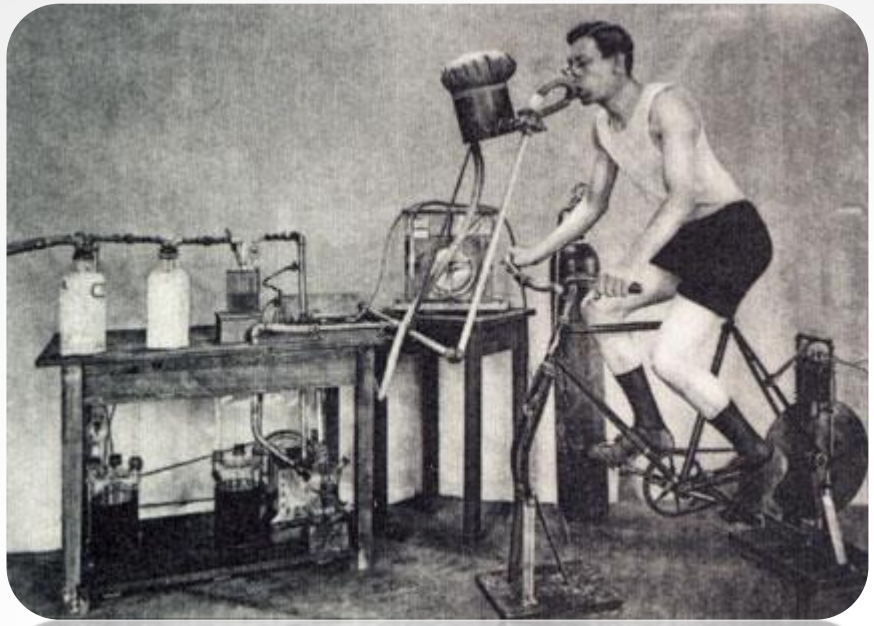

The Scientific Preparation and Monitoring of the Elite Athlete

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Sports Medicine and Performance Center
UNIVERSITY OF COLORADO | SCHOOL OF MEDICINE

IN PARTNERSHIP WITH BOULDER COMMUNITY HEALTH

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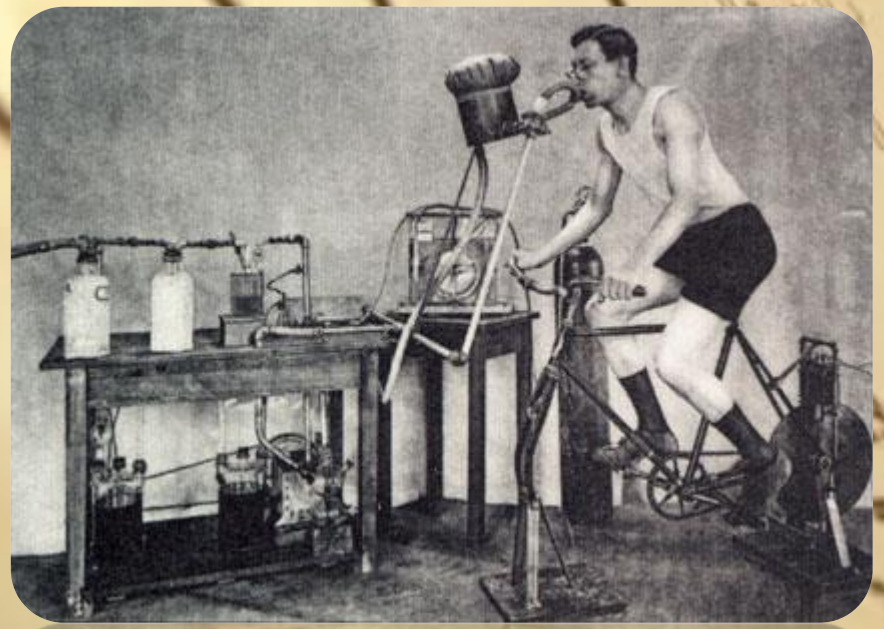


We have seen amazing advances in science in the sport

Denying the scientific approach in the XXI century is denying progress

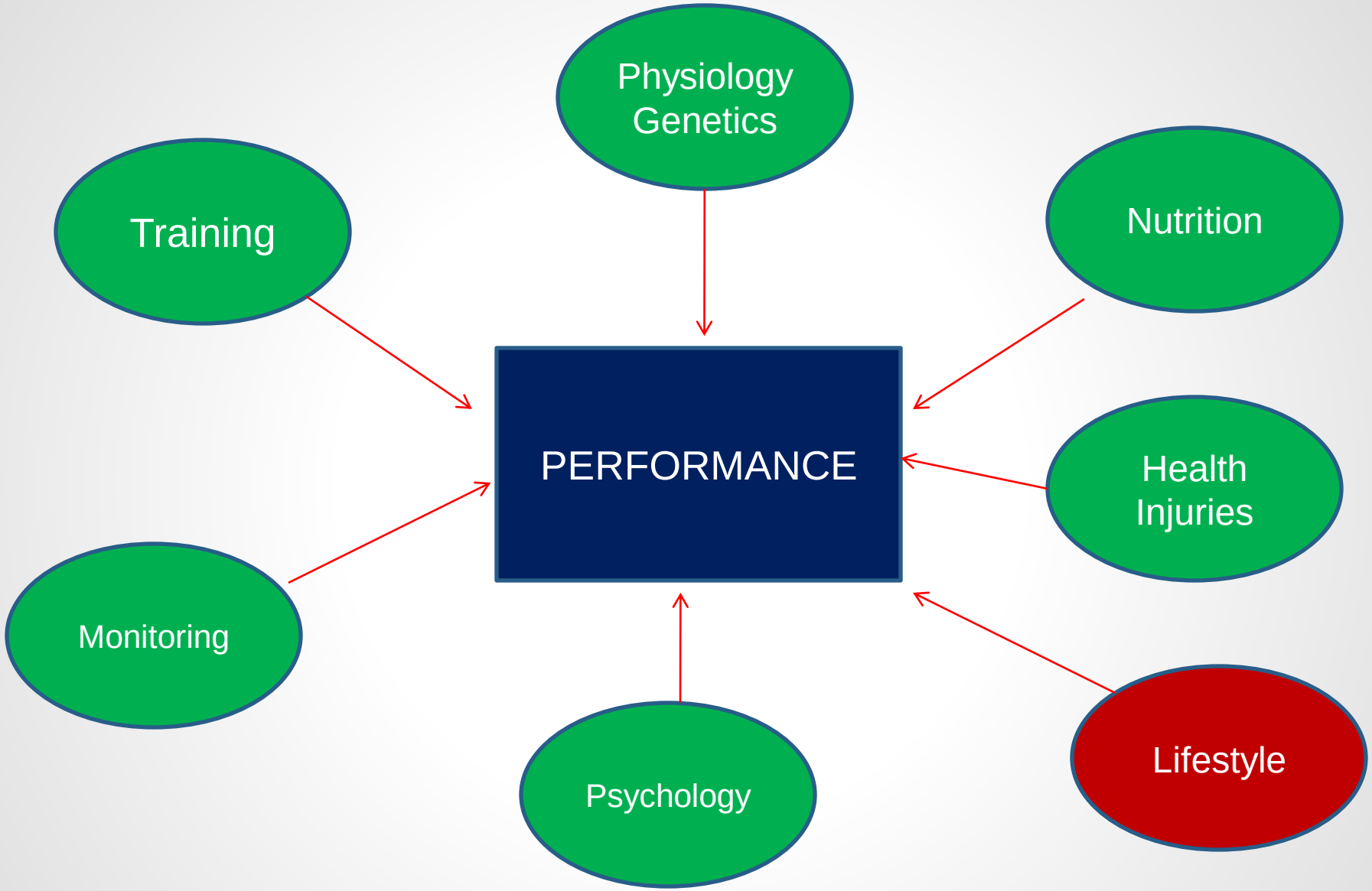
However, when it comes to training & coaching many coaches and athletes don’t rely on science

Marginal gains are thought to be the scientific approach…But they are just that: Marginal gains…That 1%…

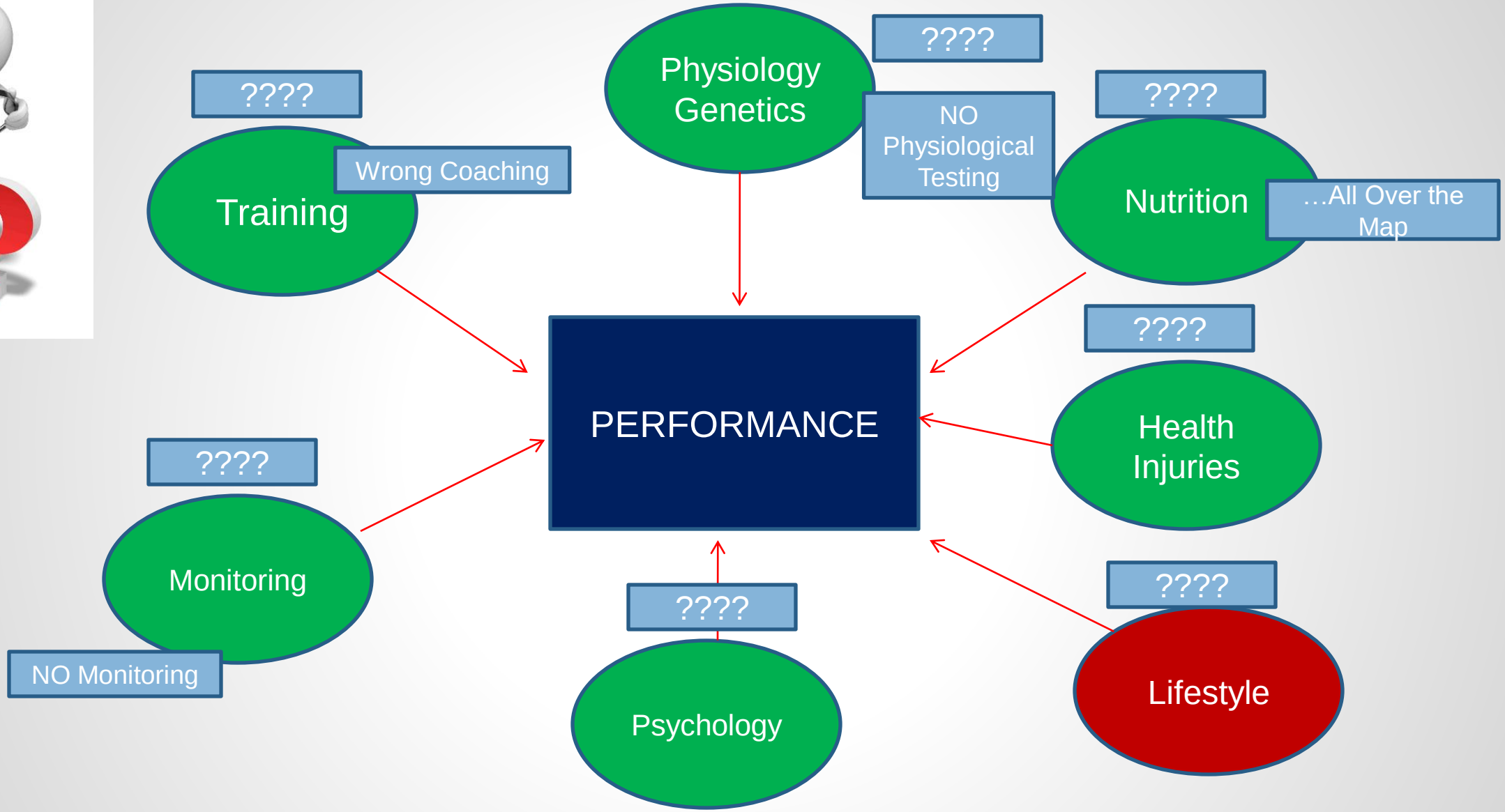
The Major gains (The ABC’s) however are not achieved many times because the scientific approach is not applied by coaches and athletes

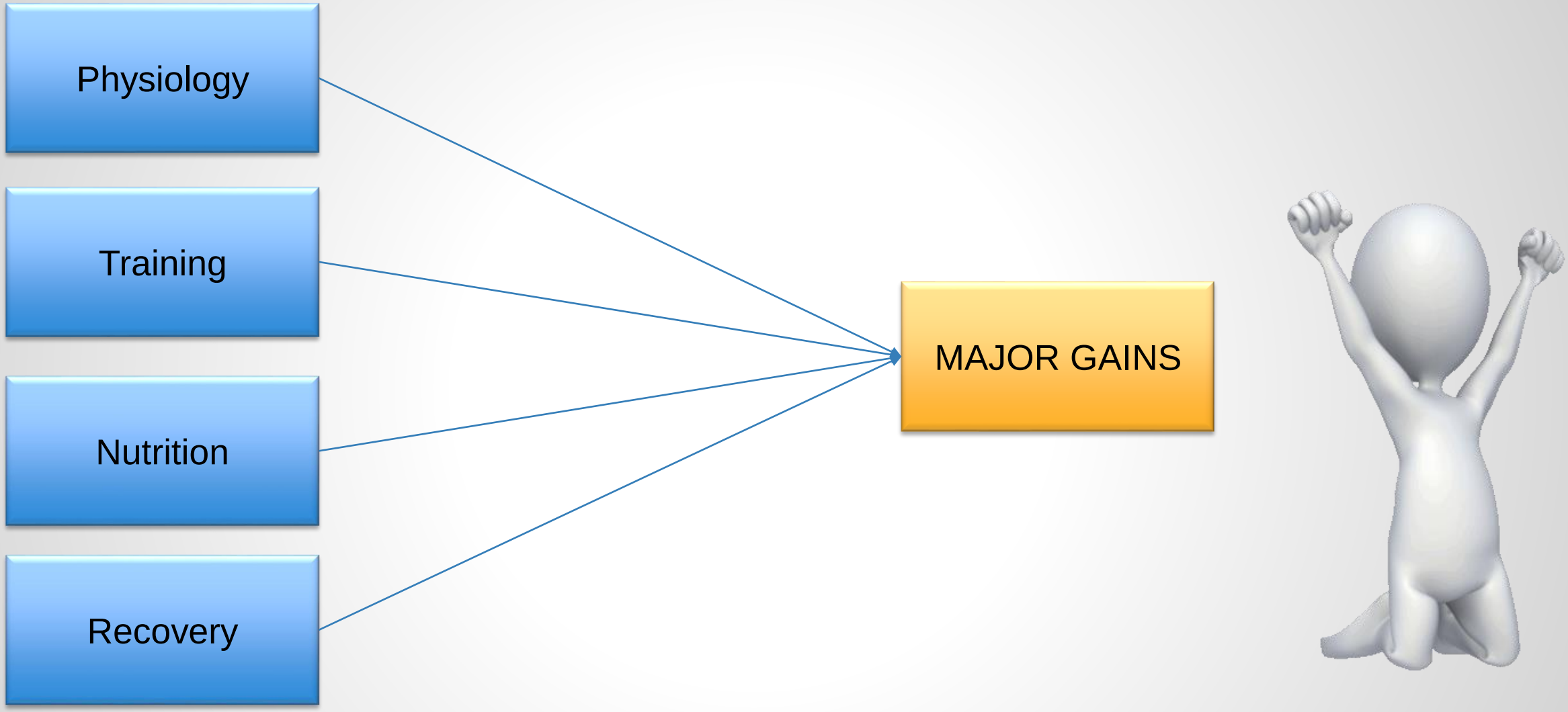
Today's Main Topics

Determinants of Performance



HOW MANY ELEMENTS DO WE CONTROL???




Physiology
Training
Nutrition
Recovery
MAJOR GAINS

MARGINAL GAINS

MAJOR GAINS

Vs

MARGINAL GAINS

…….That 1%

Medicine of Cycling™

THE MAJOR GAINS
What Training Really Elicits

Muscle Metabolism is Absolutely Key in Endurance Performance

Endurance Training is mainly about improving at the Metabolic Level

What are the Principles of Training?

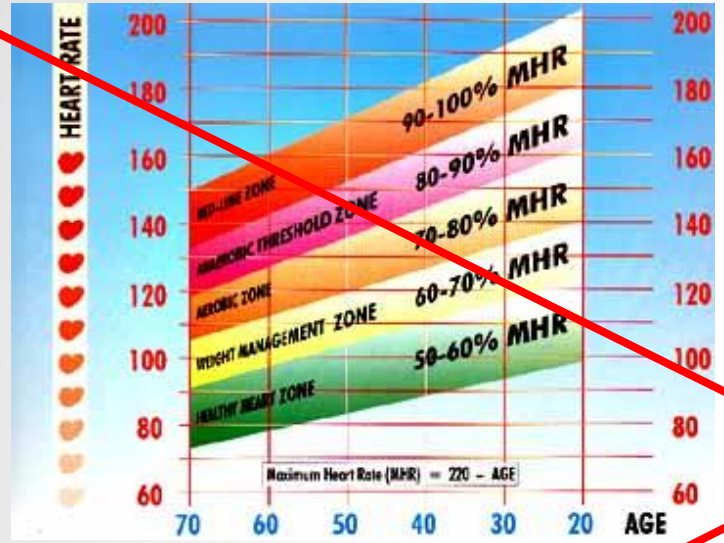
- Specificity
- Individuality
- Overload
- Progression
- Adaptation
- Recovery

Training Individualization
Why is it so important?

Each Body is DIFFERENT!. We have DIFFERENT Metabolism and Physiology and therefore different parameters and training zones!!

The Only way to Individualize training scientifically is to know who we are working with

We MUST measure the physiology and metabolism of who are we working with



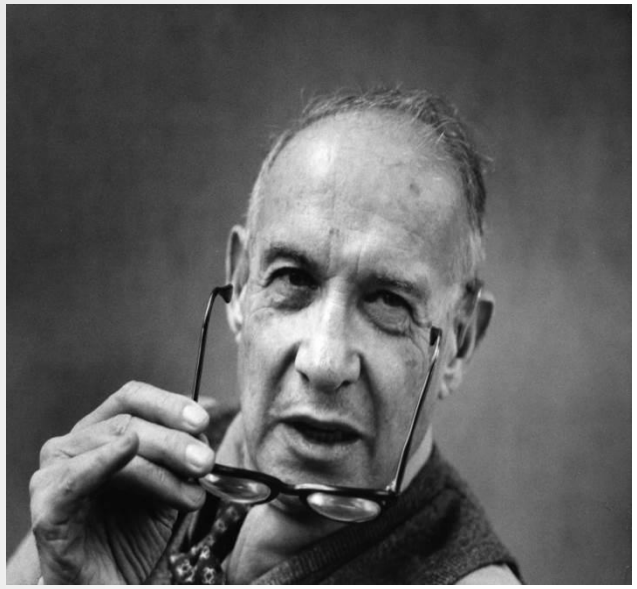
Training Intensity Zones
www.i-multisport.com

Heart Rate Zones (cycling and running)	Swim Pace (time per 100)
ZONE 1 Recovery pace	
ZONE 2 Aerobic base pace	T-pace + 10 sec
ZONE 3 Aerobic tempo pace	T-Pace + 5 sec
ZONE 4 Sub-LT "race" pace	T-Pace
ZONE 5A Super-LT pace	T-Pace
ZONE 5B Anaerobic effort	T-Pace – 5 sec
ZONE 5C All out sprinting effort	

Intensity	Zone	Accomplishment	Borg
LOW	1	Low Endurance	2
	2	Basic Endurance	3
MEDIUM	3	Tempo	5
	4	Road Race	6
HIGH	5	Speed training above Threshold	7
	6	VO_2 max training Anaerobic sprint	10

Heart Rate Training Zones

Zone/Level	Name	Range	Edwards[1]	Coggan[2]	Edwards[1]	Coggan[2]
1	Active Recovery	Low	50%		97	
		Mid	55%		107	
		High	60%	< 68%	116	
2	Endurance	Low	60%	69%	116	121
		Mid	65%	76%	126	133
		High	70%	83%	136	145
3	Tempo	Low	70%	84%	136	147
		Mid	75%	89%	146	156
		High	80%	94%	155	165
4	Threshold	Low	80%	95%	155	166
		Mid	85%	100%	165	175
		High	90%	105%	175	184
5	VO2max	Low	90%	> 106%	175	
		Mid	95%		184	
		High	100%		194	
Enter LTHR ==========>		175	Coggan[2]	Ref. Dr. Andy Coggan		
Enter HRmax ==========>		194	Edwards[1]	Ref. Sally Edwards		



Peter Drucker

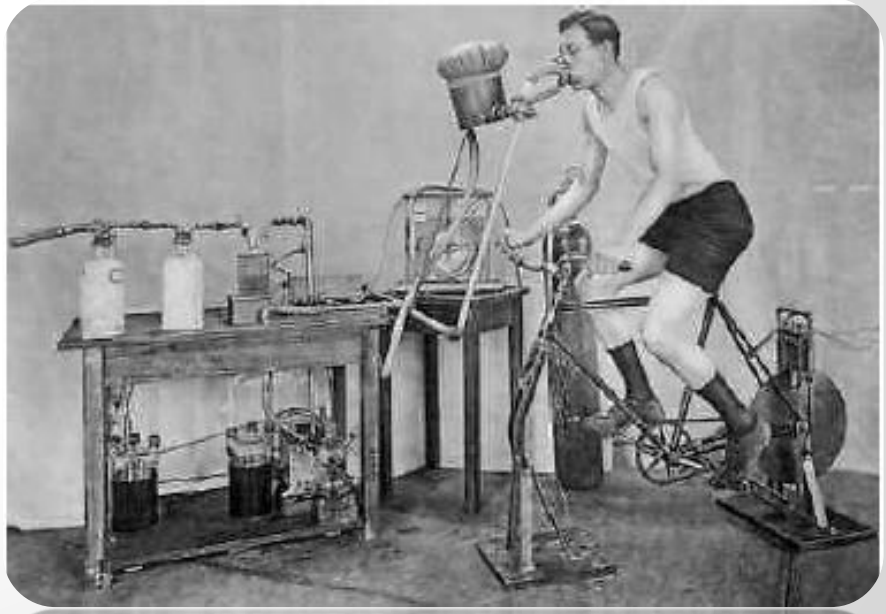
-The man who invented Management
-Father of Business Analytics
-Father of Modern Business Corporation

What Gets Measured, Gets Managed" –Peter Drucker

Physiological Testing

- The foundation of any scientific-based training program- Coaching 101

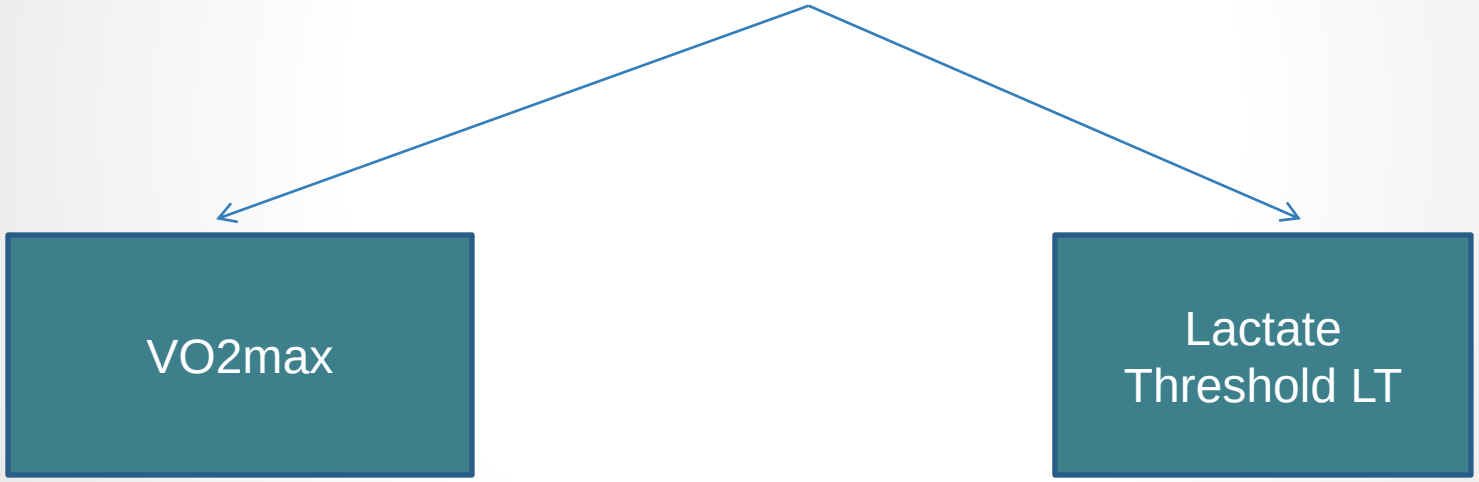
- It is crucial to establish the physiological and metabolical parameters of each athlete in order to prescribe the most accurate and scientific-based training program.
- Evaluation of the “engine” of an athlete.
- Evaluation of the weak and strong points.
- Evaluation of quantity and quality of training



Traditional View

Exercise Physiology LAB

Exercise Physiology/Human PERFORMANCE Lab



[redacted]

Exercise Physiology Lab

*** VO2 max ***

Patient Information

Name: ,
Age: 25 yrs
Height: 72.5 in (184 cm)

File number: 11A-Ultra
Sex: M
Weight: 158.0 lb (71.8 kg)

Test time: 2010/10/27 10:41
Doctor: Mattern
Tech:

Test Protocol

Test degree: Maximal
Exercise device: Treadmill

Test Environment

Insp. temp.: 22.0 deg C
Insp. humidity: 32.0 %
Insp. O2: 20.94 %
(STPD to BTPS: 1.2580)

Baro. pressure: 733.0 mmHg
Exp. flow temp.: Mean of room temp. and 37.0 deg C
Insp. CO2: 0.03 %

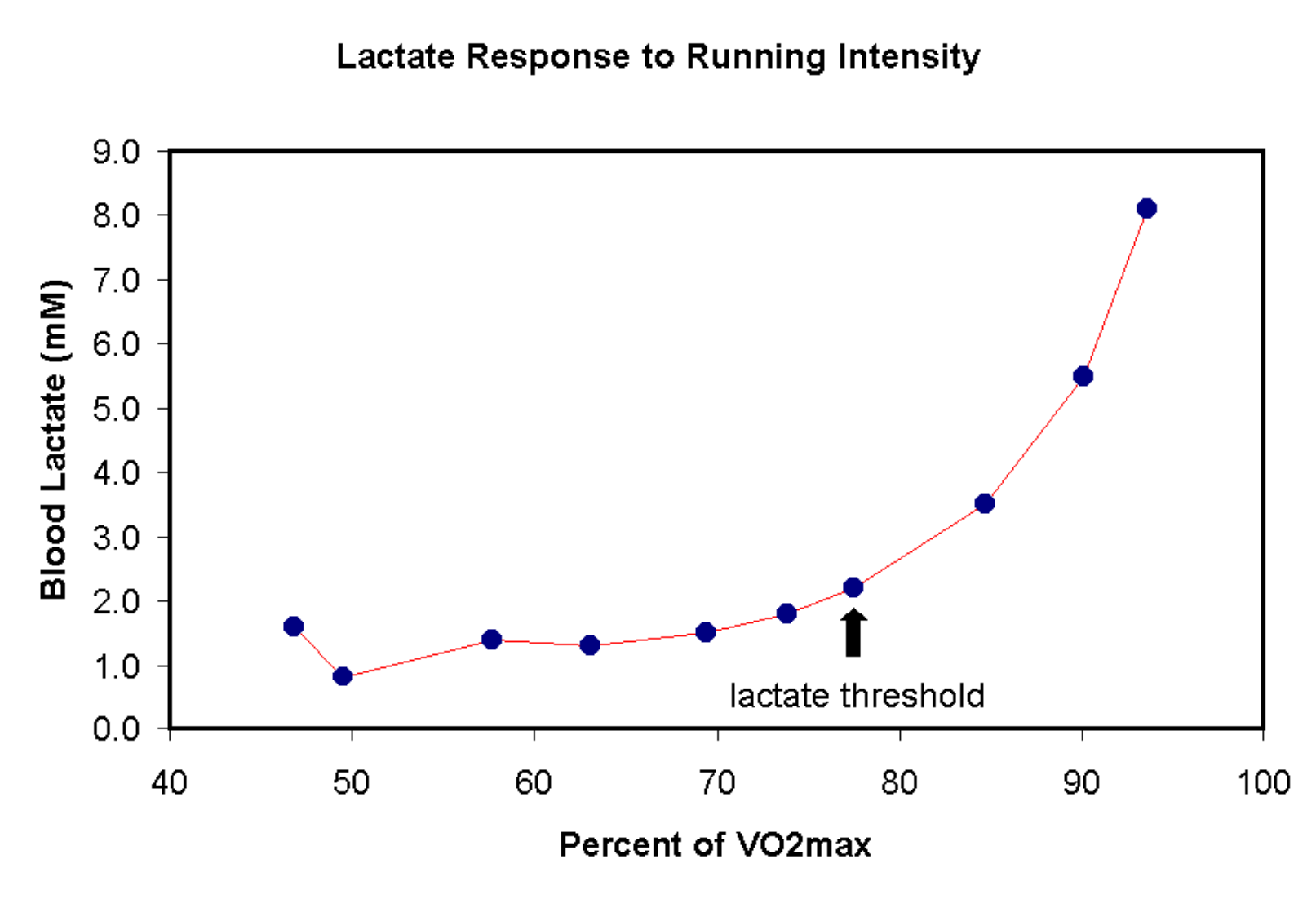
Base Values for Sampling

Base O2: 20.94 %

Base CO2: 0.03 %

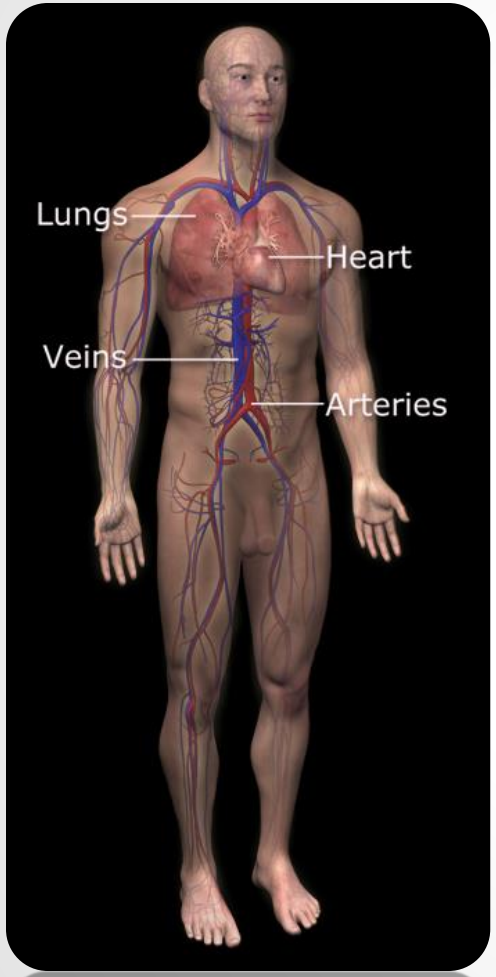
Measured O2: 20.95%, CO2: 0.02%

TIME min:sec	$\dot{V}O_2$ STPD L/min	$\dot{V}O_2$/kg STPD ml/kg/m	$\dot{V}E$ ATPS L/min	$\dot{V}CO_2$ BTPS L/min	$\dot{V}E$ BTPS L/min	RER	FEO2 %	FECO2 %	RR BPM	TE sec	TI sec	HR bpm
0:16	1.03	14.3	23.51	1.10	25.68	0.85	16.07	4.31	22	1.49	2.65	106
0:30	1.37	19.1	28.39	1.38	31.01	0.80	15.60	4.50	21	1.60	2.82	112
0:45	1.78	24.8	31.91	1.67	34.86	0.75	14.86	4.83	23	1.58	2.58	116
1:02	1.76	24.5	30.87	1.67	33.73	0.75	14.72	4.98	18	1.89	3.25	113
1:15	1.97	27.4	33.45	1.86	36.54	0.75	14.52	5.12	23	1.59	2.63	114
1:31	2.20	30.6	37.38	2.11	40.83	0.76	14.50	5.21	22	1.65	2.67	121
1:48	1.98	27.6	35.88	2.02	39.20	0.81	14.83	5.18	22	1.65	2.77	126
2:00	2.28	31.7	39.95	2.29	43.64	0.80	14.65	5.28	25	1.46	2.38	125
2:17	2.37	33.0	42.85	2.42	46.81	0.81	14.82	5.21	25	1.40	2.38	125
2:31	1.75	24.4	33.96	1.85	37.10	0.84	15.20	5.03	25	1.32	2.40	124
2:48	2.49	34.7	43.11	2.52	47.10	0.80	14.56	5.38	21	1.71	2.78	126
3:01	2.56	35.7	46.43	2.69	50.72	0.83	14.80	5.34	22	1.82	2.68	130
3:17	2.39	33.2	45.34	2.61	49.52	0.87	15.04	5.29	23	1.57	2.60	129
3:31	2.22	30.8	43.83	2.47	47.88	0.88	15.26	5.18	25	1.50	2.38	127
3:48	1.86	25.9	35.17	2.01	38.41	0.86	15.03	5.27	18	2.00	3.33	129
4:01	2.89	40.2	46.86	2.91	51.18	0.80	14.14	5.71	23	1.50	2.62	130
4:16	2.39	33.3	42.19	2.50	46.09	0.83	14.63	5.46	21	1.56	2.85	138
4:30	2.99	41.7	52.18	3.18	57.00	0.84	14.55	5.61	25	1.39	2.38	138
4:45	2.63	36.6	50.38	2.94	55.03	0.89	15.07	5.37	23	1.53	2.55	142
5:00	2.33	32.5	43.37	2.55	47.38	0.87	14.92	5.42	25	1.37	2.41	135
5:15	2.87	40.0	51.36	3.05	56.10	0.84	14.71	5.47	23	1.54	2.55	136
5:31	2.74	38.1	51.79	3.05	56.57	0.88	15.00	5.42	22	1.57	2.67	138
5:45	2.78	38.6	52.26	3.09	57.09	0.88	14.97	5.43	22	1.58	2.66	138
6:00	2.61	36.3	50.54	2.96	55.21	0.90	15.12	5.39	23	1.49	2.57	137
6:16	2.77	38.5	52.17	3.06	56.99	0.88	14.98	5.41	23	1.53	2.55	137
6:32	2.67	37.2	52.04	2.99	56.85	0.89	15.17	5.28	26	1.25	2.29	139
6:45	2.67	37.1	50.72	2.95	55.41	0.88	15.04	5.35	31	1.19	1.90	135
7:01	2.79	38.9	53.59	3.07	58.54	0.87	15.10	5.28	27	1.22	2.22	138
7:15	2.05	28.6	42.22	2.35	46.12	0.91	15.45	5.13	29	1.18	2.03	135
7:30	1.48	20.6	30.59	1.66	33.42	0.89	15.50	4.99	20	1.98	3.04	127
7:47	1.57	21.8	28.25	1.65	30.86	0.84	14.77	5.39	18	1.86	3.23	105
8:03	1.48	20.5	26.94	1.55	29.43	0.84	14.85	5.30	19	1.92	3.21	107
8:15	1.32	18.4	26.27	1.47	28.69	0.88	15.28	5.16	19	1.83	3.08	99
8:30	1.11	15.5	22.99	1.26	25.11	0.90	15.49	5.06	16	2.21	3.69	98
8:47	1.07	15.0	22.48	1.25	24.56	0.92	15.52	5.12	18	1.87	3.33	100
9:01	1.22	17.0	25.44	1.40	27.79	0.92	15.52	5.08	21	1.47	2.87	109
9:17	1.04	14.4	23.43	1.24	25.60	0.95	15.90	4.87	19	1.88	3.12	101
9:32	1.14	15.9	26.49	1.38	28.93	0.96	16.01	4.81	20	1.75	3.01	100
9:46	1.05	14.6	24.79	1.30	27.08	0.98	16.09	4.82	22	1.65	2.74	103
10:00	0.96	13.4	23.50	1.21	25.67	1.00	16.23	4.74	16	2.16	3.62	104
10:15	1.21	16.9	27.98	1.52	30.56	1.00	15.96	5.00	17	2.05	3.61	111
10:33	0.94	13.1	22.25	1.21	24.31	1.02	16.06	5.00	16	2.27	3.62	109
10:49	0.87	12.2	21.28	1.14	23.25	1.03	16.17	4.93	15	2.65	4.10	106
11:03	0.82	11.3	18.98	1.03	20.73	1.00	15.99	5.00	13	2.81	4.47	104

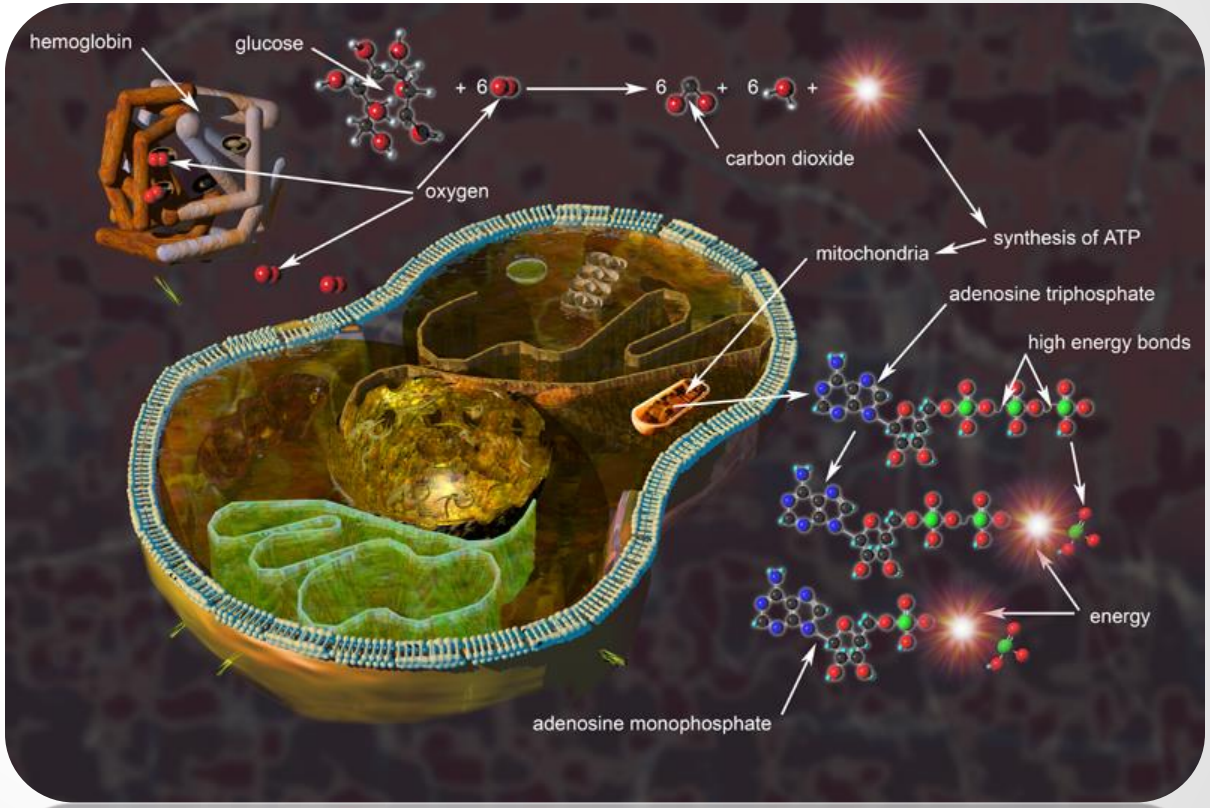

Lactate Response to Running Intensity
Blood Lactate (mM)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
40
50
60
70
80
90
100
Percent of VO2max
lactate threshold

WORTHLESS!!

Central Adaptations

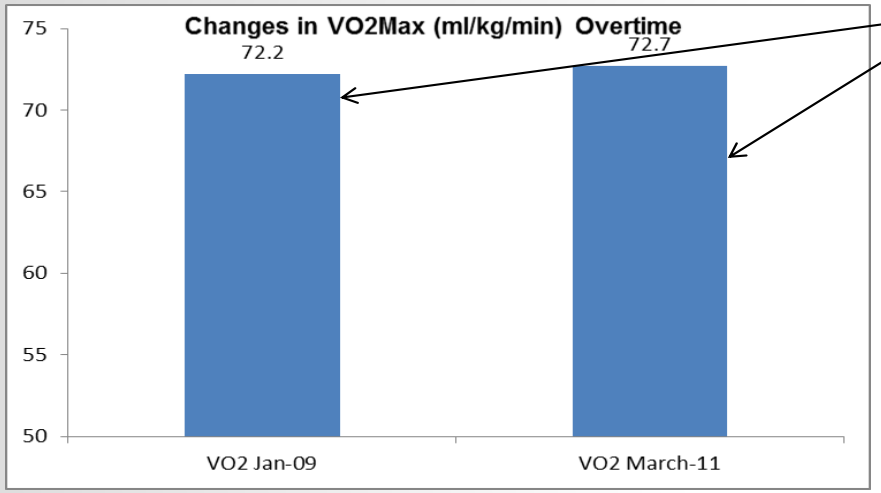


Local Adaptations

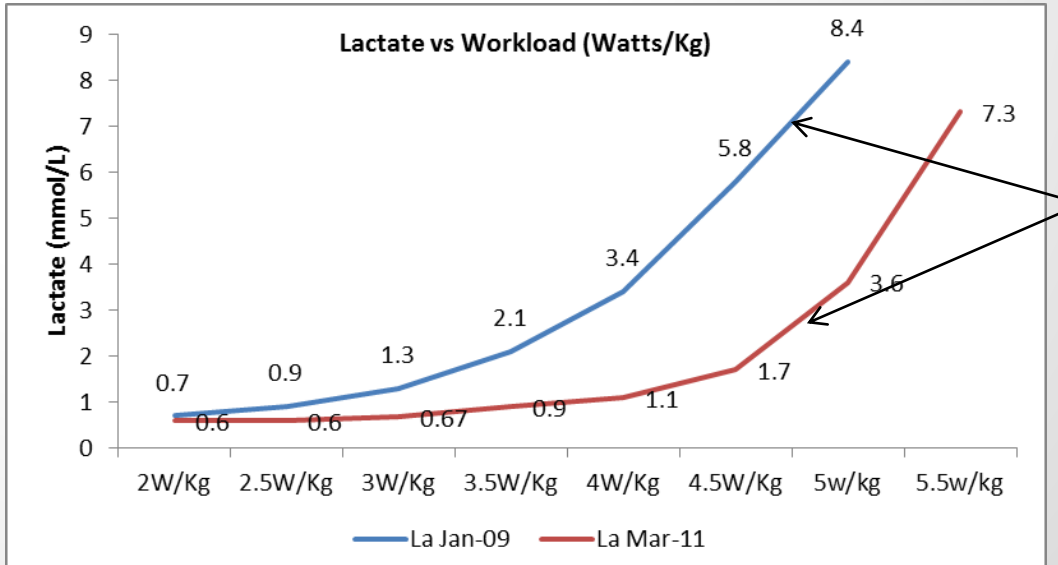


Improvement in Performance but not necessarily in Vo2max

Professional 32 y.o. male cyclist

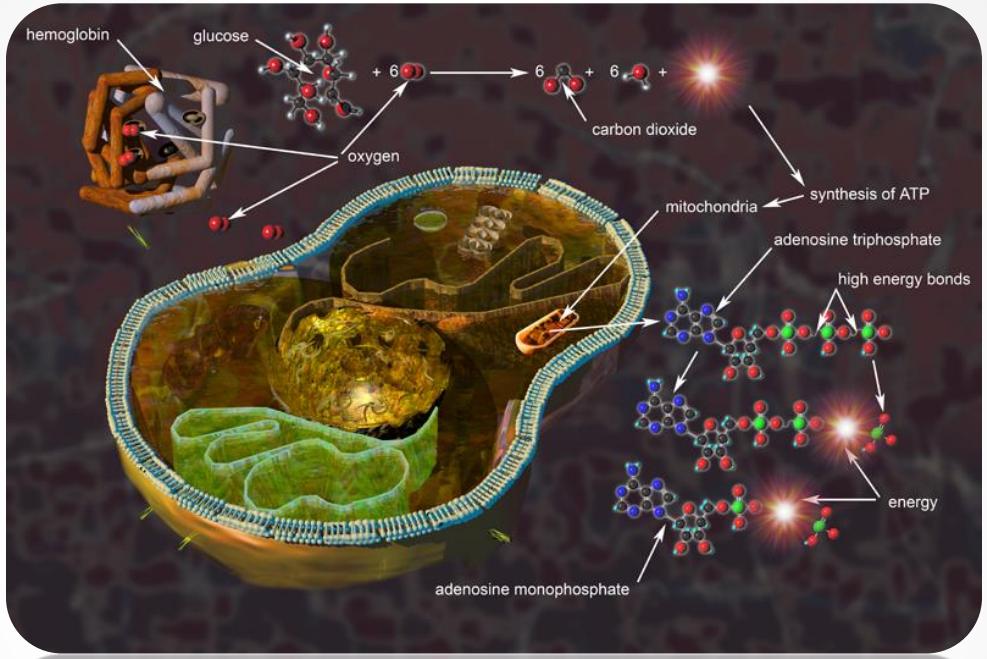


No Improvement in VO2max



Very important Improvement in Lactate Clearance Capacity

Local Adaptations
Cellular Level



-The events happening at the cellular level ultimately make the difference
-A mediocre athlete can have the highest VO2max but not the best cellular adaptations to exercise

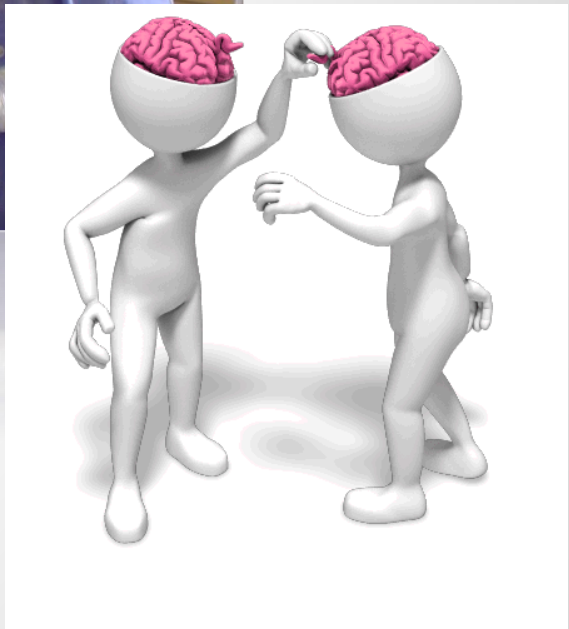
Physiological Testing- Coaching 101

Main Parameters

- Lactate Metabolism
- Fat metabolism
- Carbohydrate Metabolism
- VO2max
- Metabolic Efficiency

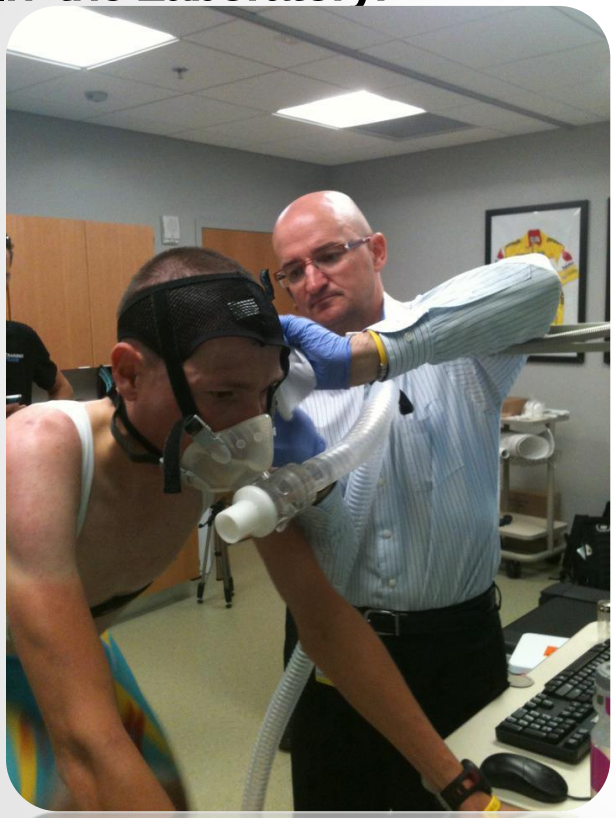
-Only with the evaluation of these parameters it is possible to establish an appropriate and Individual training program for an athlete

- Otherwise, without testing…..We are guessing!



Physiological/Metabolic Testing

In the Laboratory:



In the Field:

Ryder Hesjedal
2012 Tour of Italy (Giro) Winner

Tom Danielson
1st Stage 4 of US Pro Cycling Challenge 2012

Rory Sutherland
Winner of Queen Stage of US Pro Cycling Challenge 2012

In the Field:

CU Football

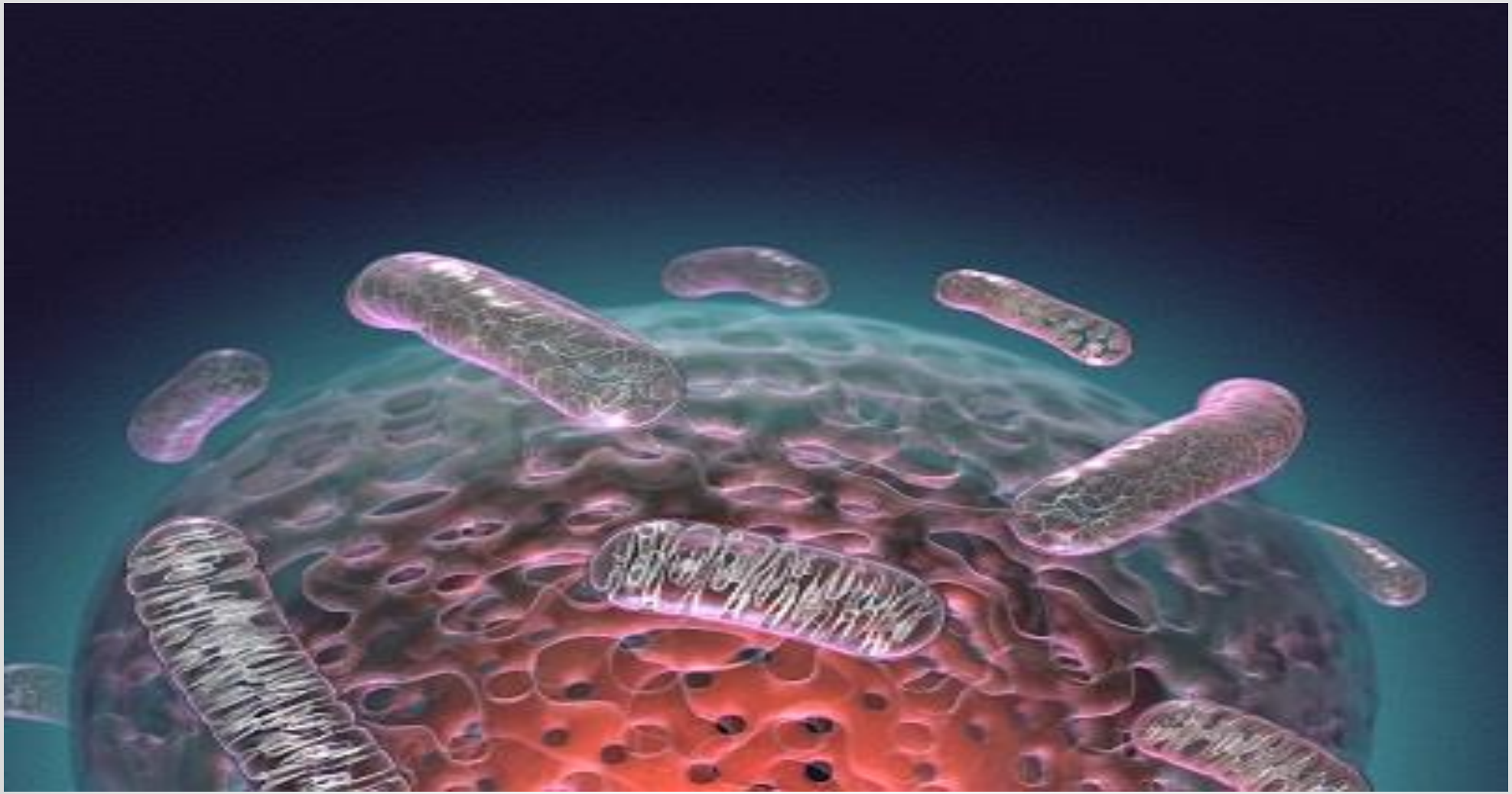
Colorado Rapids

Physiological/Metabolic Testing

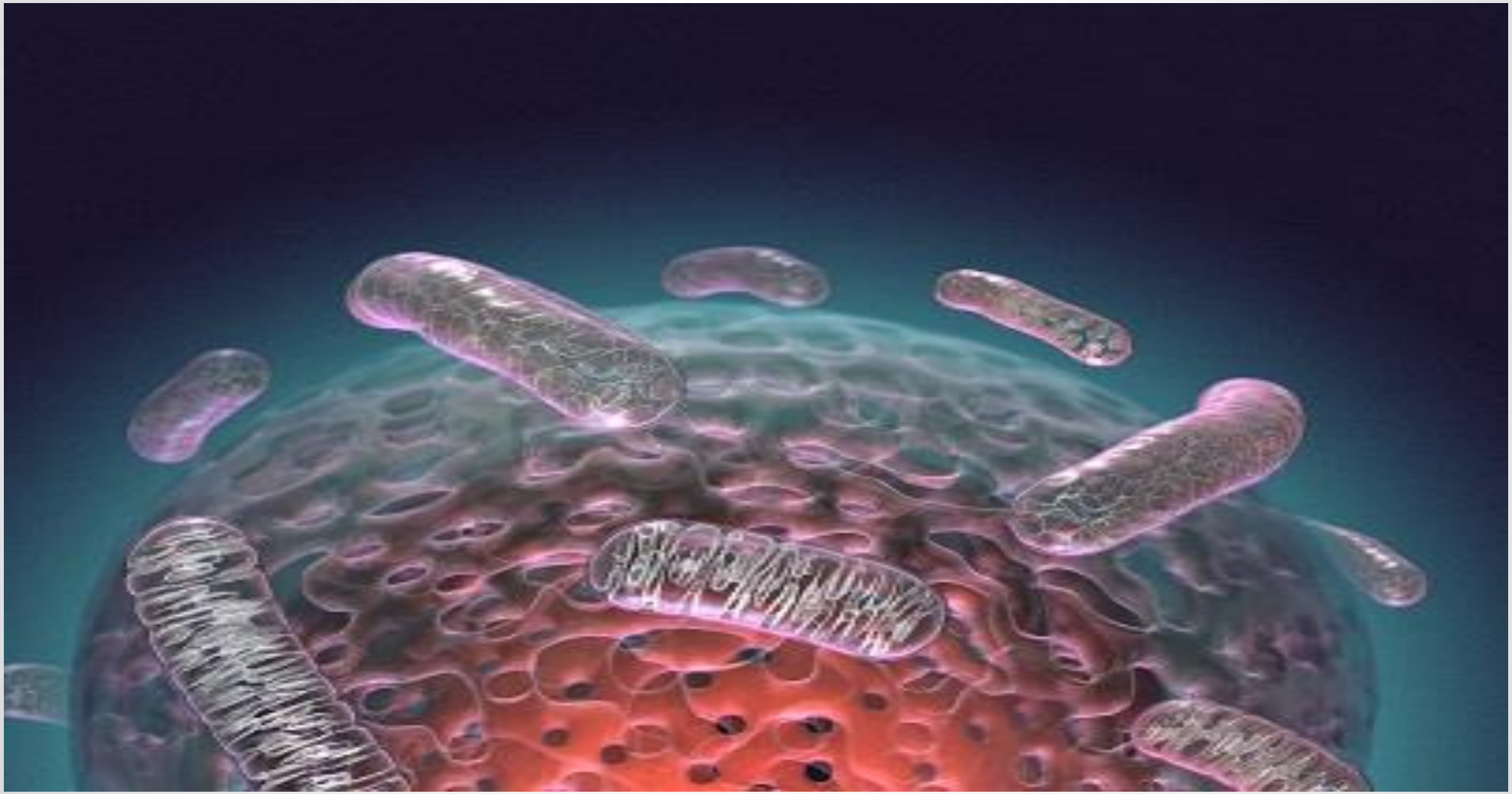
Physiological/Metabolic Testing

Physiological/Metabolic Testing

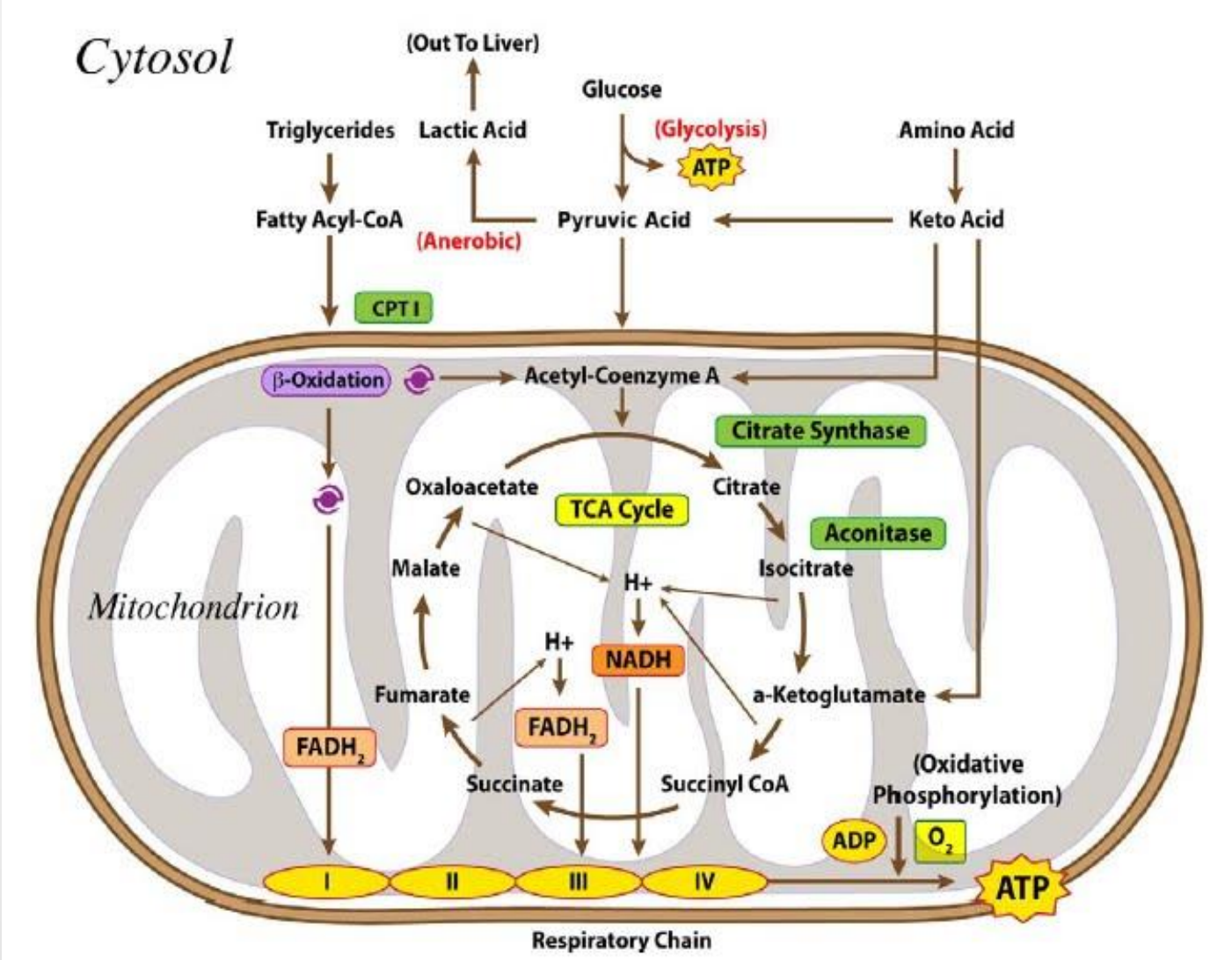
Cellular and Metabolic Mechanisms Behind Performance



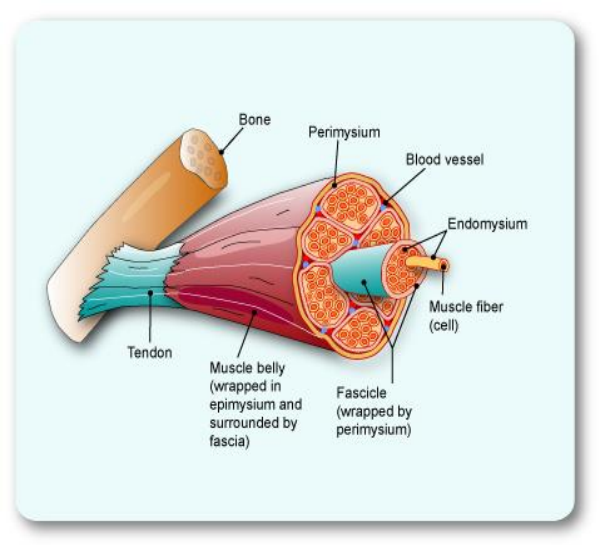
Mitochondrion is the Absolute King in Metabolism

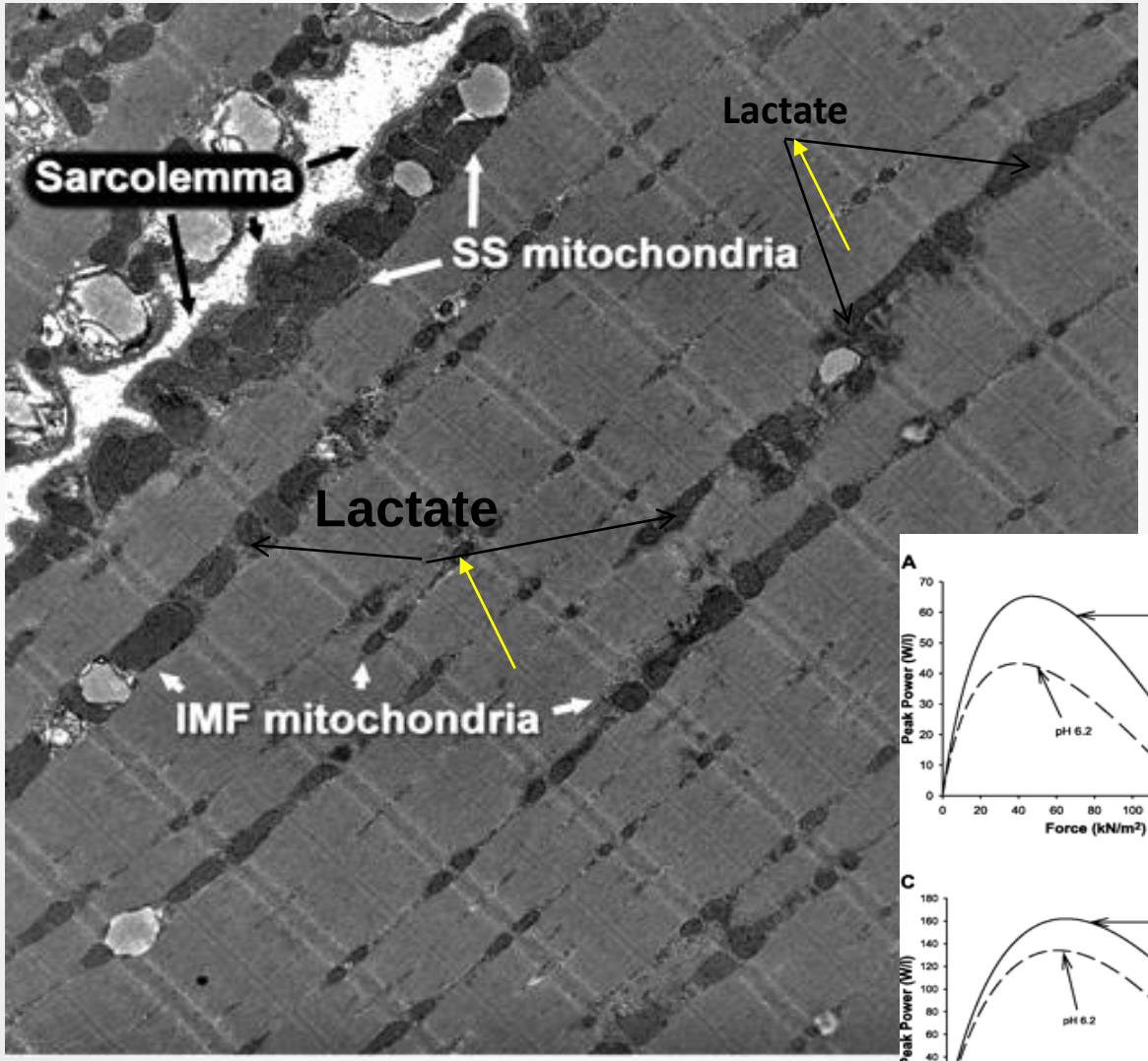


Mitochondrion is the Absolute King in Metabolism

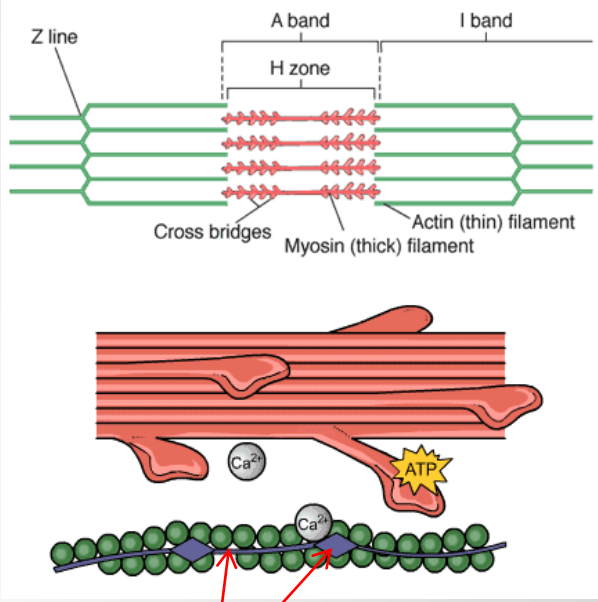


Mitochondria and Performance
Lactate Metabolism



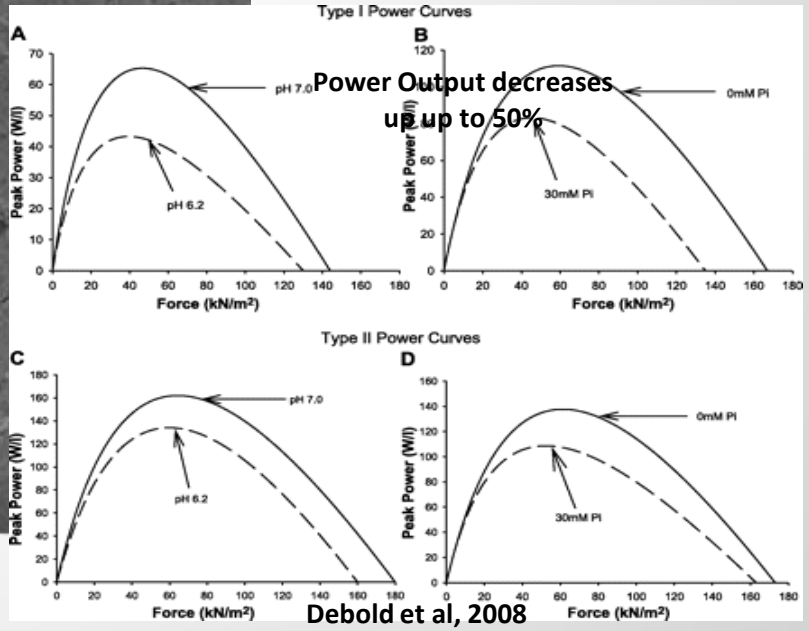


Skeletal Muscle Fiber



H+ H+ H+ H+ H+ H+

Lactate



Power Output decreases up up to 50%

Debold et al, 2008

Differences in Lactate Metabolism

	JC	AC	PC	WPC
W_{peak}	317 ± 23[1, 2]	338 ± 26[3, 4]	370 ± 32[1, 3]	401 ± 29[2, 4]
$W_{peak} \cdot kg^{-1}$	4.91 ± 0.28[5, 6]	5.09 ± 0.21[7]	5.27 ± 0.39[5, 8]	6.10 ± 0.31[6, 7, 8]
3.5 $W \cdot kg^{-1}$	1.8 ± 0.2[d, e, f, g]	1.3 ± 0.2[d]	1.3 ± 0.1[e, h]	1.0 ± 0.4[f, g, h]
4.0 $W \cdot kg^{-1}$	3.0 ± 0.9[i, j, k]	2.1 ± 0.7[i, l]	1.8 ± 0.6[j, m]	1.3 ± 0.2[k, l, m]
4.5 $W \cdot kg^{-1}$	6.6 ± 2.0[n, ñ, o]	4.6 ± 1.3[n, p, q]	3.2 ± 1.0[ñ, p, r]	1.88 ± 0.4[o, q, r]
5.0 $W \cdot kg^{-1}$	10.1 ± 2.1[s, t]	8.7 ± 2.0[u, v]	5.8 ± 1.5[s, u, w]	3.1 ± 0.9[t, v, w]
5.5 $W \cdot kg^{-1}$		9.35 ± 3.26	7.86 ± 2.16	5.64 ± 1.29
6.0 $W \cdot kg^{-1}$				8.63 ± 0.50
6.5 $W \cdot kg^{-1}$				11.4 ± 1.21

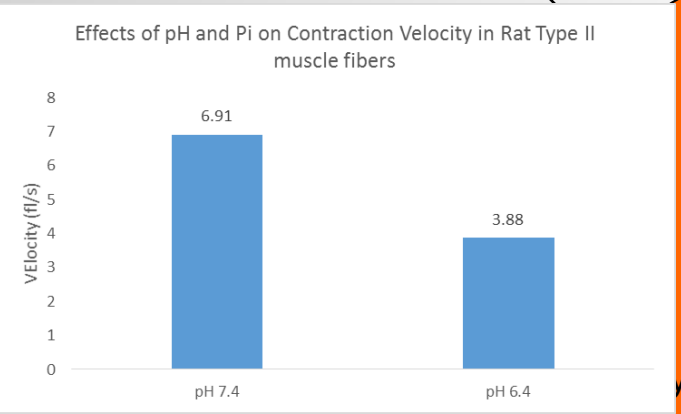
- **WPC Criteria:**
  - **Tour de France, Italy and Spain winners or podium finishers.**
  - **World Champions.**
  - **UCI Pro Tour stage races or "classics" winners.**

San Millán et al. Physiological Differences Between Road Cyclists of Different Categories. A New Approach. *Med Sci Sports Exerc 41:S48. 2009*

Muscle Lactate Clearance

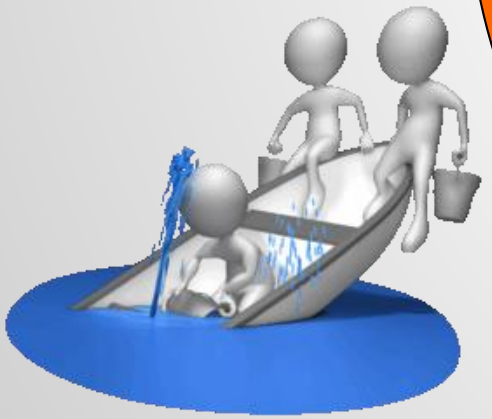
FFA (free fatty acids)

Type I muscle cells
SLOW TWITCH



Nelson et al, 2014

recruited:
y -Long
"Tempo riding"



Glucose

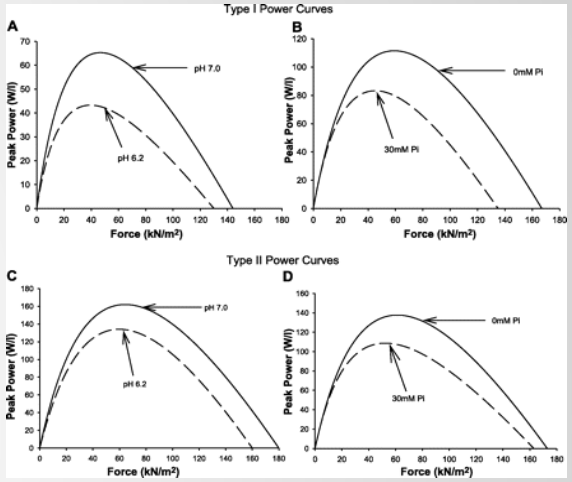
Type IIa muscle cells
FAST TWITCH

Mainly recruited:
Mild-Intense
Exercise.
Competition

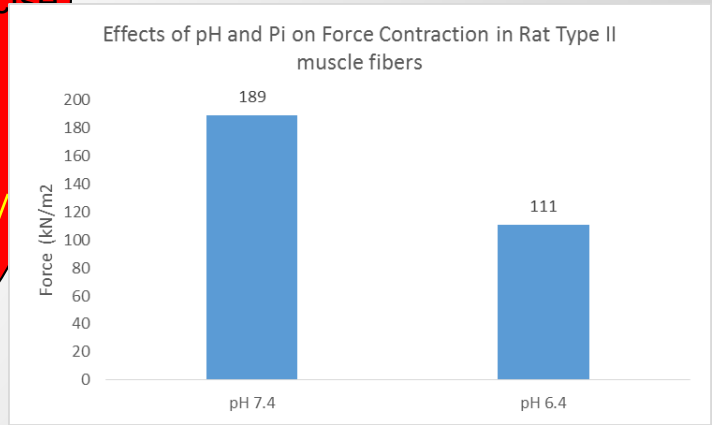
Glucose +
ATP + PC

Type IIb muscle cells
FAST TWITCH

Mainly recruited:
-Sprinting,
Intense Exercise



Debold et al, 2008



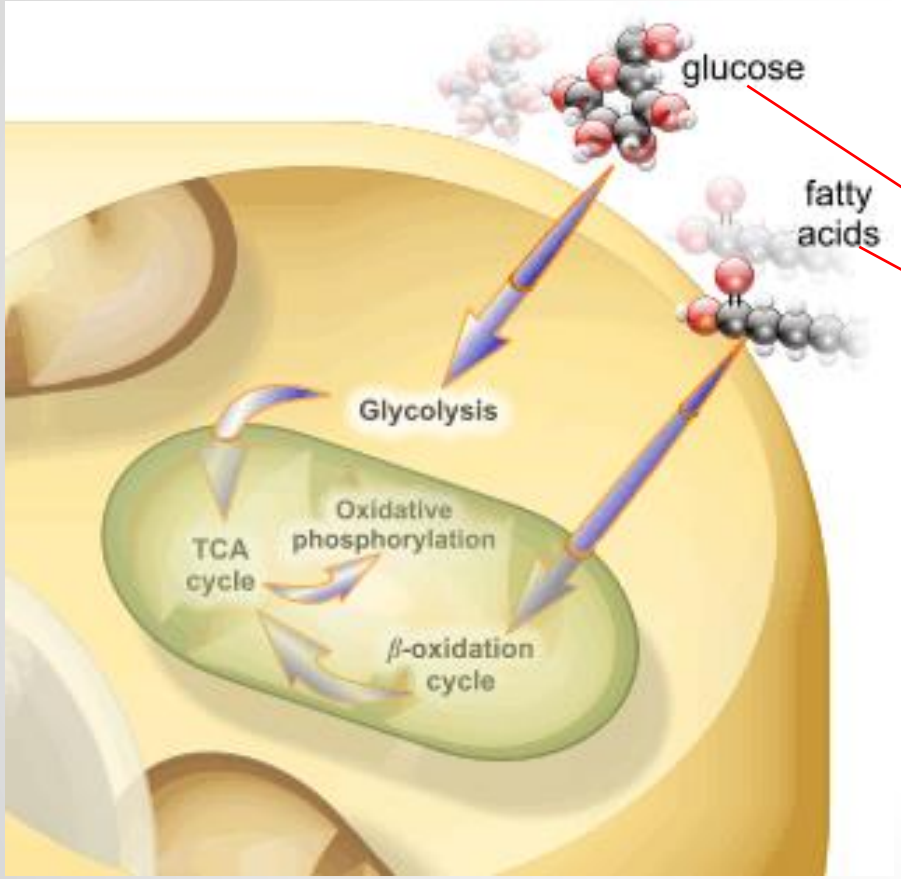
Nelson et al, 2014

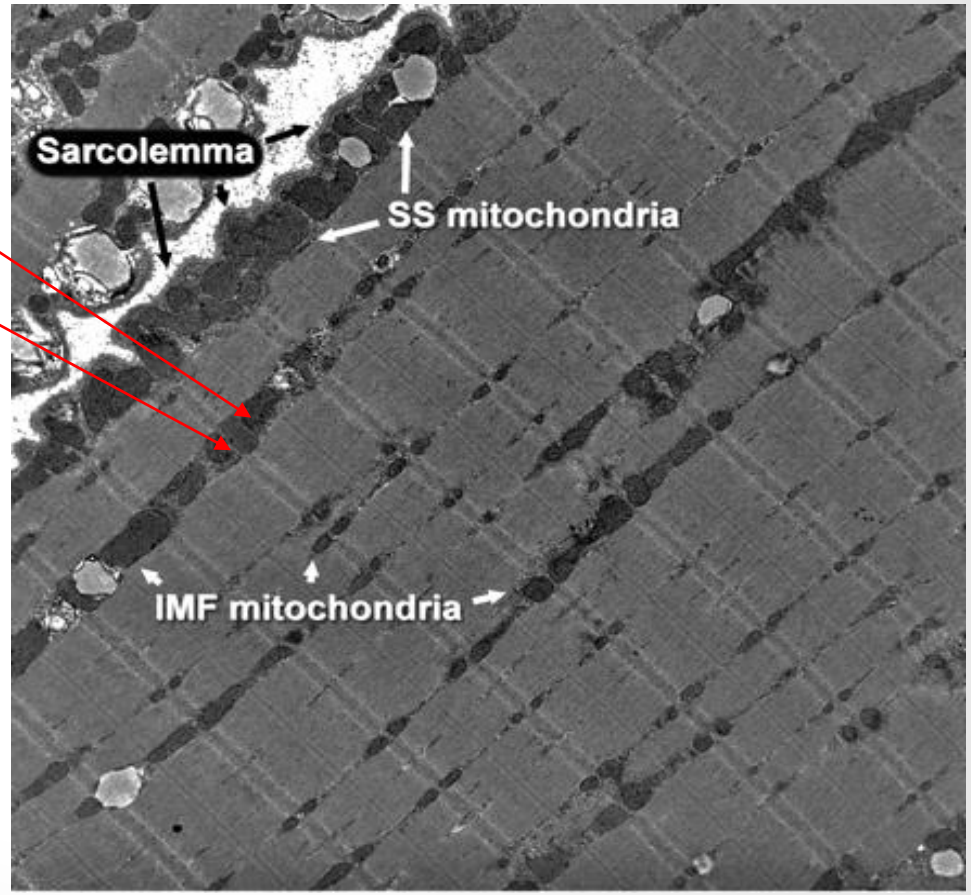
H+ H+ H+ H+ H+ H+ H+ H+

Lactate

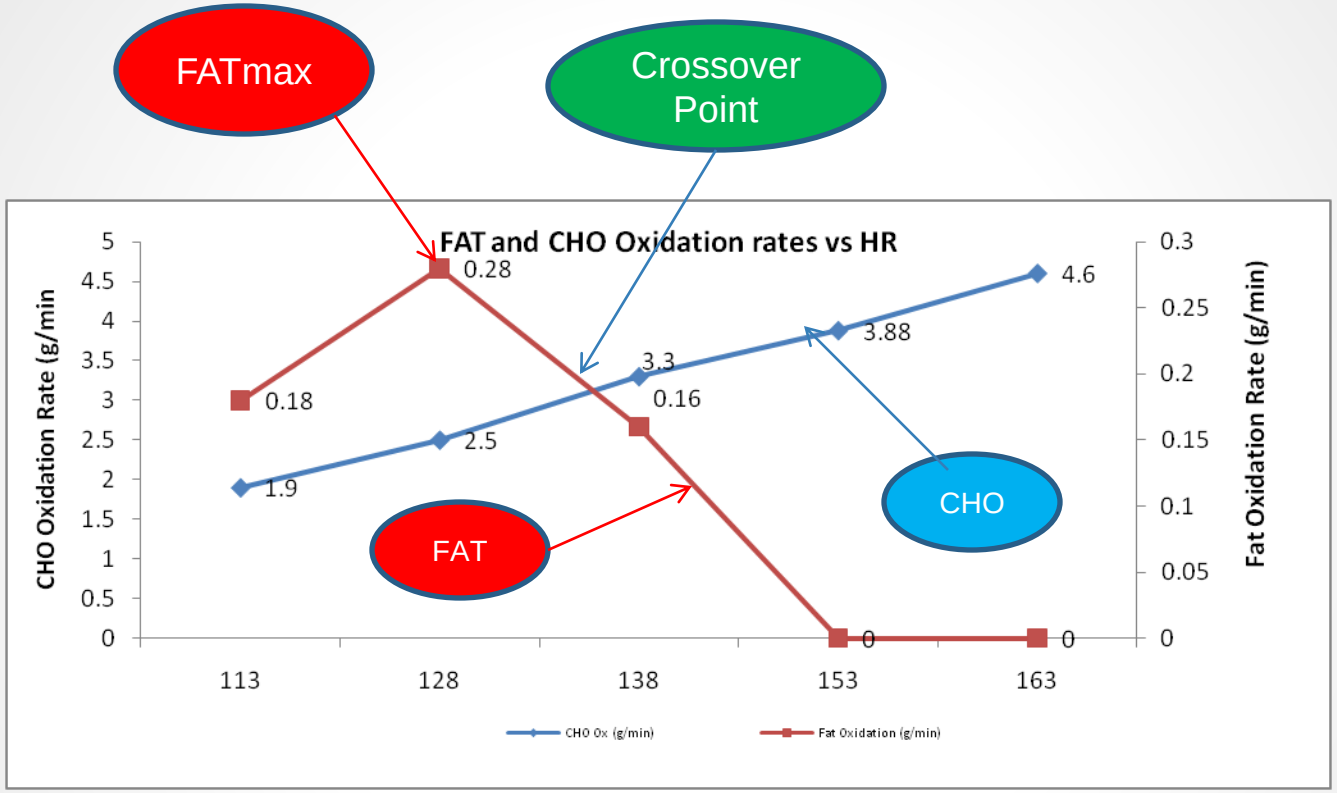
Lactate

Mitochondria and Performance
Substrate Utilization



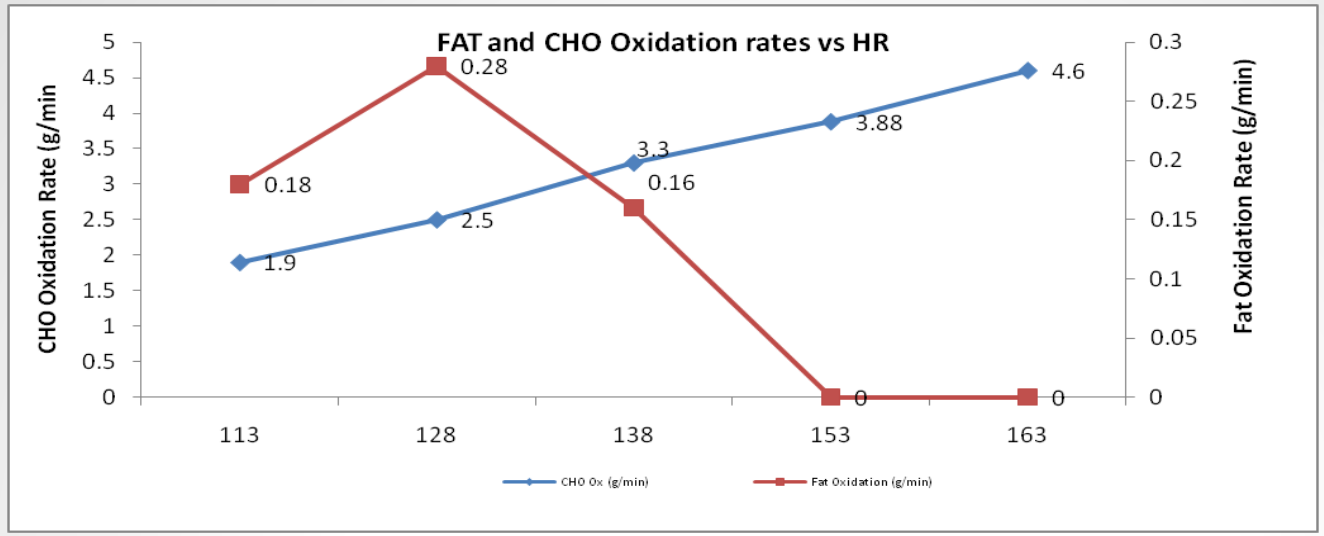


Substrate Utilization

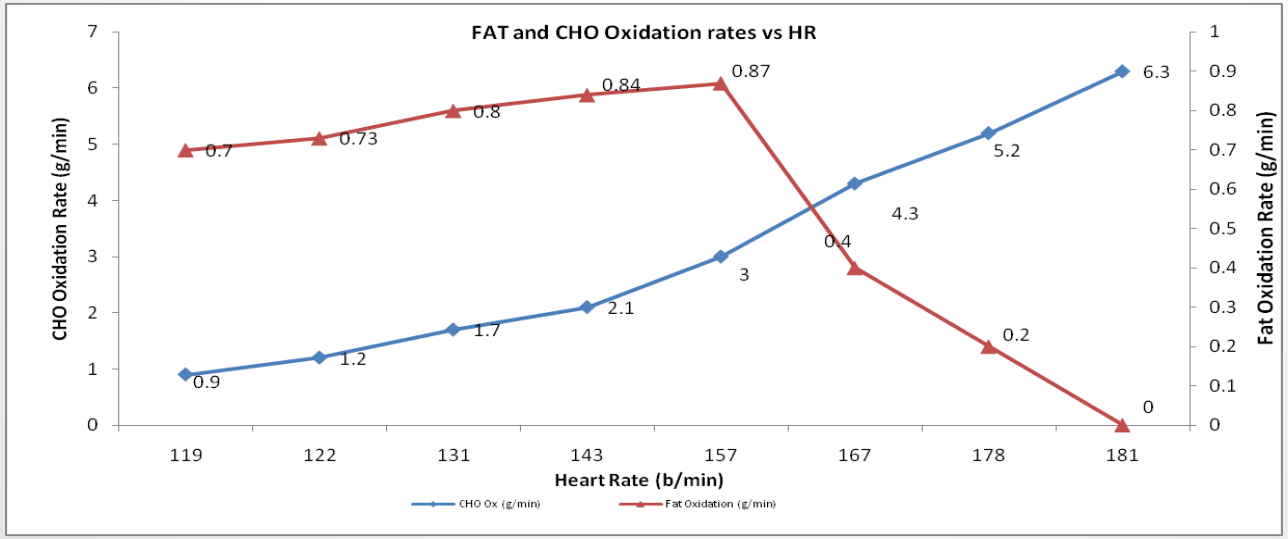


•*San Millán, I.; Gotshall, R.W.; González-Haro, C.; Gil, J.; Irazusta, J.* Sensitivity of Crossover Concept to Discriminate Different Levels of Performance: A New Approach.
Med Sci Sports Exerc 40:293. 2008.
•*González-Haro, C.; San Millán, I*. Application of the Crossover Concept to UCI Pro Tour Level Professional Cyclists: A New Approach.
Med Sci Sports Exerc 40:396-397. 2008

Recreational Athlete

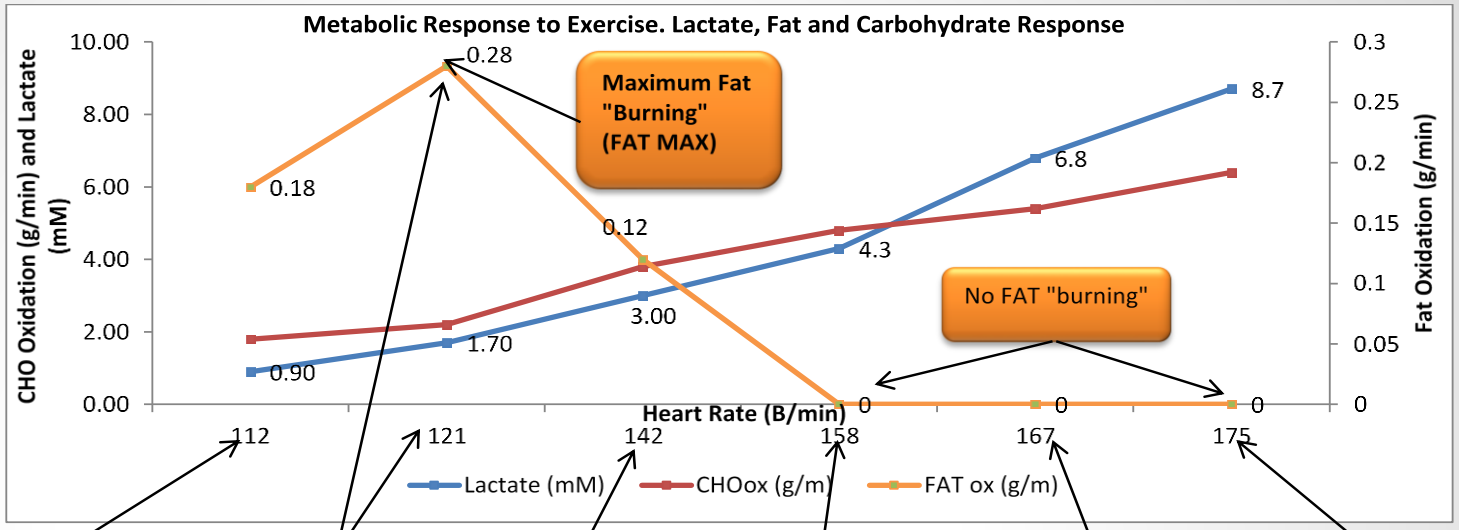


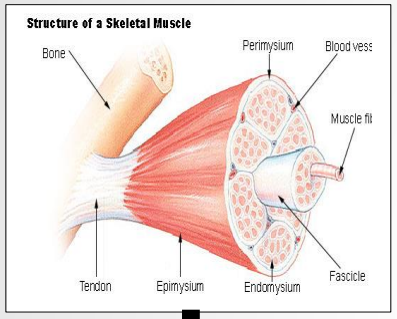
World Class Athlete

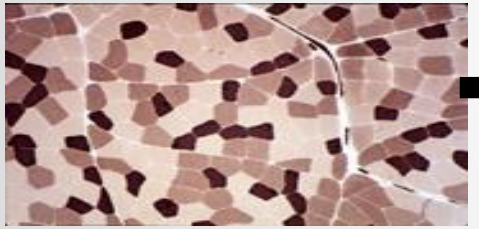


San Millán's Lab Data

The Metabolic Map







Z1 Training Zone

Z2 Training Zone

Z3 Training Zone

Z4 Training Zone

Z5 Training Zone

Z6 Training Zone

TYPE I FIBER (RED)
SLOW TWITCH
OXIDATIVE SYSTEM
(AEROBIC)
Mainly recruited:
Easy -Long
"Tempo Exercise"

FAT IS MAIN FUEL USED
This Happens in the Mitochondria. That's why these fibers have the highest mitochondrial content

GLUCOSE IS MAIN FUEL USED

TYPE IIa FIBER
(WHITE/RED)
FAST TWITCH
GLYCOLYC SYSTEM
(AEROBIC)
Mainly recruited:
Mild-Intense Exercise.
Competition

TYPE IIb FIBER
(WHITE)
SUPER FAST TWITCH
PC & GLYCOLYTIC
SYSTEM (ANAEROBIC)
Mainly recruited:
Maximal Exercise
Sprinting
Weight Lifting

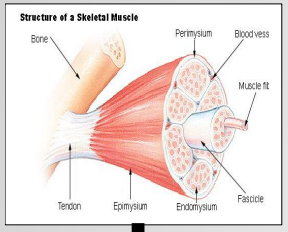
ATP+PC
Main Fuels

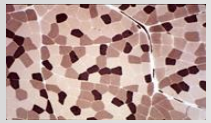
Muscle Fiber Recruitment. TYPE I Fibers (Slow Twitch) **TYPE IIa Fibers (Fast Twitch)** **TYPE IIb Fibers (Super-Fast Twitch)**

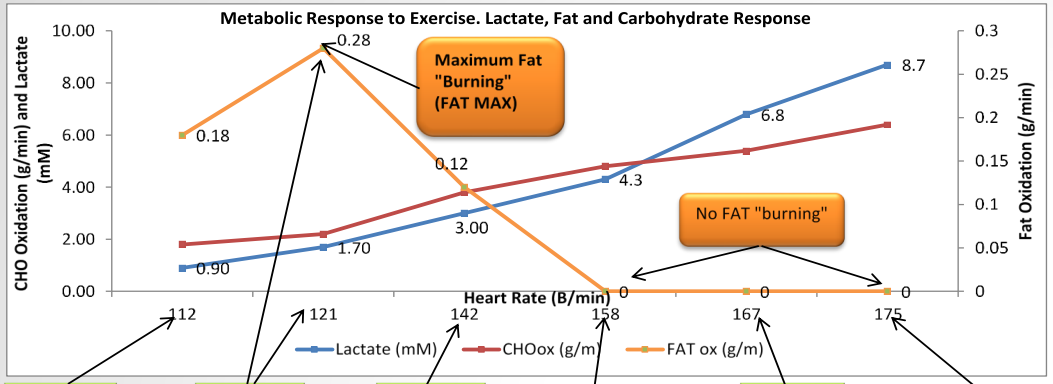
As Exercise intensity increases, muscles need to contract faster and stronger so faster muscle fibers need to be recruited. Fuel needs also change. Fat provides energy at low-moderate intensities (Z1-Z2) but it is not fast enough to provide energy at higher intensities, so Glucose is then the preferred fuel.

San Millán. 2013

The Metabolic Training Concept







Z1 Training Zone | Z2 Training Zone | Z3 Training Zone | Z4 Training Zone | Z5 Training Zone | Z6 Training Zone

FAT IS MAIN FUEL USED
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TYPE I FIBER (RED)
SLOW TWITCH
OXIDATIVE SYSTEM
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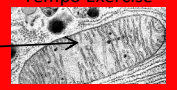
Mainly recruited:
Easy -Long
"Tempo Exercise"



GLUCOSE IS MAIN FUEL USED

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FAST TWITCH
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Mainly recruited:
Mild-Intense Exercise.
Competition

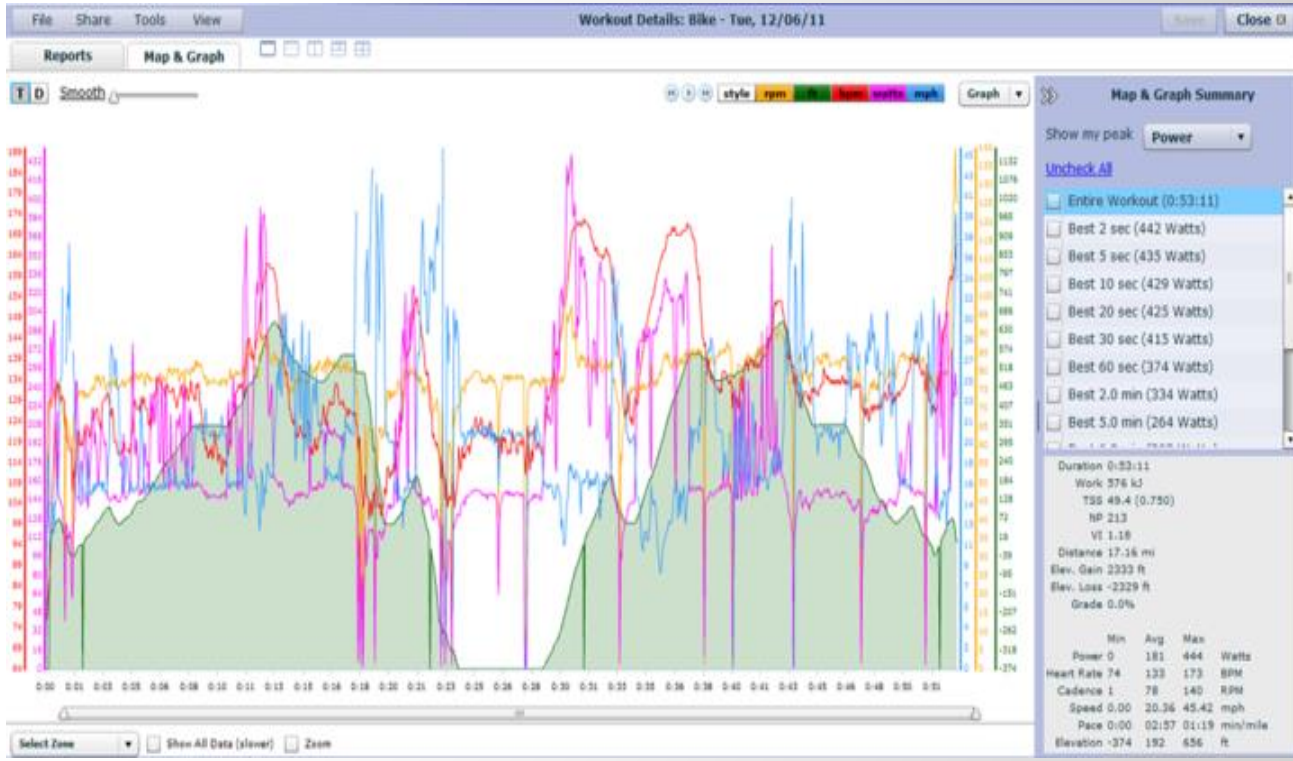
TYPE IIb FIBER
(WHITE)
SUPER FAST TWITCH
PC & GLYCOLYTIC
SYSTEM (ANAEROBIC)
Mainly recruited:
Maximal Exercise
Sprinting
Weight Lifting

ATP+PC Main Fuels

Zone	Type of training/Fule mainly used/Type of Fiber		
Z1	*Easy- Recovery/Fat/Type I*		
Z2	*"Endurance"/Fat/Type I*		
Z3	*"Intensive Endurance"/Fat-CHO/Type I-IIa*		
Z4	*"Lactate threshold"/CHO/ Type IIa*		
Z5	*" Above Lactate threshold"/CHO/Type IIa- IIb*		
Z6	*"Anaerobic"/CHO-ATP-PC/ Type IIb*		

San Millán. 2013

Training Monitoring and Quantification



Medicine of Cycling™

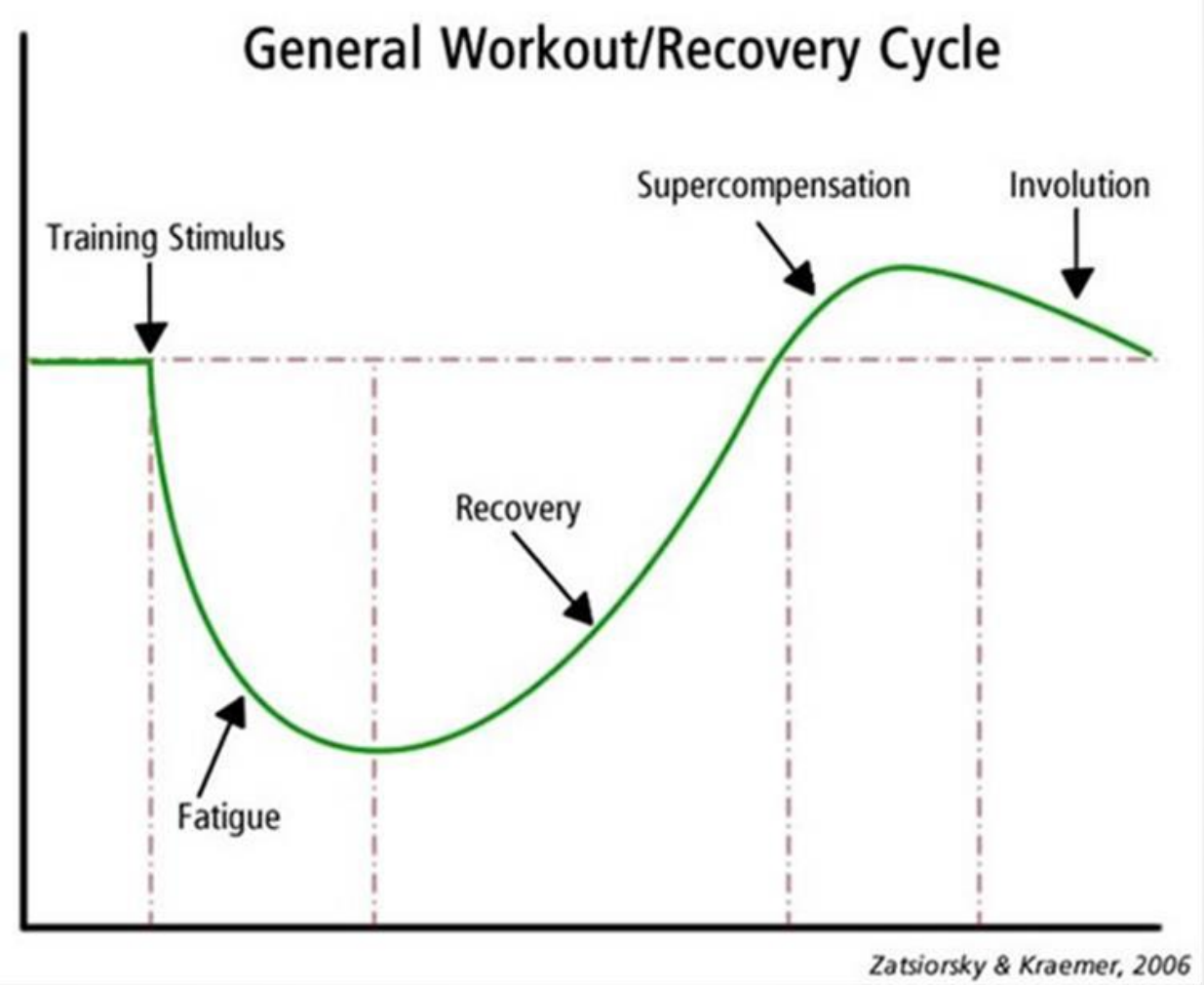
Monitoring of Overtraining

Monitoring of Overtraining

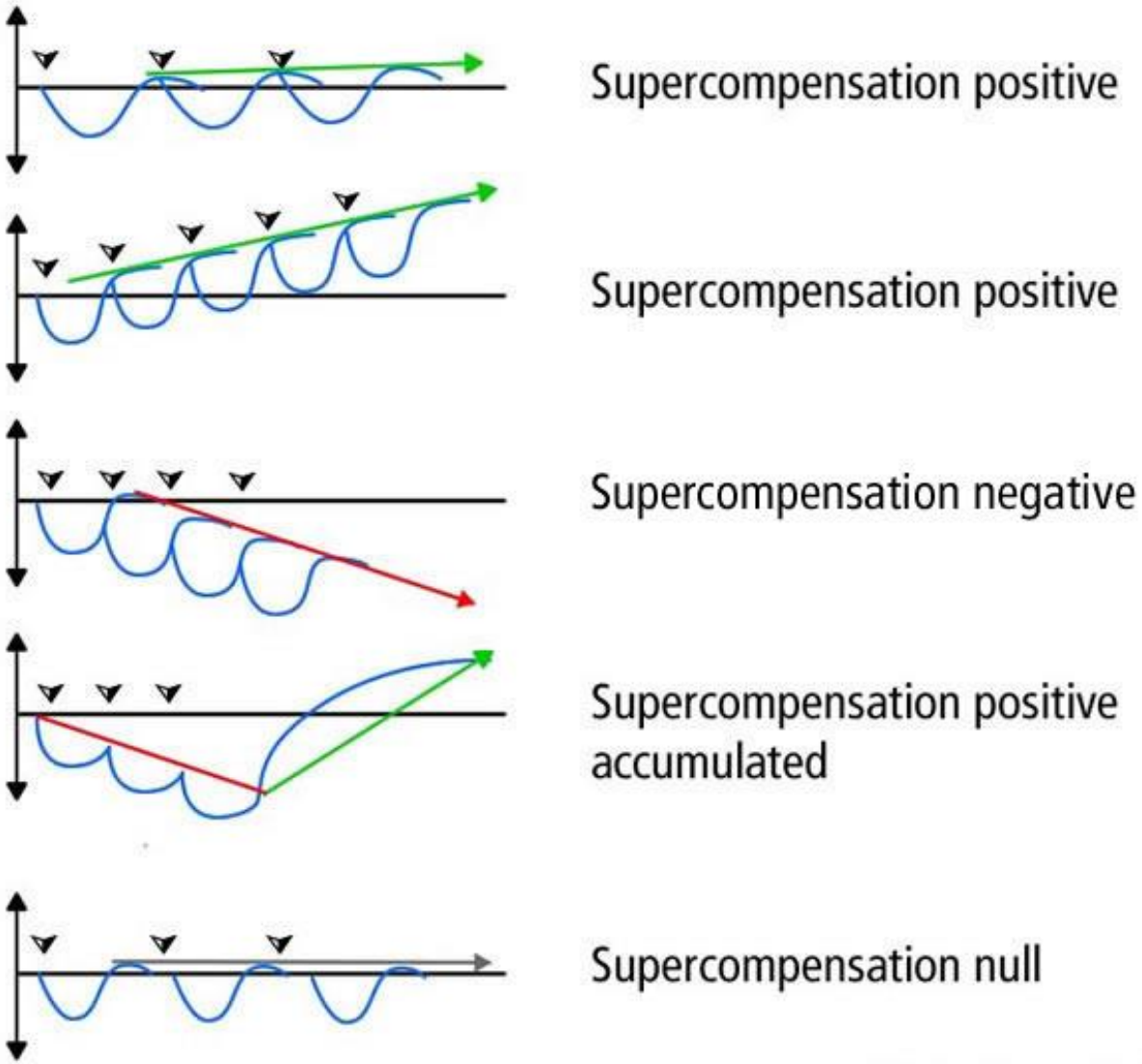
Preventing Overtraining is KEY

It is important to measure and monitor different important parameters throughout the season

We need to apply a scientific approach

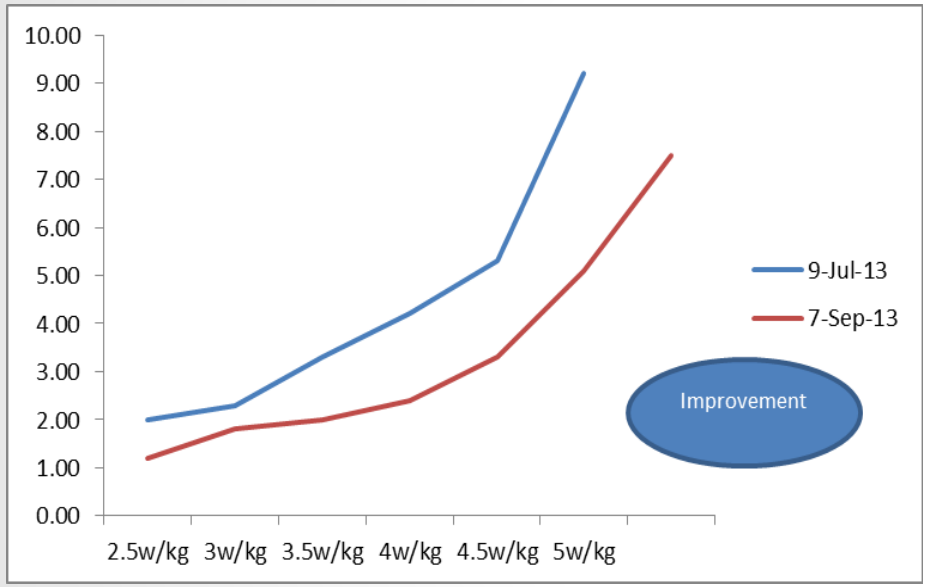

General Workout/Recovery Cycle
Training Stimulus
Supercompensation
Involution
Recovery
Fatigue
Zatsiorsky & Kraemer, 2006

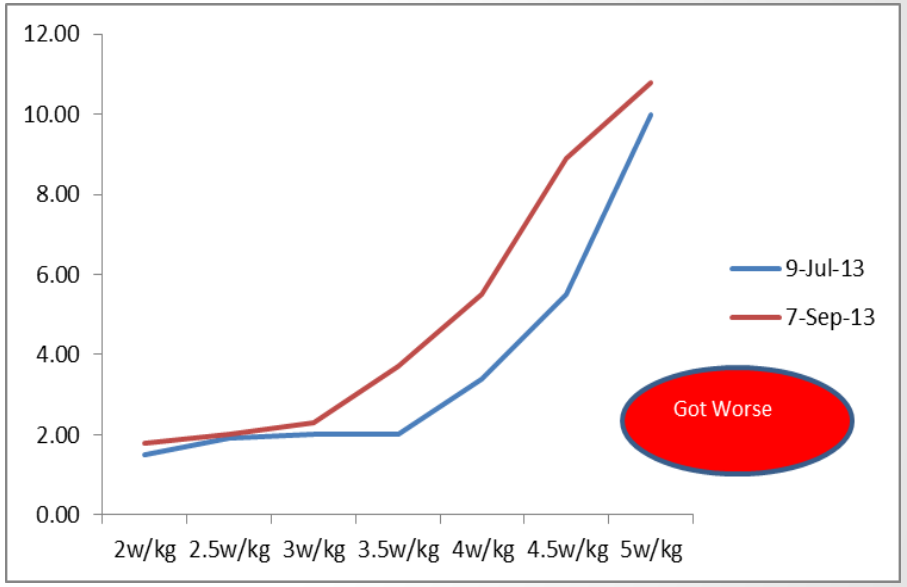
Supercompensation Models



Zatsiorsky & Kraemer, 2006

Physiological Monitoring throughout the season

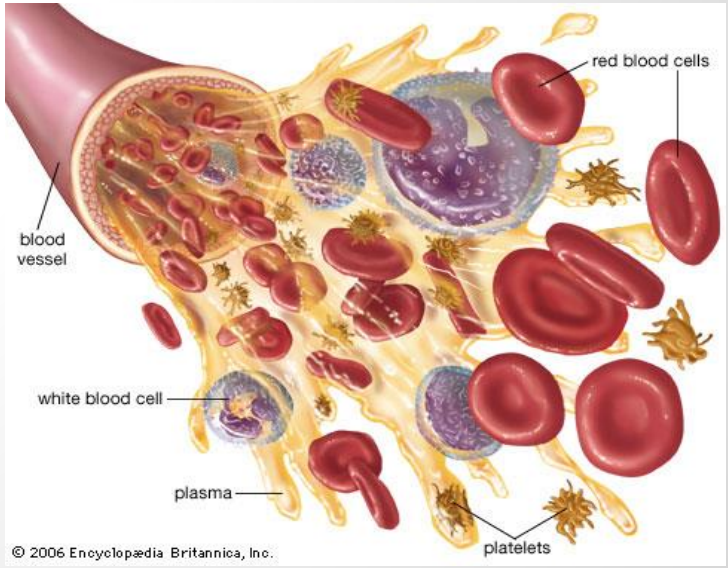




Blood lactate levels vs power output

Hematological Monitoring of Overtraining

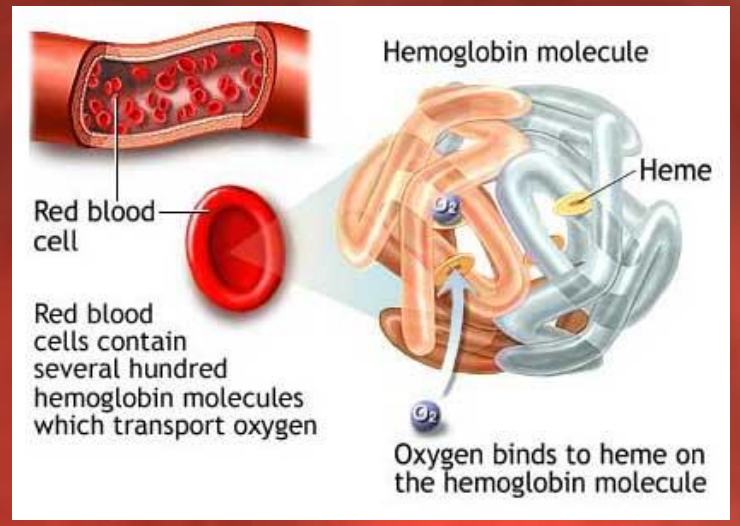
- Essential to prevent Overtraining before it happens
- Diagnose Overtraining in time
- One of the most important tools for an elite athlete and Coach
- Essential to have a scientific and clinical approach
- The answer is in the blood



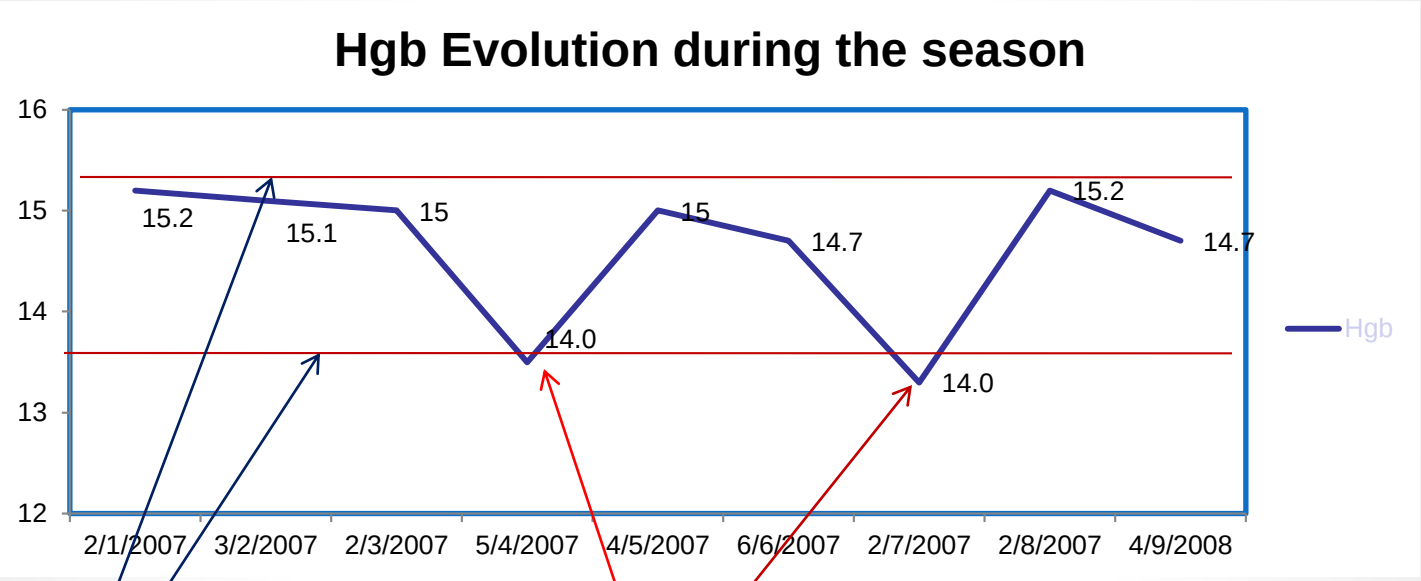
Monitoring of Overtraining

- There are many parameters in the blood indicators of many different physiological conditions
  - **Hematological**
  - **Biochemical**
  - **Hormonal**
  - **Serological**

- About 200 Billion RBC's are destroyed daily. So 200 Billion have to be replaced daily



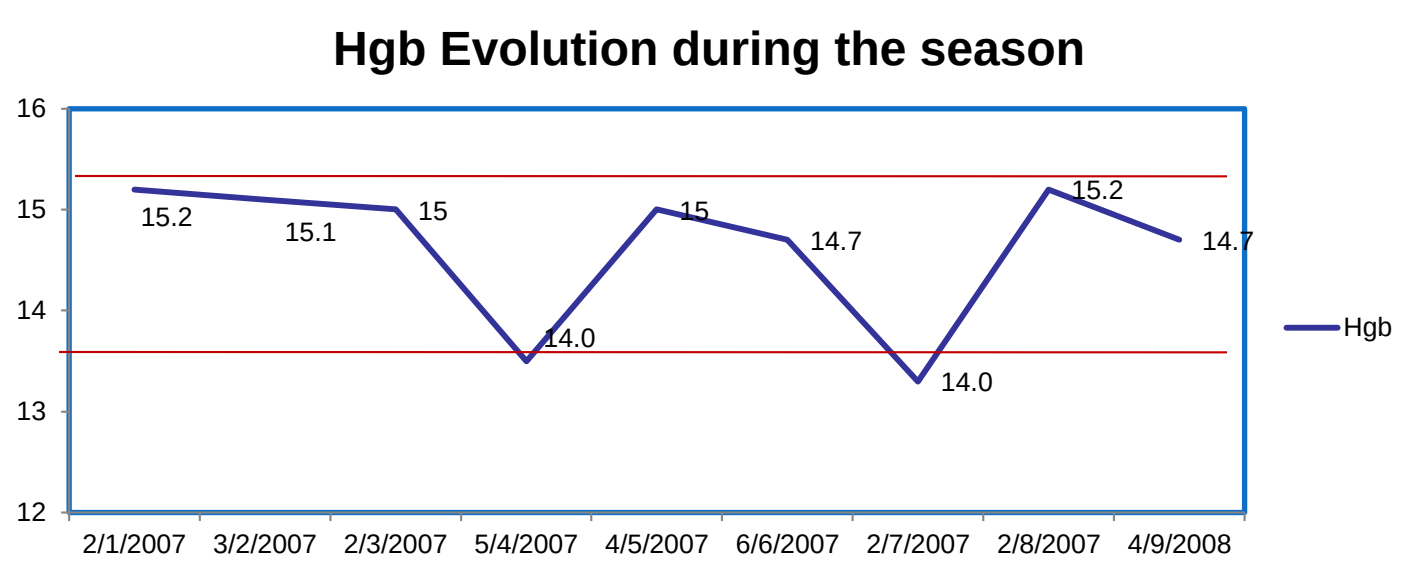
Hematological Monitoring Throughout the Season
Bolood Profiling



- **DETECTION, INTERVENTION AND CORRECTION**

- Optimum Performance Frame

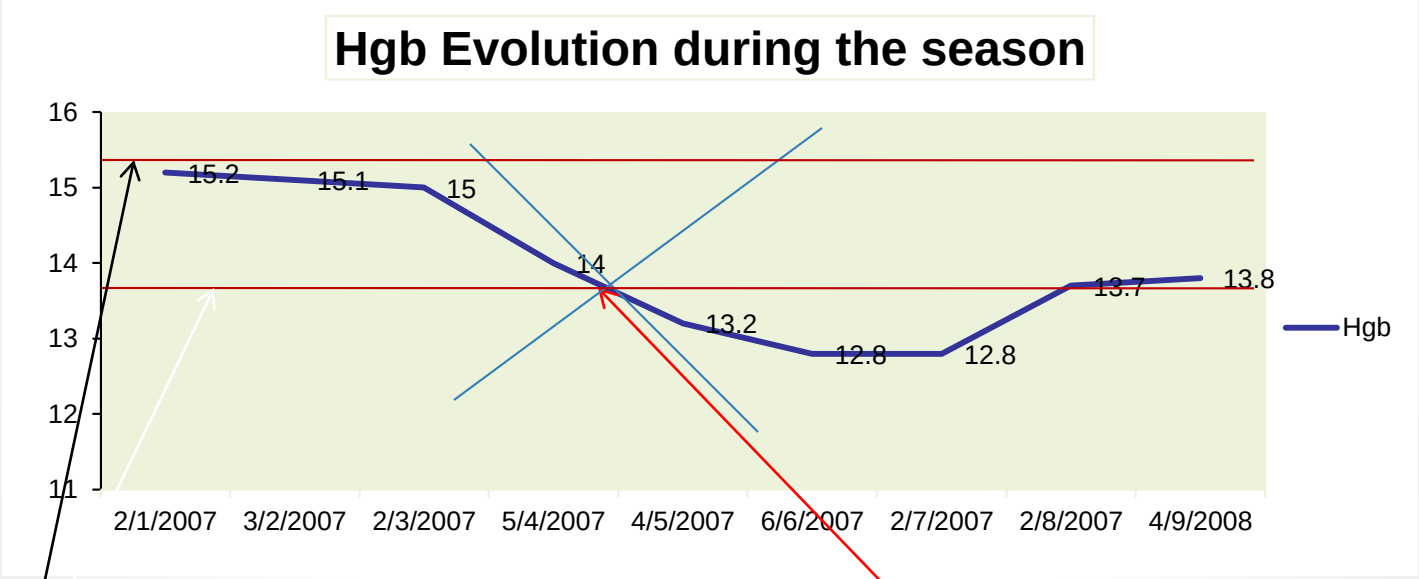
Hematological Monitoring Throughout the Season
Bolood Profiling



- **15g/dl Hgb x 1.34 mL O2 = 20.1g/dl O2**
- **14.0g/dl Hgb x 1.34 mL O2 = 18.76 g/dl O2**

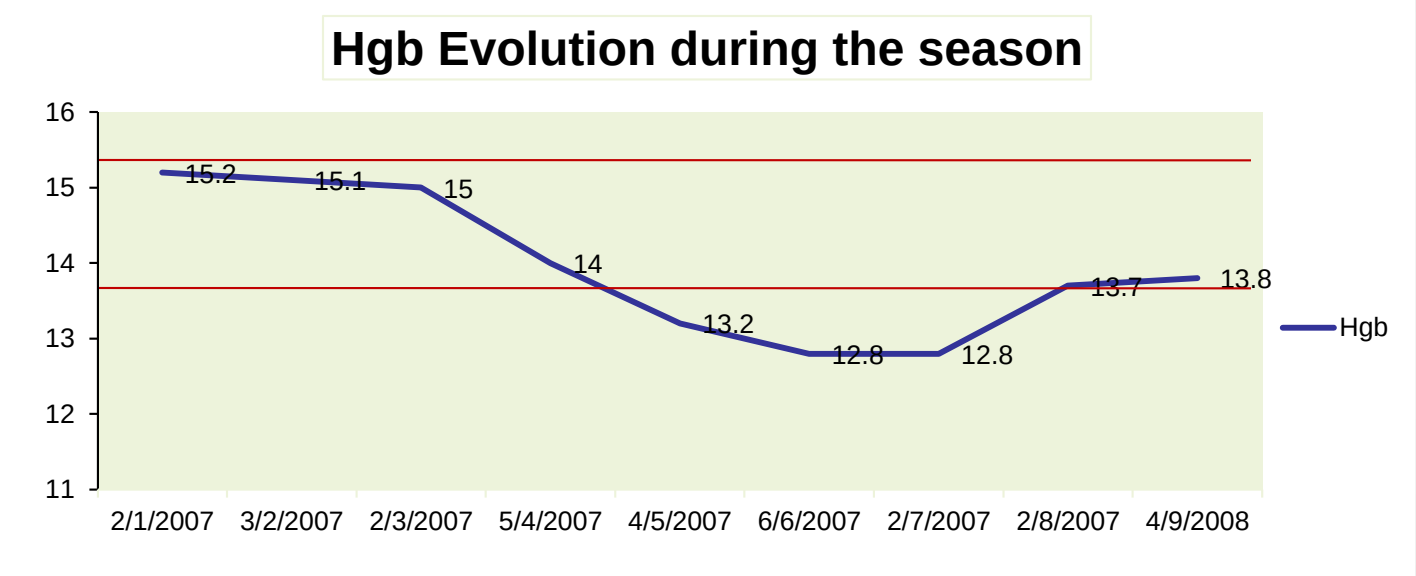
-6.8%

Hematological Monitoring Throughout the Season
Bolood Profiling



- **NO Detection, Intervention ,correction = OVERTRAINING!!**
- Optimum Performance Frame

Hematological Monitoring Throughout the Season
Bolood Profiling



- **15g/dl Hgb x 1.34 mL O2 = 20.1g/dl O2**
- **12.8g/dl Hgb x 1.34 mL O2 = 17.15 g/dl O2**

-15% !

Hematological Monitoring Throughout the Season
Bolood Profiling

Muscle Damage

- Healthy muscle
- Muscle Injury

- Sarcomere
- Z-Lines

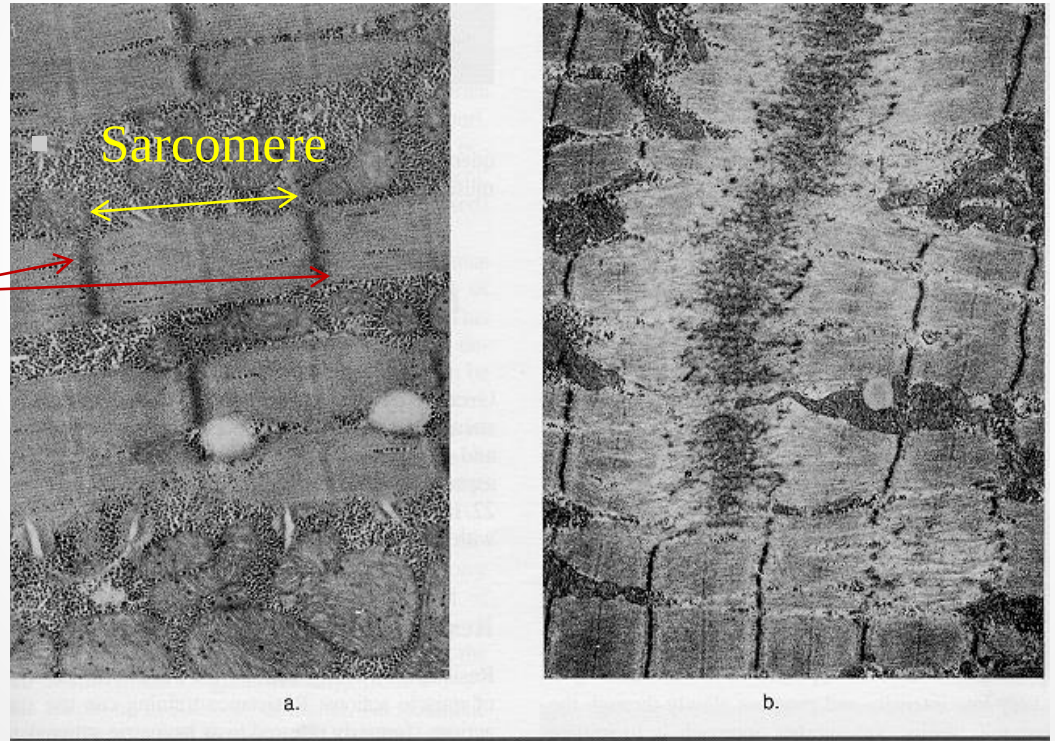
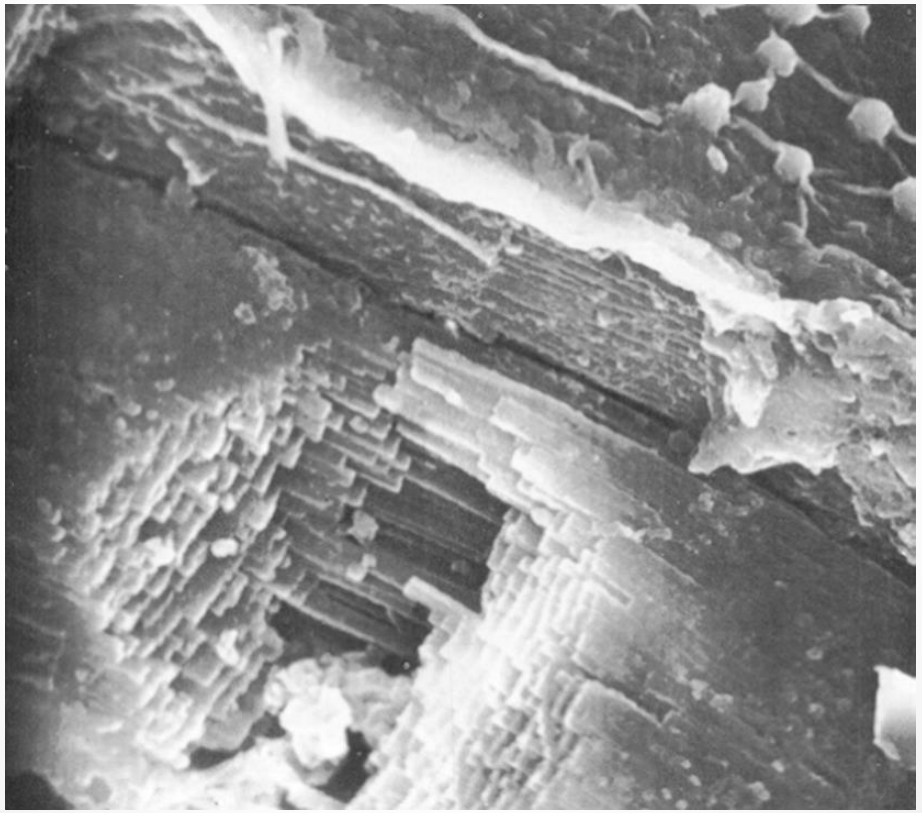


Figure 4.11 (a) An electron micrograph showing the normal arrangement of the actin and myosin filaments and Z disk configuration in the muscle of a runner before a marathon race. (b) A muscle sample taken immediately after a marathon race shows Z disk streaming caused by the eccentric actions of running. Reprinted from Hagerman et al. (1984).

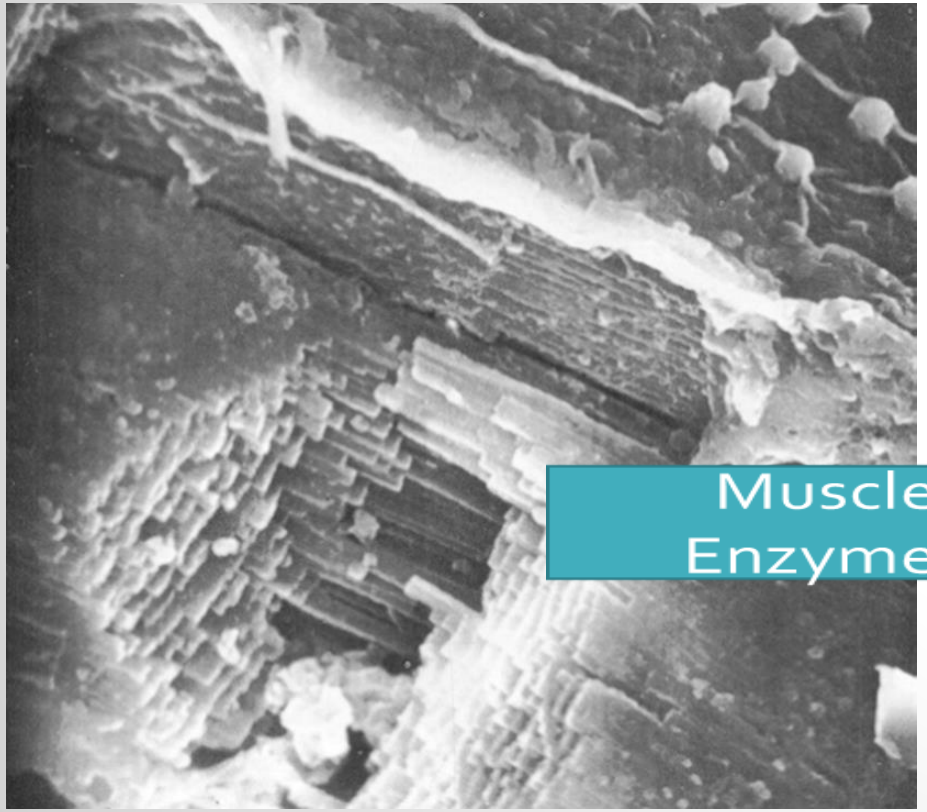
Hematological Monitoring Throughout the Season
Bolood Profiling

-Microrupture

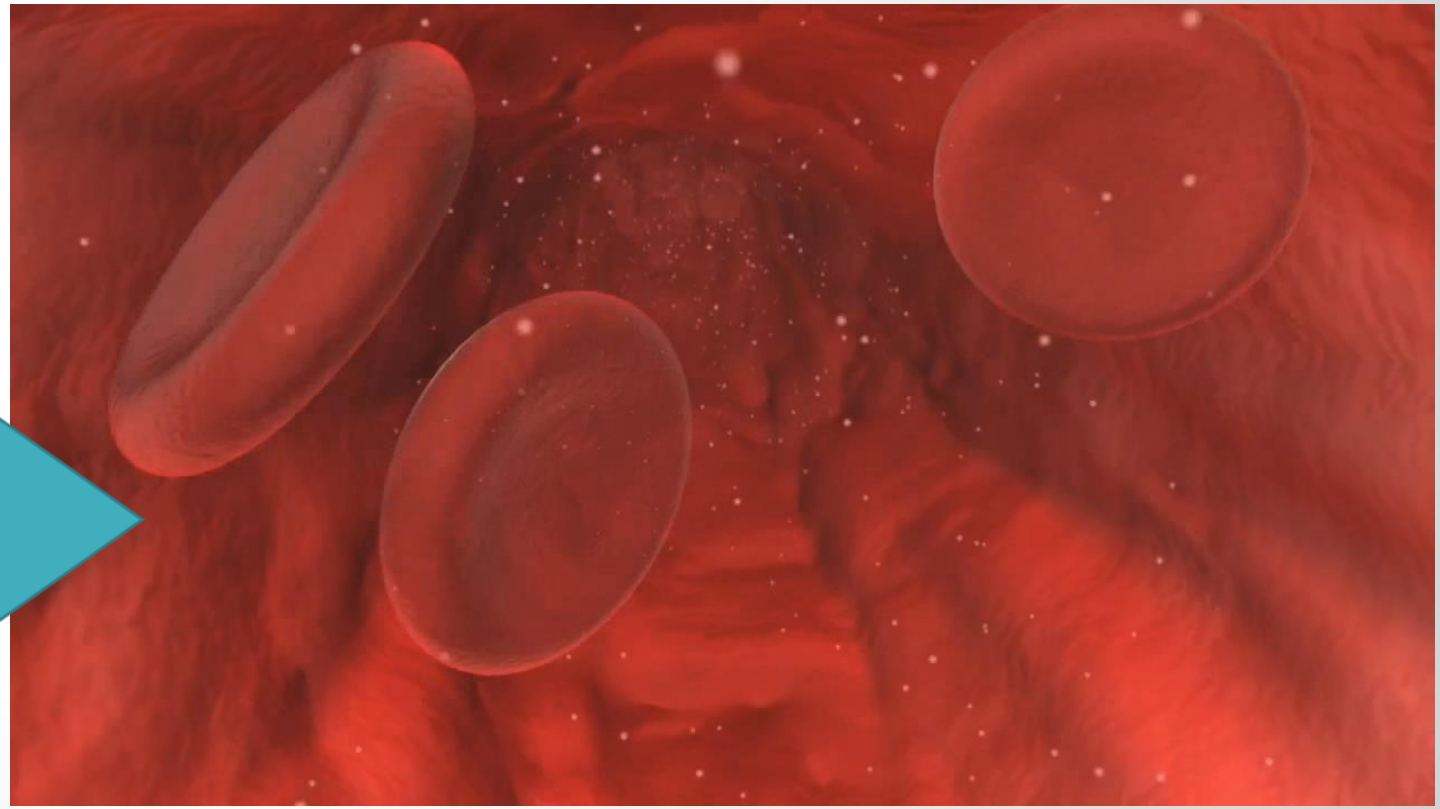


Hematological Monitoring Throughout the Season
Bolood Profiling

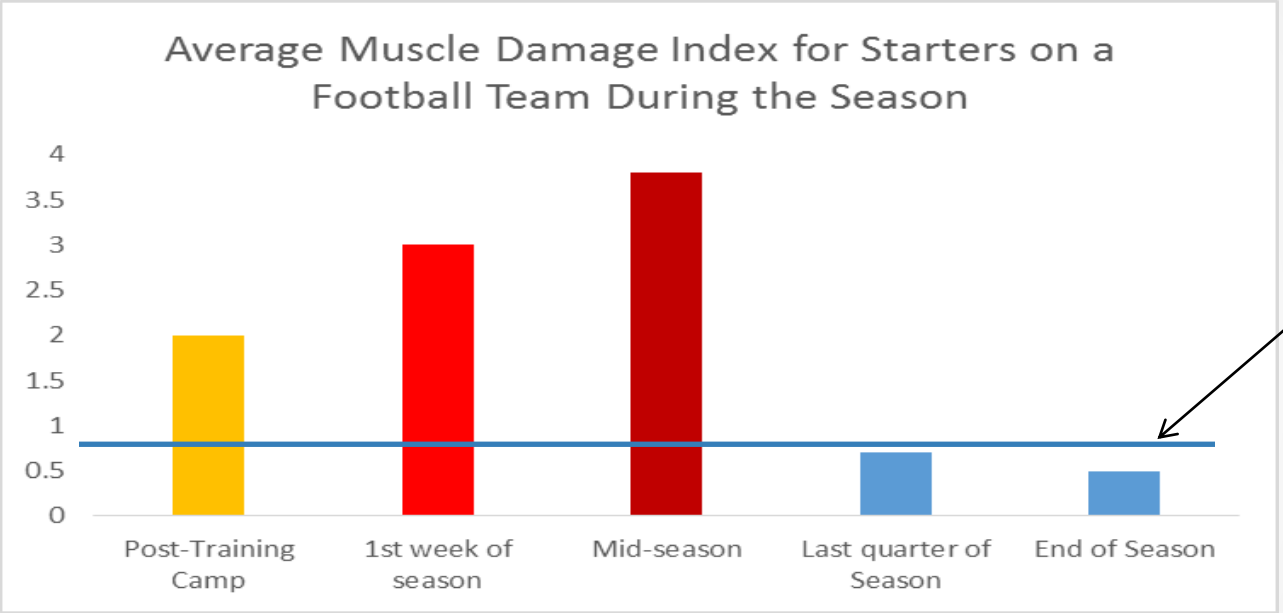
Muscle Damage



Muscle Enzymes



Hematological Monitoring Throughout the Season
Bolood Profiling

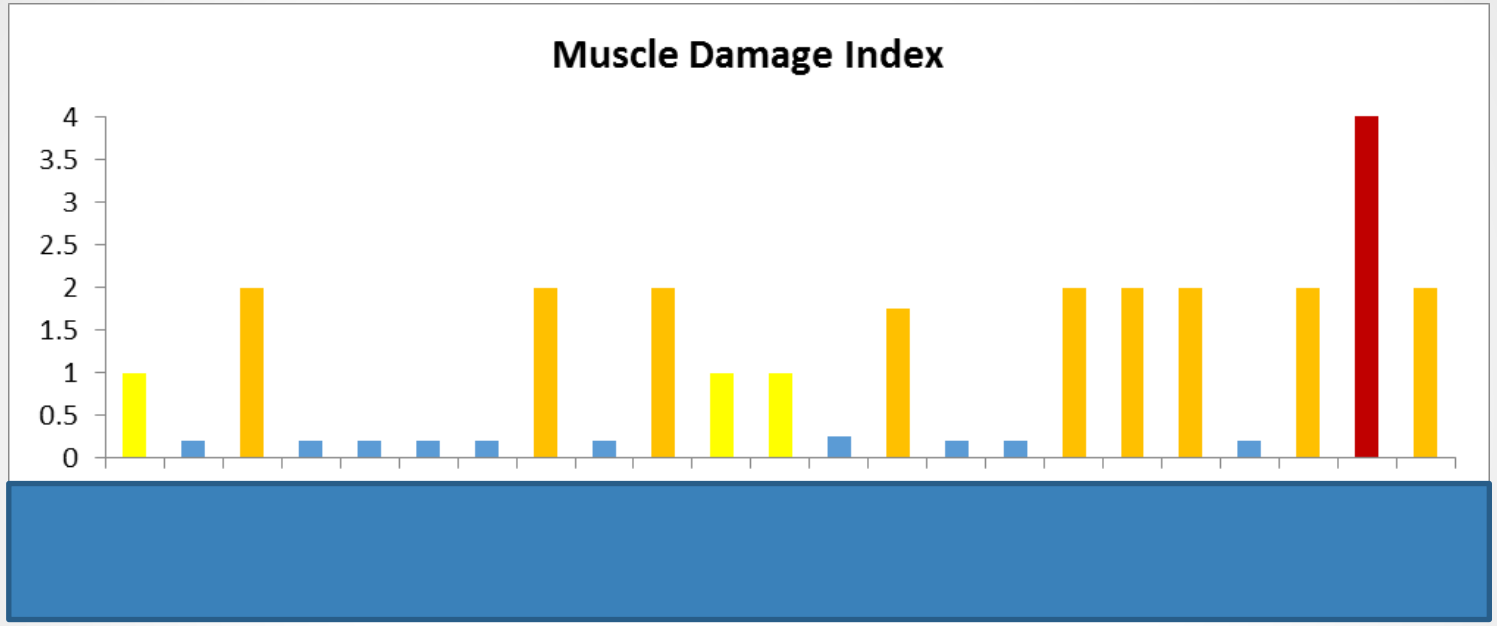


Normal Levels

0	No Damage
1	Mild Damage
2	Moderate Damage/slight Risk of Injury
3	Important Damage/Moderate Risk of Injury
4	Very High Damage/ Hihg Risk of Injury

Decrease in Injury rate: 3x!

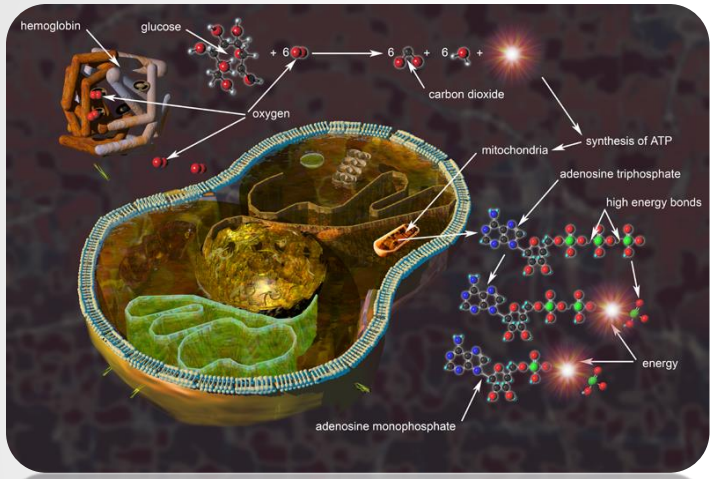
Hematological Monitoring Throughout the Season
Bolood Profiling

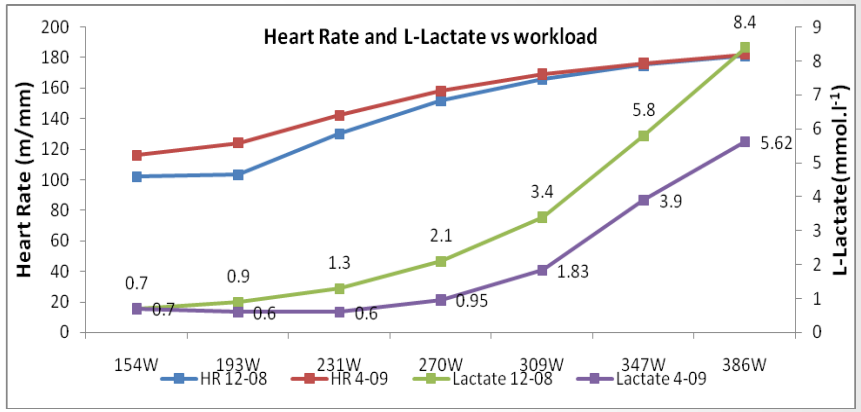


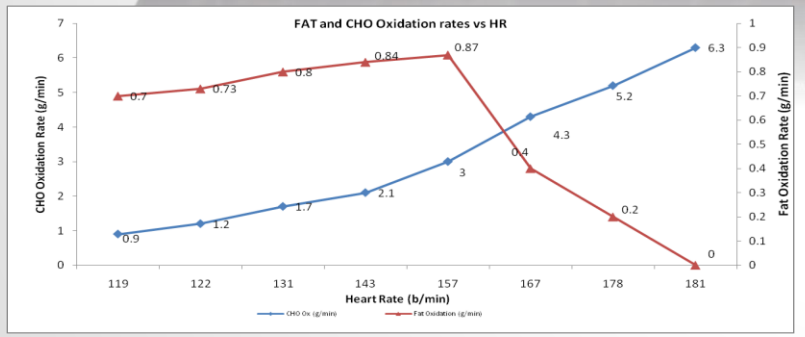
No Damage
Mild Damage
Moderate Damage/slight Risk of Injury
Important Damage/Moderate Risk of Injury
Very High Damage/ Hihg Risk of Injury

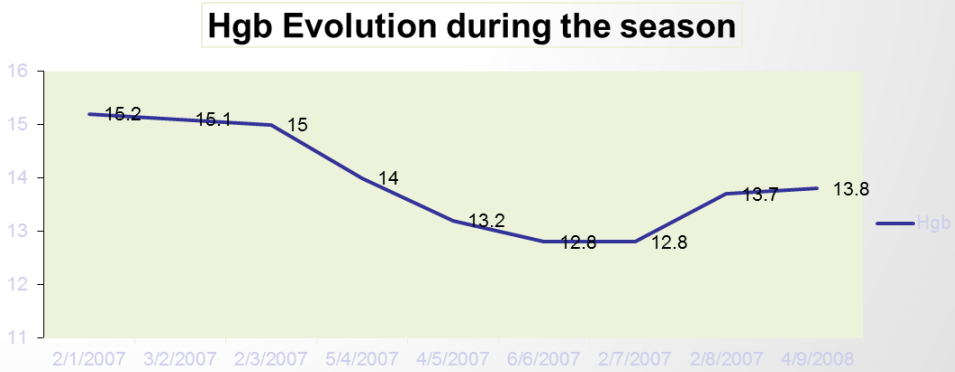
Marginal Gains. How important are they?

Aren’t Major Gains what we should be focusing on First?



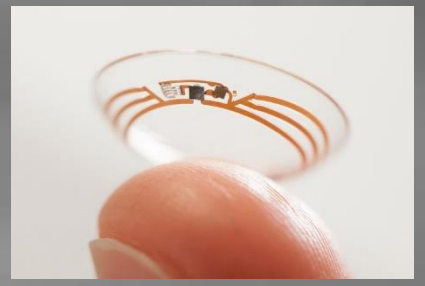


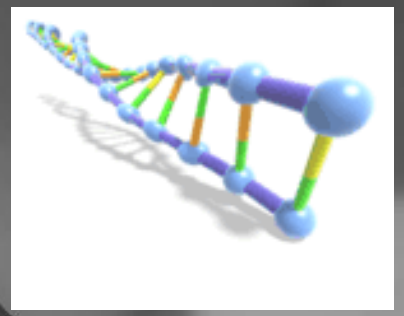


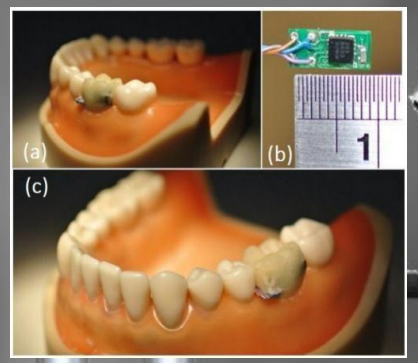


Where is the Future?

The Biosensors







Summary

- **Scientific Training maximizes and utilizes all possible resources**

- **The Goal is to utilize 100% of genetic potential**
- **No Scientific Training= minimization and under-utilization of potential**
- **Overtraining is a great unknown affecting many Athletes and it should be assessed properly by a professional**
- **A true Scientific Training Necessary to make it to the next level**

Sports Medicine and Performance Center

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