The muscular system

The primary function of muscle tissue is to produce movement, whether this is the external movement of our limbs enabling us to move around, or the movement of our internal organs ensuring our heart continues to beat, our food passes along the digestive tract, and so on.

Types of muscle tissue

There are three types of muscle tissue: skeletal, cardiac and smooth. Whilst they share some characteristics, they differ from one another in their location, their control system via the endocrine & nervous systems, and in their microscopic anatomy.

Skeletal/Voluntary Muscle

- Most skeletal muscles are attached to the skeletal system enabling us to move around
- They are striated (striped) since they consist of dark & light bands
- Each muscle is comprised of bundles of muscle fibres, which in turn are made up of bundles of muscle filaments. It is the arrangement of these filaments in relation to each other that gives this type of muscle tissue its striated appearance
- Most have a **voluntary** action since they are under conscious control
- Most are also capable of involuntary control such as our reflexes or shivering
- **These are the muscles that we, as yoga teachers, are primarily concerned with!**

Cardiac Muscle

- Found only in the heart
- It is also striated as it is also comprised of bundles of fibres, but it has extra connections between the fibres that are not found in other muscles. These extra links are thought to be connected with the special need of the heart muscle to function efficiently throughout our entire lifespan.
- It possesses an involuntary action, although there are reports yogis can alter theirs!
- The heartbeat is initiated by the pacemaker and adjusted by the actions of several hormones and neurotransmitters

Smooth/Involuntary Muscle

- Located in the walls of hollow internal structures such as the blood vessels, airways and most organs
- Non-striated or smooth
- Usually under involuntary control

Types of muscle fibres

Muscle fibres run parallel to their direction of pull, note **they only pull** they cannot push.

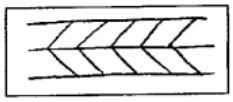
The skeletal muscles are sometimes named according to their shape, direction of fibres, position, function or number of attachment points.

Strap muscles where there is no tendon meaning they are fixed from bone to bone. They are relatively weak. eg. intercostals

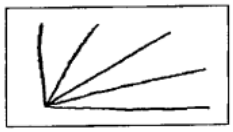
Fusi-form muscles are spindle shaped with tendons at both ends. They are usually very mobile and with good strength. e.g. biceps

Quadrate muscles stabilise joints e.g. at side of knees

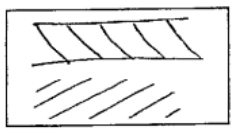
Triangular muscles have great strength e.g. jaw muscles



Pennate muscles contain many short fibres and ends of tendons. They are lie in the direction of the pull of the muscles possessing good strength but a small range of movement e.g. calf muscles



Multi pennate are as above but contain multiple sets e.g. deltoids



Sheet muscles provide support, protection or simply covering e.g. latissimus dorsi, abdominal muscles

It is often helpful to imagine the direction in which the muscle tissue lies as this indicates what movement it can create, remembering that to create movement the muscle will be attached to bones, usually across a joint. For instance the thigh muscles, the quadriceps, are vertical muscles running down the thigh and across the knee joint and when contracted they can lift the patella, the knee cap.

Functions of muscle tissues

- **Producing body movement**
  Here the skeletal muscles act with the bones and joints to create movement. ***One or more skeletal muscles must cross at a joint to produce movement.***

- **Stabilizing body position**
  Skeletal muscle contractions stabilize joints and maintain body positions, especially the postural muscles which continuously contract to maintain posture. ***Yoga helps us to stop using the wrong muscles to stabilize the body, if we continue to use secondary muscles they become taut creating tension or eventually become weakened as they become exhausted through overuse.***

- **Regulating organ volume**
  Smooth muscles in the form of ring like sphincters act to close various organs so regulating fluids within. ***Sometimes in yoga we work with the sphincter muscles such as when perfoming ashwini mudr, the contractiom of the anal muscles.***

- **Moving substances within the body**
  Each type of muscle is able to move particular substances within the body. For example cardiac muscle pumps blood throughout the body, the flow of blood being

regulated via the changing diameter of the blood vessels. This is possible with the help of smooth muscle located within the walls of the blood vessels. Smooth muscle also performs many functions such moving food through the digestive tract and urine through the urinary system. Skeletal muscles promote the flow of lymph and help with the venous return to the heart. ***The practice of asana is very helpful here since we help to flush through inner organs as we move, toxins are moved away from tissues and new oxygen and nutrients are brought in; twists in particular are excellent. As areas are worked the blood supply is increased and all tissues benefit keeping them younger and more elastic. Asanas are very good at helping the lymphatic system move lymph since, unlike the cardiovascular system, it has no pump and relies on the squeezing and releasing action of movement; inversions can be especially helpful at moving lymph from the feet and legs to the lymph nodes at the groin.***

- **Producing heat**
  Muscle contractions produce heat and help to maintain body temperature. They can also help to warm the body through involuntary contractions such as 'shivering'. ***The mat we use for yoga is generally called a tapas mat and one translation of tapas is 'heat', a great deal of heat can be generated even by standing statically in a yoga asana!***

Properties of muscle tissue

- **Electrical excitability**

  They have the ability to respond to certain stimuli by producing electrical signals. These stimuli may be electrical stimuli arising in the muscle tissue itself (autorhythmic) or by chemicals, hormones, neurotransmitters etc.

- **Contractibility**

  They have the ability to contract when stimulated by an action potential. There are two types of contraction:

  Isometric contraction is where the muscles contract but your joints don't move and muscle fibres maintain a constant length. "Metric" means 'measure', but isometric does not necessarily refer to movement but to the ability to contract the muscle between its two ends, holding the muscle at the same length under resistance. This gives muscles bulk, strengthens the body and helps us to avoid degenerative conditions such as osteoporosis.

  Here the load exceeds the muscle tension so there is no movement created.

  Isometric exercises are typically performed against an immovable surface for example, pressing your palm against a wall. This type of stretching is rarely used in sports because they favour moving stretching it is however used to very good effect in yoga.

  Isotonic contraction is where a body part is moved and the muscle shortens. "Iso" means 'same or equal' and "tonic" means 'tone'. It therefore refers to 'normal' movement where there is minimal resistance. Examples of isotonic movement include walking, running etc.

  Here muscle tension exceeds the load being exerted so movement is created.

Although sit-ups, push-ups and pull-ups are isotonic, lifting free weights, like dumbbells and barbells, is considered the classic form of isotonic exercise. Yoga also utilises this type of stretching.

There are two types of isotonic contraction:

I. **Concentric contraction**: the entire muscle length shortens as there is contraction against the resisting force, usually occurring when lifting a load such as when as for instance when the biceps brachii muscle shortens concentrically to lift a book.

II. **Eccentric contraction/lengthening:** muscle length is contracted but gradually extends as continues to resist a load, usually occurring when controlling a downwards movement against gravity such as when we set a book down by slowly extending the elbow, we can accomplish this by allowing the muscles as a whole to become longer whilst keeping **some of the muscle fibres** in a state of **contraction** i.e. muscle increases in length under tension, while resisting gravity

"In Hatha yoga we can see concentric shortening and eccentric lengthening in many situations. A simple example is when the back muscles shorten concentrically to lift the torso up from a standing forward bend, then when we slowly lower to the ground the back muscles resist the force of gravity, that is they are eccentrically lengthening." (1)

Within yoga we use both isotonic & isometric movements. Yoga asanas tend to involve a large number of isometric contractions; this is because in most asanas you will hold a position with resistance against gravity, meaning over time, this will increase your strength and stamina. By stretching muscles slowly and gradually and holding the stretch for a time, you will also achieve an increase in flexibility producing long strong muscles.

In Yoga, we usually follow an asana with an opposite type of movement. This also alternately squeezes, relaxes, and stretches the smooth muscles, resulting in improved overall health and wellbeing, as blood circulation is facilitated.

- **Extensibility**

  They have the ability to stretch without being damaged

- **Elasticity**

  They have the ability to return to their original shape after contraction or extension.

  Although here as you may remember pregnancy releases the hormone relaxin and this allows for more flexibility as muscles and connective tissues relax, however if a student works at 100% of the possible range of movement they may find tissue will not return completely to its natural state. It is reported that this heightening of relaxin can last up to one year after the birth so great care must be taken.

Skeletal muscles

Remember that we are primarily concerned with the voluntary skeletal muscles.

Each skeletal muscle is a separate organ composed of hundreds to thousands of fibres. Connective tissues surround muscle fibres and whole muscles, and blood vessels and nerves penetrate into the muscles.

To understand how skeletal muscles can generate tension, to enable movement, we need to look at its anatomy.

The skeletal muscle consists of individual muscle fibres bundled into fascicles and surrounded by three connective tissue layers that are extensions of the deep fascia. **This design gives strength rather like a rope made of lots of smaller ropes.**

The deep fascia allows for free movement of muscles, carries nerves, blood and lymphatic vessels, and fills spaces between muscles.

The three layers of connective tissue extend from the deep fascia to further protect and strengthen skeletal muscles.

Many fascicles are large enough to be seen by the naked eye rather like the 'grain' seen in a piece of meat.

All three connective tissue layers (epimysium around the whole muscle, the perimysium around the fascicles and the endomysium around the individual muscle fibres) may extend beyond the muscle fibres to form a **tendon,** a cord of dense regular connective tissue which attaches the **muscle to** the periosteum of the **bone**. (see figure A above). An example is the calcaneal tendon of the gastrocnemius muscle i.e. the Achilles tendon of the calf. If a tendon is broad and flat then it is known as an aponeurosis such as the galea aponeurosis of the skull.

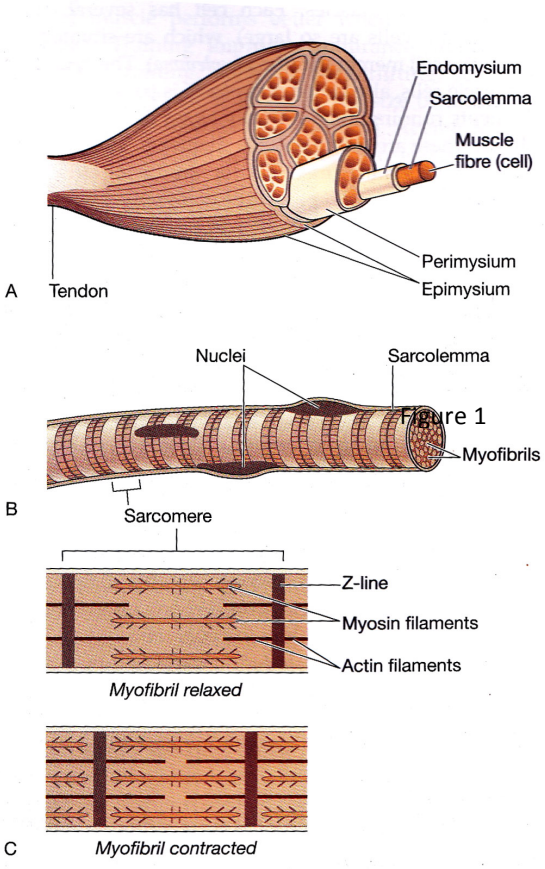


Figure 1

How skeletal muscles function

The sliding filament mechanism

If we examine voluntary skeletal muscles then we can see the striated muscle tissue see figure 1 above from Ross & Wilson (3). This 'stripy' appearance is due to the chemical composition of the filaments that make up the muscle. The filaments are composed of two proteins, actin and myosin, which form a single protein called actomyosin. When the muscle receives a signal from the brain telling it to contract then the actin filaments are pulled along the myosin filaments by electro-chemical activity. As the filaments slide along each other the muscle is shortened, this is called the sliding filament mechanism (see C above)

At first when the muscles are activated it is purely the surrounding connective tissue that is pulled upon, this is called the stage of **passive tension** but then as the tension increases and the surrounding connective tissue becomes taut the bones are pulled upon creating movement, the stage of **active tension.**

The neuromuscular junction

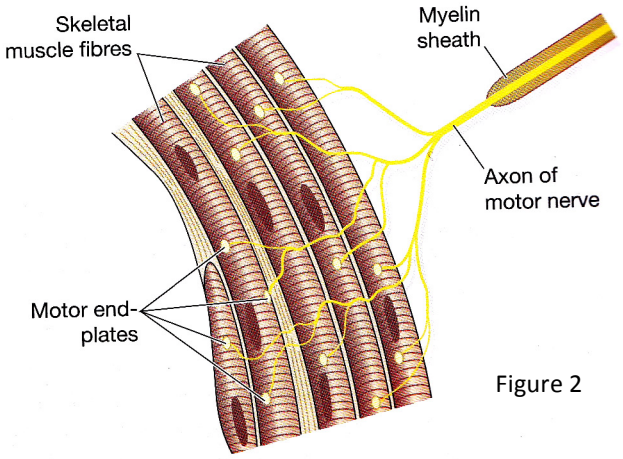


Figure 2

The skeletal muscles are served by the nerves of the somatic motor neurons. Lookig at figure 2 from Ross & Wilson (3) you will see how the somatic motor neurons possess an axon that extends from the spinal cord or brain into a group of muscles. Each axon is wrapped by a myelin sheath that aids the conductivity of nerve impulses. Nerve impulse can travel up to 100miles per second. Where the motor neuron meets the muscle fibre the axon terminals expand into a cluster of synaptic bulbs, there is usually a small gap here, this junction is called the Neuromuscular Junction; it is here that 'messages' in the form of various chemicals called neurotransmitters, in particular acetylcholine (Ach), cross the gap. These neuromuscular junctions are generally found at the centre of the length of muscle tissue so that the action potentials arise here and they can easily propagate the potential simultaneously throughout the muscle.

Each nerve ending from a motor nerve stimulates a single muscle fibre or a group of a few muscle fibres. The muscle fibre or fibres can either be in a state of on or off meaning a muscle can be partially contracted by activating just a few motor units or fully contracted by activating all motor units.

This 'all or nothing' principle also means those muscles requiring fine movement will have a much lower muscle fibre to nerve ratio, for instance the muscles of the face or hands will have more nerves to fibres and those like the gluteus muscles will have less nerves to fibres.

"It is a well-known fact in sports science that movements requiring effort will increase:
• The number of nerve branches reaching the muscles contracted
• The number of neuromuscular connections (synapses)
• The quantity of neurotransmitters exchanged between muscles and nerves at the synapse

This happens with any regular exercise program, including dance, sports, gymnastics, martial arts and Yoga. By practicing the multiple variety of asanas - standing, sitting, supine, prone, inverted etc - and by gradually being introduced to more challenging positions, Yoga practitioners improve their neuromuscular function (i.e, strength, stamina, and flexibility) and coordination.

Practicing yoga with knowledge and control of your muscles refines your technique and provides safety, ease, and pleasure in your sadhana (regular practice). Knowing which muscles you need to contract voluntarily, which to relax, and in which to allow stretch will help your body to cooperate better." (2)

Sometimes, you may need to contract the same muscles being stretched, for precision and self-protection, which tends to strengthen them more; Our body is certainly extraordinary!

The fuel for the muscles

Skeletal muscles have a good supply of blood through arteries and veins. Capillaries act to bring in oxygen and nutrients and remove heat and the waste products of metabolism. The fuel required for the movement of muscle filaments is glucose, a simple form of sugar. Complex sugars and starches are broken down in the digestive system to form glucose. Glucose is carried by the bloodstream and is stored in the liver and the muscle fibres in the

form of glycogen, so that it is immediately available. To convert glycogen into energy the muscles use oxygen which is also carried by the bloodstream.

When glucose is metabolised in the presence of oxygen, pyruvic acid and carbon dioxide are produced as waste products. These waste products are quickly dispersed through the blood stream. This is **aerobic respiration**, i.e. respiration where oxygen is utilized.

However if when performing intensive exercise, such as sprinting, the body cannot take enough oxygen to the muscles then the body switches to **anaerobic respiration**. Here the muscles can continue to contract for a short duration without oxygen. When glycogen is metabolized without oxygen then lactic acid is produced as a byproduct and this remains within the muscle. The muscle cannot sustain this kind of action for very long since the lactic acid accumulates causing muscle fatigue and the muscle will seize (cramp). There is an oxygen debt whereby more oxygen is required to oxidize the lactic acid so that it can then be transported away in the bloodstream. This is why many sprinters pant heavily after a sprinting race.

When muscular effort has been prolonged or too intense for the oxygen to be replaced quickly enough then the muscle will ache afterwards. This is because the lactic acid has been left within the tissue as a sticky waste product. It prevents the muscle filaments from smoothly sliding over one another. Friction is caused, giving the sensation of pain.

The Origin and Insertion for muscles

Tendons attach muscle to bone as an extension of the muscle sheath and are used to create movement.

All movement throughout the body is created by the pull of muscles against bone. Muscles are linked to the bones via tendons, extensions of the muscle's sheath of connective tissue. Each muscle has at least two points at which it connects with the bone; at the point where the muscle begins it is called the origin and the point at which it ends is called the insertion, although they are sometimes simply called 'attachments' as when we move differently a muscle's insertion point can become the origin and vice versa.

Indeed when the force travels from insertion to origin, the posture is easier to hold. If the force is obligated to travel in the opposite direction, the posture becomes more difficult and challenging, but also strengthening. For instance the biceps brachi of the upper arm flex the arm at the shoulder and when we are standing with arms overhead then the insertion point at the radius has lifted the arm so this is relatively easy whereas if performing a handstand where arms are still overhead now the effort is downwards from the origin at the scapula making it more difficult to hold.

Sudden movements, improperly performed may overstretch a tendon. When they are overstretched or 'pulled' then they must be rested, with a cold compress administered initially followed by alternating hot and cold compresses at a later stage. An elastic support can be used to alleviate pain. If a tendon is torn then this may require surgical intervention. These conditions may arise if an individual attempts strenuous exercise prior to a warming preparation.

Ligaments attach bone to bone, as a binding support.

Like tendons ligaments are comprised of fibrous connective tissue however ligaments are specifically designed to help bind the joints so offering support. Ligaments connect bone to bone and can be perceived as a type of internal elastic bandage.

If taken beyond their normal range of movement they too can be overstretched or torn. There is often pain accompanied by a soft puffy swelling caused by the escape of fluid into the surrounding tissues. Rest is required and supportive strapping can be used. Hot and cold compresses are useful once the swelling has reduced.

Note when injured tendons and ligaments take a long time to heal because there is very little blood supply reaching them, three months minimum.

Remember during pregnancy pregnant women must never overstretch or they may find after childbirth their ligaments remain loose and their protective, supportive role is lost.

Muscle Tone

Tone is used to describe the state of slight tension required by muscles to maintain their normal postural functions. It can also be used to describe the efficiency with which the muscles can switch from their resting to active state.

The minimum tension does not cause fatigue but when there is bad posture then excessive tension is required to maintain the body.

When an individual possesses poor muscle tone their muscles may appear to be 'flabby' and they may move 'floppily'. As we age there is also a loss in muscle tone and this is most visible within the facial muscles.

Sometimes yoga students appear very flexible but it will often be the case that there is no tone, this is especially the case if you are working with young disabled students.

Antagonistic Pairs

There are approximately 600 muscles within the body but fortunately we do not need to know them all! The other good news is they often work in antagonistic pairs.

Many muscles work in pairs, known as antagonistic pairs. One muscle must relax in order for another muscle to contract. The prime mover is called the **agonist** and the muscle that must relax or hold is the **antagonist.** For example when the triceps (agonist) contracts to draw on the radius & ulna to straighten the arm then the biceps (antagonist) must necessarily relax.

There are also **fixator** muscles that act to stabilize a joint during movement or weight bearing actions and **synergists** that aid the prime mover or agonist muscle. They often act to neutralize undesired movement.

The way in which muscle work in concert to create movement is often quite elaborate!

Muscle Facts

Water within the body accounts for about 65% of our body weight and of the remaining 35%:

Fat	Bone marrow	Viscera	Connective tissue/skin	Blood	Muscle
14%	14%	12%	9%	8%	43%

So in real terms our muscles account for approximately 15% of our total body weight.

(1) Coulter H.D. (2001) Anatomy of Hatha Yoga, 1st edition, Honesdale PA: Body and Breath Inc, p26
(2) Hately S. Maffey L. & Kapetaniou L.S. (1999) 3D Anatomy For Yoga: The Essential Guide, London: Primal Pictures Ltd (DVD)
(3) Waugh A. & Grant A. (2006) Ross and Wilson Anatomy & Physiology in Health and Illness, 10th edition London:Churchill & Livingstone pp 415-416