Chapter 10

The Muscular System and Homeostasis

Chapter 10 The Muscular System and Homeostasis

In this chapter, you will learn:

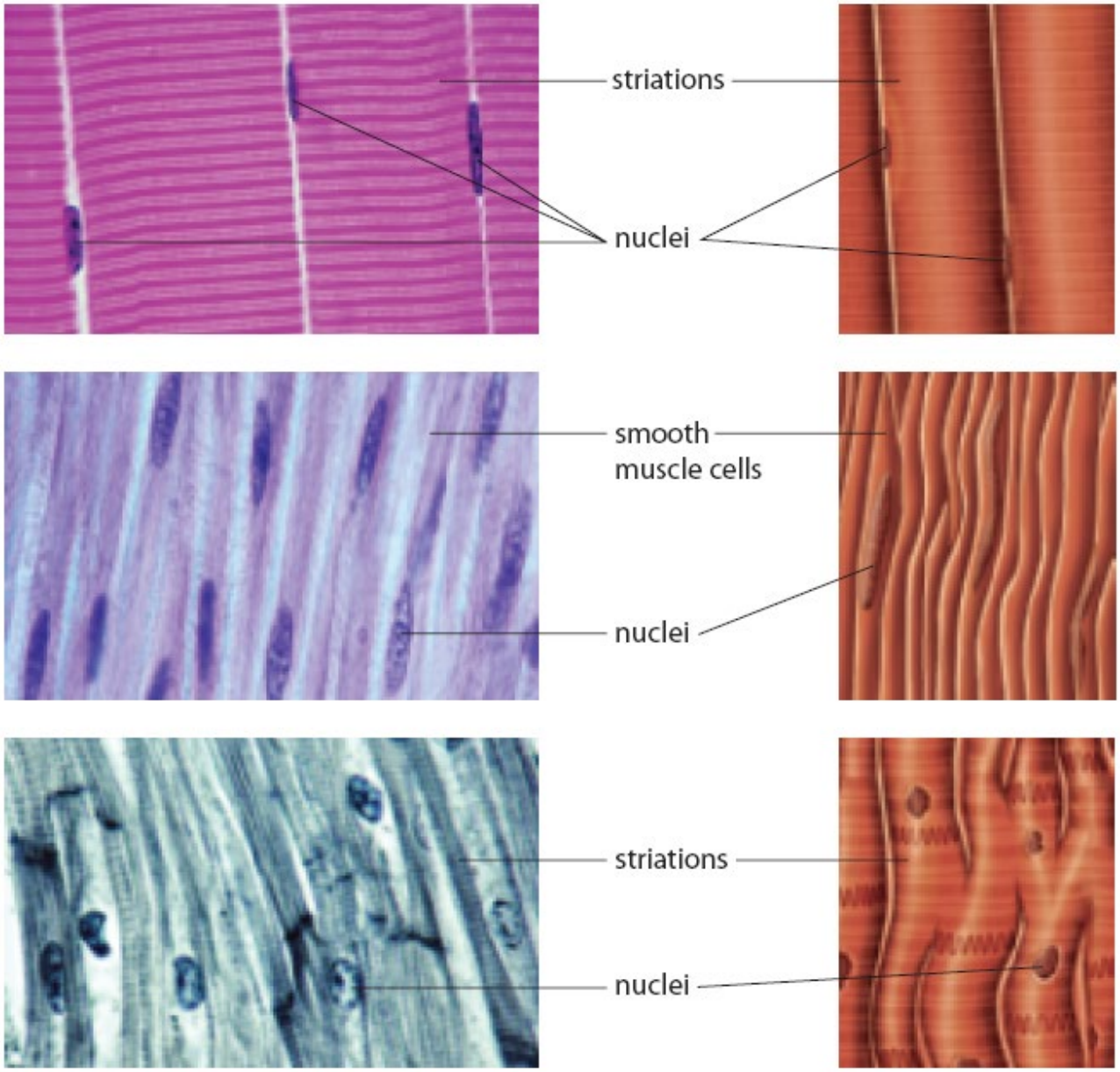
- There are three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle.
- Skeletal muscle produces body movement, maintains body temperature, and provides support for the body.
- Muscle fibres are filled with myofibrils that house thin (actin) and thick (myosin) contractile protein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

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

Muscle Cells



Skeletal muscle cells
- are striated and tubular
- have many nuclei
- contract voluntarily
- are usually attached to bones of the skeleton

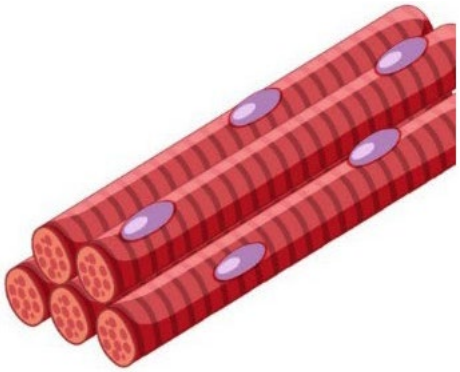
Smooth muscle cells
- are non-striated
- have one nucleus
- contract involuntarily
- are found in the walls of internal organs

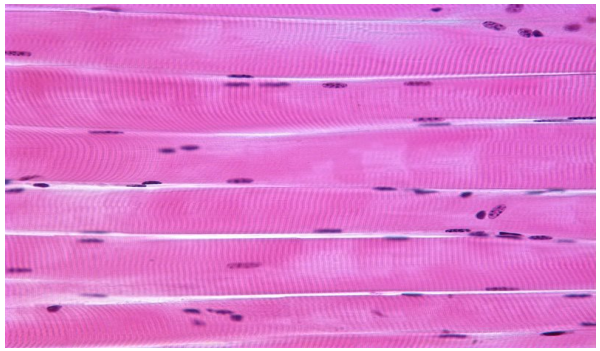
Cardiac muscle cells
- are striated, tubular, and branched
- have one nucleus
- contract involuntarily
- are found in the walls of the heart

Types of Muscle Cells:

- **Skeletal muscle** (3:20in) cells are tubular, striated (bands of light and dark), and very long.

- Skeletal muscle has many functions; it is attached to bones and causes movements of the body.





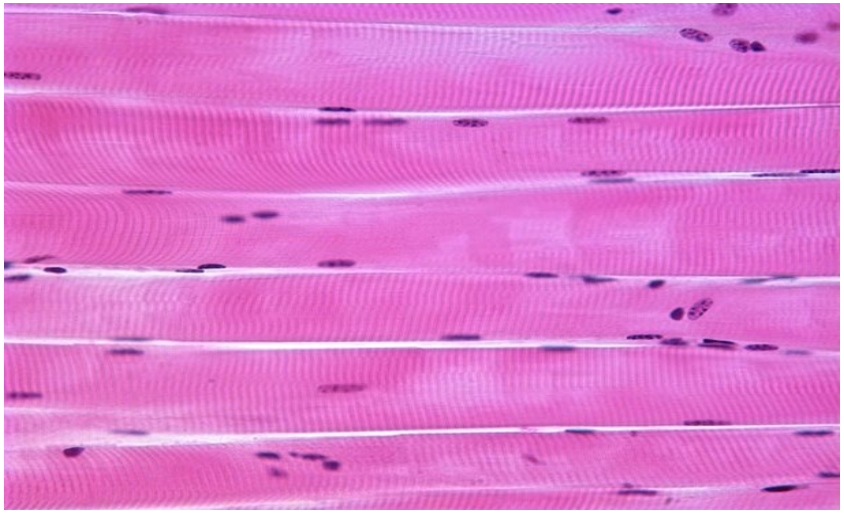
Cooperation of Skeletal Muscles

- 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

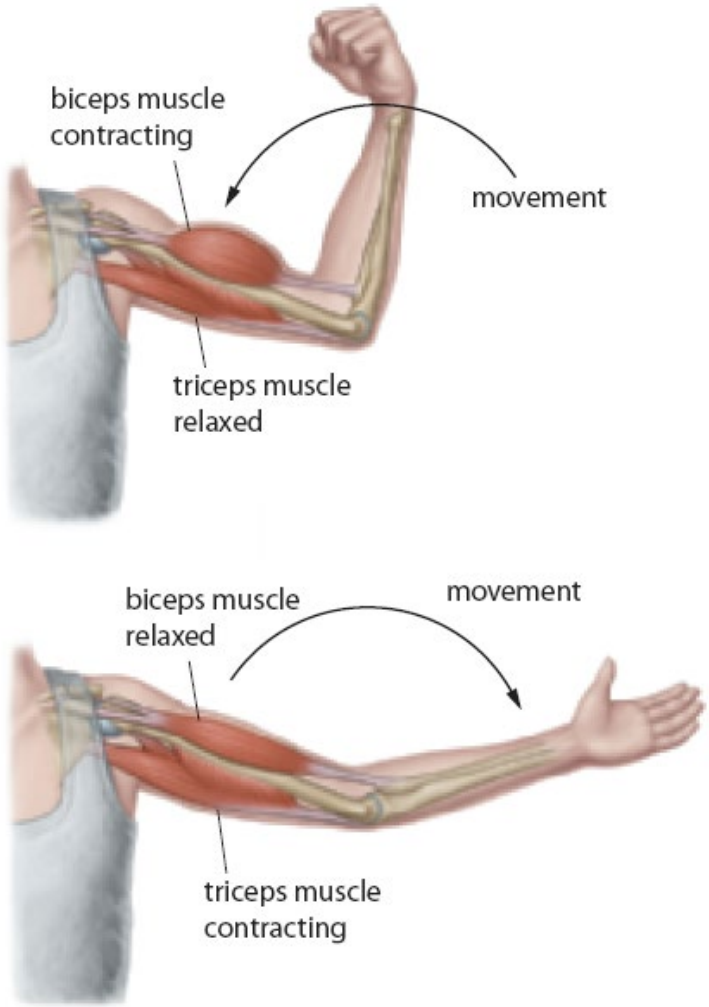
Skeletal Muscle Cells:

- Cells are very long and have **many nuclei**.
- Because of their thin, elongated structure, skeletal muscle cells are often referred to as **fibres** rather than cells.
- Contraction is **voluntary**.

- There are over 600 skeletal muscles in the human body.
- Ex: biceps
  triceps
  quads



Skeletal Muscle Function



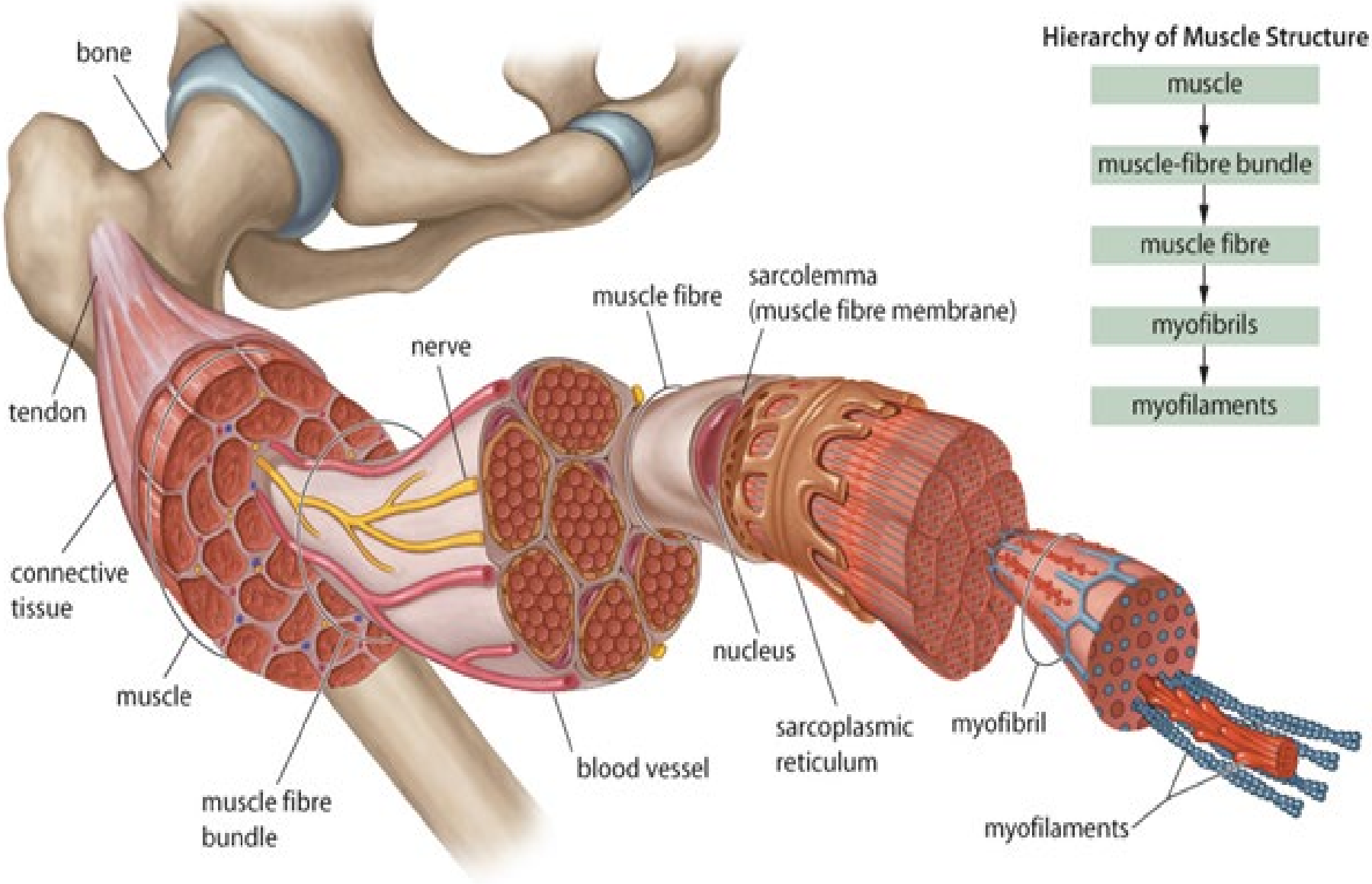
- Skeletal muscle supports the body.
- Skeletal muscle makes the bones move.
- Skeletal muscle helps to maintain a constant body temperature.
- Skeletal muscle helps to protect the internal organs and stabilize the joints

Structure of Skeletal Muscles

- A **muscle** consist of **muscle fibre** bundles (each surrounded by a layer of connective tissue), blood vessels and nerves.

- Each **muscle fibre** is made up of many **myofibrils**, which are composed of two kinds of **myofilaments** (actin and myosin).

Muscle fibres = Muscle cells


bone
tendon
connective tissue
muscle
muscle fibre bundle
nerve
muscle fibre
sarcolemma (muscle fibre membrane)
nucleus
blood vessel
sarcoplasmic reticulum
myofibril
myofilaments
Hierarchy of Muscle Structure
muscle
muscle-fibre bundle
muscle fibre
myofibrils
myofilaments

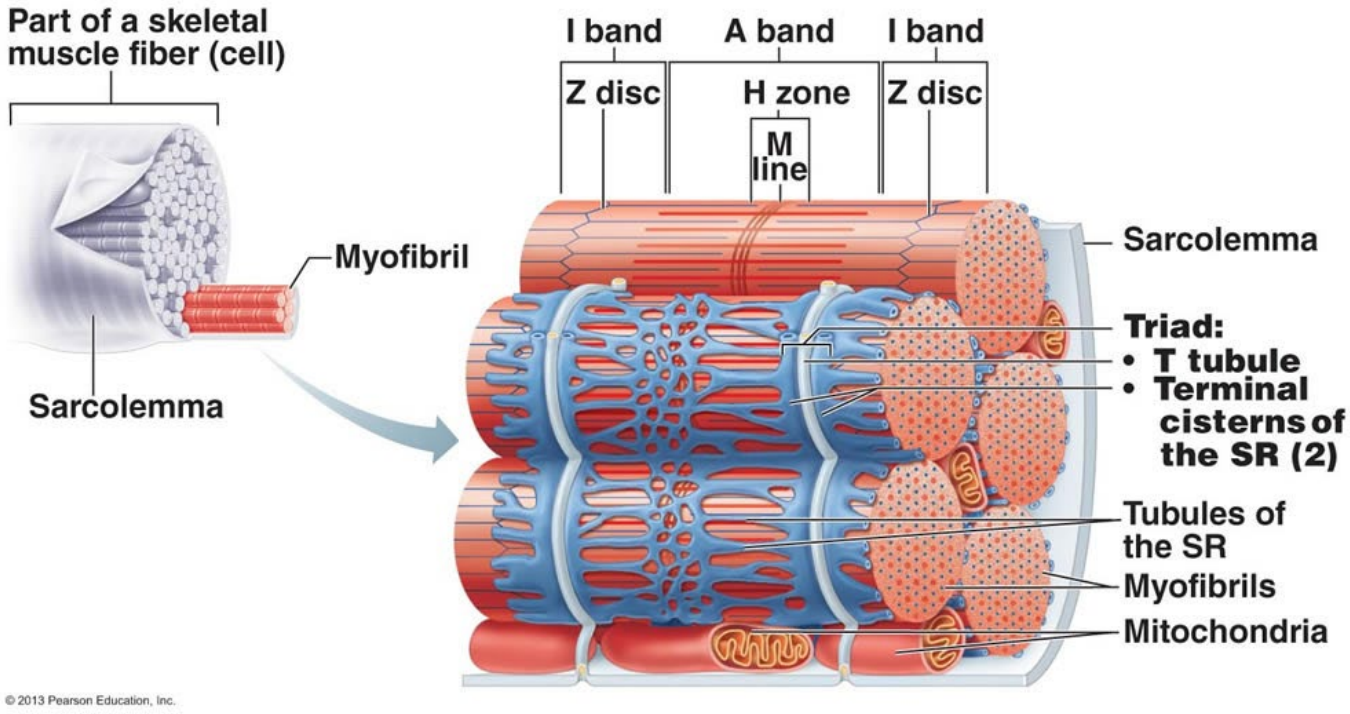
Skeletal Muscle

- Most of the volume of muscle fibres consists of hundreds of thousands of cylindrical subunits called **myofibrils**.
- Each myofibril is made of even smaller **myofilaments** which contain protein structures responsible for muscle contraction.
- The rest the volume of a muscle fibre consists of numerous mitochondria (about 300 per fibre) and other common cell organelles.

Skeletal Muscle

- The cell membrane of a muscle fibre is called the **sarcolemma**.

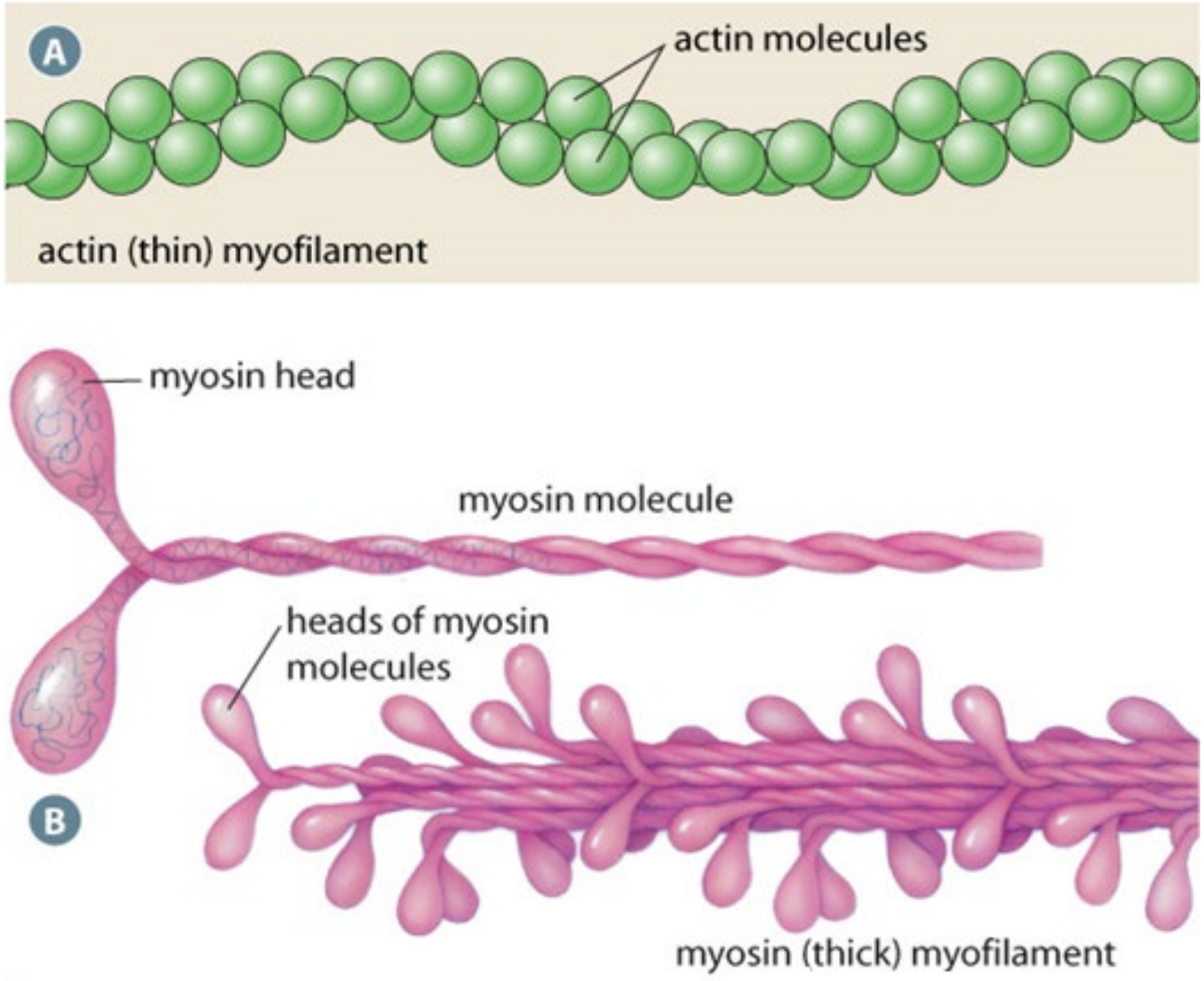
- The cytoplasm of a muscle fibre is called the **sarcoplasm.**



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

Free diving
Diving reflex

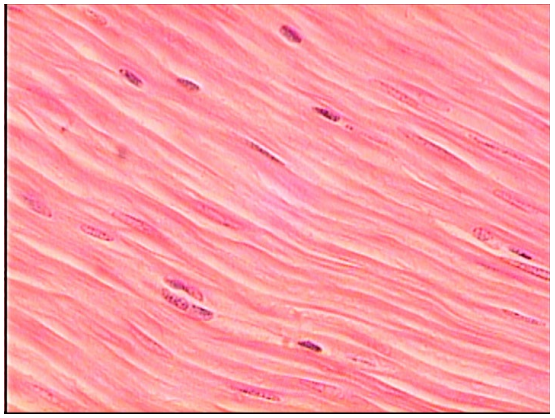
Myofilaments



Types of Muscle Cells:

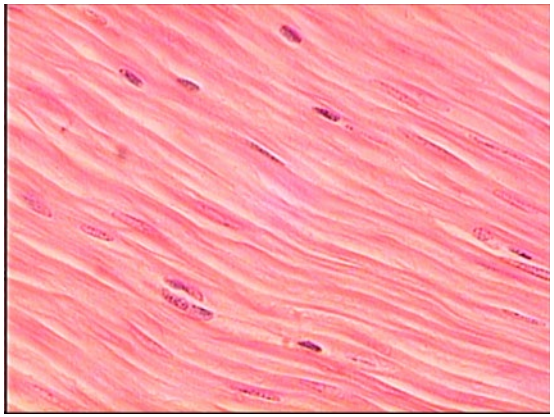
- **Smooth muscle** lines the walls of blood vessels and the digestive tract where it serves to advance the movement of substances.

- Due to its arrangement of actin and myosin filaments, smooth muscle does not have the striated appearance of skeletal muscle.



Smooth Muscle Cells:

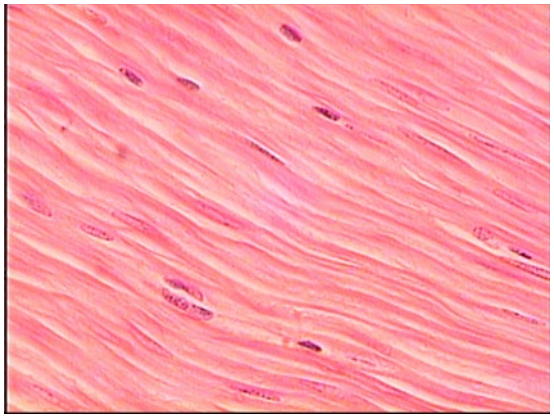
- Cells are long, tapered at each end and arranged in parallel lines forming sheets.
- Each cell has one nucleus.
- Contraction is controlled and relatively slow, but can sustain prolonged contractions without fatiguing.



Smooth Muscle Cells:

- Contractions are **involuntary.**

- Found in:
  - Iris of the eye
  - Certain blood vessels
  - In the walls of hollow internal organs



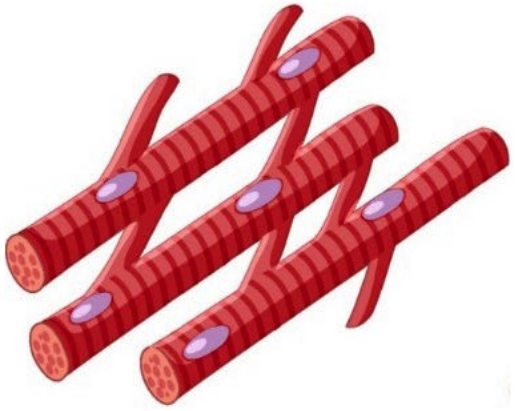
Types of Muscle Cells:

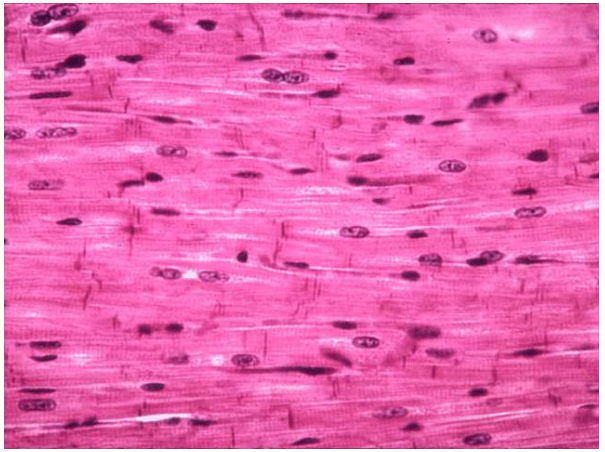
- **Cardiac muscle** is responsible for the rhythmic contractions of the heart. Although **striated**, cardiac muscle differs from skeletal muscle in that it is highly **branched** with cells connected by gap junctions.

- In addition, cardiac muscle generates its own electrical impulses, which spreads rapidly throughout muscle tissue, allowing it to contract without external stimulation.

Cardiac Muscle Cells:

- The cells are **tubular** and **striated** and have one nucleus.
- Cells are **branched,** creating a net-like structure.
- Contractions are **involuntary**.





Muscle Cells

- Both smooth muscle and cardiac muscle depend on mitochondrial activity to provide the energy-rich ATP molecules.

- Unlike these two, skeletal muscle may be required to contract rapidly and to remain contracted for long periods of time.

- Skeletal muscle relies on both **aerobic and anaerobic respiration** for ATP production.

Patterns of Muscle Contraction

- The patterns of contraction by the three kinds of muscles differ.

  - **Smooth muscle (involuntary)** contracts slowly and maintains its contractions over a long period of time

  - each contraction of **cardiac muscle (involuntary)** is followed by a rest period, thus varying the rate of contraction.

  - **Skeletal muscles (voluntary)** contract according to the Sliding Filament Model

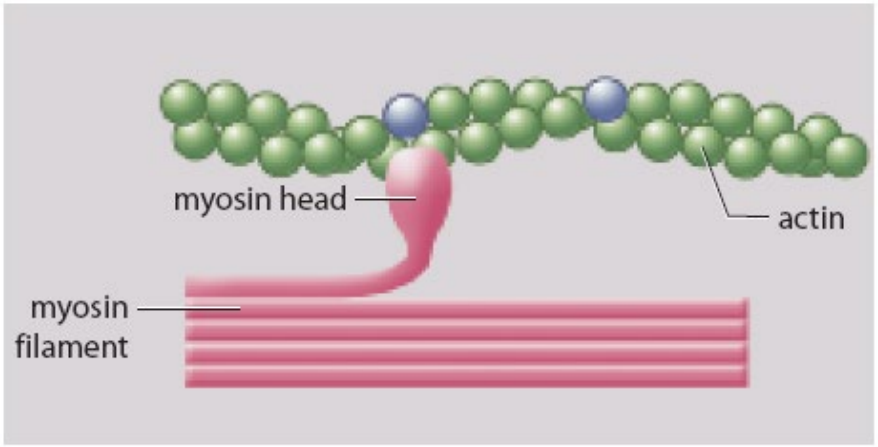
Muscle Contractions – Sliding Filament Model

- Muscle contraction involves the movement of the thick myosin filaments past the thin actin filaments.
- The “heads” of the myosin filaments attach to the actin and then bend and pull the actin filaments toward the middle, making the entire unit shorter (contracted).
- When a myofilament contracts the myosin heads move first in a back and inward motion similar to that of flexing your wrist.
- Since the actin myofilament is chemically bonded to the myosin head the actin is pulled along with the myosin heads as they flex.

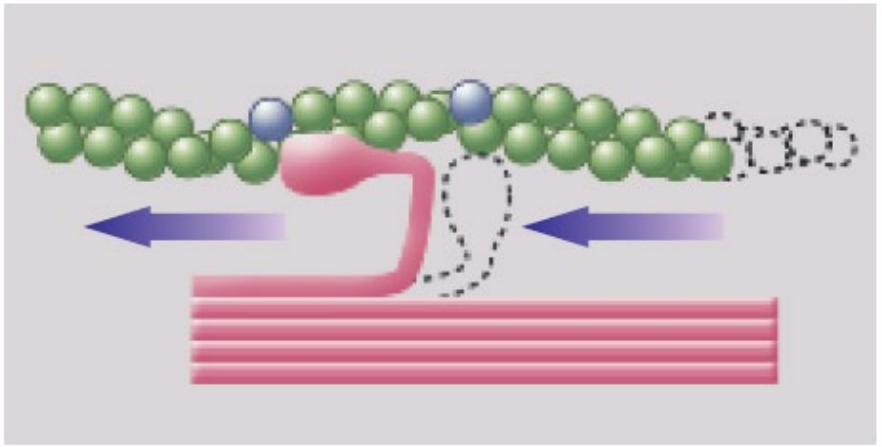
Sliding Filament Model

- One after another the myosin heads flex and in effect "walk" step by step along the actin.
- Each step requires one molecule of ATP to provide the energy to reposition the myosin after each flex.

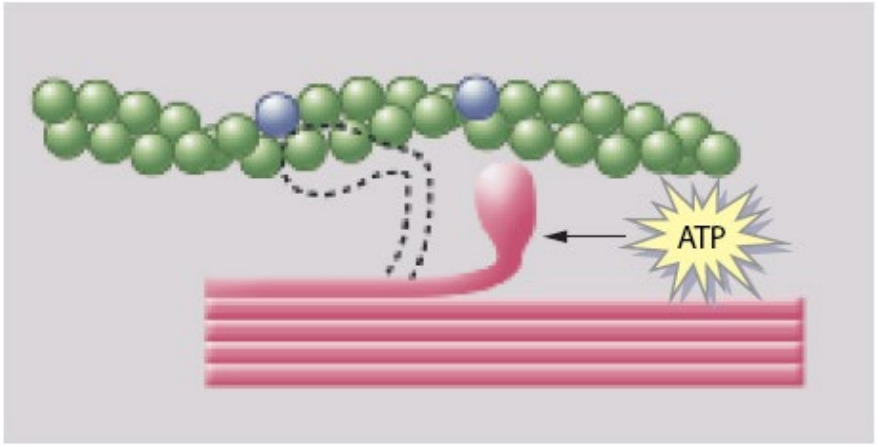
The Movement of Actin and Myosin



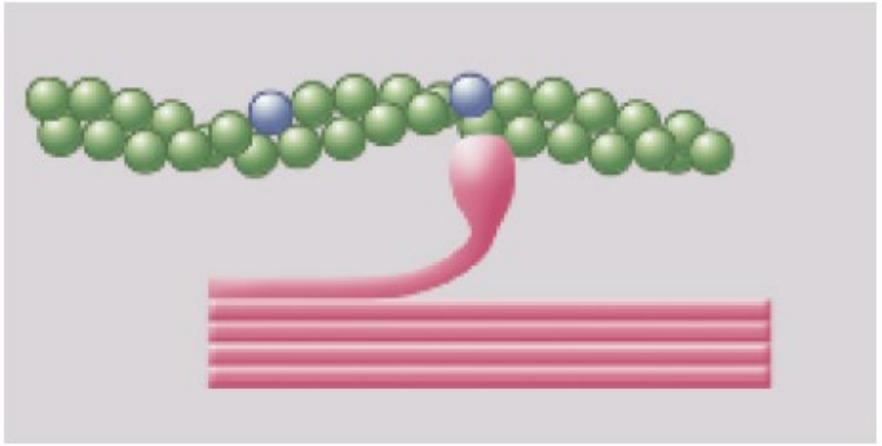
A The myosin head is attached to actin.



B The myosin head flexes, advancing the actin filament.



C The myosin head releases and unflexes, powered by ATP.



D The myosin reattaches to actin farther along the fibre.

Muscle Contractions – Sliding Filament Model

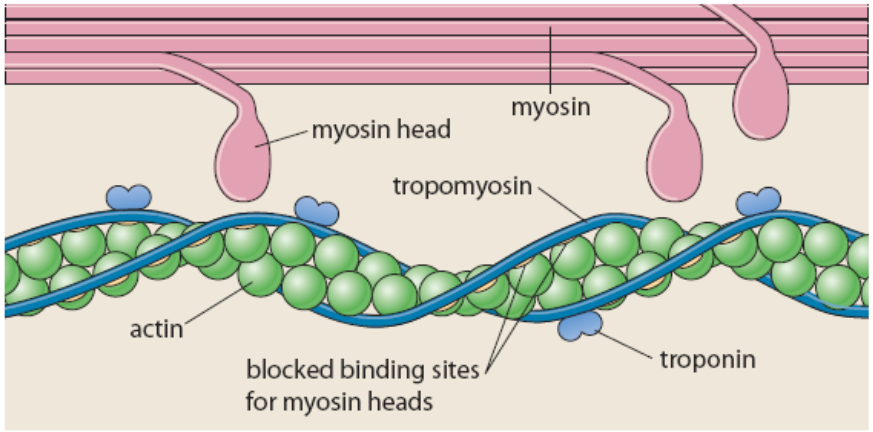
- The myosin can only attach to the actin when the binding sites are exposed.
- When a muscle is relaxed the binding sites are blocked by a protein called tropomyosin.

Muscle Contractions – Sliding Filament Model

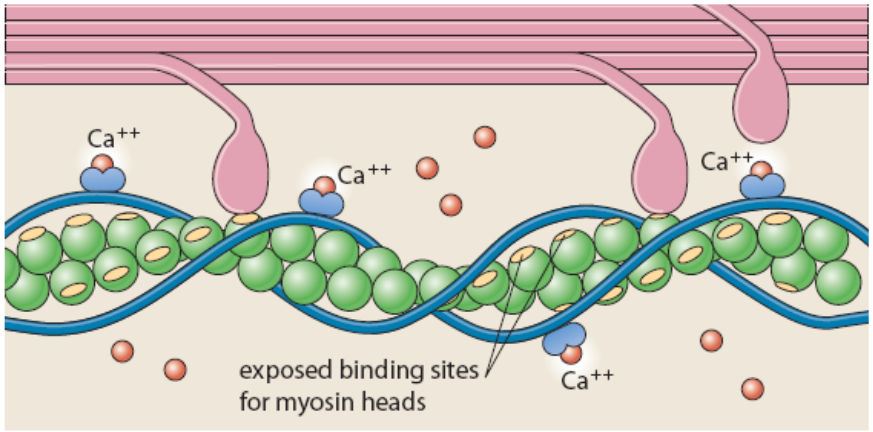
- When a nerve impulse stimulated a muscle, it causes calcium ions to be released from the sarcoplasmic reticulum.

- Calcium binds to troponin, this causes the tropomyosin to be shifted away from the myosin binding sites

Calcium Controls Muscle Contractions



A The muscle is at rest. A long filament, composed of the protein molecule tropomyosin, blocks the myosin binding sites of the actin molecule. Without actin's ability to bind with myosin at these sites, muscle contraction cannot occur.



B Calcium ions have bonded to another protein molecule, troponin, which is part of the actin myofilament. The resulting complex repositions the tropomyosin, exposing the myosin binding sites of actin. The myosin heads can bind to the actin, and contraction occurs.

Muscle Contractions – Sliding Filament Model

- Myosin binds to the actin filaments, and with the energy from ATP, the myosin heads bend and pull the actin filaments toward each other, shortening the filament.

- ATP is also required to detach myosin from the actin so as it can join to another site further along.

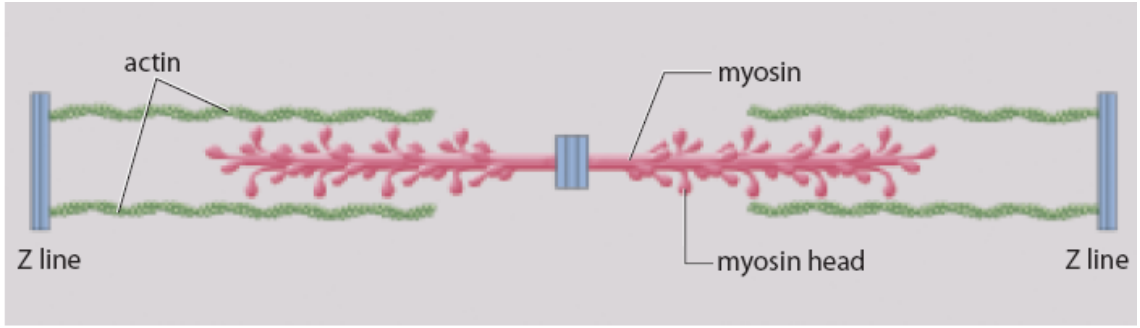
Z Lines

- The actin is anchored at one end of each myofilament at a position called the **Z line.** Therefore, its movement pulls the Z line along with it.

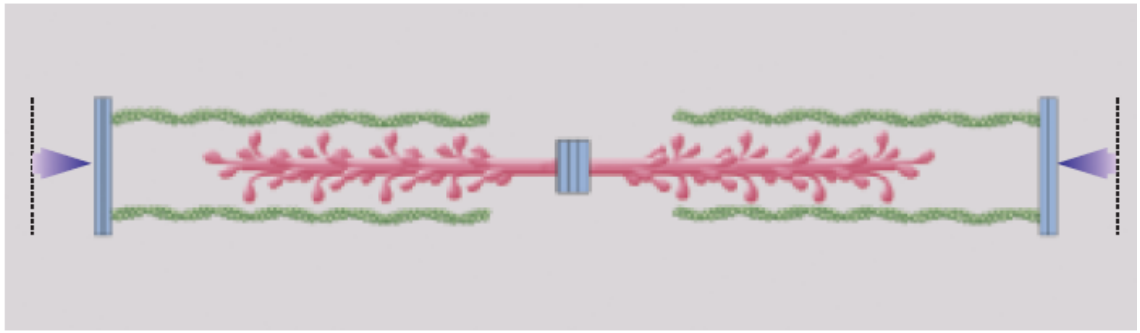
- With one actin myofilament being pulled inward in one direction and another being pulled inward in the opposite direction the two pairs of molecules drag the Z lines together causing the muscle to contract.

Sliding Filament Model

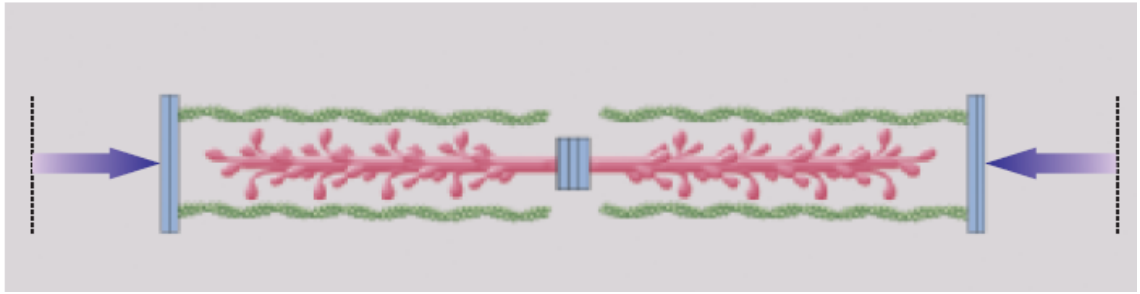
A The heads on the two ends of the myosin filament are oriented in opposite directions. When the heads attach to the actin, they bend toward the centre of the myosin.



B As one end of the myosin filament draws the actin filament and its attached Z line toward the centre, the other end of the myosin filament does the same.



C Both Z lines move toward the centre, and contraction occurs.



Final High level review

Energy Sources for Muscles

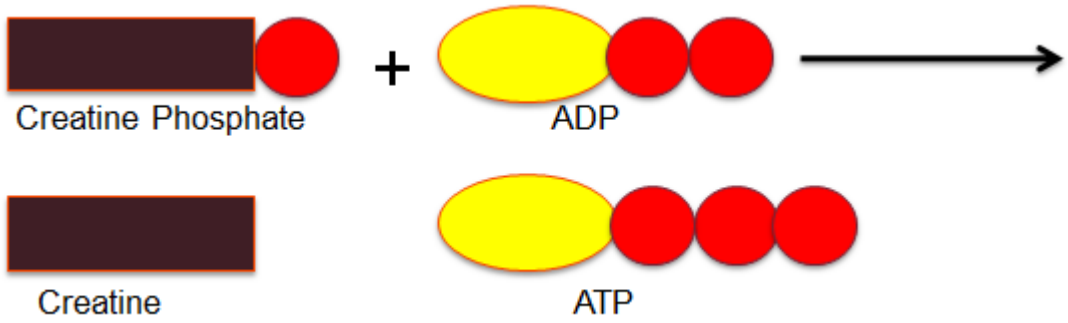
- ATP produced before strenuous exercise lasts only a few seconds.

- The muscles then aquire ATP in three different ways depending on availability of oxygen.

    1. Breakdown of creatine phosphate
    2. Aerobic cellular respiration
    3. Fermentation

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.

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

Complications of the Muscular System

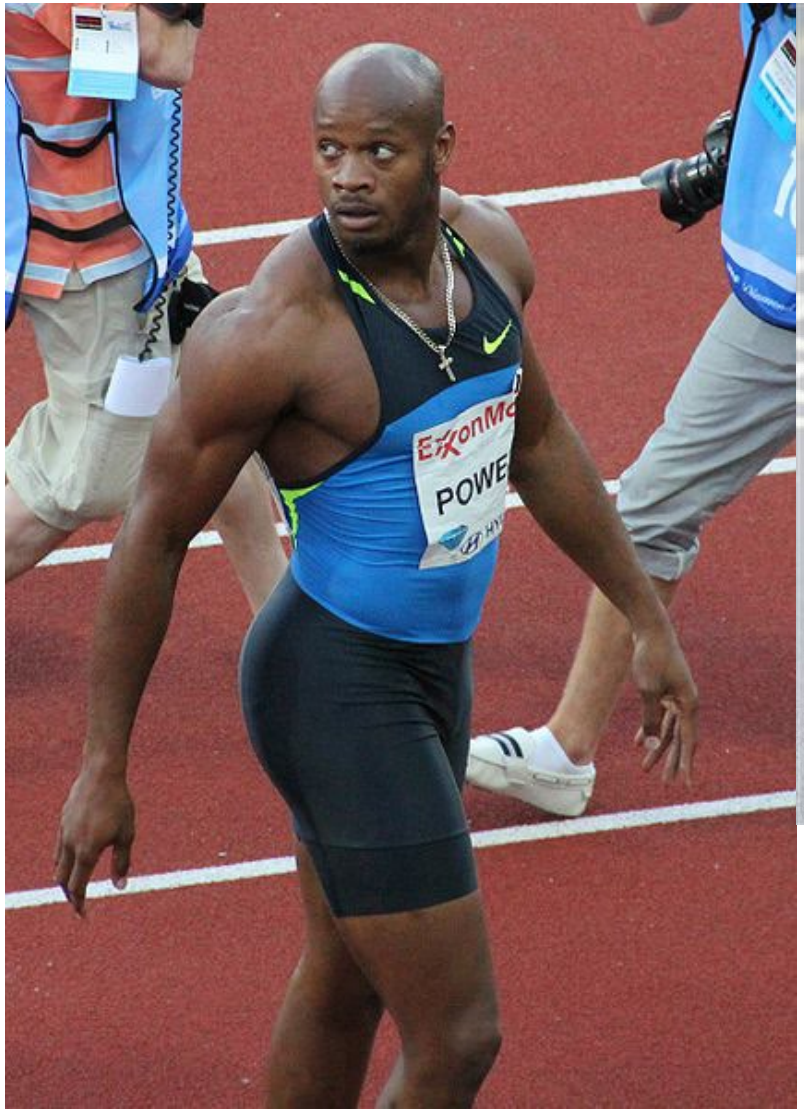
- Muscles are generally vulnerable to injuries that result from sudden stress
- However, muscles are one of the few organ groups whose activity can be impaired through lack of use
- Muscular atrophy results from a lack of movement of the muscle

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 Muscles

- **Slow-Twitch Fibres: (Type I Fibres)**
  - Tend to be aerobic
  - Contract slowly but resist fatigue (endurance)
  - They tire only when their fuel supply is gone.
  - Many mitochondria
  - Surrounded by dense capillary beds and draw more blood than fast-twitch fibres.
  - Abundant supply of glycogen means prolonged production of ATP as long as oxygen is available.


POWE


UGANDA
KENYA
KIPROTICH
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KIRUI

Fast vs Slow Twitch Muscles

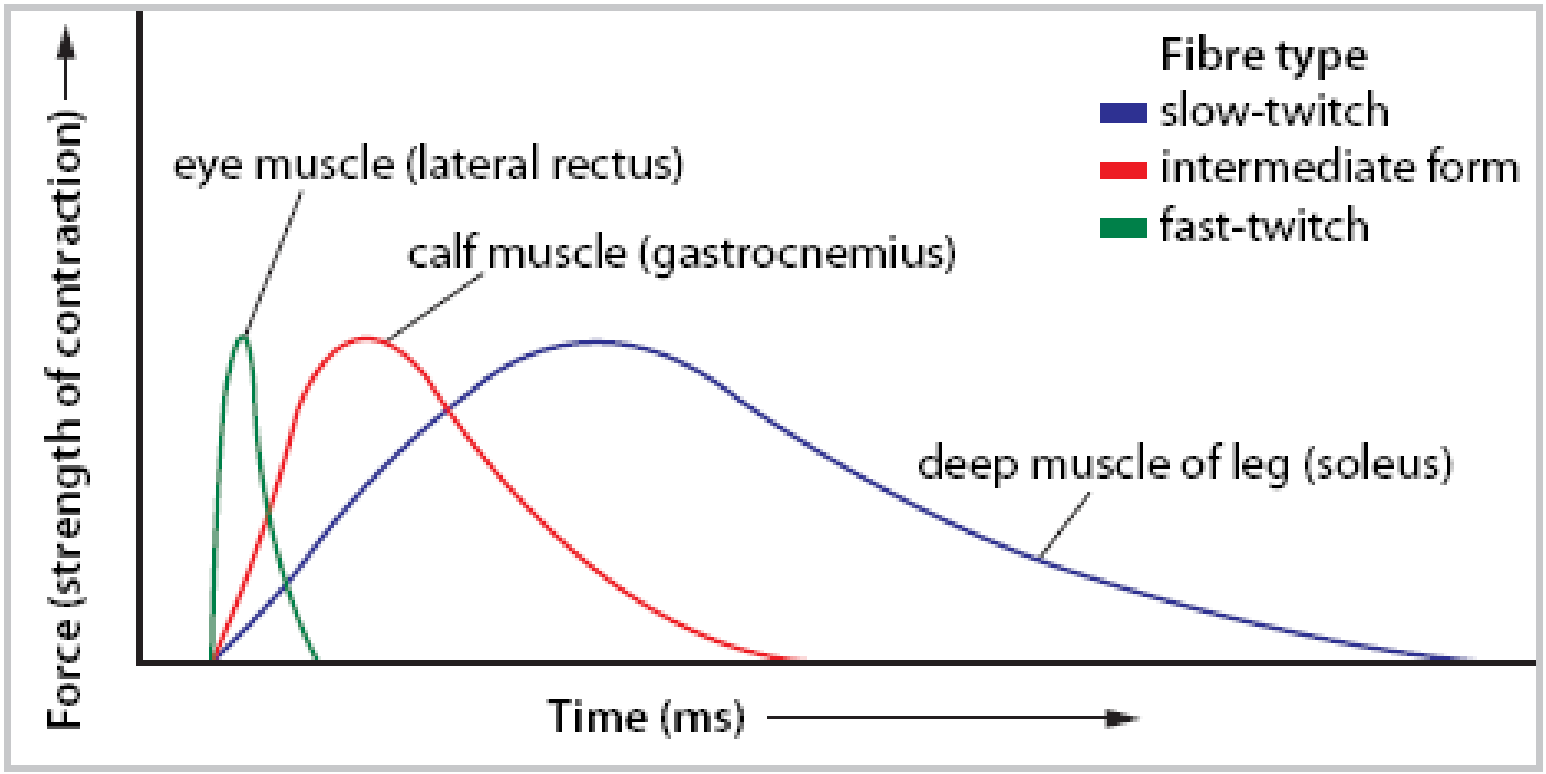
- **Fast-Twitch Fibres: (Type II Fibres)**
  - Depend on anaerobic respiration
  - Vulnerable to lactic acid build-up and muscle fatigue.
  - Adapted for the rapid generation of power (sprinting, weight lifting)
  - Rich in glycogen
  - Fewer mitochondria
  - Fewer blood vessels

- Fast twitch vs slow twitch

Fast vs Slow Twitch Muscles

- **Intermediate Form:**
  - Human muscles have a third intermediate form of muscle fibers.
  - These are fast-twitch but with a high oxidative capacity and are therefore more fatigue resistant.
  - Endurance training increases the proportion of these fibers.
  - However, heredity also plays a large role in the proportion of fast-twitch and slow-twitch fibers in the body.

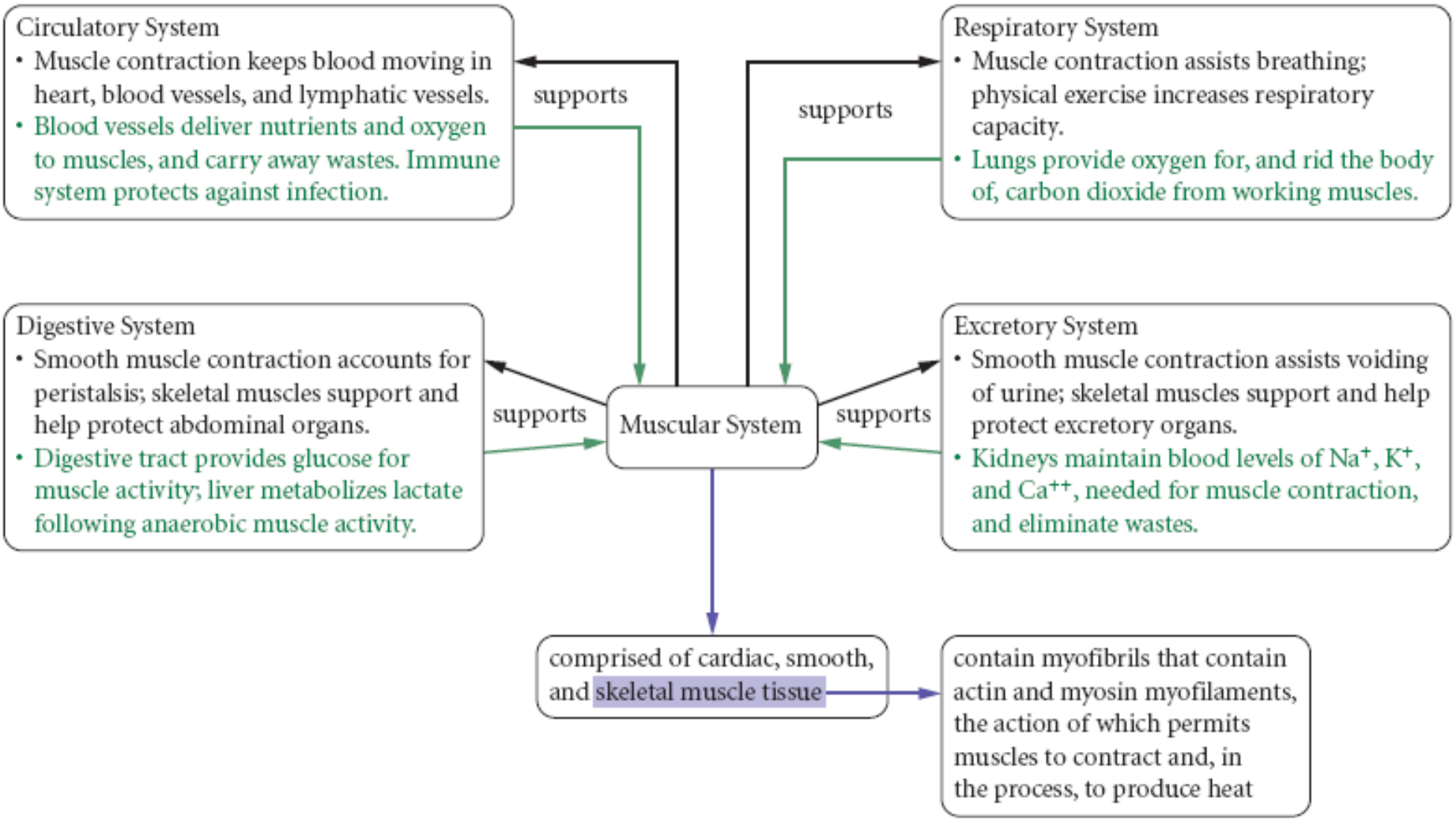
Skeletal muscles have different proportions of fast-twitch and slow-twitch fibres. Thus, the force and response times of their contractions differ.



Common Muscular System Disorders

- 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 – a permanent shortening and stiffening of muscles, tendons, skin, and surrounding tissues, leading to a loss of normal joint movement
- Fibromyalgia – chronic muscle pain that can lead to fatigue and lack of sleep. Caused by trauma, or disease
- Delayed onset muscle soreness
- Myositis – muscle inflammation

Concept Organizer



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?
- Achillies repair

Chapter 10 Summary

- All muscles do their work by contracting (shortening). Relaxation is the passive state of a muscle. There are three types of muscle cells: skeletal, smooth, and cardiac.
  - Skeletal muscle cells are attached to the bones of the skeleton, have many nuclei, are striated and tubular, and contract voluntarily.
  - Smooth muscle cells are found in the walls of internal organs, have one nucleus, are not striated, and contract involuntarily.
  - Cardiac muscle cells form the walls of the heart; have one nucleus, are striated, tubular, and branched; and contract involuntarily.
- The fact that skeletal muscles can only either contract or relax means they can pull but not push. Therefore, they must work in pairs to move any part of the body—a relaxed muscle is only lengthened when the opposing muscle contracts to stretch it. Skeletal muscle contractions are explained by the sliding filament model.
- MS
- Professor Dave Explains