Muscular System

Skeletal Muscle Anatomy
Muscle Types

- **Skeletal muscle**
- **Cardiac muscle**
- **Smooth muscle**

Just a reminder: there are three types of muscle tissue. We'll focus mainly on skeletal muscle, but it’s important to keep the others in mind. Cardiac muscle makes up the walls of the heart. It’s cells are short, branched, striated, uninucleate and attached end-to-end at intercalated discs. Cardiac muscle tissue is *autorhythmic* – it can generate its own action potentials without influence from the nervous system.

Smooth muscle surrounds the walls of hollow organs (as well as a few other locations) and contracts in wave-like motions to push substances in a forward direction – food through the digestive tract, blood through the large veins, etc. Smooth muscle cells are non-striated, small, and uninucleate.
Skeletal muscle cells are very long and, for this reason, they are multinucleate. All skeletal muscle has a striated appearance because of the internal structure (which we’ll see shortly). The dark striations are called A bands while the light ones are called I bands. (Think of the second letters of the words dArk and llight.) Generally, skeletal muscle movements are under voluntary control. Reflexes, though, are not usually voluntary, though they are caused by skeletal muscle contractions. Skeletal muscles are bound in dense connective tissue sheaths in three ways, as we’ll see shortly.
Muscle cells are generally long and skinny, so we sometimes call them muscle fibers. Each muscle fiber is sheathed by a thin layer of dense connective tissue called endomysium. Muscle fibers are collected together into bundles of many muscle fibers called fascicles. Each fascicle is held together by another dense connective tissue sheath called perimysium. Finally, several fascicles are bundled together to make an entire muscle. Muscles are sheathed by yet another dense connective tissue layer, this one called the epimysium. The epimysium actually extends beyond the end of the muscle, where it becomes a tendon and attaches the muscle to a bone.
Skeletal Muscle Fibers

- **Myofibrils**
  - Contractile units
  - Divided into **sarcomeres** by Z discs
- **Sarcoplasmic reticulum (SR)**
  - Ca\(^{2+}\) storage
- **Sarcolemma**
  - T-tubules
- **Sarcoplasm**

Let's zoom in now on an individual muscle fiber. Remember that these are the muscle cells themselves. Muscle cells can do something unique that no other cells can do: they can contract. Since muscle fibers are so specialized, it's no surprise that they have some specialized organelles and structures.

The plasma membrane of a muscle fiber is called a **sarcolemma**. It's similar to the plasma membranes of most cells, with one major specialization: it has pockets, called T-tubules (transverse tubules), that protrude deep into the cells. When a muscle contracts, an electric charge is carried along the membrane, and these tubules allow the charge to be carried deep within the cell.

The smooth endoplasmic reticulum of a muscle fiber is called **sarcoplasmic reticulum (SR)** for short). The SR stores calcium ions in a relaxed muscle. When the SR becomes excited by an action potential, the calcium is released from the SR, starting a series of events leading to muscle contraction.

The cytoplasm of a muscle fiber is called **sarcoplasm**.

The most important, most unique organelle found inside muscle fibers are **myofibrils**. They are special organelles made of overlapping myofilaments. Myofibrils extend the entire length of a muscle fiber. During muscle contraction, the myofilaments inside the myofibrils slide over one another, causing the entire myofibril to shorten. This results in muscle contraction.
Another view of the inside of a muscle fiber.
Now let's zoom in even further and look at the inside of a myofibril. Recall that a myofibril is the contractile organelle found only in muscle fibers. Myofibrils consist of a long series of chambers, called sarcomeres, joined end-to-end sort of like the cars of a train. The walls that separate sarcomeres are called Z-discs. The figure above shows parts of 3 sarcomeres linked end-to-end. The vertical purple lines represent Z-discs.
A myofilament is a narrow structure made of specific proteins. Myofibrils consist of layers of overlapping myofilaments of two types (actin and myosin, as we'll see in the next slide). When a muscle contracts, these myofilaments slide across one another, shortening the sarcomeres and the myofibrils.

Another landmark for sarcomeres is an invisible line down the center of each sarcomere, called the M line. The M line is a tiny band of proteins that keeps some of the myofibrils lined up in the center of the sarcomere.
There are two types of myofilaments that overlap one another in each sarcomere. Protroducing medially from the Z discs of each sarcomere are thin filaments. Since the thin filaments are made largely of actin proteins, we usually call them actin myofilaments. In a relaxed muscle, the actin filaments point towards each other, but do not touch (they are pulled closer together during muscle contraction).

Suspended in the center of each sarcomere are thick filaments. Since the thick filaments are made from bundles of myosin proteins, we usually call them myosin myofilaments. The myosin filaments do not attach directly to the Z discs, but they are suspended by a thin core of protein called titin.
It is the overlapping actin and myosin filaments that gives muscles their “striated” appearance. Since myosin filaments are so much thicker than actin filaments, the areas rich in myosin filaments appear dark under the microscope (less light passes through). These are the A bands. Note that there is a narrow region at the center of each A band (in a relaxed muscle) where there is myosin, but no actin. This lighter area is called the H zone. The spaces between the ends of the myosin filaments are the I bands.
Each of the A bands in this micrograph is where myosin is stacked up. Each of the I bands is where there is actin, but no myosin. If you look closely, you can see the darker Z discs in the center of each I band. And if you look *really* closely, you can see the H zones in the middle of some of the A bands.
This is a blown-up version of the picture on the previous slide with a few sarcomere diagrams overlaid on it. You should be able to easily identify the I bands, A bands, H zones and Z discs now. (You should also be able to explain what causes each.)
Another view of what we’ve just seen.
This is a preview of how the overlapping myofilaments result in muscle contraction. The myosin filaments actually have little heads which can attach to the actin filaments and move them during muscle contraction. This is called the **sliding filament mechanism**.
So, when a muscle is contracted, the actins slide together. The H zone disappears, as do the I bands.