

ME 411 / ME 511

Biological Frameworks for Engineers

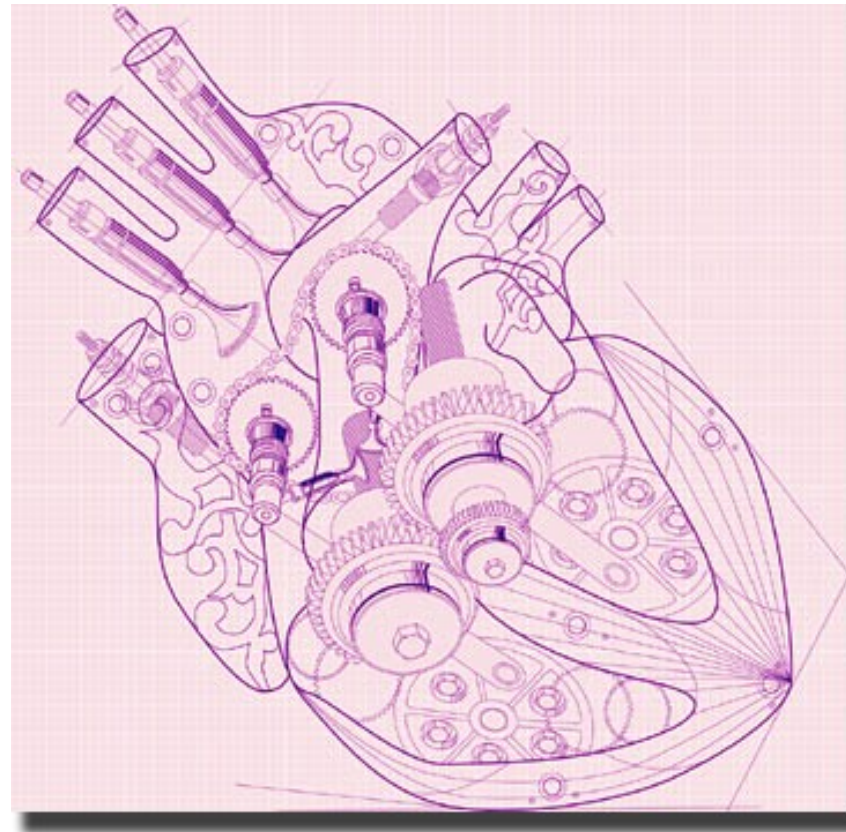
Class Organization

- HW7 due today
- Final Exam
 - Take-home format
 - Turn in paper copy
 - Prof. Sniadecki's office (MEB 318)
 - Due on Wed 12/11.

ME 411 / ME 511

The Heart

A Mechanical Pump?

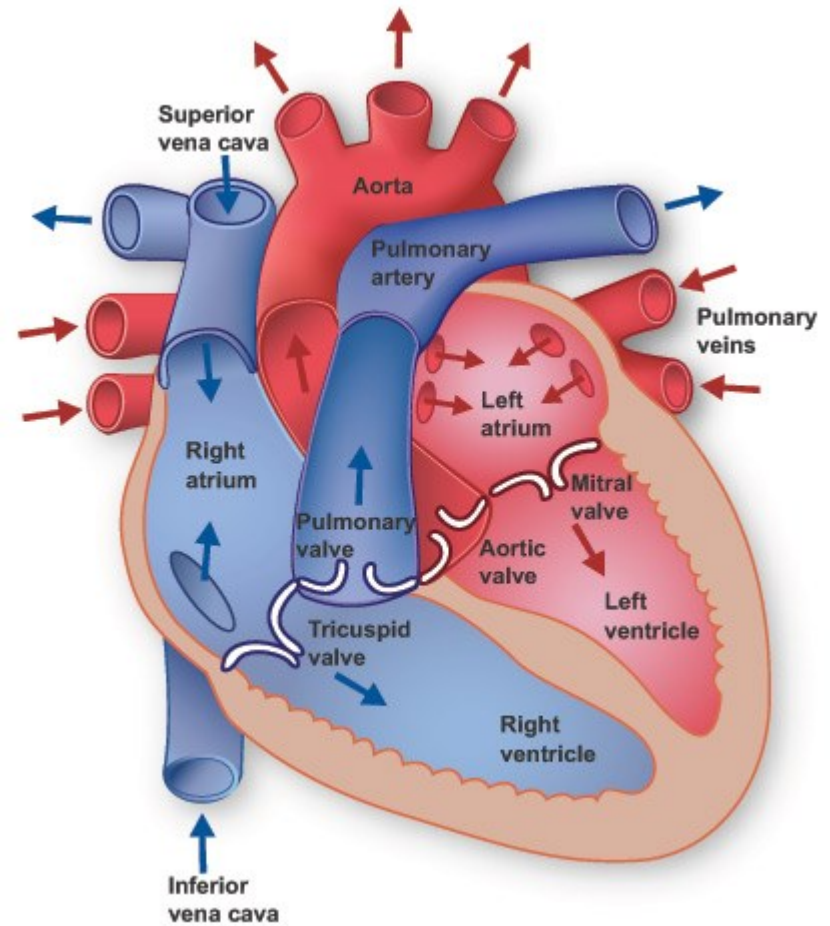


'Mechanical Heart' by Nicola Hawes

Cover of Nature Review Molecular Cell Biology January 2009

Anatomy

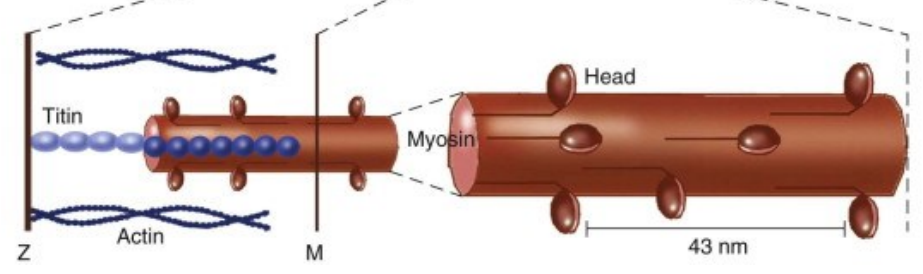
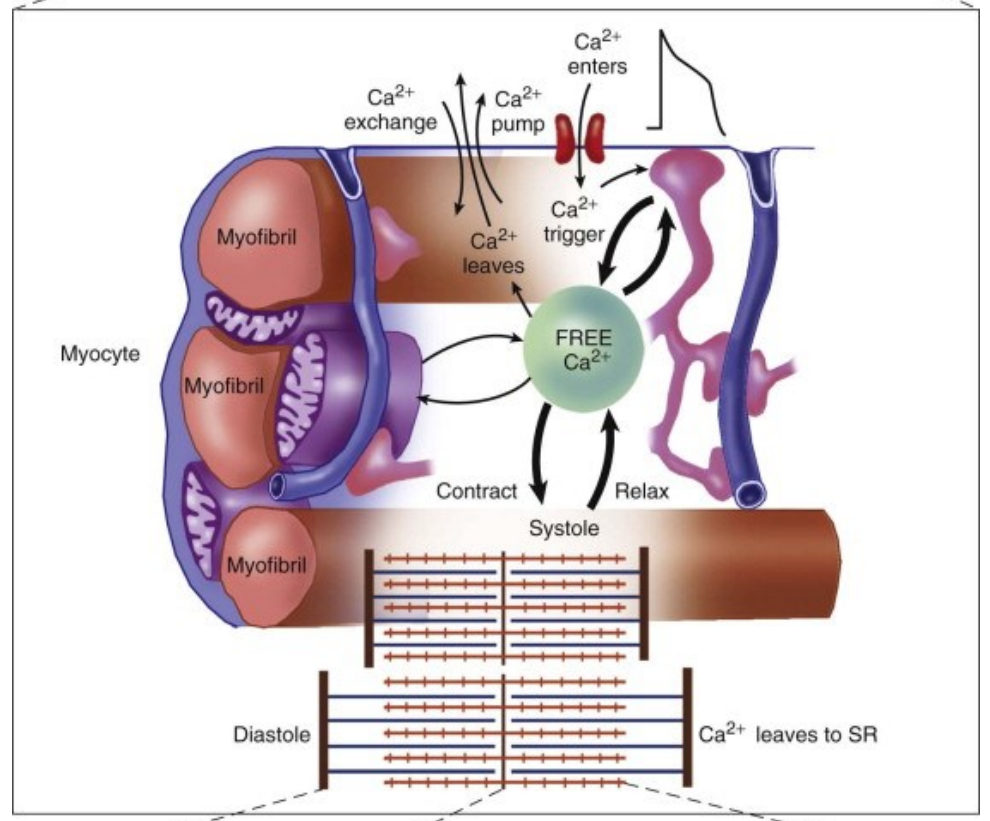
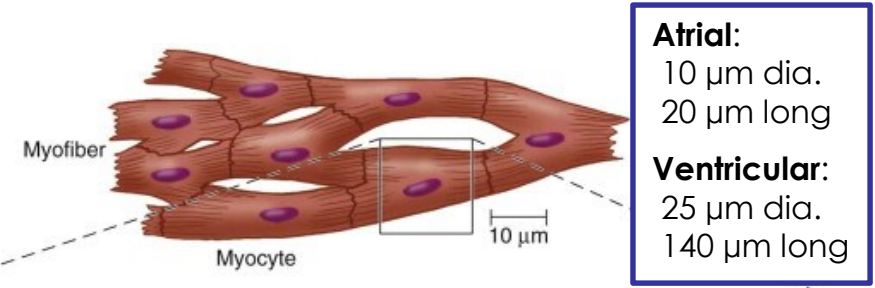
- **Two pumps in series**
 - Right vs. left side
- **Chambers**
 - Atrium vs. ventricle
- **Check valves**
 - Tricuspid and mitral valves
 - Pulmonary and aortic valves
- **Contraction cycle**
 - Systole = Contraction
 - Diastole = Relaxation



Cardiomyocytes

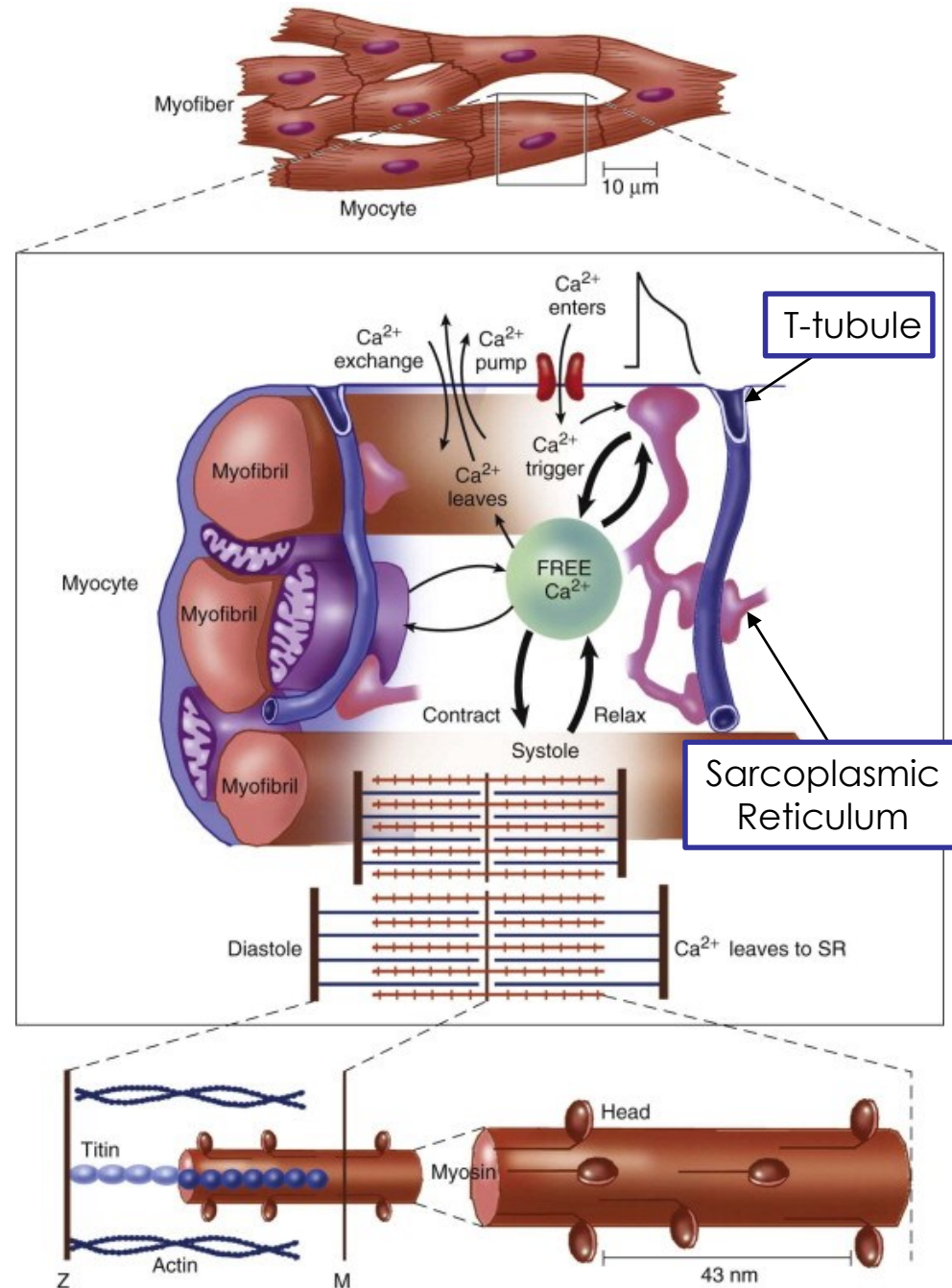
- **Contractile units**
 - Half of cell is contractile proteins
 - A quarter to a third is mitochondria
- **Calcium spike causes systole**

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



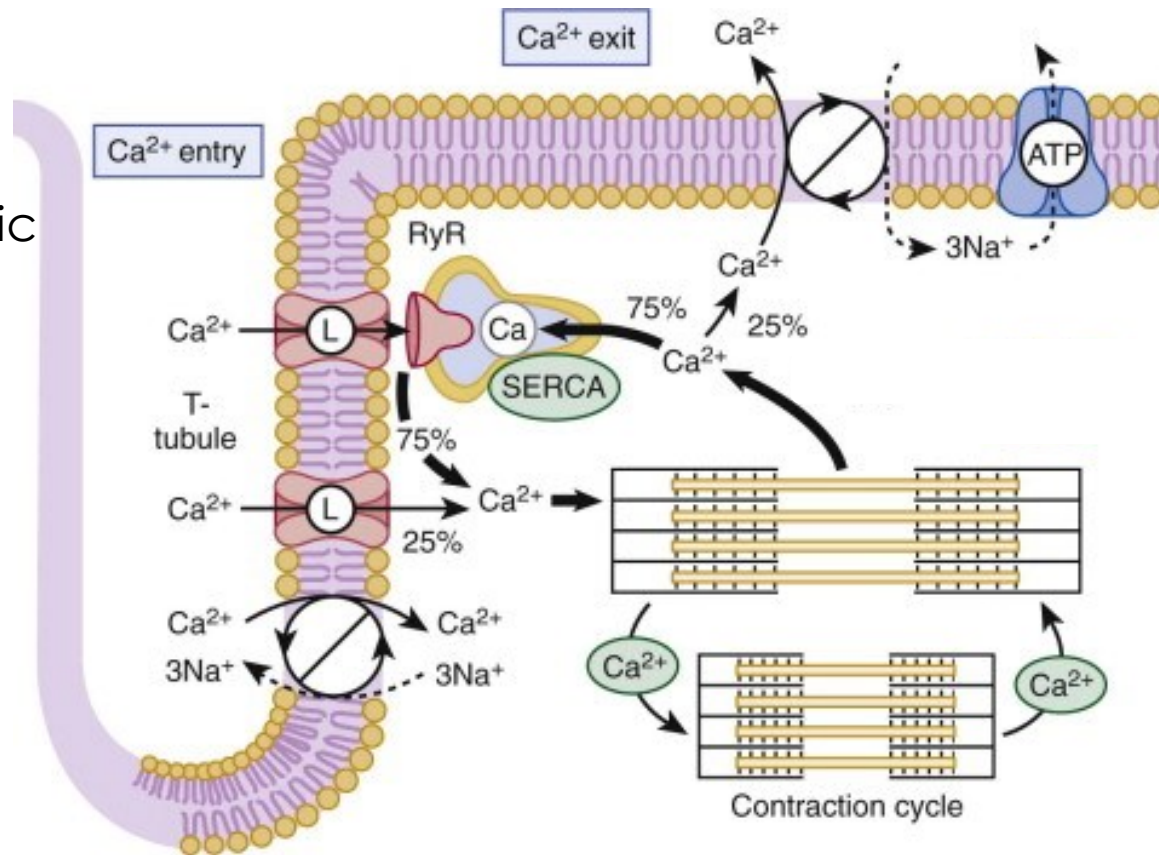
Heart Beat

- **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
 - Ca^{2+} stored in sarcoplasmic reticulum (SR)

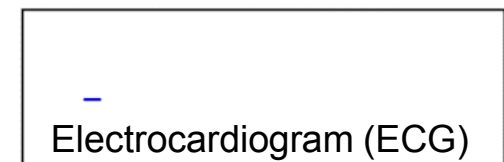
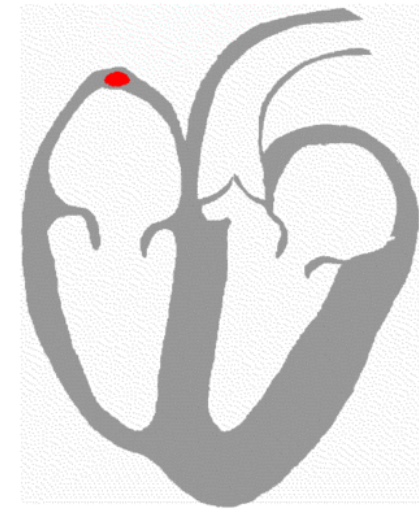
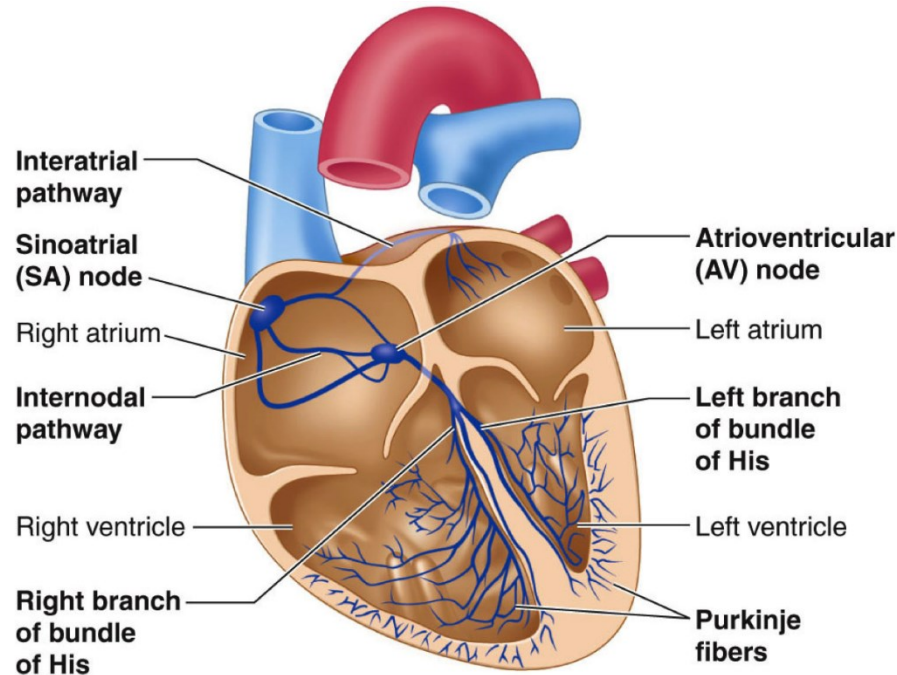


Calcium Handling

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

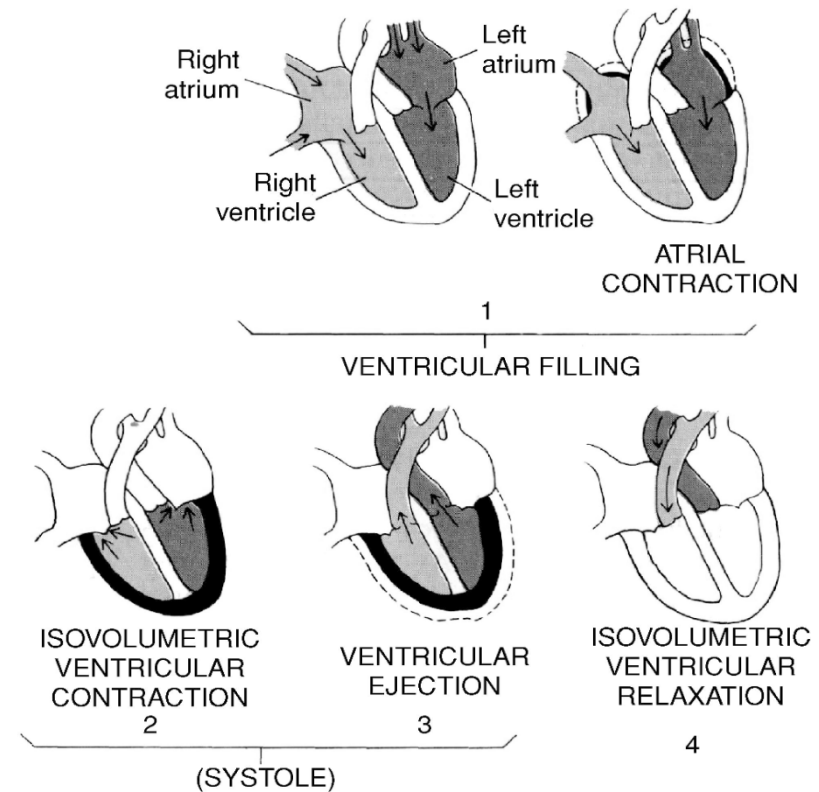
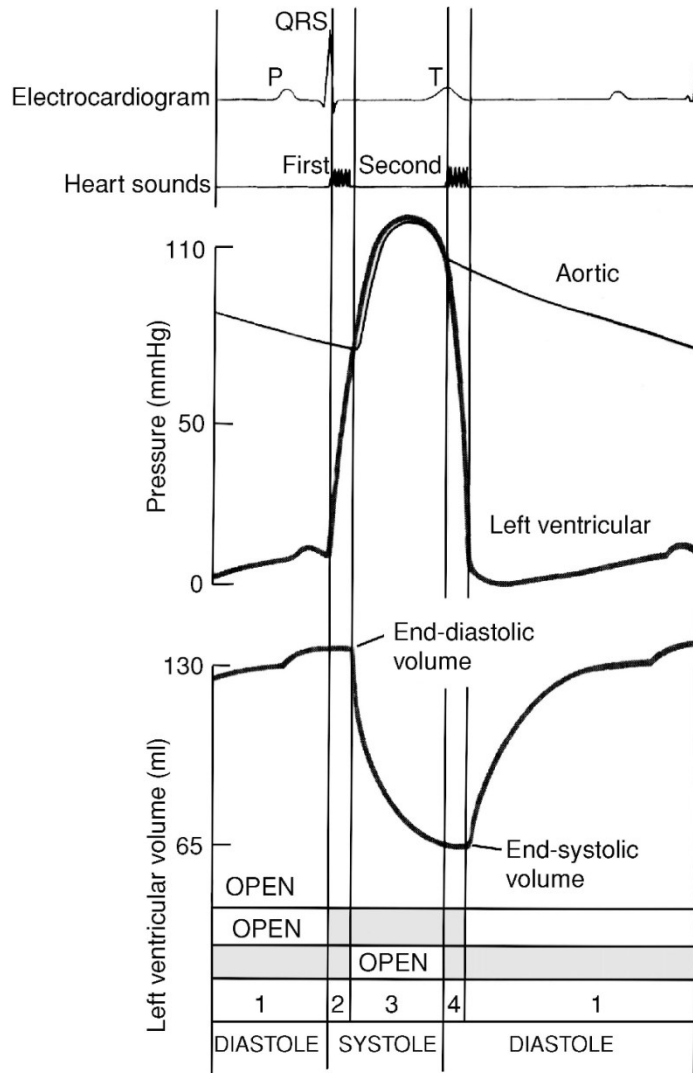


Heart Signal



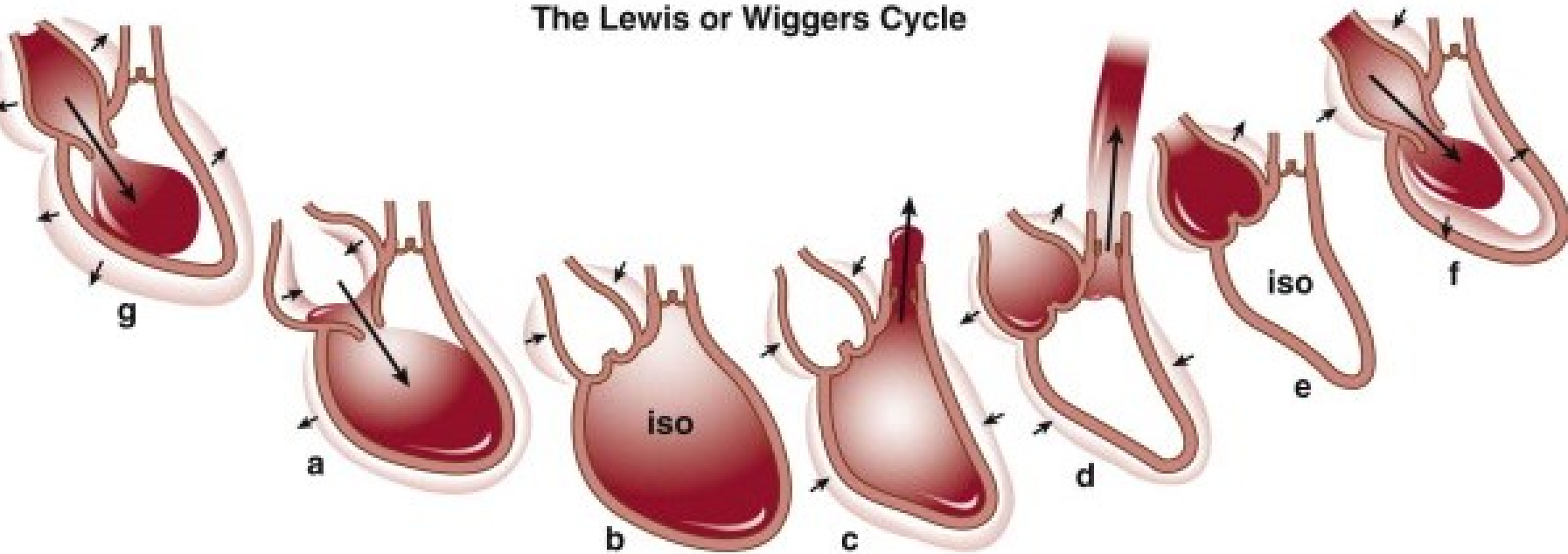
- Nodes (SA and AV) are natural pacemakers
- Purkinje fibers conduct the electrical signal

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)

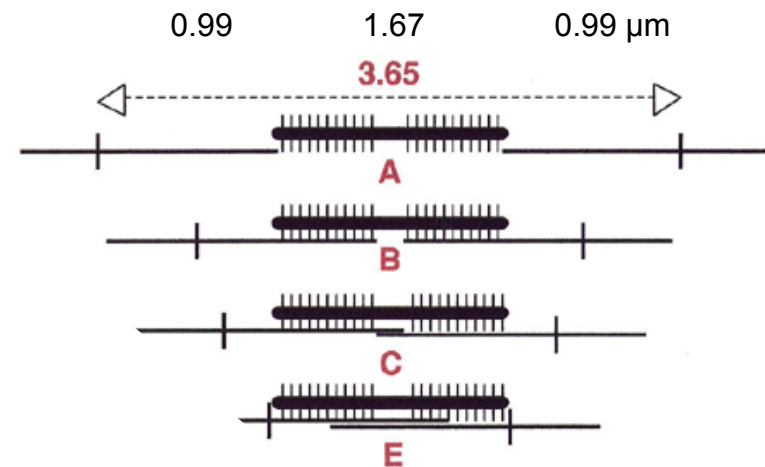
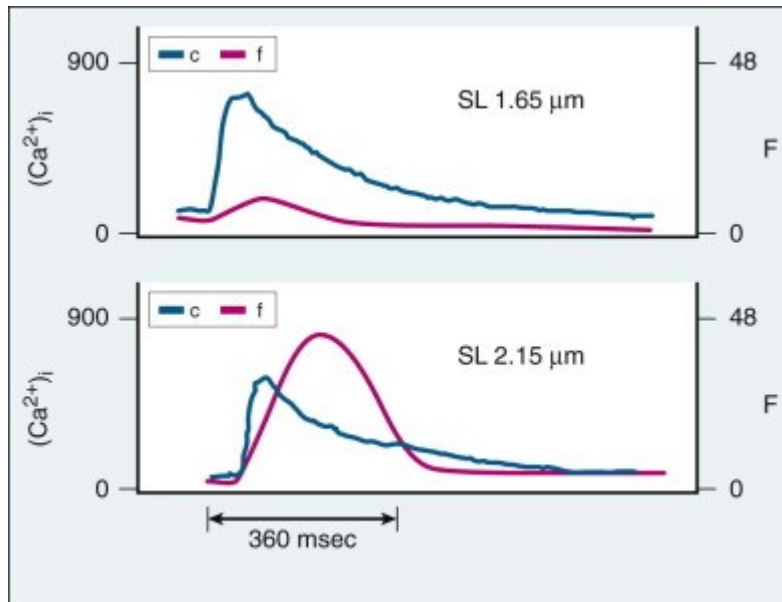
Relaxation and reduced ejection (d)

Isovolumic relaxation (e)

Frank-Starling Law

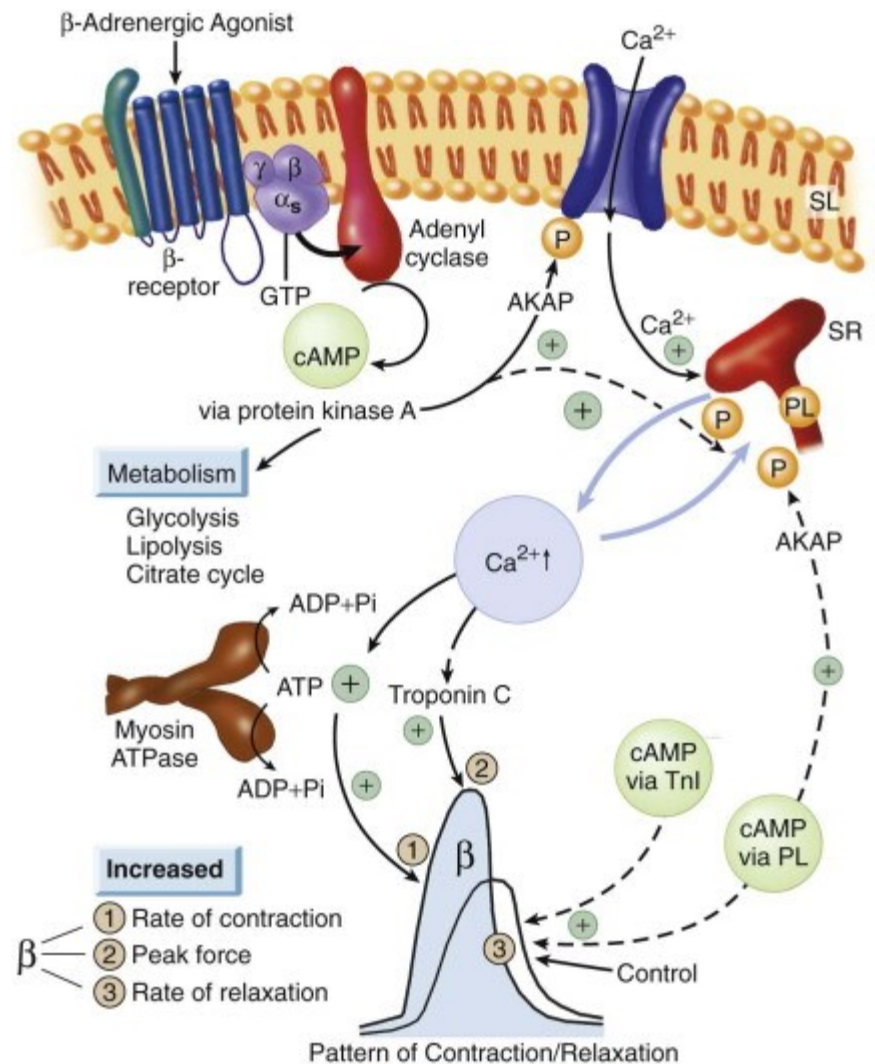
Systolic stroke volume increases with volume of blood in heart chamber at end of diastole

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



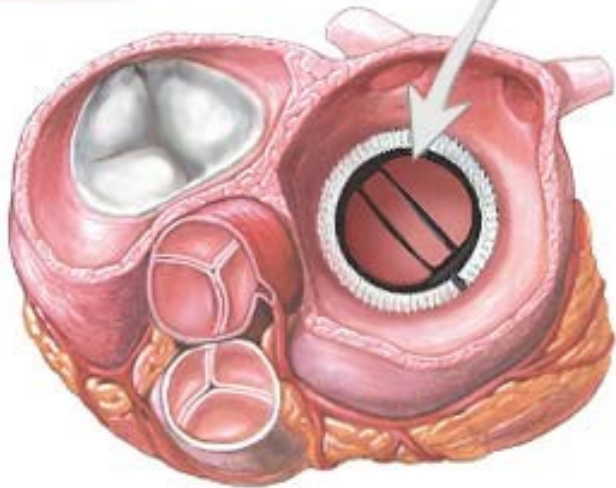
Beta-Adrenergic Stimulation

- 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



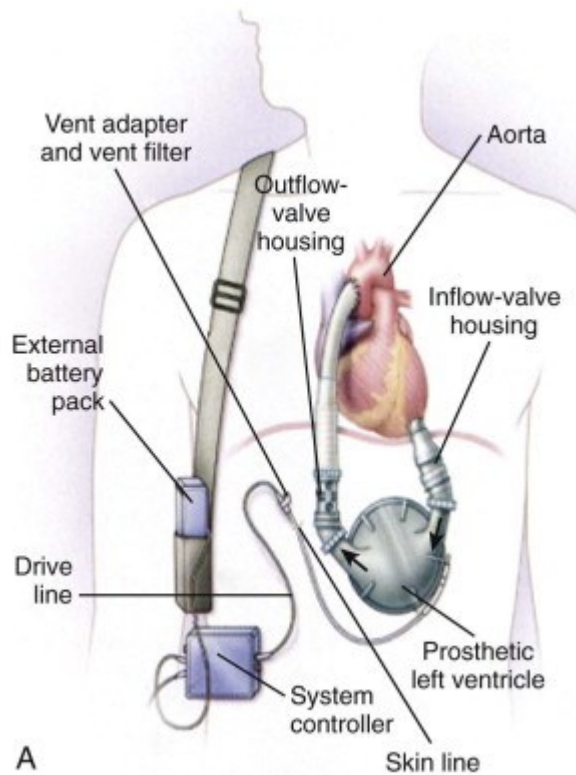
ADAM.



ADAM.

Replacement Parts

- Left-Ventricle Assistive Device

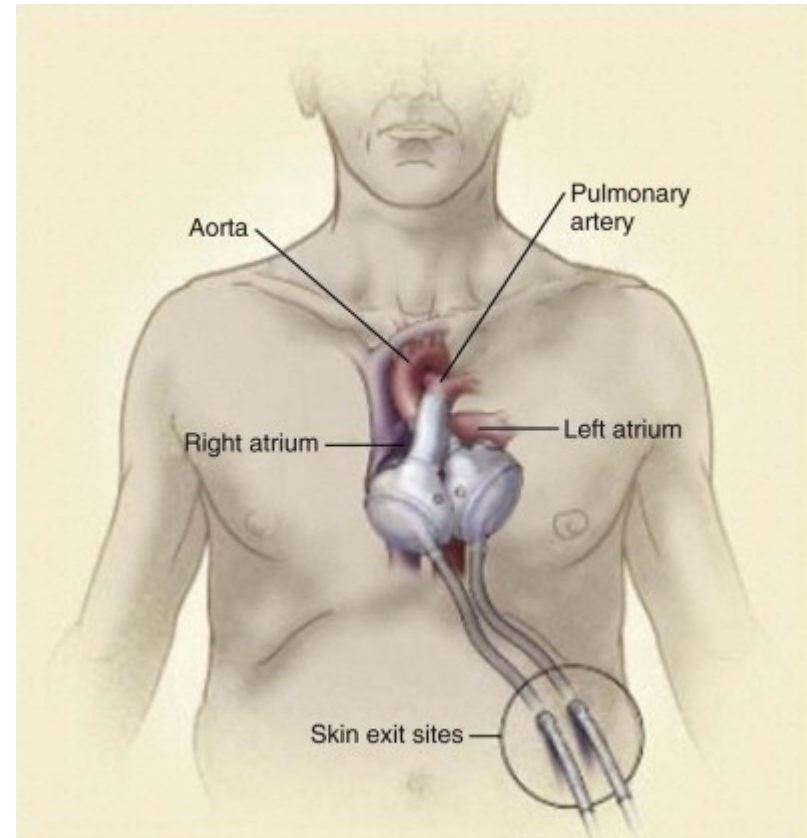


Replacement Parts

- Total Artificial Heart

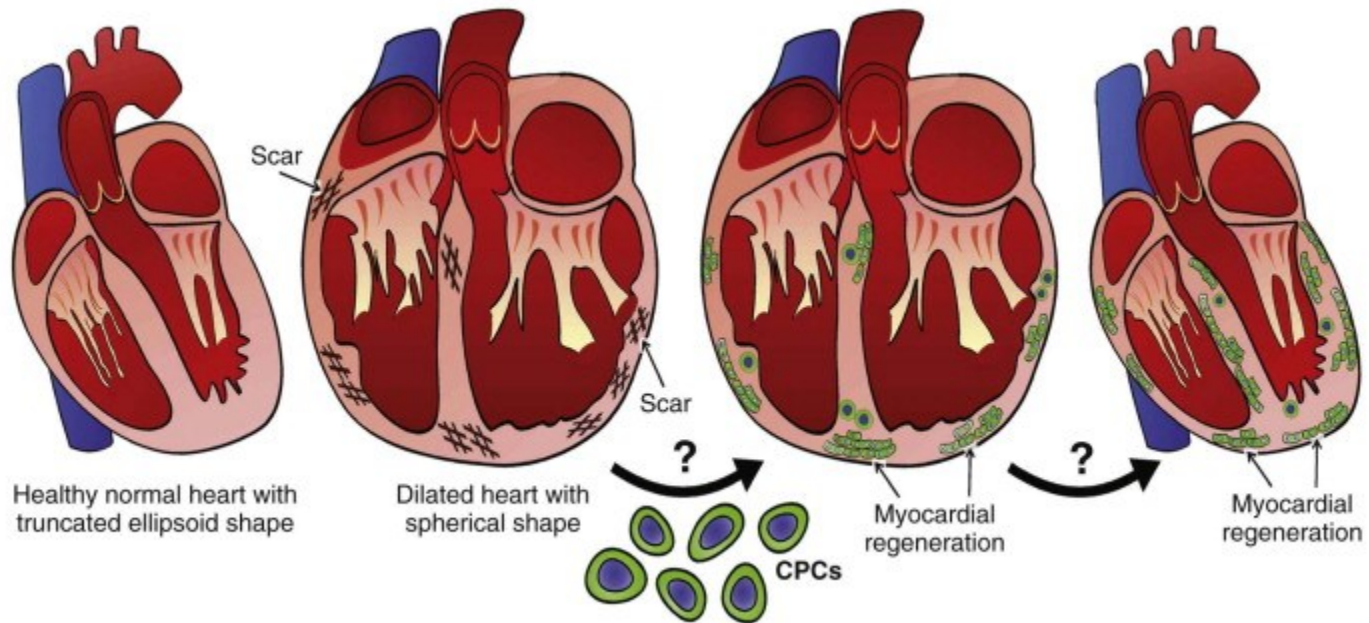


CardioWest SynCardia



Replacement Parts

- Cardiac Stem / Progenitor Cells (CPC)



Questions?