10.1 Movement and Muscle Tissue

In this section, you will:

• **observe** and **compare** the three types of muscle tissue
• **describe**, in general, the action of actin and myosin in muscle contraction and heat production
• **identify** the sources of energy for muscle contraction
Types of Muscles

- **Cardiac Muscles**: heart muscles: Found only in the heart
  - Involuntary contraction and relaxation.
    - Controlled by nerves of the autonomic nervous system

- **Skeletal Muscles**
  - Unlike cardiac and smooth muscles, these types of muscles are voluntarily controlled.
    - Allow you to walk, talk, ride a bike, swim, jump, etc. Skeletal muscles attach to bones by tendons.
    - Skeletal muscles are key in helping you keep warm.
    - 80% or all energy used in muscle contraction is lost as heat!

- **Smooth Muscles**: Lining of gut and organs
  - Found in the hollow parts of the body, for instance the lining of organs such as: the stomach, esophagus, uterus, and walls of blood vessels.
  - Similar to cardiac muscles contraction, smooth muscle contraction is involuntary.

Muscle Cells

Skeletal muscle cells
- are long and slender
- form many sarcomeres
- are usually attached to bones of the skeleton

Smooth muscle cells
- are short and stout
- have one nucleus
- contract involuntarily
- attach to the walls of internal organs

Cardiac muscle cells
- are branched, tubular, and branched
- have one nucleus
- contract continuously
- are found in the walls of the heart

Review:

- What are the three types of muscle?
- How are each different?
Muscle Function

- Skeletal muscle supports the body.
- Skeletal muscle makes the bones move.
- Helps to maintain a constant body temperature.
- Skeletal muscle helps to protect the internal organs and stabilize the joints.

Muscle Fibres

Structure of Skeletal Muscles

- An individual section of the myofilament is called a sarcomereme.
- The length of one sarcomereme is defined by the Z-Line. The Z-lines anchors the actin to each other and to the bone.
- The length of the myosin is defined by the A-Band. It contains both actin and myosin.
- The I-Band only contains actin and is the space in between 2 myosin.
- The H-Zone is the empty space between 2 actin. Myosin is only found in this space.

Components of Skeletal Muscle Fibres

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle fibre</td>
<td>single muscle cell</td>
<td>responsible for muscle contractions</td>
</tr>
<tr>
<td>myoglobin</td>
<td>oxygen-binding pigment (similar to hemoglobin) in a skeletal muscle fibre</td>
<td>stores oxygen for use during muscle contractions</td>
</tr>
<tr>
<td>sarcoplemma</td>
<td>membrane of a muscle fibre</td>
<td>surrounds the muscle/fibre and regulates the entry and exit of materials</td>
</tr>
<tr>
<td>sarcoplasm</td>
<td>cytoplasm of a muscle fibre</td>
<td>is the site of metabolic processes for normal cell activities, contains myoglobin and glycogen (which stores energy for muscle contractions)</td>
</tr>
<tr>
<td>sarcoplasmic reticulum</td>
<td>smooth endoplasmic reticulum in a muscle fibre</td>
<td>stores calcium ions needed for muscle contractions</td>
</tr>
<tr>
<td>Myofibrils</td>
<td>organized bundles of myofilaments; cylindrical structures, as long as the muscle fibre itself</td>
<td>contain myofilaments that are responsible for muscle contractions</td>
</tr>
<tr>
<td>thick filament</td>
<td>fine myofilament composed of bundles of protein called myosin (about 11 nm in diameter)</td>
<td>binds to actin and causes muscle contractions</td>
</tr>
<tr>
<td>thin filament</td>
<td>fine myofilament composed of strands of protein called actin (about 5 nm in diameter)</td>
<td>binds to myosin and causes muscle contractions</td>
</tr>
</tbody>
</table>
The Mechanism of Muscle Contraction

- **Actin**: a myofilament that consists of two strands of protein (actin) that are wrapped around each other.
- **Myosin**: ten times longer than actin and different in shape (rod like with globular heads)

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The Movement of Actin and Myosin

**Sliding Filament Model**

1. **The heads at the two ends of the myosin filament are oriented perpendicular to the actin filament.**
2. **When the heads attach to the actin, they tend toward the center of the myosin.**
3. **As one end of the myosin filament slides, the actin filament and its attached heads move.**
4. **Both the actin and myosin arrows tend toward the center and contract the muscle.**

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**Calcium Controls Muscle Contractions**

1. **Calcium ions bind to a calcium-binding protein, tropomyosin, which is a part of the actin-filament wall.**
2. **This binding causes tropomyosin the tropomyosin-binding sites of actin.**
3. **The myosin heads can bind to the actin, and contraction occurs.**
During each contraction:

• 1) A neurotransmitter is released from a nerve to the muscles, signaling contraction
• 2) The muscle cell's endoplasmic reticulum release Calcium (Ca$^{2+}$ ions) near the actin
• 3) Calcium ions attach to the actin and this then allows myosin to attach to the actin, forming an *Actin-Myosin Cross-Bridge*
• 4) The actin and myosin attach and de-attach, over and over. With each re-attachment of the actin the muscle fibers get pulled closer together. This carries on until full contraction of the muscles occurs.

Creatine phosphate builds up and is stored in resting muscle (purple). For muscle to contract (green), needs ATP.

(A) When muscle contracts it breaks down stored creatine phosphate
(B) To continue, the muscle carries out aerobic cellular respiration as long as oxygen is available
Fermentation takes place if oxygen is limited—lactate builds up. Once the muscle resumes resting (purple), creatine phosphate builds up again.

Summary: Chapter 10 The Muscular System and Homeostasis
Summary:
• Three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle.
• Skeletal muscle produces body movement, maintains body temperature, and provides support for the body.
• Muscle fibres are filled with myofibrils that house thin (actin) and thick (myosin) contractile protein myofilaments.
• Actin and myosin slide past each other during a muscle contraction.
• Creatine phosphate, fermentation, and aerobic cellular respiration provide energy for muscle contractions.

10.2 Muscles, Health, and Homeostasis

In this section, you will:
• **Explain** how the skeletal muscles of the motor system support other body systems to maintain homeostasis
• **identify** conditions that impair the healthy functioning of muscles and technologies that are used to treat or prevent these conditions
• **describe** the benefits of exercise for maintaining the healthy structure and functioning of muscles
Muscular Atrophy

Muscular dystrophy is a collective term for several hereditary conditions in which the skeletal muscles degenerate, lose strength, and are gradually replaced by fatty and fibrous tissue that impairs blood circulation; this, in turn, accelerates muscle degeneration in a fatal spiral of positive feedback.

Botulism is a potentially fatal muscular paralysis caused by a toxin produced by the bacterium *Clostridium botulinum*; the toxin prevents the release of a muscle-stimulating compound (acetylcholine) released by muscle-related cells of the nervous system, thus leading to paralysis.

Cramps are painful muscle spasms triggered by strenuous exercise, extreme cold, dehydration, salt (electrolyte) imbalance, low blood glucose, or reduced blood flow.

Contracture is abnormal muscle shortening not caused by nerve stimulation; can result from inability to remove calcium ions from the sarcoplasm or from the contraction of scar tissue (as in people who have experienced severe burns).

Fibromyalgia is chronic muscular pain and tenderness often associated with fatigue and sleep disturbances; can be caused by infectious diseases, physical or emotional trauma, or medications.

Crush syndrome is shock-like state following massive crushing of the muscles (as in, for example, the aftermath of an earthquake, the collapse of a building following an explosion, or a traffic accident); associated with high fever, heart irregularities caused by potassium ions released from the muscles, and kidney failure caused by blockage of the renal tubules with myoglobin released by the traumatized muscles.

Delayed onset muscle soreness is pain, stiffness, and tenderness felt from several hours to a day after strenuous exercise, associated with trauma to the muscles, disruptions in the myofibrils and sarcolemma, and increased levels of myoglobin and muscle fibre enzymes in the blood.

Myositis is muscle inflammation and weakness resulting from infection or an autoimmune disease.

Muscle Twitch

- **Muscle twitch** – is a muscle contraction that lasts a fraction of a second that occurs in three stages:
  - Latent stage – time between stimulus and initiation of the contraction
  - Contraction stage – time it takes for the muscle fibers to shorten
  - Relaxation stage – time it takes for the muscle to return to its regular length.

Myograms

These graphs show the force of muscle contraction with time. **(A)** A simple muscle twitch has three periods: latent, contraction, and relaxation. **(B)** When a muscle is not allowed to relax completely between stimuli, the contraction gradually increases in intensity until it reaches a maximum, which is sustained until the muscle fatigues.
Types of Twitch

- **Slow twitch** – smaller muscle fibers that contract slowly and resist fatigue because they are surrounded by more blood vessels and have more mitochondria.
  - i.e. postural back muscles, leg muscles
- **Fast twitch** – larger muscle fibers that contract quickly to give more power, but depend upon anaerobic energy production. They are rich in glycogen, and have fewer mitochondria and blood vessels surrounding them.
  - i.e. lateral rectus muscle in the eye, biceps

Skeletal muscles have different proportions of fast-twitch and slow-twitch fibres. Thus, the force and response times of their contractions differ.

The effects of exercise

- **Endurance training** – increases the development of slow-twitch muscle fibres and has no impact on the size of the muscles.

- **Resistance / strength training** – thickens fast-twitch muscles, causing an increase in muscle size.

**Continued...**

- **Tetanus**: a state of constant muscle contraction. Often caused by bites, or rusted metals entering the blood stream.
- **Muscle spasms**: involuntary contraction of a muscle. Often caused by a pinched nerve.
Homework:

• Page 349
• Questions: 1,2,3,6,8-13

Chapter 10 Review

• What body systems do muscles support?
• How do muscles support these systems?
• Explain the difference in muscle composition between a person who is not active versus someone who is very active?
• Describe two different types of muscle injuries. Recommend appropriate treatments for each.
• Explain how muscles change with strength training? With endurance training? With inactivity?

Summary: Chapter 10 The Muscular System and Homeostasis

Summary:
• Three types of skeletal muscle—slow-twitch, fast-twitch, and an intermediate type—are found in different parts of the body.
• Muscles atrophy with inadequate stimulation and can hypertrophy with appropriate repeated stimulation.
• The muscular system works with other body systems to maintain homeostasis.