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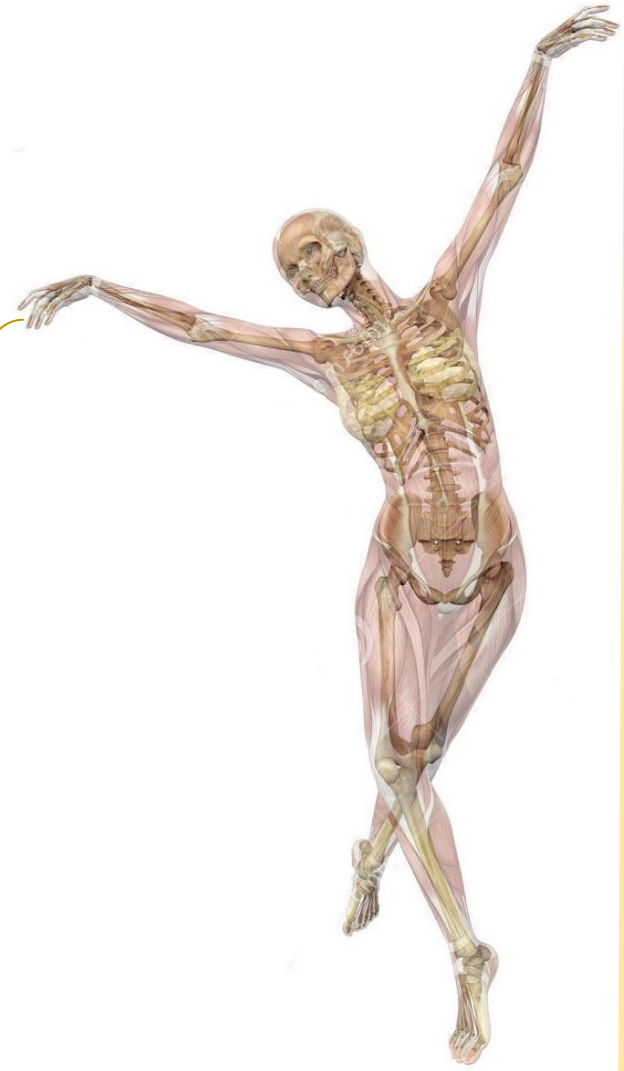
Physical and physiological factors in athletic performance



- Red : important
- Black : in male / female slides
- Pink : in female slides only
- Blue : in male slides only
- Green : notes
- Gray : extra

Objectives

1.Identify the muscle metabolic systems and the nutrients used in exercise to regenerate ATP: Phosphocreatine-creatine system, Glycogen-lactic acid system, Aerobic system.

2. Explain the recovery of the muscle metabolic systems after exercise and the phenomena of oxygen debt.

3. Discuss the effects of smoking on pulmonary ventilation in exercise.

4.Correlate between heart diseases and the athletic performance in old age.

5.Describe the changes in body fluids and salts in exercise.

6. Interpret the effects of drugs on athletes.

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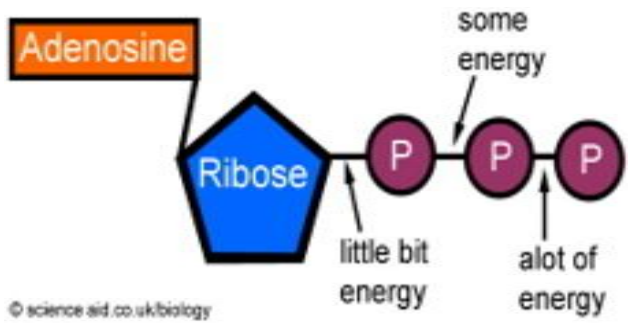
Metabolic pathways in skeletal muscle:

1-Adenosine triphosphate (ATP) is the only direct energy source used through muscle contraction



2-The Demand and Mechanism of ATP production varies according to type of work done:

At rest: a muscle cell contains a small amount of ATP, which is not enough once contraction begins

as such muscle cells must be ready to initiate ATP production to keep up with the increased consumption of ATP molecules

Energy for Muscle Contraction:

Mitochondria in the muscle converts:

- glucose,
- fatty acids,
- amino acids

(From our nutrition)

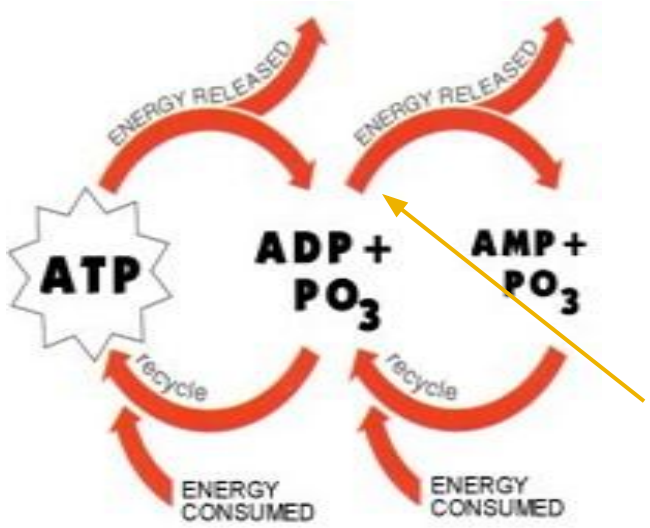
into ATP (Adenosine-PO3 ~ PO3 ~ PO3)

All the ATP stored in the muscle is sufficient only for 3 seconds of muscle power. (~ half of 50-meter dash)

As such resting muscle cells have energy stored in other forms

(e.g Creatine Phosphate (CP), glycogen, etc.)

to convert ADP into ATP



Each of the last 2 phosphate bonds stores 7300 calories per mole of ATP.

This means that NOT all of the energy in our body is in the form of ATP, and it can formed whenever the body requires more ATP

~ = Approximately

ATP regeneration:

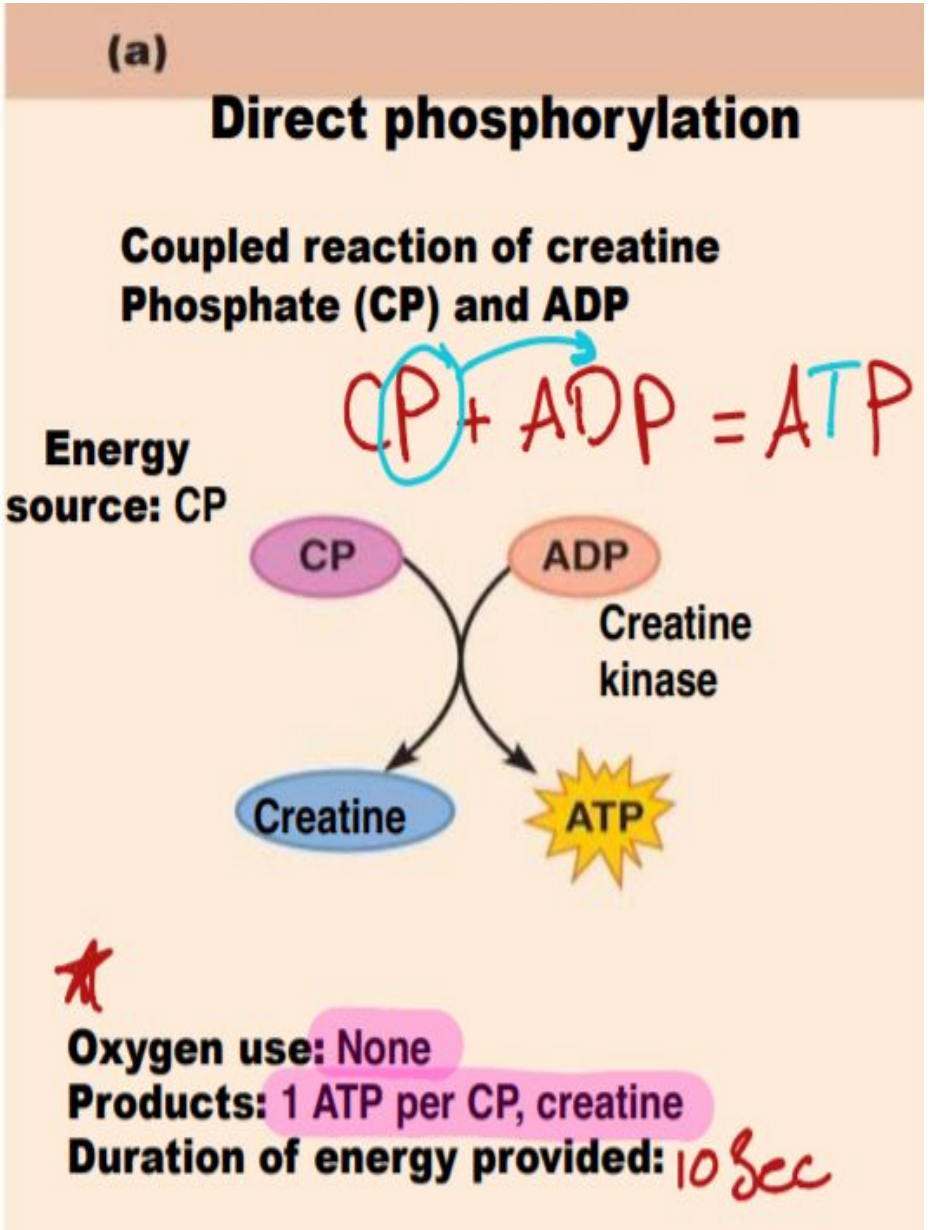
As we begin to exercise, we almost immediately use all of our stored ATP within sec

ATP is regenerated from ADP by 3 pathways:

Immediate	Short-term	Long-term
1-Direct phosphorylation of ADP by creatine phosphate (CP)	2-Anaerobic pathway glycolysis → lactic acid	3-Aerobic oxidation of fatty acids in the mitochondria

- more details in the next few slides.

I-Phosphocreatine-creatine system (creatine ~ Po3):



1-Phosphagen energy system:

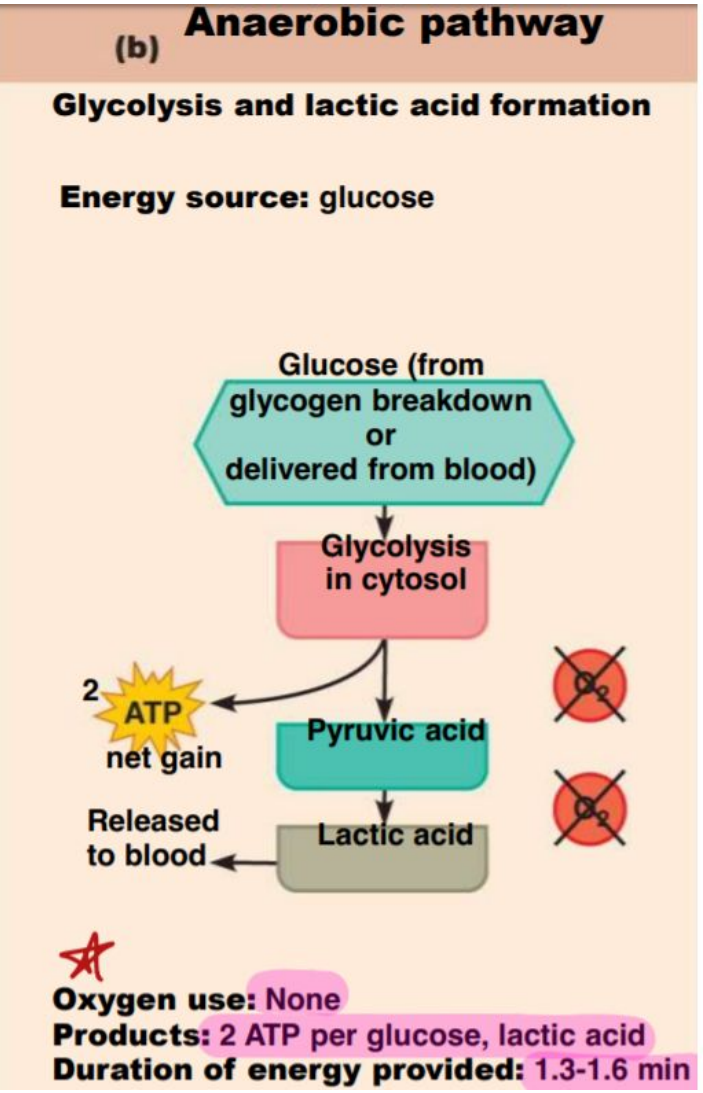
- Energy formed of ATP + CP.
- Useful for **maximal short bursts of muscle power** (~100m dash)
- 8-10 seconds
- No O_2 use

2-CP: Contains a high energy phosphate bond of 10,300 calories/mol
Most muscle cells have **2- 4** times as much **CP as ATP**
"the number of CP in cell = number of available ATP"

3-Energy transfer from **CP to ATP** is fast in less than a **fraction of a second**

4-Energy from CP is immediately available for contraction just like that of stored ATP

2- Glycogen-Lactic acid System (anaerobic Metabolism):



1-Primary energy source **for peak muscular activity**
Provides **1.3-1.6 min** of **maximal** muscle activity

2-Produces **2 ATP** molecules per molecule of glucose (coming from blood.)
"very low ATP production per glucose molecule"

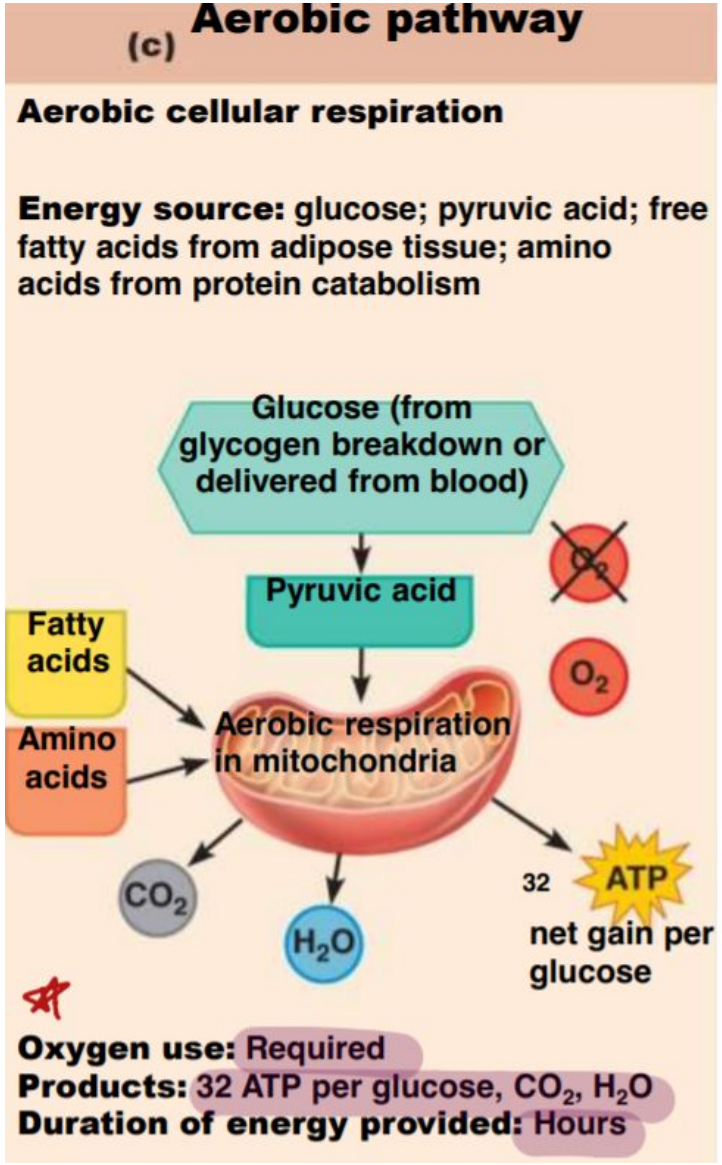
3- No Oxygen
4- Source of energy: Carbohydrate (glycolysis)

Glycogen -> Glucose -> 2 pyruvic acid +2 ATP + 2 NADH ->2 lactic acid +2 NAD+
-> goes to blood -> to Liver-> converted to Glucose (gluconeogenesis)
-> blood ->back to muscle again

Anaerobic metabolism is inefficient b/c:
-Large amounts of glucose are used for small ATP returns
-Lactic acid is produced leading to muscle fatigue

Which type of sports uses anaerobic metabolism?
-Sports that requires bursts of speed and activity (e.g..basketball.)

3- Aerobic Metabolism



1- primary energy source of resting muscles

converts glucose into glycogen & creates energy storage compounds (CP)

2- During rest and light to moderate exercise, aerobic metabolism contributes 95% of necessary ATP

3- It breaks down fatty acids, pyruvic acid (glycolysis), and amino acids

4- Produces 34 ATP molecules per glucose molecule

Comparing the Energy Supply of the 3 pathways:

"Which one is Speedly Produse ATP Per Min?

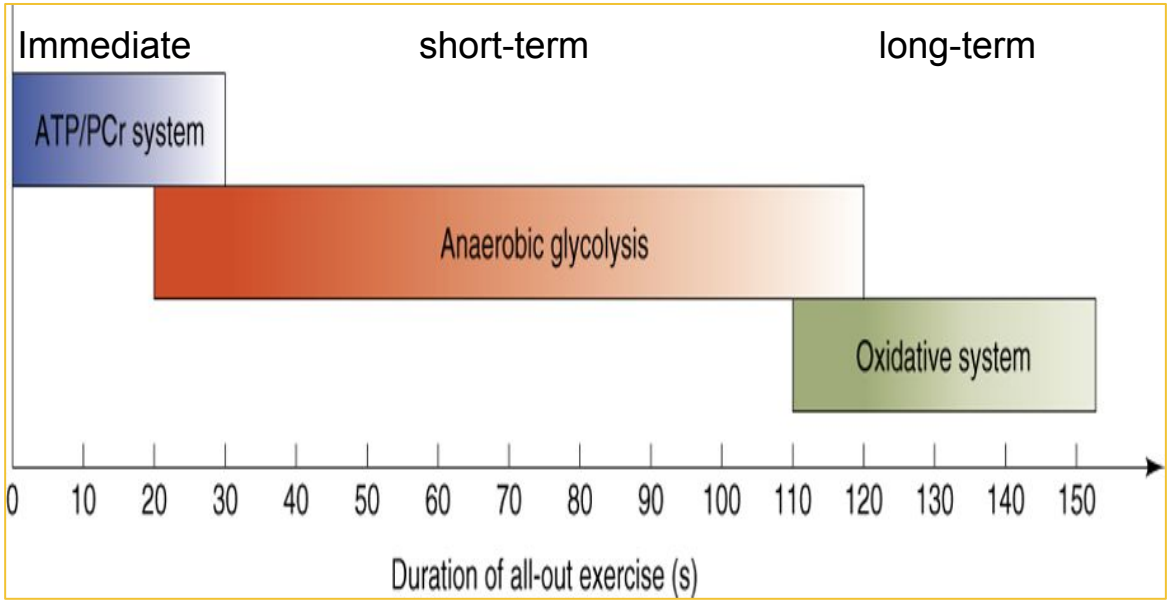
ATP generation per minute are the following:

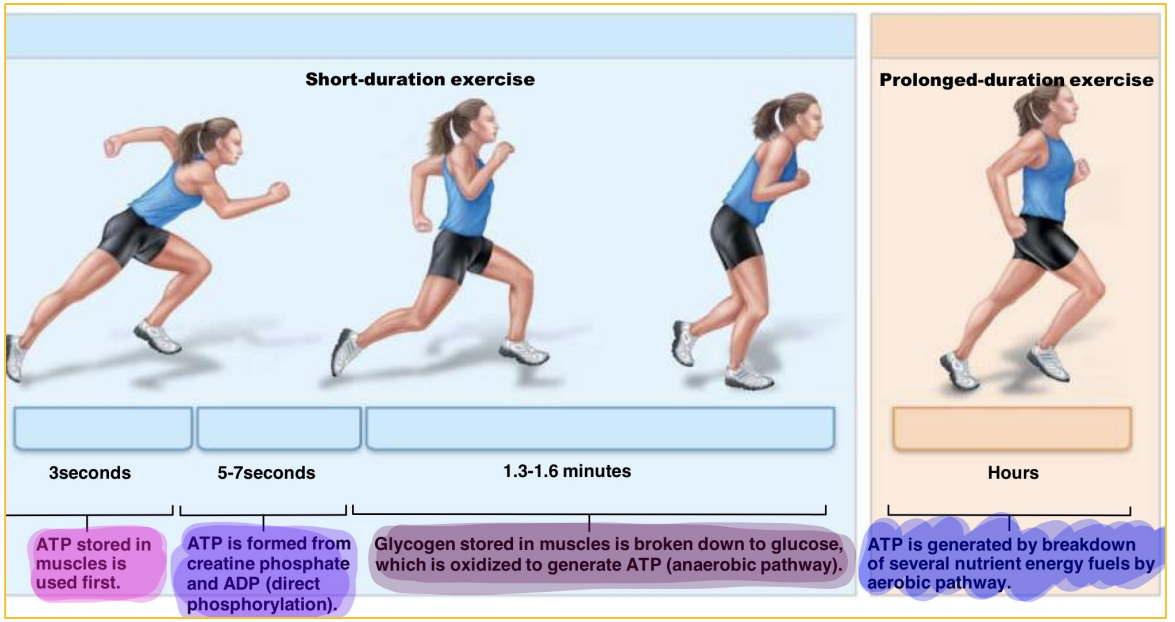
	Moles of ATP/min
Phosphagen system	4
Glycogen-lactic acid system	2.5
Aerobic system	1

"Can Stay for too long?"

When comparing the same systems for endurance, the relative values are the following:

	Time
Phosphagen system	8-10 seconds
Glycogen-lactic acid system	1.3-1.6 minutes
Aerobic system	Unlimited time (as long as nutrients last)





Energy systems used in various sports:

Doctor notes:
You should know few examples of each

Phosphagen system : almost entirely

- 100 meter dash
- jumping
- Weight lifting
- Diving
- Football dashed

Phosphagen system +lactic acid system

- 200 meter dash
- Basketball
- Baseball home run
- Ice hockey dashes

Lactic acid system : mainly

- 400 meter dash
- 100 meter swim
- Tennis
- Soccer

Lactic acid system + Aerobic system.

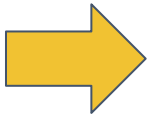
- 800 meter dash
- 2000 meter rowing
- 400 meter swim
- 1500 meter run
- 1 mile run
- 200 meter swim
- 1500 meter skating
- Boxing

Aerobic system

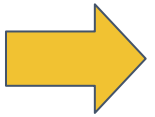
- 10,000 meter skating
- Cross-country skiing
- Marathon run
- Jogging

Recovery of muscle metabolic systems after exercise:

Energy from CP reconstitutes ATP



Energy from glycogen-lactic acid system reconstitute the phosphagen system (CP+ATP)



Energy from oxidative metabolism of aerobic system reconstitute all other systems: glycogen, lactic acid system and CP&ATP

"This mean each pathway will help the previous one to restore/refill the molecule that has been used to allow it to be used again."

شرح اضافي: اعتبروا هذي الثلاث pathways كأنها : اخوك الصغير"cp" ، انتي"anaerobic" وأبوك"aerobic".
اخوك الصغير ماعنده إلا ريالات يالله تكفيه ، انتي عندك 100 ريال يمديها تكفيك وتقدرين تعوضين اخوك الصغير بكم ريال ، ابوك عاد مكشكش يمدي يصرف فلوسه على نفسه ويعطيك انتي واخوك.

Lactic acid causes fatigue so it should be removed by:

1- A portion converted into pyruvic acid that is oxidized by all body tissues

2- The major remaining part is converted to glucose in the liver to restore glycogen stores in muscles

Recovery of aerobic system after exercise

"Oxygen Debt":

we said in the previous slide that the aerobic system helps the other pathways to restore their molecules, but how can it refill itself?

1-Definition: **Oxygen Debt** the amount of extra O_2 that must be taken after exercise to restore the muscles to the resting conditions. When a person stops exercising, the rate of oxygen uptake does not immediately return to pre-exercise levels; it returns slowly (that's why the person continues to breathe heavily for some time afterward)

2-This extra oxygen is used to repay the oxygen debt (7% debt with interest) acquired during exercise

Oxygen Debt is about 11.5 L of O_2

How does our body consume this 11.5 L ?

→ **2 L** of stored O_2 (0.5 L in lungs + 0.25 L dissolved in body fluids+1.0 L combined with Hb + 0.3 L stored in muscle myoglobin)

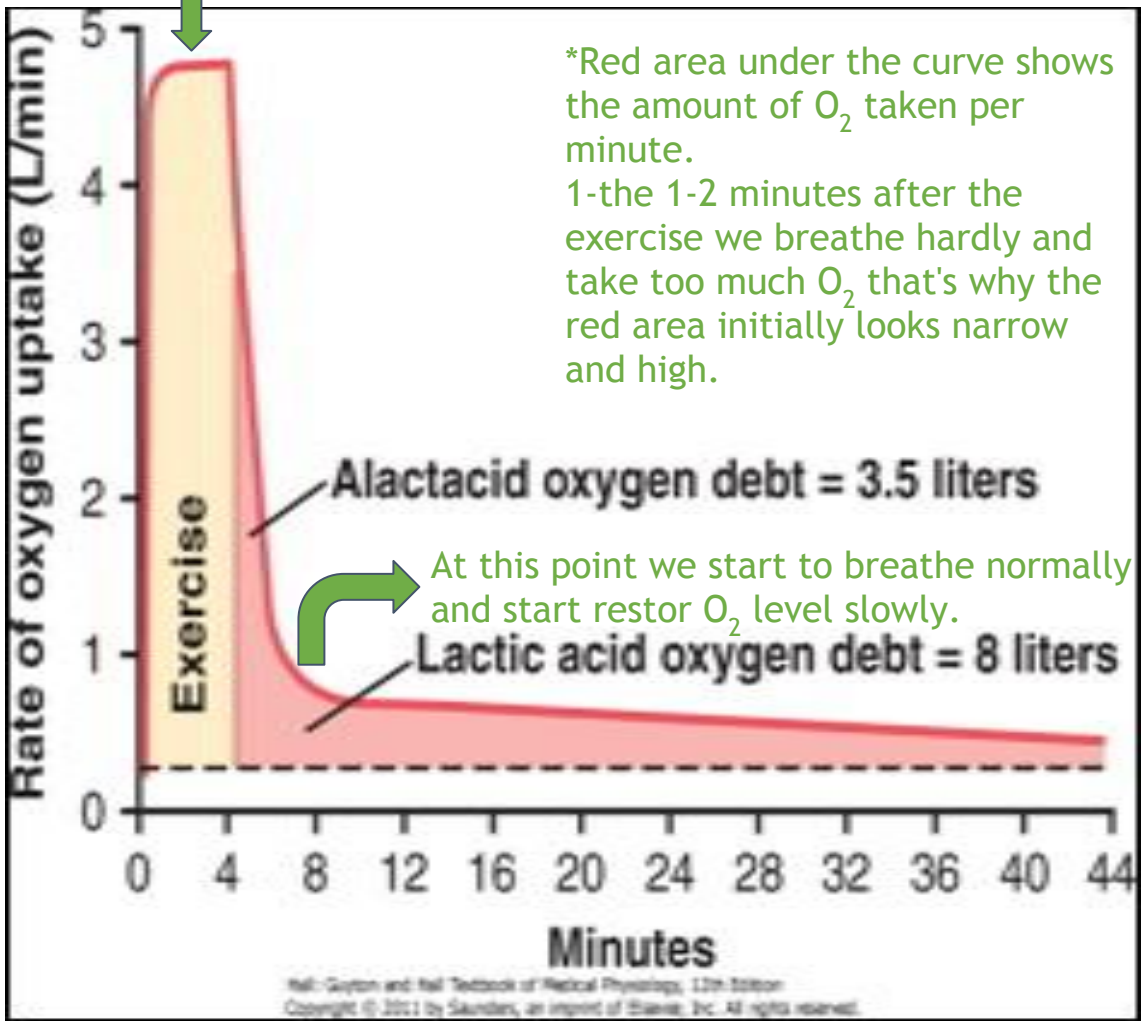
"used within 1min of heavy exercise or for aerobic metabolism."

→ **9 L** more O_2 to reconstitute the phosphagen & glycogen-lactic acid systems.

Cont...

- At first O_2 uptake is high & fast to refill stored O_2 & phosphagen system (alactacid O_2 debt= 3.5 L).
- The later portion of O_2 debt takes 40 minutes for lactic acid system removal, it is of lower level breathing (lactic acid O_2 debt =8 L)

we consume approximately 4.6L in 4min of exercising but we our body will restore the O_2 level in 44 min.



*Red area under the curve shows the amount of O_2 taken per minute.
1-the 1-2 minutes after the exercise we breathe hardly and take too much O_2 that's why the red area initially looks narrow and high.

At this point we start to breathe normally and start restor O_2 level slowly.

Helpful video

Recovery of muscle glycogen:

1- Reduction of glycogen stores by heavy exercise needs days to be replenished

2- On high CHO "carbohydrates" diet, recovery occurs in 2 days

3- On high fat, high protein or on no food all show very little recovery

Message:

1- Athletes (unlike us) should have high CHO diet before exercise

2- Not to participate in exhausting exercises during 48 hours of a preceding the event

Nutrients used during muscle activity:

1- During **early** stages of exercise body use **CHO** of muscle and liver glycogen. Also in **intense** muscle activity the body uses **fats** and very little amino acids

2- If endurance athletic events last longer than 4-5 hours & during exhaustion muscle glycogen is depleted & muscle depend on fats

3- Glucose solution given to athletes to drink during athletic event supply 30-40% of energy required during prolonged event as marathon race

Effects of smoking on pulmonary ventilation in exercise:

- Nicotine
  - **constricts** terminal **bronchioles**
  - **increases resistance** of **airflow**
  - **paralyzes** the **cilia** of the respiratory surface
- Irritation causes **increased fluid secretion** in the bronchial tree and **swelling** of epithelial layer
- leading to fluid and waste accumulation and reduced performance
- Chronic smokers may develop emphysema
  - obstruction of bronchioles
  - chronic bronchitis
  - destruction of alveoli
    - so slight exercise causes <u>respiratory distress</u>

Effects of heart disease and old age on athletic performance:

Cardiac diseases that **reduce cardiac output** (C.O.P) will reduce muscle power

Patients with congestive heart failure have **little muscle power** to even walk on the floor

(they do however have enough power to walk on the ceiling)

There is a 50% decrease in C.O.P between ages 18-80, a decrease in maximal breathing capacity, & a decrease in muscle mass and therefore in muscle power with age

Effect of body fluids and salts in exercise:

- 1 hour of endurance exercise causes **5-10 pounds of weight loss** in hot environment due to sweat
- Enough sweat loss reduces performance **5-10%**
- May lead to **cramps, nausea, etc…**
- Sodium tablets and fluids containing potassium in the form of fruit juice is given to athletes
- Acclimatization(تأقلم) to exercise by gradual increase over 1-2 weeks instead of maximal exposure is needed

Body fitness prolongs life:

Studies show that body fitness (exercise & weight control) have the benefit of a prolonged life (50-70)

Why?

1. Reduces CVD, brain stroke and kidney disease due to high HDL, low blood pressure,cholesterol & LDL
2. Reduces insulin resistance and type 2 diabetes
3. Reduces the risk of breast, prostate, and colon cancers
4. Reduces obesity

LDL = Low-density lipoprotein (bad cholesterol)
HDL = High-density lipoproteins (good cholesterol)

Drugs and athletes:

1- **Caffeine increase** athletes performance

2- **Male sex hormone** (Androgens) & other steroids increase athletes performance, but they increase the risk of heart attacks due to hypertension, increased LDL & decreased HDL

3- Male sex hormones decrease testicular functions & decrease natural testosterone secretion in males 2,3 happen when males take androgen from external sources

4- Women develop facial hair, stoppage of menses, ruddy skin and bass voice **if** they take androgens

5- Amphetamine & cocaine improve performance but overuse reduced performance as they are psychic stimuli

-> the action of these drugs in addition to epinephrine and norepinephrine (hormones of adrenal medulla) secreted during exercise leads to death by ventricular fibrillation

Quiz

SAQ

Q1- if female take Androgens from external source, what will she develop?

Q2- what is Oxygen debt?

Answers

SAQ1- facial hair ,stoppage of menses, ruddy skin and bass voice

SAQ2-is the amount of extra O2 that must be taken after exercise to restore the muscles to the resting conditions.

1) How much time can anaerobic Metabolism provide?		2) Which one of the following pathways is the primary energy source of resting muscles?	
A.	3 second	A.	Phosphagen system
B.	10 second	B.	Aerobic system
C.	1.3-1.6 minute	C.	Anaerobic system
D.	1 hour	D.	Ki energy
3) An example of an exercise that depends mainly on the phosphagen system?		4) How many ATP molecules are produced by Anaerobic system?	
A.	jumping	A.	1 ATP
B.	boxing	B.	2 ATP
C.	soccer	C.	3 ATP
D.	tennis	D.	34 ATP

Answers key: 1)C 2)B 3)A 4)B

Team leaders

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Thank you

@physiology438

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