Chapter 11 – The Heart

https://www.pinterest.com/pin/165788830009278918/
Heart Facts

• About the size of your fist
• Lies in the **Mediastinum**
• Widest portion called the base (sits behind 2\textsuperscript{nd} rib)
• Point at bottom = apex
  – points towards the left
IMPOSTER!
Figure 11.1a Location of the heart within the thorax.

Superior vena cava

Pulmonary trunk

Diaphragm

Aorta

Parietal pleura (cut)

Left lung

Pericardium (cut)

Apex of heart
Figure 11.1b Location of the heart within the thorax.

- **Midsternal line**
- **2nd rib**
- **Diaphragm**
- **Point of maximal intensity (PMI)**
- **Sternum**
Figure 11.1c Location of the heart within the thorax.

- Mediastinum
- Heart
- Left lung

Posterior
Functions

• Pumps blood in one direction
• Keeps oxygen rich and oxygen poor blood separate
• Supplies blood pressure
• Supplies every cell in the body with blood
The Cardiovascular System

- The Heart
  - Located in the mediastinum
- Blood Vessels
  - Pulmonary Circuit
  - Systemic Circuit
Coverings of the Heart

• Deep to Superficial
  – Visceral pericardium
    • Pericardial fluid
  – Parietal pericardium
  – Fibrous pericardium
    (anchors heart to mediastinum)
Figure 11.2 Heart wall and coverings.

- Pericardium
- Myocardium
- Pulmonary trunk
- Fibrous pericardium
- Parietal layer of serous pericardium
- Pericardial cavity
- Epicardium (visceral layer of serous pericardium)
- Myocardium
- Endocardium
- Heart chamber
- Heart wall
- Pericardial cavity
- Pericardium
- Myocardium
- Epicardium
- Heart wall
3 layers of the heart wall

- Deep to superficial
  - **Endocardium**: lines the heart chambers
    Made of endothelium
  - **Myocardium**: actual cardiac (heart) muscle
  - **Epicardium** = outermost layer
    visceral pericardium
Chambers of the Heart

• Superior Chambers
  – Receiving chambers
    • Right Atrium
    • Left Atrium

• Inferior Chambers
  – Discharging chambers
    • Right Ventricle
    • Left Ventricle
Figure 11.5 Anatomical differences in right and left ventricles.

- Right ventricle
- Muscular interventricular septum
- Left ventricle
The Heart: Valves

- Allow blood to flow in only one direction
- Four valves
  - Atrioventricular valves – between atria and ventricles
    - Bicuspid/Mitral valve - left side of heart
    - Tricuspid valve – right side of heart
  - Semilunar valves between ventricle and artery
    - Pulmonary semilunar valve
    - Aortic semilunar valve
Heart Valves

• AV valves
  – Anchored in place by chordae tendineae (“heart strings”)
  – Open during heart relaxation and closed during ventricular contraction

• Semilunar valves
  – Closed during heart relaxation but open during ventricular contraction

• These valves open and close in response to pressure changes in the heart
Division between Rt. & Lf Heart

- Pulmonary Circuit (Right Atrium & Ventricle)
- Intraventricular Septum
- Systemic Circuit (Left Atrium & Ventricle)
Right Heart

• Right Atrium receives oxygen poor blood from 3 veins
  1. Superior Vena Cava
  2. Inferior Vena Cava
  3. Coronary Sinus

• Rt. Atrium pumps blood into the Right Ventricle through a valve = Atrioventricular valve (AV)
  – Rt. AV valve is called the TRICUSPID VALVE
Tricuspid Valve – 3 flaps
Right Heart

- Blood enters Rt Ventricle
- Out the rt. ventricle via the Semilunar Valve (pulmonary semilunar)
- Into the pulmonary trunk
- Pulmonary trunk splits to the Rt. & Lf. Pulmonary arteries
- Pulmonary arteries to the lungs
Left Heart

- Oxygen rich blood back to the heart from the lungs in the Pulmonary Veins
- Into the Left Atrium
- Into the Left Ventricle thru Bicuspid Valve
  - Mitral Valve
Left Heart

• Blood is forced (thick wall muscle) out of the left ventricle thru the Semilunar Valve (aortic semilunar)

• Aorta –
  – first branch to the coronary arteries
    • Nourish the heart itself
  – Branches to rest of the body
Figure 11.4 The systemic and pulmonary circulations.

**Pulmonary Circuit**
- Pulmonary arteries
- Pulmonary veins
- Venae cavae
- Right atrium
- Right ventricle
- Left atrium
- Left ventricle
- Capillary beds of lungs where gas exchange occurs

**Systemic Circuit**
- Aorta and branches
- Capillary beds of all body tissues where gas exchange occurs

**KEY:**
- Oxygen-rich, CO\textsubscript{2}-poor blood
- Oxygen-poor, CO\textsubscript{2}-rich blood
Operation of Heart Valves

**Operation of the AV valves**

1. Blood returning to the heart fills atria, putting pressure against atrioventricular valves; the atrioventricular valves are forced open.
2. As the ventricles fill, atrioventricular valve flaps hang limply into ventricles.
3. Atria contract, forcing additional blood into ventricles.

**Figure 11.4 (a)**

- Ventricles contract, forcing blood against atrioventricular valve cusps.
- Atrioventricular valves close.
- Chordae tendineae tighten, preventing valve flaps from evert ing into atria.

**AV valves open**

**Operation of the semilunar valves**

As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open.

**Figure 11.4 (b)**

- Aorta
- Pulmonary trunk
- Semilunar valve open
- As ventricles relax, and intraventricular pressure falls, blood flows back from arteries, filling the cusps of semilunar valves and forcing them to close.

**Semilunar valve closed**
Heart Sounds

• Through the stethoscope, the beating of the heart that we hear is from the closing of the valves
  
  • First sound = lub
    – Closing of both AV valves (tricuspid and bicuspid) when blood fills the ventricles.
  
  • Second sound = dub
    – Closing of both semilunar valves after blood has been expelled from the ventricles.

• Any extra sounds (murmurs) heard are due to leaky valves
Valve Pathology

- Incompetent valve = backflow and re-pump
- Stenosis = stiff= heart workload increased
- May be replaced
Coronary Circulation

• Blood supply directly to the heart tissue
• From aorta to lf. and rt. coronary branches
• After feeding the heart
• Blood supply returns to rt. Atrium via the coronary sinuses
Blood Flow

- All arteries branch **FROM** the aorta
- All veins branch **INTO** the Superior and Inferior Vena Cava
Dorsal aorta

Right atrium

Pulmonary artery

Left atrium

Right ventricle

Left ventricle

Vena cava

Pulmonary vein

Body capillaries

Lung capillaries
Gas Exchange
Rt. Atrium

Tricuspid Valve

Rt. Ventricle

Pulmonary Semilunar Valve

Pulmonary Trunk

Pulmonary Arteries

Lungs

Gas Exchange

Pulmonary Veins

Left Atrium
Pulmonary Gas Exchange
Systemic Circulation

- Left Atrium
- Bicuspid Valve (Mitral Valve)
- Left Ventricle
- Aortic Semilunar Valve
- Aorta
- Arteries
- Heart and Body Tissues
- Gas Exchange
- Body Veins
- Superior/Inferior Vena Cava

https://www.youtube.com/watch?v=qmpd82mpVO4
Conduction System of the Heart

- Intrinsic conduction system: heart contracts automatically
- Heart beats about 2.5 billion times in a lifetime
- About 5 liters of blood is recycled in a heart beat!
Conduction System...

SA node (Sinoatrial node):
- Near upper posterior wall of the right atrium
- Pacemaker of the heart
- Initiates heartbeat and the atria contract
Conduction System...

AV node (Atrioventricular node):

• Near the base of the right atrium
• By the interatrial septum
• Receives input from the SA node
• Passes it to the AV bundle (bundle of His)
Conduction system...

**AV bundle (Bundle of His)**
- In the interventricular septum
- Transfers signal to the Purkinjee fibers

**Purkinjee fibers**
- In the ventricular walls
- Signal causes ventricular contraction

**Intercalated discs (gap junctions)**
- Pass signal to every cardiac cell
Figure 11.7 The intrinsic conduction system of the heart.

- Superior vena cava
- Sinoatrial (SA) node (pacemaker)
- Atrioventricular (AV) node
- Right atrium
- Bundle branches
- Purkinje fibers
- Left atrium
- Atrioventricular (AV) bundle (bundle of His)
- Purkinje fibers
- Interventricular septum
Pig Heart Dissection

- https://www.youtube.com/watch?v=FN7aVXEkFzg
Heart Attach Video

• [Discovery Channel] Body Story - Episode 3 - The Beast Within
Now, on to the Cardiac Cycle...

- All the events that occur in one heartbeat
- Average Heart Rate – about 70-75 beats/minute
  – Range 60-100 beats/minute
- Both sides of the heart contract together
- Contraction is initiated by the SA Node
Cardiac Cycle – one complete heartbeat

**Systole:** Contraction of the heart muscle
- First, both atria contract
- Then, both ventricles contract

**Diastole:** Relaxation of the heart muscle
- Both atria relax
- Followed by the relaxation of both ventricles
Atrial Systole: Phase 1

- Both atria contract
- Ventricles are relaxed
- Blood enters both ventricles through the open AV valves
- Semilunar (pulmonary and aortic) stay closed
- AV valves (tricuspid and bicuspid) close – Atrial systole ends
  - First heart sound - lub
- Lasts about = 0.15 sec
Ventricular Systole: Phase 2

- Both ventricles contract
- Both atria are relaxed at this time
- Blood is pushed into the aorta & pulmonary trunk through the semilunar valves
- Semilunar valves close
  - Second heart sound - dub
- Takes about 0.30 sec
Atrial and Ventricular Diastole:  
Phase 3

- Both Atria and Ventrices are relaxed
- Blood returns to the right atrium via venae cavae (SVC and IVC)
- Blood returns to the left atrium via pulmonary veins
- Blood also flows passively into the ventricles
- Both AV valves are open
- Both semilunar valves are closed
- Takes about 0.40 seconds
- [https://www.youtube.com/watch?v=5tUWOFO6wEnk](https://www.youtube.com/watch?v=5tUWOFO6wEnk)
Figure 11.8 Summary of events occurring during the cardiac cycle.

1. Mid-to-late diastole (ventricular filling)
2. Ventricular systole (atria in diastole)
3. Early diastole
Cadiac Output (CO)

• CO - Volume of blood pumped out of each ventricle in one minute

• Stroke Volume (SV) – amt of blood pumped by each ventricle in one contraction (about 70mL)

• Heart Rate – about 75 beats/min
Cardiac Output

- CO depends on heart rate and stroke volume
  \[ CO = HR \times SV \]
- 75 beats/min x 70mL/beat
- \[ CO = 5250\text{mL/min} \rightarrow 5.25 \text{ L/min} \]
Cardiac Output

- CO of an average human = 5.25 L/minute
- This equals the total blood volume in our bodies!
- Can be affected by changes in heart rate or SV

[Link to YouTube video](https://www.youtube.com/watch?v=bUW-2GHfX64)
Figure 11.9 Influence of selected factors on cardiac output.

Crisis stressors (physical or emotional trauma; increased body temperature; exercise)

Low blood pressure

High blood pressure or blood volume

Exercise

Decreased blood volume (hemorrhage)

Sympathetic nervous system activity

Activation of skeletal muscle and respiratory “pumps”

Crisis has passed

Hormones: epinephrine, thyroxine

Increased venous return

Decreased venous return

Parasympathetic nervous system controls (via vagus nerves)

Increased contractile force of cardiac muscle

Heart rate (beats/min)

Stroke volume (ml/beat)

Cardiac output (ml/min)

KEY:

Increases, stimulates

Reduces, inhibits

Initial stimulus

Physiological response

End result
Heart Rate

- Regulated by the cardioregulatory center
  - Located in medulla oblongata
- Controlled by the autonomic nervous system
- Parasympathetic nervous system
  - Slows heart rate via vagus nerve
- Sympathetic nervous system
  - Increases heart rate
Measuring HR: Pulse
EKG (ECG)

- Electrocardiogram
- Records the electrical activity of the myocardium (layer with the heart muscle)
EKG (ECG)

• **P wave:** Atrial depolarization
  – impulse started at the SA node travels down the atria (atria are about to contract)

• **QRS complex:** Ventricular depolarization
  – Followed by the excitation of Purkinjее fibers
  – Ventricles are about to contract

• **T wave:** ventricular repolarization
  – Ventricles are about to relax
Arrhythmias

• Bradycardia
  – HR of fewer than 60 beats/minute

• Tachycardia
  – HR of more than 100 beats/minute

• Fibrillation
  – Rapid uncoordinated beating

https://www.youtube.com/watch?v=v3b-YhZmQu8
Blood Vessels

- **TUNICS** = layers of tissue
- **LUMEN** = where blood flows
3 layers – Tunics (except capillaries)

• Innermost layer = Tunica intima
  – epithelial tissue

• Middle layer = Tunica media
  – Connective tissue (elastic and collagen fibers) & smooth muscle

• Outermost layer = Tunica externa or adventitia
  – irregular connective tissue, containing both elastic and collagenous fibers
Figure 11.10a Structure of blood vessels.

(a) Artery

Vein
Figure 11.10b Structure of blood vessels.

**Artery**
- Lumen
- Arteriole
- Capillary network

**Tunica intima**
- Endothelium
- Loose connective tissue
- Internal elastic lamina

**Tunica media**
- Smooth muscle
- Elastic fibers
- External elastic lamina

**Tunica externa**
- Collagen fibers

**Vein**
- Lumen
- Lumen
- Veinule
- Capillary
- Basement membrane
- Endothelial cells

Valve
Arteries VS. Veins

- Carry blood away from the heart
- Small arteries = arterioles
- Largest arteries are about as thick as a thumb
- **Blood rich in oxygen**
  - Except pulmonary arteries
- Flows under high pressure (highest in aorta because close to left Ventricle)

- Carry the blood to the heart
- Smallest veins = venules
- **Blood low in oxygen**
  - Except in pulmonary veins
- Thin walls
- Flows under low pressure (lowest in Vena Cava furthest from left Ventricle)
- Contains valves in the lumen
Figure 11.20 Blood pressure in various areas of the cardiovascular system.
Capillaries

• Thin and fragile
• One epithelial cell thick
• Exchange of oxygen and carbon dioxide takes place through the thin capillary wall.
• RBCs inside the capillary release their oxygen which passes through the wall and into the surrounding tissue
• Tissue releases its waste products which passes through the wall and into the red blood cells
• Capillary networks – capillary beds
  – Blood flow through the capillary bed = microcirculation
Capillaries

- Capillary beds consist of two types of vessels:
  1. Vascular shunt
  2. True capillaries
- Entrances to capillary beds are guarded by precapillary sphincters
- Exchanges with tissue cells occur across walls of true capillaries
- When precapillary sphincters are closed, blood bypasses the local area via the vascular shunt
Figure 11.12a Anatomy of a capillary bed.

Precapillary sphincters

Vascular shunt

Terminal arteriole

True capillaries

Postcapillary venule

(a) Sphincters open; blood flows through true capillaries.
Figure 11.12b Anatomy of a capillary bed.

(b) Sphincters closed; blood flows through vascular shunt.
Fetal Circulation

• Exchange of $O_2$ and $CO_2$ takes place in the placenta
• Umbilical vein is $O_2$–rich blood
  – Travels towards the heart of the fetus via the mother and placenta
• Umbilical veins leads to the ductus venosus which allow blood to enter the fetal inferior vena cava then into the rt. atrium
Fetal Circulation from the Rt Atrium

• Right atrium - Right ventricle - pulmonary arteries – lungs
  – Only about 10% of the blood flow enters the pulmonary circuit.

OR

• Rt. atrium directly into the left atrium through a detour
  Foramen ovale (oval hole)
Fetal Circulation from the Rt Atrium

- Right Atrium - right ventricle - pulmonary trunk directly into – aorta via a shunt called the ductus arteriosus,
After Birth

• Umbilical cord is cut
• Baby takes first breath
• Lungs inflate with oxygen
• Rush of oxygen rich blood from lungs into the left atrium causes a flap to cover the foramen ovale
Major Vessels of the Body

• you will need to learn the major arteries and veins of the body and which vessels supply which areas of the body – Please refer to the Blood Vessels Color plate.
Systemic Arterial System

- Superficial temporal artery
- Posterior auricular artery
- Common carotid artery
- External carotid artery
- Internal carotid artery
- Vertebral artery
- Subclavian artery
- Aorta and arch
- Brachiocephalic trunk
- Pulmonary artery
- Axillary artery
- Cardiac artery
- Deep brachial artery
- Thoracic aorta
- Brachial artery
- Celiac trunk
- Aorta
- Superior mesenteric artery
- Radial artery
- Renal artery
- Interosseous artery
- Gonadal artery
- Ulnar artery
- Inferior mesenteric artery
- Deep palmar arch
- Common iliac artery
- Superficial palmar arch
- External iliac artery
- Inferior mesenteric artery
- Deep femoral artery
- Femoral artery
- Femoral artery
- Popliteal artery
- Descending genicular artery
- Anterior tibial artery
- Peroneal artery
- Posterior tibial artery
Arteries of the Chest and Upper Extremity
Superficial arteries and veins of face and scalp

- Parietal emissary vein
- Frontal branch of superficial temporal artery and vein
- Parietal branch of superficial temporal artery and vein
- Superficial temporal artery and vein
- Anterior auricular artery
- Occipital artery and vein
- Middle temporal artery and vein
- Posterior auricular artery and vein
- Retromandibular vein
- External jugular vein
- Internal carotid artery
- External carotid artery
- Internal jugular vein
- Zygomatico-orbital artery
- Supraorbital artery and vein
- Supratrochlear artery and vein
- Angular artery and vein
- Infraorbital artery and vein
- Transverse facial artery and vein
- Facial artery and vein
- Lingual artery and vein
- Common carotid artery

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Veins with Valves

- Some veins contain **valves** – prevent blood from flowing backwards
A Normal vein

- Valve
- Normal blood flow

B Varicose vein

- Abnormal blood flow
- Dilated vein
- Deformed valve
- Skin bulging
- Thin wall of vein

Normal vein

Varicose vein
Superficial temporal vein
External jugular vein
Subclavian vein
Brachiophalic vein
Axillary vein
Brachial vein
Cepalic vein
Basilic vein
Median cubital vein
Medial antebrachial veins
Superficial venous palmar arch
Small saphenous vein

Facial vein
Internal jugular vein

Superior vena cava
Hepatic vein
Renal vein
Gonadal vein
Inferior vena cava
Common iliac vein
Internal iliac vein
External iliac vein

Deep femoral vein
Femoral vein
Great saphenous vein
Popliteal vein

Anterior tibial vein
Posterior tibial vein
Doral venous arch

Illustration provided by: Leslie Laurien, MSMA
Venous System of the Trunk and Upper Limb
Aging and the Cardiovascular System

- Arteriosclerosis
- Atherosclerosis
- Hypertension
- Stroke
- Myocardial Infarction
- Congestive Heart Failure

"Yes! That was very loud Mr. Trainer, but I said I wanted to hear your HEART!"
Atherosclerosis

- Buildup of fatty plaques in the walls of blood vessels.
- Causes – usually high cholesterol diet (LDL’s)
Arteriosclerosis

• Stiffening/hardening of the arteries
• Due to high blood pressure over time/smoking/diet/ atherosclerosis
Hypertension

- When a person’s blood pressure is elevated at all times (140/90 is considered high)
- Caused by stress, diet, inactivity, smoking, salt, alcohol, genetics
Myocardial Infarction/Heart Attack

- Damaged heart tissue due to blockage in the coronary arteries interrupting blood flow to the heart muscle cells
- Caused by high bp, atherosclerosis, poor diet (LDL’s), alcohol, diabetes
Stroke

• Disturbance of blood flow to the brain usually because of a blocked or burst artery
• Caused by smoking, poor diet, hypertension, diabetes, advanced age
Congestive Heart Failure

• The heart stops pumping because the heart muscles have been weakened by a previous attack, virus, or high blood pressure

• Diabetes/alcohol aggravate situation
Keeping your Heart Healthy!

• Don’t smoke
• Get active
• Eat a healthy diet (limit fats)
• Maintain a healthy weight
• Get regular check-ups