Ventilation, Oxygenation, Acid Base Balance, ABGs

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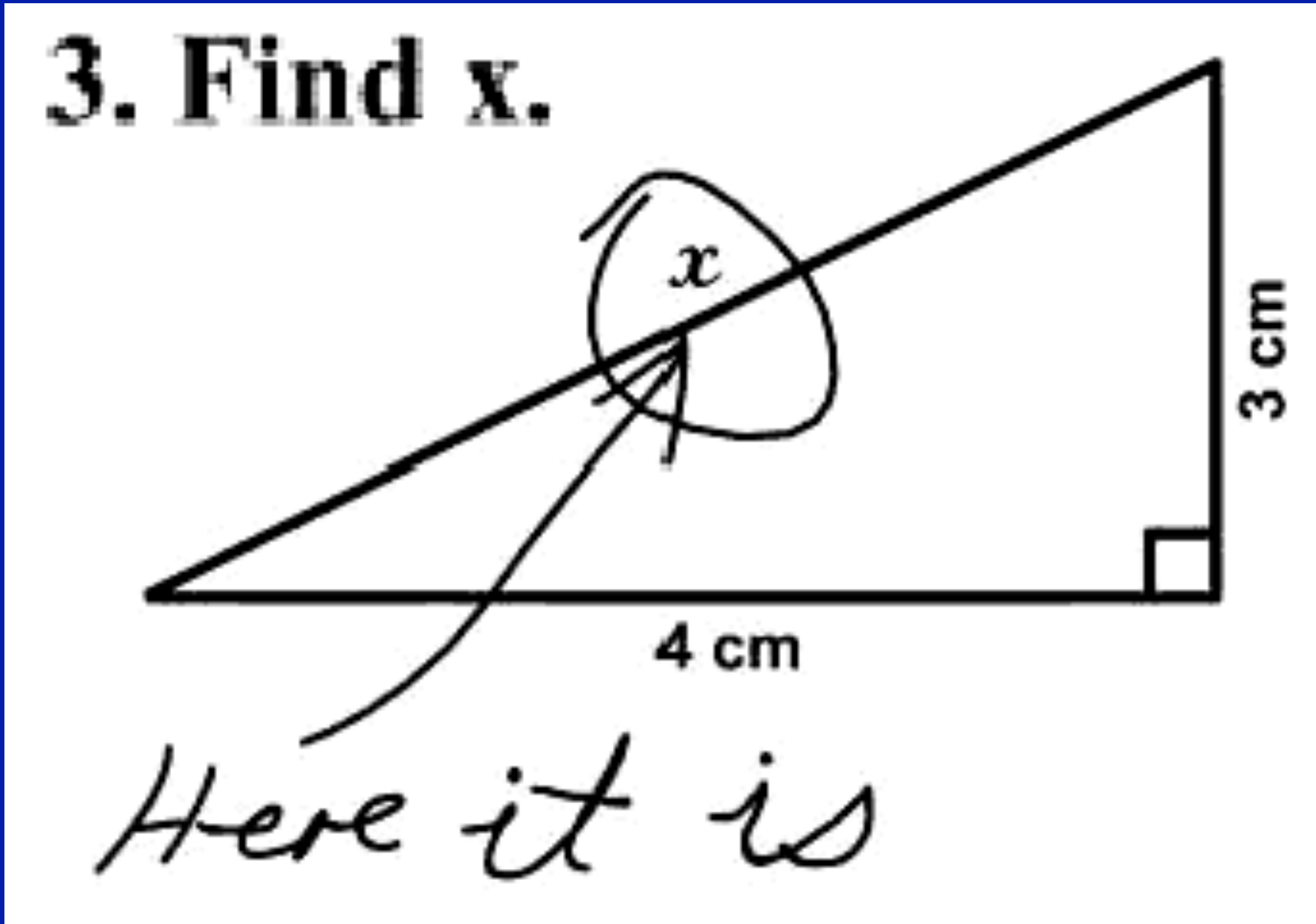
Ninewells


3. Find x.
x
3 cm
4 cm
Here it is

A proton approaches a long line of positive charge so that with it's initial trajectory it would intersect the line. The line has a uniform charge density of 5 nanoC/m. If the proton starts off with velocity 300 km/s a distance 1 km from the line charge, what is the distance of closest approach?

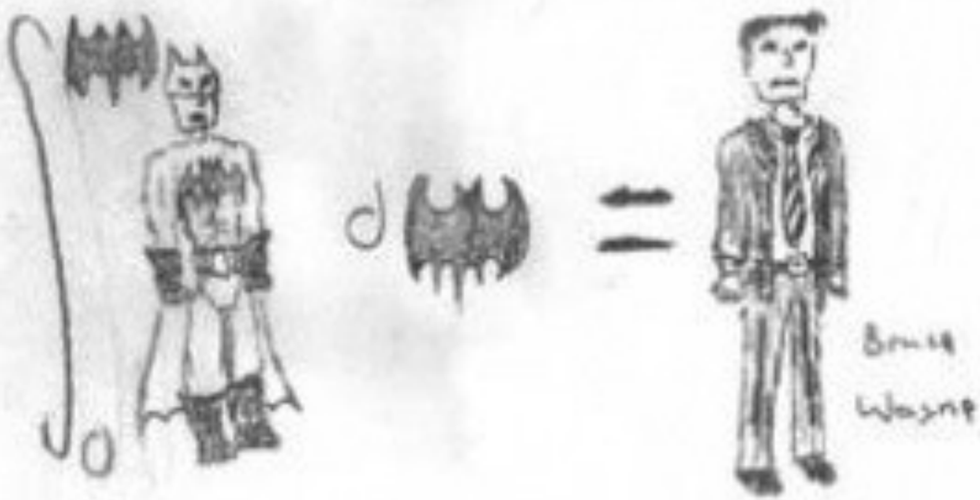
Mass of proton=1.67E-27 kg

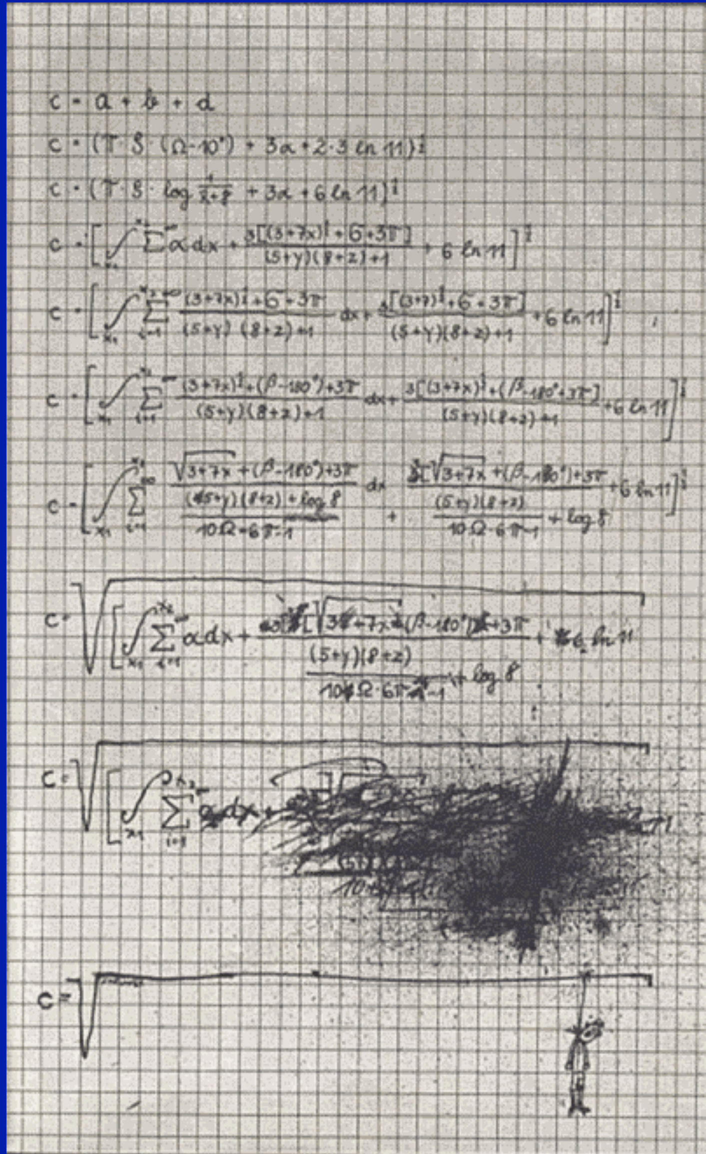
K=8.99E9 Nmm/CC

Hint: find the field and potential that affect the proton.

Problem

Use calculus to find the identity of Batman.




c = a + b + d
c = (π · S · (Ω - 10°) + 3α + 2 · 3 ln 11)^½

What do lungs do?

1. Oxygenate the blood
2. Remove CO_2

- Essentially that is it

Ventilation

- The act of breathing in an out
- Lungs are like bellows

What happens if these go wrong?

1. Failure of oxygenation
   - Hypoxaemic Respiratory Failure
   - Type I Respiratory Failure
2. Failure of Ventilation
   - Hypercapnic Respiratory Failure
   - Type II Respiratory Failure

Oxygen Delivery

- DO_2
- Oxygen delivered to the tissues

- $DO_2 = CaCO_2 \times CO$
- $CaCO_2 = (SaO_2 \times Hg \times k) + (PaO_2 \times 0.003)$
- $DO_2 = [(SaO_2 \times Hg \times k) + (PaO_2 \times c)] \times CO$

Hypoxia

- Lack of Oxygen in the tissues
- Various causes

Types of hypoxia

- Hypoxaemic
  - Low PaO_2
  - Low SaO_2
- Anaemic
  - Low Hb
- Circulatory
  - Low CO
- Histocytoxic
  - Normal DO_2 but poor uptake

Hypoxaemia

- $pO_2 < 8.0$
- Or
- Inappropriately low pO_2 for a given FiO_2
  - pO_2 should be ~ 10 kPa lower than the FiO_2
  - 40 % O_2 = 40 kPa thus pO_2 ~ 30 kPa

Causes of Hypoxemia

- Low FiO_2
  - Altitude
  - Incorrect gas mixtures
- Hypoventilation
  - Central respiratory suppression
    - Usually associated with Hypercapnia

Causes of Hypoxaemia

- V/Q Mismatch
  - Perfusing some areas
  - Ventilating others
- Deadspace
  - Ventilating Lung without perfusion
- Shunting
  - Perfusing Lung without ventilation

Deadspace

- Pulmonary Embolus
- Vasculitis
- Pulmonary Haemorrhage
- Emphysema
- Being ventilated via ETT and a Ventilator

Shunting

- Almost everything else
- Pneumonia
- Interstitial lung disease
- Pneumonitis
- Cardiac Shunt
- Asthma
- COPD

How to treat *Hypoxaemia*

- Supplemental O_2
- Treat the underlying pathology
- May need ventilating - ICU

A Word On Oxygen Delivery

- Air - 21 % O_2
- Fixed percentage O_2 masks
  - Work by Venturi effect
  - Fixed flow = fixed oxygen percentage
  - 24, 28, 35, 40, 60 %
- Hudson Mask
  - Variable Flow
  - Variable oxygen percentage
  - Max 15l ~ 60 %
- Non-rebreathing mask
  - Has resevoir bag
  - ~ 80 % FiO_2

Hypercapnic Respiratory Failure

- Hypercapnia - high levels of CO_2 in the blood
- Hypercarbia - high levels of CO_2 in the tissues
- They're the same, as CO_2 diffuses freely across tissue membranes

Hypercapnia

- Caused by ventilatory failure
- Usually due to
  - Weakness
  - Exhaustion
  - Hypoventilation

Acute Type II Respiratory Failure

- Usually have normal respiratory function in quiescence
- Something happens to cause hypoventilation
- Hypoventilation causes hypoxaemia initially, then hypercapnia

- Respiratory center
- Spinal cord
- Motor neurons
- Neuromuscular junction
- Respiratory muscles
- Work of breathing
- Lungs

Causes of Hypercapnic Respiratory Failure

- Respiratory Centre
- Spinal Cord
- Motor Neurons
- NMJ
- Respiratory Muscles
- Work of Breathing
- Lungs

- Opiate Overdose
- MS
- MND
- Myaesthenia Gravis
- Myopathy
- Exhaustion - Asthma
- COPD

Acute Type II Respiratory Failure

- Opiate overdose
  - Central respiratory suppression
  - Hypoventilation
  - Hypxaemia
  - Hypercabia
- Naloxone

Acute Type II Respiratory Failure

- Muscle Weakness
  - Guillain Barré syndrome
  - Respiratory muscle weakness
  - Hypoventilation
  - Hypoxaemia
  - Hypercapnia
- Support ventilation - IPPV / NIV

Consequences of Type II Respiratory Failure

- Increasing pCO_2
- Increasing $[H^+]$
- Decreasing pH

- Acidosis kills your patient

Respiratory Acidosis

- As pCO_2 increases H^+ is buffered by HCO_3
- HCO_3 increases and pH returns to normal
- **Chronic Respiratory Acidosis with Metabolic Compensation**

Chronic Type I Respiratory Failure

- All the same causes as acute
- We usually see this in COPD

- Always look at the ABG HCO_3^- or venous bicarbonate

The Drive to Breathe

- Conscious drive to breathe
- Stretch receptors
- Hypercapnic Drive
- Hypoxic Drive

Respiratory center

Spinal cord

Motor neurons

Neuromuscular junction

Respiratory muscles

Work of breathing

Lungs

The COPD Patient

- Poor respiratory muscle strength
- Easy fatigability
- Lungs don’t work properly

- Chronic hypoventilation
- Chronic hypercapnia

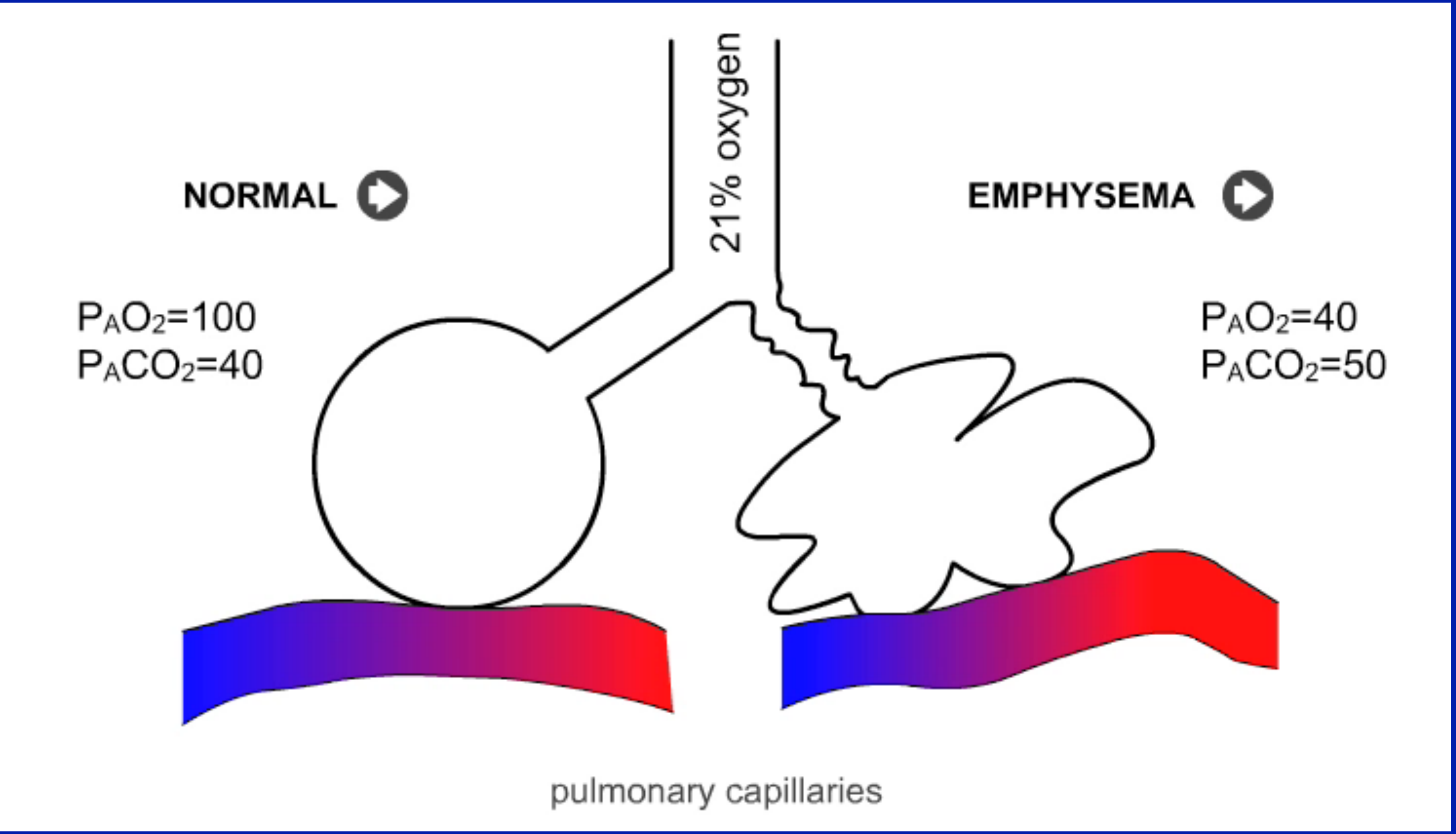
The COPD Patient

- Conscious drive to breathe - usually present
- Stretch receptors - damaged by emphysema
- Hypercapnic drive - lost due to elevated pCO_2
- Hypoxic drive - only remaining drive

V/Q Mismatching

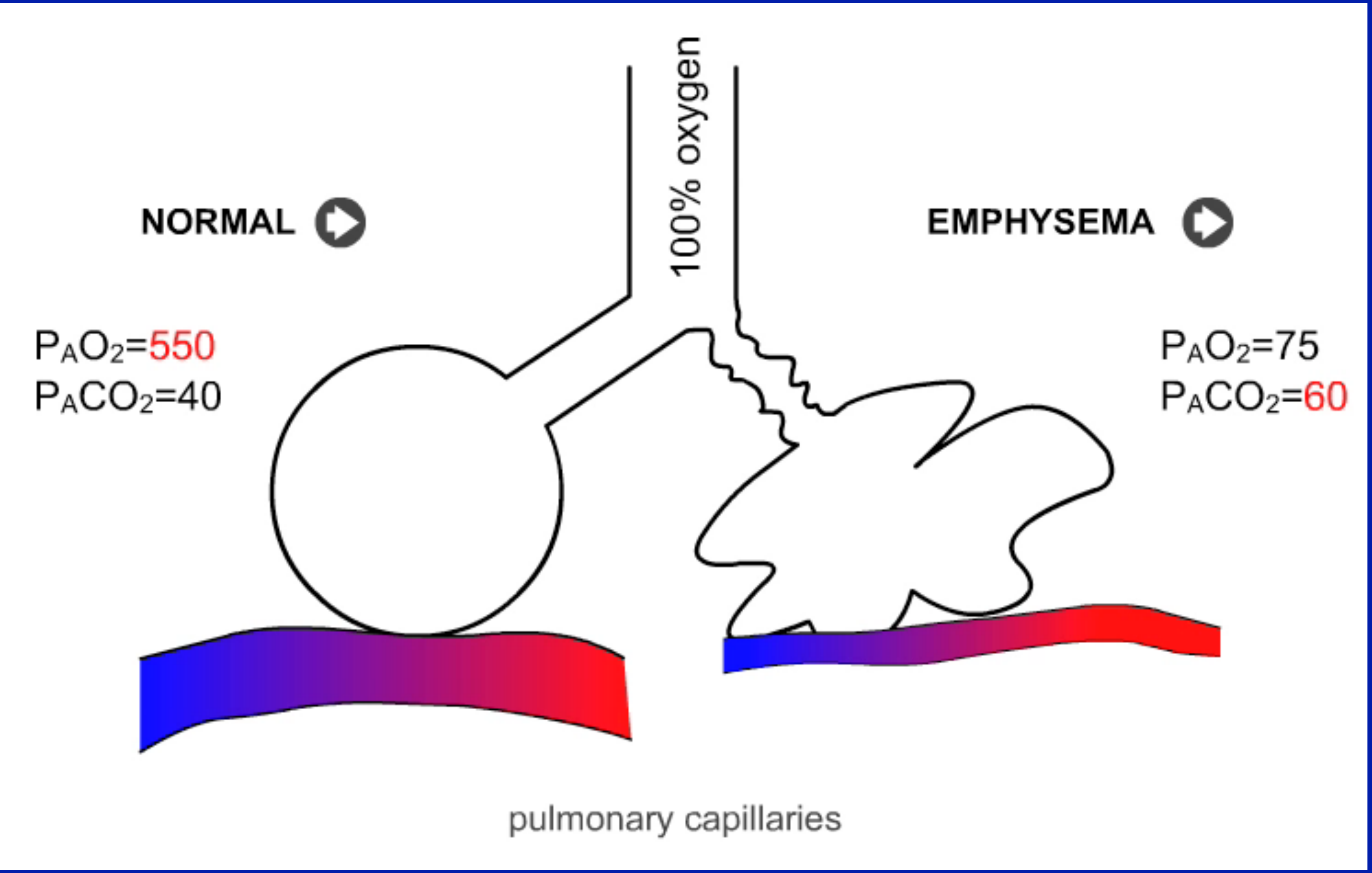
- Lack of Hypoxic Drive is not enough to explain CO2 retention
  - Most patients with COPD exacerbations are tachypnoiec, not brady.
- V/Q mismatch is a more likely explanation
- Hypoxic vasoconstriction prevents mismatch
- Excess Oxygen administration reverses hypoxic vasoconstriction

Normal life….



21% oxygen
NORMAL
EMPHYSEMA
PAO2=100
PACO2=40
PAO2=40
PACO2=50
pulmonary capillaries

If given 100 % oxygen….



Mrs Wheezy

- COPD for 20 years
- Can only walk 20 yds on the flat
- Comes in to 15 with acute exacerbation
- ABGS:
  - pO_2 = 16
  - pCO_2 = 11
  - HCO_3^- = 41
  - pH = 7.01
  - SaO_2 = 100 %

What are you going to do?

- Can you explain her ABGs?
- What do you think her conscious level is?
- How much FiO_2 is she on, do you think?
- Is this a common problem in ward 15?
- What's your first step?

Mr Oedema

- Has poor LV function on recent echo
- Ejection fraction of 12 %
- Very breathless overnight
- Seen in A&E
- Given treatment
- Sent to 15

Mr Oedema

- ABGs:
  - pO_2 = 16
  - pCO_2 = 11
  - HCO_3^- = 12
  - pH = 7.01
  - SaO_2 = 99 %

What are you going to do?

- Can you explain his ABGs?
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General Measures

- Relative hypoxaemia is safe, and will not harm your patient
- Controlled oxygen therapy is *always* the therapy of choice
- If patient *at risk* of Chronic Type 2 Failure, treat as though they do, and do ABG
- If patients *shown not* to have Chronic Type 2 Failure, aim for higher SaO_2

Prescribe $SaO_{2,}$ not FiO_2

- Life threatening illness
  - High flow O_2 until stable, then do ABG
- Chronic Type 2 Respiratory Failure
  - Proven, or high risk
  - 88 – 92 %
- Everything else
  - 94 – 98 %

What Kills Your Patient?

- Hypoxaemia?
- Hypercapnia?
- Hypercarbia?
- Onions?

- **Acidosis**
- **Lactic or Hypercarbic**

Acid Base Balance

- Complicated?
- Important
- Management Decisions
- Silent sickness

Student Sickness

- 20 year old man
- Ate hospital canteen food 4 days ago
- Non specifically unwell for 3 days
- Nausea
- Headache
- Vomiting for 1 day

Investigations

- U&E Upper Limit of Normal, dehydration
- LFTs Normal
- FBC Normal
- HR 120
- RR 40
- BP 120/60
- ECG Normal

Student Sickness

- Diagnosis: Gastroenteritis
- Conservative management
- Oral fluids
- Reassured
- Discharged
- Found dead 4 hours later

ABG

- Same man has an ABG checked
- pO_2 12.8
- pCO_2 1.2
- pH 6.98
- HCO_3^- 2.4
- Metabolic Acidosis
- Glucose 34

Silent Sickness

- DKA
- Given appropriate treatment
- Discharged on insulin 4 days later

Acid Base Balance

- There's an tricky way, and an easy way.
- I'll show you the easy way.
- First you need to accept some assumptions…
- Changes is CO_2 are respiratory
- Changes in HCO_3 are metabolic

Outcome Codes

Parameter	Change	Outcome Code	Change	Outcome Code
pH	High	Alkali	Low	Acid
pCO_2	High	Acid	Low	Alkali
HCO_3	High	Alkali	Low	Acid

Translation

- First thing is to translate the numbers into the outcome code
- From the outcome codes we can ascertain what is primary, what is secondary, what is compensation
- Trust me, it’s simple

An Example

Parameter	Result	Change	Outcome Code	Translation
pH	7.01	Low	Acid	Acidaemia
pCO_2	5.0	Normal	Normal	No Respiratory Component
HCO_3	8	Low	Acid	Primary Change

Another Example

Parameter	Result	Change	Outcome Code	Translation
pH	7.5	High	Alkali	Alkalaemia
pCO_2	5.0	Normal	Normal	No Respiratory Component
HCO_3	45	High	Alakali	Primary Change

And Another Example

Parameter	Result	Change	Outcome Code	Translation
pH	7.12	Low	Acid	Acidaemia
pCO_2	8.0	High	Acid	Primary Change
HCO_3	25	Normal	Normal	No metabolic component

It gets more tricky now

Parameter	Result	Change	Outcome Code	Translation
pH	7.12	Low	Acid	Acidaemia
pCO_2	12.0	High	Acid	Primary Change
HCO_3	35	High	Alkali	Compensatory Metabolic Change

How about now?

Parameter	Result	Change	Outcome Code	Translation
pH	7.35	Normal	Normal	Normal
pCO_2	8.0	High	Acid	Primary Change
HCO_3	35	High	Alkali	Metabolic Compensation

So…

- Now you can analyse any blood gas you see.
- Told you it was simple

Chronic vs Acute Respiratory Failure

Parameter	Type 1 Failure	Acute Type 2 Failure	Chronic Type 2 Failure	Acute on Chronic Type 2 Failure
pO_2	Low	Low	Low	Low
pCO_2	Normal	High	High	Very High
HCO_2	Normal	Normal	High	High

Jock has COPD

- Very wheezy all night
- Very short of breath this morning
- Found by his wife, drowsy
- Brought to A&E
- Given 80 % O_2 by SAS and A&E
- He’s getting worse

Results

- Here's some results:
- ABG:
  - $pO_2 = 10$
  - $pCO_2 = 9$
  - $HCO_3^- = 20$
  - $pH = 7.21$

What are you going to do?

- Explain the ABGs
- What's your first move?