9.1B: Slow-Twitch and Fast-Twitch Muscle Fibers

Skeletal muscle contains different fibers which allow for both rapid short-term contractions and slower, repeatable long-term contractions.

Learning Objectives

- Describe the different types of skeletal muscle fibers and their respective functions

Key Points

- Slow-twitch fibers rely on aerobic respiration to fuel muscle contractions and are ideal for long term endurance.
- Fast-twitch fibers rely on anaerobic respiration to fuel muscle contractions and are ideal for quick contractions of short duration.

Key Terms

- **aerobic**: A combination of glycolysis and the Krebs cycle, an efficient but slow way of producing ATP.
- **anaerobic**: Glycolysis alone, an inefficient but quick way of producing ATP with pyruvate converted to lactate.
- **glycolysis**: The breakdown of glucose (or other carbohydrates) by enzymes, generating ATP and pyruvate.
- **slow-twitch**: Type I fibers characterized as muscles with long contraction duration, associated with endurance.
- **Krebs cycle**: A sequence of reactions which converts pyruvate into carbon dioxide and water, generating further adenosine triphosphate (ATP).
- **fast-twitch**: Type II fibers which are characterized by fast muscle contractions of short duration.
Skeletal muscle fibers can be further subdivided into slow and fast-twitch subtypes depending on their metabolism and corresponding action. Most muscles are made up of combinations of these fibers, although the relative number substantially varies.

**Slow Twitch (Type 1)**

Slow-twitch fibers are designed for endurance activities that require long-term, repeated contractions, like maintaining posture or running a long distance. The ATP required for slow-twitch fiber contraction is generated through aerobic respiration (glycolysis and Krebs cycle), whereby 30 molecules of ATP are produced from each glucose molecule in the presence of oxygen. The reaction is slower than anaerobic respiration and thus not suited to rapid movements, but much more efficient, which is why slow-twitch muscles do not tire quickly. However, this reaction requires the delivery of large amounts of oxygen to the muscle, which can rapidly become rate-limiting if the respiratory and circulatory systems cannot keep up.

Due to their large oxygen requirements, slow-twitch fibers are associated with large numbers of blood vessels, mitochondria, and high concentrations of myoglobin, an oxygen-binding protein found in the blood that gives muscles their reddish color. One muscle with many slow-twitch fibers is the soleus muscle in the leg (~80% slow-twitch), which plays a key role in standing.

**Fast Twitch (Type II)**

Fast-twitch fibers are good for rapid movements like jumping or sprinting that require fast muscle contractions of short duration. Unlike slow-twitch fibers, fast twitch-fibers rely on anaerobic respiration (glycolysis alone) to produce two molecules of ATP per molecule of glucose. While much less efficient than aerobic respiration, it is ideal for rapid bursts of movement since it is not rate limited by need for oxygen. Lactate (lactic acid), a byproduct of anaerobic respiration, accumulates in the muscle tissue reducing the pH (making it more acidic, and producing the stinging feeling in muscles when exercising). This inhibits further anaerobic respiration. While this may seem counter-intuitive, it is a feedback cycle in place to protect the muscles from over-exertion and resultant damage.

As fast-twitch fibers generally do not require oxygenation, they contain fewer blood vessels and mitochondria than slow-twitch fibers and less myoglobin, resulting in a paler color. Muscles controlling eye movements contain high numbers of fast-twitch fibers (~85% fast-twitch).

**Determination and Alteration of Muscle Type**

While there is evidence that each person has a unique proportion of fast-twitch versus slow-twitch muscles determined by genetics, more research is required. Regardless, repeated exercise that prioritizes one type of muscle fiber use over the other can lead to improvements in an individual’s ability to perform that activity through alterations in the number and composition of fibers associated with improvements in the respiratory and circulatory systems.