Respiration
PHS 101 6th lecture

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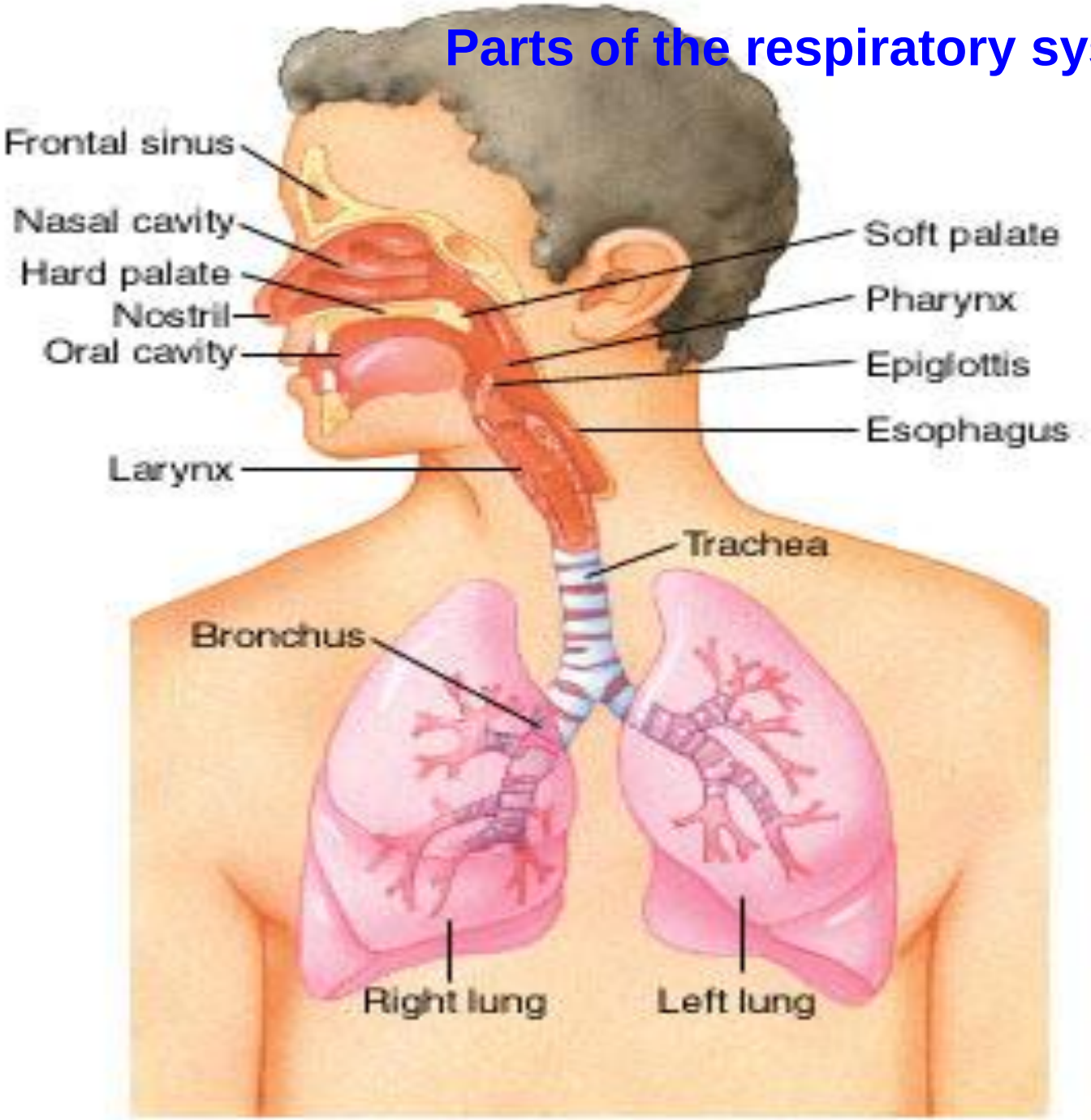
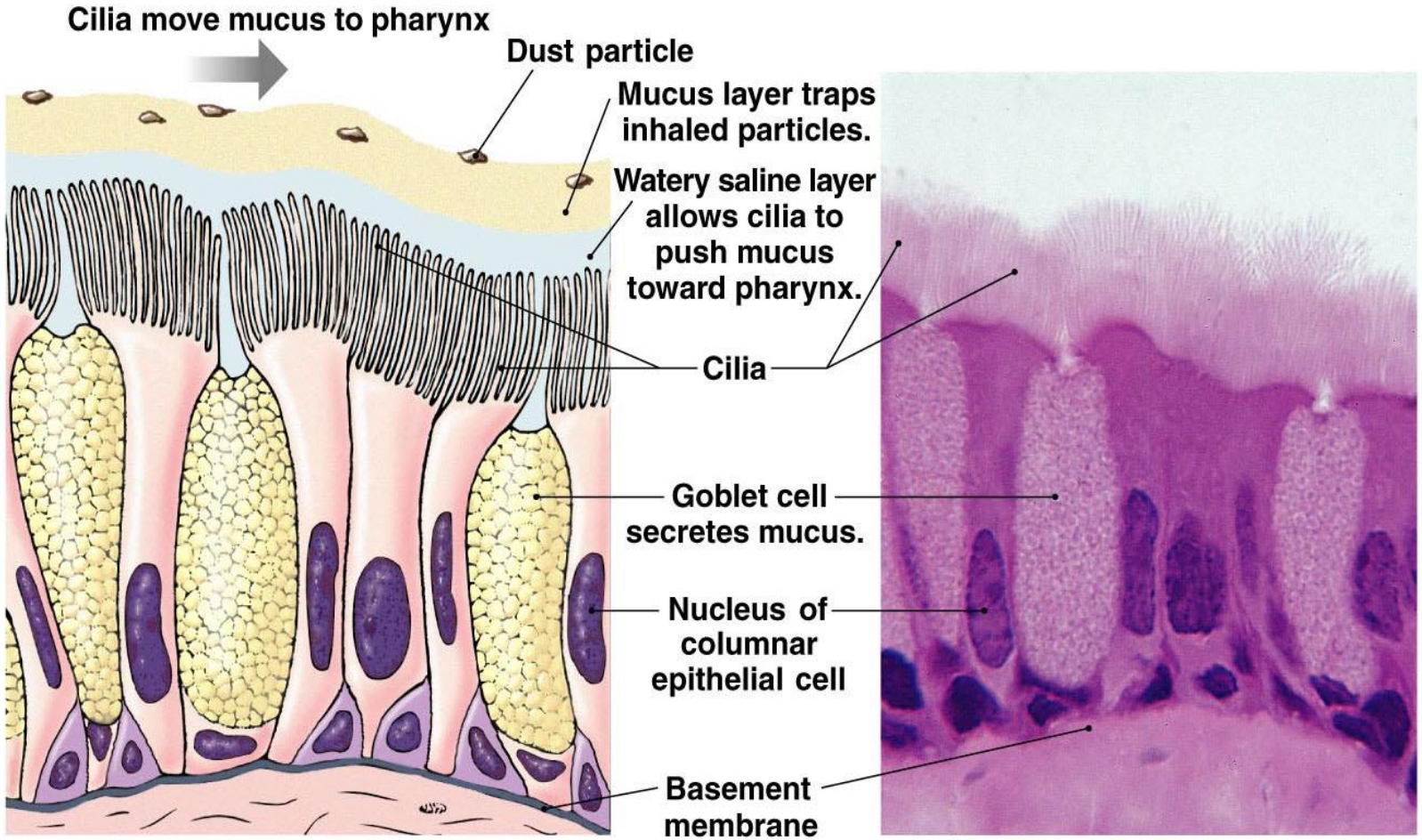
Respiration is the exchange of oxygen and carbon dioxide between the atmosphere and the body cells, including inhalation and exhalation; diffusion of oxygen from alveoli to blood and of carbon dioxide from blood to alveoli; and transport of oxygen to and carbon dioxide from body cells.

Types of respiration

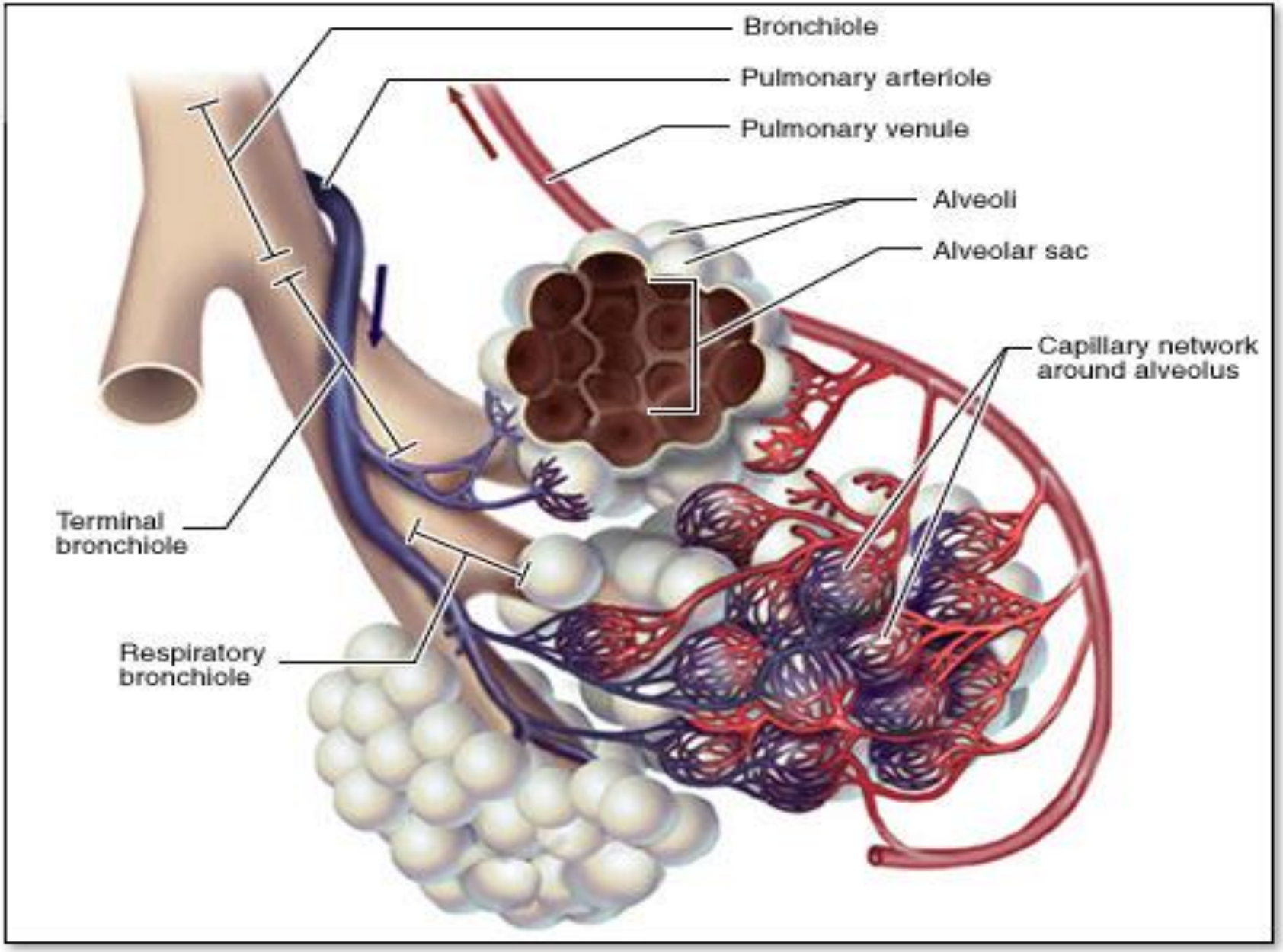
- **External respiration:** exchange of gases between air in the lungs and blood.
- **Internal respiration:** exchange of gases between the body cells and blood.
- **Cellular respiration:** the use of oxygen by the body cells in oxidation of food stuffs to produce energy.

Parts of the respiratory system





Ciliated epithelium of the trachea

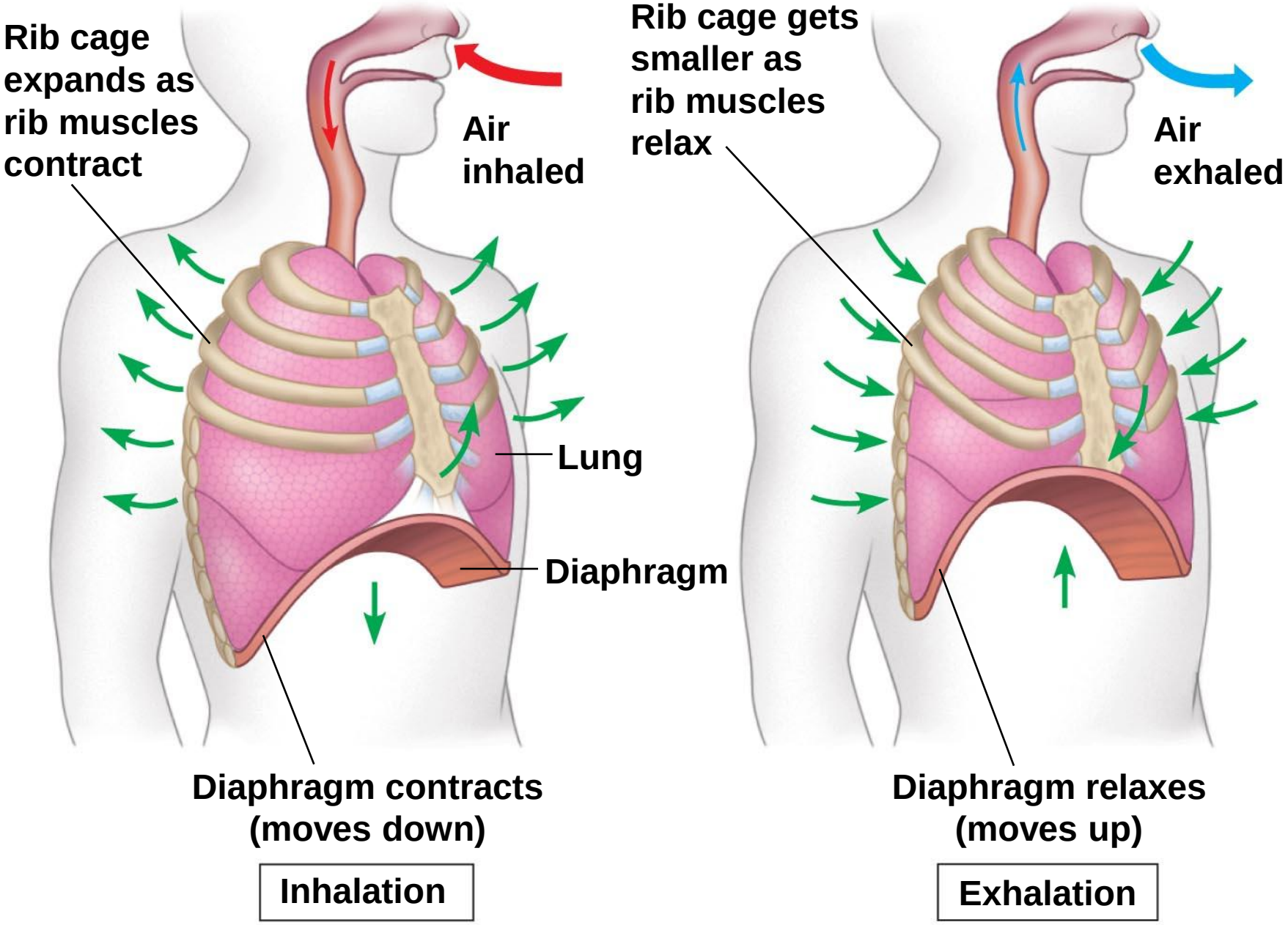


Number of alveoli in human lungs range from 600-700 million/two lungs which form a surface area of about 50-90 m^2

Inspiration and Expiration

- **Inspiration**
  - **Ribs are pushed to outside and upward by the contraction of external intercostal muscles.**
  - **Diaphragm contracts and moves downwards.**
  - **Thoracic cavity increases in size and lung space increases**
  - **Pressure gradient causes gas to flow into the lungs**
- **Expiration**
  - **External intercostal muscles and diaphragm relax and return to normal position decreasing the size of thoracic cavity and decreasing lung space.**
  - **Pressure gradient causes air to flow to outside.**

LE 22-7a



Lungs expand and contract in response to changes in pressure inside the chest cavity.

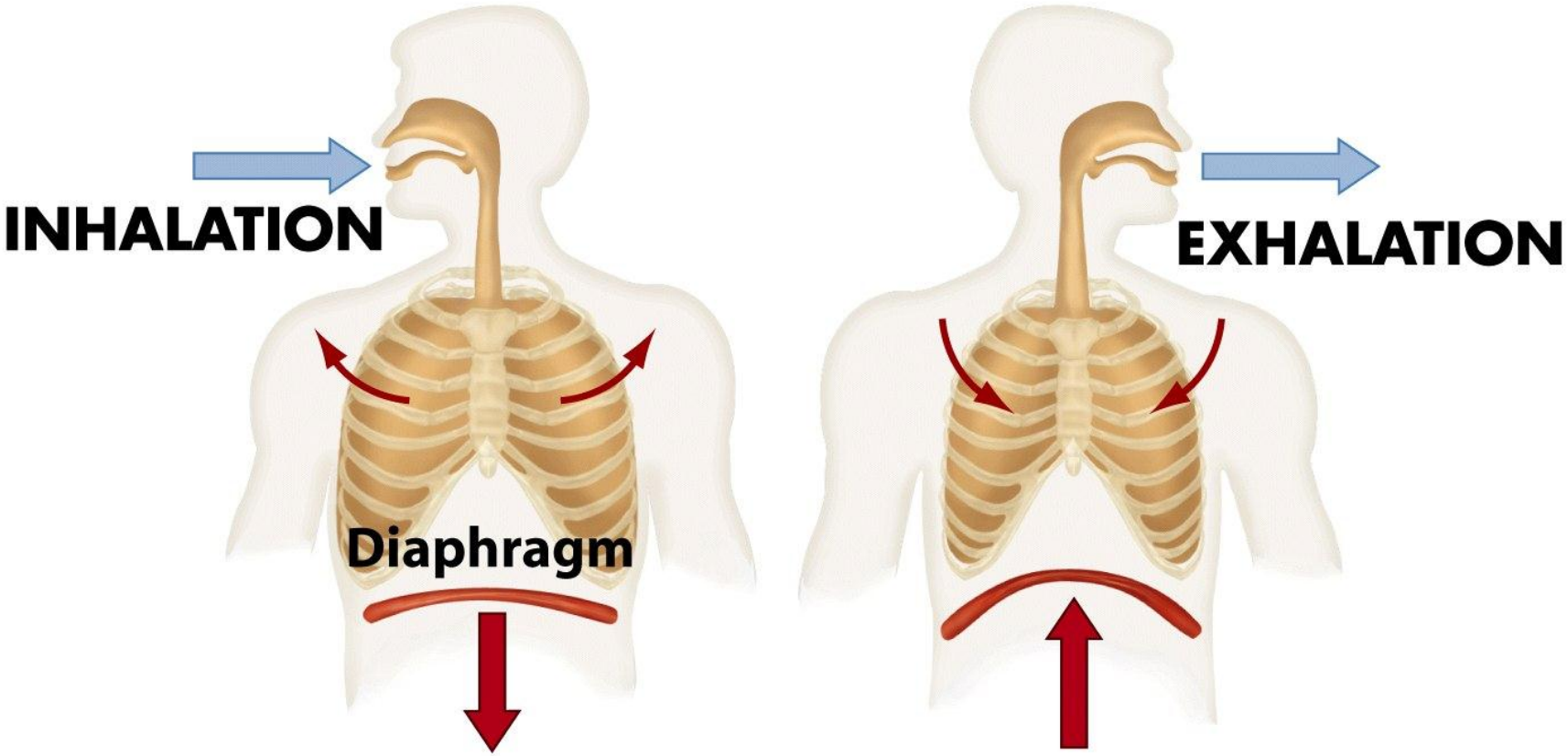
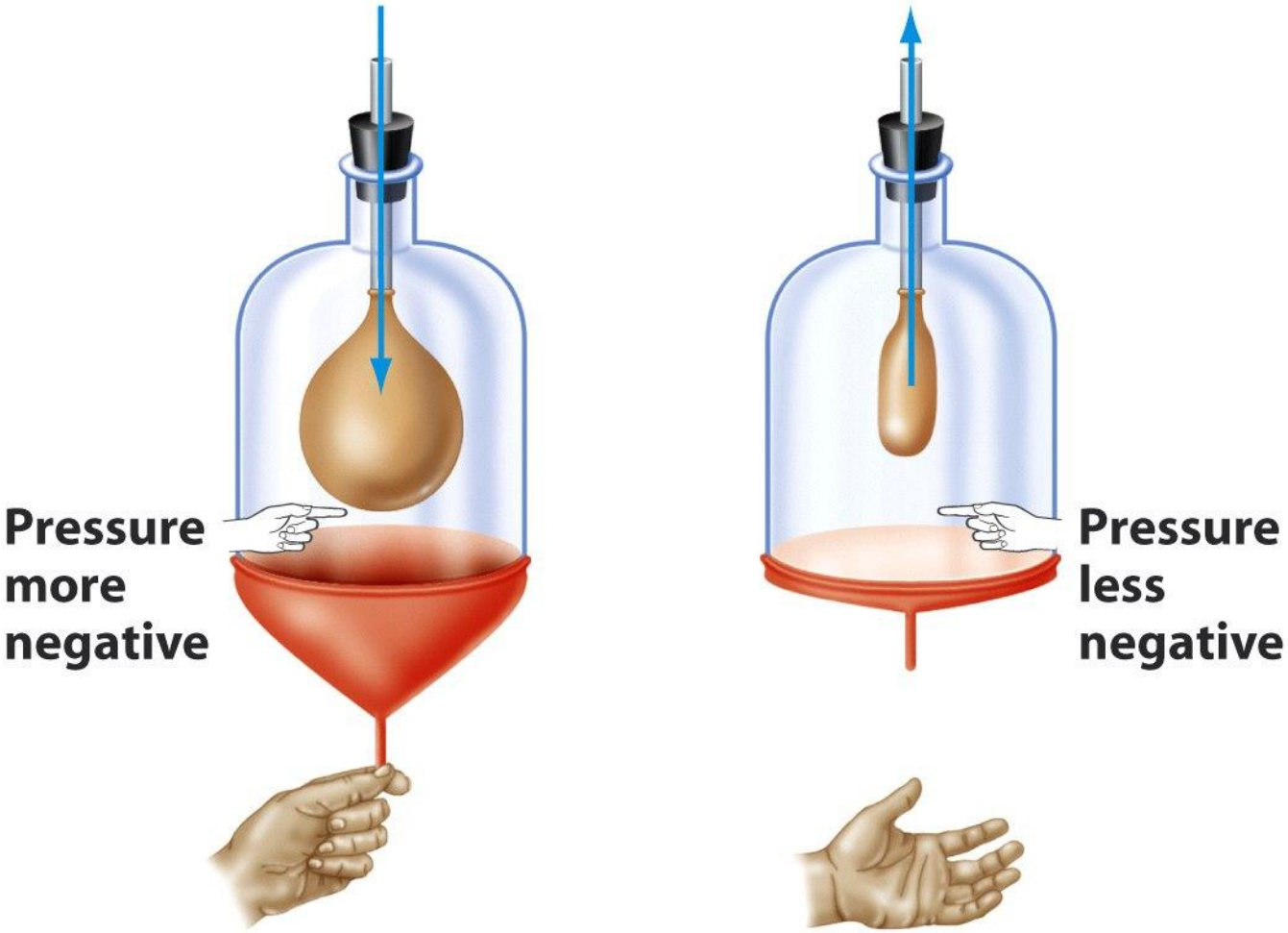


Figure 44-9a Biological Science, 2/e

Ventilatory forces can be modeled by a balloon in a jar.

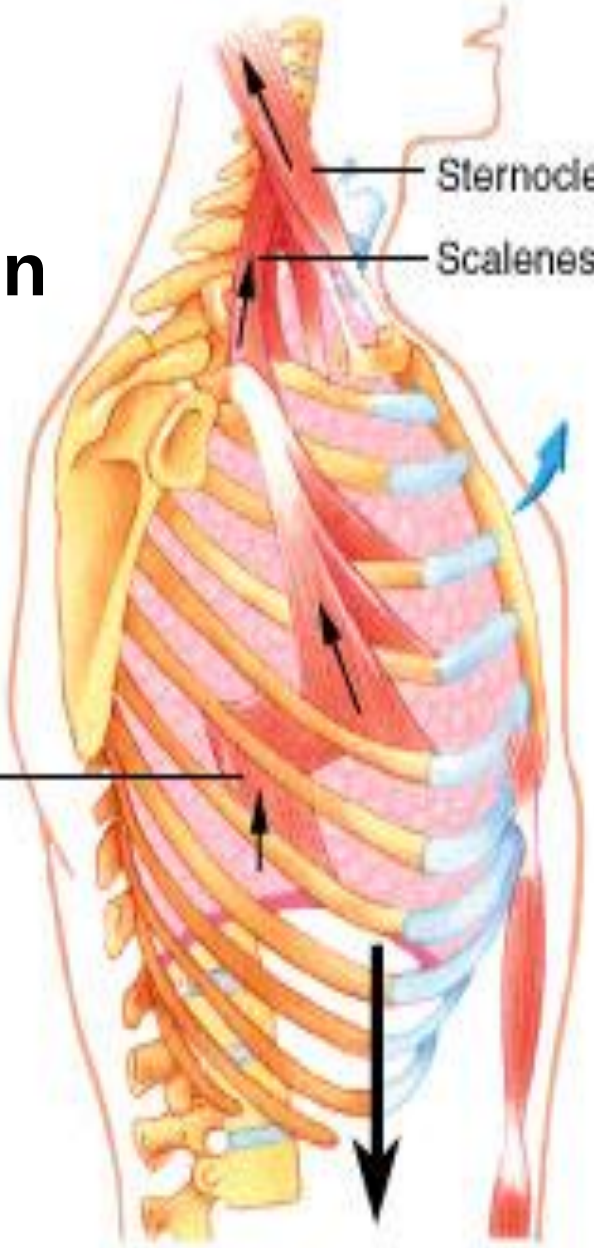


When the diaphragm is pulled down, the balloon inflates.

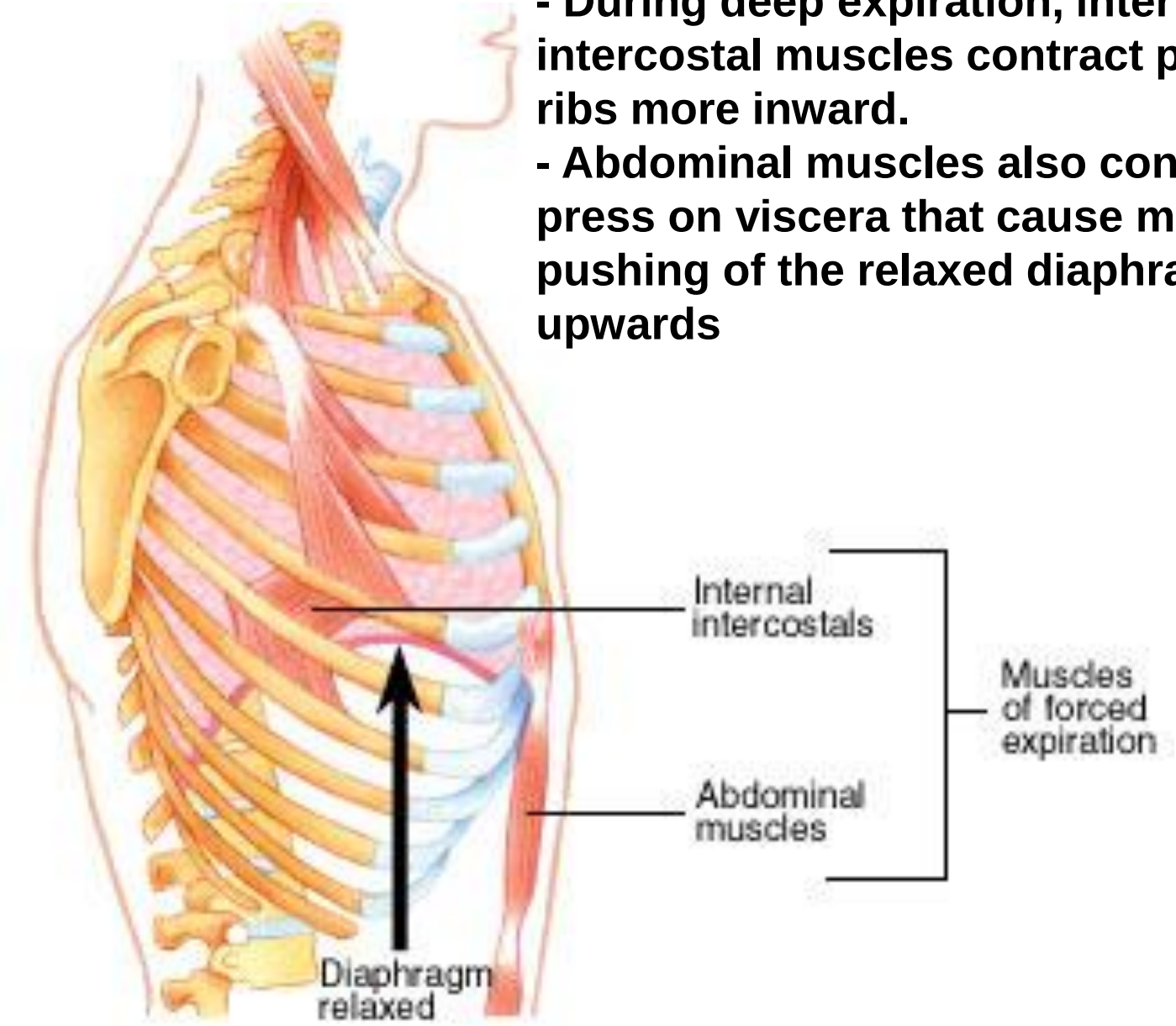
When the diaphragm is released, the balloon deflates.

Figure 44-9b Biological Science, 2/e

Quiet inspiration



- During deep expiration, internal intercostal muscles contract pulling ribs more inward.
- Abdominal muscles also contract to press on viscera that cause more pushing of the relaxed diaphragm to upwards

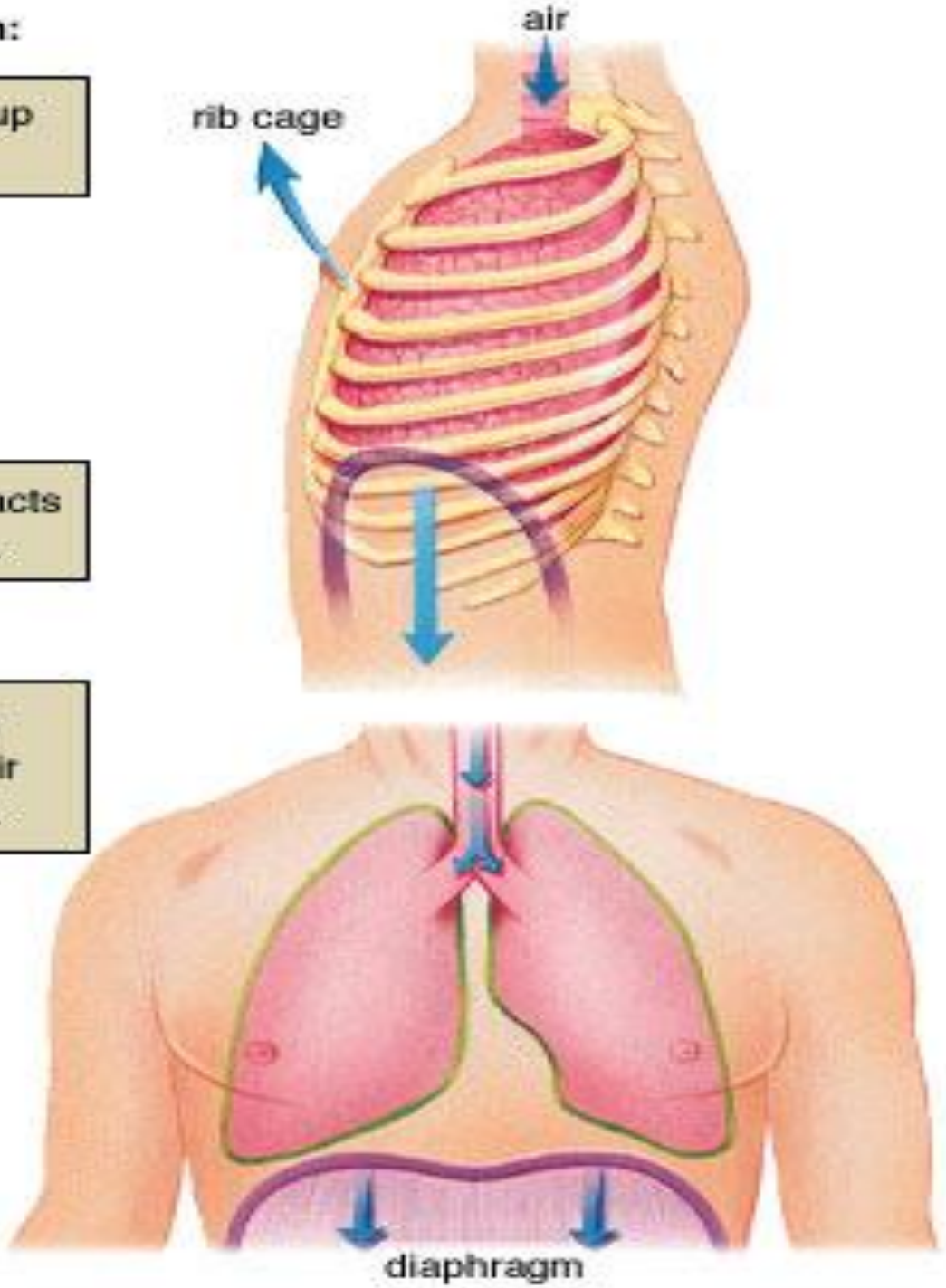


During Inspiration:

Rib cage moves up and out.

Diaphragm contracts and moves down.

Pressure in lungs decreases, and air comes rushing in.

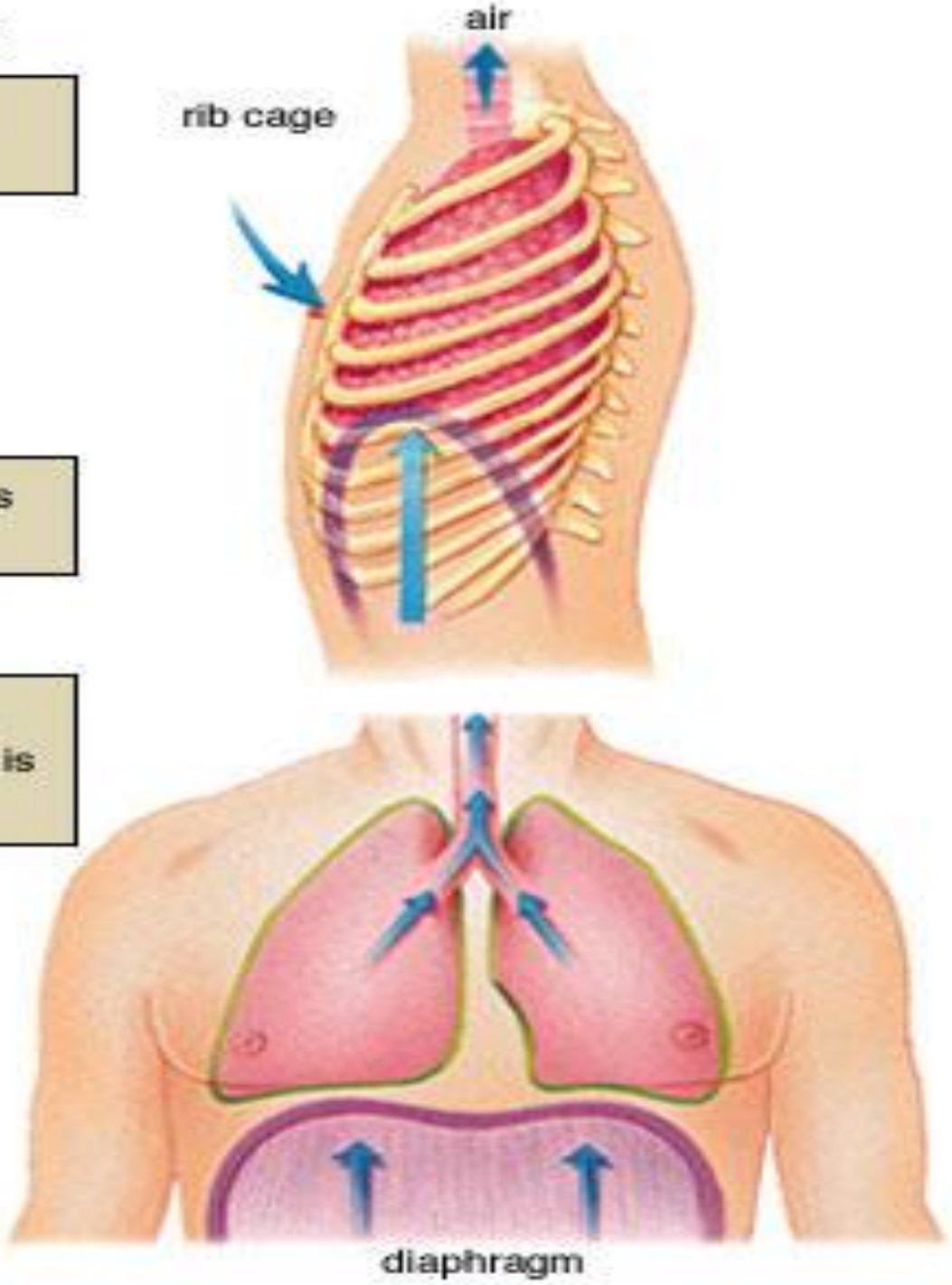


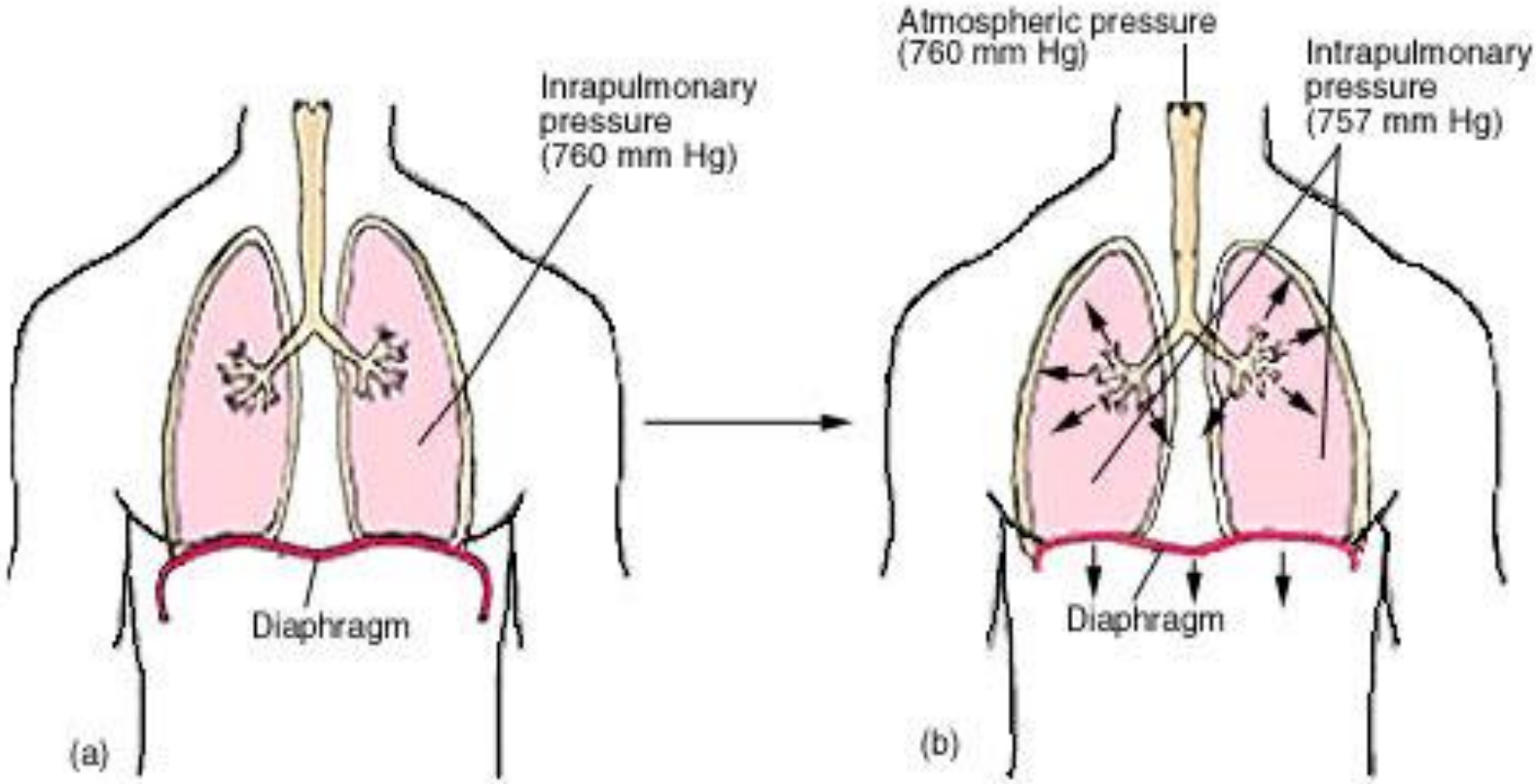
During Expiration:

Rib cage moves down and in.

Diaphragm relaxes and moves up.

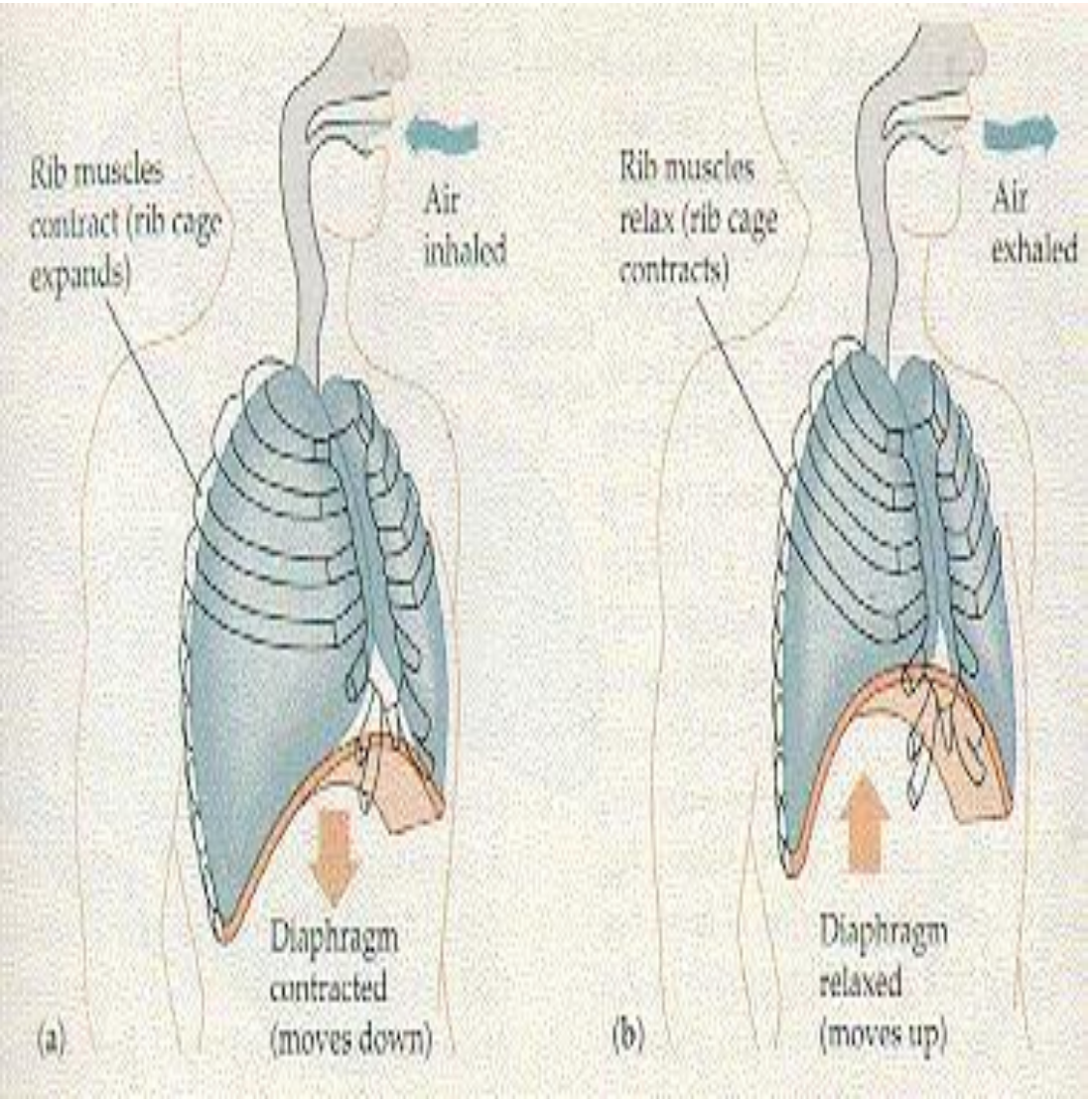
Pressure in lungs increases, and air is pushed out.





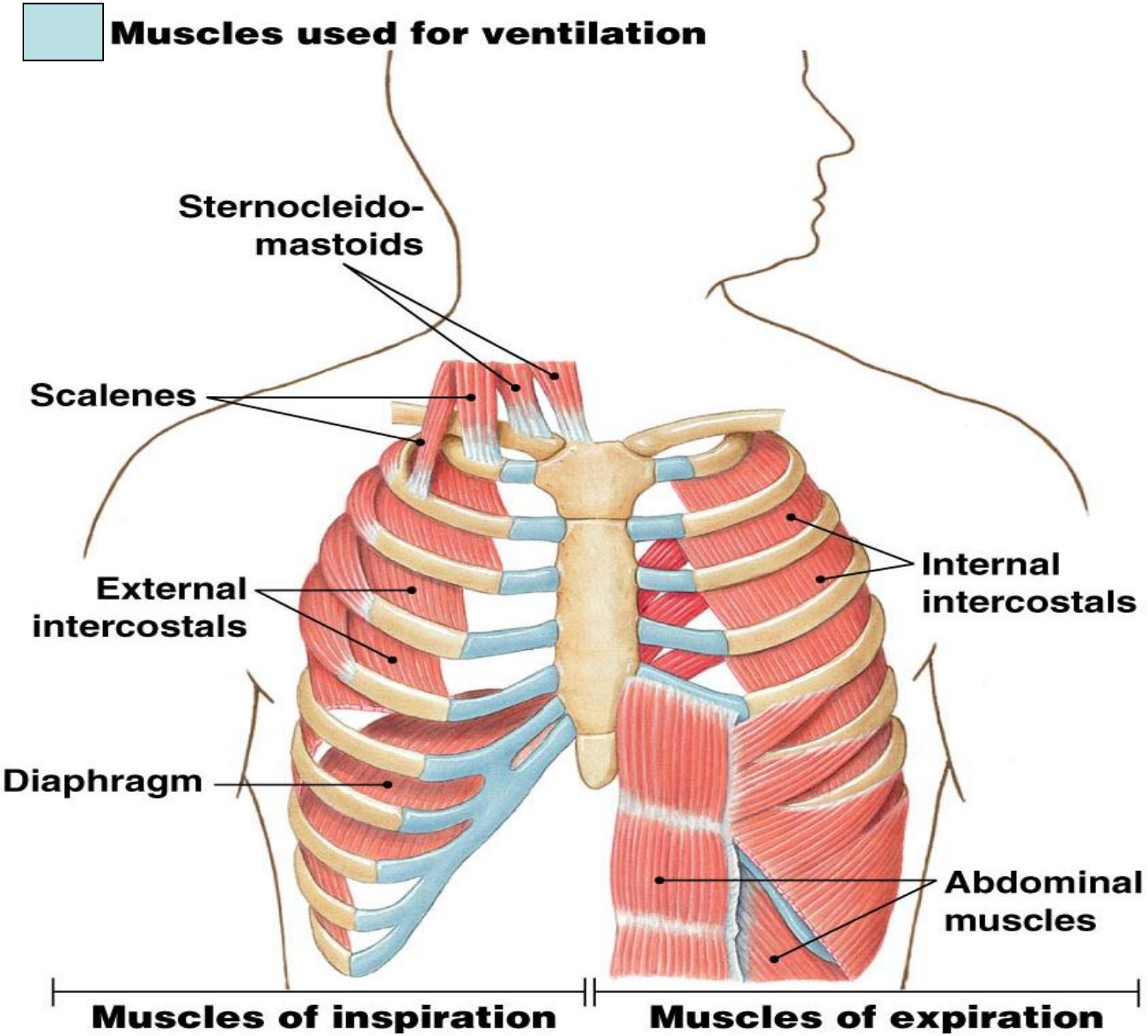
Pressure Changes during Inspiration

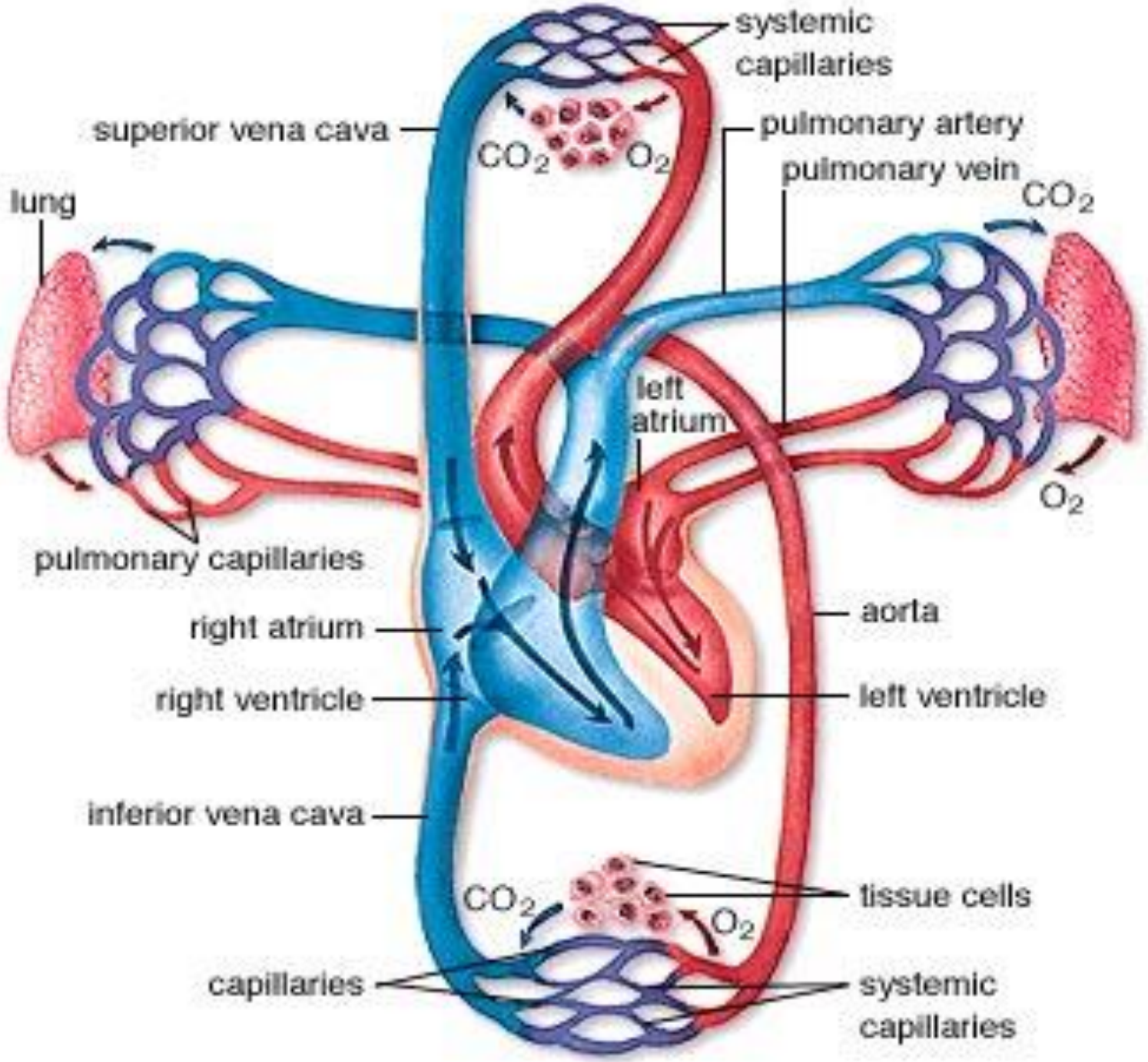
(a) Prior to inspiration, the intrapulmonary pressure is 760 millimeters of mercury (mm Hg). (b) The intrapulmonary pressure decreases to about 757 mm Hg as the thoracic cavity enlarges, and atmospheric pressure forces air into the airways.



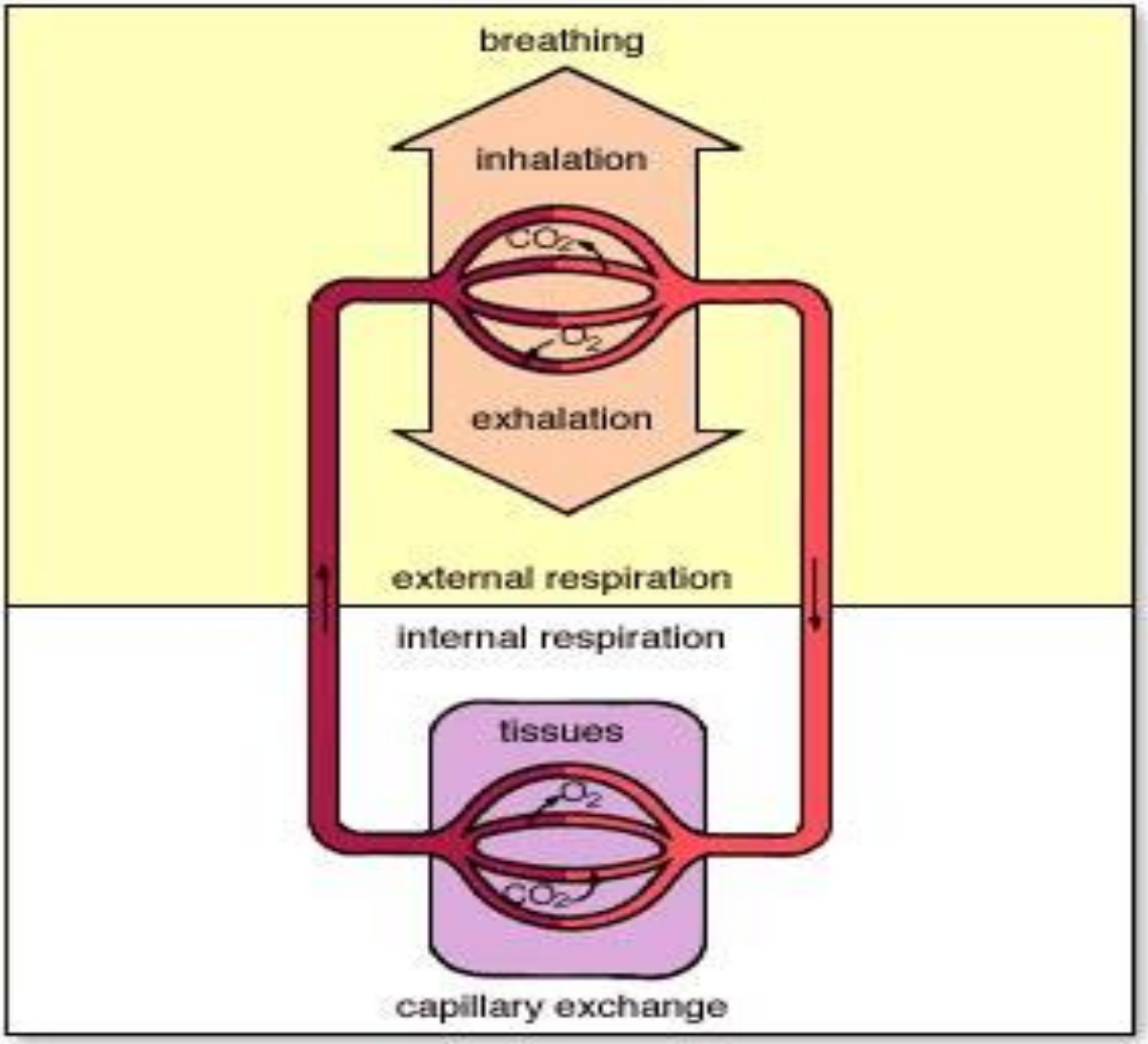
Breathing

During inspiration, the diaphragm and the external intercostal muscles contract. The diaphragm moves downwards increasing the volume of the thoracic (chest) cavity, and the external intercostal muscles pull the ribs up expanding the rib cage and further increasing this volume. In contrast to inspiration, during expiration the diaphragm and intercostal muscles relax. This returns the thoracic cavity to it's original volume, increasing the air pressure in the lungs, and forcing the air out .


Muscles used for ventilation
Sternocleido-
mastoids
Scalenes
External
intercostals
Diaphragm
Internal
intercostals
Abdominal
muscles
Muscles of inspiration
Muscles of expiration


systemic capillaries
superior vena cava
CO_2
O_2
pulmonary artery
pulmonary vein
lung
CO_2
left atrium
O_2
pulmonary capillaries
aorta
right atrium
right ventricle
left ventricle
inferior vena cava
tissue cells
CO_2
O_2
capillaries
systemic capillaries

Gas Exchange Systems



Transport of O_2 and CO_2 in the blood

Oxygen is transported in two forms

1- 98% bind with haemoglobin (Hb) to form oxyhaemoglobin.

2- 2% are physically dissolved in blood plasma.

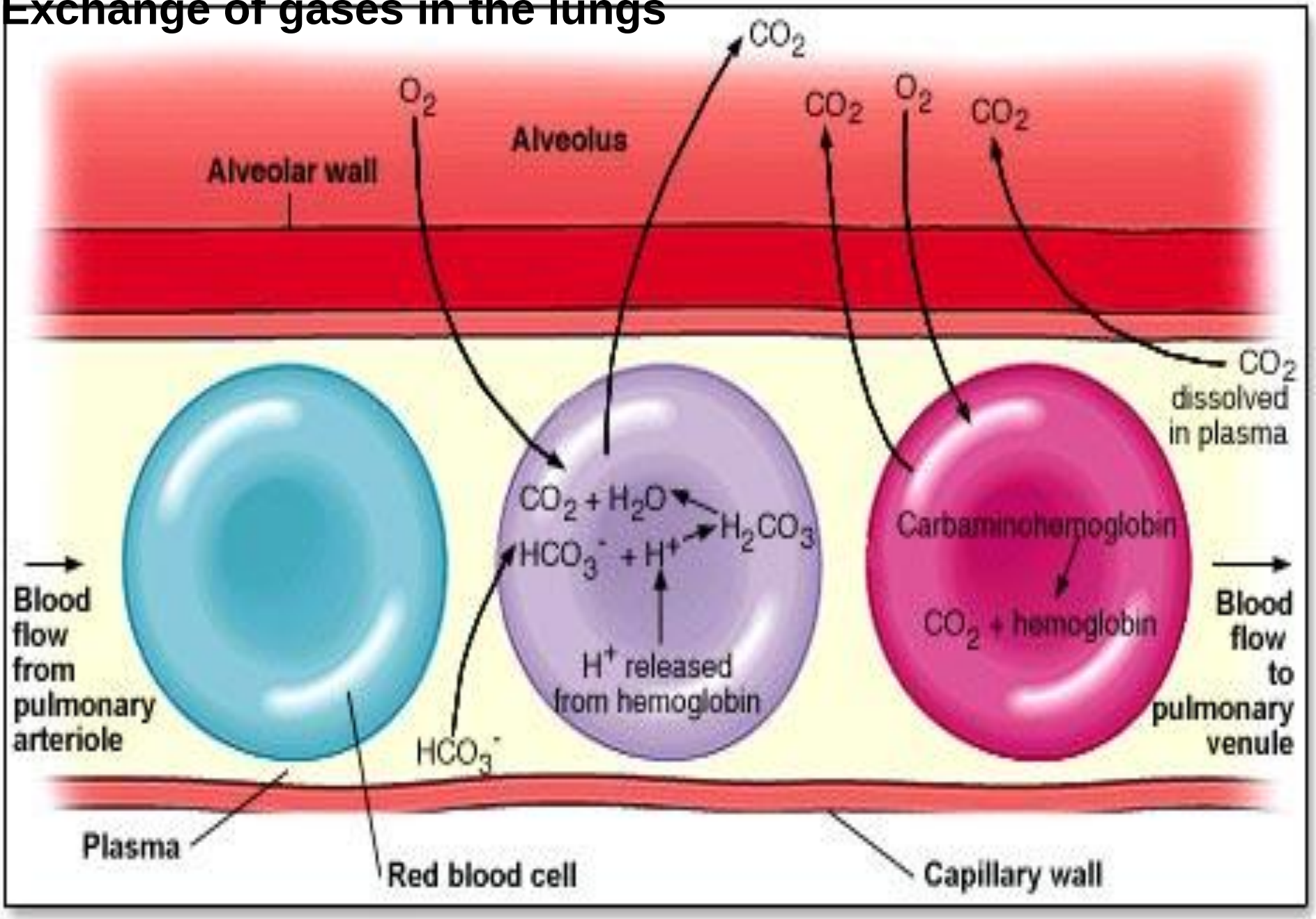
Carbon dioxide is transported in three forms:

1- Less than on third (about 25%) enter RBCs and combine with Hb to form carbaminohaemoglobin (carboxy Hb).

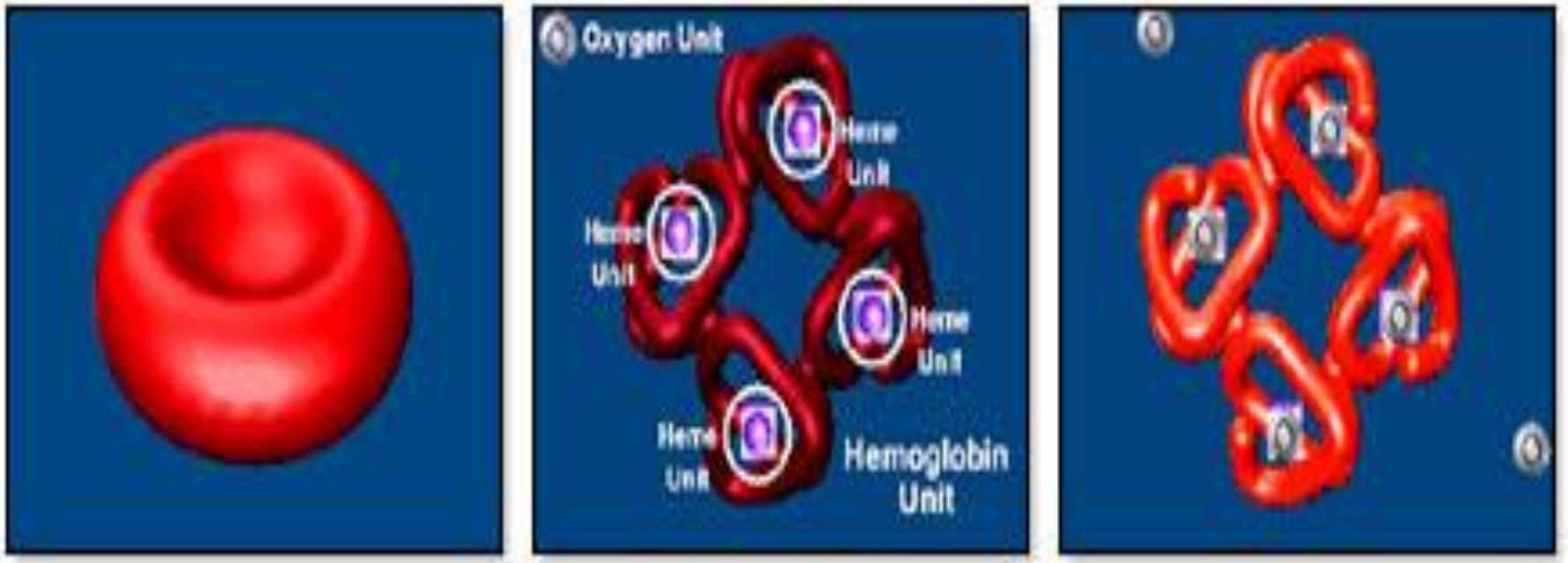
2- About two thirds (about 67%) enter RBCs and form bicarbonate

3- 8% are physically dissolved in the blood plasma.

Exchange of gases in the lungs



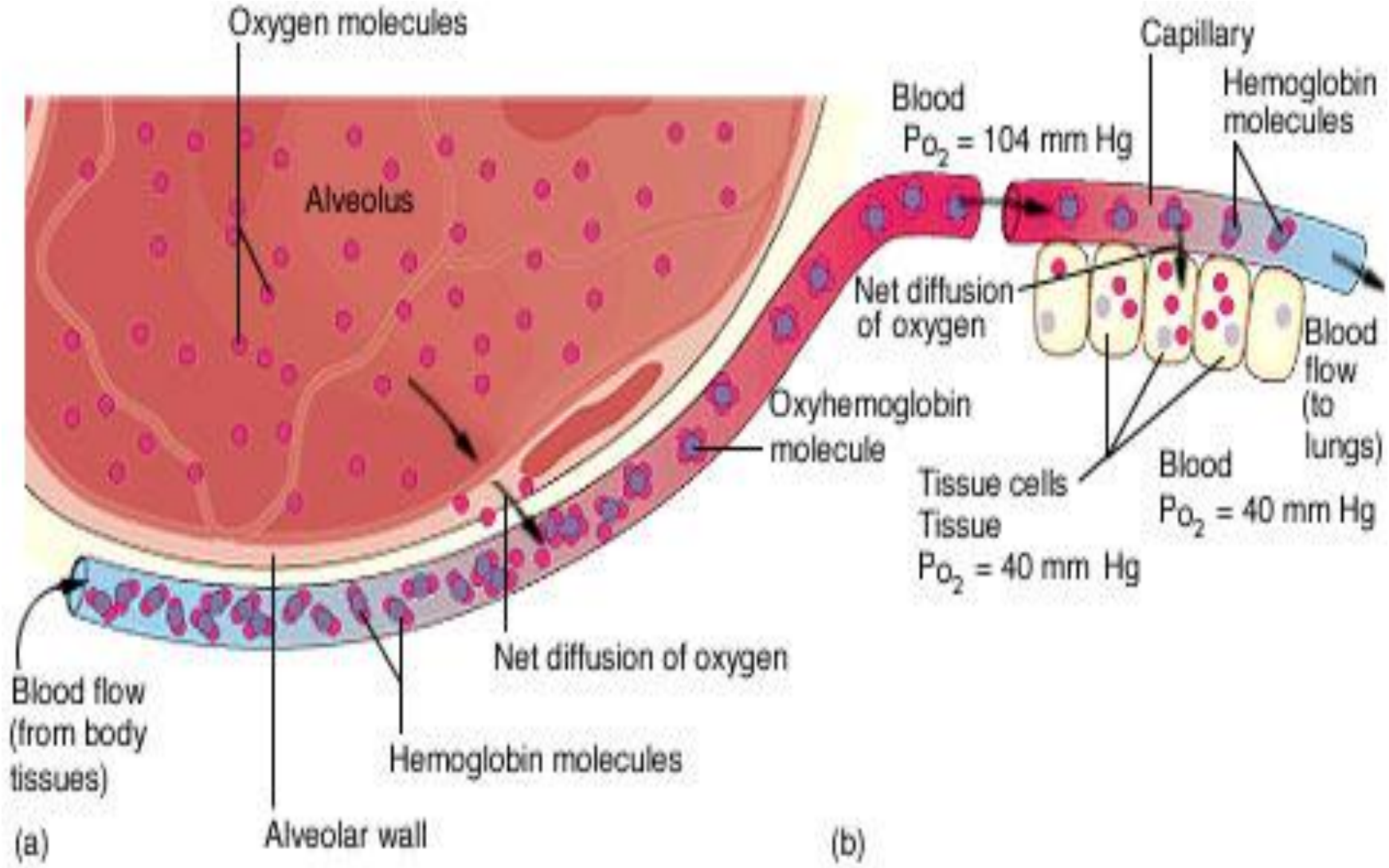
Gas Transport



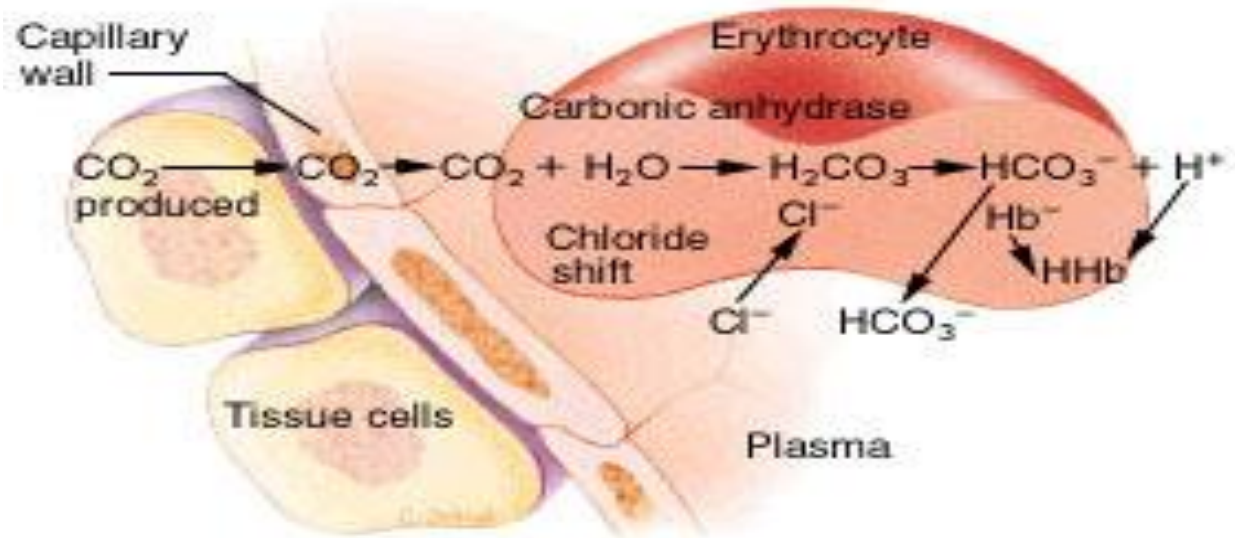
Click on the frames above to view the animation.

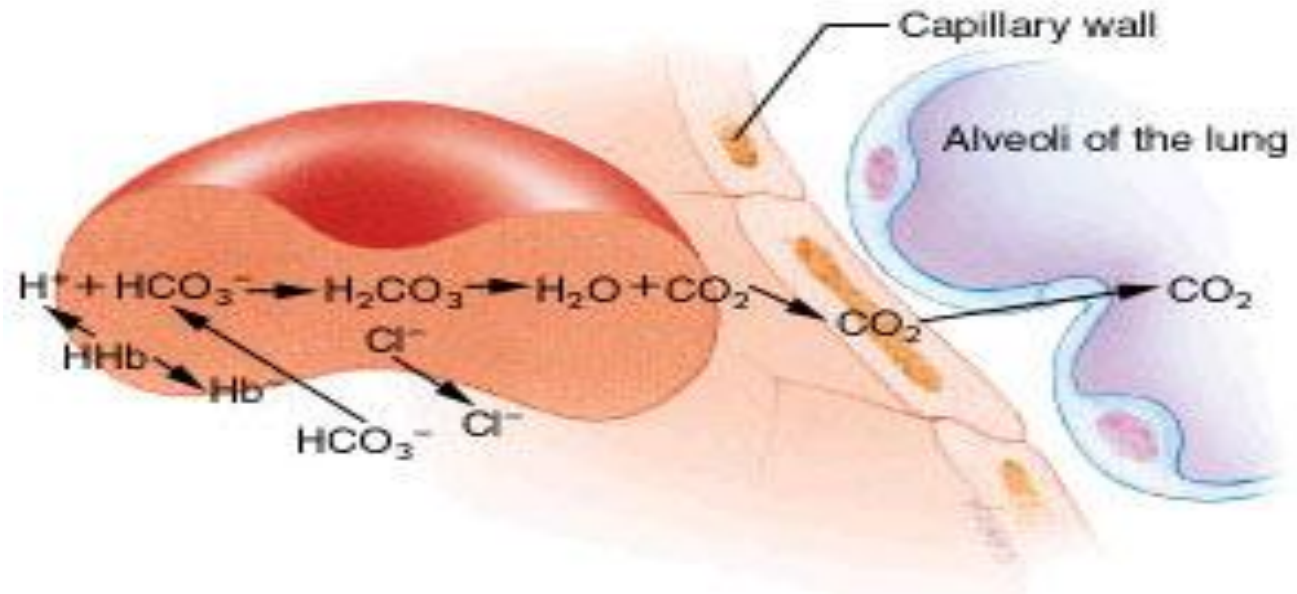
Each red blood cell contains 280 million hemoglobin molecules. Hemoglobin is folded protein with four iron-containing heme groups. Each heme unit binds with one oxygen unit. As a hemoglobin unit becomes oxygenated, its color changes to a brighter red. Collectively, this molecular color change is evident in the bright red color associated with arterial blood.

Gas Transport
Oxygen transport

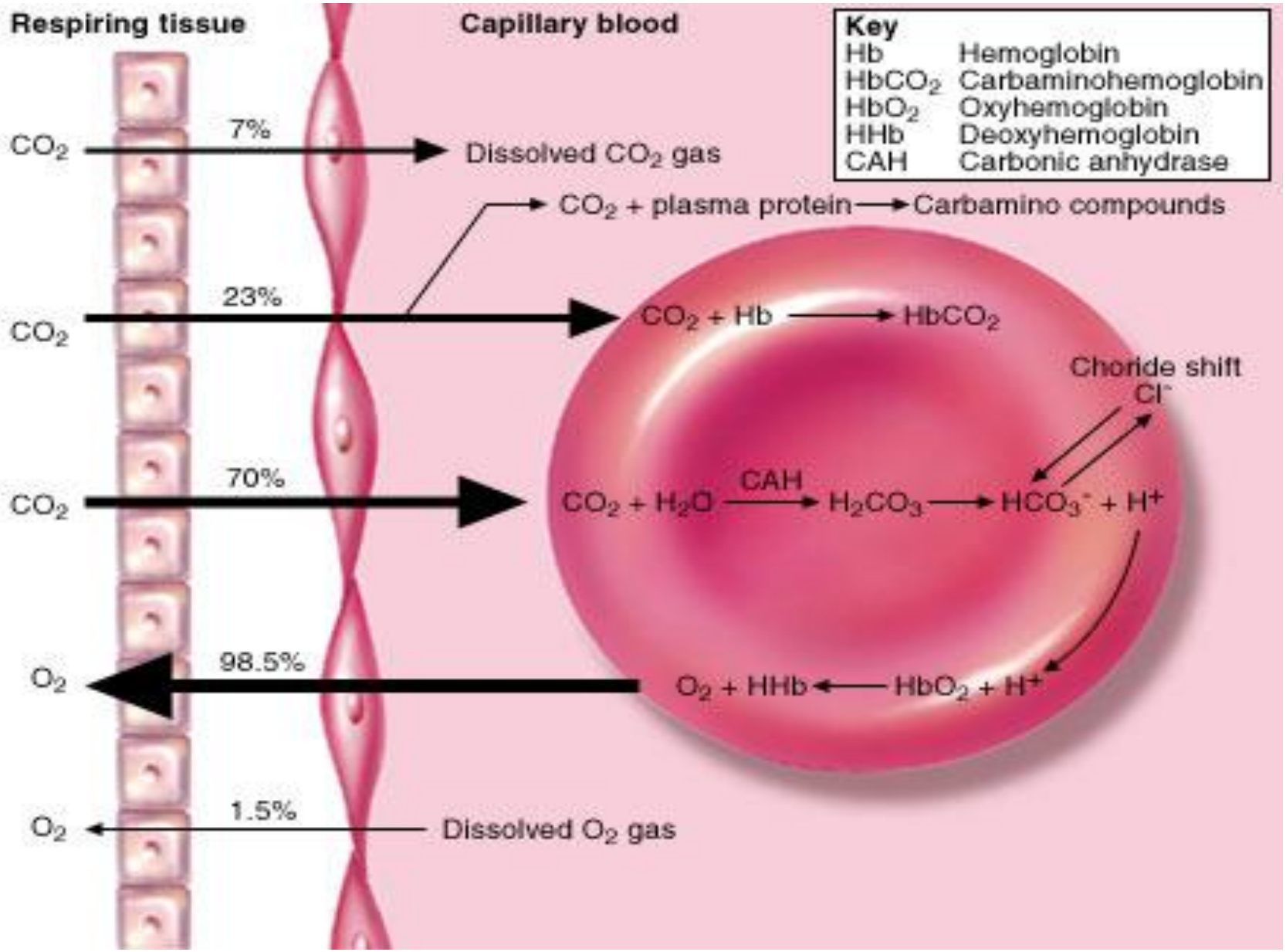


Gas Transport
CO_2 transport

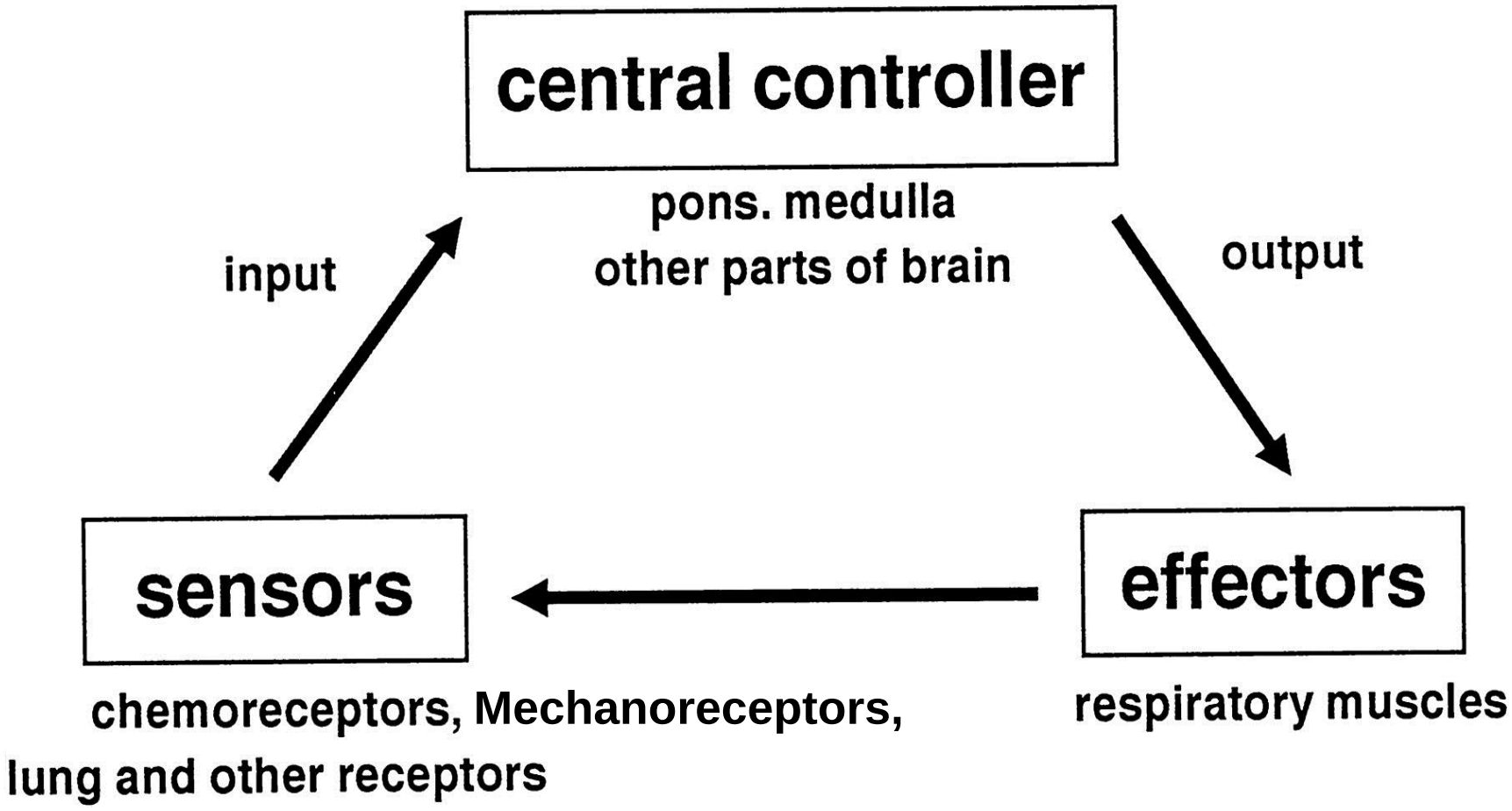


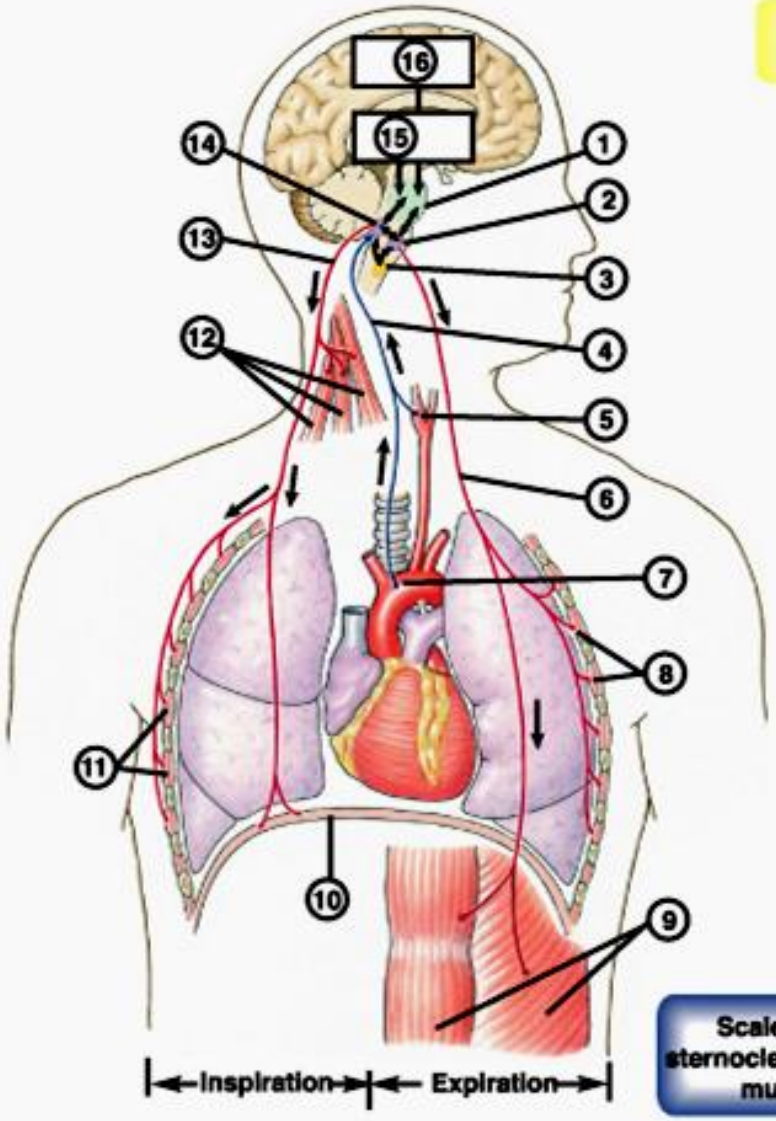


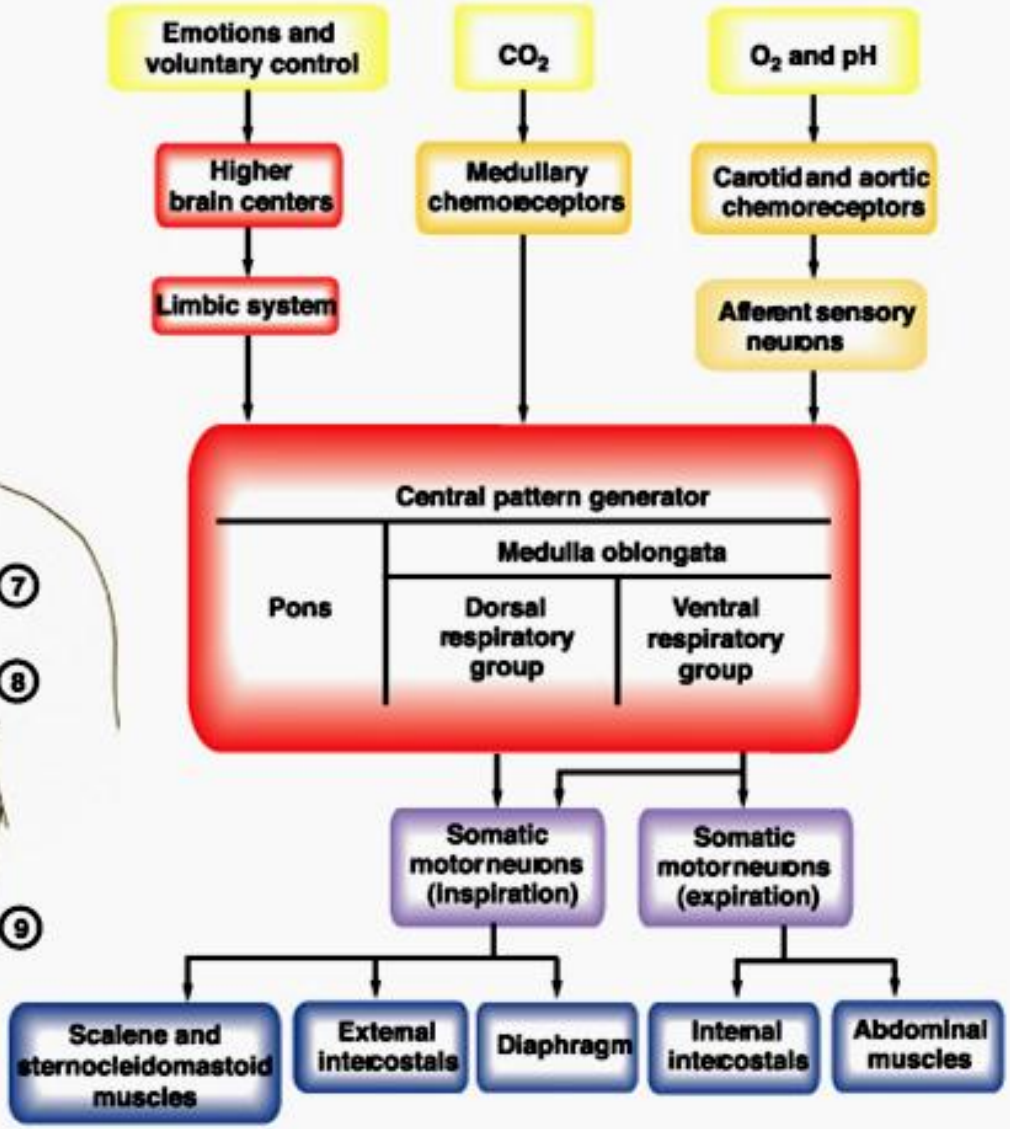
Gas Transport



Respiration





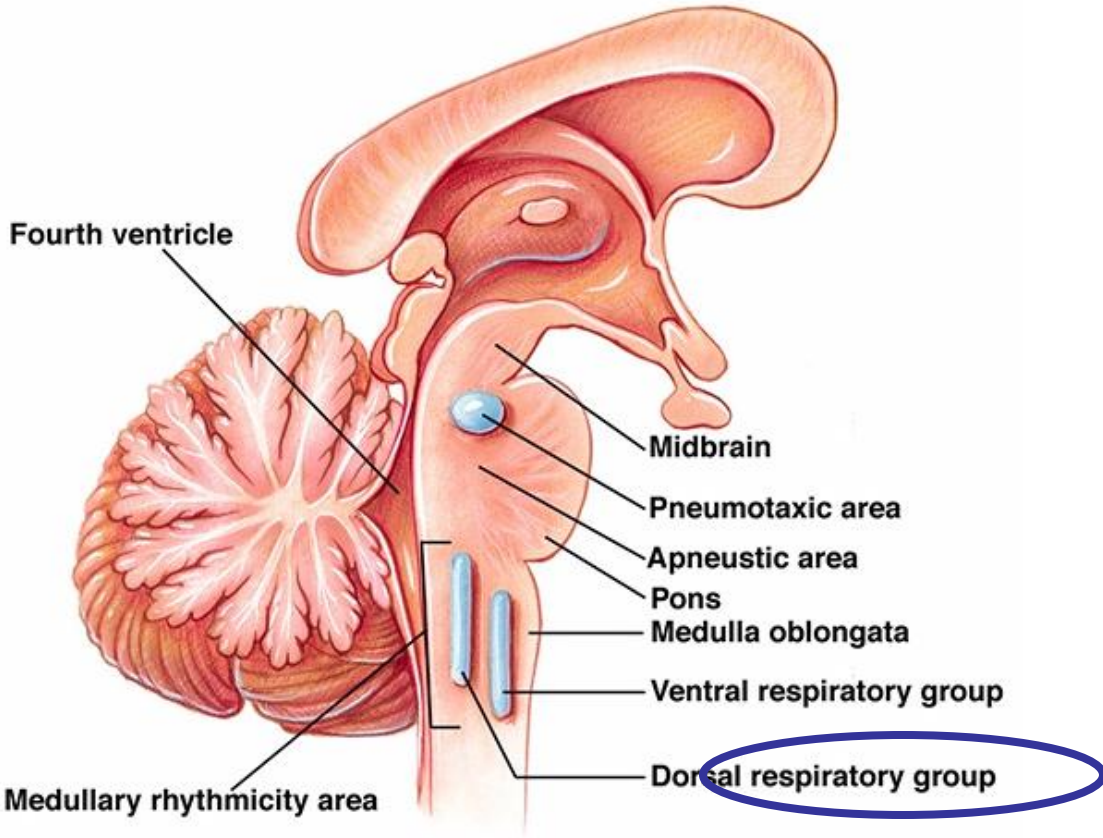


KEY
- Stimuli
- Sensory receptors
- Afferent neurons
- Integrating centers
- Efferent neurons
- Effectors

Figure question: Match the numbers on the figure to the boxes of the map.

Control of Ventilation

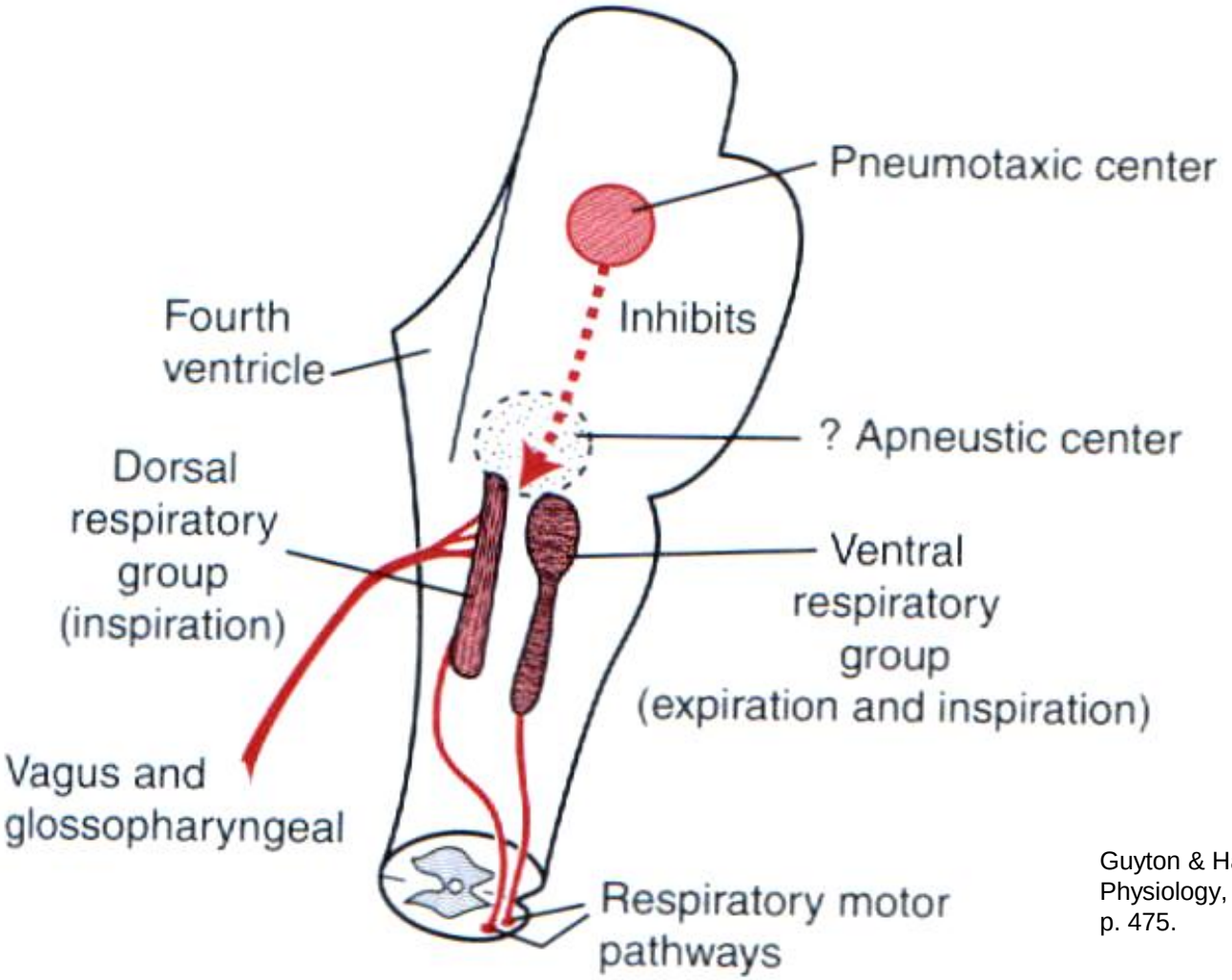
- Respiratory control center
  - Receives neural and humoral input
    - Feedback from muscles
    - CO_2 level in the blood
  - Regulates respiratory rate



Control of Respiration DRG

- The dorsal respiratory group (DRG) is responsible for normal quiet inspiration.
- At usual blood gas levels, DRG generates action potentials spontaneously about 15 times per minute.
- The output from these is mainly to the diaphragm and external intercostal muscles and is responsible for inspiration during quiet breathing.
- The DRG can be considered the main respiratory pacemaker at rest.

Brainstem Respiratory Centers



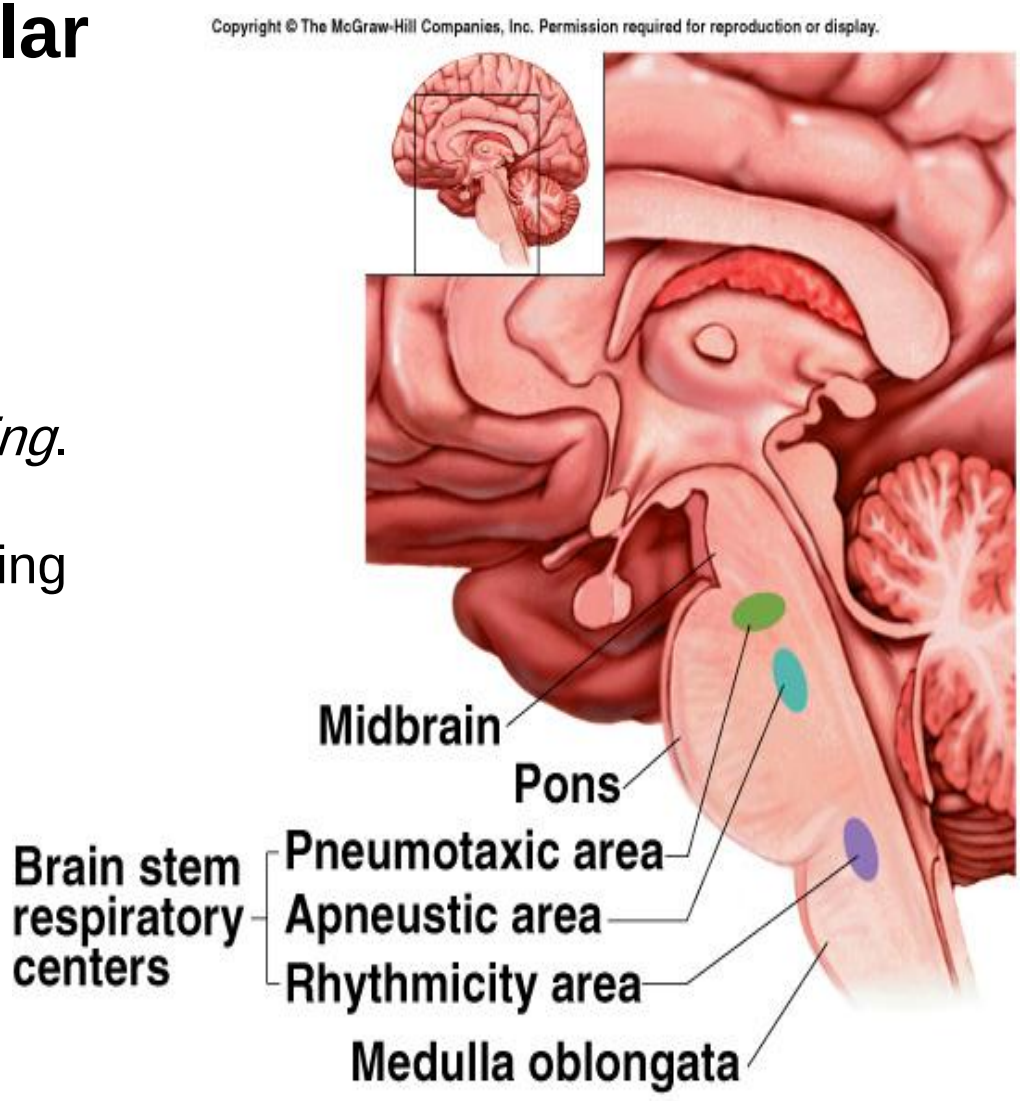
Guyton & Hall, Textbook of Medical Physiology, 10th ed., 2000, Saunders p. 475.

Brainstem Respiratory Centers

- Dorsal Respiratory Group—Quiet inspiration
- Ventral Respiratory Group—Forceful inspiration and active expiration
- Pneumotaxic Center—Influences inspiration to shut off
- Apneustic Center—Prolongs inspiration

Brain Stem Respiratory Centers

- Neurons in the **reticular formation of the medulla oblongata** form the ***rhythmicity center***.
  - *Controls automatic breathing*.
  - Consists of interacting neurons that fire either during inspiration (I neurons) or expiration (E neurons).



Rhythmicity Center

- **I neurons located primarily in dorsal respiratory group (DRG):**
  - *Regulate activity of phrenic nerve*.
  - Regulate the activity of external intercostal nerve
    - Project to and stimulate spinal interneurons that innervate respiratory muscles.
- **E neurons located in ventral respiratory group (VRG):**
  - *Passive process*.
    - Controls motor neurons to the internal intercostal muscles.
- ***Activity of E neurons inhibit I neurons***.
  - *Rhythmicity of I and E neurons may be due to pacemaker neurons*.

Brain Stem Respiratory Centers

(continued)

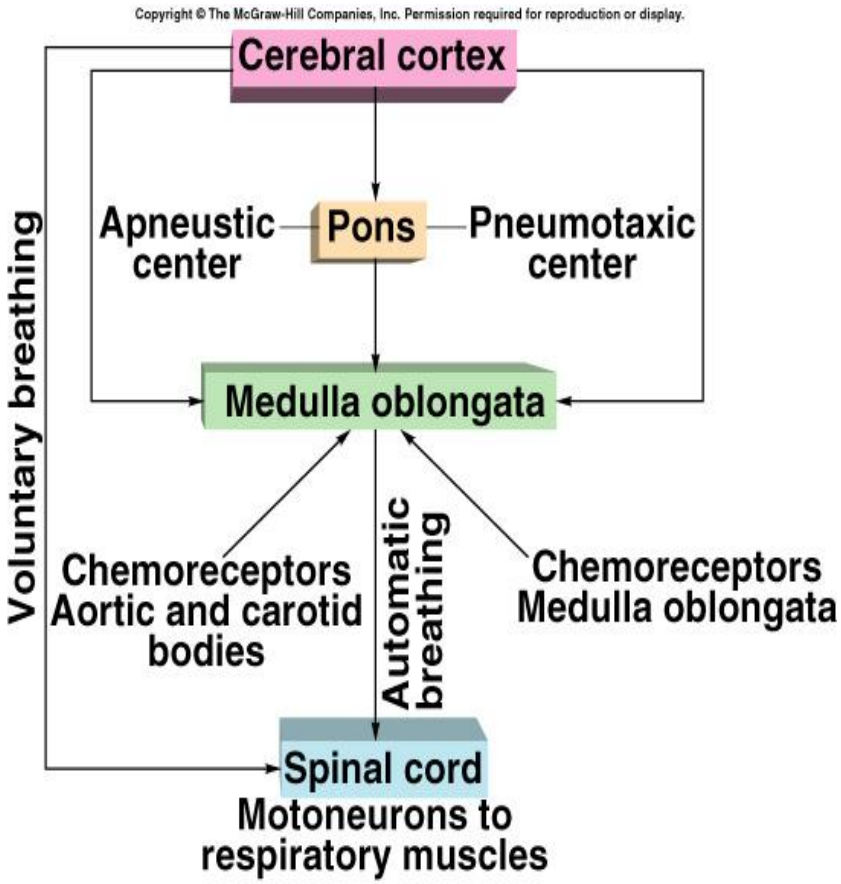
- ***I neurons*** project to, and stimulate spinal motor neurons that innervate respiratory muscles.

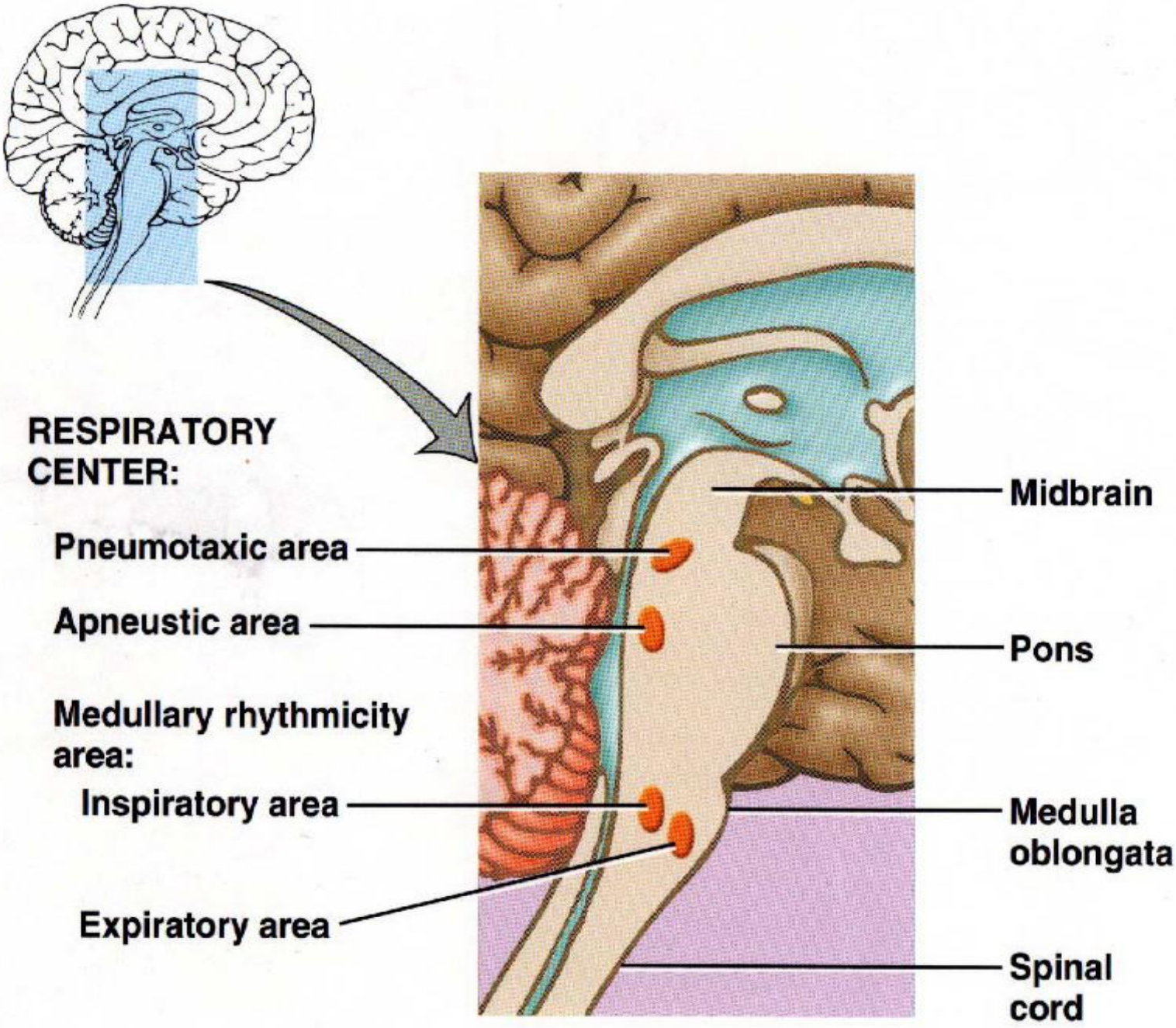
- Expiration is a passive process that occurs when the I neurons are inhibited.

- **Activity varies in a reciprocal way.**

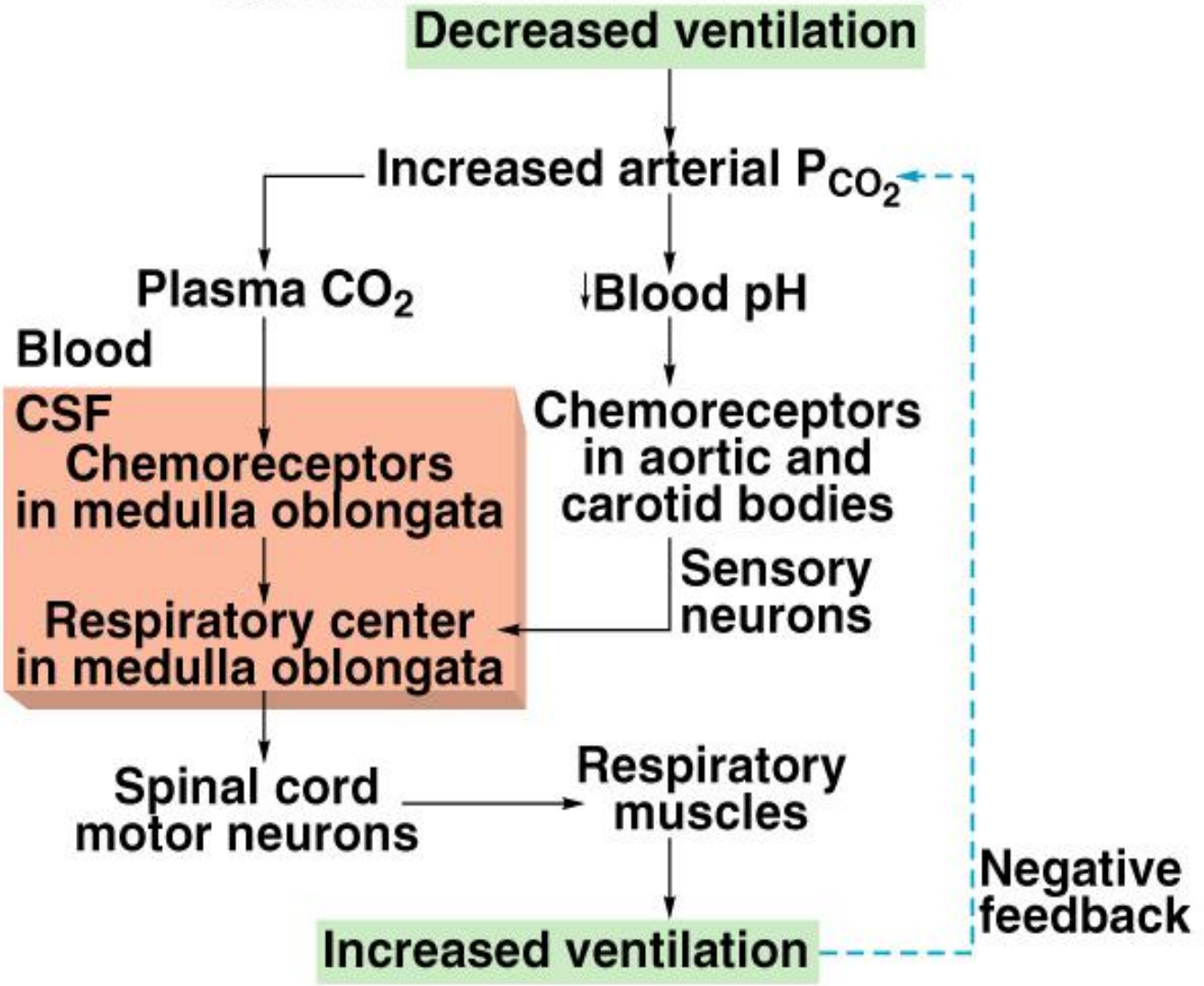
Pons Respiratory Centers

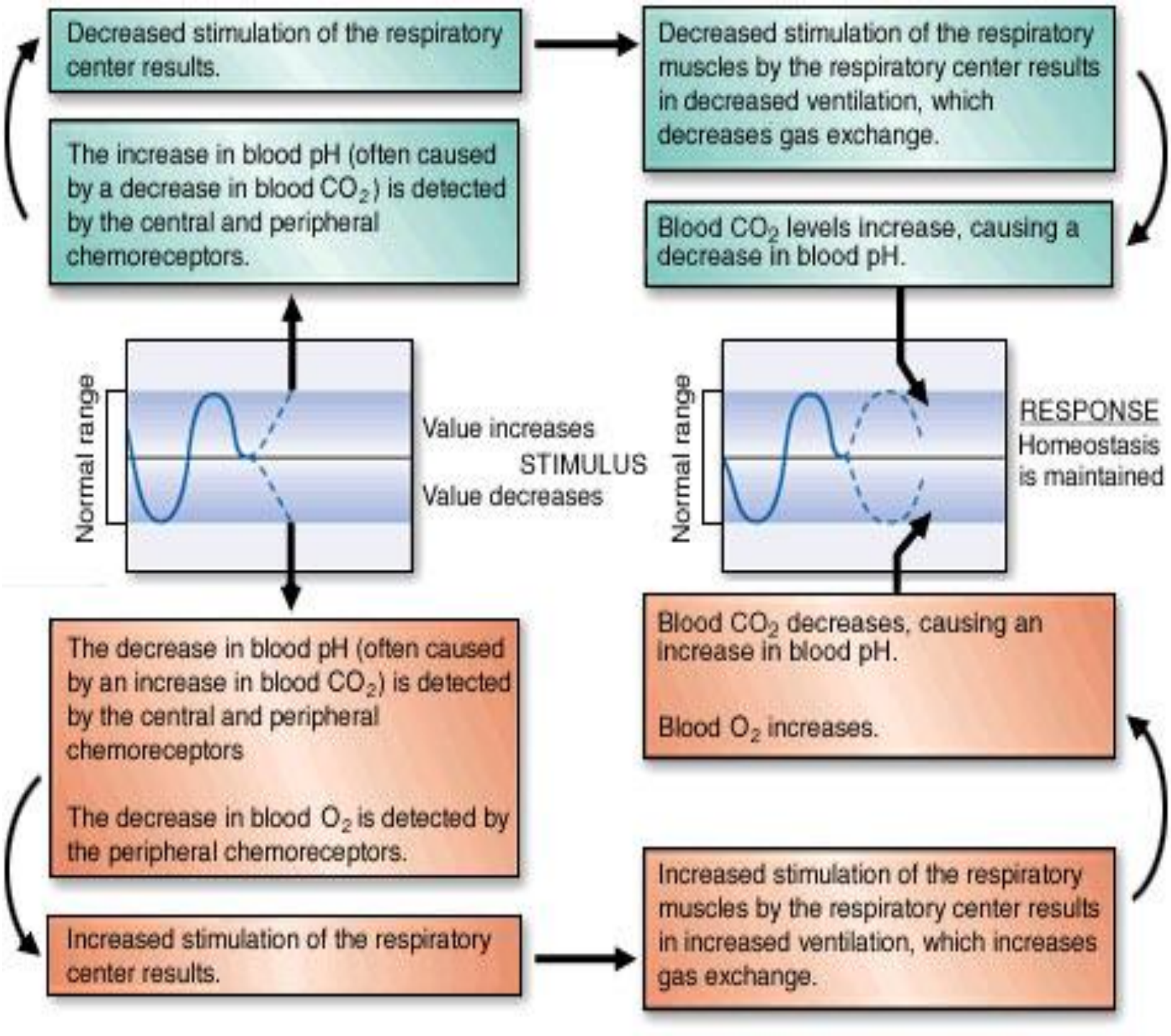
- **Activities of medullary rhythmicity center is influenced by pons.**
- ***Apneustic center*.**
  - *Promotes inspiration by stimulating the I neurons in the medulla.*
- ***Pneumotaxic center*.**
  - *Antagonizes the apneustic center.*
  - *Inhibits inspiration.*




RESPIRATORY CENTER:
Pneumotaxic area
Apneustic area
Medullary rhythmicity area:
Inspiratory area
Expiratory area
Midbrain
Pons
Medulla oblongata
Spinal cord

Chemoreceptor Control of Breathing

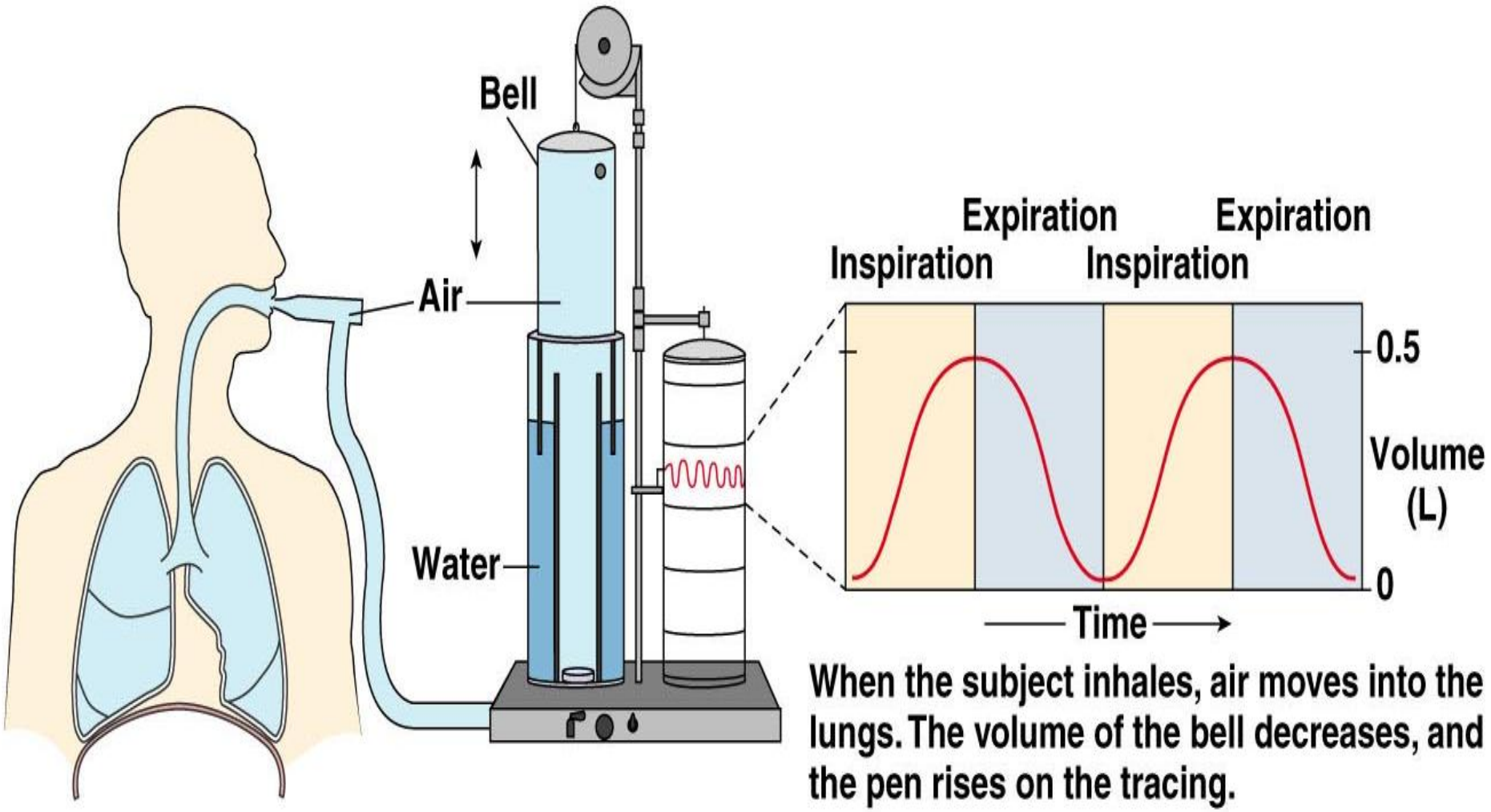



Decreased stimulation of the respiratory center results.
Decreased stimulation of the respiratory muscles by the respiratory center results in decreased ventilation, which decreases gas exchange.
The increase in blood pH (often caused by a decrease in blood CO_2) is detected by the central and peripheral chemoreceptors.
Blood CO_2 levels increase, causing a decrease in blood pH.
Normal range
Value increases
STIMULUS
Value decreases
Normal range
RESPONSE
Homeostasis is maintained
The decrease in blood pH (often caused by an increase in blood CO_2) is detected by the central and peripheral chemoreceptors
The decrease in blood O_2 is detected by the peripheral chemoreceptors.
Blood CO_2 decreases, causing an increase in blood pH.
Blood O_2 increases.
Increased stimulation of the respiratory center results.
Increased stimulation of the respiratory muscles by the respiratory center results in increased ventilation, which increases gas exchange.

Respiratory volumes and capacities

The measurement of air that comes in and out of the lungs is known as spirometry and the apparatus used is known as spirometer

- **Tidal air volume (V_T)** (the volume of air that enters the lungs during normal inspiration or leaves the lungs during expiration)= 500 ml
- **Complemental air volume (CV) (inspiratory reserve volume; IRV)** (excess volume of air inhaled above tidal air volume during forceful respiration) or in other words, it is the additional amount of air entering the lungs during forced inspiration = 3000 ml
- **Supplemental air volume (SV) (expiratory reserve volume; ERV)** (excess volume of air exhaled above tidal air volume during forceful respiration) = 1000 -1200 ml.
- **Residual air volume (RV)** (the amount of air that remains in lungs after deep expiration) = 1200 ml
- **Functional residual capacity (FRC)** (the amount of air that remains in lungs after resting expiration)
- Total lung capacity (TLC) = V_T + IRV + ERV +RV
- Vital capacity = V_T + IRV + ERV
- Inspiratory capacity (IRC) = V_T + IRV
- Expiratory capacity (ERC) = V_T + ERV



When the subject inhales, air moves into the lungs. The volume of the bell decreases, and the pen rises on the tracing.

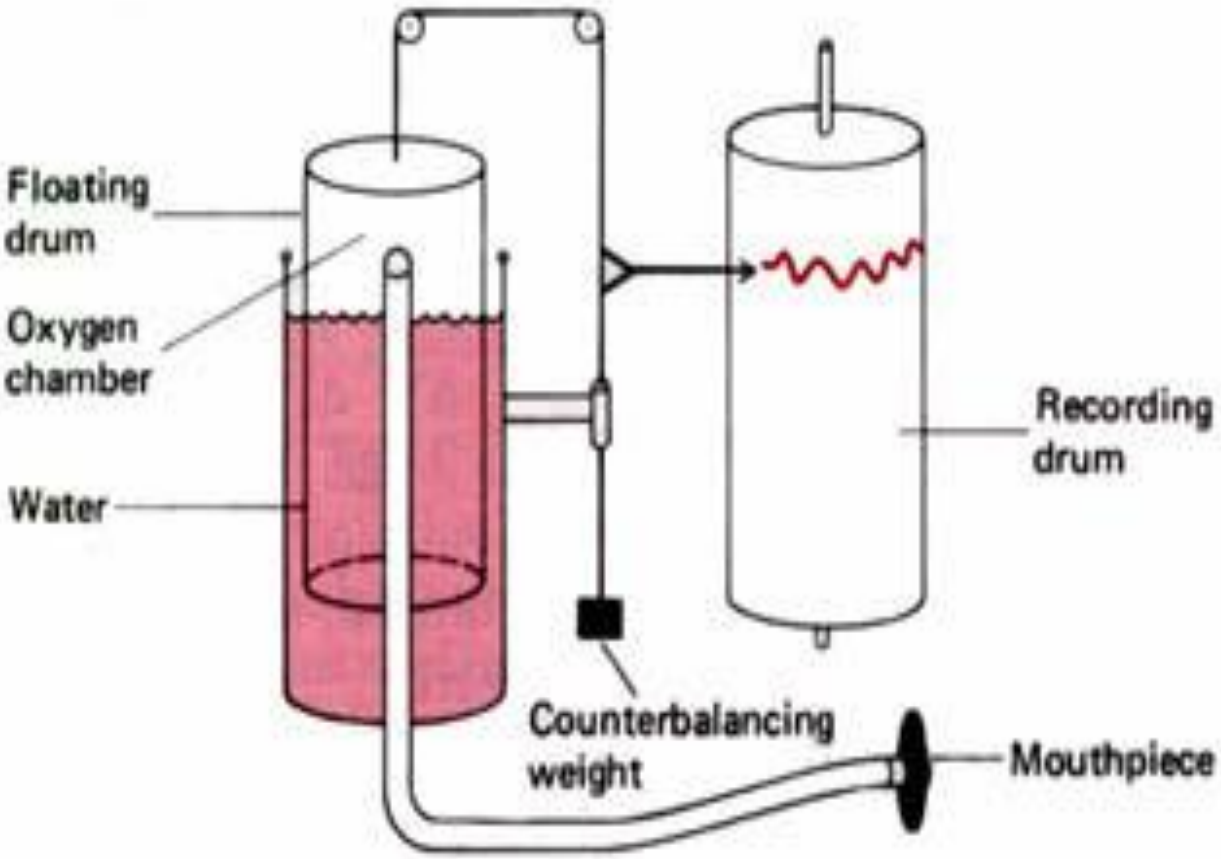
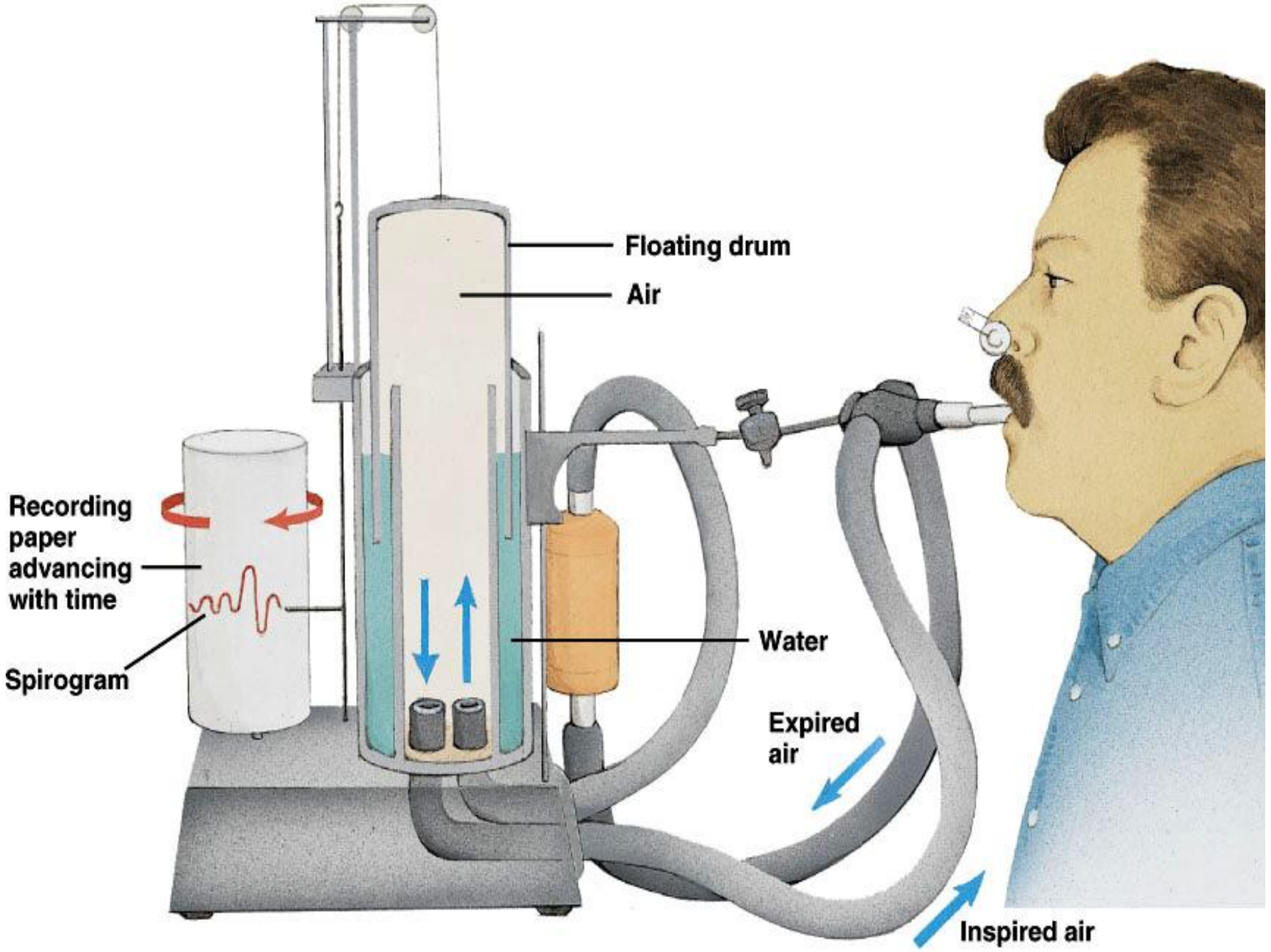
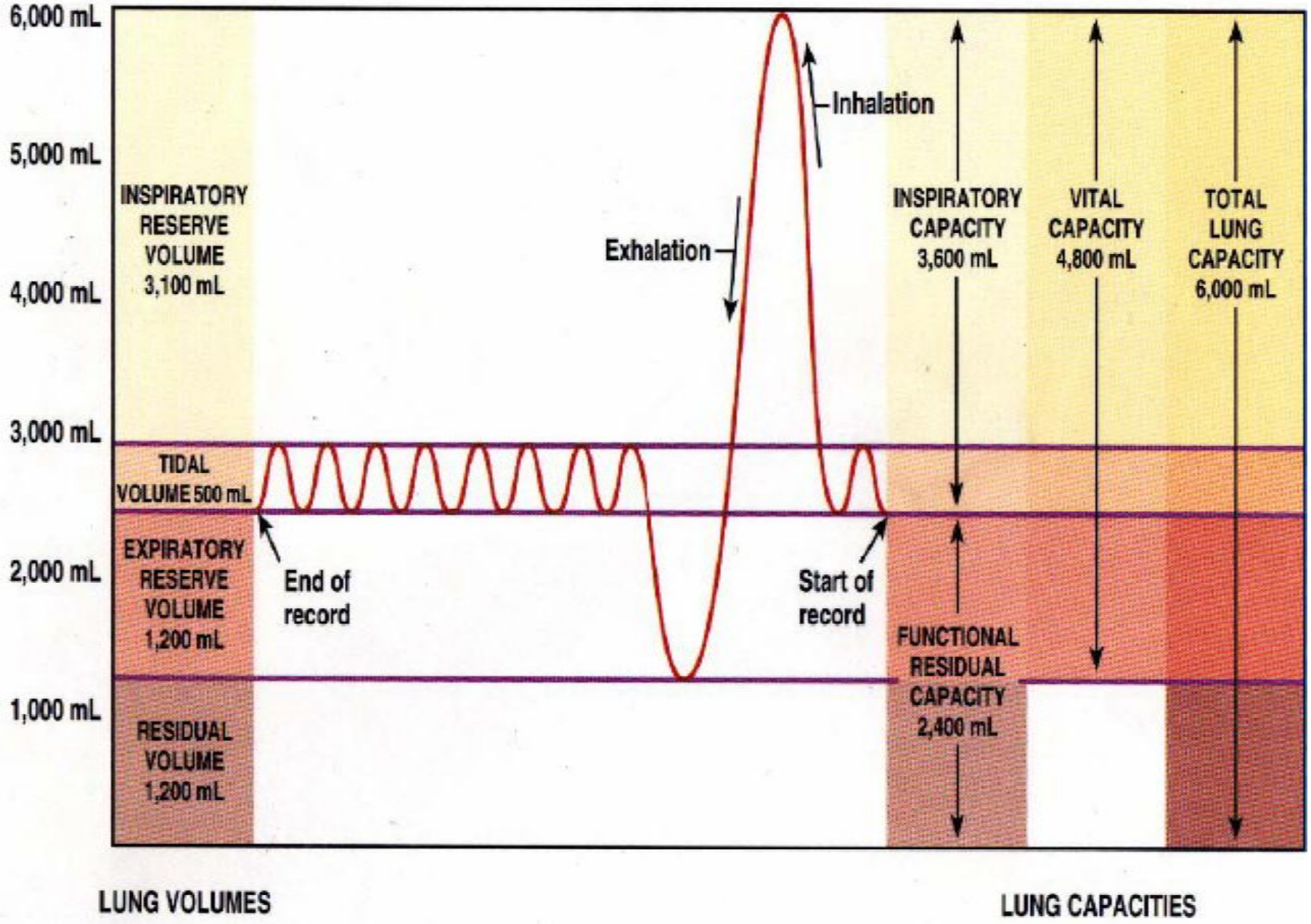
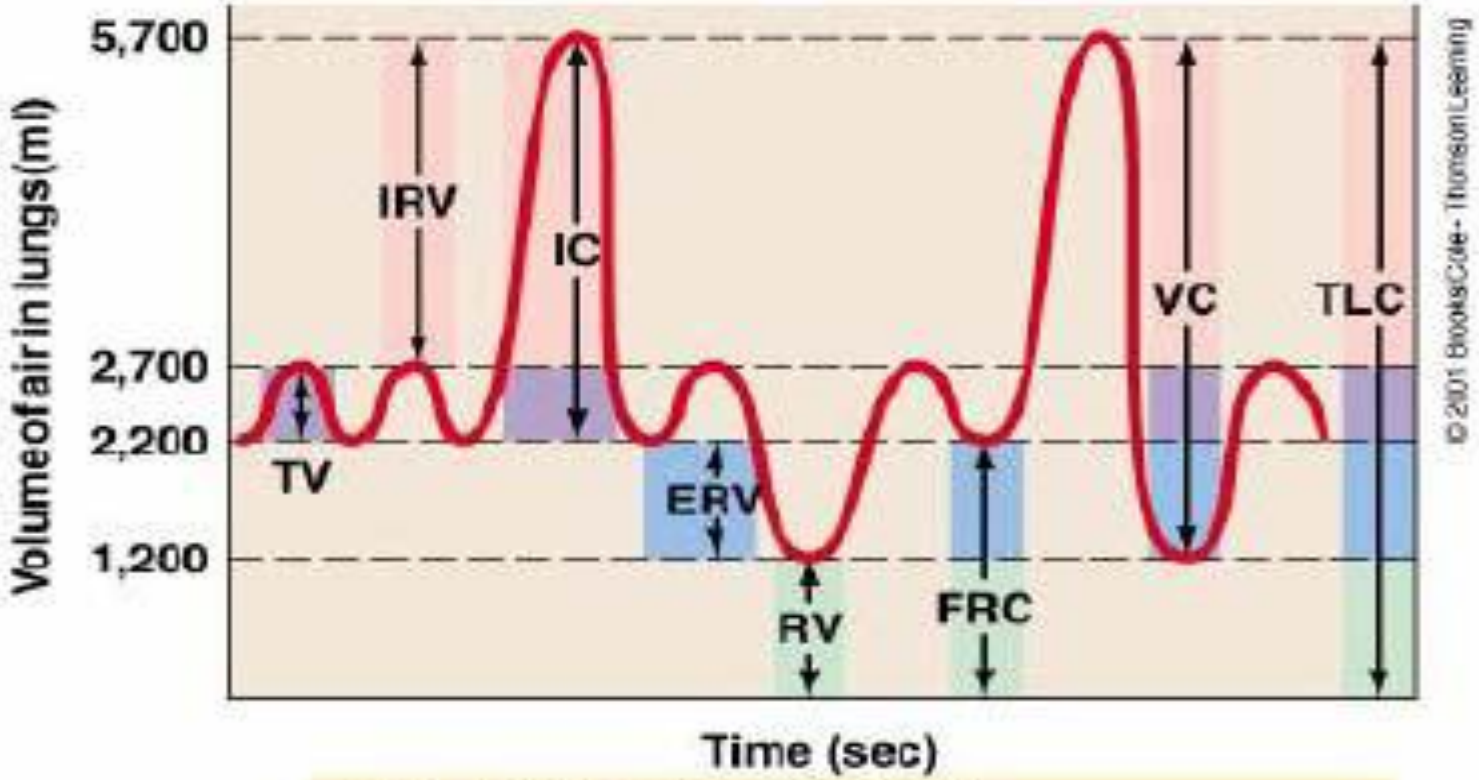


Figure A spirometer.


Floating drum
Air
Recording paper advancing with time
Spirogram
Water
Expired air
Inspired air

Respiratory volumes and capacities





TV = Tidal volume (500 ml)
IRV = Inspiratory reserve volume (3,000 ml)
IC = Inspiratory capacity (3,500 ml)
ERV = Expiratory reserve volume (1,000 ml)
RV = Residual volume (1,200 ml)
FRC = Functional residual capacity (2,200 ml)
VC = Vital capacity (4,500 ml)
TLC = Total lung capacity (5,700 ml)

Values are for a young healthy male, values for females are somewhat lower