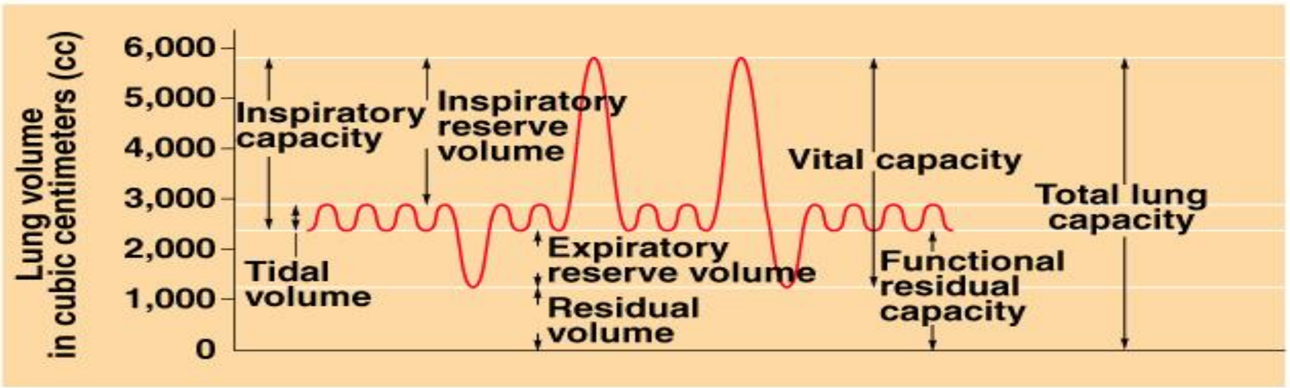
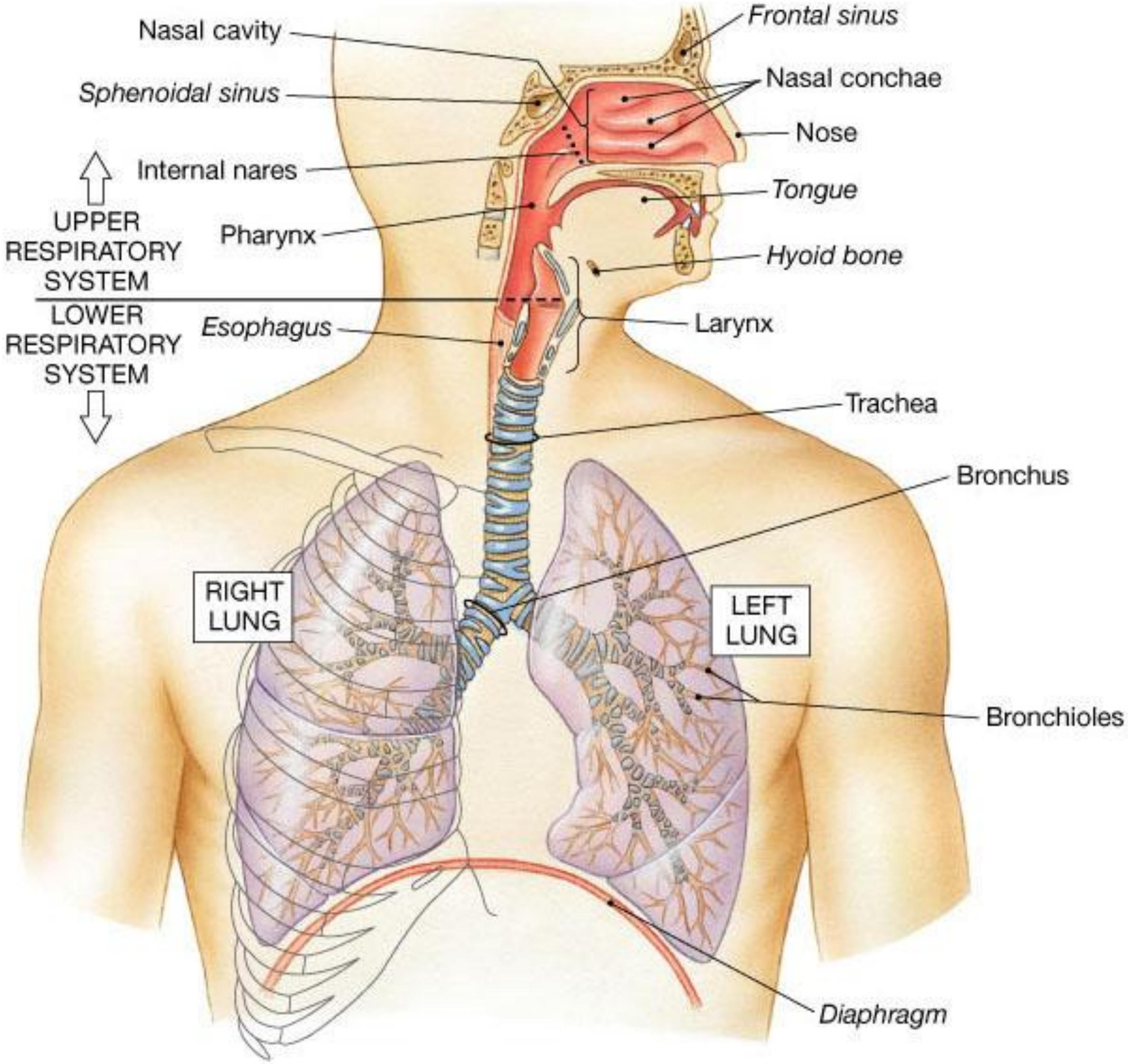
Respiratory Physiology



Functions of the respiratory system

- Moving air to the exchange surface of the lungs
- Gas exchange between air and circulating blood
- Protection of respiratory surfaces (from dehydration, temperature changes, and defending the RS from invading pathogens)
- Production of sound
- Provision for olfactory sensations

The Components of the Respiratory System

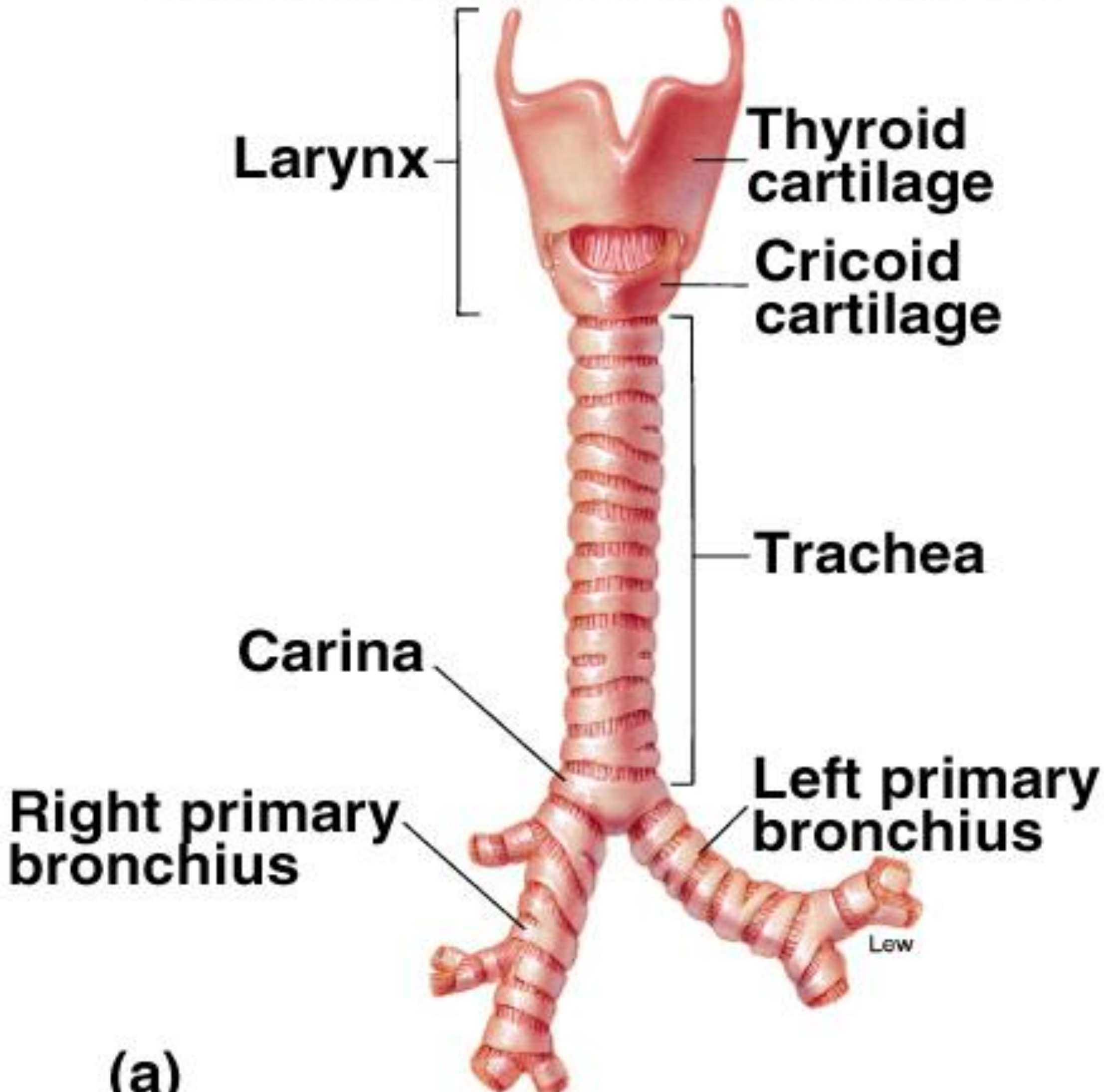


The Components of the Respiratory System

- **Conducting Zone.**
- **Respiratory Zone**

Conducting Zone

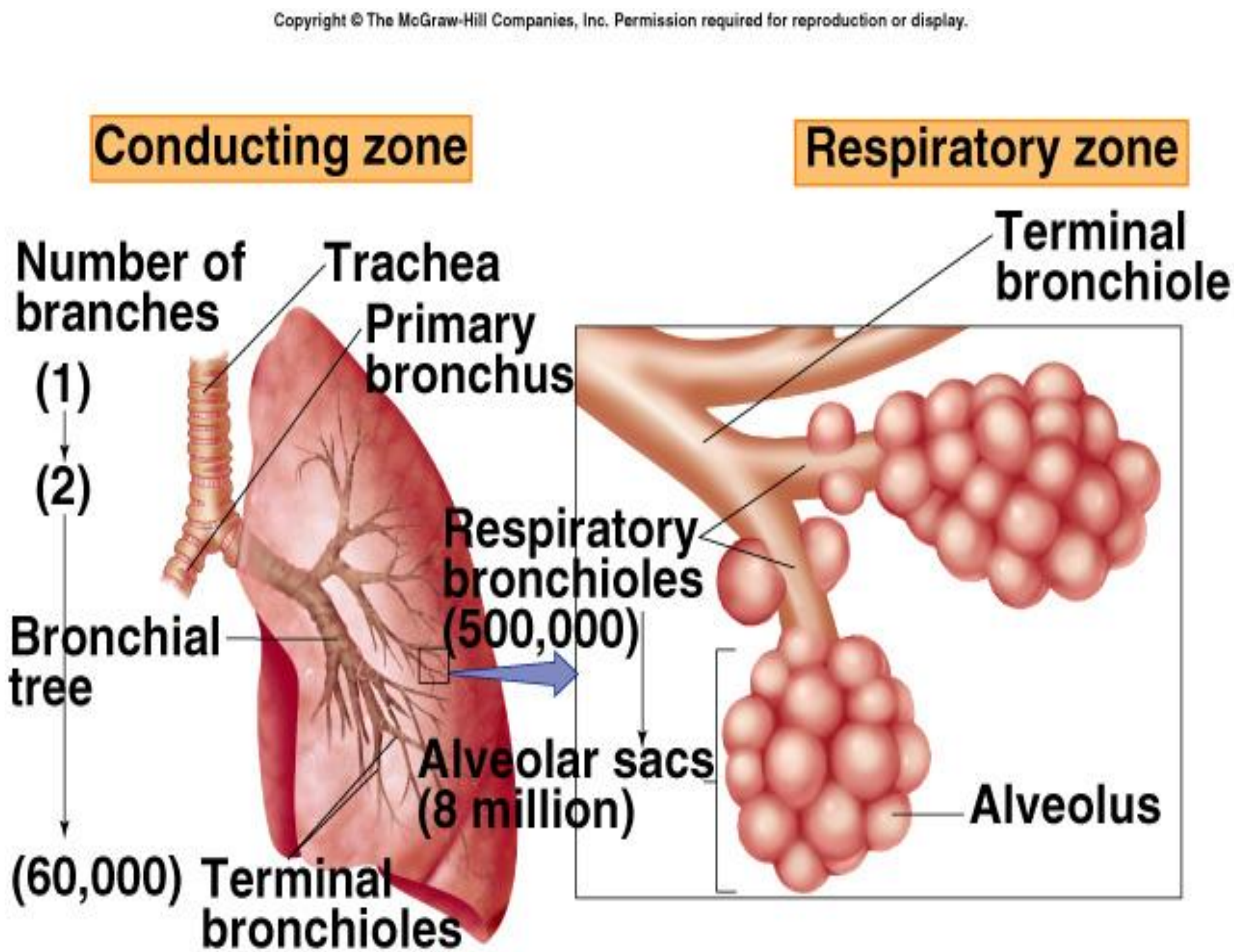
- All the structures air passes through before reaching the respiratory zone.
- **Function:**
- Warms and humidifies inspired air.
- Filters and cleans:
  - Mucus secreted to trap particles in the inspired air.
  - Mucus moved by cilia to be expectorated.



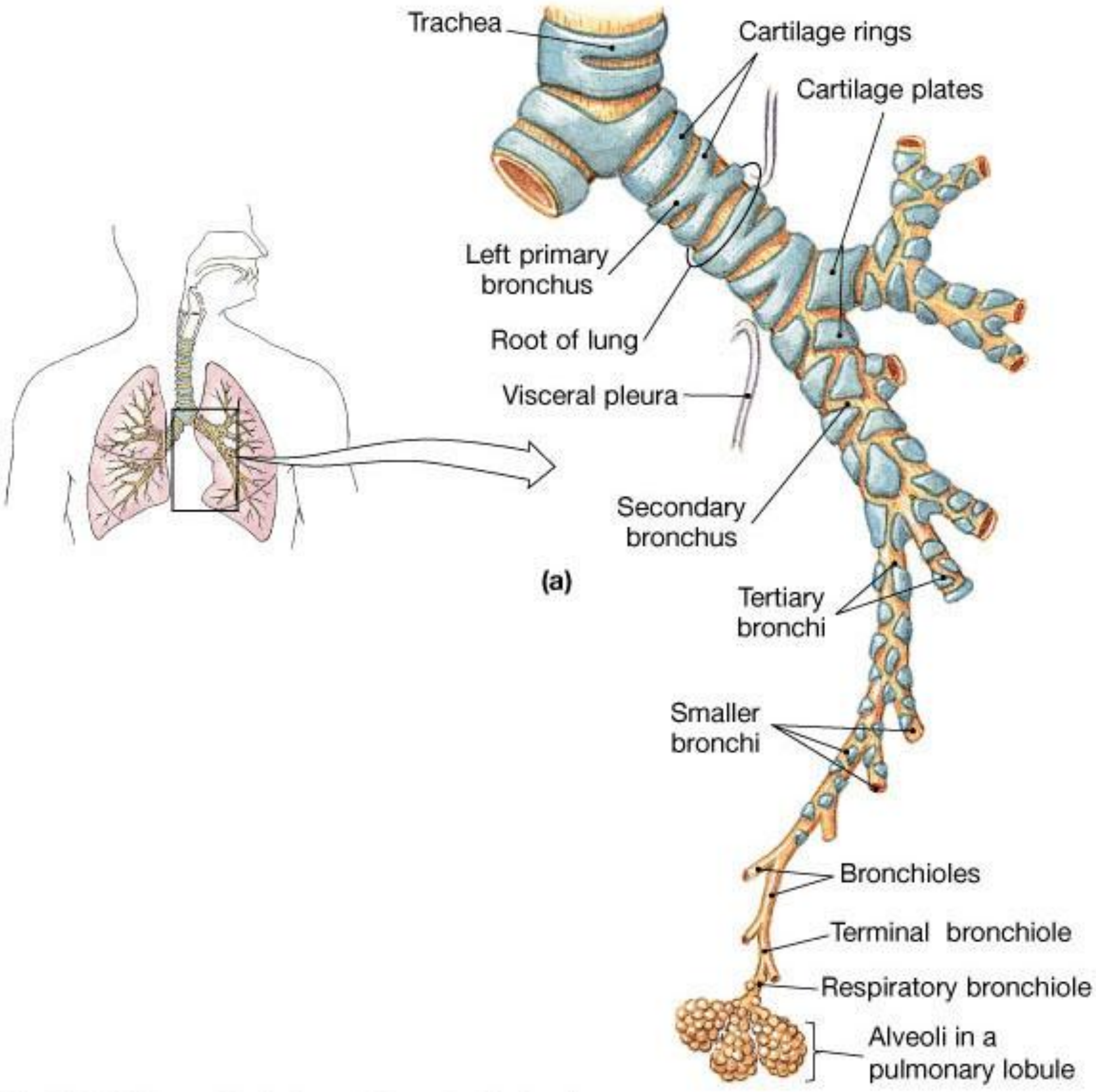
(a)

Respiratory Zone

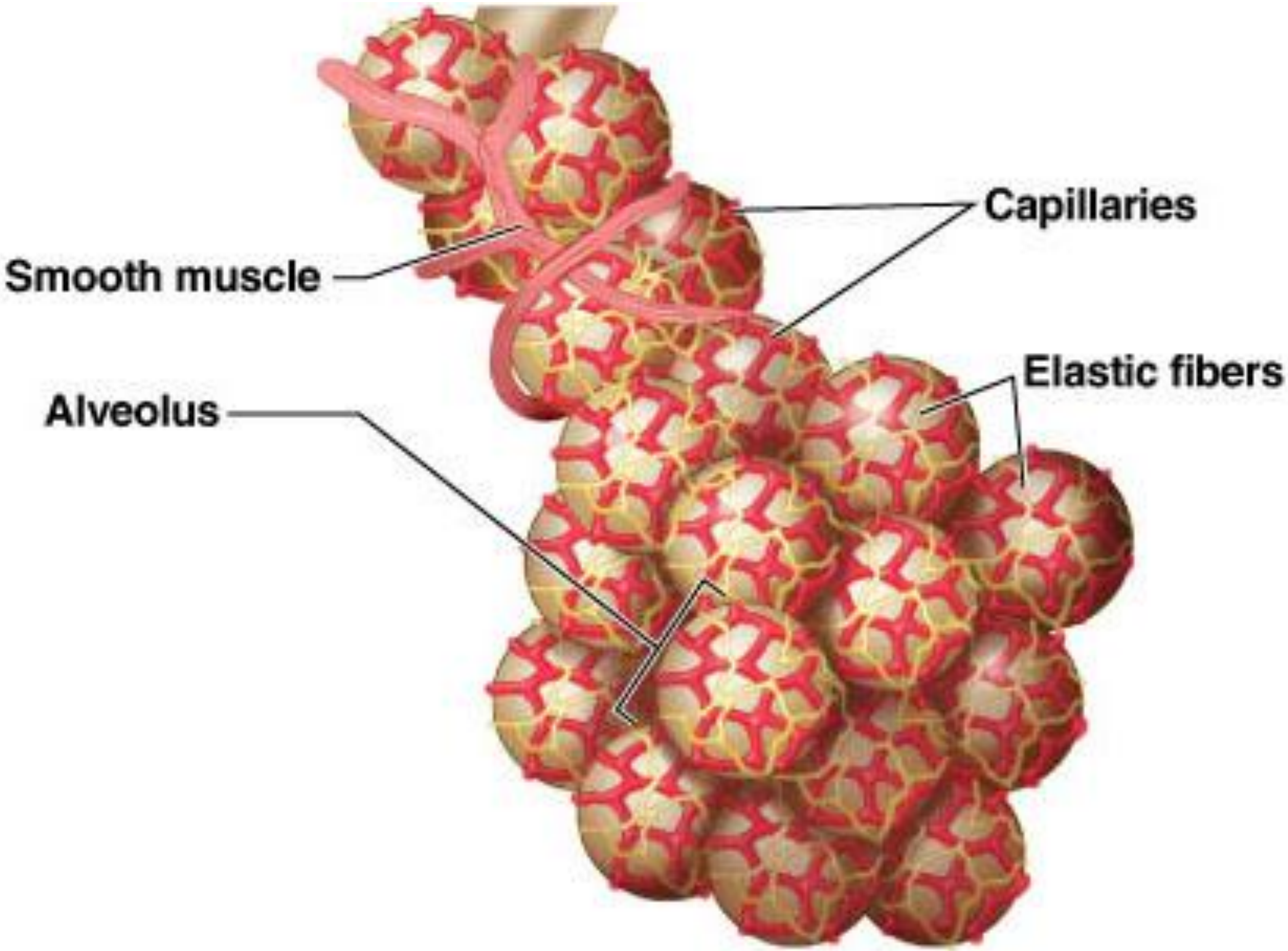
- Region of gas exchange between air and blood.
- Includes respiratory bronchioles and alveolar sacs.



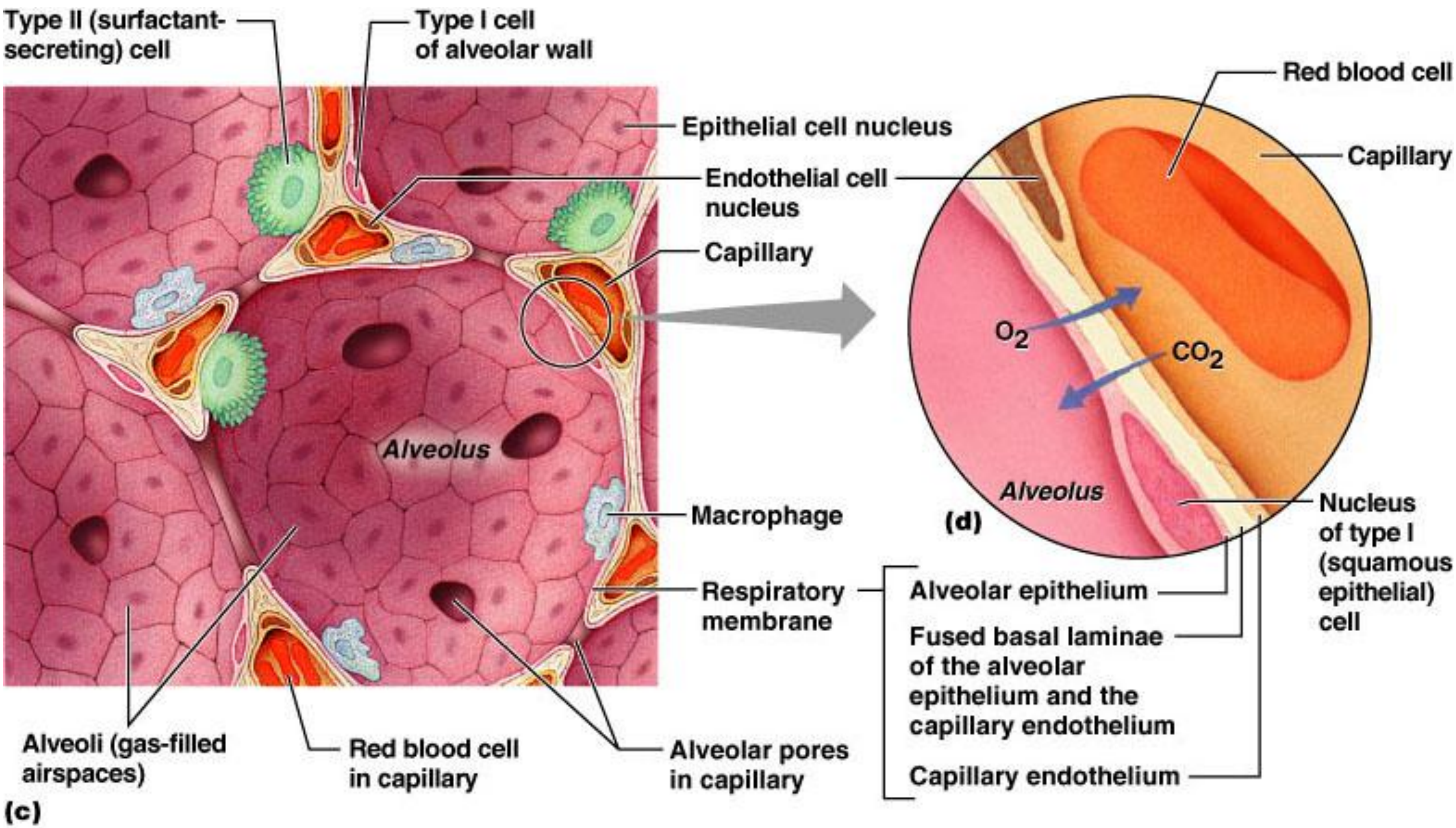
The Bronchi and Lobules of the Lung



Respiratory Membrane



Respiratory Membrane



Respiratory Membrane

- This air-blood barrier is composed of:
  - Alveolar and capillary walls
  - Their fused basal laminas
- Alveolar walls:
  - Are a single layer of type I epithelial cells
  - Permit gas exchange by simple diffusion
- Type II cells secrete **surfactant**

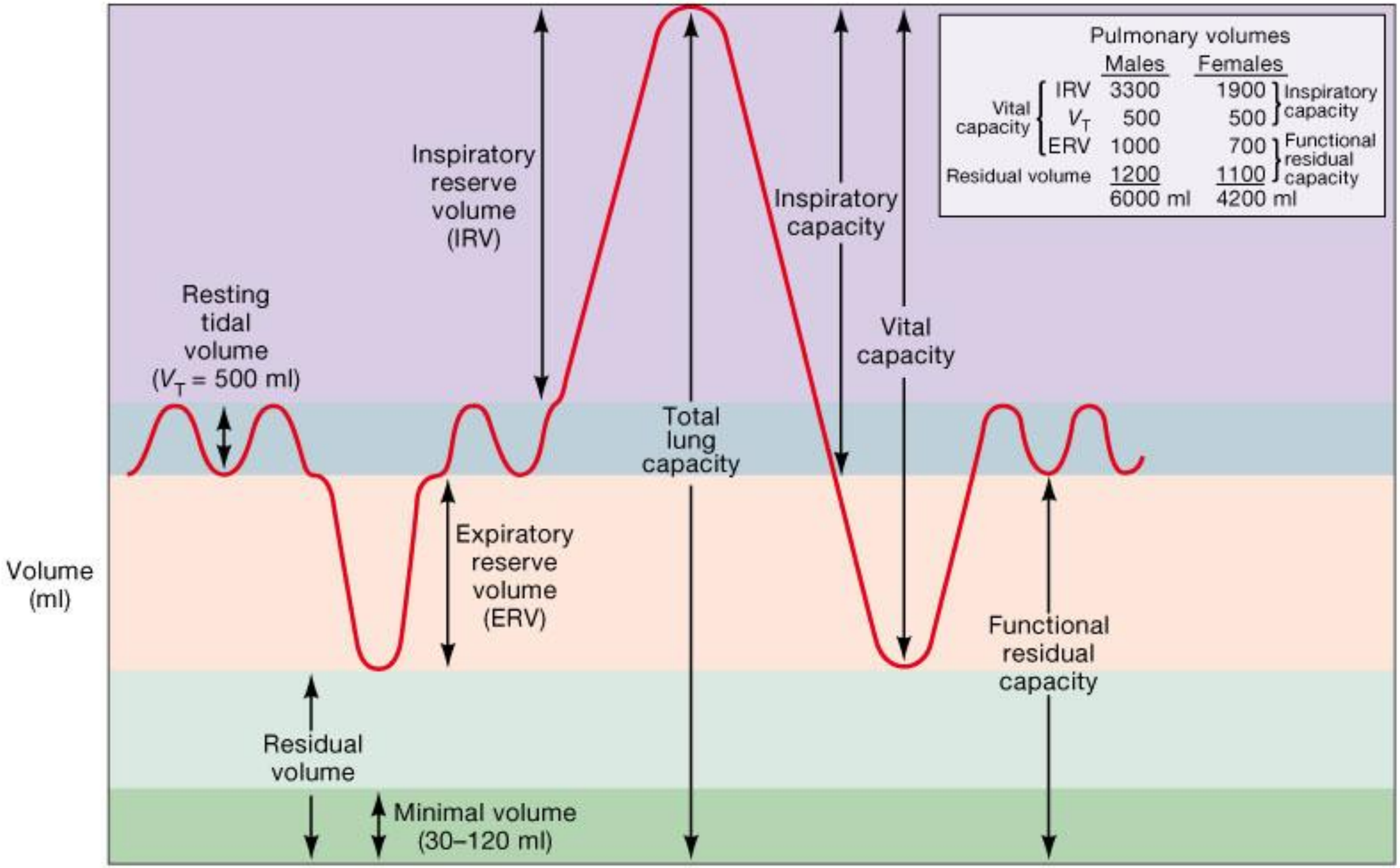
Respiratory Volumes

- **Tidal volume (TV)** – air that moves into and out of the lungs with each breath (approximately 500 ml)
- **Inspiratory reserve volume (IRV)** – air that can be inspired forcibly beyond the tidal volume (2100–3200 ml)
- **Expiratory reserve volume (ERV)** – air that can be evacuated from the lungs after a tidal expiration (1000–1200 ml)
- **Residual volume (RV)** – air left in the lungs after maximal forced expiration (1200 ml)

Respiratory Capacities

- **Inspiratory capacity (IC)** – total amount of air that can be inspired after a tidal expiration (IRV + TV)
- **Functional residual capacity (FRC)** – amount of air remaining in the lungs after a tidal expiration
(RV + ERV)
- **Vital capacity (VC)** – the total amount of exchangeable air (TV + IRV + ERV)
- **Total lung capacity (TLC)** – sum of all lung volumes (approximately 6000 ml in males)

Respiratory Volumes and Capacities



Dead Space

- The volume of the airways that does not participate in gas exchange
- **Anatomical dead space** – volume of the conducting respiratory passages (150 ml)
- **Functional dead space** – alveoli that cease to act in gas exchange due to collapse or obstruction
- **Physiological dead space** – sum of alveolar and anatomical dead spaces

Mechanics of Breathing

Pulmonary Ventilation

- The physical movement of air into and out of the lungs

Air movement

- Movement of air depends upon
  - **Boyle's Law**
    - Pressure and volume inverse relationship
    - Volume depends on movement of diaphragm and ribs

Inspiration

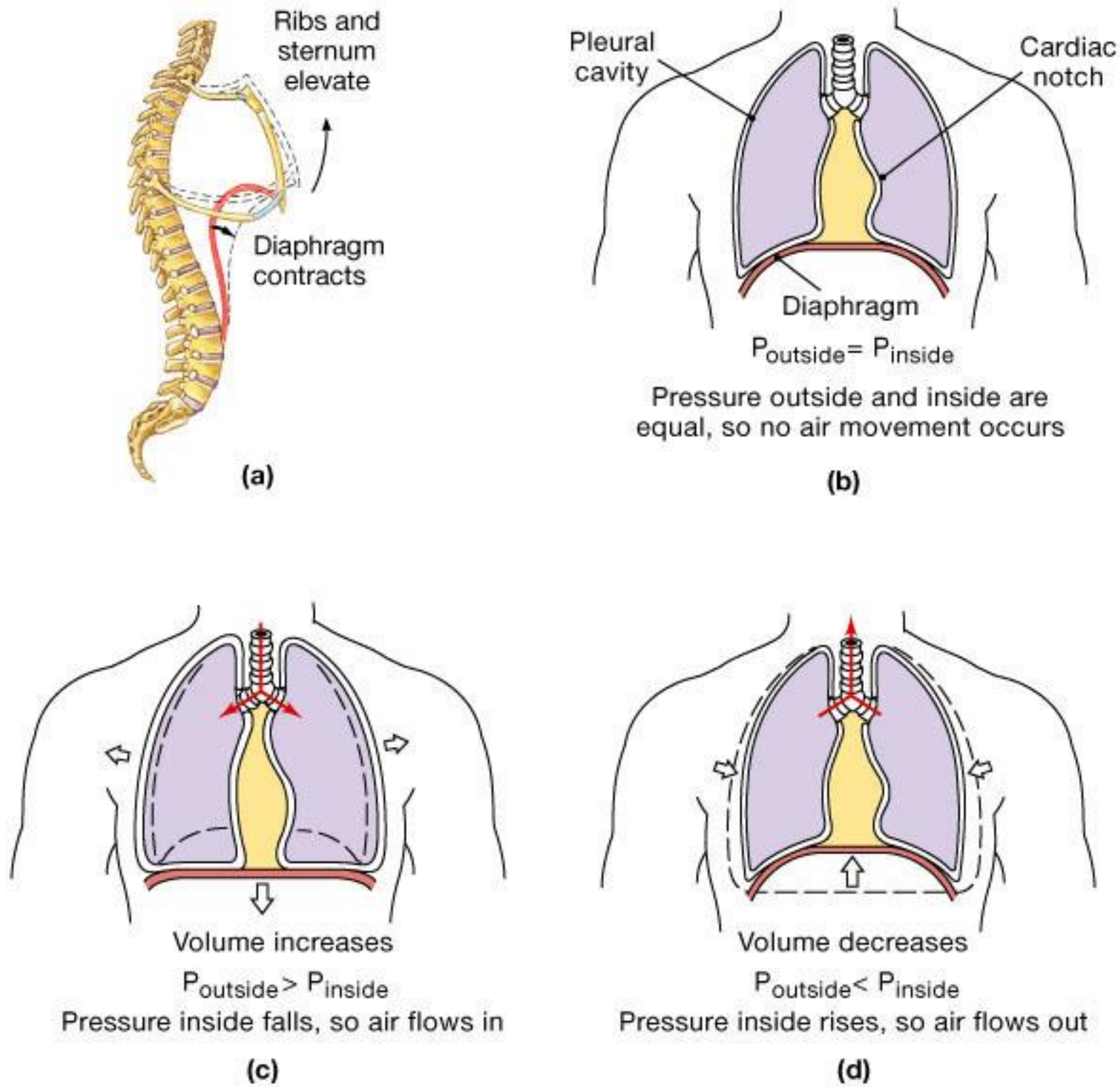
- **<u>Inspiration</u>**
- Diaphragm contracts -> increased thoracic volume **vertically.**
- Intercostals contract, expanding rib cage -> increased thoracic volume **laterally.**
- **Active**

- More volume -> lowered pressure -> air in.
- (Negative pressure breathing.)

Expiration

- **<u>Expiration</u>**
  - Due to recoil of elastic lungs.
  - **Passive**.
  - Less volume -> pressure within alveoli is above atmospheric pressure -> air leaves lungs.
  - Note: Residual volume of air is always left behind, so alveoli do not collapse.

Mechanisms of Pulmonary Ventilation

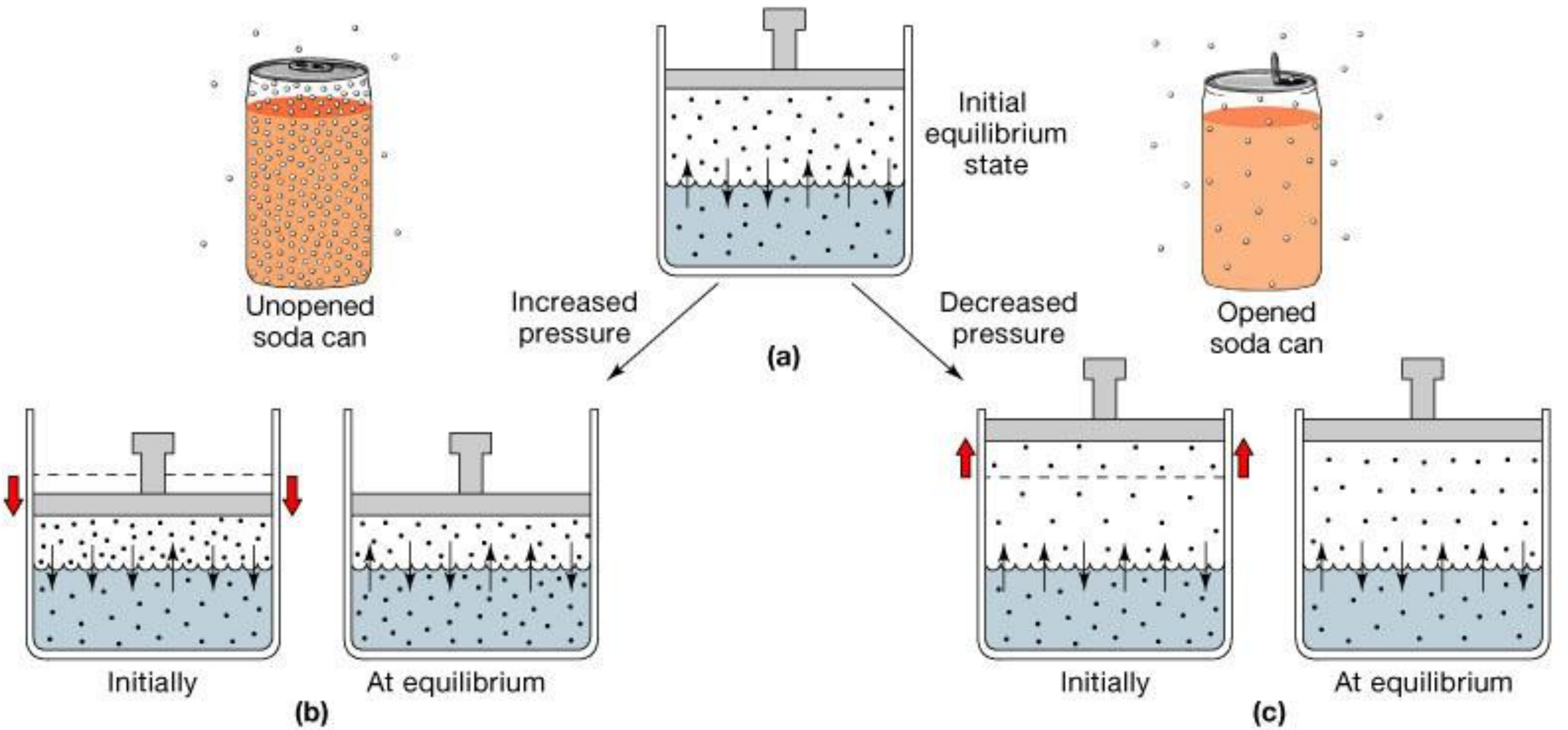


Gas Exchange

The gas laws

- Daltons Law and partial pressure
  - Individual gases in a mixture exert pressure proportional to their abundance
- Diffusion between liquid and gases (Henry's law)
  - The amount of gas in solution is directly proportional to their partial pressure

Henry's Law and the Relationship between Solubility and Pressure

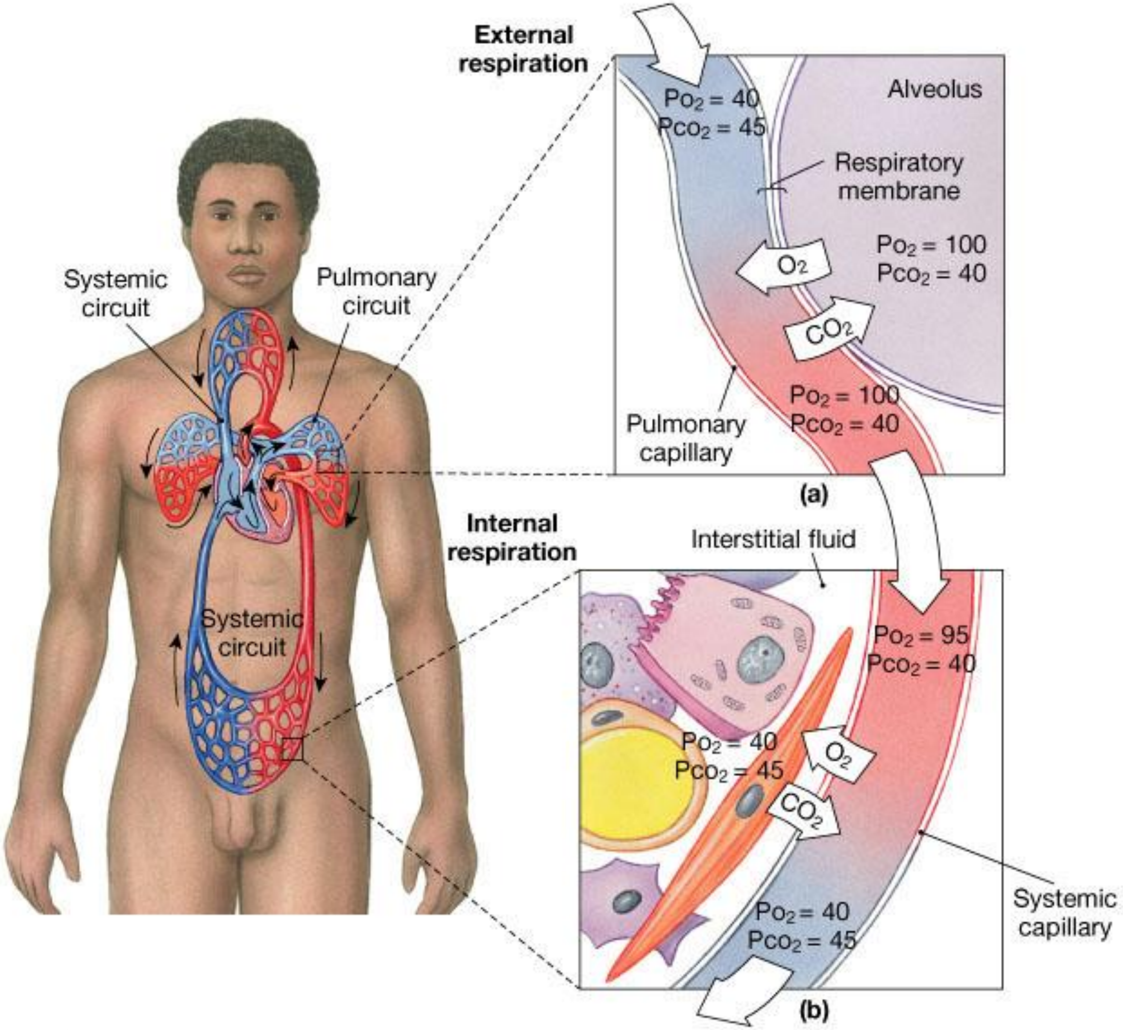


Diffusion and respiratory function

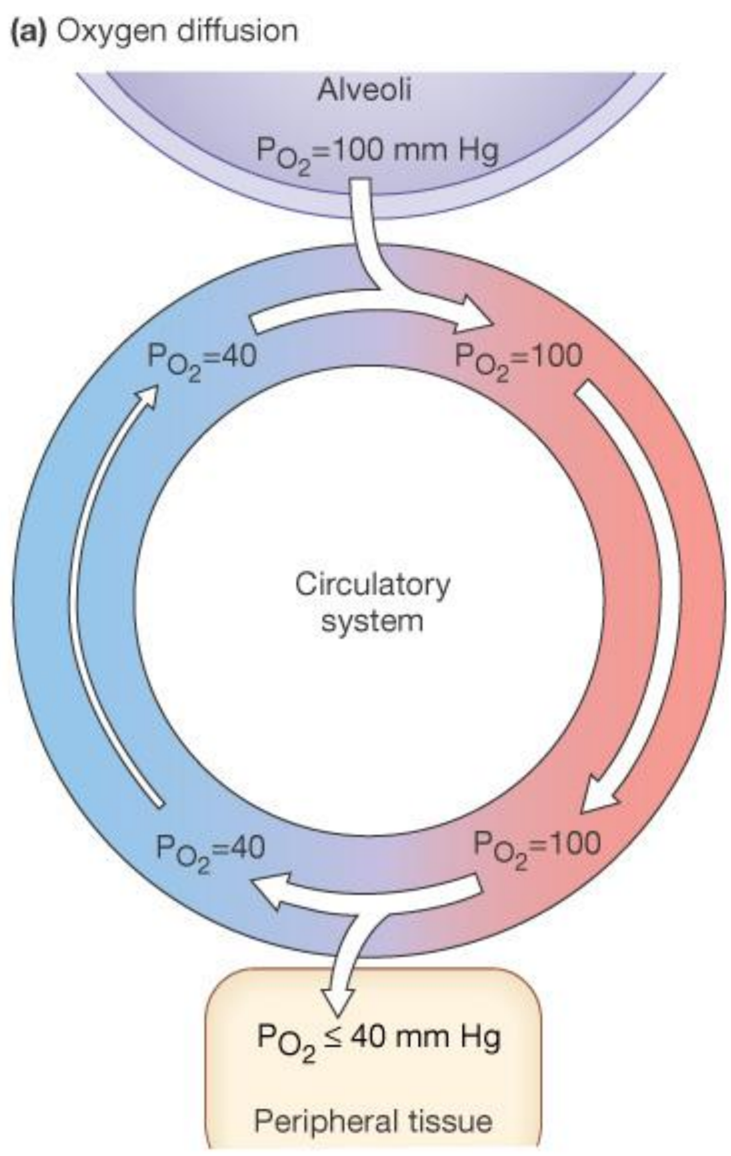
- **Gas exchange across respiratory membrane is efficient due to:**
  - Differences in partial pressure
  - Small diffusion distance
  - Lipid-soluble gases
  - Large surface area of all alveoli
  - Coordination of blood flow and airflow

Gas Pickup and Delivery

An Overview of Respiratory Processes and Partial Pressures in Respiration

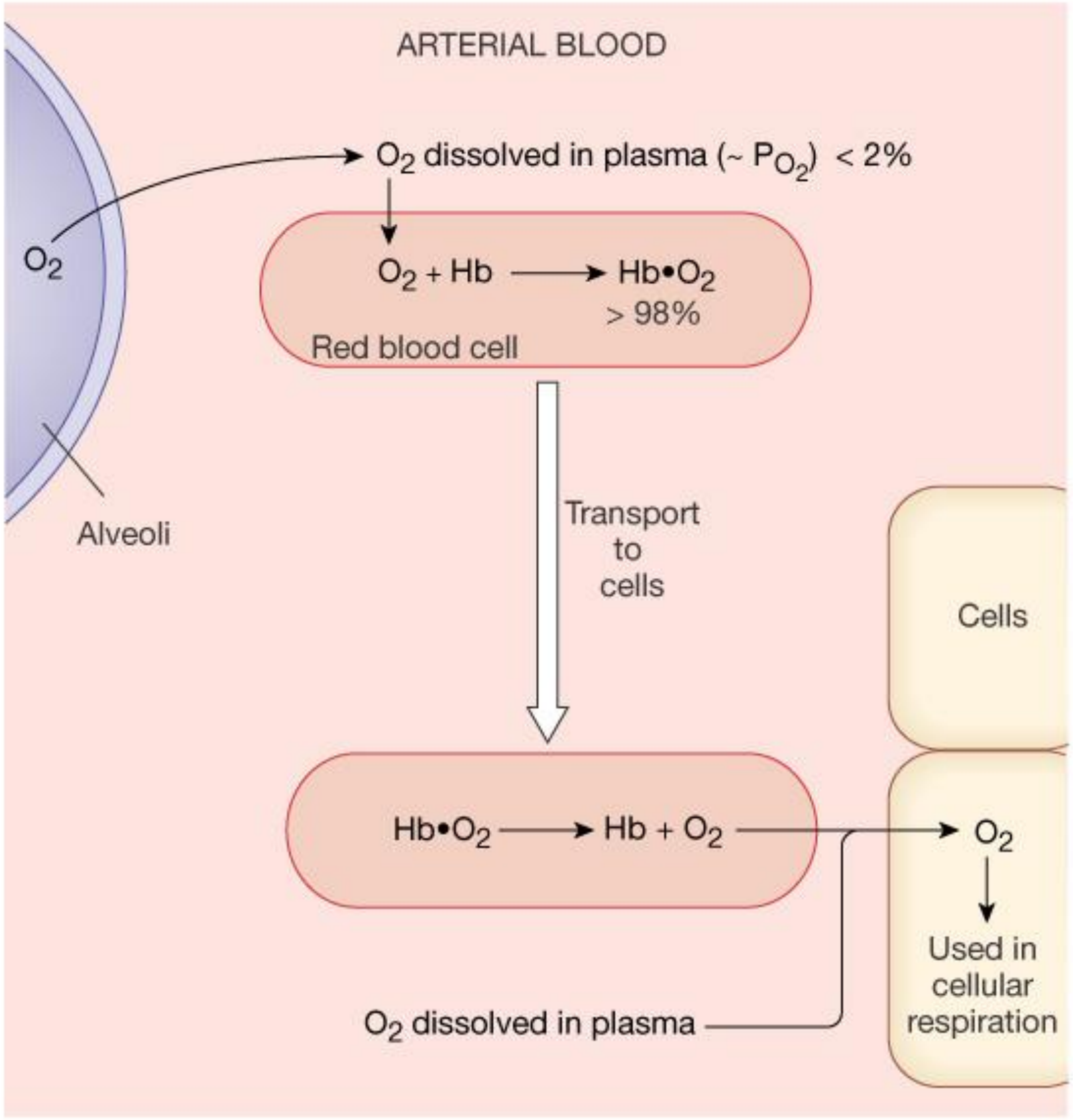


Gas Exchange in the Lungs and Tissues: Oxygen



Gas Transport in the Blood: Oxygen

- 2% in plasma
- 98% in hemoglobin (Hb)
- Blood holds O_2 reserve



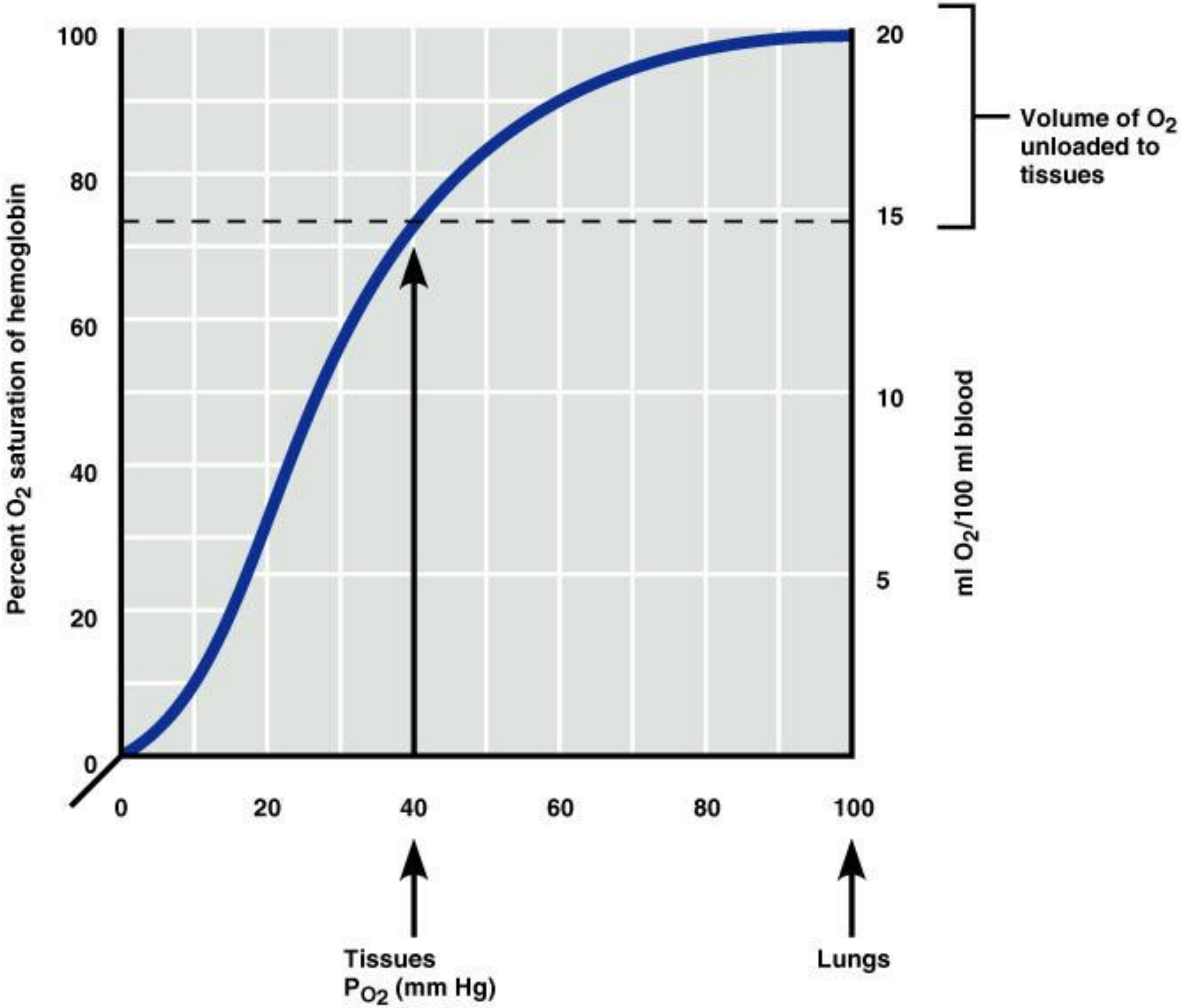
Oxygen transport

- Carried mainly by RBCs, bound to hemoglobin
- The amount of oxygen hemoglobin can carried is dependent upon:
  - P_{O2}
  - pH
  - temperature
  - DPG
- Fetal hemoglobin has a higher O_2 affinity than adult hemoglobin

Hemoglobin Transport of Oxygen

- 4 binding sites per Hb molecule
- 98% saturated in alveolar arteries
- Resting cell P_{O2} = 40 mmHg
- Working cell P_{O2} = 20 mmHg
- More unloaded with more need
- 75% in reserve at normal activity

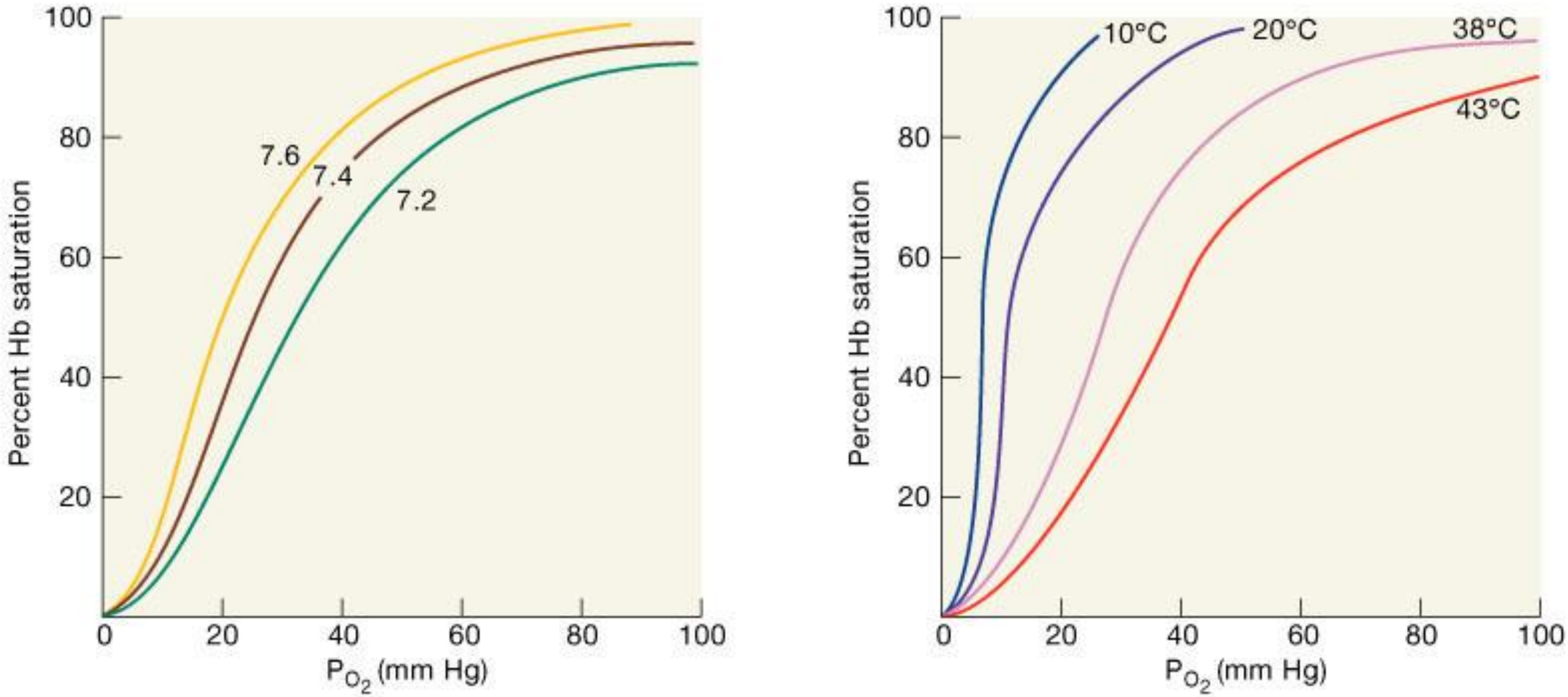
Hemoglobin Saturation Curve



Factors Influencing Hemoglobin Saturation

- Temperature, pH, P_{CO_2}, and DPG
  - Increase of temperature, P_{CO_2}, and DPG and decrease of pH :
    - Decrease hemoglobin's affinity for oxygen
    - Enhance oxygen unloading from the blood
  - Decreases of temperature, P_{CO_2}, and DPG and the increase of pH act in the opposite manner
- These parameters are all high in systemic capillaries where oxygen unloading is the goal

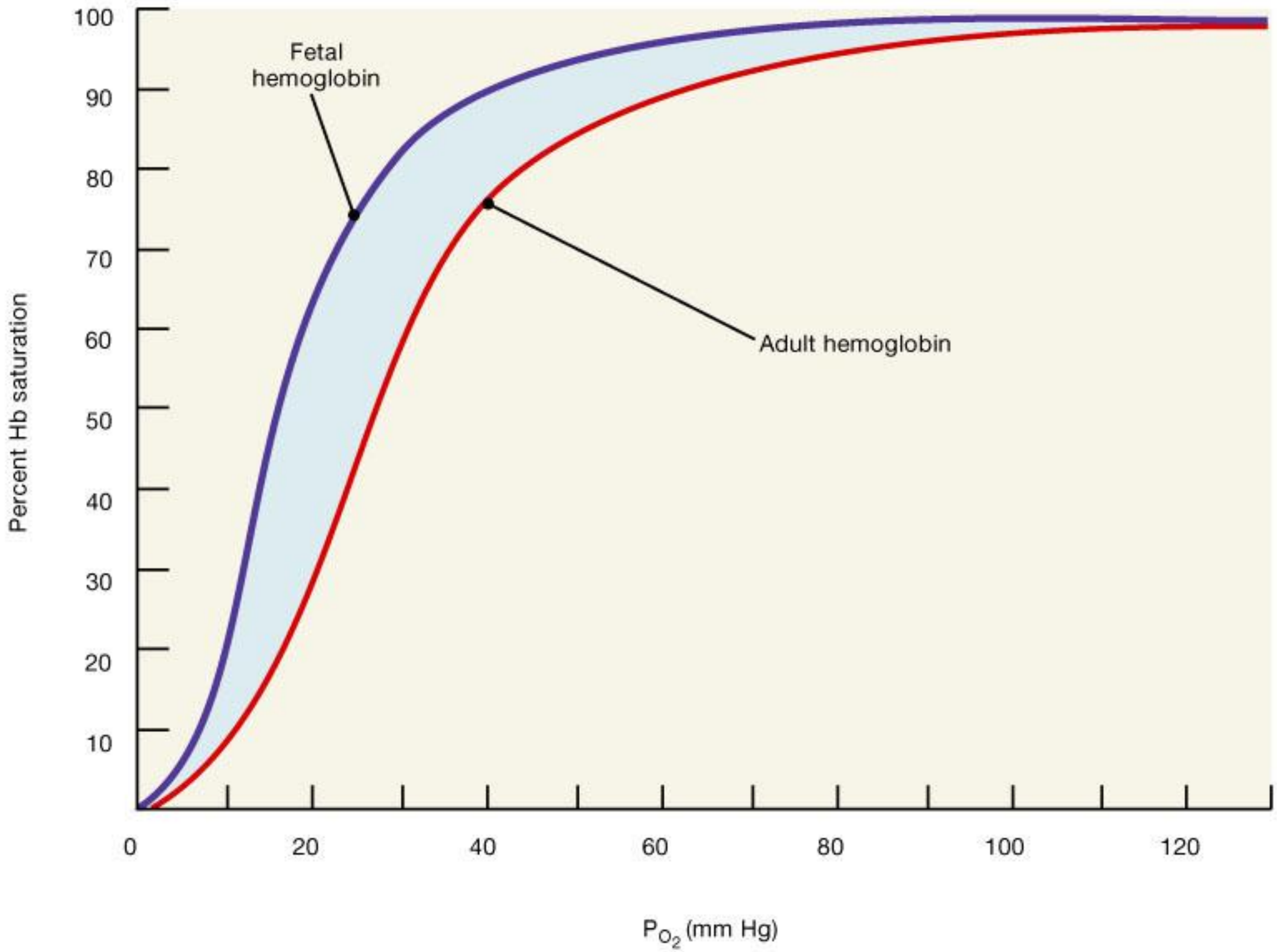
The Effect of pH and Temperature on Hemoglobin Saturation



(a) Effect of pH

(b) Effect of temperature

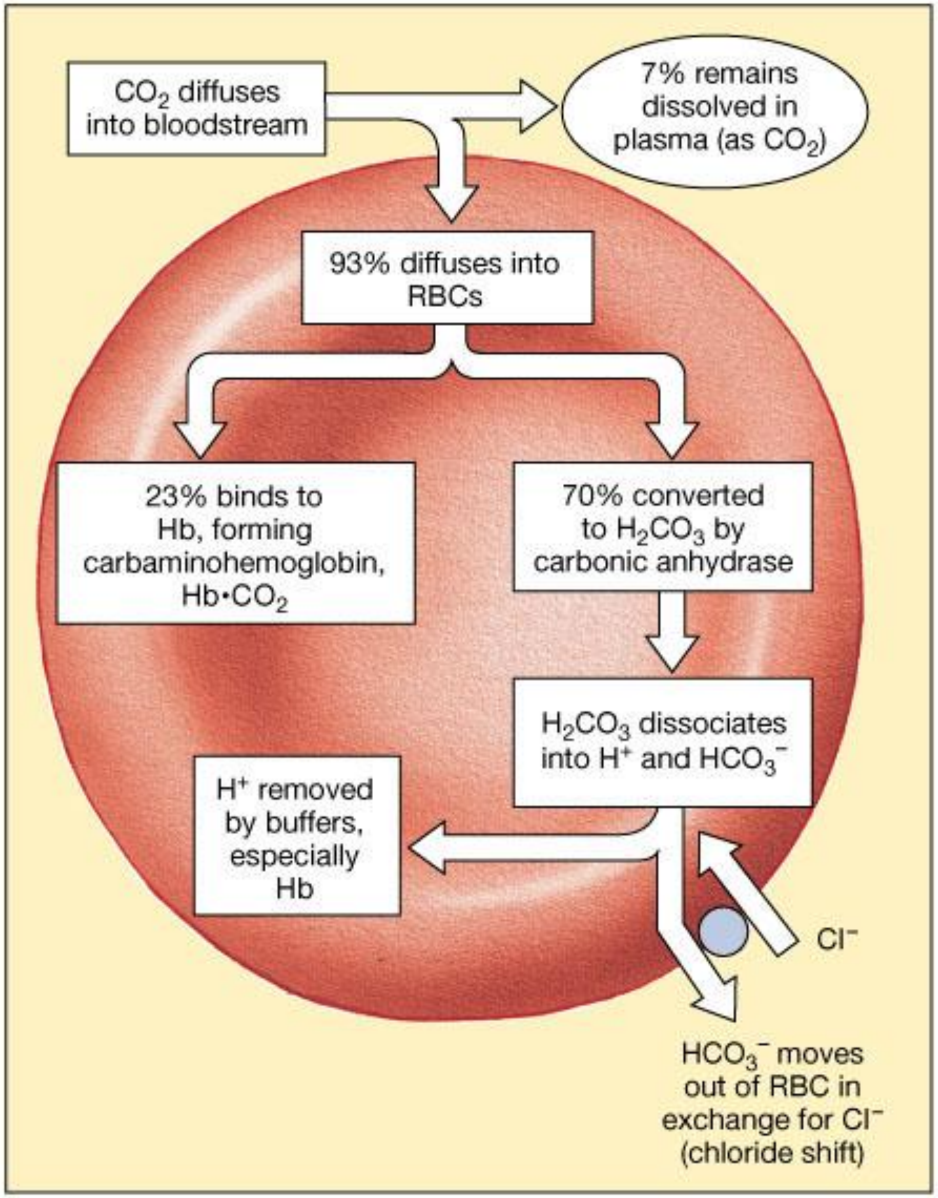
A Functional Comparison of Fetal and Adult Hemoglobin



Carbon dioxide transport

- 7% dissolved in plasma
- 70% carried as carbonic acid
  - buffer system
- 23% bound to hemoglobin
  - carbaminohemoglobin
- Plasma transport

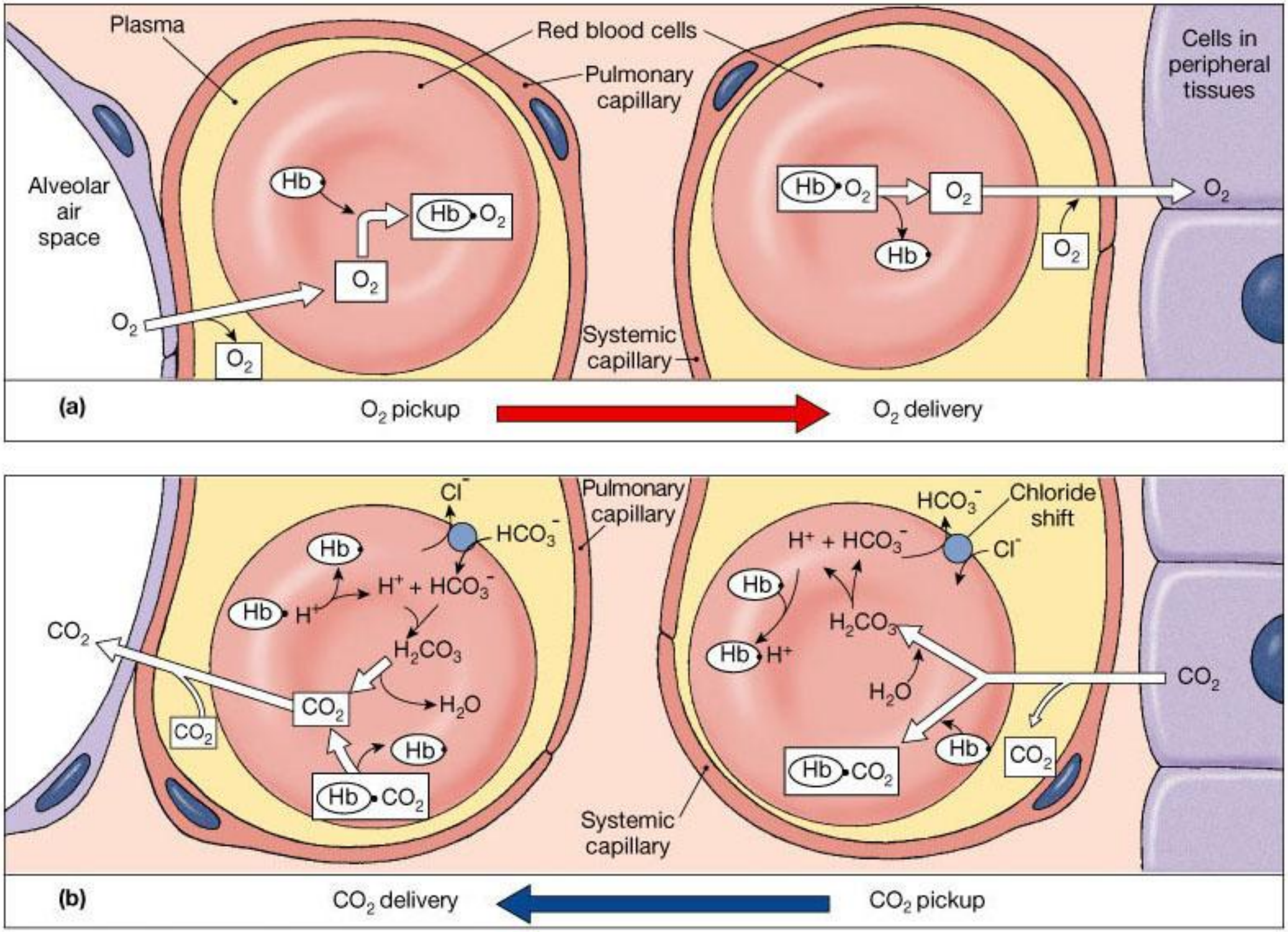
Carbon Dioxide Transport in Blood



Summary of gas transport

- Driven by differences in partial pressure
- Oxygen enters blood at lungs and leaves at tissues
- Carbon dioxide enters at tissues and leaves at lungs

A Summary of the Primary Gas Transport Mechanisms



Control of Respiration

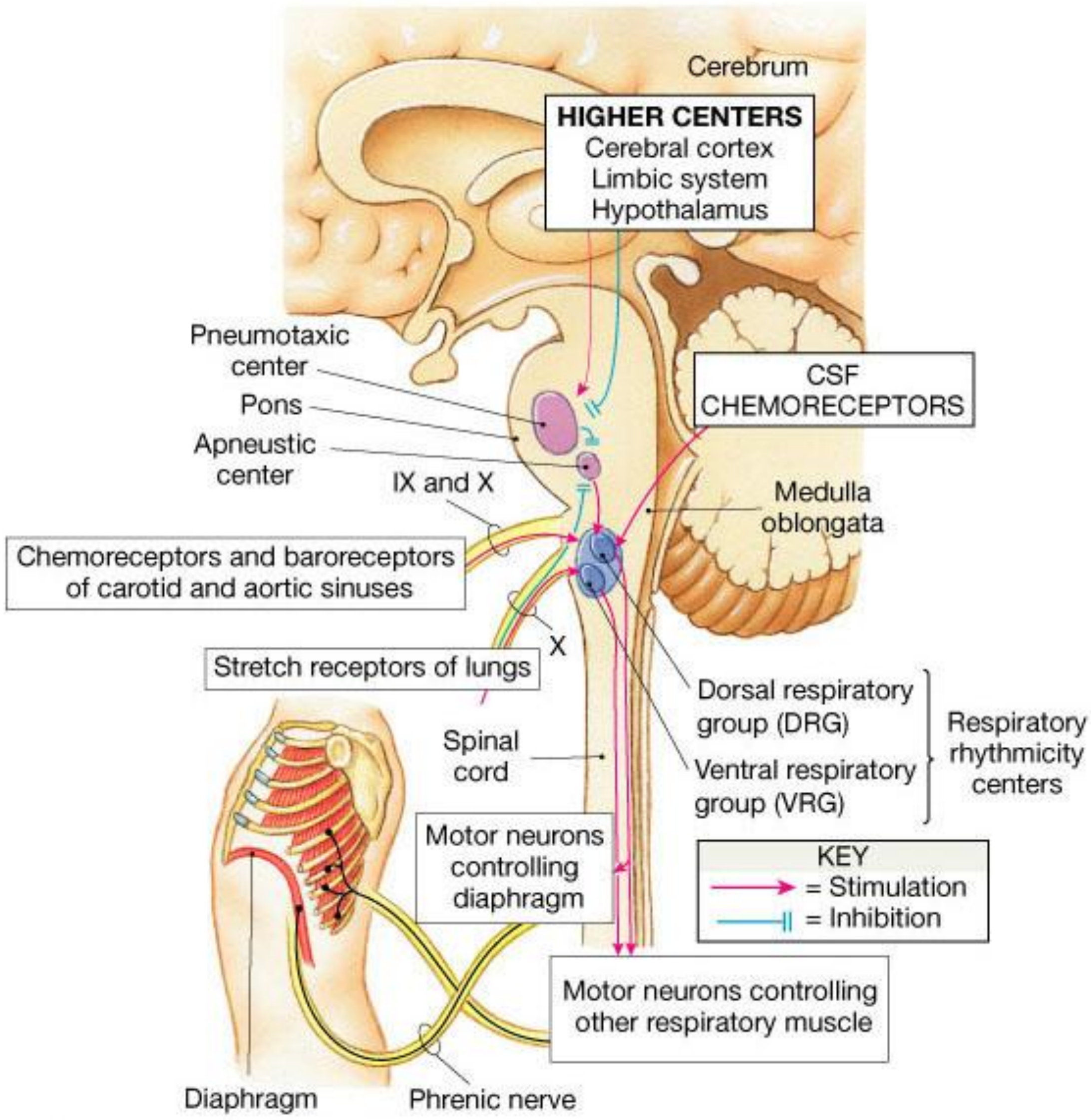
Respiratory centers of the brain

- Medullary centers
  - Respiratory rhythmicity centers set pace
- Dorsal respiratory group (DRG)– inspiration
- Ventral respiratory group (VRG)– forced breathing

Respiratory centers of the brain

- Pons
  - Apneustic and pneumotaxic centers:
    - regulate the respiratory rate and the depth of respiration in response to sensory stimuli or input from other centers in the brain

Respiratory Centers and Reflex Controls



Chemoreceptors

- Chemoreceptors are located throughout the body (in brain and arteries).

  - **chemoreceptors** are more sensitive to changes in P_{CO_2} (as sensed through changes in pH).

- Ventilation is adjusted to maintain **arterial PCo_2** of 40 mm Hg.

Medullary Respiratory Centers