CARDIVASCULAR SYSTEM
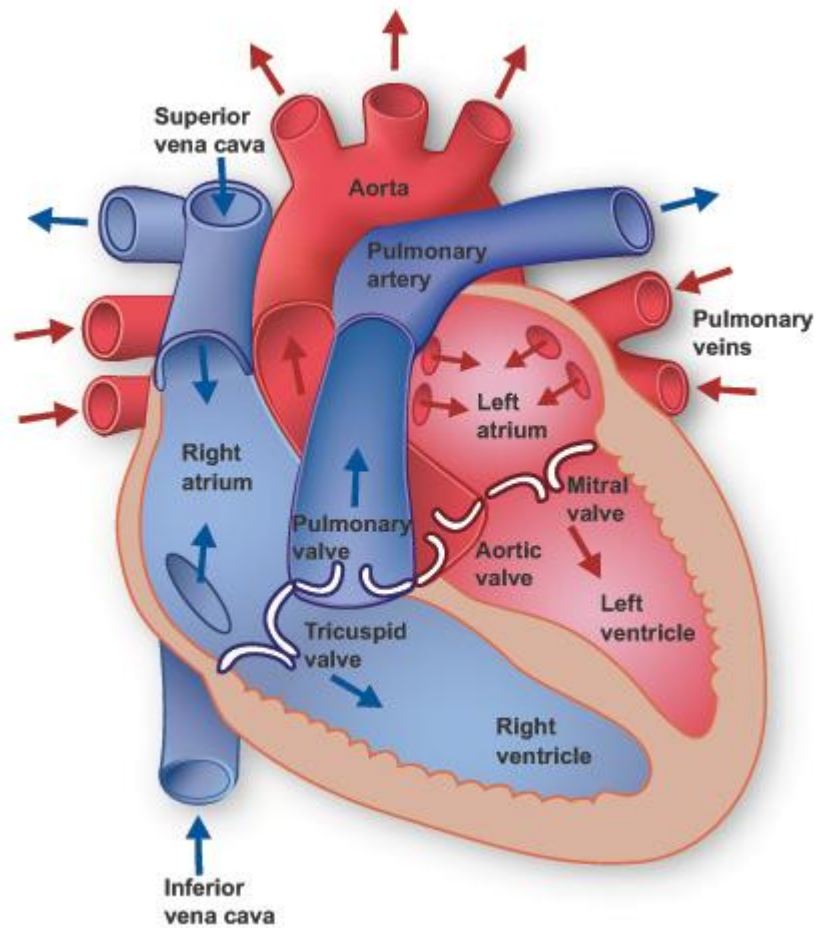
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Kaan Yücel
M.D., Ph.D.
http://fhs121.org

SUMMARY

The heart has two sides. The right side of the heart (right heart) receives poorly oxygenated (venous) blood from the body through the superior vena cava (SVC) and inferior vena cava (IVC) and pumps it through the pulmonary trunk and arteries to the lungs for oxygenation. The left side of the heart (left heart) receives well-oxygenated (arterial) blood from the lungs through the pulmonary veins and pumps it into the aorta for distribution to the body. The four chambers of the heart are: right and left atria and right and left ventricles. The atria are receiving chambers that pump blood into the ventricles (discharging chambers). The synchronous pumping actions of the heart's two atrioventricular (AV) pumps (right and left chambers) constitute the cardiac cycle.

The coronary arteries, the first branches of the aorta, supply the myocardium and epicardium. The right and left coronary arteries arise from the corresponding aortic sinuses. The heart is drained mainly by veins that empty into the coronary sinus and partly by small veins that empty into the right atrium. The sinuatrial (SA) node is the pacemaker of the heart. The SA node initiates and regulates the impulses for the contractions of the heart. The atrioventricular (AV) node distributes the signal to the ventricles through the AV bundle.

The pericardium is a fibroserous membrane that covers the heart and the beginning of its great vessels. The pericardium is a closed sac composed of two layers. The tough external layer, the fibrous pericardium, is continuous with the central tendon of the diaphragm. The internal surface of the fibrous pericardium is lined with a glistening serous membrane, the parietal layer of serous pericardium.

The right and left brachiocephalic veins are formed by the union of the internal jugular and subclavian veins. They unite to form the SVC and shunt blood from the head, neck, and upper limbs to the right atrium.

The ascending aorta begins at the aortic orifice. Its only branches are the coronary arteries. The arch of the aorta (aortic arch), the curved continuation of the ascending aorta. The usual branches of the arch are the brachiocephalic trunk, left common carotid artery, and left subclavian artery. The brachiocephalic trunk, the first and largest branch of the arch of the aorta divides into the right common carotid and right subclavian arteries.

1. HEART

The vascular system is divided into (a) the blood vascular system [heart and blood vessels for the circulation of the blood] and (b) lymph vascular system. The latter consists of lymph glands and lymphatic vessels, through which a colorless fluid, the lymph, circulates.

The two systems communicate with each other. They are intimately associated developmentally.

The heart is the central organ of the blood vascular system. It consists of a hollow muscle. By its contraction the blood is pumped to all parts of the body through a complicated series of tubes. These tubes are called as arteries.

The walls of the blood vessels of the cardiovascular system usually consist of three layers or tunics:

💗 tunica externa (adventitia)-the outer connective tissue layer;

💗 tunica media-the middle smooth muscle layer (may also contain varying amounts of elastic fibers in medium and large arteries);

💗 tunica intima-the inner endothelial lining of the blood vessels.

Arteries are usually further subdivided into three classes. We take into consideration: 1.the variable amounts of smooth muscle and elastic fibers at the tunica media, 2. overall size of the vessel, 3. function.

a. Large elastic arteries contain substantial amounts of elastic fibers in the tunica media. They allow expansion and recoil. This helps maintain a constant flow of blood to the heart. An example is the aorta.

 b. Medium muscular arteries are composed of a tunica media with mostly smooth muscle fibers. This characteristic allows these vessels to regulate their diameter and control the flow of blood to different parts of the body. An example is the radial artery.

c. Small arteries and arterioles control the filling of the capillaries and directly contribute to the arterial pressure in the vascular system.

Veins carry the blood to the heart. The direction of the blood flow is from the body to the heart. For the arteries, it is the opposite.

Veins also are subdivided into three classes.

a. Large veins contain some smooth muscle in the tunica media. Examples of large veins are the superior vena cava, and the inferior vena cava.

b. Small and medium veins superficial veins in the upper and lower limbs and deeper veins of the leg and forearm are examples.

c. Venules are the smallest veins and drain the capillaries.

The arteries undergo enormous ramification in their course throughout the body, and end in minute vessels, called arterioles, which in their turn open into a close-meshed network of microscopic vessels, termed capillaries. After the blood has passed through the capillaries it is collected into a series of larger vessels, called veins, by which it is returned to the heart. The passage of the blood through the heart and blood-vessels constitutes what is termed the circulation of the blood. The heart looks trapezoidal in the anterior-posterior dimensions. But in 3-D, it looks like a tipped-over pyramid.

The **heart** is a cruical organ of the human body. We can only stand for five to six minutes without blood travelling in our vessels. You can see the heart as a self-adjusting suction and pressure pump. The function of this pump is to send blood to all parts of the body.

1.1. The two sides of the heart: right heart & left heart

The right side of the heart (right heart) receives poorly oxygenated (venous) blood from the body through the superior vena cava (SVC) and inferior vena cava (IVC) and pumps it through the pulmonary trunk and arteries to the lungs for oxygenation. The left side of the heart (left heart) receives well-oxygenated (arterial) blood from the lungs through the pulmonary veins and pumps it into the aorta for distribution to the body.

1.2. The four chambers of the heart

The heart has four chambers: right and left atria and right and left ventricles. The atria are receiving chambers that pump blood into the ventricles (the discharging chambers). The synchronous pumping actions of

the heart's two atrioventricular (AV) pumps (right and left chambers) constitute the cardiac cycle. The cycle begins with a period of ventricular elongation and filling (diastole) and ends with a period of ventricular shortening and emptying (systole).

1.3. The heart sounds

Two heart sounds are heard with a stethoscope. The first sound is a "lub" sound. The blood is transferred from the atria into the ventricles. The second sound is a "dub" sound. Here the ventricles expel blood from the heart. The heart sounds are produced by the snapping shut of the oneway valves that normally keep blood from flowing backward during contractions of the heart.

1.4. The layers of the heart

The wall of each heart chamber consists of three layers, from superficial to deep:

•Endocardium, a thin internal layer

•Myocardium, a thick, helical middle layer composed of cardiac muscle.

•Epicardium, a thin external layer

1.5. Fibrous skeleton of the heart (Cardiac skeleton)

The cardiac skeleton is a collection of dense, fibrous connective tissue in the form of four rings with interconnecting areas in a plane between the atria and the ventricles. The four rings of the cardiac skeleton surround the two atrioventricular orifices, the aortic orifice and opening of the pulmonary trunks. They are the anulus fibrosus.

The fibrous skeleton of the heart:

•   Keeps the orifices of the AV and semilunar valves patent and prevents them from being overly distended by an increased volume of blood pumping through them.

•   Provides attachments for the leaflets cusps of the valves and myocardium as well.

•   Forms an electrical "insulator," by separating the myenterically conducted impulses of the atria and ventricles so that they contract independently and by surrounding and providing passage for the initial part of the AV bundle of the conducting system of the heart.

1.6. Sulci/Grooves in the heart

Externally, the atria are demarcated from the ventricles by the coronary sulcus (atrioventricular groove), and the right and left ventricles are demarcated from each other by anterior and posterior interventricular (IV) sulci (grooves).

1.7. Apex and base of the heart

The heart has one apex located inferiorly, and one base located superiorly. The heart is placed in the thoracic cavity. The apex projects forward, downward, and to the left. The base is opposite to the apex. It's in a posterior direction.

The apex of the heart:

•   Is formed by the inferolateral part of the left ventricle.

•   Lies posterior to the left 5th intercostal space in adults, usually approximately 9 cm (a hand's breadth) from the median plane.

•   Remains motionless throughout the cardiac cycle.

•   Is where the sounds of mitral valve closure are maximal (apex beat); the apex underlies the site where the heartbeat may be auscultated on the thoracic wall.

The base of the heart:

•   Is the heart's posterior aspect (opposite the apex).

•   Is formed mainly by the left atrium, with a lesser contribution by the right atrium.

•   Receives the pulmonary veins on the right and left sides of its left atrial portion and the superior and inferior venae cavae at the superior and inferior ends of its right atrial portion.

1.8. The four surfaces of the heart

1. **Anterior (sternocostal) surface**, faces anteriorly and consists mostly of the right ventricle with some of the right atrium on the right and some of the left ventricle on the left

2. **Diaphragmatic (inferior) surface**, formed mainly by the left ventricle and partly by the right ventricle; it is related mainly to the central tendon of the diaphragm.

3. **Right pulmonary surface**, faces the right lung, is broad and convex, and is formed by the right atrium.
4. **Left pulmonary surface**, faces the left lung, is broad and convex, and consists of the left ventricle and a portion of the left atrium.

1.9. RIGHT ATRIUM

The right atrium forms the right border of the heart and receives venous blood from the SVC, IVC, and coronary sinus. Through the right atrioventricular ori**fi**ce, the right atrium discharges the poorly oxygenated blood it has received into the right ventricle.

The ear-like **right auricle** is a conical muscular pouch that projects from this chamber like an add-on room, increasing the capacity of the atrium as it overlaps the ascending aorta. Rough, muscular anterior wall composed of **pectinate muscles** (L. musculi pectinati).

The **opening of the coronary sinus**, a short venous trunk receiving most of the cardiac veins, is between the right AV orifice and the IVC orifice. The interatrial septum separating the atria has an oval, thumbprint-size depression, the **oval fossa** (L. *fossa ovalis*), which is a remnant of the **oval foramen** (L. *foramen ovale*) and its valve in the fetus.

1.10. RIGHT VENTRICLE

The right ventricle forms the largest part of the anterior surface of the heart, a small part of the diaphragmatic surface, and almost the entire inferior border of the heart. The right ventricle receives blood from the right atrium through the right AV (tricuspid) orifice. The interventricular septum lies between the two ventricles, bulging into the right ventricle.

The interior of the right ventricle has irregular muscular elevations (**trabeculae carneae**). The right ventricle receives blood from the right atrium through the **right AV (tricuspid) orifice**.

Tendinous cords (L. chordae tendineae) attach to the free edges and ventricular surfaces of the cusps, much like the cords attaching to a parachute. The tendinous cords arise from the apices of papillary muscles. They are conical muscular projections with bases attached to the ventricular wall. The papillary muscles begin to contract before contraction of the right ventricle, tightening the tendinous cords and drawing the cusps together. Thanks to the cords, attached to adjacent sides of two cusps, the cusps of the tricuspid valve are prevented from prolapsing (being driven into the right atrium) as ventricular pressure rises. Thus regurgitation of blood (backward flow of blood) from the right ventricle back into the right atrium is blocked during ventricular systole by the valve cusps.

The **interventricular septum** is composed of muscular and membranous parts. It is obliquely placed partition between the right and left ventricles. It forms part of the walls of each ventricle. The **septomarginal trabecula (moderator band)** is a curved muscular bundle which carries part of the right branch of the AV bundle, a part of the conducting system of the heart. This "shortcut" across the chamber seems to facilitate conduction time.

1.11. LEFT ATRIUM

The **left atrium** forms most of the base of the heart. The valveless pairs of right and left pulmonary veins enter the atrium. The tubular muscular left auricle creates an extra space. It projects anteriorly. The wall of the left atrium (also right atrium) is trabeculated with pectinate muscles. The right atrium forms the superior part of the left border of the heart. It overlaps the root of the pulmonary trunk. A semilunar depression in the interatrial septum indicates the floor of the oval fossa. The surrounding ridge is the **valve of the oval fossa** (L. valvulae foramen ovale).

1.12. LEFT VENTRICLE

The left ventricle forms the apex of the heart, nearly all its left (pulmonary) surface and border, and most of the diaphragmatic surface. Because arterial pressure is much higher in the systemic than in the pulmonary circulation, the left ventricle performs more work than the right ventricle.

The interior of the left ventricle has:

• A smooth-walled, non-muscular, superoanterior outflow part, the aortic vestibule, leading to the aortic orifice and aortic valve.

• A double-leaflet mitral valve that guards the left AV orifice.

Both atria and ventricles have muscular elevations in order to increase the strength of the pumping function.

1.13. VASCULATURE OF THE HEART

The blood vessels of the heart comprise the coronary arteries and cardiac veins, which carry blood to and from most of the myocardium.

1.13.1. Arterial Supply of the Heart

The coronary arteries, the first branches of the aorta, supply the myocardium and epicardium. The right and left coronary arteries arise from the corresponding aortic sinuses. Anastomoses between the branches of the coronary arteries exist, which enables the development of the collateral circulation. The coronary arteries supply both the atria and the ventricles. The right coronary artery (RCA) arises from the right side of the ascending aorta. The left coronary artery (LCA) arises from the left side of the ascending aorta.

1.13.2. Venous Drainage of the Heart

The heart is drained mainly by veins that empty into the coronary sinus and partly by small veins that empty into the right atrium.

1.14. STIMULATING, CONDUCTING, AND REGULATING SYSTEMS OF HEART

The conducting system consists of nodal tissue that initiates the heartbeat and coordinates contractions of the four heart chambers, and highly specialized conducting fibers for conducting them rapidly to the different areas of the heart. The impulses are then propagated by the cardiac striated muscle cells so that the chamber walls contract simultaneously. Impulse generation and conduction can be summarized as follows:

• The sinu-atrial node: SA node (pacemaker of the heart; in the right atrium) initiates an impulse that is rapidly conducted to cardiac muscle fibers in the atria, causing them to contract.

• The impulse spreads by myogenic conduction, which rapidly transmits the impulse from the SA node to the atrioventricular (AV) node. The AV node is in the right atrium.

• The signal is distributed from the AV node through the AV bundle and its branches (the right and left bundles), which pass on each side of the IVS to supply subendocardial branches to the papillary muscles and the walls of the ventricles.

1.14.1. Innervation of the Heart

Innervation of the heart is through the autonomic nerves (both sympathetic and parasympathetics) from the cardiac plexus.

2. SEPTAL DEFECTS

Atrial Septal Defects (ASD): is a congenital anomaly of the interatrial septum, a hole between the two atria. Clinically significant ASDs vary widely in size and location and may occur as part of more complex congenital heart disease. Large ASDs allow oxygenated blood from the lungs to be shunted from the left atrium through the ASD into the right atrium, causing enlargement of the right atrium and ventricle and dilation of the pulmonary trunk. This left to right shunt of blood overloads the pulmonary vascular system, resulting in hypertrophy of the right atrium and ventricle and pulmonary arteries.

Ventricular Septal Defects (VSD): The membranous part of the IVS is the common site of ventricular septal defects (VSDs). VSDs rank **first on all lists of cardiac defects**. A VSD causes a left to right shunt of blood through the defect. A large shunt increases pulmonary blood flow, which causes severe pulmonary disease (hypertension, or increased blood pressure) and may cause cardiac failure.

3. VALVULAR HEART DISEASES

Disorders involving the valves of the heart disturb the pumping efficiency of the heart. Valvular heart disease produces either stenosis (narrowing) or insufficiency. Stenosis is the failure of a valve to open fully, slowing blood flow from a chamber. Insufficiency or regurgitation, on the other hand, is failure of the valve to close completely, usually owing to nodule formation on (or scarring and contraction of) the cusps so that the edges do not meet or align. This allows a variable amount of blood (depending on the severity) to flow back into

the chamber it was just ejected from. Both stenosis and insufficiency result in an increased workload for the heart. Because valvular diseases are mechanical problems, damaged or defective cardiac valves can be replaced surgically in a procedure called **valvuloplasty**.

Mitral Valve Insufficiency:
- Scarring and shortening of the cusps results in insufficiency
- Restricts the outflow of the left ventricle and leads to the hypertrophy of the myocardium
- During ventricular systole, blood regurgitates back to the left atrium.
- A hurt murmur will be heard.

Mitral Valve Stenosis:
- Narrowing of the mitral orifice.
- Restricts the outflow of the left atrium.

Pulmonary Valve Stenosis:
- Narrowing of the pulmonary valve due to the fused cusps.
- Restricts the outflow of the right ventricle and leads to the hypertrophy of the myocardium.

Pulmonary Valve Incompetence:
- Incomplete closure of the cusps due to thickening of their free margins due to a disease.
- During diastole, blood regurgitates back to the right ventricle from the pulmonary trunk.
- Heart murmur (a pathologic sound) could be heard by a stethoscope. Murmur is produced due to the turbulence caused by the blood passing from a narrow opening into a larger vessel or chamber.

Aortic Valve Stenosis:
- Aortic valve stenosis is the **most frequent valve abnormality**.
- Blood is unable to flow freely from left ventricle to aorta.
- Aortic stenosis causes extra work for the heart, resulting in left ventricular hypertrophy.

Aortic Valve Insufficiency:
- During diastole blood regurgitates from aorta back to the left ventricle.

3. AUSCULTATORY AREAS OF THE VALVES & HEART SOUNDS

On listening to the heart with a stethoscope, one can hear two sounds. The first sound is produced by the contraction of the ventricles and the closure of the tricuspid and mitral valves. The second sound is produced by the sharp closure of the aortic and pulmonary valves. It is important for a physician to know where to place the stethoscope on the chest wall so that he or she will be able to hear sounds produced at each valve with the minimum of distraction or interference.

- The **tricuspid valve** is best heard over **the right half of the lower end of the body of the sternum**.
- The **mitral valve** is best heard over the apex beat, that is, at the level of the **fifth left intercostal space**, 9 cm from the midline.
- The **pulmonary valve** is heard with least interference over the medial end of the **second left intercostal space**.
- The **aortic valve** is best heard over the medial end of the **second right intercostal space**.

Heart sounds (You can listen to the heart songs on line from the link 📺 1 2 3 4

4. PERICARDIUM

The pericardium is a fibroserous membrane that covers the heart and the beginning of its great vessels. The pericardium is a closed sac composed of two layers.

The pericardium is a closed sac composed of two layers:

1) Fibrous pericardium (external)
continuous with the central tendon of the diaphragm

2) Serous pericardium (internal)

Parietal layer

Visceral layer (epicardium)

The pericardial cavity is the potential space between opposing layers of the parietal and visceral layers of serous pericardium. It normally contains a thin film of fluid that enables the heart to move and beat in a frictionless environment.

5. VESSELS IN THE BODY

5.1. GREAT VESSELS

The right and left brachiocephalic veins are formed by the union of the internal jugular and subclavian veins. The brachiocephalic veins unite to form the superior vena cava (SVC). The superior vena cava (SVC) returns blood from all structures superior to the diaphragm, except the lungs and heart. It ends by entering the right atrium of the heart. The ascending aorta begins at the aortic orifice. Its only branches are the coronary arteries, arising from the aortic sinuses. The arch of the aorta (aortic arch) is the curved continuation of the ascending aorta. The usual branches of the arch are the brachiocephalic trunk, left common carotid artery, and left subclavian artery.The ligamentum arteriosum, the remnant of the fetal ductus arteriosus, passes from the root of the left pulmonary artery to the inferior surface of the arch of the aorta.

5.2. ARTERIES IN THE BODY

What happens to descending aorta (thoracic aorta) which is the continuation of the arch of aorta is that after passing through the diaphragm, it becomes the abdominal aorta which finally terminates as common iliac arteries . These arteries bifurcate into external and internal iliac arteries.

The **external iliac arteries**, after passing below the inguinal ligament, will become **femoral arteries**. The femoral arteries will supply the lower limbs. On both sides, these arteries will continue as **popliteal arteries** back in the "popliteal fossa". The popliteal artery branches into anterior and posterior tibial arteries. The anterior tibial artery becomes the dorsal pedis artery (dorsal artery of the foot) while passing over the ankle joint.

The **subclavian artery** continues as axillary artery. The axillary artery becomes brachial artey on both arms. The brachial artery divides into ulnar and radial arteries at the elbow. Distally, the ulnar artery swings laterally across the palm. It forms the superficial palmar arch. The deep palmar arch is basically formed as the continuation of the radial artery. Both the brachial artery (in the arm), and femoral artery (in the thigh) have a deep branch as the most important/largest branch [deep artery of the arm (profunda brachii artery), deep artery of thigh (profunda femoris artery)].

The **common carotid artery** divides into external carotid artery and internal carotid artery. The external carotid artery basically supplies blood to the face and neck, and the internal one to the brain. The external carotid artery has important branches such as lingual artery, facial artery.

At the bifurcation, the common carotid artery and the beginning of the internal carotid artery are dilated. This dilation is the **carotid sinus** and contains receptors that monitor changes in blood pressure and are innervated by a branch of the glossopharyngeal nerve [IX].   Another accumulation of receptors in the area of the bifurcation is responsible for detecting changes in blood chemistry, primarily oxygen content. This is the **carotid body** and is innervated by branches from both the glossopharyngeal [IX] and vagus [X] nerves.

The other artery of the brain is the vertebral artery which is a thick branch of the subclavian artery.

5.3. VEINS IN THE BODY

Although arteries are generally located in deep, well-protected body areas, many veins are more superficial and some are easily seen and palpated on the body surface. Most deep veins follow the course of the major arteries, and with a few exceptions, the naming of these veins is identical to that of their companion arteries. While major systemic arteries branch off the aorta, the veins converge on the **vena cava**.

Blood returns to the **right atrium** of the heart through the vena cava. Veins draining the head and arms empty into **superior vena cava**. Veins draining the lower body empty into **inferior vena cava**.

The veins listed below begin distally and move proximally to the heart.

Veins Draining into the Superior Vena Cava

- **Radial** and **ulnar veins** are deep veins draining the forearm. They unite to form the **brachial vein**. It drains the arm. It empties into the **axillary vein**.
- **Cephalic vein** provides superficial drainage of the lateral aspect of the arm and empties into the axillary vein.

- **Basilic vein** provides superficial drainage of the medial aspect of the arm into the **brachial vein**.
The basilic and cephalic veins are joined at the anterior aspect of the elbow by the **median cubital vein**. (This vein is often the site for blood removal for the purpose of blood testing.) The **dorsal venous arch of the hand** is drained into the basilica medially and cephalic veins laterally.
- **Subclavian vein** receives blood from the arm through the **axillary vein** and from the skin and muscles of the head through the **external jugular vein**.
- **Left & right brachiocephalic veins** drain the subclavian, vertebral, and internal jugular veins on their respective sides. The brachiocephalic veins join to form the **superior vena cava**, which enters the heart.

Veins Draining into the Inferior Vena Cava

- The **inferior vena cava**, which is much longer than the superior vena cava, returns blood to the heart from all body regions below the diaphragm.
- *Anterior and posterior tibial veins* and the *peroneal (or fibular) vein* drain the calf and foot. The **posterior tibial vein** becomes the **popliteal vein** at the knee and then the **femoral vein** in the thigh. The **femoral vein** becomes the **external iliac vein** as it enters the pelvis.
- **Great saphenous veins** are the longest veins in the body. They receive the superficial drainage of the leg. They are on the medial side of the leg and thigh and drain into the femoral vein. On the lateral side of the leg is the small saphenous vein. It empties into the popliteal vein.
Each left and right common iliac vein is formed by the union of the external iliac vein and the internal iliac vein (which drains the pelvis) on its own side. The common iliac veins join to form the inferior vena cava, which then ascends superiorly in the abdominal cavity.

5.4. LYMPHATIC SYSTEM

Lymphatic vessels form an extensive and complex interconnected network of channels, which begin as "porous" blind-ended lymphatic capillaries in tissues of the body and converge to form a number of larger vessels, which ultimately connect with large veins in the root of the neck.

Lymphatic vessels mainly collect fluid lost from vascular capillary beds during nutrient exchange processes and deliver it back to the venous side of the vascular system. Also included in this interstitial fluid that drains into the lymphatic capillaries are pathogens, cells of the lymphocytic system, cell products (such as hormones), and cell debris.

The fluid in most lymphatic vessels is clear and colorless and is known as **lymph**. There are lymphatic vessels in most areas of the body except the brain, bone marrow, and avascular tissues such as epithelia and cartilage.

The movement of lymph through the lymphatic vessels is generated mainly by the indirect action of adjacent structures, particularly by contraction of skeletal muscles and pulses in arteries. Unidirectional flow is maintained by the presence of valves in the vessels.

Lymph nodes are small (0.1-2.5 cm long) encapsulated structures that interrupt the course of lymphatic vessels and contain elements of the body's defense system, such as clusters of lymphocytes and macrophages.

All lymphatic vessels coalesce to form larger trunks or ducts, which drain into the venous system at sites in the neck where the internal jugular veins join the subclavian veins to form the brachiocephalic veins (venous angle). The major lymphatic trunks (right lymphatic duct and thoracic duct) enter the venous angles formed by the convergence of these veins

- Lymph from the right side of the head and neck, the right upper limb, right side of the thorax, and right side of the upper and more superficial region of the abdominal wall is carried by lymphatic vessels that connect with veins on the right side of the neck (right lymphatic trunk)
- lymph from all other regions of the body is carried by lymphatic vessels that drain into veins on the left side of the neck (thoracic duct)

The **thoracic duct** is a major lymphatic channel that begins in the abdomen, passes superiorly through the thorax, and ends in the venous channels in the neck.

Lymphatic drainage of the body by the two main lymphatic trunks