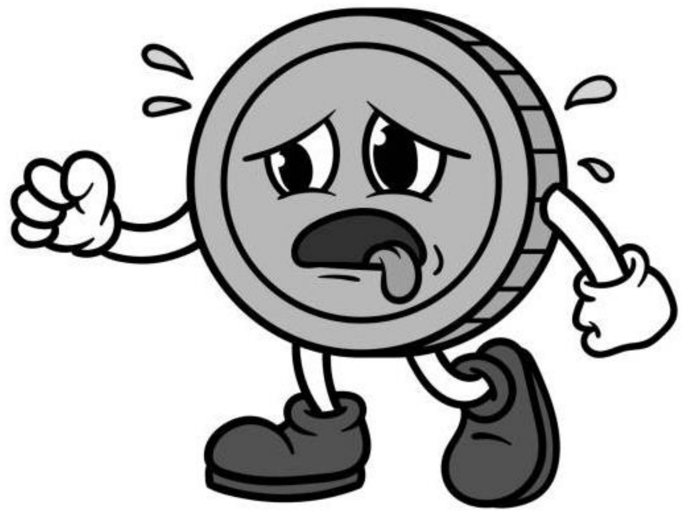
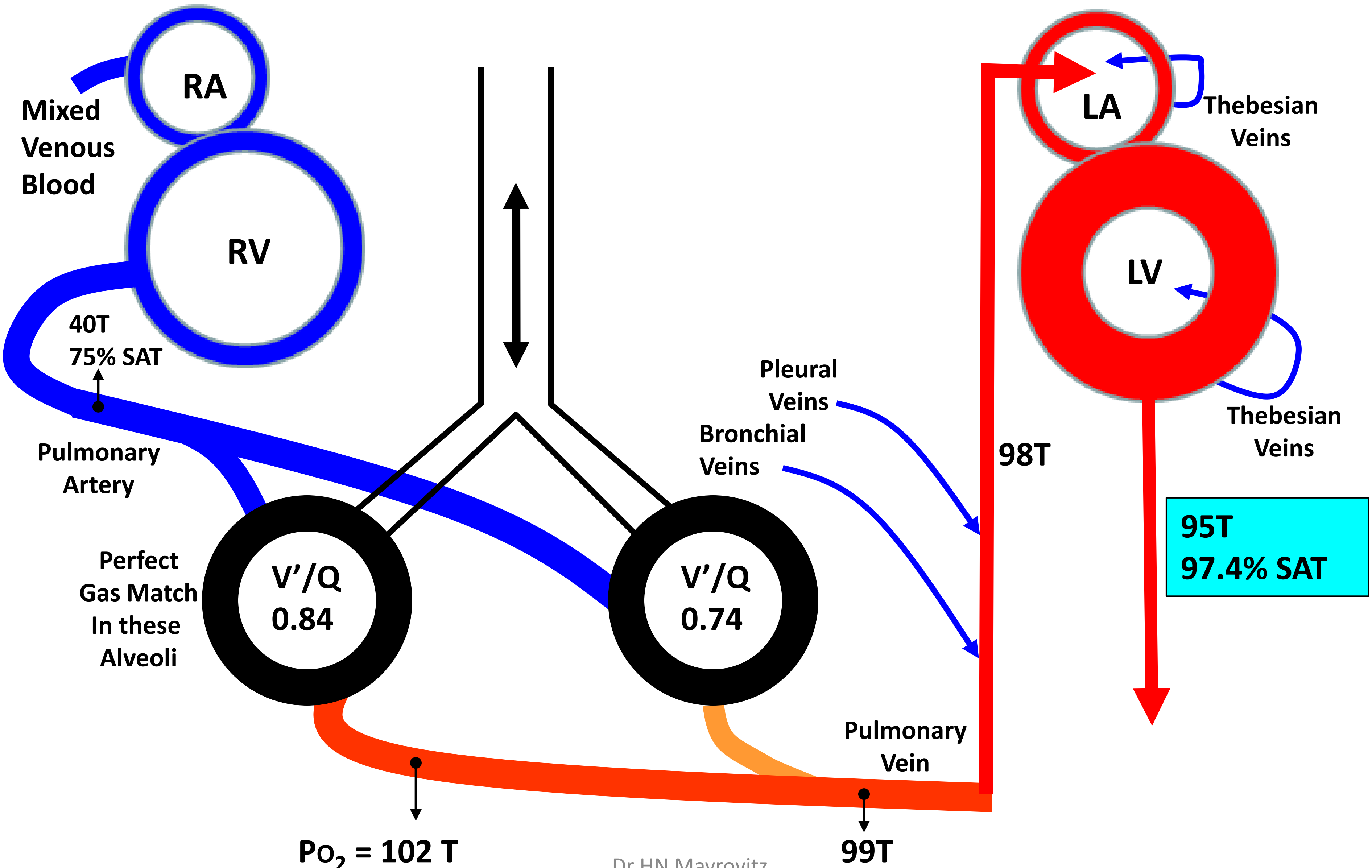
KPCOM Respiratory System Lecture
03/28/2025 1110-1200

Shunts and Hypoxic Mechanisms



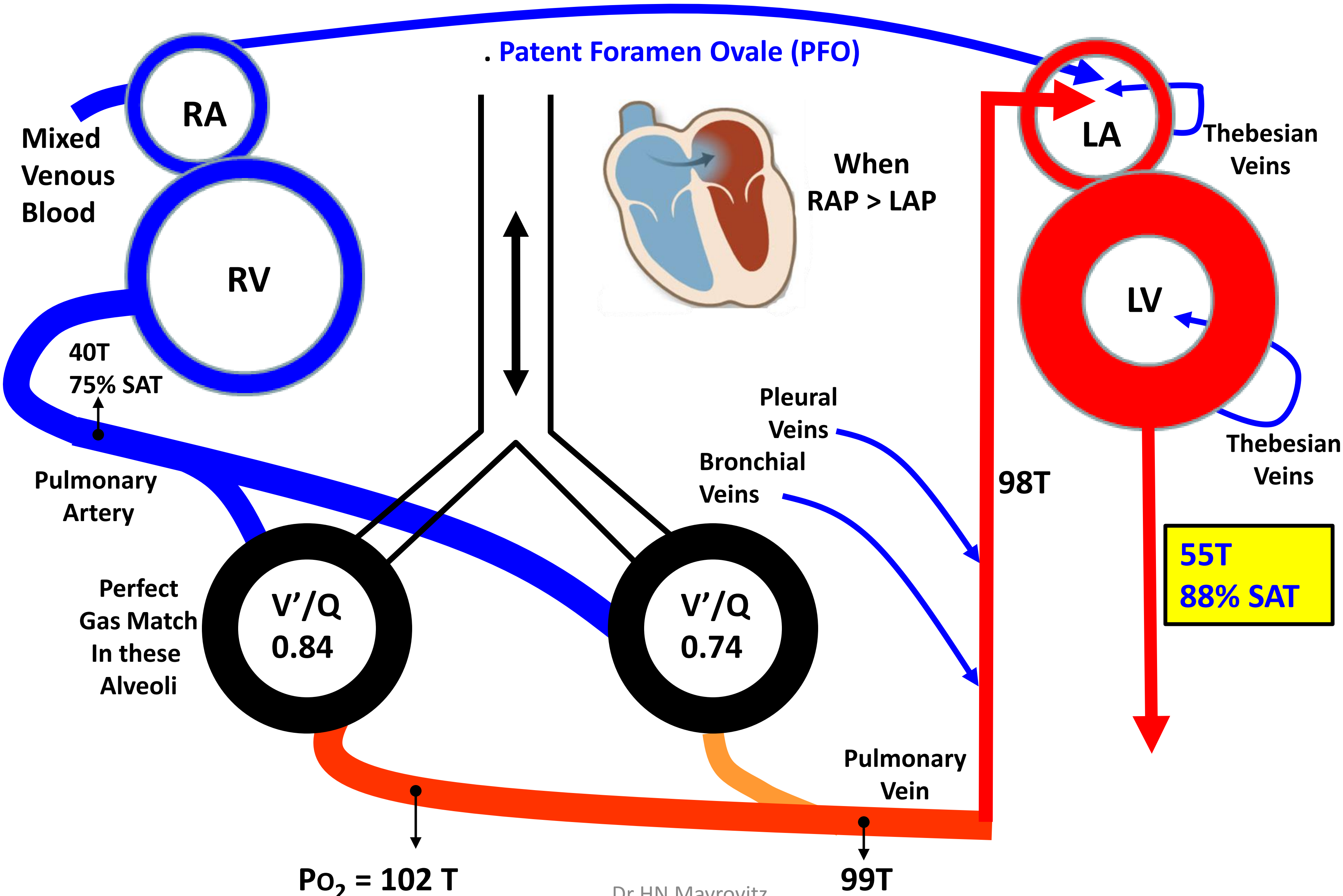
HN Mayrovitz PhD
mayrovit@nova.edu
drmayrovitz.com

Shunts: Mixing Low O_2 with Higher O_2: Normal



Dr HN Mayrovitz

Shunts: Mixing Low O_2 with Higher O_2: Not Normal



Shunts: Quantitative Aspects – Shunt Equation

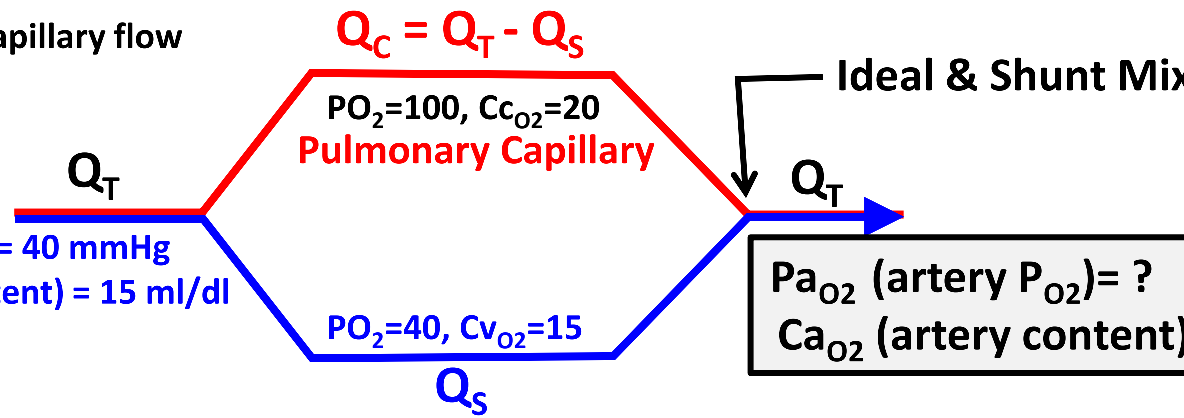
Q_S represents the shunt flow that would cause the measured arterial gas tensions

Q_C is the ideally matched capillary flow

Q_T is the cardiac output

Pc_{O2} (capillary P_{O2}) = 100 mmHg
Cc_{O2} (capillary content) = 20 ml/dl

Pv_{O2} (venous P_{O2}) = 40 mmHg
Cv_{O2} (venous content) = 15 ml/dl



Pa_{O2} (artery P_{O2})= ?
Ca_{O2} (artery content)=?

(1) $Q_S \times Cv_{O2} + (Q_T - Q_S) \times Cc_{O2} = Q_T \times Ca_{O2}$

Amt shunted — Amt not shunted — Total Amt

$$Ca_{O2} = Cc_{O2} - \frac{Q_S}{Q_T}(Cc_{O2} - Cv_{O2})$$

Rearrange (1)

Suppose equal shunt and capillary flows ($Q_S = Q_C \rightarrow Q_S/Q_T = 0.5$)

What is arterial O_2 content in ml/dl?

A. 14.5
B. 15.5
C. 16.5
D. 17.5
E. 20.5

$$Ca_{O2} = Cc_{O2} - 0.5\ (Cc_{O2} + Cv_{O2}) = 17.5\ \text{ml/dl}$$

SAT = 17.5/20

How would you determine the corresponding Pa_{O2}?

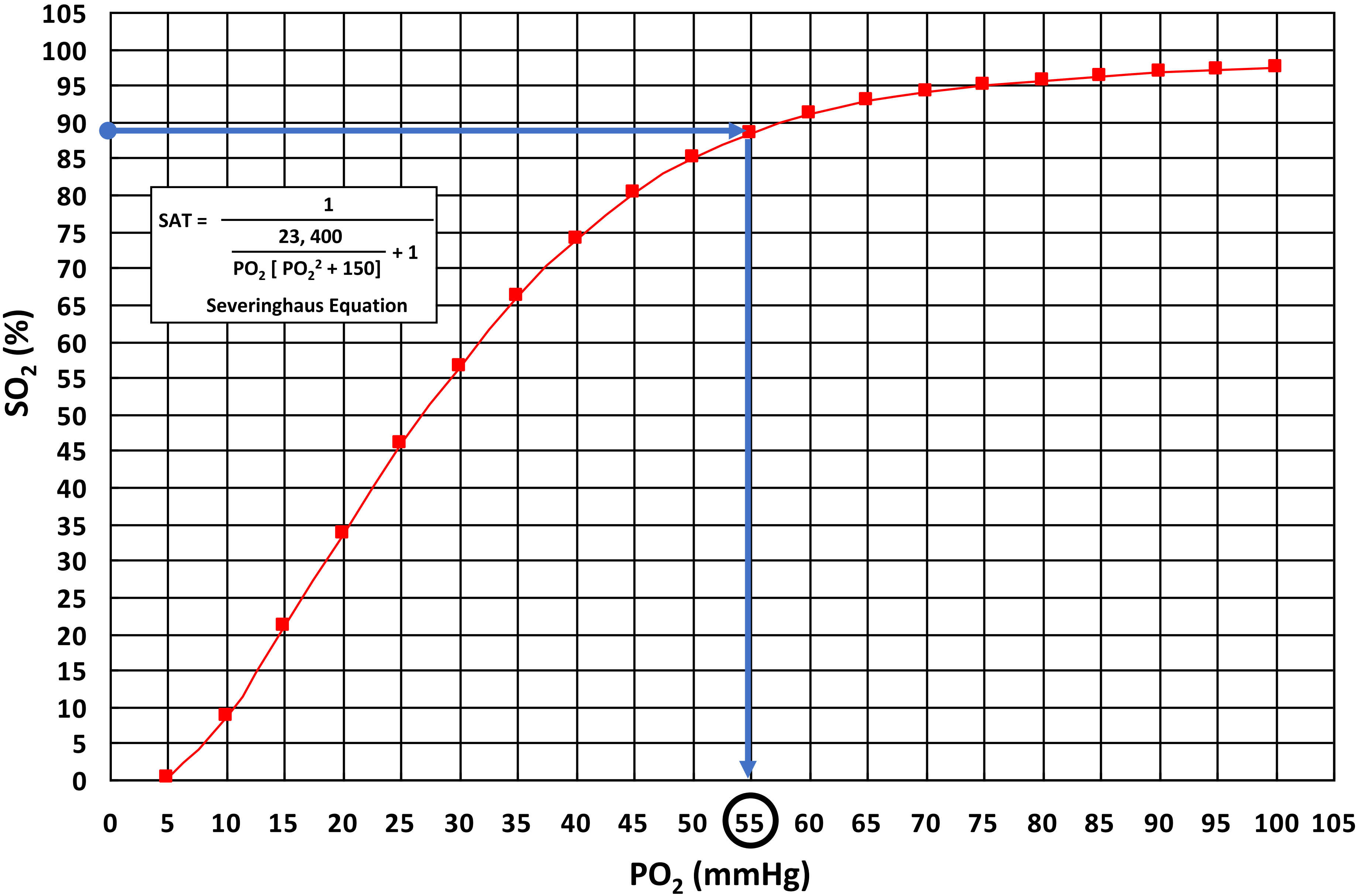
Use SO_2 curve or equation and get $Pa_{O2} \approx 55$ mmHg →

$$SAT = \cfrac{1}{\cfrac{23,400}{PO_2\ [\ PO_2^2 + 150]} + 1}$$

Severinghaus Equation

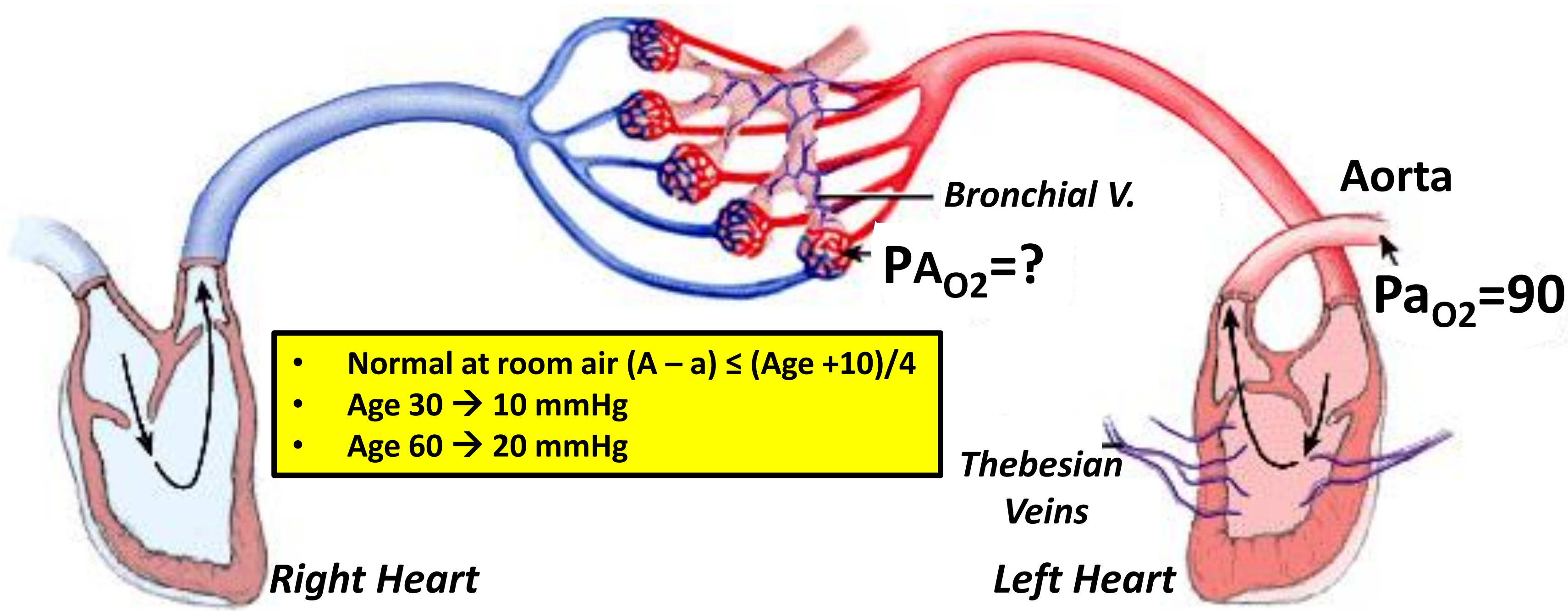
Dr HN Mayrovitz

Blood Oxygen SAT vs PaO_2



$$SAT = \frac{1}{\frac{23,400}{PO_2[PO_2^2 + 150]} + 1}$$

The (A – a) PO_2 Gradient



- Normal at room air (A – a) ≤ (Age +10)/4
- Age 30 → 10 mmHg
- Age 60 → 20 mmHg

Mary is a 60-year-old retired nurse who has just been evaluated for participation in a respiratory-related research study. As part of the study the following initial measurements were made. PA_{CO2} = 40 mmHg, respiratory quotient (R = 0.8) and her arterial oxygen tension (Pa_{O2} = 90 mmHg). Is her (A – a) gradient normal?

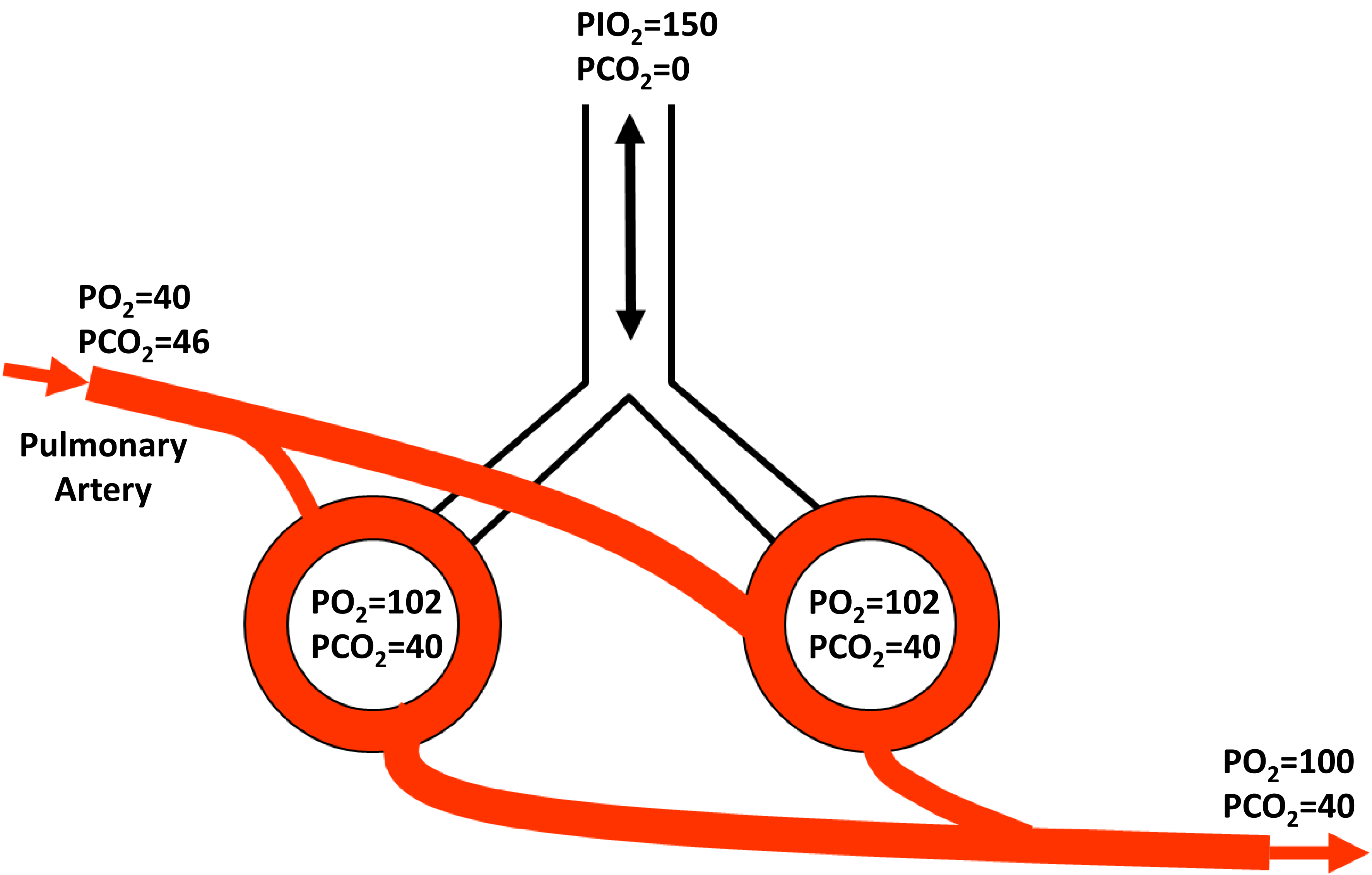
$$PA_{O2} \approx FIO_2\,(P_{ATM} - 47) - Pa_{CO2} / R$$

$$PA_{O2} \approx 0.21 \times (760 - 47) - 40/.8 = 150 - 50 = 100 \text{ mmHg}$$

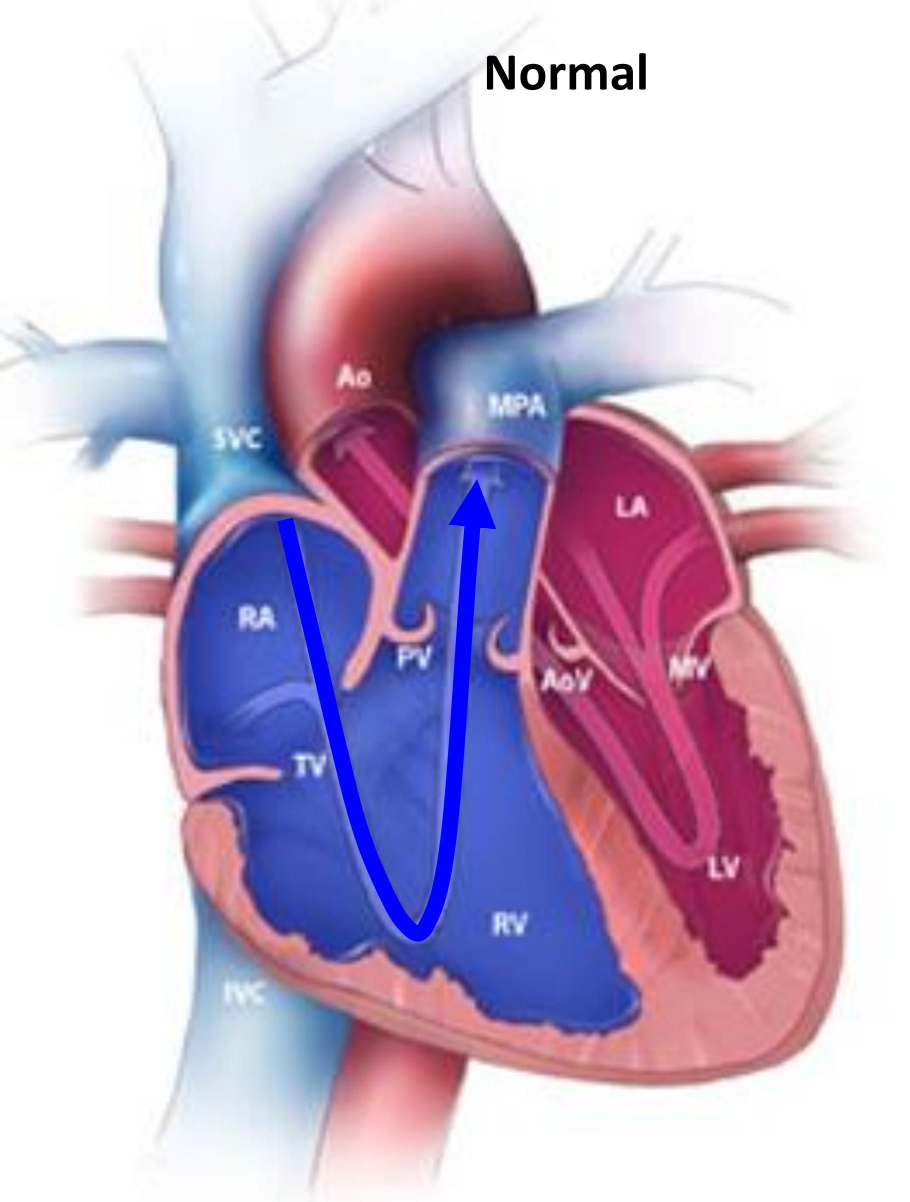
$$A - a = 100 - 90 = 10 \text{ mmHg}$$

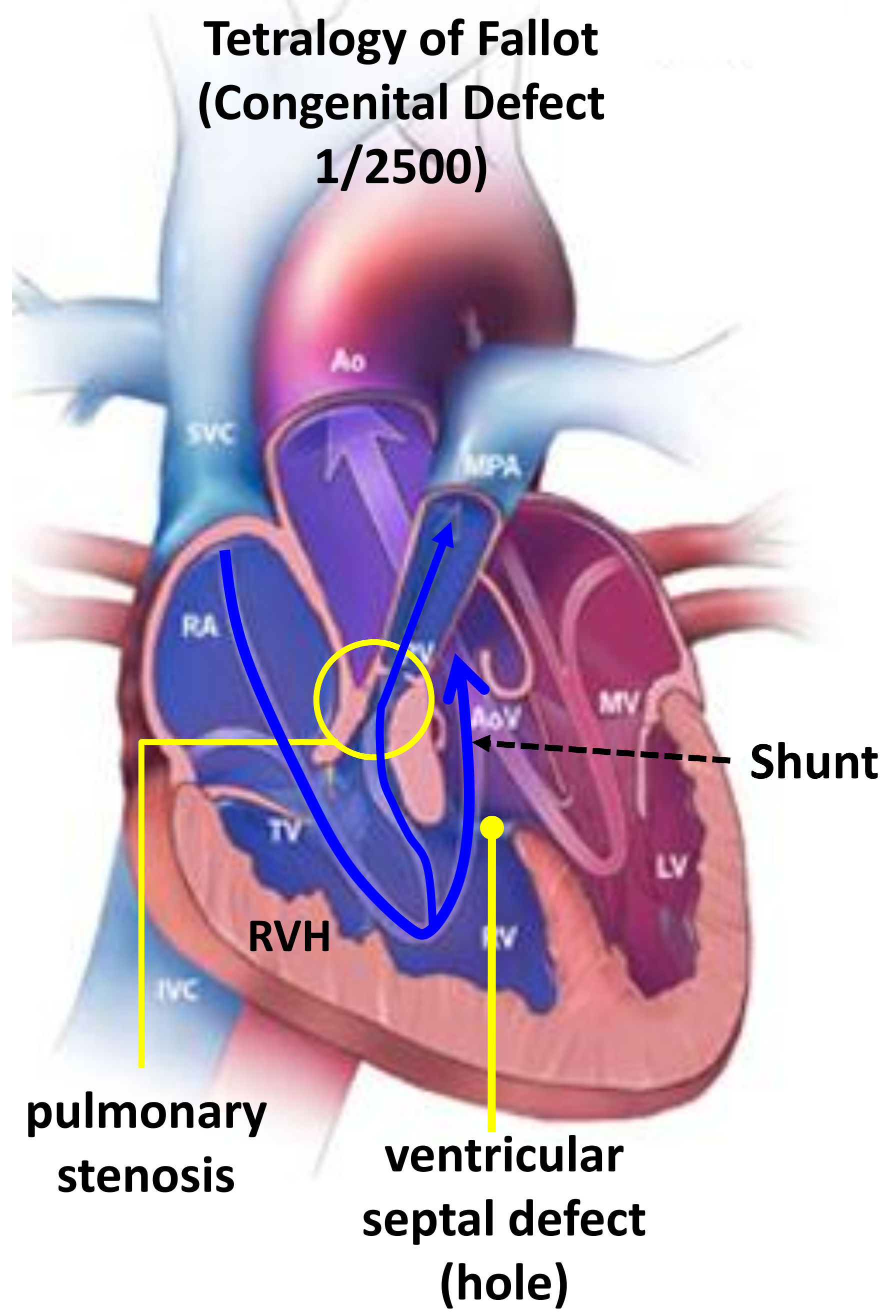
Shunt Examples

Normal: No Significant Shunting



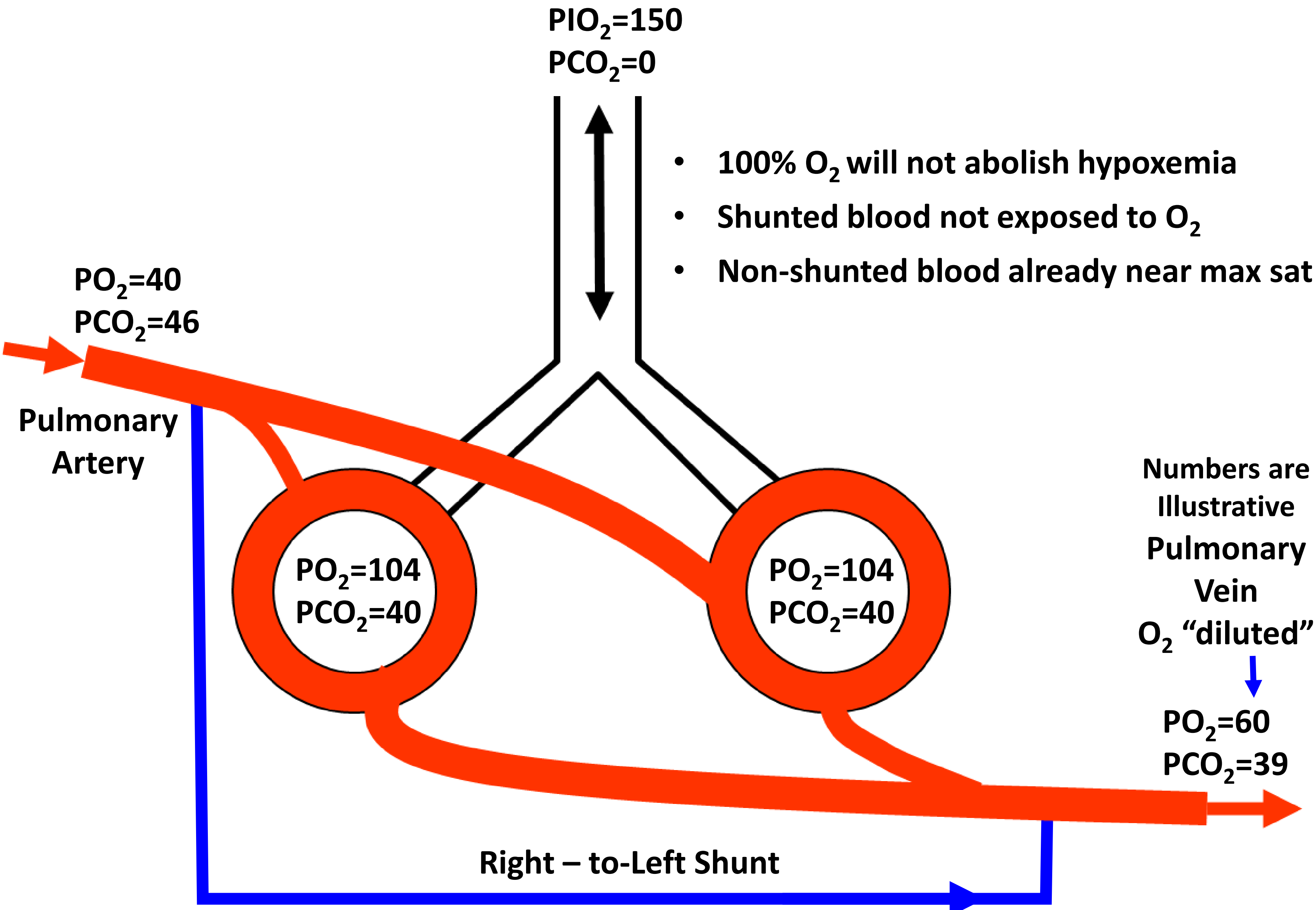
Clinical Correlation: Tetralogy of Fallot Right-to-Left Shunt



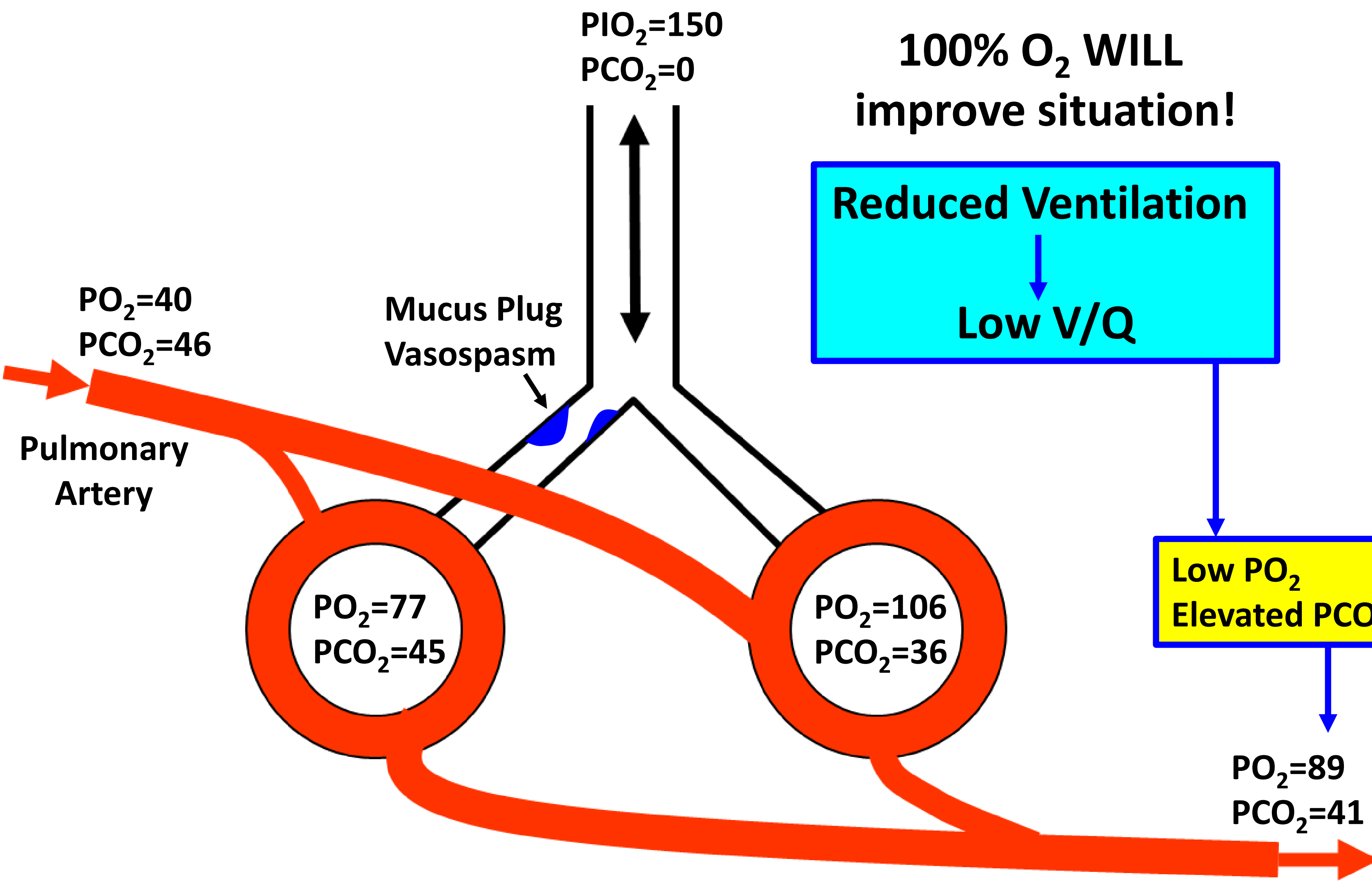


Anatomical Shunt (Right-to-Left)

- 100% O_2 will not abolish hypoxemia
- Shunted blood not exposed to O_2
- Non-shunted blood already near max sat



Intrapulmonary Shunt



Hypoxic Processes

Oxygen Deficiency –Terms and Definitions

ANOXIA = No O_2

HYPOXEMIA = Hypoxic Hypoxia

= Low arterial blood PO_2

HYPOXIA = Inadequate O_2 Available for Tissue Needs

Hematological Hypoxia

Low Hb to bind/carry O_2 but normal PO_2

e.g. Anemia or Carbon Monoxide Poisoning

Ischemic Hypoxia

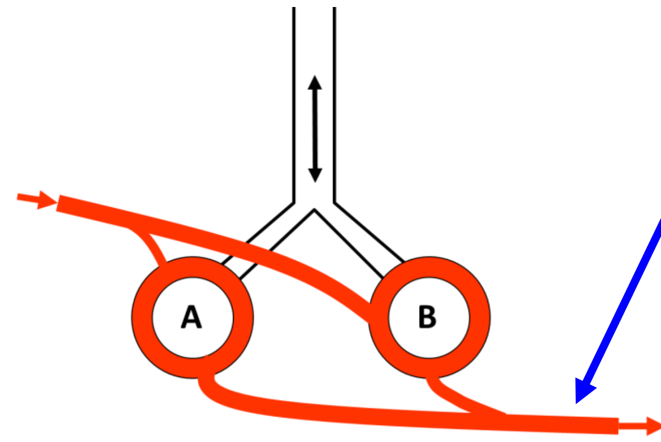
Low tissue O_2 due to low flow (blood PO_2 is normal)

Histotoxic Hypoxia

Normal O_2 supplied but can't be utilized by tissue;

e.g. Cyanide Poisoning

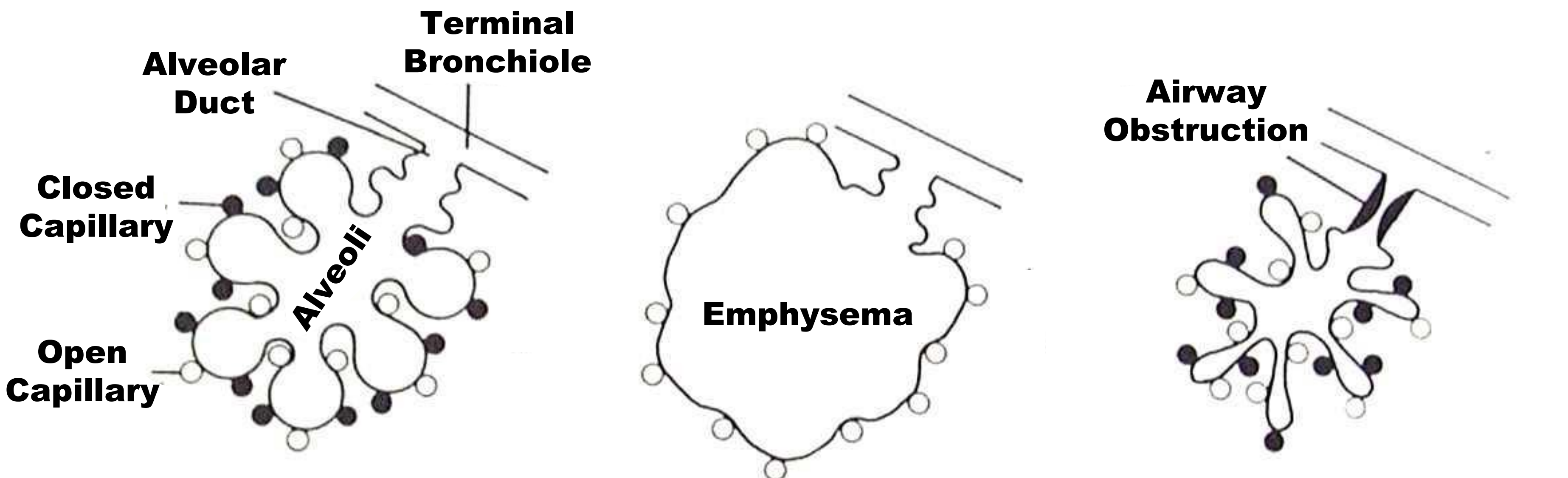
Mechanisms – Hypoxemia – Low O_2 in Blood



PROCESS	EXAMPLE
Reduced O_2 in inspired air ------>	Altitude Fires
Inadequate Ventilation ----------->	CNS depression (anesthesia) Neural deficit Muscle deficit
Diffusion Abnormality ---------->	Edema, Fibrosis
Shunts ------------------------------>	Anatomical Functional
V/Q mismatching ---------------->	Airway block → low v/Q Embolus → Low v/Q Alveolar DS → Low v/Q

Altered Gas Exchange

Alterations in Effective Gas Exchange



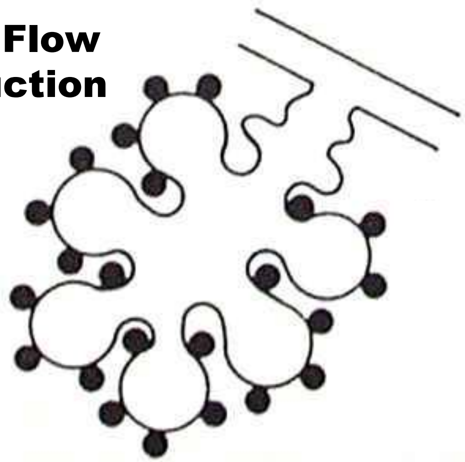
Normal

Destroyed alveolar walls
and some capillaries

Reduced Alveolar ventilation
Functional Deadspace

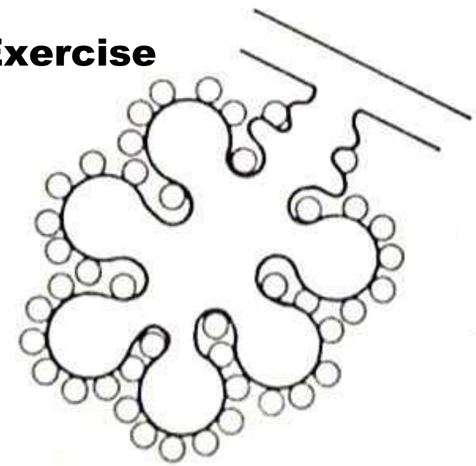
Alterations in Effective Gas Exchange

Blood Flow Obstruction



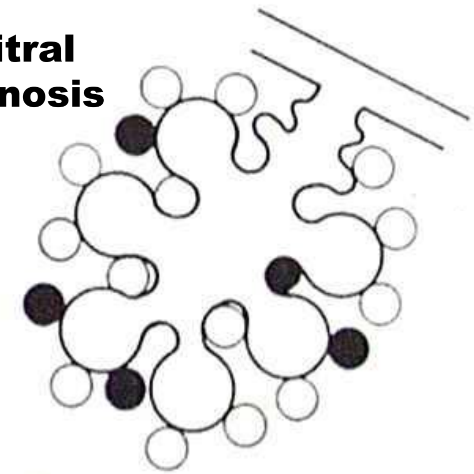
Reduced Capillary Flow
Functional Deadspace

Exercise



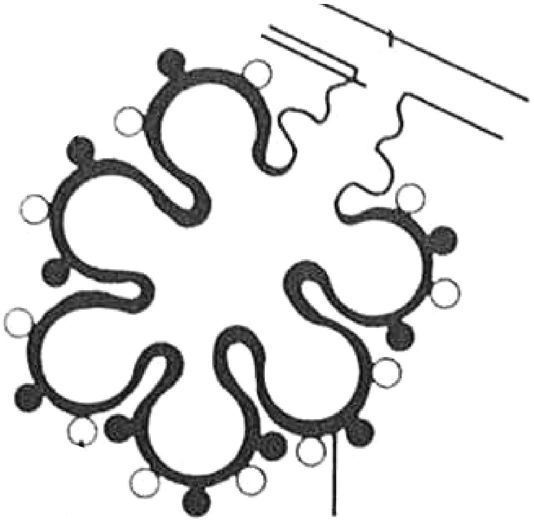
Capillary Recruitment
Gas-Blood Flow match

Mitral Stenosis

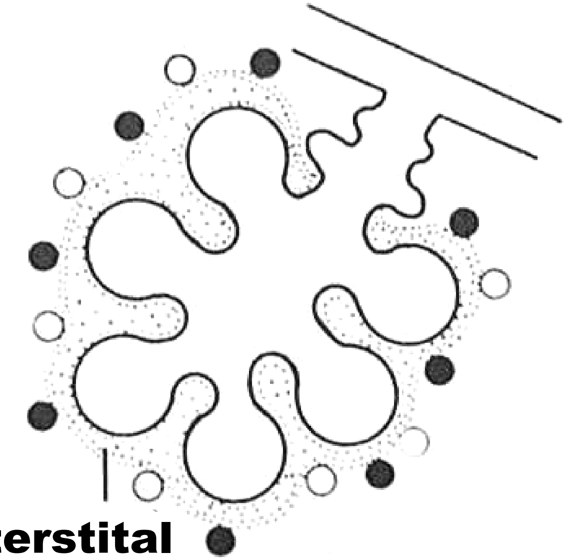


Enlarged Capillaries
Exchange Area increased

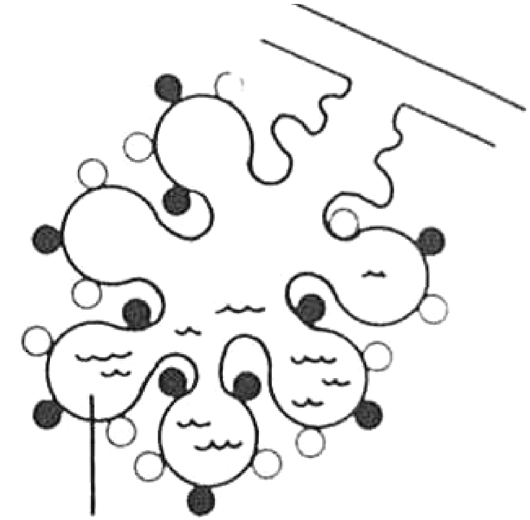
Alterations in Effective Gas Exchange



Thickening of Alveolar Epithelium



Widening of space increases distance from alveolus to capillary



Edema or exudates causes alveoli to be non - ventilated

Interactive Review Questions

What would be the effect of 100% O2 in the presence of an anatomical shunt? Essentially nothing

Which agent would cause histotoxic hypoxia? Cyanide

What type of hypoxia is caused by carbon monoxide poisoning? Hematological

A pulmonary emboli that block 30% of lung blood vessels does what to the lung V'/Q ratio?

CO is diverted to remainder of vessels so V'/Q decreases

What physical processes is affected by alveolar edema?

Gas diffusion and lung compliance

What is alveolar dead space?

Ventilated but not perfused = wasted ventilation

What is the affect of alveolar dead space on CO_2 content of blood exiting these alveoli? Increase

Interactive Review MCQs

15 seconds each

A pneumothorax that occurs at a lung volume of about 85% of TLC will result in:
A. outward movement of thorax
B. outward movement of the lung
C. inward movement of both the lung and thorax
D. outward movement of the lung and thorax
E. inward movement of the lung but outward movement of the thorax

Which pulmonary feature largely accounts for the normally high value of lung interstitial oncotic pressure?
A. Low pulmonary capillary hydrostatic pressure
B. High pulmonary capillary oncotic pressure
C. High value of pulmonary lymphatic flow
D. Low value of pulmonary capillary reflection coefficient
E. High value of total pulmonary blood flow

At FRC, which of the following is true?
A. Lung compliance is at, or near, its minimum value
B. Pulmonary vascular resistance is near its maximum value
C. Chest wall recoil is at its minimum value
D. Chest wall recoil is at its maximum value
E. Chest wall and lung recoil are equal and oppositely directed

Which one of the following statements is true regarding airway resistance?
A. It decreases as the lung expands because airways lengthen
B. It is largest in smaller airways because of their smaller diameter
C. Its value decreases with increasing lung volume
D. If increased, it will tend to cause airway collapse during inspiration
E. Its increase is the main finding in restrictive lung disease

End Respiration Physiology Lecture 4