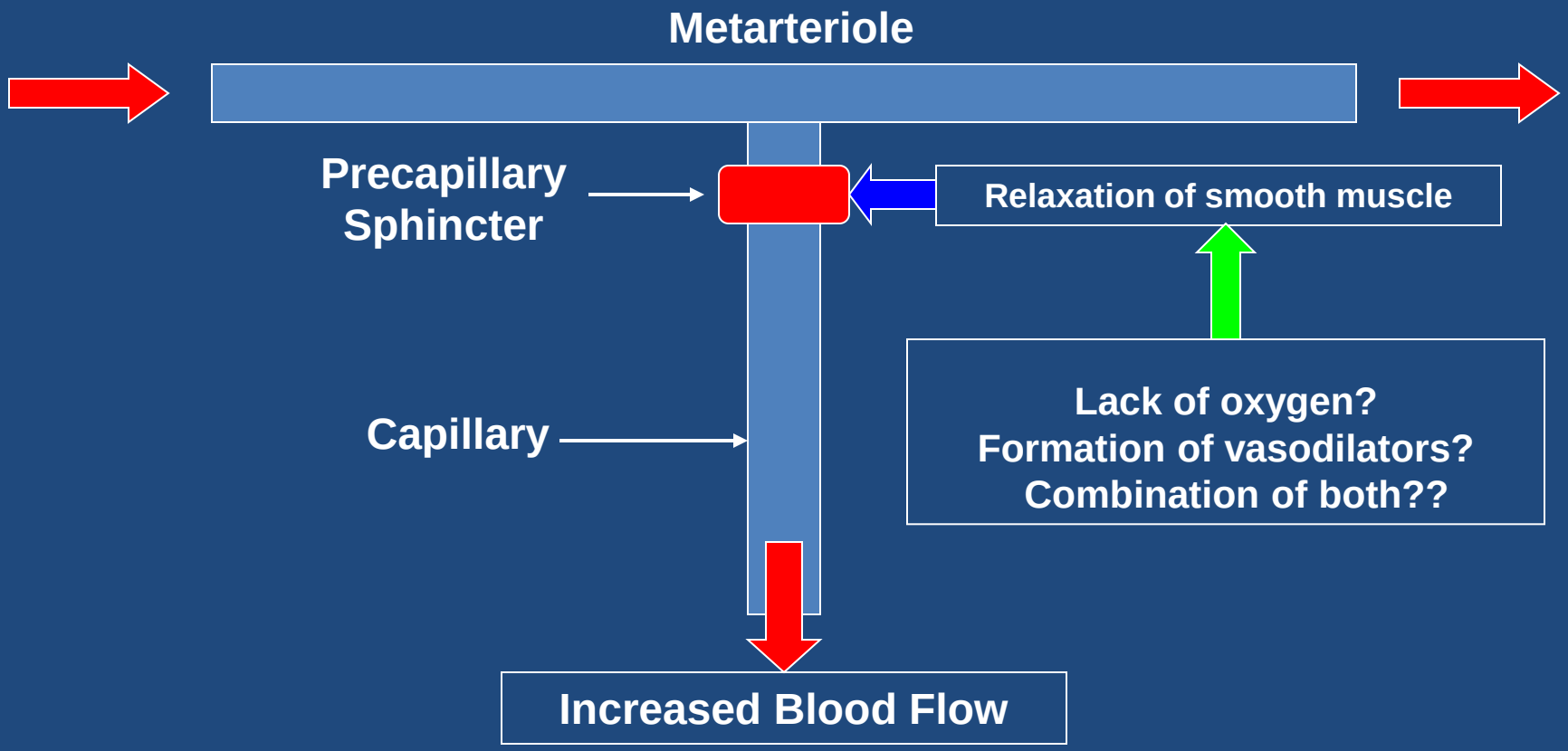
This causes:

Vasodilation and increased blood flow by chemical factors like:-

- **1- ↑ Adenosine**
- **2- Lack of oxygen**
- **3- ↑ Nitric oxide**
- **4- ↑ Prostaglandins**
- **5- ↑ K^+**
- **6- ↑ H^+**
- **7- ↑ Lactate**
- **8- ↑ Adenine nucleotides**

Adenosine, which is formed from ATP during cardiac metabolic activity, causes coronary vasodilatation.

Metabolic Control of Blood Flow



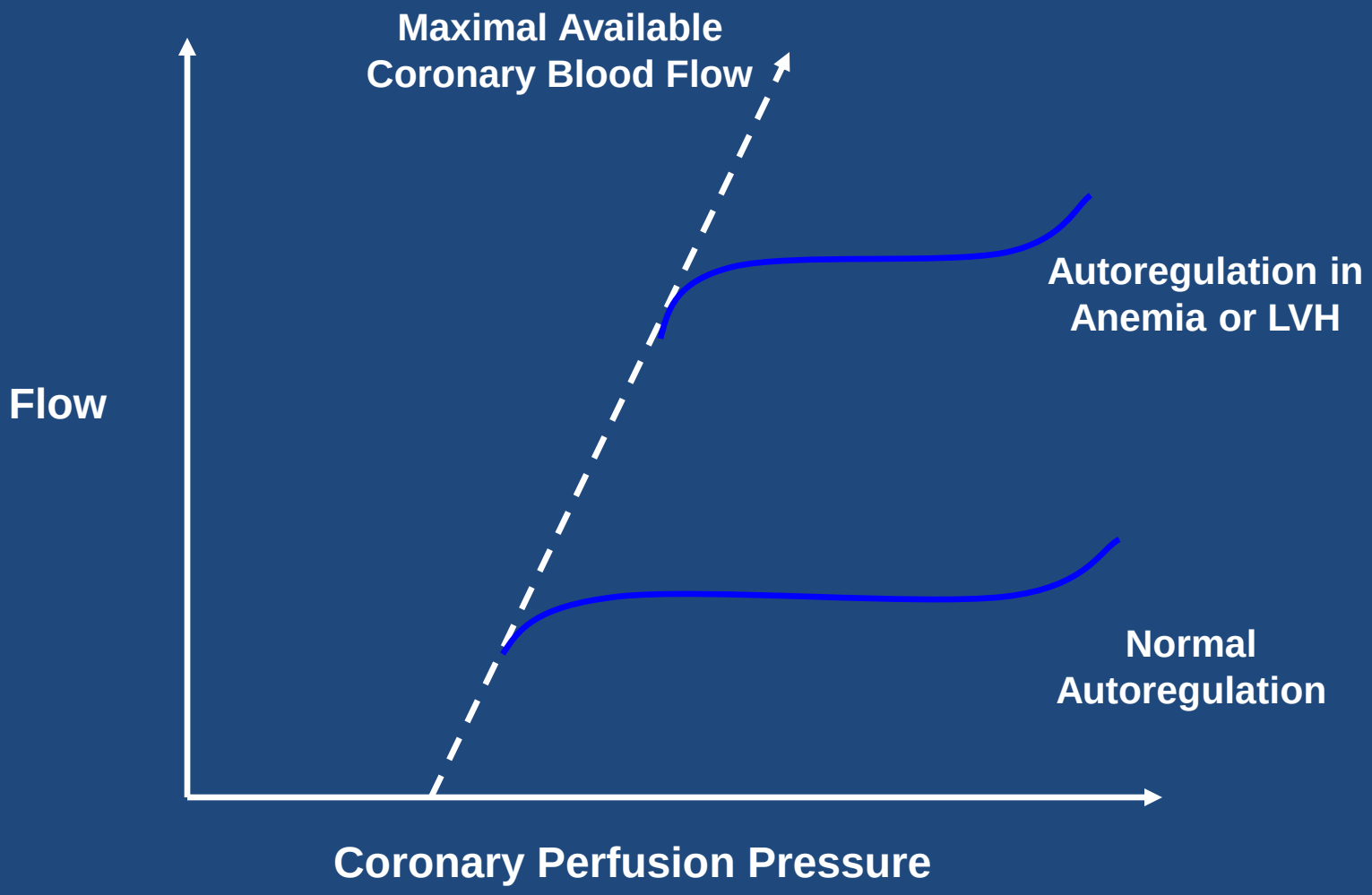
2- Auto regulation

Ability of a vascular network to maintain constant blood flow over a range of arterial pressures.

Auto regulation is an independent determinant of coronary blood flow.

The set point at which coronary blood flow is maintained depends on myocardial oxygen consumption (MVO2).

Autoregulation



3- Endothelial Control of Coronary vascular Tone

Damage to endothelial cells will lead to:

1- Decreased Nitric Oxide and Prostacyclin production.

2- Increased Endothelin production.

This will lead to:

1- Vasoconstriction.

2- Vasospasm.

3- Thrombosis.

4- Neural Control

Coronary blood flow is controlled predominantly by local metabolic, auto regulatory, and endothelial factors.

Neural control of the coronary circulation complements the above local effects.

Neural Control

Sympathetic Control:

- **Alpha = constrict coronary vessels.**
- **Beta = dilate coronary vessels.**
  - **$Beta_1$ in conduit arteries.**
  - **$Beta_2$ in resistance arterioles.**

Parasympathetic Control:

- **Acetylcholine**
  - **Vasodilation in healthy subjects.**
  - **Vasoconstriction in patients with atherosclerosis.**

5- Extravascular Compressive Forces

The heart influences its blood supply by the squeezing effect of the contracting myocardium on the blood vessels coursing through the heart.

Extravascular Compressive Forces

Left Ventricle:

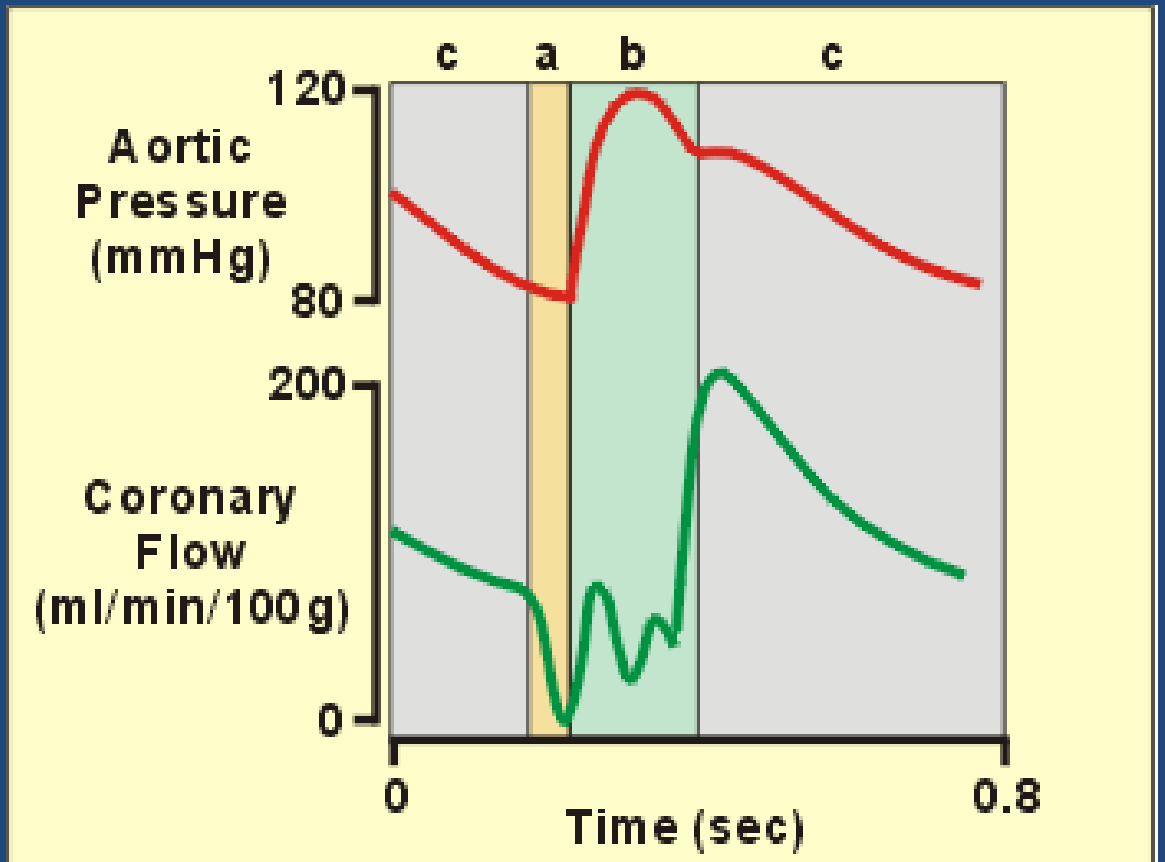
Early Systole > Initial Flow Reversal.

Remainder of Systole > Flow follows aortic pressure curve, but at a much reduced pressure.

Early Diastole > Abrupt pressure rise **(80-90% of LV flow occurs in early diastole).**

Remainder of Diastole > Pressure declines slowly as aortic pressure decreases.

Extravascular Compressive Forces



Pulsatile nature of left coronary artery blood flow. Flow is lower during phases of isovolumetric contraction (a) and ejection (b) than during diastole (c).

Extravascular Compressive Forces

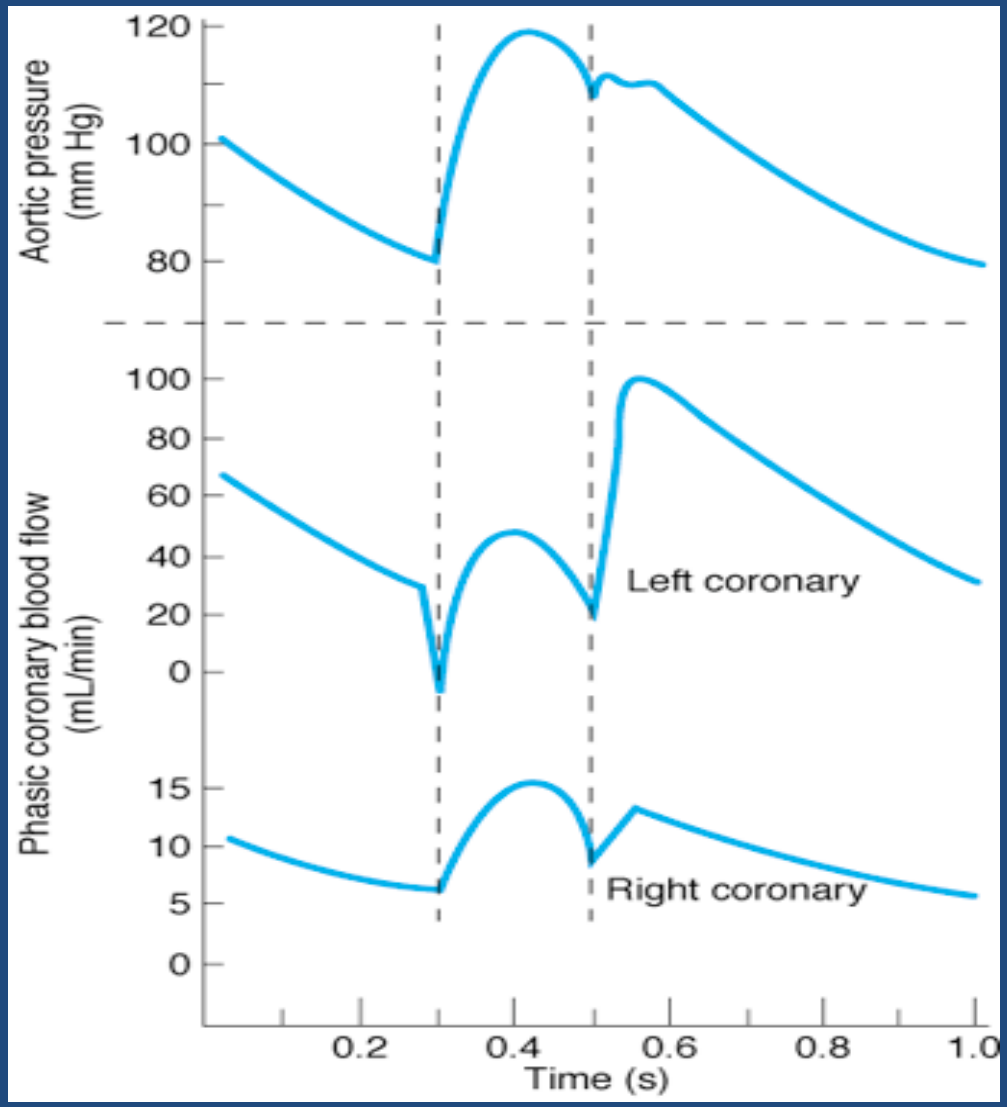
Right Ventricle:

Lower pressure generated by thin right ventricle in Systole.

No reversal of blood flow during early systole.

Systolic blood flow constitutes a much greater proportion of total blood flow.

CORONARY BLOOD FLOW DURING SYSTOLE AND DIASTOLE



Transmural Distribution of Myocardial Blood Flow

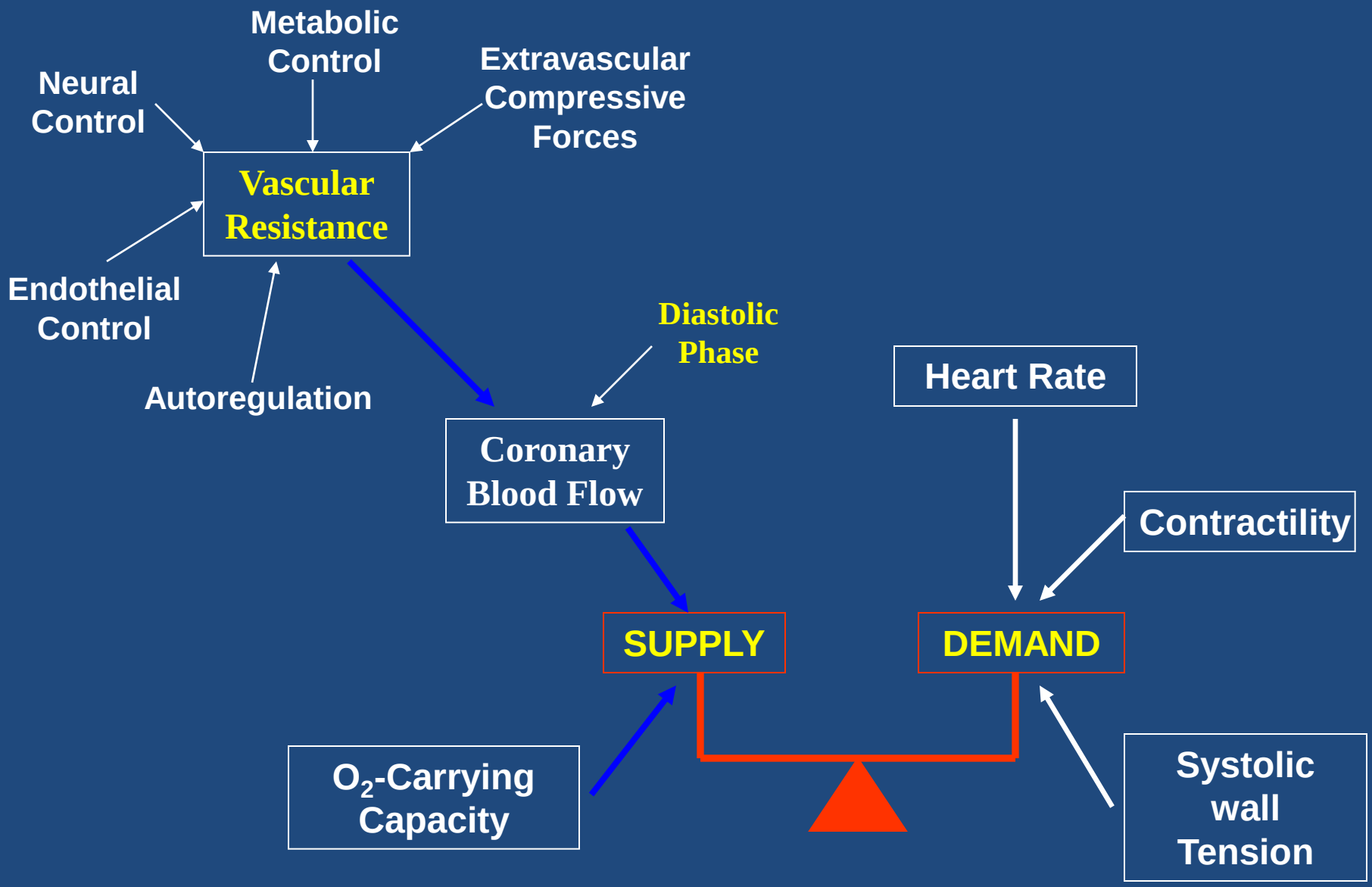
Extravascular compressive forces are greater in the subendocardium (inner) and least near the subepicardial Layer (outer).

Under normal resting conditions this does not impair subendocardial blood flow as increased flow during diastole Compensates.

Transmural Distribution of Myocardial Blood Flow

The subendocardium is more susceptible to ischemia than the midmyocardium or Subepicardium.

Determinants of Myocardial Oxygen Supply and Demand


Metabolic Control
Neural Control
Extravascular Compressive Forces
Vascular Resistance
Endothelial Control
Autoregulation
Diastolic Phase
Heart Rate
Coronary Blood Flow
Contractility
SUPPLY
DEMAND
O_2-Carrying Capacity
Systolic wall Tension

Factors Increasing Myocardial Oxygen Consumption

1- Increased Heart Rate.

2- Increased Inotropy (Contractility).

3- Increased Afterload.

4- Increased Preload.

Changes in preload affect myocardial oxygen consumption less than do changes in the other factors.

NEUTRIENT SUPPLY TO HEART

Heart uses primarily free fatty acids and to lesser extent glucose and lactate for metabolism.

Angina:

Angina pectoris:-

Characterized by chest pain (discomfort) may radiate to neck, jaw, left arm.

Classical (exertional angina) – increase with exertion.

Clinically normal & diagnosis by description.

Angina:

Investigation:

ECG may be normal between attacks.

Exercise ECG – 75% positive, Normal results does not exclude the condition.

Treatment for attack:

Stop exercise
Glyceryl trinitrate 0.5mg under the tongue.
(side effects → headache)

Myocardial infraction:

Most common cause of death.

Clinical features:
Chest pain – even at rest & last for hours.

Severe pain – sudden onset, but can develop gradually.

Associated with: sweating, vomiting.

20% no pain.

Hypotension.

Investigation:-

Cardiac enzyme – CK (creatine kinase),

AST (aspartate aminotrasferase), LDH (lactic dehydrogenase)

ECG:

Q wave, ST elevation, T inversion.

Q wave – full thickness infraction.