Pulmonary ventilation revision

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Pulmonary Ventilation Revision Q

- 1. Which of the following lung volumes or capacities can be measured by spirometry?

- (A) Functional residual capacity (FRC)
- (B) Physiologic dead space
- (C) Residual volume (RV)
- (D) Total lung capacity (TLC)
- (E) Vital capacity (VC)

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- 2. An infant born prematurely in gestational week 25 has neonatal respiratory distress syndrome. Which of the following would be expected in this infant?

- (A) Arterial PO_2 of 100 mm Hg
- (B) Collapse of the small alveoli
- (C) Increased lung compliance
- (D) Normal breathing rate
- (E) Lecithin:sphingomyelin ratio of greater than 2:1 in amniotic fluid

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- 3. A 12-year-old boy has a severe asthmatic attack with wheezing. He experiences rapid breathing and becomes cyanotic. His arterial PO_2 is 60 mm Hg and his PCO_2 is 30 mm Hg. To treat this patient, the physician should administer

- (A) an α1-adrenergic antagonist
- (B) a β1-adrenergic antagonist
- (C) a β2-adrenergic agonist
- (D) a muscarinic agonist
- (E) a nicotinic agonist

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- 4. Which of the following is true during inspiration?

- (A) Intrapleural pressure is positive
- (B) The volume in the lungs is less than the functional residual capacity (FRC)
- (C) Alveolar pressure equals atmospheric pressure
- (D) Alveolar pressure is higher than atmospheric pressure
- (E) Intrapleural pressure is more negative than it is during expiration

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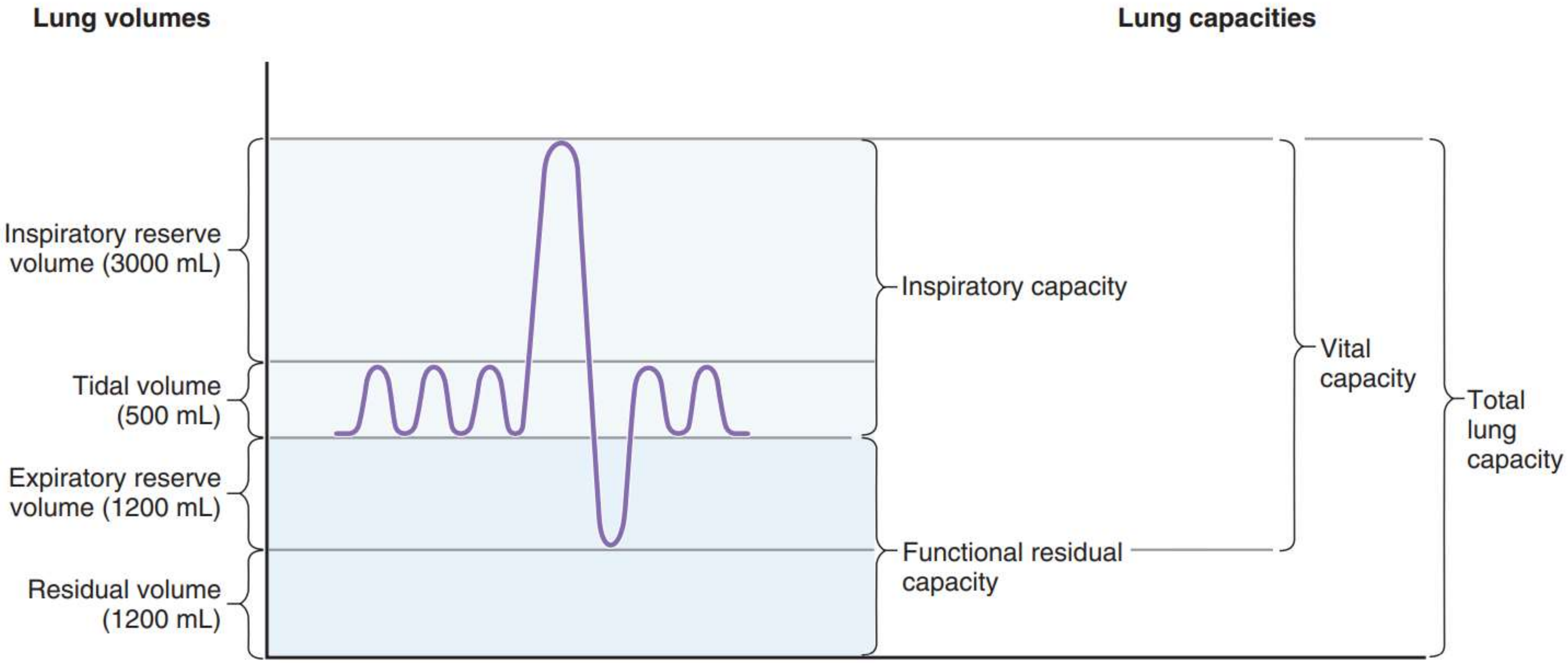
- 5. A 35-year-old man has a vital capacity (VC) of 5 L, a tidal volume (VT) of 0.5 L, an inspiratory capacity of 3.5 L, and a functional residual capacity (FRC) of 2.5 L. What is his expiratory reserve volume (ERV)?

- (A) 4.5 L
- (B) 3.9 L
- (C) 3.6 L
- (D) 3.0 L
- (E) 2.5 L
- (F) 2.0 L
- (G) 1.5 L


Lung volumes
Lung capacities
Inspiratory reserve volume (3000 mL)
Tidal volume (500 mL)
Expiratory reserve volume (1200 mL)
Residual volume (1200 mL)
Inspiratory capacity
Functional residual capacity
Vital capacity
Total lung capacity

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- 6. Which volume remains in the lungs after a tidal volume (VT) is expired?

- (A) Tidal volume (VT)
- (B) Vital capacity (VC)
- (C) Expiratory reserve volume (ERV)
- (D) Residual volume (RV)
- (E) Functional residual capacity (FRC)
- (F) Inspiratory capacity
- (G) Total lung capacity

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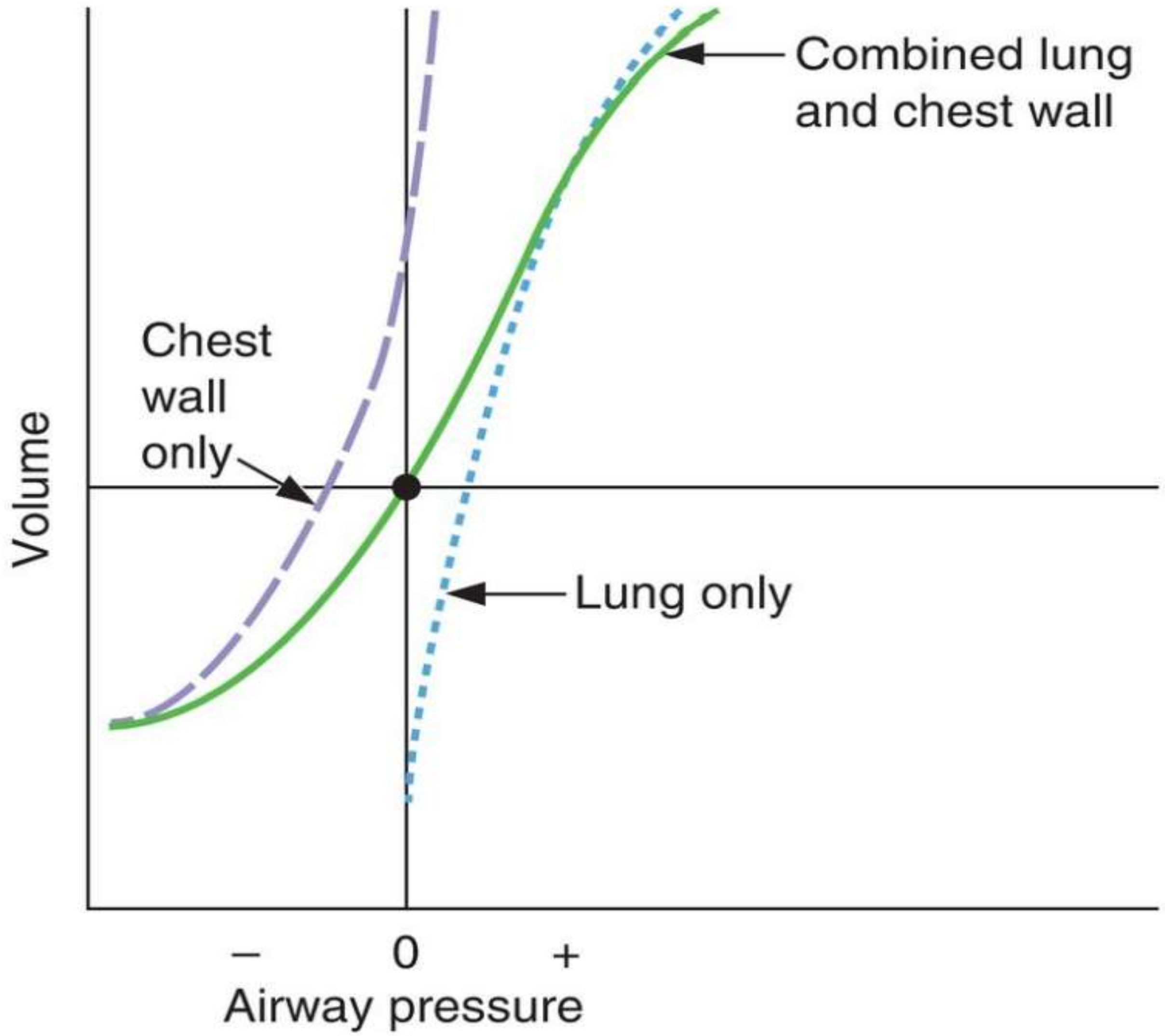
- 7. Which of the following is illustrated in the graph showing volume versus pressure in the lung–chest wall system?



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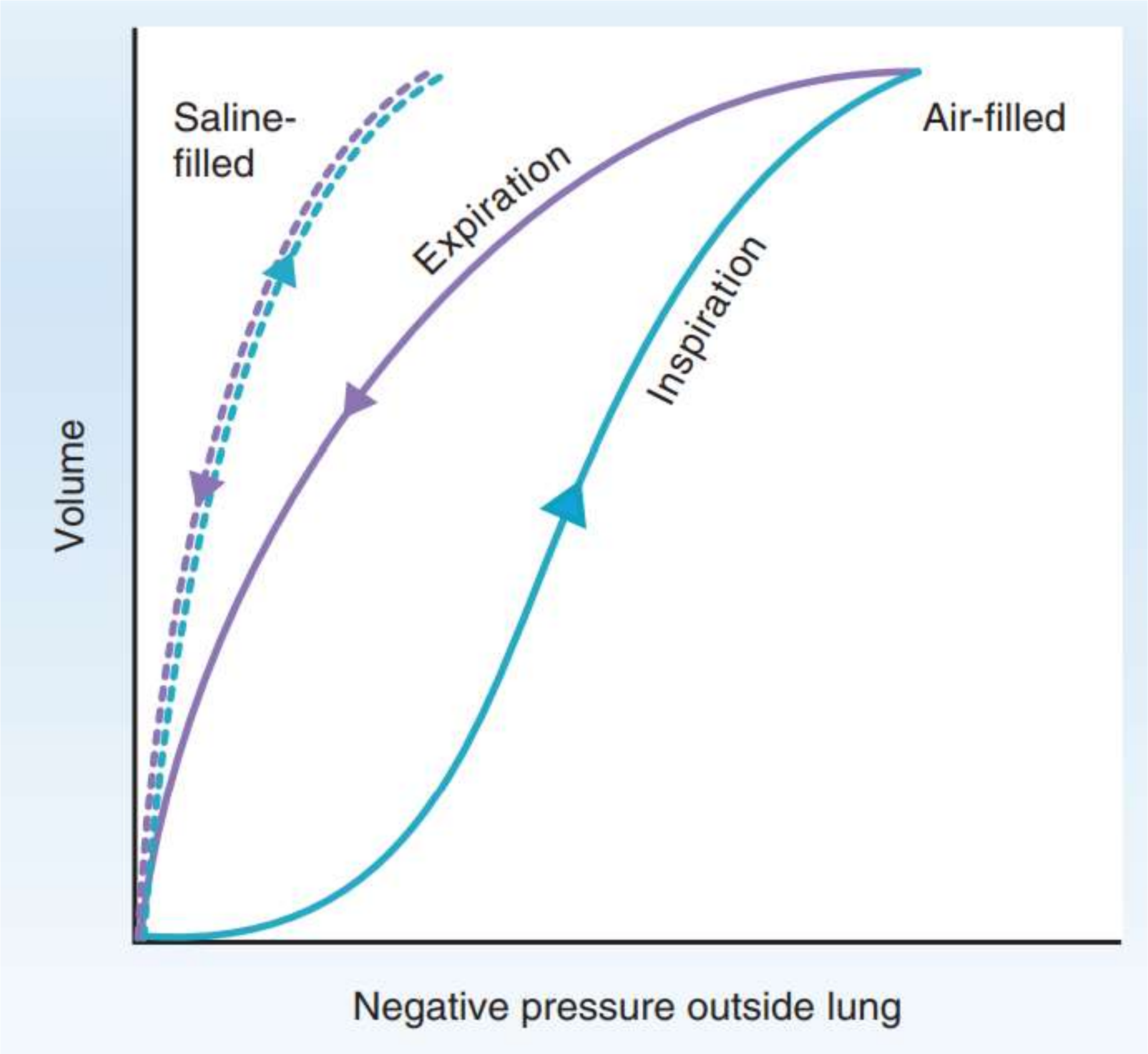
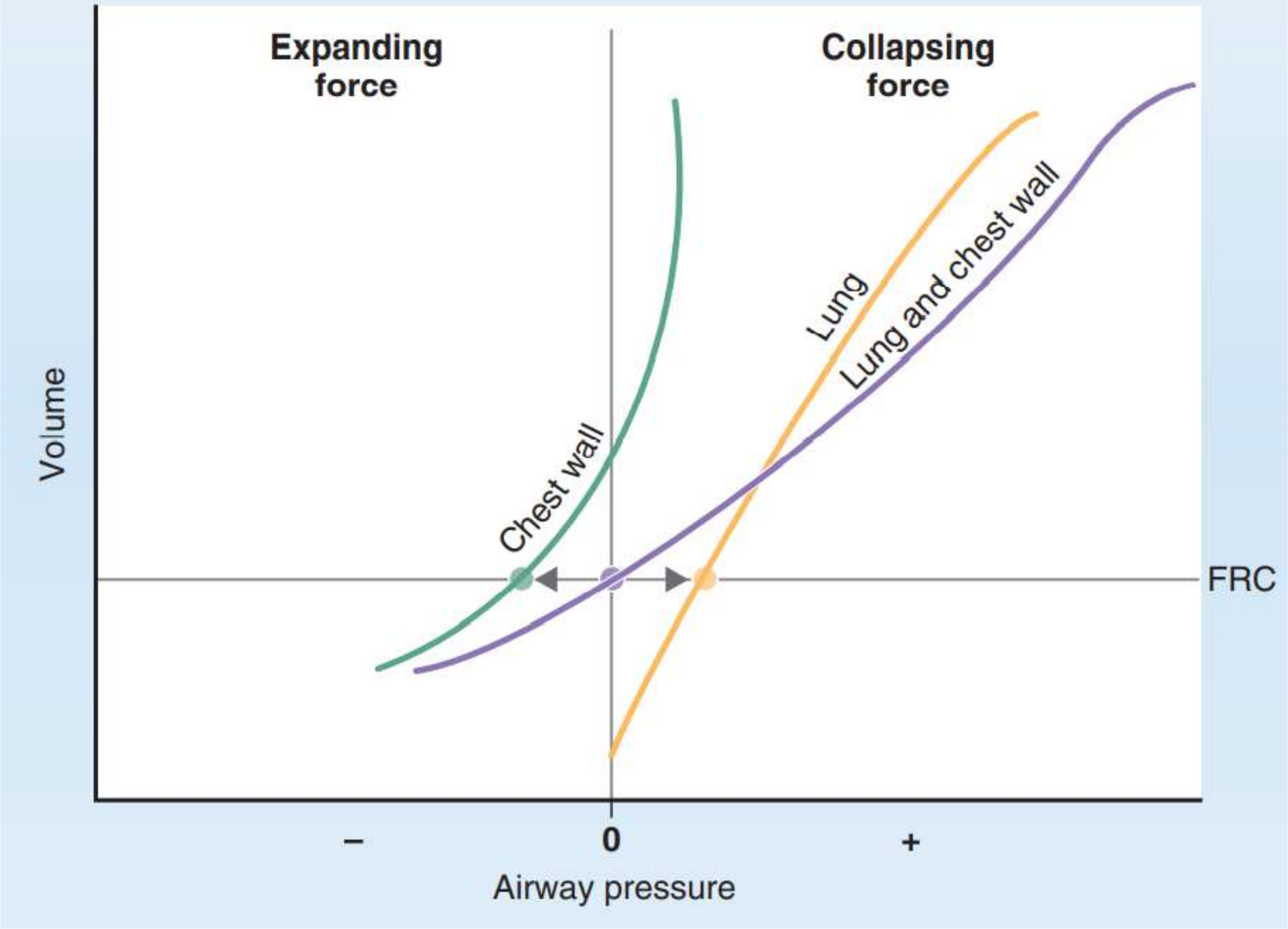
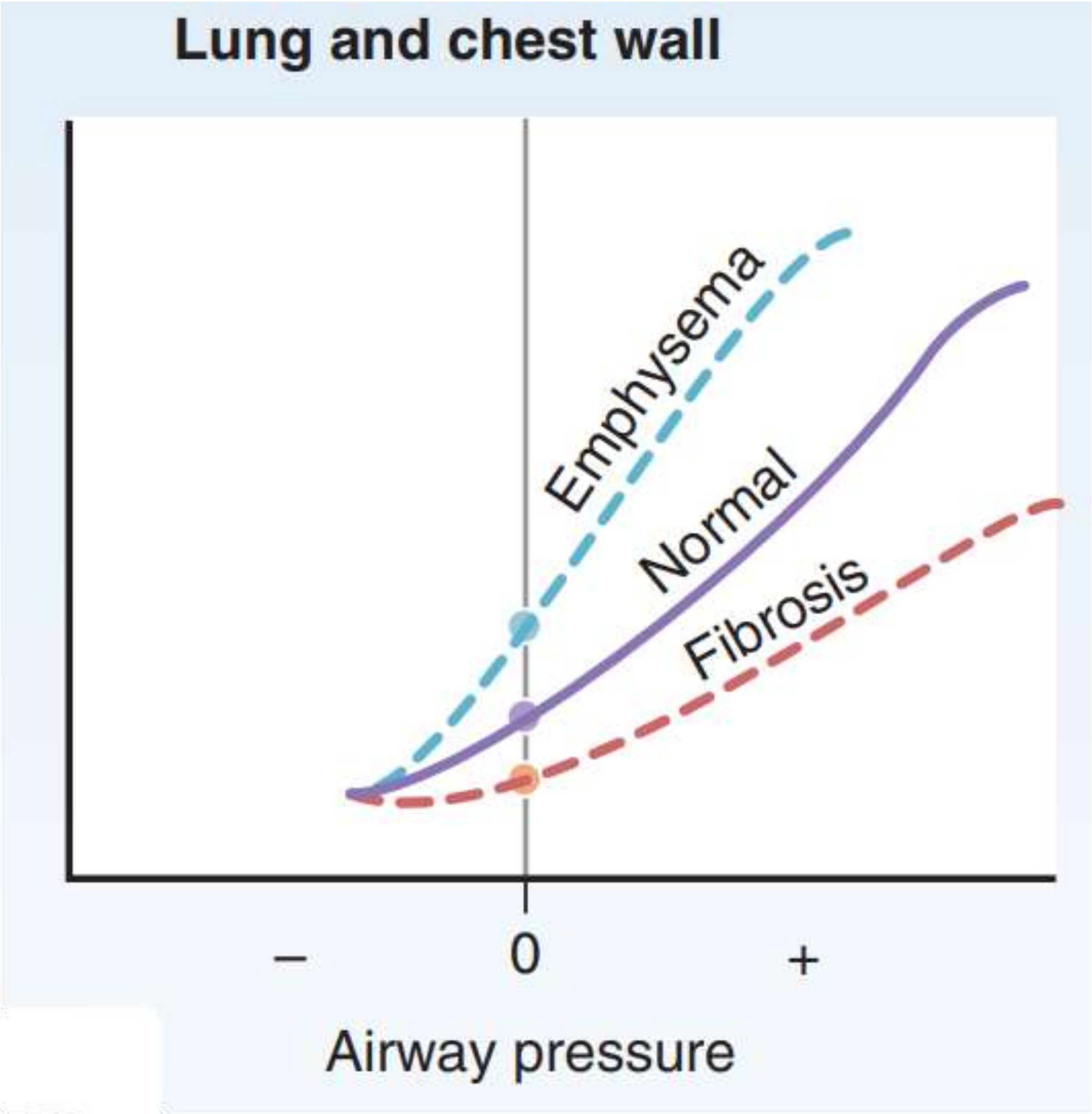
- 7. Which of the following is illustrated in the graph showing volume versus pressure in the lung–chest wall system?

- (A) The slope of each of the curves is resistance
- (B) The compliance of the lungs alone is less than the compliance of the lungs plus chest wall
- (C) The compliance of the chest wall alone is less than the compliance of the lungs plus chest wall
- (D) When airway pressure is zero (atmospheric), the volume of the combined system is the functional residual capacity (FRC)
- (E) When airway pressure is zero (atmospheric), intrapleural pressure is zero

Compliance of the lung




Expanding force
Collapsing force
Chest wall
Lung
Lung and chest wall
FRC
Volume
–
0
+
Airway pressure


Lung and chest wall
Emphysema
Normal
Fibrosis
–
0
+
Airway pressure

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- 8. Which of the following is the site of highest airway resistance?

- (A) Trachea
- (B) Largest bronchi
- (C) Medium-sized bronchi
- (D) Smallest bronchi
- (E) Alveoli

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- 9. Which volume remains in the lungs after a maximal expiration?

- (A) Tidal volume (VT)
- (B) Vital capacity (VC)
- (C) Expiratory reserve volume (ERV)
- (D) Residual volume (RV)
- (E) Functional residual capacity (FRC)
- (F) Inspiratory capacity
- (G) Total lung capacity

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- 10. A healthy 65-year-old man with a tidal volume (VT) of 0.45 L has a breathing frequency of 16 breaths/min. His arterial PCO_2 is 41 mm Hg, and the PCO_2 of his expired air is 35 mm Hg. What is his alveolar ventilation?

- (A) 0.066 L/min
- (B) 0.38 L/min
- (C) 5.0 L/min
- (D) 6.14 L/min
- (E) 8.25 L/min

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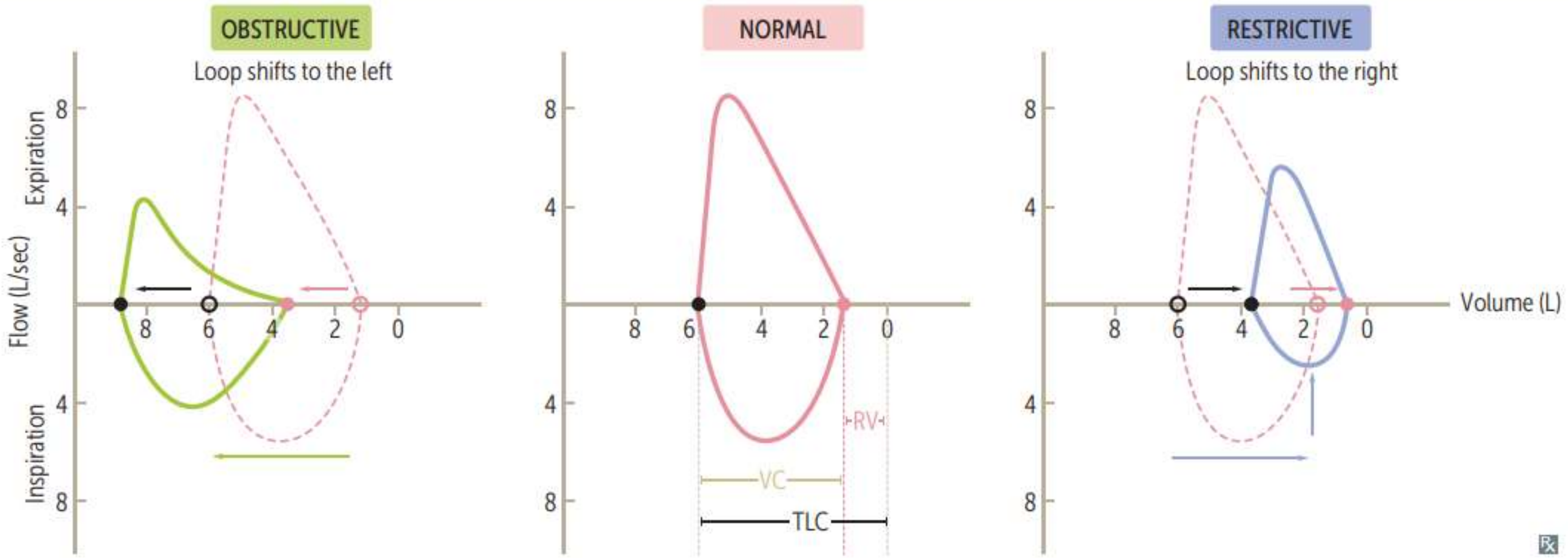
- 11. In a maximal expiration, the total volume expired is

- (A) tidal volume (VT)
- (B) vital capacity (VC)
- (C) expiratory reserve volume (ERV)
- (D) residual volume (RV)
- (E) functional residual capacity (FRC)
- (F) inspiratory capacity

Flow-volume loops

FLOW-VOLUME PARAMETER	Obstructive lung disease	Restrictive lung disease
RV	↑	↓
FRC	↑	↓
TLC	↑	↓
FEV_1	↓↓	↓
FVC	↓	↓
FEV_1/FVC	↓ FEV_1 decreased more than FVC	Normal or ↑ FEV_1 decreased proportionately to FVC



Gas exchange

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Gas exchange

- Gas exchange in the respiratory system refers to diffusion of O_2 and CO_2 in the lungs and in the peripheral tissues.
- O_2 is transferred from alveolar gas into pulmonary capillary blood and, ultimately, delivered to the tissues, where it diffuses from systemic capillary blood into the cells.
- CO_2 is delivered from the tissues to venous blood, to pulmonary capillary blood, and is transferred to alveolar gas to be expired.

Boyle’s law

- Boyle’s law is a special case of the general gas law.
- It states that, at a given temperature, the product of pressure times volume for a gas is constant.
- Thus:
- $P_1 V_1 = P_2 V_2$

Dalton's law of partial pressures

- It states that the partial pressure of a gas in a mixture of gases is the pressure that gas would exert if it occupied the total volume of the mixture.

- Thus, partial pressure is the total pressure multiplied by the fractional concentration of **dry gas**:
- Px = PB X F

Partial pressure

- The relationship for **humidified gas** is determined by correcting the barometric pressure for the water vapor pressure. Thus:

$$P_X = (P_B - P_{H_2O}) \times F$$

where

P_X = Partial pressure of gas (mm Hg)

P_B = Barometric pressure (mm Hg)

P_{H_2O} = Water vapor pressure at 37°C (47 mm Hg)

F = Fractional concentration of gas (no units)

SAMPLE PROBLEM. Calculate the partial pressure of O_2 (Po_2) in dry inspired air, and compare that value to the Po_2 in humidified tracheal air at 37°C. The fractional concentration of O_2 in inspired air is 0.21.

SOLUTION. The P_{O_2} of dry inspired air is calculated by multiplying the pressure of the mixture of gases (i.e., the barometric pressure) by the fractional concentration of O_2, which is 0.21. Thus *in dry inspired air,*

$$\begin{aligned} P_{I_{O_2}} &= 760 \text{ mm Hg} \times 0.21 \\ &= 160 \text{ mm Hg} \end{aligned}$$

The P_{O_2} of humidified tracheal air is lower than the P_{O_2} of dry inspired air because the total pressure must be corrected for water vapor pressure (or 47 mm Hg at 37°C). Thus *in humidified tracheal air,*

$$\begin{aligned} P_{I_{O_2}} &= (760 \text{ mm Hg} - 47 \text{ mm Hg}) \times 0.21 \\ &= 713 \text{ mm Hg} \times 0.21 \\ &= 150 \text{ mm Hg} \end{aligned}$$

Dissolved gases

- Henry’s law deals with gases dissolved in solution (e.g., in blood). Both O2 and CO2 are dissolved in blood (a solution) en route to and from the lungs.

- at equilibrium, the partial pressure of a gas in the liquid phase equals the partial pressure in the gas phase.

- Henry’s law is used to convert the partial pressure of gas in the liquid phase to the concentration of gas in the liquid phase (e.g., in blood).

$$C_X = P_X \times \text{Solubility}$$

where

C_X = Concentration of dissolved gas (mL gas/100 mL blood)

P_X = Partial pressure of gas (mm Hg)

Solubility = Solubility of gas in blood (mL gas/100 mL blood per mm Hg)

Dissolved gases

- it is important to understand that the **concentration of a gas in solution applies only to dissolved gas that is free in solution** (calculated with Henry's law), and it does not include any gas that is present in bound form (e.g., gas bound to hemoglobin or to plasma proteins).

SAMPLE PROBLEM. *If the PO_2 of arterial blood is 100 mm Hg, what is the concentration of dissolved O_2 in blood, given that the solubility of O_2 is 0.003 mL O_2/100 mL blood per mm Hg?*

SOLUTION. To calculate the concentration of dissolved O_2 in arterial blood, simply multiply the Po_2 by the solubility as follows:

$$[O_2] = Po_2 \times \text{Solubility}$$
$$= 100 \text{ mm Hg} \times 0.003 \text{ mL } O_2/100 \text{ mL blood per mm Hg}$$
$$= 0.3 \text{ mL}/100 \text{ mL blood}$$

Fick’s law

- Transfer of gases across cell membranes or capillary walls occurs by **simple diffusion**.

- For gases, the rate of transfer by diffusion is directly proportional to the driving force, a diffusion coefficient, and the surface area available for diffusion; it is inversely proportional to the thickness of membrane barrier.

$$\dot{V}x = \frac{DA\Delta P}{\Delta x}$$

where

$\dot{V}x$ = Volume of gas transferred per unit time

D = Diffusion coefficient of the gas

A = Surface area

ΔP = Partial pressure difference of the gas

Δx = Thickness of the membrane

Diffusion of gases

- There are two special points regarding diffusion of gases:
- (1) The driving force for diffusion of a gas is the partial pressure difference of the gas (ΔP) across the membrane, not the concentration difference.
- Thus if the PO_2 of alveolar air is 100 mm Hg and the PO_2 of mixed venous blood that enters the pulmonary capillary is 40 mm Hg, then the partial pressure difference, or driving force, for O_2 across the alveolar/pulmonary capillary barrier is 60 mm Hg (100 mm Hg − 40 mm Hg).

Diffusion of gases

- (2) The **diffusion coefficient** of a gas (D) is a combination of the usual diffusion coefficient, which depends on **molecular weight, and the solubility** of the gas.

- The diffusion coefficient of the gas has enormous implications for its diffusion rate, as illustrated by differences in the diffusion rates of CO_2 and O_2.

- The diffusion coefficient for **CO_2** is approximately **20 times** higher than the diffusion coefficient for **O_2**; as a result, for a given partial pressure difference, CO_2 diffuses approximately 20 times faster than O_2.

Additional references

- BRS Physiology, Costanzo, 7th edition.
- Harrison’s principles of internal medicine, 21st edition.

Thank you