Cardiovascular Physiology

Heart Physiology

for the heart to work properly contraction and relaxation of chambers must be coordinated

cardiac muscle tissue differs from smooth and skeletal muscle tissues in several ways that suit its function in the heart

Histology of Heart

cardiac muscle fibers (=cardiocytes)

relatively short, thick branched cells, 50-100 µm long

striated → myofibrils are highly ordered

usually 1 nucleus per cell

rather than tapering cells are bluntly attached to each other by gap junctions = intercalated discs

→ myocardium behaves as single unit

but atrial muscles separated from ventricular muscles by conducting tissue sheath

→ atria contract separately from ventricles

→ need constant supply of oxygen & nutrients to remain aerobic

→ greater dependence on oxygen than skeletal muscles

Conducting System

cardiac muscle cells are not individually innervated as are skeletal muscle cells → they are self stimulating

the rhythmic beating of the heart is coordinated and maintained by the heart conducting system

heart has some specialized fibers that fire impulses to coordinate contraction of heart muscle

innervated by autonomic NS
sympathetic stimulation can raise rate
parasympathetic stimulation can lower rate

cconducting system consists of:

**SA Node**
- intrinsic rhythm
- 70-75 beats/min
- initiates stimulus that causes atria to contract
  (but not ventricles directly due to separation)

**AV Node**
- picks up stimulus from SA Node

**AV Bundle** (Bundle of His)
- connected to AV Node
- takes stimulus from AV Node to ventricles

**Purkinje Fibers**
- takes impulse from AV Bundle out to cardiac muscle fibers of ventricles causing ventricles to contract

the heart conducting system generates a small electrical current that can be picked up by an electrocardiograph

**=electrocardiogram (ECG; EKG)**

ECG is a record of the electrical activity of the conducting system
ECG is NOT a record of heart contractions

![ECG waveform](image)

**P wave** = passage of current through atria from SA Node
- conduction through atria is very rapid

**QRS wave** = passage of current through ventricles from AV Node – AV Bundle – Purkinje Fibers
- impulse slows as it passes to ventricles

**T wave** = return to “resting” conditions

by comparing voltage **amplitudes** and **time intervals**
between these waves from several leads can get
idea of how rapidly the impulses are being conducted and how the heart is functioning

**Cardiac Cycle**

1 complete heartbeat (takes ~ 0.8 seconds)

consists of:

- **systole** → contraction of each chamber
- **diastole** → relaxation of each chamber

two atria contract simultaneously
as they relax, ventricles contract

relation of ECG to cardiac cycle

contraction and relaxation of ventricles produces characteristic **heart sounds**: lub-dub

- **lub** = systolic sound
- **dub** = diastolic sound

contraction of ventricles and closing of AV valves
shorter, sharper sound
ventricles relax and SL valves close

abnormal sounds: “**murmurs**” → defective valves
congenital
rheumatic (strep antibodies)
septal defects

**Cardiac Output**

= The amount of blood that the heart pumps/min

\[
\text{CO} = \text{Heart Rate} \times \text{Stroke volume}
\]

\[
= 75 \text{b/m} \times 70 \text{ml/b}
\]

\[
= 5250 \text{ ml/min (}=5.25 \text{ l/min})
\]

~ normal blood volume

during strenuous exercise heart may increase output 4 or 5 times this amount

**A. Heart Rate:**

innervated by **autonomic** branches to SA and AV nodes (antagonistic controls)
cardiac control center in **medulla** (cardiac center)

receives sensory info from:

- **Baroreceptors** (stretch)
  - in aorta and carotid sinus
  - increased stretch $\rightarrow$ slower

- **Chemoreceptors**
  - monitor carbon dioxide and pH
  - more CO$_2$ or lower pH $\rightarrow$ faster

any marked, persistent changes in rate may signal cardiovascular disease

**B. Stroke Volume:**

healthy heart pumps $\sim$60% of blood in it

$\rightarrow$ normal SV $\sim$70 ml

also each side of heart must pump exactly the same amount of blood with each beat

$\rightarrow$ otherwise excess blood would accumulate in lungs or in systemic vessels

eg. if Rt heart pumped 1 ml more per beat

$\rightarrow$ within 90 minutes the entire blood volume would accumulate in the lungs

Stroke Volume is affected mainly by:

- mean arteriole pressure
  - systemic blood pressure
    = back pressure

**Physiology of Blood Vessels**

Blood circulates by going down a **pressure gradient**

$\rightarrow$ to understand circulation we must understand blood pressure

**Blood Pressure**

= the driving force of the blood flowing through blood vessels

measured as mmHg [ 100 mm Hg = 2 psi, tire $\sim$35psi]

changes in pressure are the driving force that moves blood through the circulatory system
blood pressure is created by

1. **the force of the heart beat**

   the heart maintains a high pressure on the arterial end of the circuit

2. **peripheral resistance**

   → back pressure, resistance to flow

   eg **atherosclerosis** inhibits flow → raises blood pressure

**Measuring Blood Pressure**

use sphygmomanometer

usually measure pressure in the **brachial artery**

procedure:
   a. increase pressure above systolic to completely cut off blood flow in artery
   b. gradually release pressure until 1st spurt (pulse) passes through cuff = systolic pressure
   c. continue to release until there is no obstruction of flow; sounds disappear = diastolic pressure

**normal BP** = 120/80 (range: 110-140 / 75-80 [mm Hg])

**top number** = systolic pressure
   force of ventricular contraction

**bottom number** = resistance of blood flow
   may be more important
   indicates strain to which vessels are continuously subjected
   also reflects condition of peripheral vessels

**Bloodflow in Veins**

flow of blood in veins is due to presence of 1 way valves and venous “pumps”

**1 - way valves**

prevent backflow
most abundant in veins of limbs

quiet standing can cause blood to pool in veins and may cause
fainting

varicose veins: “incompetent” valves, esp. superficial veins may be due to heredity, prolonged standing, obesity pregnancy

hemorrhoids: varicosities of anal veins due to excessive pressure from birthing or bowel movements

venous pumps
muscular pump (=skeletal muscle pump) during contraction veins running thru muscle are compressed and force blood in one direction (toward heart)

respiratory pump
inspiration: creates pressure gradient in Inferior Vena Cava to move blood toward heart
expiration: increasing pressure in chest cavity forces thoracic blood toward heart

veins function to collect blood and act as blood reservoirs with large lumens and thin walls they can accommodate relatively large volumes of blood →60-70% of all blood is in veins at any time

largest veins = sinuses eg. coronary sinus, dural sinus

blood is “stored” in venous sinuses

most organs are drained by >1 venous branch even more common than alternate arterial pathways

→ occlusion of veins rarely blocks blood flow

removal of veins during bypass surgery usually not traumatic

Capillaries

actual site of exchange of materials → the rest is pumps and plumbing

thin walled - single cell layer thick

extremely abundant in almost every tissue of body
most of 62,000 miles of vessels
but only contains ~5% of blood in body

each capillary <1mm long

usually no cell >.1 mm away from a capillary
total surface area of all capillaries in body is estimated at 7000 ft²
→ spread 250ml (~1 cup) over 1.5 basketball courts

variable pressure 35 – 15 mm Hg; ave=25-12 mmHg

**Capillary Beds**
capillaries ( usually 10 –100) are organized into capillary beds

functional groupings of capillaries
→ functional units of circulatory system

arterioles and venules are joined directly by **metarterioles**
(become **thoroughfare channels** after capillaries branch off)
capillaries branch from metarterioles
1-100/bed
cuff of smooth muscle surrounds origin of capillary branches
= **precapillary sphincter**

amount of blood entering a bed is regulated by:
a. vasomotor nerve fibers
b. local chemical conditions