Circulatory System

major connection between external and internal environment:
everything going in or out of body must go through the circulatory
system to get to where its going

two major transport systems in body:
circulatory (cardiovascular) system
lymphatic system

circulatory system works in conjunction with lymphatic system
circulatory system consists of “plumbing” and “pumps”:

1. blood travels within a closed system of vessels;
   never leaves vessels
2. has muscular pump that helps to move it

is one of first organ systems to appear in developing embryo
→ heart is beating by 4th week

General Functions of these Transport Systems:

Transport functions:

1. Pick up food and oxygen from digestive and respiratory systems and deliver
   them to cells
2. pick up wastes and carbon dioxide from cells and deliver to kidneys and
   lungs
3. Transport hormones, NO, enzymes etc throughout the body

Homeostasis functions:

4. maintain fluid and electrolyte balances in tissues and cells
5. maintain acid/base balances in tissues and cells
6. help regulate temperature homeostasis
   transfers excess heat from core to skin for removal

Protective Functions:

7. Protect body from infection = “immune system”
**The Heart**

about size and shape of closed fist

beats >100,000 x’s/day (~103,680 b/d)

lies in mediastinum, behind sternum

lower border of heart (=apex) lies on diaphragm

heart is enclosed in its own sac, = pericardium
  (=pericardial sac) (parietal pericardium) composed of tough fibrous outer layer and inner serous membrane

outer surface of heart is also covered with serous membrane (= visceral pericardium) (=epicardium) continuous with the pericardium

between the 2 membranes is pericardial fluid ⇒ lubrication

**wall of heart:**
- **epicardium** = visceral pericardium
  thin & transparent serous tissue
- **myocardium** = cardiac muscle cell
  most of heart
  branching, interlacing contractile tissue
  acts as single unit (gap junctions)
- **endocardium** = delicate layer of endothelial cells
  continuous with inner lining of blood vessels
  [endocarditis]

interior of heart is subdivided into **4 chambers**:
- **atria** = two upper chambers
  with auricles
  smaller, thinner, weaker
- **ventricles** = two lower chambers
  larger, thicker, stronger
  left ventricle much larger and thicker than right ventricle

There are 4 major vessels attached to heart:
- **2 arteries** (take blood away from heart):
  - **aorta**
    - from left ventricle
  - **pulmonary trunk**
    - from right ventricle
- **2 veins** (bring blood back to heart):
  - **vena cava** (superior & inferior)
- to right atrium
  quickly splits into 2 pulmonary arteries
  **pulmonary veins** (4 in humans)
- to left atrium

There are also 4 one-way valves that direct flow of blood through the heart in one direction:

**2 Atrioventricular (AV) valves**
- held in place by **chordae tendinae**
- attached to **papillary muscles**
  - prevent backflow (eversion)
    - keeps valves pointed in direction of flow
- **bicuspid** (Mitral) valve
  - separates left atrium and ventricle
  - consists of two flaps of tissues
- **tricuspid** valve
  - separates right atrium and ventricle
  - consists of three flaps of tissues

**2 Semilunar valves**
- at beginning of arteries leaving the ventricles
  - **aortic SL valve**
    - at beginning of aorta
  - **pulmonary SL valve**
    - at beginning of pulmonary trunk

**Histology of Heart**

cardiac muscle fibers:
  - striated → myofibrils are highly ordered
  - 1 nucleus
  - branched cells

separated by intercalated discs
  → myocardium behaves as single unit
  - but atrial muscles separated from ventricular muscles by conducting tissue sheath
  → atria contract separately from ventricles

**Conducting System**

heart has some specialized fibers that are modified cardiac muscle cells

don’t contract; fire impulses that coordinate contraction of heart muscle
innervated by autonomic NS

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
if SA Node is not functioning it can act as a pacemaker
= ectopic pacemaker (usually slower intrinsic rhythm)

**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

P wave = passage of current through atria
from SA Node
atrial depolarization

QRS wave = passage of current through
ventricles from AV Node – AV Bundle – Purkinje Fibers
ventricular depolarization
**T wave** = repolarization of ventricles
(atrial repolarization is masked by QRS)

by measuring intervals between these waves can get idea of how rapidly the impulses are being conducted

amplitude of waves also gives info on condition of conducting system and myocardium

**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

ventricular systole (atrial diastole) = 0.3 sec
ventricular diastole = 0.5 sec

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

**Blood Pressure**
the force of the blood flowing through blood vessels measured as mmHg

**Measuring Blood Pressure**

use sphygmomanometer

usually use 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** = 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

blood circulates by going down a **pressure gradient:**

pressure gradient depends on:
   a. force of heart beat
   b. peripheral resistance
      - counteracts pressure

**Abnormal Blood Pressure**

**Hypotension**

low BP → systolic <100
usually not a cause for concern
→ often associated with long healthy life
but.
in some may produce dizziness when standing up too quickly (esp in older patients)
may be due to severe bleeding and lead to circulatory shock
may hint at poor nutrition
eg. <blood proteins

**Hypertension**
if transient is normal:
  adaptation during fever, exercise, strong emotions
if persistent is a cause for concern
  30% of those >50 yrs old suffer from hypertension
  usually asymptomatic for first 10-20 yrs = silent killer
prolonged hypertension is a major cause of:
  heart failure
  vascular disease
  kidney failure
  stroke
  aneurysms

high blood pressure affected by:
  heredity
  gender: men slightly higher risk of HBP
  age: risk increases after age 35
  race: African Americans at higher risk

**Blood Vessels & Circulation**

blood flows in closed system of vessels over 60,000 miles of vessels (mainly capillaries)

- **arteries** ➔ **capillaries** ➔ **veins**
  (25%) (5%) (70%)

- **arteries & arterioles**
  - take blood away from heart to capillaries

- **capillaries**
  - actual site of exchange

- **venules & veins**
  - bring blood from capillaries back to heart

arranged in **two circuits**:
  **pulmonary:** heart ➔ lungs ➔ heart
  rt ventricle ➔ pulmonary arteries (trunk) ➔ lungs ➔ pulmonary veins ➔ left atrium
**systemic:**  heart → rest of body → heart
  left ventricle→aorta→body→vena cava→rt atrium

heart is a double pump
  oxygen deficient blood in pulmonary vein and vena cava → usually blue on models

walls of arteries and veins consist of three layers:
  **tunica adventitia**
  outer fibrous connective tissue
  **tunica media**
  middle smooth muscle
  **tunica intima** (=interna)
  inner endothelium

**Arteries:**
  thick layer of connective tissue for strength
  heavily muscular to withstand pressure
  large lumen

**Veins:**
  generally have a greater diameter than arteries
  but thinner walls
    → more **compliant**
  three layer are all thinner than in arteries
  tunica adventitia is thickest of three
  but not as elastic as arteries
  little smooth muscle

**Capillaries:**
  consist of only a single layer of squamous epithelium
  = endothelial layer (=tunica intima)

### Anatomy of Circulatory System

**Major Arteries and Veins**

see lab

**Special Circulation Patterns**

1. **Cardiac Circulation**
   R & L Coronary Artery branch from aorta just behind aortic valve
   blood enters when Left Ventricle relaxes
   veins drain into coronary sinus
   which empties into Right Atrium beneath entrance
of Inferior Vena Cava

2. **Hepatic Portal System**
   veins from spleen, stomach, pancreas, gall bladder, and intestines
   superior and inferior mesenteric merge to form hepatic portal vein
   do not take blood directly to vena cava
   instead take it to liver for “inspection”
   - phagocytic cells remove toxins
   - vitamins and minerals are stored

3. **Circle of Willis**
   two pairs of arteries
   internal carotids
   vertebral
   interconnect to form a circle of connecting arteries at base of brain
   → more than one route for blood to get to brain

4. **Fetal Circulation**
   fetus gets food and oxygen from mom doesn’t need lungs or liver
   a. umbilical arteries
      from internal iliac
   b. umbilical veins
      to hepatic ven
   c. ductus venosus
      bypasses fetal liver
   d. foramen ovale
      between rt and lft atrium
      most blood bypasses pulmonary circuit
   e. ductus arteriosis
      connects pulmonary artery to aorta
      most blood bypasses pulmonary circuit

**Physiology of Blood Vessels**

**Arteries**
most organs receive blood from >1 arterial branch
provides alternate pathways

**Veins**
low pressure:
larger veins near 0

movement of blood in veins is not pressure driven by the heart
venous blood flows due to:

1. **constriction of walls by ANS**
   minor effect
   muscle layer is very thin,
   veins are very compliant

2. **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
   increased venous pressure

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

3. **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
   60-70% of all blood is in veins at any time

largest veins = **sinuses**
eg. coronary sinus, dural sinus

blood “stored” in venous sinuses can be used as a **self transfusion** when stimulated in an emergency

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
most of 62,000 miles of vessels
usually no cell >.1 mm away from a capillary
thin walled - single cell layer thick
extremely abundant in almost every tissue of body

blood flows slowest in capillaries
provides greatest opportunity for exchange to occur

**Capillary Beds**

functional groupings of capillaries = **capillary beds**
→ functional units of circulatory system

arterioles and venules are joined directly by
**metarterioles** (=thoroughfare channels)

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

**Vasomotor Control System**
circulation involves **differential distribution** of blood to various body regions
active body parts receive more blood than inactive parts
blood volume must be shifted to parts as they become more active

blood circulates because of **pressure gradients**

pressure gradients are created through
- cardiac output
- peripheral resistance

**vasomotor control center** in medulla

works in conjunction with cardiac centers

**Disorders of the Circulatory System**

1. **Varicose Veins**
   - can occur anywhere on body but most common on legs
   - veins in legs are largest in body and must counteract gravity to get blood back to the heart
   - veins become enlarged and valves fail to prevent backflow of blood
   - often associated with tired, achy, or feeling of heavy limbs
   - most common in superficial saphenous veins
     → they are poorly supported by surrounding tissues
   - many factors contribute to likelihood of varicose veins:
     - **heredity**
     - **age** esp occur betw 18 and 35 yrs, peaks betw 50 and 60 yrs
     - **gender** women are 4 to 1 times more likely to get them
     - **pregnancy** sometimes form during pregnancy (8-20% chance) then disappear afterwards
     - **lifestyle:** prolonged sitting or standing daily

   Transposition of the Great Vessels
   - the child will develop normally until they begin to walk
   - the right ventricle will be unable to pump enough blood through systemic circuit