Al-Mustaqbal University
College of Engineering & Technology
Biomedical Engineering Department

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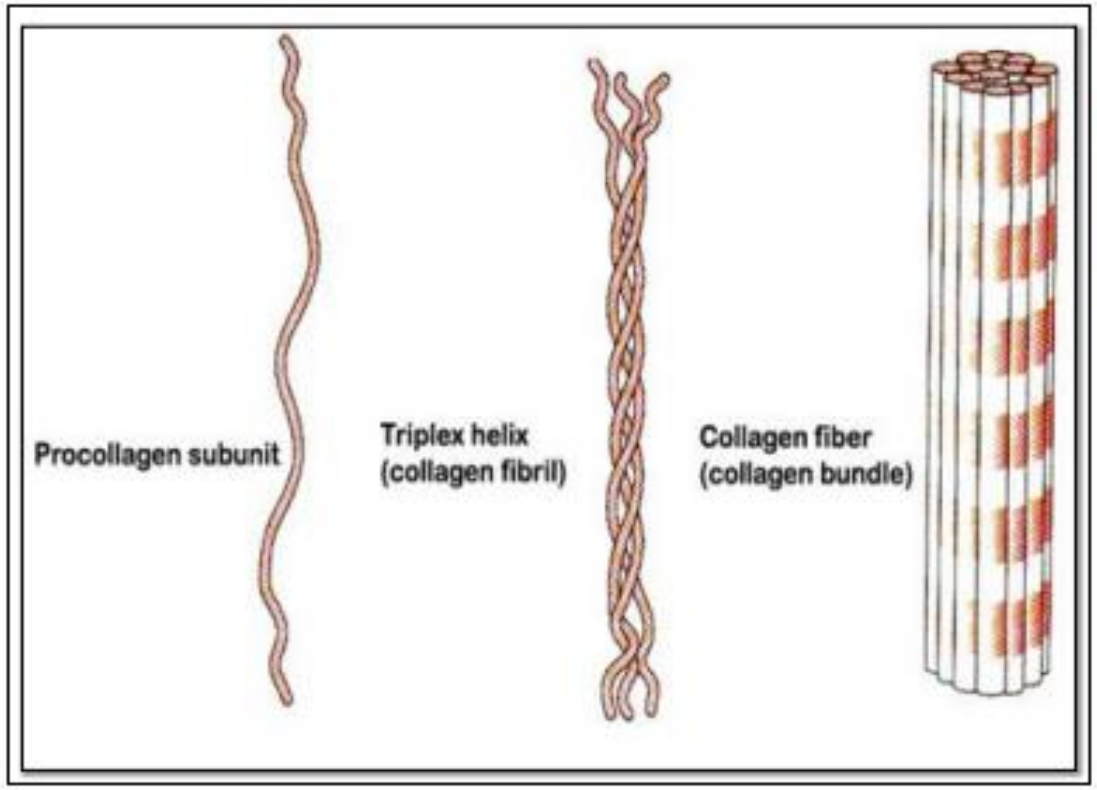
Lecture No.:-3

Lecture Title: [Biomechanics of Soft Tissues]

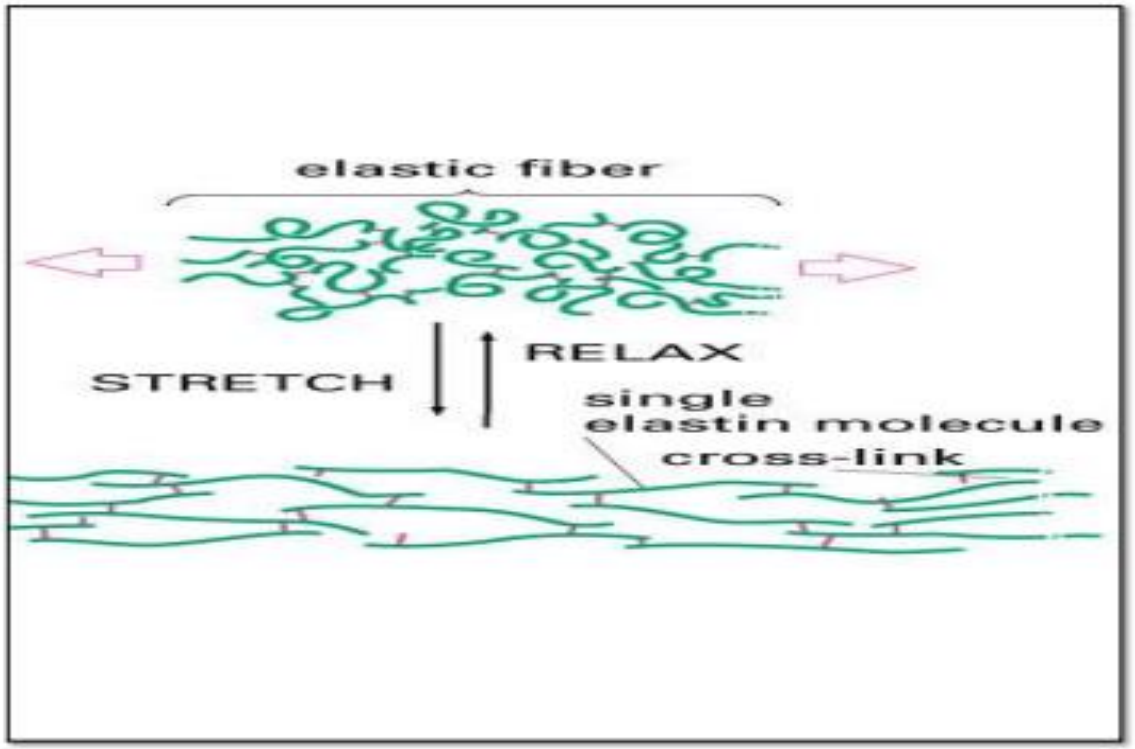
Introduction

Soft tissues include skin, cardiovascular tissues, articular cartilage, muscles, tendons and ligaments. All soft tissues are composite materials. Collagen and elastin fibers are the common components of soft tissues and they have most important properties affecting the overall mechanical properties of the soft tissues in which they exist.

- Collagen is a protein in shape of crimped fibrils which are joined together into fibers. Fibril can be considered as a spring and every fiber as an assemblage of fibril springs. The function of collagen is to withstand axial tension. As collagen fibers have high aspect ratio (length to diameter ratio), they are not effective to withstand compressive loads. Collagen fiber acts like a mechanical spring as it stores the energy supplied to it by stretching the fiber. When the load is removed, the stored energy is used to return to the unstretched state.

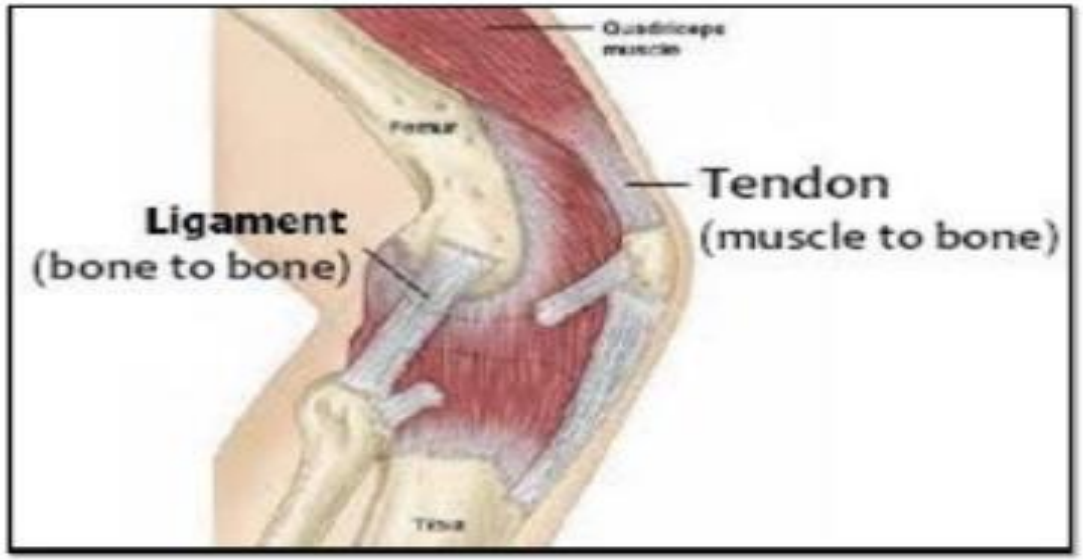


Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Elastin is another fibrous protein and its properties are similar to the properties of rubber. Elastin fibers consists of elastin and microfibril. Elastin fibers are highly extensible and the extension is reversible even at high strain. In other words elastin fibers have a low elastic modulus.



TENDONS AND LIGAMENTS

Both tendons and ligaments are fiberous connective tissues. Ligaments are supporting tissues. They join bones and provide support to the joints for stability. Tendons are connective tissues and they join muscles to the bones. Another function of tendons is to help in executing joint motion by transmitting mechanical force from muscles to bones.

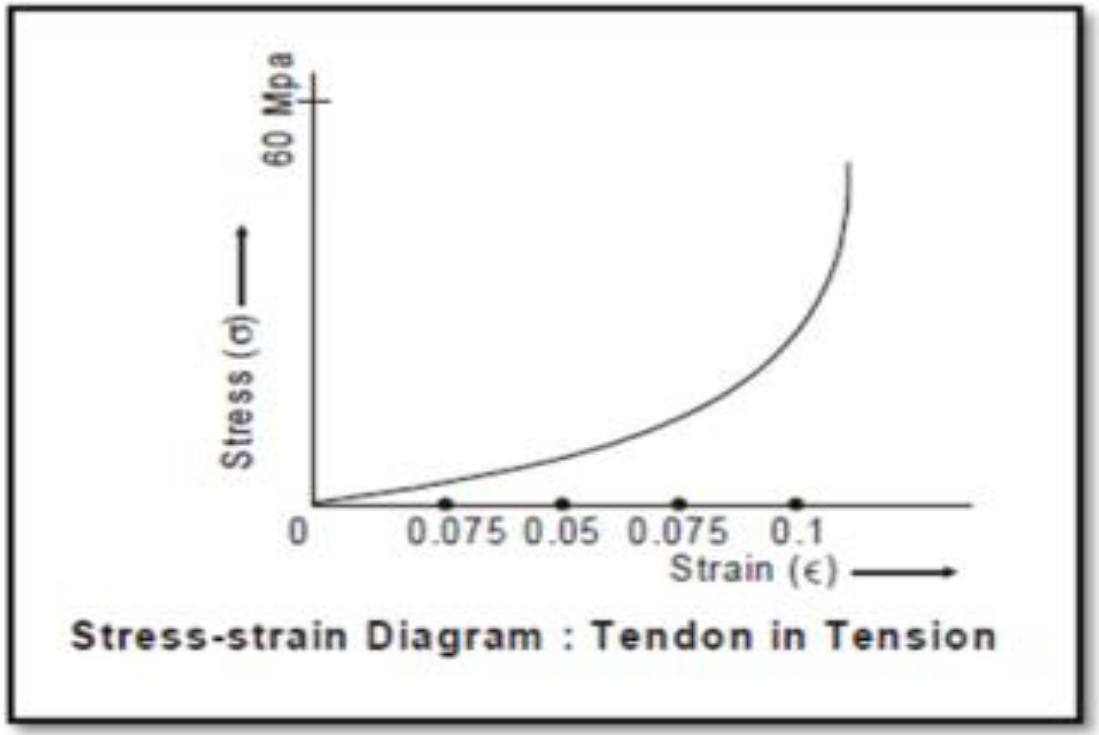


Both tendons and ligaments are passive tissues i.e., they can not generate force by contraction as done by muscles. Tendons have higher modulus of elasticity (Stiffer) to stand higher stresses with small strain.

They also have higher tensile strength. Hence at joints where space is limited, tendons enable the attachments of muscles with the bones. Since tendons can support large loads with small strains, hence tendons enable the muscles to transmit forces to the bones without wasting energy in its stretching.

The mechanical behavior of both tendons and ligament depends upon their composition which vary considerably in each direction of loading. The stress and strain diagram for a typical tendon is as shown in the figure.

- As collagen fibers of tendon require very little force to straighten and rubber like elastin fibers of tendon also do not require very high force, we get a large strain (up to 0.05) with a small applied force. The curve is flat in this portion. The tendon becomes stiffer after this as the crimp is straightened. Hence stiff and viscoelastic nature of the collagen fibers begin to take higher load with slight strain. Tendons are tested to function in the body up to ultimate strains of about 0.1 and ultimate stresses of about 60 MPa.



Stress-strain Diagram : Tendon in Tension

THE MUSCULAR SYSTEM

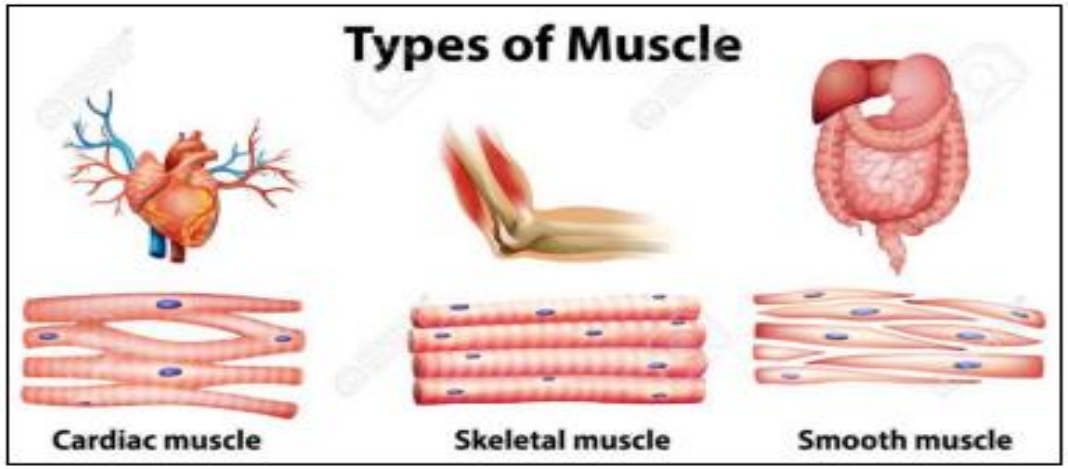
Muscle tissue is specialized for contraction. When muscle cells contract, they shorten and bring about some type of movement.

There are three types of muscle tissue:

1- Skeletal muscle.

2- Smooth muscle.

3- Cardiac muscle.



There are more than 600 muscles in the human body. Most of these muscles are attached to the bones of the skeleton by tendons. A few muscles are attached to the undersurface of the skin. The primary function of the muscular system is to move the skeleton.

The muscle contractions required for movement also produce heat, which contributes to the maintenance of a constant body temperature.

The other body systems directly involved in movement are the:

1- nervous system,

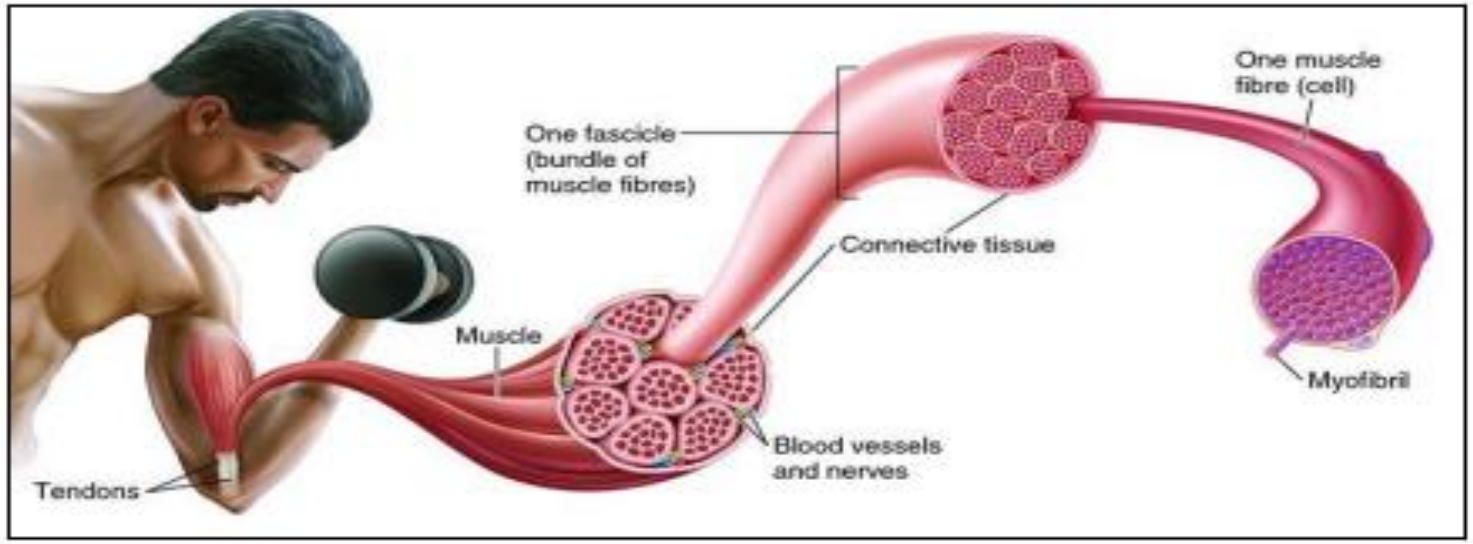
2- respiratory system, and

3- circulatory system.

The nervous system transmits the electrochemical impulses that cause muscle cells to contract. The respiratory system exchanges oxygen and carbon dioxide between the air and blood. The circulatory system brings oxygen to the muscles and takes carbon dioxide away.

MUSCLE STRUCTURE

All muscle cells are specialized for contraction. When these cells contract, they shorten and pull a bone to produce movement. Each skeletal muscle is made of thousands of individual muscle cells, which also may be called muscle fibers.



Depending on the work a muscle is required to do, variable numbers of muscle fibers contract. When picking up a pencil, for example, only a small portion of the muscle fibers in each finger muscle will contract. If the muscle has more work to do, such as picking up a book, more muscle fibers will contract to accomplish the task.

MUSCLE ARRANGEMENTS

Muscles are arranged around the skeleton so as to bring about a variety of movements. The two general types of arrangements are the opposing antagonists and the cooperative synergists.

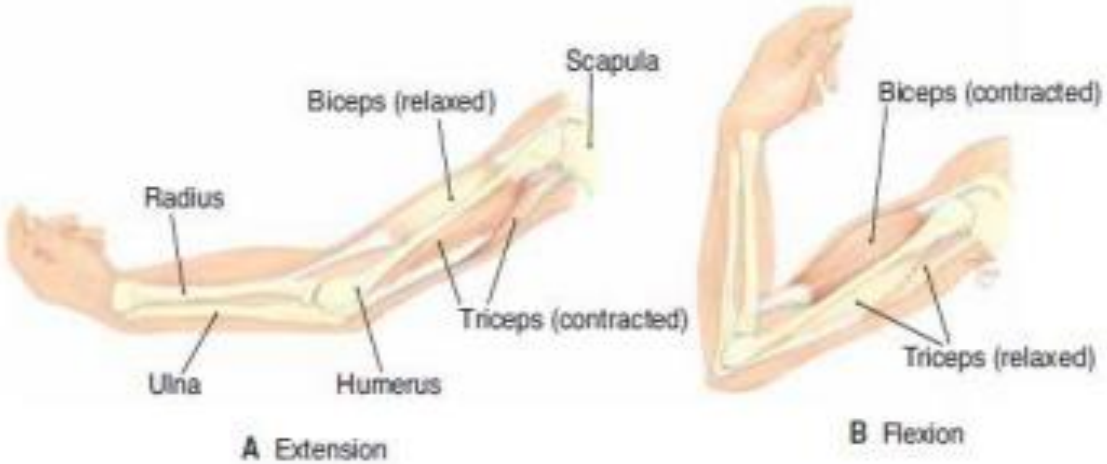


Figure 7–1. Antagonistic muscles. (**A**) Extension of the forearm. (**B**) Flexion of the forearm.

THE ROLE OF THE BRAIN

- Even our simplest movements require the interaction of many muscles, and the contraction of skeletal muscles depends on the brain.
- The nerve impulses for movement come from the frontal lobes of the cerebrum.

The cerebrum is the largest part of the brain; the frontal lobes are beneath the frontal bone. The motor areas of the frontal lobes generate electrochemical impulses that travel along motor nerves to muscle fibers, causing the muscle fibers to contract.