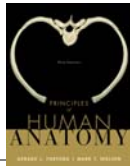


## Chapter 10 Muscular Tissue



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### Introduction

- The scientific study of muscles is known as **myology** (*myo*= muscle; *logy*= study of).
- Muscular tissue accounts for ~45% of total body mass.
- Most of the work generated by the body (e.g., pumping blood, moving food through the GI tract, creating words used in conversation, maintaining posture, and producing the movements of our skeletons, is a result of the activity of muscles.

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### Overview of muscle tissue

- There are three types of muscular tissue: skeletal, cardiac, and smooth.
- These types differ from one another in their anatomy, location, & how they are controlled.
- Muscle tissue functions by sustained contractions, or alternating contraction/relaxation.
- Muscle functions depend upon a number of physiological properties.

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### Types of muscular tissue

- **Skeletal muscle**
  - Named because it moves bones of the skeleton.
  - Is **striated** (microscopic bands) and **voluntary** (contraction can be voluntarily controlled).
- **Cardiac muscle**
  - Found only in the heart, it is striated and *involuntary* (contraction isn't consciously controlled).
- **Smooth muscle**
  - Found in the walls of tubes such as blood vessels.
  - Is unstriated & involuntarily controlled by the ANS.

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## Microscopic anatomy of skeletal muscle fiber (Fig. 10.2)

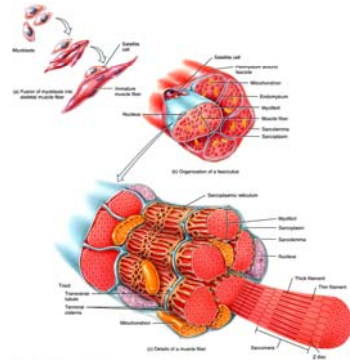


Figure 10.2: "Skeletal Muscle Fiber"  
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## Microscopic anatomy of a skeletal muscle fiber.

- Muscle fibers while very small in diameter (~100  $\mu\text{m}$ ), run the length of the muscle bundle and are usually measured in inches.
- Muscle fibers are multinucleate, form before birth, and last a lifetime.
- Muscle growth after being born is due to *hypertrophy* (increased cell size) rather than *hyperplasia* (increased cell numbers).

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## Microscopic anatomy – Sarcolemma, T tubules, and sarcoplasm.

- Sarcolemma= plasma membrane of a skeletal muscle fiber.
- T tubules= extensions of the sarcolemma that tunnel throughout the muscle fiber, are open to the outside, and are filled with ISF.
- Sarcoplasm= cytoplasm of a skeletal muscle fiber.

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## Microscopic anatomy – Myofibrils and sarcoplasmic reticulum.

- **Myofibrils** are nonmembrane bound organelles. They are 50x smaller in diameter than the muscle fiber (2  $\mu\text{m}$ ), and extend the entire length of the muscle fiber.
- **Sarcoplasmic reticulum** (SR) is like smooth endoplasmic reticulum in nonmuscle cells.
- SR stores  $\text{Ca}^{++}$  until needed. Release of  $\text{Ca}^{++}$  into the sarcoplasm couples electrical excitation to muscle contraction.

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## Microscopic anatomy – Muscular atrophy.

- **Muscular atrophy** refers to a wasting of muscle due to the loss of myofibrils within muscle fibers.
- Atrophy from unused muscles is termed *disuse atrophy* (reversible) because the flow of nerve impulses to muscle fibers is greatly reduced.
- Atrophy from the loss of the nerve supply to a muscle is called *denervation atrophy* (irreversible). The muscle will shrink considerably, with muscle fibers replaced by fibrous connective tissue.

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## Microscopic anatomy – Filaments and the sarcomere.

- Myofibrils are made of **thick filaments** and **thin filaments** which in turn are made of protein.
- These filaments are arranged in special compartments called **sarcomeres** (the functional unit of contraction).
- The pattern of overlap of thick & thin filaments consists of zones and bands which cause the striated appearance of skeletal muscle.
  - A band:
  - I band:
  - H zone:

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## Muscle proteins – general points

- Myofibrils are built from three kinds of proteins.
- **Contractile proteins** generate force during contraction by sliding past each other rather than literally shortening.
- **Regulatory proteins** help switch the contraction process on and off.
- **Structural proteins** keep thick and thin filaments in proper alignment, give the myofibril elasticity and extensibility, and link the myofibrils to the sarcolemma and extracellular matrix.

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## Muscle proteins – contractile & regulatory

- Myosin is the major component of thick filaments.
  - Myosin functions as a motor protein that achieves movement by converting the chemical energy into mechanical energy.
- Actin is the major component of thin filaments.
  - Thin filaments also contain the regulatory proteins, tropomyosin and troponin.
  - Tropomyosin and troponin regulate the interactions between actin and myosin.

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## Muscle proteins – structural

- **Structural proteins** contribute to the alignment, stability, elasticity, and extensibility of myofibrils.
- **Titin, myomesin, and dystrophin** are key structural proteins.
  - Titin is a huge protein that anchors a thick filament to both a Z disc and the M line, and it accounts for much of the elasticity and extensibility of myofibrils.
  - Myomesin proteins form the M line, bind to titin, and connect adjacent thick filaments to one another.
  - Dystrophin reinforces the sarcolemma and helps transmit tension generated by the sarcomeres to the tendons. It does so by linking thin filaments to proteins of the sarcolemma. In turn, these membrane proteins attach to proteins in the connective tissue that surrounds muscle fibers.

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## Sarcomere Anatomy

(Fig. 10.3)

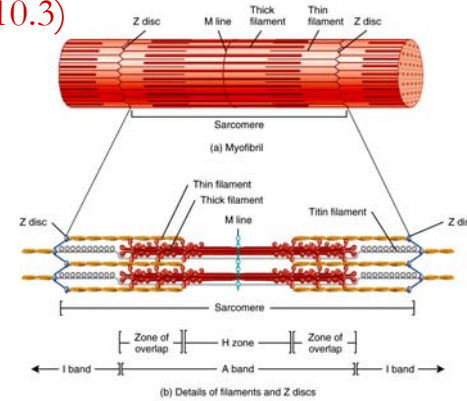


Figure 10.3: Tortora - PHK 11e  
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## TEM Showing Zones and Bands of a Sarcomere (Fig. 10.4)



Figure 10.4: Tortora - PHK 11e  
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## Structure of Thin and Thick Filaments (Fig. 10.5)

(Fig. 10.5)

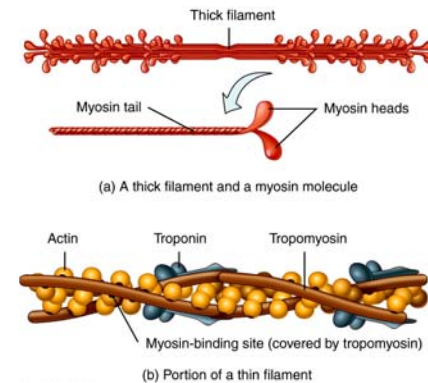


Figure 10.5: Tortora - PHK 11e  
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## Nerve and Blood Supply

- Most skeletal muscles receive one nerve that supplies them with motor and sensory functions. Other muscles (e.g., sheetlike muscles of the body wall), receive multiple nerves.
- Nerves typically enter a muscle with blood vessels as a unit called a **neuromuscular bundle**.
- These nerves carry both sensory and motor information.

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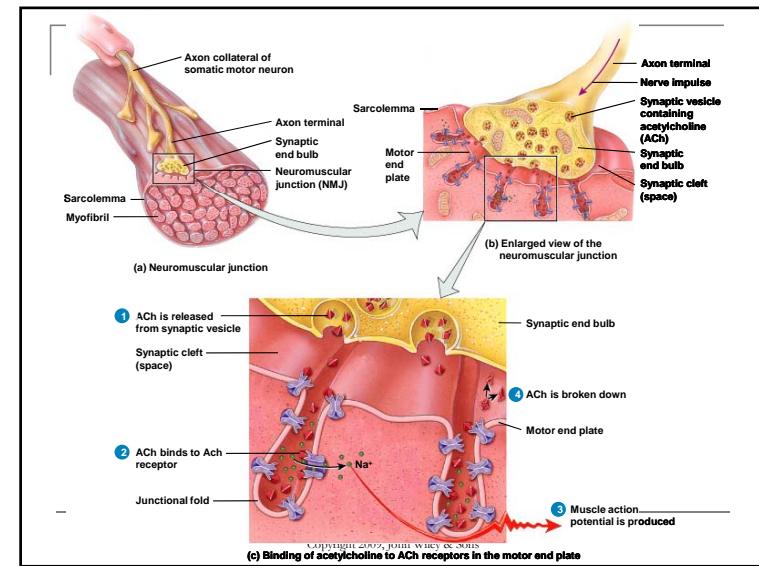
## Nerve and Blood Supply – continued

- Individual cells (neurons) that innervate skeletal muscle fibers are called **somatic motor neurons**.
- The point of near-contact between a somatic motor neuron and a skeletal muscle fiber is called a **neuromuscular junction (NMJ)**.
- Each muscle fiber has one NMJ, yet the axon of a somatic motor neuron branches out and forms NMJs with many different muscle fibers. A somatic motor neuron plus all the skeletal muscle fibers it stimulates is called a **motor unit**.

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## Structure of the NMJ Process Diagram Step-by-Step Figure 10.6

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## Contraction of Skeletal Muscle Fibers

- Nerve impulses cross the NMJ from the somatic neuron to the sarcolemma through the actions of acetylcholine (ACh).
- Muscle impulses move inside the muscle fiber via the T tubules causing  $\text{Ca}^{++}$  to be released into the sarcoplasm from the SR.
- $\text{Ca}^{++}$  couples electrical excitation to contraction, making it possible for the thick and thin filaments to slide past each other, and shortening the sarcomere.

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## Sliding Filament Mechanism (Fig. 10.7)

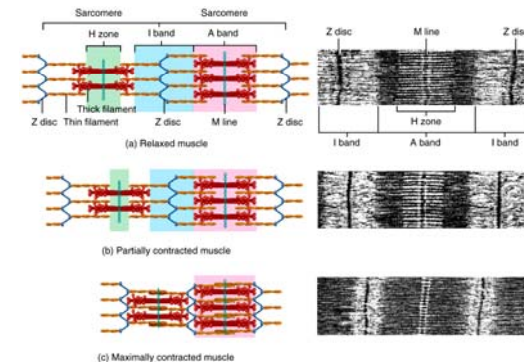


Figure 10.07 Tortora-Pick 11e.  
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## Muscle Tone

- Even while at rest, a skeletal muscle exhibits **muscle tone**, a small amount of tension due to weak, involuntary contractions of its motor units.
- To sustain muscle tone, motor unit groups are alternately contract and relax which keeps skeletal muscles firm, without producing bodily movements.
- This is very important in maintaining posture (e.g., while sitting).

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## Types of Skeletal Muscle Fibers

- Skeletal muscle fibers vary in their content of myoglobin (an  $\text{O}_2$ -binding protein).
- Muscle fibers high in myoglobin are called **red muscle fibers**, while those that are low in myoglobin are called **white muscle fibers**.

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## Skeletal Muscle Fiber Classification

- Skeletal muscle fibers can be categorized according to the rate at which they contract and relax. So, a fiber may be called 'slow' or 'fast' depending on how rapidly ATP is broken down.
- Plus, skeletal muscle fibers are categorized according to the metabolic reactions used to generate ATP and in how quickly they fatigue.
- Based on these characteristics, skeletal muscle fibers are classified as:
  - slow oxidative fibers,
  - fast oxidative-glycolytic fibers, and
  - fast glycolytic fibers.

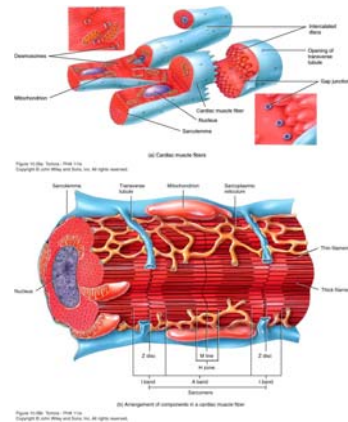
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## Exercise and Skeletal Muscle Tissue

- The relative ratio of FG and SO fibers is genetically determined and helps account for individual differences in physical performance. For example,
  - Those with more FG fibers often excel in activities that require periods of intense activity, such as weight lifting or sprinting.
  - Those with more SO fibers are better at activities that require endurance, such as long-distance running.
- Although the total number of skeletal muscle fibers usually does not increase, the characteristics of those present can change in response to specific exercise regimes.

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## Histology of Cardiac Muscle (Fig. 10.8)



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## Cardiac Muscle Cells

- Striated, involuntary, branched, & uninucleate
- Intercellular connections points (intercalated discs) contain structural and electrical connections, called desmosomes and gap junctions, respectively.
- Cardiac tissue is capable of **autorhythmicity**, an ability to spontaneously generate impulses that trigger contraction.

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## Smooth Muscle Tissue

- Involuntary, non-striate, uninucleate, & tapered cells.
- There are two types of smooth muscle:
  - Single-unit smooth muscle
    - More common
    - Autorhythmic cells linked by gap junctions
    - Found in the walls of small blood vessels and many visceral organs
  - Multi-unit smooth muscle
    - Less common
    - Contraction requires neuronal stimulation
    - Found in large arteries, and respiratory airways

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## Smooth Muscle Tissue – continued

There are numerous differences between the physiology of smooth muscle cells and other muscle tissues.

- Length of contraction
- Cell size
- Differences in filament types and ratios
- Greater regeneration capability

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## Histology of smooth muscle tissue (Fig. 10.9)

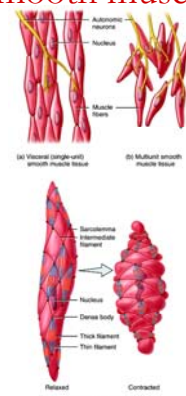


Figure 10.09 Tortora - PHA 11e  
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