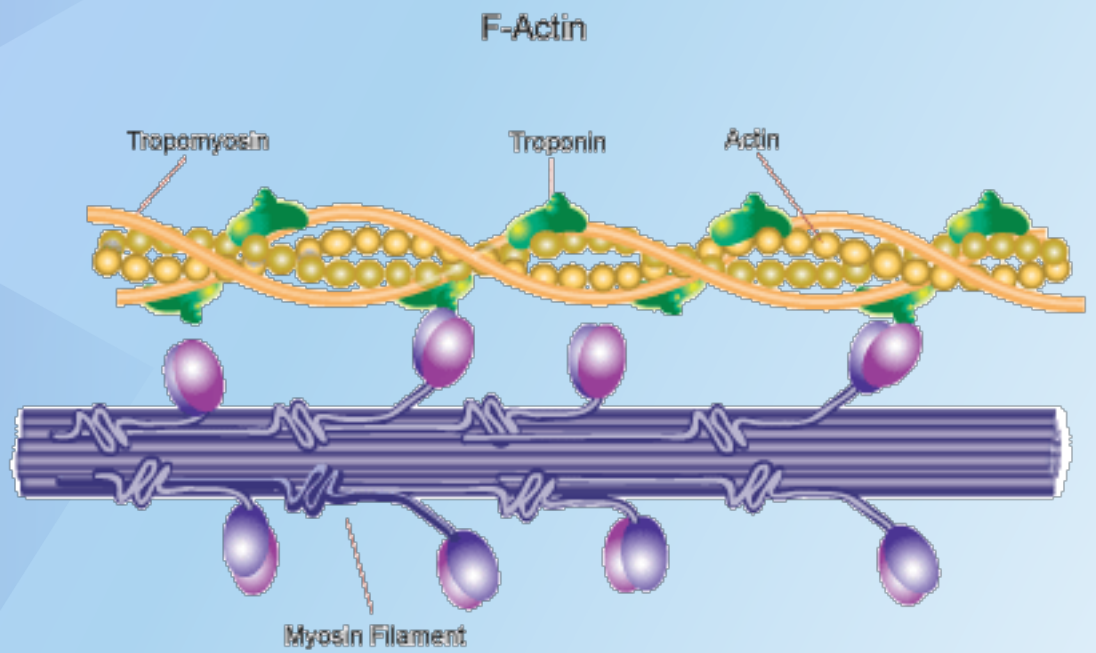
Cardiac Muscle Contraction

Muscle fiber structure

Thick filament

- Myosin



Organized in sarcomeres

Thin filament

- Actin
- Tropomyosin
- Troponin

Let’s draw! ☺

Contractility (*inotropism*)

Positive inotropic effects

- Increase contractility
- Increase:
  - Rate of tension development
  - Peak tension

Negative inotropic effects

- Decrease contractility
- Decrease:
  - Rate of tension development
  - Peak tension

Contractility is directly correlated with the intracellular [Ca^{2+}]

Autonomic Effects

Back to the board!

Effects of heart rate on contractility

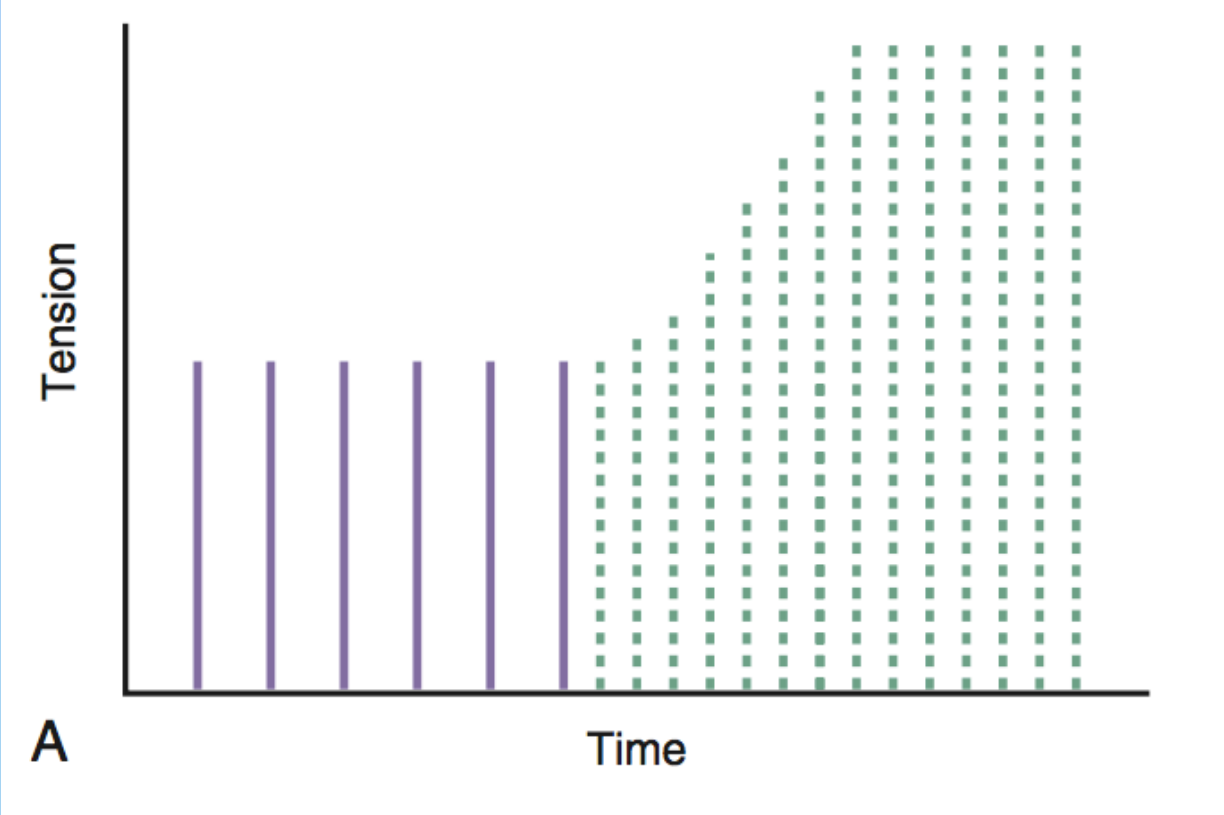
- Increased heart rate → increased contractility

Why?

1. Increased heart rate = more action potentials
   - This increases the total volume of trigger Ca^{2+} that enters the cell
   - If the increase in heart rate is caused by sympathetic stimulation, then the volume of Ca^{2+} influx per action potential is also increased
2. Increased Ca^{2+} influx = more Ca^{2+} stored in sarcoplasmic reticulum
   - Ca^{2+} uptake is further increased if caused by sympathetic stimulation (*phospholamban*)

Positive staircase effect

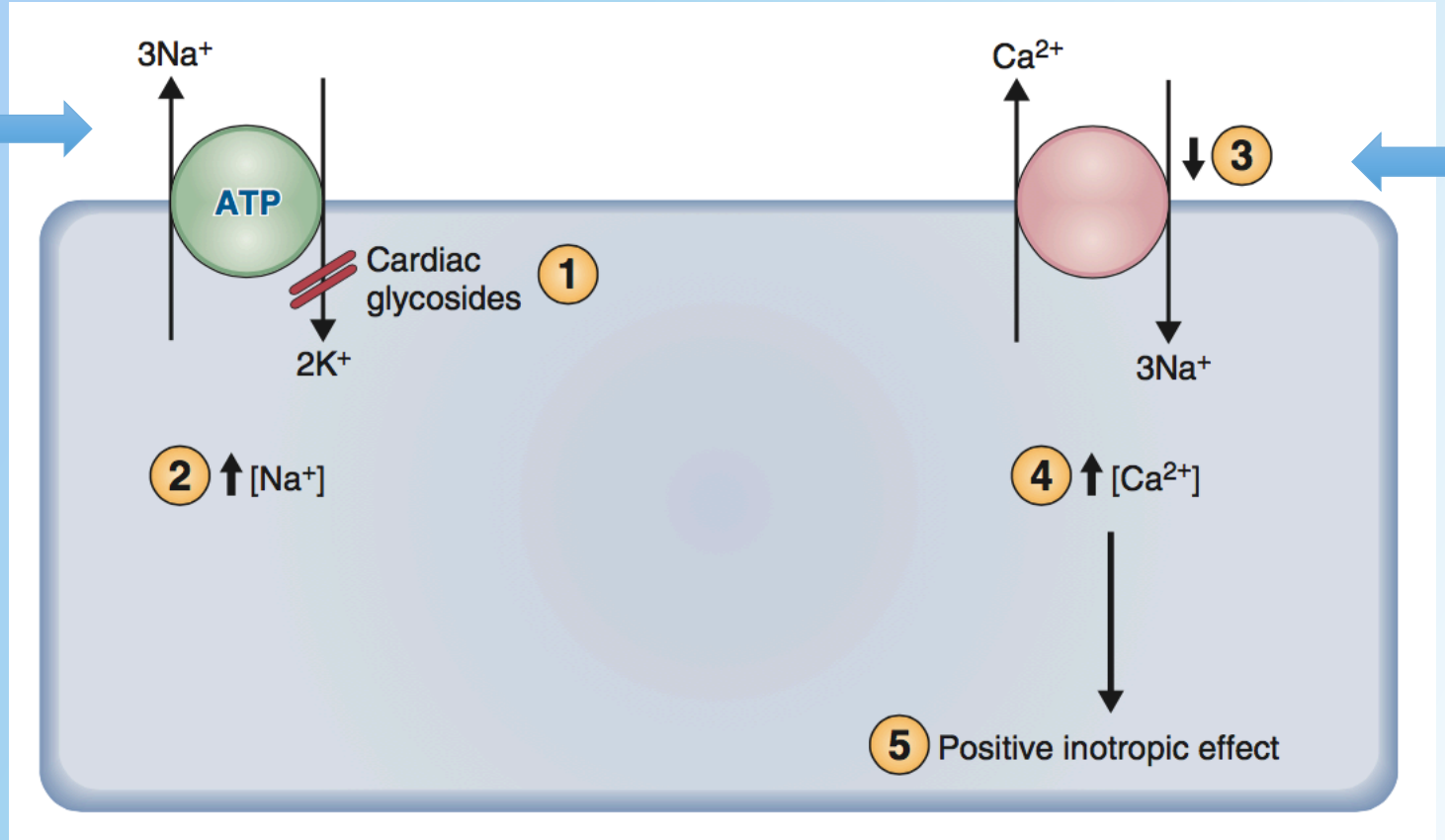
- Pattern of increase in tension when heart rate is increased



Cardiac glycosides

- Positive inotropic agents (e.g digoxin, ouabain)
- Inhibit Na^+-K^+ ATPase

Activity is dependent on ATP



Activity is dependent on [Na^+] gradient

Length-tension relationship

- Contractility is based on length/ tension of muscle fibers
- L_{max} tension > long fiber tension > short fiber tension
  - L_{max} = 2.2 micrometers

- Increasing muscle length increases Ca^{2+} sensitivity of troponin C and Ca^{2+} release from SR

Frank-Starling relationship

BUT FIRST.....

~~definitions~~

- Preload – the degree of overlap of muscle filaments
  - Same as end-diastolic fiber length
- Afterload – the pressure that the heart must pump against

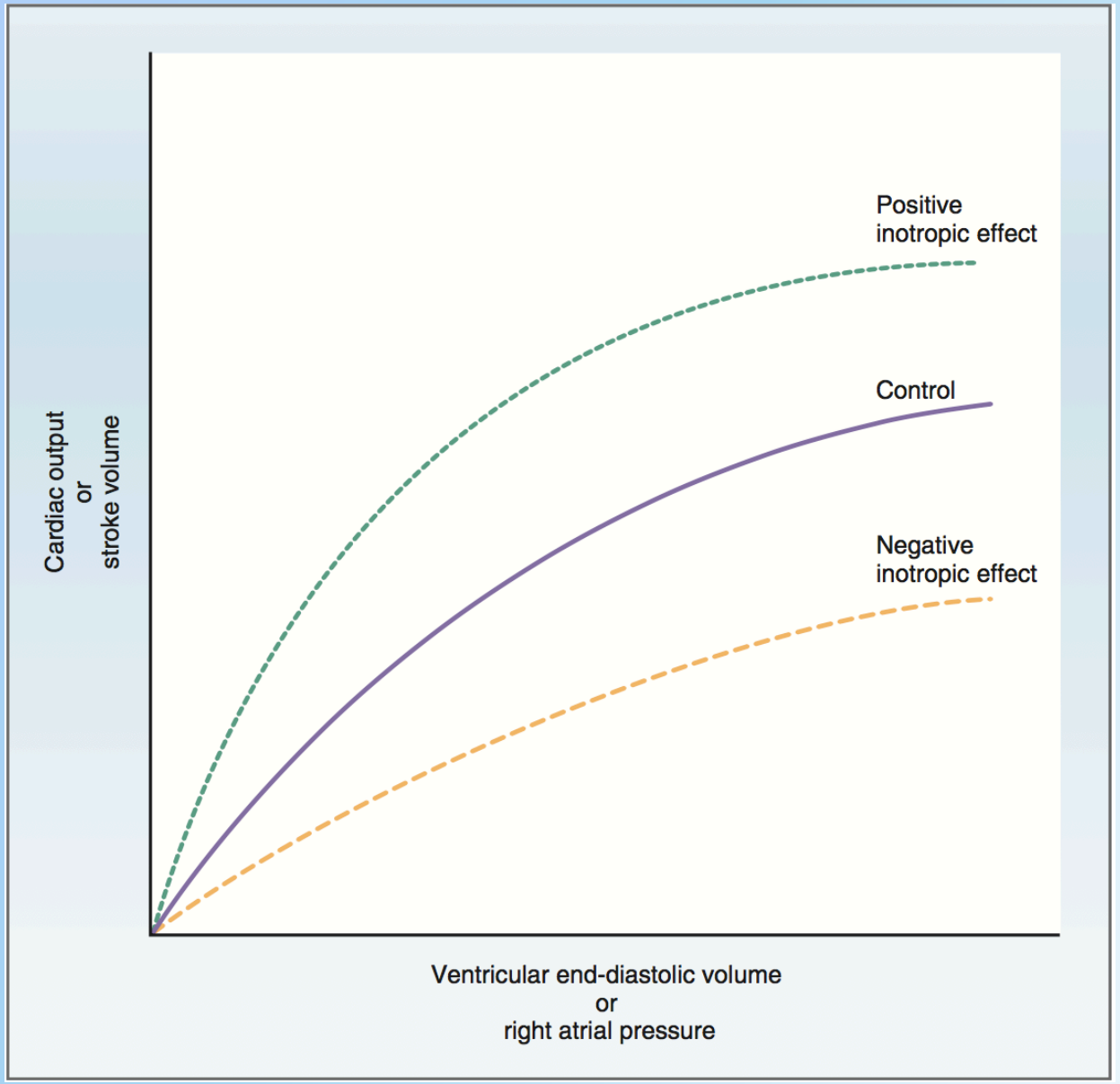
~~~more definitions~~~

- Stroke volume – amount of blood ejected per contraction
  - Usually about 70mL
- Ejection fraction – fraction of end-diastolic volume ejected per contraction
  - Usually around 55%
  - Indicator of contractility
- Cardiac output – amount of blood ejected per unit time
  - CO = SV*HR
  - E.g 5L/min

Frank-Starling relationship

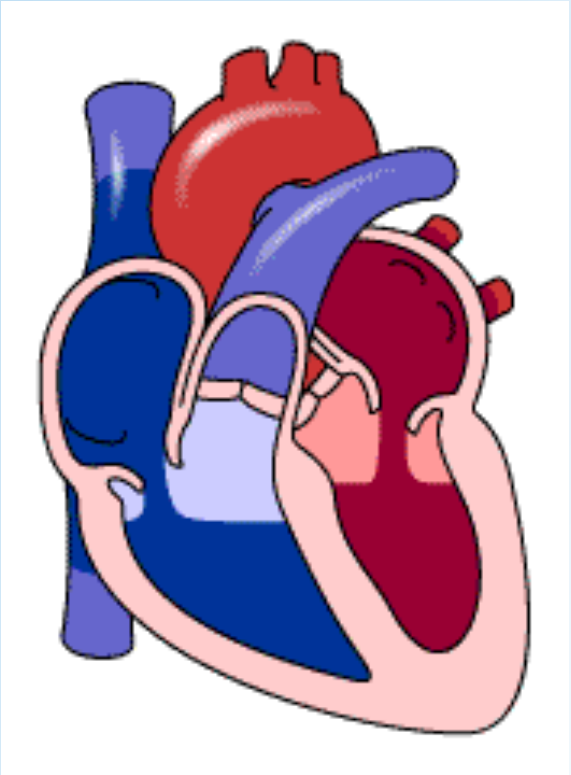
- *"the volume of blood ejected by the ventricle depends on the volume present in the ventricle at the end of diastole"*
- CO and SV are dependent on preload
  - Preload = Venous Return
- If VR is increased, CO will increase
- If VR is decreased, CO will decrease

- Increasing volume stretches muscle fiber length (preload!)


Positive
inotropic effect
Control
Negative
inotropic effect
Cardiac output
or
stroke volume
Ventricular end-diastolic volume
or
right atrial pressure

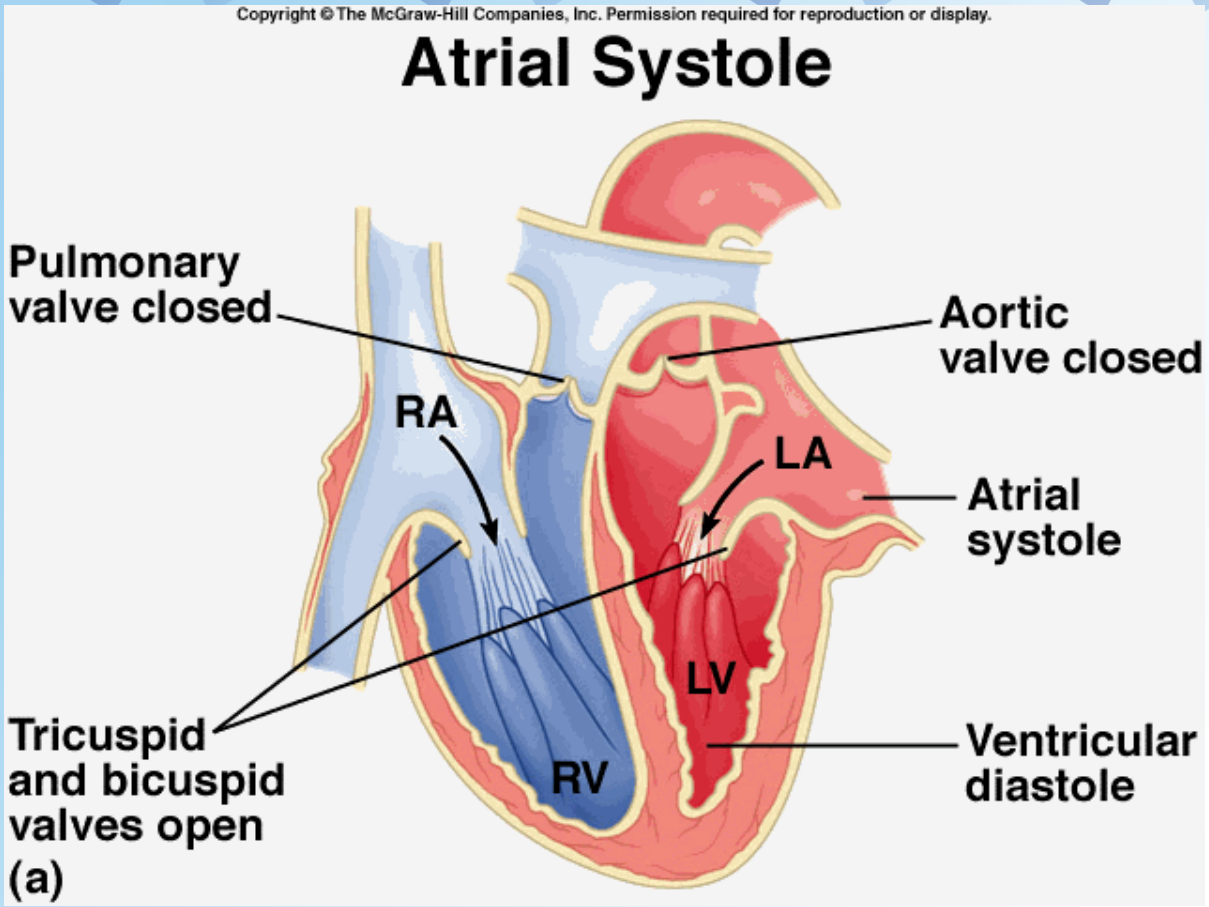
Cardiac cycle

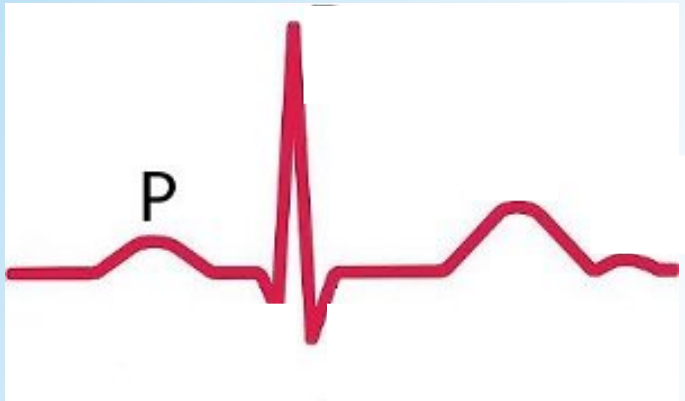
1. Atrial systole
2. Isovolumetric ventricular contraction
3. Rapid ventricular ejection
4. Reduced ventricular ejection
5. Isovolumetric ventricular relaxation
6. Rapid ventricular filling
7. Reduced ventricular filling



Atrial systole

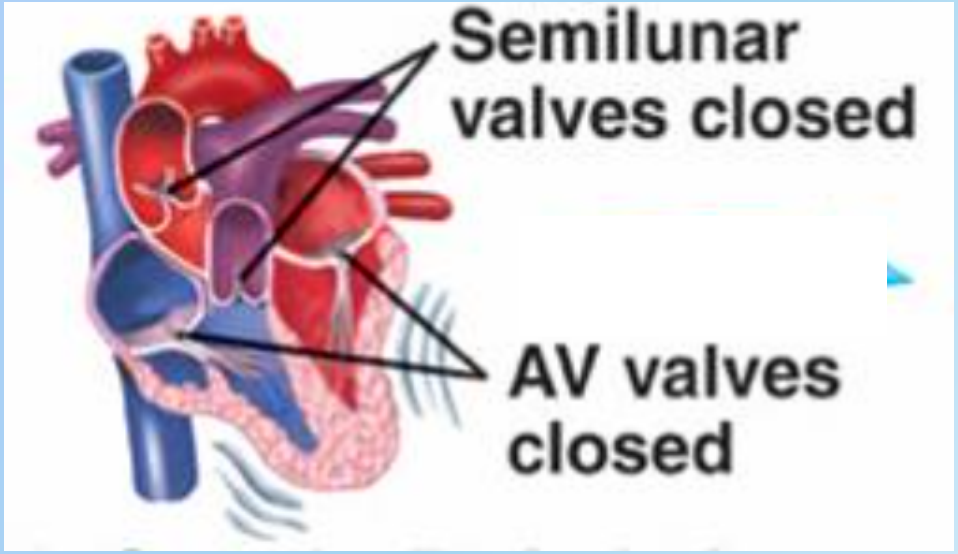
- Contraction of the left atrium
- Preceded by P wave on ECG
- Mitral valve is open
  - Passive ventricular filling precedes atrial systole

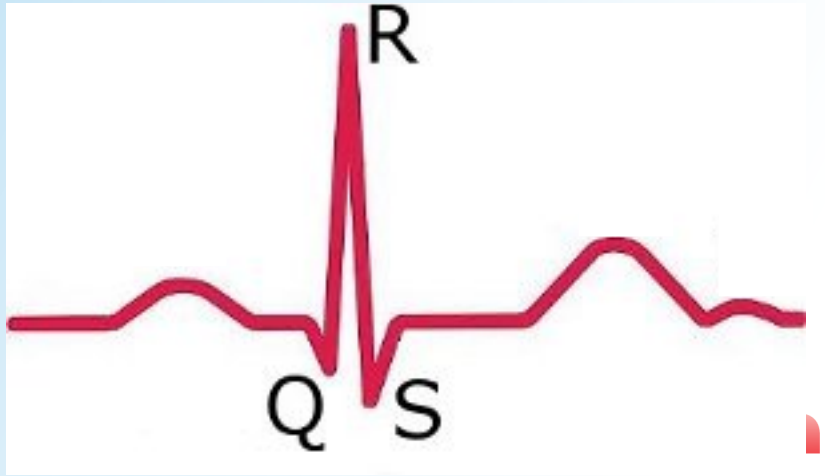




Isovolumetric ventricular contraction

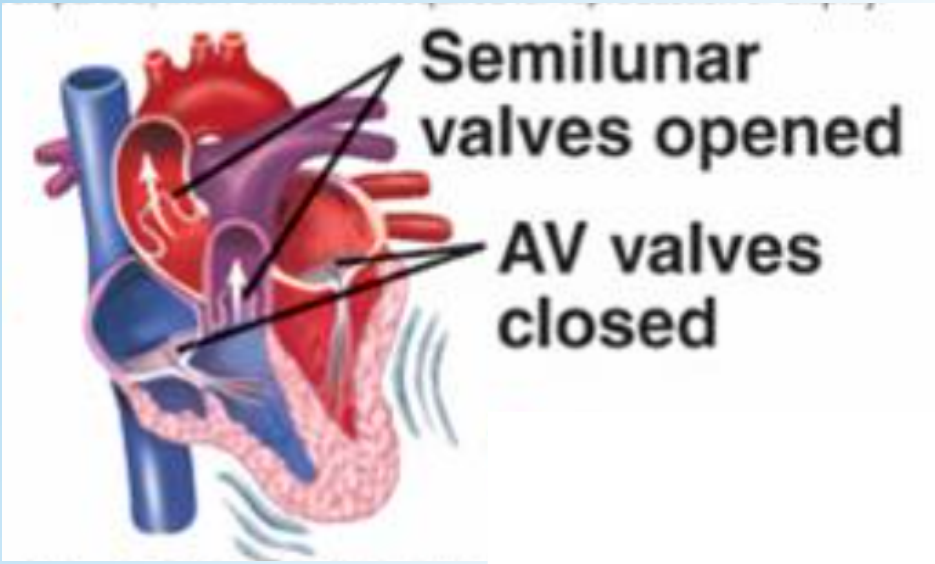
- Begins during QRS complex
- Closes mitral valve (S1)
- Ventricular volume stays the same; pressure increases

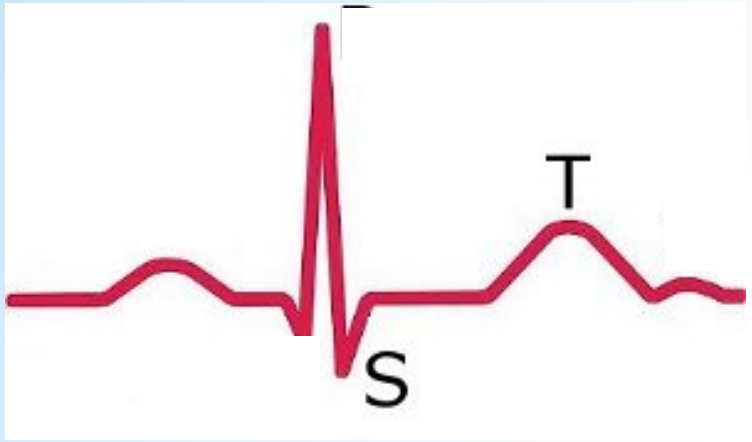




Ventricular ejection

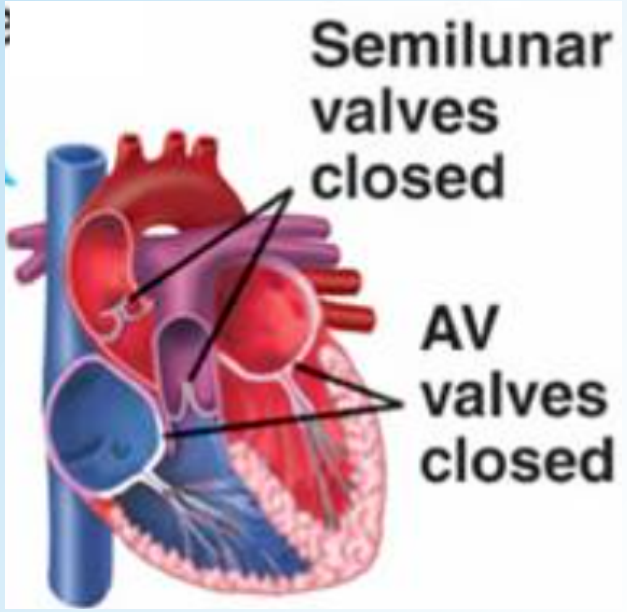
- Aortic valve opens when ventricular pressure becomes greater than aortic pressure
- Rapid ejection
  - Large pressure gradient
  - Most of stroke volume is ejected here
  - Atria begin to fill for next cardiac cycle
  - ST segment
- Reduced ejection
  - Small pressure gradient/ volume ejection
  - Ventricles are no longer contracting
  - T wave

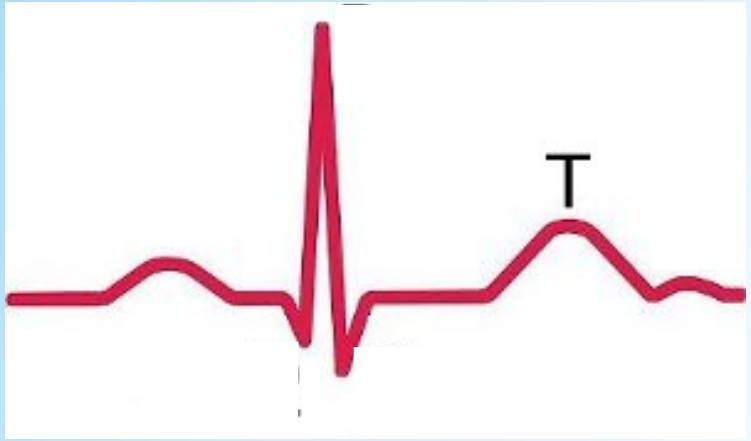




Isovolumetric ventricular relaxation

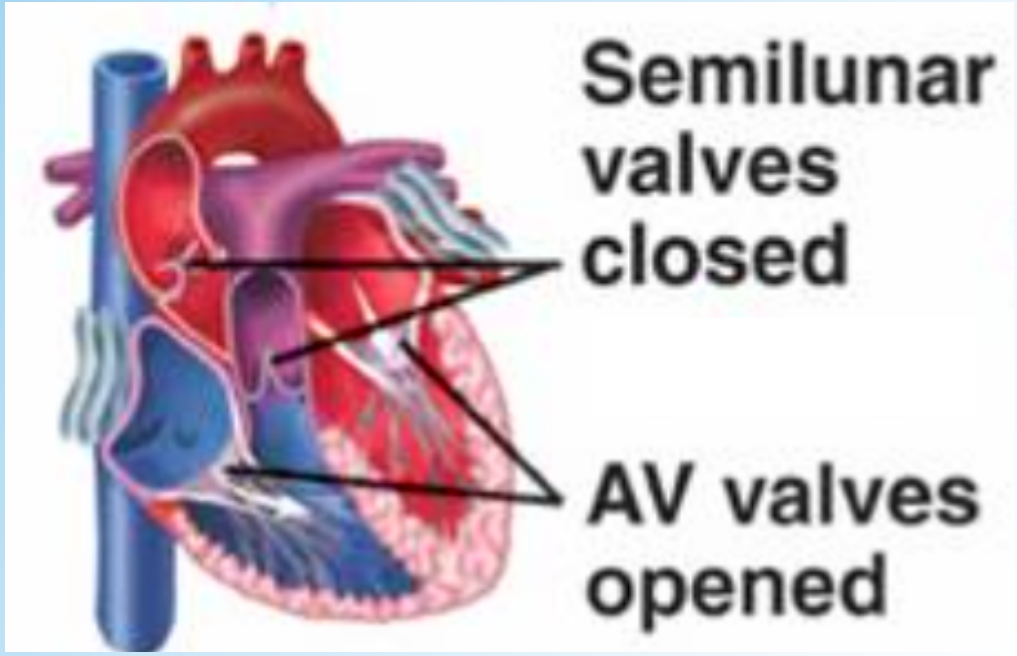
- Ventricles are fully repolarized
- End of T wave
- Left ventricular pressure decreases
- Aortic valve closes (S2)

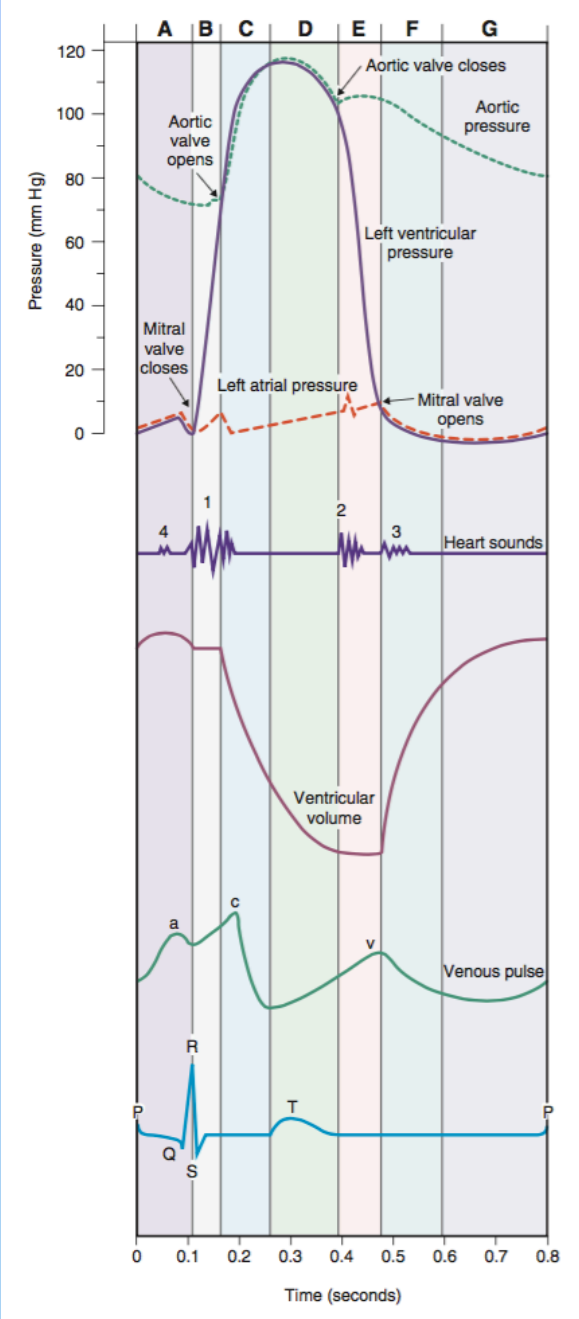




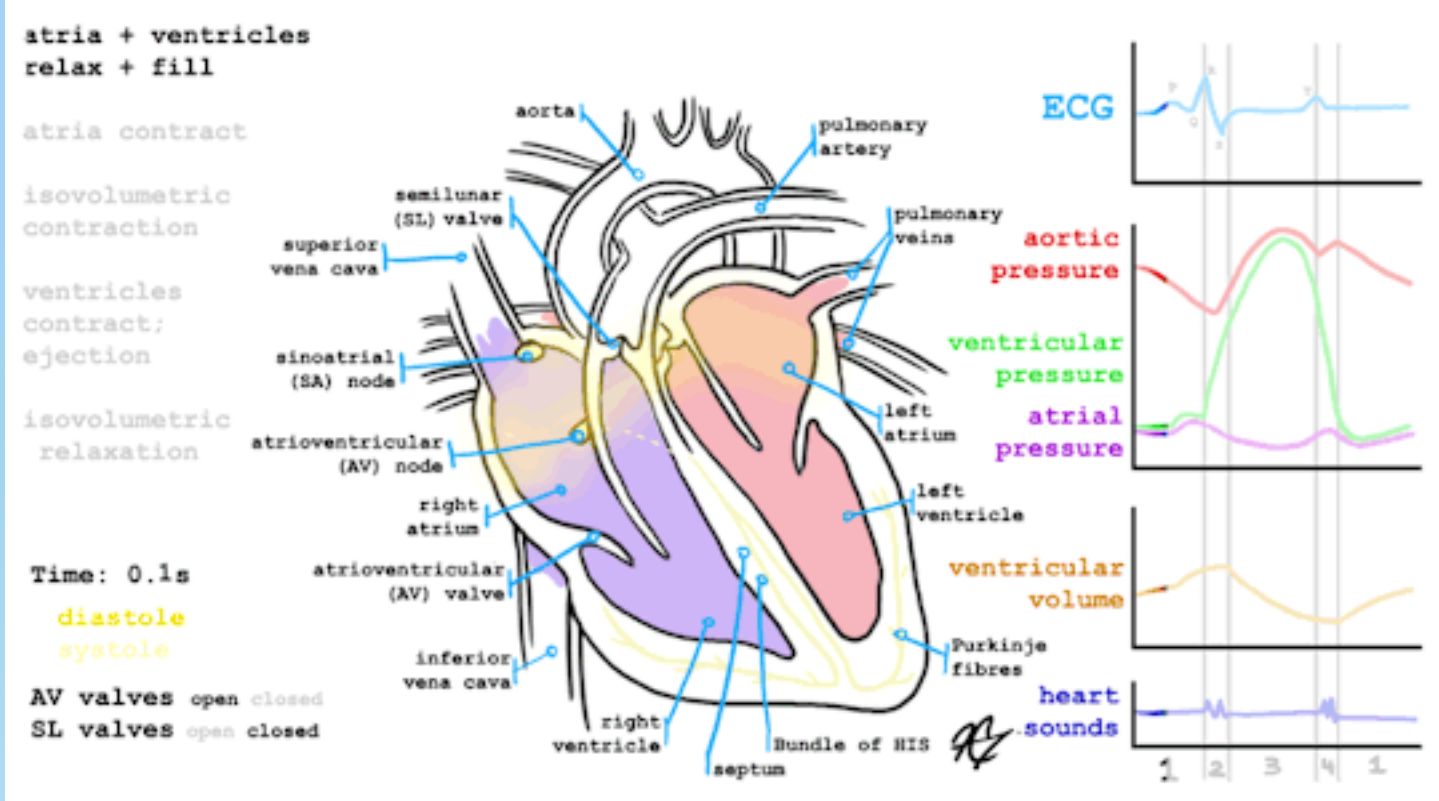
Ventricular filling

- Mitral valve opens
- Rapid
  - Ventricular pressure remains low
- Reduced (*Diastasis)*
  - Longest phase of cardiac cycle





An ECG marks electrical events – this marks electrical AND mechanical events



Pressure-Volume Loop

- Putting it all together ☺
- Back to the board!