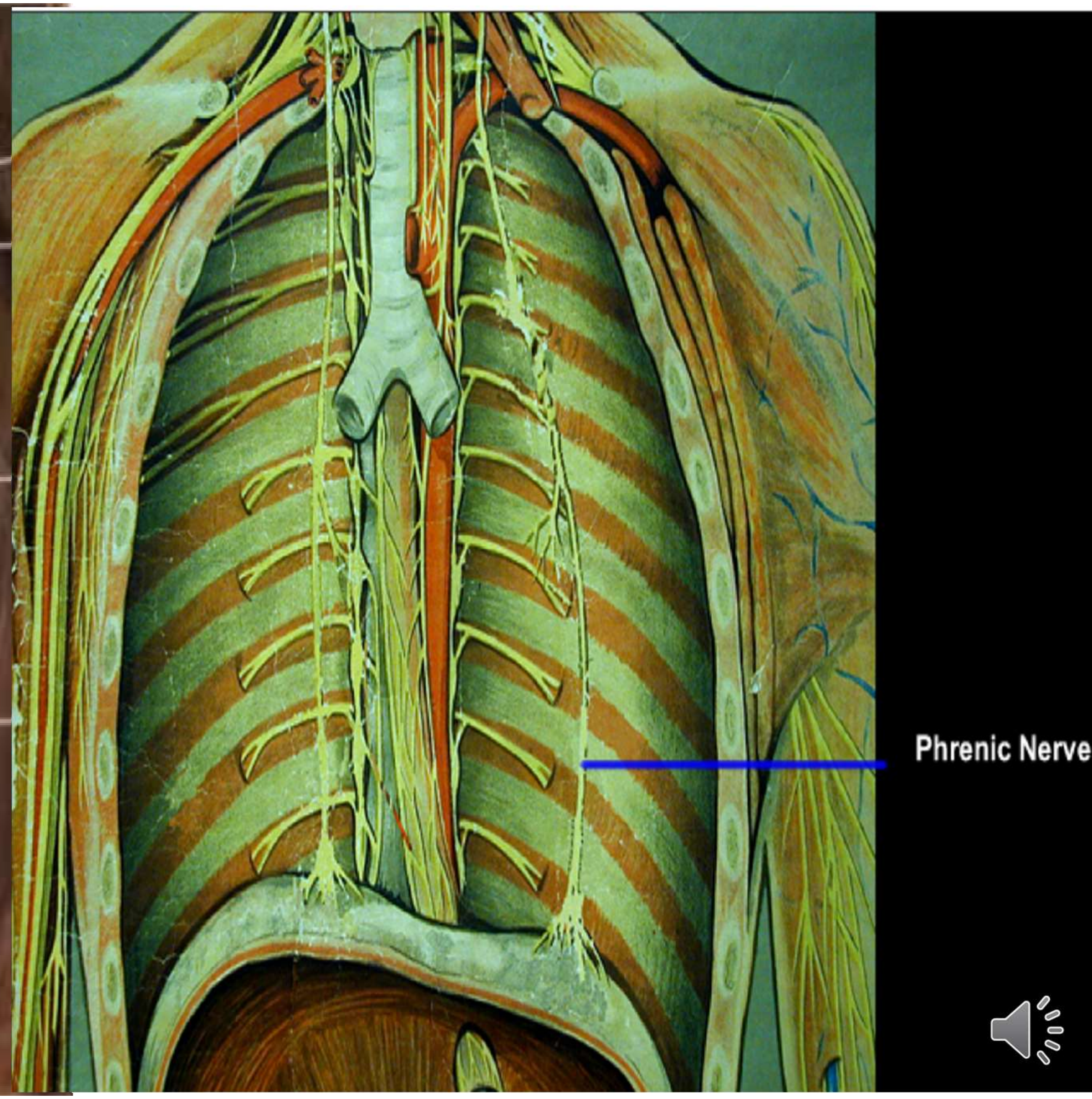
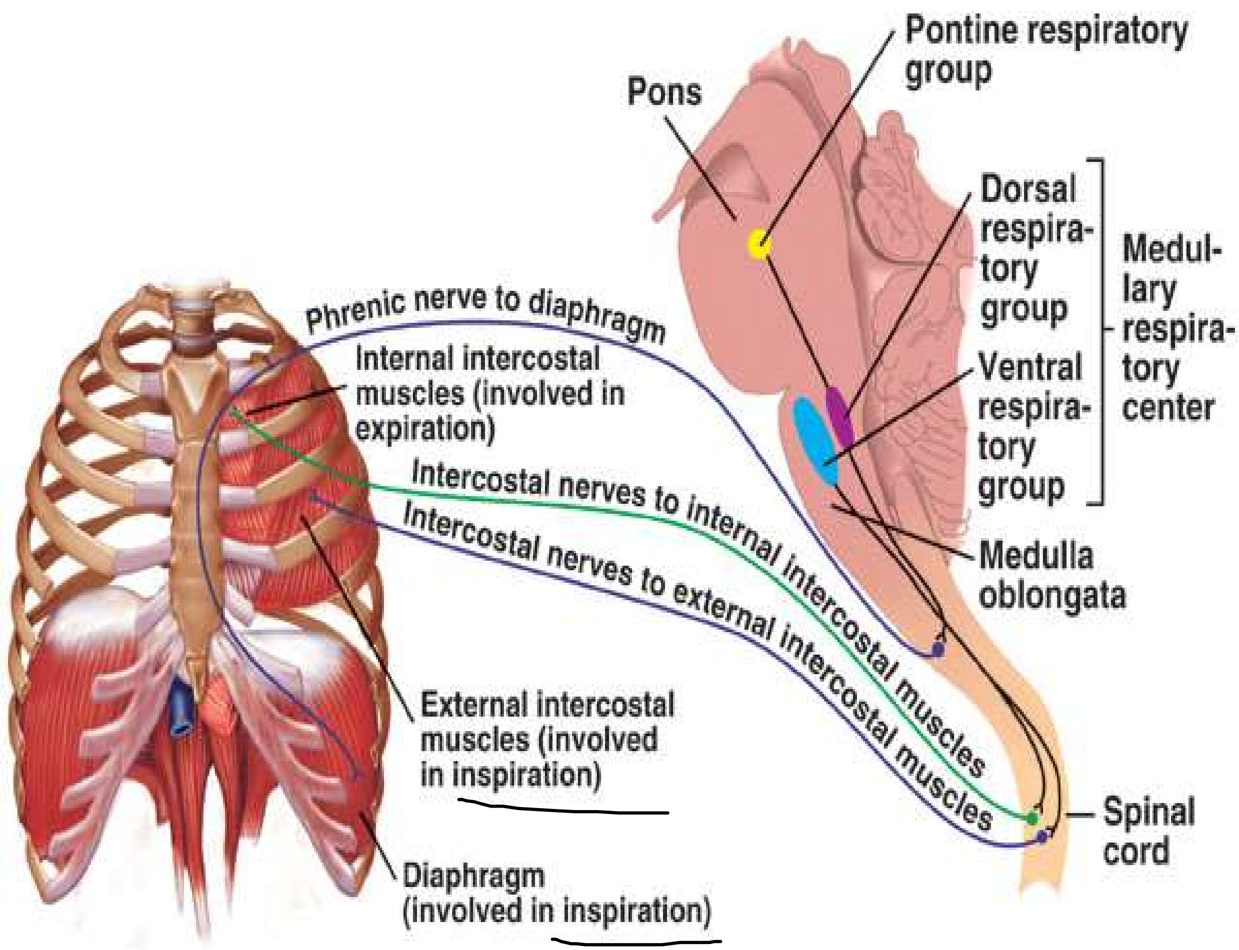
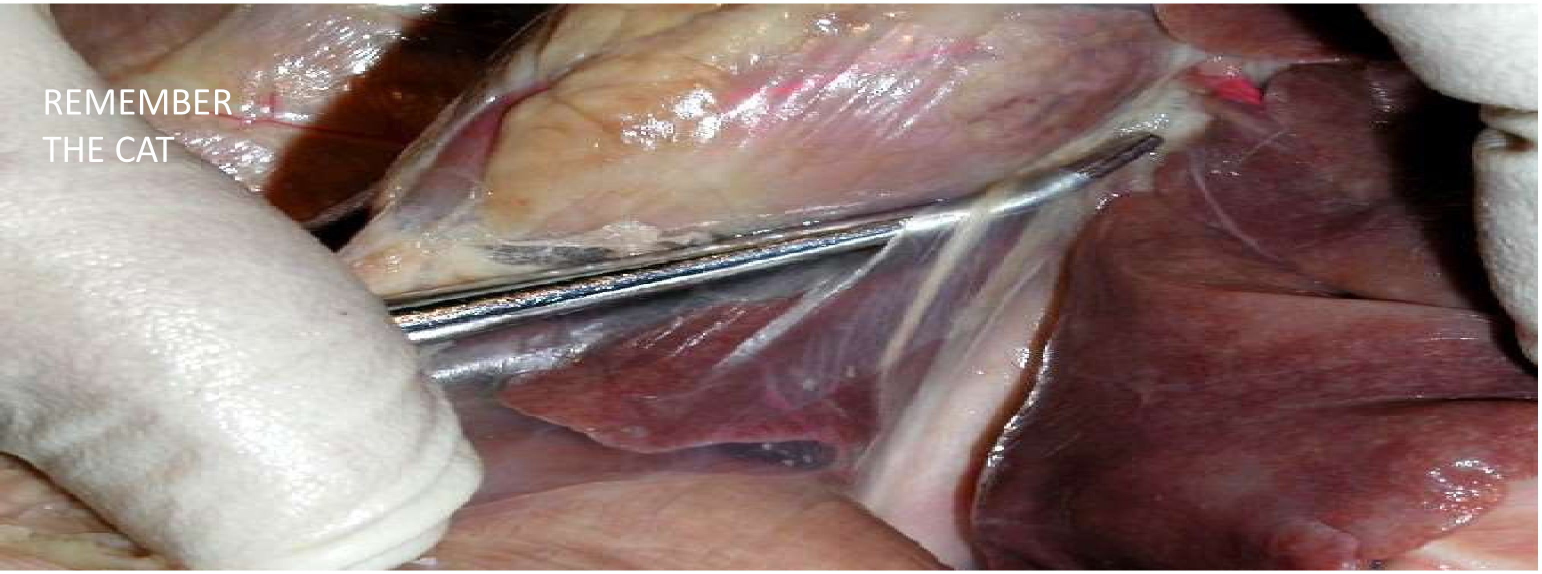
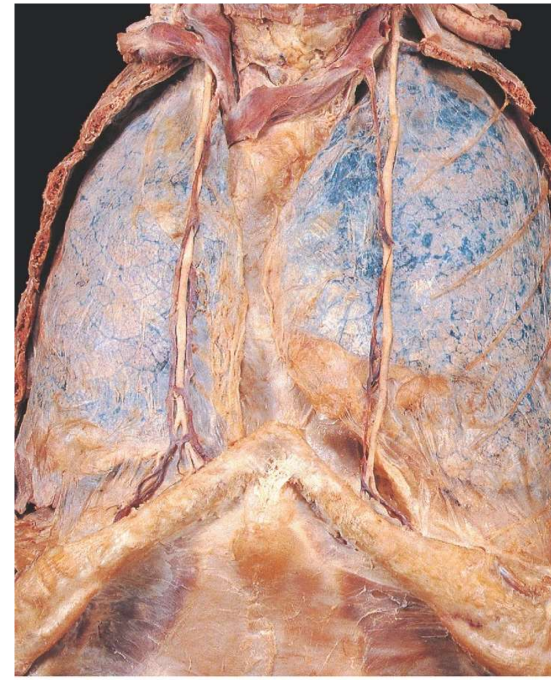
Respiratory Physiology part 3

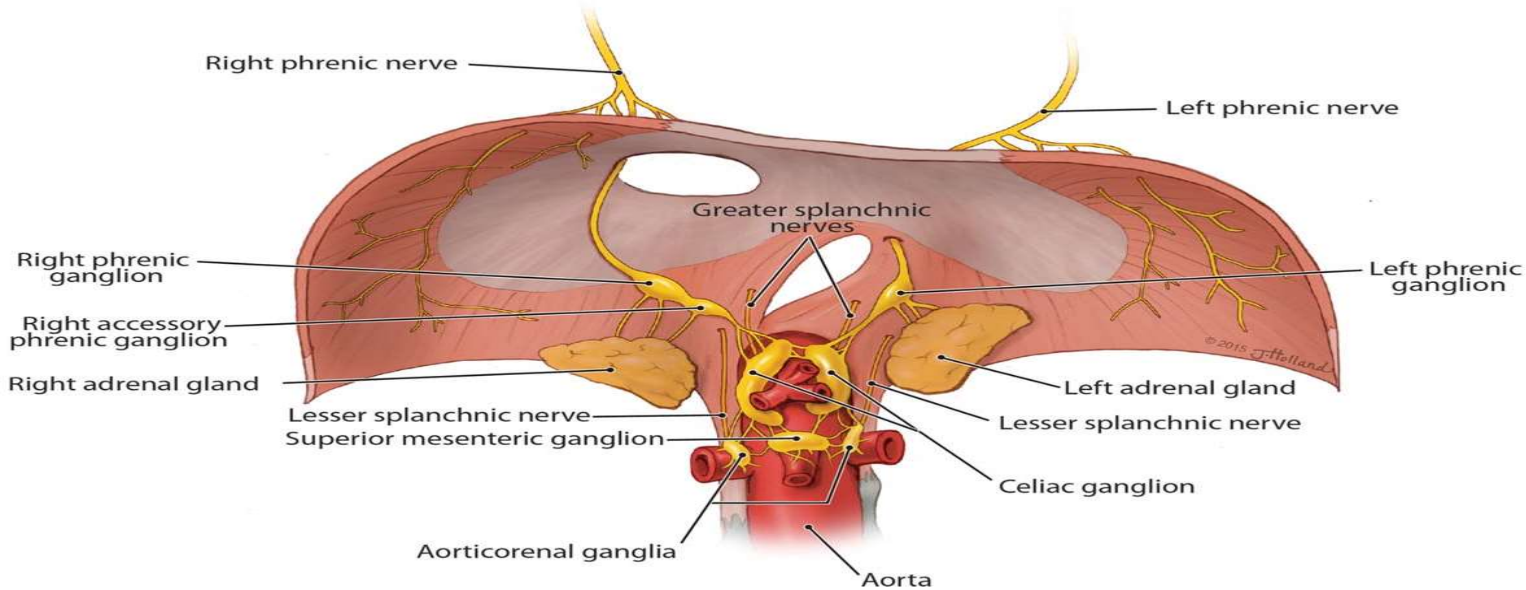
D. HAMMOUDI, MD

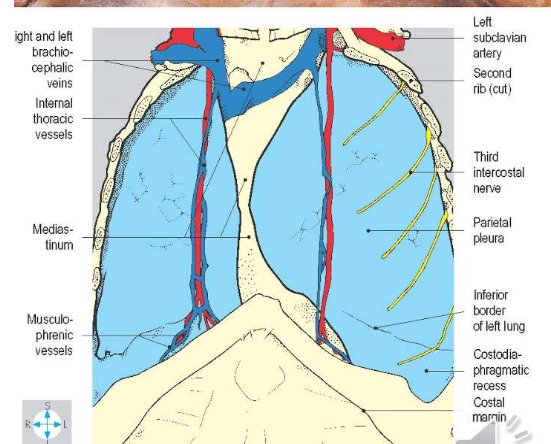

Phrenic Nerve


Pontine respiratory group
Pons
Dorsal respira-tory group
Medul-lary respira-tory center
Ventral respira-tory group
Phrenic nerve to diaphragm
Internal intercostal muscles (involved in expiration)
Intercostal nerves to internal intercostal muscles
Intercostal nerves to external intercostal muscles
Medulla oblongata
External intercostal muscles (involved in inspiration)
Spinal cord
Diaphragm (involved in inspiration)









ig. 2.17 Removal of the anterior chest wall has exposed the internal thoracic vessels and costal pa
f the parietal pleura, through which the lungs are visible.

- **Respiratory muscles** – diaphragm and other muscles that promote ventilation

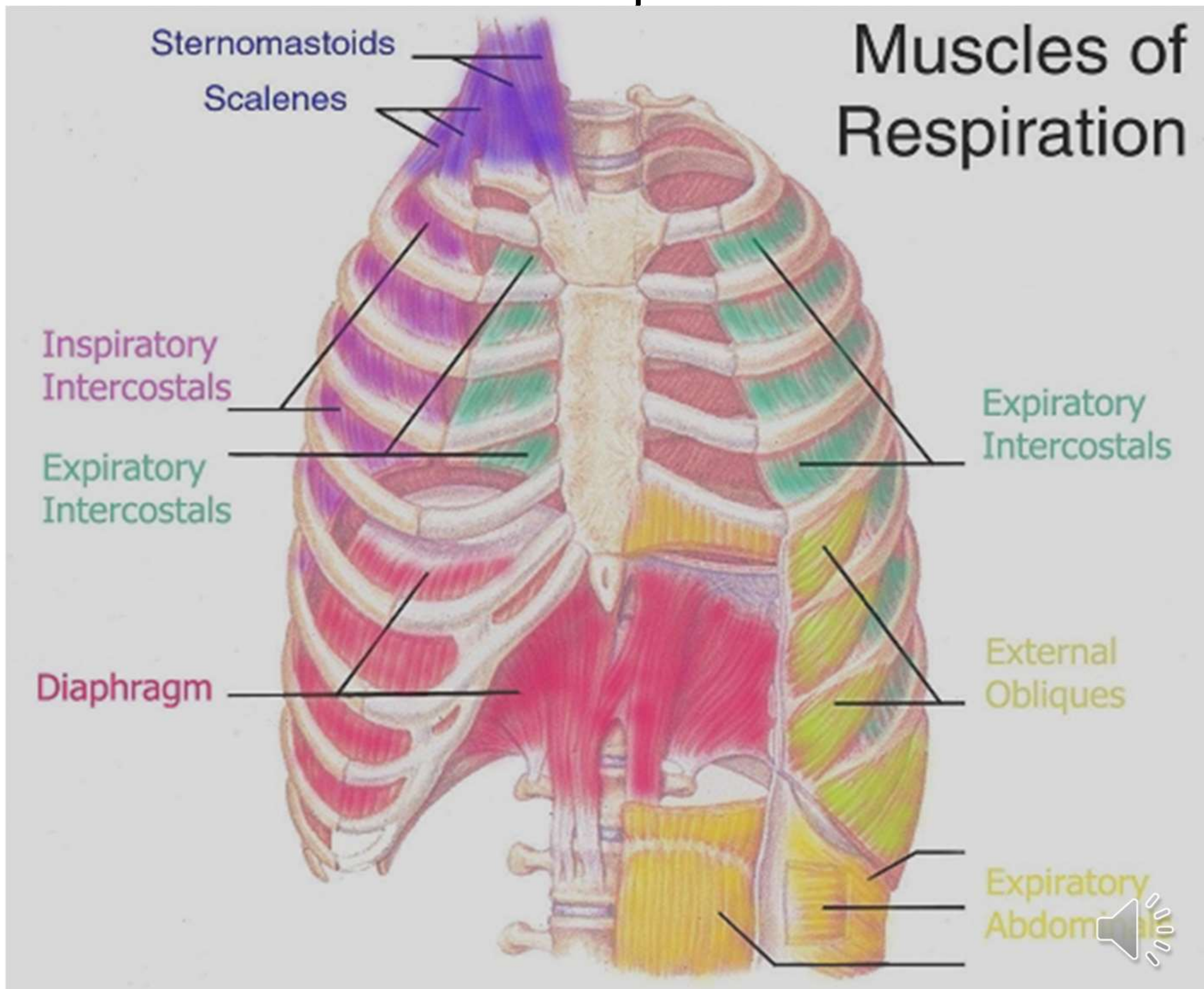
Contraction of external intercostal muscles

- > elevation of ribs & sternum
- > increased front- to-back dimension of thoracic cavity
- > lowers air pressure in lungs
- > air moves into lungs

Contraction of diaphragm

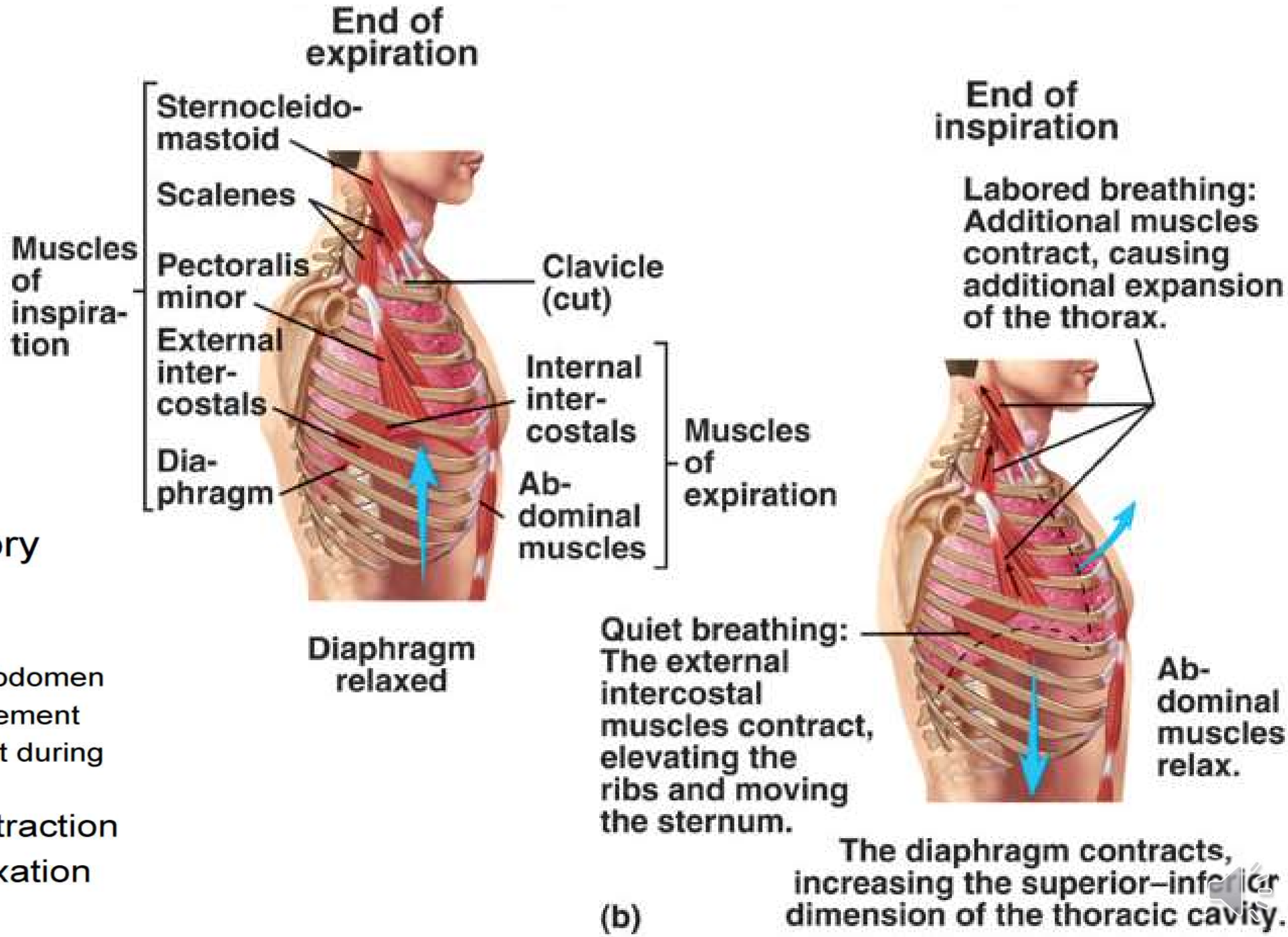
> diaphragm moves downward

- ➢ increases vertical dimension of thoracic cavity
- ➢ > lowers air pressure in lungs
- ➢ > air moves into lungs:

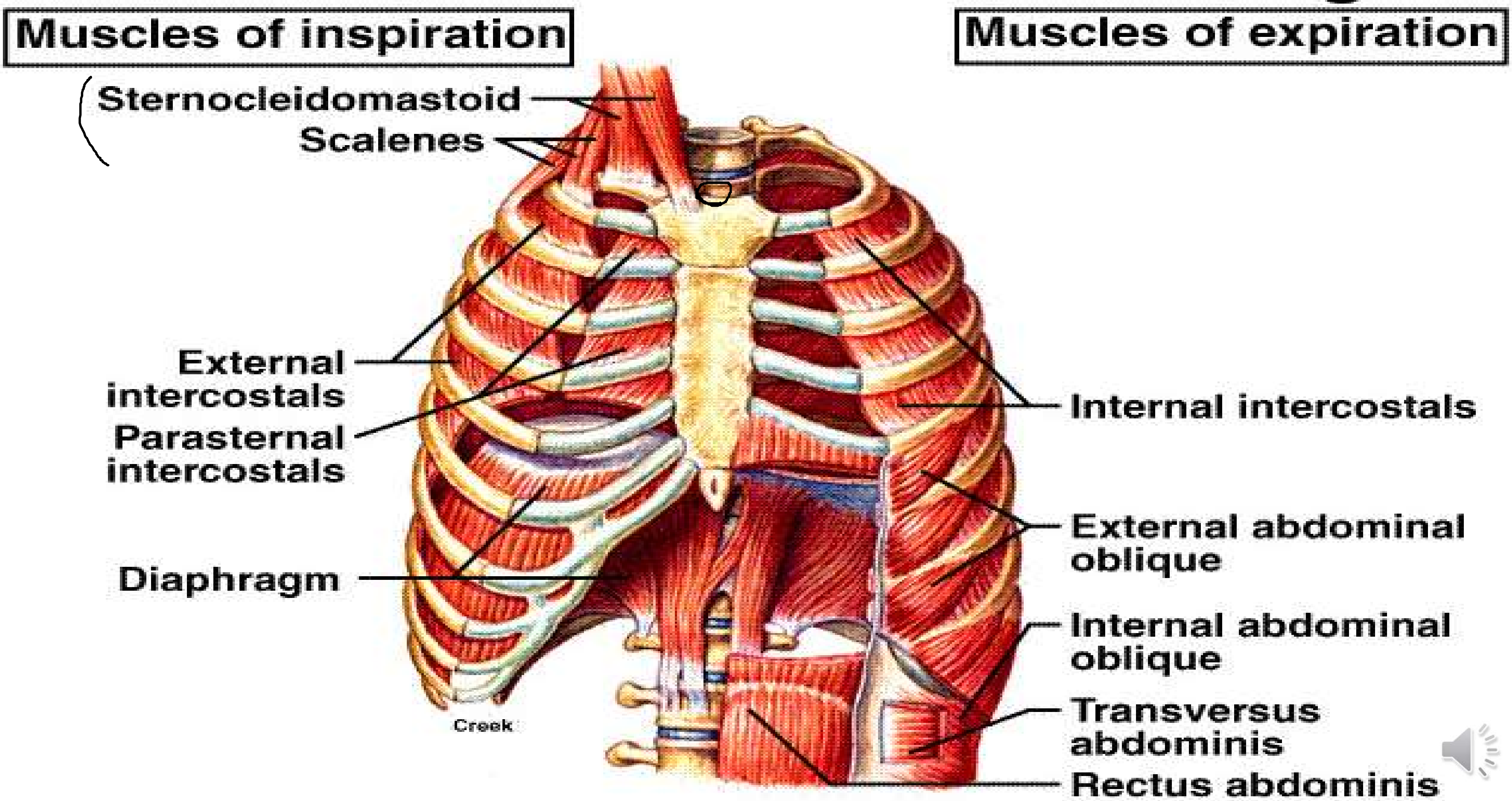


Thoracic Walls Muscles of Respiration

- Primary Ventilatory Muscles
  - Diaphragm
    - Divides Chest/Abdomen
    - 75% of gas movement
    - 1.5cm movement during quiet breathing
  - Inspiration – contraction
  - Expiration – relaxation
    - Elastic Recoil



Muscles Involved in Breathing



Muscles of respiration

Quiet breathing:

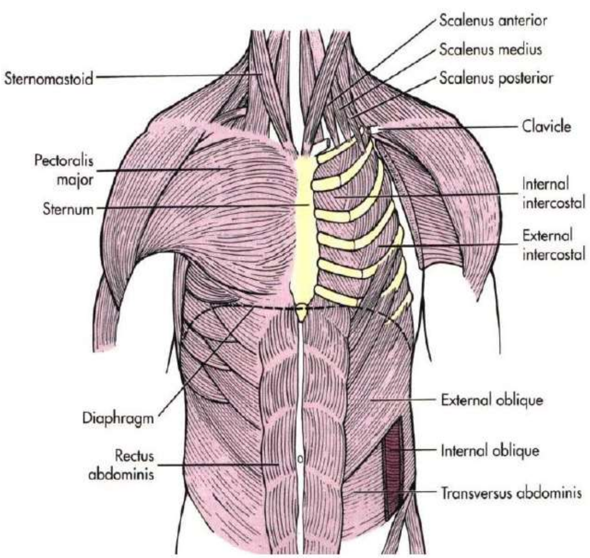
Inspiration—diaphragm.

Expiration—passive.

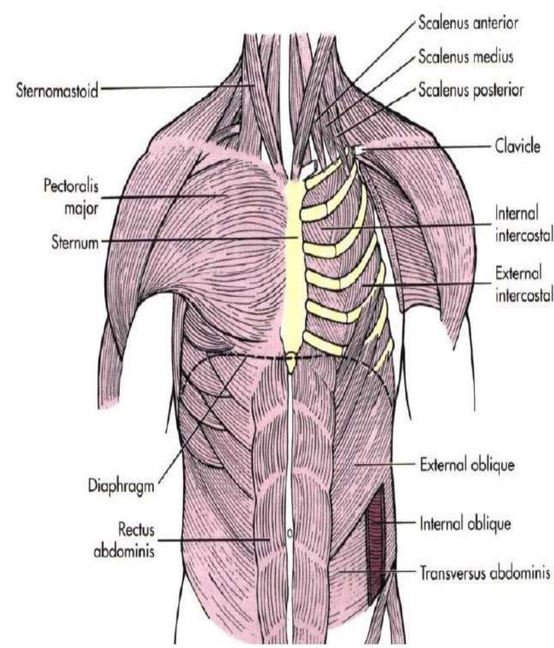
Exercise:

Inspiration—external intercostals, scalene muscles, sternomastoids.

Expiration—rectus abdominis, internal and external obliques, transversus abdominis, internal intercostals.



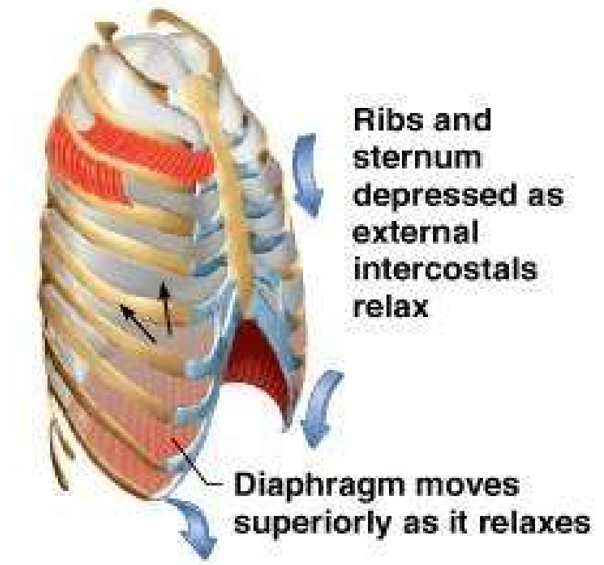
- Scalene Muscles
  - Neck muscles
  - Attach to 1st /2nd rib
  - Assist ventilatory demands
  - Alveolar pressure > -10cmH20
- Sternomastoid
  - Manubrium / clavicle
- Pectoralis Major
  - Clavicle / sternum

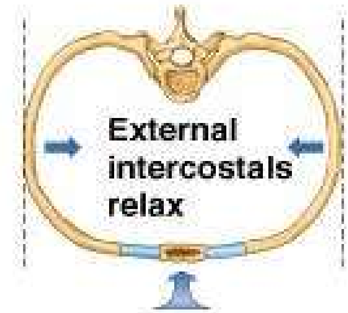


- Abdominal Muscles
  - External oblique
  - Internal oblique
  - Transverse abdominus
  - Rectus abdominus
- Inactive during quiet breathing
- Active > 40L/min

Expiration

1. Inspiratory muscles relax (diaphragm rises; rib cage descends due to recoil of costal cartilages)
↓
2. Thoracic cavity volume decreases
↓
3. Elastic lungs recoil passively; intrapulmonary volume decreases
↓
4. Intrapulmonary pressure rises (to +1 mm Hg)
↓
5. Air (gases) flows out of lungs down its pressure gradient until intrapulmonary pressure is 0

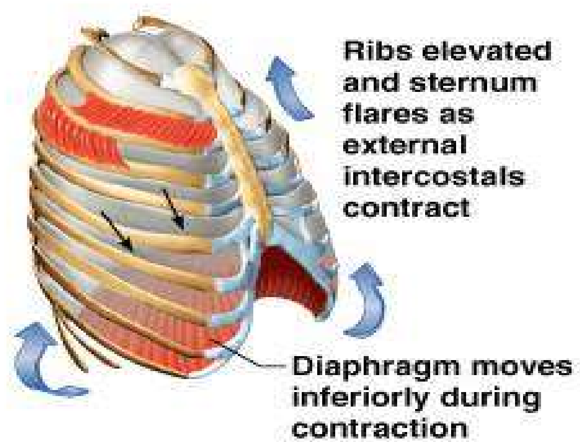


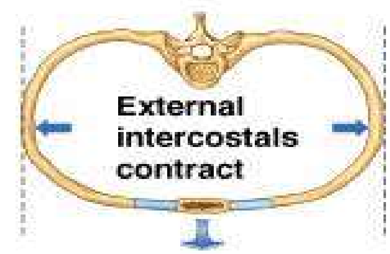


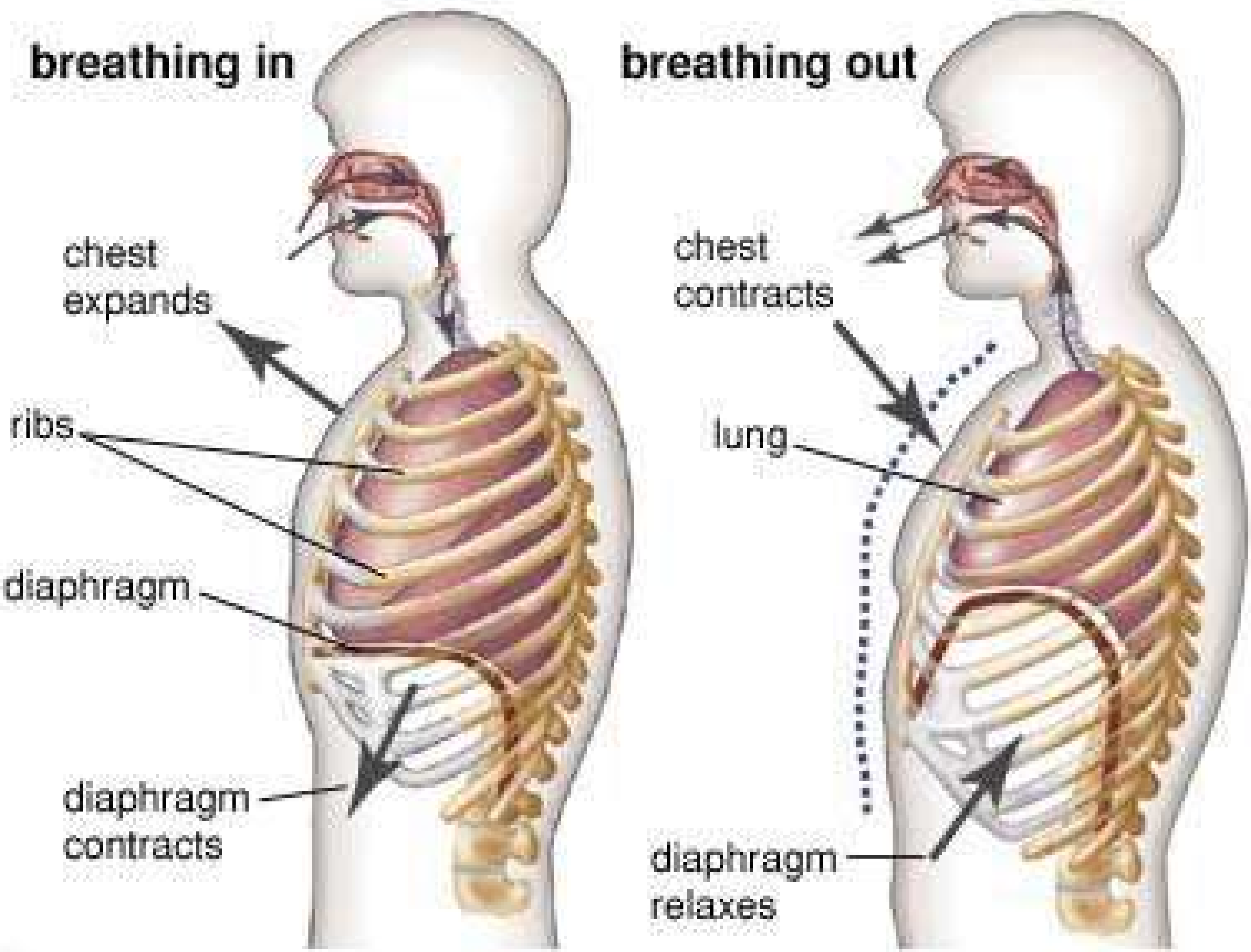
	Sequence of events	Changes in anterior-posterior and superior-inferior dimensions	Changes in lateral dimensions

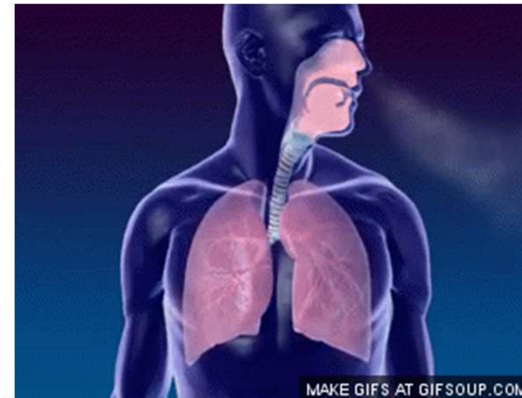
Inspiration

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)






breathing in
chest
expands
ribs
diaphragm
diaphragm
contracts
breathing out
chest
contracts
lung
diaphragm
relaxes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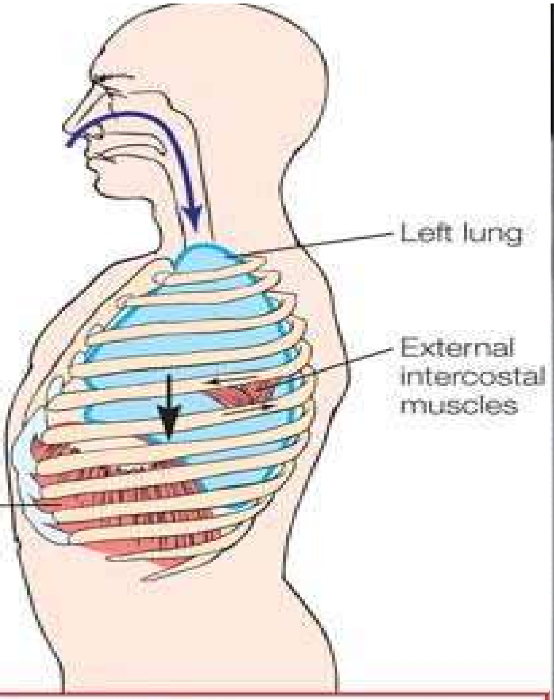
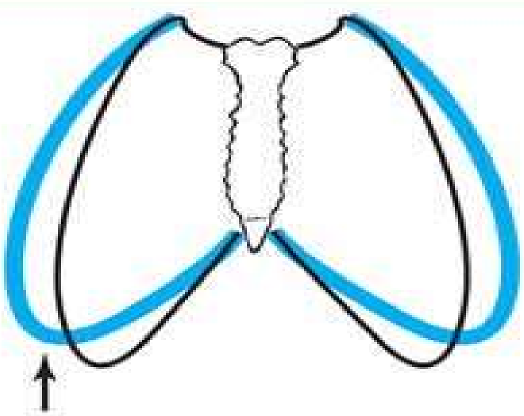
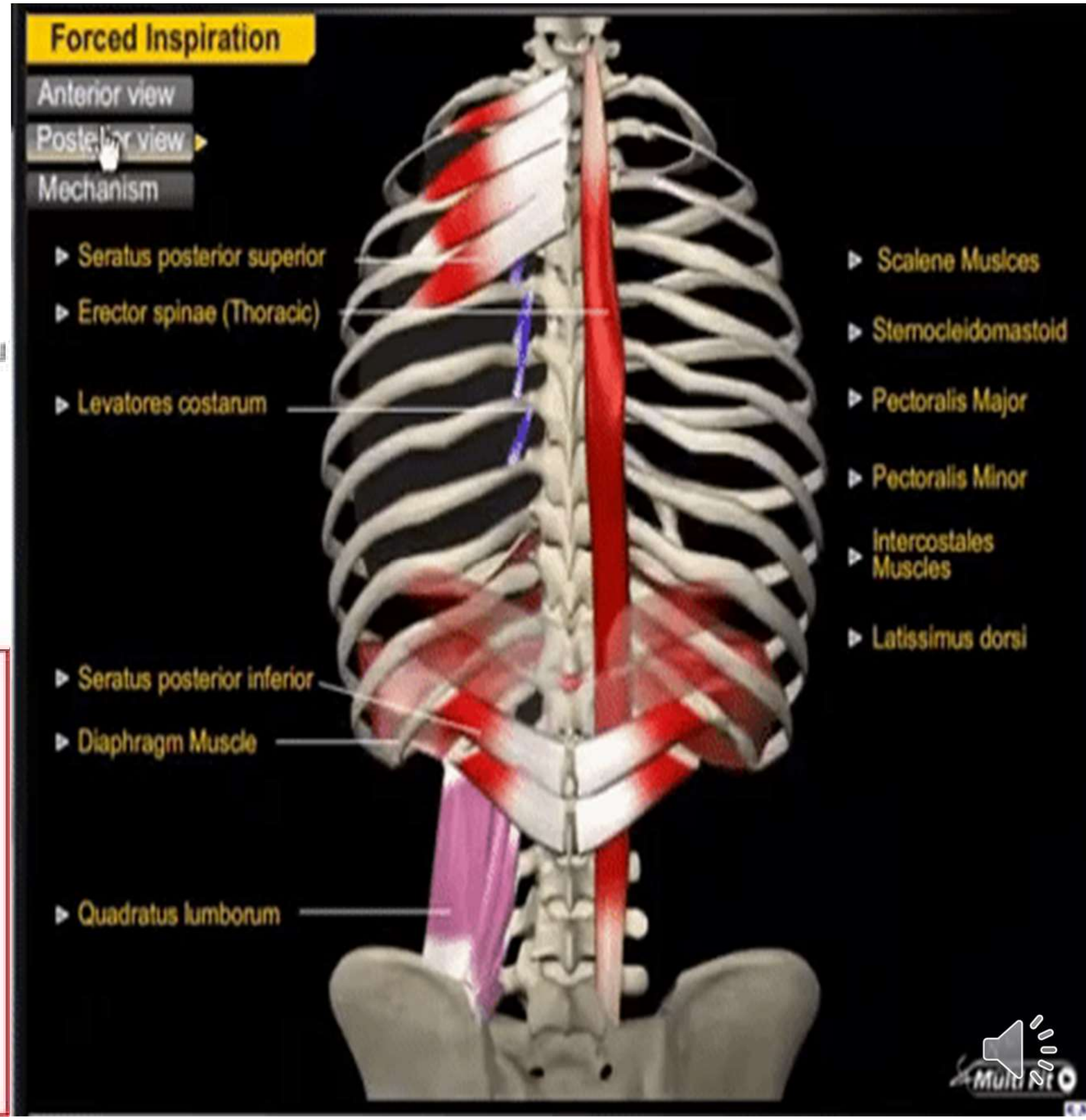
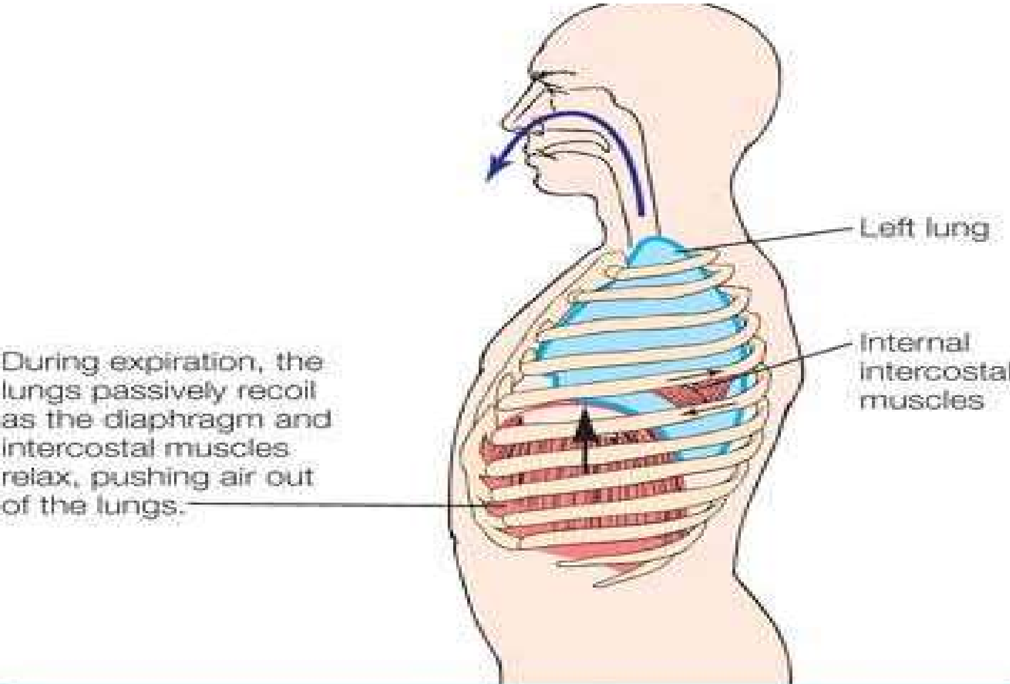
During inspiration, the diaphragm contracts (pressing the abdominal organs downward and forward) and the external intercostal muscles also contract. The rib cage expands, the volume of the thoracic cavity increases, and air rushes in to equalize the pressure.

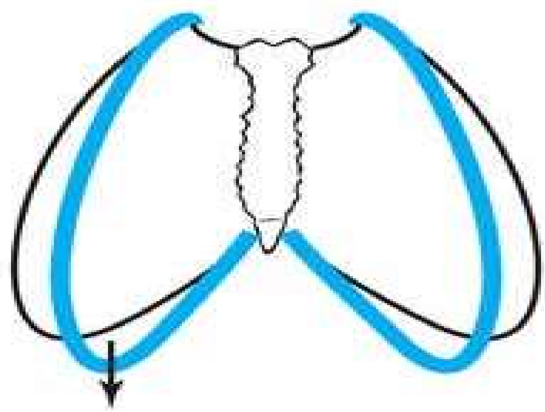




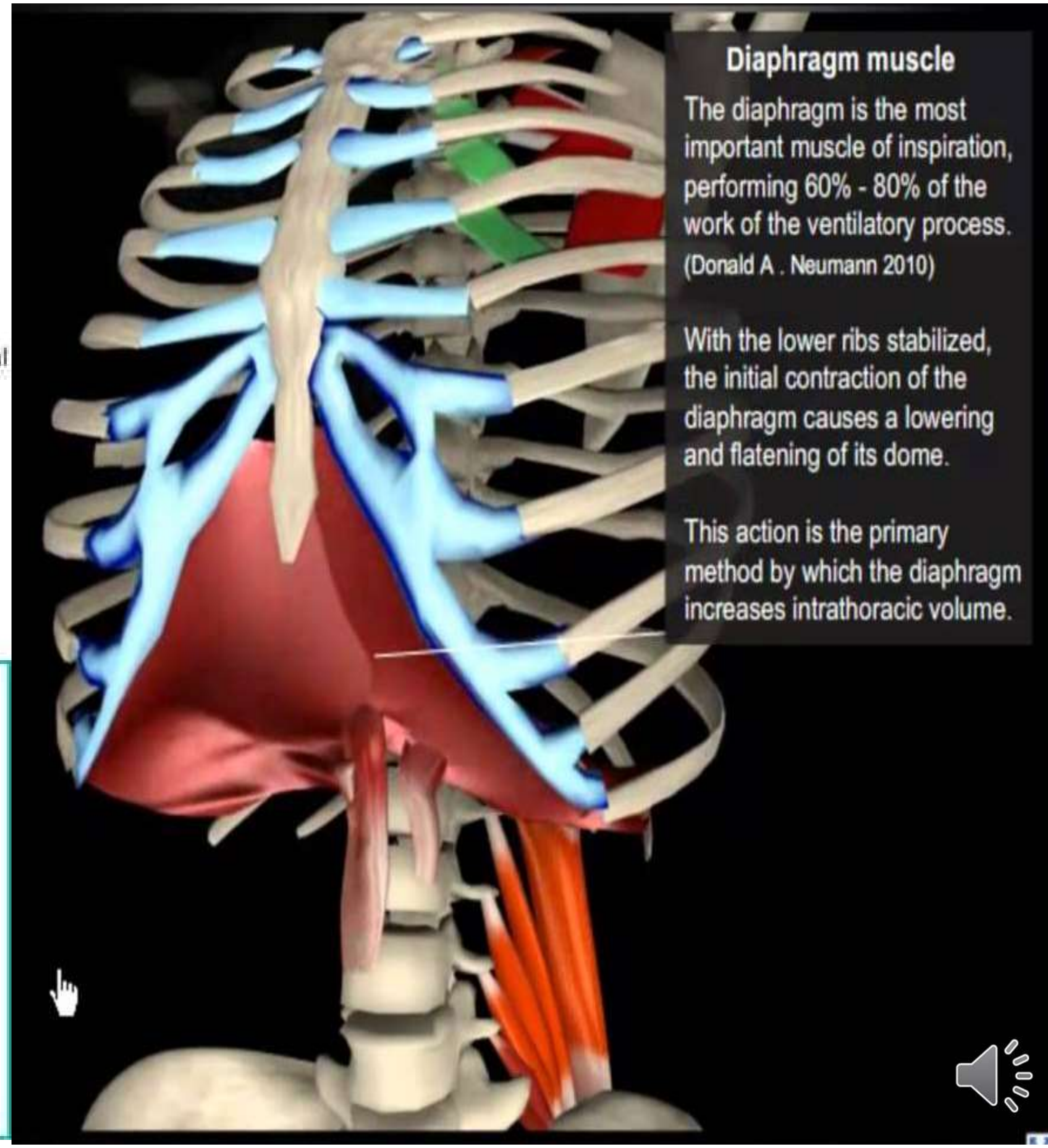
Action of the rib cage in inspiration







Action of the rib cage in expiration



Deep Forceful Breathing

- ***Deep Inhalation***

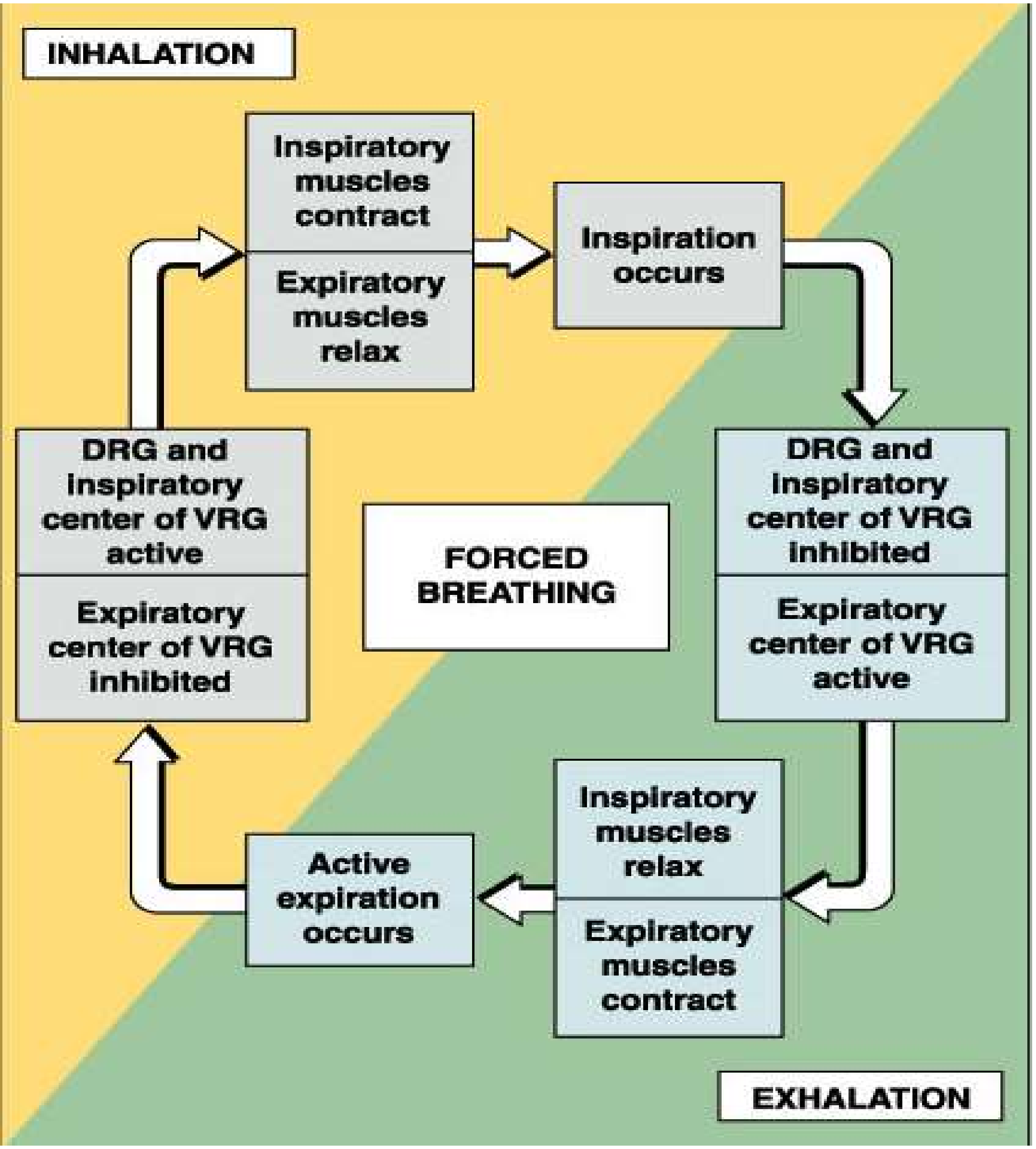
  During deep forceful inhalation accessory muscles of inhalation participate to increase size of thoracic cavity

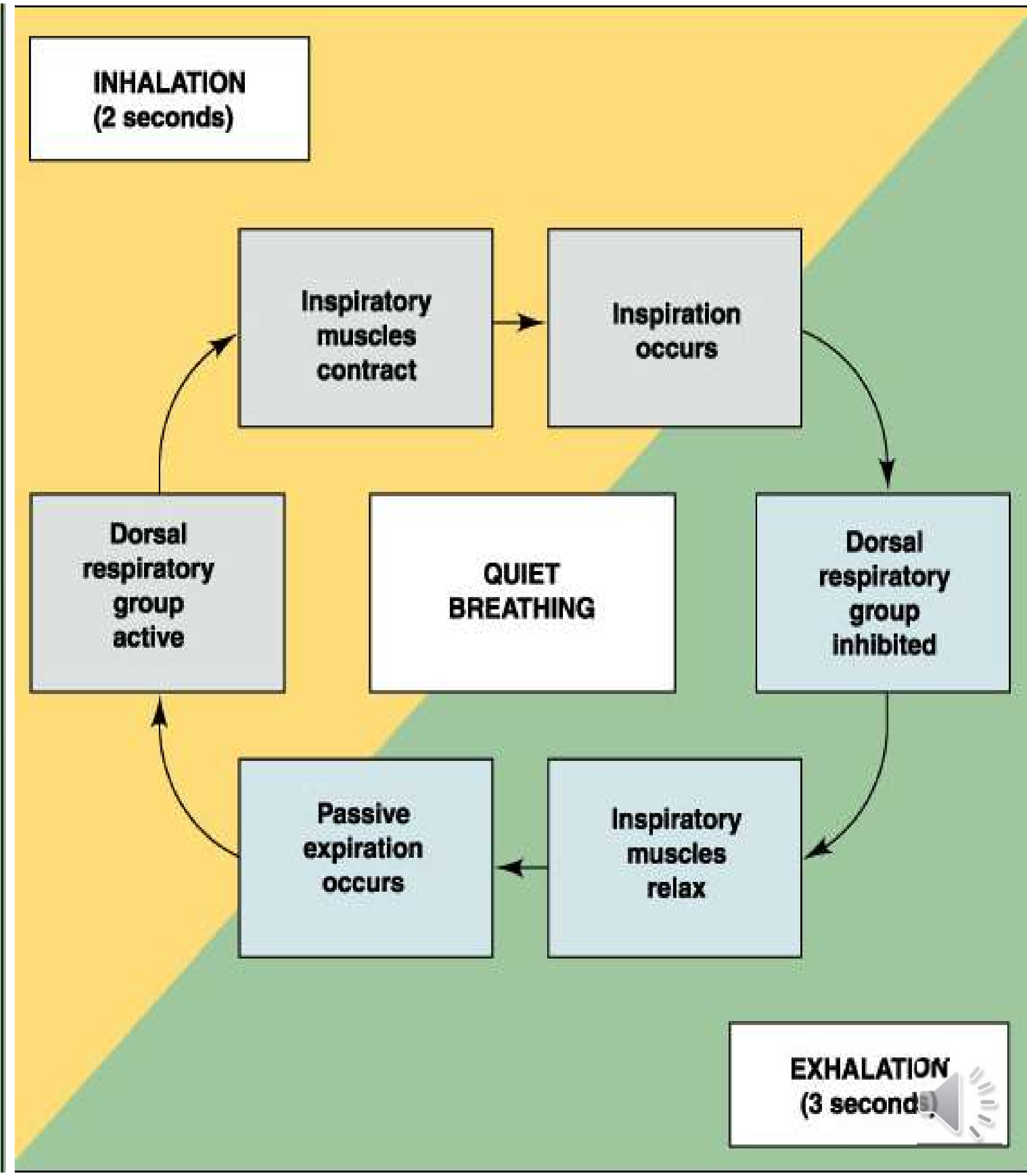
  - **Sternocleidomastoid – elevate sternum**
  - **Scalenes – elevate first two ribs**
  - **Pectoralis minor – elevate 3rd–5th ribs**

- ***Deep Exhalation***

  Exhalation during forceful breathing is active process

  - **Muscles of exhalation increase pressure in abdomen and thorax**
    - Abdominals
    - Internal intercostals


INHALATION
Inspiratory muscles contract
Expiratory muscles relax
Inspiration occurs
DRG and inspiratory center of VRG active
Expiratory center of VRG inhibited
FORCED BREATHING
DRG and inspiratory center of VRG inhibited
Expiratory center of VRG active
Inspiratory muscles relax
Expiratory muscles contract
Active expiration occurs
EXHALATION


INHALATION
(2 seconds)
Inspiratory muscles contract
Inspiration occurs
Dorsal respiratory group active
QUIET BREATHING
Dorsal respiratory group inhibited
Passive expiration occurs
Inspiratory muscles relax
EXHALATION

Respiratory center

Regulation of respiration takes place centrally in the respiratory center located in the reticular formation of the medulla oblongata and pons.

Medullary center

Function: creates rhythmic innervation of the respiratory muscles and is influenced by various respiratory stimuli

Dorsal respiratory group

- Responsible for inspiration
- Input: peripheral chemoreceptors and mechanoreceptors (via the vagus and glossopharyngeal nerve)
- Output: phrenic nerve

Ventral respiratory group

- Responsible for expiration
- Expiration is usually passive, only becoming active during physical exercise.

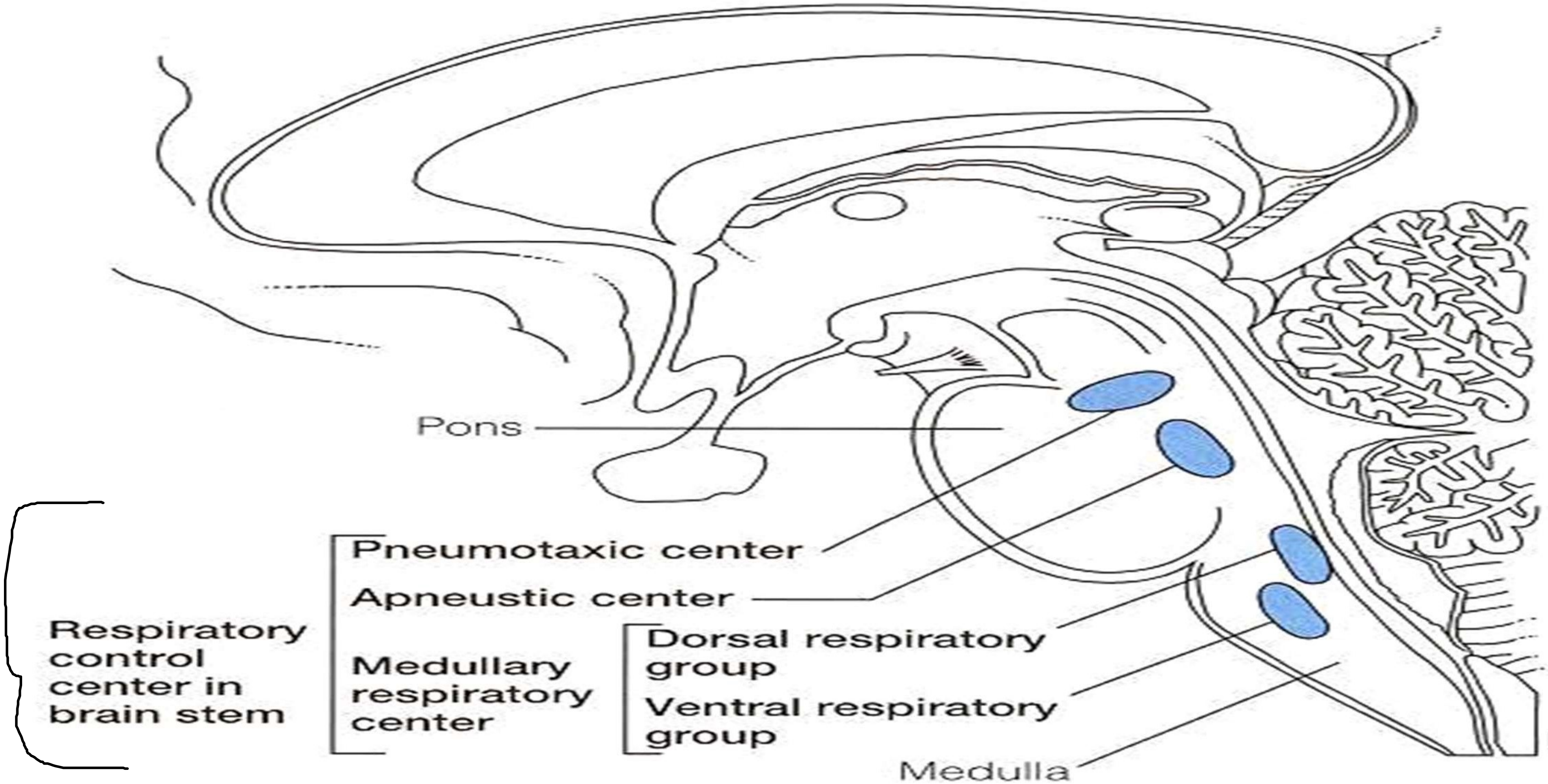
Expiration at rest is mainly driven by elastic properties of the lung tissue.

Pontine center

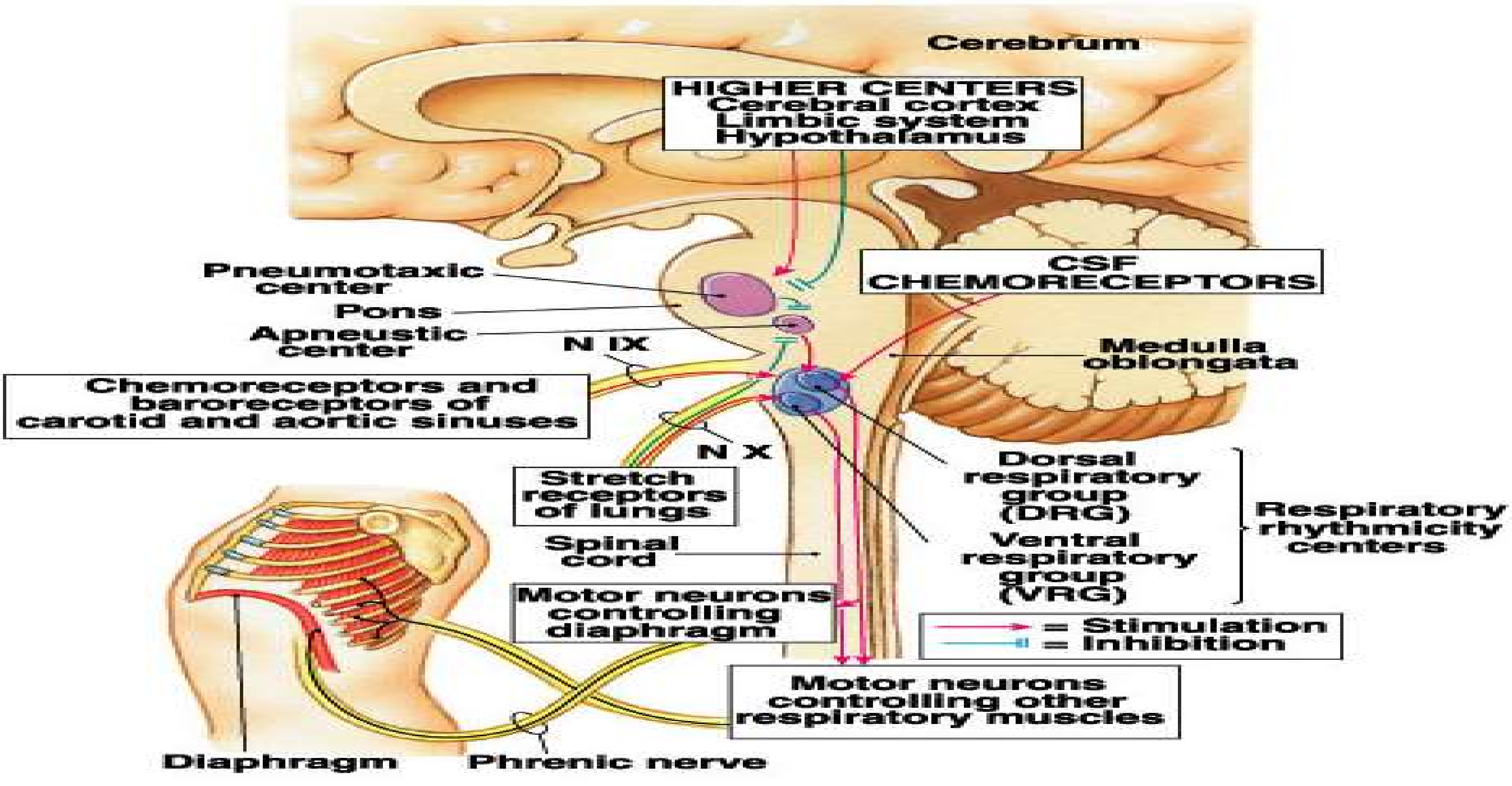
- **Function**: modifies the activity of the medullary center

- **Apneustic center**
    - **Controls the intensity of breathing**
    - Promotes deep gasping inspiration (apneusis) by stimulation of the dorsal respiratory group and inhibition of the pneumotaxic center

- **Pneumotaxic center**
    - **Controls the respiratory rate** and pattern of breathing
    - Limits or delays inspiration

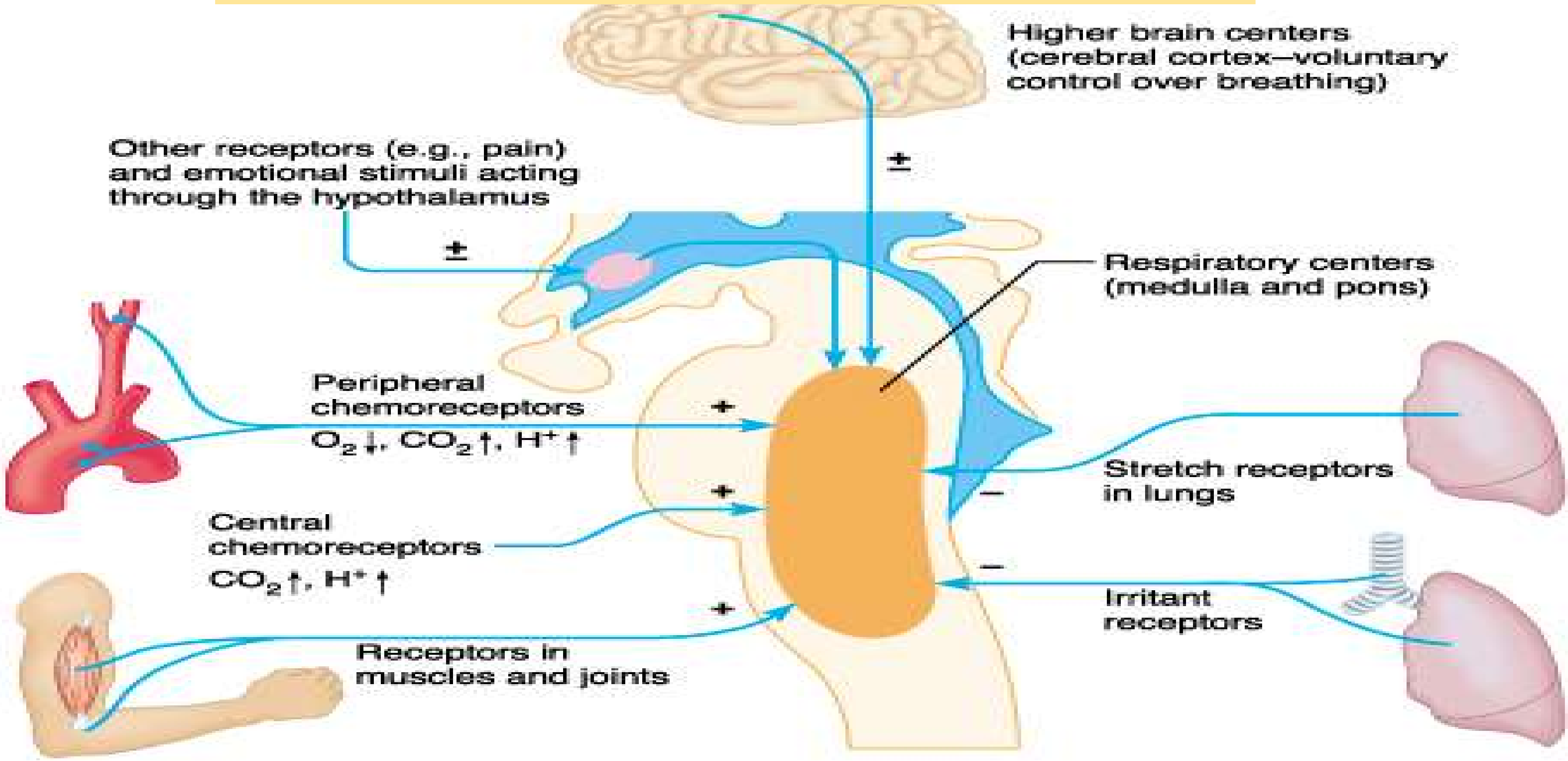


Pons
Pneumotaxic center
Apneustic center
Respiratory control center in brain stem
Medullary respiratory center
Dorsal respiratory group
Ventral respiratory group
Medulla



Cerebrum
HIGHER CENTERS
Cerebral cortex
Limbic system
Hypothalamus
CSF CHEMORECEPTORS
Pneumotaxic center
Pons
Apneustic center
N IX
Medulla oblongata
Chemoreceptors and baroreceptors of carotid and aortic sinuses
N X
Dorsal respiratory group (DRG)
Ventral respiratory group (VRG)
Respiratory rhythmicity centers
Stretch receptors of lungs
Spinal cord
Motor neurons controlling diaphragm
= Stimulation
= Inhibition
Motor neurons controlling other respiratory muscles
Diaphragm
Phrenic nerve

Factors Influencing Respiration



Central Chemoreceptors

Responsive to increased arterial PCO2

Act by way of CSF [H+] .

Peripheral Chemoreceptors

Responsive to decreased arterial PO2

Responsive to increased arterial PCO2

Responsive to increased H+ ion concentration.

Carotid bodies

Sensitive to: PaO_2, $PaCO_2$, and pH

Afferents in glossopharyngeal nerve.

Aortic bodies

Sensitive to: PaO_2, $PaCO_2$, but not pH

Afferents in vagus

Receptors

Central chemoreceptors in the medulla oblongata: detect ↑ pCO_2 and ↓ pH

Peripheral chemoreceptors in aorta and carotids (carotid body) via CN IX and CN X : detect ↓ pO_2 (< 60 mmHg), ↑ pCO_2, and ↓ pH

Mechanoreceptors in the airways and respiratory muscles

Respiratory stimuli

- ↑ pCO_2 : strongest respiratory drive under normal conditions
- ↓ pO_2
  - **Strongest respiratory drive in chronic hypercapnia (e.g., in COPD)**
  - **The respiratory center** develops a tolerance for increased pCO_2..
- ↓ pH
- **Nonspecific stimuli:** fever, pain, norepinephrine

- **A chronically elevated $pCO_2 \geq 70$ mmHg (e.g., in COPD) inhibits the respiratory center instead of stimulating it.**
- **Hyperventilation can reduce the $PaCO_2$ and thus the respiratory drive; this technique is used, for example, by divers before a dive.**

Limits the degree of inspiration and prevents overinflation of the lungs

Normal adults. Receptors are not activated at end normal tidal volumes.

Become Important during exercise when tidal volume is increased.

Become Important in Chronic obstructive lung diseases when lungs are more distended.

Infants. Probably help terminate normal inspiration.

Including pulmonary inflation reflex and pulmonary deflation reflex

Receptor: Slowly adapting stretch receptors (SARs) in bronchial airways.

Afferent: vagus nerve

Pulmonary inflation reflex:

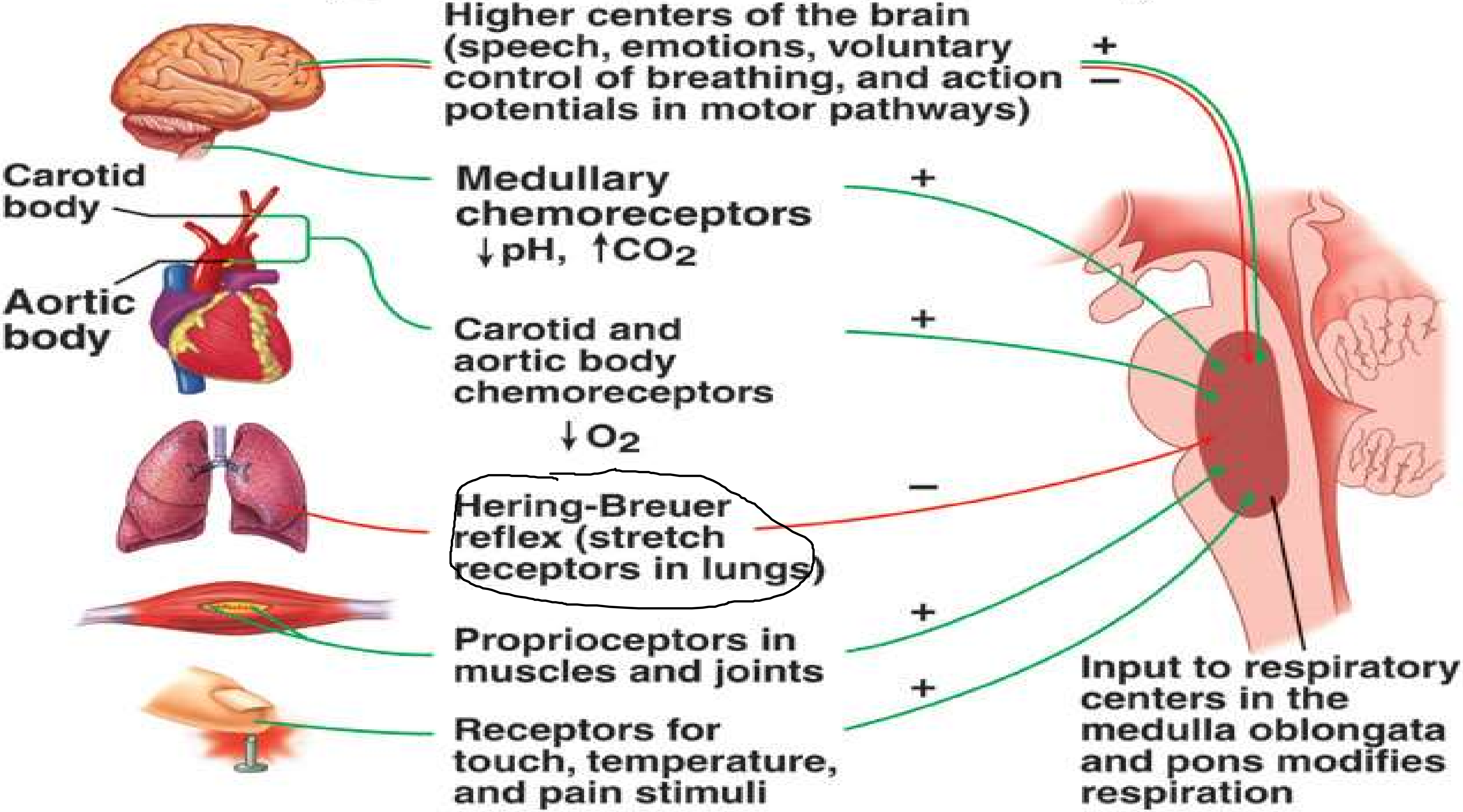
- Terminate inspiration.
- By speeding inspiratory termination they increase respiratory frequency.
- **Sustained stimulation of SARs:** causes activation of expiratory neurons

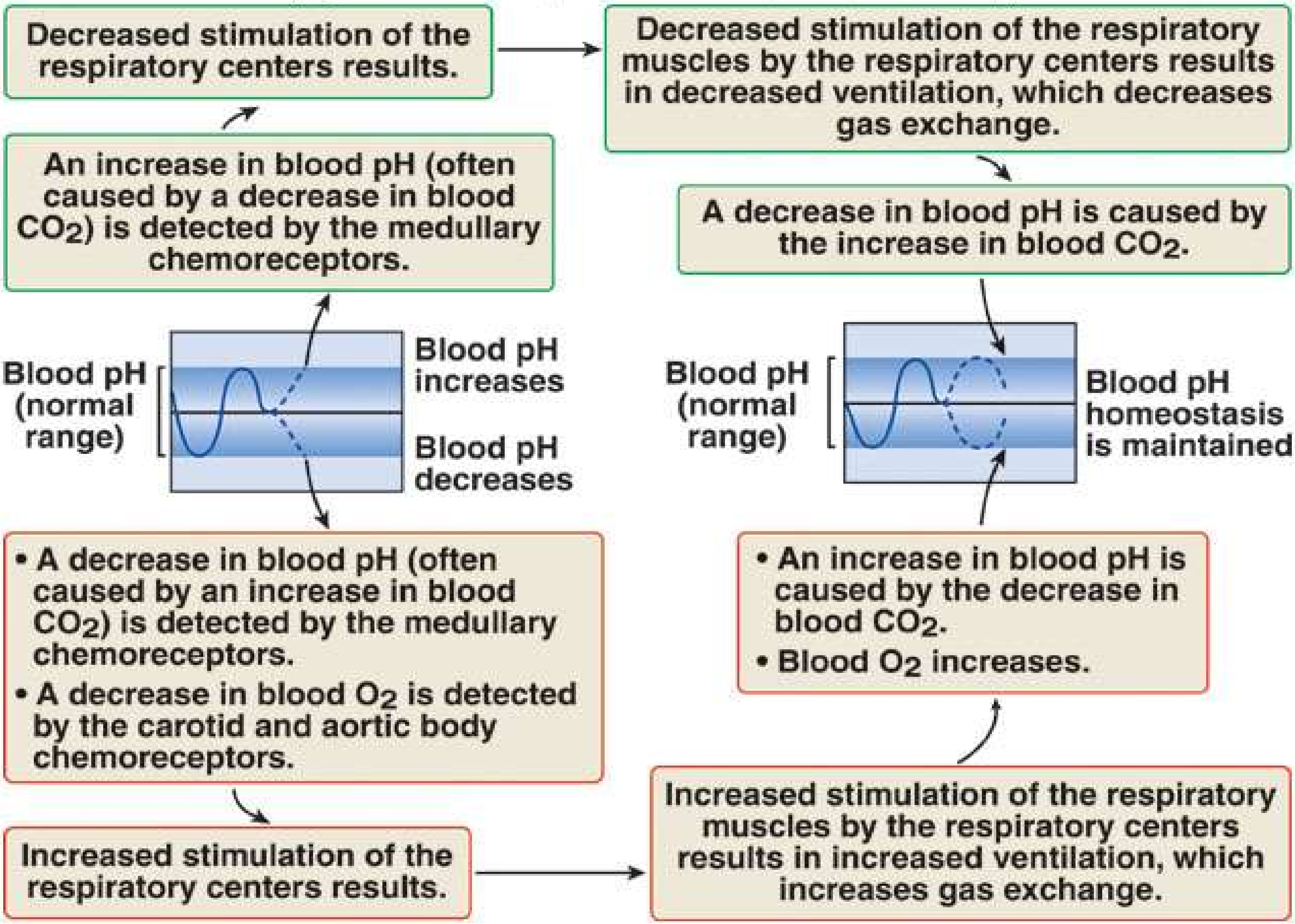
- **Hering-Breuer inflation reflex**
    - Inhibits inspiration to prevent over-inflation of the lungs and alveolar damage
    - Mediated by pulmonary stretch receptors and vagal afferents

- **Diving reflex:** immersion of the head triggers peripheral vasoconstriction redirection of blood to the heart and brain, and slowed pulse rate, which optimizes respiration

- **Spinal cord responses:** recruitment of additional respiratory muscles (e.g., to compensate hypoventilation) via stimulation of motor neurons by the respiratory center

- **Upper airway** responses (e.g., coughing, sneezing)


Higher centers of the brain (speech, emotions, voluntary control of breathing, and action potentials in motor pathways)
+
−
Carotid body
Aortic body
Medullary chemoreceptors
↓pH, ↑CO_2
+
Carotid and aortic body chemoreceptors
↓O_2
+
Hering-Breuer reflex (stretch receptors in lungs)
−
Proprioceptors in muscles and joints
+
Receptors for touch, temperature, and pain stimuli
+
Input to respiratory centers in the medulla oblongata and pons modifies respiration


Decreased stimulation of the respiratory centers results.
Decreased stimulation of the respiratory muscles by the respiratory centers results in decreased ventilation, which decreases gas exchange.
An increase in blood pH (often caused by a decrease in blood CO_2) is detected by the medullary chemoreceptors.
A decrease in blood pH is caused by the increase in blood CO_2.
Blood pH (normal range)
Blood pH increases
Blood pH decreases
Blood pH (normal range)
Blood pH homeostasis is maintained
• A decrease in blood pH (often caused by an increase in blood CO_2) is detected by the medullary chemoreceptors.
• A decrease in blood O_2 is detected by the carotid and aortic body chemoreceptors.
• An increase in blood pH is caused by the decrease in blood CO_2.
• Blood O_2 increases.
Increased stimulation of the respiratory centers results.
Increased stimulation of the respiratory muscles by the respiratory centers results in increased ventilation, which increases gas exchange.

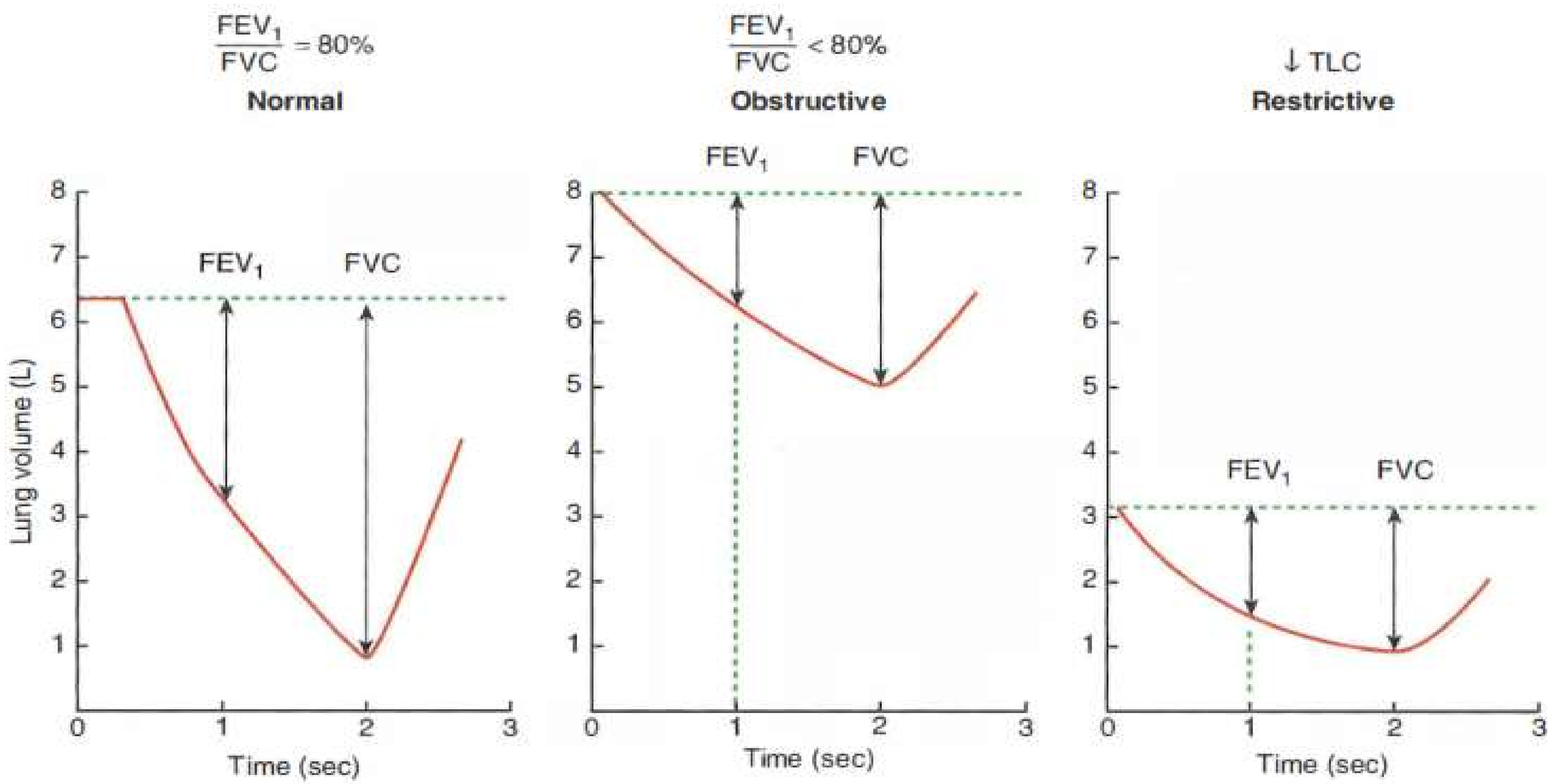
- **Pulmonary circulation**
- In healthy individuals the resistance is low and the compliance is high.
- Blood flow is equivalent to cardiac output (∼ 5 L/min).
- **Distribution of blood flow**: depends on the position of the body and is precisely regulated in relation to the ventilation to optimize gas exchange
- **Standing and sitting position:** due to gravity, circulation is highest in the lung base
- **Supine position:** nearly equal distribution of the blood throughout the lung

Characteristics of pulmonary blood flow THE REMINDER		
Location	**Blood flow**	**Pressures**
Apical segments	Lowest	Alveolar pressure > arterial pressure > venous pressure
Middle segments	Medium	Arterial pressure > alveolar pressure > venous pressure
Basal segments	Highest	Arterial pressure > venous pressure > alveolar pressure

In order to keep the ventilation-perfusion ratio constant, the vessels of the lungs react to hypoxia with vasoconstriction. In contrast, hypoxia in other organs causes vasodilation to increase perfusion

.

Obstructive vs. restrictive lung disease



Note: Obstructive lung volumes > normal (↑ TLC, ↑ FRC, ↑ RV); restrictive lung volumes < normal. In both obstructive and restrictive, FEV_1 and FVC are reduced, but in obstructive, FEV_1 is more dramatically reduced, resulting in a ↓ FEV_1/FVC ratio.

Characteristics of pathological breathing patterns just for your information for your future		
Pathological breathing patterns	**Characteristics**	**Common causes**
Kussmaul breathing	•Hyperventilation • with a deep, labored, breathing pattern (to eliminate excess CO_2)	•Metabolic acidosis(e.g., diabetic ketoacidosis •, uremia)
Cheyne-Stokes respiration	•Cyclic, crescendo-decrescendo pattern of breathing with intermittent periods of apnea •	•Damage to respiratory center • (e.g., stroke) •Central sleep apnea •Heart failure
Biot respirations (cluster breathing)	•Irregular breathing followed by regular or irregular periods of apnea	•↑ Intracranial pressure •Brain damage (e.g., trauma, stroke) •Opioid • use
Agonal respirations	•Labored breaths, gasping, myoclonus • and grunting, often prior to terminal apnea • and death; can last seconds to hours.	•Cardiocirculatory arrest
Rapid, shallow breathing	•Rapid, shallow breaths with low tidal volume •.	•Pain (e.g., rib fracture) •Post-extubation, weaning from mechanical ventilation •Pneumonia •, pulmonary edema •Asthma •, COPD •Anxiety