Use of Altitude/Hypoxic Training by Olympic Athletes

ASPC Americas Continental Forum

Coldeportes High Performance Center
Bogota, COL
29 October – 01 November 2014

Randall L. Wilber, PhD, FACSM
Senior Sport Physiologist
United States Olympic Committee

Gracias / Obrigado!

Kamsa hamnida (Korean)
Danke schön (German)
Ameseginalhu (Ethiopia)
Спасибо (Russian)
Arigato (Japanese)
Asante sana(Swahili/Kenyan)
Meitaki Ma'ata (Maori)
Paldies (Latvian)
Fa'afetai (Samoan)
Dziękuję (Polish)
Terima kasih (Malaysian + Indonesian)
Gracias (Spanish)
धन्यवाद (Hindi)
Dank u wel (Dutch)
Merci beaucoup (French)
شكراً جزيلاً (Arabic)
Kiitoksia (Finnish)
ευχαριστώ (Greek)
Благодаря (Bulgarian)
Grazie (Italian)
Obrigado (Portuguese/Brazilian)
Cheers (Australian / New Zealand)
Mahalo (Hawaiian)
Xie xie (Chinese)
Thank you (English)

Felicitaciones!

"There is no higher ideal for the human race, than promoting peace through international sport."

Baron Pierre de Coubertin
Founder of the Modern Olympic Games

Randall L. Wilber, PhD, FACSM

US Olympic Committee

TRACK/CC COACH (1976-1993)

- Pennsylvania
- Wisconsin
- Florida

SPORT PHYSIOLOGIST (1993-present)

US Olympic Committee

- Salt Lake City 2002
- Athens 2004
- Torino 2006
- Beijing 2008
- Vancouver 2010
- London 2012
- Sochi 2014

US Olympic Training Center
Colorado Springs

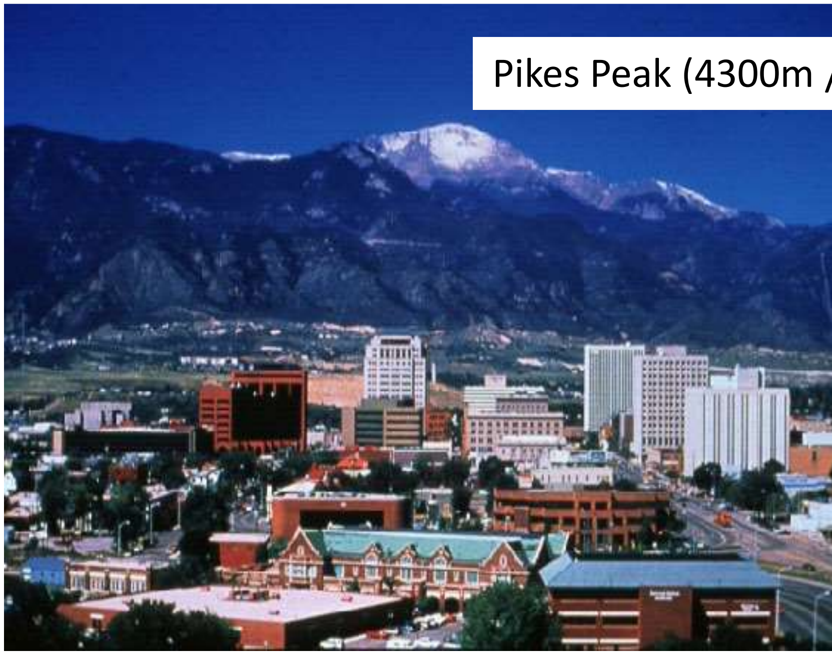

Environmental
Physiology

Use of Altitude/Hypoxic Training by Olympic Athletes

- **Introduction**
- **Altitude Training Models**
  - LH + TH
  - LH + TL
  - LL + TH
- **Practical Recommendations**
  - Preparation Before the Altitude Training Camp
  - During the Altitude Training Camp
  - Return to Sea Level After the Altitude Training Camp
  - Annual Plan for Altitude Training
- **Physiological Benefits**
- **Summary & Resources**

US Olympic Training Center

Colorado Springs



Pikes Peak (4300m / 14,115ft)

Colorado Springs (1885m / 6180ft)

USOC Sport Science Center of Excellence

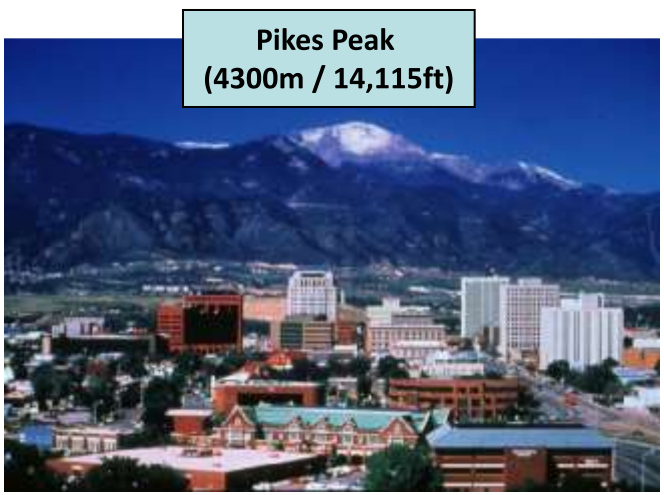
Colorado Springs

USOC Sport Science Center of Excellence

High Altitude Training Center

US Olympic Training Center

Colorado Springs 1860 m / 6200 ft



Colorado Springs
(1860+ m / 6200+ ft)

1

US Olympic Training Center
(1860 m / 6200 ft)

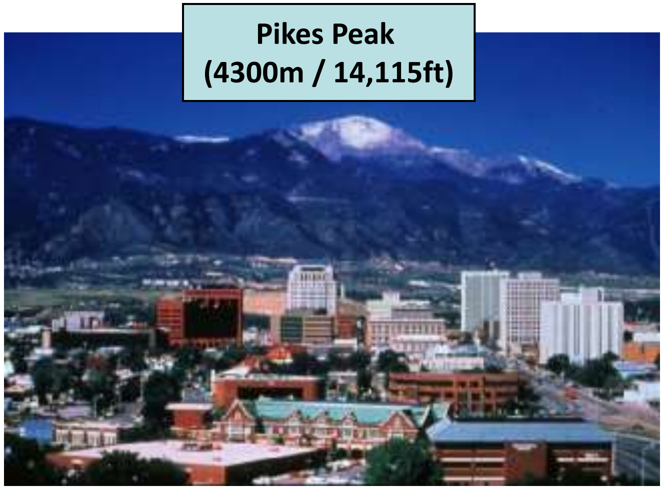
US Olympic Training Center

Colorado Springs 1860 m / 6200 ft

US Air Force Academy

Colorado Springs 2000-2300 m / 6560-7544 ft

US Air Force Academy
(2000-2300 m / 6560-7544 ft)



Colorado Springs
(1860+ m / 6100+ ft)

2

1

US Olympic Training Center
(1860 m / 6100 ft)

US Air Force Academy

Colorado Springs 2000-2300 m / 6560-7544 ft

US Air Force Academy

Colorado Springs   2000-2300 m / 6560-7544 ft

U.S. AIR FORCE

Woodland Park Recreational Area

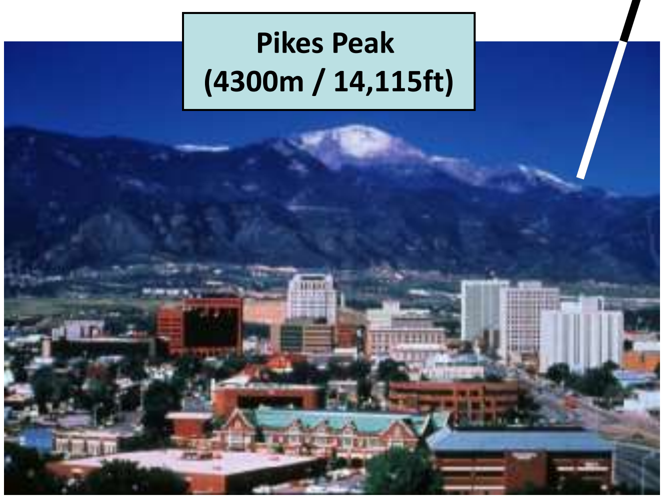
Woodland Park 2745-2775 m / 9000-9100 ft

Woodland Park
(2745-2775 m / 9000-9100 ft)

US Air Force Academy
(2000-2300 m / 6560-7544 ft)

3

2



1

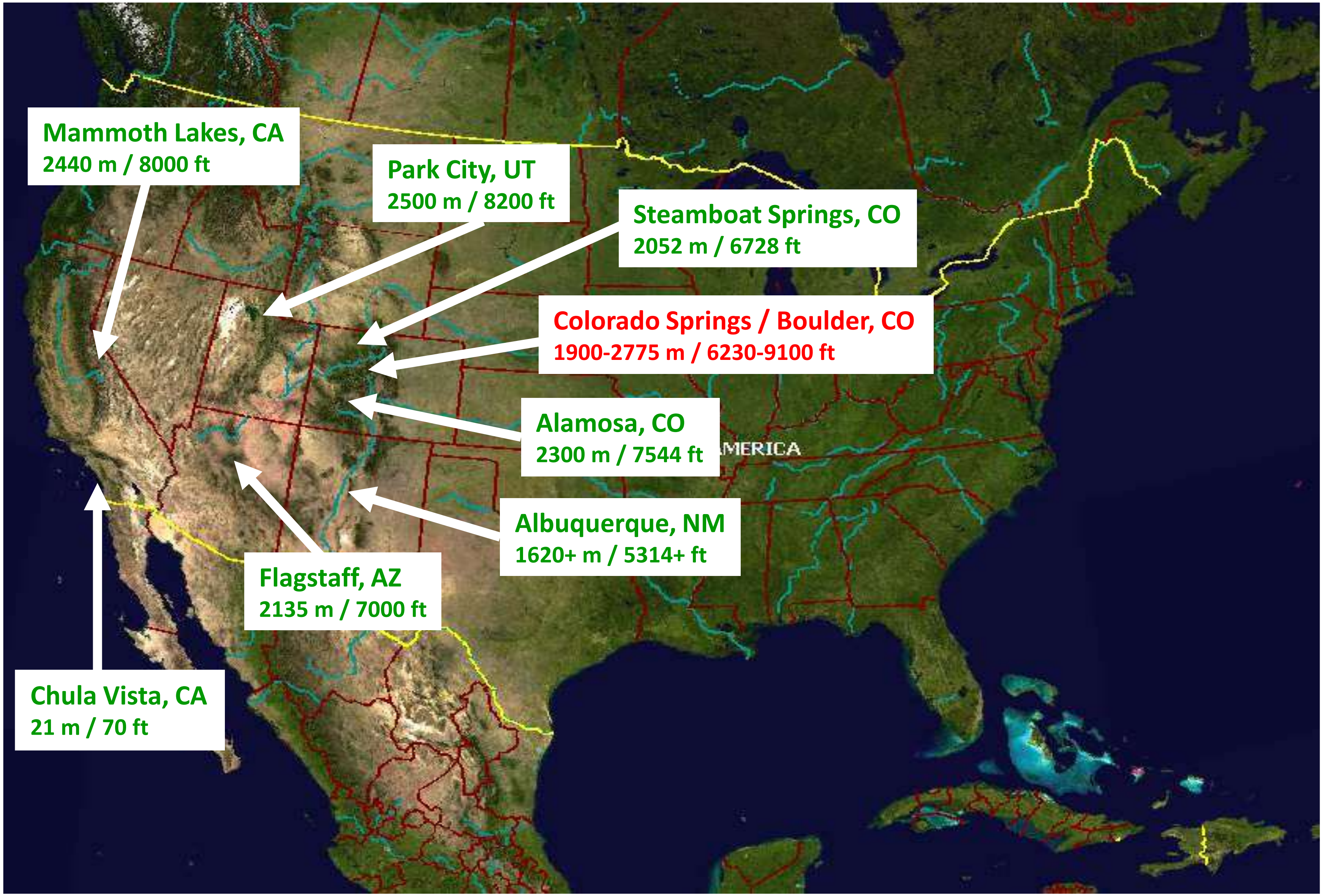
Colorado Springs
(1860+ m / 6100+ ft)

US Olympic Training Center
(1860 m / 6100 ft)

Woodland Park Recreational Area

Woodland Park 2745-2775 m / 9000-9100 ft

Team USA Altitude Training Network



“Altitude” defined

EXTREME/LETHAL Altitude
>7500 m

HIGH Altitude
3000 - 7500 m

MODERATE Altitude
1500 - 3000 m

LOW Altitude
<1500 m

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ALTITUDE / HYPOXIC TRAINING

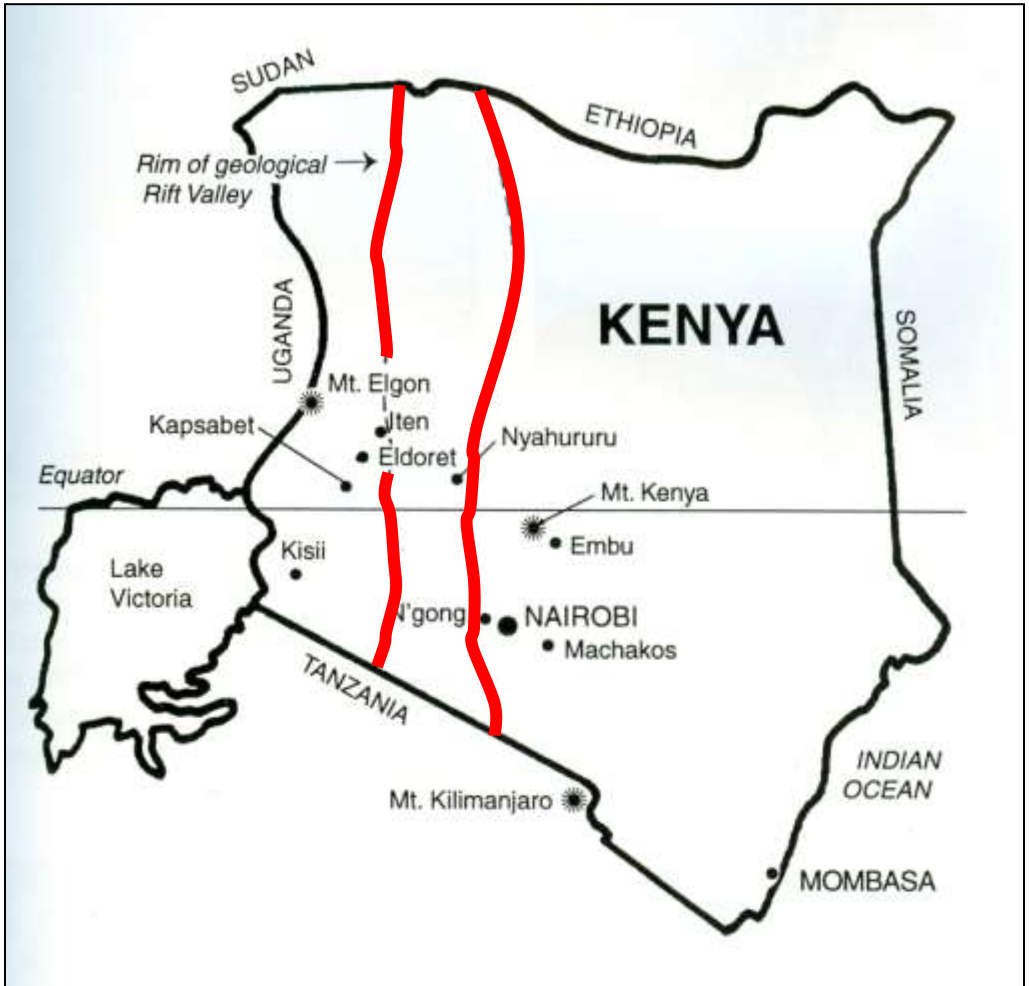
LH + TH


Gebrselaissie
Tergat


27:18.20
27:18.29
0.005%

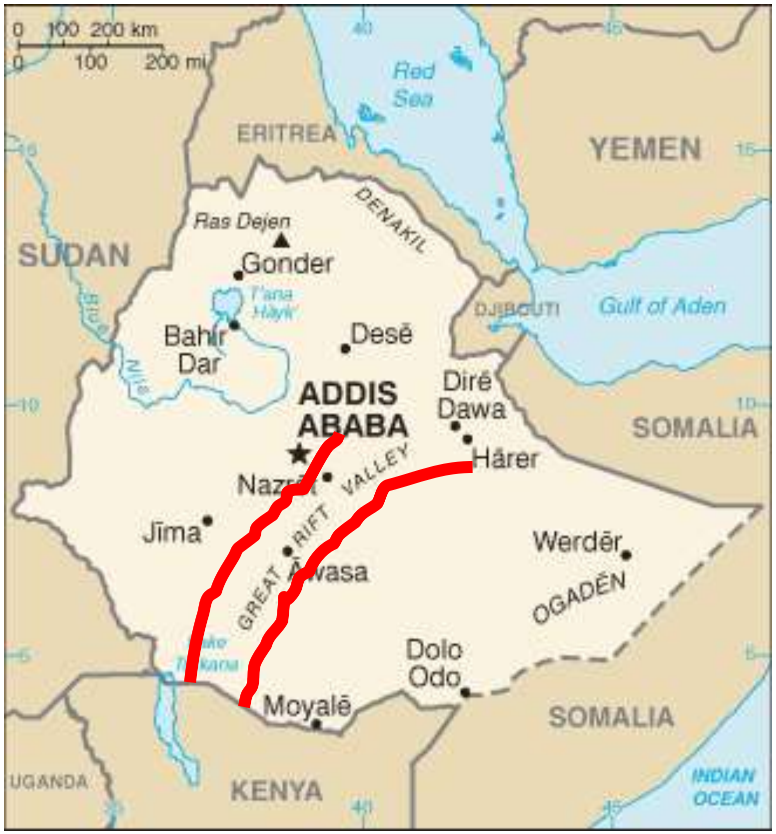
Kenya

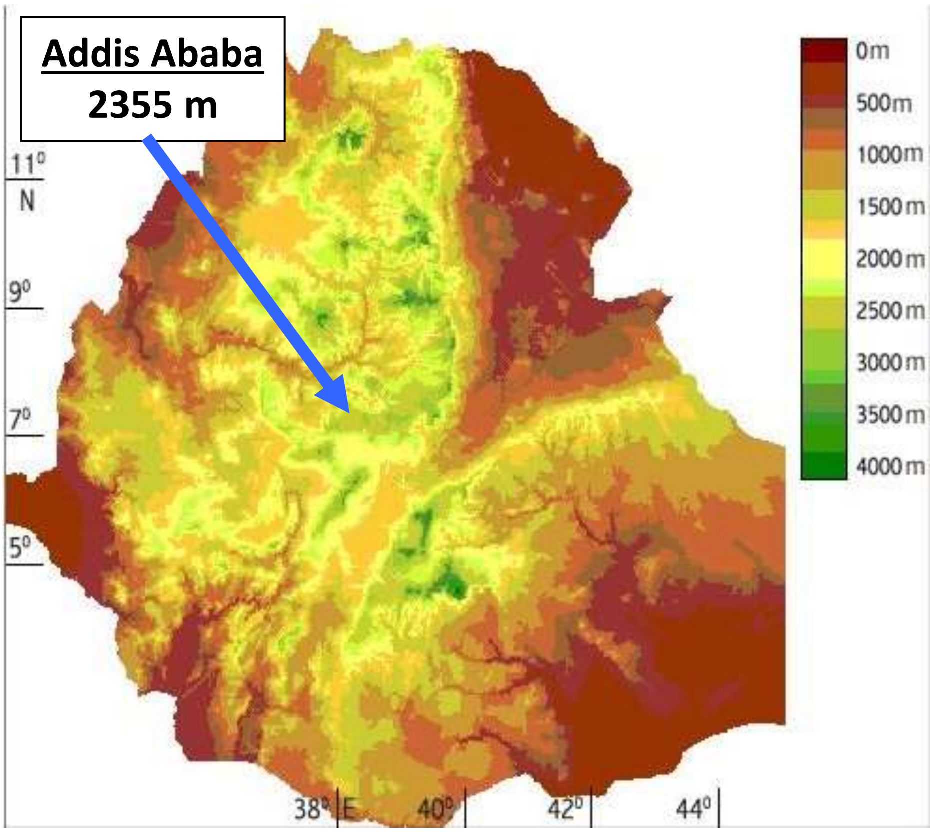
Great Rift Valley (2300 m)



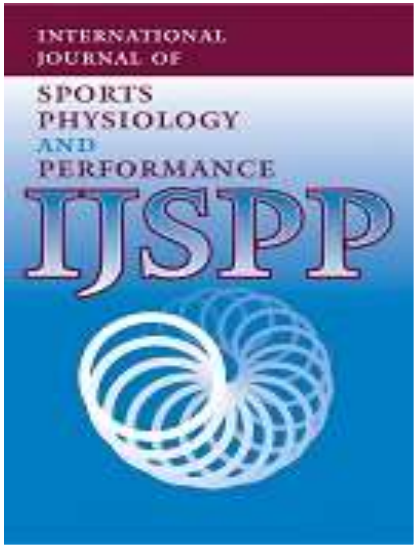
Ethiopia

Great Rift Valley (2300 m)





LH + TH
Kenya and Ethiopia



Kenyan and Ethiopian Distance Runners: What Makes Them So Good?

Randall L. Wilber and Yannis P. Pitsiladis
June 2012

[based on proceedings of 2011 ACSM Annual Meeting]

Kenyan and Ethiopian Distance Runners

Hypothetical Model for Success

Biomechanical & Physiological

Ectomorphic somatotype leading to exceptional biomechanical and metabolic economy.

Kenyan and Ethiopian Distance Runners

Hypothetical Model for Success

Psychological #1

High motivation to succeed for the purpose of improving socio-economic status.

Psychological #2

"Tradition of Excellence"

Kenyan and Ethiopian Distance Runners

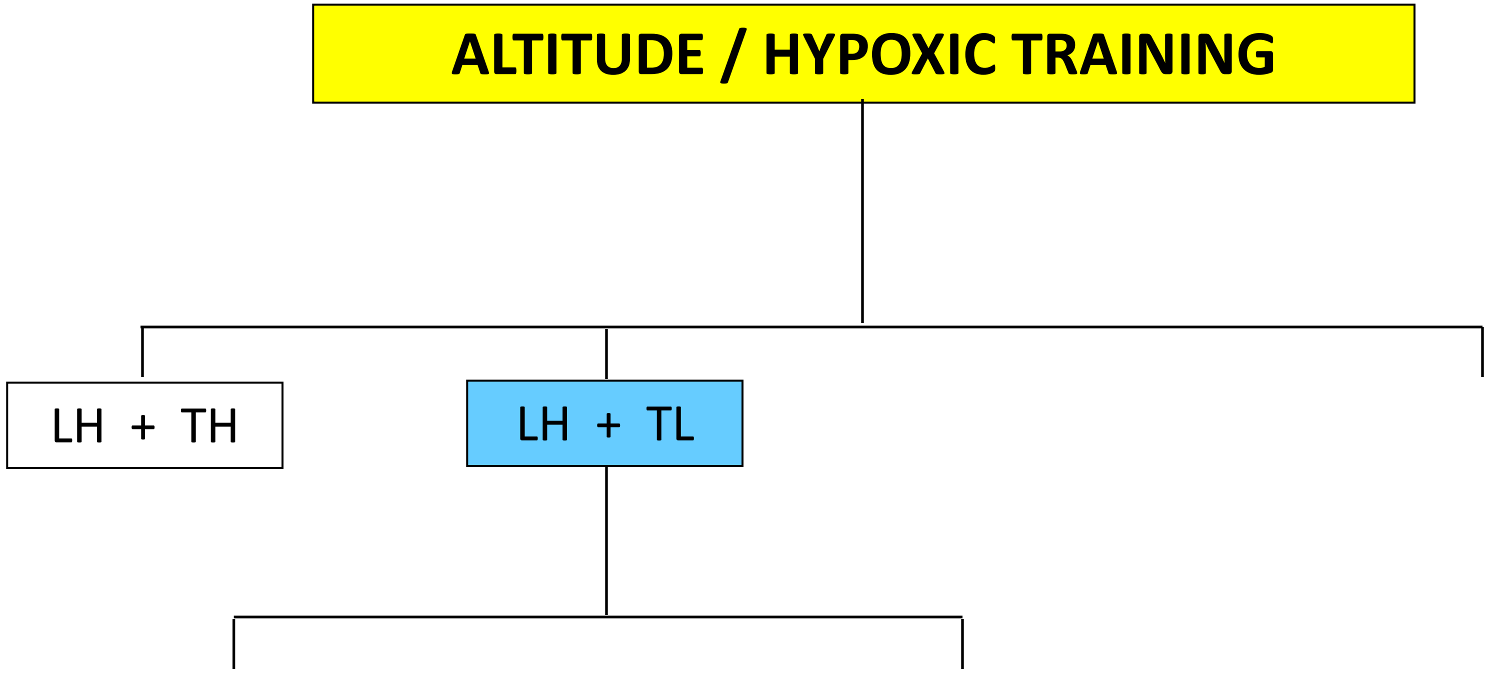
Hypothetical Model for Success

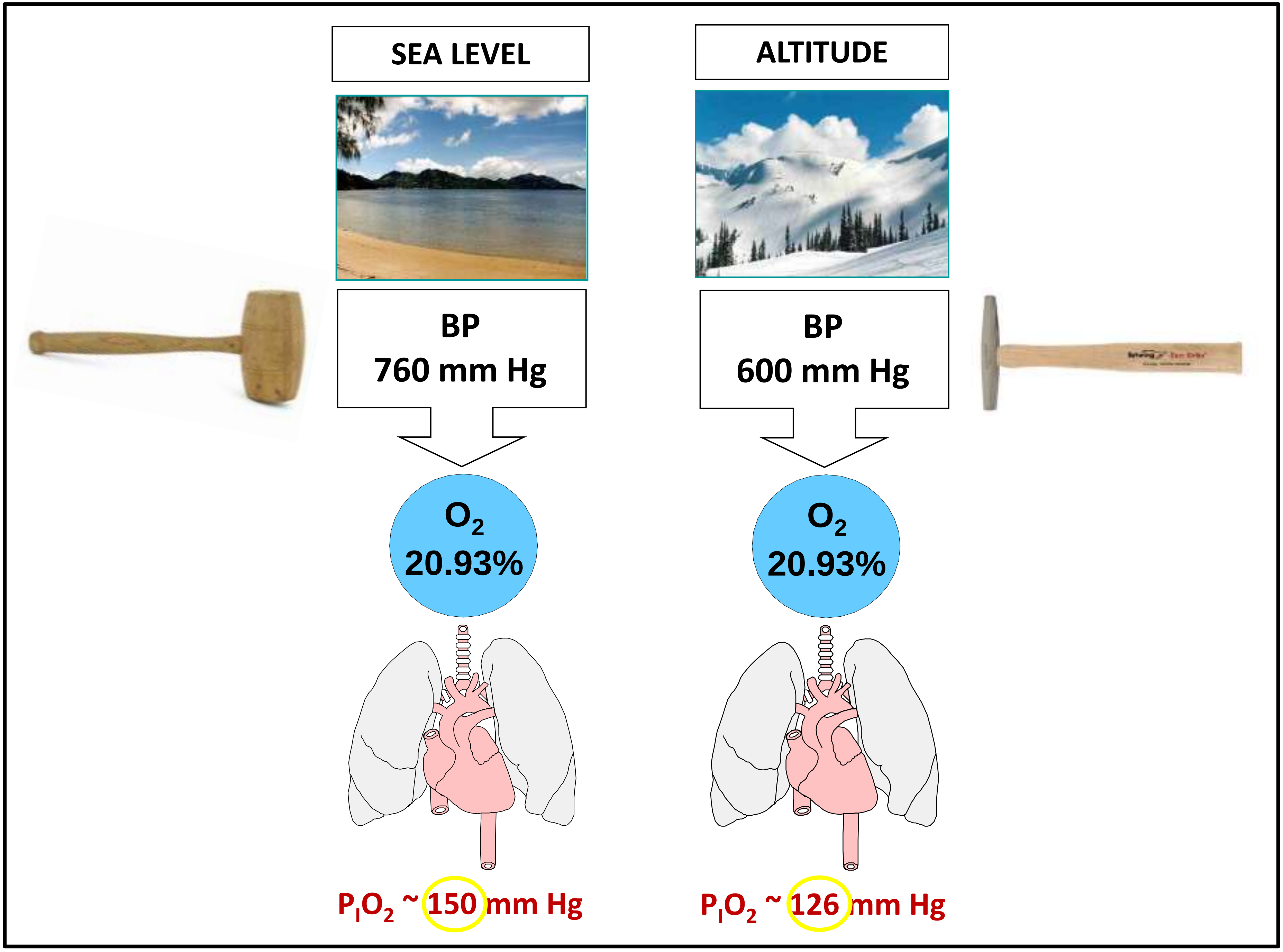
Training #1

Consistent aerobic training at young age as main method of transport to/from school.

Training #2

Moderate-volume, high-intensity training at altitude (2000-3000 m)

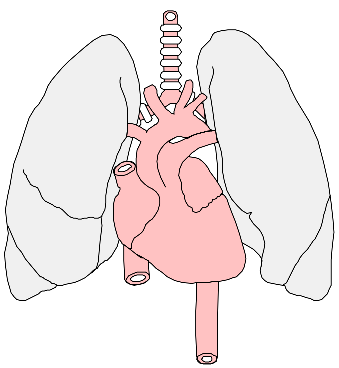

ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL


SEA LEVEL
ALTITUDE
BP
760 mm Hg
BP
600 mm Hg
O_2
20.93%
O_2
20.93%
P_IO_2 ~ 150 mm Hg
P_IO_2 ~ 126 mm Hg

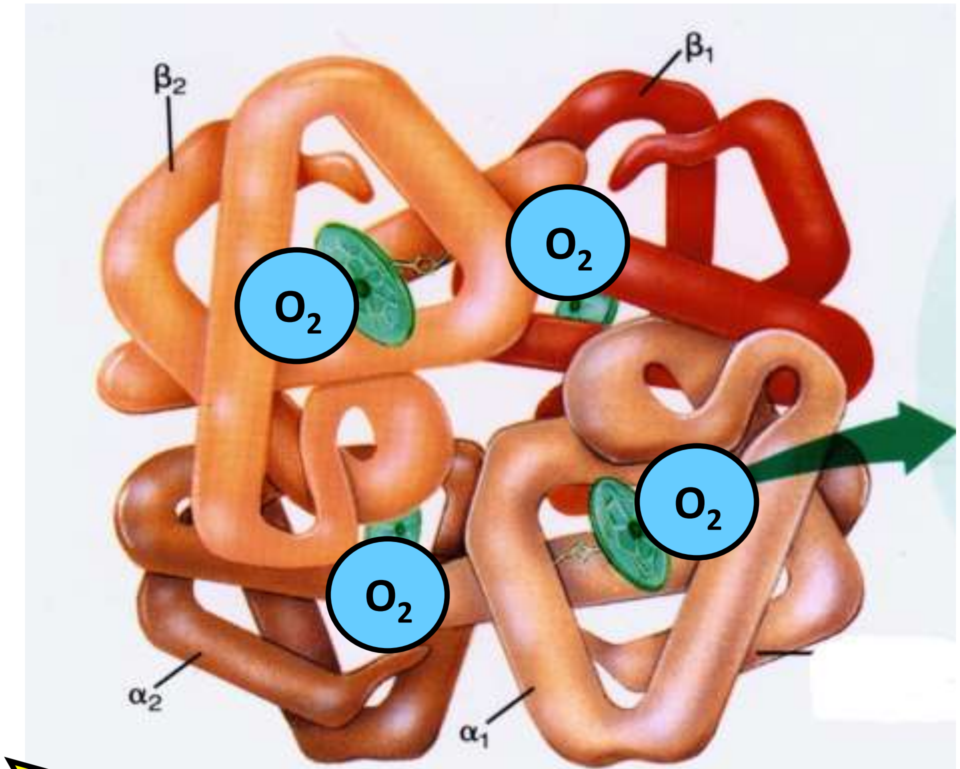
ALTITUDE

BP
600 mm Hg

O_2
20.93%

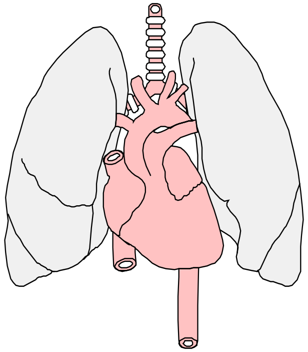


P_IO_2 ~ 126 mm Hg



(a) Hemoglobin

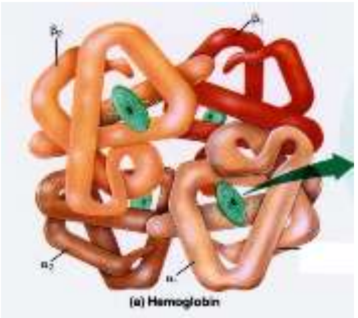
ALTITUDE



$\downarrow P_IO_2$

$\downarrow P_aO_2$

$\downarrow S_aO_2$



$\downarrow VO_2$ max

↓ Aerobic Performance

↓ Training Capacity

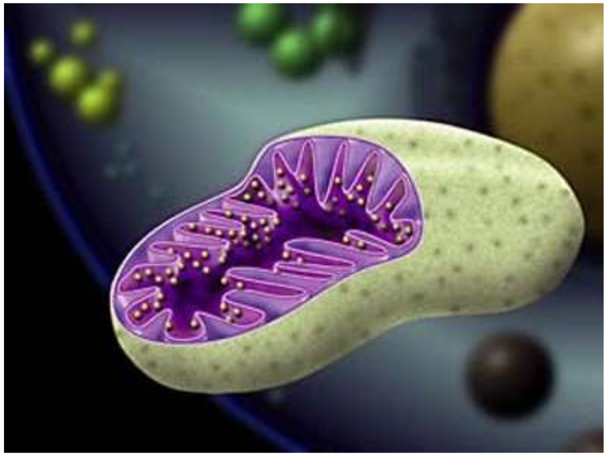
LH + TL

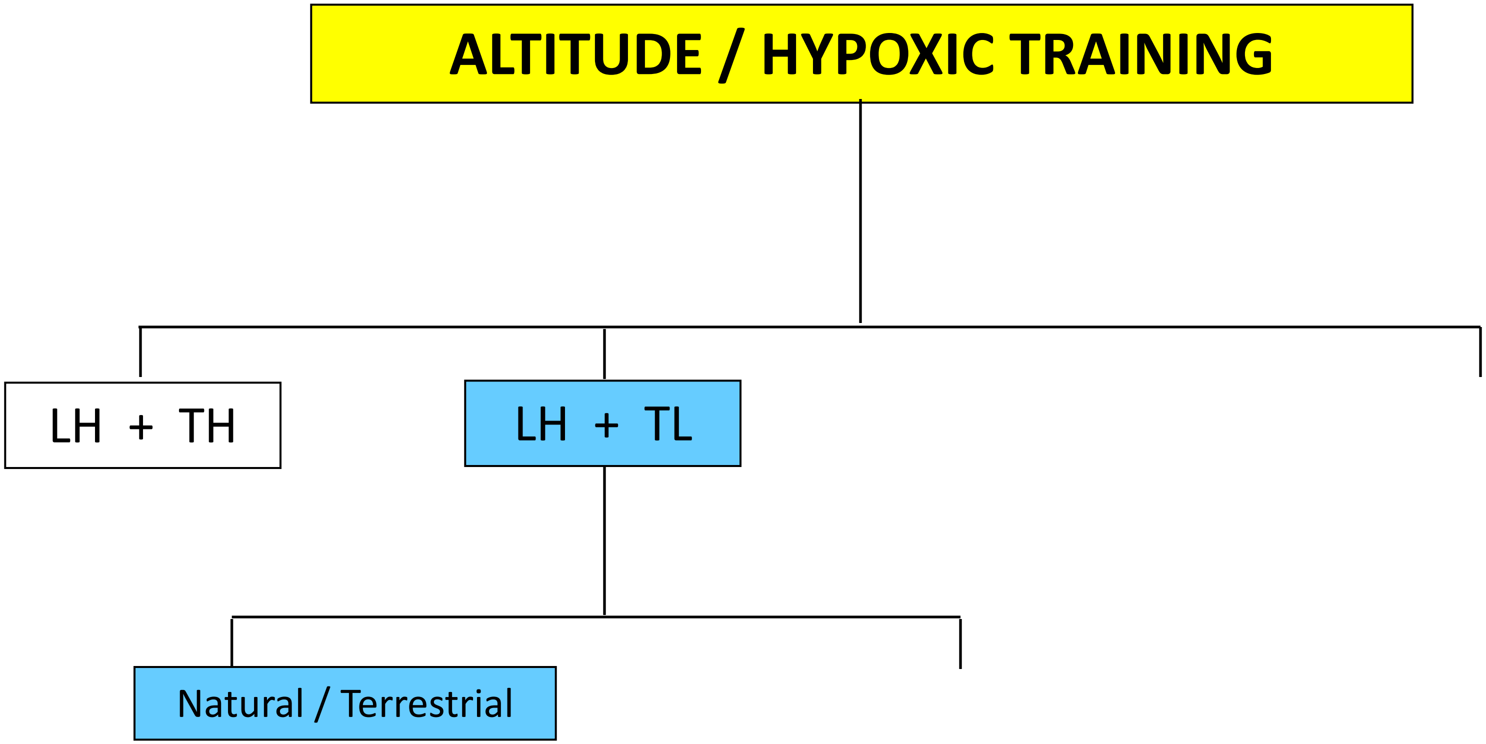
Theoretical Foundation

LH + TL

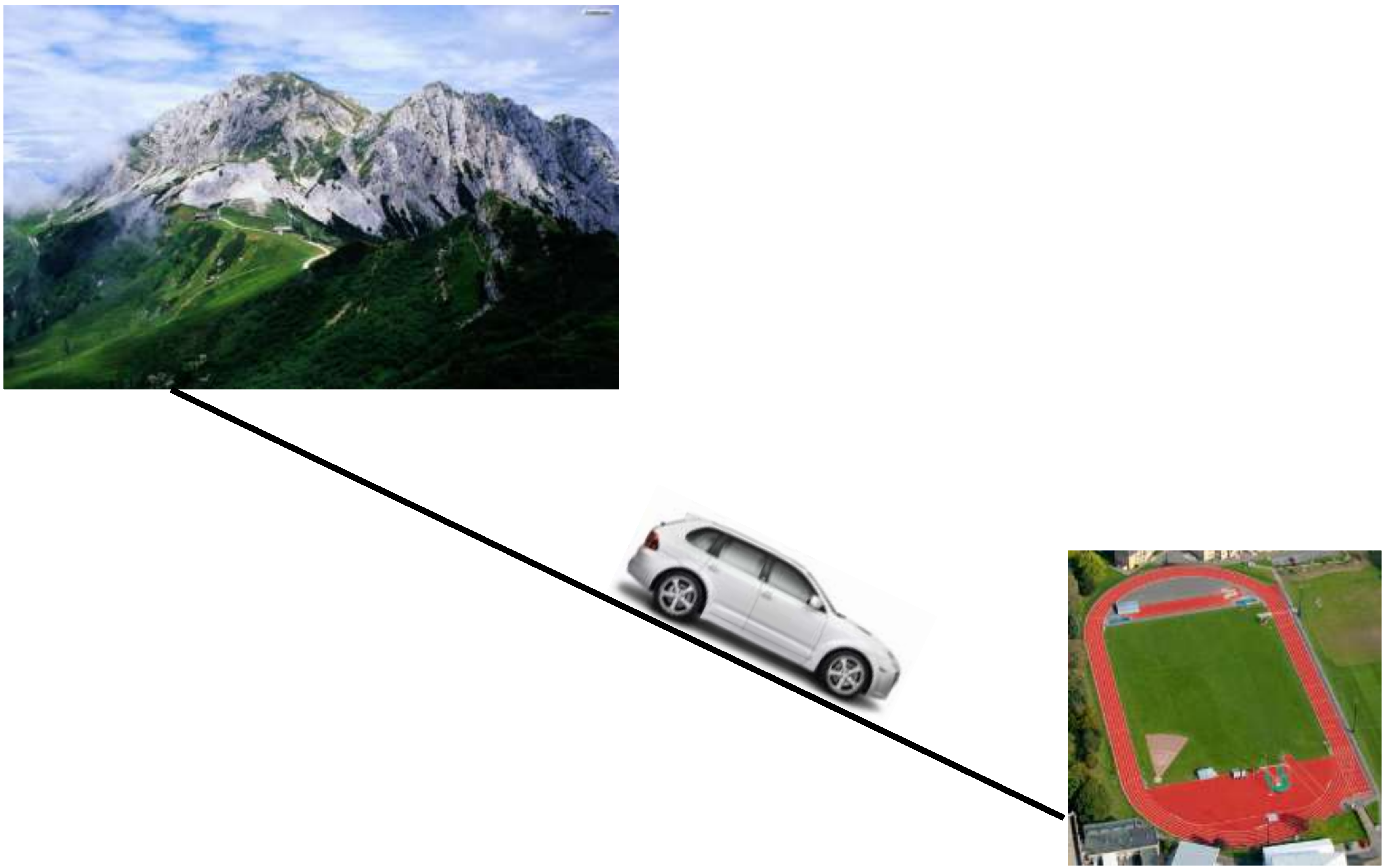
HEMATOLOGICAL

PERIPHERAL



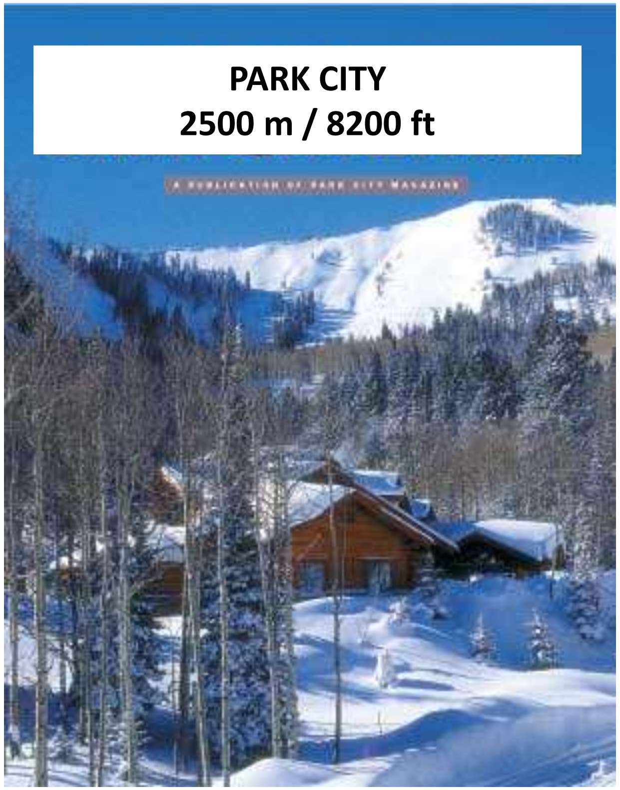

ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL
Natural / Terrestrial

LH + TL
Natural/Terrestrial Hypobaric Hypoxia



LH + TL

Natural/Terrestrial Hypobaric Hypoxia



LH + TL

Natural/Terrestrial Hypobaric Hypoxia

SALT LAKE 2002

3

1

4

WRs 2

torino 2006

3

3

1

vancouver 2010

1

2

1

LH + TL

Natural/Terrestrial Hypobaric Hypoxia

LH + TL

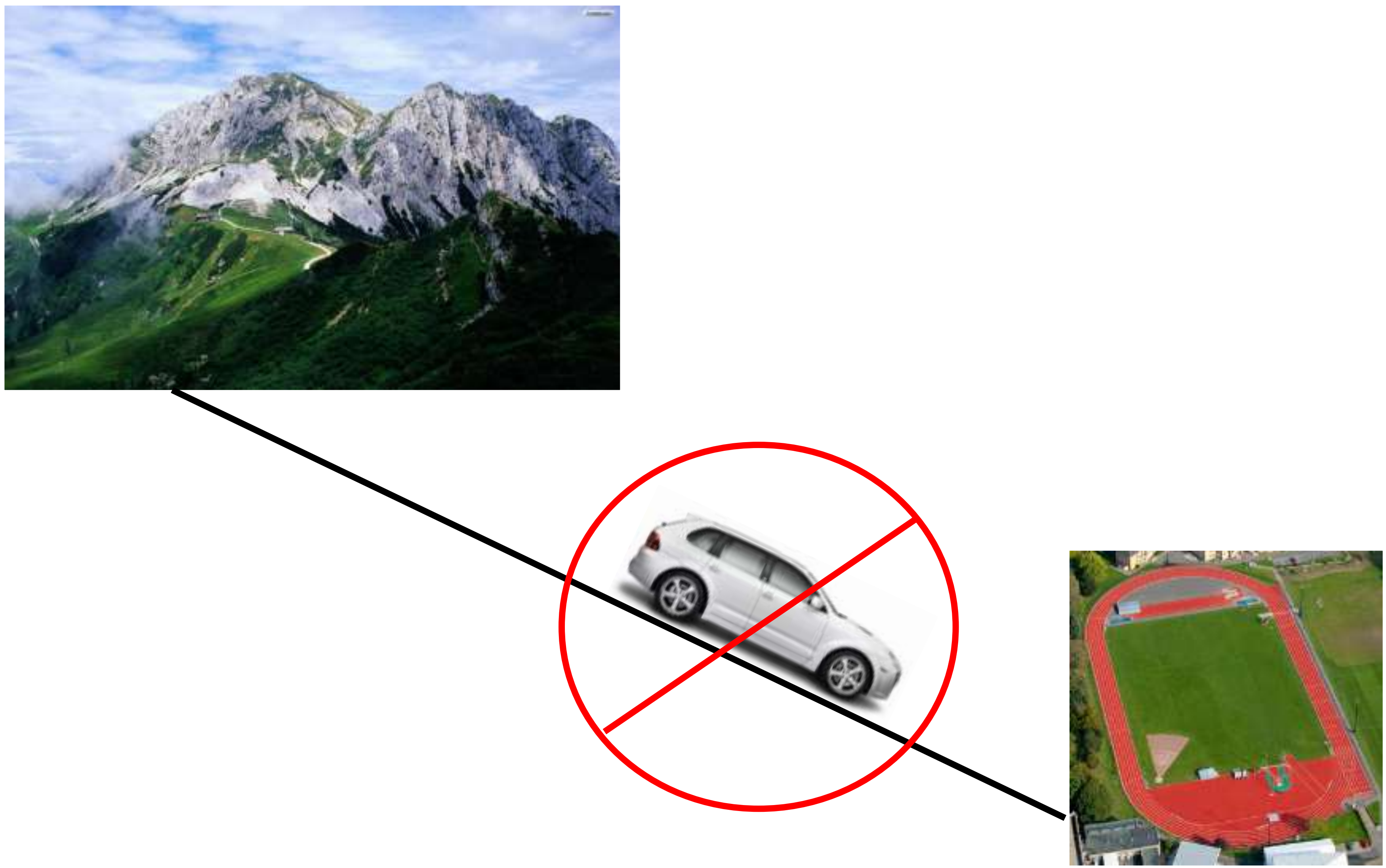
Natural/Terrestrial Hypobaric Hypoxia

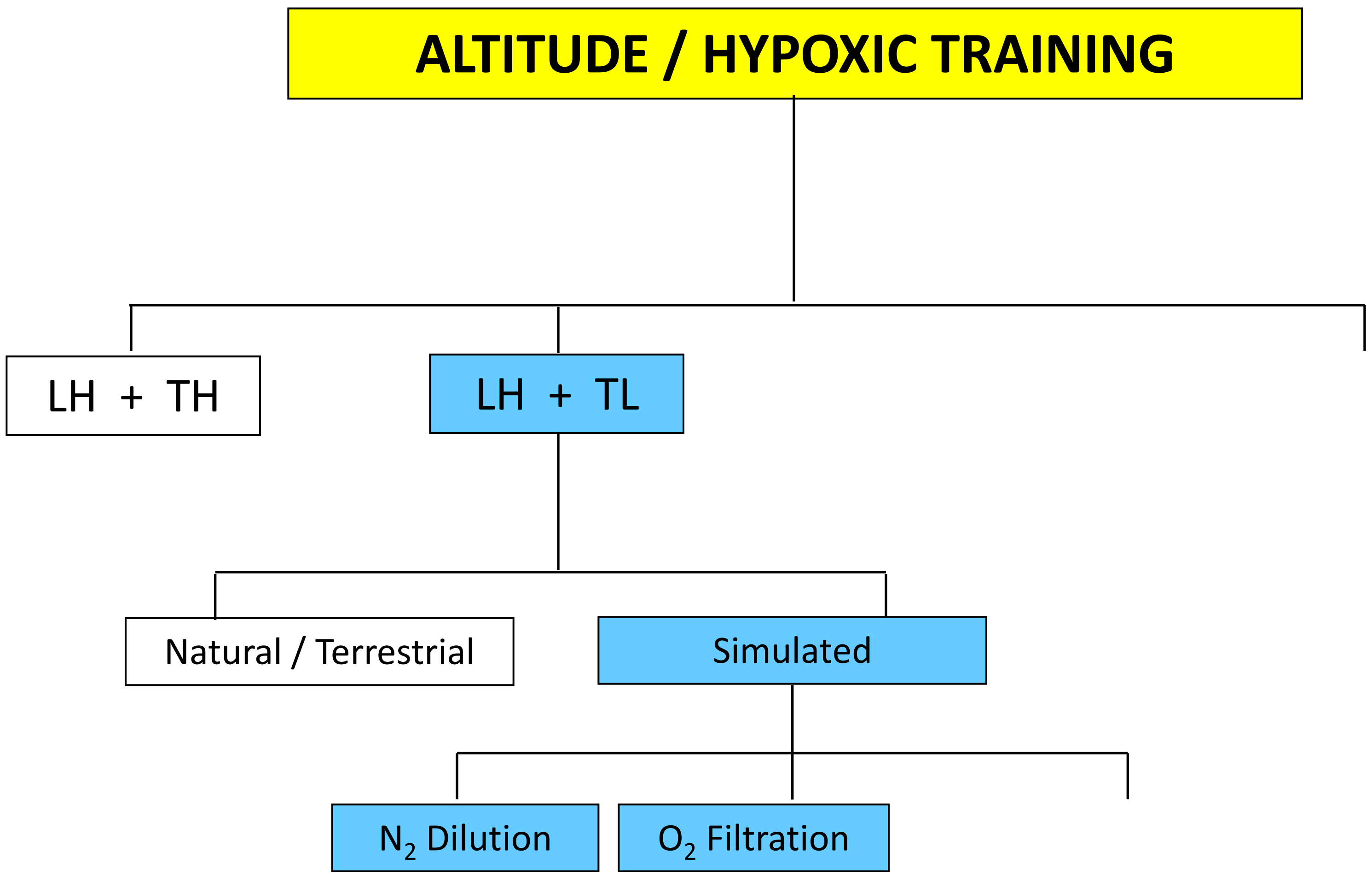
LH + TL

Natural/Terrestrial Hypobaric Hypoxia

LH + TL

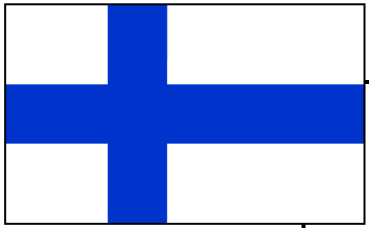
Natural/Terrestrial Hypobaric Hypoxia




ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL
Natural / Terrestrial
Simulated
N_2 Dilution
O_2 Filtration

LH + TL

Normobaric Hypoxia via N_2 Dilution



Nitrogen apartment

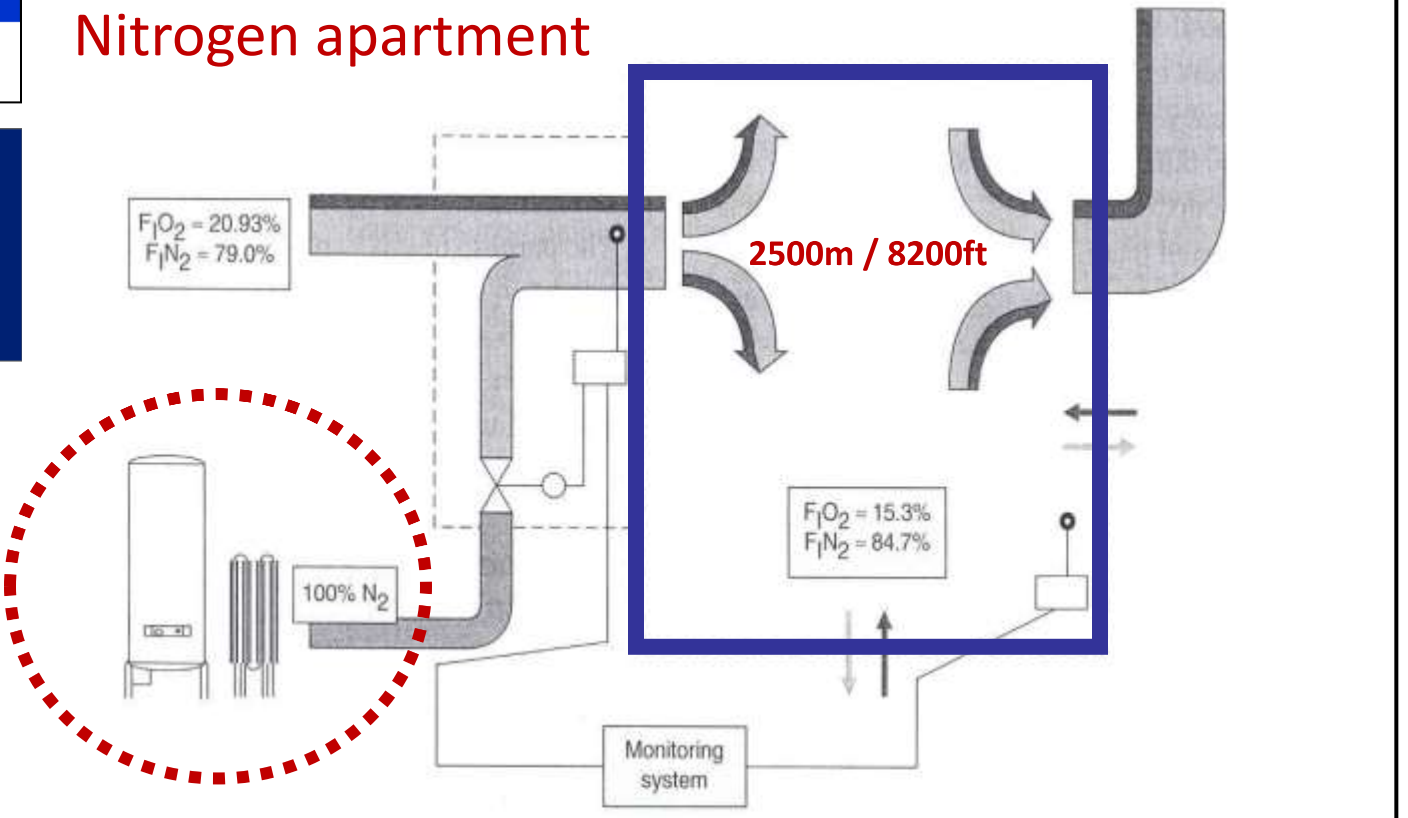


Fig. 1. Schematic representation of a normobaric hypoxic apartment. F_IN_2 = fraction of inspired nitrogen; F_IO_2 = fraction of inspired oxygen.

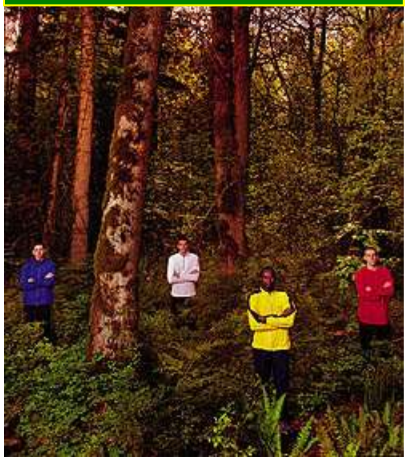
LH + TL

Normobaric Hypoxia via O_2 Filtration

LH + TL

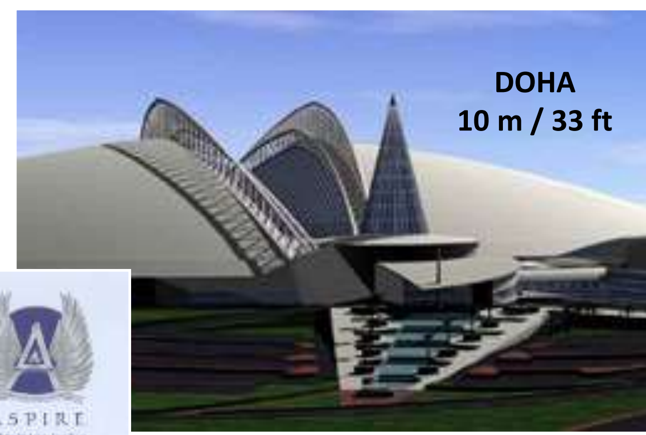
Normobaric Hypoxia via O_2 Filtration

NIKE Oregon Project
PORTLAND
52.5 m / 173 ft



JISS
Japan Institute of Sports Sciences

北京体育大学
BEIJING SPORT UNIVERSITY



ASPIRE

Simulated Altitude
Legal and Ethical Issues

Artificially-Induced Hypoxic Conditions:

"In response to our stakeholders who requested that there be full consideration of hypoxic conditions in the context of the Prohibited List, WADA performed a scientific and ethical review of the matter, and engaged in a thorough consultation with experts and stakeholders. While we do not deem this method appropriate for inclusion on the List at this time, we still wish to express the concern that, in addition to the results varying individually from case to case, use of this method may pose health risks if not properly implemented and under medical supervision."

Richard Pound
WADA Chairman
September 16, 2006

WORLD ANTI-DOPING AGENCY
play true

Simulated Altitude

Legal and Ethical Issues

Decree of the Italian Ministry of Health

13.04.2005. Section 5. Subsection M.1

03 June 2005

. . . "all hypobaric/hypoxic practices are currently prohibited in Italy" . . .

BLITZ DEI NAS NEL VICENTINO PRIMA DEL VIA DELLA 10ª TAPPA

Incubo doping sul Giro McEwen vince, il suo team però rischia l'espulsione

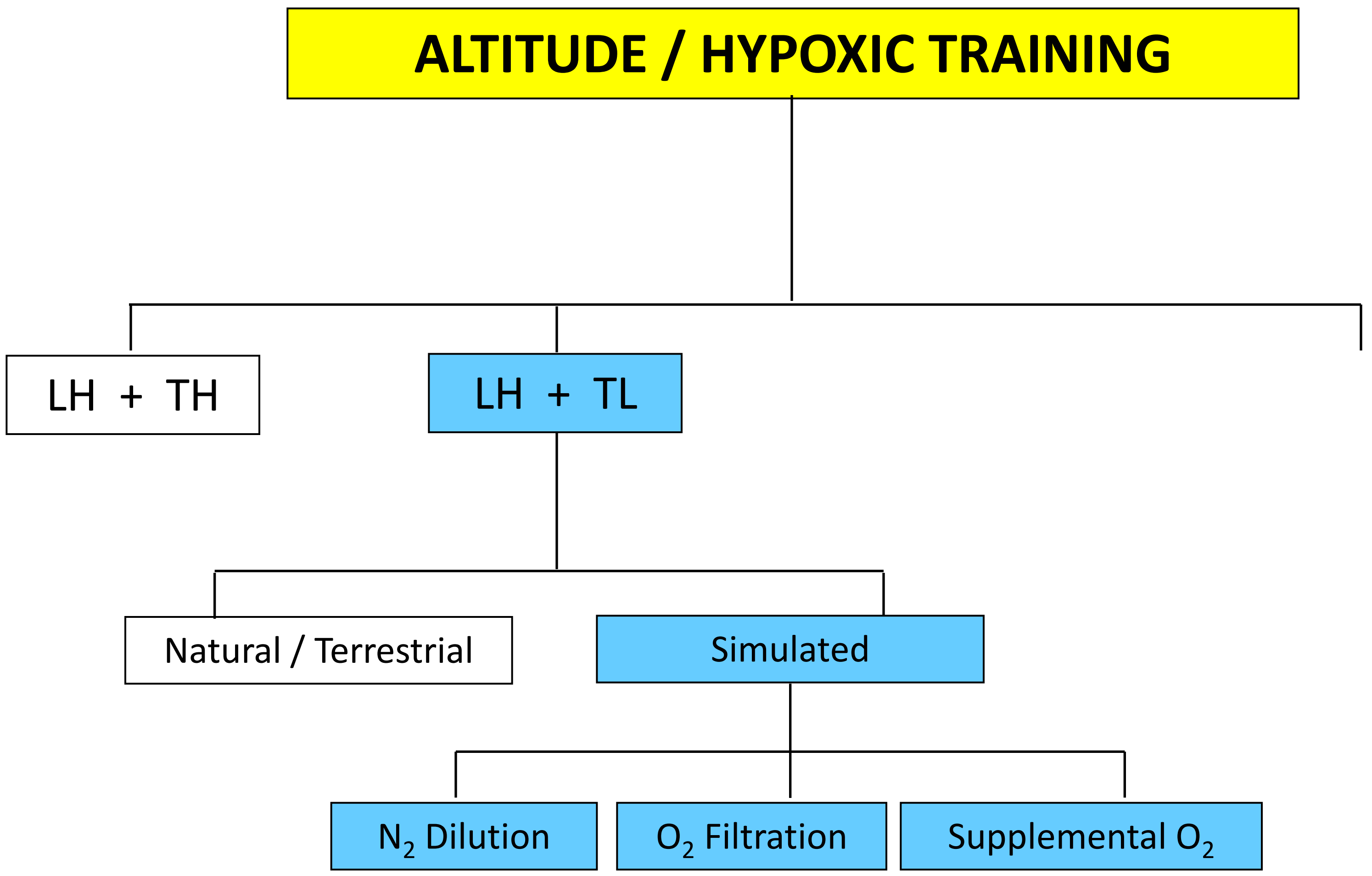
Sequestrati in hotel farmaci e macchinari vietati dalla legge italiana
La Davitamon si difende: «Tanto rumore perché Petacchi ha perso»

2005 Giro d'Italia
Stage 10
18 May 2005

Simulated Altitude

Legal and Ethical Issues

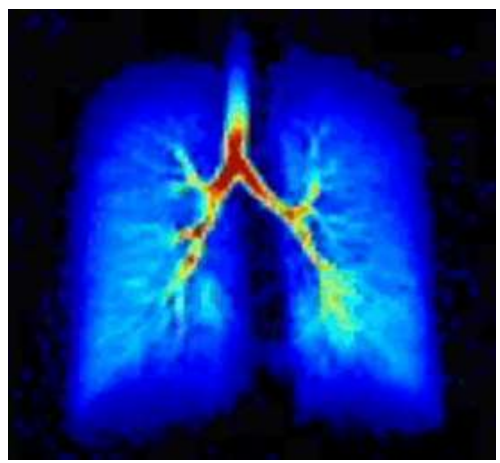
The International Olympic and Paralympic Committees have prohibited the use of simulated altitude devices within the boundaries of the Olympic Village since the 2000 Sydney Olympics, and this mandate is expected to apply to all future summer and winter Olympic Games.


ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL
Natural / Terrestrial
Simulated
N_2 Dilution
O_2 Filtration
Supplemental O_2

Colorado Springs
(1860 m / 6200 ft)

BP
610 mm Hg

O_2
20.93%

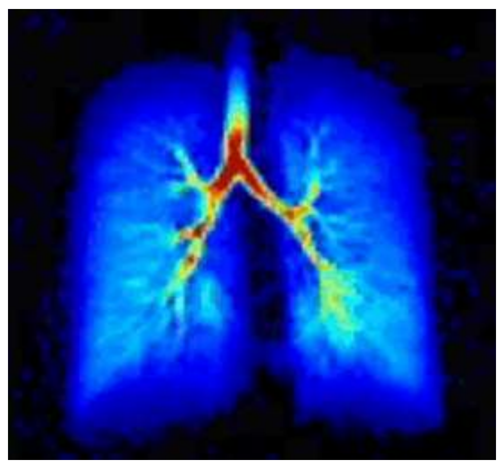


P_IO_2 ~ 128 mm Hg

Colorado Springs
(1860 m / 6200 ft)

BP
610 mm Hg

O_2
20.93%

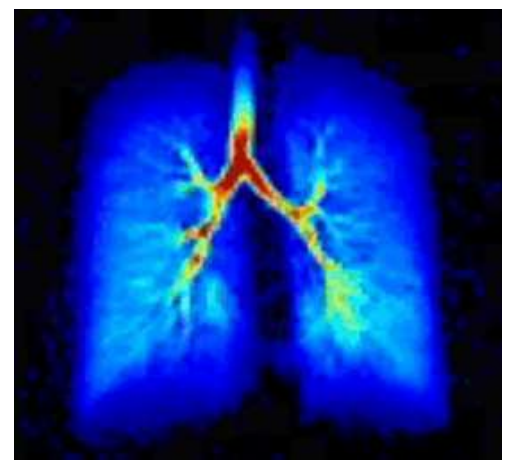


P_IO_2 ~ 128 mm Hg

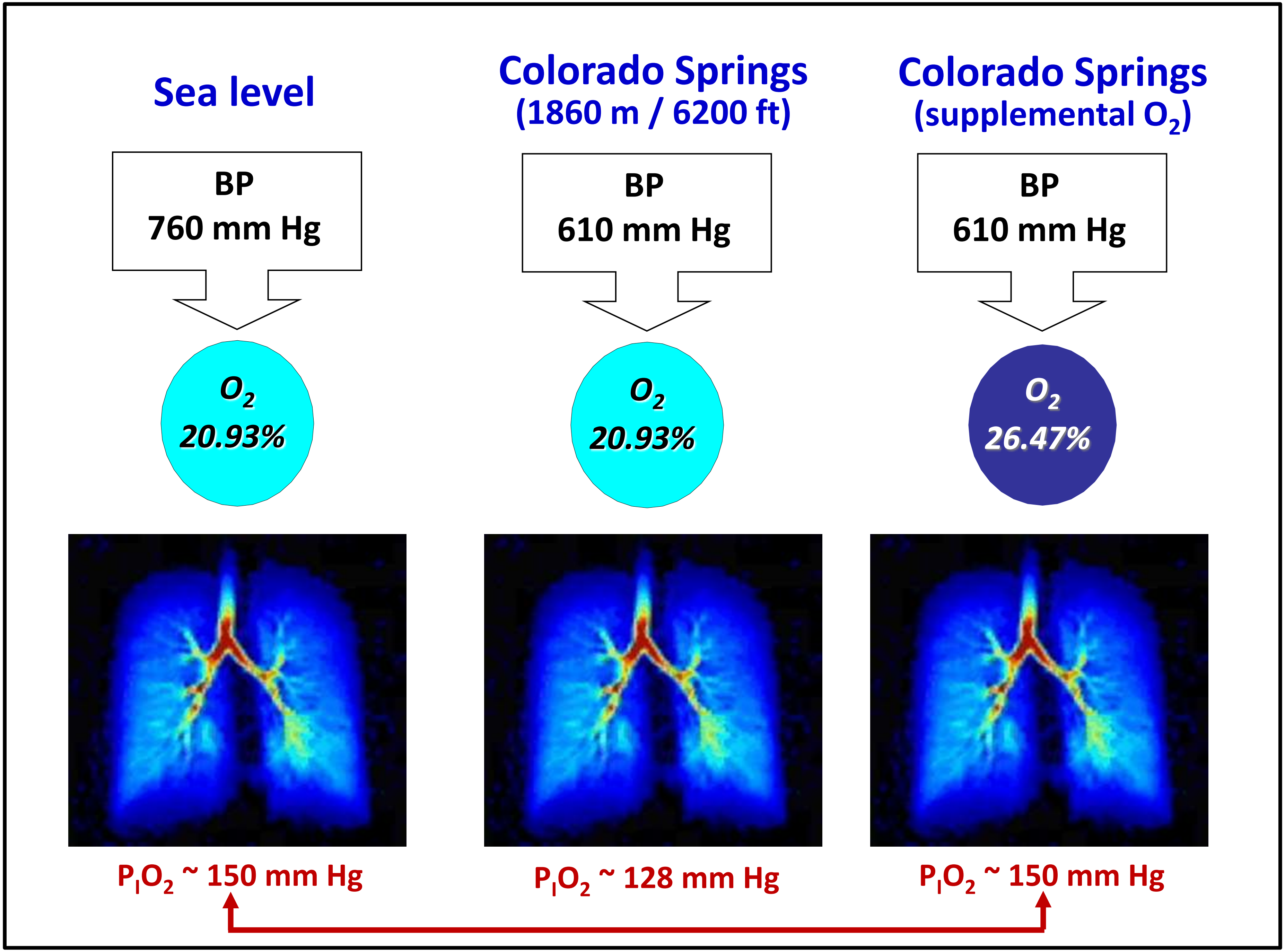
Colorado Springs
(supplemental O_2)

BP
610 mm Hg

O_2
26.47%



P_IO_2 ~ 150 mm Hg


Sea level
Colorado Springs
(1860 m / 6200 ft)
Colorado Springs
(supplemental O_2)
BP
760 mm Hg
BP
610 mm Hg
BP
610 mm Hg
O_2
20.93%
O_2
20.93%
O_2
26.47%
P_IO_2 ~ 150 mm Hg
P_IO_2 ~ 128 mm Hg
P_IO_2 ~ 150 mm Hg

2010 PROHIBITED LIST

M1. ENHANCEMENT OF OXYGEN TRANSFER

The following are prohibited:

1) Blood doping, including the use of autologous, homologous or heterologous blood or red blood cell products of any origin.

2) Artificially enhancing the uptake, transport or delivery of oxygen, including but not limited to perfluorochemicals, efaproxiral (RSR13) and modified haemoglobin products (e.g., haemoglobin-based blood substitutes, microencapsulated haemoglobin products), excluding supplemental oxygen.

US Olympic Training Center: Colorado Springs

Athlete Performance Laboratory 1860 m / 6200 ft

Supplemental O_2 Training (LH + TLO_2)

USOC Sport Science Center of Excellence

High Altitude Training Center

LH + TL

Hypobaric Normoxia via Supplemental O_2 (LH + TLO_2)

US
SPEEDSKATING

Photo credit: Dr. Andy Subudhi

UTAH OLYMPIC OVAL
1425 m / 4675 ft

LH + TL

Hypobaric Normoxia via Supplemental O_2 (LH + TLO_2)

<u>SOLDIER HOLLOW, UT</u>

1685 – 1750 m

5528 – 5742 ft

LH + TL

Hypobaric Normoxia via Supplemental O_2 (LH + TLO_2)

Effect of F_IO_2 on Physiological Responses and Cycling Performance at Moderate Altitude

RANDALL L. WILBER[1], PAIGE L. HOLM[1], DAVID M. MORRIS[1], GEORGE M. DALLAM[2], and SAMUEL D. CALLAN[3]

[1]*Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO;* [2]*Department of Exercise Science, Health Promotion and Recreation, Colorado State University–Pueblo, Pueblo, CO; and* [3]*Sport Science Department, USA Cycling, Colorado Springs, CO*

Effect of F_IO_2 on Oxidative Stress during Interval Training at Moderate Altitude

RANDALL L. WILBER[1], PAIGE L. HOLM[1], DAVID M. MORRIS[1], GEORGE M. DALLAM[2], ANDREW W. SUBUDHI[3], DENNIS M. MURRAY[4], and SAMUEL D. CALLAN[5]

[1]*Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO;* [2]*Department of Exercise Science, Health Promotion and Recreation, Colorado State University–Pueblo, Pueblo, CO;* [3]*The Orthopedic Specialty Hospital, Salt Lake City, UT;* [4]*Oxis Research, Portland, OR; and* [5]*Sport Science Department, USA Cycling, Colorado Springs, CO*

Application of Altitude/Hypoxic Training by Elite Athletes

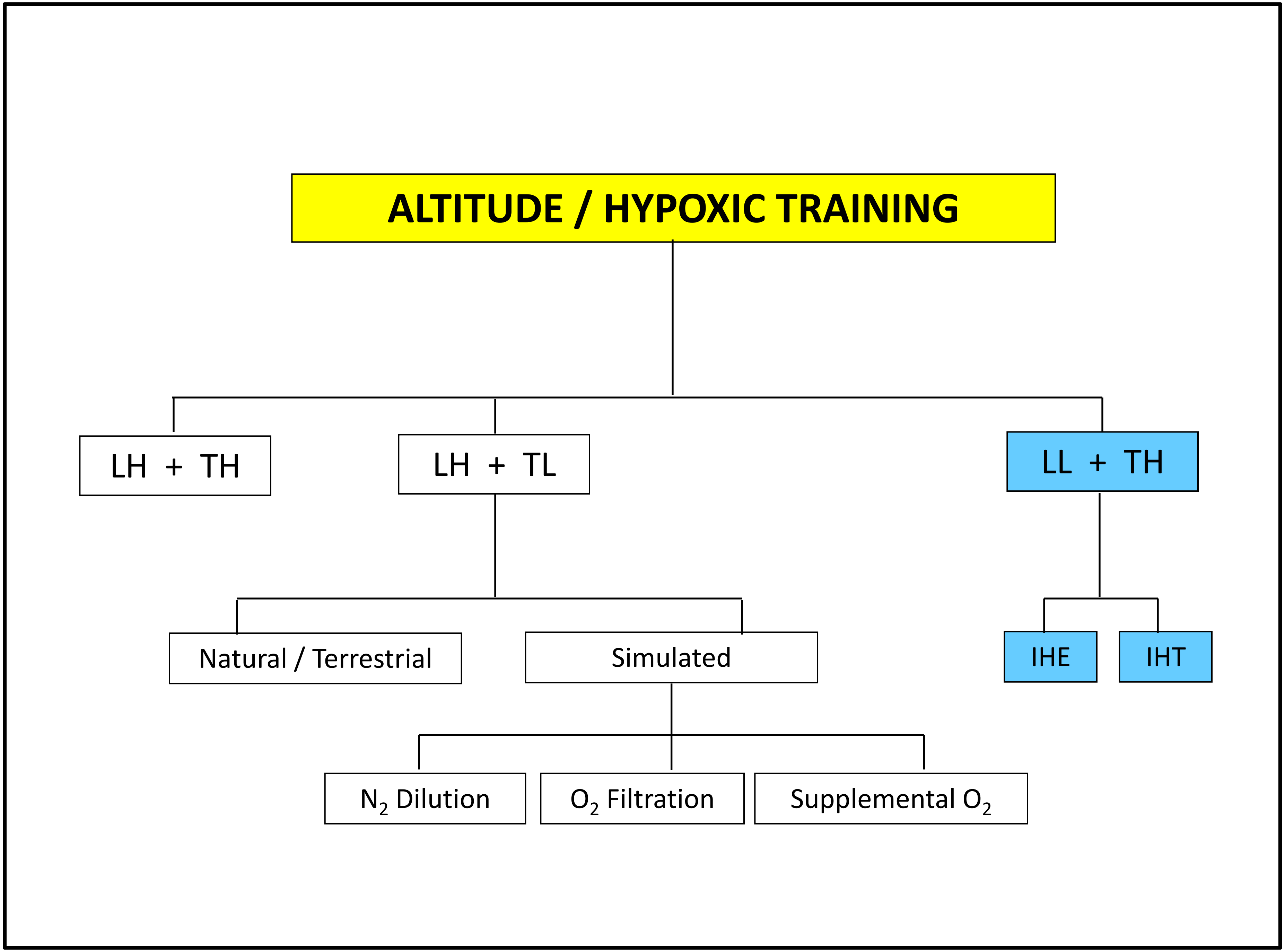
RANDALL L. WILBER

Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO

Effect of Hypoxic "Dose" on Physiological Responses and Sea-Level Performance

RANDALL L. WILBER[1], JAMES STRAY-GUNDERSEN[2], and BENJAMIN D. LEVINE[3]

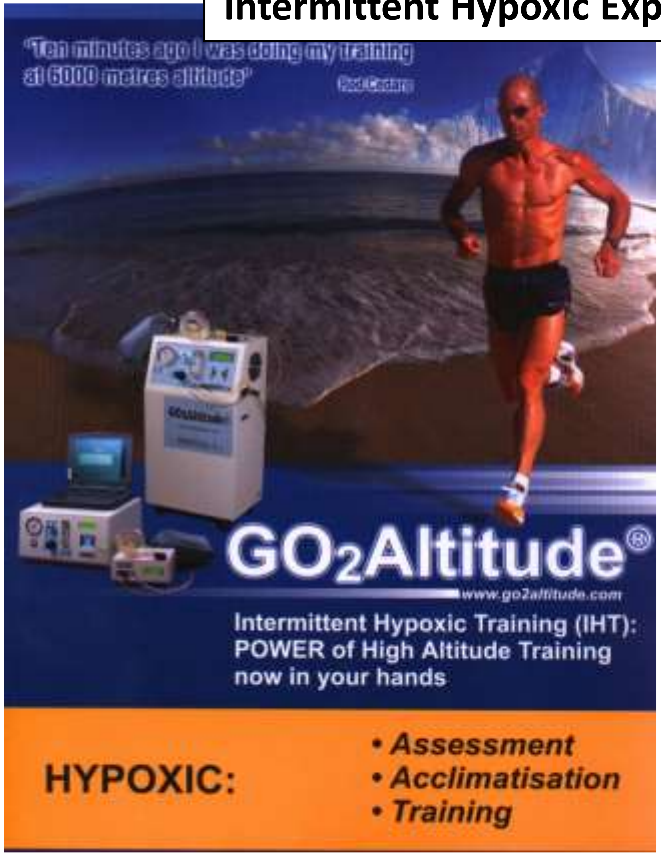
[1]*Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO;* [2]*Department of Health, University of Utah, Salt Lake City, UT; and* [3]*Institute for Exercise and Environmental Medicine, Presbyterian Hospital of Dallas, University of Texas Southwestern Medical Center, Dallas, TX*

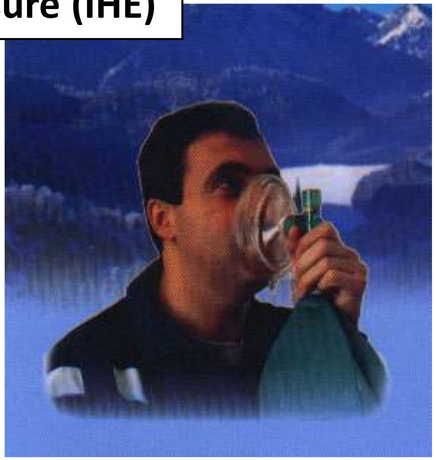

ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL
LL + TH
Natural / Terrestrial
Simulated
IHE
IHT
N_2 Dilution
O_2 Filtration
Supplemental O_2

LL + TH

Intermittent Hypoxic Exposure (IHE) / Training (IHT)

Intermittent Hypoxic Exposure (IHE)





Altitrainer 200®

Intermittent Hypoxic Training (IHT)

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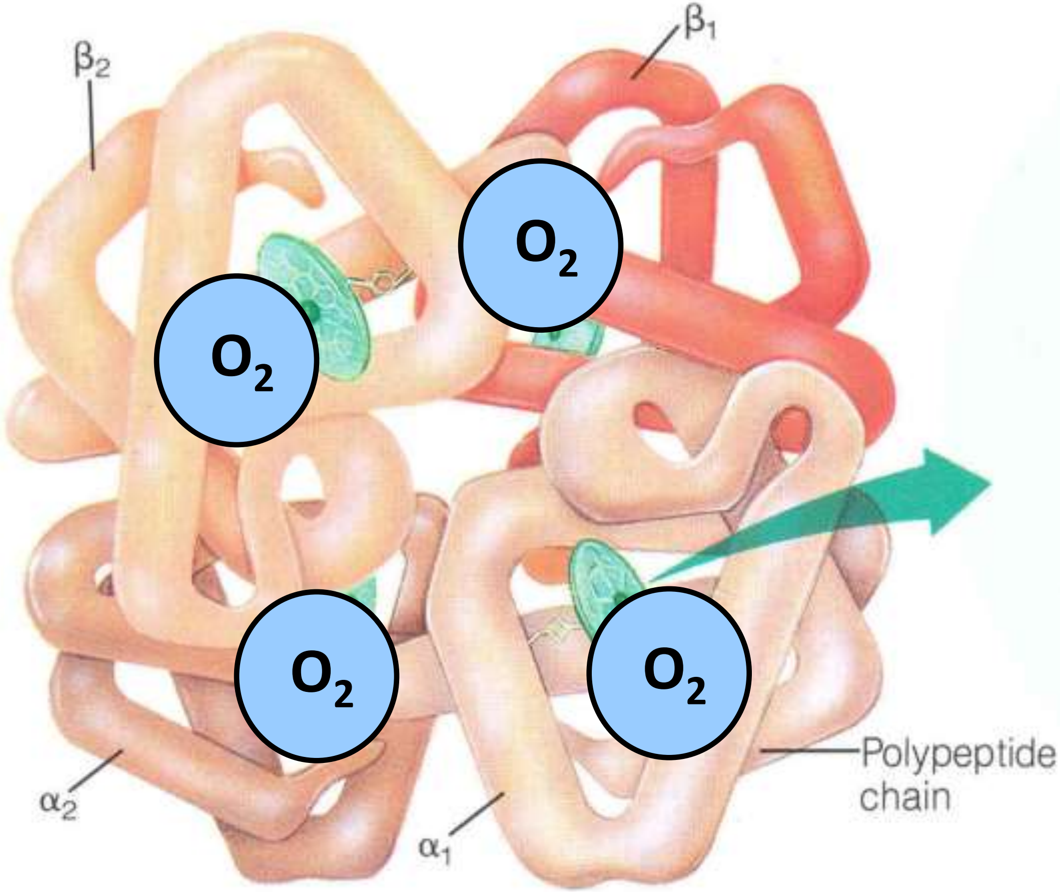
- **Summary & Resources**

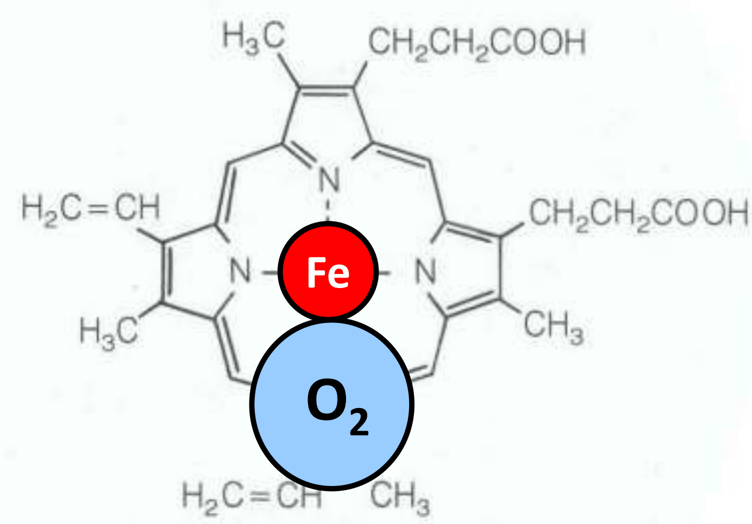

BEFORE Altitude Training Camp

Altitude Training
Contraindications

- Poor level of fitness
- Bacterial or viral infection
- Fe-depleted
- Fe-deficient non-anemia
- Fe-deficient anemia
- Sickle-cell trait or anemia
- Medications that might affect the kidneys and EPO response
- Medications that might exacerbate diuresis
- Chronic sleep disorders



(a) Hemoglobin



(b) Iron-containing heme group

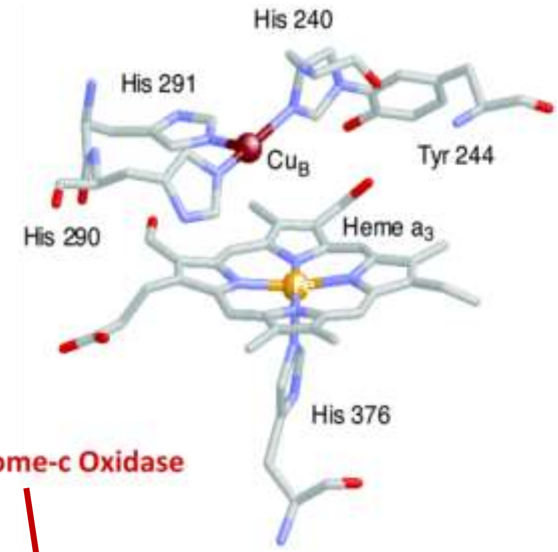
IRON SUPPLEMENTATION

Ferrous sulfate

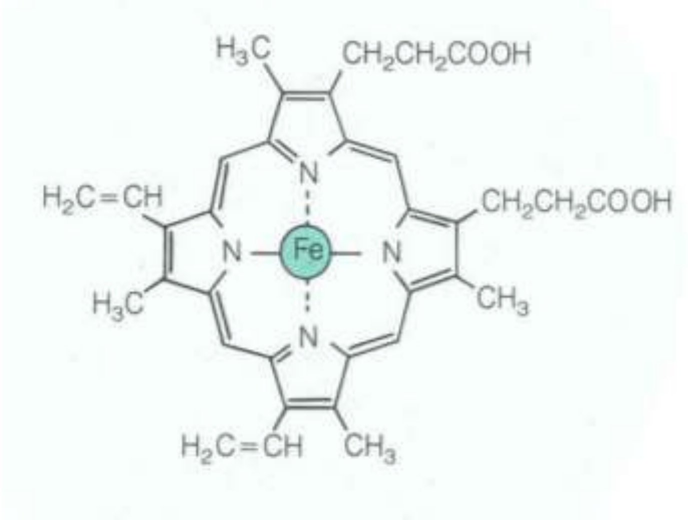
If serum Ferritin is low:

- Attention to “heme Fe” in diet.
- Moderate Fe supplementation
  - 120-130 mg “elemental Fe” divided into 2 doses
  - taken with Vitamin C
  - taken 30 min before or 60 min after meals to increase absorption and decrease GI distress
  - taken daily

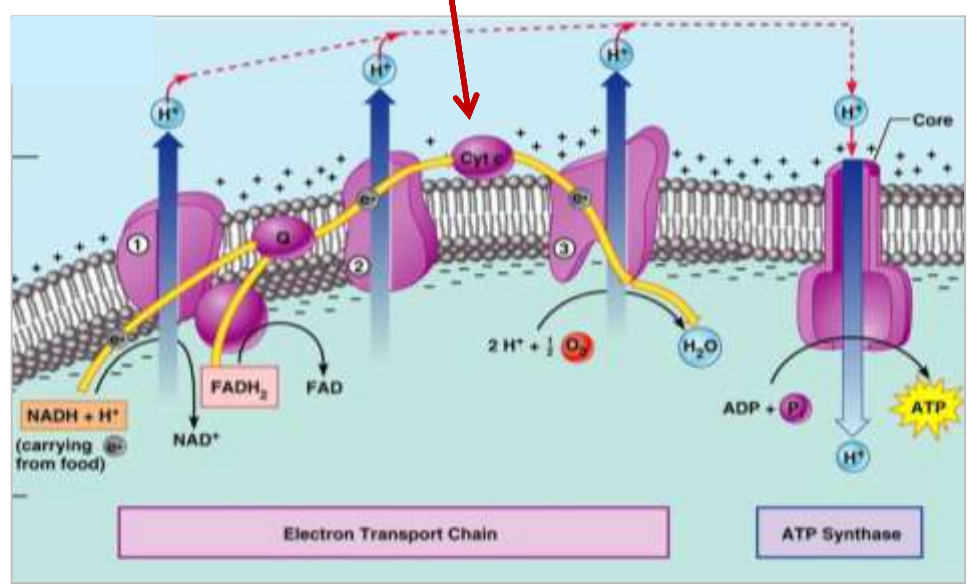
IRON SUPPLEMENTATION



Hemoglobin



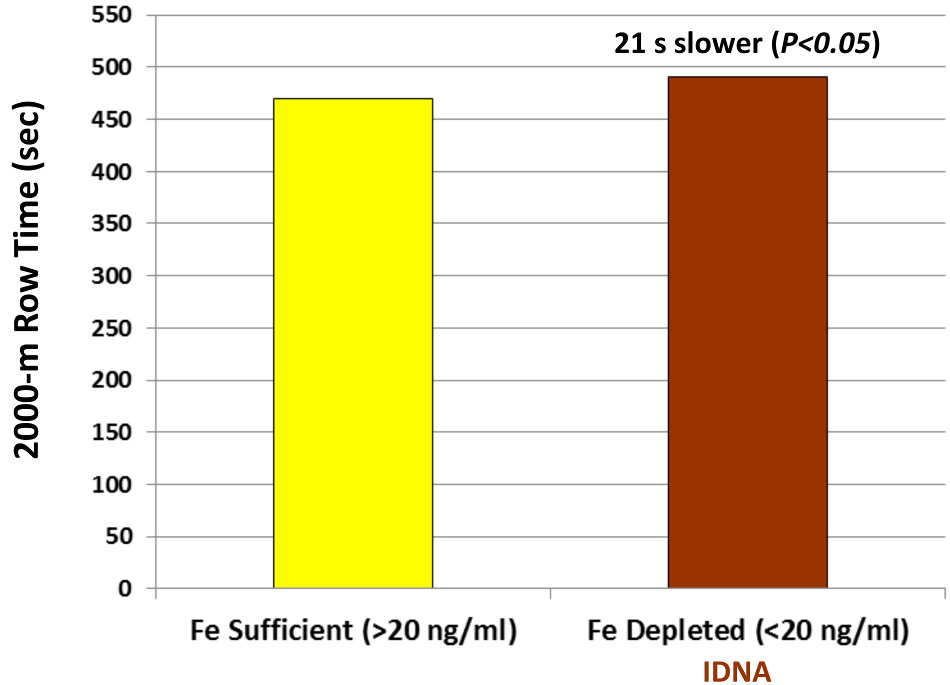
Cytochrome-c Oxidase



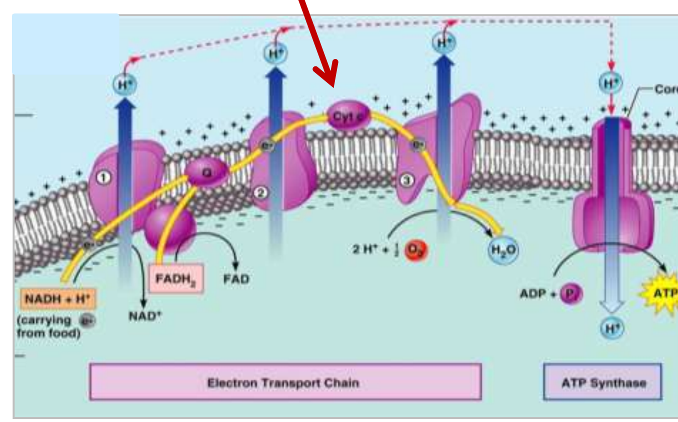
Impact of Iron Depletion Without Anemia on Performance in Trained Endurance Athletes at the Beginning of a Training Season: A Study of Female Collegiate Rowers

Diane M. DellaValle and Jere D. Haas

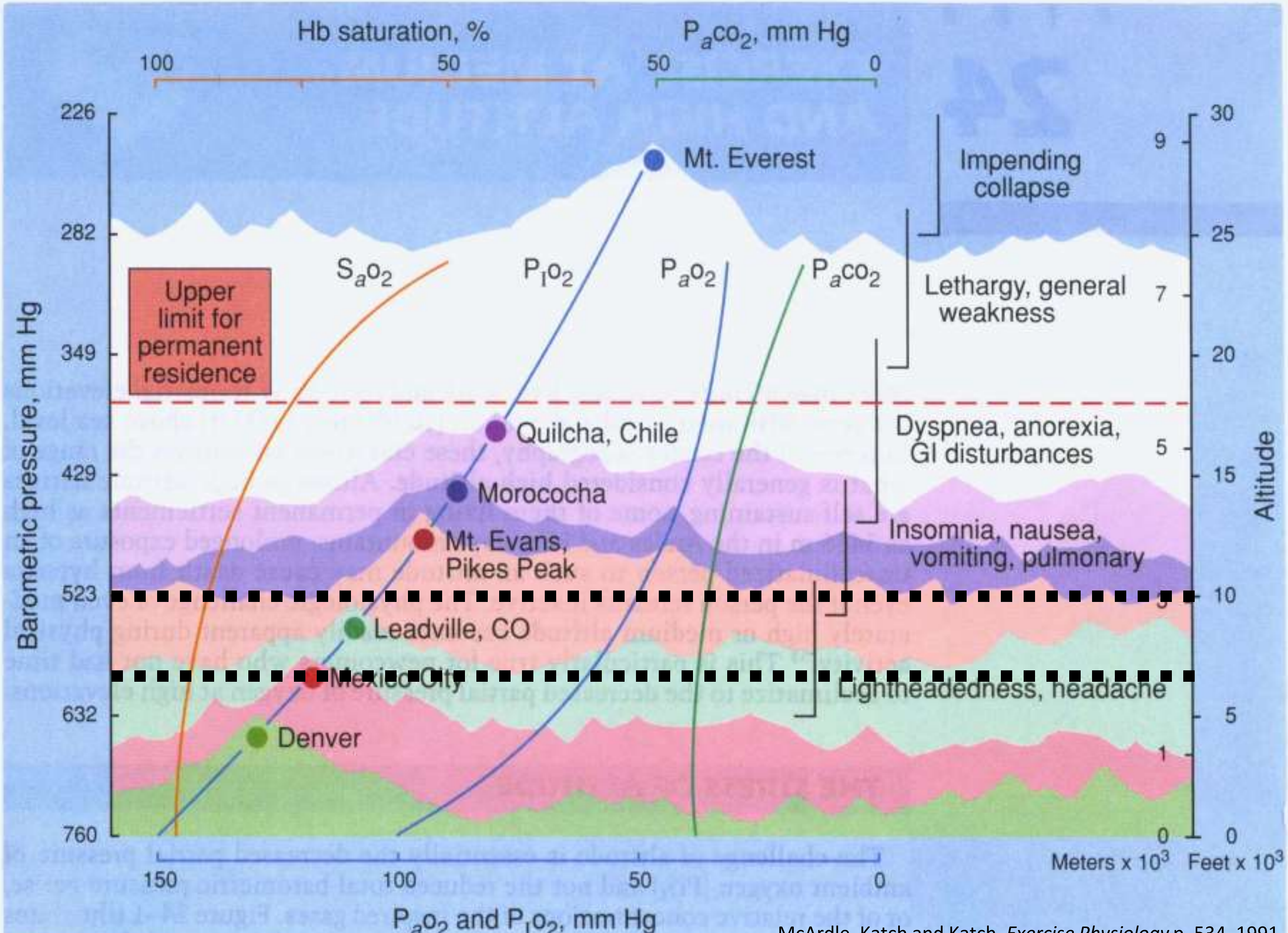
International Journal of Sport Nutrition and Exercise Metabolism, 2011, 21, 501-506



Cytochrome-c Oxidase




DURING Altitude Training Camp



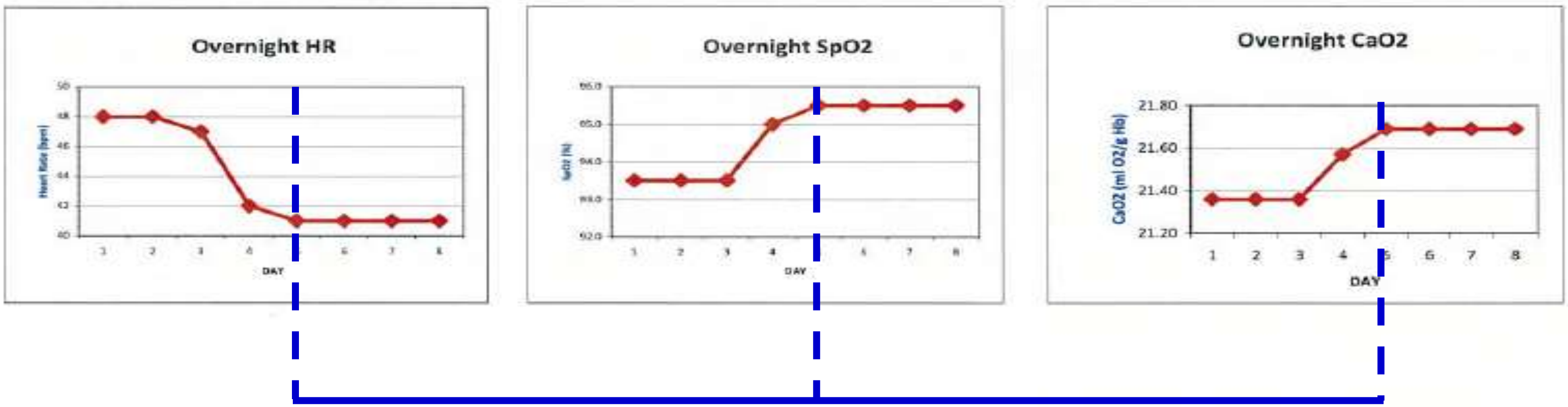
McArdle, Katch and Katch. *Exercise Physiology* p. 534, 1991


SpO2 (%)
Pulse (bpm)
100
95
90
85
80
75
70
255
240
225
210
195
180
165
150
135
120
105
90
75
60
45
30
88
1:00
1:05
1:10
1:15
1:20
1:25
1:30
1:35
1:40
1:45
1:50
1:55
2:00
File Data:
TEST
1
10
60
M

NAME
USA Biathlon
Altitude Training Camp
Antholz, ITALY (1644 m / 5392 ft)
July 29 to August 7, 2010

Day	HR	SpO2	CaO2	Glucose	USG
F 7/30/10	48	93.5	21.36	82	1.028
SAT 7/31/10	48	93.5	21.36	82	1.027
SUN 8/1/10	47	93.5	21.36	83	1.028
M 8/2/10	42	95.0	21.57	84	1.020
TU 8/3/10	41	95.5	21.69	92	1.018
W 8/4/10	41	95.5	21.69	91	1.019
TH 8/5/10	41	95.5	21.69	91	1.020
F 8/6/10	41	95.5	21.69	92	1.019
				Normal=65-99	

Hydration Status	USG
Serious DH	> 1.030
Significant DH	1.020 - 1.030
Minimal DH	1.010 - 1.020
Well hydrated	< 1.010

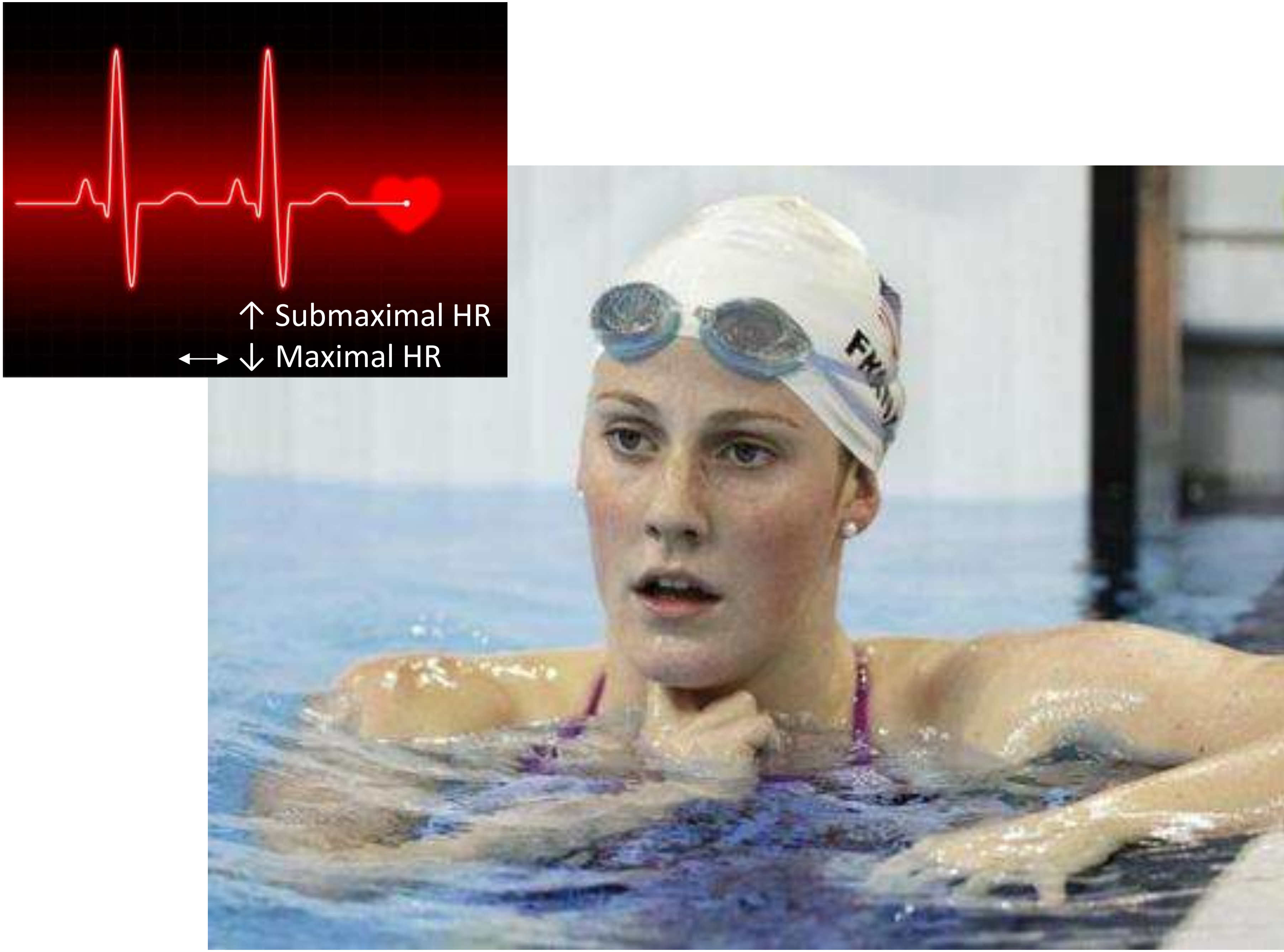


ACCLIMATIZATION = Day 5

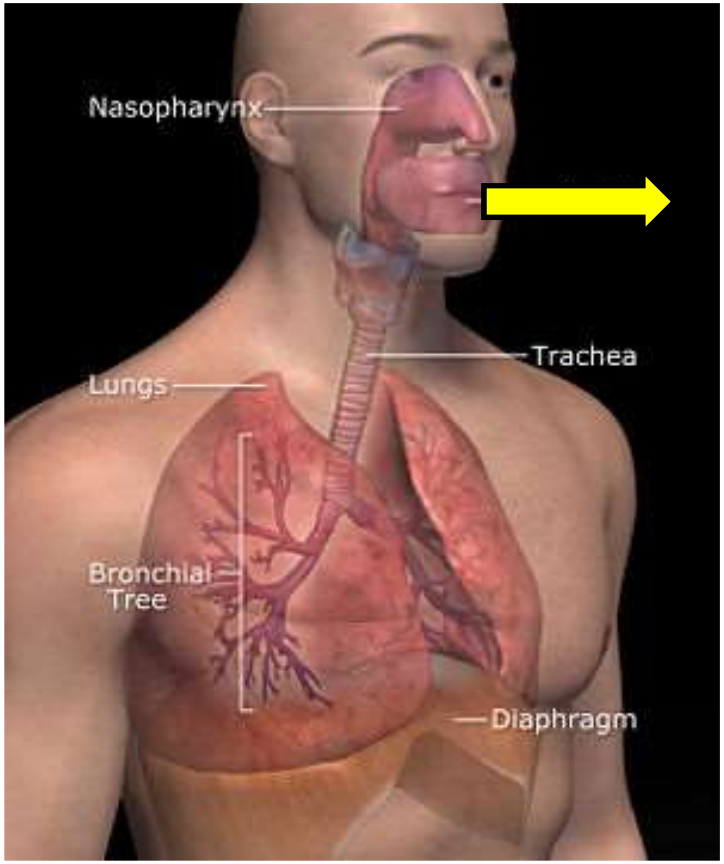
TRAINING PROGRESSION

Base model: combination between hypoxic training and normoxic training in the preparatory training period									
ALTITUDE									
SEA LEVEL									
Training load	Very high								
	High								
	Medium								
	Low								
	Very low								
Training Int		Int ≤ VT_1 strength training	Int ≤ VT_1 Int ≤ VT_2 strength training	Int ≤ VT_1 Int ≤ VT_2 Int ≤ MAP strength training					
Days		7	7	7	7	7	7	7	7

Millet et al. *Sports Med*. 40:1-25, 2010


↑ Submaximal HR
↔ ↓ Maximal HR

DEHYDRATION

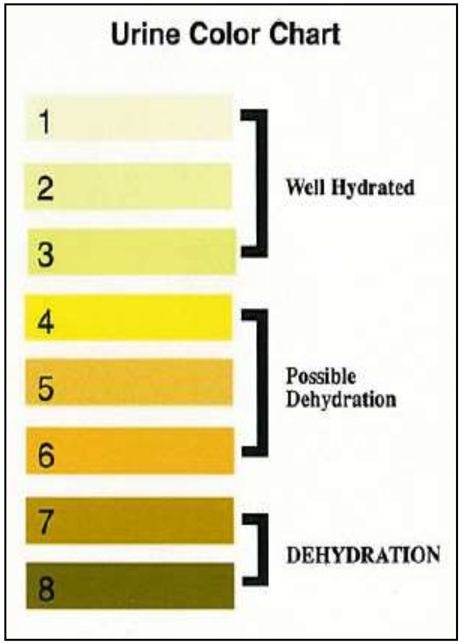


Respiratory H_2O loss

Urinary H_2O loss

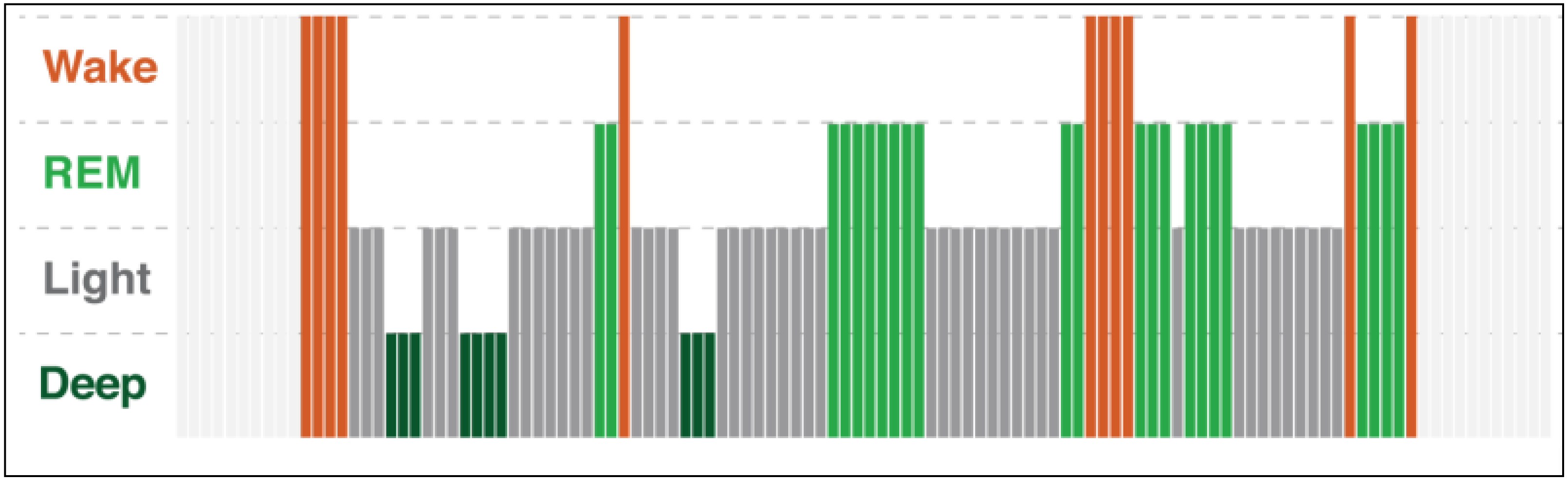
Monitor dehydration

- Post-WO total body weight (TBW)
- Drink 10-12 oz fluid for every pound lost
- Check post-WO urine color and/or urine specific gravity (USG)



Hydration Status	USG
Well hydrated	< 1.010
Minimal dehydration	1.010 – 1.020
Significant dehydration	1.020 – 1.030
Serious dehydration	> 1.030


Wake
REM
Light
Deep
zeo
10:00 PM
Now Tracking
zeo


Wake
REM
Light
Deep

TEAM USA

Training Questionnaire

USA TRACK & FIELD

NAME ______________________________ DATE ______________

LOCATION ____________________________

IN THE LAST 24 HOURS . . . HAVE YOU EXPERIENCED:

HEADACHE
- _____ No headache
- _____ Light headache
- _____ Painful headache
- _____ Severe, incapacitating headache

GASTROINTESTINAL
- _____ No GI problems
- _____ Poor appetite or nausea
- _____ Moderate nausea or vomiting
- _____ Severe nausea and vomiting

FATIGUE
- _____ Not tired or weak
- _____ Light fatigue/weakness
- _____ Moderate fatigue/weakness
- _____ Severe fatigue/weakness

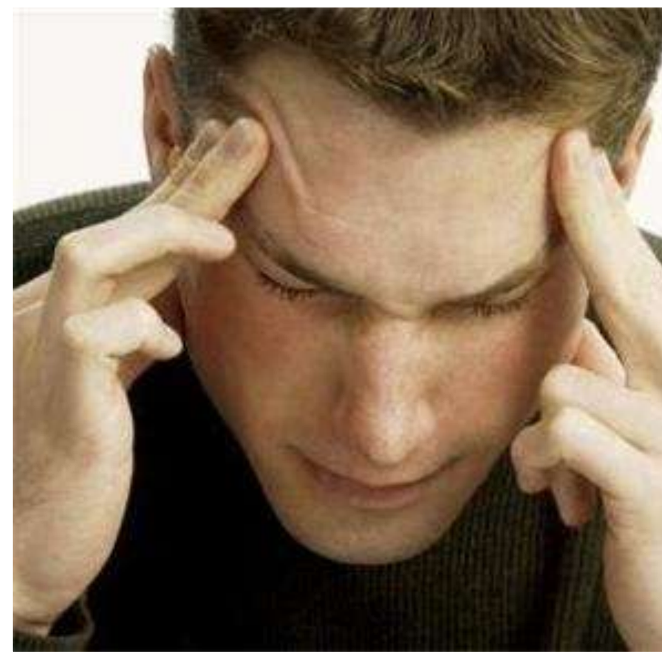
SLEEP
- _____ Slept well as usual
- _____ Did not sleep as well as usual
- _____ Poor night's sleep . . . woke many times
- _____ Could not sleep at all

ILLNESS
- _____ No illness
- _____ Minor illness, but it has not significantly limited my training/racing
- _____ Illness that has forced me to take 2-3 days off [list illness here___________________]
- _____ Illness that has forced me to take >3 days off [list illness here___________________]

INJURY
- _____ No injury
- _____ Minor injury, but it has not significantly limited my training/racing
- _____ Injury that has forced me to take 2-3 days off [list injury here___________________]
- _____ Injury that has forced me to take >3 days off [list injury here___________________]

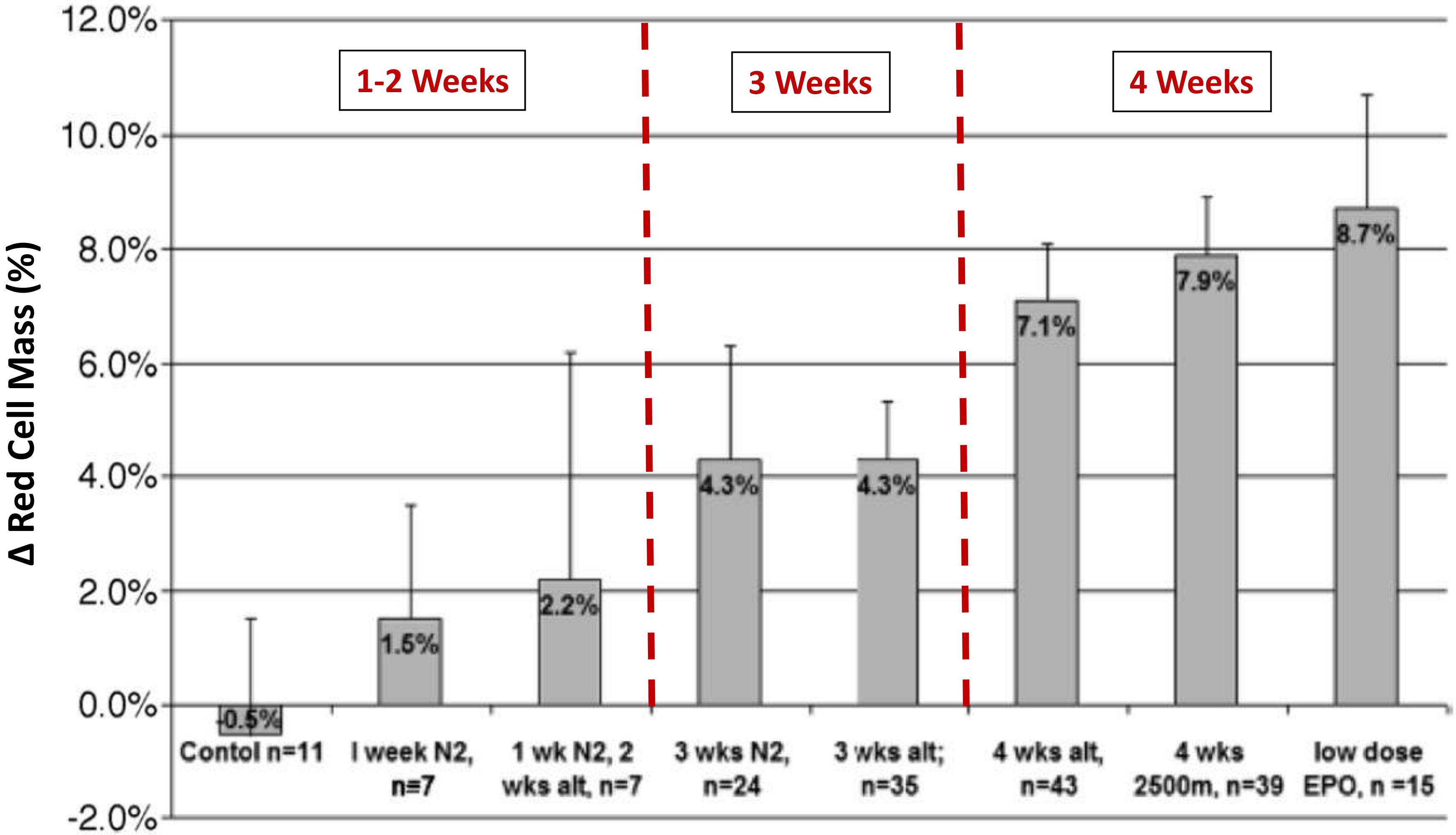
IS THE CURRENT TRAINING LOAD
- _____ Too Hard
- _____ Just Right
- _____ Too Easy

COMMENTS [Please list any specific aches, pains or injuries. Please list any other comments]:



Effective “Dose”

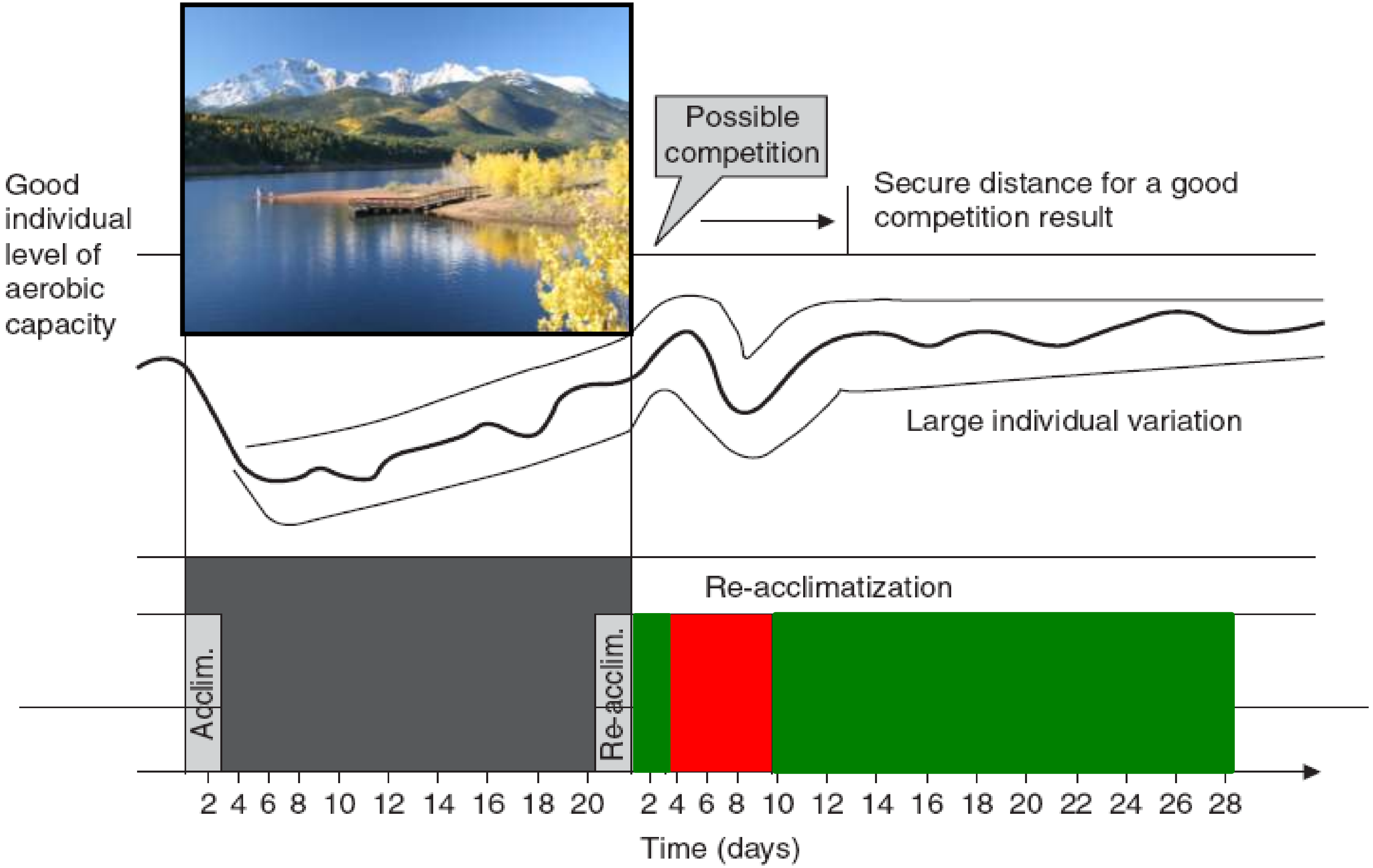
Weeks



RL Wilber, J Stray-Gundersen & BD Levine. *MSSE* 39:1590-1599, 2007


AFTER Altitude Training Camp

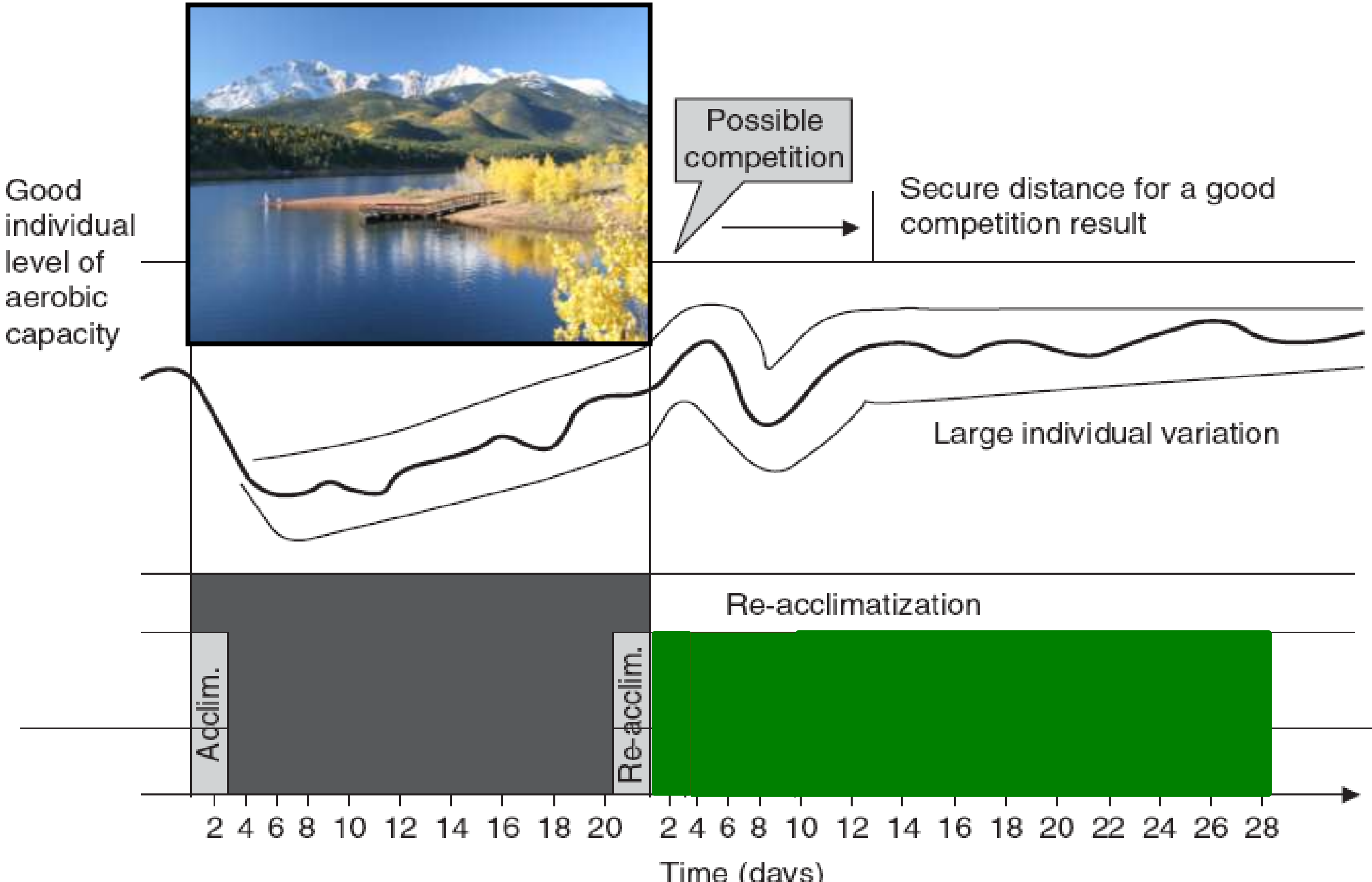
Return to Sea Level



Millet et al. *Sports Med*. 40:1-25, 2010

Fuchs & Reiss. *Trainerbibliothek* 27:128, 1990

Return to Sea Level



Millet et al. *Sports Med*. 40:1-25, 2010

Fuchs & Reiss. *Trainerbibliothek* 27:128, 1990


Annual Plan for Altitude Training

US Olympic Training Center

Colorado Springs 1860 m / 6200 ft

MICHAEL PHELPS
Beijing 2008
8 Gold medals
22 Olympic medals

MISSY FRANKLIN
London 2012
4 Gold medals

ALLISON SCHMITT
London 2012
3 Gold medals

Use of Altitude/Hypoxic Training by Olympic Athletes

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  - LH + TL
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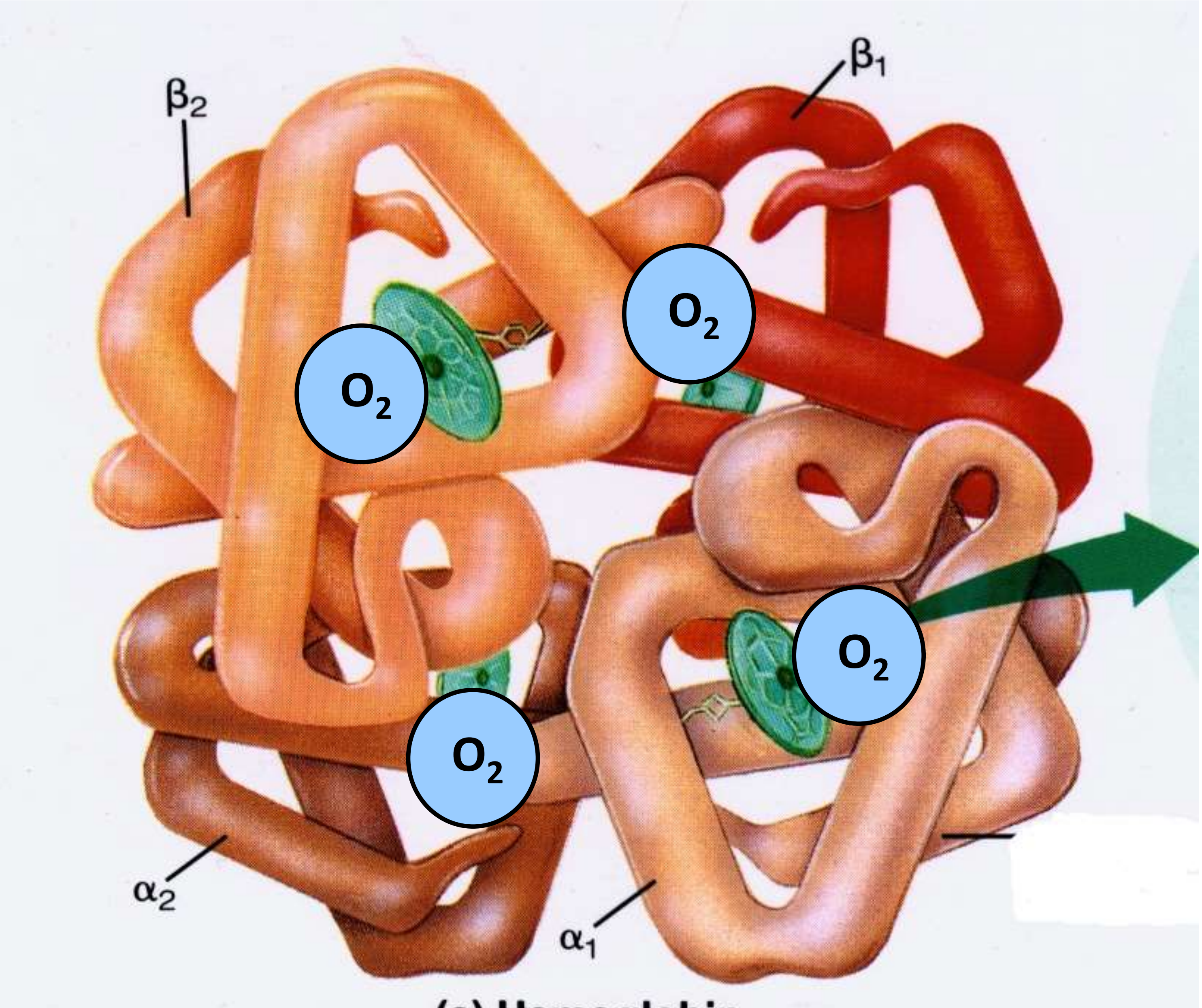
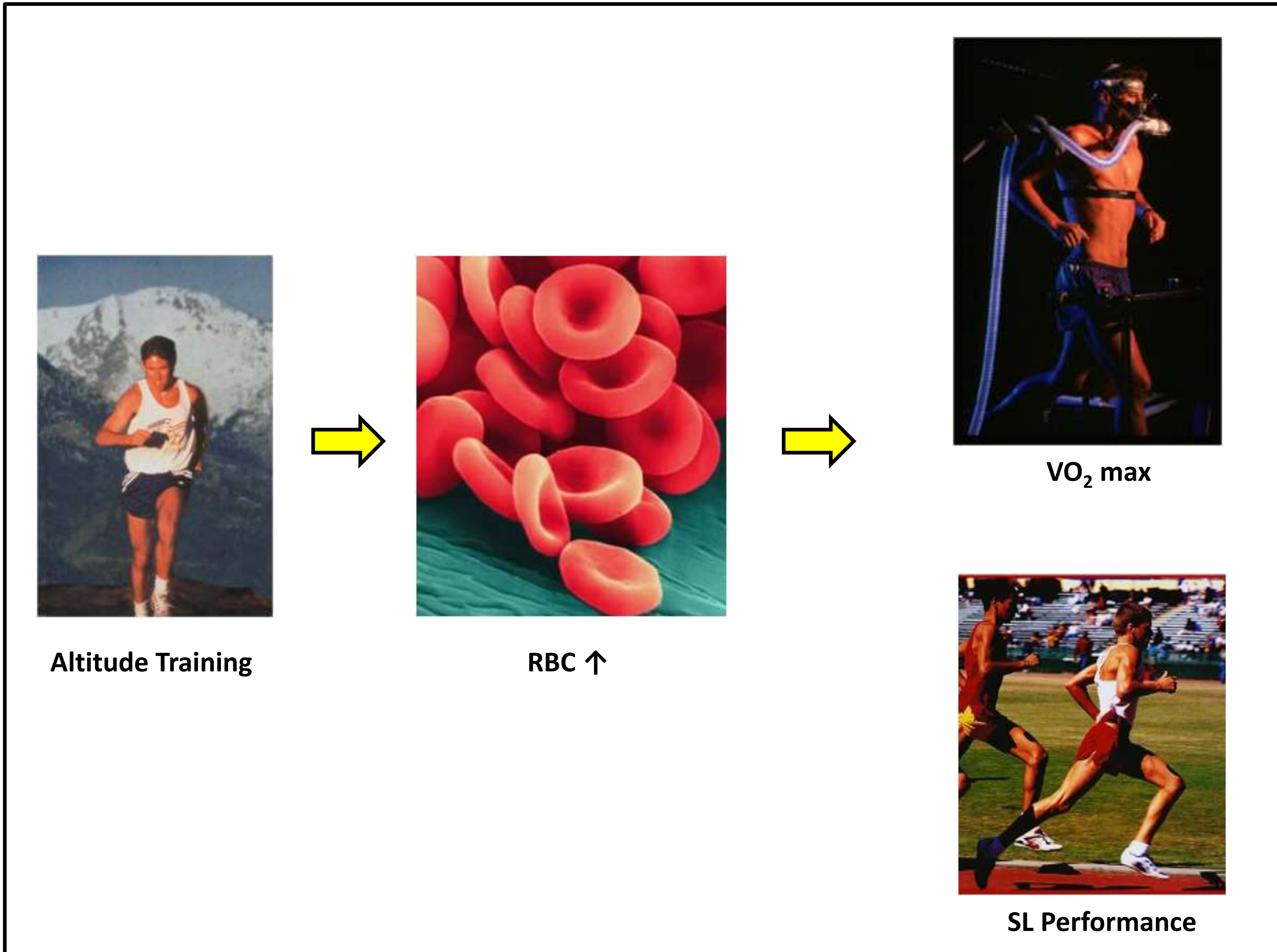
- **Physiological Benefits**
- **Summary & Resources**

Physiological Benefits

RBC

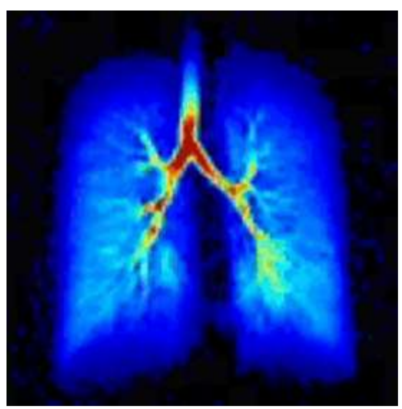


(a) Hemoglobin


Altitude Training
RBC ↑
VO2 max
SL Performance

Physiological Benefits

RBC

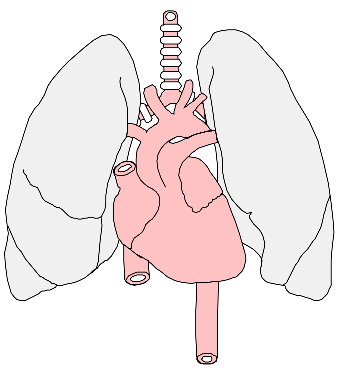


Hypoxic Ventilatory Response (HVR)

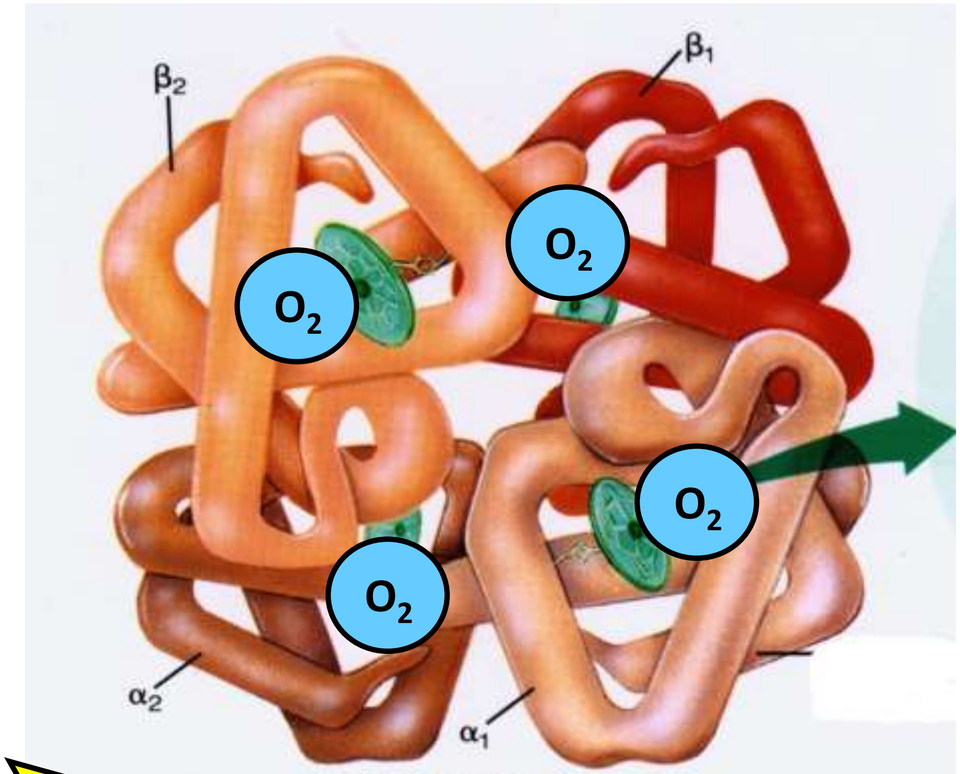
ALTITUDE

BP
600 mm Hg

O_2
20.93%

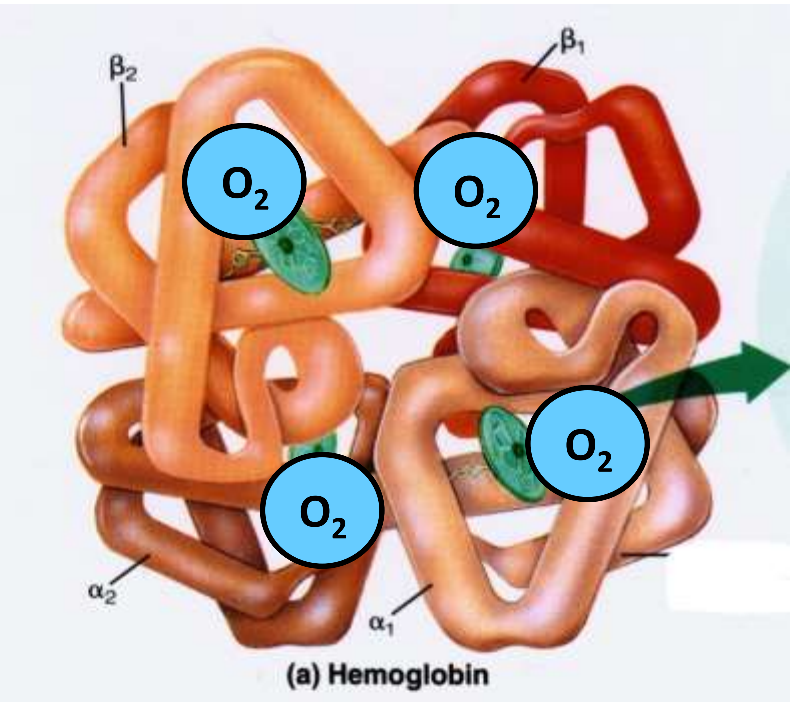


P_IO_2 ~ 126 mm Hg

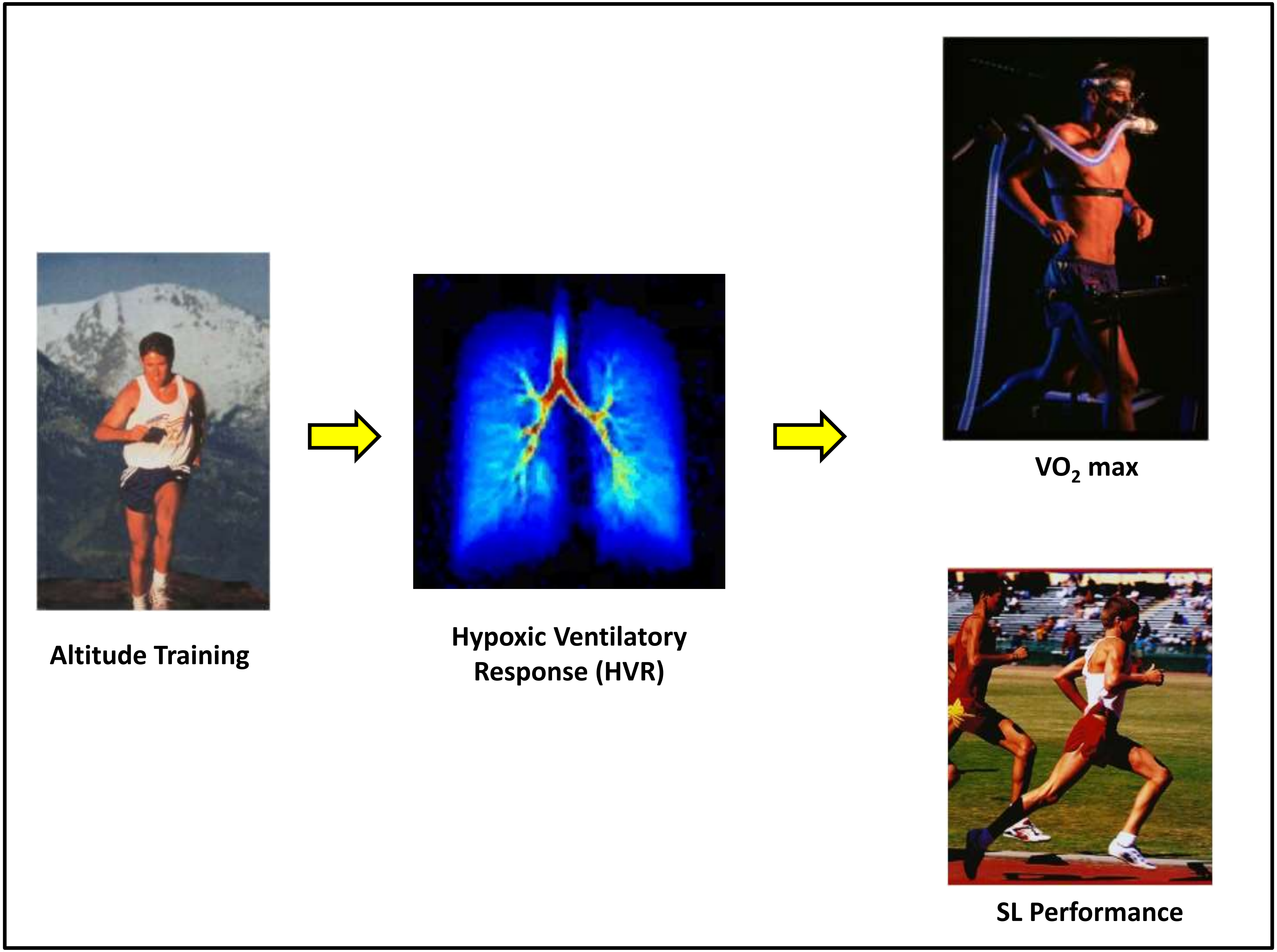


(a) Hemoglobin

HYPOXIC VENTILATORY RESPONSE

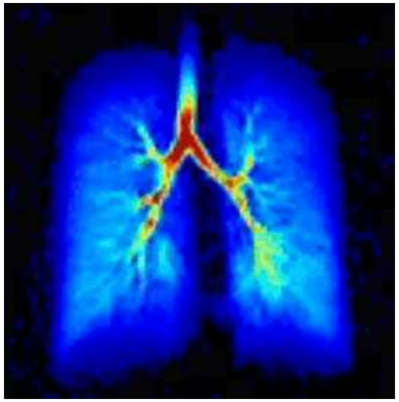


(a) Hemoglobin

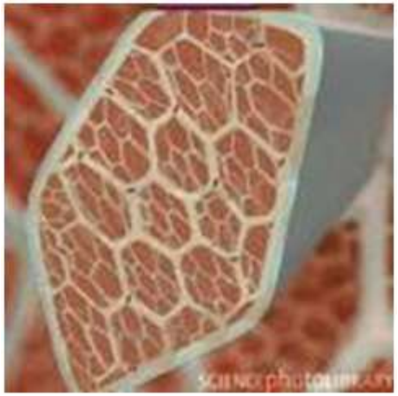

Altitude Training
Hypoxic Ventilatory Response (HVR)
VO2 max
SL Performance

Physiological Benefits

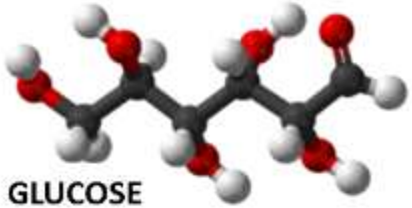
RBC



Hypoxic Ventilatory Response (HVR)



Skeletal mm. Buffering Capacity



GLUCOSE

PFK

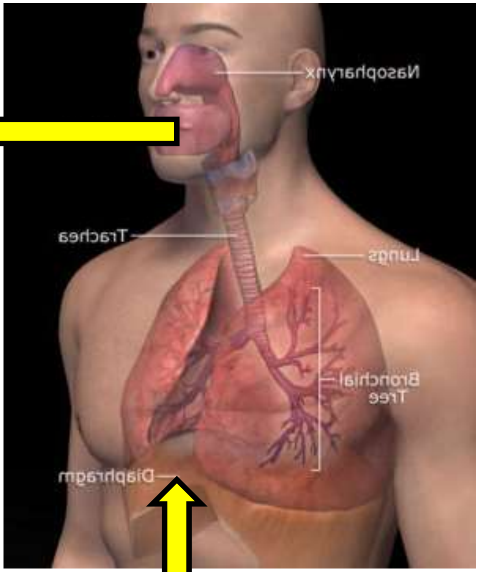
2 Pyruvic acid

<u>NO</u> O_2

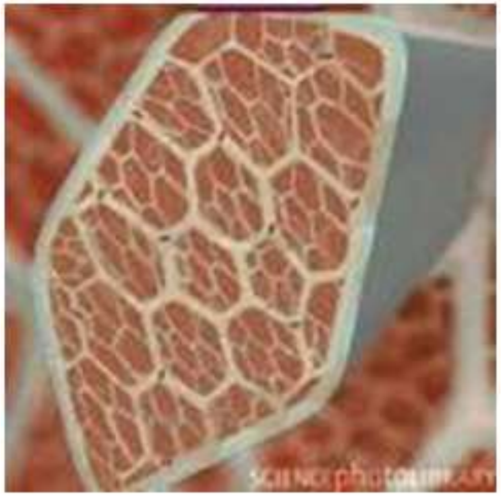
2 Lactic acid + 2 ATP

$C_3H_5O_8^-$ + H^+

LACTATE

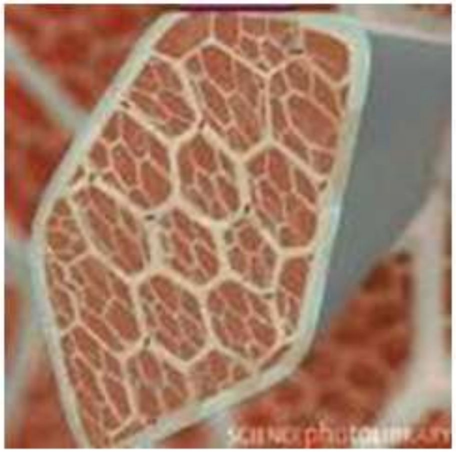


H_2O + CO_2



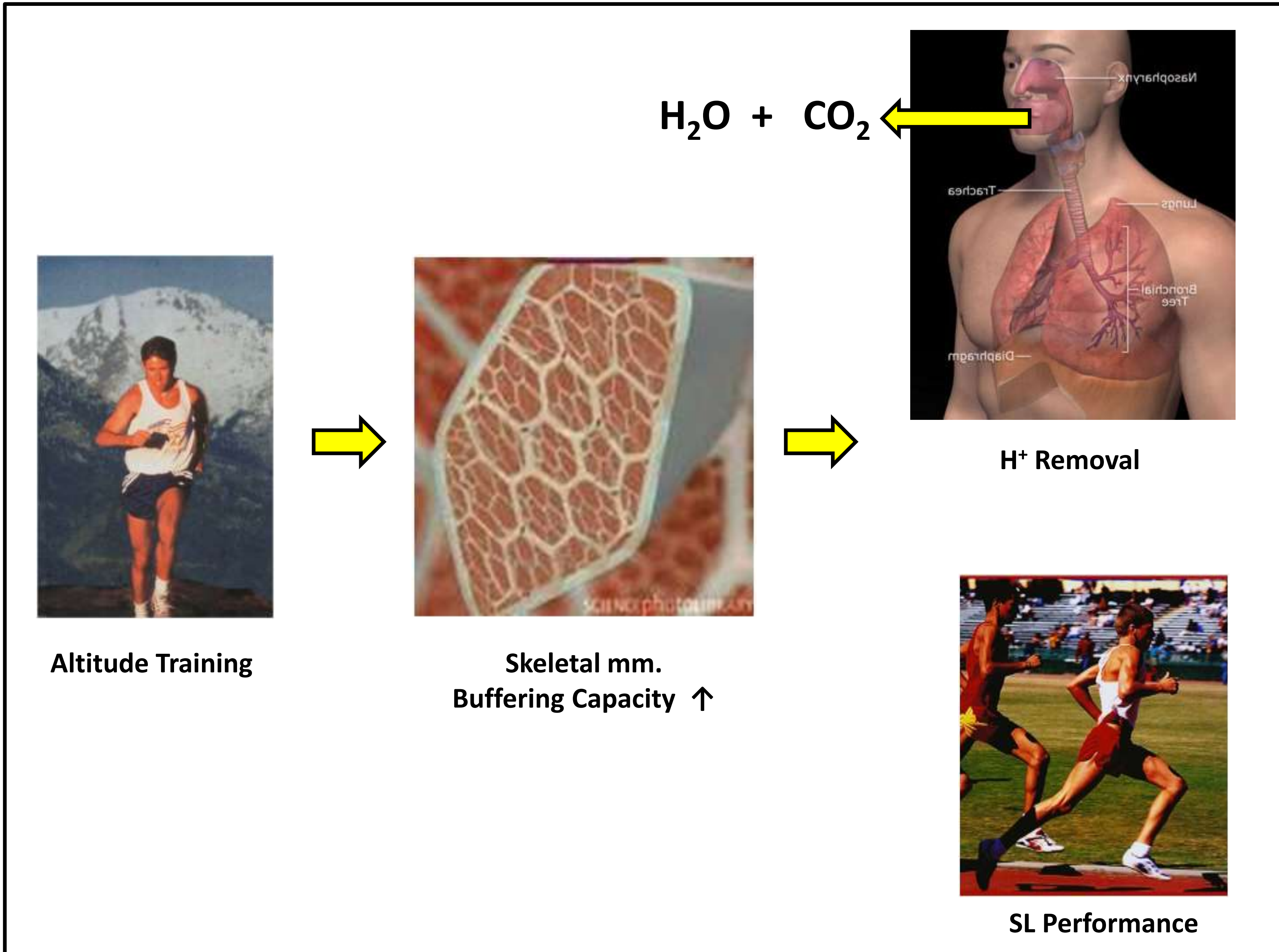
H^+ + HCO_3^- -----> H_2CO_3

BICARBONATE BUFFER

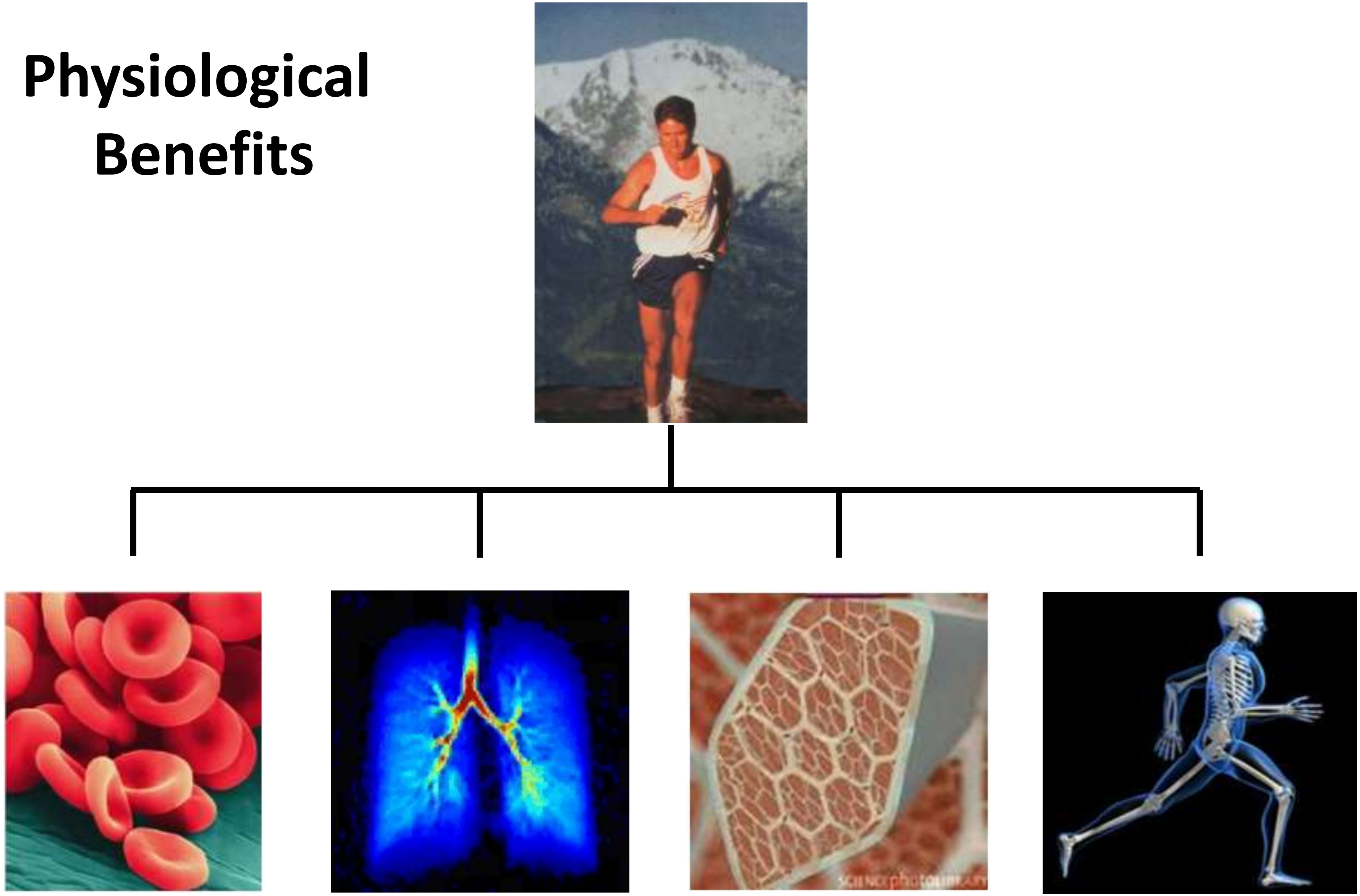


$C_3H_5O_8^-$ + H^+

LACTATE


H_2O + CO_2
H^+ Removal
Altitude Training
Skeletal mm.
Buffering Capacity ↑
SL Performance

Physiological Benefits

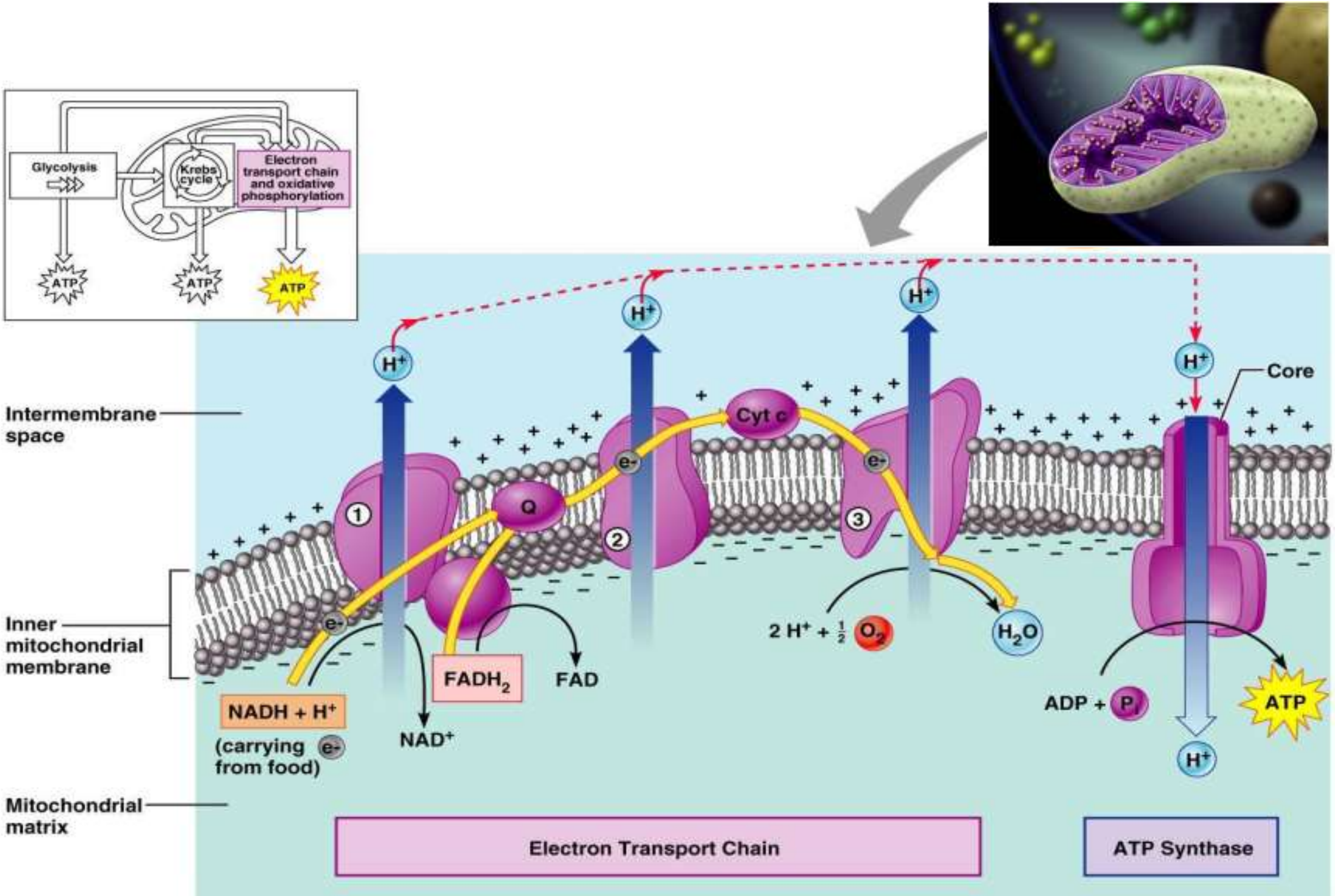


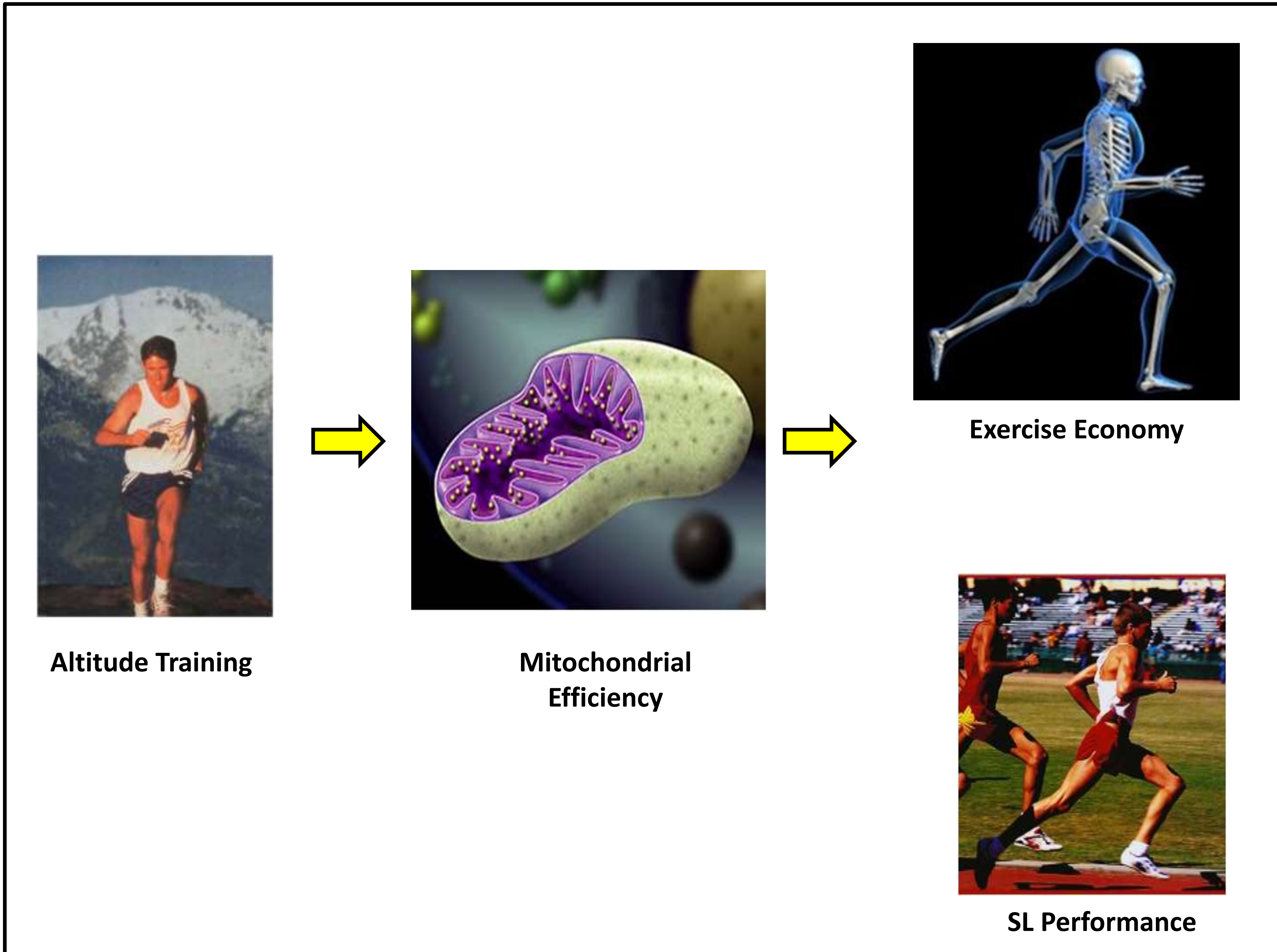
RBC

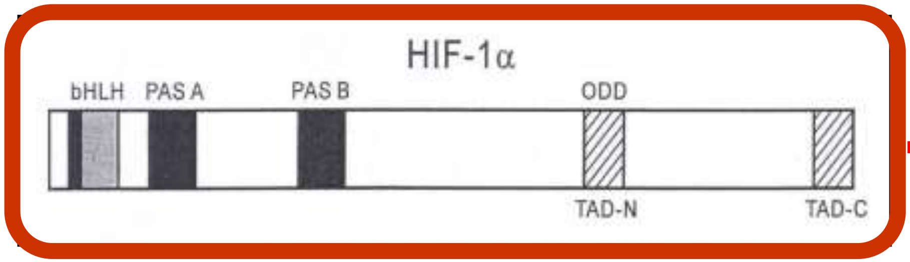
Hypoxic Ventilatory Response (HVR)

Skeletal mm. Buffering Capacity

Exercise Economy


Glycolysis
Krebs cycle
Electron transport chain and oxidative phosphorylation
ATP
ATP
ATP
Intermembrane space
Inner mitochondrial membrane
Mitochondrial matrix
H+
H+
H+
H+
H+
Core
Cyt c
Q
e-
1
2
3
NADH + H+
(carrying e- from food)
NAD+
FADH2
FAD
2 H+ + 1/2 O2
H2O
ADP + Pi
ATP
Electron Transport Chain
ATP Synthase


Altitude Training
Mitochondrial Efficiency
Exercise Economy
SL Performance



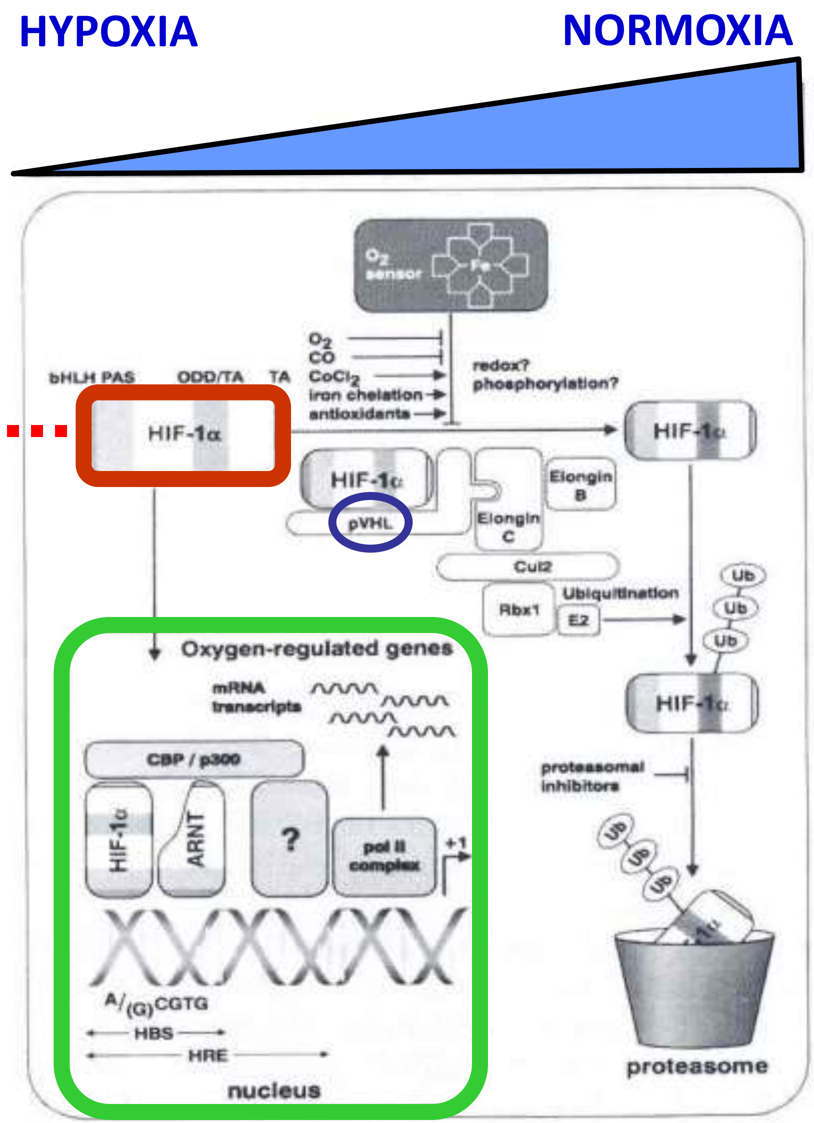


FIG. 5. Schematic representation of the regulation of HIF-1complex-mediated gene transcription by hypoxia (Wenger et al., 1999)

Caro, J. *High Altitude Medicine & Biology*. 2:145-154, 2001

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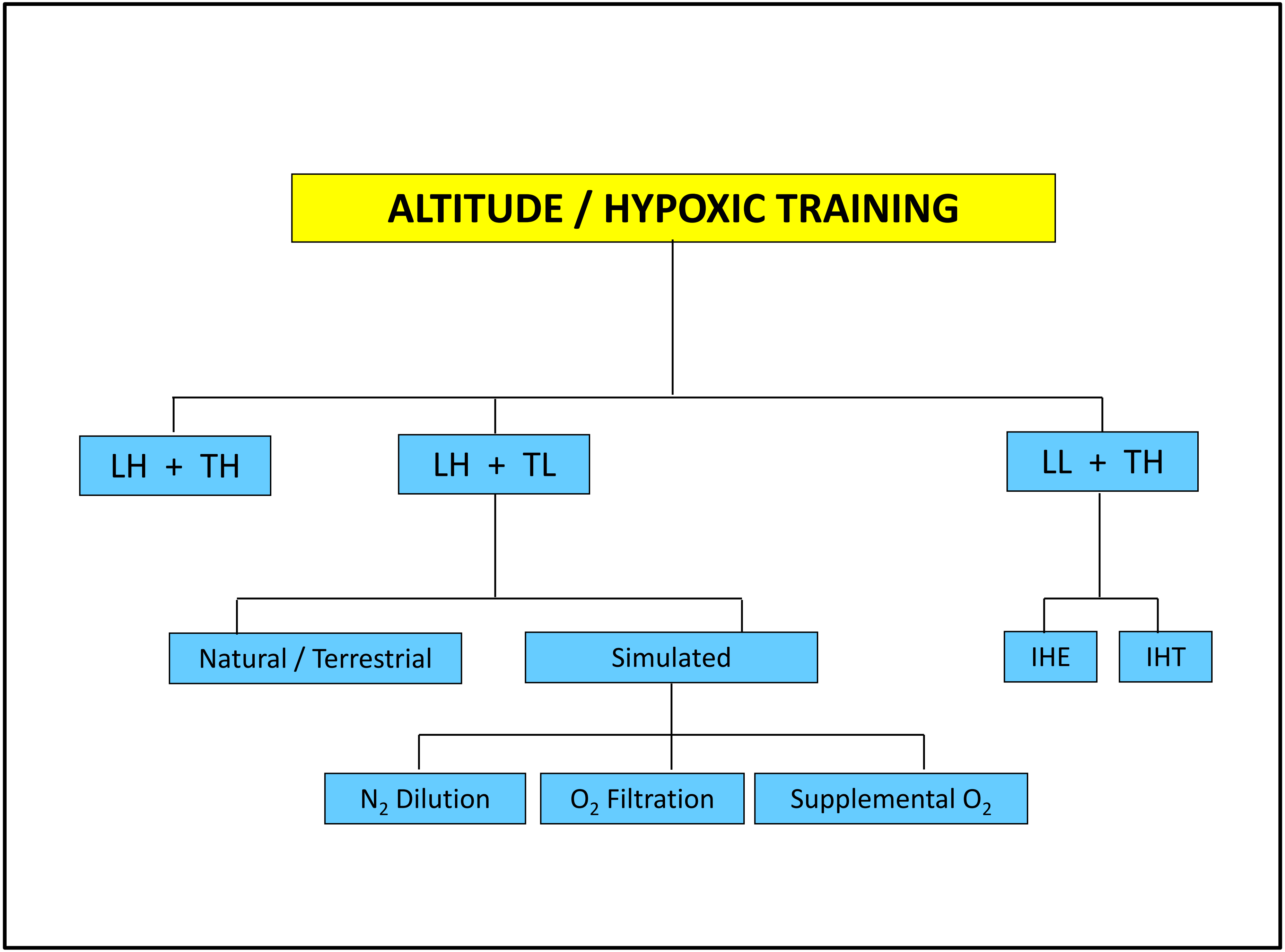
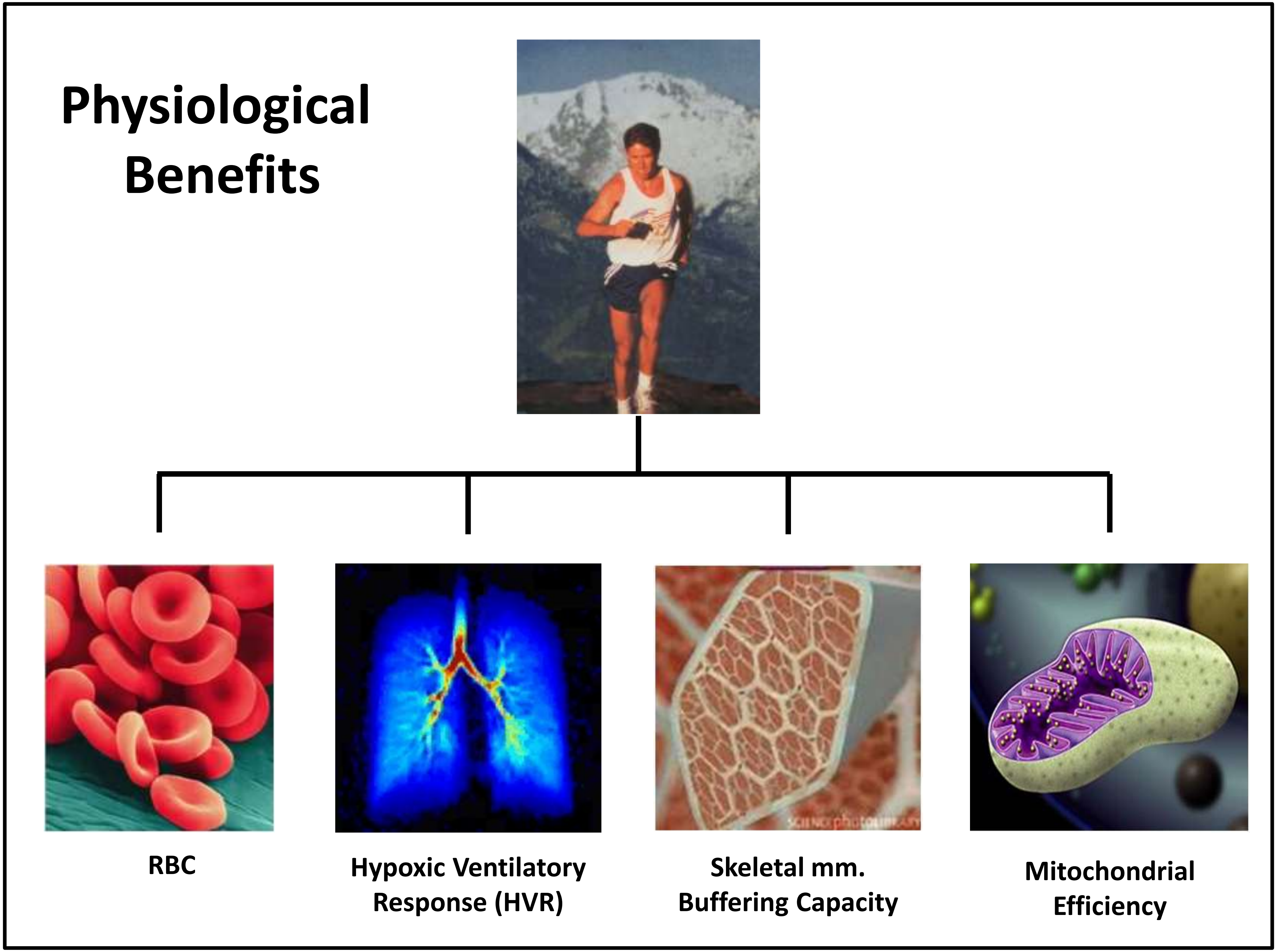
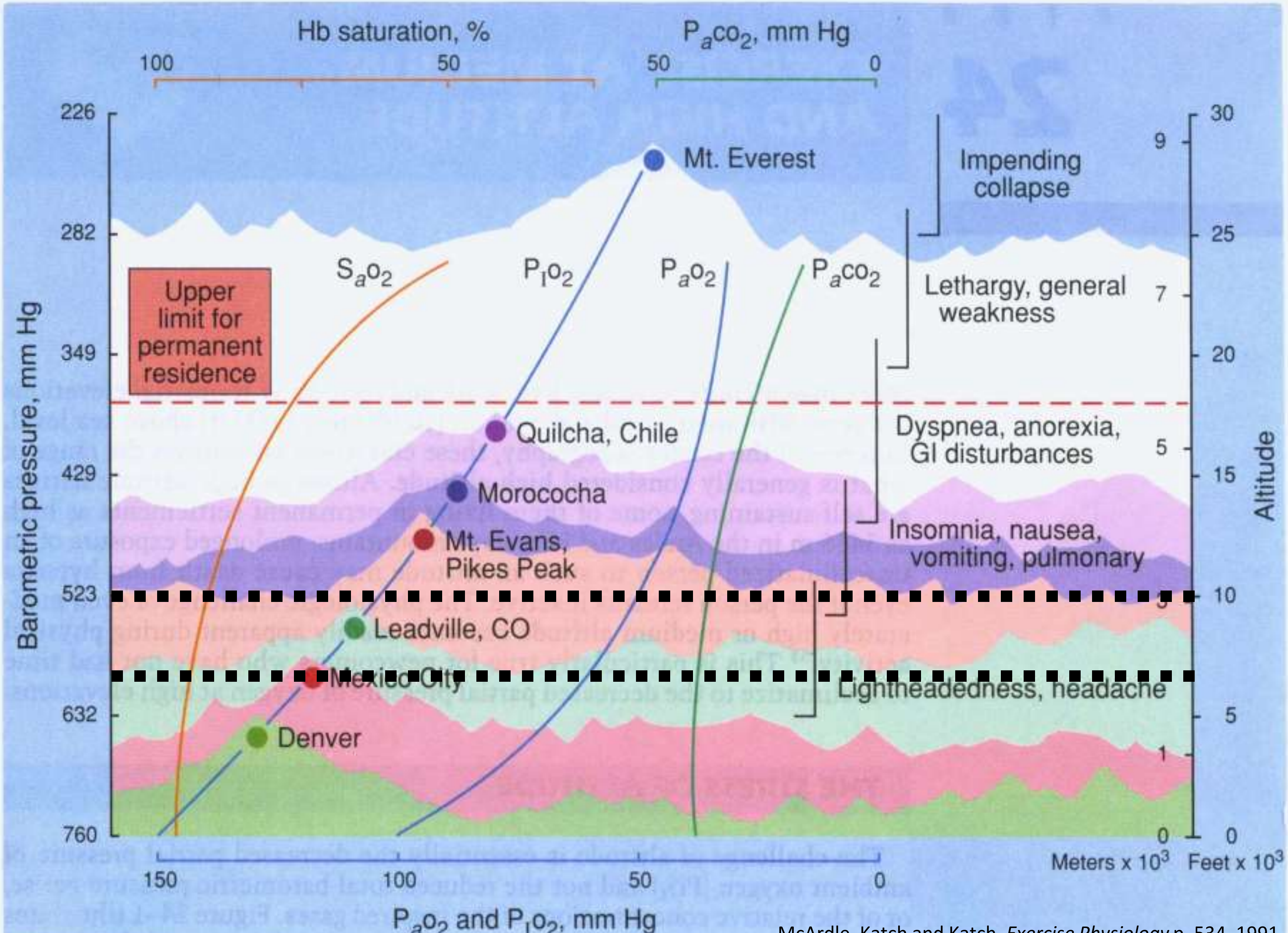


ALTITUDE / HYPOXIC TRAINING
LH + TH
LH + TL
LL + TH
Natural / Terrestrial
Simulated
IHE
IHT
N_2 Dilution
O_2 Filtration
Supplemental O_2

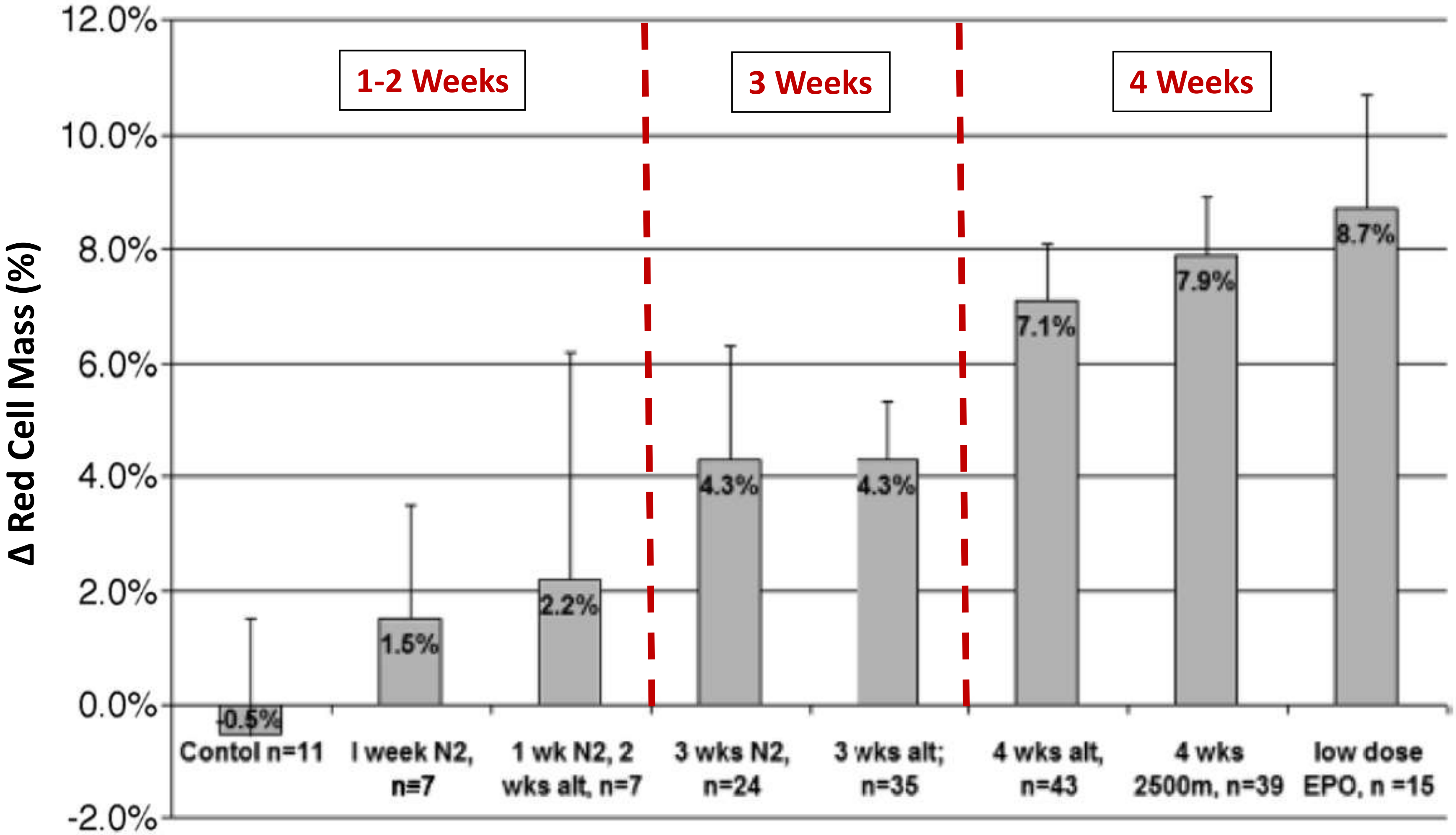

Physiological Benefits
RBC
Hypoxic Ventilatory Response (HVR)
Skeletal mm. Buffering Capacity
Mitochondrial Efficiency



McArdle, Katch and Katch. *Exercise Physiology* p. 534, 1991

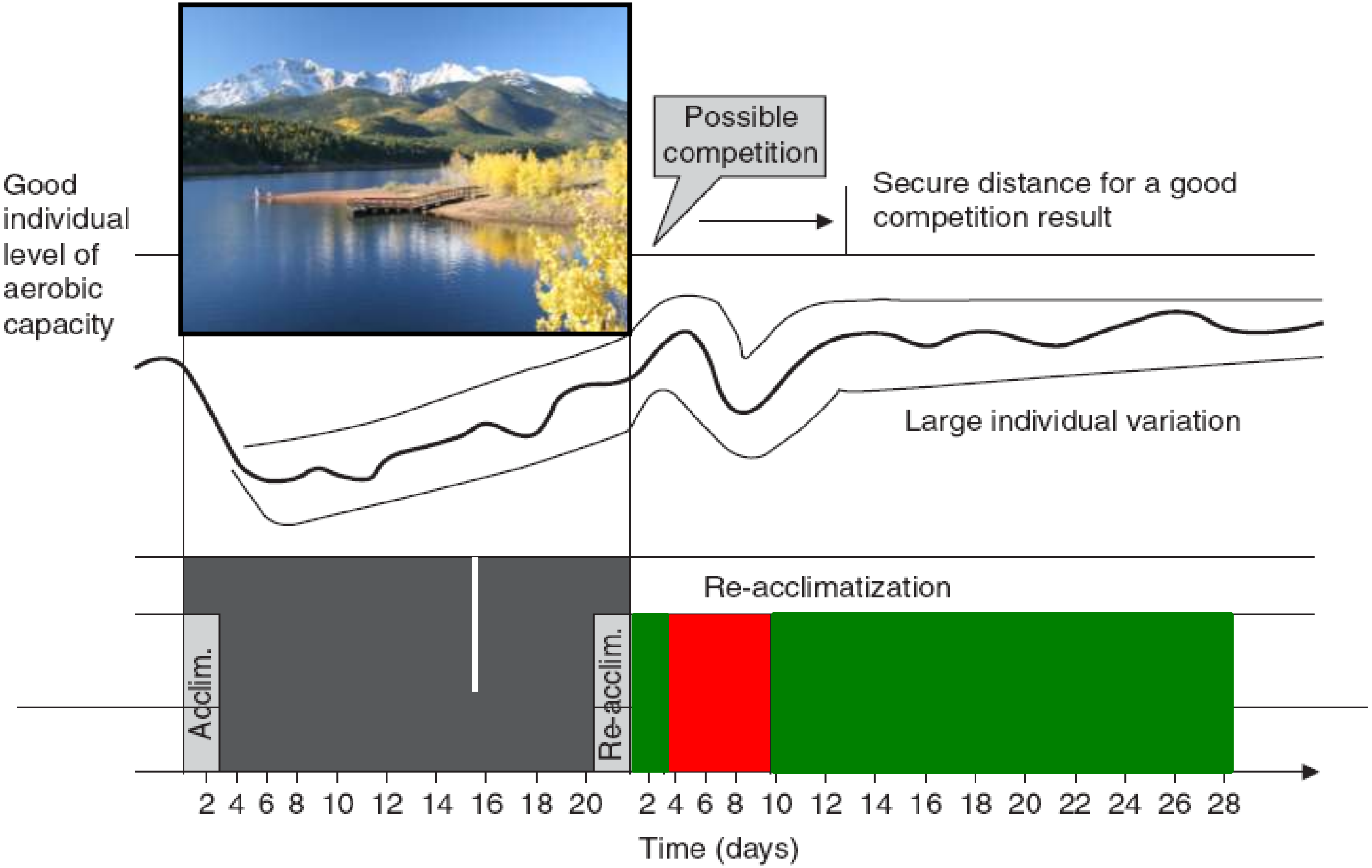
Effective "Dose"

Weeks



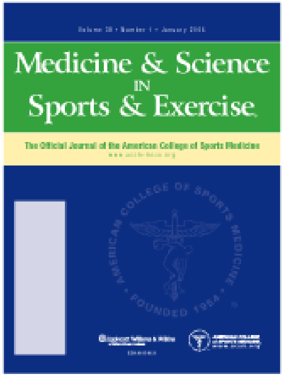
RL Wilber, J Stray-Gundersen & BD Levine. *MSSE* 39:1590-1599, 2007

Return to Sea Level



Millet et al. *Sports Med*. 40:1-25, 2010

Fuchs & Reiss. *Trainerbibliothek* 27:128, 1990

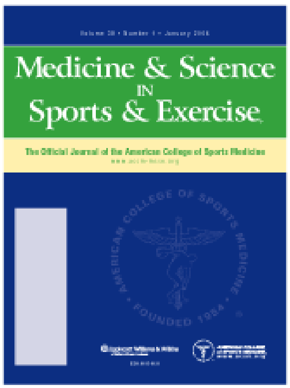


Application of Altitude/Hypoxic Training by Elite Athletes

RANDALL L. WILBER

Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO

MSSE, 39: 1610-1624, 2007

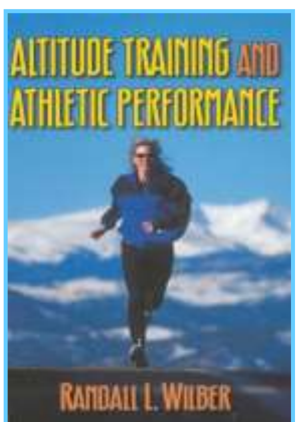


Effect of Hypoxic "Dose" on Physiological Responses and Sea-Level Performance

RANDALL L. WILBER[1], JAMES STRAY-GUNDERSEN[2], and BENJAMIN D. LEVINE[3]

[1]*Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO;* [2]*Department of Health, University of Utah, Salt Lake City, UT; and* [3]*Institute for Exercise and Environmental Medicine, Presbyterian Hospital of Dallas, University of Texas Southwestern Medical Center, Dallas, TX*

MSSE, 39: 1590-1599, 2007



Altitude Training and Athletic Performance

www.humankinetics.com

Gracias!

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