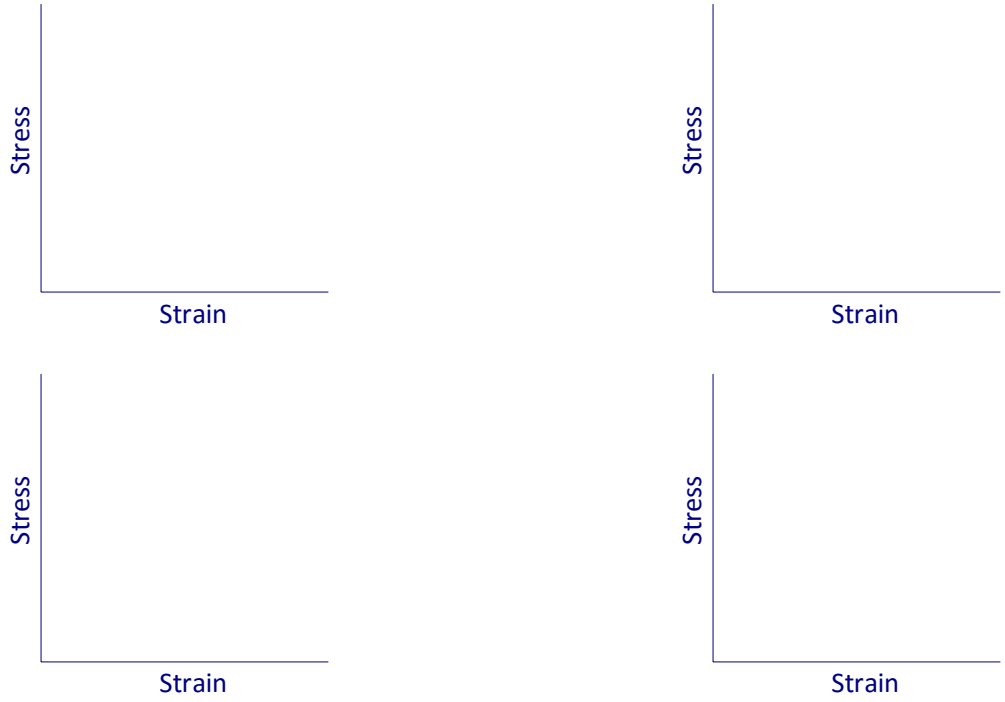
Session 2, Lecture 2, Mechanical behavior of soft tissue

Soft tissue

: Most solid tissues are soft (unlike bone)

- **Structural Properties**

Exercise



- **Elastic material**

Elastic behavior of tissue

- The main fibrous ECM proteins are collagen, elastin, fibronectin, and laminin

Elastin

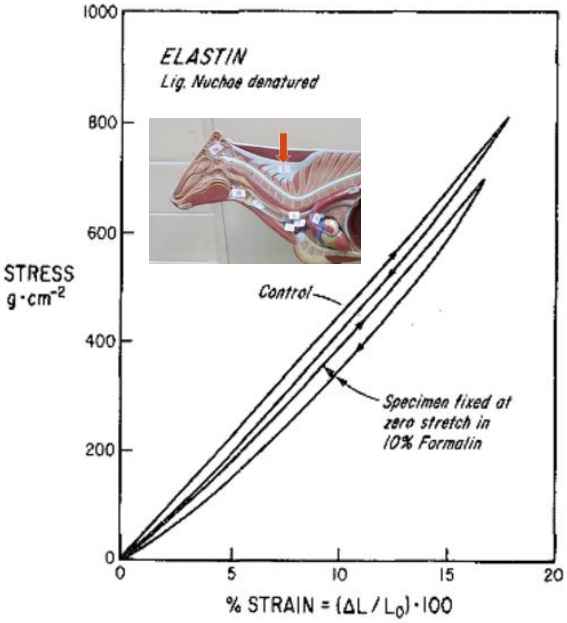


Figure 1 The stress-strain curve of elastin. The material is the ligamentum nuchae if cattle, which contains a small amount of collagen that was denatured by heating at 100°C for an hour. Such heating does not change the mechanical properties of elastin. The specimen is cylindrical with rectangular cross-section. Loading is uniaxial.

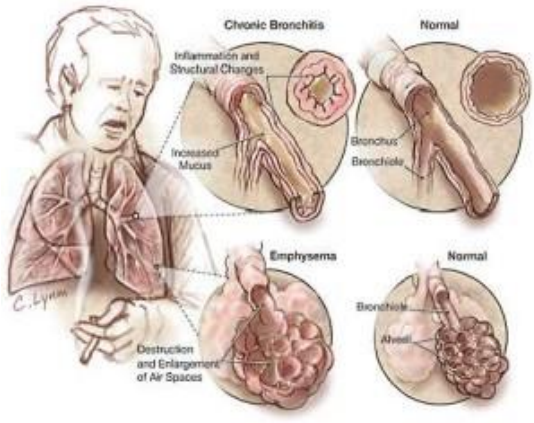


Figure 2. Emphysema

Collagen

- The most abundant fibrous protein, high stiffness

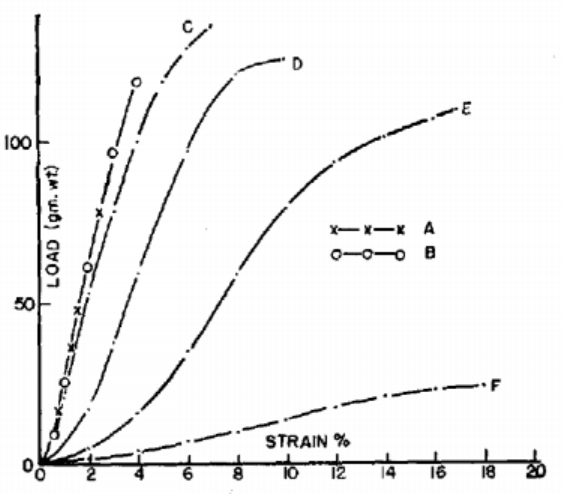


Figure 3. A typical set of load-strain cures showing the effect of a series of successive stretches on the behavior of the rat tail tendon. The rate of straining was 2 %/min, the temperature was 21°C. (A) the tendon returned to its original length. (B) extended past the "safe limit" (C) the tendon has become weaker

Viscoelastic behavior of tissue

- In other connective tissue, elastin and collagen together form a unit of composite material. The straight elastic fibers attached to the bent collagen fibers can have the mechanical properties exhibited by the composite material
- Skin: 75% collagen, elastin 4%
- Blood vessel: the ratio of elastin and collagen is 2 in thoracic aorta(d=1.16cm) and ½ for elsewhere

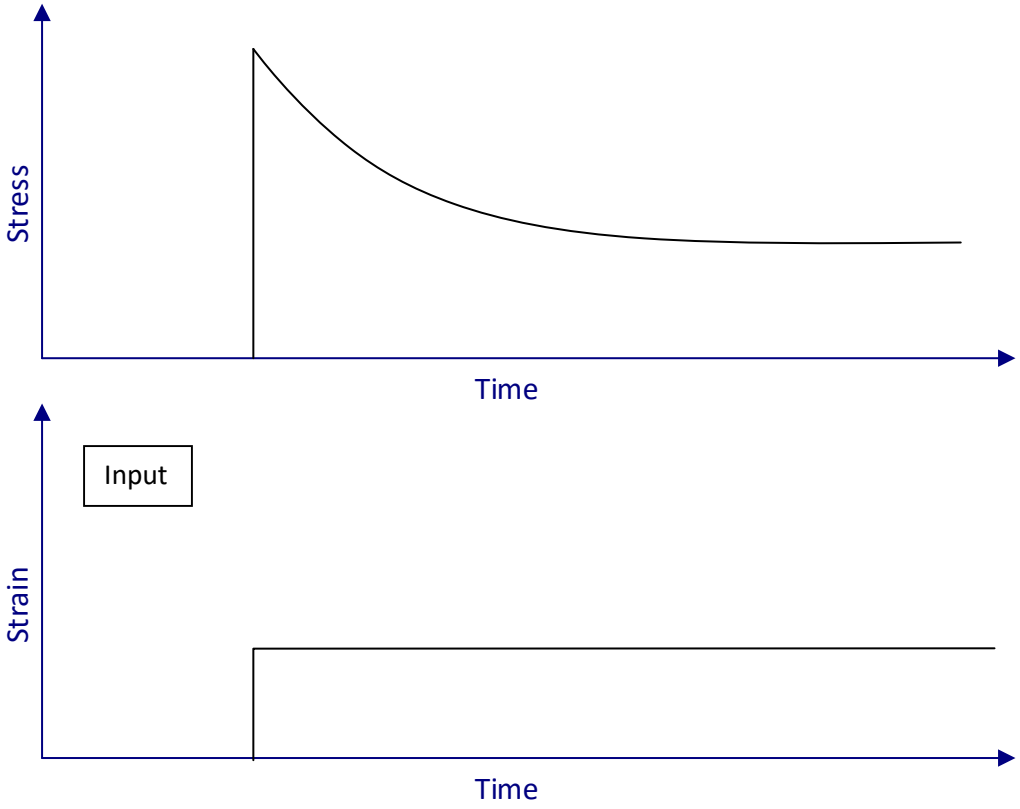
- **Viscoelastic material**

1. Soild material with some 'fluid-like' characteristics
2. Polymer plastics and most biological material
3. Dependence on the rate of straining
4. Loading and unloading curves do not coincide (hysteresis loop)
5. Some permanent deformation may occur

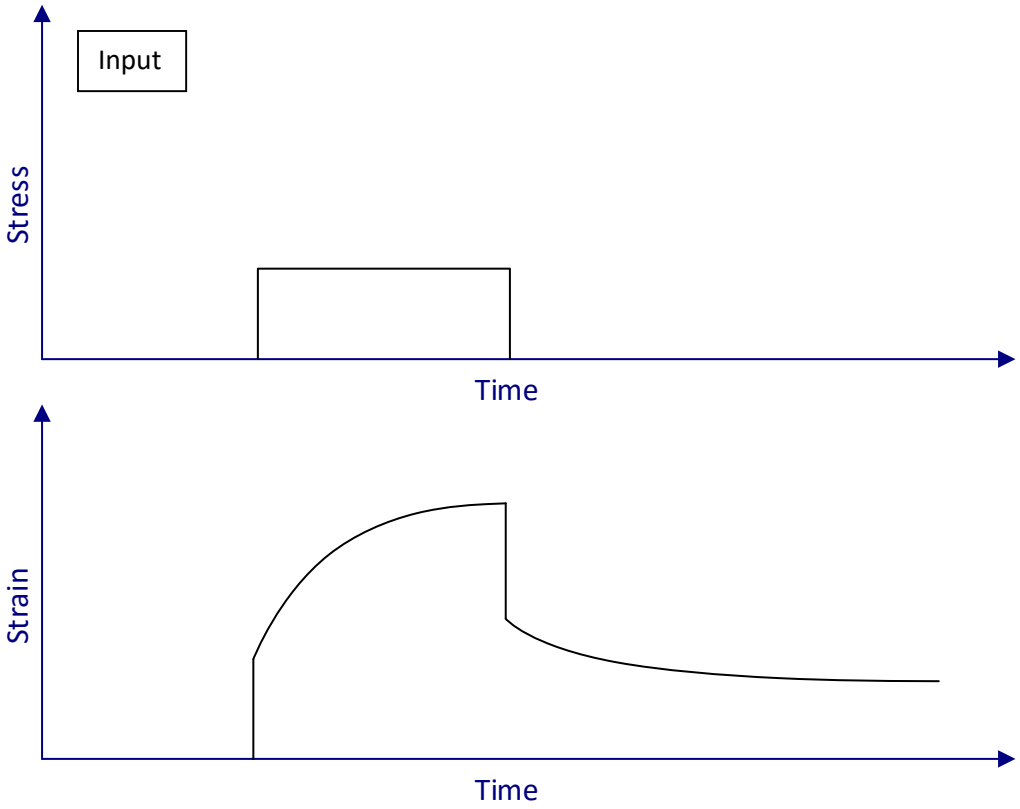
Basically the relationship between stress and strain depends on time or frequency

Viscoelastic Testing

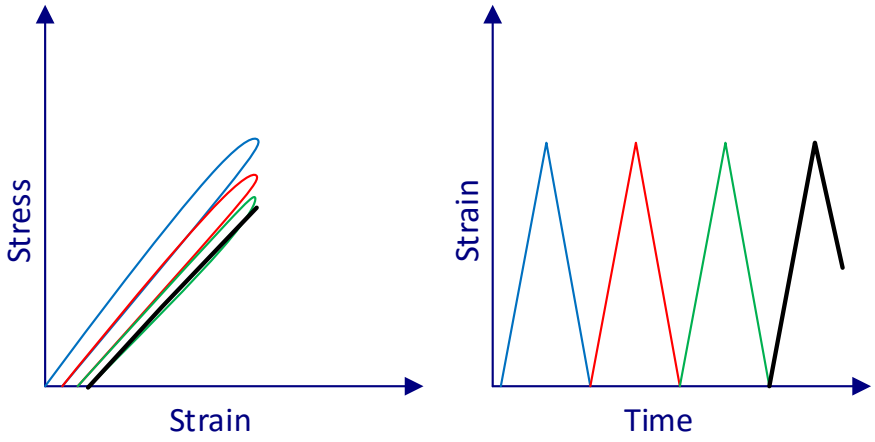
1. Stress relaxation – straining a material at constant strain



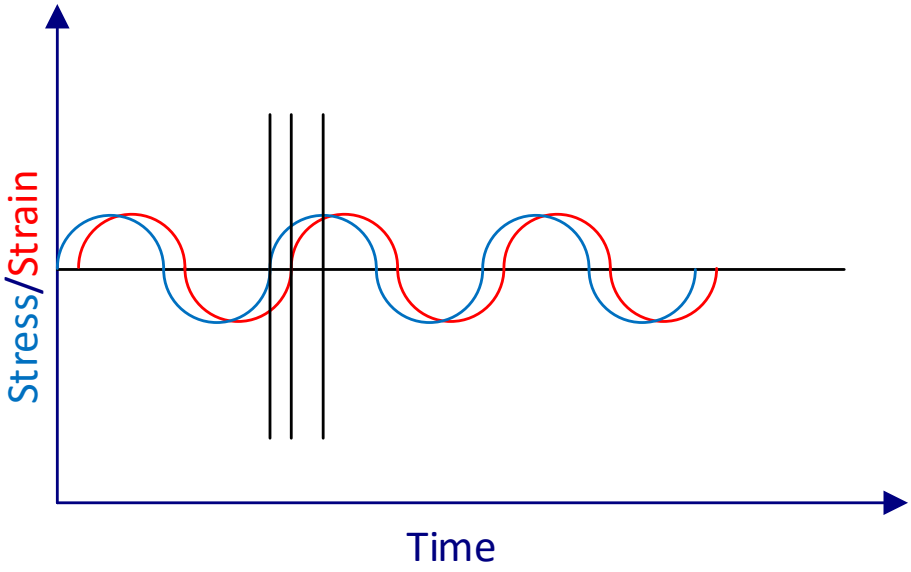
2. Creep – loading a material at a constant stress (compliance test)



3. Oscillatory Response Test (Dynamic Mechanical Analysis)
    a. time dependence – removed by preconditioning



    b. frequency sweep



Examples

(1) Spinal Disks: The disks creep under the body weight, that is they shorter with time. Lying down allows the spinal disks to recover and this means the most people are taller in the morning than in the evening.

(2) Skin tissue: This can be seen by pinching the skin of the hand. It takes time to recover back to its original flat position. The longer the skin is held in the pinched position, the longer it takes the recover. The more rapidly it is pinched, the less it takes to recover. Also, skin is aging material, so its physical properties change over time. Younger skin recovers more rapidly than older skin.

Lumped Parameter Models (Linear viscoelastic models)

- Lumped representations

(1) Linear spring - the elastic solid behavior

(2) Linear dashpot – the viscous fluid behavior

(3) Contractile element – Effect of contractility of a muscle

- Maxwell (fluid) Model

- Voigt (solid) Model

- Standard Linear Solid (Kelvin Solid)

- Another three-parameter model (Homework 5)

- Viscoelastic responses of those models

  (1) Stress relaxation

(2) Creep