CPL Theory
Human Factors (HUF)

CHUF 2 – Environmental Effects

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2. Amendment Record

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAA document management procedures.

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10	Fix spelling error of Valsalva	Robin Pickhaver Samantha Maguire	20/09/19

3. Disclaimer

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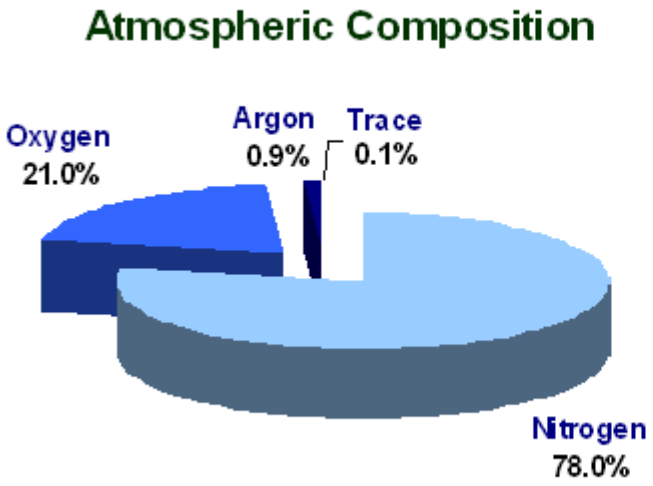
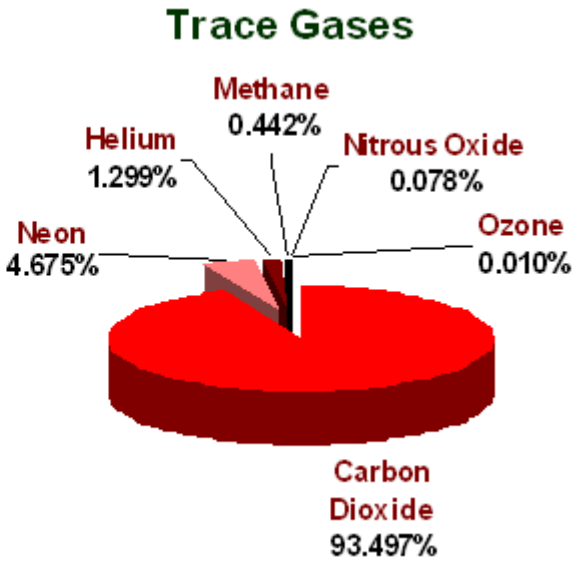
COMPOSITION OF THE ATMOSPHERE

Composition of the Atmosphere

- The atmosphere contains:
  1. **78% nitrogen**
  2. **21% oxygen**
  3. **1% other trace gases**





- Note: the **composition stays constant** as altitude increases – **oxygen percentage does NOT decrease!**

Composition of the Atmosphere

- Our bodies interact with these gases via the **cardiovascular system**

- The purpose of this system is to **oxygenate** and **pump blood** around the body

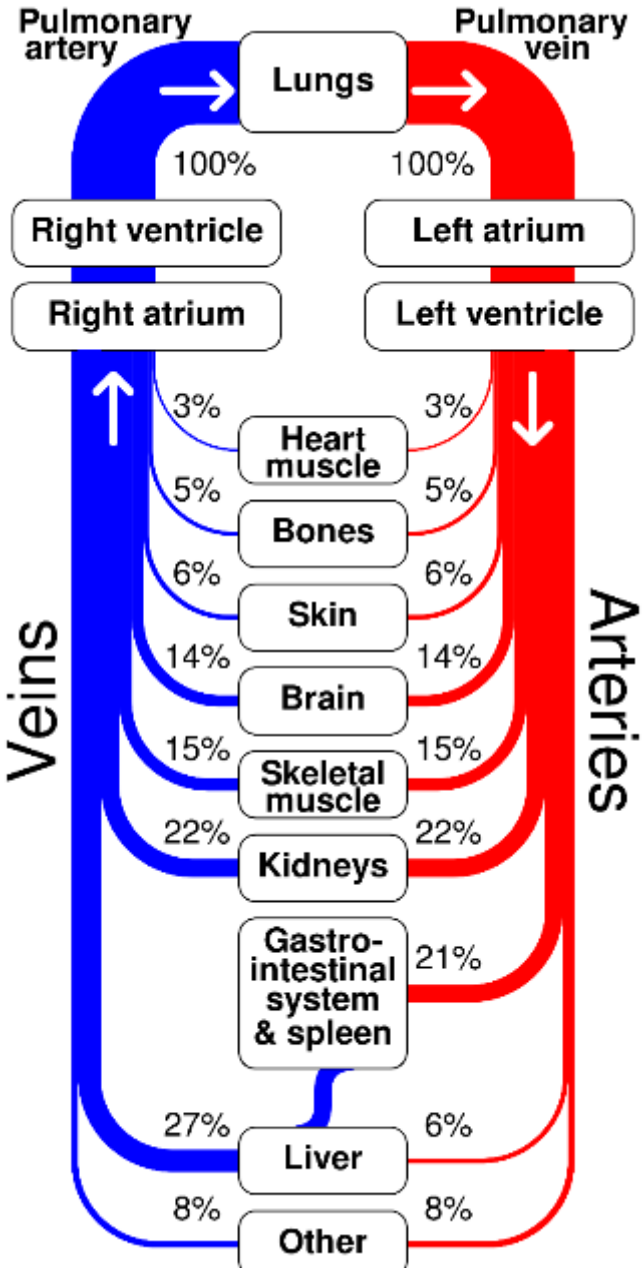
- The basic function is as follows:

1. The heart pumps **oxygenated** blood around the body through **arteries**

2. The **haemoglobin** inside **red blood cells** in the blood stream **carries oxygen** and supplies it to various organs

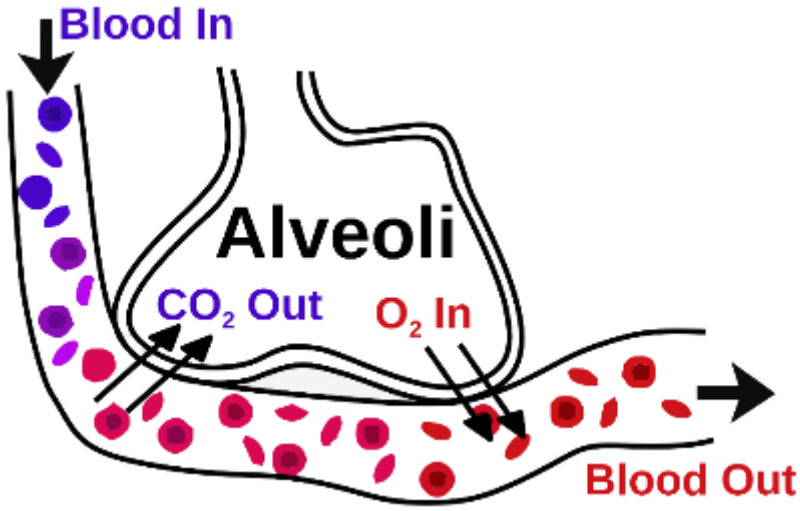
3. This **de-oxygenated** blood then flows back to the heart through **veins**

4. From the veins, the blood is sent to the lungs where it **releases carbon dioxide** and **collects oxygen**



Composition of the Atmosphere

- On the ground, the brain controls this by monitoring the level of **CO2 in the blood**
- If CO2 levels increase (due to physical exertion), the brain sends a command to increase the rate of breathing and we get “puffed”
- However, at altitude, CO2 levels do not increase – therefore the brain sends no command to alter the breathing rate
- Despite no change in breathing, a lack of oxygen occurs due to the **decreased partial pressure** of oxygen as altitude increases



- At sea-level, oxygen partial pressure is:

  21% of 1013 hPa = 213 hPa

- At 36,090ft, oxygen partial pressure is:

  21% of 226 hPa = 47 hPa

- The transfer of oxygen from the alveoli to the bloodstream requires **sufficient partial pressure** within the lungs

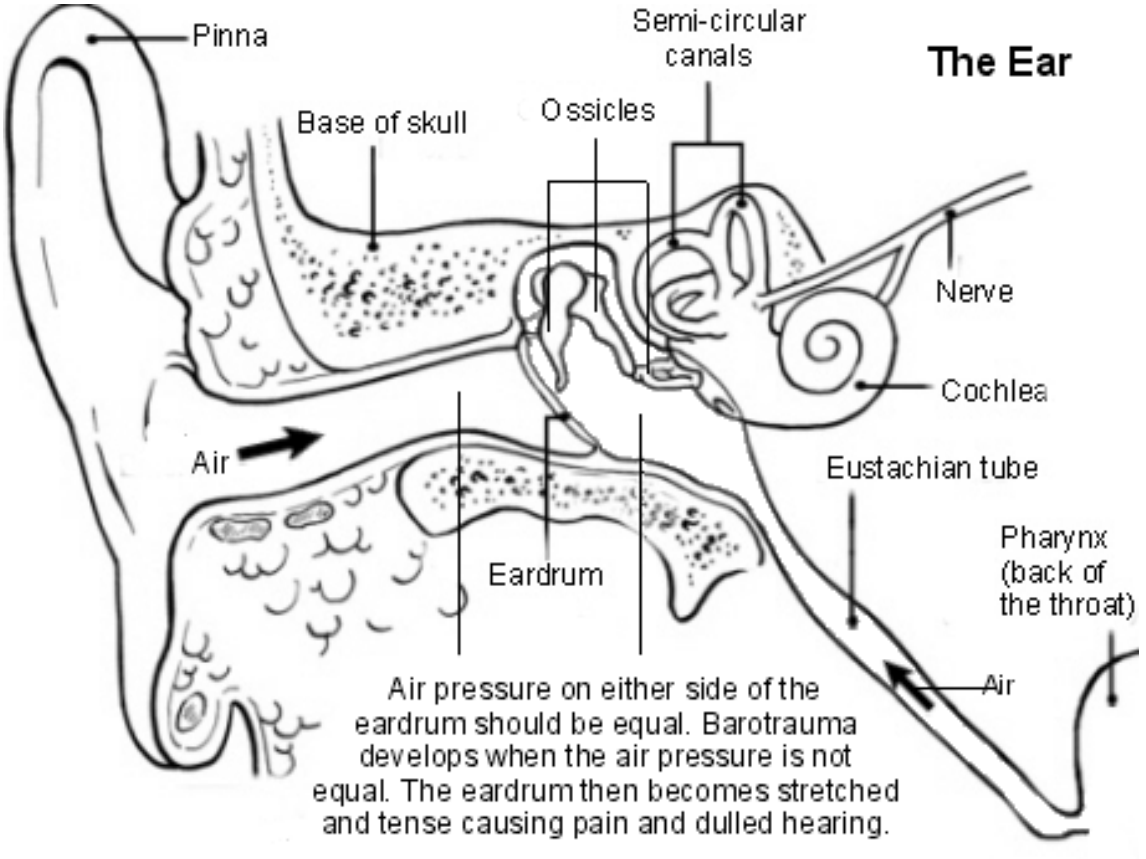
BAROTRAUMA

Barotrauma

- **As altitude increases** (in a climb) and pressure decreases, **the gases trapped in our bodies** – such as in the stomach, intestines, sinuses, middle ear or even a decaying tooth – **tend to expand**

- Under normal circumstances, they will escape into the atmosphere

- However, **if they become trapped** e.g. due to a blocked nose, they may cause pain, known as **barotrauma**



Barotrauma

- The main causes of pain during **descent** will be most likely due to:

  1. The ear and sinuses will naturally vent via the nostrils/ear cavity

  2. The stomach will naturally vent via the mouth (burping)

  3. The large bowel will naturally vent via the anus (farting)

- The main causes of pain during **ascent** will be most likely due to:

  1. An air pocket trapped in a tooth cavity

  2.Gases trapped in the small bowel

- Note that certain foods are more gaseous than others and may cause this effect

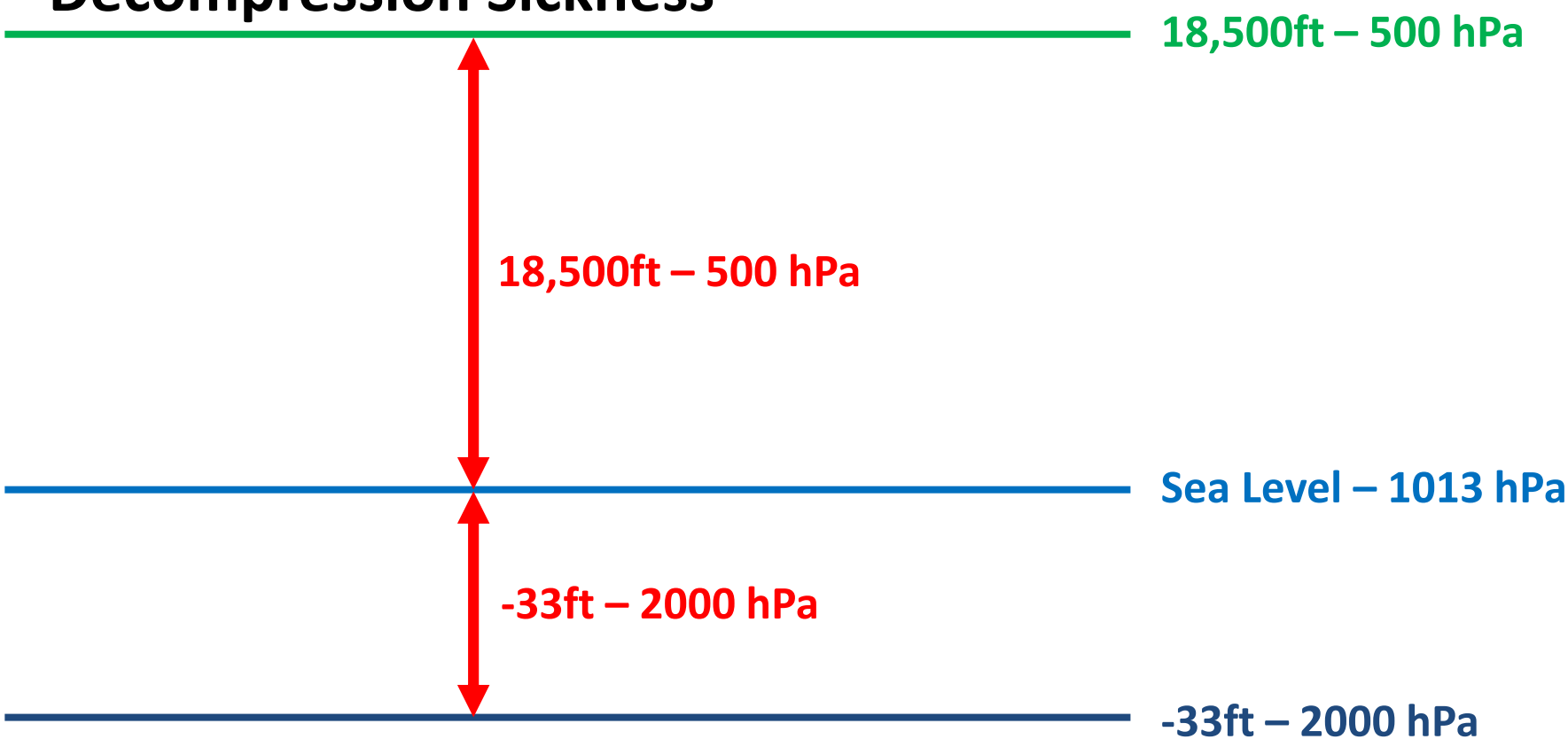
- In fact, **green vegetables/legumes** are most likely to cause gas!

Barotrauma

- Barotrauma due to a **head cold/ear infection is more likely during descent**
- Unlike the climb, natural venting is much more difficult during a descent and this means that pain would be caused by the greater pressure of the ambient air trying to force its way **back in to the sinus/ear**
- Pain can be relieved by holding the nose and blowing, which opens up the ear cavity to equalise the pressure
- This is known as the **Valsalva Manoeuvre**
- However, this should be avoided if you have an ear infection as **it may blow the infection further into the inner ear**

DECOMPRESSION SICKNESS

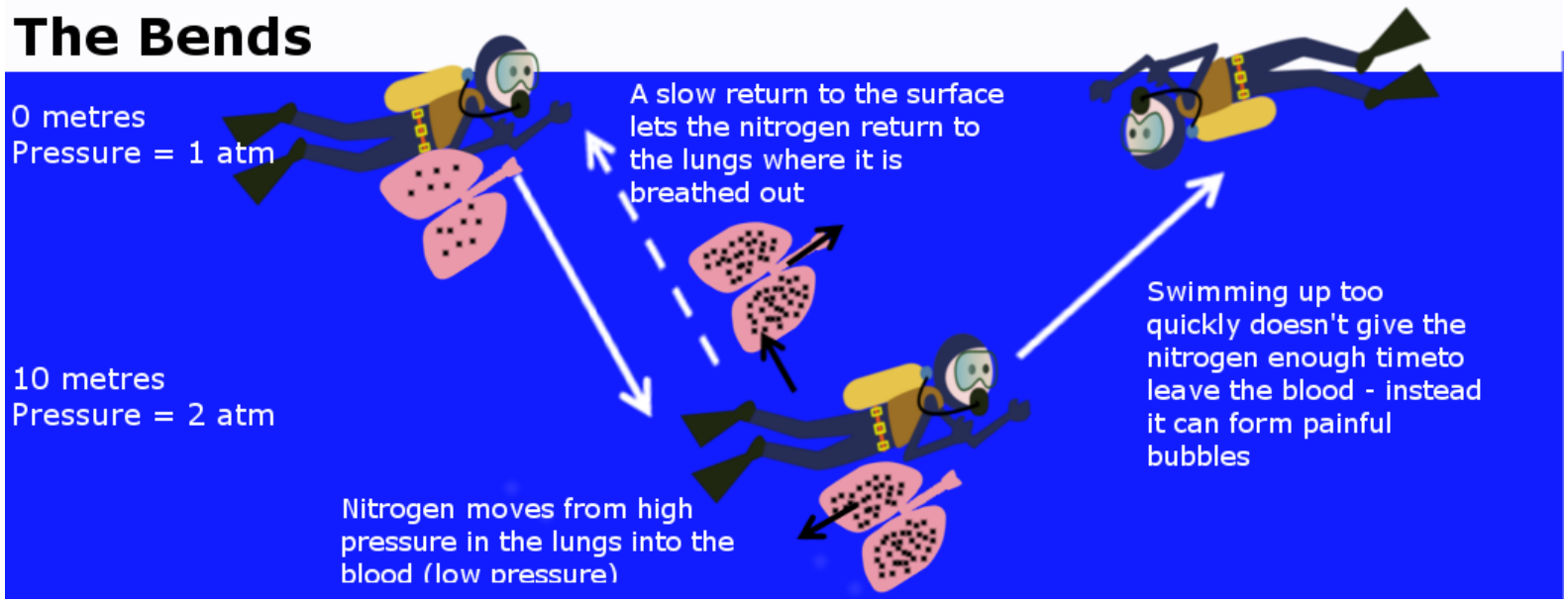
Decompression Sickness



- Whilst it is necessary to climb to **18,500ft to halve normal sea level pressure**, it can be doubled by descending to only **33ft (10m) in water**

Decompression Sickness

- Due to the increased pressure when descending during a sea dive, an increased amount of nitrogen from breathing air is absorbed into the blood



- A diver returning to the surface too quickly will suffer the **“bends”**

- This is the **excess nitrogen from the blood bubbling** out into the muscles and joints, causing extreme pain

- In extreme cases, death results from gas bubbles in the heart of the brain

SCUBA DIVING

SCUBA Diving

- To avoid decompression sickness, it is recommended that after a session of SCUBA diving, you should not fly for:

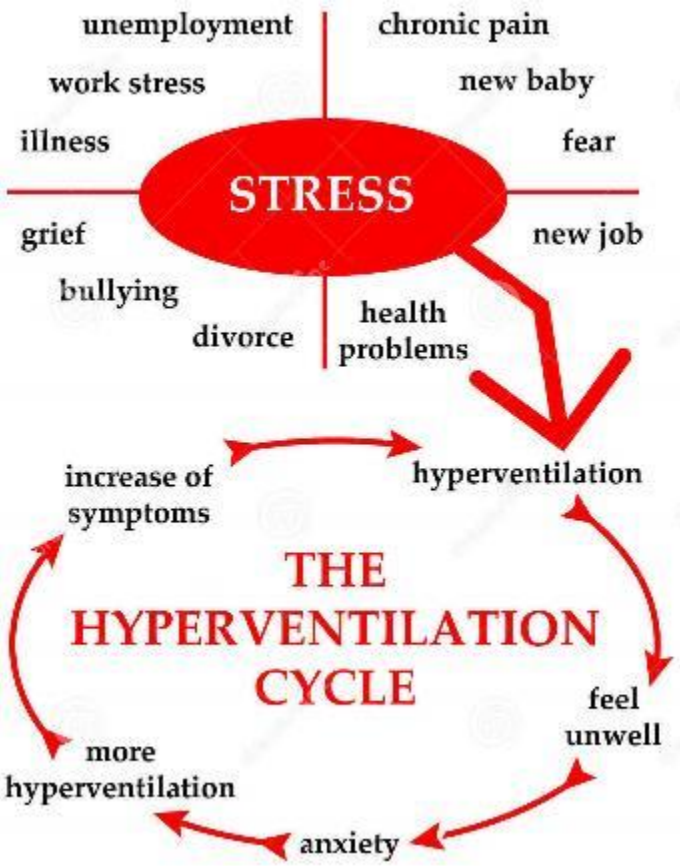
1. **4 hours after diving where no decompression stops were needed**
2. **12 hours after diving LESS than 4 hours duration with decompression stops**
3. **48 hours after diving MORE than 4 hours duration with decompression stops**

- Note: decompression stops are required for dives reaching a depth greater than 33ft (10m)

HYPERVENTILATION

Hyperventilation

- Hyperventilation is basically **over-breathing -** breaths are **heavier** and **more frequent**
- Since the amount of oxygen absorbed is dependant upon the **partial pressure**, **not the volume** of oxygen, this will not really increase oxygen levels
- However, it will **expel CO2** from the lungs
- A small amount of CO2 is actually required in the body and hyperventilation will **alter the body's acid balance**
- The symptoms include:
  1. **Light-headedness**
  2. **Tingling in face, hands and feet**
  3. **Dizziness**
  4. **Fall in blood pressure**
  5. **Loss of consciousness**



Hyperventilation

- The main cause is anxiety or excitement, but can also be brought on by airsickness, a hot environment or even body vibration in turbulence

- Some techniques to restore natural breathing are:

  1. Consciously slow the rate of your breathing

  2. Hold your breath

  3. Breathe into a paper bag

- This will increase Carbon Dioxide levels in the body to a normal amount

HYPOXIA

Hypoxia

- Hypoxia occurs when **insufficient oxygen** is available to the body for it to function
- At high altitude, this is due to **insufficient "partial pressure" of oxygen**

Hypoxia

- At 10,000ft, the blood is still about 90% saturated with oxygen and a normal healthy person will feel no hypoxic symptoms

- As height is increased beyond 10,000ft, the partial pressure of oxygen drops and this restricts the transfer of oxygen from the lungs into the bloodstream

- Usually, pilots and passengers will be provided with **supplemental oxygen** to counter this effect through means of **cabin pressurisation** or an **oxygen mask**

- Below are some useful facts to remember regarding supplemental oxygen:

    1. At **33,700ft** (without pressurisation), it is necessary to breathe **100% pure oxygen** to maintain a normal blood saturation level

    2. At **40,000ft** (without pressurisation), it is necessary to breathe **100% pure oxygen under pressure** to maintain a normal blood saturation level

- Please revise **CAO 20.4.7** – Carriage & Use of Supplemental Oxygen for **pilots, crew & passengers**

Hypoxia

- The symptoms of hypoxia are:

1. A feeling of warmth and wellbeing

2. Overconfidence and a false sense of security

3. Light-headedness

4. Giddiness

5. Hyperventilation

6. Blue discolouration of fingernails and lips

7. Deterioration in ability to write and coordinated movement

8. Failure of vision and hearing

9. Eventually a loss of consciousness

Hypoxia

- Hypoxia is insidious in its very as most of these symptoms are not noticed by the sufferer – in fact, he/she will strenuously deny that there is anything wrong, and might even laugh and sing

- Note that the only way to differentiate between hypoxia and hyperventilation is **cyanosis**

Hypoxia

- Hypoxia can occur at any altitude and is more likely at higher altitudes
- However, it can occur much earlier in a climb to altitude if:

  1. You are overweight

  2. You drink lots of alcohol

  3. You are tired or unfit

  4. You are cold

  5. You smoke

- For smokers, the CO from cigarette smoke displaces oxygen to the extent that you might already be at the equivalent of **8000ft** while still **on the ground (BT pp 67)**
- Degradation of **night vision** due to lack of oxygen begins at about **4000'**

Hypoxia

- If the signs of hypoxia are noticed, the best action is to:

1. Breathe normally

2. Use oxygen if available

3. Descend to a lower altitude

4. Land as soon as possible

Hypoxia – Time of Useful Consciousness

- Note that you only have a certain amount of time to carry out the previously mentioned actions

- **The Time of Useful Consciousness or Effective Performance Time (EPT)** refers to the time available for clear thinking and action before becoming increasingly hypoxic and unconscious

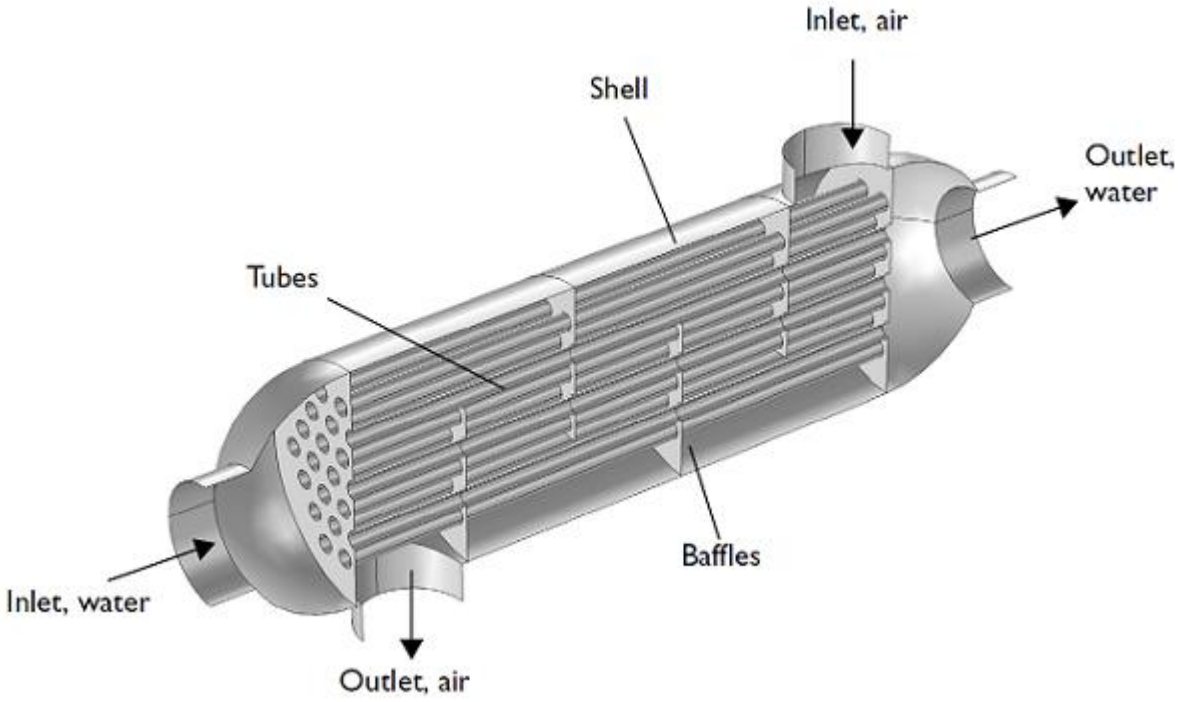
Altitude (ft)	Moderate Activity (pilot)	Minimal Activity (passenger sitting quietly)
20,000 ft	10 minutes	20 minutes
25,000 ft	3 minutes	5 minutes
30,000 ft	1 minutes	3 minutes
40,000 ft	12 seconds	15 seconds

- **Note that compared to sitting quietly, oxygen intake during an emergency can increase by a factor of 20!**

CARBON MONOXIDE POISONING

Carbon Monoxide Poisoning

- CO can cause a serious problem for pilots as it displaces oxygen in the bloodstream
- The most probably cause is a faulty cabin heater
- Cabin heaters often use a heat exchanger to transfer warmth from the exhaust system (containing CO) into the cockpit. If a leak is present, then exhaust fumes can enter the cockpit



Carbon Monoxide Poisoning

- The symptoms are:

1. **Feeling warm and sluggish**
2. **Headache**
3. **Weakness and nausea**
4. **Vomiting and loss of muscular power (in extreme cases)**
5. **Loss of consciousness and eventually death**

Carbon Monoxide Poisoning

- Smelling exhaust gases, feeling any of the above symptoms or noticing the CO Detector, you should:

  1. Shut off Cabin Heat or any other vent

  2. Open fresh air vents

  3. Use oxygen if available

  4. Land as soon as possible

- Altitude has a significant effect on CO Poisoning

- So does smoking, as there will already be some CO in the blood from tobacco smoke

ACCELERATION “G” EFFECTS

Acceleration "G" Effects

Positive G

- **Positive manoeuvres** involve the **backwards movement of the control column**
- When the aircraft pitches up, the pilot is pushed into the seat and feels **heavier**
- **Blood is forced towards the lower part of the body** and the extremities, resulting in reduced blood pressure and oxygen to the brain and eyes
- **Heart rate increases** to compensate
- This means a pilot may experience:
  1. **Grey Out**
  2. **Tunnel Vision**
  3. **Black Out**
  4. **G-LOC**

- Generally, vision is lost first and is a warning that incapacitation is imminent

- **Unconsciousness**
- **Brain death**

Acceleration "G" Effects

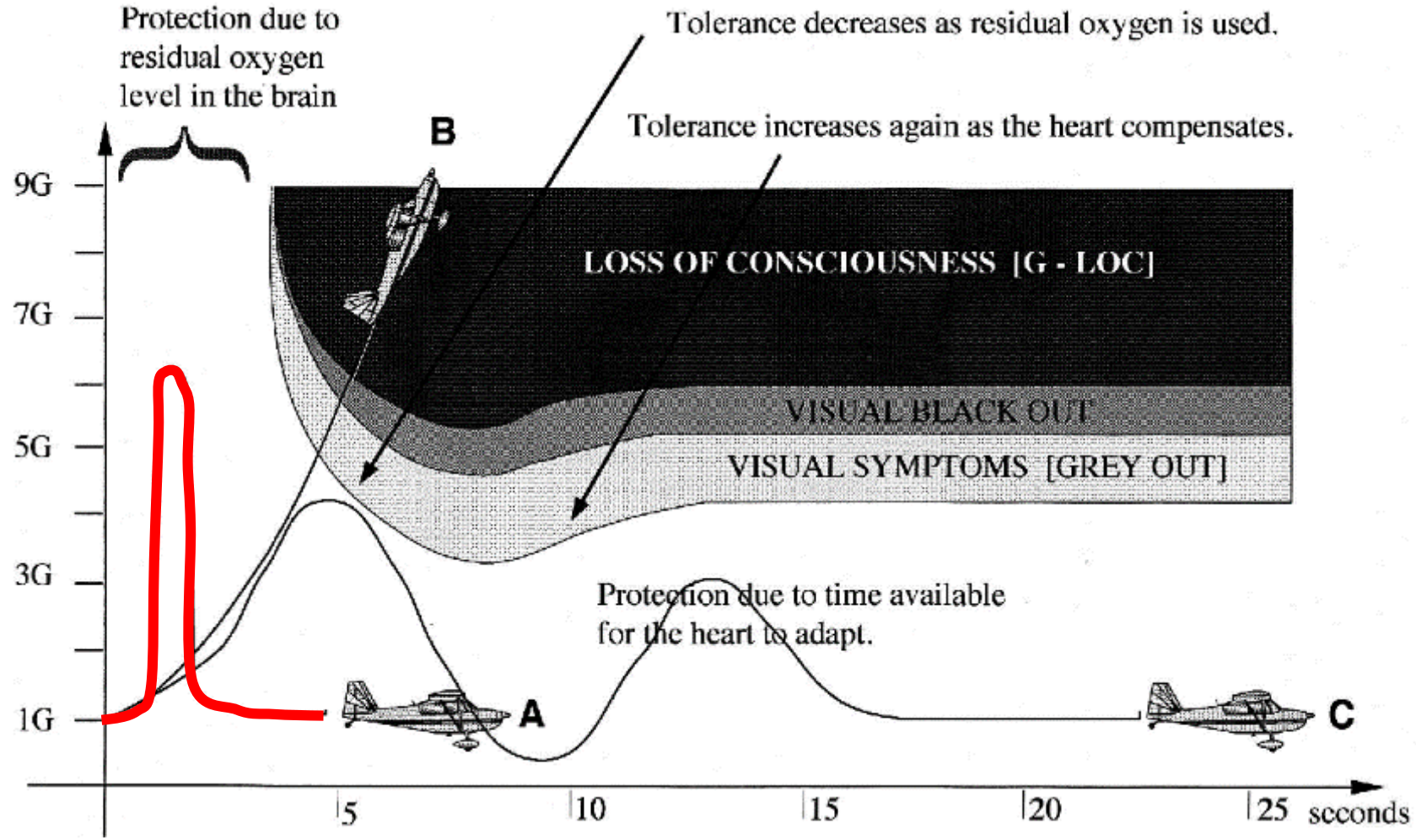
- Each pilot will have their own individual G tolerances
- Below are the average threshold values for Grey Out, Black Out and G-LOC

Symptom	Average Threshold	Deviation	Standard Range
Grey Out	4.1 G	± 0.7 G	2.2 to 7.1 G
Black Out	4.7 G	± 0.8 G	2.7 to 7.8 G
G-LOC	5.4 G	± 0.9 G	3.0 to 8.4

Acceleration "G" Effects

Positive G

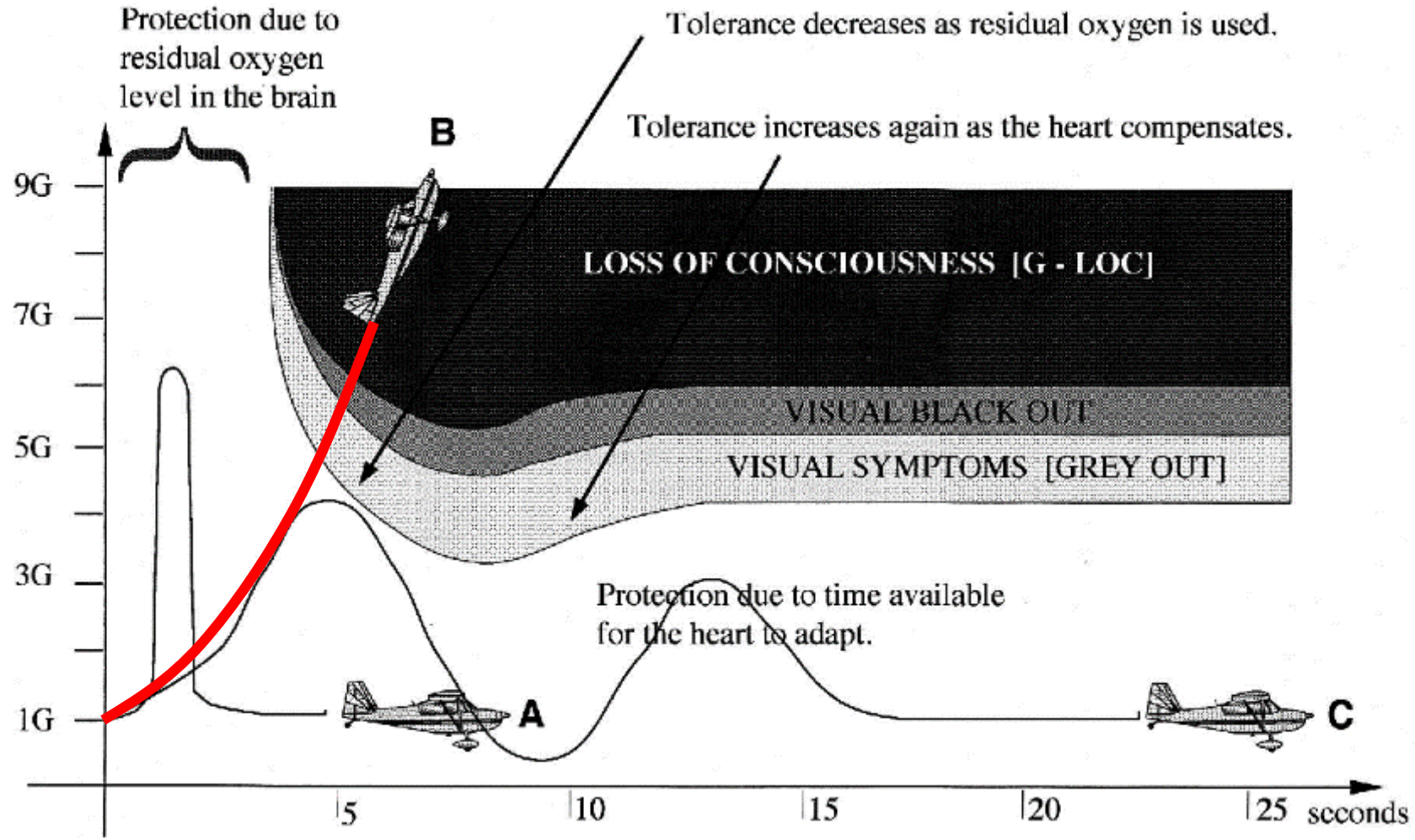
- **Aircraft A** pulls high G but for a short duration – the brain is able to cope due to residual oxygen present in the brain before the manoeuvre



Acceleration "G" Effects

Positive G

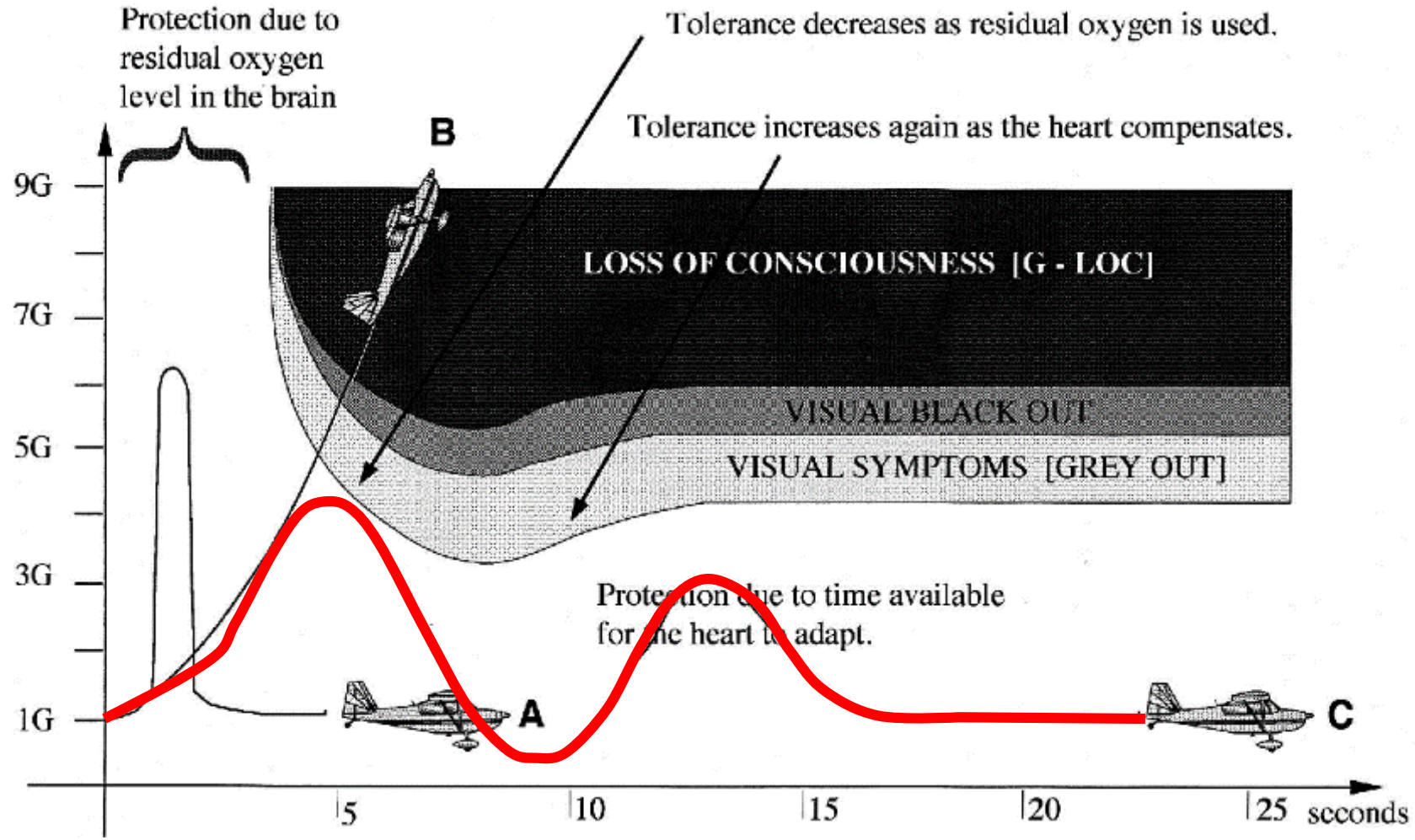
- **Aircraft B** pulls high G over a longer time – residual oxygen is used up and heart rate increases but eventually the body will not be able to cope



Acceleration "G" Effects

Positive G

- **Aircraft C** performs a loop, showing the G at each stage



Acceleration "G" Effects

Improving G-Tolerance

- Our bodies can be trained to withstand extreme G forces

- Factors proven to increase G-Tolerance include:

1. Physical fitness

2. Tensing the stomach muscles

- Reduces the blood flow towards your lower body

3. G-Belts/G-Suits

- Increases pressure on stomach muscles and leg muscles to prevent blood flow to lower body

4. A more reclined seating position

- Brings the heart and brain closer to same level – less effort required for hear to pump blood

Acceleration "G" Effects

Decreasing G-Tolerance

- The following factors may de-crease tolerance to G-loads:

1. **Hypoglycaemia (low blood sugar)**
2. **Heat stress**
3. **Hypoxia**
4. **Respiratory infections such as the common cold**

https://www.youtube.com/watch?v=Yjg6mRFzZzE

Acceleration "G" Effects

Negative G

- Negative manoeuvres involve the **forwards movement of the control column**
- When the aircraft pitches down, the pilot is lifted off the seat and feels **lighter**
- Blood and body organs are forced towards the head, possibly causing haemorrhaging of small blood vessels in the eyes, nosebleed and headache
- **Heart rate decreases** to compensate
- Sometimes, the lower eyelid can be forced up and over the eye, causing **"red out"**
- Humans can withstand fewer Negative G Forces than Positive G Forces **(-3G is the safe limit for a healthy person)**