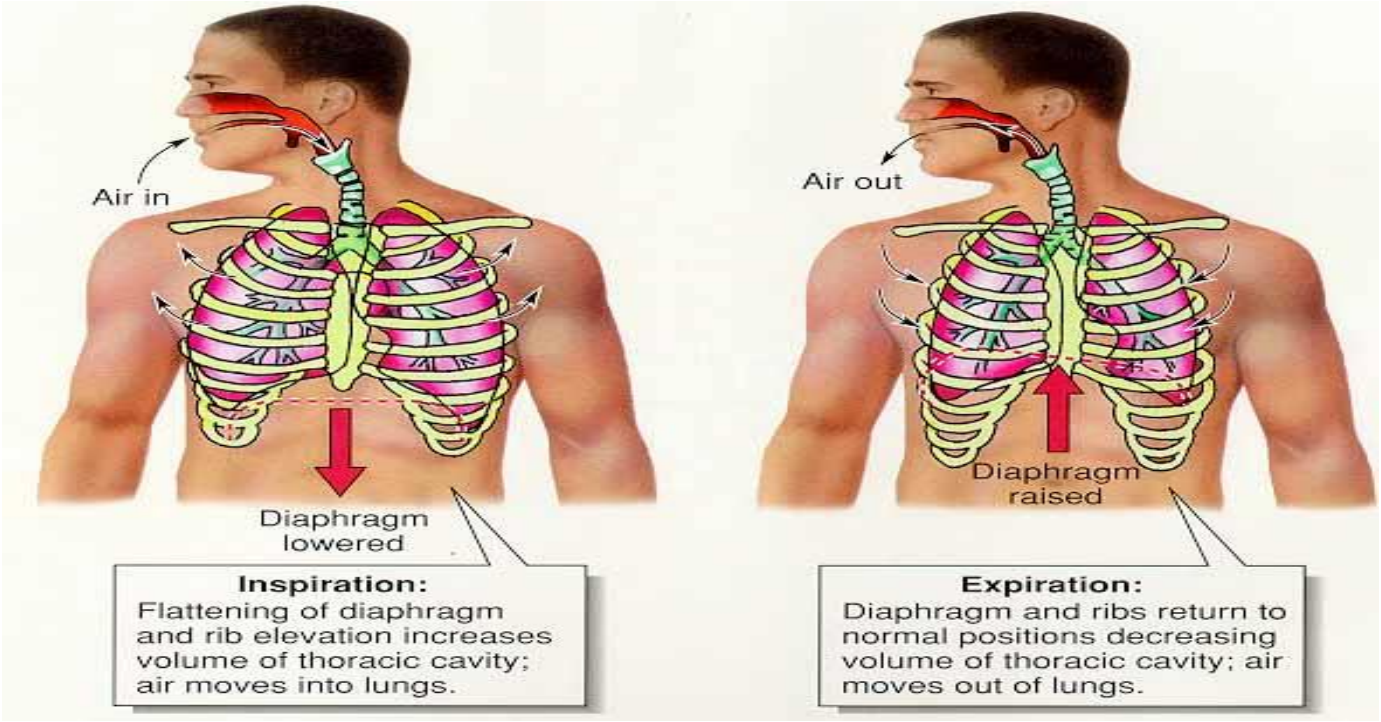
Mechanics of Breathing



Dr. Rehab F Gwada

Objectives of lecture

At the end of this lecture the student will able to:

- Explain the mechanics of breathing .
- Identify the respiratory muscles and its role in the mechanics of breathing.
- Recognize the Factors affecting breathing rate.
- Review the respiratory volumes & capacities.

Mechanics Of Breathing

- The movement of air into and out of the lungs (**ventilation**) results from a pressure difference between the thoracic cavity and the atmosphere.

- This pressure difference is created by changing the volume of the thoracic cavity.

Inspiration

- ✓ An active process requiring muscle contraction
- ✓ Diaphragm and ext. Intercostal muscles contract
- ✓ Thoracic cavity expands
- ✓ Pleural cavity pressure decreases
- ✓ Lung surface is pulled outward
- ✓ Alveolar pressure decreases below atmospheric pressure causing air to rush in

Mechanics Of Breathing

- **Inspiratory Muscles**

1. Diaphragm [major muscle contributes 75%]
2. External Intercostals contribute 25%

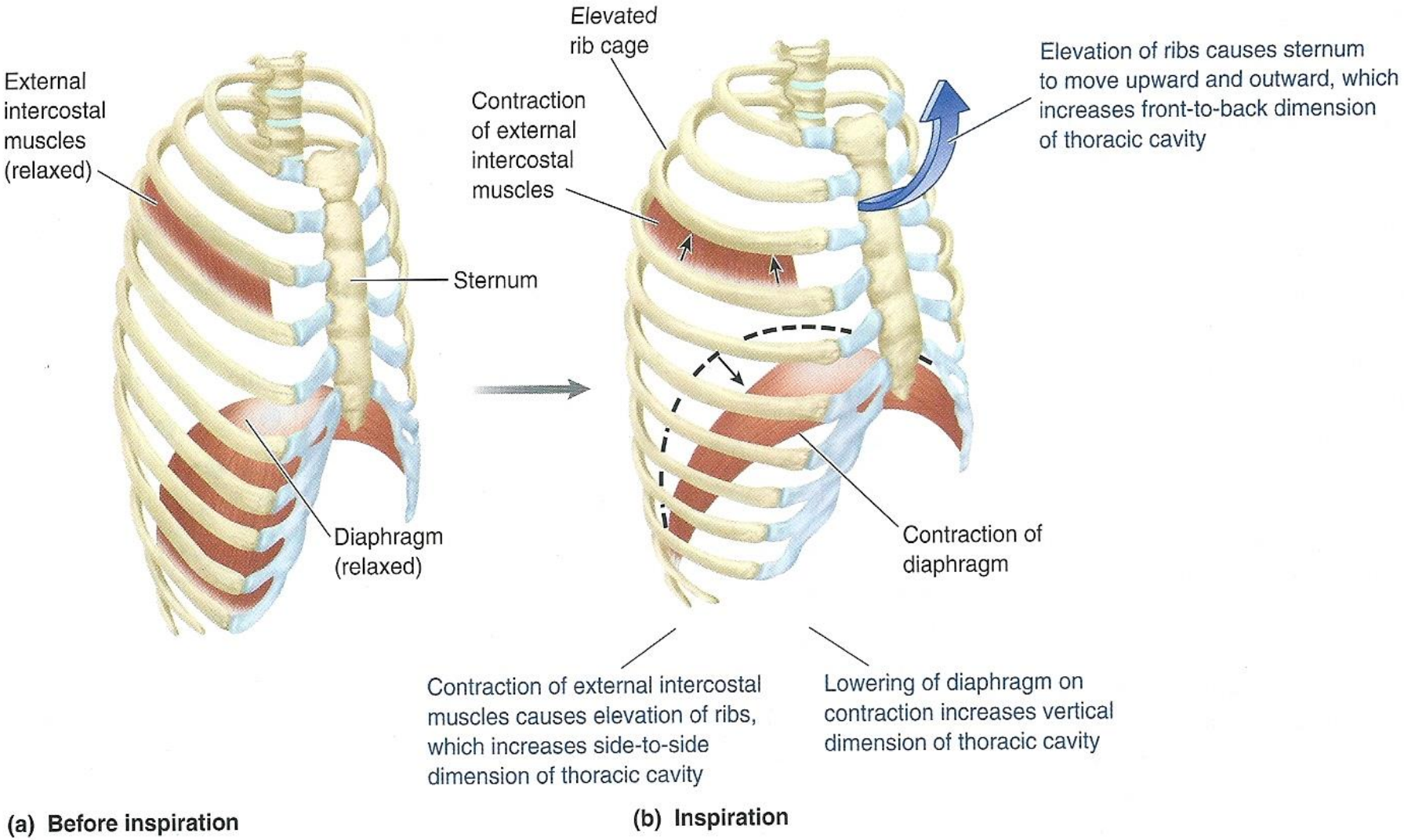
1. Diaphragm

- When Diaphragm contracts [on stimulation of phrenic nerve C3, C4, C5], it descends down and increases vertical diameter of the chest .
- During quiet breathing, Diaphragm descends about 1cm but during deep inspiration it may descend up to 5cm.

Inspiratory Muscles

2. External Intercostals

- When external intercostal muscle contracts, they elevate the ribs and the sternum upward and outward.
- Enlarge the thoracic cavity in lateral [side to side] and anterio-posterior [front to back] dimensions.
- Intercostal nerves activate these intercostal muscles.



● **FIGURE 13-12 Respiratory muscle activity during inspiration and expiration.** (a) Before inspiration, all respiratory muscles are relaxed. (b) During *inspiration,* the diaphragm descends on contraction, increasing the vertical dimension of the thoracic cavity. Contraction of the external intercostal muscles elevates the ribs and subsequently the sternum to enlarge the thoracic cavity from front to back and from side to side.

Inspiration

- Before Inspiration, intra-alveolar pressure is equal to atmospheric pressure , so no air is flowing into or out of lungs.
- As the thoracic cavity enlarges [due to contraction Inspiratory muscles] the lungs also expand to fill the large thoracic cavity.
- As the lungs enlarge, the intra-alveolar pressure drops by 1mmHg
- Establish the pressure gradient that favors air flow from higher atmospheric pressure to lower alveolar pressure till pressure equalizes. .

Intra-pleural Pressure during Inspiration

- During Inspiration, the intra-pleural pressure falls [-2mmHg], as a result of expansion of the thorax compared to Intra-pleural pressure before inspiration.

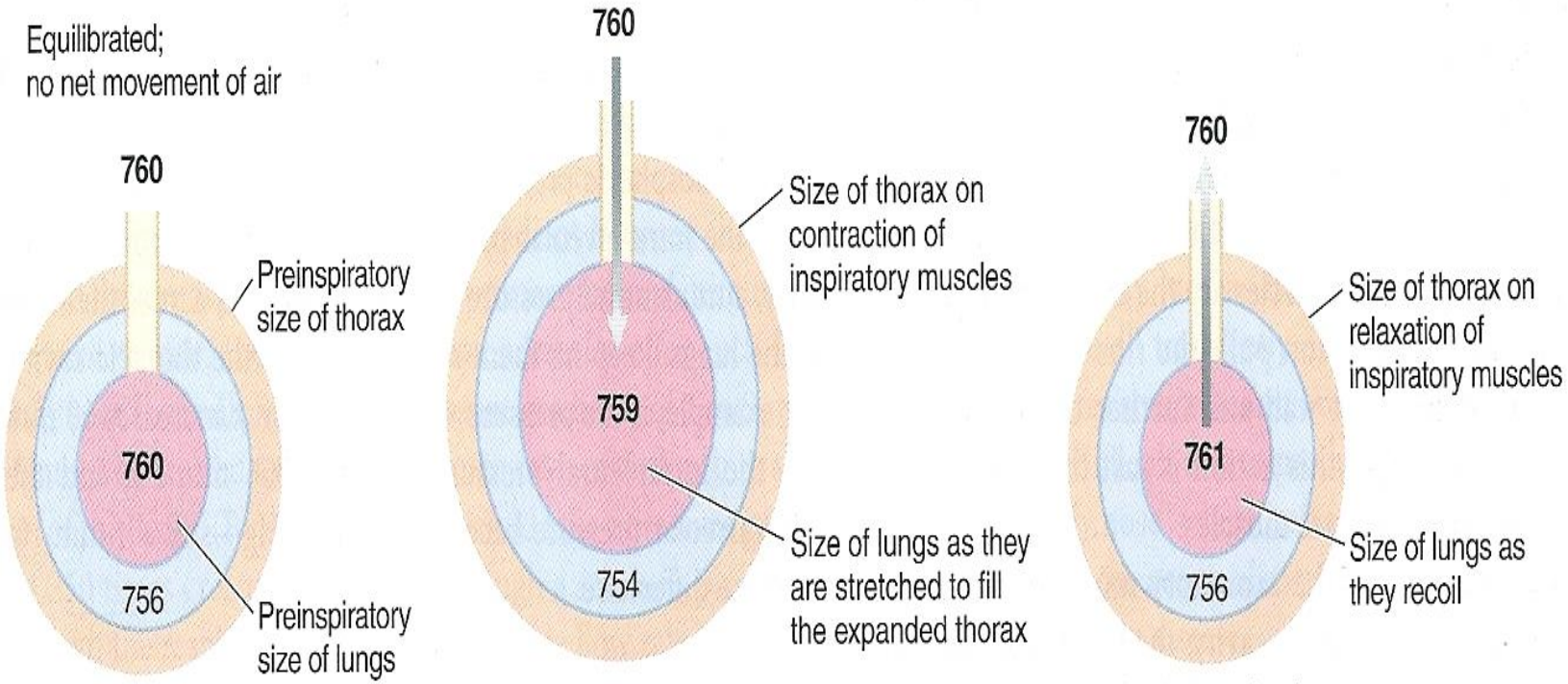


FIGURE 13-13 Changes in lung volume and intra-alveolar pressure during inspiration and expiration. (a) Before inspiration, at the end of the preceding expiration, intra-alveolar pressure is equilibrated with atmospheric pressure, and no air is flowing. (b) As the lungs increase in volume during inspiration, the intra-alveolar pressure decreases, establishing a pressure gradient that favors the flow of air into the alveoli from the atmosphere; that is, an inspiration occurs. (c) As the lungs recoil to their preinspiratory size on relaxation of the inspiratory muscles, the intra-alveolar pressure increases, establishing a pressure gradient that favors the flow of air out of the alveoli into the atmosphere; that is, an expiration occurs.

Forced inspiration
Accessory Muscles Of Inspiration

- They work with diaphragm and external intercostals.

Accessory Inspiratory Muscles Are:

- Sternocleidomastoid
- Scalenus
- Trapizus
- Pectoralis major
- Pectoralis minor
- Serratus ant. &post.superior

Accessory Muscles Of Inspiration

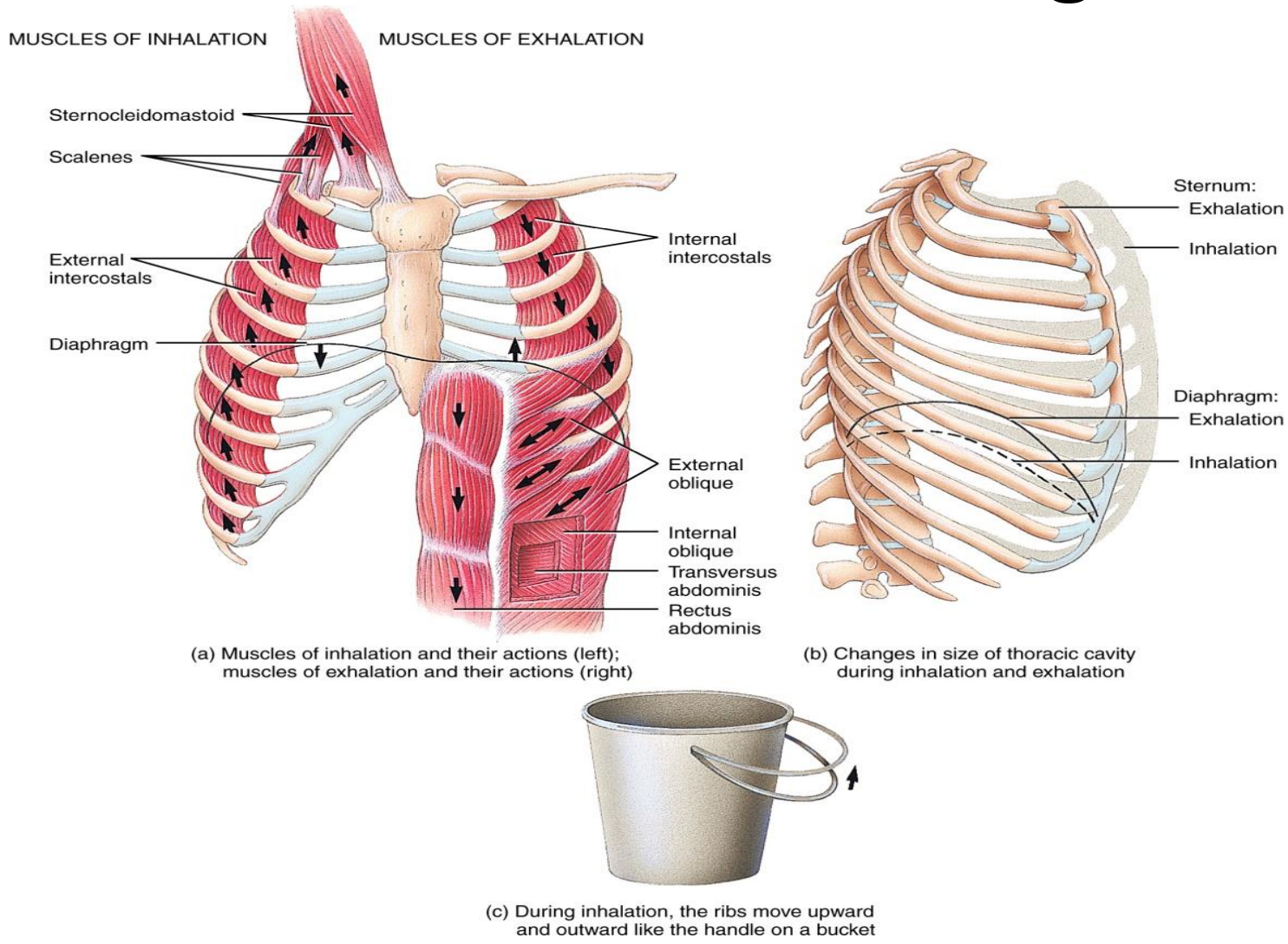
- Contraction of Accessory muscles → causes lifting of sternum and elevation of upper ribs, → enlarging the upper portion of thoracic cavity → lungs expand more, → further dropping intra-alveolar pressure.

→ more inward flow of air occurs.

Expiration

- ✓ Expiration is a passive process, no muscle contraction required.
- ✓ Diaphragm and external intercostals relax.
- ✓ Thoracic cavity decreases in size.
- ✓ stretched lungs recoil to their original [pre-Inspiratory] size, due to their elastic properties.
- ✓ Pleural pressure rises by 1mmHg.
- ✓ Alveolar press. Greater than atmospheric
- ✓ Air flows out

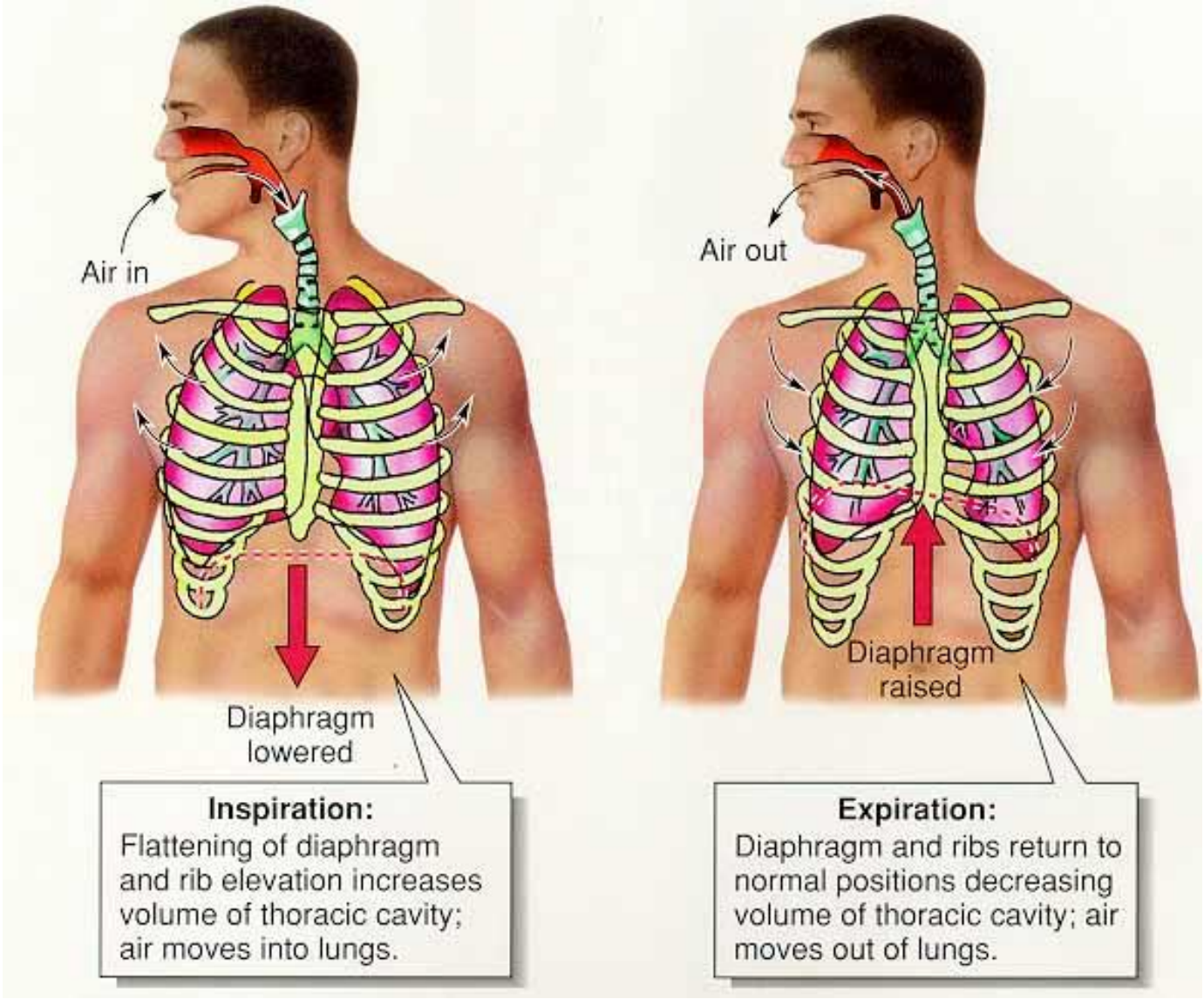
Muscles of breathing



(a) Muscles of inhalation and their actions (left); muscles of exhalation and their actions (right)

(b) Changes in size of thoracic cavity during inhalation and exhalation

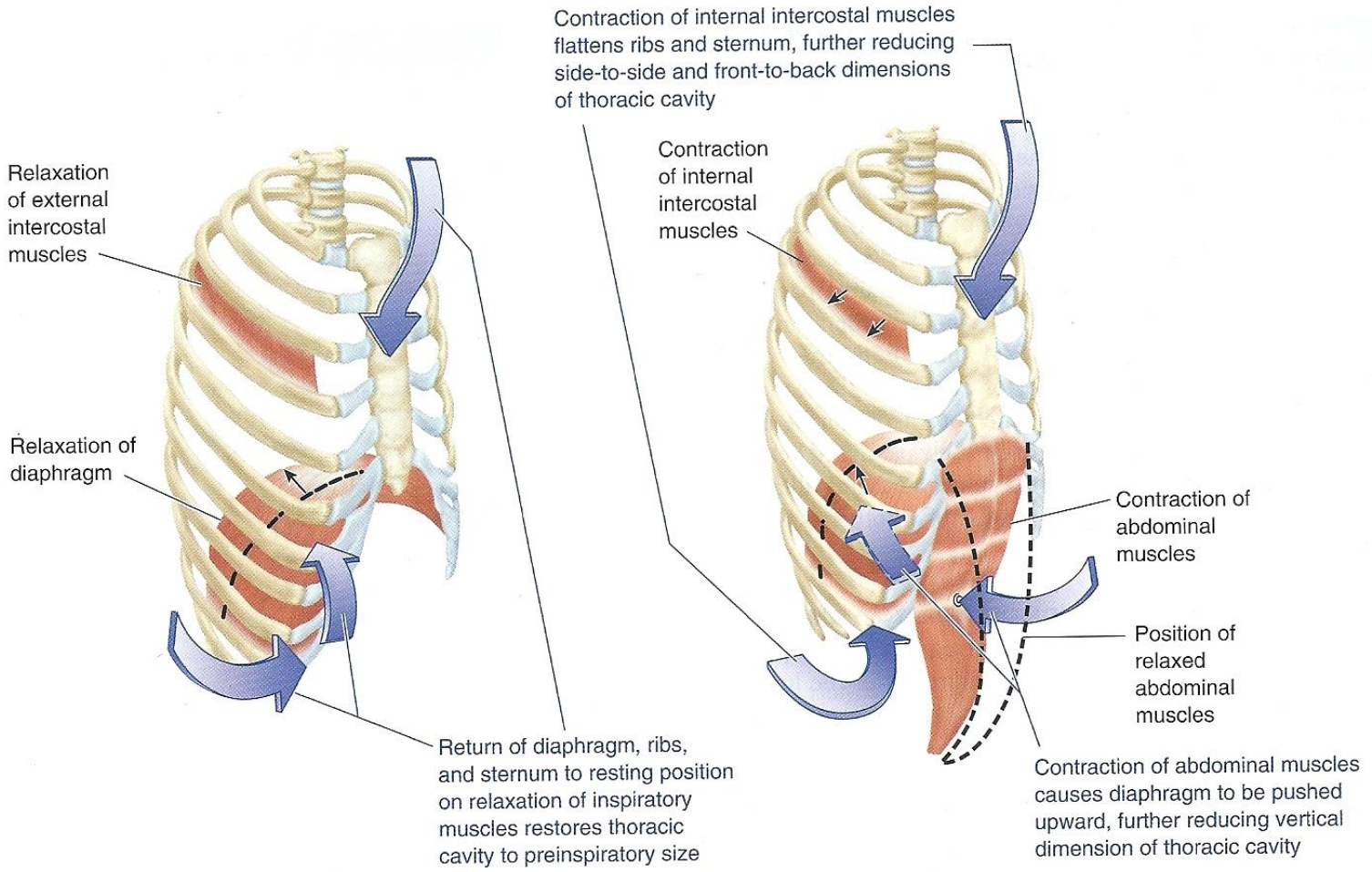
(c) During inhalation, the ribs move upward and outward like the handle on a bucket


Air in
Diaphragm lowered
Inspiration:
Flattening of diaphragm and rib elevation increases volume of thoracic cavity; air moves into lungs.
Air out
Diaphragm raised
Expiration:
Diaphragm and ribs return to normal positions decreasing volume of thoracic cavity; air moves out of lungs.

Forced Exhalation

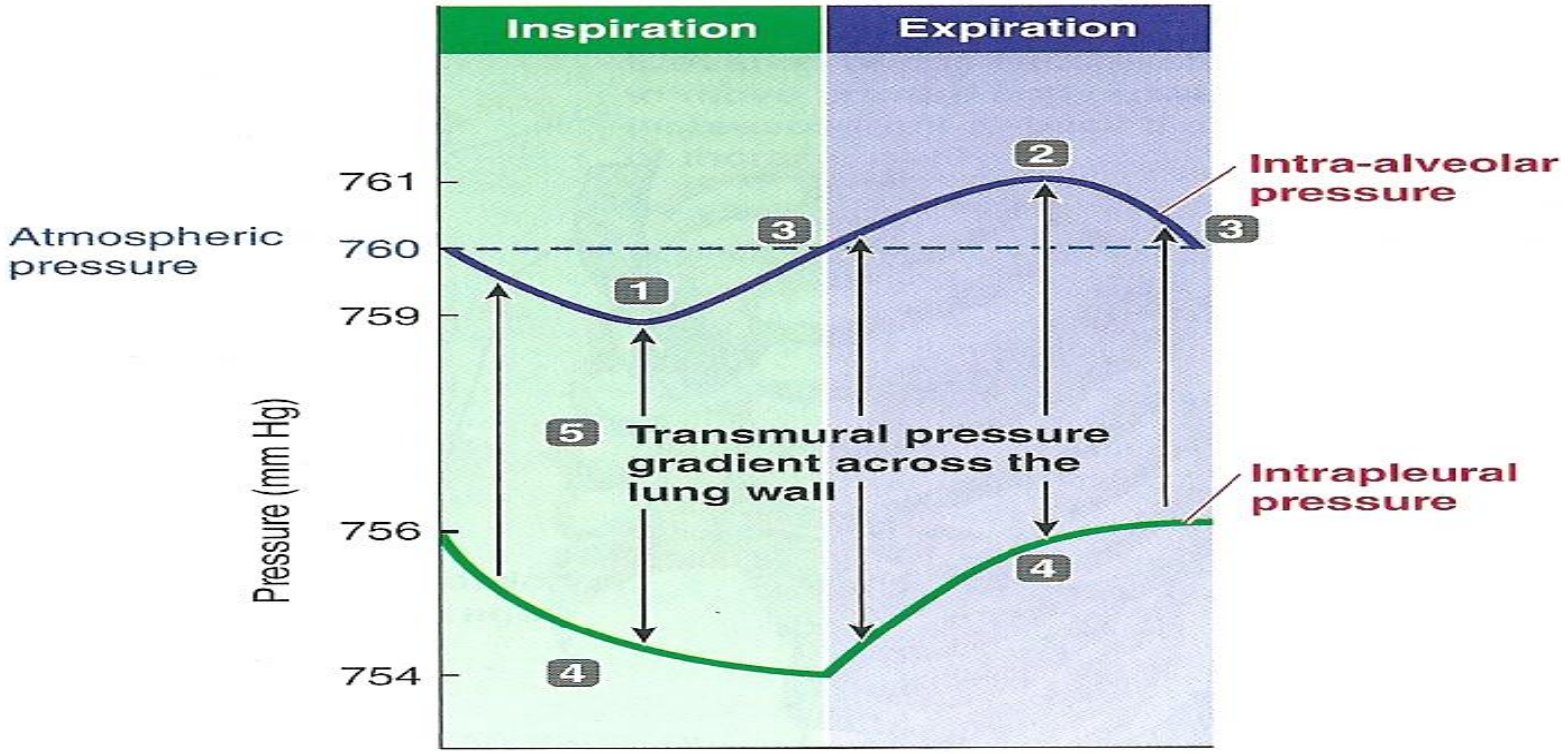
- During a forced exhalation, the **internal** intercostal muscles contract, pull the ribs down &in .
- The abdominal muscles contract ➡ raising intra-abdominal pressure ➡ push the diaphragm ➡ further decrease in thoracic volume ➡ more raising pleural pressure & alveolar pressure ➡ more drive air out .

- These muscles are used to counteract the effects of obstructive pulmonary disorders.



(c) Passive expiration **(d) Active expiration**

● **FIGURE 13-12** *(continued)* (c) During *quiet passive expiration,* the diaphragm relaxes, reducing the volume of the thoracic cavity from its peak inspiratory size. As the external intercostal muscles relax, the elevated rib cage falls because of the force of gravity. This also reduces the volume of the thoracic cavity. (d) During *active expiration,* contraction of the abdominal muscles increases the intra-abdominal pressure, exerting an upward force on the diaphragm. This reduces the vertical dimension of the thoracic cavity further than it is reduced during quiet passive expiration. Contraction of the internal intercostal muscles decreases the front-to-back and side-to-side dimensions by flattening the ribs and sternum.



1 During inspiration, intra-alveolar pressure is less than atmospheric pressure.

2 During expiration, intra-alveolar pressure is greater than atmospheric pressure.

3 At the end of both inspiration and expiration, intra-alveolar pressure is equal to atmospheric pressure because the alveoli are in direct communication with the atmosphere, and air continues to flow down its pressure gradient until the two pressures equilibrate.

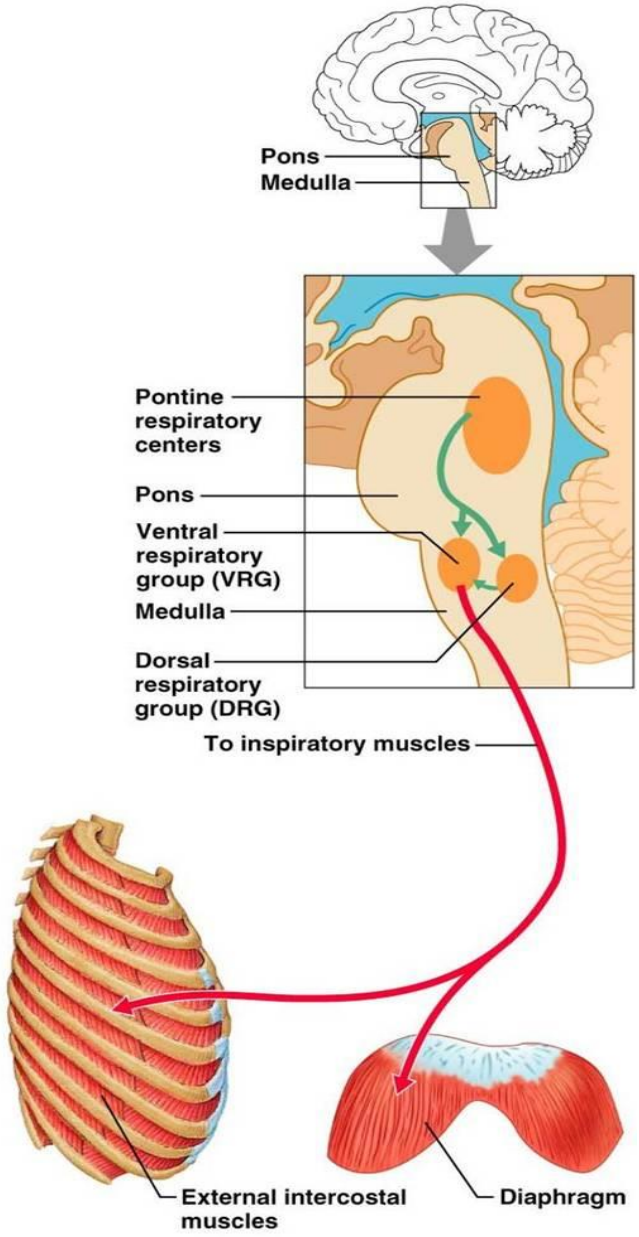
4 Throughout the respiratory cycle, intrapleural pressure is less than intra-alveolar pressure.

5 Thus, a transmural pressure gradient always exists, and the lung is always stretched to some degree, even during expiration.

● **FIGURE 13-14 Intra-alveolar and intrapleural pressure changes throughout the respiratory cycle.**

Respiratory Control

- Homeostasis in breathing involves the regulation of CO_2 and O_2 levels in the body. These gas levels are regulated by 2 control systems:
  - **Nervous control**: an area in the brain called the respiratory centre (medulla oblongata) has nerve fibers that connect it to the muscles of the rib cage and the diaphragm
  - **Chemical control**: chemical receptors in the walls of arteries detect changes in levels of CO_2 and send signals to the respiratory centre.



Air way resistance affects Air flow

- ✓ Air flow depends on the resistance offered by air ways (bronchi and bronchioles).
- ✓ Resistance will increase if the radius of conducting air ways (bronchi) gets smaller.
- ✓ Air ways are supplied by Autonomic Nervous System [ANS].
- ✓ Parasympathetic ANS – causes broncho-constriction (decreases the radius of bronchioles) therefore increases the air way resistance.
- ✓ Sympathetic ANS and Epinephrine
- ✓ They cause broncho-dilation (increase the radius of bronchioles) therefore decrease the air way resistance.

which allows for greater alveolar oxygen exchange

Factors affecting breathing rate

- ✓ Breathing can be affected by internal body conditions and environmental conditions
  - ✓ Internal:
    - ✓ Increased levels of CO_2 in the blood
    - ✓ Respiratory disease (common cold, influenza, TB)
    - ✓ Amount of cellular activity (muscle cells require more energy when they are worked, therefore the amount of gas exchange will increase)
  - ✓ b) Environmental:
    - ✓ At higher altitudes, the air is thinner and contains less O_2, therefore breathing rate increases
    - ✓ Emotion
    - ✓ Dust, pollen
    - ✓ Smoke (carbon cannot be filtered)
    - ✓ Industrial chemicals (CO, ammonia, methane cause inflammation of respiratory tissue)

Question??

- When you sit in the drivers seat at rest,

Which muscles are contributing the majority of your breathing?

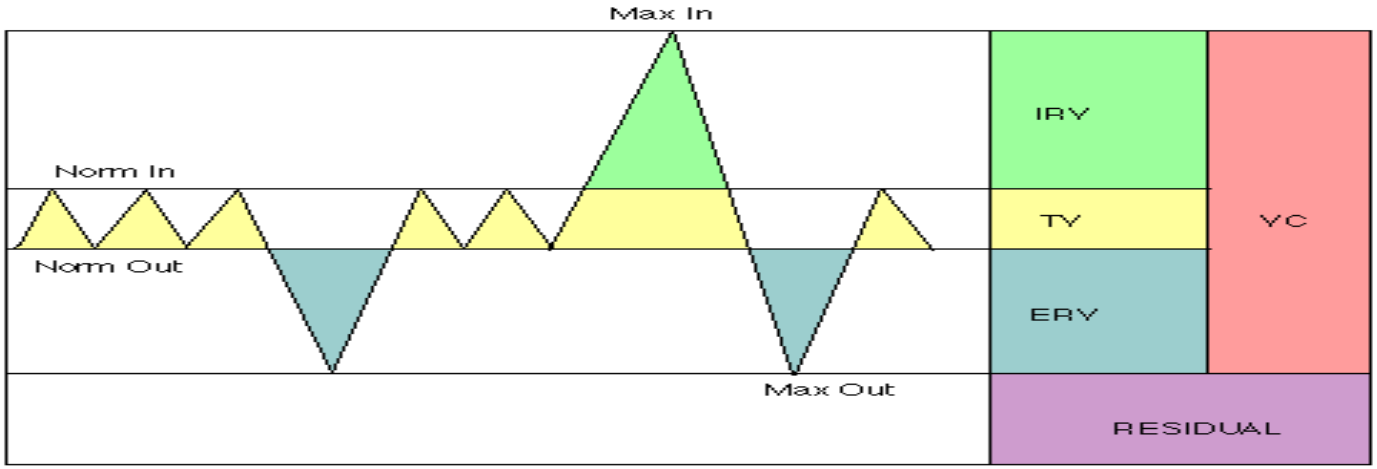
1. Internal intercostals
2. External intercostals
3. Accesory muscles
4. Diaphragm
5. Psoas major

Pulmonary Ventilation

- The total amount of air moved in and out of the lungs each minute.
  - depends upon 2 factors:
    - The size of each breath (tidal volume: TV)
    - The number of breaths/minute : BR (breathing rate))

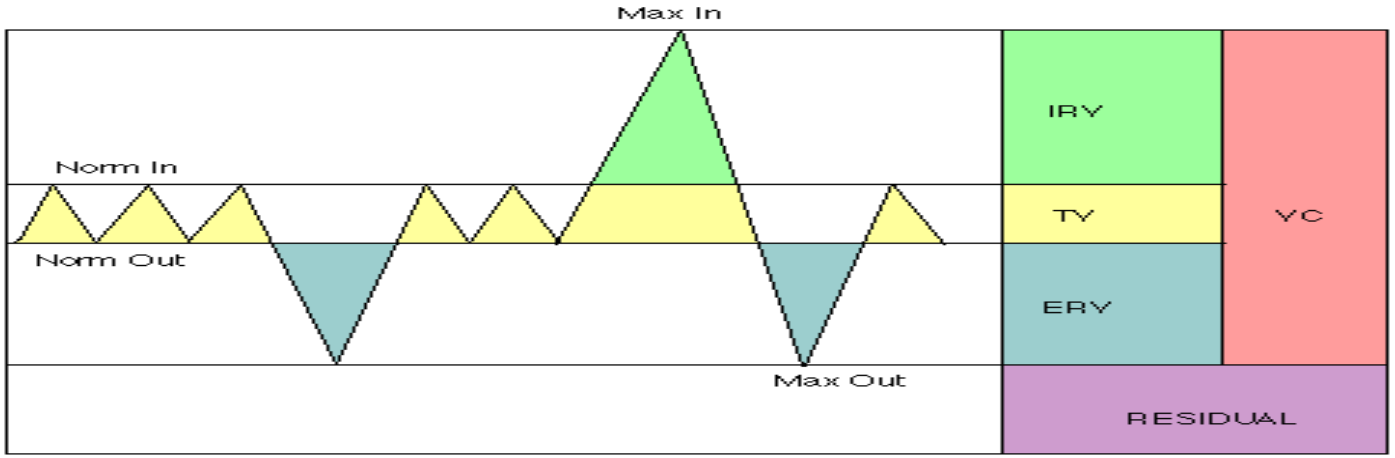
Respiratory Volumes

- **Tidal Volume (TV)**- amount of air inspired or expired in normal breathing
- **Inspiratory Reserve Volume (IRV)** - amount of air that can inhaled forcibly over tidal volume
- **Expiratory Reserve Volume (ERV)** - amt. of air that can be forcibly exhaled after a tidal expiration



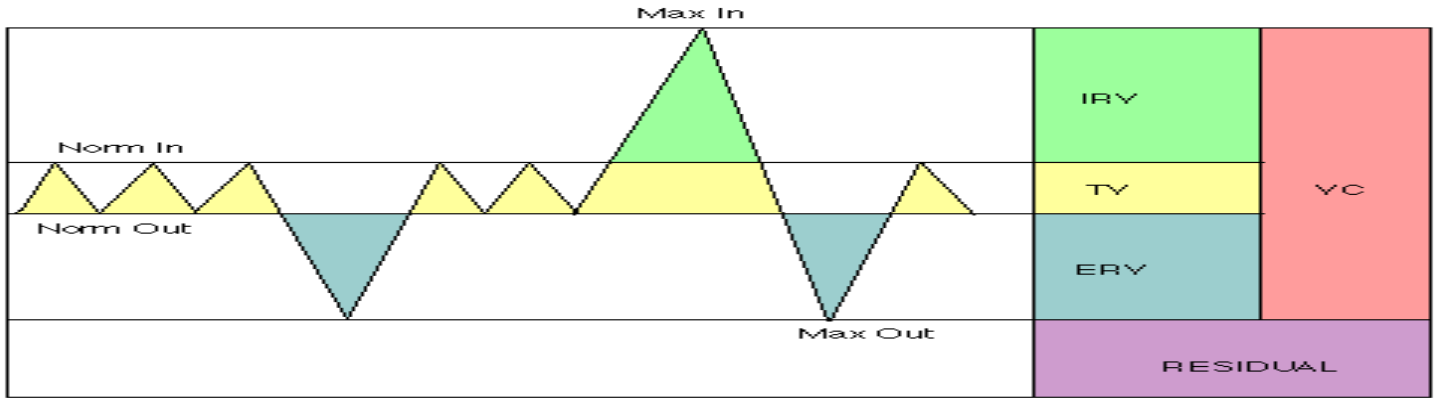
Respiratory Volumes

- **Residual Volume (RV)**: air remaining in lungs after a forced expiration
- **Vital Capacity (VC)**: total amt. of exchangeable air (TV + IRV +ERV)
- **Total Lung Capacity:** VC + RV = air contained in fully inflated lung



Respiratory Capacities

- **inspiratory capacity (IC) -** the maximum amount of gas that can be inhaled after a normal (unforced) exhalation. IC = IRV + TV
- **functional residual capacity (FRC) -** the amount of gas left in the lungs after a normal (unforced) exhalation. FRC = ERV + RV



ANY Q?