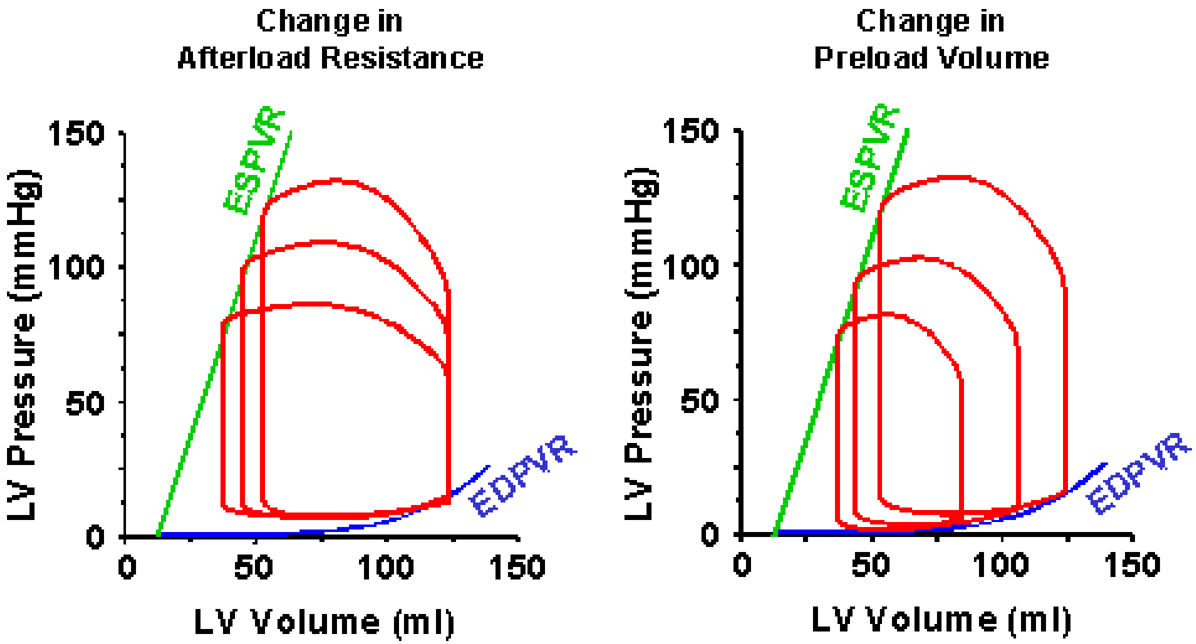
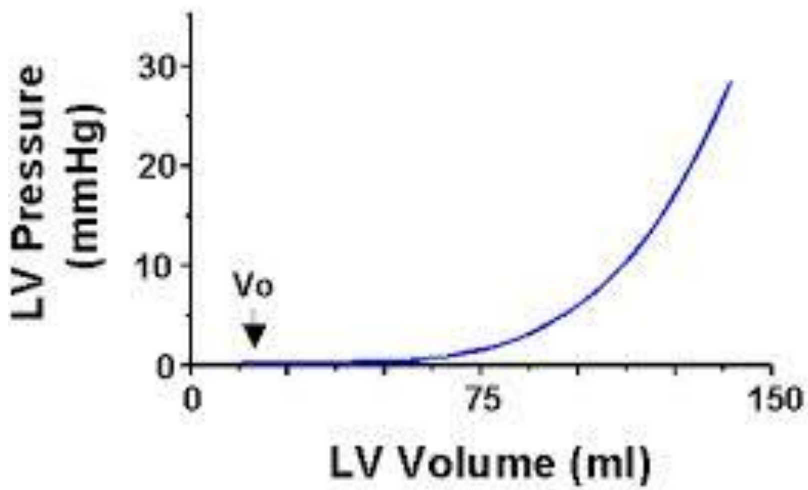
BE172 Week 5: Cardiac Mechanics

Mechanical function of the frog ventricle using an isolated heart system

Pressure volume loops

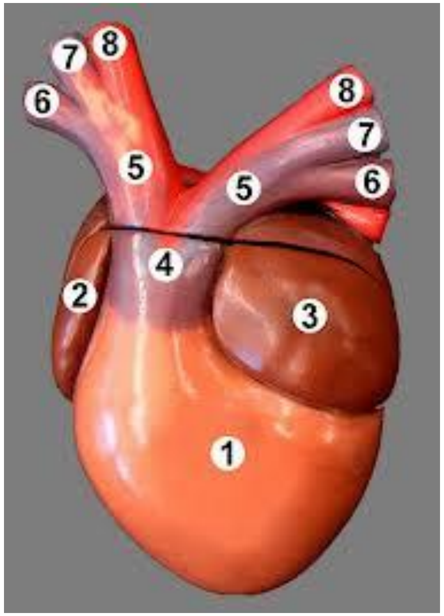


Our goal will be to examine only the passive filling curve, or the end-diastolic pressure volume curve

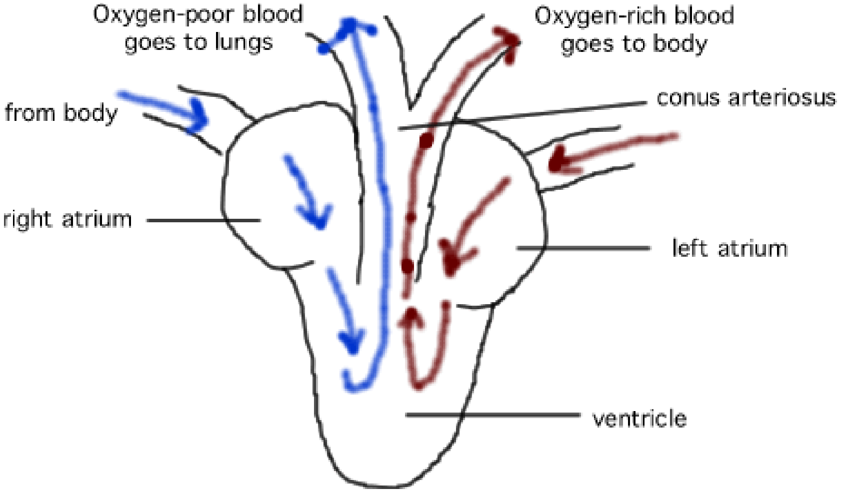


- Non-linear as with most biological tissues
- Has viscoelastic and hysteresis characteristics….for next week!
- Measure experimentally by “arresting” the cells, passive only.

Frog heart anatomy



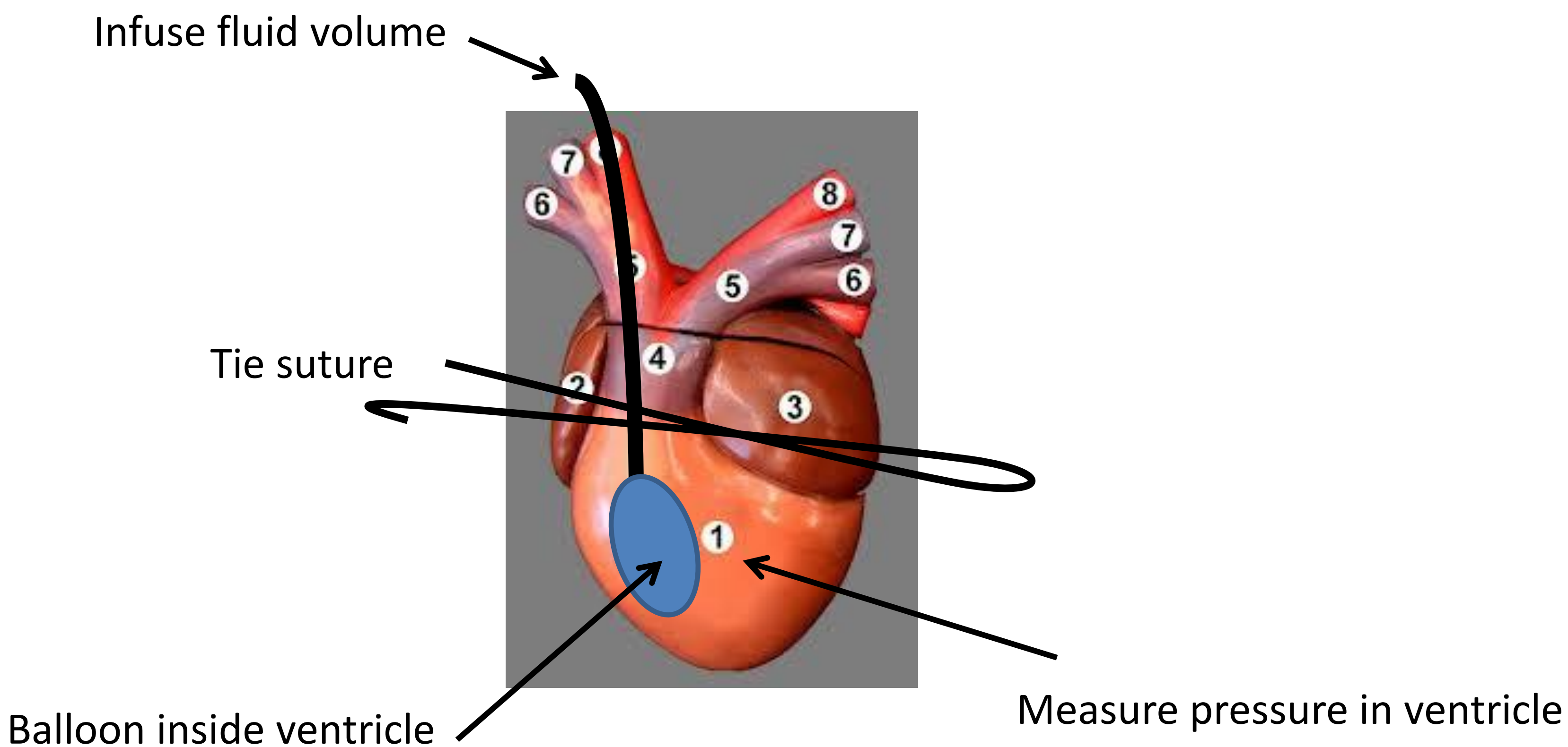
1 –ventricle; 2,3 – atria; 5 – left and right aortas



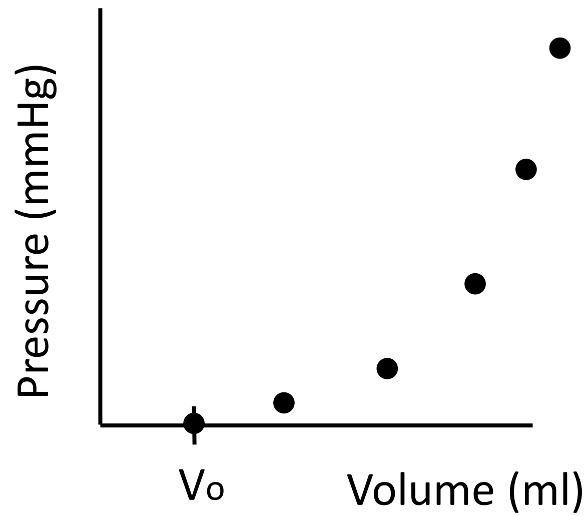
- One ventricle, pumps all blood
- 2 atria for collecting blood from body and lungs
- 5-8 mm outer diameter

Measure a pressure volume curve

Inflate ventricle, use static loading pressure, measure infused volume

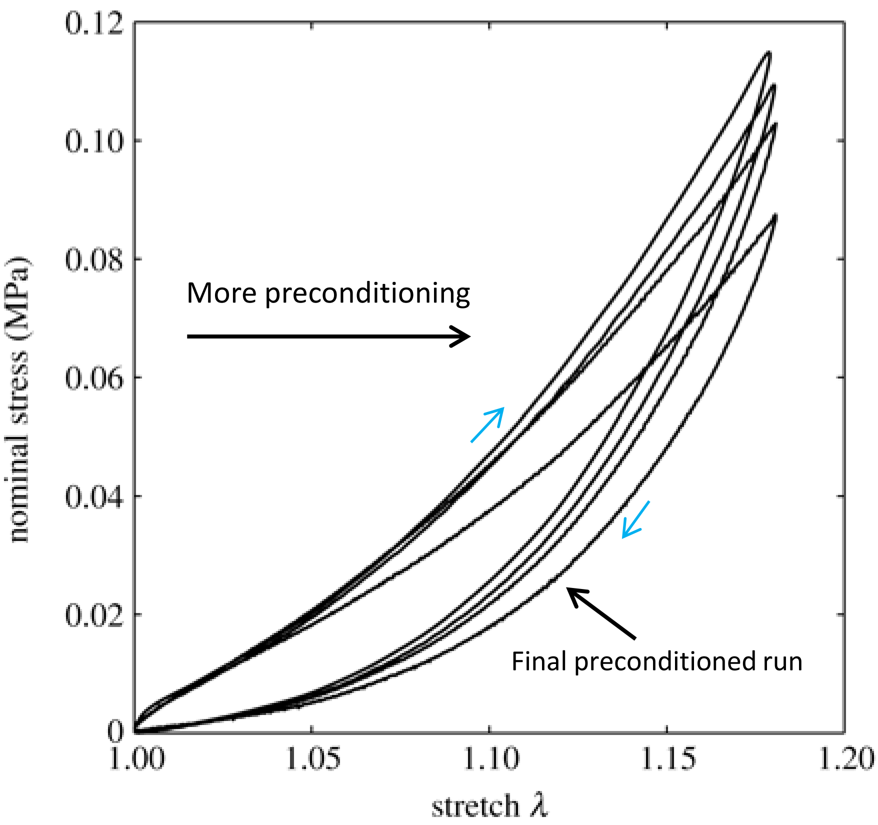


Experimental pressure-volume curve

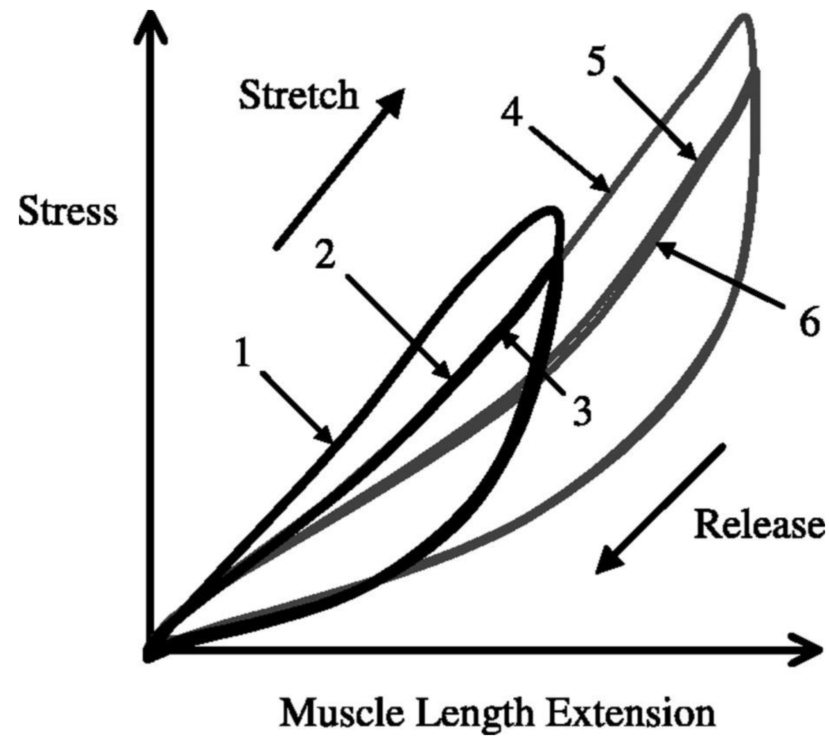


- 6-8 points as usual
- Infusion part of cycle only (pseudoelastic assumption)
- Find Vo from imaging or other methods

Preconditioning



Strain Softening



- Start with preconditioned “control” PV curve
- Inflate to higher pressure (higher stress/strain)
- Material will permanently “soften”, leading to a shift in the PV curve

Residual Stress in the ventricle

Cut ring of tissue

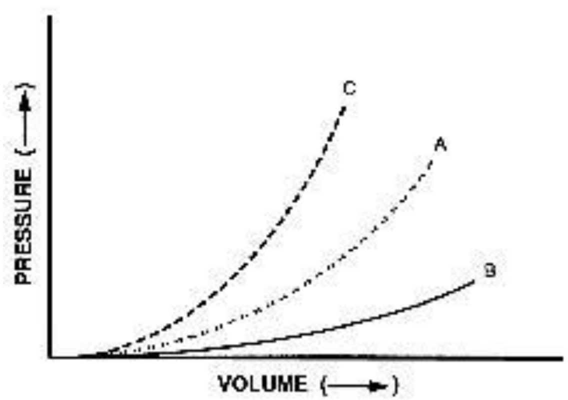
Unloaded, with residual stress

Radial cut, Stress-free

- Heart has residual stress, helps normalize gradients of stress during inflation
- See effects of residual stress by comparing stress-free state to no-load state
- Measure "opening angle", which is a function of the amount of circumferential residual stress

Experiment highlights

- Isolate and arrest frog heart. KCl solution will keep tissue in a passive state
- Mount heart on infusion apparatus to measure pressure and infused volume
- Precondition with at least 3 full inflation-deflation cycles
- Record preconditioned PV curve: add video imaging for ventricular dimensions
- Record information for post-experiment estimate of V_o
- Strain softening and residual stress experiments



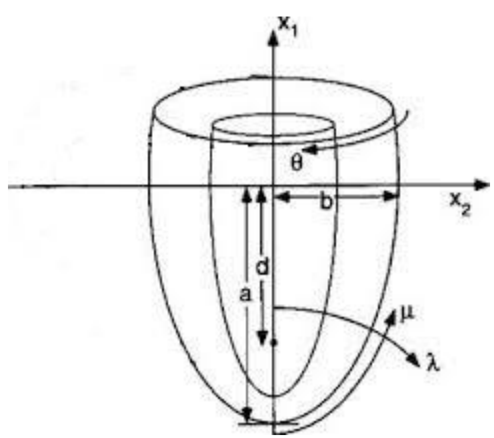
Model the Heart with FEM

- Finite Element Method: Solve a boundary value problem in mechanics
- Many, many simplifying assumptions to enable solution in a couple hours!
  - Assume: linear material, no residual stress, isotropic, simple geometry
- Use the Cardiac Mechanics Research group (cmrg.ucsd.edu) FEM "Continuity"
  - Inputs for the model:

    Unloaded geometry (simple spheroid, need inner/outer radii and height)

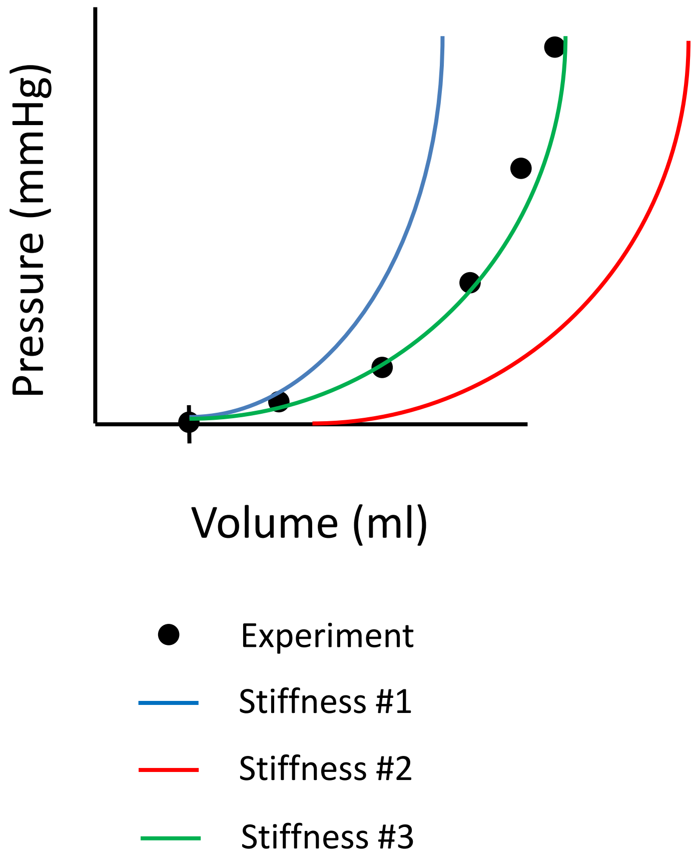
    Inflation pressure steps/maximum pressure (proper units)

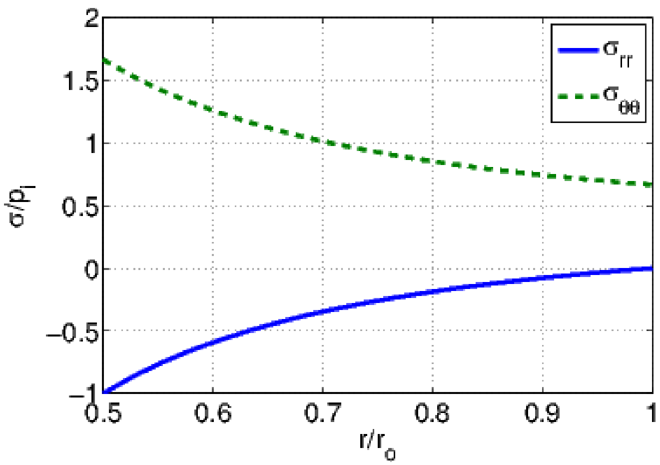
    Material properties: don't know these, make an initial educated guess



Goals of FEM:

- "Optimize" for material properties (tissue stiffness)
- Use model with optimized material to estimate inflation stress





Stress distributions from inner to outer wall