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**, **excitable**, **elastic**, and **extensible**. In the body, muscle tissue provides movement of a specific body part, or movement of the whole body. 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 movement or "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 a skeletal muscle helps us to identify its function. The term **origin** of a skeletal muscle refers to the more fixed (less movable), or more stable structure of attachment, most often a bony landmark. The term **insertion** is the other site of attachment which is less fixed (more movable) or the less stable 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 area and causes an **action** or body movement at an articulation that it travels over.

The actions of skeletal muscle is usually concentrated at the point of the insertion, and not where the bulk of the muscle is seen, which will tend to be "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 of our body and one reason why skeletal muscle activity has such a big impact on the entire body.

<u>The main functions of skeletal muscle are:</u>

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 skeletal muscle activity. This is partly due to the high usage of ATP when muscles contract.

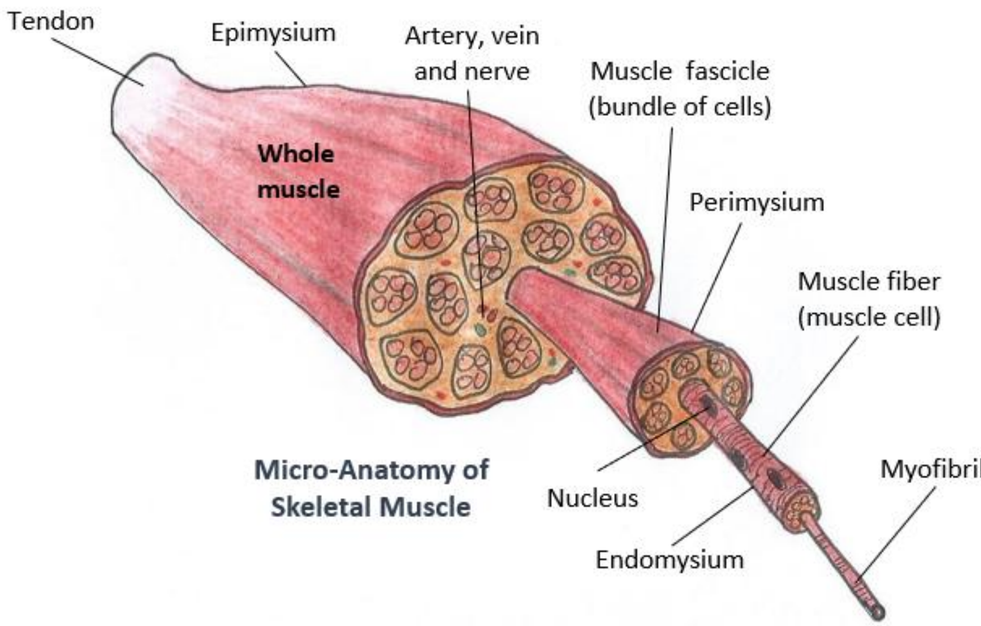
4. Guard orifices for entrances and exits, the actions of this muscle controls the opening/closing of passageways in the form of sphincters.

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. **Whole Muscle** wrapped in epimysium (whole muscle can be 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

Recall 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 fascicular arrangements of skeletal muscle. Note: 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 (uni-, bi- and multi- pennate). 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.

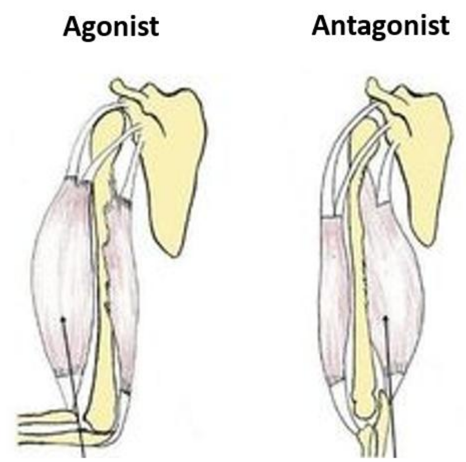
b) ***Bipennate***: The fascicles insert into the tendon from *two opposite sides* so the muscle "grain" resembles a feather. The **rectus femoris** of the thigh is a classic bipennate muscle.

c) ***Multipennate (tripinnate)***: 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 a multipennate muscle.

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 generation. Skeletal muscle fibers may shorten to about 70% of their resting length when they contract, so 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 because of how many muscle fibers they have.

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.



Biceps brachii - agonist for flexion at elbow

Triceps brachii - antagonist resists flexion at elbow

A. Prime Mover (Agonist)

Produces desired action of a certain movement.

B. Synergist

Assists the prime mover in the same action.

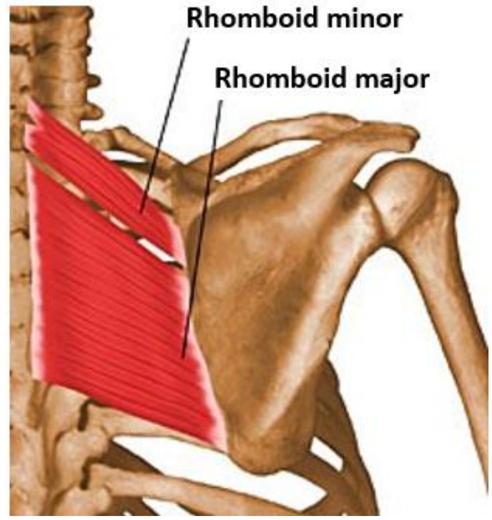
C. Antagonist

Opposes the action of the prime mover, restores original position.

In the diagram at right, the biceps brachii are the ***prime movers*** in **flexion** at the elbow, which is opposed by the action of the triceps brachii which are the ***antagonists*** causing **extension** at the elbow. The brachialis and brachioradialis are both ***synergistic*** muscles for the biceps brachii as the prime mover.

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, iliocostalis, 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 **650** 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 **rhomboid major** and **rhomboid minor** that stabilize the scapula indicate the relative sizes in their names (see figure above).

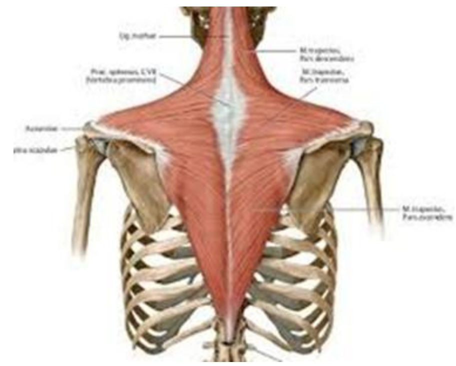
With regard to the length of muscles, the term **longus** refers to the longest of a group, as in the adductor longus, which is thinner than the adductor magnus and runs essentially parallel to it. The term **brevis** identifies the shortest of a group. The adductor brevis runs across the thigh to assist 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’ because it is well developed in trained swimmers.

The Shape or Appearance of the Muscle

The various shape of a muscle can also be involved in muscle names. Some common shapes when naming muscles are the following: trapezoids, triangles, cylinders, rhomboids, saw toothed and flat.

A **trapezoid** has a shape like a kite or looks somewhat like a diamond (see right). 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 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).

These rectus muscles 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

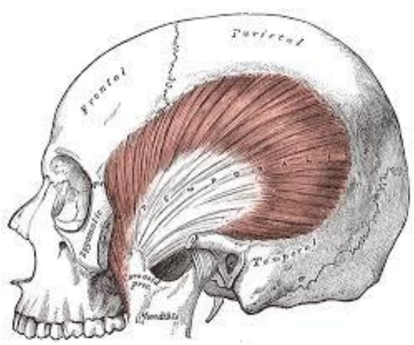
A few muscles are named after their function in the body. The **risorius** is a facial muscle that is crucial for the expressions of smiling and laughter. This name comes from the Latin word "risus" which means "laugh".

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.

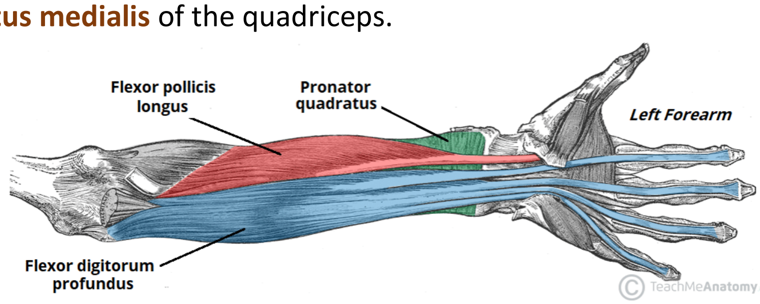
Location and Relative Position

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 combined actions of **skeletal muscle**, **movable joints** and **bones** create the movement of body parts. This process involves the specific arrangement of elements from these 3 systems which create the various **lever systems** in the body.

The purpose of lever systems in the body is to **confer advantage** to a body movement by making the movement either **faster** or **more forceful**, but it can never confer both of these at the same time.

A **lever** is an elongated rigid object, and in the human body **bones** act as levers. For any lever system, we need to identify the **Fulcrum** (**F**), the **Effort arm** (**E**) and the **Resistance** (**R**).

Levers move on a fixed pivot point called the **Fulcrum** (**F**) when a force is applied to it. In the body **movable (diarthrotic) joints** act as the fulcrum. The force in a lever is called the **effort arm** (**E**) and is powered by the action of **skeletal muscles**. The **resistance** (**R**) or **load** is the **weight of the body part** being moved.

There are **3 Classes of Levers** in the Human Body: **First**, **Second** and **Third** Class Levers.
The class of lever is determined by the arrangement of these **3** elements, the **F**, the **E** and the **R**, along a segment of the lever, which in the body is a bone.

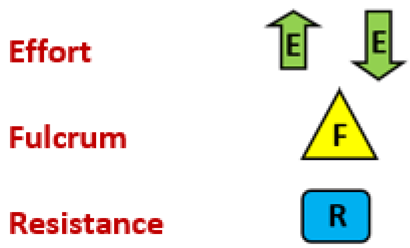
Recap - in the Body:

The **Fulcrum (F)** is a **Movable Joint.**

The **Effort arm (E)** is the force generated by the contraction of **Skeletal Muscle**.

The **Resistance (R)** or Load is the **weight of Body Part** being moved.

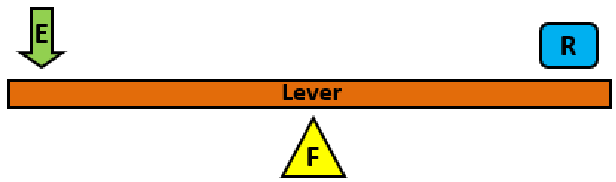
To create a simplified sketch of a lever system, all we need to do is place the **3** elements (**F**, **E** and **R**) in the correct orientation along the bone for each class of lever. This will be done for each of the three classes of levers discussed on the following pages. The elements first be displayed using the icons in the images below for each elements, follow by the specific example of each lever system in the body.



Specific Examples of Classes of Levers

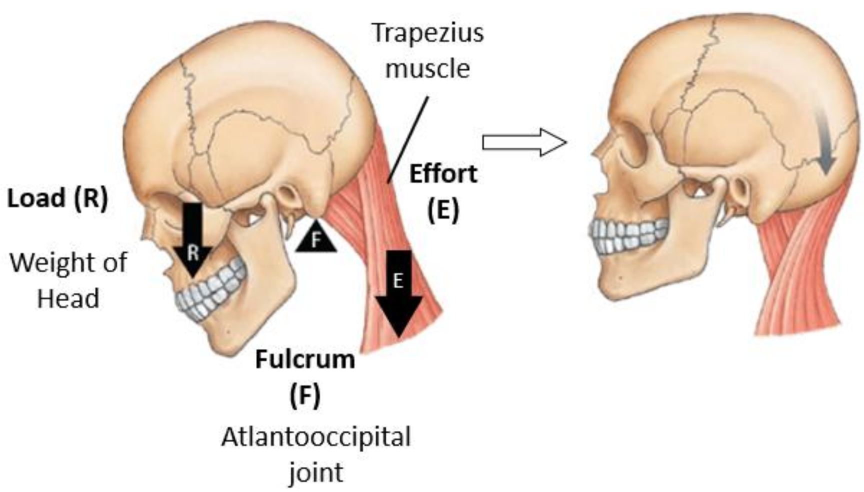
1st Class Lever
In a first-class lever, the **Fulcrum** is in the middle, somewhere in between where the **Effort** arm is applied at one end, and the other end bears the **Resistance** or load.

*The arrangement looks like a **seesaw**.*



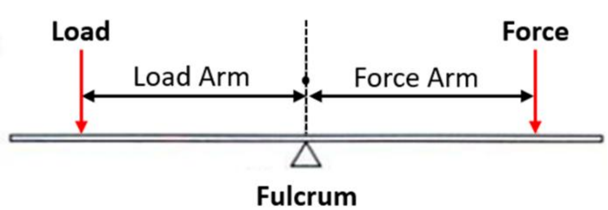
Specific Example of a First Class Lever in the Body = **Flexion and Extension at the Neck (or of the Head).** The **F**ulcrum is the **atlantooccipital joint**, the articulation between the occipital condyles and the first cervical vertebra called the **atlas**. The name of this joint has the atlas first using 'atlanto-' as the prefix with the -o- conjoiner, followed by the full occipital term.

The **action** at this joint is **extension** at the neck (or of the head), moving the head upward, the effort arm is the **trapezius** muscle. This action is shown in the diagram below.



The opposing action to this is **flexion** at the neck (or of the head) occurs by the **effort arm (E)** contraction of the **sternocleidomastoid** muscles, which, if the head were in the anatomical position, pull the face and head down toward the ground, flexing the neck on the same **fulcrum (F)**, the **atlantooccipital joint**. The **resistance (R)** or load being moved is the **weight of the head**.

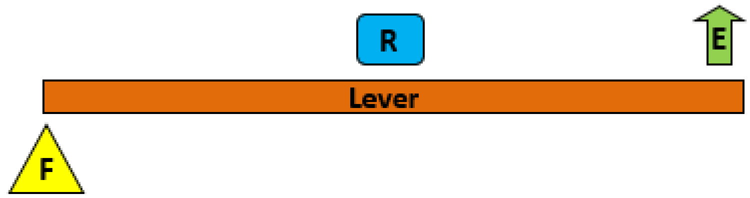
The opposing action to this is flexion at the neck (or of the head), via the **sternocleidomastoid** muscles, which pull the face toward the ground. Recall, the type of advantage is determined by the ratio of the Load arm (weight) and the Force arm (effort) arm (see below). The arrangement in the body provides primarily for a **mechanical advantage** (flexion-extension) at this joint, rather than speed, although it will depend on the muscles being use and their distance from the fulcrum. Some first-class levers in the body operate at a mechanical advantage (for strength), while others operate at a mechanical disadvantage (for speed and distance).



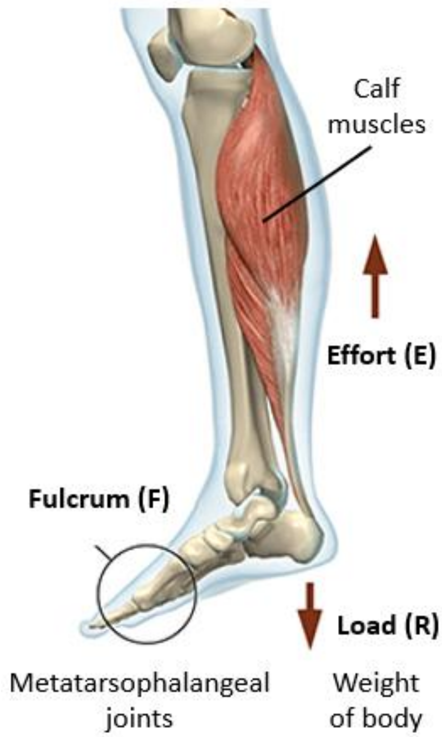
2nd Class Lever

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.

The arrangement looks like a wheelbarrow.



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

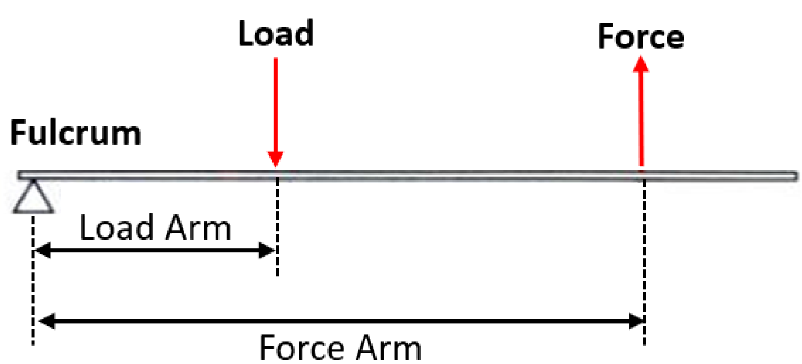


Second-class levers are uncommon in the body, possibly the only example is standing on your tippy toes, and the proper anatomical descriptions of this action is called **plantarflexion**.

The Fulcrum is the **metatarsophalangeal joints I through V**, the articulations at the ball of your foot, between the metatarsals of the foot and the proximal phalanges of the toes.

The Effort arm being the **3 sural muscles** of the calf - the **gastrocnemius**, the **soleus** and the **plantaris**. In a calf raise, the effort comes from the gastrocnemius muscle, which is attached to your calcaneus bone via the calcaneal or **Achilles tendon**.

The load comes from your body weight and the extra weight you are holding; this force acts on the lever system through the tibia. Contraction of the calf muscles lifts the Resistance of the load, which is the **weight of the body**.



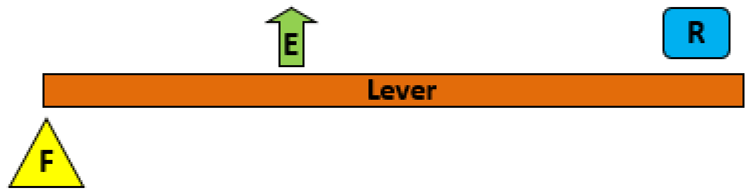
As seen in the Force arm to Load arm diagram above, this arrangement results in a bigger Force arm to Load arm ratio, making the second class lever the most mechanically advantageous. In fact, all 2nd class levers in the body work at a **mechanical advantage** because the muscle insertion is always farther from the fulcrum than the load. Speed and range of motion are sacrificed for strength.

In this arrangement with the load is in the middle, the force (effort) arm is farthest from the fulcrum and the act of plantarflexion can move much more weight than elbow flexion, even if your bicep is just as strong as your calf.

3rd Class Lever

In a third-class lever, the **Effort** arm is in the middle and is applied between the **Resistance** (load) and the **Fulcrum**. These levers are speedy and always operate at a mechanical disadvantage, which means it increases the range of motion or distance (and thus speed). A good example everyday 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.

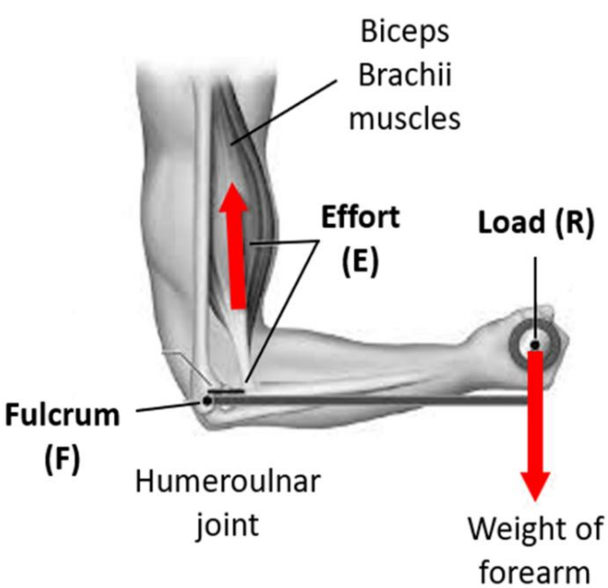
The arrangement looks like a drawbridge.



<u>Specific Example of a Third Class Lever in the Body</u> = **Flexion and Extension 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.

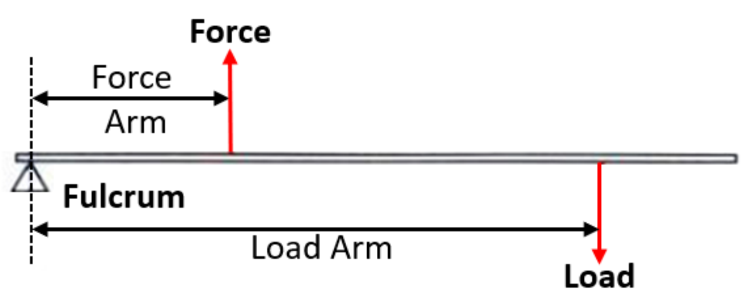
Third-class lever systems permit a muscle to be inserted very close to the joint across which movement occurs, which allows rapid, extensive movements (as in throwing) with relatively little shortening of the muscle. Muscles involved in third-class levers tend to be thicker and more powerful.

The Fulcrum (F) in this specific 3rd class lever 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 one involves the humeroulnar hinge joint. This action is called **Flexion at the elbow**.

The Effort arm (E) is the **biceps brachii**. Contraction of the biceps brachii pulls the forearm closer to the humerus and lifts the Resistance (R) 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 sits on the posterior aspect of the humerus and all of them insert into the olecranon process of the ulna, such that when they pull, it extends the forearm. From the diagram above at right (the lengths), it can be seen that the load is a lot farther away from the fulcrum than the force or effort, thus it requires a larger effort to hold smaller load.

The arrangement of the 3rd class lever requires a greater force (operates at a mechanical disadvantage) but allows the load to travel a **greater distance**. With a Force arm of less than one (a mechanical disadvantage), force is lost but speed and range of movement are gained (**speed lever**).

The systems that operate at a mechanical advantage (**power levers**) are slower, more stable, and are used when strength is the priority in the movement.

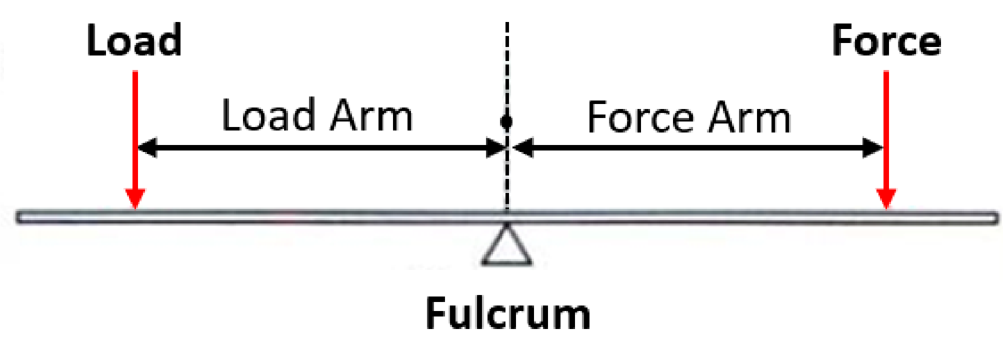
Additional Information on Levers: Power vs Speed

The information below is not discussed in any detail during lecture, but is included here because it provides additional information regarding the aspects of how levers can be modified to change their application.

We know that the function of a lever system in the body is to augment body movement in such a way as to confer some kind of advantage. A lever allows a given effort to move a heavier load, or to move a load farther and faster than it otherwise could. In any instance, a lever can only increase the power or increase the speed, and it can never both of these things at the same time.

The factor that determines which type of advantage will be conferred has to do with the distance of the **load** or the **force** from the **fulcrum** (as seen in the diagram below).

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.

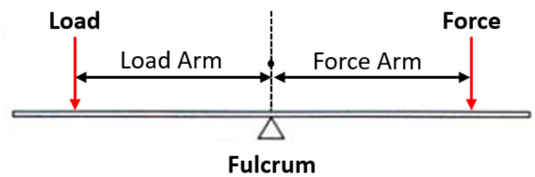


If, on the other hand, the resistance is far from the fulcrum and the effort arm is applied near the fulcrum, the force exerted by the muscle must be greater than the load to be moved or supported. This lever system operates at a **mechanical disadvantage** and thus can be considered a **speed or range of motion advantage lever**.

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 a small difference in the site of a muscle's insertion can translate into large differences in the amount of force a muscle must generate to move (overcome the resistance of) a given load.

As a recap, let's look at a basic example of a lever. Act like you need to move a really heavy rock. To lift it, you strategically position a cinder block down, and using a shovel, you place the middle of the handle resting on the block, this would be a first class lever system. When you apply a downward force (effort) with your hands at the end of the shovel, it leverages the rock (load). If your hands and the rock are equally distant from the cinder block (fulcrum), then your Force (effort) arm and load arm are equal. To make it easier, move the cinder block closer to the rock. This moves the fulcrum closer to the load, decreasing the load arm and increasing the effort arm, making the lever more efficient and allowing you to lift the rock while applying less force. You could try this at home!

Again, the location of the force (effort) and the load (resistance) in relation to the proximity of the fulcrum dictates the advantage the lever provides. The diagrams shown throughout these notes have included illustrations that display the 'load arm' and the 'force arm', as seen and defined below.



- **Load arm** (Resistance): The distance between fulcrum and the load, which is the distance between the joint and load.

- **Force arm** (Effort): The distance between the fulcrum and the force, and in the body it's the distance between the joint and the muscle's insertion site.

Force Arm to Load Arm Equilibrium Ratio

It's all about equilibrium. The efficiency of a lever relies on the equilibrium ratio of the force applied (**Force Arm**) to the resistance (**Load Arm**).

The equation for equilibrium is: Force x Force Arm = Load x Load Arm

The greater the ratio of the Force arm to the Load arm, the easier it is to move the load = **mechanical advantage**.

The greater the ratio of the Load arm to the Force arm, the less easier it is to move the load but it will have a greater distance moved (speed) = **range of motion advantage** (mechanical disadvantage).

The mechanical advantage can be greater or less than 1, depending on the relative lengths of the Force and Load arms. In the image above the ratio of the load arm to the Force arm are the same, or 1, and this means that the type of advantage can change if the ratio changes.

If the Force Arm ratio is greater than 1, it has a mechanical advantage.

If the Force Arm ratio is less than 1, it has a mechanical disadvantage, which means a speed or distance advantage.

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.

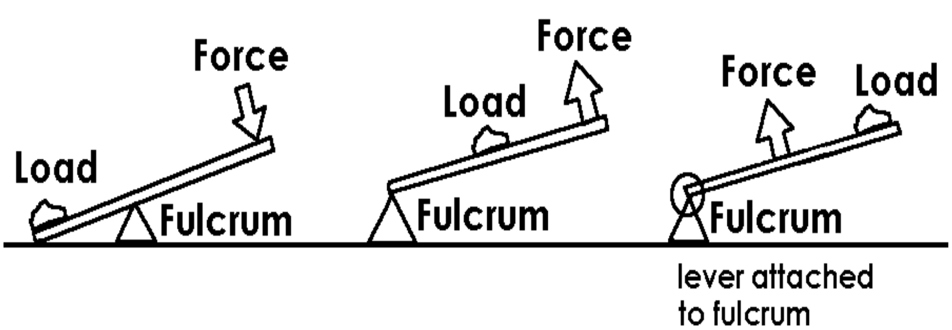
2nd Class Lever => This class of lever provides **mechanical advantage**. It enables great loads to be moved, but speed and distance are sacrificed. The resistance or load is in the middle. The power of this lever is determined by the distance between the fulcrum and the effort arm.

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 the type, all levers follow the same basic principle:

- If Effort arm is farther than load from fulcrum = lever operates at a **mechanical advantage**.
- If Effort arm is closer than load to fulcrum = lever operates at a **mechanical disadvantage**.

Table 1. Comparison of the Advantages and Disadvantages of the Lever Classes

Lever Class	Advantage	Disadvantage
1st Class If effort arm is closer to the fulcrum.	**Range of Motion** The load moves farther than the effort. (*Head moves farther up/down than neck muscles contract*)	**Effort Required** Requires larger effort to hold a smaller load.
1st Class If resistance (load) is closer to the fulcrum.	**Effort Required** Smaller effort will move larger load.	**Range of Motion** The load moves shorter distance than the effort.
2nd Class	**Effort Required** Smaller effort will move larger load. (*One calf muscle can lift entire body weight*)	**Range of Motion** The load moves a shorter distance than the effort. (*Calf muscle contracts farther than the distance that the heel comes off the floor*)
3rd Class	**Range of Motion** The load moves farther than the effort. (*Short bicep contraction moves the hand far*)	**Effort Required** Requires larger effort to hold smaller load. (*Bicep tension greater than weight in hand*)