Physiological and metabolic demand of Middle and Long Distance runners

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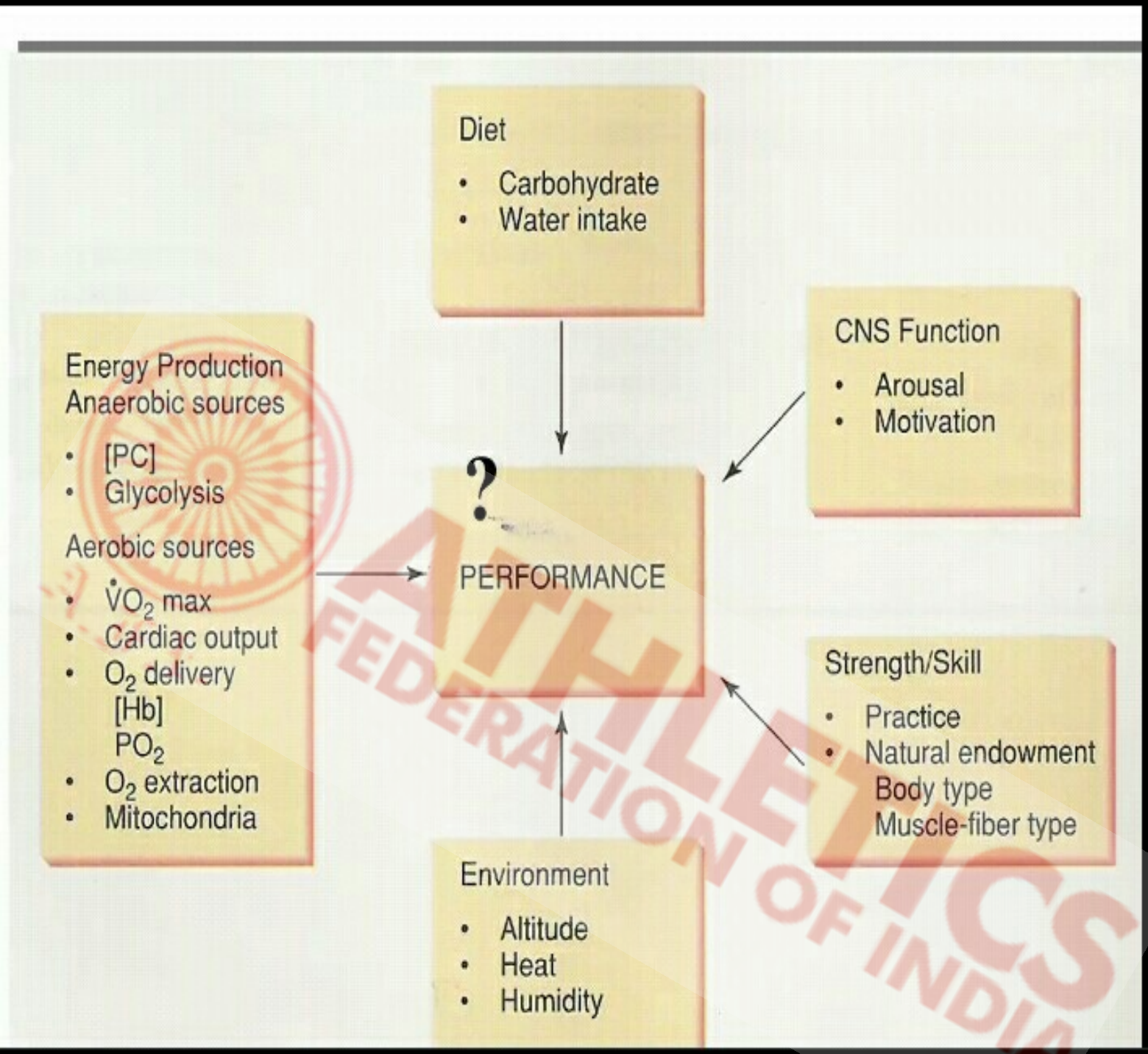

Diet
• Carbohydrate
• Water intake
CNS Function
• Arousal
• Motivation
Energy Production
Anaerobic sources
• [PC]
• Glycolysis
Aerobic sources
• $\dot{V}O_2$ max
• Cardiac output
• O_2 delivery
[Hb]
PO_2
• O_2 extraction
• Mitochondria
?
PERFORMANCE
Strength/Skill
• Practice
• Natural endowment
Body type
Muscle-fiber type
Environment
• Altitude
• Heat
• Humidity

Energy substrates (Nutrients) that gives us energy:

Carbohydrates	Digestion	Glucose
Fats		Fatty acids
Proteins		Amino Acids

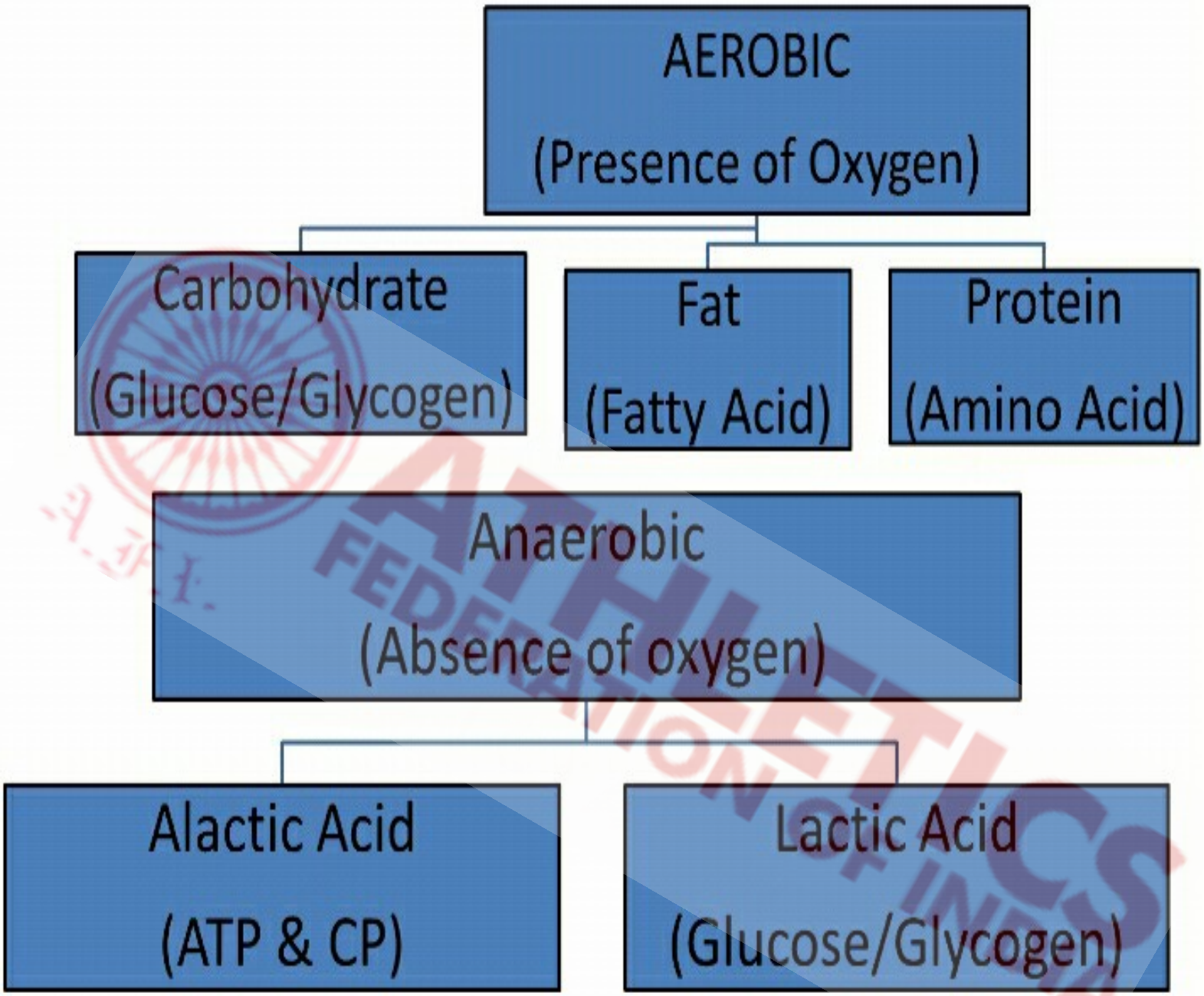
They are used to produce ATP or stored

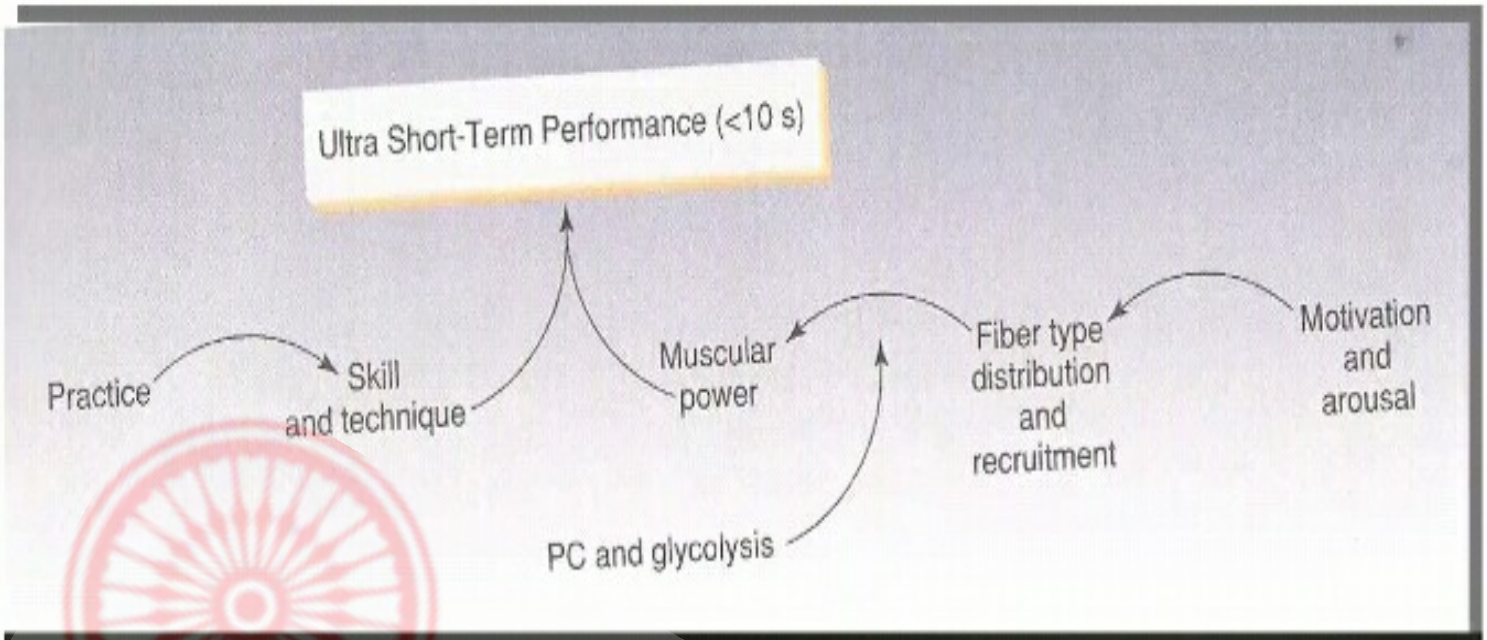
Body Stores of Fuels and Energy

	g	kcal
Carbohydrates		
Liver glycogen	110	451
Muscle glycogen	500	2,050
Glucose in body fluids	15	62
Total	625	2,563
Fat		
Subcutaneous and visceral	7,800	73,320
Intramuscular	161	1,513
Total	7,961	74,833

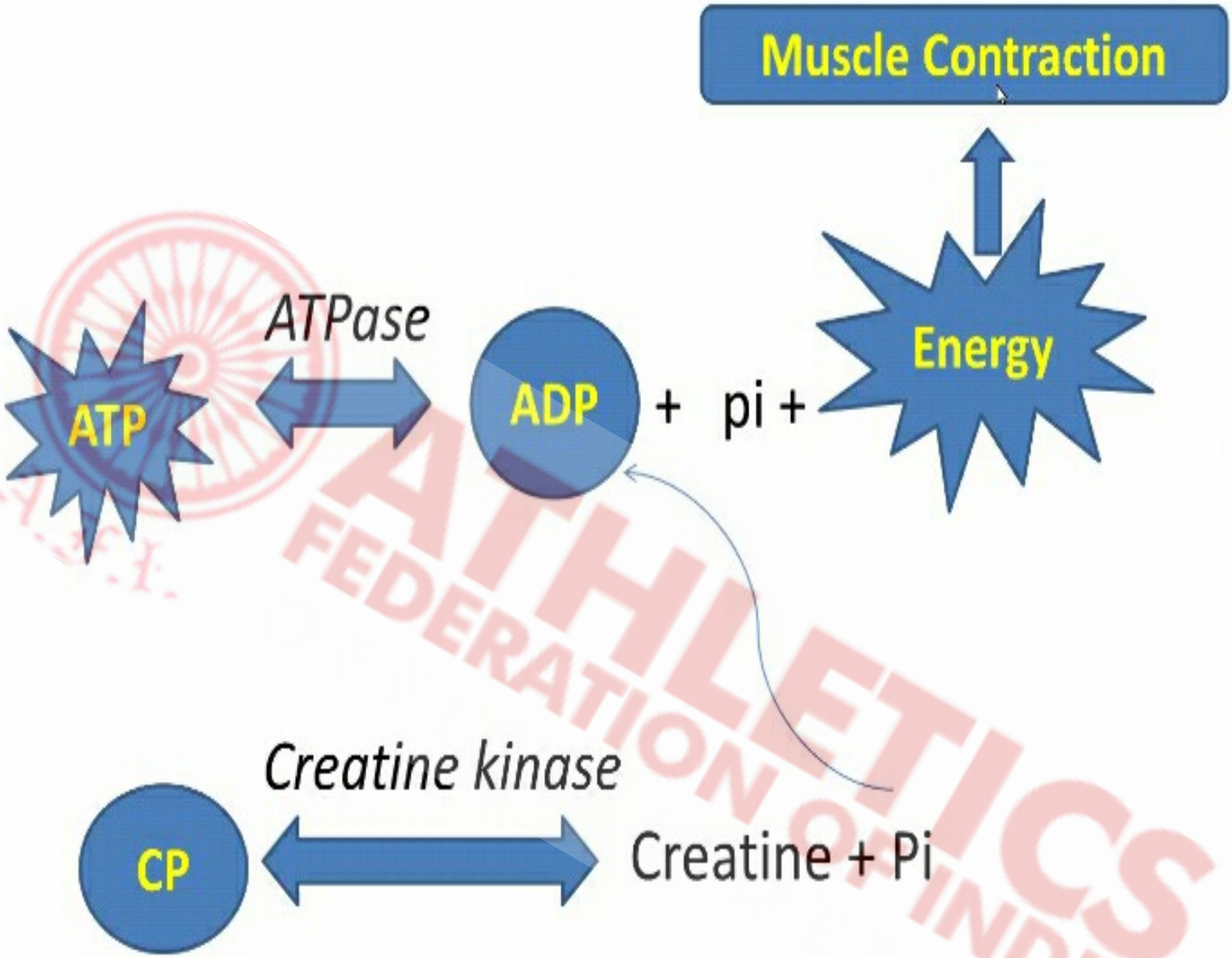
Note. These estimates are based on an average body weight of 65 kg (143 lb) with 12% body fat.

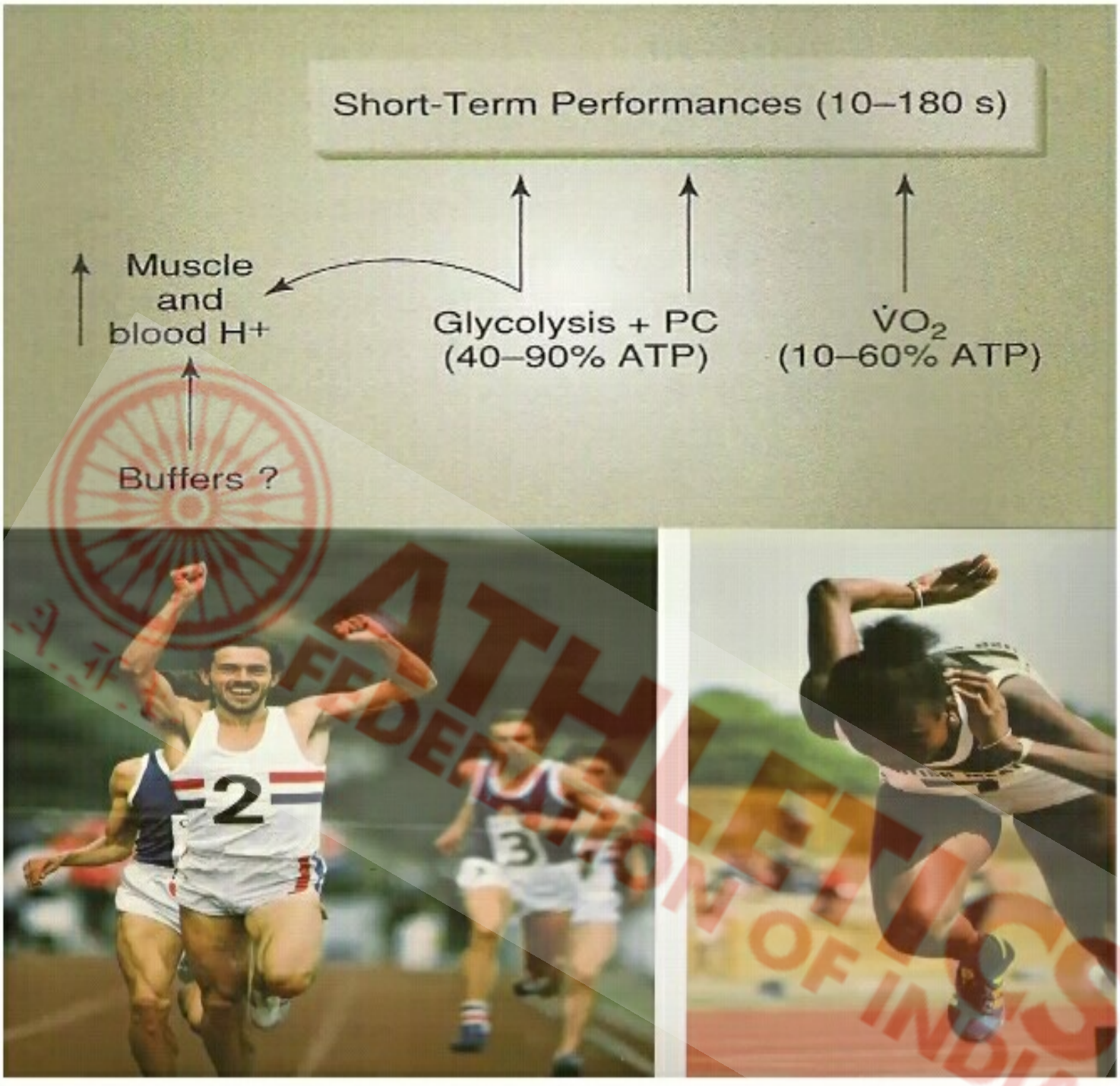
ENERGY SYSTEMS

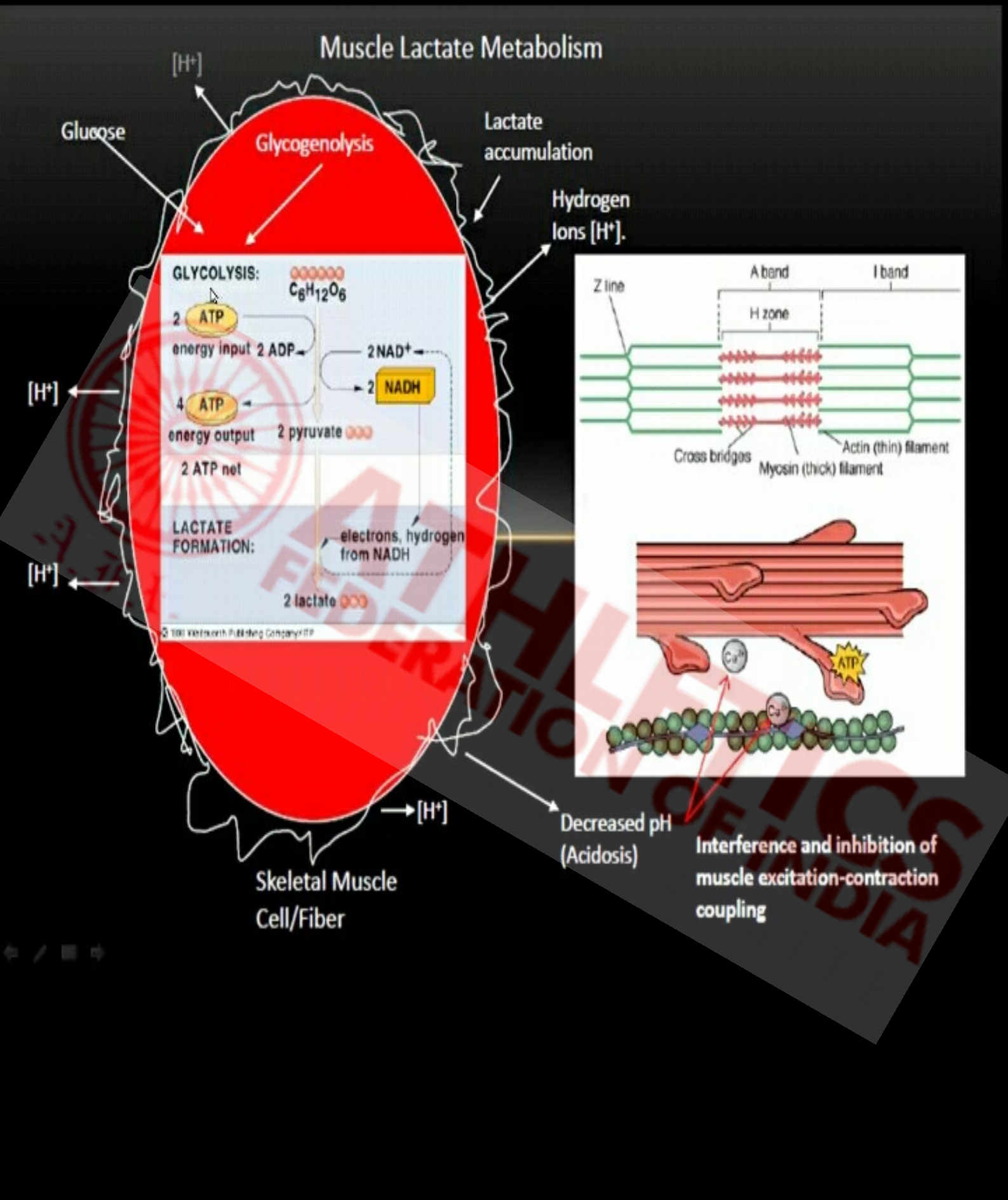




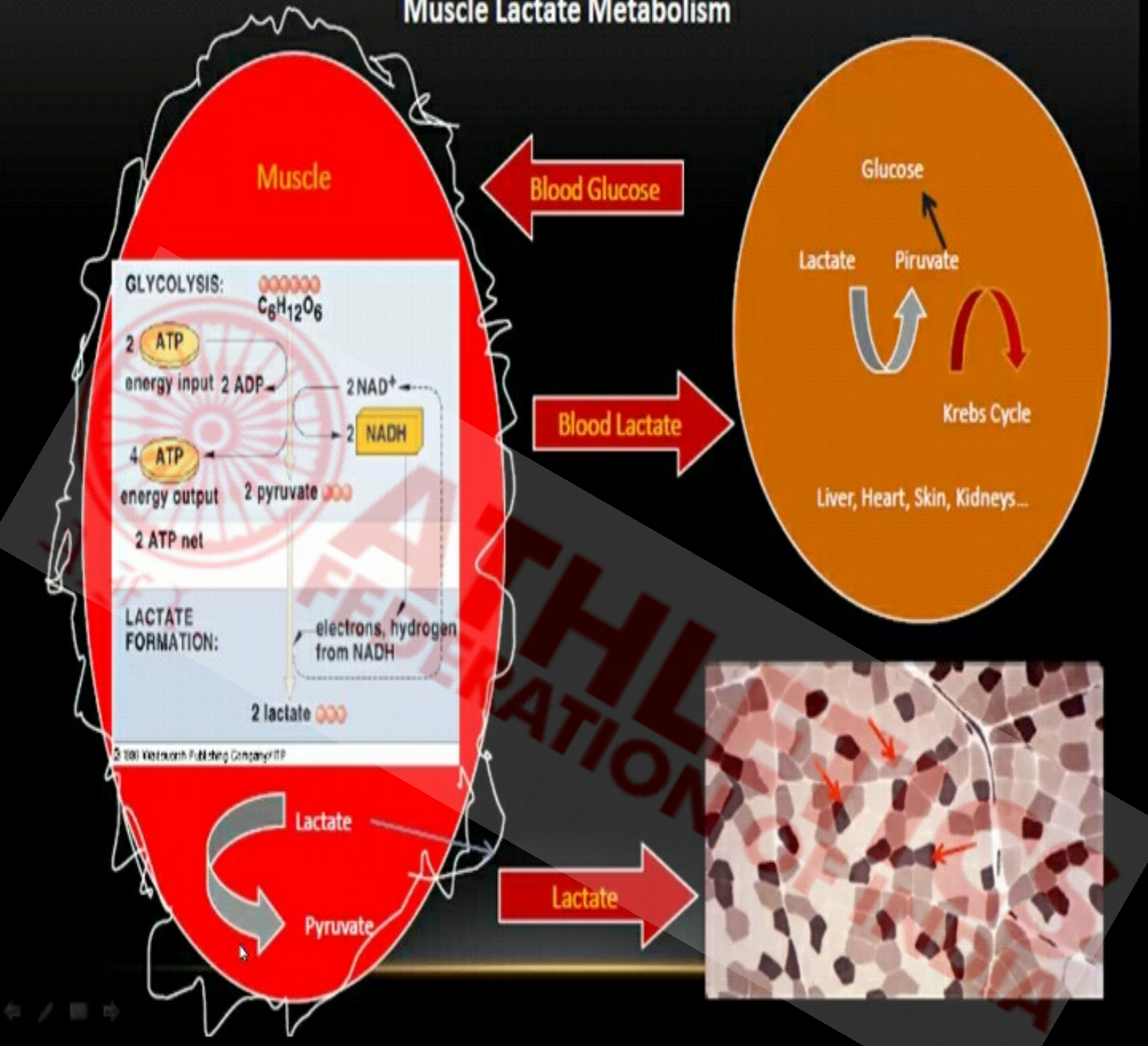
The ATP-CP/Phosphagen Energy System



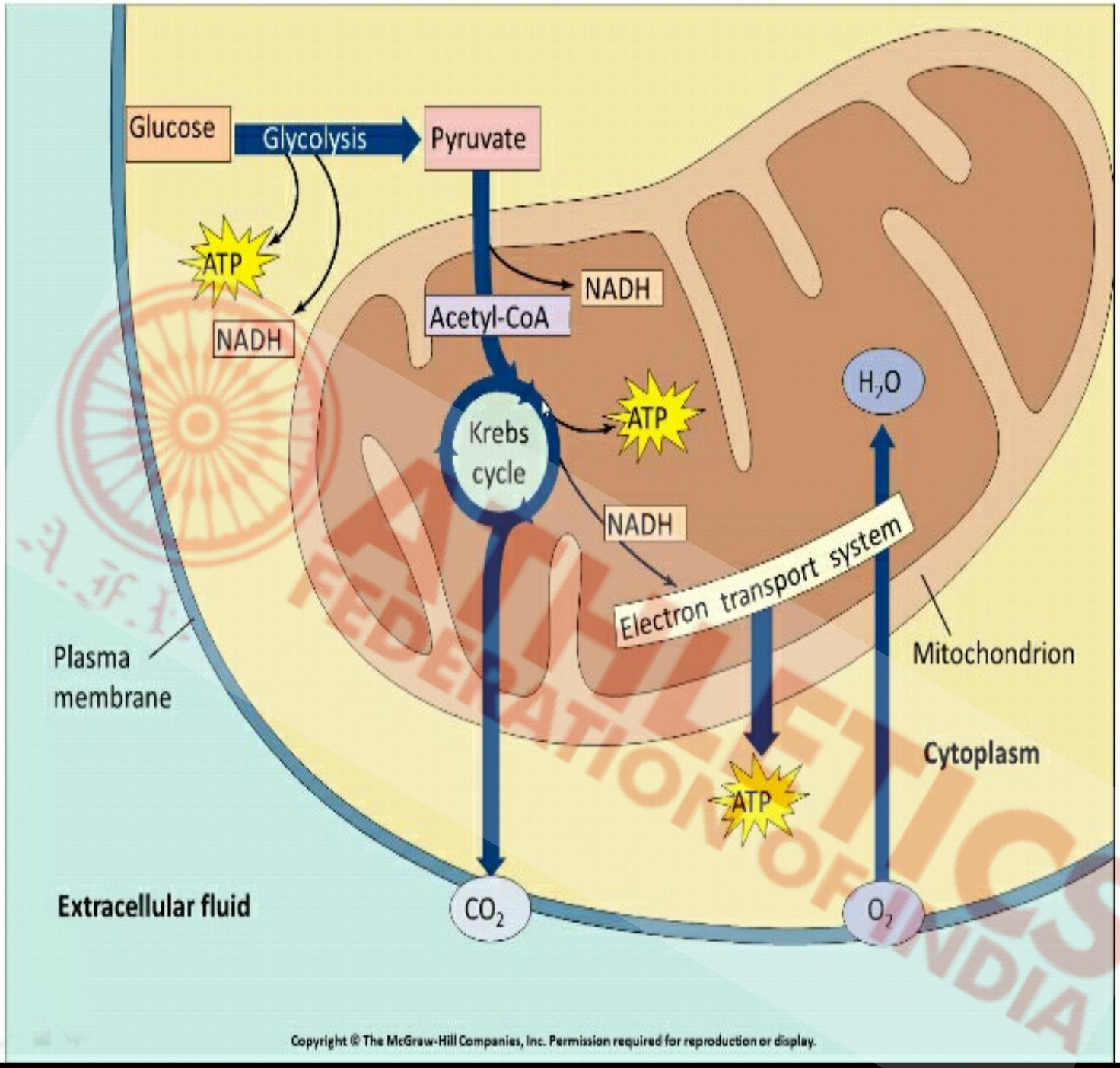


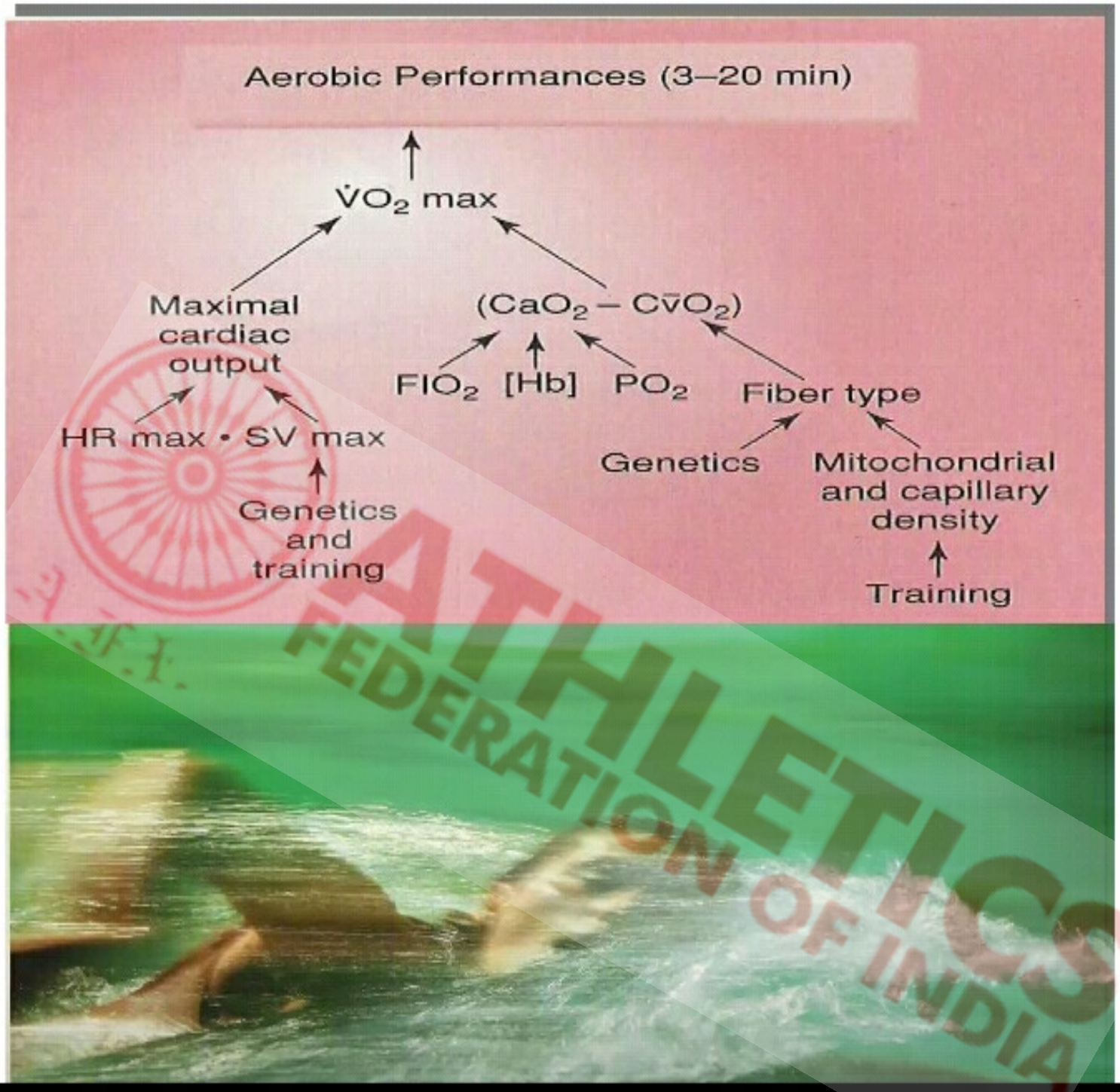

Muscle Lactate Metabolism
[H+]
Glucose
Glycogenolysis
Lactate accumulation
Hydrogen Ions [H+].
GLYCOLYSIS:
$C_6H_{12}O_6$
2 ATP
energy input
2 ADP
2 NAD^+
2 NADH
4 ATP
energy output
2 pyruvate
2 ATP net
LACTATE FORMATION:
electrons, hydrogen from NADH
2 lactate
[H+]
[H+]
[H+]
Z line
A band
I band
H zone
Cross bridges
Actin (thin) filament
Mycosin (thick) filament
ATP
Decreased pH (Acidosis)
Interference and inhibition of muscle excitation-contraction coupling
Skeletal Muscle Cell/Fiber

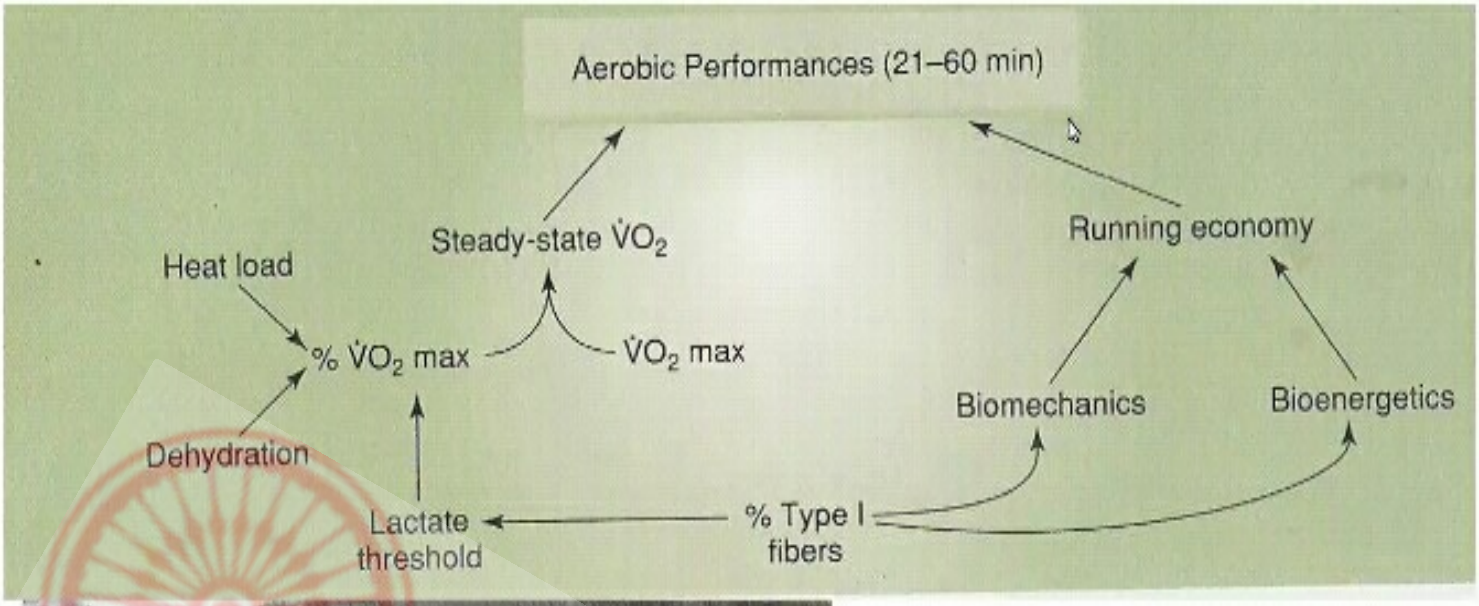
Muscle Lactate Metabolism

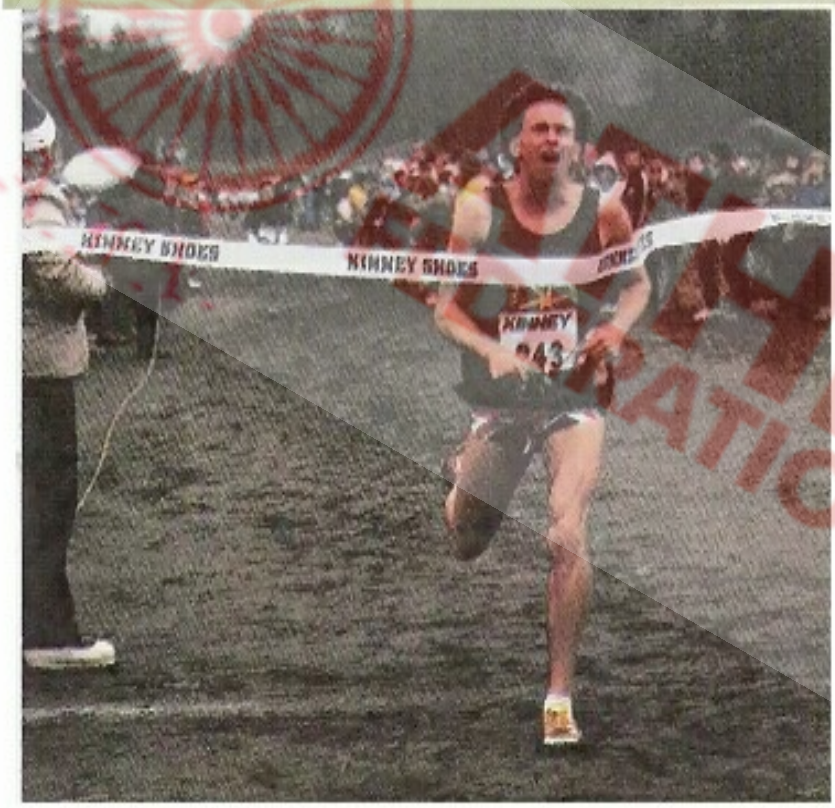


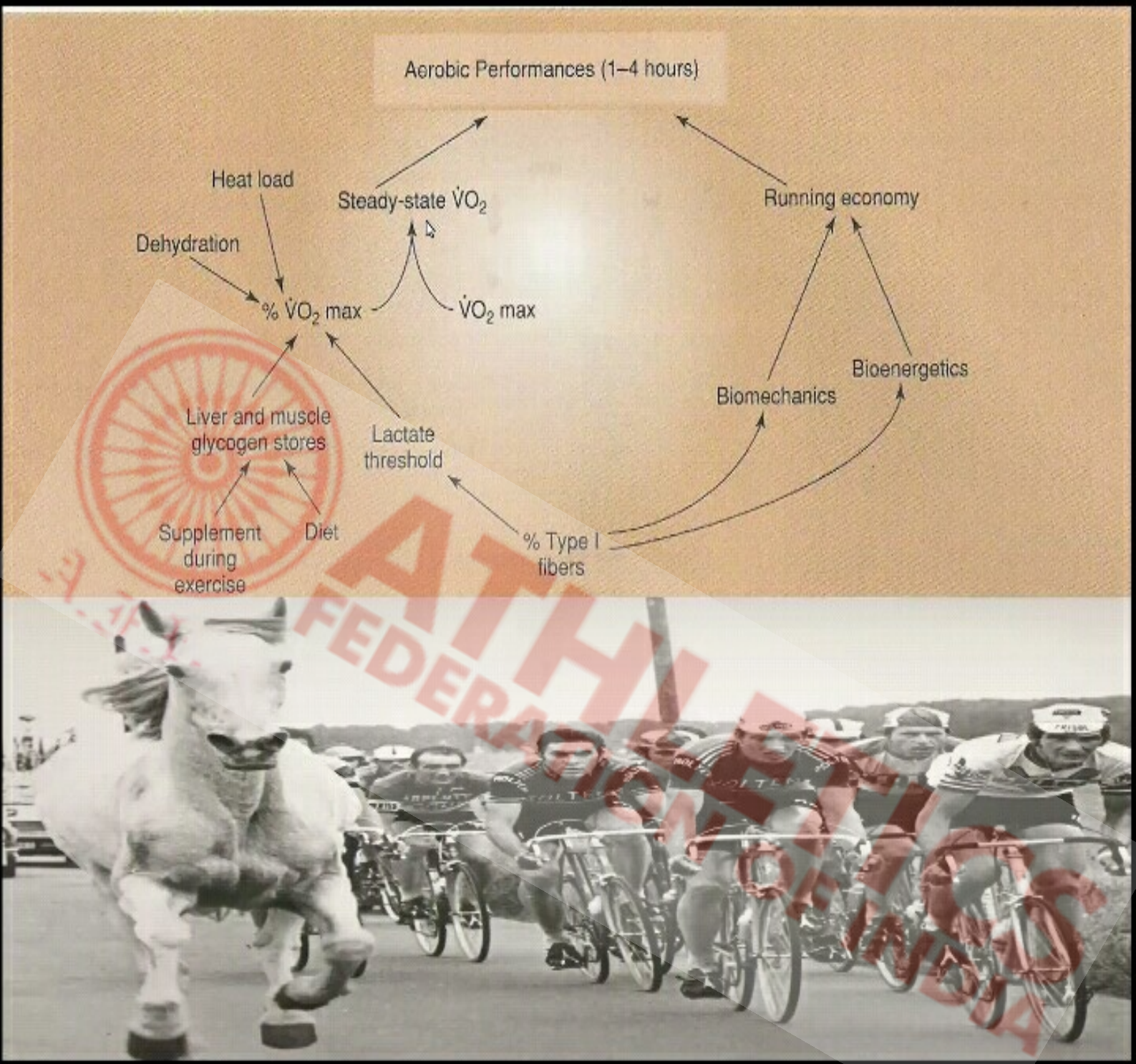
Aerobic process of energy release



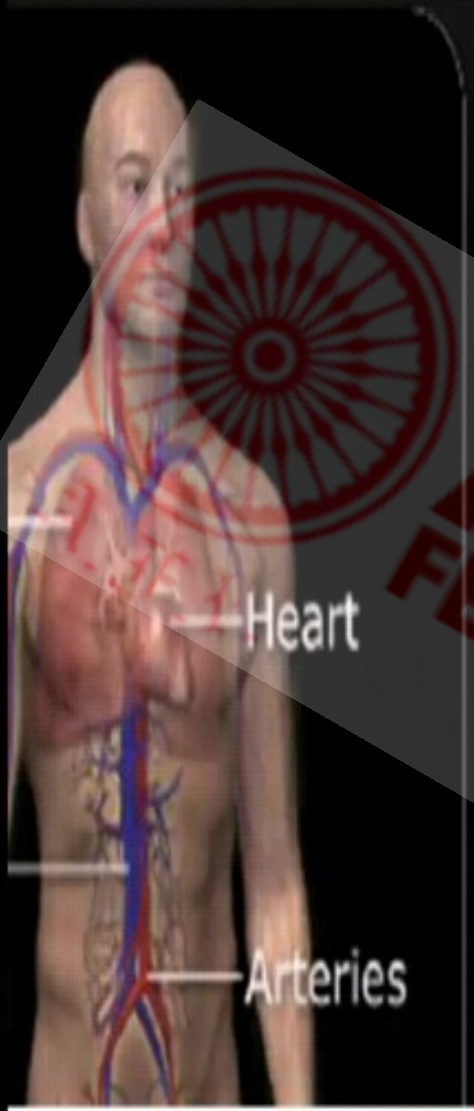


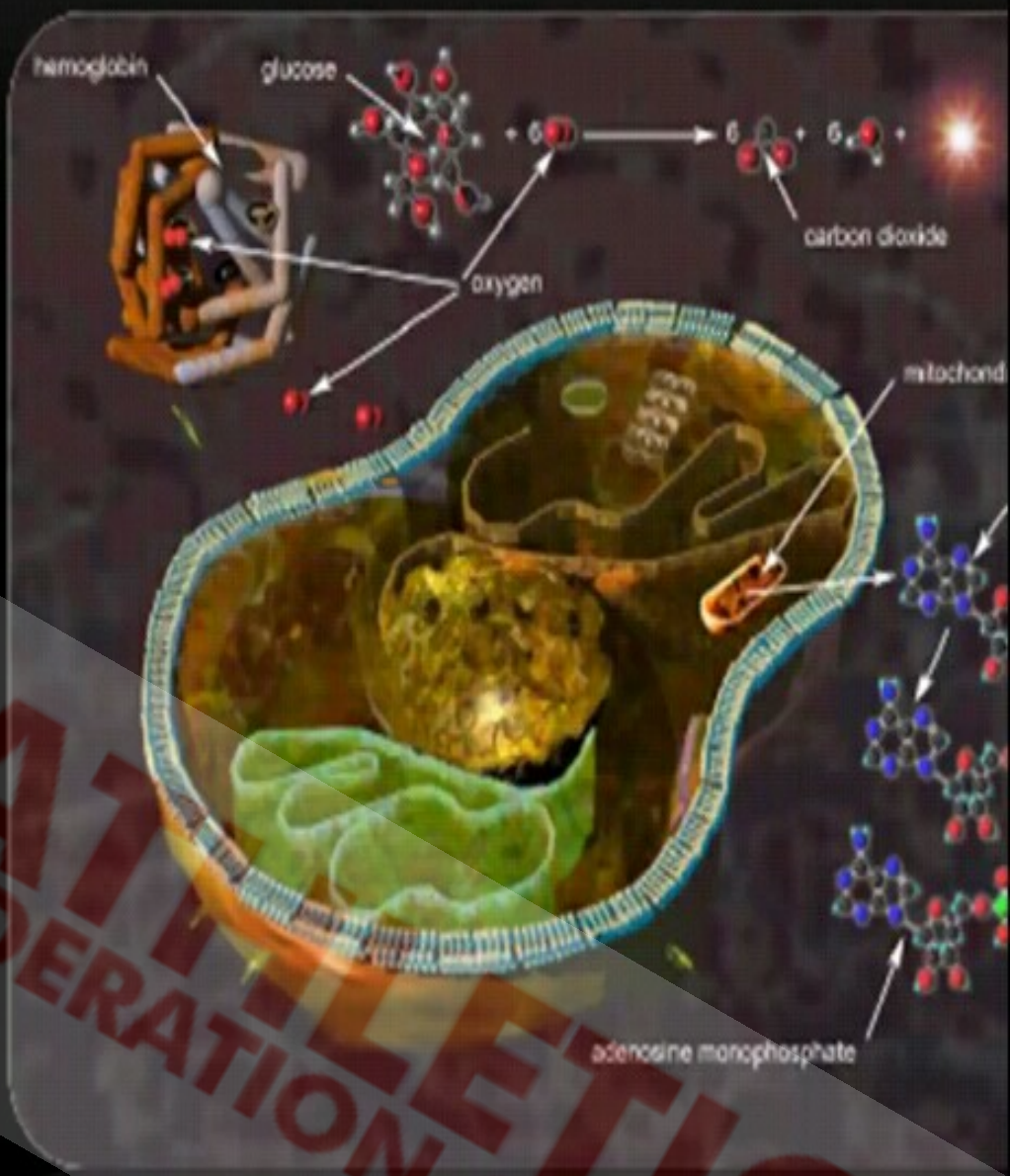

Aerobic Performances (21–60 min)
Steady-state $\dot{V}O_2$
Running economy
Heat load
% $\dot{V}O_2$ max
$\dot{V}O_2$ max
Biomechanics
Bioenergetics
Dehydration
Lactate threshold
% Type I fibers


KINNEY SHOES
KINNEY SHOES
KINNEY


Aerobic Performances (1–4 hours)
Heat load
Steady-state $\dot{V}O_2$
Running economy
Dehydration
% $\dot{V}O_2$ max
$\dot{V}O_2$ max
Bioenergetics
Biomechanics
Liver and muscle glycogen stores
Lactate threshold
Supplement during exercise
Diet
% Type I fibers

Central Adaptation





-The events happening at the cellular le
make the difference

MAP TRAINING INTENSITY

<AT

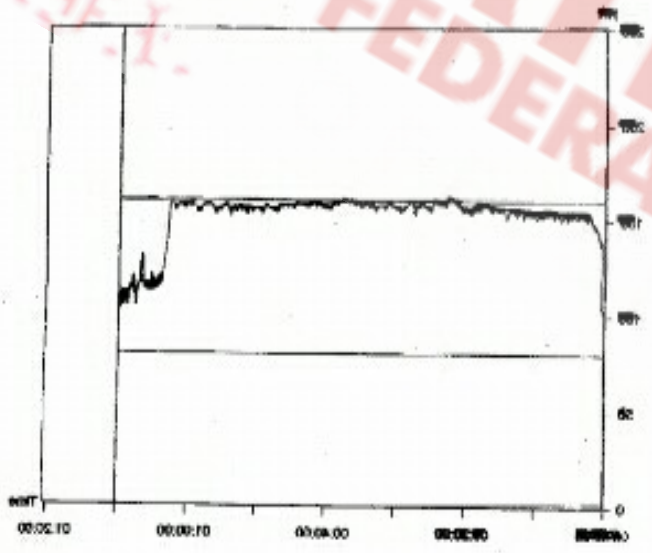
Central

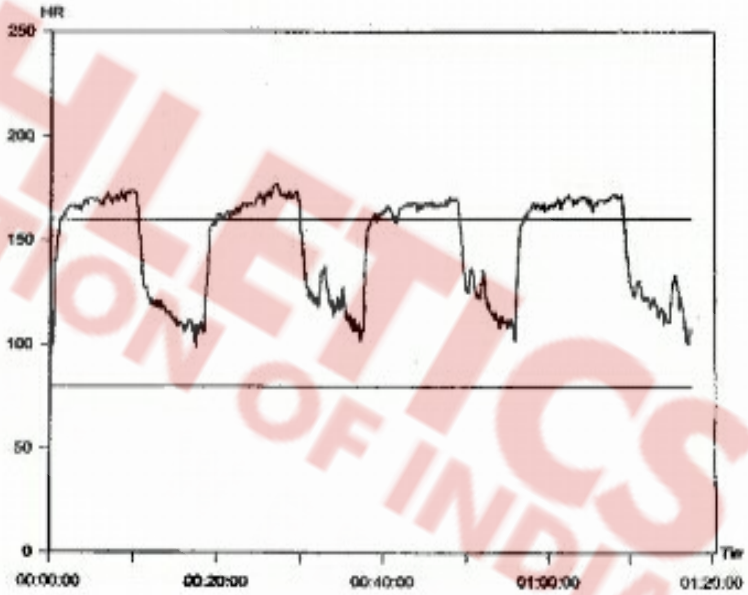
↑ Cardiovascular adaptation

95-100% MAP

Peripheral

↑ Localised muscular adaptation





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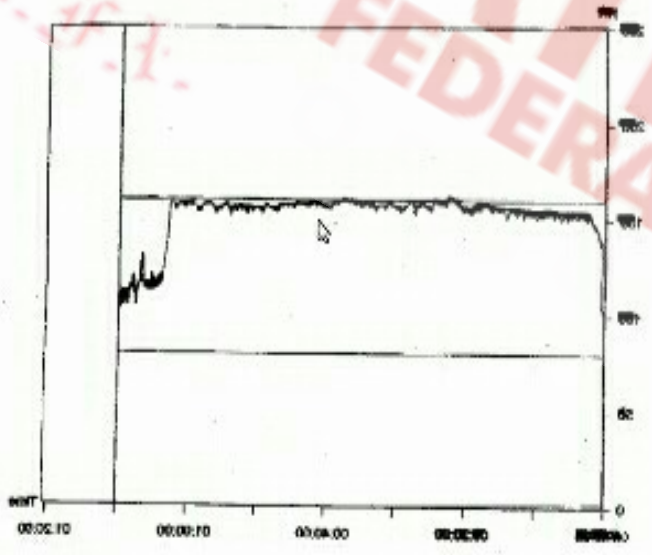
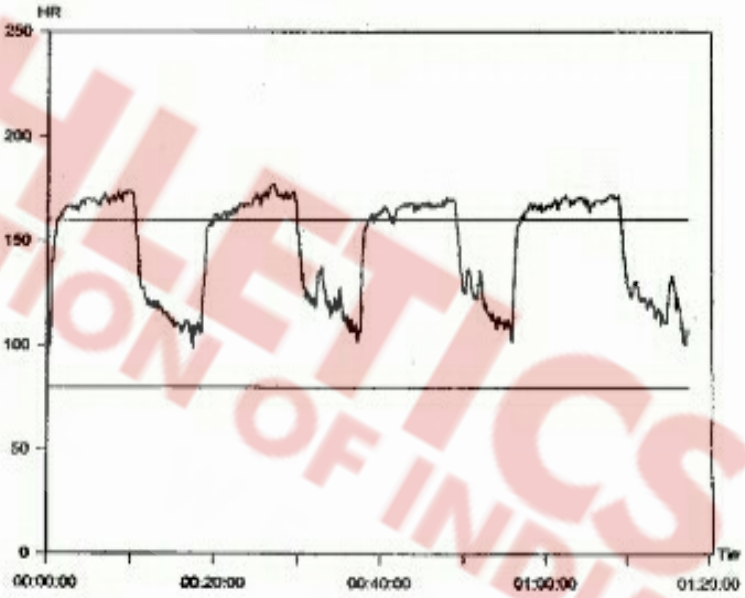
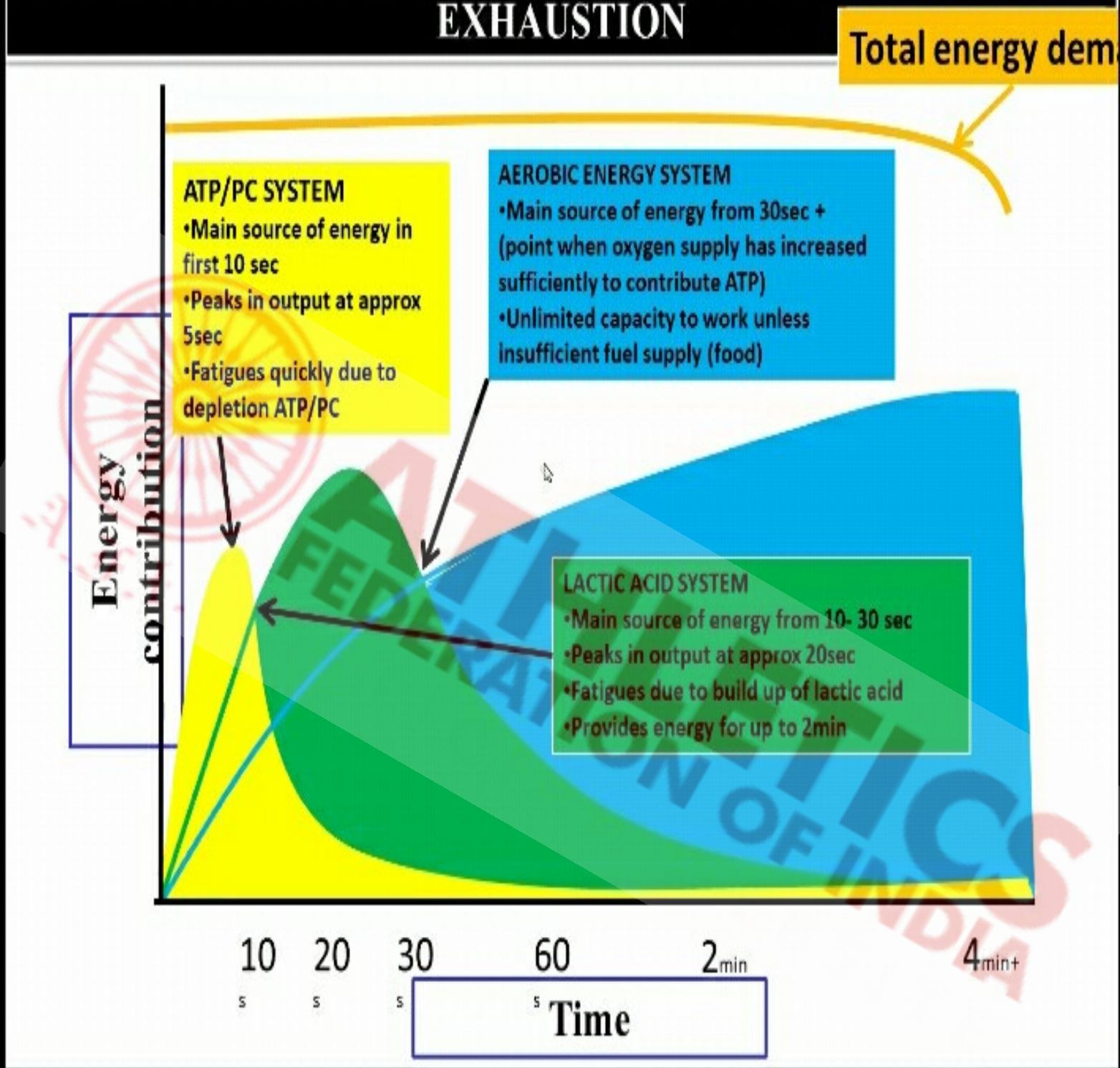




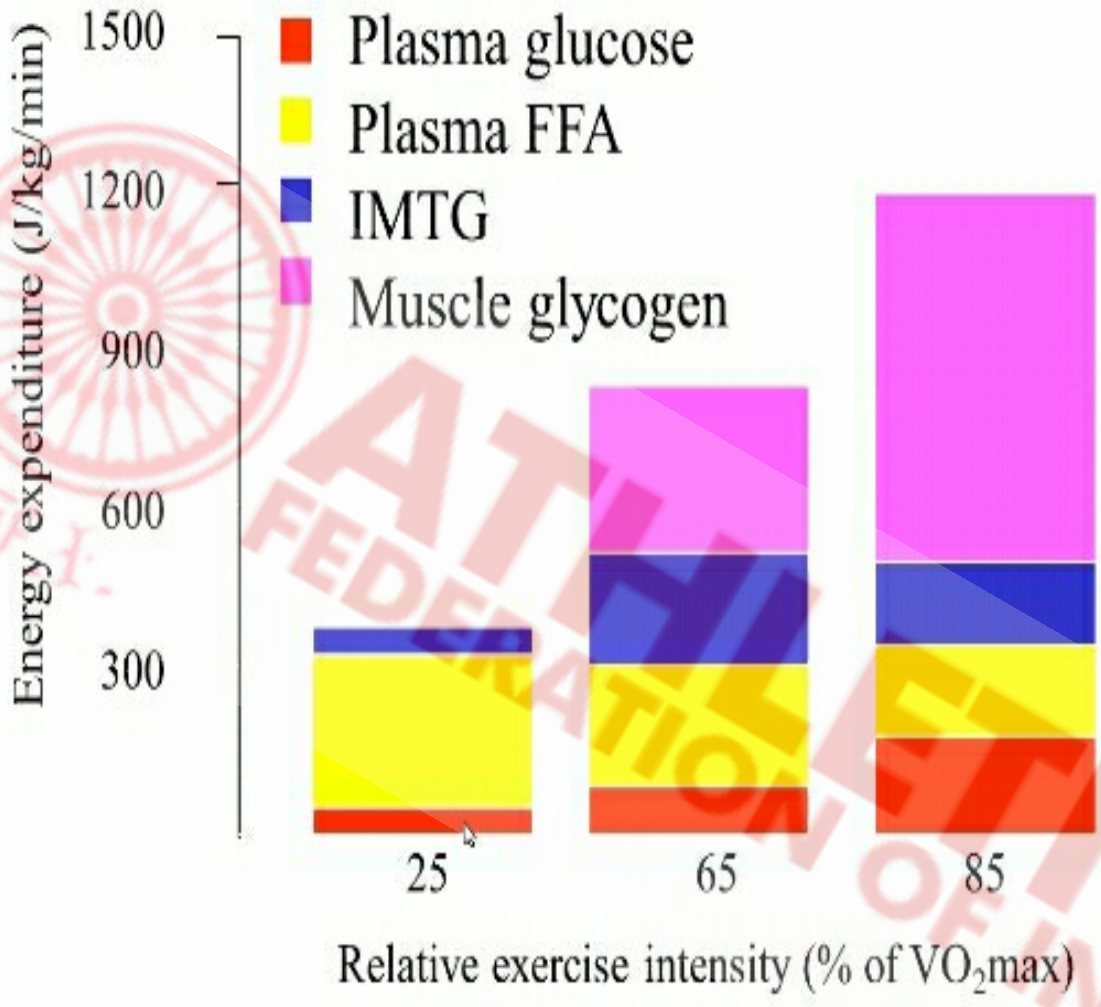
ENERGY SYSTEM INTERPLAY DURING EXERCISE TO EXHAUSTION



Energy system	Aerobic(long term)	Anaerobic (short term)	Anaerobic Alactic (immediate)
Fuel source	Circulated nutrients (oxygen as a catalyst)	Glycogen (stored carbohydrate) in the muscle and liver	Stored **ATP and CP**
Limit of fuel source	The body's ability to process **oxygen.**	At 100% intensity: 10 seconds to 2 minutes "The limiting factor at maximum intensity is the build up of glycogen stores"	Upto 10 seconds
Byproducts	ATP, CO2, H2O	ATP, **Lactic acid**	ATP, Creatine
Intensity of exercise when system is dominant	Low to moderate: higher intensities for efforts lasting longer than 2 minutes "Significant overlap with anaerobic system **at higher intensities** for events longer than 2 minutes"	High to very high for longer than 10 seconds (upto 2 or 2.5 minutes at maximum intensity)	Very high intensity: explosive movements (upto 10 seconds, unless stores have time to replenish)

Energy system	Aerobic(long term)	Anaerobic (short term)	Anaerobic Alactic (immediate)
Recovery of fuel stores after use	Highly dependant on intensity Lower intensity, **6 to 24 hours** Higher intensity, **24 to 36 hours**	Rate of **lactic acid removal** **25% in 10 minutes** **50% in 25 minutes** **100% in 75 minutes** "low intensity can help "flush" lactic acid out of the muscles and facilitate faster recovery Replenishment of **glycogen** following **continuous,** high intensity endurance activities **60% in 10 hours** **100% in 48 hours** Replenishment of glycogen following **intermittent activity** **40% in 2 hours** **55% in 2 hours** **100% in 24 hours** :Inorder to replenish glycogen stores, athletes must consume carbohydrate rich foods"	**50% replenished in 30 seconds** **2 minutes for complete restoration (if resting)**
Athletic abilities developed by training this system	**Aerobic power** (highest intensity that still involves the aerobic oxygen system) Aerobic endurance (ability of the body to supply muscles with oxygen for long periods) Muscular endurance	**Muscular endurance** (repeated muscle contractiopns) **Speed Endurance**(moving as fast as possible: 10 seconds to 2 minutes)	**Power** (moving against resistance or a force as fast as possible) **Maximum speed** (upto 10 seconds)
Use in triathlon	Dominant system in triathlon: all components	Supplement to aerobic capacity at high intensities (e.g. surges, accelerations,	Race starts, surges, rapid accelerations and/or power increases upto 10 se conds

METABOLISM: Effects of Exercise Intensity



Romijn et al. *Am. J Phsyiol. Endocrin. Metab.* 265: E380-E391, 1993.

Table II. Estimates of anaerobic and aerobic energy contribution during selected periods of maximal exercise

Duration of exhaustive exercise (sec)	% Anaerobic	% Aerobic[a]
0-10	94	6
0-15	88	12
0-20	82	18
0-30	73	27
0-45	63	37
0-60	55	45
0-75	49	51
0-90	44	56
0-120	37	63
0-180	27	73
0-240	21	79

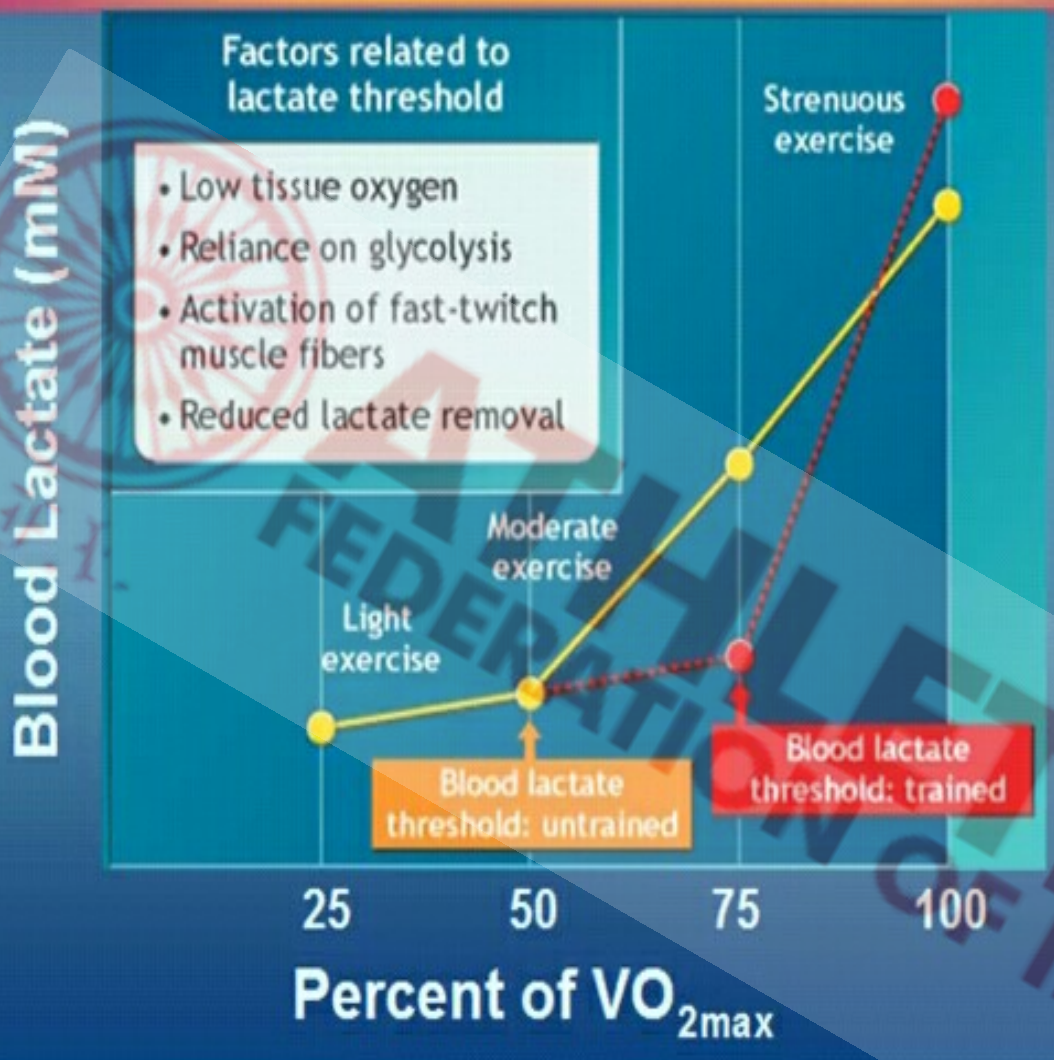
WHAT IS LACTATE?

- Glycolysis yields Pyruvate
- In anerobic glycolysis Pyruvate is converted to Lactic acid
- Lactic acid is highly unstable, dissociates
- Na+ / K+ Lactate

WHEN DOES IT INCREASE?

- Increases as exercise intensity increases
- Steep increase at 50 - 60% of VO2 Max
- Anaerobic Threshold / Lactate Threshold / Lactic Acid Inflection Point
- Onset of Blood Lactate Accumulation – 4 mmol/litre

Blood Lactate as a Function of Training



Fiber type: Determine your performance

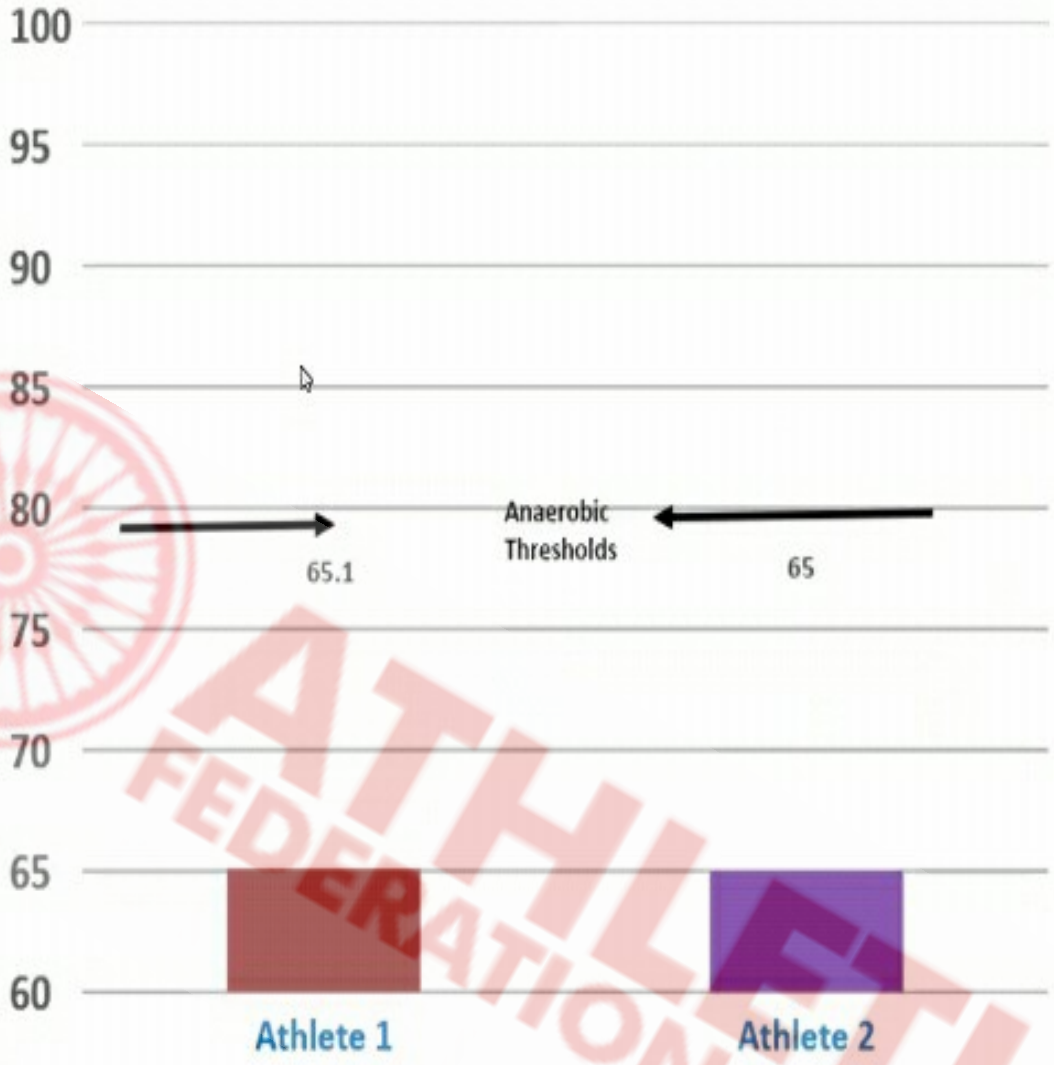
Fiber type can indirectly be assessed by EMG (motor recruitment, force generation etc.)

Long Distance	400m / 800m	Short Sprints
Type 1	**Type 2A**	**Type 2B**
Slow twitch	Fast twitch oxydative	Fast twitch glycolytic

Low → High

Fatigue rate

Anaerobic threshold point would determine the ability of Athlete



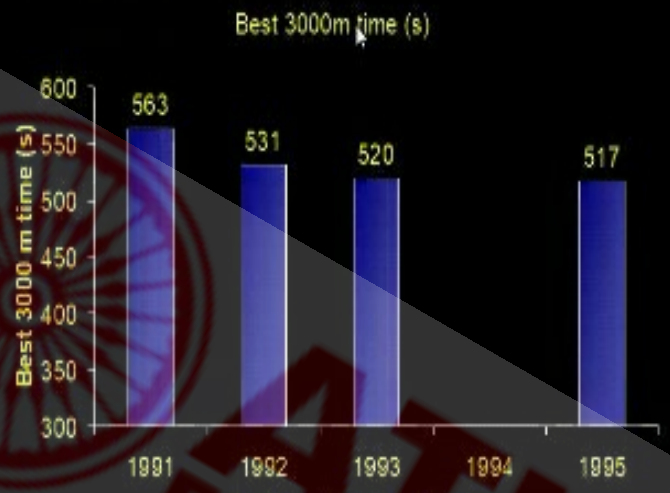
VO_{2max} of 2 Athletes with different ATs. Athlete-2 is better adopted with higher AT

The functional significance of the lactate threshold (T_{lac})

- Whilst a high VO_2 max is a prerequisite for success in endurance events…
- The ability to sustain a high % of $VO_{2\ max}$ without accumulating fatigue is of greater importance
  - T_{lac} is a functional index of muscle metabolism
  - Lactate **inhibits lipolysis** (utilisation of fat)
  - **Accelerated glycogen utilisation** above T_{lac}
  - Well-trained marathon runners operate just above T_{lac}
- T_{lac} is a functional index of muscle fatigue
  - High levels of H+ interfere with:
    - **enzyme activity**
    - **cross-bridge attachments**

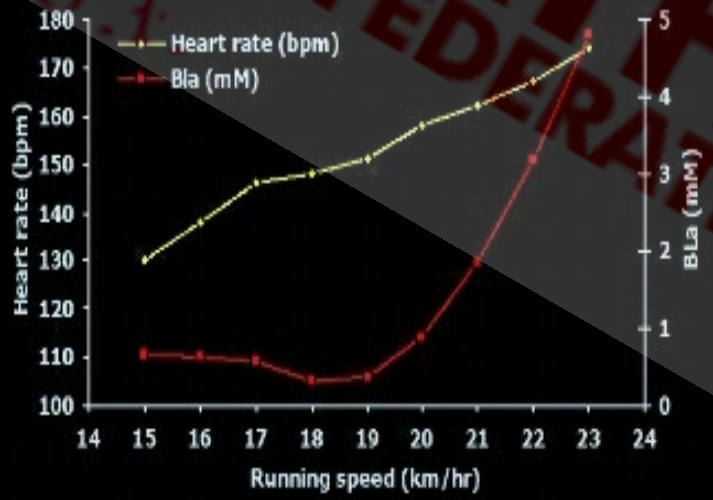
Lactate threshold even influences high-intensity performance

Case study: Jones, A. M. (1998). A five year physiological case study of an Olympic runner. *Brit. J. Sports Med.***32**: 39-43



The functional significance of the lactate threshold (T_{lac})

- Identifying the T_{lac} is importance to endurance athletes:
  - Sets the highest work-rate that can be sustained without fatigue or rapid glycogen depletion
  - Useful for setting upper limit of 'aerobic' or 'steady' training



Imbalance between rates of glycolysis and mitochondrial respiration

Hydrogen release in glycolysis

- Glycolysis requires NAD^+ to 'strip' the H^+ atom from 3-phophoglyceradehyde
  - H^+ are passed to NAD^+ to from NADH

Imbalance between rates of glycolysis and mitochondrial respiration

Hydrogen release in glycolysis

- Glycolysis requires NAD^+ to 'strip' the H^+ atom from 3-phophoglyceradehyde
  - H^+ are passed to NAD^+ to from NADH
- NADH transports H^+ to electron transport chain where they are used to re-synthesise ATP

Factors that influence the production and oxidation of lactate

How does endurance training help raise the lactate threshold?

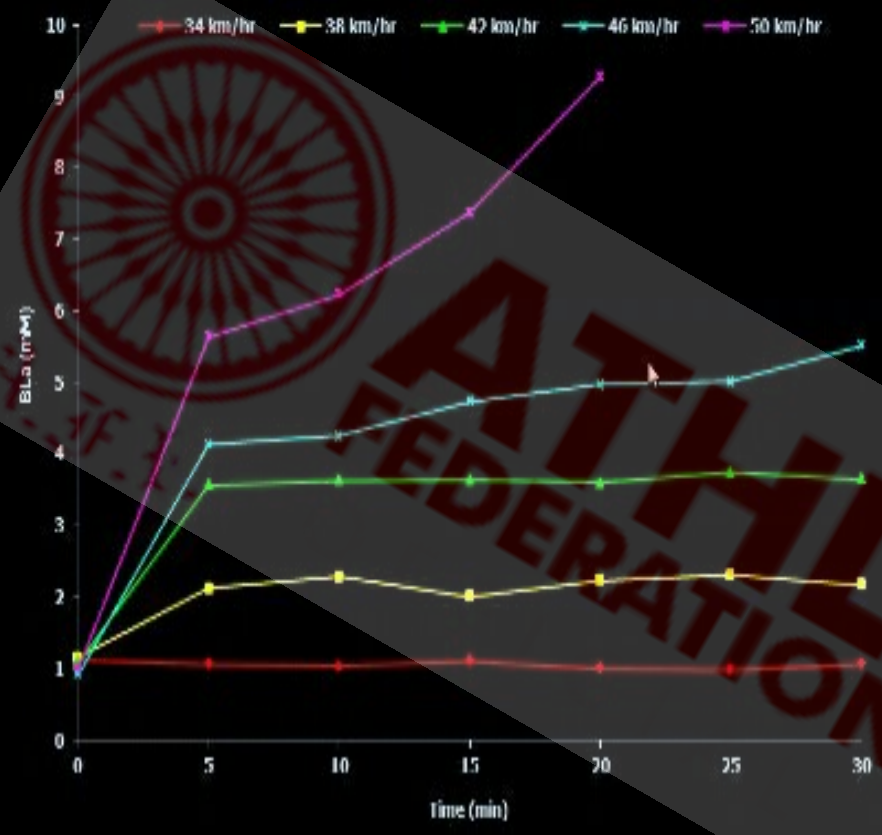
1. **Increased delivery of O_2**
   - ↑ SV = ↑ cardiac output
   - ↑ Capillarisation

2. **Increased utilisation of O_2**
   - ↑ Mitochondrial volume and enzyme content
   - ↑ Capillarisation

1 + 2 = lower necessity for anaerobic glycolysis at a given workload
= lower lactate production

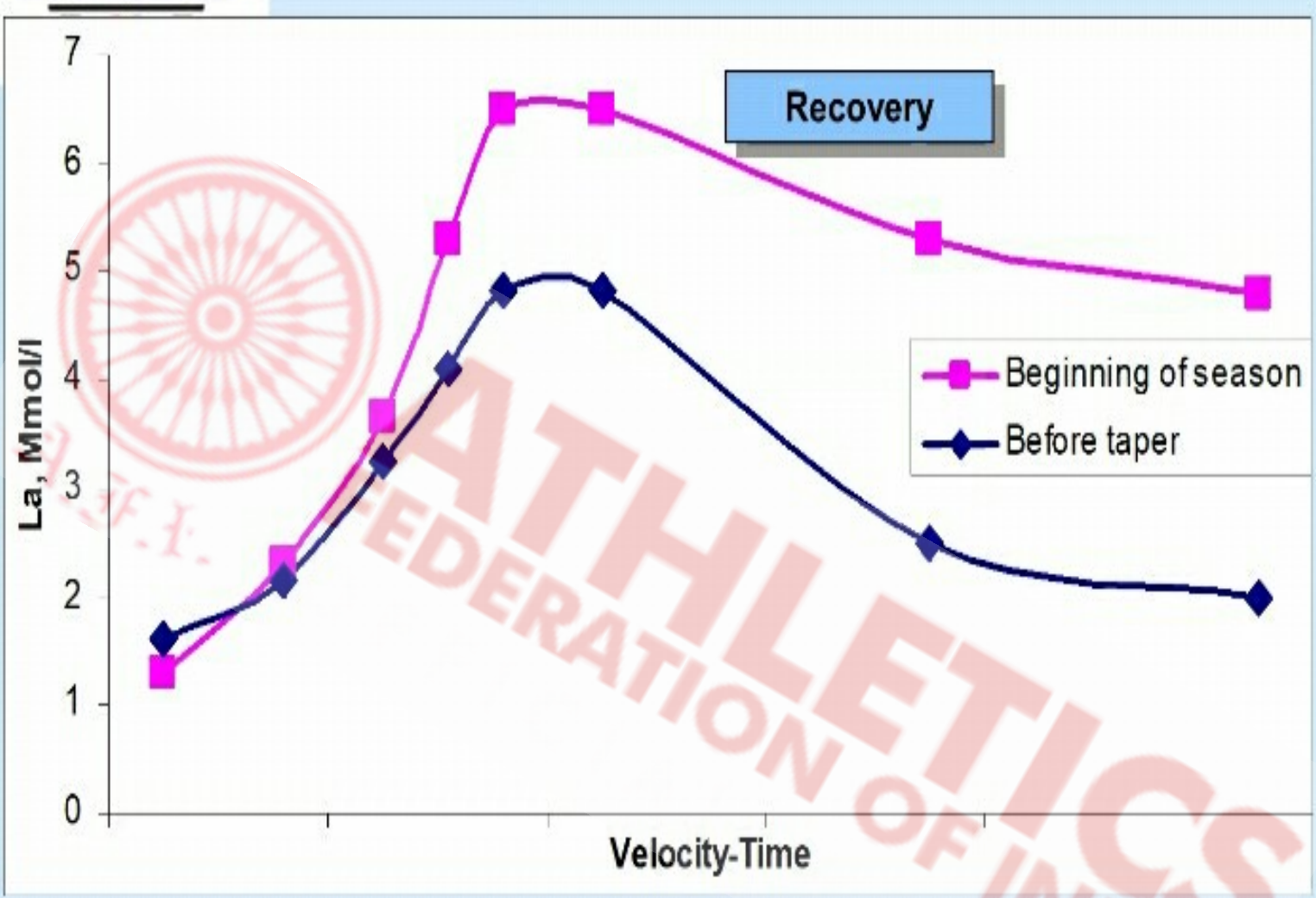
3. **Increased oxidation of lactate**
   - ↑ LDH heart type : LDH muscle type
   - ↑ Capillarisation
   - ↑ lactate transporters

Maximal lactate steady state (MLSS)

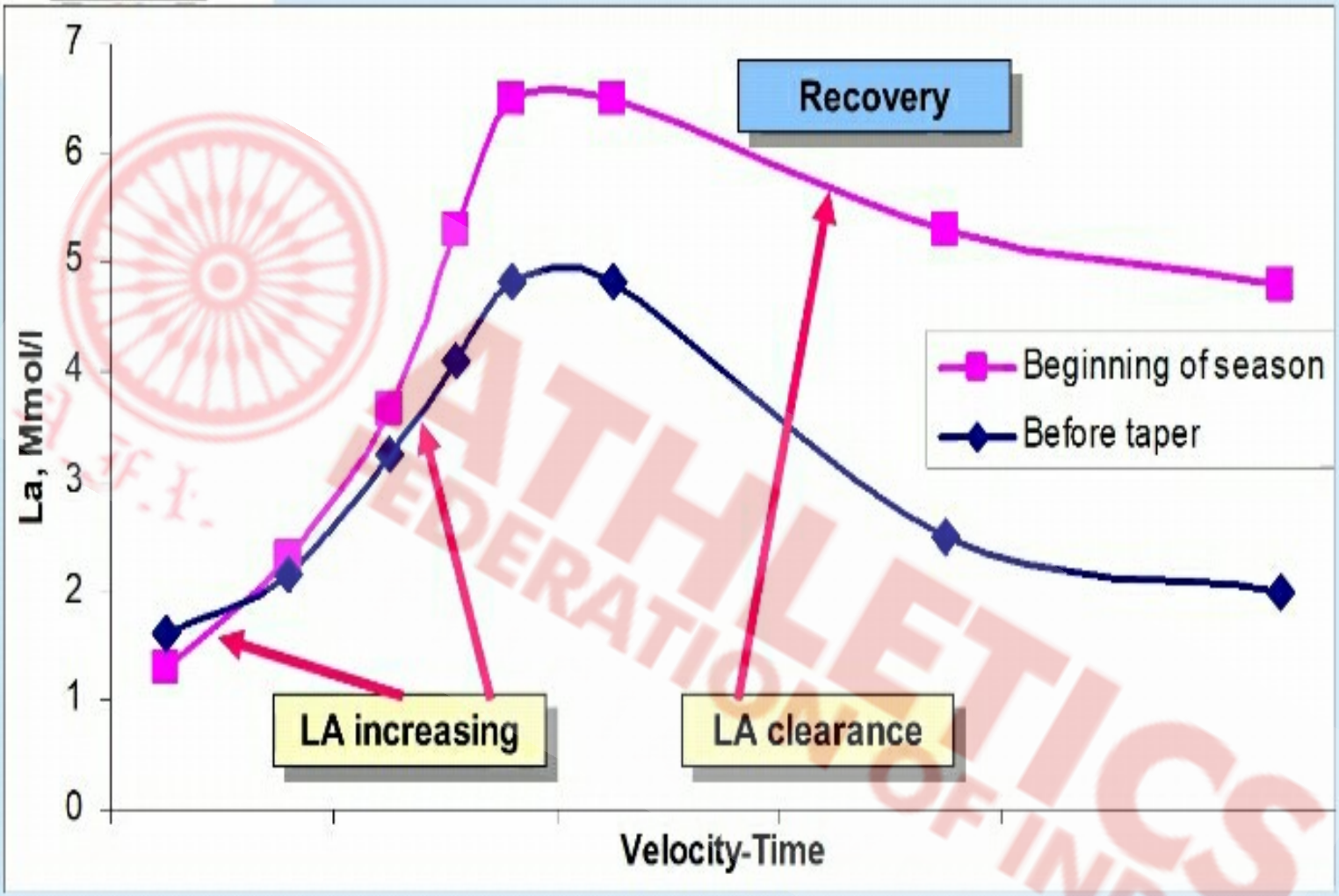


- In constant-load exercise individuals can actually sustain an intensity higher than the T_{lac}, at which blood [La] is **greater than at rest** but **not increasing** over time
- The highest intensity that can be sustained where there is a balance between lactate production and its removal from the blood is known as the **maximal lactate steady state** (MLSS) (Heck et al 1985)

Lactate Profile



Lactate Profile



Monitoring: (Aerobic capacity/ indices)

- Maximal oxygen uptake (VO_{2max})
- And running economy

Table 7.7

Characteristics of Several Types of Cyclic Exercises From an Energetics Viewpoint

Type of exercise	Anaerobic	Aerobic-anaerobic		Aerobic		
Duration of exercise (min)	1–2	3–10	11–35	36–90	90–360	>360
Oxygen uptake (% $\dot{V}O_2$max)	95–100	95–100	90–95	80–95	60–85	50–60
Aerobic/anaerobic ratio	50:50	80:20	85:15	95:5	98:2	99:1
Energy expenditure (kJ/·min) kJ (total)	160 160–320	120 320–1200	110 1200–3700	105 3900–8400	80 8400–25,300	75 >27,000
Breakdown of glycogen in muscle (%)	10	30	40	60	80	95
Blood lactate (mmol/·L)	18	20	14	8	4	2
Free fatty acids in plasma (mmol/·L)	0.5	0.5	0.8	1.0	2.0	2.5

Zones of Training Workload for Young Athletes in Endurance Events

Exercise energetics	Goals	Time of main exercise (min)	Blood lactate (mmol/·L)	Heart rate (bpm)	Training mean
Aerobics	1. Regeneration, maintenance, and adaptation to long-lasting exercises and improved economy	45–120 up to 150 up to 180	1.5–2.5 1.0–2.0	130–150 100–130	Regeneration runs Extensive runs
	2. Development of aerobic power and capacity	15–45	2.5–4.0	150–180	Endurance runs Fartlek Cross-country runs
Aerobic-anaerobic	3. Intensive exercises for improved performance	8–20 1–3	4.0–7.0	170–190	Intensive endurance runs Long repetition runs Extensive interval runs
Aerobic-anaerobic	4. Critical exercises	2–8 1–3	7.0–10.0	180–200	Endurance tempo runs Intensive interval runs Time trials
Anaerobic	5. Over critical	40 s 15–40 s	>10.0	Up to 200	Speed endurance runs Tempo runs Time trials
Anaerobic	6. Maximal	Up to 15 s	Individual		Speed-development runs Short repetitions of maximal or sub-maximal velocities

Lactate Values of Various Running Exercises in Top-Level Marathon Runners

Exercise	Blood lactate (mmol/L)	Exercise intensity (% of marathon velocity)
Recovery workout	1.0	<80
Extensive endurance	1.0–1.1	80–90
Intensive endurance	1.3	90–97
Tempo endurance	2.0	100
Extensive intervals (fartlek)	3.0	105
Intensive intervals	>8.0	