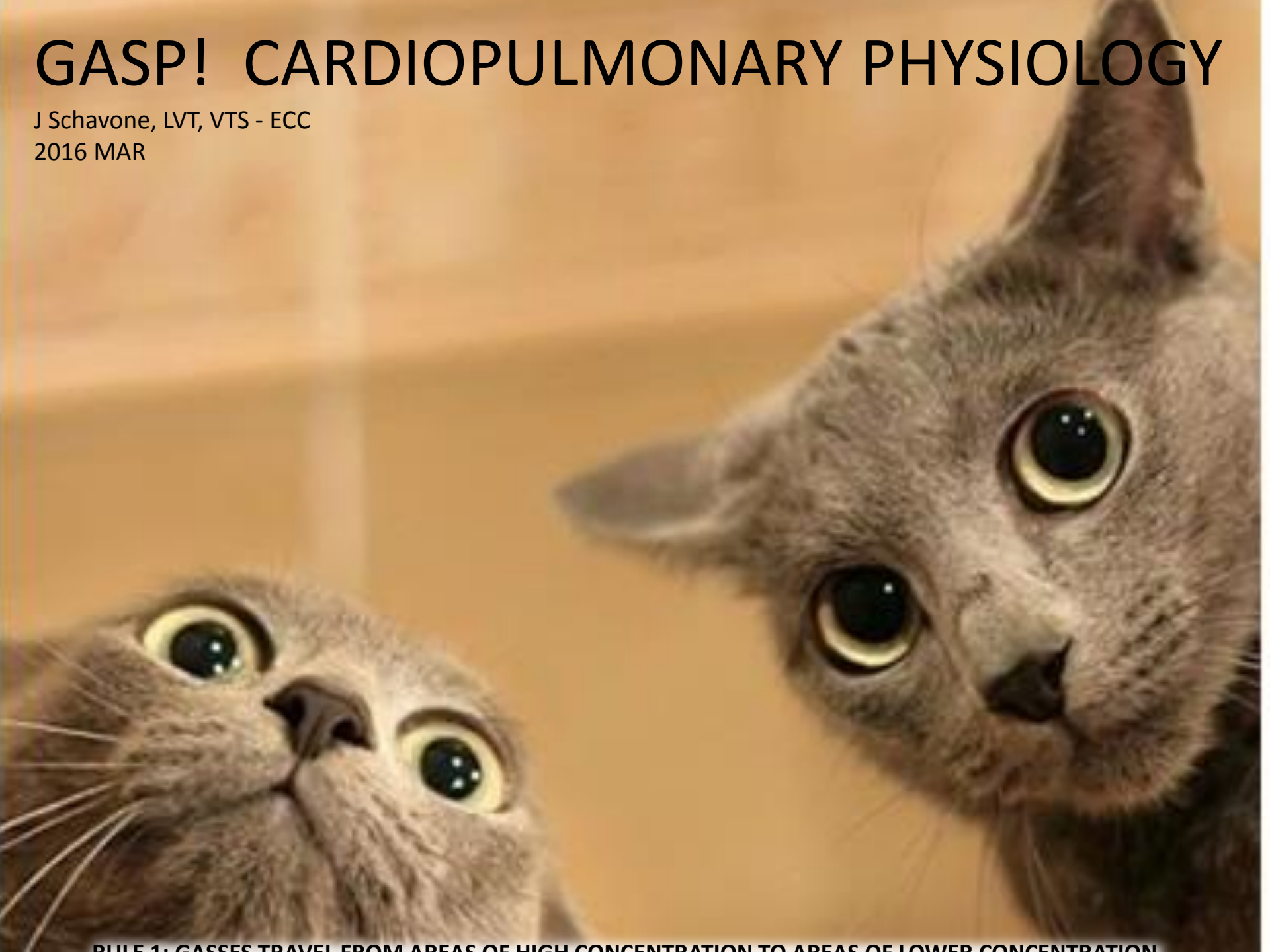
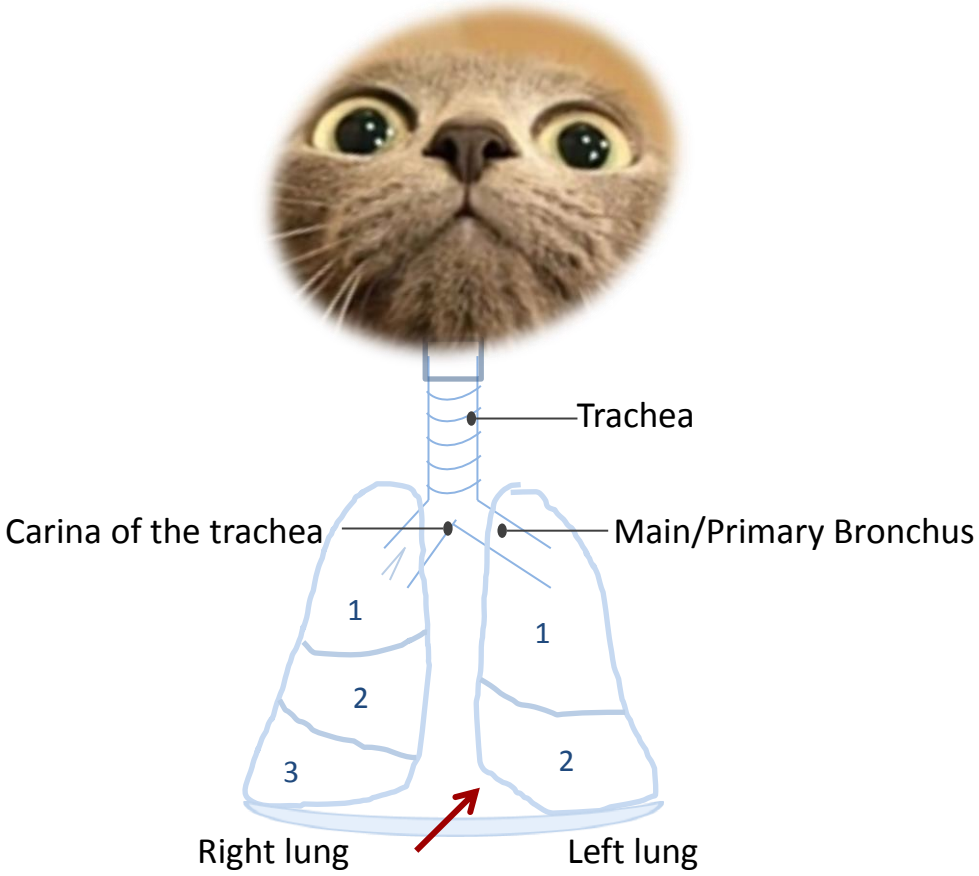
GASP! CARDIOPULMONARY PHYSIOLOGY

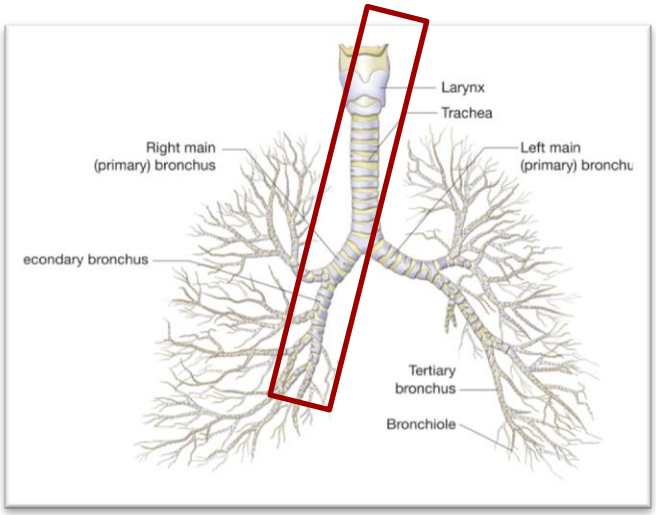
J Schavone, LVT, VTS - ECC
2016 MAR



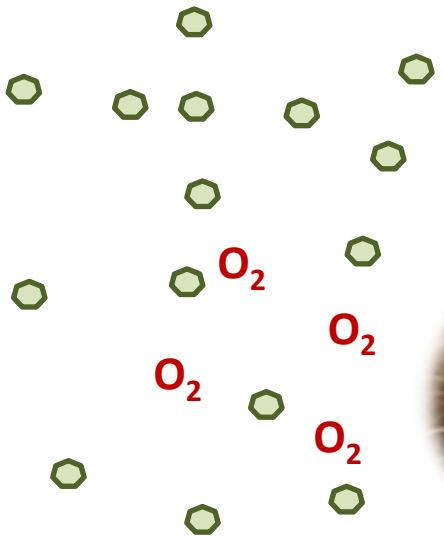
BASIC ANATOMY

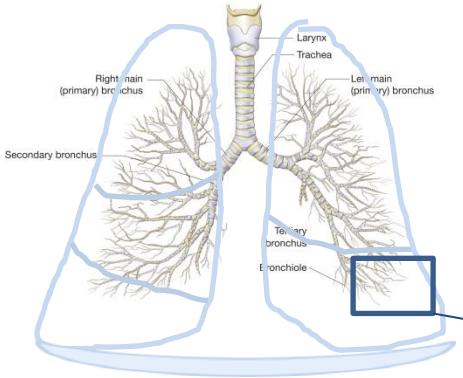
Respiratory tract





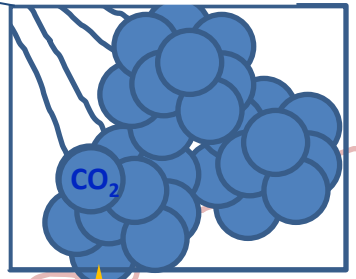
INSPIRATION





Alveolus

Alveoli

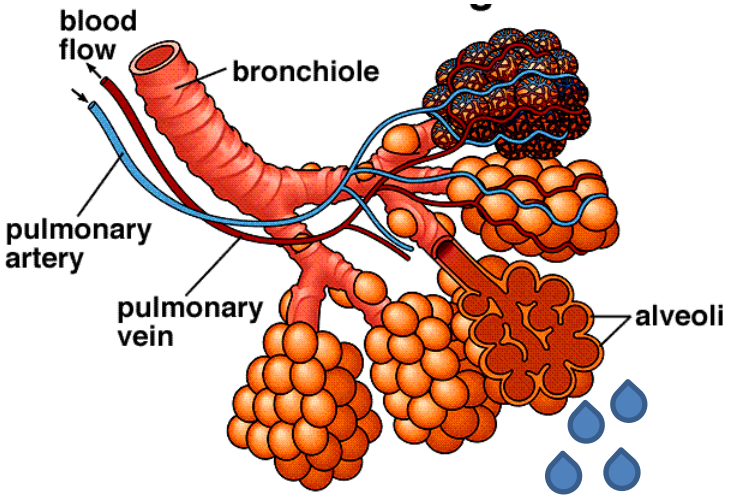


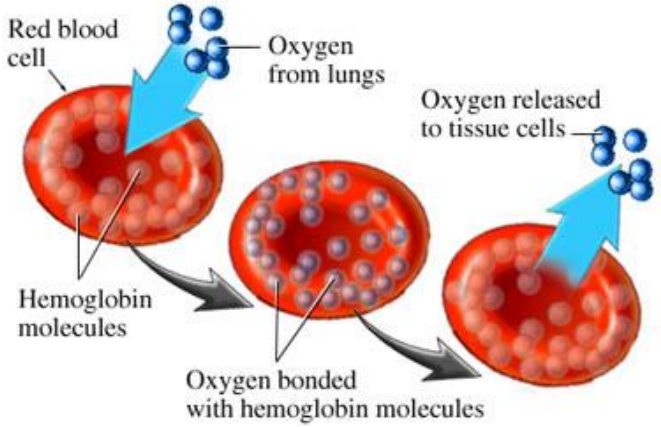
L

R

Pulmonary Parenchyma

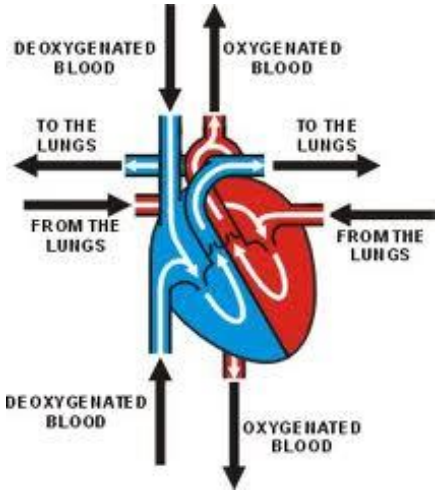
GAS EXCHANGE





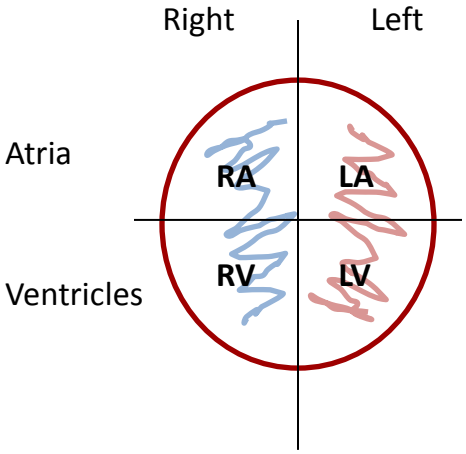
BASIC PHYSIOLOGY

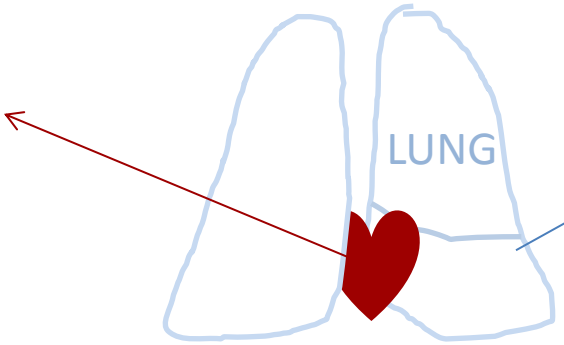
Cardiopulmonary circulation

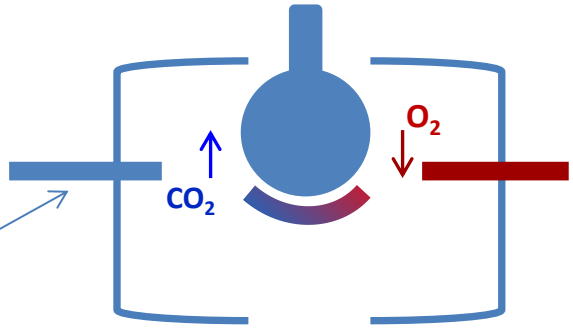


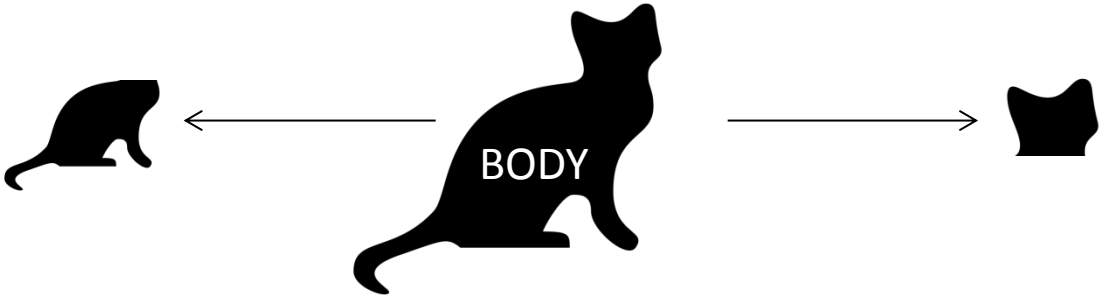
BASIC PHYSIOLOGY

Cardiopulmonary circulation

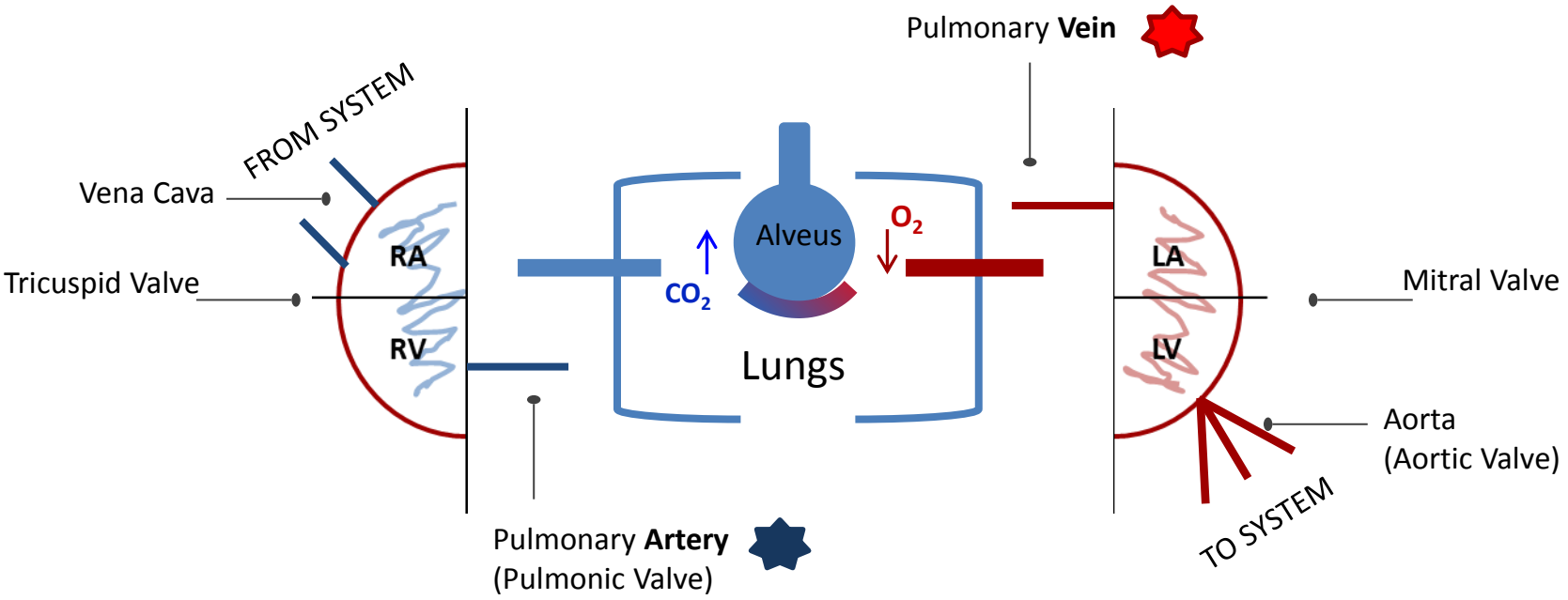






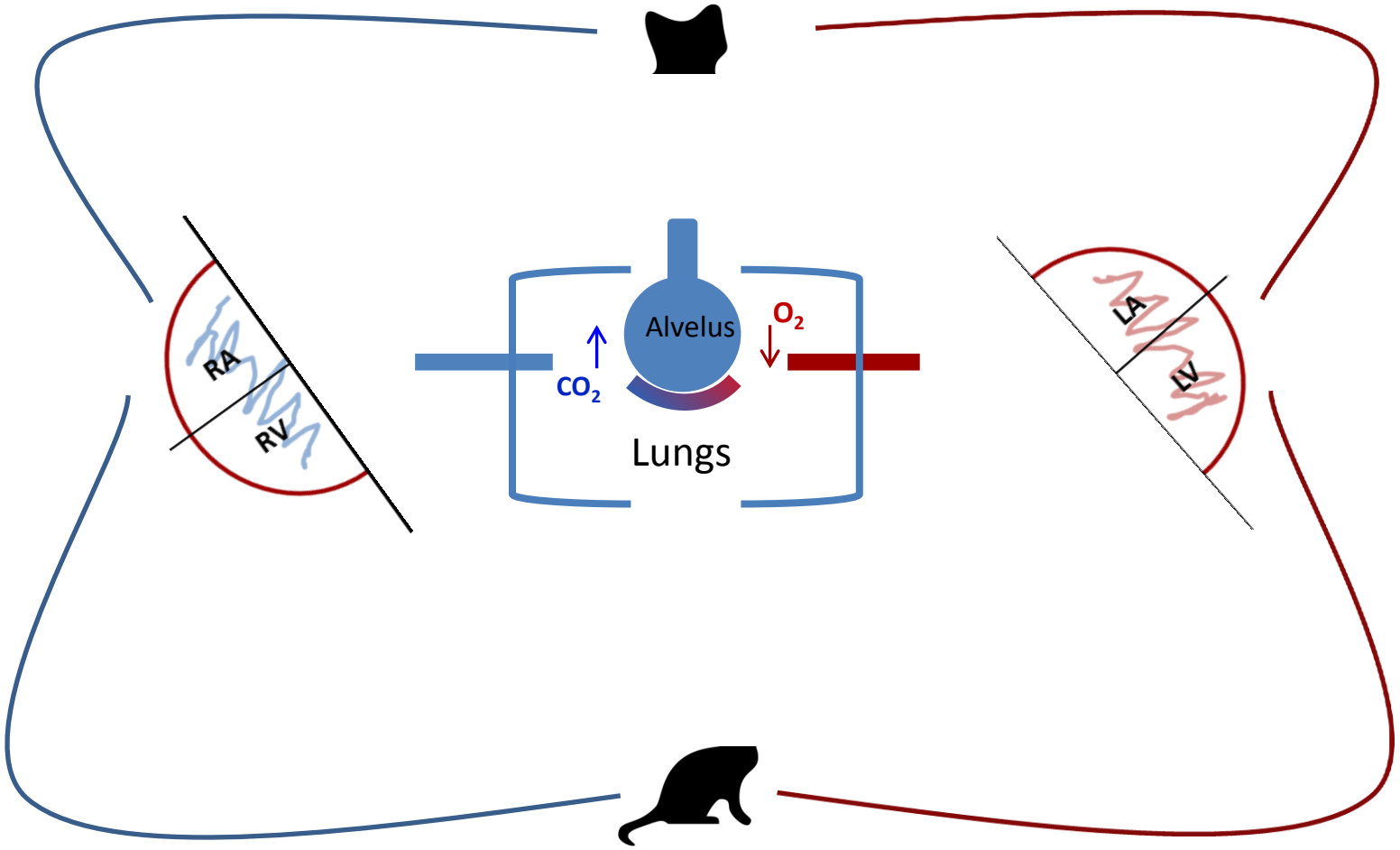


CARDIOPULMONARY CIRCULATION



CARDIOPULMONARY CIRCULATION

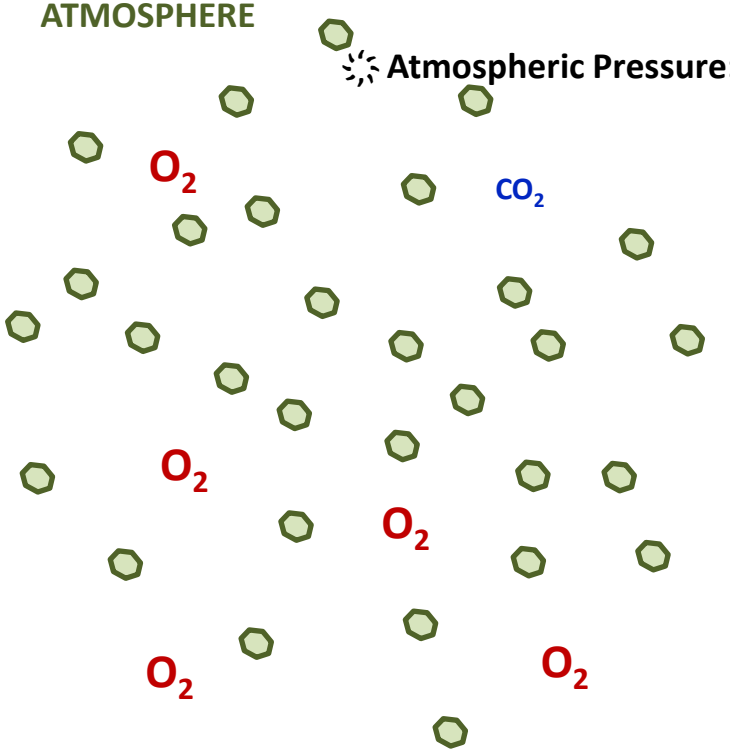
Simplified



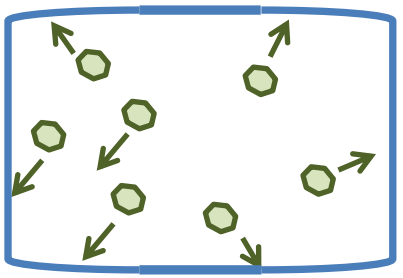
PRESSURE

ATMOSPHERE

Atmospheric Pressure: 760mmHg
(Sea level)



CLOSED SYSTEM : 10 mL



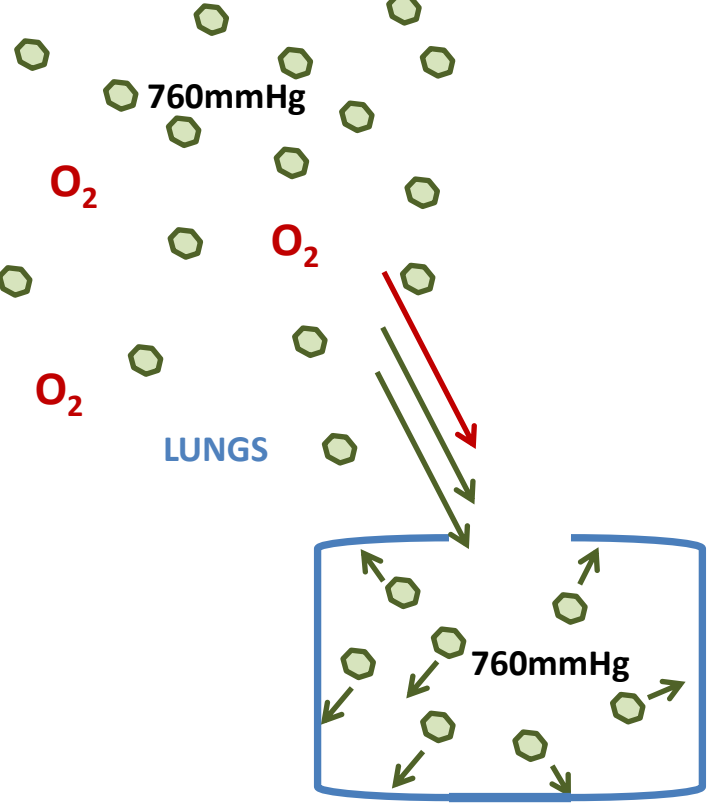
4u / 10mL

7u / 10mL

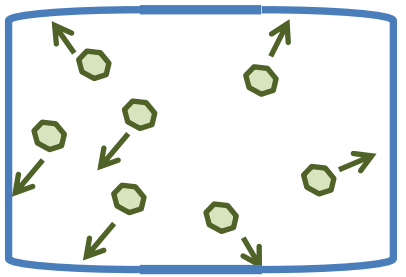
RULE 2: ↑CONCENTRATION = ↑PRESSURE

PRESSURE GRADIENTS

Spontaneous Inspiration



CLOSED SYSTEM 7u / 10mL



7u / 12mL

↑CONCENTRATION = ↑PRESSURE

↑VOLUME =↓CONCENTRATION = ↓PRESSURE

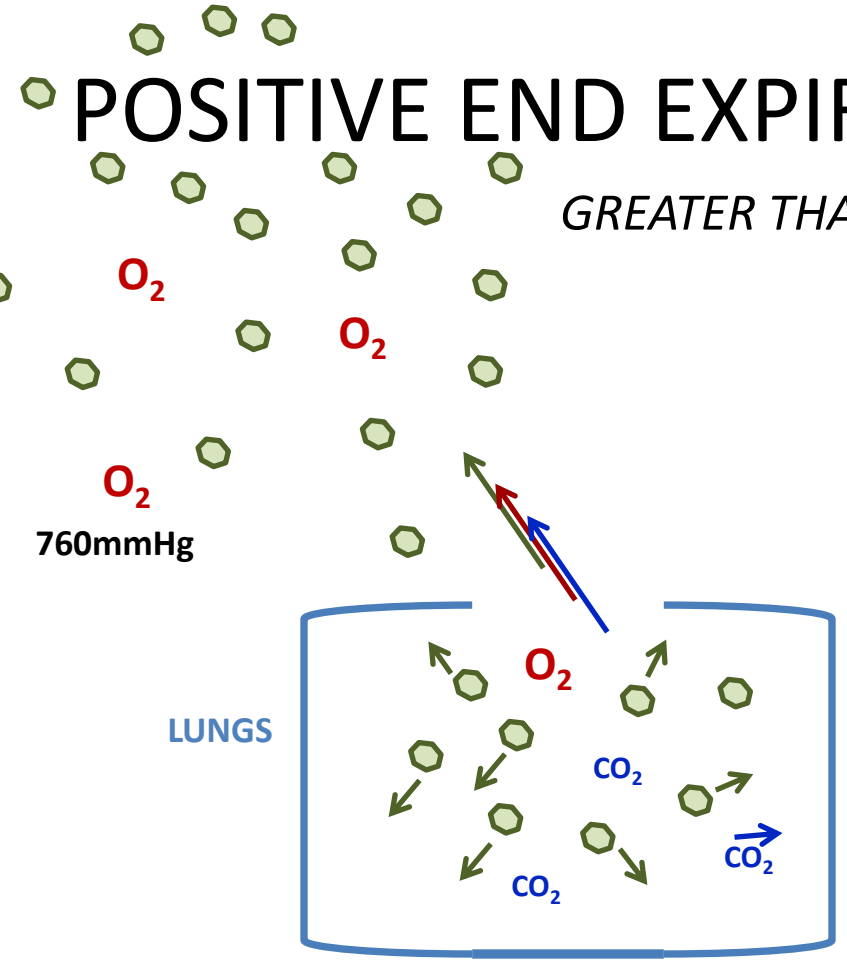
↑VOLUME ↓PRESSURE → GAS INFLUX

CLINICALLY APPLICABLE POINTS

- Inflation of lungs during spontaneous inspiration is a passive process
- Positive pressure ventilation (manual or mechanical) may cause trauma to lung tissue

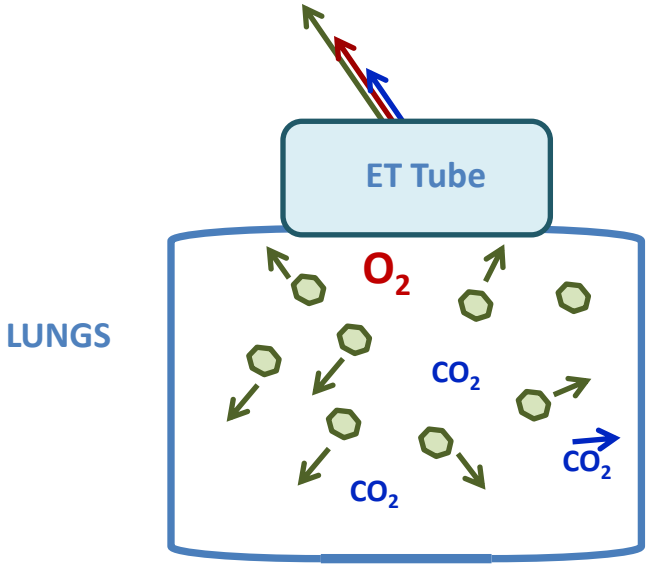
POSITIVE END EXPIRATORY PRESSURE (PEEP)

GREATER THAN ATMOSPHERIC END-EXPIRATORY PRESSURE



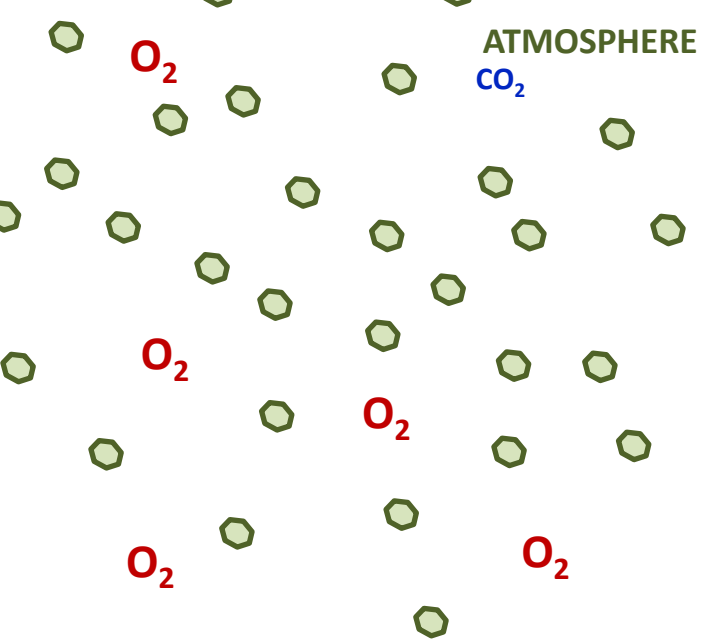
↓VOLUME = ↑PRESSURE

NORMAL EXPIRATION
(neutral @ 760mmHg)

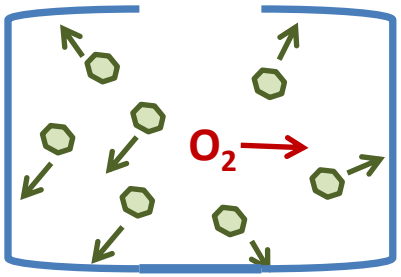


↓VOLUME = ↑PRESSURE

PEEP (often set at 1-5mmHg)
(increased @ 761-766mmHg)



PARTIAL PRESSURES

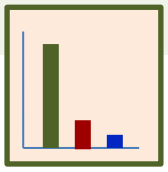


CONTAINER

THE TOTAL INTERNAL PRESSURE OF A CONTAINER* WILL ALWAYS EQUAL THE SUM OF THE INDIVIDUAL PRESSURES OF THE GASSES WITHIN THAT CONTAINER

Atmospheric Pressure: 760mmHg

GAS CONTENT OF ROOM AIR	
GAS NAME	%
Nitrogen (N_2)	78 %
Oxygen (O_2)	21 %*
Carbon Dioxide (CO_2)	0.08 %
TRACE	0.9 %



ROOM AIR

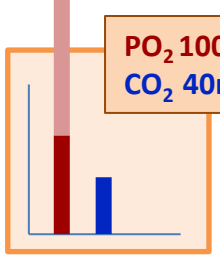
CALCULATE THE PO_2 :

760mmHg x 0.21 = PO_2 159.60mmHg

PARTIAL PRESSURE OF O_2 AND CO_2 THROUGHOUT THIS CYCLE				
	ATMOSPHERE	ALVEOLI	PULMONARY **a**RTERY (ARTERIAL CIRCULATION)	PULMONARY VEIN (VENOUS CIRCULATION)
O_2	PO_2 =160mmHg	P_AO_2 =103mmHg	PaO_2 =40mmHg	PaO_2 =100mmHg
CO_2	CO_2 =0mmHg	C_AO_2 =40mmHg	CaO_2 =45mmHg	CaO_2 =40mmHg

APPROX CONCENTRATIONS

*Fraction of Inspired Oxygen (FiO_2) of room air = 0.21



ARTERIAL BLOOD

VENTILATION AND OXYGENATION

CARBON DIOXIDE

- **Normocapnea: PCO_2 < 45 (dog),** < 38(cat)
- Hypercapnea: > normal
- Severe Hypercapnea: ≥ 50
- Hypocapnea: < 35

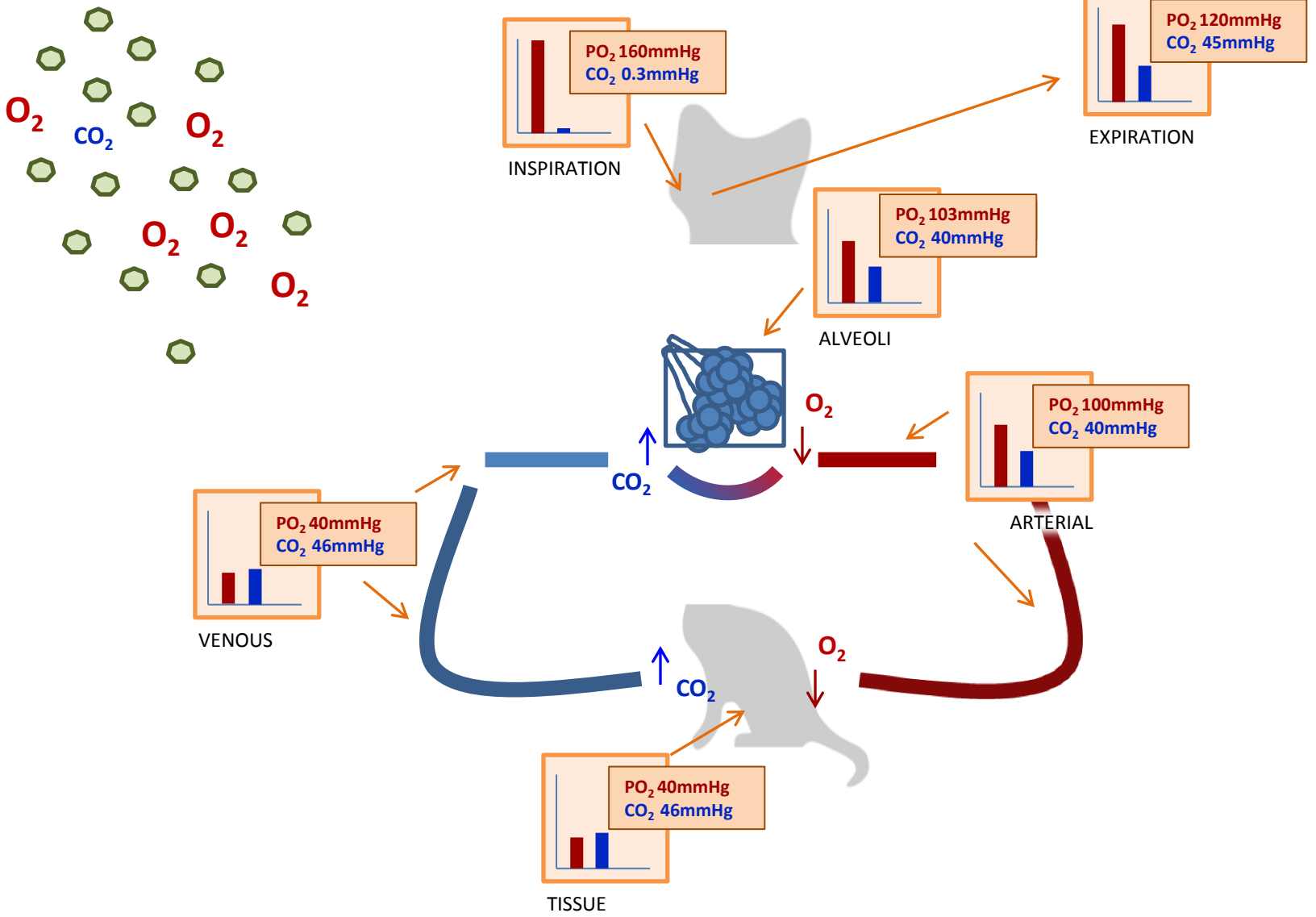
OXYGEN

- **Normoxemia: PaO_2 ≈100mmHg**
- Hypoxemia: PaO_2 <80 mmHg, SPO2 <95%
- Severe Hypoxemia: PaO_2 <60 mmHg, SPO2 <90%
- *Hyperoxemia*

Saturation and PaO2 SPO2	PaO_2
98-99%	100-600 mmHg
99%	120 mmHg
95-96%	80 mmHg
90-91%	60 mmHg

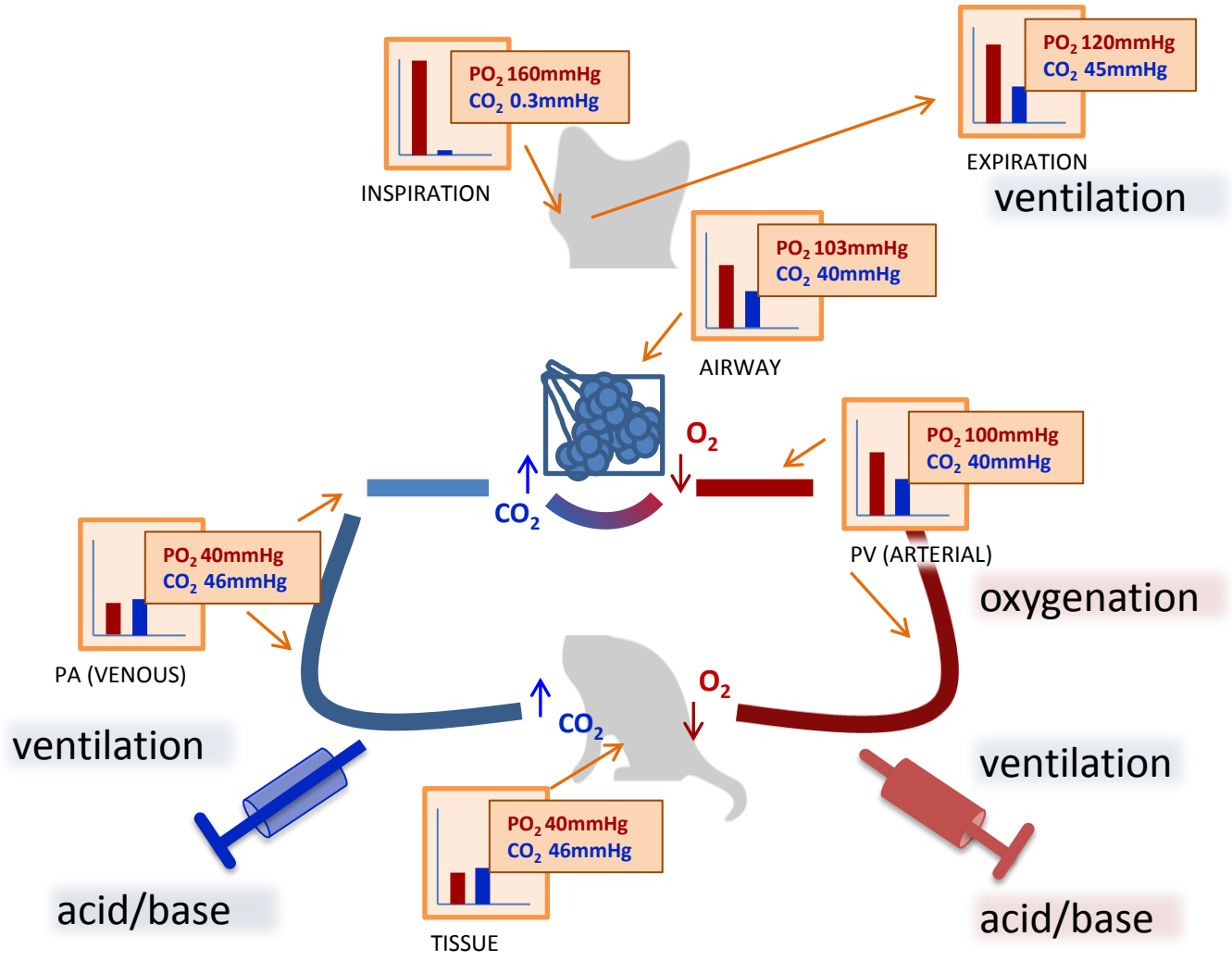
Affected by temperature and pH

OXYGEN AND CARBON DIOXIDE

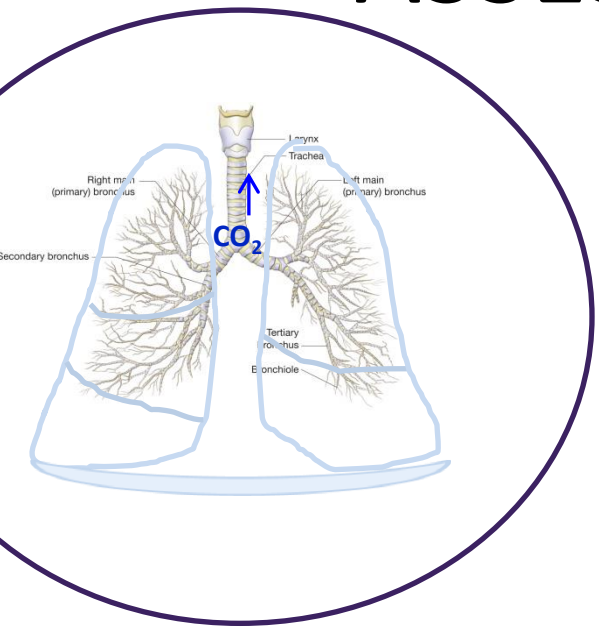


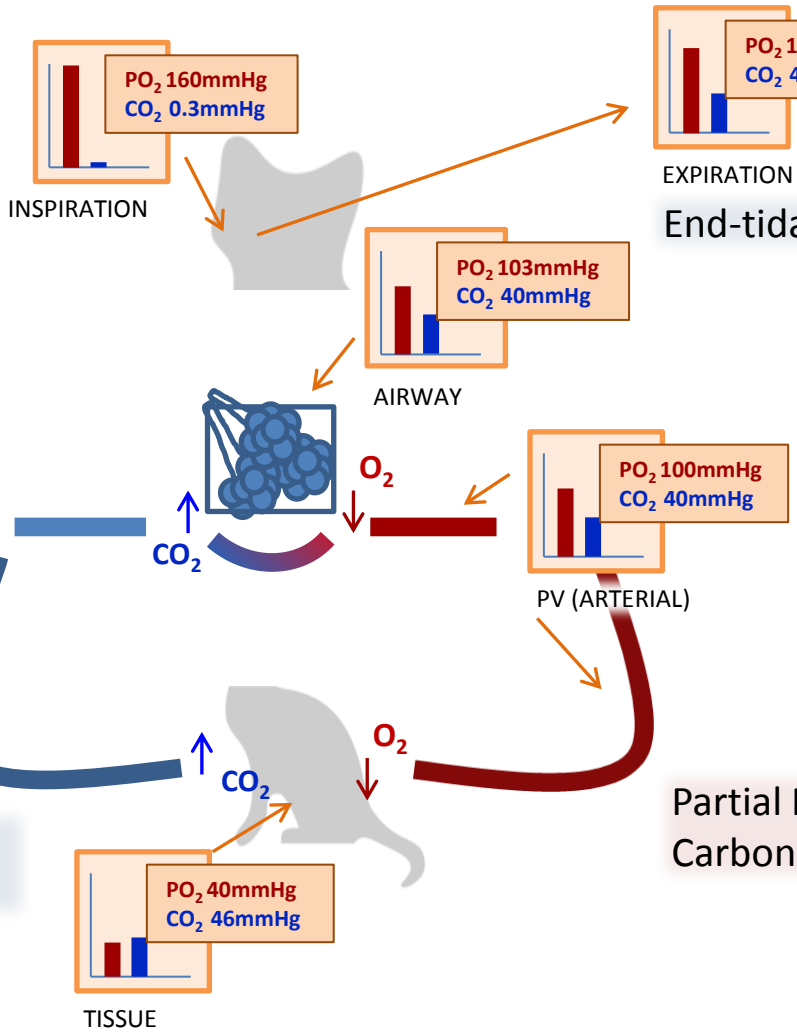
CLINICAL APPLICATIONS OF CONCEPT

Assessment of ventilation, oxygenation, and lung function

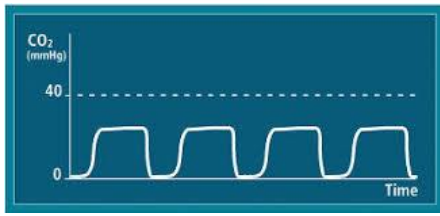


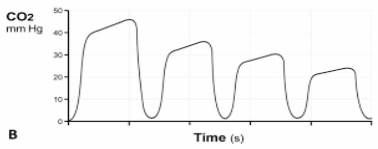
ASSESSMENT OF VENTILATION





End-tidal Carbon Dioxide ($ETCO_2$)

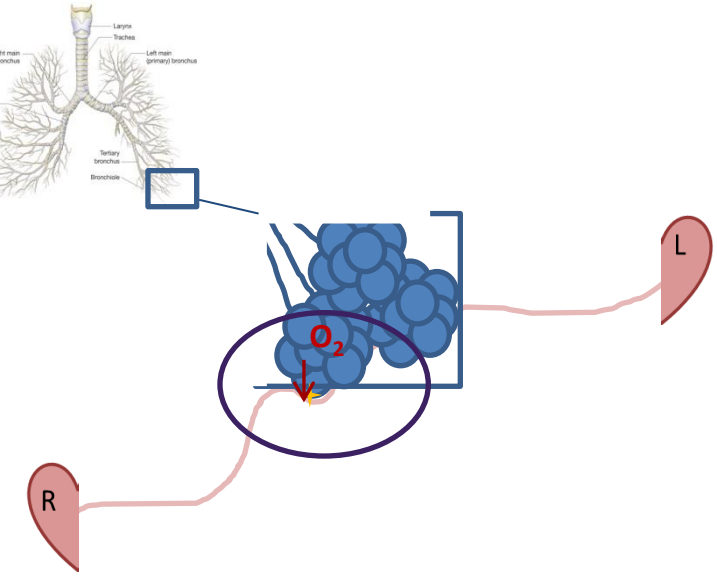


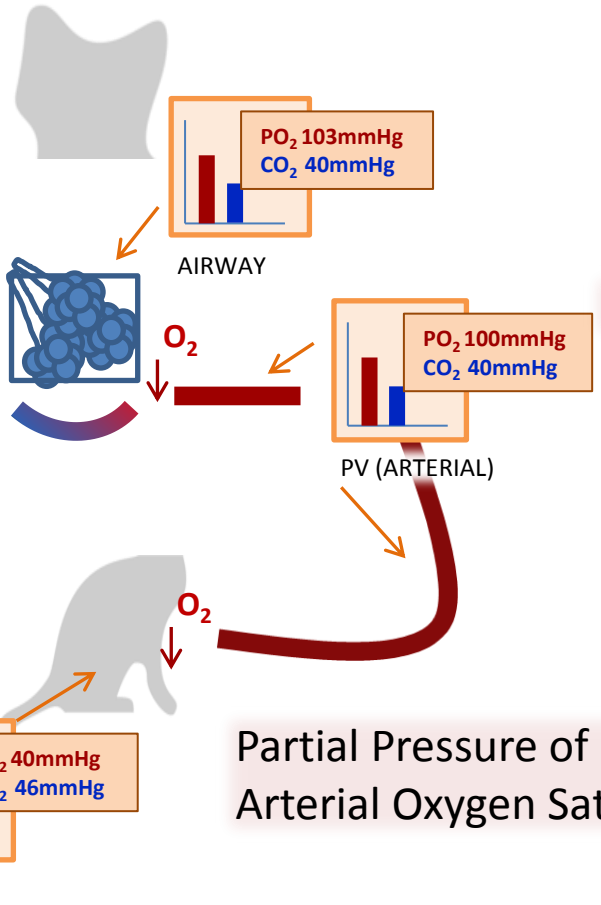


Partial Pressure of Venous Carbon Dioxide ($PvCO_2$)

Partial Pressure of arterial Carbon Dioxide ($PaCO_2$)

ASSESSMENT OF OXYGENATION

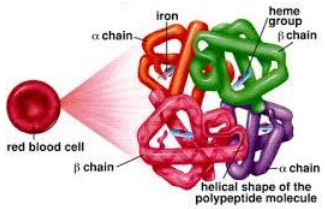




Pulse Oximetry (SPO_2)

Partial Pressure of arterial Oxygen (PaO_2)
Arterial Oxygen Saturation (SaO_2)

HEMOGLOBIN SATURATION (SPO2)



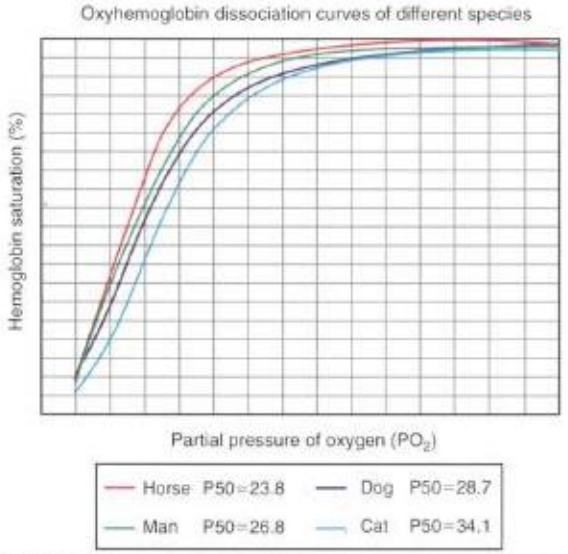
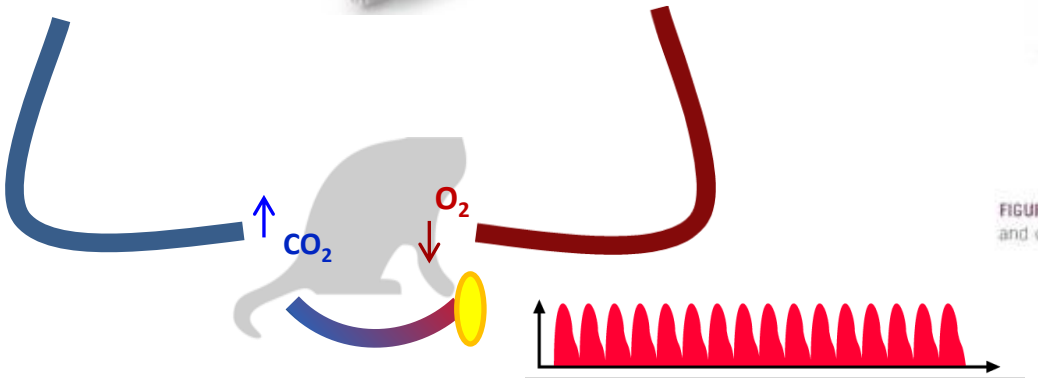
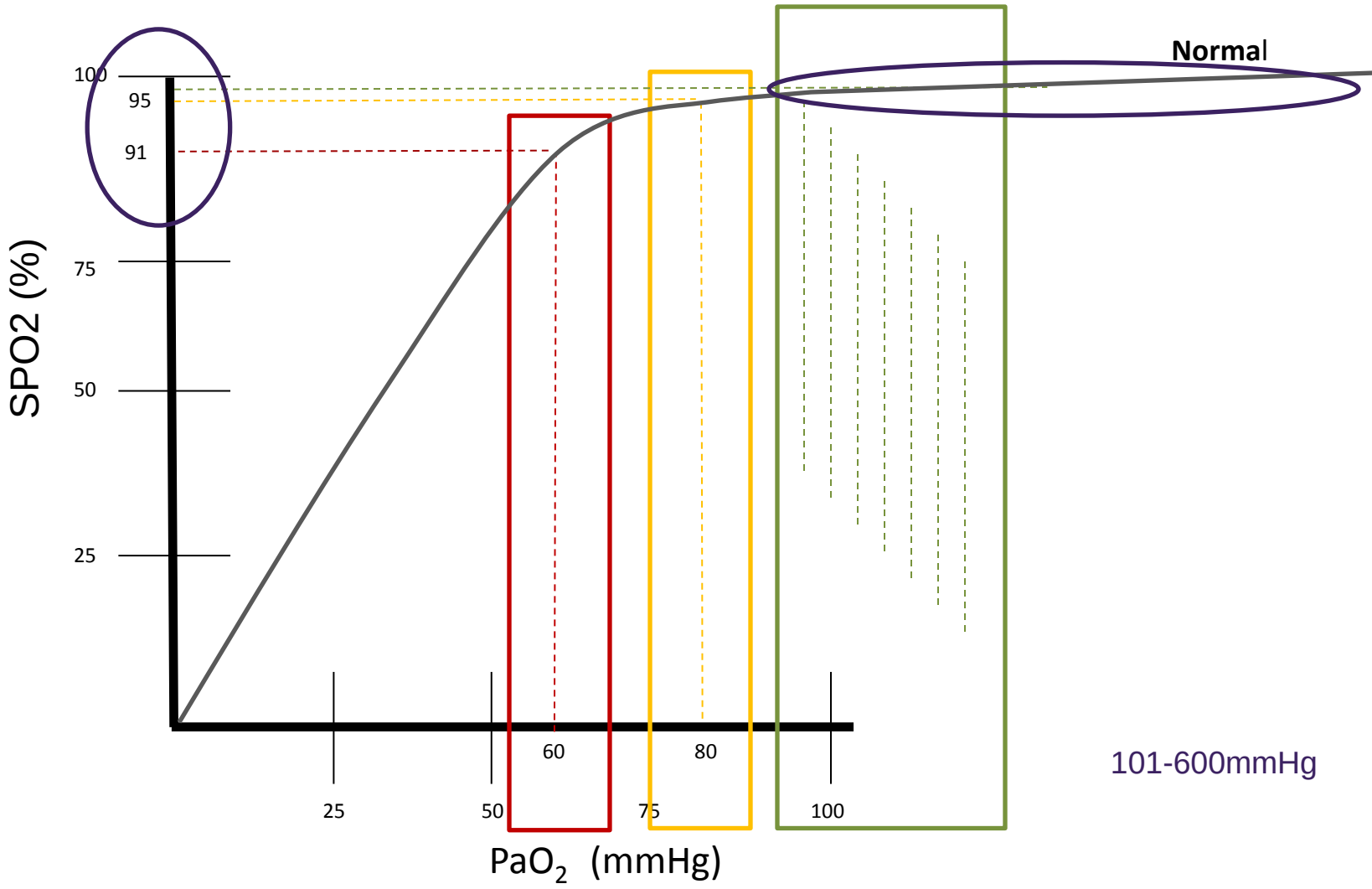


FIGURE 15-1 Oxyhemoglobin dissociation curves for the horse, man, dog, and cat.[8]



Silverstein/Hopper Small Animal Critical Care Medicine. Ed 2

CLINICAL APPLICATION OF CONCEPT

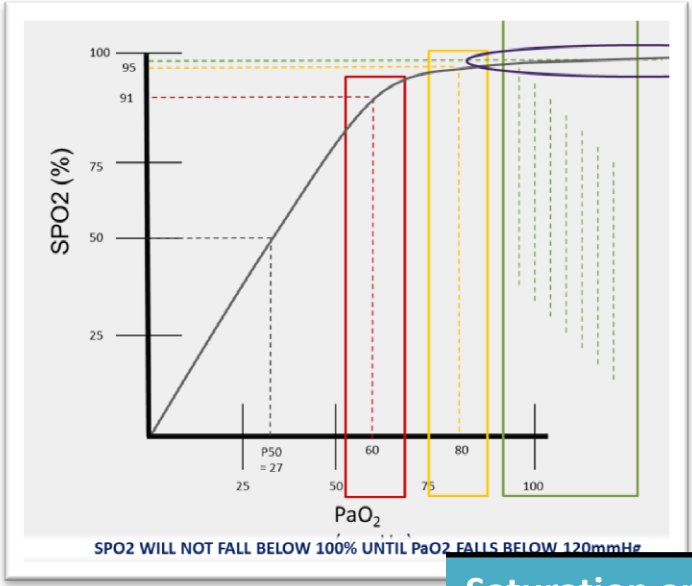


SPO2 WILL NOT FALL BELOW 100% UNTIL PaO^2 FALLS BELOW 120mmHg

PULSE OXIMETRY

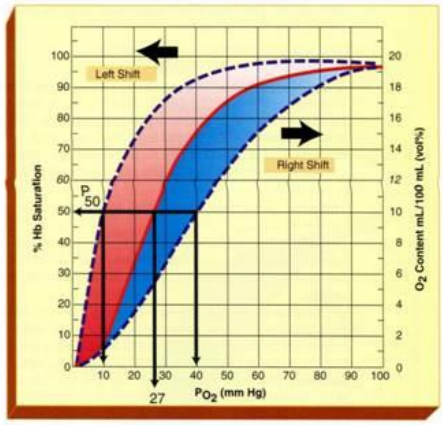
"With these…caveats, pulse oximeters noninvasively, continuously, and automatically monitor very well the parameter they were designed to measure- hypoxia"

SC Haskins, DVM, MS, DACVAA, DACVECC



Saturation and PaO2 SPO2	PaO_2
98-99%	100-600 mmHg
99%	120 mmHg
95-96%	80 mmHg
90-91%	60 mmHg

Affected by temperature and pH

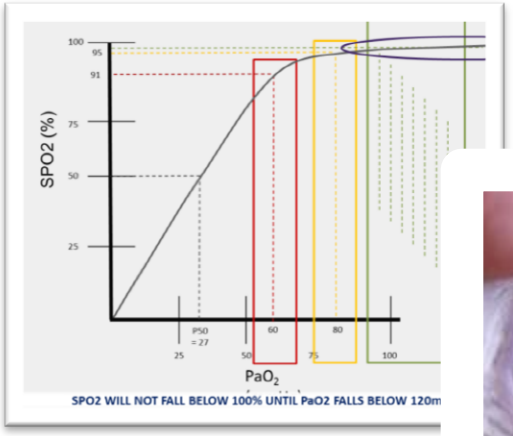


unknown original source

NOTE ON CYANOSIS

Recognition of cyanosis requires an absolute concentration of deoxygenated hemoglobin of 5g/dl

1. If a dog has a hemoglobin concentration of 15g/dl – cyanosis would manifest when SPO_2 had decreased to 67% (PaO_2 37 mmHg)
2. An anemic dog with a hemoglobin concentration of 5g/dl would die of hypoxemia and resultant tissue hypoxia long before manifesting cyanosis.



ASSESSMENT OF LUNG FUNCTION

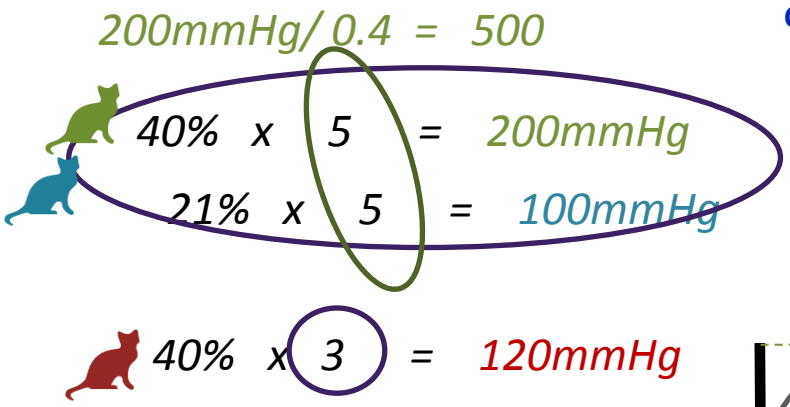
A – a Gradient (PAO_2 – PaO_2)

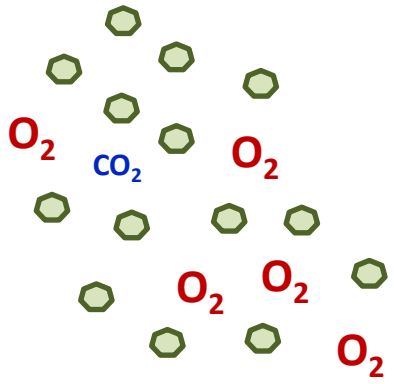
- Animals breathing room air
- Normal 5-15mmHg

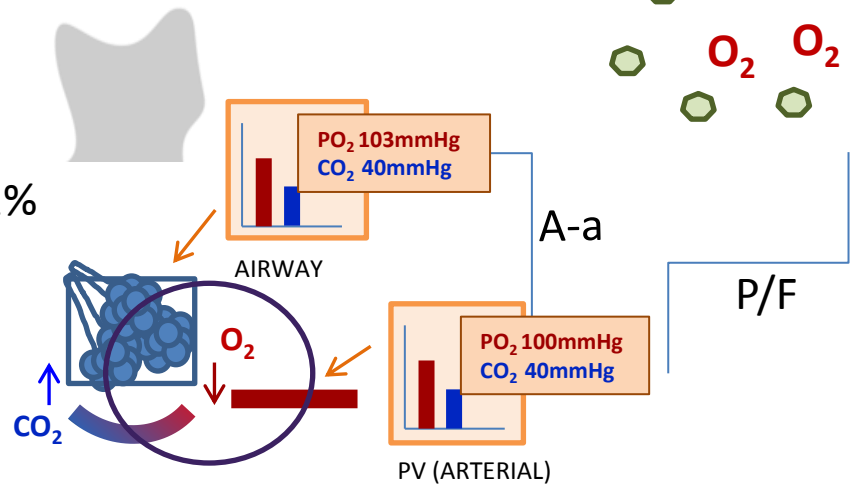
Oxygen Index (PaO_2/FiO_2)

- In cases breathing FiO2 > 21%
- Normal 500

*Fraction of Inspired Oxygen (FiO_2)

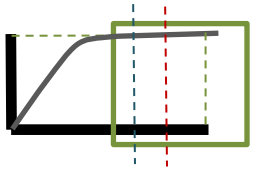






Partial Pressure of arterial Oxygen (PaO_2)

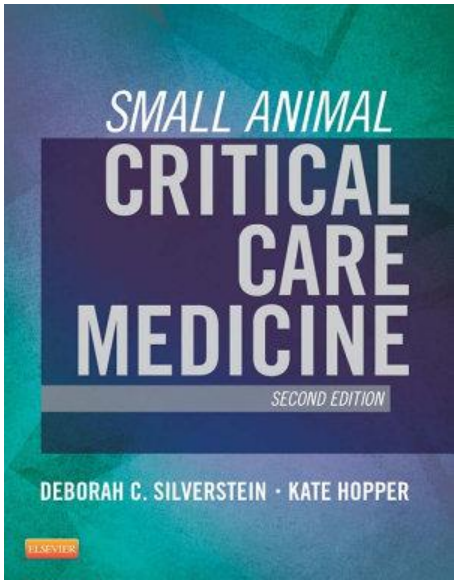
HEMOGLOBIN SATURATION (SPO_2)

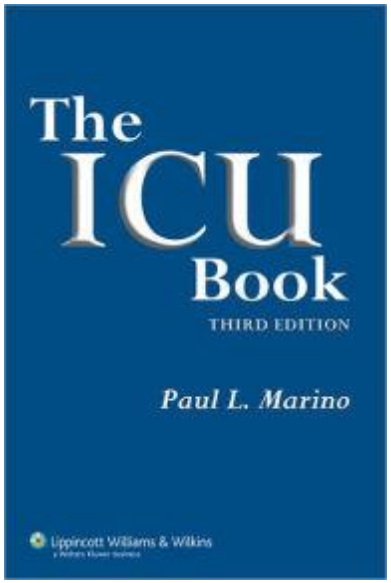


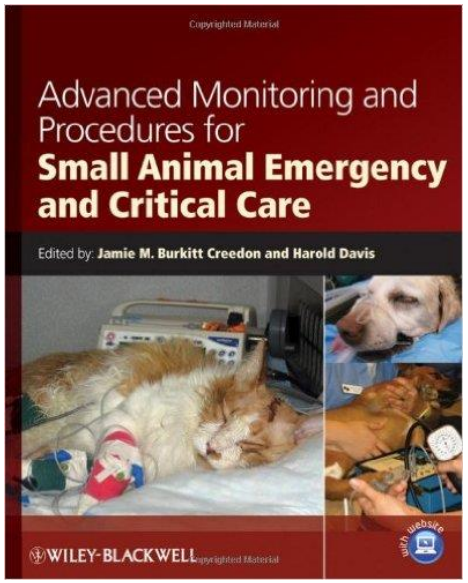
ABG SAMPLING AND HANDLING

- Ideally – as anaerobically as possible
- Ideally - run the samples as soon as possible
- Ideally – avoid excessive dilution (anticoagulants)

SUGGESTED READING







VARIOUS HELPFUL TABLES

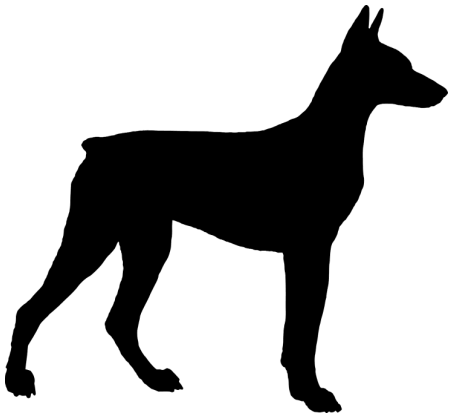
Normal Venous and Arterial Blood Gas Values		
Value	Venous	Arterial
pH	7.38-7.43	7.35-7.45
PO_2	35-40	80-100
PCO_2	41-52	35-45
HCO_3-	24-28	22-26
Saturation	≈75%	> 98%

ATMOSPHERIC PRESSURE AT ALTITUDE		
City	Altitude	AP
Charleston, SC (Sea Level)	0 ft	760mmHg
Cleveland, OH	500 ft	747mmHg
Denver, CO	5280 ft	640mmHg
Mt. Everest	29,028 ft	253mmHg

1 cmH_20 = 0.736mmHg

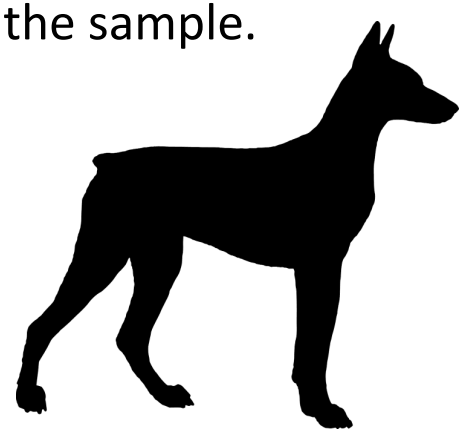

QUESTIONS?

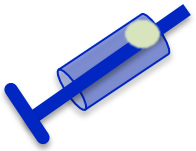
CASE EXAMPLE



Multiple Choice:

Question: You have successfully obtained an arterial blood gas sample from a Doberman. You are very proud of yourself. Unfortunately you were so excited that you did not notice an air bubble in the syringe. Sonya did notice, but ran the sample.





Sample type: Arterial blood sample

Objective: PaO_2 evaluation

Draw time: 2:30pm

Run time: 3:20pm

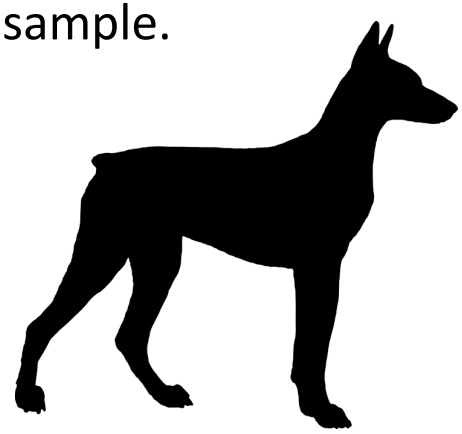
Will your doctor likely use this sample to evaluate this patients lung function?

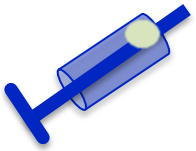
a. Sure thing!

b. No Way!

Multiple Choice:

Question: You have successfully obtained an arterial blood gas sample from a Doberman. You are very proud of yourself. Unfortunately you were so excited that you did not notice an air bubble in the syringe. Sonya did, but ran the sample.





Sample type: Arterial blood sample

Objective: PaO_2 evaluation

Draw time: 2:30pm

Run time: 3:20pm

Do you expect the presence of the air bubble to:

a. ~~Have no effect on the result~~

b. Artificially raise the resultant PaO_2 value

c. Artificially lower the resultant PaO_2 value

d. It's just not that simple

Multiple Choice:

Question: You have successfully obtained an arterial blood gas sample from the FOLLOWING TWO Doberman dogs…..

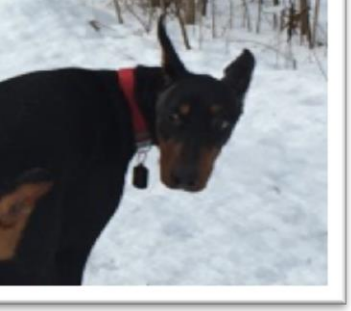
Sample type: Arterial blood sample

Objective: PaO_2 evaluation

Draw time: 2:30pm

Run time: 3:20pm

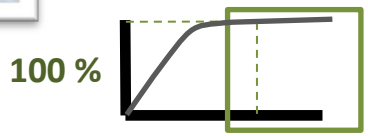
IMG_0636.MOV



NORMAL DOG

FiO_2 = 0.21 or 21%

21 X 5 = >100



PaO_2 100 / FiO_2 0.21 = 500

PATIENT

FiO_2

EXPECTED PaO_2

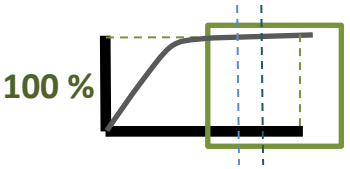
EXPECTED SP02

ACTUAL O2 INDEX

DCM DOG

FiO_2 ≈ 0.40 or 40%

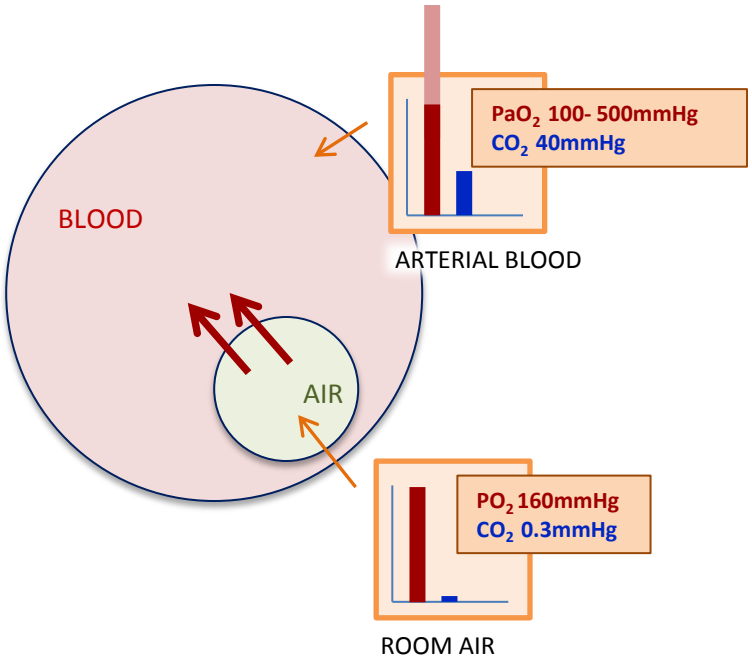
50 X 5 = >250



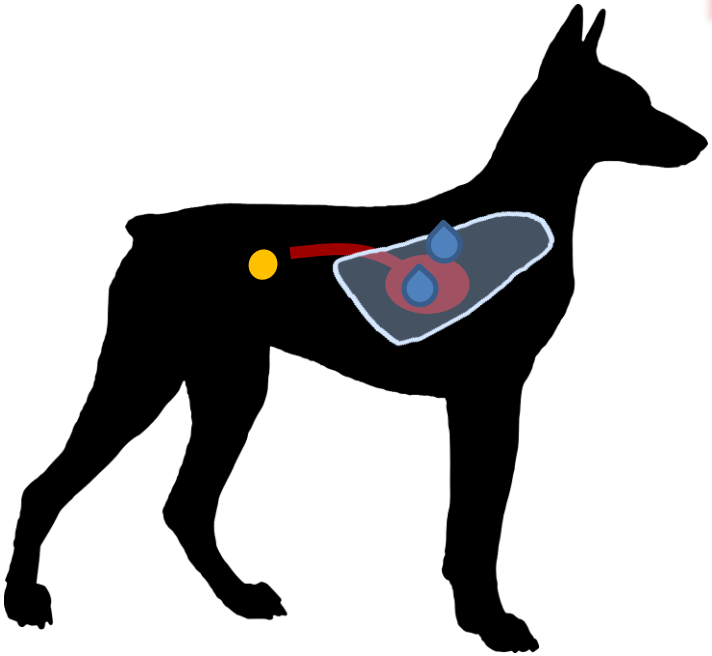
PaO_2 250 / FiO_2 0.5 = 500

PaO_2 200 / FiO_2 0.5 = 400

Day 2: PaO_2 150 / FiO_2 0.35 =



PATHOPHYSIOLOGY



PROGRESSIVE SYSTOLIC DYSFUNCTION & CARDIAC DILATION

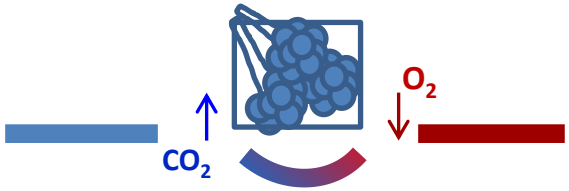
DECREASED FORWARD FLOW

CHRONIC RENIN ANGIOTENSIN ALDOSTERONE SYSTEM ACTIVATION

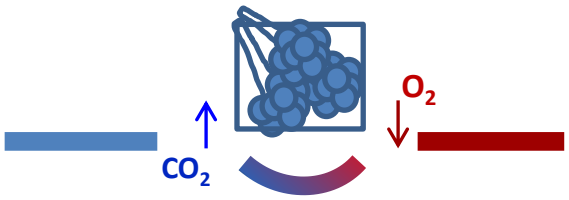
RETENTION OF SODIUM AND WATER

CONGESTIVE HEART FAILURE (PULMONARY EDEMA)

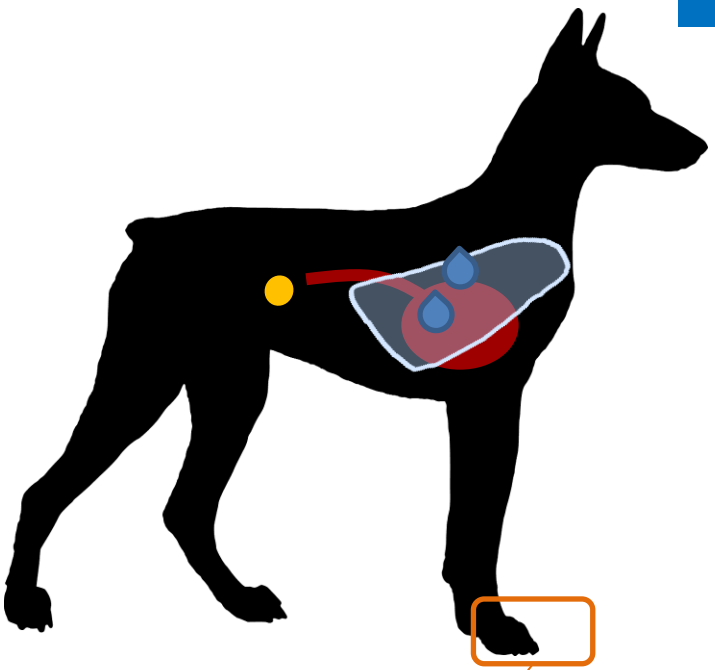
DECREASED O2 DELIVERY TO THE TISSUES

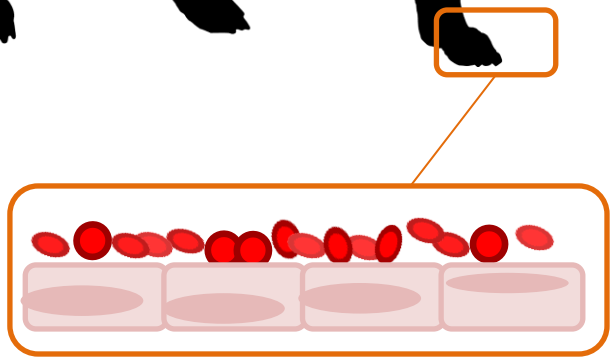


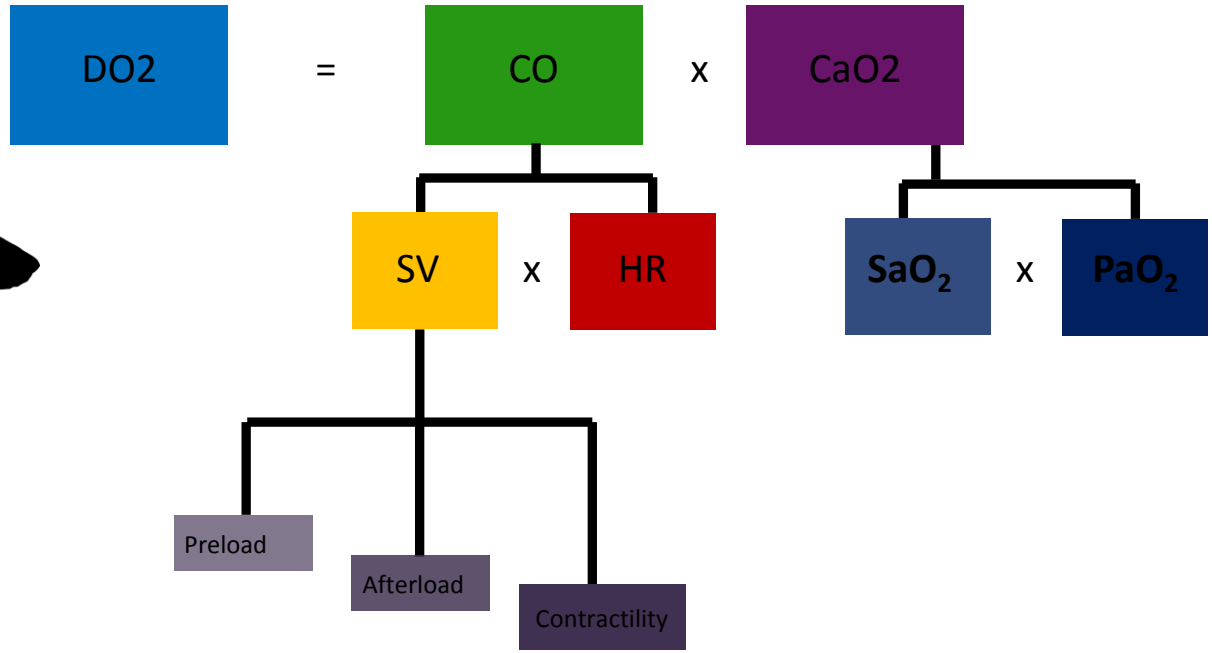
$$CaO_2 = (1.34 \times Hgb \times SaO_2) + (0.003 \times PaO_2)$$



DELIVERY OF OXYGEN (DO_2)







OXYGEN DEMAND (VO_2)

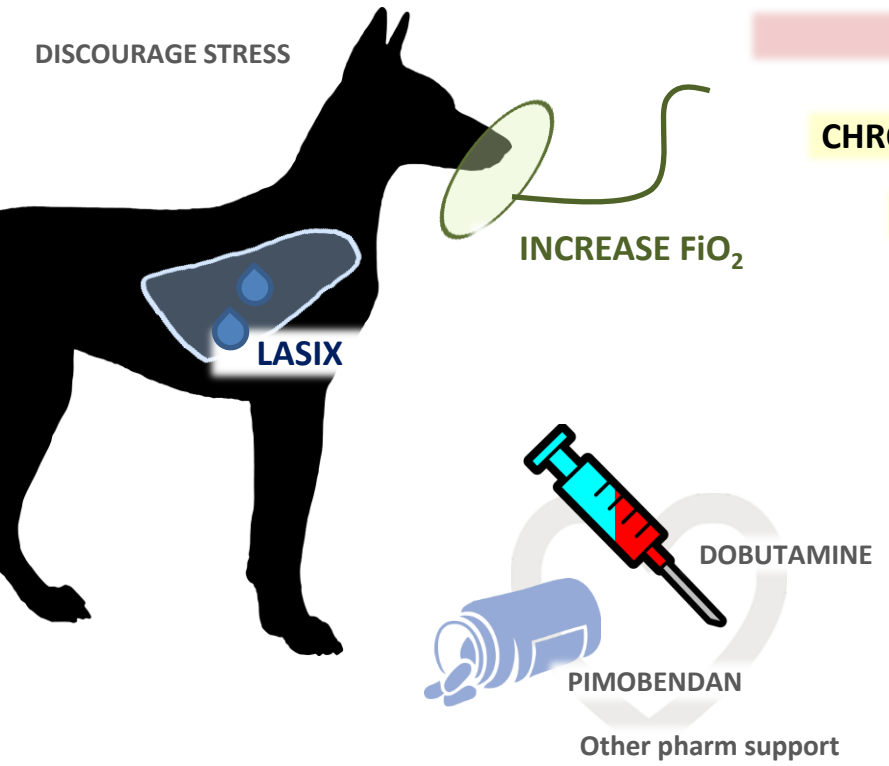
OXYGEN DELIVERY (DO_2)

NORMALLY $DO_2 > VO_2$

$VO_2 > DO_2$ = SHOCK

(CLASSIFICATION)

WHAT DID WE DO TO HELP HIM?



CARDIAC DILATION & PROGRESSIVE SYSTOLIC DYSFUNCTION

DECREASED FORWARD FLOW

CHRONIC RENIN ANGIOTENSIN ALDOSTERONE SYSTEM ACTIVATION

RETENTION OF SODIUM AND WATER

CONGESTIVE HEART FAILURE

DECREASED O2 DELIVERY TO THE TISSUES