THE DIAPHRAGM

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I – INTRODUCTION:

- The diaphragm is a musculo-aponeurotic partition separating the chest (thorax) from the abdomen.
- It is traversed by the esophagus, blood vessels, and nerves.
- It is the essential muscle for respiratory dynamics.

II - DESCRIPTIVE ANATOMY:

1. Shape:

The diaphragm forms a double dome, with an inferior concavity, of unequal height, with the right dome being higher than the left.

2. Dimensions:

The transverse diameter clearly outweighs the anteroposterior diameter.

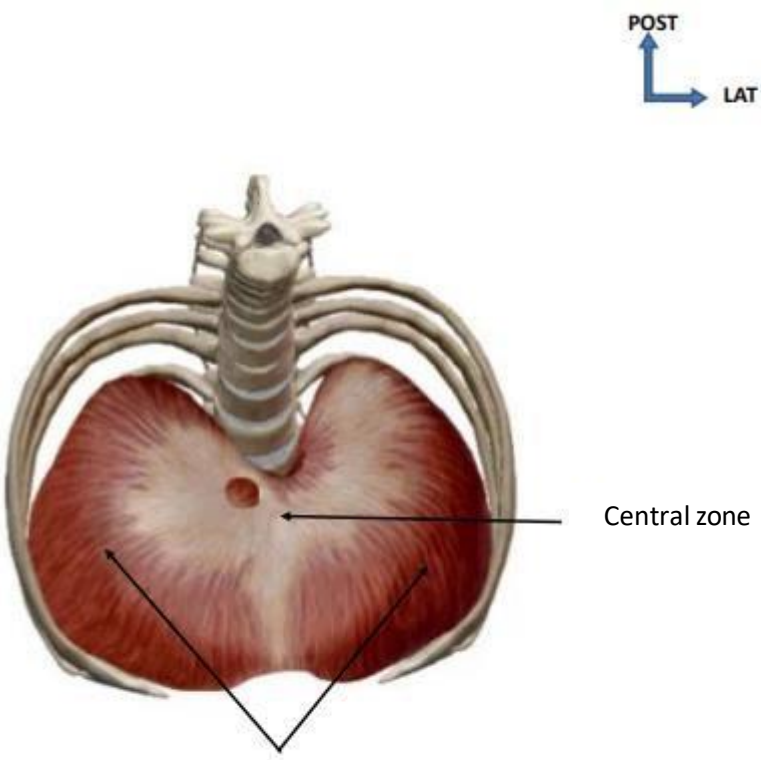
3. Position:

- In forced expiration, the diaphragm reaches the 4th rib on the right and the 5th rib on the left.
- During inspiration, the domes descend by two intercostal spaces.

4. Constitution:

The diaphragm is formed by:

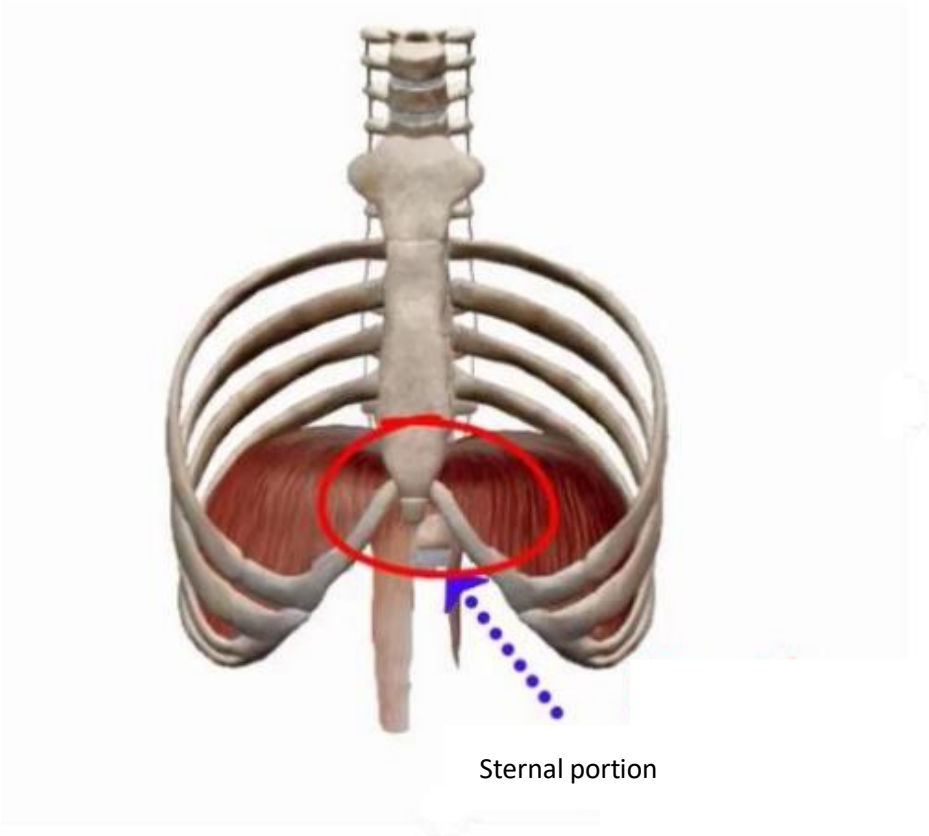
- A **peripheral muscular zone**, formed by a series of sternal, costal, and lumbar bundles.
- A **central tendinous zone**, known as the **phrenic center**.



Superior view of the diaphragm

a. Muscular bundles:
They can be subdivided into three portions:

Sternal portion:
This is represented by two bundles that stretch from the base of the xiphoid process to the anterior border of the phrenic center. The two bundles define an **avascular opening**, known as the **Marfan slit**.



Sternal portion

Chondro-costal portion:

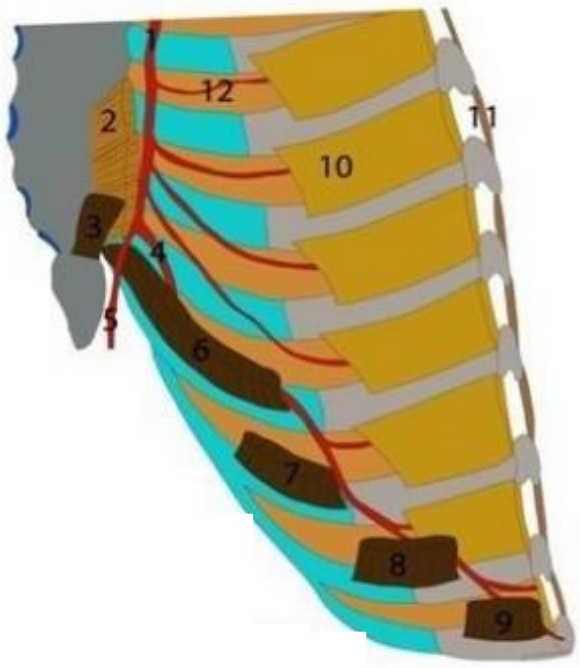
This portion consists of an **osseous segment** and an **aponeurotic segment**.

- **Osseous segment**: The diaphragm attaches to the internal surface of the last six ribs:
    - On the three lower ribs, the attachment is purely costal.
    - On the three upper ribs, the attachment is chondral.
- **Aponeurotic or intercostal segment**: The muscle fibers attach to the two Senac arches, connecting the 12th rib to the 11th rib, and the 11th rib to the 10th rib.

This chondro-costal portion is separated from the sternal portion by an opening called the Larrey slit or costoxiphoid hiatus, through which the internal thoracic artery passes.

***Note**: Weak points may exist through this hiatus, potentially leading to hernia formation (i.e., Larrey slit hernias).*

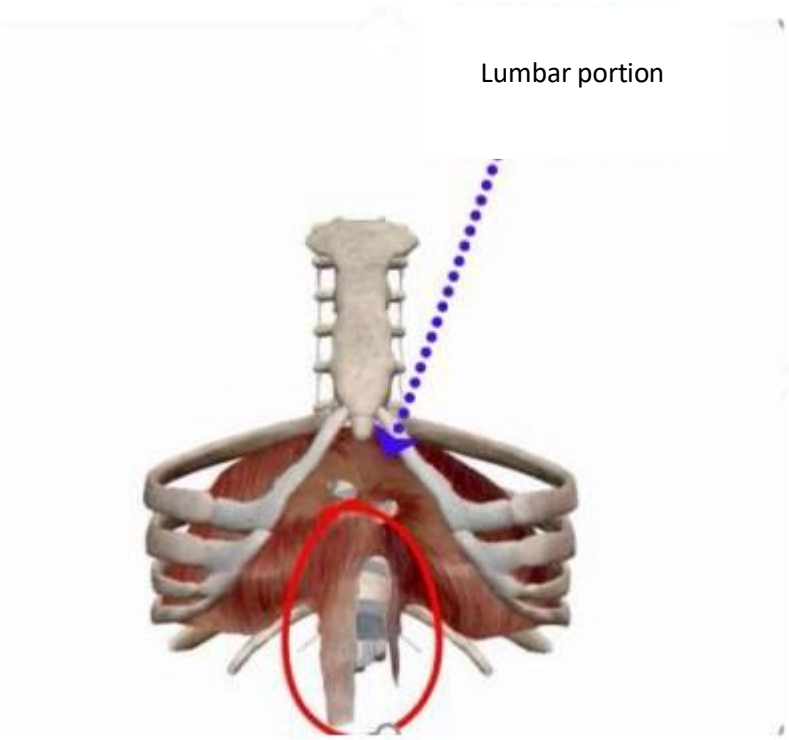
Costochondral attachments of the diaphragm (right side – posterior view)



1- Internal mammary artery
2- Transversus thoracis muscle
3- Sterno-xiphoid bundle of the diaphragm
4- Musculophrenic branch of the internal mammary artery
5- Attachements of the 7th costal cartilage
6- Attachements of the 8th costal cartilage
7- Attachements of the 9th costal cartilage and rib
8- Attachements of the 10th costal cartilage
9- Internal intercostal muscle
10- Innermost intercostal muscle
11- Internal intercostal artery

Lumbar portion:

This portion consists of a **medial segment** and a **lateral segment**.



Medial segment or the pillars of the diaphragm:

- Known as the pillars of the diaphragm.
- These pillars are located on either side of the midline, inserting on the anterior surface of the lumbar vertebrae and the intervertebral discs.

- **Main pillars**:
  Origin:

  ✓ **Right pillar**: Inserts on the anterior surface of the first three lumbar vertebrae and the intervertebral discs.

  ✓ **Left pillar**: Smaller and less powerful, it inserts on the anterior surface of the first two lumbar vertebrae.
  The two pillars cross their internal fibers at the midline, forming a raphe, the fibrous bed of the aorta.
  Each pillar ascends obliquely forward and upward, uniting with the opposite pillar in front of the aortic orifice to form the median arcuate ligament.

  Termination: Each pillar gives rise to two **bundles**:

  ✓ **Internal bundle**: Crosses with the opposite bundle in front of D12, encircling the esophageal orifice above.

  ✓ **External bundle**: Ascends toward the posterior notch of the central tendon.

- **Accessory pillars**:
  Origin: From the anterolateral part of the second lumbar vertebra.

  Path: Obliquely ascends upward and outward, following the main pillar.

  Termination: Their fibers extend to the posterior border of the central tendon, outside the external fibers of the main pillar.

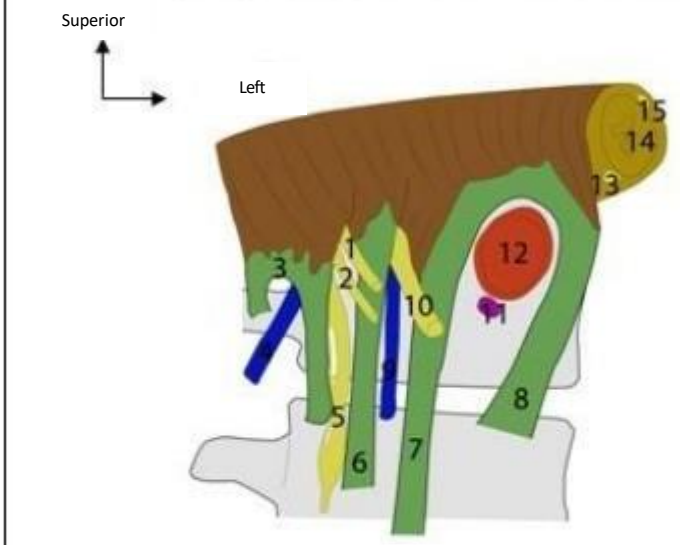
Lateral segment or diaphragmatic arches:

These **arcuate ligaments** are two in number and are primarily part of the aponeroses of the lumbar muscles:

- **Psoas arch** (or **internal arcuate ligament**):
  This ligament stretches from the lateral side of L2 to the base of the costal process of L1.
- **Quadratus lumborum muscle arch** (or diaphragmatic cinched ligament):
  This forms a fibrous bridge, extending from the summit of the costal process of L1 to the summit of the 12th rib.

The fibrous bundle detached from this arch ascends to insert on the posterior edge of the lateral leaflet of the central tendon. This bundle is sparsely distributed in its middle part, creating a true hiatus or **costolumbar hiatus of Henlé.**

Diaphragmatic pillars of the right side : anterior view



1- Right lesser splanchnic nerve
2- Least splanchic nerve
3- Psoas arcade
4- Ascending lumbar vein
5- Accessory pillar (right side)
6- Main pillar (right side)
7- Main pillar (left side)

1- Internal root of the azygos vein
2- Right great splanchic nerve
3- Thoracic duct
4- Aorta
5- Right vagus nerve
6- Esophagus
7- Left vagus nerve

b. Phrenic center:

Shape:

- The central tendon of the diaphragm is a thin aponeurosis, pearly white and shiny in appearance.
- It is trefoil-shaped, with three leaflets: ventral, right, and left.

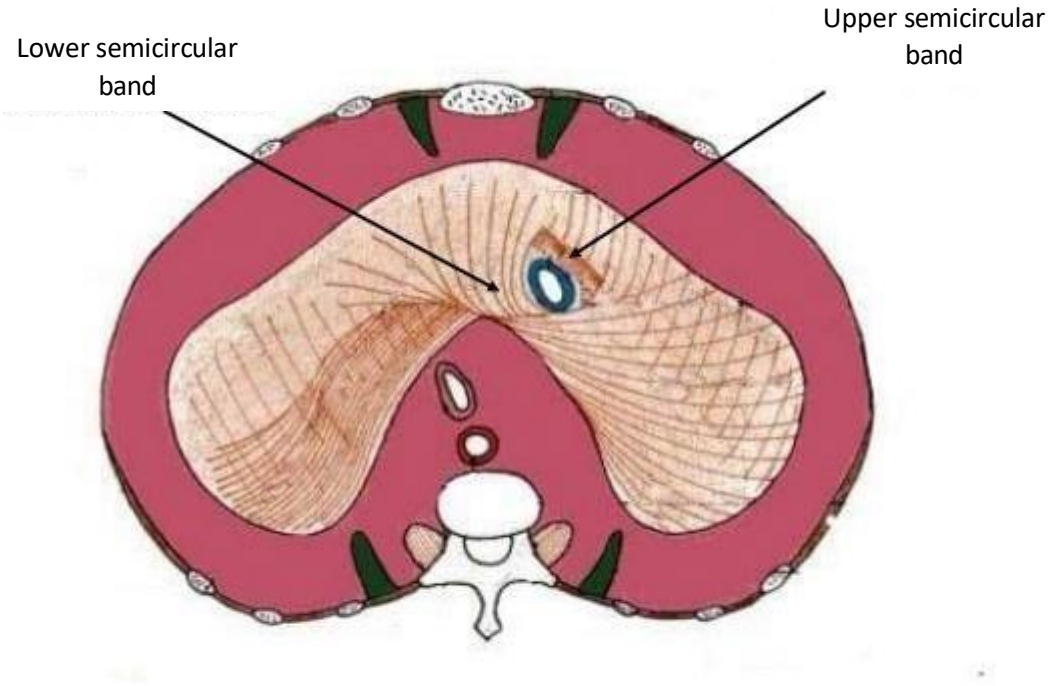
Constitution:

The central tendon is made up of two types of fibers:

- Fundamental fibers: Originating from various fascicles, these fibers are directed towards the anterior leaflet and the lateral leaflets.
- Association fibers: Condensed into two bands:
    - Upper semicircular band: Stretched from the right leaflet to the anterior leaflet.

- Lower semicircular band: Stretched from the right leaflet to the left leaflet.

These two bands enclose the quadrilateral opening of the inferior vena cava on the right side of the midline.



Superior view of the diaphragm

5. Orifices:

The partition formed by the diaphragm between the thoracic and abdominal cavities has numerous openings and weak points that create a communication between the two cavities.

a. Main orifices:

There are three main orifices:

- **Foramen of the inferior vena cava**: Located in the phrenic center, it is projected at the level of the T8-T9 intervertebral disc. It is also traversed by branches of the right phrenic nerve.
- **Esophageal hiatus**: Positioned at the middle of the muscular fibers, it is projected at the level of the T10 thoracic vertebra. It also allows passage for the right and left vagus nerves.

***Note**: The esophageal opening plays a significant role in esophagogastric continence, as the muscular ring derived from the pillars acts as a sphincter.*

- **Aortic hiatus**: Bounded by the body of the T12 vertebra and the median arcuate ligament, it is also traversed by the thoracic duct.

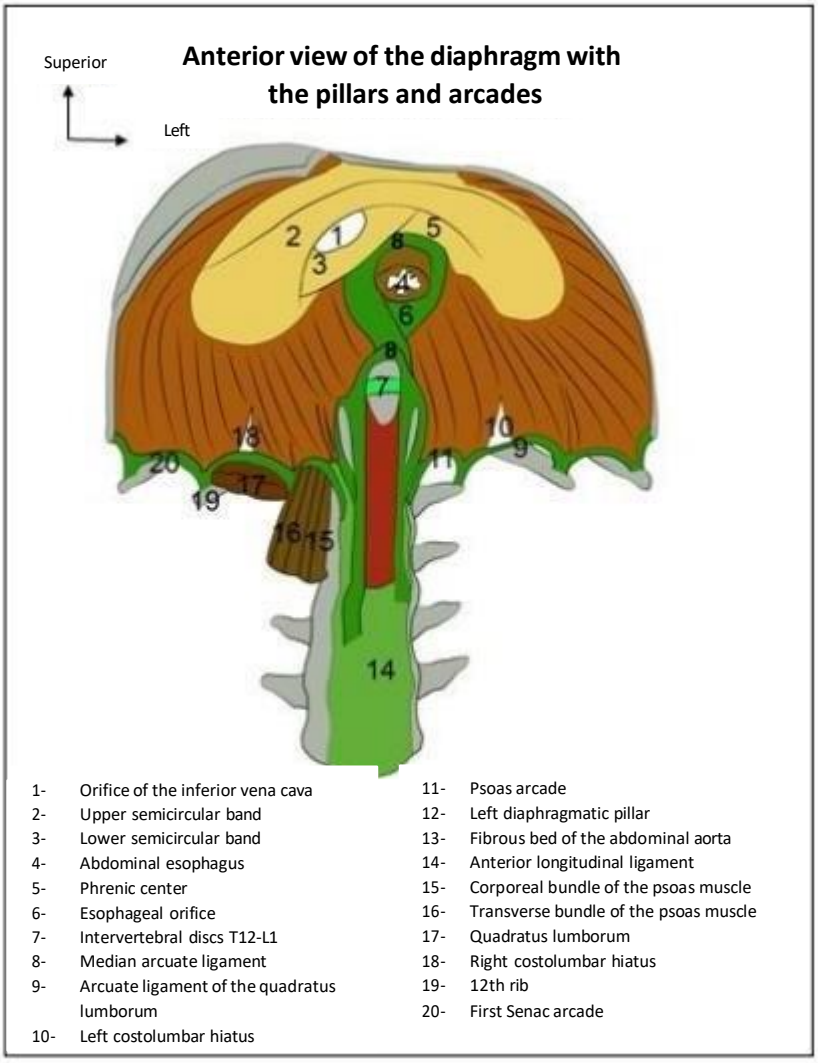
b. Accessory orifices:

These are all vascular and nerve-related:

- **Anterior orifices**:
    - **Marfan's slit**: Retro-xiphoid, located between the sternal fascicles of the diaphragm. It is avascular, and no structures pass through it.
    - **Larrey's slit**: Between the sternal and chondro-costal portions, it allows the passage of the abdominal branch of the internal mammary artery.

- **Lateral orifices**: Between the different chondro-costal fascicles, allowing passage for the intercostal nerves (from the 7th to the 11th).

- **Posterior orifices**: Between the pillars and the arcuate ligaments of the lumbar portion:
    - Between the main and accessory pillars, a medial hiatus allows the passage of the greater splanchnic nerve and the internal root of the azygos veins.
    - Between the accessory pillar and psoas arcade, a lateral hiatus contains (from top to bottom): the lesser splanchnic nerve, the inferior splanchnic nerve, and the sympathetic chain.
    - Under the psoas arcade, the ascending lumbar vein ascends between the two planes of the psoas.
    - In the costal-lumbar hiatus, the lymphatic trunks and connective tissue facilitate communication between the subpleural and retro-renal spaces.



III – ANATOMICAL RELATIONS:

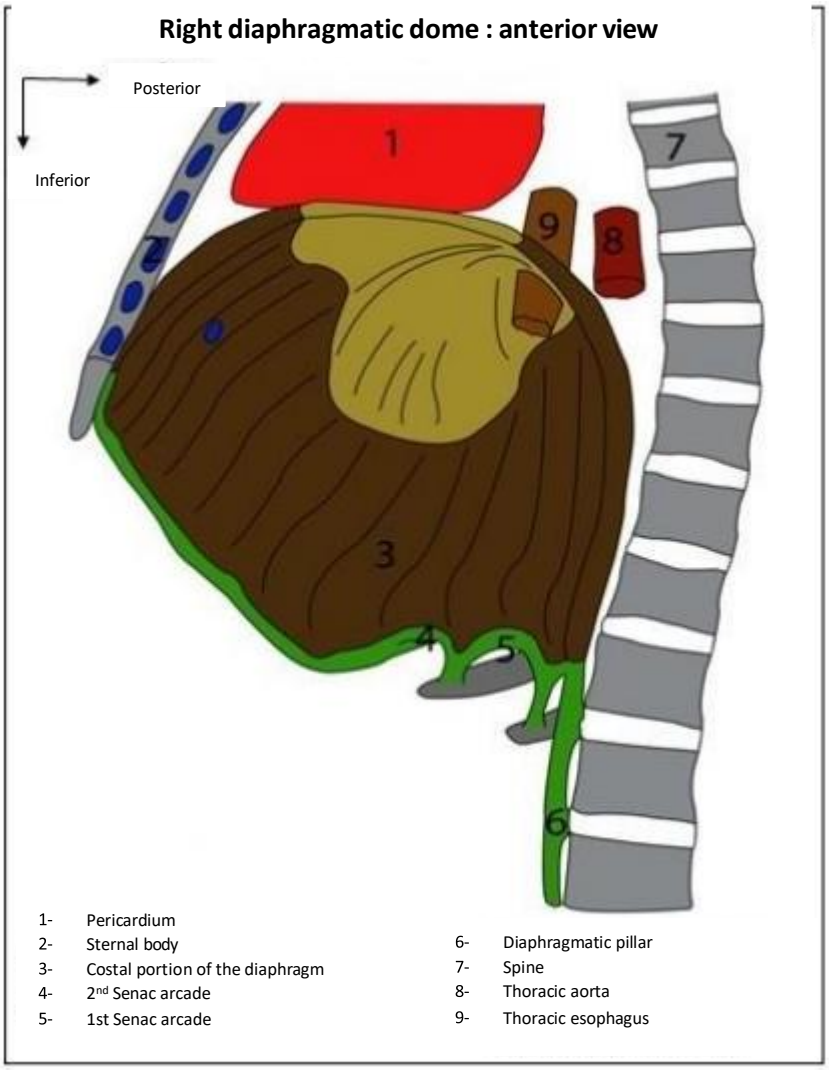
From a topographical point of view, the diaphragm can be divided into two portions:

- **Horizontal portion**: Antero-superior
- **Vertical portion**: Postero-inferior.

Horizontal portion (or diaphragmatic dome):

Superior or thoracic surface:

It is in contact at the center with the mediastinum, and at the periphery with the pleuropulmonary cavity.



Inferior or abdominal surface:

It is largely covered by the peritoneum and is in contact with the following structures:

- **On the right**:
  - The superior and posterior faces of the liver. It is attached to the diaphragm by the suspensory ligament, which divides the inter-hepatic space into two secondary cavities.

***Note**: These cavities can be sites for subphrenic abscesses.*

- **On the left**:
  From the medial portion to the lateral portion, it is in contact with:
  - The abdominal esophagus
  - The greater curvature of the stomach

- The left lobe of the liver
- The spleen
- The left colic flexure.

Vertical portion - the pillars and arcades:

The pillars have the following relationships:

- **Superiorly**: With the celiac region of Luschka, centered posteriorly by the abdominal aorta.
- **Inferiorly**: With the duodeno-pancreatic block.

The arcades are in contact on each side with:

- The posterior face of the kidney.
- The posterior face of the adrenal gland.

IV – VASCULARIZATION – INNERVATION – LYMPHATIC DRAINAGE SYSTEM

1. Arterial vascularization:

The arterial vascularization originates from four sources:

- **Superior phrenic arteries**: Branches of the thoracic aorta, supplying adjacent parts of the diaphragm.
- **Inferior phrenic arteries**: Branches of the abdominal aorta, providing branches to the inferior surface of the diaphragm.
- **Internal thoracic arteries**: Each gives rise to the pericardiacophrenic and musculophrenic arteries.
- **The last five intercostal arteries**: Supply the periphery of the diaphragm.

2. Venous vascularization:

- Follows the arteries and drains into the subclavian veins or the azygos system.

- Some veins drain into the hepatic veins.

3. Lymphatic drainage system:

The diaphragmatic lymphatics form **two networks**:

- On the superior surface (supradiaphragmatic network):
    - **Anteriorly**: Drains into the pre-pericardial lateral nodes and, on the left, into the mediastinal nodes.
    - **Posteriorly**: Drains into the peri-esophageal nodes and juxta-aortic lumbar nodes.
- On the inferior surface (subperitoneal network):
    - Subdiaphragmatic drainage:
        - **Right side** → Inferior diaphragmatic nodes.
        - **Left side** → Juxta-aortic nodes.
    - Trans-diaphragmatic drainage:

      Connects to the juxta-phrenic nodes and retro-xiphoid nodes.

Note: *Through perforating anastomoses, infections can spread between the two surfaces of the diaphragm.*

3. Innervation:

a. Motor innervation:

- Controlled by the right and left phrenic nerves, which originate from the cervical plexus (C4).
- They travel through the supraclavicular region, anterior mediastinum, and spread across the superior surface of the diaphragm.
- Each phrenic nerve gives off three branches:
    - Anterior branch → Supplies the sternal and anterior chondro-costal portions.
    - Lateral branch → Supplies the lateral chondro-costal portion.
    - Posterior branch → Supplies the diaphragmatic crura (pillars).

Note:

- *Phrenic nerve paralysis can be unilateral, leading to hemidiaphragm immobility seen on fluoroscopy.*
- *It may occur after cervical vertebral manipulation, causing trauma to nerve roots.*

b. Sensory innervation:

- Provided by the last six intercostal nerves.

VI – CLINICAL APPLICATIONS:

❖ **Diaphragmatic paralysis**:

- Paralysis of one half of the diaphragm (hemidiaphragm) occurs due to phrenic nerve damage.
- Since each dome has independent innervation, the other half remains functional.
- Radiographic diagnosis:
    - Paradoxical movement: instead of descending during inspiration, the paralyzed dome moves upwards, pushed by abdominal viscera compressed by the healthy, active half.
    - During expiration, the paralyzed dome collapses due to intrapulmonary pressure.

❖ **Congenital diaphragmatic hernia:**

- A portion of the stomach and intestine herniates into the thoracic cavity through a posterolateral diaphragmatic defect.
- Most common on the left side → Bochdalek hernia.
- Caused by improper diaphragm development.
- Leads to pulmonary hypoplasia, contributing to high neonatal mortality.

VII - CONCLUSION:

The diaphragm is a vital muscle in humans, playing a primary role in inspiration and a secondary role in abdominal wall resistance. Its pathologies vary, as do the methods for its examination, highlighting the importance of understanding its anatomy.