# An Introduction to Muscle Anatomy and Function[•]

This section should give you some appreciation of the complexity of biological systems

I. Types of Muscles

A. **Skeletal (Voluntary)** – a **striated** (banded) type.

1. These muscles normally make up the largest portion of a person's lean body mass;

2. they are the muscles that are responsible for all voluntary movements (movements controlled by the central nervous system and which typically are directed at some sort of interaction with the environment.

3. These muscles only contract in response to instructions from the central nervous system.

4. Clearly, these are the muscles that we will be most concerned with in this course.

To a lesser degree, we will also learn about two other types of muscles. These are both not so much concerned with behavior as with physiological processes:

B. **Smooth** – very different from skeletal but very important in physiological regulation. Smooth muscles:

1. Help to regulate the flow of blood -- for instance, when these "vascular smooth muscles" contract, less blood will flow into a particular tissue -- for example a skeletal muscle. By contrast, when they relax, more blood flows

2. They control the movement of food through the digestive system.

3. The control many of functions of the urogenital system (we'll not be very concerned with these in this course) but to give one important example -- the uterus, whose contractions result in birth, is a smooth muscle.

4. We will see that they sometimes they are controlled by the nervous system and other times by chemicals in the blood or even by their own internal controls. Thus a crucial difference -- while nervous control is absolutely required for skeletal muscles, smooth muscles can, to a degree, work with out nervous stimulation!

– 5. Lastly, these muscles are **not striated.** We will see what this means shortly

C. **Cardiac** – the contracting muscle of heart, it looks quite a bit like skeletal muscle (for example, it is striated) but acts much like smooth muscle (it does not require nervous system input to function -- although we will see that the nervous system does normally matter).

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II. Skeletal muscles -- a system approach – we will need to know about the skeleton, muscle and nervous systems to understand function.

A. Remember, no skeletal muscle works without "orders" from the nervous system

B. No skeletal muscle exerts force except through the skeletal system. The order of coverage will be muscle, nerve, then bones. Reading assignment is especially important for muscle – material on bones will all come via lecture.

III. What do muscles do? -- A quick overview

A. Muscles have two states -- they are either **relaxed** or **contracted**. We will see what this means on a cellular level shortly.

1. When muscles contract, this means they shorten.

2. When muscles relax, they DO NOT LENGTHEN UNLESS SOME FORCE CAUSES THEM TO LENGTHEN. It is very important that you always keep this in mind.

B. **Cardiac and smooth muscles tend to enclose some volume and then work by squeezing on that volume**. By contrast, this sort of thing is very rare in skeletal muscles. Instead, skeletal muscles tend to be set up such whatever force **they exert is along a line**. The best way to view a skeletal muscle is to think of it as a tissue where contraction tends to move both ends of the muscle towards its center.

> Make a drawing of this. Now, if the muscle has a constant volume during a contraction (which it does since it is made up of a certain number of cells) what will happen to its shape when it contracts?
> **A quick note** -- from now on, until I say otherwise, "muscle" means skeletal muscle.

1. Normally muscles are set up so that one end is essentially anchored -- it cannot move. This end is called the **origin**. Typically, the anchor point is a bone that remains in a fixed position during a particular movement.

2. The opposite end is typically attached to something that can move -- another bone but one whose position is free to change. This end is called the insertion.

> You should know the muscle in your upper arm called the biceps (biceps brachii). Find the origin and insertions by feeling this muscle when it is relaxed and contracted.

IV. Structure of Skeletal Muscles

A. Think of Muscles as having contractile tissue and connective tissue components.

1. **Connective Tissue**

(a) These are made of proteins that are made in cells and then placed outside of the muscle cells in a highly organized manner.

(b) These proteins **<u>cannot actively contract</u>** -- they work more like rubber bands. They can be stretched and they can store energy when stretched and release energy when the force causing the stretch is removed.

(c) Their job is to:

(i) transmit force and

(ii) to protect the muscle

> When I say protect, I have more in mind than simply acting as a sort of barrier around muscle cells. We will see that connective tissues help prevent muscles from ripping when large forces are applied to the muscles -- such as happens when you land after a jump or any number of other events. We will have more to say about this later.

2. One way to talk about connective tissues is by where they are found:

a. They can connect muscle to bone, or in some cases, muscles to other muscles. These connective tissues are called **<u>TENDONS</u>**. Here's a bit more about tendons.

1. Typically one is found at the **<u>origin</u>** and one at the **<u>insertion</u>**.

2. Tendons are elastic (they are somewhat like rubber bands) but they are different in that they are relatively stiff -- thus they are not "super stretchy" but nor are they rigid.

3. They are primarily composed of a fiber-like <u>structural protein</u> called **<u>collagen</u>**. However, they also contain some amount of a "stretchier" (more **<u>compliant</u>**) structural protein, **<u>elastin</u>**.

b. Muscles are also wrapped by connective tissue.

1. These wrappings are collectively called **<u>FASCIA</u>**. (not fascist!)

2. The fascia functions are (a) <u>protection</u> and (b) <u>connection</u> – they hold the muscle together into a functional unit.

3. To illustrate, there are several layers of this wrapping. All of the functional units of the muscle (the **muscle fibers**) are surrounded by connective tissue.

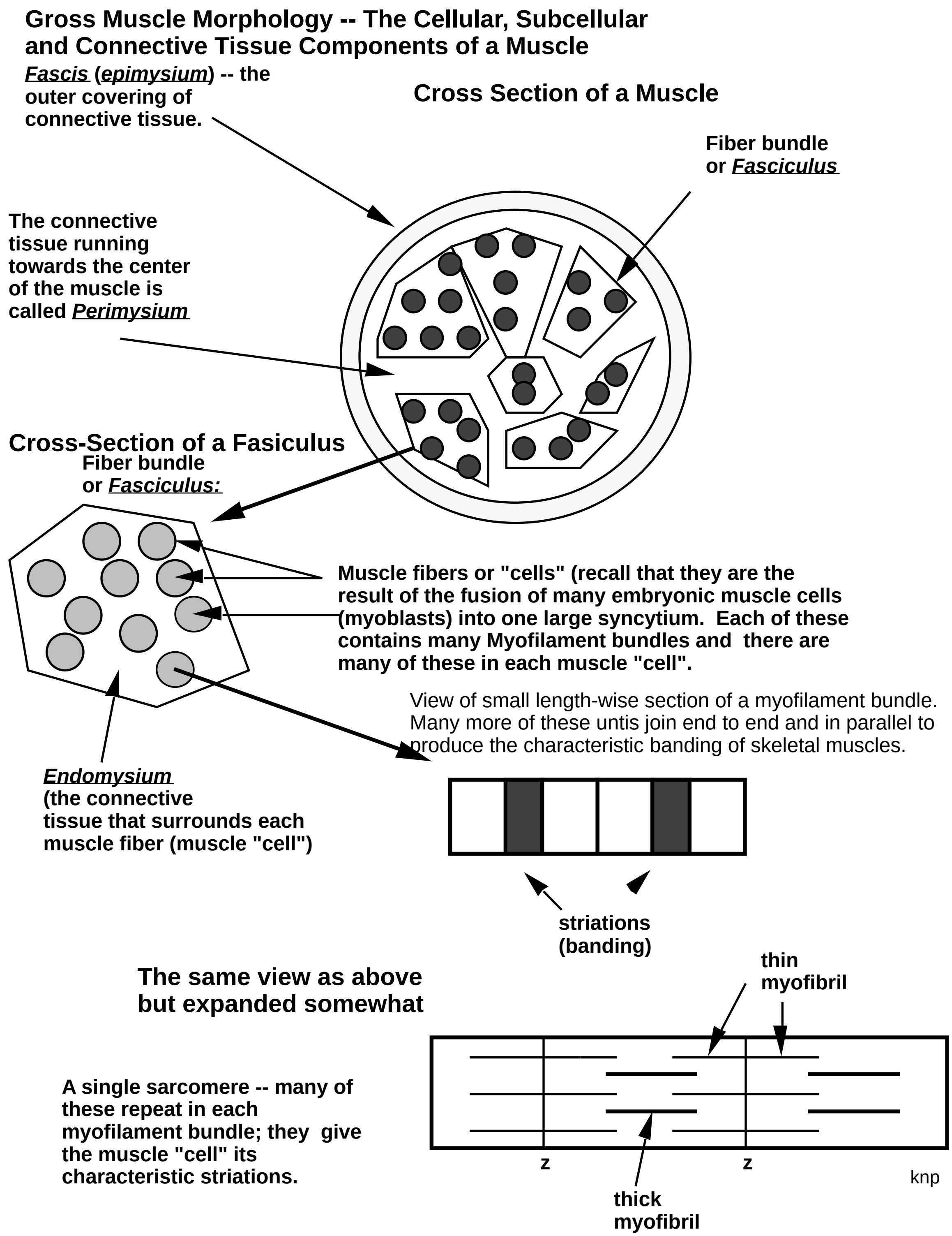
a. **Endomysium** – around individual muscle fibers.

b. **Perimysium** – around each <u>fasiculus</u> (a group of fibers).

c. **Epimysium** – around entire muscle.

4. Like tendon connective tissues are principally proteins, but in this case there is a higher percentage of elastin. This makes the

connective tissue “stretchier”.  Below is a picture of the fascia (drawn for another class):




*Please note that these diagrams are only schematic and are greatly limited by my "artistic ability"*

5. Other connective tissue is found associated with the many blood vessels

2. **Muscle Cells (fibers)**

a. These are large, multinucleate cells formed by the fusion of smaller cells early in fetal development (second trimester). They are the thickest cells in the body and only some nerve cells (neurons) exceed them in length

b. As mentioned above, each fiber is wrapped in connective tissue (endomysium) (see previous figure).

c. They provide the contractile (active force). To some degree they are also elastic.

IV. The Functional Parts of a **Muscle Fiber** (skeletal muscle cell)

**A. Support systems**:

**1. Sarcoplasm**: glycolysis reactions, stores of glycogen

2. **Mitochondria** – aerobic metabolism

3. **Nuclei and ribosomes** – source of new protein molecules that are a part of increase in strength and changes in aerobic or anaerobic capacity.

B. **Membrane system** – the place where foods and wastes enter and leave and the main avenue for communication/coordination.

**1. Sarcolemma -- the membrane surrounding the cell**

a. It is the only place nutrients and wastes can enter or leave the cell -- controls what gets in and out.

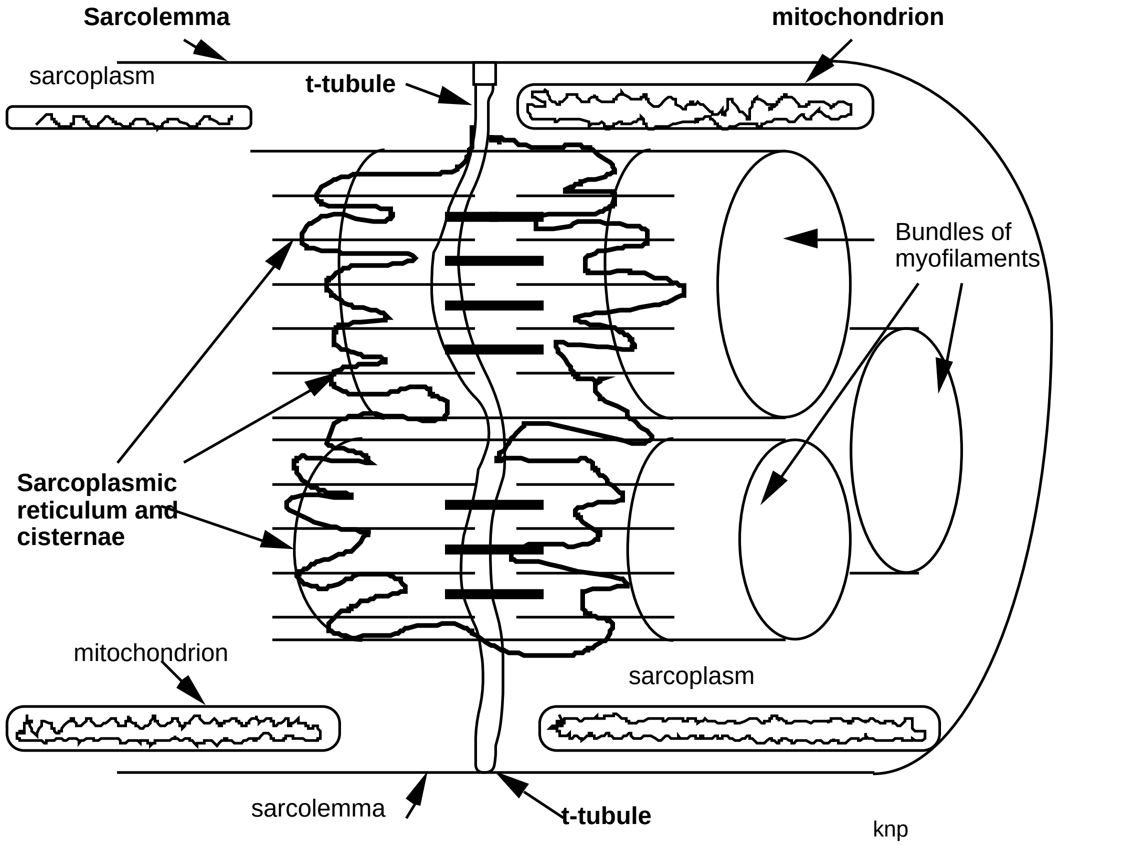
b. It is also the place where “nerve impulses” -- **action potentials (APs)** are conducted. These are signals that move rapidly along the cell.

2. **t-tubule system**: tubes that are continuous with the sarcolemma. They pass from one side of the cell to the other at regular intervals. They are closely associated with the sarcoplasmic reticulum (see below) -- functionally they are an avenue for APs to enter the cell. More about this later.

3. Internal membrane system (**Sarcoplasmic reticulum or SR**). This is an extensive internal membrane system that controls the release of Ca++ ions. We will see later that when an AP is conducted from the sarcolemma into the t-tubules, this causes the SR to release Ca++ into the sarcoplasm (get all that terminology?) for the duration of the AP. The Ca++ in turn allows the contraction to proceed. When the AP is over, the SR captures the Ca++ in the sarcoplasm. This ends the contraction.

On the next page is a picture showing the SR, Tubules, and some other elements of skeletal muscle cells that will be covered shortly:

**Some of the Histological Elements of a Single Skeletal Muscle Cell (Muscle Fiber)**

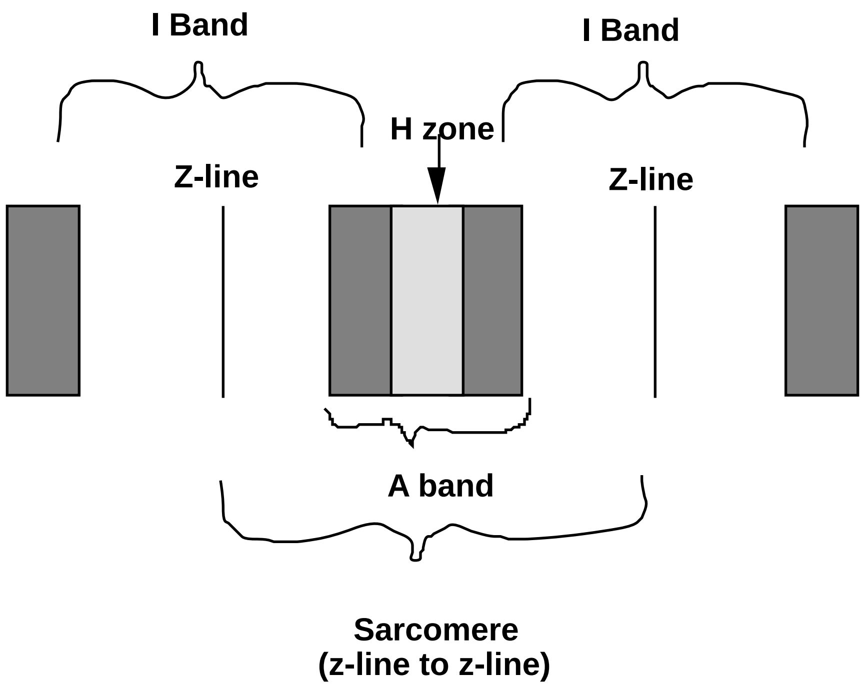



**A section of a single muscle cell. Please note that in most cells there would be many more bundles of myofibrils in parallel with each other. Note also that each bundle is composed of large numbers of sarcomeres lined up in series -- this is a very small length of the overall muscle cell. Note that near the center of sarcomeres, <u>t-tubules</u> cross the cell. They are closely associated with the <u>sarcoplasmic reticulum</u> but they are actually tubular invaginations of the sarcolemma. Specialized areas of the SR called <u>cisternae</u> sequester and release $Ca^{++}$.**

C. **<u>Contractile system:</u>**

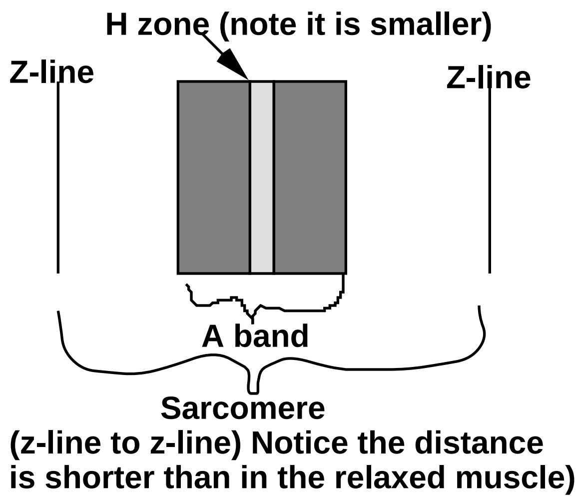
1. First, realize that most of the muscle fiber is filled with the proteins that are responsible for the contraction (see the drawing above -- the contractile proteins are called **"myofilament bundles"**).
2. You should think about the these as if they were cables running from one side of the cell to the other. These "cables" are responsible for the striations (the banding ) we observe in muscle. (see previous diagram).
3. When an individual bundle is closely observed, it can be seen (with a microscope) that there is a repeating structure of bands. (see textbook and next fig. In these notes). In a relaxed state, this repeating structure is:

4. It is called a **sarcomere** and it is a complete, functional unit of contraction. The sarcomere extends from one **Z-line** to the next. There are thousands of sarcomeres in each cell-- they exists in long continuous lines (**in series**) and also in groups that lie adjacent to each other (in **parallel**). See the previous diagram.




5. On either side of the Z-line is a relatively clear area that extends between two adjacent sarcomeres. This is called the **Isotropic Band** or **I-Band**.
6. In the center of each sarcomere is a dark area that is a bit lighter in the center in a relaxed sarcomere but overall is darker than the I-band. For our purposes, this dark region is called the **Anisoptropic band (A-band)**. The less dark central region in the A-band is called the **H-zone.**

7. When a muscle contracts, there are changes in the sarcomere. These can be seen in the next figure:




- The Z-lines move closer to each other
- The H band gets smaller and perhaps even disappears
- However, the overall thickness of the A band remains the same.

When biologists first used a microscope to see the changes in muscle in going from the relaxed to the contractile state (early 1900s) , the changes appeared to be almost magical. As materialists, however, the challenge was to discover the actual physical explanation for the behavior we have just looked at. So, in the next set of notes we will review the discoveries that led to an explanation for what we see above.