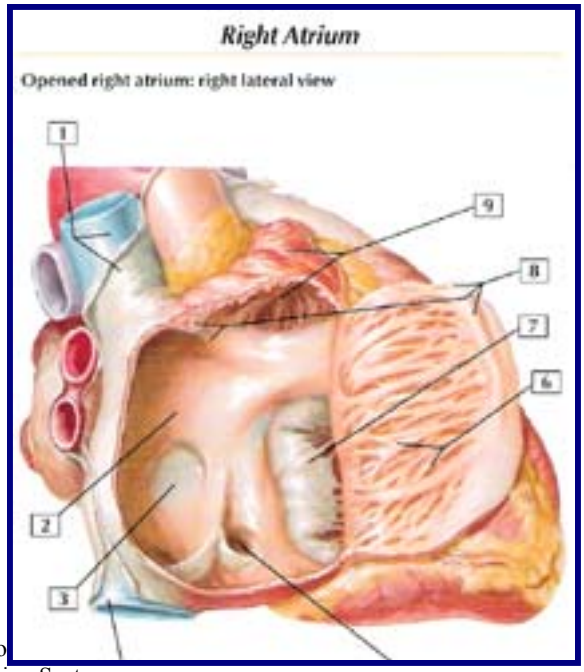
Dissection 12:
The Heart and Mediastinum

Objective 1)
Trace the course of blood through the right side of the heart, indicating the internal structures of the atrium and ventricle and the anatomical disposition of each of the valves. Identify the anatomic location of elements of the impulse conducting system of the heart.

A). Course of blood on the right side:
- i. Deoxygenated blood enters the right atrium (RA) from the superior and inferior vena cava and the coronary sinus.
- ii. De-O_2 blood enters the right ventricle (RV) through the tricuspid valve and right AV orifice to the inflow tract posteriorly.
- iii. The de-O_2 blood makes a U-shaped path through the RV to its outflow tract (conus arteriosus) and leaves superiorly and to the left through the pulmonary valve.
- iv. Blood flows out through the pulmonary trunk to the pulmonary arteries to the lungs.

B). Right atrium and its internal structures:
- i. Forms the right border of the heart.
- ii. Has right auricle – a small, conical, muscular pouch projecting over the ascending aorta increasing atrial capacity.
  1. The right auricle is the remnant of the primordial right atrium.
- iii. The coronary sinus receives blood from the cardiac veins and drains into the RA posteriorly.
  1. Derivative of the embryonic venous sinus – sinus venosus.
- iv. Interior of RA:
  1. Sinus venarum: smooth, thin-walled posterior part that the SVC, IVC, and coronary sinus dump into
     a. Formed from incorporation of the sinus venosus into the RA
  2. Pectinate muscles: rough muscular wall of RA (L. musculi pectinati)
  3. Opening of the SVC: into superior part at level of right 3rd costal cartilage
  4. Opening of the IVC: into inferior part almost in line with the SVC at



approximately the level of the 5th costal cartilage

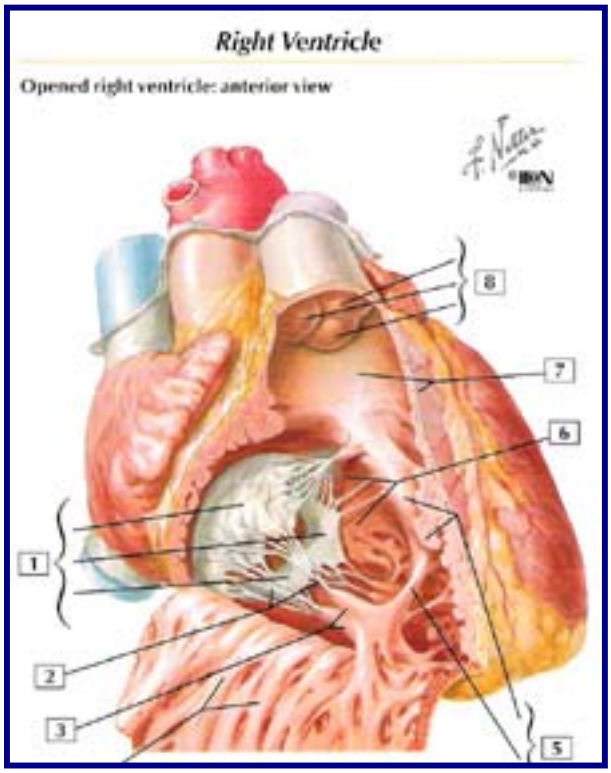
5. Opening of the coronary sinus: b/ the right AV orifice and the IVC orifice
6. Right AV orifice: through which the RA discharges the de-O_2 into the RV
7. Terminal crest: indication of the separation of the sinus venarum and auricle internally
    a. Called the terminal groove on the outside
8. Interatrial septum: separates the atria
9. Fossa ovale: thumbprint-sized depression in the interatrial septum that is a remnant of the foramen ovale and its valve in the fetus

C). Right ventricle and its internal structures:

i. Forms most of the largest part of the anterior surface, small part of the diaphragmatic surface, and almost the entire inferior border of the heart.

ii. Superiorly the RV tapers into an arterial cone – the conus arteriosus – that leads into the pulmonary trunk.

iii. Interior of RV:



1. Trabeculae carneae: irregular muscular elevations in the RV
2. Supraventricular crest: separates the ridged muscular wall of the inflow part of the chamber from the smooth wall of the conus arteriosus (outflow part).
3. Tricuspid valve: 3-cusped valve that guards the right AV orifice to prevent back flow into the RA and located posterior to the body of the sternum at the level of the 4th and 5th intercostal spaces.
    a. Anatomical disposition: thin, attached to the fibrous ring that surrounds the orifice, and need to be held in place to prevent them from opening into the RA and allowing back flow.
4. Chordae tendineae: attach to the free edges and ventricular surfaces of the anterior, posterior, and septal cusps.
    a. B/c they attached to the sides of the two cusps, they keep the cusps from separating and inverting during systolic pressure, and thus, prevent regurgitation.
5. Papillary muscles: muscles attached to the RV wall and chordae tendineae that arise from their apices. 3 in the RV (anterior, posterior, and septal), and contract before RV contraction and stay contracted through systole to tense and pull the tricuspid valve closed.

6. Interventricular (IV) septum: strong, oblique partition b/ the ventricles forming walls of each.
    a. Has superoposterior membranous portion that is thin and continuous with the fibrous skeleton and a thick muscular portion that bulges into the RV.
7. Septomarginal trabeculae (moderator band): curved muscular bundle that runs from the inferior part of the IV septum to the base of the anterior papillary muscle. It carries part of the right bundle of the AV bundle. Provides a "short cut" across the chamber of the ventricle to the anterior papillary muscle.
8. Right AV orifice
9. Conus arteriosus is smooth on inside
10. Pulmonary valve: 3 cusps (anterior, right, and left) and b/ the conus arteriosus and pulmonary trunk. It is located at the apex of the conus arteriosus at the level of the 3rd costal cartilage.
    a. Anatomical disposition: Thicker and concave when viewed superiorly. Don't need to be tethered, open into the pulmonary trunk, and close when ventricular pressure is below pulmonary artery pressure. Prevent regurgitation to the RV. Prevented from sticking to pulmonary trunk by pulmonary sinuses – spaces at origin of pulmonary trunk b/ dilated wall of vessel and cusp that fill with blood as lubricant.

D). Impulse conducting system of the heart:

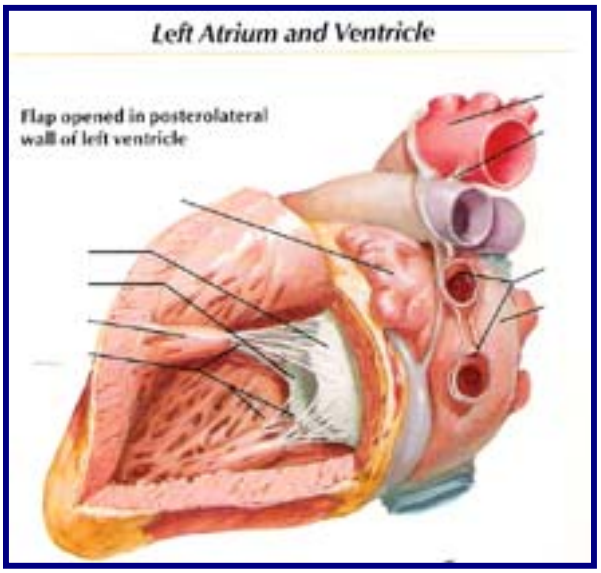
i. Conduction pathway: SA node → atrial muscle fibers → AV node → AV bundle/ Bundle of His → Right and left bundle branches → Subendocardial branches/ Purkinje fibers → Papillary and ventricular muscle cells
ii. Sinoatrial (SA) node: located anterolaterally just deep to the epicardium at the junction of the SVC and the right atrium.
iii. Atrioventricular (AV) node: located in the posteroinferior region of the interatrial septum near the opening of the coronary sinus.
iv. Atrioventricular (AV) bundle: located through the fibrous skeleton of the heart and along the membranous part of the IV septum.
v. Right and left bundle branches: start at the junction of the membranous and muscular IV septum deep to the endocardium and ramify into the subendocardial branches (Purkinje fibers) that extend into the walls of the ventricles.
vi. Septomarginal trabeculae: located from the inferior part of the IV septum to the base of the anterior papillary muscle.

Objective 2)
Trace the course of blood through the left side of the heart, indicating the internal structures of the atrium and ventricle and the anatomical disposition of each of the valves. Compare the course of blood through the heart and great vessels in fetal life to that in adults.

E). Course of blood on the left side:

i. Oxygenated blood enters the left atrium (LA) from the right and left pairs of pulmonary veins.

ii. O_2 blood enters the left ventricle (LV) through the mitral valve and left AV orifice to the inflow tract.
iii. The O_2 blood makes a U-shaped path through the LV to its outflow tract (aortic vestibule) and leaves superoanteriorly through the aortic valve.
iv. Blood flows out through the aortic orifice to the aorta and to the body.



F). Left atrium and its internal structures:
i. Forms most of the base of the heart.
ii. The <u>left auricle</u> forms the superior part of the left border of the heart and overlaps the pulmonary trunk.
iii. Interior of LA:
1. A larger <u>smooth-walled part</u>
2. A smaller <u>muscular auricle</u> lined with <u>pectinate muscles</u>
3. <u>Four pulmonary veins</u> (2 superior and 2 inferior) entering into the posterior wall
4. Slightly thicker wall than the RA
5. <u>Interatrial septum</u> that slopes posteriorly and to the right
6. <u>Left AV orifice</u> through which the LA discharges the O_2 blood into the LV

G). Left ventricle and its internal structures:
i. Forms the apex of the heart, nearly all of the left (pulmonary) surface and border, and most of the diaphragmatic surface.
ii. Thicker walls (more than 2x) than the RV and does more work.
iii. Interior of LV:
1. <u>Mitral valve</u>: double leaflet (anterior and posterior cusps) that guards the left AV orifice. Located posterior to the sternum at the level of the 4^{th} costal cartilage.
a. Anatomical disposition: thin, attached to the fibrous ring that surrounds the orifice, and need to be held in place to prevent them from opening into the LA and allowing back flow.
2. <u>Conical cavity</u> that is longer than that of the RV
3. Walls covered with thick muscular ridges – <u>trabeculae carneae</u> – that are more numerous than the RV
4. <u>Anterior and posterior papillary muscles</u> that are larger than those in the RV
5. Chordae tendineae
6. <u>Aortic vestibule</u>: smooth-walled superoanterior outflow part of LV
7. <u>Aortic orifice</u>: opening to aorta located in the right posterosuperior part and is surrounded by a fibrous ring

8. Aortic valve: 3 cusps (right, posterior, and left). Located obliquely placed to the left of the sternum at the level of the 3rd intercostal space.
    a. Anatomical disposition: Thicker and concave when viewed superiorly. Don't need to be tethered, open into the aorta, and close when ventricular pressure is below aortic pressure. Prevent regurgitation to the LV. Prevented from sticking to aorta by aortic sinuses – spaces at origin of pulmonary trunk b/ dilated wall of vessel and cusp that fill with blood; the left and right aortic sinuses have the opening to the left and right coronary arteries, respectively.

H). Differences in fetal circulation than adult circulation:

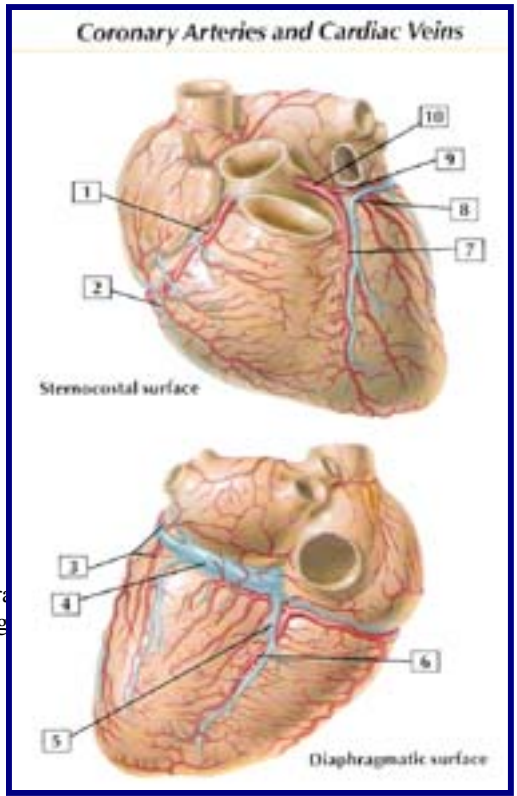
i. *Fully oxygenated blood* traveling in the umbilical vein goes to the liver or to the right atrium. Half of the blood from the umbilical vein bypasses the liver via the ductus venosus, which connects the umbilical vein with the IVC. The rest of the blood from the umbilical vein flows through the sinusoids of the liver and then enters the IVC through the hepatic veins. From the IVC, blood flows into the *right atrium*. Thus, the RA is receiving both deoxygenated blood from the SVC, IVC and coronary sinus and oxygenated blood from the IVC by way of the umbilical vein. Some of the blood passes from the *RA* to the *RV*, and most of it passes through the 1-way valve, the foramen ovale, in the interarterial septum, from the *RA* to the *LA*. Blood in the RV goes through the pulmonary valve into the *pulmonary trunk*. The ductus arteriosus allows blood to pass from the root of the *left pulmonary artery* into the arch of the *aorta*. The purpose of the ductus arteriosus and the foramen ovale is to divert blood from the developing lungs, which are not involved in gas exchange during fetal life. Blood that makes it to the lungs from the *pulmonary arteries* then goes to the *LA* via the pulmonary veins. Blood flows from *LA* to *LV* through the mitral valve, and from the LV to the *aorta* via the aortic valve. From the aorta, blood flows into the systemic vasculature. The umbilical arteries carry deoxygenated blood from the *descending aorta* of the fetus to the placenta for gas exchange.
    1. The interatrial septum has an opening – the foramen ovale – that shunts blood from the RA to the LA to minimize blood to the nonfunctioning fetal lungs.
    2. The ductus arteriosus passes from the root of the left pulmonary artery to the inferior surface of the arch of the aorta and shunts blood to the aorta to bypass the fetal lungs. In the adult, it is closed and become connective tissue and is known as the ligamentum arteriosum.

Objective 3)
Follow the course of blood through each of the major coronary vessels. Describe the venous return from heart musculature and the location of these veins and relationship with the coronary arteries as they drain into the coronary sinus.

I). Right coronary artery (RCA): Arises from the right aortic sinus and follows the coronary (AV) groove (sulcus) b/ the atria and ventricles.
    i. Near its origin, the RCA usually gives off an ascending sinoatrial nodal branch to supply the SA node.

ii. The RCA continues to descend in the coronary groove to give off the right marginal branch that supplies the right border of the heart as it runs towards (but does not reach) the apex of the heart.
iii. After giving off the right marginal branch, the RCA turns left and continues in the coronary groove on the posterior aspect of the heart moving to the crux of the heart (junction of the septa and walls of all 4 chambers).
iv. At the crux, the RCA gives off the AV nodal branch, which supplies the AV node.
v. The RCA then gives off the large posterior IV artery, which runs in the posterior IV groove to supply both ventricles and give off perforating IV septal branches.
vi. Near the apex of the heart the RCA anastomoses with the circumflex and anterior IV septal branches of the LCA.
vii. Typically, the RCA supplies:
    1. The right atrium
    2. Most of the right ventricle
    3. Part of the left ventricle (diaphragmatic surface)
    4. Part of the IV septum (usually posterior 1/3)
    5. The SA node (in approximately 60%)
    6. The AV node (in approximately 80%)

J). Left coronary artery (LCA): Arises from the left aortic sinus and passes b/ the left auricle and the pulmonary trunk in the coronary groove.
i. At the left end of the coronary groove – located just left of the pulmonary trunk – the LCA divides into two branches: the anterior IV branch and the circumflex branch.
ii. The anterior IV branch (Left Anterior Descending branch, LAD branch) passes along the IV groove to the apex of the heart where it turns around the inferior border of the heart and anastomoses with the posterior IV branch of the RCA. The anterior IV branch supplies both ventricles and the IV septum.
    1. In most people, the anterior IV artery gives off the lateral (diagonal) branch, which descends on the anterior surface of the heart.
iii. The circumflex branch of the LCA is smaller and follows the coronary groove around the left border of the heart to the heart's posterior border. The circumflex branch terminates on the posterior aspect of the heart and often anastomoses with the posterior IV branch of the RCA.
    1. The circumflex branch gives off a SA nodal branch in 40% of people, which ascends on the posterior surface of the left atrium to the SA node.
    2. The left marginal artery, a branch of the circumflex branch, follows the left margin of the heart and supplies the left ventricle.
iv. Typically, the LCA supplies:
    1. The left atrium
    2. Most of the left ventricle



3. Part of the right ventricle
4. Most of the IV septum (usually the anterior 2/3), including the AV bundle of conducting tissue through its perforating septal branches.
5. The SA node (in approximately 40%)

K). Venous return of the heart:

i. The heart is drained primarily by the coronary sinus and small anterior cardiac veins to the right atrium and the smallest cardiac veins to the other chambers.

ii. The coronary sinus, the main vein of the heart, is a wide venous channel that runs from left to right in the posterior part of the coronary groove. It receives blood from the great cardiac vein (on the left), the middle and small cardiac veins (on the right), the left posterior vein, the left marginal veins, and the oblique vein of the left atrium.

1. The great cardiac vein runs in the IV groove of the heart along side of the anterior IV branch of the LCA. It will drain into the left side of the coronary sinus.
2. The middle cardiac vein runs with the posterior IV branch of the RCA in the posterior IV groove before it drains into the right side if the coronary sinus.
3. The small cardiac vein runs with the right marginal branch of the RCA and the RCA in the coronary groove before it drains into the right
4. The left posterior vein runs b/ the middle cardiac vein and left marginal vein on the posterior wall to the middle of the coronary sinus.
5. The left marginal vein runs with the left marginal branch of the circumflex branch of the LCA along the left margin of the heart before it dumps into the left side if the coronary sinus.

iii. The smallest cardiac veins (L. venae cordis minimae) are minute vessels that begin in the capillary beds of the myocardium and open directly into the chambers of the heart, chiefly the atria. They are valveless communications with capillary beds of the myocardium and may carry blood both ways providing collateral circulation to heart musculature.

Objective 4)
Trace the course of the vagus nerve through subdivisions of the mediastinum. Identify its major branches and target organs. Identify the sympathetic trunk, the greater, lesser, and least splanchnic nerves.

L). Vagus nerves (CN X): Start bilaterally from the medulla, exit the cranium, and run posterolateral to the carotid arteries in the neck. Each one enters the superior mediastinum posterior to the respective brachiocephalic vein and sternoclavicular joint.

i. Right vagus nerve:

1. Enters the thorax anterior to the right subclavian artery, where it gives rise to the right recurrent laryngeal nerve, which hooks around underneath the right subclavian artery and ascends b/ the trachea and esophagus to supply the larynx.
2. The right vagus nerve continues posteroinferiorly through the superior mediastinum on the right side of the trachea. It passes

posterior to the right brachiocephalic vein, SVC, and root of the right lung. Here it beaks up into numerous branches to contribute to the pulmonary plexus.

3. It usually leaves the pulmonary plexus as one nerve, passes to the esophagus to break up and contribute to the esophageal plexus and cardiac plexus before passing to the abdomen.

ii. Left vagus nerve:

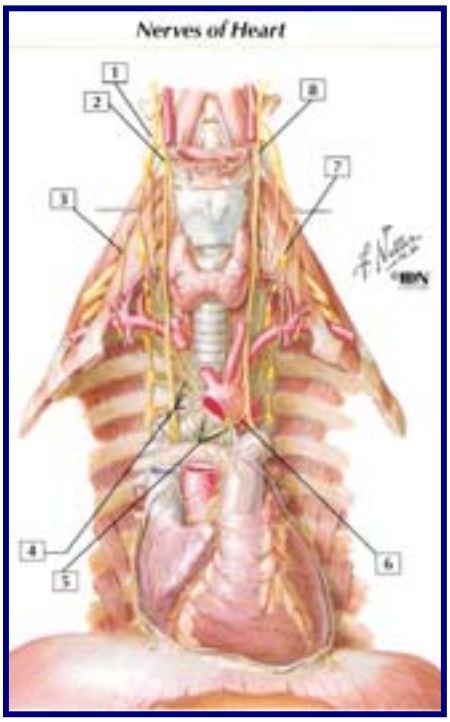
1. Enters the thorax and mediastinum b/ the left common carotid and left subclavian arteries and posterior to the left brachiocephalic vein. When it reaches the left side of the aortic arch, it diverges posteriorly fro the left phrenic nerve and is separated from it by the left superior intercostal vein. As the left vagus nerve curves medially at the inferior border of the aortic arch, it gives off the left recurrent laryngeal nerve, which passes inferior to the arch just posterolateral to the ligamentum arteriosus and ascends to the larynx in a groove b/ the trachea and esophagus.
2. The left vagus nerve continues and passes posteriorly to the root of the left lung and breaks up into many branches to the pulmonary and cardiac plexuses. A single nerve reforms and goes to join fibers of the esophageal plexus before passing to the abdomen.

M). Plexuses:

i. Pulmonary plexus: Forms along the roots of the lungs and extends along bronchial subdivisions. Parasympathetic constrict and sympathetic dilate.

ii. Cardiac plexus: From arch of the aorta and posterior surface of the heart, fibers extend along coronary arteries and to the SA node. Parasympathetic slows heart; sympathetic speeds it up.

iii. Esophageal plexus: Distal to tracheal bifurcation and forms around the esophagus. Goes to the glands and smooth muscle of inferior 2/3 of esophagus.



N). Sympathetic nerves:

i. Sympathetic trunk: The thoracic sympathetic trunks lie against the heads of the ribs in the superior part of the thorax, the costovertebral joints in the midthoracic level, and the sides of the vertebral bodies in inferior part of the thorax. These trunks get preganglionic sympathetic fibers from the intermediolateral column of the spinal cord. There they can synapse with cell bodies in the paravertebral ganglia in the thoracic sympathetic trunks and leave via gray rami communicantes as postganglionic sympathetic fibers, or they can just pass through and leave as splanchnic nerves.

1. The sympathetic trunks contribute postganglionic fibers to the cardiac plexus, pulmonary plexus, and the esophageal plexus.

ii. Lower thoracic splanchnic nerves: Also known as the greater (from T5-T9 or 10), lesser (from T10-T11), and least (from T12) splanchnic nerves. They

are part of the abdominopelvic splanchnic nerves because they supply viscera inferior to the diaphragm. They consist of preganglionic sympathetic fibers from 5^{th} -12^{th} sympathetic ganglia, which pass through the diaphragm and synapse in prevertebral ganglia in the abdomen to supply most abdominal viscera.

Objective 5)
Identify the innervation of the diaphragm and indicate its segmental source and the pathways taken by these nerves to reach their destination. Identify the parietal, visceral and fibrous pericardia and their relationship to the parietal pleura.

O). The phrenic nerves innervate the diaphragm and come from the anterior rami of cervical spinal nerves C3, C4, and C5. The phrenic nerves are the sole motor innervation of the diaphragm, and approximately 1/3 of its fibers are sensory. (The peripheral parts of the diaphragm receive their sensory innervation from the lower 6 or 7 intercostal nerves and the subcostal nerves (which come from ventral rami of the thoracic vertebrae at the corresponding level)). Each phrenic nerve enters the superior mediastinum b/ the subclavian artery and the origin of the brachiocephalic vein.

i. Right phrenic nerve: Passes along the right side of the right brachiocephalic vein, SVC, and pericardium over the right atrium. It also passes anterior to the root of the right lung and descends on the right side of the IVC to the diaphragm passing through the caval opening (foramen).
ii. Left phrenic nerve: Descends b/ the left subclavian and left common carotid arteries, crosses the left surface of the arch of the aorta anterior to the left vagus nerve, and passes over the left superior intercostal vein. It then descends anterior to the root of the left lung and runs along pericardium, superficial to the left atrium and ventricle of the heart, where it penetrates the diaphragm to the left of the pericardium.

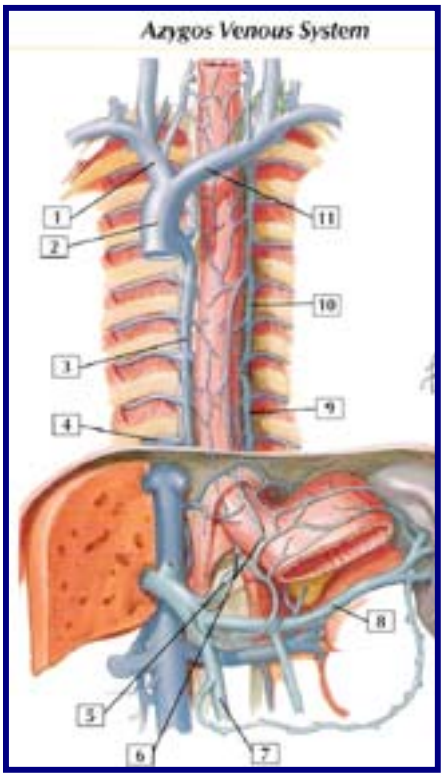
P). Pericardium is double-walled fibroserous sac that encloses the heart and the roots of its great vessel.

i. Fibrous pericardium: the tough external fibrous layer of the sac that is the outer layer and bound to the central tendon of the diaphragm. It is tough enough to prevent the overfilling of the heart.
ii. Serous pericardium: single layer of flattened cells forming the epithelium that lines both the internal surface of the fibrous pericardium and the external surface of the heart.
    1. Parietal layer of the serous pericardium lines the fibrous pericardium.
    2. Visceral layer of the serous pericardium lines the epicardium of the heart.
iii. The pericardium lies deep to the mediastinal parietal pleura on its sides and deep to the costal parietal pleura on its anterior side.

Objective 6)
Trace the drainage of blood into the azygos system of veins and indicate any collateral connections to other parts of the systemic venous system. Trace the flow of lymph through the thoracic duct. Indicate the source of afferent lymphatics to the duct (whether or not they are present in your cadaver) and its termination.

Q). Azygos system: On each side of the vertebral column and it drains the back thoracoabdominal walls, as well as the mediastinal viscera. The azygos system exhibits much variation, not only in its origin but also in its course, tributaries, anastomoses, and termination.

i. The azygos vein lies on the right side of the vertebral bodies. It is formed by the ascending lumbar veins and the right subcostal vein. It receives blood from the posterior intercostal veins and ascends to join the SVC. It can also receive blood from the vertebral venous plexuses that drain the back, vertebrae and structures in the vertebral canal. It also receives blood from the mediastinal, esophageal, and bronchial veins.



ii. The hemiazygos vein is formed by the left subcostal and ascending lumbar veins. It usually drains intercostal veins from about intercostal space 9 to 11 before crossing over to join the azygos vein.

iii. The accessory hemiazygos vein is a connection of posterior intercostal veins on the left side of the body from about intercostal spaces 5 to 8 that crosses over to join the azygos vein superior to the hemiazygos vein.

iv. The posterior intercostal vein of the 1st intercostal space usually ascends to drain directly into the brachiocephalic vein.

v. The posterior intercostal veins of the 2nd to 4th intercostal spaces join to form the superior intercostal vein which ascends to join the brachiocephalic vein.

vi. The azygos vein forms a collateral pathway b/ the SVC and IVC and drains blood from the posterior walls of the thorax and abdomen.

vii. The azygos vein ascends in the posterior mediastinum, passing close to the right sides of the bodies of the inferior eight thoracic vertebrae. It arches over the superior aspect of the root of the right lung to join the SVC.

viii. In addition, to the posterior intercostal veins, the azygos vein communicates with the vertebral venous plexus that drain the back, vertebrae, and structures in the vertebral canal. The azygos vein receives the mediastinal, esophageal, and bronchial veins.

ix. Collateral Connections:

1. The azygos vein can also arise from anastomoses with the IVC and/or renal vein and the lumbar veins to form a collateral connection between the IVC and SVC.
2. There can be connections between the superior intercostal vein and the accessory hemiazygos.
3. The superior intercostal vein can also join the azygos vein directly.

4. In some people, an accessory azygos vein parallels the main azygos vein on the right side.
5. Other people have no hemiazygos system of veins.
6. A clinically important, although uncommon, variation is when the azygos system receives all the blood from the IVC, except that from the liver. In these people the azygos system drains all the blood inferior to the diaphragm except from the digestive tract.
7. If an obstruction of the SVC occurs superior to the entrance of the azygos vein, blood can drain inferiorly into the veins of the abdominal wall and return to the right atrium through the IVC and azygos system of veins.

R). Thoracic duct:

i. In the posterior mediastinum, it conveys most of the lymph (from lower limbs, pelvic cavity, abdominal cavity, left side of the thorax, left side of the head, neck, and left upper limb).
ii. Originates in the chyle cistern in the abdomen and ascends through the aortic hiatus in the diaphragm. It ascends b/ the thoracic aorta on its left, the azygos vein on the right, the esophagus anteriorly, and vertebral bodies posteriorly. It turns to the left at the T4, T5, or T6 vertebrae, posterior to the esophagus, and ascends into the superior mediastinum.
iii. The thoracic duct receives branches from the middle and upper intercostal spaces of both sides through several collecting trunks. It also receives branches from posterior mediastinal structures.
iv. Near its termination, it often receives the jugular, subclavian, and bronchomediastinal lymphatic trunks.
v. It usually empties into the venous system near the union of the left internal jugular and subclavian veins – the left venous angle – or origin of the left brachiocephalic vein.