Respiratory Physiology



Respiratory physiology

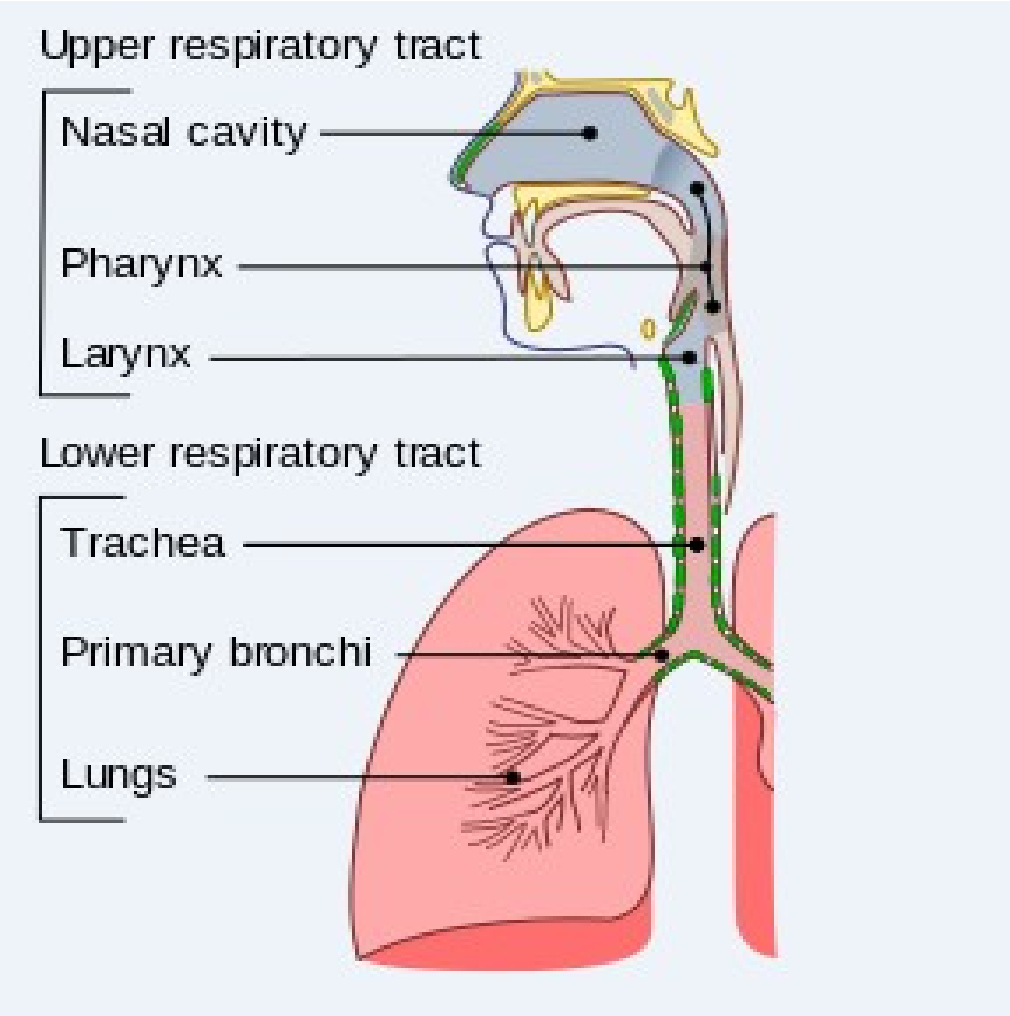
Basic functions of the respiratory system:

- **Gas exchange –supply oxygen to aerobic tissues in the body and remove carbon dioxide as a waste product.**
- **Regulation of acid-base balance**
- **Conversion of ang-I to ang-II by the action of ACE**
- **Involved in defence**

The Respiratory Tract

- Series of tubes that function as **airway passages.**
- **Upper respiratory tract:**
  - **Nose, pharynx, larynx** and associated structures.
  - Function:
    - To **filter, warm** and **humidify** incoming air.
- **Lower respiratory tract:**
  - **Trachea, bronchi, lungs**.

The Respiratory Tract



Nasal Cavity

Nasal airway

-moistens air

-warms air

-filters inspired air

Pharynx

- Funnel-shaped tube of skeletal muscle
- Common passageway for:

✓Food

✓Fluid

✓Air

- Located between:
  - ✓Nasal cavity and mouth superiorly
  - ✓Larynx and esophagus inferiorly

Larynx (Voice Box)

- Attaches to the hyoid bone and opens into the laryngopharynx superiorly
- It connects the pharynx to trachea and serves as **first portion of air passage**;
- Continuous with the trachea inferiorly
- The **three** functions of the larynx are:
  - ✓To provide a patent airway
  - ✓To act as a switching mechanism to route air and food into the proper channels
  - ✓Responsible for voice production

Trachea (Windpipe):

- **Rings of cartilage** maintain **shape of trachea**, to **prevent it from closing.**
- **Forks into two bronchi.**

Bronchi

- Result of tracheal bifurcation
- Air reaching the bronchi is:
  - ✓Warmed and cleansed of impurities
  - ✓Saturated with water vapor
- Bronchi subdivide into **secondary bronchi**, each supplying a **lobe of the lungs**
- Air passages undergo 23 orders of branching in the lungs

Bronchioles:

- **Fine tubes that allow passage of air**
- **Smooth muscle layer constricts bronchioles**
- **Epithelium of bronchioles** is covered with **cilia** and **mucus**.
  - Mucus traps dust and other particles.
  - **Ciliary Escalator**: **Cilia beat upwards** and **remove trapped particles from lower respiratory airways.**

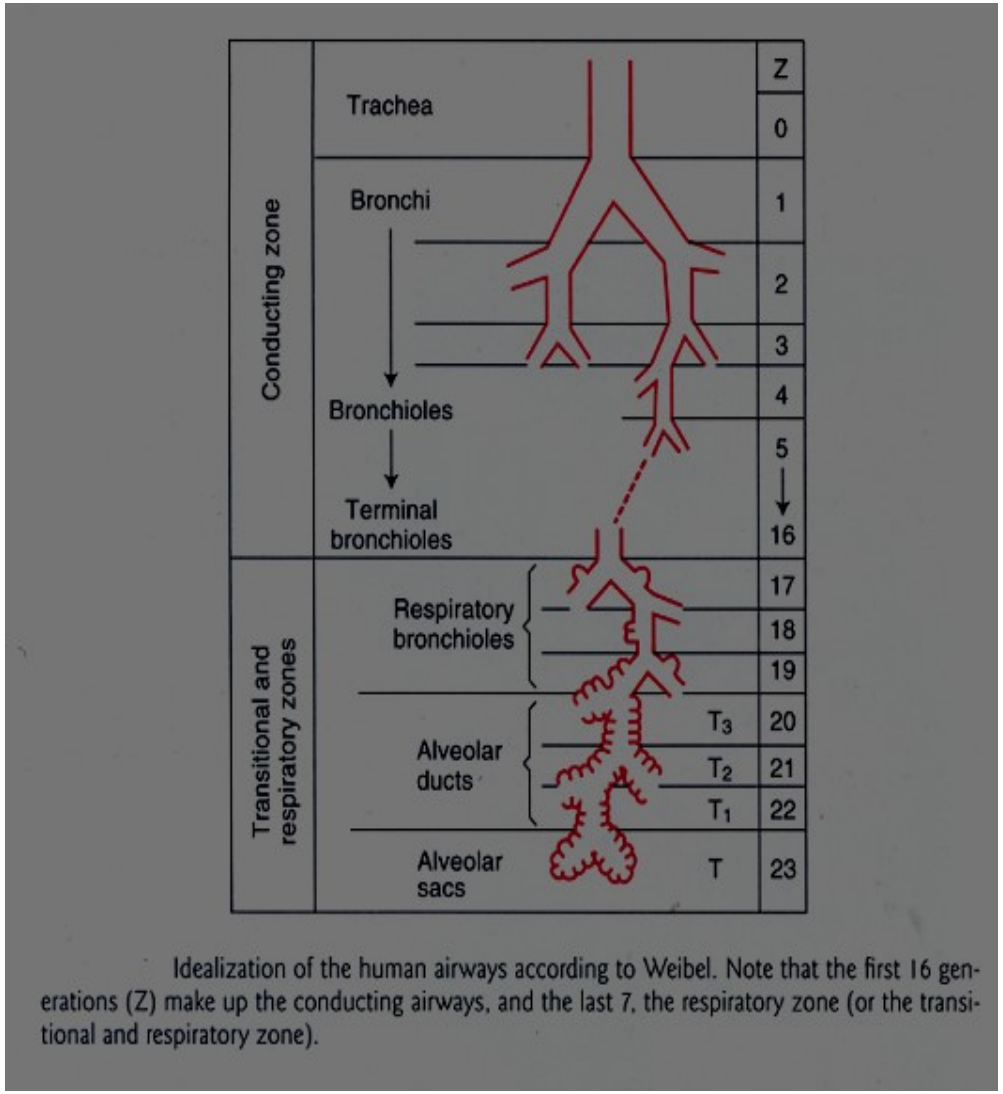
The Respiratory Organs

- **Conducting zone:**
  - **Respiratory passages** that carry air to the site of gas exchange
  - **Filters, humidifies** and **warms air**

    -nasal cavity
    -pharynx
    -larynx
    -trachea
    -bronchi

Respiratory Zone

- Site of gas exchange
- Composed of
  - Respiratory bronchioles
  - Alveolar ducts
  - Alveolar sacs



Idealization of the human airways according to Weibel. Note that the first 16 generations (Z) make up the conducting airways, and the last 7, the respiratory zone (or the transitional and respiratory zone).

Alveoli

- Alveoli are small out-pouching or tiny air sacs that are final branching of the respiratory tree.
- The lungs contain about **300 million alveoli** whose surface area is **>70m^2.**
- **They serve as primary sites of exchange of O_2 and CO_2.**

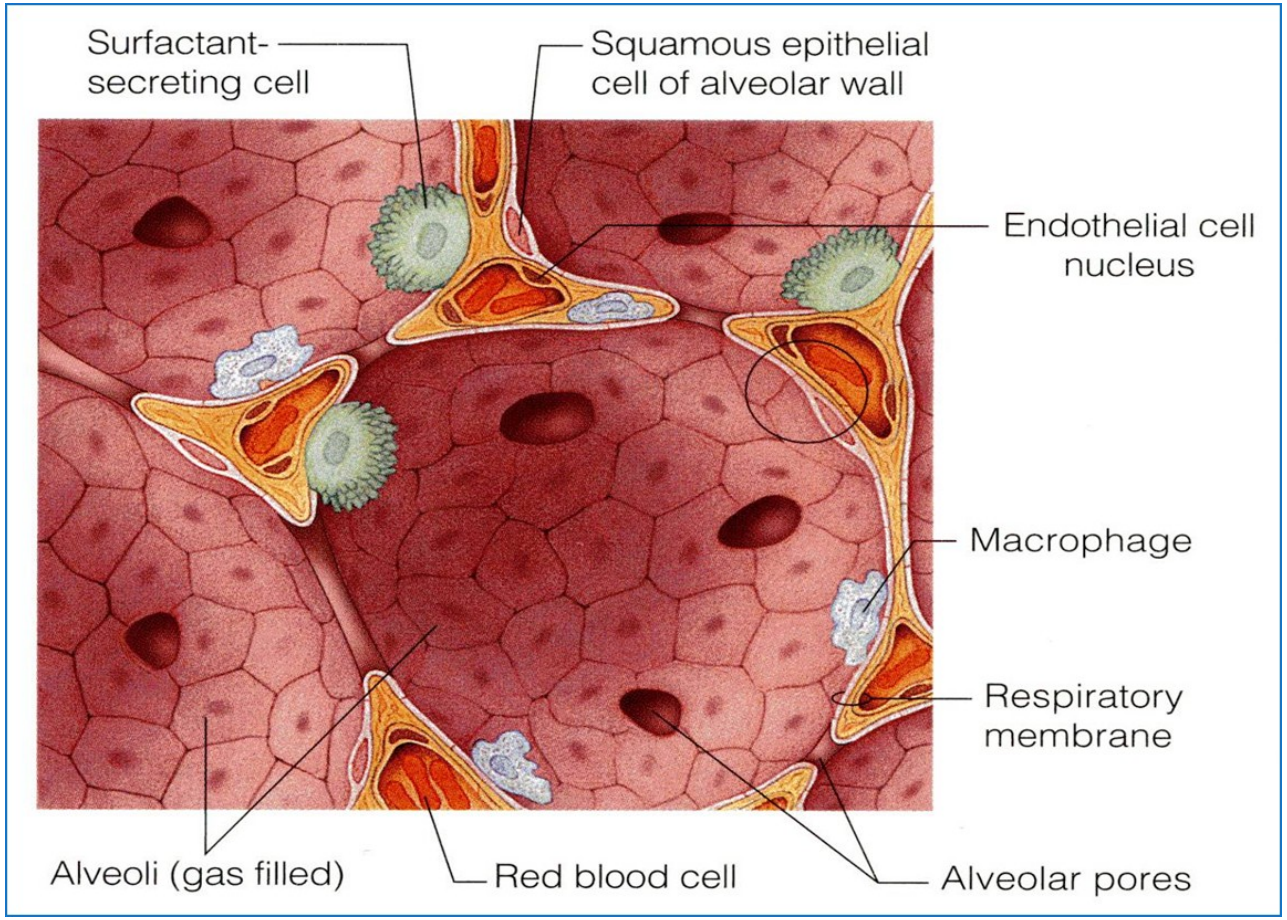
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- Alveoli have walls made up of:
  - **Type I pneumocytes** are major lining cells with simple thin squamous epithelium.
    - **Gas exchange** takes place here.
  - **Type II pneumocytes** are less in number and constitute thick granulocytes that are responsible for the production of **surfactants**.
  - **Type III pneumocytes** are large **phagocytic macrophage cells** found in alveolar cavities.
    - These cells keep alveolar surfaces sterile by **removing debris** and **microbes.**

Surfactant

- **Phospholipid** produced by alveolar **type II cells**.
- **Lowers surface tension**, which reduces the tendency of alveoli to collapse.
  - Reduces attractive forces of hydrogen bonding

Scattered among the squamous epithelial cells are *rounded secretory epithelial cells* — **type II alveolar cells** or pneumocytes — *which secrete pulmonary surfactant,* a complex mixture of phospholipids.



Lungs

- There are two lungs
- **Left lung** – separated into upper and lower lobes
- **Right lung** – separated **into three lobes**

✓Superior

✓Middle

✓Inferior

Lungs and Pleural Coverings

- **Pleural Coverings:**

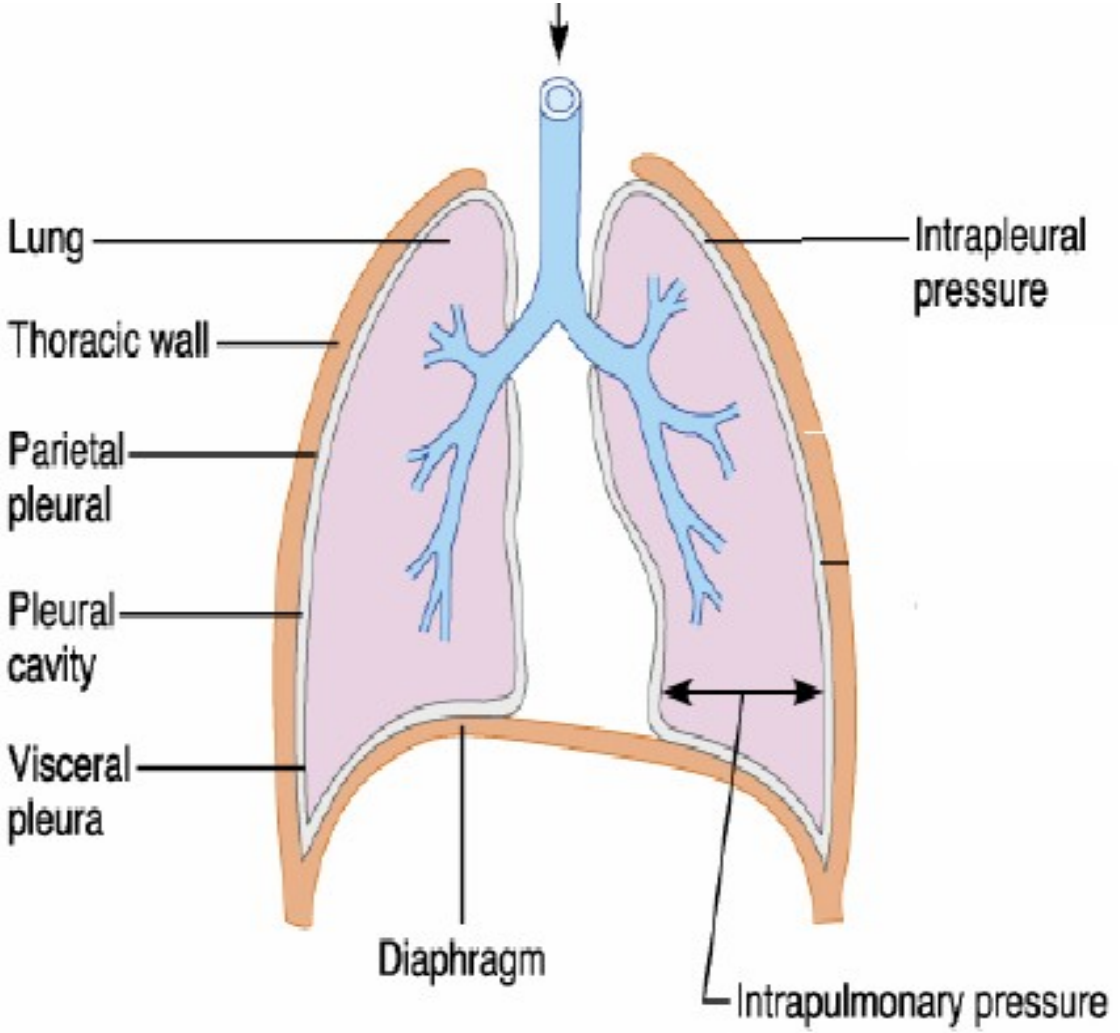
-double layered serosa

-**parietal pleura** lines the thoracic wall

-**pulmonary or visceral pleura** which covers the lung surface

-**pleural cavity** is the space between the two layers

-**pleural fluid** fills the cavity, which assists in producing breathing movements by acting as a lubricant



Stages of Respiration

1. Pulmonary ventilation: Breathing.
gas exchange between the atmosphere and lungs

2. External respiration:

- **Gas exchange** between **capillaries(blood)** and air at **alveoli(lung).**
  - O_2 (oxygen) in air diffuses into blood.
  - CO_2 (carbon dioxide) in blood diffuses into air.
  - Oxygen loading and Carbon dioxide unloading

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3. Transport of respiratory gases:

- Between the **lungs** and the **cells of the body**.
  - Performed by the **cardiovascular system**.
  - Blood is the transporting fluid.

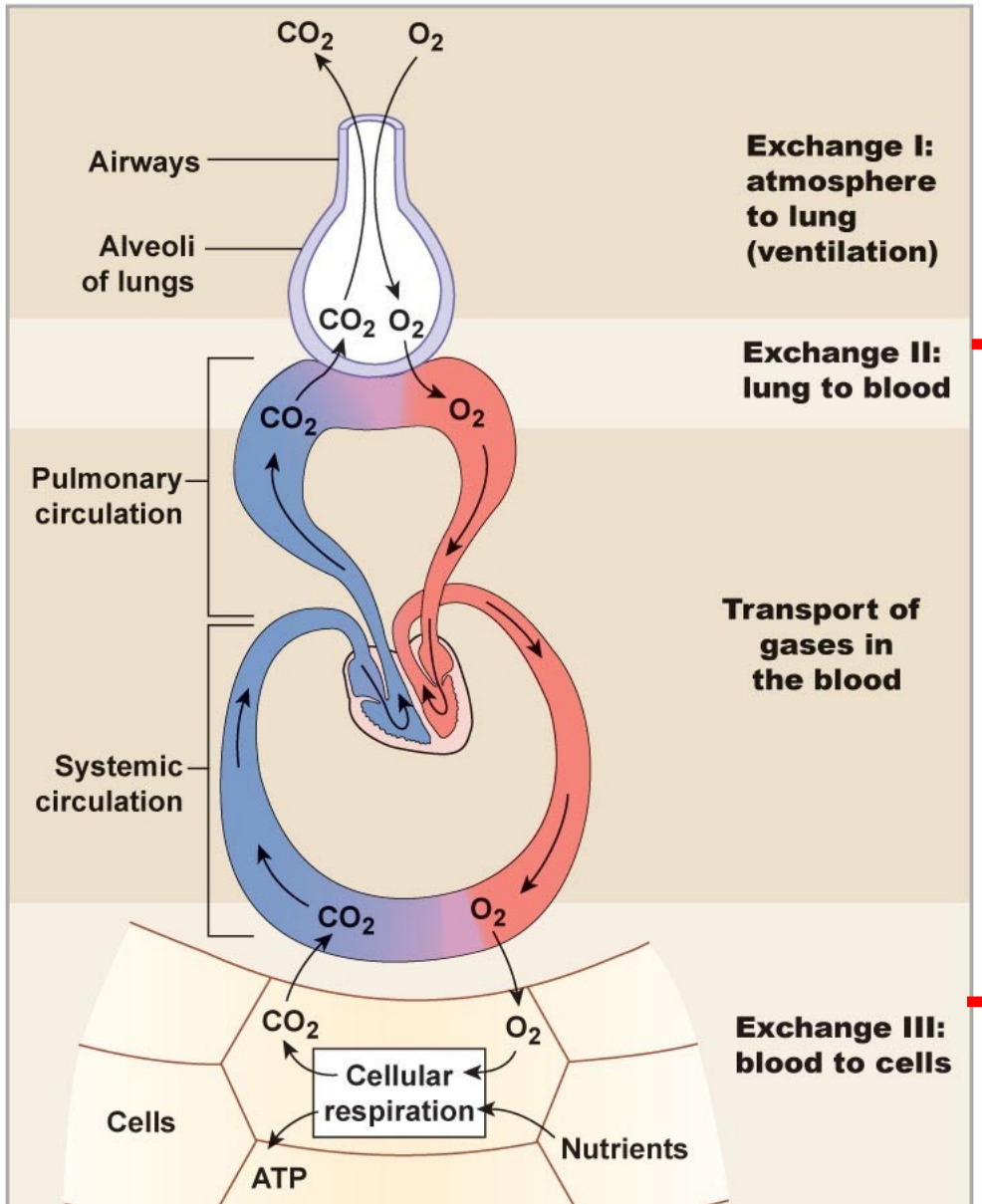
4. Internal respiration:

- Gas exchange in **capillaries between blood** and **tissue cells.**
- O_2 in blood diffuses into tissues.
- CO_2 waste in tissues diffuses into blood.

Cellular Respiration

- **0_2 utilization:**
  - Oxygen (O_2) is used by the all body cells.
- O_2 needed in **conversion of glucose to cellular energy (ATP).**
- **Carbon dioxide** (CO_2) is produced as a **waste product**.
- **The body's cells die if either the respiratory or cardiovascular system fails.**

Schematic View of Respiration



External Respiration

Internal Respiration

Dead space

- Dead space is defined as the **part of the respiratory tract**, where **gaseous exchange does not take place.**
- Air present in the dead space is called **dead space air.**

Anatomical Dead Space

- **Not all of the inspired air reaches the alveoli.**
- As fresh air is inhaled it is mixed with anatomical dead space.

BLOOD SUPPLY TO THE LUNG

- Two separate blood supplies:
  - **Pulmonary** circulation
  - **Bronchial** circulation

Phases of respiration

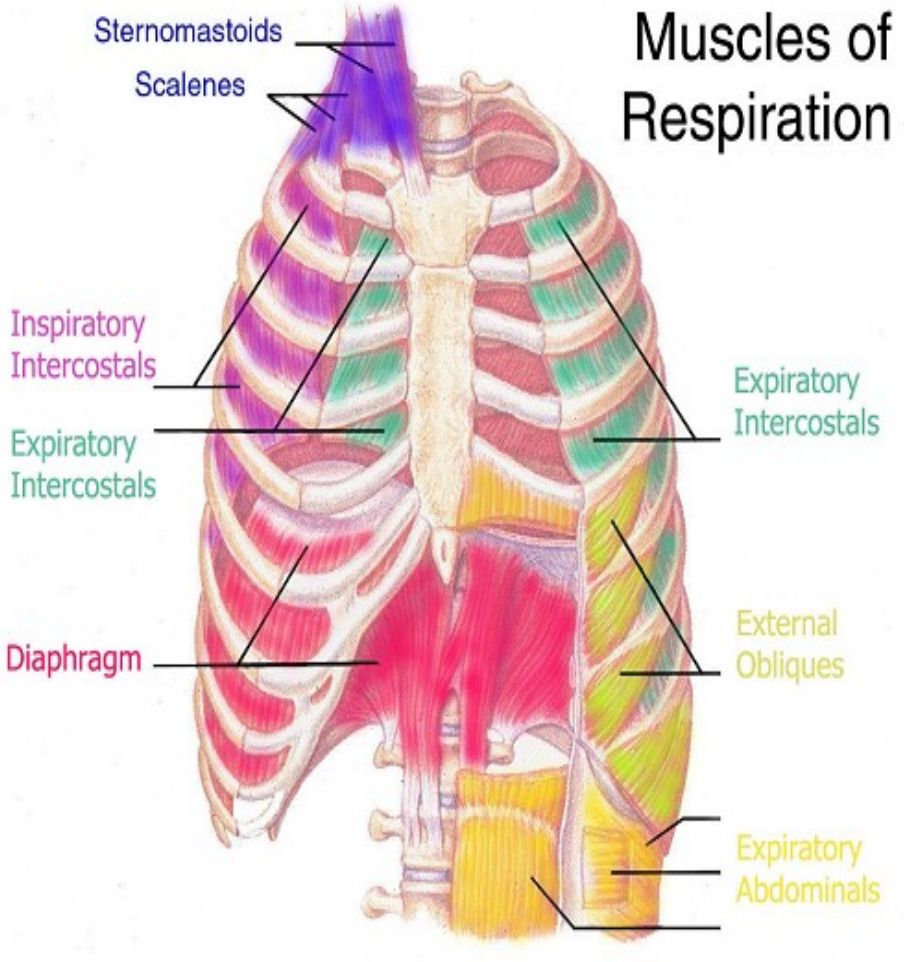
- During normal breathing:

  Respiration occurs in two phases:

  - **Inspiration** is an **active process**

    and

  - **Expiration** is a **passive process**.



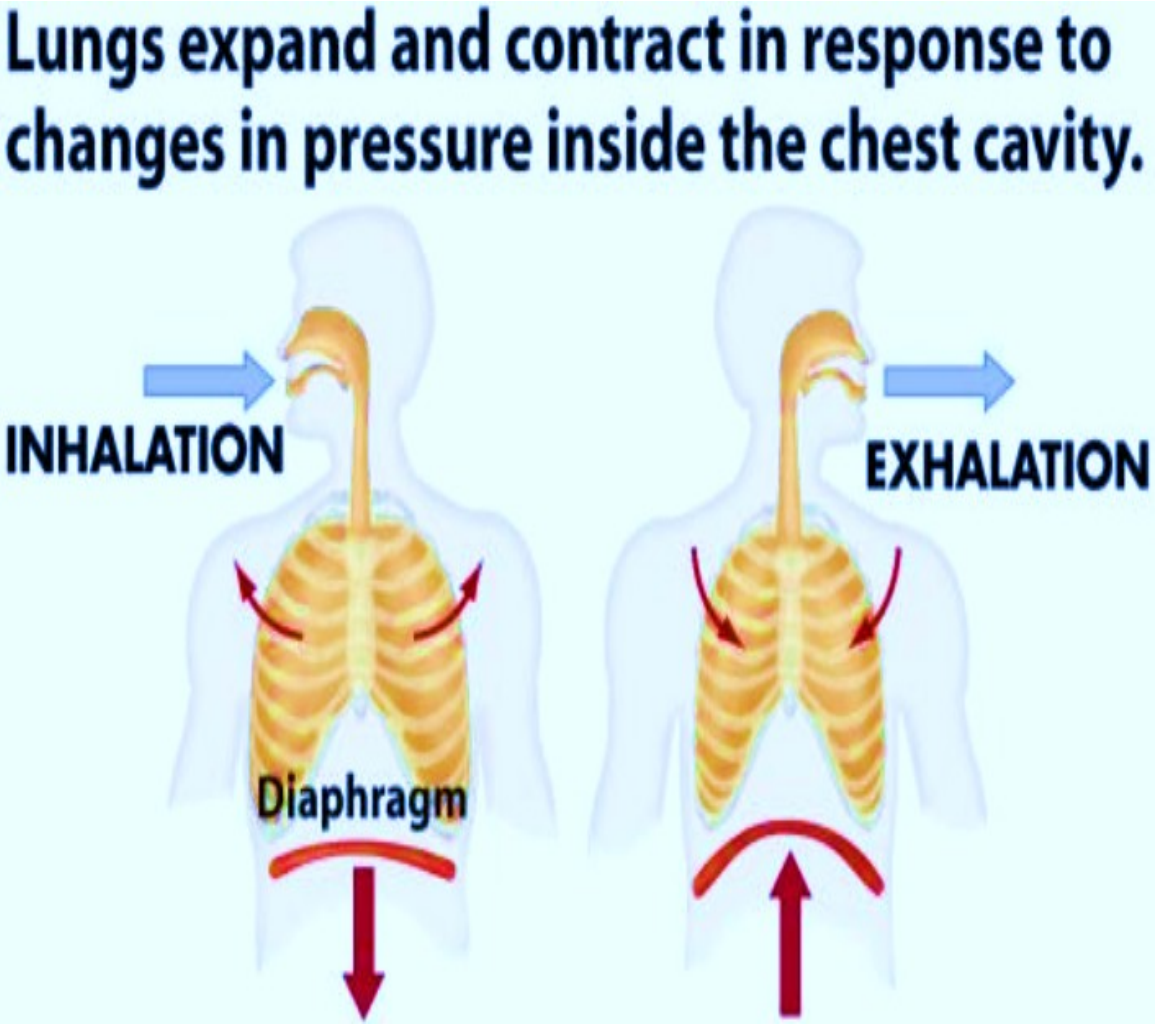
Inspiration

- **The external intercostal muscles plus the diaphragm** contract to bring about inspiration
- **Contraction of external intercostal muscles** → elevation of ribs & sternum → ↑ antero-posterior dimension of thoracic cavity → lowers air pressure in lungs → moving of air into lungs
- **Contraction of diaphragm** → movement of the diaphragm downward → ↑ vertical dimension of thoracic cavity → lowering of air pressure in the lungs → movement of air into the lungs
- The lungs are stretched and intrapulmonary volume increases
- Intrapulmonary pressure drops below atmospheric pressure
- Intrapleural pressure drops below atmospheric pressure
- Air flows into the lungs until pressures equalizes

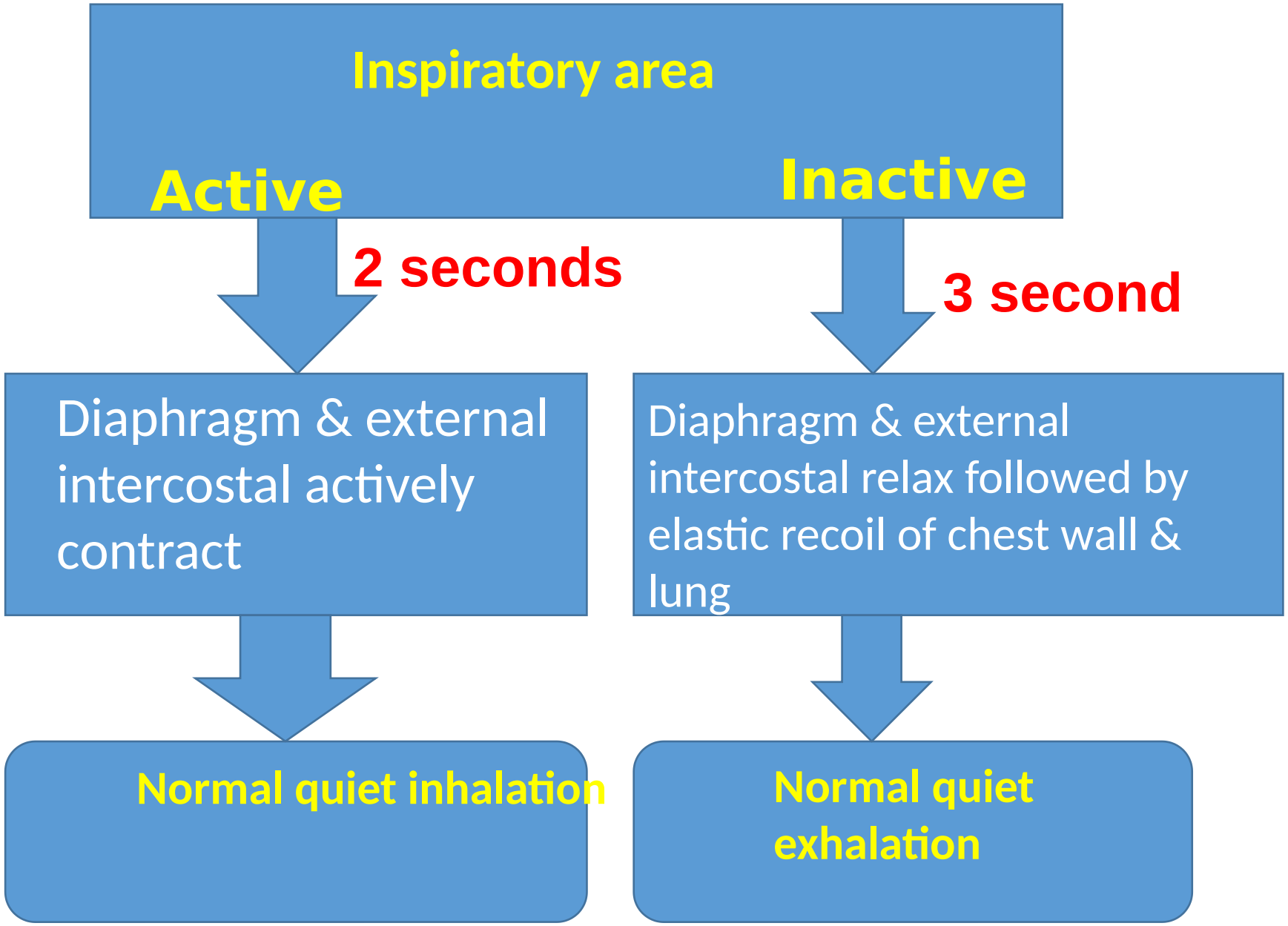
Expiration

- during which air **leaves** the lungs
- Inspiratory muscles relax and the rib cage descends
- Thoracic cavity volume decreases
- Elastic lungs recoil passively and intrapulmonary volume decreases
- Intrapulmonary pressure rises above atmospheric pressure
- Gases flow out of the lungs down the pressure gradient until pressures equalize

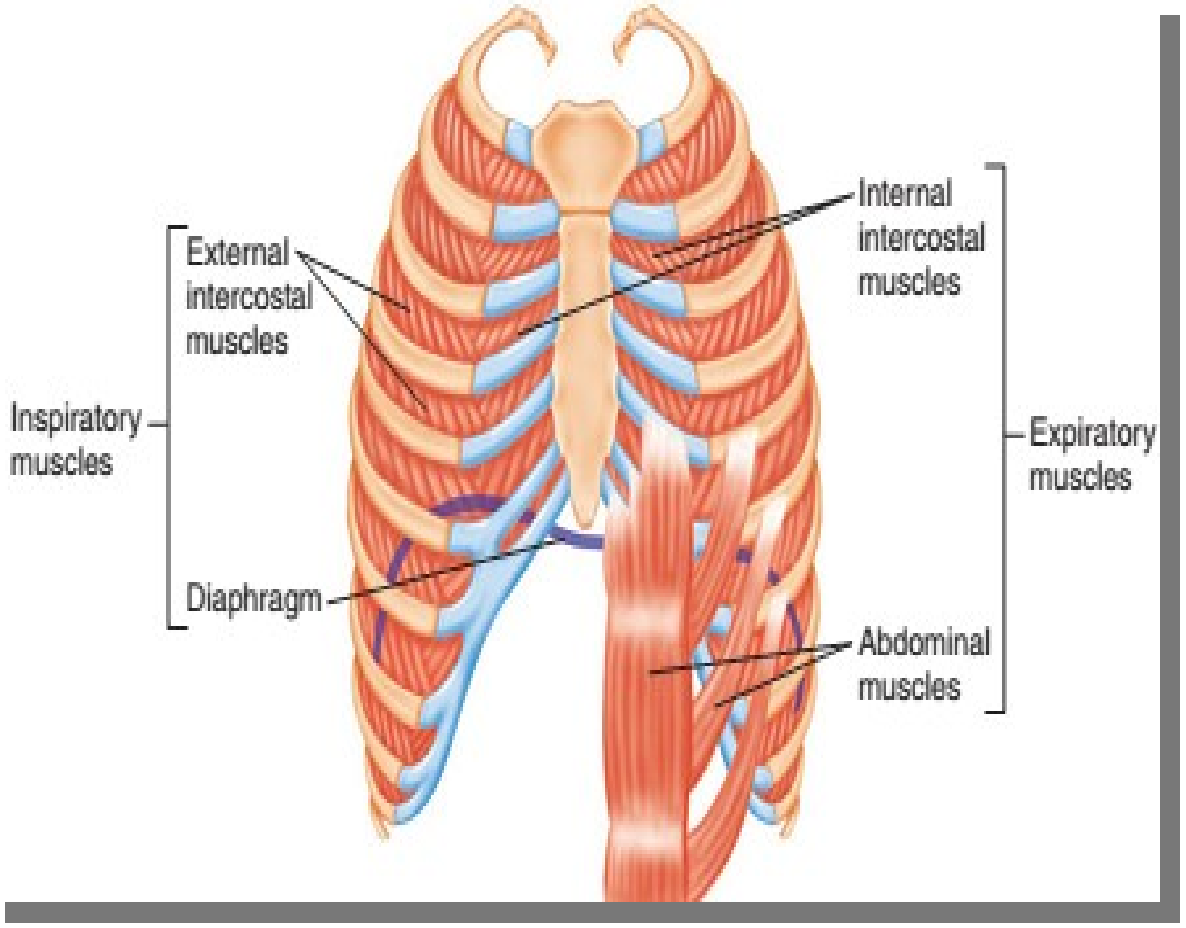
Phases of Respiration

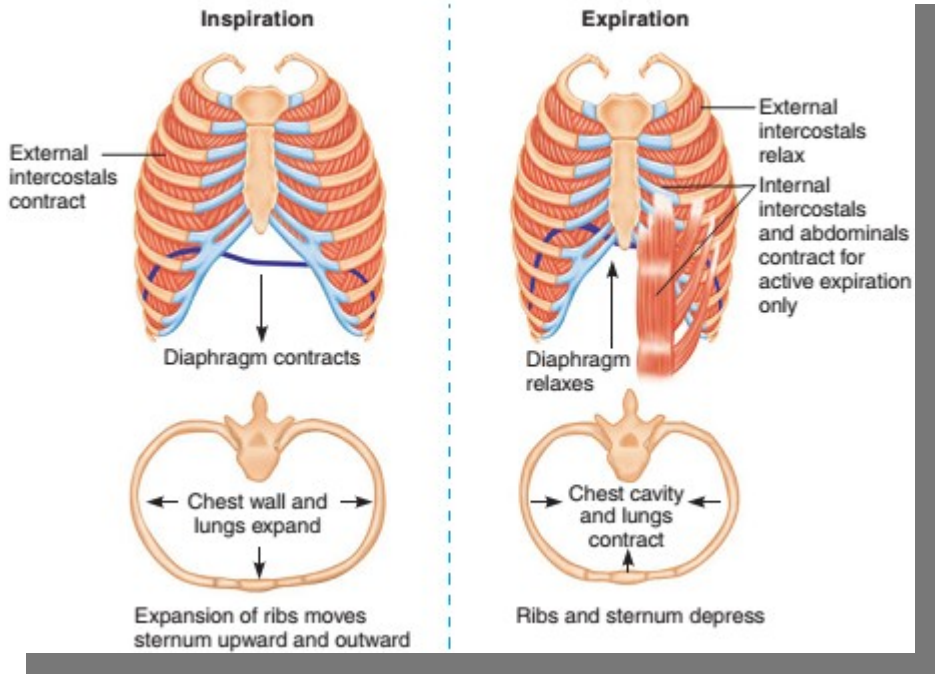


During normal quiet breathing



Respiratory muscles





Normal Respiratory Rate at Different Age

- **Newborn** : 30 to 60 breaths/minute.
- **Early childhood** : 20 to 40 breaths/minute.
- **Late childhood** : 15 to 25 breaths/minute.
- **Adult**:
  - At **rest**: **10 - 20 breaths/minute**,
  - During **maximum exercise**: **40 - 45 breaths/minute**.

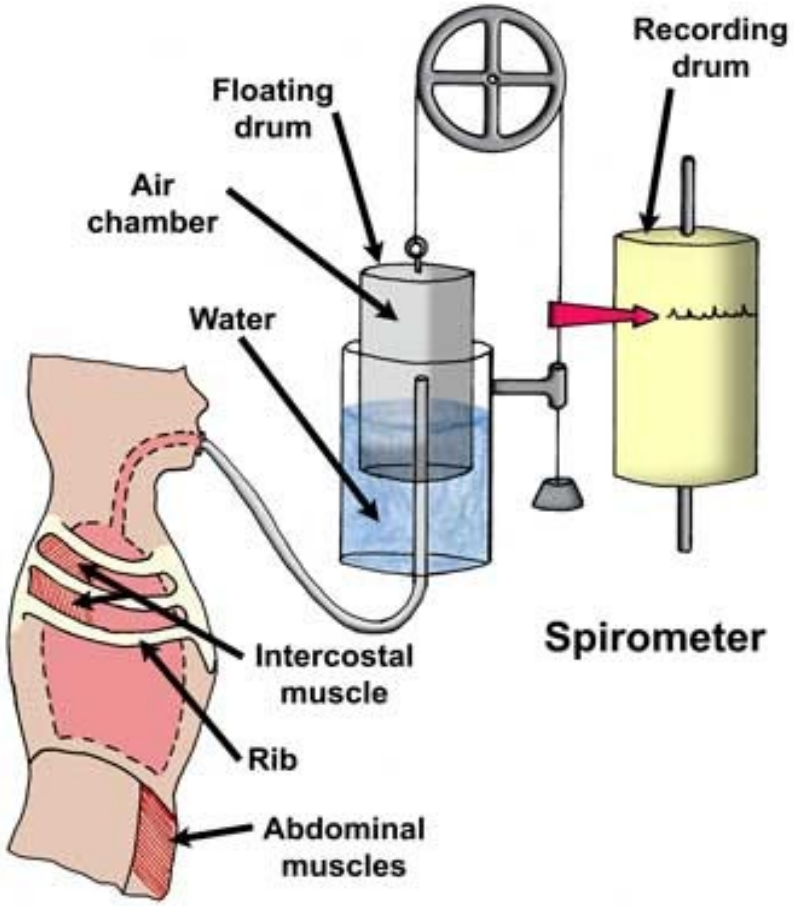
Pulmonary Function Tests

- **Spirometry:** is a **method of assessing lung function** by measuring the volume of air that the patient can expel from the lungs after a maximal inspiration.

Pulmonary Function Tests

- **Spirometer**: is an instrument for measuring lung volumes and capacities.

- Consists of a hollow bell inverted over water, used to evaluate respiratory function



Lung volumes and capacities

- A **lung volume** refers to a basic volume of the lung,
- **lung capacities** are the sum of two or more basic lung volumes

Minute ventilation (MV): the total volume of air inhaled and exhaled each minute

- **MV**: RR x TV ⎵ 15 breaths/min x 500 mL/breath = 7.5 liters/min

Tidal volume (TV):

- Volume of air inhaled or exhaled with each breath during normal breathing (0.5 L)

Cont’d

Inspiratory reserve volume (IRV):

- Maximal volume of air inhaled at the end of a normal inspiration (3 L)

Expiratory reserve volume (ERV):

- Maximal volume of air exhaled at the end of a tidal volume (1.1L)

Residual volume (RV):

- The volume of gas remains in the lung after maximal expiration (1.2 L)

Cont’d

Inspiratory capacity (IC):

- Maximal volume of air inhaled after a normal expiration (3.5L) (TV+IRV)

Functional residual capacity (FRC):

- The volume of gas that remains in the lung at the end of a passive expiration (3.5L or 40 % of the maximal lung volume) (ERV+RV)

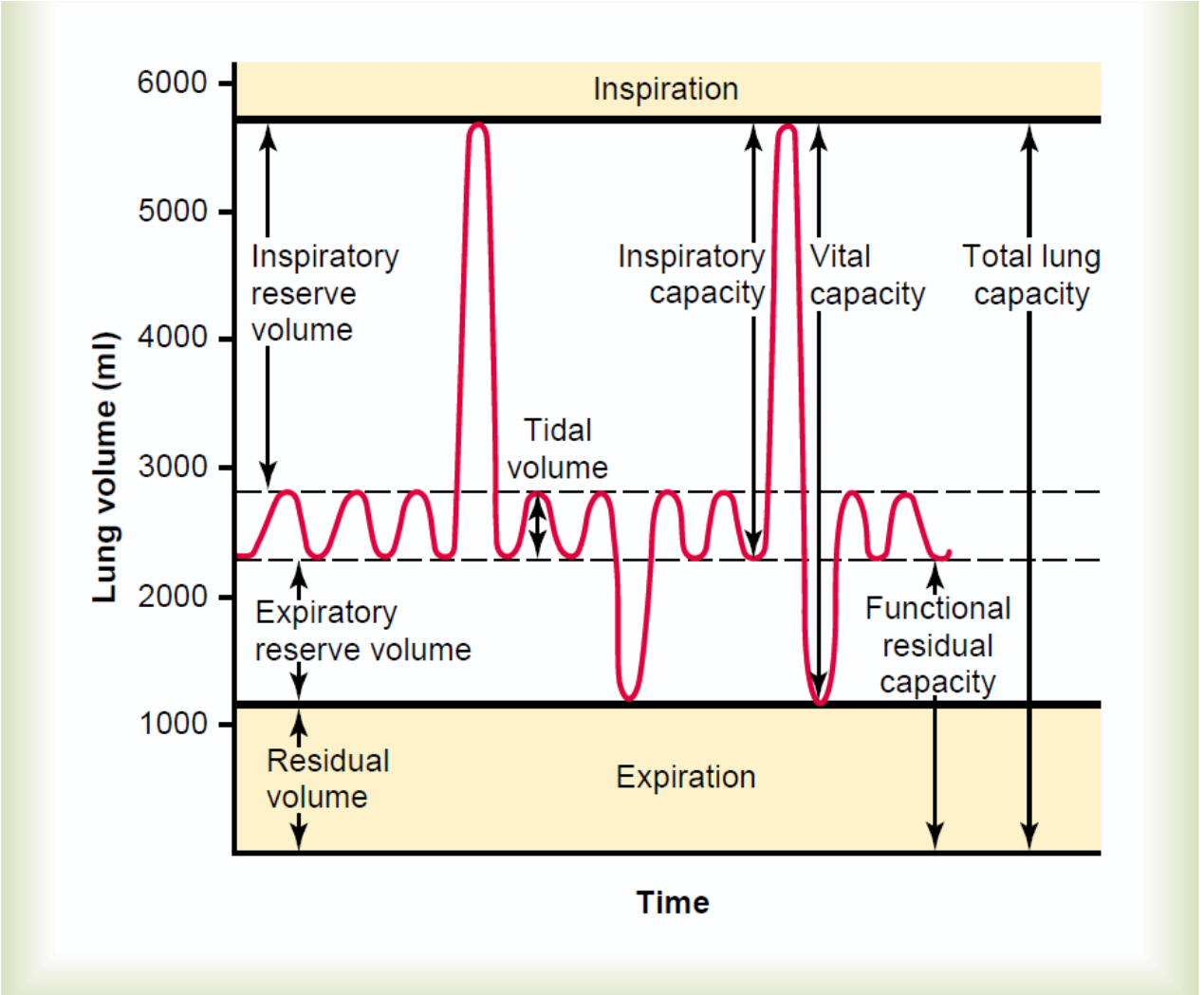
Vital capacity (VC):

- The maximum volume of air that can be moved out during a single breath following a maximal inspiration (4.6)

Cont'd

Total lung capacity (TLC):

- The maximal lung volume that can be achieved voluntarily (5.8 L) (**IRV+ERV+TV+RV**)



Gas transport

- Gas diffuse from high to low partial pressure

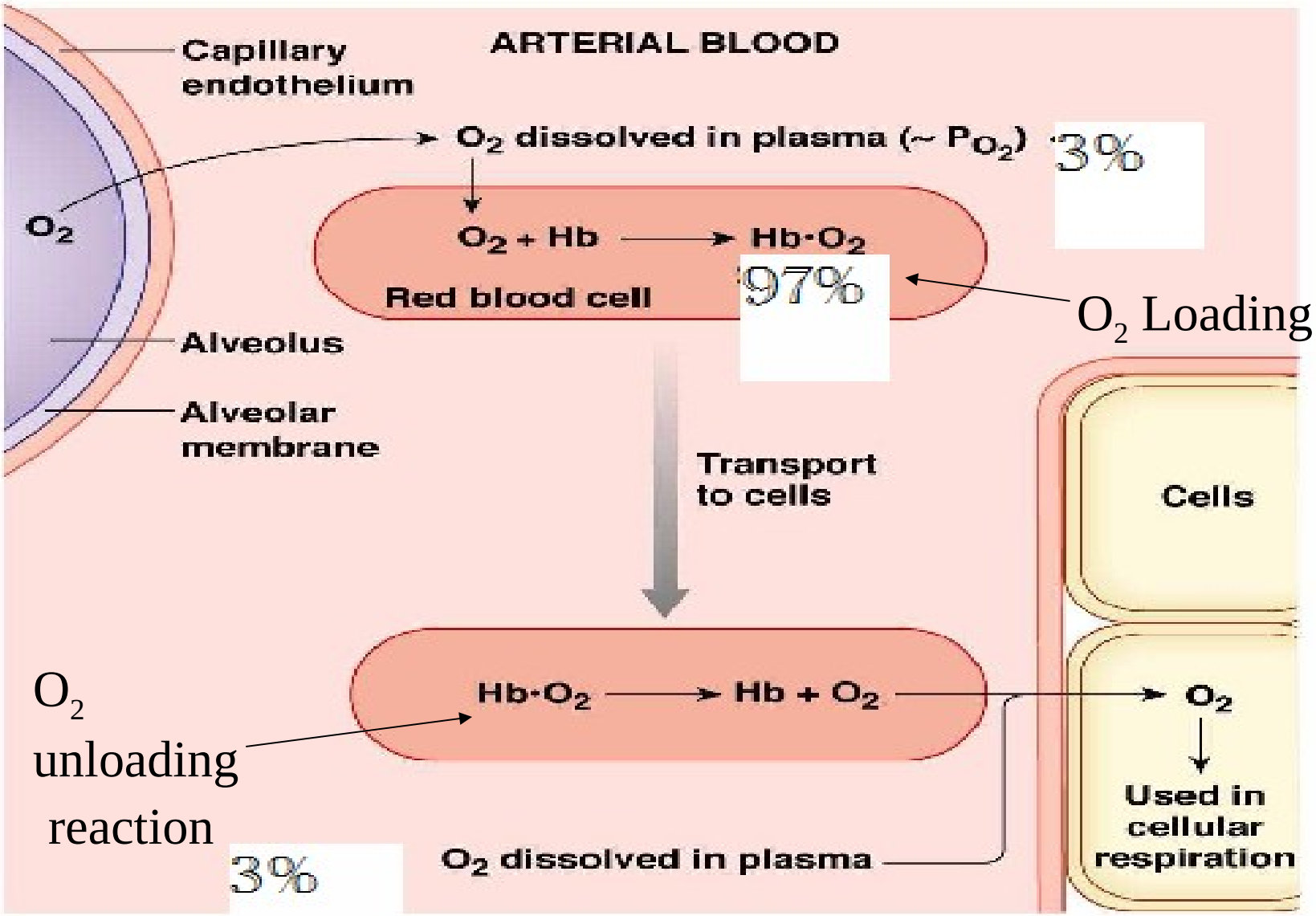
Oxygen transport

- Occurs in two forms: **dissolved** and **bound to hemoglobin**

  - Being bound to hemoglobin –oxy-Hb within red blood cells (chemical form)-97%

  - Being dissolved in plasma-3% (physical form)

Oxygen Transport cont'd...



O_2 Loading rxn

O_2 unloading reaction

Cont’d

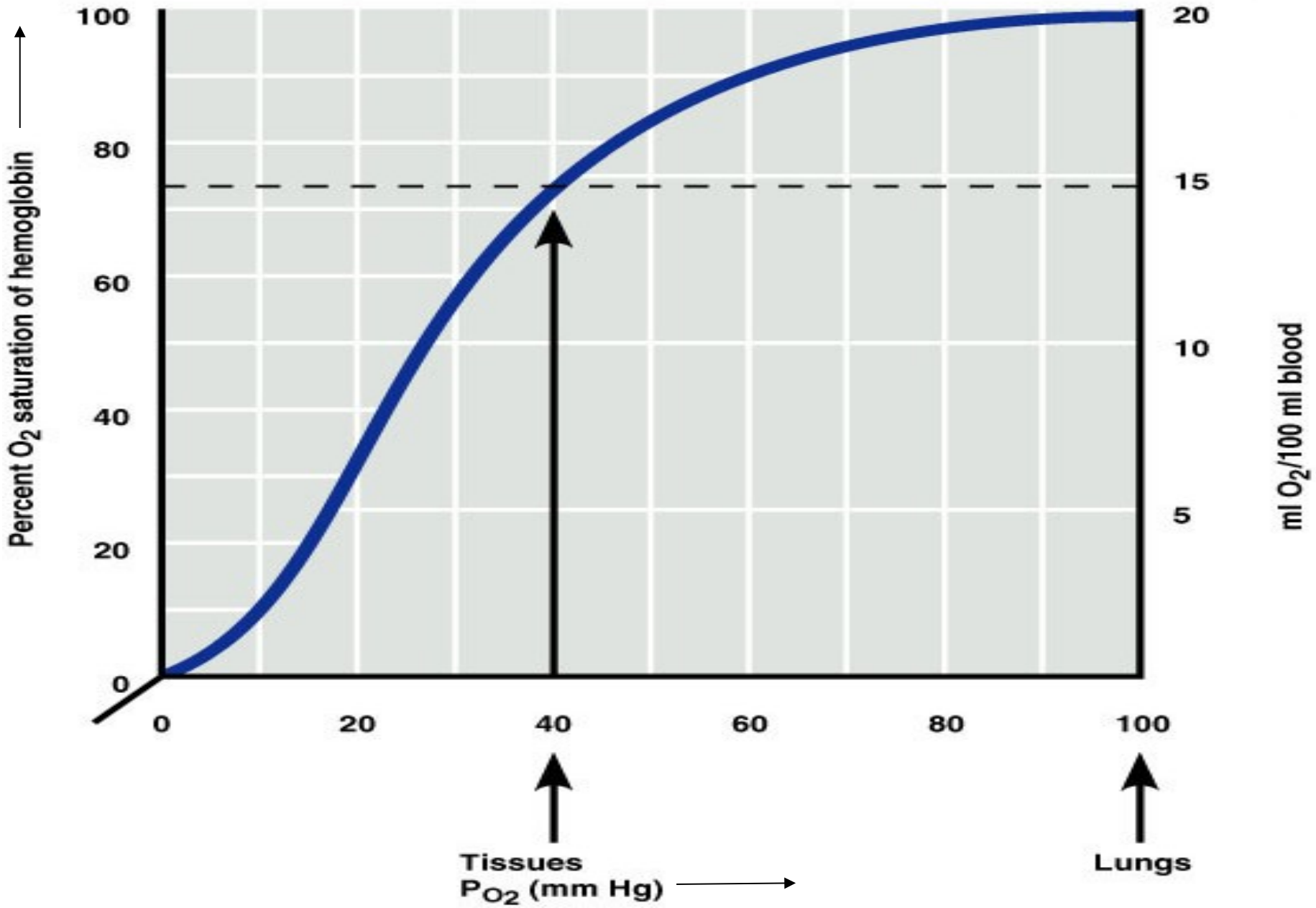
Oxygen bound to hemoglobin (Hb):

- Hb form a loose, easily reversible combination with O2
- When not combined with O2, Hb is referred to as **reduced hemoglobin or deoxyhemoglobin;**
- when combined with O2, it is called **oxyhemoglobin (HbO2):**

Cont’d

- Hb is considered *fully saturated when all the Hb present* is carrying its maximum O2 load.
- Most important factor determining the % Hb saturation is the ***PO2* of the blood.**
- The higher the PO2, the more O2 combines with Hb
- When blood *PO2* increases ▭ curve shift toward the right side ▭ increasing formation of HbO2 (**increased % Hb saturation).**

Oxygen-Hemoglobin Saturation Curve



Carbon dioxide transport

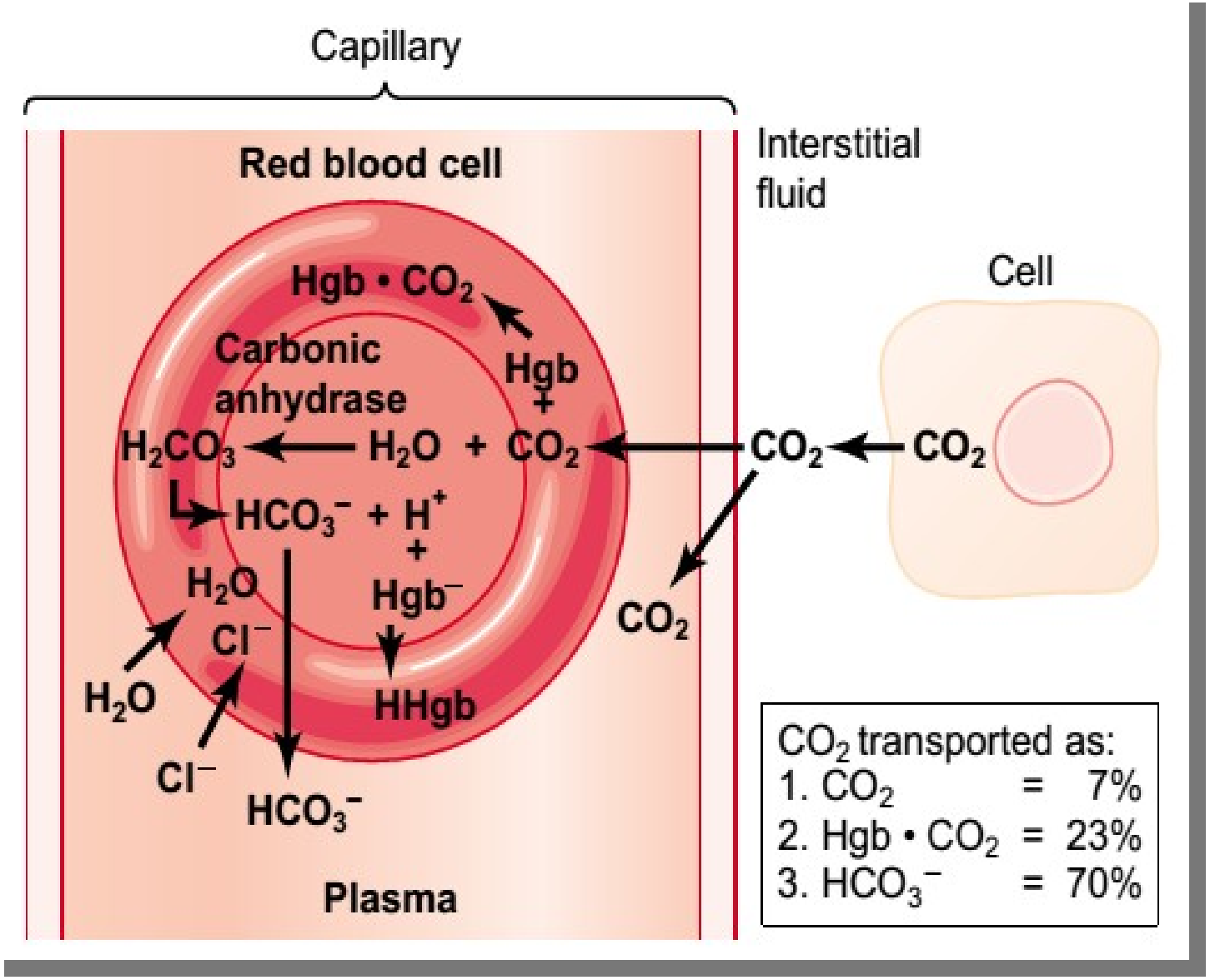
- Carbon dioxide is transported in three forms:

➢ In the form of **bicarbonate -70%**

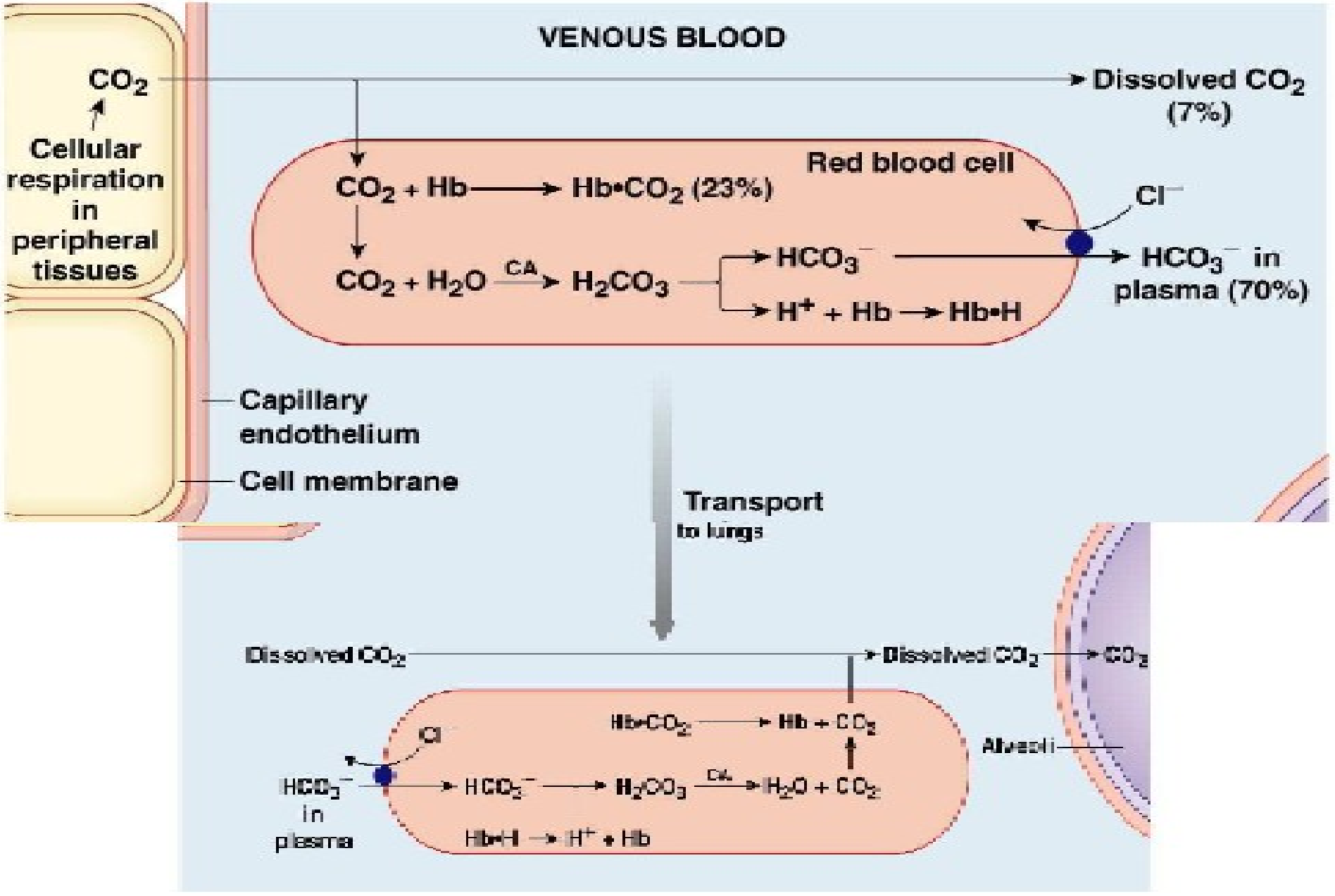
➢ In the form of **carbaminohemoglobin-23%**

➢ **Dissolved in plasma-7%**

Cont'd


Capillary
Red blood cell
Interstitial fluid
Cell
Hgb • CO_2
Carbonic anhydrase
Hgb
H_2CO_3
H_2O + CO_2
CO_2
CO_2
HCO_3^- + H^+
+
H_2O
Hgb^-
Cl^-
CO_2
H_2O
HHgb
Cl^-
HCO_3^-
Plasma
CO_2 transported as:
1. CO_2 = 7%
2. Hgb • CO_2 = 23%
3. HCO_3^- = 70%

Carbon Dioxide Transport



Regulation of respiration

- Can be **neural** and **chemical** control of respiration

1. **Neural control of respiration**

- Respiratory centers found in the brain stem generate the rhythmic pattern of breathing.

Medullary respiratory center: Primary respiratory control center

- Consists of neuronal cell bodies within the medulla
- Contains inspiratory and expiratory areas

Cont'd

- Two neuronal clusters: **dorsal respiratory group (DRG)** and **ventral respiratory group (VRG)**.

Dorsal respiratory group (DRG): consists mostly of ***inspiratory*** *neurons*

- When the DRG inspiratory neurons fire, **inspiration takes place**
- When they cease firing, **expiration occurs**.
- **Generate the basic rhythm of ventilation**

Cont’d

Ventral respiratory group (VRG): is composed of inspiratory neurons and expiratory neurons

- **Both of which remain inactive during normal quiet breathing.**
- It is especially important in **active expiration**

Pontine centers (pneumotaxic and apneustic centers):

- **Exert “fine-tuning” influences over the medullary center**
- To produce normal, smooth inspirations and expirations.

Cont’d

Pneumotaxic center: sends impulses to the DRG that help “switch off” the inspiratory neurons, limiting the duration of inspiration.

- When the pneumotaxic area is more active, breathing rate is more rapid

Apneustic center: prevents the inspiratory neurons from being switched off

- Thus, providing an extra boost to the inspiratory drive e.g. **apneusis** (prolonged inspiratory gasps)

Cont'd

2. Chemical control of respiration:

- **Two** types of chemoreceptors: peripheral and central chemoreceptors

Peripheral chemoreceptors: are found in aortic and carotid bodies in the neck region.

- Detect changes in:PO_2 exclusively, PCO_2 and H^+

Central Chemoreceptors: found in the medullary region of brain stem.

Respiratory Acid-Base Balance

Respiratory Acidosis

- **Hypoventilation.**
- **Accumulation of CO_2 in the tissues.**
  - **pH decreases.**
  - **Plasma HCO_3^- decreases.**
  - **P_{CO2} increases.**

Respiratory Alkalosis

- **Hyperventilation.**
- **Excessive loss of CO_2.**
  - **pH increases.**
  - **Plasma HCO_3^- increases.**
  - **P_{CO2} decreases.**

Lung diseases

- Airway diseases that alter airflow.
- **restrictive** and **obstructive** disease

Restrictive diseases:

- Characterized by limited lung expansion, reduced lung volumes, and usually decreased expiratory flow rates

E.g. pulmonary fibrosis, TB and scoliosis

Cont’d

Obstructive disease:

- characterized by increased airway resistance causing reduced expiratory airflow rates
- Always associated with airway dysfunction

E.g. asthma