Physical and Psychological Factors Affecting Sport Performance

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Aerobic glycolysis

- For each mole of glucose that is split into pyruvic acid, 2 moles of ATP are formed. However, when stored glycogen in a cell is split to pyruvic acid, each mole of glucose in the glycogen gives rise to 3 moles of ATP. The reason for this difference is that free glucose entering the cell must be phosphorylated by using 1 mole of ATP before it can begin to be split; this is not true of glucose derived from glycogen because it comes from the glycogen already in the phosphorylated state, without the additional expenditure of ATP. *Thus, the best source of energy under anaerobic conditions is the stored glycogen of the cells. (Guyton)*

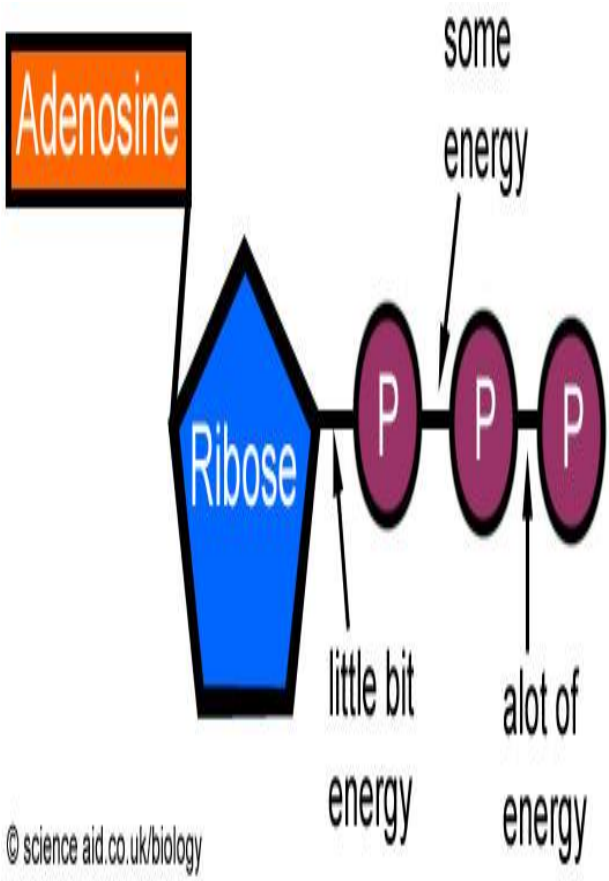
Objectives

By the end of this lecture students should be able to :

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. Discus the effects of smoking on pulmonary ventilation in exercise.
4. Correlate between heart diseases and the athletic performance in old age.
5. Analyze the changes in body fluids and salts in exercise.
6. Interpret the effects of drugs on athletes.

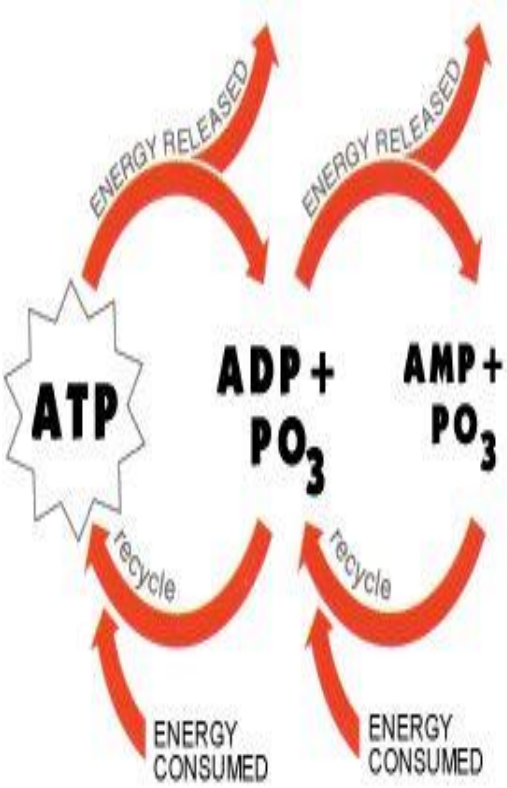
Metabolic pathways in skeletal muscle

- Adenosine triphosphate (ATP) is the only energy source used directly by muscles for contractile activities.
- The **demand** and the **mechanism** of ATP production vary according to the type of work done.
- 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.



Energy for Muscle Contraction

- Mitochondria in the muscle converts glucose, fatty acids, and amino acids into ATP **Adenosine-PO3 ~ PO3 ~ PO3**
- Each of the last 2 high energy phosphate bonds in ATP stores 7300 calories per mole of ATP.
- All ATP stored in the muscle is sufficient for only 3 seconds of muscle power. (Enough for half of a 50-meter dash).
- So resting muscles must have energy stored in other forms e.g Creatine Phosphate (CP), glycogen, etc.



ATP regeneration

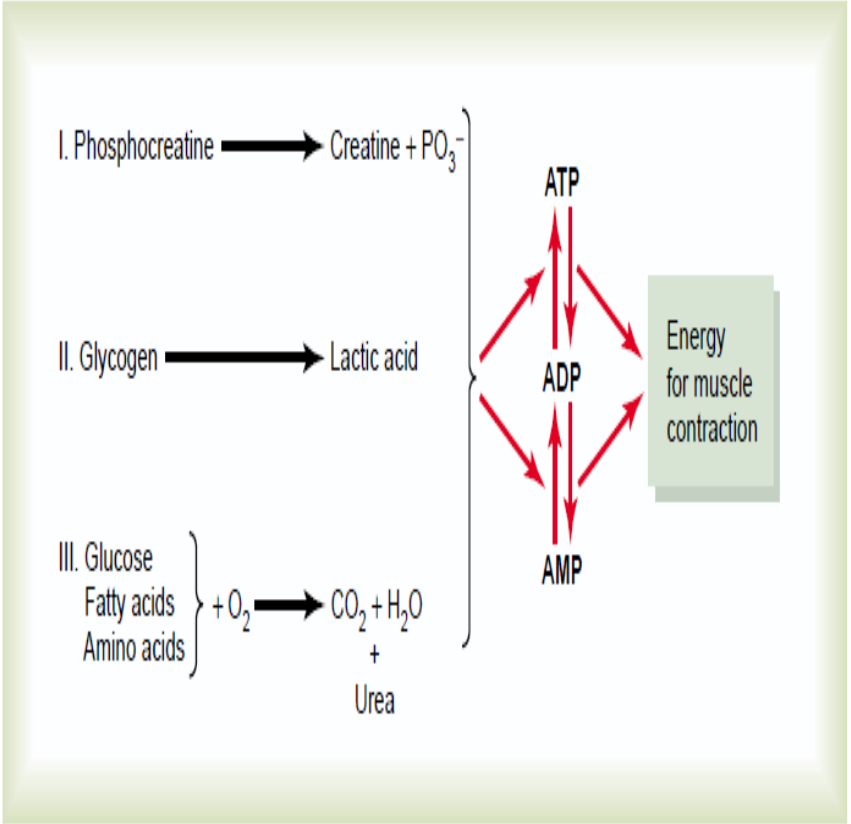
- As we begin to exercise, we almost immediately use our stored ATP within few seconds.

ATP is regenerated from ADP by 3 pathways:

1-Direct phosphorylation of ADP by **creatine phosphate** (CP).

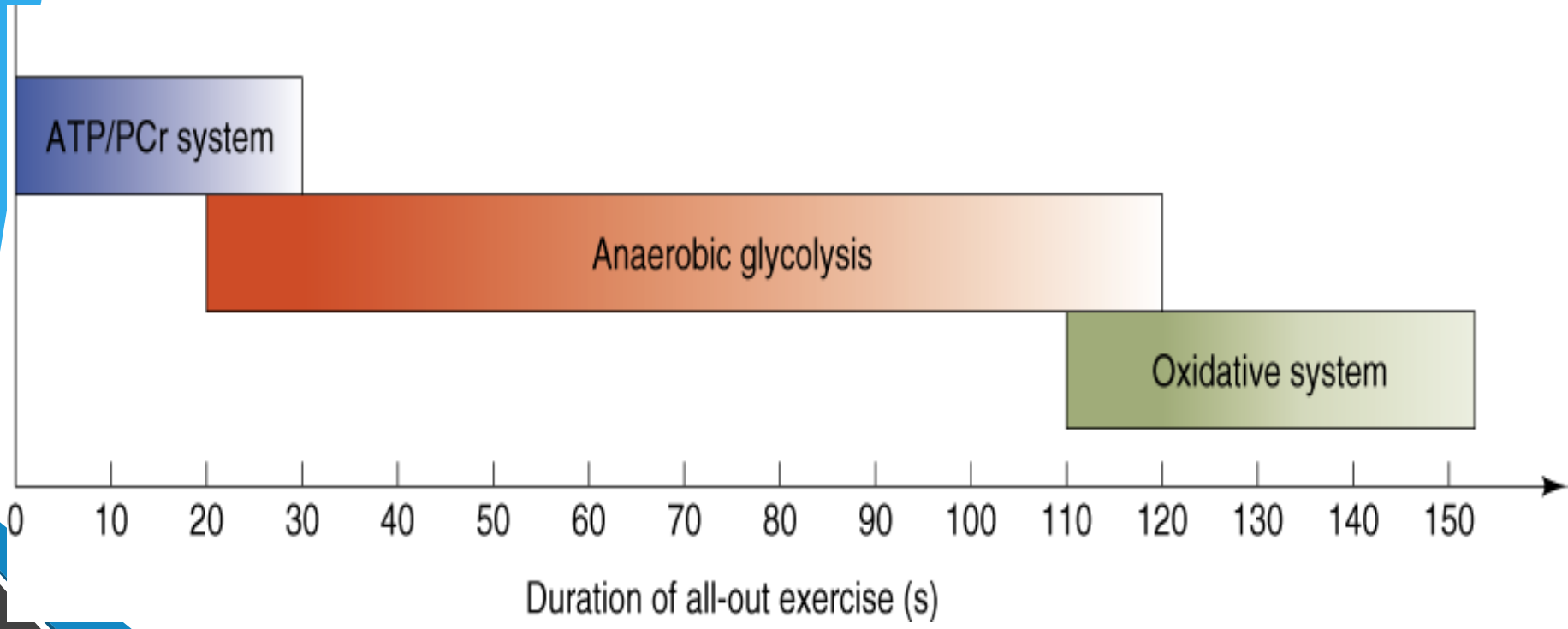
2-Anaerobic pathway (glycolysis → lactic acid).

3-Aerobic oxidation of fatty acids in the mitochondria

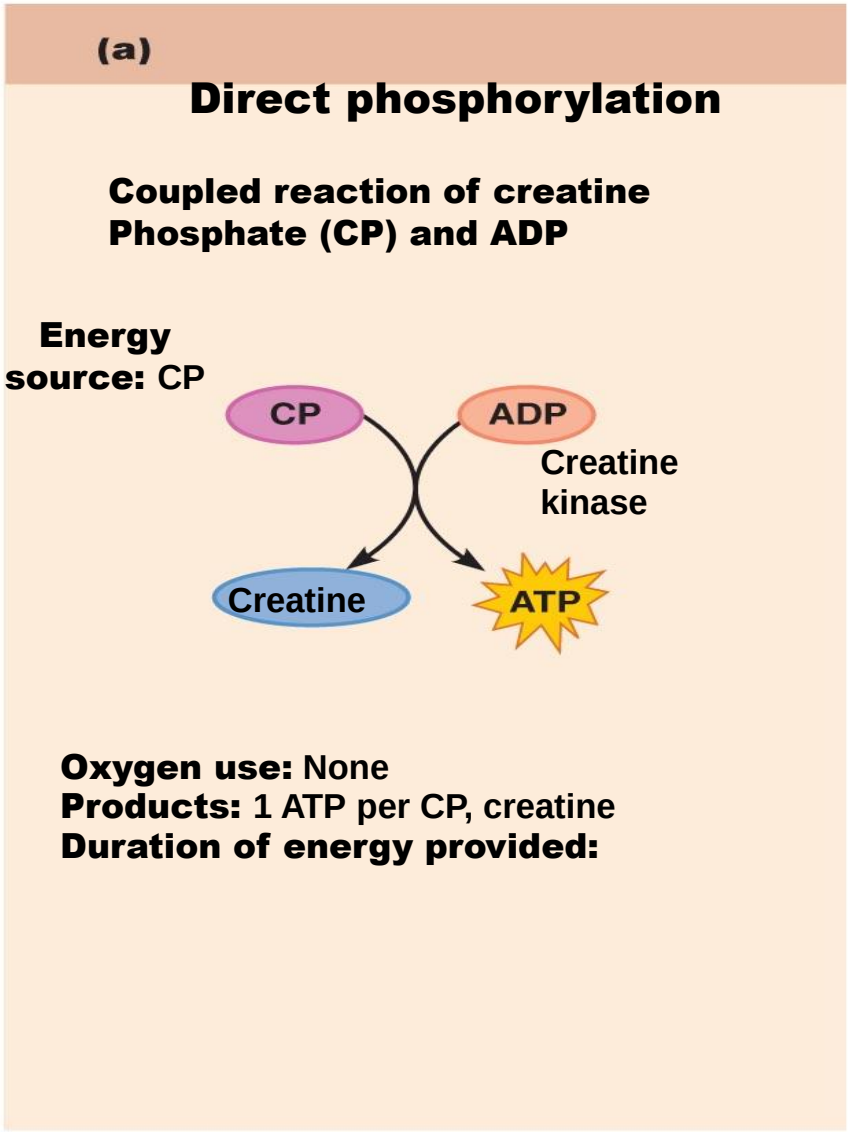


INTERACTION OF ENERGY SYSTEMS

Immediate **Short-term** **Long-term**



1-Phosphocreatine-creatine system (creatine ˜ Po3)



CP: Contain high energy phosphate bond of 10,300 calories/mole.

Most muscle cells have 2- 4 times as much CP as ATP.

Energy transfer from CP to ATP occurs within a small fraction of a second .

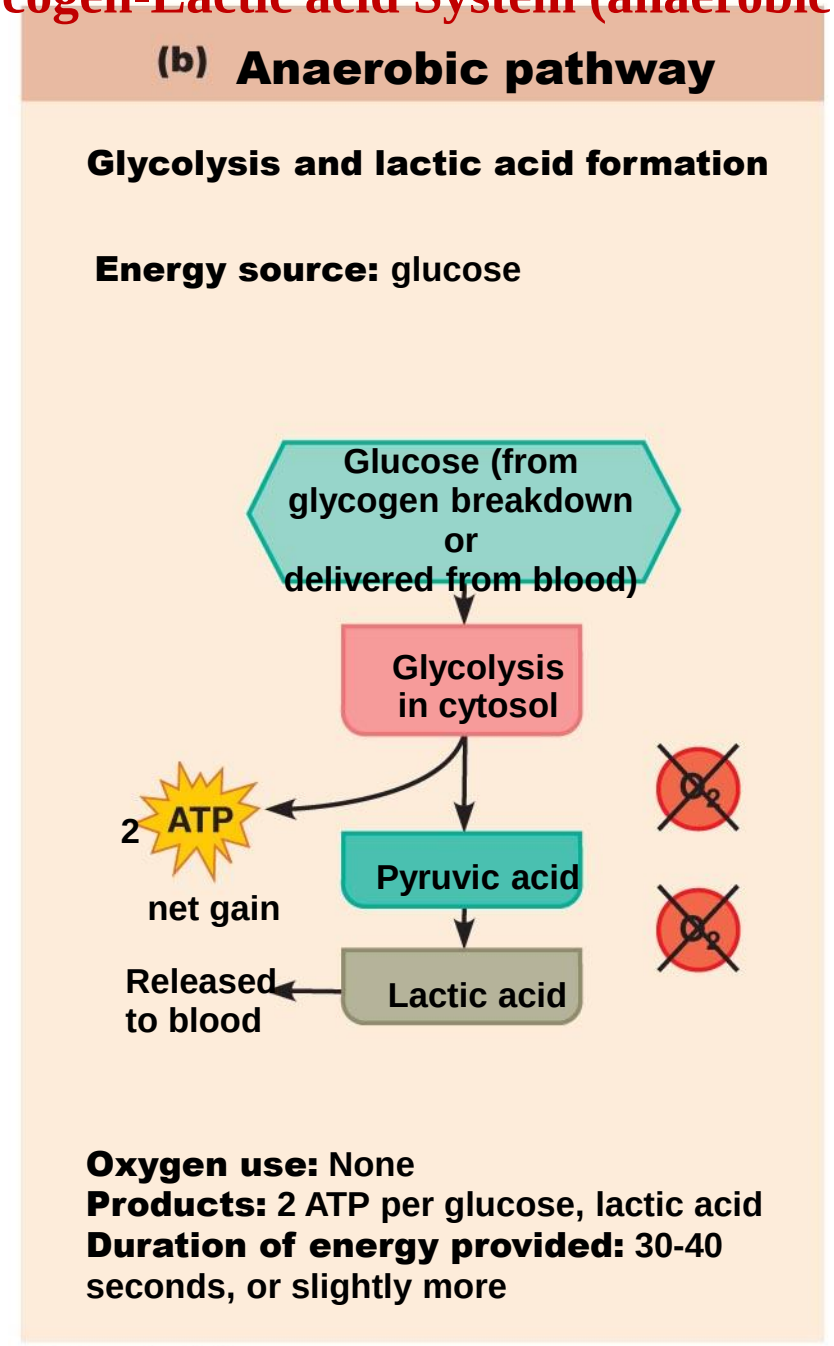
Energy of muscle CP is immediately available for contraction just as stored energy of ATP.

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)**.

2- Glycogen-Lactic acid System (anaerobic Metabolism)



Anaerobic

- Without oxygen
- Source of energy: Carbohydrate (glycolysis)
- Lactate & ATP

Anaerobic Glycolysis (Glycogen-Lactic acid system)

- Is the primary energy source for peak (sever) muscular activity. It provides 1.3-1.6 minutes of maximal muscle activity.
- Produces **2 ATP** molecules per molecule of glucose.
- The process of anaerobic metabolism can maintain ATP supply for **about 45-60s.**
- Glycogen → Glucose → 2 pyruvic acid (2 ATP + 2 NADH)
- 2 Pyruvic acid → 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.

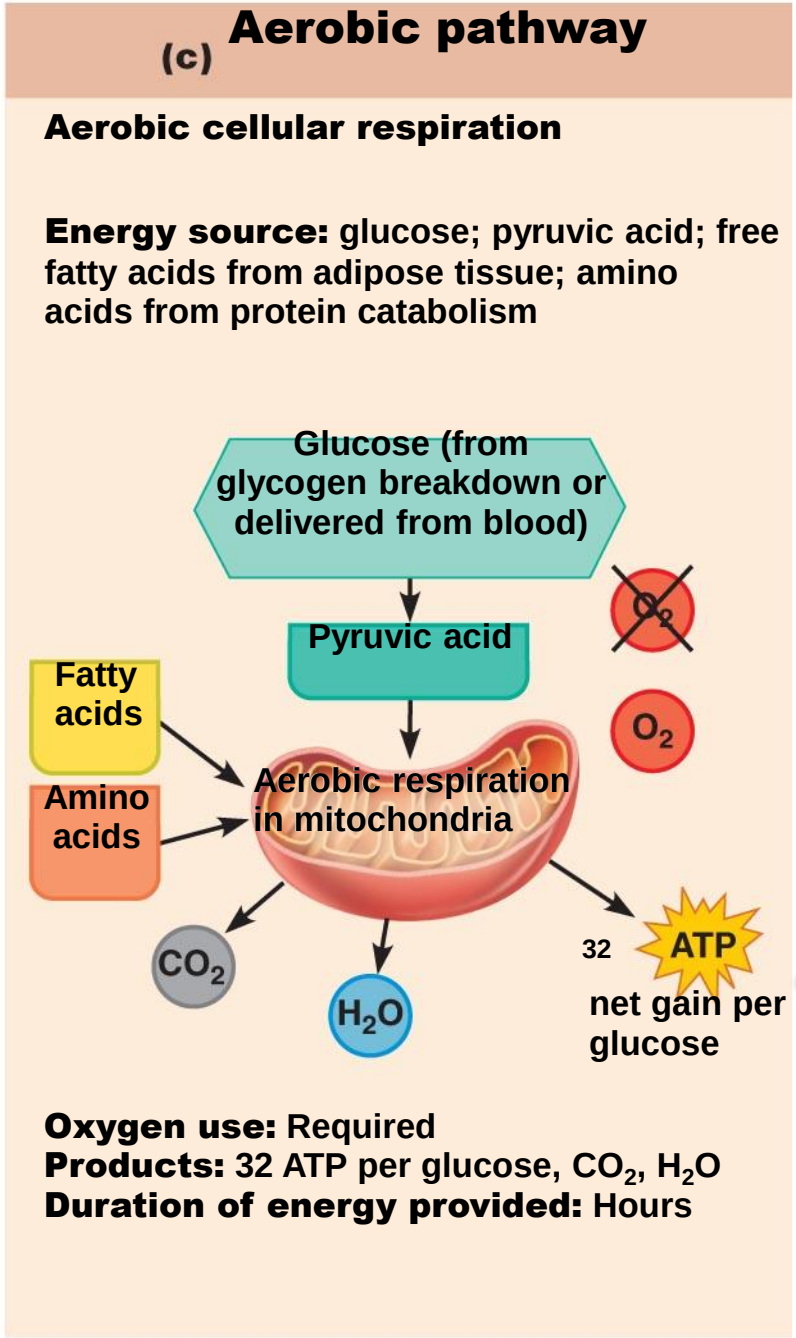
Anaerobic metabolism is inefficient… Why?

- Large amounts of glucose are used for very small ATP returns.
- Lactic acid is produced whose presence contributes to muscle fatigue.

Which type of sports uses anaerobic metabolism?

- Sports that requires bursts of speed and activity, e.g., basketball.

3- Aerobic Metabolism



Aerobic

With oxygen

Source of energy: mainly **fatty acids**, then carbohydrate, amino acids

CO_2, H_2O & ATP

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 34 ATP molecules per glucose molecule.

Comparing the Energy Supply of the Phosphagen System, Anaerobic and the Aerobic systems

ATP generation per minute are the following:

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

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)

Figure 9.20 Comparison of energy sources used during short-duration exercise and prolonged-duration exercise.

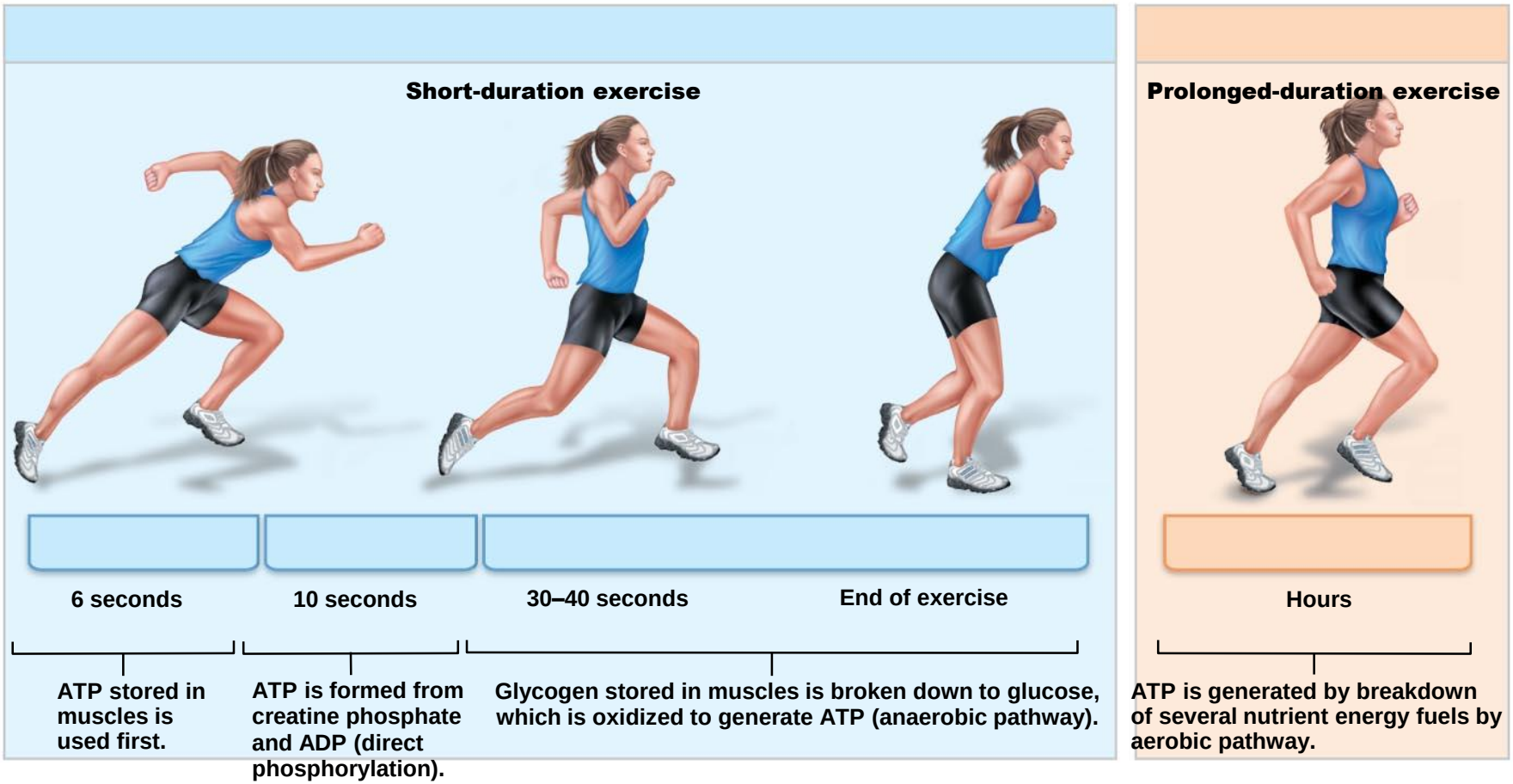


Table 84–1

Energy Systems Used in Various Sports

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

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

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

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 remaining is changed into glucose in the liver to replenish glycogen stores of muscles.

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.

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 some time afterward).

This extra oxygen is used to repay the **oxygen debt** acquired during exercise.

Oxygen Debt is about 11.5 L of O2

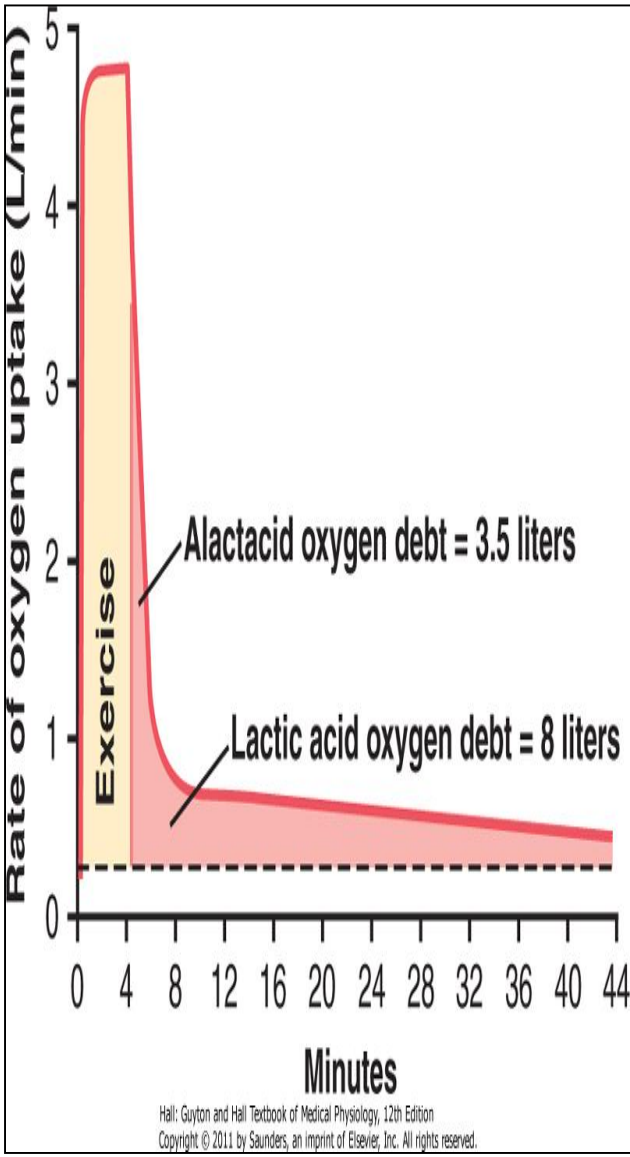
a- 2 L of stored O2 (0.5 L in lungs + 0.25 L dissolved in body fluids+1.0 L combined with Hb + 0.3 L stored in muscle myoglobin)

-This is used within a minute of heavy exercise or for aerobic metabolism.

b- 9 L more O2 to reconstitute the phosphagen & glycogen-lactic acid systems.

-At first O2 uptake is high & fast to refill stored O2 & phosphagen system (this is called alactacid O2 debt= 3.5 L)

- The later portion of O2 debt takes 40 minutes for lactic acid system removal, it is of lower level breathing, It is called (lactic acid O2 debt =8 L)



Recovery of muscle glycogen

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

-On high CHO diet, recovery occurs in 2 days.

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

Message:

1- Athlete should have high CHO diet before exercise.

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

- Read Guyton & Hall: Textbook of Medical Physiology 12E

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

- Nicotine constricts the terminal bronchioles and increases resistance of airflow into and out of the lungs.
- Smoke irritation causes increased fluid secretion into the bronchial tree and swelling of epithelial layer.
- Nicotine paralyze the cilia of the respiratory epithelial cell surface.
- All lead to fluid and waste accumulation and reduced level of performance.
- 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

- Cardiac diseases that reduce cardiac output (C.O.P) will reduce muscle power.
- Patient with congestive heart failure has little muscle power to even walk on the floor.
- There is 50% ↓ in C.O.P between age 18-80 years, ↓ in maximal breathing capacity, ↓ in muscle mass and therefore in muscle power with age.

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Effect of body fluids and salts in exercise

- Exercise for 1 hour during endurance athletic event causes 5-10 pounds of weight loss in hot humid atmosphere due to sweat loss.
- Loss of enough sweat reduces performance 5-10% and may lead to cramps, nausea & serious effects, so it should be replaced.
- Sodium tablets and supplemental fluids containing potassium in the form of fruit juice is required to athletes.
- Acclimatization to exercise by gradual increase over 1-2 weeks instead of maximal exposure is needed.

Drugs and athletes

- Caffeine increase athletes performance.
- Male sex hormone (Androgens) & other anabolic steroids increase athletes performance but they ↑ the risk of heart attacks due to hypertension, ↑ LDL and ↓ HDL.
- Male sex hormones ↓ testicular functions & ↓ natural testosterone secretion in males.
- Women develop facial hair, stoppage of menses, ruddy skin and bass voice if they take androgens.
- Amphetamine & cocaine improve performance but overuse reduce performance they are psychic stimuli.
  -the action of these drugs in addition to epinephrine and norepinephrine (hormones of adrenal medulla) secreted during exercise leading to death by ventricular fibrillation.
- Read Guyton & Hall: Textbook of Medical Physiology 12E

Body fitness prolongs life

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

Reasons:-

1-It reduces CVD, heart attacks, brain stroke and kidney disease due to low blood pressure, low blood cholesterol, low LDL, and high HDL.

2-It reduces insulin resistance and type 2 diabetes.

3-Improved fitness reduces the risk of breast, prostate, and colon cancers and reduces obesity.

Thank you