# Dead space and its measurement

Dead space is the volume of ventilated air that does not participate in gas exchange.

**Anatomical dead space** is the volume of air that fills the conducting zone, about 150 mL (~30% of normal tidal volume). It is measured by the **nitrogen washout (Fowler)** technique:

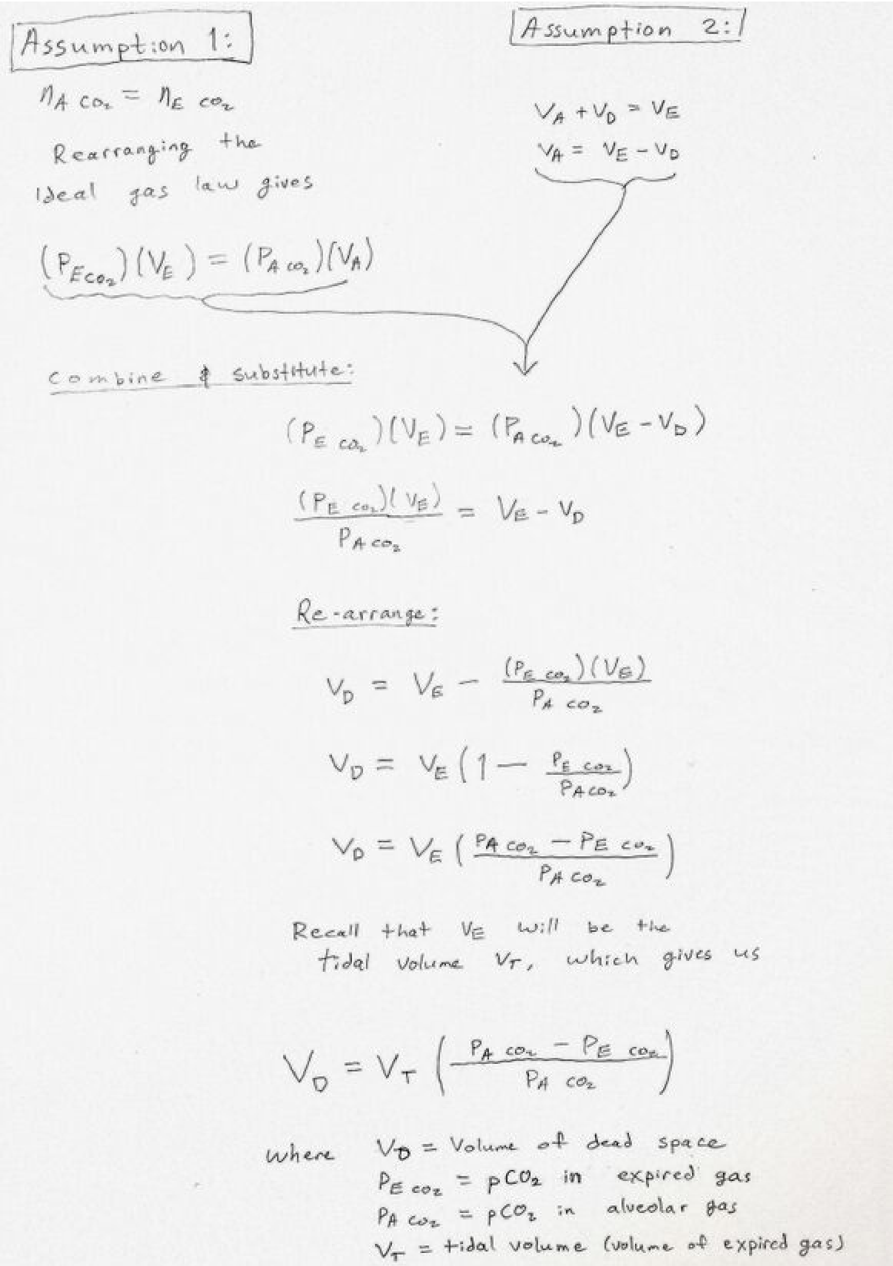
1. Subject breathes in pure $O_2$
2. Most of the $O_2$ mixes with the air already in the alveoli (75% $N_2$)
3. The gas in the anatomical dead space remains as pure $O_2$ because it remains up in the conducting zone
4. When the gas is expired, the pure $O_2$ is expired first. This volume is equal to the dead space. *Note that in practice, $O_2$ is replaced by $N_2$ more gradually, as a sigmoid curve. However, it is quick enough that it can be approximated (averaged out) as an abrupt transition.*

**Alveolar dead space** includes those parts of the respiratory zone that do not participate in gas exchange. In the ideal healthy adult, this is zero.

**Physiological dead space** is the sum of the anatomical dead space and the alveolar dead space. It is found using the **Bohr method**. The subject breathes in normal room air, and respiration (production of $CO_2$) happens everywhere, except in the volume occupied by the dead spaces. One can assume that

1. The molar amount of $CO_2$ produced in the alveoli ($n_{A\ CO2}$) will be the same amount that is expired ($n_{E\ CO2}$)
2. The volume of the alveoli ($V_A$) that participated in gas exchange, together with the physiological dead space ($V_D$), will equal the volume of the expired air: $V_A+V_D=V_E$

We can apply these assumptions to the ideal gas law ($PV = nRT$) to derive an equation for the physiological dead space:



**Assumption 1:**

$n_{A\,CO_2} = n_{E\,CO_2}$

Rearranging the ideal gas law gives

$(P_{E\,CO_2})(V_E) = (P_{A\,CO_2})(V_A)$

**Assumption 2:**

$V_A + V_D = V_E$

$V_A = V_E - V_D$

Combine & substitute:

$$(P_{E\,CO_2})(V_E) = (P_{A\,CO_2})(V_E - V_D)$$

$$\frac{(P_{E\,CO_2})(V_E)}{P_{A\,CO_2}} = V_E - V_D$$

Re-arrange:

$$V_D = V_E - \frac{(P_{E\,CO_2})(V_E)}{P_{A\,CO_2}}$$

$$V_D = V_E\left(1 - \frac{P_{E\,CO_2}}{P_{A\,CO_2}}\right)$$

$$V_D = V_E\left(\frac{P_{A\,CO_2} - P_{E\,CO_2}}{P_{A\,CO_2}}\right)$$

Recall that $V_E$ will be the tidal volume $V_T$, which gives us

$$V_D = V_T\left(\frac{P_{A\,CO_2} - P_{E\,CO_2}}{P_{A\,CO_2}}\right)$$

where $V_D$ = Volume of dead space
$P_{E\,CO_2}$ = $pCO_2$ in expired gas
$P_{A\,CO_2}$ = $pCO_2$ in alveolar gas
$V_T$ = tidal volume (volume of expired gas)

## References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Costanzo, L., 2019. *Physiology - Board Review Series*. 7th ed. Philadelphia: Wolters Kluwer, p.116.