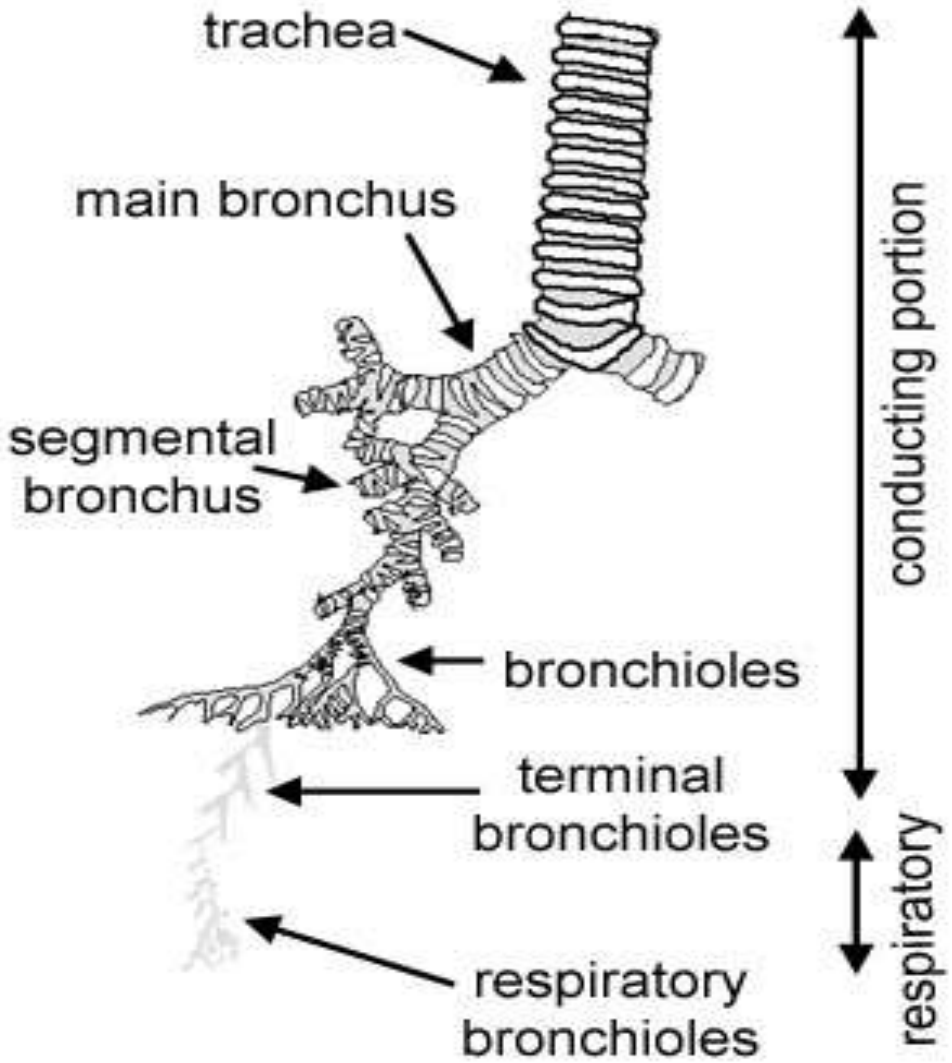
Mechanics of Respiration

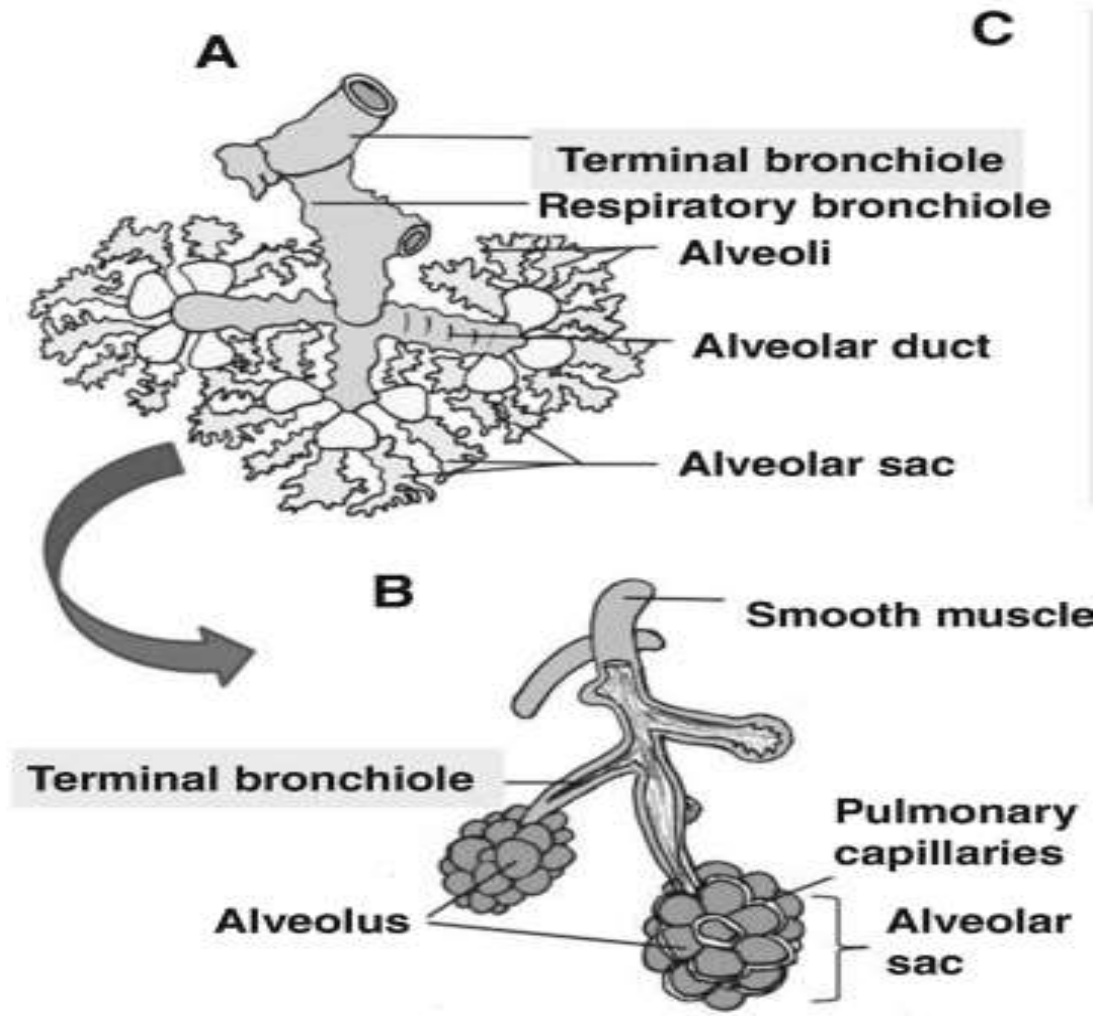
PY6.2.1
Describe the mechanics of normal respiration, pressure changes during ventilation

Objectives:

- To study the role of muscles acting during inspiration and expiration.
- To study the process of inspiration and expiration.
- To study the respiratory pressures and pressure-flow-volume changes during the respiratory cycle.

- **Eupnoea:**
  Rhythmic act of quiet breathing
- Control is in the ‘centers’ in the brain stem
- Inspiration----active process
- Expiration----passive in quiet breathing


trachea
main bronchus
segmental bronchus
bronchioles
terminal bronchioles
respiratory bronchioles
conducting portion
respiratory

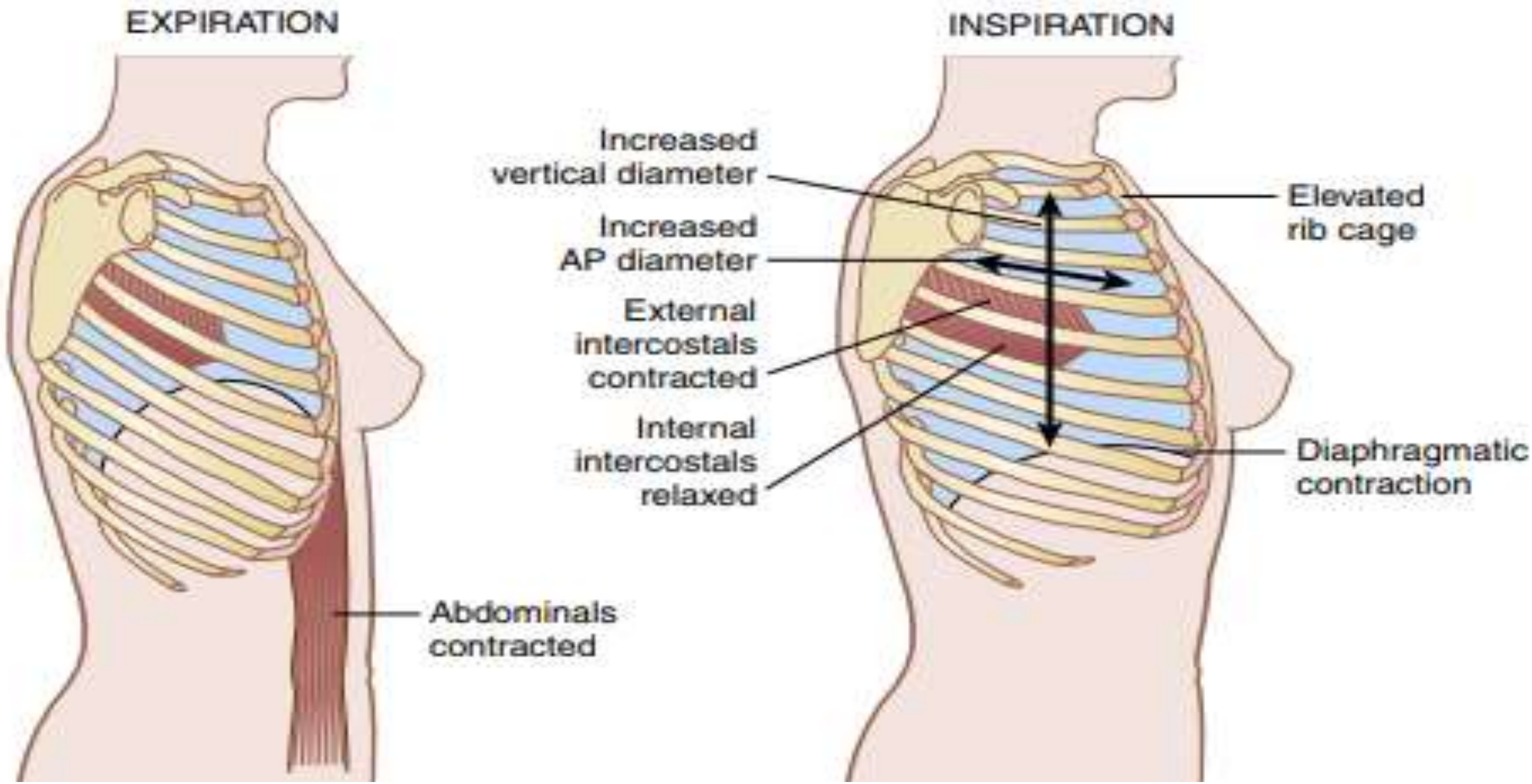

A
C
Terminal bronchiole
Respiratory bronchiole
Alveoli
Alveolar duct
Alveolar sac
B
Smooth muscle
Terminal bronchiole
Pulmonary capillaries
Alveolus
Alveolar sac

- In quiet respiration, an adult breaths 6-7 l/min
- Breathing rate is 12-14/min
- Tidal volume is 500 ml/min

- At rest, 250 ml of O2 per minute is utilized and 200 ml of CO2 is expired.
- Heavy exercise:

  Pulmonary ventilation----80L/min

  Oxygen usage: 3.5 L/min


EXPIRATION
INSPIRATION
Increased vertical diameter
Increased AP diameter
External intercostals contracted
Internal intercostals relaxed
Elevated rib cage
Diaphragmatic contraction
Abdominals contracted

MUSCLES ACTING DURING INSPIRATION AND EXPIRATION

Inspiratory muscles

1. Diaphragm
2. External Intercostal muscles

Accessory Inspiratory muscles

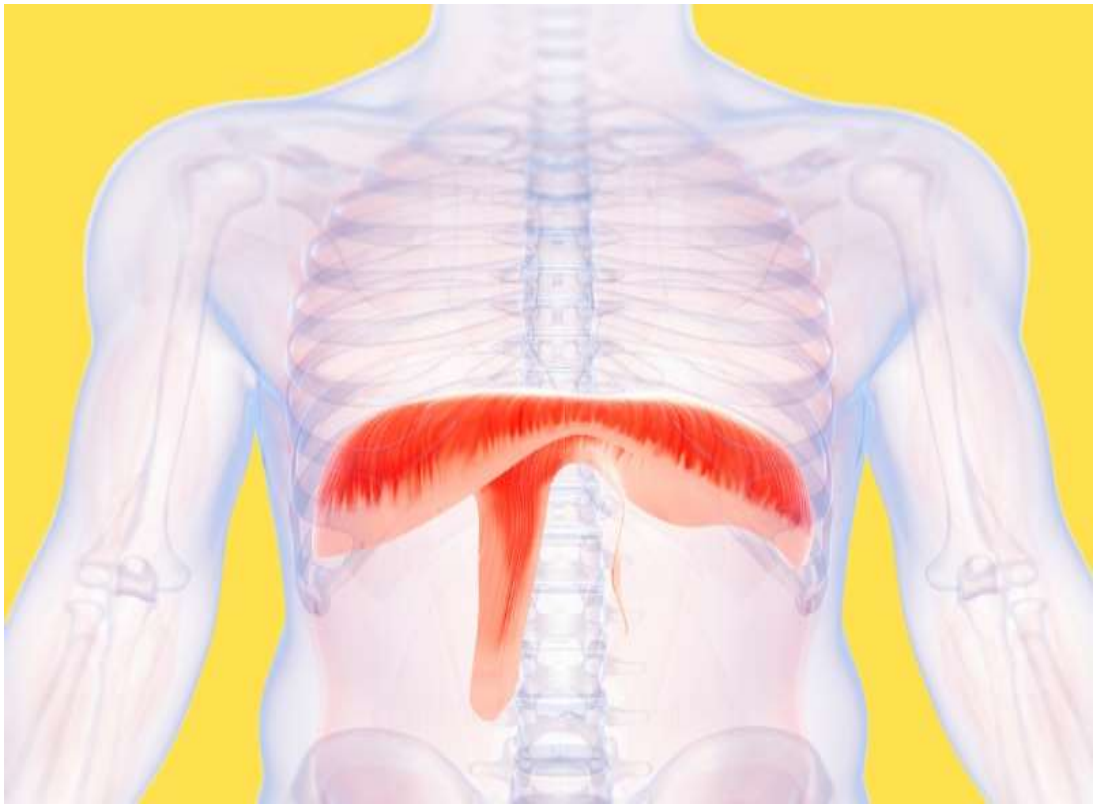
1. Sternocleidomastoid
2. Anterior serrati
3. Scaleni
4. Alae nasi

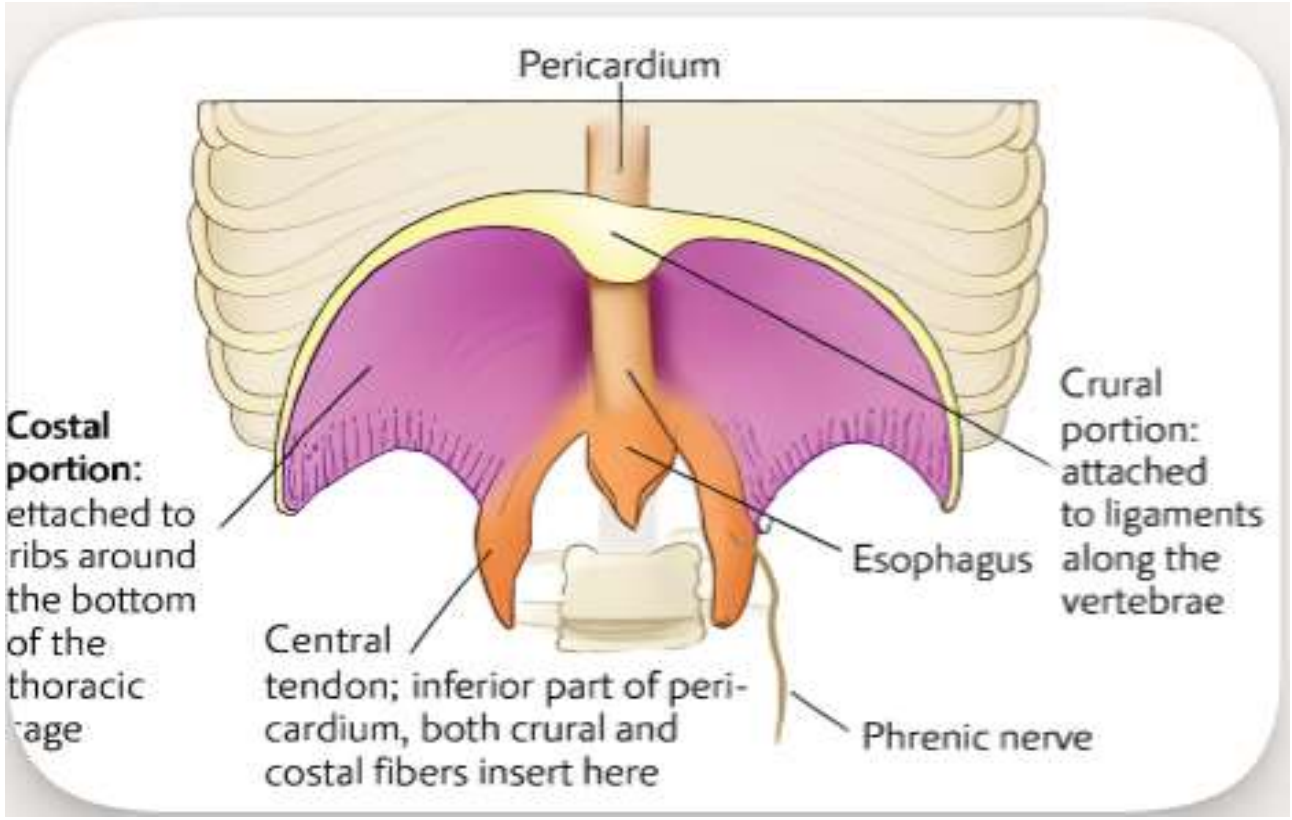
Expiratory muscles (Hyperventilation)

1. Rectus Abdominus
2. Internal intercostal muscles
3. Internal and external oblique
4. Transverse abdominis

Primary muscles of Inspiration

- **Diaphragm**
- 75% of total work done during tidal respiration is by diaphragm----- **main muscle of inspiration**
- **Supplied by phrenic nerve that arise from C3-5**
- Transection of the spinal cord above the third cervical segment is fatal and requires artificial respiration





- Central tendinous portion of diaphragm descends 1.5 cm during normal tidal respiration and 7cm during forced respiration increasing the vertical diameter of the thoracic cage.

- **Diaphragm muscle does not get fatigued.**

  Why?

Type of respiration

- **Abdominothoracic respiration (men)**

  In men, breathing is **predominantly diaphragmatic.**

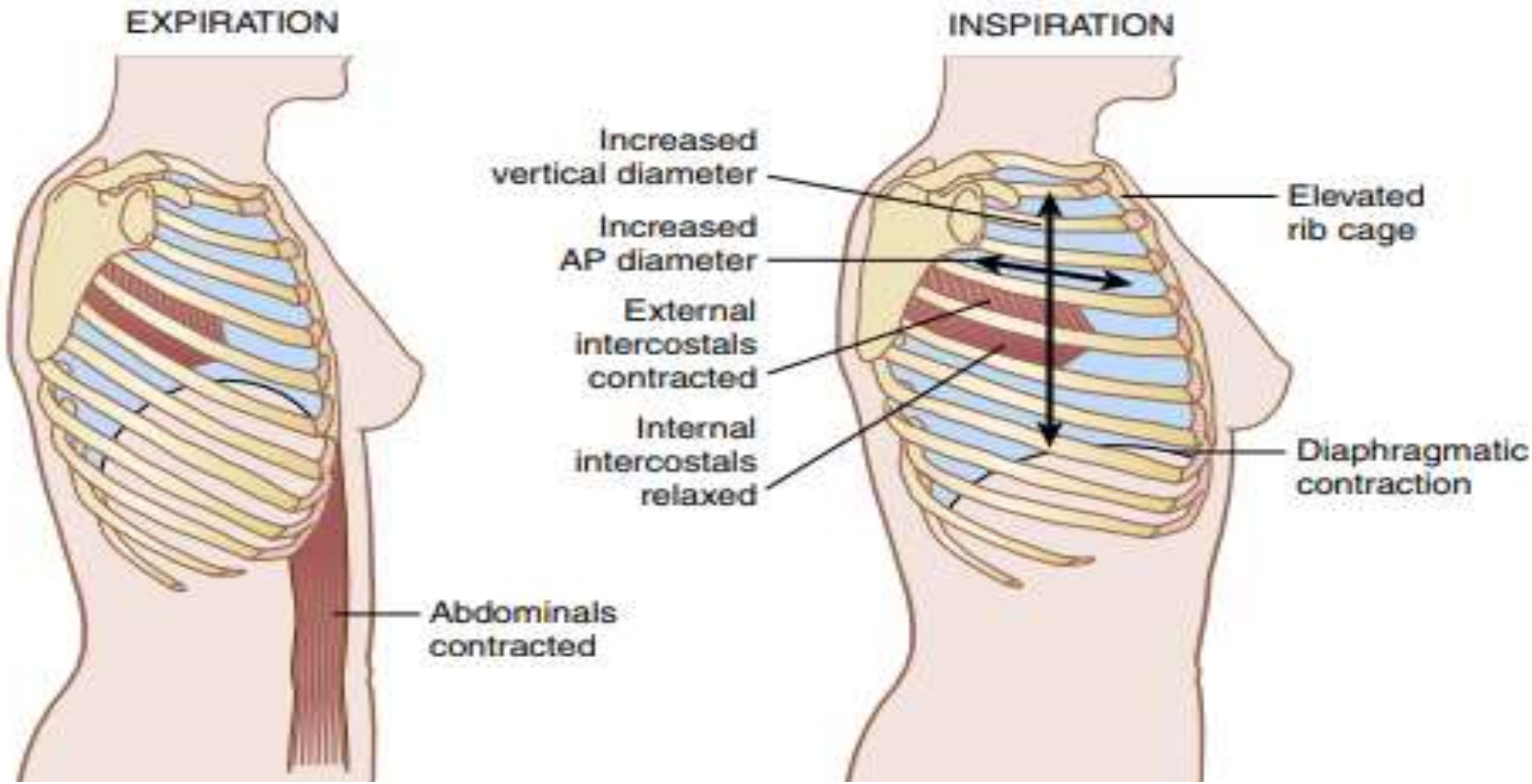
- **Thoracoabdominal respiration (women):**

  In women, breathing is **predominantly thoracic**.

External Intercostal Muscles

- **Origin:** From the inferior border of the rib above.
- **Insertion:** To the superior border of the rib below.
- External intercostal spans between adjacent ribs, filling the intercostal spaces.
- They lie superficial to the internal intercostals.

- Extend from the tubercle of the rib posteriorly to the costochondral junction anteriorly.
- Fibers run obliquely downward and forward — like **putting your hands in your pockets.**
- **External Intercostal muscle----supplied by intercostal nerves T1-T12.**


EXPIRATION
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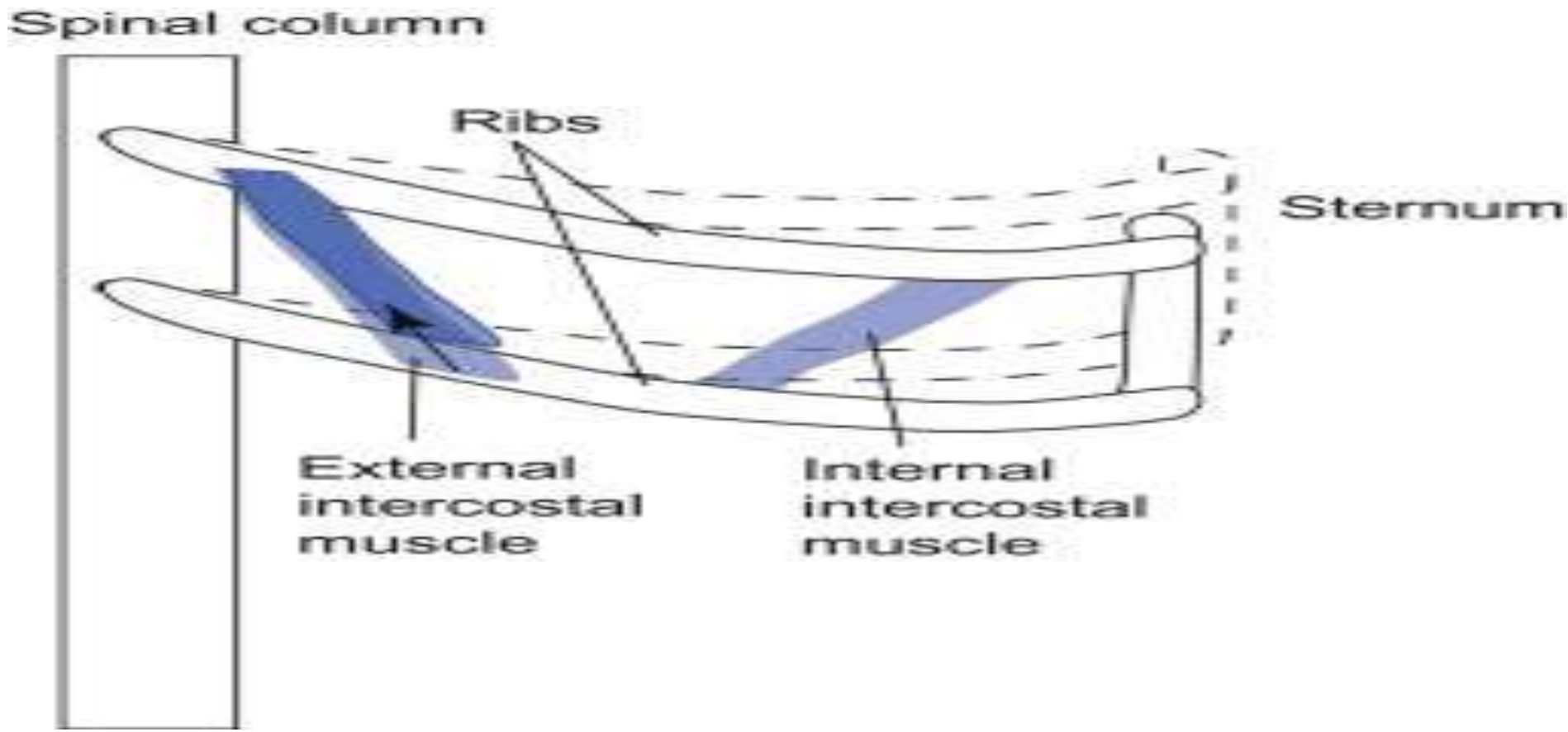
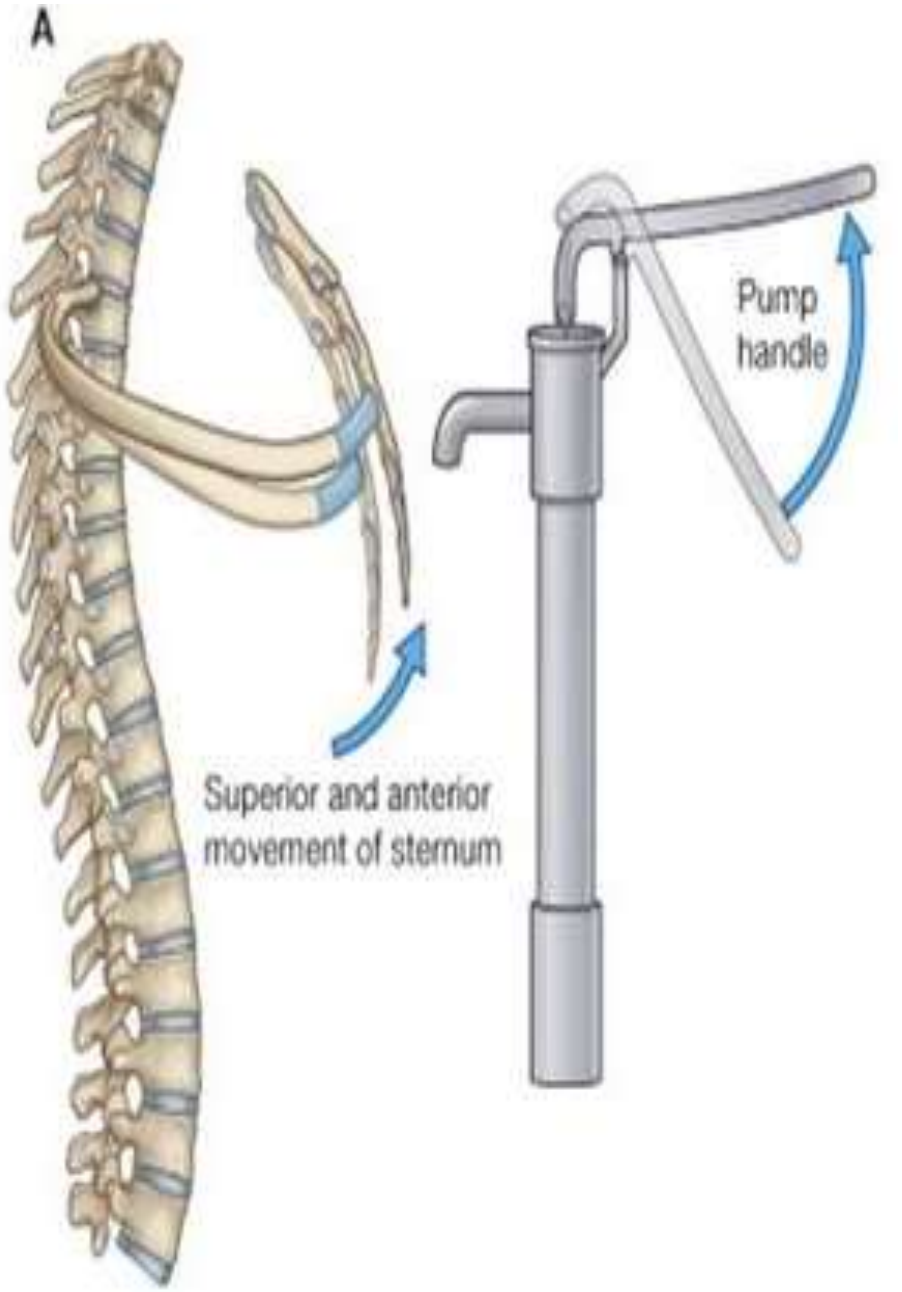
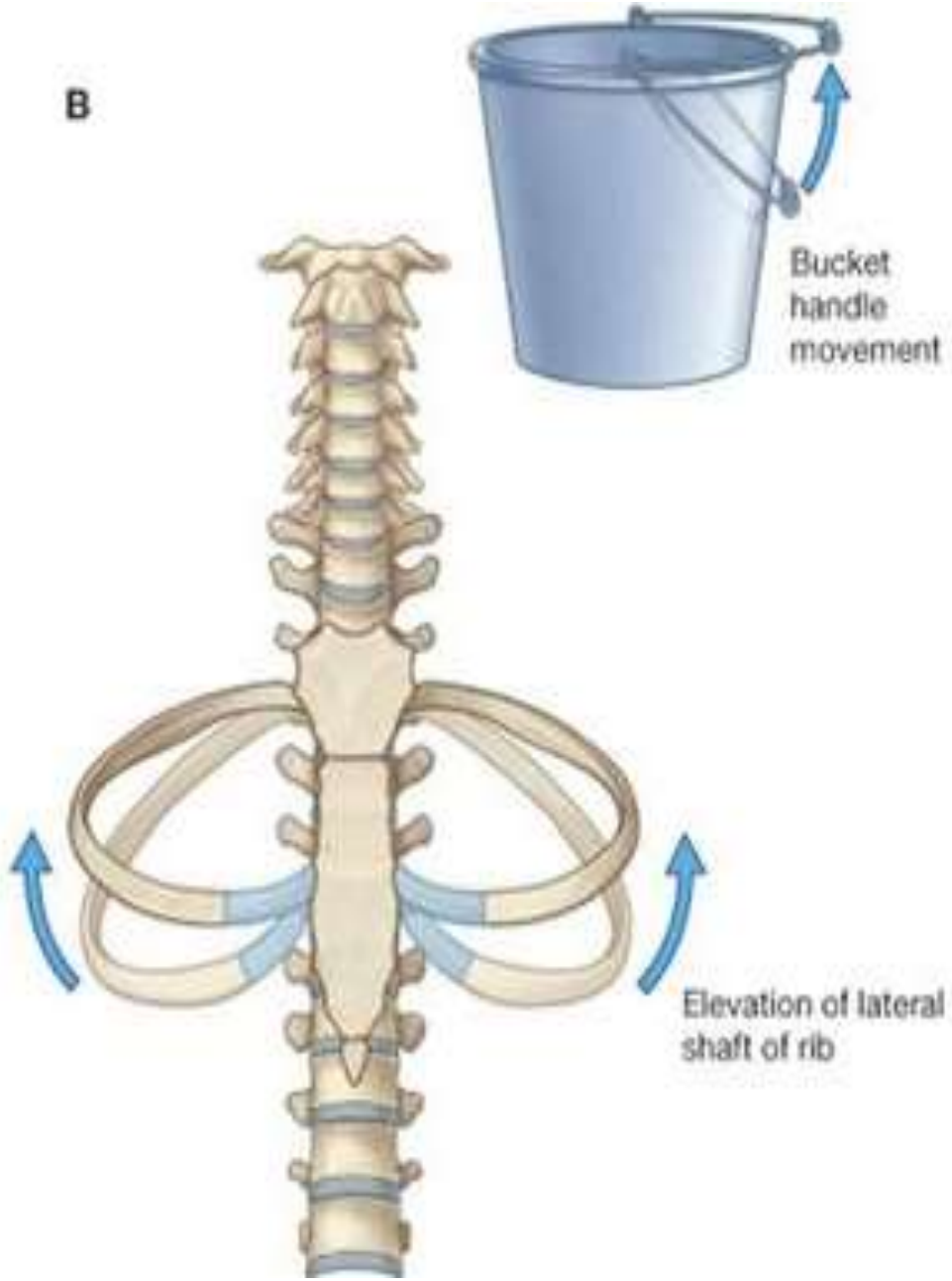
Intercostal Muscles





External Intercostal muscles contraction moves **Upper 2-6 ribs upwards and forwards**--- to increase the antero-posterior diameter of thoracic cage--**pump handle** movement.

ribs 7-10 to arch outwards to increase transverse thoracic movement----**bucket handle movement.**



- **Impaired movement (e.g., rib fractures, ankylosing spondylitis) reduces chest expansion and compromises respiration.**

- **Accessory inspiratory muscles:**

  - **Sternocleidomastoid muscle:** Lifts the sternum and increase the A-P diameter of thoracic lid.

  - Scaleni muscles lifts first pair of ribs increasing the AP diameter

Muscles of expiration:

- **Tidal expiration is a passive process**

Elastic recoil of the lungs and chest wall pushes air out without requiring expiratory muscle contraction.

- **The “Braking Action” of Inspiratory Muscles**
- In the **early phase of expiration**, inspiratory muscles (like the diaphragm and external intercostals) don’t relax instantly.

- Instead, they **maintain a low-level contraction**.

  - slows the rate of lung recoil.

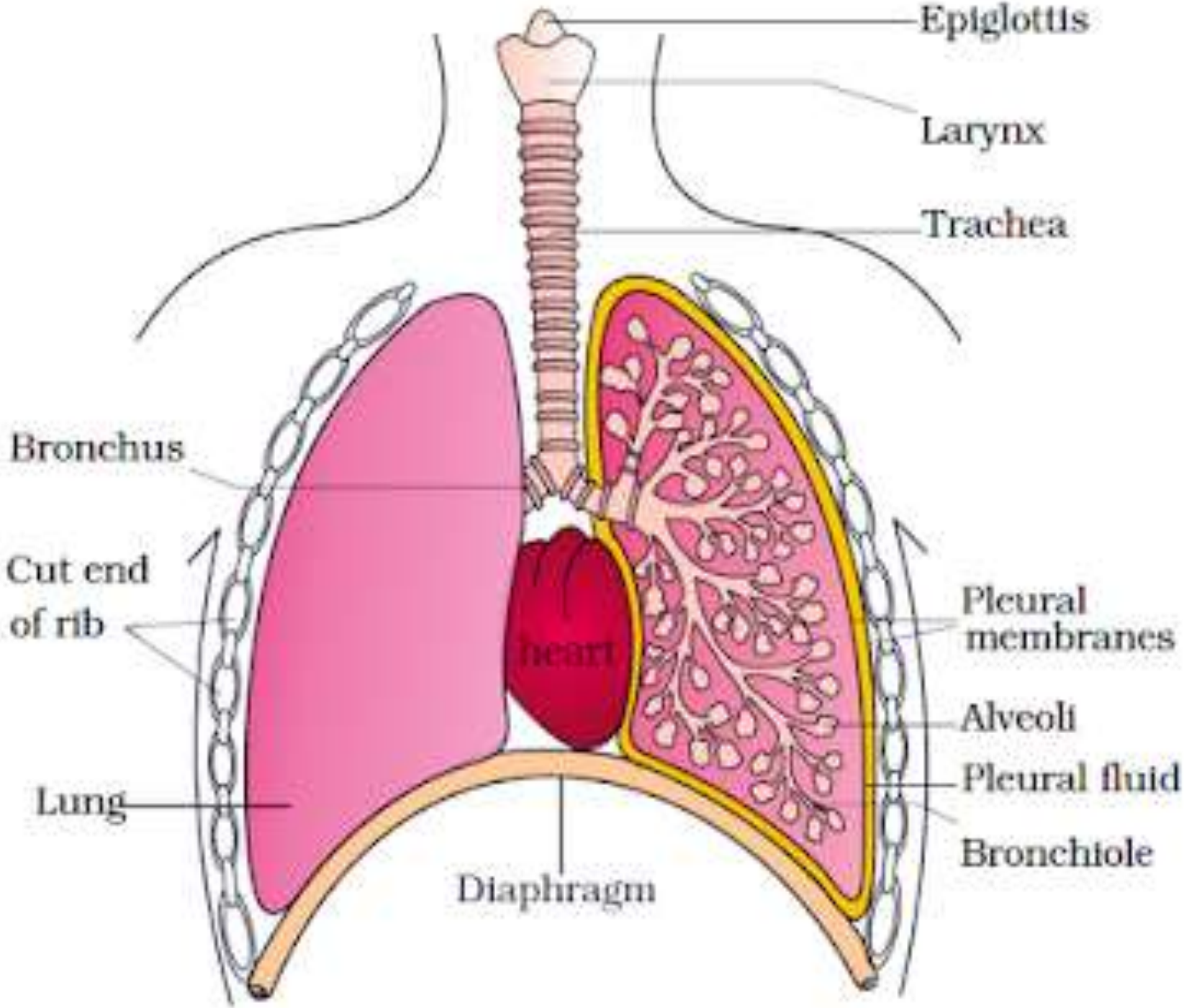
  - It prevents airway collapse (especially in smaller bronchioles).

  - It ensures expiration is **gradual and controlled**, allowing for efficient gas exchange.

- **During forced expiration:**

  - internal intercostal muscles---- bring ribcage down and backwards-------- decreasing the AP diameter

  - Abdominal recti----decrease AP diameter and elevate diaphragm to decrease vertical diameter


Epiglottis
Larynx
Trachea
Bronchus
Cut end of rib
heart
Pleural membranes
Alveoli
Pleural fluid
Bronchiole
Lung
Diaphragm

PRESSURES THAT CAUSE MOVEMENT OF AIR IN AND OUT OF THE LUNGS

- **Intra-pleural pressure or Intra-thoracic pressure**
- **Intra-alveolar or Intrapulmonary pressure**
- **Trans-pulmonary pressure**
- **Transthoracic pressure**

Intrapleural Pressure or Intrathoracic pressure

- **Intrapleural Pressure or Intrathoracic pressure:**

  It is the pressure within the intrapleural space i.e between the 2 layers of pleura.

- **The pressure that allows the lung distension or it is the pressure around the lungs.**

- **Intrapleural pressure is always negative**
- -5 cm of H2O: at the end of tidal expiration or beginning of tidal/quiet inspiration.

  -7.5 cm of H2O: at the end of tidal inspiration

Why IPP is always negative?

- Pleural fluid is constantly pumped into the lymphatics with suction pressure.
- This pumping creates the negative pressure in pleural space

Significance of negative IPP

- **Prevents collapse of alveoli:**

  alveoli have natural tendency to recoil or collapse

- **Increase the venous return:**

  Negative IPP increases venous return by suction effect that pulls the blood from the abdominal veins in thorax

Factors affecting IPP

Physiological Factors

- Non-uniform

At the base of the lungs: -2cm H_2O

weight of the lungs compresses the pleura at the base and dissipates the negative pressure

- **At the apex of the lungs**: -10cm H_2O
- **During deep inspiration:**

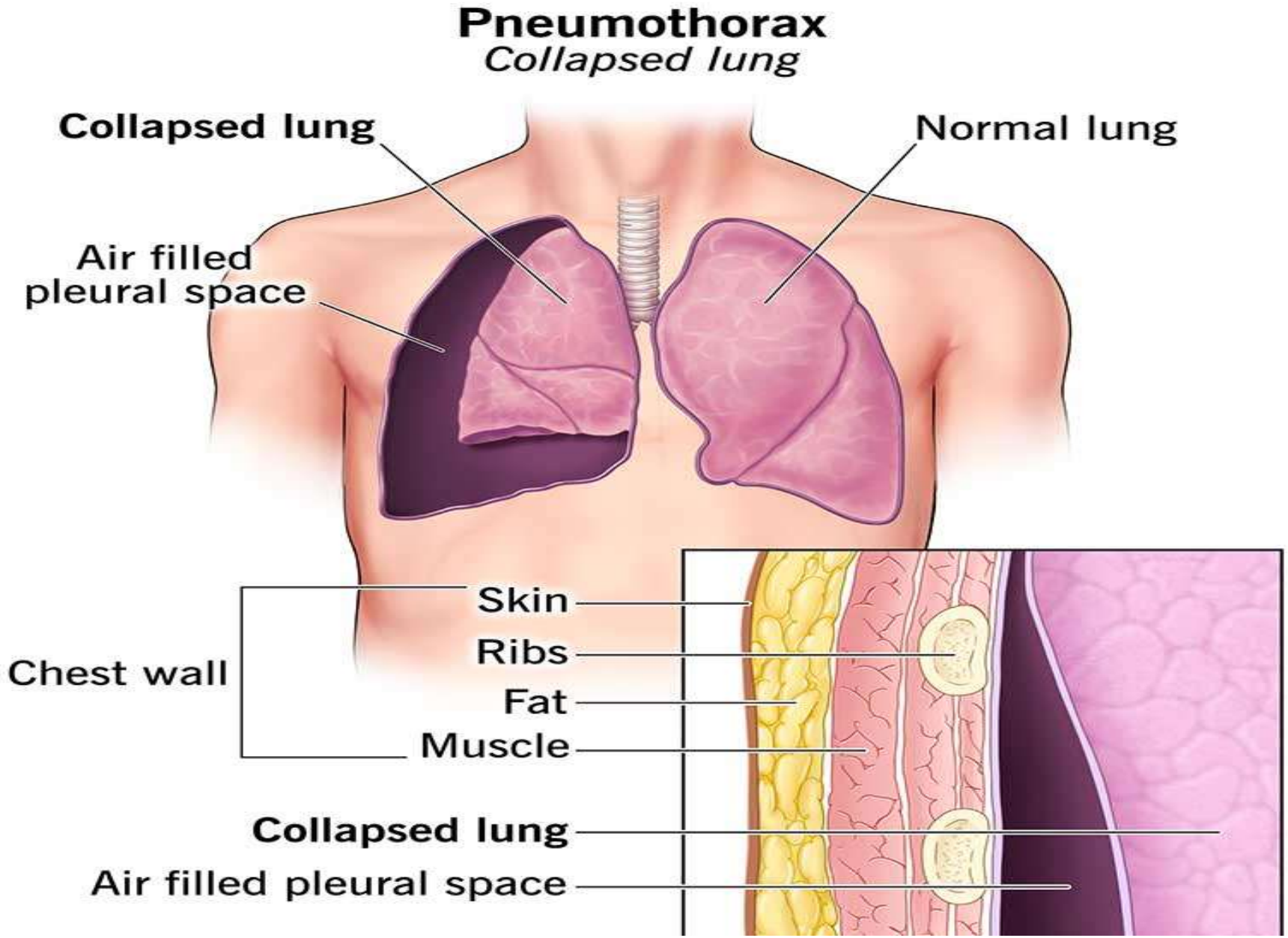
  More forceful inspiration--- the intrapleural pressure becomes more negative up to -30cmH2O

- First cry of a neonate produces -140 cm H_2O of intrathoracic pressure
- **Mullers manoeuvre:**
  - Forced inspiration against closed glottis
  - It is -100 to -140 cm H_2O
- **Forceful expiration produces positive intrathoracic pressure**
- **Valsalva manoeuvre:**
  - Forced expiration against closed glottis
  - It is +150 cm H_2O

Factors affecting IPP

Pathological Factors

- Emphysema----loss of lung elasticity----barrel shaped chest
- Pneumothorax------air in pleural cavity-----collapse of the lung


Pneumothorax
Collapsed lung
Collapsed lung
Normal lung
Air filled
pleural space
Chest wall
Skin
Ribs
Fat
Muscle
Collapsed lung
Air filled pleural space

Measurement of IPP

- **Directly:**

  by inserting a catheter inside the space

- **Indirectly:**

  by measuring the intraoesophageal pressure

Intra-alveolar or Intrapulmonary pressure

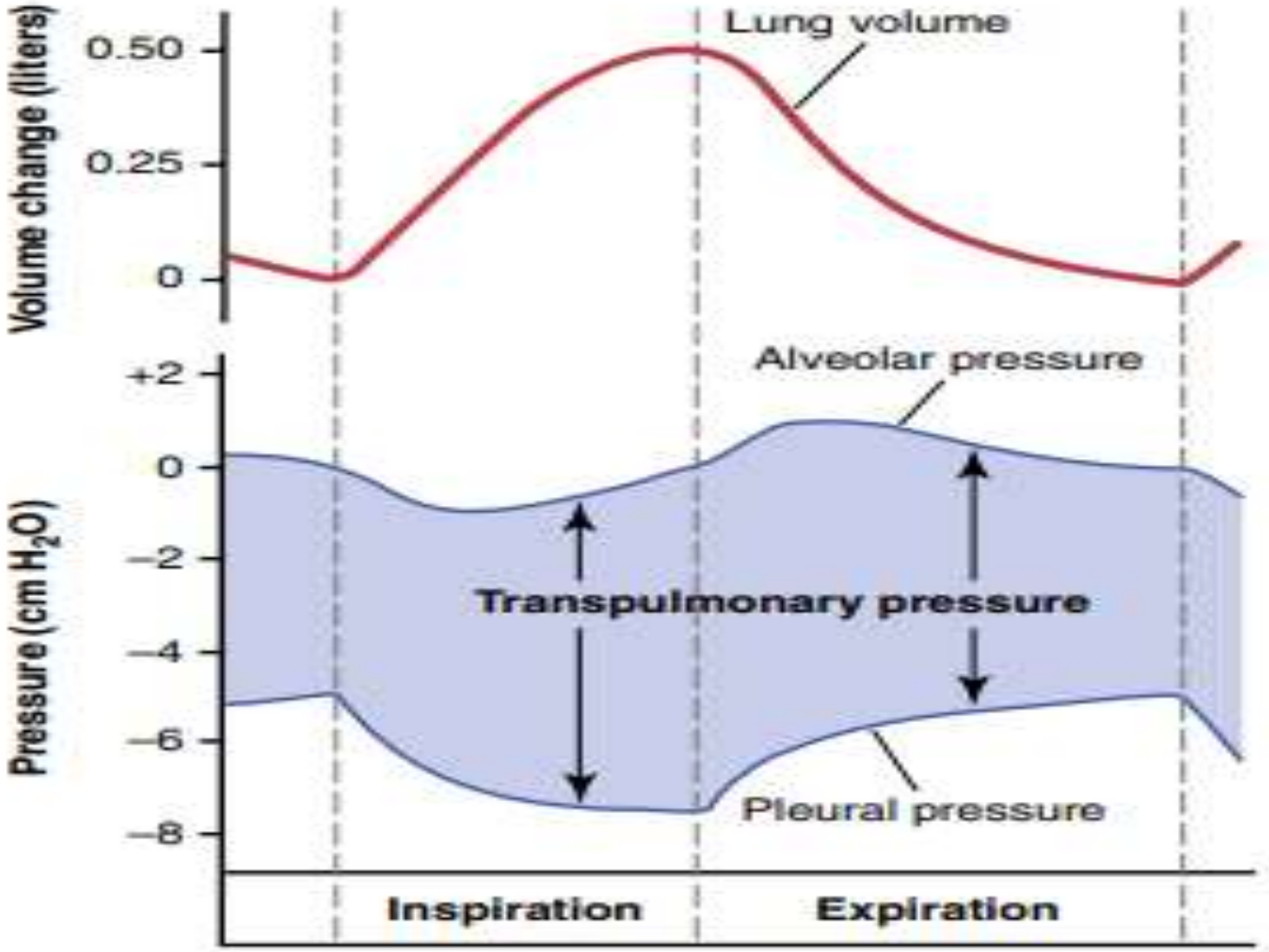
- It is the pressure within the alveolar space or within lungs.
- At the end of quiet/tidal expiration IAP is 0 that is equal to atmospheric pressure.

- At the beginning of inspiration intrapleural pressure is-1 cmH_2O: pulls the air inside.
- At the beginning of expiration it is +1 cmH_2O: expels the air out.

Trans-pulmonary pressure

- **It is the difference between the intra-alveolar and the intrapleural pressure**.
- It is the net pressure on the wall of the alveoli.

Changes in the lung volume, alveolar pressure and transpulmonary pressure during normal quiet breathing



PRESSURES THAT CAUSE MOVEMENT OF AIR IN AND OUT OF THE LUNGS

- Chest wall tissues are elastic in nature and have a tendency to expand.
- Alveoli have tendency to collapse or recoil inwards.

- 2/3rd of alveolar recoil pressure----surface tension of fluid lining the alveoli
- 1/3rd of alveolar recoil pressure----due to elastic nature of alveolar tissue
- At the end of tidal expiration chest wall expansion exactly balances alveolar recoil.

Events in Inspiration

Respiratory centers in medulla initiates the stimuli for respiration

These impulses are carried via nerve to the inspiratory muscles

The diaphragm and other inspiratory muscle

Chest wall expands increasing the volume thorax

Intrapleural pressure becomes more negative(from -5cm H_2O to -7.5cm H_2O

Events in Inspiration

The alveolar pressure decreases below the atmospheric pressure

The alveoli inflates as airflows into them until alveolar pressure reaches atmospheric pressure

Events in Expiration

Respiratory centers terminates the inspiratory impulses

The diaphragm and other inspiratory muscles relax

Chest wall retracts decreasing the the volume thorax

Intrapleural pressure becomes less negative

The alveolar pressure increases above the atmospheric pressure

Events in Expiration

The alveoli undergo elastic recoil forcing air out

The alveoli deflates as airflows out of them until alveolar pressure reaches atmospheric pressure