MECHANISM OF RESPIRATION

RESPIRATORY MOVEMENTS

INTRODUCTION

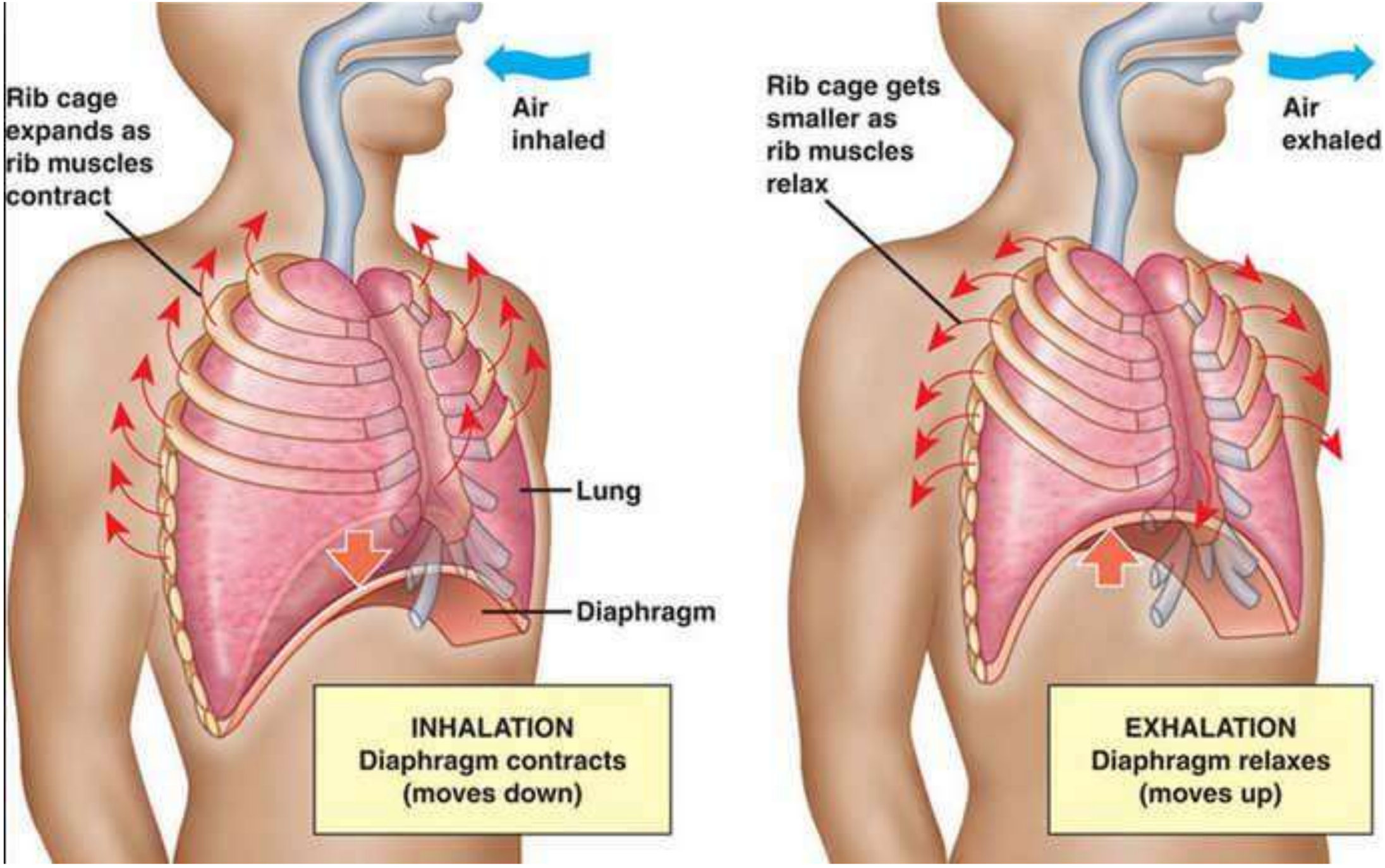
Respiration occurs in two phases namely inspiration and expiration.

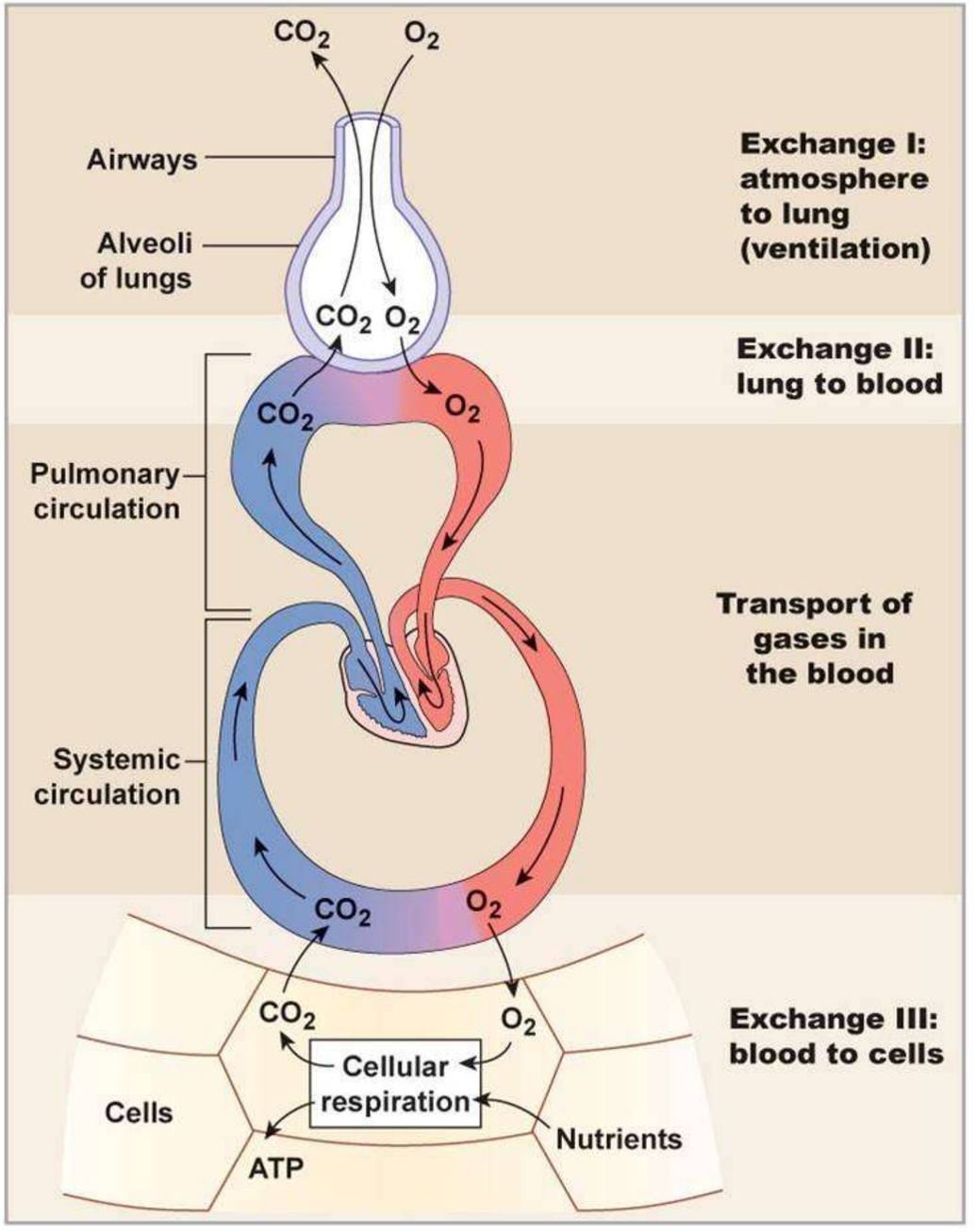
During inspiration, thoracic cage enlarges and lungs expand so that air enters the lungs easily.

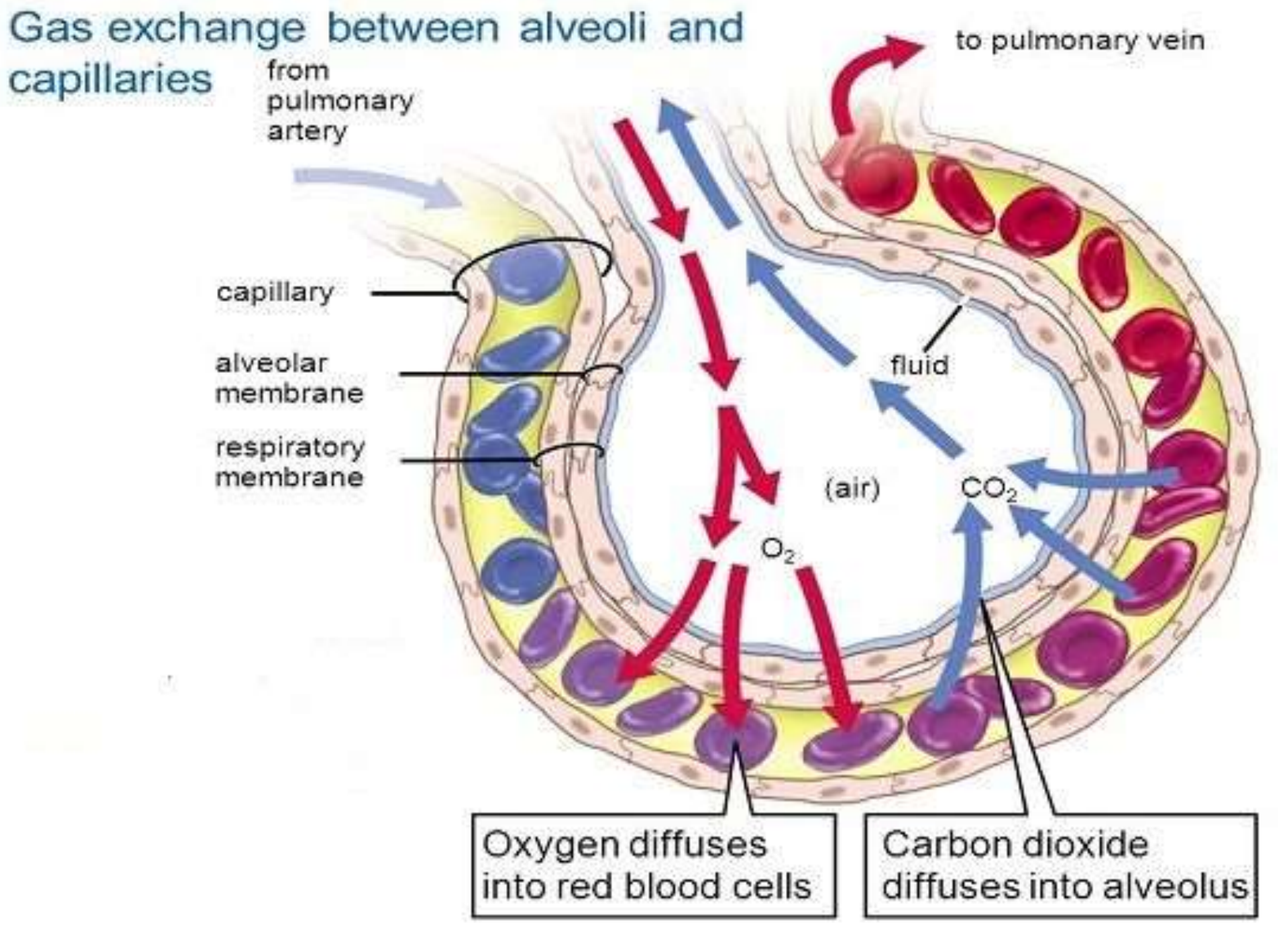
During expiration, the thoracic cage and lungs decrease in size and attain the pre

inspiratory position so that air leaves the lungs easily.

During normal quiet breathing, inspiration is the active process and expiration is the passive process


Rib cage expands as rib muscles contract
Air inhaled
Lung
Diaphragm
INHALATION
Diaphragm contracts
(moves down)
Rib cage gets smaller as rib muscles relax
Air exhaled
EXHALATION
Diaphragm relaxes
(moves up)





MUSCLES OF RESPIRATION

Respiratory muscles are of two types:

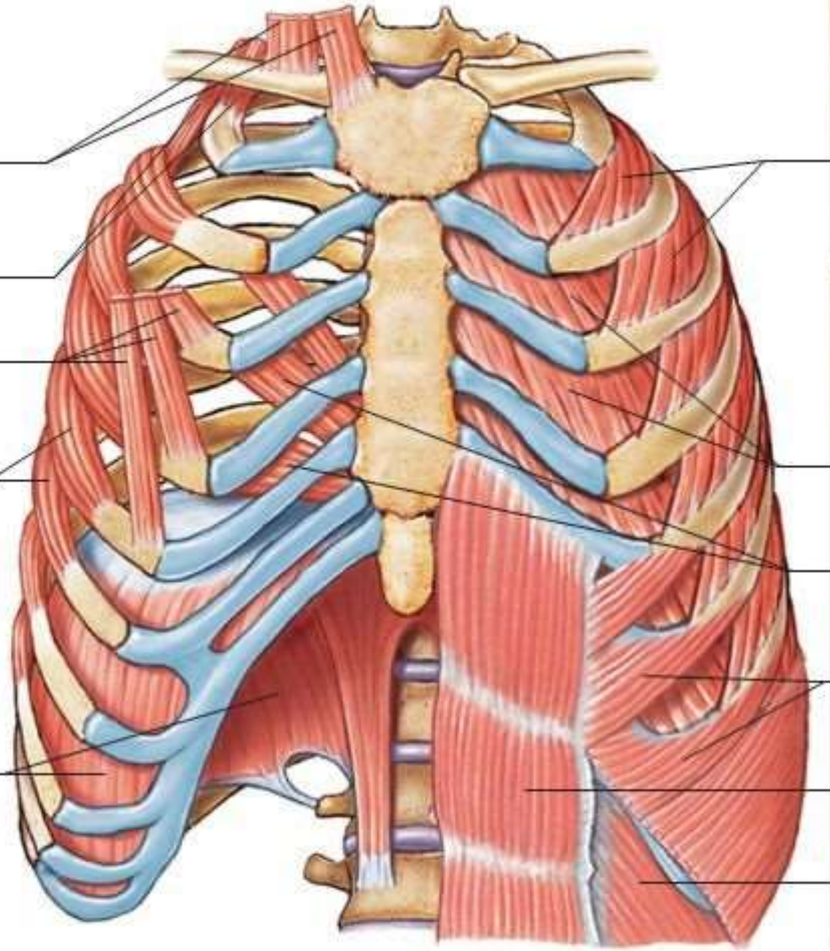
1. **Inspiratory muscles**
2. **Expiratory muscles.**

However, respiratory muscles are generally classified into two types:

1. **Primary or major respiratory muscles**, which are responsible for change in size of thoracic cage during normal quiet breathing.
2. **Accessory respiratory muscles** that help primary respiratory muscles during forced respiration.

Figure 24.16 Respiratory Muscles and Pulmonary Ventilation (1 of 4)

1 The Respiratory Muscles



Accessory Respiratory Muscles (Inhalation)

- Sternocleidomastoid muscle
- Scalene muscles
- Pectoralis minor muscle
- Serratus anterior muscle

Primary Respiratory Muscles (Inhalation)

- Diaphragm

Primary Respiratory Muscles (Inhalation)

- External intercostal muscles

Accessory Respiratory Muscles (Exhalation)

- Internal intercostal muscles
- Transversus thoracis muscle
- External oblique muscle
- Rectus abdominis
- Internal oblique muscle

EXPIRATORY MUSCLES

Primary expiratory muscles

Primary expiratory muscles are the internal intercostal muscles, which are innervated by intercostal nerves.

Accessory expiratory muscles

Accessory expiratory muscles are the abdominal muscles

Muscles of inspiration

Accessory

Sternocleidomastoid (elevates sternum)

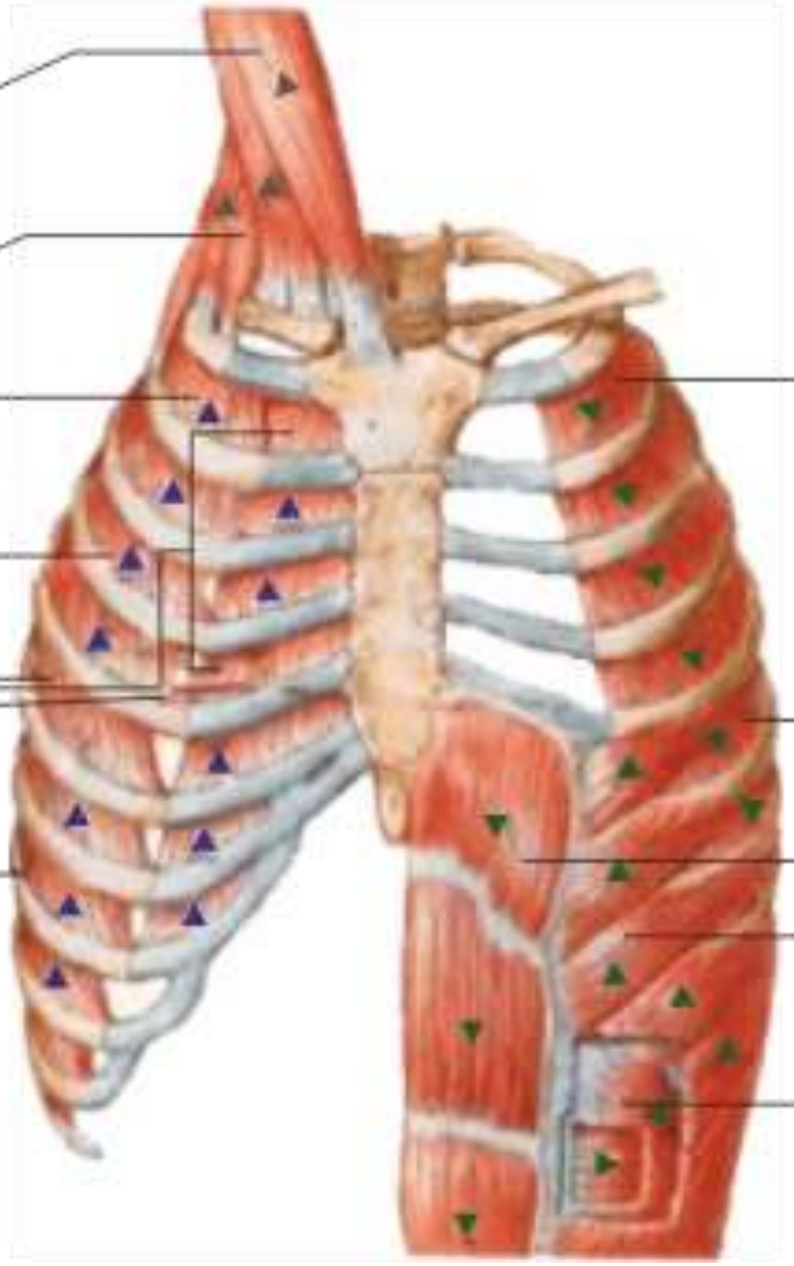
Scalenes group (elevatae upper ribs)

Not shown: Pectoralis minor

Principal

External intercostals interchondral part of internal intercostals (also elevates ribs)

Diaphragm (dome descends, thus increasing vertical dimensionof thorac cavity; also elevates lower ribs)



Muscles of expiration

Quiet breathing

Expiration results from passive, elastic recoil of the lungs, dib cage and diaphragm

Active breathing

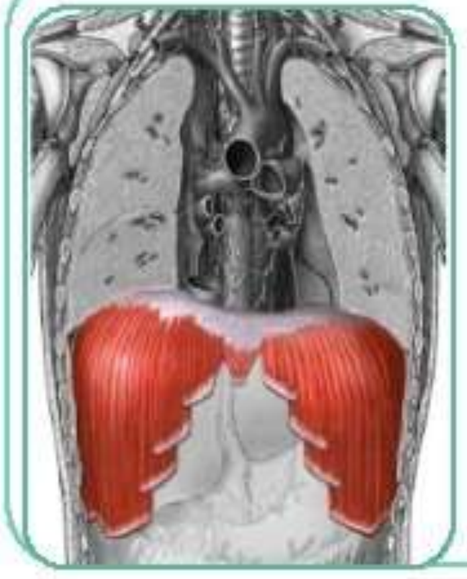
Internal intercostals, except interchondral part (pull ribs down)

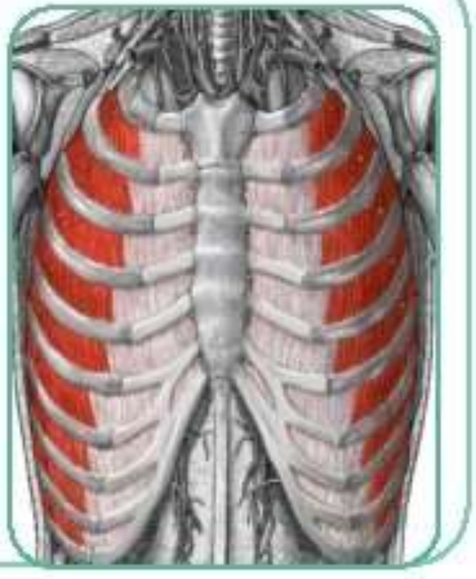
Abdominals (pull ribs down, compress abdominal contents thus pushing diaphragm up)

Note shown Quadratus lumborum (pulls ribs down)

Inspiratory Muscles

Muscles used in **rest** and **forced inspiration**

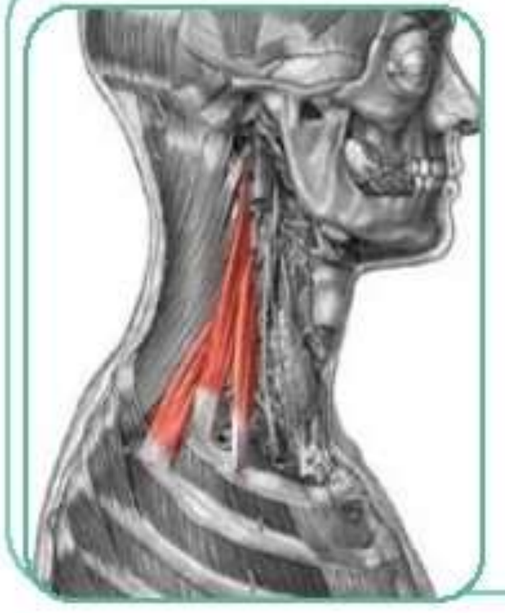


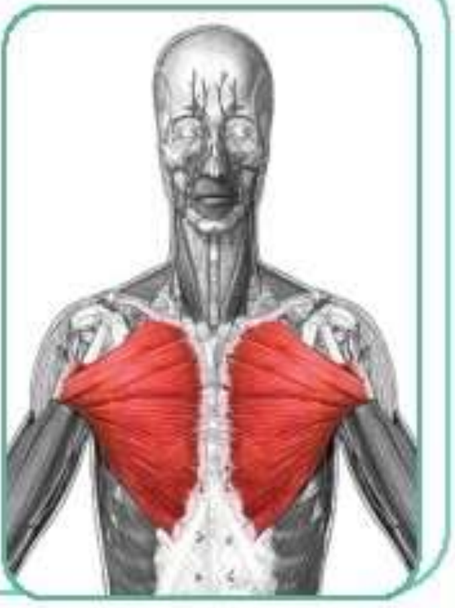


Diaphragm : most important muscle in inspiration

Rib elevators: **external intercostal muscles**

Accessory muscles
(only during <u>forced</u> inspiration) :





Muscles attaching cervical vertebrae to first & second rib: **scalene muscles**

Muscles attaching thoracic cage to upper limb: **pectoralis major**

Note:
Why are the accessory muscles listed in anatomy different from the ones in physiology? Because they are BOTH correct.
Grey's Anatomy:
"Any muscles attaching to the ribs can potentially move one rib relative to another and therefore act as accessory respiratory muscles."

SUMMARY OF RESPIRATORY MOVEMENTS

Inspiration

- **Quiet Inspiration (active)**

Contraction (Descent) of diaphragm → Increase in **vertical** diameter

Elevation of ribs (external intercostal) → Increase in:
- **anteroposterior** diameter
- **lateral** diameter

- **Forced Inspiration (active)**

Accessory muscles of inspiration:
1. Pectoralis major
2. Scalene muscles

Expiration

- **Quiet Expiration (passive)**

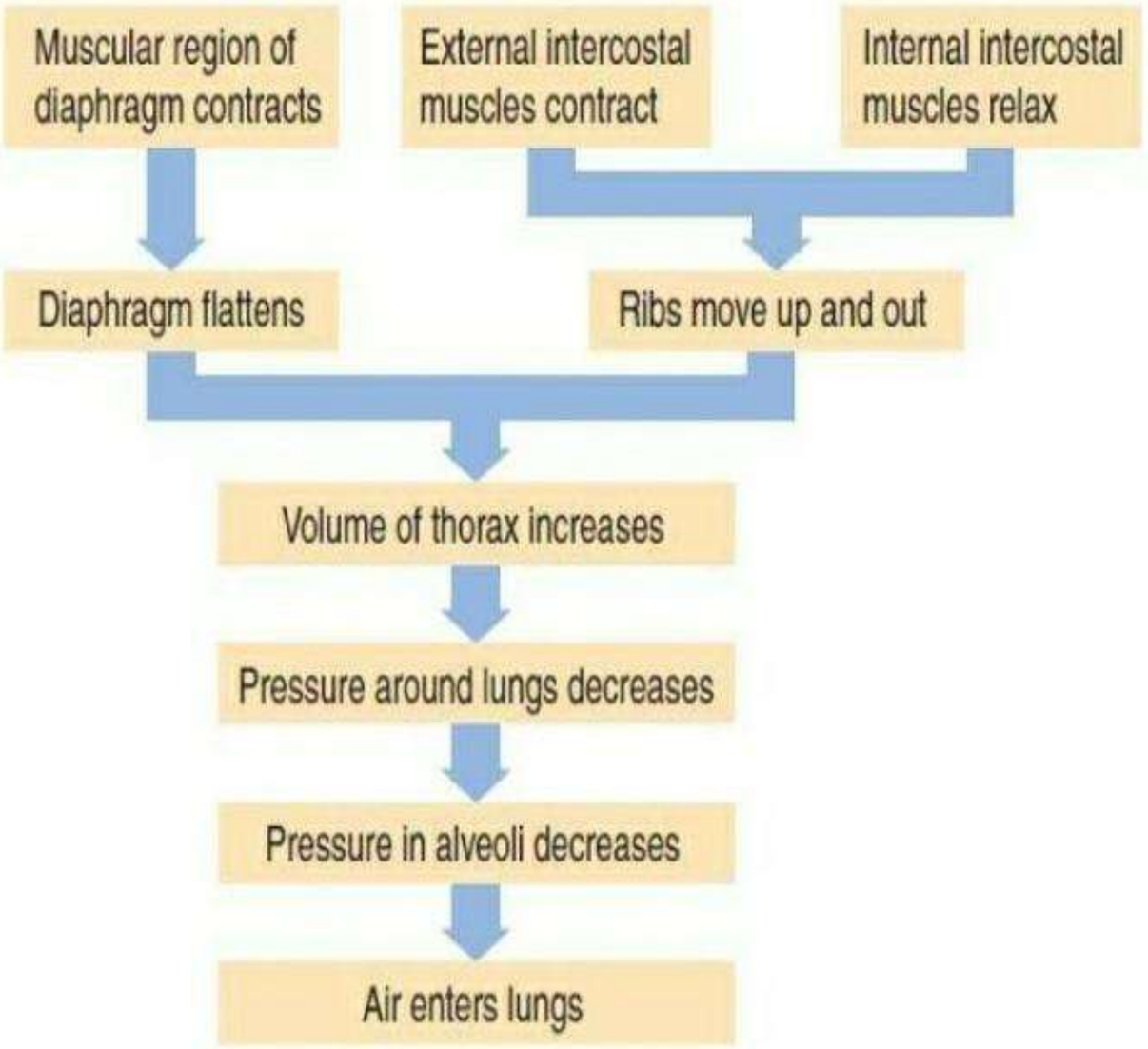
1. Elastic recoil of lung
2. Relaxation of diaphragm & external intercostal

- **Forced Expiration (active):**

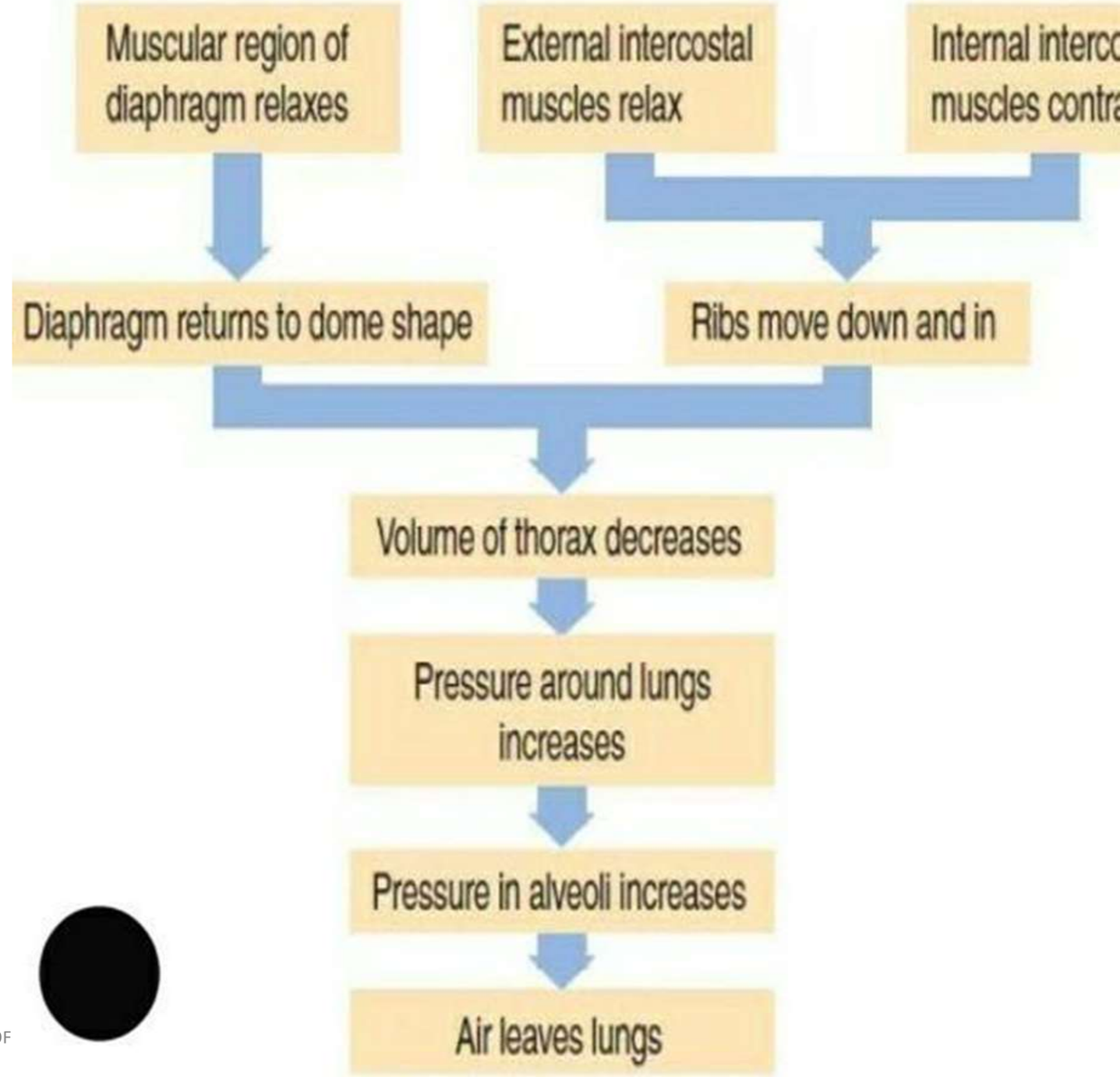
Contraction of anterior abdominal wall muscles → Compression of abdominal viscera → Ascent of diaphragm

Depression of ribs (rest of intercostal muscles)

Mechanism of Inhalation



Mechanism of Exhalation



ANISM OF

Events in inspiration and expiration

Inspiration	Expiration
Respiratory centre initiates the stimuli during inspiration. ↓ The diaphragm and exspiratory muscles contract. ↓ The thoracic volume increases as the chest wall expands. ↓ The intra pulmonary pressure is reduced. ↓ The alveolar pressure decreases than the atmospheric pressure ↓ Air is taken inside due to expansion of alveoli. ↓ Air flows into the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get inflated.	Respiratory centre terminates the stimuli during expiration. ↓ The diaphragm relax but internal intercostal muscles contract. ↓ The thoracic volume decreases as the chest wall contracts. ↓ The intra pulmonary pressure is increased. ↓ The alveolar pressure increases than the atmospheric pressure. ↓ Air is sent out due to the contraction of alveoli. ↓ Air flows out of the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get deflated.

MOVEMENTS OF THORACIC CAGE

Inspiration causes enlargement of thoracic cage.

Thoracic cage enlarges because of increase in all diameters, viz. **anteroposterior, transverse and vertical diameters.**

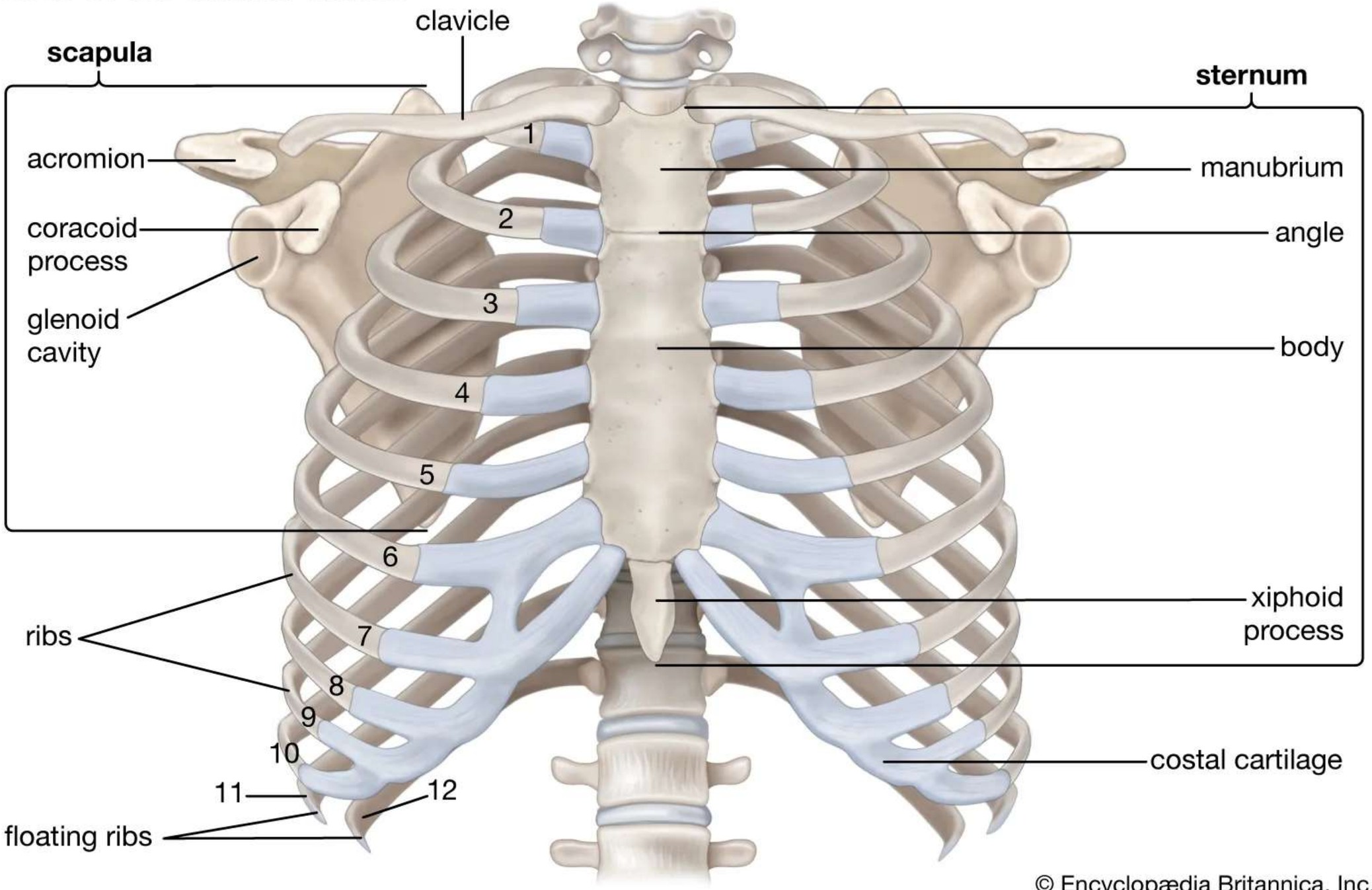
Anteroposterior and transverse diameters of thoracic cage are increased by the elevation of ribs.

Vertical diameter is increased by the descent of diaphragm.

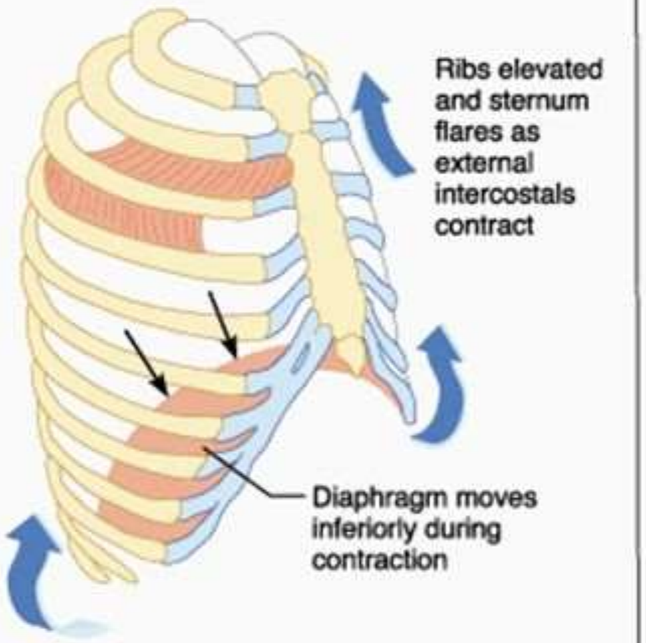
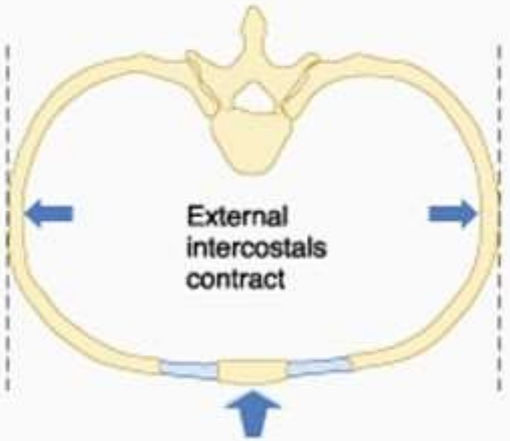
In general, change in the size of thoracic cavity occurs because of the movements of four units of structures:

1. **Thoracic lid**
2. **Upper costal series**
3. **Lower costal series**
4. **Diaphragm**

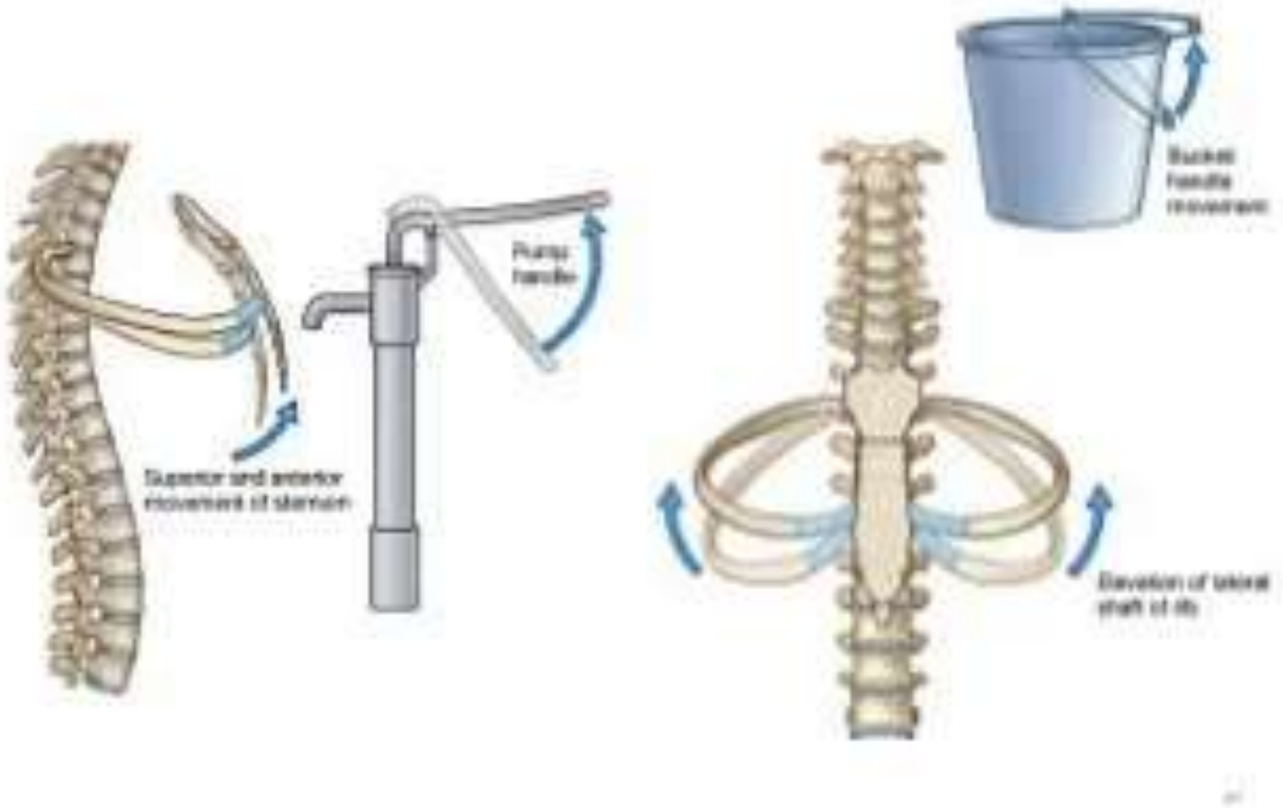
Bones of the human thorax



The Thoracic Cage Movement: Inspiration

	Sequence of events	Changes in anterior-posterior and superior-inferior dimensions	Changes in lateral dimensions
Inspiration	① Inspiratory muscles contract (diaphragm descends; rib cage rises) ↓ ② Thoracic cavity volume increases ↓ ③ Lungs stretched; intrapulmonary volume increases ↓ ④ Intrapulmonary pressure drops (to –1 mm Hg) ↓ ⑤ Air (gases) flows into lungs down its pressure gradient until intrapulmonary pressure is 0 (equal to atmospheric pressure)		

MOVEMENTS OF RIB CAGE



1. THORACIC LID

Thoracic lid is formed by manubrium sterni and the first pair of ribs.

It is also called **thoracic operculum.**

Movement of thoracic lid increases the anteroposterior diameter of thoracic cage.

Due to the **contraction of scalene muscles**, the first ribs move upwards to a more horizontal position.

This **increases the anteroposterior diameter of upper thoracic cage**

2. UPPER COSTAL SERIES

Upper costal series is constituted by second to sixth pair of ribs.

Movement of upper costal series **increases the anteroposterior and transverse diameter of the thoracic cage.**

Movement of upper costal series is of two types:

i. Pump handle movement

ii. Bucket handle movement.

PUMP HANDLE MOVEMENT

Contraction of external intercostal muscles causes elevation of these ribs and upward and forward movement of sternum.

This movement is called pump handle movement.

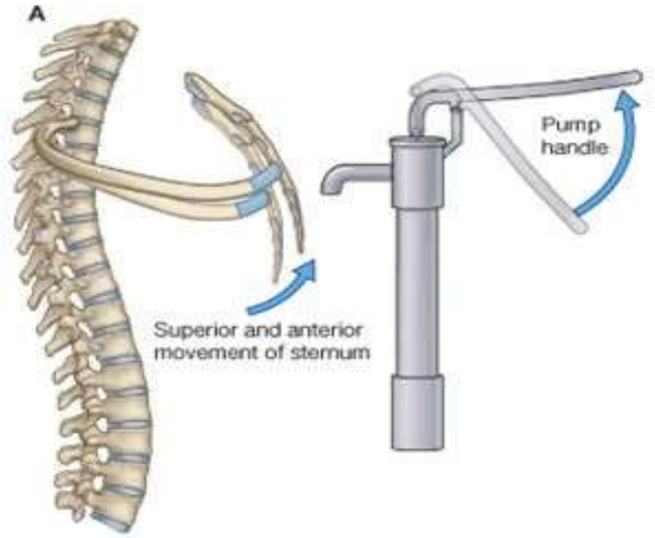
It **increases anteroposterior diameter** of the thoracic cage.

RESPIRATORY MOVEMENTS
B- MOVEMENTS OF RIBS

PUMP HANDLE MOVEMENT

Elevation of ribs

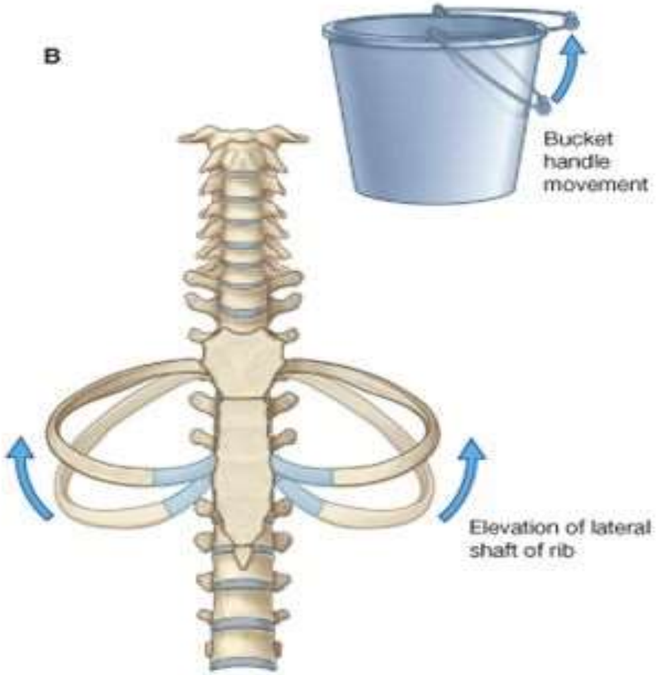
Increase in antero-posterior diameter of thoracic cavity

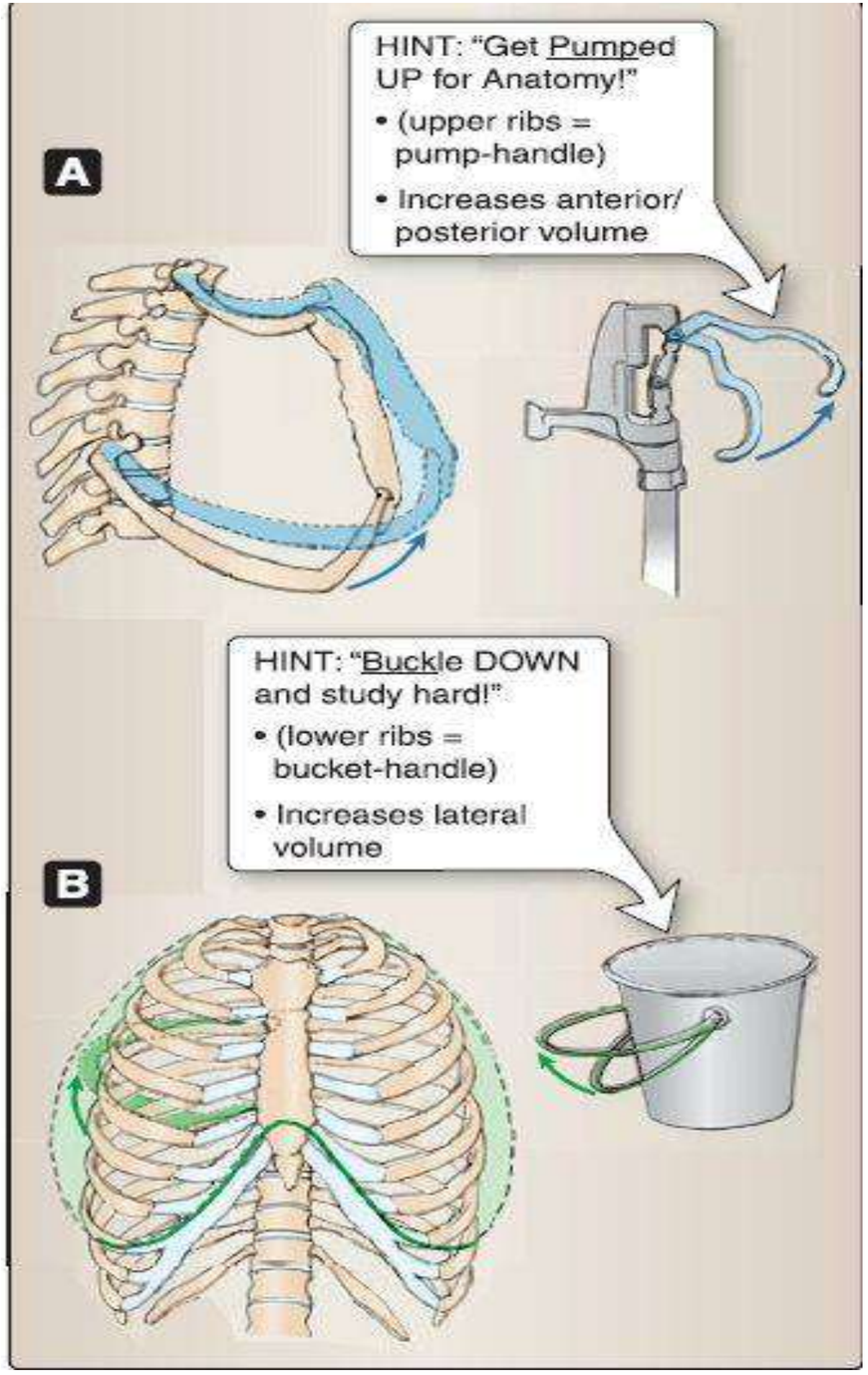


BUCKET HANDLE MOVEMENT

Elevation of ribs

Increase in lateral diameter of thoracic cavity




HINT: "Get Pumped UP for Anatomy!"
• (upper ribs = pump-handle)
• Increases anterior/ posterior volume
A
HINT: "Buckle DOWN and study hard!"
• (lower ribs = bucket-handle)
• Increases lateral volume
B

BUCKET HANDLE MOVEMENT

Simultaneously, the central portions of these ribs (arches of ribs) move upwards and outwards to a more horizontal position.

This movement is called bucket handle movement and it **increases the transverse diameter of thoracic cage.**

3. LOWER COSTAL SERIES

Lower costal series includes **seventh to tenth pair of ribs.**

Movement of lower costal series increases the transverse diameter of thoracic cage by bucket handle movement.

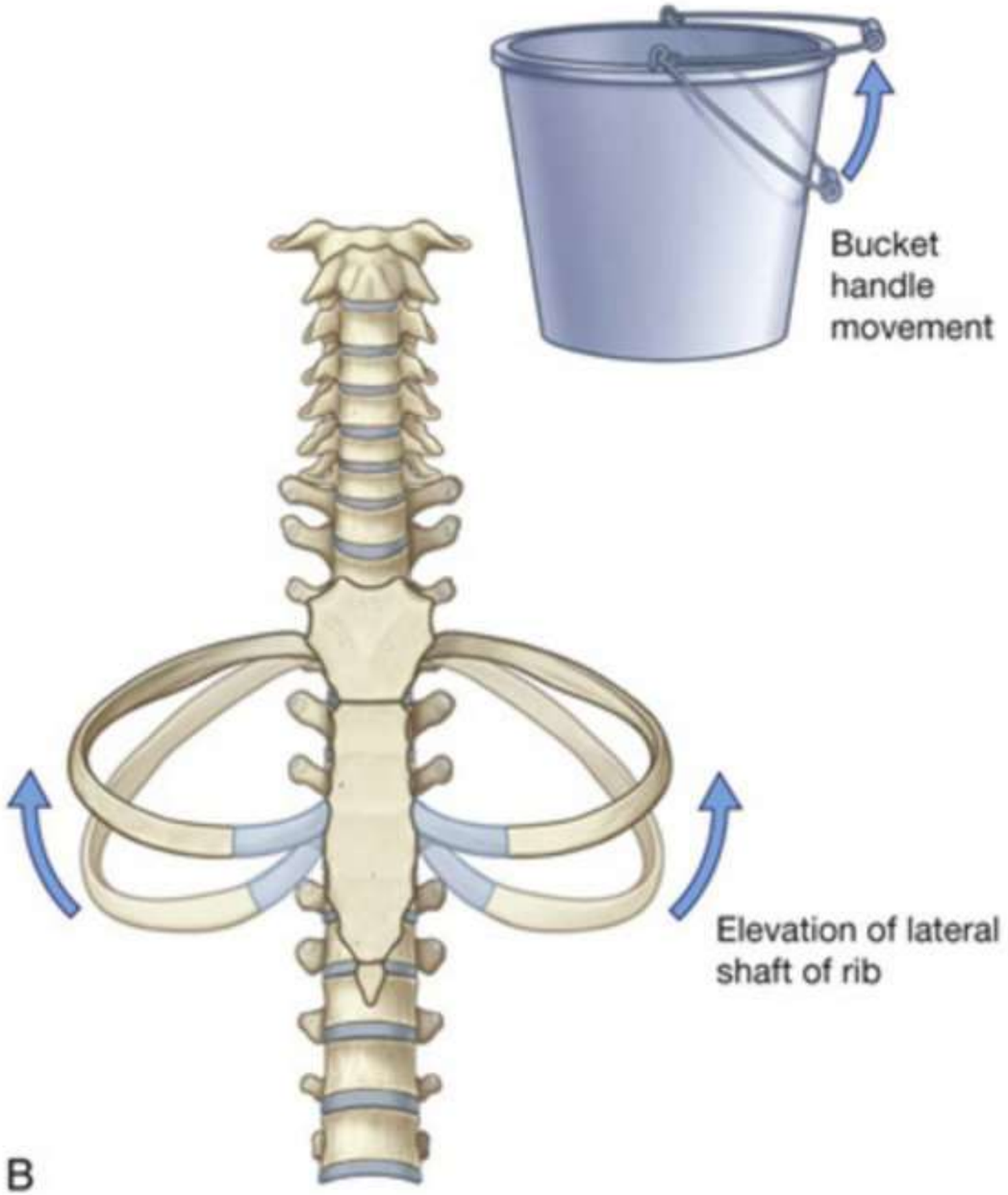
Bucket handle movement

Lower costal series of ribs also show bucket handle movement by swinging outward and upward.

This movement increases the transverse diameter of the thoracic cage.

Eleventh and twelfth pairs of ribs are the floating ribs.

These ribs are not involved in changing the size of thoracic cage.


Bucket
handle
movement
Elevation of lateral
shaft of rib
B

4. DIAPHRAGM

Movement of diaphragm increases the vertical diameter of thoracic cage.

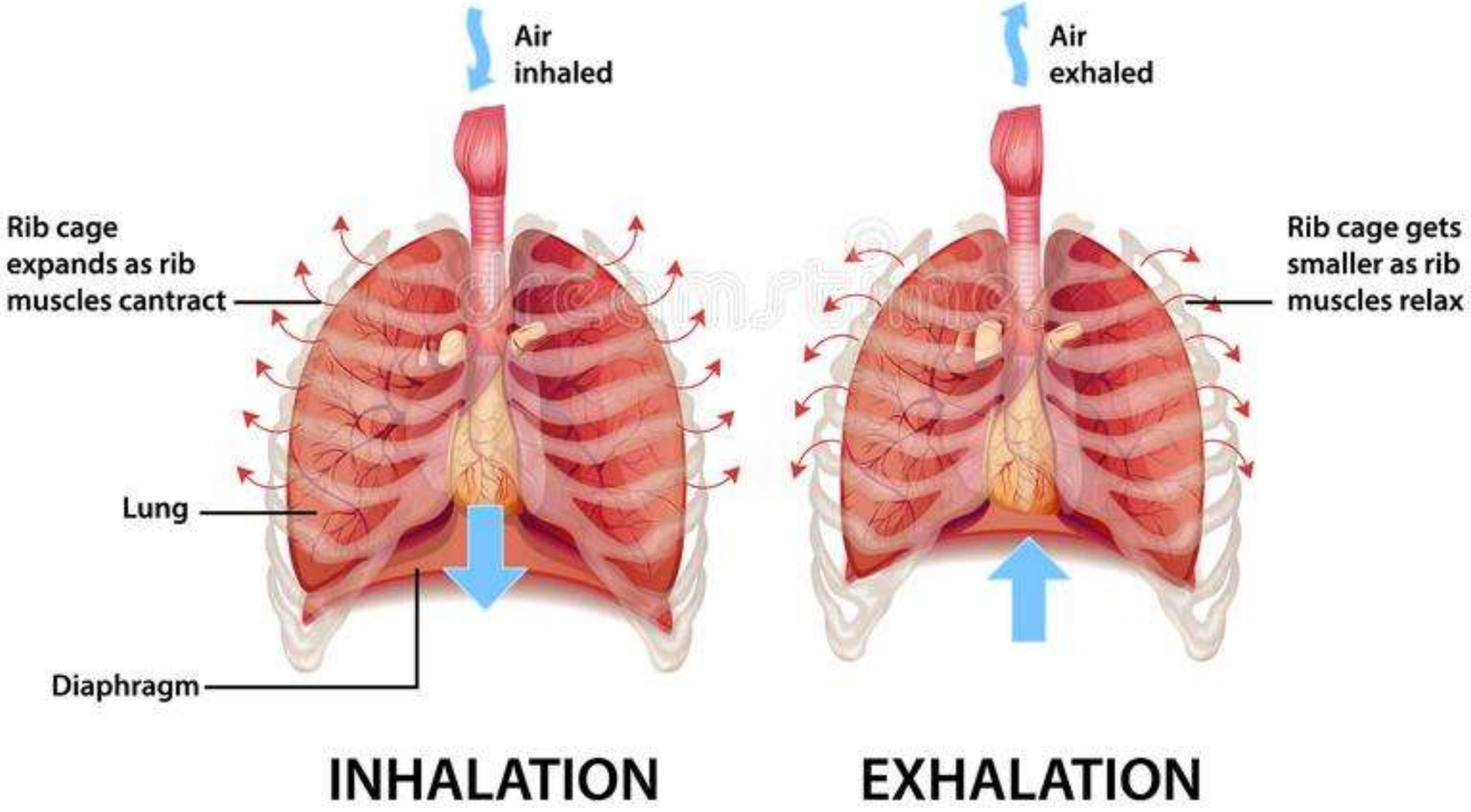
Normally, before inspiration the diaphragm is dome shaped with convexity facing upwards.

During inspiration, due to the contraction, muscle fibers are shortened.

But the central tendinous portion is drawn downwards so the diaphragm is flattened.

Flattening of diaphragm increases the vertical diameter of the thoracic cage.

THE DIAPHRAGM FUNCTIONS IN BREATHING



MOVEMENTS OF LUNGS

During inspiration, due to the enlargement of thoracic cage, the negative pressure is increased in the thoracic cavity.

It causes **expansion** of the lungs.

During expiration, the thoracic cavity **decreases in size** to the pre inspiratory position.

Pressure in the thoracic cage also comes back to the preinspiratory level.

It compresses the lung tissues so that, the **air is expelled out of lungs.**

COLLAPSING TENDENCY OF LUNGS

Lungs are under constant threat to collapse even in resting conditions because of certain factors.

Factors Causing Collapsing Tendency of Lungs

Two factors are responsible for the collapsing tendency of lungs:

1. **Elastic property of lung tissues:** Elastic tissues of lungs show constant recoiling tendency and try to collapse the lungs

2. **Surface tension:** It is the tension exerted by the fluid secreted from alveolar epithelium on the surface of alveolar membrane. Fortunately, there are some factors, which **save the lungs from collapsing.**

Factors Preventing Collapsing Tendency of Lungs

In spite of elastic property of lungs and surface tension in the alveoli of lungs, the **collapsing tendency of lungs is prevented** by two factors:

1. **Intrapleural pressure:** It is the pressure in the pleural cavity, which is always negative. Because of negativity, it keeps the lungs expanded and prevents the collapsing tendency of lungs produced by the elastic tissues.

2. **Surfactant:** It is a substance secreted in alveolar epithelium.
It reduces surface tension and prevents the collapsing tendency produced by surface tension.

SURFACTANT

Surfactant is a surface acting material or agent that is responsible for lowering the surface tension of a fluid.

Surfactant that lines the epithelium of the alveoli in lungs is known as pulmonary surfactant and it **decreases the surface tension on the alveolar membrane.**

Source of secretion of pulmonary surfactant

Pulmonary surfactant is secreted by two types of cells:

1. **Type II alveolar epithelial cells** in the lungs, which are called surfactant secreting alveolar cells or pneumocytes. Characteristic feature of these cells is the presence of microvilli on their alveolar surface.

2. **Clara cells,** which are situated in the bronchioles. These cells are also called bronchiolar exocrine cells.

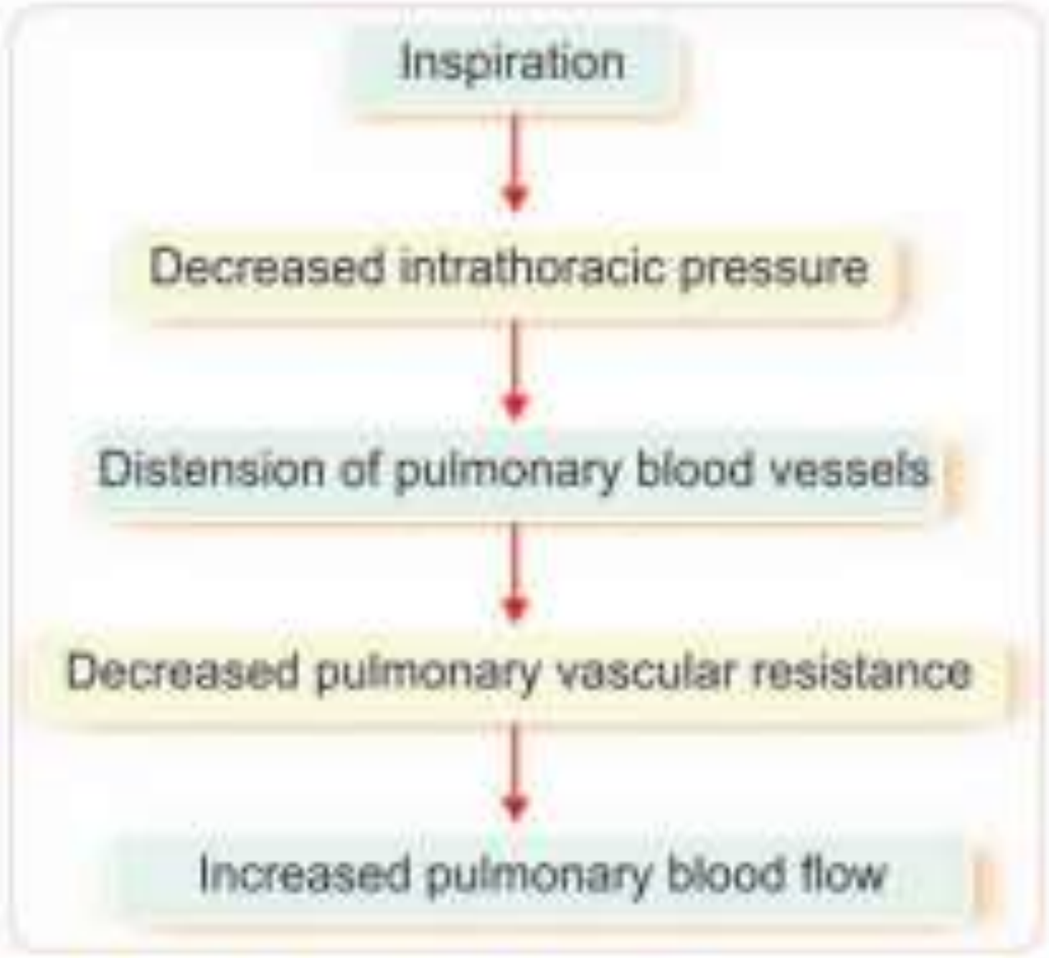


FIGURE 119.1: Schematic diagram showing increase i
pulmonary blood flow during inspiration

3. NERVOUS FACTORS

Stimulation of sympathetic nerves under experimental conditions increases the pulmonary vascular resistance by vasoconstriction and the stimulation of parasympathetic, i.e. vagus nerve decreases the vascular resistance by vasodilatation.

However, under physiological conditions, it is doubtful whether autonomic nerves play any role in regulating the blood flow to lungs.

4. CHEMICAL FACTORS

Excess of carbon dioxide or lack of oxygen causes vasoconstriction.

The cause for pulmonary vasoconstriction by hypoxia is not known.

But it has some significance. If some part of lungs is affected by hypoxia, there is constriction of capillaries in that area.

Thus, blood is directed to the alveoli of neighboring area where gaseous exchange occurs.

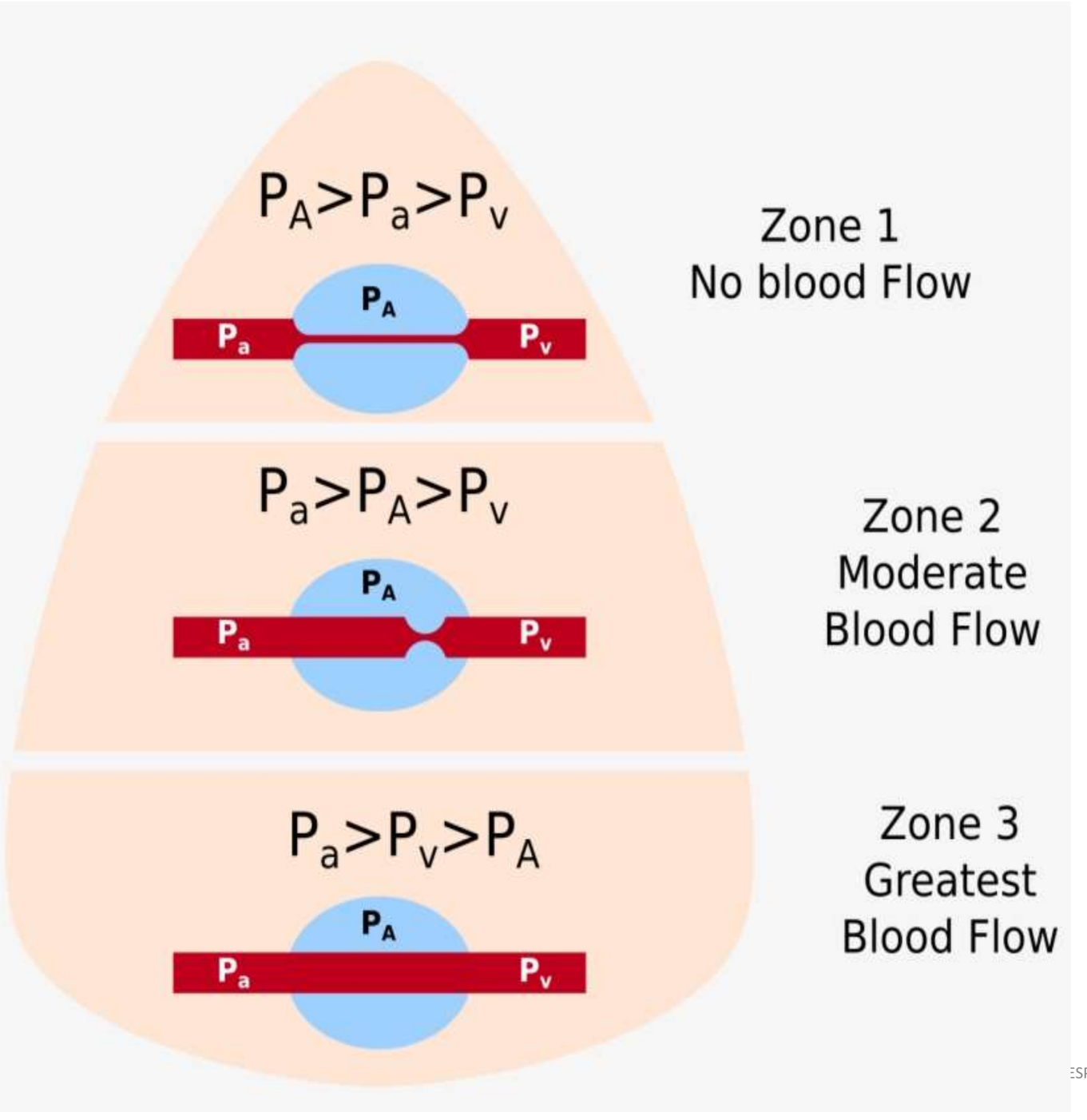
5. GRAVITY AND HYDROSTATIC PRESSURE

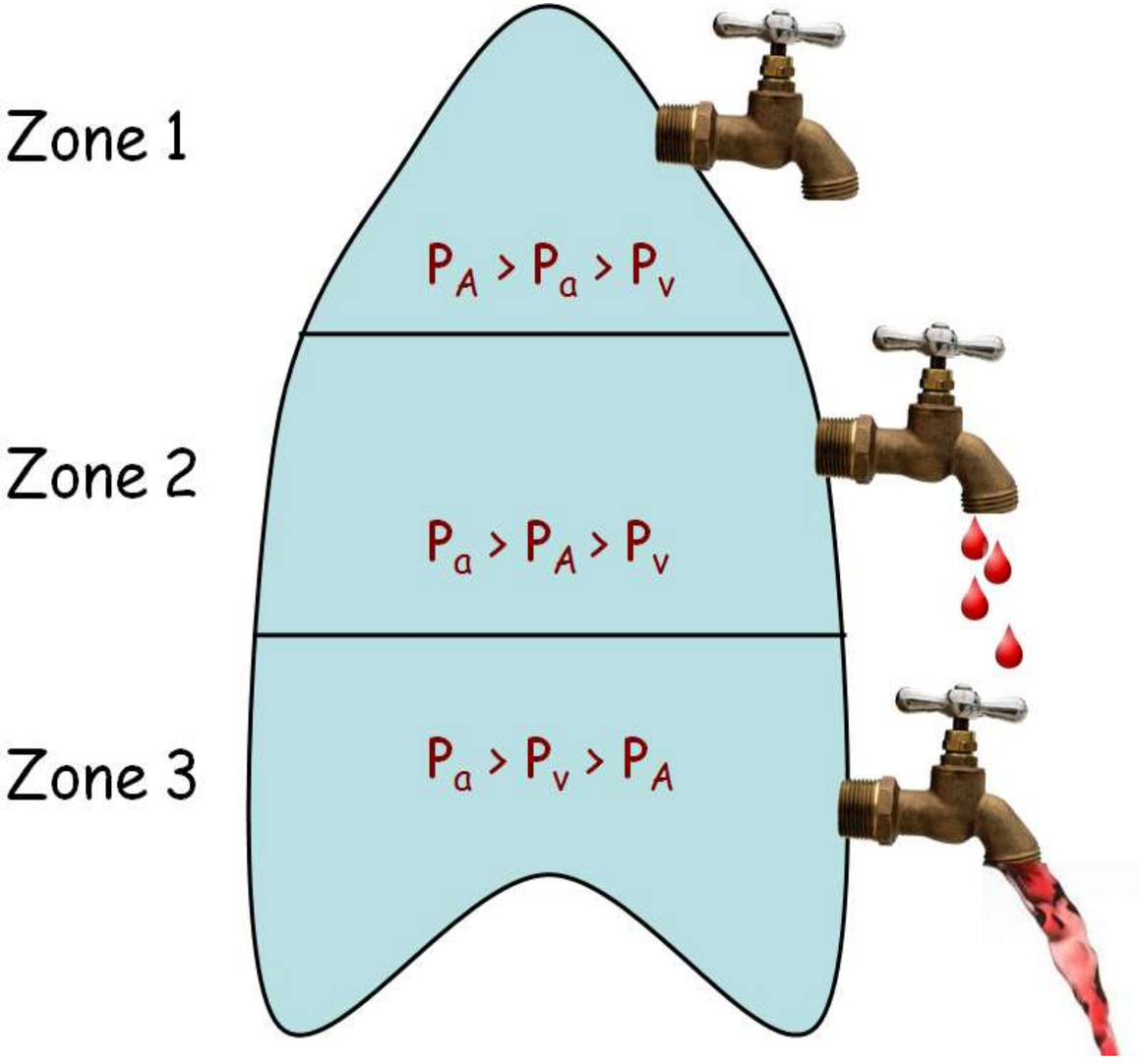
Normally in standing position, blood pressure in lower extremity of the body is very high and in upper parts above the level of heart, the pressure is low.

This is because of the effect of gravitational force.

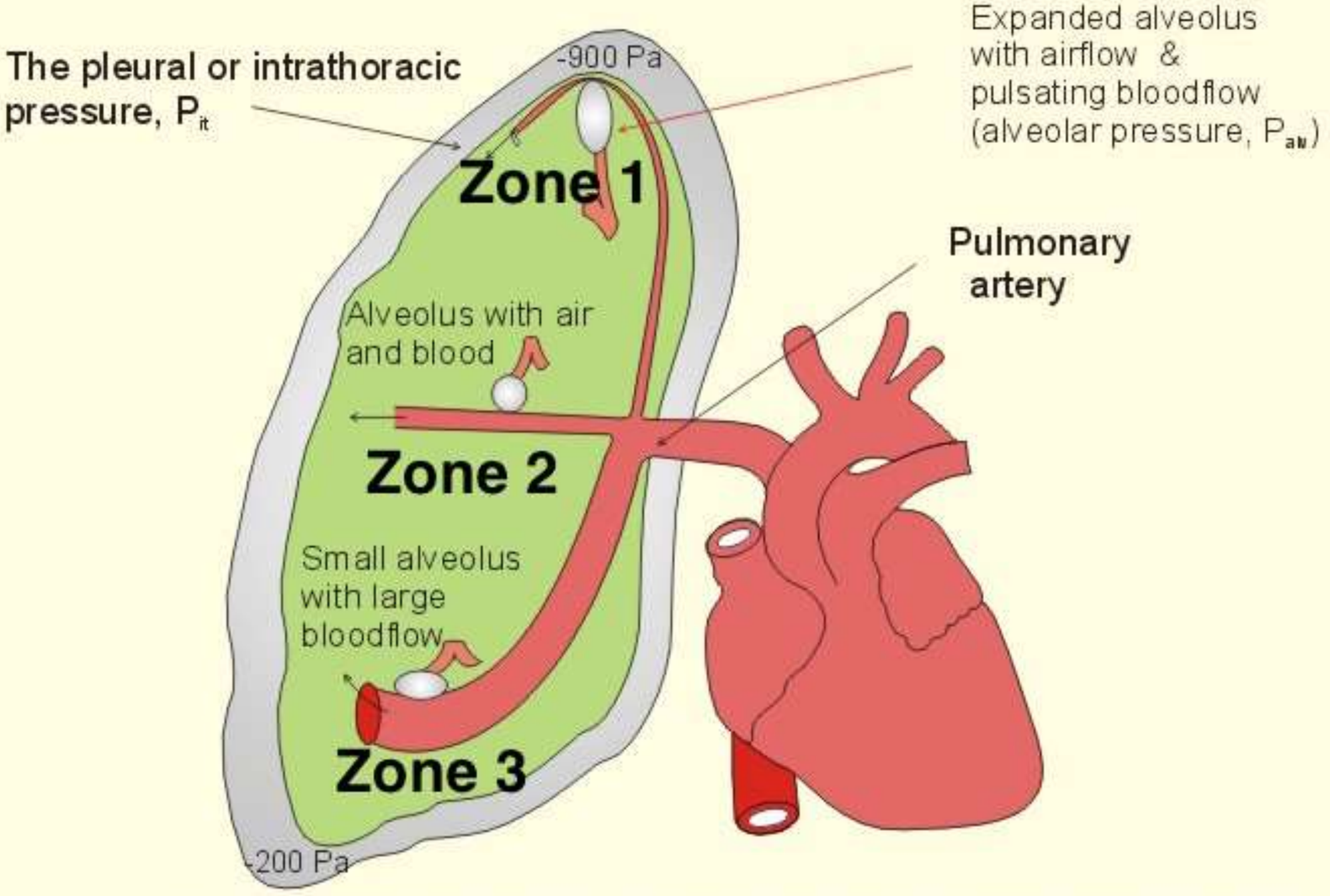
A similar condition is observed to some extent in lungs also.

Pulmonary vascular pressure varies in different parts of the lungs:


$P_A > P_a > P_v$
P_A
P_a
P_v
Zone 1
No blood Flow
$P_a > P_A > P_v$
P_A
P_a
P_v
Zone 2
Moderate
Blood Flow
$P_a > P_v > P_A$
P_A
P_a
P_v
Zone 3
Greatest
Blood Flow


Zone 1
Zone 2
Zone 3
$P_A > P_a > P_v$
$P_a > P_A > P_v$
$P_a > P_v > P_A$

Three Alveoli In The Upright Lung



The intrapleural pressure gradient is largest in the upper lung region

Fig.14-5

KMc

ZONE OF PERFUSION

- **Zone 1: No blood flow**

Reason: More negative intrapleural pressure→ alveoli size↑ & lower arterial pressure due to gravity → decrease diameter of vessels

- **Zone 2:** Intermittent blood flow

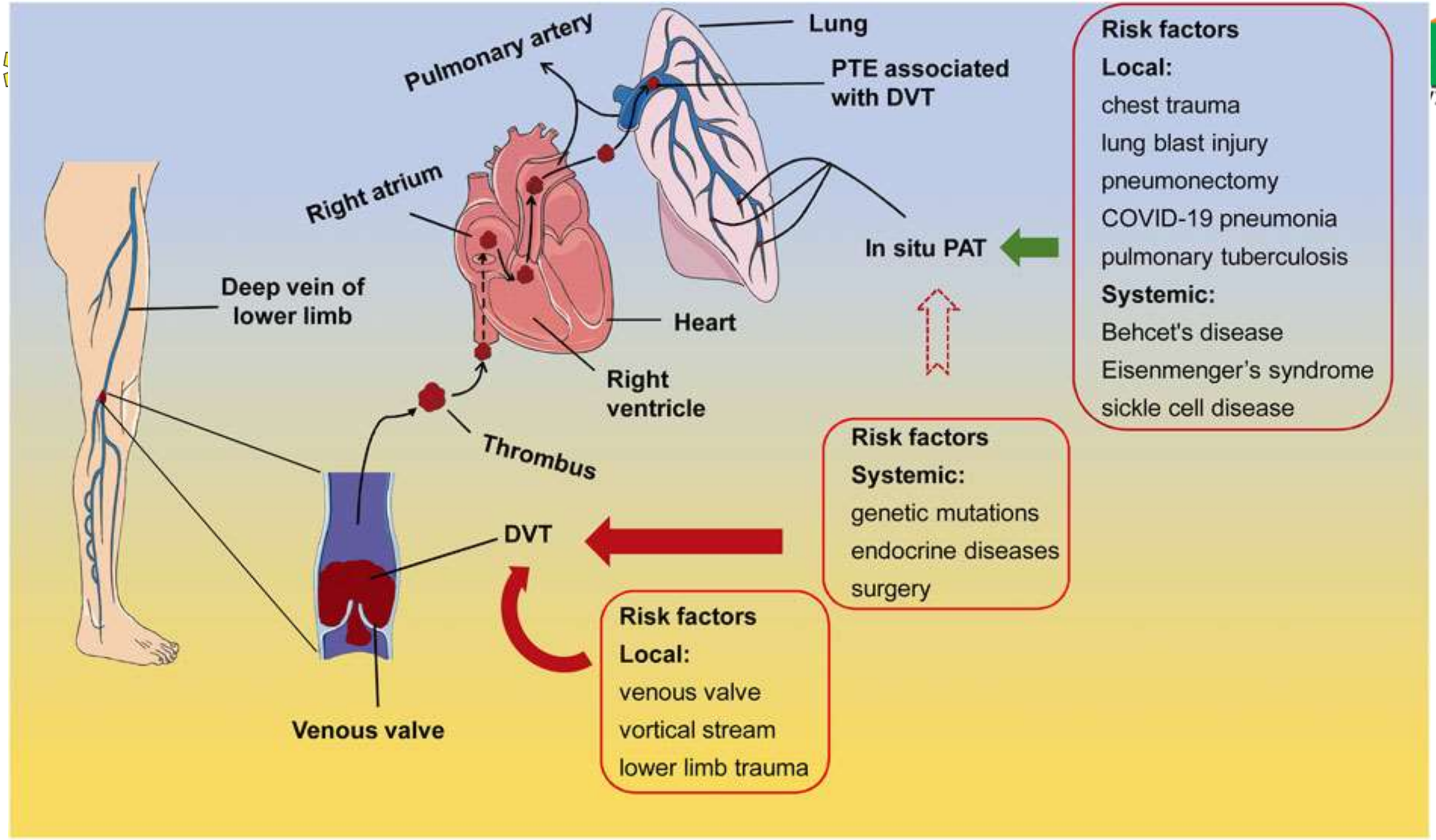
Reason: arterial pressure is greater than alveolar and venous pressure. Whereas, venules pressure are less than alveolar pressure → venules are collapsed

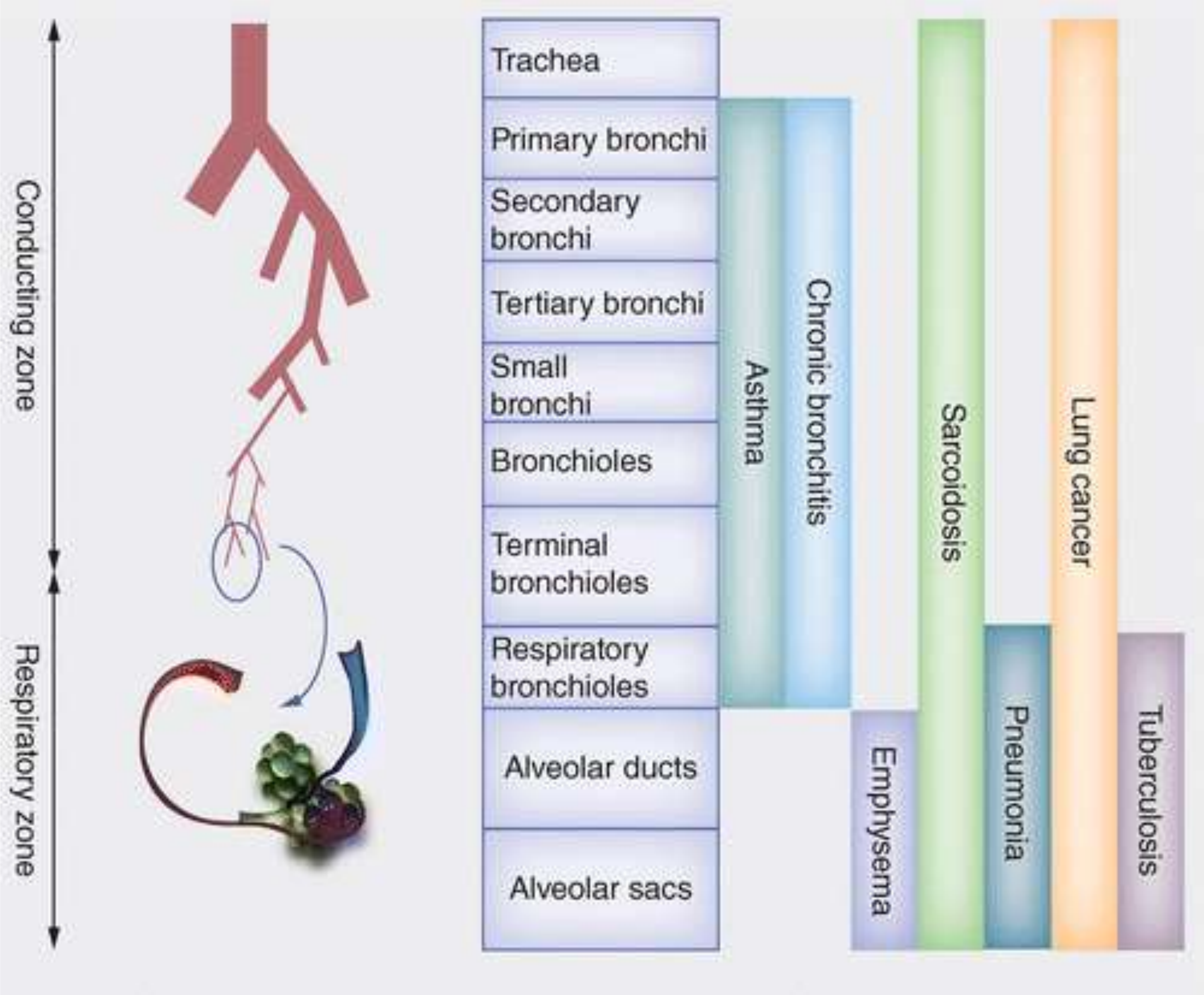
- **Zone 3:** Continuous blood flow

Reason: Due to gravity, there is high pressure → vasodilation → more blood flow

Apical Portion – Zone 1

under these conditions, there is no gaseous exchange in this zone of lungs.
So, it is considered as the part of physiological dead space, which is ventilated but not perfused.
And, the ventilation-perfusion ratio increases.
It may lead to growth of bacteria, particularly tubercle bacilli making this part of lungs susceptible for tuberculosis


Pulmonary artery
Lung
PTE associated with DVT
Right atrium
In situ PAT
Deep vein of lower limb
Heart
Right ventricle
Thrombus
DVT
Venous valve
Risk factors
Local:
chest trauma
lung blast injury
pneumonectomy
COVID-19 pneumonia
pulmonary tuberculosis
Systemic:
Behcet's disease
Eisenmenger's syndrome
sickle cell disease
Risk factors
Systemic:
genetic mutations
endocrine diseases
surgery
Risk factors
Local:
venous valve
vortical stream
lower limb trauma


Conducting zone
Respiratory zone
Trachea
Primary bronchi
Secondary bronchi
Tertiary bronchi
Small bronchi
Bronchioles
Terminal bronchioles
Respiratory bronchioles
Alveolar ducts
Alveolar sacs
Asthma
Chronic bronchitis
Emphysema
Sarcoidosis
Pneumonia
Lung cancer
Tuberculosis

PULMONARY HYPERTENSION

(High blood pressure in lungs)

Affects 75 million people globally / approx. 80% living in low-income and middle-income countries (LMICs)

75 million people

6 common causes in LMICs (HIV, bilharzia, heart failure, chronic lung disease, blood clots in the lungs and blood disorders)

6 common causes

In SA, risk of pulmonary hypertension increases because of HIV, bilharzia, TB and chronic obstructive pulmonary disease

8/10 cases in LMICs remain undiagnosed

Opportunities to research, define and investigate drivers of the disease in LMICs

Need for a clearer overview of the total number of cases (newly diagnosed and existing) by using national registries and frequently reviewing national databases in LMICs

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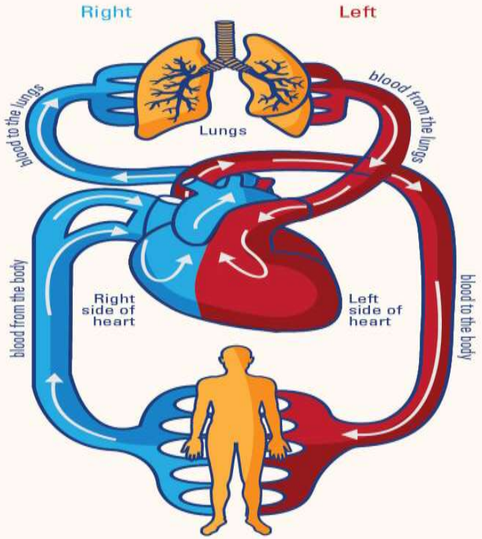
MECHANISM OF RESPIRATION

What's the Connection?

Your HEART Can Affect Your Breathing



The heart and lungs work together to make sure the body has the oxygen-rich blood it needs to function properly.

1. The Pulmonary Loop
The right side of the heart picks up the oxygen-poor blood from the body and moves it to the lungs for cleaning and re-oxygenating.

2. The Systemic Loop
Once the blood is re-oxygenated, the left side of the heart moves the blood throughout the body, so that every part receives the oxygen it needs.

The close connection between the heart and lungs means that breathing problems can be caused by issues in either the heart or lungs, or both.

Pay attention to breathing and heart functions. Remember that both the heart and lung can be sources of breathing problems. See the doctor when something does not seem right.

Symptoms of a Heart/Lung Condition Can Include:

- unexplained shortness of breath
- low oxygen levels
- chest pain
- near-fainting/ fainting
- fatigue
- palpitations
- heart failure

Common Problems Related to the Heart/Lung Connection Are:

- exercise intolerance
- fatigue
- irregular heartbeats
- sleep apnea
- asthma
- bronchitis
- weak heart muscle
- shortness of breath
- emphysema
- pulmonary hypertension
- heart attack

Interesting Facts

100,000 heartbeats a day

1,500 miles of airways

5 quarts of blood pumped per minute

16 seconds for blood to travel from the heart to the toes and back

15 to 25 breaths per minute

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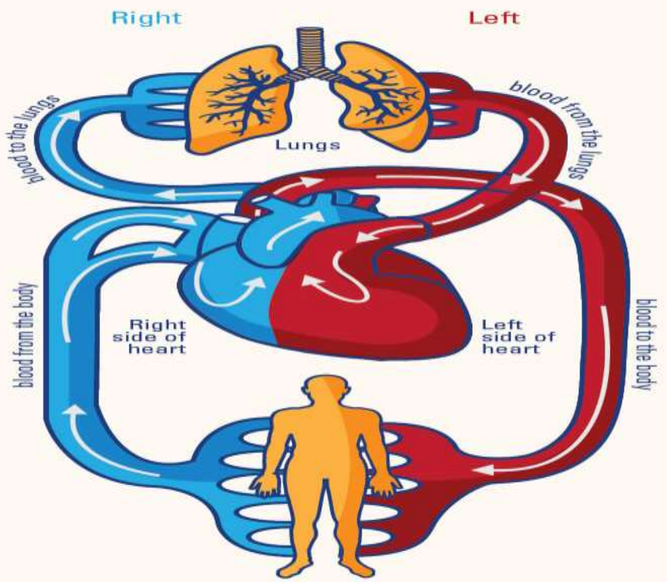
What's the Connection?

Your HEART Can Affect Your Breathing



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The close connection between the heart and lungs means that breathing problems can be caused by issues in either the heart or lungs, or both.

Pay attention to breathing and heart functions. Remember that both the heart and lung can be sources of breathing problems. See the doctor when something does not seem right.

Symptoms of a Heart/Lung Condition Can Include:

- unexplained shortness of breath
- low oxygen levels
- chest pain
- near-fainting/ fainting
- fatigue
- palpitations
- heart failure

Common Problems Related to the Heart/Lung Connection Are:

- exercise intolerance
- fatigue
- irregular heartbeats
- sleep apnea
- asthma
- bronchitis
- weak heart muscle
- shortness of breath
- emphysema
- pulmonary hypertension
- heart attack

Interesting Facts

100,000 heartbeats a day

1,500 miles of airways

5 quarts of blood pumped per minute

16 seconds for blood to travel from the heart to the toes and back

15 to 25 breaths per minute

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