

ME 411 / ME 511

# Biological Frameworks for Engineers

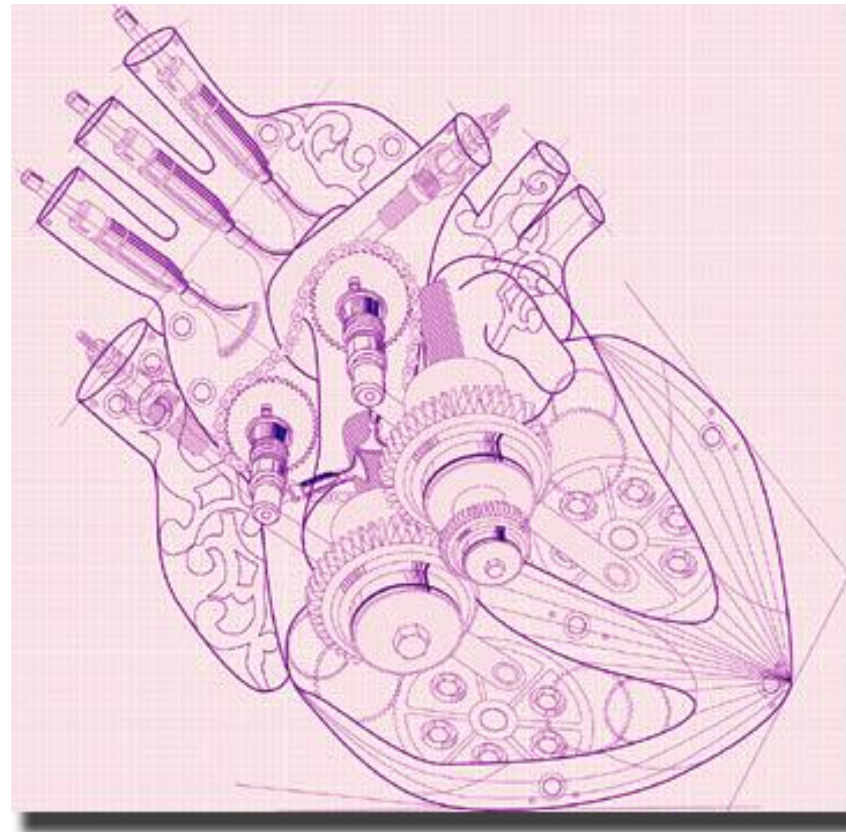
# Class Organization

- HW7 due on Friday
- Final Exam
  - Take-home format
  - Turn in paper copy
    - Nikita's office (AERB 328)
    - Doors lock at 5pm
    - Due on Wed 12/10
- Course Evaluations on Friday
  - Bring a pencil

ME 411 / ME 511

# The Heart

# A Mechanical Pump?

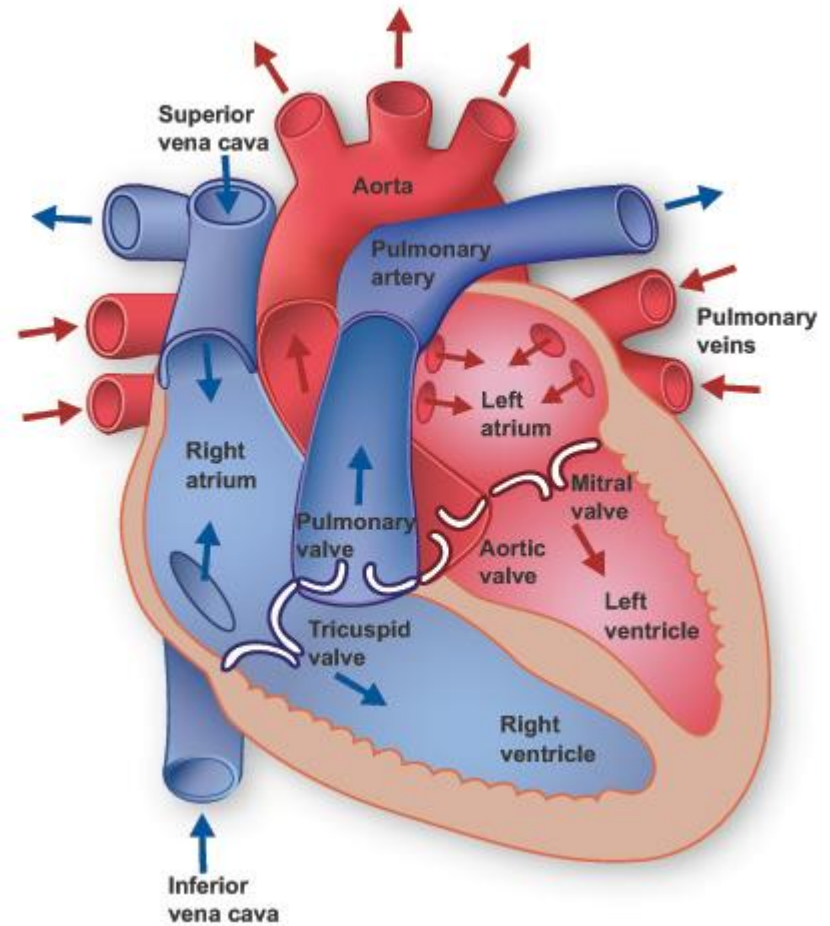


'Mechanical Heart' by Nicola Hawes

Cover of Nature Review Molecular Cell Biology January 2009

# Anatomy

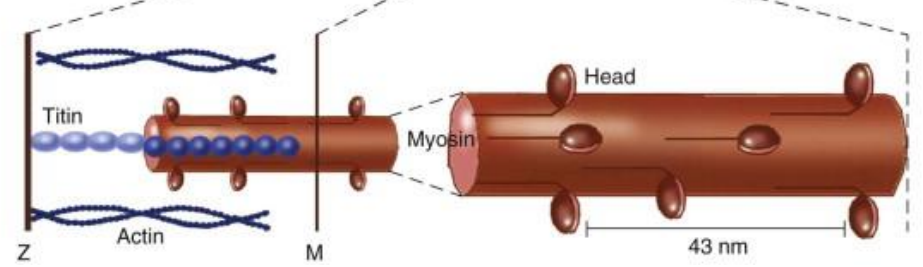
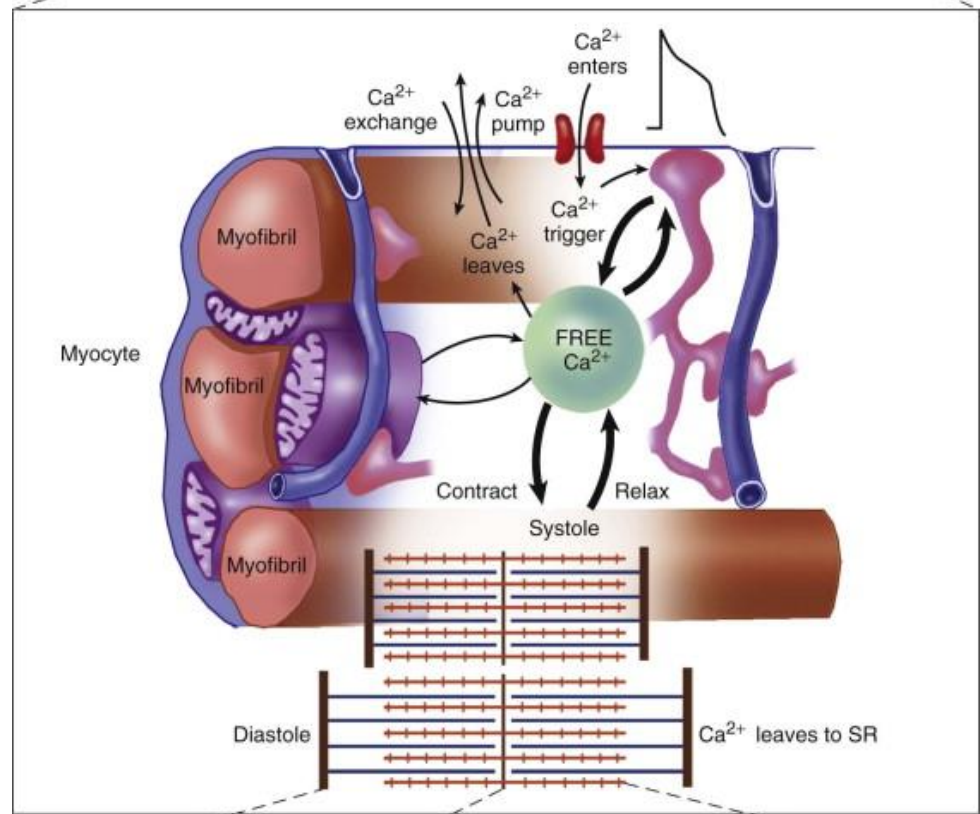
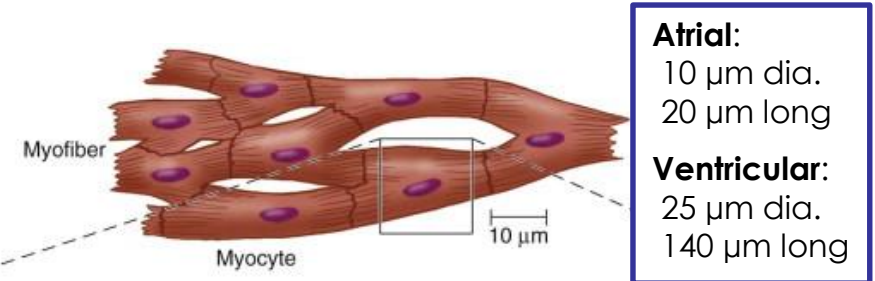
- **Two pumps in series**
  - Right vs. left side
- **Chambers**
  - Atrium vs. ventricle
- **Check valves**
  - Tricuspid and mitral valves
  - Pulmonary and aortic valves
- **Contraction cycle**
  - Systole = Contraction
  - Diastole = Relaxation



# Cardiomyocytes

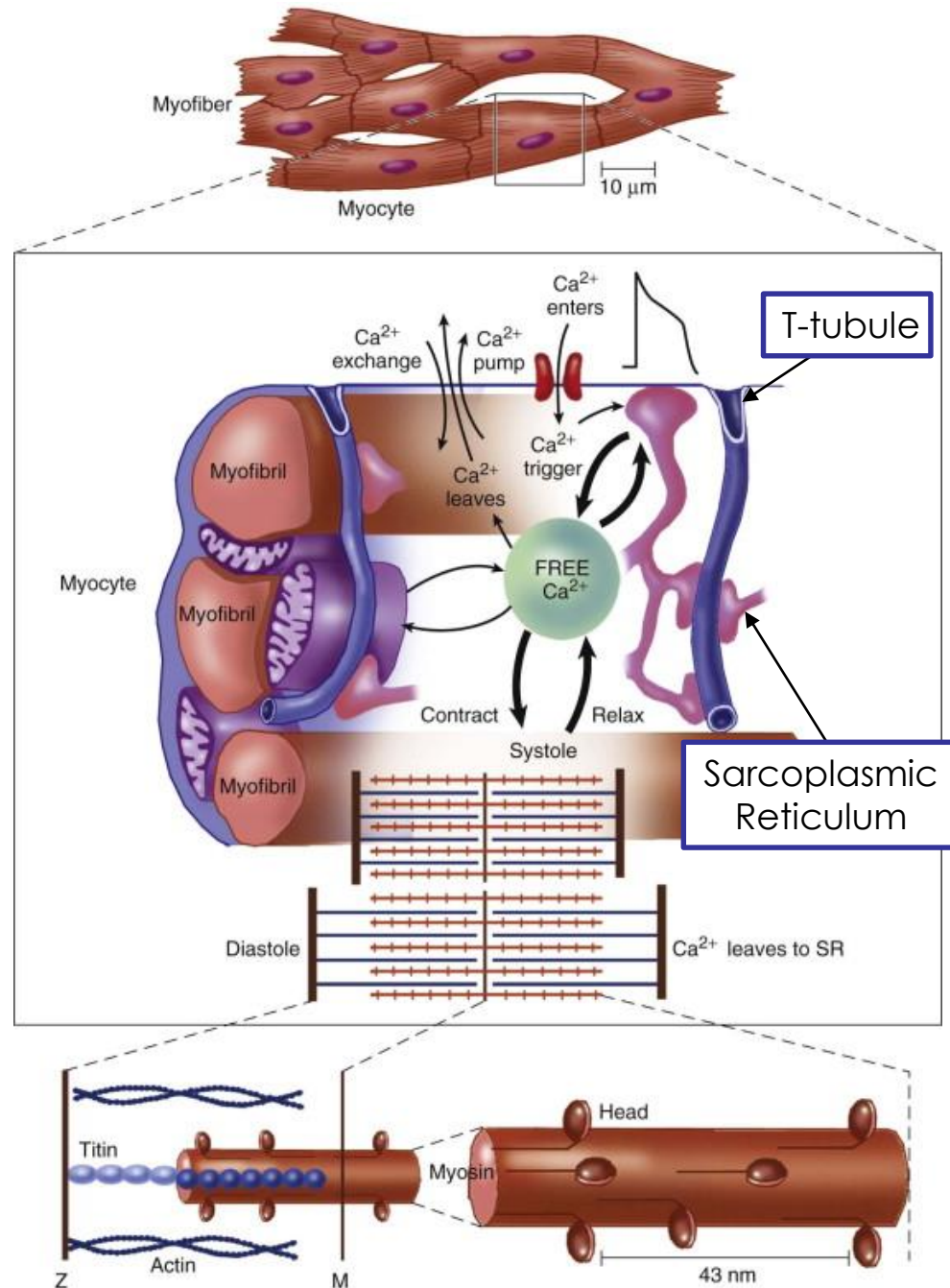
- **Contractile units**
  - Half of cell is contractile proteins
  - A quarter to a third is mitochondria
- **Calcium spike causes systole**

Troponin C → Troponin I → Tropomyosin → Myosin binding → Cross-bridge formation
- **Vascular pressure causes diastole**



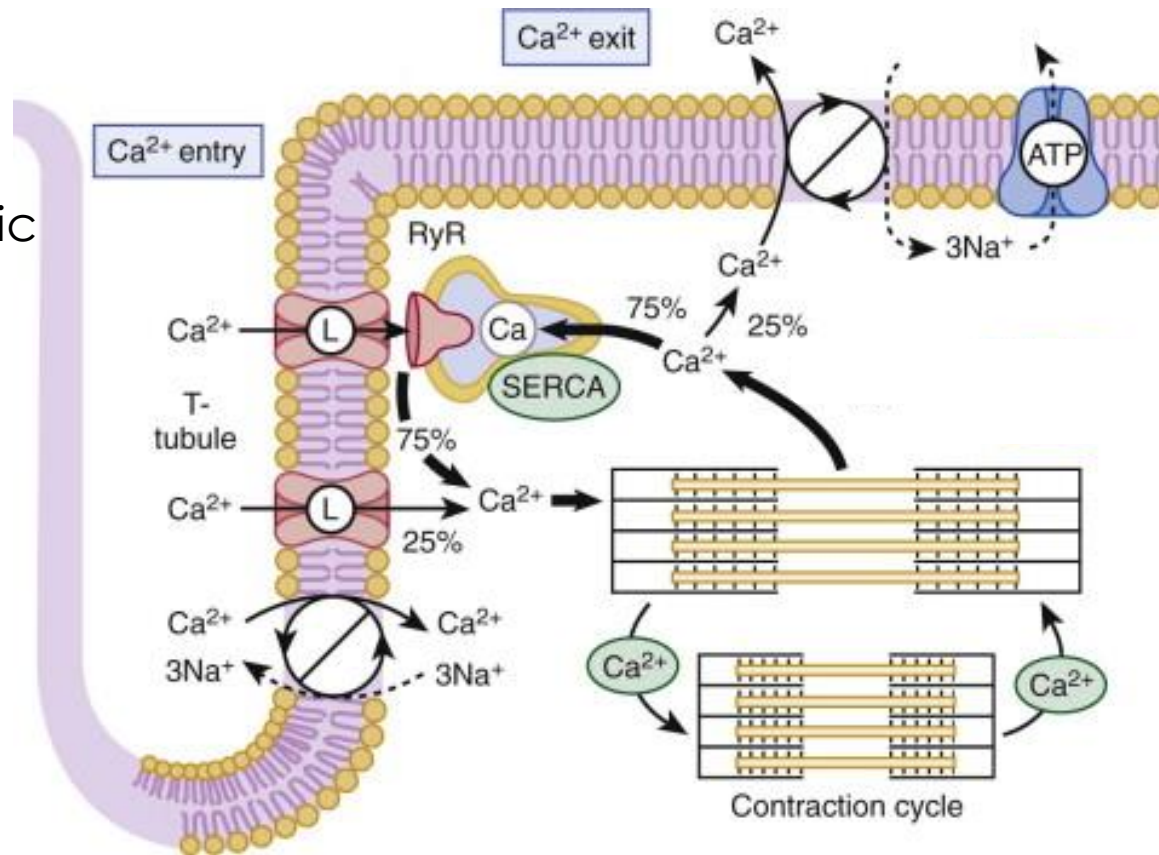
# Heart Beat

- **Trigger:**
  - Electrical excitation causes small influx of calcium ions at surface of T-tubules
- **Amplification:**
  - Calcium influx causes release of large amounts of calcium from storage
  - $\text{Ca}^{2+}$  stored in sarcoplasmic reticulum (SR)



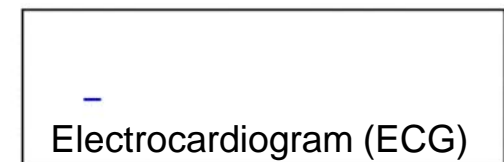
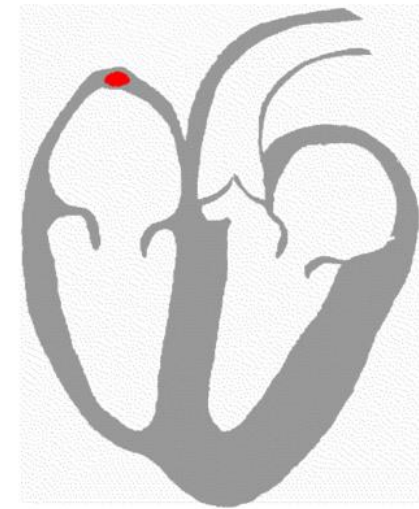
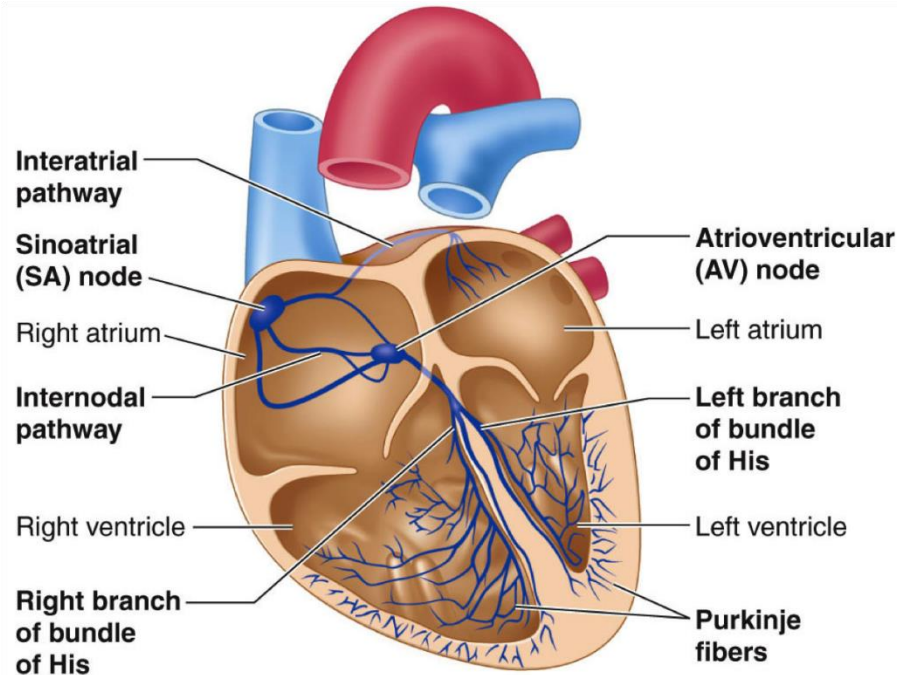
# Calcium Handling

- **Burst valve:**
  - Ryanodine receptor (RyR)
- **Vacuums:**
  - Sarcoendoplasmic reticulum  $\text{Ca}^{2+}$ -ATPase (SERCA)
  - $\text{Na}^{+}/\text{Ca}^{2+}$  exchanger



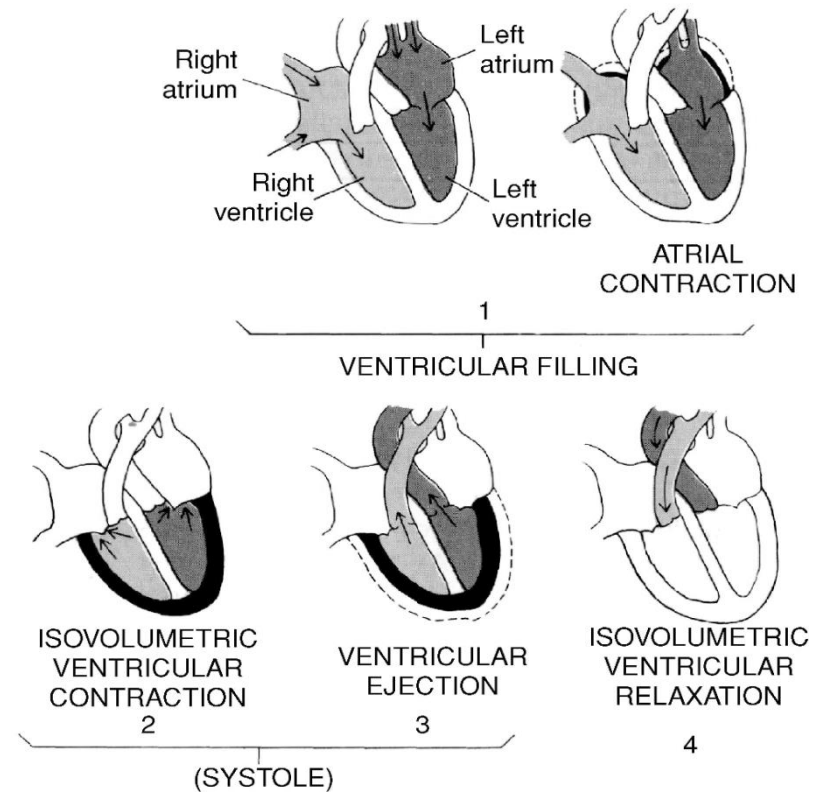
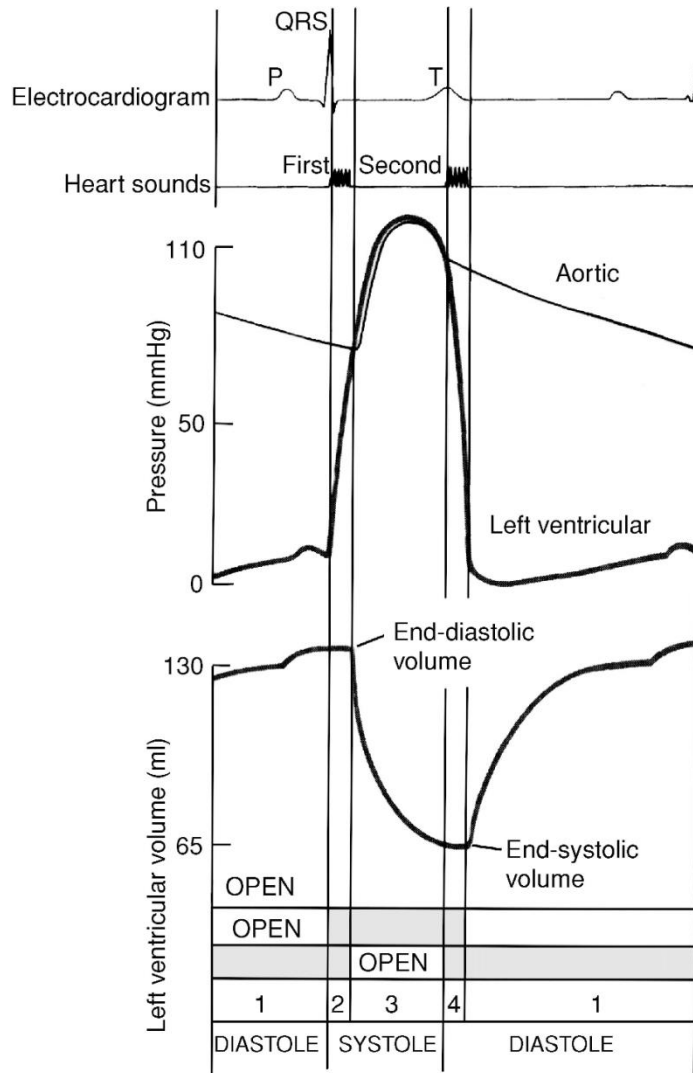


# Heart Signal



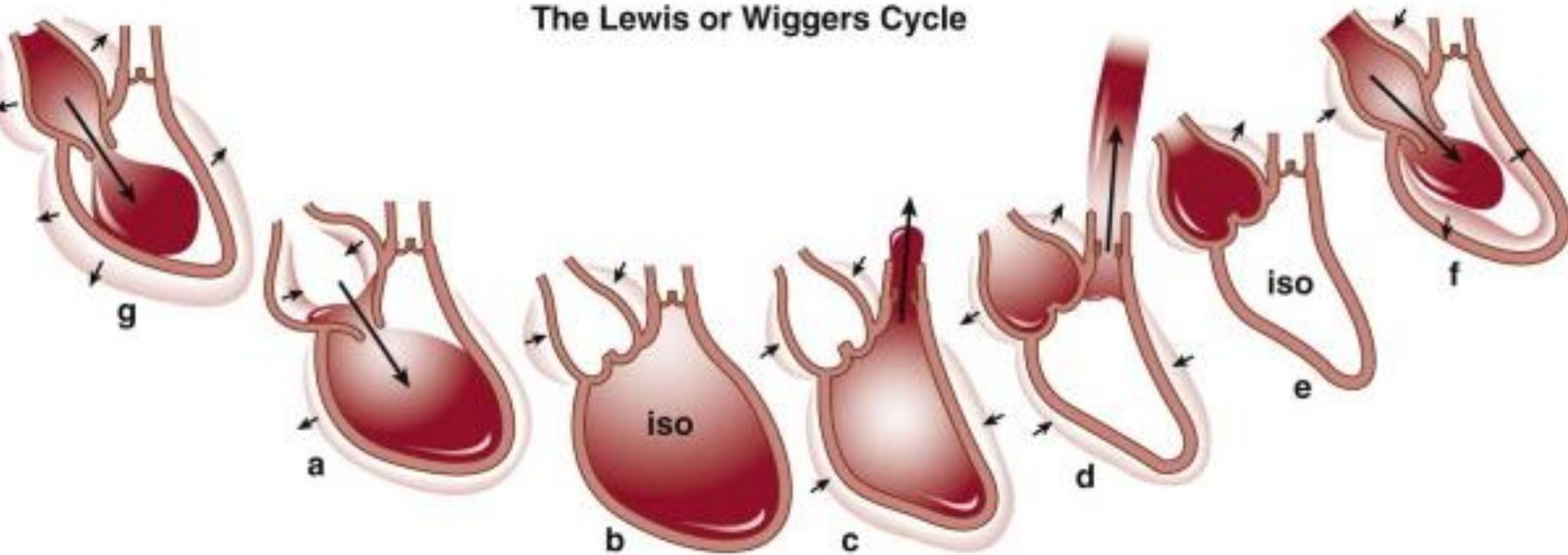
- Nodes (SA and AV) are natural pacemakers
- Purkinje fibers conduct the electrical signal

# Cardiac Cycle



# Cardiac Cycle

The Lewis or Wiggers Cycle



Slow filling (diastasis) (g & f)

Atrial systole or booster (a)

Isovolumic contraction (b)

Maximal ejection (c)

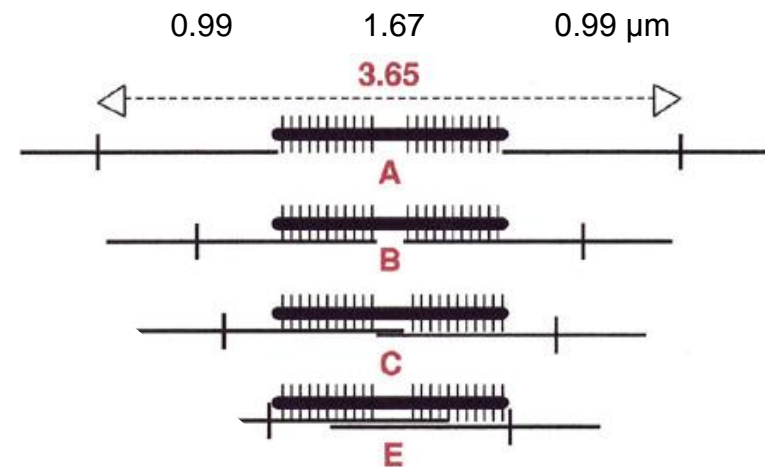
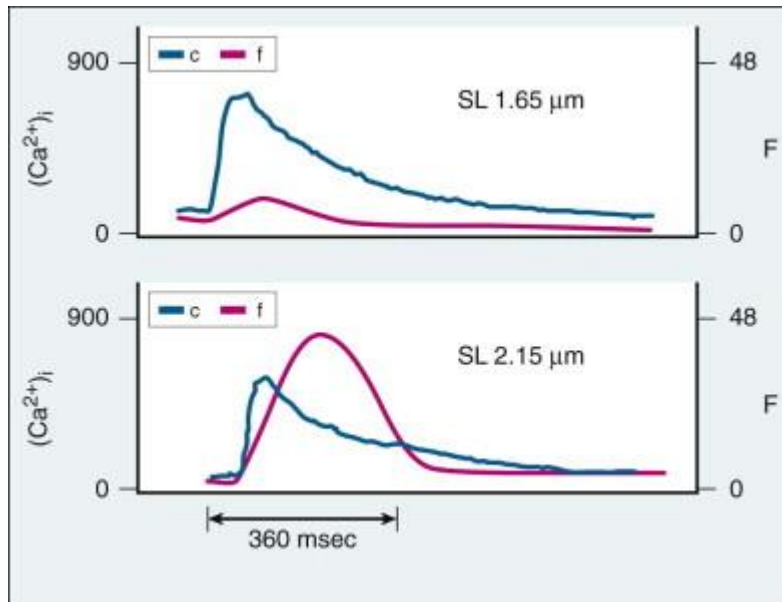
Relaxation and reduced ejection (d)

Isovolumic relaxation (e)

# Frank-Starling Law

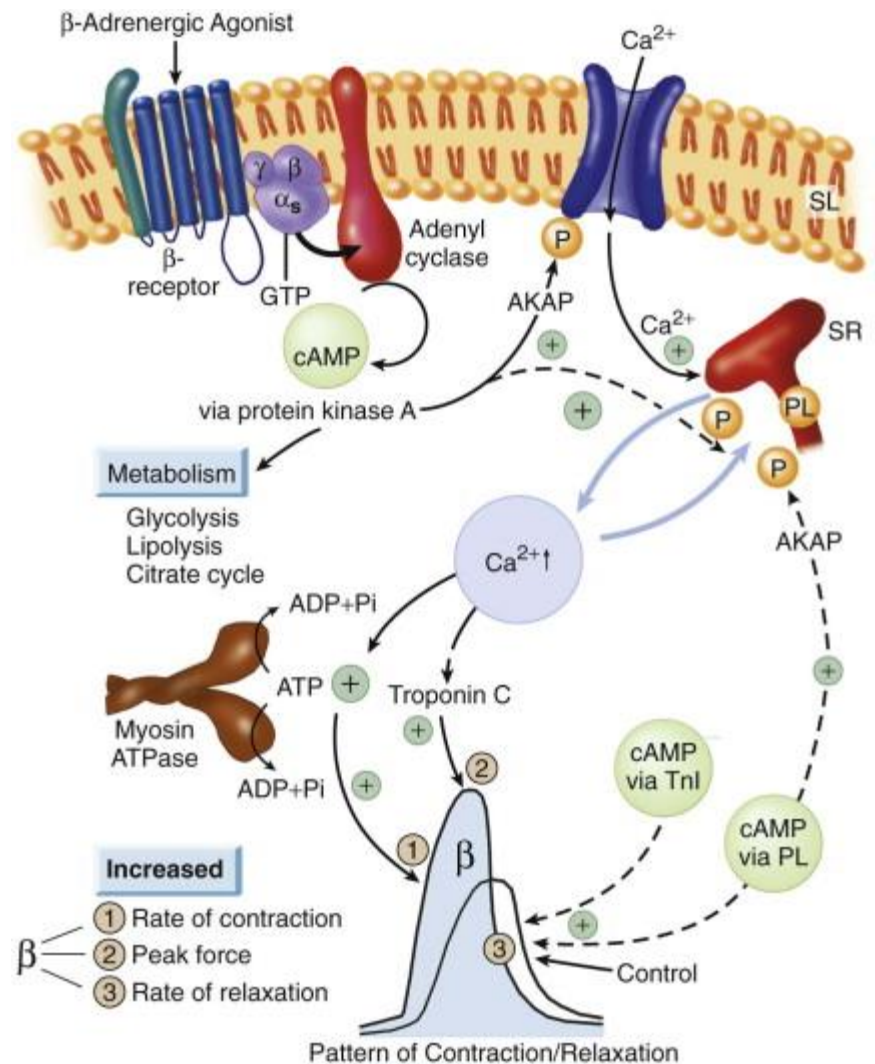
*Systolic stroke volume increases with volume of blood in heart chamber at end of diastole*

- Force-length relationship for sarcomeres
- Ensures fluid does not accumulate in pulmonary or systemic circulation



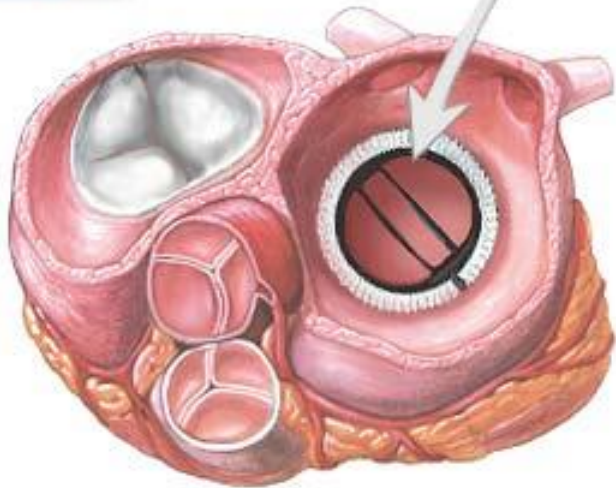
# Beta-Adrenergic Stimulation

- Causes increased heart rate and perfusion rate
- Agonists
  - Epinephrine (adrenaline)
  - Norepinephrine (stress hormone)
- Improves calcium opening at T-tubule



# Replacement Parts

- Heart Valves – 100,000/yr



Mechanical valve

Biological valve (human or porcine)



Mechanical valve



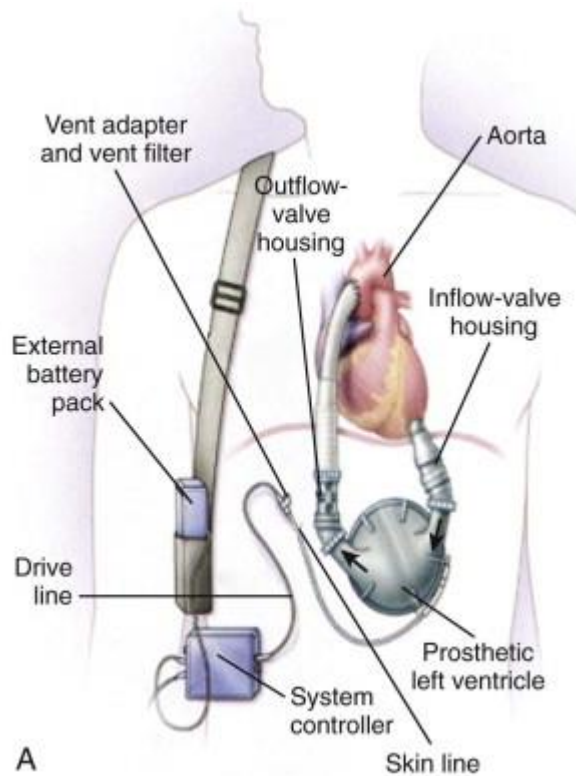
ADAM.



ADAM.

# Replacement Parts

- Left-Ventricle Assistive Device

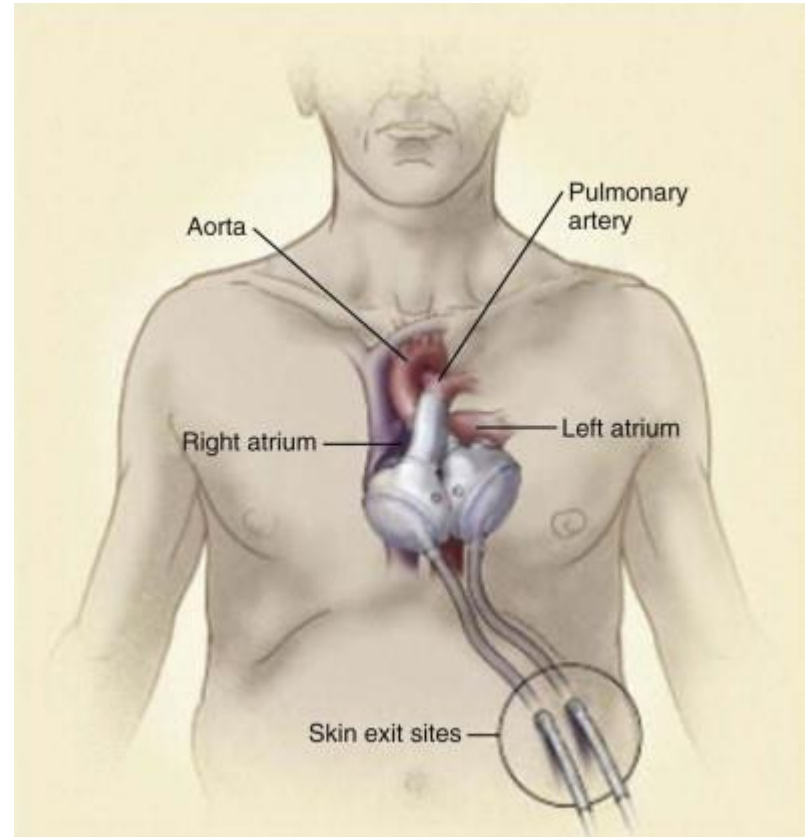


# Replacement Parts

- Total Artificial Heart



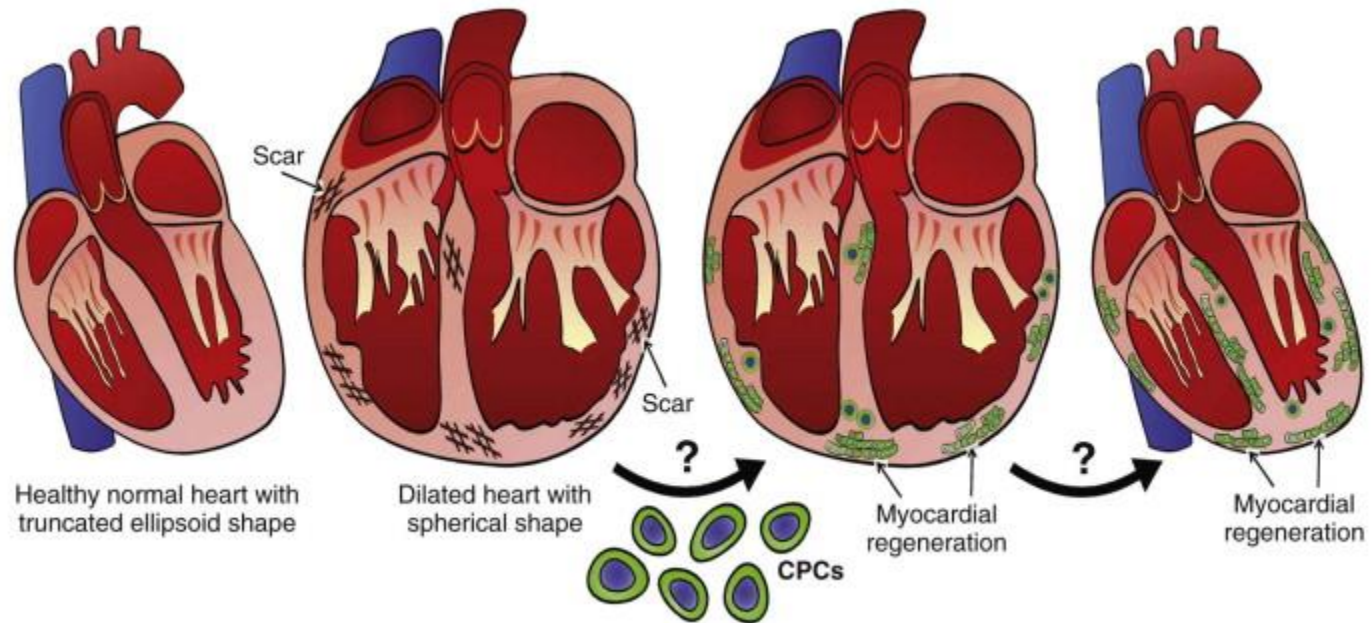
CardioWest SynCardia





# Replacement Parts

- Cardiac Stem / Progenitor Cells (CPC)



Questions?