Anatomy Lecture Notes Section 3: Skeletal Muscle

Muscle Tissue

Muscle tissue is the third type of the four primary tissues we will explore. From our brief introduction to tissues in the first section, we know there are three main types of muscle tissue: **Cardiac**, **Skeletal** and **Smooth muscle**. These three tissues have similar properties and yet have very different roles in the body.

Regardless of the specific type of muscle, all muscle tissue shares four important properties: They are contractile, elastic, extensible, and excitable. In the body, muscle tissue provides movement of the whole or a specific body part. In this section the focus is on skeletal muscle only.

Skeletal Muscle Tissue and Muscle Organization

Skeletal muscle is almost always attached to bones of the skeleton and must cross at least one articulation (joint) to have a detailed action in the body. When examining skeletal muscles in anatomy, it is important to understand that they have a beginning (origin) and an end (insertion). Knowing the origin and insertion of skeletal muscle helps us to identify its function. The term **origin** of a skeletal muscle refers to the more fixed or stable structure that it is attached to, this is most often a bony landmark. The term **insertion** is the site that it is also attached to which is the less fixed or more moveable end or structure. In the appendicular skeleton, the origin is more *proximal*, and the insertion is more *distal*. When a skeletal muscle contracts it pulls on the insertion and causes an **action** or body movement at an articulation.

Skeletal muscles usually act as though they are all concentrated at the point of the insertion and not where the bulk of the muscle is seen, which will tend to lie "upstream" to the body part being moved. For example, the muscles which move the upper arm actually originate from the axial skeleton of the chest and upper back; those muscles moving the fingers of the hand reside in the forearm; muscles moving the leg originate on the thigh, and so on.

I. Functions of the Skeletal Muscular System

In the human body, skeletal muscle accounts for about 40% of body mass in males, and 30% of body mass in females. That is a significant proportion and is one reason why skeletal muscle activity has such a big impact on the entire body. The main functions of skeletal muscle are:

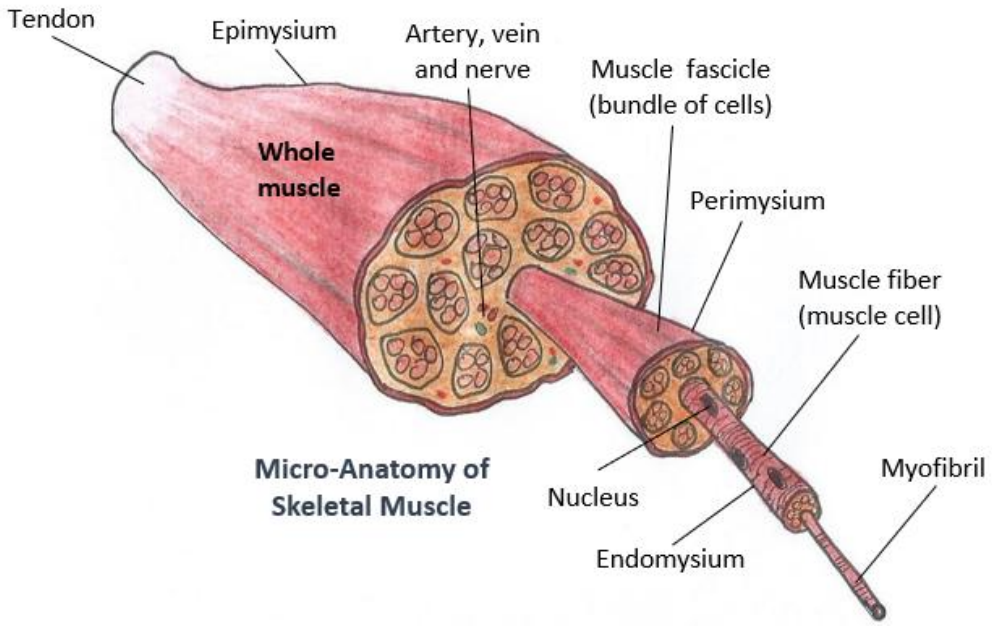
1. Body movement. By pulling on bones and leveraging articulations, skeletal muscle can move specific body parts, or the whole body.
2. Posture maintenance and protection of other tissues is provided by this tissue.
3. Heat production is greatly augmented by the activity of skeletal muscle. This is partly due to its high rate of ATP use when contracting.
4. Guard orifices for entrances and exits, the actions of this muscle controls the opening/closing of passageways in the form of sphincters.

The longest muscle in the human is the **sartorius** (the tailor's muscle) of the thigh. It can measure up to almost 24 inches! Before we delve into muscles we can see on the skeleton, we will take a quick look at the microanatomy of skeletal muscle.

II. Structural Arrangement Skeletal Muscle Cells

Microanatomy of Skeletal Muscle

Skeletal **muscle cells** are also called **muscle fibers**, though they are not fibers, they can give the appearance of a bundle of fibers. The connective tissue naming system (nomenclature) follows an established pattern using the prefixes **endo**- within or inside; **peri**- around; and **epi**- upon; in addition to the root suffix -**mysium** for muscle. Therefore, a single muscle cell (fiber) is wrapped in a dense irregular connective tissue called **endomysium.** A bundle of muscle fibers is then wrapped in more connective tissue called **perimysium**, this bundle is a muscle fascicle. Wrapped again as a bundle of fascicles with another covering called **epimysium**, this is referred to as a whole muscle (see image below).



All of these layers of connective tissue collectively form the cord-like **tendons** or sheet-like aponeuroses at the ends of muscle; these structures most often attach to bone and sometimes soft tissue at the *origin* and *insertion* of the muscle.

An analogy would be to take a straw that is individually wrapped in paper – the straw is the muscle cell, the paper covering is the endomysium. A bundle of these straws then wrapped up together again with paper, that covering is the perimysium, and the structure is a muscle fascicle. A bundle of these fascicles could then be wrapped again with another covering, which is the epimysium, to make a whole muscle.

Quick look at **Skeletal Muscle**: From whole muscle visible with the unaided eye, to the microscopic.

Large ↓ Small

1. Muscle wrapped in epimysium (whole muscle, seen with the naked eye).
2. Fascicles wrapped in perimysium (creates the muscle patterns seen in gross anatomy).
3. Muscle fibers (cells) wrapped in endomysium (long, cylindrical and multinucleated).
4. Myofibrils – the protein structures inside the muscle cell (*microscopic*).
5. Myofilaments – the two main structural elements of muscle (*sarcomere*).
    i. myosin – thick myofilament
    ii. actin – thin myofilament

III. Muscle Control and Motor Units

A. **Motor Unit** – this is the number of muscle fibers (cells) innervated by one motor neuron. This may be very small consisting of only a few fibers or large consisting of many hundreds of fibers.

B. **Muscle Tone** – this is continuous contraction of some motor units to maintain some tension in the muscle continuously, important for maintaining posture.

C. **Hypertrophy** – this is when muscle gets larger from use. The muscle cells get larger by adding more myofilaments, not by becoming more numerous.

D. **Atrophy** - the loss of muscle mass from disuse, resulting in fewer myofilaments being made

Note: Trophy means 'nourishment' but implies 'growth'. Hyper- means 'above normal' and a- means 'without'.

IV. Types of Skeletal Muscle Fibers

A. Fast Twitch Fibers - fast acting, with high energy requirements.

B. Slow Twitch Fibers - contain more myoglobin so contraction, though slower, can be sustained.

C. Intermediate Twitch Fibers - have attributes of both fast and slow twitch muscle fibers, exercise (or lack thereof) can change muscle to become more similar to one type or another.

V. Classification of Skeletal Muscles by Organization of Muscle Fascicles

Remember that all skeletal muscle is made up of fascicles, which are bundles of muscle fibers, and the **fascicular arrangements** have patterns that can be seen with the naked eye. The muscle fascicle patterns result in muscles with different shapes and functional capabilities. As we have seen, anatomy uses a number of different parameters to classify structures, and here is this section we will examine the 4 different muscle fascicular arrangements of skeletal muscle. Remember, the names of the categories are referring to the pattern generated by the arrangement of the fascicles in skeletal muscle.

1. **Circular** – fascicles arranged in a circular pattern - usually act as sphincters.
2. **Parallel** - fascicles run parallel the entire length of the muscle, permit maximum shortening.
3. **Convergent** - fascicles converge on a narrow insertion from multiple directions of a board origin, permits range of directional motions.
4. **Pennate** - short fascicles that attach at angles to a central tendon. These provide less shortening but are more powerful in the force they generate upon contraction.

Circular

The fascicular pattern is circular when the fascicles are arranged in concentric rings. Muscles with this arrangement surround external body openings, which they close by contracting. The general term used for these kinds of muscles is "sphincter". Examples include the **orbicularis oris** of the mouth and **orbicularis oculi** of the eyes.

Parallel

The fascicles in a parallel arrangement, there are two categories: a) Strap-like and b) Fusiform.

a) In Strap-like muscles the length of the fascicles run parallel to the long axis of the muscle and the width of the origin is basically the same as the width of the insertion, so it resembles a strap, a great example of this type of muscle the **sartorius** muscle of the thigh. It is called the tailor's muscle and it is also the longest muscle in the human body. The **rectus abdominis** is another example.

b) In Fusiform muscles the ends are tapered like a cigar or football and are often called spindle-shaped with an extended thicker belly in the middle. A great example of this type of muscle is the **biceps brachii** of the arm.

Convergent

A convergent muscle has a broad origin, and its fascicles converge toward a narrow insertion area. Such a muscle is triangular, or fan shaped like the **pectoralis major** muscle of the anterior thorax, and the **piriformis** of the gluteal muscles.

Pennate Muscles

The word origin of pennate is penna, meaning 'feather', because they look a little like feather dusters. In a pennate muscle pattern, the fascicles attach to a **central tendon** that runs the length of the muscle. They often attach obliquely (at an angle) from one or more sides. Pennate muscles come in three forms:

a) ***Unipennate***: The muscle fascicles insert into the central tendon from *one side of the tendon only*, as in the **extensor digitorum** of the forearm, and **extensor digitorum longus** muscle of the leg.

b) ***Bipennate***: The fascicles insert into the tendon from *two opposite sides* so the muscle "grain" resembles a feather. The **rectus femoris** of the thigh is a classic bipennate muscle.

c) ***Multi or tripennate***: These muscles look like many feathers side by side, with all their quills inserted into one large tendon. The **deltoid** muscle which forms the roundness of the shoulder is multipennate.

The arrangement of skeletal muscle fascicles determines the range of motion and the power of that muscle. The presentation from circular to pennate arrangement is in the general order of weak to strong muscle force generated. Skeletal muscle fibers may shorten to about 70% of their resting length when they contract, the longer and more parallel they are, the more the muscle can shorten. Muscles with parallel fascicle arrangements shorten the most but are not usually very powerful. Muscle power depends more on the total number of muscle fibers (cells) in the muscle: The greater the number of muscle fibers, the greater the power. The stocky bipennate and multipennate muscles, which pack in the most fibers, shorten very little but are extremely powerful.

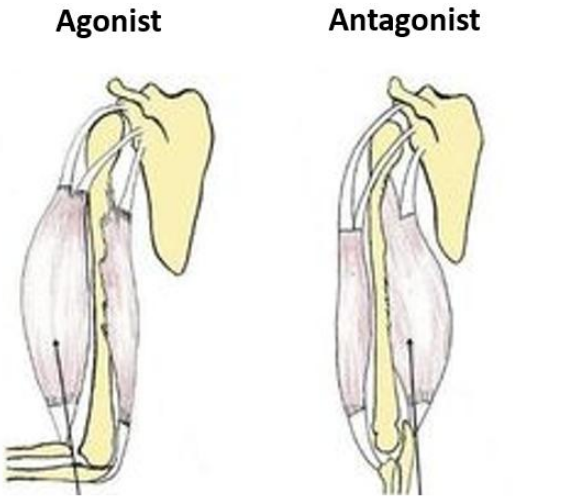
VI. Actions of Muscles

The action of a specific muscle may change depending on the actions of other muscles. In general, muscles are typically arranged in what are called antagonistic muscle groups, such that the prime mover or the agonist has an opposing action to the antagonist.

A. **Prime Mover** (Agonist) - produces desired action of a certain movement.

B. **Synergist** - assists prime mover.

C. **Antagonist** - opposes action of prime mover, restores original position.



Biceps brachii - agonist for flexion at elbow

Triceps brachii - antagonist resists flexion at elbow

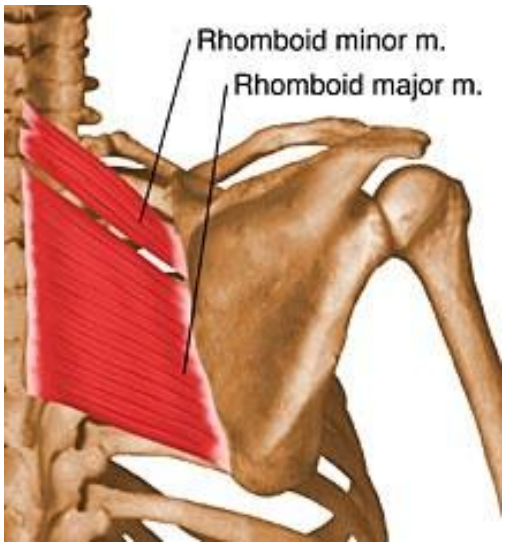
In the diagram at right, the action of **flexion** at the elbow is opposed by **extension** at the elbow.

VII. Names of Muscles – Muscle names include a lot of valuable information. Including:

- **Size** - magnus, minor, longus, brevis, etc.
- **Shape** - deltoid (triangular), teres (cylindrical), etc.
- **Orientation** of the muscle fibers - rectus, oblique, transverse, etc.
- **Action** of the muscles - adductor, flexor, tensor, extensor, supinator, etc.
- **Number of Heads** of a muscle - bi (two), tri (three) and quad (four).
- **Origin and Insertion** of the muscle - sternocleidomastoid, stylohyoid, ileocostalis, zygomaticus, etc.
- **Muscle Function** or Specific Features - serratus, sartorius, buccinators, etc.
- **Location and Relative Position** of the muscle - abdominis, femoris, pectoralis, subscapularis, etc.

For example, the two muscles shown to the right have two components to their names:

- Rhomboid refers to the ***shape***
- Major and Minor denotes their relative ***sizes***



There are Eight (8) basic categories for the Naming of Muscles
Interestingly, virtually all muscles are named based on one or more of the following criteria listed below. If you are familiar with these criteria - and their Latin, Greek and even French equivalents - then you already know a lot of information about the muscle. You don't have to memorize all approximately 799 muscles to be anatomically conversant.

Here are the basic criteria:

Size
When it comes to the size of skeletal muscles, the information included in the name about its size are usually related to the relative sizes of one muscle to another one in the same group. In general, they are either large, small, short or long. The largest muscle in a related group of muscles is often referred to as **maximus** or **magnus**. An example that you're familiar with is the gluteus maximus. Gluteus is Latin for your rear end, or more anatomically correct, your buttock. Thus, gluteus **maximus** identifies the largest muscle in that region, that's the main muscle that you sit on. There are two other muscles in this group, the gluteus **medius** and the gluteus **minimus**, their names indicate their relative sizes. Another example is the adductor magnus, the large muscle running down the inner thigh that pulls the leg back to midline. The rhomboideus **major** and rhomboideus **minor** that stabilize the scapula indicate the relative sizes in their names (see figure above).

With regard to the length of muscles, the term **longus** refers to the longest of a group, as in the adductor longus, which is thinner than the adductor magnus and runs essentially parallel to it. The term **brevis** identifies the shortest of a group. The adductor brevis runs across the thigh to assist in pulling the thigh in towards your body's midline as opposed to down the length of your inner thigh as do the adductor magnus and minimus. In Latin, the word "latus" means "side." Thus, latissimus identifies the largest muscle "in

width" in a group. Latissimus dorsi is the name of the large muscles that run from under your arms, across your "sides," and then across the middle of your back. Bodybuilders refer to these as their "lats", it is often called the 'swimmer's muscle', as it is well developed in trained swimmers.

Shape
Some common shapes when naming muscles are the following: trapezoids, triangles, cylinders, saw toothed and flat.

A **trapezoid** has a shape like a kite or looks somewhat like a diamond. The trapezius muscle is the large superficial muscle that is located on the superior portion of the back. The tip of the kite or diamond is attached to the nuchal region (nape of neck), the two corners attach or insert into each shoulder area, while the inferior portion originates from the spinous processes of the thoracic (vertebral) region of the back.

The fourth letter in the Greek alphabet is delta, which is drawn in the shape of a triangle Δ. Therefore, the term deltoid is applied to a very large and powerful muscle that is triangular shaped and sits on the top of the shoulder. The very useful aspect of studying the skeletal system and bony landmarks prior to examining muscles is that the structural names often give clues about what might attach to that bone. For instance, the deltoid tuberosity of the humerus is the insertion point of the deltoid muscle.

The Latin verb for saw is "serrare." In anatomy serratus means saw-toothed in shape and can be applied in many systems of the body; some sutures of the skull are serrated because they look like a jagged knife's edge. The muscle called the serratus anterior holds your scapula (shoulder blade) to your ribs and originates from the anterior aspect of individual ribs and exhibits a saw-like appearance from the pattern it makes, hence its name. There is also the serratus posterior, located on the posterior aspect of the ribs

The French word for flat is "plat", as in the word plateau. The thin superficial muscle called the platysma is very broad and flat, with its origin across the upper clavicles, running up across the anterior and lateral aspects of the neck, finally ending by inserting into the mandible. Its primary role is to hold the other muscles of the neck in place and help with facial expressions. It can also function to tense your neck and depress (lower) your jaw (mandible).

Two important muscles of the shoulder are the teres major and teres minor muscles. Teres is Latin for "cylindrical" or rounded, and the major and minor denote their relative sizes. The pronator teres is a muscle located in the forearm and its shape is round or cylindrical. The pronator portion of the name denotes its action, as it medially or internally rotates the forearm, which is called pronation of the forearm.

Orientation of the Muscle Fibers
Orientation of a whole muscle refers to how the muscle fibers (cells) are bundled together into fascicles. The fascicular arrangement of muscles can be seen with the naked eye and when observing whole muscle, the pattern can be seen in the in the body. In general, the muscle orientations are transverse (perpendicular to longitudinal arrangement), parallel, or diagonal in relation to the anatomical position.

The Latin word rectus means to rectify, to make right or to straighten out. It is often applied for naming muscles whose fibers run parallel to the midline of the body. The rectus abdominis, for example, is the muscle of the abdominal that runs down from the lower anterior portion of the ribcage to the pubic bones. They are paired muscles and run parallel on either side of the belly button (umbilical region). They are

bisected transversely by a type of fibrous tissue called tendinous inscriptions, this gives them a sectioned appearance, and when they are highly developed muscles (and there is not much abdominal fat) they are called a ‘six-pack’, because of their appearance. Some can also display an 8-pack.

The term oblique comes from the old French and means "at an angle." In the abdominal region there are both external oblique and internal oblique muscles, which run one on top of the other, with their fibers running at an angle to the midline and perpendicular to each other. These are the muscles just lateral to the rectus abdominis, these work when you do sit-ups and touch each elbow to the opposite leg.

Transverse means running perpendicular to the longitudinal axis of the body, and the transversus abdominis is an example. Its name indicates the orientation or direction of the muscle fascicles and also the location in the body (abdomen). The four abdominal muscles mentioned (rectus abdominis, external oblique, internal oblique and the transversus abdominis), are all named in part with regard to their muscle orientation. The transversus abdominis muscle runs across the length of the body (transversely) and is the deepest of the abdominal muscles.

The Action of the Muscle

When a muscle contracts it causes an “action” of a body part. Basically, all muscles will span across at least one articulation, and at a movable articulation they will have a specific action. Muscles often work in groups and if one group of muscles causes flexion at a specific joint, then part of their name may reflect that action. By definition, flexor muscles decrease the angle between the two bones at a joint. The flexor pollicis longus is a muscle in the forearm that pulls on the thumb and causes it to flex inward toward the palm. The action of the muscle is reflected in its name. The longus indicates that it is the longest muscle in this group. This muscle happens to be very long, as it runs the full length of the forearm from the elbow to the thumb. The term "pollicis" is Latin for thumb, and so the name of this muscle also describes the location. Many muscle names can literally be translated and give a lot of information. For example, the flexor pollicis longus translates into “the long muscle that flexes the thumb”.

Other muscles might extend, rotate internally or externally, elevate, depress, rotate around a joint, move body parts away from a midline or pull them back towards the midline, etc. and often some of that information is being relayed in its name. Extensors are the muscles that counter flexors. They increase the angle between two articulating bones at a joint. The extensor pollicis longus, therefore, is the long muscle in the forearm that straightens out the thumb back into anatomical position once it's been flexed.

Pronators turn limbs so that they face downwards or backwards. The Latin word "pronus" means "face down" - as in lying prone. If you hold your arm out in front of you, palm up, it's the pronator teres muscle that allows you to rotate the forearm at the elbow so that the palm is facing downwards – or posterior when in the anatomical position. As mentioned previously, "teres" is Latin for "rounded or cylindrical" which is a reference to the shape of the muscle. Again, as mentioned earlier in the section regarding shape, the pronator teres is a rounded muscle whose action is to pronate the forearm.

The counter or opposite action to a pronator is a supinator. Supinator comes from the Latin word supinum, which means "lying on your back". The supinator muscle in the forearm has an opposing action to the pronator teres, in that it laterally or externally rotates the forearm so that the palm of that hand is facing forward (anterior), as opposed to being pronated, or facing posteriorly.

Levators are muscles that elevate or lift a body part up. The levator scapulae is a muscle that pulls the scapula up, as in the action of shrugging the shoulders. Depressors have the opposite action of levators; they pull things downward or open. The depressor anguli oris is a muscle found at each corner of the mouth. The term oris means mouth and the term angle often means “corner” in anatomy. When this muscle contracts it pulls the corners of the mouth downward, making a frowny face.

In terms of actions in the body, to abduct something is to take it away from midline, while to adduct is to bring it back to midline. Therefore, abductor muscles move bones away from the midline in the body. For example, the gluteus medius is an abductor because its action is to pull the thigh out, away from the midline. This term is used both generically to describe the action of any muscle that moves a body part away from the midline and as part of the formal name of a handful of muscles such as the abductor pollicis brevis, which pulls the thumb away from the palm.

Adductors move the bones back towards the midline. Both the adductor longus and the adductor brevis are located in the inner thigh and can be considered ‘groin’ muscles. Tensor muscles make things rigid. When the tensor fascia latae muscle of the lateral thigh contracts, it tightens and gets rigid to support the knee. Sphincters close openings, for example the anal sphincter. Also, the orbicularis oculi and orbicularis oris also function to close an opening.

Number of Heads of a Muscle

A small number of muscles are named after the number of heads they have, which can be viewed as a point of origin (attachment) they have. A very well-known example would be the biceps brachii in your arm. It has two heads, which is what “bi” and “ceps” literally means. Brachium in Latin is for branch, such that brachii is the plural in Latin for branches. In this case, that part of the name is referring to the region of the body called the brachial region. The triceps brachii located on the posterior aspect of the arm has three heads, as reflected in its name. The quadriceps femoris on the anterior thigh has four heads and is in the femoral region, hence its name.

Origin and Insertion

Some muscles are named after the parts of the body where they start and end, or their origin and insertion. For example, the sternocleidomastoid muscle originates from both the sternum and clavicle (breastbone and collarbone) and inserts into the mastoid process of the temporal bone, which is just posterior to the ear. A muscle on the arm is called the coracobrachialis because it originates of the coracoid process of the scapula and inserts on the medial anterior shaft of the humerus or the brachium.

Named by Function

A few muscles are named after their function in the body. The risorius is a facial muscle that is crucial for the expressions of smiling and laughter. This name comes from the Latin word "risus" which means "laugh". The muscle named the masseter comes from the Greek word masticate which means to "chew". This muscle originates from the zygomatic arch and inserts predominantly on the angle of the mandible and is the most powerful of the muscles that are responsible for moving the human jaw. The sartorius muscle is from the Latin word for "tailor". It originates from the lateral pelvis region - specifically from the anterior superior iliac spine - and runs across the thigh to insert at the medial proximal anterior aspect of the tibia (just inferior to the knee joint). This muscle pulls the leg up at the knee while simultaneously rotating it internally. It is used to cross the legs in the manner of an old-time tailor sitting on the floor and sewing material together, hence the name.

Location and Relative Position

As we have already seen by exploring the other categories for naming muscles, some muscles are named for where they are located in the body. The temporalis muscle is an important muscle for chewing and is named after its location: It sits in the temporal fossa of the temporal bone. Likewise, the zygomaticus muscles are located and attached to the zygomatic (cheek) bone. Some muscles are deep or superficial to others; for example the flexor digitorum superficialis is on top of the flexor digitorum profundis. Profound indicating deepness. Also, the vastus lateralis is lateral to the vastus medialis of the quadriceps.

Body Movement

VIII. Lever Systems

In the body, the operation of most skeletal muscles involves leverage by creating an arrangement using various **lever systems** to move body parts. The purpose of using lever systems is to give advantage to the body movement, making it either faster or more forceful, but never both of these at the same time.

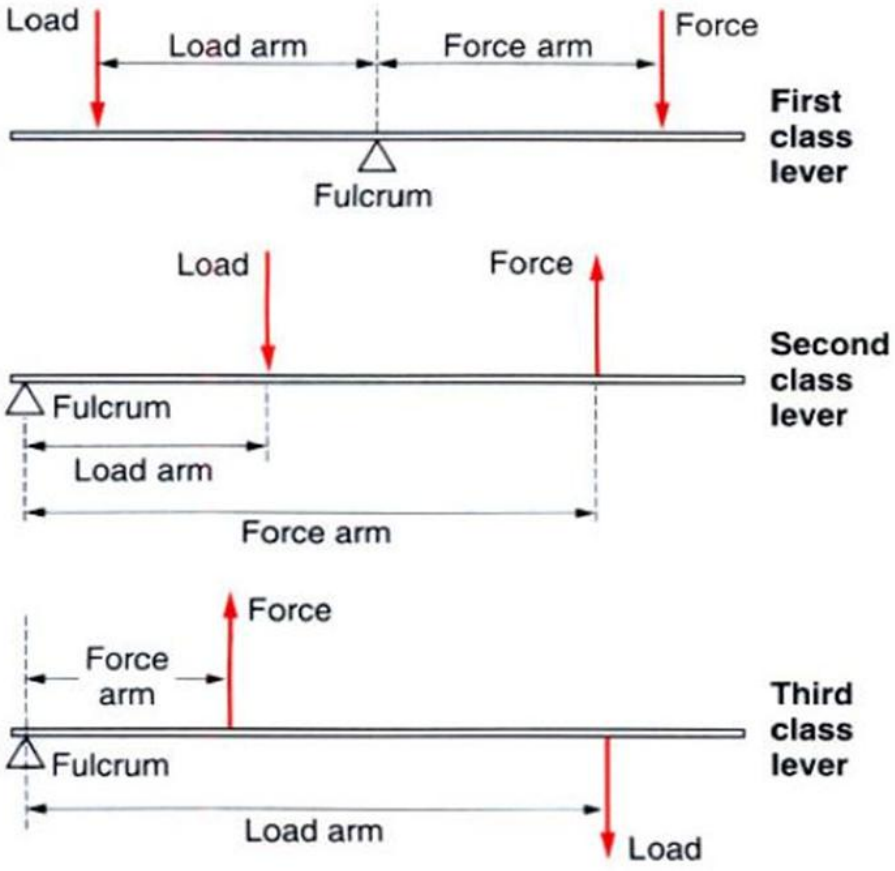
A **lever** is an elongated rigid object, and in the human body **bones** act as levers. These levers move on a fixed pivot point called the **fulcrum** when a force is applied to it. The force applied to a lever is often called the **effort arm**. In the body, the effort arm is powered by the action of **skeletal muscles**. Muscle contraction is used to move the body part which is described as the **resistance** or **load**. The pivot is called the fulcrum, and in the human body **movable joints** act as fulcrums.

Levers: Power versus Speed

The function of a lever system in the body is to augment body movement in such a way as to confer advantage. A lever allows a given effort to move a heavier load, or to move a load farther and faster, than it otherwise could. If the load, which is usually referred to as the **resistance**, is close to the **fulcrum** and the effort arm is applied far from the fulcrum, a small effort exerted over a relatively large distance can move a large load over a small distance. Such a lever is said to operate at a **mechanical advantage** and is commonly called a **power lever** – as it is conferring an **advantage of force** to the body movement. For example, a person can lift a car with a power lever or jack. The car moves up only a small distance with each downward push of the handle, but relatively little muscle effort is needed to lift a very heavy object.

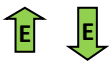
If, on the other hand, the resistance is far from the fulcrum and the effort arm is applied near the fulcrum, the force exerted by the muscle must be greater than the load to be moved or supported. This lever system is a **speed lever** and operates at a **mechanical disadvantage**. Speed levers are useful because they allow a load to be moved rapidly or a large distance with a wide range of motion. Swinging a baseball bat or using a shovel is an example. As you can see, small differences in the site of a muscle's insertion can translate into large differences in the amount of force a muscle must generate to move a given load or resistance.

There are **3 Classes of Levers** in the Human Body: First, Second and Third Class Levers.



Quick Summary of Lever Systems in the Human Body:
Bones act as **Levers**.
Movable Joints are the **Fulcrum (F)**.
Skeletal Muscle is the force that is the **Effort arm (E)**.
Body Part being moved is the load or **Resistance (R)**.
For any lever system, we need to identify the fulcrum (**F**), the effort arm (**E**) and the resistance (**R**).

Specific Examples of Classes of Levers
Depending on the relative position of the three elements, the **Effort**, the **Fulcrum**, and the **Resistance** or load, a lever belongs to one of three classes. To create a simplified sketch of a lever system, all we need to do is place the three elements in the correct orientation for each class of lever.

Effort 

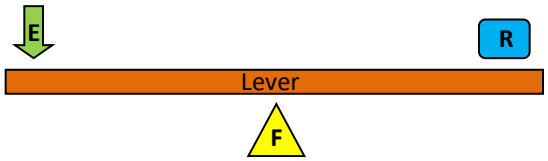
Fulcrum 

Resistance 

1st Class Lever

In a first-class lever, the Fulcrum is in the middle, somewhere in between where the Effort arm is applied and the other end that bears the Resistance or load.

The arrangement looks like a seesaw.



Some first-class levers in the body operate at a mechanical advantage (for strength), but others, operate at a mechanical disadvantage (for speed and distance). As described previously in these notes, the type of advantage conferred in this class of lever depends on the distance between the F and the other 2 elements.

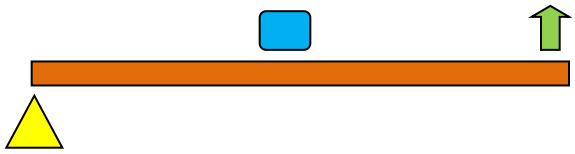
Specific Example of a First Class Lever in the Body = Extension of the head.

The Fulcrum is the **atlantooccipital** joint, the articulation between the atlas and the occipital condyles. Action at this joint can be called extension at the neck or extension of the head. Note: The opposing action to this is flexion at the neck or of the head. The Effort arm is the **trapezius** muscle. Contraction of the trapezius pulls the back of the head up off your chest and returns it to the anatomical position. The Resistance or load being moved is the **weight of the head**.

2nd Class Lever

In a second-class lever, the resistance is in the middle, the effort arm is applied at one end of the lever and the fulcrum is located at the other end. It can be seen to resemble a wheelbarrow, having the weight of the load being contained in the middle and the muscle pulling at the opposite end of the pivot-like fulcrum. All second-class levers in the body work at a mechanical advantage because the muscle insertion is always farther from the fulcrum than the load. Speed and range of motion are sacrificed for strength.

The arrangement looks like a wheelbarrow.



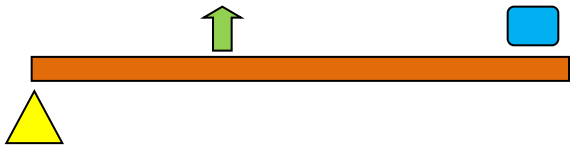
Specific Example of a Second Class Lever in the Body = Plantarflexion.

Second-class levers are uncommon in the body, possibly the only example is standing on your tippy toes. The Fulcrum is the **metatarsophalangeal joints I through V**, the articulations between the metatarsals of the foot and the proximal phalanges. This action is called **plantarflexion**. The Effort arm being the 3 sural muscles of the calf - the gastrocnemius, the soleus and the plantaris. Contraction of the calf muscles lifts the Resistance of the load, which is the **weight of the body**.

3rd Class Lever

In a third-class lever, the effort arm is in the middle and is applied between the load and the fulcrum. These levers are speedy and always operate at a mechanical disadvantage, a good example outside of the body is a drawbridge. This is the most common lever arrangement in the human body. Most skeletal muscles of the body act in third-class lever systems.

The arrangement looks like a drawbridge.



Specific Example of a Third Class Lever in the Body = Flexion of the Forearm.

An example is the activity of the biceps brachii muscle of the arm, lifting the distal forearm and anything carried in the hand. Third-class lever systems permit a muscle to be inserted very close to the joint across which movement occurs, which allows rapid, extensive movements (as in throwing) with relatively little shortening of the muscle. Muscles involved in third-class levers tend to be thicker and more powerful.

The Fulcrum is the hinge action of **humeroulnar joint**, the articulation between the trochlea of the humerus and the trochlear notch of the ulna. Note: There are two different articulations at the elbow joint. This action is called **Flexion at the elbow**. The Effort arm is the biceps brachii. Contraction of the biceps brachii pulls the forearm closer to the humerus and lifts the Resistance of the load, or the **weight of the forearm and hand**. The opposite action to this is extension at the elbow which is achieved by contraction of the triceps brachii. This group of 3 muscles sit on the posterior aspect of the humerus and all insert into the olecranon process of the ulna, such that when they pull, it extends the forearm.

In the lever systems that operate at a mechanical disadvantage (the **speed levers**) force is lost but speed and range of movement are gained. The systems that operate at a mechanical advantage (the **power levers**) are slower, more stable, and used when strength is the priority.

Summary and Overview of the 3 Classes of Levers in the Human Body

1st Class Lever => These levers can provide either advantage, depending on the arrangement of the EFR in terms of the distance between the elements:

1) If the E to F distance is greater than the F to R distance = **Mechanical Advantage**.
2) If the E to F distance is less than the F to R distance = **Speed Advantage**.

In other words, the advantage conferred will depend on the placement of fulcrum within this lever.

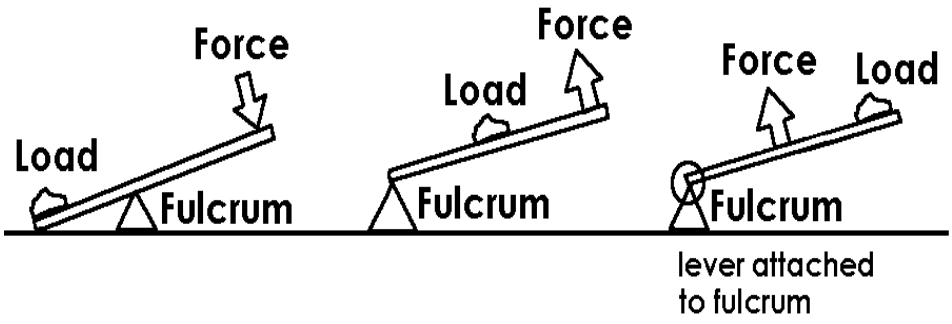
2nd Class Lever => This class of lever provides **mechanical advantage**. It enables great loads to be moved, but speed and distance are sacrificed. The resistance or load is in the middle. The power of this lever is determined by the distance between the fulcrum and the effort arm.

3rd Class Lever => This class of lever provides a **speed advantage**. It enables great speed but not strength. The effort arm is in the middle. The speed of this lever is determined by differences in distance between the F and the E and the E from the R.

1) If the distance between F and E is short while the distance between E and R is long = Fast movement but harder work.
2) If the distance between F and E is long while the distance between E and R is short = Slower movement but easier work.

The speed advantage that is conferred will depend on the placement of the effort arm relative to the fulcrum and the placement of the load.

Diagram of the Three different Classes of Levers in the Body



Regardless of type, all levers follow the same basic principle:

- Effort farther than load from fulcrum = lever operates at a mechanical advantage
- Effort nearer than load to fulcrum = lever operates at a mechanical disadvantage