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

<u>Histology of Heart</u>

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

<u>Conducting System</u>

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

conducting 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

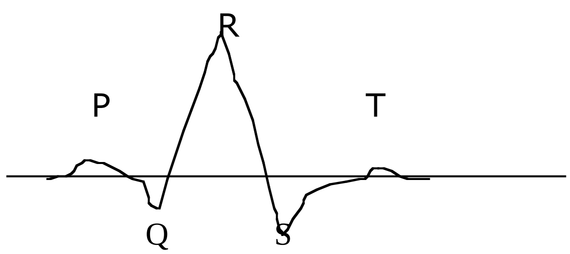
AV Bundle (Bundle of His)
- connected to AV Node
- takes stimulus from AV Node to ventricles

Purkinje Fibers
- takes impulse from AV Bundle out to cardiac mucscle 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



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
contraction of ventricles and closing of AV valves
dub = diastolic sound
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

CO	**=**	**Heart Rate**	**X**	**Stroke volume**
	=	75b/m	X	70ml/b
	=	5250 ml/min (=**5.25 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 → slower
- **Chemoreceptors**
  - monitor carbon dioxide and pH
  - more CO_2 or lower pH → faster

any marked, persistent changes in rate may signal cardiovascular disease

B. Stroke Volume:

healthy heart pumps ~60% of blood in it
→normal SV = ~70 ml

also each side of heart must pump exactly the same amount of blood with each beat
→ otherwise excess blood would accumulate in lungs or in systemic vessels

eg. if Rt heart pumped 1 ml more per beat
→ 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**
→ 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 ~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 1^{st} 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 ft^2
→ 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