VENTILATION

VENTILATION

In general, the word ‘ventilation’ refers to circulation of replacement of air or gas in a space.

In respiratory physiology, ventilation is the rate at which air enters or leaves the lungs.

Ventilation in respiratory physiology is of two types:

1. **Pulmonary ventilation**
2. **Alveolar ventilation.**

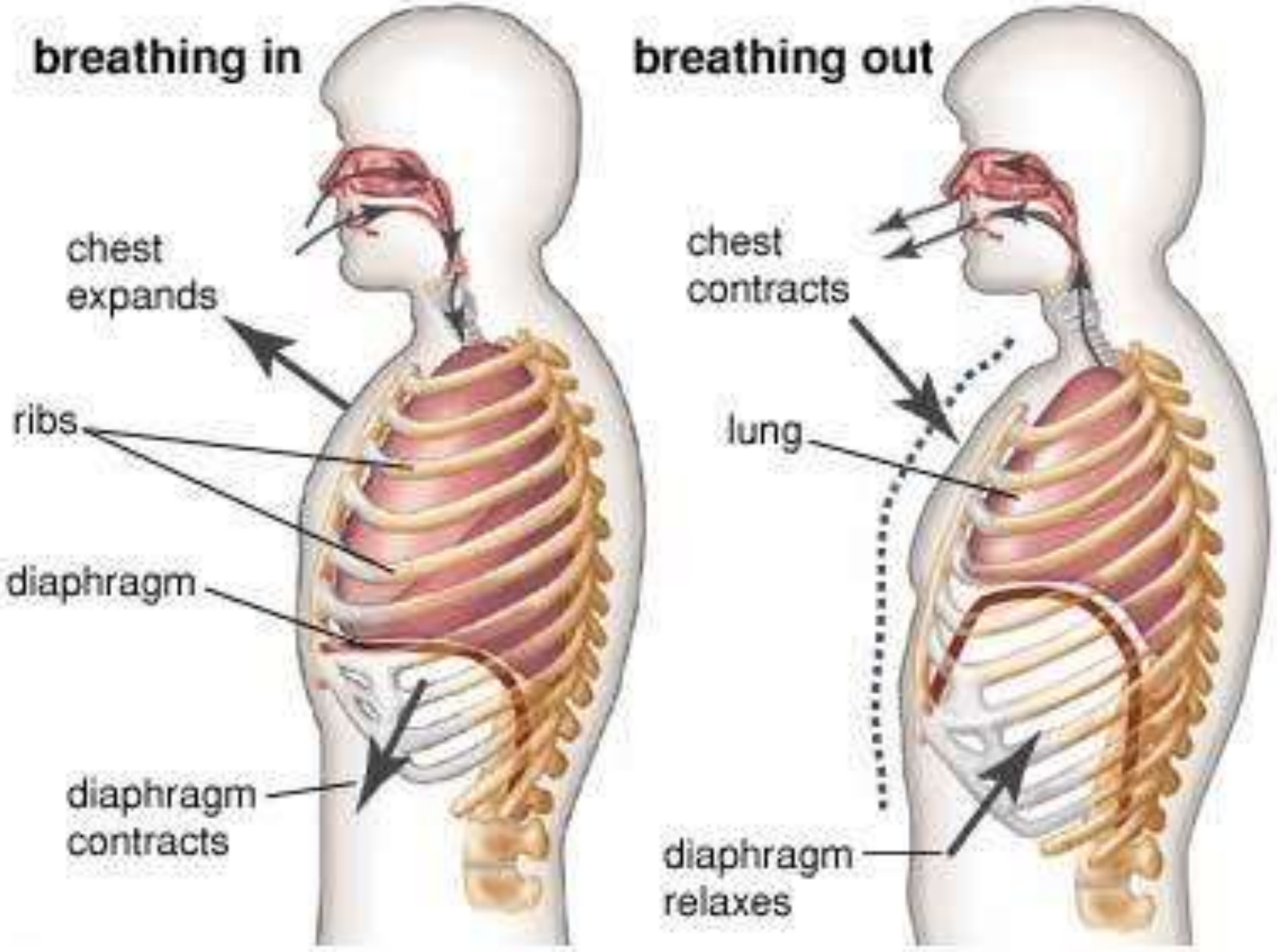
PULMONARY VENTILATION

DEFINITION

Pulmonary ventilation is defined as the volume of air moving in and out of respiratory tract in a given unit of time during quiet breathing.

It is also called **minute ventilation or respiratory minute volume** (RMV).

Pulmonary ventilation is a cyclic process, by which fresh air enters the lungs and an equal volume of air leaves the lungs.


breathing in
chest
expands
ribs
diaphragm
diaphragm
contracts
breathing out
chest
contracts
lung
diaphragm
relaxes

NORMAL VALUE AND CALCULATION

Normal value of pulmonary ventilation is 6,000 mL (6 L)/minute.

It is the product of tidal volume (TV) and the rate of respiration (RR).

It is calculated by the formula:

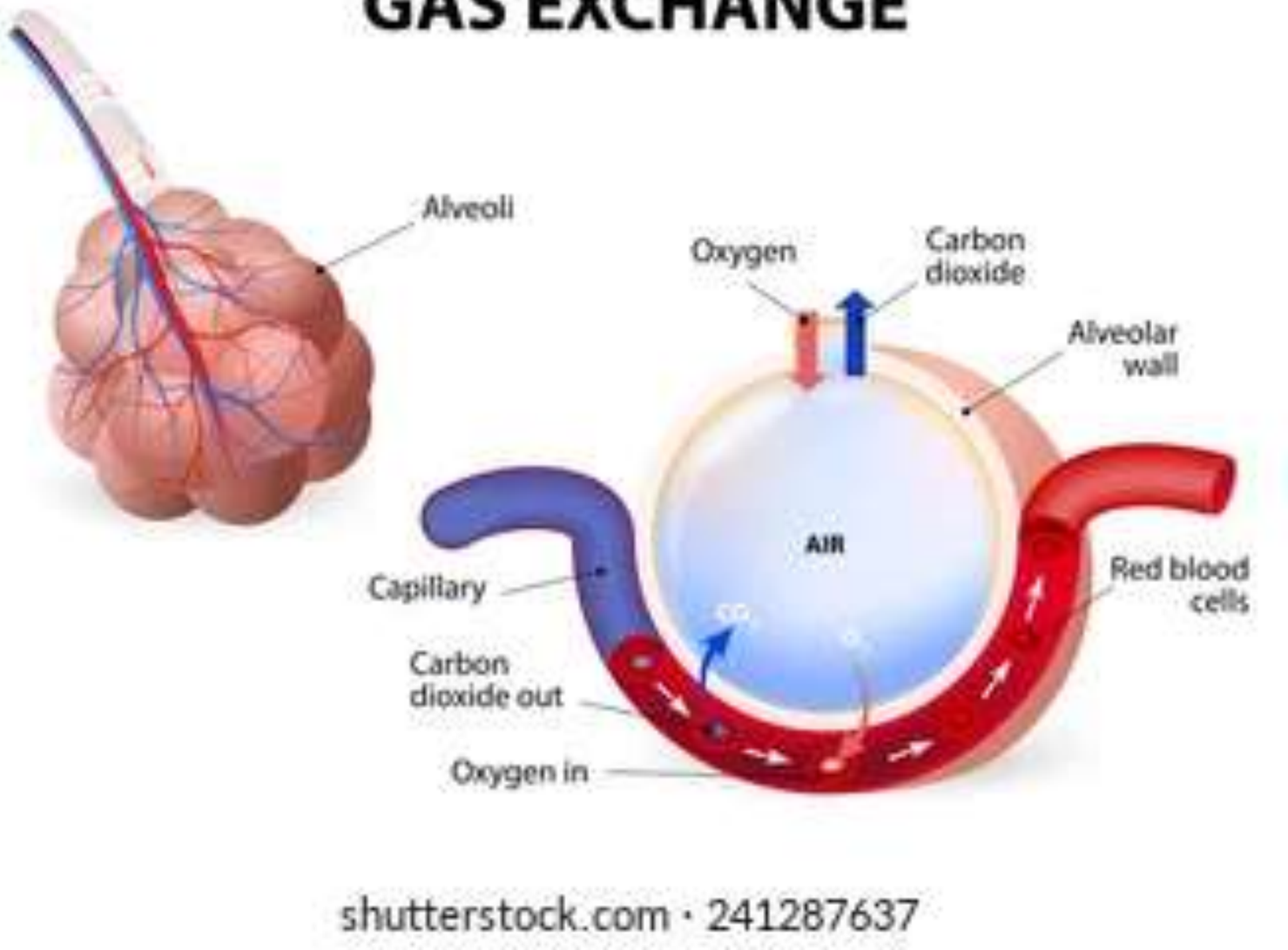
Pulmonary ventilation = Tidal volume × Respiratory rate = 500 mL × 12/minute = 6,000 mL/minute

ALVEOLAR VENTILATION

DEFINITION

Alveolar ventilation is the amount of air utilized for gaseous exchange every minute.
Alveolar ventilation is different from pulmonary ventilation.
In pulmonary ventilation, 6 L of air moves in and out of respiratory tract every minute.
But the whole volume of air is not utilized for exchange of gases.
Volume of air subjected for exchange of gases is the alveolar ventilation.
Air trapped in the respiratory passage (dead space) does not take part in gaseous exchange.

ALVEOLUS GAS EXCHANGE



NORMAL VALUE AND CALCULATION

Normal value of alveolar ventilation is 4,200 mL (4.2 L)/ minute.

It is calculated by the formula:

Alveolar ventilation = (Tidal volume – Dead space) x Respiratory rate = (500 – 150) mL × 12/minute = 4,200 mL (4.2 L)/minute.

DEAD SPACE

DEFINITION

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.**

TYPES OF DEAD SPACE

Dead space is of two types:

1. Anatomical dead space
2. Physiological dead space

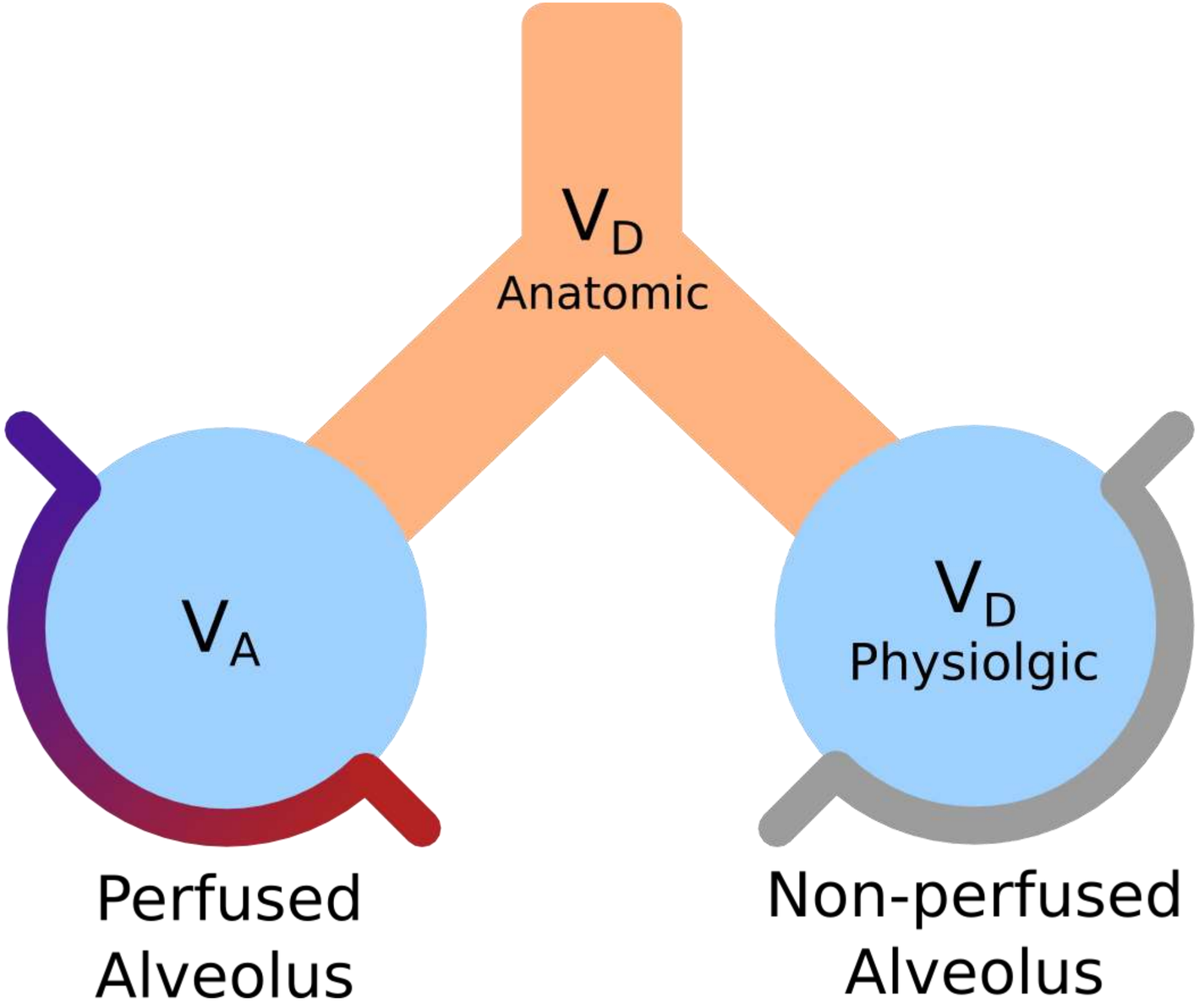
ANATOMICAL DEAD SPACE

Anatomical dead space extends from **nose up to terminal bronchiole**.

It includes nose, pharynx, trachea, bronchi and branches of bronchi up to terminal bronchioles.

These structures serve only as the passage for air movement.

Gaseous exchange does not take place in these structures.


V_D
Anatomic
V_A
V_D
Physiolgic
Perfused
Alveolus
Non-perfused
Alveolus

PHYSIOLOGICAL DEAD SPACE

Physiological dead space includes anatomical dead space plus two additional volumes.

Additional volumes included in physiological dead space are:

1. Air in the alveoli, which are non-functioning.

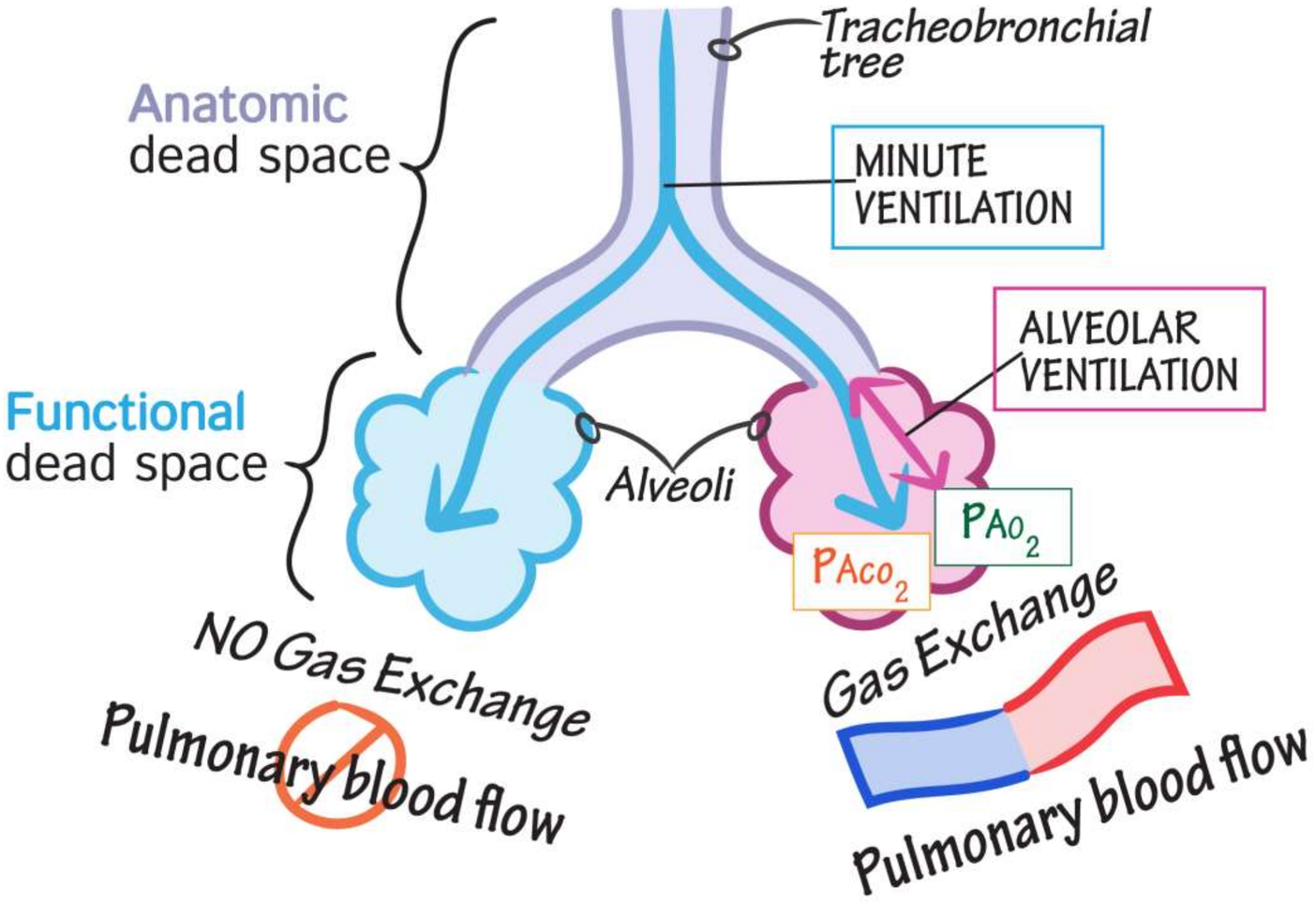
In some respiratory diseases, alveoli do not function because of dysfunction or destruction of alveolar membrane.

2. Air in the alveoli, which do not receive adequate blood flow.

Gaseous exchange does not take place during inadequate blood supply.

These two additional volumes are generally considered as **wasted ventilation.**

Physiologic Dead Space



WASTED VENTILATION AND WASTED AIR

Wasted ventilation is the volume of air that ventilates physiological dead space.

Wasted air refers to air that is not utilized for gaseous exchange.

Dead space air is generally considered as wasted air.

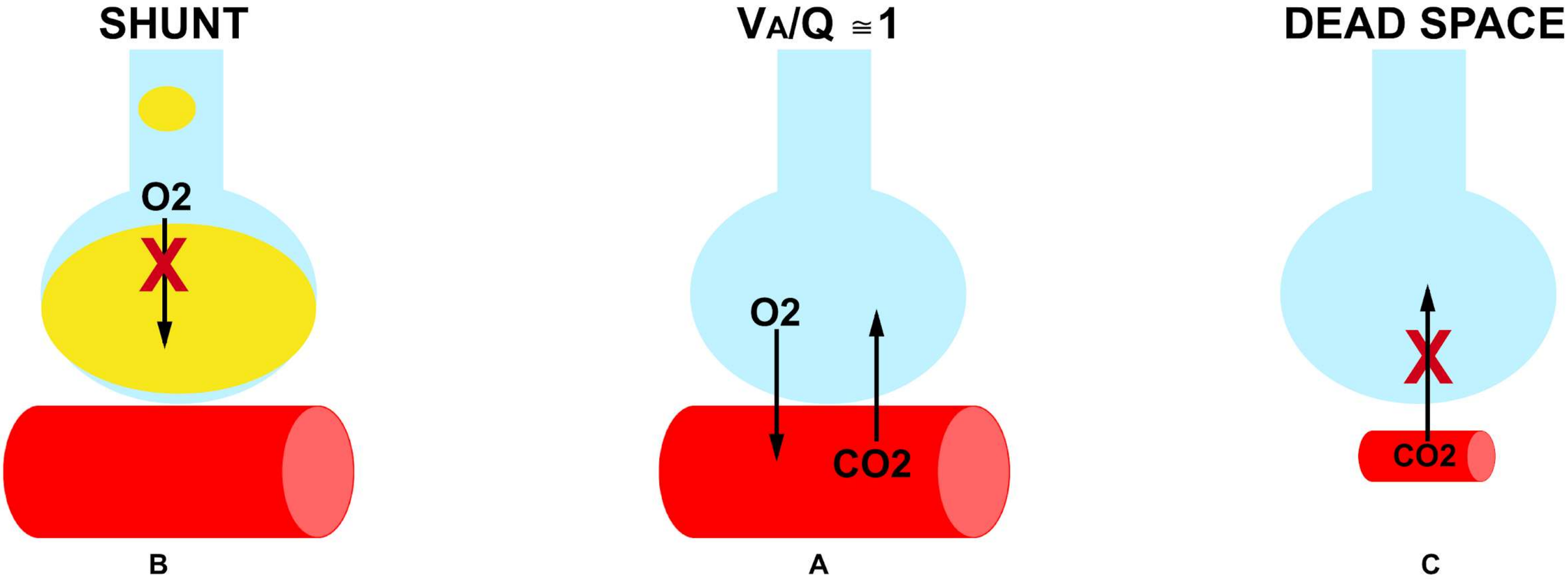


Figure 13. Schematic presentation of (V/Q) ratio for a single alveolus. **A**. represent a normal unit. **B**. Shunt unit is shown wherein alveolus is not ventilated (e.g. due to alveolar filling disorders such as pneumonia, pulmonary edema, or mucous plug) but is perfused.**C**. Dead space unit (alveolus is ventilated but not perfused).

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NORMAL VALUE OF DEAD SPACE

Volume of normal dead space is 150 mL.

Under normal conditions, physiological dead space is equal to anatomical dead space.

It is because, all the alveoli are functioning and all the alveoli receive adequate blood flow in normal conditions.

Physiological dead space increases during respiratory diseases, which affect the pulmonary blood flow or the alveoli.

VENTILATION-PERFUSION RATIO

DEFINITION

Ventilation-perfusion ratio is the ratio of alveolar ventilation and the amount of blood that perfuse the alveoli.

It is expressed as VA/Q.

VA is alveolar ventilation and Q is the blood flow (perfusion).

NORMAL VALUE AND CALCULATION

Normal Value Normal value of ventilation-perfusion ratio is about 0.84.

COLLAPSING TENDENCY OF LUNGS

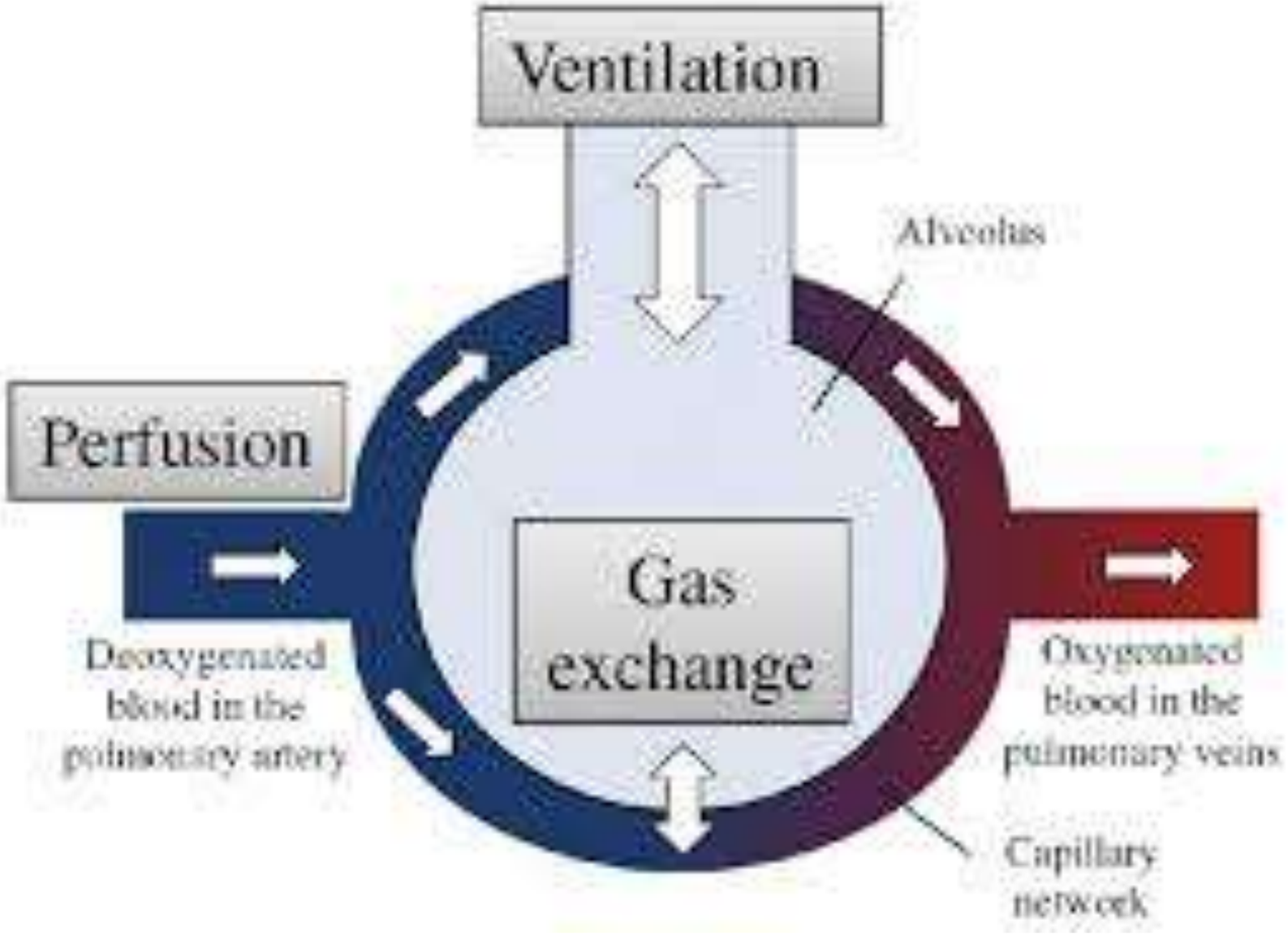
Lungs are under constant threat to collapse even in resting conditions because of certain factors.

SIGNIFICANCE OF VENTILATIONPERFUSION RATIO

Ventilation-perfusion ratio signifies the gaseous exchange.

It is affected if there is any change in alveolar ventilation or in blood flow.

Ventilation without perfusion = dead space Perfusion without ventilation = shunt


Ventilation
Alveolus
Perfusion
Gas exchange
Deoxygenated blood in the pulmonary artery
Oxygenated blood in the pulmonary veins
Capillary network

WASTED AIR AND WASTED BLOOD

Ventilation-perfusion ratio is not perfect because of existence of two factors on either side of alveolar membrane

These factors are:

1. Physiological dead space, which includes wasted air

2. Physiological shunt, which includes wasted blood

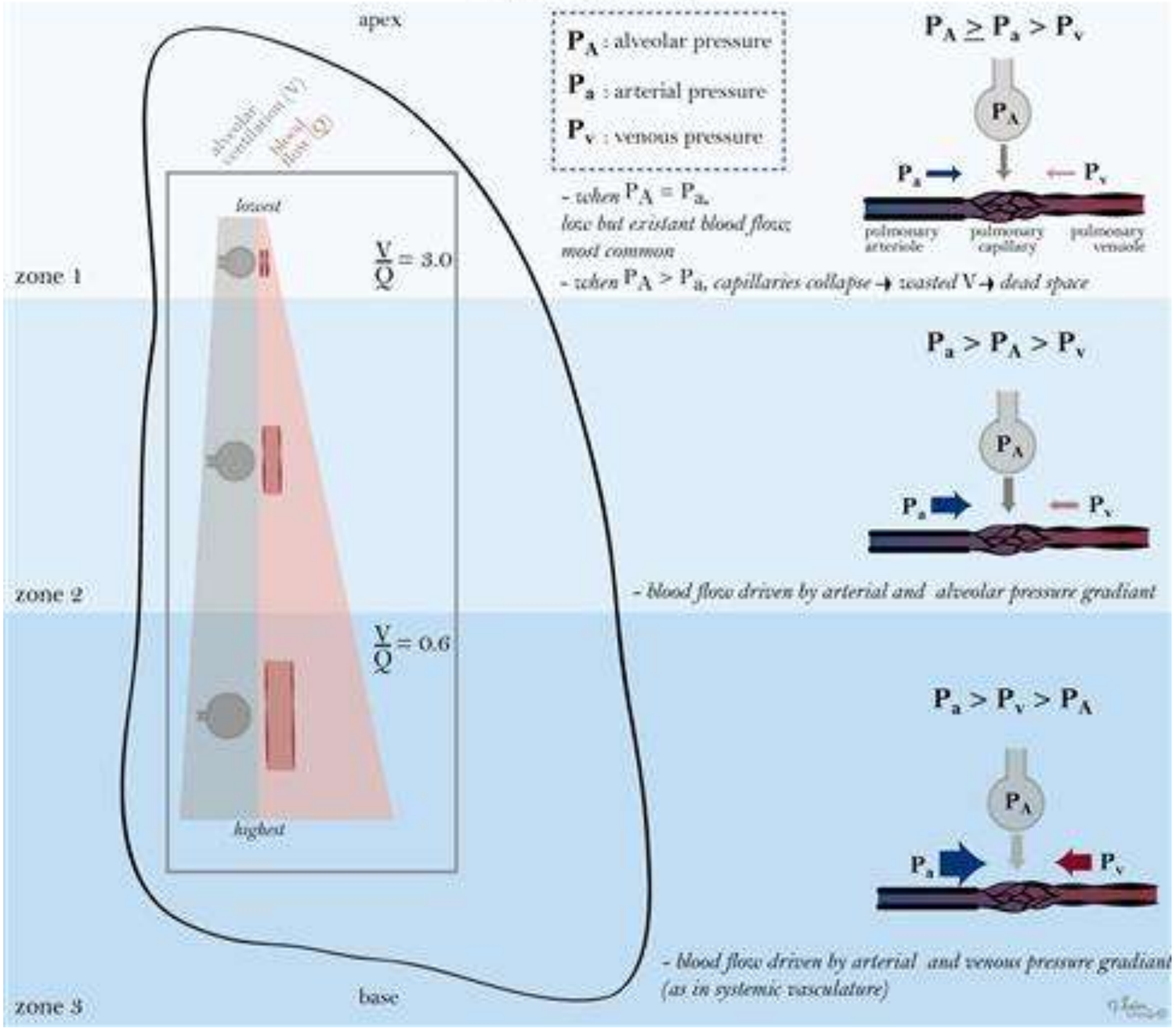
VARIATIONS IN VENTILATION- PERFUSION RATIO

Physiological Variation

1. Ratio increases, if ventilation increases without any change in blood flow
2. Ratio decreases, if blood flow increases without any change in ventilation
3. In sitting position, there is reduction in blood flow in the upper part of the lungs (zone 1) than in the lower part (zone 3).

Therefore, in zone 1 of lungs ventilation-perfusion ratio increases three times. At the same time, in zone 3 of the lungs, because of increased blood flow ventilation-perfusion ratio decreases .

Physiologic V/Q



Pathological Variation

In chronic obstructive pulmonary diseases (COPD), ventilation is affected because of obstruction and destruction of alveolar membrane.

So, ventilation-perfusion ratio reduces greatly.

INSPIRED AIR, ALVEOLAR AIR AND EXPIRED AIR

INSPIRED AIR

DEFINITION

Inspired air is the atmospheric air, which is inhaled during inspiration.

ALVEOLAR AIR

DEFINITION

Alveolar air is the air present in alveoli of lungs

Alveolar Air Vs Inspired Air Alveolar air is different from inspired air in four ways:

1. Alveolar air is partially replaced by the atmospheric air during each breath
2. Oxygen diffuses from the alveolar air into pulmonary capillaries constantly
3. Carbon dioxide diffuses from pulmonary blood into alveolar air constantly
4. Dry atmospheric air is humidified, while passing through respiratory passage before entering the alveoli.

RENEWAL

Alveolar air is constantly renewed.

Rate of renewal is **slow during normal breathing.**

During each breath, out of 500 mL of tidal volume only 350 mL of air enters the alveoli and the remaining quantity of 150 mL (30%) becomes dead space air.

Hence, the amount of alveolar air replaced by new atmospheric air with each breath is only about 70% of the total alveolar air.

Thus, **350 Alveolar air = × 100 = 70% 500**

Slow renewal of alveolar air is responsible for prevention of sudden changes in concentration of gases in the blood

EXPIRED AIR

DEFINITION

Expired air is the amount of air that is exhaled during expiration. It is a combination of dead space air and alveolar air.

COMPOSITION

Concentration of gases in expired air is somewhere between inspired air and alveolar air.

METHOD OF COLLECTION

Expired air is collected by using **Douglas bag**

TABLE 123.1: Composition of inspired air, alveolar air and expired air

Air	Inspired (atmospheric) air		Alveolar air		Expired air	
Gas	Content (mL%)	Partial pressure (mm Hg)	Content (mL%)	Partial pressure (mm Hg)	Content (mL%)	Partial pressure (mm Hg)
Oxygen	20.84	159.00	13.60	104.00	15.70	120.00
Carbon dioxide	0.04	0.30	5.30	40.00	3.60	27.00
Nitrogen	78.62	596.90	74.90	569.00	74.50	566.00
Water vapor, etc.	0.50	3.80	6.20	47.00	6.20	47.00
Total	100.00	760.00	100.00	760.00	100.00	760.00