Heart

Structure

Physiology of blood pressure and heartbeat
Location and Anatomy
Location and Anatomy

- **Pericardial cavity**: surrounds, isolates, and anchors heart
  - **Parietal** pericardium lined with **serous membrane**
Location and Anatomy

- **Pericardium**: Simple epithelium (serous membrane) over CT (loose CT proper + adipose)
- **Myocardium**: Cardiac muscle
- **Endocardium**: inner chamber; simple epithelium over CT
Mammalian Circulatory System

- Four chambered heart
- Thick arteries
- Thin veins
- Capillary beds at lungs, head, forelimbs, abdomen, hindlimbs
Anatomy

• **Chambers**
  – **Atria**: Right & Left; blood collector
  – **Ventricles**: Right & Left; blood pump

• **Vessels**: Transport
  – **Arteries**: Pulmonary (lungs), Aorta (body)
  – **Veins**: Vena cava, pulmonary

• **Valves**: Prevent backflow
  – **Atrioventricular** (AV): tri- & bicuspid
  – **Semilunar**: Pulmonary & aortic
Valves prevent backflow

- Blood in aorta is at higher pressure than ventricle
- Attempted backflow is stifled by semi-lunar valve collapse
Cardiac cycle: Heart sounds

- **Cause** = forceful closure of valves by high pressure blood
- 1st heart sound: **lubb**
  - Beginning of systole; results from closure of AV valve
- 2nd heart sound: **dupp**
  - Beginning of diastole; results from closure of semilunar valves
Blood Supply

(a) Anterior view

- Superior vena cava
- Aortic semilunar valve
- Right atrium
- Right coronary artery
- Posterior interventricular artery
- Right marginal artery
- Right ventricle

(b) Anterior view

- Aortic arch
- Pulmonary trunk
- Left coronary artery
- Left atrium
- Circumflex artery
- Left marginal artery
- Anterior interventricular artery
- Left ventricle
- Superior vena cava
- Right atrium
- Middle cardiac vein
- Coronary sinus
- Great cardiac vein
- Left ven tricle
- Into right atrium
- Posterior vein of left ventricle
- Small cardiac vein
- Right ventricle
Blood supply issues

• **Ischemia**
  – Stroke (reduced blood supply to brain) induced by blocked artery

• **Angina**
  – Gradual blockage of coronary artery or vessel causing inadequate blood flow to cardiac muscle

• **Infarction** (Heart Attack)
  – Dead tissue that results from cessation of nutrient flow & waste removal

• **Fibrillation**
  – Ventricular contraction due to multiple AP production
How does coordinated contraction occur?

- **Nodes**: Autorythmic pacemakers
  - Innervated by neurons of MO

- **Purkinje fibers**: signal propagators

- **Intercallated discs** of cardiac muscle
Pacemakers

- **Sinoatrial (SA)**
  - Depolarize atria; coordinated contraction follows

- **Atrioventricular (AV)**
  - Depolarize ventricles; rely on large diameter **purkinje fibers** to help deliver AP; coordinated contraction of ventricles
How is tetanus prevented?
The Plateau phase deafens myocardia

1. **Rapid Depolarization**
   - Cause: Na$^+$ entry
   - Duration: 3–5 msec
   - Ends with: Closure of voltage-gated (fast) sodium channels

2. **The Plateau**
   - Cause: Ca$^{2+}$ entry
   - Duration: ~175 msec
   - Ends with: Closure of slow calcium channels

3. **Repolarization**
   - Cause: K$^+$ loss
   - Duration: 75 msec
   - Ends with: Closure of slow potassium channels

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(a) Cardiac muscle

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AP differences

- **Plateau phase**: "long", slow repolarization phase allows **complete** relaxation of myocardium
  - Caused by opening of Ca\(^{2+}\) channels in plasma membrane
    - What does Ca\(^{2+}\) do when those channels open?
- Prevents tetanus
  - Safety mechanism
  - What would happen if AP arrivals came too frequently?
ECG

• **P wave:**
  – Depolarization of atria; 
    *precedes atrial systole*

• **QRS wave:**
  – Depolarization of ventricles; 
    *precedes ventricular systole*

• **T wave:**
  – Repolarization of ventricles; 
    *precedes ventricular diastole*
Cardiac cycle: 1

- Begin systole
- Ventricles begin to contract
- AV valves close
Cardiac cycle: 2

- **Continue systole**
- **Ventricles continue contracting**
- **Ventricular pressure exceeds arterial pressure**
- **Semilunar valves open and blood leaves heart**

2. **Systole continued**
   Continued ventricular contraction causes the pressure in the ventricle to exceed the pressure in the pulmonary trunk and aorta. As a result, the...
Cardiac cycle: 3

- Begin diastole
- Ventricles begin to relax
- Semilunar valves close as arterial pressure exceeds ventricular pressure

3. **Beginning of diastole**
   At the beginning of ventricular diastole the ventricles relax, and the semilunar valves close (the second heart sound).
Cardiac cycle: 4

- **Diastole continues**
- **AV valves open as atrial bp exceeds ventricular bp**
  - Fill to about 70% of max. volume

4. **Diastole continued**
The AV valves open and blood flows into the ventricle and the ventricles fill to approximately 70% of their volume.
Cardiac cycle: 5

- Diastole ends
- Atria contract and complete ventricular filling
Cardiac cycle: overview

- --- = Left Ventricle
- --- = Aorta
- --- = Left Atria
Cardiac cycle

- --- = Left Ventricle
- --- = Aorta
- --- = Left Atria
Cardiac cycle: Heart sounds

• **Cause** = forceful closure of valves by high pressure blood

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Heart sounds indicate key events

- Valves open & close where pressure traces cross
Cardiac output

- **Cardiac output** = \( CO \) (mL/min): volume of blood pumped by left ventricle each minute
- **Stroke volume** = \( SV \) (mL/beat): volume of blood pumped out of both ventricles with each contraction
- **Heart rate** = \( HR \) (beats/min)
- Starlings law: governs cardiac output
  - the degree to which the ventricular walls are stretched by returning blood determines the stroke volume