Gas Exchange Computer Lab

請先進入下列網址:
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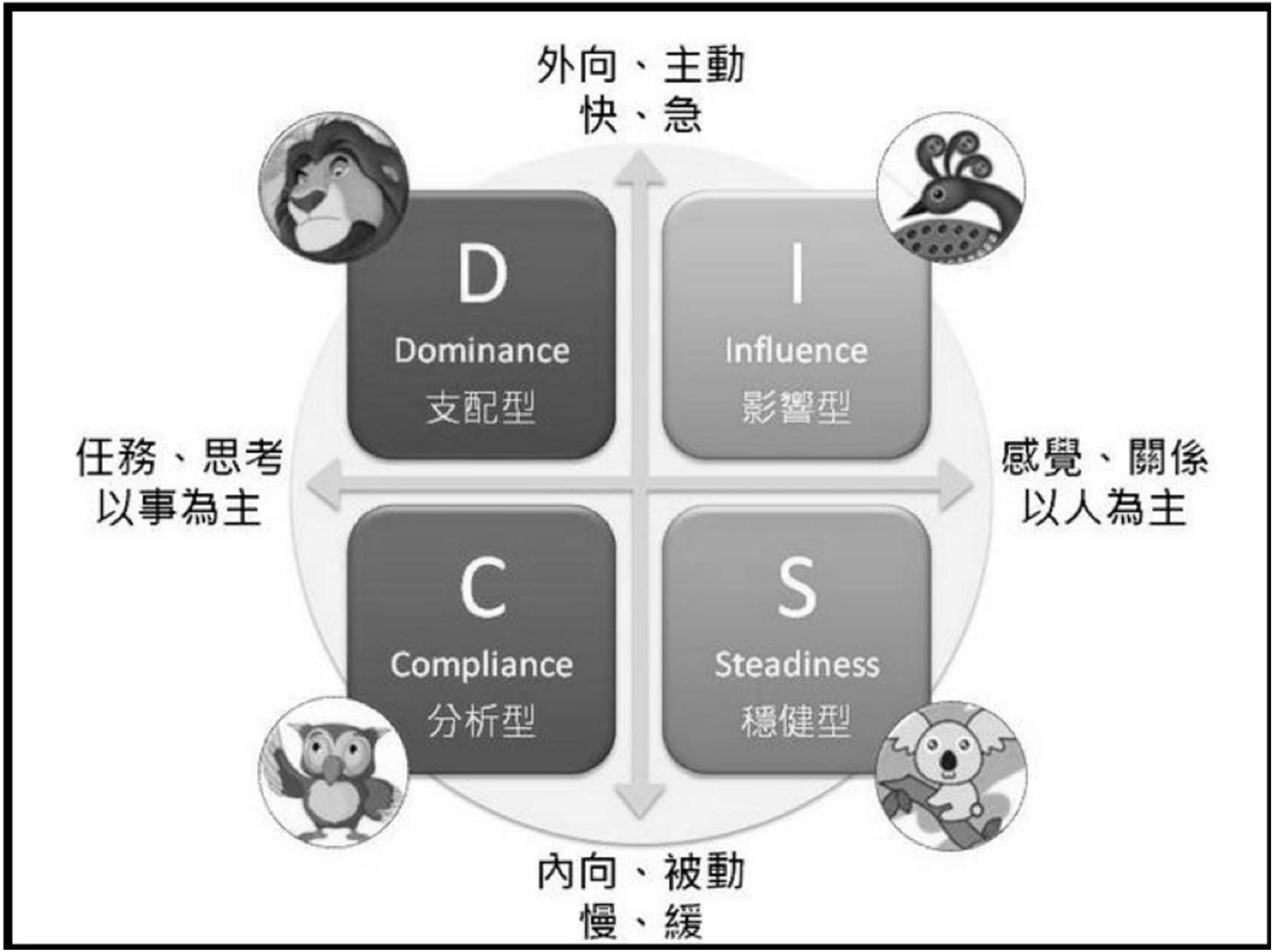
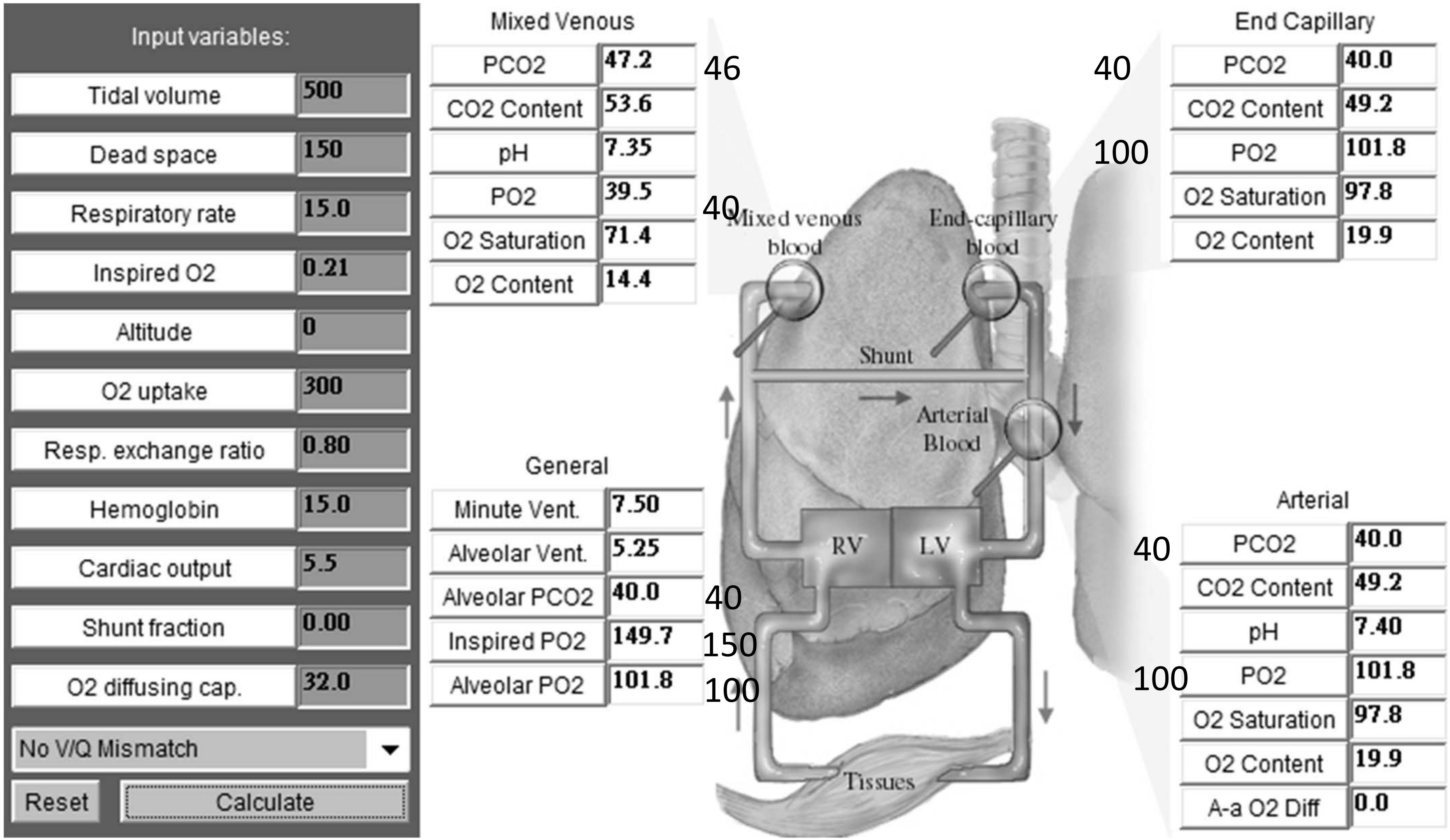

外向、主動
快、急
D
Dominance
支配型
I
Influence
影響型
任務、思考
以事為主
感覺、關係
以人為主
C
Compliance
分析型
S
Steadiness
穩健型
內向、被動
慢、緩

Gas Exchange Computer Lab



*請問當呼吸速率增加為2倍時,
每分鐘通氣量($\dot{V}_E$)如何變化?

A. 增加2倍

B. 增加4倍

C. 減少2倍

D. 不變

*請問當呼吸速率增加為2倍時,

肺泡通氣量($\dot{V}_A$)如何變化?

A. 增加2倍

B. 增加4倍

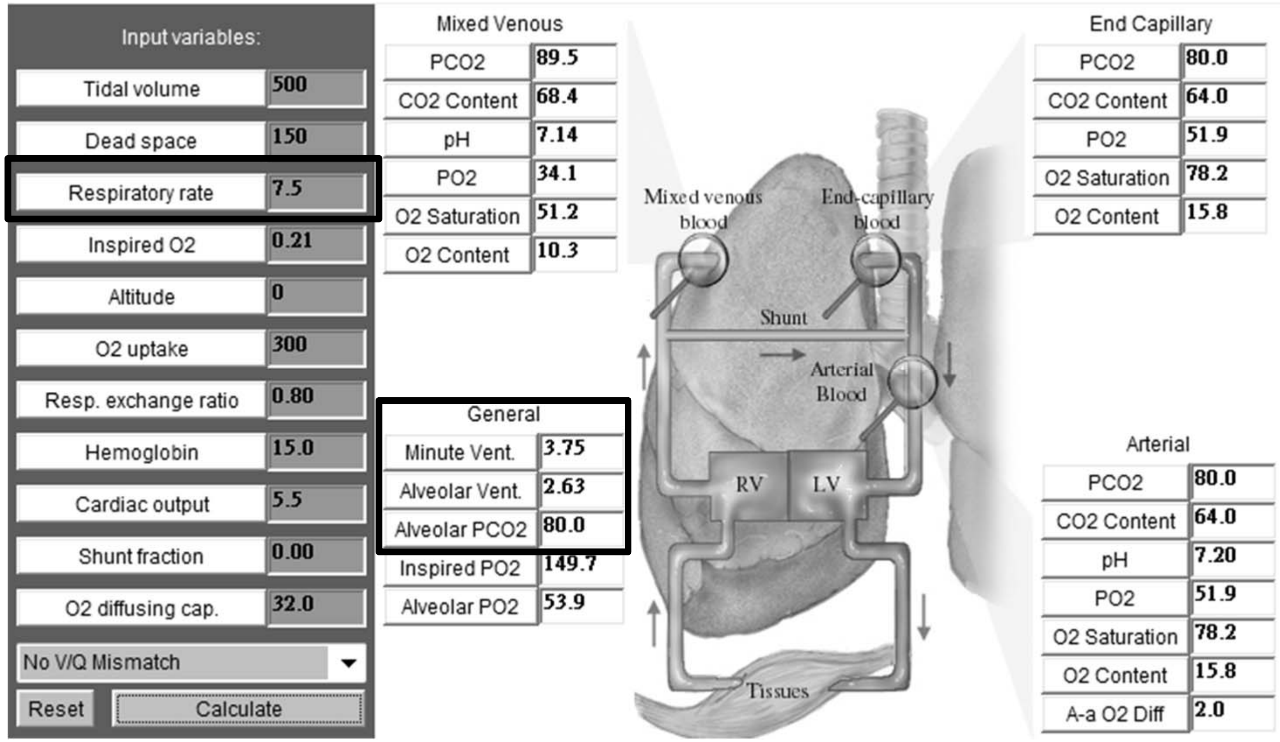
C. 減少2倍

D. 不變

Ventilation

Changes in respiratory rate cause proportionate changes in minute ventilation ($\dot{V}_E$) and alveolar ventilation ($\dot{V}_A$)

- if respiratory frequency is reduced by half → $\dot{V}_{E,}$ $\dot{V}_A$ reduce by half
- $\dot{V}_E$ = 0.5 x 15 =7.5 L/min → $\dot{V}_E$ = 0.5 x 7.5 =3.75 L/min
- $\dot{V}_A$ = (0.5-0.15) x15 =5.25 L/min → $\dot{V}_A$ = (0.5-0.15) x 7.5 =2.625 L/min



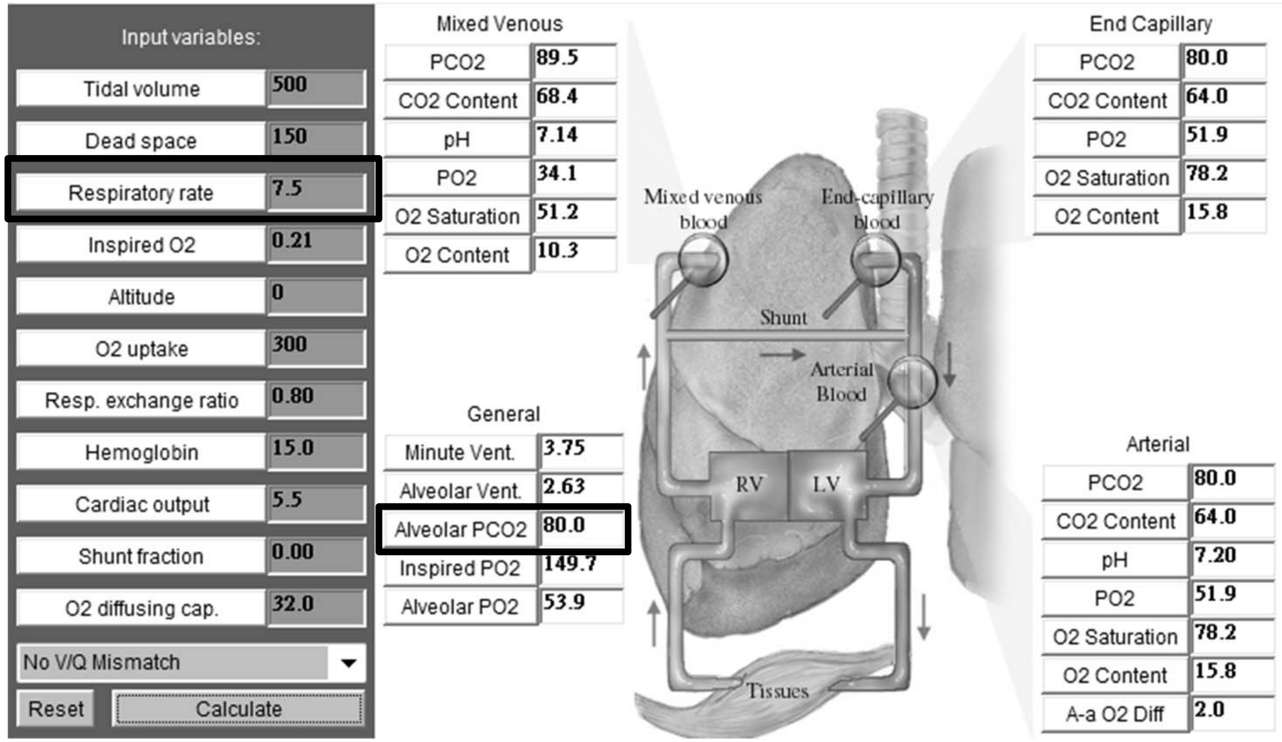
*請問當肺泡通氣量($\dot{V}_A$)增加為2倍時, 二氧化碳分壓(P_{CO2})如何變化?

A. 增加2倍
B. 增加4倍
C. 減少2倍
D. 不變

Ventilation

Changes in alveolar ventilation ($\dot{V}_A$) cause reciprocal changes in alveolar P_{CO2}

- if respiratory frequency is reduced by half → Pa_{CO2} double until out of physiology range
- Pa_{CO2}: 40 mmHg → 80 mmHg



*請問當二氧化碳分壓(P_{CO2})
增加為2倍時,
肺泡氧分壓($P_{A}o_2$)變為多少?

A. 100 mmHg

B. 53.3 mmHg

C. 149.7 mmHg

D. 40 mmHg

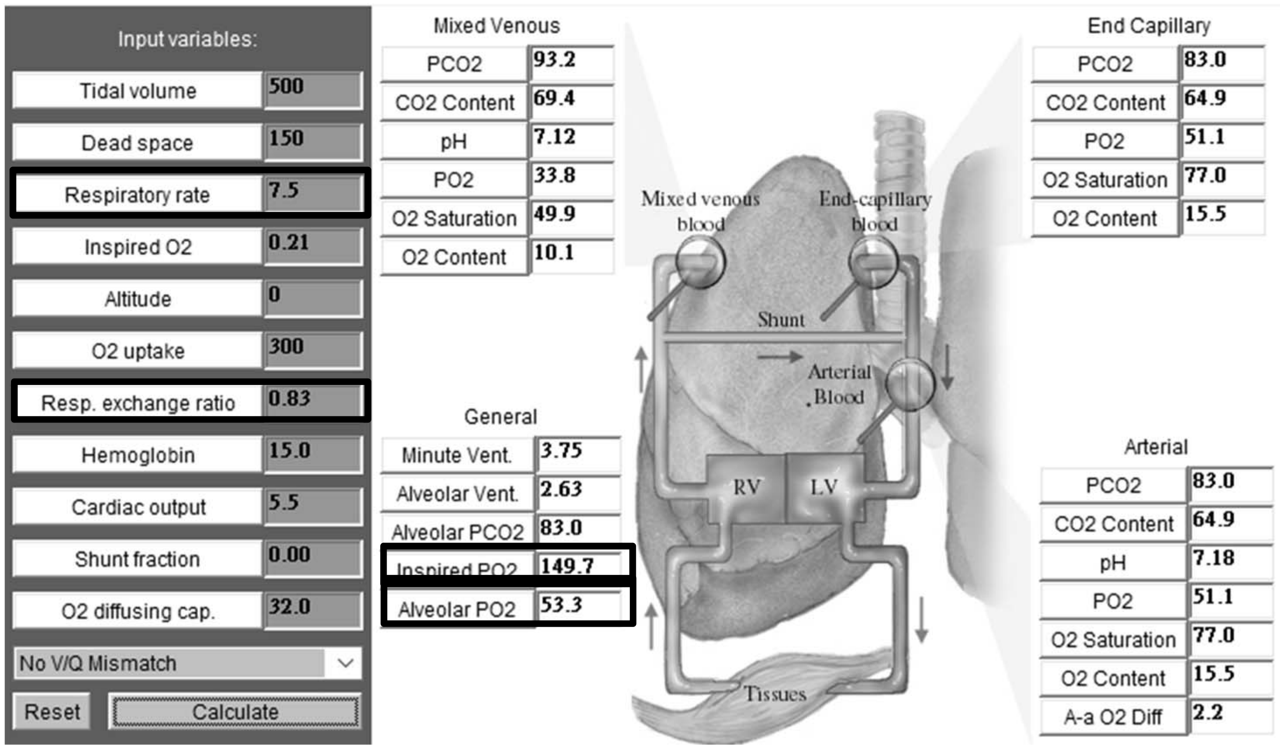
Ventilation

Alveolar P_{O2} (P_Ao_2) can be calculated using the alveolar air equation

P_Ao_2 = input O_2 – output O_2

$$= F_{IO2}\,(P_{atm} - P_{H2O}) - \frac{P_{ACO2}}{R}$$

$$=149.7 - (80/0.83) = 53.3 \text{ mmHg}$$

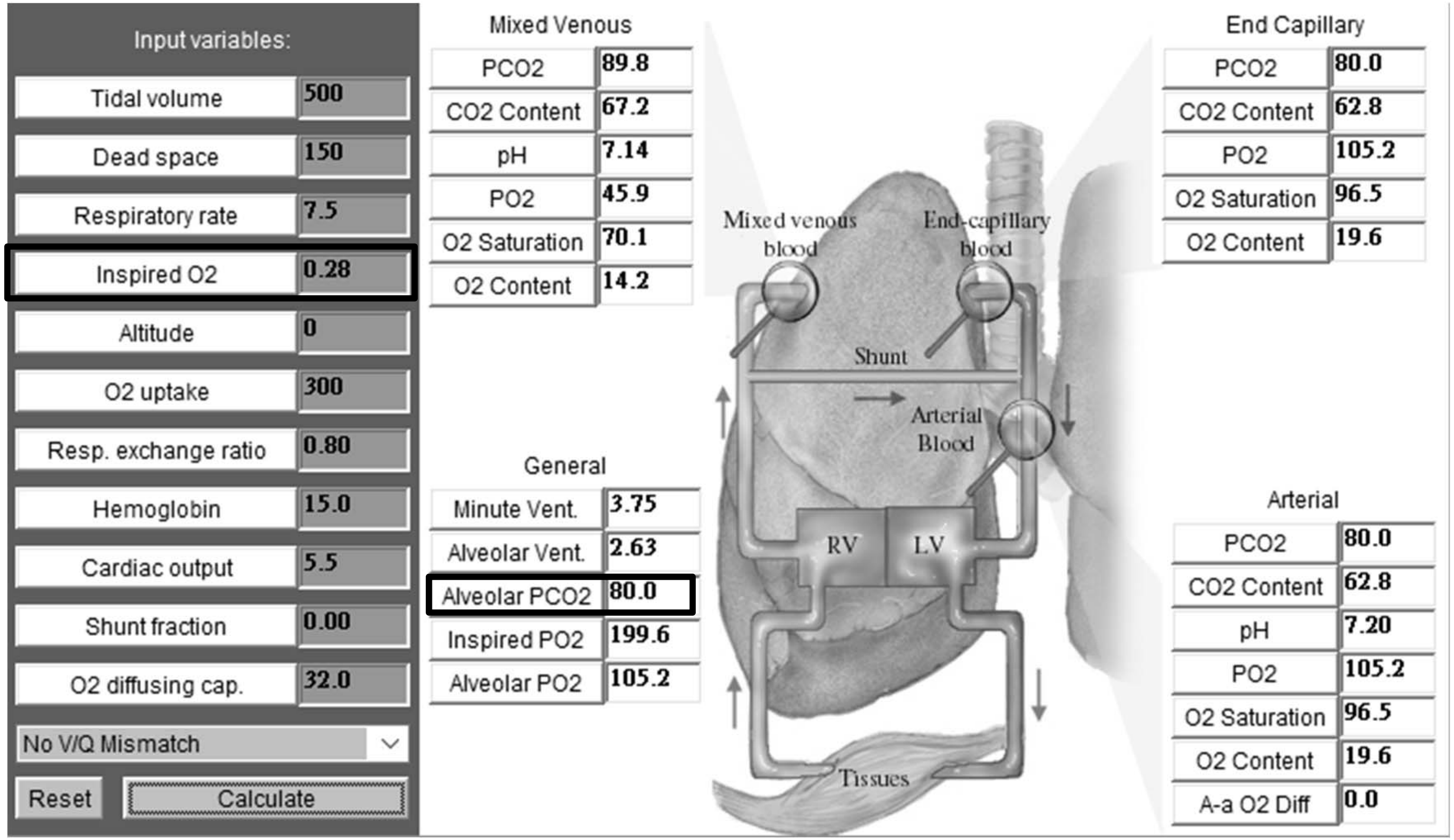


*請問當受試者吸入2倍濃度的氧後，二氧化碳分壓(P_{CO_2})如何變化？

A. 增加2倍
B. 增加4倍
C. 減少2倍
D. 不變

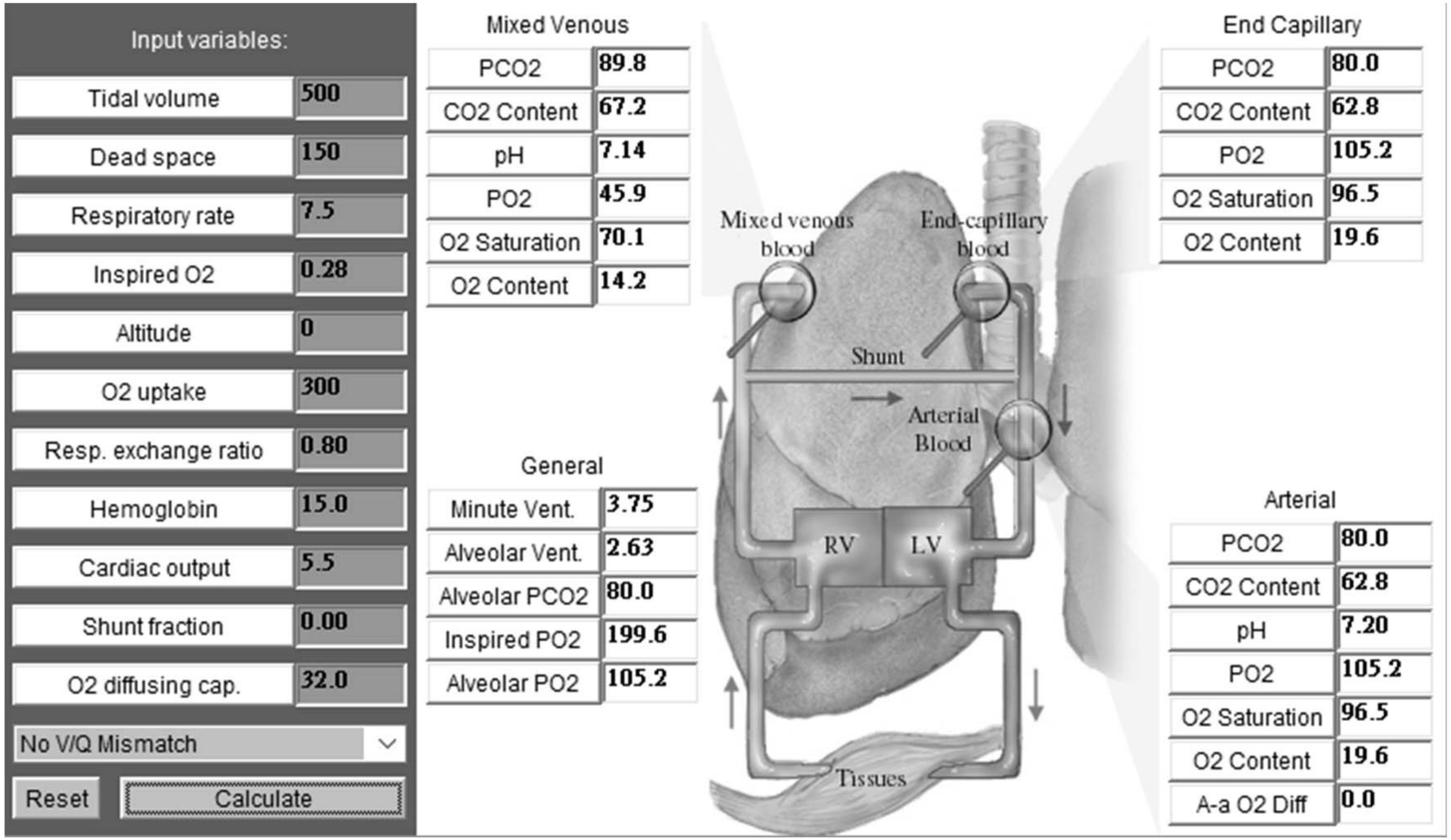
Ventilation

- Changing inspired O_2 has no direct effect on P_{CO2}
- Alveolar (and arterial) P_{CO2} is determined only by CO_2 production and alveolar ventilation



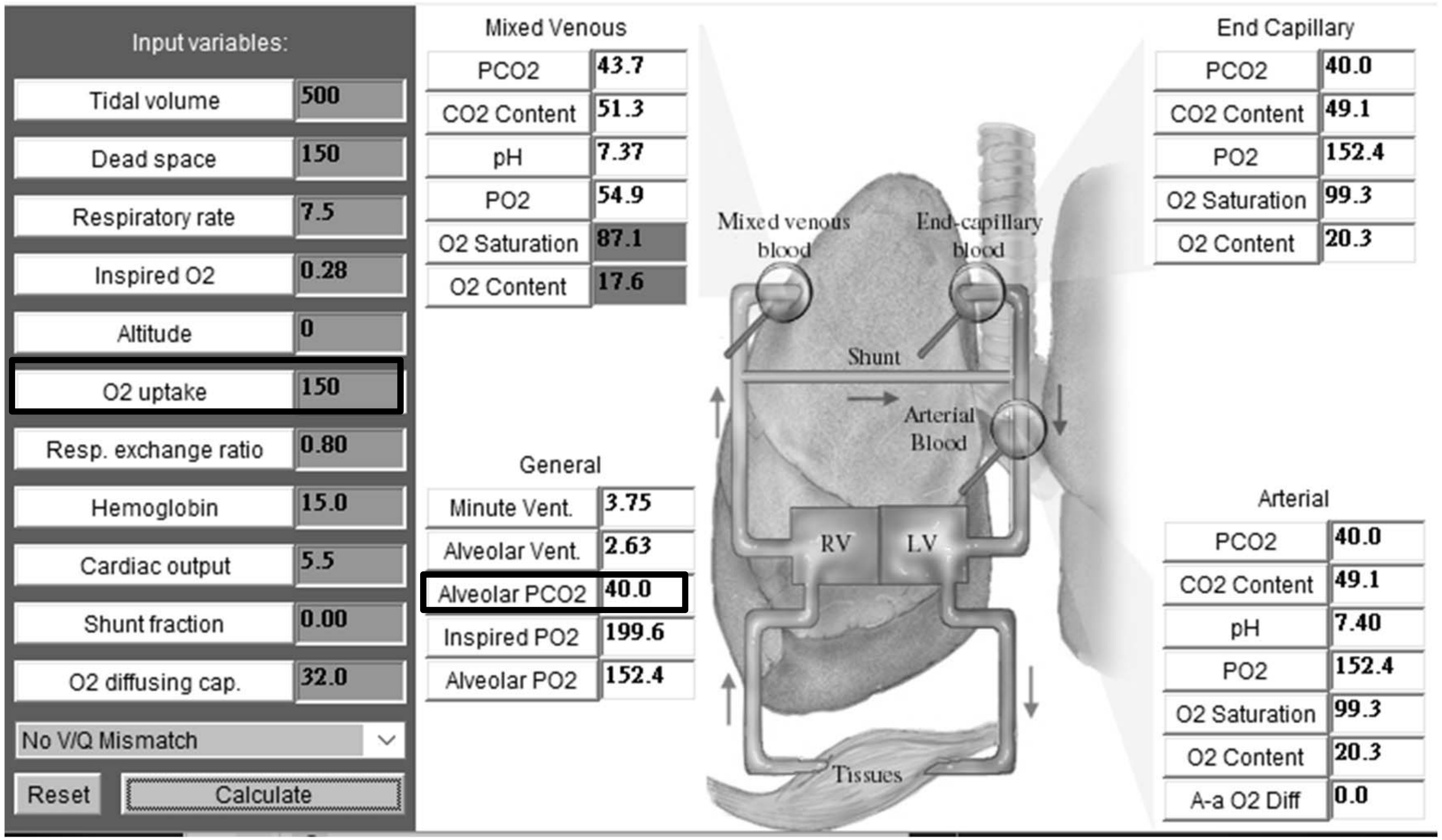
Ventilation

- How to change $Paco_2$ back to 40 mmHg?



Ventilation

- How to change $Paco_2$ back to 40 mmHg?
  - Reduce O_2 uptake from 300 to 150 ml/min



*請問當潮氣容積如何變化時，
會使二氧化碳分壓減少2倍？

A. 增加2倍

B. 增加，但倍數小於2倍

C. 減少2倍

D. 不變

Ventilation

Changes in P_{CO2} are not inversely proportional to changes in V_T, but rather to changes in V_A, i.e., $(V_T - V_D)$

		Experiment #3	
	Normal	Predicted	Measured
F_{IO2}	0.21		
V_T	500	850	
V_D	150		
f	15		
$\dot{V}_E$	7.5		
$\dot{V}_A$	5.25		
P_{aCO2}	40	20	20
P_{AO2}	101.8	125.6	125.7
P_{aO2}	101.8	↑ ↓ ↔	125.7
Arterial pH	7.4	↑ ↓ ↔	7.5

$Paco_2$ = 40 → 20 mmHg

→ meaning alveolar ventilation increase 2x

i.e., (5.25 x 2) / 15 = 0.7

$V_T = V_D + V_A$

0.15 + 0.7 = 0.85 (850 ml)

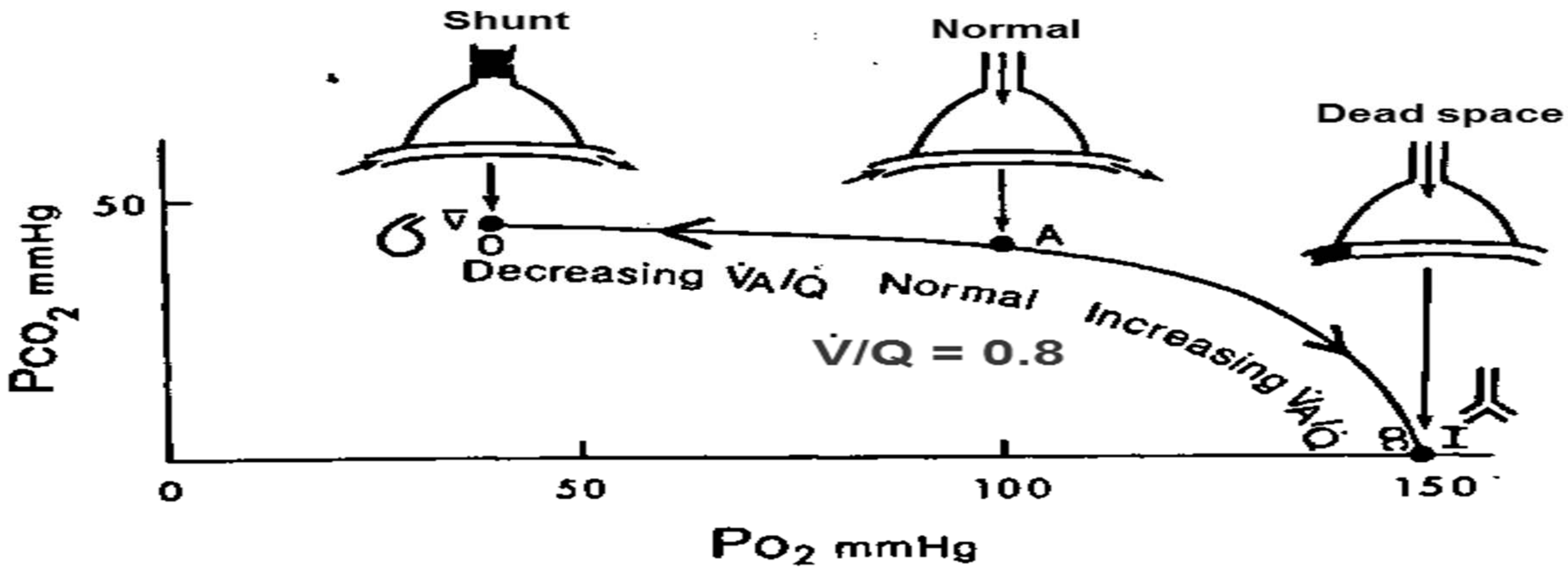
*請問當分流(shunt)比例增加時，肺泡後血管氧分壓及二氧化碳分壓如何變化?

A. Pao_2劇烈增加, $Paco_2$緩和減少
B. Pao_2劇烈減少, $Paco_2$緩和增加
C. Pao_2緩和增加, $Paco_2$劇烈減少
D. Pao_2緩和減少, $Paco_2$劇烈增加

Shunt

P_{CO2} in arterial blood is very little affected, because P_{CO2} of mixed venous blood is only about 6 mm Hg higher than arterial

	Normal	Increasing shunt			
Shunt	0	0.05	0.10	0.20	0.30
PaO_2	101.8	87.5	77.5	63.7	54.1
$PaCO_2$	40	40.4	40.8	41.8	43.1



*當受試者動脈氧分壓降低的原因是分流(shunt)所致,請問讓他吸入高濃度的氧後,動脈氧分壓的影響如何?

A. 明顯增加Pao_2

B. 明顯降低Pao_2

C. Pao_2增加不顯著

D. Pao_2降低不顯著

Shunt

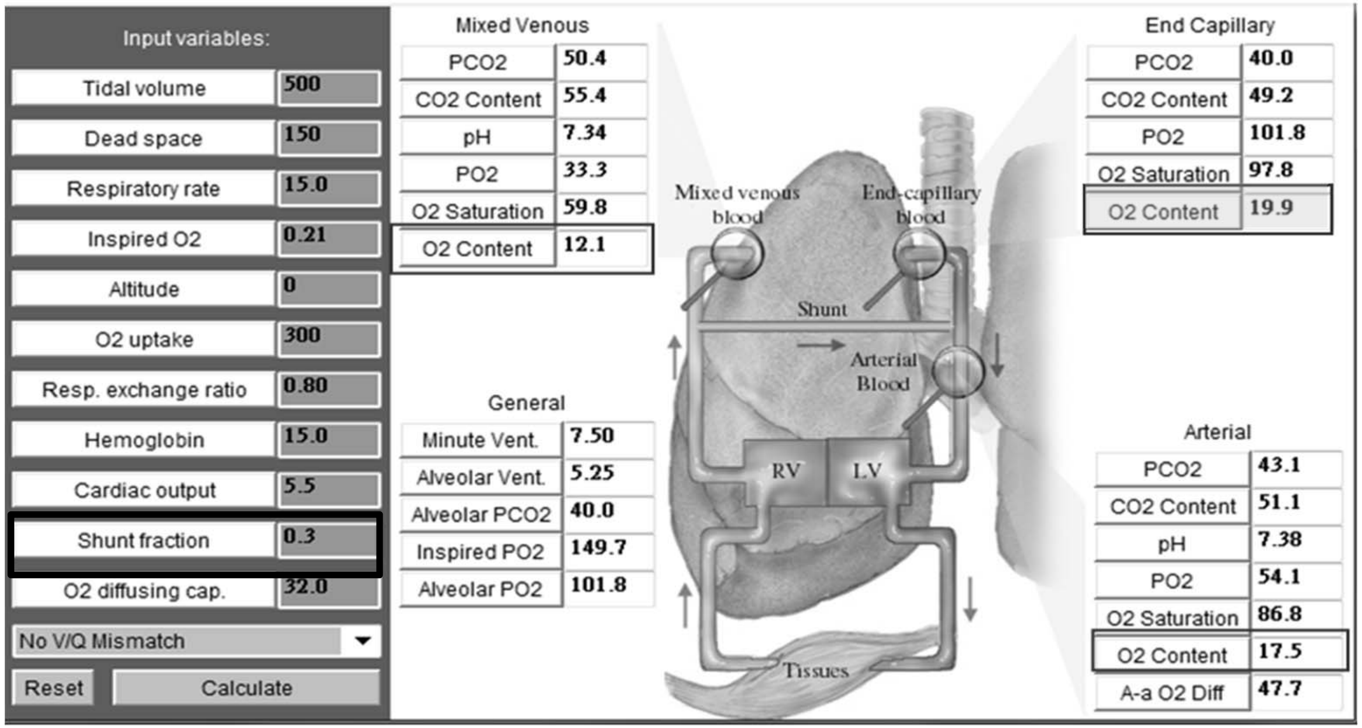
Increasing FI_{O2} in the presence of a shunt results in only a slight rise in arterial P_{O2} (54.1 → 59.0 mmHg)

	Normal	Increasing shunt	30% O_2
Shunt	0	0.30	0.30
PaO_2	101.8	54.1	59.0
$PaCO_2$	40	43.1	43.2

Shunt

Use shunt equation to calculate post-capillary O_2 content (Cco_2), when Shunt fraction is 0.3

- $0.3 = \dfrac{Cco_2 - Cao_2}{Cco_2 - Cvo_2} = \dfrac{Cco_2 - 17.5}{Cco_2 - 12.1}$
- Cco_2 = 19.81 ml/dl



*請問當肺的$\dot{V}/Q$降低時, 肺泡後血管的二氧化碳分壓如何變化?

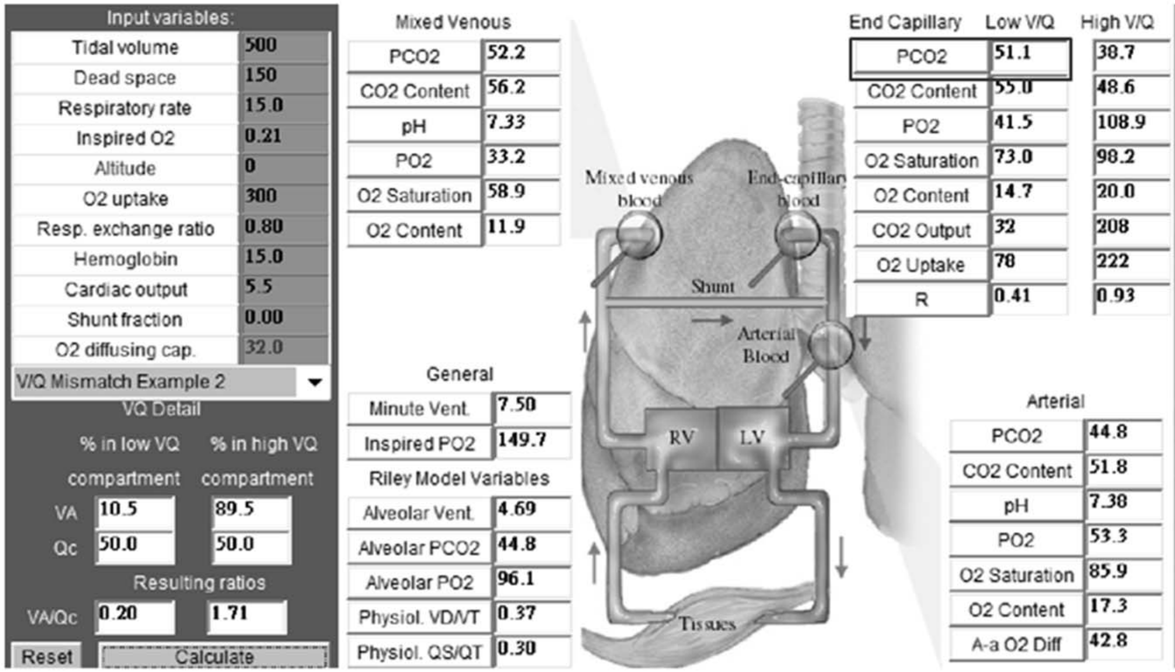
A. Pco_2劇烈增加
B. Pco_2劇烈減少
C. Pco_2緩和增加
D. Pco_2緩和減少

$\dot{V}/Q$ Imbalance

If a portion of the lungs has a low $\dot{V}/Q$ ratio compared with the rest of the lung, that portion contributes poorly oxygenated blood to the mixture

→ The effect is similar to having a portion with normal $\dot{V}/Q$ ratio plus a shunt

→ P_{CO_2} increase in low $\dot{V}/Q$ (shunt) (40 → 51.1 mmHg)



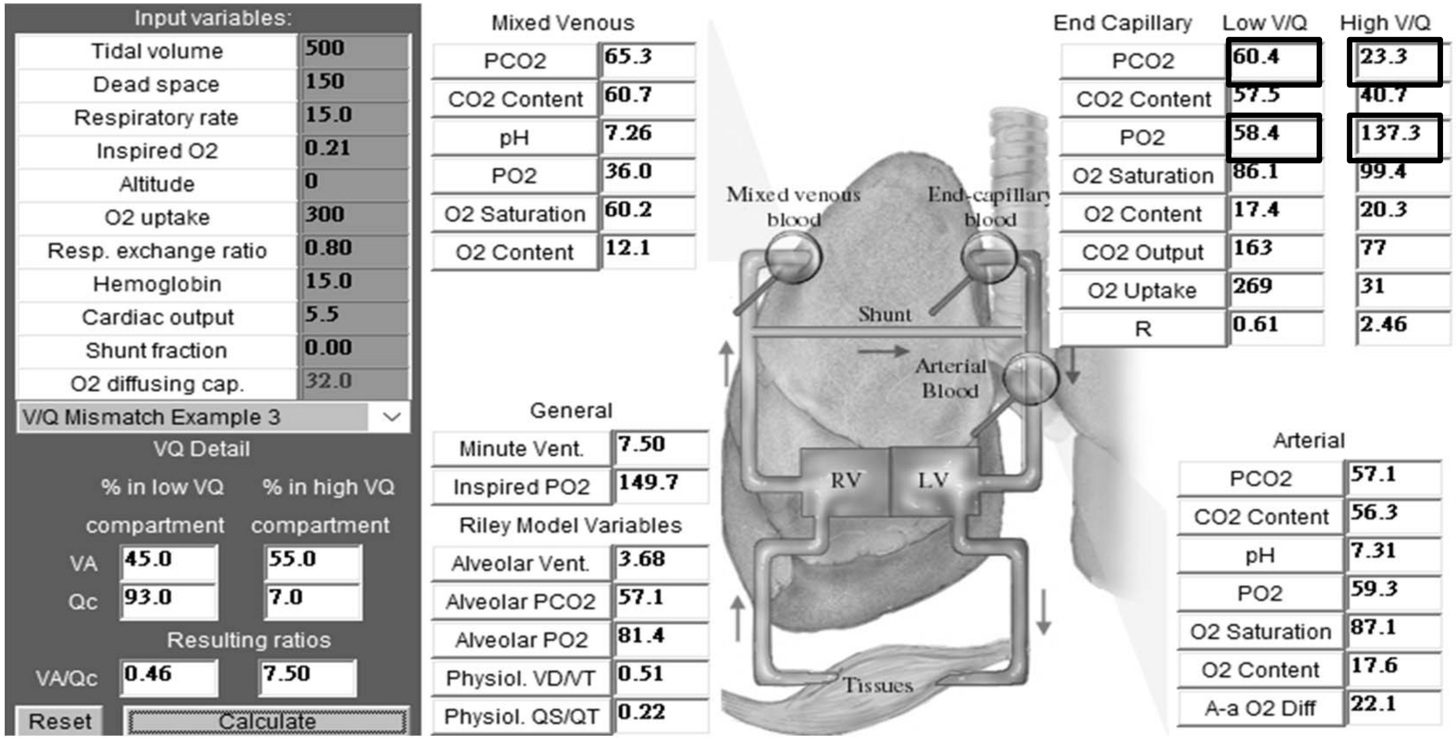
*請問當肺的$\dot{V}/Q$上升時, 肺泡後血管的二氧化碳分壓如何變化?

A. Pco_2劇烈增加
B. Pco_2劇烈減少
C. Pco_2緩和增加
D. Pco_2緩和減少

$\dot{V}/Q$ Imbalance

If there is a portion with high $\dot{V}/Q$ ratio, the effect is similar to a portion with normal $\dot{V}/Q$ ratio plus a dead space

→ end capillary P_{CO_2} decrease



*請問當肺的$\dot{V}/Q$上升時, 若肺泡通氣量保持不變, 則動脈的二氧化碳分壓如何變化?

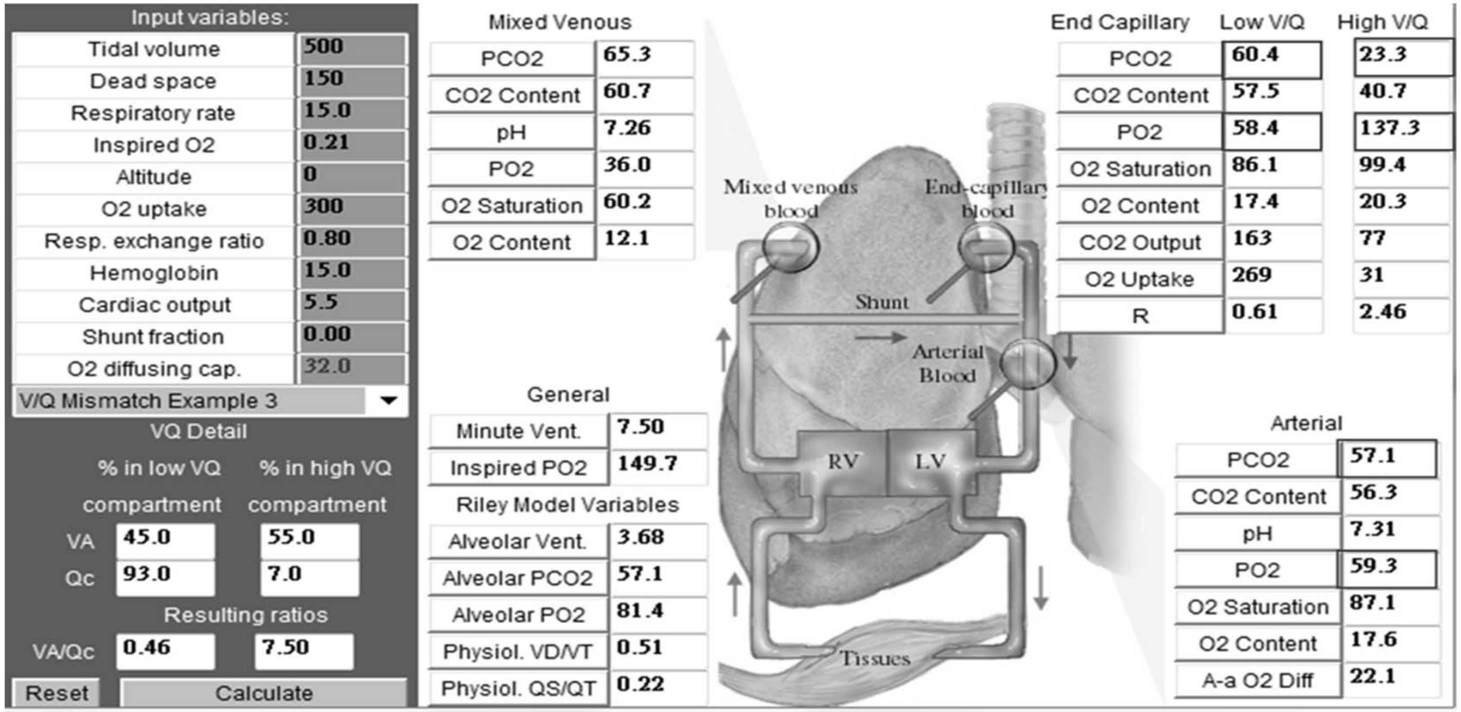
A. Pco_2增加
B. Pco_2減少
C. Pco_2不變

$\dot{V}/Q$ Imbalance

If there is no compensatory increase in total minute ventilation, the dead space ventilation

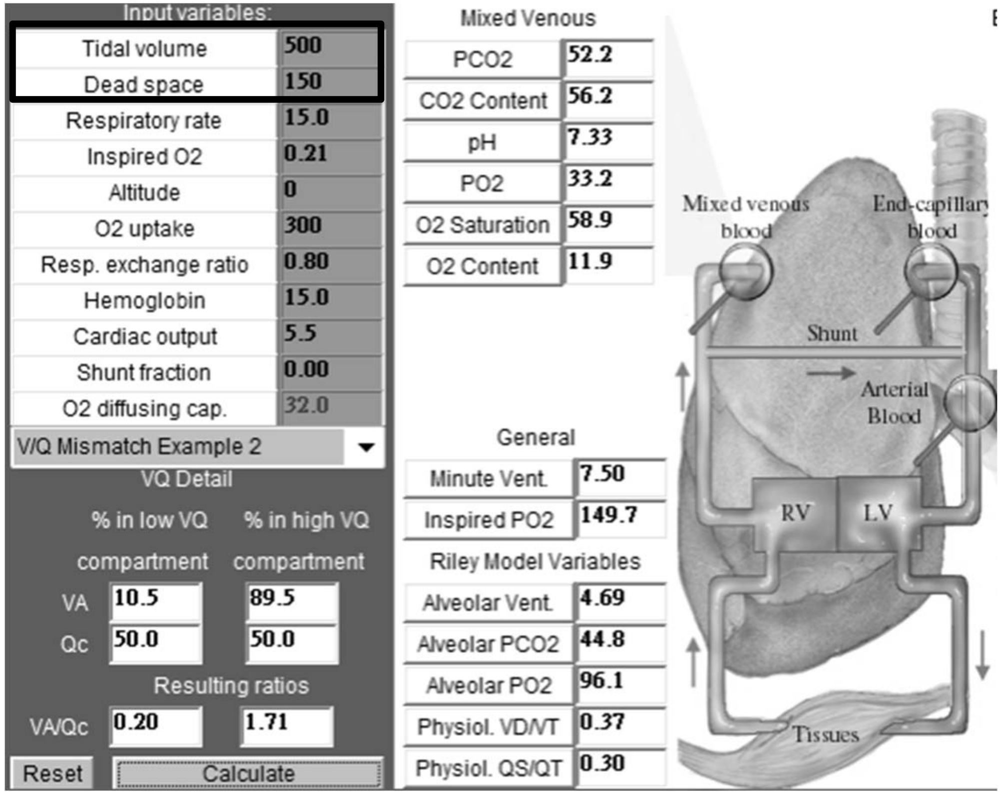
→ a lower alveolar ventilation

→ a rise in arterial P_{CO2}



$\dot{V}/Q$ Imbalance

Riley Model shows a physiological dead space ratio of 0.37, plus a shunt ratio of 0.30. Calculate the normal anatomic dead space ratio and alveolar dead space ratio?



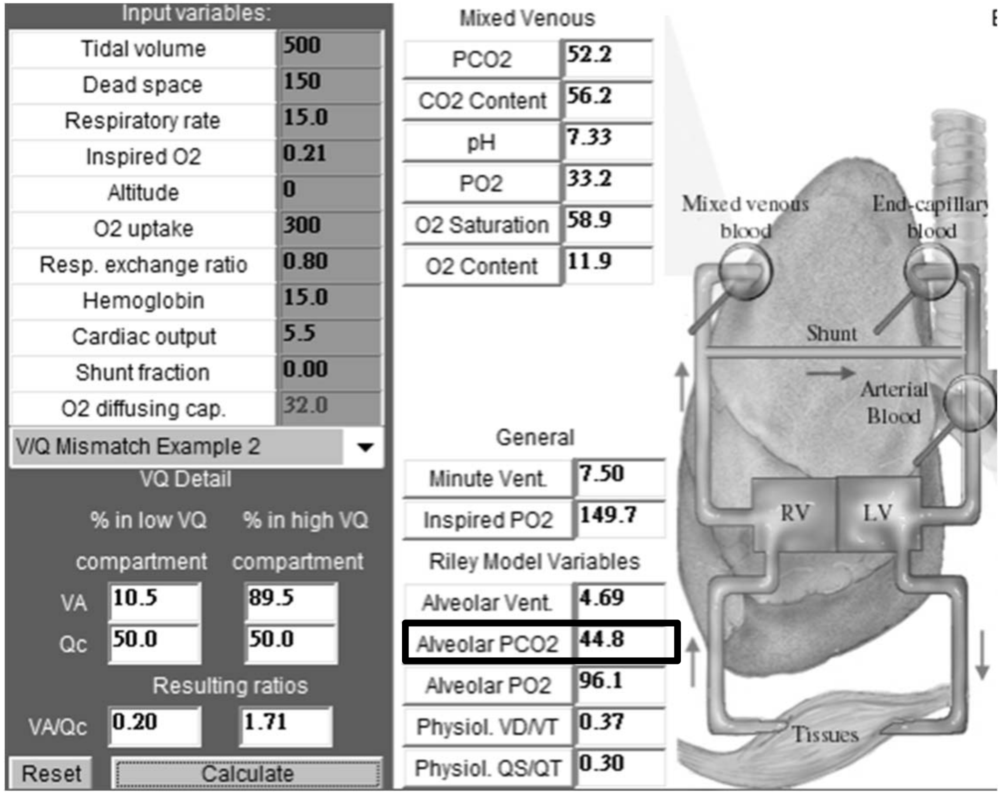
Physiological V_D =
Alveolar V_D + Anatomical V_D

Anatomic dead space ratio = 150 / 500 = 0.3

Alveolar dead space ratio = 0.37 – 0.3 = 0.07

$\dot{V}/Q$ Imbalance

Riley Model shows a physiological dead space ratio of 0.37, what is the value of expired CO_2 (Pe_{CO2})?



$V_D / V_T = (P_Aco_2 - Peco_2) / P_Aco_2$

$0.37 = (44.8 - Peco_2) / 44.8$

$Peco_2 = 28.224$ mmHg

*請問當肺的擴散效率變差時，
肺泡與動脈間的
氧分壓差(A-a difference)如何變化？

A. 減少
B. 增加
C. 不變
D. 有時增加，有時減少

Diffusion

- Normally there is plenty of alveolar-capillary difference, and equilibrium occurs before the RBC leaves the capillary
- As DL falls lower, the capillary P_{O2} will then fail to equilibrate, and arterial P_{O2} will drop

	Normal	Lower D_L			
D_LO_2	32	12	10	8	6
O_2 uptake	300	300	300	300	300
Resp rate	15	15	15	15	15
QT (CO)	5.5	5.5	5.5	5.5	5.5
P_AO_2	101.8	101.8	101.8	101.8	101.8
PaO_2	101.8	101.8	101.6	98.9	76.9
A-a O_2 diff	0	0	0.2	2.8	24.8

Diffusion

- Increasing O_2 uptake, as with exercise, requires a larger gradient and thus exaggerates the problem resulting from a low DL
- An increase in F_{IO2} raises P_{AO2} and therefore the O_2 gradient, so that equilibration is restored

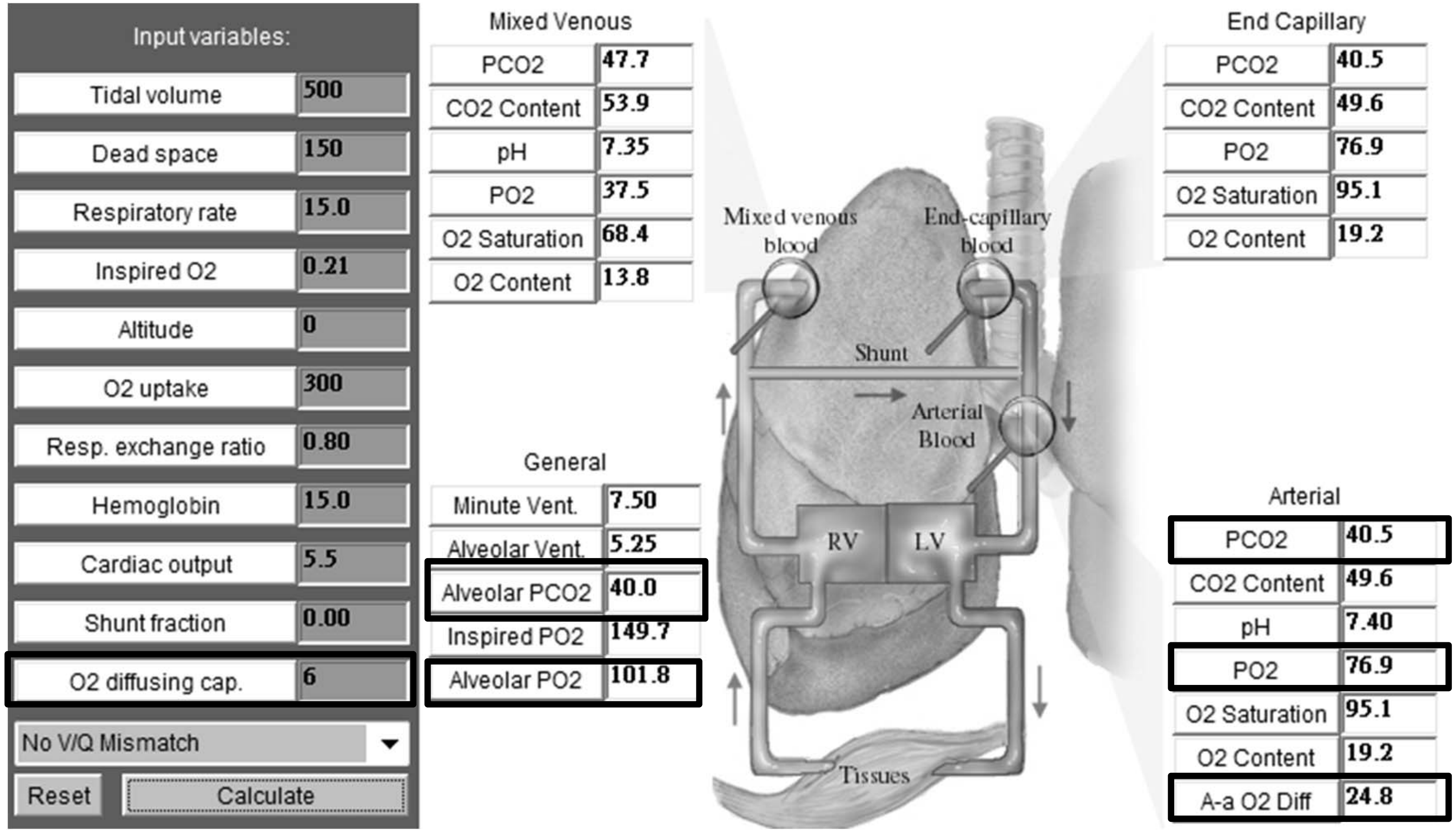
	Normal	Lower D_L	Exercise	30% O_2
D_LO_2	32	6	6	6
O_2 uptake	300	300	450	450
Resp rate	15	15	22.5	22.5
QT (CO)	5.5	5.5	8.25	8.25
PAO_2	101.8	101.8	101.8	166.8
PaO_2	101.8	76.9	32.4	166.4
A-a O_2 diff	0	24.8	69.4	0.4

*請問當肺的擴散效率變差時,
肺泡與動脈間的
二氧化碳分壓差如何變化?

A. 增加
B. 減少
C. 不變
D. 有時增加, 有時減少

Diffusion

CO_2 is so diffusible that no significant A-a CO_2 gradient can exist, even when O_2 transport is severely impaired



Cardiac Output

If cardiac output falls with everything else held constant, how will blood gas values change?

Due to cardiac output decreases → tissue hypoxia

→ venous P_{O2} decreases

→ venous O_2 saturation decreases

	Normal	Predicted	Lower output		
QT	5.5	5.0	5.0	4.0	3.0
$PaCO_2$	40	↑ ↓ ↔	40	40	40
PaO_2	101.8	↑ ↓ ↔	101.8	101.8	101.8
PvO_2	39.5	↑ ↓ ↔	37.8	34	28.7
SvO_2	71.4	↑ ↓ ↔	68.7	61.3	48.9

Hemoglobin

How does anemia affect gas exchange?

- Blood-gas machine only measures oxygen dissolved in the blood plasma
- Similar to decrease in cardiac output,

  anemia → tissue hypoxia → Pvo_2, Svo_2 decreases

	Normal	Low Hemoglobin	
Hb	15	10	7.5
$PaCO_2$	40	40	40
PaO_2	101.8	101.8	101.8
PvO_2	39.5	31.6	25.7
SvO_2	71.4	58.4	45.5

The End!

References:

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- KE Barrett et. al., Ganong’s Review of Medical Physiology
- SI Fox, Human Physiology
- JB West, Respiratory Physiology: the essentials