

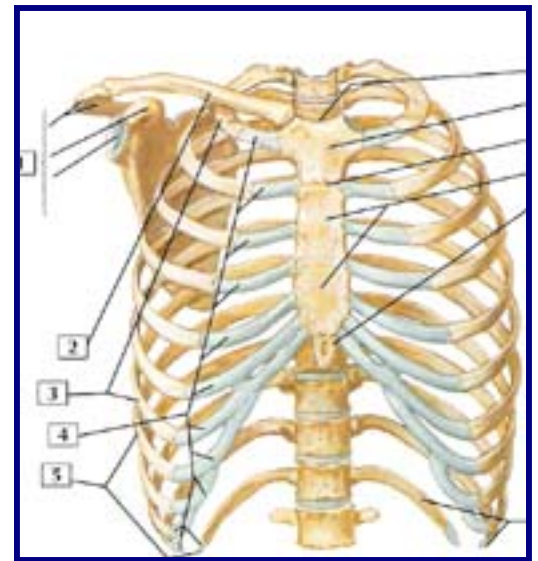
Objective 1)

Identify and compare typical and atypical ribs. Identify osseous portions of the sternum. Describe joints, ligaments and movements associated with respiration. Identify, give function and innervation of intercostal muscles and the diaphragm. Identify the muscles that are considered to be accessory muscles of respiration.

A). Ribs: There are twelve ribs that make up the rib cage by articulating with the sternum anteriorly and the vertebrae posteriorly.

i. Typical ribs (3-9): Typical ribs have three attachments to the thoracic vertebrae: one to the vertebra above and two to the same level vertebrae (its body and transverse process). In the anterior, the ribs attach to cartilage that articulates with the sternum (breastbone). The ribs have several parts:

1. Head: has 2 facets for attachment to 2 thoracic vertebral bodies separated by the crest of the head; the same number vertebra and the one above it. (E.g. Rib 4 articulates with T4 and T3).
2. Neck: between head and tubercle.
3. Tubercle: lateral to the neck, articulates with the transverse process of the same numbered thoracic vertebrae. Have smooth articular part for articulating with the corresponding transverse process of the vertebrae and a rough nonarticular part for attachment of the costotransverse ligament.
4. Body:
 - a. Angle: lateral to the tubercle and is part of the attachment of the iliocostalis muscle.
 - b. Shaft (Body): forms the lateral chest wall.
 - c. Costal Groove: contains the vein, artery, and nerve for each intercostal space.



ii. Atypical ribs

1. Rib 1: Shortest, broadest, and most sharply curved. Only has one articulation with vertebra T1 and no costal groove because it has grooves on the superior surface for the subclavian artery and vein, which are separated by the scalene tubercle the insertion sight for the anterior scalene muscle
2. Rib 2: Different angle of orientation than the typical ribs; it is oriented intermediately between the first and typical ribs.

3. Rib 10: Has only one facet articulating with T10
 4. Rib 11 and 12: (floating ribs): Has one facet articulating with the vertebrae. Do not articulate with anything to the anterior and have no tubercle-transverse process interaction and no necks.
- B). Sternum: Has 3 main parts and forms middle of the anterior part of the chest wall.
- i. Manubrium: The superior part (@ T3-T4 level); has the jugular notch; and articulates with the clavicles at the clavicular notches; also articulates with the first and second costal cartilages; the inferior border articulates with the body of the sternum at the manubriosternal joint (this surface elevation that is produced is the sternal angle). It is anterior to the arch of the aorta.
 - ii. Body: composed of the 2nd-5th sternbrae (fused) and @ T5-T9 level. Articulates with the second through seventh costal cartilages @ costal notches and at the lower end it articulates with the xiphoid process.
 - iii. Xiphoid Process: The lower tip of the sternum @ T10 level. Made of hyaline cartilage and ossifies and is an important marker for CPR.
- C). Joints, Movements, and Ligament associated with respiration
- i. Intervertebral joints:
 1. Symphysis joint b/ bodies of vertebrae with intervertebral discs in between.
 2. Ligaments: anterior and posterior longitudinal ligaments
 - ii. Costovertebral joints:
 1. Synovial plane joint b/ the head of each rib and the inferior costal facet of the body of the superior vertebrae and the costal facet of the body of the inferior vertebrae.
 2. Ligaments: radiate and intra-articular ligaments of the head of the rib
 - iii. Costotransverse joints:
 1. Synovial plane joints b/ the articulation of the tubercle of the rib and the transverse process of the corresponding vertebrae.
 2. Ligaments: lateral and superior costotransverse
 - iv. Sternocostal joints:
 1. B/ 1st rib and sternum: primarily cartilaginous joint b/ 1st costal cartilage and manubrium
 2. B/ 2nd to 7th ribs and sternum: synovial plane joints b/ the 2nd to 7th costal cartilages and the body of the sternum
 3. Ligaments: anterior and posterior radiate sternocostal
 - v. Sternoclavicular joints:
 1. Saddle type joint b/ the sternal end of the clavicle with the manubrium and 1st costal cartilage.
 2. Ligaments: anterior and posterior sternoclavicular ligaments and costoclavicular ligaments
 - vi. Costochondral joints:
 1. Primarily cartilaginous joints b/ lateral end of costal cartilage and sternal end of rib
 2. Ligaments: cartilage and bone are held together by the periosteum → no movements around this joint
 - vii. Interchondral joints:
 1. Synovial plane joint b/ costal cartilages of 6th-7th, 7th-8th, and 8th-9th ribs
 2. Ligaments: interchondral ligaments
 - viii. Movements:

1. Movements of the thoracic wall and diaphragm increase intrathoracic volume during inspiration and decrease it during expiration.
 2. During inspiration, the vertical diameter of the diaphragm increases as the central diaphragm descends.
 3. During expiration, the central part of the diaphragm returns decreasing pressure; the lungs move, and the domes of the diaphragm ascend.
 4. The transverse diameter of the thorax increases with intercostal muscle contraction raising the middle of the ribs → bucket-handle movement.
 - a. The downwardly curved ribs ascend pivoting @ both ends. They move superolaterally like a bucket handle being raised.
 5. The anteroposterior diameter of the thorax increases with intercostal muscle contraction because the ribs (primarily 2nd – 6th move around their costovertebral joints causing the ends of the ribs to raise → pump-handle movement.
 6. Sternum is elevated as well, especially the inferior portion.
- D). Intercostal muscles: innervated by the intercostal nerves. These are the ventral rami of the thoracic spinal nerves. These run parallel to the ribs in the intercostal space deep to the internal intercostal muscles below the vessels. Also, a collateral branch runs parallel to the ribs along the lower border of the space.
- i. External Intercostal Muscles:
 1. Runs anteroinferiorly from the inferior border of the superior rib to the rib below. Seen best on the posterior thoracic wall because deficient anteriorly where replaced by the external intercostal membrane.
 2. Elevates ribs
 - ii. Internal Intercostal Muscles:
 1. Runs posteroinferiorly, deep to the external intercostal muscles and deficient posteriorly where they are replaced by the internal intercostal membrane, so seen best on the anterior thoracic wall.
 2. Depresses ribs
 - iii. Innermost Intercostal Muscles:
 1. Form a deep layer of muscles on the thoracic cage seen on the lateral border of the rib cage spanning one space and linking ribs to ribs.
 2. Probably elevate ribs
- E). Diaphragm: Separates the thoracic cavity from the abdominal cavity.
- i. Motor nerve fibers to the diaphragm reach it via the phrenic nerves. Sensory fibers from the muscle and adjacent pleura and peritoneum are also carried in this nerve. The diaphragm is striated skeletal muscle and is supplied by somatic motor nerve fibers. These are contributed to the phrenic nerve by the third, fourth, and fifth cervical segmental nerves.
 - ii. Pushes down into the abdomen to increase the intrathoracic volume to decrease pressure for inspiration.
- F). Accessory muscles of respiration:
- i. Transverse thoracic:
 1. From posterior surface of lower sternum to internal surface of costal cartilages 2-6
 2. Innervated by intercostal nerve
 3. Depress ribs

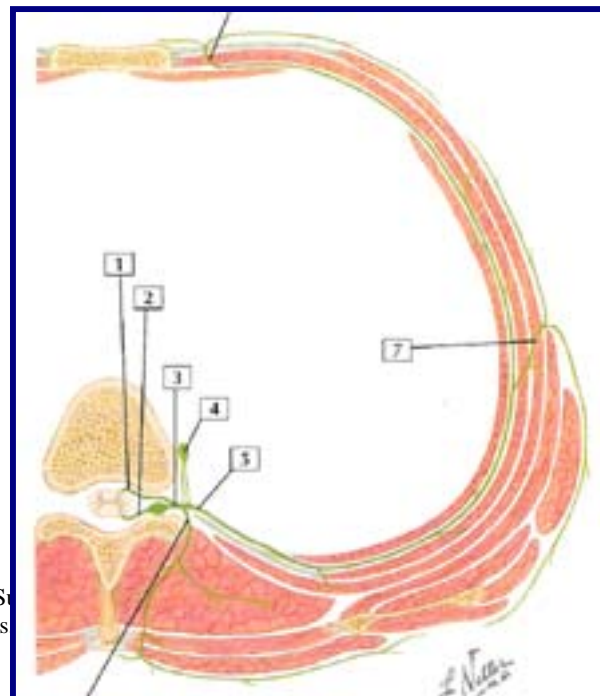
- ii. Subcostal:
 1. From internal surface of ribs near their angles to superior borders of 2nd or 3rd ribs below
 2. Innervated by intercostal nerve
 3. Elevates ribs
- iii. Levator costarum:
 1. From transverse processes of T7-T11 to subadjacent ribs b/ tubercle and angle
 2. Innervated by posterior rami of C8-T11
 3. Elevates ribs
- iv. Serratus posterior superior:
 1. From ligamentum nuchae and spinous processes of C7-T3 to superior borders of 2nd – 4th ribs
 2. Innervated by 2nd – 5th intercostal nerves
 3. Elevates ribs
- v. Serratus posterior inferior:
 1. From spinous processes of T11-L2 to inferior borders of 8th – 12th ribs
 2. Innervated by 9th – 12th intercostal nerves
 3. Depresses ribs
- vi. Scalenes: elevate 1st and 2nd ribs during forced inspiration and are innervated by anterior rami of cervical spinal nerves.

Objective 2)

Follow the course of a nervous impulse from a given spot on the surface of the thorax to the spinal cord or from the spinal cord to an intercostal muscle. Trace the course of autonomic neurons in the thorax. Indicate the origin, location and termination of the pre- and postganglionic elements.

G). Sensory: Anteriorly, the sensory portions of the intercostal nerves appear on the skin near the sternum piercing the costal cartilage and coursing in the subcutaneous tissue. The lateral cutaneous portions pierce the external and internal intercostal muscle at approximately the midaxillary line and run anteriorly and posteriorly. The nerves then b/ the internal and innermost intercostal muscles to the anterior rami of the spinal nerve and into the dorsal root ganglion and into the dorsal horn. The posterior cutaneous nerves run into the posterior rami, into the dorsal root ganglion, and into the dorsal horn of the spinal cord. Will form dermatomes.

H). Motor: A typical motor nerve begins in the ventral horn of the spinal cord where the cell body of the motor neuron is located. The axon of the motor neuron is the ventral root, which joins to run parallel to the dorsal root in the



spinal nerve. The posterior rami innervate deep back, and the anterior rami run across the internal surface of the innermost intercostal muscle near the middle of the intercostal space. At the angles of the ribs, the nerves jump into the intercostal grooves just inferior to the intercostal arteries and continue b/ the innermost and internal intercostal muscles. Collateral branches arise near the angles of the ribs to innervate the muscles. Will form myotomes (group of muscles innervated by one pair of intercostal nerves).

- I). Sympathetic: The cell bodies of the sympathetic nerves are found in the intermediolateral column (IML) from T1 to L2. The *preganglionic* fibers travel out of the spinal cord in the ventral root, join the spinal cord and travel to the *paravertebral* ganglion, or the sympathetic chain ganglion, via the white rami communicantes. The sympathetic *preganglionic* fibers are short, running from the spinal cord to the nearby ganglia. They synapse in the ganglion on the *postganglionic* fibers that exit the ganglion via the gray rami communicantes to join anterior rami of the nearest spinal nerve, including all of the intercostal nerves. Thus, the sympathetic nerve fibers are distributed through the branches of all spinal nerves to the thorax.
- i. The splanchnic nerves are preganglionic sympathetic nerves that come from the paravertebral sympathetic chain without synapsing and go to prevertebral ganglia in the abdomen. The greater splanchnic nerve comes off of T5-T9 and can be seen on the posterior chest wall.
- J). Parasympathetic: The parasympathetic *preganglionic* axons of the thorax leave the CNS via CN X, the vagus nerve. Its cell bodies are also found in the IML. Parasympathetic *preganglionic* axons travel all the way to the organ where they synapse in the ganglion near the organ or inside the organ. Thus, they have long *preganglionic* and short *postganglionic* axons. The right vagus supplies the pulmonary, esophageal, and cardiac plexuses as it travels behind the esophagus into the abdomen. The pulmonary plexuses are along the branches of the bronchial tree and have the postsynaptic cells in them. The left vagus supplies the same plexuses as it travels anterior to the esophagus into the abdomen. Parasympathetic axons to the lungs cause bronchoconstriction.

Objective 3)

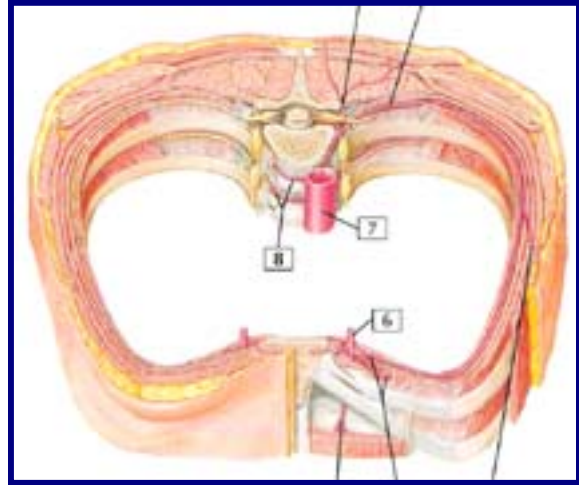
Trace the flow of blood into and out of a typical intercostal space. Indicate the organization of the arterial and venous elements, possible collateral vascular pathways and their relationships to the different muscles of the thoracic wall.

- K). Anterior intercostal arteries (AIA):
- i. In intercostal spaces 1-6, the AIA branch off the internal thoracic artery.
 - ii. The AIA in the intercostal spaces 7-9 come off the musculophrenic artery, a terminal branch of the internal thoracic.
 - iii. Travel between the internal intercostals and the innermost intercostals supplying the anterior thoracic wall (intercostal muscles, overlying skin, and parietal pleura).
 - iv. Eventually AIAs form an anastomosis with the corresponding PIAs.
- L). Posterior intercostal arteries (PIA):
- i. PIA to first two intercostal spaces comes off posterior (supreme) intercostal artery, a branch of the costocervical trunk.
 - ii. The rest branch off the descending aorta.

- iii. They travel between the internal intercostals and the innermost intercostal muscles supplying the posterior wall.
- iv. Also give off dorsal branches to supply collateral circulation to the spinal cord.
- v. Eventually PIAs form an anastomosis with the corresponding AIAs.

M). Internal thoracic artery:

- i. From the subclavian artery and passes inferiorly and lateral to the sternum b/ costal cartilages and internal intercostal muscles to divide into the superior epigastric and musculophrenic arteries.
- ii. Supplies the anterior intercostal spaces by AIAs 1-6.



N). Subcostal artery:

- i. From the thoracic aorta and courses along the inferior border of 12th rib.
- ii. Supplies the muscles of anterolateral abdominal wall.

O). Intercostal veins:

i. Posterior intercostal veins (PIV):

1. There are 11 posterior intercostal veins and one subcostal vein on each side.
2. Most drain into the azygos vein on the right side and the hemiazygos veins (the accessory hemiazygos and the hemiazygos) on the left side. These then drain into the superior vena cava.
3. The first posterior intercostals on both sides are different in that they drain into the brachiocephalic veins.
4. The second and third veins on the left side ONLY combine to form the left superior intercostal vein that then drains into the left brachiocephalic.
5. Will anastomose with the AIVs

ii. Anterior intercostal veins (AIV):

1. Drain into the internal thoracic vein to the anterior, which then drains into the subclavian veins.
2. Will anastomose with the PIVs.

P). **IMPORTANT TIP: THE VEIN, ARTERY, AND NERVE OF EACH INTERCOSTAL SPACE TRAVELS IN THIS ORDER (VAN) TOP TO BOTTOM** (i.e. the vein is on top of the artery that is on top of the nerve).

Objective 4)

Identify the parietal and visceral pleura, their different components, and the pleural recesses. Indicate the surface projection of the parietal and visceral pleura.

- Q). Pleura: The two pleura are continuous at the root of the lung. The space between the two is called the pleural cavity.

- i. Visceral pleura: Covers the lungs and is indistinguishable from the surface of the lungs. It invests them including the surfaces within the horizontal and oblique fissures. It cannot be dissected from the lungs.
 - ii. Parietal pleura: Lines the wall of the thoracic cavity. Runs in the anterior from the second costosternal junction down to the eighth rib where it travels laterally to the tenth rib; in the posterior, ends at the twelfth rib and the T12 junction. The lungs lay two ribs above the pleura. The parietal pleura is composed of several parts:
 - 1. Costal pleura: lines the ribs, intercostal spaces, sides of the vertebral bodies and the back of the sternum → the internal surface of the thoracic wall.
 - a. Costal pleura is separated from the internal surface of the thoracic wall by endothoracic fascia. Allows surgery into the thoracic wall but stay outside the pulmonary cavity.
 - 2. Diaphragmatic pleura: lines the superior side of the diaphragm.
 - a. Also has endothoracic fascia b/ the diaphragm and the diaphragmatic pleura.
 - 3. Mediastinal pleura: lines the lateral boundary of the mediastinum (the midline region that contains the heart, great vessels, trachea, and esophagus).
 - 4. Cervical pleura: Extends into the root of the neck through the thoracic aperture forming a cup-shaped dome over the apex of the lung. The summit of the cervical plexus extends 2 to 3 cm superior to the level of the medial 1/3 of the clavicle at the level of the neck at the first level.
 - 5. Pulmonary ligament: A double fold of the parietal pleura (where the visceral and parietal layers of pleura meet) below the root of the lung.
- R). Pleural cavity: potential space b/ the visceral and parietal layers of pleura. Contains a capillary layer of serous pleural fluid so layers of pleura can slide past each other during breathing.
- S). Lines of pleural reflection: The relatively abrupt lines along which the parietal changes direction from one wall of the pleura to another.
 - i. Sternal line of pleural reflection: Sharp or abrupt and occurs where the costal pleura becomes continuous with the mediastinal pleura anteriorly.
 - ii. Costal line of pleural reflection: Sharp and occurs where the costal pleura becomes continuous with the diaphragmatic pleura inferiorly.
 - iii. Vertebral line of pleural reflection: Much rounder, gradual reflection where the costal pleura becomes continuous with the mediastinal pleura posteriorly.
- T). Pleural Recesses: Places where the lungs do not completely occupy the pleural cavities during expiration. The left recess is potentially bigger because of the cardiac notch in the left lung. The inferior borders of the lungs move further into the pleural recesses during deep inspiration and retreat from them during expiration.
 - i. Costodiaphragmatic: The pleural-lined “gutters” that surround the upward convexity of the diaphragm inside the thoracic wall. B/ the ribs and the diaphragm.
 - ii. Costomediastinal: Similar but smaller pleural recesses are located posterior to the sternum where the costal pleura is in contact with the mediastinal pleura. B/ the ribs and the mediastinum (anterior).
- U). Surface anatomy of the pleura:

- i. The pleura start above the sternoclavicular joint and move inferior deep to the sternum bilaterally.
- ii. The left pleural reflection moves laterally and then inferiorly at the cardiac notch to reach the level of the 6th costal cartilage.
- iii. At 8th rib the pleura is at the midclavicular line, 10th rib the midaxillary line, 12th rib scapular line proceeding towards the spinous process of T10 and then go to the spinous process of T12. The parietal pleura extends two ribs below the lungs.

Objective 5)

Identify the lobes of the right and left lungs. Identify impressions made on the surfaces of each lung by surrounding structures. Identify the surface projections of the bony landmarks of the thoracic wall and the major thoracic viscera (lung [and the fissures], the visceral and parietal pleura, heart, pericardium and the great vessels).

V). Right lung: The right lung has three lobes (superior, middle, and inferior); the horizontal fissure separates the superior and middle lobes; the oblique fissure separates the middle and inferior lobes. The right lung is larger and heavier, but it is shorter and wider because the right diaphragmatic dome is higher.

W). Left lung: The left lung only has two lobes (superior and inferior); the oblique fissure separates the two lobes. The left lung also has the lingula, which is a tongue-like projection of the superior lobe that resembles a tiny middle lobe. The cardiac notch is the impression made by the heart.

X). Lung impressions:

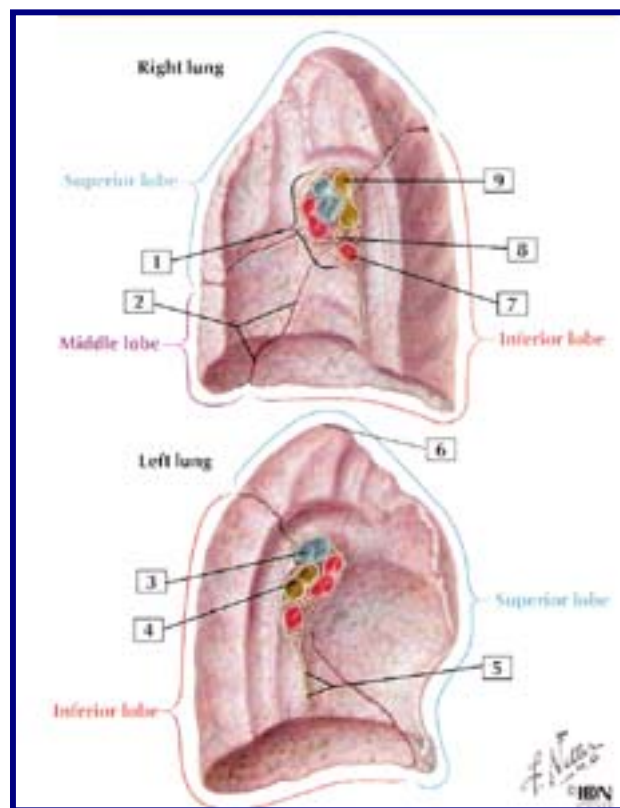
- i. Impressions found on both lungs:
 1. Posterior and lateral: ribs and intercostal spaces
 2. Mediastinal: heart and mediastinum
 3. Inferior: diaphragm
 4. Superior: first rib and trachea

ii. Right side only

1. Esophagus
2. Superior and inferior vena cava
3. Azygos and brachiocephalic veins
4. Phrenic nerve

iii. Left side only

1. Left cardiac impression
2. Left common carotid artery



3. Thoracic duct
 4. Phrenic and vagus nerves
 5. Descending aorta and aortic arch
- Y). Surface landmarks:
- i. Sternum:
 1. Manubrium: Has the jugular notch (b/ the clavicles) and sternal angle (where rib 2 meets sternum). The arch of the aorta and the superior vena cava are posterior to it and the angle lies at the T4/T5 disc level.
 2. Body: Lies above the epigastric fossa, makes up part of the sternal angle, and has the infrasternal angle.
 3. Xiphoid process: Crucial landmark for CPR @ the T9 level.
 - ii. Clavicles
 - iii. Ribs and cartilages: The thoracic vertebral bodies articulate with the ribs to define the posterior thoracic cavity. Costal cartilage connects ribs 1-7 to the sternum while the costal cartilage of ribs 8-10 connect to the cartilage of rib 7. Thus the lower portion of the anterior thoracic wall is cartilaginous and forms the costal margin.
 - iv. Lungs and pleura:
 1. Cervical pleura and apices of the lungs pass through the superior thoracic aperture into the root of the neck superior and posterior to the clavicles.
 2. The anterior borders of the lungs lie adjacent to the anterior line of the reflection of the parietal and pleura as far inferiorly as the 4th costal cartilages.
 3. The anterior border of the left lung is more deeply indented by its cardiac notch.
 4. The left pleural reflection moves laterally and then inferiorly at the cardiac notch to reach the level of the 6th costal cartilage.
 5. At 8th rib the pleura is at the midclavicular line, 10th rib the midaxillary line, 12th rib scapular line proceeding towards the spinous process of T10 and then go to the spinous process of T12. The parietal pleura extends two ribs below the lungs.
 6. The oblique fissure extends from the level of the spinous process of T2 posteriorly to the 6th costal cartilage anteriorly 5 cm from the midline.
 7. The horizontal fissure of the right lung extends from the oblique fissure along the 4th rib and costal cartilage anteriorly.
 - v. The cardiac notch lies under the fifth intercostal space, lateral to the sternal border.
 - vi. The bifurcation of the trachea (carina) is at or below the sternal angle and slightly to the right. The right main bronchus is 2.5 cm down from the carina, and the left main bronchus is 5 cm down from it.
 - vii. Heart:
 1. The apex is in the 5th or 6th interspace just medial to the midclavicular line.
 2. Right border: from 3rd costal cartilage to the costal cartilage 1 cm from the right sternal line
 3. Lower border: across the xiphisternal junction to the apex
 4. Left border: from the apex to the 2nd intercostal space 1 cm from the left margin of the sternum

viii. Great vessels:

1. The right brachiocephalic vein, superior vena cava, and inferior vena cava are above and below the heart along the right margin of the sternum.
2. The left brachiocephalic vein runs obliquely from the left sternoclavicular joint to join the right brachiocephalic vein behind the 1st costal cartilage.
3. The aorta arches up to the middle of the manubrium.
4. The pulmonary arteries are below the aortic arch.

Objective 6)

Identify branches of the pulmonary arteries and the tributaries of pulmonary veins on the hilar surface of each lung. Describe the flow of lymph from each lung and the location of lymph nodes associated with the lung (whether or not they are present in your cadaver). Trace the lymphatic drainage of the thoracic walls, pleura, and lungs.

- Z). Pulmonary arteries: Each lung has a large pulmonary artery that arises from the pulmonary trunk at the level of the sternal angle. The pulmonary arteries pass to the corresponding root of the lung and give off a branch to the superior lobe before entering the hilum. Within the lung each artery descends and divides into lobar (2 on left and 3 on right) and segmental arteries (10 each lung) following the bronchi.
- AA). Pulmonary veins: Two pulmonary veins arise on each side – right and left superior and inferior pulmonary veins that drain the segments of the lungs. The inferior PV's drain the inferior lobes, while the superior PV's drain the superior lobe and lingula of the left and the middle and superior lobes on the right. They arise from pulmonary capillaries forming uniting into larger vessels. The intersegmental veins drain blood from adjacent bronchopulmonary segments into the intersegmental veins in the septa b/ the segments. A main vein drains each bronchopulmonary segment and forms the pulmonary veins.
- BB). Right hilum: The pulmonary veins are inferior and the pulmonary arteries are anterior.
- CC). Left hilum: The pulmonary artery is superior and the pulmonary veins are inferior and anterior.
- DD). Lymph nodes and drainage:
- i. Superficial lymphatic plexus: Lies deep to the visceral pleura and drains the lung parenchyma and visceral pleura. Lymph from this plexus drains into the bronchopulmonary lymph nodes (hilar lymph nodes) in the hilum of the lung.
 - ii. Deep lymphatic plexus: Located in the submucosa of the bronchi and in the peribronchial connective tissue. It is largely concerned with draining structures that form the root of the lung. Lymphatic vessels from this plexus drain into the pulmonary lymph nodes located along the lobar bronchi. At the hilum of the lung, they drain into bronchopulmonary lymph nodes.
 - iii. Lymph from the superficial and deep lymphatic plexuses drain into the bronchopulmonary lymph nodes, and they drain into the superior and inferior tracheobronchial lymph nodes, superior and inferior to the bifurcation of the trachea respectively.
 - iv. Lymph from the tracheobronchial lymph nodes passes to the bronchomediastinal lymph trunks. These trunks usually terminate on each side at the junction of the subclavian and internal jugular veins. The right bronchomediastinal trunk may first merge with other lymphatic trunks

converging here to form the very short right lymphatic duct. The left bronchomediastinal trunk terminates into the thoracic duct.

- v. The superficial lymphatic plexus drains lymph from the visceral pleura.
- vi. Lymph from the parietal pleura drains into lymph nodes of the thoracic wall – intercostal, parasternal, mediastinal, and phrenic lymph nodes.
- vii. A few vessels from the cervical pleura drain into the axillary lymph nodes.