PHYSIOLOGY TEAM444

Low & High Altitudes

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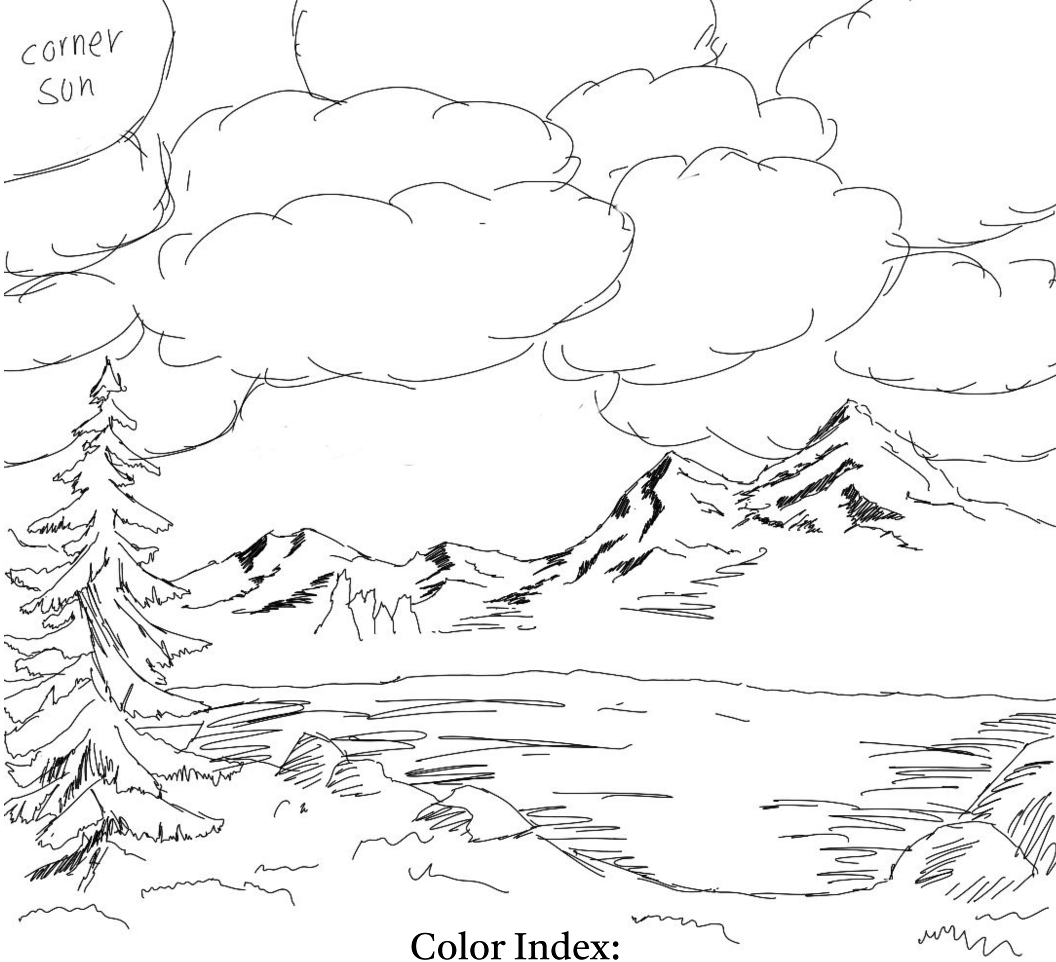


Color Index:
-Main Text -Important -Notes
-Boy Slides -Girl Slides -Extra

Special Thanks to Hasan Alsughayir for the Sketch <3

Male Dr: Syad Shahid Habib
Female Dr: Felwa Al-zaid

Objectives

01 Describe the effects of exposure to low and high barometric pressures on the body.

02 Describe the body acclimatization to low barometric pressure.

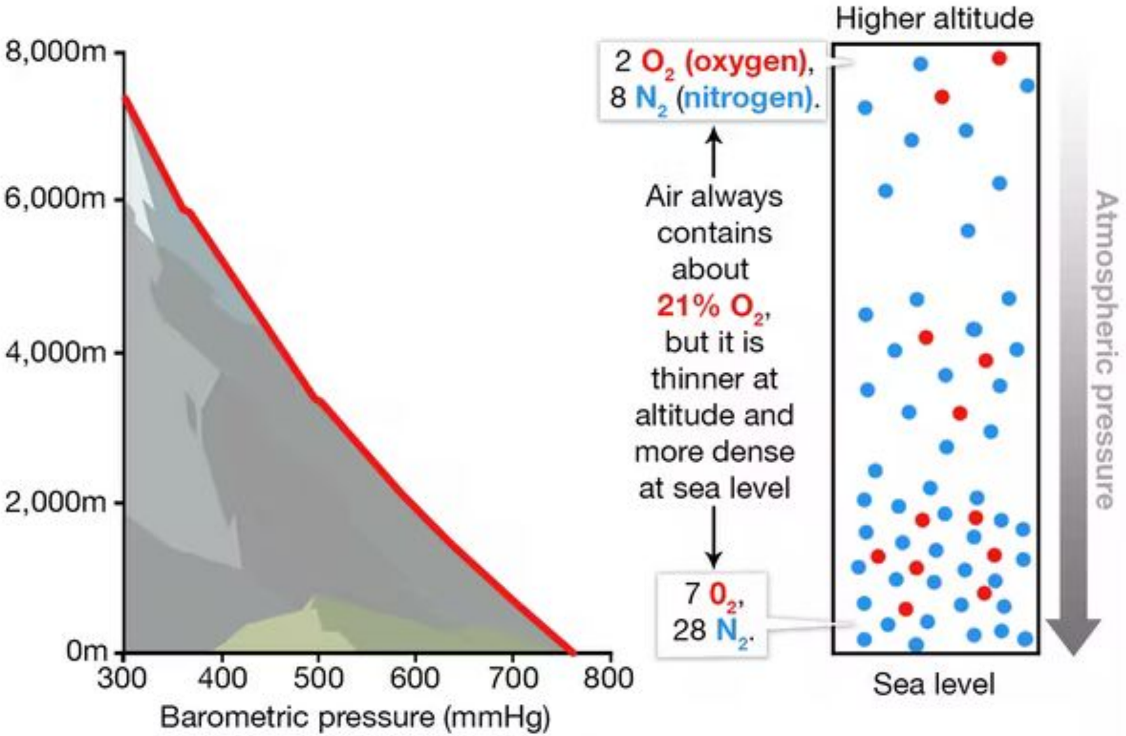
03 Define decompression sickness and explain how it can be avoided.

04 Understand the effects of high nitrogen pressure, and nitrogen narcosis.

05 Describe the manifestations of acute and chronic mountain sickness.

(Female Dr.: Cross this objective out from your slides)

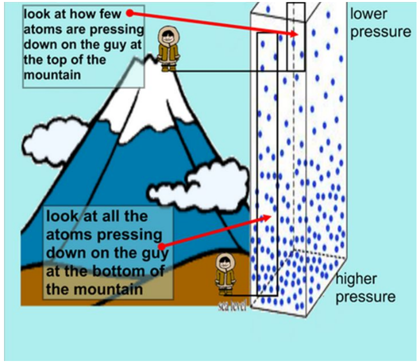
The impact of altitude on oxygen level

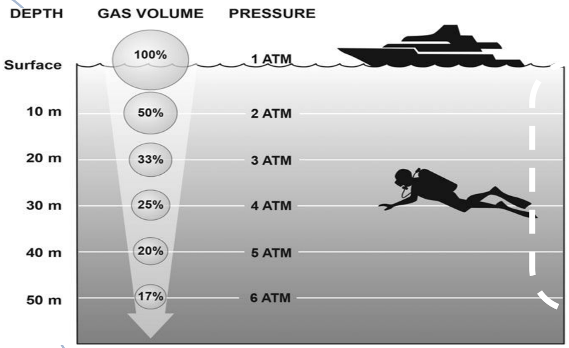


The set point is the sea level, so it's our reference (1 ATM/760 mm Hg)

EFFECT OF INCREASED BAROMETRIC PRESSURE (DEEP SEA DIVING)

- When human descends below the sea, the pressure around them is increased.
- To prevent the lungs from collapse, air must be supplied also under high pressure.
- This exposes the blood in the lungs to extremely high alveolar gas pressure **(hyperbarism).**
- Under certain limits these high pressures cause tremendous alterations in the physiology of the body.





- The surrounding pressure increases by 1 atmosphere for every 10 meter (33 feet) of depth in sea water. So the diver is exposed to 2 atmospheric pressures,Therefore at a depth of 31 meter (100 feet) in the ocean the diver is exposed to a pressure of 4 atmospheres.
- These problems confront SCUBA.

SCUBA Apparatus

Female Slides Only

(Female Dr.: Not for exam only for you to know)

- The scuba, or self- contained underwater breathing apparatus, used by recreational, scientific, commercial, and military divers.
- It permits divers to move independently under water.

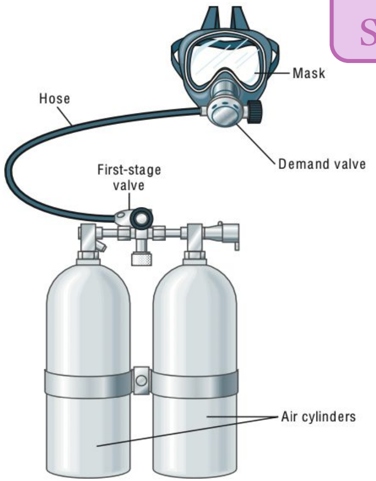


Figure 45-4. Open-circuit demand type of SCUBA.

This system consists of the following components:

1. One or more tanks of compressed air.
2. A first-stage "reducing" valve for reducing the very high pressure from the tanks to a low pressure level.
3. A combination inhalation "demand" valve and exhalation valve.
4. A mask and tube system with small "dead space."

EFFECT OF INCREASED BAROMETRIC PRESSURE (DEEP SEA DIVING) Cont.

Important Slide

1 Effect of depth on the volume of the gases:

- At depth there is compression of gases to smaller and smaller volumes. I.e 1L (sea level)→1/2 L at 33 feet and so on.

2 Effect of depth on density of gases:

- There is an increase in the density of gas and hence increased work of breathing.

3 Nitrogen effect at high nitrogen pressure:

- **Nitrogen will have 2 principle effects:**

Nitrogen narcosis (Anesthetic effect)

Decompression sickness

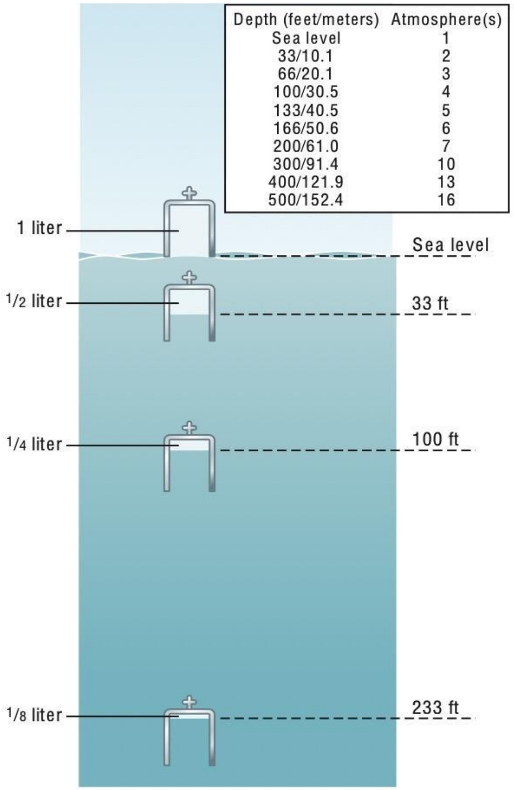


Figure 45-1. Effect of sea depth on pressure (*top*) and on gas volume (*bottom*).

EFFECT OF HIGH PARTIAL PRESSURES OF INDIVIDUAL GASES ON THE BODY

Male Slides Only

N_2 NARCOSIS AT HIGH NITROGEN PRESSURES

- Like Alcohol intoxication.
- N_2 dissolves & reduces neuronal excitability.

O_2 TOXICITY AT HIGH PRESSURES

- Effect of High Po2 on Blood Oxygen Transport…↑in dissolved form.
- Effect of High Alveolar Po2 on Tissue Po2.
- Acute Oxygen Poisoning
breathing O_2 at 4 atm PO2 (Po2 =3040 mmHg) will cause brain seizures followed by a coma in 30 to 60 minutes.
- Chronic Oxygen Poisoning Causes Pulmonary Disability…congestion, pulmonary edema, and atelectasis.

CO_2 TOXICITY AT GREAT DEPTHS IN THE SEA

CO_2 can build up in the dead space air of the apparatus and be rebreathed by the diver. Up to an alveolar CO_2 pressure (Pco2) of about 80 mm Hg, which is twice that of a normal alveoli, the diver usually tolerates.

[Dr. Andrew Huberman interesting video on how CO2 levels kills free divers.]

Oxygen toxicity when breathing hyperbaric air (Effect of Very High PO2 on Blood Oxygen Transport)

Important Slide

- When the PO2 in the blood rises above 100 mmHg, the amount of oxygen dissolved in the water of the blood increases markedly.

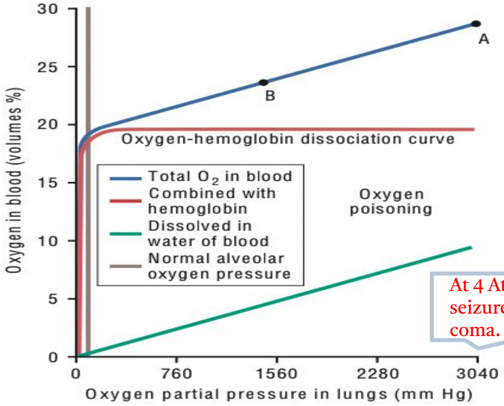
- **Acute Oxygen Poisoning :**
  The extremely high tissue PO2 that occurs when oxygen is breathed at very high alveolar oxygen pressure can be detrimental to many of the body's tissues.

- At **4** atmospheres pressure of oxygen (PO2 = 3040 mm Hg) will cause **brain seizures followed by coma** in most people within 30 to 60 minutes.

- Other symptoms include nausea, muscle twitching, dizziness, disturbances of vision, irritability, and disorientation.

- Molecular oxygen (O2) has little capability of oxidizing other chemical compounds. Instead, it will first be converted into an "active" form of oxygen called: oxygen free radicals, For example: superoxide and hydrogen peroxide.

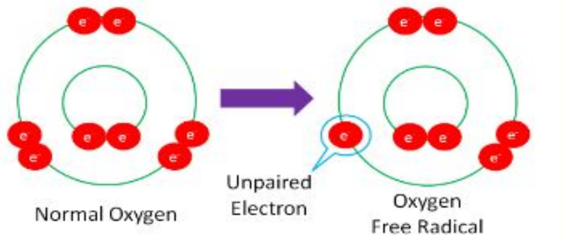
- At high levels, these oxygen free radicals can have serious destructive and even lethal effects on the cells.



At 4 Atm there's seizure leading to coma.

Figure 45-2. Quantity of O_2 dissolved in the fluid of the blood and in combination with hemoglobin at very high Po_2 values.

In the normal range of alveolar PO2 (<120mm Hg), almost of the total O2 in the blood is accounted for by dissolved O2.



NITROGEN NARCOSIS

1 Nitrogen, like most other anesthetic gases, dissolves freely in the fats of the body including the membranes and other lipid structures of the neurons (after one hour).

2 This leads to alteration of the electrical conductance of the membranes, reduces their excitability and subsequent narcosis develops.

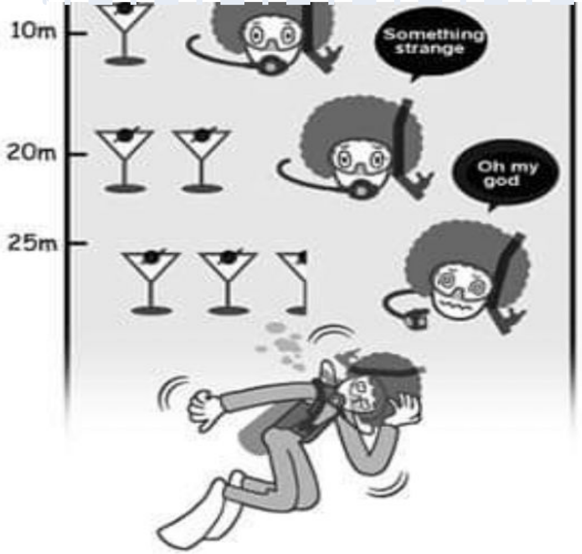
At 120 feet: the diver loses orientation and many of his care.

At 150 feet: there is a feeling of euphoria and drowsiness and impaired performance.

At higher pressure: loss of coordination and finally, coma might develop.

Feet	Liters
0	1
33	2
100	4
200	7
300	10

Nitrogen dissolved in the body at different depths.

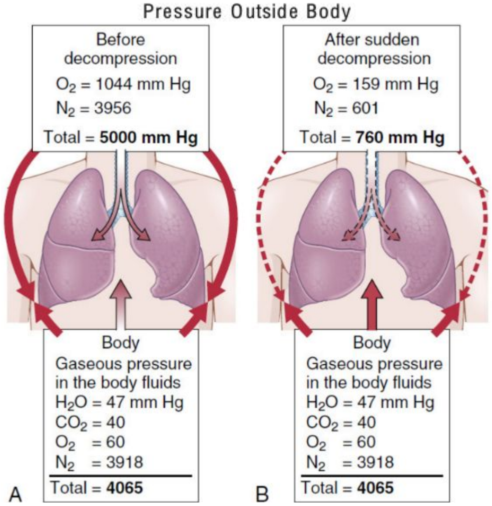


Decompression Sickness (Bends, Compressed Air Sickness, Caisson Disease, Diver's Paralysis, Dysbarism).

It is a syndrome caused by a decrease in the ambient pressure which occur in animal and human when the tissues of the body contain an excess of physically inert gas.

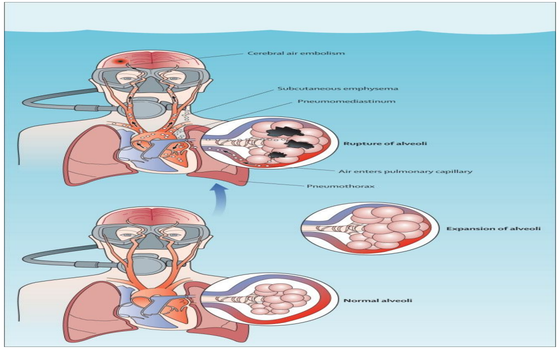
During descent, the high partial pressure of nitrogen (encountered when breathing compressed air at depth) forces this gas into solution in body tissue particularly in fat (it has a high N2 solubility).

On ascending, this inert gas comes out of physical solution forming a **gaseous phase (bubbles)**, leading to symptoms and signs.



During **slow** ascent:
N2 is **slowly** removed from the tissue since the partial pressure is higher than that in the arterial blood and alveolar gas.

If decompression is rapid:
Bubbles of gaseous nitrogen are released, in tissues and blood, causing the symptoms of decompression sickness (the bends or caisson disease).



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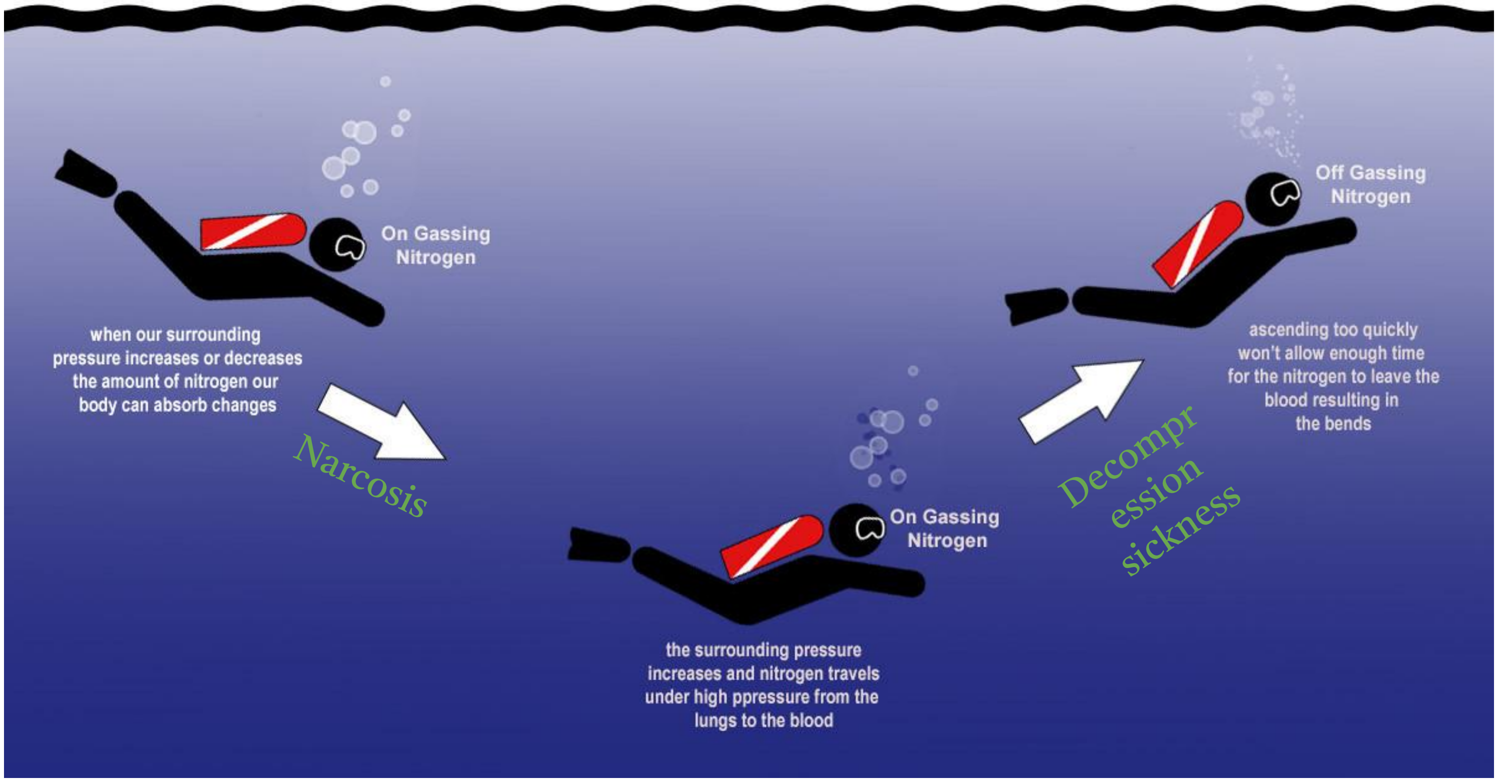
Decompression sickness



Symptoms and signs of decompression sickness (DS)

1 **The mildest form of DS** is fatigue or drowsiness after decompression.

2 **Locally** there is skin itch

3 Other severe symptoms may occur e.g.:
Bubbles in the tissues cause severe pains particularly around the joints.

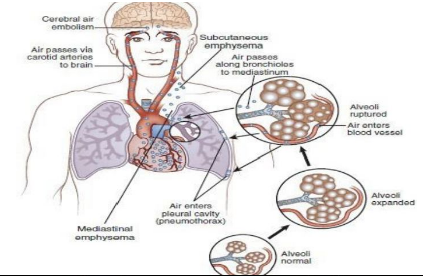
4 **Neurological symptoms** include paresthesia, itching, paralysis, and inner ear disturbances.

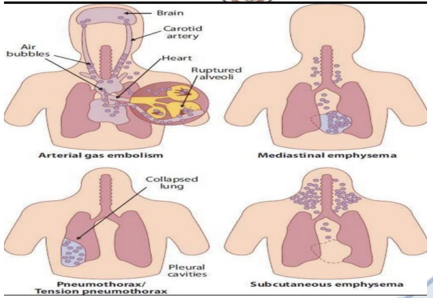
4 **Thoracic pains:** dyspnea, substernal pain, cyanosis, and cough.

5 **Bubbles in the coronary arteries** may cause myocardial damage.

6 **Decompression sickness shock**, capillaries become permeable to plasma and hypovolemia rapidly develops.

7 **Edema may be prominent and shock** is also usually complicated by pulmonary edema.





Treatment of decompression symptoms (DS)

- Rapid recompression in a pressure chamber followed by slower decompression.

- This reduces the volume of the bubbles and forces them back into solution.

- In a very deep dives, the risk of decompression sickness can be reduced if a helium-O2 mixture is breathed during the dive.

- Also it is important to reduce the oxygen concentration in the gaseous mixture to avoid oxygen toxicity that would cause seizures .

Treatment of decompression sickness DS Cont.

Helium is more desirable than nitrogen in deep dives because it has :

Summary:
- **less** narcotic
- **less** soluble
- **less** density
- **less** molecular weight

1. 1/4 - 1/5 the narcotic effect of nitrogen on CNS.
2. 1/7 the molecular weight of nitrogen.
3. Low density leading to decreased airway resistance of diver.
4. Helium is about 1/2 as soluble as nitrogen in body fluids. This reduces the quantity of bubbles that can form in tissues when the diver is decompressed after diving.
5. Diffuses out of the tissues during decompression several times as rapidly as does nitrogen, thus reducing the problem of decompression sickness.

Male Slides Only

* If you don't want to memorize the table (i don't think you can) at least understand the extra notes in the bottom. *

Effect of low oxygen pressure on the body

(Aviation-ascend to high altitude)

			Breathing Air			Breathing Pure Oxygen		
Altitude (ft/m)	Barometric Pressure (mm Hg)	P_{O_2} in Air (mm Hg)	P_{CO_2} in Alveoli (mm Hg)	P_{O_2} in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)	P_{CO_2} in Alveoli (mm Hg)	P_{O_2} in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)
0	760	159	40 (40)	104 (104)	97 (97)	40	673	100
10,000/3048	523	110	36 (23)	67 (77)	90 (92)	40	436	100
20,000/6096	349	73	24 (10)	40 (53)	73 (85)	40	262	100
30,000/9144	226	47	24 (7)	18 (30)	24 (38)	40	139	99
40,000/12,192	141	29				36	58	84
50,000/15,240	87	18				24	16	15

Doctor focused on this column

Effects of Acute Exposure to low atmospheric pressures on Alveolar gas concentration and arterial oxygen saturation.

How does high altitude cause hypoxia? -> it decreases Patm -> decreases inspired/alveolar/arterial PO2 -> hypoxia

What does Higher altitudes do to PaCO2?-> it decreases it(respiratory alkalosis) why? Because low oxygen stimulates peripheral chemoreceptors -> hyperventilation -> low PaCO2

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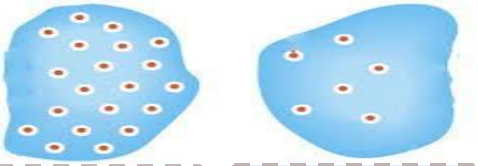
Effect of low oxygen pressure on the body

(Aviation-ascend to high altitude)



Oxygen in air at sea level

Oxygen in air at altitude

At the sea level the barometric pressure is 760 mmHg.

At 10,000 feet above sea level it is 523 mmHg

At 50,000 feet 87 mmHg.

This decrease in barometric pressure is the basic cause of all the hypoxia problems in high altitude in physiology.

Alveolar PO2 at different altitudes

1. As the barometric pressure decreases, the oxygen partial pressure decreases proportionally, remaining less than 21 % of the total barometric pressure.
2. Even at high altitude CO2 is continuously excreted from the pulmonary blood into the alveoli. Also, water vaporizes into the inspired air from the respiratory surfaces
3. Therefore, these two gases dilute the oxygen in the alveoli, thus reducing the oxygen concentration and therefore hypoxia develops.

Location	PO2
Sea level	159 mmHg
20000 Feet	40 mmHg
50000 Feet	18 mmHg

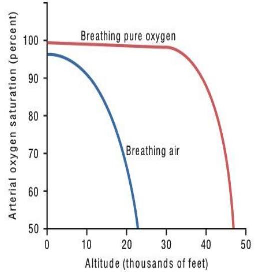


Figure 44-1. Effect of high altitude on arterial oxygen saturation when breathing air and when breathing pure oxygen.

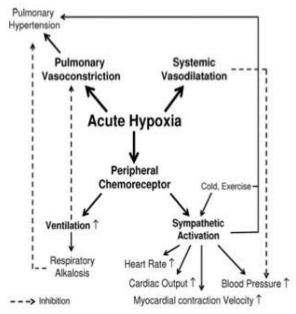
Effects of Acute Hypoxia

Important Slide

At 12.000 feet (3700m)	Above 18,000 feet (5500m)	Above 23,000/20,000 feet (6100m)
• Drowsiness. • Lassitude. • Mental and muscle fatigue. • Sometimes headache. • Occasionally nausea. • Sometimes euphoria (happiness).	All the effects at 12,000 and 1- Twitching 2-Or **convulsions** Convulsion = تشنج 	Coma (for un-acclimatized person)

- Acute cerebral edema. This edema is believed to result from local vasodilation of the cerebral blood vessels, which is caused by the hypoxia
- Acute pulmonary edema. The cause of acute pulmonary edema is still uncertain.
- Hypoxic hypoxia (inspiratory hypoxia) stimulates an increase in cerebral blood flow (CBF) maintaining oxygen delivery to the brain.

بالعربي: لان المخ مافيه أكسجين (بسبب الارتفاع) الجسم كردة فعل بيزيد كمية الدم الي توصل للمخ عشان يعوض نقص الاكسجين، واذا زاد الدم(الي يعتبر سائل اصلا) بشكل كبير ايش بيسوي؟ edema

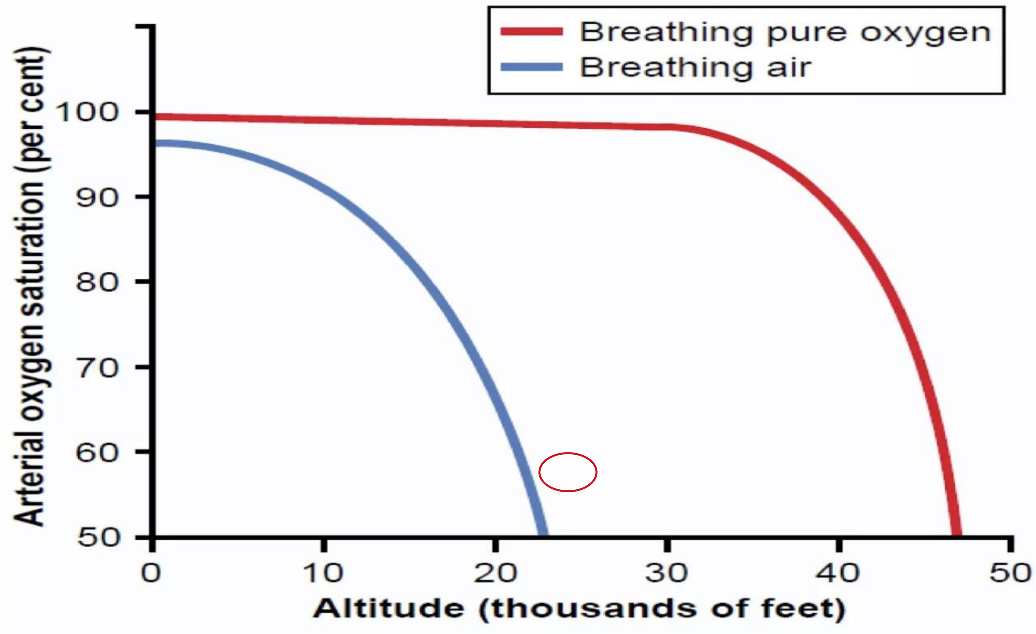


The "Ceiling" When Breathing Air and When Breathing Oxygen in an Unpressurized Aeroplane.

Male Slides Only

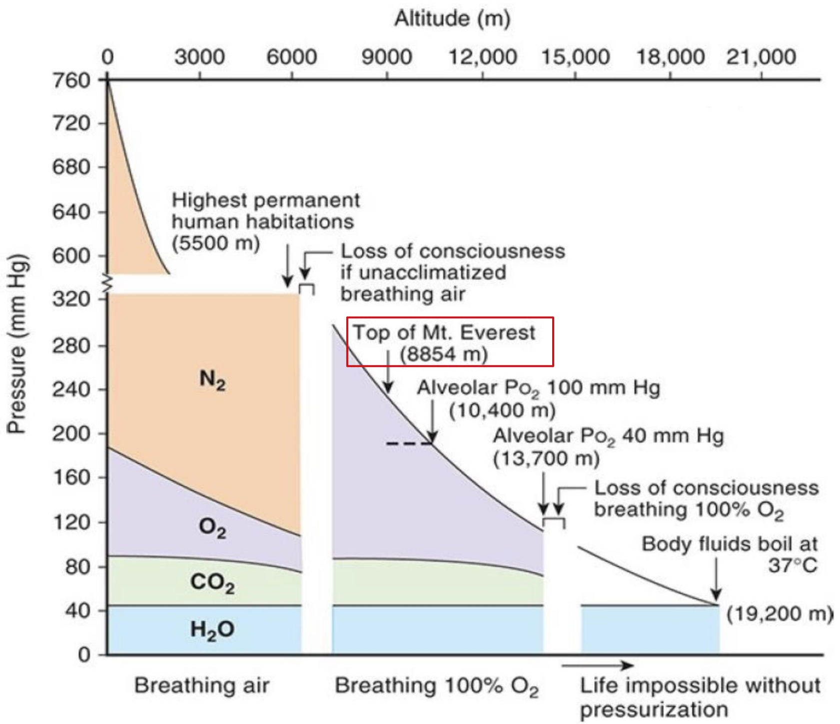
the arterial saturation at 47,000 feet when one is breathing O2 is about 50% and is equivalent to the arterial O2 saturation at 23,000 feet when one is breathing air

Upto the ceiling for an aviator for short exposure times in an unpressurized airplane when breathing air is about 23,000 feet for 50%O2Sat above which he will become unconscious



Difference in Work Capacities

Female Slides Only



Acclimatization	Work capacity (% of Normal)
Unacclimatized	50
Acclimatized for 2 months	68
Native living at 13,200 feet but working at 17,000 feet	87

Chronic Breathing of Low O_2 Stimulates Respiration (Phenomenon of "Acclimatization")

- Mountain climbers who ascend a mountain slowly, over a period of days rather than hours, can breath much more deeply and therefore can withstand far lower atmospheric O_2 concentrations than when they ascend rapidly. This phenomenon is called acclimatization. So Acclimatization means the process or result of becoming accustomed to a new climate or to new conditions

- The reason for acclimatization is that, within 2 to 3 days, the respiratory center in the brain stem loses about four fifths of its sensitivity to changes in PCO_2 and hydrogen ions.

- The excess blow-off of CO_2 that normally would inhibit an increase in respiration fails to occur and low O_2 can drive the respiratory system to a much higher level of alveolar ventilation than under acute conditions.

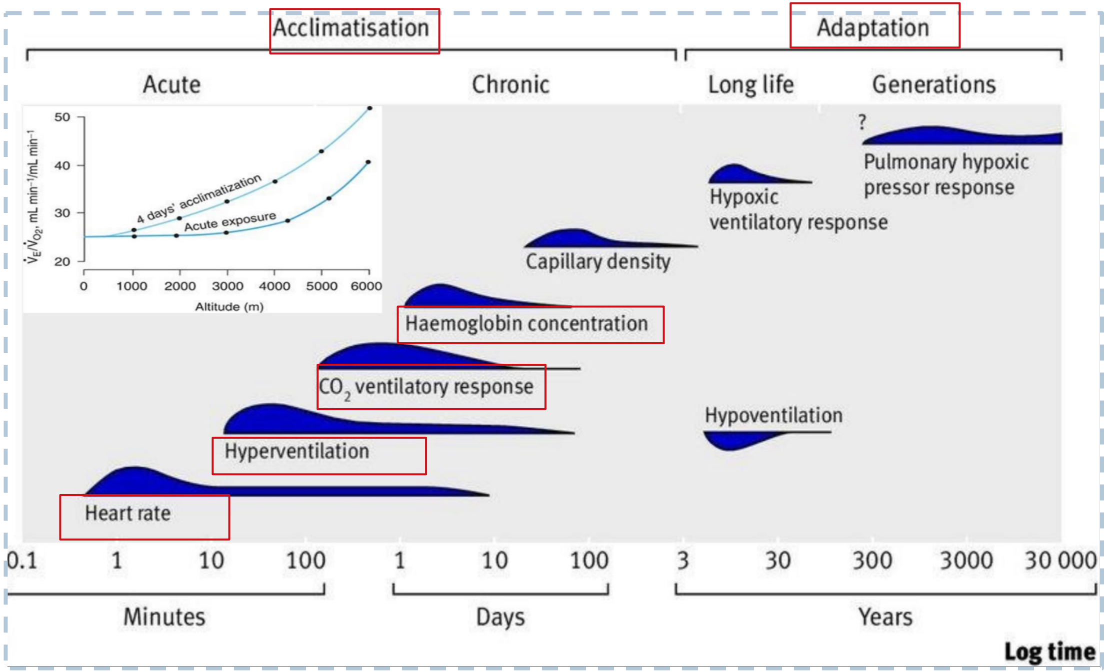
- Instead of the 70 percent increase in ventilation that might occur after acute exposure to low O_2, the alveolar ventilation often increases 400 to 500 percent after 2 to 3 days of low O_2, which helps immensely in supplying additional O_2 to the mountain climber.

- A person remaining at high altitudes for days , weeks or years becomes more and more acclimatized to low PO_2. So that it causes fewer deleterious effects on the body and it becomes possible for the person to work harder without hypoxic effects or to ascend to still higher altitude.

بالعربي: لما تصعد الجبل بشكل تدريجي على مدى ايام بيصير عندك تكيف ليه؟ لان زي ما قلنا بسلايد 15 مستويات الco2 بتقل بالدم فهذا الشي المفروض يقلل الventilation. فالتكيف هو انه جسمنا يعتمد على كمية الاكسجين بالدم كمعيار للتنفس عوضا عن الco2. فحتى لو كان الco2 منخفض زي ماندري لما تصعد بالمرتفعات، لسى بيضل الشخص يتنفس بسرعة لان الاكسِجين نازل عنده.

Male Slides Only

Chronic Breathing of Low O2 Stimulates Respiration — Phenomenon of “Acclimatization”



The difference between Adaptation and Acclimatization

- Adaptation is a long-term permanent adjustment of a group of organisms to a changing environment.
- Acclimatization is a short-term rapid temporary adjustment of an organism to a changing environment.

Here know that acclimatization methods don’t happen all at the same time. there is short term and long term:

First: heart rate -> respiratory rate ->..... See graph

Important Slide

Responses (Principle means) of Acclimatization

You should understand this table because its like a summary of the lecture

1. Increase in pulmonary ventilation.
2. Increased red blood cells. (via increasing EPO *remember foundation*)
3. Increased diffusing capacity of the lungs.
4. Increased vascularity of the tissues.
5. Increased ability of the cells to utilize oxygen despite the low PO2 through increased number of mitochondria and oxidative enzymes activity.

Parameter	Response to High Altitude
Alveolar P_{O_2}	↓ (due to decreased barometric pressure)
Arterial P_{O_2}	↓ (hypoxemia)
Ventilation rate	↑ (hyperventilation due to hypoxemia)
Arterial pH	↑ (respiratory alkalosis due to hyperventilation)
Hemoglobin concentration	↑ (increased red blood cell concentration)
2,3-DPG concentration	↑
O_2-hemoglobin dissociation curve	Shifts to right; increased P_{50}; decreased affinity
Pulmonary vascular resistance	↑ (due to hypoxic vasoconstriction)
Pulmonary arterial pressure	↑ (secondary to increased pulmonary resistance)

Important Slide

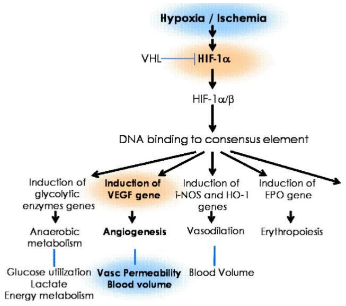
HYPOXIA-INDUCIBLE FACTORS (HIFs)

A "MASTER SWITCH" FOR THE BODY'S RESPONSE TO HYPOXIA

HIFs are DNA-binding transcription factors that respond to decreased oxygen availability and activate several genes that encode proteins needed for adequate oxygen delivery to tissues and energy metabolism. HIFs are found in virtually all oxygen-breathing species, ranging from primitive worms to humans.

- Some of the genes controlled by HIFs, especially HIF-1, include the following:

1. Genes associated with vascular endothelial growth factor, which stimulates angiogenesis.
2. Erythropoietin genes that stimulate red blood cell production
3. Mitochondrial genes involved with energy utilization.
4. Glycolytic enzyme genes involved with anaerobic metabolism.
5. Genes that increase availability of nitric oxide, which causes pulmonary vasodilation.



Hypoxia -> HIFs (transcription factors) -> activates the genes 1,2,3,4,5 above

In the presence of adequate oxygen, the subunits of HIF required to activate various genes are downregulated and inactivated by specific HIF hydroxylases.

The MASTER SWITCH

In hypoxia, the HIF hydroxylases are themselves inactive, allowing the formation of a transcriptionally active HIF complex that permits the body to respond appropriately to hypoxia.

Male Slides Only

Important Slide

Acute & chronic mountain sickness

ACUTE Mountain Sickness

- Acute cerebral edema due to cerebral vasodilation
- Pulmonary Edema due to blood flow which is forced through fewer still un-constricted pulmonary vessels increasing capillary pressure and thus causing edema.

CHRONIC Mountain Sickness

1. The red blood cell mass and hematocrit become exceptionally high (secondary polycythemia).this leads to increasing viscosity thus slowing the blood flow (more RBC -> more viscosity -> less flow speed
2. The pulmonary arterial pressure becomes elevated even more than the normal elevation that occurs during acclimatization. vasoconstriction→ Right Heart failure and then CCF (more Pulm. Art. pressure = more work on Right Ventricle = Right Heart Failure sometimes called **cor pulmonale**)
3. Vasoconstriction causes pulm blood shunting to non alveolar vessels
4. The peripheral arterial pressure begins to fall
5. Death often follows unless the person is moved to a lower altitude

CCF: Congestive Cardiac(heart) Failure

مهم **تفهمون** الملخصات هذي لانها متعلقة باللكتشرات الي قبل وهذي so don't skip it

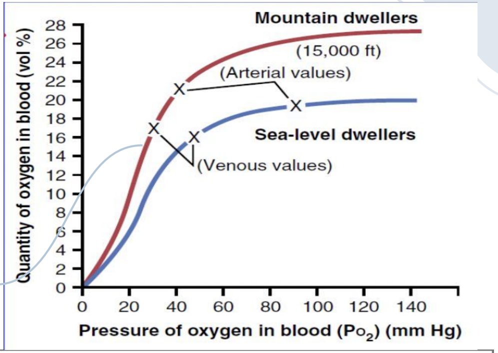
Summary

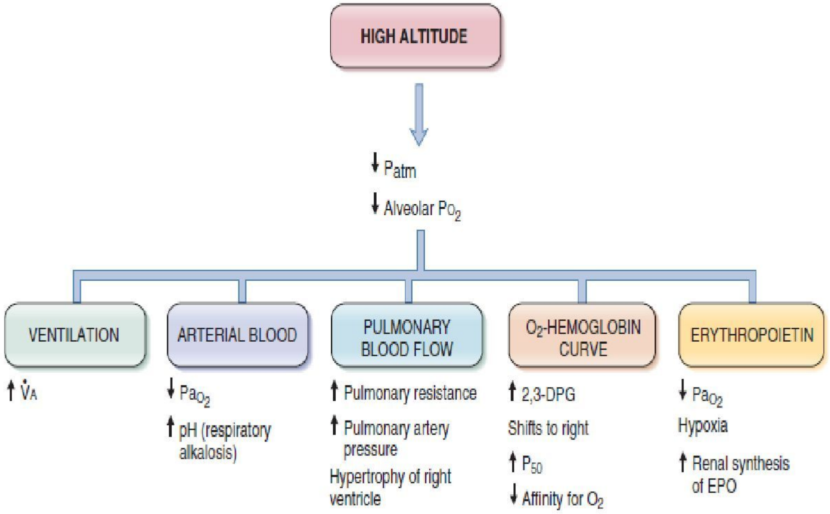
Acclimatization to low PO2

Important

Via Bohr Effect:

Oxygen-hemoglobin dissociation curves in high-altitude and sea level residents





MCQs

Q1:a person lives in high altitude for weeks what is the acclimatisation method he used?			
A-Decrease 2,3DPG	B-Increase RBC	C-Increase the affinity Hb to O2	D-Decreased tissue metabolism
Q2:The effect of depth on gases:			
A-Increases density	B-decreases volume	C-increases barometric pressure	D-All of the above
Q3:What is the effect of acute hypoxia at 19,000 feet			
A-Coma	B-Sadness	C-convulsions	D-None of the above

1-B 2-D 3-C

MCQs

Q4:An increase in pulmonary vascular resistance and pulmonary arterial pressure indicates what change in altitude?			
A- ↓Altitude	B- ↑Altitude	C-No change in altitude	D- At floor level
Q5:Q5:Which of the following is a response of acclimatization to high altitudes?			
A- Decreased Ventilation	B-Increased H+ ions	C- Increased 2,3 DPG	D-Decreased tissue metabolism
Q6:Which of the following is NOT a reason why Helium is used instead of Nitrogen in the treatment of decompression sickness			
A- Less molecular weight	B- Less narcotic effect	C- Less diffusion out of the tissue	D- Lower density

4- B 5-C 6-C

SAQs

Q1: Enumerate responses of acclimatisation?

Q2: What are the 5 inducible factors that will restore the body's metabolism when the body is exposed to hypoxia?

Q3: What is the effect of high alveolar pressure in the lungs on oxyhemoglobin saturation?

A1: slide 22

A2: Slide 23

A3: at high atmospheric pressure (4ATM) high PAO2 can cause oxygen toxicity:

- Toxic free radical accumulation
- Seizure and comma
- Pulmonary disability

Ahmad Addas
Ibrahim Albabtain
Leena Shagrani
Rimaz Alhammad

Abdulmohsen Alrahaimi
Abdulaziz Nasser
Abdullah Almarwan
Saud Alsaeed
Abdullah Almutlaq
Talal Alrobaian
Khalid Al Tameem
Zyad Alshuhail
Abdulaziz Alobathani
Moath Alabdulsalam

Omar Alattas
Khalid Alkanhal

Marwah Fal
Ghala Alyousef

Basma Al-ghamdi
Aljoharah Alyahya
Samiyah Sulaiman
Noreen Almarabah
Aram Alzahrani
Lina Aljameel
Layal Alkhalifah
Hessa Alamer
Aleen Muneif
Farah Aldriweesh

physiology.444ksu@gmail.com