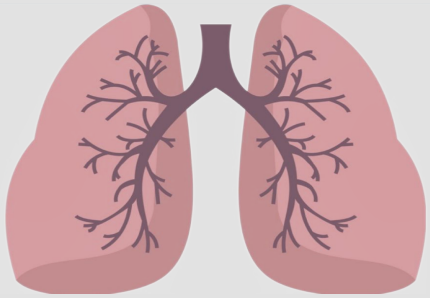
Effects of low and high gas pressure on the body



Respiratory Block

Physiology 439 team work

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

Editing file

@Physiology_439

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.**

Effect of Increased Barometric Pressure (Deep Sea Diving)

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.

Effect of Increased Barometric Pressure (Deep Sea Diving)

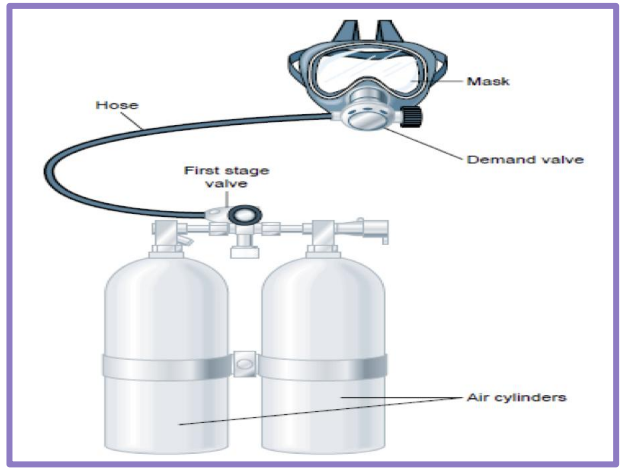
The surrounding pressure increases by 1 atmosphere for every 10 meters (33 feet) of depth in sea water.
So the
diver is exposed to 2 atmospheric pressures.

⇨

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

〓

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



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.

Effect of depth on density of gases:

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

Nitrogen effect at high nitrogen pressure:

Nitrogen will has 2 principle effects:
* Nitrogen narcosis (anesthetic effect).
* Decompression thickness.

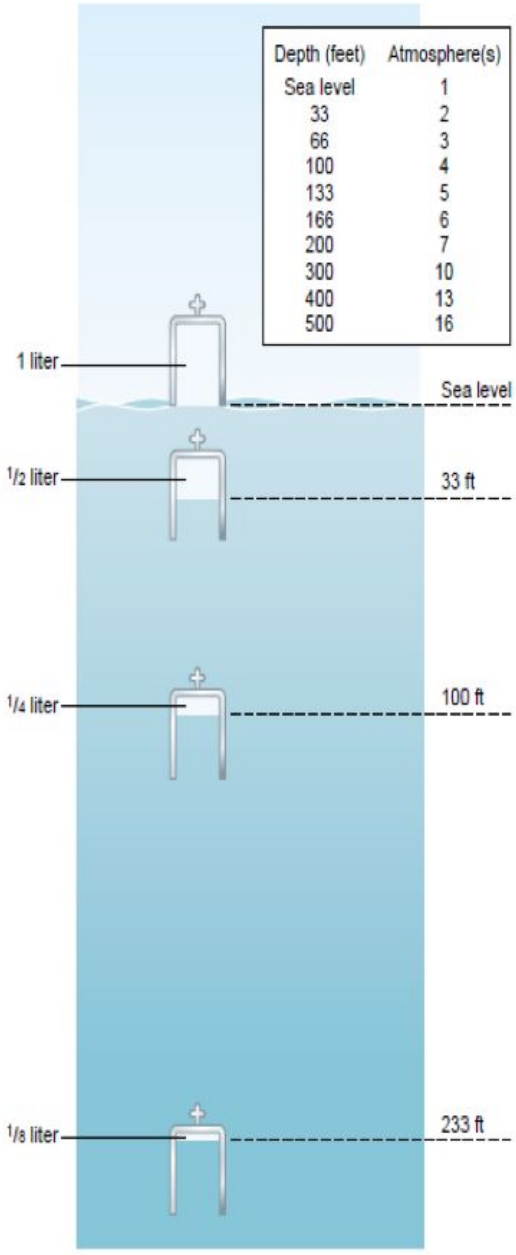


Figure 44–1

Effect of sea depth on pressure (*top table*) and on gas volume (*bottom*).

Oxygen toxicity when breathing hyperbaric air

(effect of very high PO2 on blood oxygen transport):

PO2 in the blood rises above 100 mm Hg → 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.

مؤذ/ ضار

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
  - Muscle twitching
  - Nausea
  - Dizziness
  - Disturbances of vision
  - Irritability
  - Disorientation

Cont. Oxygen toxicity at a high PO2.

Molecular oxygen (O2) has little capability of oxidizing other chemical compounds.Instead, it must first be converted into an “active” form of oxygen called oxygen free radicals. e.g superoxide and hydrogen peroxide.

الأكسجين نفسه ما يسوي شي لكن
الاكتف فورم منه هو اللي يسبب لنا
oxygen toxicity

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

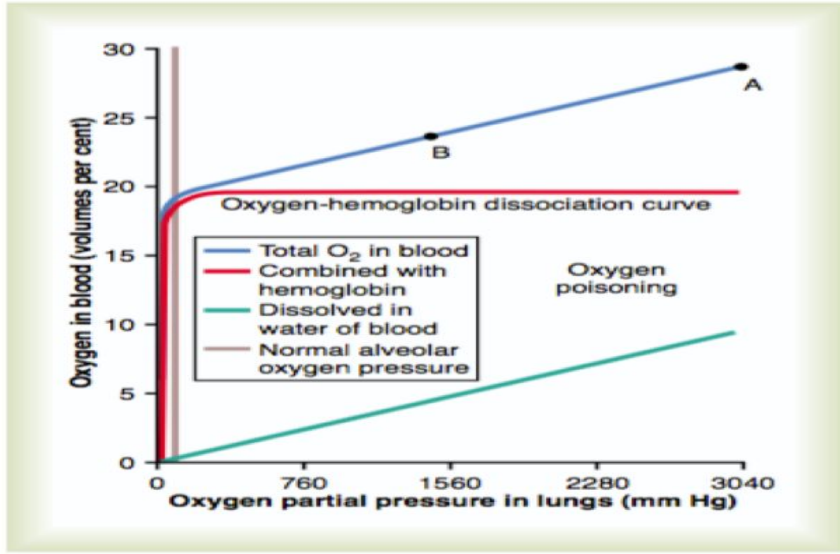


Figure 44–2

Quantity of oxygen dissolved in the fluid of the blood and in combination with hemoglobin at very high Po_2s.

Nitrogen narcosis

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

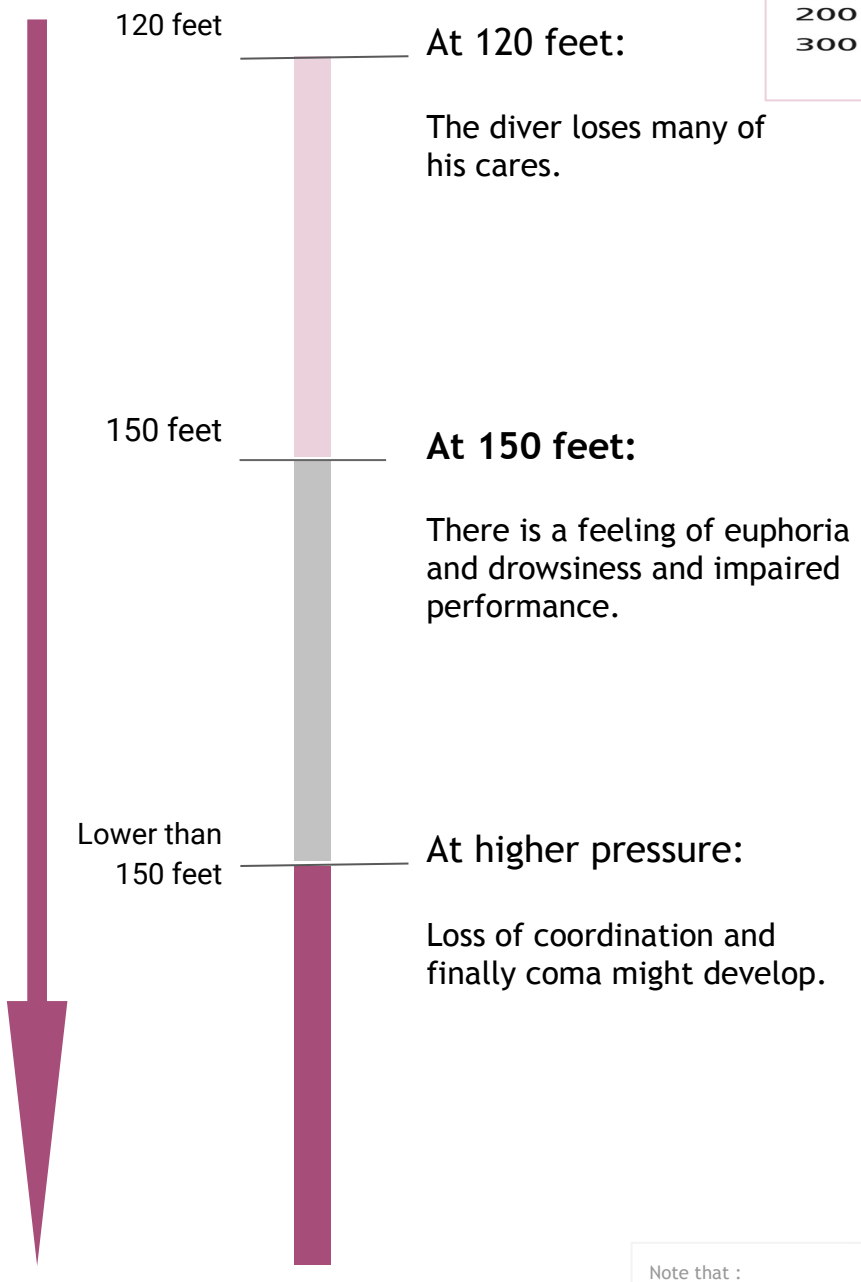
This leads to

alteration of the electrical conductance of the membranes:

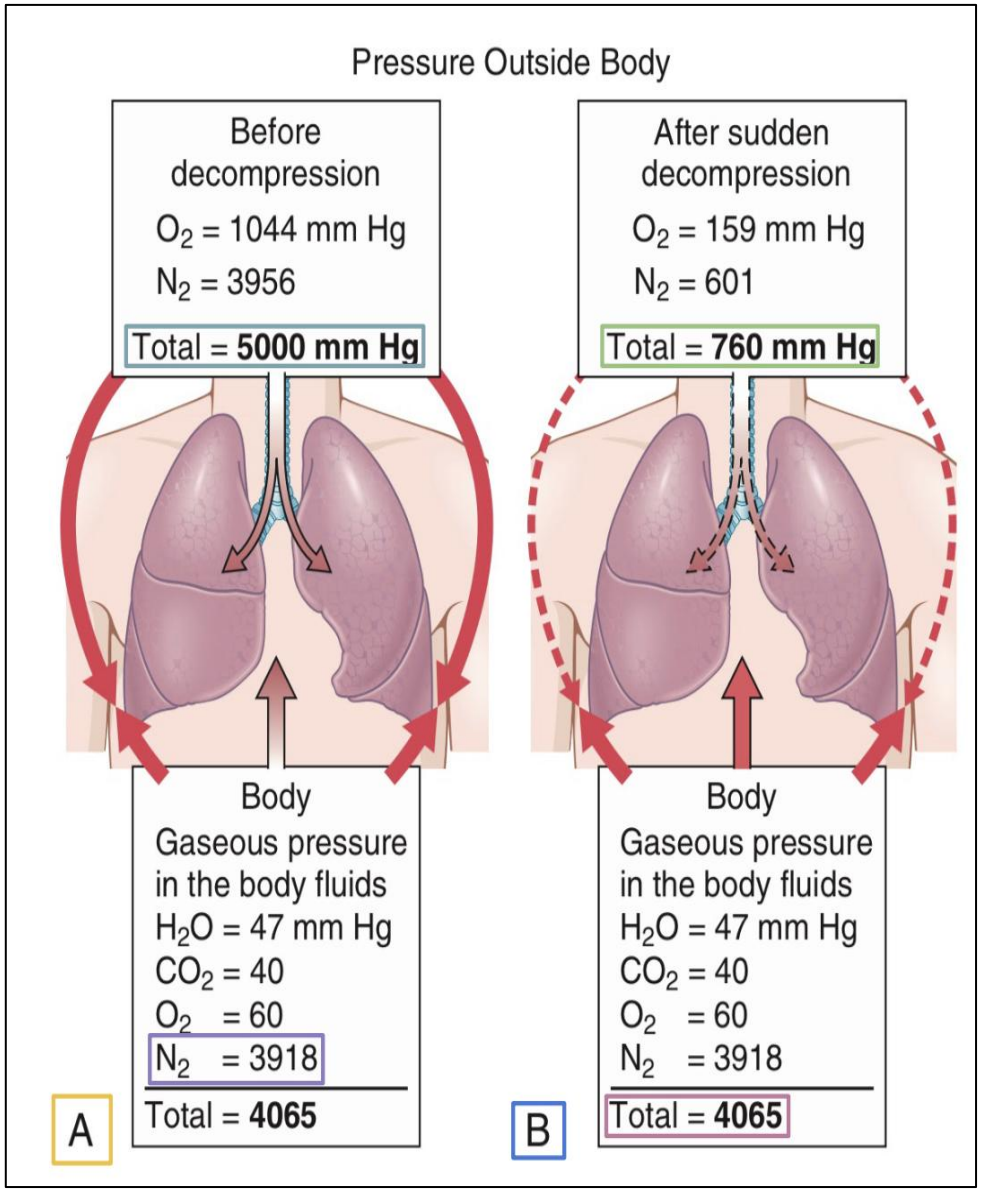
reduces their excitability

and subsequent narcosis develops.

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



Note that :
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



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.

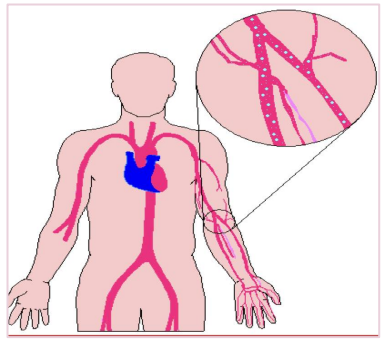
However, when the diver **suddenly** rises to sea level Figure B, the pressure on the outside of the body becomes only 1 atmosphere (760 mm Hg), while the gas pressure inside the body fluids is the sum of the pressures of water vapor, CO_2, O_2, and nitrogen, or a total of 4065 mm Hg, 97 percent of which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

Decompression Sickness (Caisson's Disease)

known as: 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.



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).

On ascending

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

Symptoms & signs of decompression sickness (DS)

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

Decompression sickness shock
capillaries become permeable to plasma and hypovolemia rapidly develop

The mildest form of DS
is fatigue or drowsiness after decompression, and local skin itch.

Bubbles in the coronary arteries
may cause myocardial damage.

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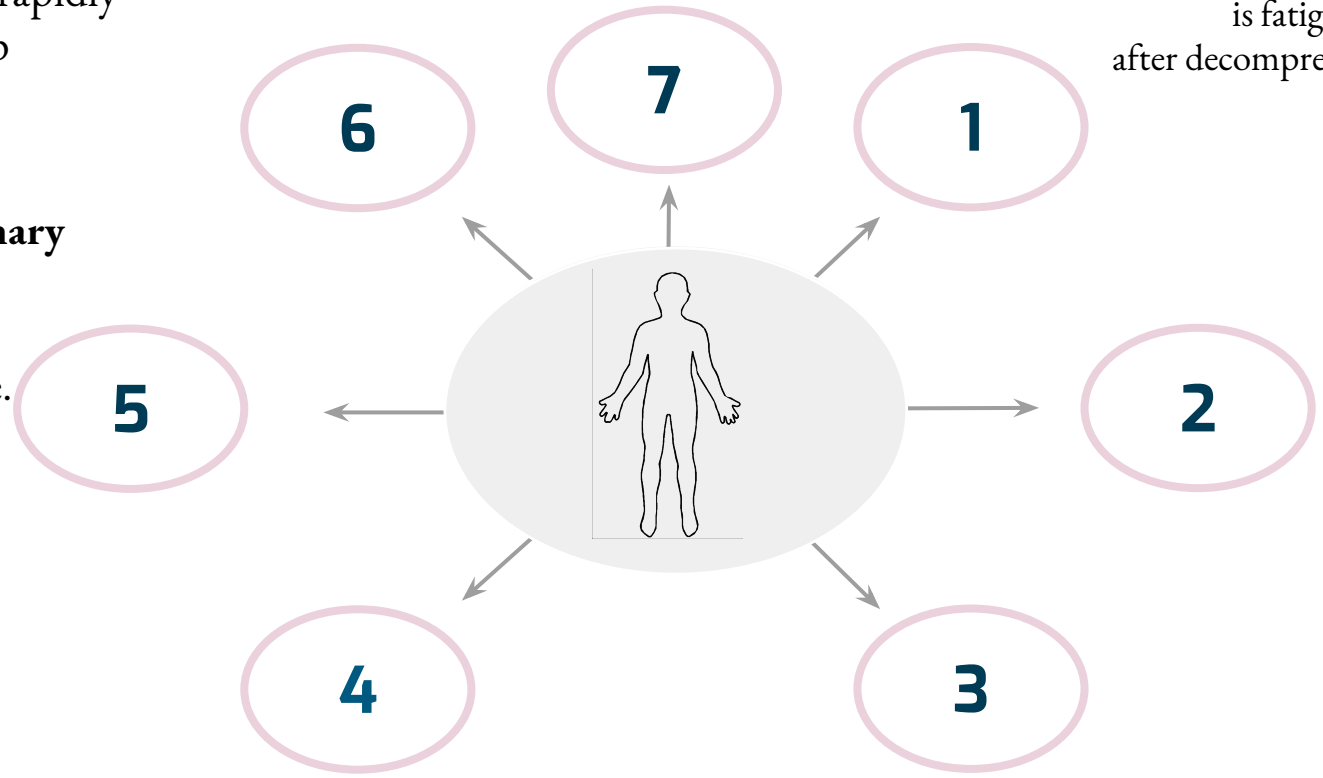
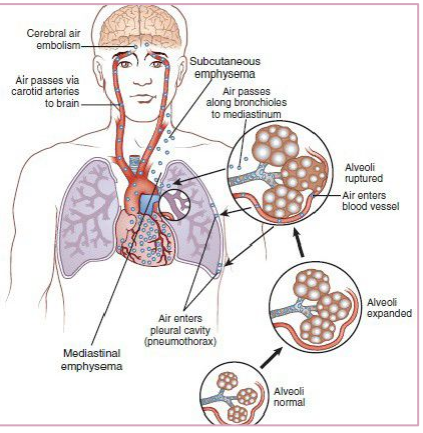


sever symptoms may occur e.g
bubbles in the tissues cause severe pains particularly around the joints.

Thoracic pains
dyspnea, substernal pain, cyanosis, and cough.

.

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



Note that: Hypovolemia is is not dehydration, it is volume depletion, volume contraction or decreased volume in intravascular extracellular fluids to be specific .

Treatment of decompression symptoms

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.

Why is Helium more desirable than nitrogen in deep dives?

• 1/7 the molecular weight of nitrogen. • ¼-1/5 the narcotic effect of nitrogen on CNS. • low density leading to decreased air way resistance of diver.	• Diffuses out of the tissues during decompression several times as rapidly as does nitrogen, thus reducing the problem of decompression sickness • 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.

Effects of low oxygen pressure on the body (Aviation-ascend to high altitude)

At the sea level the barometric 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 hypoxia problems in high altitude in physiology.

Alveolar PO2 at different altitudes

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

1. • At sea level PO2=159 mmHg.
2. • At 20,000 feet PO2=40 mmHg.
3. • At 50,000 feet PO2=only 18 mmHg.

• 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.

• Therefore, these two gases (co2 , H2o) dilute the oxygen in the alveoli, thus reducing the oxygen concentration and therefore hypoxia develops.

From female slide

باختصار : كلما ارتفعنا لمناطق عالية كل ماقل ال barometric pressure وقل معه ال PO2 , بعدين لما يدخل ال conductive zone يصير له Humidification ويقل زيادة , ولما يدخل ال Alveoli يقل بعد اكثر فا بالتالي ال PO2 اللي بالدم راح يقل ويسبب ال hypoxia

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 (for 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.

كل هذي الاعراض تصير للشخص اللي مو متأقلم يعيش بمناطقع عالية ، زي اللي يبي يحطم رقم قياسي.

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

1

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 O2 concentrations than when they ascend rapidly. This phenomenon is called acclimatization.

يعني اذا رقيت شوي شوي خلال ايام بدال ساعات بتلاحظ انك تتنفس بشكل افضل و اعمق
وتقدر تتحمل نقص الاكسجين و هذي هي باختصار ال acclimatization

2

The reason for acclimatization is that, within 2 to 3 days, the respiratory center in the brain stem loses about four fifths (80%) of its sensitivity to changes in PCO2 and hydrogen ions.

Important note :Po2 doesn’t play a major role of control breathing in a normal person
It Must reach below 60 mmHg To stimulate peripheral chemoreceptors

3

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.

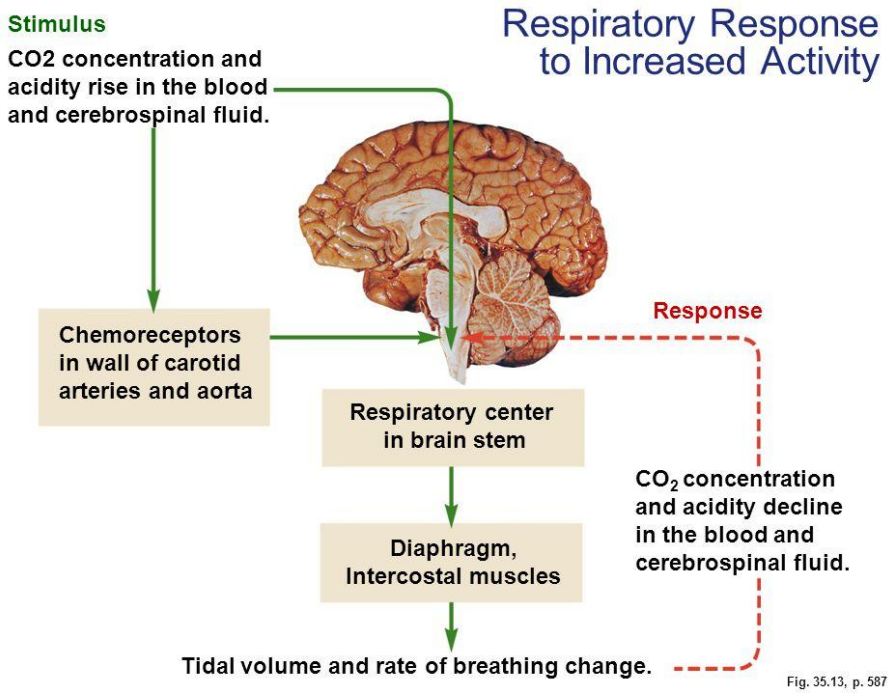
4

The excess ventilatory blow-off of CO2 that normally would inhibit an increase in respiration fails to occur, and low O2 can drive the respiratory system to a much higher level of alveolar ventilation than under acute conditions.

5

Instead of the 70 percent increase in ventilation that might occur after acute exposure to low O2, the alveolar ventilation often increases 400 to 500 percent after 2 to 3 days of low O2, which helps immensely in supplying additional O2 to the mountain climber.

Explanation to previous slide

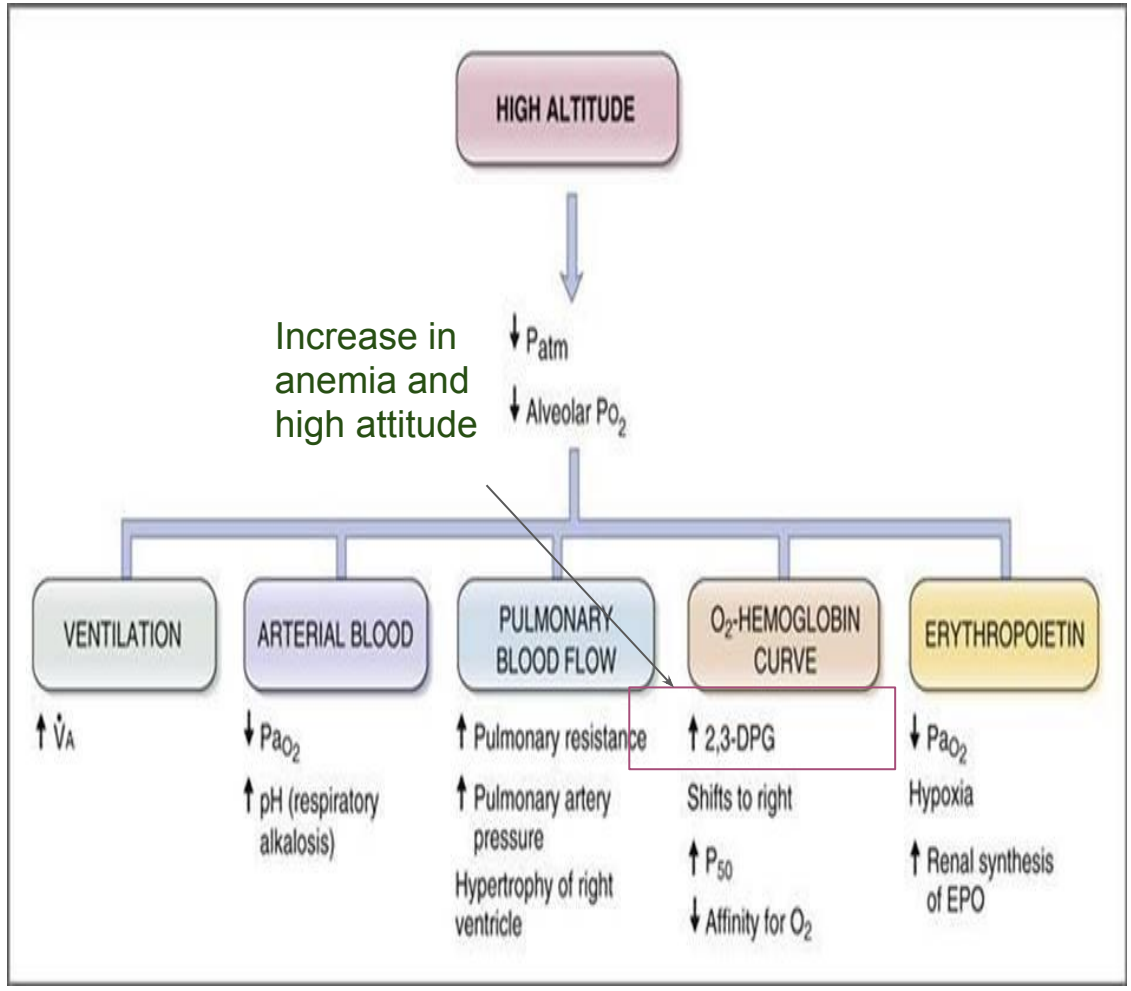


- اول ما الشخص يرتفع مكان عالي في اقل من 2-3 ايام ال peripheral chemoreceptors الموجودة فال carotid and aortic bodies حساسه لنقص ال PO2 اللي بالدم فلما يوصل اقل من 60 تروح تحفز ال respiratory center ويصير hyperventilation
ولكن في مشكلة هي ال Co2 كميته طبيعيه وينتج بشكل طبيعي و مع ال hyperventilation راح يصيرله washing out ويسبب alkalosis لان زي ماحنا عارفين ال co2 مرتبط بال H+ فا اذا قل ال co2 قل H+ ورفعلنا ال PH .
لما يقل ال co2 زي ماقلنا بيقل الH+ وراح يسوي تثبيط لل respiratory center فا راح يكون عندنا قوتين متعاكستين واحد يحفز والثاني يثبط عملية ال hyperventilation .

- طيب كيف راح تنحل هذي المشكلة ؟ عندنا ال respiratory center جدا حساس لاي تغيير بال PCO2 ولكن في غضون 2-3 ايام ال respiratory center راح يبدا يفقد حساسيته تجاه التغيير فال PCO2 يعني راح يتنازل عن المقاييس والمعايير اللي كان حاطها يعني الPH اللي كان 7.3 يرضى انه يكون اقل بشوي وكذالك Pco2 اللي كان 45 يتنازل انه يكون اقل بشوي وبكذا يصير عندنا hyperventilation وكذلك washing out of co2 .

Acclimatization to low PO2

A person remaining at high altitudes for days , weeks or years becomes more and more acclimatized to low PO2.
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.



من صالح الشخص اللي في الhigh attitude يكون shift to the right عشان ال affinity تقل ويتوفر أكسجين للخلايا والأنسجة بسهوله

Principle means of acclimatization

01 Increase in pulmonary ventilation

02 Increased red blood cells

03 Increased diffusing capacity of the lungs.

04 Increased vascularity of the tissues.

05 Increased ability of the cells to utilize oxygen despite the low PO2 through increased number of mitochondria and oxidative enzymes activity.

TABLE 5.4 Summary of Adaptive Respiratory Responses to High Altitude

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)

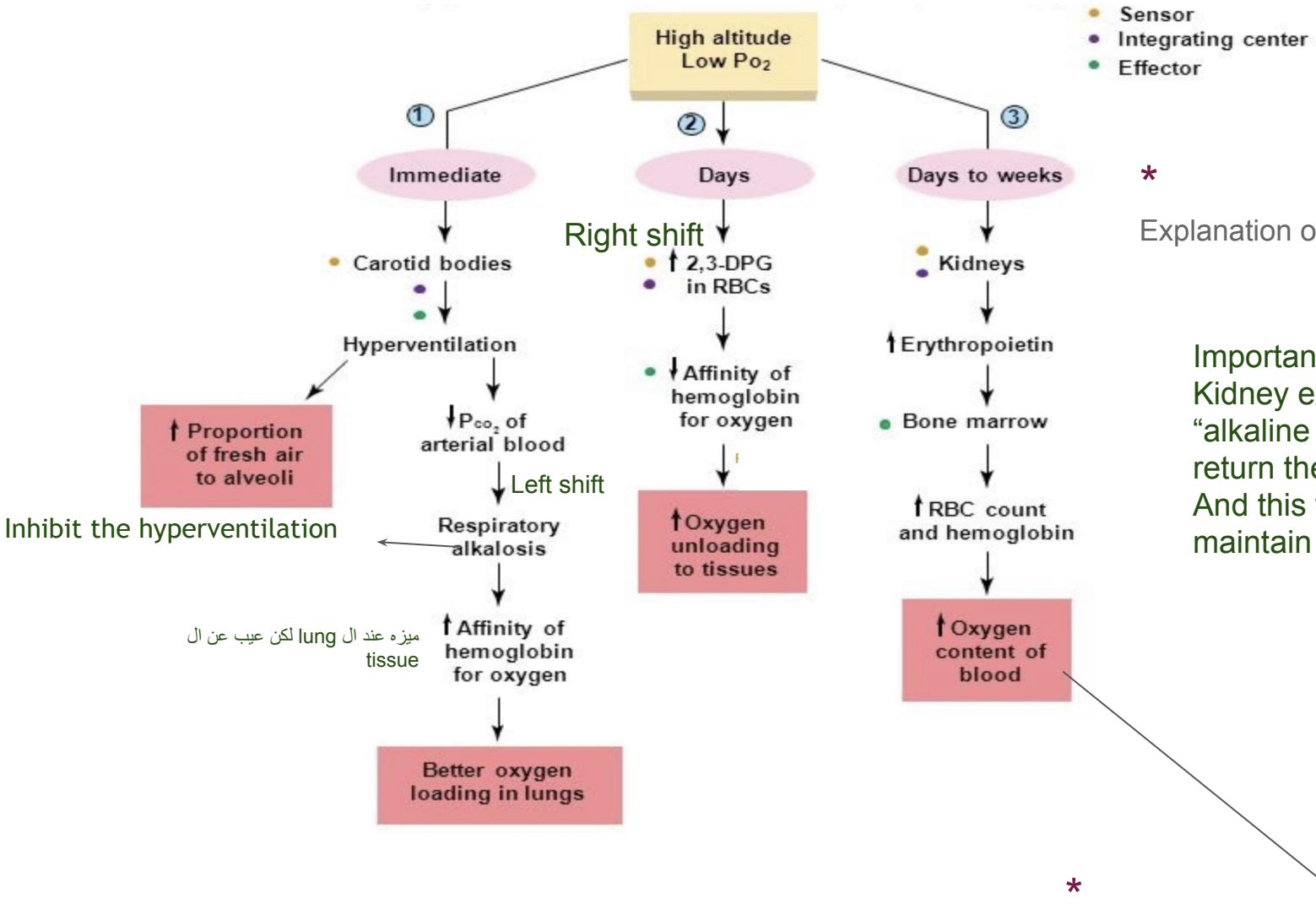
2,3-DPG, 2,3-diphosphoglycerate.

note

Tissue to acclimatize (more capillary)

Cells to acclimatize (more mitochondria and oxidative enzyme)

Important For SAQs



*

Explanation of this point below

Important note:
Kidney excrete more bicarbonate "alkaline in nature" And
return the hydrogen "acid in nature"
And this will decrease The PH,so maintain the hyperventilation

*

More hemoglobin —— more oxygen carrier so more oxygen content

From Linda :Decrease in O2 delivery to the kidney causes increased"production of hypoxia-inducible factor 1α".
Hypoxia-inducible factor 1α directs synthesis of mRNA for EPO, which promote development of more red blood cells and more hemoglobin.
hypoxia-inducible factor 1a= is a growth factor that is synthesized in kidneys in response to hypoxia

Quiz

1.The effect of depth on gases:

A) decreases volume
B) Increases density
C) increases work of breathing
D) increases barometric pressure
E) All of the above

2.Which of the following effects alters electrical conductance and reduces their excitability?

A) Decompression sickness
B) Free radicals
C) Nitrogen narcosis
D) All of the above

3.How do we prevent the lung from collapsing under high barometric pressure (Deep sea diving)?

A) Supply low pressure air.
B) Supply high pressure air.
C) Hyperventilation
D) Hypoventilation

4.The main reason for acclimatization is?

A) loss of sensitivity to changes in CO2 and H+
B) loss of sensitivity to changes in O2
C) increased sensitivity to changes in CO2 and H+
D) increased sensitivity to changes in O2

1)E 2)C 3)B 4)A

SAQS

1. What are the principle means of acclimatization?
2. What are the main factors that maintain hyperventilation?
3. At high altitude what happens to the O2-Hemoglobin dissociation curve?

1. Hyperventilation,increased RBCs,increased diffusion capacity,increased vascularity and increased utilization of O2.
2. washing out of bicarbonate by the kidney and return the H+ PH. decrease the sensitivity of the respiratory center to the Pco2 .
3. First the curve will be shifted to the left due to an increase in affinity, after days the curve will shift to the right due to a decrease in affinity.

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