Low and high altitude

Respiratory block

PHYSIOLOGY 438 TEAMWORK

- Red: important
- Black: in male / female slides
- Pink: in female slides only
- Blue: in male slides only
- Yellow: notes
- Gray: extra information
- Textbook: Guyton + Linda

Editing file

Twitter account

Objectives

1. Describe the effects of exposure to low and high barometric pressures on the body.
2. Describe the body acclimatization to low barometric pressure.
3. Define decompression sickness and explain how it can be avoided.
4. Understand the effects of high nitrogen pressure, and nitrogen narcosis.

Helpful video

Effect of Increased Barometric Pressure (Deep Sea Diving)

760 mmHg is the atmospheric pressure

When human **descend below** the sea, the pressure around them **INCREASES.**

↓

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.

Helpful video

Effect of increased barometric pressure (Deep sea diving)

The surrounding pressure increases by 1 atmosphere for every 10 meters (33 feet) of depth in sea water.

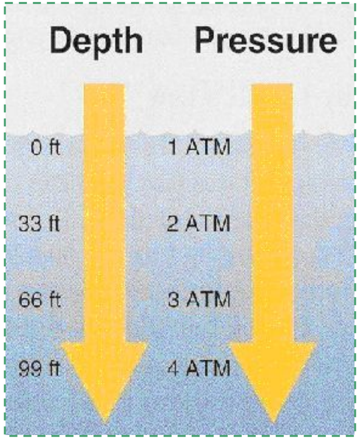
→

Therefore at a depth of 31 meter (100 feet) in the ocean the diver is exposed to a pressure of 4 atmospheres .
1 atm "from air" +3 atm "1 for each 10m" = 4.

=

These problems confront SCUBA (self contained underwater breathing apparatus.)

Therefore, a person 33 feet beneath the ocean surface is exposed to 2 atmosphere pressure,one is the atmospheric pressure caused by the weight of the air above the water and the second atmosphere by the weight of the water itself.



SCUBA Apparatus

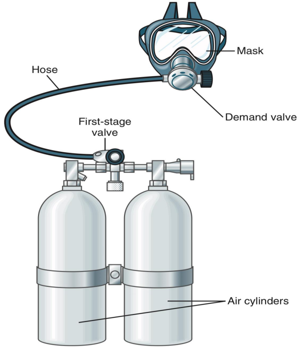


Figure 45-4. Open-circuit demand type of SCUBA.

Effect of Increased Barometric Pressure (Deep Sea Diving)

Helpful video

01 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.

Boyle's law: Volume to which a given quantity of gas is compressed is inversely proportional to the pressure.

02 Effect of depth on density of gases:

- Increase in the density of gas and hence increased work of breathing.

Increase air resistance in the airway is like swallowing jelly instead of water. Increase in pressure cause the gas molecules to be more close to each other so the space will decrease between the molecules, and this decrease in space makes the gas too thick and like liquids

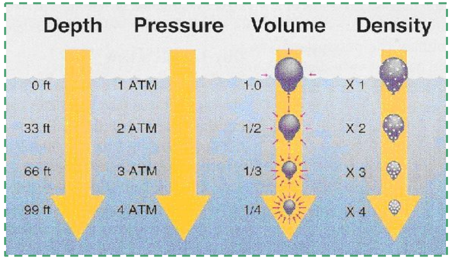
03 Nitrogen effect at high nitrogen pressure:

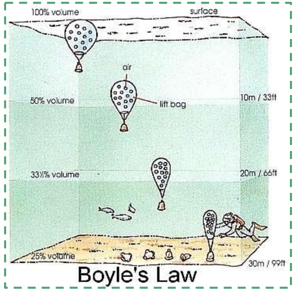
Has 2 principle effects:

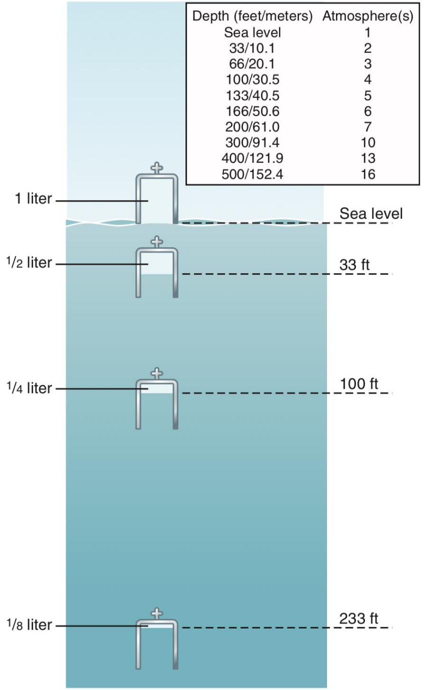
- Nitrogen narcosis (anesthetic effect)
- Decompression sickness.

Nitrogen is the most element from respiratory elements that's affected by Henry's law

Henry' law: " the amount of dissolved gas (الميوعة) is proportional to its partial pressure in the gas phase".







Depth (feet/meters)	Atmosphere(s)
Sea level	1
33/10.1	2
66/20.1	3
100/30.5	4
133/40.5	5
166/50.6	6
200/61.0	7
300/91.4	10
400/121.9	13
500/152.4	16

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

Oxygen toxicity when breathing hyperbaric air

Effect of Very High PO_2 on Blood Oxygen Transport

When the Po_2 in the blood rises above 100 mmHg → the amount of oxygen dissolved in the water of the blood increases markedly.

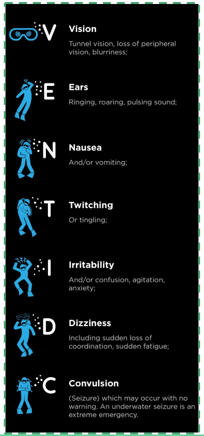
Acute Oxygen Poisoning

The extremely high tissue Po_2 that occurs when oxygen is breathed at very high alveolar oxygen pressure can be **detrimental** to many of the body's tissues.

In other words Acute Oxygen Poisoning is:
a Condition resulting from the harmful effects of breathing molecular Oxygen (O_2) at increased partial pressure.

At 4 atmospheres pressure of oxygen (Po_2 = 3040 mm Hg) will cause

- brain seizures → followed by coma in most people within 30 to 60 minutes.
- Other symptoms include
  - nausea
  - muscle twitchings
  - dizziness
  - disturbances of vision
  - irritability
  - disorientation



Cont. Oxygen toxicity at a high PO2

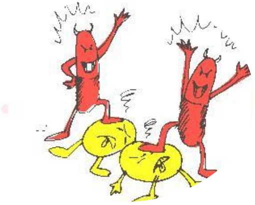
1- Molecular oxygen (O_2) has little capability of oxidizing other chemical compounds

2- Instead, it must first be converted into an active form of oxygen

3- called oxygen free radicals. e,g superoxide and hydrogen peroxide.

So the cause of oxygen toxicity is not the oxygen itself but the active form of it —>the free radicals

Oxygen



oxygen free radicals

Active form

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

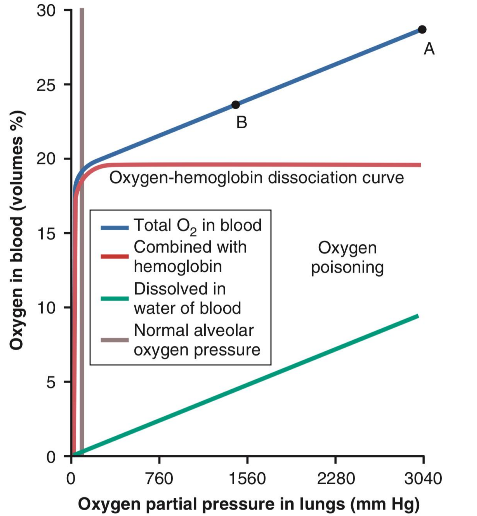


Figure 45-2. Quantity of O_2 dissolved in the fluid of the blood and in combination with hemoglobin at very high Po_2 values.

Nitrogen Narcosis

Nitrogen like most other anesthetic gases, <u>dissolve freely</u> in the fats of the body including the membranes and other lipid structures of the neurons.

This leads to

alteration of the electrical conductance of the membranes:

reduces their excitability

and subsequent narcosis develops.

120 feet

At 120 feet:

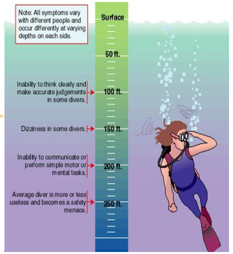
The diver loses many of his cares.

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

150 feet

At 150 feet:

There is a feeling of euphoria and drowsiness and impaired performance.



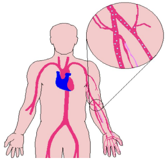
Lower than 150 feet

At higher pressure:

Loss of coordination and finally coma might develop.

Nitrogen diffuse into blood only in high pressure altitudes and it can cross BBB and has an anesthetic response.
Nitrogen is five times as soluble in fat as in water

Decompression Sickness (Caisson's Disease)



Other names: Bends, Compressed Air Sickness, Caisson Disease, Diver's Paralysis, Dysbarism.

It is a syndrome caused by a decrease in the ambient (surrounding) pressure which occur in animal and men when the tissues of the body contain an excess of physically inert (does not undergo chemical reactions) gas.

On ascending

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

During slow ascent

N_2 is slowly removed from the tissues since the partial pressure there is higher than that in the arterial blood and alveolar gas. To avoid getting caisson's disease

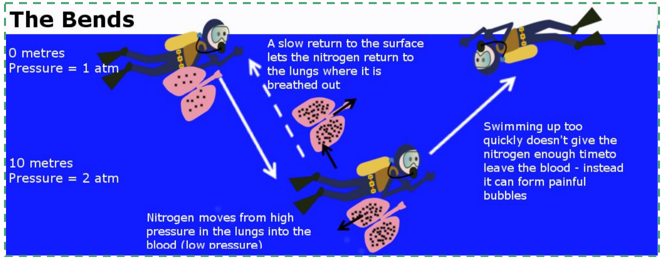
If decompression is rapid

bubbles of gaseous nitrogen are released, in tissues and blood, causing the symptoms of decompression sickness (the bends or caisson disease). Happens when the diver gets out of the water fast.

Under the sea (under high pressure) the nitrogen inside our body is in a liquid like form that's why when ascending too fast the nitrogen is converted quickly into gas and forms bubbles in the blood

During descending

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 N_2 solubility).

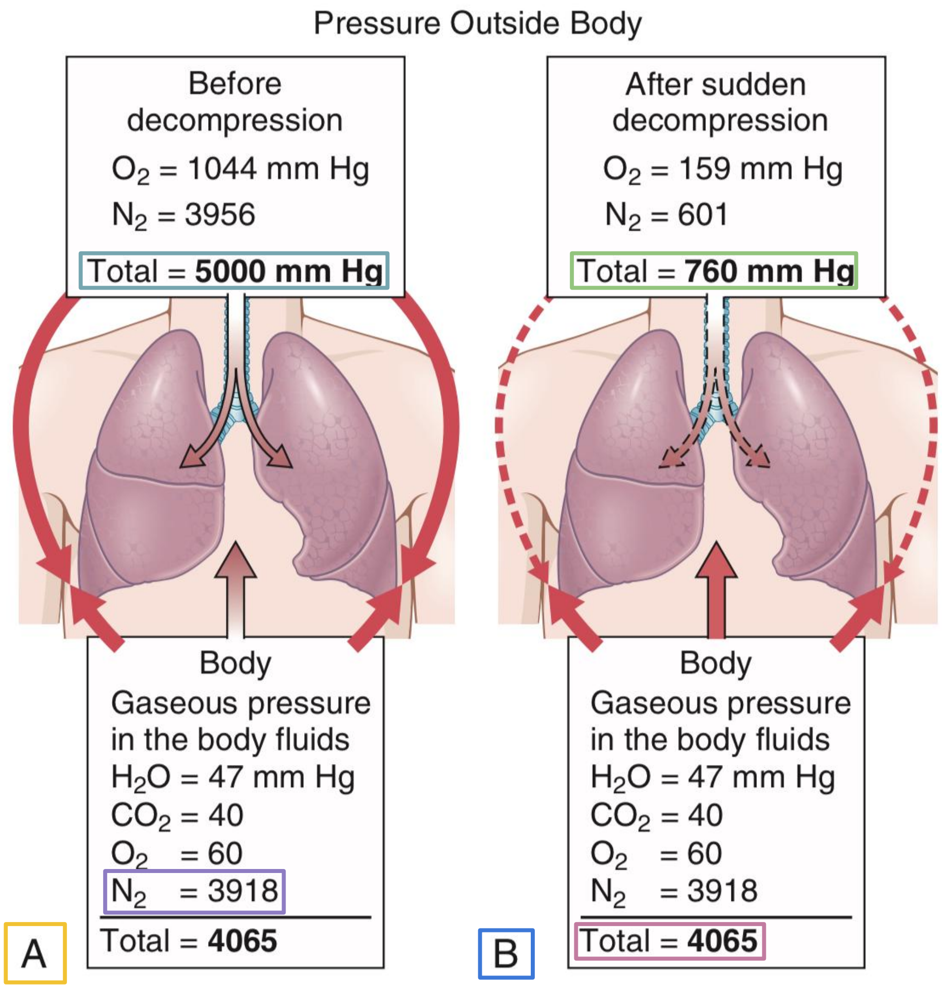


More explanation

Decompression sickness

Decompression sickness – also called the bends, Caisson sickness or divers' disease – is a life-threatening condition caused by a buildup of nitrogen bubbles in the bloodstream and body tissues.

Cause: As a diver descends, pressure increases, causing nitrogen to be absorbed into the body tissues. The diver must ascend slowly to allow the nitrogen to escape out of the body. If the diver ascends too fast, the nitrogen becomes bubbles in the tissue and bloodstream.



From Guyton:

The principles underlying bubble formation. In Figure A, the diver's tissues have become equilibrated to a high dissolved nitrogen pressure (PN_2 = 3918 mm Hg), about 6.5 times the normal amount of nitrogen in the tissues. As long as the diver remains deep beneath the sea, the pressure against the outside of his or her body (5000 mm Hg) compresses all the body tissues sufficiently to keep the excess nitrogen gas dissolved.

However, when the diver **suddenly** rises to sea level Figure B, the pressure on the outside of the body becomes only 1 atmosphere (760 mm Hg), while the gas pressure inside the body fluids is the sum of the pressures of water vapor, CO_2, O_2, and nitrogen, or a total of 4065 mm Hg, 97 percent of which is caused by the nitrogen.

Obviously, this total value of 4065 mm Hg is far greater than the 760 mm Hg pressure on the outside of the body.

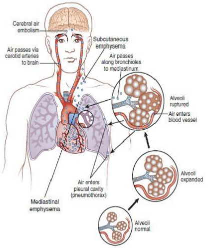
➔ Therefore, the gases can escape from the dissolved state and form bubbles, composed almost entirely of nitrogen, both in the tissues and in the blood, where they plug many small blood vessels. The bubbles may not appear for many minutes to hours because sometimes the gases can remain dissolved in the "supersaturated" state for hours before bubbling.

Symptoms & signs of Decompression Sickness (DS)

Mild symptoms:

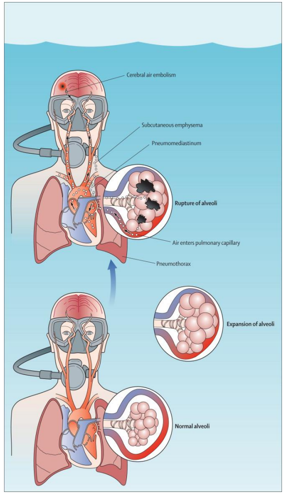
1. **fatigue** or **drowsiness** after decompression.
2. Locally there is skin **itch**.

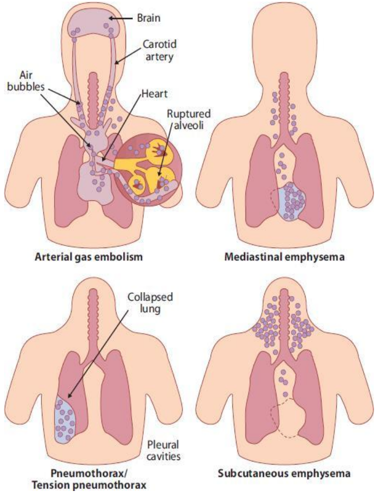


Severe symptoms:

1. **bubbles** in the tissues cause severe pains particularly around the **joints**.
2. **Neurological** symptoms include **paresthesia** -تنميل-, **itching, paralysis**, and **inner ear disturbances**.
3. Thoracic pains: **dyspnea**, **substernal pain**, **cyanosis**, and **cough**.
4. Bubbles in the coronary arteries may cause **myocardial damage** “the bubbles will block the blood vessels”.
5. Decompression sickness shock, capillaries become permeable to plasma and **hypovolemia** (decrease in blood volume) rapidly develop.
6. **Edema** may be prominent and **shock** is also usually complicated by pulmonary edema.





Treatment of decompression symptoms

A- **Rapid** recompression in a pressure chamber followed by **slower** decompression. Thus stimulating what would have happened if the diver was decompressed slowly

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

2 In a very deep dives, the risk of decompression sickness can be **reduced** if a helium-O_2 mixture is breathed during the dive.

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

Treatment of decompression symptoms

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

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. so it easily diffuses from capillary to alveoli and leaves the body

The advantage of Nitrogen in the gas mixture is to dilate so we replace it with Helium which is also has a dilating effect

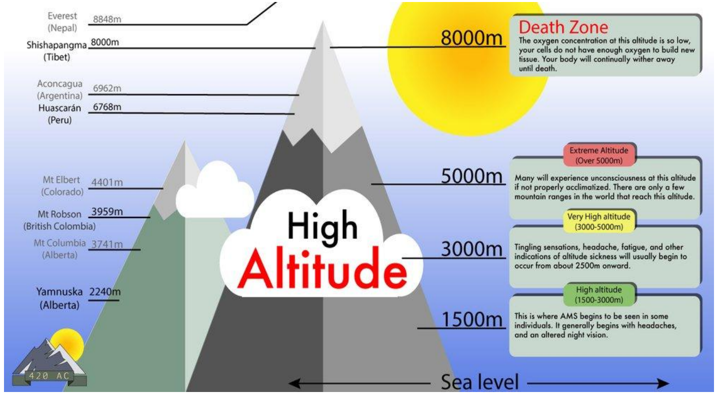
Helpful video

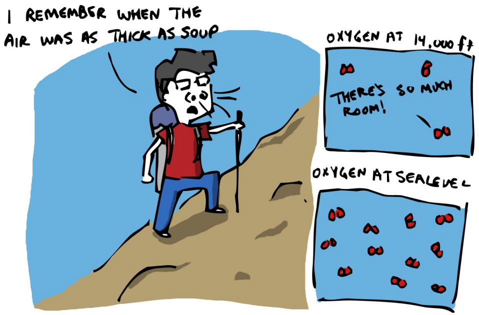
Effects of low oxygen pressure on the body

(Aviation-ascend to high altitude)

- ➢ At the sea level the barometric pressure (another term for atmospheric pressure) is 760 mmHg
- ➢ At 10,000 feet is 523 mmHg
- ➢ At 50,000 feet 87 mmHg.

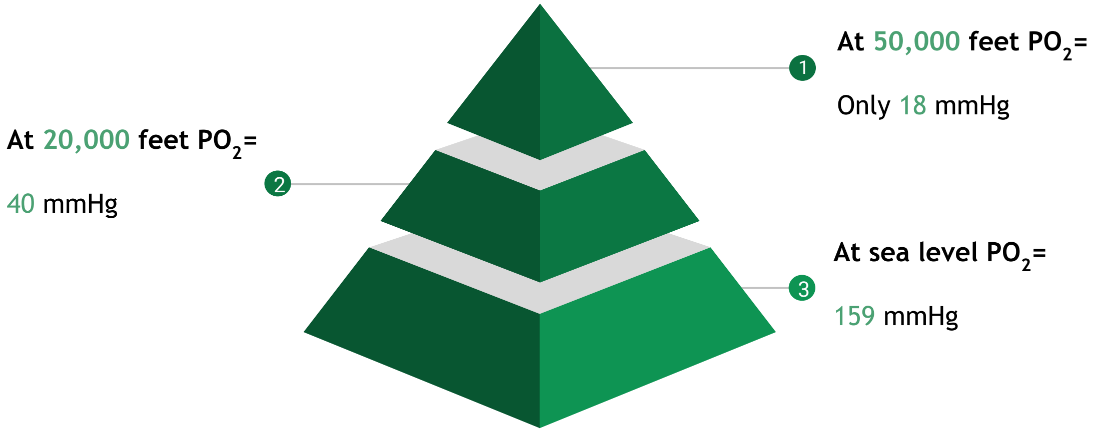
This decrease in barometric pressure is the basic cause of all the problems of hypoxia in high altitude physiology. Because that's mean decreasing in O_2 concentration—> Hypoxia





Alveolar PO_2 at different altitudes

- As the **barometric pressure** decreases, the **oxygen partial pressure** decreases **proportionally**, remaining less than 21% of the total barometric pressure.



- Even at high altitude CO_2 is continuously excreted from the pulmonary blood into the alveoli. Also, water vaporizes into the inspired air from the respiratory surfaces.
- Therefore, these two gases dilute the oxygen in the alveoli, thus reducing the oxygen concentration and therefore **hypoxia develops**.

Effects of acute hypoxia

At 12,000 feet

- Drowsiness
- Lassitude ارهاق
- Mental and muscle fatigue
- Sometimes headache
- Occasionally nausea
- Sometimes euphoria (happiness).

Above 18,000 feet

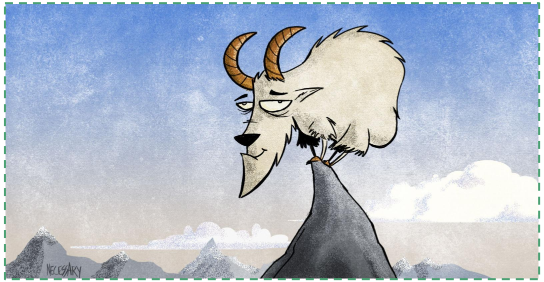
- All the effects at 12,000 and
1-Twitching
2-Or convulsions
(contraction of big muscles)

Above 23,000 feet

- Coma (the un-acclimatized person)

One of the most important effects of hypoxia is decreased mental proficiency, which decreases judgment, memory, and performance of discrete motor movements.

Acclimatization to Low PO_2



- 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.

Principle means of acclimatization

Helpful video

1. **Increased** pulmonary ventilation.
2. **Increased** red blood cells.
(if there is decrease in O_2 the kidney will respond by producing Erythropoietin which will go to the bone marrow and synthesize RBCs + Hb, so more O_2 will be carried on Hb and more O_2 will be transferred to the tissue).
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 PO_2 through increased number of mitochondria and oxidative enzymes activity.

From Guyton:

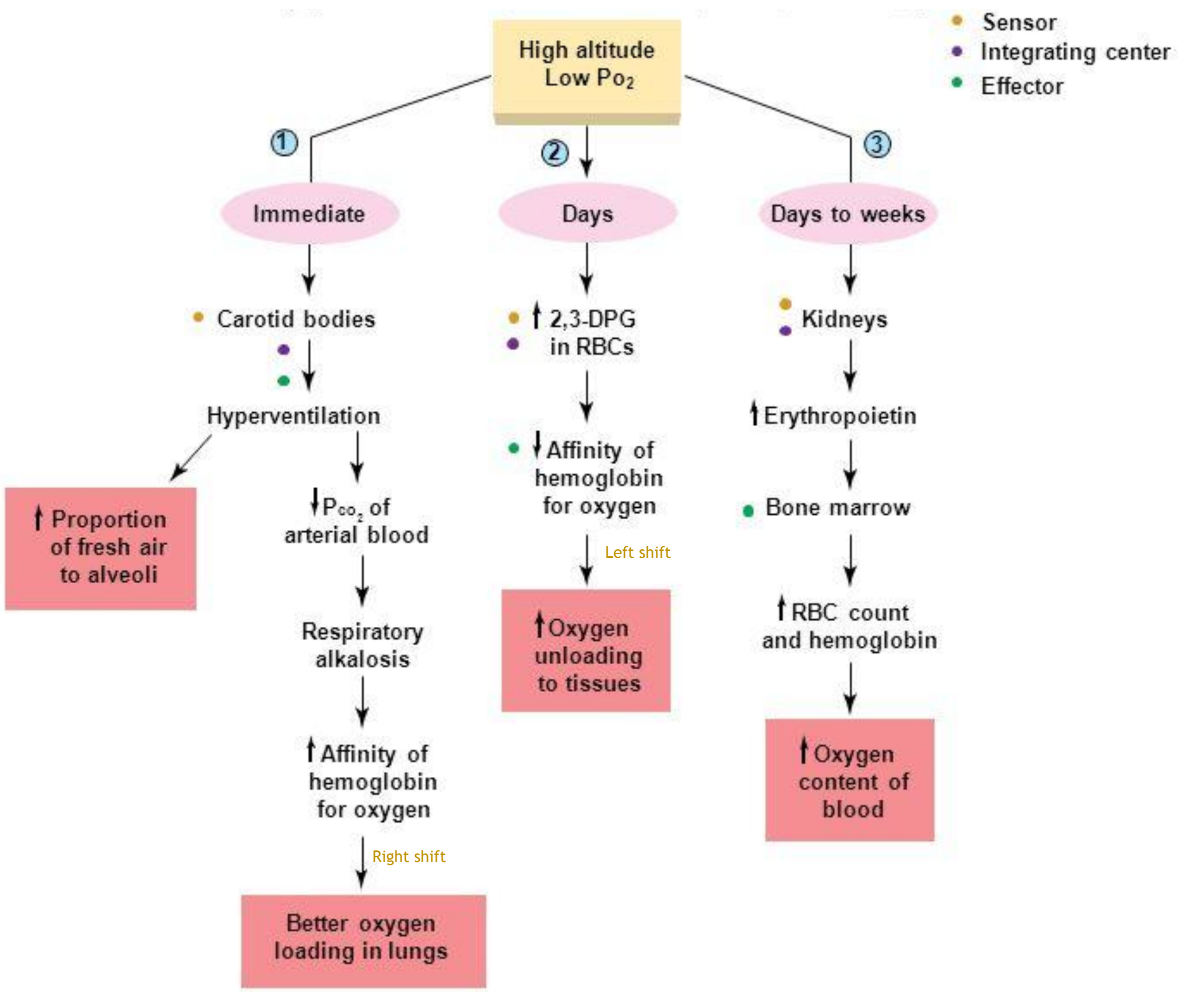
girl's doctor recommended us to read this part from Guyton

Chronic Breathing of Low Oxygen Stimulates Respiration Even More—The Phenomenon of "Acclimatization"

Mountain climbers have found that when they ascend a mountain slowly, over a period of days rather than a period of hours, they breathe much more deeply and therefore can withstand far lower atmospheric oxygen concentrations than when they ascend rapidly. This is called acclimatization.

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 Pco2 and hydrogen ions.

Therefore, the excess ventilatory blow-off of carbon dioxide that normally would inhibit an increase in respiration fails to occur, and low oxygen 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 oxygen, the alveolar ventilation often increases 400 to 500 percent after 2 to 3 days of low oxygen; this helps immensely in supplying additional oxygen to the mountain climber.


Sensor
Integrating center
Effector
High altitude
Low P_{O_2}
1
2
3
Immediate
Days
Days to weeks
Carotid bodies
Hyperventilation
↑ Proportion of fresh air to alveoli
↓ P_{CO_2} of arterial blood
Respiratory alkalosis
↑ Affinity of hemoglobin for oxygen
Right shift
Better oxygen loading in lungs
↑ 2,3-DPG in RBCs
↓ Affinity of hemoglobin for oxygen
Left shift
↑ Oxygen unloading to tissues
Kidneys
↑ Erythropoietin
Bone marrow
↑ RBC count and hemoglobin
↑ Oxygen content of blood

Quiz

You don't understand why we choose this answer?
Click here to read the explanations

1- A diver is breathing 21% oxygen (O_2) at a depth of 132 feet. The diver's body temperature is 37°C, and partial pressure of carbon dioxide (Pco_2) = 40 mm Hg. What is the alveolar partial pressure of oxygen (Po_2)?

A. 149 mm Hg
B. 380 mm Hg
C. 578 mm Hg
D. 738 mm Hg

2- Which of the following is true regarding a healthy recreational scuba diver at a depth of 66 feet in the Caribbean Sea?

A. Her lungs are smaller than normal
B. She has an elevated arterial Po_2 and a normal Pco_2
C. All gas partial pressures in her blood (O_2, nitrogen [N_2], CO_2, and water vapor) are elevated

3- A man is planning to leave Miami (at sea level) and travel to Colorado to climb Mount Wilson (14,500 feet, barometric pressure = 450 mm Hg). Before his trip he takes acetazolamide, a carbonic anhydrase inhibitor that forces the kidneys to excrete bicarbonate. What response would be expected before he makes the trip?

A. Alkalotic blood
B. Normal ventilation
C. Elevated ventilation
D. Normal arterial blood gases

4- A diver carries a 1000-liter metal talk-box with an open bottom to a depth of 66 feet so that two divers can insert their heads and talk beneath the water. A person on the surface of the water pumps air into the box until the 1000-liter box is completely filled with air. How much air from the surface is required to fill the box (in liters)?

A. 1000
B. 2000
C. 3000
D. 4000

SAQ

1- How can person in high altitude complete his life normally with out "hypoxia"?

2- What is the effects of Acute oxygen poisoning?

Answers

1- 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.

2- brain seizures, Other symptoms include nausea, muscle twitchings, dizziness, disturbances of vision, irritability, and disorientation.

Key answers:

1-D 2-B 3-C 4- C

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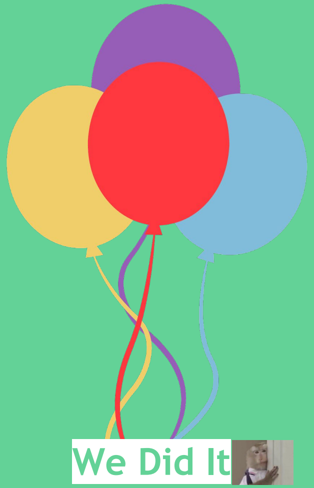
Physiology Respiratory Block ✓



Special thanks to <u>Rema AlMutawa</u> and <u>Deema almaziad</u> for their efforts in this block.

Good luck

Let’s all hope that physiology’s department gives us a chance to breathe!