Physiology 439

MED439
KING SAUD UNIVERSITY

8

Physical & Physiological Factors Affecting Athletic Performance

Editing file

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Red: Important
Black: In Male & Female slides
Blue: In male slides
Pink: In female slides
Gray: Notes & extra information

Objectives

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

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

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

04 Correlate between heart diseases and the athletic performance in old age

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

06 Interpret the effects of drugs on athletes.

Metabolic Pathways in Skeletal Muscles

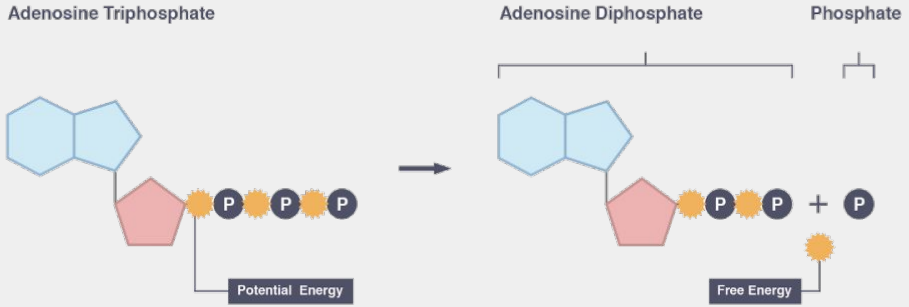
العضلة عندها مخزون ATP جاهز مباشرة للإستخدام لكنه قليل وينفذ بسرعة.. بعد ماينفذ راح تتجه العضلة لطرق أخرى لإعادة إنتاج الـATP ،وعندها ٣ طرق ممكنة.

Adenosine triphosphate (ATP): Adenosine-PO3 ~PO3 ~PO3−
is the **only** energy source used directly by the muscles for contractile activities.

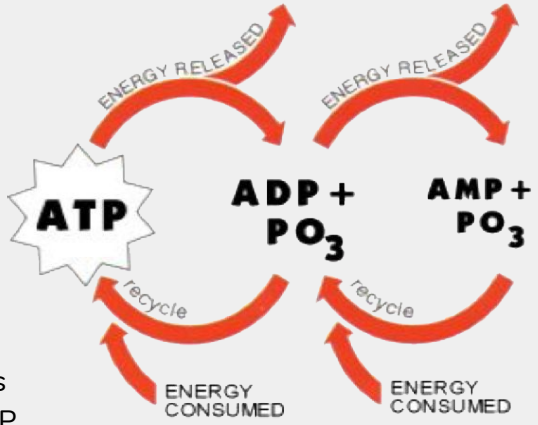
At rest, a muscle cell contains a small store of ATP, but it cannot rely on this ATP once it begins contracting.

Muscle cell must get ready to ATP production to keep pace with the increased rate of utilization.

The **demand** and the **mechanism** of ATP production vary according to the type of work done



Energy For Muscle Contraction



1. Mitochondria in the muscle converts glucose, fatty acids, and amino acids into ATP (Adenosine-PO3 ~ PO3 ~ PO3).
2. Each of the last 2 high energy phosphate bonds in ATP stores 12,000 calories per mole of ATP.
3. All ATP stored in the muscle is sufficient for only 1- 2 seconds of muscle power. (Enough for half of a 50-meter dash).
4. So resting muscles must have energy stored in **other forms** e.g Creatine Phosphate (CP), glycogen, etc. to convert ADP into ATP

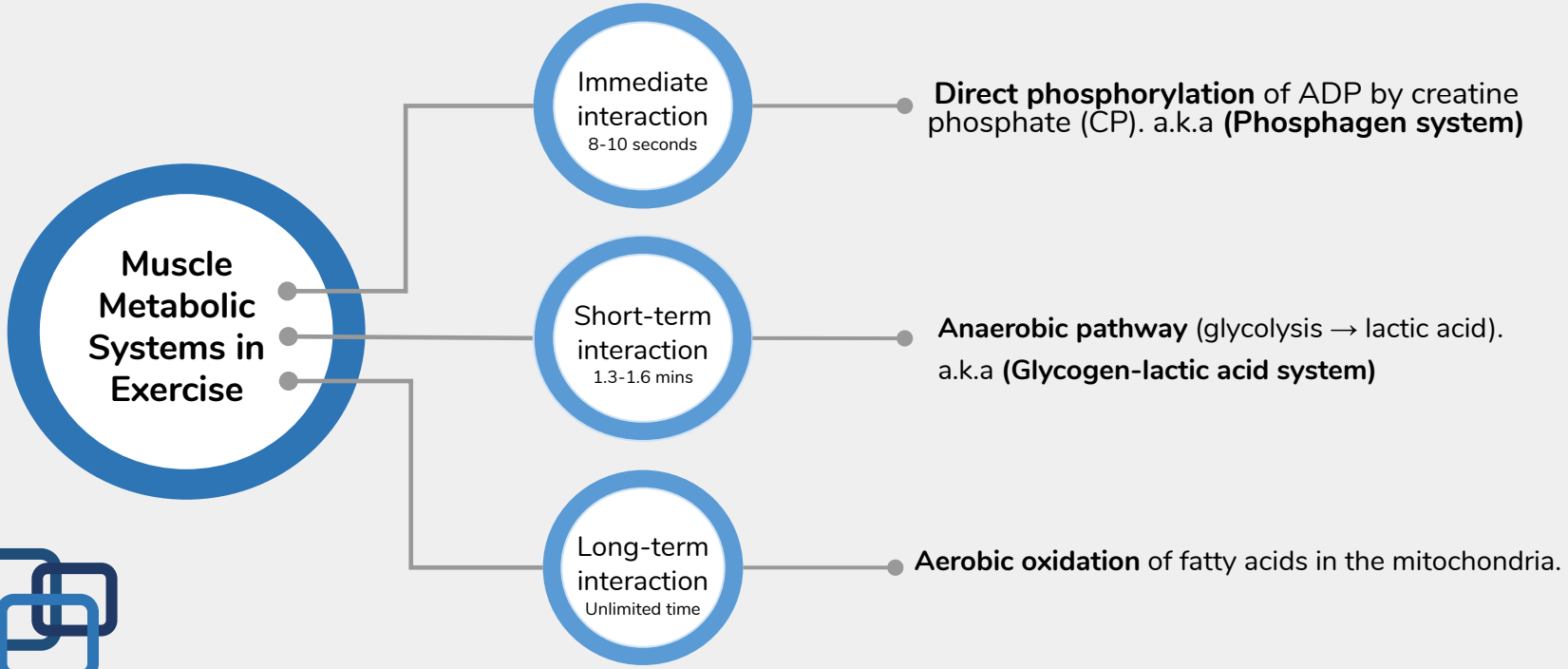
الـ ATP يحتوي على رابطتين فوسفات (طاقتهم عالية).

إذا انكسرت الأولى راح يصير ADP ويعطيني ١٢٠٠٠ كالوري/مول.

إذا انكسرت الثانية راح يصير AMP ويعطيني ١٢٠٠٠ كالوري/ مول أخرى.

ATP Regeneration

- As we begin to exercise, we almost immediately use our stored ATP within few seconds, and it will changed into ADP.
- After 1-2 secondes all ATP in the muscle is depleted , only ADP is left. How can we regenerate ATP? by **3 pathways**:



شرح الصورة:
باختصار الفوسفات اللي في الـPhosphocreatine راح تنتقل للـADP أول مايجون سوا.

وقتها الـADP بتصير ATP وخذ لك طاقة بس لاتتبسط واجد لأن بعد 8-10 ثواني بيخلص عليك الـPhosphocreatin

1-Phosphocreatine-Creatine System (Direct Phosphorylation)

- Creatine phosphate (creatine ~ Po3)(CP): Contain high energy phosphate bond of 13,000 calories/mole. (for each molecule of CP)
- Most muscle cells have 3-8 times as much CP as ATP.
- Energy transfer from CP to ATP occurs within a small fraction of a second .
- Energy of muscle CP is immediately available for contraction just as stored energy of ATP.
  - Lasts only 8 to 10 secondes, **NO** use of O_2

Phosphagen Energy System:

- Formed of combined amounts of cell ATP + CP.
- Together provide maximal muscle power for 8-10 seconds (enough for 100 meter run).
- Energy of phosphagen system is useful for **maximal short bursts of muscle power (8-10 seconds)**.

اكسرسايز عنيفة لكن مش طويلة

2- Anaerobic Glycolysis (Glycogen-Lactic Acid System)

- The primary energy source for peak (sever) muscular activity. It provides 1.3-1.6 minutes of maximal muscle activity.
- Used in sports that requires bursts of speed and activity, e.g. basketball
- Occurs in absence of oxygen and results in breakdown of glucose to yield ATP and lactic acid
- Produces 2 ATP molecules per molecule of glucose coming from blood.

Glycogen → **Glucose** → **2 pyruvic acid (2 ATP + 2 NADH)** → **2 lactic acid** (2 NAD^+) → Lactic acid diffuses out of muscles → blood → taken by the liver → Glucose (by gluconeogenesis) → blood → taken by the muscle again.

Anaerobic metabolism is inefficient. why?

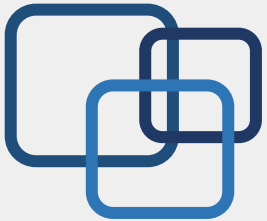
1. Large amounts of glucose are used for very small ATP returns.

   it is very "**expensive**".

   لأني ممكن اطلع من الجلوكوز 34 ATP لو دخل الميتوكوندريا
   بينما هنا 2 ATP بس

2. Lactic acid is produced whose presence contributes to muscle fatigue.

   Lactic acid causes fatigue & pain.



- Main source for our daily activity.
- No waist product so it is unlimited (as much nutrients as you have).
- can last for hours.
- requires O_2

3- Aerobic Metabolism

Is the primary energy source of resting muscles (to convert glucose into glycogen. and to create energy storage compounds as (CP).

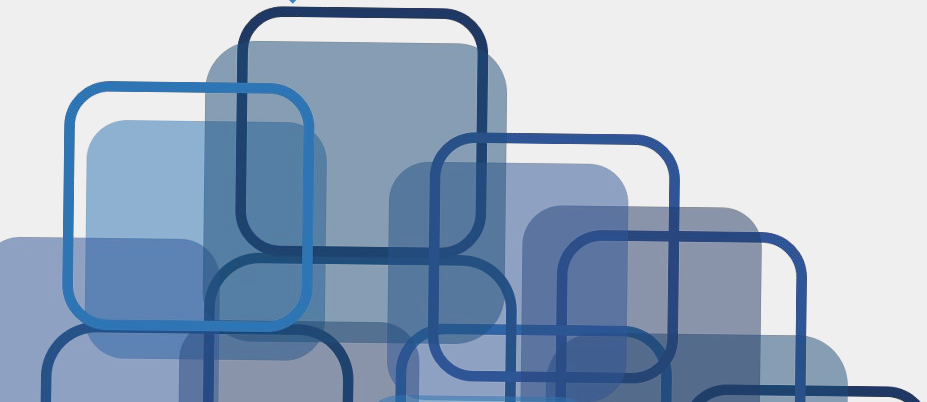
During rest and light to moderate exercise, aerobic metabolism contributes 95% of the necessary ATP.

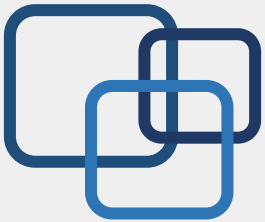
It breaks down **fatty acids**, **pyruvic acid** (made via glycolysis), and **amino acids**.

Produces 36 * ATP molecules per glucose molecule.

* 34 + (2 ATP was made outside before glucose enters the mitochondria)

Both 36 and 34 are right as long as they are in the same range





Comparing the Energy Supply of The Three Pathways

	What?	When?	Time (comparing the **endurance**)	Example	Energy	Moles of ATP/min	Notes
Muscle's stored of ATP. it is already there, it is NOT a pathway!!	-	Immediately available	Lasts for 1-2 secondes	Half of a 50-meter dash	In ATP: there are 2 phosphate bonds, each can produce 12,000	-	ATP جاهز لكن ينفذ بسرعة وراح تتجه العضلة لأحد الـpathways الثلاثة لإعادة تكوين الـATP
Pathways **Direct phosphorylation** (Phosphocreatine-Creatine System)	Energy transfer from CP to ATP	Immediately available	Lasts for 8-10 seconds	100 meter run	In CP: there is a high energy phosphate bond of 13,000 calories/mole.	4	حل سريع وجاهز لكنه محدود جدًا والـCP يخلص بسرعة
Anaerobic system (Glycogen-lactic acid system)	primary energy source for peak (sever) muscular activity.	After CP is depleted and phosphagen system is shut down	Lasts for 1.3-1.6 minutes.	Sports that requires burst of speed and activity , eg: Basketball	Produce 2 ATP per glucose molecule.	2.5	مكلف (ياخذ جلوكوز كثير مقابل ATP قليل) ومدته قصيرة نسبيًا ومشكلته أنه يفرز Lactic acid واللي بدوره راح يسبب fatigue
Aerobic system (oxidative system)	primary energy source of resting muscles	Prolonged exercise	Unlimited (as long as nutrients last)	Marathon run	Produce 36 ATP per glucose molecule.	1	unlimited ويمثل ٩٥٪ من الـ metabolism في الجسم بشكل يومي لكنه بطيء مره

Energy Systems Used in Various Sports

Know a few examples of each.

ممكن يجيكم عليها سؤال

Phases can integrate; it isn't a must that a phase end so the other phase can start

Table 84–1

Energy Systems Used in Various Sports

Phosphagen system, almost entirely
- 100-meter dash
- Jumping
- Weight lifting
- Diving
- Football dashes

قصير

Phosphagen and glycogen-lactic acid systems
- 200-meter dash
- Basketball
- Baseball home run
- Ice hockey dashes

Glycogen-lactic acid system, mainly
- 400-meter dash
- 100-meter swim
- Tennis
- Soccer

متوسط

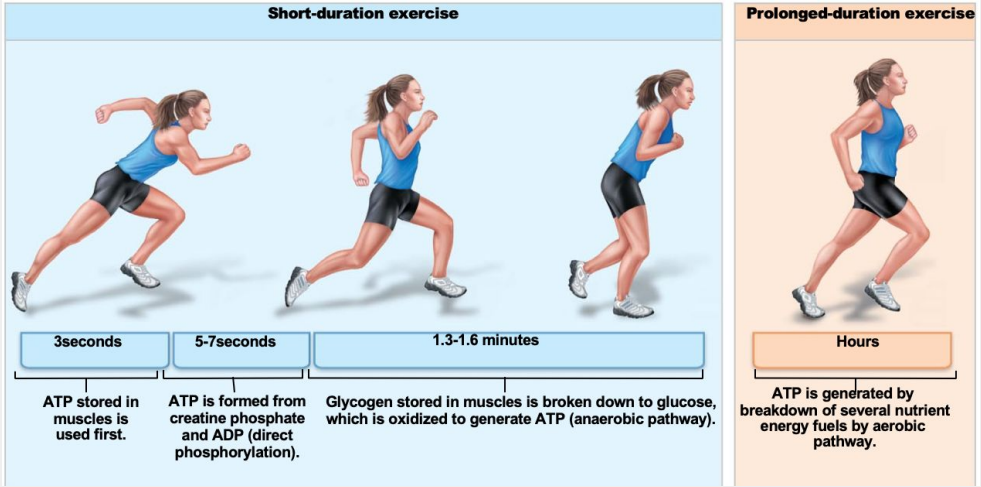
Glycogen-lactic acid and aerobic systems
- 800-meter dash
- 200-meter swim
- 1500-meter skating
- Boxing
- 2000-meter rowing
- 1500-meter run
- 1-mile run
- 400-meter swim

Aerobic system
- 10,000-meter skating
- Cross-country skiing
- Marathon run (26.2 miles, 42.2 km)
- Jogging

بطيء

Scenario: Mohammed climbed the stairs to bring his jacket. what is the source of energy he used?

Answer: climbing the stairs take seconds/minutes so he used glycogen-lactic acid system (Anaerobic system).



Recovery of Aerobic System After Exercise (Oxygen Debt)

Oxygen Debt is the amount of extra O_2 that must be taken after exercise to restore the muscles to the resting conditions.

This extra consumption of oxygen is used to repay the oxygen debt acquired during exercise is called **repaying the oxygen debt.**

- When a person stops exercising, the rate of oxygen uptake does not immediately return to pre-exercise levels.
- It returns slowly (the person continues to breathe heavily for at least a few minutes and sometimes for as long as 1 hour thereafter).

بعد التمرين أكيد بيتكون بالجسم lactic acid والاوكسجين اللي فيه راح يصير depleted طبعًا
والـCP أكيد بلقاه مخلص
والـATP صار ADP.

"طيب بعد ما أنا عملت الاكسرسايز الدنيا قوا اخبارها إيييه؟ خربانه"

"يبقى لازم بعد الحفلة دي نرجع كل شيء لمكانه ونرجع البيت زي ماستلمناه"

- **Oxygen debt is about 11.5 L of O_2 and the additional oxygen is used to:**

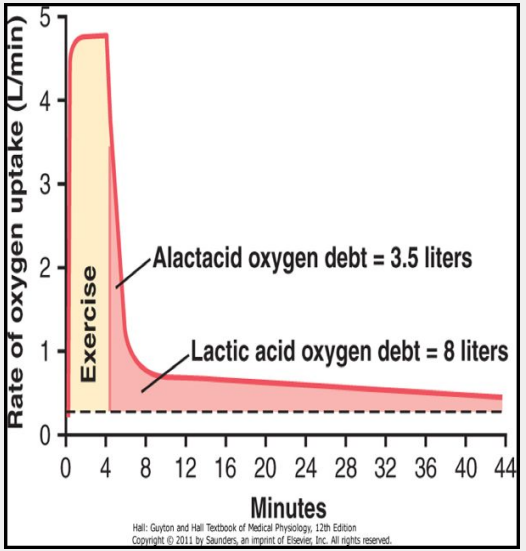
كل ما ارتفعت اللياقة يقل هذا الرقم

1- Reconvert the lactic acid that has accumulated during exercise back into glucose,
2- Reconvert adenosine monophosphate and ADP to ATP,
3- Reconvert creatine and phosphate to phosphocreatine,
4- Re-establish normal concentrations of oxygen bound with hemoglobin and myoglobin, and
5- Raise the concentration of oxygen in the lungs to its normal level.

Extra Info. From Guyton

Contd..

The body normally contains about 2 liters of stored oxygen that can be used for aerobic metabolism even without breathing any new oxygen. This stored oxygen consists of the following: (1) 0.5 liter in the air of the lungs, (2) 0.25 liter dissolved in the body fluids, (3) 1 liter combined with the hemoglobin of the blood, and (4) 0.3 liter stored in the muscle fibers, combined mainly with myoglobin, an oxygen-binding chemical similar to hemoglobin.



In heavy exercise, almost all this stored oxygen is used within a minute or so for aerobic metabolism. Then, after the exercise is over, this stored oxygen must be replenished by breathing extra amounts of oxygen over and above the normal requirements. In addition, about 9 liters more oxygen must be consumed to reconstitute both the phosphagen system and the lactic acid system. All this extra oxygen that must be “repaid,” about 11.5 liters, is called the oxygen debt.

Recovery of Muscle Metabolic Systems After Exercise

Energy from CP reconstitute 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 & CP & ATP.

Lactic acid causes fatigue so it should be removed by:

1-Portion converted into pyruvic acid that is oxidized by all body tissues.

2-The major remaining part is changed into glucose in the liver to replenish glycogen stores of muscles.

What is the most substance that lactic acid is converted to ?

Answer: Pyruvic acid

Recovery of Muscle Glycogen

01 Reduction of glycogen stores by heavy exercise needs days to be replenished.

02 On high CHO diet, recovery occurs in 2 days

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

04 Athlete should have high CHO diet before exercise

05 Not to participate in exhausting exercise during 48 hours preceding the event.

Nutrients Used During Muscle Activity

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.

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

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

1

Nicotine:

- Constricts the terminal bronchioles.
- Increases resistance of airflow into and out of the lungs.
- Paralyze the cilia of the respiratory epithelial cell surface.

2

Smoke irritation

Smoke irritation causes increased fluid secretion into the bronchial tree and swelling of epithelial layer.

3

Leading to:

- Fluid and waste accumulation
- Reduced level of performance.

4

Chronic Smokers May Develop Emphysema

- obstruction of bronchioles
- chronic bronchitis
- destruction of alveoli

so slight exercise cause **respiratory distress.**

Effects of Heart Disease and Old Age on Athletic Performance

Recall muscle power is the amount of work that the muscle perform in a period of time (kg-m/min)

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

2. Patient with **congestive heart failure** has little muscle power to even walk on the floor.

3. **Decrease in muscle power with age.**

   - 50% Decrease in C.O.P between age 18-80 years.
   - Decrease in maximal breathing capacity
   - Decrease in muscle mass.

Effect of Body Fluids & Salts in Exercise

1

Exercise for 1 hour during **endurance athletic** event causes 5-10 pounds of weight loss in hot humid atmosphere **due to sweat loss.**

2

Loss of enough sweat reduces performance 5-10% .

May lead to cramps, nausea & serious effects, so it should be replaced.

3

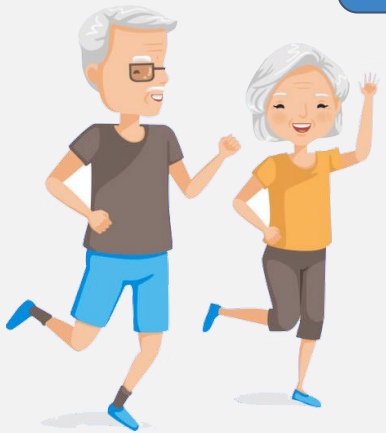
Sodium tablets and supplemental fluids **containing potassium** in the form of fruit juice is required to athletes.

4

Acclimatization (تأقلم) to exercise by **gradual increase** over 1-2 weeks instead of maximal exposure is needed

Muscle endurance: is the ability of muscles to sustain repeated contractions against a resistance for a period of time.*437

Body Fitness Prolongs Healthy Life



Studies shows that body fitness, **exercise & weight control** have additional benefit of prolonged life (between 50-70).

WHY?

- It reduces CVD, heart attacks, brain stroke and kidney disease due to low blood pressure, low blood cholesterol, low LDL, and high HDL.
- It reduces insulin resistance and type 2 diabetes.
- Improved fitness reduces the risk of breast, prostate, and colon cancers and reduces obesity.

LDL: low-density lipoprotein (bad cholesterol)

HDL: high-density lipoprotein (good cholesterol)

CVD: cardiovascular diseases

Drugs & Athletes

01

Caffeine increase athletes performance.

02

Male sex hormone (Androgens) & other anabolic steroids:

- Increases athletes' performance.
- Increases the risk of heart attacks due to hypertension.
- Increase LDL. increasing LDL increases the risk of CVD
- Decrease HDL.
- Decrease testicular functions.
- Decrease natural testosterone secretion in males.

03

When women use **Androgens:**

- develop facial hair.
- stoppage of menses.
- ruddy skin and bass voice.

04

Amphetamine & cocaine improve performance

- But **overuse** reduces performance, they are **psychic stimuli.***Have a "psychological effect"
- The action of these drugs in addition to **epinephrine** and **norepinephrine** (hormones of **adrenal medulla**) secreted during exercise lead to **death by ventricular fibrillation**.

SUMMARY

First way of ATP regeneration

The phosphagen system (also called the CP-ATP system) is the quickest way to resynthesize ATP. Creatine phosphate (CP), which is stored in skeletal muscles, donates a phosphate to ADP to produce ATP. During rest the ATP will help to restore CP.

Second way of ATP regeneration

Glycogen-lactic acid system occurs in absence of oxygen and results in breakdown of glucose to yield 2 ATP and lactic acid.

Third way of ATP regeneration

Aerobic metabolism requires oxygen and breaks down glucose to produce a net yield of 34 ATP, and it is the primary ATP resynthesizing source in 95% of our daily activities.

Oxygen Debt

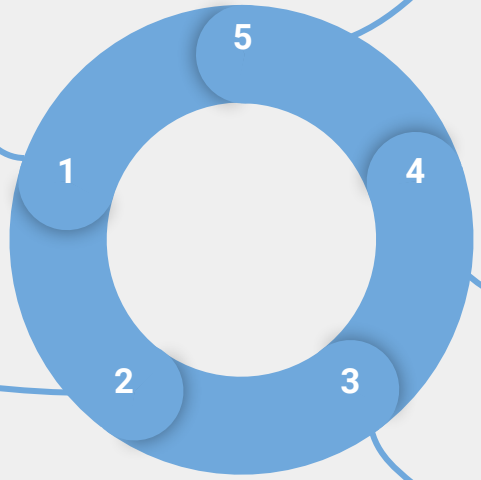
Oxygen Debt is the amount of extra O_2 that must be taken after exercise to restore the muscles to the resting conditions.

Effects & Drugs

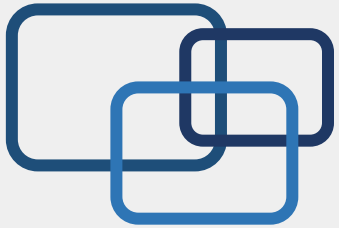
- Smoking, heart diseases, aging, body fluids, and salt can affect the exercise.

- Exercise can prolong our life.

- Caffeine, androgenes, amphetamine, and cocaine can increase athletic performance.



Test your knowledge on Physical & physiological factors affecting athletic performance here!



QUIZ!

MCQs

Q1: How many ATP molecules per one molecule of glucose is produced in anaerobic glycolysis:			
A) 38	B) 2	C) 36	D) 4
Q2 : Cardiac disease that reduce cardiac output will:			
A) increase muscle power	B) decrease muscle power	C) increase in HDL	D) A&B
Q3 : Is the primary energy source of resting muscles:			
A) anaerobic glycolysis	B) phosphorylation	C) ATP	D) aerobic metabolism
Q4 :Converts glucose< fatty acids, and amino acids into ATP in the muscle:			
A) nucleus	B) phosphagen energy system	C) mitochondria	D) aerobic metabolism
Q5 : A bodybuilder focuses mainly on proteins in his diet, his glycogen recovery in his muscles is:			
A) Fast	B) slow	C) intermediate	D) none of these
Q6 : The uptake of androgens can..... the body HDL			
A) Increase	B) regulate	C) decrease	D) reverse

SAQ

Q1: What are the pathways for regenerating ATP from ADP ?

Q2: List 2 forms of stored energy in the muscles rather than ATP

MCQs key answer :
1) B
2) B
3) D
4) C
5) B
6) C

SAQ answer key :

1)
- ~~Direct phosphorylation~~
- ~~Anaerobic pathway~~
- ~~Aerobic oxidation~~

2)
- ~~Creatine Phosphate~~
- ~~Glycogen~~

Physiology 439

THANK YOU

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Question bank