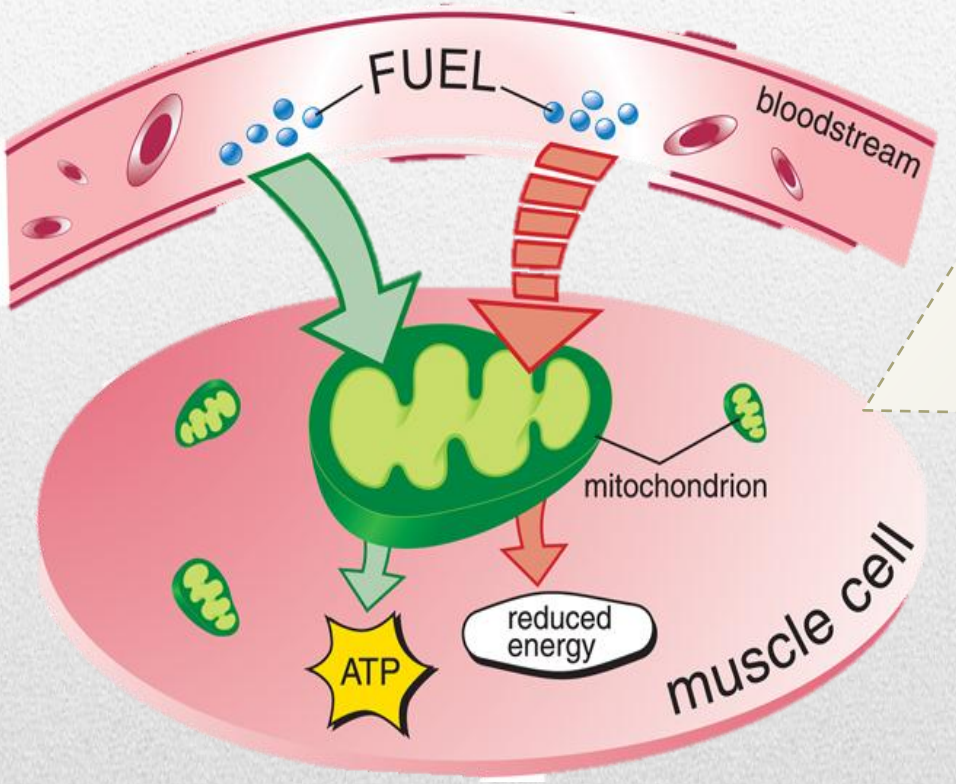
Aerobic & Anaerobic Metabolism in Muscles



- احمر = مهم
- أسود = مثل ماهو موجود بالسلايدات
- أخضر = مذكور عند البنات فقط
- أزرق = مذكور عند الأولاد فقط
- برتقالي = توضيح
- بنفسجي = شرح اضافي

OBJECTIVES

Upon completion of this lecture ،students should be able to :

- Recognize the importance of ATP as energy source in skeletal muscle.
- Understand how skeletal muscle derive and utilize ATP for energy.
- Differentiate between energy metabolism in red and white muscle fibers.

ENERGY REQUIREMENTS AND SOURCE OF ENERGY FOR SKELETAL MUSCLE

ATP as energy source

- The nucleotide coenzyme **adenosine triphosphate (ATP)** is the most important form of chemical energy stored in cells
- Breakdown of ATP into ADP+PO releases energy
- This energy is used for all body functions (biosynthesis, membrane transport, muscle contraction, etc.).
- Muscles typically store limited amounts of ATP – enough to power 4-6sec of activity
- So resting muscles must have energy stored in other ways .

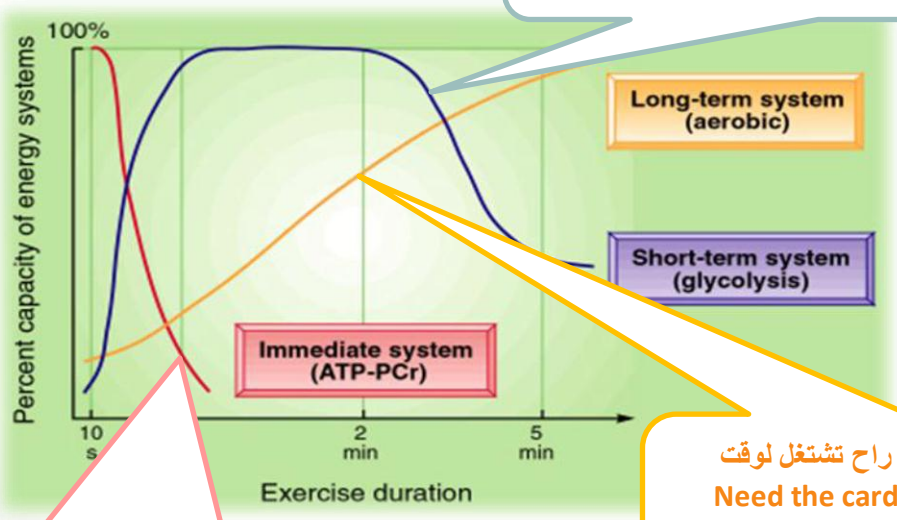
العضلة تخزن كمية قليلة من ATP على صورته الحرة حتى تستخدمه في بداية الـ activity ، يُفقد او يخلص بسرعه ← عشان كذا ما تقدر تخزن كل الـ ATP بصورة حرة وانما كمحتوى في مواد اخرى.

Production of ATP:

Contraction requires huge amounts of ATP. Muscle fibers produce ATP in three ways:

1. Creatine phosphate
2. Aerobic metabolism
3. Anaerobic metabolism

في (anaerobic) العضلة راح تشتغل لحد معين بعدين تتعب. It goes to decrease because fatigue of the muscle



THREE SYSTEMS OF ENERGY

في (aerobic) العضلة راح تشتغل لوقت طويل بدون ما تتعب. Need the cardio and respiratory function very well to gain more oxygen

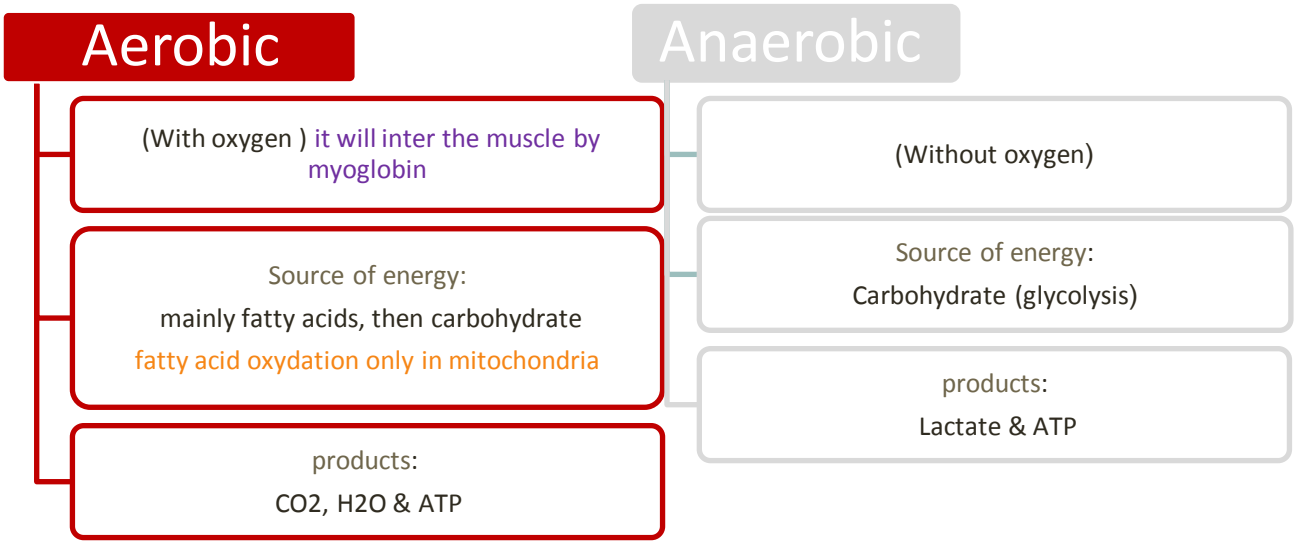
اول شي يستهلك وراح يخلص بسرعة. Creatine phosphate

ARP-PCr system : in which the generation of ATP is coupled with the exergonic (energy-releasing) breakdown of phosphocreatine stored in muscle cells.

Energy Requirements

- ♣ The three energy systems often operate simultaneously during physical activity.
- ♣ Relative contribution of each system to total energy requirement differs markedly depending on exercise intensity & duration.
- ♣ Magnitude of energy from anaerobic sources depends on person's capacity and tolerance for lactic acid accumulation (Athletes are trained so that they will have better tolerance for lactic acid).
- ♣ As exercise intensity diminishes and duration extends beyond 4 minutes, energy become more dependent on aerobic metabolism.

ENERGT METABOLISM

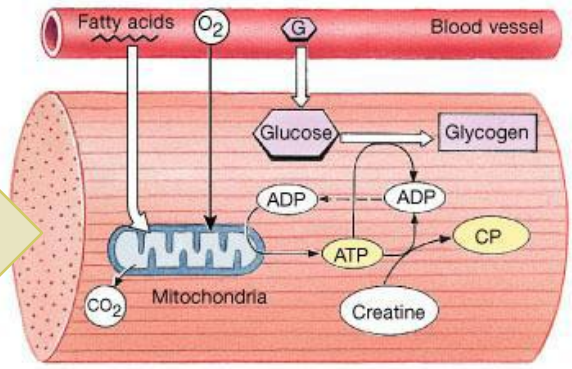


MUSCLE METABOLISM

♣ During rest:

Muscle convert glucose → glycogen ,and creatine → creatine phosphate

The energy required for the synthesis is produced by taking FA from blood and oxidizing it,

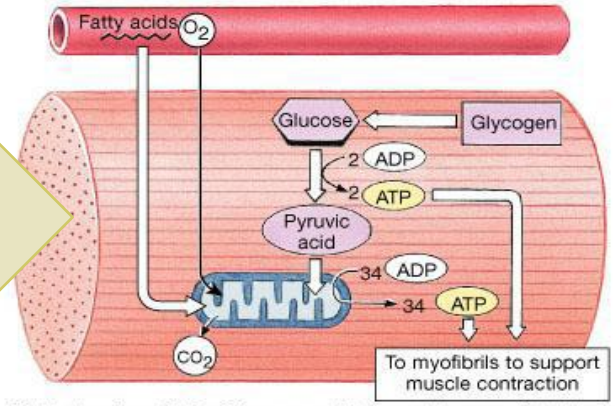


(a) Resting muscle: Fatty acids are catabolized; the ATP produced is used to build energy reserves of ATP, CP, and glycogen.

♣ During moderate activity:

Moderate = Lower intensity, longer duration →

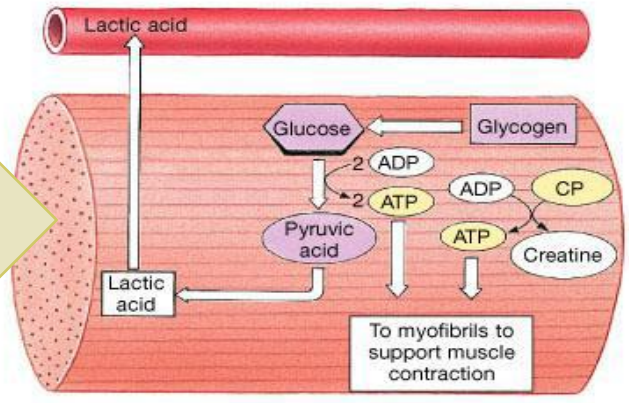
aerobic metabolism (walking for long time)



(b) Moderate activity: Glucose and fatty acids are catabolized; the ATP produced is used to power contraction.

♣ During peak activity:

Peak = short duration and high intensity effort → anaerobic metabolism (running for 30 min)

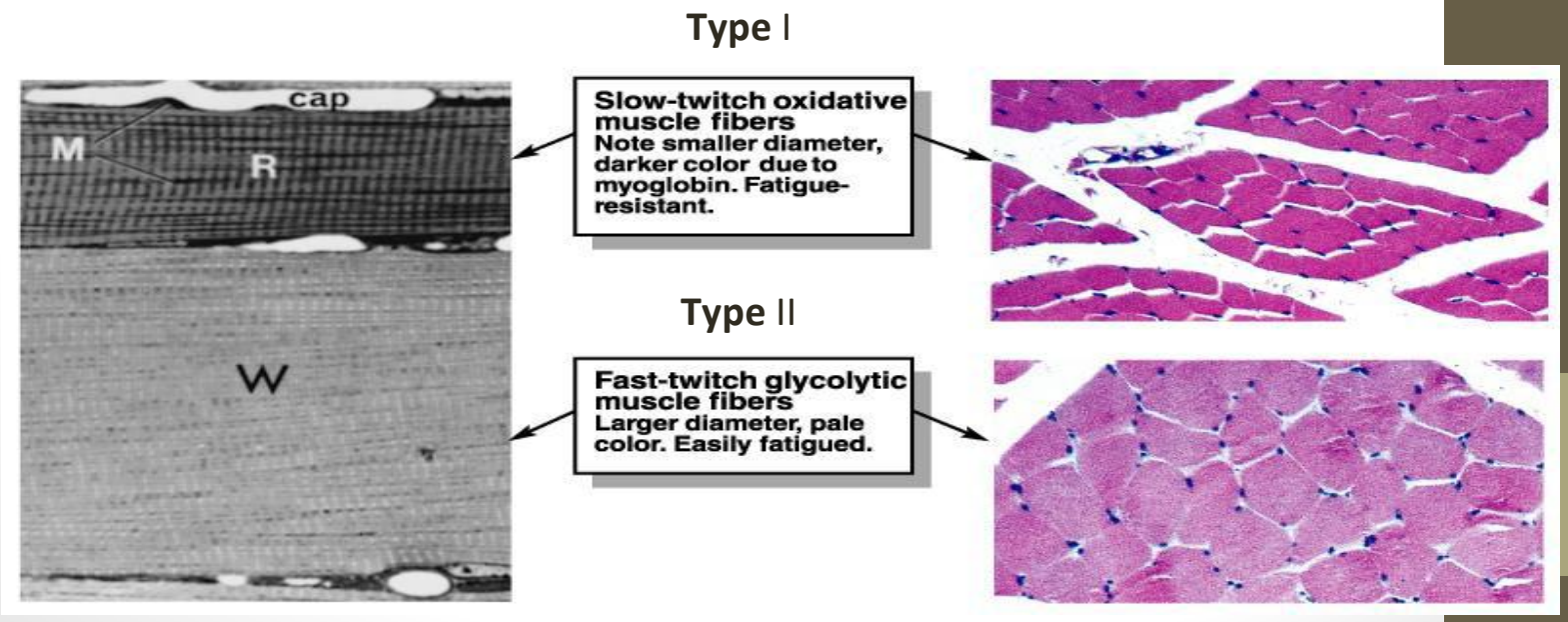


(c) Peak activity: Most ATP is produced through glycolysis, with lactic acid as a by-product. Mitochondrial activity (not shown) now provides only about one-third of the ATP consumed.

TYPES OF SKELETAL MUSCLE FIBERS

Mainly :

Slow fibers (Red, oxidative)	Fast fibers (White, Glycolytic)
Half the diameter of fast fibers	Large in diameter
- Take three times as long to contract after stimulation - Can contract for long periods of time	Produce rapid, powerful contractions of short duration
Abundant mitochondria	Relatively few mitochondria
Extensive capillary supply	Contain densely packed myofibrils
High concentrations of myoglobin To supply muscle with oxygen	Large glycogen reserves
Fatigue resistant	Easily fatigued
Obtain their ATP mainly from FA β-oxidation, TCA cycle, and the ETC	Obtain their ATP mainly from Anaerobic glycolysis



Why do chickens have white breast meat and dark leg meat? Why do migrating ducks have dark breast meat?

Because as we said, Relative contribution of each system to total energy requirement differs markedly depending on exercise intensity & duration.

- الدجاجة لا تطير، ولكنها تبذل مجهود كبير في وقت قصير اثناء محاولتها الطيران← anaerobic ← type II
- الطيور المهاجرة تبذل مجهود منتظم لوقت طويل ← aerobic ← type I

Remember:

there are two types of exercises :

- Peak : short duration, high intensity → anaerobic (running for 30 min)
- Moderate: Lower intensity, longer duration → aerobic (walking for long time)

MUSCLE FATIGUE

Fatigued muscle no longer contracts due to:

- Buildup of lactic acid (low pH of sarcoplasm) Which it is not normal environment sarcoplasm
- Exhaustion of energy resources (ADP & ATP)
- Ionic imbalance Between K, Na, Ca

How would a fatigued muscle be able again to contract؟

- Recovery period: Begins immediately after activity ends.
- Oxygen debt (excess post-exercise oxygen consumption) Amount of oxygen required during resting period to restore muscle to normal conditions

WHAT IS GOING ON IN RESTING MUSCLE?

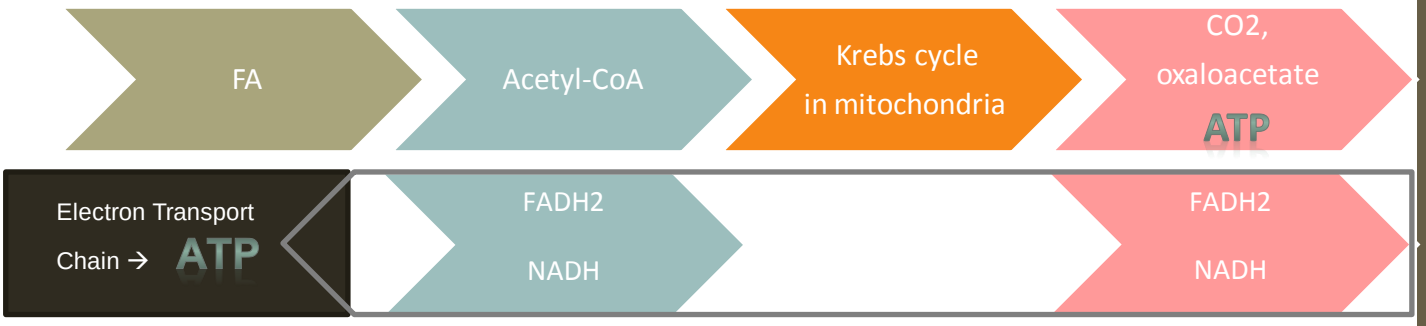
Resting Muscle and the Krebs Cycle

1. Resting muscle fibers typically takes up fatty acids from the blood stream.

2. Inside the muscle fiber, the (in the mitochondria) to produce Acetyl-CoA & several molecules of NADH and FADH2

3. Acetyl-CoA will then enter the Krebs cycle (in the mitochondria) → CO2, ATP, NADH, FADH2, and oxaloacetate

4. NADH and FADH2 will enter the Electron Transport Chain. (in the inner mitochondrial membrane) → synthesis of ATP



ATP Use in the Resting Muscle Cell (The muscles actually not resting, it working by synthesis molecules and it need ATP)

ATP is necessary for cellular housekeeping duties, e.g.:

- for glycogenesis: forming glycogen (storage form of glucose)
- to create creatine phosphate (energy storage compound)

Working Muscle

As we begin to exercise, we almost immediately use our stored ATP

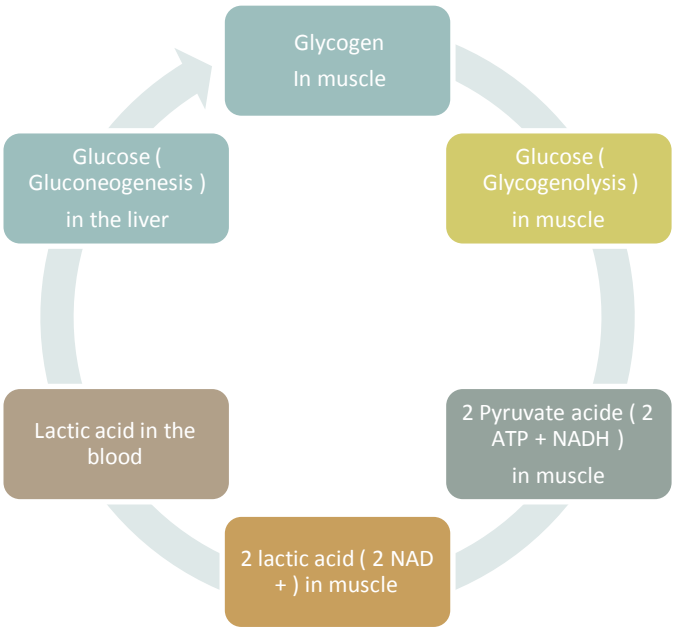
For the next 15 seconds or so, we turn to the creatine-phosphate .

This system dominates in events such as the 100m dash or lifting weights

After the phosphagen system is depleted, the muscles must find another ATP source .

The process of anaerobic metabolism can maintain ATP supply for about 45-60s .

Anaerobic Metabolism



It usually takes a little time for the respiratory and cardiovascular systems to catch up with the muscles and supply O^2 for aerobic metabolism .

Anaerobic metabolism is inefficient …Why ؟

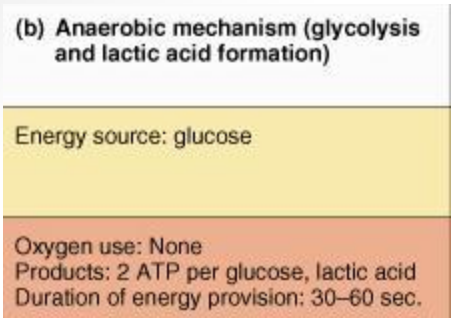
◦Large amounts of glucose are used for very small ATP returns .

2 ATP per glucose (aerobic is efficient)

◦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 .

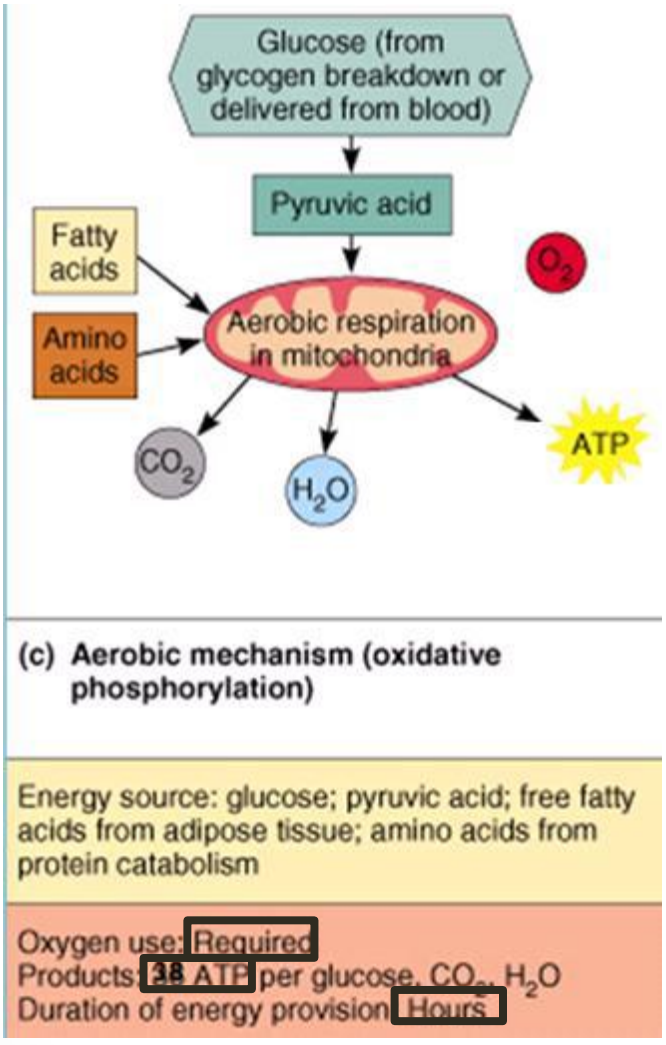


Aerobic Metabolism :

Occurs when the respiratory and cardiovascular systems have“ caught up with ”the working muscles .

◦Prior to this, some aerobic respiration will occur thanks to the muscle protein ،myoglobin ،which binds and stores oxygen .

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

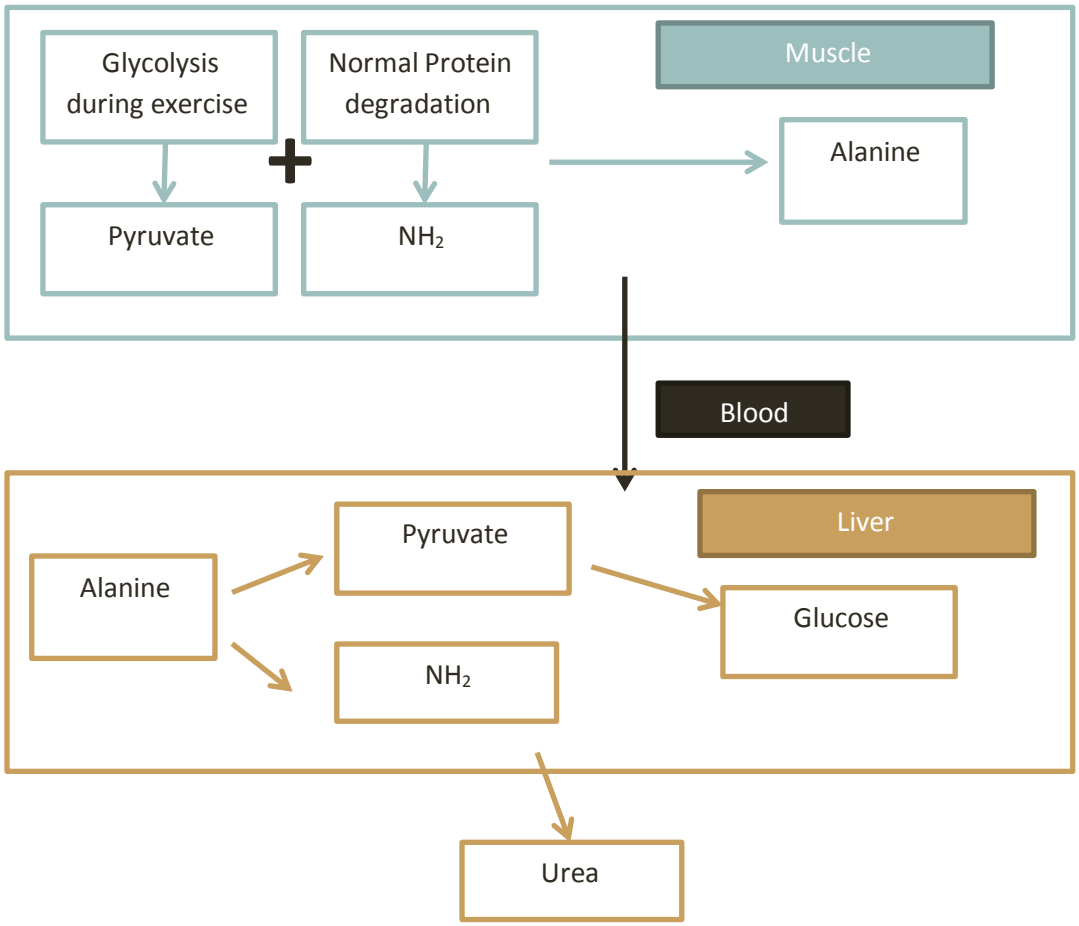


The Cori cycle

Liver converts lactate into glucose via gluconeogenesis

The newly formed glucose is transported to muscle to be used for energy again.

The glucose-alanine cycle



Pyruvate from glycolysis during exercise and NH2 produced from normal protein degradation produce Alanine
This alanine is transported through the blood to liver
liver converts alanine back to pyruvate
The newly formed glucose is transported to muscle to be used for energy again

Qs:

1- in anaerobic metabolism, the source of energy is :

- ♣ FA
- ♣ Carbohydrates
- ♣ Proteins
- ♣ Lactic acid

2- Slow fibers :

- ♣ Take short time to contract after stimulation
- ♣ use glycolysis to produce energy
- ♣ contract for long periods
- ♣ Easily fatigued

3- Anaerobic metabolism is inefficient due to :

- ♣ Small amount of Glucose and ATP
- ♣ Large amount of ATP
- ♣ Lactic acid is produce which contributes in muscle fatigue

4- In the glucose-alanine cycle, alanine converted to pyruvate in :

- ♣ Kidney
- ♣ Intestine
- ♣ Liver
- ♣ Muscle