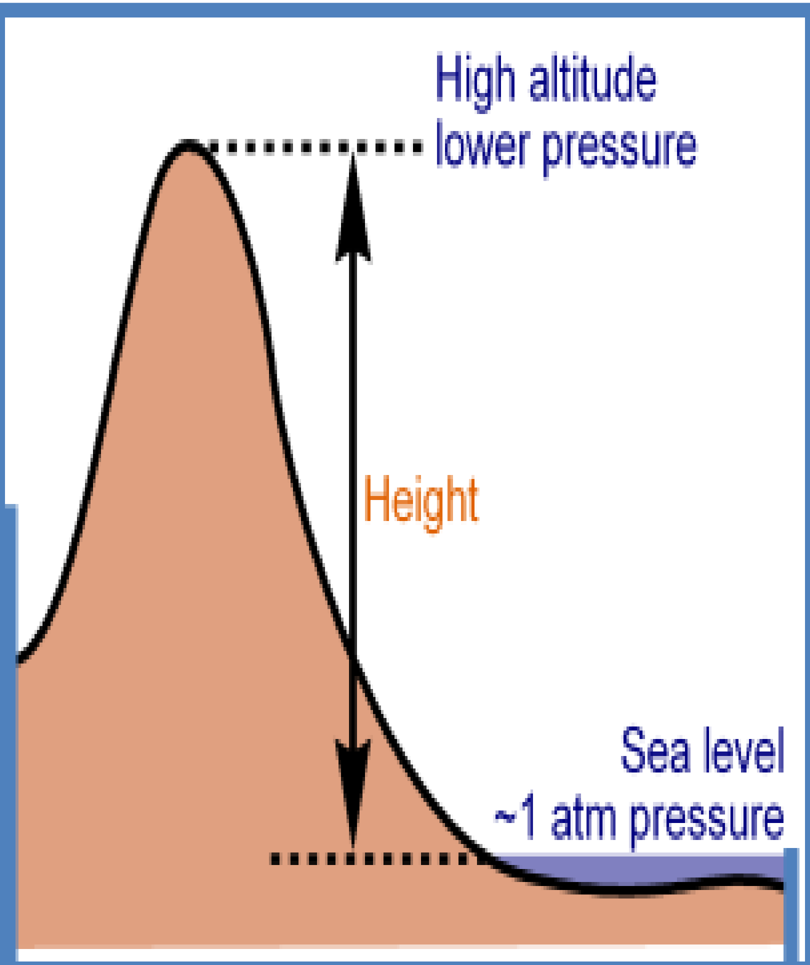
MSc II YEAR

III UNIT

HIGH ALTITUDE

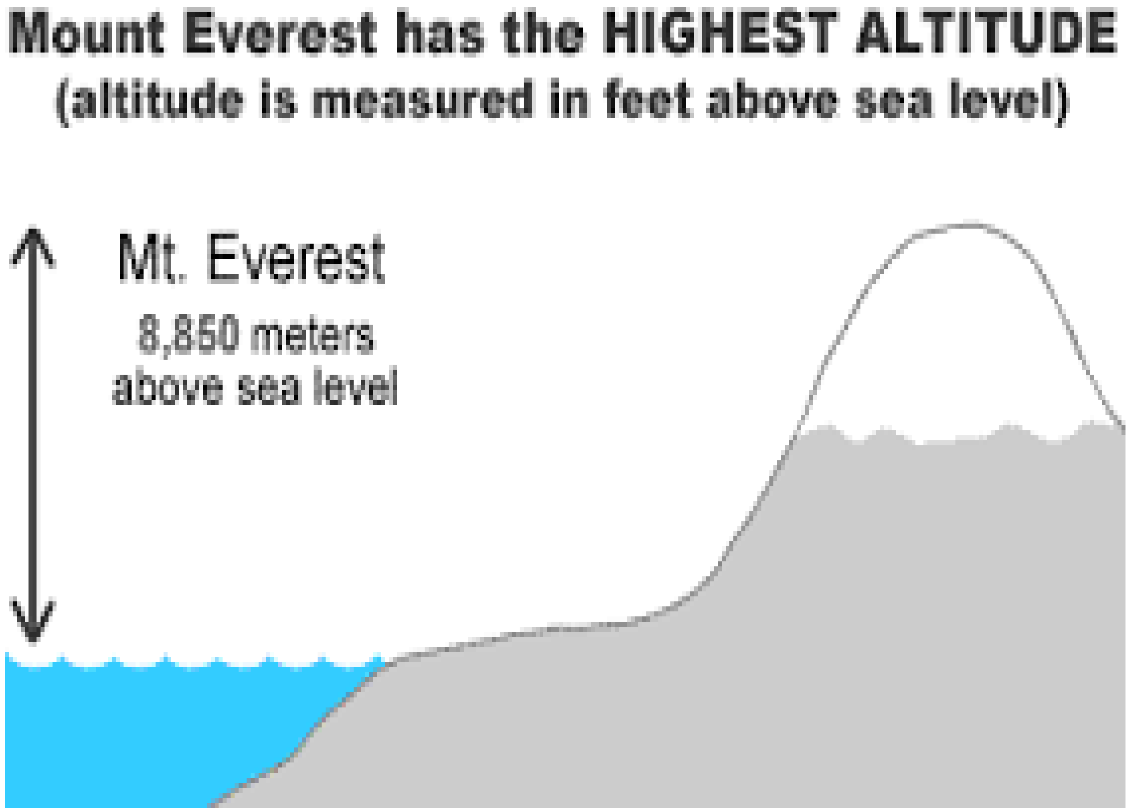
people are most comfortable with **barometric pressure** of 30 inches of mercury (inHg). When it rises to 30.3 inHg or higher, or drops to 29.7 or lower, the risk of heart attack increases.

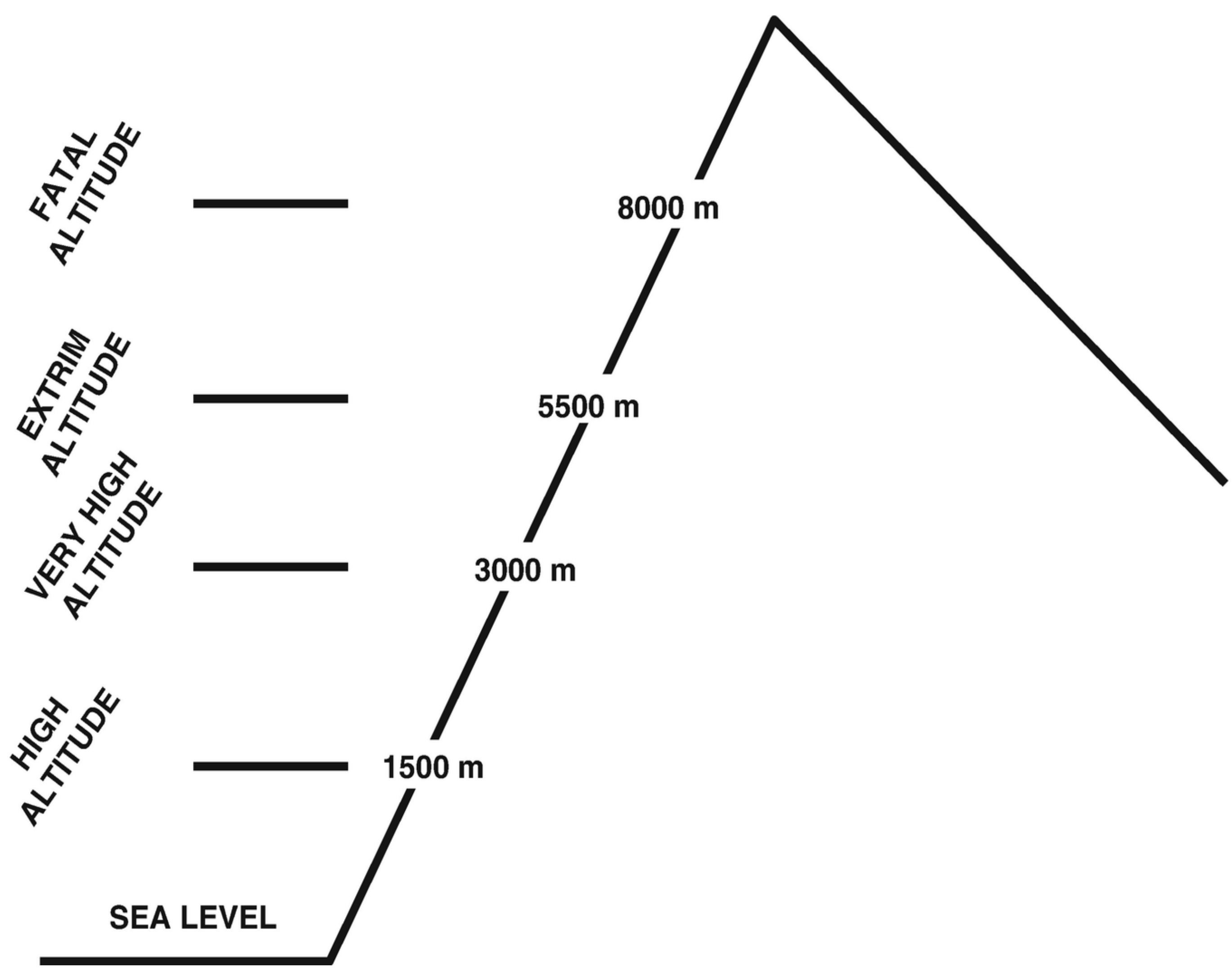


The depth (distance from top to bottom) of the atmosphere is greatest at sea level and decreases at higher altitudes.
With greater depth of the atmosphere, more air is pressing down from above. Therefore, air pressure is greatest at sea level and falls with increasing altitude.

Barometric pressure is the weight of the atmosphere that surrounds us. Barometric pressure often drops before bad weather. Lower air pressure pushes less against the body, allowing tissues to expand. Expanded tissues can put pressure on joints and cause

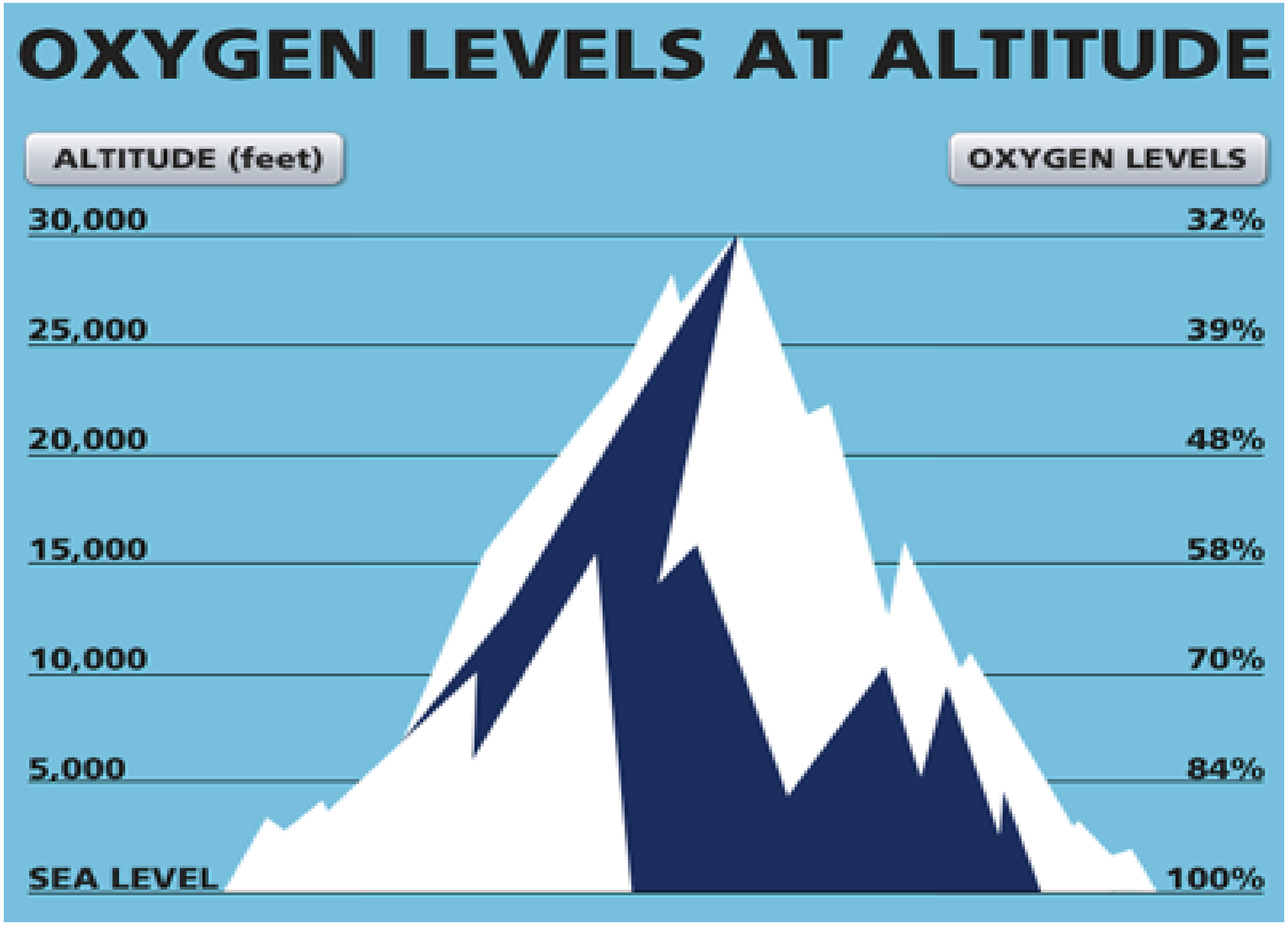
29,029 feet


Mount Everest has the HIGHEST ALTITUDE
(altitude is measured in feet above sea level)
Mt. Everest
8,850 meters
above sea level


FATAL ALTITUDE
8000 m
EXTRIM ALTITUDE
5500 m
VERY HIGH ALTITUDE
3000 m
HIGH ALTITUDE
1500 m
SEA LEVEL

Altitude	Air Pressure (PSI, or pounds per square inch)
Sea level	14.7 PSI
10,000 feet (3,048 meters)	10.1 PSI
20,000 feet (6,096 meters)	6.8 PSI
30,000 feet (9,144 meters)	4.4 PSI
40,000 feet (12,192 meters)	2.7 PSI

air contains 20.9% **oxygen** at all **altitudes**, lower **air** pressure at high **altitude** makes it feel like there is a lower percentage of **oxygen**.



HIGH ALTITUDE DIFFER FROM SEA LEVEL

- 1. Atmospheric Pressure is low at high altitude.
- 2. Partial Pressure of O2 is low(PO2).
- 3. Environmental temperature is low (it decreases by2 degree C for every 300 mts.
- 4. Wind Velocity is high.
- 5. The acceleration due to gravity decreases by 0.3 cm/sec2 for every 1000m of altitude.

Physiological responses to high altitude hypoxia:

- Divided into following two---

I) Acute responses (accommodation)

II) Long term responses (acclimatization)

<u>Accomodation</u>

Refers to immediate reflex adjustments of respiratory and cardiovascular system to hypoxia

<u>Acclimatization</u>

Refers to changes in body tissues in response to long term exposure to hypoxia

Acclimatisation

1. Partial Pressure of o2 at an altitude of 2500 m is about 76mm. of Hg as compared to 103mm.of Hg at sea level.
2. In such conditions Blood supplied to the lungs is 90% saturated as compared to 97% saturation at sea level.
3. It causes impairment of diffusion capacity of the lungs.
4. To overcome this there are certain changes occur in the body in various system.

Respiratory system

- Breathing becomes faster and deeper i.e hyper ventilation starts during rest and exercise. Hyperventilation washes away carbon dioxide from the body. Low carbon dioxide level further stimulate the respiration.

Acclimatization at high altitude:

- Various physiological readjustments and compensatory mechanisms in body that reduces the effects of hypoxia in permanent residents at high altitude.
- It is done by-
  - A great increase in pulmonary ventilation
  - Increase diffusion capacity of lung
  - Increased ability of the tissue cells to use O_2
  - Increased vital capacity

ACCLIMATIZATION AT HIGH ALTITUDE:

Air → Lungs → Blood → Tissue

- Delivery of atmospheric O2 to the tissues normally involve 3 stages---with a drop in PO2 at each stage.
- When the starting PO2 is lower than normal, body undergoes acclimatization so as to—

(i)↓ pressure drop during transfer
(ii)↑ oxygen carrying capacity of blood
(iii) ↑ ability of tissues to utilize O2

- With longer stay at high altitude ,body is able to adjust by certain physiological adaptations..

Cardiovascular system

- The hematological changes further enhance the transport of oxygen from lungs to the tissues.
- 1. Hemoglobin concentration increases up tp 30%.
- 2. Red blood cell increases and cause hemoconcentration.
- 3. Cardiac output increases, this increase in cardiac output amounts to 1% at an altitude of

  5500m.

. Heart rate at maximal and submaximal exercise is increased.

Long term adaptation

- Within 2-3 weeks, cellular level changes occur;
- 1. increased mitochondrial enzymes.
- 2. Increase in hemoglobin formation.
- 3. increase in myoglobin.

All these changes help in the oxygen transport and utilization at the cellular level.

Time of acclimatization

- It depends on the height of altitude 3 to 4 weeks are required for adaptation at 3000 m. Generally, acclimatization for competitive events should be longer as the altitude becomes higher.

the importance of training at altitude

- Physiologist and coaches have tried to find out whether an individual trained at moderate altitude shows a considerable increase in physical work capacity and also the performance, whether these changes persist for a period till the competition?

Aerobic Process

- The training at altitude results in increased level of hemoglobin, red blood cells, blood volume, mitochondrial enzyme as a result of this VO2 max is improved.
- Majority of scientists have reported controversial findings.
- They did not find any effect of training on VO2 max at high altitude. Although, changes in heart rate at basal, rest and recovery have been found. These changes are comparable to vigorous training at sea level.

HYPERCAPNIC- HYPOXIC TRAINING

Saunders et al. (2013). 1% Hb increase after altitude training eventually results in .6 - .7% VO2 max increase.

- Zoretić, D., Grčić-Zubčević, N. and Zubčić, K.: THE EFFECTS OF HYPERCAPNIC-HYPOXIC TRAINING.

Cont……

- Again some scientist have shown the improvement in the maximal aerobic capacity by stimulated altitude training. It is not described that how much was the effect of altitude alone.
- The effect of high altitude acclimatization remains only for 1-2 weeks. If the competitions are held within the period, the athlete may have slight edge for oxygen transport system. Athletes may have advantage only if the competition are held at high altitude.

Anaerobic Process

- Blood lactate concentration remains higher at the sub maximal work load at high altitude as compared to the sea level. However, the maximum concentration of lactic acid remains almost same as at sea level. It indicate that anaerobic process stats at relatively lower work load.

Exercise and Sport Performance at Altitude

- **Anaerobic performance unaffected**
  - For example, 100 to 400 m track sprints
  - ATP-PCr and anaerobic glycolytic metabolism
  - Minimal O_2 requirements
- **Thinner air → less air resistance**
  - Improved swim and run times (up to 800 m)
  - Improved jump distances
  - Throwing events, varied effects

Exercise and Sport Performance at Altitude

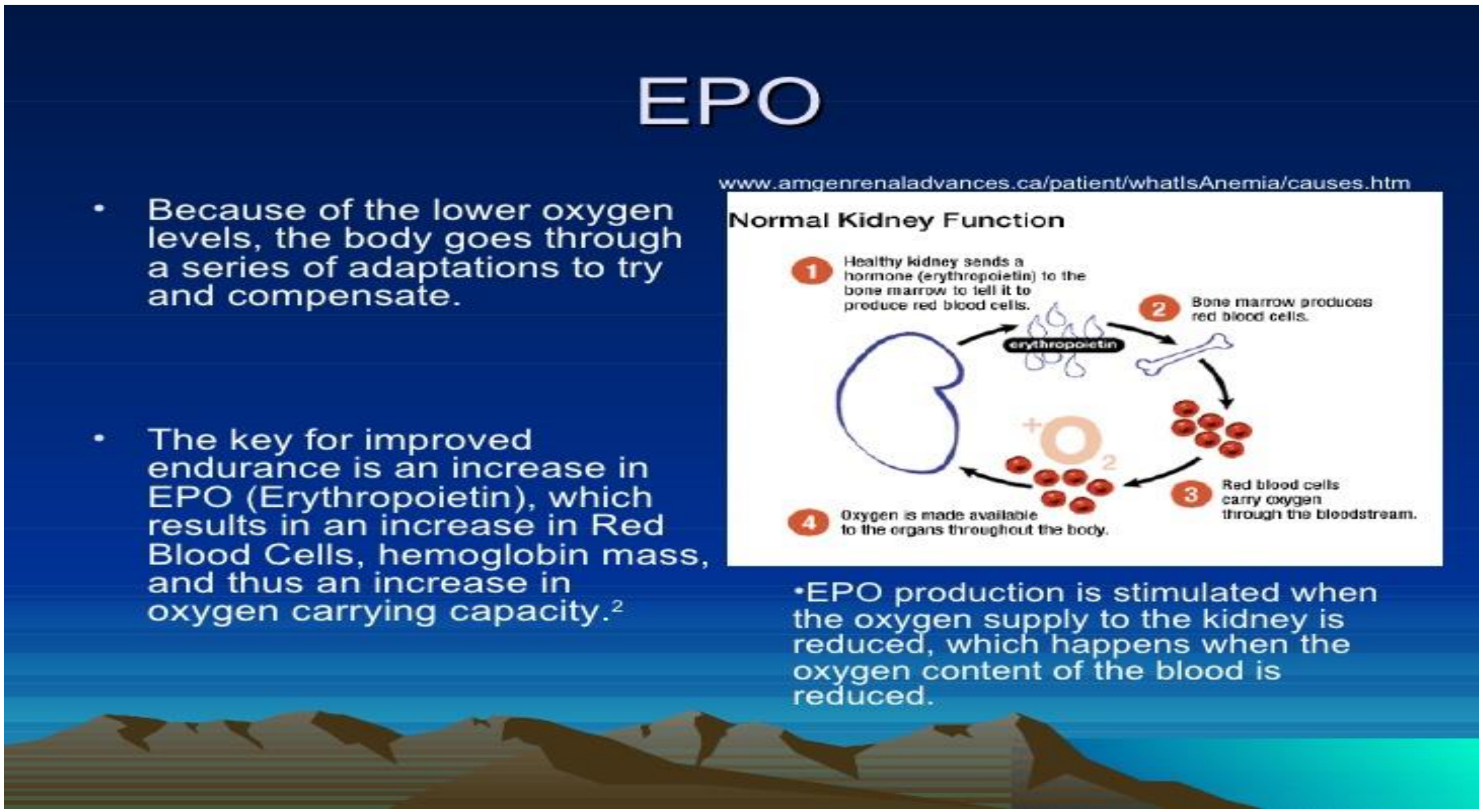
- **$\dot{V}O_{2max}$ ↓ as altitude ↑ past 1,500 m**
  - Atmospheric PO_2 <131 mmHg
  - Due to ↓ arterial PO_2 and $\dot{Q}_{max}$
  - Drops 8 to 11% per 1,000 m ascent
- **Mt. Everest ascent study, 1981**
  - $\dot{V}O_{2max}$ ↓ from 62 to 15 ml/kg/min
  - If sea level $\dot{V}O_{2max}$ <50 ml/kg/min, could not climb without supplemental oxygen

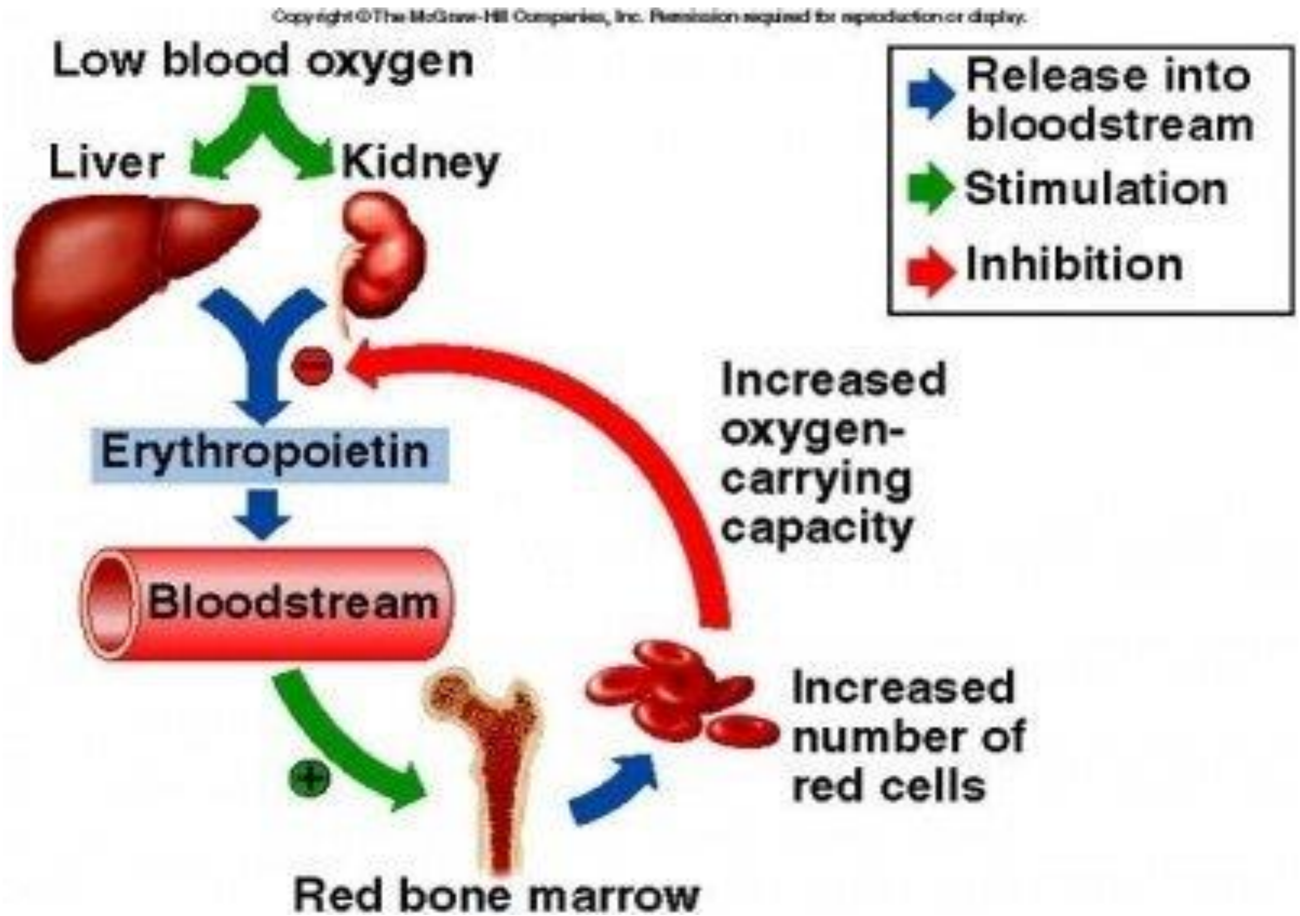
(continued)

Theory behind Altitude Training

- Physiology of High Altitude:
  - At altitude, the partial pressure of oxygen (P O2) is lower than at sea level. Meaning there is less oxygen per volume of air.
  - Rate of diffusion depends on the pressure difference, moving from an area of high concentration to low concentration.
- Oxygen cascade:
  - Is the oxygen driving force (partial pressure of oxygen) from the ambient air to lungs, blood, and cells. Driving force is diminished at altitude, thus rate of diffusion and oxygen cascade is slowed.

Erythropoietin (EPO) is a hormone produced primarily by the kidneys, with small amounts made by the liver. EPO plays a key role in the production of red blood cells (RBCs), which carry oxygen from the lungs to the rest of the body





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Low blood oxygen
Liver
Kidney
Release into bloodstream
Stimulation
Inhibition
Erythropoietin
Increased oxygen-carrying capacity
Bloodstream
Increased number of red cells
Red bone marrow

What is Altitude Training?

- Altitude training is the practice by some endurance athletes of training for several weeks at high altitude
- At this altitude the air still contains approximately 20.9% oxygen, but the barometric pressure and thus the partial pressure of oxygen is reduced
- Depending very much on the protocols used, the body may adapt to the relative lack of oxygen hypoxia
- When the athletes travel to competitions at lower altitudes they will still have a higher concentration of red blood cells for 10-14 days, and this gives them a competitive advantage
- The increase in red blood cells can mean 3% - 5% more speed, endurance, and power

- **What is High Altitude Training?**

- Athletes choose to train at high altitude due to the underlying benefits of intermittent hypoxia training – in essence regular exposure to an environment where oxygen availability is reduced due to natural or artificial methods.
- At higher altitudes (increased height above sea level) as atmospheric pressure decreases, the air has a reduced partial pressure of oxygen, meaning less oxygen is available in the environment to be used by the body.

- The consequence of this change in oxygen pressure is for the body to produce greater amounts of EPO (erythropoietin) in the kidneys, which subsequently means an increase in red blood cells produced. *Theoretically* then, when the athlete competes (at sea level,) there is a greater amount of oxygen carrying red blood cells available and a greater transport of oxygen to the muscles for metabolism.
- There are different specifications as to what is considered “high altitude“- the most commonly used being the Bärtsch classification.
- According to this position statement, altitude above sea level beyond 3000m (*9840 feet)* is considered “high” altitude, with *500-2000m* being “low” altitude and *2000-3000m* being “moderate” altitude. If you ascend above *>5500m* (think about the height of Mount Kilimanjaro) this is considered “extreme” altitude!

Live High- Train Low

- Developed in early 1990's by Dr. Stray-Gunderson and Dr. Levine.
- Sleep high to get EPO, RBC mass increase.
- Train low to keep intensity of training up, and keep neuromuscular adaptations
- Research
  - After 4 wks, Increased VO2max, 5k performance, and RBC (Gunderson)
  - Also, a significant increase in serum EPO concentration, erythrocyte volume (5%) and hemoglobin concentration (9%)
  - All of which were statistically different than the control groups training at sea level or always at altitude.
- Still, there is a very high individual response using this method.

WILBER, R. L. et al. (2007). Effect of Hypoxic "Dose" on Physiological Responses and Sea-Level Performance. *Medicine and* Science in *Sports and Exercise.* 39 (9):1590-1599

Simulated Altitude

- Altitude Tents
- Altitude House
- Intermittent hypoxic Training (IHT)
- Decrease the concentration of oxygen via nitrogen dilution or oxygen filtration.

Intermittent Hypoxic Training

- Athletes train at simulated high altitudes
- Most research has found that there was no increase in EPO or an improvement in endurance performance.
  - Glyde-Julian *et al.* (2004) Intermittent normobaric hypoxia does not alter performance or erythropoietic markers in highly trained distance runners. *Journal of Applied Physiology* 96(5): 1800-1807
  - Rodriquez,F. (2007). Performance of runners and swimmers after four weeks of intermittent hypobaric hypoxic exposure plus sea level training. J Appl Physiol. 103(5):1523-35
  - Roels, B. (2007). Effects of intermittent hypoxic training on cycling performance in well-trained athletes. Eur J Appl Physiol. 101(3):359-68

Altitude Exposure Techniques

- Various techniques have been devised in order to expose the athlete to the beneficial effects of high altitude whilst not reducing their ability to train effectively
- Live High – Train High
- Live Low – Train High
- Live High – Train Low

- The typical altitudes used are around 2000-2500m, which in itself reduces the risk of some of the unhelpful effects of altitude exposure

Live-high, Train-high

- In the live-high, train-high regime, an athlete lives and trains at a desired altitude
- The stimulus on the body is constant because the athlete is continuously in a hypoxic environment
- Maximum exposure to altitude
- Evidence of a positive effect at sea level is controversial
- Less support for this method amongst experts
- After long periods of training at altitude, highly trained athletes returning to sea level do not exhibit increased red blood cell count or improved performance on 4000m cycling tests

Live-low, Train-high

- The athlete is exercising in a low oxygen environment, whilst resting in a normal oxygen environment
- Some interesting findings suggesting that this technique might work
- No good studies showing that the technique makes any difference to the ultimate competitive performance of the athlete at sea-level
- Training intensity is reduced so some athletes may find that they actually lose fitness using this regime.

Live-high, Train-low

- The body will acclimatise to altitude by living there, whilst training intensity can be maintained by training at (or near) sea level
- The beneficial effects of altitude exposure are harnessed whilst some of the negative ones are avoided
- The residence at altitude must be for more than 12 hours per day and for at least 3 weeks
- Improvements in sea-level performance have been shown in events lasting between 8 and 20 minutes
- Athletes of all abilities are thought to benefit
- A non-training elevation of 2,100–2,500 metres (6,900–8,200 ft) and training at 1,250 metres (4,100 ft) or less has shown to be the optimal approach for altitude training

Artificial altitude

- In an effort to reduce the financial and logistical challenges of traveling to altitude training sites, scientists and manufactures have developed artificial altitude environments that simulate the hypoxic conditions of moderate altitude
- Altitude simulation systems have enabled protocols that do not suffer from the tension between better altitude physiology and more intense workouts
- Such simulated altitude systems can be utilized closer to competition if necessary

Methods used for training in hypoxia

- Supplemental Oxygen
- Hypoxic Sleeping Devices
  - CAT Hatch
  - Hypoxic Tent System
- Intermittent Hypoxic Exposure (IHE)
  - IHE at Rest
  - IHE During Exercise

Hypoxic Sleeping Devices

- This systems are designed to allow athletes to sleep high and train low

CAT Hatch

- It is a cylindrical hypobaric chamber
- Can simulate altitudes up to approximately 4575m

Hypoxico Tent System

- This modality can be installed over a standard double or queen-sized bed.
- simulates elevations up to approximately 4270m

Intermittent Hypoxic Exposure (IHE)

- Is based on the fact that brief exposures to hypoxia (1.5 to 2.0 hours) stimulate the release of EPO

- Athletes typically use IHE while at rest or in conjunction with a training session

- The IHE allows the athlete to 'live low-train high'

- Athletes typically use IHE while at rest, or in conjunction with a training session

- Data regarding the effect of IHE on hematological indices and athletic performance are minimal and inconclusive

Application of Altitude/Hypoxic Training by Elite Athletes

RANDALL L. WILBER Athlete Performance Laboratory, United States Olympic Committee,
Colorado Springs, CO

Med. Sci. Sports Exerc., Vol. 39, No. 9, pp. 1610–1624, 2007.

- At the Olympic level, differences in performance are typically less than 0.5%. This helps explain why many contemporary elite endurance athletes in summer and winter sport incorporate some form of altitude/hypoxic training within their year-round training plan, believing that it will provide the competitive edge to succeed at the Olympic level.
- This paper has presented both anecdotal and scientific evidence relative to the efficacy of several contemporary altitude/hypoxic training models and devices currently used by Olympic-level athletes for the purpose of legally enhancing performance.
- Live high + train low altitude training is employed by elite athletes using:
  - Natural/terrestrial altitude
  - Normobaric hypoxia via nitrogen dilution (e.g., nitrogen apartment) or oxygen filtration (e.g., hypoxic tent)
  - Hypobaric normoxia via supplemental oxygen

High Altitude or Nitrogen House

- In Finland, a Finnish sport physiologist Heikki Rusko had designed a "high-altitude house"
  - The air inside the house, which is situated at sea level, is at normal pressure but modified to have a low concentration of oxygen, about 15.3% (below the 20.9% at sea level) - roughly equivalent to the amount of oxygen available at 2,500 m (8,200 ft) altitude
  - Athletes live and sleep inside the house, but perform their training outside (at normal oxygen concentrations at 20.9%)
  - Research conducted by Heikki Rusko on six elite cross-country skiers suggests that training in the nitrogen house is just as effective as training at altitude
  - He found that changes in critical blood markers and submaximal heart rate
  - Lactate were similar among athletes who trained in the nitrogen house compared to athletes who trained at an altitude camp

- Artificial altitude can also be used for hypoxic exercise, where athletes train in an altitude simulator which mimics the conditions a high altitude environment
- Athletes are able to perform high intensity training at lower velocities and thus produce less stress on the musculoskeletal system
- Beneficial to an athlete who suffered a musculoskeletal injury and is unable to apply large amounts of stress during exercise which would normally be needed to generate high intensity cardiovascular training
- Hypoxia exposure for the time of exercise alone is not sufficient to induce changes in hematologic parameters
- Hypoxico Inc pioneered the artificial altitude training systems in the mid 1990s

- Specially designed software ensures the effective use of high altitude climate
- Assisted by the software and several sensors within the hypoxic training room a full automatic control panel processes the climate-data collected and ensures a consistent atmosphere in the cabin
- The hypoxic training is fully acclimatized
- The temperature within the hypoxic training room can be altered before and during the stay or training
- The system also automatically controls the carbon dioxide level in the room keeping the concentration below 0.5 vol % at all times

- Very user friendly for the athletes

- Establishing a pre-selected height in the hypoxic room takes about 30-40 min (for altitudinal levels above 3000m it may take longer but not more than 1 hour)

- At any point of time 6-8 athletes can undergo altitude training within the room

- Within the hypoxia room all types of training equipment can be placed

- A group of athletes with similar physical, physiological & performance parameters can be subjected to altitude training and the response can be compared

Training under artificial altitude conditions

Compared to the training in natural high-altitude settings, training in low-lands brings along the following advantages:

- The habitual day-to-day life can be maintained
- An optimal nutrition can be kept up
- Medical and psychological assistance can be secured
- Independance of weather and climatical conditions
- Avoiding all physical complaints that are being related to low air pressure and extremely dry mountain air

Training under artificial altitude conditions

- Avoidance of long travels and high travel costs
- Providing innovative, methodological solutions for training
- While endurance training can be performed under hypoxia, intensive training can be performed just the same day under normal conditions
- Prior to high-altitutde travels, the training provides the possibility to specifically adapt to the respective atmospherical conditions

SLEEP HIGH, TRAIN LOW EVERYWHERE!

- The altitude house or nitrogen house can be used to simulate moderate altitude living atmosphere at sea level and to stimulate EPO at sea level in athletes, and the living high and training low approach seems to give all the benefits of altitude acclimatization and seems to have the potential to avoid the problems related to normal altitude training

- It seems to provide the best approach for the enhancement of the sea-level performance in athletes

- Can be built almost anywhere as a fixed or mobile facility

- It may be the most cost-effective way to deal with teams of athletes - they offer the athlete a fair, safe and cost effective altitude training system