MEDICINE
KING SAUD UNIVERSITY

Physiology Team 436

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RESPIRATORY
BLOCK

Effects of Low and High Gas Pressure on the Body

Red: very important.
Green: Doctor's notes.
Pink: formulas.
Yellow: numbers.
Gray: notes and explanation.

Physiology Team 436 – Respiratory Block Lecture 10

Lecture: If work is intended for initial studying.
Review: If work is intended for revision.

Objectives

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

Effect of Increased Barometric Pressure (Deep Sea Diving)

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

To prevent the lungs from collapsing, air must be supplied at 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 (i.e. nitrogen narcosis).

* Exposure to high pressure means more O_2 comes in, so there will be an increase in P_{o2}

Cont.

The surrounding pressure increases by 1 atmosphere every 10 meters (33 feet) of depth in sea water (1atm=760mmHg).

Therefore at a depth of 31 meters (100 feet) in the ocean the diver is exposed to a pressure of 4 atmospheres.

Therefore, a person 33 feet beneath the ocean surface is exposed to 2 atmospheres pressure, 1 atmosphere of pressure caused by the weight of the air above the water and the second atmosphere by the weight of the water itself.

How we got the numbers:

You add 1atm every 10 meters below sea level:

31 meters /10 meters =3

3*1atm(in water) + 1atm(above water) = 4atm

* It has amount an of O_2 which will give the diver the same PO_2 at the depth he is going to (يعني بيعطي ضغط نفس الضغط اللي بيجيه لو نزل للعمق اللي يبغاه، بيصير فيه توازن بالتالي ما يصير شي للرئة)

At 66 feet, the pressure is 3 atmospheres, and so forth..
These problems confront SCUBA (Self Contained Under Water Breathing Apparatus)*

Effect of Increased Barometric Pressure (Deep Sea Diving)

Effect of depth on the volume of the gases – Boyle's Law:

- Compression of gases to smaller and smaller volumes.
- 1L (sea level)→1/2 L at 33 feet and so on.
- Volume to which a given quantity of gas is compressed is inversely proportional to the pressure.
- This is a principle of physics called Boyle's law, which is extremely important in diving physiology because increased pressure can collapse the air chambers of the diver's body, especially the lungs, and often causes serious damage.

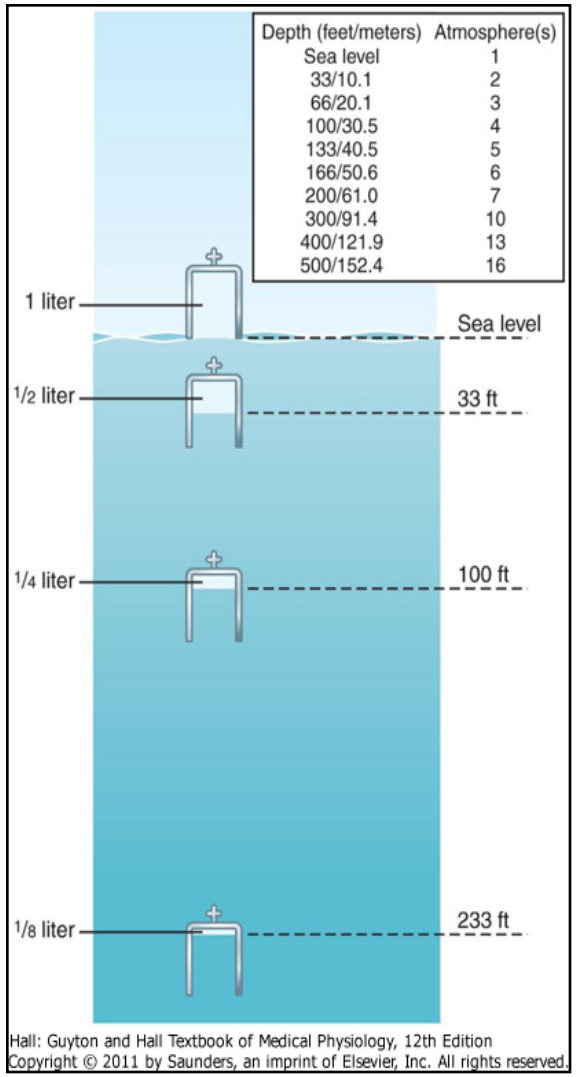
Effect of depth on the density of gases:

- Increase in density of gas and hence increased work of breathing.
- Increase air resistance in the airway like swallowing jelly instead of water

زيادة كمية الضغط بتؤدي إلى تقارب جزيئات وبالتالي بتقل المساحة بين الجزيئات، هذا التقارب يخلي الغاز كثيف جدًا وشبيه بالسوائل

Nitrogen effect at high nitrogen pressure:

- Has 2 principle effects:
- * Nitrogen narcosis (anesthetic effect).
- * Decompression sickness. Results in nitrogen dissolved in the tissues in a liquid form.



Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition

كل ما ننزل ٣٣ قدم الضغط بيزيد واحد وينقص حجم الهواء الي جوا الكاس ب ١/٢

Nitrogen Narcosis

When neurons become less excitable = anesthesia effect.

Nitrogen is a very soluble gas so when it enters through the capillaries it becomes a liquid form in the body with toxic effect

Here nitrogen is shown to have similar effects to alcohol consumption.

Nitrogen like most other anesthetic gases, dissolves 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, and therefore reduces their excitability and subsequent narcosis develops.

ONLY IN MALES' SLIDES

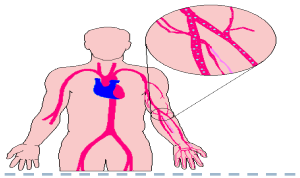
- About 4/5 of the air is nitrogen. At sea-level pressure, the nitrogen has no significant effect on bodily functions but at high pressures it can cause varying degrees of narcosis.
- Nitrogen narcosis has characteristics similar to those of alcohol intoxication.

At 120 feet: The diver exhibits cheerful behavior and loses his cares.

At 150-200 feet: There is a feeling of euphoria يكون فرحان جدًا كأنه ماخذ مخدر and drowsiness دوخه and impaired performance.

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

Decompression Sickness (Cassion's Disease)



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

وبين كل ارتفاع أخليه شوي ما أرفعه عشان أقدر أخلي النيتروجين يطلع من جسمه بسهوله)، الطريقة الصحيحة هي إني أرفعه بشوي شوي،

Upon Ascent

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

During slow ascent (decompression is fast) 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 Cassion's disease)

During fast ascent (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.

The high partial pressure of nitrogen (encountered when breathing compressed air at depth) forces this poorly soluble gas into solution in body tissue particularly in fat (it has a high N_2 solubility).

Upon Descent

Decompression Sickness (Cassion's Disease) (The Bends)

- Breathes air under high pressure for a long time -> **nitrogen dissolved in the body fluids increases.**

- And because nitrogen is **not metabolized by the body**, it remains dissolved in all the body tissues until the nitrogen pressure in the lungs is decreased back to some lower level, however, **this removal often takes hours to occur** and **is the source of multiple problems** collectively called **decompression sickness.**

- If the diver suddenly comes back to the surface of the sea, **nitrogen bubbles can develop** in the body fluids either intracellularly or extracellularly -> **decompression sickness**.

- Due to decompression, gases can escape from the dissolved state and form actual bubbles; in both tissues and 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)

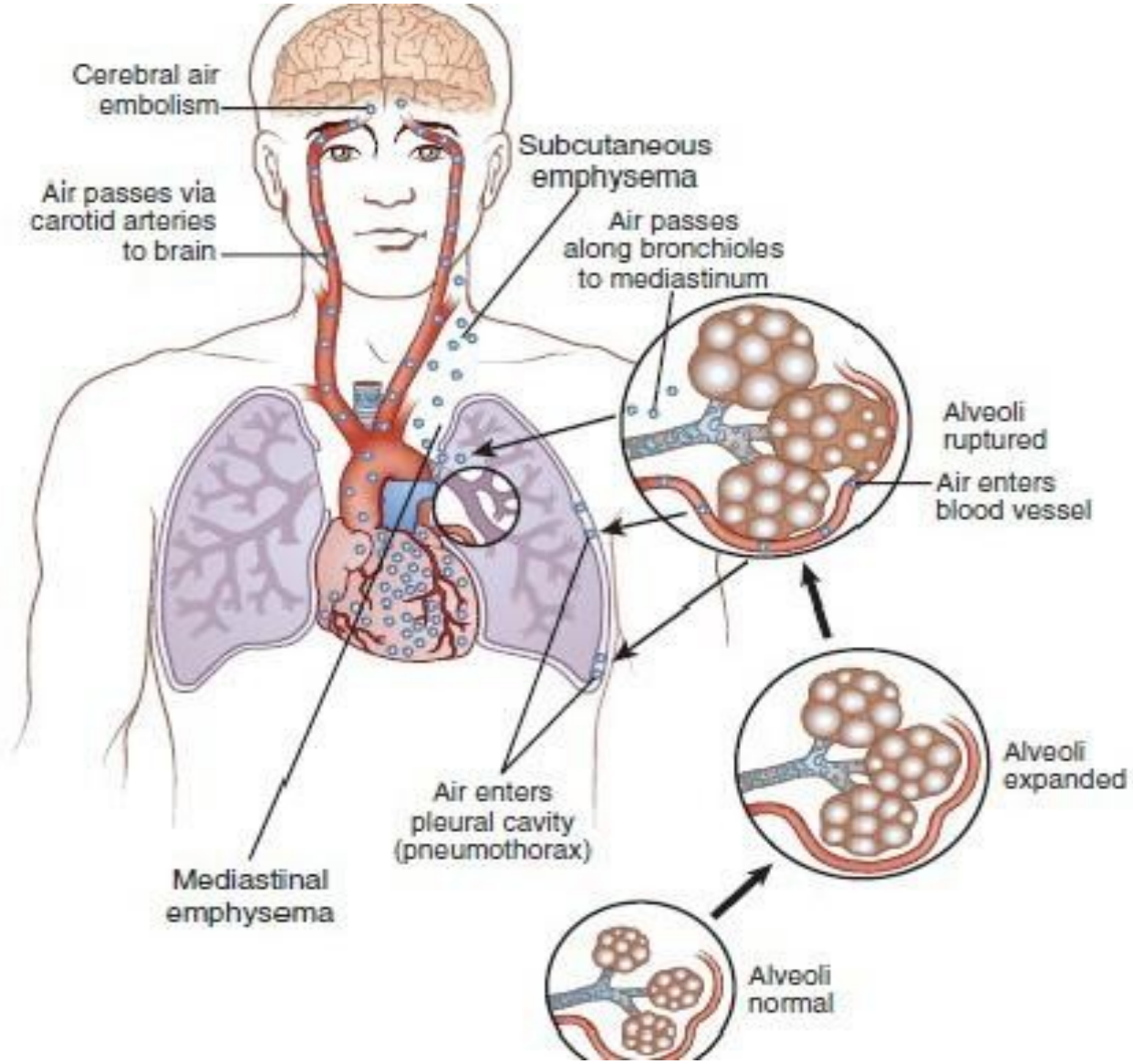


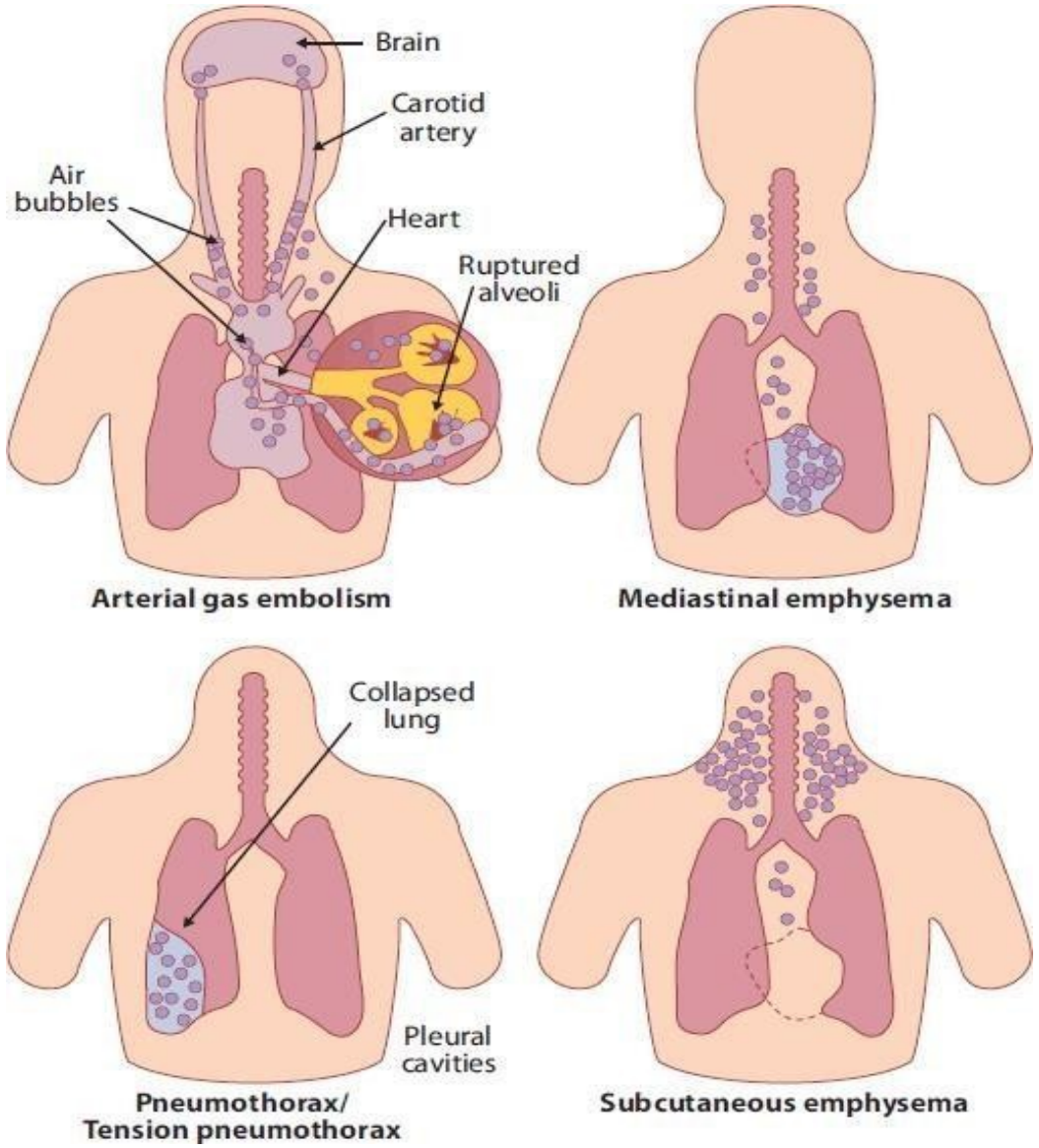
- The **mildest** form of DS is

1. **Fatigue or drowsiness** after decompression.
2. **Local skin itch.**

- Other **severe** symptoms may occur e.g.:

1. **Bubbles in the tissues** cause severe pain particularly around the joints (counts for the term bend).
2. **Neurological symptoms** include paresthesia (numbness and tingling)تنميل , itching, paralysis, and inner ear disturbances.
3. **Thoracic pains:** Dyspnea (shortness of breath), substernal pain, cyanosis and cough.
4. **Bubbles in coronary arteries** may cause myocardial damage (because the bubble will close the blood vessel).
5. **Decompressing sickness shock:** capillaries become permeable to plasma and hypovolemia (decrease in blood volume) rapidly develop.
6. **Edema** may be prominent, shock is usually complicated by pulmonary edema.


Cerebral air embolism
Subcutaneous emphysema
Air passes via carotid arteries to brain
Air passes along bronchioles to mediastinum
Alveoli ruptured
Air enters blood vessel
Alveoli expanded
Air enters pleural cavity (pneumothorax)
Mediastinal emphysema
Alveoli normal


Brain
Carotid artery
Air bubbles
Heart
Ruptured alveoli
Arterial gas embolism
Mediastinal emphysema
Collapsed lung
Pleural cavities
Pneumothorax/ Tension pneumothorax
Subcutaneous emphysema

Treatment of Decompression Symptoms

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

(Thus simulating what would have happened if the diver was decompressed slowly)

- This reduces the volume of the bubbles and forces them back into solution.
- In very deep dives, the risk of decompression sickness can be reduced if a helium-O_2 mixture is breathed during the dive.

Put the diver into a pressurized tank to lower the pressure gradually back to normal atmospheric pressure, by using this time schedule:

10 minutes at 50 feet depth

17 minutes at 40 feet depth

19 minutes at 30 feet depth

50 minutes at 20 feet depth

84 minutes at 10 feet depth

ONLY IN MALES' SLIDES

Cont.

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

- 1/4-1/5 the narcotic effect of nitrogen on CNS.
- 1/7 the molecular weight of nitrogen.
- Low density leading to decreased airway resistance of diver.
- High diffusion through tissues (so it easily diffuses from capillary to alveoli and leaves the body).
- 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 (avoiding decompression sickness).

High Altitude (Low Pressure)

Table 43-1. Effects of Acute Exposure to Low Atmospheric Pressures on Alveolar Gas Concentrations and Arterial Oxygen Saturation*

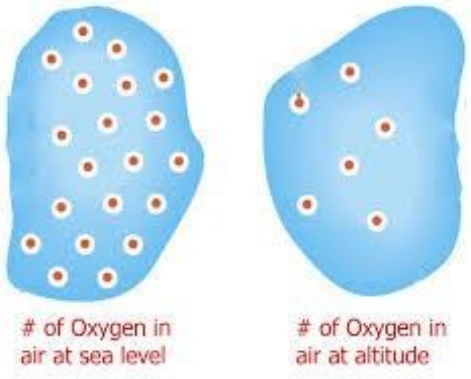
			Breathing Air			Breathing Pure Oxygen		
Altitude (ft/meters)	Barometric Pressure (mm Hg)	P_{O_2} in Air (mm Hg)	P_{CO_2} in Alveoli (mm Hg)	P_{O_2} in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)	P_{CO_2} in Alveoli (mm Hg)	P_{O_2} in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)
0	760	159	40 (40)	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

*Numbers in parentheses are acclimatized values.

Effects of Low Oxygen Pressure on the Body (Aviation-Ascend to High Altitude)

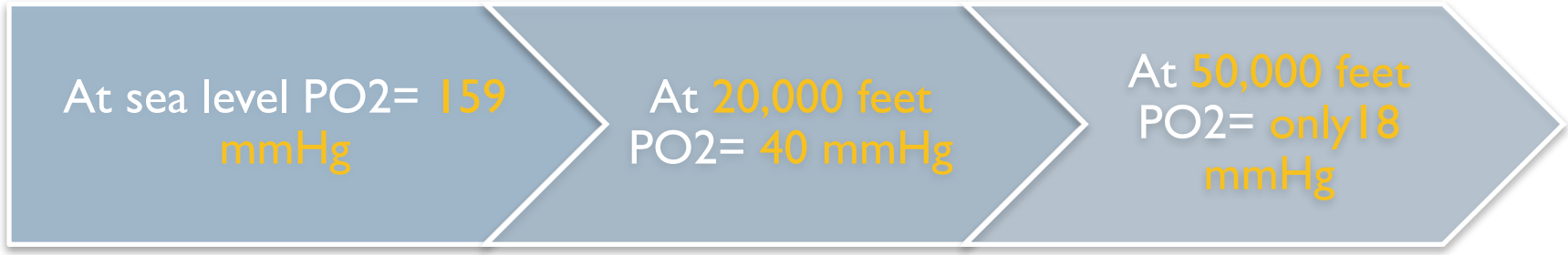
- At the sea level the **barometric pressure** (another term for atmospheric pressure) is 760 mmHg
- At 10,000 feet is 523 mmHg
- At 50,000 feet 87 mmHg.

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



Alveolar PO2 at Different Altitudes

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



- At high altitudes, carbon dioxide is continuously excreted from the pulmonary blood into the alveoli. Also, water vaporizes into the inspired air from the respiratory surfaces.
- These two gases dilute the oxygen in the alveoli, thus reducing the oxygen concentration, therefore, **hypoxia develops.** (CO2 + water vapor dilutes o2 → hypoxia.)

Effects of Acute Hypoxia

At 12000 feet

- Drowsiness
- Lassitude ارهاق
- Mental and muscle fatigue
- Headache sometimes
- Occasionally nausea
- Euphoria (happiness) sometimes

Above 18000 feet

- All the effects at 12000 and

1. Twitching
2. Convulsions (contraction of big muscles)

Above 23000 feet

- Coma (the un-acclimatized person)
- Shortly followed by death

عشان كذا لمن يبغى شخص يطلع مرتفعات لازم يدرب نفسه على التسلق بارتفاع قليل بعدين ارتفاع أكثر فأكثر وهكذا، عشان يتعود جسمه

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

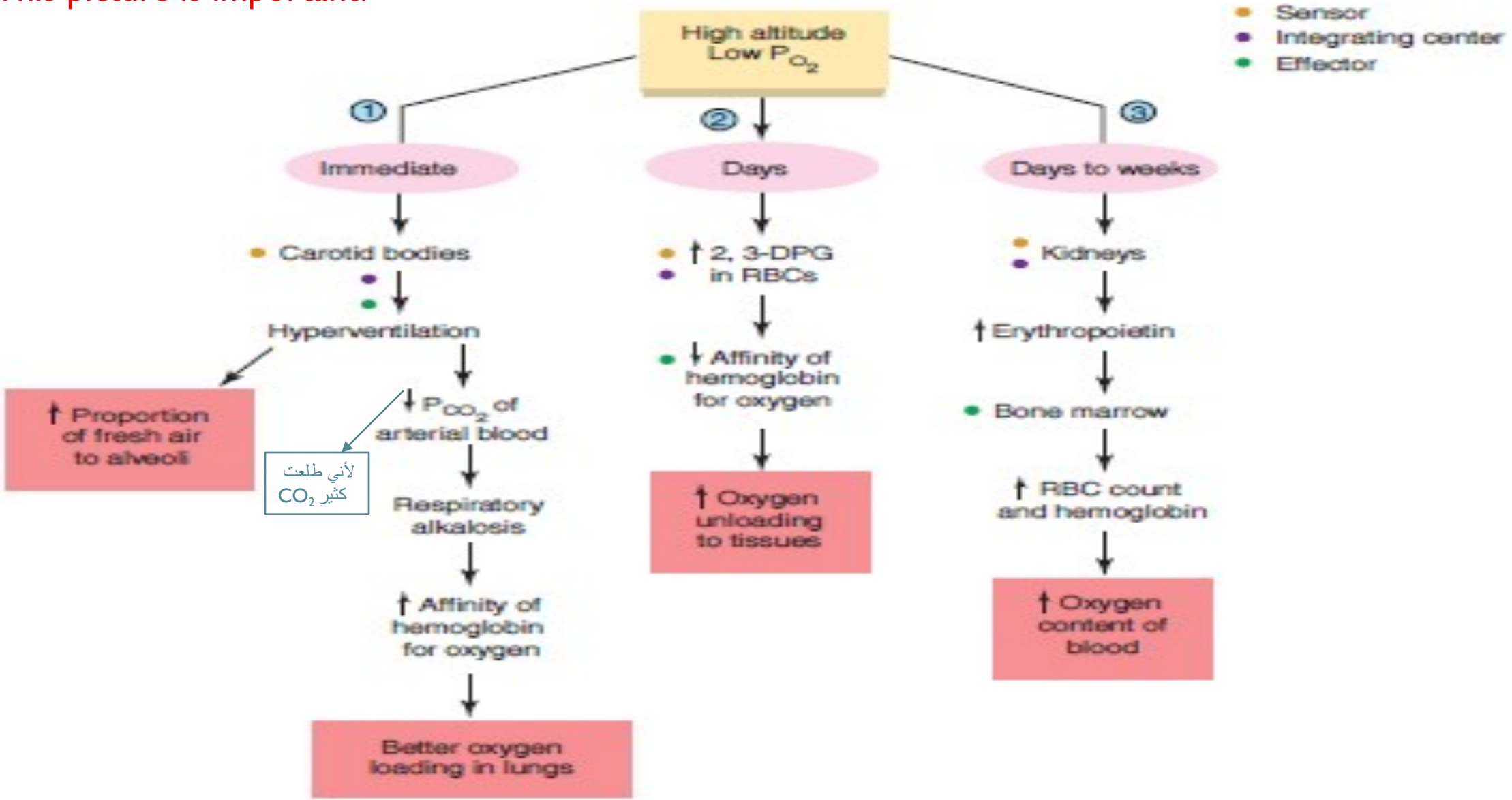
Acclimatization to Low PO2

- A person remaining at high altitudes for days, weeks or years becomes more and more acclimatized to low PO2. Acclimatization is important to prevent or have fewer deleterious effects on the body so it becomes possible for the person to work harder without hypoxic effects or to ascend to a higher altitude.

- **Principle means of acclimatization:**

1. Increase in 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 PO2.

*This picture is important!



Quiz

- https://www.onlineexambuilder.com/lecture-10/exam-129895

Link to Editing File

(Please be sure to check this file frequently for any edits or updates on all of our lectures.)

References:

- Girls' and boys' slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

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