Energy transfer & exercise

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Objective

- Define the energy
- Understand what is ATP
- Define and describe the energy systems
- Outline the energy stores
- Understand what happen at recovery from exercise

Introduction

- Energy :-

•the ability to perform work.

•Energy is required for muscle contraction and other biological work such as digestion, nerve conduction, secretion of glands, etc.

•Chemical energy needed for several metabolic processes

•Metabolism :-

•the sum total of all chemical reactions occurring in the body

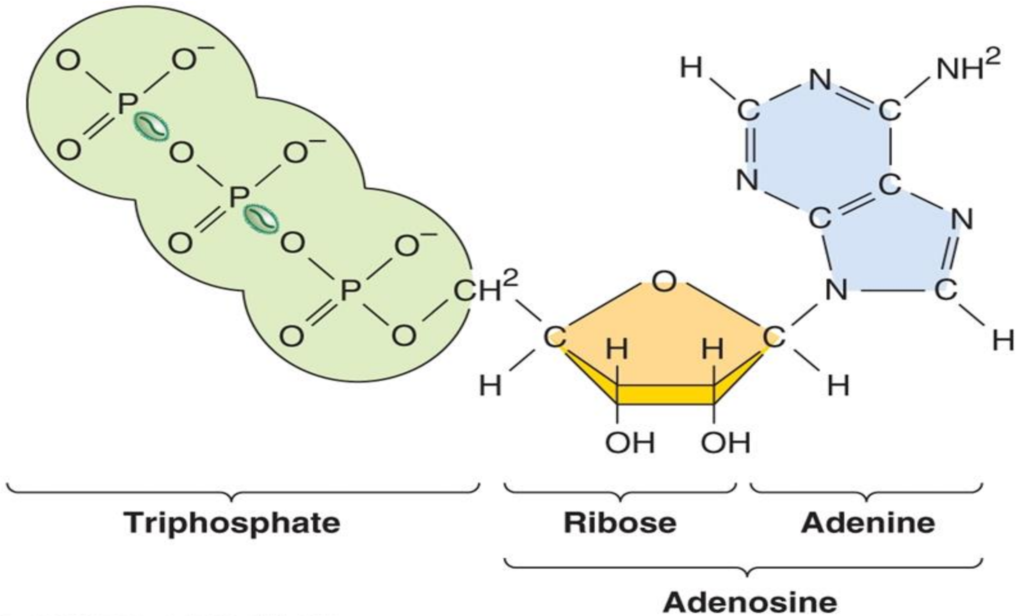
- Exergonic reactions: result in energy release
- Endergonic reactions: result in stored or absorbed energy
- Bioenergetics: flow of energy change within human body

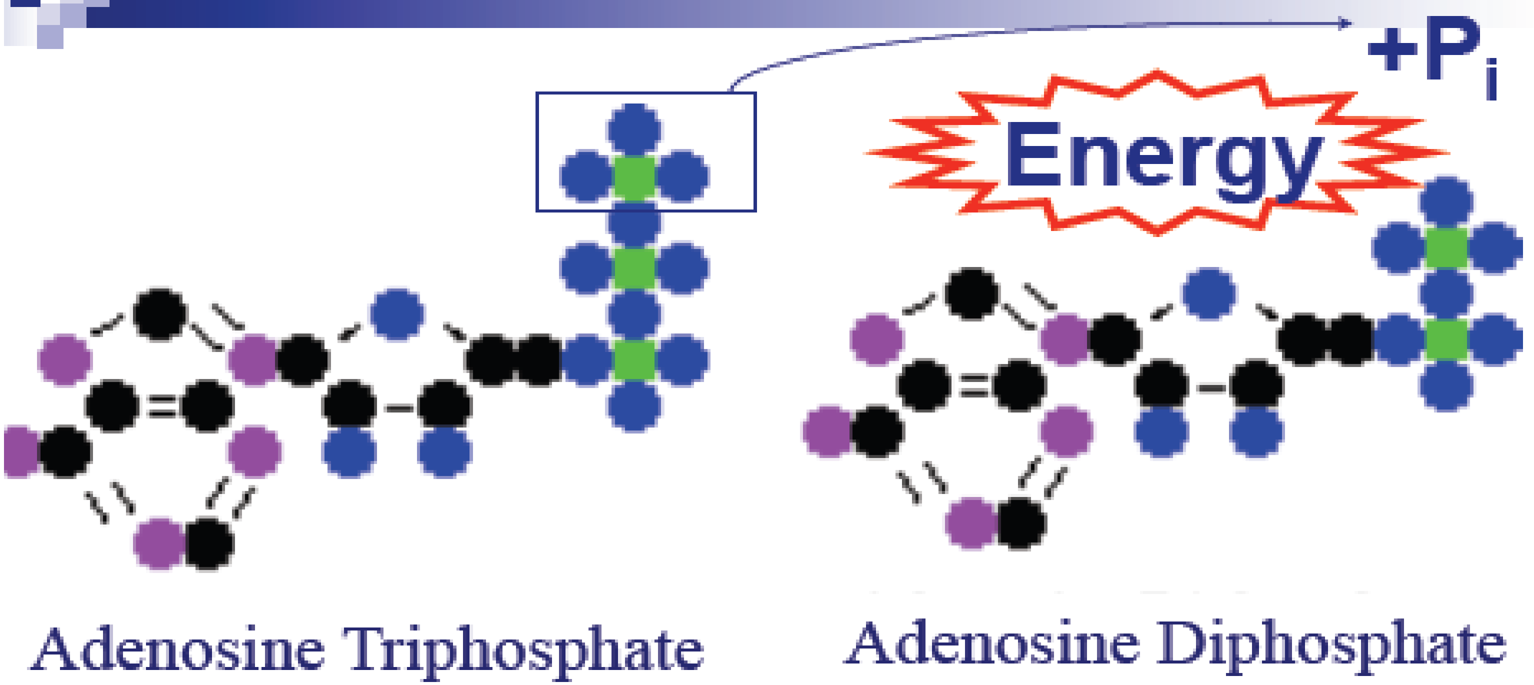
Adenosine Triphosphate (ATP)

- Potential energy transferred from food to fuel muscle.

- Cells don't get Energy directly from food, it must be broken down into:
- ATP-adenosine triphosphate
- ✓ High-energy compound used to fuel body during rest & exercise.
- ✓ Composed of adenine & ribose (adenosine) + 3 phosphates

ATP structure :





✓Hydrolysis: cleavage of phosphate bond releases energy

✓ATP + H2O ➡ ADP + Pi + energy

Energy Stores

Marconutrients that give us energy

- Carbohydrates
- Fats
- Proteins

Digestion

Glucose

Fatty acids

Amino Acids

Carbohydrate Stores

- Carbohydrates provide a rapid and readily available source of energy for most of the activities.
- It converted to glucose which can function in one of these 4 ways:

➢ Used directly by cells for energy

➢ Storage as glycogen in the muscles and liver(glucogenesis)

➢ Converted to fat for energy storage

➢ Provide carbon skeletons to synthesize non-essential amino acids

Important Carbohydrate conversions

- Glucogenesis :- glucose → glycogen
- Gluconeogenesis :- protein → glucose
- Glycogenolysis :- glycogen → glucose

Fat Store

- Fat is stored predominantly as adipose tissue.
- contributes about 50% of energy requirement during light and moderate exercise. As exercise continues , it supply more than 70% of energy needs.
- Requires more oxygen for aerobic breakdown.

Fat

- The contribution of fat to energy requirement during exercise depend on:

- 1- Fatty acid release from triacylglycerol in fat storage sites
- 2- delivery in the circulation to muscle tissue as free fatty acid bound to blood albumin

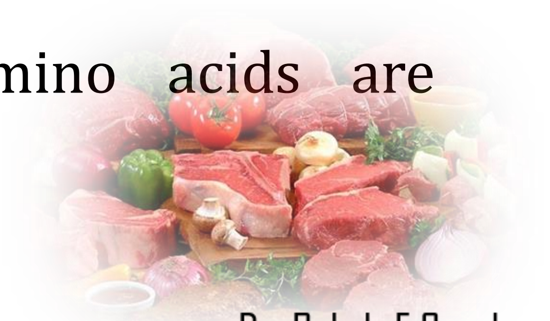
Protein Stores

- Can only supply up to 5% to 10% of the energy needed to sustain prolonged exercise.

- Amino acids are the subunits of proteins, the body required 20 different AA.

- Protein is used as a source of energy, particularly during prolonged activity, but it must first be broken down into amino acids before then being converted into glucose.

- only a small amount of protein or amino acids are metabolized to provide energy.



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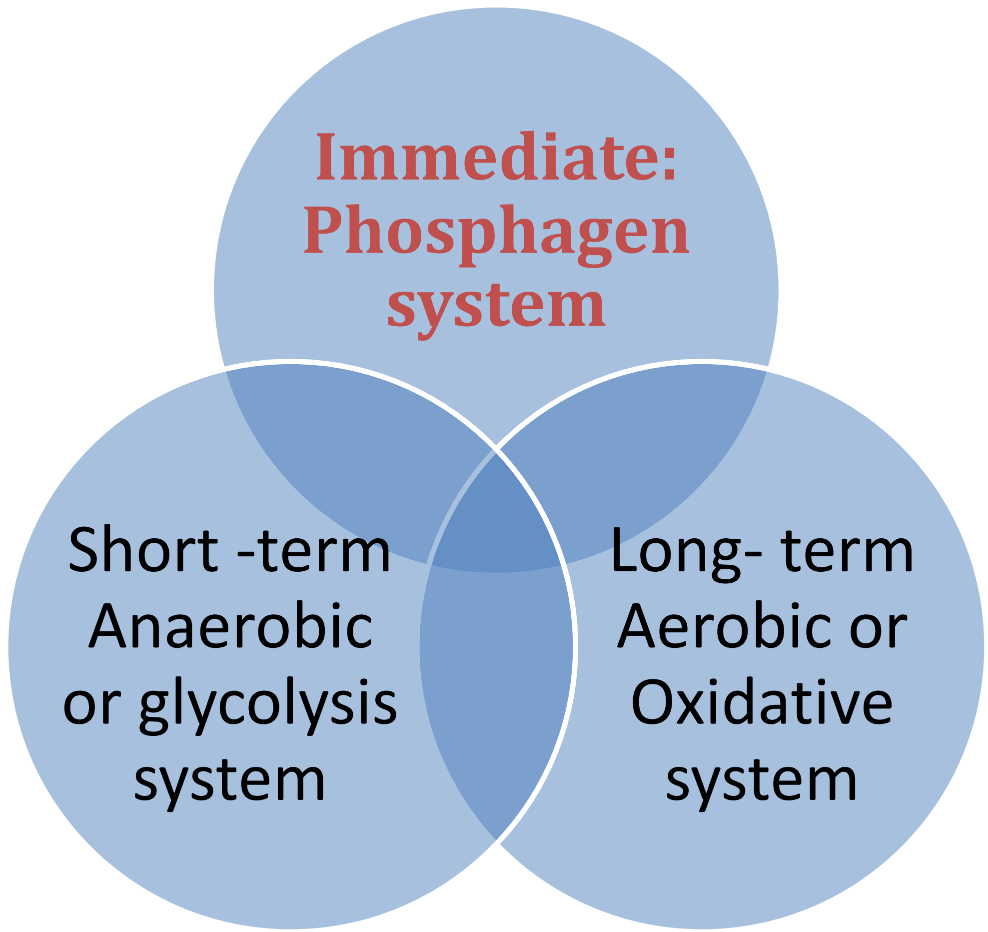
Energy Usage During Exercises

Energy Systems



- **Anaerobic Processes**
  processes which do not require the presence of oxygen delivered by the blood.
- **Aerobic Processes**
  processes which require the presence of oxygen delivered by the blood

Phosphagen Energy System

- This system relies on stored ATP and to a larger extent, creatine phosphate, to provide immediate energy. (Stored within skeletal muscle)

- Will take place during the transition from rest to exercise, and during the transition from one exercise intensity to a higher intensity.

- It does not need oxygen.

- It leaves no waste products.

- The energy stored in creatine phosphate is then used to "recharge" ADP, converting it back to ATP

ATP-CP (Phosphagen) System

Biologic Work

$$ATP \xleftrightarrow[ATPase]{} ADP + P_i + \text{Energy}$$

$$CP \xleftrightarrow[\text{Creatine Kinase}]{} C + P_i + \text{Energy}$$

Principle of Coupled Reactions

All-out power for approximately 10 seconds

This immediate energy source is only utilized for brief, high intensity bursts of activity such as a 100-meter dash, lifting a heavy weight, or any other activity that involves a maximum, short burst of power .

Such activities usually last ten seconds or less due to the fact that muscles store only limited amounts of CP and ATP.

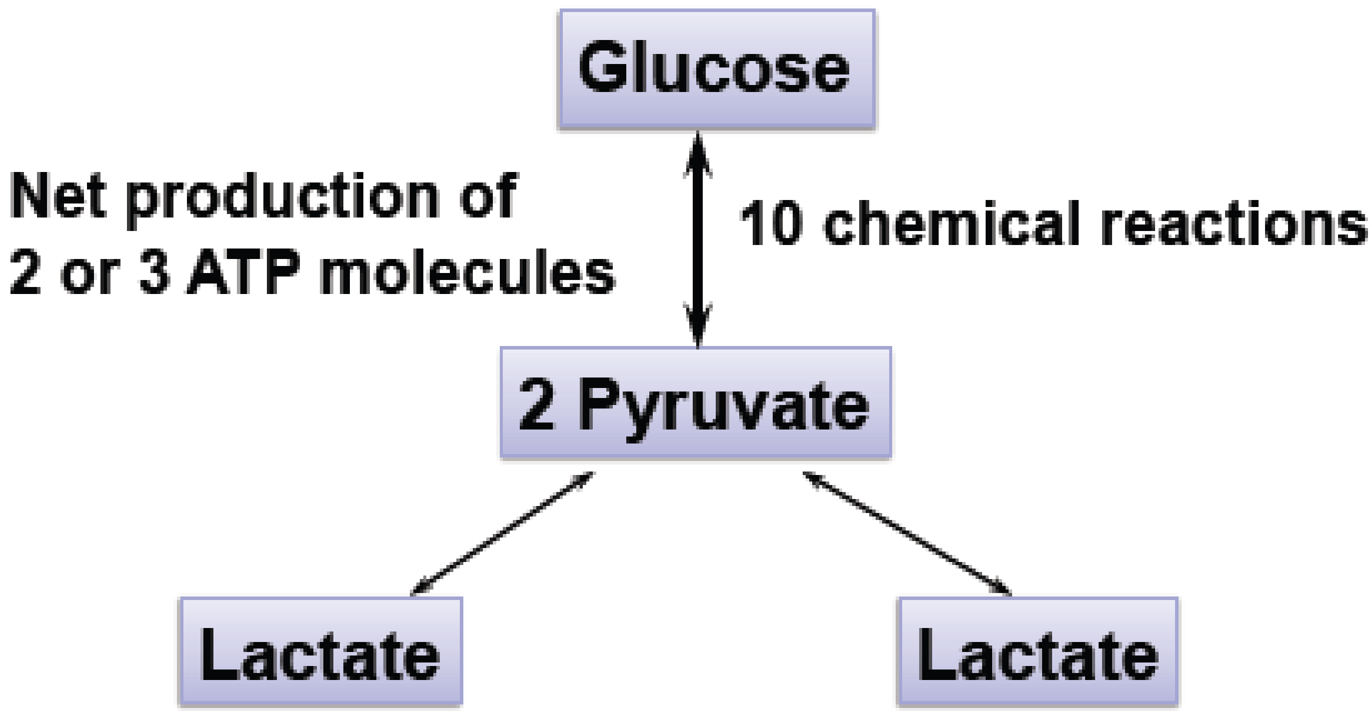
When **creatine phosphate** is used up, the body must call on other systems of energy transfer to sustain continued activity. (maximal intensity exercise lasting longer than 10 seconds)

Anaerobic or Glycolysis Energy System

- To continue strenuous exercise beyond a brief period, the energy comes from glucose and stored glycogen(in Ms.& liver) during anaerobic process of glycolysis.

- Is the breakdown of glucose to pyruvic acid in the cytoplasm of a cell.
- When oxygen demands exceed oxygen supply, pyruvate is converted to lactate.
- Provides enough energy for high intensity work that can last from 1-2 minutes in duration or until fatigue sets in. Such fatigue is due to lactic acid build-up in the muscles. (Lactic acid is a by-product of the glycolytic process).

Anaerobic Glycolysis
The Glycolytic System



Activities powered mainly by lactic acid energy system

- Last phase of mile run, 400 m run
- 100 m swim
- Multiple sprint sports: ice hockey, field hockey, and soccer

The advantage of anaerobic glycolysis is that it is able to supply ATP at a high rate and within a short time.

The disadvantage of anaerobic glycolysis is that it provides only 2 ATP molecules from each molecule of glucose. So, anaerobic glycolysis is rapid but not economic.

Aerobic or Oxidative Energy System

- known as the Mitochondrial respiration
- This occurs when adequate oxygen is available.
- This system can provide muscles with energy for unlimited period according to the supply of nutrients .
- This system is used during lower levels of activity when there is enough energy being delivered to the working muscles to clear away all the Pyruvic Acid.

Long Term :Aerobic Energy System

- Produces ATP in mitochondria of cells.

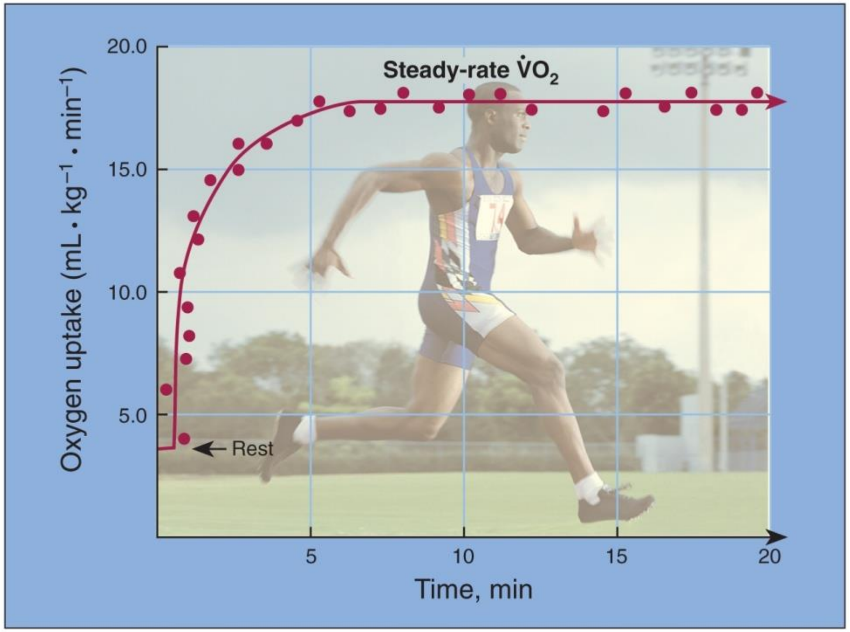
- Is the primary method of energy production during endurance events.

- At lower levels of activity FATS can be used as a muscle fuel.
- Aerobic exercises -continuous, rhythmic activity-large muscle groups.

- During exercise, VO2 rises rapidly until “steady rate”(balance of energy required and ATP produced).

Long Term : the Aerobic Energy System

- The use of oxygen by cells is called *oxygen uptake (VO_2).*
- Oxygen uptake rises rapidly during the first minute of exercise.
- Between 3rd and 4th minute a plateau is reached and VO_2 remains relatively stable.
- Plateau of oxygen uptake is known as *steady rate.*



Aerobic or Oxidative Energy System

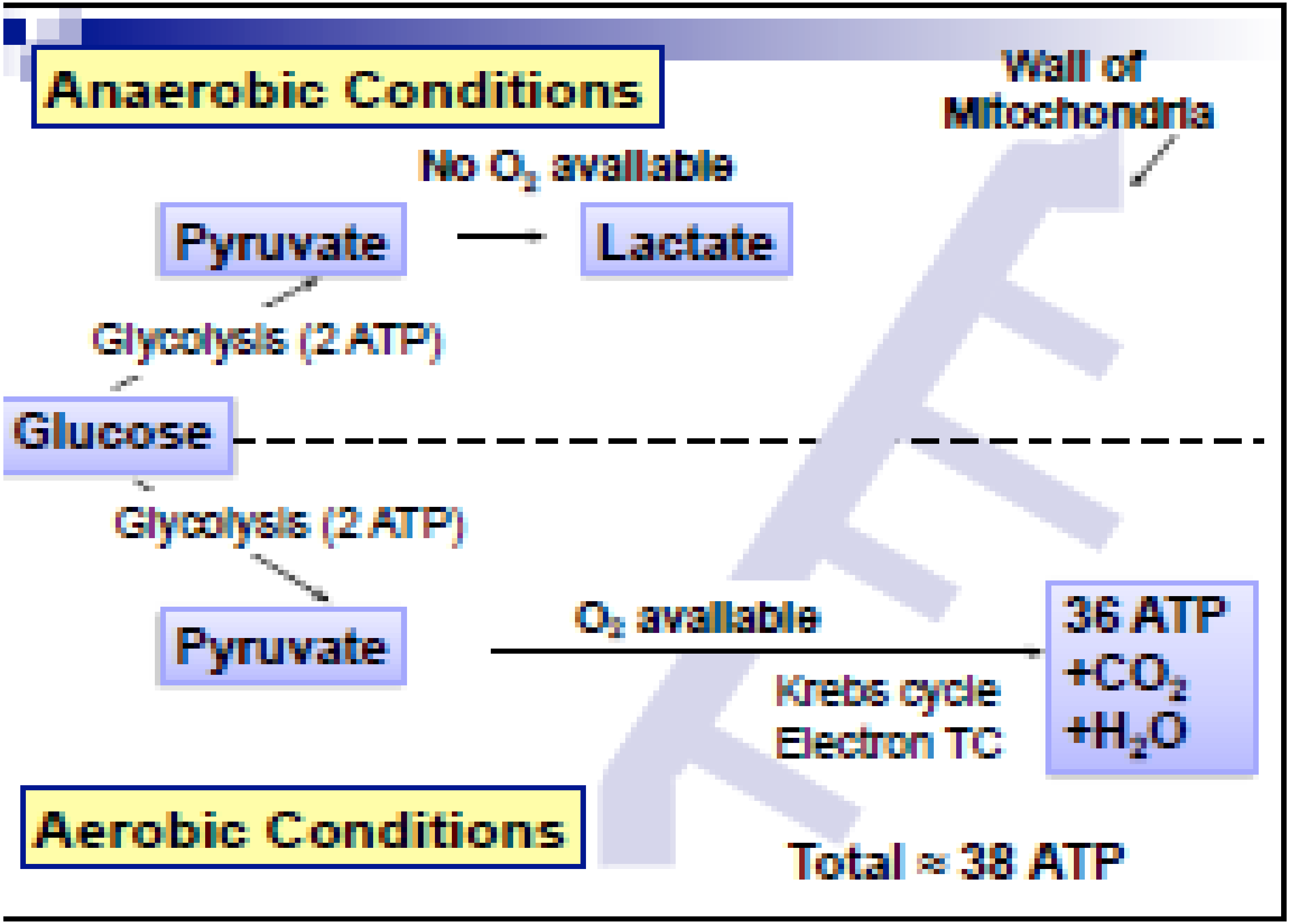
- As a general rule, the more intense the activity the more GLUCOSE is used instead of FAT.

- Predominates in the majority of daily activities and lower intensity, long-duration sports.
- An all-out effort of 2 minutes is approximately 50% aerobic and 50% anaerobic.


Oxidation of Carbohydrate

The main thing is to see the approximate increase in ATP yield between anaerobic breakdown (2 or 3 ATP) versus aerobic breakdown (38 ATP)

$$\textbf{BI. Glucose} + \mathbf{6O_2} \xrightarrow[\text{(Kreb's cycle)}]{\text{Aerobic oxidation}} \mathbf{6CO_2 + 6H_2O + 38ATP}$$



Anaerobic Conditions
Wall of Mitochondria
No O_2 available
Pyruvate
Lactate
Glycolysis (2 ATP)
Glucose
Glycolysis (2 ATP)
Pyruvate
O_2 available
Krebs cycle
Electron TC
36 ATP
$+CO_2$
$+H_2O$
Aerobic Conditions
Total ≈ 38 ATP

Aerobic Breakdown of a Glycogen Molecule

Glycogen

Glucose

Pyruvate

Acetyl - CoA

Kreb's cycle

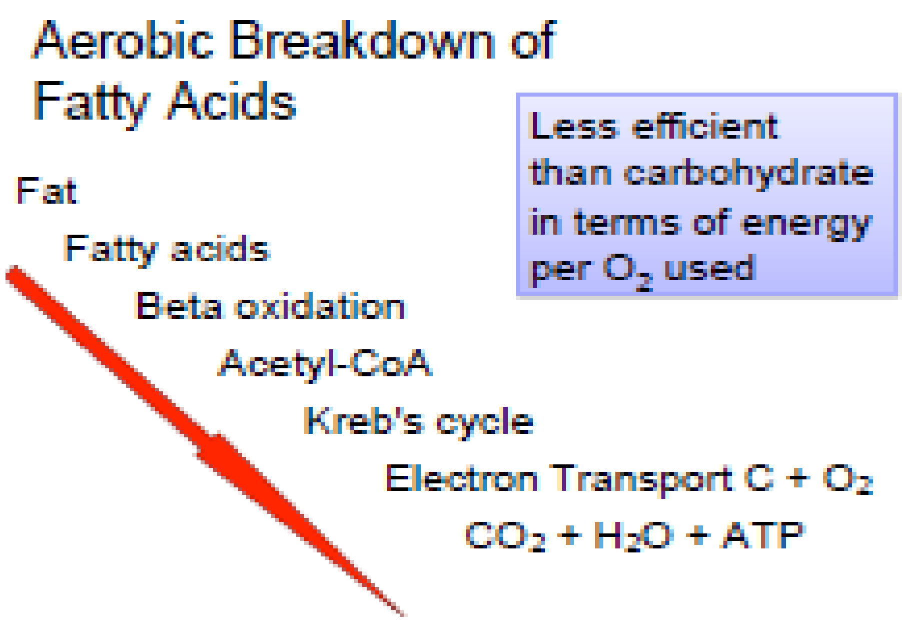
Electron Transport C + O_2

$CO_2 + H_2O + ATP$

Fat oxidation

- Lipolysis – breakdown of triglycerides into glycerol and free fatty acids (FFA's).
- Fat oxidation requires more oxygen and generates more energy than carbohydrate oxidation.

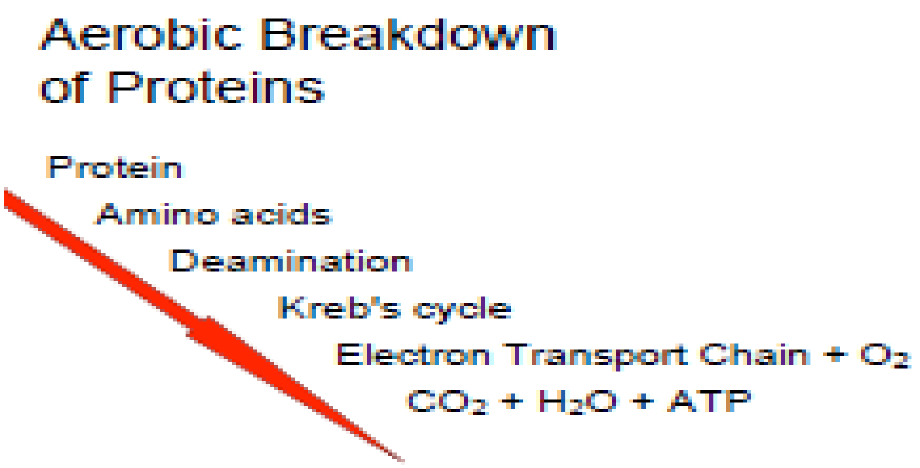
$$\textbf{Free fatty acids} + \mathbf{O_2} \xrightarrow{\text{Aerobic oxidation}} \mathbf{CO_2} + \mathbf{H_2O} + \textbf{ATP}$$



Energy Release From Protein

- Research findings indicate that protein breakdown above the resting level occurs during exercise of long duration when carbohydrate stores become low.

- It has been suggested as much as 15% of the energy during strenuous long duration exercise can come from protein.



In Exhausted Muscles

- there is an emergency metabolism for the supply of ATP.
- This is done by combining two ADP molecules to reform one ATP molecule, and one AMP (Adenosine Mono-Phosphate) molecule.

$$ADP + ADP \longrightarrow ATP + AMP$$

Relative contribution of aerobic and anaerobic energy during maximal physical activity of various durations.

	Duration of Maximal Exercise								
	Seconds			Minutes					
	10	30	60	2	4	10	30	60	120
% anaerobic	90	80	70	50	35	15	5	2	1
% aerobic	10	20	30	50	65	85	95	98	99

What Happens During Recovery?

Bodily processes do not immediately return to resting level after exercise ceases.

The difference in recovery from light to strenuous exercise related to the specific metabolic and physiologic processes in each exercise.

Blood lactate does not accumulate with either steady rate aerobic exercise or brief 5-10 sec. effort powered by high energy phosphate. So, recovery proceeds rapidly.

What Happens During Recovery?

- While anaerobic exercise powered mainly by rapid glycolysis causes lactate build up & significant disruption in physiological processes . This requires more time for complete recovery.
- Incomplete recovery time hinders the performers (e.g. basket ball, hockey , tennis)
- Procedures for speeding recovery from exercise classify as:

Passive Recovery(person inactive during it)

Active Recovery (often called cooling down), involve sub maximum aerobic exercise immediately after ex.

The following occur during recovery :

- Resynthesize of high energy phosphates.
- Replenishment of oxygen in the blood .
- Replenishment of bodily fluids.
- Replenishment of Ms. Myoglobin
- Resupply of a small energy cost to sustain an elevated circulation and ventilation .

Optimum recovery from steady-rate exercise

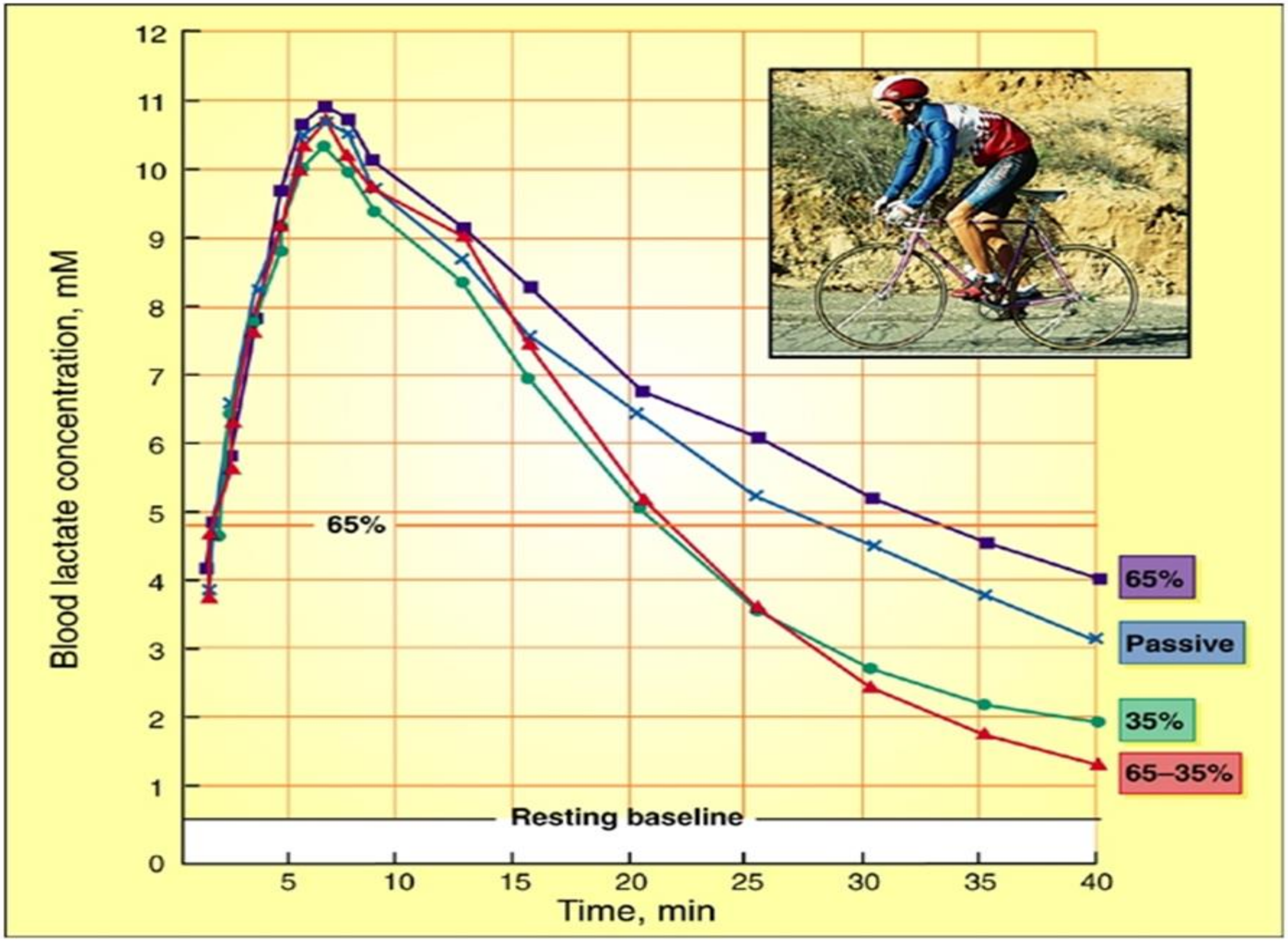
Most people can perform exercise below 55% to 60%with little or no blood lactate accumulation.

Passive recovery recommended in such cases because ex. Elevates total metabolism and delay recovery.

Optimum recovery from non steady-rate exercise

Strenuous physical activity causes accumulation of lactate . As work intensity increases, the level of lactate increases sharply, and the exerciser feels exhausted.

Moderate aerobic exercise during recovery from Strenuous physical activity is clearly better for facilitating lactate removal compared to passive recovery.



Blood lactate concentration, mM
Time, min
65%
Resting baseline
65%
Passive
35%
65–35%

Thanks