**CHAPTER 15: CARDIOVASCULAR SYSTEM**

**OBJECTIVES:**

1. List the organs that compose the cardiovascular system and discuss the general functions of this system.

2. Describe the location, size, and orientation of the human heart.

3. Define the term *cardiology*.

4. Describe the structure of the heart in terms of its coverings, layers, chambers, valves, and blood vessels.

5. Name the function of serous fluid around the heart.

6. Give another name for epicardium.

7. Describe the structure and function of the interventricular septum.

8. Explain why the atria are passive chambers, while the ventricles are active.

9. Name the function of heart valves.

10. Distinguish between AV and SL valves in terms of location, structure, and when they close.

11. Define/describe the terms *chordae tendineae, papillary muscle*, and *trabeculae carneae*.

12. Name (and locate) the veins that deposit their blood into the atria of the heart (which atria? deox- or oxygenated?).

13. Name (and locate) the arteries that take blood away from the heart (from which ventricle? deox-or oxygenated blood?).

14. Distinguish between pulmonary, coronary and systemic circulation.

15. Track a drop of blood through the following circulations:

a. heart/ lungs/ heart;

b. through myocardium;

c. to the body (in general).

16. Define the terms ischemia and hypoxia, and explain how they are related to the pathologic conditions of angina pectoris and myocardial infarction.

17. Discuss what causes reperfusion damage.

18. Explain the significance of each component of the cardiac conduction system and trace how the cardiac impulse travels through the myocardium.

19. Name the common term for the sinoatrial (SA) node.

20. Discuss the physiological stages of cardiac muscle contraction and trace how they appear on graph plotting mV vs. time.

21. Explain why the refractory period between cardiac muscle contractions is so long.

22. Trace a typical ECG and label each wave or complex and explain what event of the CCS corresponds to each wave.

23. Name the term referring to all of the events associated with one heartbeat.

24. Define the terms *systole* and *diastole*.

25. Outline the phases of the cardiac cycle in terms of what is happening in the ECG trace, mechanical events (contraction or relaxation), atrial pressure, ventricular pressure, ventricular volume, aortic pressure and timing.

26. Discuss heart sounds in terms of what they represent, how they sound, how they are detected and their significance.

27. Define the terms *cardiac output (CO), heart rate (HR)*, and *stroke volume (SV)*.

28. Discuss the factors that regulate heart rate.

29. Explain what is meant by the human cardiovascular system being a "closed system".

30. Define the term *hemodynamics*.

31. Compare and contrast the 3 types of blood vessels in terms of the following:

a. direction of blood-flow (in terms of the heart),

b. wall structure (# of layers and components of those layers),

c. gas concentrations and

d. pressure.

32. Define the term *anastomoses*.

33. Describe how arterioles play a major role in regulating blood flow to capillaries.

34. Discuss the major event that occurs at capillaries.

35. Compare and contrast continuous, fenestrated and sinusoidal capillaries in terms of structure and location.

36. Define the terms *blood flow* and *circulation time* and give the value of the normal circulation time in a resting adult.

37. Discuss the factors that affect cardiac output.

38. Define the term *blood pressure*, name the type of blood vessels where blood pressure is significant, and name the normal (average) value in a resting adult.

39. Define the term *blood resistance* and discuss the three major factors that determine it.

40. Explain the processes by which materials are exchanged through a capillary.

41. Locate the neural cardiovascular center on a mid-sagittal diagram of the brain, explain where impulses sent to it are first detected, and explain where its outgoing impulses are directed and what happens when they get there.

42. List the hormones involved in regulation of blood pressure and blood flow.

43. Define the terms *tachycardia* and *bradycardia*.

44. Distinguish between the pulmonary and systemic circuits (circulatory routes).

45. Track a drop of blood through the following:

a. from the right fingers to the left ear;

b. from the stomach to the left fingers;

c. from the right toe to the left kidney;

d. from the right kidney to the right side of the brain.

46. Name the branches of the ascending aorta, aortic arch, thoracic aorta, and abdominal aorta, and denote what body region they supply with blood.

47. Explain what happens to the aorta at the brim of the pelvis.

48. Although the venous circuit is essentially parallel to the arterial circuit, list the differences between the two.

49. Name the longest vein in the body and the venipuncture site.

50. Discuss hypertension.

I. **INTRODUCTION**

The major function of the cardiovascular system is to circulate substances throughout the body. In other words, its organs function to supply cells & tissues with oxygen & nutrients and also to remove wastes (CO2 & urea) from cells and tissues.

If cells do not receive O2 & nutrients and wastes accumulate, cells will die!

Remember this is the cardiovascular **system** (See Fig 15.1, page 543), which is composed of the heart and blood vessels. Blood, a connective tissue is circulated through these organs.

**Cardiology** is the study of the heart and the diseases associated with it.

II. **STRUCTURE OF THE HEART**

 A. **Location and Size of the Heart:** See Fig 15.2, page 543 and 15.3, page 544, and Fig 15.4, page 544.

 1. Location = within mediastinum.

 2. Size = closed fist; 300g (adult).

 3. Base = wide superior border;

 4. Apex = inferior point.

B. **Coverings of Heart** = Three membranes:

See Fig 15.4, page 544 and Fig 15.5, page 545.

1. **Serous Pericardium**

 a. **visceral** pericardium = innermost delicate epithelium + CT covering surrounding the heart muscle;

 b. **parietal** pericardium = inner lining of fibrous pericardium;

\* Recall the **pericardial cavity** between a & b, filled with **serous fluid for lubrication**.

2. **Fibrous Pericardium** = outermost tough, fibrous protective CT layer that prevents overstretching of the heart.

C. **Wall of the Heart**: composed of 3 layers:

See Fig 15.5 and Table 15.1, page 545.

 1. epicardium = visceral pericardium;

 2. myocardium = cardiac muscle tissue (recall characteristics);

 bulk of heart;

 3. endocardium = smooth inner lining of heart chambers and valves.

II. **STRUCTURE OF THE HEART**

D. **Heart Chambers and Valves** (Fig 15.6, page 547).

 1. The upper chambers are called **atria** (plural).

 a. Right and left atrium are separated by the **interatrial septum**;

b. Atria receive blood from veins (PASSIVE);

c. are thin walled chambers.

\* Note that ear-like flaps called auricles cover the atria

 See Fig 15.4, page 544**.**

\* Note the location of the **fossa ovalis**, which is remnant of the fetal foramen ovale (page 908).

 2. The lower chambers are called **ventricles**.

 a. Right and left ventricle are separated by the **interventricular septum**;

b. Ventricles pump blood from the heart into arteries (ACTIVE);

c. are thick walled chambers.

\* Note the **trabeculae carneae,** which is the irregular inner surface (ridges and folds) of the ventricles.

3. **Atrioventricular valves** (AV valves)

 See Fig 15.6, page 547, and Fig 15.8 & 15.9, page 548.

a. The **tricuspid** valve lies between the right atrium and ventricle;

b. The **bicuspid** valve lies between the left atrium and ventricle (Mitral Valve);

c. Structures associated with AC valves:See Fig 15.7, page 548.

* **Chordae Tendineae** = tendon-like, fibrous cords that connect the cusps of AV valves to the papillary muscle (inner surface) of ventricles; prevent cusps from swinging back into atria.
* **Papillary Muscle** = the muscular columns that are located on the inner surface of the ventricles.

4. **Semilunar valves** (SL valves)

a. The **pulmonary SL valve** lies within the pulmonary trunk;

1. The **aortic SL valve** lies within the aorta.

\* See Heart Valve Summary Table 15.2, page 549.

II. **STRUCTURE OF THE HEART**

 E. **Skeleton of the Heart**

 1. Rings of dense CT around the four valves

 2. Mass of dense CT in the interventricular septum

 3. Provide attachment sites for valves and cardiac muscle fibers.

F. **Major Blood Vessels** associated with the Heart

See Fig 15.13, page 552.

 1. **Arteries carry blood away from the heart**.

a. carry blood that is **high in O2 & low in CO2**, except pulmonary arteries that are low in O2 & high in CO2;

 b. **Aorta** carries blood from the left ventricle to the body;

c. **Pulmonary arteries** carry blood from the right ventricle to the lungs (via the **pulmonary trunk**).

d. **Coronary arteries** carry blood to the myocardium.

 2. **Veins carry blood toward the heart**.

 a. carry blood that is **high in CO2 & low in O2**, except the pulmonary veins that are high O2 & low CO2.

 b. **Superior vena cava** brings blood from the head and upper limbs;

 c. **Inferior vena cava** brings blood from the trunk and lower limbs;

 d. **Coronary sinus** (posterior surface) brings blood from the myocardium;

* All of the above deposit their blood into the right atrium!

e. **Pulmonary veins** bring blood from the lungs to the left atrium:

* 2 from right lung;
* 2 from left lung.

3. Other features:

a. Note the presence of the **ligamentum arteriosum,** which is a remnant of the fetal ductus arteriosus. See Figure 15.13a, page 552.

b. See also page 908.

II. **STRUCTURE OF THE HEART**

G. **Paths of Blood through the Heart** and Lungs (Pulmonary Circuit)

See Fig 15.10, page 550 and Fig 15.11, page 551.

1. right atrium (deoxygenated blood)

(tricuspid valve)

2. right ventricle

 (pulmonary semi-lunar valve)

3. pulmonary trunk

4. pulmonary arteries

5. capillaries (alveoli) in lungs

6. pulmonary veins

7. left atrium

(bicuspid or Mitral valve)

8. left ventricle

 (aortic semi-lunar valve)

9. ascending aorta

\* Note how the ascending aorta arches over the pulmonary trunk and heads downward forming the thoracic aorta and abdominal aorta.

II. **STRUCTURE OF THE HEART**

H. **Blood Supply to the Heart:** Coronary Circulation (i.e. Pathway through Myocardium or how the heart muscle itself is supplied with blood).

See Fig 15.15, page 553.

1. ascending aorta (oxygenated blood)

2. coronary arteries (1st and 2nd branch of aorta)

a. **left coronary artery**

b. right coronary artery

\* Definition:

**Anastomoses** = connections between 2 or more branches of arteries that supply the same region with blood.

* provide alternate routes for blood to reach a particular region;
* many in heart.

3. capillaries in myocardium (exchange of gases)

4. cardiac veins (deoxygenated blood)

a. great cardiac vein;

b. middle cardiac vein.

5. coronary sinus

6. right atrium

II. **STRUCTURE OF THE HEART**

I**. Summary of Pulmonary, Coronary and General Systemic Circulations**



III. **Angina Pectoris and Myocardial Infarction (MI)**

See blue box on page 551 and introduction on page 542.

Blood clots, fatty atherosclerotic plaques, and smooth muscle spasms within the coronary vessels lead to most heart problems.

 A. Definitions:

1. **Ischemia** = reduction of blood flow;

2. **Hypoxia** = reduced oxygen supply due to ischemia;

3. **Angina pectoris** ("strangled chest") = severe pain that accompanies myocardial ischemia.

a. crushing chest pain radiating down left arm;

b. labored breathing, weakness, dizziness, perspiration;

c. occurs during exertion, fades with rest;

d. relieved by nitroglycerin.

4. **Myocardial Infarction (MI)** = "heart attack".

a. death of portion of myocardium;

b. caused by a thrombus (stationary blood clot) or embolus (moving blood clot) in a coronary artery;

c. may cause sudden death if conduction system is disrupted (see below) and ventricular fibrillation occurs;

d. treatments include clot-dissolving agents (i.e. TPA and streptokinase), along with heparin or angioplasty.

5. **Reperfusion Damage** occurs when an oxygen deprived (hypoxic) tissue's blood supply is reestablished.

a. due to formation of oxygen free radicals;

b. damage to enzymes, neurotransmitters, nucleic acids and phospholipids;

c. implicated in a number of diseases including heart disease, Alzheimer's, Parkinson's, cataracts, and rheumatoid arthritis and contributes to aging;

d. **Anti-oxidants** defend the body against this damage and include the enzyme catalase, Vitamin E, C, and beta-carotene.

I. **CARDIAC CYCLE**

A. **Introduction**

1. includes all of the events associated with one heartbeat;

2. The atria and ventricles alternately contract and relax (i.e. when the two atria contract, the two ventricles relax and vice versa).

3. Blood flows from areas of high pressure to areas of low pressure. As a chamber of the heart contracts, pressure increases, while as a chamber relaxes, pressure decreases.

4. Definitions: See Fig 15.16, page 554.

a. **Systole** = phase of contraction;

b. **Diastole** = phase of relaxation.

5. A complete cardiac cycle includes systole and diastole of both atria, and systole and diastole of both ventricles.

B. **General Summary of Cardiac Cycle** (Keyed on at the end of this outline)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Phase | **VENTRICULAR****CONTRACTION****(SYSTOLE)** | **ATRIAL****RELAXATION****(diastole)** | **VENTRICULAR****RELAXATION****(DIASTOLE)** | **ATRIAL****CONTRACTION****(systole)** |
| BloodFlow |  |  |  |  |
| Valves |  |  |  |  |
| pressure |  |  |  |  |

I. **CARDIAC CYCLE**

C. **Specific Phases of the Cardiac Cycle:**

**Fig 15.17, page 555** shows the relation between the heart's ECG and mechanical events (contraction and relaxation), and the consequent changes in atrial pressure, ventricular pressure, ventricular volume, and aortic pressure during the cardiac cycle.

1. **Relaxation (Quiescent) Period** (Early ventricular diastole)

a. follows T-wave;

b. Ventricular pressure drops;

c. SL valves close;

d. **isovolumetric** relaxation for brief time;

e. When ventricular pressure drops below atrial pressure, AV valves open;

f. 0.4 seconds.

2. **Ventricular Filling** (Mid to Late ventricular Diastole)

a. Rapid ventricular filling occurs just after AV valves open (remember atria had filled during ventricular contraction);

b. SA Node fires (P wave), atria contract, and remainder of ventricular filling occurs;

c. ventricles have completed filling = **end-diastolic volume**

c. Atria relax, ventricles depolarize (QRS complex).

d. 0.1 seconds.

3. **Ventricular Systole**

a. Impulse passes through AV Node and then through ventricles;

b. Ventricles contract;

c. Ventricular pressure increases rapidly;

d. AV valve close:

* **Isovolumetric Contraction Phase** (constant volume) = start of contraction to opening of SL valves = 0.05 sec;
* **Ventricular Ejection Phase** = opening of SL valves to closing of SL valves;
* **End-systolic volume** reached when ventricle finish emptying

e. 0.3 seconds.

 \* Stroke Volume = End-diastolic volume minus end-systolic volume

II. **HEART SOUNDS** (lub-dup) See Fig 15.18, page 557.

A. **Introduction**

 These sounds can be heard through a physician's stethoscope. They represent the closing of heart valves, and therefore help in diagnosing any problems occurring in the valves.

B. **Sounds**

 1. **lub** = closing of AV valves (ventricular systole);

 loud and long.

 2. **dup**: closing of SL valves (ventricular diastole);

short and sharp.

C. **Significance**

 If the closing of the valve cusps is incomplete, some blood may leak back = **murmur**.

III. **CARDIAC MUSCLE FIBERS**

A. Review the differential ion concentrations that maintain a cell's Resting Membrane Potential (RMP):

B. **Physiology of Contraction**

1. **Rapid depolarization due to opening of Na+ channels:**

a. Contractile fibers of the heart have a resting potential of -90mV;

b. When the potential is brought to -70mV by excitation of neighboring fibers, certain sodium (Na+) channels open very rapidly;

c. Na+ ions rush into the cytosol of fibers and produce a rapid depolarization.

2. **Plateau due to opening of Ca++ channels**

a. Ca++ channels open;

b. Ca++ ions enter cytosol of fibers from ECF;

c. Ca++ ions pour out of SR into cytosol;

d. Depolarization is maintained for 0.25 seconds (250msec).

e. Ca++ binds troponin ... contraction.

Note that epinephrine increases contraction force by increasing Ca++ influx, and drugs called calcium channels blockers (i.e. verapamil) reduce Ca++ inflow and therefore diminish the strength of a heartbeat.

III. **CARDIAC MUSCLE FIBERS**

 B. **Physiology of Contraction**

3. **Repolarization due to opening of K+ channels**

a. K+ channels open;

b. K+ ions diffuse out of fibers;

c. Na+ and Ca++ channels close;

d. -90mV resting potential is restored.

\* **Refractory Period** = the time following a contraction when a second contraction cannot be triggered.

a. longer than contraction itself;

b. necessary for ventricles to relax and fill with blood before again contracting to eject the blood.

 4. **Strength of Contraction**

 a. Within physiologic limits increased stretch of cardiac muscle fiber will increase the strength of contraction

 b. Caused because cardiac muscle is at less than optimal length when the heart is at resting rate

 c. The **Frank-Starling Law of the Heart** says that strength (and therefore stroke volume) increases as venous return **(preload)** increases

 d. Basically this means that as blood flows into the heart, it must be pumped out

IV. **Cardiac Conduction System (CCS)**

There are specialized areas of cardiac muscle tissue (1%) in the heart that are **autorhythmic (self-exciting)**. These cells compose the CCS and are responsible for initiating and distributing cardiac (electrical) impulses throughout the heart muscle (i.e. cause the heart to beat). These specialized areas together coordinate the events of the cardiac cycle, which makes the heart an effective pump.

A. **Components of CCS**: **See Fig 15.19 and Fig 15.20, page 558**.

1. **Sinoatrial Node (S-A Node)**:

a. located in right uppermost atrial wall;

b. **PACEMAKER** = self-exciting tissue (rhythmically and repeatedly [60-100 per minute] initiates cardiac impulses);

c. Impulse travels throughout atrial fibers via gap junctions in intercalated discs to the...

IV. **Cardiac Conduction System (CCS)**

A. **Components of CCS:**

2. **Atrioventricular Node (A-V Node)**:

a. located in interatrial septum;

b. serves as a delay signal that allows for ventricular filling;

c. Cardiac impulse then enters the...

3. **Atrioventricular** **(AV) Bundle (Bundle of His):**

a. only electrical connection between the atria and ventricles;

b. located in the superior interventricular septum;

c. Impulse enters both ...

4. **Right and left bundle branches**

a. lead downward through interventricular septum toward apex, and impulse finally reaches...

5. **Purkinje Fibers** (Conduction Myofibers)

a. large diameter conduction myofibers;

b. located within the papillary muscles of the ventricles;

c. conduct the impulse into the mass of ventricular muscle tissue.

 d. cause ventricles to contract which forces blood out.

 B. **Summary Table of CCS** (Keyed at the end of this outline)

|  |  |  |  |
| --- | --- | --- | --- |
| **CCS COMPONENT** | **LOCATION** | **SIGNIFICANCE** | **SENDS CARDIAC IMPULSE TO ...** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

V. **ELECTROCARDIOGRAM (ECG) See Fig 15.22, page 559.**

A. Definition ECG = a recording of the electrical changes that occur in the myocardium during the cardiac cycle (see below);

 B. Instrument used to record an ECG = electrocardiograph;

C. used to determine if:

1. the conduction pathway is normal;

2. the heart is enlarged;

3. certain regions are damaged.

1. Rules to remember:
	1. Depolarization precedes contraction;
	2. Repolarization precedes relaxation.

E. **Three waves per heartbeat**:

1. **P wave** is a small upward wave.

a. represents atrial depolarization (spreads from SA node throughout both atria);

b. 0.1 sec after P wave begins, atria contract.

2. **QRS Complex**

a. begins as a downward deflection; continues as large, upright, triangular wave; ends as a downward wave;

b. represents onset of ventricular depolarization (spreads throughout ventricles);

c. shortly after QRS begins, ventricles start to contract.

3. **T wave**

a. dome-shaped, upward deflection;

b. represents ventricular repolarization;

c. occurs just before ventricles start to relax;

d. shape indicates slow process.

\* P-Q Interval and S-T segment

F. Abnormal ECG's: See Fig 15.23, page 560.

1. enlarged P = enlargement of an atrium possibly due to mitral stenosis;

2. enlarged Q wave = MI;

3. enlarged R wave = ventricular hypertrophy.

 VI. **CARDIAC OUTPUT (CO)**

 A. Definition CO = the volume of blood pumped by each ventricle in one minute;

B. CO = heart rate (HR) x stroke volume (SV)

C. SV = volume of blood pumped out by a ventricle with each beat;

D. Normal CO = 5 liters.

VII. **Regulation of Cardiac Cycle / Heart Rate**

 A. Autonomic Nervous System: See Fig 15.24, page 561.

 Recall that cardiovascular center is located in medulla of brainstem.

1. parasympathetic (normal) decreases; **cardioinhibitor reflex center**

2. sympathetic (stress) increases; **cardioacceleratory reflex center**

B. Chemicals

1. hormones (i.e. epinephrine increases);

2. ions

a. calcium increases;

b. potassium and sodium decreases.

C. Age (decreases)

D. Sex

1. females increased;

2. males decreased.

 E. Temperature

F. Emotion

G. Disease

I. **INTRODUCTION**

The blood vessels form a **closed system** of tubes that carry blood away from the heart, transport it to all the body tissues and then returns it to the heart. **Hemodynamics** is the study of the forces involved in accomplishing that feat.

II. **TYPES OF BLOOD VESSELS:**

1. **Arteries carry blood away from the heart**.

 **See Fig 15.25a, page 565 and Fig 15.32, page 569.**

1. strong and thick-walled vessels;

2. walls have three distinct layers:

a. **tunica interna (intima)** surrounds lumen and is composed of:

• a layer of endothelium (simple squamous epithelium),

• a basement membrane,

• an internal elastic lamina.

b. **tunica media** is the thickest layer composed of:

• smooth muscle cells;

• elastic fibers.

1. **tunica externa (adventitia)** is the outermost layer composed of

• elastic fibers

 • collagen fibers.

3. carry blood that is under **great pressure**.

4. carry blood that is **high in oxygen** and low in carbon dioxide, except the pulmonary arteries;

5. branch and give rise to thinner vessels called **arterioles**.

6. may unite with branches of other arteries supplying the same region forming **anastomoses** (i.e. providing alternate routes).

II. **TYPES OF BLOOD VESSELS:**

B. **Arterioles**

**See Fig 15.26 and Fig 15.27, page 565.**

1. very small arteries;

2. deliver blood to capillaries in tissues;

3. play a major role in regulating blood flow to capillaries, and therefore **regulate blood pressure**:

a. **Vasoconstriction** (contraction) = decrease vessel volume = decreased blood flow = increased blood pressure.

b. **Vasodilation** = increases vessel volume = increased blood flow = decreased blood pressure.

\* This will be discussed in greater detail later.

C. **Capillaries** are the smallest, thinnest blood vessels.

See Fig 15.29 and 15.30, page 567.

1. permit the exchange of gases, nutrients and wastes between blood and tissues;
2. connect arterioles to venules;

3. are composed of only a single layer of endothelium and basement membrane.

4. three types: based on structure and permeability

a. **continuous capillary** = the plasma membranes form a continuous, uninterrupted ring around the lumen; found in skeletal, smooth muscle, CT's and lungs.

b. **fenestrated capillary** = the endothelial plasma membranes contain pores (holes); found in the glomeruli of kidneys and villi of small intestine.

c. **sinusoids** = contain spaces between the endothelial cells with basement membranes being incomplete or absent; found in liver and spleen.

5. **Capillary Arrangement** varies by tissue supplied

 a. Higher cellular needs (brain, muscle) = more elaborate network

 b. Lower cellular needs = less branching

 6. Regulation of Capillary Blood Flow

 a. Smooth muscles control blood entry into capillary beds

 b. Metabolic need controls precapillary sphincter

II. **TYPES OF BLOOD VESSELS:**

D. **Capillary Exchange: See Fig 15.31, page 568.**

Gases, nutrients, and wastes are exchanged between blood in capillaries and tissues in three ways:

1. **diffusion**

a. most common;

b. substances include oxygen, CO2, glucose, & hormones,

c. Lipid-soluble substances pass directly through endothelial cell membrane;

d. Water-soluble substances must pass through fenestrations or gaps between endothelial cells.

2. **vesicular transport** (endo/exocytosis);

3. **bulk flow** (filtration and absorption).

 a. filtration

* hydrostatic (blood) pressure pushes small solutes and fluid out of capillary
* colloid osmotic pressure (osmosis) draws fluid back into capillary
* net affect is fluid loss at the beginning of capillary bed but most is regained by the end of the capillary bed
* fluid not regained enters lymphatic vessels (next chapter)
* a special situation occurs in the kidney (Chapter 20)

E. **Venules and Veins**

 1. **Venules and** **Veins carry blood toward the heart**;

2. Venules extend from capillaries and merge together to form veins;

3. **thin-walled** vessels with 3 tunics:

Fig 15.25b, page 565 and 15.32, page 569:

a. tunica intima = endothelium and basement membrane;

b. **tunica media** = thin layer of smooth muscle;

**much thinner than artery;**

c. tunica externa = elastic and collagen fibers.

See Fig 15.25a & b, page 565 and Fig 15.32, page 569 to compare the structure of a vein with an artery.

4. carry blood under **low pressure**;

II. **TYPES OF BLOOD VESSELS:**

E. **Venules and Veins**

5. contain **valves**;

See Fig 15.33, page 569.

6. carry blood that is **high in carbon dioxide** and low in oxygen, except the pulmonary veins.

 7. Veins are large and therefore serve as a blood reservoir, especially in the skin

F. **Blood Distribution throughout Body**:

See Fig 15.34, page 570.

1. 60-70% in systemic veins and venules;

2. 10-12% in systemic arteries and arterioles;

3. 10-12% in pulmonary vessels;

4. 8-11% in heart;

5. 4-5% in systemic capillaries.

**\* See Table 15.3, page 570 for a summary of blood vessel structure and function**.

 G. **Major Blood Vessel Summary Table (Keyed at the end of this outline)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of Blood****Vessel** |  |  |  |
| **Function (i.e. direction of blood flow in terms of heart)** |  |  |  |
| **Wall structure (layers and layer components)** |  |  |  |
| **Concentration of gases (oxygen and carbon dioxide)** |  |  |  **N/A** |
| **Pressure of blood carried** |  |  |  **N/A** |

III. **HEMODYNAMICS: THE PHYSIOLOGY OF CIRCULATION**

A. **Blood Pressure:**

 1. Definition: Blood pressure = the pressure exerted by blood on the wall of blood vessel.

2. Definition: **Pulse** = the pressure wave that travels through arteries following left ventricular systole.

a. strongest in arteries closest to heart;

b. commonly measured in radial artery at wrist;

c. Normal pulse = 70-80 bpm;

* tachycardia > 100 bpm;
* bradycardia < 60 bpm.

 3. Measuring BP: See Clinical Application 15.3, page 572-573.

 a. Instrument used is called a **sphygmomanometer** ;

 b. Brachial artery is typically used;

 c. Procedure will be addressed in laboratory.

 B. **Arteries**

 2. In clinical use, we most commonly refer to **arterial blood pressure** , because the blood pressure in the veins is essentially insignificant.

 3. The arterial blood pressure rises to its **maximum during systole (contraction) and falls to its lowest during diastole (relaxation)**.

 4. In a normal adult at rest, the BP = **120 mm Hg/ 80 mm Hg.**

C. **Arterial Blood Pressure**

**See Fig 15.36, page 573.**

1. Heart Action (**cardiac output):**

a. **CO** is the volume of blood pumped by each ventricle each minute;

* **the volume of blood that is circulating through the systemic (or pulmonary) circuit per minute;**
* **5 liters/minute** is normal adult.

 b. CO is affected by:

* stroke volume (SV);
* heart rate (HR);

(Remember that CO = HR X SV);

 2. Blood Volume (increase in blood volume increases BP)

See Fig 15.39, page 576.

a. Normally fairly constant

 III. **HEMODYNAMICS: THE PHYSIOLOGY OF CIRCULATION**

 C. **Arterial Blood Pressure**

 3. Peripheral Resistance (R = opposition to blood flow usually due to friction)

 a. Resistance is the opposition to blood flow primarily due to friction. This friction depends on three things:

* Blood viscosity (↑ viscosity: ↑R: ↑ bp)
	+ normally constant
	+ direct relationship
		- * + Total blood vessel length (↑ blood vessel length: ↑ R: ↑ bp)
	+ normally constant
	+ direct relationship
		- * + Blood Vessel Radius (↑ radius: ↓ R: ↓ bp).
	+ **MOST significant factor in determining Blood Pressure**
	+ **Indirect relationship**

D. **Control of Blood Pressure:**

1. **BP = CO X PR**

 a. altering CO or PR alter BP directly

 b. to alter CO either HR or SV (therefore blood volume) can be used

 c. to alter PR either viscosity, vessel length, or vessel radius can be used

 d. in total any one ore combination of HR, SV or PR is used to alter BP

 e. Mechanical, neural, and chemical (hormone) factors affect SV and HR

 f. Neural and hormonal controls are used for PR

 2. **Mechanical Factors Affecting Blood Pressure**

 a. Venous return **(preload)**

* + - * + heart can only pump the blood that is returned to it
				+ increased preload increases the stretch of cardiac muscle fibers
				+ The **Frank-Starling Law of the Heart** says that strength (and therefore stroke volume) increases as venous return **(preload)** increases
				+ Basically this means that as blood flows into the heart, it must be pumped out

 III. **HEMODYNAMICS: THE PHYSIOLOGY OF CIRCULATION**

D. **Control of Blood Pressure:**

3. **Neural Regulation**: See Fig 15.24, page 561.

 a. The **cardiovascular (CV) center** and vasomotor center are located in the **medulla** of the brain stem.

 b. Input to centers:

 Nerve impulses are sent to the centers from three areas:

1. Higher brain centers;

2. **Baroreceptors** (or pressoreceptors) that detect changes in BP in aorta and carotid arteries;

3. **Chemoreceptors** that detect changes in key blood chemical concentrations (H+, CO2, and O2).

 c. Center Output:

 1. Nerve impulses are sent from the CV center to the SA Node of heart;

2. Nerve impulses are sent from the vasomotor center to the smooth muscle of peripheral blood vessels (i.e. arterioles).

 d. Negative-Feedback Regulation:

See Figures 15.39, page 576 and 15.40, page 577.

 1. **If BP is too high**:

* + - * + BP increase is detected by baroreceptors in the carotid a. or aorta;
				+ They send an impulse to CV and vasomotor centers;
				+ The CV center interprets that message and sends a signal to the SA Node which **decreases heart rate,** lowering CO and bp**;**
				+ The vasomotor center sends an impulse to the peripheral arterioles causing vasodilation, which lowers bp.

 2. If BP is too low...

* exact opposite of above
* plus hormonal response

III. **HEMODYNAMICS: THE PHYSIOLOGY OF CIRCULATION**

D. **Control of Blood Pressure:**

4. **Hormonal Control**

Several hormones affect BP by acting on the heart, altering blood vessel diameter, or adjusting blood volume.

a. *Hormones that increase BP:*

* **Epinephrine and norepinephrine**

**\*** increases CO (rate & force of contraction) and causes vasoconstriction of arterioles.

* **Antidiuretic hormone (ADH)**

\* increases reabsorption of water by the kidneys (DCT), and causes vasoconstriction of arterioles during diuresis and during hemorrhage.

* **Angiotensin II**

\* has four different targets that cause vasoconstriction of arterioles and causes the secretion of aldosterone (discussed in greater detail in Chapter 20).

* **Aldosterone**

**\*** increases Na+ and water reabsorption in the kidneys (PCT).

b. *Hormones that decrease BP:*

* **Atrial natriuretic peptide (ANP)**

\* causes vasodilation of arterioles and promotes the loss of salt and water in urine.

\* See blue box on page 546.

* **Histamine**

\* causes vasodilation of arterioles (plays a key role in inflammation).

III. **HEMODYNAMICS: THE PHYSIOLOGY OF CIRCULATION**

E. Venous Blood Flow

 1. Very low pressure

 2. Flow is assisted by skeletal muscle contractions squeezing veins

 3. Blood can only flow one directions (toward heart) because of valves

 4. Respiratory movements also assist by varying intrathoracic pressure causing pumping action

 F. Central Venous Pressure

 1. The pressure of blood in right atrium

 2. If the heart is weak blood remains in the right atrium after systole, causing increased pressure

 3. This leads to backing up of blood in right atrium (congestive heart failure)

 4. Normal heart action keeps central venous pressure near 0 (zero).

IV. **PATHS OF CIRCULATION:**

A. **Pulmonary Circuit** = the vessels that carry blood from the right ventricle to the lungs, and the vessels that return the blood to the left atrium:

See Fig 15.42, page 581.

1. pulmonary trunk

2. right and left pulmonary arteries (deoxygenated blood)

3. capillaries in lungs

4. right and left pulmonary veins (oxygenated blood)

IV. **PATHS OF CIRCULATION:**

B. **Systemic Circuit** = the vessels that carry blood from the heart to body cells and back to the heart.

1. **Arterial System**:

See Fig 15.53, page 592 for general overview.

a. The **aorta** is divided into the following regions:

* **ascending aorta;**
* **aortic arch;**
* **thoracic aorta;**
* **abdominal aorta;**

\* The abdominal aorta terminates at the brim of the pelvis and branches into each leg = common iliac arteries.

b. **Principal Branches of the Aorta**

 There are **many arteries that branch from these regions of the aorta** and supply blood to many areas of the body. The arteries you will need to know are listed below, and the body part they supply with blood, follows in parentheses:

 • **Branches of the ascending aorta:**

 1. right **coronary a**. (myocardium);

 2. left **coronary a**. (myocardium).

 • **Branches of the aortic arch: See Fig 15.44, page 583.**

 1. **brachiocephalic a**. (right side of head and right arm):

Fig 15.49, a. **right subclavian a**. (right arm):

page 587.

* vertebral a. (cervical vertebrae/skull)

Fig 15.46, pg 585.

 1. basilar a. (brain)

Fig 15.48, page 586. a. Circle of Willis (brain)

* axillary a. (armpit)

 1. brachial a. (upper arm)

 a. radial a. (lateral forearm);

 b. ulnar a. (medial forearm)

 • palmar arches (palm)

 1. digital a. (fingers)

IV. **PATHS OF CIRCULATION:**

 B. **Systemic Circuit**

1. **Arterial System**:

• **Branches of the aortic arch:**

1. **brachiocephalic a**

 b. **right common carotid a.** (right side of head)

 • external carotid a. (scalp)

 • internal carotid a. (brain)

 2. **left common carotid artery** (left side of head):

 a. external carotid a.

 b. internal carotid a.

 3. **left subclavian artery** (left arm):

 Branches follow same pattern as right subclavian artery

• **Branches of thoracic aorta**:

1. intercostals (intercostal/chest muscles);

2. superior phrenics (superior diaphragm);

3. bronchial arteries (bronchi of lungs);

4. esophageal arteries (esophagus).

• **Branches of abdominal aorta**: See Fig 15.45a&b, pg 584.

1. inferior phrenics (inferior diaphragm);

2. celiac trunk (artery):

a. common hepatic a. (liver);

b. left gastric a. (left stomach);

c. splenic artery (spleen);

3. superior mesenteric (small intestine, cecum, ascending/transverse colon, pancreas);

4. suprarenals (adrenals);

5. renal arteries (kidneys);

6. gonadal arteries (ovarian/testicular);

7. inferior mesenteric (descending/sigmoid colon, rectum).

• **Branches of Common Iliac Arteries** (right and left):

See Fig 15.52, page 590.

1. external iliac a. (lower extremities)

a. femoral a. (thigh)

• popliteal a. (knee region)

1. posterior tibial a. (lower leg)

a. plantar arteries (heel, foot, and toes).

2. anterior tibial a.

a. dorsalis pedis a. (foot and toes).

IV. **PATHS OF CIRCULATION:**

 B. **Systemic Circuit**

 2. **Venous System: See Overview Figure 15.60, page 597.**

Veins, that return blood to the heart after gas, nutrient, and waste exchange, usually follow pathways that are **parallel to the arteries** that supplied that particular region with blood. The veins you'll need to learn are identical to the arterial list with the following exceptions:

a. **jugular veins** (head); See Fig 15.54, page 593.

* external jugular vein (face and scalp);
* internal jugular vein (brain).

b. **median cubital vein** (venipuncture site): Fig 15.55, pg 593.

c. Note that there are **2 brachiocephalic veins**. The union of the subclavian and jugular veins on each side forms them.

See Fig 15.56, page 594.

d. **Superior Vena Cava** (formed by the union of the left and right brachiocephalic veins = head and upper limbs).

f. **coronary sinus** (cardiac veins);

* **cardiac veins** (caps of myocardium).

g. hepatic vein (drains hepatic portal system):See Fig 15.57, page 594.

* hepatic **portal vein** (drains gastric, mesenteric and splenic veins);

 1. gastric vein (stomach);

2. mesenteric veins (intestines);

3. splenic vein (spleen);

\* These veins do not drain directly into the inferior vena cava. Instead, the blood drained from these abdominal organs travels to the liver via the portal vein. Recall the hepatic portal system discussed during digestion.

h. **great saphenous vein** = the longest vein in the body. Extends from the medial ankle to the external iliac vein.

See Fig 15.59, page 596.

j. **Inferior Vena Cava** (drains veins from abdominal & lower limbs).

i. **Azygous System – azygous vein** (right) and **hemiazygous** (left)

* drain intercostal veins and lumbar veins

IV. **PATHS OF CIRCULATION:**

C. **Tracing Blood flow**

1. From **right fingers** to **left ear**:

right finger capillaries to

right digital veins to

right venous palmar arches to

right radial or ulnar vein to

right brachial vein to

right axillary vein to

right subclavian vein to

right brachiocephalic vein to

superior vena cava to

right atrium...

left ventricle to

aorta (ascending and arch) to

left common carotid artery to

left external carotid artery to

left ear capillaries.

Could the above tracing have been different at any points?

2. From the stomach to the left fingers.

3. From the right toe to the left kidney.

4. From the right kidney to the ride side of brain.

V. **LIFE SPAN CHANGES**

1. Cholesterol deposits in arteries as one ages.
	1. Accumulation causes hypertension and cardiac disease (see below).
2. Cardiac cells are replaced by fibrous connective tissue and fat as one ages.
3. Blood pressure increases with age, while resting heart rate decreases.
4. Moderate exercise correlates to lowered risk of heart diseases in the elderly.

VI. **Disorders/Homeostatic Imbalances of the Cardiovascular System**:

 A. Implantable Defibrillator. See introduction on page 542.

B. Pericarditis. See beige box on page 543.

C. Mitral Valve Prolapse. See beige box on page 546.

D. Angina Pectoris and Myocardial Infarction. See beige box on page 551.

1. Familial Amyloidosis. See beige box on page 558.
2. Arrhythmias. See Clinical Application 15.1, pages 562-563.
3. Abnormal Calcium or Potassium Levels. See beige box on page 561.
4. Blood Vessel Disorders. See Clinical Application 15.2, pages 571.
5. Hypertension. See Clinical Application 15.5, page 578.
6. Cardiac Tamponade. See beige box on page 579.
7. Pulmonary Edema. See beige box on page 581.
8. Molecular Causes of Cardiovascular Disease. See Clinical Application 15.7, pages 598 and 599.
9. Coronary Artery Disease (CAD). See Clinical Application 15.8, page 600.

VII. **Other Interesting Applications Concerning the CV System**

1. Heart Transplantation. See Clinical Application 15.1, page 556.
2. Space Medicine. See Clinical Application 15.4, page 574.
3. Exercise and the CV System. See Clinical Application 15.6, page 580.

VIII. **Clinical Terms Related to the Cardiovascular System.** See page 601.

IX. **Innerconnections of the Cardiovascular System**. See page 602.

# Summary Table of CCS

|  |  |  |  |
| --- | --- | --- | --- |
| **CCS COMPONENT** | **LOCATION** | **SIGNIFICANCE** | **SENDS CARDIAC IMPULSE TO ...** |
| Sinoatrial Node | right uppermost atrial wall | Pacemaker; initiates cardiac impulse 60-100 times per minute | Atrioventricular Node |
| Atrioventricular Node | interatrial septum | delay signal to allow for ventricular filling | Atrioventricular Bundle |
| Atrioventricular Bundle | superior interventricular septum | only electrical junction between atria & ventricles | right and left bundle branches |
| right and left bundle branches | lateral interventricular septum | passes signals down to apex | Purkinje fibers |
| Purkinje fibers | in papillary muscles of ventricles | conduct impulse to the mass of ventricular myocardium and forces blood out | N/A |

# General Summary of Cardiac Cycle

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Phase | **VENTRICULAR****CONTRACTION****(SYSTOLE)** | **ATRIAL****RELAXATION****(diastole)** | **VENTRICULAR****RELAXATION****(DIASTOLE)** | **ATRIAL****CONTRACTION****(systole)** |
| Bloodflow | Blood is forced from ventricles into arteries. | Atria fill with blood. | Ventricles fill with blood. | Blood is forced from atria into ventricles. |
| Valves | SL openAV closed | SL openAV closed | AV openSL closed | AV openSL closed |
| Pressure | V high | A low but rises as filling continues | V low but rises as filling continues | A high |

**Major Blood Vessel Summary Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of Blood****Vessel** | **Arteries** | **Veins** | **Capillaries** |
| **Function (i.e. direction of blood flow in terms of heart)** | **carry blood away from heart** | **carry blood toward heart** | **exchange site for gases, nutrients & wastes between blood and tissues;****connect arterioles and venules.** |
| **Wall structure (layers and layer components)** | **three tunics:****innermost = tunica intima (endothelium plus basement membrane);****middle = tunica media (thick smooth muscle plus elastic fibers);****outermost = tunica adventitia (collagen and elastic fibers)** | **same three tunics as arteries but tunica media is much thinner; equipped with valves** | **only tunica intima (single layer of endothelium plus its basement membrane)** |
| **Concentration of gases (oxygen and carbon dioxide)** | **high in oxygen;****low in carbon dioxide, except pulmonary arteries** | **high in carbon dioxide; low in oxygen, except pulmonary veins** |  **N/A** |
| **Pressure of blood carried** | **high** | **low so they are equipped with valves** |  **N/A** |

## Chapter 15: Cardiovascular System

# I. Introduction

A. The cardiovascular system includes the heart and blood vessels.

B. Without blood circulation, the tissues lack oxygen and nutrients and waste accumulates.

# II. Structure of the Heart

A. Size and Location of the Heart

1. An average size of an adult heart is generally 14 cm long and 9 cm wide.

2. The heart is bounded laterally by the lungs, anteriorly by the sternum, and posteriorly by the vertebral column.

3. The base of the heart lies beneath the second rib.

4. The apex of the heart is at the level of fifth intercostal space.

B. Coverings of the Heart

1. The pericardium is a covering that enclosed the heart and the proximal ends of the large blood vessels to which it attaches.

2. The fibrous pericardium is the outer fibrous layer of the pericardium.

3. The visceral pericardium is a serous membrane that is attached to the surface of the heart.

4. The parietal pericardium is a serous membrane that lines the fibrous layer of the pericardium.

 5. The pericardial cavity is the space between the visceral pericardium and parietal pericardium.

6. Serous fluid reduces friction between the pericardial membranes as the heart moves.

C. Wall of the Heart

1. The three layers of the heart wall are endocardium, myocardium, and pericardium.

2. The epicardium is composed of a serous membrane that consists of connective tissue covered by epithelium, and it includes blood capillaries, lymph capillaries, and nerve fibers.

3. The middle layer is the myocardium.

4. The myocardium is composed of cardiac muscle tissue.

5. The inner layer is the endocardium.

6. The endocardium consists of epithelium and connective tissue that contains manly elastic and collagenous fibers. It also contains blood vessels and Purkinje fibers.

7. The endocardium of the heart is continuous with the inner lining of the blood vessels attached to the heart.

D. Heart Chambers and Valves

1. The two upper chambers of the heart are the right atrium and the left atrium.

2. The two lower chambers of the heart are the right ventricle and the left ventricle.

3. Auricles are small, earlike projections of the atria.

4. The interatrial septum separates the right and left atrium.

5. The interventricular septum separates the right and left ventricles.

6. An atrioventricular orifice is an opening between an atrium and a ventricle.

7. An atrioventricular orifice is protected by an A-V valve.

8. The atrioventricular sulcus is located between the atria and ventricles.

9. The right atrium receives blood from the superior and inferior vena cavae and the coronary sinus.

10. The tricuspid valve is located between the right atrium and right ventricle and functions to prevent the back flow of blood into the right atrium.

 11. Chordae tendinae are fibrous strings and function to prevent cusps of A-V valves from swinging back into atria.

12. Papillary muscles are located in ventricular walls and contract when the ventricles contract.

13. The right ventricle receives blood from the right atrium.

14. The right ventricle pumps blood into the pulmonary trunk.

15. The pulmonary trunk divides into pulmonary arteries.

16. Pulmonary arteries deliver blood to the lungs.

17. The pulmonary valve is located between the right ventricle and pulmonary trunk and opens when the right ventricle contracts.

18. Pulmonary veins carry blood from the lungs to the left atrium.

19. Blood passes from the left atrium into the left ventricle.

20. The mitral valve is located between the left atrium and left ventricle and functions to prevent the back flow of blood into the left atrium.

21. The left ventricle pumps blood into the aorta.

22. The aortic valve is located between the left ventricle and aorta and opens when the left ventricle contracts.

23. The tricuspid and mitral valves are also called A-V valves because they are positioned between atria and ventricles.

24. The pulmonary and aortic valves are also called semilunar valves

because of their structures.

E. Skeleton of the Heart

1. The skeleton of the heart is composed of rings of dense connective tissue and other masses of connective tissue in the interventricular septum.

2. The skeleton of the heart provides attachments for the heart valves and for muscle fibers.

F. Path of Blood Through the Heart

1. Blood that is low in oxygen and rich in carbon dioxide enter the right atrium of the heart through venae cavae and the coronary sinus.

2. As the right atrium contracts, blood passes into the right ventricle.

3. When the right ventricle contracts, blood moves into the pulmonary trunk.

4. From the pulmonary arteries blood enters the lungs.

5. The blood loses carbon dioxide in the lungs and picks up oxygen.

6. Freshly oxygenated blood returns to the heart through pulmonary veins.

7. The pulmonary veins deliver blood to the left atrium.

8. When the left atrium contracts, blood passes into the left ventricle.

9. When the left ventricle contracts, blood passes into the aorta.

G. Blood Supply to the Heart

1. The first two branches of the aorta are the left and right coronary arteries.

2. Coronary arteries supply blood to the tissues of the heart.

3. The circumflex artery is located in the atrioventricular groove between the left atrium and left ventricle and supplies blood to the walls of the left atrium and left ventricle.

4. The anterior interventricular artery is located in the anterior interventricular groove and supplies blood to walls of both ventricles.

5. The posterior interventricular artery is located the posterior interventricular groove and supplies the posterior walls of both ventricles.

6. The marginal artery is located along the lower border of the heart and supplies blood to the wall of the right atrium and right ventricle.

7. Blood flow in coronary arteries is poorest during ventricular contraction because the contracting myocardium interferes with blood flow and the openings of the coronary arteries are partially blocked by cusps of the aortic valve.

8. Cardiac veins drain blood that passes through the capillaries of the myocardium.

9. The coronary sinus is an enlarged vein on the posterior surface of the heart.

# III. Heart Actions

A. Introduction

1. Atrial systole is atrial contraction.

2. Ventricular diastole is ventricular relaxation.

3. Atrial diastole is atrial relaxation.

4. Ventricular systole is ventricular contraction.

5. When the atria of the heart contract, the ventricles relax.

6. When the ventricles of the heart contract, the atria relax.

B. Cardiac Cycle

1. During a cardiac cycle, the pressure within the heart chambers rises and falls.

2. The pressure in the ventricles is low during ventricular diastole.

3. During diastole, the A-V valves are open.

4. About 70% of the blood flows passively from the atria into ventricles and the remaining blood is pushed into the ventricles when the atria contract.

5. As ventricles contract, the A-V valves snap shut.

6. When the pressure in the atria is lower than venous pressure, blood flows from the veins into atria.

7. During ventricular systole, ventricular pressure increases and the pulmonary valves open.

8. As blood flows out of the ventricles, ventricular pressure decreases.

9. The semilunar valves close when the pressure in the ventricles is lower than pressure in the aorta and pulmonary trunk.

C. Heart Sounds

1. Heart sounds are produced by the movement of blood through the heart and by the opening and closing of heart valve.

2. The first heart sound is lubb and occurs during ventricular contraction.

when the A-V valves snap shut.

3. The second heart sound is dupp and occurs during ventricular relaxation when the pulmonary valves snap shut.

4. A murmur is an abnormal heart sound.

D. Cardiac Muscle Fibers

1. A functional syncytium is a mass of merging cells that act as a unit.

2. Two syncytiums of the heart are in the atrial walls and the ventricular walls.

3. The atrial syncytium and ventricular syncytium are connected by fibers of the cardiac conduction system.

E. Cardiac Conduction System

1. The cardiac conduction system consists of an S-A node, atrial syncytium, junctional fibers, A-V node, A-V bundle, bundle branches, Purkinje fibers, and a ventricular syncytium.

2. The S-A node is located in the wall of the right atrium and initiates one impulse after another.

3. The S-A node is called the pacemaker because it generates the heart’s rhythmic contractions.

4. As a cardiac impulse travels from the S-A node into the atrial syncytium, it goes from cell to cell via gap junctions.

5. Conducting fibers deliver impulses from the S-A node to the A-V node.

 6. The A-V node is located in the inferior part of the interatrial septum and provides the only normal conduction pathway between the atrial and ventricular syncytiums.

7. Impulses are delayed as they move through the A-V node because this allows time for atria to contract.

8. From the A-V node, impulses pass to the A-V bundle.

9. The A-V bundle is located in the superior part of the interventricular septum and gives rise to bundle branches.

10. Purkinje fibers carry impulses to distant regions of the ventricular myocardium.

11. The ventricular myocardium contracts as a functioning unit.

12. Purkinje fibers are located in the inferior portion of the interventricular septum, papillary muscles, and in the ventricular walls.

13. The ventricular walls contract with a twisting motion because the muscle fibers in the ventricular walls form irregular whorls. The twisting motion produces a pushing motion.

14. Contraction of the ventricles begins at the apex of the heart and pushes blood superiorly toward the aortic and pulmonary semilunar valve.

F. Electrocardiogram

1. An electrocardiogram is a recording of the electrical changes that occur in the myocardium during a cardiac cycle.

2. An ECG is recorded by placing electrodes on the skin and connecting the electrodes to an instrument that respond to very weak electrical changes by moving a pen on a moving strip of paper.

3. A P-wave is produced when atrial fibers depolarize.

4. A QRS-wave is produced when ventricular fibers depolarize.

5. A T-wave is produced when the ventricular fibers repolarize.

6. Physician’s use ECG patterns to assess the heart’s ability to conduct impulses.

G. Regulation of Cardiac Cycle

1. The volume of blood pumped changes to accommodate cellular requirements.

2. The parasympathetic nerve to the heart is the vagus nerve

3. The vagus nerve innervates the S-A and A-V nodes.

4. The vagus nerve can alter heart rate by secreting acetylcholine onto the nodes.

5. Sympathetic fibers reach the heart via the accelerator nerves.

6. The endings of accelerator nerves secrete norepinephrine which increases the rate and force of myocardial contractions.

7. The cardiac control center controls the balance between the inhibitory actions of the parasympathetic nervous system and the stimulatory actions of the sympathetic nervous system.

8. Baroreceptors detect pressure changes.

9. When baroreceptors in the aorta detect an increase in pressure, they signal the cardioinhibitory center of the medulla oblongata.

10. If blood pressure is too high, the medulla oblongata sends parasympathetic impulses to the heart to decrease heart rate.

11. If venous blood pressure increases abnormally, sympathetic impulses flow to the heart and heart rate and contraction increases.

12. Rising body temperature increases heart action.

13. The most important ions that influence heart action are potassium and calcium.

# IV. Blood Vessels

A. Introduction

1. Blood vessels form a closed circuit of tubes that carries blood from the heart to cells and back again.

2. Five types of blood vessels are arteries, arterioles, capillaries, venules, and vein.

3. Arteries conduct blood away from the heart and to arterioles.

4. Venules and veins conduct blood from capillaries and to the heart.

5. The capillaries are sites of exchange of substances between the blood and the body cells.

B. Arteries and Arterioles

1. Arteries are strong, elastic vessels that are adapted for carrying the blood away from the heart under high pressure.

2. Arteries give rise to arterioles.

3. The three layers of the wall of an artery are the endothelium, tunica media, and tunica adventitia.

4. The inner layer of an artery is called endothelium and functions to provide a smooth surface for blood flow and prevents blood clotting.

5. The middle layer of an artery is called the tunica media and is composed of smooth muscle fibers.

6. The outer layer is the tunica adventitia and consists of connective tissues with collagenous and elastic fibers.

7. The vasa vasorum of an artery is a series of blood vessels that supply the wall of large arteries.

8. The sympathetic nervous system innervates smooth muscle in arteries and arterioles.

9. Vasomotor fibers stimulate smooth muscle cells to contract, decreasing the diameter of the vessel.

10. Vasoconstriction is the contraction of smooth muscle cells in blood vessel walls.

11. Vasodilation is the relaxation of smooth muscle cells in the walls of blood vessels and occurs when the blood vessel diameter increases.

12.Changes in the diameters of arteries and arterioles greatly influence blood flow and pressure.

13. The wall of a very small arteriole consists of an endothelium and some smooth muscle cells and connective tissue.

14. Metarterioles are branches of arterioles and help regulate blood flow to an area.

15. Arteriovenous shunts are connections between arterioles and venous pathways.

C. Capillaries

1. Introduction

a. The smallest diameter blood vessels are capillaries.

b. Capillaries connect arterioles to venules.

c. The wall of a capillary consists of endothelium.

2. Capillary Permeability

a. The most permeable capillaries are located in the liver, spleen, and red bone marrow.

b. Protective and tight capillaries are located brain.

3. Capillary Arrangement

a. The higher a tissue’s rate of metabolism, the denser its capillary networks.

b. Tissues richly supplied with capillaries are muscle and nervous tissues.

c. Tissues that lack capillaries are cartilage and epithelial tissues.

d. During exercise, blood is directed to capillary networks of skeletal muscle and it bypasses some of the capillary networks of the digestive tract.

4. Regulation of Capillary Blood Flow

a. Precapillary sphincters are located at the opening of capillaries and their function is control the flow of blood into a capillary.

b. When cells have low concentrations of oxygen, precapillary sphincters relax and blood flow increases.

5. Exchanges in the Capillaries

a. The vital function of exchanging gases, nutrients, and metabolic by-products between the blood and the tissue fluid surrounding body cells occurs in the capillaries.

b. Biochemicals move through capillary walls by diffusion, filtration, and osmosis.

c. Diffusion is the most important means of transfer.

d. Oxygen and nutrients diffuse out of the capillary walls into surrounding cells because they are in a lower concentration in surrounding cells.

e. Carbon dioxide and other wastes diffuse into the capillary blood because they are in a lower concentration in the capillary blood.

f. Plasma proteins generally remain in the blood because they are too big to cross through capillary walls.

g. In filtration, hydrostatic pressure forces molecules through a membrane.

h. In the capillaries, the force for filtration is provided by blood pressure.

i. Blood pressure is greater at the arteriole end of the capillary.

j. Colloid osmotic pressure is osmotic pressure and is created by plasma proteins in the blood of capillaries.

k. At the arteriolar end of the capillary, filtration predominates.

l. At the venular end of the capillary, osmotic pressure predominates.

D. Venules and Veins

1. Venules are blood vessels that continue from capillaries and merge to form veins.

2. The middle layer of the wall of a vein is very thin and poorly developed compared to that of an artery.

3. The function of valves in veins is keep blood flowing toward the heart.

4. Veins also function as blood reservoirs.

# V. Blood Pressure

A. Introduction

1. Blood pressure is the force the blood exerts against the inner walls of the blood vessels.

2. Blood pressure most commonly refers to pressure in arteries.

B. Arterial Blood Pressure

1. Systolic pressure is the maximum pressure and is created when the ventricles contract.

2. Diastolic pressure is the minimum pressure and is created when the ventricles relax.

3. A pulse is the alternate expanding and recoiling of an arterial wall.

4. Common places to detect a pulse are the radial artery, the brachial artery, the carotid artery, the temporal artery, the facial artery, the femoral artery, the popliteal artery, and the posterior tibial artery.

C. Factors that Influence Arterial Blood Pressure

1. Heart Action

a. Stroke volume is the volume of blood discharged from the ventricle with one contraction.

b. Cardiac output is the volume of blood discharged from a ventricle in one minute.

c. If stroke volume or heart rate increases, cardiac output increases.

2. Blood Volume

a. Blood volume equals the sum of the formed elements and plasma volumes in the vascular system.

b. Blood pressure is normally directly proportional to blood volume.

3. Peripheral Resistance

a. Peripheral resistance is the friction between blood and the walls of the blood vessels.

b. If peripheral resistance increases, blood flow decreases and blood pressure increases.

c. Dilation of blood vessels reduces peripheral resistance.

4. Viscosity

a. Viscosity is the thickness of a fluid.

b. As blood viscosity rises, blood pressure increases.

c. Blood cells and plasma proteins contribute to blood viscosity.

D. Control of Blood Pressure

1. Blood pressure is determined by cardiac output and peripheral resistance.

2. Cardiac output depends on the stroke volume and heart rate.

3. Stroke volume is the difference between EDV and ESV.

4. End Diastolic Volume is the volume of blood in each ventricle at the end of ventricular diastole.

5. End Systolic Volume is the volume of blood in each ventricle at the end of the ventricular systole.

6. Factors affecting stoke volume and heart rate are mechanical, neural, and chemical.

7. Preload is the mechanical stretching of a ventricular wall prior to ventricular contraction.

8. The greater the EDV, the greater the larger the preload lengthening of myocardial fibers.

9. Starling’s Law of the Heart is the relationship between fiber length and force of contraction.

10. The more blood that enters the heart, the greater the ventricular distention, the stronger the ventricular contractions, the greater the stroke volume and the greater the cardiac output

11. The less blood that returns from veins to the heart, the less ventricular distension, the weaker the ventricular contractions, the lesser the stroke volume and the lesser the cardiac output.

12. Starling’s Law of the Heart ensures that the volume of blood discharged from the heart is equal to the volume entering the heart.

13. If blood pressure rises, baroreceptors initiate the cardioinhibitory reflex which decreases blood pressure.

14. If blood pressure falls, the cardioaccelerator reflex occurs which increases sympathetic stimulation to the heart, which increases heart rate and cardiac output, which increases blood pressure.

15. Other factors that increase heart rate and blood pressure are emotional responses, exercise, and a rise in body temperature.

16. When arterial blood pressure suddenly increases, baroreceptors signal the vasomotor center, and sympathetic outflow to arterial walls decreases, which results in a decrease in blood pressure.

17. Chemicals that influence peripheral resistance are carbon dioxide, oxygen, and hydrogen ions.

E. Venous Blood Flow

1. Blood pressure decreases as the blood moves through the arterial system into capillary networks.

2. Blood flow through the venous system largely depends on skeletal muscle contractions and valves in veins.

3. The squeezing action of skeletal muscles helps push blood toward the heart.

4. During inspiration, the pressure in the thoracic cavity is reduced and the pressure in the abdominal cavity increases.

5. An increases in abdominal pressure will squeeze blood out of abdominal veins.

6. Venoconstriction is the constriction of a vein and occurs when some blood is lost from veins.

F. Central Venous Pressure

1. Central venous pressure is the pressure within the heart.

2. Central venous pressure is of special interest because it affects the pressure within the peripheral veins.

3. Other factors that increase central venous pressure are an increase in blood volume or widespread venoconstriction.

4. An increase in central venous pressure can lead to peripheral edema.

# VII. Paths of Circulation

A. Introduction

1. The two major pathways of blood vessels are the pulmonary circuit and the systemic circuit.

2. The pulmonary circuit consists of vessels that carry blood from the heart to the lungs and back to the heart.

3. The systemic circuit carries blood from the heart to all parts of the body, except the lungs, and back again.

B. Pulmonary Circuit

1. Blood enters the pulmonary circuit as it leaves the right atrium.

2. The pulmonary trunk divides into pulmonary arteries.

3. Within the lungs the pulmonary arteries divide into lobar arteries.

4. The lobar branches give rise to arterioles that continue into capillary networks.

5. The blood in the arteries and arterioles of the pulmonary circuit is low in oxygen.

6. Gases are exchanged between the blood and the air as the blood moves through alveolar capillaries.

7. The arterial pressure in the pulmonary circuit is less than in the systemic circuit because the right ventricle contracts with a force less than that of the left ventricle.

8. Higher osmotic pressure of the blood removes any fluid that gets into the alveoli.

9. Blood entering the venules of the pulmonary circuit is oxygen rich.

10. Venules merge to form veins.

11. Pulmonary veins return blood to the left atrium and this completes the pulmonary circuit.

C. Systemic Circuit

1. Freshly oxygenated blood moves from the left atrium to the left ventricle.

2. Contraction of the left ventricle forces blood into the systemic circuit.

3. The systemic circuit includes the aorta and its branches that lead to all of the body tissues, as well as the companion system of veins that returns blood to the right atrium.

**VIII.** **Arterial System**

A. Introduction

1. The aorta is the largest diameter artery in the body.

2. The aorta extends upward from the left ventricle, arches over the heart to the left, and descends just anterior and to the left of the vertebral column.

B. Principal Branches of the Aorta

1. The ascending aorta is the first portion of the aorta.

2. An aortic sinus is a swelling of the aortic wall.

3. Coronary arteries arise from the aortic sinus.

4. Aortic bodies are small structures located within the aortic sinuses

 and contain chemoreceptors that sense blood concentrations of oxygen and carbon dioxide.

5. Three arteries originating from the aortic arch are the brachiocephalic artery, the left common carotid artery, and the left subclavian artery.

6. The brachiocephalic artery supplies blood to the tissues of the upper limb and head.

7. The brachiocephalic divides into the right common carotid artery and the right subclavian.

8. The common carotids supply blood to the head and neck.

9. The subclavian arteries supply blood to the arms.

10. The descending aorta is located the portion of the aorta that moves through the thoracic and abdominal cavity.

11. The thoracic aorta is portion of the descending aorta above the diaphragm.

12. Branches of the thoracic aorta are the bronchial, pericardial, and esophageal arteries.

13. The abdominal aorta is the portion of the descending aorta below the diaphragm.

14. Branches of the abdominal aorta are celiac, phrenic, superior mesenteric, suprarenal, renal, gonadal, inferior mesenteric, lumbar, and middle sacral arteries.

15. The celiac artery gives rise to gastric, splenic, and hepatic arteries which supply upper portions of the digestive tract, spleen and liver.

16. Phrenic arteries supply the diaphragm.

17. The superior mesenteric artery branches to many parts of the intestinal tract.

18. The suprarenal arteries supply the adrenal glands.

19. The renal arteries supply the kidneys.

20. The gonadal arteries supply the ovaries and testes.

21. The inferior mesenteric artery branches into arteries leading to the descending colon, sigmoid colon, and the rectum.

22. Lumbar arteries supply muscle of the skin and posterior abdominal wall.

23. The middle sacral artery supplies the sacrum and coccyx.

24. The abdominal aorta terminates near the brim of the pelvis and divides into common iliac arteries.

25. The common iliac arteries supply lower regions of the abdominal wall, the pelvic organs, and the lower extremities.

C. Arteries of the Neck, Head, and Brain

1. Branches of the subclavian and common carotids supply structures within the neck, head, and brain.

2. The main divisions of the subclavian artery to the neck, head, and brain are the vertebral, thyrocervical, and costocervical arteries.

3. The common carotid artery communicates with these regions by means of the internal and external carotid arteries.

4. The vertebral arteries arise from the subclavian arteries and supply the base of the neck.

5. A basilar artery is formed by the union of vertebral arteries.

6. The basilar artery divides into posterior cerebral arteries

 that supply portions of the occipital and temporal lobes of the cerebrum.

7. The cerebral arterial circle is formed by the anterior and posterior cerebral arteries.

8. Functions of the cerebral arterial circle are supply brain tissue and to provide alternate routes through which blood can reach brain tissue in the event of an arterial occlusion.

9. Thyrocervical arteries give rise to branches to the thyroid gland, parathyroid glands, larynx, trachea, esophagus, and pharynx.

10. Costocervical arteries carry blood to muscles of the neck, back and thoracic wall.

11. The common carotid arteries ascend deeply within the neck and divide to form internal and external carotid arteries.

12. The external carotid artery gives off branches to structures of the neck, face, jaw, scalp, and base of skull.

13. Main branches off external carotid arteries are superior thyroid, lingual, facial, occipital and posterior auricular arteries.

14. The superior thyroid artery supplies the hyoid bone, larynx, and thyroid gland.

15. The lingual artery supplies the tongue and salivary glands.

16. The facial artery supplies the pharynx, palate, chin, lips, and nose.

17. The occipital artery supplies the back of the scalp, the meninges, the mastoid process, and muscles of the neck.

18. The posterior auricular artery supplies the ear and scalp over the ear.

19. The external carotid artery terminates by dividing into maxillary and superficial temporal arteries.

20. The maxillary artery supplies the teeth, gums, jaws, cheek, nasal cavity, eyelids, and meninges.

21. The temporal artery supplies the parotid glands and various regions of the face and scalp.

22. The major branches of the internal carotid artery are ophthalmic, posterior communicating, and anterior choroid arteries.

23. The ophthalmic artery supplies the eyeball and various muscles and accessory organs within the orbit.

24. The posterior communicating artery forms part of the circle of Willis.

25. The anterior choroids artery supplies the choroid plexus and structures within the brain.

26. The internal carotid artery terminates by dividing into anterior and middle cerebral arteries.

27. The middle cerebral artery supplies the lateral surfaces of the cerebrum.

28. The anterior cerebral artery supplies the medial surfaces of the cerebrum.

29. A carotid sinus is an enlargement of each carotid artery and contains baroreceptors that control blood pressure.

D. Arteries to the Shoulder and Upper Limb

1. As it passes into the arm, the subclavian artery becomes the axillary artery.

2. The axillary artery supplies structures of the axilla and chest wall.

3. The axillary artery becomes the brachial artery.

4. The brachial artery gives rise to deep brachial artery.

5. The branches of the brachial artery supply structures of the arm.

6. Within the elbow, the brachial artery divides into ulnar and radial arteries.

7. The branches of the ulnar artery supply structures on the ulnar side of the forearm.

8. The branches of the radial artery supply structures on the radial side of the forearm.

9. Blood supply to the wrist, hands, and fingers come from branches of the radial and ulnar arteries.

E. Arteries to the Thoracic and Abdominal Walls

1. The internal thoracic artery is a branch of a subclavian artery.

2. The internal thoracic artery gives off two anterior intercostal arteries to each of the upper six intercostal spaces.

3. The anterior intercostals arteries supply intercostal muscles and mammary glands.

4. The posterior intercostals arteries arise from the aorta and enter the intercostal spaces between the third through the eleventh ribs.

5. The posterior intercostals arteries supply intercostal muscles, the vertebrae, the spinal cord, and deep muscles of the back.

 6. Branches of the internal thoracic and external iliac arteries provide blood to the anterior abdominal wall.

7. Phrenic and lumbar arteries supply the posterior and lateral abdominal wall.

F. Arteries to the Pelvis and Lower Limb

1. The abdominal aorta divides to form common iliac arteries.

2. The common iliac arteries provide blood to pelvic organs, gluteal and lower limbs.

3. Each common iliac divides into internal and external iliacs.

4. The internal iliac artery gives off branches to pelvic organs and muscles, genitals, and gluteal muscles.

5. Branches of the internal iliac artery are iliolumbar, gluteal, internal pudendal, vesical, middle rectal, and uterine arteries.

6. The iliolumbar arteries supply the ilium and muscles of the back.

7. Superior and inferior gluteal arteries supply gluteal muscles, pelvic muscles, and skin of the buttocks.

8. Internal pudendal arteries supply muscles to the distal portion of the alimentary canal, external genitals, and the hip joint.

9. Superior and inferior vesical arteries supply the urinary bladder, seminal vesicles, and prostate gland.

10. Middle rectal arteries supply the rectum.

11. Uterine arteries supply the uterus and vagina.

12. The external iliac artery provides the main blood supply to the lower limbs.

13. Two branches of the external iliac artery are inferior epigastric and deep circumflex arteries.

14. The inferior epigastric artery and deep circumflex artery supply muscles and skin of the lower abdominal wall.

15. The external iliac artery becomes the femoral artery.

16. The femoral artery gives off branches to muscles and superficial tissues of the thigh.

17. Important subdivisions of the femoral artery are superficial circumflex iliac artery, superficial epigastric artery, pudendal arteries, deep femoral, and deep genicular arteries.

18. Superficial circumflex iliac arteries supply skin and lymph nodes of the groin.

19. Superficial epigastric arteries supply skin of lower abdominal wall.

20. Superficial and deep external pudendal arteries supply skin of lower abdomen and external genitalia.

21. Deep femoral arteries supply the hip joint and thigh muscles.

22. Deep genicular arteries supply thigh muscles and knee joint.

23. The popliteal artery is derived from the femoral artery.

24. Branches of the popliteal artery supply the knee joint and muscles of the thigh and calf.

25. The popliteal artery divides into anterior and posterior tibial arteries.

26. The anterior tibial artery supplies skin and muscles of the leg.

27. The dorsalis pedis artery is derived from the anterior tibial artery.

28. The posterior tibial artery supplies skin and muscles of the leg.

29. The posterior tibial artery divides into medial and lateral plantar arteries which supply the foot.

30. The peroneal artery is the largest branch of the posterior tibial artery and supplies the ankle and foot.

**IX**. **Venous System**

A. Characteristics of Venous Pathways

1. The vessels of the venous system begin with the merging capillaries into venules, venules into small veins, and small veins into larger ones.

2. Venous pathways are hard to follow because veins commonly connect in irregular networks.

3. The larger veins typically parallel arteries.

4. The veins from most body parts converge into superior and inferior vena cavae.

B. Veins from the Head, Neck, and Brain

1. The external jugular veins drain blood from the face, scalp, and superficial regions of the neck.

2. The external jugular veins empty into subclavian veins.

3. The internal jugular veins arise from numerous veins and venous sinuses of the brain and from deep veins in various parts of the face and neck.

4. The brachiocephalic veins are formed from internal jugular and subclavian veins.

5. The brachiocephalic veins merges to give rise to the superior vena cava.

C. Veins from the Upper Limb and Shoulder

1. A set of deep veins and a set of superficial veins drain the upper limb.

2. The deep veins generally parallel the arteries in each region.

3. The superficial veins connect in complex networks beneath the skin

 and also communicate with deep vessels of the upper limb.

4. The main vessels of the superficial network are the basilic and cephalic veins.

5. The basilic vein is located along the back of the forearm on the ulnar side and along the anterior surface of the elbow and joins the brachial vein.

6. The axillary vein is formed by basilic and brachial veins.

7. The cephalic veins are located on the lateral side of the upper limb and empties into the axillary vein.

8. Beyond the axilla, the axillary vein becomes the subclavian vein.

9. The median cubital vein is located on the lateral side of the forearm and in the bend of the elbow and is often a site for the retrieval of a blood sample.

D. Veins from the Abdominal and Thoracic Walls

1. Tributaries of the brachiocephalic and azygos veins drain the abdominal and thoracic walls.

2. The azygos vein originates in the dorsal abdominal wall and ascends

 through the mediastinum on the right side of the vertebral columns.

3. The azygos vein drains muscle tissue of the thoracic and abdominal walls.

4. Tributaries of the azygos vein include posterior intercostal veins, hemiazygos veins, and ascending lumbar veins.

5. The posterior intercostals veins drain intercostal spaces.

6. The superior and inferior hemiazygos veins drain posterior intercostal veins.

7. The ascending lumbar veins drain lumbar and sacral regions.

E. Veins from the Abdominal Viscera

1. Veins carry blood directly to atria of the heart, except those of the hepatic portal system.

2. The hepatic portal vein drains the stomach, intestine, pancreas, and spleen and carries blood to the liver.

3. The hepatic portal system is the venous pathway that includes the hepatic portal vein and the hepatic sinusoids.

4. Tributaries of the hepatic portal system include gastric veins, superior mesenteric, and splenic veins.

5. The gastric veins drain the stomach.

6. Superior mesenteric veins drain the intestines.

7. Splenic veins drain the spleen, pancreas, and a portion of the stomach.

8. The blood flowing to the liver in the hepatic portal system is oxygen poor and nutrient rich.

9. The liver metabolizes the nutrients.

10. Kupffer cells are located in hepatic sinusoids and function to phagocytize microbes.

11. Blood leaves the liver through hepatic veins.

12. Hepatic veins empty blood into the inferior vena cava.

13. Veins that empty into the inferior vena cava are lumbar, gonadal, renal, suprarenal, and phrenic veins.

F. Veins from the Lower Limb and Pelvis

1. Veins that drain the lower limb can be divided into deep and superficial groups.

2. The deep veins of the leg have names that correspond to arteries that they accompany.

3. The popliteal vein is formed from tibial veins.

4. The femoral vein originates from the popliteal vein.

5. The external iliac vein originates from the femoral vein.

6. The small saphenous vein begins in the lateral portion of the foot and passes upward behind the lateral malleolus.

7. The small saphenous vein ascends along the back of the calf and joins the popliteal vein.

 8. The great saphenous vein originates on the medial side of the foot

 and ascends upward along the medial side of the leg and thigh, and eventually joins the femoral vein.

9. The longest vein of the body is the great saphenous vein.

10. The saphenous veins communicate with deep veins of the leg and thigh.

11. In the pelvic region, vessels leading to internal iliac veins carry blood away from organs of reproduction, urinary, and digestive systems.

12. Tributaries that form the internal iliac vein are gluteal, pudendal, vesical, rectal, uterine, and vaginal veins.

13. The common iliac veins are formed from external iliac and internal iliac veins.

14. The common iliac veins merge to form inferior vena cava.

# X. Life-Span Changes

1. Sixty percent of men over the age of sixty have at least one narrowed coronary artery.

2. Some degree of cholesterol deposition in blood vessels may be part of normal aging.

3. During exercise, cardiac output decreases with age.

4. Cardiovascular disease may cause enlargement of the heart.

5. The number of cardiac muscle fibers in the heart fall and fibrous and adipose tissue increases.

6. With age, heart valves begin to thicken.

7. Systolic blood pressure increases with age.

8. The increase in systolic blood pressure is due to the decreasing diameters and elasticity of arteries.

9. Resting heart rate decreases with age.

10. With age, changes in arteries include thickening of the tunica interna and a decrease of elasticity.

11. The number of capillaries declines with age.

12. Exercise can help maintain a “young” vascular system.