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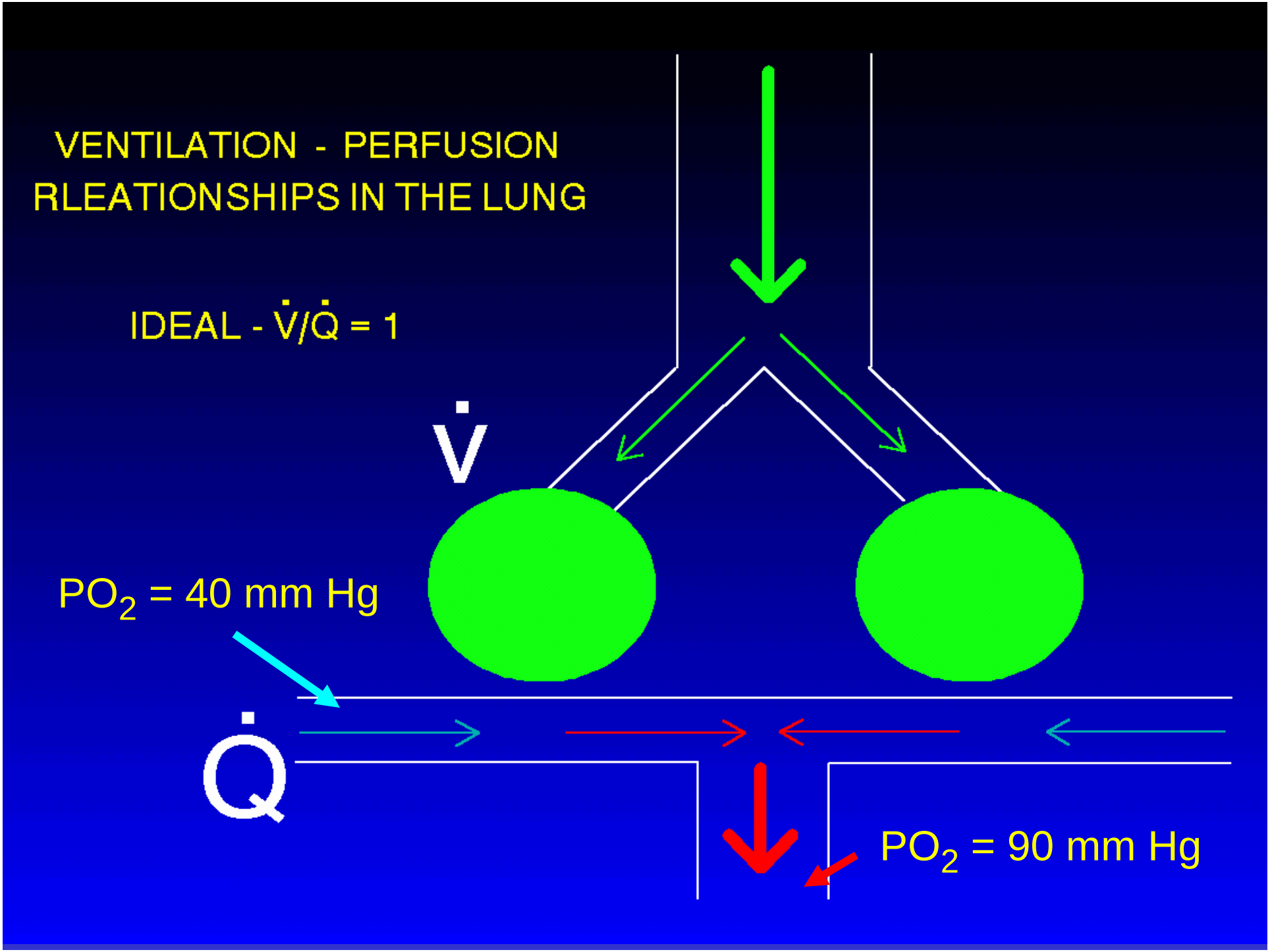
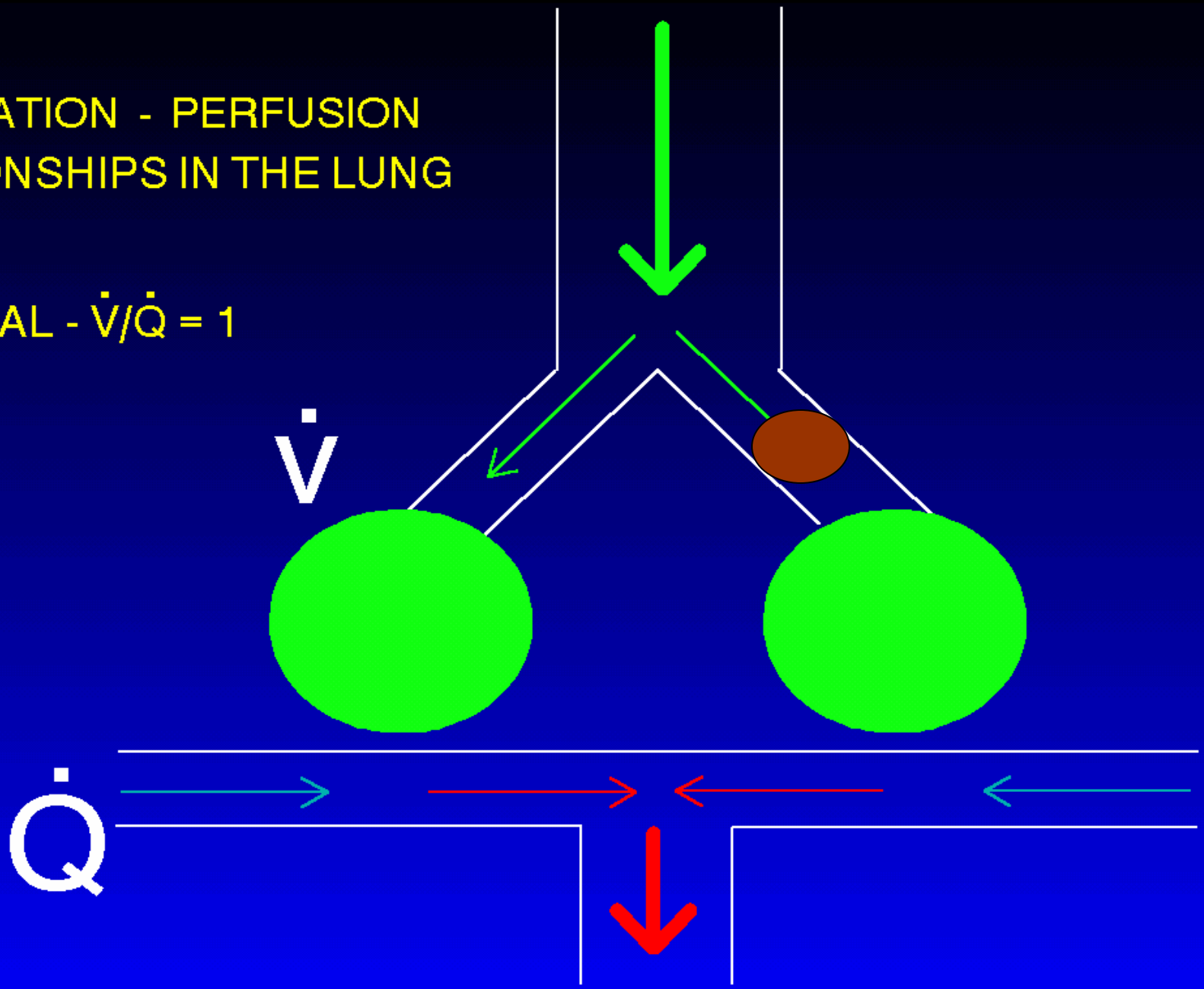
VASCULAR RESISTANCE IN THE PULMONARY CIRCULATION IS ONE-TENTH THAT OF THE SYSTEMIC CIRCULATION

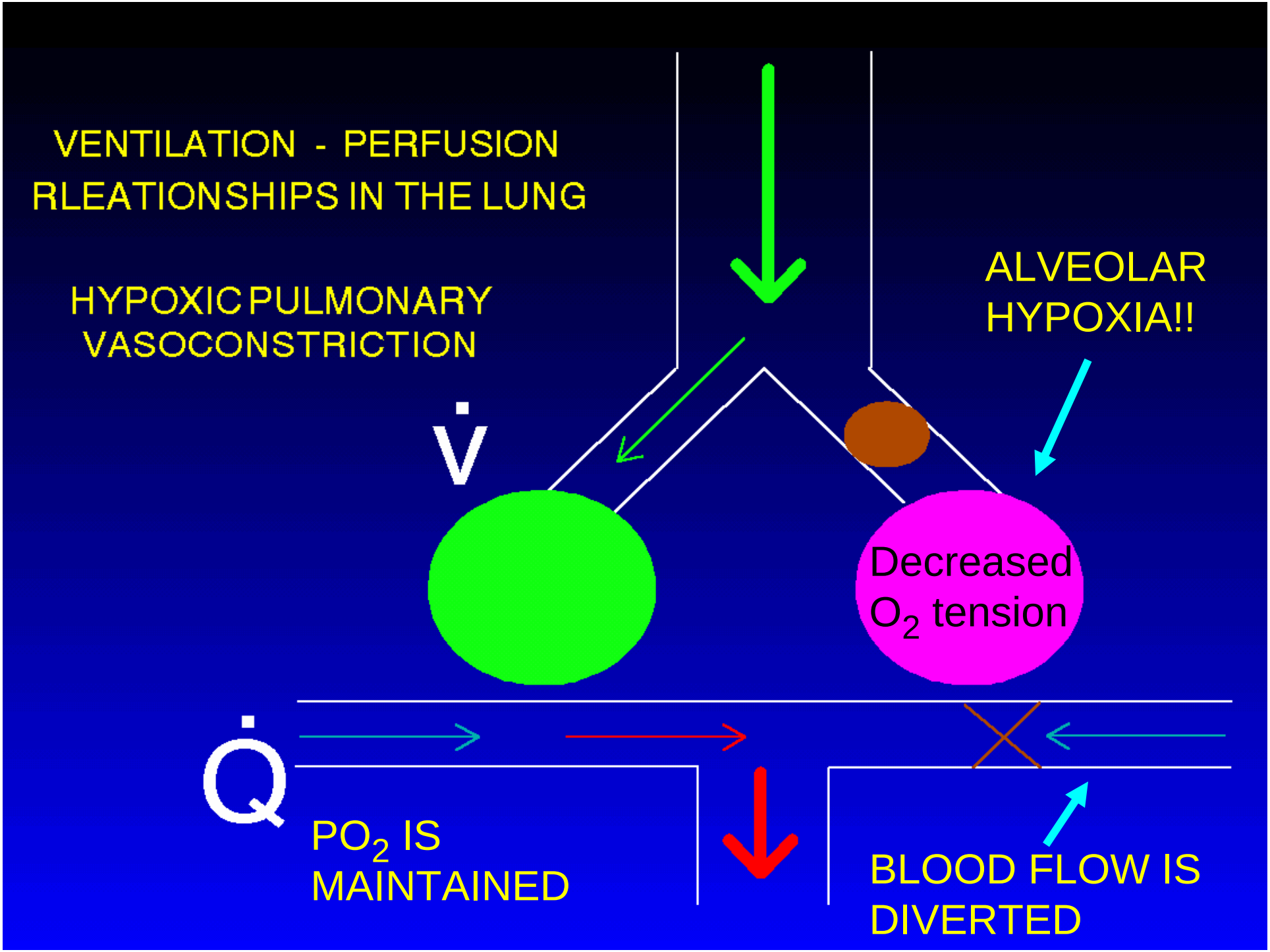
WITHIN THE PULMONARY CIRCULATION, BLOOD FLOW MUST BE DIRECTED TO WELL VENTILATED (OXYGENATED) ALVEOLI, THAT IS, VENTILATION MUST BE MATCHED WITH PERFUSION

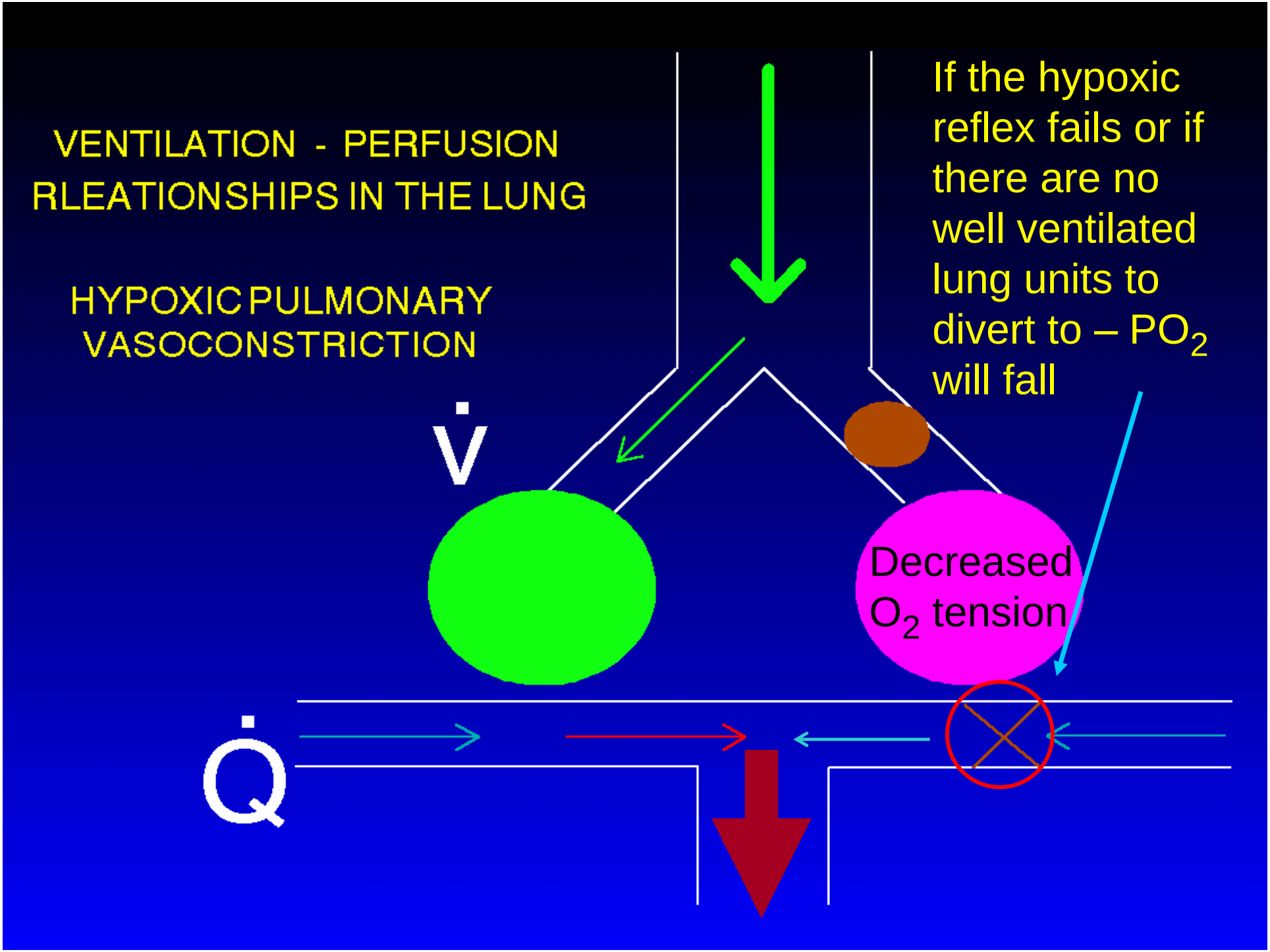

VENTILATION - PERFUSION
RLEATIONSHIPS IN THE LUNG
IDEAL - V̇/Q̇ = 1
V̇
PO2 = 40 mm Hg
Q̇
PO2 = 90 mm Hg

VENTILATION - PERFUSION
RLEATIONSHIPS IN THE LUNG

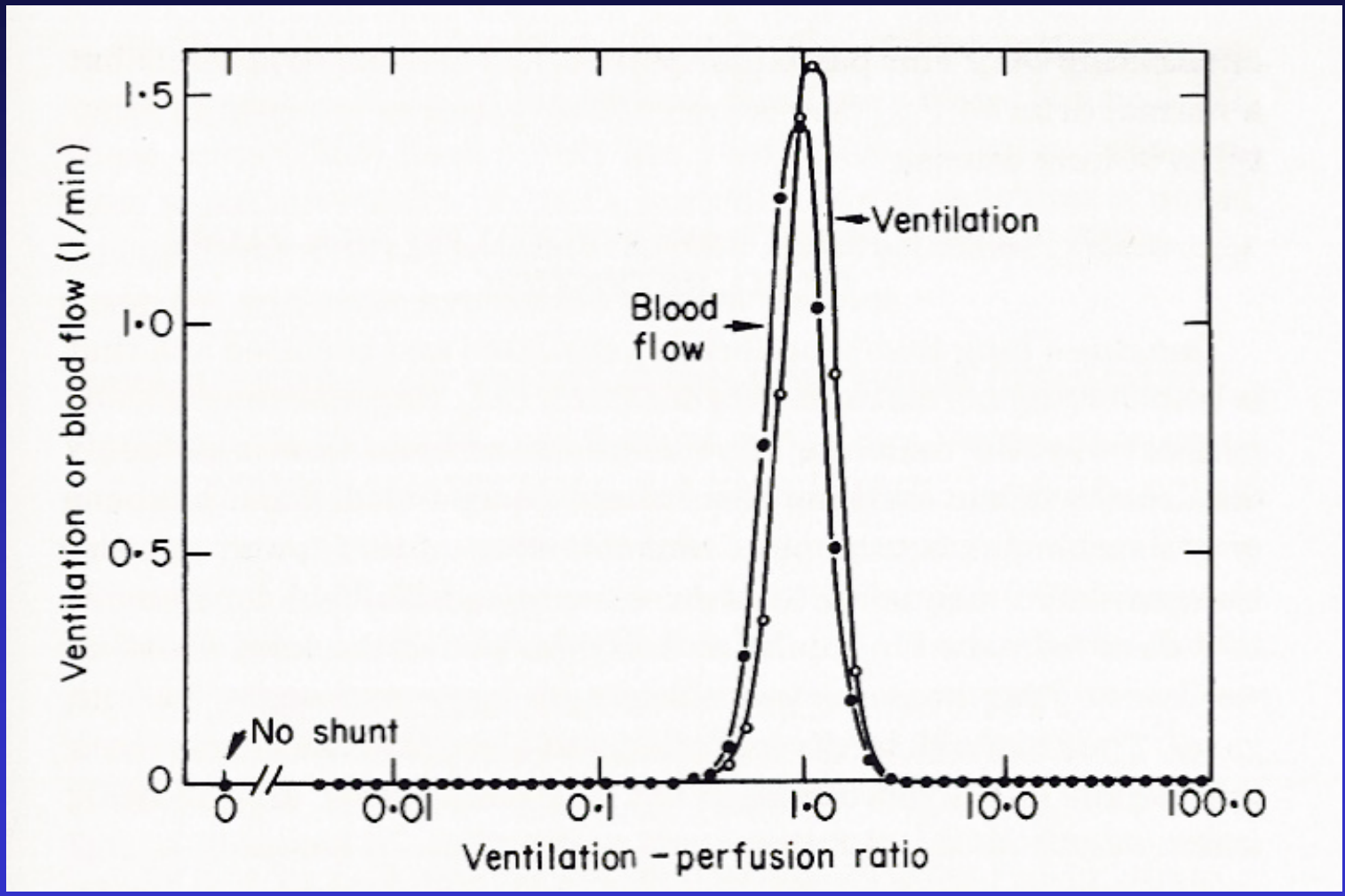
IDEAL - $\dot{V}/\dot{Q} = 1$




VENTILATION - PERFUSION
RLEATIONSHIPS IN THE LUNG
HYPOXIC PULMONARY
VASOCONSTRICTION
ALVEOLAR
HYPOXIA!!
V̇
Decreased
O_2 tension
Q̇
PO_2 IS
MAINTAINED
BLOOD FLOW IS
DIVERTED


VENTILATION - PERFUSION
RLEATIONSHIPS IN THE LUNG
HYPOXIC PULMONARY
VASOCONSTRICTION
If the hypoxic reflex fails or if there are no well ventilated lung units to divert to – PO_2 will fall
$\dot{V}$
Decreased O_2 tension
$\dot{Q}$

Ventilation – Perfusion $\dot{V}/\dot{Q}$ Matching



How much oxygen is in the alveolus? What is “normal”?

To answer this question we need to review the alveolar gas equation: $P_AO_2 = F_iO_2(P_B-P_{H2O}) – P_aCO_2 / R$

Where:

P_AO_2 = alveolar oxygen tension

F_iO_2 = the fraction of inspired oxygen

P_B-P_{H2O} = barometric – water vapor pressure

P_aCO_2 = arterial carbon dioxide tension

R = the respiratory quotient

How much oxygen is in the alveolus? What is “normal”?

To answer this question we need to review the alveolar gas equation: $P_AO_2 = F_iO_2(P_B-P_{H2O}) – P_aCO_2 / R$

So: $P_AO_2 = 0.21 (760 \text{ mm Hg} – 47\text{mm Hg}) – 40\text{mm Hg}/ 0.8$

Thus: $P_AO_2 = 99$ mm Hg

“normal” P_AO_2 is approximately 99 mm Hg

The Sprague modification of the alveolar gas equation (room air only): $150 - P_aCO_2 \times 1.25$

How much oxygen is in the alveolus? How much is in the arterial blood?

What is the alveolar – arterial oxygen difference ($A\text{-}aDO_2$)

What are “normal” blood gas values?

pH = 7.35 to 7.45 units

PCO_2 = 35 to 45 mm Hg

PO_2 = >85 to 90

So what is the normal $A\text{-}aDO_2$? 10 to 15 mm Hg

ON ROOM AIR

Case # 1:

How do you approach the problem?

The answer begins with Dalton's gas laws:

#1; the pressure of a mixture of gasses equals the sum of the partial pressures of the constituent gasses.

#2; so long as no chemical change occurs, each gas in a mixture of gasses is absorbed by a given volume of solvent in proportion not to the local pressure of the mixture, but to the partial pressure of that gas.

Case # 1:

What does that mean?

#1; the pressure of a mixture of gasses equals the sum of the partial pressures of the constituent gasses.

In the alveolus, the mixture of gasses contains nitrogen, water vapor, trace gasses, oxygen and carbon dioxide.

At the end of a breath, the pressure in the alveolus = atmospheric pressure.

So.. $P_B = PN_2 + P_{H2O} + P_{\text{trace gasses}} + PO_2 + PCO_2$

Or.. $PO_2 + PCO_2$ = a constant

Case # 1:

What does that mean?

If PO_2 + PCO_2 = a constant, then what can we conclude would occur if the alveoli are inadequately ventilated?

In the case of alveolar hypoventilation, what happens to the PCO_2? How do we detect this?

If PO_2 + PCO_2 = a constant, then what happens if PCO_2 increases?

How do you determine if the increase in PCO_2 explains the measured decrease in PO_2?

SOLVE THE ALVEOLAR GAS EQUATION!

$P_AO_2 = F_iO_2(P_B - P_{H2O}) - P_aCO_2 / R$

So: $P_AO_2 = 0.21$ (760 mm Hg – 47mm Hg) – 60mm Hg/ 0.8

Thus, under the best possible conditions:

$P_AO_2 = 74$ mm Hg

The animal's : $P_aO_2 = 66$ mm Hg , so what is the $AaDO_2$?

The $AaDO_2 = 74 – 66$ or 8 mm Hg

So what can you do to save the animal?

Case # 2:

How do you approach the problem?

The answer begins with the alveolar gas equation:

$$P_AO_2 = F_iO_2(P_B - P_{H2O}) - P_aCO_2 / R$$

So: $P_AO_2 = 0.21\ (760\ mm\ Hg - 47 mm\ Hg) - 50\ mm\ Hg / 0.8$

$$P_AO_2 = 87\ mm\ Hg$$

The animal's : $P_aO_2 = 50\ mm\ Hg$, so what is the $AaDO_2$?

The $AaDO_2 = 87 - 50$ or 37 mm Hg

Does decreased alveolar ventilation explain some or all of the observed reduction in P_aO_2?

Something else is going on here! How would you figure it out?

Maybe we have a problem with the distribution of blood flow in the lung, i.e., ventilation and perfusion are poorly matched. How would you approach that question?

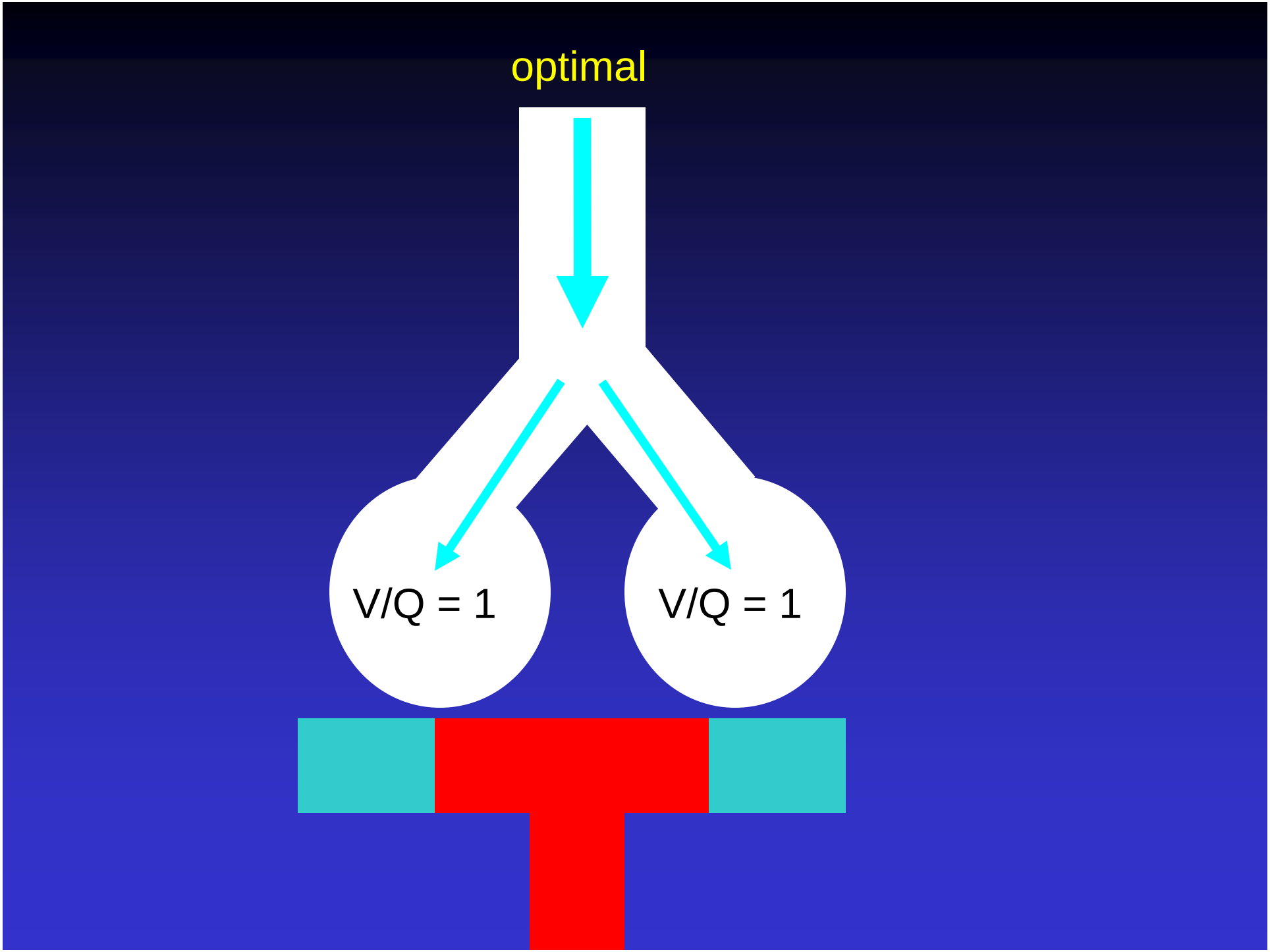
The concept of VENOUS ADMIXTURE

Venous admixture is said to occur when blood passes through the lung without being properly oxygenated.

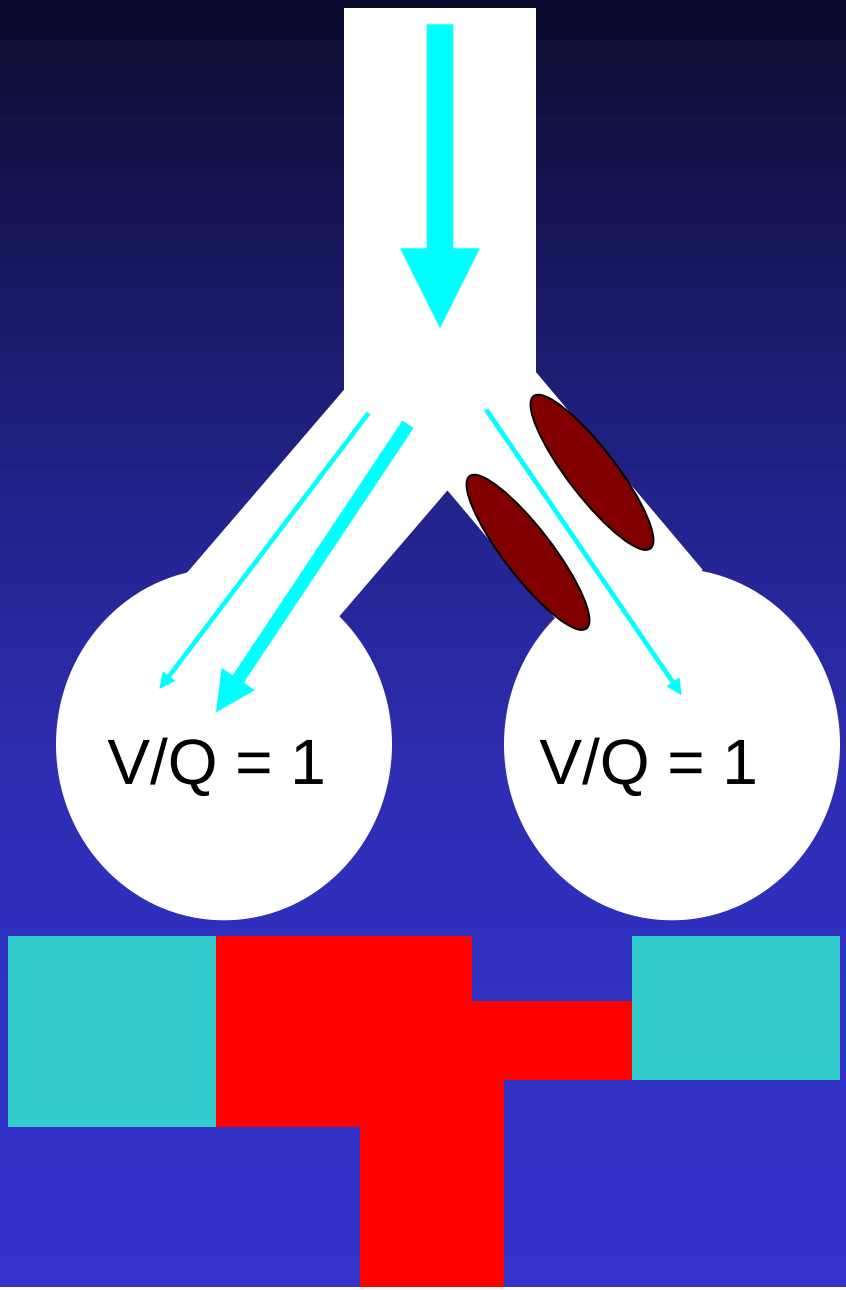
To let us use this idea, I propose that you consider Venous admixture to be divided into two types.

These are termed V/Q MISMATCH and SHUNT

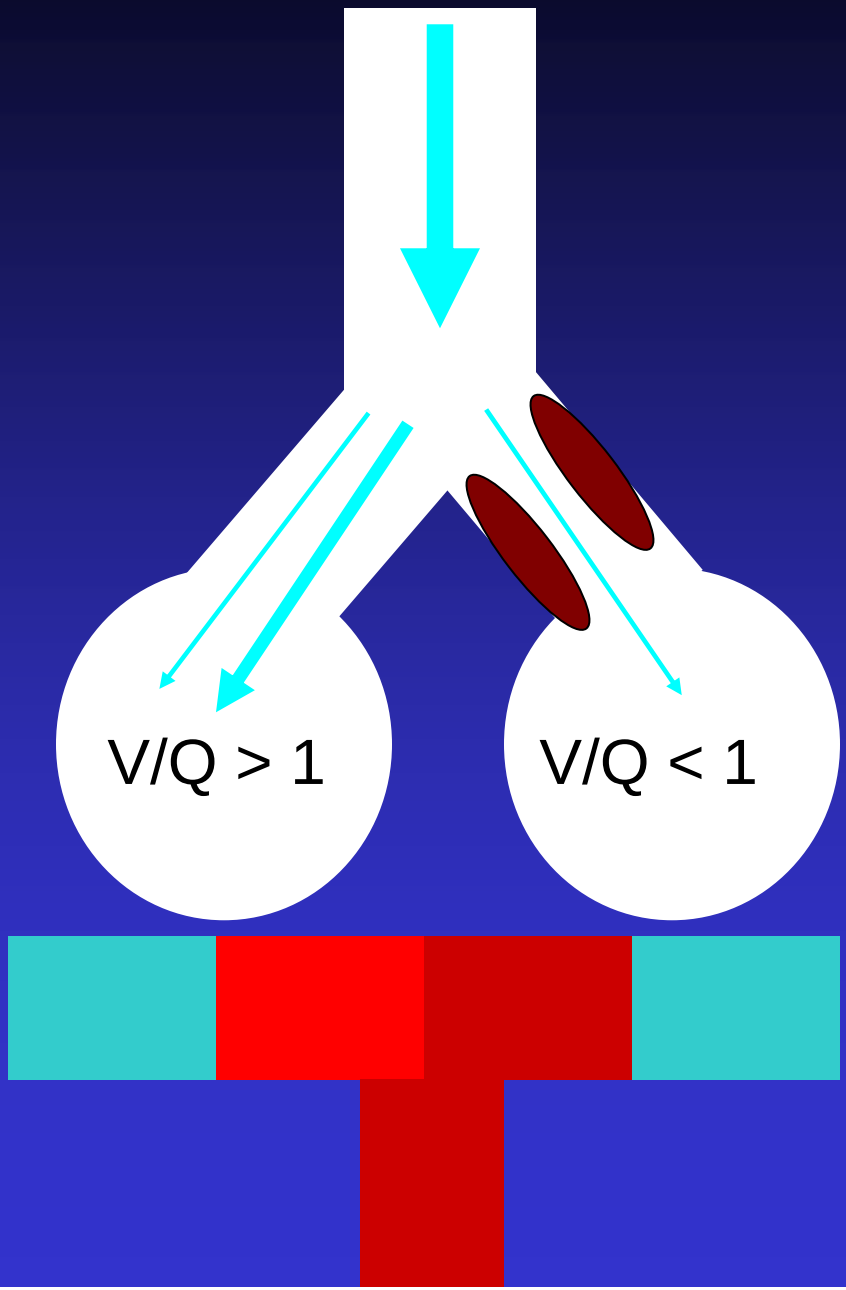
Lets see which applies to our case


optimal
V/Q = 1
V/Q = 1

COMPENSATION

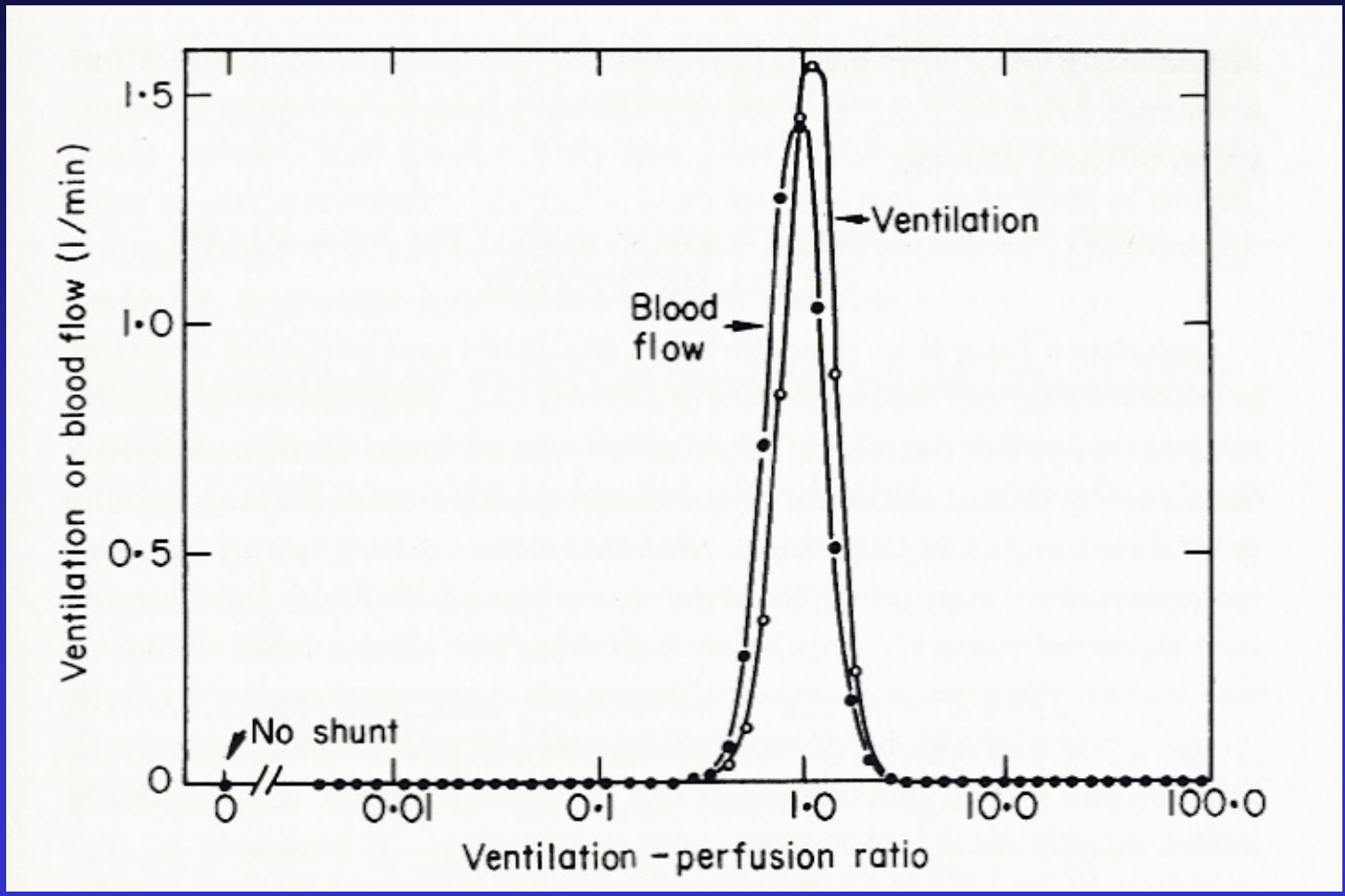


V/Q MISMATCH

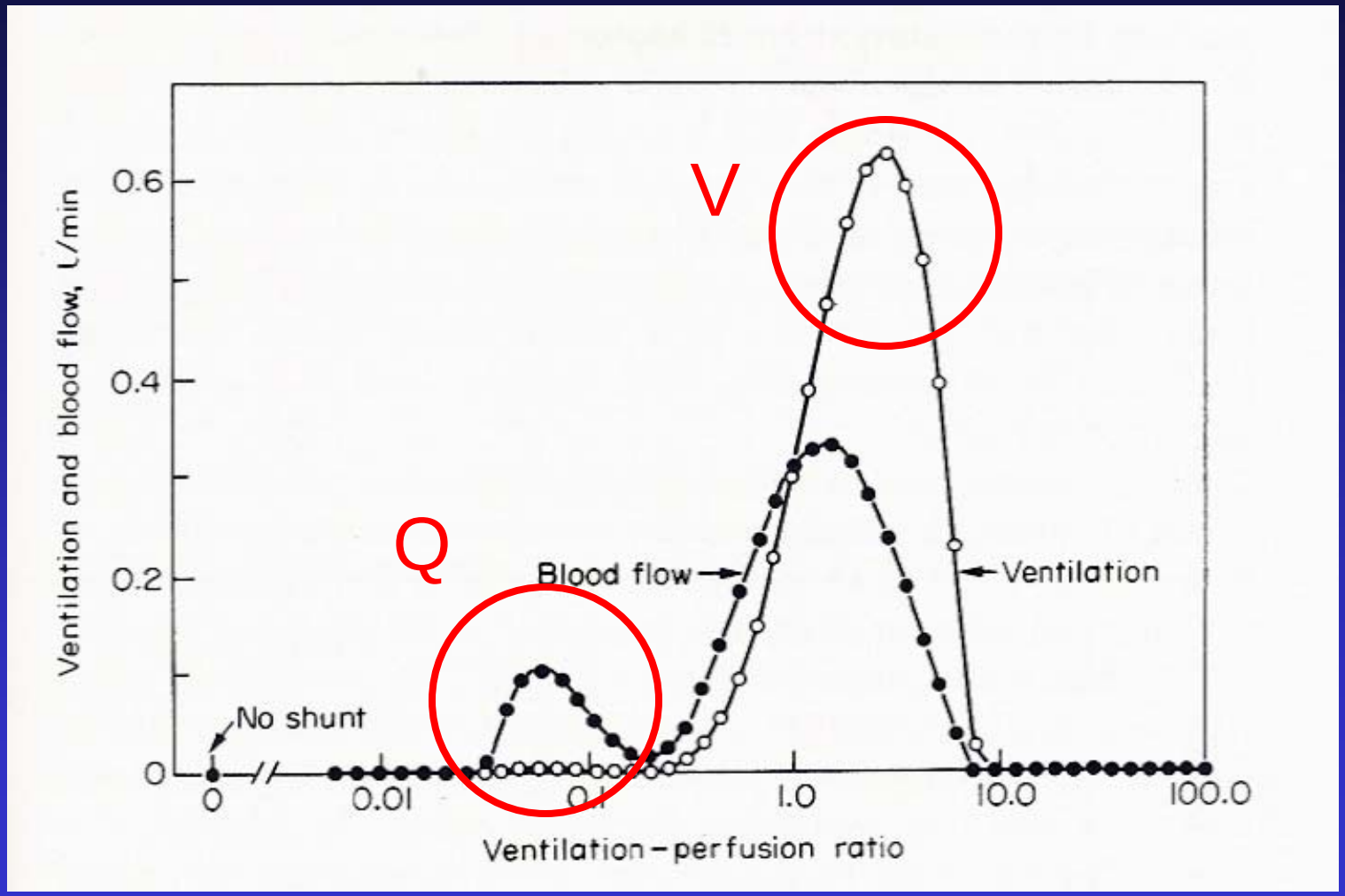


WHAT IF BLOOD FLOW DIVERSION FAILS?

Ventilation – Perfusion $\dot{V}/\dot{Q}$ Matching



Ventilation – Perfusion $\dot{V}/\dot{Q}$ Mismatch

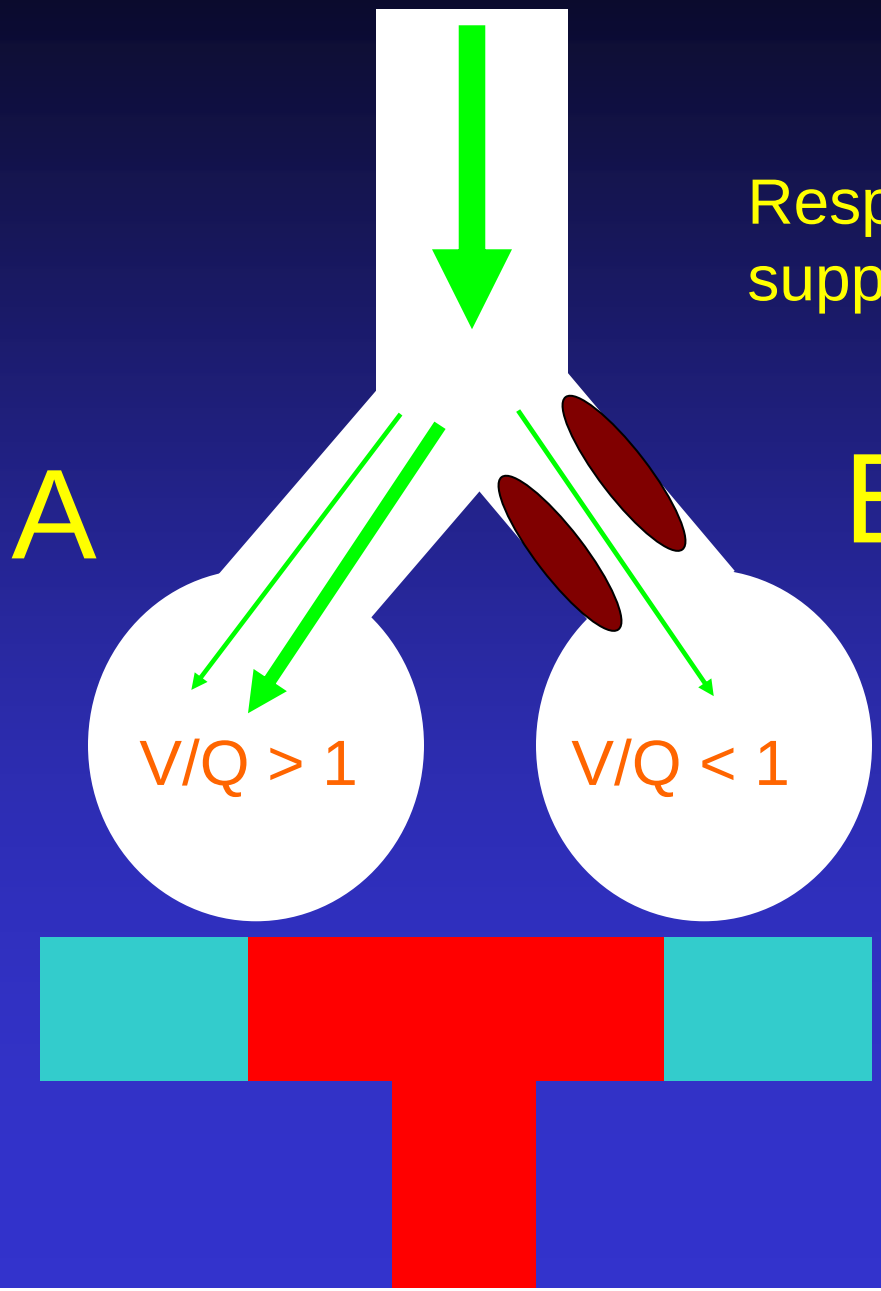


How would confirm that this is the mechanism responsible for the reduced oxygen tension in this case?

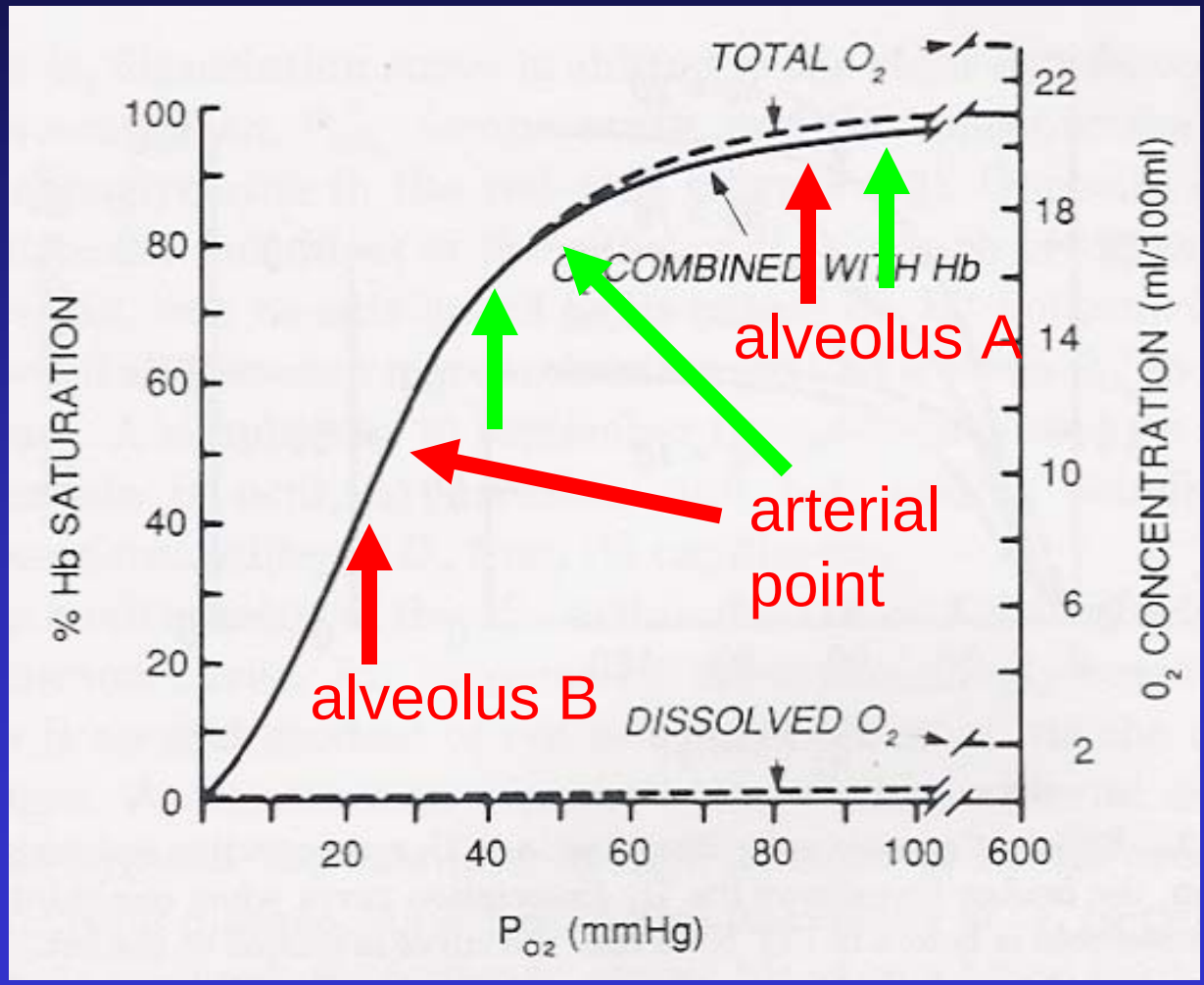
What therapy would you employ?

Provide a small amount of supplemental oxygen for the animal.

V/Q MISMATCH



Response to supplemental oxygen


TOTAL O_2
O_2 COMBINED WITH Hb
DISSOLVED O_2
% Hb SATURATION
O_2 CONCENTRATION (ml/100ml)
P_{O_2} (mmHg)
100
80
60
40
20
0
22
18
14
10
6
2
20
40
60
80
100
600
alveolus A
arterial point
alveolus B

Case # 3:

How do you approach the problem?

Do you need the alveolar gas equation:

$$P_AO_2 = F_iO_2(P_B - P_{H2O}) - P_aCO_2 / R$$

Does decreased alveolar ventilation explain some or all of the observed reduction in P_aO_2?

Something else is going on here! How would you figure it out?

Maybe we have a problem with the distribution of blood flow in the lung, i.e., ventilation and perfusion are poorly matched. How would you approach that question?

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To let us use this idea, I propose that you consider venous admixture to be divided into two types.

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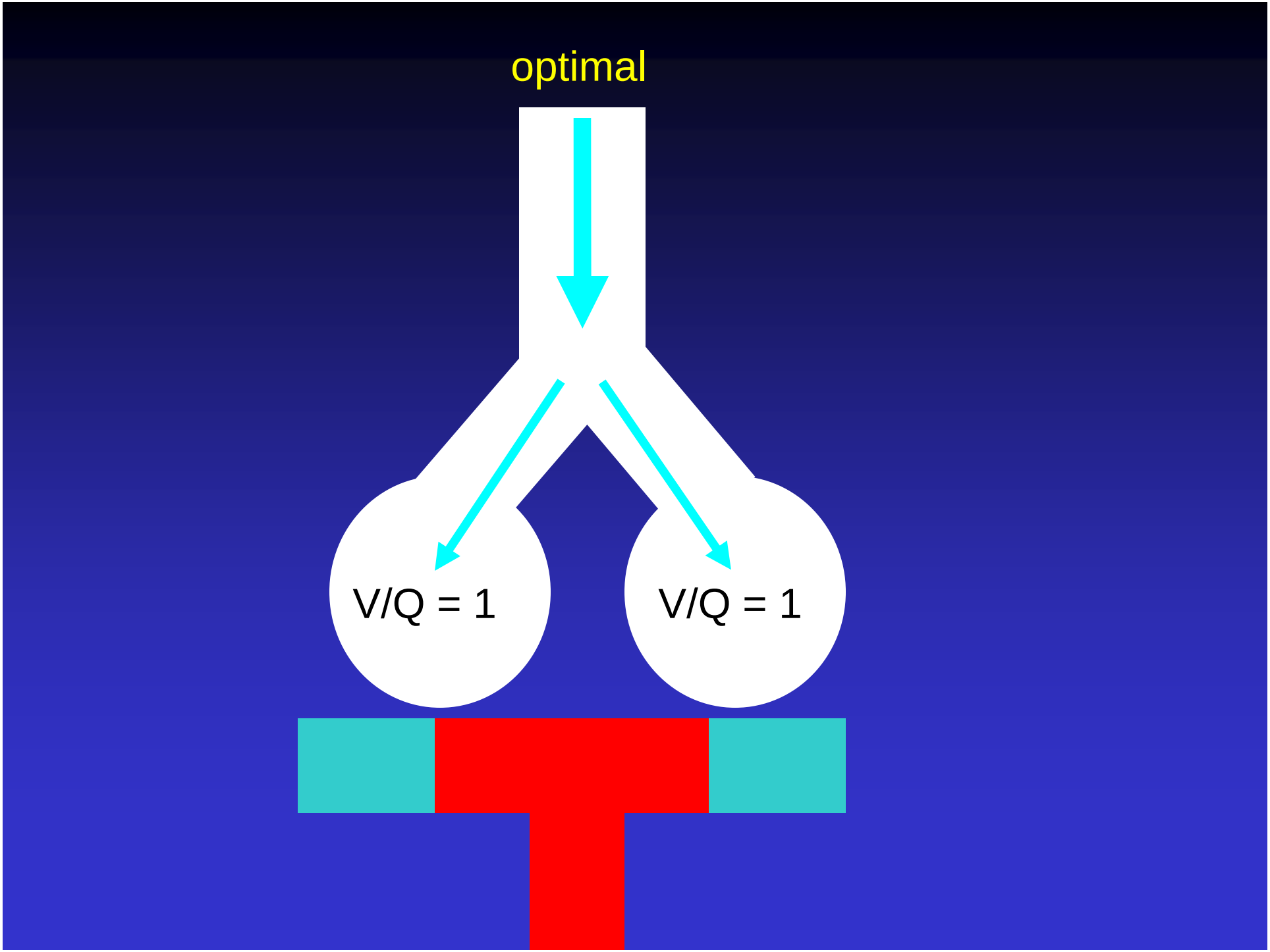
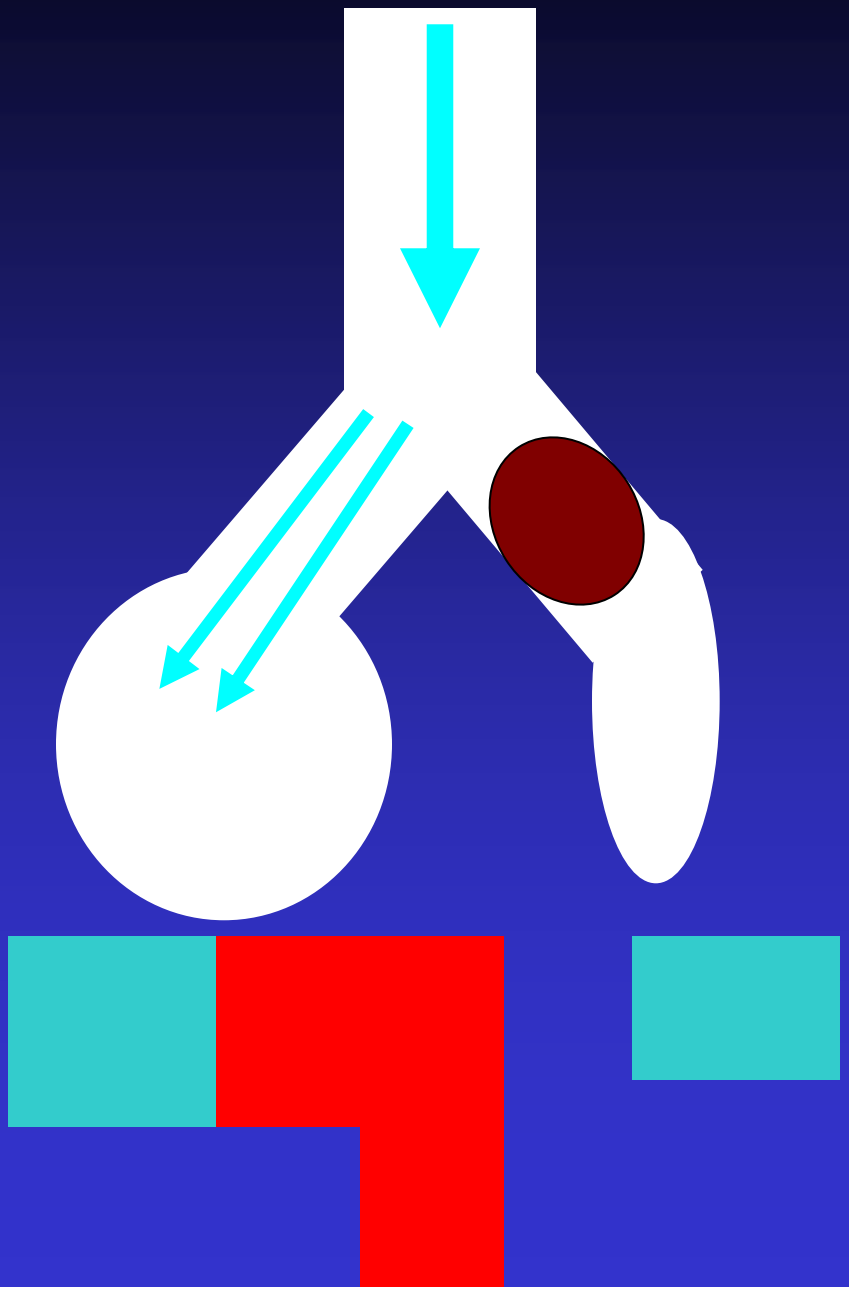
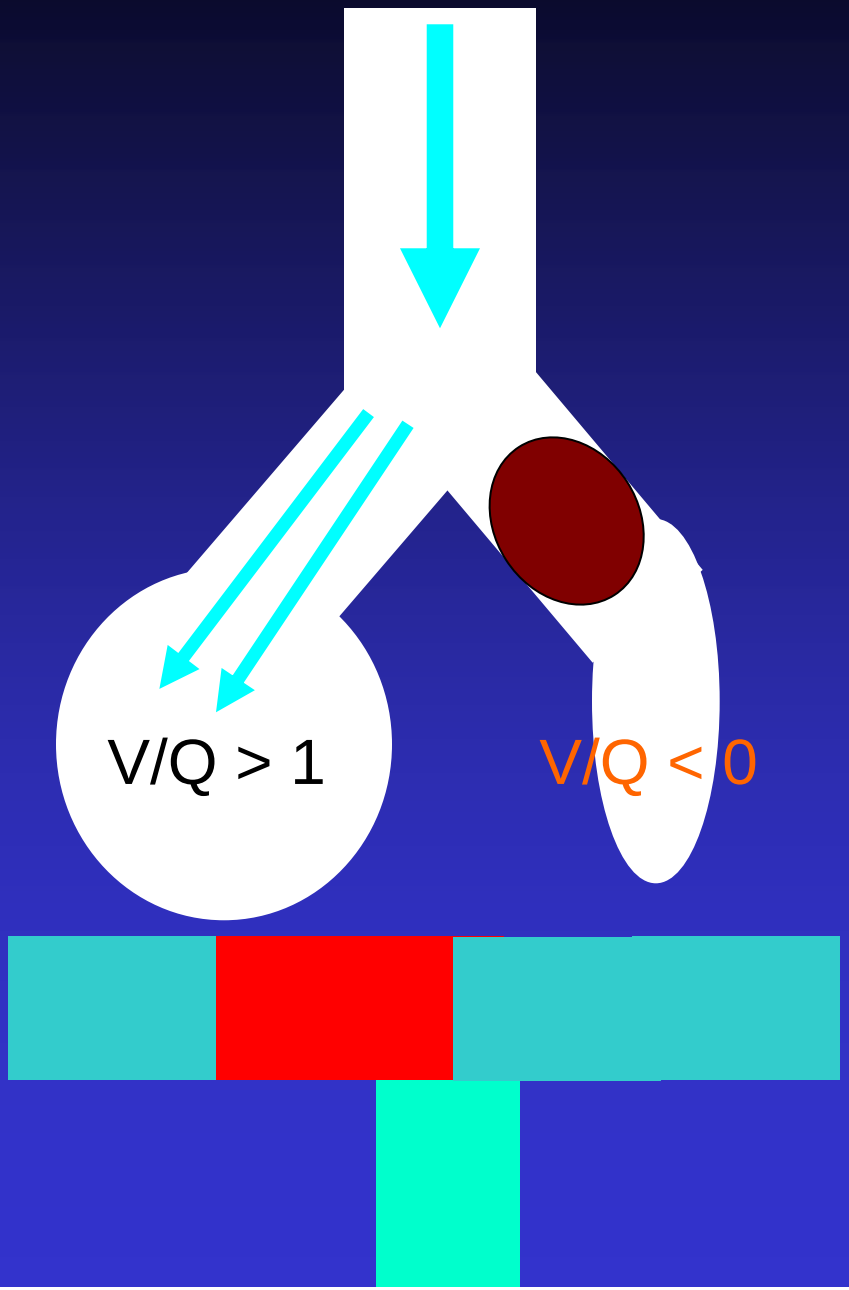
Lets see which applies to our case


optimal
V/Q = 1
V/Q = 1

COMPENSATION



SHUNT



WHAT IF BLOOD FLOW DIVERSION FAILS?

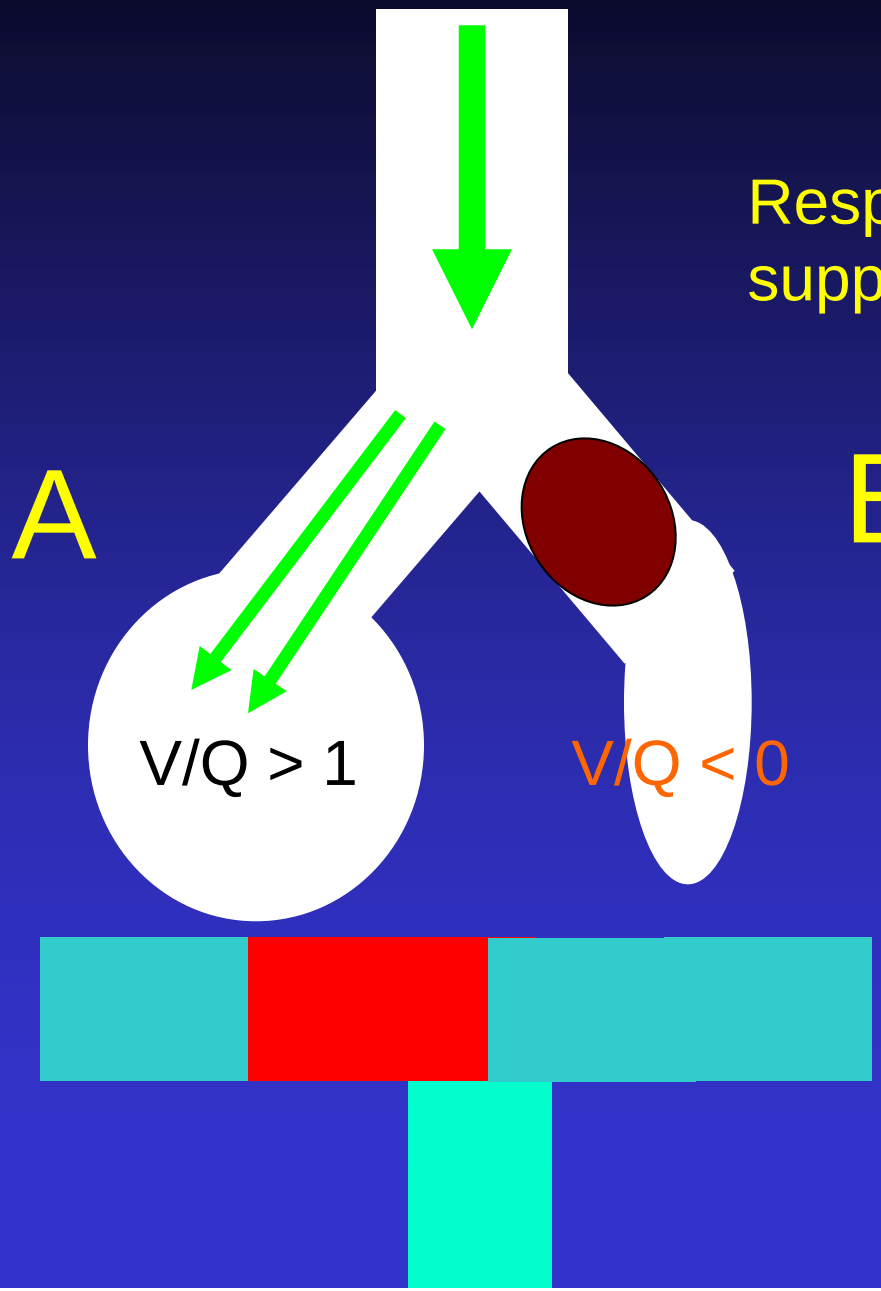
How would confirm that this is the mechanism responsible for the reduced oxygen tension in this case?

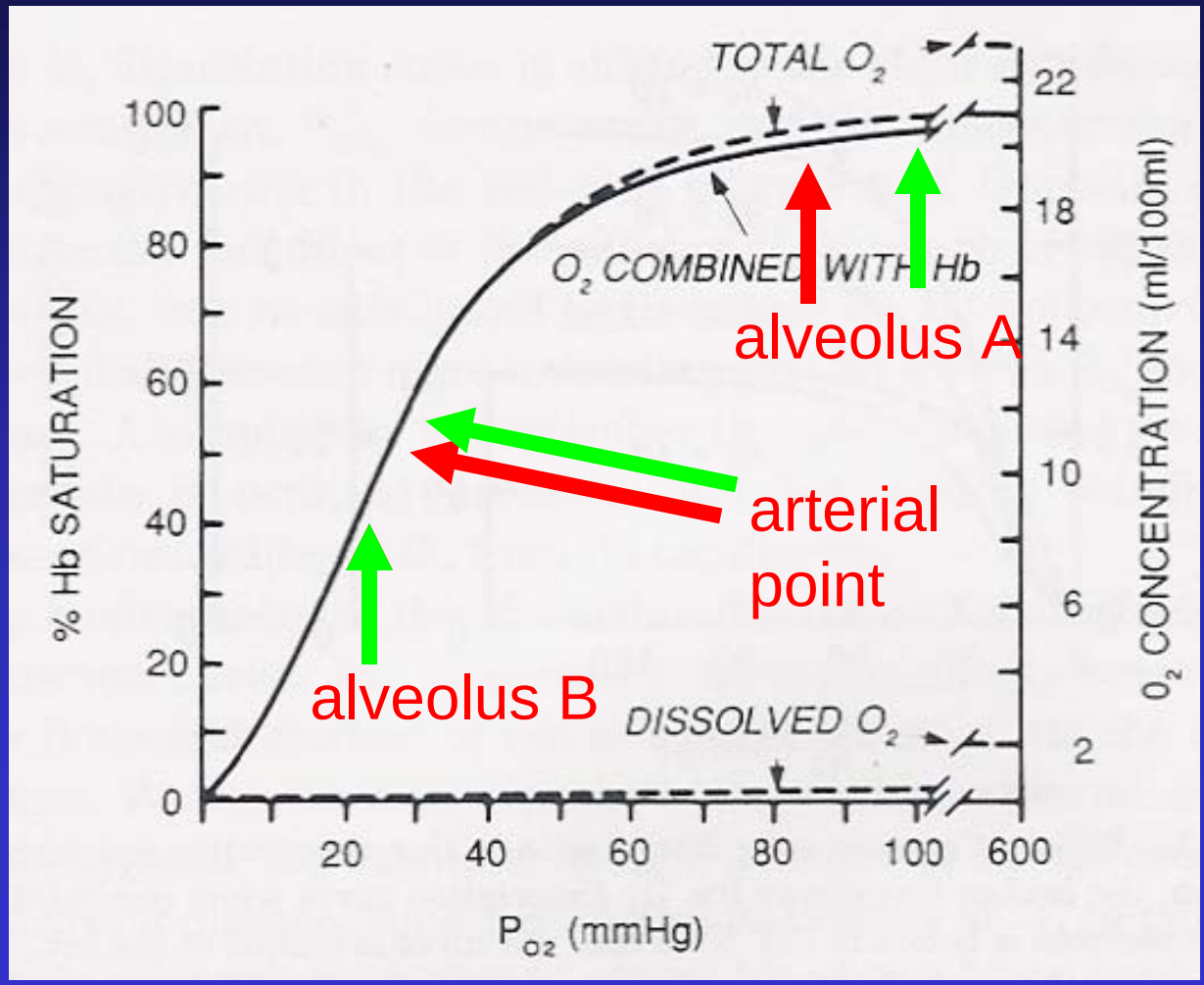
What therapy would you employ?

Provide supplemental oxygen for the animal -

80% oxygen via mechanical ventilator.

Response to supplemental oxygen



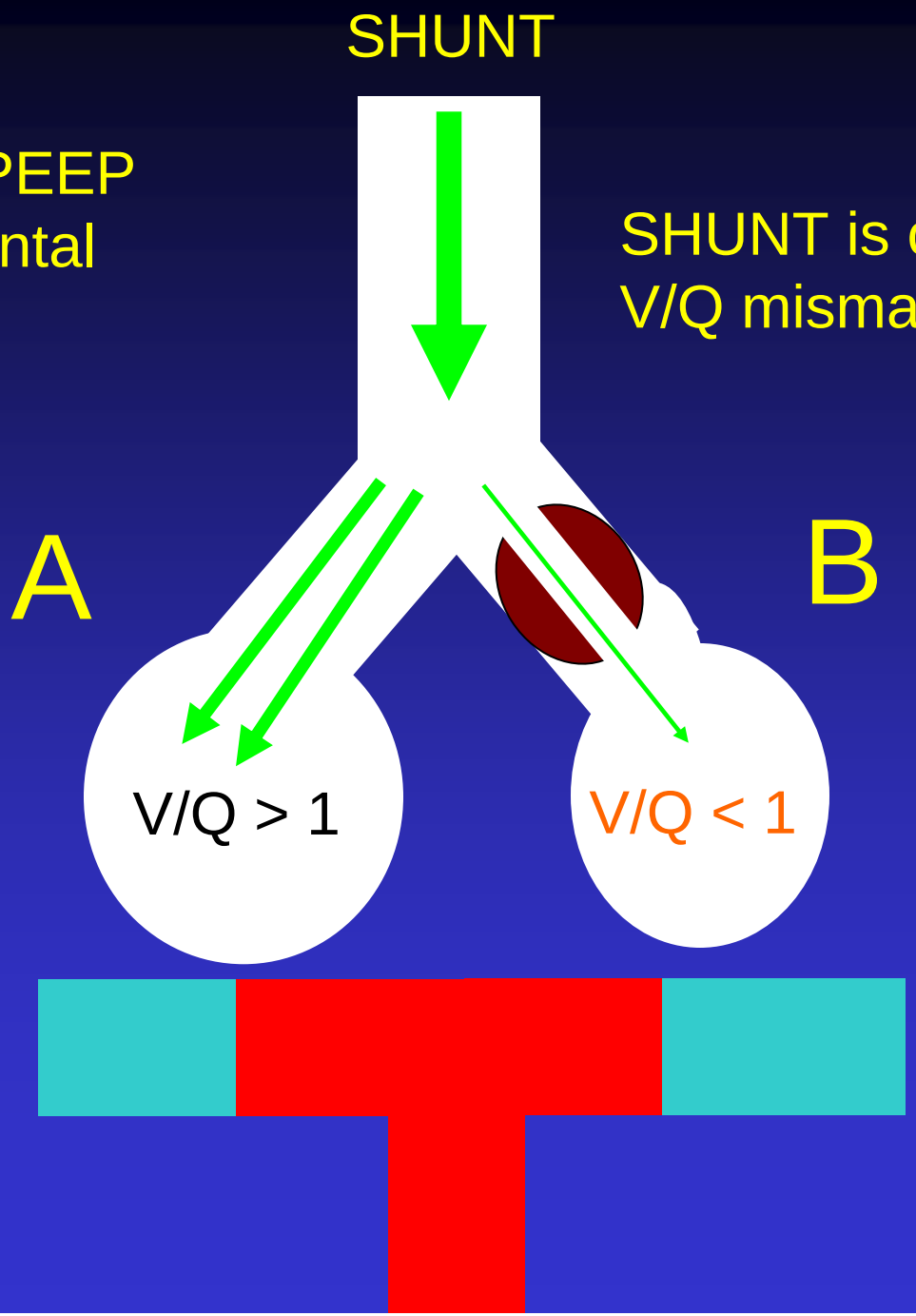

TOTAL O_2
O_2 COMBINED WITH Hb
DISSOLVED O_2
alveolus A
arterial point
alveolus B
% Hb SATURATION
O_2 CONCENTRATION (ml/100ml)
P_{O_2} (mmHg)
100
80
60
40
20
0
22
18
14
10
6
2
20
40
60
80
100
600

Oh great, what do you do now?

Can we convert shunt to V/Q mismatch? If so, how?

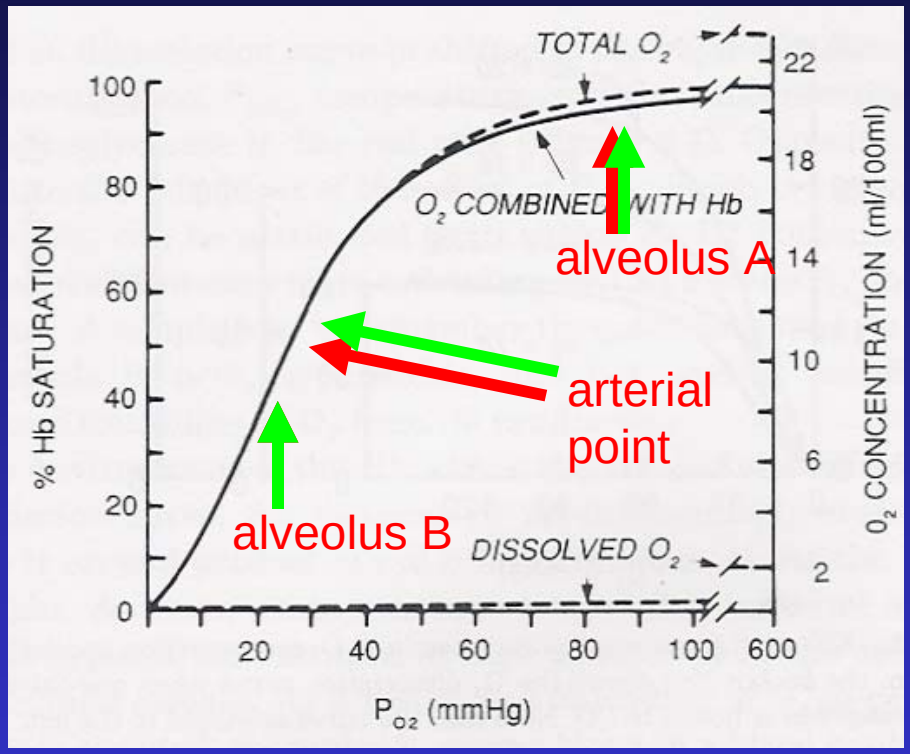
Positive end expiratory pressure –
AKA; PEEP

Response to PEEP and supplemental oxygen

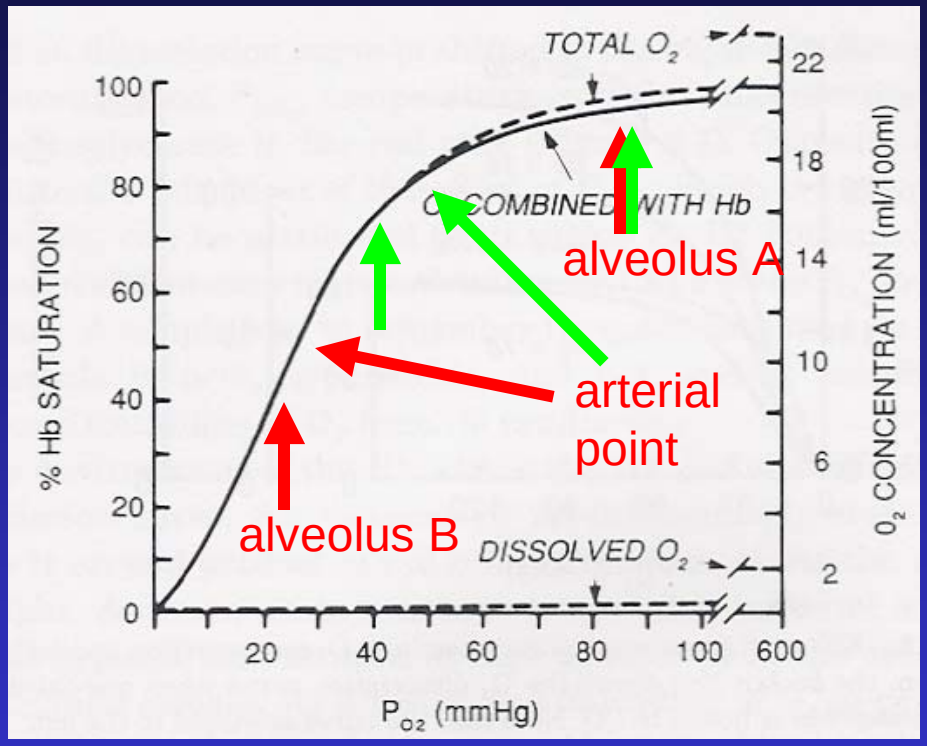


SHUNT is converted to V/Q mismatch

RESPONSE TO SUPPLIMENTAL OXYGEN – WHY PEEP IS SO VALUABLE



SHUNT



V/Q MISMATCH

(SHUNT + PEEP)