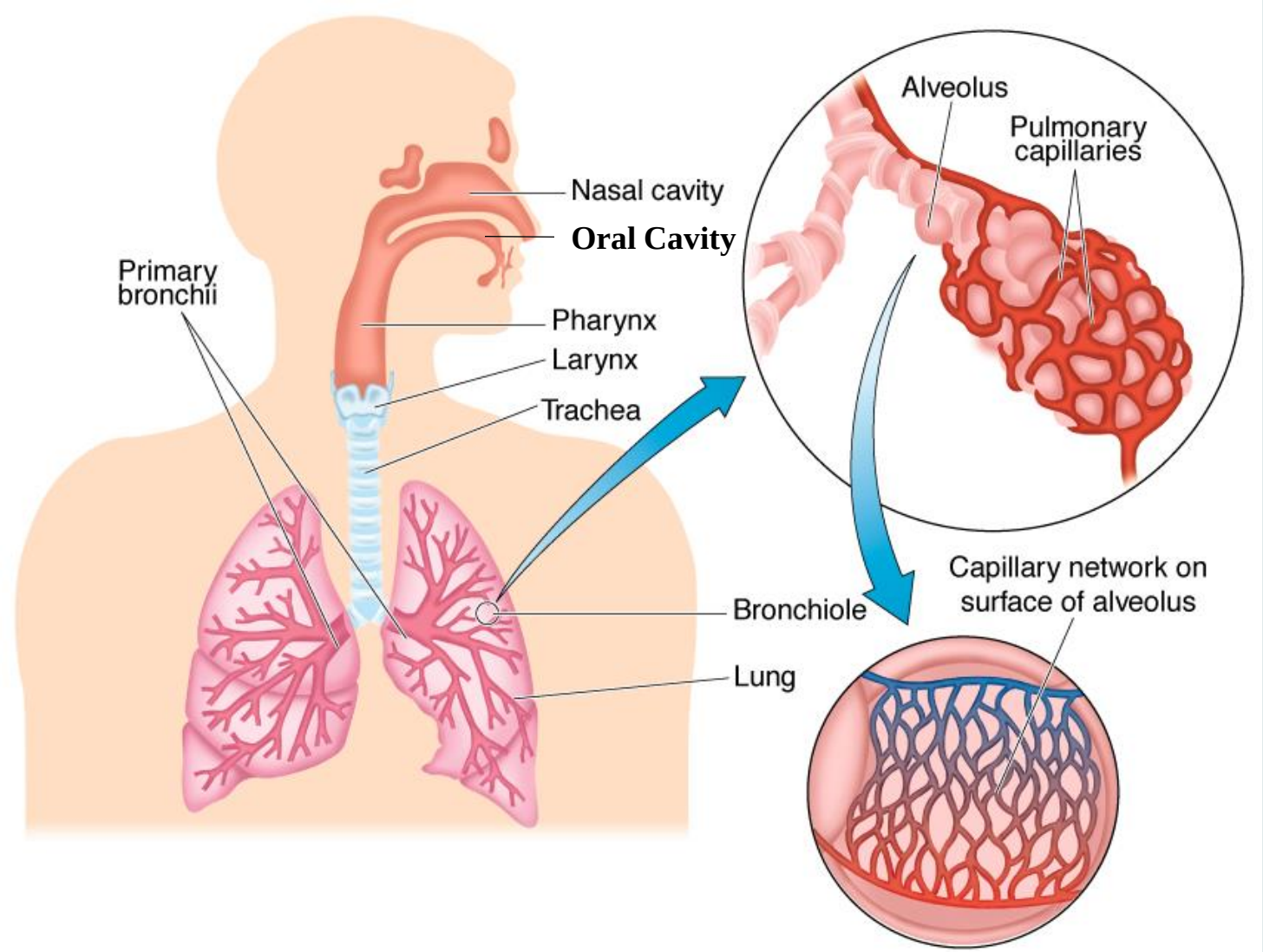
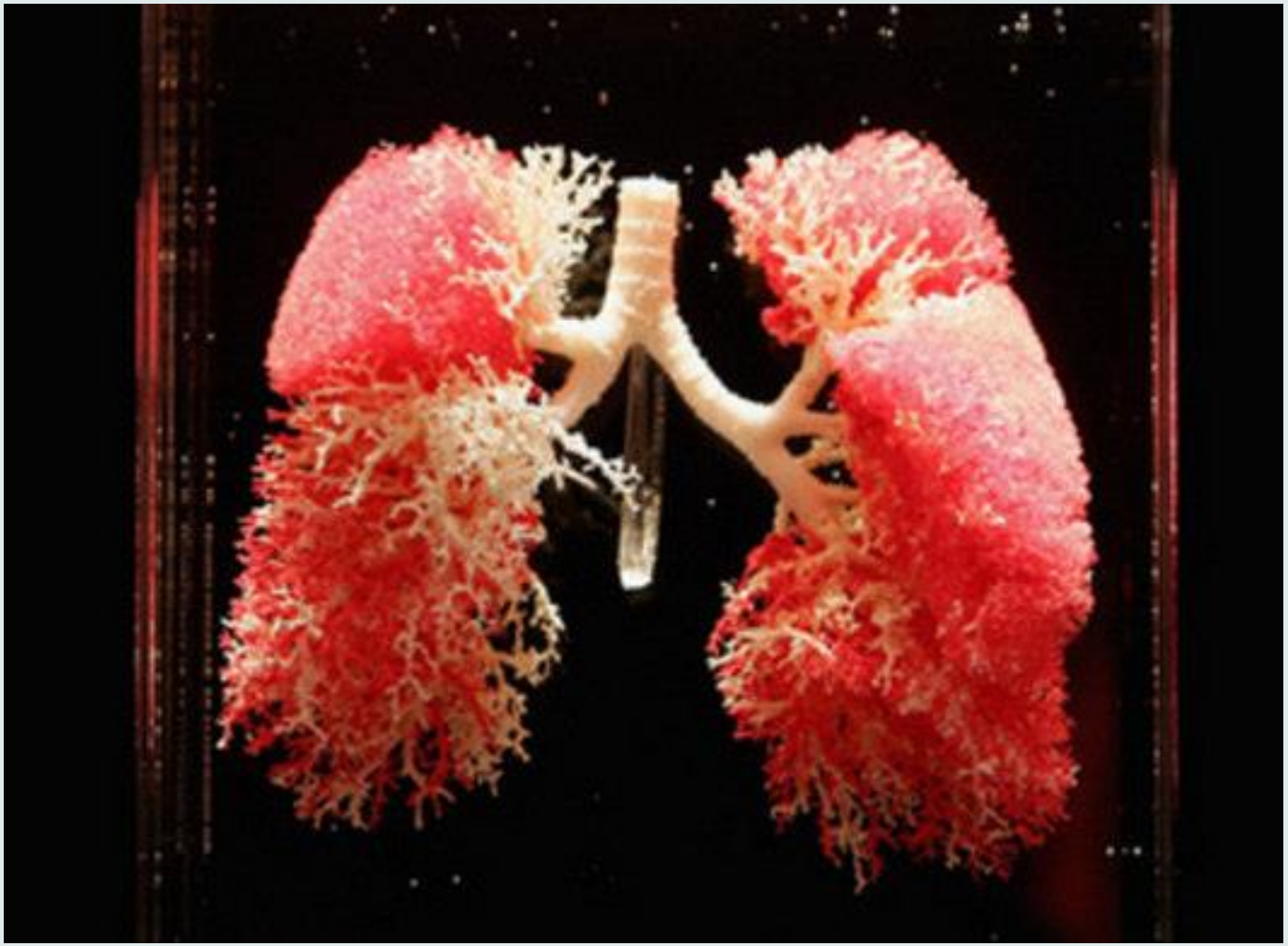
Pulmonary Structure and Function

Anatomy of Ventilation



Lungs



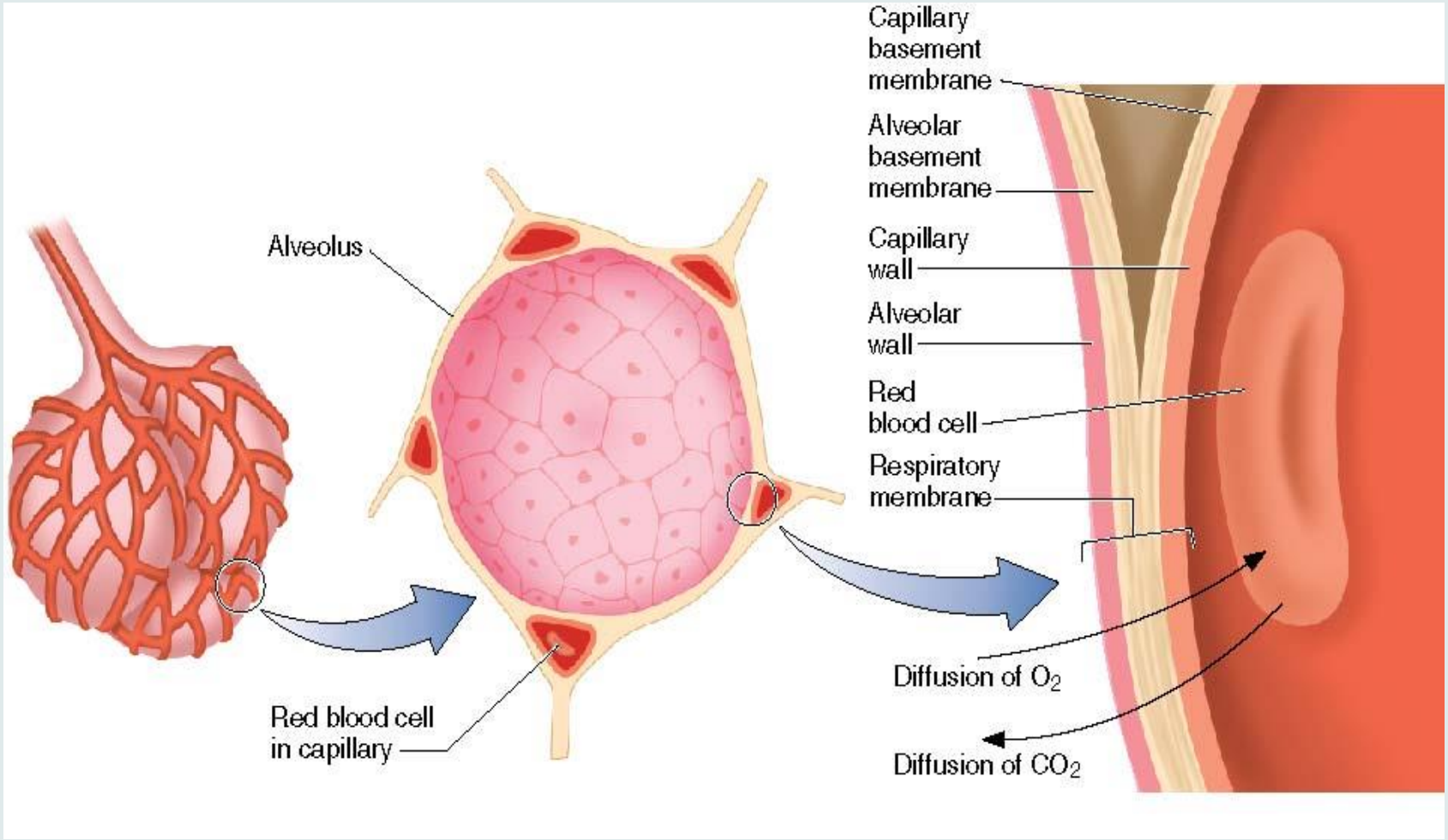
Lungs

- Lungs provide the gas exchange surface that separates blood from the surrounding alveolar gaseous environment
- Oxygen transfers from alveolar air into alveolar capillary blood while the blood's carbon dioxide moves into the alveoli and then into ambient air
- An average-sized adult's lungs weigh approximately 1 kg, and has a volume of 4-6 L
- If spread out the lung would have a surface area of 50 – 100m^2

The Alveoli

- More than 600 million alveoli, approximately 0.3mm in diameter
- Receive the largest blood supply of all the organs
- Capillaries and alveoli lie side by side with the thinnest surface possible to facilitate rapid exchange of gases
- Pores of Kohn disperse surfactant over respiratory membranes to reduce surface tension for easier alveolar inflation
- Pores of Kohn also allow for gas interchange between adjacent alveoli.

Respiratory Membrane



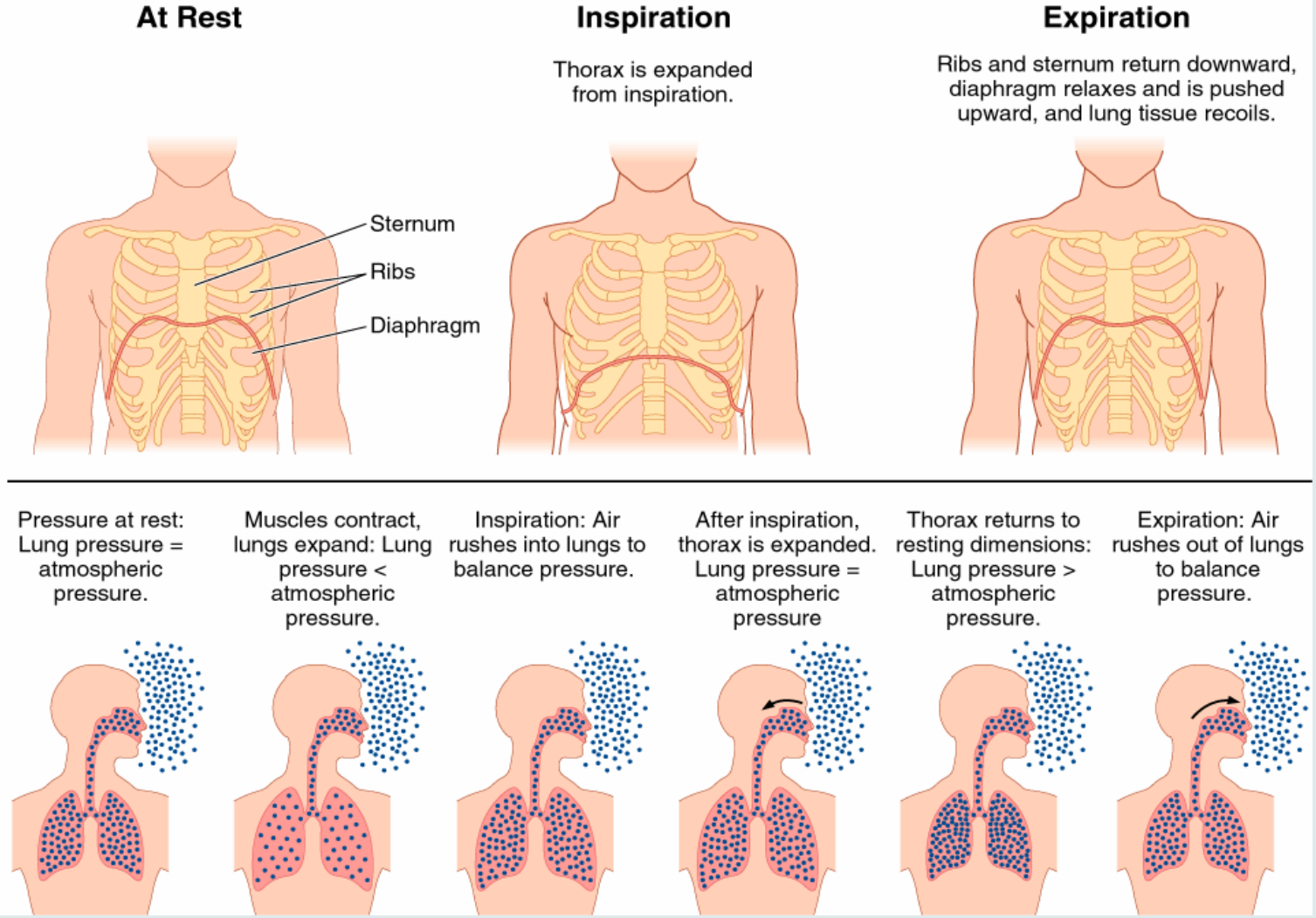
Fick's Law

- Fick's law governs gas exchange rate through the alveolar membranes:
  - Gases diffuse through a tissue at a rate proportional to surface area, pressure differential, and inversely proportional to its thickness.
- In the alveoli, gas pressure rapidly equilibrates on either side of the alveolar-capillary membrane by a process of diffusion.

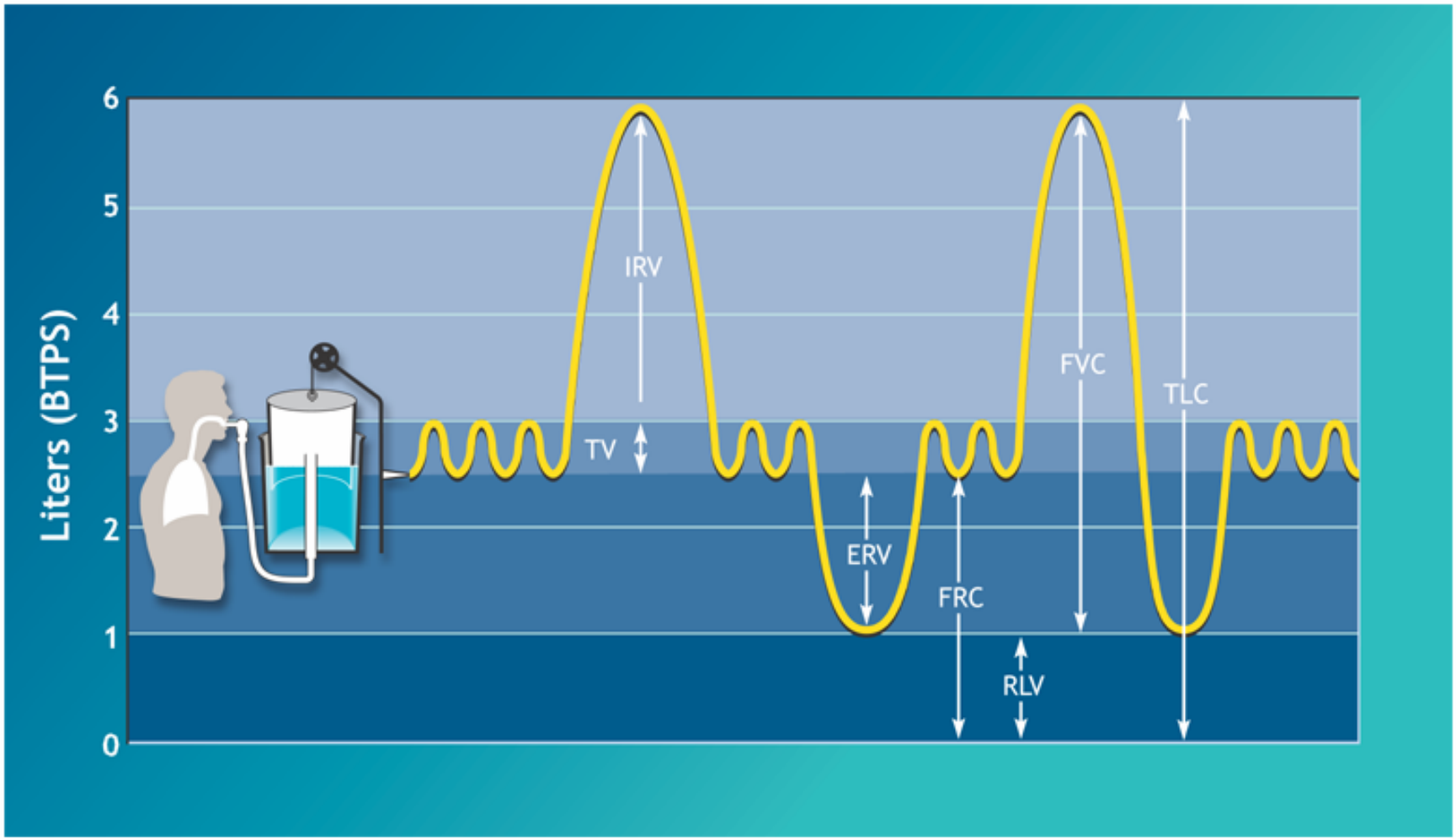
Stages of Respiration

- Pulmonary ventilation
  - Process of air moving in and out of the lungs
- Pulmonary Diffusion
  - Process of moving O_2 from the lungs into the blood and CO_2 from the blood into the lungs
- Transport of O_2 and CO_2 via the blood
- Capillary diffusion
  - Process of exchanging O_2 and CO_2 between the capillary blood and the metabolically active tissue

Pulmonary Ventilation



Lung Volumes & Capacities



Lung Volumes & Capacities

Lung volume/capacity	Definition	Average values (mL) Men	Women
Tidal Volume (TV)	Volume inspired or expired per breath	600	500
Inspiratory Reserve Volume (IRV)	Maximum inspiration at end of tidal inspiration	3000	1900
Expiratory Reserve Volume (ERV)	Maxium expiration at end of tidal expiration	1200	800
Total Lung Capacity (TLC)	Volume in lungs after maximum inspiration	6000	4200
Residual Lung Volume (RLV)	Volume in lungs after maximum expiration	1200	1000
Forced Vital Capacity (FVC)	Maximum volume expired after maximum inspiration	4800	3200
Inspiratory Capacity (IC)	Maximum volume inspired following tidal expiration	3600	2400
Functional Residual Capacity (FRC)	Volume in lungs after tidal expiration	2400	1800

Residual Lung Volume

- RLV allows an uninterrupted exchange of gases between the alveoli and blood
- RLV increases with age with a proportional decrease in IRV and ERV
- Age related increase in RLV can be lessened with regular aerobic exercise
- RLV temporarily increases following an acute bout of exercise

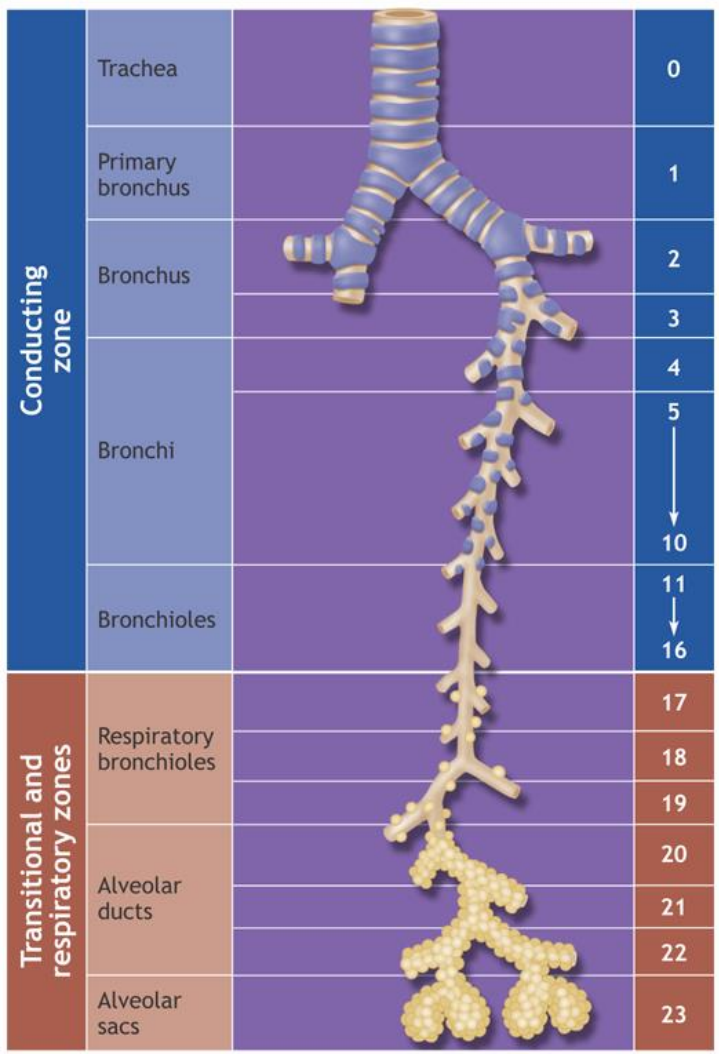
Dynamic Lung Volumes

- Dynamic ventilation depends upon
  - Maximal FVC of lungs
  - Velocity of flow
- Velocity of flow is influenced by lung compliance and resistance to flow.

Minute Ventilation

- Minute ventilation
  - Volume of air breathed each minute $\dot{V}_E$
  - TV x Number of breaths per minute (fB)
- Minute ventilation increases dramatically during exercise.
  - Approximately 6 – 12 L.min^{-1} at rest
  - Average person ~ 100 L.min^{-1} at maximal exercise
  - Values up to 200 L.min^{-1} have been reported
- Despite huge $\dot{V}_E$, TVs rarely exceed 60% FVC.

Alveolar Ventilation



Alveolar Ventilation

- Conducting Zone = Anatomic dead space
  - Averages ~ 150 – 200 mL
- At rest only ~ 350 mL of the 500 mL TV enters alveoli with each respiratory cycle.

Dead Space and Tidal Volume

- Anatomic dead space only increases slightly as TV increases.
- Despite the slight increase in dead space, increases in TV result in more effective alveolar ventilation.
- Increased depth of breathing is more effective than increased rate of breathing.

Dead Space and Tidal Volume

- Example 1: Increasing breathing frequency
  - $\dot{\mathbf{V}}_{\mathbf{E}}$ = 50 L.min^{-1}
  - TV = 500 mL, *f*B = 100 breaths per minute
  - Alveolar ventilation = 35,000 mL.min^{-1}
- Example 2: Increasing breathing depth
  - $\dot{\mathbf{V}}_{\mathbf{E}}$ = 50 L.min^{-1}
  - TV = 1,000 mL, *f*B = 50 breaths per minute
  - Alveolar ventilation = 42,500 mL.min^{-1}

FEV – to – FVC Ratio

- FEV_1/FVC indicates pulmonary airflow capacity.
- Healthy people average ~ 85% of FVC in one second.
- Obstructive diseases result in significantly lower FEV_1/FVC.
- The delineation point for airway obstruction is equal to 70% or less.

Maximum Voluntary Ventilation

- MVV evaluates ventilatory capacity with rapid and deep breathing for 15 seconds.
  - MVV = 15 second volume × 4
- MVV in healthy individuals averages 20 - 25% more than ventilation that occurs during maximal exercise.