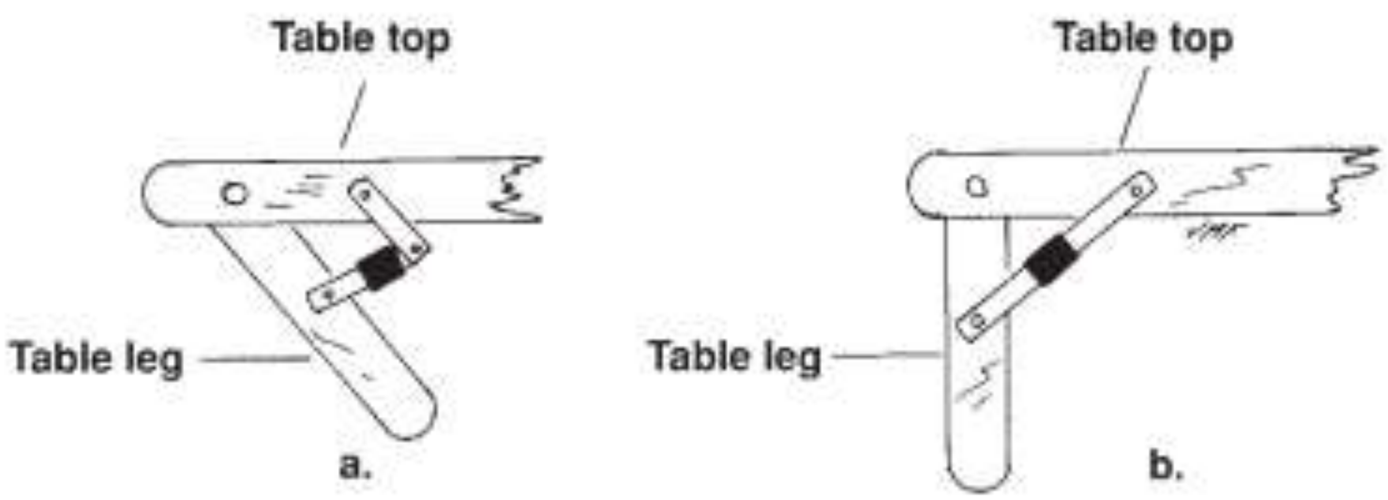
SNS College of Physiotherapy

JOINT STRUCTURE AND FUNCTION

INTRODUCTION

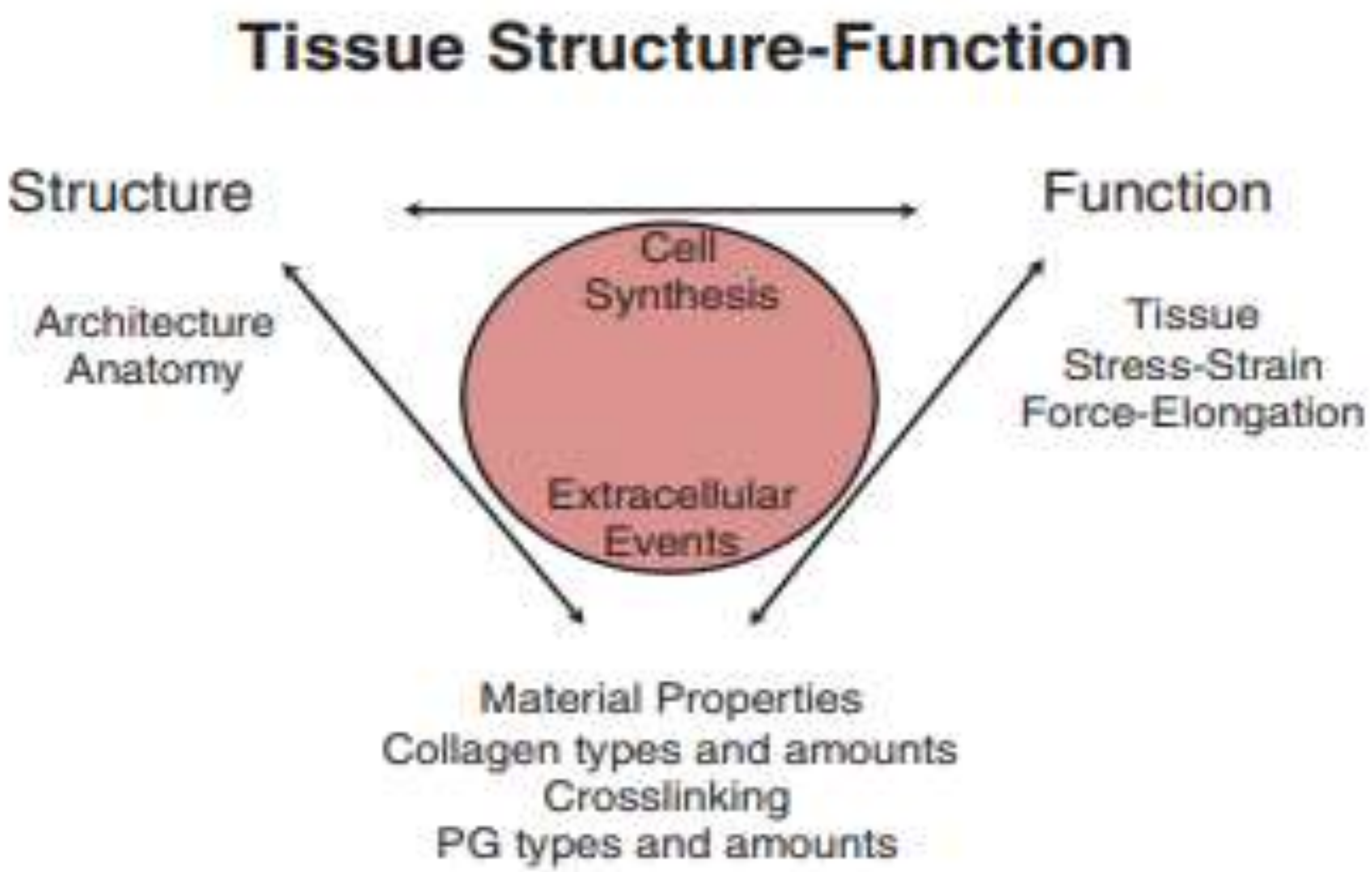
JOINT DESIGN

- The joints of the human body serve functions similar to those of joints used in the construction of buildings, furniture, and machines.
- Joints connect different segments together and may allow movement between those segments.
- The design of the joint will reflect these demands



▲ **Figure 2-2** ■ The "Flex foot" facilitates gait by its design and composition. The curved blade bends during loading and then assists with propulsion. A change in material affects how much the structure bends and how much energy it provides to subsequent forward movement.

- Once joints and tissues have assumed their final structural form, they can still be influenced by changes in functional demands.
- All components of human joints—bone, muscles, ligaments, cartilage, tendon—can adapt to functional demands.
- Frequently, for the therapist, this involves interventions aimed at restoring changes that have occurred as a result of inactivity or immobilization.
- Knowledge of the amount and types of loads that occur during normal loading conditions may allow the therapist to tailor the rehabilitation process to optimize tissue structure and function.



▲ **Figure 2-3** ■ Form determines the overall structure of connective tissues, but the characteristics of the tissue are affected by functional use. Collagen type, crosslinks, and PG type and amount all can be affected by the type and amount of stress applied to the tissue. Alternatively, the tissue may adapt to altered function by becoming larger, longer, or shorter. The size of the tissue and its composition will determine the types of loads the tissue can bear; these loads will likewise signal the cells to synthesize the appropriate type and amount of tissue and either dictate or facilitate extracellular events (such as crosslinking) that enhance tissue function.

- **Basic Principles**
- A joint (articulation) connects one component of a structure with one or more other components.
- The design of a joint and the materials used in its construction depend partly on the function of the joint and partly on the nature of the components.
- If the function of a joint is to provide stability or static support, the joint will have a different design than when the desired function is mobility. In general, design becomes more complex as functional demands increases.

Materials Found in Human Joints

Structure of Connective Tissue

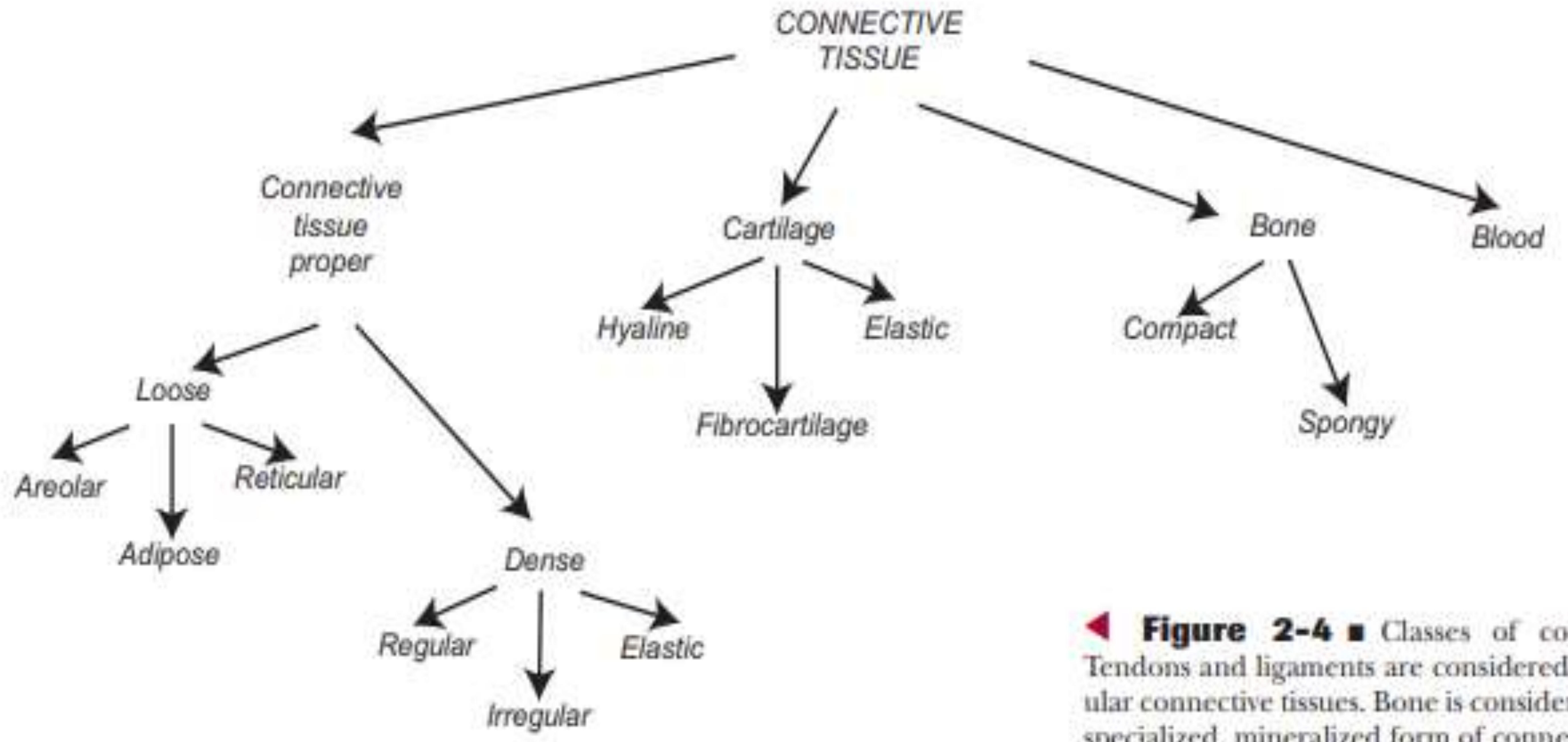


Figure 2-4 ■ Classes of connective tissue. Tendons and ligaments are considered to be dense regular connective tissues. Bone is considered to be a highly specialized, mineralized form of connective tissue.

EXTRACELLUALR MATRIX

INTERFIBRILLAR COMPONENT

Glycoproteins

Proteoglycans (PGs)

(Composed of repeated disaccharides units)

Glycosaminoglycans (GAGs)

- N-acetylgalactosamine(GalNAc)
- N-acetylglucosamine(GlcNAc)

GlucuronateIduronate.

FIBRILLAR COMPONENT

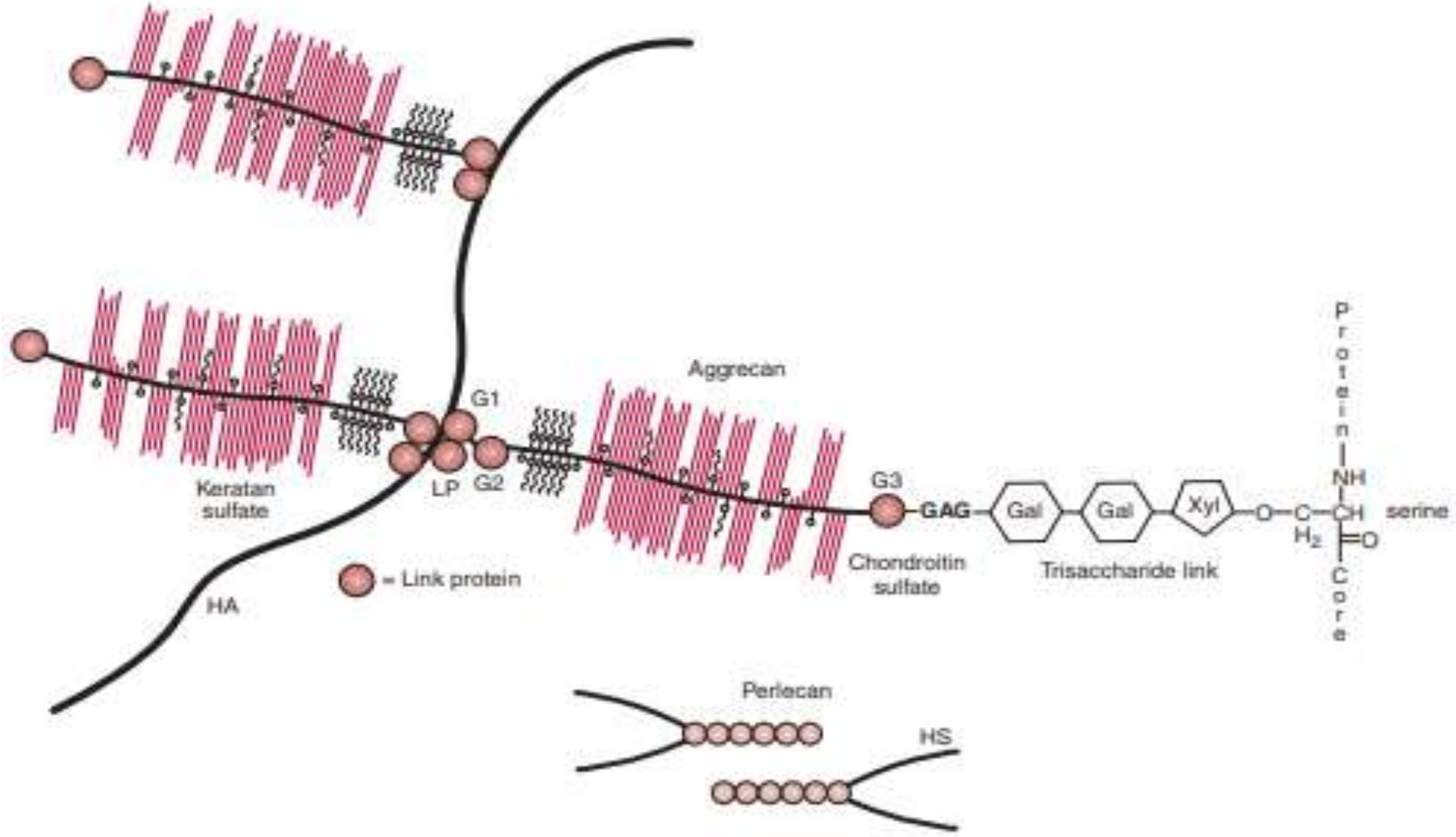
Collagen

Elastin

cell

Table 2-1 Connective Tissue Cell Types

Type	Name	Location and Function
Fixed	Fibroblast	Found in tendon, ligament, skin, bone, etc. Creates mostly type I collagen
	Chondroblast	Differentiated fibroblast found in cartilage Produces mostly type II collagen
	Osteoblast	Differentiated fibroblast found in bone Produces type I collagen and hydroxyapatite
	Osteoclast	Monocyte-derived, found in bone Responsible for bone resorption
	Mast cells	Found in various connective tissues Inflammatory mediators
	Adipose cells	Found in adipose tissue Produce and store fat
	Mesenchyme cells	Undifferentiated cells found primarily in embryo and in bone marrow Can differentiate into any connective tissue cell
Transient	Lymphocytes	White blood cells that have surface proteins specific for antigens
	Neutrophils	White blood cells involved in fighting infection
	Macrophages	Derived from monocytes, move into specific tissues, involved in immune response
	Plasma cells	B lymphocytes producing antibodies



▲ **Figure 2-5** ■ In the extracellular matrix, large complexes of PGs with other matrix molecules are found. Aggrecan is the largest of these PGs. Aggrecan is covalently modified by both chondroitin sulfate (CS) and keratan sulfate (KS) chains and noncovalently associated to a hyaluronan (HA) chain.

Table 2-4 Glycoproteins

Classification	Name	Comments
Cartilage	Asporin	Related to decorin and biglycan, found in cartilage Increases in osteoarthritis
	Chondronectin	Attaches chondrocytes to type II collagen
	Chondroadherin (CHAD)	Found in cartilage Binds to cells via integrin Function unknown
Bone	Osteoadherin	Found in bone trabeculae Binds to cells via integrin
	Osteonectin	Binds to hydroxyapatite, collagens, growth factors, osteoadherin; inhibits cell spreading
	Osteopontin	Binds to osteoclast via integrin Assists osteoclast function
	Osteocalcin (BGP)	Thought to be involved in bone formation
Basement membrane	Laminin	Binds type IV collagen, HS, integrin (cell membrane)
	Entactin	Interacts with laminin
Multiple sites	Collagen	Structural component
	Fibronectin	Interacts with cell-surface receptors, blood-clotting components, denatured collagen, cytoskeleton, GAGs
	Tenascin	Function unclear; increases in developing or healing tissue
Synovial fluid	Lubricin	Adheres to articular surface to provide boundary lubrication

GAG, glycoaminoglycan; HS, heparan sulfate.

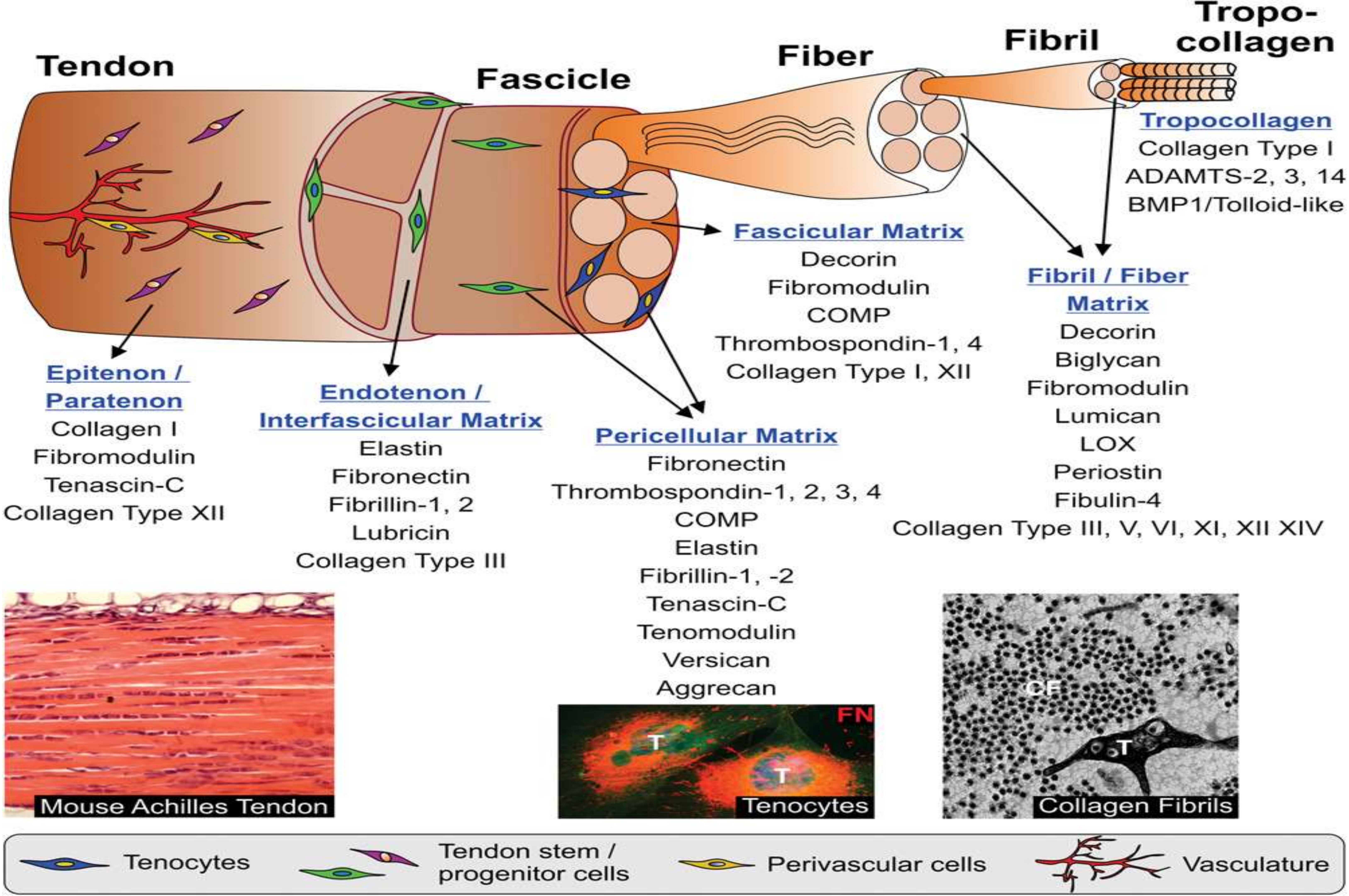
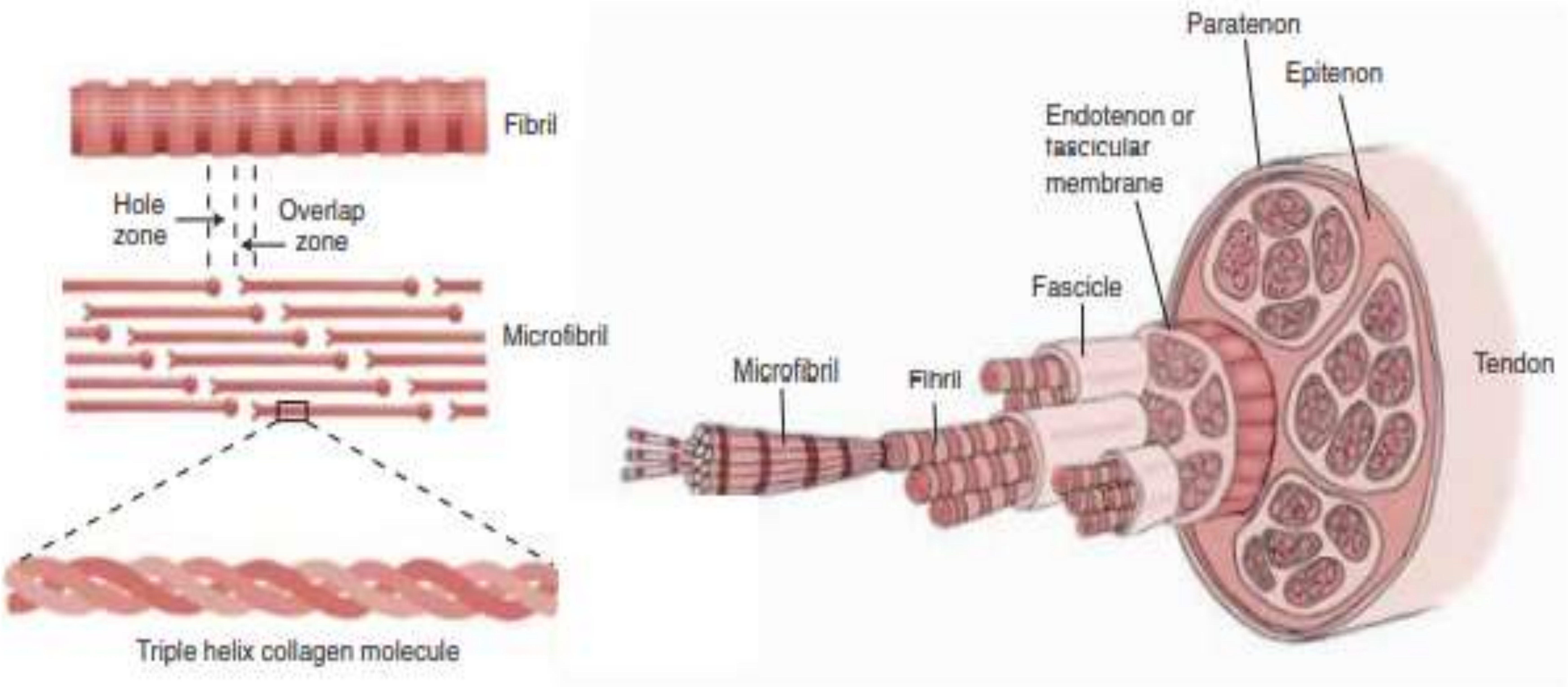

Tendon
Fascicle
Fiber
Fibril
Tropo-collagen
Tropocollagen
Collagen Type I
ADAMTS-2, 3, 14
BMP1/Tolloid-like
Fascicular Matrix
Decorin
Fibromodulin
COMP
Thrombospondin-1, 4
Collagen Type I, XII
Fibril / Fiber Matrix
Decorin
Biglycan
Fibromodulin
Lumican
LOX
Periostin
Fibulin-4
Collagen Type III, V, VI, XI, XII XIV
Epitenon / Paratenon
Collagen I
Fibromodulin
Tenascin-C
Collagen Type XII
Endotenon / Interfascicular Matrix
Elastin
Fibronectin
Fibrillin-1, 2
Lubricin
Collagen Type III
Pericellular Matrix
Fibronectin
Thrombospondin-1, 2, 3, 4
COMP
Elastin
Fibrillin-1, -2
Tenascin-C
Tenomodulin
Versican
Aggrecan
Mouse Achilles Tendon
FN
T
T
Tenocytes
CF
T
Collagen Fibrils
Tenocytes
Tendon stem / progenitor cells
Perivascular cells
Vasculature

Table 2-5	Collagen Types	
Classification	**Type**	**Common Locations**
Fibrillar	I	Tendons, bone, ligaments, skin, anulus fibrosis, menisci, fibrocartilage, joint capsules, cornea Accounts for 90% of body collagen
	II	Hyaline articular cartilage, nucleus pulposus, vitreous humor
	III	Skin, blood vessels, tendons ligaments
	V	Cartilage, tendons
	XI	Cartilage, other tissues (associated with type V)
	IX	Cartilage, cornea (found with type II)
Fibril-associated	XII	Tendons, ligaments (found with type I)
	XIV	Fetal skin and tendons
	IV	Basement membrane
Network forming	X	Hypertrophic cartilage
	VIII	Unknown
Filamentous	VI	Blood vessels, skin
Anchoring	VII	Anchoring filaments



▲ **Figure 2-6** ■ Dense connective tissues such as tendon have a hierarchical structure from the molecule to the entire tissue.

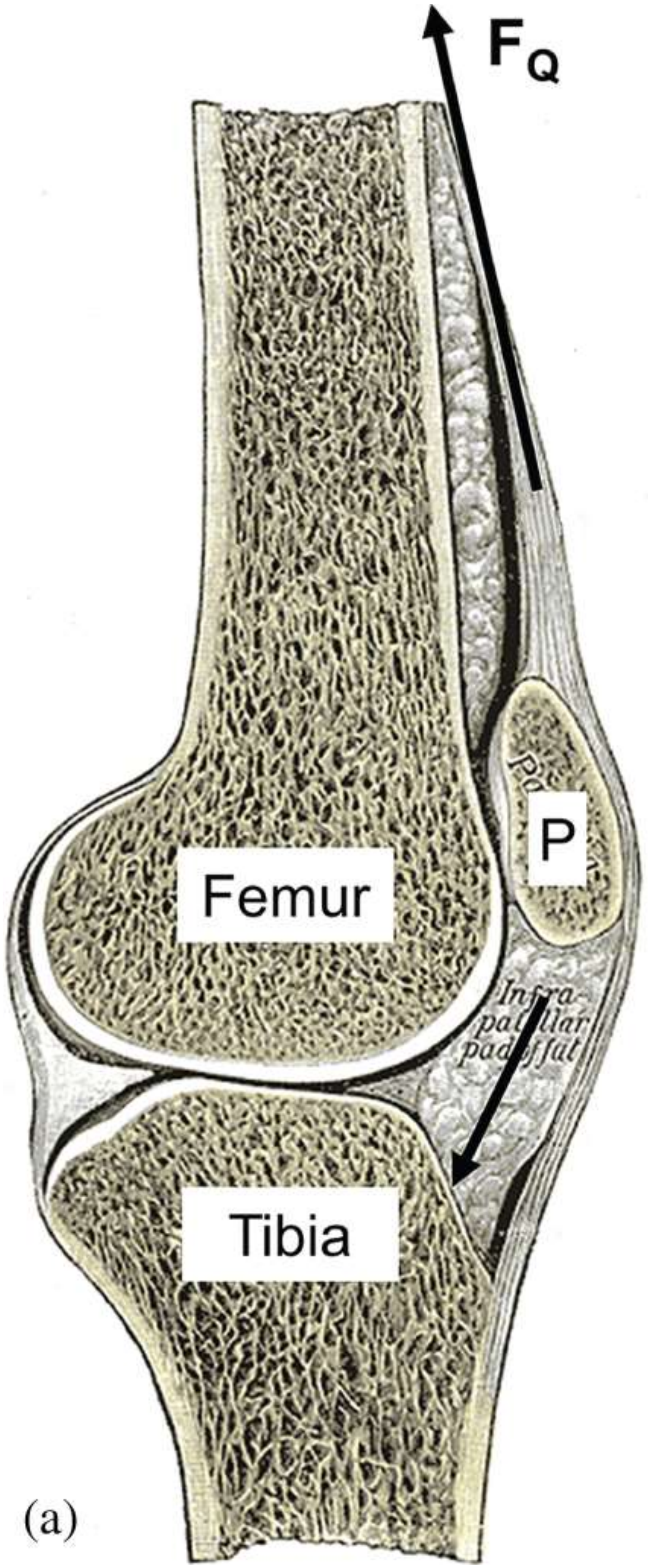
SPECIFIC CONNECTIVE TISSUE STRUCTURES

■ Ligaments

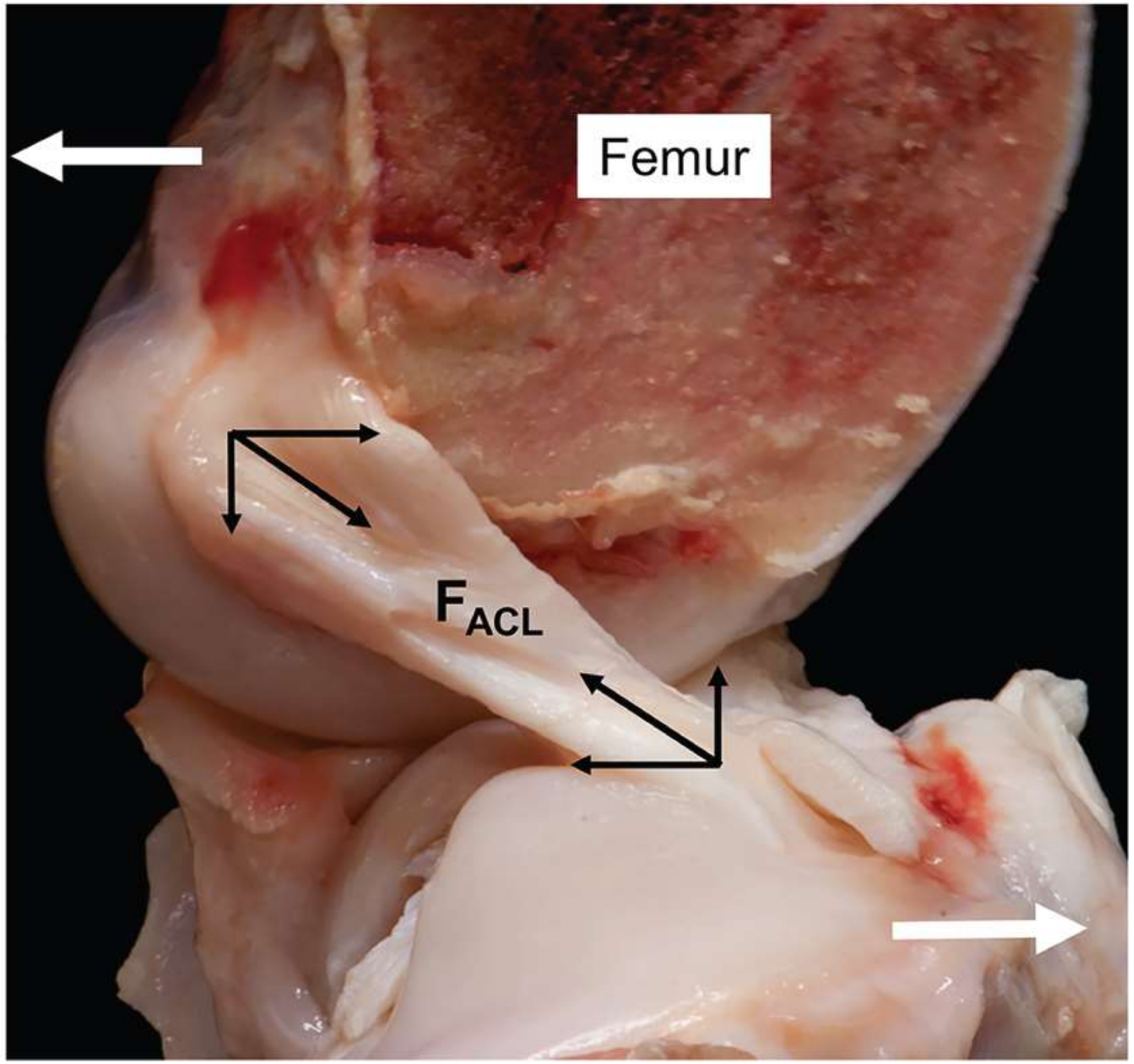
Ligaments connect one bone to another, usually at or near a joint.

Some ligaments blend with the joint capsules and may be difficult to identify because they appear as thickenings in the capsule (e.g., anterior band of the inferior glenohumeral ligament).

Other ligaments are distinct, easily recognizable structures often appearing as dense white bands or cords of connective tissue (e.g., anterior cruciate ligament [ACL])



(a)



(b)

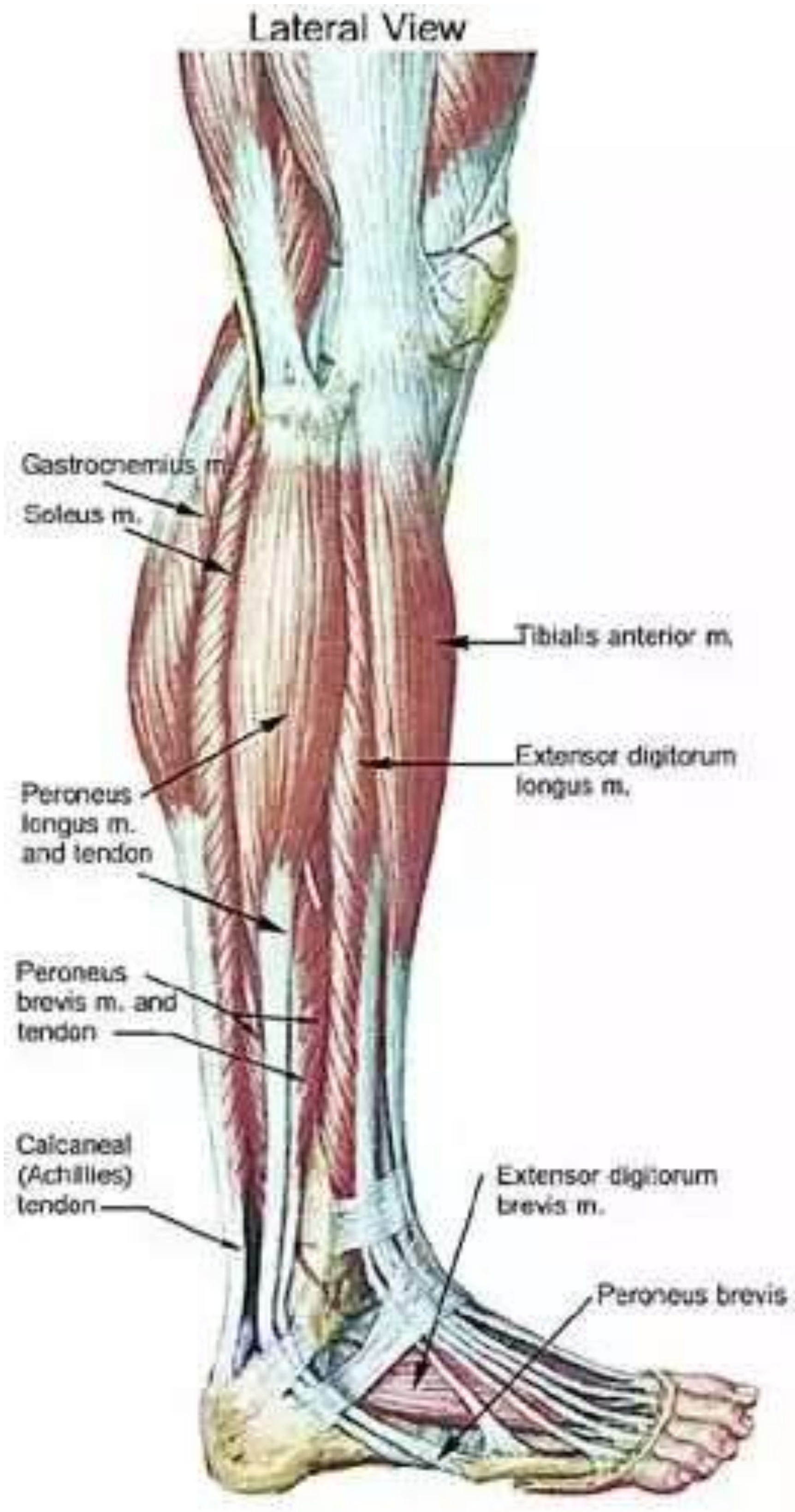
Ligaments & tendons

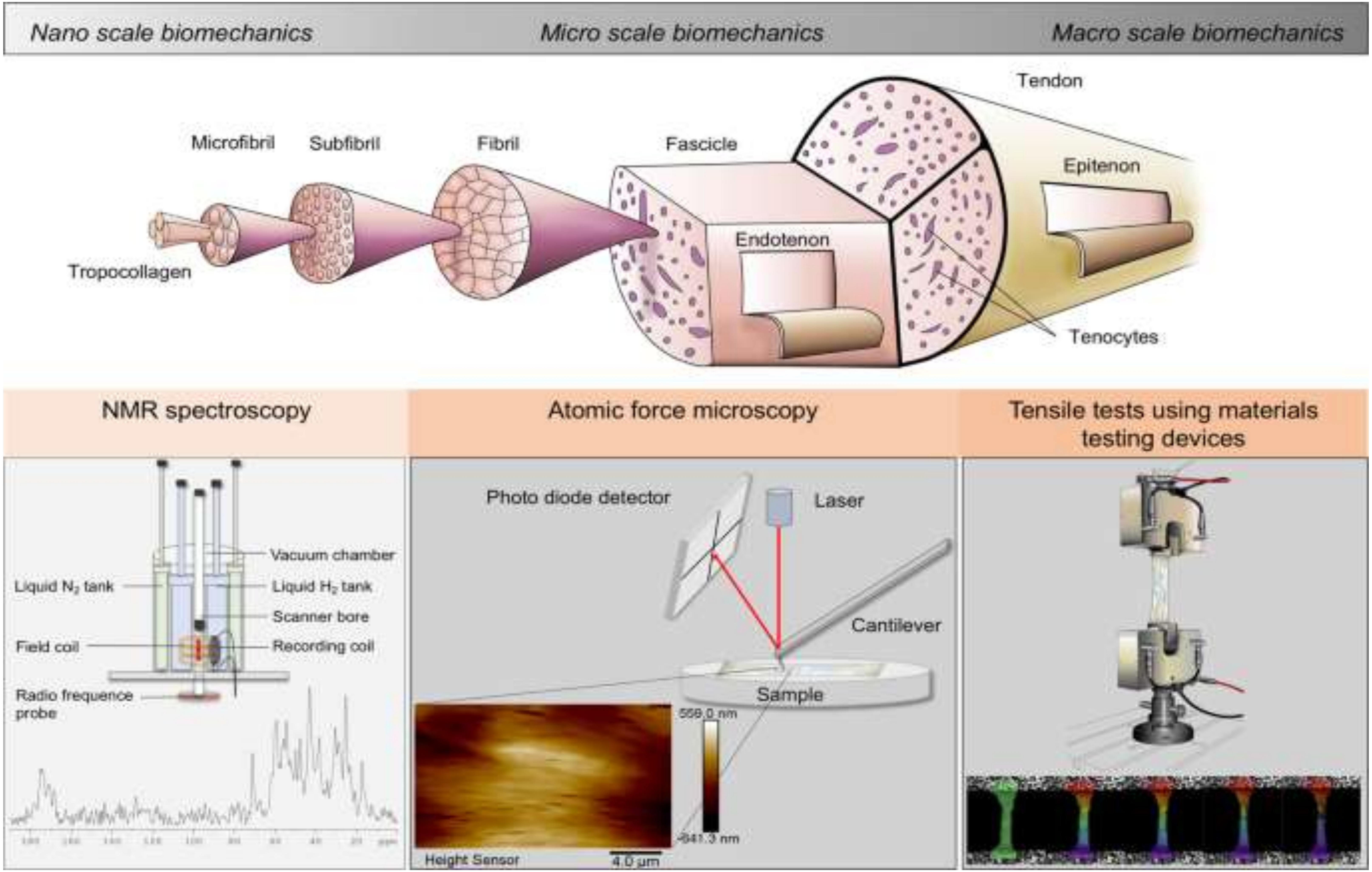
- Fibroblasts (20%)
- Extracellular matrix (80%)
  - Fibres (60–70%)
    - Collagen I
    - Collagen III
    - Elastin
  - Ground substances (20–30%)
    - Glycosaminoglycans & proteoglycans adhesion proteins
    - Water

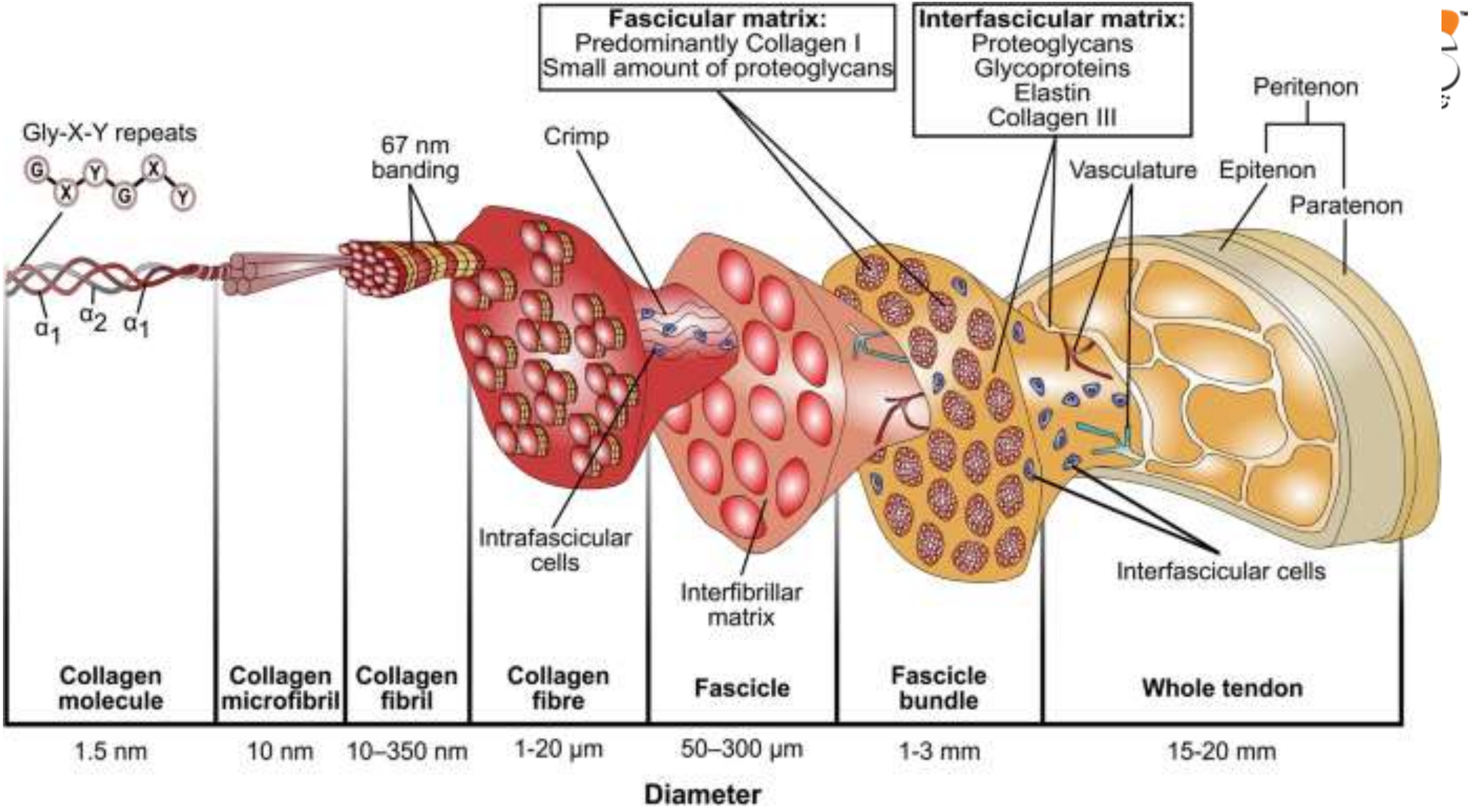
	Collagen I	Collagen III	Elastin	Glycosaminoglycans & proteoglycans adhesion proteins	Water
Ligament	70–80%	10%	Varies with ligaments Values not reported	1–5%	>95%
Tendon	95–99%	1–5%	scarce	<2%	<95%

TENDONS

- Tendons have approximately the same composition and basic structure as ligaments.
- The fibrillar component is composed primarily of type I collagen, with lesser amounts of type III and type V collagen and of type IV collagen associated with the basal lamina of the fibroblasts.
- Tendons contain slightly more type I collagen and slightly less type III collagen than do ligaments.



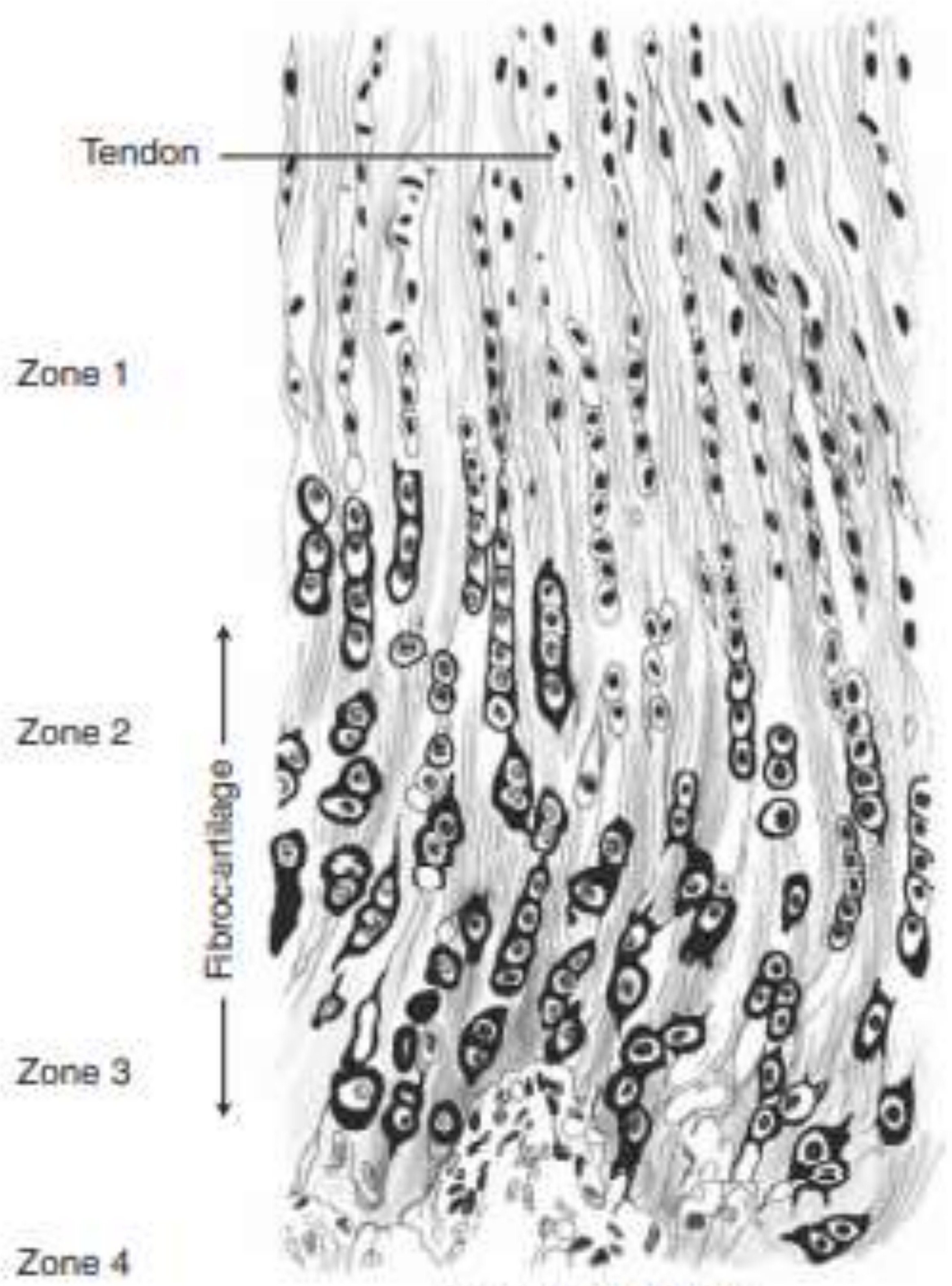

Nano scale biomechanics
Micro scale biomechanics
Macro scale biomechanics
Tendon
Microfibril
Subfibril
Fibril
Fascicle
Epitenon
Tropocollagen
Endotenon
Tenocytes
NMR spectroscopy
Atomic force microscopy
Tensile tests using materials testing devices
Vacuum chamber
Liquid N2 tank
Liquid H2 tank
Scanner bore
Field coil
Recording coil
Radio frequence probe
Photo diode detector
Laser
Cantilever
Sample
Height Sensor
4.0 µm


Fascicular matrix:
Predominantly Collagen I
Small amount of proteoglycans
Interfascicular matrix:
Proteoglycans
Glycoproteins
Elastin
Collagen III
Peritenon
Gly-X-Y repeats
G
X
Y
G
X
Y
67 nm banding
Crimp
Vasculature
Epitenon
Paratenon
α1
α2
α1
Intrafascicular cells
Interfibrillar matrix
Interfascicular cells
Collagen molecule
Collagen microfibril
Collagen fibril
Collagen fibre
Fascicle
Fascicle bundle
Whole tendon
1.5 nm
10 nm
10–350 nm
1-20 μm
50–300 μm
1-3 mm
15-20 mm
Diameter

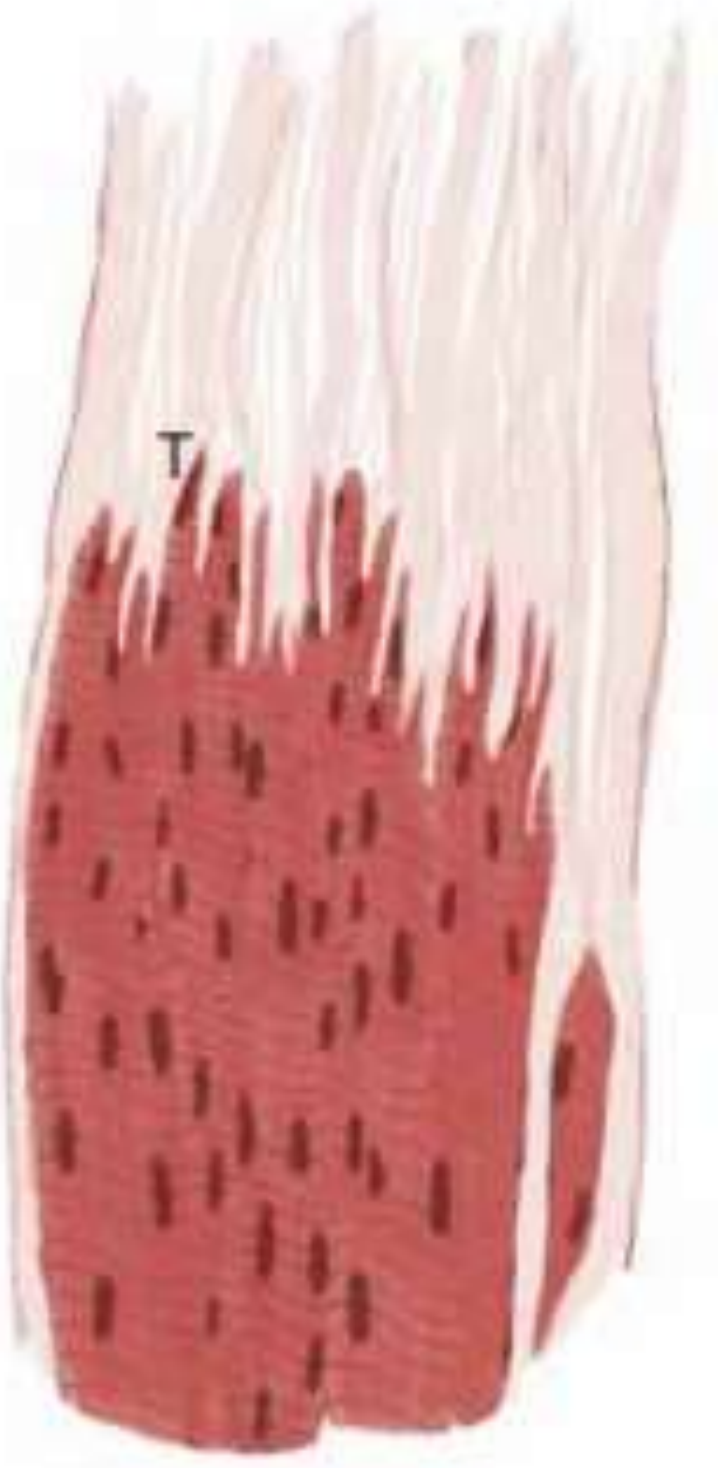
- There are two types of tendon attachments to bone: fibrocartilaginous and fibrous.
- The fibrous entheses may be subdivided into two categories: periosteal and bony.
- The attachment of tendon to muscle at the myotendinous junction (MTJ) comprises interdigitation between collagen fibers and muscle cells.
- Surface friction and direct connections between collagen and PGs and the basal lamina and integrins in the muscle cell membrane create a strong interaction

- The endotendon also encloses type 3 collagen fibrils,nerves,lymphatic vessels and blood vessels.
- The sheath that encloses entire tendon is called epitenon.
- Paratenon is sheath of tissue that is attached to outer surface of epitenon.
- The epitenon and paratenon are together called as peritendon.
- Peritendon may become synovium filled sheath called tenosynovium where there is high levels of friction.

- Tendons also have two types of bony attachment : fibrocartilaginous and fibrous.
- The fibrocartilaginous attachments has 4 zones.
- The first zone contains tendon proper
- The second contains fibrocartilage and marks the beginning of transition from tendon to bone.
- The third zone contains mineralized fibrocartilage
- The fourth zone contains bone.



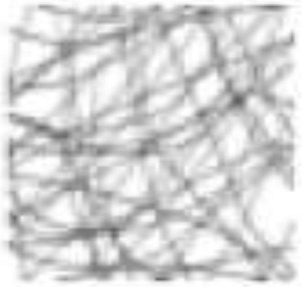
▲ **Figure 2-7** ■ The bone-tendon (or ligament) junction. There are four zones, from pure tendon (zone 1) to bone (zone 4). In between, the material gradually transitions from fibrocartilage (zone 2) to mineralized fibrocartilage (zone 3).



▲ **Figure 2-8** ■ The muscle-tendon junction. The muscle cells interdigitate with the tendon (T). There are direct connections between the muscle cell membrane and fibroblasts, PGs, and collagen. The endotenon blends into the endomysium, and the epitenon blends into the epimysium, which forms a meshwork of connective tissue around the muscle fibers.

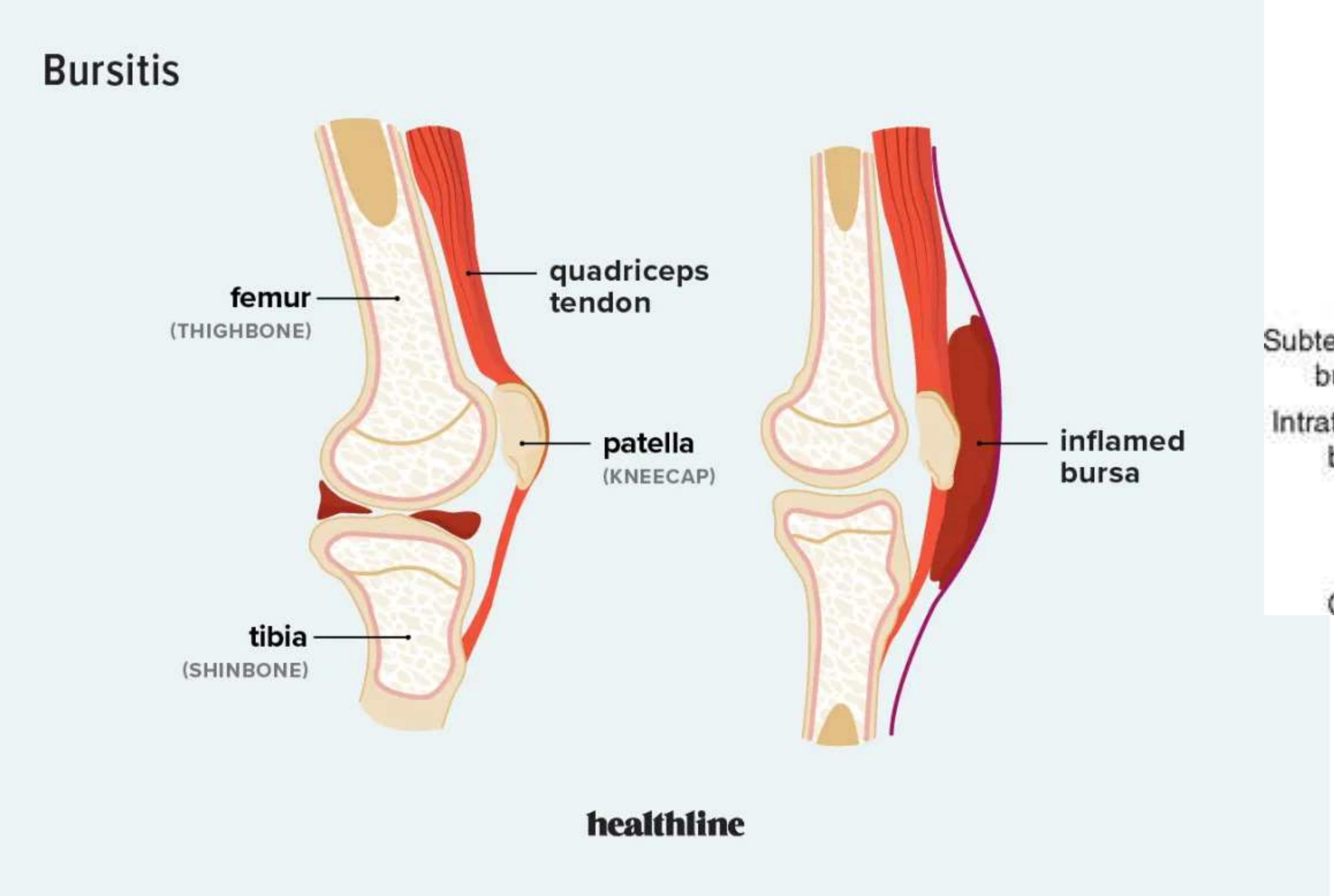
	Ligament	Tendon
		

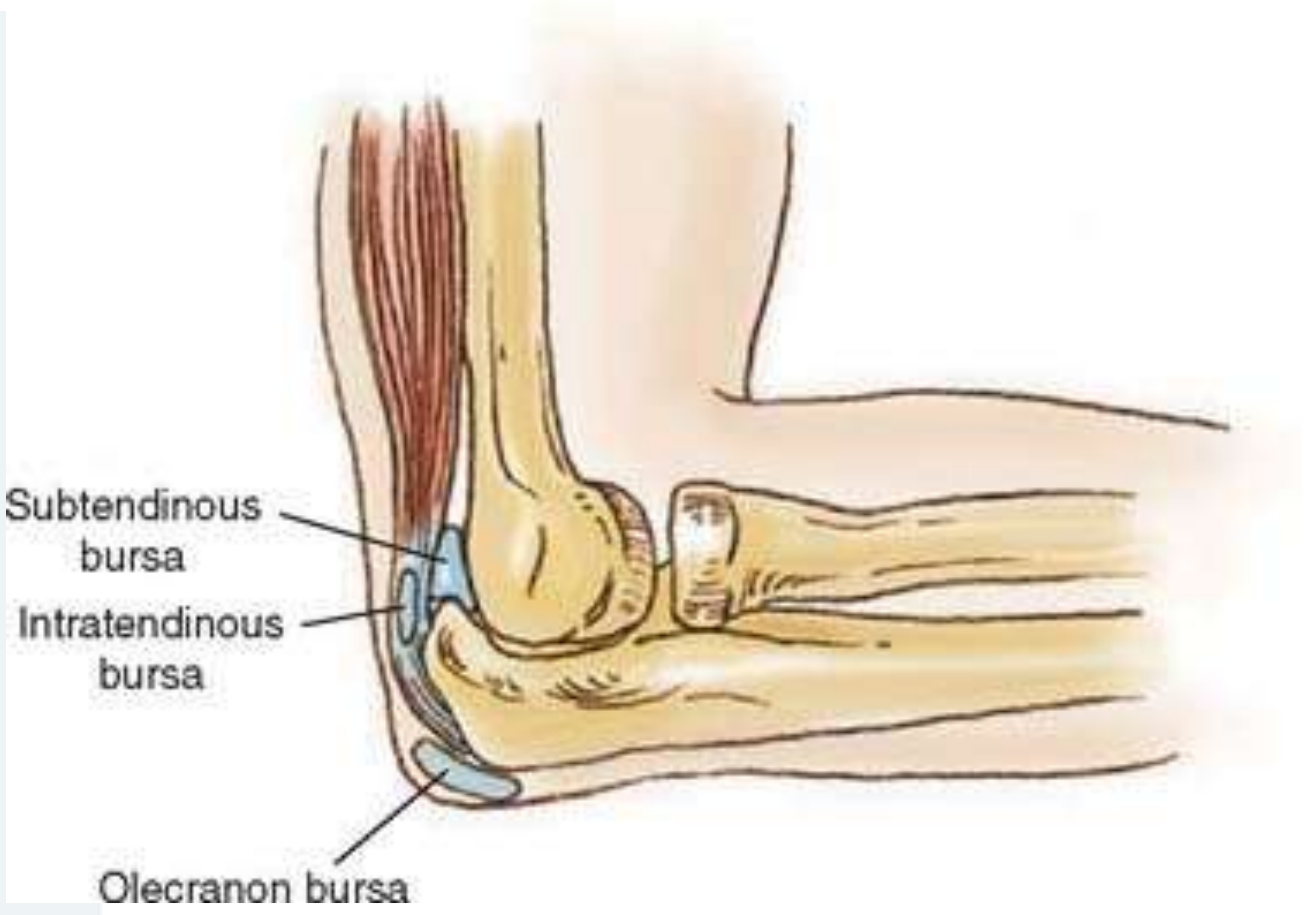
Ligaments act to connect bones together around joints while tendons acts to connect muscles to bones

		Ligament	Tendon
	**Cell type**	Fibroblasts.	Tenocytes (Fibroblast like cells).
	**Native ECM**	-Less collagen content. -Glycosaminoglycan. -More water content.	-Abundant collagen content. -Proteoglycan. -Elastin.
	Engineered constructs ECM	-Asporin. -Tenomodulin.	- Versican. - Proteoglycan 4. - SOD3.
	**Mechanical Properties**	- Maximum tensile strength ranges from 4.4 up to 660 MPa for both tissue types. - Maximum strain of both structures ranges between 18 to 30%. - Estimated Young's modulus ranges between 0.2 up to 1.5 GPa for both.	

Bursae

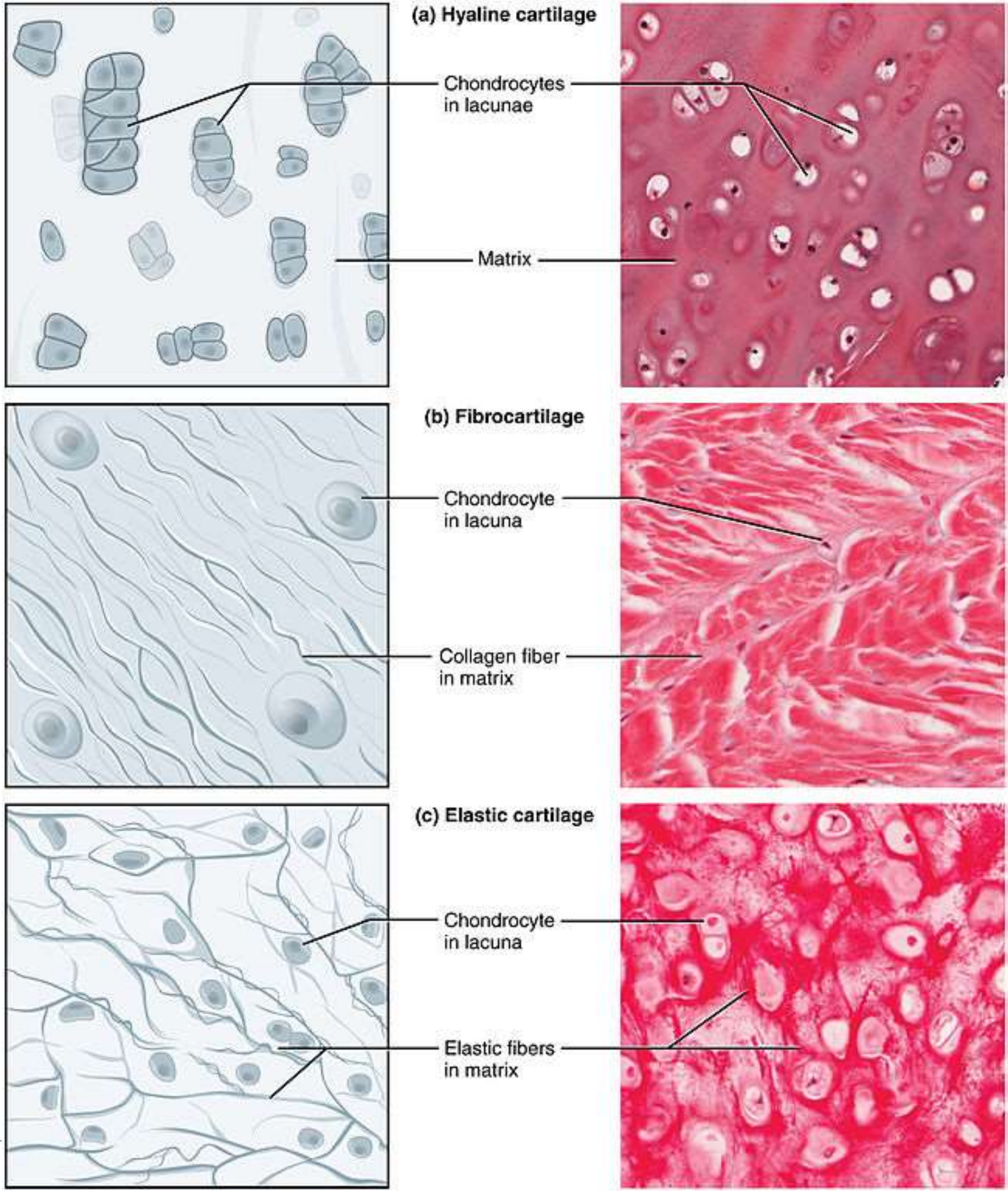
- Bursae, which are similar in structure and function to tendon sheaths, are **flat sacs of synovial membrane** in which the inner sides of the sacs are separated by a fluid film.
- Bursae are located where moving structures are in tight approximation: that is, between tendon and bone, bone and skin, muscle and bone, or ligament and bone.
- Bursae located between the skin and bone, such as those found between the patella and the skin and between the olecranon process of the ulna and the skin, are called subcutaneous bursae.
- Subtendinous bursae lie between **tendon and bone, and submuscular bursae lie between muscle and bone.**


Bursitis
femur
(THIGHBONE)
quadriceps tendon
patella
(KNEECAP)
tibia
(SHINBONE)
inflamed bursa
healthline

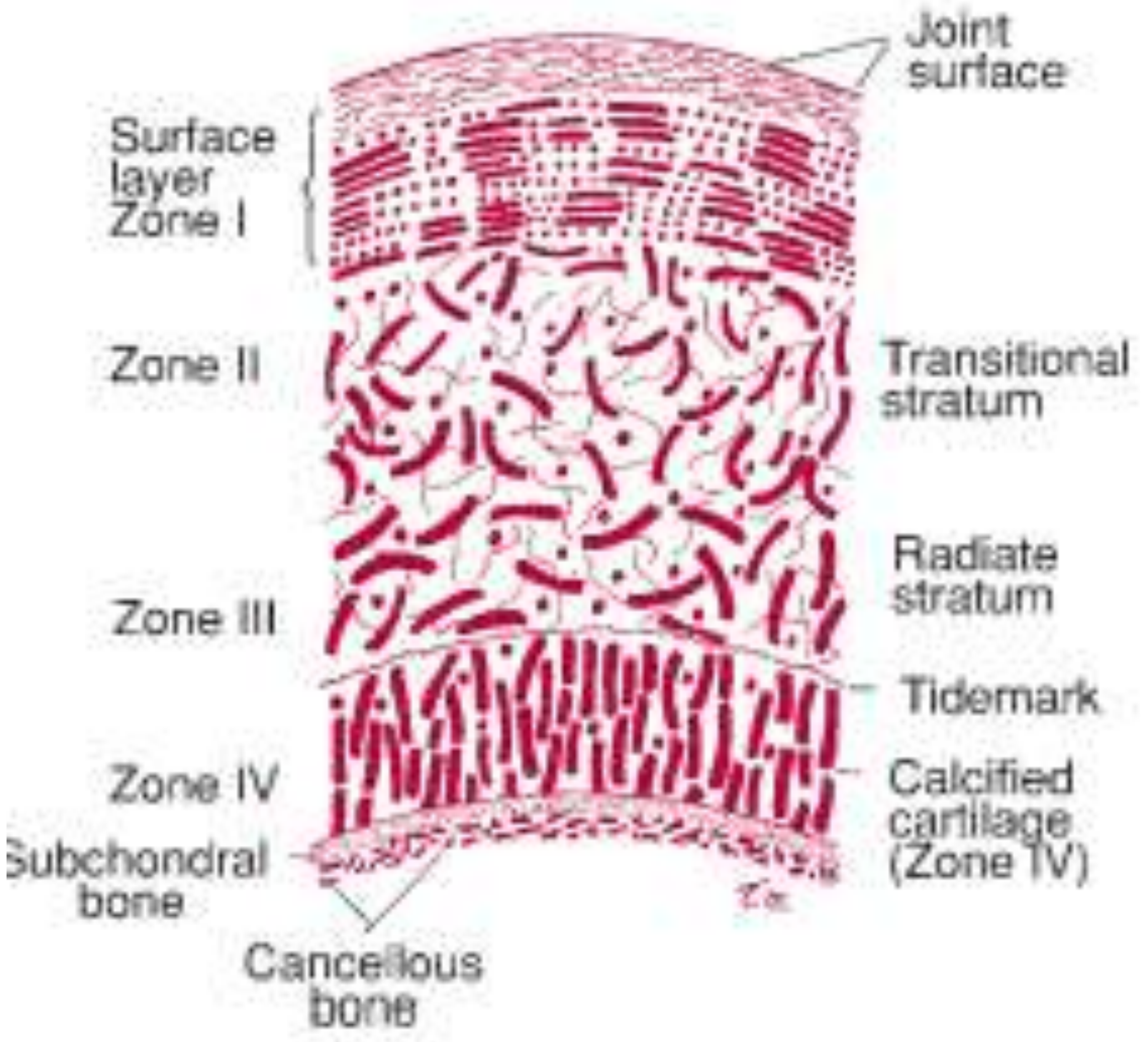

Subtendinous bursa
Intratendinous bursa
Olecranon bursa

CARTILAGE

- Cartilage is usually divided into the following types: **(white) fibrocartilage, (yellow) elastic cartilage, and (articular) hyaline cartilage.**



- Three distinct layers or zones of articular cartilage are found on the ends of the bony components of synovial joints.
- In the outermost layer (zone 1), the radially oriented type II collagen fibers are arranged parallel to the surface.
- This smooth outermost layer of the cartilage helps to reduce friction between the opposing joint surfaces and to distribute forces over the joint surface.



▲ **Figure 2-9** ■ Structure of hyaline cartilage.

- In the second and third zones, type II collagen fibers are randomly arranged and form an open latticework.
- permits deformation and helps to absorb some of the force imposed on the joint surfaces.
- In the third layer (radiate stratum), some collagen fibers lie perpendicular to the surface and extend across the interface between uncalcified and calcified cartilage to find a secure hold in the calcified cartilage referred to as the fourth zone, lies adjacent to subchondral bone and anchors the cartilage securely to the bone.

- The interface between the calcified and uncalcified cartilage is called the **tidemark.** The tidemark is important because of its relation to **growth,aging ,injury and healing.**

- The cartilage has no cellular turn over, the tissue is hypocellular and avascular, relies on diffusion for its nutrient supply, contains only terminally differentiated cells.
- The replacement of calcified layer of articular cartilage with bone occurs by **endochondral ossification.**
- PGs attract a large volume of water ,creating an osmotic swelling pressure in the cartilage. As the interfibrillar matrix expands ,tension is created in collagen network, creating an opposing force, keeping PGs and water contained.

Bone

- Bone is the hardest of all connective tissues
- The organic material gives bone its flexibility and tensile strength while the inorganic material gives bone its compressive strength.
- Bone cells include **fibroblasts, osteoblasts, osteocytes, osteoclasts.**
- Fibroblasts produce **type 1 collagen and other extracellular matrix components.**
- The osteoblasts are the **primary bone forming cells responsible for synthesis of bone and deposition and mineralization**.
- Osteoblasts also secrete procollagen into the matrix

- Osteoclasts are responsible for bone resorption.
- Bone has two layers, outer dense layer called compact or cortical bone and the inner spongier bone calledcancellous/trabecular/spongy bone.
- In cancellous bone the calcified tissue forms thin plates called trabeculae that are laid down in line with stress placed on the bone.
- Increase /decrease in bone density in other areas occur in response to loads placed on the bones.

- The periosteum is a fibrous layer that covers the entire surface of the bone except the articular surface.
- Collagen fibers from ligaments and tendons blend into periosteum and sharpey's fibers pass from the periosteum to deeper layers of bone.
- The periosteum is a reservoir for cells that are needed for growth and repair.
- If the periosteum and underlying bone are damaged as a result of trauma or surgery, the healing capacity of the bone will be decreased.

- At microscopic level ,both cortical and cancellous bone show two distinct types of bone architecture: **woven and lamellar.**
- In woven bone collagen fibers are irregularly arranged to form a pattern of alternating coarse and fine fibers that resemble woven material.
- **Woven bone** is young bone found in newborns, fracture callus, metaphyseal regions of long bones.
- **Lamellar bone** requires an extracellular matrix framework to form and constitutes adult skeleton.

- The change in bone shape (form) to match function is wolff's law.
- The application of new forces causes osteoblast activity to increase and as a result bone mass increases.
- With reduction of usual forces osteoclast activity predominates and bone mass decreases.
- Internal influences such as aging and nutritional , metabolic and disease process also affect bone remodelling.

- An imbalance between bone synthesis and resorption ,in which osteoclasts break down or absorb the bone at a faster rate than osteoblasts can rebuild the bone results in osteoporosis.
- In osteoporosis bone have decreased mineral density and are susceptible to fracture.
- Bone mineralization may also be decreased while cells continue to synthesise other elements of extracellular matrix - **osteopinea**

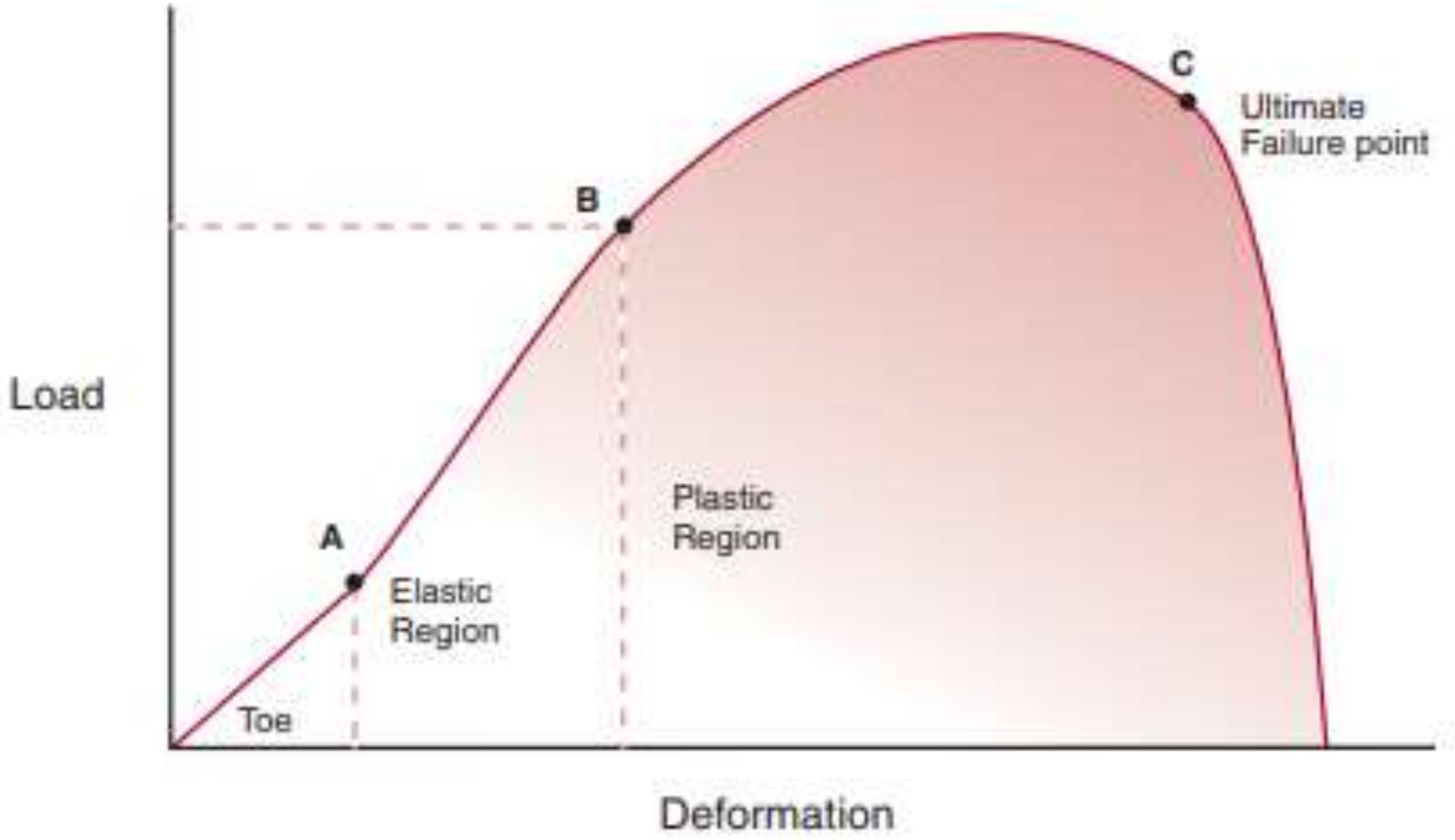
GENERAL PROPERTIES OF CT

- Materials that display the same mechanical behaviour, no matter the direction in which the forces are applied are called **isotropic materials.**
- Heterogenous connective tissues behave differently depending on the size and direction of applied forces, therefore called **anisotropic .**
- Connective tissues change their structure or composition in response to the applied forces.
- The ability of the connective tissues to respond to load alterations is **SAID principle(specific adaptation to imposed demand)**

❖ MECHANICAL BEHAVIOUR

- **Load, force and elongation**
- Load is the force applied to the structure.
- The magnitude, direction, and rate of force application as well as size and composition of the tissue will affect the tissues response to load.
- When forces acts on the object , it produces **deformation.**
- A tensile force produces elongation.
- A compressive load produces compression.

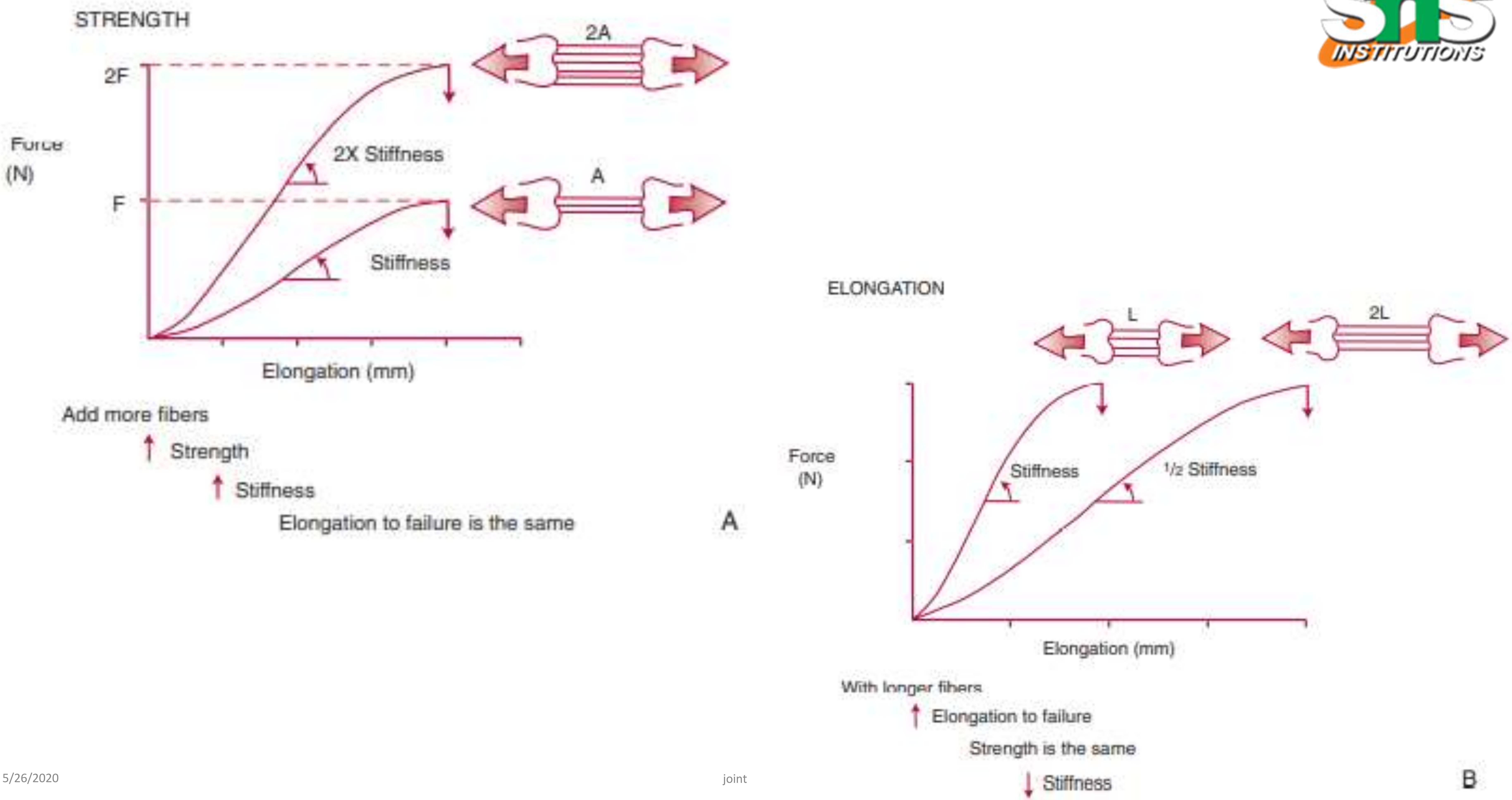
- The load deformation curve is the result of plotting the applied load against deformation, providing information about the strength properties of a particular material.
- The load deformation curve shows elasticity, plasticity, ultimate strength and stiffness of the material, as well as the amount of energy that the material can absorb before it fails.
- The portion of the curve between point **A and B is the elastic region.**
- If the load is confined to the elastic region, the deformation of the material will not be permanent and the structure will return to its original dimension immediately after the load is removed.



Load
C
Ultimate
Failure point
B
Plastic
Region
A
Elastic
Region
Toe
Deformation

- After point B ,the yield point at the end of the elastic region, the material will no longer immediately return to the original state when the load is removed, though it may recover in time.
- The portion between B and C is plastic region. The structure will appear to be intact after the load is removed but will not return to its original length(permanent deformation)
- If loading continues through the plastic region, the material will continue to deform until it reaches the ultimate failure point C.
- The load applied when this point is reached is the **failure load.**

- A structure with greater cross sectional area can withstand more force with less deformation than a structure of same original length with less cross sectional area.
- If two tissues are composed of the same material, the tissue with greater cross sectional area will have greater tensile strength (stiffness) and the longer tissue will be less stiff.
- The load deformation curve reflects the structural properties of the structure.
- **Tensile force-newtons, compressive force – pascals, compression or elongation in units of length.**



STRENGTH
2A
2F
Force (N)
2X Stiffness
A
F
Stiffness
Elongation (mm)
Add more fibers
↑ Strength
↑ Stiffness
Elongation to failure is the same
A
ELONGATION
L
2L
Force (N)
Stiffness
½ Stiffness
Elongation (mm)
With longer fibers
↑ Elongation to failure
Strength is the same
↓ Stiffness
B

STRESS AND STRAIN

- When load is applied to a structure, forces within the material are produced to oppose the applied forces. The forces within the material depend on the composition of the material.
- When the applied force is tensile, stress can be calculated.
- Stress is the force per cross sectional unit of the material, and expressed as
  - **S=F/A   s-stress, f- force applied, a-area.**
- Stress is expressed in pascals.

- Percentage change in the length or cross section of a structure or material is called strain.
    - strain= (L2-L1)/ L1
    - L1- original length, L2-final length
- Strain is expressed as percentage and therefore has no units.
- The type of stress and strain in human tissue depends on:

. **Material**

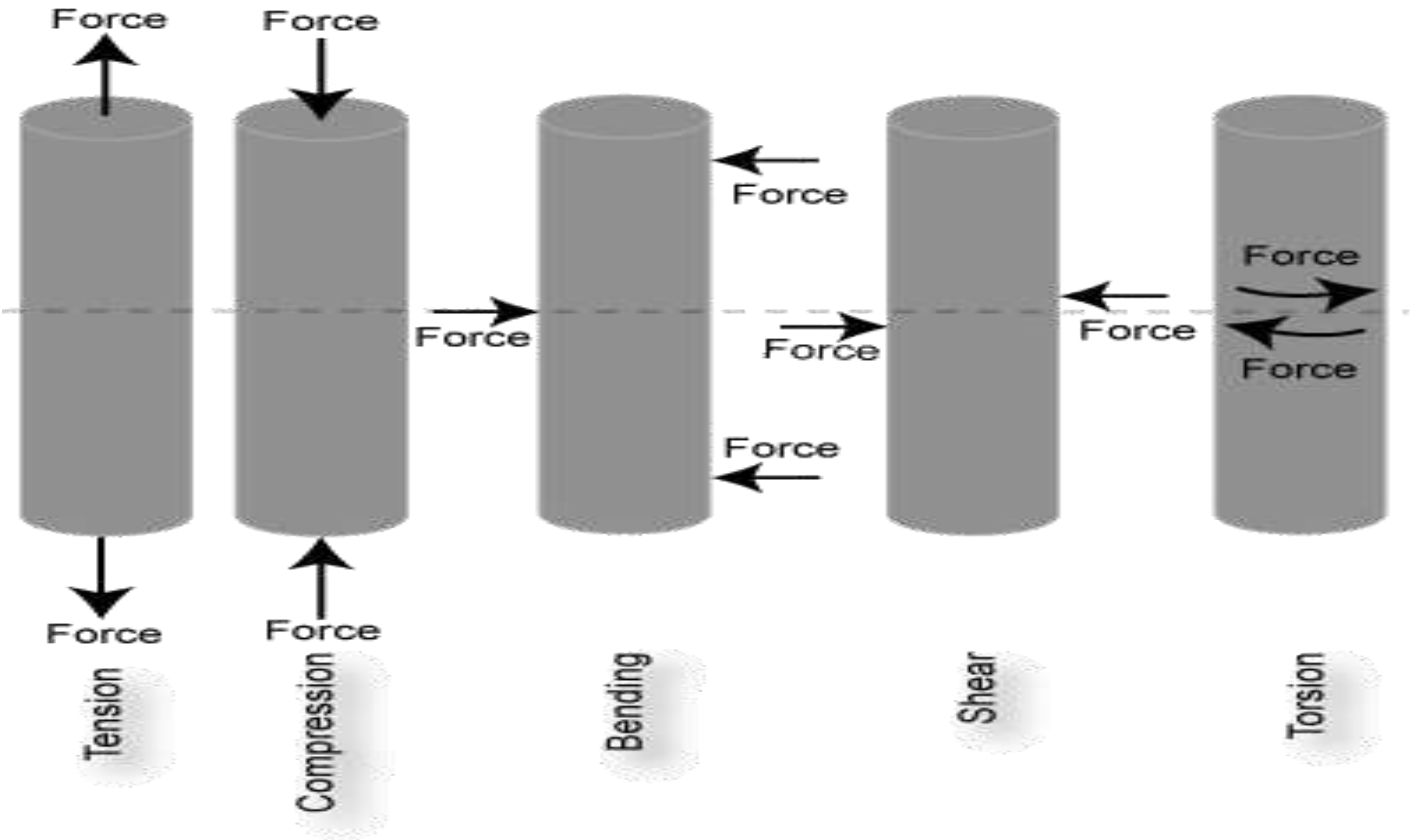
. **Type of load**

. **Point at which the load is applied**

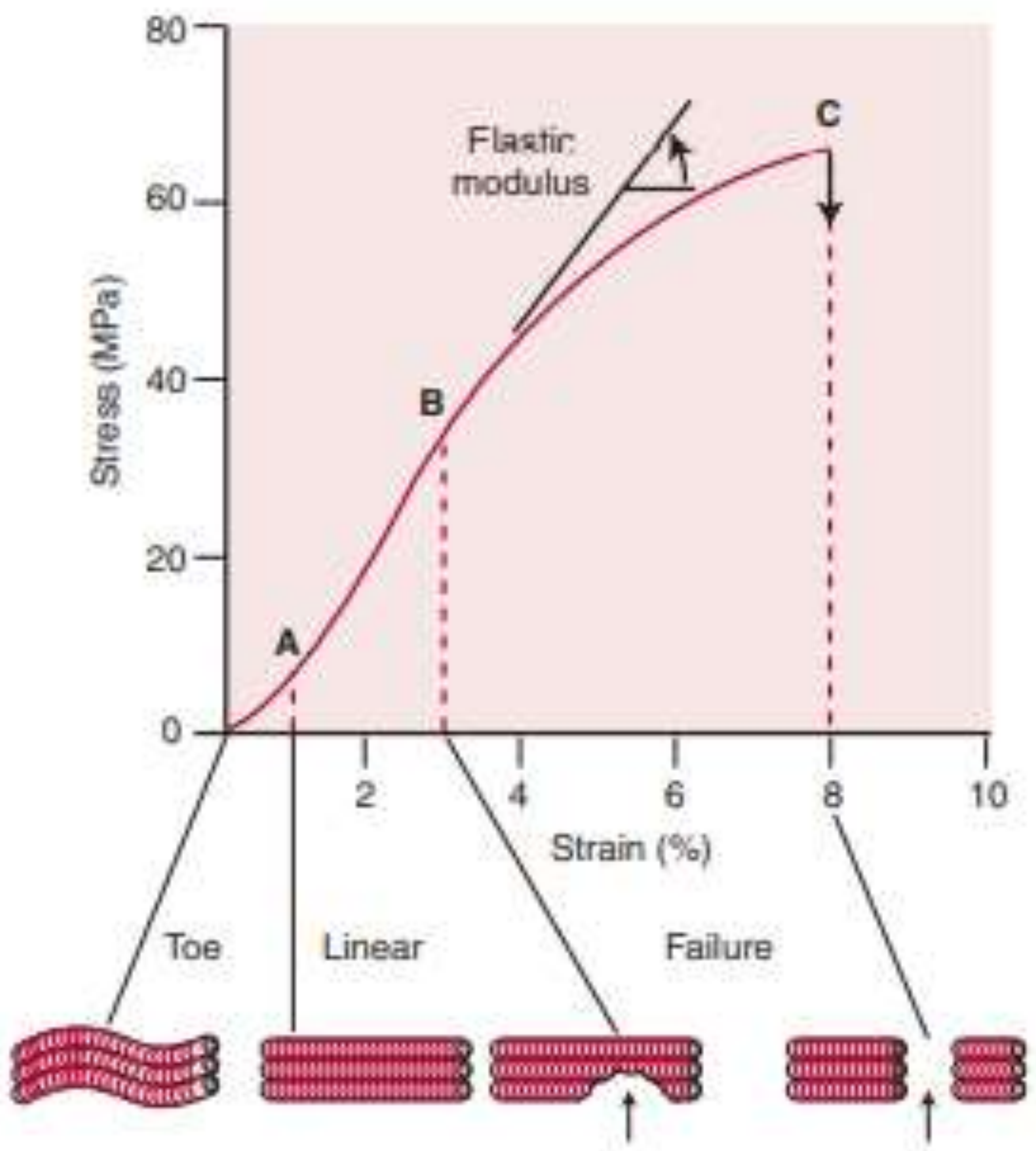
. Direction and magnitude of the load

. Rate and duration of load.

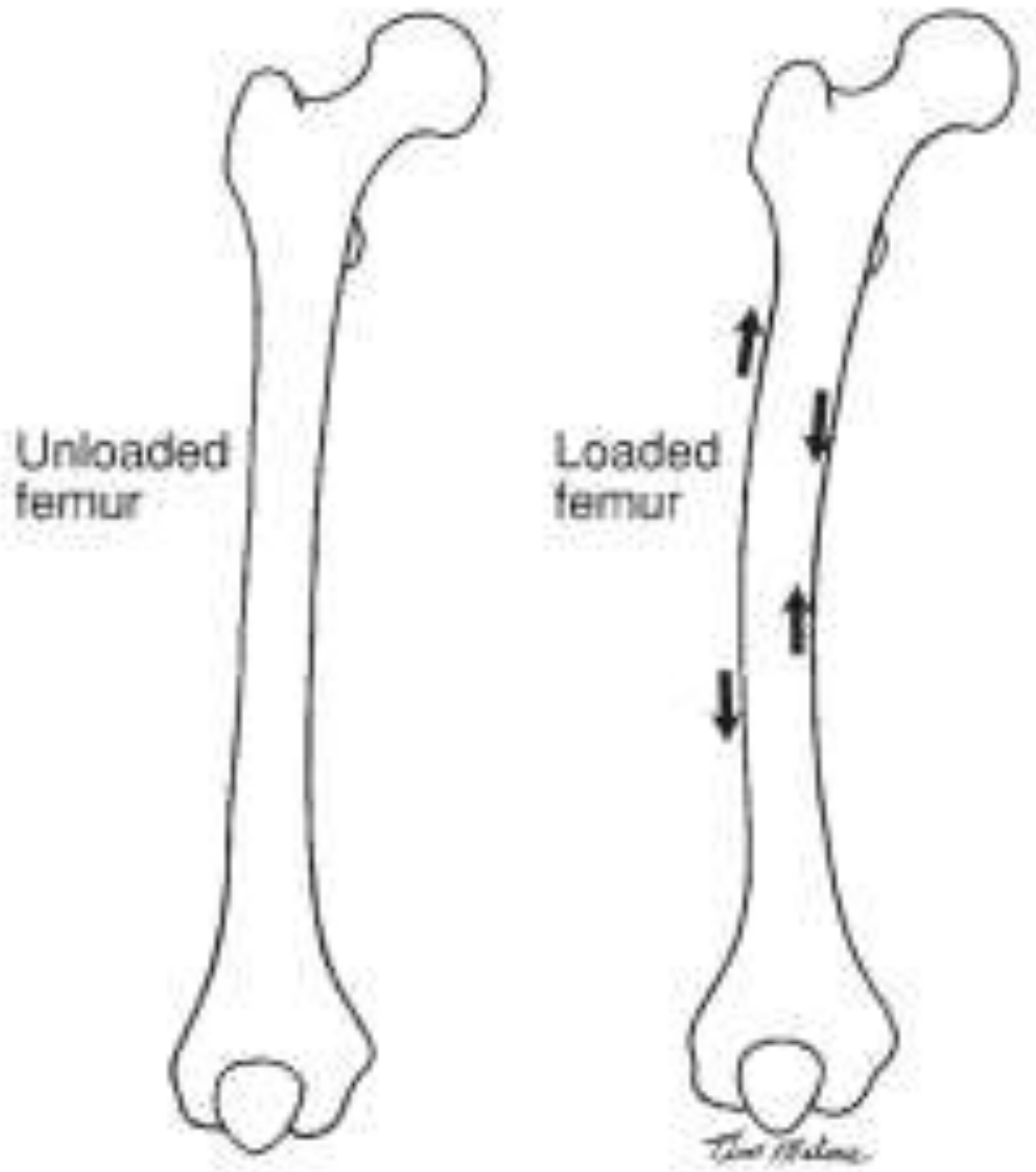
- When a structure can no longer support a load, the structure has failed.
- Ultimate stress is the stress just before the material fails.
- Ultimate strain is the strain at the same point.
- If two applied forces act along the same line but in opposite direction they create a distractive or tensile load and cause tensile stress and tensile strain in the structure or material.


Force
Force
Force
Force
Force
Force
Force
Force
Force
Force
Force
Force
Tension
Compression
Bending
Shear
Torsion

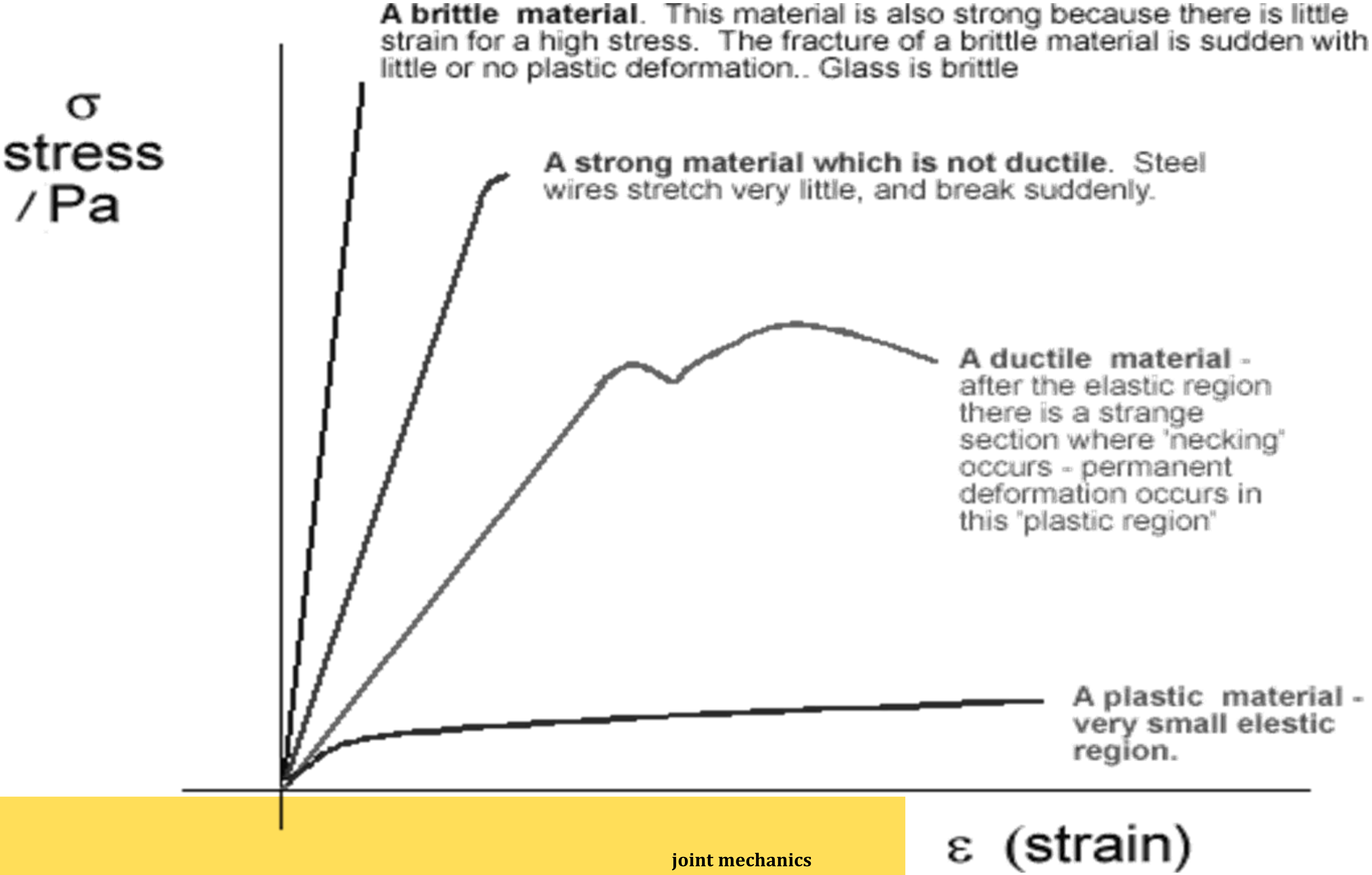
- If two applied forces act in a line towards each other, they constitute compressive loading and compressive stress, and so a compressive strain will develop.
- If two applied forces are parallel and applied in opposite direction but are in line with one another they constitute shear loading.
- Forces applied perpendicular to the long axis of a structure constitutes torsional loading
- When bending forces are applied to a structure ,both tensile and compressive stress and strain are created.



▲ **Figure 2-14** ■ An example of a stress-strain curve for collagenous materials. The results are independent of tissue dimensions and thus reflect the material of which the tissue is made. A-B is the elastic region, and B-C the plastic region. Failure usually occurs at about 8% to 10% strain.



▲ **Figure 2-13** ■ Stress and strain in a long bone. The arrows that point away from each other on the convex side of the bone indicate tensile stress and strain. The arrows that point toward each other on the concave side of the bone indicate compressive stress and strain in the structure.


A brittle material. This material is also strong because there is little strain for a high stress. The fracture of a brittle material is sudden with little or no plastic deformation.. Glass is brittle
σ
stress
/Pa
A strong material which is not ductile. Steel wires stretch very little, and break suddenly.
A ductile material - after the elastic region there is a strange section where 'necking' occurs - permanent deformation occurs in this "plastic region"
A plastic material - very small elestic region.
ε (strain)

Young’s modulus

- Young’s modulus(E) or modulus of elasticity of a material under compressive or tensile loading is represented by the slope of the linear portion of the curve between point A and point B
- The modulus of elasticity is a measure of the material’s stiffness (resistance to external loads)
- A value for stiffness can be found by dividing the change in stress by the change in strain for any two consecutive sets of points in the elastic range of the curve.

- The inverse of stiffness is compliance.
- If the slope of the curve is steep and the modulus of elasticity is high ,the material exhibits high stiffness and low compliance.
- If the slope of the curve is gradual and the modulus of elasticity is low, the material exhibits low stiffness and high compliance.

▪ Load deformation and stress strain curves

- Each material has its own stress and strain curve.

- The first region of the curve is called **toe region**
- Very little force is required to deform the tissue as the crimp pattern is straightened and PGs and GAGs allow sliding.
- In this region minimal amount of force produces **large amount of deformation(elongation), stress is low**
- The second portion of the curve A to B is elastic region in which **elongation has a linear relationship with stress.**
- Additional force creates an equal stress and strain in the tissue. Collagen fibrils are stretched and resisting applied force.

- The second region stress strain curve reflects the type of collagen, fibril size and cross linking among collagen molecules. When the load is removed the ligament or tendon will return to its original dimension, though the return will take some time.
- In the **third region (B – C) ,plastic region**, the failure of collagen fibers begins, and the ligament or tendon no longer returns to its original length after the force is removed.
- If the force is applied **beyond the plastic region**, the remaining collagen fibrils experience increased stress and create macrofailure of the tissue.

- If the failure occurs in the middle of the structure through disruption of connective tissue fibers, it is called rupture.
- If the failure occurs at the bony attachment of the ligament or tendon it is called avulsion
- When the failure occurs within the bony tissue it is called **fracture.**
- **Slow loading rates create avulsions or fractures and fast loading creates tears.**

❖VISCOELASTICITY

- Elasticity
- Collagen and elastin content
- Length change and applied load are directly proportional

TIME

RATE

- Work done and energy in an elastic material.
- Viscosity is materials resistance to flow
- **Water and PG content**
- Viscosity reduces as the temperature increases / slow loading
- Increases when pressure increases / rapid loading

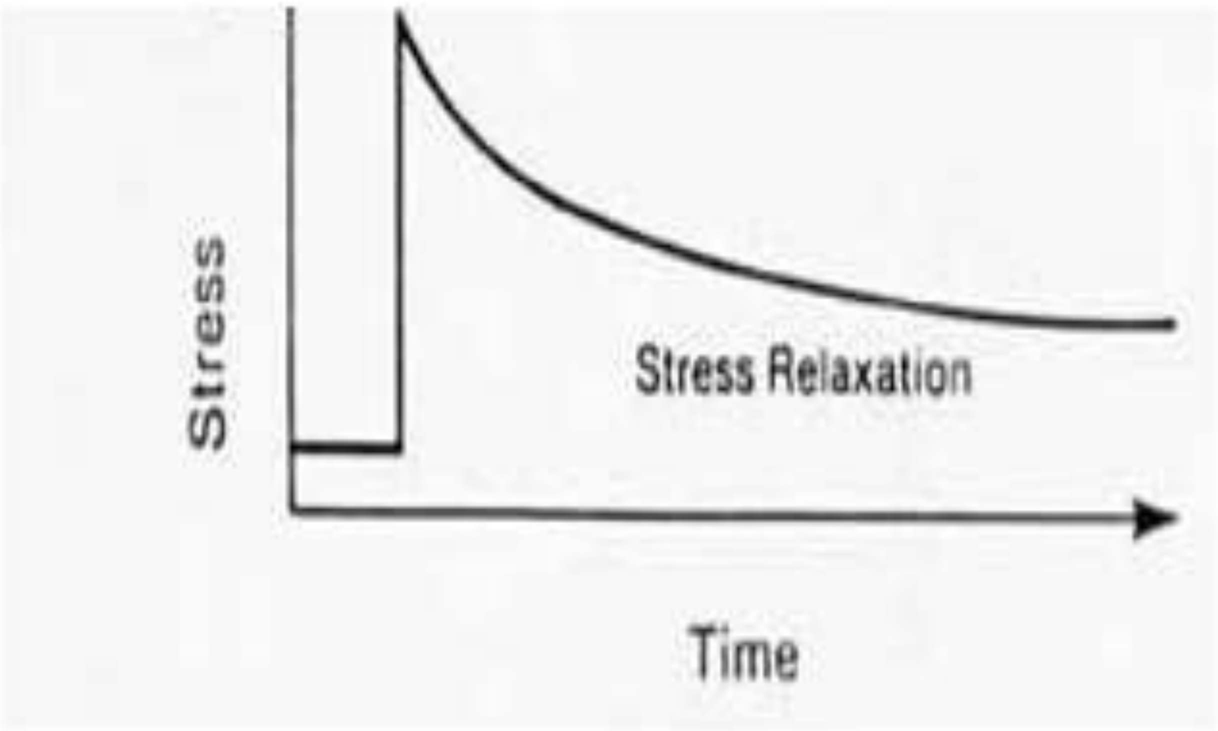
❖ TIME AND RATE DEPENDENT PROPERTIES

Tensile → deformation ← compressive

- Creep
- Constant load and length change
- Recovery
- Loading and unloading

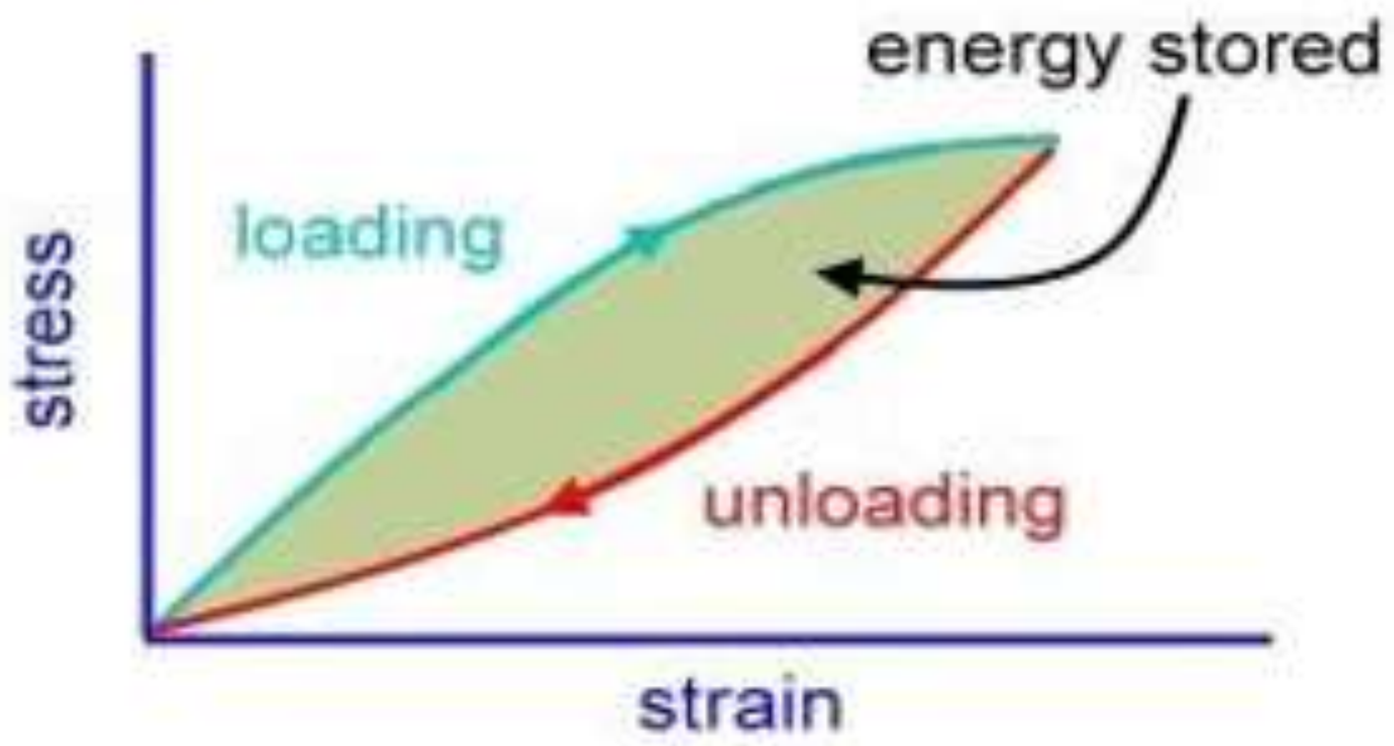
- Stress relaxation

- When a tissue is stretched to a fixed length and held there, the force needed to maintain this length will decrease with time



- Hysteresis

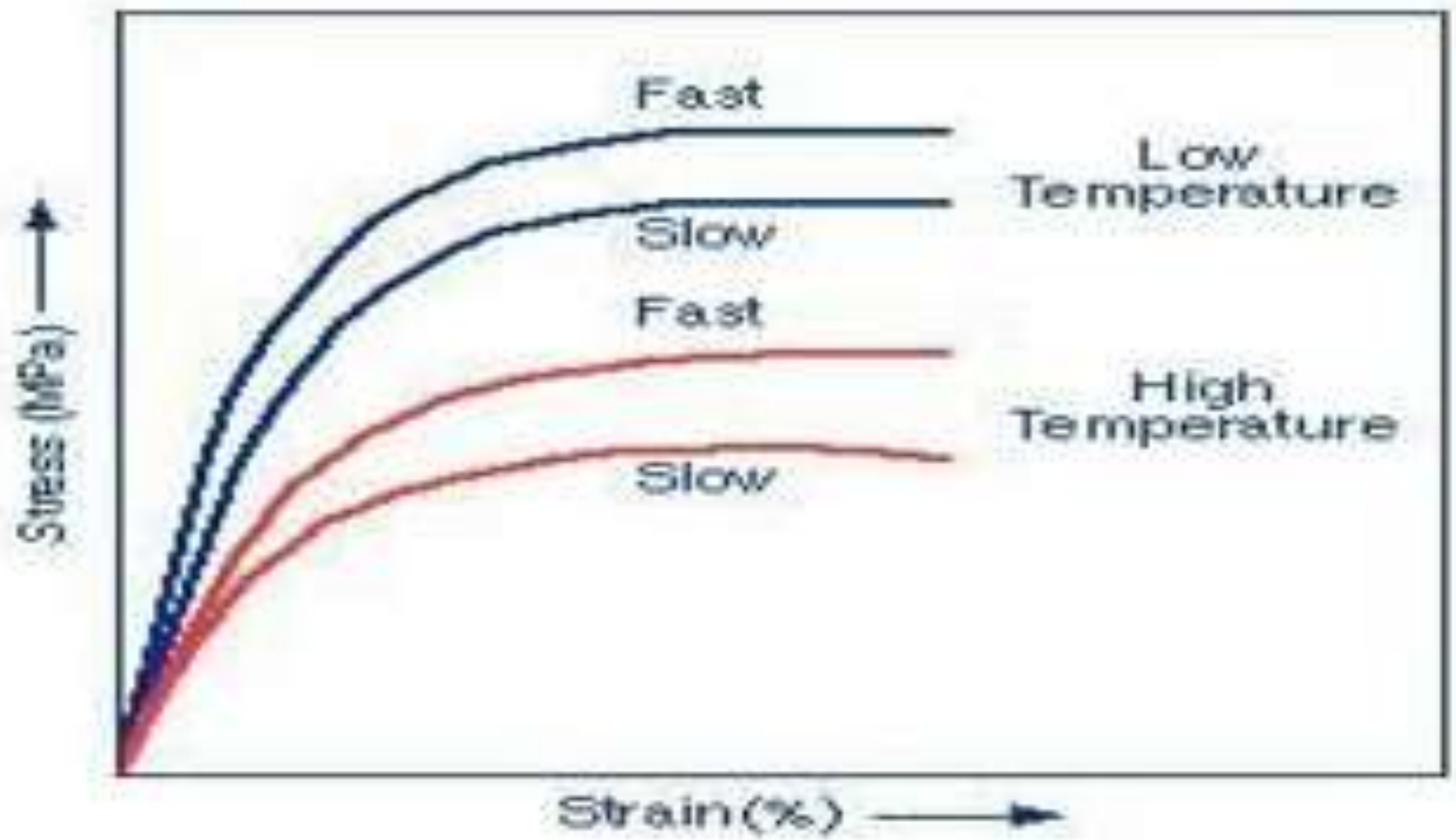
- Energy dissipated by elongation and heat released



Hysteresis

- Strain rate sensitivity

-



❖ PROPERTIES OF SPECIFIC TISSUES

- BONE- Cortical bone(2%) is stiffer than cancellous bone(75%)

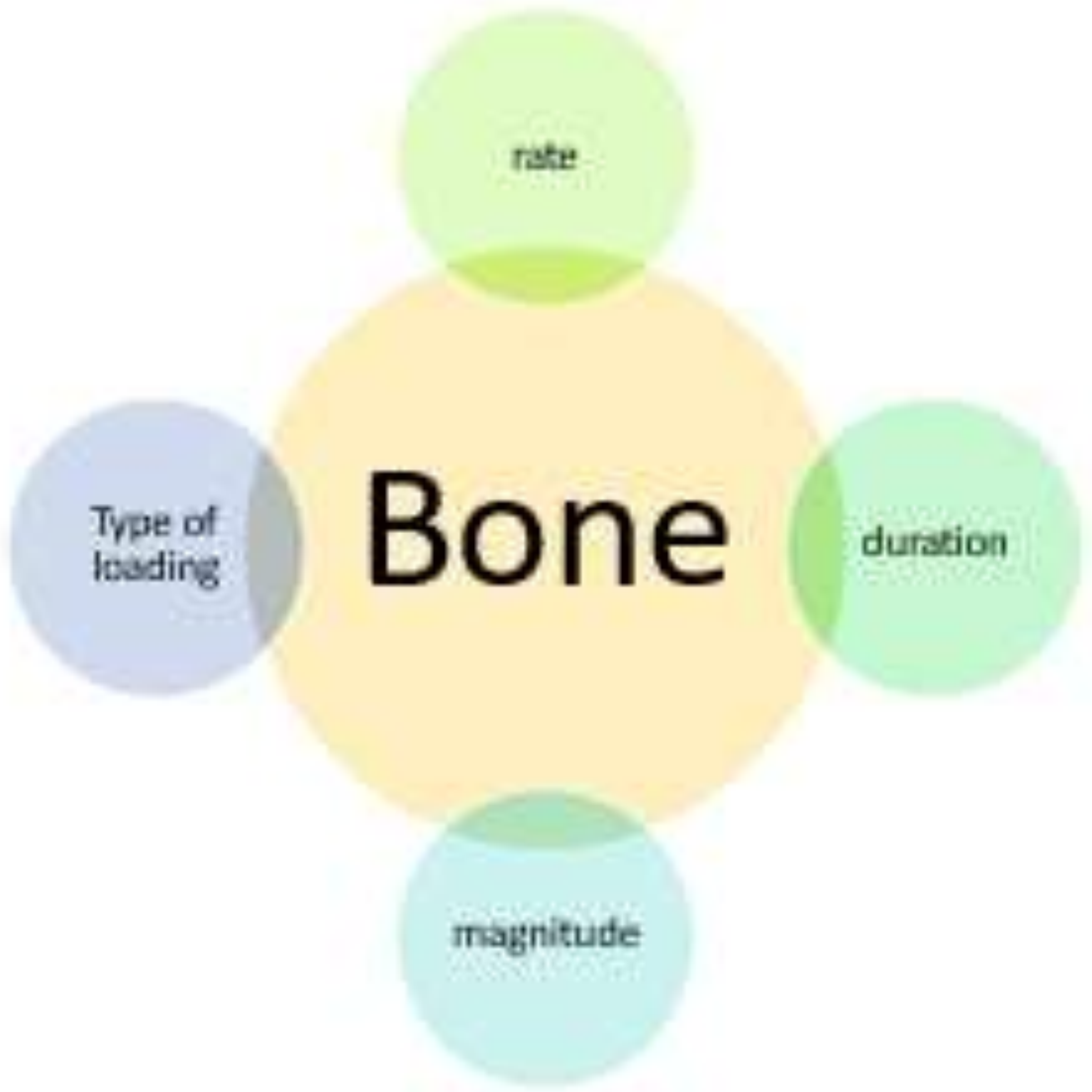
- Stiff – rapid load

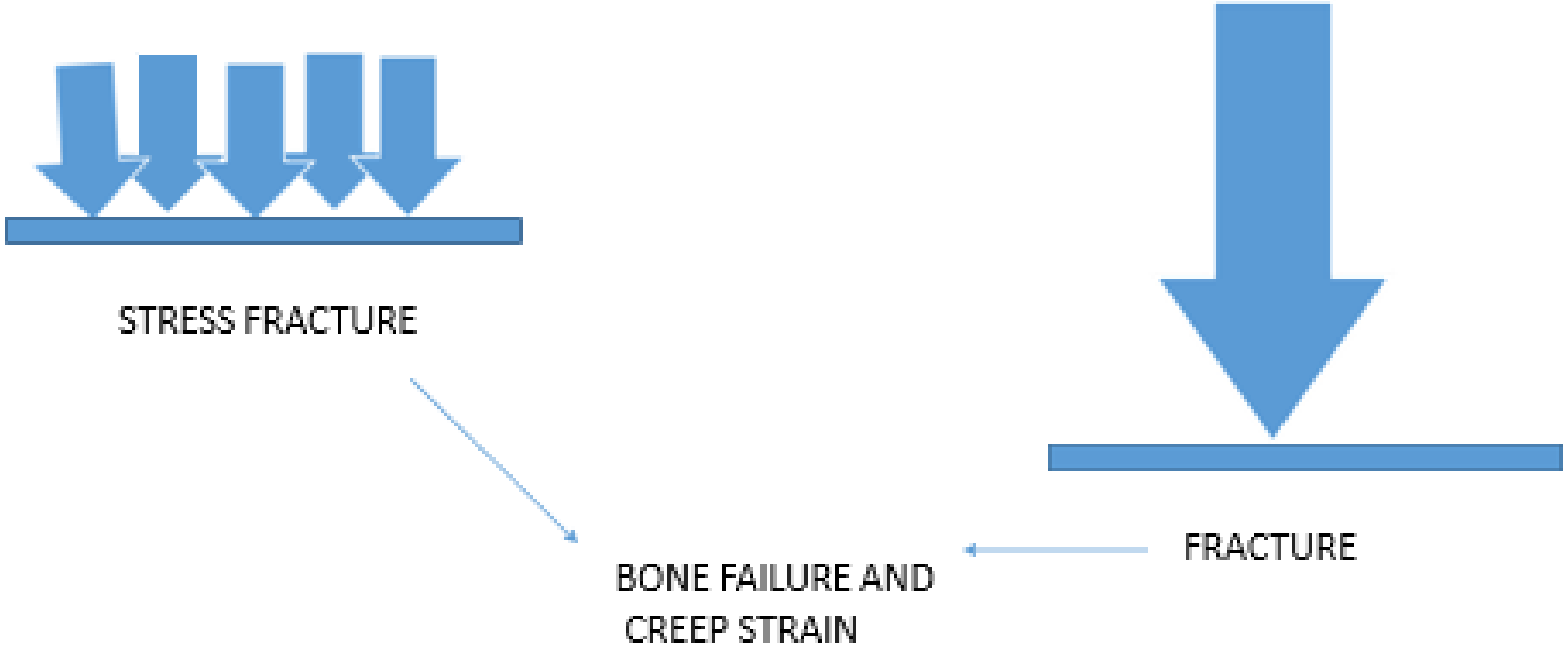
- Creep takes long time to appear in stiff materials.

load → Small period → High stress → Low strain

load → Longer period → Low stress → High strain

- Load reduces – weaker bone




STRESS FRACTURE
FRACTURE
BONE FAILURE AND
CREEP STRAIN

- TENDONS

- Creep when subjected to tensile loading
- Muscle contraction and tendon crimp

Toe region → Little stress → Little strain

↓

increase the force

stretch the straight

↓

collagen fibers

↓

Linear /elastic region → Linear relation ship between applied force and deformation → Collagen fibers are loaded directly and may be damaged

↓

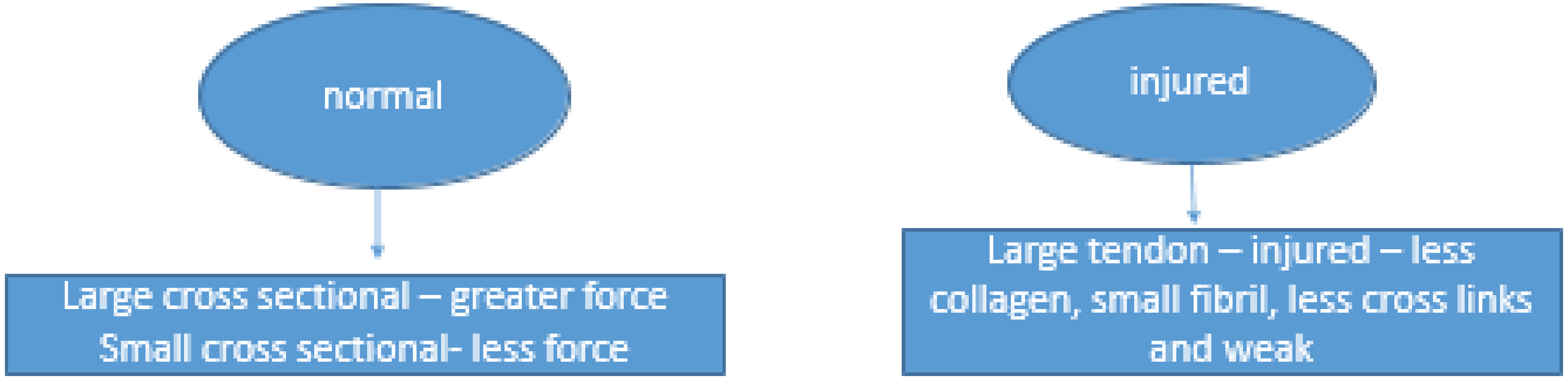
increase the loading

Slip between collagen molecules within fibrils → Interfibrillar slip between fibers → Collagen fiber disruption

↓

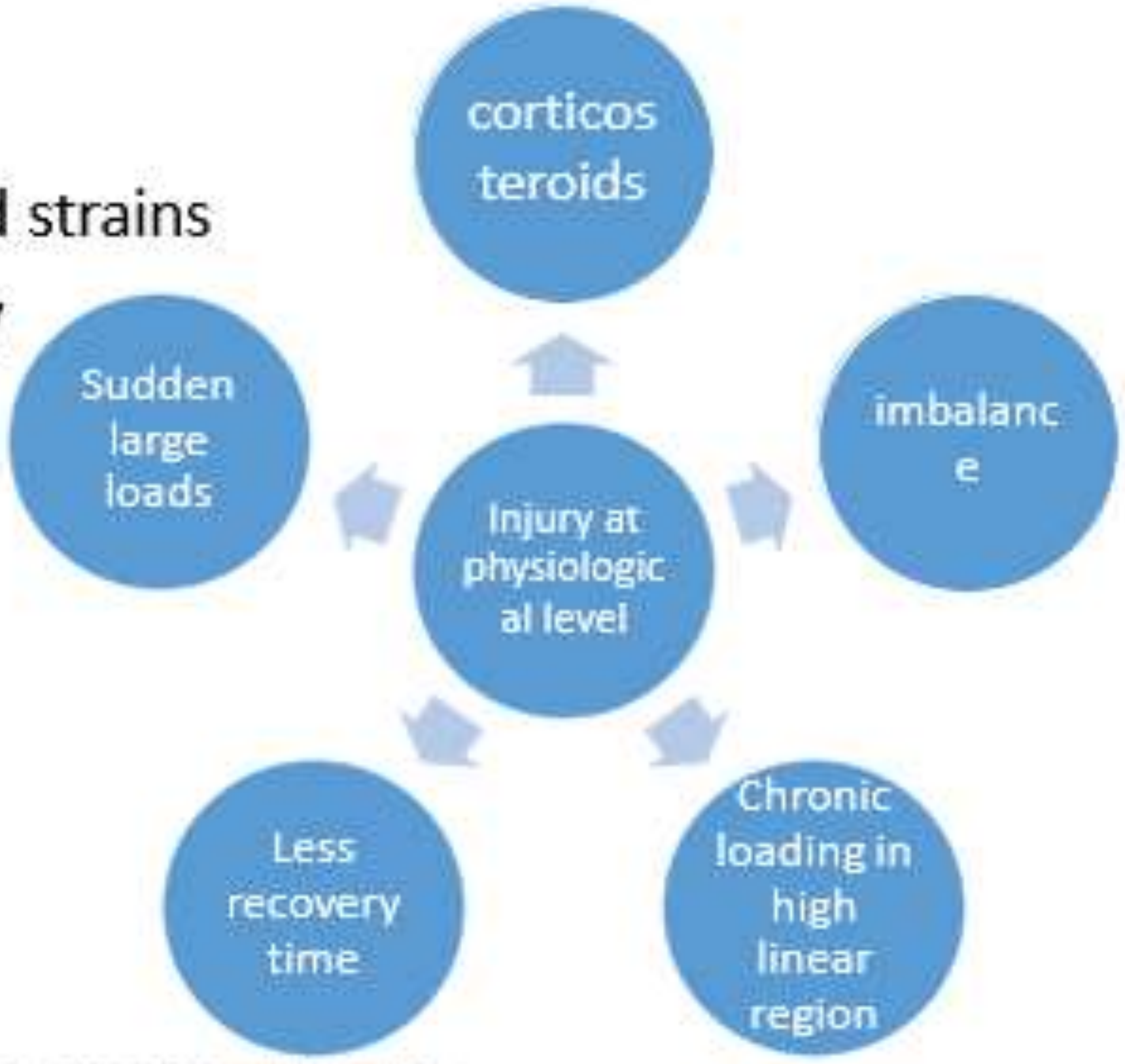
Straightened and weak fibers fail first

- Normal activities of everyday



- Changes in composition
- Enthesis is common site for degenerative changes.

- Myotendinous junction and strains
- Immobilization and atrophy



- LIGAMENTS
  - Withstands forces in all directions without being damaged but are less resistant to tensile stress.
  - Immobilization and recovery > 12 months
- CARTILAGE

Fibrillar portion of ECmatrix + Swelling pressure + Friction due to fluid flow = Resist applied load

- Compression of the cartilage reduces the volume of the cartilage and increases the pressure and causes the fluid to flow out.

- Fluid flow through EC matrix causes frictional resistance to the fluid within the tissues (frictional drag)

Rapid out flow of fluid-rapid deformation → Diminished fluid flow- diminishes deformation → Ceases when applied load equals compressive stress

- When the compressed PGs and water push against the collagen fibers it creates hoop stresses.
- Toe region in cartilage–frictional drag
- Toe region in ligaments and tendons – straightening of collagen fibers.
- Shear stress in the cartilage develop between calcified layer and subchondral bone.

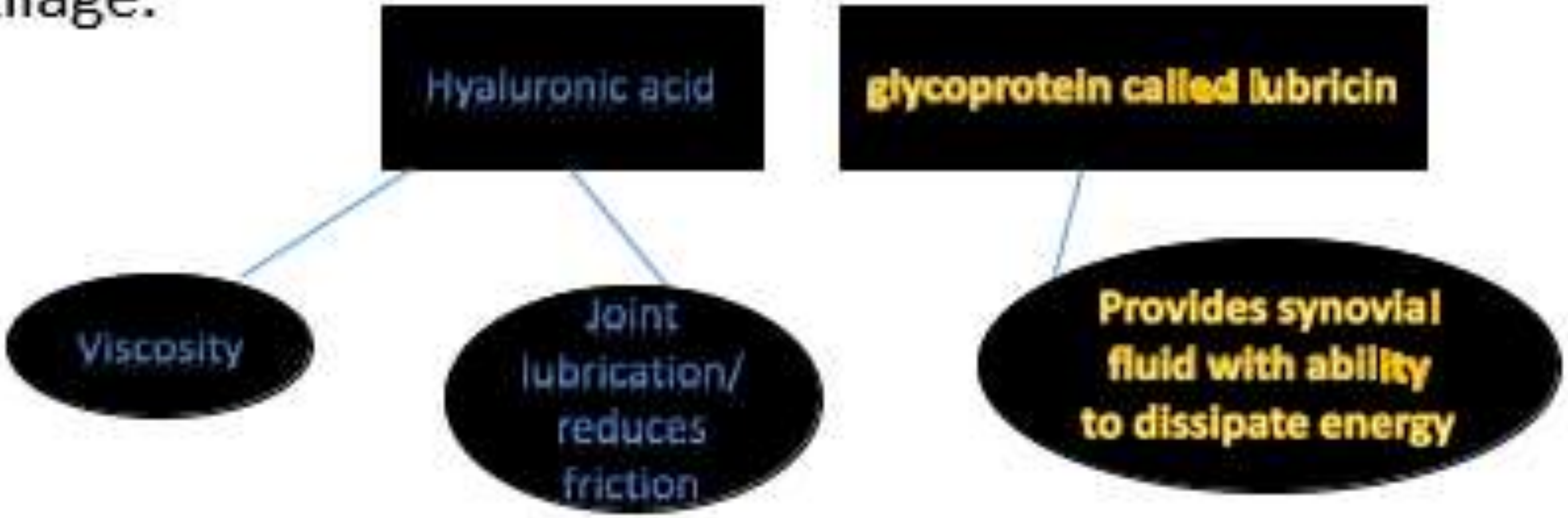
JOINTS

ASSIGNMENT

- **Classification**
- **Joint capsule**

- SYNOVIAL FLUID

- Covers the inner layer of joint capsule and articular cartilage
- Keeps joint lubricated and reduces friction, nourishes the hyaline cartilage.

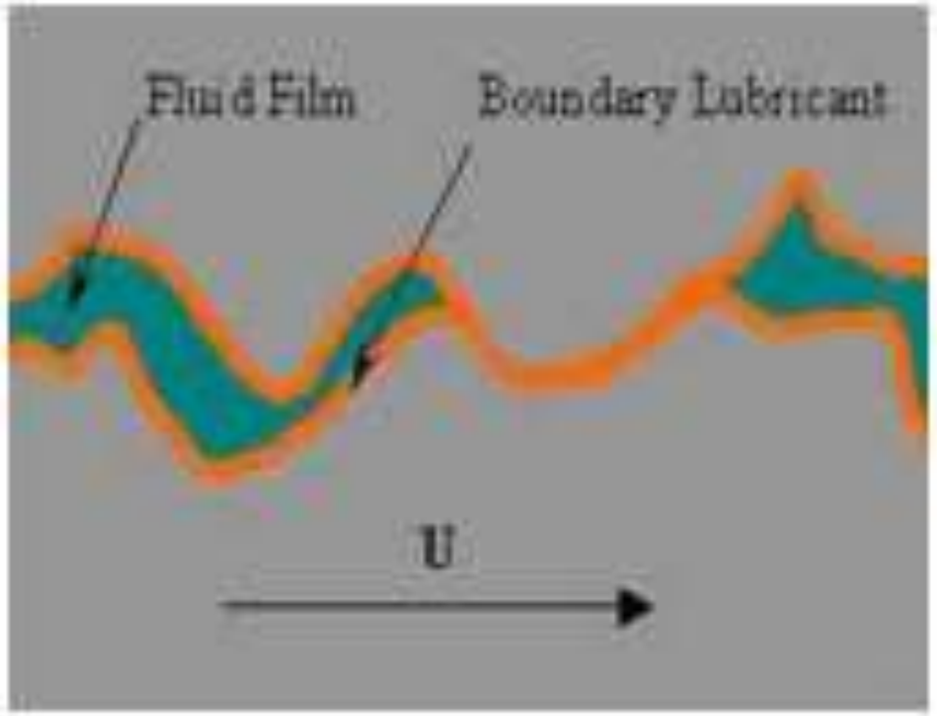


- All viscous substance resist shear load. High rate- less viscous(thixotropic)
- Rapid movement – reduces the viscosity –less resistance to motion.
- High temperature – less viscous and vice versa.

- JOINT LUBRICATION

- Models of lubrication

Boundary lubrication



- Load bearing surface coated with molecules that separates opposing surfaces touching each other
- Effective at low loads.
- These contain lubricin

Fluid film lubrication

Hydrostatic (weeping)

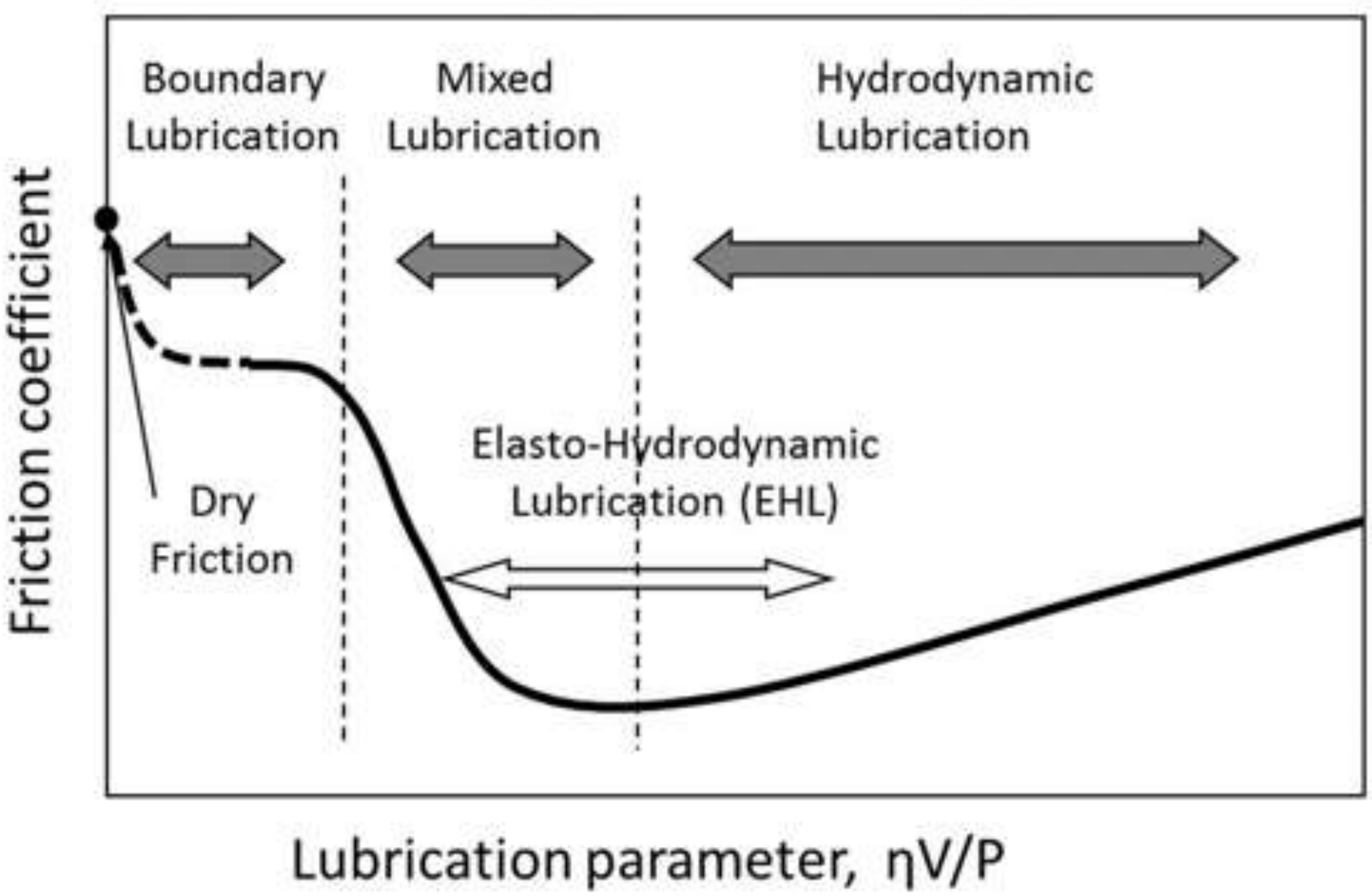
boosted

Squeeze film

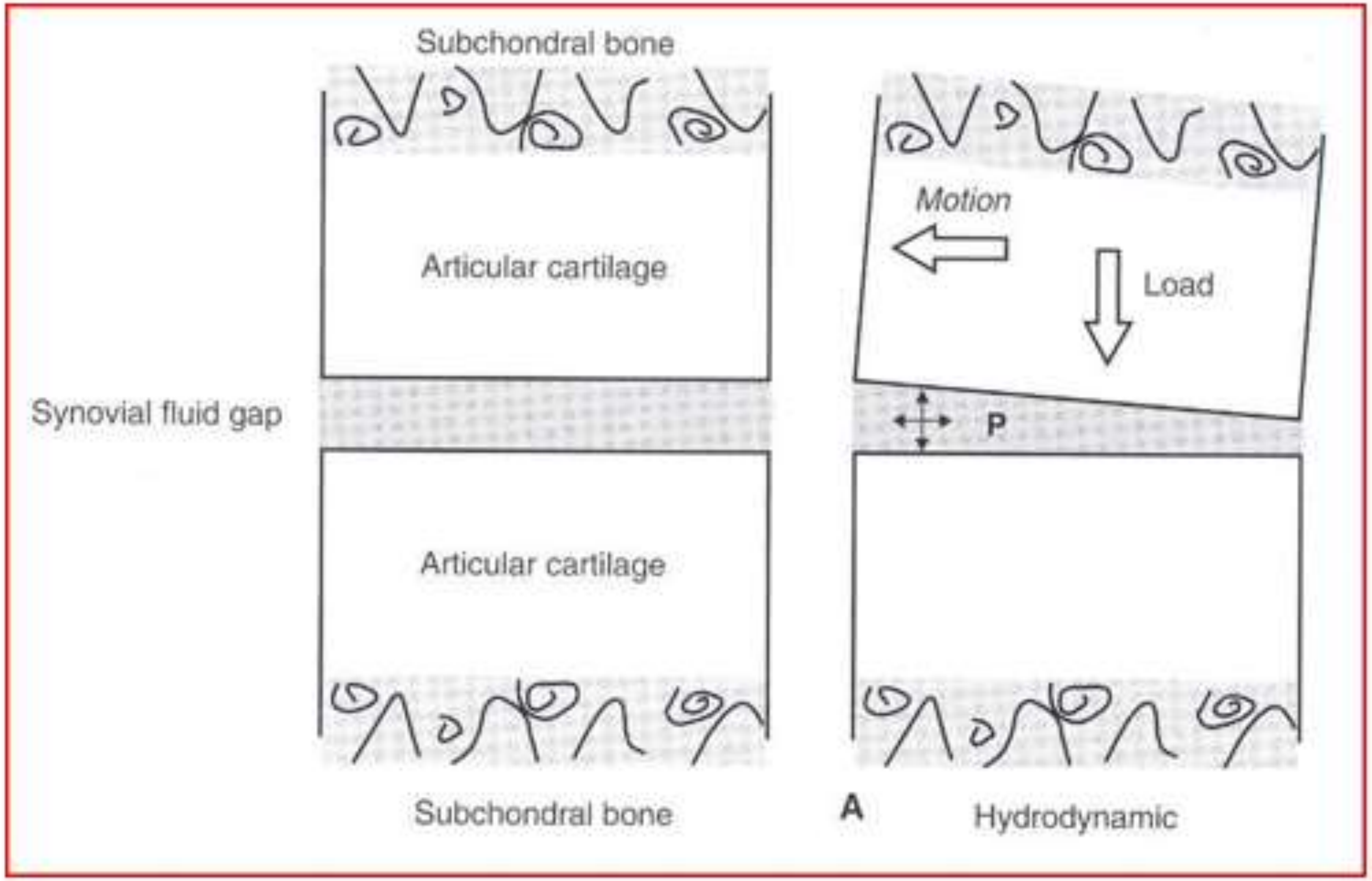
hydrodynamic

Elastohydodynamic=hydrodynamic+squeeze film

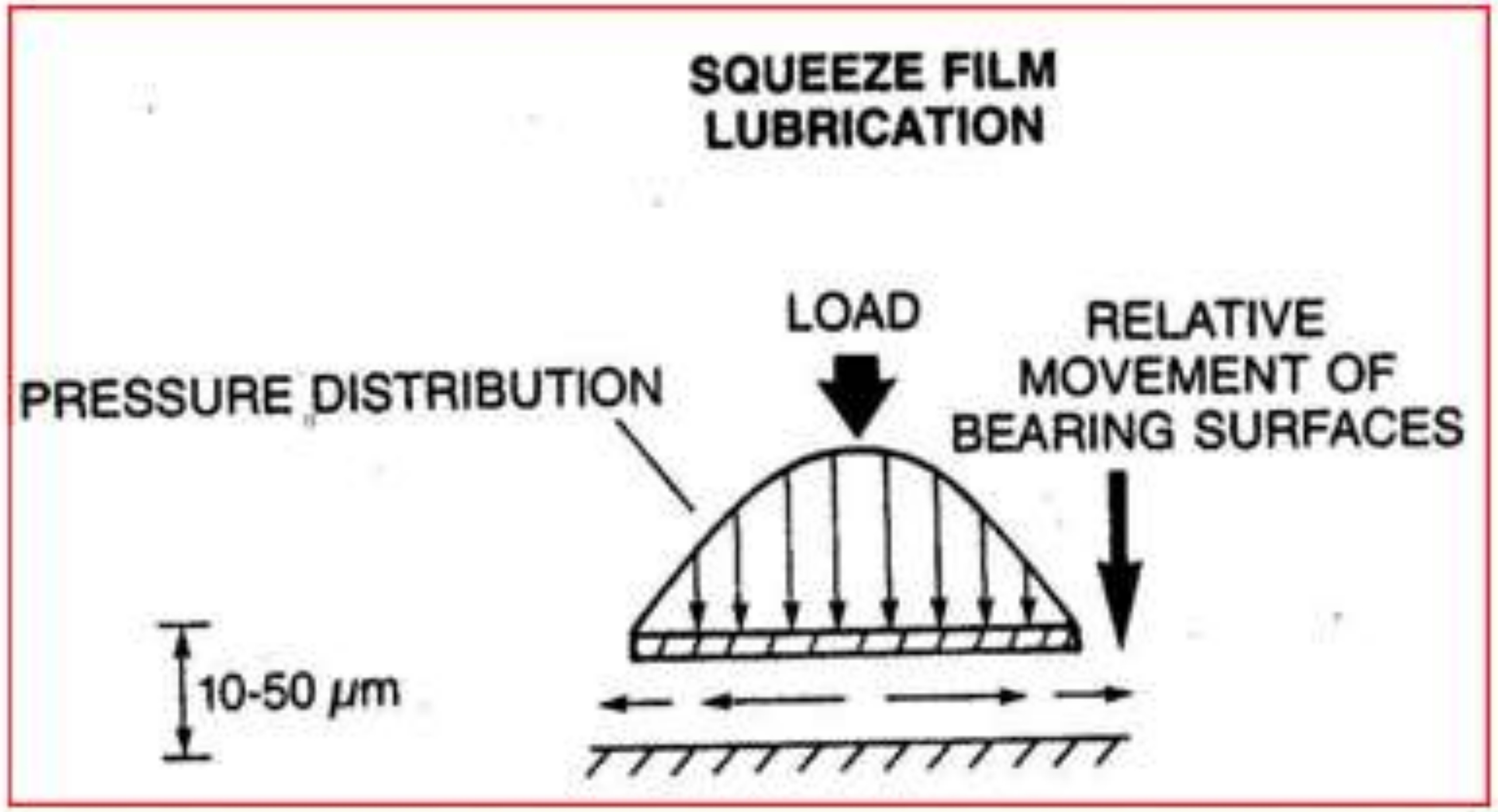
- Separates the joint surfaces


Boundary
Lubrication
Mixed
Lubrication
Hydrodynamic
Lubrication
Friction coefficient
Dry
Friction
Elasto-Hydrodynamic
Lubrication (EHL)
Lubrication parameter, ηV/P

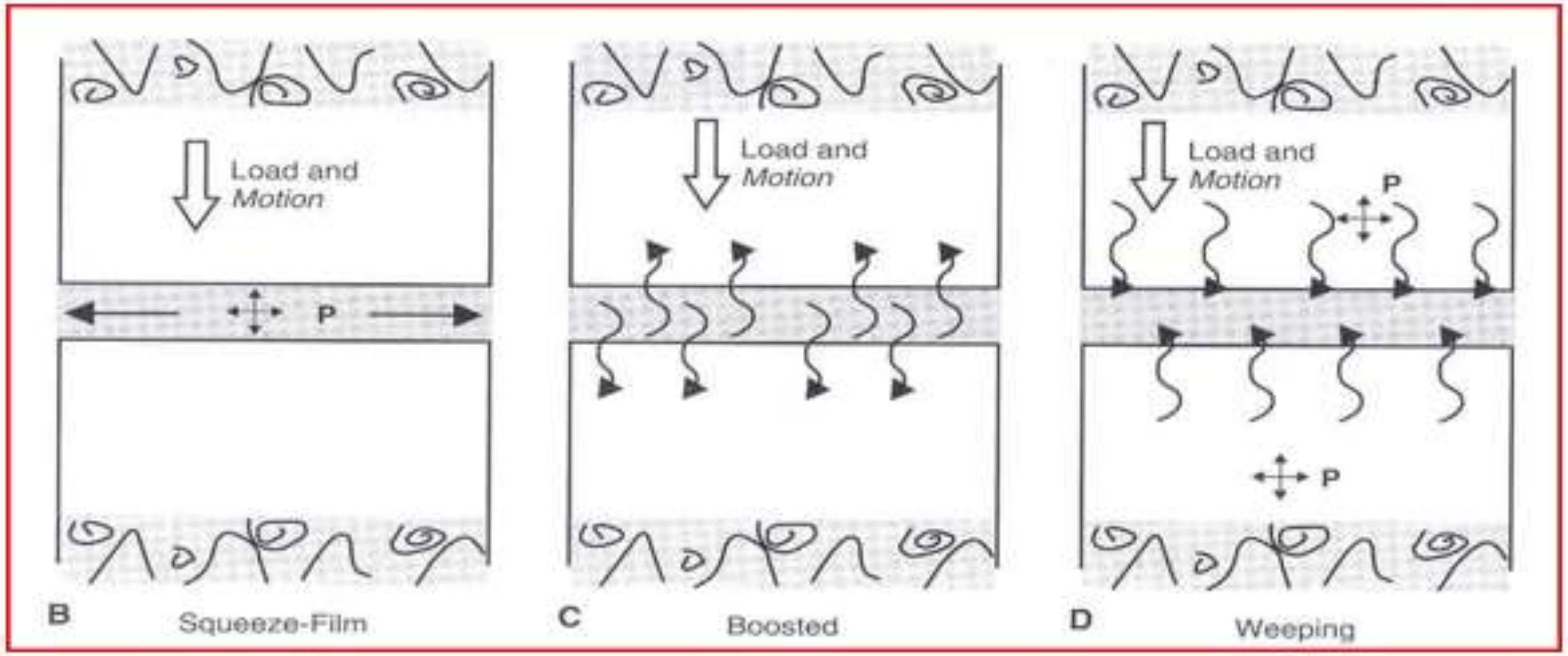
- In hydrostatic lubrication load bearing surfaces are held apart by film of lubricant maintained under pressure. This is by the contraction of the muscles/ compression.
- The fluid moves only into the joint and not the subchondral bone.
- Removal of the load
- In hydrodynamic lubrication a wedge of fluid is created when he non parallel opposing forces slide on each other.


Subchondral bone
Articular cartilage
Synovial fluid gap
Articular cartilage
Subchondral bone
Motion
Load
P
A
Hydrodynamic

- In squeeze film lubrication pressure is created in the fluid film by the movement of articular surfaces that are perpendicular to one other.
- As the surfaces move closer together they squeeze the fluid film out of the area of contact. In cases where there is high load maintained for short duration.



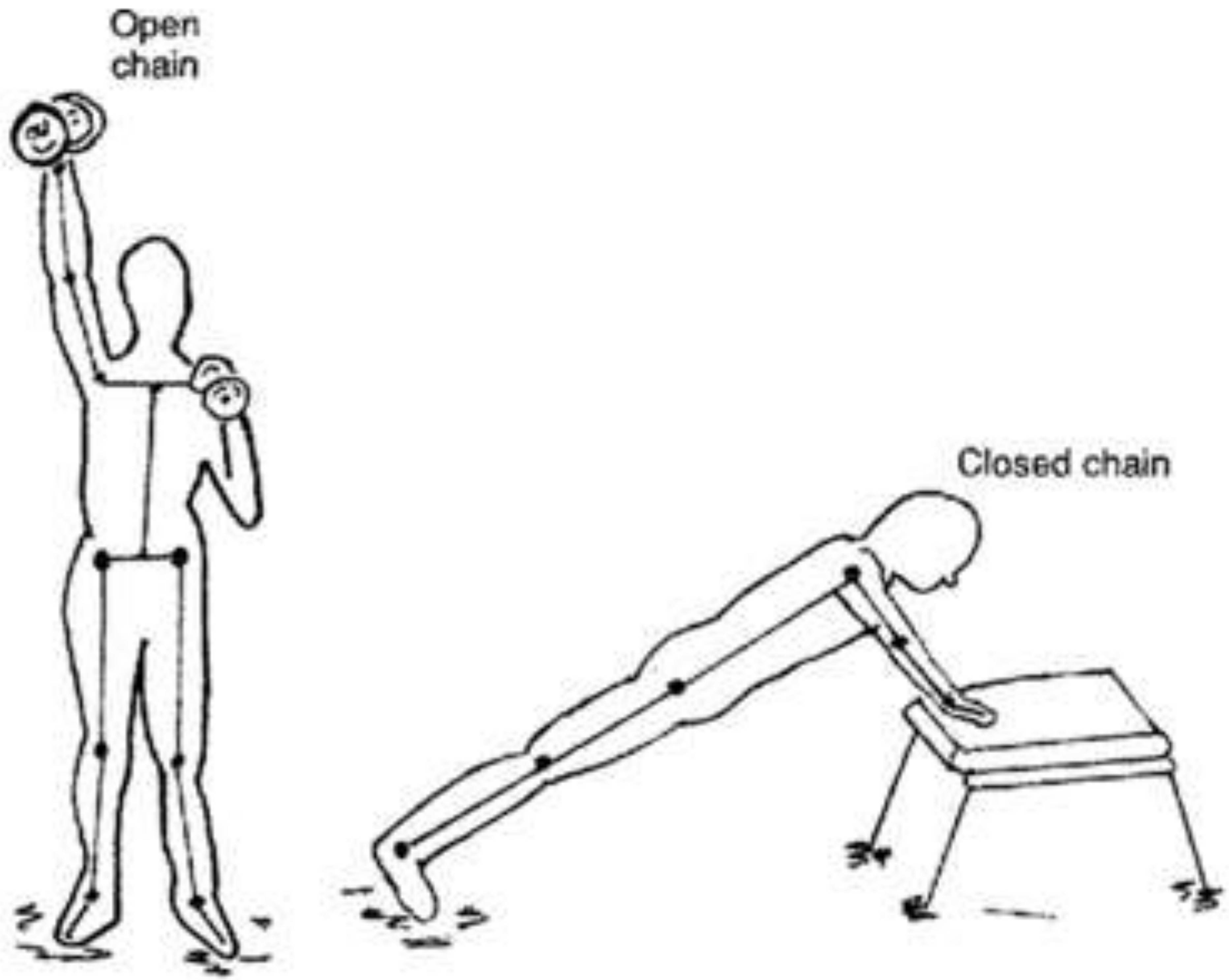
- In elastohyrodynamic model, the fluid film is maintained at certain thickness as the elastic cartilage deforms slightly to maintain an adequate layer of fluid between the opposing joint surfaces.



JOINT FUNCTION

❖ KINEMATIC CHAINS

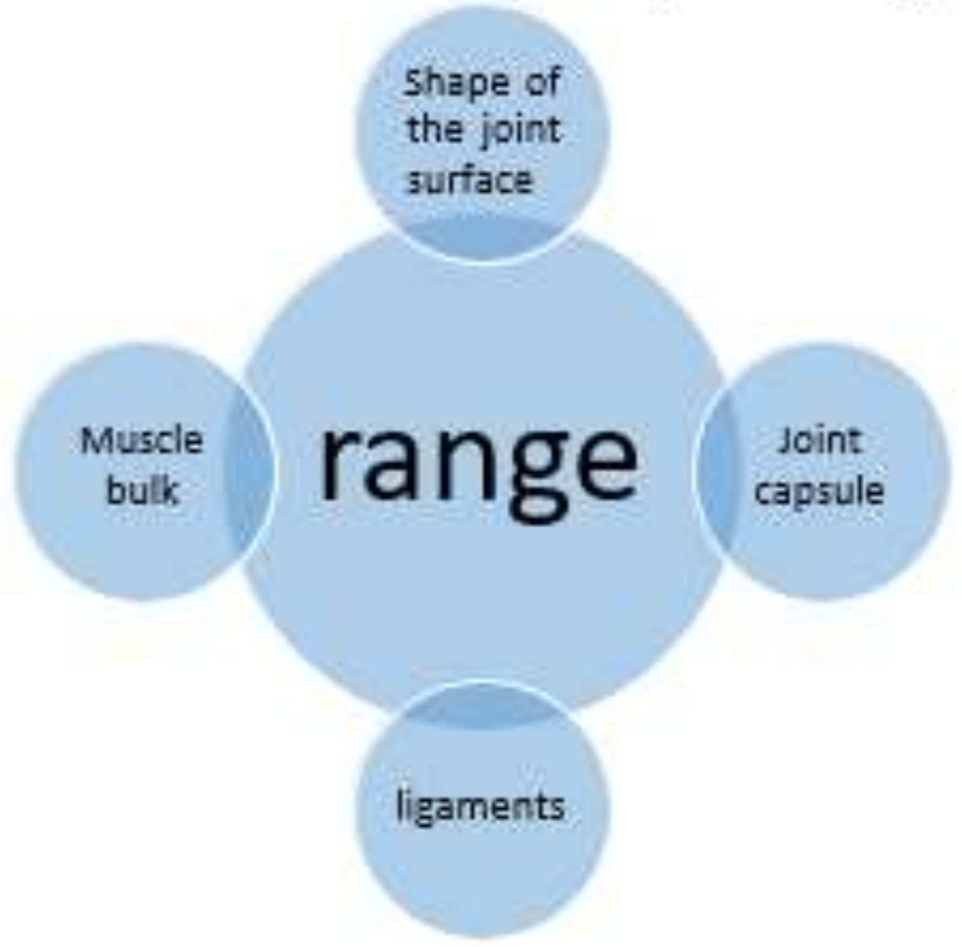
- In open kinematic chain, distal end of the chain is free to move and one joint can move independently of the other in the chain.
- In closed chain , both the proximal and distal ends of the chain are fixed .movement at one joint creates the movement in one or more joints of the chain.
- Closed chain occurs in weight bearing conditions.
- Open chain occur in non weight bearing.
- Limitations.


Open chain
Closed chain

❖ JOINT MOTION

- Range of motion

-normal ROM is called anatomical or physiological ROM.



- The sensation experienced by the examiner performing passive physiological movements at the joint is called end feel
- The ROM is pathological when the motion at the joint exceeds or ails to reach the normal anatomic limits of motion.

■ Osteokinematics

- It is the rotary movement of the bones in space during physiological joint motion.
- Plane: axis: direction of movement

- Arthrokinematics

- Also called accessory motion
- These are the movements between adjacent joint surfaces that accompany voluntary osteokinematic movement.
- Roll, slide, spin