Muscle Metabolism

Background

- ATP is the source of energy for muscle contraction.
  *recall: ATP hydrolysis allows myosin head to cock*

- Muscles store a very limited amount of ATP (4-6 seconds worth at most).

- ATP must be regenerated if contraction is to continue beyond 4-6 seconds.

- ATP can be generated by one of three pathways....
Muscle Metabolism

Aerobic Metabolism/Cellular Respiration

1. Description:
   - Occurs in mitochondria, requires oxygen, and involves a complex sequence of chemical reactions.

2. Chemical Formula:
   - \[ \text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy} (36 \text{ ATP}) \]

3. When this system is used:
   - Used during prolonged, endurance activities which maintain a constant heart rate
   - As long as there is enough oxygen available relative to ATP demand, a muscle will utilize aerobic metabolism.
   - Posture, most daily movements, marathon runs, bike riding
Muscle Metabolism

Anaerobic Metabolism/Glycolysis

1. Description:
   - When muscles contract vigorously, the bulging muscles compress blood vessels within, impairing oxygen delivery.
   - This pathway can occur in the absence of oxygen.

2. Chemical Formula:
   - \( \text{Glucose} \rightarrow \text{lactic acid} + \text{energy (2 ATP)} \)

3. When this system is used:
   - When large amounts of ATP relative to available \( \text{O}_2 \) are needed. Usually for exercise about 30-40 seconds long.
   - *Tennis, soccer, 100 meter swim*
Muscle Metabolism

Anaerobic Metabolism/Creatine Pathway

1. Description:
   - Utilizes the molecule *creatine phosphate* to regenerate ATP, after stored ATP is depleted.

2. Chemical Formula:
   - *Creatine phosphate* + ADP $\rightarrow$ *Creatine* + ATP (1 ATP)

3. When this system is used:
   - Mobilized at the beginning of exercise, before other pathways ‘kick in’.
   - Creates enough energy for about 15 seconds of contraction.
   - *100 meter dash, weightlifting*
# Muscle Metabolism

## Summary

<table>
<thead>
<tr>
<th></th>
<th>Creatine Pathway</th>
<th>Glycolysis Pathway</th>
<th>Aerobic Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires Oxygen</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Amount of ATP</td>
<td>1 ATP</td>
<td>2 ATP</td>
<td>36 ATP</td>
</tr>
<tr>
<td>Duration</td>
<td>15 sec</td>
<td>30-60 sec</td>
<td>hours</td>
</tr>
<tr>
<td>By-product</td>
<td>creatine</td>
<td>lactic acid</td>
<td>CO$_2$, H$_2$O</td>
</tr>
<tr>
<td>Advantages</td>
<td>• rapid energy</td>
<td>• quick energy</td>
<td>• more ATP/glucose</td>
</tr>
<tr>
<td></td>
<td>• easily mobilized</td>
<td>• does not require oxygen</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• waste products are easy to excrete</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>• small amount of creatine available</td>
<td>• less ATP/glucose</td>
<td>• slower</td>
</tr>
<tr>
<td></td>
<td>• small amount of ATP</td>
<td>• lactic acid produces muscle fatigue</td>
<td>• limited by oxygen</td>
</tr>
</tbody>
</table>
Muscle Metabolism

Fast Twitch/Slow Twitch Muscle

- **Slow-twitch muscle fiber**
  - is aerobic
  - has steady power
  - has endurance

- **Fast-twitch muscle fiber**
  - is anaerobic
  - has explosive power
  - fatigues easily
## Muscle Metabolism

### Fast Twitch/Slow Twitch Muscle

<table>
<thead>
<tr>
<th>Fast Twitch</th>
<th>Slow Twitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack myoglobin and are lighter in color</td>
<td>Contains myoglobin and are dark in color</td>
</tr>
<tr>
<td>Contain few mitochondria</td>
<td>Contain many mitochondria</td>
</tr>
<tr>
<td>Primarily anaerobic – does not need O₂ and produces lactic acid</td>
<td>Primarily aerobic – uses O₂ and produces CO₂ and H₂O</td>
</tr>
<tr>
<td>Fatigue easily</td>
<td>Fatigue slowly</td>
</tr>
<tr>
<td>Produce more forceful contraction</td>
<td>Produce less forceful contraction</td>
</tr>
<tr>
<td>Increase in size with training</td>
<td>Do not increase in size</td>
</tr>
</tbody>
</table>
Muscle Fatigue

Definition: the state of physiological inability to contract

Causes

1. Occurs when ATP production fails to keep up with ATP use.
   - Note: this is a relative deficit of ATP, as opposed to total absence of ATP which leads to a continuous state of contraction (rigor mortis, writer's cramp)

2. Accumulation of lactic acid and ionic imbalances also contribute.
   - decreases muscle pH
   - causes burning sensation
   - interferes with actin/myosin binding