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# Alveolar Ventilation

M1 – Cardiovascular/
Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

# Monday 11/17/08, 9:00
# Ventilation

20 slides, 50 minutes

1. Static Volumes
   a) Tidal volume
   b) Dead space volume
   c) Alveolar volume
2. Minute volumes
3. **Alveolar Ventilation**
4. **Composition of Respiratory Gases**

# Functional Volumes (mL)

$V_T$ **Tidal volume is the volume of each breath.**

$V_D$ **Dead space volume has no gas exchange.**
**- conducting airways (anatomic)**
**- non-perfused alveoli (alveolar)**

$V_A$ **Alveolar volume has gas exchange.**

# DEAD SPACE $V_D$

## Physiological Dead space (volume)

sum of anatomical and alveolar dead space

### Anatomical Dead Space (volume)

volume of air in airways that can not exchange gases with blood - typical value about 150 ml or 1 ml per pound body weight.

### Alveolar Dead Space (volume)

volume of alveoli that are ventilated but do not receive a blood flow and thus no gas exchange. Small in normal lung but can be very large in some pulmonary diseases.

# Tidal Volume ($V_T$)

$$V_T = V_D + V_A$$

**The tidal volume is the sum of the dead space volume and the alveolar volume.**

$$V_A = V_T - V_D$$

**The alveolar volume is the difference between the tidal volume and the dead space volume.**

# Breaths per Minute & Alveolar Ventilation

**Normal respiratory rate is about**

**12 to 15 breaths /minute.**

**Alveolar ventilation ($\dot{V}_A$) is calculated by**

**multiplying the respiratory rate times the volume.**

- **Indicates a rate or "per min" as in mL/min.**

# Minute Volume (Rate X $V_T$) or Total Ventilation or Minute Ventilation

$$\dot{V}_T \equiv \dot{V}_E$$

$$\dot{V}_T = \text{Rate} \times V_T$$

6000 mL/min = 12 b/min X 500 mL/b

or from previous example

7500 mL/min = 15 b/min X 500 mL/b

BUT

Same rate applies to $V_D + V_A$

# Breaths per Minute (book example)

$$n(V_A) = n(V_T) - n(V_D)$$

Thus, if $n = 12$ breaths per minute in the example above:

$$4200\,\frac{\text{ml}}{\text{min}} = 6000\,\frac{\text{ml}}{\text{min}} - 1800\,\frac{\text{ml}}{\text{min}}$$

The alveolar ventilation ($\dot{V}_A$) in liters per minute is equal to the minute volume ($\dot{V}_E$) minus the volume wasted ventilating the dead space per minute ($\dot{V}_D$):

$$\dot{V}_A = \dot{V}_E - \dot{V}_D$$



$$\dot{V}_T \equiv \dot{V}_E$$

# Alveolar Ventilation

**But** $\dot{V}_T \equiv \dot{V}_E$

$\dot{V}_A = \dot{V}_T - \dot{V}_D$ or

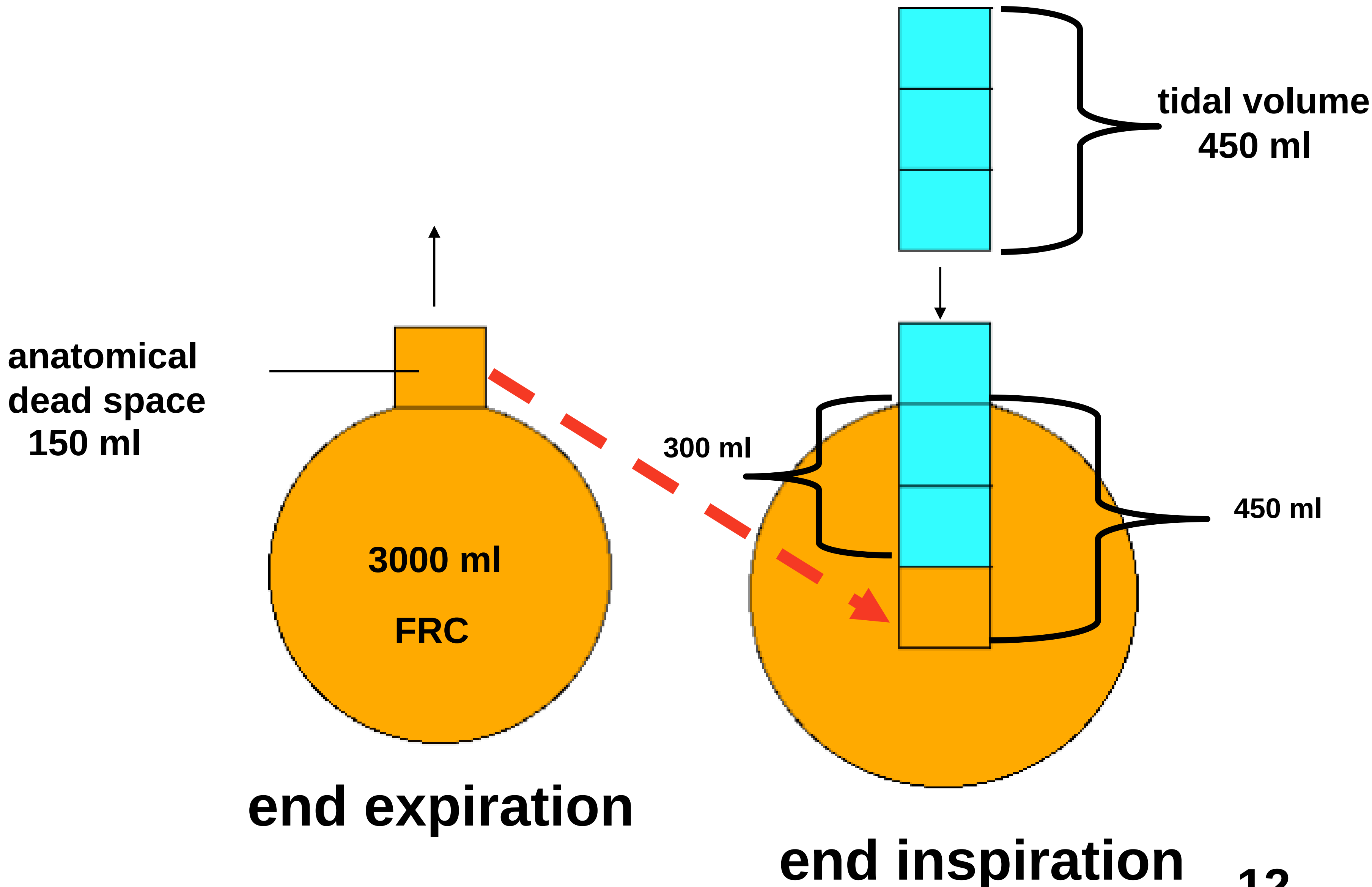
$\dot{V}_A = \dot{V}_E - \dot{V}_D$

which is the same as

$\dot{V}_A = \text{Rate}\,(V_E - V_D)$ or

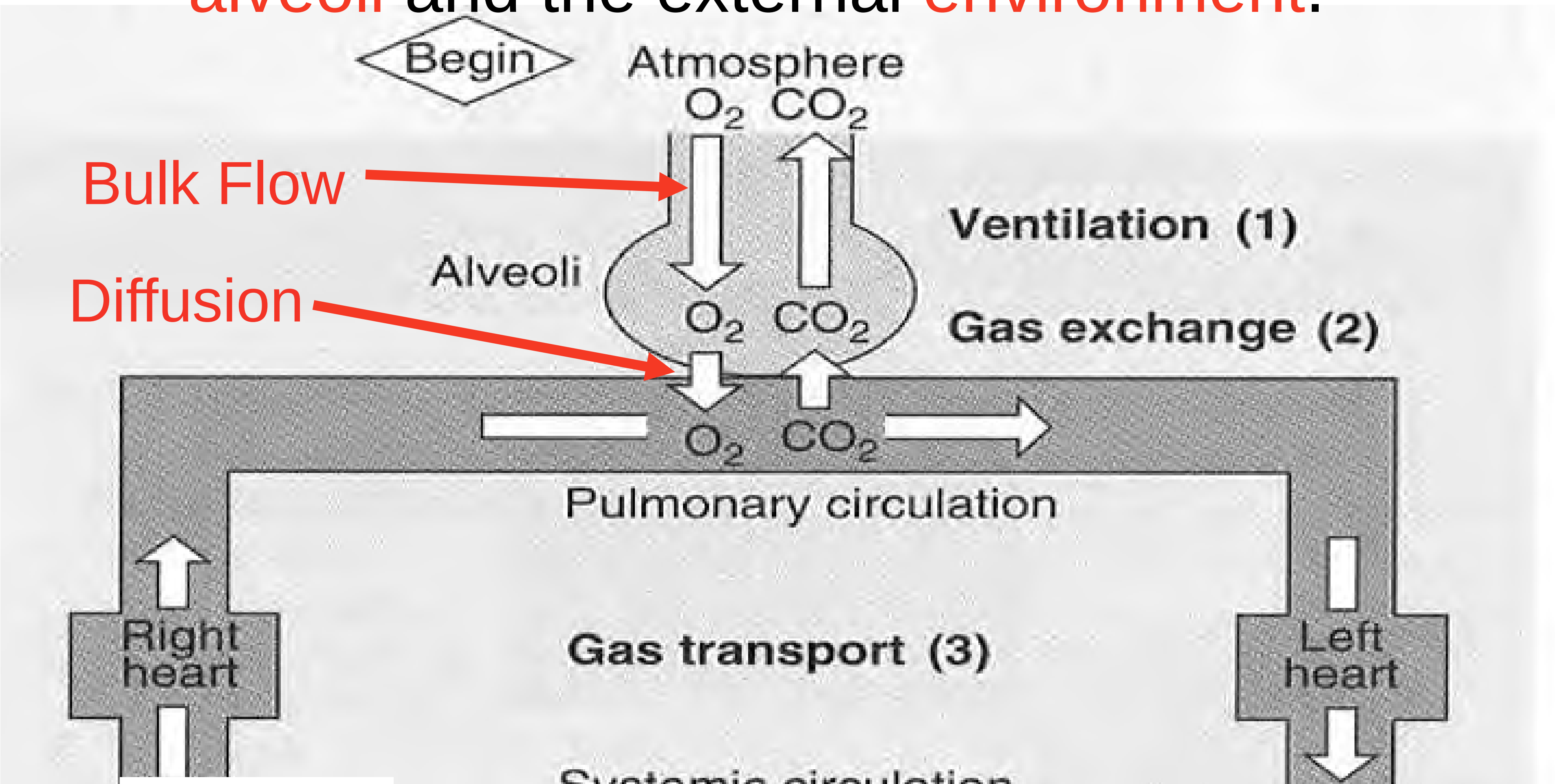
$= \text{Rate}\,(V_T - V_D)$

# Alveolar Ventilation



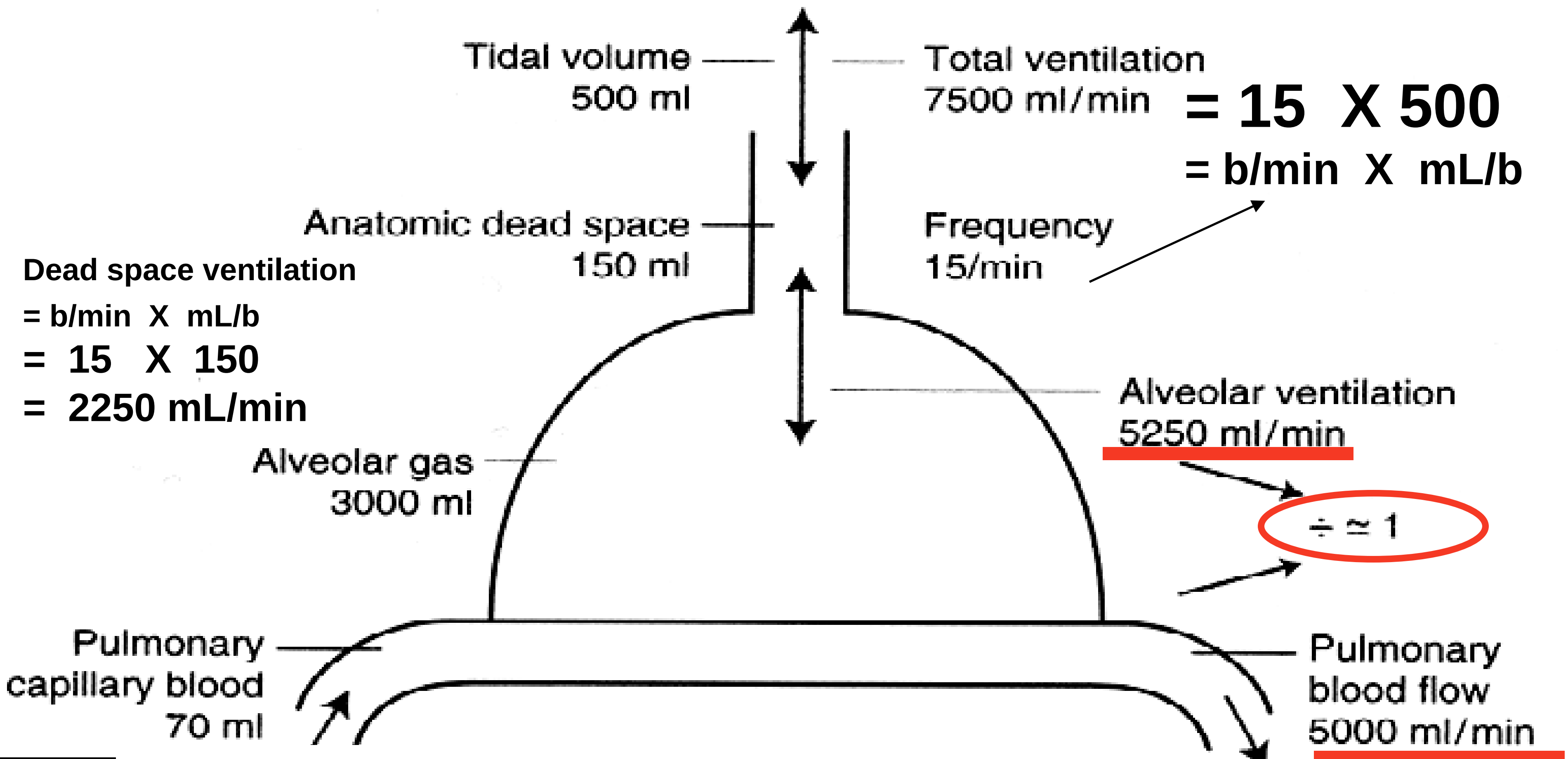
# Alveolar Ventilation

Is the exchange of gas between the alveoli and the external environment.



**Alveolar ventilation = Total ventilation - Dead space ventilation**

| | | | | |
|---|---|---|---|---|
| b/min X mL/b | = | b/min X mL/b | - | b/min X mL/b |
| 17 X 350 | = | 15 X 500 | - | 15 X 150 |
| 5250 ml/min | = | 7500 ml/min | - | 2250 ml/min |

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**Alveolar ventilation is approximately equal to pulmonary blood flow (cardiac output).**

## Effect of rate & tidal volume on ALVEOLAR VENTILATION

$$\dot{V}_A = R \, (V_T - V_D)$$

$$4200 \text{ mL/min} = 12 \, (500 - 150)$$

| $V_T$ | R | $\dot{V}_E$ ml/min | $\dot{V}_A$ ml/min | |
|---|---|---|---|---|
| 150 | 40 | 6000 | 0 | no alveolar ventilation |
| 500 | 12 | 6000 | 4200 | normal ventilation |
| 1000 | 6 | 6000 | 5100 | excess ventilation |

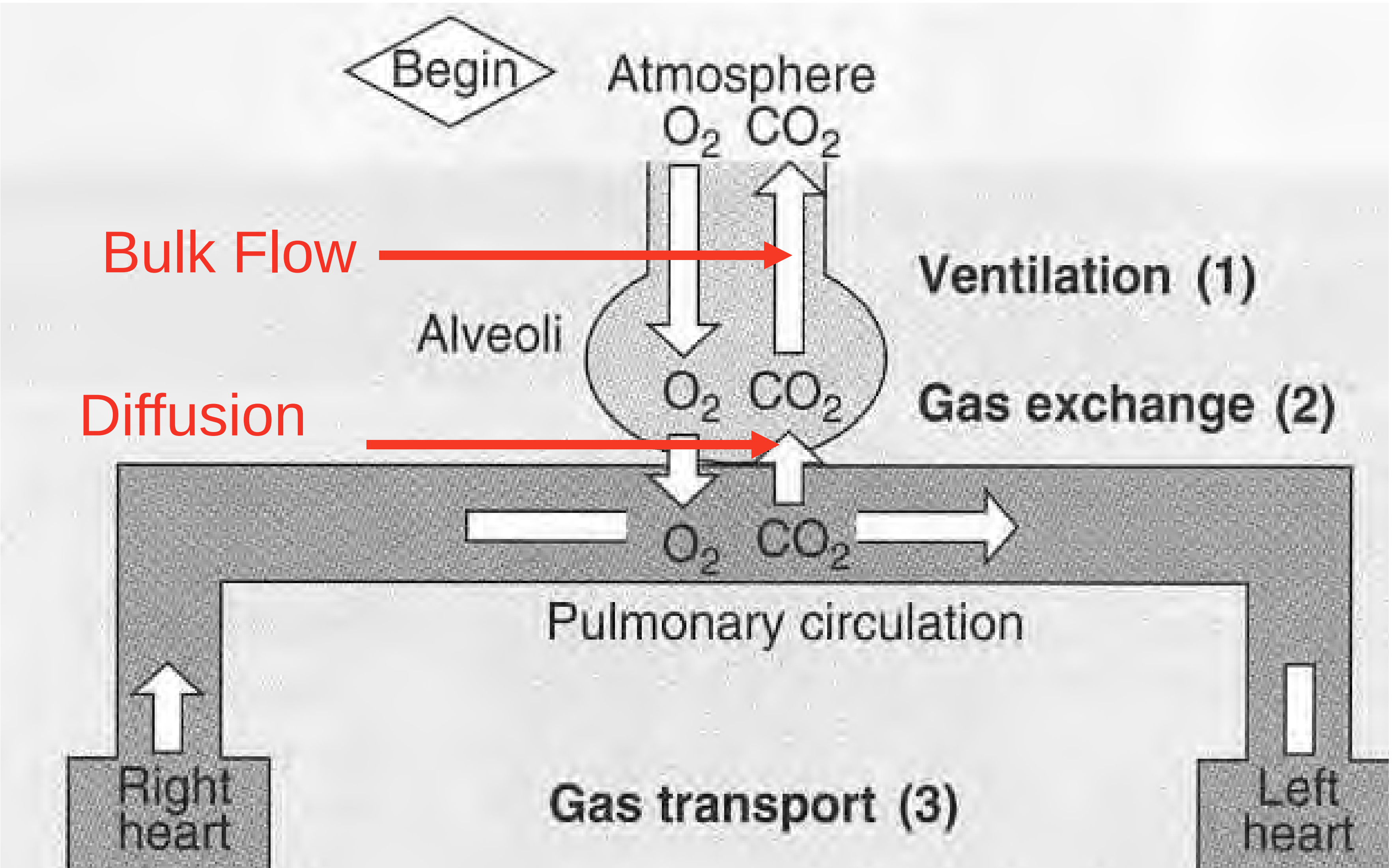
Fixed $\dot{V}_E$ & $V_D$

# Composition of Respiratory Gas

| | |
|---|---|
| **What do we breath?** | **Air** |
| **What do we breath in?** | **Air & moisture** |
| **What do we breath out?** | **Air, $CO_2$ & $H_2O$** |
| **What is air made of?** | **$N_2$ and $O_2$ mostly** |
| **How measure?** | **Partial Pressure** |

**Partial pressure of a gas is equal to its fractional concentration times the total pressures of all gases in mixture. (Dalton's Gas Law)**

# STEPS IN RESPIRATION



# Dalton's Law of Partial Pressures

The total pressure exerted by a mixture of gases is equal to the sum of the partial pressures that each gas would exert if it alone occupied the entire volume.

**Total pressure of air (barometric)**

$$P_{air} = P_{O2} + P_{CO2} + P_{N2} + P_{x}$$

$$100\% = 21\% + 0.03\% + 78\% + 0.9\%$$

$$760 \text{ mm Hg} = 160 + 0.2 + 593 + 7$$

$$P_{O2} = 21\% \times 760 = 160 \text{ mm Hg}$$

**Where does the 760 mmHg come from ??**

# Origin of 760 mmHg - effect of ALTITUDE

| | Altitude ft | $P_B$ mm Hg | % $O_2$ | $PO_2$ mm Hg |
|---|---|---|---|---|
| Sea level | 0 | 760 | 21% | 160 |
| Ann Arbor | 800 | 737 | 21% | 155 |
| Denver | 5,200 | 640 | 21% | 134 |
| Mt Everest | 29,028 | 253 | 21% | 53 |

## Standard Conditions for Measuring Gas Volumes

**The volume of a pure gas (V) at STPD is directly proportional to the number of moles (n) of that gas (1 mole gas = 22.4 liters STPD), R (gas constant) and T**

$$PV = nRT$$

$$V = n \frac{RT}{P} \quad \text{constant}$$

**Standard Temperature, Pressure, Dry = STPD**

**T = 273 ° absolute (0 ° Celsius)**

**$P_b$ = 760 mm Hg at sea level**

**21% of dry air pressure is due to oxygen thus 0.21 X 760 = 160 mmHg $PO_2$**

**Dry (no water vapor)**

# WATER PARTIAL PRESSURE

**The gas partial pressure of water in equilibrium with liquid water depends only on the temperature. The higher the temperature the higher partial pressure due to water.**

**At body temperature (37 C °) the $P_{H_2O}$ = 47 mmHg**

$$P_b = P_{H_2O} + P_{dry}$$

The water added by the body **dilutes** the other gases such that all their partial pressures go down !!

760 = 47 + 713

$$P_{O_2} = 0.21 \; ( P_b - P_{H_2O} ) = 150 \text{ mm Hg}$$

Not the 160 mmHg of dry air

That is why the partial pressure of oxygen in <u>inspired</u> air is lower than dry room air.

$P_{I_{O_2}}$ = inspired oxygen

The partial pressure of oxygen in the air that enters the body is reduced by the addition of water vapor.

Inspired air is diluted with water vapor until saturated.

$$P_{I_{O_2}} = \%\ O_2\ (P_b - P_{H20})$$

# So why alveolar $PO_2$ so low??

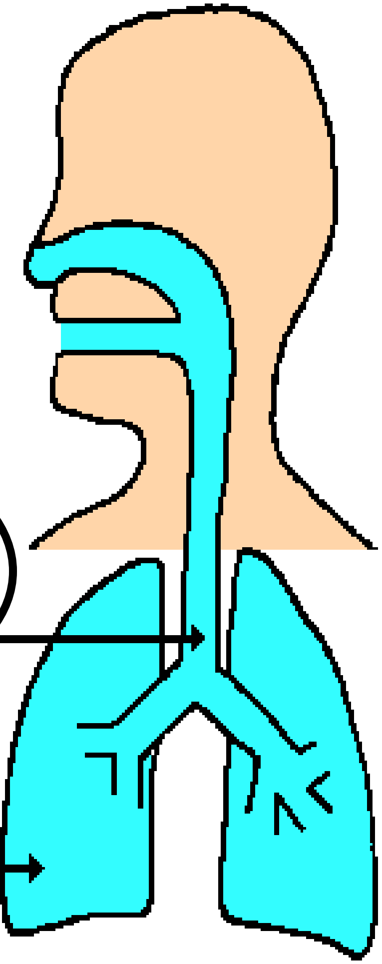
Dry air

$P_{bO_2}$ = % $O_2$ $P_b$ = 160 mm Hg

Humidified air

$P_{IO_2}$ = % $O_2$ ($P_b$ - $P_{H20}$) = 0.21 x 713 = 150 mm Hg

$P_{AO_2}$ = 104 mm Hg



??Alveolar air partial pressure of oxygen ??

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