

**M U N I**  
**M E D**

# **CARDIOVASCULAR PHYSIOLOGY**

**E-C coupling. Heart as a pump.**

# EXCITATION – CONTRACTION COUPLING

Events connecting electrical activity of the heart (depolarization of sarcolemma), **EXCITATION**

and its mechanical response, **CONTRACTION**

Link between these events is **Ca<sup>2+</sup>**

## FUNCTION

- Triggering of contraction
- Regulation of contraction force

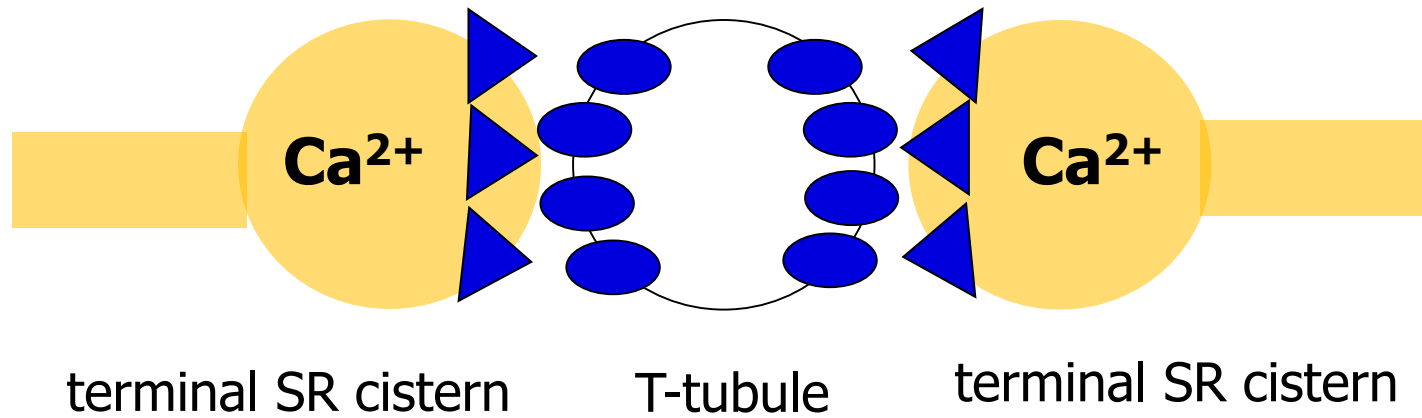
# KEY STRUCTURES / ORGANELLES / RECEPTORS

- Transverse tubules of sarcolemma (T-tubules)
  - Sarcoplasmic reticulum (SR)
  - Calcium channels:
- DHPR** (dihydropyridine receptor) in T-tubules/sarcolemma
- RYR** (ryanodine receptor) in SR
- SARCOTUBULAR SYSTEM**
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# FUNCTIONAL ORGANISATION of SARCOTUBULAR SYSTEM

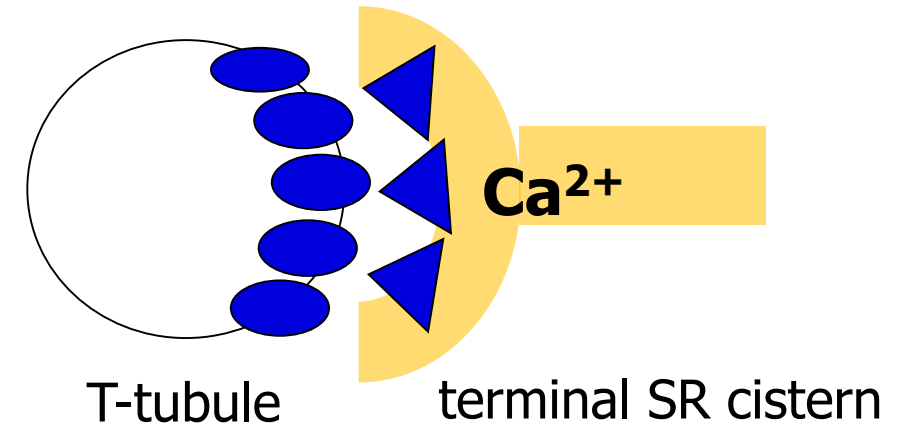
## RHABDOMYOCYTE

### TRIAD



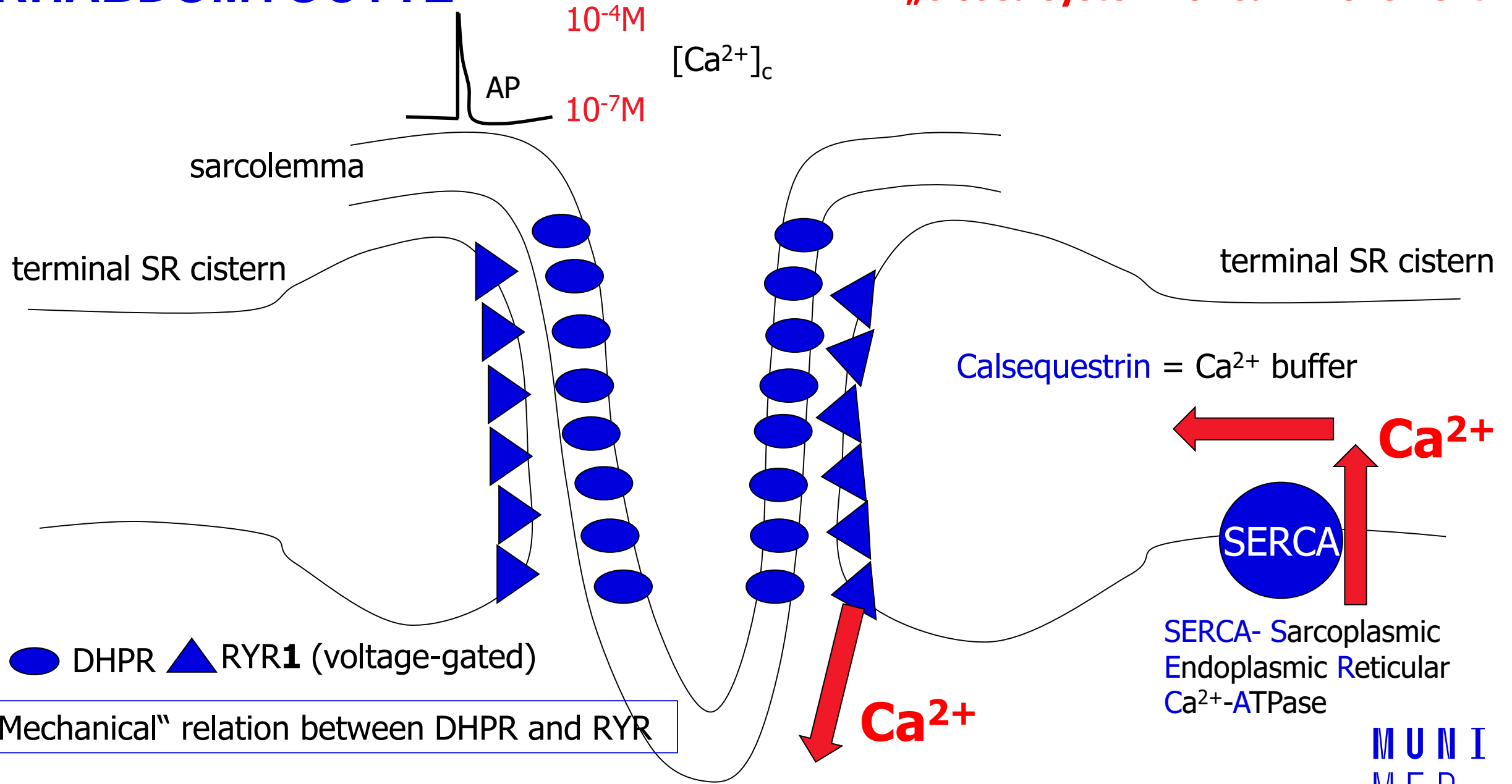
## CARDIOMYOCYTE

### DIAD

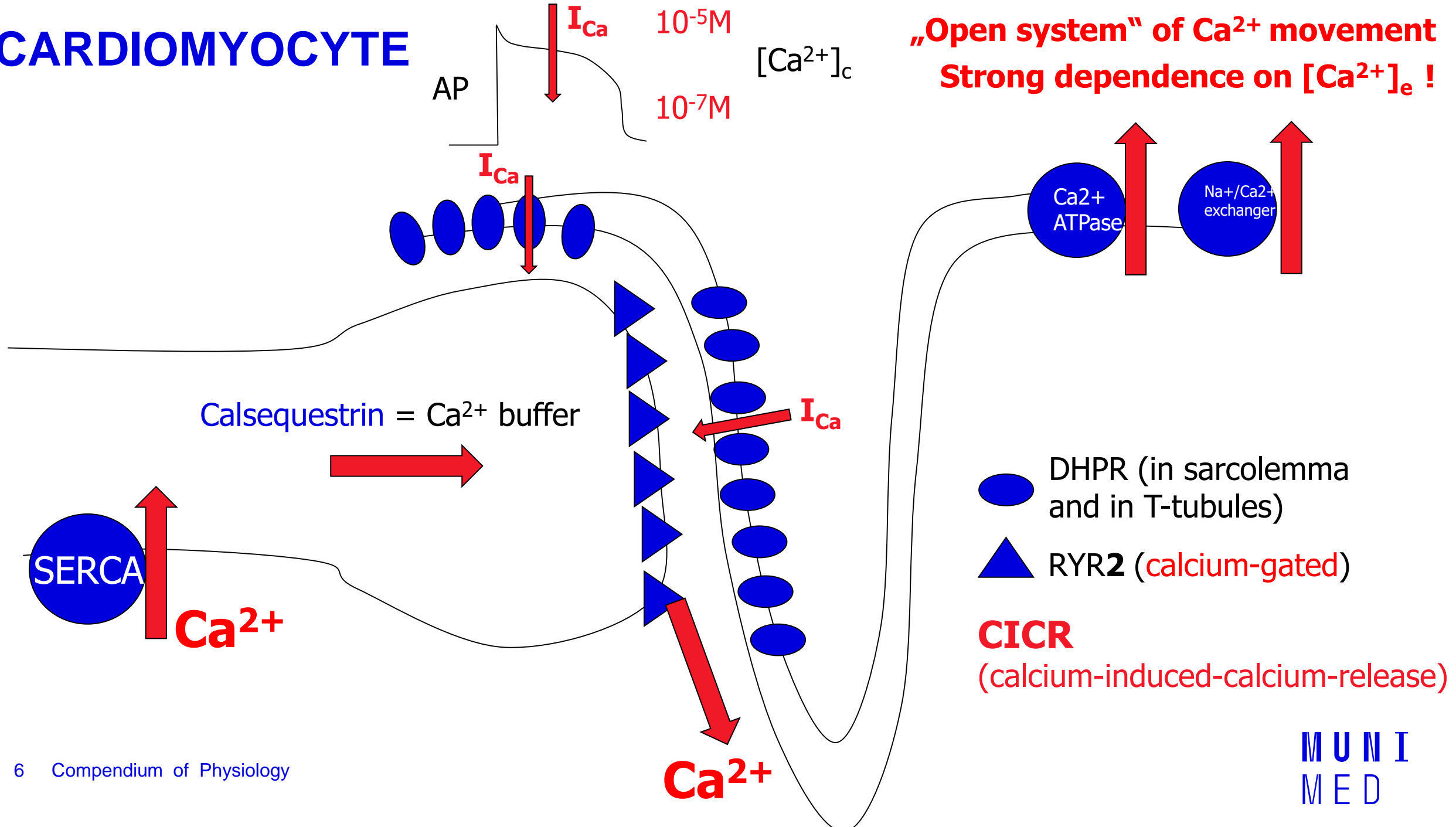


# RHABDOMYOCYTE

„Closed system“ of  $\text{Ca}^{2+}$  movement



# CARDIOMYOCYTE



„Open system“ of  $Ca^{2+}$  movement  
Strong dependence on  $[Ca^{2+}]_e$  !

Calsequestrin =  $Ca^{2+}$  buffer

SERCA

$Ca^{2+}$

$I_{Ca}$

$Ca^{2+}$

$Ca^{2+}$   
ATPase

$Na^{+}/Ca^{2+}$   
exchanger

● DHPR (in sarcolemma  
and in T-tubules)

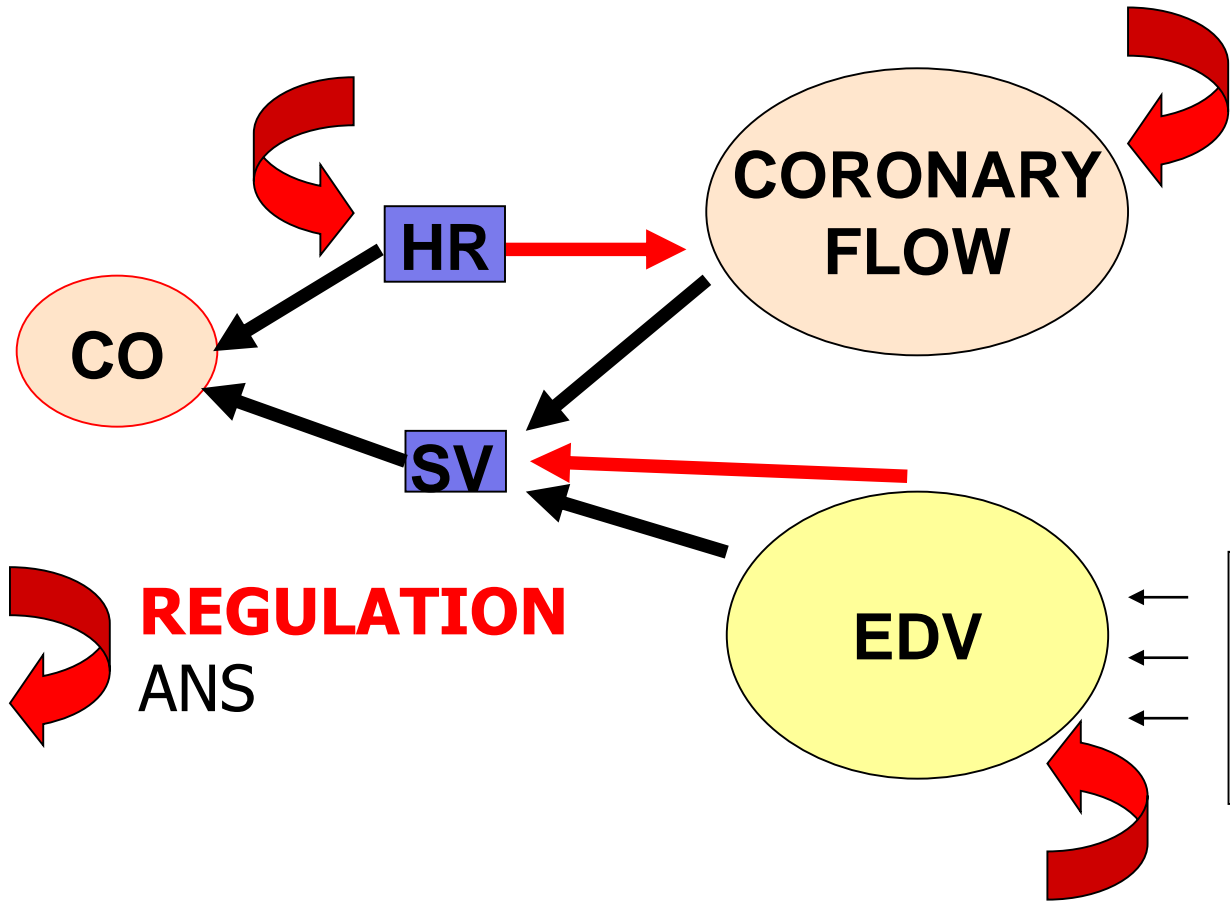
▲ RYR2 (calcium-gated)

**CICR**  
(calcium-induced-calcium-release)

# HEART AS A PUMP

# CARDIAC OUTPUT (CO)

$$LV = RV$$



$$CO = HR \times SV \quad 5l/min$$

$$SV = EDV - ESV \quad 70ml$$

$$\text{Ejection fraction} \quad EF = \frac{EDV - ESV}{EDV} \quad >60\%$$

← Venous return  
← Compliance  
← Aortal pressure

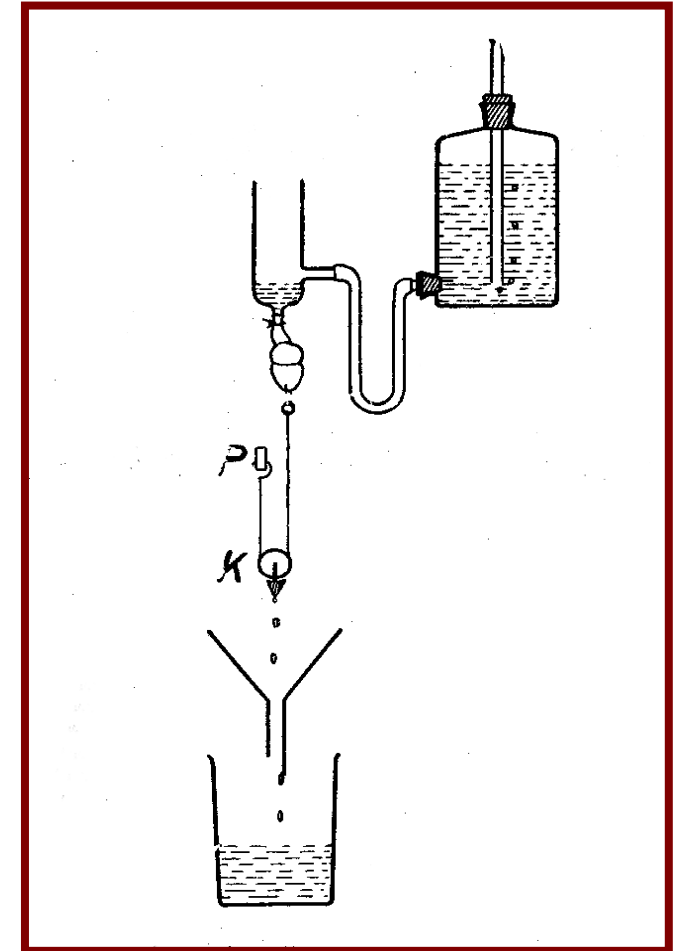
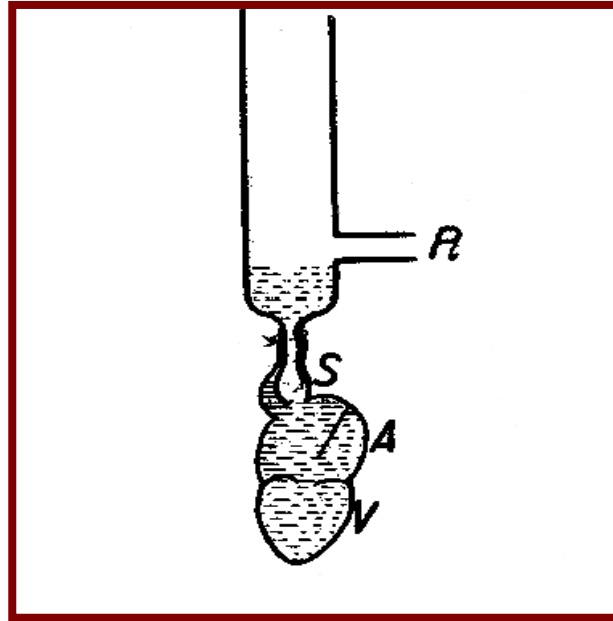
**CONTRACTILITY**  
Ability to contract  
Depends on tissue perfusion  
(substrates and oxygen supply for  
ATP production; Ca<sup>2+</sup> availability)

**AUTOREGULATION of cardiac contraction**  
Heterometric: Starling law  
Homeometric: Frequency effect





Henry Pickering Bowditch  
(1840 – 1911)



## HOMEOMETRIC AUTOREGULATION (FREQUENCY EFFECT)

During increasing HR (stimulation frequency) the force of developed contraction rises

Ratio between intra- and extracellular calcium concentrations increases

**CARDIAC RESERVE** = maximal CO / resting CO

**4 - 7**

**CORONARY RESERVE** = maximal CF / resting CF

**3,5**

**CHRONOTROPIC RESERVE** = maximal HR / resting HR

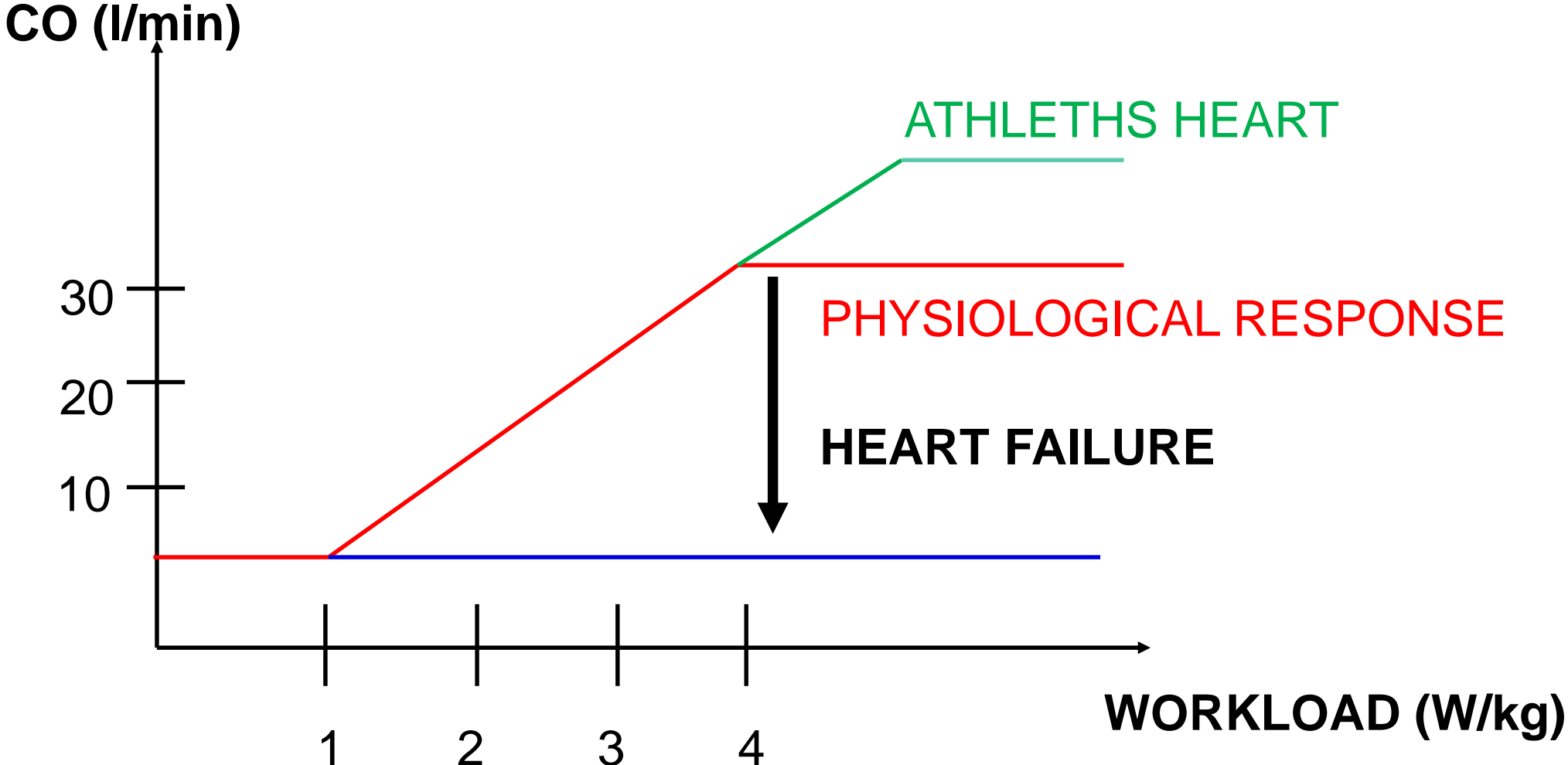
**3 - 5**

**VOLUME RESERVE** = maximal SV / resting SV

**1,5**

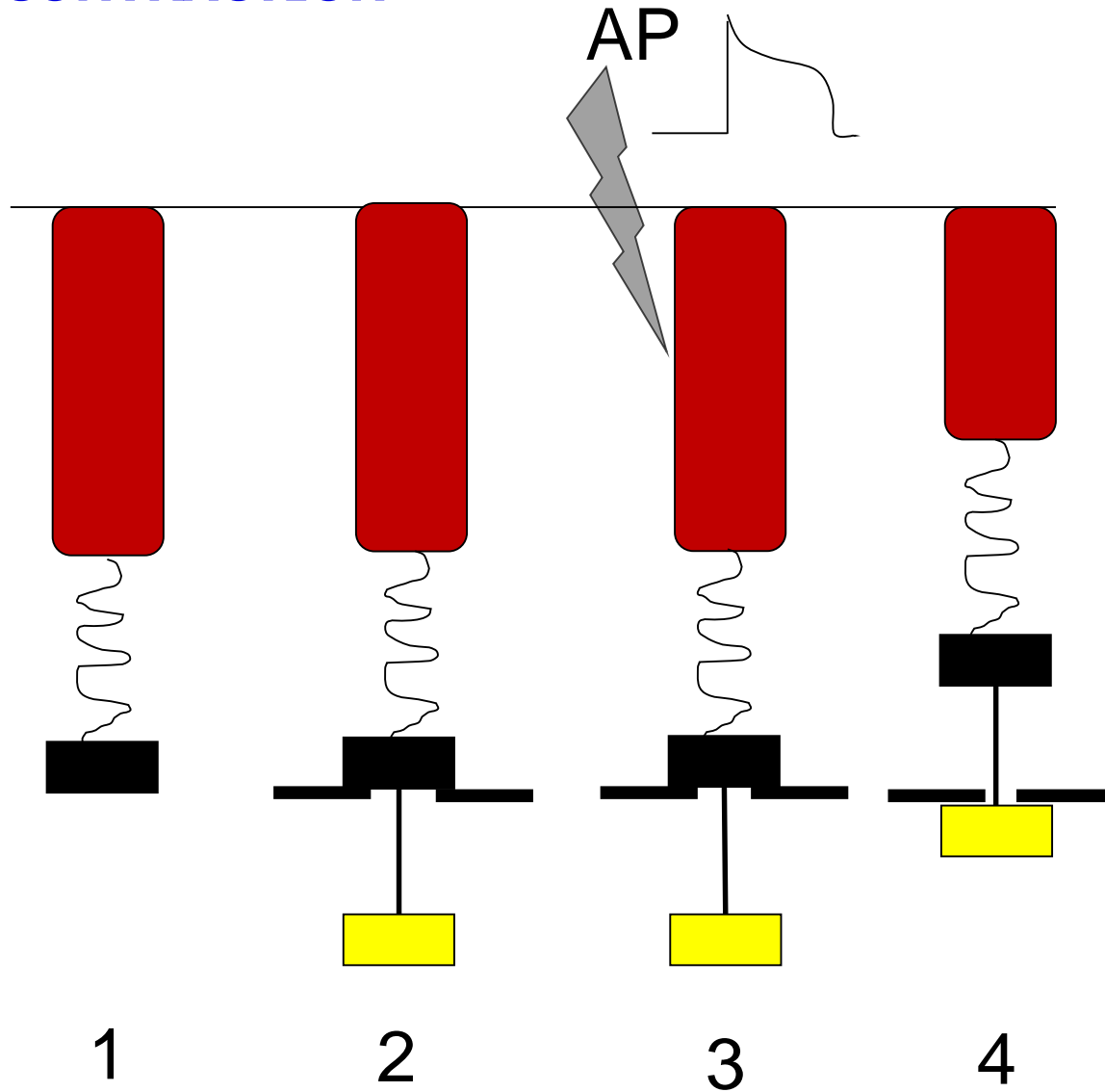
CO = cardiac output  
CF = coronary flow  
HR = heart rate  
SV = stroke volume

# CARDIAC RESERVE



# AFTERLOADED CONTRACTION

# PRELOAD, AFTERLOAD



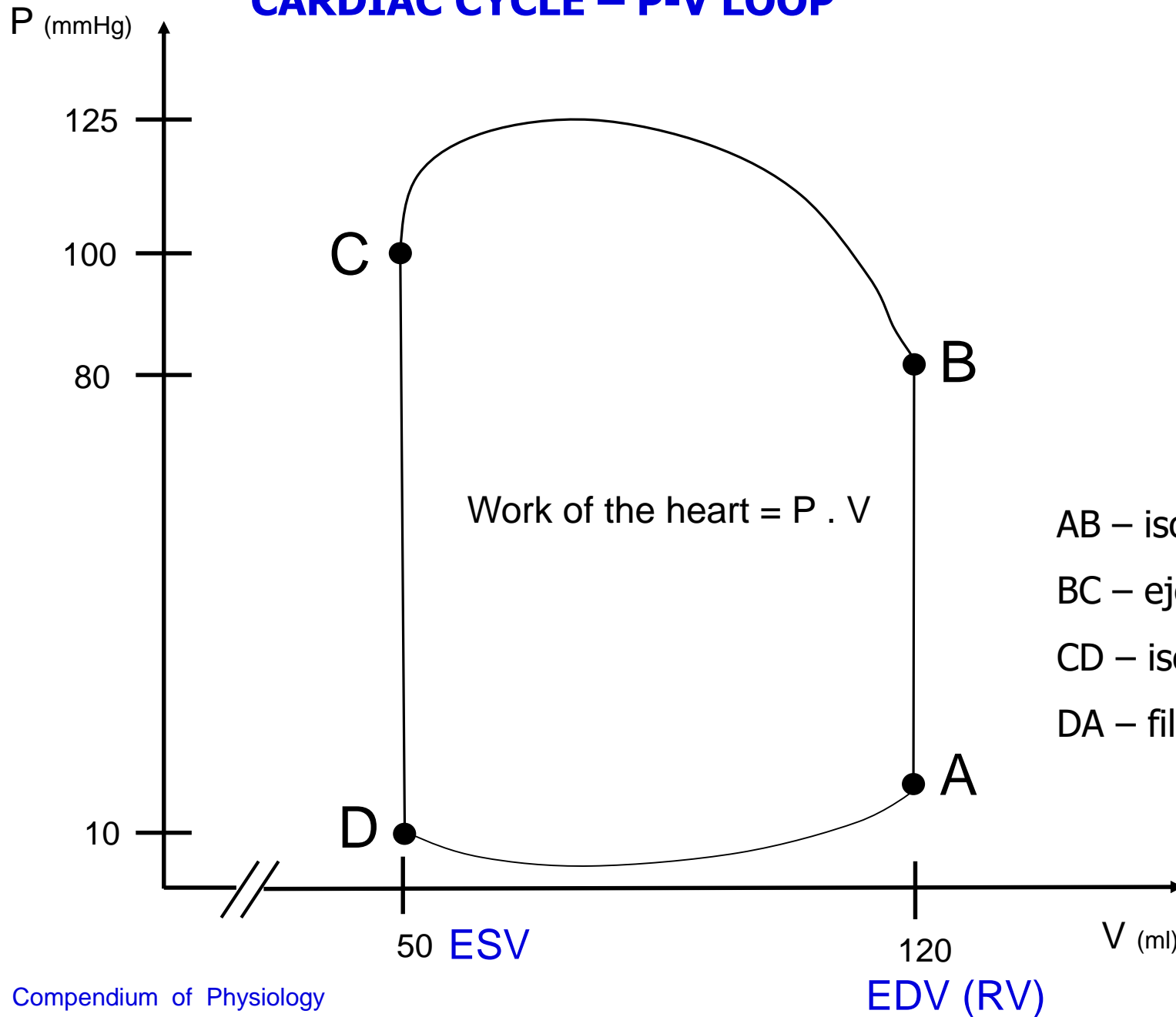
**PRELOAD**  
(~ enddiastolic filling)



**AFTERLOAD**  
(~ pressure which must be developed)



# CARDIAC CYCLE – P-V LOOP



LAPLACE law:

$$T = P \cdot R / h$$

$$\uparrow P = T \cdot \uparrow H / \downarrow r$$

AB – isovolumic contraction

BC – ejection

CD – isovolumic relaxation

DA – filling

# HEART SOUNDS

Caused by vibration of various anatomical structures and event. blood:

- **Closure and stretching of valves**
- Isovolumic contraction of heart muscle (papillary muscles, tendons)
- Turbulent blood flow

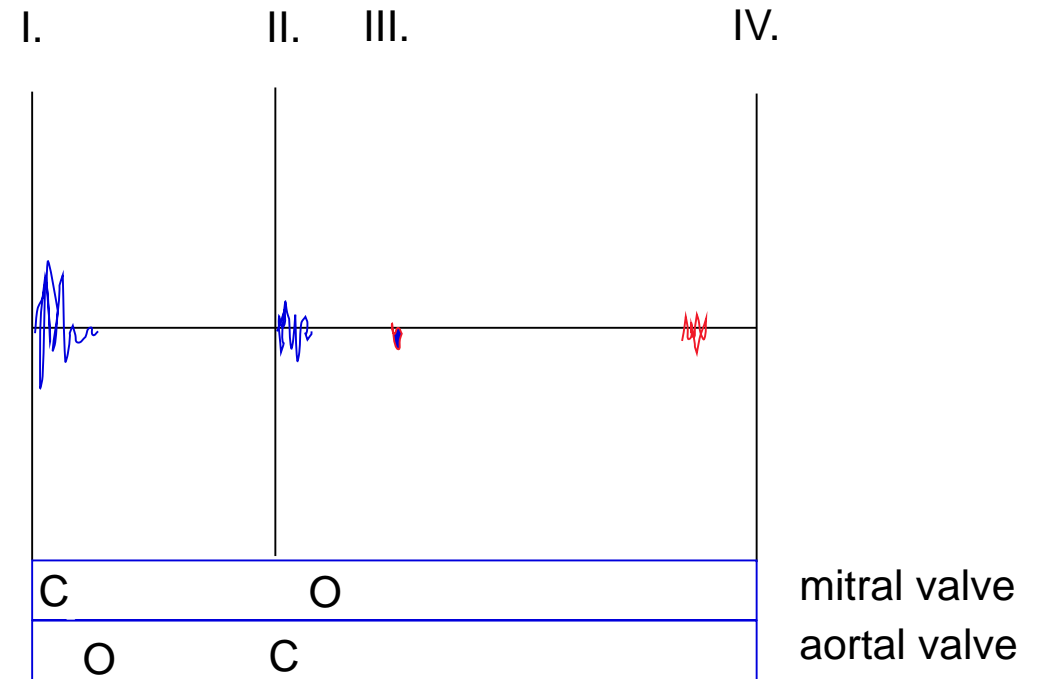
**I. – mitral (+ tricuspidal) valve closure**

**II. - aortal (+ pulmonary) valve closure**

III. - fast filling of ventricles - **pathological**

IV. - contraction of atria – **mostly pathological**

→ **Vibration of ventricular wall**



O – open, C - closed

# MURMURS – pathological phenomena based on turbulent blood flow

## 1. SYSTOLIC

- Stenosis – aortal, pulmonary (1)
- Regurgitation – mitral, tricuspidal (2)

## 2. DIASTOLIC

- Stenosis – mitral, tricuspidal (3)
- Regurgitation – aortal, pulmonary (4)

## 3. SUSTAINED:

- Defects of septum

