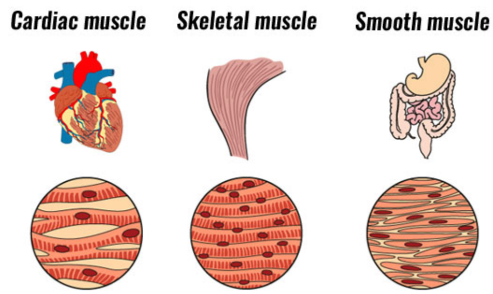
Review of Basic Muscle Anatomy & Theory for Spanda® Yoga Therapists

There are three types of muscle found in the human body: skeletal, smooth and cardiac.

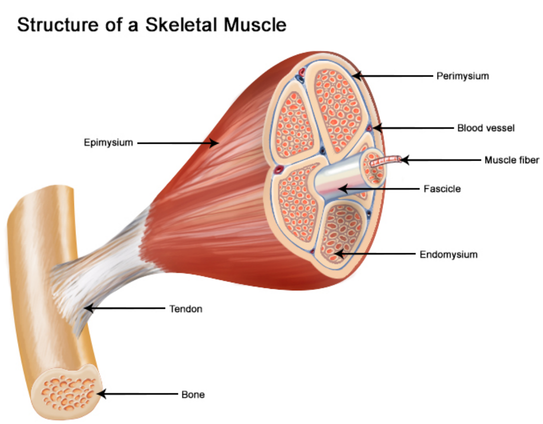


Skeletal muscles are those which attach to bones and facilitate movement of our skeletons, called striated (striped) muscles due to their appearance. Different types classified based on their speed of contraction: Type 1 (slow twitch), Type (fast twitch) 2A and 2B.

Smooth muscle, also sometimes known as involuntary muscle, is found in the walls of hollow organs such as the Stomach, Bronchi and in the walls of blood vessels. This muscle type is stimulated has slow, rhythmical contractions used in controlling internal organs.

Cardiac (heart) muscle found solely in the walls of the hear, has similarities with skeletal muscles in that it is striated and with smooth muscles in that its contractions are not under conscious control. Cardiac muscle is highly resistant to fatigue due to the presence of a large number of mitochondria, myoglobin and a good blood supply allowing continuous aerobic metabolism.

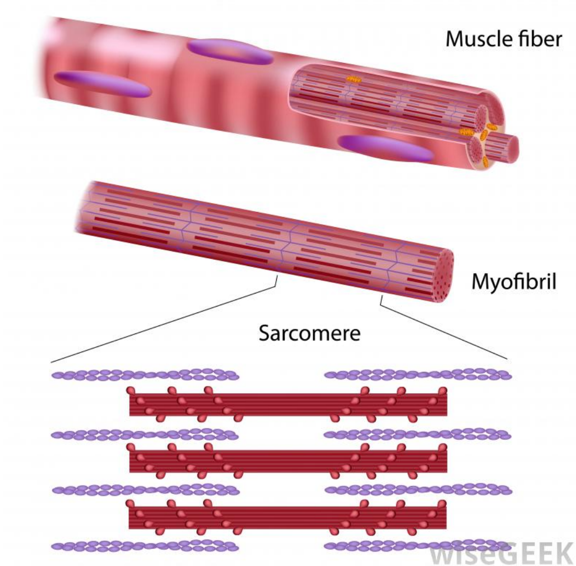
Skeletal Muscle Structure



Each muscle is made up of skeletal muscle tissue, connective tissue, nerve tissue, and vascular tissue. Skeletal muscles are widely varied in size and shape.

Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a fasciculus and is surrounded by a layer of connective tissue called the perimysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium.

Skeletal muscle cells (fibers) are soft and fragile, so connective tissue coverings support and protection them and allow them to withstand the forces of contraction. These firm coverings also provide pathways for blood vessels and nerves and extend beyond the fleshy part of the muscle (it's "belly") to form thick ropelike tendons or broad sheet-like aponeurosis. These attach to bone or other connective tissues.



Myofibrils are long filaments of contractile fibers that run parallel to each other to form muscles fibers. They're made up of repeating subunits called sarcomeres.

The sarcomeres are the contractile units of our muscles.

The sliding filament theory is the method by which muscles are thought to contract. A sarcomere is the smallest unit of a skeletal muscle that can contract. A muscle fibril will consist of chains of sarcomeres, like railroad cars on a long train.

Here are the main players involved:

- **Myofibril:** A cylindrical organelle running the length of the muscle fiber, containing Actin and Myosin filaments.
- **Sarcomere**: The functional unit of the Myofibril, divided into bands (the cars of the train).
- **Actin**: A thin, contractile protein filament, containing 'active' or 'binding' sites.
- **Myosin**: A thick, contractile protein filament, with protusions known as Myosin Heads.

Supporting Actors:

- **Titin**: (connectin) is a protein that functions as a molecular spring responsible for the passive elasticity of muscle. Titin the Z line to the M line in the sarcomere and contributes to force transmission at the Z line and resting tension in the I band region. It limits the range of motion of the sarcomere in tension, thus contributing to the passive stiffness of muscle.
- **Tropomyosin:** An actin-binding protein which regulates muscle contraction.
- **Troponin:** A complex of three proteins, attached to Tropomyosin.

Here is what happens in detail. The process of a muscle contracting can be divided into five sections:

1 A nervous impulse arrives at the neuromuscular junction, which causes a release of a chemical called Acetylcholine. The presence of Acetylcholine causes the depolarisation of the motor end plate which travels throughout the muscle by the transverse tubules, causing Calcium (Ca+) to be released from the sarcoplasmic reticulum.

2 In the presence of high concentrations of Ca+, the Ca+ binds to Troponin, changing its shape and so moving Tropomyosin from the active site of the Actin. The Myosin filaments can now attach to the Actin, forming a cross-bridge.

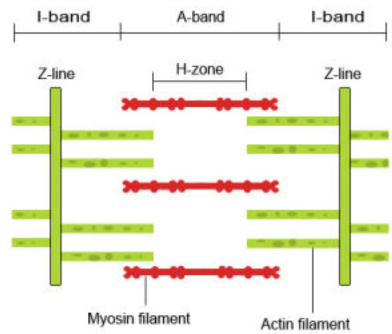
3 The breakdown of ATP releases energy which enables the Myosin to pull the Actin filaments inwards and so shortening the muscle. This occurs along the entire length of every myofibril in the muscle cell.

4 The Myosin detaches from the Actin and the cross-bridge is broken when an ATP molecule binds to the Myosin head. When the ATP is then broken down the Myosin head can again attach to an Actin binding site further along the Actin filament and repeat the **'power stroke'**. This repeated pulling of the Actin over the myosin is often known as the ratchet mechanism.

5 This process of muscular contraction can last for as long as there is adequate ATP and Ca+ stores. Once the impulse stops the Ca+ is pumped back to the Sarcoplasmic Reticulum and the Actin returns to its resting position causing the muscle to lengthen and relax.

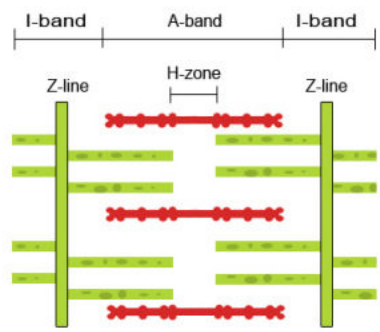
This process is also called ratcheting. A single power stroke results in only a shortening of approximately 1% of the entire muscle. To achieve overall shortening of up to 35%, the entire process must be repeated many times. It is thought that whilst half of the cross-bridges are active in pulling the Actin over the Myosin, the other half are looking for their next binding site (like crawling!)

Stretched Muscle



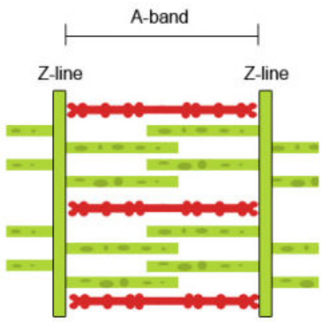
Looking at the diagram above again, shows a stretched muscle where the I - bands and the H - zone is elongated due to **reduced overlapping of the myosin and actin filaments.** There would be reduced muscle strength because few cross bridges can form between the actin and myosin.

Partially Contracted Muscle



The diagram above shows a partially contracted muscle where there is more overlapping of the myosin and actin with lots of potential for cross bridges to form. The I - bands and H - zone are shortened.

Fully Contracted Muscle



The diagram above shows a fully contracted muscle with lots of overlap between the actin and myosin. Because the thin actin filaments have overlapped there is a reduced potential for cross bridges to form again. Therefore, there will be low force production from the muscle.

Types of Muscle Contraction

Isotonic Contractions

Isotonic contractions are those which cause the muscle to change length as it contracts moving the body. There are two types:

Concentric

Concentric contractions cause the muscle to shorten as it contracts. An example is bending the elbow from straight to fully flexed, causing a concentric contraction of the Biceps Brachii muscle. Concentric contractions are the most common type of muscle contraction and occur frequently in daily and sporting activities.

Eccentric

Eccentric contractions are the opposite of concentric and occur when the muscle lengthens as it contracts. This occurs when lowering the dumbbell down in a bicep curl. The muscle is still contracting to control the weight as the joint extends, the bicep muscle is lengthening.

Another very common example is the quadriceps muscles at the front of the thigh when landing from a jump. As you land the quadriceps on the top of the thigh strongly contract as they lengthening. This type on contraction puts a lot of strain through the muscle and is commonly involved in muscle injuries. Plyometric training (hopping and bounding) involve a lot of eccentric muscle contractions.

Isometric Contractions

Isometric contractions are when there is no change in the length of the working muscles. This occurs when carrying objects and in holding yoga poses. Another example is when you grip something, such as a tennis racket. There is no movement in the joints of the hand, but the muscles are contracting to provide force sufficient enough to keep a steady hold on the racket.

The amount of force a muscle is able to produce during an isometric contraction depends on the length of the muscle at the point of contraction. Each muscle has an optimum length at which maximum isometric force can be produced.

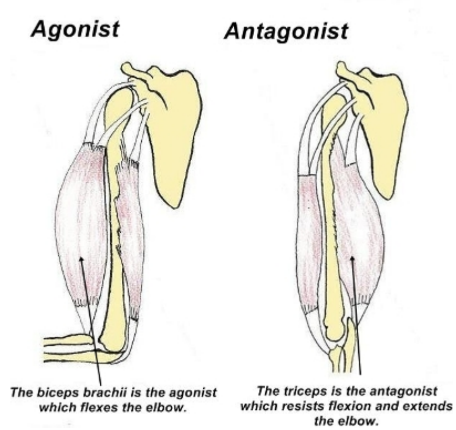
Muscle Roles: Agonist, Antagonist, Stabilizer, Fixator

Muscles work together to produce the myriad bodily movements of which we are capable. Any particular muscle's role will change depending on the movement. Synergy refers to two or more things working together. When a group of muscles work together to optimally perform a given motor task this is known as a *muscle synergy*.

Usually, the muscles directly involved in producing a certain joint movement are called **agonists** and muscles that are indirectly involved are sometimes called **synergists**. These muscles, which contribute to a movement indirectly, could more clearly be called **supporters**. While some muscles work together, in a concentric fashion, to produce a movement, others work in other ways to help cancel out other movements, such as the unwanted movement of another bone that the muscle attaches to, or by opposing the movement that could occur in an undesired plane of motion. The movement produced is the net result of all the different forces produced by the various muscles involved.

Generally, the four roles a muscle can fulfill during movement are as follows:

1. Agonist: the muscle(s) that provides the major force to complete the movement; also called ‘prime movers’. In the bicep curl which produces flexion at the elbow, the biceps muscle is the agonist, as seen in the image below. The agonist is not always the muscle that is shortening (contracting concentrically). In a bicep curl the bicep is the agonist on the way up when it contracts concentrically, and on the way down when it contracts eccentrically. This is because it is the prime mover in both cases.



Agonist and Antagonist Relationship of Biceps and Triceps Muscle

2. Antagonist: the muscles that oppose the agonist. During elbow flexion where the bicep is the agonist, the tricep muscle is the antagonist. While the agonist contracts causing the movement to occur, the antagonist typically relaxes so as not to impede the agonist, as seen in the image above. The antagonist doesn't always relax though, another function of antagonist muscles can be to slow down or stop a movement. We would see this if the weight involved in the bicep curl was very heavy, when the weight was being lowered from the top position the antagonist tricep muscle would produce a sufficient amount of tension to help control the movement as the weight lowers.

3. Stabilizer: the muscle(s) that stabilizes a joint around which movement is occurring. This helps the agonist function effectively. They can also help to create the movement. In the bicep curl the synergist muscles are the brachioradialis and brachialis which assist the biceps to create the movement and stabilize the elbow joint.

4. Fixator: the muscle(s) that stabilize the origin of the agonist and the joint that the origin spans (moves over) in order to help the agonist function most effectively. In the bicep curl this would be the rotator cuff muscles, the 'guardians of the shoulder joint'. The majority of fixator muscles are found working around the hip and shoulder joints.

Basic Ideas on Muscle Training for Yoga Therapy

Resistance Training

People usually train their muscles for strength, endurance, size, or a combination of these. There are many systems and schools of thought on how best to train for each. Many people desire a specific outcome from their training but unknowingly train in ways contrary to their goals. We'll focus on muscle strength and endurance.

Muscle composition is hereditary for the most part consisting of different types of fibers called slow twitch—or type 1—and fast twitch—or type 2. Slow twitch fibers are responsible for endurance—the ability to go long on a treadmill or cycle. If you have a predomination of slow twitch fibers, you are better adapted to muscular endurance—you are able to perform long cardio sessions and multiple repetitions of a lighter weight.

Fast twitch come in types A and B. Type A help you to endure a long sprint or carry a heavy object across the room, while type B are recruited for short, explosive moves, such as jumping or heaving a very heavy weight. A person with more fast-twitch fibers is more adept at muscular strength--lifting heavy weights for a few repetitions.

You may be predisposed constitutionally to excel in strength, muscle size (hypertrophy) or endurance, but anyone can train and make headway in gaining their desired result. For our purposes as yoga therapists, we are primarily concerned with the basics of:

- strength (also called resistance) and
- endurance training.

Muscular strength is a muscle's capacity to exert force against resistance. Your ability to bench press a barbell weighing 150 lbs. for one repetition is a measure of your muscular strength.

Due to several cultural factors such as implicit misogyny in the fashion industry, women often are afraid to train strength train as they believe their muscles will grow in size and make them appear unattractive, or at the least be unable to fit into tight fitting styles of popular clothing. So exercise classes often include training with light weights and multiple repetitions to avoid "bulk." While this does enhance the ability muscles to lift light weights for more and more repetitions, it does not build muscle, not significant improve strength beyond a very limited amount. If muscle tissue is not created, there is nothing to sculpt to look lean and toned. Women, for the most part, do not have the muscle fiber size and type or the testosterone that creates "huge" unfeminine muscles.

Resistance or strength training improves muscle strength by making muscles work against a force or weight. Free weights and weight machines, bands, weighted balls or bells, and body weight provide resistance most commonly. Beginners are advised to train 3-2 times a week, with 48 hours of rest necessary for muscle repair between sessions. It is helpful to vary any program after about 6 or 8 weeks to maintain and improve progress.

Creating a Basic Resistance Training Program

Before doing the strengthening movements, warming up is essential. In gyms you'll often see people start with light aerobic exercise like walking on a treadmill or peddling on a stationary bike for about five minutes. Dynamic stretching involving slow controlled movements through a full range of motion are also important to prepare your muscles and let them know what length you want them to remain! V*inyasa* movements are a terrific warm-up! Also, all the good alignment and breath support principles of yoga transfer perfectly to this kind of training.

A typical beginner's strength training program involves:

- 8 to 10 exercises that work the major muscle groups of the body and are performed two to three times a week.
- beginning with one set of each exercise consisting of 8-12 repetitions (reps), no more than twice a week.
- Once that is in place then gradually increase to two to three sets of each exercise. - Once 12 reps of an exercise is no longer a challenge, it is time to progress to greater challenge.

It is often very interesting to note the effects of changing training variables. In both strength and endurance training intensity, frequency and duration are factors. More specifically, changing the number of repetitions, the groups of repetitions called sets. The amount of resistance or weight, and the frequency of training will impact the results. Also allowing for more or less rest between sets, in more advanced training can play a role as well.

To improve, the movements done need to be hard enough. After about 4-6 weeks or consistent training, the neuromuscular system adapts. Exercises need to be a challenge but not so much that alignment and breath support cannot be maintained. This is called the principle of **progressive overload**.

For someone who is out of shape or coming back from an illness or injury most of their initial increase in strength is due to a phenomenon called neural adaptation. This means that the nerves servicing the muscles change their behavior. The nerves fire more frequently (prompting increased muscle contraction) and more motor units are recruited to perform the contraction. The muscle gains strength but remains the same size at first, and it not visibly different. In time, muscle cells respond to continuous resistance training by increasing in size and appearing more toned.

The muscles respond in size and strength as they are forced to adapt, most resistance training experts advise changing up the exercises done in some way every 4-6 weeks. Ways to continue to improve include incremental changes. Here are some common ones:

- Increase the number of repetitions.
- Increase the training time by 10 or 15 minutes.

- Increase the frequency of training sessions (keeping in mind that each muscle needs at least 48 hours of recovery time.) Split sets can allow more frequent training by splitting body parts focused on over the different days of the week: i.e. upper then lower.
- Increase the weight by about 5 to 10 percent.
- Cross-train with other activities such as swimming or running.

Muscular endurance refers to the ability to perform a specific muscular action for a prolonged period of time. For example, your ability to run a marathon is due to muscular endurance.

Muscle endurance resistance training requires lighter weight than what would be used for strength training. The amount of weight can be determined by experimenting the number of repetitions possible. For endurance the person should be able to lift the weight 15-20 before fatiguing. This type or training is helpful when someone is rehabilitating from illness or of course, for endurance events, although strength training can be useful in both cases as well! It is also useful to develop the load bearing of connective tissue.

The principles of resistance training involve manipulation of the number of repetitions (reps), sets, tempo, rest, exercises and force to overload a group of muscles and produce the desired change in strength, endurance, or size. General rules of thumb:

- muscle power – 1 to 6 RM per set
- muscle strength/power – 3 to 12 RM per set
- muscle strength/size – 6 to 20 RM per set
- muscle endurance – 15 to 20 or more RM per set.

Specific combinations of reps, sets, exercises, resistance and force will determine the type of muscle development achieved.

Flexibility Training

For activities that demand both strength and flexibility it is important to train for both things. After resistance training, muscles tend to remain in a decreased range of motion, so it is important to elongate them afterward, so they will retain their length, ease and range of motion. A muscle that can lengthen before it contracts can contract with more force.

As with most method of training, there are various schools of thought on flexibility training. Recent research has shown that dynamic stretching, moving the body through an increased range of motion, is a superior way over static or held stretches to prepare the body for activity. This would be like warming up with Spanda *pawanmuktanasana*. After activity, or at the end of a flow yoga class, or exercise class, it is helpful to perform static stretches. This helps to increase and maintain muscle length, as well as to cleanse the muscle tissue after intense use.

Also, as in classical *yogasana*, flexibility will increase as stretches are done with respect to a full range of motion. This can be worked into gradually during a single training session and as well after sufficient warming up and over time.

Flexibility training is categorized into three types:

- Dynamic –moving the body or a limb through an increased range of motion and in multiple planes of motion using bodyweight. Dynamic stretching is considered an active stretch since the muscle is contracting and relaxing.

- Static-active – ability to maintaining a joint or limb in an extended position using the strength of the muscles (holding the leg up in *padaghusthasana*) for a designated period of time.
- Static-passive – maintaining a joint in a stretched position using the help of gravity or some apparatus for a designated length of time – usually a minimum of 30 seconds *(upavisthakonasana*).

Ballistic stretching (also called bounce stretching) involves forcibly stretching muscles by performing quick, powerful movements. In general, this type of stretching increases chance of injury by micro-tearing muscle fibers and does little to actually improve flexibility. Rather, it causes muscles to tighten up significantly.

Also, once a muscle has reached it maximum length, continuing to stretch it only stretches ligaments and stresses tendons. If a ligament is overstretched it can return to original length after a few weeks of rest, however if it is repeatedly over stretched it becomes slack. When this happens, the joint is loosened, and further injury is likely. Ligaments can tear when stretched beyond 6 percent increase of normal length. Tendons should not stretch at all. Excess stretching leads to joint instability and injury.

There are various other advanced stretching techniques that combine elements of both passive stretching and active stretching, typically performed with the help of another person, such a press and stretch techniques.

Other things to improve flexibility that aren't stretching are:
- massage – breaks up restrictions in muscles and tissues, self, foam rollers and yoga balls
- relaxation – to counteract stress and balance out chronic holding patterns
- diaphragmatic breathing – promotes lowering of tone and movement of *prana* through entire body thus supporting the muscular system (nourishing and cleansing it).
- Hydration – a large part of muscle composition, muscles function better and are less injury prone when well hydrated.

Videos Viewed

Skeletal Muscle:
https://www.youtube.com/watch?v=MZJ6kTKDFmw

On Muscle Structure:
https://www.youtube.com/watch?v=Ktv-CaOt6UQ

On Muscle Contraction:
https://www.youtube.com/watch?v=I80Xx7pA9hQ

On Protective Responses: Sensory organs in muscle units
https://www.youtube.com/watch?v=t6DhSK_1fio