Slide Guide 2

Human Physiology BMS 653
LC55F-LC57-F
Respiratory Section

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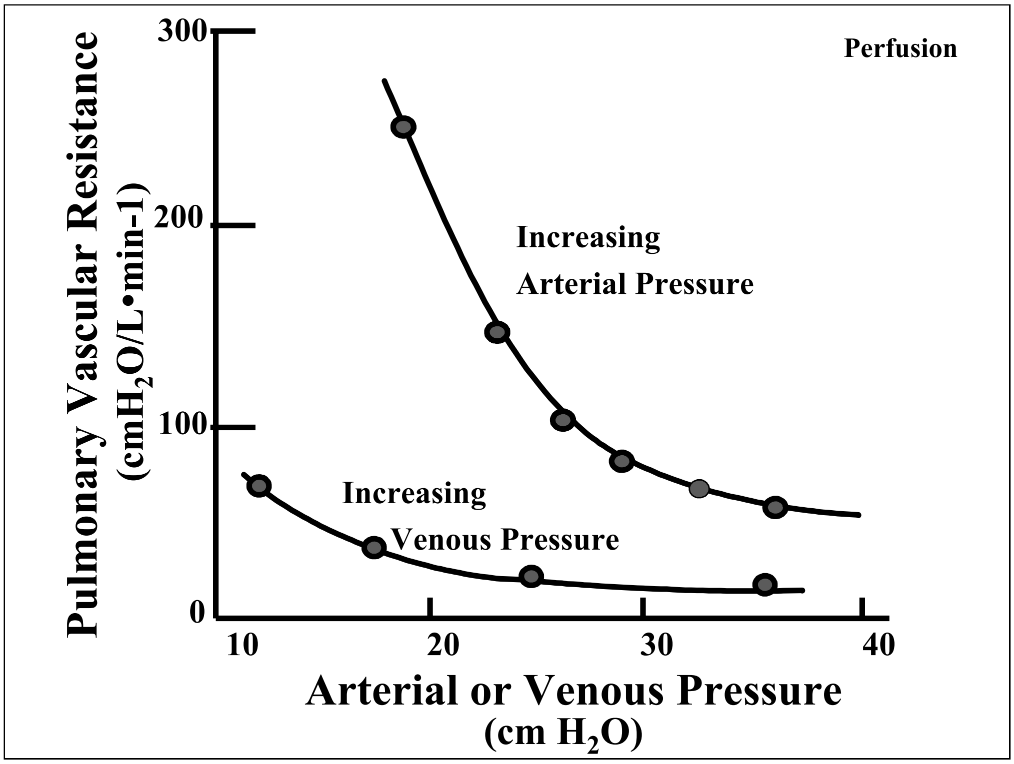
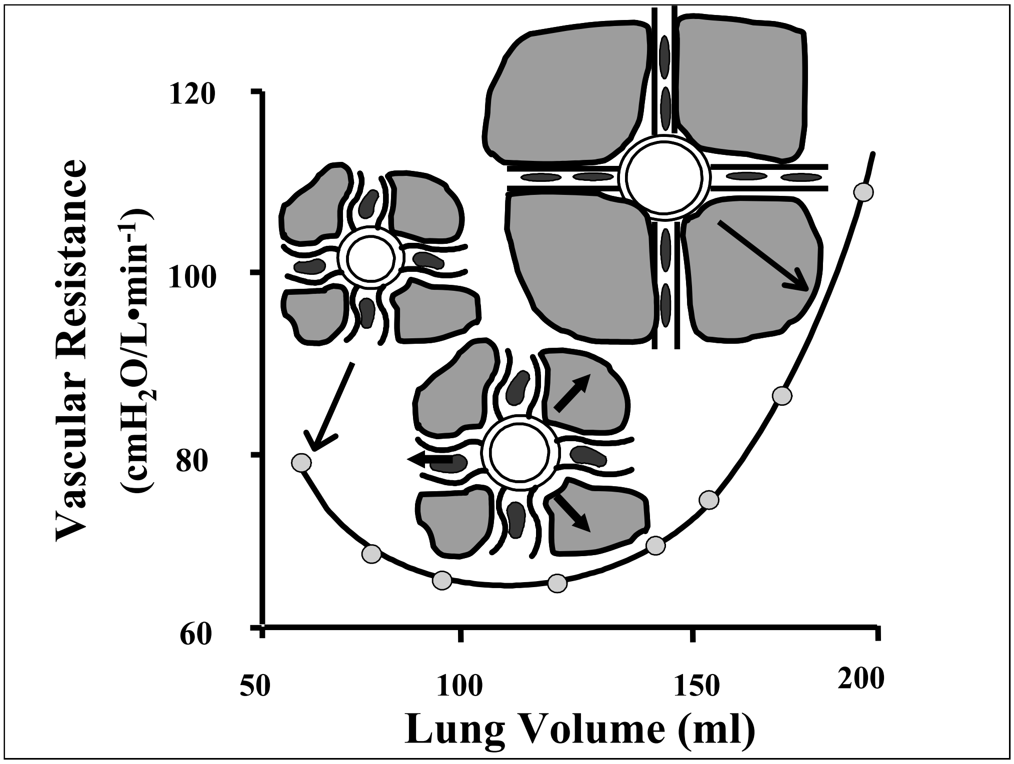
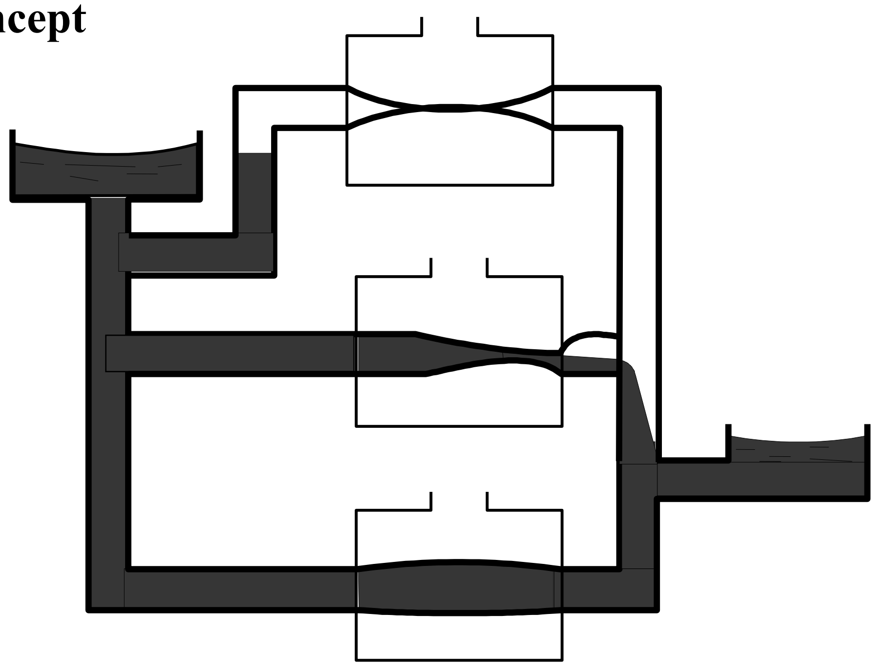

Perfusion
Pulmonary Vascular Resistance
($cmH_2O/L \cdot min^{-1}$)
300
200
100
0
Increasing
Arterial Pressure
Increasing
Venous Pressure
10
20
30
40
Arterial or Venous Pressure
(cm H_2O)

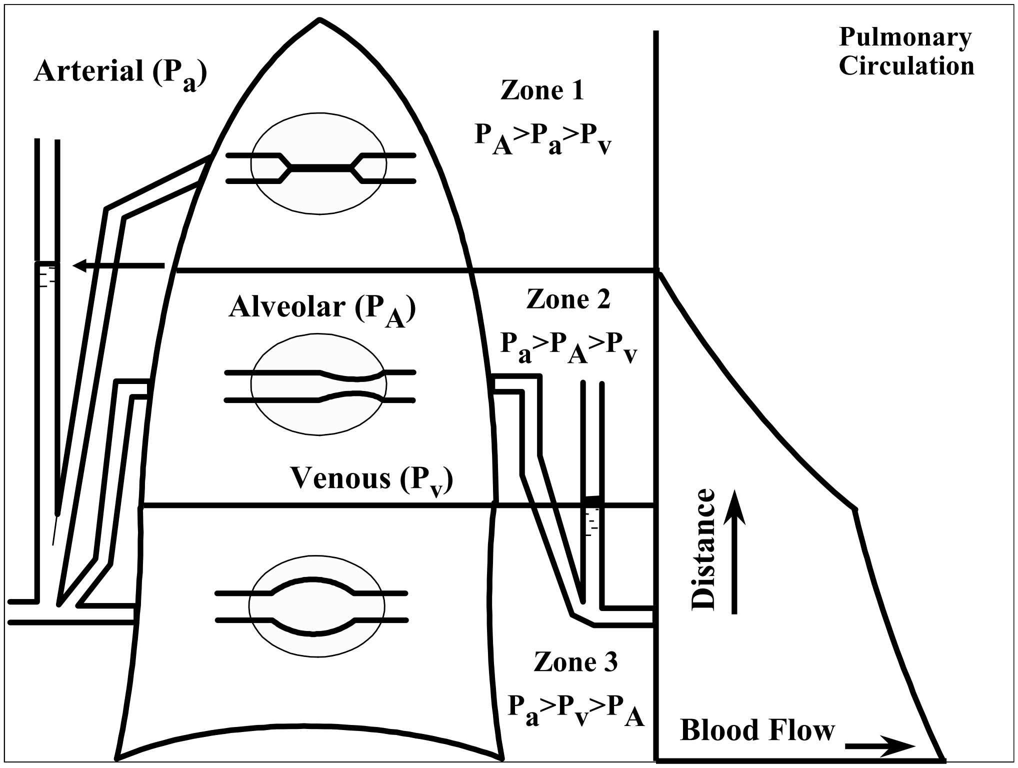


Vascular Resistance
(cmH2O/L•min-1)
120
100
80
60
50
100
150
200
Lung Volume (ml)

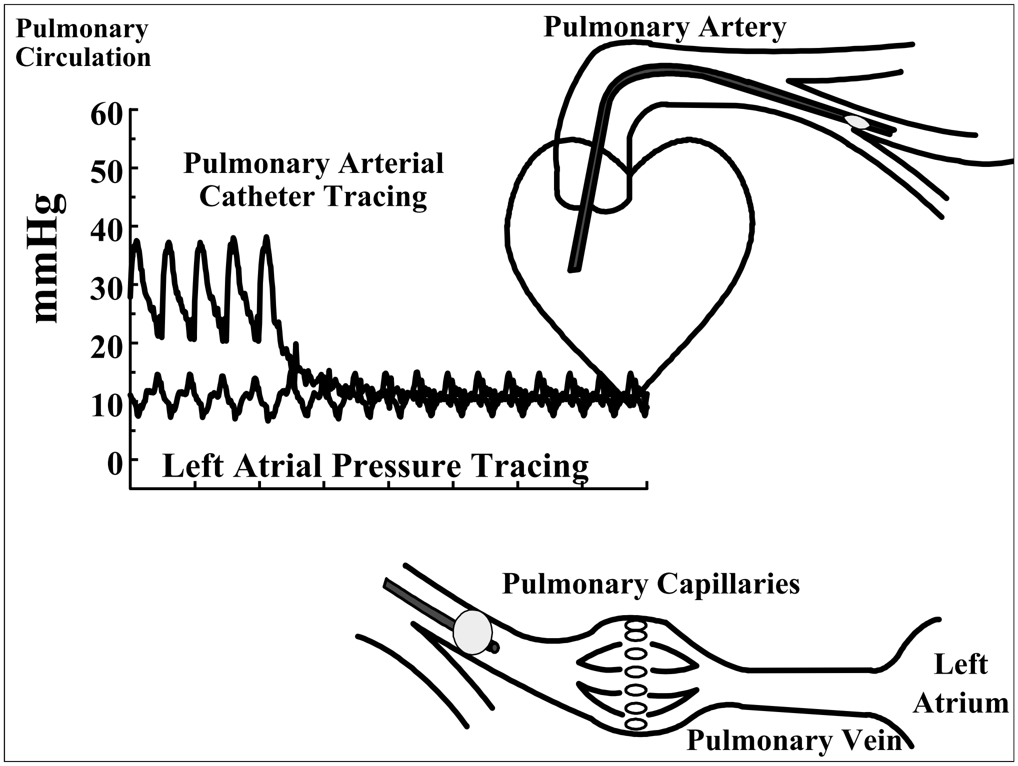
The Starling Resistor Concept

Pulmonary Circulation

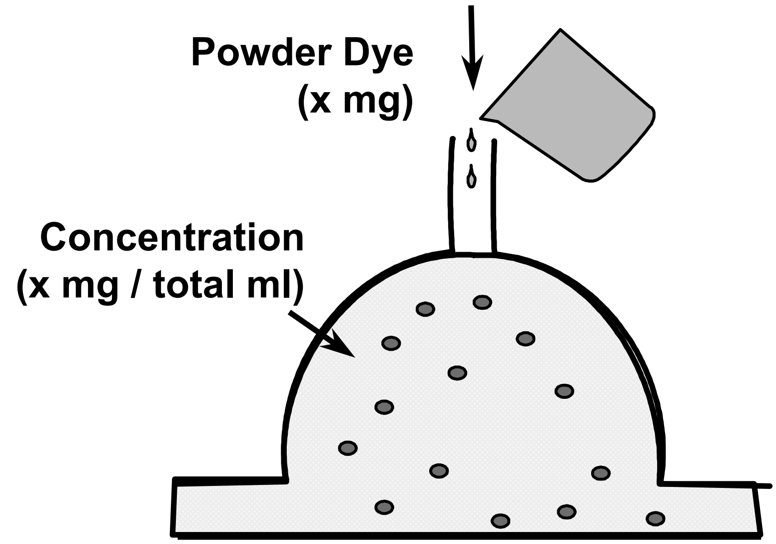


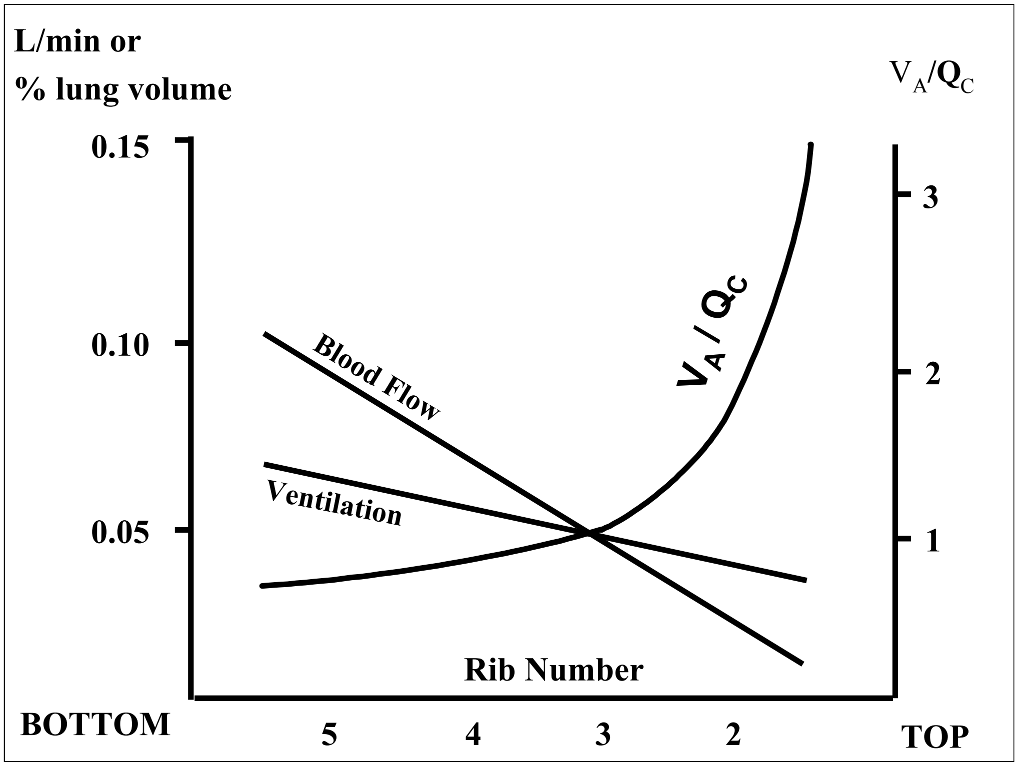


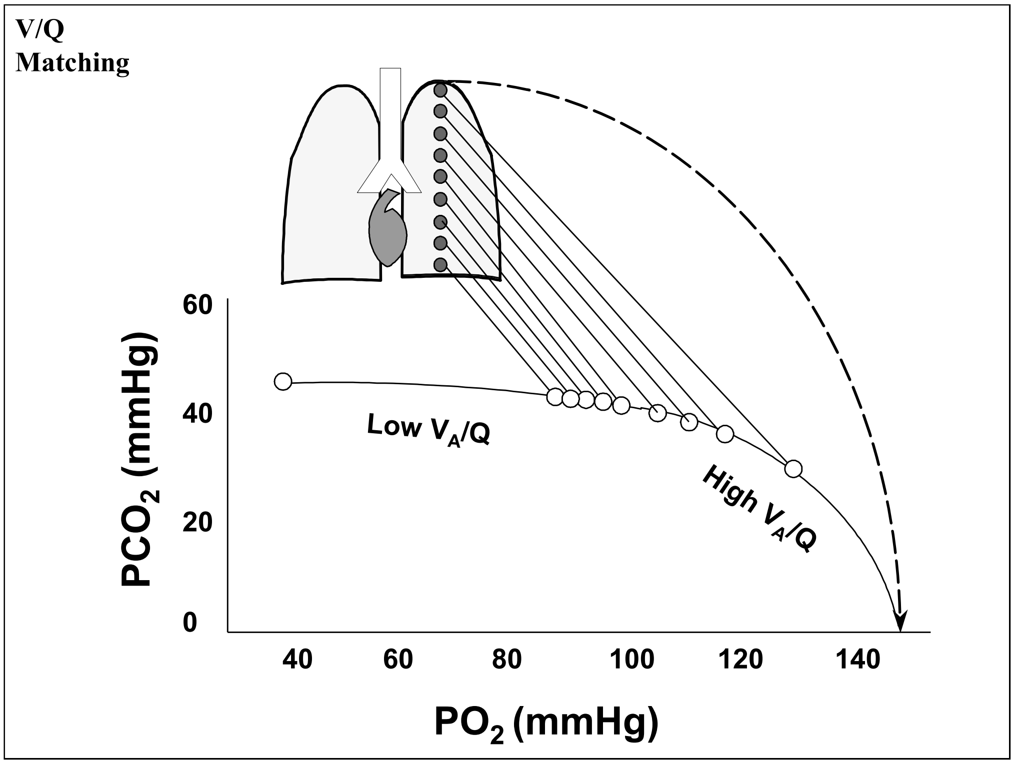
Pulmonary
Circulation
Arterial (Pa)
Zone 1
PA>Pa>Pv
Alveolar (PA)
Zone 2
Pa>PA>Pv
Venous (Pv)
Distance
Zone 3
Pa>Pv>PA
Blood Flow

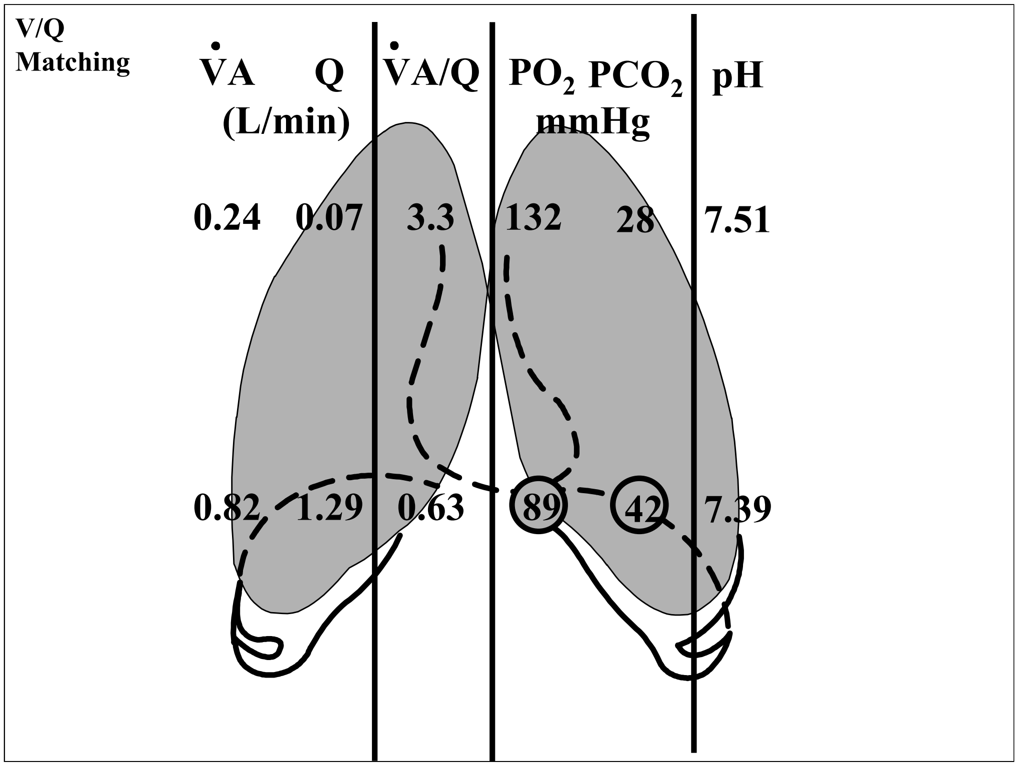

Pulmonary
Circulation
Pulmonary Artery
60
50
40
30
20
10
0
mmHg
Pulmonary Arterial
Catheter Tracing
Left Atrial Pressure Tracing
Pulmonary Capillaries
Left
Atrium
Pulmonary Vein

V/Q
Matching



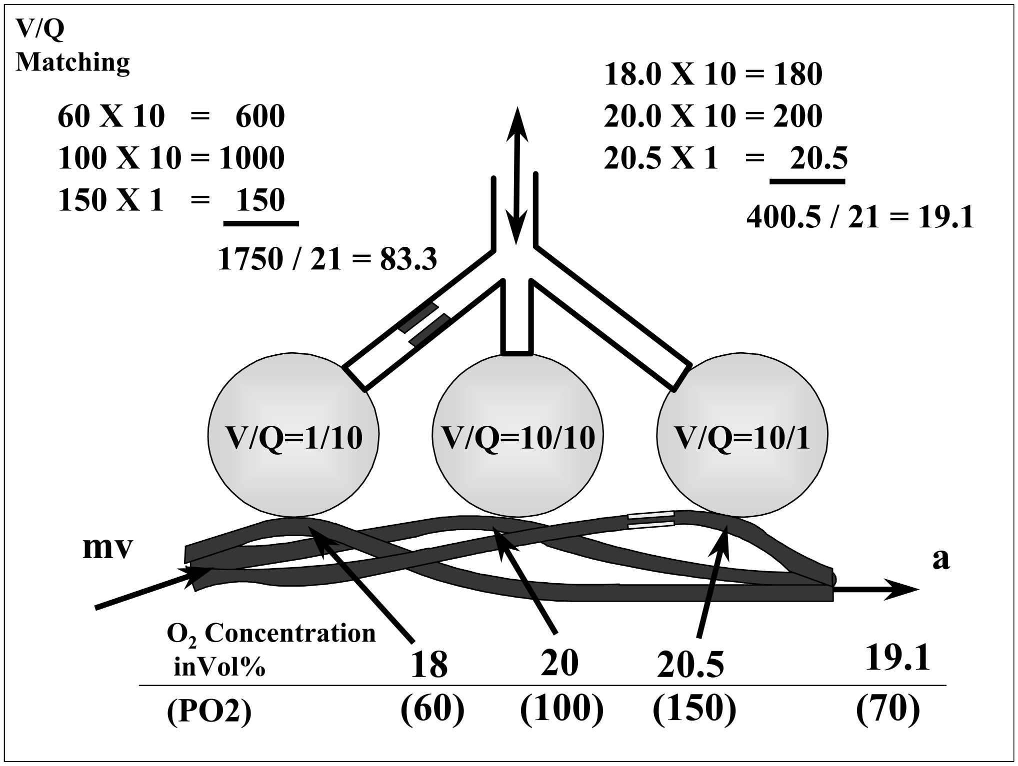

L/min or
% lung volume
V_A/Q_C
0.15
0.10
0.05
3
2
1
Blood Flow
Ventilation
V_A / Q_C
Rib Number
BOTTOM
5
4
3
2
TOP

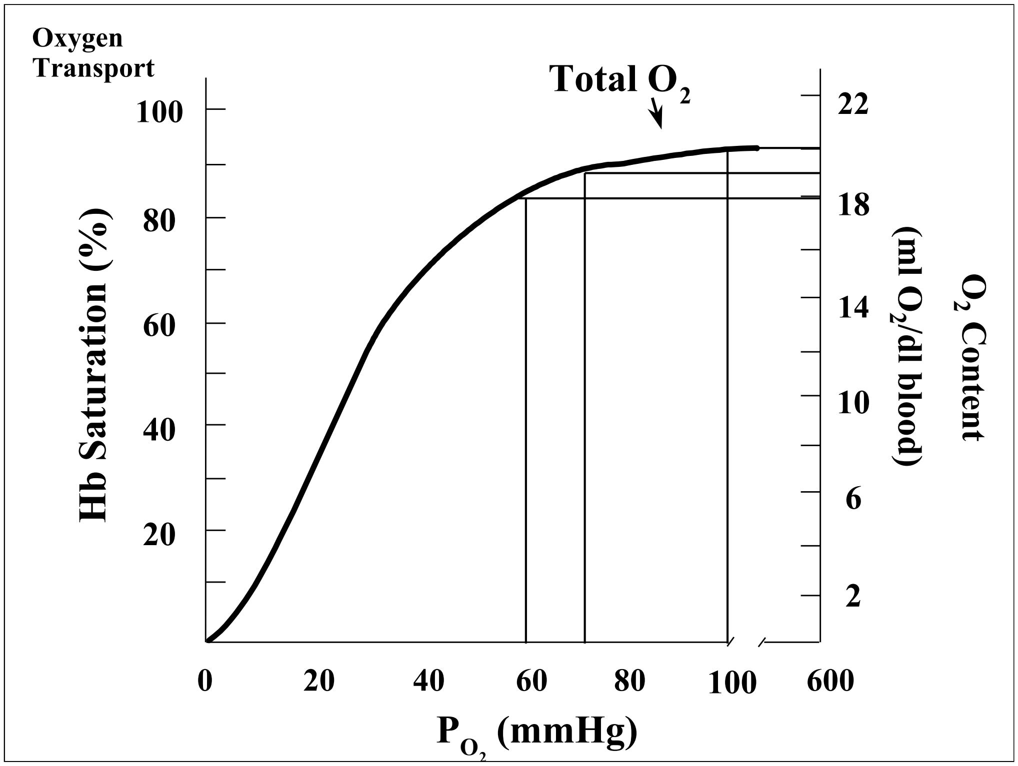

V/Q
Matching
60
40
20
0
PCO2 (mmHg)
Low VA/Q
High VA/Q
40
60
80
100
120
140
PO2 (mmHg)


V/Q
Matching
V̇A
Q
(L/min)
V̇A/Q
PO2
PCO2
mmHg
pH
0.24
0.07
3.3
132
28
7.51
0.82
1.29
0.63
89
42
7.39

Why is arterial PO_2 lower than average (ideal) alveolar PO_2?

- When pulmonary veins joins combining volumes of blood that have different oxygen concentrations, the final concentration of oxygen is a simple, linear function of
  - Oxygen content of each volume
  - Sum of the volumes (final volume)
- PO_2 *is not* a simple linear function of oxygen content or concentration.


V/Q
Matching
60 X 10 = 600
100 X 10 = 1000
150 X 1 = 150
1750 / 21 = 83.3
18.0 X 10 = 180
20.0 X 10 = 200
20.5 X 1 = 20.5
400.5 / 21 = 19.1
V/Q=1/10
V/Q=10/10
V/Q=10/1
mv
a
O_2 Concentration inVol%
18
20
20.5
19.1
(PO2)
(60)
(100)
(150)
(70)



Oxygen
Transport
Total O_2
100
80
60
40
20
Hb Saturation (%)
22
18
14
10
6
2
O_2 Content
(ml O_2/dl blood)
0
20
40
60
80
100
600
P_{O_2} (mmHg)

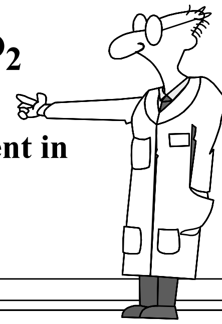
If PAO_2 normally averages 100 mmHg,

why is average PaO_2 =95 mmHg??

1. **V/Q differences from apex to base**
2. **Shunt**

To understand both influences we must remember:

- **arterial O_2 content is a function of the contributing sources' relative volumes and O_2 contents.**
- **the relationship between PO_2 and O_2 content in the presence of Hb.**



V/Q Matching

Alveolar Gas Equation

$$PAO_2 = FIO_2 \, (P_B - P_{H2O}) - PACO_2 \left[FIO_2 + \frac{(1-FIO_2)}{R} \right]$$

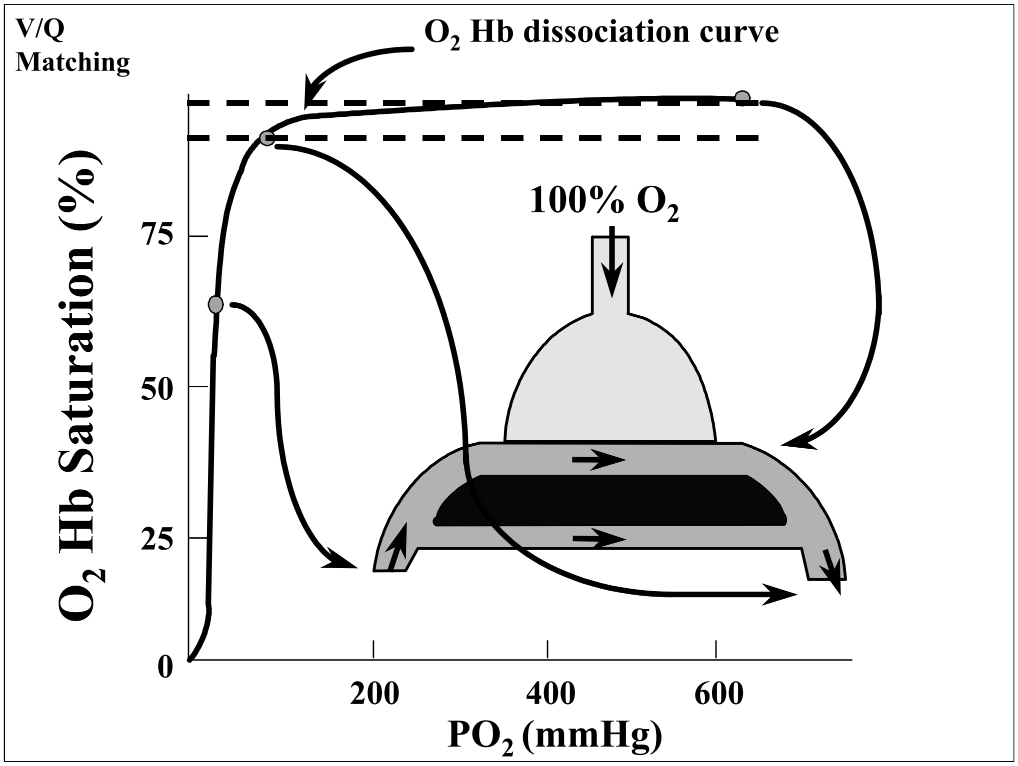
$$0.21 \;*\; (747-47) \;\; - 40 \left[0.21 + \frac{(1-0.21)}{0.8} \right]$$

$$\underbrace{\left[0.21 + \frac{(1-0.21)}{0.8} \right]}_{1.2}$$

1.2
(range 1.0-1.2

= 147 - 47

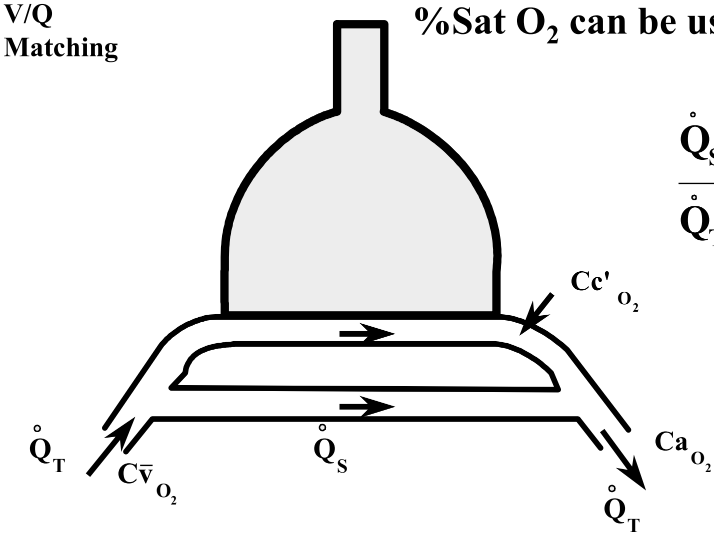
=100


V/Q
Matching
O_2 Hb dissociation curve
100% O_2
O_2 Hb Saturation (%)
75
50
25
0
200
400
600
PO_2 (mmHg)

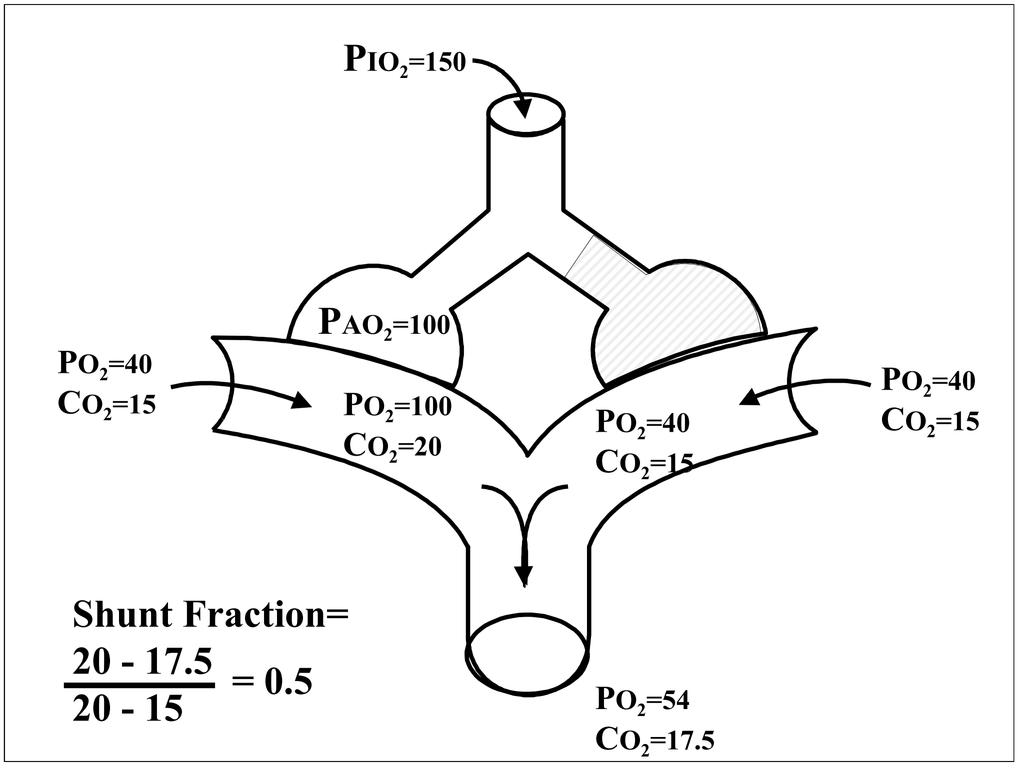
V/Q Matching

%Sat O_2 can be used in place of C

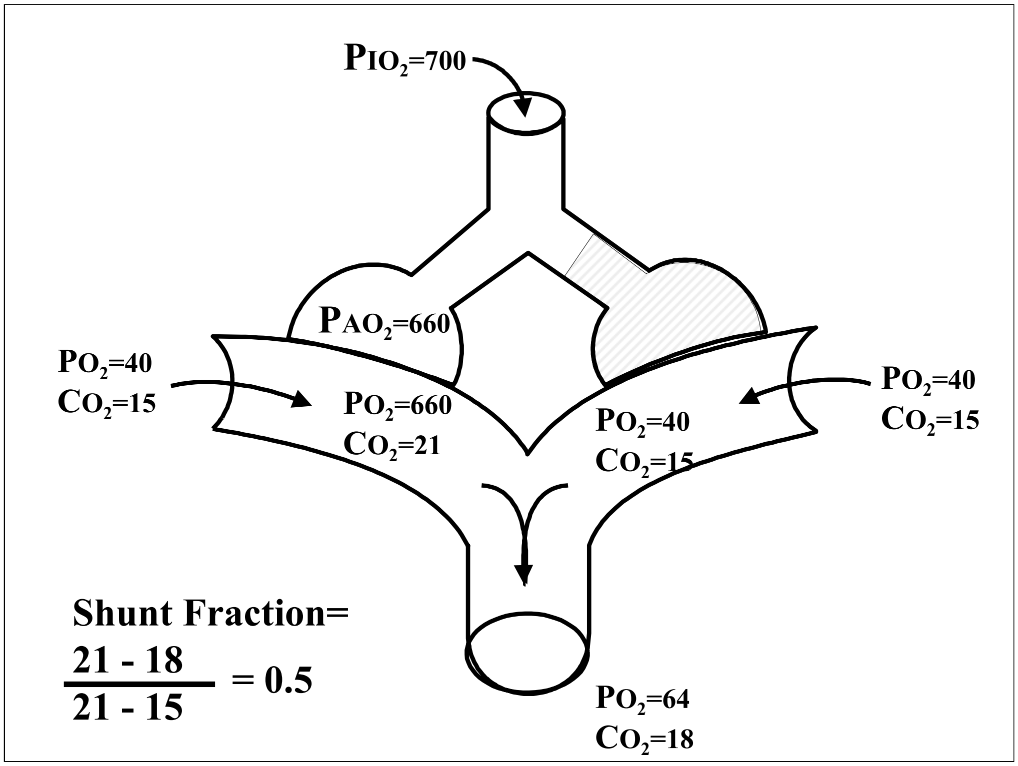
$$\frac{\dot{Q}_S}{\dot{Q}_T} = \frac{Cc'_{O_2} - Ca_{O_2}}{Cc'_{O_2} - C\bar{v}_{O_2}}$$

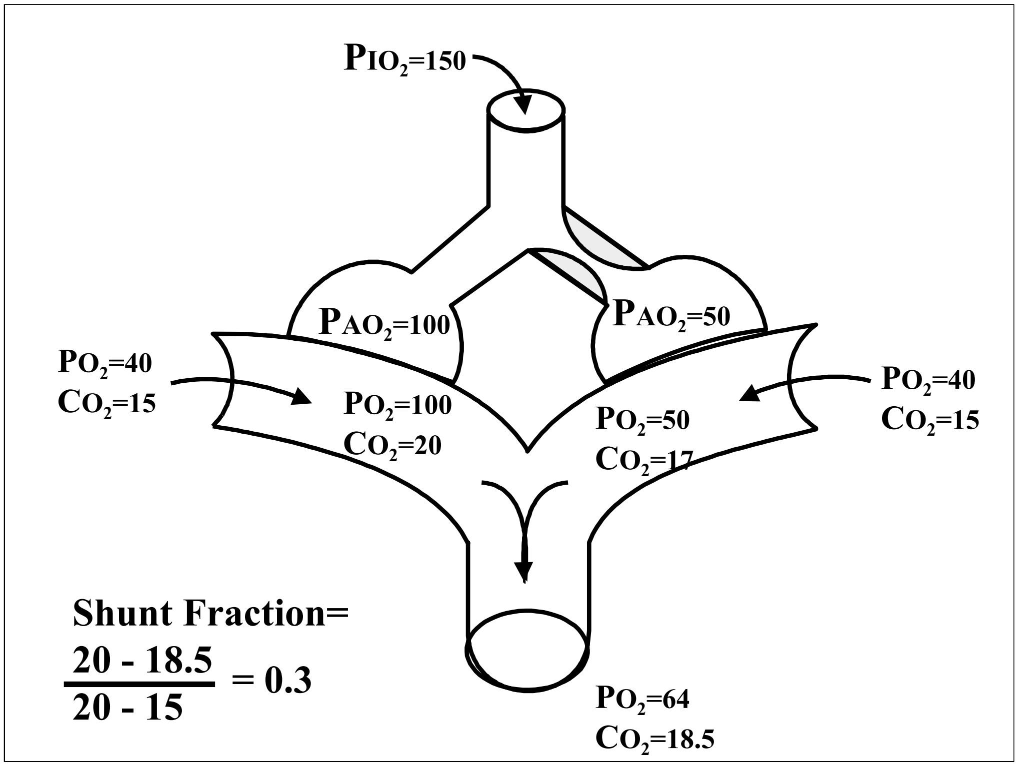


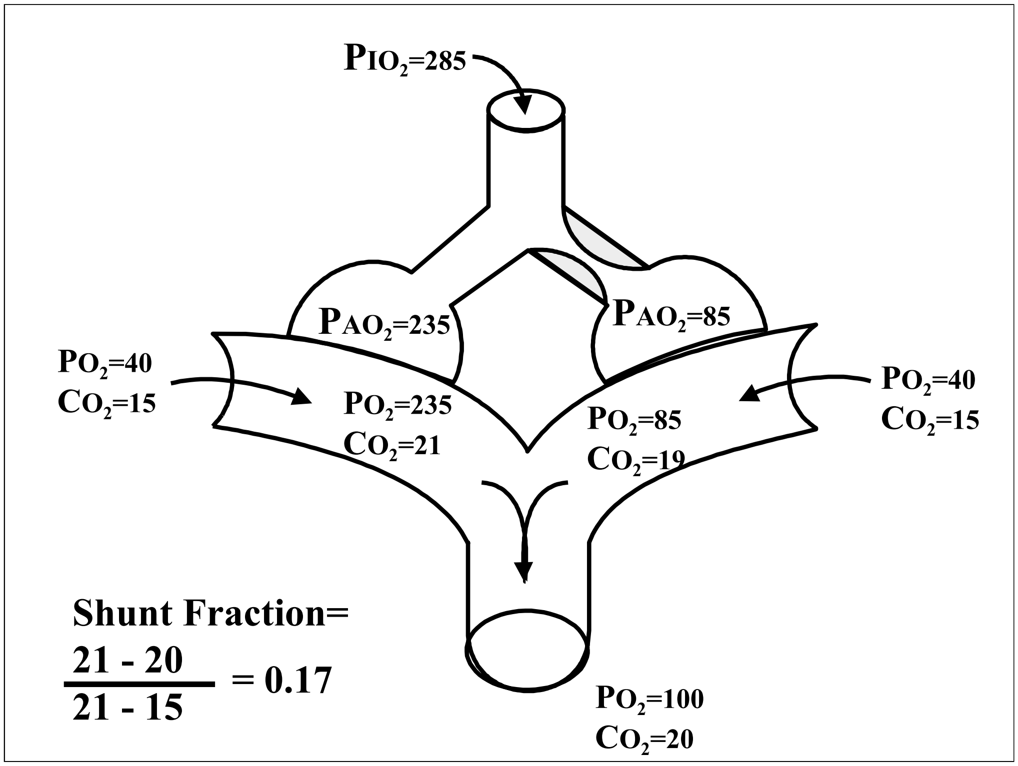
If breathing 100% O_2, **the shunt fraction can be approximated as 1% of the cardiac output for every 20 mmHg PAO_2-PaO_2 difference.**



P_{IO_2}=150
P_{AO_2}=100
PO_2=40
CO_2=15
PO_2=100
CO_2=20
PO_2=40
CO_2=15
PO_2=40
CO_2=15
Shunt Fraction=
$\frac{20 - 17.5}{20 - 15} = 0.5$
PO_2=54
CO_2=17.5


PIO2=700
PAO2=660
PO2=40
CO2=15
PO2=660
CO2=21
PO2=40
CO2=15
PO2=40
CO2=15
Shunt Fraction=
21 - 18
21 - 15
= 0.5
PO2=64
CO2=18


PIO2=150
PAO2=100
PAO2=50
PO2=40
CO2=15
PO2=100
CO2=20
PO2=50
CO2=17
PO2=40
CO2=15
Shunt Fraction=
20 - 18.5
20 - 15
= 0.3
PO2=64
CO2=18.5


P_{IO_2}=285
P_{AO_2}=235
P_{AO_2}=85
PO_2=40
CO_2=15
PO_2=235
CO_2=21
PO_2=85
CO_2=19
PO_2=40
CO_2=15
Shunt Fraction=
$\frac{21 - 20}{21 - 15} = 0.17$
PO_2=100
CO_2=20

Case Study

- The following data is obtained from a man with smoke inhalation injury who is breathing 100% oxygen:
  - PaO_2 190 mmHg
  - $PaCO_2$ 36 mmHg
  - SaO_2 59%
  - COHb 40%
  - pH 7.47

$$1.0 * (747-47) - 36 \left[1.0 + \frac{(1-1)}{0.8} \right]$$

700 - 36 = 664 mmHg

$$\mathbf{PAO_2 - PaO_2 = 474}$$

Qs = 474/20 = 23.7%

Case Study

- A patient presents with pneumonia which involves the entire left lung, sparing the right. The following data is obtained on ambient air
  - PaO_2 52 mmHg SaO_2 75%
  - $PaCO_2$ 39 mmHg $SmvO_2$ 60%
- On 50% oxygen, the data obtained are:
  - PaO_2 65 mmHg SaO_2 80%
  - $PaCO_2$ 35 mmHg $SmvO_2$ 60%

0.21 * (747-47) - 39 * 1.2

147 - 47 = 100 mmHg

0.50 * (747-47) - 35 * 1.125

350 - 39 = 311 mmHg

Shunt Fraction=

$$\frac{97 - 75}{97 - 60} = 0.59$$

Shunt Fraction=

$$\frac{98 - 80}{98 - 60} = 0.47$$

Case Study

- **In one lung anesthesia, only one lung (referred to as the dependent lung) is ventilated, while the non-dependent lung is not ventilated. Blood flow to the non-ventilated lung becomes shunt flow. This is in addition to any shunt flow through the dependent lung. During such a procedure the following data were obtained:**
    - **mvO_2 content 15 ml/dl**
    - **aO_2 content 19 ml/dl**
- **Assuming that oxygen content of blood leaving well ventilated regions of the dependent lung is 20 ml/dl, the calculated shunt fraction is**

Shunt Fraction=

$$\frac{20 - 19}{20 - 15} = 0.20$$