Chapter 10

The Muscular System and Homeostasis

Goals for this Chapter:

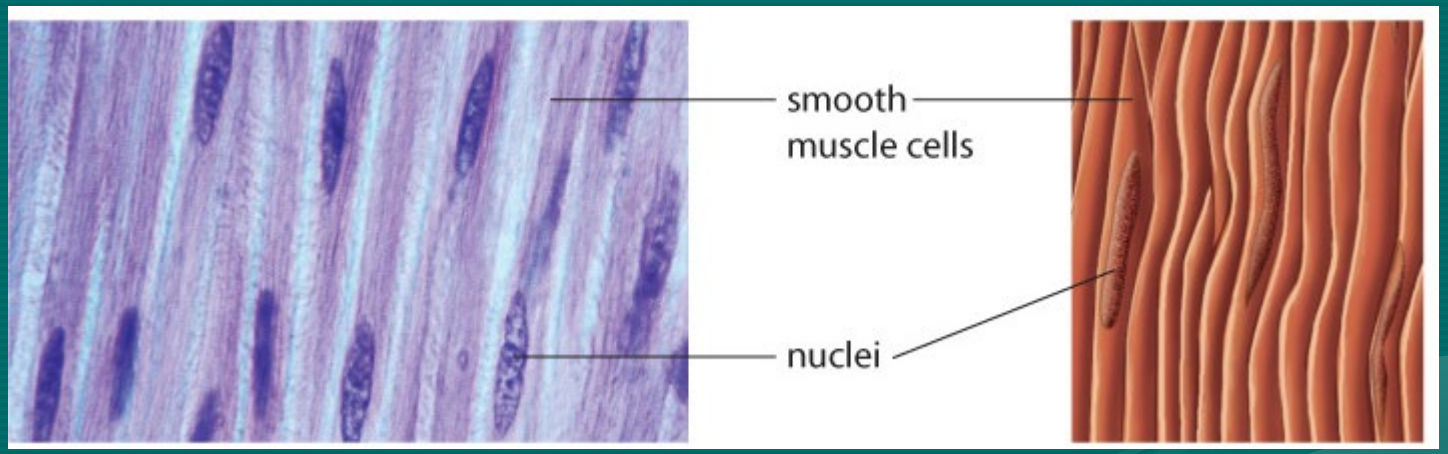
1. Observe and compare the three types of muscle tissue
2. Describe the action of actin and myosin in muscle contraction and heat production
3. Identify the sources of energy for muscle contraction
4. Explain how skeletal muscles support other body systems
5. Identify conditions that impair the healthy functioning of muscle systems
6. Describe the benefits of exercise for maintaining healthy muscles

10.1 – Movement and Muscle Tissue

- There are three types of muscle tissue:

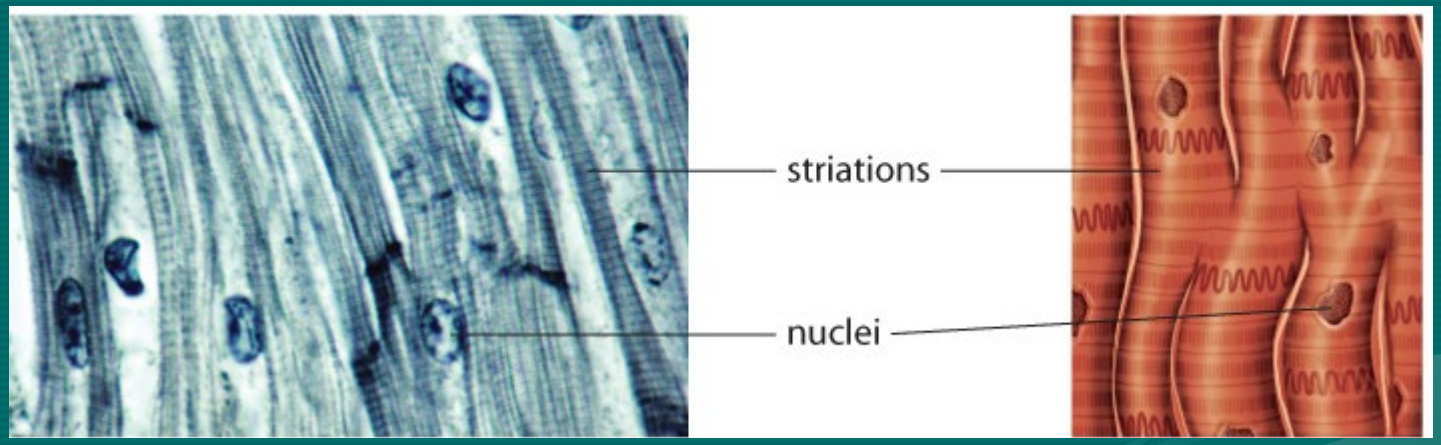
1. Smooth muscle – found in walls of blood vessels, digestive system, etc.
2. Cardiac muscle – specialized muscle found in the heart
3. Skeletal muscle – composes the large skeletal muscles that support and move the body

Smooth Muscle



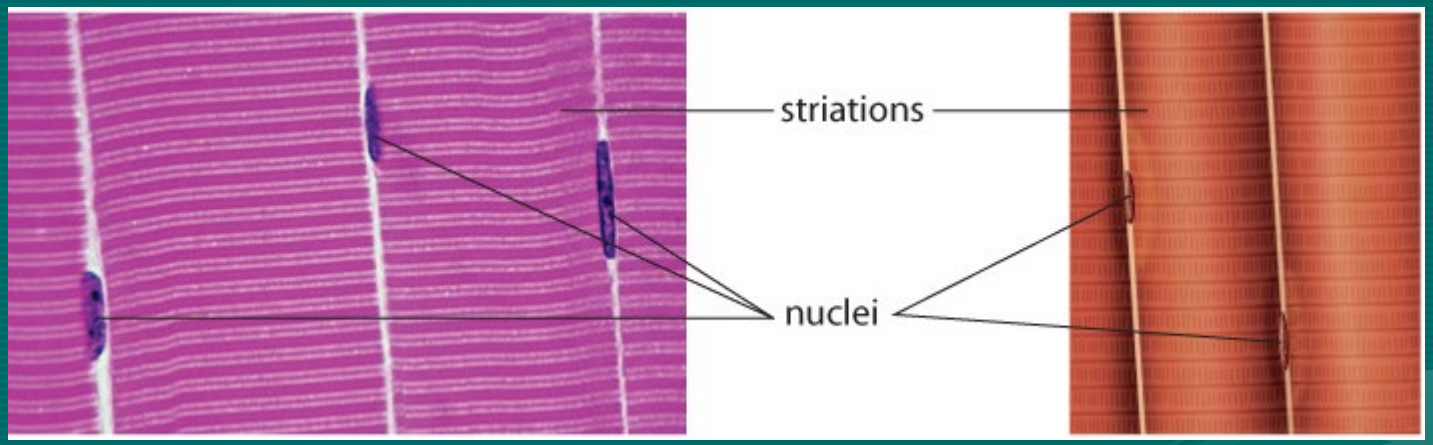
- Properties:
  - Non-striated (don't have differing bands of muscle) or uniform
  - Have one nucleus
  - Contract involuntarily
  - Found in walls of organs

Cardiac Muscle



- Properties:
  - Striated (differing horizontal bands of light and dark patterns in the muscle)
  - Have one nucleus
  - Contracts involuntarily
  - Found in the walls of the heart

Skeletal Muscle



- Properties:
  - Striated (have light and dark bands)
  - Multiple nuclei throughout
  - Contracts voluntarily
  - Usually attached to bones

The Functions of Skeletal Muscle

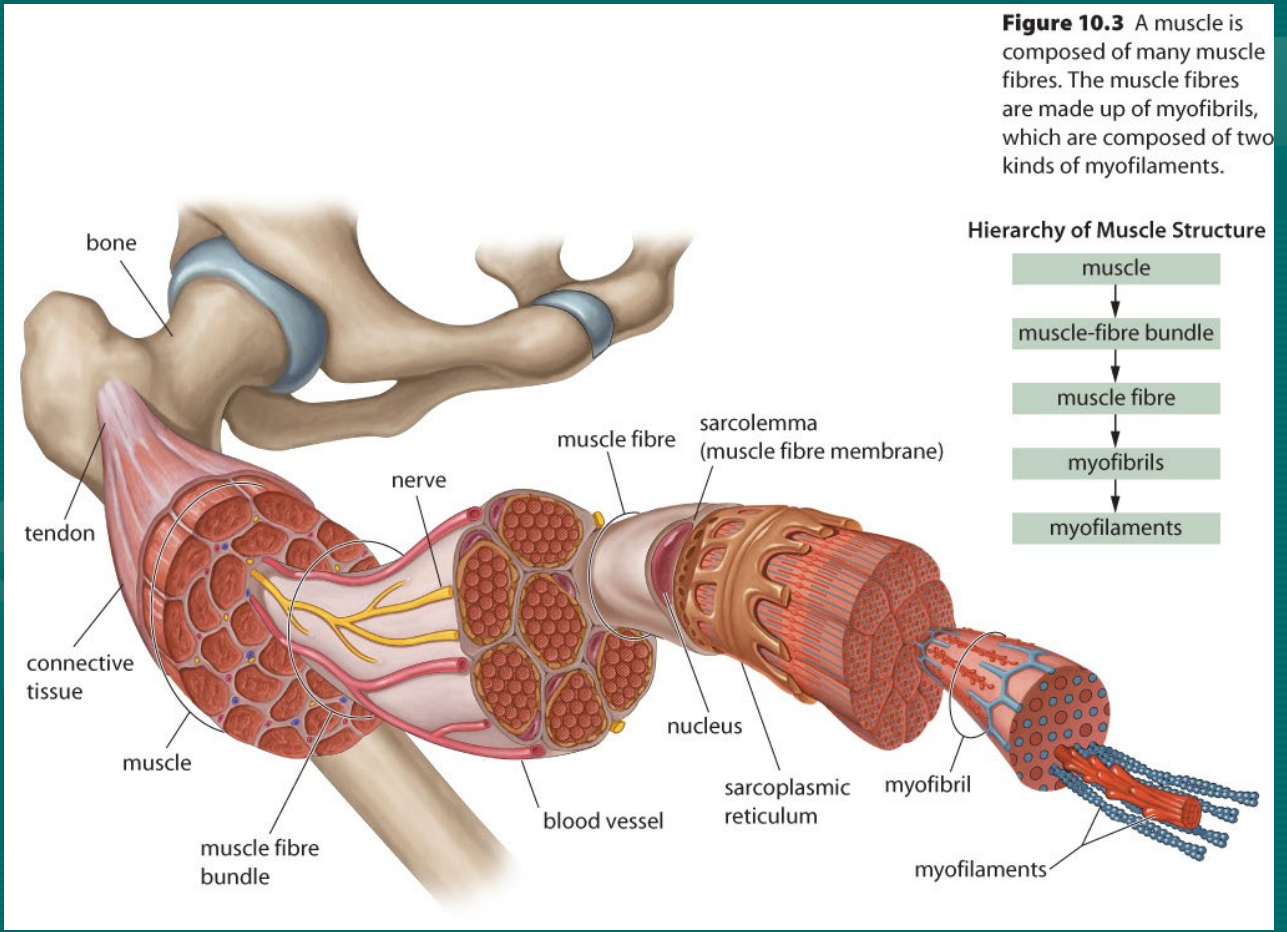
- Skeletal Muscle has 4 main functions:
  1. Move bones in order to move our bodies
  2. Used to pump blood through veins
  3. Used to support the body (allowing for standing, sitting upright, and balancing)
  4. Helps to maintain our body temperature. Muscle contractions use energy that can heat up the muscle and the surrounding tissue / blood vessels.

Cooperation of Skeletal Muscles

- All skeletal muscles pull – they cannot push
- Therefore, to move parts of the body, muscles work in pairs
- For instance, to bend your elbow, the biceps muscle must contract
- To return the arm to a straightened state, the triceps muscle contracts

The Composition of Muscle

- Skeletal muscle consists of numerous bundles of muscle fibres



The Mechanism of Muscle Fibre Contractions

- Muscle contraction relies on the action between two types of myofilaments – actin and myosin
- Actin is a pair of protein strands woven together that resembles a string of beads
- The myosin myofilament consists of protein molecules wound together
- The myosin filaments have “heads” that stick out

Contraction

1. The myosin head is attached to the actin filament
2. The myosin head then flexes, moving the actin filament
3. The myosin head releases and unflexes, powered by ATP
4. The myosin head reattaches to the actin filament in a new location

Contraction Animation

The Sliding Filament Model

- The actin "slides" past the myosin, and this movement is therefore known as the "sliding filament model"
- The actin is anchored to a position within the striated muscle known as a Z line
- When a muscle contracts, the actin moves and along with it, the Z line also moves
- These Z lines are attached to the membranes of other cells in the tissue, causing the contraction of the entire muscle

Calcium Ions and Contraction

- Initially, when a muscle is relaxed, the myosin heads are ready to bind to actin but they cannot bind
- This is because a protein known as tropomyosin prevents their binding
- The tropomyosin can be moved by another protein known as troponin, which is activated when calcium is bonded to it
- Therefore, when muscles contract, Ca^{2+} ions diffuse into the myofibrils and attaches to troponin, allowing the myosin heads to bind with actin

Calcium Ion Action Animation

Energy For Muscle Contraction

- ATP provides energy for muscles
- However, the method through which this ATP is produced can vary
- There are three methods that our bodies can use to produce ATP:

1. Creatine Phosphate Breakdown

- Creatine phosphate is a high energy molecule.
- It helps to regenerate ATP at the site of muscles by losing a phosphate molecule and adding it to ADP.
  - creatine phosphate + ADP → ATP + creatine

2. Aerobic Cellular Respiration

- When oxygen is present, it will enter the muscle cells and undergo aerobic cellular respiration in the mitochondria.
- Oxygen combines with glucose to form carbon dioxide, water, and ATP

3. Fermentation

- When oxygen is not present (sometimes referred to as "oxygen debt"), aerobic cellular respiration is not an option.
- Instead, in animals, lactate fermentation occurs.
- This involves glycolysis breaking down glucose into 2 ATP molecules and a lactate molecule. The process will reverse once oxygen is present again.

10.2 – Muscles, Health, and Homeostasis

- Even at rest, muscles are still contracting at some level
- We rely on proper muscle tone to maintain our posture, and to keep us upright

Complications of the Muscular System

- Muscles are generally vulnerable to injuries that result from sudden stress
- However, muscles are one of the few organ groups whose activity can be impaired through lack of use
- Muscular atrophy results from a lack of movement of the muscle

Common Muscular System Disorders (p345)

- Muscular Dystrophy – genetic, degeneration of skeletal muscle which can lead to death
- Botulism – bacteria releases a neurotoxin that affects nervous/muscle system – can be fatal
- Cramps
- Contracture
- Fibromyalgia – chronic muscle pain that can lead to fatigue and lack of sleep. Caused by trauma, or disease
- Crush syndrome
- Delayed onset muscle soreness
- Myositis

Exercise & Muscle Contraction

- Regular exercise allows muscles to develop and use energy more efficiently
- Regularly used muscles grow due to the increase in the size of the individual muscle fibre, not because of the increase in the number of fibres
- The increase in the size of muscles is known as hypertrophy

Muscle Twitch

- When a muscle is stimulated to a sufficient degree, it will contract quickly or "twitch"
- If these stimuli are given in rapid succession, the twitches will build and create a full contraction
- This contraction can continue until the muscle expends its energy reserves and becomes fatigued

Fast vs. Slow Twitch

- Slow-Twitch (Type I) muscle fibres contract slowly but resist fatigue
- These fibres produce their energy aerobically as they have a large amount of myoglobin & mitochondria
- Fast-Twitch (Type II) fibres are adapted for the rapid generation of power, but they fatigue quickly
- These fibres often depend on anaerobically produced energy

Homeostasis

- Our muscular system allows us to maintain homeostasis
- Our muscles generate heat through the use of ATP during contraction, and muscles allow blood vessels to contract and dilate to move warm blood throughout the body
- As well, many of our processes in our other body systems rely on the movement of muscles to regulate actions