ENERGY SYSTEMS

in swimming

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Bob Bowman

Capacity vs. **Utilisation**

Investment in the future

Performance NOW

Utilisation sacrifices Long Term Potential

CAPACITY - POWER

Ideal in competition

Be able to empty your tanks (AE-AN) through their power

The main pathways of energy recycling are

- non-aerobic metabolism (creatine phosphate)
- anaerobic metabolism (anaerobic glycolysis)
- aerobic metabolism.

METABOLISM -> The process of storing and releasing the energy.

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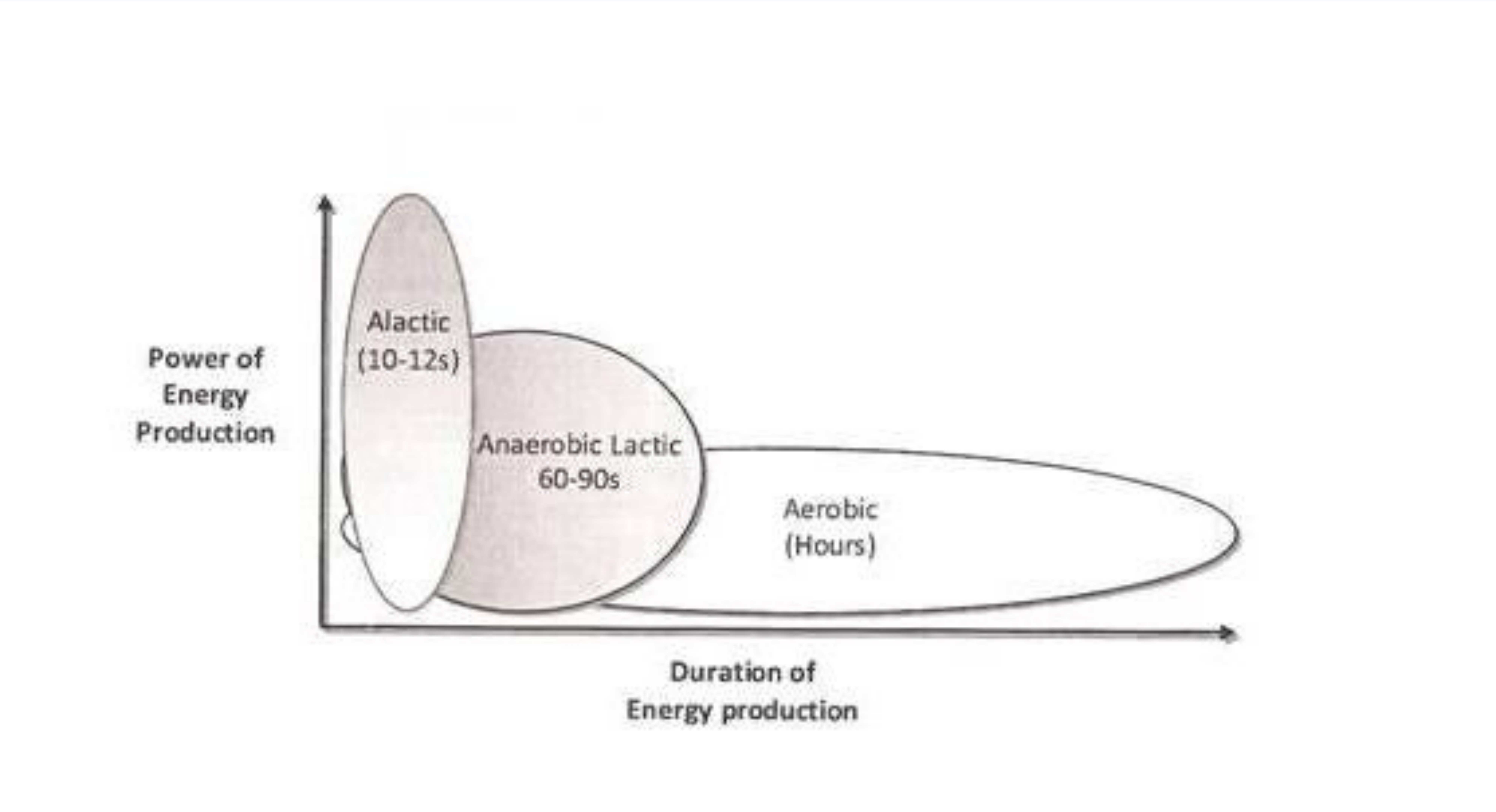

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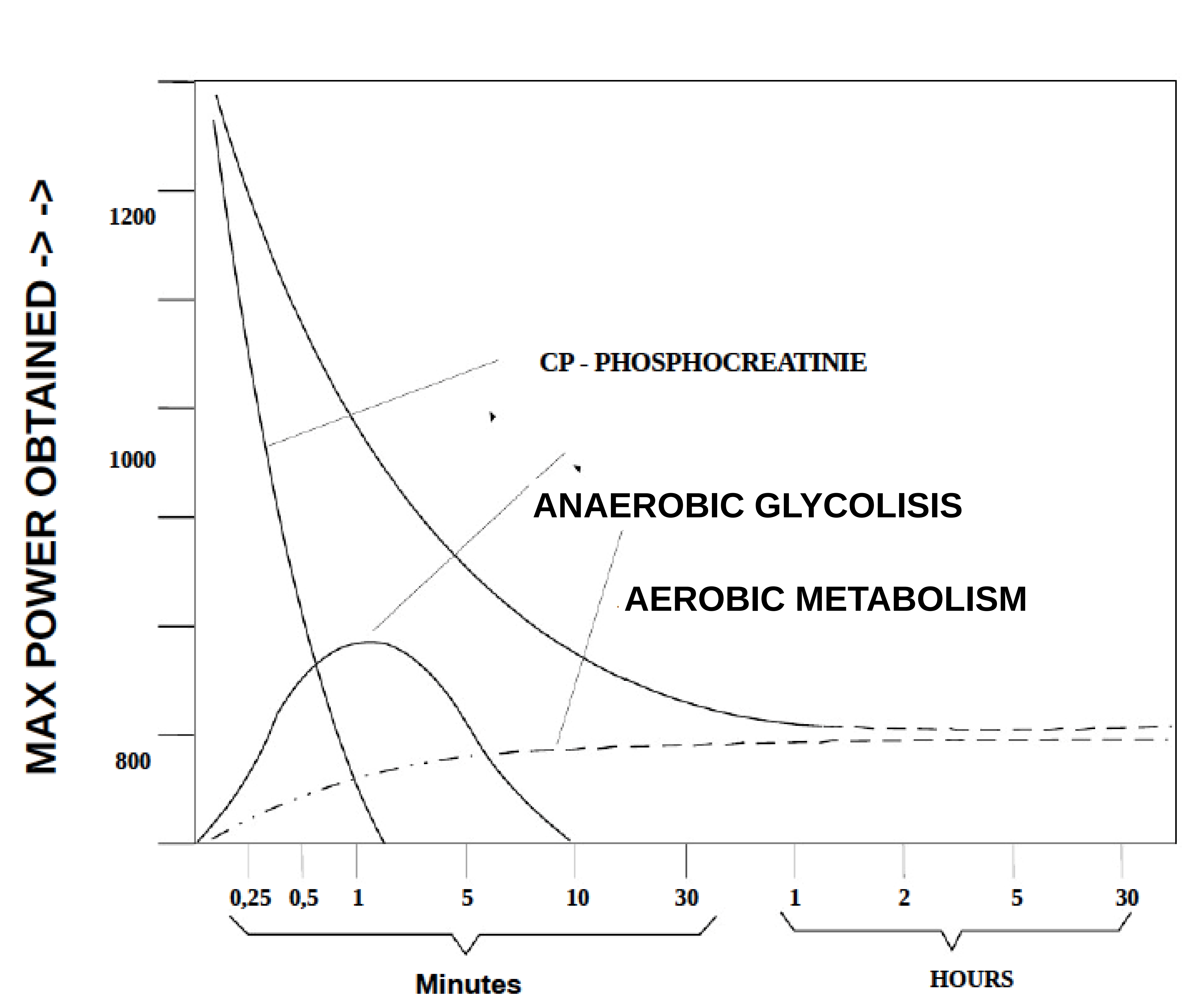


WHERE the energy ?

Energy is stored in different forms and pathways are used to convert it into accessible energy that an athlete can use to perform work.

At any given time, more pathways, not just one, may be engaged in energy production, dominance of an energy source depends on the duration and intensity of the exercise. Usually workload is broken into several energy "zones" based on the duration and intensity of the training.

Energy "zones" allow athletes and coaches to develop a specific pathway of energy recycling and to quantify, track, and plan the physiological adaptations desired for a specific event.

Swimming sets of different duration and intensity are supported by energy from different sources.

During high intensity short-term swimming, energy is mainly recycled through the anaerobic system.

It is a fast and non-oxidative way of energy recycling.

During low intensity activity, the energy is recycled the most aerobically, using oxygen.

This way is slow, but more efficient than the anaerobic way

Improvement of one energy system does not influence another one.

When athletes swim long distances, they develop mostly aerobic energy sources.

High intensity swimming develops the anaerobic energy sources.

Different swimming events require the training of different energy systems.

The same swimming set can be swum in different energy zones.

For example, swimmers can swim sets with higher or lower intensities.

This will recruit different pathways of energy recycling.

The preparation of competitive swimmers requires evaluation of individual swimming intensities in each energy zone.

The same swimming intensity or even heart rate affects the energy recycling pathways differently when athletes are at different stages of the season (i.e., in the beginning of the season, after a sickness, or at peak performances).

Adaptation in athletes to the same swimming intensity depends on their current condition, types of muscle fibers, training history, and other factors.

Therefore, it is important to test athletes during a season and to select appropriate swimming intensities (i.e. using heart rate, lact-production check etc.) to train different energy zones.

Energy Forms In The Body

Adenosine Triphosphate (ATP) is the only source of potential chemical energy in the body. It consists of one molecule of protein (adenosine) and three molecules of phosphate.

Muscle cells always contain free ATP, which reduces to ADP (adenosine diphosphate) and releases the energy during the first few seconds of work.

Decomposition of ATP into ADP releases the energy and phosphoric acid, which increases the acid environment in the muscles. Then other energy storage forms are used to recycle ADP back to ATP through different pathways.

Energy forms in the body include:

- Adenosine Triphosphate (ATP)
- Creatine Phosphate (CP)
- Glycogen (glucose)
- Fats
- Proteins

AEROBIC METABOLISM

The oxidative process of recycling ATP primarily from glycogen. It is a slow process of recycling ATP. **Glycogen for aerobic metabolism is stored in muscle, liver, and blood.**

Fats and proteins can be involved in aerobic metabolism also, but this process is very slow (long distance swimming).
Aerobic metabolism is the main energy system for distances longer than 4 min.

The longer distance, the more energy derived from aerobic metabolism. Aerobic metabolism takes place in a small intracellular organelle called mitochondria. Aerobic metabolism has low power, high capacity, and high efficiency.

AE Metabolism - limiting factors

If oxygen consumption (VO2) is an index of metabolic activity sustained by energy which develops from oxidative degradation of caloric stocks (degradable substrates: carbohydrates), in this case it is evident that the maximum consumption of oxygen (VO2max) represents the maximum power that can be developed by the body on the basis of oxidative processes alone (the maximum retching capacity of aerobic ATP).

DEGRADABLE SUBSTRATES ARE THE LIMITS OF AEROBIC WORK

Carbohydrates: substrate preferably used at the beginning and during the first phase of work (then lipids become the predominant fuel).

VO2max is a global and integrated measure of all those O2 transport mechanisms to the external environment, until its use in the mitochondria of the muscle fiber.

Capacity to take O2 - O2 transport capacity - Capacity utilization

Anthropometric and personal data factors

Environmental factors: Altitude,Temperature, Noise, Pollution

Working capacity in athletes depends more on the rate of recycling ATP (from CP, glycogen, fats and proteins) than on the amount of ATP.

Thanks to training, ATP-CP increases less than 20%, while working capacity (swimming velocity) increases more dramatically.

Pathways of Energy Metabolism

There are three main pathways of energy metabolism:

1. Creatine Phosphate (immediate non-oxidative way of energy recycling)
2. Anaerobic Metabolism (anaerobic-glycolitic non-oxidative way of energy recycling)
3. Aerobic Metabolism (oxidative way of energy recycling)

Metabolism of Creatine Phosphate is the process of recycling ATP from CP. CP is stored in muscle cells.

It very rapidly recycles ATP from ADP. Usually after 2-3 seconds of high intensity work, free ATP stores in muscle cells are depleted. Then CP phosphate is involved to recycle ATP.

After 10-15 seconds of high intensity work the rate of recycling ATP from CP is slowed down.

Creatine Phosphate has very high power, low capacity, and low efficiency.

DEVELOPING

sets

UK/US Swimming suggestions

Ref. Maglischo - Sokolovas - Urbanchek - Vorontsov

DEVELOPING ANAEROBIC

Examples of swimming sets and distances that develop anaerobic metabolism:

distances of 50 to 300 M,

high intensity swimming sets
6-16 x 25 M
4-8 x 50 M
2-4 x 100 M
2 x 200 M

DEVELOPING AEROBIC

Examples of swimming sets and distances that develop aerobic metabolism:

distances of 2000 M and longer, low and middle intensity swimming sets with short rest interval

20 and more x 100 M
10 and more x 200 M
7 and more x 300 M
5 and more x 400 M

TRAINING ZONES 1

The Five Zone Classification is based on sources of energy recycling:

Zone 1 – aerobic recovery
Zone 2 – aerobic development
Zone 3 – mix aerobic anaerobic
Zone 4 – anaerobic
Zone 5 – creatine phosphate

Since both zones 1 and 2 are aerobic, often these zones are combined leaving four major energy zones (aerobic, mix, anaerobic, and creatine phosphate).

Swimming sets in these zones depends on the rest interval and intensity.

Sample Construction Tools for Workout Creation (US)

Energy System	Duration of Set	Distance	Rest	HR	LA	Energy Supply
EN1	15-90 min	300-4000	10-30s	50 BBM	1-3 LA	Aerobic (oxidative)
EN2	15-50 min	100-2000	10-40s	40-30 BBM	2-3 LA	Aerobic (oxidative)
EN3	8-30 min	100-800	30-90s	30-20 BBM	4-10 LA	Mix (aerobic anaerobic)
SP1	5-20 min	50-200	1:1-1:2 W:R	Max HR	10-16 LA	Anaerobic (non oxidative)
SP2	5-10	25-100	1:2-1:6 W:R	Max HR	10-20 LA	Anaerobic (Creatine Phosphate)

EXAMPLES OF TRAINING SETS IN ENERGY ZONES - 1

USING A 15”-20” REST INTERVAL

Distance in meters or yards	Zone 4 SP1-2	Zone 3 EN2-3	Zone 1&2 EN1 & REC
	(number of repetitions)		
25	4-16	18-60	62 & more
50	2-7	8-26	27 & more
75	1-4	5-16	17 & more
100	1-3	4-12	13 & more
150	1-2	3-8	9 & more
200	1	2-6	7 & more
400		1-3	4 & more

EXAMPLES OF TRAINING SETS IN ENERGY ZONES - 2

USING A 30”-40” REST INTERVAL

Distance in meters or yards	Zone 5 SP3	Zone 4 SP1-2	Zone 3 EN2-3	Zone 1&2 EN1 & REC
	(number of repetitions)			
15	6-8			
25	3-4	6-20	22-70	72 & more
50	1	2-9	10-32	33 & more
75		1-6	8-21	22 & more
100		1-4	5-15	16 & more
150		1-3	4-10	11 & more
200		1-2	3-7	8 & more
400			1-4	5 & more

IT’S all RELATIVE

All energy zones are relative.
There are no borders between energy zones.
However, each zone has a primary pathway for energy recycling.

Understanding energy zones is helpful in classifying swimming sets and developing particular pathways for energy recycling.

It is recommended to use five energy zones with senior swimmers.

The training of age group swimmers does not require using all five energy zones. Some zones might be combined and used as one broader zone.

For instance, zones one and two could be combined to form the aerobic zone, while zones four and five could be combined to form the anaerobic zone.

This will decrease the number of energy zones for age group swimmers from five to three zones: aerobic, mix, and anaerobic

RESUMING

Phosphagen
The phosphagen system is our immediate duration energy system, lasting around 10 seconds.
It basically uses the ATP stored directly in your muscles to produce energy quickly. After about 10-12 seconds, the body starts utilizing simple carbohydrates or glucose as a fuel source, rather than ATP.

Glycolytic
The glycolytic system requires the chemical breakdown of sugars in the body to fuel muscles for activity. Training this system leads to a better utilization of glucose and a greater duration of exercise at a higher intensity.

Aerobic
The aerobic system begins to be utilized for medium intensity activities and utilizes oxygen to fuel the body. Unlike the anaerobic pathways, training your aerobic system yields little improvements in speed, power or strength and actually leads to a degradation of muscle tissue, the latter of which we know improves body composition and increases basal metabolic rate.

Energetic Contribution - Different distances %

	AER	LACT	ALACT	mM
50	5-15	50-60	25-40	8-13
100	35-45	35-50	15-20	12-18
200	60-70	25-30	10-12	12-18
400	70-80	15-20	6-8	10-16
800	80-90	5-15	3-4	8-12
1500	85-95	3-10	2-3	6-10

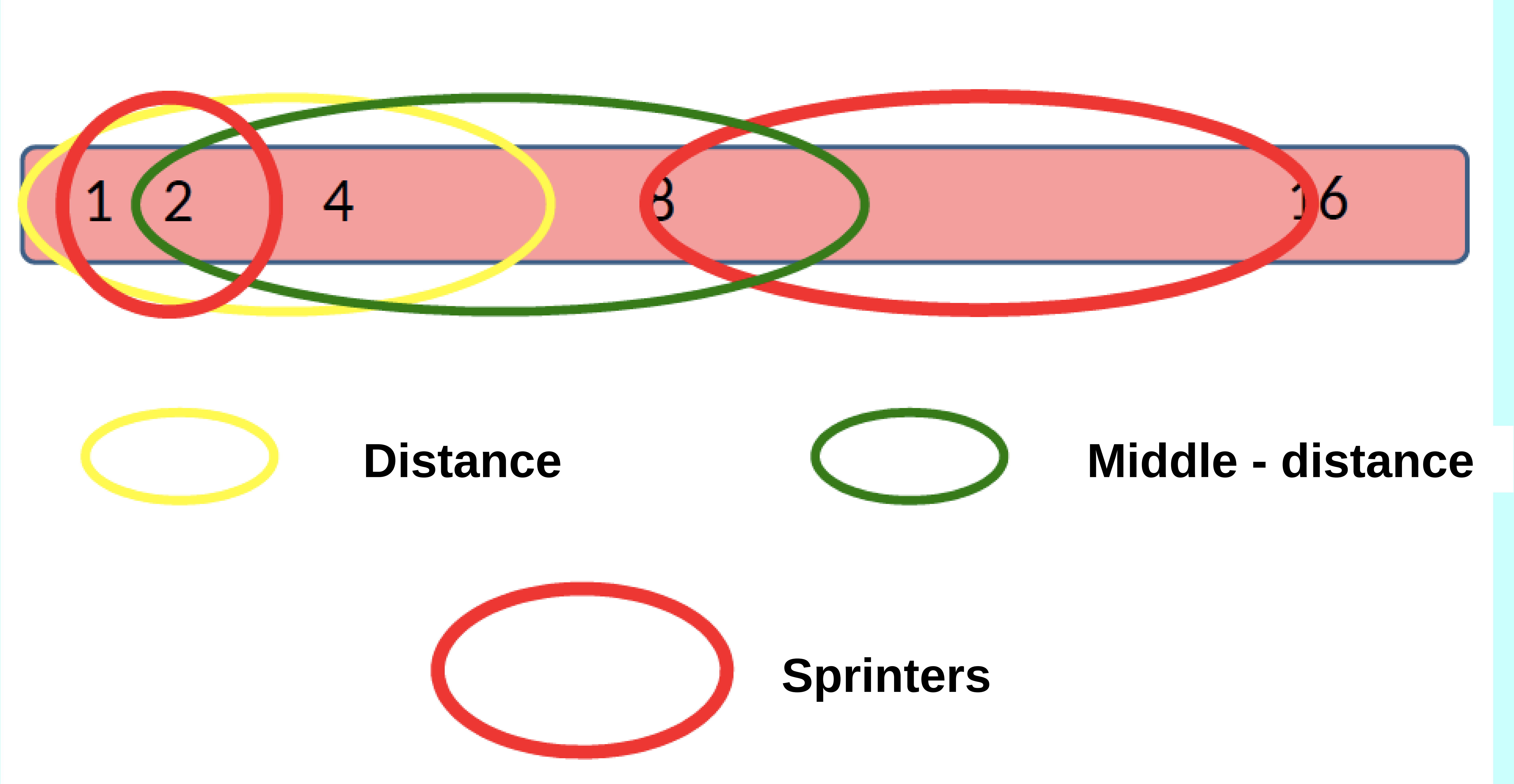
Maglischo

TAKE INTO ACCOUNT

Preparing sets, managing distances, races …..

SYSTEM	LATENCY
AN AL	Fractions of seconds
AN L	10/15 seconds
AE	45/80 seconds

Swimmers and lactate production



Heterocronism model

Heterocronism/hours	VO2	AN - TOLERANCE	AN - PEAK
VO2	72	24	6
AN - TOLERANCE	24	48	24
AN - PEAK	6	24	48

Recovery time after exhaustive muscular work

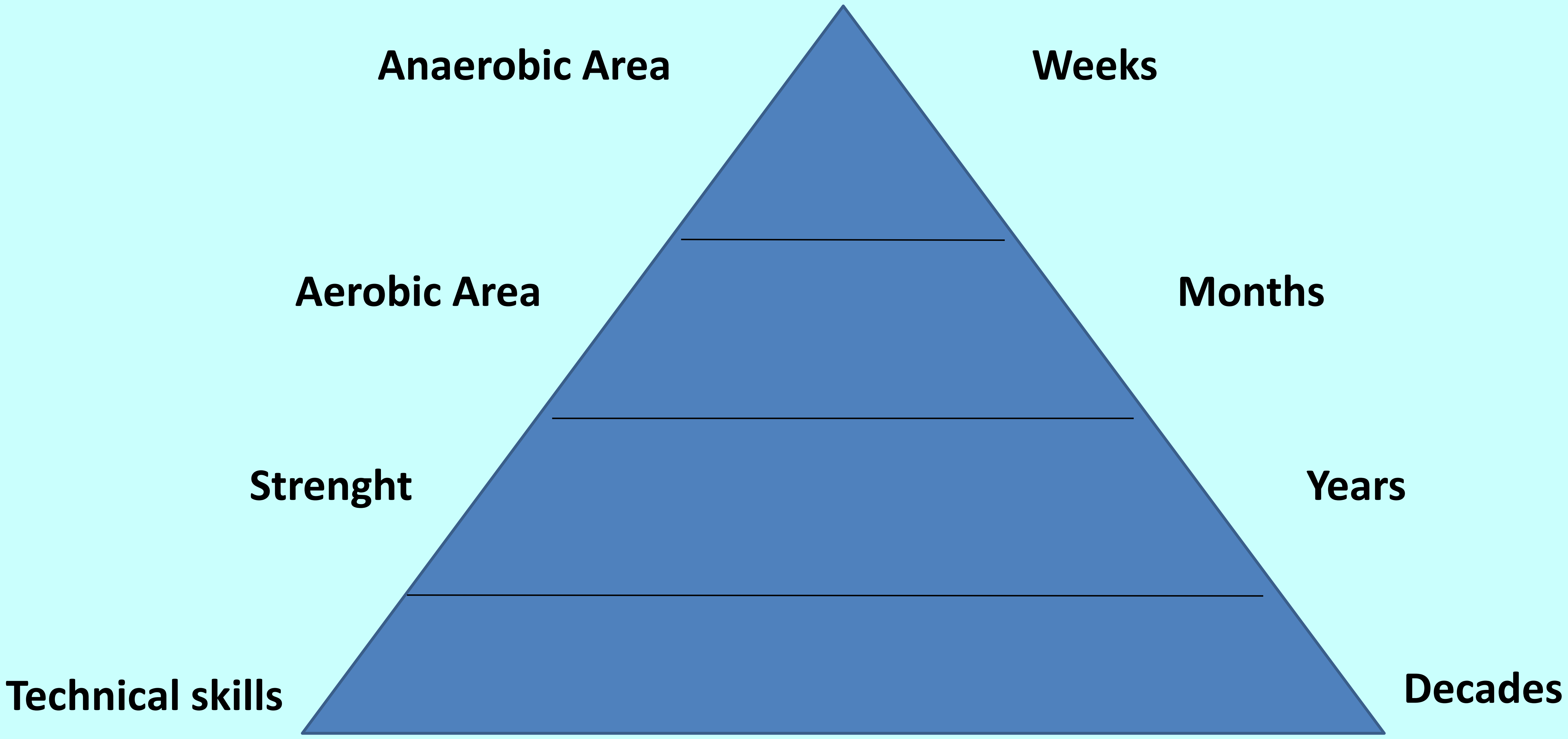
Restoration of phosphages	2-3 minutes
Acid Lactic disposal	30-60 minutes
Restoration of hepatic glycogen	6-24 hours
Restoration of muscle glycogen	12-48 hours
Synthesis of muscle proteins	36-72 hours

AE contribution 1st half	Lactate (Mm)	AE contribution 2nd half
100 - 25% or less	More than 2/3rd of the final	50% or more
200 - 50% or less	More than 2/3rd of the final	75% or more
400 - 70% or less	Slightly less than 2/3 of the final	80% or more

Contribution of different energy mechanisms in different performance according Colwin

DIST	ATP/CP	AN	AE
50	55	40	5
100	15	50	35
200	10	30	60
400	5	25	70
1500	0	15	85

Temporal adaptation's hierarchy according Counsilman & Counsilman 1991



Colwin - Maglischo - Sweetenham - Atkinson

SYSTEMS / ASPECTS	% LOSS	TIME IN WEEKS
AEROBIC CAPACITY VO2 MAX	7% 12%	2 weeks 12 weeks
ANAEROBIC THRESHOLD	17% 8-10%	12 weeks 4 weeks
MUSCLE GLYCOGEN	Up to 40%	4 weeks
AE/AN ENDURANCE	50%	3 weeks
ANAEROBIC ENZYMES	0	4-12 weeks
STRENGHT AND POWER	7-15%	1-4 weeks
FLEXIBILITY	100%	4/5 weeks
PERFORMANCE	2-3 seconds 6-8 seconds	1 week 3 weeks

Lactate produced tends to grow for a few minutes after the race (3' to 7'), followed by a first phase of fast removal and decrease of values, followed by another phase in which the further decrease is much slower.

If devices like “lactate-pro” are not available, this option could be considered.
After swimming the first 600 meters, a lactate fall of 50% is observed, while the next decrease can be determined from the following table.

Mm/l MAX	600 m	1000 m	1400 m	1800 m
8	4	2	1	
10	5	2.5	1.25	
12	6	3	1.5	
14	7	3.5	1.75	1
16	8	4	2	1
18	9	4.5	2.25	1.1
20	10	5	2.5	1.25

Hvala !

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