



---

---

---

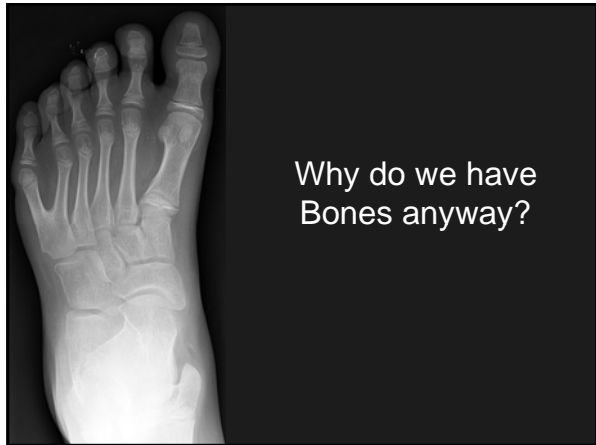
---

---

---

---

---



---

---

---

---

---

---

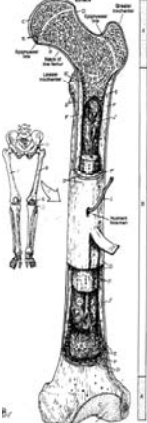
---

---

Terrestrial animals in particular require support, without which they would collapse under their own body weight.

Aquatic animals are able to survive without extensive skeletal systems because the water supports their bodies.

Both Arthropods and Vertebrates are capable of independent **movement** because they have muscles that can move parts of their skeletons.



---

---

---

---

---

---

---

---

Some invertebrates such as those in the phyla Porifera (sponges) lack skeletal systems altogether.

However they have adapted to their aquatic environment and have mineral deposits in their tissues that contribute to support and protection.

**Joints are the connections between skeletal segments that allow for movement.**

If you were wondering a fully mature *Homo sapien* has 206 bones.



---

---

---

---

---

---

---

---

An **exoskeleton** is an external skeleton that supports and protects an animal's body.

All arthropods (such as insects, spiders and crustaceans) and many other invertebrate animals (such as shelled mollusks) have exoskeletons.

Lobsters have a tough outer shell which provide rigidity and shape to their bodies.



Molting: An exoskeleton may interfere with an animal's growth. To overcome this, arthropods go through a process called **molting** in which they shed their exoskeleton and replace it with a new, larger one.

---

---

---

---

---

---

---

---

**Cicada Exoskeletons can be found stuck to sides of trees. Cicadas spend most of their life underground but move above ground, molt, reproduce, lay eggs and die.**

**Growth is limited by an insect's exoskeleton not only because of its weight (a result of its surface area to volume ratio) but by the inability of a chitin shell to grow.**



---

---

---

---

---

---

---

---

An insect's exoskeleton not only acts as a protective covering over the body, but also as a surface for **muscle attachment** (allowing for movement), a **water-tight barrier**, and a **sensory interface** with the environment.



DARPA and the U.S. military are working on the Berkeley lower-extremity exoskeleton (Bleex). The exoskeleton system has two hydraulic leg braces that include 40 electronic sensors, a monitoring computer and an internal-combustion engine. The exoskeleton is attached to the legs of the soldier and allows for backpack loads upwards of 220 lb. to be carried with ease.

---

---

---

---

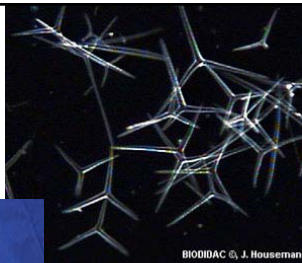
---

---

---

---

Exoskeletons offer protection by shells, carapaces (consisting of calcium compounds or silica) and chitin exoskeletons.



Porifera (**sponges**) possess simple endoskeletons that consist of calcium or silica **spicules** and a spongin fiber network.



Venus' Flower Basket

---

---

---

---

---

---

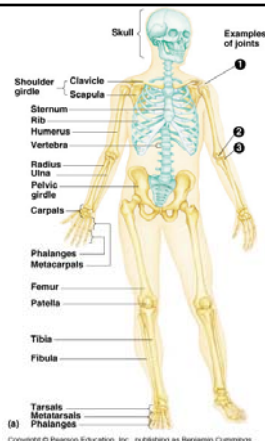
---

---

**Bone is a type of living tissue that has been hardened with minerals to form an endoskeleton in vertebrate animals.**

**Bones support body structures, protect internal organs, and in conjunction with muscles facilitates movement.**

**Bones are also involved with blood cell formation, the storage of calcium and minerals.**




---

---

---

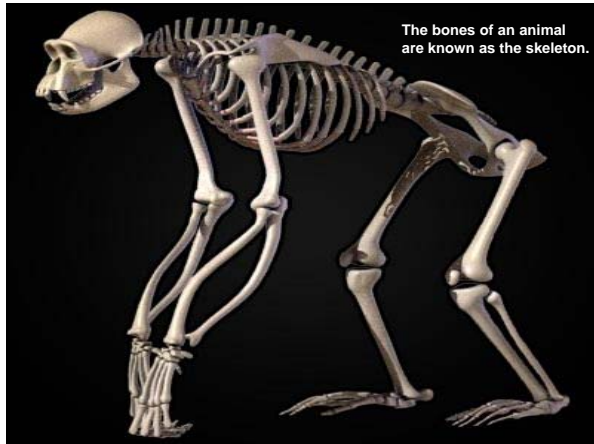
---

---

---

---

---



---

---

---

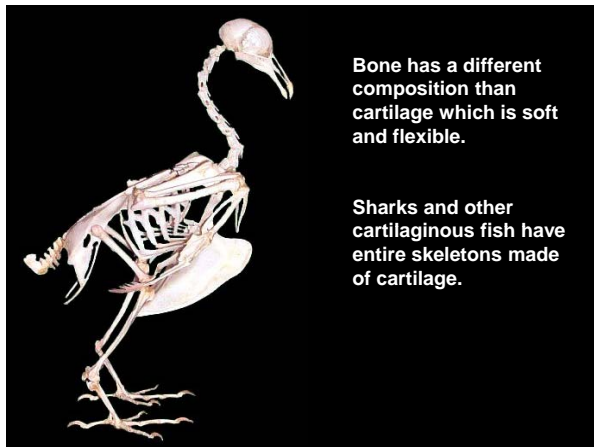
---

---

---

---

---



---

---

---

---

---

---

---

---

Long bones are tubular in structure.

The central shaft of a long bone has a hollow middle—the medullar cavity filled with bone marrow.

The ends of the bone are mostly spongy bone covered by a relatively thin layer of compact bone.

In children, long bones are filled with red marrow, which is gradually replaced with yellow marrow as the child ages.

**Long Bone**

Epiphysis

Articular cartilage

Epiphyseal line

Spongy bone

Medullary cavity

Nutrient foramen

Endosteum

Periosteum

Diaphysis

Epiphysis

Articular cartilage

---

---

---

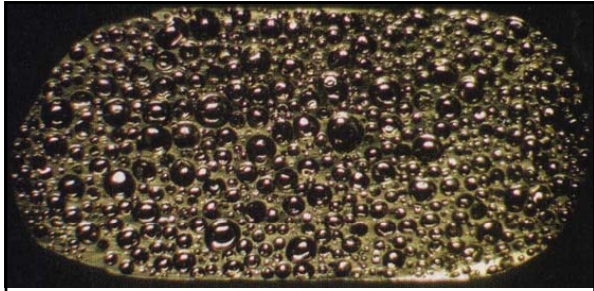
---

---

---

---

---



Metal foam is what you get when you add a foaming agent, powdered titanium hydride, to molten aluminum, then let it cool. The result is a very strong substance that is relatively light, with 75-95% empty space. Because of its favorable strength-to-weight ratio, metal foams have been proposed as a construction material for space colonies. Some metal forms are so light that they float on water.

Spongy Bone has similar characteristics in that it is very light weight but strong.

---

---

---

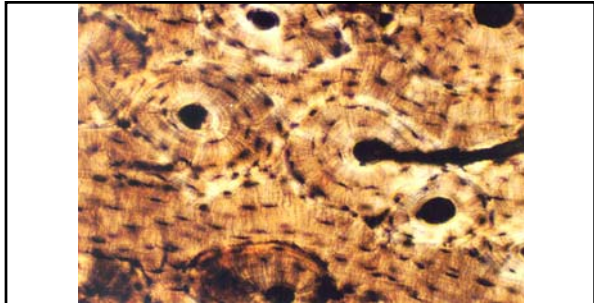
---

---

---

---

---



Haversian canals are a series of tubes around narrow channels formed in the bone. The Haversian canals allow blood vessels and nerve cells to reach throughout the bone and communicate with osteocytes in spaces within the dense bone matrix that contain the living bone cells.

---

---

---

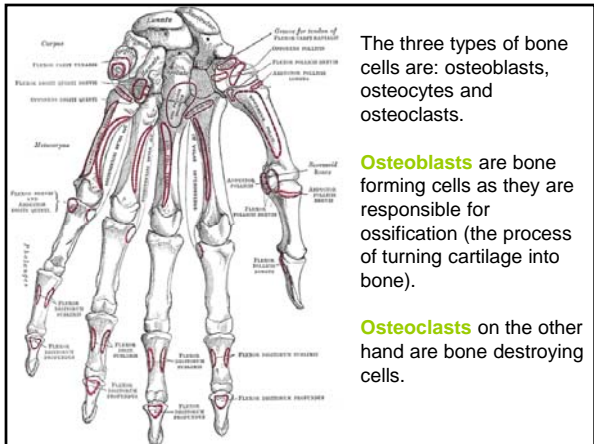
---

---

---

---

---



The three types of bone cells are: osteoblasts, osteocytes and osteoclasts.

Osteoblasts are bone forming cells as they are responsible for ossification (the process of turning cartilage into bone).

Osteoclasts on the other hand are bone destroying cells.

---

---

---

---

---

---

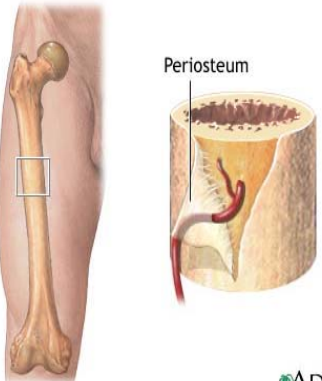
---

---

All bones are enclosed by an outer membrane called the periosteum.

This "bone skin" supplies the blood vessels and nerves to the bone.

The blood vessels are able to pass through the Haversian canals that form a passageway to the spongy bone.



Periosteum

ADAM

---

---

---

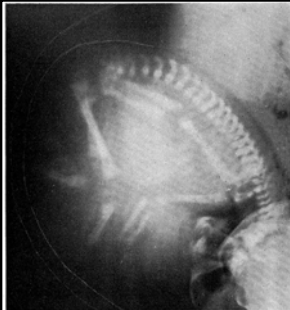
---

---

---

---

---



A fetal xray  
In humans ossification is not completed until the age of 25.

Osteoblasts are the cells that conduct the process of ossification, which is the replacement of cartilage with bone.

**Bone is a living material made from calcium compounds with the help of vitamin D, which aids calcium absorption from the blood.**

Not all cartilage is replaced with bone. In particular cartilage at the ends of bones provide smooth joint surfaces.

---

---

---

---


---

---

---

---

**Types of Joints**



Ball and Socket

Hinge

Pivot

Gliding

Fixed

(b) © Pivot joint  
Copyright © Pearson Education, Inc. publishing as Benjamin Cummings.

---

---

---

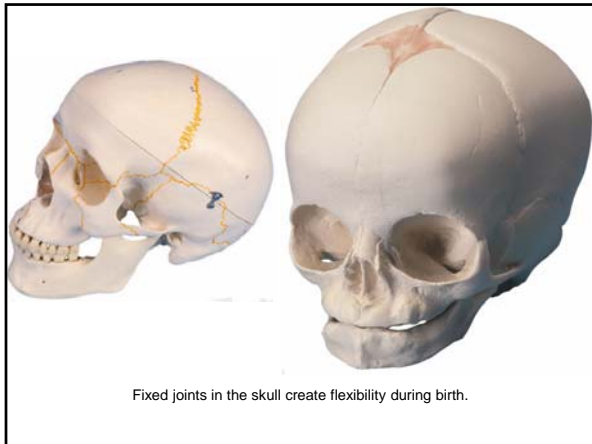
---

---

---

---

---



Fixed joints in the skull create flexibility during birth.

---

---

---

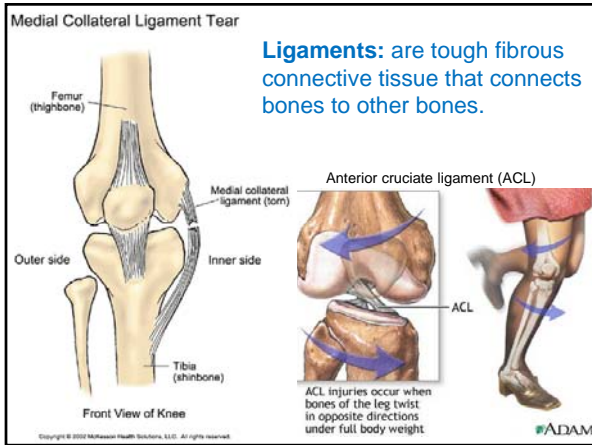
---

---

---

---

---



**Ligaments:** are tough fibrous connective tissue that connects bones to other bones.

---

---

---

---

---

---

---

---

Endoskeletons	
Advantages	Disadvantages
Organisms with Endoskeletons	
Exoskeletons	
Advantages	Disadvantages
Organisms with Exoskeletons	
Composition of Skeletons:	

---

---

---

---

---

---

---

---

Endoskeletons	
<b>Advantages</b> 1. Protection 2. light weight, strong 3. allow movement 4. support body 5. Able to grow	<b>Disadvantages</b> 1. does not prevent water loss 2. does not protect entire body 3. heavy 4. requires energy to maintain
<b>Organisms with Endoskeletons:</b> Humans, Cats Dogs, Snakes, Fish	
Exoskeletons	
<b>Advantages</b> 1. Protection 2. prevent water loss 3. allow movement 4. support body	<b>Disadvantages</b> 1. heavy 2. molt to grow 3. unrepairable
<b>Organisms with Exoskeletons</b>	
<b>Composition of Skeletons:</b>	

---

---

---

---

---

---

---

---

---

---

Endoskeletons	
<b>Advantages</b> 1. Protection 2. light weight, strong 3. allow movement 4. support body 5. Able to grow	<b>Disadvantages</b> 1. does not prevent water loss 2. does not protect entire body 3. heavy 4. requires energy to maintain
<b>Organisms with Endoskeletons:</b> Humans, Cats Dogs, Snakes, Fish	
Exoskeletons	
<b>Advantages</b> 1. Protection 2. prevent water loss 3. allow movement 4. support body	<b>Disadvantages</b> 1. heavy 2. molt to grow 3. unrepairable
<b>Organisms with Exoskeletons</b>	
<b>Composition of Skeletons:</b>	

---

---

---

---

---

---

---

---

---

---

Endoskeletons	
<b>Advantages</b> 1. Protection 2. light weight, strong 3. allow movement 4. support body 5. Able to grow	<b>Disadvantages</b> 1. does not prevent water loss 2. does not protect entire body 3. heavy 4. requires energy to maintain
<b>Organisms with Endoskeletons:</b> Humans, Cats Dogs, Snakes, Fish	
Exoskeletons	
<b>Advantages</b> 1. Protection 2. prevent water loss 3. allow movement 4. support body	<b>Disadvantages</b> 1. heavy 2. molt to grow 3. unrepairable
<b>Organisms with Exoskeletons</b> Arthropods, Crabs, insects, spiders	
<b>Composition of Skeletons:</b> Endoskeleton: calcium Exoskeleton: chitin	

---

---

---

---

---

---

---

---

---


---

# Muscles

There are more than 600 muscles in the human body.

Muscle Tissue is composed of long, excitable cells capable of considerable contraction.

Because movement is so important for animals it is usually the most abundant tissue, and accounts for much of the energy-consuming cellular work in an active animal.



---

---

---

---

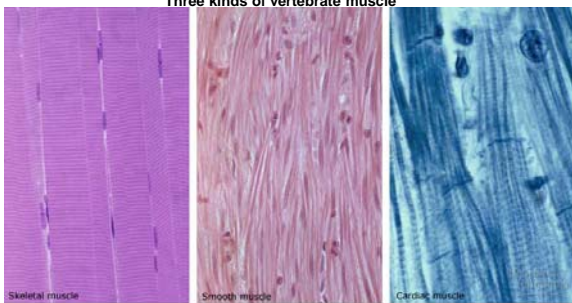
---

---

---

---

### Three kinds of vertebrate muscle



Skeletal muscles also called striated muscle are multinucleated and move bones

Smooth muscles control involuntary movements such as breathing and digestion

Cardiac muscle is found only in the heart. It is branched and fast acting

---

---

---

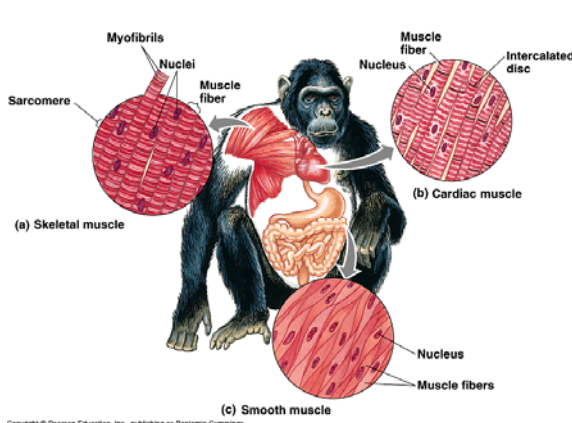
---

---

---

---

---



(a) Skeletal muscle: Myofibrils, Nuclei, Sarcomere, Muscle fiber

(b) Cardiac muscle: Nucleus, Intercalated disc, Muscle fiber

(c) Smooth muscle: Nucleus, Muscle fibers

Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

---

---

---

---

---

---

---

---

**Muscle tissue is controlled either you or your body**

**Skeletal**- attached to the bone by tendons- **voluntary control** - striated overlapping parallel filaments

**Cardiac**- striated but branched- **self stimulating**

**Smooth**- walls of internal organs- **involuntary control** -lacks cross striations- slow long contractions

---

---

---

---

---

---

---

---

**Muscles are Paired**

**Flexor:** decreases the angle of a joint

**Extensor:** increases the angle of a joint

**muscles can only contract**

(a) (b)

Since muscles can only contract they must always work in pairs to enable movement.

---

---

---

---

---

---

---

---

A **tendon** (or sinew) is a tough band of fibrous connective tissue that connects **muscle to bone**.

They are similar to ligaments except that ligaments join one bone to another. Tendons are designed to withstand tension.

Typically tendons connect muscles to bones; together a combination of tendons and muscles can **only exert a pulling force**.

**The Achilles tendon** is the thickest and strongest tendon in the human body

---

---

---

---

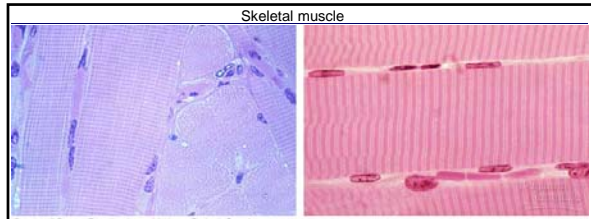
---

---

---

---





Fibers of Skeletal Muscle are made up of smaller units called **fibrils**.

Each fibril consists of many **microfilaments** made of the proteins **actin** and **myosin**.

Skeletal Muscles attach to bones with tendons

---

---

---

---

---

---

---

---

Muscle Tissue is composed of **long, excitable cells capable of considerable contraction**. Arranged in parallel within the cytoplasm of muscle cells are large numbers of microfilaments made of two kinds of contractile proteins **ACTIN** and **MYOSIN**.

---

---

---

---

---

---

---

---

The fibers of striated muscle are closely packed. Each muscle fiber is made up of fibrils, which consist of many microfilaments. It is the arrangement of these filaments that gives skeletal muscle its striped appearance.

When a nerve impulse is received that exceeds the cell's action potential. The thick myosin and thin actin filaments slide over each other to contract the fibril.

**This contraction is all or nothing.**

The number of fibrils that have been signaled determines the strength of the overall muscle contraction. After a fibril contracts it must wait a short while before it can contract again.

Depending on what definition of "strongest" is used, many different muscles in the human body can be characterized as being the "strongest."

The masseter or jaw muscle is the strongest. The 1992 Guinness Book of Records measures of a bite strength of 4337 N for two seconds. What distinguishes the masseter is not anything special about the muscle itself, but its advantage in working against a much shorter lever arm than other muscles.

---

---

---

---

---

---

---

---

**The structure of skeletal muscle**

**Sliding Filament hypothesis**

Fibers of Skeletal Muscle are made up of smaller units called fibrils each fibril consists of many microfilaments (made of the proteins actin and myosin).

Thick filaments are made of myosin and hang out in between thin ones filaments made of actin.

The thin filaments are attached at their ends to vertical Z lines.  
The thick filaments have bridges to connect them to the thin filaments during contraction.

This unit of thick and thin filaments between two z lines is called a sarcomere.

Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

---

---

---

---

---

---

---

---

---

---

---

---

- Thick filaments are made of myosin and hang out between thin filaments made of actin.
- This unit of thick and thin filaments between two z lines is called a sarcomere.

---

---

---

---

---

---

---

---

---

---

---

---

**The sliding-filament model of muscle contraction**

When a sarcomere (and therefore muscle) contracts it probably does so by sliding the thin filaments past the thick ones.

This is stimulated by the release of Calcium ions (causes bridges to connect) and then the use of ATP to bend the bridges causing the sarcomere to become smaller (less wide)

Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.

---

---

---

---

---

---

---

---

---


---

---

---

Type I Skeletal Muscle better known as slow oxidative or "**slow twitch muscle**." This red muscle is dense with capillaries and is rich in mitochondria and myoglobin (muscles use myoglobin to hold oxygen in the same way RBCs use hemoglobin), giving the muscle tissue its characteristic red color. It can carry more oxygen and sustain aerobic activity. The Dark Meat of a turkey or chicken is made up of slow twitch fibers. This type of muscle is good for long strenuous activities

Light meat is more properly known as "**fast twitch muscle**" and is good for quick bursts of energy. As it is less dense in mitochondria and myoglobin (less myoglobin = light color). This is the fastest muscle type in humans. It can contract more quickly and with a greater amount of force than slow twitch muscle, but can sustain only short, **anaerobic bursts** of activity before a build-up of lactic acid in tissue begins to interfere with muscular contraction and causes pain and muscle failure.




---

---

---

---

---

---

---

---

CC(O)C(=O)O

## Lactic acid Fermentation

CC(O)C(=O)O

During prolonged activity the amount of Oxygen diffusing into the muscle cells is not equal to the amount being used in aerobic respiration.  
**Thus an oxygen debt occurs.**

Once the available ATP is used up the cells must borrow ATP based on the expectation of future oxygen. Think of muscles as your own little Wall Street futures trader. Lactic Acid Fermentation is the same process used by bacteria who cause milk to go bad.

When your cells break down glycogen (a stored form of glucose) without oxygen around they create lactic acid and a just a few molecules of ATP.

This system of making ATP is not as efficient as aerobic respiration which can make as many as 38 ATP. Plus the waste product of **lactic acid** impedes Ca<sup>+</sup> ions and therefore eventually leads to your muscles being unable to function. Once the muscle activity is stopped or slowed, **the oxygen debt is paid off by breaking down the lactic acid.**

This is the basic reason you get tired and your muscles burn after exercise.

---

---

---

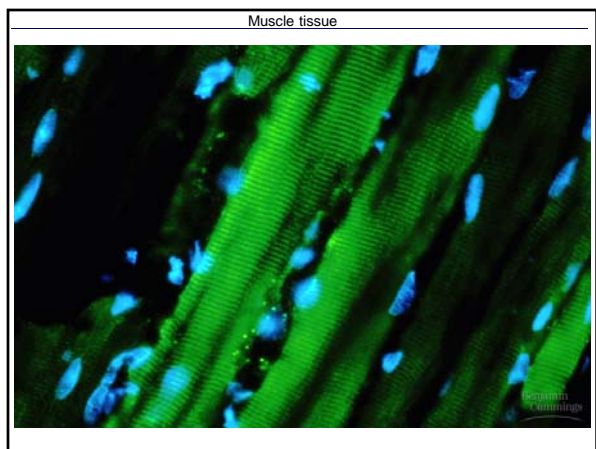
---

---

---

---

---




---

---

---

---

---

---

---

---

**Reflex Arc**

During a **reflex act** a stimulus is received by the nerves of your body and a command is sent to your voluntary skeletal muscles before the information is sent to your brain.

This occurs in situations where the safety of your body is at risk.

For example when you step on something sharp your leg muscles are told to contract (so as to pull your foot off the object) so your leg has moved before the pain signal reaches your brain. By the time you say ouch what was that you are no longer stepping on the object.

A reflex is a way for your body to override your control over voluntary muscles.

---

---

---

---

---

---

---

---

---

---

**Muscle Types in the Body**

	Striated (skeletal)	Cardiac	Smooth
Voluntary/ Involuntary			
Cells Striated/Smooth			
Contracts Quick/Slow			
Stays contracted for a long/short period			
Locomotion			
Peristalsis			
Involved in Reflex arc			
Typically found			

---

---

---

---

---

---

---

---

---

---

**Muscle Types in the Body**

	Striated (skeletal)	Cardiac	Smooth
Voluntary/ Involuntary	voluntary		
Cells Striated/Smooth	striated		
Contracts Quick/Slow	quick		
Stays contracted for a long/short period	short		
Locomotion	yes		
Peristalsis	no		
Involved in Reflex arc	yes		
Typically found	Legs /arms		

---

---

---

---

---

---

---

---

---

---

<b>Muscle Types in the Body</b>			
	<b>Striated (skeletal)</b>	<b>Cardiac</b>	<b>Smooth</b>
<b>Voluntary/ Involuntary</b>	voluntary	involuntary	
<b>Cells Striated/Smooth</b>	striated	striated	
<b>Contracts Quick/Slow</b>	quick	quick	
<b>Stays contracted for a long/short period</b>	short	short	
<b>Locomotion</b>	yes	no	
<b>Peristalsis</b>	no	no	
<b>Involved in Reflex arc</b>	yes	no	
<b>Typically found</b>	Legs /arms	heart	

---

---

---

---

---

---

---

---

---

---

<b>Muscle Types in the Body</b>			
	<b>Striated (skeletal)</b>	<b>Cardiac</b>	<b>Smooth</b>
<b>Voluntary/ Involuntary</b>	voluntary	involuntary	involuntary
<b>Cells Striated/Smooth</b>	striated	striated	smooth
<b>Contracts Quick/Slow</b>	quick	quick	slow
<b>Stays contracted for a long/short period</b>	short	short	long
<b>Locomotion</b>	yes	no	no
<b>Peristalsis</b>	no	no	yes
<b>Involved in Reflex arc</b>	yes	no	yes
<b>Typically found</b>	Legs /arms	heart	Digestive system

---

---

---

---

---

---

---

---

---

---