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The Physiology of Running: From Cellular Energy to Field Testing and Health Concerns

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MUSCULAR CELL ENERGY

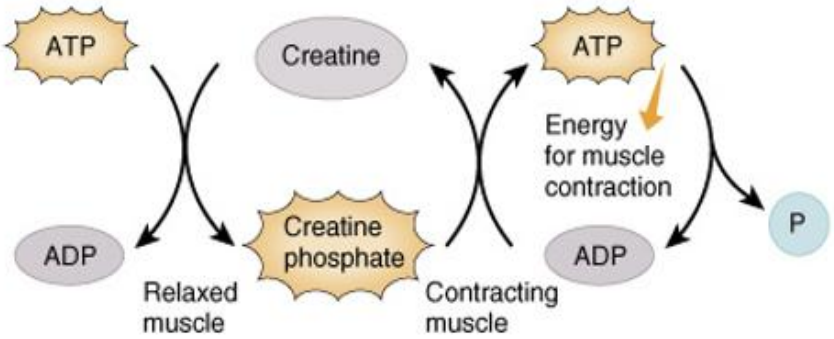
- *PHOSPHAGEN SYSTEM*
- *ANAEROBIC METABOLISM*
- *AEROBIC METABOLISM*

MUSCULAR CELL ENERGY

PHOSPHAGEN SYSTEM *(sprints up to 100m)*

1. *ATP (3s of maximal muscle contraction)*
2. *CP (5-7s of maximal muscle contraction)*

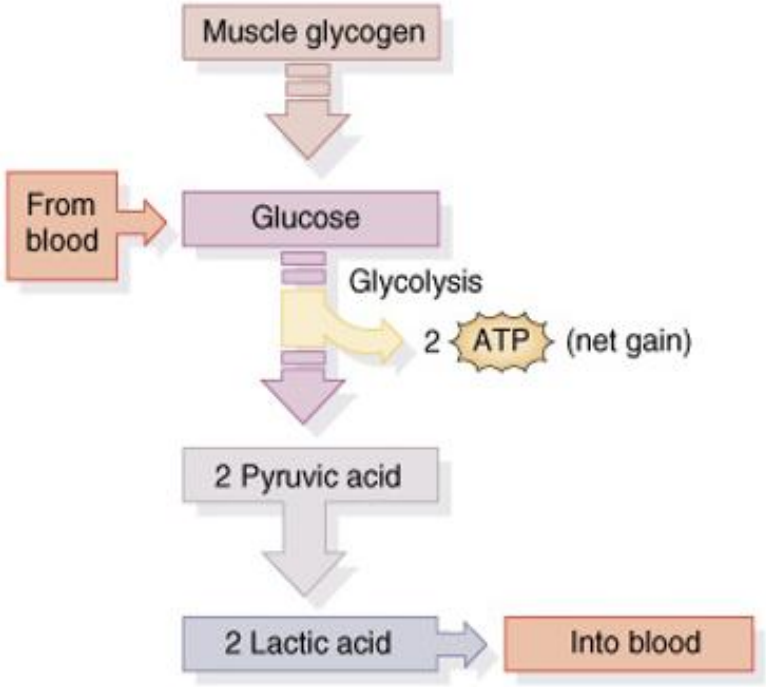
Energy is hidden in phosphate bonds – it is released when the phosphate group is separated from the parent molecule



MUSCULAR CELL ENERGY

ANAEROBIC METABOLISM *(200-800m run)*

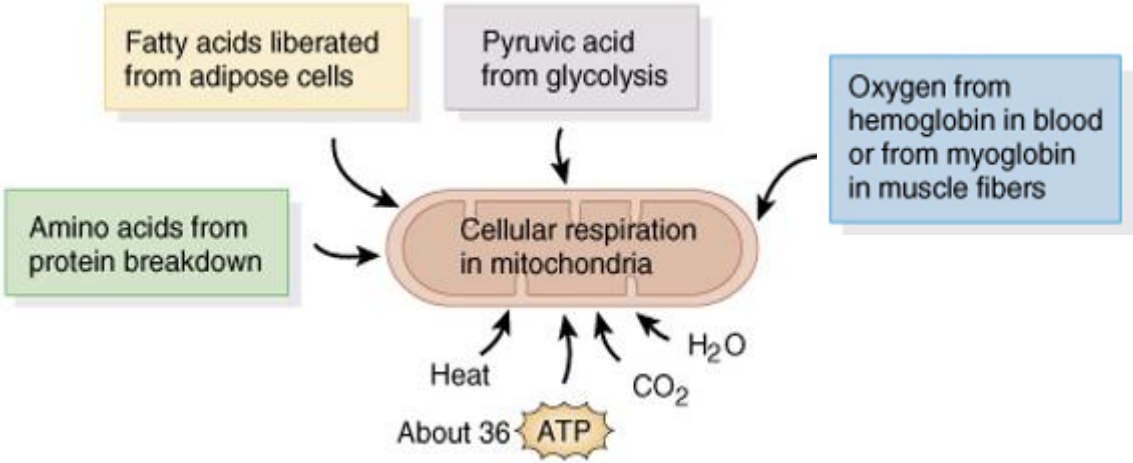
- *The source of energy is glycogen in the muscles. It is broken down into glucose, which then, without the presence of oxygen, brokes down into lactate, thery producing ATP.*
- *The system is 2.5x faster than aerobic.*
- *1.3-1.6 min of muscle contraction*



MUSCULAR CELL ENERGY

AEROBIC METABOLISM (aerobic cellular respiration) *(10km run)*

- *Energy source: glycogen, fatty acids, (amino acids)*
- *They are broken down in the presence of oxygen,the products are ATP, CO2 and water*
- *Available indefinitely*



FIELD TESTING

=FUNCTIONAL ASSESSMENT OF RUNNING PERFORMANCE

TYPES OF ACTIVITIES RELATED TO INDIVIDUAL ENERGY SOURCES

CHEMICAL PROCESSES	**PHOSPHAGEN SYSTEM**	**ANAEROBIC METABOLISM**	**AEROBIC METABOLISM**
ENERGETIC PACE	Explosive	Fast	Slow
SOURCE OF ENERGY	ATP, CP	Glycogen	Glycogen, FA
ENERGY SUPPLY	Very small	Limited	Unlimited
FATIGUE FACTOR	Depletion of energy supply	Lactic acid	None
KINESIOLOGY ACTIVITIES	Jumps, throws, sprints	Cyclic activities 20-180 s	Cyclic activities over 180s

LONG AND MIDDLE DISTANCE RUNNING

- Middle distance: 800m, 1500m
- Long distance: 3000m – 42km

The main way to **obtain energy** is by burning carbohydrates in the presence of oxygen, but some energy is also produced without oxygen (consumption of creatine phosphate and anaerobic glycolysis).

ENERGY EQUIVALENTS

- **800m**: 120% VO_2max
- **1500m**: 110% VO_2max
- **3000m zapreke**: 100% VO_2max
- **5000m**: 96% VO_2max
- **10km**: 92% VO_2max
- **42km**: 85% VO_2max

→ anaerobic capacity is less important at longer running distances

PERFORMANCE INDICATORS

- ***1500-5000m:***
  - Maximal oxygen consumption (VO_2max)
- **> 5000m:**
  - Running economy
  - Lactate treshold
  - Maximal lactate balance
- TESTING SHOULD BE CARRIED OUT AT LEAST EVERY 3-4 MONTHS

TREADMILL TEST

1. PART: oxygen consumption, HR in [lactate] at different running paces

- Initial warm up 10-15 min
- Incline 1%; initial pace according to the runner's ability
- 3min/level, increasing by 1km/h
- 5-9 levels; test ends before the runners exhaustion; for runners who run > 5000m until exhaustion (VO_2max Δ 5%)

Runners level	Initial pace
World class men	15 km/h
World class women	13 km/h
Potentially world class men	14 km/h
Potentially world class women	12 km/h
National class men's juniors	13 km/h
National class women's juniors	11 km/h

TREADMILL TEST

2. PART: maximal oxygen consumption

- Athlete should run as long as he/she can
- Running speed: final speed from the first part - 2 km/h
- Incline increases by 1% every min
- Duration of the test 5-10min
- Lactate immediately after the test and at 1, 3, 5, 7 and 10 min after the test (800 and 1500 m runners)

MAXIMUM OXYGEN CONSUMPTION

Partially worse VO2max can be compensated by a good running economy and a high lactate threshold

RUNNERS ABILITY	VO_2max (ml/kgmin)
World class men	80 - 90
World class women	70 - 80
International class men	70 - 80
International class women	60 - 70
National class men	65 - 75
National class women	55 - 65
National class men's juniors	60 - 70
National class women's juniors	50 - 60

RUNNING ECONOMY

RUNNING ECONOMY AT 16 km/h in 1% inclination

VO_2 = ml/kgmin

Rough assessment:

- 44-47 ml/kg min = excellent
- 47-50 ml/kgmin = very good
- 50-54 ml/kgmin = average
- 55-58 ml/kgmin = poor

RUNNING ECONOMY AT ANY PACE (ml/kgkm)

Running economy (ml/kgkm) = VO_2 (ml/kgmin) / (pace (km/h) / 60)

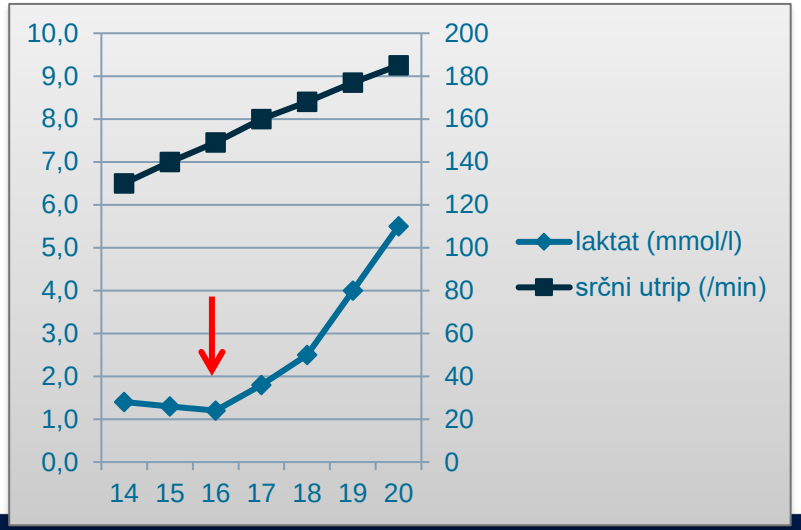
Ocena:

- 170-180 ml/kgkm = excellent
- 180-190 ml/kgkm = very good
- 190-200 ml/kgkm = above average
- 200-210 ml/kgkm = below average
- 210-220 ml/kgkm = poor

LACTATE TRESHOLD 1 (AEROBIC TRESHOLD)

= first increase in lactate above resting values

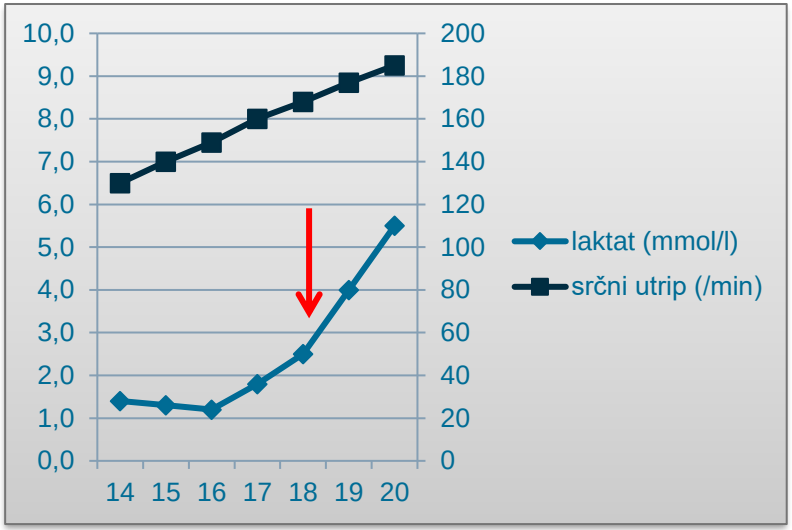
→ lactate threshold speed is a good predictor of average marathon running speed = boundary between easy running and running in balance



LACTATE TRESHOLD 2 (ANAEROBIC TRESHOLD)

= sudden increase in blood lactate (usually 1-2 km/h after lactate threshold 1)

- the difference is smaller in long-distance runners and larger in middle-distance runners
- is at approx. 90% of SFmax;
- usually between 2 and 4 mmol/l
- the speed at which we reach Lt2 is held for a maximum of 60min - recommended for running 21km



>3 hours	**Aerobic / Base** Pace for longer events. You are still very efficient (fat-burning) at this pace.	142 - 158	217 - 254
LT1 // VT1			
30-90 min	**Tempo / Sub-Threshold** Intense but can find a balance. Carbohydrate utilization increases and fueling becomes more important.	158 - 170	254 - 283
LT2 // VT2			
20-60 min	**Threshold** Intense but can find a balance. Lactate is slowly accumulating.	170 - 178	283 - 297
4-12 min	**Maximum** Breathless, broken speech. Lactate is rapidly accumulating.	178 - 201	297 - 377

60s TEST FOR MIDDLE DISTANCE RUNNERS

1. Initial warm-up
2. 4% gradient; speed 20km/h for women and 22 km/h for men
3. Pre- and immediate post-test lactate
4. The closer to the competition period, the lower the post-test lactate values should be
5. It is possible to continue until exhaustion (aerobic components are included)

ADDITIONAL TESTS

- Lung function
- Blood tests:
  - Haemogram
  - Iron
  - Ferritin
- Mobility (especially important for middle-distance runners)
- Leg muscle strength assessment (vertical jump)

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

The finish line and sidelines of a running race can sometimes look a little bit like medical chaos: people throwing up, bent over, some laying on the ground or stumbling around. Of course, the vast majority of those athletes don't end up in the medical tent, they're just tired or overexerted.

But, some of the runners do need medical help and a small number will need very serious medical assistance.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Marathons, on average, see medical encounters of about 2% of the field.

Weather is the biggest factor in determining how many athletes will need medical assistance, with the rate of medical encounters more than doubling in “hot” years and the number of heat-related issues skyrocketing.

Important factors:

- humidity
- direct heat stress
- acclimatization of the athlete population
- running distance

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

The absolute most common issues runners come into medical tents for—both on-course and post-finish—are typically musculoskeletal and soft tissue, GI, or heat-related. That means blisters, cuts, cramps, strains, joint pain, nausea, bloating, and GI distress.

But there are some serious conditions we should be aware of.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exercise associated collapse

= when runners are unable to stand up after finishing a race is not actually likely to be caused by dehydration;

- nearly 90% of non-musculoskeletal or skin issues were exercise associated collapse (accounting for nearly 60% of total encounters).
- It is the most common medical condition at race finish lines.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke

The next most common medical issue at the end of a race is heat-related, with various events finding heat-related issues to account for 20-30% of medical encounters.

But exertional heat stroke is the most serious of those conditions, when an athlete's core body temperature has risen above 40 degrees C and does not come down.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke

In an analysis of 100,000 runners across 10K road races, 600 medical encounters occurred with 25% of them being heat-related and 94 requiring ice tube water immersion for exertional heat stroke.

In Williams' tracking of Twin Cities Marathon data over 26 years, they had 3,269 medical encounters with about 30 *severe* exertional heat stroke—meaning a core rectal temperature of over 42,8 degrees C—and four heat stroke transfers to the hospital.

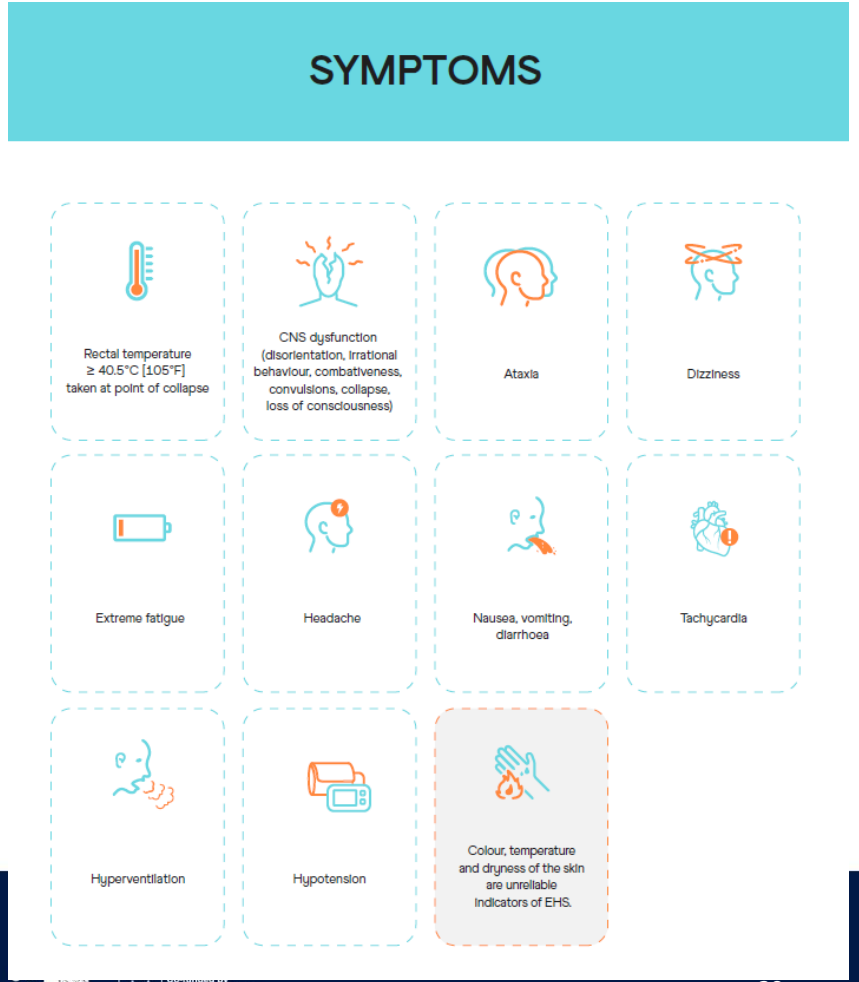
THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke

WBGT	Continuous activity and races	Training and interrupted physical activity	
°C		Non-acclimatized, untrained	Accilmatized, trained
<10	No increased risk	activity	Normalna aktivnost
10.1 - 18.3	No increased risk. Heat stroke can occur		
18.4 - 22.2	The risk is increasing (cramps, exhaustion, stroke). High-risk persons under supervision or abandoning activity	Increase the rest:activity ratioPay attention to fluid intake	Normal activity Watch your fluid intake
22.3 - 25.6	Increased risk for all participants	Increase break:activity ratio Reduce activity time	Normal activity Watch your fluid intake
25.7 - 27.8	Highly increased risk for the unacclimatised and untrained	Increase break:activity ratio Decrease activity and reduce activity time	Normal activity Watch your fluid intake
27.9 - 30	**Cessation of activity**	Break:activity ratio 1:1 Reduce activity and shorten activity time Limit vigorous activity Control participants with ↑risk	Activity planning Supervising participants with higher risk
30.1 – 32.2		**Cessation of activity**	Limit vigorous activity and daily exposure to heat and humidity
>32.3			**Cessation of activity**

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke



THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke

Treating heat stroke requires cooling the athlete, either through ice tub immersion or a rotating system of ice cold wet towels that are changed when they get warm and ice packs.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exertional heat stroke

PREVENTION=ACCLIMATIZATION

- Adaptation to the environment
- Physiological changes involving the cardiovascular system, skin, plasma volume, evaporation, blood flow through the skin
- First results after just 2 weeks of training

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

PRACTICAL TIPS FOR TRAININGS AND COMPETITIONS IN HOT ENVIRONMENT

1. Exercise appropriately (planning, preparation and training)
2. Do the acclimatisation process
3. Avoid extreme weather conditions
4. Change training times (morning, midday, evening)
5. Wear appropriate clothing
6. Hydration : Ensure adequate fluid intake 24 hours before the event. An intake of 500mL of fluid half an hour before the activity is recommended. No more than 1000mL/1h (body load)
7. Fluid intake during the activity itself does not reduce the risk of heat cramps, exhaustion or stroke. Drinking after feeling thirsty has been shown to be most beneficial
8. Fluid intake between 200 and 800mL/1h. For activities up to 1 hour, plain water is sufficient. Over 1 hour, rehydration fluid (water, electrolytes, sugar)

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exercised associated hyponaetremia (EAH)

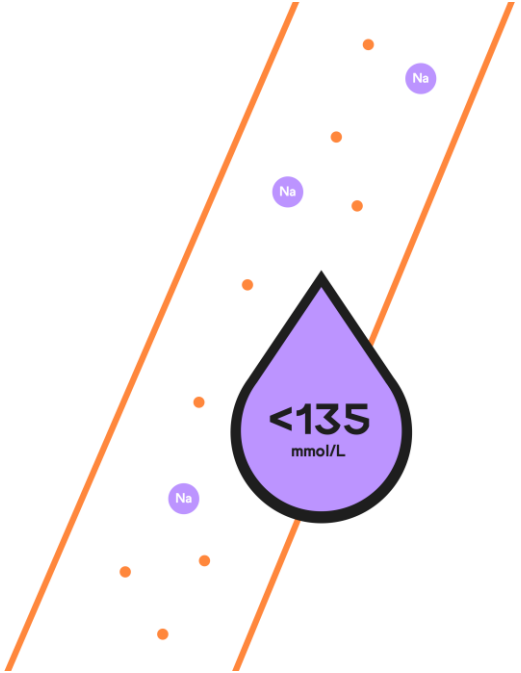
Hyponaetremia is the next most common serious medical issue. Asymptomatic mild EAH has been found to actually have an incidence of up to 12-13% of marathon runners, when blood levels were tested, but it's the symptomatic EAH we need to worry about.

EAH is typically caused by drinking too much fluid (water or commercially available sports drinks) AND CAN BE FATAL!

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

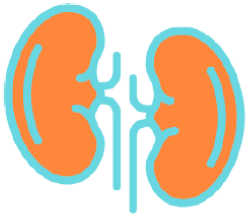
Exercised associated hyponaetremia (EAH)

Hyponaetremia is when blood sodium levels fall below 135mmol/L. This can be extremely serious if sodium serum levels fall too low and can be **especially serious if symptoms are mistaken for dehydration and more water is consumed, further dropping sodium levels.**



THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

MECHANISM OF EAH



Fluid retention is enhanced by an increase in an anti-diuretic hormone, also called arginine vasopressin (fluid retention hormone), which is released during exercise.

It may be over-stimulated by factors associated with muscle breakdown and altered kidney function during running.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exercised associated hyponaetremia

Most frequently this occurs in athletes, as EAH, because of over-hydration, and a common symptom to observe would be weight gain because of the inability to urinate out or sweat excess fluid. However, the symptoms of EAH can be as mild as nausea, dizziness, and a headache, and can progress to altered mental states and seizures.

THE MOST COMMON MEDICAL ISSUES AT RUNNING RACES

Exercised associated hyponaetremia

Medical best practice would be to have a way to test serum sodium levels in the med tent at large events, otherwise medical personnel will have to rely on symptomatic case assessments.

If the athlete is able to keep food down, then treatment in most cases would be consumption of **salty food and high-sodium concentrated broths**, but if an athlete is overly nauseous or symptoms are serious, then a hypertonic saline solution may be necessary.

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QUESTIONS?