Chapter 20 (1)

The Heart
Learning Objectives

• Describe the location and structure of the heart

• Describe the path of a drop of blood from the superior vena cava or inferior vena cava through the heart out of the aortic arch, listing all chambers, valves, and vessels involved.

• State the function of the atria, valves, chordae tendinae, papillary muscles, and ventricles of the heart
(a) Anterior external view showing surface features
(c) Posterior external view showing surface features
Circulatory Circuits of the Heart

- Pulmonary circuit
  - right side of heart to lungs
  - carries blood to lungs for gas exchange and back to heart // low pressure

- Systemic circuit
  - left side of heart to all tissue of body except lungs
  - supplies oxygenated blood to all tissues of the body and returns it to the heart // high pressure

O$_2$-poor, CO$_2$-rich blood

O$_2$-rich, CO$_2$-poor blood
Circulatory Circuits of the Heart

– Coronary circuit

• part of the systemic circuit

• aortic recoil moves blood into the coronary arteries

• supply the myocardiocytes (the cells making the walls of the heart) with blood circulation
(a) Elastic aorta and arteries stretch during ventricular contraction
Blood continues to flow toward capillaries

Left ventricle relaxes (diastole) and fills with blood

(b) Elastic aorta and arteries recoil during ventricular relaxation
Cardiovascular System Circuit

- **Left side of heart**
  - fully oxygenated blood arrives from lungs via pulmonary veins (100% Hb-O2)
  - blood sent to all organs of the body via aorta
  - high pressure “side”

- **Right side of heart**
  - lesser oxygenated blood arrives from inferior and superior vena cava (75% Hb-O2)
  - blood sent to lungs via pulmonary trunk
  - low pressure “side”
4. In pulmonary capillaries, blood loses CO₂ and gains O₂

3. Pulmonary trunk and pulmonary arteries

5. Pulmonary veins (oxygenated blood)

2. Right ventricle

6. Left atrium

1. Right atrium (deoxygenated blood)

7. Left ventricle

10. Superior vena cava

8. Aorta and systemic arteries

9. In systemic capillaries, blood loses O₂ and gains CO₂

(b) Path of blood flow through systemic and pulmonary circulations
Position, Size, and Shape

• heart located in mediastinum, between lungs

• **base** – wide, superior portion of heart, blood vessels attach here

• **apex** - inferior end, tilts to the left, tapers to point

• 3.5 in. wide at base

• 5 in. from base to apex

• 2.5 in. anterior to posterior

• weighs 10 oz.
(b) Anterior view of the heart in the thoracic cavity
(a) Anterior external view showing surface features
Left common carotid artery
Left subclavian artery
Arch of aorta
Descending aorta
Left pulmonary artery
Left pulmonary veins
LEFT ATRIUM
Coronary sinus (in coronary sulcus)
LEFT VENTRICLE
POSTERIOR INTERVENTRICULAR SULCUS (deep to fat)
Brachiocephalic trunk
Superior vena cava
Ascending aorta
Right pulmonary artery
Right pulmonary veins
RIGHT ATRIUM
Right coronary artery
Inferior vena cava
Middle cardiac vein
RIGHT VENTRICLE
(c) Posterior external view showing surface features
Heart Position

(a) Sternum

(b) Lungs

Diaphragm

3rd rib

Thoracic vertebra

Right ventricle

Sternum

Pericardial cavity

Left ventricle

Interventricular septum

Anterior

Posterior
(a) Inferior view of transverse section of thoracic cavity showing the heart in the mediastinum.
Blood Flow Through Heart

- Right atria
- Right ventricle
- Pulmonary truck into pulmonary circulation (lungs)
- Left atria
- Left ventricle
- Aorta to systemic circulation (all tissues of body except lungs)
- (see next slide)

Note: blood enters the right atria via superior vena cava, inferior vena cava, coronary sinus, and thebesian veins (highest concentration in right atria and lowest concentration in left ventricle)

Note: blood flow through the heart is different than the pumping action of the heart // pumping action occurs as two separate pumps working “in phase” /// first action is to move blood downward in both pumps – followed by both pumps moving blood upward
Blood Flow Through Heart

1. Blood enters right atrium from superior and inferior venae cavae.
2. Blood in right atrium flows through right AV valve into right ventricle.
3. Contraction of right ventricle forces pulmonary valve open.
4. Blood flows through pulmonary valve into pulmonary trunk.
5. Blood is distributed by right and left pulmonary arteries to the lungs, where it unloads CO₂ and loads O₂.
6. Blood returns from lungs via pulmonary veins to left atrium.
7. Blood in left atrium flows through left AV valve into left ventricle.
8. Contraction of left ventricle (simultaneous with step 3) forces aortic valve open.
10. Blood in aorta is distributed to every organ in the body, where it unloads O₂ and loads CO₂.
11. Blood returns to heart via venae cavae.

Blood starts transit through heart in right atria / blood pressure and heart valves direct flow of blood / no valves associated with inferior or superior vena cava.
(a) Path of blood flow through heart
Pericardium and Heart Wall

- Pericardial cavity
- Fibrous layer
- Serous layer
- Epicardium
- Myocardium
- Endocardium
- Pericardial sac
(b) Simplified relationship of serous pericardium to heart
Pericardium

- **Pericardium**
  - double-walled sac (pericardial sac) that encloses the heart
  - fibrous pericardium with inner and outer surface
  - allows heart to beat without friction, provides room to expand
  - resists excessive expansion
  - anchored to diaphragm inferiorly and sternum on anterior surface

- **Parietal pericardium**
  - outer wall of sac
  - superficial **fibrous layer** of connective tissue
  - a deep, thin **serous layer**
Pericardium

- **Visceral pericardium (epicardium)**
  - simple squamous epithelium / heart covering
  - serous lining of pericardial sac // turns inward at base of heart to cover the heart surface

- **Pericardial cavity** // space inside the pericardial sac filled with 5 - 30 mL of pericardial fluid

- **Pericarditis** // inflammation of the membranes // painful friction rub with each heartbeat
Heart Wall

- **Epicardium** (visceral pericardium)
  - serous membrane covering heart
  - adipose in thick layer in some places
  - coronary blood vessels travel through this layer

- **Myocardium**
  - layer of cardiac muscle proportional to work load
  - muscle spirals around heart which produces wringing motion
Heart Wall

- **Endocardium**
  - smooth inner lining of heart and blood vessels
  - covers the valve surfaces and continuous with endothelium of blood vessels

- **Fibrous skeleton of the heart**
  - framework of collagenous and elastic fibers
  - provides structural support and attachment for cardiac muscle and anchor for valve tissue
  - electrical insulation between atria and ventricles important in timing and coordination of contractile activity
(a) Portion of pericardium and right ventricular heart wall showing divisions of pericardium and layers of heart wall
Four Chambers of the Heart

- **Superior chambers**
  - right and left atria
  - two superior chambers
  - receive blood returning to heart from pulmonary veins and vena cava
  - auricles (seen on surface) allow chambers to expand volume
  - both upper chambers contract together to move blood downward into the right and left ventricles
Four Chambers of the Heart

- Inferior chambers
  - right and left ventricles
  - both ventricles contract together
  - right ventricle pump blood into pulmonary truck
  - left ventricle pump blood into aorta

Note: heart is a four chamber pump // low pressure and high pressure sides // blood circulates through heart however blood flow moves as an “atrial downward” phase followed by a “ventricular upward” phase
External Anatomy - Anterior

- **atrioventricular sulcus**
  - separates atria and ventricles

- **interventricular sulcus**
  - lies over the interventricular septum that divides the right ventricle from the left
  - anterior and posterior

- **Note:** sulci are grooves on surface of heart that contain coronary arteries, as well as other heart arteries and veins
SCHEME OF DISTRIBUTION

Ascending aorta

Right coronary artery
- Posterior interventricular branch

Marginal branch

Left coronary artery
- Anterior interventricular branch
- Circumflex branch
(a) Anterior external view showing surface features
Anterior view of coronary arteries and their major branches
(b) Anterior external view

- Brachiocephalic trunk
- Superior vena cava
- Ascending aorta
- Right pulmonary veins
- Left subclavian artery
- Left common carotid artery
- Arch of aorta
- Ligamentum arteriosum
- Left pulmonary artery
- Left pulmonary veins
- Pulmonary trunk
- Right auricle of right atrium
- Right atrium
- Coronary sulcus
- Right ventricle
- Left auricle of left atrium
- Left ventricle
- Anterior interventricular sulcus

Dissection Shawn Miller, Photograph Mark Nielsen
Left common carotid artery
Left subclavian artery
Arch of aorta
Descending aorta
Left pulmonary artery
Left pulmonary veins
LEFT ATRIUM
Coronary sinus (in coronary sulcus)
LEFT VENTRICLE
POSTERIOR INTERVENTRICULAR SULCUS (deep to fat)
Brachiocephalic trunk
Superior vena cava
Ascending aorta
Right pulmonary artery
Right pulmonary veins
RIGHT ATRIUM
Right coronary artery
Inferior vena cava
Middle cardiac vein
RIGHT VENTRICLE
(c) Posterior external view showing surface features
Internal Anatomy - Anterior

Aorta
Right pulmonary artery
Superior vena cava
Right pulmonary veins
Interatrial septum
Right atrium

Fossa ovalis (1)
Right AV (tricuspid) valve
Tendinous cords
Trabeculae carneae
Right ventricle
Inferior vena cava

Ligament Atriosum (2)
Left pulmonary artery
Pulmonary trunk
Left pulmonary veins
Pulmonary valve
Left atrium
Aortic valve
Left AV (bicuspid) valve
Left ventricle
Papillary muscle
Interventricular septum
Endocardium
Myocardium
Epicardium

Notes: (1) foramen ovale / (2) Dutus Atriosum / fetal structures to redirect blood into systemic circulation
Heart Chambers – Internal Structures

- interatrial septum
  - wall that separates atria

- pectinate muscles
  - internal ridges of myocardium in right atrium and both auricles

- interventricular septum
  - muscular wall that separates ventricles

- trabeculae carneae
  - internal ridges in both ventricles
Internal Anatomy - Anterior

(Notes: (1) foramen ovalis / (2) Dutus Atriosum / fetal structures to redirect blood into systemic circulation)
Frontal plane

Ascending aorta
Superior vena cava
Right pulmonary artery
PULMONARY VALVE
Right pulmonary veins
Opening of superior vena cava
FOSSA OVALIS
RIGHT ATRIUM
Opening of coronary sinus
Opening of inferior vena cava
TRICUSPID VALVE
RIGHT VENTRICLE
Inferior vena cava

Left common carotid artery
Left subclavian artery
Brachiocephalic trunk
Arch of aorta
Ligamentum arteriosum
Left pulmonary artery
Pulmonary trunk
Left pulmonary veins
LEFT ATRIUM
AORTIC VALVE
BICUSPID (MITRAL) VALVE
CHORDAE TENDINEAE
LEFT VENTRICLE
INTERVENTRICULAR SEPTUM
PAPILLARY MUSCLE
TRABECULAE CARNEAE
Descending aorta

(a) Anterior view of frontal section showing internal anatomy
(b) Anterior view of partially sectioned heart
(c) Inferior view of transverse section showing differences in thickness of ventricular walls
Heart Valves

- Right AV (tricuspid) valve
- Fibrous skeleton
- Openings to coronary arteries
- Aortic valve
- Pulmonary valve

Posterior

Left AV (bicuspid) valve

Note: atria have been removed to show AV valves
Note: all valves are “built” into the atrioventricular septum / it is a strong connective tissue transverse plane / this also prevents action potentials from moving into ventricles via gap junctions

ANTERIOR

Pulmonary valve
Left coronary artery
Aortic valve
LEFT FIBROUS TRIGONE
RIGHT FIBROUS TRIGONE
Bicuspid valve
LEFT ATRIOVENTRICULAR FIBROUS RING

PULMONARY FIBROUS RING
CONUS TENDON
Right coronary artery
AORTIC FIBROUS RING
Tricuspid valve
RIGHT ATRIOVENTRICULAR FIBROUS RING

POSTERIOR

Superior view (the atria have been removed)
(d) Superior view with atria removed: pulmonary and aortic valves closed, bicuspid and tricuspid valves open
(f) Superior view of atrioventricular and semilunar valves
Heart Valve Functions / Atrioventricular

- controls blood flow between atria and ventricles

- Valves open and close due to blood pressure between chambers guarded by valves

- right AV valve has 3 cusps (tricuspid valve)

- left AV valve has 2 cusps (mitral or bicuspid valve)

- chordae tendineae – connective tissue fibers that connect AV valves to papillary muscles on floor of ventricles

- papillary muscles prevent AV valves from flipping inside out or bulging into the atria when the ventricles contract
Left atrium

Left ventricle

(a) Bicuspid valve open

(b) Bicuspid valve closed
AV Valve Mechanics

• When ventricles relax
  – pressure drops inside the ventricles
  – semilunar valves close as blood attempts to back up into the ventricles from the vessels
  – AV valves open
  – blood flows from atria to ventricles

• When ventricles contract
  – AV valves close as blood attempts to back up into the atria
  – pressure rises inside of the ventricles
  – semilunar valves open and blood flows into great vessels
(a) Bicuspid valve open

(b) Bicuspid valve closed
(c) Tricuspid valve open
Heart Valves / AV Valves

Tendinous cords

Papillary muscle
Heart Valve Function / Semilunar

- control flow into pulmonary trunk and aorta // the great arteries of the heart
- these valves open and close because of blood flow and pressure
- pulmonary semilunar valve // between right ventricle and pulmonary trunk
- aortic semilunar valve // between left ventricle and aorta
- semilunar valves do not have chordae tendineae
- cusps of valves close as ventricles relax and blood starts to flow back towards ventricles // backflow of blood fill cusps which cause them to close
Endoscopic View of Semi Lunar Heart Valve
No papillary muscles or cordae tendinae

(g) Superior view of aortic valve

Semilunar cusp of aortic valve
Function of Heart Valves

- Valves ensure a one-way flow of blood through the heart
- Blood flows from an area of high pressure to an area of low pressure
- The pressure difference across the valve open and close these valves