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5.1.1 Review Your Key Terms

- actin
- agonist (prime mover)
- antagonist
- cross bridge formation
- fast twitch (FT) fibre
- fixator
- muscle biopsy
- muscle fibre
- myofibril
- myofilament
- myosin
- sarcolemma
- sarcomere
- skeletal muscle
- sliding filament theory
- slow twitch (ST) fibre
- striated muscle
- synergist
- tendon
- tropomyosin
- troponin

5.1.2 Muscle Teamwork

Bending or straightening the elbow requires the coordinated interplay of the biceps and triceps muscles. Briefly explain the relationship between these two muscles during flexion and extension of the elbow, and identify which muscle is the agonist and antagonist in both cases.

An agonist–antagonist relationship occurs between the biceps and triceps muscles of the arm. When one muscle contracts (draws together) to move the bone, the other relaxes, allowing the bone to move.

When the biceps (agonist) contracts to flex the elbow joint (A), the triceps (antagonist) relaxes and allows the bend.

When the triceps (agonist) contracts to extend the elbow joint (B), the biceps (antagonist) in turn relaxes.
5.1.3 Bundle of Muscle

Label the components of skeletal muscle below, and explain how its structure is similar to an electrical cord.

![Image of muscle structure and function]

The cylinder-shaped muscle cells (fibres) are each made up of a number of myofibrils, and are surrounded by a connective tissue sheath (sarcolemma); a variable number of fibres are enclosed together by a thicker connective tissue sheath to form a bundle of fibres. This is similar to the structure of an electrical cord, which has bundles of coloured wires with numerous copper wires enclosed within each bundle. These bundles are then also housed within a larger sheath, just as numerous muscle fibre bundles make up a larger muscle belly.

5.1.4 Striated Appearance

Skeletal muscle is considered striated because of the alternating light and dark bands that appear when viewed under a microscope. Fill in the appropriate numbers on the microscopic view below using the labels provided.

1 A band  
2 H zone  
3 I band  
4 M line  
5 sarcomere  
6 Z line
5.1.5 Contractile Components

The various components within a sarcomere are arranged specifically for muscle contraction. In the figure below, identify and label the overlap zones within the myofibril.

During a muscle contraction, it is the sliding of the thin actin filaments over the thick myosin filaments that causes shortening of the muscle to create movement – a phenomenon known as the sliding filament theory. Highlight the filaments that are attached to the Z line in the figure above. [Thin actin filaments should be highlighted.]

5.1.6 Flex It and Sketch It

The following schematic diagrams illustrate sarcomeres at various points of muscle contraction. Identify which diagram shows the sarcomeres at rest, contracted, and stretched. Then sketch a sarcomere that is overcontracted in the space provided, and briefly explain how the myofibril differs in this state of contraction. Be sure to use the terms actin, myosin, sarcomere, and cross bridge.

<table>
<thead>
<tr>
<th>Schematic Diagram</th>
<th>State of Contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>At rest</td>
</tr>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>Stretched</td>
</tr>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>Contracted</td>
</tr>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>Overcontracted</td>
</tr>
</tbody>
</table>

When the sarcomeres are too close together, as would occur when the muscle is shortened (over-contracted), the cross bridges actually interfere with one another as they try to form between the myosin (heads) and actin filaments. This results in a fewer number of effective cross bridges being formed, and a decreased ability to develop force.
5.1.7 Optimal Joint Angle

In your own words, explain the graph below showing maximal muscle force changes throughout elbow flexion.

As a joint moves through its range of motion, the muscles move from a stretched position to a compressed position, and at some point pass through the **optimal joint angle**, the optimal length for maximal force development. Maximal force is developed when an optimal number of cross bridges are formed, which occurs at an optimal joint angle. During flexion of the elbow joint, maximal force development increases as the joint angle increases until the optimal joint angle between 90 and 120 degrees. Increasing the joint angle beyond this optimal angle results in reduced maximal force development.

5.1.8 Muscle Fibre Types

Complete the table below, which describes the characteristics of Type I and Type II muscle fibres.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contraction speed</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Microscopic appearance (colour)</td>
<td>Red</td>
<td>White</td>
</tr>
<tr>
<td>Capacity for aerobic energy supply</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Diameter (muscle fibre size)</td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td>Number of surrounding capillaries</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Fatigue resistance</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Contraction strength/Power production</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Sporting event</td>
<td>Endurance: long-distance running, swimming, cycling</td>
<td>Power: 100 m sprint</td>
</tr>
</tbody>
</table>
5.1.9 Fast or Slow?

For the list of sporting events/activities listed below, indicate the relative involvement of slow twitch and fast twitch muscle fibres (high or low). The first example has been filled in for you.

<table>
<thead>
<tr>
<th>Sport/Activity</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500-metre run*</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Marathon</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Olympic wrestling*</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Basketball</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Distance swimming</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Hip-hop dancing at a club</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Volleyball</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>High jumping</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>100-metre sprint</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Springboard diving</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

* Both fibre types may be high in some individuals.

For the muscle biopsy image below, highlight or colour the areas that represent Type II fibres. How can you distinguish these fibres from Type I fibres?

_Muscle fibres can be divided into the categories of fast twitch (FT or Type II) (also called white fibres based on their microscopic appearance) and slow twitch (ST or Type I) (also called red fibres based on their microscopic appearance)._
5.2 NERVE–MUSCLE INTERACTION AND ADAPTATION TO EXERCISE
(Textbook pages 108-113)

5.2.1 Review Your Key Terms

- all-or-none principle
- biological adaptation
- central nervous system (CNS)
- intermuscle coordination
- intramuscle coordination
- motor end plate
- motor unit
- muscle force deficit
- peripheral nervous system (PNS)

5.2.2 Sensory and Motor Activity

Using the figure below as a guide, discuss the process involved as information is transferred along sensory to motor pathways. Use different colours to highlight the direction of afferent and efferent transmission.

The sensory receptors collect information from the various sensors located throughout the body (skin, eyes, ears, etc.) and transmit (afferent transmission) the information to the brain (central nervous system) where it is processed in a specific region of the cortex and acted upon. Decisions are sent via motor pathways (efferent transmission) to muscles and joints for execution. The motor neurons are involved directly in conducting the signals from the CNS to activate muscle movement.

5.2.3 Trainable vs. Non-trainable

The performance capacity of muscle is determined by several trainable and non-trainable factors. For the following list of factors, indicate whether the correct column is checked off.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Trainable</th>
<th>Non-trainable</th>
<th>True (T) or False (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary density of muscle</td>
<td>✓</td>
<td></td>
<td>T</td>
</tr>
<tr>
<td>Elasticity of muscle and its tendons</td>
<td></td>
<td>✓</td>
<td>F</td>
</tr>
<tr>
<td>Fibre diameter</td>
<td>✓</td>
<td></td>
<td>T</td>
</tr>
<tr>
<td>Fibre structure (ST or FT fibres)</td>
<td>✓</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Inter-muscle coordination</td>
<td></td>
<td>✓</td>
<td>F</td>
</tr>
<tr>
<td>Intra-muscle coordination</td>
<td>✓</td>
<td></td>
<td>T</td>
</tr>
<tr>
<td>Nerve impulse frequency</td>
<td></td>
<td>✓</td>
<td>F</td>
</tr>
<tr>
<td>Number of fibres</td>
<td>✓</td>
<td></td>
<td>F</td>
</tr>
</tbody>
</table>
5.2.4 Muscle Fibre Recruitment

The recruitment of muscle fibres during resistance work depends on the level of muscle tension. In your own words, explain the graph below.

Recruitment of muscle fibres during resistance work depends on the level of muscle tension. As the tension rises, more and more of the various fibre types are recruited into the movement as shown by the curves. Muscle tension below 25 percent of one's maximal resistance recruits mostly ST fibres. At higher resistance, FT fibres also become active.

Furthermore, which fibre is involved depends upon the muscle force that needs to be mobilized, and also the rate of acceleration of the mass to be moved. High accelerations of small loads and low accelerations of high loads require the intensive involvement of the FT fibres. Also, it is primarily the FT fibres that generate the explosive-type movements requiring a lot of strength.
CHAPTER
Muscle Structure and Function

Studying Human Movement and Health

ANSWERS

Multiple Choice

1. Which of the following statements about tendons is false:
A) Tendons are bundles of collagen fibres.
B) Like muscle, tendons also have the ability to shorten or contract.
C) Tendons function to move various parts of the skeleton in response to skeletal muscle contraction.
D) One end of the tendon is usually linked to bone and the other to a skeletal muscle.
E) None of the above.

Answer: B

2. The contractile unit of a muscle is:
A) muscle fibre
B) myofilament (myofibril)
C) sarcomere
D) myosin
E) actin

Answer: C

3. Which of the following statements regarding muscle fibre types is true:
A) The number of FT and ST fibres does not vary from one individual to another.
B) Most skeletal muscles contain both FT and ST fibres.
C) Individual performance differences cannot be attributed to the varying percentages of the muscle fibre types.
D) The number of FT and ST fibres varies from one muscle to another.
E) Both B and D.

Answer: E

4. Which of the following statements regarding the motor unit is true:
A) Each motor unit can consist of a different number of muscle fibres.
B) All muscle fibres of one particular motor unit are always the same fibre type.
C) A muscle can be composed of a different number of motor units.
D) Each muscle fibre can be innervated by only one motor unit.
E) All of the above.

Answer: E

5. Which of the following statements regarding the differences between trained and untrained individuals is false:
A) Trained individuals have a larger muscle mass and therefore can produce greater force.
B) Trained individuals further develop strength only by improving intramuscle coordination.
C) Trained individuals can activate a larger number of muscle fibres to produce greater force.
D) Trained individuals have a much smaller muscle force deficit.
E) None of the above.

Answer: B

Fill in the Blanks

Fill in the blanks for the following statements using words from the word bank below. Place the corresponding letter from the word bank in the blank spaces provided.

1. The structure of muscle tissue determines its specific function.
2. The specific function of muscle tissue is to contract.
3. The agonist is also known as the prime mover.
4. In strength training, an individual's performance improvements occur through a process of biological adaptation.
5. The end of the muscle attached to the bone that does not move is called the origin, while the point of attachment of the muscle on the bone that moves is the insertion.

Word Bank

a. activation d. insertion g. size
b. biological adaptation e. origin h. structure
c. contract f. prime mover i. synergist

True or False

Indicate whether each statement is true (T) or false (F). If the statement is false, provide the correct answer.

1. There are fibre types with characteristics that fall in between the extremes of Type I and Type II.

Answer: true

2. Most skeletal muscle is attached to another skeletal muscle, and its contraction is responsible for supporting and moving the skeleton.

Answer: false (Correct: bone)
3. Untrained individuals can normally activate up to 60 percent of the motor units of a muscle at the same time.

Answer: true

4. Simultaneous and additive shortening of sarcomeres within muscle fibres ultimately leads to muscle contraction.

Answer: true

5. The specific number of fibres in a motor unit of any given muscle varies.

Answer: true

Think and Link

1. Match the following terms with their corresponding function/characteristic. Terms can be matched with more than one answer.

<table>
<thead>
<tr>
<th>Term</th>
<th>Answer</th>
<th>Function/Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agonist/prime mover</td>
<td>F</td>
<td>A) A muscle or group of muscles opposing a desired action</td>
</tr>
<tr>
<td>Antagonist</td>
<td>A</td>
<td>B) Muscle that acts as an antagonist during bending of the elbow (i.e., flexion)</td>
</tr>
<tr>
<td>Biceps</td>
<td>D</td>
<td>C) The muscles surrounding the joint being moved and supporting it in the action</td>
</tr>
<tr>
<td>Triceps</td>
<td>B</td>
<td>D) Muscle that acts as an agonist during bending of the elbow (i.e., flexion)</td>
</tr>
<tr>
<td>Synergists</td>
<td>C</td>
<td>E) Muscle groups that steady joints closer to the body axis</td>
</tr>
<tr>
<td>Fixators</td>
<td>E &amp; G</td>
<td>F) A muscle or group of muscles producing a desired action/movement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G) The muscles holding your shoulder girdle to your rib cage during hand-over-hand rope climbing</td>
</tr>
</tbody>
</table>

2. Knowing what you do about muscle fibre types, explain why there is a difference between white and dark meat on a chicken (a flightless bird). Would this differ for birds that fly south for the winter? Do a little research, and summarize the differences between white and dark meat.

Chickens have both fast and slow twitch muscle fibres just as humans do, and this is reflected in the dark (red) meat and white meat found in the different parts of the chicken. Since they use their legs for standing and walking for long periods of time, chicken thighs are predominantly made up of slower contracting, fatigue-resistant slow twitch (red) fibres that rely on oxygen, while the wings and breast are made up of more fast twitch (white) fibres to support the brief bursts of power and energy. The dark meat areas would therefore have a greater capillary and oxygen supply than the white meat areas.

Birds that fly south would possess more slow twitch fibres in the wings to support the long flight south. Since they are not known for strength and power, birds (including chickens) would not possess an abundance of fast twitch glycolytic fibres.
Two Great Athletes – Two Completely Different Body Types

Compare and contrast the following two athletes by answering the questions that follow.

**Athlete 1 – Sprinter**
Rhemie is a world-class French Canadian sprinter. He has trained all his life to represent Canada at the Olympics and to break the world record in the 100-metre sprint. Rhemie is 183 cm tall and has a mass of 86 kg. He is extremely well built, with a muscular body type. His best time in the 100 metres is 9.60 seconds.

**Athlete 2 – Marathon Runner**
Akwaee is an established marathon runner from Kenya – a world champion in the 42-km (26-mile) event. He is 183 cm tall and has a mass of 70 kg. Akwaee is extremely lean, with a linear body type. He can run a 4-minute mile and has a personal best marathon time of 2 hours and 4 minutes.

1) Of the three types of muscle in the human body, which type is more efficient in Akwaee – the marathon runner?

*The three types of muscle in the human body are smooth muscle, cardiac muscle, and skeletal/striated muscle. The latter two are more efficient in Akwaee (the marathon runner).*

2) Muscles work in collaboration with each other. As one muscle flexes, another muscle extends. The muscle known as the agonist is the **prime mover**, and the opposing muscle is called the **antagonist**. The synergists are the muscles **surrounding** the joint being moved. Other muscles that steady joints closer to the body axis so that the desired action can occur are called **fixators**.

3) Both athletes go through rigorous total-body training. Fill in the blanks in the chart below outlining how muscles work together during training.

<table>
<thead>
<tr>
<th>Movement/Action</th>
<th>Agonist</th>
<th>Antagonist</th>
<th>Synergists</th>
<th>Fixators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>Hamstrings</td>
<td>Quadriceps</td>
<td>Muscles surrounding the knee joint</td>
<td>Muscles in the posterior hip – gluteals</td>
</tr>
<tr>
<td>Lifting</td>
<td>Abdominals/Core</td>
<td>Spinal erectors</td>
<td>Hip flexors</td>
<td>Abdominals</td>
</tr>
<tr>
<td>Climbing</td>
<td>Deltoid and latissimus dorsi</td>
<td>Pectorals</td>
<td>Muscles of the neck (trapezius) and shoulders</td>
<td>Shoulder girdle (SITS)</td>
</tr>
<tr>
<td>Pushing</td>
<td>Pectorals, deltoids, triceps</td>
<td>Upper back – latissimus dorsi, trapezius</td>
<td>Deltoids</td>
<td>Core muscles of back/torso</td>
</tr>
</tbody>
</table>
4) Which athlete possesses more fast twitch (Type IIa) muscle fibres? Who possesses more slow twitch (Type I) muscle fibres? Who do you think possesses more Type IIb muscle fibres? Explain your answer.

Rhemie has more fast twitch fibres, while Akwaee has more slow twitch fibres. Rhemie possesses more type IIb muscle fibres because he is more muscular as a sprinter and therefore uses more fast twitch muscles during his activity.

5) Other than their athletic training, what major factor influences their muscle fibre composition?

Genetics (heredity) will be the major factor influencing muscle fibre composition.

6) Explain the concepts of intramuscular coordination and intermuscular coordination. In your answer state which athlete would be more proficient in each type of coordination.

The capacity to activate motor units simultaneously is known as intra-muscle coordination. Although it is impossible to use all the motor units of a muscle at the same time, many highly trained power athletes are able to activate up to 85 percent of their available muscle fibres simultaneously, thus generating great strength. Since Rhemie is a power sprinter, he would be more proficient in intra-muscle coordination.

The interplay between agonist and antagonist muscles is of particular importance to the quality of inter-muscle coordination. The greater the participation of muscles and muscle groups, the higher the importance of inter-muscle coordination for strength capacity. During explosive movements (e.g., sprinting), a considerable number of motor units in cooperating muscles are synchronously activated (i.e., quadriceps), while the motor units of the antagonist muscles relax (i.e., hamstrings). For this reason, Rhemie would also be more proficient in inter-muscle coordination.

7) Akwaee decides that he wants to train like a sprinter, engaging in a vigorous strength training regime to help him improve his marathon time. Is this the right approach to training for a marathon runner? What will happen to Akwaee if he continues to train with explosive strength-based movements/exercises?

Akwaee will develop more fast twitch muscle fibres and could potentially lose some of his cardiovascular endurance training this way. It is not beneficial for Akwaee to train like a sprinter if he wants to continue to run marathons. Akwaee should continue to train like a marathon runner to continue to improve his oxygen-carrying capacity and further develop his type I muscle fibres.

8) In the space below, design a sport-specific training program with at least four exercises for either Rhemie (sprinter) or Akwaee (marathon runner).

Answers will vary.