The Heart

- Generates high PRESSURE
- Blood flows
- Tissue perfusion
- $O_2$ & nutrients delivered
- $CO_2$ & wastes removed
- Cells stay alive!
- Mediastinum
- Apex
- Base
- Diaphragm
- Medial
- Anterior
- Posterior
Fibrous Pericardium

- Collagenous sac
- Encloses ♥
- Anchors ♥ to surrounding structures
- Prevents distention of the ♥
Serous Pericardium

• Fibrous pericardium
• Pericardial cavity
• Parietal serous pericardium
• Visceral serous pericardium
3 Layers of the Heart Wall

- Epicardium (Visceral serous pericardium)
- Myocardium
- Endocardium
Heart Chambers

• 4 chambers.

• 2 superior atria.

• 2 inferior ventricles.
Right Ventricle

Systemic Circuit

Left Ventricle

Right Atrium

Pulmonary Circuit

Left atrium
- Receives deO$_2$ blood from systemic circuit
- Receives 3 main vessels
  - SVC
  - IVC
  - CS
- Sends blood thru the tricuspid orifice (past the tricuspid valve) to the RV
Left Atrium

- Receives $O_2$ blood from pulmonary circuit
- Receives 4 vessels
  - Pulmonary veins
- Sends blood thru the mitral orifice (past the mitral valve) to the LV
Interatrial Septum separates deO$_2$ blood from O$_2$ blood

- Adult contains
  - Fossa ovalis

- Fetus contains
  - Foramen ovale
How/Why do the fetal atria connect?

- Foramen ovale allows blood flow from RA to LA
- RA BP > LA BP
- Bypasses pulmonary circuit
Ventricles

- Inferior chambers.
- Muscular pumps.
- Separated by IV septum
- Trabeculae carneae
Right Ventricle

- Receives deO₂ blood from RA.
- Pumps to pulmonary circuit via the pulmonary trunk.
- Pulmonary semilunar valve
- Tricuspid valve
Left Ventricle

- Receives $O_2$ blood from LA.
- Pumps to systemic circuit via the aorta.
- Aortic semilunar valve
- Mitral valve
Left Ventricle vs. Right Ventricle

- Volume
- Pressure
- Muscle
In a normal heart the amount of blood entering the pulmonary trunk every 5 minutes is ______________ the amount of blood entering the aorta every 5 minutes.
Coronary Circuit - special branch of the systemic circuit

- Provides blood to the heart wall.
- All 3 layers need \( \text{O}_2 \)/nutrient delivery and \( \text{CO}_2 \)/waste removal.
  - Myocardium most of all.
Coronary Circuit

- Left Ventricle
  - Aorta
  - Coronary Arteries
    - Coronary Capillaries
    - Coronary Veins
      - Coronary Sinus
        - Right Atrium
Heart Valves

- Prevent backflow.

- 2 atrioventricular (AV)
  - Tricuspid
  - Mitral

- 2 semilunar
  - Pulmonary
  - Aortic.
• Tricuspid valve is **open** when RAP > RVP.

• Mitral valve is **open** when LAP > LVP.
• Tricuspid valve is **closed** when RAP < RVP.

• Mitral valve is **closed** when LAP < LVP.
Semilunar Valves

• “Pocket valves”
• No chordae tendineae
• No papillary muscles.
Pulmonary valve is open when $RVP > \text{Pulmonary Trunk P}$.

Aortic valve is open when $LVP > \text{Aortic P}$.
Pulmonary valve is closed when $RVP < \text{Pulmonary Trunk P.}$

Aortic valve is closed when $LVP < \text{Aortic P.}$
Stanley has an incompetent atrioventricular valve. This means that the valve is open when it should be closed. As a result, there is a buildup of blood and fluid in his pulmonary circuit.

Which heart valve is the incompetent one?
Theo has a stenotic atrioventricular valve. This means that the valve is *too narrow when it is open*. As a result, there is a buildup of blood and fluid in his pulmonary circuit.

Which heart valve is the stenotic one?
Myocardium

- In between epicardium and endocardium
- Mostly cardiac muscle tissue
- Also contains fibrous skeleton of the heart
Fibrous Skeleton of the Heart = Dense CT surrounding the cardiac valves.

• Origin/insertion for cardiac muscle cells.

• Electrically isolates atria from ventricles.

• Physically separates atria from ventricles.
Cardiac Contractile Cells

- Contract and generate the pumping force of the heart.

Striation

Branching

Intercalated Disc
Intercalated Discs Contain 2 Structures:

- **Gap junctions**
  - Electrically join CM cells
  - Allows for coordinated synchronized contraction.

- **Desmosomes**
  - Mechanically join CM cells
  - Prevents CM cells from separating.
Autorhythmic Cells

- Spontaneously and rhythmically depolarize.

1. Sinoatrial node
2. Atrioventricular node
3. Atrioventricular bundle
4. Right/left bundle branches
5. Purkinje fibers.
• From fastest to slowest:
  – SA node
  – AV node
  – AV bundle
  – Bundle branches
  – Purkinje fibers

• Who sets the pace?
Depolarization wave slows down at the AV node. This allows the atria to contract before the ventricles.
The electrical signal goes down the septum – not the sides or front or back.
Look where ventricular contraction starts. Analogous to toothpaste squeezing.
Medullary Cardiac Centers

- Cardioacceleratory center
- Cardioinhibitory center
- Sympathetic cardiac nerves
- Norepinephrine
- Innervates nodes and ventricular myocardium
- Increased heart rate and contractile force.
- Vagus nerve (CN X)
- Acetylcholine
- Innervates nodes
- Decreased heart rate
Vagal Tone

Resting parasympathetic influence on the heart.

What about during exercise?

Resting sympathetic influence on the heart.
What would happen to HR in each of the following situations:

- Increased CAC activity
- Increased CIC activity
- Infusion of a drug that blocked ACh
- Infusion of a drug that mimics NE
- Severe damage to the CIC
- Cutting the vagus nerve
Heart rate is also affected by...
Cardiac Cycle

- All the events associated with one heartbeat.

- Includes systole and diastole of all chambers.

- Pressures and volumes of all 4 chambers change in a predictable way during each cycle.
Phases of the Cardiac Cycle

- Ventricular Filling
- Isovolumetric Relaxation
- Isovolumetric Contraction
- Ventricular Ejection
Ventricular Filling

- LV volume is increasing.
- Mitral valve is open.
- LVP < LAP
- LV is in diastole.
- Aortic valve is closed.
- LVP < Aortic P
Ventricular Filling

- First 80% vs. Last 20%
  - Passive
  - Due to atrial systole

- End Diastolic Volume.
Ventricular Filling

- Ventricular volume (ml)
- Pressure (mm Hg)

Time

- Aorta
- Left atrium
- Left ventricle
Isovolumetric Contraction

- LV contracts and LVP begins to rise.

- LVP quickly exceeds LAP and AV valves shut.

- However Aortic P is still really high so the ASL doesn’t open yet.
Isovolumetric Contraction

- Mitral valve is closed.
- Aortic valve is closed.
- LV volume is not changing.
- LVP > LAP
- LVP < Aortic P
Isovolumetric Contraction

- **Ventricular volume (ml)**
- **Pressure (mm Hg)**
- **Time**

- **EDV**
- **Aorta**
- **Left ventricle**
- **Left atrium**
Ventricular Ejection

• LV is still contracting and now LVP exceeds Aortic P

• Aortic valve is now open.

• And LV volume will decrease.

• Mitral valve is still closed because LVP > LAP
The amount that leaves is called the stroke volume.

The amount that remains is called the end systolic volume.
Ventricular Ejection

Why isn’t the entire EDV ejected?
Stroke Volume

- Vol. ejected by a ventricle per cardiac cycle.

- Stroke Volume = End diastolic volume – End systolic volume

- SV = EDV – ESV

- Ventricular Balance
Calculate the stroke volume in this example.
Ventricular Ejection

Graph showing the pressure (mm Hg) over time with different lines representing various parts of the heart, including the left ventricle and left atrium.
Isovolumetric Relaxation

- LV relaxes and LVP begins to drop.

- LVP drops below Aortic P and semilunar valves shut.

- However LVP is still much higher than LAP so the mitral valve doesn’t open yet.
Isovolumetric Relaxation

- Mitral valve is shut.
- Aortic valve is shut.
- LV volume is not changing.
- LVP > LAP
- LVP < Aortic P
Isovolumetric Relaxation

Ventricular volume (ml)

Time
Isovolumetric Relaxation

Pressure (mm Hg)

Time

Aorta
Left ventricle
Left atrium
• Given that:
  – Aortic Pressure = 82mmHg
  – Left Atrium Pressure = 11mmHg
  – Left Ventricle Pressure = 61 mmHg and falling

• Answer the following:
  – The mitral valve is…
  – The tricuspid valve is…
  – The aortic semilunar valve…
  – The pulmonary semilunar valve is…
  – LV volume is…
  – LA volume is…
  – The current phase of the cardiac cycle is…
  – The previous phase of the cardiac cycle was…
  – The next phase of the cardiac cycle will be…
  – The most recent heart sound was caused by…
  – The next heart sound will be caused by…
Cardiac Output

- Volume of blood pumped by a ventricle per minute.

- \( \text{Cardiac Output} = \text{Heart Rate} \times \text{Stroke Volume} \)

- Units are mL/min or L/min.
Hector had a cardiac output of 6000 mL/min and a heart rate of 100 beats/minute. How much blood left his heart during each cardiac cycle?

a) 58.6 mL  
b) 62 mL  
c) 100 mL  
d) 120 mL  
e) 180 mL
Ventricular Imbalance

1. Right ventricular output exceeds left ventricular output.
2. Pressure backs up.
3. Fluid accumulates in pulmonary tissue.

1. Left ventricular output exceeds right ventricular output.
2. Pressure backs up.
3. Fluid accumulates in systemic tissue.
Regulating Stroke Volume

- Primary influence on stroke volume is:
  - Preload

- Other influences:
  - Contractility
  - Afterload
Preload

• Degree of ventricular stretch.

• In other words – the EDV
More blood returns to the heart.

Ventricular stretch increases

Overlap between actin & myosin gets more optimum

Ventricular tension increases

Stroke volume increases
• Whatever goes in the heart gets pumped out.
• Strength of ventricular squeezing regardless of how stretched it is.

• ↑ in contractility will cause SV to increase.

• Norepinephrine and epinephrine
Afterload

• Pressure that the LV must overcome in order to open the semilunar valve and eject blood.

• Aortic blood pressure.
Suppose Aortic P is high:

- More energy will be expended on opening the ASV.
- Less energy will be available for ejecting blood.
- SV would then decrease.
• How would each of the following affect SV?
  
  – Activation of the CAC
  
  – Infusion of epinephrine
  
  – A decrease in time between heart beats
  
  – Hypocalcemia and a resulting decrease in contractility
• How does endurance training affect:
  – Left ventricular contractility
  – Left ventricle chamber size
  – Coronary circulation