Do Now:

What is the neurotransmitter that is released from the neuron at the NMJ?
When it binds to sarcolemma receptors, what occurs?
To what does calcium bind? What occurs when this bond forms?

Muscular System - Part III

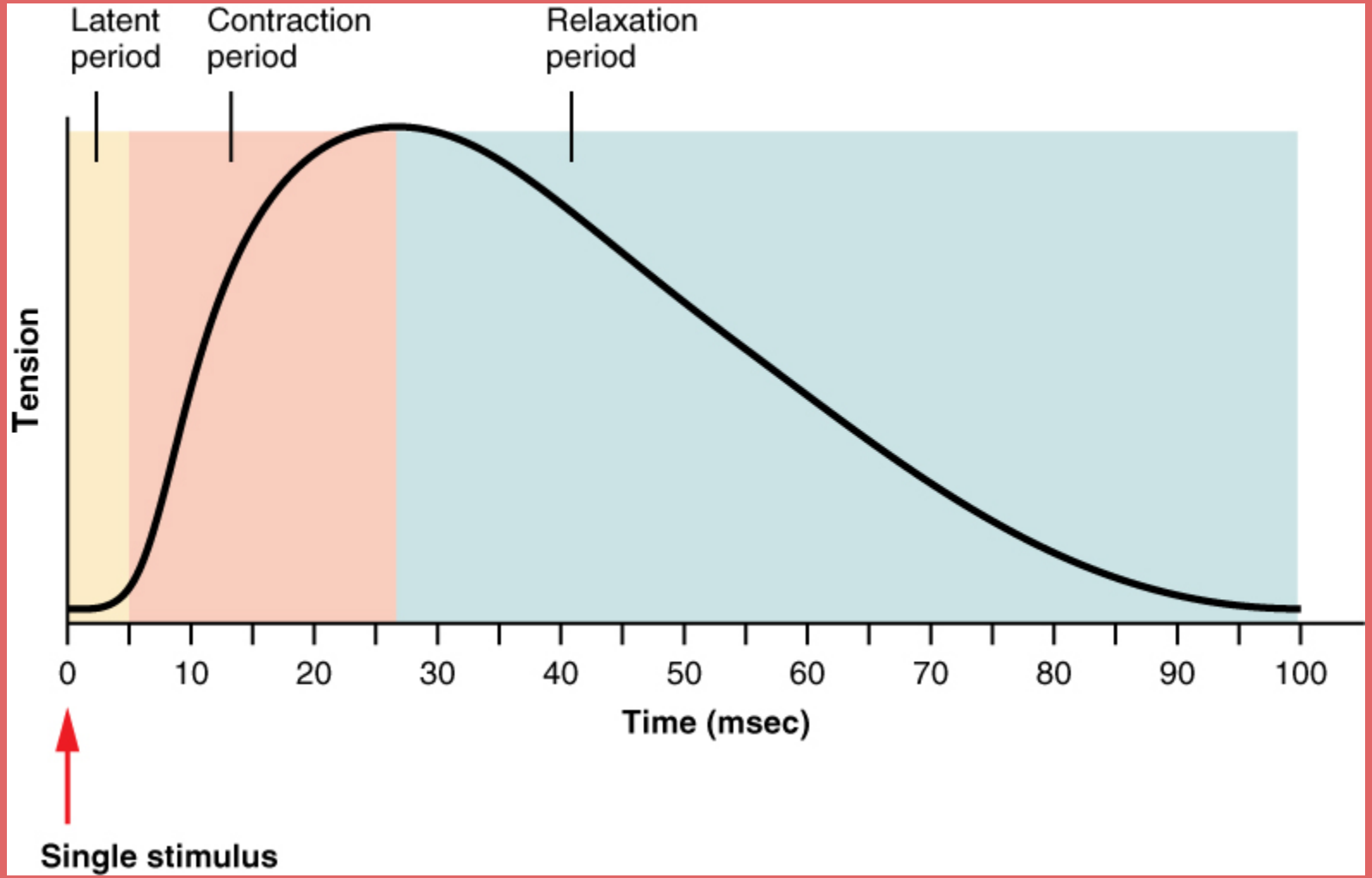
Tension, Contractions, & Metabolism

Motor Unit

- Involves a motor neuron & all of the muscle cells it stimulates.
  - When the neuron stimulates all of the muscles it innervates will contract.
- Small Motor Units
  - Fine control muscles
- Large Motor Units
  - Weight-bearing muscles

Muscle Twitch

- Motor unit's response to a single action potential of its motor neuron
  - Three phases
    - Latent period: time between stimulation and the onset of muscle contraction
      - cross bridges begin to cycle but muscle tension is not yet measurable
    - Period of Contraction
      - cross bridges are active
      - if tension becomes great enough to overcome the resistance of the load, the muscle shortens
    - Period of relaxation
      - contractile force declines, muscle tension decreases to zero, returns to initial length

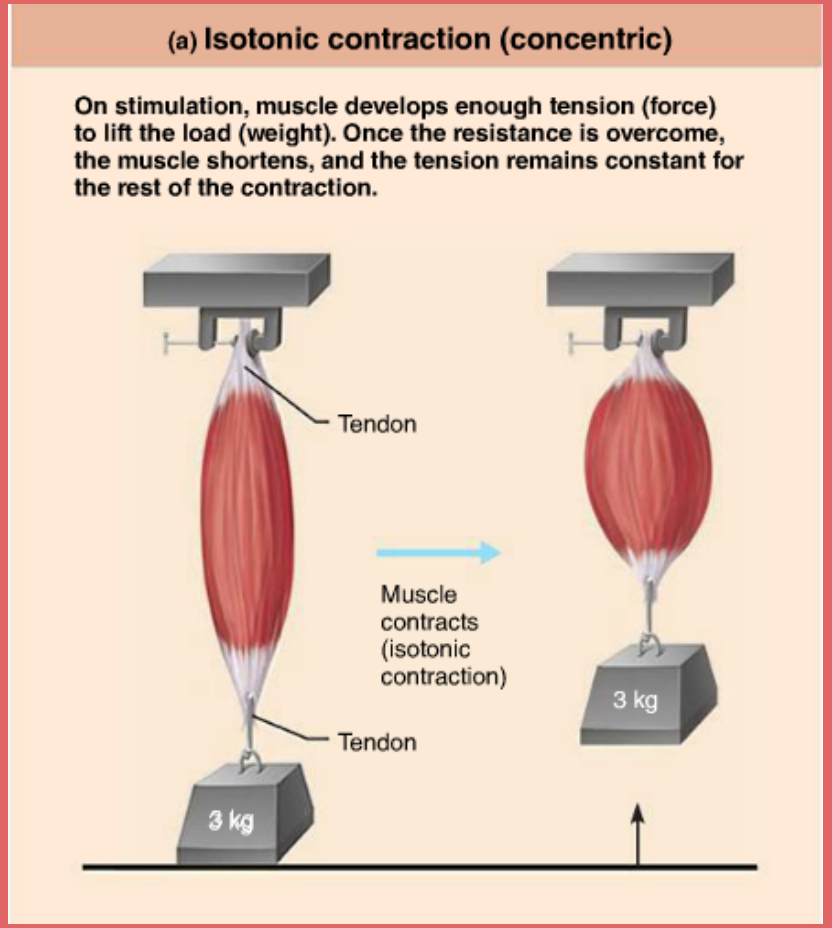

Latent period
Contraction period
Relaxation period
Tension
0
10
20
30
40
50
60
70
80
90
100
Time (msec)
Single stimulus

Muscle Tension

- Force exerted by a contracting muscle on an object.
  - Load - opposing force exerted on the muscle by the weight of an object to be moved.
- Isometric Tension
- Isotonic Tension

Isotonic Tension

- Muscle tension develops, muscle overcomes the load, & the muscle shortens.
  - measures the amount of the muscle shortening.

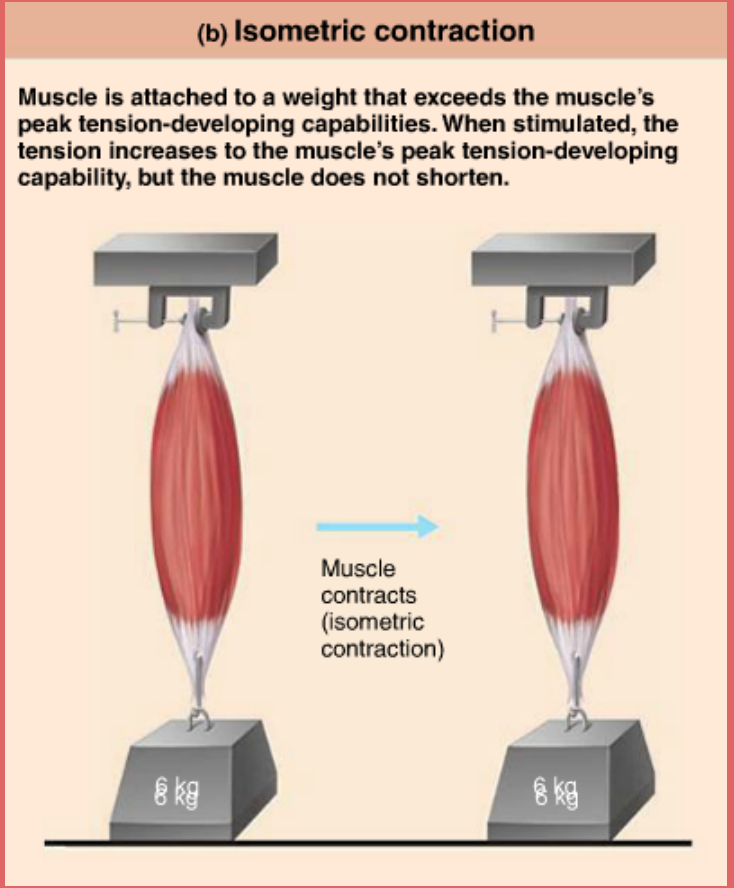


Isotonic Contractions

- Muscle length changes
- Moves a load
- Two types of isotonic contractions:
  - Concentric
    - Muscle shortens & does work
  - Eccentric
    - Muscle generates force as it lengthens (stretched)

Isometric Tension

- Muscle tension develops but the load is not moved.
  - measures increasing muscle tension.



Isometric Contractions

- Muscle neither shortens or lengthens
- Tension builds until muscle reaches it tension capacity
- Contraction occurs to hold an upright or stationary position

Muscle Tone

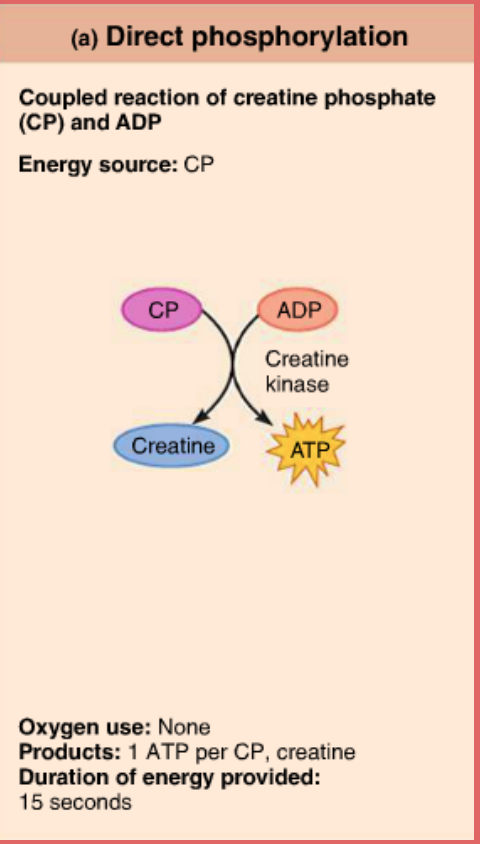
- Low levels of contractile activity in relaxed muscle
  - Keeps the muscle healthy and ready to act
- Due to spinal reflexes activating one group of motor units and then another in response to activated stretch receptors in muscles
- Helps stabilize joints and maintain posture

Muscle Metabolism

Provides Energy for Contraction

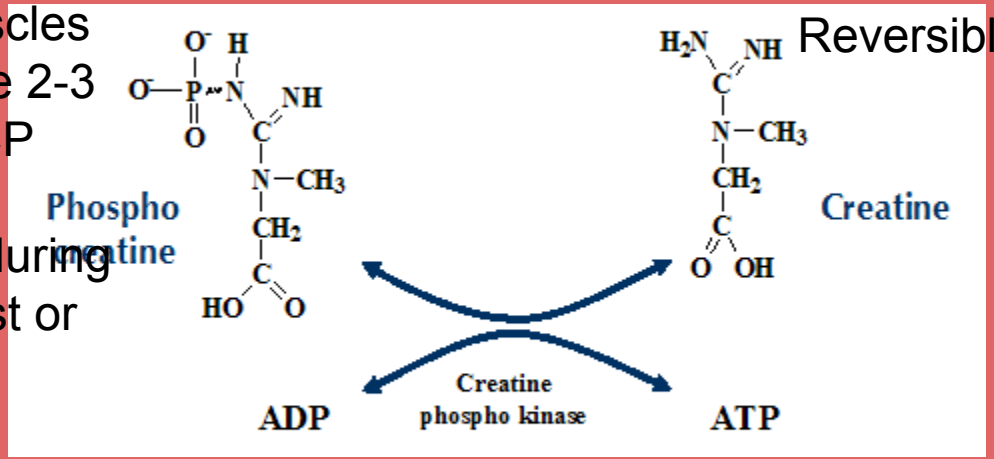
- ATP is the form of energy used for contractions (it is the only energy source used).
  - ATP must be regenerated as fast as it is used.
  - Muscles can only store 4 to 6 seconds of ATP.
  - Can be regenerated within a fraction of a second:
    - Direct phosphorylation of ADP by creatine phosphate
    - Anaerobic, glycolysis, converts glucose to lactic acid
    - Aerobic Respiration

Direct Phosphorylation



Fastest Pathway

- unique high-energy molecule stored in muscles
- muscles store 2-3 times more CP then ATP
- replenished during periods of rest or inactivity

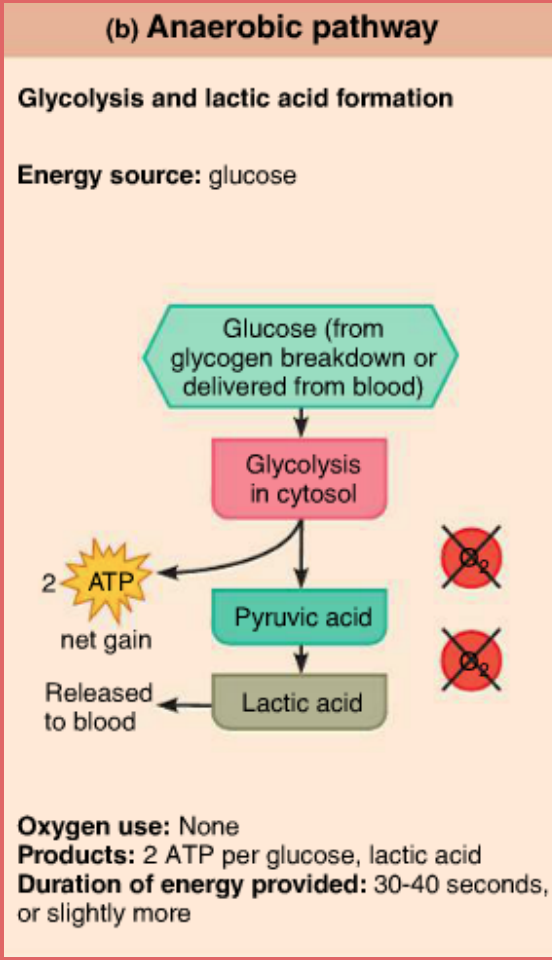


Reversible

Enzyme that catalyzes rxn

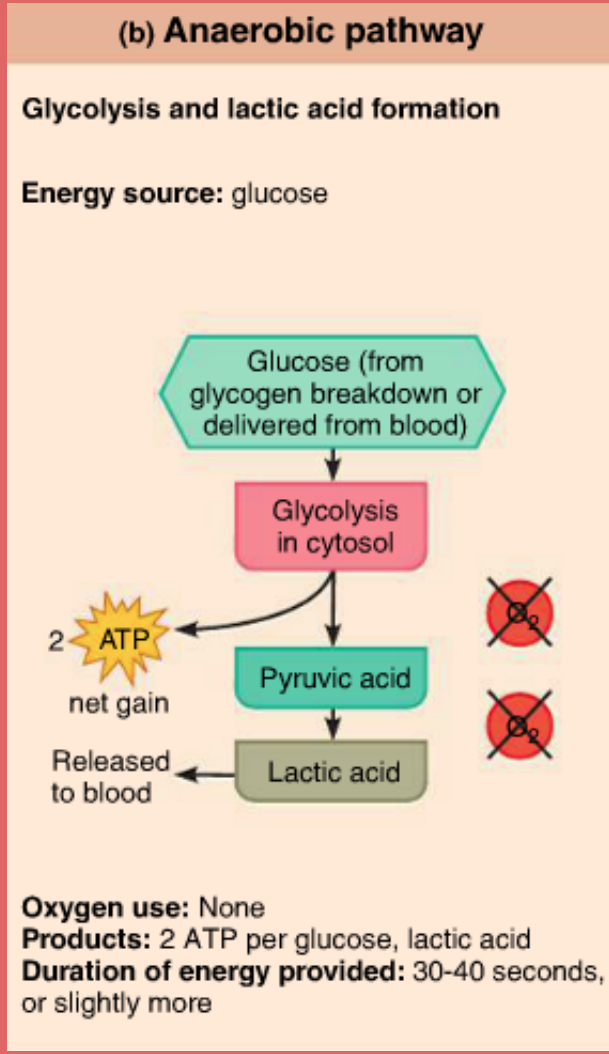
Anaerobic Pathway

- when ATP and CP are exhausted
- break down glucose from blood or glycogen stored in the muscle
- Glycolysis: glucose breaks down to two pyruvic acid molecules releasing small amounts of ATP
- When muscles contract vigorously and contractile activity reaches 70% of max possible, bulging muscles compress the blood vessels, impairing blood flow and oxygen delivery → anaerobic glycolysis



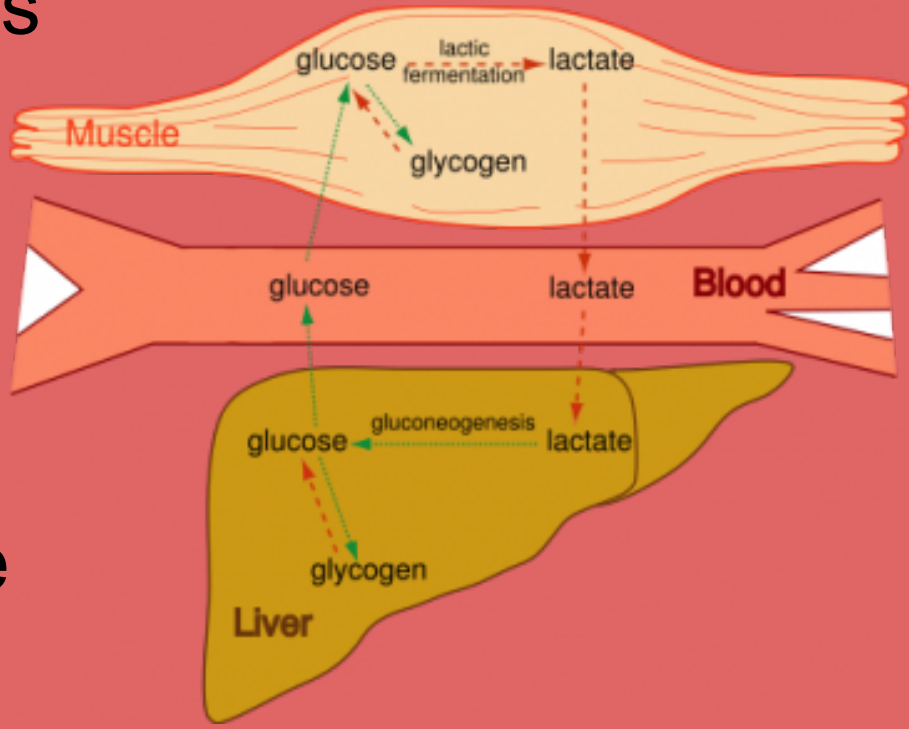
Anaerobic Glycolysis

- Energy yielding conversion of glucose to **lactic** acid when sufficient oxygen is not available
- Lactic acid
  - diffuses out of muscles into bloodstream
  - liver cells can reconvert to pyruvic acid or glucose for further muscle use, or glycogen for storage



Anaerobic Pathway

- harvests only about 5% as much ATP as aerobic pathway but 2 ½ times faster
  - readily fuels spurts vigorous exercise
- Huge amounts of glucose used to produce small amounts of ATP



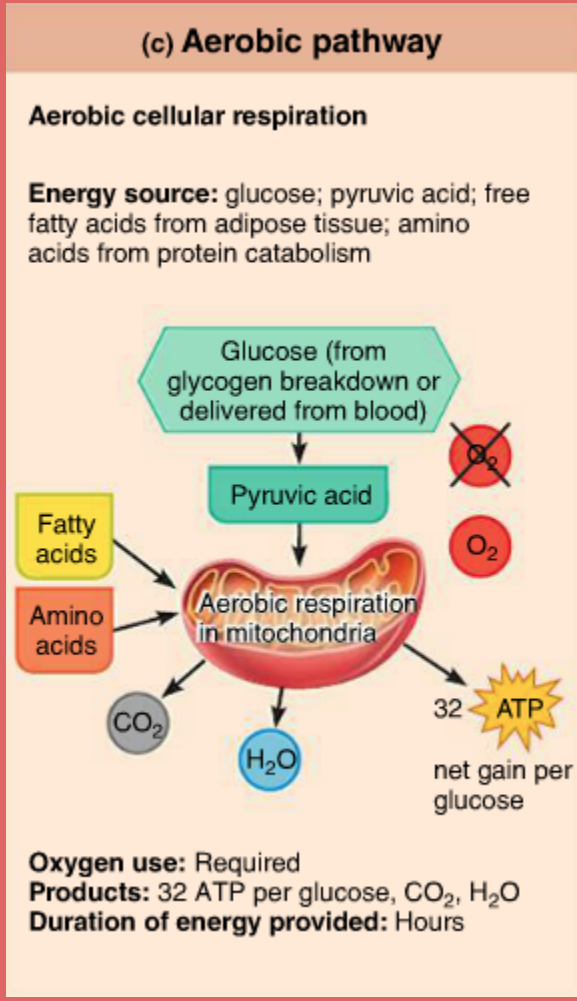
Aerobic pathway

- Occurs in mitochondria
- Sequence of chemical reactions that break the bonds of fuel molecules and release energy to make ATP

1. Glycolysis
2. Glucose + oxygen → carbon dioxide + water + ATP

diffuses out of muscle into the blood to be removed by lungs

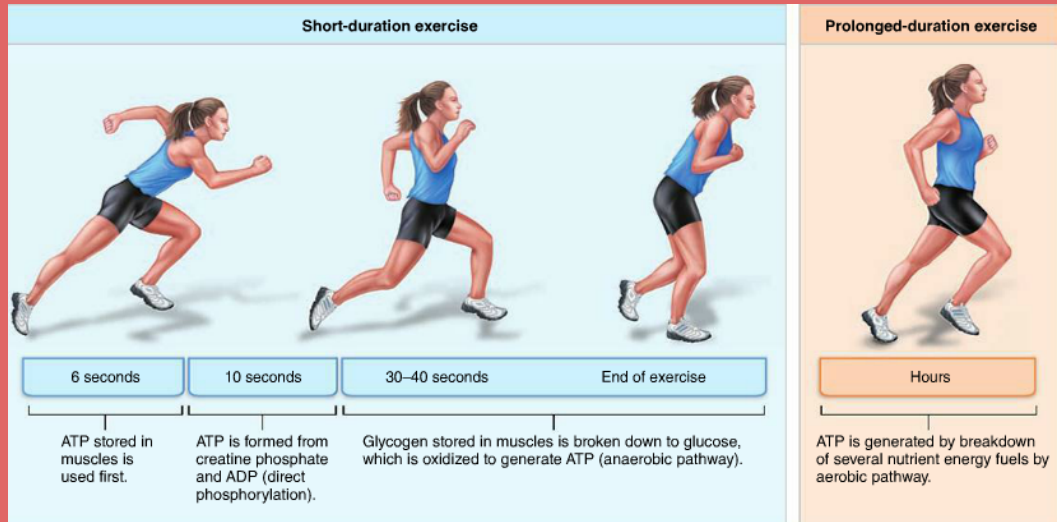
- Produces high yield of ATP
- Slow because of many steps
- Requires continuous delivery of oxygen and nutrients



Energy systems used during sports

Aerobic endurance: length of time a muscle can continue to contract using aerobic pathways

Anaerobic Threshold: the point at which muscle metabolism converts to anaerobic glycolysis



Muscle Fatigue

- A state of physiological inability to contract even though the muscle still may be receiving stimuli
  - Muscle fatigue occurs when:
    - ATP production fails to keep pace with ATP use
    - There is a relative deficit of ATP, causing contractures
    - Ionic imbalances are present
    - Intense exercise produces rapid muscle fatigue (with rapid recovery)

Muscle Fatigue Occurs When cont..

- Na+-K+ pumps cannot restore ionic balances quickly enough
- Low-intensity exercise produces slow-developing fatigue
- Sarcoplasmic Reticulum is damaged and Ca2+ regulation is disrupted

Heat Production

- Only 20-25% of the energy released in muscle activity is useful as work.
- The other 75-80% of the energy is released as heat.
  - Dangerous levels of heat are prevented by radiating the heat from skin and sweating (cools the body).